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3-Dimensional High-Resolution Solar Spectro-Polarimetry

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Abstract. In order to obtain information on the magnetic field on the sun in two spatial dimensions, a spectro-polarimeter of high spatial, spectral, and temporal resolution was built in the German Vacuum Tower Telescope (VTT) at the Observatorio del Teide/Tenerife. The two-dimensional spectrometer in the VTT, using a Universal Birefringent Filter (UBF) and a Fabry-Perot Interferometer (FPI) to obtain narrow-band filtergrams with a spectral resolution of the order of $3 \cdot 10^5$ (approx. 22 mÅ at 6303 Å) and a spatial resolution of 0.2 arcsec/pixel (Bendlin et al. 1992, Bendlin and Volkmer 1993), was extended to work as a spectro-polarimeter for measuring Stokes-I and Stokes-V profiles.

1. The two-dimensional spectro-polarimeter

Figure 1 gives a schematic representation of the spectro-polarimeter. In front of the UBF, a polarization analyser consisting of a quarter-wave plate followed by two crossed calcites with their axes turned by $\pm 45°$ with respect to that of the $\lambda/4$-plate splits the incoming beam into one of right and one of left circular polarization (Stokes-(I+V), Stokes-(I–V)) before the spectral analysis is performed. The filter combination consisting of the UBF and FPI mentioned above decreases the spectral bandwidth, so that finally narrow-band images are obtained with a 12-bit Peltier-cooled slow-scan CCD. Scanning through a line with 40 wavelength positions ($\Delta\lambda \approx 10$ mÅ) for the profile and the adjacent continuum is accomplished within a few seconds by tuning only the FPI. By means of a beamsplitter and another CCD, white-light images of the same field of view are taken strictly simultaneously with the narrow-band images to have the possibility of correcting for image motion and seeing-induced distortions. A $\lambda/8$-plate is inserted in front of the polarimeter to compensate for the instrumental polarization of the coelostat system, the primary mirror, and some flat mirrors.

2. Specifications of the spectro-polarimeter

Spectral range: 4000 Å to 7800 Å
Spectral resolution: $\frac{\lambda}{\Delta\lambda} = 3 \cdot 10^5$ (variable)
Finesse (FPI): 45
Free spectral range: 1Å at 6302 Å (variable)

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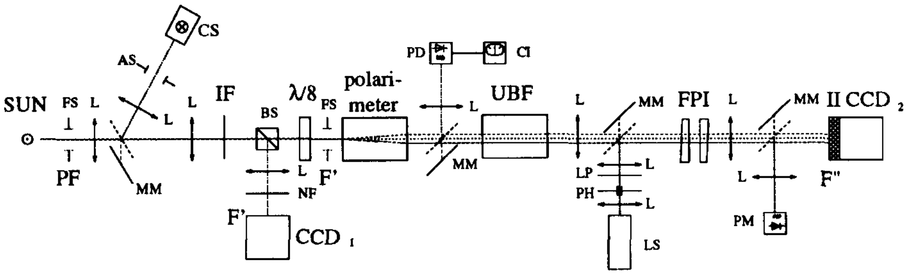

Figure 1. The two-dimensional spectro-polarimeter. Legend: FS: field stop, PF: prime focus, L: lens, MM: movable mirror, IF: interference filter, BS: beamsplitter cube, $\lambda/8$: $\lambda/8$-plate, F', F'': foci, polarimeter: Stokes-V polarimeter, UBF: universal birefringent filter, FPI: Fabry-Perot interferometer, II: image intensifier, CCD: slow-scan CCD, AS: aperture stop, CS: continuum source, NF: neutral density filter, PD: photodiodes, CI: compensation indicator, LP: linear polarizer, PH: pinhole ($\o = 30\mu m$), LS: He-Ne laser source, PM: photomultiplier

Field of view: 25.6" × 17.8" (max. 57.2" × 17.8")
Beamsplitting caused by the polarimeter: 4 mm at F' (18" at CCD_2)
Spatial resolution: 0.4 arcsec (0.2 arcsec/pixel, variable)
Image acquisition rate: ≈ 7.25 images/s (field of view: 26" × 18")
≈ 3.5 images/s (maximum field of view)

3. Observations

Time series of white-light pictures and narrow-band images taken simultaneously were obtained in various lines from active and quiet regions. The Stokes-V polarimeter split every narrow-band image into one of right and one of left circular polarization (Stokes-(I+V), Stokes-(I–V)). For each scan, about 40 narrow-band filtergrams were obtained at different wavelength positions, yielding a line profile for every pixel in the field of view.

In the data reduction, seeing-induced effects were reduced via a destretching algorithm. Instrumental effects such as polarization and wavelength shifts were compensated for by different techniques. From each line profile, a set of parameters was derived, such as line-core and continuum intensity, velocity, Stokes-V signal, and line width. Thus, the temporal development of the observed solar features could be studied extensively.

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References

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