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A new method to calibrate MOF-based instruments

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Abstract. We present a method for calibrating every instruments based on the magneto-optical filter (MOF) technology (Cacciani et al. 1978). The method allows to determine the operating characteristics of the filter and to find if spurious transmissions are present in the transmission profile due to an incorrect operating temperature or to the degradation of the filter. These characteristics are inferred by modelling the blue and/or red line intensity images acquired with the MOF system. We applied the method to the observations performed with the VAMOS instrument.

Key words. Sun: solar instrumentation – Sun: magneto-optical filter – Sun: solar oscillations

1. The method

We assumed:

1. the solar line profile is a Voigt function (H) with line parameters: a (damping parameter) and σ (Doppler width);
2. the MOF intensity measurement refers to a single point λ for each passband, i.e. λ_b (λ_r) is the average wavelength position of the MOF blue (red) transmission profile respect to the line center. We call it the *working point*.

With these assumptions we wrote the measured blue and red intensity (hereafter I_b and I_r) extracted along a diameter of the full-disk image as: $I = 1 - H(a, (\lambda - \Delta\lambda)/\sigma)$ where $\Delta\lambda$ is the sum of the gravitational red-shift and of the Doppler shift due to the Earth-Sun relative velocity. To better compare simulations and observations we multiply the simulated intensity I by the limb-darkening function directly calculated from the center-to-limb of data.That is to include into simulations some effects due to the seeing. We choose the North-South diameter of the Sun in order to eliminate the influence of the solar rotation. The three model parameters a, σ, λ are determined applying a least-squares fit for non-linear function to I_b and I_r data. In the case of a significant contribution of spurious central transmission, we expect that λ_b and λ_r are shifted towards the center of the transmission profile. However, notice that in this case the fit parameters may be less defined respect to the case in which the MOF profile has only two peaks.

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2. VAMOS data

We exercised the method on data acquired with the VAMOS instrument installed at INAF-OAC in Naples (Oliviero et al. (2002)). We acquired images at different MOF temperature

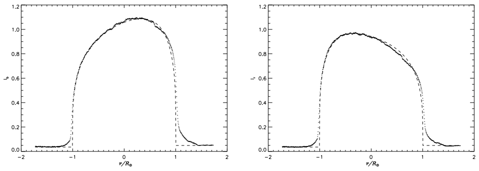

Fig. 1. I_b (left panel) and I_r (right panel) profiles of 2002 April $T = 130°C$ data (dots). The best fit (dashed line) is obtained with model parameters set at: $a_b = 0.33$, $\sigma_b = 0.22$ Å, $\lambda_b = -108$ mÅ, and $a_r = 0.32$, $\sigma_r = 0.20$ Å, $\lambda_r = 100$ mÅ.

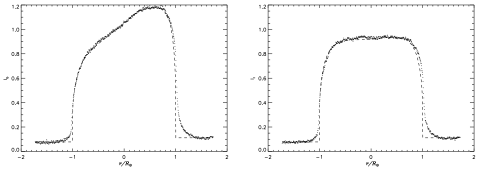

Fig. 2. I_b (left panel) and I_r (right panel) profiles of 2003 June $T = 130°C$ data (dots). The best fit (dashed line) is obtained with model parameters set at: $a_b = 0.33$, $\sigma_b = 0.08$ Å, $\lambda_b = -6$ mÅ, and $a_r = 0.31$, $\sigma_r = 0.09$ Å, $\lambda_r = 23$ mÅ.

and dates in order to study the effect of the aging of the cell. For the sake of simplicity, we show here only results related to 2002 April with MOF temperature set at $130°C$ and 2003 June $T = 130°C$ and $T = 160°C$ data. On each run (made of twenty full-disk dark-corrected images of the Sun, taken with 30 s cadence alternatively in blue and red wings of the potassium resonance line) we performed the temporal average of the blue (red) images to reduce contributions of spurious velocity fields. We thus obtained only one blue (red) image for each run. From it, we extracted the blue (red) intensities (the I_b and I_r profiles) along a narrow strip centered on the East-West diameter of the Sun and we calculated their spatial average.

3. Results

Best fits and the I_b and I_r VAMOS data are shown in Fig. 1, 2 and 3. After one year of use of the instrument, the intensity profiles are changed (Figures 1 and 2). Since both the runs were acquired with the same instrumental setup, we inferred that 2003 June MOF transmission profile is changed due to a lowering of the optical thickness of the potassium inside the MOF cell. In this case we expect that, as also reported in Cacciani et al. (1994), spurious contributions appear in the transmission profile. The obtained λ_b and λ_r values (see the caption of Fig. 2) suggested that the $130°C$ 2003 June transmission profile has not only two peaks. Due to the magnetic field applied to the VAMOS cell, we expected values not lower than $\lambda_{b,r} = \pm 50$ mÅ. By increasing the cell temperature up to the value $160°C$ (Fig. 3), the correct optical thickness inside the MOF cell is re-established. The obtained model parameter values (see caption of Fig. 3) assure us we improved the MOF passband shape contrasting the effect of the aging of the filter.

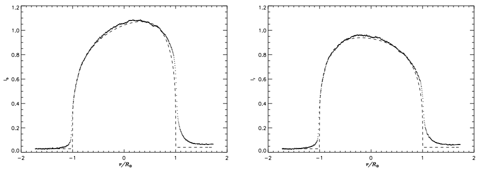

Fig. 3. I_b (left panel) and I_r (right panel) profiles of 2003 June $T = 160°C$ data (dots). The best simulation (dashed line) is obtained with: $a_b = 0.27$, $\sigma_b = 0.26$ Å, $\lambda_b = -112$ mÅ, and $a_r = 0.29$, $\sigma_r = 0.32$ Å, $\lambda_r = 111$ mÅ.

4. Perspectives

The method here presented enables to extract quickly information about the shape of the MOF transmission profile. In order to further check and to improve our observational method, we plan to compare its results with those obtained with the diode laser now operative at *Laboratorio di Fisica Solare* of the INAF-OAC in Naples.

References

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