Spectroheliograms recorded using the CCD camera in the OAUC, Coimbra.

A. Garcia, Observatório Astronómico da Universidade de Coimbra, Coimbra, Portugal, adriana@mat.uc.pt
M. Klvaňa, Astronomical Institute AS CR, Ondřejov, Czech Republic, mklvana@asu.cas.cz
M. Sobotka, Astronomical Institute ASCR, Ondřejov, Czech Republic, msobotka@asu.cas.cz
V. Bumba, Astronomical Institute AS CR, Ondřejov, Czech republic, bumba@asu.cas.cz

Abstract: Spectroheliograms in the OAUC (Coimbra, Portugal) have been photographed in the spectral line of Ca II continuously since 1926 and, since 1990, spectroheliograms in H-alpha have been photographed as well. Since 2007, all the spectroheliograms have been recorded using a CCD camera. Specifications of the camera, including the new optical scheme of the spectrograph, were published in the previous paper (Klvaňa et al., 2006). On the data recorded in 2010 we demonstrate the good quality of spectroheliograms taken during standard observing conditions, influence of clouds, and the effects introduced by a visualization filter.

1. INTRODUCTION

The usage of CCD cameras opens new extended possibilities in the processing of spectra. Unlike the classical spectroheliograms registered on the photographic emulsion, from the digitized spectra we can obtain spectroheliograms in different, exactly defined wavelengths and calculate Doppler velocities. The drawback of the digital recording is the necessity to archive a large amount of data, which brings some problems. According to the experience, the long-term archiving of spectroheliograms on the photographic emulsion is still more simple and reliable.

2. THE SPECTROHELIOGRAPH

The original spectroheliograph was based on mechanical principles. Due to the transversal shift of the objective lens, the solar disc moved gradually across the entrance slit of the spectroheliograph and, at the same time, a photographic plate moved synchronously in front of the exit slit. The moving plate was exposed by a narrow part of the spectrum that passed through the exit slit. This way, the whole solar disc in the selected narrow wavelength band was recorded on the plate. It was possible to obtain spectroheliograms in four wavelengths on the spectroheliograph in Coimbra: 6562.8 Å (H_α), 6558.7 Å (H_α continuum), 3933.7 Å (CaII K3), and 3932.3 Å (CaII K1). It was necessary to acquire the spectroheliograms in each wavelength separately.

The curvature of spectral lines originating in the spectrograph was compensated by curved entrance and exit slits. The resulting image of the solar disc was then exactly circular (Klvaňa et al., 2007).

The mechanical system of the instrument is designed and made so well that even after 80 years of operation it does not show signs of wear. When the photographic plates were replaced by a CCD camera in 2007, this mechanical concept was preserved. After the modification of the spectroheliograph, the CCD camera does not record only a specific wavelength but a whole segment of the spectrum. The series of spectra for gradually changing positions of the solar disc on the entrance slit is digitized and stored in a computer. By selection of wavelength in the spectral segment, spectroheliograms in different wavelengths can be composed (Klvaňa et al., 2006). Thus, only two measurements are necessary to obtain all four spectroheliograms mentioned above.

The utilization of the CCD camera opened the possibility to measure full-disc Dopplergrams (Garcia et al., 2010). At present, we measure Dopplergrams in the line H_α (see Fig. 6).
3. SPECTROHELIOTOGRAMS VISUALIZATION

The photographic emulsion has a non-linear relation between the incident light intensity and the density of the resulting image. This relation is approximately logarithmic: \( D = \ln(I) \). Consequently, the photographic emulsion can register a large range of intensities. Bright and dark parts of the spectroheliogram do not saturate thanks to the non-linearity of the photographic transfer function.

The linear characteristics of the CCD chip and the low number of light levels used for visualization (256 compared to 4096 levels of a 12-bit CCD chip) is not suitable for a direct visualization (e.g. on a monitor) of spectroheliograms. Better results can be obtained using non-linear transfer functions or a spatial filtering of the image.

The transfer functions shown in Fig. 1 transform 12-bit digitized values of the CCD chip to 8-bit values used by a monitor or a printer. These functions (W – white, P – prominence, N – no correction, D – dark, B – black) are utilized to visualize different objects in the image (W, P – prominences, N – filaments and disc structures, D, B – emissions, see Fig. 2). The function N corresponds to a linear intensity transfer (Klvaňa et al., 2007).

![Fig. 1: Transfer functions W-white, P-prominences, N-no correction, D-dark, B-black, suitable for the visualization of spectroheliograms.](image)

**Obr. 2:** Application of the transfer functions B, D, N, P, W, and the Z-filtering on a spectroheliogram.

![Image of spectroheliogram in Hα processed by Z-filtering. This method depicts all details present in the image and it is suitable for visualization. However, it cannot be used for photometric analysis. The darkening below the prominence is an artifact caused by the filtering method (cf. Fig. 4).](image)

**Fig. 3:** Spectroheliogram in Hα processed by Z-filtering. This method depicts all details present in the image and it is suitable for visualization. However, it cannot be used for photometric analysis. The darkening below the prominence is an artifact caused by the filtering method (cf. Fig. 4).

**Fig. 4:** The unfiltered spectroheliogram of Fig. 3 does not show the darkening below the prominence. The transfer function W, used in this case, depicts the prominence and its surroundings, but structures on the disc are weak. Different transfer functions should be used to show all the details.
To get an overview of all details present in the spectroheliogram, a filtering method based on the combination of median filter and unsharp masking is used (Z-filtering). This method (Garcia et al., 2010) modifies local contrasts and enhances the details. It is suitable for the simultaneous visualization of all objects on and around the disc but cannot be used for photometric and physical analyses. The modification of local contrasts may lead to an misinterpretation of observed effects. An example is the darkening below the prominence in Fig. 3. This darkening caused by the Z-filtering is false and it is not observed in Fig. 4, where the transfer function W was used instead of the image filtering.

Fig. 5: Spectroheliogram in Hα processed by Z-filtering. Inclined strips on the disc are caused by the disturbing effect of clouds.

4. PROPERTIES OF SPECTROHELIOGRAMS

The quality of spectroheliograms depends mainly on observing conditions. Frequent occurrence of clouds severely affects the spectroheliograms. A fast motion of clouds does not deform the spectroheliogram but produces false structures (strips) that uncontrollably change the brightness and it is impossible to remove them. Although the recording of one observation takes only 70 sec., not always it is possible to obtain a good spectroheliogram (Fig. 5).

The diffraction-limited resolution of the telescope is below 1"; the best real resolution of spectroheliograms, according to observing conditions, is around 2". Examples of spectroheliograms acquired with the Coimbra spectroheliograph in the spectral lines Hα and CaII K3 during good observing conditions are shown in Figs. 6 and 7.

Currently, a method of full-disc Doppler velocity measurement is developed (Garcia et al., 2010). The method is based on two moving virtual slits that measure the intensity in the spectral-line wings. The distance of the slits, constant for a given Dopplergram, may control the depth in the solar atmosphere, where the velocities are measured. At present, the Doppler velocities are measured in the Hα line. An example of a Dopplergram is displayed in Fig. 8.

Fig. 6: Spectroheliogram in the Hα line, processed by the method of Z-filtering.

Fig. 7: Spectroheliogram in the CaII K3 line, processed by the method of Z-filtering.

Fig. 8: Dopplergram of the solar disc in Hα.
5. CONCLUSIONS

During the period of modernization of the spectroheliograph at the Astronomical Observatory of the Coimbra University, we successfully solved the problem of visualization of spectroheliograms that is connected with the transition from photographic plates to CCD detectors. The presented results show a good quality of the spectroheliograms acquired by means of digital technology. CCD detectors become a full-valued substitution of photographic techniques, without an interruption of the continuity of long-term observations with the spectroheliograph in Coimbra. Newly, the digital technology makes it possible to obtain full-disc Doppler velocity measurements and reduces the number of necessary measurements to one half, compared to the original photographic method.

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REFERENCES: