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SOLAR Hα AND WHITE LIGHT TELESCOPE AT HVAR OBSERVATORY

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Abstract. Recently, the double solar telescope at Hvar Observatory was equipped with the fourth generation of acquisition hardware and software. It provides a valuable instrument to study rapid changes of chromospheric and photospheric features in great detail. The telescope consists of two Carl Zeiss refractors (photosphere d=217mm, chromosphere d=130mm) mounted as one unit on a German parallax mounting. Using a field of view of about 7 and 11 arcmin, it aims to produce high-resolution high-cadence imaging of active regions on the Sun. New Pulnix TM-4200GE 12-bit CCD cameras allow to obtain time series with a cadence up to 30 images per minute.

Key words: solar observations - telescope - photosphere - chromosphere

1. Introduction

The double solar telescope was installed in 1972 at Hvar Observatory based on an agreement between the Faculty of Geodesy of the University of Zagreb and the Astronomical Institute of the Czechoslovak Academy of Sciences. It was equipped with two Carl Zeiss refractors using Hα and white light filters. The main purpose of the Hvar solar telescope was to perform solar photosphere and chromosphere photography using the optimal angular and time resolution following observation routines performed at Ondrejov Observatory (for details see Ambrož *et al.*, 1977). Due to the rapid evolution of electronics and computers, continuous development of the telescope and its acquisition systems was necessary.

The original photographic material acquisition system was replaced by a video-recording system in 1997 (Klvaňa and Bumba, 1997), and then in 2004 with a 1MPix 10-bit CCD camera (Otruba, 2005). However, both previous acquisition systems suffered from an interference of strong radio transmitters placed at the Observatory.

In 2010, the fourth generation of acquisition hardware and software was installed and some improvements on the optical telescope design were made. Hvar Observatory implemented the identical acquisition system as the Kanzelhöhe Solar Observatory (KSO) due to similar telescope layout and to benefit from the know-how gained at KSO (Otruba *et al.*, 2008; Hirtenfellner-Polanec *et al.*, 2011). The aim was to complement KSO photosphere (Otruba *et al.*, 2008) and chromosphere (Otruba, 2005; Otruba and Pötzi, 2003) full-disc images by Hvar active-region high-resolution images.

The new installed Pulnix TM-4200GE 12-bit CCD cameras allow higher spatial resolution and time cadence. Additionally, the greater dynamic range of CCD chip improves simultaneous observations of very bright (e.g. flares) and much dimmer phenomena (e.g. prominences and loops). Furthermore, the new hardware is not affected by strong transmitter interferences as some strong sources of the interference were recently shifted to a new location and the new hardware is less prone to the interference. Since new CCD chips in the Pulnix TM-4200GE cameras are larger (15x15 mm) than in the previous Pulnix TM-1010 cameras (9x9 mm), the optical system was slightly changed and adjusted.

2. Instrumentation

2.1. The Photospheric Telescope

The main objective of the Hvar photospheric telescope is an achromatic doublet with a diameter of 217 mm and focal length of 2450 mm (Ambrož *et al.*, 1977). The optical system shown in Figure 1 consists of a Baader AstroSolar photo film, iris diaphragm, Baader solar continuum and UV/IR cut filter, 75mm lens and Pulnix TM-4200GE CCD camera. The adjustable iris diaphragm controls the amount of light in the telescope together with the AstroSolar photo film which reduces the sunlight intensity to about 0.001%. The Solar Continuum Filter is designed to enhance the visibility of solar granulation and sunspot details by transmitting a specific spectral region around 540 nm, free of emission and absorption lines thus boosting the contrast and reducing the effects of atmospheric turbulence.

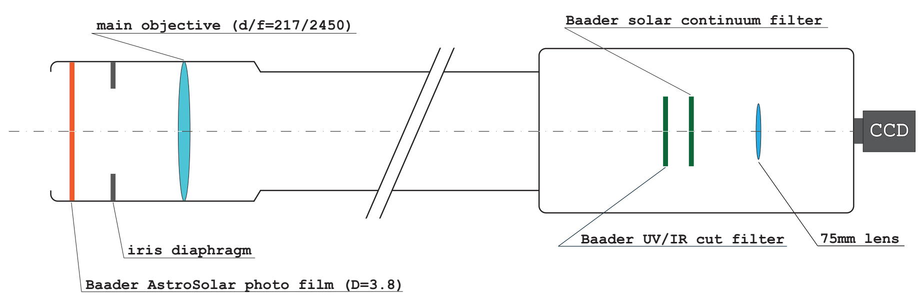

Figure 1: Schematic overview of the photosperic telescope

Prior to 2009, the photosperic telescope used only an iris diaphragm to reduce the amount of light which enters the telescope. The remaining light was then reduced with a prism before entering the camera. To avoid telescope heating and picture degradation due to the turbulence inside the telescope, a solar filter was placed in front of the telescope tube. Because of the expensive maintenance (humid environment) instead of a glass filter a Baader AstroSolar film was used, having neutral density 3.8 to allow shorter exposure times. Under ideal circumstances the AstroSolar film has similar properties as a glass filter with the surface flatness of $1/10\ \lambda$. The image quality was further improved by using the Solar Continuum Filter.

The measured field of view of the corresponding system is about 11.28 arcmin, yielding a resolution of 0.33 arcsec/pixel with 2048x2048 pixels CCD camera. However, this resolution can not be achieved in practice, because of the ideal theoretical diffraction limit of the 217mm objective, which is 0.6 arcsec at the observing wavelength band of 540nm. Even with the perfect optics this value is also never reached in the Earth's atmosphere, where the spatial resolution is about 1 arcsec in the case of the best seeing conditions. Furthermore, the images are slightly oversampled (the Nyquist rate is 0.5 arcsec) thus improving resolution, reducing aliasing and noise by image processing. Compared to the KSO full disc resolution (Otruba *et al.*, 2008) which is slightly undersampled, this is a clear advantage.

2.2. The Chromospheric Telescope

The optical system of the chromospheric telescope consists of an energy reduction filter, adjustable iris diaphragm, main objective, auxiliary lens, Hα filter and Pulnix TM-4200GE CCD camera (see Figure 2). The main objective is an achromatic doublet with a diameter of 130 mm and focal length of 1950 mm (Ambrož *et al.*, 1977). The energy reduction filter blocks most of the sunlight, thus decreasing the heating and turbulence inside the telescope. A Baader research grade filter with 0.2Å passband is used.

The corresponding field of view is about 7.15 arcmin and the 4MPix CCD camera gives the theoretical resolution of 0.21 arcsec/pixel. However, due to the telescope theoretical diffraction limit of 1.3 arcsec (130mm objective at a wavelength of 656nm) and atmosphere interference of about 1 arcsec the obtained images are slightly oversampled. This gives the same advantages as already mentioned for the photospheric telescope.

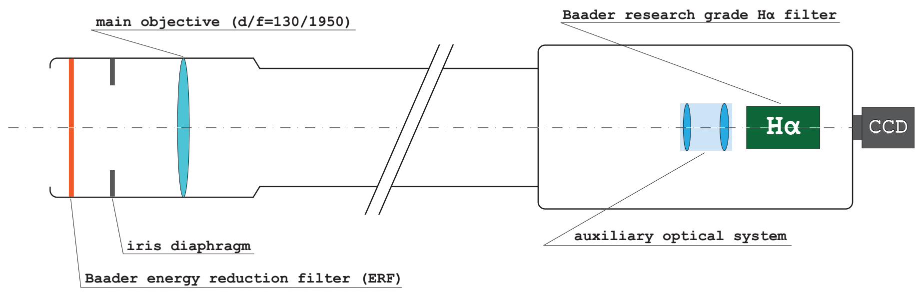

Figure 2: Schematic overview of the chromosperic telescope

3. Data Storage

The telescope CCD cameras are connected by a gigabit internet cable to 2 windows PCs in the control room below the dome. The acquisition software is almost identical to that at KSO, which allows watching the real-time images, and making the data time-series saved in the FITS and JPEG format with corresponding information headers (for detailed information see Hirtenfellner-Polanec *et al.*, 2011; Otruba, 2005). The software also regulates the exposure time automatically and performs frame selection (the

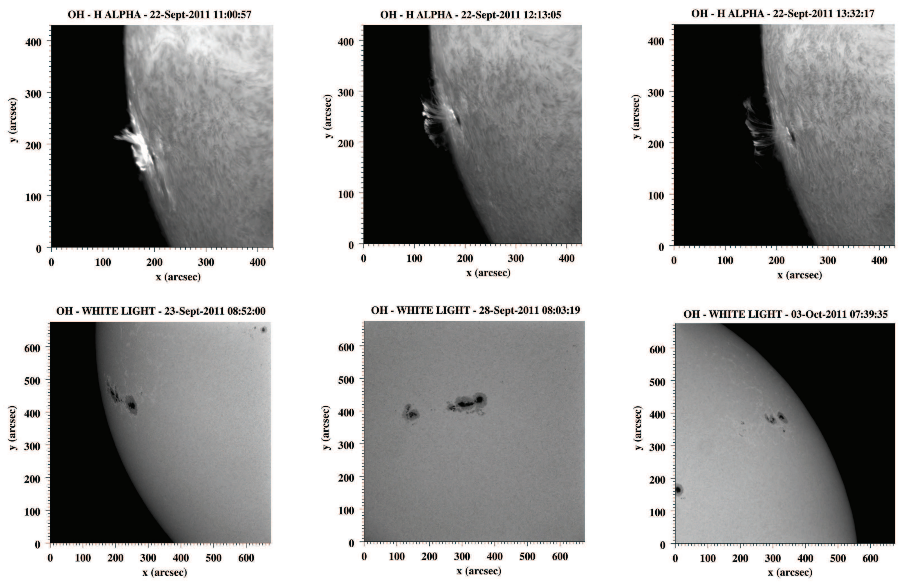

Figure 3: The upper panels show the chromospheric images of the X1.4 flare from sunspot group 1302 on 22 September 2011. The lower panels show the photospheric images of the same sunspot group 1302 evolution during almost 2 weeks. All images were processed with IDL and Solar Soft software.

camera records seven frames per second), which is employed to select moments of good seeing. A standard time series uses the image cadence of four images per minute for the chromosphere and one image per minute for the photosphere. However, a resolution up to 30 images per minute is available for specific purposes.

With the aim to manage the processing, archiving and distribution of large amount of data automatically, the own data management system based on CESAR (Central European Solar Archives; Otruba and Egarter, 2007) and KODA (Kanzelhöhe Data Archive; Hirtenfellner-Polanec *et al.*, 2011) is currently under development.

4. Observations

The first regular chromospheric and photospheric observations began in May 2011 after the installation, adjustment and testing of the new equipment.

Figure 3 shows an example of chromospheric and photospheric observations obtained during the recent solar activity.

There is still a problem of the old tracking system which doesn't have the ability to make fine adjustments to correct tracking errors. However, in September 2011 the mechanical tracking error was significantly reduced by adjusting the telescope mount axes. A new electronic system for computerized tracking and control of the telescope is currently manufactured and should be installed in summer 2012 to allow a better telescope positioning and tracking.

Acknowledgements

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