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New equipment for measuring stellar magnetic fields at the 6 m telescope

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Abstract. Three devices for measuring stellar magnetic fields at the 6 m telescope are discussed. These are: the polarization analyzer with slicers, the back-and-forth magnetometer and the fiber-fed magnetometer. The first two are placed on the Nasmyth platform near the slit of the Main Stellar Spectrograph and used to measure the magnetic field with high efficiency or high precision in the blue or yellow spectral region and the fiber-fed magnetometer is placed at the prime focus of the 6 m telescope and used in the red.

1 The analyzers of polarization with slicers for the MSS

The mean seeing during observations with the 6 m telescope is about 3 arcsec. The width of slit of the Main Stellar Spectrograph (MSS) is equivalent to 0.5 arcsec. There are large losses of light. The double slicers are used in new analyzers to increase the efficiency of measurements. Each analyzer consists of an achromatic waveplate, which can be rotated and take two positions (0°or 45°), a diaphragm of the 5 arcsec, a dichroic polarizer, a double slicer and a slit (Fig. 1). Two slicers were tested: the Bowen-Walraven slicer and a laminated one. The laminated slicer is two blocks of glass plates in the form of different length parallelepipeds (Chountonov, Perepelitsin 1999). Its advantages are portability, scrambling and absence of defocusing. Besides, its central element looks like decker and causes no light losses. The demerits are the following: inconvenience of extraction and composition of "sliced" spectra since every sliced spectrum is shifted with respect to the neighboring one by a value corresponding to the width of the plate; the spectra prove to be of different intensity because of polarization caused by the spectrograph. In Bowen-Walraven slicer this polarization is practically unnoticeable, for the polarizing prizm is turned relative to the slit by 36° (a turn of 45° would be ideal). It gives almost equal intensities of the Zeeman components at the CCD detector. The number of strips is 14: 7 strips are for one polarization. There are the spectra of 53 Cam in Fig. 2 recorded with the double slicer. The first 14 spectra at the top of the figure were recorded at the 0° position of the achromatic wave plate and the next 14 spectra — at 45°. The extracted and integrated Zeeman spectra are at the bottom of the figure. The Zeeman shift corresponds to a magnetic field of about 2 kG.

2 Back-and-forth magnetometer for the MSS

The light from a star passes through the liquid crystal modulator, which can be in two states to create phase shifts of 180° and 0°, and is deflected by the Mooney rhomb to the spectrograph slit. The Mooney rhomb is in the capacity of the flat diagonal mirror of the spectrograph and serves at the same time as the achromatic quarter-wave phase retarder. Behind the spectrograph slit (decker) there is a unit of two calcite plates (Savart plate) which split the beam in two beams.

The essence of the recording mode is that the charge pattern accumulated in a given state of the modulator is not read after a short elementary exposure but transferred to a specified number of lines. Then a synchronous switching of the electrooptical modulator state occurs, the signal is being accumulated during the next elementary exposure with further backward transfer to the same number of lines. The system recovers the original state and the process is repeated. After accumulation of the necessary number of charges the process

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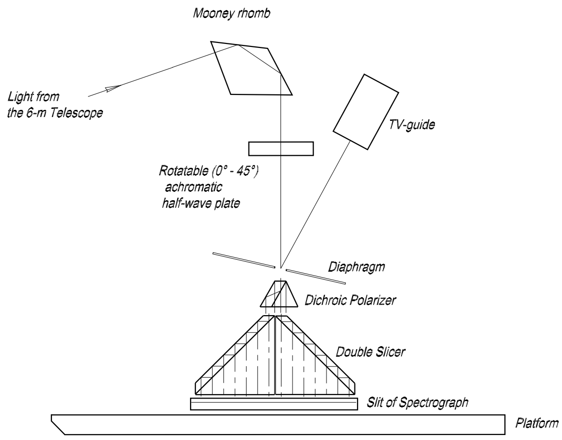

Figure 1: *A schematic diagram of the analyzer with the double slicer.*

is discontinued and the accumulated image pattern is digitized. The influence of light fluctuations on the spectrograph slit is reduced in this mode, and for recording spectra in left and right circularly polarized light the same pixels are used, i.e. the necessity for flat-fielding is ruled out.

Now the CCD1040×1160 is replaced by a back illuminated CCD 2048×2048. The inefficiency of charge transfer of this CCD is essentially lower (it equals 10^{-6} against 2.5×10^{-5}). But in the red region there occurs an interference phenomenon (fringes), which does not allow high precision to be acheaved. Because of this, we had to go over to the blue region of the spectrum. The liquid crystal modulator cannot operate in a wide spectral range, for this reason, it was replaced by an achromatic half waveplate which is located after Mooney rhomb and rotates every half a period of about 2 s. Figure 3 gives Zeeman spectra of 53 Cam in the region of 4500 Å : the 4 upper spectra were recorded when the shifting of the image and rotating of the phase plate were phased. One can see that two inner spectra are shifted to the left relative to the outer ones. The next 4 spectra shown in the lower part of the figure were taken during the next exposure. In this case the plate was rotated in antiphase with the previous exposure. One can see that the two inner spectra are shifted to the right relative to the outer ones. The Zeeman shifts obtained in the two exposures are equal in magnitude but opposite in sign. Such a procedure is necessary for reliability of measurements.

The crossdispersor can be mounted and consequently the spectra can be recorded simultaneously at 3900 Å and at 5850 Å of the 3-d and 2-nd orders. These spectra are shown in Fig. 4.

3 Fiber-fed echelle spectropolarimeter for the prime focus of the 6 m telescope

The spectropolarimeter is intended for measuring the linear and circular polarization along the profiles of spectral lines. The beam of light from a star goes through the rotatable waveplate and then the diaphragm. After the collimation by the lens, the beam is divided by the liquid-crystal (LC) polarizer into two linearly polarized beams and they are projected by two lenses on the inputs of the fiber cables. The other side of the LC-polarizer is used to input light from an incandescent lamp for the flat-fielding procedure and from a neon lamp. Five years ago the light was transmitted by two-fiber cables to the Nasmyth platform for the MSS. Today, because of the narrow spectral region and the instability of the MSS, a newly created special-purpose echelle spectrograph is used. This spectrograph does not require any additional matching lens. It is suspended in the ball and socket joint for stability and it is fiber-fed. The length of the fiber cable is 1.5 m. There are 2×7 fibers for the stellar spectrum in orthogonal polarization and the 15-th one for the reference spectrum. Fig. 5 shows the principal diagram of the echelle magnetometer, and the stellar echelle Zeeman spectra are presented in Fig. 6. Hα is in the second order from the left. The reciprocal dispersion is about 0.15 Å /pix, the spectral region of one order is about 160 Å. No light was sent through the reference fiber.

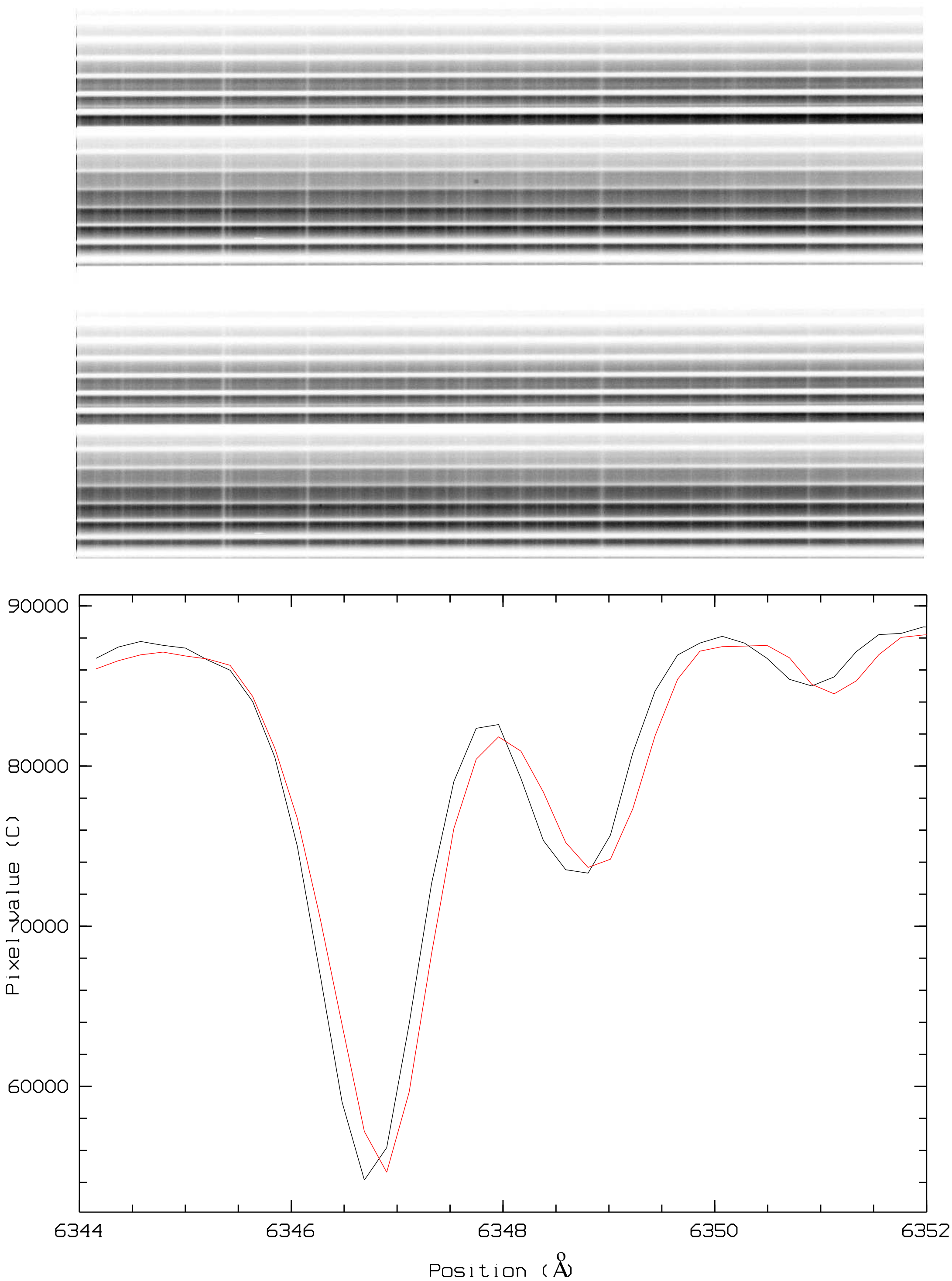

Figure 2: *The Zeeman spectra of 53 Cam recorded with the analyzer with the double slicer.*

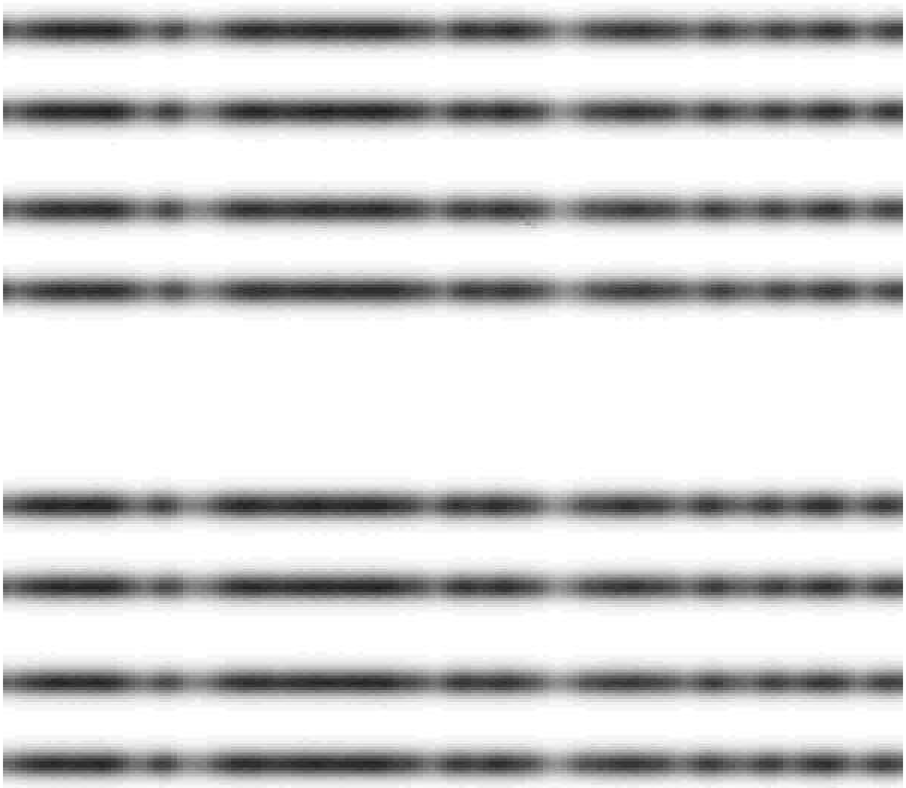

Figure 3: *The Zeeman spectra of 53 Cam recorded in the back-and-forth mode in the region of 4500 Å. The upper 4 spectra were recorded in phase and 4 lower spectra – in antiphase.*

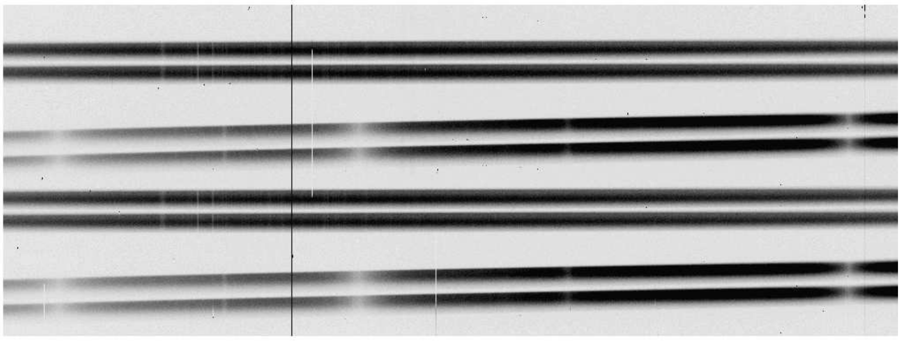

Figure 4: *Spectra recorded in back-and-forth mode in the region of 3900 Å and 5850 Å simultaneously using the crossdisperser.*

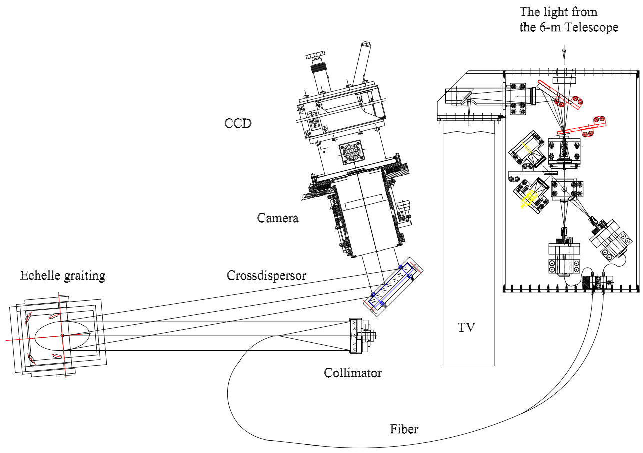

Figure 5: *The principal diagram of the echelle magnetometer.*

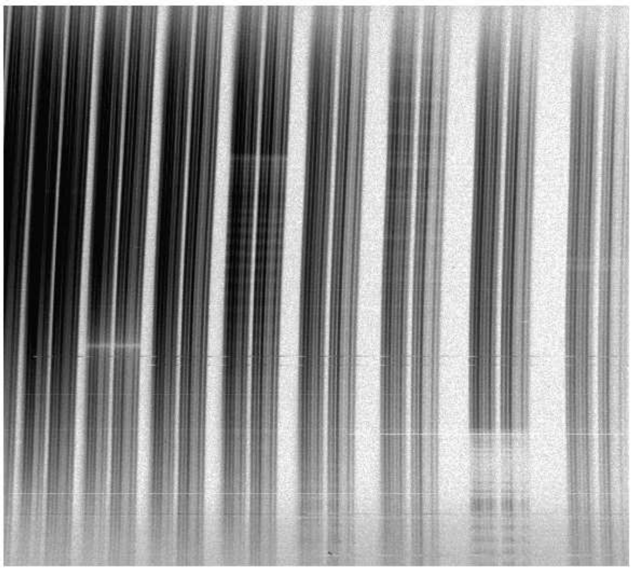

Figure 6: *The stellar echelle Zeeman spectrum.*

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References

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