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A Low–Resolution Spectropolarimeter for Zeeman Measurements of Stellar Magnetic Fields

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Abstract. We present a new spectropolarimeter based on the low–resolution slit spectrograph Boller & Chivens of the National Institute of Astronomy (Mexico) 2.1 m telescope. The instrument is intended to measure stellar longitudinal magnetic fields of stars from 8^m to 16^m with a characteristic accuracy from ≈ 0.5 kG to ≈ 10 kG .

Key words: instrumentation: polarimetry – magnetic fields – stars: individual (WD1658–441) – stars: magnetic fields – stars: white dwarfs

1 Introduction

Low–resolution spectropolarimeters are intended mainly for spectropolarimetric studies of faint objects. A significant part of these studies is related to their magnetism. The following studies are among the most important to be mentioned:

- *1. Magnetism of white dwarfs.*

  The investigation of white dwarf stars (WDs) is of fundamental importance for the understanding of stellar and galactic evolution, as WDs represent the final evolutionary stage of more than 90 % of all stars. Nowadays, we believe that the general properties and evolution of WDs are understood fairly well. However, there are several important problems that still need to be properly addressed, especially those connected with the group of about two hundred isolated magnetic white dwarfs (MWDs) (Angel et al., 1981; Schmidt &Smith, 1995; Liebert et al., 2003; Valyavin et al., 2003; Aznar Cuadrado et al., 2004) the origin of which is still not quite well understood.

- *2. Magnetism of hot subdwarf stars*

  The presence of kilogauss magnetic fields has been reported in hot subdwarf stars comparatively recently (Elkin, 1996; O'Toole et al., 2005). The importance of hot subdwarf star studies to the theory of stellar evolution is clear due to the fact that they exhibit a variety of evolutionary channels to the white dwarf stage (Greenstein & Sargent, 1974; Heber, 1986; Saffer et al., 1994, Williams et al., 2001a,b).

- *3. Magnetic fields in cataclysmic systems*

  A large number of great historical results in the studies of cataclysmic binary systems has come from the broad–band polarimetry and low–resolution spectropolarimetry. One of the most important of these studies is related to the discovery of polars. To review these results see, for instance, Wickramasinghe (1995)

This brief presentation illustrates the importance of low-resolution spectropolarimetry in the studies of cataclysmic and degenerate stars. Here we introduce a new spectropolarimeter mounted at the 2.1-m telescope of the National Astronomical Observatory (Ensenada, Mexico).

2 Spectropolarimeter: Design

The spectropolarimeter is based on the Cassegrain focus spectrograph B&Ch at the 2.1 m telescope of National Institute of Astronomy (Ensenada, Mexico). The instrument is intended for classic long–slit, low–resolution spectroscopy with several modes of resolution from $R\,500$ to $R\,4000$.

The polarimetric analyzer that we use in the spectropolarimetric mode consists of a rotatable quarter–wave plate for polarimetric modulation of circular polarization, and a Savart plate as a beam–splitter. In the present design (the design is very similar to that presented by Naidenov et al. (2002)) we decided to use the polymer quarter–wave plate (Samoylov et al., 2004) instead of the frequently used Quartz/MgF_2 crystal wave plate or Fresnel rhombs. The used polymer QWP gives the wave retardation of $0.25 \pm 0.007\lambda$ in the $4000 \sim 8000$ Å range (Samoylov et al., 2004), and ripple below 0.1 %. Outside of this region magnetic observations are also possible, but with some depolarization factor which should be measured and taken into account in the observations of standard stars.

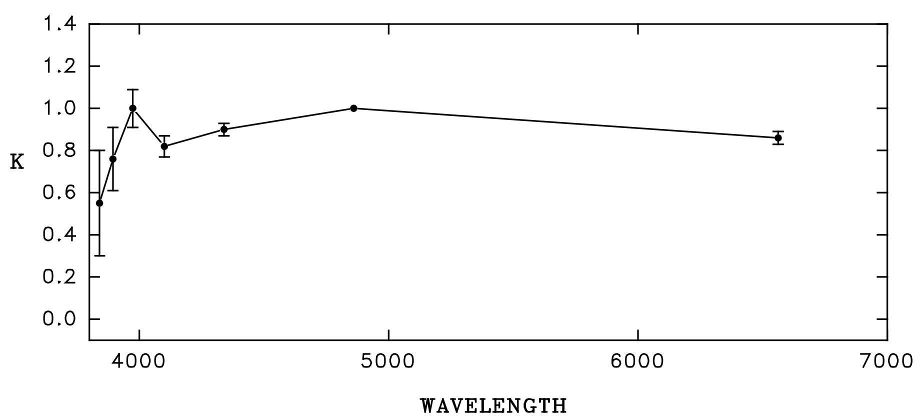

Figure 1: Magnetic sensitivity **k** over wavelengths

In order to estimate the depolarization factor (sensitivity of the instrument in the mode of circular polarization registration as a function of wavelength λ) we carried out observations of different magnetic stars with a well-known behaviour of their longitudinal magnetic fields. Obtaining circular polarizations, and measuring the longitudinal magnetic fields B_l at each of the Balmer lines we estimated $k(\lambda)$ as a relationship $\frac{B_l(\lambda_i)}{B_l(defacto)}$, where $B_l(\lambda_i)$ is a result of the measurement of the field at an individual spectral line i, and $B_l(defacto)$ is a "defacto" result taken from other studies. The depolarization function in the system *polarization optics + spectrograph + telescope* is presented in Fig. 1. As can be seen, in the wavelength region between 3900 Å and 7000 Å k characteristically varies from 0.8 to 1 what is an acceptable result.

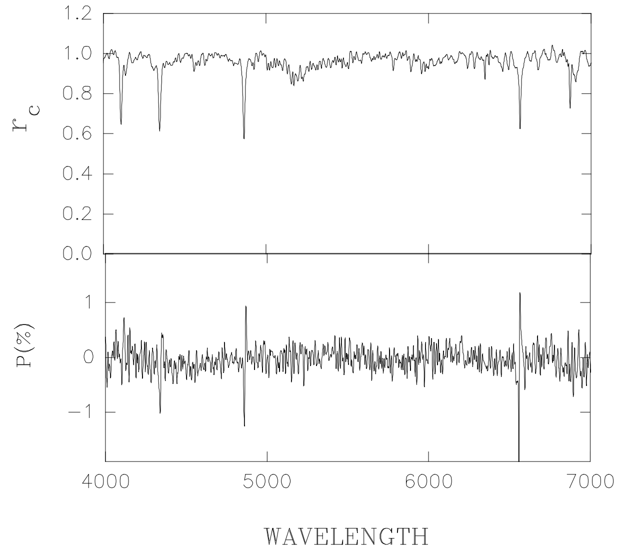

Figure 2: Spectrum (upper plot) and circular polarization (lower plot) of the star HD 215441

3 Tests

In order to test the instrument we carried out the observations of two well–known magnetic stars: HD 215441 (the Babcock's star, $m_V \approx 9^m$), and a strong magnetic white dwarf WD 1658+441 ($m_V \approx 15^m$, $B_l \approx 800$ kG). In the tests the B&Ch was used to derive the Stokes V profiles from the spectra of magnetic stars obtained with the grating 400 gv/mm that provides the interval from about 3600 Å to 7000 Å. With a slit width of 1 arcsec, the spectral resolving power was about 1000.

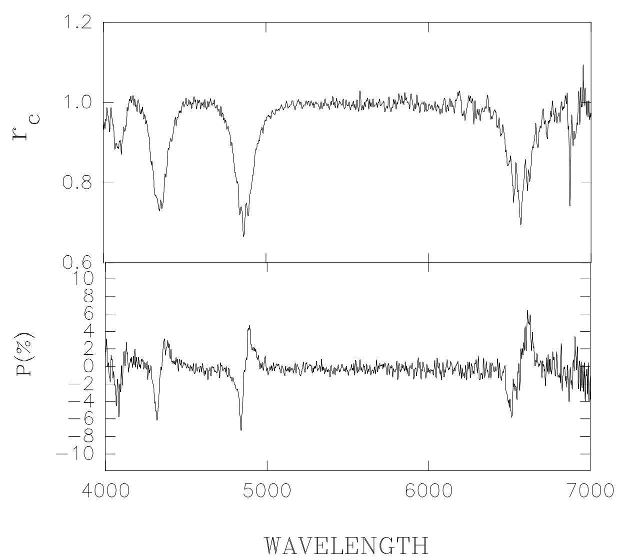

Figure 3: Spectrum (upper plot) and circular polarization (lower plot) of the magnetic white dwarf WD 1658+441

The derived intensity and circular polarization spectra of the studied stars are presented in Fig. 2 and Fig. 3. The spectra of a zero polarization standard are presented in Fig. 4. The Zeeman circular polarization in the observations of the star HD 215441 was registered once in the phase of its

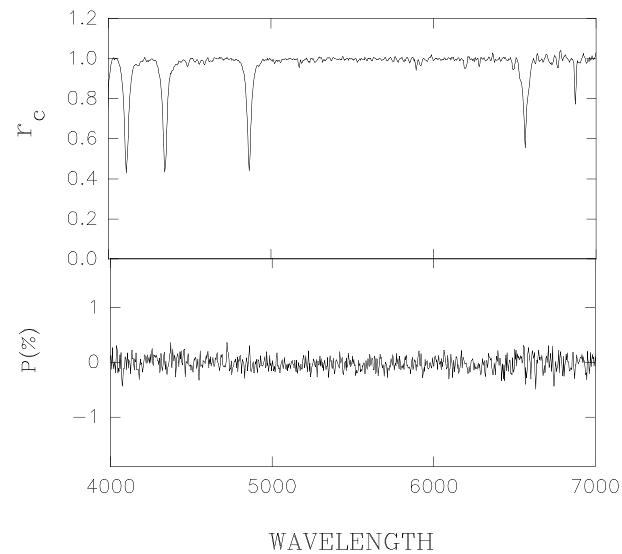

Figure 4: Spectrum (upper plot) and circular polarization (lower plot) of the zero polarization standard

maximal rotationally modulated longitudinal magnetic field. The measurements of the field using the Balmer lines yielded the result $B_l = +20.2 \pm 0.6$ kG. Measurements of the field of the magnetic white dwarf WD 1658+441 provide $B_l = +824 \pm 12$ kG, what is also a canonical result for this star (Shtol' et al., 1997).

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