COMMISSIONS 27 AND 42 OF THE IAU
INFORMATION BULLETIN ON VARIABLE STARS

Number 6019

Konkoly Observatory
Budapest
10 April 2012

HU ISSN 0374 – 0676

MAGNETIC FIELD AND SPECTRAL VARIABILITY OF THE Of?p STAR CPD−28 2561

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Walborn (1973) introduced the Of?p category for massive O stars displaying recurrent spectral variations in certain spectral lines, sharp emission or P Cygni profiles in He I and the Balmer lines, and strong C III emission lines around 4650 Å. Only five Galactic Of?p stars are presently known: HD 108, NGC 1624-2, CPD−28 2561, HD 148937, and HD 191612 (Walborn et al. 2010). Using the high-resolution ESPaDOnS spectropolarimeter, installed on the 3.6-m Canada-France-Hawaii Telescope, and the NARVAL spectropolarimeter at the Bernard Lyot telescope, mean longitudinal magnetic fields of the order of a few hundred gauss were detected in two Galactic Of?p stars, HD 191612 (Donati et al. 2006) and HD 108 (Martins et al. 2010). The detection of a mean longitudinal magnetic field $\langle B_z \rangle = -254 \pm 81$ G in the third Of?p star HD 148937 using FORS 1 at the VLT was previously reported by Hubrig et al. (2008) and was later confirmed by additional observations by Hubrig et al. (2011) and Wade et al. (2012). Our observations of the fourth Of?p star, CPD−28 2561, in 2010 with FORS 2 (Hubrig et al. 2011) enabled us to detect a magnetic field at a significance level of more than 3σ in a single observation. A successful attempt has been made to measure the magnetic field in the fifth Of?p star, NGC 1624-2 (Wade et al., in preparation).

Due to the relative faintness of the Of?p star CPD−28 2561 with $m_{\rm V} = 10.1$, it was only scarcely studied in the past. Levato et al. (1988) acquired radial velocities of 35 OB stars with carbon, nitrogen, and oxygen anomalies and found variability of a few emission lines with a probable period of 17 days. Walborn et al. (2010) mentioned that CPD−28 2561 undergoes extreme spectral transformations very similar to those of HD 191612, on a timescale of weeks, inferred from the variable emission intensity of the C III $\lambda\lambda$, 4647-4650-4652 triplet.

In this work we report on our new observations obtained in 2011 using FORS 2 at the VLT indicating the presence of a variable mean longitudinal magnetic field. Polarimetric spectra were obtained with the GRISM 600B and the narrowest slit width of 0.″4 to achieve a spectral resolving power of $R \sim 2000$. The use of the mosaic detector made of blue optimized E2V chips and a pixel size of 15 μm allowed us to cover a large spectral range, from 3250 to 6215 Å, which includes all hydrogen Balmer lines from Hβ to the Balmer jump. More details on the observing technique with FORS 1/2 and the data reduction can be found for example in Hubrig et al. (2004) and references therein. Using the method

Table 1: Longitudinal magnetic fields measured with FORS 2 in the Of?p star CPD−28 2561. All quoted errors are 1σ uncertainties.

MJD	$\langle B_z \rangle_{\rm all}$ [G]	$\langle B_z \rangle_{\rm hydr}$ [G]
55338.969	−381±122	−534±167
55685.982	99±82	65±108
55686.984	−44±80	6±102
55687.980	269±81	281±90

described in the same place, we obtained the mean longitudinal magnetic field $\langle B_z \rangle$, which is the component of the magnetic field parallel to the line of sight, averaged over the visible stellar hemisphere, weighted by the local emergent spectral line intensity. It is diagnosed from the slope of a linear regression of V/I versus the quantity $-\frac{g_{\rm eff} e}{4\pi m_e c^2}\lambda^2 \frac{1}{I}\frac{{\rm d}I}{{\rm d}\lambda}\langle B_z \rangle + V_0/I_0$, where V is the Stokes parameter that measures the circular polarization, I is the intensity observed in unpolarized light, $g_{\rm eff}$ is the effective Landé factor, e is the electron charge, λ is the wavelength, m_e is the electron mass, c is the speed of light, ${\rm d}I/{\rm d}\lambda$ is the derivative of Stokes I, V_0/I_0 is a constant, and $\langle B_z \rangle$ is the mean longitudinal magnetic field. The results of our measurements are presented in Table 1. Longitudinal magnetic fields were measured in two ways: using the entire spectrum including all available absorption lines (Column 2) and using only the absorption hydrogen Balmer lines (Column 3). The lines that show evidence of emission were not used to determine the magnetic field strength.

Our spectropolarimetric observations of this star indicate that the magnetic field is variable, but owing to the small number of measurements it is not possible to estimate the magnetic/rotation period. The new measurements obtained on May 5 and May 6 2011 are close to zero, while for the measurement carried out on May 7 2011 we achieve a 3 σ detection. This behaviour of the magnetic field can probably be explained by the strong geometric dependence of the longitudinal magnetic field, i.e. various orientation of the field at different rotation phases.

Spectropolarimetric observations on three consecutive nights in 2011 reveal strong variations in both the longitudinal magnetic field strength and several hydrogen and helium line profiles. The variation of He I λ4026, He I λ5876, and of Hβ on such a short time scale were not reported in the literature yet. A few examples of the detected spectral line profile variations are presented in Fig. 1. Apart from the He I λ4026 line, the contribution of a variable emission component is well visible in the other three lines. The profile of the He I λ4026 line appears only weakly variable. These variations have an amplitude of about 1–2% of the continuum level and can likely be explained by rotation modulation.

The line He II λ4686 exhibited strong emission during our observations in 2010, which transforms to a much weaker P Cygni line profile with a weak blue shifted absorption in 2011. A contribution of the emission component is clearly seen in the profile of the He I λ5876 line in 2010, but its presence can only be suspected in the variable line depth observed in 2011. A strong emission component is well visible in the line center of Hβ in 2010. The shape of the line profile of Hβ is similar to the behaviour of the Hα line profile in the spectra of 19 Cep presented in Fig. 13 of Kaper et al. (1997) and in Fig. 1 of Kholtygin et al. (2003).

Acknowledgments: Based on VLT observations in visitor mode (ESO programme 087.D-0049(A)).

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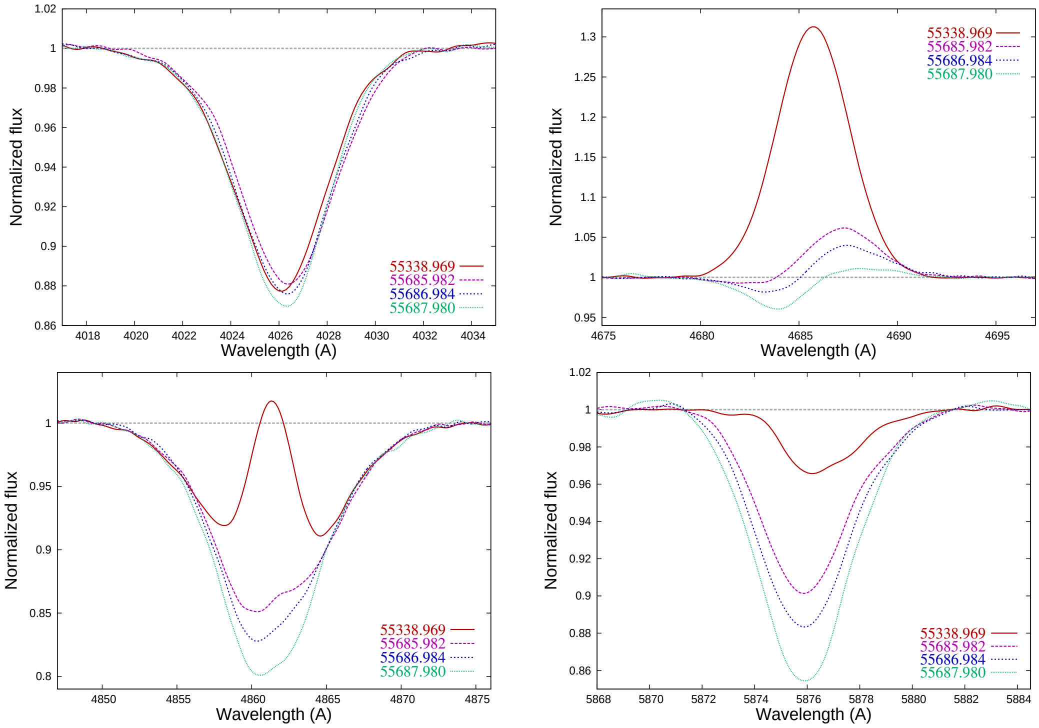

Figure 1. Distinct profile variability observed in the He I λ4026 (top left), He II λ4686 (top right), Hβ (bottom left), and He I λ5876 (bottom right) lines.