A magnetic study of the δ Scuti variable HD 21190 and the close solar-type background star CPD −83° 64B

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ABSTRACT
HD 21190 is a known δ Scuti star showing Ap star characteristics and a variability period of 3.6 h discovered by the Hipparcos mission. Using Gaia DR1 data for an astrometric analysis, it was recently suggested that HD 21190 forms a physical binary system with the companion CPD −83° 64B. An atmospheric chemical analysis based on HARPS observations revealed the presence of overabundances of heavy and rare-earth elements, which are typically observed in chemically peculiar stars with large-scale organized magnetic fields. Previous observations of HD 21190 indicated a magnetic field strength of a few hundred Gauss. The presence of a magnetic field in CPD −83° 64B remained unexplored. In this work, we reanalyse this system using Gaia DR2 data and present our search for the magnetic field in both stars based on multi-epoch HARPSpol high-resolution and FORS 2 low-resolution spectropolarimetric observations. The Gaia DR2 results clearly indicate that the two stars are not physically associated. A magnetic field detection at a significance level of more than 6σ (⟨Bz⟩all = 230 ± 38 G) was achieved for the δ Scuti variable HD 21190 in FORS 2 observations using the entire spectrum for the measurements. The magnetic field appears to be stronger in CPD −83° 64B. The highest value for the longitudinal magnetic field in CPD −83° 64B, ⟨Bz⟩all = 590 ± 104 G, is measured at a significance level of 4.9σ. Furthermore, the high-resolution HARPSpol observations of this component indicate the presence of pulsational variability on a time scale of tens of minutes.

Key words: stars: individual: HD 21190, CPD −83° 64B – stars: magnetic field – stars: oscillations

1 INTRODUCTION
HD 21190 is a known δ Scuti variable star showing Ap star characteristics. Using time-series photometry obtained by the Hipparcos mission, Koen et al. (2001) discovered a variability period of 3.6 h. According to these authors, the spectral classification of HD 21190 is F2 III SrEuSi, making it the most evolved Ap star known. González et al. (2008) used the Ultraviolet and Visible Echelle Spectrograph (UVES; Dekker et al. 2000) time-series of HD 21190 to search for pulsational line profile variations and were able to show that this star presents the best example of a δ Scuti star with moving bumps in its line profiles, which is characteristic for high-degree pulsations. The weak longitudinal magnetic field of HD 21190, ⟨Bz⟩hyd = 47 ± 13 G, was detected by Kurtz et al. (2008) from Focal Reducer low dispersion Spectrograph (FORS1; Appenzeller et al. 1998) observations in spectropolarimetric mode. Re-observation of this target, ⟨Bz⟩hyd = 237 ± 75 G and ⟨Bz⟩all = 254 ± 60 G using FORS 2 (Hubrig & Schöller 2016) with the same setup as Kurtz et al. (2008) confirmed the magnetic field detection.

A recent astrometric analysis (Niemczura et al. 2017) using Gaia DR1 data (Gaia Collaboration et al. 2016) showed that the δ Scuti variable HD 21190 forms a physical binary system with CPD −83° 64B at an angular distance of about 19′. An atmospheric chemical analysis based on observations with the High Accuracy Radial velocity Planet Searcher polarimeter (HARPSpol; Snik et al. 2008) yielded the abundances of 24 chemical elements in the atmosphere of HD 21190 and 28 chemical elements in CPD −83° 64B.

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Table 1. Gaia DR2 astrometry, radial velocities, and derived physical parameters of HD 21190 and CPD –83° 64B.

| Object       | RA\(^a\) [degrees] | DE\(^a\) [degrees] | Plx [mas] | distance\(^b\) [pc] | pmRA [mas yr\(^{-1}\)] | pmDE [mas yr\(^{-1}\)] | RV [km s\(^{-1}\)] | Teff [K] | radius \(R_\odot\) |
|--------------|---------------------|---------------------|---------|-----------------------|------------------------|------------------------|---------------------|---------|--------------|
| HD 21190     | 47.473840           | -83.531459          | 4.9811±0.0492 | 196.9±20.3          | -6.152±0.127         | +21.742±0.093         | -26.06±3.43          | 6798±97  | 3.85±0.07    |
| CPD –83° 64B| 47.432566           | -83.528743          | 4.0170±0.0542 | 247.2±13.4          | -0.210±0.143         | +24.116±0.098         | -26.06±3.43          | 5800±122 | 1.44±0.06    |

Notes:

\(^a\) Gaia DR2 coordinates are for (J2000, epoch 2015.5) and were rounded to 0.000001 degrees; \(^b\) estimated distances with their lower and upper bounds of their confidence intervals according to Bailer-Jones et al. (2018) were rounded to 0.1 pc; \(^c\) Gaia DR2 effective temperatures and their uncertainties were rounded to 1 K.

Niemczura et al. (2017) obtained the atmospheric parameters \(T_\text{eff} = 6900±100\) K and \(\log g = 3.60±0.20\) for HD 21190 and \(T_\text{eff} = 5850±50\) K and \(\log g = 4.3±0.1\) for CPD –83° 64B. The abundance analysis of HD 21190 showed that all the studied heavy and rare-earth elements appear overabundant, confirming the peculiar nature of this star. The abundance pattern for CPD –83° 64B appears mostly solar with modest enhancements of heavy and rare-earth elements.

With the most recent release of the Gaia DR2 data (Gaia Collaboration et al. 2018), it became possible to re-investigate the physical connection between the two stars. In the following, we present a brief analysis of these results. Further, while a few spectropolarimetric observations were obtained in the past for HD 21190, the presence of a magnetic field in CPD –83° 64B remained unexplored. We present our recently acquired multi-epoch high- and low-resolution spectropolarimetric observations for both objects.

2 GAIA DR2 RESULTS

Based on Gaia DR1 data, Niemczura et al. (2017) considered HD 21190 and CPD –83° 64B to be a wide binary system. However, the new Gaia DR2 (Gaia Collaboration et al. 2018) data clearly rule out a physical connection between these two objects and show that CPD –83° 64B is an unrelated background star appearing close to HD 21190. The Gaia DR2 data of HD 21190 and CPD –83° 64B, including parallaxes (and distance estimates by Bailer-Jones et al. (2018)), proper motions, the radial velocity of CPD –83° 64B, and derived physical parameters, are listed in Table 1. These data are discussed in the following subsections.

2.1 Astrometry

The physical association of HD 21190 and CPD –83° 64B previously asserted by Niemczura et al. (2017) was mainly based on the common proper motion derived by these authors using the same three epochs of modern non-photographic positional measurements for both sources, including Gaia DR1 (Gaia Collaboration et al. 2016) positions. The corresponding proper motions agreed within their error bars (about ±2 mas yr\(^{-1}\)). Niemczura et al. (2017) also considered the proper motions published in two different catalogues involving Gaia DR1 data, namely the 5th United States Naval Observatory CCD Astrograph Catalog (UCAC5) of Zacharias, Finch, & Frouard (2017) and the Tycho-Gaia Astrometric Solution (TGAS) of Lindegren et al. (2016). The difference between the TGAS proper motion of HD 21190 and the UCAC5 proper motion of CPD –83° 64B was found to be even smaller than 1 mas yr\(^{-1}\).

Whereas the Gaia DR2 proper motion of HD 21190 deviates by less than about 0.7 mas yr\(^{-1}\) from the above mentioned previous proper motion measurements, large discrepancies of 6–7 mas yr\(^{-1}\) in RA and 2–5 mas yr\(^{-1}\) in DE are found for CPD –83° 64B (see our Table 1 and Table 1 in Niemczura et al. (2017)). With the much higher precision of the Gaia DR2 proper motions (errors of the order of 0.1 mas yr\(^{-1}\) for both stars), the two stars can not be considered a common proper motion pair any longer.

The difference in their Gaia DR2 parallaxes is about 20 times larger than the formal errors (see Table 1). By simply inverting the parallaxes, we derive distances of 200.8 pc for HD 21190 and 248.9 pc for CPD –83° 64B, very similar to the distance estimates of Bailer-Jones et al. (2018) given in Table 1. Therefore, CPD –83° 64B lies about 50 pc further away than HD 21190. The new distances of both objects are much larger than the TGAS-based distance of HD 21190 (165 pc) that was used by Niemczura et al. (2017) as their assumed common distance.

We have also checked how reliable the astrometric data of both stars are with respect to various Gaia DR2 quality flags as discussed by Lindegren et al. (2018). Although the two stars lie beyond the 100 pc horizon used by Lindegren et al. (2018) for defining a high-quality sample (their “Selection C”) of 242,582 objects within 100 pc, they otherwise fulfill all their selection criteria applied to astrometric and photometric quality flags.

2.2 Radial velocity

A radial velocity measurement is reported in Gaia DR2 for only one of the two stars, CPD –83° 64B (see Table 1). This radial velocity is only slightly larger than the value of +19±0.5 km s\(^{-1}\) measured by Niemczura et al. (2017). On the other hand, a much larger radial velocity of +34.0±1.3 km s\(^{-1}\) was reported by the Radial Velocity Experiment (RAVE) DR5 (Kunder et al. 2017). As we found no hint on possible problems with the RAVE measurements of this star, it is possible that CPD –83° 64B is a close binary unresolved in Gaia DR2.

2.3 Physical parameters

Astrophysical parameters, including stellar effective temperatures, radii and luminosities, were derived for 77 million sources (Andrae et al. 2018) by using the Gaia DR2 photometry and parallaxes. These parameters are part of Gaia DR2. In Table 1 we show the Gaia DR2 effective temperatures and radii of HD 21190 and CPD –83° 64B. The effective temperatures are in good agreement with the values
estimated by Niemczura et al. (2017) in their analysis of the chemical abundances using high-resolution HARPSpol spectra.

3 OBSERVATIONS

The high-resolution spectropolarimetric observations of HD 21190 and CPD −83° 64B were obtained with HARPSpol attached to ESO’s 3.6 m telescope (La Silla, Chile). HD 21190 was observed on 2016 June 15, 18, and 19, while CPD −83° 64B was observed on 2016 June 16. Each observation consisted of subexposures with exposure times varying between 23 and 32 min for HD 21190 and between 18 and 30 min for CPD −83° 64B. The quarter-wave retarder plate was rotated by 90° after each subexposure. All spectra have a resolving power of about 110,000 and cover the spectral range 3780–6910 Å, with a small gap between 5250 Å and 5337 Å. The reduction and calibration of these spectra was performed using the HARPS data reduction software available on La Silla. The normalization of the spectra to the continuum level is described in detail in Hubrig et al. (2013). A summary of all HARPSpol observations is given in Table 2. The columns list the heliocentric Julian date (HJD) for the middle of the subexposures, the exposure time, and the signal-to-noise ratio (S/N) of the spectra.

Due to the rather short pulsation period of HD 21190 of 3.6 h discovered by Koen et al. (2001), the shape of the line profiles in the high-resolution spectropolarimetric observations is changing significantly over the pulsational cycle. Recently, Järvinen et al. (2017) showed that such high-resolution observations of pulsating variable stars frequently fail to deliver credible measurement results, if the whole sequence of subexposures at different retarder waveplate angles has a duration comparable to the timescale of the pulsation variability. To minimize the impact of pulsations on the magnetic field measurements, we asked for observing time with FORS2 mounted on the 8 m Antu telescope of the Very Large Telescope. FORS2 is a multi-mode instrument equipped with polarisation analysing optics comprising super-achromatic half-wave and quarter-wave phase retarder plates, and a Wollaston prism with a beam divergence of 22° in standard resolution mode. The exposure time with such an instrument is only of the order of a couple of minutes and no impact of pulsation on the field measurements is expected.

The acquired nine observations of HD 21190 and six observations of CPD −83° 64B summarized in Table 3 were spread between 2017 September and 2018 February. The columns list the modified Julian dates (MJD) for the middle of the exposure and the S/N in the Stokes I spectra around 5400 Å.

4 MAGNETIC FIELD ANALYSIS USING HIGH-RESOLUTION HARPS SPECTROPOLARIMETRY

To study the presence of a magnetic field in HD 21190 and CPD −83° 64B we employed the Least-Squares Deconvolution (LSD) technique (Donati et al. 1997). This technique combines line profiles (using the assumption that line formation is similar in all lines) centred at the position of the individual lines given in the line mask and scaled according to the line strength and sensitivity to a magnetic field (i.e. to a Landé factor). The resulting average profiles (Stokes I, Stokes V, and N) obtained by combining several lines, yield an increase in S/N as the square root of the number of lines used and therefore in sensitivity to polarization signatures. The diagnostic N profiles are usually used to identify spurious polarization signatures. They are calculated by combining the subexposures in such a way that the polarization cancels out.

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**Table 2.** Logbook of all individual subexposures of the spectropolarimetric observations of HD 21190 (left) and CPD −83° 64B (right) with HARPSpol. The columns give the heliocentric Julian date of mid-exposure, the exposure time, and the achieved S/N in the Stokes I spectra around 6450 Å.

| HJD 2450000+ | Exp. time (s) | S/N | HD 21190 | CPD −83° 64B |
|-------------|--------------|-----|----------|--------------|
| 57554.9222  | 1500         | 83  | 57555.8892 | 1800         |
| 57554.9400  | 1500         | 79  | 57555.9104 | 1800         |
| 57557.9197  | 1900         | 193 | 57555.9316 | 1800         |
| 57557.9409  | 1700         | 209 | 57555.9488 | 1100         |
| 57558.9206  | 1450         | 116 |               |               |
| 57558.9372  | 1360         | 124 |               |               |

**Table 3.** Logbook of the FORS2 observations of HD 21190 (left) and CPD −83° 64B (right). The columns list the modified Julian date of mid-exposure and the achieved S/N in the Stokes I spectra around 5400 Å.

| HD 21190 | CPD −83° 64B |
|----------|--------------|
| MJD      | S/N          | MJD | S/N         |
| 58003.2985 | 1665 | 58003.2660 | 1205 |
| 58031.233 | 3134 | 58031.1826 | 1200 |
| 58033.041 | 3107 | 58035.2615 | 1355 |
| 58035.2202 | 4117 | 58049.3210 | 955  |
| 58044.2433 | 3400 | 58080.0461 | 930  |
| 58116.0827 | 3500 | 58116.1296 | 1200 |
| 58150.0854 | 2570 |               |     |
| 58162.0494 | 2520 |               |     |
| 58207.0463 | 2540 |               |     |
Line masks for each component were constructed using the Vienna Atomic Line Database (VALD; e.g. Kupka et al. 2011; Ryabchikova et al. 2015) based on the stellar parameters of both targets. Only the lines that are present in the stellar spectra are used. Further, obvious line blends and lines in telluric regions were excluded from the line list. The mean longitudinal magnetic field is evaluated by computing the first-order moment of the Stokes $V$ profile according to Mathys (1989):

$$\langle B_z \rangle = -2.14 \times 10^{11} \frac{\int \nu V(\nu) d\nu}{\lambda_{g_0} \epsilon_n \int [\nu-I(\nu)] d\nu}$$

where $\nu$ is the Doppler velocity in km s$^{-1}$, and $\lambda_0$ and $g_0$ are the mean values for the wavelength (in nm) and the Landé factor obtained from all lines used to compute the LSD profile, respectively. We note that this equation is valid only in the velocity domain.

For HD 21190 we constructed a line mask containing 156 metallic lines with a mean Landé factor $g_{\text{eff}} = 1.32$ based on the stellar parameters $T_{\text{eff}} = 6900 \pm 100$ K and log $g = 3.6 \pm 0.2$ obtained by Niemczura et al. (2017). Since the subexposure times of 23–32 min of the HARPSpol observations of this ñ Scuti variable are rather long, constituting a significant fraction of the pulsation cycle, the observed line profiles exhibit very strong pulsational variability, leading to pulsational wavelength shifts that affect the magnetic field measurements. The impact of the pulsations is clearly visible in Fig. 1, where we present the LSD Stokes $V$ and $I$ profiles calculated for individual subexposures.

To exclude the pulsational impact on the magnetic field measurements, we decided to carry out the measurements of the line shifts between the spectra $(I+V)_0$ and $(I-V)_0$ in the first subexposure and the spectra $(I+V)_{90}$ and $(I-V)_{90}$ in the second subexposure separately (e.g. Hubrig et al. 2011; Järvinen et al. 2017). No definite magnetic field detection with a false alarm probability (FAP) $< 10^{-5}$ was achieved in the HARPSpol observations of HD 21190. Only for the first subexposure obtained during the first observing night we obtain $\langle B_z \rangle = 87 \pm 33$ G with a false alarm probability (FAP) of $5.8 \times 10^{-3}$, indicating a marginal detection. We classify the magnetic field measurements making use of the FAP (Donati et al. 1992), considering a profile with FAP $< 10^{-5}$ as a definite detection, $10^{-5} \leq \text{FAP} < 10^{-3}$ as a marginal detection, and FAP $\geq 10^{-3}$ as a non-detection.

The chemical abundance analysis of CPD $-$83° 64B by Niemczura et al. (2017) revealed that it is a G-type star with $T_{\text{eff}} = 5850 \pm 50$ K and log $g = 4.3 \pm 0.1$. The LSD Stokes $I$ and $V$ profile, together with the diagnostic null profile $N$, obtained using 730 metallic lines with a mean Landé factor $g_{\text{eff}} = 1.27$ are presented in Fig. 2. However, as Fig. 2 shows, the LSD null profile $N$ does not appear flat, indicating a possible presence of variability also in this star. Similar features were also observed in the null profiles of other G-type stars (see e.g. Marsden et al. 2014). Therefore, to minimize the impact of pulsations on the magnetic field measurements, we analysed the presence of a magnetic field on each individual subexposure in a similar way as for HD 21190. In Fig. 3 we present the LSD Stokes $I$ and $V$ profiles of CPD $-$83° 64B for each individual subexposure and the comparison of the individual LSD Stokes $I$ profiles with the average LSD Stokes $I$ profile. The distinct line profile variability, probably caused by the presence of pulsations, is clearly visible in the bottom panel displaying differences between the Stokes $I$ profiles computed for the individual subexposures and the average Stokes $I$ profile. As we show later in Sect. 6, the rotation pe-
period of CPD $-83^\circ$ 64B is too long for variability to be caused by spots.

Only marginal field detections were achieved for the individual subexposures with field strengths varying from $-103$ G to $218$ G, the best FAP value attained was $4 \times 10^{-5}$. To summarize, our high-resolution HARPSpol observations of light, $d$, are certainly affected by the presence of pulsations and do not allow us to make any definite conclusion on the presence or absence of a longitudinal magnetic field in either star.

5 MAGNETIC FIELD ANALYSIS USING LOW-RESOLUTION FORS 2 SPECTROPOLARIMETRY

A description of the assessment of the presence of a longitudinal magnetic field using FORS 1/2 spectropolarimetric observations was presented in our previous work (e.g. Hubrig et al. 2004a,b, and references therein). Rectification of the $V/I$ spectra was performed in the way described by Hubrig et al. (2014b). Null profiles $N$ are calculated as pairwise differences from all available $V$ profiles so that the real polarisation signal should cancel out. From these, $3\sigma$-outliers are identified and used to clip the $V$ profiles. This removes spurious signals, which mostly come from cosmic rays, and also reduces the noise. A full description of the updated data reduction and analysis will be presented in a separate paper (Schöller et al., in preparation, see also Hubrig et al. 2014b).

The mean longitudinal magnetic field, $\langle B_z \rangle$, is measured on the rectified and clipped spectra based on the relation following the method suggested by Angel & Landstreet (1970):

$$\frac{V}{I} = \frac{g_{\text{eff}} e \lambda^2}{4\pi m_e c^2} \frac{1}{\lambda} \frac{dI}{d\lambda} \langle B_z \rangle,$$

where $V$ is the Stokes parameter that measures the circular polarization, $I$ is the intensity in the unpolarized spectrum, $g_{\text{eff}}$ is the effective Landé factor, $e$ is the electron charge, $\lambda$ is the wavelength, $m_e$ is the electron mass, $c$ is the speed of light, $dI/d\lambda$ is the wavelength derivative of Stokes $I$, and $\langle B_z \rangle$ is the mean longitudinal (line-of-sight) magnetic field.

The longitudinal magnetic field was measured in two ways: using the entire spectrum including all available lines, or using exclusively hydrogen lines. Furthermore, we have carried out Monte Carlo bootstrapping tests. These are most

| MJD          | $\langle B_z \rangle_{\text{all}}$ (G) | Signif. $\sigma$ | $\langle B_z \rangle_{\text{hydr}}$ (G) | $\langle B_z \rangle_{\text{B}}$ (G) |
|--------------|----------------------------------|------------------|--------------------------------------|----------------------------------|
| 54343.2791$^1$ | -                                | -                | 47±13                                | -                                |
| 57462.0051$^2$ | $-254\pm60$                      | 4.3              | $-237\pm75$                         | 54±62                            |
| 58003.2985    | 246±61                           | 4.0              | 174±91                              | 19±57                            |
| 58031.1233    | 129±44                           | 2.9              | 96±68                               | $-39\pm35$                       |
| 58033.0411    | 257±64                           | 4.0              | 200±97                              | 26±44                            |
| 58035.2202    | 173±35                           | 4.9              | 148±54                              | 5±24                             |
| 58044.2433    | 230±38                           | 6.1              | 132±61                              | 43±30                            |
| 58116.0827    | 137±35                           | 3.9              | 159±57                              | $-21\pm27$                       |
| 58150.0854    | 46±39                            | 1.2              | 45±62                               | 29±41                            |
| 58162.0494    | $-15\pm27$                       | 0.6              | $-23\pm66$                         | $-3\pm28$                        |
| 58207.0463    | 160±62                           | 2.6              | 211±96                              | $-9\pm60$                        |

Note:
1 The measurement at MJD 54343.2791 was previously reported by Kurtz et al. (2008).
2 The measurement at MJD 57462.0051 was previously reported by Hubrig & Schöller (2016).
often applied with the purpose of deriving robust estimates of standard errors (e.g. Steffen et al. 2014). The measurement uncertainties obtained before and after the Monte Carlo bootstrapping tests were found to be in close agreement, indicating the absence of reduction flasks. The results of our magnetic field measurements, those for the entire spectrum or only for the hydrogen lines are presented for HD 21190 and CPD –83° 64B in Tables 4 and 5, respectively. Distributions of the mean longitudinal magnetic field values as a function of MJD obtained for both stars are presented in Figs. 4 and 5.

For HD 21190, the values for the longitudinal magnetic field \( \langle B_z \rangle_{\mathrm{all}} \) vary roughly between –250 G and 250 G, with the measurement \( \langle B_z \rangle_{\mathrm{all}} = 230 \pm 38 \) G at a significance level of 6.1σ. The magnetic field appears to be stronger in CPD –83° 64B although the uncertainties of the field determination in this component are higher due to its faintness with \( m_V = 10.8 \). The highest value for the longitudinal magnetic field, \( \langle B_z \rangle_{\mathrm{all}} = 509 \pm 104 \) G, is measured at a significance level of 4.9σ.

6 Period Analysis

Based on the new distance estimates presented in Table 1 and the apparent magnitudes of the stars (the ASCC-2.5 catalogue; Kharchenko 2001, \( V = 7.604 \) for HD 21190 and \( V = 10.815 \) for CPD –83° 64B), we obtain for both targets the absolute visual magnitudes \( M_V = 1.10 \pm 0.05 \) and \( M_V = 3.85 \pm 0.03 \), respectively. After applying the corresponding bolometric corrections of 0.028 and – 0.067 (Flower 1996), we obtain the luminosity \( \log(L/L_\odot) = 1.44 \pm 0.01 \) for HD 21190 and the luminosity \( \log(L/L_\odot) = 0.38 \pm 0.01 \) for CPD –83° 64B. Using the Stefan-Boltzmann law with the effective temperature values derived from high-resolution spectra by Niemczura et al. (2017), we derive stellar radii of \( 3.69 \pm 0.07 \) \( R_\odot \) and \( 1.51 \pm 0.03 \) \( R_\odot \). The obtained radii are identical within the uncertainties with the radii estimated using the Gaia DR2 data presented in Table 1. With these radii and the \( \text{vsini} \) values of \( 74 \pm 3 \) km s\(^{-1} \) and \( 3.1 \pm 0.7 \) km s\(^{-1} \) from Niemczura et al. (2017), we obtain upper limits for the rotation period: \( P_{\text{rot}} < 2.5 \pm 0.1 \) d for HD 21190 and \( P_{\text{rot}} < 25 \pm 4.2 \) d for CPD –83° 64B.

Magnetic Ap and Bp stars usually exhibit photometric, spectral and magnetic variability with the rotation period. Unfortunately, in our study, the number of available magnetic field measurements is only eleven (including two previously published measurements) for the primary component and only six for the secondary component. We nevertheless tried to detect the most probable rotation period for HD 21190 by calculating the frequency spectrum. Our analysis was performed using a non-linear least squares fit to the multiple harmonics utilizing the Levenberg-Marquardt method (Press et al. 1992). For each trial frequency we performed a statistical F-test of the null hypothesis for the absence of periodicity (Seber 1977). The resulting F-statistics can be thought of as the total sum including covariances of the ratio of harmonic amplitudes to their standard deviations, i.e. a signal-to-noise ratio.

The highest peak in the periodogram calculated for the magnetic field measurements including the previously published values corresponds to a period of \( 1.02471 \pm 0.00045 \) d with an FAP of \( 2.89 \times 10^{-9} \). The distribution of the mean longitudinal magnetic field values phased with this period is presented in Fig. 6 in the left panel. Using the above estimated stellar radius \( R = 3.69 \pm 0.07 \) \( R_\odot \), \( \text{vsini} = 74 \pm 3 \) km s\(^{-1} \), and the rotation period \( P_{\text{rot}} = 1.02471 \pm 0.00045 \) d, we obtain \( \nu_{\text{eq}} = 182 \pm 4 \) km s\(^{-1} \) and an inclination angle of the stellar rotation axis to the line of sight \( i = 24 \pm 2^\circ \).

In the case when only the new measurements of the magnetic field are used, the highest peak in the periodogram corresponds to a period of \( 1.64933 \pm 0.00043 \) d with an FAP of \( 2.01 \times 10^{-6} \). The distribution of the most recent mean longitudinal magnetic field values phased with this period is presented in Fig. 6 in the right panel. This period leads to \( \nu_{\text{eq}} = 101 \pm 2 \) km s\(^{-1} \) and an inclination angle of the stellar rotation axis to the line of sight \( i = 47 \pm 1^\circ \).

We note that due to the rather low number of magnetic field measurements, our results on the period search are only tentative and should be verified by additional spectropolarimetric observations.
7 DISCUSSION

The recent atmospheric chemical analysis of Niemczura et al. (2017) based on HARPSpol observations confirmed the presence of chemical peculiarities in HD 21190. According to the authors, HD 21190 is currently the only known case of an Ap star with a detected magnetic field that shows δ Scuti pulsations. CPD −83° 64B appeared mostly solar with modest enhancements of heavy and rare-earth elements.

Although previous studies showed that HD 21190 exhibits δ Scuti pulsations, the possible presence of pulsations in CPD −83° 64B was discovered in the current work exclusively through spectroscopic observations. Pulsations in solar-like stars are mainly acoustic modes excited by turbulent convection like in the Sun, and are predicted for all main-sequence and post-main-sequence stars cool enough to harbour an outer convective envelope (e.g. Di Mauro 2016). Future spectroscopic and photometric monitoring will be worthwhile to characterize this short-time variability in CPD −83° 64B.

Whereas the previous astrometric analysis (Niemczura et al. 2017) using Gaia DR1 data (Gaia Collaboration et al. 2016) showed that the δ Scuti variable HD 21190 forms a physical binary system with CPD −83° 64B at an angular distance of about 19°, the more recent Gaia DR2 results clearly indicate that the two stars are not physically associated.

The initial idea to search for magnetic fields in HD 21190 and CPD −83° 64B originated under the aspect that both targets are physical components of a wide binary. A detection of magnetic fields in components of a wide binary could possibly be related to the most important issue related to the nature of magnetic chemically peculiar stars, namely the origin of their magnetic fields, which is still not properly understood. A scenario for the origin of the magnetic fields of Ap stars, in which these stars result from the merging of two lower mass protostars, was suggested by Ferrario et al. (2009). In this scenario, the binaries that are observed now are triple systems earlier in their history. If the hypothesis that the magnetic field originates in dynamos driven by violent mixing of stellar plasma when two stars merge is valid, one would expect that only very few magnetic massive stars are found in close binaries. Indeed, close binary or multiple systems with the particular combination of a magnetic and a non-magnetic star or two magnetic stars are very rare. Among the studied binary systems with A and late B-type primaries, only two systems, HD 98088 and HD 161701, are known to have a magnetic Ap star as a component (Babcock 1958; Hubrig et al. 2014a). Should a wide third component be essential to lead to mergers and thus to Ap stars with a magnetic field, this wide component should still be physically bound to the magnetic Ap star and be detectable as a wider binary component (Mazeh & Shaham 1979). Unfortunately, the new astrometric analysis of HD 21190 and CPD −83° 64B showed that these two objects are not such a wide pair.

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