The very slow rotation of the magnetic O9.7 V star HD 54879

S. Hubrig1,† S. P. Järvinen1, M. Schöller2, and C. A. Hummel2

1Leibniz-Institut für Astrophysik Potsdam (AIP), An der Sternwarte 16, 14482 Potsdam, Germany
2European Southern Observatory, Karl-Schwarzschild-Str. 2, 85748 Garching, Germany

ABSTRACT

The first FORS2 spectropolarimetric observation of the longitudinal magnetic field of HD 54879 of the order of $-600\text{G}$ with a lower limit of the dipole strength of $\sim 2\text{kG}$ dates back to 2014. Since then observations showed a gradual decrease of the absolute value of the mean longitudinal magnetic field. In the course of the most recent monitoring of HD 54879 using FORS2 spectropolarimetric observations from 2017 October to 2018 February, a longitudinal magnetic field strength change from about $-300\text{G}$ down to about $-90\text{G}$ was reported. A sudden increase of the absolute value of the mean longitudinal magnetic field and an accompanying spectral variability was detected on 2018 February 17. New FORS2 spectropolarimetric data obtained from 2018 December to 2019 February confirm the very slow magnetic field variability, with the field decreasing from about $150\text{G}$ to $-100\text{G}$ over two months. Such a slow magnetic field variability, related to the extremely slow rotation of HD 54879, is also confirmed using high-resolution HARPSpol and ESPaDOnS spectropolarimetry. The re-analysis of the FORS2 polarimetric spectra from 2018 February indicates that the previously reported field increase and the change of the spectral appearance was caused by improper spectra extraction and wavelength calibration using observations obtained at an insufficient signal-to-noise ratio. The presented properties of HD 54879 are discussed in the context of the Of?p spectral classification.

Key words: stars: individual: HD 54879 – stars: early-type – stars: atmospheres – stars: variables: general – stars: magnetic fields

1 INTRODUCTION

Only few massive O-type stars possess strong large-scale organized magnetic fields. One of them, the O9.7 V star HD 54879 was detected as magnetic by Castro et al. (2015) using the FOcal Reducer low dispersion Spectrograph (FORS2; Appenzeller et al. 1998) and the High Accuracy Radial velocity Planet Searcher in polarimetric mode (HARPSpol; Snik et al. 2008). The authors reported the presence of a $-600\text{G}$ longitudinal magnetic field with a lower limit of the dipole strength of $\sim 2\text{kG}$. Numerical MHD simulations describing the interaction of the magnetic field of this star with its wind were recently discussed by Hubrig et al. (2019). In the same work, Hubrig et al. (2019) presented 26 new FORS2 spectropolarimetric observations of HD 54879 obtained from 2017 October 4 to 2018 February 21 showing a change of the mean longitudinal magnetic field from about $-300\text{G}$ down to about $-90\text{G}$. The authors also reported on a sudden, short-term increase of the absolute value of the mean longitudinal magnetic field on the night of 2018 February 17, measuring a longitudinal magnetic field of $-833\text{G}$. The inspection of the FORS2 spectrum acquired during that night also indicated a change in spectral appearance and a decrease of the radial velocity by several $10\text{km s}^{-1}$.

Since such an unusual behaviour was not observed for other massive magnetic stars, we decided to monitor the magnetic field variability again and obtained data between 2018 December and 2019 February. In the following, we report on our results obtained from these most recent FORS2 spectropolarimetric observations, indicating a very slow change of the magnetic field related to slow stellar rotation. High-resolution spectropolarimetric observations confirm the results of the magnetic field measurements made using low-resolution FORS2 spectropolarimetric observations. Our new results are also discussed in the context of the previous detection of a short-term field increase and the change of spectral appearance.
2 OBSERVATIONS AND MAGNETIC FIELD ANALYSIS

24 new spectropolarimetric observations of HD 54879 with FORS2 were obtained between 2018 December 16 and 2019 February 15 in the framework of our programme 0102.D-0285 executed in service mode at the ESO VLT. Among them, five observations were obtained outside the weather specifications and appear underexposed with signal-to-noise ratios $(S/N) \leq 1300$, whereas one observation yielded saturated spectra. In the following, we will discuss the 18 unsaturated high $S/N$ spectra, while we discuss the five lower $S/N$ spectra in more detail in Sect. 5.

All spectra were observed with the GRISM 600B and the narrowest available slit width of $0.′′1$ to obtain a spectral resolving power of $R \approx 2000$. The observed spectral range from 3250 to 6215 Å includes all Balmer lines, apart from Hα, and numerous helium lines. Further, in our observations, we used a non-standard readout mode with low gain (200kHz,1×1,low), which provides a broader dynamic range, hence allowing us to reach a higher $S/N$ in the individual spectra. The extraction of the parallel and perpendicular beams on the FORS2 raw data was carried out using a pipeline written in the MIDAS environment by T. Szeifert, (in the following called the MIDAS pipeline). More details on the observational and reduction methods can be found in Hubrig et al. (2019) and references therein.

The results of the measurements are listed in Table 1, where the first two columns give the modified Julian dates (MJDs) for the middle of the exposure and the $S/N$ values of the spectra. The results of our magnetic field measurements, those for the entire spectrum and those using only the hydrogen lines, are presented in Columns 3 and 4, followed by the measurements using all lines in the null spectra. Null spectra $N$ are calculated as pairwise differences from all available Stokes $V$ profiles so that the real polarization signal should cancel out.

| MJD   | $S/N$ | $〈B_z 〉_{\text{all}}$ (G) | $〈B_z 〉_{\text{hyd}}$ (G) | $〈B_z 〉_N$ (G) |
|-------|-------|---------------------------|---------------------------|-----------------|
| 58468.1062 | 1740 | 153±91 | 216±169 | 12±89 |
| 58474.3364 | 2210 | 82±63 | 32±140 | 34±65 |
| 58478.3144 | 2910 | 5±59 | 135±123 | 4±66 |
| 58479.2787 | 2220 | −71±88 | 40±137 | −44±80 |
| 58480.0776 | 2340 | −32±102 | 24±148 | 19±112 |
| 58482.2096 | 2390 | 42±65 | −49±97 | −6±63 |
| 58483.0487 | 1520 | −20±107 | −101±170 | 78±103 |
| 58484.1973 | 2040 | 38±81 | 76±123 | 15±79 |
| 58488.1147 | 2620 | −55±73 | −21±128 | 74±78 |
| 58489.3414 | 1870 | −48±92 | −24±129 | −12±88 |
| 58493.3380 | 2300 | −65±59 | 81±99 | 23±63 |
| 58496.0606 | 2110 | −22±81 | −89±105 | −78±78 |
| 58511.0924 | 2280 | 67±80 | 14±107 | −52±83 |
| 58524.0605 | 2440 | 45±67 | −19±98 | 16±65 |
| 58525.1362 | 1980 | 125±103 | 61±138 | −41±99 |
| 58526.2129 | 2080 | 50±82 | 117±132 | 10±78 |
| 58527.1349 | 2210 | −102±88 | 39±138 | −35±89 |
| 58529.1940 | 1960 | −107±99 | −292±160 | −68±103 |

Figure 1. Top panel: Distribution of the mean longitudinal magnetic field values of HD 54879 using the entire spectrum (open blue circles) and those using only the hydrogen lines (open red triangles) as a function of MJD between the years 2014 and 2019. Open black squares and filled stars indicate high-resolution spectropolarimetric observations with HARPS and ESPaDOns, respectively. Bottom panel: Distribution of the mean longitudinal magnetic field values of HD54879 measured with FORS2 as a function of MJD between 2018 December 16 and 2019 February 15.

The distribution of the mean longitudinal magnetic field values as a function of MJD is presented in Fig. 1. In the top panel of this figure, we show all FORS2 longitudinal magnetic field measurements acquired between 2014 February 8 and 2019 February 20. The most recent measurements obtained from December 2018 to February 2019 are presented in the bottom panel. While the few observations from 2014 and 2015 indicated a mean longitudinal magnetic field of the order of $−500\, \text{G}$ to $−900\, \text{G}$, we observe in the last years a significantly weaker longitudinal magnetic field with values between $−300\, \text{G}$ and $+150\, \text{G}$. The strongest longitudinal magnetic field of positive polarity of $150\, \text{G}$ was measured on 2019 February 15. These measurements together with those presented by Hubrig et al. (2019) indicate that the rotation period of HD 54879 is very long, at least several years, and that from 2017 October to 2019 February we are observing the star at rotational phases with the best visibility of the magnetic equator. A small scatter in the measurements of the magnetic field is frequently observed in massive O-type stars and is most likely due to contamination by the immediate stellar environment with a denser cooling disc, confined to the magnetic equatorial plane (e.g. Hubrig et al. 2015; Shultz & Wade 2017). However, the scatter we see in the measurements presented in Fig. 1 is within the uncertainties represented by the error bars.
As already reported by Järvinen et al. (2017), three spectropolarimetric observations of HD 54879 were obtained with the HARPS polarimeter attached to ESO’s 3.6 m telescope (La Silla, Chile) at a spectral resolution of about 115 000 on 2014 April 22, and on 2015 March 11 and March 14. The published values of the mean longitudinal magnetic field showed a change from −578 G in 2014 to −487 G in 2015. Recently, nine ESPaDOnS (Echelle SpectroPolarimetric Device for the Observation of Stars; Donati et al. 2006) spectra with a spectral resolution of 65 000 obtained between 2014 November and 2018 January became publicly available in the CFHT archive. Among them, two observations were obtained on the same night on 2014 November 9. To measure the longitudinal magnetic field, we employed the least-squares deconvolution (LSD) technique, allowing us to achieve a much higher S/N in the polarimetric spectra. The LSD technique combines line profiles (assumed to be identical) centred on the position of the individual lines and scaled according to the line strength and sensitivity to a magnetic field. The details of this technique and of the calculation of the Stokes I and Stokes V parameters can be found in the work of Donati et al. (1997). The line masks employed in the measurements of the longitudinal magnetic fields, one with 127 lines including the He and the metal lines and the second one with 113 metal lines, were constructed using the Vienna Atomic Line Database (VALD3; Kupka et al. 2011) and the stellar parameters \( T_{\text{eff}} = 30.5 \, \text{kK} \) and \( \log g = 4.0 \) reported by Shenar et al. (2017). The calculated LSD Stokes I and Stokes V profiles for each observing epoch are presented in Fig. 2. The measurements using both line masks are listed in Table 2 along with the modified Julian dates for the middle of the exposure, the exposure times, and the S/N values of the spectra. In all cases the false alarm probability was less than 10^{-10}. Notably, the distribution of data points obtained for the high-resolution spectropolarimetric observations in Fig. 1 fits the low-resolution FORS2 measurements very well, indicating that the measurements using low resolution spectropolarimetry are fully consistent with those made with other instruments.

3 HIGH-RESOLUTION SPECTROPOLARIMETRY OF HD 54879

To check the consistency of the low-resolution FORS2 magnetic field measurements with measurements using high-resolution spectropolarimeters, we overplotted in Fig. 1 these FORS2 measurements with high-resolution longitudinal magnetic field measurements obtained from archival data. We discuss these observations in the following section.

4 ROTATION PERIOD AND SHORT-TERM VARIABILITY

The magnetic field measurements presented in Fig. 1 at MJDs between 56908 and 58529 suggest that the rotation period of HD 54879 is very long. Assuming that the negative field extremum reaches a value of −500 G to −900 G, measured in 2014 February, and not having reached yet this value by 2019 February, it is very likely that the rotation cycle is longer than five years.

Additional evidence for a very long rotation period follows from the consideration of the variability of the Hα line profiles. Previous studies of magnetic massive stars revealed a correlation between the absolute value of the mean longitudinal magnetic field and the strength of the Hα emission in the sense that the strongest Hα emission appears at phases of maximum absolute value of the mean longitudinal magnetic field (Sundqvist et al. 2012). Also the light curves in the visible and the X-ray emission strengths usually display a positive correlation with the absolute value of the mean longitudinal magnetic field. In Fig. 3a we present profiles of Hα emission observed in the high-resolution ESPaDOnS spectra. The shape of the Hα emission observed in these spectra obtained from 2014 November to 2018 January is extremely variable, changing between a triple-peak and a double-peak
We present our measurements of equivalent width (EW) presented in Table A1 in the work of Shenar et al. (2017), who detect the lowest emission EW in 2017 February. The observations of the Hα profile variability presented by these authors in their Figure 13 go back to 2009. However, none of the displayed Hα profiles shows such a low emission level as observed in 2017 January in the ESPaDOnS spectra. Since other massive magnetic stars show a variability of the Hα emission strength with the stellar rotation period, the fact that the lowest Hα emission profile has been observed only once since 2009 may suggest that the rotation period of HD 54879 is longer that 9 yr.

In Fig. 3b and 3c we show the variability of Hα on different, much shorter time scales. The two profiles overplotted in Fig. 3b were observed in ESPaDOnS spectra on a time scale of 17 d, whereas those presented in Fig. 3c have a time lapse of only 88 min. A small variability in the line cores of C III 5696 and Si III 5697 on a time scale of a few minutes can be seen in Fig. 3d, which is however on the same scale as the noise in the continuum and will need higher S/N data for verification. The observed short-term spectral variability is not expected to be caused by changes in the star’s stellar parameters, but might be related to the wind or immediate environment of the star, including a denser cooling disc confined to the magnetic equatorial plane (e.g. Martins et al. 2012). In absence of sufficient centrifugal support due to the slow rotation, material accumulated in the disc and located below the corotation radius falls back onto the stellar surface.

It is of interest that the typical Of?p star HD 108 with a rotation period of several decades shows He i and Balmer line variability on time-scales of days, similar to the observed short-term variability of HD 54879. A short-term variability on the time scale of hours was reported for another Of?p star, CPD −28° 2561, by Hubrig et al. (2015). The variability domain of minutes or tens of minutes in magnetic O-type stars remains however until now unexplored due to the lack of suitable spectroscopic and photometric time-series.

Apart from Hα, also the H ii 4686 line is a very sensitive stellar wind indicator and can be used to study the variability in high-resolution HARPSpol and ESPaDOnS spectra. In Fig. 4 we present our measurements of equivalent widths and radial velocities of this line in spectra obtained from 2014 October to 2018 January. The equivalent widths (EWs) measured on the HARPSpol spectra appear larger than those measured in the ESPaDOnS spectra, probably due to the much higher spectral resolution of HARPSpol. In spite of the large dispersion of measurements in the spectra

![Figure 3](image1.png)

**Figure 3.** Stokes I profiles recorded in ESPaDOnS spectra showing variability of the Hα line profile on short- and long-term scales. The small changes found in the line cores of the C III 5696 and Si III 5697 lines on a time scale of a few minutes and displayed in panel d are of the same order as the noise in the continuum and need to be verified with higher S/N data.

![Figure 4](image2.png)

**Figure 4.** Equivalent widths (left panel) and radial velocities (right panel) of the He ii 4686 line measured in the high-resolution HARPS and ESPaDOnS spectra obtained from 2014 April to 2018 January.
obtained in the last years, it appears quite possible that the distribution of the data points for the ESPaDOnS spectra indicates a small decrease of the strength of the He\textsc{ii}\ 4686 line in 2018. The results of the radial velocity measurements presented in this figure on the right side show a slightly decreasing trend, which however is of the order of the measurement accuracies.

The first radial velocity measurement reported in the literature, $v_{\text{rad}} = 15.6 \pm 1.4 \text{ km s}^{-1}$ by Neubauer (1943), was followed by the work of Boyajian et al. (2007), who reported $v_{\text{rad}} = 35.4 \pm 1.4 \text{ km s}^{-1}$. Castro et al. (2015) compared in their Table 4 the radial velocity measurement of 29.5 $\pm$ 1.0 km s\(^{-1}\) from one HARPS spectrum with other measurements in the literature and concluded that HD 54879 could be a member of a long-period binary system. Our own measurements using the ESPaDOnS Stokes I spectra and employing the LSD technique indicate that the radial velocity slightly decreased to $v_{\text{rad}} = 27.0 \pm 0.1 \text{ km s}^{-1}$ measured on the most recent ESPaDOnS spectra obtained in 2018 January. In Fig. 5 we present the compiled literature measurements complemented by the three HARPS and nine most recent ESPaDOnS observations. A very slow but gradual decrease in radial velocity can probably be considered as real in view of the high measurement accuracy reached in high-resolution spectropolarimetric observations using the LSD technique and indicates that HD 54879 could be a member of a binary system with a very long orbital period. Obviously, future monitoring of HD 54879 with high-resolution spectroscopy is necessary to confirm the observed decrease in EWs and radial velocities.

We also tested whether it is possible to use the low resolution of FORS2 observations to study the variability of the He\textsc{ii} 4686 line over the time interval from 2017 October 4 to 2019 February 15. The radial velocity changes for the He\textsc{ii} 4686 line in FORS2 spectra acquired between 2017 October 4 and 2018 February 21 are presented in Fig. 6 on the left side and those measured on the spectra obtained between 2018 December 16 and 2019 February 15 on the right side of the same figure. It is obvious that the scatter of the data points presented in both panels is too big to allow us to make any conclusion on the variability of the radial velocities. This result is in line with the previous inconclusive search of periodicity by Hubrig et al. (2019) using FORS2 radial velocities.

On the left panel of Fig. 7 we present the equivalent widths (EWs) of the He\textsc{ii} 4686 line measured in the FORS2 spectra obtained from 2017 October 4 to 2018 February 21 and those from 2018 December 16 to 2019 February 15 on the right side. No significant changes in line intensities are detected during both observing runs.

5 STUDYING FORS2 SPECTRA WITH INSUFFICIENT SIGNAL-TO-NOISE RATIO

Rather unexpectedly, our analysis of the underexposed FORS2 spectra from the observations between 2018 December and 2019 February showed that they are similar to the spectra obtained in the previously reported observations acquired with a S/N of about 1130 on 2018 February 17 (Hubrig et al. 2019), for which an increase of the absolute value of the mean longitudinal magnetic field, a change in spectral appearance, and a decrease of the radial velocity by several 10 km s\(^{-1}\) were reported. While such a behaviour was observed only once in the FORS2 observations acquired from 2017 October to 2018 February, it was detected in all five recent observations with a S/N below 1300. As an example, we present in Fig. 8 two FORS2 observations recorded with a S/N of about 830 on the same night on 2019 January 1 and separated by just 25 min. The first observation at MJD 58485.1143 resulted in a $(B_\nu)$ measurement compatible with a non-detection, while the second observation at MJD 58485.1234 gave $(B_\nu) = -1300 \pm 220$ G, using all lines. This spurious field increase at MJD 58485.1234 is accompanied by a spurious change of spectral appearance, including the increase of all absorption hydrogen and He\textsc{i} lines and the decrease of higher ionisation lines like He\textsc{ii}, C\textsc{iii} and S\textsc{iv}, and by a radial velocity shift of over 100 km s\(^{-1}\).

In Fig. 9 we show the overplotted Stokes I spectra for He\textsc{i} 4922 line profiles corresponding to subexposures in observations of varying quality recorded on two
Figure 8. Variability of line profiles detected in Stokes $I$ spectra recorded on the same night of 2019 January 1 and separated by only 25 min. The spectra were extracted using the MIDAS pipeline.

Figure 9. Stokes $I$ line profiles of He I 4922 over the full sequence of FORS 2 subexposures obtained on a time scale of tens of seconds at MJD 58480.0776 (top) and on MJD 58487.2308 (bottom). While the extracted spectra at a higher $S/N$ of 2340 (top) do not show a stable line profile, the extracted spectra at a lower $S/N$ of 1278 (bottom) show significant wavelength jumps.

Figure 10. Stokes $I$ line profiles of He I 4922 over the full sequences of FORS 2 subexposures obtained on a time scale of tens of seconds at MJD 58487.2366 at a $S/N$ of 2340. The spectral extraction was carried out using the pipeline written in the MIDAS environment (top) and the ESO FORS pipeline (bottom). While the MIDAS pipeline shows no wavelength shifts between the different exposures, the ESO FORS pipeline leads to wavelength shifts up the about 2 Å. The difference in fluxes between the two pipelines is caused by different ways in handling the absolute flux scale.

different nights, the observation obtained with a $S/N = 2340$ at MJD 58480.0776 and that with a $S/N = 1120$ at MJD 58487.2366. According to the atmospheric parameters presented by Castro et al. (2015), HD 54879 has already evolved from the ZAMS and is passing through the β Cephei instability strip. However, we are convinced that such short-term spectral variability is not real, as we never detected it in previous observations of this and other targets and it solely appears in data with insufficient $S/N$.

Further, we investigated if an alternative spectrum extraction could result in more stable wavelengths also for the spectra with insufficient $S/N$. For this, we employed the ESO FORS pipeline based on the Reflex toolkit and tailored to the polarimetric mode of FORS 2 (PMOS). However, as can be seen in Fig. 10, the ESO FORS pipeline has issues with wavelength stability even for higher $S/N$ data. While most of the higher $S/N$ spectra gave similar results when determining the longitudinal magnetic field, when compared to the MIDAS pipeline results, we concluded that the ESO FORS PMOS pipeline in its current form is not delivering proper results.
6 DISCUSSION

The new FORS2 spectropolarimetric data obtained from 2018 December to 2019 February confirm the very slow magnetic field strength variability in HD 54879. While the few observations from 2014 and 2015 indicated a mean longitudinal magnetic field value of the order of \(-500\, G\) to \(-900\, G\), we observe in the last years a significantly weaker magnetic field with a mean longitudinal magnetic field value between \(-300\, G\) and \(+150\, G\). The strongest longitudinal magnetic field of positive polarity of \(150\, G\) was measured on the night of 2018 December 16. After this date, the longitudinal magnetic field is gradually decreasing, reaching a value of about \(-100\, G\) on 2019 February 15. This slow magnetic field variability, related to the extremely slow rotation of HD 54879, is also confirmed using high-resolution HARPS and ESPaDOnS spectropolarimetry. Assuming that the negative field extremum reaches a value of \(-500\, G\) to \(-900\, G\), measured in 2014 February, the rotation cycle is expected to be longer than five years. Additional evidence for a very long rotation period, longer than nine years, follows from the consideration of the variability of the Hα line profiles. However, since very long rotation periods are best determined from magnetic field variability, future monitoring of HD 54879 should include both, the follow-up of the changes of the Hα line profile and of the measurements of the longitudinal magnetic field.

The analysis of the new FORS2 polarimetric spectra indicates that the previous detection of a significant field increase and a change of the spectral appearance is due to improper spectra extraction and wavelength calibration, using observations obtained at an insufficient signal-to-noise ratio.

Among the previously detected magnetic O-type stars, five are classified as Of?p stars. The primary characteristic for the Of?p stars, according to the definition by Walborn (1972), is a variable and comparable emission strength of the C\textsc{iii} blend (C\textsc{iii} \(\lambda\lambda 4647-4650-4652\)) with respect to the neighboring variable emission N\textsc{iii} blend (N\textsc{iii} \(\lambda\lambda 4634-4640-4642\)). The observed C\textsc{iii} blend in these stars is strongly variable, exhibiting transitions from absorption line profiles to emission line profiles at certain rotation phases. The presence of variable emission in the C\textsc{iii} blend is indicative of circumstellar structure around the Of?p stars, related to their magnetospheres. However, the emission in the C\textsc{iii} blend disappears entirely in late O-type stars (Walborn et al. 2010) and is thus missing in HD 54879, meaning that a selective emission effect cannot be observed in HD 54879. Obviously, the Of?p classification is very narrow as it is limited to stars with spectral types in the range O4f?p–O8f?p, with temperatures between 34.5 kK and 41 kK. HD 54879 is significantly cooler with \(T_{\text{eff}} = 30.5\, \text{kK}\) and this is the main reason why no association with the Of?p class has been done so far.

On the other hand, many properties of HD 54879 are similar to those of Of?p stars. The Hα emission line in HD 54879 presented in Fig. 3 is highly variable. In analog to the C\textsc{iii} blend, the presence of the Hα emission in Of?p stars is related to their magnetospheres and its variability is expected to trace dense environments in Of?p stars. This line is frequently used to determine their rotation periods.

A remarkable resemblance of the ultraviolet (UV) spectra of HD 54879 and the Of?p star NGC 1624-2 with a dipole strength of \(\sim 20\, \text{kG}\) estimated by Wade et al. (2012) was recently discussed by David-Uraz et al. (2019). The authors report that despite of the later spectral type of HD 54879, its UV spectrum is surprisingly similar to the UV spectrum of NGC 1624-2 obtained at a rotational phase of nearly magnetic equator-on view. Both stars exhibit the lowest \(v\sin i\) and macroturbulent velocity \(v_{\text{mac}}\) values known among the magnetic O-type stars (Shenar et al. 2017) and do not show nitrogen excess (Castro et al. 2015). Alike the spectral appearance of the Of?p star NGC 1624-2, the high-resolution HARPS spectra display weak emission lines belonging to various metal lines, indicating that the line formation in the atmosphere of HD 54879 can be similarly complex.

As we discussed in Sect. 4, the rotation period of HD 54879 is probably longer than nine years. Also Of?p stars are known as a class of slowly rotating magnetic massive stars with the longest rotation period of about 50-60 yr suggested for the Of?p star HD 108 (Naze et al. 2001). Furthermore, recent analyses of the XMM-Newton spectra of HD 54879 by Shenar et al. (2017) and Hubrig et al. (2019) indicate over-luminosity by at least one order compared to other O-type stars with similar spectral types. Such an excess of X-ray luminosity is typical for all Of?p stars, for which X-ray spectra are usually well described by multi-
temperature thermal plasma models. All of these properties suggest that HD 54879 is an analogue to the Of?p stars and only misses the Of?p classification criteria because of its lower temperature.

In respect to the possible binary nature of HD 54879, it was suggested in recent years that three out of five Of?p stars are members of binary systems. Long-term radial velocity changes indicating binarity were reported for the Of?p star HD 191612 (Howarth et al. 2007) who suggested $P_{\text{orb}} = 1542$ d. According to Wade et al. (2019), the Of?p star HD 148937 is likely a high-mass, double-lined spectroscopic binary (Wade et al. 2019). Also for the Of?p star HD 108 Naze et al. (2008) reported that a very long-term binary cannot be excluded. Similarly, the compilation of radial velocity measurements over tens of years indicates that HD 54879 could be a member of a long-period binary system.

The knowledge of the frequency of membership of upper main-sequence stars with radiative envelopes in wide binary systems is very important, as it can be related to the origin of their magnetic fields. It was suggested that magnetic fields may be generated by strong binary interaction, i.e. in stellar mergers, during a mass transfer, or in the course of a common envelope evolutionary phase (Tout et al. 2008). The resulting strong differential rotation (Petrovic et al. 2005) is then considered as a key ingredient for the magnetic field generation. Requiring mergers to produce magnetic stars implies that there should be almost no magnetic star in a close binary. Indeed, magnetic components in close binaries are very rare: Only three close binaries with a magnetic Ap component, HD 98088 ($P_{\text{orb}} = 5.9$ d; Babcock 1958), HD 25267 ($P_{\text{orb}} = 5$ d; Borra & Landstreet 1980), and HD 161701 ($P_{\text{orb}} = 12.5$ d; Hubrig et al. 2014), are currently known, and only two late-B type binaries with magnetic components and orbital periods below 20 d were recently detected, HD 5550 ( Alecian et al. 2016) and BD−19°5404 (Landstreet et al. 2017). The situation among early-B type stars is even more extreme, as only one early-B type short-period magnetic binary, HD 136504 (Shultz et al. 2015), is currently known. As wide binaries are widespread among Ap and late Bp stars (Mathys 2017), such wide binaries could have been born as hierarchical triple stars, where the inner binary merged.

Observations in star-forming regions indicate that almost all stars form in clusters (Lada & Lada 2003), and that the number of multiple systems within these clusters is remarkably high. Binary population synthesis simulations predict that the rate of main-sequence mergers increases with mass (e.g., de Mink et al. 2014; Schneider et al. 2015). de Mink et al. (2014) found a merger fraction of 8% in a population of B-type stars and 12% in O-type stars. Also recent observations of Ap and late Bp stars support a scenario where mergers produce magnetic stars (Mathys 2017). Clearly, future monitoring of radial velocities of massive magnetic stars is important to be able to conclude on the role of binarity for the magnetic field generation.

**ACKNOWLEDGMENTS**

Based on observations made with ESO Telescopes at the La Silla Paranal Observatory under programme IDs 191.D-0255, 0100.D-0110, and 0102.D-0285. We thank the referee G. Mathys for his constructive comments that helped to improve the paper.

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