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A spectroscopic analysis of the chemically peculiar star HD 207561★

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ABSTRACT

In this paper we present a high-resolution spectroscopic analysis of the chemically peculiar star HD 207561. During a survey programme to search for new rapidly oscillating Ap (roAp) stars in the Northern hemisphere, Joshi et al. observed significant photometric variability on two consecutive nights in the year 2000. The amplitude spectra of the light curves obtained on these two nights showed oscillations with a frequency of 2.79 mHz ($P \sim 6$ min). However, subsequent follow-up observations could not confirm any rapid variability. In order to determine the spectroscopic nature of HD 207561, high-resolution spectroscopic and spectropolarimetric observations were carried out. A reasonable fit of the calculated Hβ line profile to the observed one yields an effective temperature ($T_{\rm eff}$) and surface gravity ($\log g$) of 7300 K and 3.7 dex, respectively. The derived projected rotational velocity ($v \sin i$) for HD 207561 is 74 km s^{-1}, indicative of a relatively fast rotator. The position of HD 207561 in the Hertzsprung–Russell diagram implies that this is slightly evolved from the main-sequence and located well within the δ-Scuti instability strip. The abundance analysis indicates the star has slight underabundances of Ca and Sc and mild overabundances of iron-peak elements. The spectropolarimetric study of HD 207561 shows that the effective magnetic field is within the observational error of 100 G. The spectroscopic analysis revealed that the star has most of the characteristics similar to an Am star, rather than an Ap star, and that it lies in the δ-Scuti instability strip; hence roAp pulsations are not expected in HD 207561, but low-overtone modes might be excited.

Key words: stars: chemically peculiar – stars: individual: HD 207561 – stars: magnetic fields – stars: oscillations – stars: variables: general.

1 INTRODUCTION

In contrast to normal stars, the chemically peculiar (CP) stars are identified by the presence of abnormally strong and/or weak absorption lines of certain elements in their spectra. The two subgroups of CP stars, namely metallic-lined (Am) and A-peculiar (Ap), are important asteroseismic tools because some members of these classes show multiperiodic pulsational variability. The Am stars which are non-magnetic in nature are mostly found in short-period binary systems with orbital periods between 1 and 10 d, causing synchronous rotation with $v \sin i \leq 120$ km s^{-1} (Abt 2009). Now many Am stars are known to exhibit low-amplitude, multiperiodic variability with period range 0.25–7 h, i.e. similar to the δ-Scuti variables (Joshi et al. 2003, 2006, 2009; Smalley et al. 2011). The Ap stars showing magnetic field strengths of the order of kG exhibit variability of periods in the range 5–23 min with Johnson B amplitudes <8 mmag and spectroscopic radial velocity variations of 0.05–5 km s^{-1} (Kurtz, Elkin & Mathys 2006), and are known as rapidly oscillating Ap (roAp) stars. There is no clear correlation between photometric and spectroscopic pulsation amplitude in roAp stars, but the pulsation signal can be detected in spectroscopic

★ The present work is based on the analysis of data collected with the Russian 6-m telescope BTA operated by the Special Astrophysical Observatory of the Russian Academy of Sciences (SAO RAS).
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observations with no detection in the photometry (Hatzes & Mkrtichian 2004 – β CrB; Kochukhov et al. 2009 – HD 75445). The roAp stars possess strong abundance of rare earth elements (REEs) and almost all of them show ionization disequilibrium for Pr and Nd. Currently, about 46 such candidates are known (Joshi et al., in preparation). The light curves of many roAp stars show a double modulation. Such modulation in these stars is explained by the oblique pulsator model (Kurtz 1982). According to this, the pulsation axis is aligned with the magnetic axis, which is itself inclined to the rotation axis. As the star rotates, the observer views the pulsation modes from an aspect that varies with rotation. Treating the combined effects of rotation and magnetic field on the pulsation modes, Bigot & Dziembowski (2002) proposed the revised pulsator model where the pulsation axis lies in between the rotation and magnetic axis. In the framework of the modified oblique pulsation model, Bigot & Kurtz (2011) presented a theoretical and analytical study of the light curves associated with dipole ($l = 1$) pulsations of roAp stars. Excitation of pulsations in pulsating Am and roAp stars is governed by the κ-mechanism operating in the partial hydrogen ionization zone (Balmforth et al. 2001; Cunha 2002; Vauclair & Thádo 2004). There are a few Ap stars which show pulsation periods in the range of δ-Scuti stars (González et al. 2008; Kurtz et al. 2008), but not a single Am star is known to date where rapid oscillations are observed. Therefore, the pulsations in Am and Ap stars are important astrophysical tools to study the complex relationship between stellar pulsation and magnetic field in the presence of atmospheric abundance anomalies.

The 'Nainital–Cape' survey was initiated in 1999 between Aryabhatta Research Institute of Observational Sciences (ARIES), Nainital and the South African Astronomical Observatory (SAAO), South Africa. The main aim of this survey project was to search for and study such Ap and Am stars which are pulsationally unstable. The major results of this survey were published by Martinez et al. (2001) and Joshi et al. (2006, 2009).

Based on published Strömgren photometric indices similar to those of the then known roAp stars, we selected HD 207561 as a target star in the year 2000 (JD 2451832) to search for rapid photometric variability on a time-scale of 6–16 min. The time series photoelectric photometry of this star obtained on two consecutive nights showed an apparent photometric variability with a period ~6 min (Joshi et al. 2006). However, subsequent follow-up observations over a period of 8 years did not confirm any such rapid variability. Therefore to establish the spectral classification and magnetic nature of HD 207561, we subjected it for high-resolution spectroscopic and spectropolarimetric observations. In this paper we present the spectroscopic analysis of this star. The paper is organized as follows. In Section 2 we discuss the various astrophysical parameters calculated from the standard relations. The observations and data reduction procedure are described in Section 3. The spectroscopic data analysis is presented in Section 4. Finally, we discuss and conclude our results in Section 5.

2 HD 207561

The star HD 207561 (α_{2000} = 21 48 16; δ_{2000} = 54 23 15, V = 7.84 mag) is classified as F0 III/F0 IV (Olsen 1983). The Strömgren indices of this star are $b - y = 0.142$, $m_1 = 0.220$, $c_1 = 0.820$ and $\beta = 2.825$ (Hauck & Mermilliod 1998). From the calibrations for A-type stars given by Crawford (1979), we derive $E(b - y) = 0.018$, $\delta m_0 = -0.022$ and $\delta c_0 = -0.003$. The δm_0 and δc_0 indices indicate strong line blocking in the u and v filters and are typical of strongly peculiar Am and Ap spectra. Cowley & Cowley (1965), Bertaud & Floquet (1974) and Nicolet (1983) classified this as a marginal[1] Am star.

An apparent pulsation period of 6 min observed on two consecutive nights made HD 207561 an interesting object for further study. The knowledge of the stellar parameters allows us to clarify the general view on the nature of the studied star. Therefore, we estimated the astrophysical parameters for HD 207561 using the Strömgren and Geneva indices taken from the SIMBAD data base.

The galactic coordinates of HD 207561 ($l = 98\overset{\circ}{.}2598$ and $b = 0\overset{\circ}{.}5360$) imply its location is near the galactic plane. Taking into account the trigonometric parallax of HD 207561, $\pi = 8.57 \pm 0.56$ mas (van Leeuwen 2007), a non-zero interstellar extinction is expected. This value can be determined using the three independent methods. The calibration of Moon & Dworetsky (1985) using Strömgren indices gives $E(b - y) = 0.018$ and hence $E(B - V) = 0.026$. The equivalent width of the interstellar Na D1 line, available in our echelle spectrum, gives $E(B - V) = 0.050$ (Munari & Zwitter 1997). The value of $E(B - V) = 0.070$ derived from the reddening maps of Lucke (1978) is thought to be overestimated. Due to the higher accuracy of the first two methods, for the present study we adopted an average value of $E(B - V) = 0.038$. This corresponds to an interstellar extinction $A_V = 0.118$ mag.

The effective temperature of HD 207561 could be determined from the available photometric data. Based on the Strömgren system, two types of calibrations were implemented through the TEMPLOGG program (Stütz, Nendwich & Rogers 2002). From the calibration of Moon & Dworetsky (1985), the derived value of effective temperature, gravity, absolute magnitude and metallicity are $T_{\rm eff} = 7908 \pm 193$ K, $\log g = 4.17 \pm 0.10$ dex, $M_V = 2.52$ mag and [M/H] = 0.22, respectively. The calibration of Napiwotzki, Schoenberner & Wenske (1993) gives the values of $T_{\rm eff} = 7650 \pm 150$ K and $\log g = 4.07 \pm 0.10$ dex. The photometric data in Geneva system were also used to derive these basic parameters. Applying the calibration of Kunzli et al. (1997) on the Geneva system, the derived parameters $T_{\rm eff}$, $\log g$ and [M/H] are 7884 ± 80 K, 4.59 ± 0.06 dex and 0.19, respectively. We note that these calibrations are slightly less reliable for stars with peculiar abundances and stratified atmosphere than for normal stars. However, Smalley & Dworestsky (1993) concluded that values of $T_{\rm eff}$ and $\log g$ determined from photometry are extremely reliable and not significantly affected by metallicity. Therefore we can assume that the average photometric values of effective temperature and surface gravity are 7814 K and $\log g = 4.07$, respectively. The spectroscopic determination of these parameters is described in Section 4.1.

The bolometric corrections (BCs) from interpolation in the tables by Flower (1996) is estimated as BC = 0.031 for $T_{\rm eff} = 7815$ K and BC = 0.035 for $T_{\rm eff} = 7300$ K. The lower value of $T_{\rm eff}$ corresponds to the temperature estimated from fitting of hydrogen line Hβ. The revised *Hipparcos* parallax $\pi = 8.57 \pm 0.56$ mas (van Leeuwen 2007) and an interstellar extinction $A_V = 0.118$ mag resulting the absolute magnitude $M_V = 2.39$ mag. The luminosity parameter $\log (L_*/L_\odot)$ for HD 207561 is 0.91 mag. Using the standard relation the calculated mass and radius of the star are $M = 1.65\,M_\odot$ and $R = 1.59\,R_\odot$, respectively. The lower temperature ($T_{\rm eff} = 7300$ K) yields the larger value for the radius ($R = 1.82\,R_\odot$) and smaller value for the surface gravity ($\log g = 4.18$). These

[1] The marginal Am stars are those for which the difference between the spectral type determined from the Ca II K line and the metal lines is less than five spectral subclasses. If the difference is more than five spectral subclasses, then they are referred to as classical Am stars.

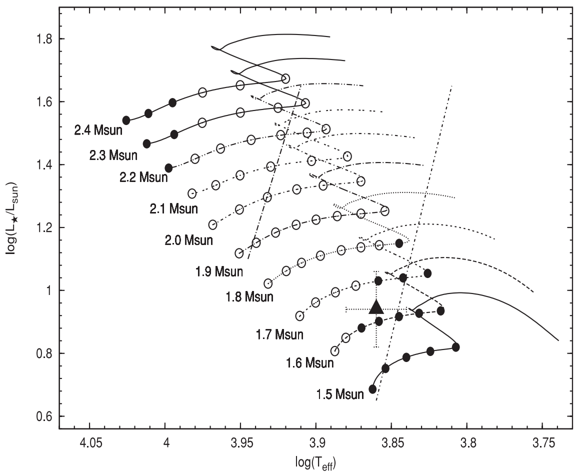

Figure 1. The location of HD 207561 in the HR diagram is shown by a triangle. The filled circles and open circles indicate the locations of pulsationally stable and unstable modes for roAp stars (Cunha 2002), respectively. Two vertical lines show the boundary of the δ-Scuti instability strip (Turcotte et al. 2000). The star HD 207561 resides well within the main-sequence region of the δ-Scuti instability strip.

basic parameters are well within the range of the δ-Scuti and roAp stars. The location of the star in the Hertzsprung–Russell (HR) diagram is shown in Fig. 1. The open circles in the figure indicate the predicted frequencies for pulsationally unstable rapid oscillation modes, while the pulsationally stable modes are shown by filled circles (Cunha 2002). The evolutionary tracks[2] of masses ranging from 1.5 to 2.4 $M_{\odot}$ are also plotted (Christensen-Dalsgaard 1993). From Fig. 1, it is evident that HD 207561 is slightly evolved from the main sequence and lies well within the δ-Scuti instability strip. Therefore, HD 207561 might exhibit pulsations similar to δ-Scuti-type variables.

3 OBSERVATIONS AND DATA REDUCTION

Due to its potential asteroseismic importance, HD 207561 was observed in both the spectroscopic and spectropolarimetric modes. The following subsections briefly summarize the details of the observation and data reduction procedure.

3.1 High-resolution spectroscopy

High-resolution spectroscopic observations were carried out from the 6.0-m Big Telescope Alt-Azimuthal (BTA) telescope at the Special Astrophysical Observatory (SAO), Nizhny Arkhyz, Russia. The first spectroscopic data were obtained on 2008 November 17 (JD 245 4788.104) with a high-resolution Nasmyth echelle spectrometer (Panchuk et al. 2009) installed on a Nasmyth platform. A single Th–Ar reference spectrum was obtained immediately after the target star spectra were acquired for wavelength calibration purposes. The data reduction procedure consists of bias subtraction, flat-fielding, stray light correction and recognizing spectral orders with further extraction of them. All the listed procedures are implemented in a set of IDL routines called REDUCE (Piskunov & Valenti 2002), and have been executed in a semi-automatic mode. The final one-dimensional spectrum covers the wavelength range from 4460 to 5930 Å, with a signal-to-noise ratio (S/N) of about

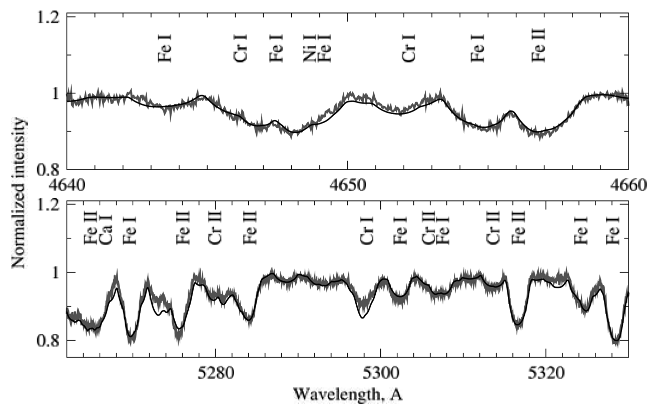

Figure 2. Two sections of the echelle spectrum of HD 207561 with identified lines.

Table 1. Spectropolarimetric observational log of HD 207561.

JD 245 0000+	Wavelength range (Å)	S/N
5702.506	4426–4978	230
5764.342	4420–4974	250
5764.508	4420–4974	200

150. The mean resolving power of spectrometer $R = 39\,000$ at that observational setting was determined from the Th–Ar lines. The continuum normalization was done with the IRAF[3] task CONTINUUM. Fig. 2 shows two parts of the normalized spectrum where the various elements are listed. The broadening of the various lines shows the clear indication of fast rotation in HD 207561.

3.2 Spectropolarimetry

A strong global-scale magnetic field is an intrinsic property of most roAp stars. To test whether HD 207561 might be an Ap star, and hence exhibit rapid oscillations, as potentially observed by Joshi et al. (2006), we searched for evidence of a magnetic field in HD 207561. The long-term usage of the above-mentioned telescope together with the main stellar spectrograph (MSS), equipped with circular polarization analyser, confirms its applicability for such kinds of searches (Kudryavtsev et al. 2006). MSS of BTA is a long-slit spectrograph equipped with circular polarization analyser that is combined with an image slicer (Chountonov 2004). The analyser has a rotatable quarter-wave plate that is able to take two fixed positions corresponding to the angles 0° and 90° relative to the birefringence crystal. The spectra were taken with an EEV CCD detector (4600 × 2048 pixels size). The mean resolving power of the spectrograph was about 15 000. Each scientific exposure actually consists of two subsequent frames when the quarter-wave plate had opposite orientation. We obtained three Zeeman spectra, one on 2011 May 21 (JD 245 5702) and other two on 2011 July 22 (JD 245 5764). The time interval between first two spectra was enough to detect magnetic field in the case of probable long-term variability. The log of spectropolarimetric observations is given in

[2] http://www.phys.au.dk/~jcd/emdl94/eff_v6

[3] IRAF is distributed by the National Optical Astronomy Observatories, which are operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.

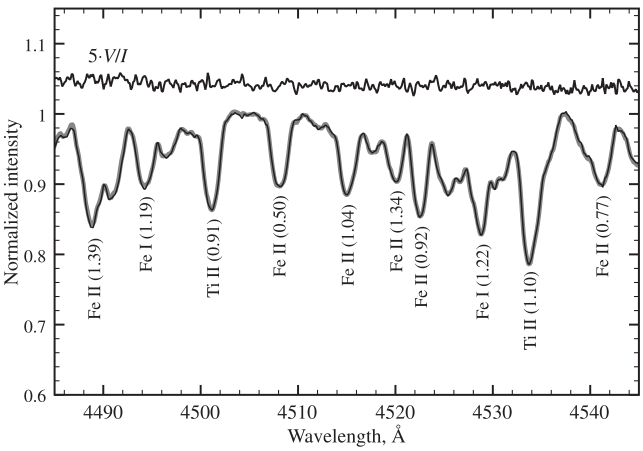

Figure 3. The polarized spectrum of HD 207561. A scaled and shifted up Stokes V parameter $V/I = (I_1 - I_2)/(I_1 + I_2)$, where I_1 and I_2 are the intensity of right and left circularly polarized spectrum, respectively, is also plotted. Grey and black profiles are circularly polarized stellar spectra. For individual lines designation of an ion and Lande factor is written.

Table 1. The data reduction of spectropolarimetric data was performed by means of a set of routines ZEEMAN written in SAO by D. O. Kudryavtsev for the ESO MIDAS system. The sequence of reduction stages is similar to the reduction scheme for echelle spectra except for some differences caused by a long-slit character of the data. For illustrational purposes, we show the polarized spectrum of HD 207561 in Fig. 3. The value of Stokes parameter is rather small; hence we scaled it by a factor of 5 and shifted upwards. The S/N of the spectra was high and due to zero magnetic field, polarized spectra are practically not resolved.

4 SPECTROSCOPIC ANALYSIS

4.1 The stellar parameters

In order to find the effective temperature and surface gravity of HD 207561, the fitting of synthetic profile of hydrogen line Hβ to the observed spectrum was also used, additionally to the photometric methods listed in Section 2. The SYNTH3 program code written by O. Kochukhov (Kochukhov 2007) was used to compute the grid of synthetic spectra in the range 4780–4930 Å. This code computes the synthetic spectra in the local thermodynamic equilibrium regime. The Kurucz model of stellar atmosphere with convection was computed with ATLAS9 code (Kurucz 1993). The list of lines from Vienna Atomic Line Database (VALD Piskunov et al. 1995; Kupka et al. 1999) acted as an input for the further spectrum synthesis. The computed spectra were then compared with an observed spectrum of HD 207561. The best fit was achieved with the following parameter set: $T_{\rm eff} = 7300 \pm 250$ K, $\log g = 3.7 \pm 0.1$ dex and [M/H] $= +0.2$. The upper panel of Fig. 4 shows the best fit between the observed and the synthetic spectra and the lower panel shows the residuals of the fit.

4.2 Chemical abundances

The presence of high overabundances of REEs is one of the known characteristics of the roAp stars. The difference by more than 1 dex between the abundances measured from first two ionized states of Nd, Pr and other REEs is another important property of these stars. It is believed that doubly ionized ions of REEs are formed in higher

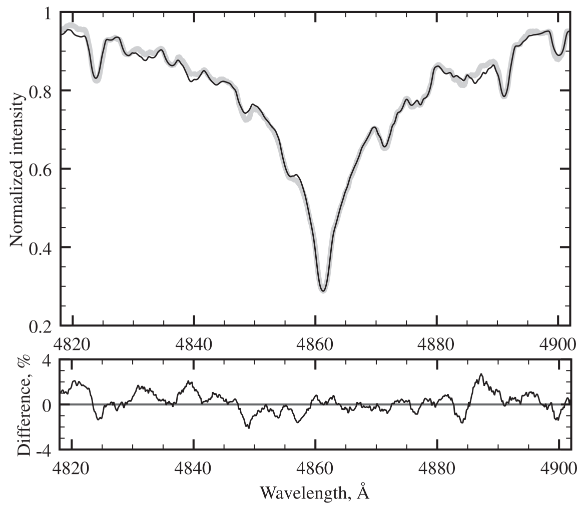

Figure 4. Comparison of the observed profile of Hβ line (grey line) with the synthetic one (black line) computed for effective temperature 7300 K, surface gravity 3.7 dex and metallicity +0.2. The bottom panel shows the residual of the fit.

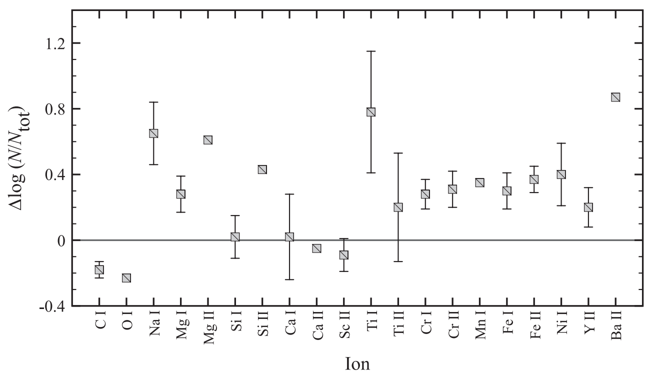

Figure 5. Derived atmospheric abundances for 14 elements relative to the Sun (Asplund, Grevesse & Sauval 2005).

layers of a stellar atmosphere (Ryabchikov et al. 2004; Kurtz, Elkin & Mathys 2007).

The projected rotational velocity of HD 207561 is $v \sin i = 74 \pm 5\,{\rm km\,s^{-1}}$ and indicates a short rotation period. Our analysis of the available spectra showed the clear presence of lines of Fe, Cr, Mg and some other elements in the blends. Comparing the observed spectra with those calculated with the SYNTH3 code, we determined the abundances of 14 elements. Assuming the microturbulence velocity $\xi_{\rm micro} = 2\,{\rm km\,s^{-1}}$, we have used the method of synthetic spectra to fit the observed profiles. Our choice of $\xi_{\rm micro}$ is based on the unknown nature of the star. $\xi_{\rm micro} = 2\,{\rm km\,s^{-1}}$ is more typical for CP Ap stars, while the metallic-line stars usually have higher velocities. However, $\xi_{\rm micro} = 2\,{\rm km\,s^{-1}}$ is a good approximation for many of the Am stars.

The results of measurements are presented in Table 3 and shown graphically in Fig. 5. These results are based on the assumption of the effective temperature and surface gravity values as they were obtained from spectroscopy. It can be seen from Table 3 that C, O, Ca and Sc show a mild deficiency, while the other elements have excess abundances, compared to solar values. Such an abundance pattern is typical for metallic-line stars. However, it is not so clear if we take the atmospheric parameters derived from photometry. In this case, most of the individual abundances will increase by about 0.2–0.3 dex and all Am star attributes will disappear. In the available spectra we cannot find any significant lines of REEs, but the modelling of a few Nd lines from the structure of blends confirms the near-solar abundance of this element. Therefore, we can conclude that HD 207561 is most probably an Am star with mild chemical peculiarities or a normal A star. The absence of significant anomalies typical for magnetic CP stars rejects the assumption about its magnetic nature.

4.3 Magnetic field measurements

Our measurements of the effective longitudinal magnetic field of the star were made by means of the classical method where a value of B_e is determined from the relation

$$B_e = \frac{\Delta\lambda}{9.34 \times 10^{-13} \times \lambda_0^2 \times \overline{g}} \text{ (G)}. \quad (1)$$

In this equation, $\Delta\lambda$ is the difference between the position of the same line in right and left circularly polarized spectra, λ_0 is a wavelength of a line in intensity spectrum and $\overline{g}$ is the mean value of Lande factor. We have used the value of $\overline{g}$ as 1.23, approximately equal to the averaged value of the individual Lande factors of the lines in the selected spectral range (Romanyuk 1984). Some of the authors used slightly different value (1.21 or similar) of the averaged Lande factor that is not crucial for the final result. Individual positions of separate lines in polarized spectra were measured using the centre-of-gravity method. Results of the magnetic measurements are presented in Table 2.

On the night of 2011 May 21 we observed Arcturus and α^2 CVn as zero-field and magnetic standard, respectively. The respective derived longitudinal fields for these stars are 205 ± 50 G ($n = 249$ lines) and 950 ± 68 G ($n = 133$ lines). The value of the magnetic field in α^2 CVn is corrected for instrumental non-zero polarization measured from Arcturus. Within the error, our measured value is close to the predicted value of B_e for α^2 CVn, i.e. about 900–950 G (Wade et al. 2000). Further, two standard stars, HD 158974 and β CrB, were also observed on the night of 2011 July 22. The measured longitudinal field of the first, zero-field standard, star is 0 ± 50 G ($n = 305$ lines). Polarized spectra of the well-known magnetic star β CrB shows the Zeeman shift corresponding to the longitudinal magnetic field $B_e = -170 \pm 50$ G ($n = 240$ lines). For this star at rotational phase 0.27, Wade et al. (2000) predict the field of about −100 G. The measured longitudinal magnetic field (corrected for instrumental polarization) in HD 207561 is given in Table 2. From the table we can conclude that the star HD 207561 does not exhibit any magnetic property.

Table 2. Results of the measurements of effective longitudinal magnetic field of HD 207561; n is the number of lines used for the analysis.

JD 245 0000+	$B_e \pm \sigma$ (G)		n
5702.506	−62	91	65
5764.342	70	93	57
5764.508	45	124	57

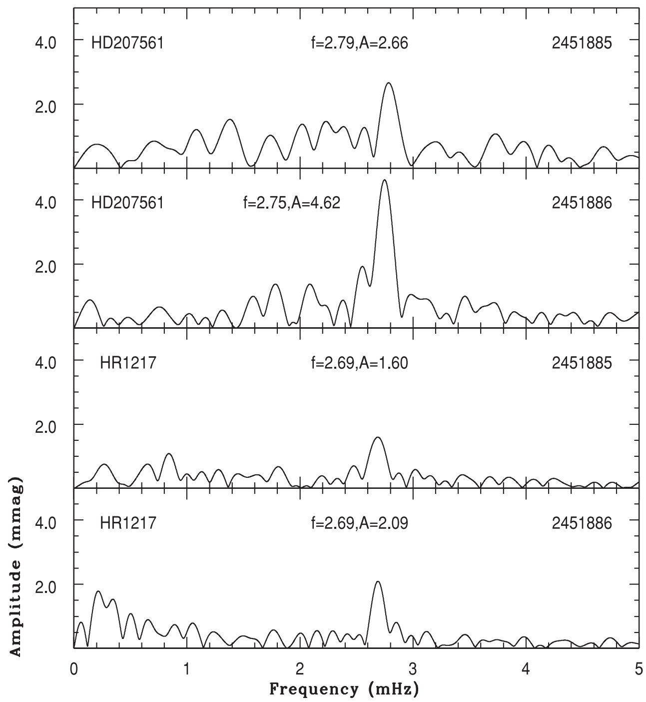

Figure 6. The B-band amplitude spectra of HD 207561 and HR 1217 obtained on two consecutive nights. HR 1217 is a well-known multiperiodic roAp star and has one pulsational frequency at 2.79 mHz, the same frequency observed on the two time series data sets of HD 207561. The frequency spectra of both the stars show a prominent peak with night-to-night amplitude modulation.

5 DISCUSSIONS AND CONCLUSIONS

The transient photometric variability observed on two consecutive observing runs placed HD 207561 in the category of potentially interesting variable stars. For the ‘Nainital–Cape’ survey, we observed each candidate star for a duration of 1–2 h, which is sufficient to reveal the roAp-like oscillations in any single photometric night (Martinez et al. 2001). Therefore, three to four candidate stars could be monitored on a particular night. On the two nights when the photometric variability of 6 min was observed in HD 207561, a well-known roAp star HR 1217 was also monitored under a multisite campaign (Kurtz et al. 2002). The top two panels of Fig. 6 show the amplitude spectra of HD 207561, while the bottom two panels show the amplitude spectra of HR 1217 on the same nights. The noise levels in the amplitude spectra of both stars are comparable to each other. HR 1217 is a multiperiodic roAp star where seven frequencies have been detected close to 2.69 mHz and one of them corresponds to 2.79 mHz. On those two particular nights, HD 207561 appeared to show similar rapid oscillations.

In an attempt to confirm the presence of rapid oscillations in HD 207561, we observed the star again on many nights between 2000 and 2008. Fig. 7 shows the samples of pre-whitened amplitude spectra of HD 207561. In none of these observations did we see any indication of rapid oscillations near the frequency 2.79 mHz. The observations were carried out with the same instrument, a three-channel photoelectric photometer used in the ‘Nainital–Cape’ survey (Ashoka et al. 2001). Generally, the observations were carried out in single-channel mode, but some occasions a nearby faint comparison star was also observed in the second channel to test whether this might have been an instrumental effect in both channels. However, the amplitude of variation in the second channel was

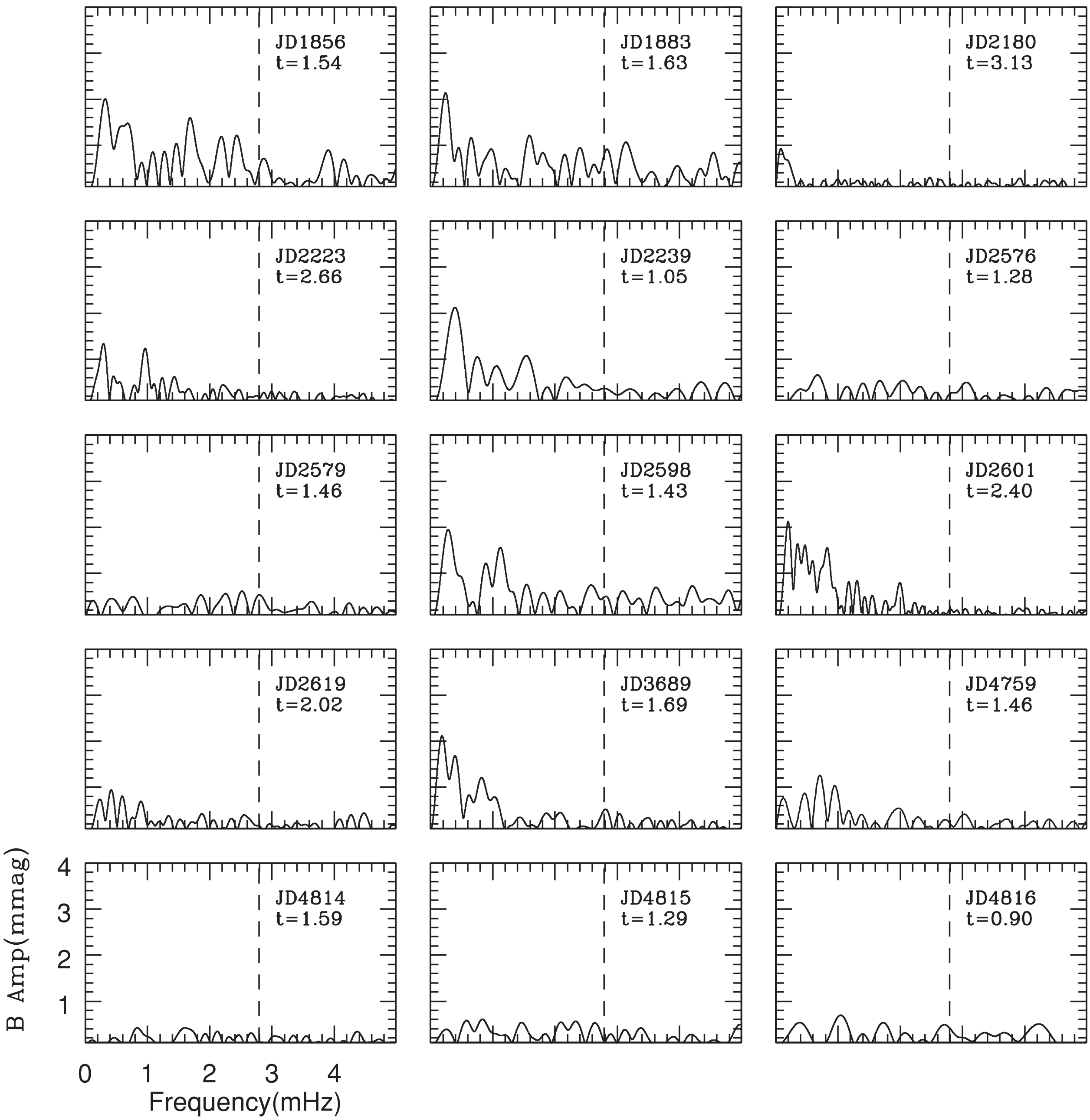

Figure 7. Samples of the pre-whitened amplitude spectra of HD 207561. The vertical dashed line indicates the frequency where photometric variability of ∼6 min was detected on two consecutive nights of the year 2000. Each panel contains the Fourier transform of an individual light curve, covering a frequency range of 0–5 mHz, and an amplitude range of 0–4 mmag. The date of the observation in Julian date (JD 245000+) and the duration of observations (*t* in hours) are mentioned in each panel.

less than 2 mmag, and no coherent pulsations were seen in the data of the comparison star (Girish 2005). In order to test for a positional dependence of the instrumental noise, we pointed the telescope at declination of HD 207561 and the observations were acquired at the same hour angle range, but with the photometer dark slide shut. In this test we did not notice any periodic variations in the dark counts. The electronics used in the photometer and alignment of its optical elements were also checked and no irregularities in the instruments were found.

By means of the high-resolution spectroscopic observations, we found that the effective temperature, surface gravity and rotational velocity of HD 207561 are 7300 ± 250 K, 3.7 ± 0.1 dex and 74 ± 5 km s^{-1}, respectively. The abundance analysis shows that HD 207561 has small underabundances of the Ca and Sc and mild overabundances of iron peak elements that are the characteristic of Am stars. It can be seen from Table 3 that C, O, Ca and Sc show a mild deficiency, while all other elements have excess abundances. Such elemental abundances are generally found in Am stars. Hence we conclude that HD 207561 is most probably an Am star with mild peculiarities.

The spectropolarimetric analysis indicates that, within the observational error of 100 G, HD 207561 is a non-magnetic star, another support for the Am classification. The location of HD 207561 in the HR diagram shows that the star is slightly evolved from the main sequence and positioned well within the δ-Scuti instability strip. Hence, as an Am star, we would not expect HD 207561 to

Table 3. Abundances of HD 207561 as determined for the case of $T_{\mathrm{eff}} = 7300$ K and log $g = 3.7$ dex are listed in the second column. The third column is the difference in abundances between the photometric and the spectroscopic sets of parameters. For comparison, the abundances of the solar atmosphere is also presented (Asplund et al. 2005).

Ion	HD 207561 log $N_{\mathrm{el}}/N_{\mathrm{tot}}$	HD 207561 Δ log $N_{\mathrm{el}}/N_{\mathrm{tot}}(7300-7815)$	Sun log (N/N_{tot})
C I	−3.78 ± 0.10	−0.05	−3.65
Na I	−5.22 ± 0.19	0.0	−5.87
Mg I	−4.27 ± 0.03	0.04	−4.51
Mg II	−4.18 (:)	0.28	−4.51
Si I	−4.29 ± 0.16	−0.22	−4.53
Si II	−4.23 (:)	0.13	−4.53
Ca I	−5.69 ± 0.24	−0.02	−5.73
Ca II	−5.68 (:)	−0.10	−5.73
Sc II	−8.74 ± 0.10	−0.34	−8.99
Ti I	−6.26 ± 0.37	−0.10	−7.14
Ti II	−6.69 ± 0.29	−0.25	−7.14
Cr I	−5.97 ± 0.07	−0.15	−6.40
Cr II	−5.88 ± 0.09	−0.21	−6.40
Fe I	−4.09 ± 0.15	−0.20	−4.59
Fe II	−4.07 ± 0.10	−0.15	−4.59
Ni I	−5.23 ± 0.18	−0.18	−5.81
Y II	−9.47 ± 0.09	−0.16	−9.83
Ba II	−9.00	0.0	−9.87

exhibit high-overtone pulsation like the roAp stars (and we therefore conclude that the 2000 detection was spurious), but it might exhibit low-amplitude δ-Scuti pulsations. Our photometric observations were optimized for detecting rapid oscillations, so we are not able to comment on the latter possibility with the data in hand. It would be interesting to further monitor HD 207561 for such oscillations in future.

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