Physical Properties of Several Young Magnetic Chemically Peculiar Stars

Eugene Semenko[1] **& Ekaterina Semenova**[2]

[1]*Special Astrophysical Observatory, Nizhnii Arkhyz, Russia, 369167*
[2]*Kazan Federal University, Kazan, Russia, 420008*

Contact Information:
Email: sea@sao.ru
ektrsemenova@gmail.com

Abstract

We report the recent measurements of a longitudinal effective magnetic field of 3 chemically peculiar stars. Magnetic fields of HD 50341 and HD 63347 change with periods previously estimated from light variations of the stars. Period of HD 201174 magnetic field changes is defined for the first time. Upon estimation of stars' physical parameters, we conclude that they are young objects of 2–3 solar masses. The study is fully based on spectropolarimetric observations obtained with the 6-m telescope of SAO RAS.

Introduction

The origin of magnetic fields in early-type stars remains an open question. In this context, magnetic chemically peculiar (mCP) stars are perfect test beds as they host global, well-organized, and stable magnetic fields combined with photometric variability and moderate rotational rate. One possible explanation is that stellar magnetic fields are relic of the fields formed due to convective motions in stellar interiors before the MS stage. CP-stars vary in the time they spent on the PMS stage which may lead to diverse observable magnetic properties. In theory, the boundary which separates stars with and without convective interiors during the Hayashi stage lays at 3 $M_\odot$. At the moment, we are searching for young PMS or near ZAMS stars of 2–3 $M_\odot$. Here, we present the analysis of properties of three selected stars which are HD 50341, HD 63347, and HD 201174. The analysis of a similar star HD 27404 is presented in [1].

Stars selection and observations

We have searched the catalog by Renson & Manfdroid [2] for poorly studied early-type stars with outlying chemical abundances. In such a way, HD 50341 and HD 63347 of B8 and B9 spectral class show a SrCrEu-type anomaly, which is more common to cooler CPs. Being bright objects of the northern hemisphere, they were considered to be good candidates for our study initiated back in 2011. Till now, we have 13 and 21 observational sets for HD 50341 and HD 63347, respectively.

HD 201174 was previously known to be a magnetic star from the observations with the 6-m telescope of SAO RAS in 2006–2007 [3]. After a short break, the star was included in our program, and its observations were resumed in 2009. Since then, we have collected 42 stellar spectra. This A0p star has the same SrCrEu-type anomalies.

Observations were carried out with the Main Stellar Spectrograph [4] of the Russian 6-m telescope in spectropolarimetric mode. Raw data reduction is done through the ZEEMAN context [5] of ESO-MIDAS.

Physical parameters

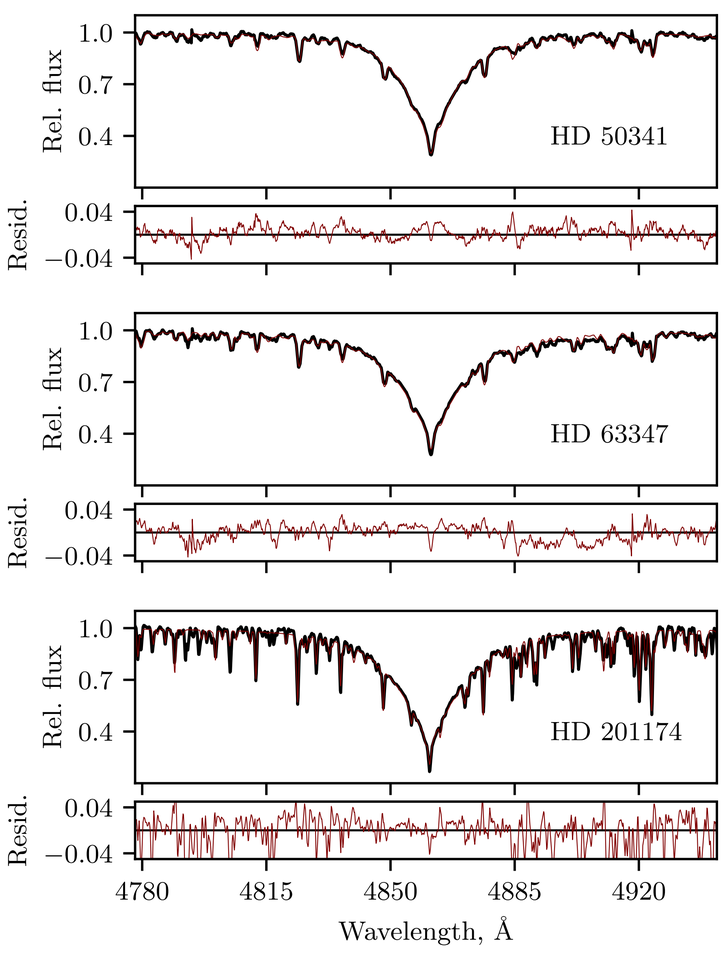

Figure 1: Hydrogen line H_β fit with the use of SME code.

We have attempted to estimate basic physical parameters from H_β spectral region using SME code assuming stars to be non-magnetic. The best fit of H_β line in spectra of HD 50341 is found to be with $T_{\rm eff} = 10800$ K and $\log g = 4.0$ which is consistent with estimations from the Geneva photometry. HD 50341 is located in the region of nonnegligible interstellar absorption. That explains the presence of interstellar Na lines in HD 50341 spectra.

HD 63347 is the least studied star in the sample. There is no data in either Geneva or Strömgren photometric system for the star. Fitting the H_β line results in $T_{\rm eff} = 11600$ K and $\log g = 4.5$. Tetzlaff *et.al.* [6] stated that HD 63347 is a run-away star of an age of 20 Myrs.

Gray & Corbally [7] found HD 201174 to be extremely peculiar A-type star. Its spectrum is rich with narrow and strong lines. Calibrations of Strömgren photometry lead to $T_{\rm eff}[u-b] = 9520$ K and $T_{\rm eff}[c1] = 9630$ K while Geneva photometry calibration results in $T_{\rm eff} = 9920$ K. The best approximation of observed profile of H_β line (Fig. 1) is achieved with $T_{\rm eff}[c1]$. HD 201174 is a MS star with surface gravity $\log g = 4.0$. Like HD 50341, the star is located in the region of significant interstellar absorption which might affect its SED.

HD 50341 and HD 63347 are rotating at a moderate rate. Projected rotational velocity in both cases does not exceed 50 km s^{-1}. Broadening of spectral lines in case of HD 201174 is mostly defined by the resolving power of the MSS ($v_{\rm e} \sin i \leqslant 20$ km s^{-1}).

Based on the available information about the brightness, effective temperature, distance to the stars, and interstellar reddening, we have estimated luminosity to be $\log L/L_\odot = 1.66$ for HD 50341 and HD 63347, and $\log L/L_\odot = 1.45$ for HD 201174. According to the physical parameters, the stars lay near ZAMS on a theoretical HR diagram (Fig. 2).

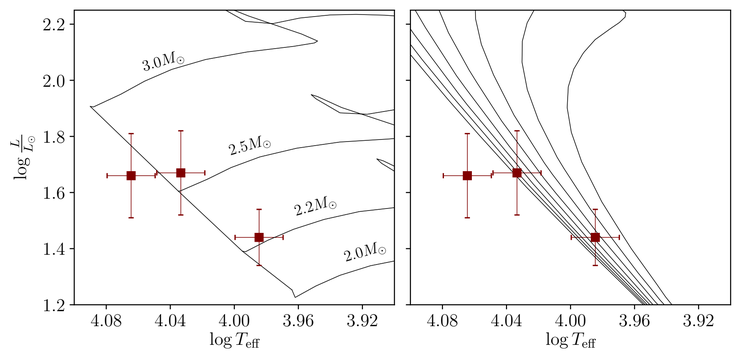

Figure 2: Position of the sample stars on a theoretical HR diagram. Isochrones are taken from Girardi *et al.* [8] and correspond to $\log t$ range from 7.8 to 8.5.

Magnetic field

Magnetic properties of the stars were obtained from time series of the effective magnetic field (B_l) measurements. To measure the longitudinal magnetic field, we use three methods which operate with the Zeeman effect manifestation in circularly polarized spectra. The first method is a modified Babcock's "positional" approach. A technique developed by Bagnulo *et.al.* [9] we have implemented as the second method. Finally, we use the Least Squares Deconvolution (so called LSD) approach which, unlike two previously described methods, allows to analyze polarization profile, not only its quantity. For a comprehensive analysis of LSD implementation and its limitations see [10].

Figures 3-5 represent the longitudinal field of three stars measured with "positional" (top panel) and Bagnulo's (bottom panel) methods phased with their rotational periods. Periods of HD 50341 and HD 63347 derived from magnetic measurements are in perfect agreement with those found in the literature. Rotational period of HD 201174 was derived, to our knowledge, for the first time.

Longitudinal field phase curves flatten at the negative extrema for HD 63347 and positive extrema for HD 201174. Thus the best-fit model is a two harmonic extension of periodic functions. Near positive extrema of HD 63347 one can see a scattering of individual points regardless of the applied method. We assume that reasons for the complex shape of the phase curves and scattering of individual measurements are external. It seems that the magnetic field topology is departed from the simple obliqued rotator model and should be described in terms of a noncentral dipole or a combination of higher order multipoles.

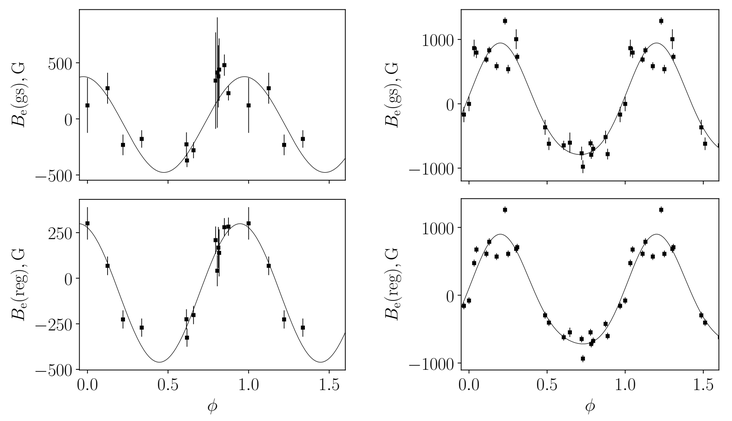

Figure 3: Phase curve of HD 50341. $P_{\rm rot} = 2\overset{\rm d}{.}5094$.

Figure 4: Phase curve of HD 63347. $P_{\rm rot} = 1\overset{\rm d}{.}7495$.

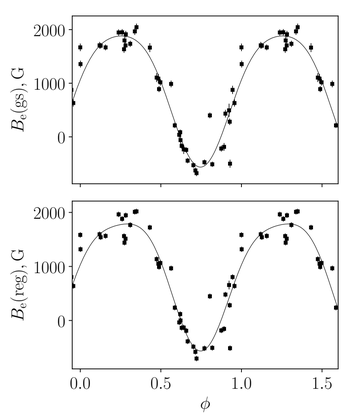

Figure 5: Phase curve of HD 201174. $P_{\rm rot} = 2\overset{\rm d}{.}43002$.

For HD 201174 dataset is large enough to provide a good coverage over the rotational period. Changing with rotational phase Stokes V LSD profile is plotted in fig. 6. In a shape of some profiles, one can see the presence of the cross-over effect.

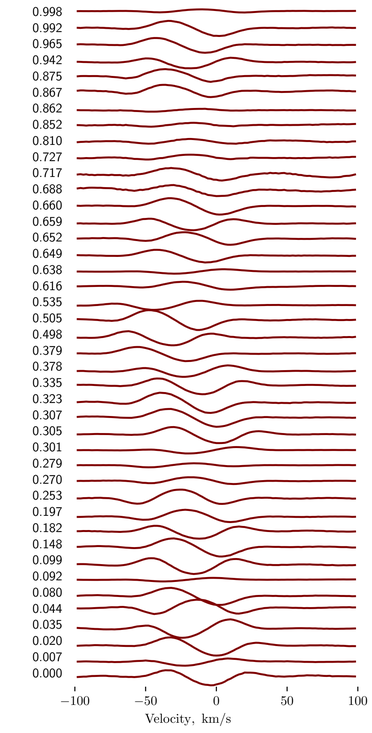

Figure 6: Phased Stokes V LSD profile of HD 201174.

Summary

Abundance anomalies and peculiarities in SED of CP-stars may lead to wrong spectral classification. Sometimes it is due to the low quality of observational data, in other cases, the reason lies in the nature of the stars. SrCrEu-type classification found in the literature for the presented stars is unusual for hot late B-stars.

We have found the presence of the magnetic field in HD 50341 and HD 63347 for the first time and confirmed magnetic nature of HD 201174. We show that phase curves of HD 63347 and HD 201174 have complex shape departing from a simple periodic function.

Our estimations of physical parameters and magnetic properties suggest that the stars are young objects of 2–3 solar masses. Therefore we may consider them as predecessors of evolved CP-stars lacking rare-earth elements and demonstrating very weak magnetic fields. Furthermore, we plan to carry out the detailed analysis of chemical composition.

References

[1] Semenko E., et.al. *Astrophys. Bulletin*, accepted
[2] Renson P., Manfroid J. *A&A*, **498**, 961 (2009)
[3] Romanyuk I.I., et al. *Astrophys. Bulletin*, **69**, 427 (2014)
[4] Panchuk V.E., et al. *Astrophys. Bulletin*, **69**, 339 (2014)
[5] Kudryavtsev D.O., et.al. *MNRAS*, **372**, 1804 (2006)
[6] Tetzlaff N., et al. *MNRAS*, **410**, 190 (2011)
[7] Gray R.O., Corbally C.J. *AJ*, **124**, 989 (2002)
[8] Girardi L., et al. *A&AS*, **141**, 371 (2000)
[9] Bagnulo S., et al. *A&A*, **389**, 191 (2002)
[10] O. Kochukhov, et.al. *A&A*. **524A**, 5 (2010)

Acknowledgements

This work is supported by the Russian Science Foundation, grant No.14-50-00043.