HR 62: A New Evolved Chemically Peculiar Late-B Star?

Tolgaahan Kılıçoğlu\textsuperscript{1} and Richard Monier\textsuperscript{2}
\textsuperscript{1}Ankara University, Faculty of Science, Department of Astronomy and Space Sciences, Döğol Cad., 06100, Yenimahalle, Ankara, Turkey; tkilicoglu@ankara.edu.tr
\textsuperscript{2}LESIA, UMR 8109, Observatoire de Paris et Université Pierre et Marie Curie Sorbonne Universités, place J. Janssen, Meudon, Paris, France; Richard.Monier@obspm.fr

Abstract. The spectrum of the evolved B8 III giant HR 62 exhibits weak He-lines and strong Mn and P lines. HR 62 therefore resembles both a HgMn star (CP3) and a He-weak PGa star (CP4).

This study is a companion project to a high resolution survey of slowly rotating late-B type stars aiming at finding new chemically peculiar stars. We have analysed the spectra of HR 62 (B8 III) and the dwarf comparison star HR 677 (B8 V) to derive their chemical abundances. Both stars have similar effective temperatures (12500 K) and projected rotational velocities (\(\sim 25\) km s\(^{-1}\)).

The medium resolution (\(R \sim 14000\)) spectra covering the wavelength range of 4380-7350 Å of HR 62 and HR 677 have been obtained with the échelle spectrograph attached to the 40 cm telescope in Ankara University Kreiken Observatory (AUKR), Turkey. We have used SYNSPEC49/SYNPLOT written by I. Hubeny, T. Lanz to compute grids of synthetic spectra and derive elemental abundances by modeling selected unblended lines.

We find that HR 62 exhibits underabundance of Si and remarkable overabundance of P and Mn with respect to the Sun. In contrast, HR 677 does not have abundances departing by more than \(\pm 0.25\) dex from solar abundances. A mass of 5.4 \(M_\odot\) and an age of 90 Myr have been estimated for HR 62.

We discuss the origin of the chemical peculiarities of HR 62 and its status as a CP star. The effective temperature of the star (12500 K) agrees well with those of HgMn (CP3) stars. Furthermore, the main sequence end of its evolutionary track also intersects the domain of He-weak CP4 stars. Hence these first results suggest that HR 62 may be a transition object between the CP4 to CP3 subgroup. However, a more detailed analysis of higher resolution spectra at shorter wavelengths (< 4380 Å) is necessary to clearly address the nature of this interesting object.

1. Introduction

The causes of the chemical peculiarities in the atmospheres of non-magnetic B and A type stars have not yet been understood fully. Atomic diffusion is one of the most likely explanations (Michaud et al. 2015). In order to test the predictions of evolutionary models including atomic diffusion, elemental abundances of a large number of CP stars should be derived.
We have selected about 100 slowly rotating bright \( V < 7^\text{m} \) late-B stars in order to look for new CP stars. A first step in this project consists in observing these objects using a 40-cm telescope equipped with a medium resolution échelle spectrograph to detect new CP stars. The CP candidates will then be observed at a higher resolution with larger telescopes. During this survey, we have found strong Mn II and P II lines in the spectrum of HR 62. This study presents the elemental abundance analysis for HR 62 and the dwarf comparison star HR 677 based on their medium resolution spectra.

2. Observations and Analysis

The medium resolution spectra (R ∼ 14000) of HR 62 and HR 677 covering the range 4380-7350 Å were obtained using the Shelyak eShel spectrograph mounted on the 40-cm telescope in Ankara University Kreiken Observatory (AUKR) in 2017. The model atmospheres were computed using ATLAS12 (Sbordone et al. 2004; Kurucz 2005) assuming local-thermodynamic, radiative and hydrostatic equilibria. Grids of synthetic spectra were computed using SYNSPEC49/SYNPLOT (Hubeny & Lanz 1995). The linelist was first constructed from R. Kurucz’s gfall.dat and then updated using VALD and NIST atomic database.

The effective temperatures of the stars were initially estimated from their spectral types and their Johnson \( BV \) magnitudes using the calibrations of Flower (1996) and Bessell et al. (1998). The color excess \( E(B - V) \) of the stars were retrieved from 3D dust map of Green et al. (2018). The same effective temperature \( (12500 \pm 500 \text{ K}) \) was found for both stars. The surface gravity of the stars were derived by modelling \( H_\beta \) lines in the spectra (Fig. 1). The logarithms of the surface gravities are \( 3.20 \pm 0.05 \) and \( 3.95 \pm 0.05 \) (gravity \( g \) in cm s\(^{-2}\)) for HR 62 and HR 677, respectively.

The masses and ages of the stars were also estimated by placing them in a log \( g - T_{\text{eff}} \) diagram (Fig. 2). The theoretical evolutionary tracks and isochrones were taken from Bressan et al. (2012). Masses of 5.40 and 3.55 \( M_\odot \) and ages of 90 and 173 Myr were found for HR 62 and HR 677, respectively. We iteratively adjusted the synthetic spectra to the observed unblended lines until the best fit was achieved in order to derive elemental abundances. We used a Levenberg-Marquardt algorithm (Markwardt 2009) for the \( \chi^2 \) minimisation. Fig. 3 illustrates the modeling of Fe, Mn, Mg, and P lines in two
Figure 2. Position of HR 62 and HR 677 on log g–Teff diagram with theoretical evolutionary models and isochrones. The other stars analyzed up to now in the same project were also taken from Kılıçoğlu & Monier (2018) and plotted for comparison.

Figure 3. Same in Fig. 1, but for Fe II, Mg II, Mn II, and P II lines.

spectral regions. Clearly Mn and P are more abundant in the atmosphere of HR 62 than in HR 677.

3. Results and Discussion

We have derived the abundances of 11 elements for HR 62 and 9 elements for HR 677. Fig. 4 shows the abundance patterns of HR 62, HR 677 and the other stars analyzed so far using the test observations of the 40-cm telescope and medium resolution échelle spectrograph in AUKR. Using the solar abundances of Grevesse & Sauval (1998), we find that the abundances of Mn and P appear to be remarkably enhanced in the photosphere of HR 62. This star also exhibits a slight overabundance of Ne, slight underabundance of He and Mg, and underabundance of Si. In contrast, the abundances of HR 677 do not depart significantly from the adopted solar composition. We cannot yet confirm
the presence of strong Ga II and Hg II lines in the spectra of HR 62 as the spectra do not extend to wavelengths shorter than 4380 Å. The abundance pattern of the star, however, suggest that it is most likely a CP3 (e.g., HgMn) star.

The position of HR 62 in the log $g$–$T_{\text{eff}}$ diagram (see Fig. 2) shows that the star has just left the main-sequence. If we trace its evolutionary track back to the main sequence, we reach the domain where the CP4 stars are. We may assume that the star could have been once of CP4 type (e.g. He-weak PGa) and now may have evolved into CP3 type. A more detailed analysis with a higher resolution spectrum of HR 62 at shorter wavelengths ($\lambda < 4380$ Å) is needed to look for the Hg and Ga lines. HR 62 may be a instance of a B-type CP giant migrating from CP4 to CP3 type.

References

Bessell, M. S., Castelli, F., & Plez, B. 1998, A&A, 333, 231
Bressan, A., Marigo, P., Girardi, L., Salasnich, B., Dal Cero, C., Rubele, S., & Nanni, A. 2012, MNRAS, 427, 127. 1208.4498
Flower, P. J. 1996, ApJ, 469, 355
Green, G. M., Schlafly, E. F., Finkbeiner, D., Rix, H.-W., Martin, N., Burgett, W., Draper, P. W., Flewelling, H., Hodapp, K., Kaiser, N., Kudritzki, R.-P., Magnier, E. A., Metcalfe, N., Tonry, J. L., Wainscoat, R., & Waters, C. 2018, MNRAS, 478, 651. 1801.03555
Grevesse, N., & Sauval, A. J. 1998, Space Sci.Rev., 85, 161
Hubeny, I., & Lanz, T. 1995, ApJ, 439, 875
Kılıçoğlu, T., & Monier, R. 2018, ArXiv e-prints. 1810.08444
Kurucz, R. L. 2005, Memorie della Societa Astronomica Italiana Supplementi, 8, 14
Markwardt, C. B. 2009, in Astronomical Data Analysis Software and Systems XVIII, edited by D. A. Bohlender, D. Durand, & P. Dowler, vol. 411 of Astronomical Society of the Pacific Conference Series, 251. 0902.2850
Michaud, G., Alecian, G., & Richer, J. 2015, Atomic Diffusion in Stars, Astronomy and Astrophysics Library, ISBN 978-3-319-19853-8. (Springer International Publishing Switzerland, 2015.)
Sbordone, L., Bonifacio, P., Castelli, F., & Kurucz, R. L. 2004, Memorie della Societa Astronomica Italiana Supplementi, 5, 93. astro-ph/0406268