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HD 185330 – chemically peculiar ^{3}He star in the *Kepler* field

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Abstract. We analyzed high-resolution spectra of the chemically peculiar ^{3}He star HD 185330. We determined its atmospheric parameters ($T_{\rm eff}, \log g, \xi$) and constrained its rotation velocity and abundance pattern. In particular, we found a large ($\times 100$) phosphorus abundance excess and evidence of ^{3}He and ^{4}He abundance stratification in the atmosphere.

Key words: stars: chemically peculiar – stars: atmospheres – stars: abundances

Chemically peculiar B-type stars showing unusually high abundances of the ^{3}He isotope in their atmospheres are rare. HD 185330 (KIC 3246460, V= 6.50 mag) was classified as ^{3}He star by Preston (1976). Several ^{3}He and ^{4}He lines are visible in its spectra. We classified HD 185330 as B5 II-IIIp following criteria presented in Gray & Corbally (2009).

The spectra of HD 185330 show weak emission lines (WELs). According to the list presented in Wahlgren & Hubrig (2004) these are, e.g., the Mn II multiplet 13, Fe II and P II lines. Some of the observed WELs remain unclassified. Theoretical explanations for the WELs are based mainly on the interlocked non-local thermodynamic equilibrium (non-LTE) effects. To explain the observed emission of the Mn II multiplet 13, these effects have to be combined with the vertical stratification of the Mn abundance (see Sigut, 2001a,b).

The high-resolution spectra of HD 185330 were taken with the HERMES (Raskin et al., 2011), HIDES (Izumiura, 1999) and TLS (see e.g. Lehmann et al., 2016) spectrographs. The atmospheric parameters were obtained following various methodologies. First, we assumed LTE and used Kurucz ATLAS9 and SYNTHE codes (Kurucz, 2005). We determined the effective temperature $T_{\rm eff} = 16300 \pm 200$ K and surface gravity $\log g = 3.7 \pm 0.1$ from Balmer and Fe II/Fe III lines, and the microturbulence $\xi = 0.5 \pm 0.5\,{\rm km\,s^{-1}}$ from Fe II lines.

Next, a hybrid non-LTE method was applied, in which we combined LTE Kurucz atmospheric models and non-LTE line formation procedures (Detail and Surface codes, see Przybilla & Butler, 2004). Using this method, we derived $T_{\rm eff} = 16400 \pm 400\,{\rm K}$ and $\log g = 3.8 \pm 0.1$ from Si II/Si III and Balmer lines, and $\xi = 0.5 \pm 0.2\,{\rm km\,s^{-1}}$ from S II and Si III lines. Finally, we applied a full non-LTE method using Tlusty and Synspec (Hubeny & Lanz, 2017) for the atmospheric model and synthetic spectra calculations. A variable abundance stratification of He isotopes and other elements was included in the model atmosphere calculations to fit the observed lines. We found that the ^{3}He and ^{4}He abundances decrease with height and that the overall abundance of ^{3}He is lower than that of ^{4}He. The abundance analyses using all these methods generally agree. In particular, the P abundance determined from LTE and full non-LTE approaches is a factor of 100 above solar. This is a typical characteristic of He-weak PGa stars, but Ga lines were not identified in the spectra of HD 185330.

HD 185330 was observed by the *Kepler* satellite during all quarters, which corresponds to a time span of about four years. A total number of 50291 data points were collected in the long-cadence mode. The analysis of the light curve gave a rotation period $P_{\rm rot} = 37.64307 \pm 0.00003\,{\rm d}$. The rotation period and projected rotation velocity $v \sin i = 3.0 \pm 0.5\,{\rm km\,s^{-1}}$ obtained from the spectroscopic analysis allow us to estimate a minimum stellar radius of about $6\,{\rm R}_\odot$.

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