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Extremely peculiar spectrum of the primary component of the eclipsing binary HD 66051

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Abstract. HD 66051 is an eclipsing and spectroscopic double-lined binary (SB2), hosting two chemically peculiar stars: a highly peculiar B star as primary and an Am star as secondary. The investigation of the new high-resolution UVES spectrum of HD 66051 allowed us to decide on the chemical peculiarity type of both components with more reliability. An analysis of TESS photometric time series data will further specify the physical parameters of the stars and the orbital parameters of the system.

Keywords. stars: chemically peculiar, binaries: eclipsing

Chemically peculiar stars are a heterogeneous group of objects characterised by surface abundances which can depart by many orders of magnitude from the solar values. Some of these peculiarities are well defined (e.g. Cr, Sr, and Eu overabundance for Ap stars). However, there is a number of B and A stars so peculiar that they defy classification (Gray & Corbally 2009). Peculiarities result from segregation of chemical elements in stellar atmospheres under the influence of atomic transport processes and, in some cases, a magnetic field.

The eclipsing and spectroscopic binary HD 66051 consists of a highly peculiar B star and an A type component. Previous analysis of high-resolution spectra and spectroscopic and photometric time-series allowed to determine the atmospheric parameters and preliminary chemical composition of both stars, orbital parameters of the system, and derive the magnetic field structure of the primary (Niemczura *et al.* 2017; Paunzen *et al.* 2018; Kochukhov *et al.* 2018).

Photometric time-series from the ROAD Observatory (Niemczura *et al.* 2017) and TESS satellite (Ricker *et al.* 2015), together with radial velocity values measured in HIDES, CASLEO, and ESPaDOnS spectra (Paunzen *et al.* 2018; Kochukhov *et al.* 2018) were used to analyse HD 66051 with the eclipsing binary modelling code PHOEBE 2.1.5 (Prša & Zwitter 2005). For both components we assumed synchronous rotation, albedo and gravity darkening coefficients equal to one due to radiative envelopes, and a logarithmic law of limb darkening. The atmospheric surface gravities $\log g$ were fitted with the model, the assumed effective temperatures $T_{\rm eff}$ were corrected during the calculations. We used the Levenberg-Marquardt method implemented in PHOEBE. The final solution was achieved after only a few iterations. The obtained parameters, namely $T_{\rm eff} = 13000$ K, $\log g = 4.0$, and $R_1 = 2.810\,{\rm R}_\odot$ for the primary, and $T_{\rm eff} = 9000$ K, $\log g = 4.4$, and $R_2 = 1.423\,{\rm R}_\odot$ for the secondary, were adopted in the following spectroscopic analysis of the SB2 spectrum of HD 66051. The high-resolution and high signal-to-noise UVES spectrum was recorded in an orbital phase that allows the separation of lines of both components in the spectrum. To perform the spectral analysis we assumed microturbulent velocity $\xi = 1\,{\rm km\,s^{-1}}$ for the primary and $\xi = 2\,{\rm km\,s^{-1}}$ for the secondary. Projected rotational velocities of both stars, $v \sin i = 30$ and $17\,{\rm km\,s^{-1}}$, respectively, were determined simultaneously with the chemical composition.

To derive information about the abundance pattern of both stars, the lines in their spectra have to be identified. We used atomic data taken from the F. Castelli's website† and R. Kurucz codes for calculating atmospheric models and synthetic spectra‡. The synthetic spectrum of the SB2 system was compared with the normalised UVES spectrum, assuming $R_2/R_1 = 0.506$ calculated with PHOEBE. The element abundances of both stars were adjusted to achieve agreement between the theoretical and observed spectrum.

The analysis of the high-resolution, high signal-to-noise UVES spectrum obtained in the framework of the ESO DDT programme 2102.D-5017(A) confirmed the peculiar nature of both system components. It became clear that the primary star is a highly peculiar object. In the spectrum of this star we found some light elements (He, Mg, Al) underabundant and all analysed iron-peak elements except Ni enhanced. Similarly, heavy and rare-earth elements are overabundant in its spectrum. Such chemical composition indicates that the primary is a Bp star. On the other hand, we identified lines of Mn, Xe, Pt, and Pb in its spectrum. Abundances of these elements are enhanced, suggesting an HgMn type. Most importantly, up to the present, overabundances of Xe were observed in HgMn and Am stars, but never in Bp star atmospheres (Ghazaryan *et al.* 2018). However, the analysis of the only Hg line identified in the primary's spectrum (398.3 nm) does not unambiguously indicate Hg overabundance because lines of other elements (e.g. Dy) are found at the same wavelength. The lines that we could identify with the secondary star indicate an abundance pattern with overabundant iron-peak, heavy, and rare-earth elements and depleted Sc, which agrees very well with the definition of Am-type objects.

The detailed investigation of the chemical abundances of the system components is difficult, mostly because of the extremely peculiar spectrum of the primary, which contains a lot of unidentified lines. This applies especially to wavelengths shorter than about 450 nm, where the spectra of both stars are very rich in spectral lines. It is obvious that the detailed analysis of abundance patterns of chemically peculiar stars clearly depends on the progress of experimental laboratory astrophysics providing reliable atomic data.

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‡ kurucz.harvard.edu

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