A deep transfer learning approach to photospheric parameters of CARMENES target stars

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Abstract

Over the last years several methods have been developed to determine accurate and precise stellar parameters for cool stars (e.g. M dwarfs). However, sometimes significant differences can be found when comparing the estimations for the same star derived from different methods: from the synthetic spectral fitting we studied in Passegger et al. (2019) to the newest deep transfer learning approach that will be published at the end of the year. In Passegger et al. (2021), we compare effective temperature (Teff), surface gravity (log g), and metallicity [M/H] of 18 well-studied M dwarfs observed with the CARMENES high-resolution spectrograph derived with different approaches, which include synthetic spectral fitting, the analysis of pseudo-equivalent widths, and machine learning. The CARMENES spectrograph, installed on the 3.5 m telescope at the Calar Alto Observatory (Spain), has two channels, covering the visible (0.52 to 0.96 μm, R=96,400) and near-infrared (0.96 to 1.71 μm, R=80,600) spectral ranges. We analyze the discrepancies in the derived stellar parameters using several analysis runs with the goal to minimize these discrepancies and find stellar parameters more consistent with literature. We find that even standardizations such as common wavelength ranges, synthetic model spectra, and continuum normalization methods do not improve the consistency in stellar parameters in M dwarfs as they do for hotter main-sequence stars, leaving mean deviations of around 50-200 K in temperature, and 0.1-0.3 dex in metallicity between the different methods.

One of the methods we used in the above analysis is presented in Passegger et al. (2020). There we introduced a Deep Convolutional Neural Network (CNN) approach to derive the fundamental stellar parameters Teff, log g, [M/H], and rotational velocity (v sin i) from high-resolution high signal-to-noise ratio spectra. We constructed an individual CNN architecture for each of the four parameters and trained them on synthetic PHOENIX-ACES spectra. After that, we applied the trained networks to the spectra of 50 M dwarfs observed with CARMENES. We compared our results to literature values, and demonstrated that our method can be used for stellar parameter determination without the need of having a huge sample of stellar spectra with known parameters, because our networks can be trained on synthetic spectra.

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To take our deep learning efforts a step further, we introduce a Deep Transfer Learning (DTL) approach in Bello-Garcia et al. (2021). This allows us to transfer external knowledge about the stellar parameters (e.g., from interferometry or FGK+M binaries) to our training set and therefore improve our results compared to literature.

Slides: in PDF

Video: https://youtu.be/NV_xtTt9GdI

Keywords: methods: data analysis, techniques: spectroscopic – stars: fundamental parameters – stars: late, type – stars: low, mass