Classification of spectral Hα lines from massive stars using machine learning methods

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Abstract

Massive stars, characterized by strong winds, are typically modeled with the approximated β-law, instead of using a complete hydrodynamic treatment. This works aims to apply a huge synthetic line database, constructed using hydrodynamic modeling, together with different machine learning methods, to yield predictions of different parameters of B-supergiants and other massive stars.

1. Hydrodynamic regimes

The mechanism driving the winds of massive stars is explained by the m-CAK theory [2, 4, 5], parametrized by the force multiplier parameters: α, k and δ. The latter produces the fast ($\delta \lesssim 0.24$) and the δ-slow ($\delta \gtrsim 0.28$) [3] hydrodynamic regimes.

2. Data set

We used the Hα lines from δ-slow models from ISOSCELES (GrId of Stellar AtmOSphere and HydrodynamiC ModELs for MassivE Stars, see Fig. 1) [1] as our main data set.

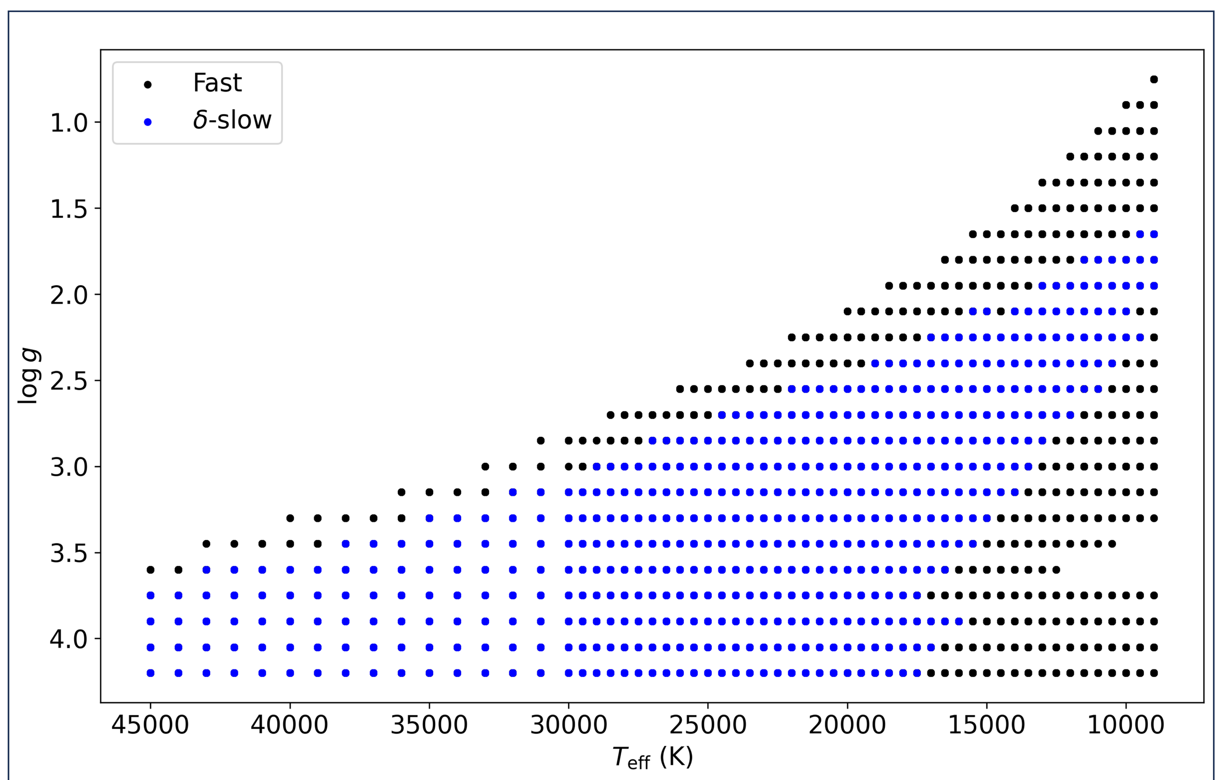

Fig. 1: Distribution of ISOSCELES parameters in the log g - $T_{\rm eff}$ space.

3. Methodology

To fit an observation, we:

- Separated our data in classes with Gaussian Mixture Models (GMM, see Fig. 2).
- Trained a Deep Neural Network (DNN) to label the lines with a class.
- Computed the χ^2-test between an observation and the lines in the predicted class.

4. Results

Applying this procedure to 12 B-supergiant stars studied previously in [6], better fits were obtained for 9 of these stars (see Fig. 3).

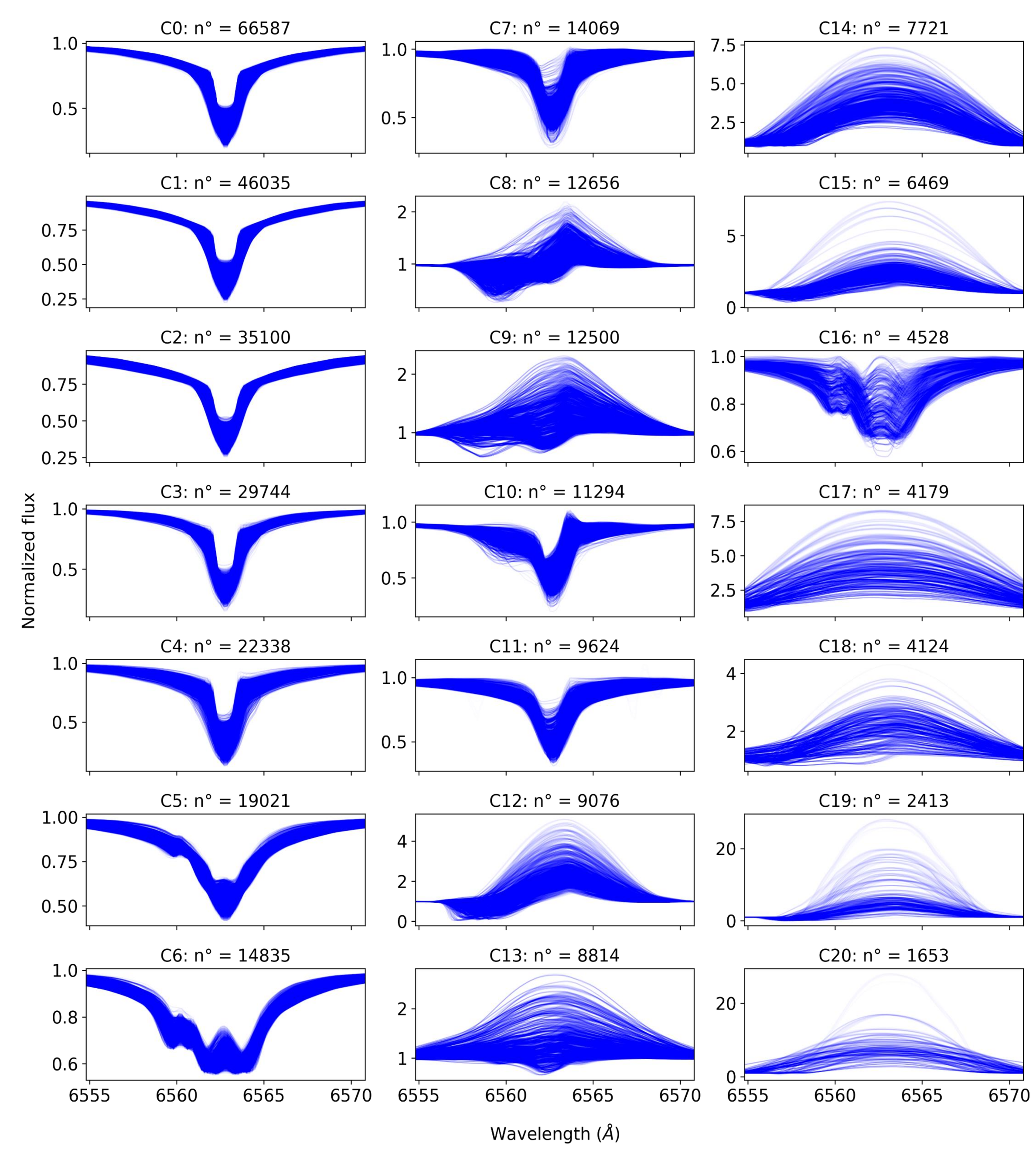

Fig. 2: Classes obtained with GMM. The titles show the number of lines in each class.

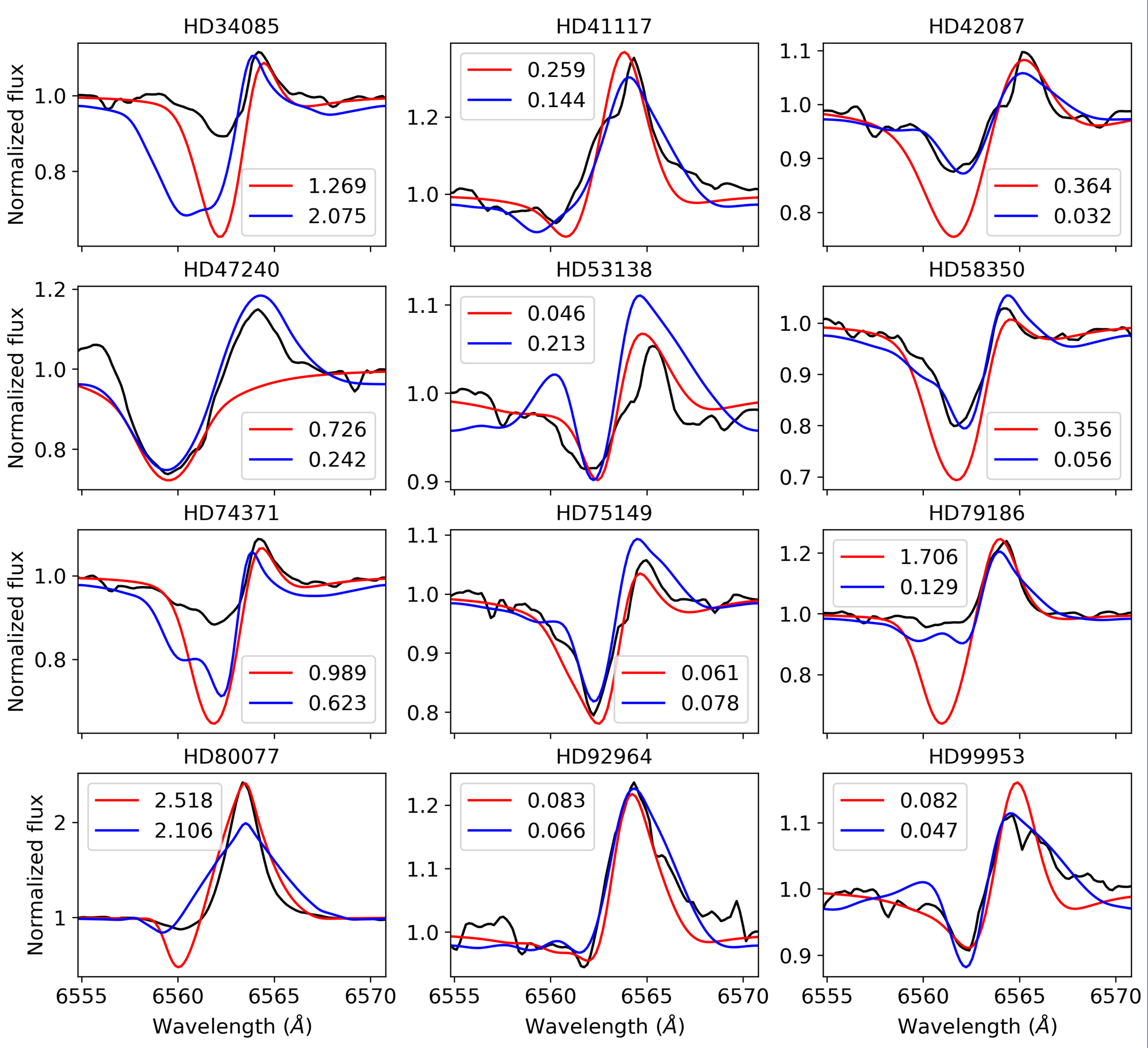

Fig. 3: Hα lines for 12 stars studied in [6]. In blue there are our fits, and in red the fits from [6]. The labels show the χ^2 values.

5. More spectral lines

Hα lines are sensible to the mass-loss ratio, but we should be using different lines to better determine other parameters. An initial test to this, with 6 lines, is shown in Fig. 4.

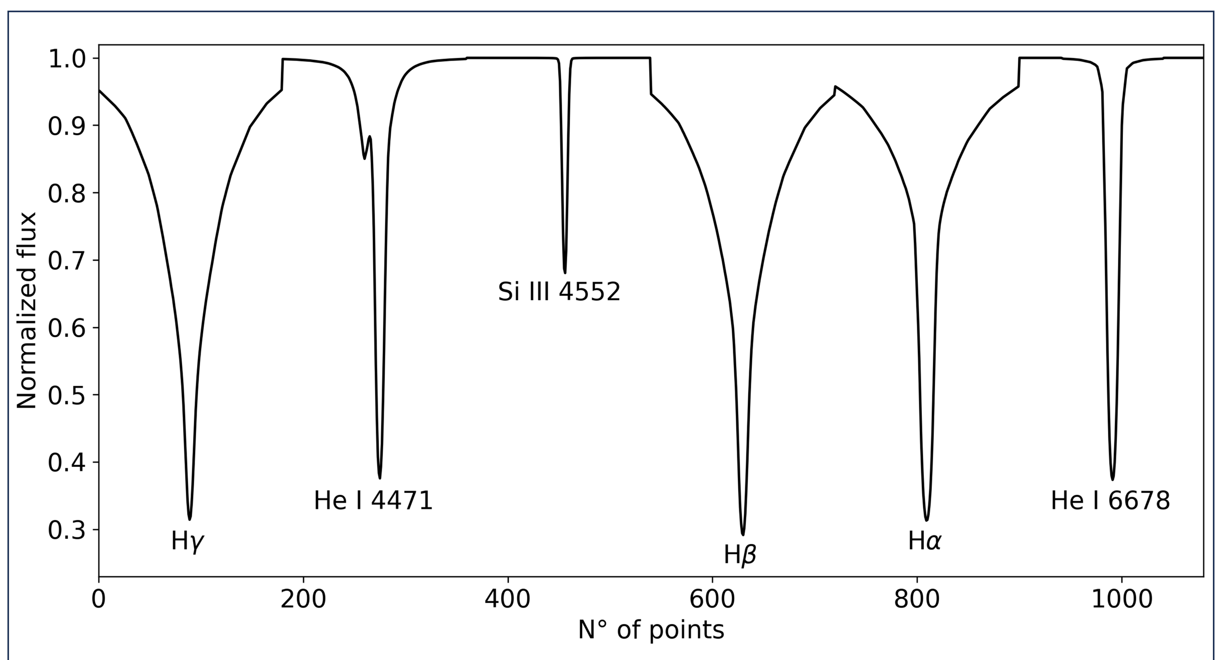

Fig. 4: Ensemble constructed with 6 different line profiles.

6. Error estimation

To estimate the error in the predictions, we plan to implement a Bayesian Neural Network (BNN), which yields distributions as results, from which a dispersion metric can be computed. An example can be seen in Fig. 5.

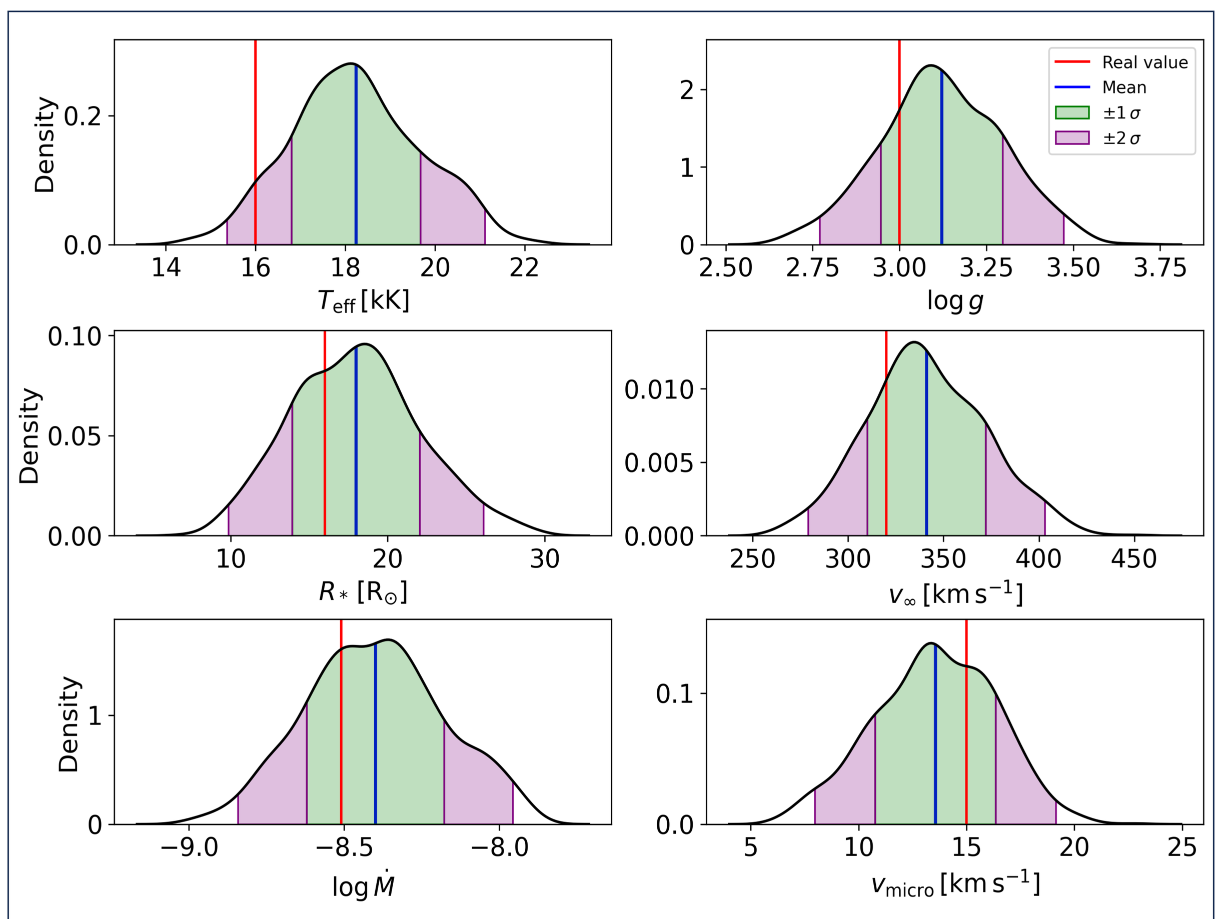

Fig. 5: Distribution of 6 parameters predicted by a BNN.

7. Discussion

- The ISOSCELES database and machine learning methods were used to make prediction to B-supergiant stars.
- Similar results to the literature were obtained, taking just a few minutes for the predictions.
- It is planned to implement a BNN with multiple lines and include fast solutions in the future.

References

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