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Playing CHESS with stars: Opening moves

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Abstract. We introduce the CHESS (CHEmical analysis Survey System) pipeline. CHESS is a workflow of automated steps to extract precise, accurate, and complete chemical information from large sets of stellar spectra. The zero point of the atmospheric parameters is anchored by a set of reference stars distributed throughout the parameter space (effective temperature, surface gravity, and metallicity). Multiple instances of differential analyses are used to achieve high precision locally. Some of the steps in the analysis are assisted by unsupervised machine learning algorithms and/or Bayesian inference.

Keywords. Catalogues; Methods: data analysis; Stars: fundamental parameters; Stars: abundances

1. Introduction

Stellar spectroscopy is a key tool in the quest of understanding the puzzle of the formation and evolution of the Milky Way and nearby galaxies. Massive spectroscopic surveys are currently feeding an on-going revolution in our knowledge of Galactic astrophysics.

With spectra available for tens of millions of stars, the new challenge is their analysis. Automatic pipelines are needed, but the comparison of their results is not always satisfactory (e.g. Smiljanic et al. 2014; Worley et al. 2024). Data-driven analysis methods are now widely used as they are fast and can reach very high precision. However, such methods need a priori knowledge of the parameters and abundances in a training sample.

Creating a high-quality training sample requires the use of more traditional methods. Our goal in this project is to develop a pipeline that can carefully extract the most and the best possible information from each analysed spectrum.

2. CHEmical Survey analysis System (CHESS)

The CHEmical Survey analysis System (CHESS) is a pipeline for the extraction of precise and accurate parameters and complete abundances from large samples of stellar spectra:

• Precision: implements multiple instances of the differential analysis method to reach high precision in the results;

• Accuracy: uses stars with independently known accurate parameters as reference in the differential analysis;

• Complete: strives to extract abundances for every single element with lines available in the wavelength range of the data;

• Data: we are currently re-analyzing the data archive of the Ultraviolet and Visual Echelle Spectrograph (UVES, Dekker et al. 2000), but expect to extend CHESS to deal with data of other instruments in the future.

In several of its steps (Fig. 1), CHESS implements unsupervised machine learning algorithms or uses Bayesian inference (in a similar way as described in Worley et al. 2024).

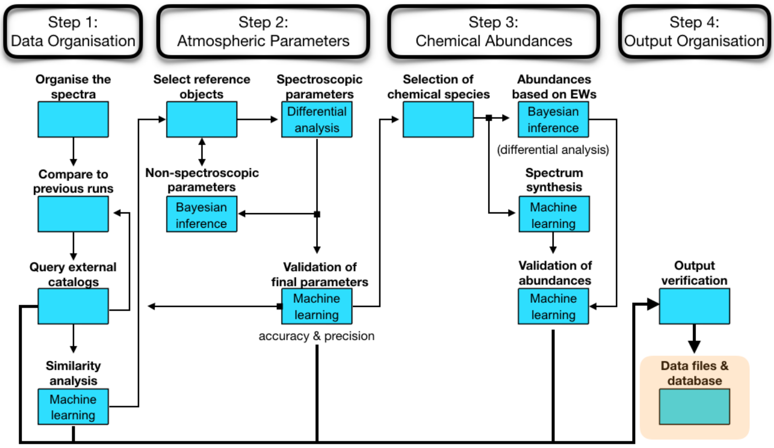

Figure 1. Schematic overview of the CHESS workflow. The ticker arrows at the bottom indicate tasks that directly feed the output organisation. By the end of the run, every input spectrum needs to be accounted for.

3. Reference stars

As reference, we use a sample of 1018 UVES spectra of 267 stars, obtained in different set ups and with distinct signal-to-noise ratios:

- Titans I. Metal-poor dwarfs and subgiants: 329 spectra of 66 stars (Giribaldi et al. 2021);
- Titans II. Metal-poor giants: 164 spectra of 32 stars (Giribaldi et al. 2023);
- Gaia FGK benchmark stars: 252 spectra of 37 stars (Soubiran et al. 2024);
- Gaia "golden sample": 304 spectra of 110 stars (Gaia collaboration et al. 2023);
- Gaia-ESO Survey K2 stars: 81 spectra of 44 stars (Worley et al. 2020).

The system of atmospheric parameters obtained by CHESS is currently anchored in the one defined by these stars, which cover the relevant parameter space relatively well.

4. Similarity analysis

We use the dimensionality reduction algorithm called t-SNE to perform a "similarity analysis" before any atmospheric parameter is known. Using directly the spectra (radial velocity corrected, continuum normalised, and homogenised to have the same wavelength range and dispersion), our implementation can identify stars that have parameters within ± 250 K in effective temperature, ± 0.2 dex in surface gravity, and ± 0.2 dex in metallicity of each other (Martínez-Fernández, Özdemir et al., in prep). See also Özdemir et al. (this volume) for a discussion of CHESS applied to stars in globular clusters.

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