The AMBRE Project: Stellar parameters for the UVES Archived Spectra

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Abstract. The goal of the AMBRE Project, in a collaboration between the Observatoire de la Côte d'Azur and ESO, is to provide homogeneously determined stellar parameters for the archived spectra of four of ESO's key spectrographs.

Presented here are the stellar parameters for the UVES archived spectra of six standard setups: Red860; Red580; Red564; Blue437; Blue390; and Blue346. We will explore the characteristics of each stellar dataset revealing the range of stars that have been observed and how they can be combined as a coherent set. The combination of the six archive sets has resulted in yet another extensive stellar sample with homogeneously defined stellar parameters. This spectral library has the potential to greatly further the use of the ESO archived spectra in a range of stellar population studies.

Keywords: stars: atmospheres, stars: fundamental parameters, stars: abundances, astronomical databases: miscellaneous, surveys

1. Introduction

In the era of large spectral analysis the AMBRE Project is addressing the task of exploiting the wealth of information that already exists within the ESO archives. The collaboration between the European Southern Observatory (ESO) and the Observatoire de la Côte d'Azur (OCA) was established in order to provide stellar parameters for the stellar spectra in the archives of the FEROS, HARPS, UVES and Flames/GIRAFFE instruments.

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The first stage of the AMBRE project, the analysis of the FEROS archived spectra, was completed in 2012 and the parameters have recently been made available through the advanced data products facility of the ESO archive. A full description of the FEROS analysis and the automated pipeline developed for the AMBRE Project is provided in Worley, de Laverny, Recio-Blanco, Hill, Bijaoui & Ordenovic (2012a). The analysis of the UVES archive spectra and HARPS archive spectra are almost complete and will be described in respectively in Worley, de Laverny, Recio-Blanco, Hill, Bijaoui & Ordenovic (2012b) and De Pascale, Worley, de Laverny, Recio-Blanco, Hill & Bijaoui (2013).

2. MATISSE & the AMBRE Synthetic Spectra Grid

The programme at the heart of the AMBRE Project is MATISSE: MATrix Inversion for Spectrum SynthEsis which is described in full in Recio-Blanco, Bijaoui & de Laverny (2006). This is a local multi-linear regression method which determines the stellar parameters of a stellar spectrum by the projection of the observed spectrum onto basis vectors known as Bθ functions. These Bθ functions are calculated from the AMBRE high resolution synthetic spectra grid which is described in de Laverny, Recio-Blanco, Worley & Plez (2012).

For each point on the synthetic grid there are Bθ functions corresponding to each of the stellar parameters (θ) being determined. For the AMBRE Project the four stellar parameters are the effective temperature (T_{\text{eff}}), the surface gravity (log g), the mean metallicity obtained from all the spectral features for any element of atomic mass greater than helium ([M/H]), and the global \( \alpha \)-element to iron abundance ratio ([\alpha/Fe]) where the \( \alpha \) elements are defined as O, Ne, Mg, Si, Ar, Ca and Ti. However not all of these elements may have spectral features present in the pertinent wavelength range.

The grid is based on the MARCS stellar atmosphere models grid (Gustafsson, Edvardsson, Eriksson, Jorgensen, Nordlund & Plez 2008), VALD atomic linelists (Kupka, Piskunov, Ryabchikova, Stempels & Weiss 1999) and molecular linelists provided by B. Plez. The grid encompasses the expected parameters for slow-rotating FGKM stars with specific parameter ranges of \( T_{\text{eff}} \) between 2 500 K and 8 000 K, log \( g \) from −0.5 to +5.5 dex, [M/H] from −5.0 to +1.0 dex and [\alpha/Fe] between −0.4 dex and +0.8 dex, although not all combinations of the parameters are available within the grid.

3. AMBRE:UVES analysis

The automated analysis pipeline which feeds reduced spectra into MATISSE was developed for the AMBRE:FEROS analysis and subsequently modified for the analyses of the HARPS and UVES data. As each dataset covered different wavelength
ranges and resolutions the configuration of wavelengths were tailored to the respective datasets. Improvements in the pipeline regarding efficiency and robustness were also implemented.

In summary the key stages of the pipeline, described in full in Worley et al. (2012a), begin first (Spectral Processing A:SPA) with the determination of radial velocities ($V_{rad}$) from a basic normalisation of the spectra, and second (SPB) with the application of the $V_{rad}$ correction, cosmic ray cleaning, normalisation, slicing to predefined wavelengths and then initial parameter determination in MATISSE. Tests at this stage allow rejection of spectra based on quality criteria. The third stage (SPC) is the crucial process of iterating between normalisation and stellar parameter determination where the synthetic spectra generated based on the stellar parameters of the previous iteration are used to normalise the spectra, thereby converging within 10 iterations on the final stellar parameters, the final normalised spectra and the final synthetic spectra.

UVES presented a more complex case than the AMBRE:FEROS analysis as there are a large variety of possible wavelength coverage in the range between 3000 Å to 11000 Å. As described in Dekker, D’Odorico, Kaufer, Delabre & Kotzlowski (2000) this high resolution optical spectrograph comprises of a blue and red arm which can be used in combination or separately. For AMBRE:UVES only spectra observed in the six standard setups were analysed. The wavelength coverage of these, the preliminary wavelengths used in AMBRE:UVES and the number of spectra/stars are illustrated in Fig. 1. The observations delivered to OCA from ESO covered the years from 2000 to the beginning of 2010. The final stellar parameters will ultimately be made available through the ESO archive as advanced data products.

In dark grey are shown regions of high telluric contamination (>20%) while light grey are the regions of less intense contamination (<5%). No telluric intensity between these two levels was detected. The telluric regions were avoided where possible, although for the RED860 setup this significantly reduced the usable wavelength regions.

### 3.1 S/N, $V_{rad}$, CCF FWHM

Key measurements were made of the spectra in order to aid in the characterisation of the UVES data set. The signal-to-noise (S/N) was measured as part of the normalisation process. The $V_{rad}$ was determined by cross-correlation of the normalised observed spectra with binary masks generated from the AMBRE Synthetic Spectra Grid using an algorithm created by C. Melo (private communication). Output from this algorithm included errors on the $V_{rad}$ ($\sigma_{V_{rad}}$) and the full-width-at-half-maximum (FWHM) of the cross-correlation function (CCF).

The S/N, $\sigma_{V_{rad}}$ and CCF FWHM with the preliminary stellar parameters from
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Figure 1. Preliminary selection of UVES wavelength ranges for each setup compared with FEROS. The number of spectra and corresponding approximate number of stars are listed in the legend for each setup.

SPB are used to characterise and set rejection thresholds for the construction of the final sample. In particular previous analyses have shown that for a S/N less than 15 the parameter determination is much less certain. This threshold was not used as a criterion in itself as the other criterion tended to reject these spectra anyway. The threshold on the $\sigma_{V\text{rad}}$ is a key criterion with the rejection threshold set at 10 km/s based on previous work. The CCF FWHM also proved to be an invaluable parameter for characterising the spectra in particular with regards to discriminating hot/fast rotating stars. These stars are not well-represented by the AMBRE grid, and their broad features produce erroneous results in the MATISSE analysis.

Fig. 2 compares the CCF FWHM of the entire UVES sample with the initial $T_{\text{eff}}$ determined in SPB. This diagnostic, shown as a density plot, clearly shows the overdensity of low CCF FWHM spectra which are well-represented by the grid but also the hot/fast rotating sample which should necessarily be discarded.

Based on such diagnostics the threshold on the CCF FWHM, $\sigma_{V\text{rad}}$ and the preliminary stellar parameters with respect to the synthetic grid boundaries have been applied to give a preliminary sample of accepted archived spectra. The number counts are presented in Table 1.

While this is the preliminary analysis, at this stage approximately 44% of the UVES archived sample have been successfully analysed for their stellar parameters. Both the $\sigma_{V\text{rad}}$ and the CCF FWHM have a significant impact on the number of stars rejected to result in the preliminary accepted ~55% of the sample.
Table 1. The preliminary spectra counts for each setup in terms of S/N; within the thresholds of $\sigma_{V_{\text{rad}}}$ and CCF FWHM; and the preliminary accepted sample.

<table>
<thead>
<tr>
<th>Setup</th>
<th>Total</th>
<th>SNR&lt;15</th>
<th>SNR\geq15</th>
<th>$\sigma_{V_{\text{rad}}}$&lt;10kms$^{-1}$</th>
<th>CCF FWHM&lt;26kms$^{-1}$</th>
<th>Prelim. Acc.</th>
<th>% Prelim</th>
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<tr>
<td>BLUE346</td>
<td>5083</td>
<td>1623</td>
<td>3460</td>
<td>3646</td>
<td>2727</td>
<td>2170</td>
<td>42.7</td>
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<tr>
<td>BLUE390</td>
<td>10791</td>
<td>3011</td>
<td>7779</td>
<td>7805</td>
<td>6653*</td>
<td>5235</td>
<td>48.5</td>
</tr>
<tr>
<td>BLUE437</td>
<td>8288</td>
<td>2480</td>
<td>5808</td>
<td>5599</td>
<td>4575</td>
<td>2850</td>
<td>34.4</td>
</tr>
<tr>
<td>RED564</td>
<td>3671</td>
<td>614</td>
<td>3057</td>
<td>3465</td>
<td>2904</td>
<td>1650</td>
<td>44.9</td>
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<tr>
<td>RED580</td>
<td>13668</td>
<td>2244</td>
<td>11424</td>
<td>10186</td>
<td>8709</td>
<td>6269</td>
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</tr>
<tr>
<td>RED860</td>
<td>5523</td>
<td>563</td>
<td>4960</td>
<td>4034</td>
<td>4203</td>
<td>2594</td>
<td>47.0</td>
</tr>
</tbody>
</table>

*BLUE390 CCF FWHM Threshold is 3 5 kms$^{-1}$
Figure 2. CCF FWHM compared with $T_{\text{eff}}$ for the identification of spectra nominally outside the parameters of the AMBRE synthetic grid.

3.2 Calibration and validation

A crucial stage in the analysis is the calibration and validation of the automated pipeline. For this key spectral atlases: Solar (Wallace, Hinkle & Livingston 1998) and Arcturus Atlases (Hinkle, Wallace, Valenti & Harmer 2000); and libraries: the PASTEL spectral library (available at Vizier) and the Gaia Benchmark Stars (see talk by P. Jofre in this proceedings) were employed. These are invaluable tools with which to validate the results of the AMBRE pipeline. The sample used for AMBRE:UVES are illustrated in Fig. 3.

The Gaia Benchmark stars are coming into use as a primary calibration sample that accurately covers the parameter space more comprehensively than any other sample. For AMBRE:UVES only 20 of the benchmarks had spectra within the archived sample, hence the additional use of the PASTEL database to determine a sample within AMBRE:UVES that could be used to globally calibrate the parameters.

3.3 Preliminary stellar parameters for UVES

The analysis of the UVES spectra is near completion, and while the values presented here are preliminary, the final catalogue will be published very shortly. In this presentation we show the initial selection of spectra that adhere to the selection criteria. The key figures are the HR diagram and the graph of $[\alpha/\text{Fe}]$ vs $[\text{Fe/H}]$, which show the
Figure 3. The sample of PASTEL stars found within AMBRE:UVES and the corresponding papers, shown in a distribution of $T_{\text{eff}}$ vs Right Ascension (RA), and $T_{\text{eff}}$ vs $\log g$. Similarly the HR diagram and [$\alpha$/Fe] vs [Fe/H] for the Gaia Benchmark sample found within AMBRE:UVES.

Figure 4. HR Diagram (left panel) and [$\alpha$/Fe] vs [Fe/H] (right panel) for the preliminary sample of the AMBRE:UVES analysis.

The analysis of archived spectra in this age of large spectroscopic surveys will serve to provide access to an untapped resource of global information regarding the stellar populations of the Milky Way. The extra layer of information that is the homoge-
neous determination of the stellar parameters allows the archive to be accessed in a new perspective and results in an extensive spectral library that can be used in stellar population as well as individual stellar analyses.

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