Determination of stellar atmospheric parameters for the X-Shooter Spectral Library

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Abstract. We present a uniform sample of stellar atmospheric parameters for the X-Shooter Spectral Library. We use full-spectrum fitting of the UVB arm of the X-Shooter spectra to obtain stellar parameters for 452 stars, and we compare the results with literature samples.

Keywords: stellar atmospheric parameters – spectral libraries – full-spectrum fitting

1. Introduction

Stellar spectral libraries are often used in stellar population modelling, and the new X-Shooter Spectral Library (XSL, Chen et al. 2014) is particularly suitable for that purpose because of its large wavelength coverage. The spectra cover the full wavelength range...
range 3000–24800 Å in three separate segments, UVB (3000–5500 Å), VIS (5300–
10200 Å) and NIR (10000–24800 Å), at a resolution of \( R \sim 10000 \). XSL covers most of the important stellar evolutionary phases in the Hertzsprung–Russell diagram and includes many different types of stars. The work presented here is done through an internal data release which has 544 preliminary UVB spectra of 483 stars.

Before the XSL spectra can be used in stellar population modelling, uniform stellar atmospheric parameters for all the stars are required. We determine the stellar parameters \( T_{\text{eff}} \), \( \log g \) and \([\text{Fe}/\text{H}]\) using full-spectrum fitting of our spectra against reference spectra. Here we show the status of the parameters as presented at the International Workshop on Stellar Spectral Libraries 2017.

### 2. Method

We used the full-spectrum fitting package ULySS (Koleva et al. 2009) to determine uniform stellar atmospheric parameters for as many XSL stars as possible. ULySS performs a \( \chi^2 \) minimisation on a pixel-by-pixel basis between an observed spectrum and a model spectrum. The synthetic spectrum was created by an interpolator that is based on a reference spectral library. We used the interpolator based on the MILES library, which covers 3500–7500 Å at a resolution of \( R \sim 2000 \) (Prugniel et al. 2011, updated in Sharma et al. 2016). It has been extensively tested and is shown to behave well, especially for FGKM stars. We performed the fit using UVB spectra between 4000–5500 Å, because that region offers the largest useful wavelength range that overlaps with the MILES interpolator. Before doing the fitting, we smoothed the XSL spectra to a resolution applicable to the MILES library. The code fits the stellar atmospheric parameters \( T_{\text{eff}} \), \( \log g \) and \([\text{Fe}/\text{H}]\), the line-spread function (LSF) parameters \( \sigma \) (broadening, instrumental and/or rotational) and \( c_z \) (radial velocity), with a multiplicative polynomial that takes out flux mismatches between model and observation.

We derived first guesses for the parameters of the spectra by running ULySS with a grid of input parameters such that the \( \chi^2 \) minimisation did not get held in a local minimum. We then used those first guesses to determine a wavelength-dependent LSF for each spectrum. That took out the known variation of the LSF in the UVB arm (Chen et al. 2014), and other additional variations of the LSF that can exist in the spectra. By using the first guesses in combination with the wavelength-dependent LSF, we could then determine the final parameters.

### 3. Parameters

The resulting parameters for 513 spectra of 452 stars are shown in Figure 1. XSL is clearly covering a large range of stellar types: it has very cool dwarfs and giants, intermediate-temperature stars and very hot stars, all at a range of metallicities.
XSL stellar parameters

Figure 1: Hertzsprung–Russell diagram of the stars in the current internal XSL data release.

We compared our parameters for the FGK stars with the homogenised MILES literature sample from Cenarro et al. (2007) for the 110 FGK stars we have in common. We found mean differences and dispersions of 54 and 139 K, 0.05 and 0.30 dex, and 0.03 and 0.18 dex for $T_{\text{eff}}$, $\log g$ and $[\text{Fe}/\text{H}]$, respectively. When we compared our parameters with those of Prugniel et al. (2011), who computed uniform parameters for the MILES spectra with ULySS and the ELODIE interpolator, those values changed to −7.8 and 51 K, −0.02 and 0.11 dex, and −0.04 and 0.07 dex. It was understandable that the dispersions were smaller than before, since both samples were computed homogeneously by the same method. If we made our comparison for the M and OBA stars, the dispersions were larger.

4. Discussion

The parameters for the coolest stars (below ~ 4000 K) cannot be relied upon when we only use the UVB region. These stars have very little flux in the blue, and consequently our fits are bad and the errors are large. In future work we will use the VIS spectra to determine parameters for the large number of cool stars in XSL.

There is also a large sample of carbon stars in XSL (Gonneau et al. 2016, 2017) for which we cannot determine reliable parameters. The model interpolator only has three dimensions ($T_{\text{eff}}$, $\log g$ and $[\text{Fe}/\text{H}]$), and carbon abundance is not one of them. From the fit shown in Figure 2, it is clear that the multiplicative polynomial is fitting the carbon features in the spectrum as continuum. Parameters for these stars could be adopted from Gonneau et al. (2017).
Figure 2: Fit of the UVB spectrum of carbon star HD202851. Top: observed spectrum multiplied by the multiplicative polynomial (light grey), best-fitting model spectrum (dark purple) and the multiplicative polynomial (dashed red line). Bottom: residuals (dark purple) and regions that are clipped from the fit (light grey). 1-σ errors are indicated.

The hottest stars (T $>\sim$ 10000 K) are also difficult to fit because they have very few lines in the spectrum. There are few hot stars in the MILES reference library, so the performance of the interpolator is rather poor. For those stars it is better to use a different fitting mechanism, or to adopt parameters from the literature.

There is similar problem for the metal-poor stars (below [Fe/H] $\sim$ −2.0). Those stars also have very few lines, and only a few metal-poor stars are present in the reference library. The metallicity range of the MILES interpolator stops at [Fe/H] = −2.8, but we have several stars with metallicities lower than that. For the most metal-poor stars there are usually good parameters from high-resolution spectroscopy already available in the literature, and which we could adopt.

5. Conclusion

We have determined uniform stellar atmospheric parameters for 452 stars in the X-Shooter Spectral Library. For some types of stars it is difficult to obtain good parameters with our current method, but for the great majority (∼70%) of the stars the results are good. The work described here is not yet final, as there is now a larger internal data release for which we will estimate the parameters. Among other things, we will include fits from the VIS spectra to improve our results.
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References

City tour.