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Stellar population models in the UV: I. Characterisation of the New Generation Stellar Library

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Abstract. We have fully characterized the NGSL stellar spectral library, which allows us to open the UV stellar spectral range for stellar population studies. We have performed the necessary steps to prepare this library for its implementation in models synthesizing SEDs of stellar cluster and galaxy spectra. We have determined and homogenized the atmospheric parameters of the stars of this library with the aid of a full spectrum-fitting algorithm, using the MILES spectral library as a template. We also have characterized the resolution of this library and corrected systematic effects in the optical spectral range to achieve a precision of 10% of the dispersion.

Keywords. stars: abundances, stars: atmospheres, stars: fundamental parameters

1. Introduction

To study extragalactic objects we use their electro-magnetic radiation. Different physical processes and different astronomical objects emit in different wavelength domains. The ultra-violet wavelengths (UV, with $E_{typ} = h\nu \geqslant 10\,\mathrm{eV}$) are irreplaceable to characterise the metallicity and the star-formation history (SFH) of young stellar populations, to study the enhancement of α-elements or the contribution of blue horizontal branch stars to the integrated fluxes. They are also of a prime importance when studying distant galaxies whose restframe UV is observed in the optical, where the current instrumentation is most developed.

To derive relevant stellar population parameters we compare the observations to predictions from stellar population synthesis models. The quality of these models relies to a great extent on the input stellar library. The most important quantities of a stellar library is its coverage of the main atmospheric parameters (temperature, metallicity and gravity), its resolution and wavelength coverage. The theoretically computed stellar libraries would have been the ideal reference, but they cannot accurately reproduce the observations (colours, line depths etc.) of individual stars. Therefore, we rely on empirical collections of spectra. At intermediate resolutions ($R \sim 2000$, currently used in the extragalactic studies), we still lack high quality stellar spectral libraries in the UV. A good enough library, covering this spectral domain is the New Generation Stellar Library (NGSL) recently released. Here we describe the preparation of the NGSL for stellar population models.

2. Data and Analysis

The New Generation Spectral Library† (Gregg *et al.* 2006) was observed with the Hubble Space Telescope Imaging Spectrograph (STIS) and consists of 374 stars with metallicities between -2.0 dex and 0.5 dex. It contains normal stars from O to M spectral types in all luminosity classes. Its wavelength coverage from 0.2 to 1.0 μm is among the widest available observational libraries at this resolution, though it misses Lyα. Its spectral resolution is R$\sim$1000. The stars of the NGSL were rigorously chosen to have a good coverage in the space of atmospheric parameters. Unfortunately, about 200 stars were not observed owing to the failure of STIS in 2004. The released library lacks some hot- and low-metallicity stars, but is well-suited to model intermediate- and old-aged stellar populations.

We applied a full spectrum fitting approach to characterise the NGSL spectra and to infer the stellar parameters. For this purpose we employed the *ULySS* package (Koleva *et al.* 2009). We followed the approach used in Prugniel *et al.* (2011) to derive (i) the LSF to describe the intrinsic resolution and its variation with wavelength, (ii) the atmospheric parameters of the stars, and (iii) the Galactic extinction on the line-of-sight of each star.

ULySS performs a parametric minimisation of the squared differences between an observation and a linear combination of non-linear models as

$$Obs(\lambda) = P_n(\lambda) \times \left(G(v_{sys}, \sigma) \otimes \sum_{i=0}^{i=k} W_i \ \mathrm{CMP}_i \left(a_1, a_2, ..., \lambda\right) \right), \qquad (2.1)$$

where $Obs(\lambda)$ is the observed one-dimensional spectrum function of the wavelength (λ), sampled in $log\lambda$; P_n is a multiplicative polynomial of degree n; and $G(v_{res}, \sigma)$ is a Gaussian broadening function parameterised by the residual velocity v_{res}, and the dispersion σ. The CMP$_i$ are k non-linear functions of any number of parameters, figuring the physical model. Their weights W_i can be constrained (to be positive in the present case).

Here we used three different specific cases of Eq. 2.1. First, to determine the broadening by comparing the stars in common between NGSL and a reference library, we used a single component that consists in a template spectrum (i.e. no non-linear parameter). Second, to determine the broadening with respect to a theoretical library, we used a positive linear combination of spectra taken from a grid. Finally, we measured the atmospheric parameters of the stars using a TGM component. TGM is a model spectrum, function of the effective temperature, surface gravity and metallicity, respectively, written as T$_{\rm eff}$, logg, and [Fe/H]. The model used for the TGM component was the MILES interpolator, presented in Prugniel *et al.* (2011). This interpolator returns a spectrum for any temperature, metallicity, and gravity where each wavelength bin is computed by an interpolation over the entire reference library.

3. Results and Conclusions

The Gaussian from Eq. 2.1 encompasses the physical broadening and the relative broadening between the observation and the model. In this case the physical broadening is mostly negligible, therefore we can characterise the line spread function (LSF, analogue to the photometric PSF) by comparing the NGSL spectra to higher resolution templates. We used ELODIE (Prugniel & Soubiran 2001) and MILES (Sánchez-Blázquez *et al.* 2006) libraries to characterise the LSF in the optical domain (with the first modification of Eq. 2.1) and UVBlue (Rodríguez-Merino *et al.* 2005) and Munari (Munari et al.

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† http://archive.stsci.edu/prepds/stisngsl/

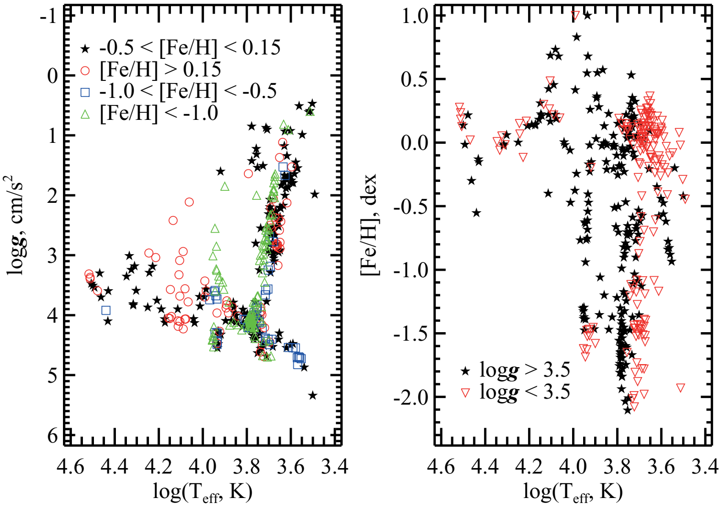

Figure 1. Resulting stellar parameter coverage for the 374 stars of the NGSL. The left panel shows their distribution in the $T_{\rm eff}$ - *logg* plane. These stars were separated into four different metallicity bins as indicated in the legend. In the right panel we plot the dwarf and giant distribution in the $T_{\rm eff}$ -[Fe/H] plane.

2005) theoretical grids to monitor the LSF in the infra-red and UV regions. The LSFs obtained with the four reference libraries are fully consistent.

The FWHM of the LSF is varying from 3 Å at the UV end to 5 Å at 5000 Å , and to 10 Å at the NIR end. The library has a roughly constant reciprocal resolution $R = \lambda/\delta\lambda \approx 1000$ and an instrumental velocity dispersion $\sigma_{ins} \approx 130\,\mathrm{km\,s^{-1}}$. Our analysis reveals a defect of the wavelength calibration of the green grating. We used a simple linear relation to correct it: $\lambda_{cor} = \lambda - 0.7(5650 - \lambda)/(5650 - 3060)$, for $3060 < \lambda < 5650$ Å, where λ is the original wavelength in Å and λ_{cor} the corrected wavelength. We find that the wavelength calibration is precise down to 0.1 px, after correcting this systematic effect.

We determined the atmospheric parameters of the NGSL stars by fitting the spectra with the third modification of Eq. 2.1. The distribution of the stars in the parameter space is shown on Fig. 3. We use the polynomial from the fit to get the extinction A_V. We derived the atmospheric parameters homogeneously. The precision for the FGK stars is 42 K, 0.24 and 0.09 dex for $T_{\rm eff}$, *logg* and [Fe/H], respectively. The corresponding mean errors are 29 K, 0.50 and 0.48 dex for the M stars, and for the OBA stars they are 4.5 percent, 0.44 and 0.18 dex. The comparison with the literature shows that our results are not biased.

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