Estimating Stellar Atmospheric Parameters by Automated Methods Using SSLs

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Abstract. Libraries of stellar spectra, such as ELODIE (Prugniel & Soubiran 2001), CFLIB (Valdes et al. 2004), or MILES (Sánchez-Blázquez et al. 2006), are used for a variety of applications, and especially in modelling stellar populations (e. g. Le Borgne et al. (2004)). In that context, apart from the completeness and quality of these spectral databases (Singh et al. 2006), the accurate calibration of stellar atmospheric parameters, temperature ($T_{\text{eff}}$), surface gravity (log $g$), and metallicity ([Fe/H]), is known to be critical (Prugniel et al. 2007; Percival & Salaris 2009). We discuss the technique of determining stellar atmospheric parameters accurately by ‘full spectrum fitting’.

Keywords: atmospheric parameters, automated methods

1. Introduction

Significant progress in the fields of optical/spectroscopic techniques and observatory instrumentation has resulted in rapid increases in volumes of astronomical data. Various ground and space-based surveys - for instance, NASA’s Hubble Space Telescope (HST), the Sloan Digital Sky Survey (SDSS York et al. 2000) and European Space Agency’s Gaia mission (Perryman et al. 2001) - provide an enormous volume of data. Observatories equipped with next-generation spectrographs such as MOONS (Cirasuolo et al. 2011) have made data collection process more efficient. The growing size of observed data requires automated methods to analyse stellar spectra and provide their parameters. One such automated method is the ‘full spectrum fitting’.

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Figure 1: Upper panels compare the derived parameters (ordinates) with the literature values (abscissae). The lower panels display the residuals.

Full spectrum fitting has been shown to be reliable in retrieving the atmospheric parameters for late A, F, G and early K spectral-type stars (Prugniel et al. 2011), but for cooler stars ($T_{\text{eff}} < 4800$ K) the reliability degrades. In this paper we present improved parameters of cool stars which were derived by full spectrum fitting. We also derive the parameters of 1065 cluster stars, belonging to 13 clusters, from SDSS. In Sec. 2 we describe briefly the method of full spectrum fitting, along with modifications in the method that give better results for cool stars. The following section, Sec. 3, presents the determination of parameters for SDSS cluster stars, together with a comparative analysis of those parameters with ones in the literature.

2. Full Spectrum Fitting Technique

We used ULySS (Koleva et al. 2009) for employing the full spectrum fitting technique. It uses a $\chi^2$ minimisation algorithm for estimating parameters. A model spectrum is generated from a spectral library by using a 'spectral interpolator'.

Parameters of cool stars using revised MILES interpolator, V2: To improve the estimation of parameters for cool stars, a sample of 331 stars ($T_{\text{eff}} \leq 4800$ K) was chosen from MILES SSL. Significant biases in the re-derived parameters of those stars were detected with the MILES interpolator (V1; Prugniel et al. 2011). We improved that by correcting the input catalogue for systematics/biases, using a new polynomial (26 terms), and by supporting the extrapolation for cool stars by incorporating spectra of stars within the range M0–M4.5 from Neves et al. (2013). A new version of the interpolator (V2; Sharma et al. 2016) was derived. A comparison of our re-determined parameters with those in the literature is shown in Fig. 1.
3. Analysis of cluster stars from SDSS

1065 cluster stars belonging to 8 globular clusters (GCs) and 5 open clusters (OCs) were analysed to estimate their atmospheric parameters and cluster metallicities. The spectra were taken from SDSS DR12, and we used ULySS with the MILES V2 interpolator to determine the parameters. To cross-validate the method, we compared the derived parameters with those from Smolinski et al. (2011) (Fig. 2). Statistics of the comparison are presented in Table 1. The results are also compared with the SDSS DR12 parameters that were obtained using the SEGUE Stellar Parameter Pipeline (SSPP) (Fig. 2). We plan to examine the systematic effects, and any dependence of the parameters on S/N, etc., to improve the determinations further.

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Table 1: Statistics from comparing the derived parameters with those of Smolinski et al. (2011).

| Cluster   | N  | $\Delta T_{\text{eff}}$(K) | $\Delta \log g$(dex) | $\Delta [\text{Fe/H}]$(dex) | Cluster |
|-----------|----|---------------------------|----------------------|-----------------------------|---------|
|           | $\mu$ | $\sigma$ | $\mu$ | $\sigma$ | $\mu$ | $\sigma$ | Type |
| M2        | 70   | -221                      | 308                  | -0.22                        | 0.70    | -0.13    | 0.37 | GC    |
| M3        | 77   | -155                      | 278                  | -0.41                        | 0.61    | -0.02    | 0.32 | GC    |
| M13       | 293  | -146                      | 339                  | -0.07                        | 0.59    | -0.10    | 0.33 | GC    |
| M15       | 98   | -271                      | 335                  | 0.36                         | 1.00    | -0.04    | 0.35 | GC    |
| M35       | 29   | -128                      | 264                  | -0.05                        | 0.27    | 0.07     | 0.09 | OC    |
| M53       | 17   | -107                      | 981                  | 0.13                         | 0.60    | 0.16     | 0.73 | GC    |
| M67       | 74   | -77                       | 144                  | -0.16                        | 0.27    | -0.04    | 0.08 | OC    |
| M71       | 17   | -200                      | 96                   | -0.61                        | 0.20    | -0.11    | 0.11 | GC    |
| M92       | 58   | -342                      | 537                  | -0.25                        | 0.99    | -0.22    | 0.40 | GC    |
| NGC2158   | 62   | -330                      | 209                  | 0.01                         | 0.40    | -0.08    | 0.07 | GC    |
| NGC2420   | 164  | 7                         | 111                  | 0.01                         | 0.21    | -0.04    | 0.10 | OC    |
| NGC5053   | 16   | -334                      | 214                  | -0.49                        | 0.37    | -0.07    | 0.49 | GC    |
| NGC6791   | 90   | -66                       | 149                  | -0.38                        | 0.31    | -0.07    | 0.05 | OC    |

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