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Coudé-feed stellar spectral library – atmospheric parameters⋆

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ABSTRACT

Context. Empirical libraries of stellar spectra play an important role in different fields. For example, they are used as reference for the automatic determination of atmospheric parameters, or for building synthetic stellar populations to study galaxies. The CFLIB (Coudé-feed library, Indo-US) database is at present one of the most complete libraries, in terms of its coverage of the atmospheric parameters space ($T_{\rm eff}$, log g and [Fe/H]) and wavelength coverage 3460–9464 Å at a resolution of ~1 Å *FWHM*. Although the atmospheric parameters of most of the stars were determined from detailed analyses of high-resolution spectra, for nearly 300 of the 1273 stars of the library at least one of the three parameters is missing. For the others, the measurements, compiled from the literature, are inhomogeneous.

Aims. In this paper, we re-determine the atmospheric parameters, directly using the CFLIB spectra, and compare them to the previous studies.

Methods. We use the ULySS program to derive the atmospheric parameters, using the ELODIE library as a reference.

Results. Based on comparisons with several previous studies we conclude that our determinations are unbiased. For the 958 F, G, and K type stars the precision on $T_{\rm eff}$, log g, and [Fe/H] is respectively 43 K, 0.13 dex and 0.05 dex. For the 53 M stars they are 82 K, 0.22 dex and 0.28 dex. And for the 260 OBA type stars the relative precision on $T_{\rm eff}$ is 5.1%, and on log g, and [Fe/H] the precision is respectively 0.19 dex and 0.16 dex. These parameters will be used to re-calibrate the CFLIB fluxes and to produce synthetic spectra of stellar populations.

Key words. stars: fundamental parameters – galaxies: stellar content

1. Introduction

Spectral libraries with a good coverage in $T_{\rm eff}$, log g, and [Fe/H] at moderate spectral resolution (1–2 Å *FWHM*) are essential in several areas of astronomy. Two important applications are the spectral synthesis of the stellar population of galaxies (e.g. Bruzual & Charlot 2003; Le Borgne et al. 2004; Vazdekis et al. 2010) and the automated classification and determination of the stellar atmospheric parameters (e.g. Katz et al. 1998). The latter application is a key step in the analysis of large spectroscopic surveys, such as RAVE (Steinmetz et al. 2006), SDSS/SEGUE, APOGEE and SEGUE-2 (Rockosi et al. 2009), the Guoshoujing Telescope[1] survey (Zhao et al. 2006) or GAIA (Perryman et al. 2001). Both the increased output of the modern instruments and the better quality of the spectra require improvements of the spectral libraries and models.

The first large library (684 stars) at the intermediate spectral resolution of ~2 Å (*FWHM*) was published by Jones (1999). It covered only two small windows of the optical range with an incomplete sampling of the atmospheric parameters. It was followed by more complete libraries improving the wavelength and parameter coverage. The most significant ones at present are the ELODIE (Prugniel & Soubiran 2001), CFLIB (Valdes et al. 2004) and MILES (Sánchez-Blázquez et al. 2006).

The ELODIE library (Prugniel & Soubiran 2001; Prugniel et al. 2007b) has a compilation of 1962 spectra of 1070 stars observed at a resolution $R \sim 42\,000$ in the range 3900–6800 Å. The library is also available at a resolution of 0.55 Å ($R \sim 10\,000$) for the population synthesis in PegaseHR (Le Borgne et al. 2004). The main limitation of this library is its restricted wavelength coverage. The CFLIB (also called Indo-US library) has a wide wavelength coverage (3460–9464 Å) at a lower resolution ($R \sim 5000$), its most important limitation is its approximate flux calibration. The youngest library in the optical range is MILES (Sánchez-Blázquez et al. 2006). With a wavelength

⋆ Tables 2 and 3 are only available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsarc.u-strasbg.fr/viz-bin/qcat?J/A+A/525/A71

1 Formerly named LAMOST, http://www.lamost.org

coverage from 3525–7500 Å, it is limited in its coverage in the red compared to CFLIB. Its resolution is only 2.3 Å (*FWHM*, $R \sim 2200$), but its flux calibration is undoubtedly more precise and is used for population synthesis (Vazdekis et al. 2010).

The reliability and accuracy of the atmospheric parameters of the stars of these libraries has direct consequences on their usage, for example in stellar populations models (Prugniel et al. 2007a; Koleva et al. 2007; Percival & Salaris 2009; Chen et al. 2010). While most of the stars of CFLIB have atmospheric parameters compiled from the literature and in general determined from high-dispersion spectra, there is a substantial fraction (∼25%) of stars with either one or more parameters unavailable. Because the flux calibration was done by fitting each observation to a spectral energy distribution with a close match in spectral type from the Pickles (1998) library, the stars with poorly known atmospheric parameters were also inaccurately calibrated. The present paper intends to re-measure these parameters homogeneously and is therefore a step toward an improvement of the flux calibration.

Various methods have been developed in the past to estimate stellar atmospheric parameters from stellar spectra in an automatic and reliable manner. One of the often used technique involves finding the minimum distance between observed spectra and grids of synthetic or observed spectra. The program TGMET, developed by Katz et al. (1998) and improved by Soubiran et al. (2000, 2003), illustrates this approach. It achieves an internal accuracy of 86 K, 0.28 dex and 0.16 dex for $T_{\rm eff}$, log g, and [Fe/H] respectively for a target F, G, or K star with signal-to-noise ratio $S/N = 100$ and 102 K, 0.29 dex and 0.17 dex at $S/N = 10$.

Re Fiorentin et al. (2007) derived atmospheric parameters from observed medium-resolution stellar spectra using non-linear regression models trained either on pre-classified observed data or synthetic stellar spectra. For the SDSS/SEGUE spectra, they reached an accuracy on the order of 150 K in the estimation of $T_{\rm eff}$, 0.36 dex in log g, and 0.19 dex in [Fe/H]. Other similar efforts include Bailer-Jones et al. (1997), Prugniel & Soubiran (2001), Snider et al. (2001), Willemsen et al. (2005), Recio-Blanco et al. (2006), Shkedy et al. (2007), Luo et al. (2008), Lefever et al. (2010), Zhang et al. (2009) and Jofré et al. (2010).

The method employed in this work uses the ULySS[2] package and consists of minimizing a χ^2 between an observed spectrum and a model spectrum. This model is adjusted at the same resolution and sampling as the observation, and the fit is performed in the pixel space. The method determines all free parameters in a single fit in order to handle properly the degeneracy between the temperature and the metallicity.

The details of the method and the process of extraction are presented in the next section. In Sect. 3 we test the quality of parameter extraction by comparing with other determinations in the literature. In Sect. 4, we give the results and conclusions of our study.

2. Analysis method

The ULySS package fits a spectrum against a non-linear model. The package has flexibility allowing one to use it for various types of tasks. For example, in Koleva et al. (2009a) it was used to retrieve the star-formation history of galaxies and in Wu et al. (2010) to analyze stellar spectra. In the present work, we will use the so-called TGM component of the package to fit the CFLIB spectra against stellar spectral models based on a new version of the ELODIE library (version 3.2). In this section, we describe this new library and the fitting method.

2.1. ELODIE 3.2

The ELODIE library is based on echelle spectra taken with the eponym spectrograph attached to the 1.93 m telescope of Observatoire de Haute-Provence. The data used to prepare the library were already processed by the data-reduction pipeline run at the telescope. They can be retrieved from the observatory archive (Moultaka et al. 2004).

The first version of the library (Prugniel & Soubiran 2001) contained 908 spectra for 709 stars, and the spectra were provided in the wavelength range 4100–6800 Å. Two upgrades were released in Prugniel & Soubiran (2004, version 3.0) and Prugniel et al. (2007b, version 3.1). The version 3 series rests on a new and larger selection of spectra from the whole archive of the instrument. There are 1962 spectra for 1070 stars within wavelength range 3900–6800 Å with a larger coverage of atmospheric parameter space.

The three lines of improvement that motivated the successive releases were (i) the data-reduction (in particular the correction of the diffuse light and the extension of the wavelength range to 3900–6800 Å); (ii) the determination of the atmospheric parameters and Galactic extinction; and (iii) the interpolator. This last point is particularly important for the present study because it is the function that returns a spectrum for a given set of atmospheric parameters by making an interpolation over the whole library (Prugniel et al. 2008).

Since the release of version 3.1, the ELODIE library has thus been continuously improved, and for the present work we use the version 3.2 that will also be described separately (Prugniel et al., in prep.). The main motivation to use this new version here is a modification of the interpolator, which now takes the natural broadening of the spectra (due to rotation) as an additional parameter.

The interpolator consists of polynomial expansions of each wavelength element in powers of log ($T_{\rm eff}$), log g, [Fe/H] and $f(\sigma)$. The last term is a function of the rotational broadening parameterized by σ, the standard deviation of a Gaussian. We used $f(\sigma) = 1 - 1/\sqrt{1+\sigma^2}$, with σ in pixels, because it is approximately proportional to the change of depth of the lines caused by the broadening. The Gaussian broadening of each spectrum was determined with ULySS using a previous version of the model, and is, therefore, relative to the "mean" rotational width for a given spectral type.

Three sets of polynomials are defined for three temperature ranges (roughly matching the OBA, FGK, and M types) with considerable overlap between them where they are linearly interpolated. For the FGK and M polynomials, 26 terms are used and for the OBA polynomials, 19 terms are used. The terms of the polynomials were chosen to be almost orthogonal, for ease of understanding their contribution and to avoid contributions of large amplitudes that cancel each other and result in a loss of precision. The inclusion of new terms was made gradually, testing those whose contribution appears to be the most important, as measured by the decrease of the total squared residuals between the original spectra and the interpolated ones. Another argument that guided the choice of the developments was the minimization of the biases between the atmospheric parameters compiled from the literature (absolute calibration), and the internal values obtained by inverting the interpolator. These biases were probed

[2] http://ulyss.univ-lyon1.fr

in different regions of the space of parameters. The final choice of the developments and the limit tuning of the three temperature ranges were based on intuitions and tests.

The coefficients of the polynomials were fitted on a sub-set of the whole library after excluding peculiar stars (these stars are listed in the table of the ELODIE 3.1 release; the corresponding list for the present version is almost unchanged and will be given in Prugniel et al., in prep.). A first interpolator is based on parameters compiled from the literature (that we call *absolute* parameters). For the stars without spectroscopic determinations of the parameters, we used photometric calibrations, or a calibration from the spectral classifications, which are obviously less accurate than the spectroscopic ones. The quality of this *absolute* interpolator is limited by the inhomogeneity and inaccuracy of the atmospheric parameters. Therefore, we fitted the observed spectra against the interpolated ones to derive revised parameters for those stars that were photometrically calibrated, and we adopted the average between the original and new parameters. We computed a second interpolator, based on these improved parameters, and used it in an iteration to measure homogeneously the atmospheric parameters for the complete library. These self-calibrated *internal* parameters are finally used to compute an *internal* interpolator, which is used for the stellar population synthesis with PegaseHR. The *internal* interpolator is more precise in the sense that the residuals between the original observations and the interpolated spectra are reduced, but it may be affected by biases owing to the imperfect modeling by polynomials.

In previous versions, the inversion of the interpolator restored biased atmospheric parameters for the intermediate temperature stars. For example, for the 13 observations of the Sun, the mean temperature obtained in version 3.1 is 5726 ± 11 K, compared to the reference temperature of 5777 K (i.e. the one adopted by Prugniel et al. 2007b from Cayrel de Strobel 1996). A careful examination revealed that this negative bias was balanced with a positive bias for the fast rotating stars. The effect of the rotation reduces the depth of the lines, which then can be fitted to a hotter temperature. Surprisingly this degeneracy links the rotation more to the temperature than to the metallicity[3]. This analysis lead us to introduce rotation terms in to the polynomial developments. With the new version, the temperature of the Sun is 5760 ± 14 K. Even if we exclude three observations from the same date (1999/12/22) which depart significantly from the 10 others, the mean temperature is 5766 ± 9 K. For the same set of observations, log g and [Fe/H] are respectively 4.33 ± 0.03 and –0.03 ± 0.02 dex compared to the reference values of 4.44 $\log g(\mathrm{cm\,s^2})$ and 0.0 dex respectively. For some reason there is apparently a small but significant bias on the surface gravity of the Sun, but the consistency for the temperature is extremely good. The comparison between the absolute and internal determination of the atmospheric parameters in various small regions of the parameter space did not reveal noticeable biases.

Another improvement in the new version concerns the ability of the interpolator to model the spectra in sparsely populated regions of the parameter space, and even to extrapolate out of the range of parameters of the library.

This has been achieved by supplementing the observed spectra with "semi-empirical" ones. We computed these semi-empirical spectra by adding the differential effect predicted in the theoretical libraries (Coelho et al. 2005; Martins et al. 2005) between two points of the parameter space to the interpolated spectrum in a reference point. We can write it as

$$S_\mathrm{s}(T_1, \log g_1, [\mathrm{Fe/H}]_1) = S_i(T_0, \log g_0, [\mathrm{Fe/H}]_0) + \Big[S_\mathrm{t}(T_1, \log g_1, [\mathrm{Fe/H}]_1) - S_\mathrm{t}(T_0, \log g_0, [\mathrm{Fe/H}]_0) \Big].$$

While (T_0, log g_0, $[\mathrm{Fe/H}]_0$) is a reference point in the parameter space where the interpolator predicts a reliable spectrum, and (T_1, log g_1, $[\mathrm{Fe/H}]_1$) is a point located outside of the region populated by the library stars, S_i is a spectrum predicted by the interpolator (previous version) and S_t are spectra from the theoretical library. S_s is the semi-empirical spectrum used to complete the library. This method guarantees the continuity between the observed and theoretical libraries and provides better approximations of the spectra than the pure theoretical spectra, which are devoid of some lines. We used these semi-empirical spectra to constrain the extrapolations toward very hot and cool stars and toward the low metalicities for hot stars. The spectra from Coelho et al. (2005) were used to extend the interpolator for the warm stars to low metallicity (down to [Fe/H] = –2.5 dex), and those from Martins et al. (2005), to extend to high and low temperatures. Note that despite a more sophisticated model (Phoenix, Hauschildt et al. 1996), these latter models do not match the observations for the cool stars, T_eff < 3500 K, in the spectral region 6300 to 6500 Å. This is certainly because of a wrong line list for the molecular absorption (Martins, priv. comm.).

The modeling of the spectra with polynomials is similar to the fitting functions for the Lick spectroscopic indices (Gorgas et al. 1993; Worthey et al. 1994). As an alternative to this global interpolation, Vazdekis et al. (2003) developed a Gaussian kernel smoothing, which may be less sensitive to biases, but is more sensitive to the errors on the atmospheric parameters and to the particularities of the stars in the scarcely populated regions of the space of parameters. In these regions, only a few stars are used for the local interpolation and the resulting spectra are therefore more subject to the cosmic variance, while this effect is smoothed for a global interpolation.

We computed interpolators both for the continuum-normalized and for the flux-calibrated versions of the library. The residuals between the observed and interpolated spectra for continuum-normalized version are lower than for the flux-calibrated version because of the additional uncertainties of the flux-calibration and correction of the Galactic extinction. In this work, we adopted the flux-calibrated version to analyze the flux-calibrated CFLIB observations.

2.2. Fitting method

The function described above is interfaced with ULySS to fit the observed spectrum with an interpolated spectrum convolved with a Gaussian and multiplied by a polynomial. The order of this polynomial is chosen to absorb any flux calibration systematics or effects of extinction. The minimization problem is written as

$$\mathrm{Obs}(\lambda) = P_n(\lambda) \times [\mathrm{TGM}(T_\mathrm{eff}, \log\ g, [\mathrm{Fe/H}], \lambda) \otimes G(v_\mathrm{sys}, \sigma)],$$

where Obs(λ) is the observed spectrum, $P_n(\lambda)$ a Legendre polynomial of degree n, and G(v_sys, σ) is a Gaussian broadening function characterized by the systemic velocity v_sys, and the dispersion σ. The free parameters of the minimization procedure are the three parameters of the TGM function: T_eff, log g and [Fe/H],

[3] By contrast, in stellar populations the broadening owing to the velocity dispersion is clearly degenerated with the metallicity (Koleva et al. 2008).

the two parameters of the Gaussian: v_{sys}, σ and the coefficients of P_n. v_{sys} absorbs the imprecision of the cataloged radial velocity of the stars that were used to reduce them in the rest frame; σ encompasses both the instrumental broadening and the effect of the rotation.

2.3. Consistency tests

As a consistency test, we determined the atmospheric parameters of the ELODIE library stars using ULySS. We compared the continuum-normalized spectra to the continuum-normalized interpolator based on the absolute parameters (i.e. compiled from the literature). We fitted the three atmospheric parameters and a broadening function, which accounts for rotation, with a rejection of the outliers.

Because the *internal* atmospheric parameters determined in the ELODIE library were also obtained from an inversion of this interpolator, we expect ULySS to return very similar results. Though the two minimization approaches are different (an adhoc downhill method designed to avoid known local minima in the case of ELODIE), both methods minimize the squared departures between the model and the observation computed on each wavelength bin. Still, the two analyses differ by significant details. In particular, while ULySS matches the rotation using a Gaussian convolution, in ELODIE it is included as specific terms in the polynomial developments of the interpolator (see Sect. 2.1).

For this test, we used only ELODIE observations with reliable absolute parameters. The number of comparison spectra are 293 for O, B, and A, 1415 for F, G, and K and 26 for M types. The biases and dispersions with respect to the *internal* determinations of the ELODIE library are shown in the left part of Table 1. The first line gives the mean formal fitting errors. The second gives the statistics using all the measurements, and the third, the statistics after excluding the values departing by more than 3σ from the mean.

The biases between the two series of measurements are not significant and the dispersions are small compared to the usual precision on this type of determinations. After checking the most deviating stars, we conclude that the main source of discrepancy comes from different modeling of the rotational broadening. The convolution method of ULySS is better, and the ELODIE interpolator should be improved. However, as this is well within the final expected errors, we will proceed with the current version.

A second test consisted in analyzing the flux-calibrated ELODIE spectra with ULySS using the flux-calibrated interpolator and the corresponding biases, and the dispersions are shown in Table 1 (right side).

The residuals of the comparisons between the two sets of atmospheric parameters are only a little higher in this second test. This was expected because this time the measurements differ not only by the fitting method, but also by the models. We can a priori estimate that the flux-calibrated interpolator is not as accurate as the continuum-normalized one, since it also *averages* the flux calibration errors (which are significant in ELODIE). We can also assume that the flux-calibrated interpolator is less precise for the same number of terms in the developments, since the spectra are more complex (they include the thermal component).

A precision better than 40 K for a F, G and K star is fully satisfactory for the present purpose, and we will not investigate solutions to improve the flux-calibrated interpolator.

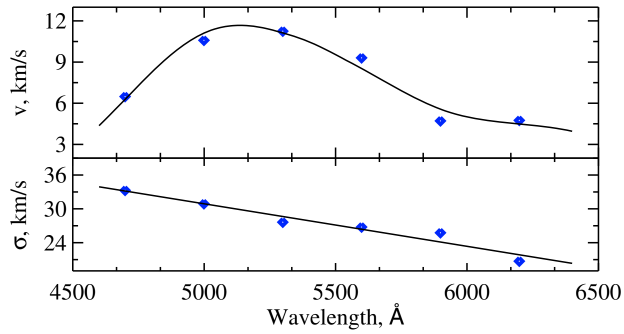

Fig. 1. Relative line-spread function of CFLIB with respect to ELODIE for HD 4307. The blue diamonds are the values derived using ULY_LSF, and the black lines are smoothed functions.

2.4. Relative line-spread function

In principle, an initial step prior to the analysis is to adapt the resolution of the model to the one of the observation, this is called line-spread function (LSF) injection. This is in general more complex than a convolution, because the relative resolution between the observation and the model may vary with wavelength (see the detailed description in Koleva et al. 2009b). However, as CFLIB was made over a period of eight years, with slightly different setups, the resolution also changes throughout the library. This would require a separate analysis of the resolution for each spectrum. This can be done with ULySS, but after testing several cases for various type of stars, we found that this was not producing significantly different results than if we simply included a simple Gaussian broadening in the fitted model. This broadening also matches the rotational broadening of the fitted star.

Figure 1 shows the relative LSF between the ELODIE library and a star from CFLIB (chosen randomly). It was evaluated with wavelength intervals of 600 Å spaced by 300 Å. The variation of the instrumental velocity dispersion (σ_{ins}) with the wavelength is significant: from 21 to 34 km s^{-1}. For this star, the atmospheric parameters without LSF injection are T_{eff} = 5803 K, log g = 4.01 dex, [Fe/H] = –0.26 dex. With LSF injection they are T_{eff} = 5787 K, log g = 3.98 dex, [Fe/H] = –0.25 dex. Figure 2 shows the corresponding fit and illustrates the general quality. We checked the same for 13 other randomly selected CFLIB observations, which represent seven different stellar spectral types, and concluded that the differences are within the uncertainties.

2.5. Error estimation

In principle, to compute the formal fitting errors we need to know the random errors on each wavelength element. Unfortunately, this information is not provided with the reduced CFLIB spectra. Therefore, we determined an upper limit to these internal errors by assuming that the residuals are entirely due to the noise (i.e. the fit is perfect and there are no residuals of physical origin). In this case, the reduced χ^2 is by definition equal to unity. To make this determination, we assumed that the noise is the same on all the wavelength elements. We performed the fit with an arbitrary value of S/N and rescaled the errors returned by ULySS by multiplying them by $\sqrt{\chi^2}$. We verified that the implementation is correct by checking that the errors do not depend on the over-sampling degree of the data.

The mean errors for the fits of the ELODIE spectra (see Table 1) are one order of magnitude smaller than the dispersion between the inversion with ULySS and the measurements

Table 1. Consistency tests with the continuum-normalized interpolator and with the flux-calibrated interpolator.

Sp. Type[a]	$\Delta T_{\rm eff}$		$\Delta\log g$(cm s^{-2})		Δ[Fe/H](dex)		Sp. Type[a]	$\Delta T_{\rm eff}$		$\Delta\log g$(cm s^{-2})		Δ[Fe/H](dex)	
	mean	rms	mean	rms	mean	rms		mean	rms	mean	rms	mean	rms
OBA		0.17%		0.008		0.006	OBA		0.17%		0.007		0.006
9/293	0.21%	3.1%	–0.022	0.129	0.029	0.128	13/293	0.39%	4.3%	–0.027	0.159	0.043	0.119
	0.18%	2.2 %	–0.016	0.096	0.029	0.125		0.34%	3.3%	–0.027	0.129	0.042	0.116
FGK		3.7 K		0.006		0.003	FGK		3.7 K		0.006		0.003
69/1415	2.3 K	38.3 K	–0.022	0.071	0.023	0.065	37/1415	–1.9 K	44.4 K	–0.028	0.086	0.023	0.069
	0.2 K	23.0 K	–0.021	0.067	0.019	0.055		–1.1 K	29.5 K	–0.025	0.079	0.023	0.063
M		1.1 K		0.006		0.003	M		1.1 K		0.006		0.003
3/26	–2.3 K	17.6 K	0.005	0.181	0.003	0.051	2/26	–2.9 K	17.8 K	–0.005	0.227	0.005	0.054
	–0.5 K	11.8 K	0.021	0.165	0.009	0.043		–2.4 K	14.0 K	–0.004	0.236	0.011	0.049

Notes. The left panel presents the parameter statistics for the continuum-normalized interpolator, and the right one for the flux-calibrated interpolator. For each stellar type group, the first line gives the formal fitting errors. The second gives the raw statistics, and the third, the statistics after rejecting the 3σ $T_{\rm eff}$ outliers. The comparisons are the ULySS values minus the ELODIE values.
[(a)] The second line gives the total number of spectra used for the comparison and the number of clipped $T_{\rm eff}$ outliers.

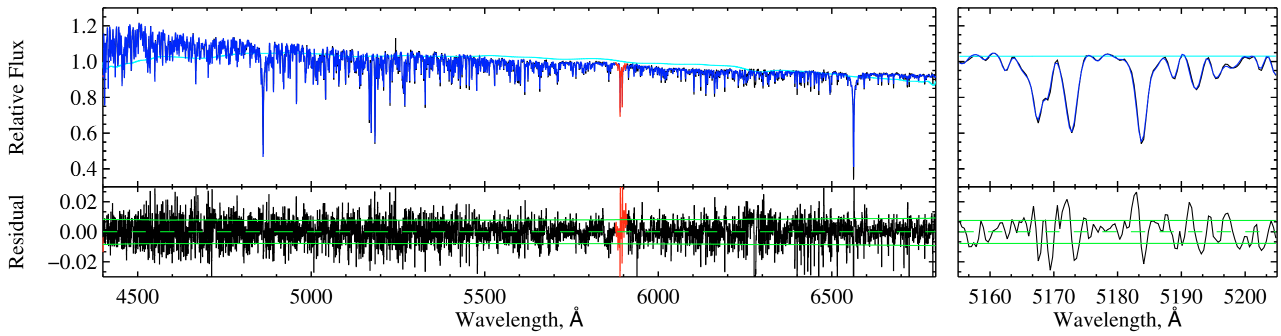

Fig. 2. Fit of the CFLIB observation HD 4307 (G2V) with a TGM component. *The top panel* shows the spectrum (in black) and the best fit in blue (both are almost superimposed and the black line can be seen only when zooming on the figure), the light blue is the multiplicative polynomial. In red we plot the flagged and masked NaD telluric lines that were not well calibrated in ELODIE library. The residuals are plotted in the bottom panels. The continuous green lines mark the 1-σ deviation, and the dashed line is the zero-axis. The right side shows a small wavelength region around Mg_b. The order of the multiplicative polynomial is $n = 70$.

in the ELODIE library. This difference is certainly caused by the correlation between the atmospheric parameters, in particular between the temperature and the metallicity, as illustrated in Koleva et al. (2009b, their Fig. 7) and to the correlation between other characteristics of the atmosphere (some other tests indicate that the data are not over-fitted; see Sect. 2.6). In any case, the internal errors are likely proportional to the formal fitting errors, and we estimate them by a simple rescaling to the dispersions reported in the right panel of Table 1, according to the spectral type.

2.6. Order of the multiplicative polynomial

To determine the optimal order of the multiplicative polynomial, n, we proceeded as suggested in (Koleva et al. 2009b). We selected some stars that are representative of all main spectral types and analyzed them with a series of values of n to find the point where the solutions become independent of n. Figure 3, compared with the similar graph presented in Koleva et al. (2009b) shows the improvement brought about by the new version of the interpolator: the plateau is reached for a lower n and the solutions are more stable. In this work, we adopt a polynomial degree $n = 70$.

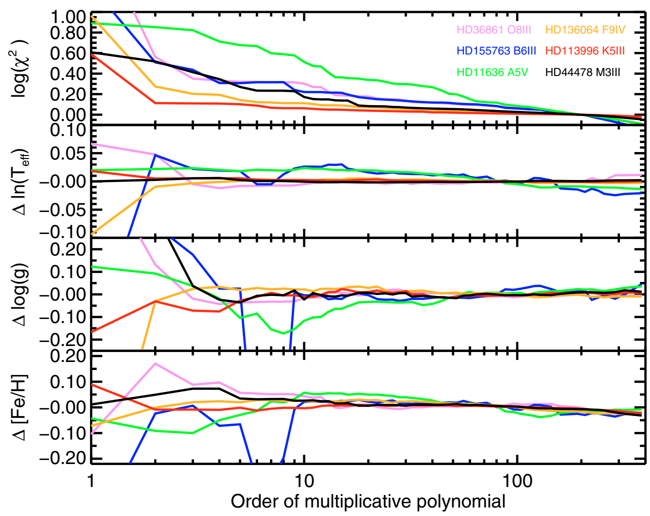

Fig. 3. Evolution of the stellar atmospheric parameter fit results ($\log(\chi^2)$, $\log(T_{\rm eff})$, $\log g$, and [Fe/H]) with increasing Legendre polynomial degree.

2.7. Analysis strategy

We classified the stars into three groups, 260 O, B & A (hereafter OBA), 958 F, G & K (hereafter FGK) and 53 M type stars. The distributions of the atmospheric parameters compiled in the

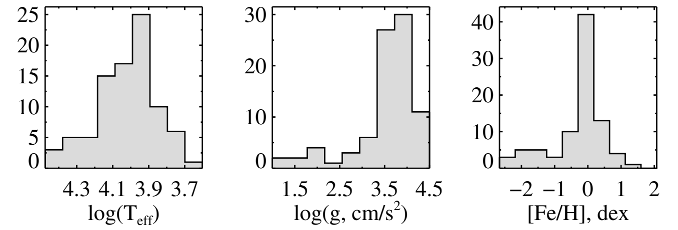

Fig. 4. Distribution of the 260 O, B, and A CFLIB stars with already partially published atmospheric parameters, actually including 87 $T_{\rm eff}$, 86 log g and 86 [Fe/H]. Note that the ordinates of the three panels are not on the same scale.

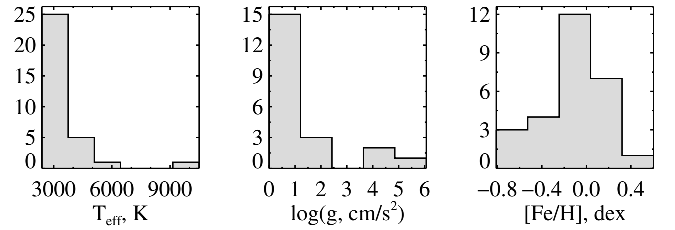

Fig. 6. Distribution of the 53 M CFLIB stars with already partially published atmospheric parameters, actually including 32 $T_{\rm eff}$, 21 log g and 27 [Fe/H]. Note that the ordinates of the three panels are not on the same scale.

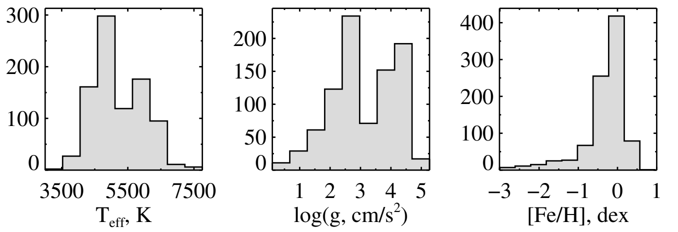

Fig. 5. Distribution of the 958 F, G, and K CFLIB stars with already partially published atmospheric parameters, actually including 895 $T_{\rm eff}$, 890 log g and 905 [Fe/H]. Note that the ordinates of the three panels are not on the same scale.

CFLIB paper are shown in Figs. 4–6 for the OBA, FGK and M types respectively.

Because ULySS performs a *local* minimization, we studied the structure of the parameter space to understand where local minima may actually occur and trap the solution. We did this with convergence maps for several stars that spanned the range of the parameters. These tests (see an example in Fig. 7) consisted in fitting the spectra from a wide grid of guesses to identify the convergence regions. According to the results we chose the following grids of guesses for the three temperature groups:

- O, B, A case, $T_{\rm eff}$ = [7000, 10 000, 18 000, 30 000] K, log g = [1.8, 3.8] cm s^{-2}, [Fe/H] = [–0.5, 0.5] dex
- F, G K case, $T_{\rm eff}$ = [4000, 5600, 7200] K, log g = [1.8, 3.8] cm s^{-2}, [Fe/H] = [–1.7, –0.3] dex
- M case, $T_{\rm eff}$ = [3100, 3600, 4100] K, log g = [1.0, 4.0] cm s^{-2}, [Fe/H] = [–0.5, 0.0] dex.

The adopted solution, i.e. absolute minimum, is the best of those obtained with different guesses.

Because the S/N in the ELODIE spectra drops notably in the blue, especially for cool stars, we restricted the fit to the wavelength range 4400–6800 Å (though using the whole 3900–6800 Å gives consistent results). Among the 1273 CFLIB stars, 885 have a complete coverage of the wavelength range (neglecting small gaps of less than 50 Å). The other stars contain gaps in the coverage. The bad pixels (e.g. emission lines, cosmic ray, bad sky subtraction, telluric lines or bad ones due to the instrument errors etc.) are automatically rejected during the fitting process by ULySS, using the clipping algorithm applied iteratively on the residuals to the fit (/CLEAN option).

3. Determination of the atmospheric parameters

In this section, we present the determination of the atmospheric parameters and the comparison with previous publications, separately for the three groups of stars with spectral types FGK, OBA, and M.

Table 2 lists the atmospheric parameters of the 1271 CFLIB stars determined with ULySS.

We could not determine the atmospheric parameters of HD 156164 (A3IV) because its observed wavelength range (6775–8648 Å) does not overlap the range of ELODIE. We rejected also HD 25329 (K1V...), whose CFLIB spectrum is apparently corrupted. We suspect that the range around H_β corresponds to another star. It may be a pointing error, possibly because of the high proper motion of this star; the A0 star HD 279382, located 3 arcmin away, may have been observed for the H_β setup.

3.1. F, G, and K stars

The majority of the stars in both CFLIB and ELODIE libraries have spectral types F, G and K; 958 of the 1273 CFLIB stars belong to these types. On the basis of our analysis, we also assigned to this group five stars without a classification. These are BD+09 3063, BD+09 3223, BD+18 2890, G 102-20 (= BD+12 853) & G 46-31 (= HIP 45554).

There are five stars with poor quality spectra or with missing regions: HD 186408 (G1.5Vb) has very low S/N in the range 4750–6070 Å and we fit only the range 6070–6800 Å. For HD 140283 (F3) we fit the range 4780–6800 Å. For HD 18474 (G5:III...) we fit the range 6010–6800 Å. HD 224458 (G8III) has a large gap 4780.6–6812.2 Å and the fit is limited to the range 3900–4780.6 Å. Finally, BD+09 3063's coverage is similarly limited to 3900–4782.6 Å.

Figure 8 compares our determinations of the atmospheric parameters with those compiled by Valdes et al. (2004, hereafter, Valdes) in the original CFLIB release, for the 877 FGK stars for which Valdes gives the three parameters. The statistics shown in Table 4 emphasize the heterogeneity of the Valdes compilation. We excluded 46 $T_{\rm eff}$, 8 log g and 5 [Fe/H] outliers.

In Appendix A we compare our determinations to the ELODIE 3.2 internal estimations and to 15 other previous studies with a significant number of F, G, and K stars in common with CFLIB. We determined the mean biases and the rms dispersion between these datasets and our series of measurement for the three parameters, after rejecting the objects whose $T_{\rm eff}$ deviate by more than 3-σ. For the comparison with ELODIE 3.2 and Nordström et al. (2004) we also excluded some log g and [Fe/H] outliers.

The summary of these comparisons is reported in Table 4. The most significant outliers are listed in Table 3 and are discussed in the Appendix.

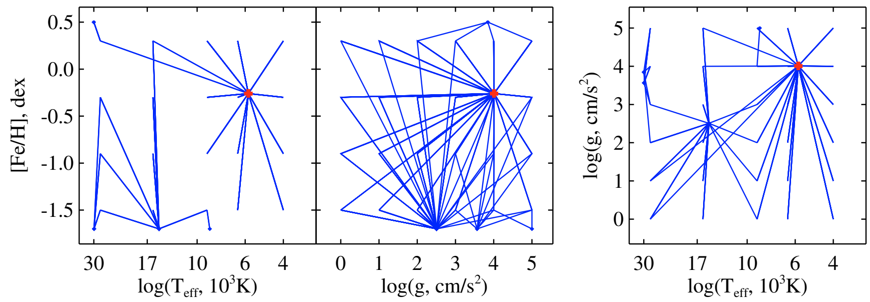

Fig. 7. Convergence maps on different projections of the parameters space for the CFLIB star HD 4307. Each vector connects a guess with the correspondng solution. The red dots show the location of absolute minimum in the three projections.

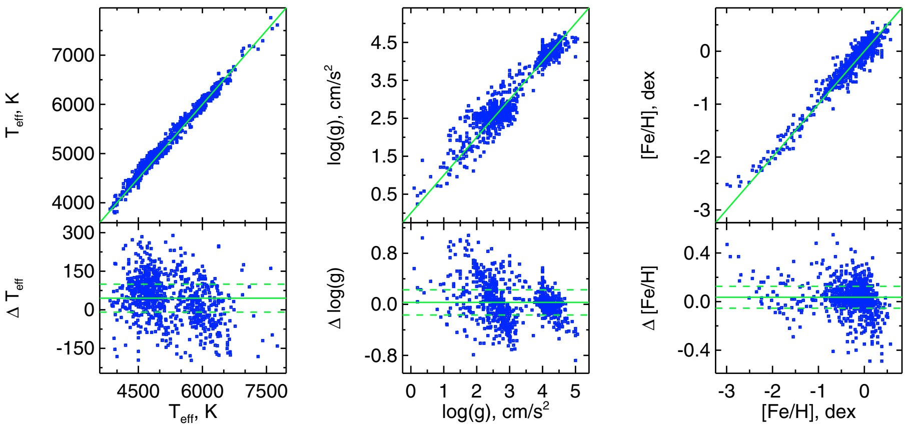

Fig. 8. Comparison of the atmospheric parameters determined by us (ordinates of *the upper panels*) with those from Valdes (abscissas). 818 FGK stars are plotted and 46 temperature, eight log g and five [Fe/H] outliers are not displayed. In *the lower panels*, we plot the differences between the values from ULySS and the literature (here Valdes). The green lines in *the upper panels* are the 1 to 1 ratios. In *the lower panels*, the continuous green lines mark the mean bias, and the dashed lines are the 1-σ deviation (computed after the rejection of the $T_{\rm eff}$ outliers). The same convention is used from Fig. A.1 to C.4 for other literature sources.

3.2. O, B, and A Stars

There are 260 O, B, and A stars in CFLIB. The determination of the atmospheric parameters for hot stars is more delicate than for the FGK stars for a couple of reasons. First, there are fewer spectral features. Second, the spectra are often more complex because of emission lines, of chemical peculiarities or of rotation. Third, there are few reference measurements in the literature and the number of stars in the ELODIE library is even smaller. For these reasons, the interpolator is less secure, and may be biased, in the sense that the interpolated spectra may differ from the templates by some systematics.

To study these systematics, we compare in Appendix B the absolute and internal parameters of the ELODIE library. We also compare our determinations with three other studies. The results are given in Table 5.

For two stars we excluded a significant region of the spectrum: for HD 206267 (O6e), the region 4785–5933 Å was not observed, and for HD 33111 (A3III), the region 4679–6012 Å has a low S/N.

3.3. M Stars

There are 53 M, S, or C stars in CFLIB. For nine of them, the fit with ULySS was not successful, in the sense that the metallicity reached the lower bound, [Fe/H] = –1.0 dex, set as a validity limit of the models (for the M stars). After a critical review of the literature and of the quality of our fit, we adopted the parameters listed in Table 7.

In Appendix C we compare our measurements with other determinations from four other compilations. The corresponding statistics is summarized in Table 6.

4. Discussion and conclusion

Nearly 300 of the 1273 stars in the Indo-US stellar spectral library (CFLIB) had one or more of the atmospheric parameters, $T_{\rm eff}$, log g, or [Fe/H], unknown.

We have determined the atmospheric parameters for 1271 (out of 1273) CFLIB stars using the ULySS package and the interpolator of the ELODIE library. ULySS optimizes the usage of all the signal information inside the spectrum, allows taking into account of the errors on each bin of the spectrum and is insensitive to the shape of the continuum. This method determines all free parameters within a single minimization, in order to properly handle the degeneracy between some parameters, e.g., temperature and metallicity. The instrumental and physical broadening of the spectra is matched with a Gaussian convolution. The distribution of the adopted parameters is presented on Figs. 9 and 10.

Based on comparisons with several previous studies we conclude that our method is robust. We derived the intrinsic external accuracy. For the 958 F, G, and K stars, the precisions on $T_{\rm eff}$, log g, and [Fe/H] are respectively 43 K, 0.13, and 0.05 dex. For the 53 M stars they are 82 K, 0.22, and 0.28 dex and for the 260 O, B, and A stars the relative precision on $T_{\rm eff}$ is 5.1%, and on log g, and [Fe/H] the precisions are 0.19 and 0.16 dex respectively.

The external comparisons also allow us to probe the existence of biases. For the FGK stars the various comparisons summarized in Table 4 indicate biases in the ranges −65 to 44 K, −0.2 to 0.1 dex and −0.06 to 0.04 dex, for temperature, gravity and metallicity respectively. For OBA stars (Table 5), they are in the ranges −1 to 4 %, −0.05 to 0.03 dex and −0.01 to 0.02 dex, and for M stars (Table 5) −100 to −30 K, −0.1 to

Table 4. External comparison of the atmospheric parameters of F, G, and K stars.

Reference	$\Delta T_{\rm eff}$ (K)		$\Delta\log g$ (cm s^{-2})		Δ[Fe/H] (dex)		No. of Stars[a]	Sp. Type
	mean	rms	mean	rms	mean	rms	/clipped	
Valdes et al. (2004)	45.1	98.7	0.03	0.30	0.04	0.13	877/46/8/5	F, G, K
ELODIE 3.2 I (2009)	17.4	41.4	0.04	0.10	0.03	0.07	387/7/1/1	F, G, K
Valenti & Fischer (2005)	–27.4	78.5	–0.11	0.16	–0.04	0.06	106/0	F, G, K
Soubiran et al. (2008)	39.9	75.1	0.09	0.27	0.03	0.10	175/8	F, G, K
Edvardsson et al. (1993)	–14.8	52.2	–0.02	0.12	0.04	0.07	129/10	F, G
Santos et al. (2004)	–46.3	74.4	–0.06	0.15	–0.02	0.07	23/2	F, G, K
Fuhrmann et al. (1998)	–27.9	41.5	–0.04	0.10	–0.01	0.03	7/0	F, G
da Silva et al. (2006)	5.0	32.4	0.11	0.17	0.01	0.06	17/1	G, K
Gray et al. (2001)	–52.9	91.8	0.06	0.28	0.03	0.11	46/4	F, G
Robinson et al. (2007)	–4.6	57.2	–0.05	0.27	0.00	0.11	26/2	F, G, K
Nordström et al. (2004)	36.8	62.0	–	–	0.03	0.08	269/15/0/2	F, G, K
Mishenina et al. (2006)	41.3	55.8	0.19	0.28	0.01	0.09	48/3	G, K
Kovtyukh et al. (2006)	42.5	64.4	–	–	–	–	69/5	G, K
Takeda (2007)	–24.3	71.3	0.00	0.13	–0.02	0.06	117/9	F, G, K
Hekker (2007)	–10.8	62.2	–0.23	0.29	0.01	0.07	132/5	G, K
Luck (2007)	–65.5	70.5	–0.18	0.24	–0.06	0.07	113/5	G, K
Sousa (2008)	–43.7	75.1	–0.07	0.16	0.00	0.05	17/2	F, G, K

Notes. The mean Δ values are computed as our determination minus those of the literature. [(a)] The first number is the total of spectra in common, the second is the number of the rejected $T_{\rm eff}$ outliers. For the comparisons with ELODIE 3.2, Valdes, and Nordström, the third and fourth are the numbers of rejected $\log g$ and [Fe/H] outliers .

Table 5. Comparison of common O, B, and A type stars with other references.

Reference	$\Delta T_{\rm eff}$(%)		$\Delta\log g$ (cm s^{-2})		Δ[Fe/H] (dex)		No. of Stars	Sp. Type
	mean	rms	mean	rms	mean	rms	/clipped	
ELODIE 3.2 A vs. I (2009)	1.33	6.32	0.07	0.25	–0.01	0.21	293/19	O, B, A
ELODIE 3.2 I (2009)	–0.84	3.36	–0.05	0.16	0.01	0.14	47/6	O, B, A
Valdes et al. (2004)	1.53	10.02	0.08	0.47	0.15	0.55	86/2	O, B, A
	1.53	10.02	0.01	0.35	0.02	0.29	86/2/5/18	O, B, A
Cenarro et al. (2007)	4.33	12.14	0.17	0.58	0.23	0.60	38/1	B, A
	4.33	12.14	0.03	0.38	–0.01	0.33	38/1/3/9	B, A

Notes. For the comparison with Valdes et al. (2004) and Cenarro et al. (2007), the statistics listed in the first line are given after excluding the temperature outliers, and the second line lists the statistics after clipping those red crosses in $\log g$ and [Fe/H] panels respectively. Numbers displayed in the column of "No. of Stars /clipped" show the clipped number in the order of $T_{\rm eff}$, $\log g$ and [Fe/H].

Table 6. Comparison of common M type stars with other references.

Reference	$\Delta T_{\rm eff}$ (K)		$\Delta\log g$ (cm s^{-2})		Δ[Fe/H] (dex)		Star num/clip
	mean	rms	mean	rms	mean	rms	
ELODIE 3.2 I (2009)	–32.9	43.7	0.16	0.34	0.03	0.08	7
Valdes et al. (2004)	–60.9	122.9	–0.08	0.32	–0.12	0.44	18/2
Cenarro et al. (2007)	–61.7	127.3	–	–	–	–	10
Cayrel et al. (2001)	–97.4	133.4	–0.11	0.30	–0.14	0.49	18

0.1 dex and −0.13 to 0.03 dex. These individual biases are symmetrical around zero, and we have no indication for a systematics in our measurements.

These determinations are particularly reliable and accurate for the FGK stars. But they appeared also valuable for both the OBA and M stars. The main limitations are for the low-metallicity blue horizontal branch stars and the stars cooler than 3300 K. In the first case, the program tends to over-estimate the metallicity. An A0 star with [Fe/H] ~ -1.5 would be retrieved at [Fe/H] ~ -0.8. In the second case, the program often converges toward a low-metallicity solution: a solar metallicity M star may be found at the low-metallicity boundary of the model. Both of these effects are certainly owing to the poor coverage of the ELODIE library in these regions of the parameter space. Also, the physical description of the hot and cool stars cannot be generally expressed by the three atmospheric parameters plus a Gaussian broadening. More elaborated models may improve the behavior of the program for these special stars, or a non-parametric approach, like TGMET, may perform better.

We will use this set of atmospheric parameters to re-calibrate the fluxes in the CFLIB library. Then, after homogenizing and correcting the line-spread functions, we will prepare high-quality stellar population models.

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Table 7. Nine late type stars,which ULySS could not successfully fit.

Name	Sp. Type	$T_{\rm eff}$ (K)	log(g) cm s^{-2}	[Fe/H] (dex)	Ref.
HD 078712	M6IIIase	3210	0.00	–0.01	A
		3101	0.23	–1.00	0
		3210	0.00	–0.11	1
		3210	0.00	0.09	1
HD 084748	M8IIIe	3070	0.78	–1.00	0&A
HD 114961	M7III	3014	0.00	–0.81	2&A
		3080	0.36	–1.00	0
HD 126327	M7.5	3000	0.00	–0.58	2&A
		3088	0.30	–1.00	0
HD 148783	M6III	3250	0.20	–0.04	A
		3146	0.45	–1.00	0
		3250	0.20	–0.01	3
		3250	0.20	–0.06	4
HD 177940	M7IIIevar	3092	0.59	–1.00	0&A
HD 187796	S...	3148	0.49	–1.00	0&A
HD 196610	M6III	3100	0.39	–1.00	0&A
HD 197812	M5Iab:	3389	0.32	–1.00	A
		3119	0.32	–1.00	0
		3389			5

Notes. First column is the star name. Second column is the stellar spectral type. Third to fifth column are the three atmospheric parameters. Sixth lists the source of the measurements. For HD 78712 we adopt the averaged parameters from Smith & Lambert (1986)'s two solutions, for HD 114961 and 126327 we adopt values from Jones (1999), for HD 148783 we adopt the averaged values of Ramírez et al. (2000) and Carr et al. (2000), for HD 197812 we use the $T_{\rm eff}$ value from Dyck et al. (1998), and adopt log g and [Fe/H] value of ULySS determination. For the remaining four stars, as no other reference could be found, we adopt our determinations in the final table.
References. (A) Adopted solution; (0) ULySS fit to the CFLIB spectrum; (1) Smith & Lambert (1986); (2) Jones (1999); (3) Ramírez et al. (2000); (4) Carr et al. (2000); (5) Dyck et al. (1998).

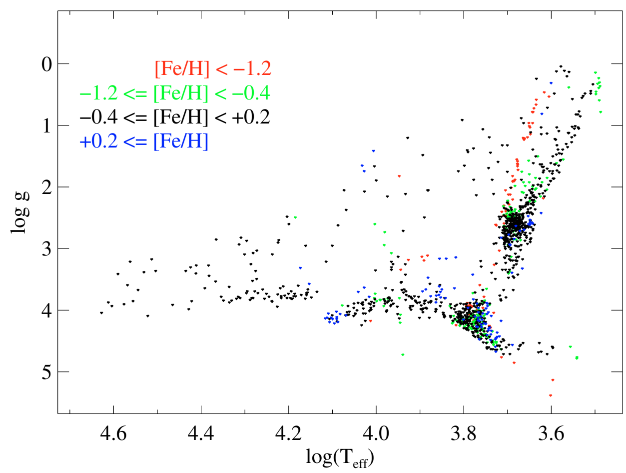

Fig. 9. Distribution in the log ($T_{\rm eff}$) – log g plane of the adopted atmospheric parameters for the 1271 CFLIB stars. The color of the symbols distinguishes the different metallicity classes.

Appendix A: External comparisons for FGK stars

In this Appendix we present the detailed comparisons between our measurements and 16 previous studies. The main outliers are individually discussed.

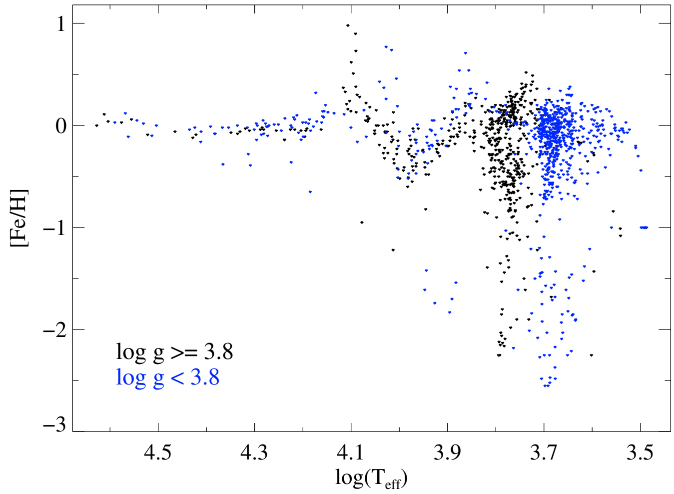

Fig. 10. Distribution in the log($T_{\rm eff}$) – [Fe/H] plane of the adopted atmospheric parameters for the 1271 CFLIB stars. The dwarfs are in black and the giants in blue.

A.1. Comparison with ELODIE 3.2

There are 206 stars in common between CFLIB and the ELODIE library, corresponding to a total of 387 ELODIE spectra. The comparison with the internal parameters of ELODIE is shown in Fig. A.1. The ELODIE parameters were determined with the interpolator computed on the continuum normalized spectra, while for the present study we used the flux-calibrated interpolator.

The dispersion between the two series of measurements of $T_{\rm eff}$ is 42 K (see Table 4). Assuming that the uncertainty is evenly shared between the two series, this implies an intrinsic precision of ~30 K, in agreement with the results of Sect. 2.3. This precision is well within the errors quoted in the literature (50 to 70 K) and we conclude that we can rely on our method. The precisions on log g and [Fe/H] are respectively 0.08 and 0.06 dex.

We detected seven $T_{\rm eff}$, one log g and two [Fe/H] outliers that we excluded from the statistics. For HD 22468 (K2:Vnk), we obtained a temperature ~390 K cooler than the one in ELODIE, $T_{\rm eff}$ ~ 5136 K, (average of two spectra). Our fit of the two ELODIE spectra returns a mean $T_{\rm eff}$ = 4771 K, consistent with our estimation. This star is an active RS CVn variable with strong emission lines (CAII K & H, Balmer lines) and a broad asymmetric cross-correlation peak reflecting the duplicity. The main component is a K1/2 star (Gray et al. 2006), for which a temperature around 4800 K is reasonable. We keep our determination in the final table.

For the second outlier, HD 72946, with three ELODIE observations, we find a temperature ~360 K hotter than the ELODIE internal determinations, $T_{\rm eff}$ = 5655 K, or the ULySS fit of the ELODIE spectra, $T_{\rm eff}$ = 5664 K. As the CFLIB observation misses the red part of the fitting wavelength range, we remade the fit starting from 3900 Å, and obtained $T_{\rm eff}$ = 5624 K. We adopt this latter solution. For the third and fourth outliers HD 183085 and 45674 we determined temperatures ~260 K warmer than the ELODIE internal estimation. However, as our solution is consistent with the ULySS fit of the ELODIE spectra, we adopt it.

There is also an obvious log g and [Fe/H] outlier, HD 178266 (K5). We find log g = 2.68 dex and [Fe/H] = 0.10 dex, while ELODIE 3.2 quotes log g = 1.76 dex and –0.50 dex (absolute) and 1.81 dex and –0.49 dex (internal). In ELODIE version 1

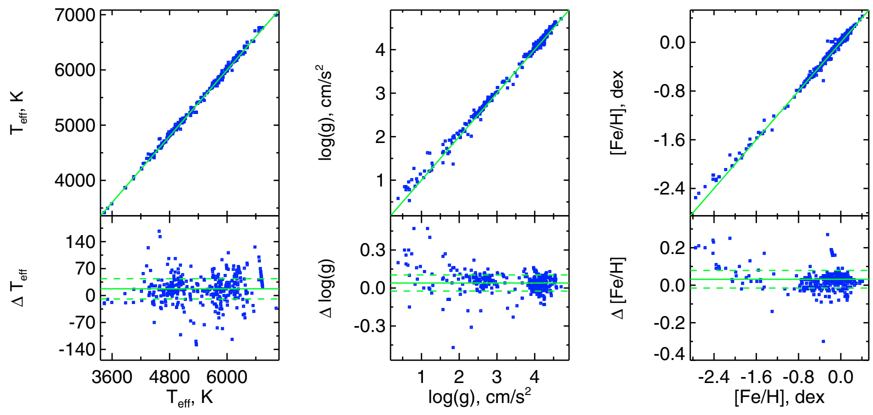

Fig. A.1. Comparison of the atmospheric parameters determined by us (ordinates, *upper panels*) with those from ELODIE 3.2 (abscissas). We plot 378 F, G, and K observations in common between the two data sets, seven outliers are not displayed. The axes are as in Fig. 8.

(Prugniel & Soubiran 2001), the star was on the dwarf sequence: $\log g = 5.27$ dex. Fitting the ELODIE spectrum with ULySS, we obtain $\log g = 2.69$ dex and [Fe/H] = 0.10 dex, in agreement with our measurement of the CFLIB spectrum, which we finally adopt.

Finally, there is another metallicity outlier, HD 22211 (G0). We obtained [Fe/H] = 0.20 dex while CFLIB quotes –0.31 dex (from ELODIE version 1) and ELODIE 3.2 gives –0.29 dex. Fitting the ELODIE spectrum, we get [Fe/H] = 0.14 dex, close to our determination, which we therefore adopt.

A.2. Comparison with Valenti & Fisher (2005)

Valenti & Fischer (2005) published a catalog of stellar properties for 1040 nearby F, G, and K dwarfs (1944 spectra) observed at a resolution $R \sim 70\,000$ by various planet search programs. Directly fitting the observations rather than equivalent widths with synthetic spectra yielded the effective temperature, surface gravity, metallicity, and projected rotational velocity. They adopted a Kurucz (1992) grid of model atmospheres generated by the ATLAS9 program (Kurucz 1993). Their precisions are 44 K for $T_{\rm eff}$, 0.06 dex for $\log g$ and 0.03 dex for [Fe/H]. Beside, they compared their measurements with Edvardsson et al. (1993), Fuhrmann et al. (1997), Fuhrmann et al. (1998), Santos et al. (2004) and Allende Prieto et al. (2004), and found mean external errors of 72 K in $T_{\rm eff}$, 0.13 dex in $\log g$, and 0.06 dex in [Fe/H].

We have identified 106 CFLIB stars in common with this work and show the comparison in Fig. A.2. The two series are consistent (see Table 4), without outliers exceeding 3σ in $T_{\rm eff}$. Our determinations are within the error estimates given by Valenti & Fischer (2005).

A.3. Comparison with Soubiran et al. (2008)

Soubiran et al. (2008) assembled two lists of mostly clump giants: 368 nearby stars ($d < 100$ pc) and 523 distant stars ($d < 1$ kpc) in the direction of the North Galactic pole. The atmospheric parameters of the former group were either estimated from their spectroscopic observations at high resolution and high signal-to-noise ratio or compiled from the literature, including in particular Mishenina et al. (2006). For the latter group, they were determined with the TGMET program (Katz et al. 1998) using ELODIE spectra.

We identified 175 stars in common with this reference, and we present the corresponding comparisons in Fig. A.3 after excluding eight $T_{\rm eff}$ outliers.

For the first outlier HD 48329 (G8Ib), we find a ~360 K warmer temperature. This star is one of the absolute calibrators in Soubiran et al. (2008), who adopted an average between the measurements by Luck (1982), Smith & Lambert (1987) and Mallik (1998). Our temperature, 4662 K, is consistent with Luck (1982)'s, 4624 K, and we keep our original measurements.

We found the second outlier, HD 72946, 324 K warmer. As the CFLIB spectrum misses the red range, we remade the fit including the blue from 3900 Å. This reduced the discrepancy to 80 K, in agreement also with the ELODIE internal determination. We adopted the results from our revised fit.

For the third outlier, HD 197964, our $T_{\rm eff} = 4762$ K is ~230 K cooler. This star is in the TGMET reference library, and the parameters given in Soubiran et al. (2008) are an average between Kyrolainen et al. (1986) and McWilliam (1990). The latter is from a photometric calibration, while the former, from a spectroscopic analysis, agrees with our determination and is also consistent with the ELODIE internal value. We adopt our original determination.

For the fourth (HD 219134) and fifth (HD 32147) outliers, our fitted temperatures are ~200 K cooler. For HD 219134, the Soubiran et al. (2008) temperature is an average between measurements by Strohbach (1970), 4710 K, Oinas (1977), 4710 K and Robinson et al. (2007), 4963 K. Our $T_{\rm eff} = 4700$ K agrees with the former two and is consistent with the ELODIE internal measurements (for two spectra). For HD 32147, the Soubiran et al. (2008) temperature is an average between Feltzing & Gustafsson (1998) and Thorén & Feltzing (2000), both from photometric calibrations. Our determined temperature, $T_{\rm eff} = 4617$ K, is consistent with the ELODIE internal value. We adopt our original determinations for these two stars.

The sixth outlier is HD 40460 (K1III). Our $T_{\rm eff}$ is 263 K warmer. The Soubiran et al. (2008) temperature is a spectroscopic determination from Cottrell & Sneden (1986).

The two ELODIE internal determinations for this star are consistent with our result and with the ULySS fit of these spectra. Therefore we adopt our original estimations.

For the seventh outlier HD 16458 (G8p...), our $T_{\rm eff} = 4410$ K is ~160 K cooler. The parameters in Soubiran et al. (2008) are averages between Sneden et al. (1981), $T_{\rm eff} = 4500$ K, Tomkin & Lambert (1983), 4600 K, Smith (1984), 4800 K, and Fernandez-Villacanas et al. (1990), 4500 K. As the blue range of the spectrum has a good S/N, we re-fitted the spectrum starting from 3900 Å and obtained $T_{\rm eff} = 4484$ K, in agreement with both Fernandez-Villacanas et al. (1990) and the ELODIE internal measurement. In Table 2 we adopt our modified solution.

For the last outlier HD 204867, our $T_{\rm eff} = 5705$ K is 243 K warmer than Soubiran et al. (2008), which is an average between

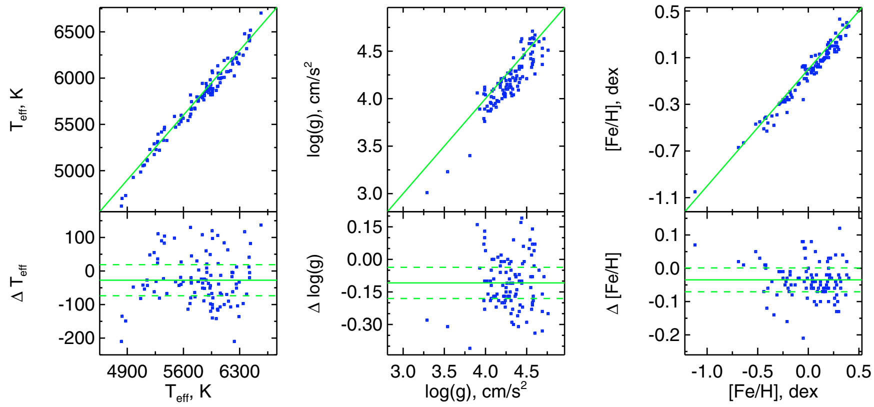

Fig. A.2. Comparison of the atmospheric parameters determined by us with those from Valenti & Fischer (2005). We plot 106 F, G, and K dwarfs in common between the two data sets. The axes are as in Fig. 8.

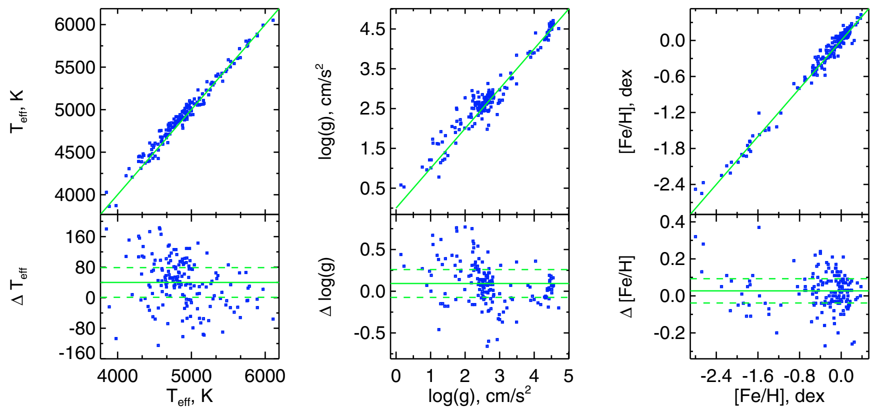

Fig. A.3. Comparison of the atmospheric parameters determined by us with those from Soubiran et al. (2008). We plot 167 F, G, and K stars in common between the two data sets, eight outliers are not displayed. The axes are as in Fig. 8.

Luck (1982), 5362 K, and Foy (1981), 5478 K. The ELODIE internal parameters are consistent with our results which we therefore adopt in Table 2.

A.4. Comparison with Edvardsson et al. (1993)

Edvardsson et al. (1993) studied the atmosphere of 189 nearby field F and G stars to provide observational constraints on the evolution of the Galactic disk. The temperature and gravity were determined with Strömgren photometry, and the [Fe/H] metallicity and detailed abundances were estimated to a precision of 0.05 dex with LTE atmosphere models.

The CFLIB has 129 stars in common with this database and the results of the comparison are shown in Fig. A.4. Ten $T_{\rm eff}$ outliers were excluded. As seen from Table 4, the deviations in the parameters are small between the two studies.

For seven of the ten outliers we find a temperature around 170 K cooler and, for the rest of them, about 100 K warmer. Six of these outliers belong also to the ELODIE library, where their internal measurements are consistent with the present determinations. The other four $T_{\rm eff}$ outliers are discussed below.

For HD 175317, our estimated temperature is ~170 K cooler than the one given by Edvardsson et al. (1993), and there is also a discrepancy of 0.20 dex in [Fe/H]. Balachandran (1990) gives photometric determinations of the parameters which are consistent with ours. Gratton et al. (1996) give $T_{\rm eff} = 6517$ K, only 38 K warmer than us. For HD 102634, our estimated temperature is 177 K cooler than Edvardsson et al. (1993)'s, but our parameters agree with the measurements of Gratton et al. (1996). For HD 220117 and 168151, our temperature is consistent with Boesgaard & Friel (1990) and Gratton et al. (1996). We adopt our original measurements for these four stars.

A.5. Comparison with Santos et al. (2004)

Santos et al. (2004) derived stellar metalicities and other parameters from a detailed $R \sim 50\,000$ spectroscopic analysis of a sample of 139 stars known or suspected to be orbited by planetary mass companions.

The errors were estimated to be on the order of 50 K in $T_{\rm eff}$, 0.12 dex in log g and 0.05 dex in metallicity. The obtained stellar parameters were found to be compatible, within the errors, with the values derived by others. In particular, the derived surface gravities were only on average 0.03 dex different from trigonometric estimates based on Hipparcos parallaxes.

We have a total of 23 F, G, and K stars common with this database. Figure A.5 shows the comparison after excluding the two outliers HD 137759 and HD 19994.

For HD 137759, our $T_{\rm eff}$ is 250 K cooler, but our atmospheric parameters are consistent with the ELODIE internal determinations and are close to Soubiran et al. (2008)'s estimates, especially the $T_{\rm eff}$ and [Fe/H]. For HD 19994, our $T_{\rm eff}$ is 209 K cooler, but closer to the photometric estimate from Edvardsson et al. (1993). The internal measurements of the two spectra from the ELODIE library are consistent with our results. For both stars we adopt our measurements.

A.6. Comparison with Fuhrmann et al. (1998)

Fuhrmann et al. (1998) used a H_α and H_β line-fitting procedure to derive the effective temperatures of F and G stars. Figure A.6

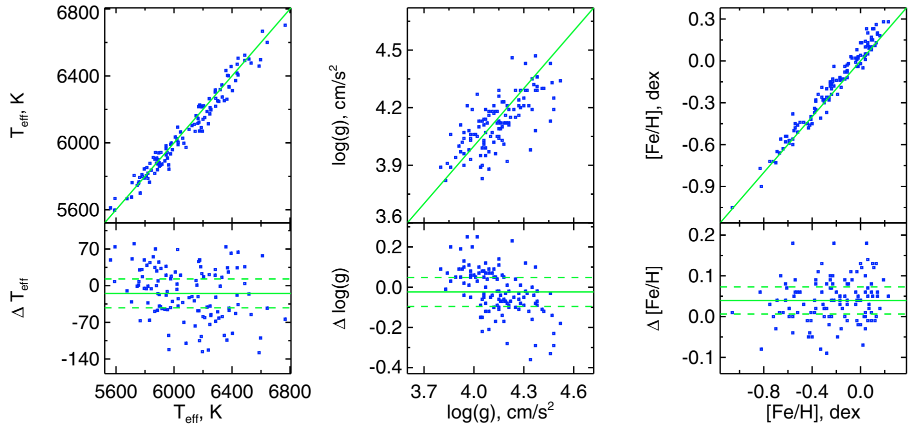

Fig. A.4. Comparison of the atmospheric parameters determined by us with those from Edvardsson et al. (1993). We plot 119 F and G stars in common between the two data sets, 10 outliers are not displayed. The axes are as in Fig. 8.

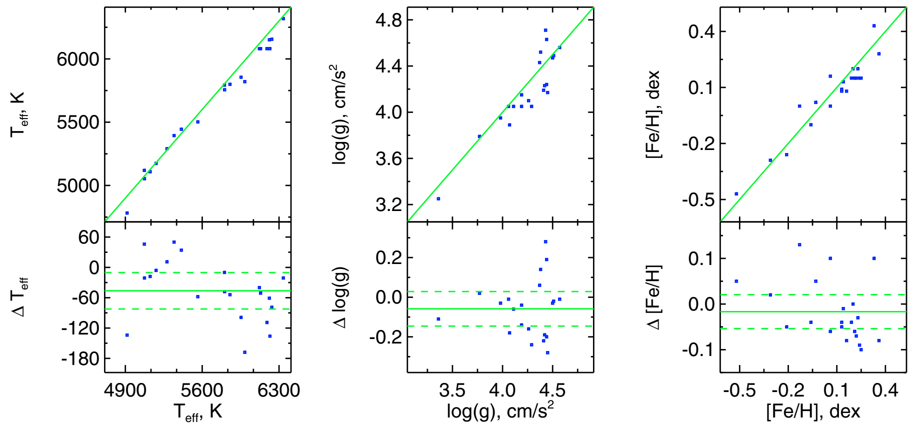

Fig. A.5. Comparison of the atmospheric parameters determined by us with those from Santos et al. (2004). We plot 21 F, G, and K stars in common between the two data sets, two outliers are not displayed. The axes are as in Fig. 8.

presents the comparison for the seven stars in common with this sample. The agreement is good.

A.7. Comparison with da Silva et al. (2006)

a SilvaDA SILVA et al. (2006) give a detailed spectroscopic analysis of 72 evolved stars observed at the resolution R = 50 000. The atmospheric parameters were obtained by adjusting the measured equivalent widths to LTE atmosphere models, imposing excitation and ionization equilibrium. A direct comparison of their results with those of other authors (Cayrel de Strobel et al. 2001) showed that their metallicity is on average systematically higher by 0.07 dex, their temperature by about 40 K, and gravity by about 0.13 dex. Their estimate of the uncertainties are 70 K on T_{eff}, 0.2 dex on log g 0.1 dex on [Fe/H].

We found 17 G and K stars in common and show the comparison in Fig. A.7. We do not see the biases found by da Silva et al. (2006). For HD 99167, our estimated T_{eff} is 191 K cooler, while the other two parameters also deviate significantly. Our estimated T_{eff} and log g are consistent with McWilliam (1990) (discussed above in Sect. A.1), but our [Fe/H] deviates by 0.30 dex compared to both da Silva et al. (2006) and McWilliam (1990). The quality of our fit is satisfactory and we adopt our determinations.

A.8. Comparison with Gray et al. (2001)

Gray et al. (2001) studied 372 late A, F, and early G type stars with the aim of understanding the nature of the MK luminosity classification for this range of spectral types. They simultaneously fitted the optical spectra (1.8 Å resolution) and Strömgren *uvby* photometry against Kurucz ATLAS9 models. They estimated the random external errors to 80 K on T_{eff}, 0.1 dex on log g and 0.10 to 0.15 dex on [Fe/H].

We present the comparison of the 46 stars in common with our sample in Fig. A.8, after excluding four T_{eff} outliers.

The star HD 25291 (F0II) is a prominent outlier. The T_{eff}, log g and [Fe/H] from Gray et al. (2001) are 7050 K, 1.85 dex and –0.21 dex respectively. Our corresponding values are 7761 K, 2.49 dex and 0.14 dex, yielding large deviations of 711 K in temperature, 0.64 dex in gravity and 0.35 dex in metallicity. This star has been a subject of a number of investigations. Andrievsky et al. (2002) give T_{eff} = 6750 K, using photometric data, and the log g = 1.00 dex was determined assuming the FeI/II ionization equilibrium. Giridhar & Arellano Ferro (2005) gave spectroscopic T_{eff} = 7250 K and log g = 1.50 dex. Kovtyukh (2007) gave 7497 K using line-depth ratios (the uncertainty is 5–30 K). Venn (1995) gave 7600 K and log g = 1.5 dex, from MgI/II ionisation equilibrium and Hγ profile fit. All the above references point to a mean log g ∼ 1.50 dex, which seems reliable. Fixing log g at this value and re-fitting the spectrum, we find T_{eff} = 7390 K, close to Kovtyukh (2007)'s value and more reasonable for a F0 star. In the final table we adopted this latter solution.

The estimates for the other three T_{eff} outliers, HD 194093, 36673 and 20902, can be improved by fitting from 3900 Å instead of 4400 Å, because the blue part of these spectra have a better quality. The internal ELODIE measurements for HD 194093 are consistent with the latter estimations, and fitting the ELODIE spectrum with ULySS also gives a similar result. For HD 20902, Luck & Lambert (1985) gave 6300 K, cooler than

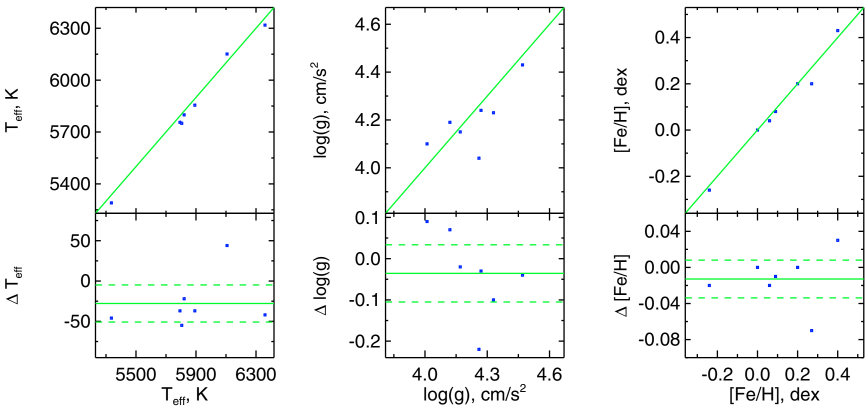

Fig. A.6. Comparison of the atmospheric parameters determined by us with those from Fuhrmann et al. (1998). We plot seven F and G stars in common between the two data sets. The axes are as in Fig. 8.

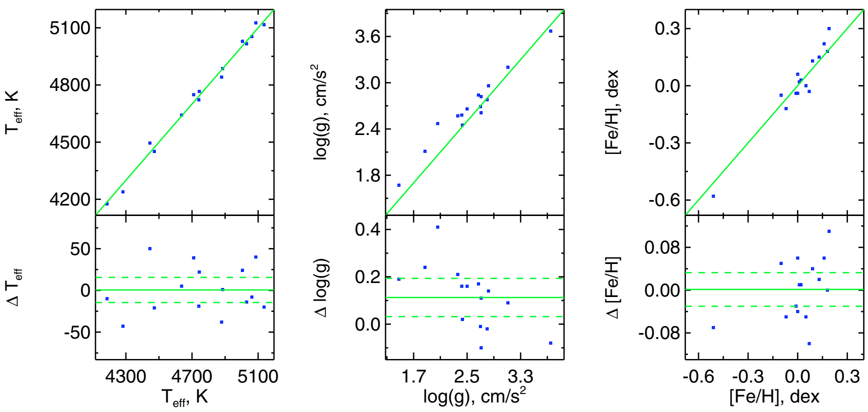

Fig. A.7. Comparison of the atmospheric parameters determined by us with those from da Silva et al. (2006). We plot 15 G and K stars in common between the two data sets, two outliers are not displayed. The axes are as in Fig. 8.

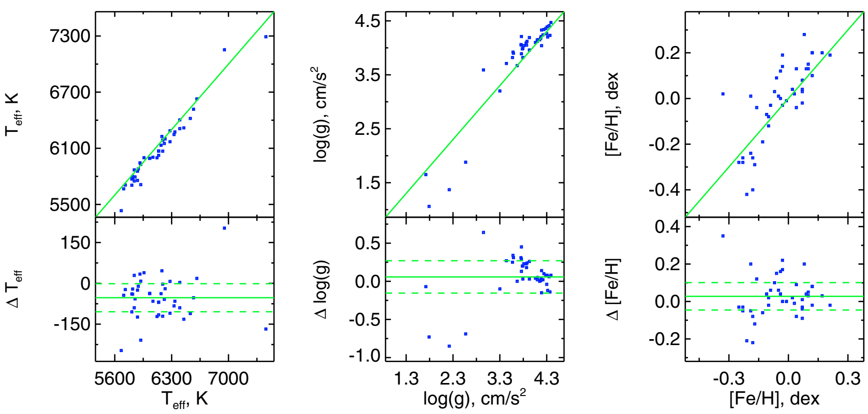

Fig. A.8. Comparison of the atmospheric parameters determined by us with those from Gray et al. (2001). We plot 42 F and G stars in common between the two data sets, four outliers are not displayed. The axes are as in Fig. 8.

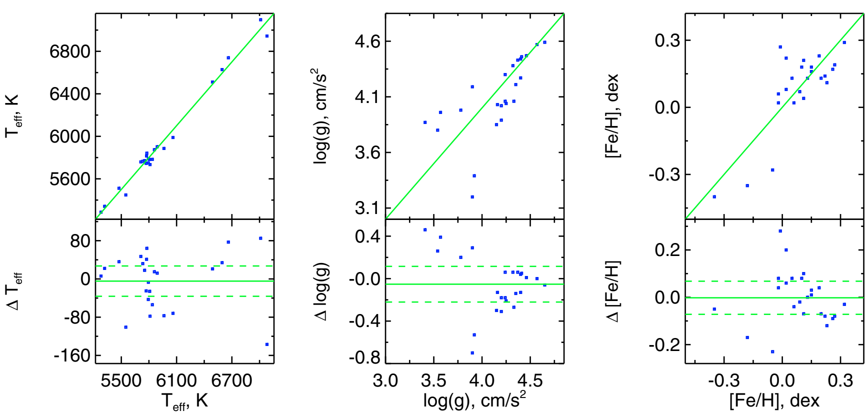

Fig. A.9. Comparison of the atmospheric parameters determined by us with those from Robinson et al. (2007). We plot 24 F, G, and K stars in common between the two data sets, two outliers are not displayed. The axes are as in Fig. 8.

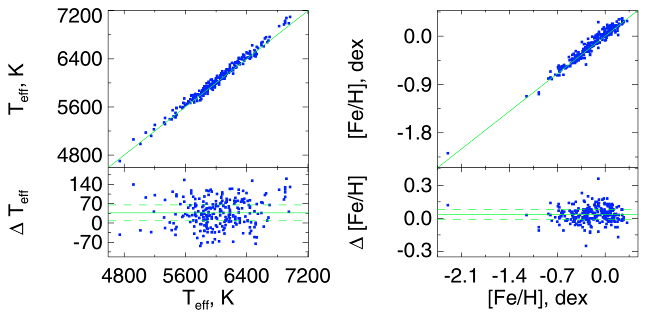

Fig. A.10. Comparison of the atmospheric parameters determined by us with those from Nordström et al. (2004). We plot 252 F, G, and K observations in common between the two data sets, 14 $T_{\rm eff}$ plus two metallicity outliers are not displayed. The axes are as in Fig. 8.

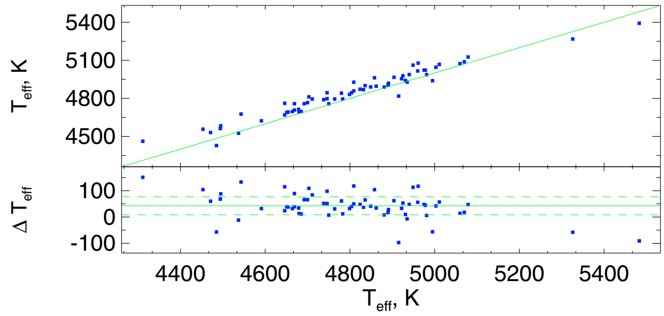

Fig. A.11. Comparison of the atmospheric parameters determined by us with those from Kovtyukh et al. (2006). We plot 64 G and K stars in common between the two data set, five outliers are not displayed. The axes are as in Fig. 8.

Gray et al. (2001) by 260 K. In Table 2 we adopt our improved determinations.

A.9. Comparison with Robinson et al. (2007)

Robinson et al. (2007) reported atmospheric parameters for 1907 stars from a low-resolution spectroscopic survey, designed to identify metal-rich F, G, K dwarfs likely to harbor detectable planets. [Fe/H], $T_{\rm eff}$ and log g were measured with the calibrations of Lick indices presented in Robinson et al. (2006). $T_{\rm eff}$ is given by a linear combination of Lick indices, [Fe/H] by a linear combination of Lick indices and $T_{\rm eff}$ and log g by a linear combination of indices and $T_{\rm eff}$ plus one nonlinear term, $T_{\rm eff}({\rm H}_{\gamma{\rm F}} + {\rm H}_\beta)$. The precision of these calibrations are cited to be 82 K, 0.13 dex and 0.07 dex on respectively $T_{\rm eff}$, log g and [Fe/H]. We identified 26 common F, G, and K stars and show the comparison in Fig. A.9 after clipping two $T_{\rm eff}$ outliers.

The first outlier, HD 219134 (K3V), was discussed in Sect. A.3. Our estimated temperature is 263 K cooler, but is consistent with the ELODIE internal determination. For the second, HD 61295 (F6II), our $T_{\rm eff}$ is 196 K warmer, but is consistent with the Luck & Wepfer (1995)'s photometric estimate. We adopt our original determinations.

A.10. Comparison with the Geneva-Copenhagen survey

The Geneva-Copenhagen radial velocity survey of the solar neighborhood (Nordström et al. 2004) has provided $T_{\rm eff}$ and [Fe/H] for 16 682 nearby F and G dwarf stars from Strömgren photometry. The effective temperatures were determined from the reddening-corrected $b-y$, c_1, and m_1 indices and the calibration of Alonso et al. (1996). Their resulting temperatures have a mean difference of only 3 K and a dispersion of 94 K compared to Barklem et al. (2002). They compared their metalicities with the homogeneous spectroscopic values from Edvardsson et al. (1993) and Chen et al. (2000). They found mean differences of 0.02 and 0.00 dex and dispersions of 0.08 and 0.11 dex, respectively.

We found 269 measurements for 266 stars in common and the corresponding comparisons are shown in Fig. A.10, after rejecting 15 $T_{\rm eff}$ outliers plus one metallicity outlier (two measurements). One of them, HD 72946, has been discussed in Sect. A.1.

For six of the outliers, HD 54322, 124244, 137510, 37088, 94280 and 165341, our estimated parameters are consistent with the Valdes' compilation. For HD 82210 our value, 5343 K, is close to McWilliam (1990) (see Sect. A.3). For HD 37394, our $T_{\rm eff}$ = 5328 K is 190 K hotter, and Perrin (1983) gives 5196 K from photometry. For HD 129132, a member of a triple system, though our determination is 200 K warmer, the quality of our fit is satisfactory. For HD 195633, we fitted $T_{\rm eff}$ = 6102 K, Nordström et al. (2004) give 5916 K, and Fulbright (2000) 6000 K from spectroscopy. For all these stars we adopt our measurements.

There is one [Fe/H] outlier HD 22468 (K2:Vnk) with two measurements in Nordström et al. (2004): [Fe/H] = −1.25 dex and −1.52 dex. Our [Fe/H] = −0.16 dex is closer to the ELODIE internal determination, [Fe/H] = −0.48 dex, and in agreement with the ULySS fit to the ELODIE spectrum: [Fe/H] = −0.23 dex ±0.07 dex. We keep our determinations.

A.11. Comparison with Kovtyukh et al. (2006)

Kovtyukh et al. (2006) made precise temperature determinations of 215 F, G, and K giants by measuring the line depths and equivalent widths of a large number of spectral lines of low and high excitation potentials and establishing ∼100 relations between $T_{\rm eff}$ and their ratios. This calibration of the line depth ratio method yielded a precision of 5 to 20 K.

We found 69 stars in common and the comparison of $T_{\rm eff}$ is shown in Fig. A.11. There is no significant outlier.

A.12. Comparison with Mishenina et al. (2006)

The atmospheric parameters of 177 clump giants of the Galactic disk were determined by Mishenina et al. (2006). The effective temperatures were estimated by the line depth ratio method calibrated by Kovtyukh et al. (2006, see above). The surface gravity was estimated using the iron ionization equilibrium and the wings of the Ca I triplet near 6100–6160 Å. The [Fe/H] was derived from FeI lines. The internal precisions are 20 K, 0.2–0.3 dex and 0.1 dex on respectively $T_{\rm eff}$, log g and [Fe/H].

We identified 48 stars in common and the comparison, excluding three $T_{\rm eff}$ outliers, is shown in Fig. A.12. These outliers were also detected in the comparison with Kovtyukh et al. (2006) and are discussed in Sect. A.11.

A.13. Comparison with Takeda et al. (2007)

We found 117 stars in common with Takeda et al. (2007), who estimated the atmospheric parameters of solar analogs from the analysis of R = 70 000 spectra. The internal precisions of this series of measurements are 17 K, 0.04 and 0.02 dex on respectively $T_{\rm eff}$, log g and [Fe/H]. The comparison is shown in Fig. A.13.

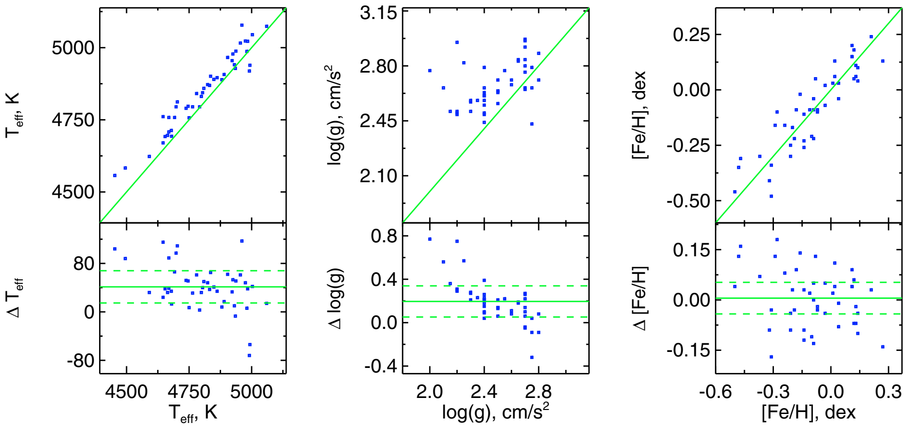

Fig. A.12. Comparison of the atmospheric parameters determined by us with those from Mishenina et al. (2006). We plot 45 G and K stars in common between the two data sets, three outliers are not displayed. The axes are as in Fig. 8.

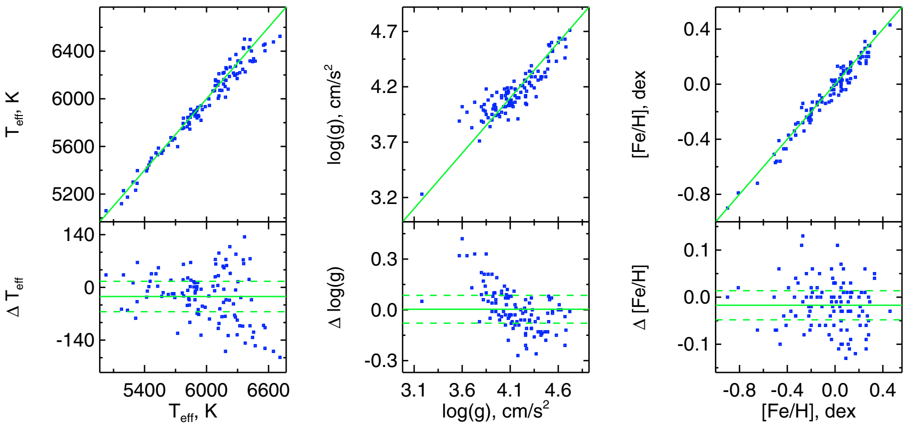

Fig. A.13. Comparison of the atmospheric parameters determined by us with those from Takeda et al. (2007). We plot 108 F, G, and K stars in common between the two data sets, nine outliers are not displayed. The axes are as in Fig. 8.

Nine $T_{\rm eff}$ outliers were clipped from the statistics given in Table 4. For eight of them HD 121370, 99747, 98991, 151769, 137510, 128167, 15798, 4307, our parameter estimations are quite close to the Valdes adopted values. For HD 224930 our temperature (5427 K) agrees with that of Soubiran et al. (2008) (5413 K) and ELODIE (5446 K), while Takeda et al. (2007) give 5681 K and Fulbright (2000) 5275 K. We maintain our original measurements.

A.14. Comparison with Hekker & Meléndez (2007)

Hekker & Meléndez (2007) used high S/N spectra at $R = 60\,000$ of 380 G and K giant stars to measure the atmospheric parameters. The effective temperatures, surface gravities, and metallicities are determined from the equivalent width of iron lines, by imposing excitation and ionization equilibria. They compared their stellar parameters with Ramírez & Meléndez (2005), an updated version of the Cayrel de Strobel et al. (2001) compilation, for 254 stars in common. They found their effective temperature and surface gravity are higher by 56 K and 0.15 dex, and with 84 K and 0.22 dex dispersion respectively. The dispersion of [Fe/H] is 0.10 dex. They found their results to be consistent with Luck & Heiter (2007).

We compare the 132 stars in common after clipping five outliers (Fig. A.13). For HD 39118 (G8III+...), our $T_{\rm eff}$ = 4927 K is 377 K hotter while the ELODIE internal temperature is 5029 K, and the ULySS fit to the ELODIE spectrum gives 5000 K. For HD 184406 and 29139 our estimates are consistent with both the Valdes compilation and with the ELODIE internal determinations. The temperatures given by Hekker & Meléndez (2007) are ∼240 K hotter. For HD 115004 and 57669, our temperatures are ∼170 K hotter, but we have no reason to question our fit. In all cases we adopt our solutions.

A.15. Comparison with Luck & Heiter (2007)

Luck & Heiter (2007) present the parameters for 298 nearby G and K giants using spectroscopy and photometry. The external uncertainty of their temperatures is on the order of ∼100 K. We compared the 113 stars found in common (Fig. A.15) and found a mean difference in temperature of –66 K (ULySS minus Luck & Heiter (2007); see Table 4).

There are a total of five $T_{\rm eff}$ outliers, HD 102328, 85503, 104979, 167768 and 126271, our temperatures are between 150–230 K lower. HD 85503 is already discussed in Sect. A.11. For HD 104979, our result (4818 K) agrees well with the ELODIE internal determination (4814 K) and with the Valdes compilation (4850 K), while Luck & Heiter (2007) give 4996 K.

A.16. Comparison with Sousa et al. (2008)

Sousa et al. (2008) give accurate stellar parameters for 451 stars using high-resolution spectra. We compared the 17 common FGK observations on Fig. A.16 where 2 $T_{\rm eff}$ outliers have been clipped.

HD 19994 (F8V) was already discussed in Sect. A.16, and the other outlier is not significant.

Appendix B: External comparisons for OBA stars

In this appendix we present detailed comparisons between our measurements and four previous studies.

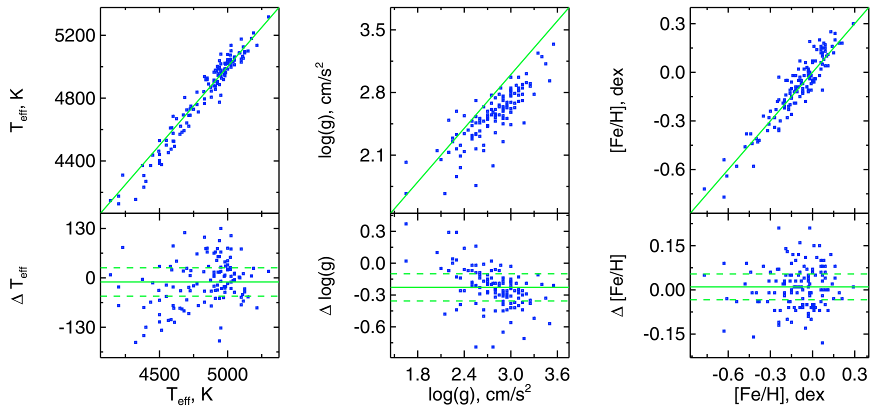

Fig. A.14. Comparison of the atmospheric parameters determined by us with those from Hekker & Meléndez (2007). We plot 127 G and K stars in common between the two data sets, five outliers are not displayed. The axes are as in Fig. 8.

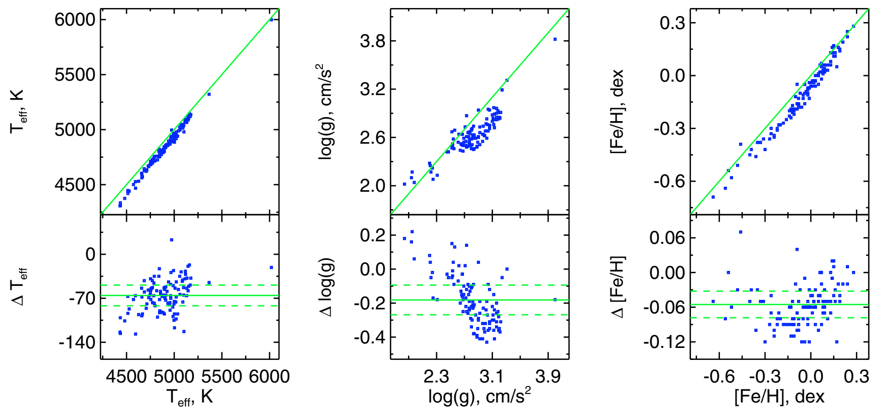

Fig. A.15. Comparison of the atmospheric parameters determined by us with those from Luck & Heiter (2007). We plot 108 G and K stars in common between the two data sets, five outliers are not displayed. The axes are as in Fig. 8.

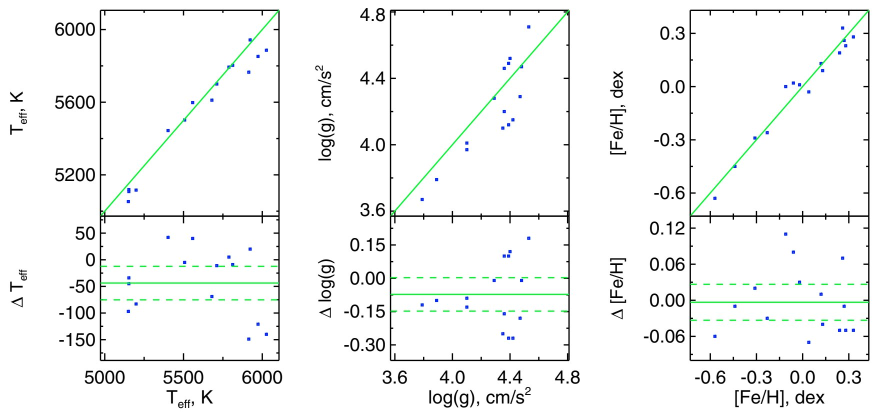

Fig. A.16. Comparison of the atmospheric parameters determined by us with those from Sousa et al. (2008). We plot 17 F, G, and K stars in common between the two data sets, two outliers are not displayed. The axes are as in Fig. 8.

B.1. Comparison between ELODIE 3.2 absolute and internal parameters

The absolute and internal atmospheric parameters of ELODIE are described in Sect. 2.1. We stress that the present comparison is different from the one in Sect. 2.3, where we used ULySS to determine the atmospheric parameters of the ELODIE observations.

There are 293 O, B, and A type stars with valid internal determinations in ELODIE stellar library. The comparison between the absolute and internal values of the parameters are shown in Fig. B.1 after excluding 18 $T_{\rm eff}$ outliers and one metallicity outlier. The comparison statistics are listed in Table 5 without these 19 outliers.

The absolute parameters of almost all of these outliers were not available from spectroscopic analyses in the literature. The temperature were estimated from the $B-V$ colur (Tycho-2 catalog of Høg et al. 2000), assuming an empirical color-temperature relation for a main-sequence star; log g were converted from the V absolute magnitude from Hipparcos and $T_{\rm eff}$, using a bolometric correction valid for a main-sequence star and an empirical mass-to-light relation. See Prugniel & Soubiran (2001) for more details.

We did not find any significant bias on the determination of the three atmospheric parameters, but the dispersions are higher than for the FGK stars. This is primarily because of the lack of accurate measurements for the reference stars.

In addition, the modeling of the atmosphere with the three fundamental parameters is an over-simplification, because the spread of other physical characteristics, which we neglected, induces a dispersion of our measurements. The modeling can probably be improved in the future, but the important point is that the present method apparently does not introduce major biases.

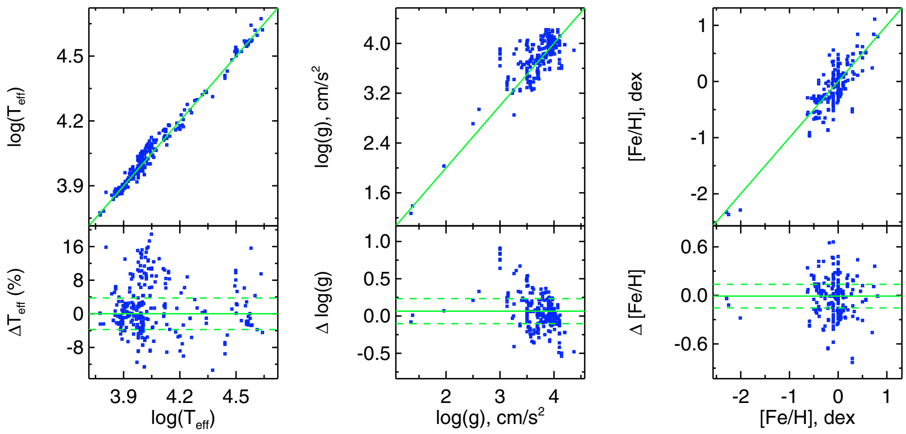

Fig. B.1. Comparison of the ELODIE 3.2 Absolute (A) and Internal (I) atmospheric parameters. We plot 274 O, B, and A type stars, 18 $T_{\rm eff}$ outliers plus one metallicity outlier are not displayed. The axes are similar as in Fig. 8, all the abscissas are the measurements of A. $T_{\rm eff}$ is in log10. *Upper panels*: the ordinates are from I; *Lower panels*: the ordinates are the difference I – A.

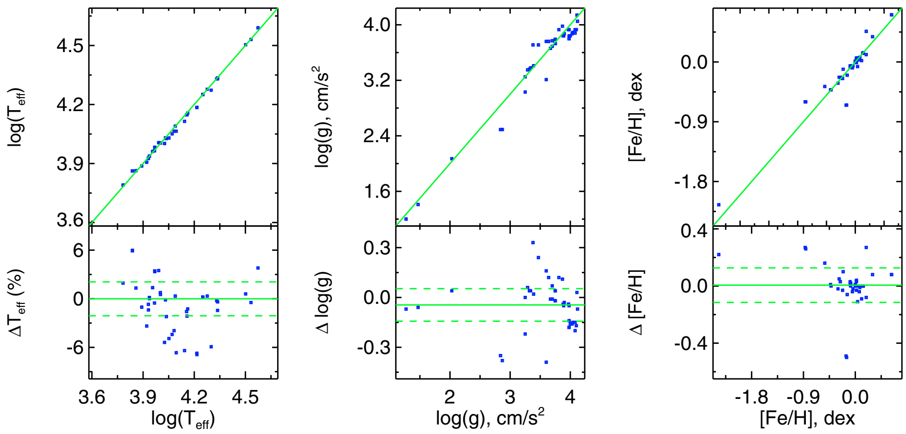

Fig. B.2. Comparison of the atmospheric parameters determined by us with those from ELODIE 3.2. We plot 41 O, B, and A type stars in common between the two data sets, six outliers are not displayed. The axes are as in Fig. 8, besides $T_{\rm eff}$ is in log10.

B.2. Comparison with ELODIE 3.2

There are 47 O, B, and A observations in common with ELODIE. The comparison with the ELODIE internal determinations is shown in Fig. B.2 after excluding six $T_{\rm eff}$ outliers.

For the first outlier, HD 212571 (B1Ve), though it is a Be type star, we could not see any emission lines in both its CFLIB and ELODIE observations, but the spectrum is quite rotationally broadened. Its ELODIE internal parameters are 20530 K, 3.29 dex, 0.01 dex, and we obtain 23278 K, 3.53 dex, –0.02 dex, which are close to the ELODIE absolute parameters, 23714 K, 3.50 dex and 0.00 dex. Fitting the ELODIE spectrum, we get 23031 K, 3.41 dex and –0.06 dex, in agreement with our measurements for CFLIB. We suppose that the discrepancy results from the different approach for modeling the effect of stellar rotation in our ULySS measurements and in the internal ELODIE measurement (see Sect. 2.3).

The second outlier, HD 5394 (B0IVpe), displays prominent H_α and H_β emission lines (rejected when performing the ULySS fit). There are two observations of this star in the ELODIE library, with determinations: [34 097 K, 3.34 dex, 0.11 dex] and [39 156 K, 3.22 dex, –1.56 dex]. Because of the emission lines, these spectra were not used to build the ELODIE interpolator. Our results [33 939 K, 3.38 dex, 0.02 dex] are close to the former ELODIE internal values. The ULySS fit of these ELODIE spectra provides 33090 K, 3.41 dex and 0.05 dex, consistent with our measurements.

For the third outlier HD 206165 (B2Ib), the ELODIE internal determinations are 19685 K, 2.94 dex and –0.27 dex, while we get 22112 K, 3.09 dex and –0.12 dex. Gies & Lambert (1992) derived 19040 K, 2.61 dex and –0.33 dex comparing Strömgren de-reddened color indices and $H\gamma$ line profiles to line-blanketed atmosphere models (Kurucz 1979). The abundances were derived using LTE Kurucz models. They quote errors of 2–4% on $T_{\rm eff}$ and 0.1 dex on log g. So the ELODIE internal solution is compatible with their measurements. The ULySS fit of the ELODIE spectrum gives 20 569 K, 2.93 dex and –0.28 dex, also consistent with the ELODIE internal determinations. We adopt this latter solution rather than our fit of the CFLIB spectrum.

The fourth outlier is HD 86986 (A1V), a blue horizontal branch star (BHB). Our determinations, 8843 K, 4.28 dex and –0.76 dex, are 676 K warmer than the ELODIE internal value. Kinman et al. (2000) and Behr (2003) give 7950 K and 7775 K respectively. The ELODIE interpolator is only weakly constrained in this region of the parameters' space, and we adopt the average of the two recent literature measurements.

For the fifth outlier, HD 176437 (B9III), the ELODIE internal parameters are 12 230 K, 4.08 dex and 0.25 dex, and we find 11 163 K, 4.06 dex and 0.15 dex. Balachandran et al. (1986) give $T_{\rm eff}$ = 10 080 K. The last outlier, HD 220825 (A0p...), is a CVn star that is discussed below in Sect. B.3. The ELODIE internal yield is 9683 K, 3.80 dex and 0.47 dex, while we find 10 375 K, 3.78 dex and 0.74 dex. This is 692 K warmer and is consistent with Searle et al. (1966): 10286 K. For these two stars, we adopt our measurements.

B.3. Comparison with Valdes et al. (2004)

Of the 260 O, B, and A stars in CFLIB, the atmospheric parameters were compiled for only 86 stars by Valdes et al. (2004). The comparison between these values and our determinations is displayed in Fig. B.3 after excluding two temperature outliers. The 18 cases where the [Fe/H] deviations between CFLIB and our

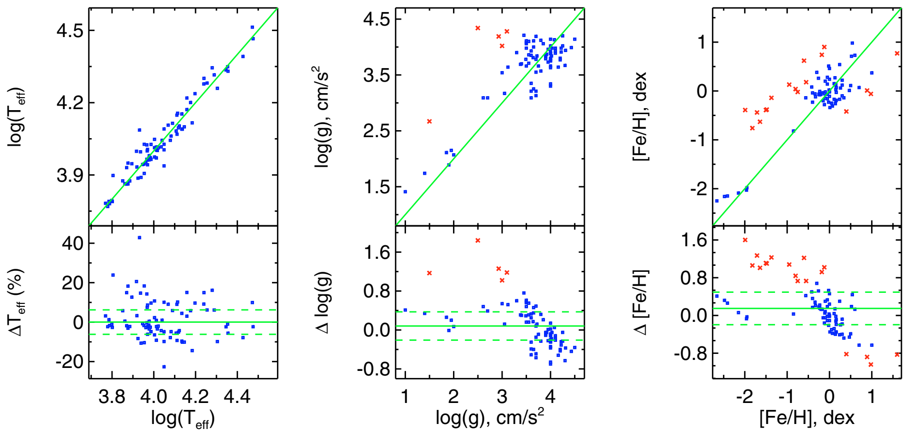

Fig. B.3. Comparison of the atmospheric parameters determined by us with those from Valdes et al. (2004). We plot 84 O, B, and A type stars in common between the two data sets. Two $T_{\rm eff}$ outliers are not displayed. Five log g and 18 [Fe/H] discrepant measurements are shown as red crosses and are discussed in the text. The axes are as in Fig. 8, besides $T_{\rm eff}$ is in log10.

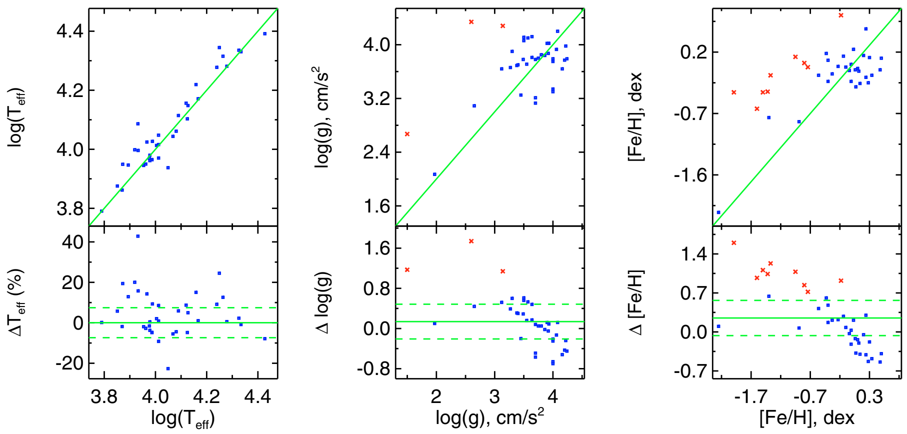

Fig. B.4. Comparison of the atmospheric parameters determined by us with those from Cenarro et al. (2007). We plot 37 B and A type stars in common between the two data sets. One $T_{\rm eff}$ outlier is not displayed. Three log g and nine [Fe/H] deviating measurements are displayed as red crosses and discussed in the text. The axes are as in Fig. 8, besides $T_{\rm eff}$ is in log10.

measurements is greater than 0.7 dex are displayed in red (right panel), as well as the five log g outliers deviating by more than 0.8 dex (central panel). These five stars, HD 105262, 161817, 18296, 2857 and 86986, have also discrepant metalicities. All these cases are discussed below.

The statistics, with and without the outliers, are reported in Table 5.

For HD 4727 (B5) and HD 39283 (A2V), the large discrepancy on $T_{\rm eff}$ is due to confusions on the designations in the Valdes compilation. Our measurements are consistent with the spectral classification.

Four stars are classified CVn, chemically peculiar stars, HD 18296, 34797, 72968 and 220825, for which Valdes adopted low metalicities taken from old curve-of-growth references. More recently, Alonso et al. (2003) studied HD 34797 and found a significant over-abundance. This supports our solution ([Fe/H] = 0.62 dex). For HD 220825, Glagolevskij et al. (2006) give [Fe/H] = 0.69 dex, consistent with our result and with the measurements on the ELODIE spectrum. We did not find any detailed analysis on the metallicity of the two last CVn, HD 18296 and 72968. Leone & Catanzaro (1998) and Takeda et al. (2009) studied another supposedly CVn star, HD 79469, and re-qualified it as a “normal” star, although we find a significant over-abundance. These comparisons tend to grant confidence in the ability of our method to retrieve the metallicity of the chemically peculiar stars, and we therefore adopt our solutions.

Among the [Fe/H] outliers are five BHB stars HD 2857, 74721, 86986, 109995 and 161817, and one post-AGB HD 105262. Their atmospheric parameters determined by Kinman et al. (2000) and Behr (2003) are consistent with the previous measurements adopted in Valdes, but more precise and reliable. As pointed out in Sect. B.2, the ELODIE interpolator is not performing well in this region. For these six stars, we obtained a mean [Fe/H] of −0.46 dex, while the average of the aforementioned references is −1.64 dex. We adopt averages of these references rather than our own measurements.

For HD 27295, we give [Fe/H] = −0.02 dex and Valdes take −0.75 dex, from Smith & Dworetsky (1993, analysis of IUE spectra). Behr (2003) obtained recently [Fe/H] = −0.95 ± 0.06 and [Mg/H] = −0.46 ± 0.05 for this main sequence chemically peculiar star. We adopt the Behr (2003) solution.

For HD 183324, Valdes quotes –1.50 dex from Sturenburg (1993). ULySS returned a value of [Fe/H] = −0.39 dex.Recently, Saffe et al. (2008) determined [Fe/H] = −1.22 ± 0.30 dex, and we adopt their solution.

The metallicity reported in Valdes for HD 60179 (Smith 1974) appears to be erroneous (transcription or conversion error). The star has a solar metallicity, and there is no disagreement with our estimate. For HD 174959, Heacox (1979) gives [Fe/H] = −0.8 (adopted by Valdes), but also [Mg/H] = −0.3 and a solar abundance of Ni. So, the low [Fe/H] may not be real. There is no other detailed analysis of this star. For HD 155763, we find [Fe/H] = 0.13 dex, while Valdes report −0.95 dex. More recently, Adelman (1998) provides $T_{\rm eff}$ = 12500, log g = 3.50 and [Fe/H] = −0.11, from R ∼ 50 000 optical spectra. For HD 175640, a typical HgMn star, we give [Fe/H] = 0.18 dex and Valdes adopt –0.55 dex from Smith & Dworetsky (1993). Castelli & Hubrig (2004) give [Fe/H] = −0.02 ± 0.10, from high quality, R ∼ 100 000, spectra. For HD 58343 (B2Vne), we estimate [Fe/H] = 0.01 dex, while Valdes quotes 0.89 dex from Kodaira & Scholz (1970). Frémat et al. (2005) determined the temperature and the surface gravity, confirming that the temperature used by Kodaira & Scholz (1970) is too hot. This may be

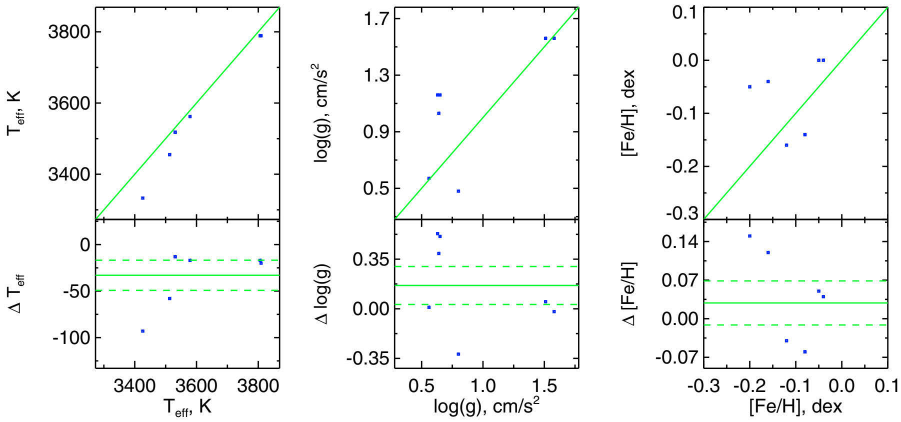

Fig. C.1. Comparison of the atmospheric parameters determined by us with those from ELODIE 3.2 for the seven M type stars in common. The axes are as in Fig. 8.

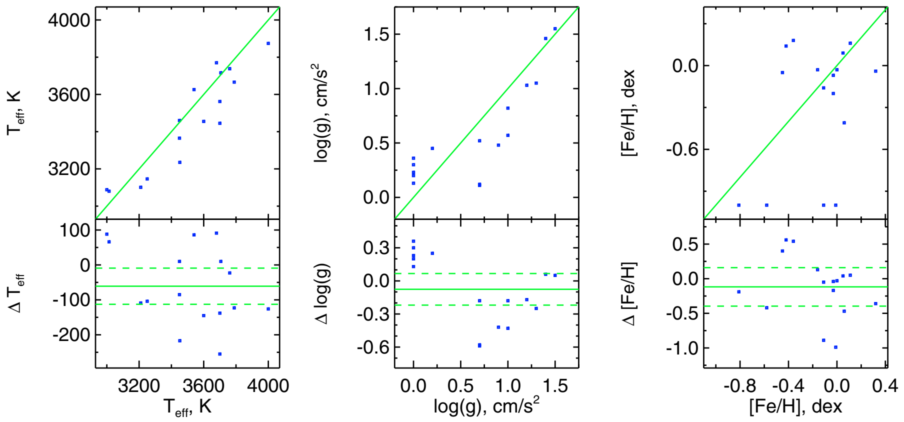

Fig. C.2. Comparison of the atmospheric parameters determined by us with those from Valdes et al. (2004). We plot 16 M type stars in common between the two data sets, two outliers are not displayed. The axes are as in Fig. 8.

an explanation for their high metallicity. For these five stars, we adopt our original measurements.

We conclude that the trends seen in Fig. B.3 are partly caused by an over-estimate of the metallicity of the metal-poor evolved stars by our analysis, and partly by inaccurate measurements in the literature.

B.4. Comparison with Cenarro et al. (2007)

Cenarro et al. (2007) compiled and homogenized the atmospheric parameters for MILES (Sánchez-Blázquez et al. 2006). This library contains 985 stars, spanning a large range in atmospheric parameters. There are 38 common B and A type stars between CFLIB and MILES, and we show the comparison in Fig. B.4 after excluding one $T_{\rm eff}$ outlier. Several log g and [Fe/H] outliers are shown by red crosses. The comparison statistics listed in Table 5 excludes the $T_{\rm eff}$ outlier and all the log g and [Fe/H] outliers.

The $T_{\rm eff}$ outlier is HD 89822, for which Valdes adopts 10 500 K from Smith & Dworetsky (1993), consistent with our estimates of 10 286 K. For this star, Cenarro et al. (2007) give an erroneous 5538 K.

Besides this detected $T_{\rm eff}$ outlier, a couple of other cases catch the attention in Fig. B.4 (left panel). The most prominent is HD 105262 (B9). Cenarro et al. (2007) and Valdes adopted the same set of parameters, and the star is already discussed in Sect. B.3. The second one is HD 206165, already discussed in Sect. B.2.

We find also nine [Fe/H] outliers displayed in red in Fig. B.4 (right panel). These are HD 2857, 27295, 74721, 105262, 109995, 155763, 174959, 183324, and 220825. Finally, there are three log g cases displayed in red in Fig. B.4 (middle panel): HD 2857, 86986, and 105262. All these stars are already discussed in Sect. B.3.

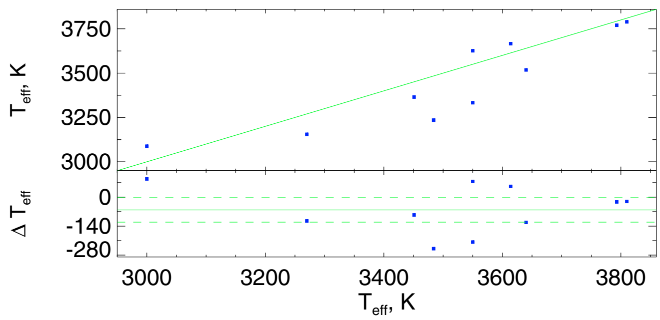

Fig. C.3. Comparison of the atmospheric parameters determined by ULySS with those from Cenarro et al. (2007) for 10 M type stars in common. The axes are as in Fig. 8.

As for Fig. B.3, the trends seen in Fig. B.4 result from a combination between wrong measurements reported in the literature and over-estimated metalicities for the metal-poor evolved stars.

Appendix C: External comparisons for M stars

In this appendix we present detailed comparisons between our measurements and four previous studies.

C.1. Comparison with ELODIE 3.2

The first comparison is with the ELODIE (version 3.2) internal parameters. There are six M and one S type common observations for five stars between the ELODIE and CFLIB library. The comparison is shown in Fig. C.1.

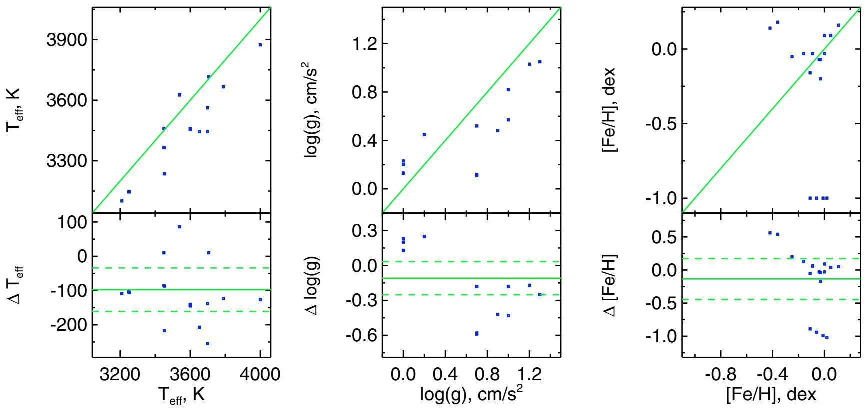

Fig. C.4. Comparison of the atmospheric parameters determined by ULySS with those from Cayrel de Strobel et al. (2001). We plot 18 M type observations in common between the two data sets, actually 12 stars. The axes are as in Fig. 8.

The most $T_{\rm eff}$ departing star is HD 175588. ELODIE internal temperature is 3426 K, while we give 3333 K.

C.2. Comparison with Valdes et al. (2004)

The comparison with the parameters compiled in Valdes et al. (2004) for 17 M and 1 S type stars is shown in Fig. C.2 after excluding two $T_{\rm eff}$ outliers. For the first, G_103-68 (M3), Valdes quote a temperature of 5511 K from Carney et al. (1994) based on photometry, while we give 3477 K, which corresponds better to the spectral type. For the other star G_176-11 (M2V), Valdes report 3544 K from Worthey et al. (1994), while we determine 3948 K, 5.13 dex and –1.43 dex for $T_{\rm eff}$, log g and [Fe/H] respectively. Soubiran et al. (2008) give 3687 K, 4.90 dex and –0.43 dex. We adopt our solution.

C.3. Comparison with Cenarro et al. (2007)

We found ten M type stars in common with Cenarro et al. (2007), but three of them lack log g and half of them miss [Fe/H] values in Cenarro et al. (2007). Therefore, we only compare the effective temperatures between our determinations and this reference, the result is shown in Fig. C.3. The most deviation with 249 K cooler is star HD 123657, Cenarro et al. (2007) give 3484 K, log $g = 0.85$ dex, ULySS fitted with 3235 K, 0.48 dex and –0.20 dex. CFLIB adopt 3452 K, 0.90 dex and –0.03 dex Smith & Lambert (1985).

C.4. Comparison with Cayrel de Strobel et al. (2001)

Cayrel de Strobel et al. (2001) present a compilation of published atmospheric parameters obtained from various sources and hence their data are inhomogeneous. The comparison between their parameters and ours is shown in Fig. C.4. We identified 11 M and 1 S type stars in common, for a total of 18 measurements in this compilation.

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