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Single stellar populations in the near-infrared

I. Preparation of the IRTF spectral stellar library⋆

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ABSTRACT

We present a detailed study of the stars of the NASA InfraRed Telescope Facility (IRTF) spectral library to understand its full extent and reliability for use with stellar population (SP) modeling. The library consist of 210 stars, with a total of 292 spectra, covering the wavelength range of 0.94 to 2.41 μm at a resolution $R \approx 2000$. For every star we infer the effective temperature ($T_{\rm eff}$), gravity ($\log g$) and metallicity ($[Z/Z_{\odot}]$) using a full-spectrum fitting approach in a section of the K-band (2.19 to 2.34 μm) and temperature-NIR colour relations. We test the flux calibration of these stars by calculating their integrated colours and comparing them with the Pickles library colour-temperature relations. We also investigate the NIR colours as a function of the calculated effective temperature and compared them in colour–colour diagrams with the Pickles library. This latter test shows a good broad-band flux calibration, important for the SP models. Finally, we measure the resolution R as a function of wavelength. We find that the resolution increases as a function of lambda from about 6 Å in J to 10 Å in the red part of the K-band. With these tests we establish that the IRTF library, the largest currently available general library of stars at intermediate resolution in the NIR, is an excellent candidate to be used in stellar population models. We present these models in the next paper of this series.

Key words. infrared: stars – stars: fundamental parameters – catalogs – methods: data analysis – techniques: spectroscopic – stars: kinematics and dynamics

1. Introduction

The near-infrared (NIR) spectral region contains several features that provide information about the stellar content of galaxies. The spectra of stellar populations in the NIR are strongly influenced by cool, late-type stars. Red giant branch (RGB) stars are old (>2 Gyr) stars that have a stronger contribution at older ages and also as a function of redder wavelengths. Thermally pulsating asymptotic giant branch (AGB) stars, on the other hand, contribute most to the integrated light of a stellar population between 1 and 3 Gyr. However, during the lifetime of a galaxy, we also find regular AGB stars contributing to the spectrum at all ages. Therefore, in order to create stellar population models for all galaxy ages, we need stellar libraries that include these stars.

Stellar libraries are compilations of stellar spectra with a certain wavelength range and resolution covering a large part of the parameter space of effective temperature, gravity and chemical abundances. These libraries can be either theoretical or empirical. Theoretical libraries are calculated using models and atmospheres that can be determined for a wide range of stellar parameters and detailed chemical abundances, at nearly unlimited spectral resolution (e.g. Westera et al. 2002; Coelho et al. 2007; Allard et al. 2012, among others). Model stellar atmospheres, however, are at present not able to reproduce the full spectra of some observed stars as a result of systematic uncertainties in our understanding of stellar atmospheres and a lack of complete atomic and molecular line lists, especially at lower temperatures. Observational or empirical libraries are compilations of observations of real stars that come with instrumental limitations such as limited resolution, incomplete correction of atmospheric absorption, and since most of the spectra come from stars in the Galactic disk, they might not be fully adequate to study stellar populations in other environments, such as elliptical galaxies. Examples of often used stellar libraries include Lançon & Wood (2000), Cenarro et al. (2001), and Sánchez-Blázquez et al. (2006).

Since hot stars dominate the light in the ultraviolet (UV), while cool stars are prominent in the NIR, it is advantageous to use a large wavelength range when studying the stellar populations of galaxies (Frogel et al. 1978; Maraston 2005). Until now, most empirical stellar libraries are found in the optical, while some are available in the near-UV, and only very few in the NIR. With these libraries it is possible to model stellar populations in globular clusters and galaxies in the optical in

⋆ The IRTF spectral library is available at irtfweb.ifa.hawaii.edu/spex/IRTF_Spectral_Library/

two ways, using line indices, mostly using the Lick-IDS system (e.g. Burstein et al. 1984; Worthey et al. 1994), and using full-spectrum fitting (FSF). Excellent full-spectrum fits have been made of dwarf galaxies (Koleva et al. 2009), elliptical galaxies (Yamada et al. 2006; Conroy & van Dokkum 2012), and globular clusters (Schiavon et al. 2004). The fits of giant elliptical galaxies show that some strong lines, most prominently the Mg *b* line at 5177 Å, cannot be fit by stellar population models using empirical libraries, indicating that the [Mg/Fe] ratios in these objects are different from that of the solar neighbourhood (Peterson 1977; Peletier 1989; Worthey et al. 1992). By now it is clear that many abundance ratios in galaxies are not the same as in the solar neighbourhood (e.g. Yamada et al. 2006; Conroy & van Dokkum 2013). To first order galaxy spectra in the optical between 4000 and 6000 Å are, however, fairly well understood.

Theoretical model atmospheres have become more and more detailed over the years, producing libraries in different wavelength ranges. The most complete libraries in the NIR include the BaSeL models (Lejeune et al. 1997, 1998; Westera et al. 2002), Tlusty models (Lanz & Hubeny 2003, 2007), and the models by Aringer et al. (2009). Compendia of stellar-type spectra formed from spectra of stars of similar type have also been made, for example by Pickles (1998), that combine various observations providing standard spectra for all spectral types and luminosity classes. Empirical libraries in the NIR include Lançon & Wood (2000), Cushing et al. (2005) and Rayner et al. (2009). Mouhcine & Lançon (2002), Maraston et al. (2009) and Conroy et al. (2009) have made stellar population models based on these libraries.

Stellar spectra observed by Rayner et al. (2009) and Cushing et al. (2005), compiled in the IRTF spectral library allow the modelling of stellar populations in the NIR. Conroy et al. (2009) used a handful of spectra in this library and Meneses-Goytia & Peletier (2012) have constructed preliminary SSP models with this library. The library is a powerful ingredient for stellar population models in the NIR owing to the large number of cool stars it contains. These stars contribute strongly in this wavelength range and their spectra are of higher resolution than their empirical predecessors in the same wavelength region such as those observed by Lançon & Wood (2000). To be able to use the IRTF spectral library for stellar population synthesis, an accurate determination of the spectral calibration and associated stellar parameters of the stars in the library must be established. A well-calibrated stellar library, with an accurate set of stellar parameters and known resolution, leads to a reliable development of models. The information that can be extracted from these models, such as integrated colours are linked to the colours of the stars.

In this series of papers, we aim to understand more about the cool stellar populations in unresolved galaxies by building single stellar population (SSP) models in the NIR and comparing them to galaxy observations. In this paper, the first in this series, we characterise the spectra in the IRTF spectral library and determine the stellar parameters, $T_{\rm eff}$, $\log g$ and metallicity ($[Z/Z_{\odot}]$) of the stars, tied to the parameters in Cenarro et al. (2007), in Sect. 3. We test the flux calibration of the library and the behaviour of the integrated colours of its stars and their stellar parameters in Sect. 4. And finally, in Sect. 5, we measure the full width at half maximum (FWHM) and resolution of the library spectra. In Fig. 1, we show the wavelength ranges used for our analysis.

In our second paper (Meneses-Goytia et al. 2015, hereafter Paper II), we calculate SSP models following a similar approach to Vazdekis et al. (2010) but using the IRTF spectral library. We calculate full spectral energy distributions (SEDs) by finding a stellar spectrum with the appropriate stellar parameters ($T_{\rm eff}$, $\log g$ and metallicity) from the stellar library using interpolation for every point on a theoretical isochrone, weighting them by an initial mass function. In the third paper in the series Meneses-Goytia et al. (in prep., hereafter Paper III), we use our models to analyse a number of composite stellar systems.

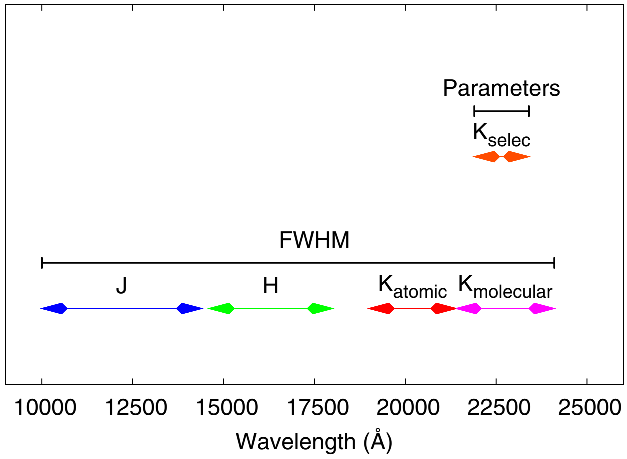

Fig. 1. Wavelength ranges used in this work. For the determination of the stellar parameters through FSF, we use a section of the *K*-band (2.19 to 2.34 μm, see Sect. 3.1). For the determination of the nominal spectral resolution (Sect. 5), we divide the wavelength range into four sections representing respectively the *J* (1.04–1.44 μm) and *H* (1.46–1.80 μm) bands, as well as the *atomic* (1.90–2.14 μm) and *molecular*-dominated (2.14–2.41 μm) ranges of the *K*-band.

2. The IRTF spectral library

The IRTF spectral library[1] is a compilation of stellar spectra observed with the medium-resolution spectrograph SpeX at the NASA Infrared Telescope Facility on Mauna Kea (Rayner et al. 2009; Cushing et al. 2005). This library covers the NIR range from 0.8 to 2.5 μm (and extends in some cases out to 5.2 μm). We focus on the spectral region for the *J*, *H* and *K*-bands (0.94 to 2.41 μm). These spectra were observed at a resolving power of $R = 2000$ ($R = \lambda/\Delta\lambda$, see below), and their continua were not normalised, keeping the strong molecular absorption features from cool stars. Keeping the spectral shape also allowed relative flux calibration between the stars, by scaling the spectra to published Two Micron All Sky Survey (2MASS) photometry (*J*, *H* and $K_{\rm s}$ mag), implying that the integrated colours obtained from the spectra are consistent with those obtained by 2MASS.

The spectral types of the 210 library stars include F, G, K, M, L, S and C types, with luminosity classes from supergiants (I) to dwarfs (V). The majority of the stars are cool stars, which dominate the light in the NIR. Around 60% of the stars are variable, including Cepheids, RR Lyrae and semi-regular variables. Additionally, some stars have two spectra, corrected and non-corrected for extinction. We kept these spectra as individual stars leaving us with a sample of 292 spectra.

[1] irtfweb.ifa.hawaii.edu/~spex/IRTF_Spectral_Library/

3. Determination of stellar parameters

A crucial step towards using a spectral stellar library for SSP modelling (see Paper II) is to accurately know the atmospheric parameters of its stars to be able to tie them to the evolutionary tracks during the modelling. Moreover, the parametric coverage of the library is vital to understand the applicable ranges in the models constructed from its stars. For this purpose we apply two methods, one in which the $T_{\rm eff}$, $\log g$ and metallicity of many of the stars in the IRTF spectral library are determined in a self-consistent way from a sample of stars with well-determined parameters (see Sect. 3.1) and another in which we use the colour-temperature relations for different regimes (see Sect. 3.2). We use parameters from the literature to establish the validity of these methods.

3.1. Full-spectrum fitting method

Here we use the *ULySS*[2] package (Koleva et al. 2009) to compare the IRTF spectra to a template library with known parameters, and to find the set of best-matching spectra. Briefly, *ULySS* fits a spectrum with a linear combination of non-linear components (in this case stellar spectra) convolved with a line-of-sight velocity distribution and multiplied by a polynomial continuum.

The parameters of the best-matching spectra along with their respective weights give the atmospheric parameters of the IRTF stars. Figure 2 shows examples of the fits for three stars (IRL003, IRL120 and IRL270) with their corresponding resulting parameters. It is important to mention that the full-spectrum fitting (FSF) approach used for measuring the atmospheric parameters was only used on a small region of the *K*-band (2.19 to 2.34 μm).

We choose as our primary template library 73 stars of the IRTF spectral library that are also found in the empirical stellar libraries MILES (Sánchez-Blázquez et al. 2006) and CaT (Cenarro et al. 2001). The parameters of those stars are determined using a compilation from the literature by Cenarro et al. (2007, hereafter C07). Additionally, we use as templates 52 stars observed in a section of the *K*-band (2.19 to 2.34 μm) by Mármol-Queraltó et al. (2008) which are also contained in the MILES and CaT libraries and for which there are also stellar atmospheric parameters available in C07.

For our analyses, we also create 108 interpolated stars whose parameters are selected from grids of different $T_{\rm eff}$, $\log g$, and four metallicities that were within the limits provided by the empirical stars of our template library. Their temperature ranges from 2500 to 6500 K, with steps of 500 K and their gravities range from −0.25 to 4.0 dex, with steps of 1.0 dex. The metallicities considered here are −0.70, −0.4, 0.0 and 0.2 dex. The spectrum of each interpolated star is obtained by interpolating between empirical spectra of stars with known parameters in our template library. We apply an interpolation scheme similar to that of Vazdekis et al. (2003), which creates a box of stellar parameters around a given point with certain stellar parameters, i.e. the parameters of the star for which we want to obtain a spectrum. This box is flexible enough to expand until a sufficient number of adequate stars are found, if necessary, and is divided into eight cubes of different sizes that have the given point as a corner. This minimises the errors due to the lack of stars in certain regions of the distribution of stars. The size of the box is inversely proportional to the density of stars found around the point and the box can be as small as the typical uncertainties of the parameters of the template library. When the boxes are determined, the spectra of the stars that form each of the eight boxes are combined into eight different spectra. As a final step, these spectra are interpolated to obtain a final spectrum with the desired stellar parameters. This step is taken because the available interpolators with *ULySS* are only for optical wavelengths. We subsequently use the *ULySS* package, along

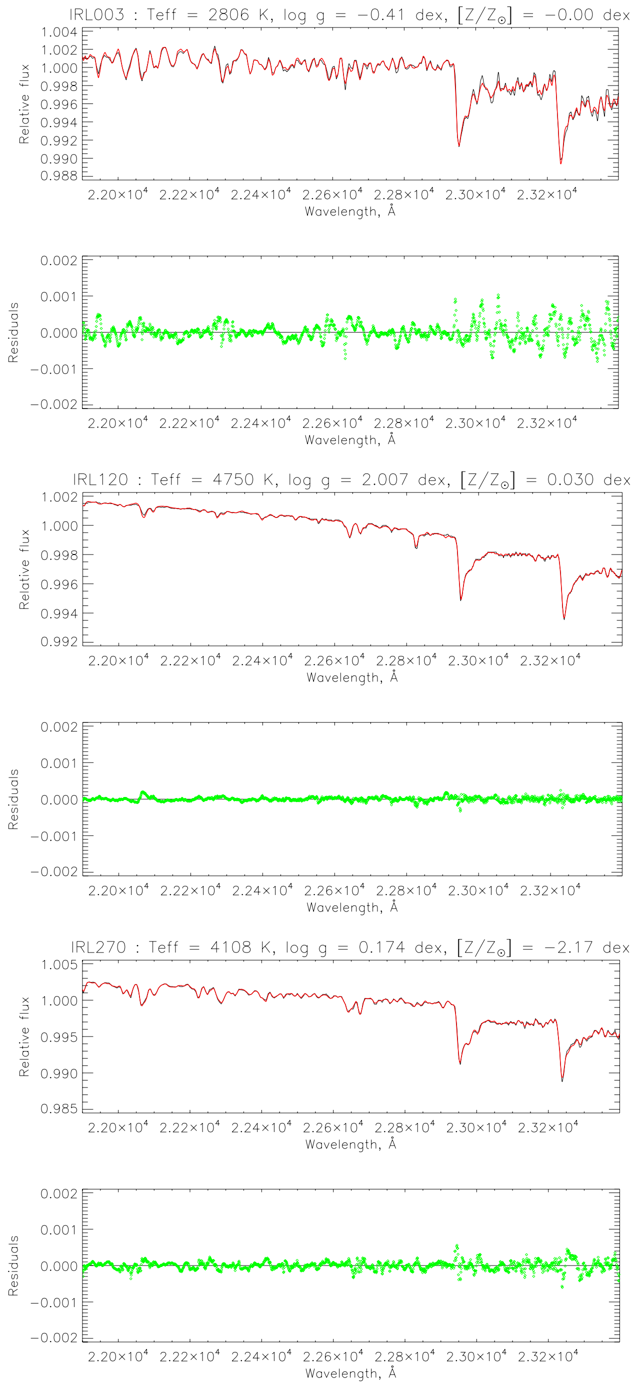

Fig. 2. Example of the results obtained with FSF. The name of the stars and the obtained parameters are given in the figure titles. In the *upper panels*, we show the observed spectrum (black lines) and the best fit model (red lines). In the *lower panels*, we show the residuals (green data points) which for these stars are less than 0.2%. For details of the fits, see text.

[2] ulyss.univ-lyon1.fr

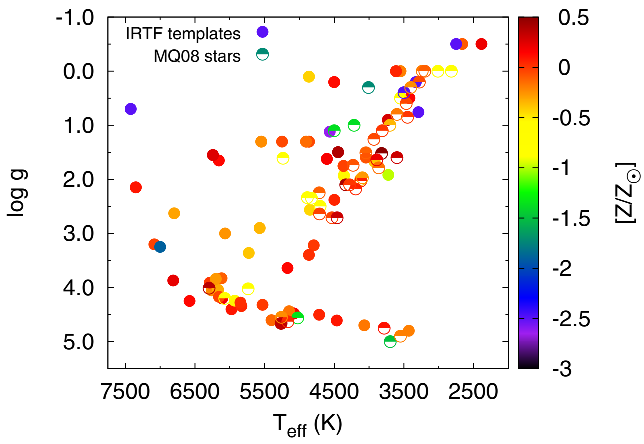

Fig. 3. HR diagram of the stars that compose the template library for the determination of stellar parameters in the IRTF spectral library. This template set is formed of 73 IRTF stars in common with the MILES and CaT empirical stellar libraries, and 52 additional stars observed by Mármol-Queraltó et al. (2008, MQ08).

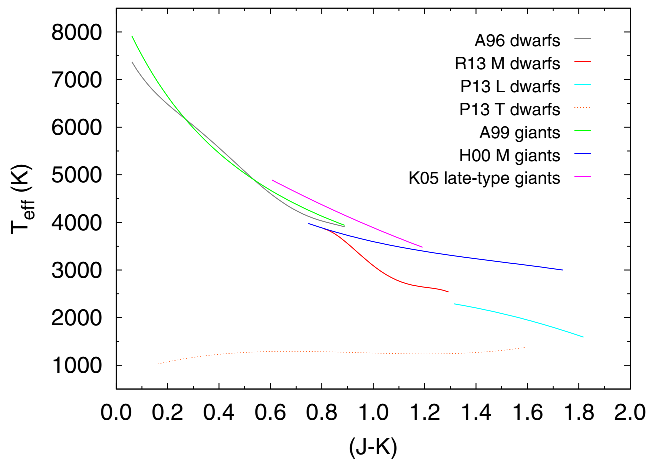

Fig. 5. Colour-temperature relations for different regimes of effective temperature and luminosity class from Alonso et al. (1996, A96), Rajpurohit et al. (2013, R13), Pecaut & Mamajek (2013, P13), Alonso et al. (1999, A99), Houdashelt et al. (2000, H00) and Kučinskas et al. (2005, K05).

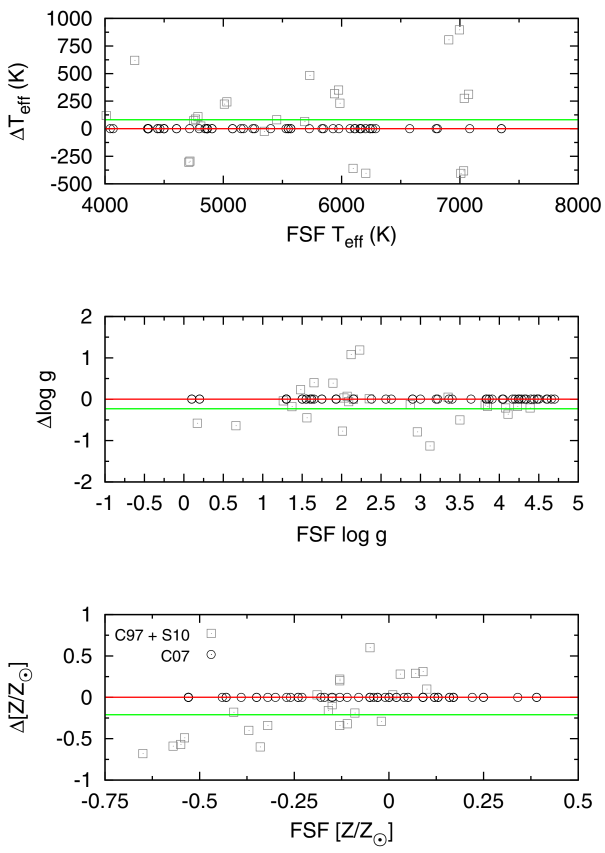

Fig. 4. Residuals from the comparison of the stellar parameters obtained from the FSF approach and the literature values from C07, S10 and C97 and the residuals (FSF – Lit). The red line is the one-to-one correlation. The green line marks the median of the differences (81 K for $T_{\rm eff}$, –0.23 for $\log g$ and –0.07 for metallicity) which represent the offset between non-C07 and C97 + S10 literature values.

with the 233 template stars described above to determine stellar atmospheric parameters in the full-spectrum approach.

We have run the FSF for the 73 IRTF-MILES stars (hereby C07-stars) not only to test this method but also to homogenise our "anchor" literature values. We have also applied the methodology to the IRTF stars with literature values from Soubiran et al. (2010, hereafter S10) and Cayrel de Strobel et al. (1997, hereafter C97), giving a combined sample of 40 stars hereby designated non-C07 stars.

Because of the lack of templates covering an adequate grid of atmospheric parameters for cool stars, the FSF method is not applied to stars with Teff below 4000 K. Therefore, below 4000 K we adopt atmospheric parameters from the literature or the colour-temperature relation method (see Sect. 3.2).

Figure 4 shows that the parameters obtained for the non-C07 stars differ from the catalogues and therefore we calculate the offset between these values from the median of the difference 81 K for $T_{\rm eff}$, –0.23 for $\log g$ and –0.07 for metallicity. We apply the corresponding offset for each parameter to the literature values for the non-C07 stars in order to homogenise the "anchor" stellar atmospheric parameters in the C07 system.

From our analyses we see that most of the stars are in the metallicity range between $\approx$–0.7 and 0.2, indicating that the IRTF spectral library is useful for NIR SP modelling mostly when working with populations near solar abundance.

3.2. T_{eff} and NIR-colour relations

For this method, we determine the temperature as a function of NIR colours. For this purpose, we use colour-temperature relations (CTR) in the NIR, specifically $(J-K)$, for different regimes of effective temperatures and luminosity classes. For giants, we use the relations of Alonso et al. (1999, A99), Houdashelt et al. (2000, H00) and Kučinskas et al. (2005, K05) which are applied to F0-K5, M0-M7 and M8-cooler stars, respectively. For dwarfs, the relations of Alonso et al. (1996, A96), Rajpurohit et al. (2013, R13) and Pecaut & Mamajek (2013, P13) are used for F0-K5, M0-M10 and L-T stars, respectively. We show these relations and their behaviour in Fig. 5.

Before applying these relations to those stars without literature parameters, we use them to re-calculate the values of the C07 and non-C07 stars in order to determine the difference between the literature values in the C07 system and colour-temperature relation results and anchor the latter values to the

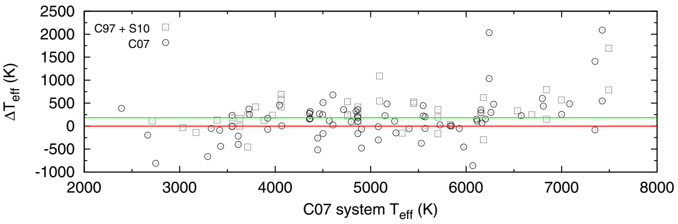

Fig. 6. Residuals from the comparison of the stellar parameters obtained from the colour-temperature relation (CTR) approach and the literature values from C07, S10 and C97 and the residual (Lit $_{\rm C10\ system}$ − CTR). The red line is the one-to-one correlation. The green line marks the median of the difference (181 K) which represents the offset in temperatures between the CTR method and literature in the C07 system.

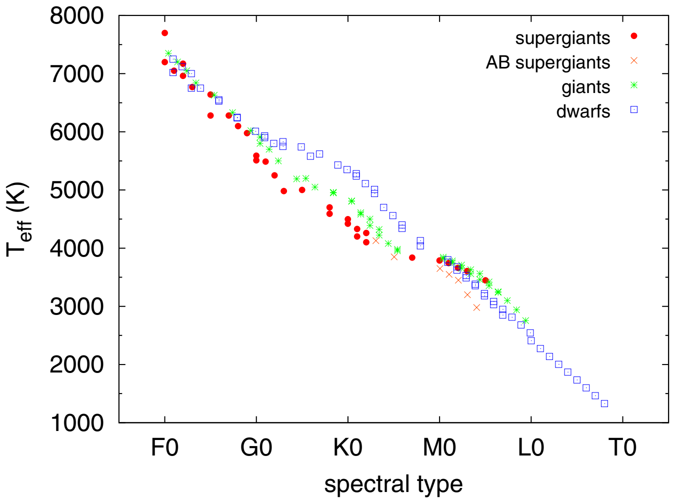

Fig. 7. Compilation of effective temperatures as a function of spectral type from Gray & Corbally (2009) and Cox (1999).

former. This comparison and the respective median offset are shown in Fig. 6. This offset (181 K) is applied to the effective temperatures from the CTR approach. We note that the large difference between literature and CTR temperatures of very bright giants is due to the variable colours as a result of stellar pulsations.

3.3. Selection of the atmospheric parameters

To assess the accuracy of the parameters we obtained with both methods, we compare the parameters of the remaining 219 IRTF stars with literature values from the catalogues of S10 and C97. When literature data are not available, we infer the stellar temperature of the stars from their stellar classification by compiling information from Gray & Corbally (2009) and Cox (1999), as shown in Fig. 7. To determine surface gravity, we use evolutionary tracks based on empirical stars as a function of temperature, gravity and spectral type from Straizys & Kuriliene (1981). In Table A.1, we show our calculated parameters, including those from the literature, and those of the template stars.

The agreement between the measured parameters by the FSF method and the literature is reasonable (as shown in Figs. 8–10), with $\sigma_{T_{\rm eff}}$ = 366 K, $\sigma_{\log g}$ = 0.36 dex and $\sigma_{[Z/Z_\odot]}$ = 0.28 dex. This technique was limited by the parameter coverage of the template library which was dominated by solar metallicity giants and dwarfs between ~3500 and 7500 K. The stars for which we

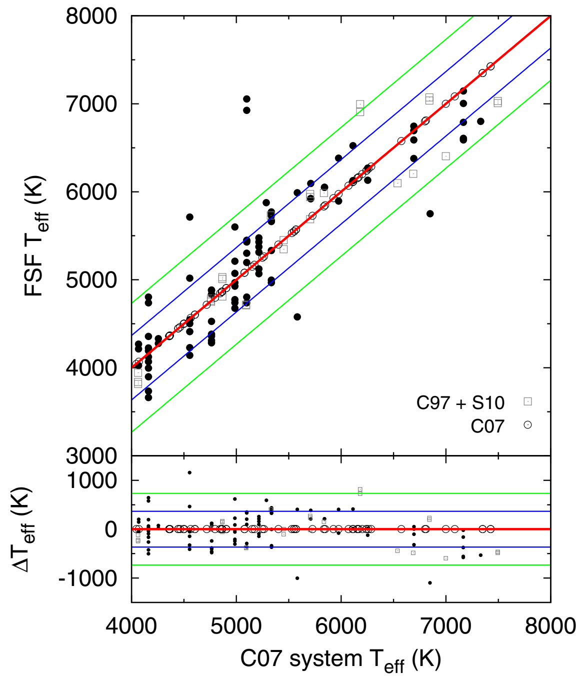

Fig. 8. Comparison of the effective temperature obtained from the FSF with literature values in the C07 system. The squares and circles are those stars with literature values from either C07, S10 or C97 already in the C07 system, for which parameters are computed using their stellar type. The black data points are stars that do not have literature values in C07, S10 or C97. The red line is the one-to-one relation. The blue and green lines mark the 1σ and 2σ confidence intervals, respectively. The residuals (FSF – Lit $_{\rm C07\ system}$) are presented in the *lower panel*.

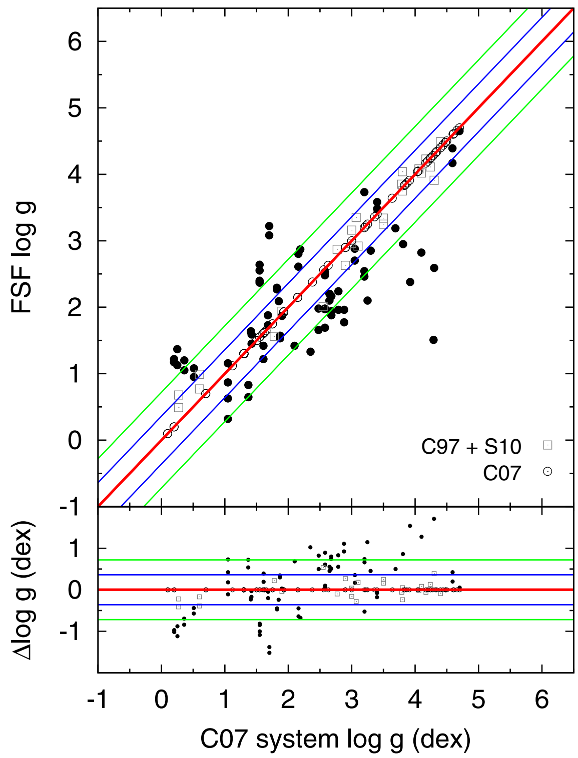

Fig. 9. As in Fig. 8 but for log g.

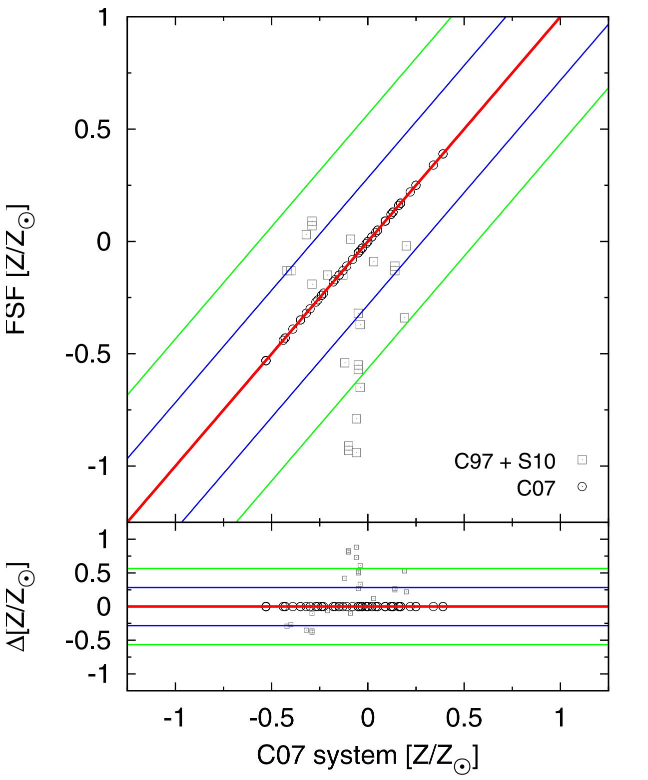

Fig. 10. As in Fig. 8 but for the stars with literature values ([Z/Z⊙]). We note that the diagram contains fewer stars than e.g. Fig. 9. This is because there are many stars without literature values, for which there is no way to determine their metallicity. For these stars we have assumed solar chemical abundances and have not plotted them here.

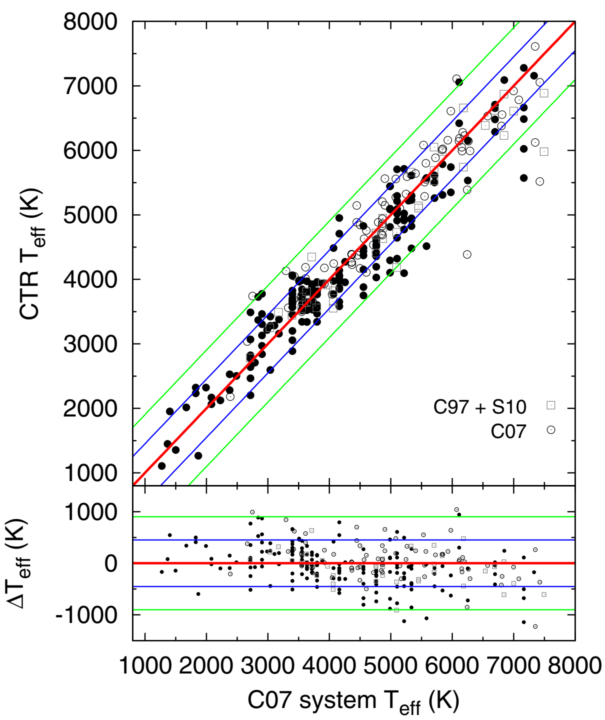

Fig. 11. As in Fig. 8 but here showing the effective temperature obtained from the $(J - K) - T_{\rm eff}$ relations shown in Fig. 5.

could not determine good parameters are late-type giants (M6 and cooler) and M, L and T dwarfs ($T_{\rm eff} < 2500$ K).

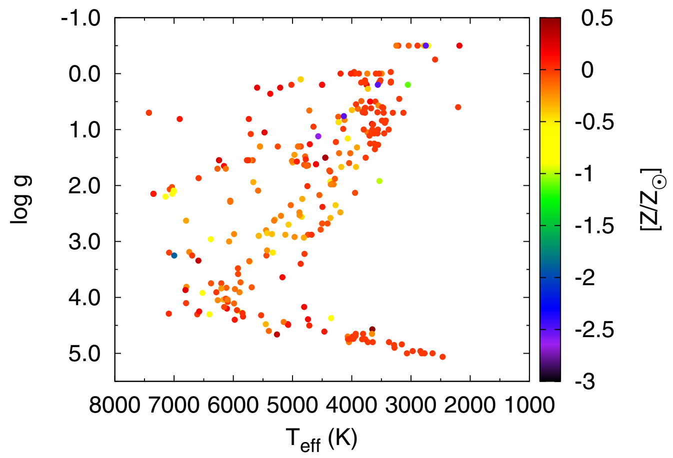

Fig. 12. Stellar atmospheric parameters for the stars of the IRTF spectral library. This shows the parameter coverage of this library for stellar population models. L- and T-type dwarfs were not included.

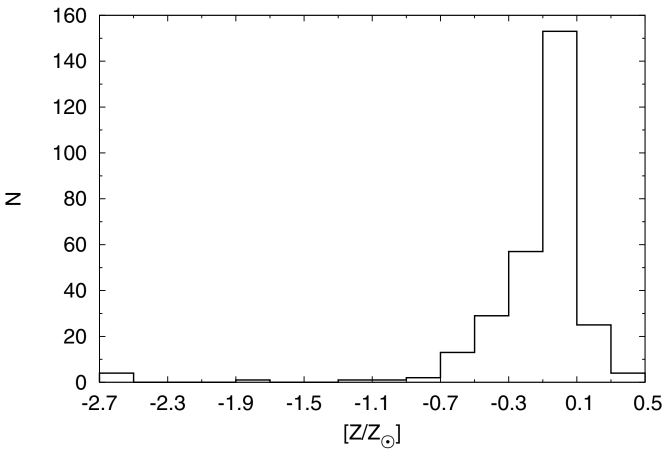

Fig. 13. Metallicity distribution function for the stars of the IRTF spectral library.

In Fig. 11 we show the resulting effective temperatures from the colour-temperature relations and the comparison with the literature values. This method also shows a good agreement with $\sigma_{T_{\rm eff}} = 451$ K, except for a few very bright giants whose colours oscillate due to stellar pulsations.

It is important to point out that these methods are independent from each other. The FSF determines the parameters of a given star by comparing its spectrum to an empirical spectral library whose stellar parameters were compiled from the literature (for details of this compilation see Cenarro et al. 2007). On the other hand, the CTR is based on the relation of observed photometry of stars and their effective temperature (see e.g. Alonso et al. 1999).

To compute the stellar population models (Paper II), we mainly use the parameters from the FSF and for those stars whose values are not in the $2\sigma_{T_{\rm eff}}$ confidence interval, we take the results from the colour-temperature relation that are also within the corresponding reliable limits. For $\log g$, we take the FSF results, or, if they are not within the $2\sigma_{\log g}$ limits, we take the literature values. We prefer not to use the mass-luminosity relations to calculate the $\log g$ because it requires assigning a particular age and metallicity making the method subject to a

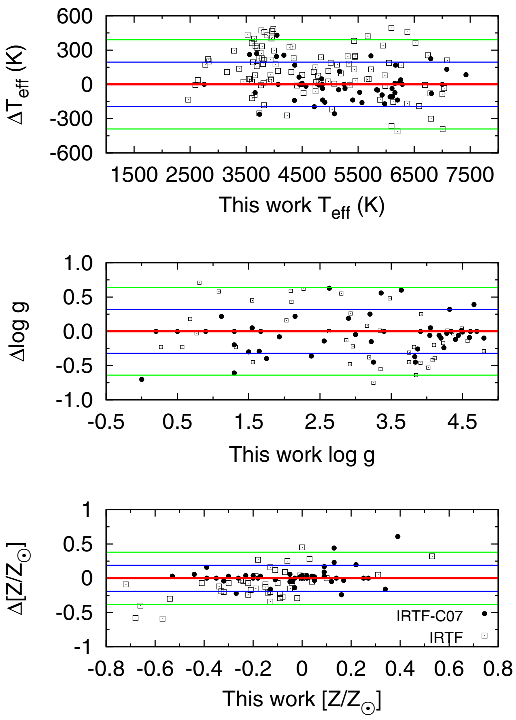

Fig. 14. Residuals from the comparison between the stellar atmospheric parameters for the stars in the IRTF spectral library and those compiled by Cesetti et al. (2013; present work – Cesetti). The circles represent the values for the IRTF stars with C07 stellar parameters and the squares the IRTF stars for which we determined their parameters. The red line is the one-to-one correlation. The blue and green lines mark the 1σ and 2σ confidence intervals, respectively.

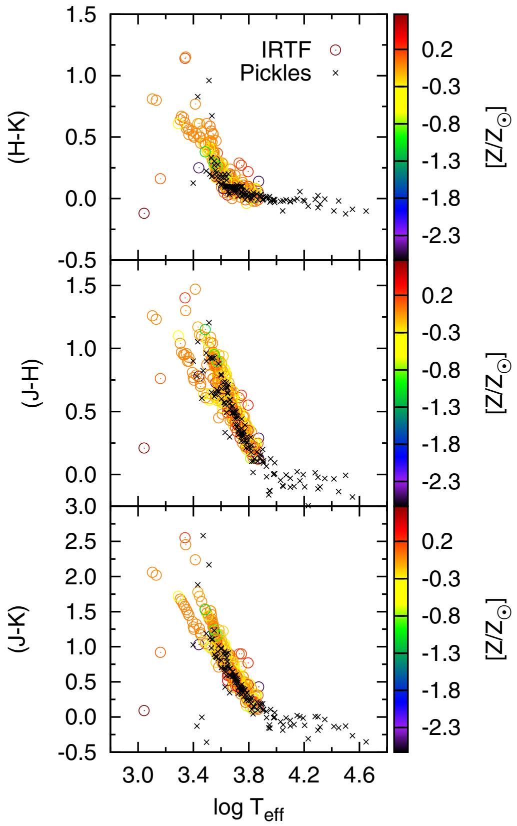

Fig. 15. Behaviour of the integrated colours of the IRTF spectral library stars as a function of effective temperature, compared with the Pickles stellar library (which is assumed to have solar metallicity).

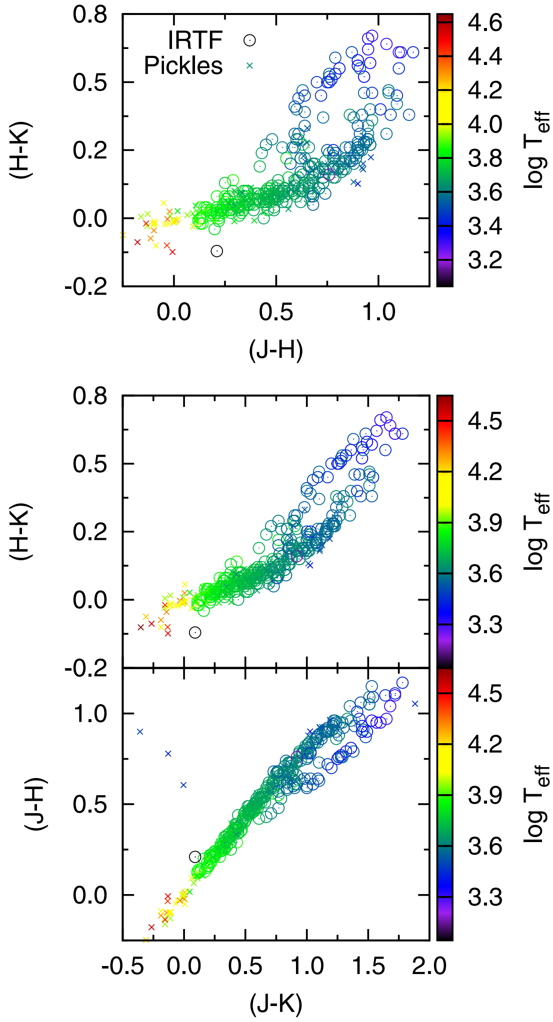

Fig. 16. Colour–colour diagrams of the stars in the IRTF spectral library, compared with the Pickles library (which is assumed to have solar metallicity).

bias. For outliers in metallicity, literature values were used if available, otherwise solar metallicity was chosen.

The calculated values within the 2σ confidence intervals (for the respective parameter) are shown in Table A.1. Figure 12 shows the HR diagram of these stars and Fig. 13 their metallicity distribution function.

3.4. Comparison with recent work

We compare the atmospheric parameters of the IRTF spectral library stars with the survey of available stellar parameters compiled from the literature by Cesetti et al. (2013). In Fig. 14 we present the residuals of the comparisons for $T_{\rm eff}$ (184 stars), $\log g$ (101 stars) and $[Z/Z_\odot]$ (95 stars). This comparison shows a reasonable agreement between our anchoring literature values from C07, our obtained ones and those from Cesetti et al. (2013), with $\sigma_{T_{\rm eff}} = 195$ K, $\sigma_{\log g} = 0.32$ dex and $\sigma_{[Z/Z_\odot]} = 0.19$ dex.

4. Flux calibration of the IRTF spectral library

In this section, we test the flux calibration of the library and the behaviour of the stellar integrated colours as a function of

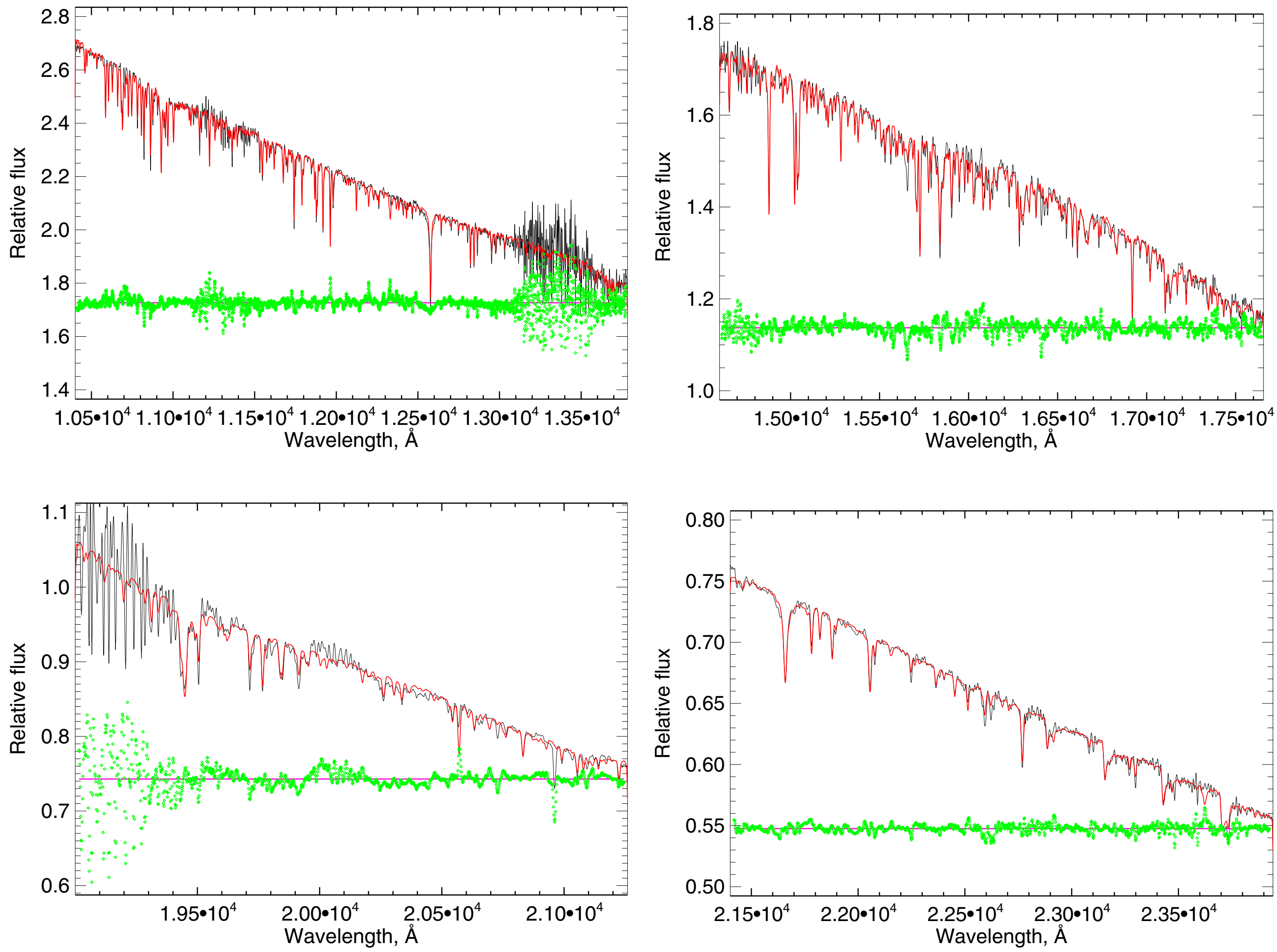

Fig. 17. Example of the FSF for a solar-like star IRL075. We show the observed spectrum (black lines), the best fit model (red lines) and the residuals (green data points). The poor fit in some regions is due to telluric absorption contamination.

the atmospheric parameters. The reliability of this calibration is important for the SP modelling when comparing to photometric observations of globular clusters and galaxies.

Relative J, H and K_s fluxes were determined by integrating the spectral flux in these NIR bands using the Vega spectrum from Colina et al. (1996) as a zero-point. We use the response curves of the J, H and K filters of the Johnson-Cousins-Glass photometric system given by Bessell et al. (1998). We present in Fig. 15 a comparison of the colours with the library of Pickles (1998) for solar metallicity stars. We can see that our inferred parameters follow the same trend as those of Pickles. We draw the same conclusion from the colour–colour diagrams in Fig. 16.

5. Determining the spectral resolution

In order to asses the accuracy of our SSP models (Paper II), it is also important to characterise the spectral resolution of the stellar library to be used and to make sure that the radial velocities of all the stars have been set to zero. Therefore, to determine the nominal spectral resolution (FWHM) of the IRTF spectral library, we fit the stars with another template library of very high resolution.

We use the recent PHOENIX BT-Settl[3] stellar models (Allard et al. 2012) as a template library. The stellar parameters of this theoretical library cover a wide range of temperature (2600–7000 K), luminosity class (from dwarfs to supergiants) and metallicity (−0.5 to 0.5 dex). In the wavelength range that we use (J, H and K-bands), the full-width at half maximum (FWHM) of the library is 0.05 Å.

The FWHM of the IRTF spectral library has been determined by comparison with the BT-Settl library. Both libraries are rebinned to a velocity scale of 25 km s^{-1}, after which the broadening of data and templates are measured using the penalised pixel-fitting method (pPXF, Cappellari & Emsellem 2004). The templates are convolved with a Gaussian and fit to each individual test spectrum to determine the FWHM. To assess the dependence of resolution on wavelength, we divide the original datasets into four wavelength bins, representing the J (1.04–1.44 μm) and H (1.46–1.80 μm) bands, the *atomic* part of the K-band (1.90–2.14 μm) and the *molecular* part of the K-band (2.14–2.41 μm), with effective wavelengths of 1.22, 1.62, 2.02 and 2.27 μm, respectively. The basic procedure is described in detail by Falcón-Barroso et al. (2011). Figure 17

[3] phoenix.ens-lyon.fr/Grids/BT-Settl/AGSS2009/SPECTRA/

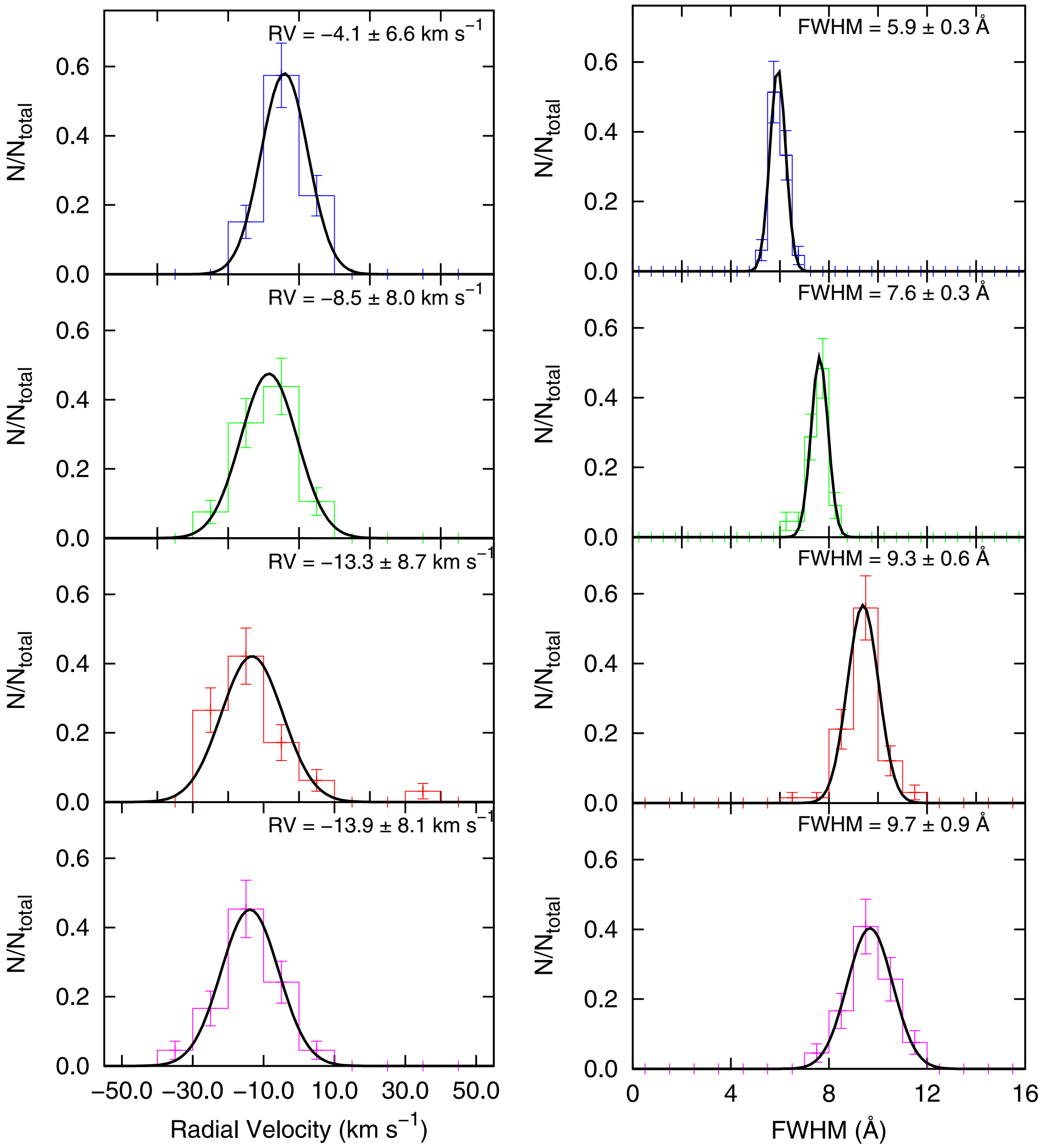

Fig. 18. *Left panels*: radial velocities of the IRTF spectral library as a function of wavelength. *Right panel*: FWHM as a function of wavelength. For the *J*-band, at 1.22 μm, the stars have an average FWHM of 5.9 ± 0.3 Å. In the *H*-band, at 1.62 μm, the peak value is 7.6 ± 0.3 Å. For the *atomic*-dominated part of the *K*-band, at 2.02 μm, the average resolution is 9.3 ± 0.6 Å. And for the *molecular*-dominated part of the *K*-band, at 2.27 μm, the average FWHM is 9.7 ± 0.9 Å.

shows an example of a solar-like star from the IRTF library and its fit using this procedure.

From this technique, we also obtain the radial velocity (RV) of the IRTF stars for each bin as shown in the left panel of Fig. 18. For the *J*-band, at 1.22 μm, most of stars have an RV of -4.1 ± 6.6 km s^{-1} (standard deviation). In the *H*-band, at 1.62 Å, the peak value is -8.5 ± 8.0 km s^{-1}. For the *atomic*-dominated part of the *K*-band, at 2.02 Å, the radial velocity is -13.3 ± 8.7 km s^{-1}, and for the *molecular*-dominated part of the *K*-band, at 2.27 Å, the RV is -13.9 ± 8.1 km s^{-1}.

In Fig. 19 we show how the FWHM, the resolution *R* and their respective scatters behave as a function of wavelength for the G stars in the library, in bin sizes of 1000 Å. As we see, the FWHM increases when going to the red.

The behaviour of the FWHM as a function of each wavelength bin is presented in the right panel histograms of Fig. 18. One can see that the resolution is not constant in wavelength, as is the case for the MILES library, but is approximately proportional with wavelength (*R* constant), but with some additional variation as a function of wavelength. For the *J*-band, at 1.22 μm, most stars have an average FWHM of 5.9 ± 0.3 Å. In the *H*-band, at 1.62 Å, the peak value is 7.6 ± 0.3 Å. For the *atomic*-dominated part of the *K*-band, at 2.02 Å, the average resolution is 9.3 ± 0.6 Å. And for the *molecular*-dominated part of the *K*-band, at 2.27 Å, the average FWHM is 9.7 ± 0.9 Å. In terms of the spectral resolution, R = 2060 ± 15, 2163 ± 16, 2153 ± 23, and 2350 ± 25 at 1.22, 1.62, 2.02, and 2.27 μm respectively.

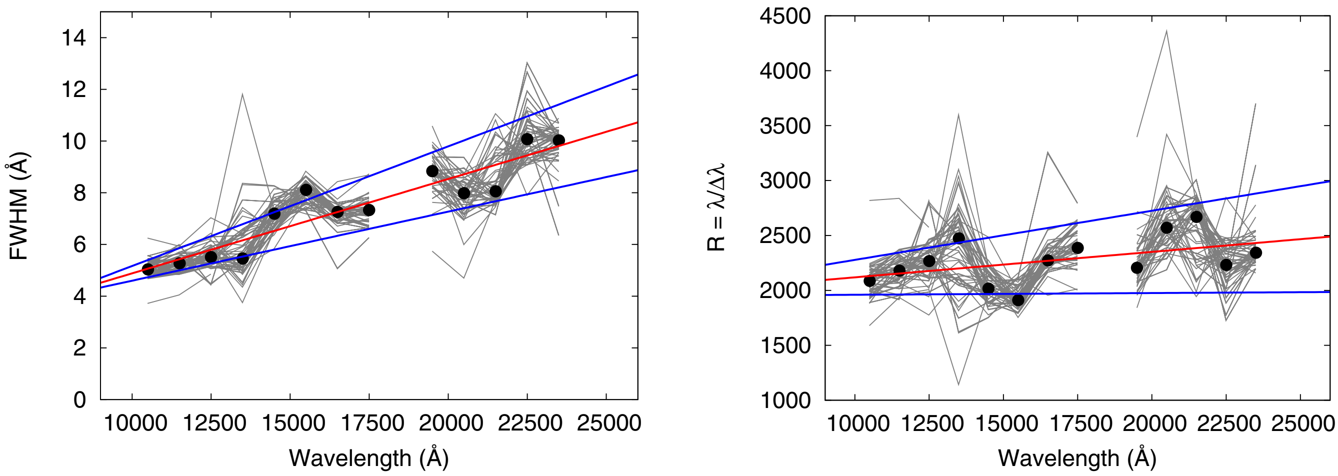

Fig. 19. Behaviour of the FWHM (*left panel*) and the resolving power R (*right panel*) of the G stars of the IRTF spectral library (grey lines) as a function of wavelength. In *both panels*, the black points represent the mean values for those effective wavelengths and the blue lines mark the mean dispersion. In the *left panel*, the red line corresponds to a liner relation of the mean FWHM for each wavelength. In the *right panel*, the red line is a linear relation of the mean R with effective wavelength.

These tests demonstrate that the resolution of this library is higher than most previous empirical libraries, such as Lançon & Wood (2000).

6. Final remarks

We have studied in detail the accuracy and characteristics of the IRTF spectral library in the J, H and K-bands. We have determined the parameter coverage of the IRTF spectral library, allowing us to understand the extent of its usefulness. We have also determined the accuracy of the flux calibration of the library. Additionally, we have measured the precise spectral resolution and radial velocity of the stars.

With these tests, we understand the possibilities and limitations of stellar population models using the IRTF spectral library as input (Paper II), over the J, H and K-bands.

Cool late-type stars have a strong influence on the integrated flux in these wavelength regions. These stars are particularly relevant for studies of early-type galaxies. Since our library has cool stars, we can get a much better handle on the relative contribution of these stars in unresolved galaxies (Paper III).

Our rebinned IRTF spectral library spectra (i.e. with a constant dispersion in wavelength) and the resulting data of the analysis and characterisation are available online[4].

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Appendix A: The stars composing the IRTF spectral library and their atmospheric parameters.

In this appendix, we compile the available information for the IRTF stars. The first column shows the ID numbers of the IRTF stars, corresponding to the order of stars adopted in Rayner et al. (2009), Cushing et al. (2005). Indented IDs indicate stars that have not been corrected for extinction. The second column lists the names given by the IRTF library database. The coordinates of each star are given in the third and fourth columns. The fifth column gives the stellar class of each star according to the IRTF library. The fifth, sixth and seventh columns present the atmospheric parameters of each star, determined from either the full-spectrum fitting method (^{FSF}), the colour-temperature relation (^{CTR}), literature compilations S10 and C97 (^{SEC}) or according to their stellar type (ST). For stars from the Cenarro et al. (2007) catalogue (labelled ^{C07}) the atmospheric parameters are determined using the full-spectrum fitting method and recovered as the same values given in the literature. Finally, the eight, ninth and tenth columns list the NIR colours of each star as calculated from the spectrum (see Sect. 4).

[4] smg.astro-research.net/

Table A.1. Reference relation for the IRTF spectral library stars.

ID	Star	RA	Dec	Class	$T_{\rm eff}$ (K)	log g	$[Z/Z_\odot]$	$(J-H)$	$(J-K)$	$(H-K)$
IRL280	BRI B0021−0214	00 24 24.63	−01 58 20.14	M9.5V	2466[CTR]	5.06[ST]	0.00[ST]	0.81	1.36	0.55
IRL147	HD 002901	00 32 47.52	+54 07 11.81	K2III	4410[FSF]	2.68[ST]	−0.07[FSF]	0.67	0.75	0.08
IRL194	2MASS J00361617+1821104	00 36 16.17	+18 21 10.47	L3.5	2324[CTR]	≥5.0[ST]	0.00[ST]	0.90	1.45	0.56
IRL181	HD 003346	00 36 46.44	+44 29 18.91	K6IIIa	3943[FSF]	2.13[ST]	−0.05[FSF]	0.84	1.05	0.21
IRL072	HD 003421	00 37 21.21	+35 23 58.20	G2Ib	5663[FSF]	1.94[FSF]	−0.33[FSF]	0.42	0.48	0.06
IRL153	HD 003765	00 40 49.26	+40 11 13.83	K2V	5073[FSF]	4.49[FSF]	0.10[FSF]	0.46	0.53	0.07
IRL252	HD 004408	00 46 32.95	+15 28 31.81	M4III	3566[CTR]	1.07[ST]	0.00[ST]	0.93	1.21	0.27
IRL260	Gl 051	01 03 19.72	+62 21 55.70	M5V	3649[CTR]	4.8 [ST]	0.00[ST]	0.61	0.92	0.31
IRL014	HD 006130	01 03 37.00	+61 04 29.36	F0II	7031[FSF]	2.15[FSF]	−0.55[FSF]	0.25	0.33	0.08
IRL013	HD 006130 ext	01 03 37.00	+61 04 29.36	F0II	7008[FSF]	2.09[FSF]	−0.57[FSF]	0.16	0.19	0.03
IRL277	IRAS 01037+1219	01 06 25.98	+12 35 53.00	M8III	3777[CTR]	0.7 [ST]	0.00[ST]	2.50	4.21	1.71
IRL082	HD 006474 ext	01 06 59.74	+63 46 23.38	G4Ia	6241[C07]	1.55[C07]	0.25[C07]	0.35	0.46	0.10
IRL083	HD 006474	01 06 59.74	+63 46 23.38	G4Ia	6241[C07]	1.55[C07]	0.25[C07]	0.55	0.77	0.22
IRL055	HD 006903	01 09 49.20	+19 39 30.26	F9IIIa	5570[C07]	2.9 [C07]	−0.35[C07]	0.36	0.42	0.06
IRL054	HD 006903 ext	01 09 49.20	+19 39 30.26	F9IIIa	5570[C07]	2.9 [C07]	−0.35[C07]	0.32	0.37	0.04
IRL202	HD 236697	01 19 53.61	+58 18 30.73	M0.5Ib	3565[CTR]	0.69[ST]	0.00[ST]	0.93	1.21	0.28
IRL201	HD 236697 ext	01 19 53.61	+58 18 30.73	M0.5Ib	3814[CTR]	0.69[ST]	0.00[ST]	0.78	0.97	0.19
IRL010	HD 007927	01 20 04.91	+58 13 53.80	F0Ia	7425[C07]	0.7 [C07]	0.00[C07]	0.29	0.43	0.14
IRL009	HD 007927 ext	01 20 04.91	+58 13 53.80	F0Ia	7425[C07]	0.7 [C07]	0.00[C07]	0.13	0.17	0.04
IRL209	BD+60265 ext	01 33 33.05	+61 33 30.73	M1.5Ib	3771[CTR]	0.61[ST]	0.00[ST]	0.76	1.01	0.24
IRL210	BD+60265	01 33 33.05	+61 33 30.73	M1.5Ib	3468[CTR]	0.61[ST]	0.00[ST]	0.97	1.33	0.36
IRL124	HD 009852	01 37 51.23	+61 51 41.74	K0.5III	4678[FSF]	2.88[ST]	0.01[FSF]	0.67	0.81	0.14
IRL123	HD 009852 ext	01 37 51.23	+61 51 41.74	K0.5III	4740[FSF]	2.88[ST]	−0.05[FSF]	0.55	0.61	0.06
IRL067	HD 010307	01 41 47.14	+42 36 48.12	G1V	5847[C07]	4.28[C07]	0.02[C07]	0.32	0.34	0.03
IRL144	HD 010476	01 42 29.76	+20 16 06.60	K1V	5150[C07]	4.44[C07]	−0.17[C07]	0.45	0.53	0.08
IRL225	HD 010465 ext	01 43 11.10	+48 31 00.36	M2Ib	3783[CTR]	0.62[ST]	0.00[ST]	0.78	1.00	0.22
IRL226	HD 010465	01 43 11.10	+48 31 00.36	M2Ib	3673[CTR]	0.62[ST]	0.00[ST]	0.84	1.09	0.26
IRL081	HD 010697	01 44 55.82	+20 04 59.33	G3Va	5688[FSF]	3.82[FSF]	−0.09[FSF]	0.36	0.44	0.08
IRL039	HD 011443	01 53 04.90	+29 34 43.78	F6IV	6288[C07]	3.91[C07]	0.00[C07]	0.27	0.35	0.08
IRL189	2MASS J02081833+2542533	02 08 18.33	+25 42 53.30	L1	2285[CTR]	≥5.0[ST]	0.00[ST]	0.90	1.49	0.58
IRL016	HD 013174	02 09 25.33	+25 56 23.59	F0III	7000[C07]	3.25[C07]	−1.90[C07]	0.18	0.19	0.01
IRL257	HD 014386	02 19 20.79	−02 58 39.49	M5III	3668[CTR]	1.04[ST]	0.00[ST]	0.63	1.10	0.47
IRL212	HD 014404 ext	02 21 42.41	+57 51 46.12	M1Iab	3952[CTR]	0.0 [SEC]	0.00[ST]	0.71	0.87	0.17
IRL213	HD 014404	02 21 42.41	+57 51 46.12	M1Iab	3593[CTR]	0.0 [SEC]	0.00[ST]	0.90	1.18	0.28
IRL242	HD 014469 ext	02 22 06.89	+56 36 14.86	M3Iab	3773[CTR]	0.16[ST]	0.00[ST]	0.75	1.00	0.25
IRL243	HD 014469	02 22 06.89	+56 36 14.86	M3Iab	3538[CTR]	0.16[ST]	0.00[ST]	0.90	1.24	0.34
IRL232	HD 014488 ext	02 22 24.29	+57 06 34.36	M3.5Iab	3525[CTR]	0.14[ST]	0.00[ST]	0.88	1.26	0.37
IRL233	HD 014488	02 22 24.29	+57 06 34.36	M3.5Iab	3340[CTR]	0.14[ST]	0.00[ST]	1.05	1.51	0.47
IRL101	HD 016139 ext	02 36 17.99	+27 28 20.36	G7.5IIIa	5123[FSF]	2.88[FSF]	−0.31[FSF]	0.47	0.57	0.10
IRL102	HD 016139	02 36 17.99	+27 28 20.36	G7.5IIIa	5069[FSF]	2.7 [FSF]	−0.41[FSF]	0.51	0.63	0.12
IRL166	HD 016068	02 36 52.80	+55 54 55.41	K3II	4285[FSF]	1.88[FSF]	−0.09[FSF]	0.78	0.94	0.15
IRL165	HD 016068 ext	02 36 52.80	+55 54 55.41	K3II	4380[FSF]	1.73[FSF]	−0.06[FSF]	0.62	0.69	0.06
IRL029	HD 016232	02 36 57.74	+24 38 53.02	F4V	6097[FSF]	4.08[FSF]	−0.02[FSF]	0.23	0.26	0.03
IRL034	HD 017918	02 53 11.69	+16 29 00.45	F5III	6695[FSF]	3.25[FSF]	0.00[ST]	0.22	0.22	0.01
IRL200	DENIS−P J0255.0−4700	02 55 03.57	−47 00 50.99	L8	1952[CTR]	≥5.0[ST]	0.00[ST]	1.10	1.72	0.61
IRL266	HD 018191	02 55 48.49	+18 19 53.90	M6III	3536[CTR]	1.92[C07]	−0.99[C07]	0.95	1.24	0.29
IRL092	HD 018474	02 59 49.79	+47 13 14.48	G5III	5878[FSF]	3.73[FSF]	−0.11[FSF]	0.46	0.50	0.03
IRL249	HD 019058	03 05 10.59	+38 50 24.99	M4IIIa	3549[CTR]	0.57[SEC]	−0.22[SEC]	0.96	1.23	0.27
IRL205	HD 019305	03 06 26.73	+01 57 54.63	M0V	3934[CTR]	4.65[ST]	0.00[ST]	0.69	0.85	0.16
IRL061	HD 020619	03 19 01.89	−02 50 35.49	G1.5V	6094[FSF]	4.04[FSF]	−0.18[FSF]	0.38	0.45	0.07
IRL109	HD 020618	03 19 55.79	+27 04 16.06	G7IV	5430[FSF]	3.16[FSF]	−0.25[FSF]	0.49	0.57	0.09
IRL279	LP 412−31	03 20 59.65	+18 54 23.31	M8V	2841[CTR]	4.96[ST]	0.00[ST]	0.72	1.17	0.45
IRL063	HD 021018 ext	03 23 38.98	+04 52 55.57	G1III	5924[FSF]	3.48[FSF]	−0.04[FSF]	0.35	0.41	0.06
IRL064	HD 021018	03 23 38.98	+04 52 55.57	G1III	5920[FSF]	3.58[FSF]	−0.04[FSF]	0.40	0.49	0.09
IRL028	HD 021770	03 32 26.26	+46 03 24.69	F4III	6204[FSF]	3.75[ST]	−0.04[SEC]	0.21	0.23	0.02
IRL286	LP 944−20	03 39 35.22	−35 25 44.09	M9V	2821[CTR]	5.0 [ST]	0.00[ST]	0.70	1.20	0.50
IRL145	HD 023082 ext	03 44 05.77	+44 53 04.91	K2.5II	4270[FSF]	1.22[FSF]	0.00[FSF]	0.63	0.73	0.10
IRL146	HD 023082	03 44 05.77	+44 53 04.91	K2.5II	4215[FSF]	1.42[FSF]	−0.16[FSF]	0.78	0.96	0.18
IRL227	HD 023475 ext	03 49 31.27	+65 31 33.50	M2II	3800[CTR]	1.0 [ST]	0.00[ST]	0.80	0.98	0.18

Table A.1. continued.

ID	Star	RA	Dec	Class	$T_{\rm eff}$ (K)	$\log g$	$[Z/Z_\odot]$	$(J-H)$	$(J-K)$	$(H-K)$
IRL228	HD 023475	03 49 31.27	+65 31 33.50	M2II	3650[CTR]	1.0 [ST]	0.00[ST]	0.88	1.12	0.23
IRL027	HD 026015	04 07 41.98	+15 09 46.02	F3V	7090[CTR]	4.29[ST]	0.04[SEC]	0.14	0.12	–0.02
IRL141	HD 025975	04 08 15.38	+37 43 38.98	K1III	4966[FSF]	2.92[FSF]	–0.24[FSF]	0.47	0.53	0.06
IRL106	HD 025877	04 09 27.57	+59 54 29.05	G7II	4904[C07]	1.3 [C07]	–0.15[C07]	0.45	0.52	0.06
IRL105	HD 025877 ext	04 09 27.57	+59 54 29.05	G7II	4904[C07]	1.3 [C07]	–0.15[C07]	0.39	0.42	0.03
IRL052	HD 027383	04 19 54.85	+16 31 21.32	F8V	6127[FSF]	4.02[FSF]	–0.05[FSF]	0.24	0.25	0.02
IRL017	HD 027397	04 19 57.70	+14 02 06.71	F0IV	6799[FSF]	4.1 [ST]	0.00[ST]	0.13	0.11	–0.02
IRL251	HD 027598	04 20 41.34	−16 49 47.91	M4III	3623[CTR]	1.07[ST]	0.00[ST]	0.90	1.15	0.25
IRL100	HD 027277	04 20 53.54	+50 16 18.20	G6III	5196[FSF]	2.54[FSF]	–0.20[FSF]	0.47	0.55	0.08
IRL037	HD 027524	04 21 31.64	+21 02 23.56	F5V	6576[C07]	4.25[C07]	0.13[C07]	0.21	0.23	0.02
IRL235	HD 028487	04 29 38.94	+05 09 51.35	M3.5III	3553[CTR]	1.27[ST]	0.00[ST]	0.96	1.22	0.27
IRL234	HD 028487 ext	04 29 38.94	+05 09 51.35	M3.5III	3603[CTR]	1.27[ST]	0.00[ST]	0.92	1.17	0.25
IRL001	HD 031996	04 59 36.34	−14 48 22.53	C7.6	2181[CTR]	–0.5[C07]	0.20[C07]	1.40	2.55	1.14
IRL207	HD 035601 ext	05 27 10.21	+29 55 15.79	M1.5Iab	3738[CTR]	0.0 [C07]	–0.20[C07]	0.79	1.03	0.24
IRL208	HD 035601	05 27 10.21	+29 55 15.79	M1.5Iab	3497[CTR]	0.0 [C07]	–0.20[C07]	0.95	1.29	0.34
IRL159	HD 035620 ext	05 27 38.88	+34 28 33.21	K3III	4367[C07]	1.75[C07]	–0.03[C07]	0.64	0.77	0.13
IRL160	HD 035620	05 27 38.88	+34 28 33.21	K3III	4367[C07]	1.75[C07]	–0.03[C07]	0.68	0.84	0.15
IRL180	HD 036003	05 28 26.09	−03 29 58.39	K5V	4464[C07]	4.61[C07]	0.09[C07]	0.61	0.72	0.11
IRL140	HD 036134	05 29 23.68	−03 26 47.01	K1III	4837[FSF]	2.24[FSF]	–0.32[FSF]	0.60	0.68	0.08
IRL211	HD 036395	05 31 27.39	−03 40 38.03	M1.5V	3651[CTR]	4.57[SEC]	0.53[SEC]	0.73	0.92	0.18
IRL197	SDSS J053951.99−005902.0	05 39 52.00	−00 59 01.90	L5	2325[CTR]	≥5.0[ST]	0.00[ST]	0.93	1.45	0.52
IRL253	Gl 213	05 42 09.26	+12 29 21.62	M4V	4063[CTR]	4.75[ST]	0.00[ST]	0.53	0.79	0.26
IRL240	HD 039045 ext	05 51 25.74	+32 07 28.89	M3III	3690[CTR]	1.25[ST]	0.00[ST]	0.86	1.08	0.22
IRL241	HD 039045	05 51 25.74	+32 07 28.89	M3III	3619[CTR]	1.25[ST]	0.00[ST]	0.90	1.15	0.24
IRL217	HD 039801 ext	05 55 10.30	+07 24 25.43	M2Ia	4190[CTR]	0.0 [C07]	0.05[C07]	0.68	0.73	0.05
IRL218	HD 039801	05 55 10.30	+07 24 25.43	M2Ia	4016[CTR]	0.0 [C07]	0.05[C07]	0.74	0.83	0.09
IRL068	HD 039949 ext	05 57 05.55	+27 18 59.95	G2Ib	5671[FSF]	1.55[ST]	–0.07[FSF]	0.41	0.48	0.07
IRL069	HD 039949	05 57 05.55	+27 18 59.95	G2Ib	5726[FSF]	1.55[ST]	–0.25[FSF]	0.47	0.58	0.11
IRL025	HD 040535	05 59 01.08	−09 22 56.00	F2III	6791[FSF]	3.81[ST]	–0.24[FSF]	0.21	0.25	0.04
IRL292	2MASS J05591915−1404489	05 59 19.14	−14 04 48.88	T4.5	1105[CTR]	≥5.0[ST]	0.67[SEC]	0.21	0.09	–0.12
IRL239	HD 040239	05 59 56.09	+45 56 12.24	M3IIb	3558[CTR]	1.0 [ST]	0.00[ST]	0.94	1.22	0.28
IRL219	HD 042581	06 10 34.61	−21 51 52.71	M1V	3937[CTR]	4.69[ST]	0.00[ST]	0.66	0.85	0.19
IRL070	HD 042454 ext	06 12 05.48	+29 29 31.72	G2Ib	5772[FSF]	1.55[ST]	–0.01[FSF]	0.36	0.40	0.05
IRL071	HD 042454	06 12 05.48	+29 29 31.72	G2Ib	5751[FSF]	1.55[ST]	0.02[FSF]	0.46	0.57	0.11
IRL290	HD 044544	06 22 23.85	+03 25 27.88	SC5.5	3055[CTR]	0.2 [ST]	–1.12[SEC]	1.15	1.53	0.38
IRL127	HD 044391 ext	06 22 47.87	+27 59 12.03	K0Ib	4786[FSF]	1.48[FSF]	–0.13[FSF]	0.54	0.66	0.11
IRL128	HD 044391	06 22 47.87	+27 59 12.03	K0Ib	4764[FSF]	1.65[FSF]	–0.11[FSF]	0.61	0.76	0.15
IRL006	HD 044984	06 25 28.17	+14 43 19.16	CN4	3248[CTR]	–0.5[ST]	–0.17[SEC]	1.01	1.41	0.40
IRL174	HD 045977 ext	06 30 07.30	−11 48 32.19	K4V	4738[FSF]	4.39[FSF]	0.14[FSF]	0.49	0.56	0.07
IRL175	HD 045977	06 30 07.30	−11 48 32.19	K4V	4805[FSF]	4.17[FSF]	0.15[FSF]	0.53	0.62	0.09
IRL007	HD 048664	06 44 40.71	+03 18 58.65	CN5	2710[CTR]	–0.5[ST]	–0.62[SEC]	1.17	1.78	0.61
IRL048	HD 051956	06 59 31.74	+00 55 00.36	F8Ib	6130[FSF]	1.7 [ST]	–0.17[FSF]	0.35	0.42	0.07
IRL047	HD 051956 ext	06 59 31.74	+00 55 00.36	F8Ib	6268[FSF]	1.7 [ST]	–0.10[FSF]	0.27	0.30	0.03
IRL248	Gl 268	07 10 01.83	+38 31 46.06	M4.5V	3772[CTR]	4.75[ST]	0.00[ST]	0.60	0.89	0.29
IRL003	HD 057160	07 20 59.00	+24 59 58.07	CJ5	2889[CTR]	–0.5[ST]	0.00[ST]	1.10	1.64	0.55
IRL099	HD 058367	07 25 38.89	+09 16 33.95	G6IIb	5009[FSF]	1.56[FSF]	–0.19[FSF]	0.49	0.57	0.09
IRL236	Gl 273	07 27 24.49	+05 13 32.83	M3.5V	3971[CTR]	4.74[ST]	0.00[ST]	0.58	0.84	0.26
IRL237	CD−314916 ext	07 41 02.62	−31 40 59.10	M3Iab	3778[CTR]	0.12[ST]	0.00[ST]	0.78	1.00	0.22
IRL238	CD−314916	07 41 02.62	−31 40 59.10	M3Iab	3517[CTR]	0.12[ST]	0.00[ST]	0.95	1.27	0.31
IRL289	HD 062164	07 42 17.46	−10 52 47.18	S5	3198[CTR]	0.45[ST]	0.00[ST]	1.06	1.44	0.38
IRL188	2MASS J07464256+2000321	07 46 42.56	+20 00 32.18	L0.5	2504[CTR]	≥5.0[ST]	0.00[ST]	0.77	1.28	0.51
IRL137	HD 063302 ext	07 47 38.52	−15 59 26.48	K1Ia	4500[C07]	0.2 [C07]	0.12[C07]	0.51	0.60	0.10
IRL138	HD 063302	07 47 38.52	−15 59 26.48	K1Ia	4500[C07]	0.2 [C07]	0.12[C07]	0.67	0.86	0.19
IRL288	HD 064332	07 53 05.27	−11 37 29.35	S4.5	3727[CTR]	0.27[SEC]	–0.41[SEC]	0.90	1.16	0.26
IRL255	Gl 299	08 11 57.57	+08 46 22.05	M4V	4055[CTR]	4.75[ST]	0.00[ST]	0.48	0.77	0.29
IRL254	Gl 299 ext	08 11 57.57	+08 46 22.05	M4V	3828[CTR]	4.75[ST]	0.00[ST]	0.45	0.71	0.27
IRL265	HD 069243	08 16 33.82	+11 43 34.45	M6III	3377[CTR]	1.0 [ST]	0.00[ST]	0.91	1.46	0.55
IRL002	HD 070138	08 19 43.09	−18 15 52.84	CJ4.5IIIa	3216[CTR]	–0.5[ST]	0.00[ST]	0.97	1.43	0.46
IRL199	2MASS J08251968+2115521	08 25 19.68	+21 15 52.12	L7.5	1355[CTR]	≥5.0[ST]	0.00[ST]	1.23	2.02	0.80

Table A.1. continued.

ID	Star	RA	Dec	Class	$T_{\rm eff}$ (K)	$\log g$	$[Z/Z_{\odot}]$	$(J-H)$	$(J-K)$	$(H-K)$
IRL264	GJ 1111	08 29 49.34	+26 46 33.74	M6.5V	3285^{CTR}	4.85^{ST}	0.00^{ST}	0.60	1.00	0.40
IRL062	HD 074395	08 43 40.37	−07 14 01.43	G1Ib	5250^{C07}	1.3^{C07}	-0.05^{C07}	0.40	0.47	0.07
IRL031	HD 075555	08 52 21.79	+44 53 51.46	F5.5III	6745^{FSF}	3.19^{FSF}	-0.22^{FSF}	0.24	0.28	0.04
IRL116	HD 075732 ext	08 52 35.81	+28 19 50.95	G8V	5079^{C07}	4.48^{C07}	0.16^{C07}	0.37	0.44	0.07
IRL117	HD 075732	08 52 35.81	+28 19 50.95	G8V	5079^{C07}	4.48^{C07}	0.16^{C07}	0.41	0.50	0.09
IRL284	LH S2065	08 53 36.19	−03 29 32.11	M9V	2638^{CTR}	5.0^{ST}	0.00^{ST}	0.79	1.32	0.53
IRL075	HD 076151	08 54 17.94	−05 26 04.05	G2V	5940^{FSF}	4.23^{FSF}	0.01^{FSF}	0.34	0.41	0.08
IRL005	HD 076221	08 55 22.88	+17 13 52.58	CN4.5	2782^{CTR}	-0.5^{ST}	-0.37^{SEC}	1.11	1.72	0.61
IRL008	HD 076846	08 59 48.94	+33 46 26.47	CR2IIIa	5582^{ST}	2.09^{FSF}	-0.15^{FSF}	0.56	0.72	0.15
IRL030	HD 087822	10 08 15.88	+31 36 14.58	F4V	6377^{FSF}	3.75^{FSF}	-0.08^{FSF}	0.21	0.24	0.03
IRL221	Gl 381	10 12 04.69	−02 41 05.07	M2.5V	3986^{CTR}	4.7^{ST}	0.00^{ST}	0.62	0.84	0.22
IRL080	HD 088639	10 13 49.70	+27 08 08.95	G3IIIb	5431^{FSF}	2.85^{FSF}	-0.41^{FSF}	0.44	0.50	0.06
IRL015	HD 089025	10 16 41.41	+23 25 02.32	F0IIIa	7083^{C07}	3.2^{C07}	-0.03^{C07}	0.18	0.21	0.02
IRL246	Gl 388	10 19 36.27	+19 52 12.06	M3V	3988^{CTR}	4.74^{ST}	0.00^{ST}	0.62	0.84	0.22
IRL186	HD 237903	10 30 25.31	+55 59 56.83	K7V	4070^{C07}	4.7^{C07}	-0.18^{C07}	0.66	0.78	0.12
IRL139	HD 091810	10 37 20.55	+56 25 52.82	K1IIIb	4525^{FSF}	2.79^{ST}	-0.06^{FSF}	0.59	0.71	0.12
IRL004	HD 092055	10 37 33.27	−13 23 04.35	CN4.5	3039^{CTR}	-0.5^{C07}	-0.10^{C07}	1.09	1.54	0.45
IRL283	DENIS−P J104814.7−395606	10 48 14.64	−39 56 06.24	M9V	3069^{CTR}	5.0^{ST}	0.00^{ST}	0.61	1.05	0.44
IRL085	HD 094481	10 54 17.77	−13 45 28.94	G4III	5347^{FSF}	2.87^{FSF}	-0.37^{FSF}	0.45	0.52	0.07
IRL256	HD 094705	10 56 01.46	+06 11 07.32	M5.5III	3561^{CTR}	0.2^{C07}	-2.50^{C07}	0.91	1.21	0.31
IRL268	Gl 406	10 56 28.86	+07 00 52.77	M6V	3158^{CTR}	4.84^{ST}	0.00^{ST}	0.64	1.03	0.39
IRL066	HD 095128	10 59 27.97	+40 25 48.92	G1V	5834^{C07}	4.34^{C07}	0.04^{C07}	0.31	0.35	0.04
IRL231	HD 095735	11 03 20.19	+35 58 11.56	M2V	4050^{CTR}	4.8^{C07}	-0.20^{C07}	0.57	0.77	0.20
IRL157	HD 099998 ext	11 30 18.89	−03 00 12.59	K3III	4176^{CTR}	1.67^{C07}	-0.39^{C07}	0.73	0.86	0.13
IRL158	HD 099998	11 30 18.89	−03 00 12.59	K3III	3930^{CTR}	1.67^{C07}	-0.39^{C07}	0.82	0.99	0.17
IRL131	HD 100006	11 30 29.03	+18 24 35.28	K0III	4810^{FSF}	2.93^{ST}	-0.32^{FSF}	0.59	0.67	0.09
IRL115	HD 101501	11 41 03.01	+34 12 05.88	G8V	5401^{C07}	4.6^{C07}	-0.13^{C07}	0.37	0.42	0.05
IRL192	2MASS J11463449+2230527	11 46 34.49	+22 30 52.74	L3	2170^{CTR}	$\geq 5.0^{ST}$	0.00^{ST}	0.95	1.57	0.62
IRL044	HD 102870	11 50 41.71	+01 45 52.99	F8.5IV	6109^{C07}	4.2^{C07}	0.17^{C07}	0.28	0.32	0.03
IRL112	HD 104979	12 05 12.54	+08 43 58.74	G8III	5030^{FSF}	2.35^{FSF}	-0.13^{FSF}	0.54	0.62	0.08
IRL281	BR B1219−1336	12 21 52.48	−13 53 10.20	M9III	3487^{CTR}	0.6^{ST}	0.00^{ST}	0.76	1.28	0.52
IRL018	HD 108519	12 27 46.30	+27 25 21.95	F0V	6608^{FSF}	4.3^{ST}	0.00^{ST}	0.16	0.20	0.04
IRL084	HD 108477	12 27 49.44	−16 37 54.63	G4III	5442^{FSF}	3.25^{ST}	-0.05^{FSF}	0.45	0.53	0.09
IRL270	HD 108849	12 30 21.01	+04 24 59.16	M7III	3491^{CTR}	0.84^{ST}	0.00^{ST}	0.92	1.30	0.38
IRL060	HD 109358	12 33 44.54	+41 21 26.92	G0V	5986^{FSF}	4.11^{FSF}	-0.13^{FSF}	0.33	0.35	0.02
IRL050	HD 111844	12 51 54.38	+19 10 05.06	F8IV	6524^{FSF}	3.92^{ST}	-0.74^{SEC}	0.13	0.13	0.00
IRL291	SDSS J125453.90−012247.4	12 54 53.93	−01 22 47.49	T2	1449^{CTR}	$\geq 5.0^{ST}$	0.00^{ST}	0.76	0.92	0.16
IRL026	HD 113139	13 00 43.69	+56 21 58.81	F2V	6810^{C07}	3.87^{C07}	0.22^{C07}	0.21	0.22	0.02
IRL191	Kelu	13 05 40.19	−25 41 05.99	L2	2125^{CTR}	$\geq 5.0^{ST}$	0.00^{ST}	0.95	1.60	0.66
IRL053	HD 114710	13 11 52.39	+27 52 41.45	F9.5V	5975^{C07}	4.4^{C07}	0.09^{C07}	0.22	0.21	–0.01
IRL154	HD 114960	13 13 57.56	+01 27 23.20	K3.5IIIb	4331^{FSF}	1.97^{FSF}	-0.13^{FSF}	0.68	0.82	0.13
IRL108	HD 114946	13 14 10.89	−19 55 51.40	G7IV	5171^{C07}	3.64^{C07}	0.13^{C07}	0.50	0.58	0.08
IRL094	HD 115617	13 18 24.31	−18 18 40.30	G6.5V	5531^{C07}	4.32^{C07}	-0.01^{C07}	0.32	0.33	0.01
IRL287	BD+442267	13 21 18.73	+43 59 13.67	S2.5	3926^{CTR}	0.55^{ST}	0.00^{ST}	0.84	1.07	0.22
IRL229	HD 120052	13 47 25.39	−17 51 35.42	M2III	3608^{CTR}	1.35^{ST}	0.00^{ST}	0.91	1.16	0.25
IRL176	HD 120477	13 49 28.64	+15 47 52.46	K5.5III	3913^{CTR}	1.32^{SEC}	-0.30^{SEC}	0.81	1.00	0.19
IRL114	HD 122563	14 02 31.84	+09 41 09.94	G8III	4566^{C07}	1.12^{C07}	-2.63^{C07}	0.58	0.68	0.10
IRL206	IRAS 14086−0730	14 11 18.03	−07 44 47.30	M10III	3601^{CTR}	0.5^{ST}	0.00^{ST}	2.15	4.12	1.98
IRL135	HD 124897 shape ext	14 15 39.67	+19 10 56.67	K1.5III	4361^{C07}	1.93^{C07}	-0.53^{C07}	0.68	0.77	0.09
IRL136	HD 124897 shape	14 15 39.67	+19 10 56.67	K1.5III	4361^{C07}	1.93^{C07}	-0.53^{C07}	0.71	0.82	0.11
IRL134	HD 124897 lines	14 15 39.67	+19 10 56.67	K1.5III	4361^{C07}	1.93^{C07}	-0.53^{C07}	0.71	0.82	0.11
IRL133	HD 124897 lines ext	14 15 39.67	+19 10 56.67	K1.5III	4361^{C07}	1.93^{C07}	-0.53^{C07}	0.68	0.77	0.09
IRL042	HD 124850	14 16 00.86	−06 00 01.96	F7III	6116^{C07}	3.83^{C07}	-0.11^{C07}	0.28	0.30	0.02
IRL043	HD 126660	14 25 11.79	+51 51 02.67	F7V	6202^{C07}	3.84^{C07}	-0.27^{C07}	0.24	0.30	0.05
IRL074	HD 126868	14 28 12.13	−02 13 40.65	G2IV	5731^{FSF}	3.35^{FSF}	-0.15^{FSF}	0.36	0.42	0.06
IRL285	LH S2924	14 28 43.23	+33 10 39.14	M9V	2772^{CTR}	5.0^{ST}	0.00^{ST}	0.76	1.26	0.50
IRL274	IRAS 14303−1042	14 32 59.89	−10 56 03.60	M8III	3306^{CTR}	0.7^{ST}	0.00^{ST}	0.79	1.38	0.59
IRL190	2MASS J14392836+1929149	14 39 28.36	+19 29 14.98	L1	2528^{CTR}	$\geq 5.0^{ST}$	0.00^{ST}	0.75	1.25	0.50
IRL275	IRAS 14436−0703	14 46 18.41	−07 15 49.80	M8III	3465^{CTR}	0.7^{ST}	0.00^{ST}	0.76	1.29	0.53

Table A.1. continued.

ID	Star	RA	Dec	Class	$T_{\rm eff}$ (K)	log g	$[Z/Z_\odot]$	$(J-H)$	$(J-K)$	$(H-K)$
IRL149	HD 132935	15 02 04.23	−08 20 40.99	K2III	$4547^{\rm FSF}$	$2.17^{\rm FSF}$	$-0.11^{\rm FSF}$	0.73	0.87	0.15
IRL148	HD 132935 ext	15 02 04.23	−08 20 40.99	K2III	$4502^{\rm FSF}$	$2.68^{\rm ST}$	$-0.07^{\rm FSF}$	0.66	0.78	0.11
IRL193	2MASS J15065441+1321060	15 06 54.41	+13 21 06.08	L3	$2064^{\rm CTR}$	$\geq 5.0^{\rm ST}$	$0.00^{\rm ST}$	0.97	1.65	0.67
IRL196	2MASS J15074769−1627386	15 07 47.69	−16 27 38.62	L5	$2234^{\rm CTR}$	$\geq 5.0^{\rm ST}$	$0.00^{\rm ST}$	0.96	1.53	0.57
IRL282	IRAS 15060+0947	15 08 25.77	+09 36 18.20	M9III	$2203^{\rm CTR}$	$0.6^{\rm ST}$	$0.00^{\rm ST}$	1.30	2.45	1.15
IRL012	HD 135153	15 14 37.31	−31 31 08.85	F0Ib	$7073^{\rm FSF}$	$2.07^{\rm FSF}$	$-0.06^{\rm SEC}$	0.21	0.29	0.08
IRL011	HD 135153 ext	15 14 37.31	−31 31 08.85	F0Ib	$7037^{\rm FSF}$	$2.03^{\rm FSF}$	$-0.06^{\rm SEC}$	0.15	0.19	0.04
IRL198	2MASS J15150083+4847416	15 15 00.83	+48 47 41.69	L6	$2014^{\rm CTR}$	$\geq 5.0^{\rm ST}$	$0.00^{\rm ST}$	1.04	1.68	0.64
IRL113	HD 135722	15 15 30.16	+33 18 53.39	G8III	$4847^{\rm C07}$	$2.56^{\rm C07}$	$-0.44^{\rm C07}$	0.54	0.65	0.11
IRL222	Gl 581	15 19 27.50	−07 43 19.44	M2.5V	$3966^{\rm CTR}$	$4.7^{\rm ST}$	$0.00^{\rm ST}$	0.59	0.84	0.26
IRL150	HD 137759	15 24 55.77	+58 57 57.83	K2III	$4498^{\rm C07}$	$2.38^{\rm C07}$	$0.05^{\rm C07}$	0.63	0.75	0.12
IRL263	HD 142143	15 50 46.62	+48 28 58.85	M6.5III	$3443^{\rm CTR}$	$0.88^{\rm ST}$	$0.00^{\rm ST}$	0.96	1.36	0.40
IRL142	HD 142091	15 51 13.93	+35 39 26.56	K1IVa	$4796^{\rm C07}$	$3.22^{\rm C07}$	$0.00^{\rm C07}$	0.51	0.58	0.07
IRL132	HD 145675	16 10 24.31	+43 49 03.52	K0V	$5264^{\rm C07}$	$4.66^{\rm C07}$	$0.34^{\rm C07}$	0.39	0.43	0.05
IRL022	BD+382803	16 35 57.28	+37 58 02.10	F2Ib	$6588^{\rm FSF}$	$1.87^{\rm FSF}$	$0.00^{\rm ST}$	0.34	0.41	0.08
IRL273	Gl 644	16 55 28.75	−08 20 10.78	M7V	$3278^{\rm CTR}$	$4.9^{\rm ST}$	$0.00^{\rm ST}$	0.59	1.00	0.41
IRL258	HD 156014	17 14 38.87	+14 23 25.01	M5Ib	$4135^{\rm CTR}$	$0.76^{\rm C07}$	$-2.50^{\rm C07}$	0.68	0.76	0.08
IRL038	HD 160365	17 38 57.85	+13 19 45.34	F6III	$6070^{\rm C07}$	$3.0^{\rm C07}$	$-0.26^{\rm C07}$	0.20	0.16	−0.04
IRL095	HD 161664 ext	17 47 45.60	−22 28 40.05	G6Ib	$4739^{\rm FSF}$	$1.64^{\rm FSF}$	$-0.07^{\rm FSF}$	0.50	0.58	0.08
IRL096	HD 161664	17 47 45.60	−22 28 40.05	G6Ib	$4804^{\rm FSF}$	$1.63^{\rm FSF}$	$-0.09^{\rm FSF}$	0.63	0.80	0.16
IRL187	HD 164136	17 58 30.14	+30 11 21.38	F2IV	$6799^{\rm C07}$	$2.63^{\rm C07}$	$-0.30^{\rm C07}$	0.24	0.26	0.02
IRL121	HD 164349 ext	18 00 03.41	+16 45 03.30	K0.5IIb	$4446^{\rm C07}$	$1.5^{\rm C07}$	$0.39^{\rm C07}$	0.49	0.52	0.03
IRL122	HD 164349	18 00 03.41	+16 45 03.30	K0.5IIb	$4446^{\rm C07}$	$1.5^{\rm C07}$	$0.39^{\rm C07}$	0.53	0.59	0.06
IRL143	HD 165438	18 06 15.19	−04 45 04.51	K1IV	$4862^{\rm C07}$	$3.4^{\rm C07}$	$0.02^{\rm C07}$	0.51	0.59	0.08
IRL093	HD 165185	18 06 23.71	−36 01 11.23	G5V	$5974^{\rm FSF}$	$3.85^{\rm FSF}$	$-0.15^{\rm FSF}$	0.29	0.34	0.05
IRL057	HD 165908	18 07 01.53	+30 33 43.68	F9V	$5928^{\rm C07}$	$4.24^{\rm C07}$	$-0.53^{\rm C07}$	0.26	0.31	0.05
IRL125	HD 165782 ext	18 08 26.51	−18 33 07.92	K0Ia	$5211^{\rm FSF}$	$0.25^{\rm ST}$	$0.20^{\rm FSF}$	0.34	0.44	0.10
IRL126	HD 165782	18 08 26.51	−18 33 07.92	K0Ia	$5600^{\rm FSF}$	$0.25^{\rm ST}$	$0.21^{\rm FSF}$	0.63	0.90	0.27
IRL119	HD 170820	18 32 13.11	−19 07 26.28	G9II	$4604^{\rm C07}$	$1.62^{\rm C07}$	$0.17^{\rm C07}$	0.69	0.89	0.20
IRL118	HD 170820 ext	18 32 13.11	−19 07 26.28	G9II	$4604^{\rm C07}$	$1.62^{\rm C07}$	$0.17^{\rm C07}$	0.53	0.63	0.10
IRL019	HD 173638 ext	18 46 43.32	−10 07 30.17	F1II	$7005^{\rm FSF}$	$2.1^{\rm FSF}$	$-0.68^{\rm FSF}$	0.14	0.14	0.00
IRL020	HD 173638	18 46 43.32	−10 07 30.17	F1II	$7146^{\rm FSF}$	$2.2^{\rm FSF}$	$-0.56^{\rm FSF}$	0.25	0.32	0.07
IRL259	HD 175865	18 55 20.10	+43 56 45.93	M5III	$3690^{\rm CTR}$	$0.5^{\rm C07}$	$0.14^{\rm C07}$	0.87	1.08	0.21
IRL056	HD 176051	18 57 01.60	+32 54 04.57	F9V	$5895^{\rm FSF}$	$3.91^{\rm FSF}$	$-0.21^{\rm FSF}$	0.36	0.40	0.05
IRL078	HD 176123 ext	18 59 26.77	−18 33 59.16	G3II	$5449^{\rm FSF}$	$2.8^{\rm FSF}$	$-0.23^{\rm FSF}$	0.42	0.48	0.06
IRL079	HD 176123	18 59 26.77	−18 33 59.16	G3II	$5302^{\rm FSF}$	$2.61^{\rm FSF}$	$-0.30^{\rm FSF}$	0.46	0.54	0.08
IRL161	HD 178208 ext	19 05 09.83	+49 55 23.39	K3III	$4882^{\rm FSF}$	$2.53^{\rm FSF}$	$-0.26^{\rm FSF}$	0.62	0.72	0.10
IRL162	HD 178208	19 05 09.83	+49 55 23.39	K3III	$4884^{\rm FSF}$	$2.48^{\rm FSF}$	$-0.23^{\rm FSF}$	0.66	0.78	0.13
IRL129	HD 179870 ext	19 13 53.58	+09 01 59.59	K0II	$4776^{\rm FSF}$	$1.53^{\rm FSF}$	$0.04^{\rm FSF}$	0.44	0.44	0.00
IRL130	HD 179870	19 13 53.58	+09 01 59.59	K0II	$4928^{\rm FSF}$	$1.57^{\rm FSF}$	$0.06^{\rm FSF}$	0.49	0.53	0.04
IRL086	HD 179821 ext	19 13 58.60	+00 07 31.92	G4Ia	$5708^{\rm CTR}$	$1.08^{\rm FSF}$	$0.00^{\rm ST}$	0.25	0.38	0.13
IRL087	HD 179821	19 13 58.60	+00 07 31.92	G4Ia	$4645^{\rm CTR}$	$0.95^{\rm FSF}$	$0.00^{\rm ST}$	0.43	0.67	0.24
IRL278	Gl 752	19 16 55.26	+05 10 08.10	M8V	$2970^{\rm CTR}$	$4.96^{\rm ST}$	$0.00^{\rm ST}$	0.64	1.09	0.45
IRL179	HD 181596	19 18 30.12	+50 13 39.42	K5III	$4275^{\rm FSF}$	$2.35^{\rm ST}$	$-0.41^{\rm FSF}$	0.80	0.98	0.18
IRL182	HD 181475 ext	19 20 48.31	−04 30 09.01	K7IIa	$3996^{\rm FSF}$	$0.65^{\rm FSF}$	$-0.37^{\rm FSF}$	0.78	0.96	0.19
IRL183	HD 181475	19 20 48.31	−04 30 09.01	K7IIa	$4124^{\rm FSF}$	$0.83^{\rm FSF}$	$-0.21^{\rm FSF}$	0.94	1.22	0.28
IRL107	HD 182694	19 23 56.50	+43 23 17.41	G7III	$5312^{\rm FSF}$	$2.63^{\rm FSF}$	$-0.19^{\rm FSF}$	0.45	0.55	0.10
IRL024	HD 182835	19 26 31.09	+00 20 18.85	F2Ib	$7350^{\rm C07}$	$2.15^{\rm C07}$	$0.09^{\rm C07}$	0.25	0.31	0.06
IRL023	HD 182835 ext	19 26 31.09	+00 20 18.85	F2Ib	$7350^{\rm C07}$	$2.15^{\rm C07}$	$0.09^{\rm C07}$	0.12	0.11	−0.01
IRL059	HD 185018	19 36 52.45	+11 16 23.53	G0Ib	$5550^{\rm C07}$	$1.3^{\rm C07}$	$-0.24^{\rm C07}$	0.41	0.48	0.07
IRL058	HD 185018 ext	19 36 52.45	+11 16 23.53	G0Ib	$5550^{\rm C07}$	$1.3^{\rm C07}$	$-0.24^{\rm C07}$	0.37	0.43	0.05
IRL168	HD 185622 ext	19 39 25.33	+16 34 16.03	K4Ib	$3736^{\rm FSF}$	$1.05^{\rm ST}$	$-0.19^{\rm FSF}$	0.74	0.92	0.18
IRL169	HD 185622	19 39 25.33	+16 34 16.03	K4Ib	$3898^{\rm FSF}$	$0.63^{\rm FSF}$	$-0.14^{\rm FSF}$	0.90	1.17	0.27
IRL035	HD 186155	19 40 50.18	+45 31 29.78	F5II	$6590^{\rm FSF}$	$3.34^{\rm FSF}$	$0.31^{\rm FSF}$	0.18	0.22	0.03
IRL156	HD 187238	19 48 11.83	+22 45 46.35	K3Iab	$4143^{\rm FSF}$	$0.99^{\rm FSF}$	$-0.01^{\rm FSF}$	0.81	1.02	0.21
IRL155	HD 187238 ext	19 48 11.83	+22 45 46.35	K3Iab	$4228^{\rm FSF}$	$0.77^{\rm FSF}$	$-0.09^{\rm FSF}$	0.63	0.73	0.10
IRL214	HD 339034 ext	19 50 11.93	+24 55 24.19	M1Ia	$3960^{\rm CTR}$	$-0.0^{\rm ST}$	$0.00^{\rm ST}$	0.64	0.87	0.22
IRL215	HD 339034	19 50 11.93	+24 55 24.19	M1Ia	$3342^{\rm CTR}$	$-0.0^{\rm ST}$	$0.00^{\rm ST}$	1.05	1.51	0.46
IRL089	HD 190113 ext	20 02 02.85	+35 38 28.01	G5Ib	$4968^{\rm FSF}$	$1.45^{\rm FSF}$	$-0.28^{\rm FSF}$	0.45	0.49	0.05

Table A.1. continued.

ID	Star	RA	Dec	Class	$T_{\rm eff}$ (K)	$\log g$	$[Z/Z_\odot]$	$(J-H)$	$(J-K)$	$(H-K)$
IRL090	HD 190113	20 02 02.85	+35 38 28.01	G5Ib	4996[FSF]	1.59[FSF]	–0.31[FSF]	0.60	0.73	0.14
IRL104	HD 333385	20 02 27.37	+30 04 25.46	G7Ia	5375[FSF]	0.36[ST]	0.14[FSF]	0.61	0.90	0.29
IRL103	HD 333385 ext	20 02 27.37	+30 04 25.46	G7Ia	5475[FSF]	1.05[FSF]	0.21[FSF]	0.29	0.38	0.10
IRL046	HD 190323	20 03 49.61	+14 58 58.74	F8Ia	5740[CTR]	0.81[ST]	0.07[FSF]	0.32	0.38	0.06
IRL045	HD 190323 ext	20 03 49.61	+14 58 58.74	F8Ia	6906[FSF]	0.81[ST]	0.09[FSF]	0.22	0.22	0.00
IRL077	HD 192713	20 15 30.23	+23 30 32.05	G3Ib	4864[C07]	0.1 [C07]	–0.43[C07]	0.48	0.57	0.09
IRL076	HD 192713 ext	20 15 30.23	+23 30 32.05	G3Ib	4864[C07]	0.1 [C07]	–0.43[C07]	0.44	0.50	0.07
IRL184	HD 194193	20 22 45.29	+41 01 33.64	K7III	4025[FSF]	1.42[FSF]	–0.14[FSF]	0.88	1.09	0.20
IRL091	HD 193896	20 23 00.79	−09 39 16.95	G5IIIa	5332[FSF]	3.2 [ST]	–0.49[FSF]	0.50	0.61	0.11
IRL244	RW Cyg ext	20 28 50.59	+39 58 54.42	M3Iab	3844[CTR]	0.16[ST]	0.00[ST]	0.74	0.95	0.21
IRL245	RW Cyg	20 28 50.59	+39 58 54.42	M3Iab	3341[CTR]	0.16[ST]	0.00[ST]	1.09	1.51	0.42
IRL267	HD 196610	20 37 54.72	+18 16 06.89	M6III	3643[CTR]	0.91[ST]	0.00[ST]	0.86	1.12	0.26
IRL230	Gl 806	20 45 04.09	+44 29 56.66	M2V	3660[FSF]	4.65[FSF]	–0.23[FSF]	0.62	0.78	0.17
IRL170	HD 201065 ext	21 05 35.78	+46 57 47.76	K4Ib	4068[FSF]	1.16[FSF]	–0.50[FSF]	0.73	0.88	0.15
IRL171	HD 201065	21 05 35.78	+46 57 47.76	K4Ib	4226[FSF]	0.87[FSF]	–0.47[FSF]	0.83	1.04	0.20
IRL041	HD 201078	21 06 30.24	+31 11 04.76	F7II	6157[C07]	1.65[C07]	0.13[C07]	0.26	0.33	0.07
IRL185	HD 201092	21 06 55.26	+38 44 31.40	K7V	4348[CTR]	4.37[SEC]	–0.72[SEC]	0.59	0.73	0.14
IRL098	HD 202314	21 14 10.28	+29 54 03.45	G6Ib	4864[C07]	1.3 [C07]	–0.05[C07]	0.51	0.66	0.14
IRL097	HD 202314 ext	21 14 10.28	+29 54 03.45	G6Ib	4864[C07]	1.3 [C07]	–0.05[C07]	0.48	0.60	0.12
IRL247	HD 204585	21 28 59.77	+22 10 45.96	M4.5IIIa	3700[CTR]	1.11[ST]	0.00[ST]	0.86	1.07	0.21
IRL216	HD 204724	21 29 56.89	+23 38 19.81	M1III	3765[CTR]	1.5 [ST]	0.00[ST]	0.78	1.01	0.23
IRL276	IRAS 21284−0747	21 31 06.51	−07 34 20.50	M8III	3130[CTR]	0.7 [ST]	0.00[ST]	0.87	1.48	0.61
IRL224	HD 206936	21 43 30.46	+58 46 48.16	M2Ia	3540[CTR]	0.0 [ST]	0.00[ST]	0.86	1.24	0.38
IRL223	HD 206936 ext	21 43 30.46	+58 46 48.16	M2Ia	3879[CTR]	0.0 [ST]	0.00[ST]	0.66	0.92	0.26
IRL271	HD 207076	21 46 31.84	−02 12 45.93	M7III	2750[C07]	–0.5[C07]	–2.50[C07]	0.78	1.03	0.25
IRL172	HD 207991 ext	21 51 55.38	+48 26 13.59	K4III	4355[FSF]	1.98[FSF]	–0.21[FSF]	0.79	0.94	0.15
IRL173	HD 207991	21 51 55.38	+48 26 13.59	K4III	4192[FSF]	2.48[ST]	–0.32[FSF]	0.84	1.02	0.18
IRL111	HD 208606	21 55 20.59	+61 32 30.52	G8Ib	4718[FSF]	0.66[FSF]	–0.16[FSF]	0.67	0.86	0.19
IRL110	HD 208606 ext	21 55 20.59	+61 32 30.52	G8Ib	4709[FSF]	1.26[FSF]	0.10[FSF]	0.54	0.64	0.10
IRL203	HD 209290	22 02 10.27	+01 24 00.82	M0.5V	3810[CTR]	4.65[ST]	0.00[ST]	0.68	0.88	0.20
IRL152	HD 212466	22 23 07.01	+55 57 47.62	K2Ia	3749[CTR]	0.2 [ST]	0.18[FSF]	0.73	1.10	0.37
IRL151	HD 212466 ext	22 23 07.01	+55 57 47.62	K2Ia	5018[FSF]	0.2 [ST]	0.02[FSF]	0.42	0.61	0.19
IRL195	2MASS J22244381−0158521	22 24 43.81	−01 58 52.14	L4.5	1267[CTR]	≥5.0[ST]	0.00[ST]	1.26	2.06	0.81
IRL033	HD 213306	22 29 10.26	+58 24 54.71	F5Ib	6052[FSF]	2.29[FSF]	–0.16[FSF]	0.40	0.47	0.07
IRL032	HD 213306 ext	22 29 10.26	+58 24 54.71	F5Ib	6052[FSF]	2.27[FSF]	–0.14[FSF]	0.34	0.37	0.03
IRL021	HD 213135	22 29 46.02	−27 06 26.22	F1V	6404[FSF]	4.3 [ST]	–0.54[FSF]	0.20	0.21	0.01
IRL204	HD 213893	22 34 35.93	+00 35 42.63	M0IIIb	4044[C07]	1.6 [C07]	–0.08[C07]	0.83	1.01	0.18
IRL261	Gl 866 ext	22 38 33.72	−15 17 57.33	M5V	3728[CTR]	4.8 [ST]	0.00[ST]	0.59	0.90	0.31
IRL262	Gl 866	22 38 33.72	−15 17 57.33	M5V	3369[CTR]	4.8 [ST]	0.00[ST]	0.64	0.98	0.34
IRL250	HD 214665	22 38 37.92	+56 47 44.28	M4III	3452[CTR]	1.07[ST]	0.00[ST]	1.04	1.35	0.31
IRL088	HD 214850	22 40 52.68	+14 32 56.97	G4V	5451[FSF]	4.48[ST]	–0.34[FSF]	0.44	0.53	0.09
IRL040	HD 215648	22 46 41.58	+12 10 22.38	F6V	6167[C07]	4.04[C07]	–0.32[C07]	0.26	0.29	0.03
IRL065	HD 216219	22 50 52.15	+18 00 07.56	G1II	5727[C07]	3.36[C07]	–0.39[C07]	0.30	0.35	0.05
IRL272	MY Cep	22 54 31.71	+60 49 38.89	M7I	2595[CTR]	–0.2[ST]	0.00[ST]	1.47	2.24	0.77
IRL178	HD 216946	22 56 25.99	+49 44 00.75	K5Ib	3839[FSF]	0.49[FSF]	–0.10[SEC]	0.95	1.24	0.29
IRL177	HD 216946 ext	22 56 25.99	+49 44 00.75	K5Ib	3817[FSF]	0.68[FSF]	–0.10[SEC]	0.90	1.16	0.26
IRL036	HD 218804	23 10 27.20	+43 32 39.15	F5V	6261[C07]	4.05[C07]	–0.23[C07]	0.27	0.32	0.05
IRL167	HD 219134	23 13 16.97	+57 10 06.08	K3V	4717[C07]	4.5 [C07]	0.05[C07]	0.56	0.67	0.10
IRL073	HD 219477	23 15 46.29	+28 14 52.43	G2II	5989[FSF]	2.87[FSF]	–0.23[FSF]	0.36	0.41	0.05
IRL051	HD 219623	23 16 42.30	+53 12 48.51	F8V	6155[C07]	4.17[C07]	–0.04[C07]	0.29	0.34	0.05
IRL220	HD 219734	23 17 44.64	+49 00 55.08	M2.5III	3658[CTR]	0.9 [C07]	0.27[C07]	0.89	1.11	0.22
IRL049	HD 220657	23 25 22.78	+23 24 14.76	F8III	6380[FSF]	2.96[FSF]	–0.66[FSF]	0.36	0.47	0.10
IRL164	HD 221246	23 30 07.41	+49 07 59.31	K3III	4359[FSF]	2.58[ST]	–0.35[FSF]	0.73	0.85	0.13
IRL163	HD 221246 ext	23 30 07.41	+49 07 59.31	K3III	4308[FSF]	1.98[FSF]	–0.19[FSF]	0.67	0.76	0.09
IRL120	HD 222093	23 37 39.55	−13 03 36.86	G9III	4750[FSF]	2.01[FSF]	0.03[FSF]	0.56	0.64	0.09
IRL269	BRI B2339−0447	23 42 02.75	−04 31 04.88	M7III	3425[CTR]	0.84[ST]	0.00[ST]	0.93	1.39	0.46

Table A.2. Additional stars from the MILES and CaT stellar libraries used as templates in the determination of the IRTF stellar temperatures, gravities and metallicities.

Star	$T_{\rm eff}$ (K)	$\log g$	$[Z/Z_{\odot}]$
BD442051	3696	5.00	−1.50
HD058521	3238	0.00	−0.19
HD069267	4043	1.51	−0.12
HD073394	4500	1.10	−1.38
HD073593	4717	2.25	−0.12
HD076813	6072	4.20	−0.82
HD078712	3202	0.00	−0.11
HD079452	4829	2.35	−0.84
HD081192	4705	2.50	−0.62
HD083425	4120	2.00	−0.35
HD083618	4231	1.74	−0.08
HD083632	4214	1.00	−1.39
HD087737	9625	1.98	−0.04
HD095735	3551	4.90	−0.20
HD096360	3550	0.50	−0.58
HD099998	3863	1.79	−0.16
HD103095	5025	4.56	−1.36
HD107213	6298	4.01	0.36
HD111631	3785	4.75	0.10
HD114038	4530	2.71	−0.04
HD114961	3012	0.00	−0.81
HD119228	3600	1.60	0.30
HD119667	3700	1.00	−0.35
HD120933	3820	1.52	0.50
HD121299	4710	2.64	−0.03
HD123657	3450	0.85	0.00
HD126327	2819	0.00	−0.58
HD130705	4336	2.10	0.41
HD131430	4190	2.18	0.04
HD134063	4885	2.34	−0.69
HD136726	4120	2.03	0.07
HD137704	4095	1.97	−0.27
HD138481	3890	1.64	0.20
HD145675	5264	4.66	0.34
HD147923	3600	0.80	−0.19
HD148783	3279	0.20	−0.06
HD149661	5168	4.63	0.04
HD154733	4279	2.10	0.00
HD164058	3930	1.26	−0.05
HD167768	5235	1.61	−0.68
HD168720	3810	1.10	0.00
HD184499	5738	4.02	−0.66
HD184786	3467	0.60	−0.04
HD185144	5260	4.55	−0.24
HD187216	3500	0.40	−2.48
HD191277	4459	2.71	0.30
HD199799	3400	0.30	−0.24
HD232078	4008	0.30	−1.73

Notes. The stellar parameters were determined by Cenarro et al. (2007).

References

Allard, F., Homeier, D., Freytag, B., & Sharp, C. M. 2012, in EAS Pub. Ser., 57, 3
Alonso, A., Arribas, S., & Martinez-Roger, C. 1996, A&AS, 117, 227
Alonso, A., Arribas, S., & Martinez-Roger, C. 1999, A&AS, 140, 261
Aringer, B., Girardi, L., Nowotny, W., Marigo, P., & Lederer, M. T. 2009, A&A, 503, 913
Bessell, M. S., Castelli, F., & Plez, B. 1998, A&A, 333, 231
Burstein, D., Faber, S. M., Gaskell, C. M., & Krumm, N. 1984, ApJ, 287, 586
Cappellari, M., & Emsellem, E. 2004, PASP, 116, 138
Cayrel de Strobel, G., Soubiran, C., Friel, E. D., Ralite, N., & Francois, P. 1997, A&AS, 124, 299
Cenarro, A. J., Gorgas, J., Cardiel, N., et al. 2001, Astrophys. Space Sci. Suppl., 277, 319
Cenarro, A. J., Peletier, R. F., Sánchez-Blázquez, P., et al. 2007, MNRAS, 374, 664
Cesetti, M., Pizzella, A., Ivanov, V. D., et al. 2013, A&A, 549, A129
Coelho, P., Bruzual, G., Charlot, S., et al. 2007, MNRAS, 382, 498
Colina, L., Bohlin, R. C., & Castelli, F. 1996, AJ, 112, 307
Conroy, C., & van Dokkum, P. 2012, ApJ, 747, 69
Conroy, C., Gunn, J. E., & White, M. 2009, ApJ, 699, 486
Cox, C. 1999, Allen's Astrophysical Quantities (Springer)
Cushing, M. C., Rayner, J. T., & Vacca, W. D. 2005, ApJ, 623, 1115
Falcón-Barroso, J., Sánchez-Blázquez, P., Vazdekis, A., et al. 2011, A&A, 532, A95
Frogel, J. A., Persson, S. E., Matthews, K., & Aaronson, M. 1978, ApJ, 220, 75
Gray, R. O., & Corbally, J., C. 2009, Stellar Spectral Classification (Princeton University Press)
Houdashelt, M. L., Bell, R. A., Sweigart, A. V., & Wing, R. F. 2000, AJ, 119, 1424
Koleva, M., Prugniel, P., De Rijcke, S., Zeilinger, W. W., & Michielsen, D. 2009, Astron. Nachr., 330, 960
Kučinskas, A., Hauschildt, P. H., Ludwig, H.-G., et al. 2005, A&A, 442, 281
Lançon, A., & Wood, P. R. 2000, A&AS, 146, 217
Lanz, T., & Hubeny, I. 2003, ApJS, 146, 417
Lanz, T., & Hubeny, I. 2007, ApJS, 169, 83
Lejeune, T., Cuisinier, F., & Buser, R. 1997, A&AS, 125, 229
Lejeune, T., Cuisinier, F., & Buser, R. 1998, A&AS, 130, 65
Maraston, C. 2005, MNRAS, 362, 799
Maraston, C., Strömbäck, G., Thomas, D., Wake, D. A., & Nichol, R. C. 2009, MNRAS, 394, L107
Mármol-Queraltó, E., Cardiel, N., Cenarro, A. J., et al. 2008, A&A, 489, 885
Meneses-Goytia, S., & Peletier, R. F. 2012, in IAU Symp. 284, eds. R. J. Tuffs, & C. C. Popescu, 32
Meneses-Goytia, S., Peletier, R. F., Trager, S. C., & Vazdekis, A. 2015, A&A, 582, A97 (Paper II)
Mouhcine, M., & Lançon, A. 2002, A&A, 393, 149
Pecaut, M. J., & Mamajek, E. E. 2013, ApJS, 208, 9
Peletier, R. 1989, Ph.D. Thesis, Rijksuniversiteit Groningen
Peterson, R. C. 1977, in BAAS, 9, 604
Pickles, A. J. 1998, PASP, 110, 863
Rajpurohit, A. S., Reylé, C., Allard, F., et al. 2013, A&A, 556, A15
Rayner, J. T., Cushing, M. C., & Vacca, W. D. 2009, ApJS, 185, 289
Sánchez-Blázquez, P., Gorgas, J., Cardiel, N., & González, J. J. 2006, A&A, 457, 787
Schiavon, R. P., Caldwell, N., & Rose, J. A. 2004, AJ, 127, 1513
Soubiran, C., Le Campion, J.-F., Cayrel de Strobel, G., & Caillo, A. 2010, A&A, 515, A111
Straizys, V., & Kuriliene, G. 1981, Ap&SS, 80, 353
Vazdekis, A., Cenarro, A. J., Gorgas, J., Cardiel, N., & Peletier, R. F. 2003, MNRAS, 340, 1317
Vazdekis, A., Sánchez-Blázquez, P., Falcón-Barroso, J., et al. 2010, MNRAS, 404, 1639
Westera, P., Lejeune, T., Buser, R., Cuisinier, F., & Bruzual, G. 2002, A&A, 381, 524
Worthey, G., Faber, S. M., & Gonzalez, J. J. 1992, ApJ, 398, 69
Worthey, G., Faber, S. M., Gonzalez, J. J., & Burstein, D. 1994, ApJS, 94, 687
Yamada, Y., Arimoto, N., Vazdekis, A., & Peletier, R. F. 2006, ApJ, 637, 200