Testing different methods for atmospheric parameters determination. The case study of the Am star HD 71297*

G. Catanzaro,† V. Ripepi and H. Bruntt

1INAF-Osservatorio Astrofisico di Catania, Via S. Sofia 78, I-95123, Catania, Italy
2INAF-Osservatorio Astronomico di Capodimonte, Via Moiariello 16, I-80131, Napoli, Italy
3Department of Physics and Astronomy, Building 1520, Aarhus University, 8000 Aarhus C, Denmark

ABSTRACT
In this paper, we present a detailed spectroscopic analysis of the suspected marginal Am star HD 71297. Our goal is to test the accuracy of two different approaches to determine the atmospheric parameters: effective temperature, gravity, projected rotational velocity and chemical abundances. The methods used in this paper are: classical spectral synthesis and the Versatile Wavelength Analysis (VWA) software.

Since our star is bright and very close to the Sun, we were able to determine its effective temperature and gravity directly through photometric, interferometric and parallax measurements. The values found were taken as reference to which we compare the values derived by spectroscopic methods. Our analysis leads us to conclude that the spectroscopic methods considered in this study to derive fundamental parameters give consistent results, if we consider all the sources of experimental errors, that have been discussed in the text. In addition, our study shows that the spectroscopic results are quite as accurate as those derived from direct measurements.

As for the specific object analysed here, according to our analysis, HD 71297 has chemical abundances not compatible with the previous spectral classification. We found moderate underabundances of carbon, sodium, magnesium and iron-peak elements, while oxygen, aluminium, silicon, sulphur and heavy elements (Z ≥ 39) are solar in content. This chemical pattern has been confirmed by the calculations performed with both methods.

Key words: stars: early-type – stars: fundamental parameters – stars: individual: HD 71297.

1 INTRODUCTION
The current era is characterized by an enormous growth of stellar data of different nature. The advent of space missions, such as CoRoT (Convection, Rotation and planetary Transits; Baglin et al. 2007) and Kepler (Borucki et al. 1997), designed to obtain precise photometry for an impressive number of stars, has led astronomers to undertake several ground-based spectroscopic campaigns in order to get as accurate as possible fundamental parameters such as effective temperature, surface gravity, projected rotational velocity and metallicity. The analysis of this huge amount of data is possible, on reasonably short time-scales, only through the use of automatic or semi-automatic procedures.

Among the various targets observed by Kepler, Am stars are assuming an ever growing importance. In fact, it was once thought that Am stars did not pulsate, and that the explanation for this is that atomic diffusion is expected to drain helium from the He II driving zone. More intensive observations have revealed that this picture is not correct and several Am stars are known to pulsate from ground-based observations [based on super Wide Angle Search for Planets (WASP) photometry; see Smalley et al. 2011] as well as from Kepler satellite data (see Balona et al. 2011). In the last paper, the authors showed that an accurate measure of the location of the pulsating Am stars in the Hertzsprung-Russell (HR) diagram is crucial to pin down effectively the pulsation models and to put observational constraint on the instability strip for pulsation in Am stars. However, for most of the investigated objects, a modern determination of the stellar parameters such as effective temperatures, gravities and chemical abundances, based on high-resolution spectroscopy is still lacking. To fill this gap, we have already started a spectroscopic campaign devoted to obtain high-resolution spectra of Am stars, being the first data obtained with the spectrograph SARG installed at the Italian telescope TNG. Our purpose in the near future is to analyse this growing amount of spectra to derive accurate stellar parameters for the investigated objects in the shortest possible time.

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† E-mail: gca@oact.inaf.it
There are several examples in the literature of papers regarding various methods for automatic (or semi-automatic) spectroscopic analysis (Ersparmer & North 2003; Niemczura, Morel & Aerts 2009; Lehmann et al. 2011; Tkachenko et al. 2012). However, it is important to ascertain the accuracy of the derived parameters obtained using different methods. A few recent papers have partially addressed this problem, reporting that significant differences can be found both in the derived stellar parameters (see e.g. Fossati et al. 2011) and/or in the estimated uncertainties in these quantities (see e.g. Molenda-Zakowicz et al. 2010).

With the aim of understanding how accurately we can derive the stellar parameters and the HR location for our sample of Am stars, we decided to concentrate our efforts on comparing the results that can be obtained by analysing the high-resolution spectrum for one star in our sample with the two methods available to us: (i) classical spectral synthesis (see Catanzaro et al. 2011; Catanzaro & Balona 2012, and references therein) and (ii) Versatile Wavelength Analysis (VWA; see Bruntt et al. 2010a,b, and references therein).

To carry out this exercise, we choose to analyse in detail the Am star HD 71297. This is the most suitable object in our sample because it is very bright ($V = 5.58$ mag) and the SARG at TNG spectrum has a very good signal-to-noise ratio (S/N). Moreover, HD 71297’s brightness allowed us to find very useful observational data in the literature, including an accurate Hipparcos parallax and interferometric measures which allow us to estimate independently from spectroscopy the stellar parameters. Thus, the main goal of this paper is to ascertain if the two quoted methods of quantitative spectral analysis lead to different or, on the contrary, to comparable results when used to exploit exactly the same observational material.

2 THE TARGET. THE AM: STAR HD 71297

HD 71297 has been classified as suspected marginal Am star by Cowley (1968), with a spectral type of A5m: (colon denotes its marginal nature). We remind readers the definition of marginal Am star as an Am star in which there is a difference of less than five subclasses between the K-line and the metal line spectral types, and in which the line strength anomalies are mild. Cowley (1968) concluded that the star exhibits only weak metallic lines, looking like the spectrum of $\beta$ Ari. This classification has been confirmed one year later by Cowley et al. (1969).

Abt & Levy (1985) searched for binarity among a sample of 60 Am stars and concluded that HD 71297 may be variable in radial velocity with a period of a hundred days. They assigned the spectral type of K5haA9mF0 to HD 71297.

This star has also been studied by Guthrie (1987) who derived atmospheric parameters, $T_{\text{eff}} = 7900$ K, $\log g = 4.2$, and calcium abundance, $\log N(\text{Ca}) = 6.33$, expressed in a scale in which $\log N(H) = 12.0$, that is practically the solar value. Later on, Kuenzli & North (1998) revisited the star, finding it a little bit cooler and less evolved, $T_{\text{eff}} = 7712$ K and $\log g = 4.06$, but still with solar calcium abundance.

No other studies have been found in the recent literature, especially no detailed analysis of the chemical pattern of its atmosphere. Thus, we chose this object as a benchmark for the two methods of analysis we would like to compare in this paper.

3 OBSERVATIONS AND DATA REDUCTION

Spectroscopic observations of HD 71297 were carried out with the SARG spectrograph, which is installed at the TNG, located in La Palma (Canarias Islands, Spain). SARG is a high-resolution cross-dispersed echelle spectrograph (Gratton et al. 2001) that operates in both single-object and long slit (up to 26) observing modes and covers a spectral wavelength range from 370 nm up to about 1000 nm, with a resolution ranging from $R = 29000$ to 164 000.

Our spectra were obtained on 2011, February 21 at $R = 57000$ using two grisms (blue and yellow) and two filters (blue and yellow). These were used in order to obtain a continuous spectrum from 3600 to 7900 Å with significant overlap in the wavelength range between 4620 and 5140 Å. We acquired the spectra for the star with an exposure time of 120 s and a S/N of at least 100 per pixel in the continuum. For example, in the region centred around the Mg triplet at 5170 Å the measured S/N is about 120.

The reduction of all spectra, which included the subtraction of the bias frame, trimming, correcting for the flat-field and the scattered light, the extraction for the orders, and the wavelength calibration, was done using the National Optical Astronomy Observatory (NOAO)/IRAF packages. The IRAF package $\text{rvcorrect}$ was used to make the velocity corrections due to Earth’s motion to transform the spectra to the barycentric rest frame.

4 STELLAR PARAMETERS FROM PHOTOMETRY, INTERFEROMETRY AND PARALLAX

Before starting with the analysis of the spectrum of HD 71297, it is extremely important to estimate the stellar parameters, mainly $T_{\text{eff}}$ and $\log g$, through independent methods, such as those based on intermediate-band photometry, parallax, interferometry etc. It is useful to have: (i) a reliable starting point for the spectroscopic analysis and (ii) a trustworthy and accurate independent evaluation of the stellar fundamental parameters to compare with.

4.1 Evaluation of $T_{\text{eff}}$ and $\log g$ from Strömgren and Geneva photometry

A first estimate of $T_{\text{eff}}$ and $\log g$ for HD 71297 can be obtained from the Strömgren photometry: $V = 5.607 \pm 0.002$, $b - y = 0.123 \pm 0.002$, $m_1 = 0.197 \pm 0.004$, $c_1 = 0.833 \pm 0.006$, $\beta = 2.831 \pm 0.003$ (Hauck & Mermillod 1998). However, it is important to check the value of $V$-band magnitude because HD 71297 is a (low-amplitude) variable star (see Balona et al. 2011). A safe average $V$ magnitude can be derived from the time series photometry in the Hipparcos ($H_p$) and Tycho ($V_T$) photometric systems. Including the uncertainties in the transformations to the Johnson $V$ system (Bessell 2000), we get $V = 5.59 \pm 0.01$ and $5.60 \pm 0.01$ mag. Finally, an additional independent measure was reported by Kuenzli & North (1998) who measured $V = 5.604 \pm 0.008$ mag. On this basis, we adopted a value of $V = 5.60 \pm 0.01$ mag for HD 71297. This value is consistent within the errors with all the above quoted evaluations.

The other Strömgren indices should be less uncertain with respect to $V$ band; however, it is likely that the errors are somewhat underestimated.

We adopted an updated version of the TEMPO2 software (Rogers 1995) to estimate $T_{\text{eff}}$ and $\log g$ by using the calibrations present in the package. We did not consider the older calibration by Balona (1984), Moon (1985) and Moon & Dworetsky (1985),

1 IRAF is distributed by the NOAO, which is operated by the Association of Universities for Research in Astronomy, Inc.
2 Available through http://www.univie.ac.at/assap/manuals/tipstricks/templogg-localaccess.html
but only the more recent ones by Napiwotzki et al. (1993), Ribas et al. (1997) and Kuenzli & North (1998). Note that the last \( \text{Calibration} \) is for the Geneva \( UBVb_1B_2V_1G \) system, whose photometry for HD 71297 is provided by Rufener (1988). These results are summarized in the first three rows of Table 1. In addition, we considered the results by Smalley & Kupka (1997) and Heiter et al. (2002) who provided \( uvby \) grids based on the Kurucz model atmospheres but with different treatment of the convection. In particular, we report in Table 1 the \( T_{\text{eff}} \) and \( \log g \) estimated by interpolating the Smalley & Kupka (1997) grids that were built using the Canuto & Mazzitelli (1991) convection treatment. Similarly, the last two columns of Table 1 list the stellar parameters obtained using two choices for the grids\(^3\) by Heiter et al. (2002): (i) standard mixing-length theory (MLT)\(^4\) with \( \alpha = 0.5 \); (ii) the Canuto et al. (1996) treatment of the convection. In all these cases, the error associated with the parameters was imposed as half the width of the grid. An inspection of Table 1 reveals some dispersion among the various calibrations both in \( T_{\text{eff}} \) and \( \log g \), even if the last three values are absolutely equivalent within the errors. Quantitatively, a simple average of the results gives \( T_{\text{eff}} = 7800 \pm 90 \text{ K} \) and \( \log g = 4.17 \pm 0.17 \text{ dex} \).

As for the interstellar reddening, \( \Delta \text{TEMPOlogg} \) gives as a result \( E(B - V) = 0.009 \pm 0.003 \text{ mag} \). This value is probably non-significant, because of the very low value of both reddening and associated uncertainty (underestimated in our opinion). Since the star is only 50 pc far from the Sun (see the next subsection), it is acceptable to neglect the effect of the interstellar absorption. This assumption was also confirmed a posteriori by looking into the spectrum of HD 71297 for the interstellar Na \( \dagger \) lines at 5890.0 and 5895.9 Å which can be used to estimate the interstellar reddening (see Munari & Zwitter 1997). Indeed, these lines are practically undetectable. To conclude, in the following analysis we have neglected the interstellar reddening.

### 4.2 Evaluation of the stellar parameters from photometry, parallax and interferometry

The \( \text{Hipparcos} \) parallax for HD 71297, \( \pi = 19.99 \pm 0.38 \text{ mas} \) (van Leeuwen 2007), allows us to estimate with the excellent accuracy of 2 per cent the distance of this object: \( d = 50 \pm 1 \text{ pc} \). It is then straightforward to calculate the visual absolute magnitude of the target: \( M_V = 2.105 \pm 0.045 \text{ mag} \). To derive the luminosity we need to evaluate first the visual bolometric correction \( B_{\text{V}} \). To this aim, we adopted the models by Bessell, Castelli & Plez (1998) where it is assumed that \( M_{\text{bol}, \odot} = 4.74 \text{ mag} \).\(^5\) We then get

\[
BC_{\text{V}} = 0.03 \pm 0.01 \text{ mag for HD 71297. We note that to obtain this value we interpolated the Bessell et al. (1998) tables by using as input the \( T_{\text{eff}} \) and \( \log g \) obtained from the photometry. The error was conservatively assumed to be 0.01 mag to take into account the observed dispersion of the photometrically derived \( T_{\text{eff}} \) and \( \log g \).

We have now estimated all the quantities needed to calculate the luminosity of HD 71297: \( \log (L/L_{\odot}) = 1.04 \pm 0.02 \).\(^6\)

Another very important piece of information is represented by the angular diameter of HD 71297, which was published by Lafraisse et al. (2010): \( \alpha = 0.367 \pm 0.025 \text{ mas} \). By using this value, together with the distance derived from \( \text{Hipparcos} \) parallaxes, \( d = 50 \pm 1 \text{ pc} \), it is straightforward to evaluate the radius of our target \( R = 1.97 \pm 0.14 R_{\odot} \).

With the observational data available for HD 71297, the most convenient way to estimate the effective temperature is from the definition of surface brightness as given in equation 14.8 of Gray (2005). After simple algebra, we get

\[
\log T_{\text{eff}} = c - 0.1 \cdot V + 0.1 \cdot BC_{\text{V}} - 0.5 \log \theta_R, \quad (1)
\]

where \( \theta_R \) is the angular radius in arcsec and \( c \) is a constant given by

\[
c = \log T_{\text{eff}}^\odot + 0.1 \cdot m_V^\odot - 0.1 \cdot BC_{\odot} + 0.5 \log \theta_R^\odot. \quad (2)
\]

To estimate \( c \) we used the Sun ‘constants’ reported by Bessell et al. (1998): \( T_{\text{eff}}^\odot = 5781 \pm 4 \text{ K} \), \( m_V^\odot = -26.76 \pm 0.01 \text{ mag} \), \( BC_{\odot} = -0.07 \pm 0.01 \text{ mag} \) and \( \theta_R^\odot = 959.61 \pm 0.01 \text{ arcsec} \). Thus, \( c = 2.58405 \pm 0.00140 \), and, from equation (1):

\[
T_{\text{eff}} = 7850 \pm 280 \text{ K}.
\]

In the error budget, the most important contributor is the angular radius (diameter) at the \(~3.5\) per cent level, being the contribution of the other quantities practically negligible. The effective temperature derived here is almost indistinguishable from that estimated directly from Strömgren and Geneva photometry, but with a larger uncertainty. Nevertheless, this evaluation appears robust, since it is based on different kind of independent measures (photometry, interferometry). Moreover, also the uncertainty can be calculated in a reliable and physical way. Hence, we decided to take a weighted average of the effective temperatures obtained with the two methods as the value to be used as a reference for comparison with spectroscopy. As a result, we obtain \( T_{\text{eff}} = 7810 \pm 90 \text{ K} \).

To estimate \( \log g \), it is convenient to use the following expression that can be easily derived from the definition of \( g \) and from the Stefan–Boltzmann relation:

\[
\log g = 4 \log(T_{\text{eff}}/T_{\text{eff}}^\odot) + \log(M/M_{\odot}) + 2 \log(\pi) + 0.4(V + BC_{\text{V}} + 0.26) + 4.44, \quad (3)
\]

\( ^3 \)These grids are available on the NEMO site www.univie.ac.at/nemo/geom/divc.cgi

\( ^4 \)Defined as the ratio \( \alpha = l/H_p \) of convective scalelength \( l \) and local pressure scale height \( H_p \).

\( ^5 \)To take into account the uncertainty on the bolometric magnitude of the Sun, in all the calculations we associated an error of 0.01 mag to this value.

\( ^6 \)Whenever possible, we have summed in quadrature the uncertainties on the single quantities when propagating the errors.

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Table 1: Evaluations of \( T_{\text{eff}} \) and \( \log g \) values of HD 71297 on the basis of various photometric systems (see the text for details).

| Photometry   | \( T_{\text{eff}} \) | \( \log g \) | Calibration                  |
|--------------|----------------------|--------------|------------------------------|
| \( uvby - \beta \) | 7700 ± 40            | 4.06 ± 0.04  | Napiwotzki, Schoenbener & Wenske (1993) |
| \( uvby - \beta \) | 7970 ± 30            | 4.28 ± 0.04  | Ribas et al. (1997)          |
| \( UBVb_1B_2V_1G \) | 7770 ± 80            | 4.46 ± 0.06  | Kuenzli & North (1998)       |
| \( uvby - \beta \) | 7770 ± 125           | 4.08 ± 0.125 | Smalley & Kupka (1997)       |
| \( uvby - \beta \) | 7800 ± 125           | 4.06 ± 0.125 | Heiter et al. (2002)         |
| \( uvby - \beta \) | 7780 ± 125           | 4.06 ± 0.125 | Heiter et al. (2002) using Canuto, Goldman & Mazzitelli (1996) |

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3 These grids are available on the NEMO site www.univie.ac.at/nemo/geom/divc.cgi

4 Defined as the ratio \( \alpha = l/H_p \) of convective scalelength \( l \) and local pressure scale height \( H_p \).

5 To take into account the uncertainty on the bolometric magnitude of the Sun, in all the calculations we associated an error of 0.01 mag to this value.

6 Whenever possible, we have summed in quadrature the uncertainties on the single quantities when propagating the errors.
where the various terms of the equation have the usual meaning and \( M/M_\odot \) is the ratio of mass of the star over mass of the Sun. Before using equation (3), we have to evaluate the mass of HD 71297. This can be safely done by adopting the calibration mass–\( M_V \) (valid for luminosity class V stars) by Malkov (2007) that was derived on the basis of a large sample of eclipsing binaries stars. Hence, by using our \( M_V \) estimate, we evaluated \( \log(M/M_\odot) = 0.248 \pm 0.05 \) dex (or \( M/M_\odot = 1.77^{+0.12}_{-0.16} \)), where the error is largely conservative and completely dominated by the dispersion of the mass–\( M_V \) relation.

Finally, applying equation (3), we obtain \( \log g = 4.17 \pm 0.06 \), again, in excellent agreement with the purely photometric evaluation but with a much smaller uncertainty. We will then use this value for comparison with spectroscopy.

Before closing this section, for completeness, it is worth estimating the age of HD 71297, taking advantage of the \( \log T_{\text{eff}} \) and \( \log(L/L_\odot) \) values estimated in this section. The location of the star in the HR diagram, together with some evolutionary tracks computed for the solar metallicity \( Z = 0.019 \) (Girardi et al. 2000), is shown in Fig. 1. Also shown are isochrones computed by Marigo et al. (2008) for the same \( Z \) and for ages ranging from \( \log t = 8.85 \) to 8.95, in steps of 0.05 (in years). The location of the star indicates a mass of \( M \approx 1.75 \pm 0.05 \) M\(_\odot\) (in perfect agreement with the value adopted above) and an age of \( t \approx 790 \pm 90 \) Myr.

In Table 2, we summarized all the astrophysical quantities for HD 71297 evaluated independently from spectroscopy.

![Figure 1. Location of HD 71297 in the HR diagram together with evolutionary tracks and isochrones for \( \log t \) ranging from 8.85 to 8.95 (step 0.05 and \( t \) in years).](image)

### Table 2. Astrophysical quantities for HD 71297 evaluated independently from spectroscopy.

| Parameter | Value          |
|-----------|----------------|
| \( \pi \) | 19.99 ± 0.38   |
| \( \alpha \) | 0.367 ± 0.025  |
| \( M_V \) (mag) | 2.105 ± 0.045 |
| \( M_{\text{bol}} \) (mag) | 2.14 ± 0.04   |
| \( T_{\text{eff}} \) (K) | 7810 ± 90     |
| \( \log(L/L_\odot) \) (dex) | 1.04 ± 0.02   |
| \( \log g \) (dex) | 4.17 ± 0.06   |
| \( R/R_\odot \) | 1.97 ± 0.14   |
| \( M/M_\odot \) | 1.77 ± 0.12   |
| Age (Myr) | 790 ± 90      |

5 ATMOSPHERIC PARAMETERS FROM SPECTROSCOPY

In this section, we will present separately the results from the analysis of the high-resolution spectra of HD 71297 as obtained with the two different approaches quoted in Section 1. We want to stress that the two analysis have been performed by using the same spectrum, prepared as described in Section 3. In this way, we can be sure that any differences arising during the analysis will not be attributed to the quality of the data, but directly to the method itself.

5.1 Stellar parameters and abundance analysis with classical spectral synthesis

This approach was already discussed in Catanzaro et al. (2011) and Catanzaro & Balona (2012), and references therein. Thus, here we briefly summarize the principal features of this method. In order to determine the optimal parameters, we minimize the difference between the observed and synthetic spectrum. Thus, we minimize

\[
\chi^2 = \frac{1}{N} \sum \left( \frac{I_{\text{obs}} - I_{\text{th}}}{\delta I_{\text{obs}}} \right)^2,
\]

where \( N \) is the total number of points, \( I_{\text{obs}} \) and \( I_{\text{th}} \) are the intensities of the observed and computed profiles, respectively, and \( \delta I_{\text{obs}} \) is the photon noise. Spectral synthesis were generated in three steps. First, we computed a local thermodynamical equilibrium (LTE) atmospheric model using the \textit{ATLAS9} code (Kurucz 1993). The stellar spectrum was then synthesized using \textit{SYNTHE} (Kurucz & Avrett 1981). Finally, the spectrum was convolved with the instrumental and rotational profiles.

As starting values of \( T_{\text{eff}} \) and \( \log g \), we used the values derived in the previous section.

To decrease the number of parameters, we computed the \( v \sin i \) of HD 71297 by matching synthetic line profiles from \textit{SYNTHE} to a number of metallic lines. The Mg I triplet at \( \lambda \lambda 5167–5183 \) Å was particularly useful for this purpose. The best fit was obtained for \( v \sin i = 7.0 \pm 0.5 \) km s\(^{-1}\). This value is slightly lower than the one published by Royer et al. (2002) of \( v \sin i = 11 \) km s\(^{-1}\).

Uncertainties in \( T_{\text{eff}} \), \( \log g \) and \( v \sin i \) were estimated by the change in parameter values which leads to an increase of \( \chi^2 \) by unity (Lampton, Margon & Bowyer 1976).

To determine stellar parameters as consistently as possible with the actual structure of the atmosphere, we performed the abundance analysis by the following iterative procedure:

(i) \( T_{\text{eff}} \) is estimated by computing the \textit{ATLAS9} model atmosphere which gives the best match between the observed \( H_\alpha \) and \( H_\beta \) lines profile and those computed with \textit{SYNTHE} (see Fig. 2). The model was computed using solar opacity distribution function (ODF) and microturbulence velocity \( \xi = 2.4 \pm 0.5 \) km s\(^{-1}\), the latter value has been calculated following the calibration \( \xi = \xi(T_{\text{eff}}, \log g) \) published by Allende Prieto et al. (2004). These two lines are the only useful lines for our purpose since they are located far from the echelle orders edges so that it was possible to safely recover the whole profiles. The simultaneous fitting of two lines led to a final solution as the intersection of the two \( \chi^2 \) isosurfaces. Another source of uncertainties is due to the difficulties in normalization as is always challenging for Balmer lines in echelle spectra. We quantified the error introduced by the normalization in at least 100 K, that we summed in quadrature with the error obtained by the fitting procedure. The final result is

\[
T_{\text{eff}} = 7500 \pm 180 \text{ K}.
\]
The surface gravity was estimated from line profile fitting of Mg I lines with developed wings. This method is based on the fact that the wings of the Mg I triplet at λλ 5167, 5172 and 5183 Å lines are very sensitive to log g variations. In practice, we have first derived the magnesium abundance through the narrow Mg I lines at λλ 4571, 5528, 5711 Å and the Mg II λ 7877 Å, and then we fitted the wings of the triplet lines by fine tuning the log g value. The magnesium abundance we got from these lines was log \( \frac{N_{\text{Mg}}}{N_{\text{tot}}} \) = -4.62 ± 0.14.

To derive log g by fitting spectral wings is essential to take into account very accurate measurements of the atomic parameters of the transitions, i.e. log \( g_f \) and the radiative, Stark and Van der Waals damping constants. Regarding log \( g_f \) we used the values of Aldenius et al. (2007), Van der Waals damping constant is that calculated by Barklem, Piskunov & O’Mara (2000) (log \( g_{\text{Waals}} \) = -7.37), the Stark damping constant is from Fossati et al. (2011) (log \( g_{\text{Stark}} \) = -5.44) and the radiative damping constant is from NIST data base (log \( g_{\text{rad}} \) = 7.99).

This procedure results in the final value of log g = 4.0 ± 0.1.

(ii) As a second step we determine the stellar abundances by computing a synthetic spectrum that reproduced the observed one. Therefore, we divide our spectrum into several intervals, 25 Å wide each, and derived the abundances in each interval by performing a χ² minimization of the difference between the observed and synthetic spectrum. The minimization algorithm has been written in IDL language, using the amoeba routine. We adopted lists of spectral lines and atomic parameters from Castelli & Hubrig (2004), who updated the parameters listed originally by Kurucz & Bell (1995).

For each element, we calculated the uncertainty in the abundance to be the standard deviation of the mean obtained from individual determinations in each interval of the analysed spectrum. For elements whose lines occurred in one or two intervals only, the error in the abundance was evaluated by varying the effective temperature and gravity within their uncertainties given in Table 3.

| Element | log \( \frac{N_{\text{Mg}}}{N_{\text{tot}}} \) | log \( g \) | log \( g_f \) |
|---------|-----------------|-----------------|-----------------|
| C       | -3.81 ± 0.12    | -3.85 ± 0.08    | 7               |
| O       | -3.29 ± 0.10    | -3.85 ± 0.08    | 7               |
| Na      | -6.11 ± 0.10    | -5.95 ± 0.10    | 2               |
| Mg      | -4.62 ± 0.14    | -4.77 ± 0.15    | 1               |
| Al      | -5.59 ± 0.08    | -5.56 ± 0.15    | 1               |
| Si      | -4.59 ± 0.13    | -4.60 ± 0.08    | 8               |
| S       | -5.00 ± 0.17    | -4.88 ± 0.10    | 2               |
| Ca      | -5.62 ± 0.15    | -5.90 ± 0.07    | 9               |
| Sc      | -9.19 ± 0.16    | -9.06 ± 0.06    | 4               |
| Ti      | -7.14 ± 0.10    | -7.20 ± 0.07    | 24              |
| V       | -8.28 ± 0.21    | -8.33 ± 0.15    | 1               |
| Cr      | -6.48 ± 0.14    | -6.55 ± 0.07    | 26              |
| Mn      | -6.92 ± 0.14    | -7.31 ± 0.09    | 7               |
| Fe      | -4.68 ± 0.15    | -4.72 ± 0.06    | 26              |
| Co      | -7.39 ± 0.08    | -7.21 ± 0.15    | 1               |
| Ni      | -6.13 ± 0.08    | -6.02 ± 0.06    | 26              |
| Cu      | -8.35 ± 0.15    | -8.57 ± 0.15    | 1               |
| Zn      | -7.97 ± 0.04    | -7.93 ± 0.07    | 2               |
| Y       | -9.86 ± 0.11    | -9.82 ± 0.09    | 4               |
| Zr      | -9.35 ± 0.13    | -9.32 ± 0.15    | 1               |
| Ba      | -9.65 ± 0.19    | -9.83 ± 0.15    | 1               |
| La      | -10.78 ± 0.16   | -10.93 ± 0.04   |                |
| Ce      | -10.46 ± 0.19   | -10.70 ± 0.15   | 1               |
| Nd      | -10.58 ± 0.16   | -10.61 ± 0.04   |                |

Table 3. Comparison among atmospheric parameters and abundances derived by spectral synthesis modelling and by vwa approach. N denotes the number of lines used with vwa package. \( T_{\text{eff}} \) is in Kelvin, log g is in dex, while \( v \sin i \) and \( \xi \) are in Km/s. Abundances are expressed in the form log \( \frac{N_{\text{Mg}}}{N_{\text{tot}}} \) An asterisk indicate that these uncertainties were re-determined in Sect. 6.
(Kupka et al. 1999). We note that we used model atmospheres interpolated in the fine grid published by Heiter et al. (2002). These models rely on the original ATLAS9 code by Kurucz (1993) but use a more advanced convection description (Kupka 1996) based on the works by Canuto & Mazzitelli (1992).

A thorough description of how VWA works can be found in Bruntt et al. (2004) and Bruntt, De Cat & Aerts (2008). Here, we recall only the main steps of the analysis.

(i) **Normalization**: the first step consists in an accurate normalization of the spectrum. This can be achieved by adopting a synthetic spectrum (with approximately the same stellar parameters as the target) as a template to properly identify (in the GUI) suitable regions to anchor the continuum of the observed spectrum.

(ii) **Setup and line selection**: atomic parameters and a preliminary model are setup on the basis of initial values for the stellar parameters. The line selection can be carried out either in automatic or manual way. We first searched for good lines (i.e. with low blending) in an automatic way, then we checked the result visually line by line on the GUI.

(iii) **Fit of the lines and check of the result**: each line is fitted by iteratively changing the abundance to match the equivalent width (EW) of the observed and calculated spectrum. The fitted lines are inspected in the GUI, problems with the continuum level or asymmetries in the line are readily identified, and these lines are discarded. This is done automatically by calculating the $\chi^2$ of the fit in the core and the wings of the lines. This is followed by a manual inspection of the fitted lines. Fig. 4 displays a few selected lines and the relative fits to demonstrate the quality of the observed data (narrow lines) and the fit with VWA (thick lines).

(iv) **Iterative estimate of $T_{\text{eff}}$, log $g$ and $\xi$**: the atmospheric parameters and the microturbulence were then refined in several steps. This was done by minimizing the correlations between the abundance of [Fe I/H] lines and EW and excitation potential (EP), and requiring good agreement between the abundances of [Fe I/H] and [Fe II/H] (the difference in abundance: $A(\text{Fe I}) - A(\text{Fe II})$ is often referred as ‘ionization balance’). This task is accomplished by inspecting the results on the GUI and calculating the needed models as required (see Fig. 5).

(v) **Chemical abundance**: on the basis of the atmospheric parameters determined from [Fe I/H] and [Fe II/H], the mean abundances for all the elements with good lines can be finally calculated.

In Fig. 5, we show the abundances of Fe for the best model ($T_{\text{eff}} = 7700 \pm 150$ K; log $g = 4.39 \pm 0.06$ dex; $v\sin i = 7.0 \pm 1$ km s$^{-1}$ and $\xi = 2.4 \pm 0.2$ km s$^{-1}$) and for a model with log $g$ decreased by 0.4 dex, i.e. a value approximately equal to that evaluated above with the Mg I triplet. The abundances are shown versus EW and EP. The open circles are Fe I and the solid circles are Fe II lines, respectively. The mean abundance and rms scatter of Fe I and Fe II lines are given in each panel. We note that in the calculation of the ionization balance we adopt the rms of the mean; hence, the uncertainties on the Fe I and Fe II abundances are significantly smaller (e.g. $\sim 0.01$–0.02 dex). Bearing this in mind, a comparison of top and bottom panels in the figure clearly shows that in the VWA framework a value log $g \approx 4.0$ dex is unlikely.

To estimate the uncertainties of the atmospheric parameters, we repeated the above outlined analysis by varying significantly $T_{\text{eff}}$, log $g$ and $\xi$ (one parameter is allowed to vary while the other two are kept fixed). In this way, we can determine when the correlations with EW and EP become significant or the ionization balance begins to deviate from equality (see Bruntt et al. 2008, for details). The same

Figure 3. Observed Mg I triplet with overimposed the synthetic one computed with the fundamental parameters derived in this section.

Figure 4. Shows six Fe II lines in HD 71297 fitted by VWA (continuous line). The wavelengths of the fitted lines are given in the bottom-right corner of each panel.
perturbed models can be used to estimate the uncertainty on the \([\text{Fe/H}]\) value by estimating the variation on its value caused by 1σ perturbation of one parameter among \(T_\text{eff}\), \(\log g\), \(\xi\) and taking fixed the other two (see Bruntt et al. 2008, for a detailed discussion). The resulting three uncertainties were summed in quadrature together with the rms scatter of \(\text{Fe}\) to obtain the final error on \([\text{Fe/H}]\). We underline that this method for the determination of the uncertainties gives only an internal estimate since the absolute temperature scale of the model atmospheres may be systematically wrong. Thus, our measures could show a good precision, but the accuracy is most likely not as good (Bruntt et al. 2010a).

It is important to note that one of the physical assumptions in the models adopted here is LTE, but deviations from LTE start to become important for stars hotter than about 6300 K, especially for stars more metal poor than the Sun. Thus, we have included the NLTE corrections in the present analysis according to Rentzsch-Holm (1996). The correction for neutral iron in our case is \([\text{Fe} \, v/H]_{\text{NLTE}} = [\text{Fe} \, v/H]_{\text{LTE}} + 0.11\) dex. When this correction is applied, \(\text{Fe}\) II (unaffected by NLTE) must be increased by adding +0.2 to \(\log g\). This correction has been applied in the results from VWA reported here.

The stellar parameters and the abundances for iron and the other measured chemical species obtained by means of VWA are shown in Table 3 and in Fig. 6, together with those derived by classical spectral synthesis, expressed in terms of solar values (Grevesse et al. 2010). The uncertainties were calculated as for iron but only for elements with at least three lines measured. For those chemical species for which less than three lines have been identified, we arbitrarily set the errors in 0.15 dex for elements with only one line and 0.10 dex for elements with two lines.

\section{Comparison of the methods}

In the previous section, we have analysed the high-resolution spectrum of the Am star HD 71297 using two different approaches:

\begin{itemize}
\item the classical spectral synthesis and VWA.
\item The results for effective temperature, gravity, \(\psi \sin i\), microturbulence and chemical abundances, obtained with the two methods have been summarized in Table 3. We can now compare between them the stellar parameters obtained with the two quoted methods, taking also into account the completely independent results obtained in Section 4 for \(T_\text{eff}\) and \(\log g\) as summarized in Table 2.
\end{itemize}

First of all, the atmospheric models we used in our calculations are both ATLAS9 based but with different convection zone treatments. In particular, in Section 5.1 it was computed using the classical treatment MLT with fixed \(\alpha = 1.25\) (Castelli, Gratton & Kurucz 1997). In Section 5.2, the model was interpolated in the fine grid by Heiter et al. (2002), which uses a more advanced convection description based on Canuto & Mazzitelli (1992, hereafter CM).

Heiter et al. (2002) investigated the effects of the different convection approaches into the Balmer lines profiles and they concluded that the observed profiles should have an accuracy of at least 0.5 per cent to clearly appreciate the differences between convection models with different efficiency.

In order to quantify these effects on our target, we computed two synthetic H\(\beta\) profiles using the same \(T_\text{eff} = 7700\) K and \(\log g = 4.39\) but with different convection models. We show this comparison in Fig. 7, where in the upper panel we compare the observed blue wing of the H\(\beta\) with overimposed the profiles computed with MLT (red dashed curve) and with CM treatment (blue dot–dashed line). In the bottom panel, we report the difference in percentage between the two models. Since the maximum difference is of the order of 1.5 per cent, indistinguishable at our level of S/N, we conclude that for our target we can neglect the differences arising from the convection models adopted.

To verify the accuracy of this conclusion, we have repeated the calculation for effective temperature, gravity and abundances as described in Section 5.1. Again, we estimated \(T_\text{eff}\) by simultaneous fitting of \(\text{H}\gamma\) and \(\text{H}\delta\) but using ATLAS9 models modified for the CM treatment convection. We obtained \(T_\text{eff} = 7600 \pm 150\) K, that
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The situation is even more complex if we take as a reference the gravity evaluated independently from spectroscopy in Section 2: \( \log g = 4.17 \pm 0.05 \) dex. This value lies halfway between the two spectroscopy-based methods, being incompatible by more than 1 and 2\( \sigma \) with respect to the results of classical spectral synthesis and \textit{VWA} methods, respectively. Thus, if we trust on interferometry and parallax we have to conclude that even high-resolution spectroscopy is unable, at least in the case HD 71297, to evaluate the \( \log g \) value better than 0.2 dex, being also the internal errors on this value underestimated for both methods.

To investigate further the accuracy of the results obtained with the two different spectroscopic analysis about \( T_{\text{eff}} \) and \( \log g \), we built the spectral energy distribution (SED) of HD 71297 (see the Appendix for all the details on the construction of the SED) as shown in Fig. 9. The figure shows the comparison of the various photometric or spectrophotometric sources with three models (in different colours and line styles), as estimated in the previous sections.\(^7\) As well known, the Balmer jump is sensitive to surface gravity (as well as to effective temperature and line blanketing), hence, looking at the ultraviolet (UV) part of the SED we can get some insight about the ‘best’ couple \( (T_{\text{eff}}, \log g) \). Even a qualitative check on the figure shows that the \( T_{\text{eff}}, \log g \) couple evaluated in Section 4.1 (from parallax and interferometry) reproduces better the SED at all wavelength. In particular, in the far-UV, the classical spectral synthesis method has the worse agreement due to the low \( T_{\text{eff}} \), whereas across the Balmer Jump, \textit{VWA} seems to have a too high \( \log g \). This reflects the fact that both spectral synthesis and \textit{VWA} methods go through a modelling that introduces errors, so it is important to discuss some of them.

The error we found in \( \log g \) by fitting the wings of the Mg-I triplet (i.e. 0.1 dex) is the formal error due to the fitting procedure. Actually, there is at least another source of error that we have to discuss and consider. The result of the modelling of a spectral line depends essentially on the atomic parameters of the transition and in particular, for what concern the width of the spectral lines, we have to pay attention to the radiative, Stark and Van der Waals damping constants. The values of these three numbers set the broadening of the line and it is straightforward to understand the importance of their accuracy on the final value of \( \log g \).

To focus our attention on this problem, we performed the following simulation: we fitted the observed profile of the Mg-I 5172.684 Å on synthetic profiles by varying the damping constants, one at a time, by an amount equal to their typical uncertainties. According to Barklem et al. (2000), we adopted 5 per cent as typical error in damping constants, obtaining that such a variation of \( \gamma_{\text{Stark}} \) and \( \gamma_{\text{VdW}} \) lead to an uncertainty in \( \log g \) equal to \( \approx \pm 0.3 \) dex. Similarly, a variation of \( \gamma_{\text{rad}} \) of 5 per cent, lead to a \( \approx \pm 0.15 \) dex uncertainty on \( \log g \). Therefore, considering these errors as random and independent, we can conclude that the final uncertainties on gravity estimated by fitting the wings of one line are given from their quadratic sum and then equal to 0.45 dex. However, since we have applied this method to all the Mg-I triplet, the final uncertainty coming from atomic parameters is 0.26 dex. Finally, considering also the formal error on the fitting procedure, we obtained the total error on \( \log g \) equal to 0.28 dex. With such an error, \( \log g \) derived with classical spectral synthesis is consistent with other values found in this study.

As for \textit{VWA}, the estimate of \( \log g \) by means of the ionization balance can be affected by overionization effects and uncertainties.
4.39 (CM model, the dotted blue line), $I_{g_0} = 1.25$. Thus, we conclude that, $g = 4.00$ (MLT model, the dashed red line), and $g = 4.17$ (the continuous black line), as a by-product is absolutely normal. A similar conclusion was reached by Cowley et al. (2012) for HD 71297 carried out with SARG at TNG. This object has been classified by Cowley (1968) as a suspected marginal metallic star, and later on Abt & Levy (1985) assigned the spectral type of kA8hA9mF0.

From direct measurements of distance and diameter, we obtained for our target the following astrophysical parameters: $T_{\text{eff}} = 7810 \pm 90$ K and $g = 4.17 \pm 0.05$. As a by-product we were able to also derive estimation of $R/R_\odot = 1.97 \pm 0.14$, $M/M_\odot = 1.77^{+0.12}_{-0.10}$ and age = 790 ± 90 Myr.

For what concerns the main part of our paper, i.e. the comparison of the two different approaches, we can summarize as follows.

(i) Classical spectral synthesis method gives us the following values: $T_{\text{eff}} = 7500 \pm 180$ K and $g = 4.10 \pm 0.28$ that are consistent with the previous values, at least within the errors. Projected rotational velocity has been evaluated in $7.0 \pm 0.5$ and $\xi = 2.4 \pm 0.5$ km s$^{-1}$. With these parameters, abundance analysis gives us a general underabundance of iron peak elements with the exception of calcium that is solar in content. Solar abundances are also shown by oxygen, yttrium, zirconium, barium and rare earths. We also tested the influence of the convection in the calculation of the synthetic spectrum. As in the case of vWA, we used Heiter et al. (2002) models to repeat the analysis, obtaining results totally consistent with those obtained with MLT theory as treated in Kurucz (1993) with no overshooting and $\alpha = 1.25$. Thus, we conclude that, at least in the case of a star as hot as HD 71297, and for the resolution and S/N of our spectrum, the results are only slightly affected by the choice about the particular treatment of convection adopted for the analysis. The same conclusion is shared by Gardiner, Kupka & Smalley (1999), who conclude that the MLT and CM models all give similarly reasonable results. On the contrary, for cooler targets the role of convection will be more significant and we will take it into account properly.

(ii) By using vWA we obtained the following parameters: $T_{\text{eff}} = 7700 \pm 150$ K and $g = 4.39 \pm 0.06$, a projected rotational velocity of $7.0 \pm 1.0$ km s$^{-1}$ and $\xi = 2.4 \pm 0.2$ km s$^{-1}$.
the experimental errors all these quantities are comparable with the ones derived with the others method. Also the abundances show a pattern similar to the one computed with classical spectral synthesis.

As a general conclusion, we can state that the methods considered in this study to derive fundamental parameters useful to characterize stellar atmosphere give consistent results, if we consider all the sources of experimental errors.

An important result of this study concern the chemical pattern found for HD 71297. Contrary to what is expected from the previous classification, our abundances (reported in Table 3) do not look like those of normal Am star (see fig. 5 in Catanzaro et al. 2011, for example). In fact, iron-peak elements show moderate underabundances, as well as carbon and sodium. Heavy elements like yttrium, zirconium, barium and rare earths, that usually in A-type stars display abundances greater than the Sun analogues (Epspamer & North 2003), are quite normal in our target.

The results shown in this paper, concerning the consistency of classical spectral synthesis and VWA approaches to the analysis of stellar spectra will allow us to confidently apply these codes to the other Am stars observed at SARG at TNG.

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REFERENCES

Abt H. A., Levy S. G., 1985, ApJ, 59, 229
Aldenius M., Tanner J. d., Johansson S., Lundberg H., Ryan S. G., 2007, A&A, 461, 767
Allende Prieto C., Barklem P. S., Lambert D. L., Cunha K., 2004, A&A, 420, 183
Baglin A., Auvergne M., Barge P., Michel E., Catala C., Deleuil M., Weiss A., 2004, A&A, 420, 834 [erratum: A&A, 324, 432 (1997)]
Balona L. A. et al., 2011, MNRAS, 414, 792
Barklem P. S., Piskunov N., O'Mara B. J., 2000, A&AS, 142, 467
Bessell M. S., 2000, PASP, 112, 961
Bessell M. S., Castelli F., Gratton R., Kurucz R. L., 1997, A&A, 318, 841 [erratum: A&A, 324, 432 (1997)]
Catalano C., Balona L., 2012, MNRAS, 421, 1222
Catalano G. et al., 2011, MNRAS, 411, 1167
Cowley A. P., 1968, PASP, 80, 453
Cowley A. P., Cowley C., Jaschek M., Jaschek C., 1969, AJ, 74, 375
Epspamer D., North P., 2003, A&A, 398, 1121
Fossati L., Ryabchikova T., Shulyak D. V., Haswell C. A., Elsmasli A., Pandey C. P., Barnes T. G., Zwintz K., 2011, MNRAS, 417, 495
Fuhrmann K., Pfeiffer M., Frank C., Reetz J., Gehren T., 1997, A&A, 323, 909
Gardiner R. B., Kupka F., Smalley B., 1999, A&A, 347, 876
Girardi L., Bressan A., Bertelli G., Chiosi C., 2000, A&AS, 141, 371
Gratton R. G. et al., 2001, Exp. Astron., 12, 107
Gray R. O., 1998, ApJ, 116, 482
Gray D. F., 2005, The Observation and Analysis of Stellar Atmospheres. Cambridge Univ. Press, Cambridge
Grevesse N., Asplund M., Sauval A. J., Scott P., 2010, Ap&SS, 328, 179
Gurtch B. N. G., 1987, MNRAS, 226, 361
Hauck B., Mermilliod M., 1998, A&AS, 129, 31
Heiter U. et al., 2002, A&A, 392, 619
Kupka F., 1996, in Adelman S. J., Kupka F., Weiss W. W., eds, ASP Conf. Ser. Vol. 108, Model Atmospheres and Spectrum Synthesis. Astron. Soc. Pac., San Francisco, p. 73
Kupka F., Piskunov N., Ryabchikova T. A., Stempels H. C., Weiss W. W., 1999, A&AS, 138, 119
Kurucz R. L., 1993, in Dworetsky M. M., Castelli F., Faraggiana R., eds, ASP Conf. Ser. Vol. 44, IAU Colloq. 138: A New Opacity-Sampling Model Atmosphere Program for Arbitrary Abundances. In: Peculiar versus Normal Phenomena in A-Type and Related Stars. Astron. Soc. Pac., San Francisco, p. 87
Kurucz R. L., Avrett E. H., 1981, SAO Special Rep., 391
Kurucz R. L., Bell B., 1995, Kurucz CD-ROM 23, SAO, Cambridge, MA
Lafarssa S., Mella G., Bonneau D., Duvert G., Delfosse X., Chesneau O., Chelli A., 2010, in Proc. SPIE Conf. Vol. 7734, Astronomical Instrumentation. SPIE, Bellingham, p. 77344E
Lampton M., Margon B., Bowyer S., 1976, ApJ, 208, 177
Lehmann H. et al., 2011, A&A, 526, 124
Malkov O. Y., 2007, MNRAS, 382, 1073
Marigo P., Girardi L., Bressan A., Gruenwegen M. A. I., Silva L., Granato G. L., 2008, A&A, 482, 883
McSwain M. V., Gies D. R., 2005, ApJ, 622, 1052
Mermilliod J. C., 1991, Catalogue of Homogeneous Means in the UBV System, Institut d’Astronomie, Université de Lausanne, Lausanne, Switzerland
Molenda-Zakowicz J. et al., 2010, Astron. Nachr., 331, 981
Moon T. T., 1985, Ap&SS, 117, 261
Moon T. T., Dworetsky M. M., 1985, MNRAS, 217, 305
Munari U., Twiter T., 1997, A&A, 318, 269
Napiwotzki R., Schoenberner D., Wesnes V., 1993, A&A, 268, 653
Niemiicura E., Morel T., Aerts C., 2009, A&A, 506, 213
Rentzch-Holm I., 1996, A&A, 312, 966
Ribas I., Jordi C., Torra J., Gimenez A., 1997, A&A, 327, 207
Rogers N. Y., 1995, Commun. Asteroseismol., 78, 1
Roye F., Grenier S., Bayiac M.-O., Gomez A. E., Zorec J., 2002, A&A, 393, 897
Rufener F., 1988, Catalogue of Stars Measured in the Geneva Observatory. Photometric System, 4th edn. Observatoire de Geneve, Sauverny
Rufener F., Nicolet B., 1988, A&A, 206, 357
Skrutskie M. F. et al., 2006, AJ, 131, 1163
Smalley B., Wilson R., 1978, Catalogue of Stellar Ultraviolet Fluxes (TD1): The Next Generation of Space Missions. Astron. Soc. Pac., San Francisco, p. 153
Smalley B. et al., 2011a, A&A, 535, A3
Thompson G. I., Nandy K., Jamar C., Monfils A., Houziaux L., Caronch D. J., Wilson R., 1978, Catalogue of Stellar Ultraviolet Fluxes (TD1): A Compilation of Absolute Stellar Fluxes Measured by the Sky Survey Telescope (S2/68) Aboard the ESRO Satellite TD-1. The Science Research Council, UK
Tkachenko A., Lehmann H., Smalley B., Debosscher J., Aerts C., 2012, MNRAS, 422, 2960
Valenti J. A., Piskunov N., 1996, A&AS, 118, 595
van der Bliek N. S., Manfroid J., Bouchet P., 1996, A&AS, 119, 547
van Leeuwen F., 2007, A&A, 474, 432 (1997)
Waller W. M., 2007, MNRAS, 382, 917
Weaver W. M., Torres-Dodgen A. Y., 1995, ApJ, 446, 300

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APPENDIX A: SPECTRAL ENERGY DISTRIBUTION

The observed SED has been obtained by merging various data sources collected from the literature. In particular, the stellar flux shown in Fig. 9 was constructed by using the following data.

(i) UV fluxes taken from TD1 satellite (Thompson et al. 1978) that covers the 1565–2740 Å range;
(ii) u, v, b, y magnitudes from Hauck & Mermillod (1998) and converted in physical units by using the calibrations given by Gray (1998); y magnitude has been derived from UBV colour via the calibration of McSwain & Gies (2005)
(iii) Geneva photometry taken from Rufener (1988) and converted in fluxes by means of the calibrations given by Rufener & Nicolet (1988);
(iv) UBV magnitudes taken from Mermilliod (1991) and converted in fluxes using Bessell et al. (1998) calibrations;
(v) spectrophotometry in the range 5800–8000 Å taken from Weaver & Torres-Dodgen (1995);
(vi) JHK magnitudes from Two Micron All Sky Survey (2MASS; Skrutskie et al. 2006), converted in physical units by using van der Bliek, Manfroid & Bouchet (1996).

As discussed in Section 4.1, we neglected the effects of interstellar reddening. In order to be consistent with the iron abundance we found in our previous analysis, each theoretical SED has to be calculated with an opacity ODF corresponding to a metalicity of [Fe/H] = −0.15. To achieve this goal, we computed for each couple of (\(T_{\text{eff}}\), \(\log g\)) two synthetic fluxes, one for ODF = [0.0] and one for ODF = [−0.5] and then we interpolated between them.

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