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Principal component analysis-based inversion of effective temperatures for late-type stars⋆ *(Research Note)*

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ABSTRACT

We show how the range of application of the principal component analysis-based inversion method of Paletou et al. (2015, A&A, 573, A67) can be extended to data for late-type stars. Besides being an extension of its original application domain, which applied to FGK stars, we also used synthetic spectra for our learning database. We discuss our results for effective temperatures in comparison with previous evaluations made available from VizieR and Simbad services at CDS.

Key words. virtual observatory tools – stars: fundamental parameters – stars: late-type

1. Introduction

Effective temperatures of late-type stars were inverted from HARPS spectra, using the principal component analysis-based (PCA) method detailed in Paletou et al. (2015). In the latter study, fundamental parameters of FGK stars were inverted using a so-called learning database generated from the Elodie stellar spectra library (see Prugniel et al. 2007) using observed spectra for which fundamental parameters were already evaluated. Also, spectra considered in the Paletou et al. (2015) study had typical spectral resolution $\mathcal{R}$ of 50 000 (Allende Prieto el al. 2004) and 65 000 (Petit et al. 2014), i.e. values significantly lower than HARPS data.

In this study, the inversion of the effective temperature, $T_{\rm eff}$, from spectra of late-type (dwarf) stars of K and M spectral types is performed using a database of synthetic spectra. We discuss hereafter comparisons with published values collected from the VizieR and Simbad services of CDS.

2. The learning database

A grid of 6336 spectra was computed using SYNSPEC-48 synthetic spectra code (Hubeny & Lanz 1992) and Kurucz ATLAS-12 model atmospheres (Kurucz 2005). The linelist was built from Kurucz (1992) `gfhyperall.dat`[1].

For our purposes, we adopted a grid of parameters such that $T_{\rm eff}$ is in a 3500–4600 K range with a 100 K step, $\log g$ is in the range of 4–5 dex with a 0.2 dex step, metallicity [Fe/H] is in a −2–+0.5 range with a 0.25 dex step and, finally, $v \sin i$ varies from 0 to 14 km s^{-1} with a 2 km s^{-1} step.

For all models, the microturbulent velocity was fixed at $\xi_{\rm t}$ = 1 km s^{-1} and [α/Fe] was set to 0. The spectral resolution of the HARPS spectrograph, i.e. $\mathcal{R}$ = 115 000 was adopted for the production of this set of synthetic spectra. We finally limited the study to a spectral band centred around the Na I D-doublet, ranging from 585.3 to 593.2 nm.

Even though the choice of Atlas for such cool stars as well as the choice of the spectral bands we considered may be questionable, we show that effective temperatures we inverted from HARPS data are realistic enough for several further studies (e.g. rotation-activity correlations vs. the spectral type).

3. Observational and reference data

We used 57 high-resolution HARPS spectra taken from the ESO Science Archive Facility. The selection targeted late-type dwarf K stars, and early-type dwarf M stars. We also gave preference to high signal-to-noise spectra. Related objects are listed in Fig. 1; see also Table 1.

All reference data were collected from VizieR catalogues, using the ASTROQUERY[2] Python modules already mentioned by Paletou & Zolotukhin (2014).

4. Results

Given the "bulk" of nearest neighbours we consider for our inversion procedure, we estimate that 150 K is a typical upper value for the uncertainty in our derived effective temperature.

⋆ Based on data obtained from the ESO Science Archive Facility.

[1] http://kurucz.harvard.edu

[2] astroquery.readthedocs.org

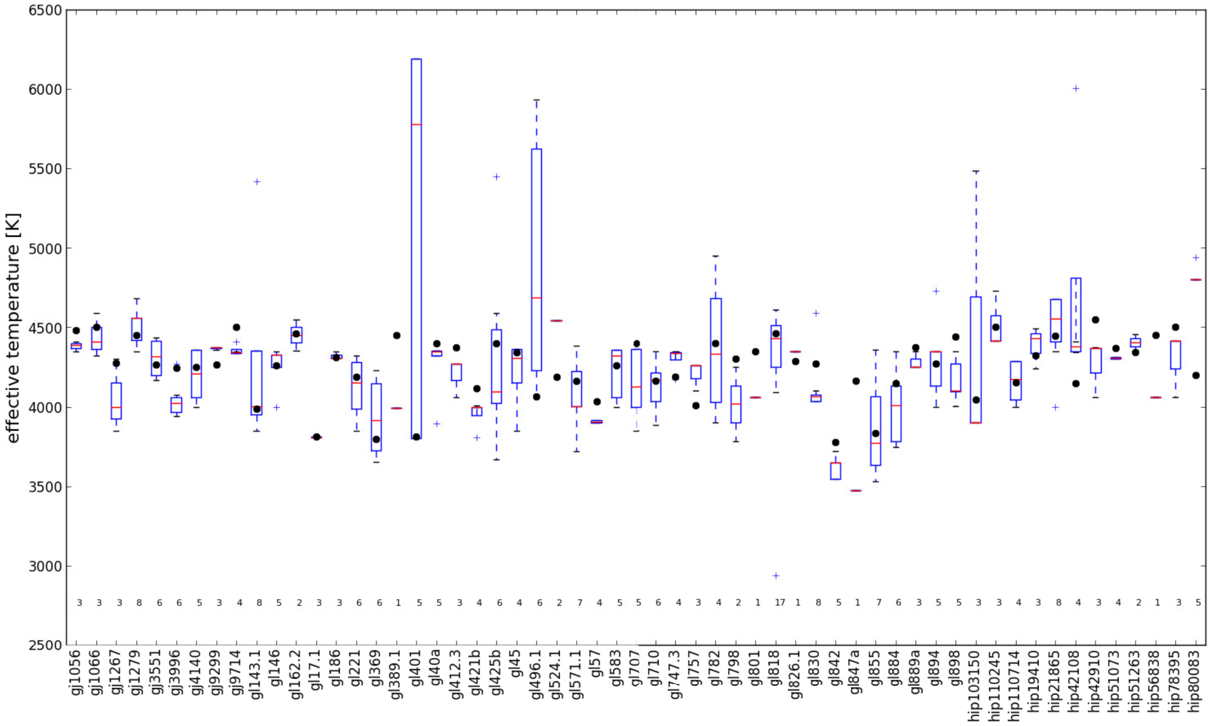

Fig. 1. Comparison between our estimate of effective temperatures (•), and the values we got from available VizieR catalogues. The latter collections are represented as classical boxplots. (The horizontal bar inside each box indicates the median, or Q_2 value, while each box extends from first quartile, Q_1, to third quartile Q_3. Extreme values, still within a 1.5 times the interquartile range away from either Q_1 or Q_3, are connected to the box with dashed lines. Outliers are denoted by a "+" symbol.) Objects we studied are listed along the horizontal axis. In addition, for each object at level $T_{\rm eff} \sim 2800$ K, we explicated the number of values found among all VizieR catalogues.

From Fig. 1, we can identify eight major outliers considering deviations from our estimate of the effective temperature and values published and made available through the VizieR service at CDS.

GL 401 is a M3V star. It is also an interesting case, from the point of view of fundamental parameters made available. We retrieved five determinations of its effective temperature, spanning an impressive range of values, as can be seen from the corresponding boxplot in Fig 1. However, our estimate of 3810 K is in excellent agreement with the recent value of 3804 K derived by Gaidos et al. (2014).

The case of the K9V star GL 496.1 is very similar. We extracted six values from VizieR, and again, the most recent value of 4075 K given by Gaidos et al. (2014) is in excellent agreement with our estimate of 4063 K. We also note the very different value of 4685 K given by Santos et al. (2013), and reported at Simbad at CDS for this object.

GL 389.1 is believed to be a K5.5V star (Gray et al. 2006). We could only identify only one data point at VizieR, an estimate of 3990 K given by Lafrasse et al. (2010, also catalogue id. II/320). Our own estimate is significantly hotter at 4450 K, which appears to be more consistent with the spectral type found at Simbad.

According to Simbad at CDS, GL 847 A is a K4 star (Van Leeuwen 2007). This is clearly not consistent with our estimate of an effective temperature of 4160 K, nor with the only value we could retrieve from VizieR, i.e. the estimate by Morales et al. (2008) yielding 3470 K. As for the precedent object, the lack of data available in catalogues makes the assessment of a reliable reference value difficult.

HIP 42108 is a K6V star (Gray et al. 2006) for which we could estimate an effective temperature of 4147 K. From available catalogues, we found the most recent estimate of 4343 K given by McDonald et al. (2012), which is also very close to the alternative estimate of Wright et al. (2003). Lafrasse et al. (2010) also report a very close estimate of 4410 K. For this object, however, Ammons et al. (2006) report a very different value of 6005 K.

A similar case of overestimation has been identified for GL 524.1. We obtained an effective temperature of 4186 K, while Ammons et al. (2006) provide a significantly larger value of 4554 K. Unfortunately, we could not find alternative estimates for this parameter for this object (there is an entry for GL 524.1 reported by Morales et al. 2008, but no $T_{\rm eff}$ value is given).

HIP 56838 is, according to Simbad, a K6V star based on the classification of Gray et al. (2006). Our estimate of its effective temperature is 4200 K, in agreement with a K6 (main sequence) spectral type, while the only VizieR data we could get is 4060 K (Wright et al. 2003). Even though this object can also be found in the Ammons et al. (2006) catalogue, no $T_{\rm eff}$ value is given there. Besides, a much cooler temperature of 3800 K, which would better correspond to a M0V spectral type, was recently given by Kordopatis et al. (2013).

HIP 80083 is quite consistently given at 4800 K (Sousa et al. 2011; Adibekyan et al. 2012; Carretta 2013), or even hotter (Ammons et al. 2006). Our inversion procedure gives an effective temperature significantly lower at 4200 K, typical of a spectral type later than K4, as indicated by Simbad at CDS.

Table 1 summarizes our results. It displays our inverted $T_{\rm eff}^{\rm (inv.)}$ and two reference values. The first one, $T_{\rm eff}^{\rm (clos.)}$, was defined as the value found in VizieR catalogues closest to our estimate, while $T_{\rm eff}^{\rm (med.)}$ is the median of all catalogue values.

Table 1. Inverted and reference effective temperatures for all objects.

Object	$T_{\rm eff}^{\rm (inv.)}$ [K]	$T_{\rm eff}^{\rm (clos.)}$ [K]	$T_{\rm eff}^{\rm (med.)}$ [K]
gj1056	4480.0	4410.0	4391.0
gj1066	4500.0	4590.0	4410.0
gj1267	4275.0	4301.0	4000.0
gj1279	4450.0	4424.0	4556.0
gj3551	4267.0	4287.0	4318.5
gj3996	4244.0	4272.0	4023.0
gj4140	4250.0	4210.0	4210.0
gj9299	4267.0	4360.0	4372.0
gj9714	4500.0	4410.0	4344.5
gl143.1	3985.0	3970.0	4001.0
gl146	4260.0	4250.0	4329.0
gl162.2	4462.5	4550.0	4452.5
gl17.1	3812.5	3809.0	3809.0
gl186	4311.0	4307.0	4307.0
gl221	4186.0	4282.0	4151.0
gl369	3796.0	3915.0	3915.0
gl389.1	4450.0	3990.0	3990.0
gl401	3810.0	3804.0	5780.0
gl40a	4400.0	4352.0	4350.0
gl412.3	4375.0	4271.0	4271.0
gl421b	4117.0	4008.0	3995.0
gl425b	4400.0	4590.0	4097.5
gl45	4340.0	4361.0	4305.5
gl496.1	4063.0	4075.0	4685.0
gl524.1	4186.0	4544.0	4544.0
gl571.1	4164.0	4060.0	4002.0
gl57	4033.0	3913.0	3906.5
gl583	4261.0	4320.0	4320.0
gl707	4400.0	4364.0	4125.0
gl710	4160.0	4130.0	4165.0
gl747.3	4186.0	4170.0	4337.0
gl757	4008.0	4100.0	4259.0
gl782	4400.0	4590.0	4330.0
gl798	4300.0	4250.0	4015.5
gl801	4350.0	4060.0	4060.0
gl818	4462.5	4444.0	4430.0
gl826.1	4287.5	4350.0	4350.0
gl830	4269.0	4100.0	4065.5
gl842	3776.0	3720.0	3649.0
gl847a	4160.0	3470.0	3470.0
gl855	3831.0	3771.0	3771.0
gl884	4147.0	4130.0	4009.5
gl889a	4371.0	4350.0	4251.0
gl894	4270.0	4350.0	4350.0
gl898	4440.0	4350.0	4101.0
hip103150	4043.0	3900.0	3900.0
hip110245	4500.0	4416.0	4416.0
hip110714	4150.0	4060.0	4172.0
hip19410	4320.0	4238.0	4432.0
hip21865	4445.5	4432.0	4555.0
hip42108	4147.0	4343.0	4380.0
hip42910	4550.0	4373.0	4368.0
hip51073	4367.0	4310.0	4305.0
hip51263	4343.0	4350.0	4403.5
hip56838	4450.0	4060.0	4060.0
hip78395	4500.0	4414.0	4414.0
hip80083	4200.0	4800.0	4800.0

Notes. Hereafter $T_{\rm eff}^{\rm (clos.)}$ was defined as the value found in VizieR catalogues closest to our inverted $T_{\rm eff}^{\rm (inv.)}$, while $T_{\rm eff}^{\rm (med.)}$ is the median of catalogues values.

Finally, to characterize our results, we first removed the eight above mentioned outliers from our objects list, which is about 14% of the original sample. Considering reference values as the one closest to our inverted effective temperature, we obtain a (mean signed difference or) bias of 21 K and a standard deviation of 90 K. If we use the median value as reference, the bias is 60 K and the standard deviation 132 K.

5. Conclusion

We have shown that the PCA-based inversion method of Paletou et al. (2015) provides realistic values for the effective temperature of late-type stars. Comparisons made between our estimates and effective temperature data found in the available literature reveals the existence of some strong discrepancies for a few objects. These discrepancies are most often related to very limited samples of estimates, so that additional investigations are clearly required for these objects.

These should consist in using different synthetic spectra, which can produce other radiative modelling tools such as Marcs (Gustafsson et al. 2008) or Phoenix, for cool stars (see e.g. Husser et al. 2013). The consideration of other spectral domains, and eventually the use of a combination of several distinct spectral domains should be explored too.

Our study also raises the more general question of the consistency between published (and made available) data, as well as the consistency between data provided by VizieR and Simbad services.

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