Estimating Stellar Fundamental Parameters Using Principal Component Analysis: Application to GES Data

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ABSTRACT: We present stellar parameters estimation method using a dimensionality reduction technique called principal component analysis (PCA), applied to a large database of synthetic spectra. This technique is essential for inverting stellar parameters of observed targets from Gaia Eso Survey.

METHOD: The main purpose of PCA is to reduce dimensionality of some dataset by searching for basis vectors that represent most of the variance in the dataset. These vectors, ***"e_k"***, are the eigenvectors of the variance-covariance matrix ***"C"*** (eq. 1) of the synthetic spectra database ***"S"***, and are obtained using the singular value decomposition (Paletou 2015, Rees 2000). Once the basis is obtained (adopted a set of 12 vectors), the synthetic spectra and the observations are projected unto this basis to obtain the projected coefficients (eq. 2 & 3). Each spectrum is then represented by only 12 components (instead of typically ~8000), and a standard chi-squared (eq. 4) is performed in this low dimensional space in order to achieve a fast inversion of the stellar parameters of the observed stars. The parameters of the synthetic spectrum having the minimum ***"d"*** will be considered as the observation fundamental parameters.

$$C = (S - \bar{S})^T \cdot (S - \bar{S}) \tag{1}$$

$$p_{jk} = (S_j - \bar{S}) \cdot e_k \tag{2}$$

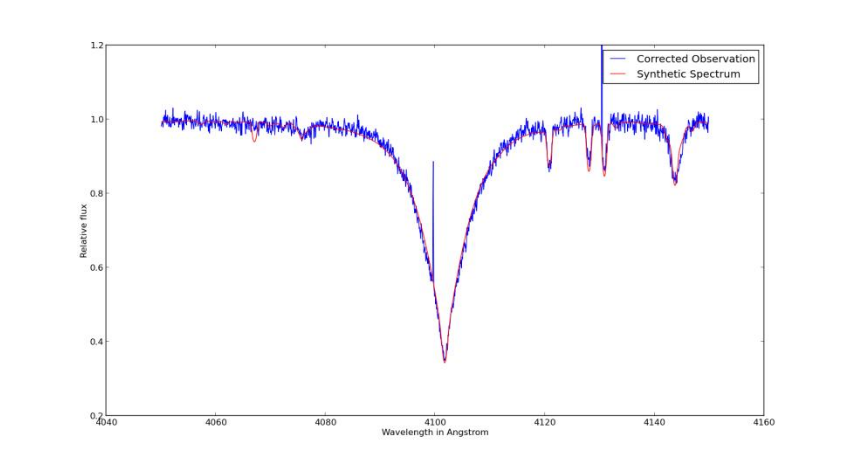
$$\rho_k = (O - \bar{S}) \cdot e_k \tag{3}$$

$$d_j^{(O)} = \Sigma_{k=1}^{k_{max}} (\rho_k - p_{jk})^2 \tag{4}$$

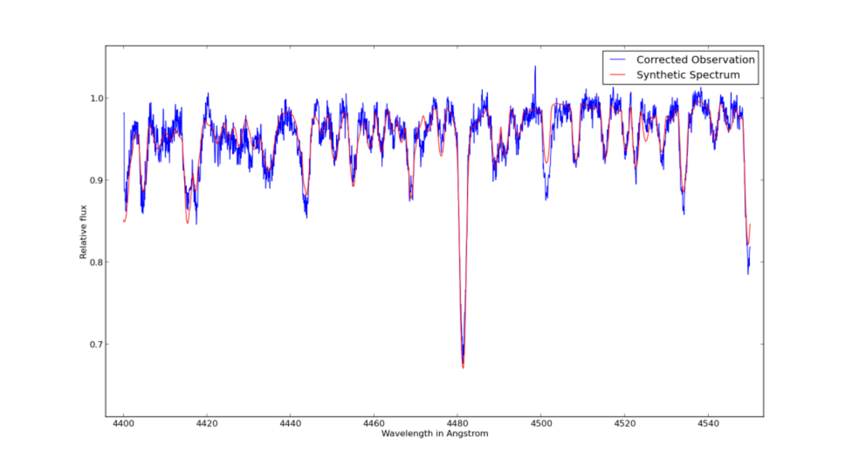
OBSERVATION DATA: The procedure was applied to more than 800 stars members of three open clusters (NGC3293, NGC6705, and Trumpler 14). The two wavelength ranges that were used are: one samples the H_δ line region [4030-4200 Å] and the second samples the [4400-4550 Å] region. These spectra were obtained from the Gaia Eso Survey using GIRAFFE/FLAMES spectrograph. The GES reduced data were used in this work.

SYNTHETIC SPECTRA: LTE model atmospheres were calculated using ATLAS9 code (Kurucz 1992) and were used as input to the spectrum synthesis code SYNSPEC48 (Hubeny & Lanz 1992) in order to compute a large grid of synthetic line profiles, over the same spectral regions as the observations. Spectra were calculated for T_{eff} between 5000 and 15000 K, gravities between 2.0 and 5.0 cgs, rotational velocities between 0 and 200 Km/s, and metallicities between -0.6 and 0.4 dex. All with a microturbulent velocity of 2 Km/s.

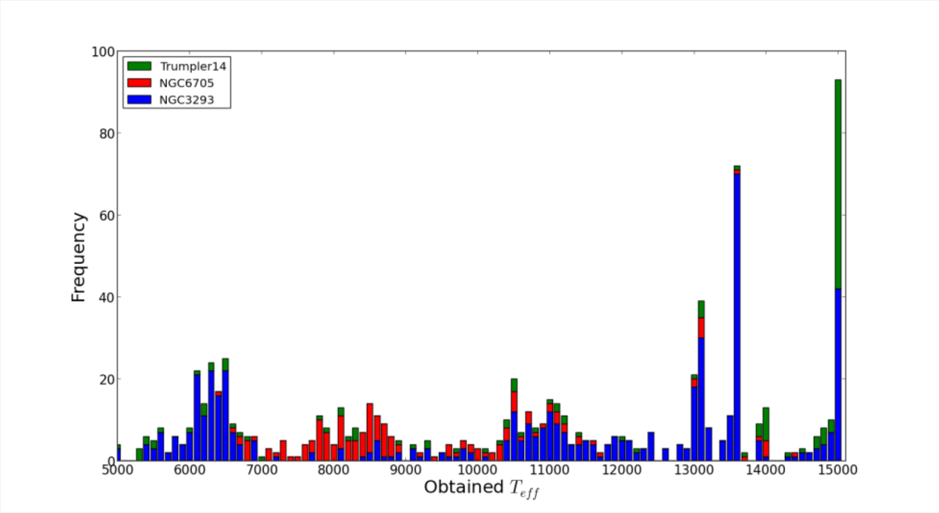
RESULTS: The inversion was applied to the observations and T_{eff}, log*g*, $v_e$sini, and [Fe/H] were obtained for ~800 stars.



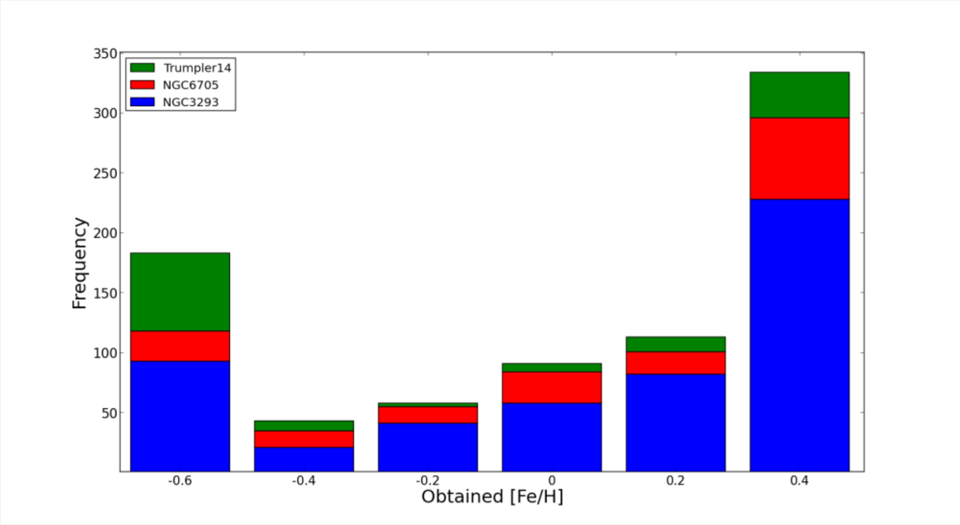
Example of the fitting of the Hδ line using the synthetic spectrum that corresponds to the minimum value of "*d*".



Example of the fitting of a region containing FeII, MgII, and TiII lines using the synthetic spectrum that corresponds to the minimum value of "*d*".



Derived effective temperatures for our sample of 800 stars member of 3 open clusters using the Hδ region.



Derived [Fe/H] for our sample of 800 stars member of 3 open clusters using the spectral region between 4400 Å and 4550 Å.

MAIN CONCLUSIONS:

-Less time consuming than other methods and very easy to implement.

- Comparison with other results have shown that the same accuracy was achieved using PCA.

FUTURE WORK:

-Include other metallicities and other microturbulent velocities.

-Merging of several regions and inverting them at the same time.

References:

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