SPADES: a Stellar Parameter Determination Software

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**ABSTRACT:**

With the large amounts of spectroscopic data available today and the very large surveys to come (e.g. Gaia), the need for automatic data analysis softwares is unquestionable. We thus developed an automatic spectra analysis program for the determination of stellar parameters: radial velocity, effective temperature, surface gravity, micro-turbulence, metallicity and most of all elemental abundances. Target stars for this software should include all types of stars. The analysis method relies on a line by line comparison of the spectrum of a target star to a library of synthetic spectra. The idea is built on the experience acquired in developing the TGMET (Katz et al., 1998, A&A,338,151; Soubran et al., 2003, A&A,398,141), ETOILE (Katz 2001, Journ. Of Astron. Data, 7, 8) and Abbo (Bonifacio & Caffau, 2003, A&A,399,1183B) softwares. This poster presents the method behind our software. The performances are illustrated with GIRAFFE-like simulated spectra in high resolution (R = 25000), in high and low signal to noise ratios (down to S/N= 30). These spectra should be close to what could be targeted by the Gaia Chemo-Dynamical Survey (GCDS).

**Need for automatic spectra analysis**

Softwares:
- Gaia EGS Survey: about 16000 stars; data: 2’000’000 stars for chemical abundances, R = 450 398 so far and about 3’000’000 expected, etc...
- Existing softwares:
  - TGMET (ETOILE), MATISSE, MIO, ESO pipeline, Ulyss, ...

**Parameters to be determined:**
- Radial velocity (Vr)
- Effective temperature (Teff)
- Metallicity ([Fe/H])
- Element abundances ([M/H])

**General idea:**
The general idea is a comparison between the observed (studied) spectrum and a grid of reference spectra with known parameters. For one parameter and one diagnostic, a 1D (in the parameters space) reference value.

1. For each parameter to be determined, one or several methods of determination (diagnostics) are possible. One is chosen.
   - The list of diagnostics for each parameter are:
     - [Fe/H]: Fe lines profile fitting.
     - [Ca/H]: Ca/Fe+ and Ni/Fe+.
     - [M/H]: Mg/Fe+.
   - For each reference grid, a line by line analysis is made (compared to global reference spectra grid).
   - For one diagnostic gives one parameter, as opposed to existing methods where one diagnostic gives all parameters.

2. For one parameter and one diagnostic, a 2D (in the parameters space) reference spectra grid is defined, varying over the parameter to be determined only. For now, the reference grid is pre-calculated using ATLAS9 (Kurucz). When needed, the software calculates a new reference grid by interpolation based on the pre-calculated one.

3. For each reference spectrum, a line by line analysis is made (compared to global methods where the analysis is done over the whole spectrum). No equivalent widths are measured. Instead the measures are based on profile fitting like methods between observed and synthetic lines.

4. Convergence: at one iteration, each parameter is determined independently from the others. The rest of the parameters is fixed to their input values. At the next iteration, all parameters values are updated and the iteration output values become the i+1 iteration input values and so on. The software stops when the differences between the parameters values at iteration i and iteration i-1 are smaller than pre-fixed values.

**Diagnostics (implemented)**

**Line fit example: Hg**

- Determination of Teff based on Hg line fit:
  1. The analysed spectrum is a synthetic spectral line. A 2D Teff reference grid is defined with Teff values around the input Teff value.
  2. We work in a spectral domain around the central line wavelength, Hg in this case. The continuum peaks (blue parson) and line peaks (green dot) are determined on the reference spectra.
  3. The local continuum of the reference spectra is then fitted to the local continuum of the studied spectrum. We visualize the observed Hg spectral domain (black line) with the superposed synthetic spectral domain (red line).
  4. The measure is done over the defined line pixels (green). In this case, it’s a quadratic difference between the observed flux and the corresponding reference line flux.

**Future work**

- On the fly reference grid calculation: dynamic call of the SYNTHE software for calculating the reference grid directly from SPADES
- Fix a method for determining micro-turbulence
- Improve the determination of Teff by excitation equilibrium
- Determine the individual errors.
- Test on known stars spectra (e.g. sun)
- First scientific use: medium to high resolution Thick Disk stars GIRAFFE spectra. Foreseen within 6 months.

**Tests**

- Reference Grid
  - SYNTHE synthetic spectra calculated from ATLAS9 models
  - Teff = 5800 K ; log g = 4.40 ; [Fe/H] = -1.0 dex ; \( \chi = 1 \text{ km/s} \); [Ca/H] = 0.0 dex ; [Ni/H] = 0.0 dex ; R=25000

- Performances
  - No significant systematic errors
  - Using the Hg line fit method for Teff determination, the precision on each parameter are:
    - \( \text{SNR} = 30 \): Teff = 3.5 K \( \text{log g} = 0.0 \) \([\text{Fe/H}] = 0.1 \text{ dex} \); [Ca/H] = 0.05 \text{ dex} ; [Ni/H] = 0.05 \text{ dex} ; [M/H] = 0.05 \text{ dex} ; [Mg/H] = 0.05 \text{ dex} ; [Al/H] = 0.05 \text{ dex} ; [Sr/H] = 0.01 \text{ dex} ; [Ba/H] = 0.009 \text{ dex} ; [Eu/H] = 0.037 \text{ dex} ; [S/H] = 0.037 \text{ dex}.
  - Using Hg also improves the determination of other parameters. This reflects a correlation between these parameters.

- Example of reference grid and fits.

**An example of reference grid and fits.**

- Diagnostic for Teff and line by line measure
- Diagnostic for log g
- Diagnostic for [Fe/H]