AUTOMATIC DERIVATION OF STELLAR ATMOSPHERIC PARAMETERS AND CHEMICAL ABUNDANCES

A. Recio-Blanco[1], **A. Bijaoui**[1], **P. de Laverny**[1], **D. Katz**[2], **F. Thévenin**[1]

[1]Observatoire de la Côte d'Azur, Cassiopée, CNRS UMR 6202, BP 4229, 06304 Nice cedex, France
[2]Observatoire de Paris, GEPI / CNRS UMR 8111, 92195 Meudon cedex, France

ABSTRACT

We present an automatic procedure for the derivation of stellar atmospheric parameters (Teff, log g, [M/H]) and individual chemical abundances from the Gaia-RVS spectra using the minimum of distances and the objective analysis. We describe the method and discuss the accuracy of the obtained results.

Key words: Gaia; Radial Velocity Spectrometer; Chemical abundances; Stellar parameters.

1. INTRODUCTION

The extraction of the chemical abundance information from the Gaia-RVS data is a crucial task for Gaia's contribution to Galactic archeology (see Recio-Blanco & Thévenin 2005). The basic idea of the chemical abundance synthesis is to calculate a spectrum, in the appropriate wavelength range, by solving the equation of radiative transfer through a stellar atmosphere, which is finally compared to the observed one. The first thing to do is to deduce the stellar effective temperature, surface gravity and global metallicity in order to select the appropriate atmospheric model for the star under analysis. In this contribution we present the first step of a pipeline which is being developed for the derivation of the individual chemical abundances from the Gaia spectra. The results for the determination of the atmospheric parameters are listed and future improvements and goals are pointed out.

2. THE METHOD

The present algorithm compares one observed spectrum with a grid of synthetic ones, using the minimum distance technique combined with the objective analysis.

Basically, the 'observed' spectrum is for the moment a synthetic one not included in the grid. Furthermore, in order to test the adopted procedure, we did not consider any inputs from the Gaia photometry although this information will strongly improve the accuracy of the derived stellar atmospheric parameters and chemical abundances. We will consider such additional information in future investigations. The procedure is summarized in Figure 1.

2.1. Grid of Synthetic Spectra

Thanks to the MARCS collaboration (Uppsala Observatory & Université Montpellier II) who provide us a large number of model atmospheres, we have built a grid of synthetic spectra over the Gaia-RVS domain (8475–8745Å with a step of 0.02Å). This grid has a range from 4000 K to 7500 K with a step of 250 K in effective temperature, from 0.0 to 5.0 with a step of 0.5 in surface gravity and from [M/H] $=-4.0$ to $+0.5$ dex in metallicity (with α-enhancement at low metallicity). We also considered different calcium abundances [Ca/Fe] $=-0.5/0.0/+0.5$ dex. All the spectra have been convolved to the RVS resolution and sampled to $d\lambda=0.24$Å (about 3 points per RVS resolution elements).

2.2. Objective Analysis and Minimum of Distances

Once the grid of synthetic spectra has been created and read, another grid of 'observed' spectra is simulated by introducing a Gaussian white noise to each spectrum of the theoretical grid. A distance matrix is calculated in the following way:

$$d(k,i)=abs(1-vs.vs) \quad (1)$$

where vs =spec$_o(k,j)\times$ spec(i,j), for j=0, gpix-1 (gpix = the number of pixels in the RVS spectra) and for i, k = 0, nfile-1 (with nfile= total number of spectra in the grid). That is, spec$_o(k,j)$ and spec(i,j) are the normalized fluxes ($\Sigma_j spec(j)=1$) of the 'observed' k spectrum and the synthetic i spectrum at $\lambda=8480+0.24j$.

We then try to recover the atmospheric parameters (effective temperature, surface gravity and global metallicity) for each simulated observed spectrum. To this purpose, a weighted mean of the individual parameters of each spectrum of the grid is derived, using a weight $=\exp(-dn)$

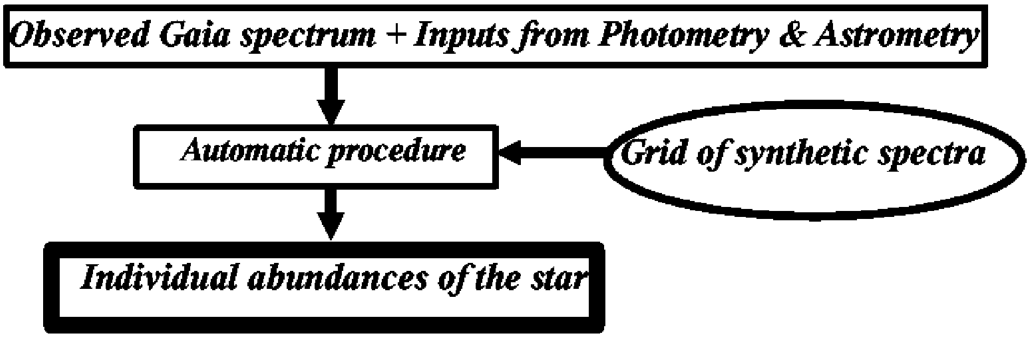

Figure 1. Proposed automatic procedure for the derivation of the stellar parameters and the individual chemical abundances.

where d is the distance between the observed and the corresponding grid spectrum. The optimal value of n depends on the signal to noise of the object spectra, being higher for lower S/N. The n parameter is for the moment optimized to give the best mean error over all the grid of parameters.

Although all the observed spectra are noised synthetic spectra with atmospheric parameters equal to some spectrum of the grid, the corresponding equal spectrum has not been considered in the parameter's derivation (as if the grid had had a hole in that place). As a consequence, the step in the parameters space is double in the immediate neighbourhood of the observed spectra considered.

3. RESULTS

Tables 1 and 2 present the preliminary results in the derivation of effective temperature, gravity and global metallicity from a complete, non continuum-normalized spectrum in the RVS wavelength range, using the grid described in Section 2.1. These errors correspond to the mean difference (in absolute value) between the correct $T_{\rm eff}$, log g or [M/H] and those recovered by the programme.

Table 1. Mean errors over all the range in atmospheric parameters covered by the grid for different values of the S/N. These values are 'pessimitic' as they include the deviations of the method for the spectra at the limits of the grid. For a better estimation see Table 2.

V	S/N	$\Delta T_{\rm eff}$	$\Delta log\ g$	$\Delta[M/H]$
$\sim$ 11.5	200	74 K	0.24 dex	0.12 dex
$\sim$ 12.5	120	83 K	0.25 dex	0.12 dex
$\sim$ 13.0	80	89 K	0.26 dex	0.12 dex
$\sim$ 13.5	50	95 K	0.26 dex	0.13 dex

The individual errors for most of the object spectra are graphically presented in Figures 2 to 3 by the error bars of each considered point. The general behaviour can be summed up in the following points:

Table 2. Percentage of spectra, among the spectra with a metallicity higher than [M/H]≥ -2.0, that have an error smaller than 50 K in $T_{\rm eff}$, 0.15 dex in log$g$ and 0.01 dex in [M/H].

V	S/N	For [M/H]≥ -2.0		
		$\leq$ 50K	$\leq$ 0.15 dex	$\leq$ 0.01 dex
$\sim$ 11.5	200	43 %	45 %	70 %
$\sim$ 12.5	120	41 %	44 %	68 %
$\sim$ 13.0	80	37 %	44 %	67 %
$\sim$ 13.5	50	34 %	43 %	67 %

- The temperature is better determined for dwarf stars than for giants.
- Gravity is generally well determined for hot stars, but problems are found for stars cooler than $\sim$ 5500 K.
- Global metallicity is well recovered for cool stars, but problems increase as temperature increases.
- Errors are higher in the limits of the grid.

Similar tests for individual chemical abundances and inputs on the stellar parameters from Gaia photometry are in progress. Several other improvements to the method and tests using spectra from the RVS simulator and real data will be also implemented.

ACKNOWLEDGMENTS

We thank the MARCS collaboration for providing us the grid of model atmospheres, B. Plez for his molecular line lists and the VALD data base for the atomic lines.

REFERENCES

Recio-Blanco, A., Thévenin, F., 2005, ESA SP-576, this volume

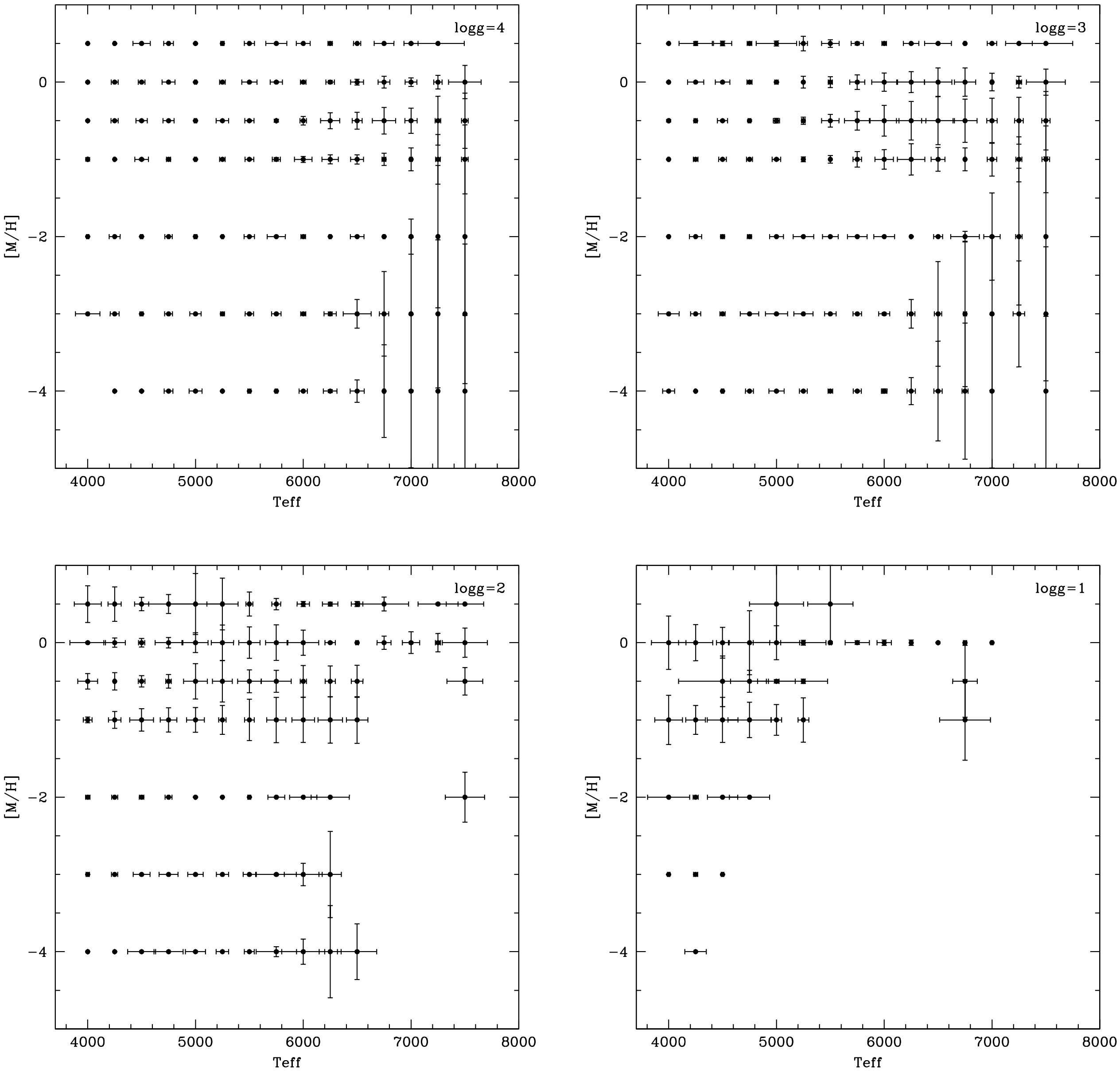

Figure 2. Errors in effective temperature and global metallicity for 4 different values of the surface gravity.

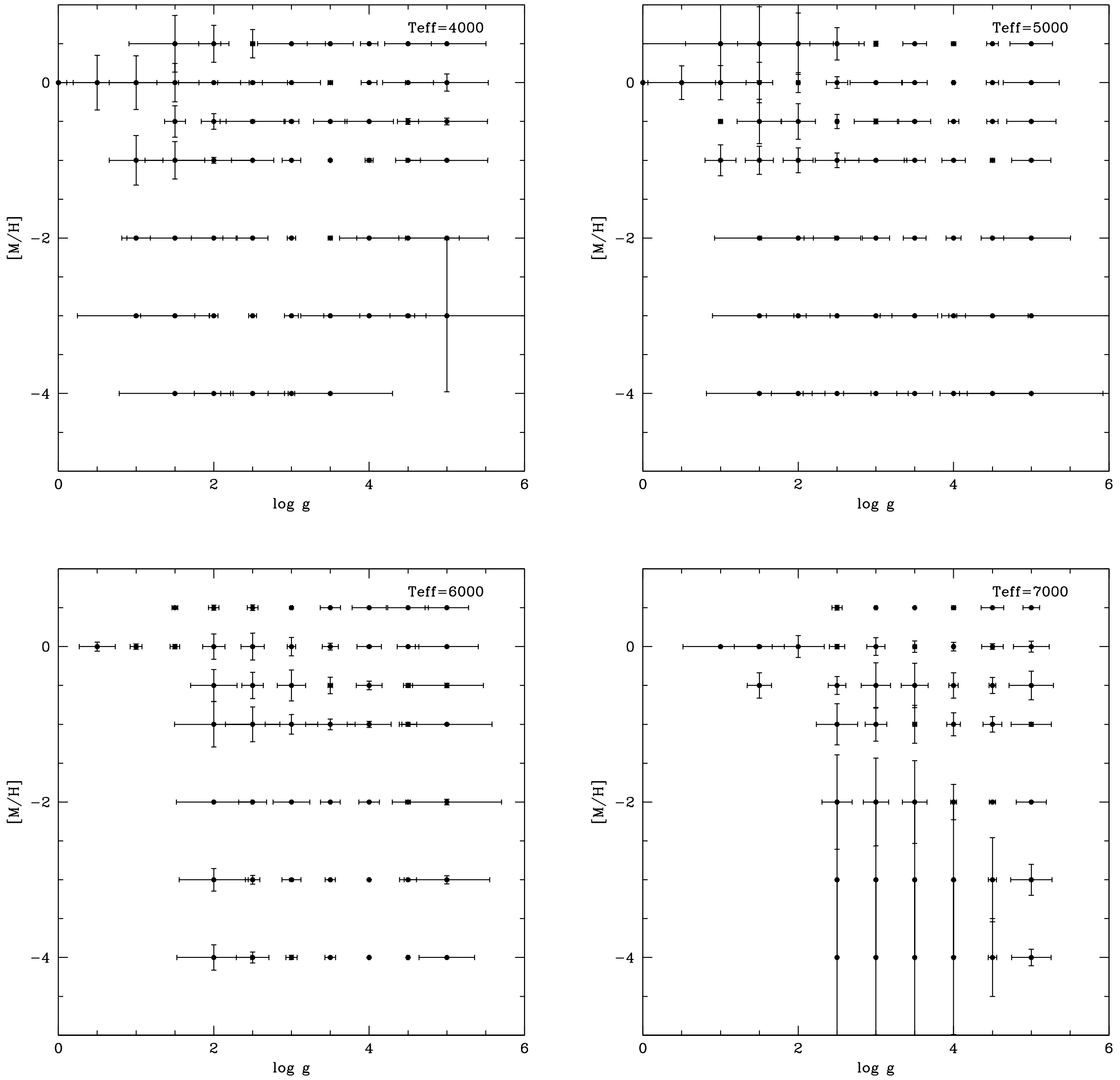

Figure 3. Errors in surface gravity and global metallicity, for 4 different values of the effective temperature.