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From stars to planets

An automated software for the Spectral Analysis of the stellar population in the CoRoT/Exoplanet fields

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Abstract. A large program of multi-fibre (FLAMES) spectroscopic observations of the stellar population in two CoRoT/Exoplanet field with the GIRAFFE/VLT, took place in spring 2008. It aims at characterizing the brightest dwarf population and providing the ground for statistical analysis of the planetary population found by CoRoT.

To perform such an ambitious analysis, we use an automated software based on the MATISSE algorithm, originally designed for the GAIA/RVS spectral analysis. This software derives the atmospheric stellar parameters: effective temperature, surface gravity and the overall metallicity.

Further improvements are foreseen in order to measure also individual abundances. By comparing the main physical and chemical properties of the host stars to those of the stellar population they belong to, this will bring new insights into the formation and evolution of exoplanetary systems and the star-planet connection.

Observations with FLAMES (VLT)

The CoRoT Space Mission, dedicated to wide-field high precision relative photometry, was launched on December 27th 2006 for an initial lifetime of two years and a half. It has two scientific programs : the detection of planetary transits and stellar interior probing with asteroseismology studies. In the exoplanet fields, CoRoT is able to monitor simultaneously up to 12 000 stars with a V-magnitude between 11.5 and 16.

To characterize the dwarf population in the exoplanet fields of CoRoT, we used the VLT multi-fibre facility FLAMES feeding simultaneously the UVES and GIRAFFE spectrographs. Two CoRoT fields were observed for 8 half-nights in May and June 2008. Due to bad weather conditions and technical problems, we could only observe $\simeq$ 1200 stars out of the 2400 originally planed.

We used the 7 UVES fibres with the RED UVES7 with simultaneous Thorium calibration mode centered at 580 nm with a resolving power of R = 47 000 to observe the best CoRoT planet candidates and the 132 MEDUSA fibres with the high resolution mode of the GIRAFFE spectrograph on the two following spectral domains :

Mg I triplet: [5143,5356] Å at R = 25 900
Ca II triplet: [8484,9001] Å at R = 16 200

To perform the spectral classification of such a large sample of spectroscopic data, we use an automatic processing and analysis pipeline. The 2276 GIRAFFE spectra should be corrected for the star's and barycentric Earth radial velocities, cosmic rays, and strong emission atmospheric lines in the Ca II triplet domain. The spectra have also to be normalized to the stellar pseudo-continuum.

Spectral analysis : the MATISSE algorithm

To analyze large amounts of spectroscopic data, an algorithm based on the spectral synthesis has been developed for the GAIA-RVS and is completely described in Recio-Blanco *et al.* (2006 MNRAS): MATrix Inversion for Spectral SynthEsis (MATISSE).

Assuming that T_{eff} (θ_0),$\log g$ (θ_1), $[M/H]$ (θ_2) should be determined, MATISSE consists in two phases :

Learning : the construction of a basis of three orthogonal functions ($B_{\theta_i}(\lambda)$) from an optimal linear combination of theoretical spectra. For a given parameter θ_i, the $B_{\theta_i}(\lambda)$ function connects the variations in the spectrum flux with the θ_i variations at each wavelength. In practice, we generated this basis using a grid of synthetic spectra (Recio *et al.* 2006) based on MARCS atmosphere models (Gustafsson *et al.* 2008) and VALD atomic data (Kupka *et al.* 2000). The spectra were calculated over the following parameter ranges:

- T_{eff} = [4 000, 8 000] K ; steps 250 K
- $\log g$ = [-1.0, 5.0] dex ; steps 0.5 dex
- $[M/H]$ = [-5.0, 1.0] dex ; steps 1 to 0.25 dex

Application : the observed stellar spectrum ($S(\lambda)$) is projected on the basis of functions previously calculated in order to determine the stellar parameter θ_i.

Results and perspectives

We investigated the impact of the noise on the results obtained with the automated software described above. We calculated the error on the estimate of the stellar parameters using a set of 1088 synthetic spectra computed of the wavelength domains of our observed spectra. We added to the synthetic spectra gaussian white noise considering different signal to noise ratio (S/N) values. We found that the total errors on the estimates are, for S/N = 10, $\Delta T_{eff} = 170.$ K, $\Delta \log g = 0.196$ dex, $\Delta[M/H] = 0.124$ dex. For spectra with S/N=50, these values become $\Delta T_{eff} = 40.$ K, $\Delta \log g = 0.059$ dex, $\Delta[M/H] = 0.037$ dex.

The calibration of the software with observed spectra is on-going using the ELODIE library (Prugniel *et al.* 2001). The automatic pipeline is ready for the Mg I triplet spectral range and under tests for the Ca II triplet spectral domain. The foreseen evolution of this software is to implement the determination of elementary abundances of key elements like CNO.

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