SF2A 2010
S. Boissier, M. Heydari-Malayeri, R. Samadi and D. Valls-Gabaud (eds)

MASSIVE SPECTROSCOPIC ANALYSIS OF THE STELLAR POPULATIONS IN THREE OF THE COROT/EXOPLANET FIELDS

J.-C. Gazzano[1,2], M. Deleuil[1], P. de Laverny[2], G. Kordopatis[2], C. Moutou[1], A. Recio-Blanco[2], A. Bijaoui[2], F. Bouchy[3, 4] and C. Ordenovic[2]

Abstract. We derived the atmospheric parameters ($T_{\rm eff}$, log g, [M/H], [α/Fe]), $V_{\rm rad}$, and $V \sin i$ for 1227 *CoRoT*/Exoplanet targets in three of the fields observed by *CoRoT*. We derived the corresponding absolute magnitude using evolutionary models. We combined 2MASS colours with a new implementation of the infrared flux method, and the $T_{\rm eff}$ from *MATISSE* to constrain the interstellar extinction. These steps allowed us to measure the stellar distances, hence deriving kinematics information. This opened the path to the study of the stellar populations found in these *CoRoT* fields. These studies showed the potential of combining a multi-fiber instrument like *FLAMES/GIRAFFE*, with an automatic tool to determine efficiently atmospheric stellar parameters, as *MATISSE*.

Keywords: techniques: spectroscopy, stars: fundamental parameters, planetary systems, general, CoRoT, galaxy: structure, kinematics, chemistry

1 Introduction

CoRoT space mission has been gathering thousands of light-curves since early 2007 (Baglin et al. 2006). The goals are to detect planetary transits and measure stellar oscillations. To support this mission, we observed with the *FLAMES/GIRAFFE* spectrometer 1914 *CoRoT* targets in three of the *CoRoT* fields, the *Long Run Anticenter 01*, *Long Run Center 01*, and *Short Run Center 01* (strategy described in Baglin et al. 2007). The objectives of these observations were to follow-up the planetary candidates detected in *CoRoT* data and to characterise the stellar populations in the *CoRoT* fields. We could perform a spectroscopic analysis on 75% of the spectra (1227 stars, Gazzano et al. 2010a). The properties of the fields observed can be found in table 1. The atmospheric parameters of the stars in these fields are mandatory for characterising the stellar populations in these Galactic directions, and could also be linked to the *CoRoT* lightcurves. Getting to know the Galactic structure and kinematics of these fields is a serious asset for understanding the planet detections in the CoRoT fields and the diametrically opposed pointing directions offers the possibility to explore different Galactic regions, with different properties.

2 Automatic spectroscopic analysis

The obvious preliminary step is to correct the spectra from the stellar radial motion. We cross correlated the spectra with a weighted mask (Baranne et al. 1996; Pepe et al. 2002) to measure the radial velocity ($V_{\rm rad}$) and an estimate of the rotational velocity ($V \sin i$). The $V_{\rm rad}$ distribution did not show peculiarities and the $V \sin i$ distribution confirmed that most of the stars rotate slowly. The derived values can be found in Gazzano et al. (2010a).

---

[1] Laboratoire d'Astrophysique de Marseille (UMR 6110), OAMP, Université Aix-Marseille & CNRS, 38 rue Frédéric Joliot Curie, 13388 Marseille cedex 13, France

[2] Université Nice Sophia Antipolis, CNRS (UMR 6202), Observatoire de la Côte d'Azur, Laboratoire Cassiopée, BP 4229, 06304 Nice, France

[3] Institut d'Astrophysique de Paris (UMR7095) CNRS, Université Pierre & Marie Curie, 98bis Bd Arago, 75014 Paris, France

[4] Observatoire de Haute-Provence, CNRS/OAMP, 04870 St Michel l'Observatoire, France

Table 1. Properties of the three Galactic directions. The columns contain, the *CoRoT* field, the number of stars with derived atmospheric parameters, the mean Galactic longitude and latitude, and the r' magnitude (SDSS filter system, Fukugita et al. 1996) range.

Sample	N_{stars}	l ($^\circ$)	b ($^\circ$)	r'
LRa01	457	212.2	-1.9	[10.7 ; 15.0]
LRc01	555	37.5	-7.5	[11.5 ; 16.0]
SRc01	215	36.8	-1.2	[11.3 ; 15.8]
Total Sample	1 227	-	-	[10.0 ; 16.0]

2.1 MATISSE

We used the *MATISSE* (MAtrix Inversion for Spectral SynthEsis) algorithm described by Recio-Blanco et al. (2006), tested and applied in Gazzano et al. (2010a). This algorithm is based on the state of the art in model of stellar atmospheres (Gustafsson et al. 2008) and spectral synthesis technique to measure efficiently and in an automatic fashion atmospheric parameters, *i.e* the effective temperature ($T_{\rm eff}$), the surface gravity (log g), the overall metallicity content ([M/H]) and the α-elements enrichment ([α/Fe]). This algorithm was indeed originally developed for the spectral analysis of spectra to be observed with the Radial Velocity Spectrometer instrument of the Gaia mission (Lindegren et al. 2008). Hence it is a reliable and very fast algorithm perfectly suitable for the spectral analysis of our sample of 1914 stars. We calibrated the atomic lines list, modifying the oscillator strength for $\sim$ 300 atomic lines to reproduce the Kurucz solar spectrum described in Hinkle et al. (2003). We interpolated a grid of 10 000 spectra with $T_{\rm eff}$, log g and [M/H] randomly chosen, and added Gaussian noise to every spectrum to evaluate the internal precision of the algorihtm. Gazzano et al. (2010a) showed that the internal error only due to the method for spectra at a signal-to-noise ratio of 20, is $\Delta T_{\rm eff} \simeq 50$ K, $\Delta \log g \simeq 0.08$ dex, Δ[M/H]$\simeq$0.05 dex, and $\Delta[\alpha/{\rm Fe}]\simeq$0.02 dex.

2.2 Literature comparison

In order to ensure the quality of the atmospheric parameters derived with *MATISSE*, we applied the entire procedure to several libraries of observed spectra analysed by different authors. We used the S^4N sample described by Allende Prieto et al. (2004), the Elodie 3.1 sample with parameters from Prugniel et al. (2007), a small sample of UVES spectra obtained in the context of the Paranal Observatory Project (POP, Bagnulo et al. 2003) and whose parameters could be also found in Prugniel et al. (2007) and giant stars spectra observed and analysed by Santos et al. (2009). We calculated the correlation between *MATISSE* and literature values for every parameter and found a correlation of 0.99 for the $T_{\rm eff}$, and 0.96 for [M/H] over the four samples mixed. The situation is not so good for the surface gravity. We found a correlation of 0.83 for the giant sample from Santos et al. (2009) and of 0.89 for the S^4N dwarfs. The latter might be due to the fact that we are comparing, for the S^4N sample spectroscopic (from *MATISSE*) and evolutionary surface gravity (derived from iso-chrones). This is not the case for the Santos et al. (2009) and this shows that it is much more difficult to derive spectroscopic gravity for giant stars. The discrepancy for [α/Fe] determination is higher, since the correlation between the two measurements is 0.75, but this might be due to the use of several abundance measures from Allende Prieto et al. (2004).

We compared this classification with the photometric one performed before *CoRoT* launch (in EXODAT, Deleuil et al. 2009) and found fairly good agreement for the brightest targets. This allowed us to characterise the population of the dwarfs in these *CoRoT* fields, to show that in the bin of magnitude r' 15 to 16, the number of dwarfs is highly underestimated by the photometric classification, particularly in the *LRc01* field. We also applied the relationship between metallicity and giant planet occurrence built during the ten past years (Udry & Santos 2007), and found a number of giant planets consistent with what *CoRoT* detected.

2.3 Absolute magnitude and stellar distances

We used the *MATISSE* atmospheric parameters to locate every star on a Y^2 iso-chrone (Demarque et al. 2004), and to derive the absolute visual magnitude. To illustrate that, we plotted on the left part of Fig 1 the logarithm

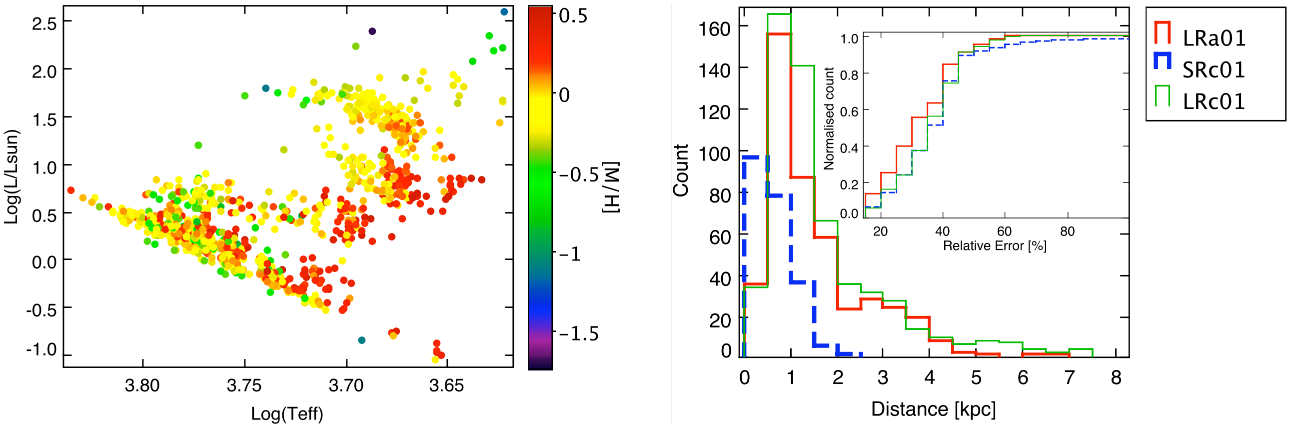

Fig. 1. Left: Hertzsprung-Russell diagram of the analysed stars with the overall metallicity colour coded. Right: distribution of the stellar distances derived by our procedure for the three Galactic directions.

of the luminosity with respect to the solar value* as a function of the effective temperature. It shows that we mostly observed main sequence F and G stars on the one hand, and K giants on the other hand. For the extinction determination, we used the *MATISSE* effective temperature with the new implementation of the infrared flux method using the 2MASS catalogue presented by González Hernández & Bonifacio (2009). This allowed us to measure the stellar distance with J band absolute and apparent magnitudes, and absorption. The derived values can be found in Gazzano et al. (2010b, in prep.). The distribution of the derived stellar distances is presented on the right part of Fig. 1. Most of the stars in the three fields are located within two kiloparsecs from the Sun. It also shows that the stellar distances are correctly determined, 80% of the entire sample having a relative error on the distance lower than 50%.

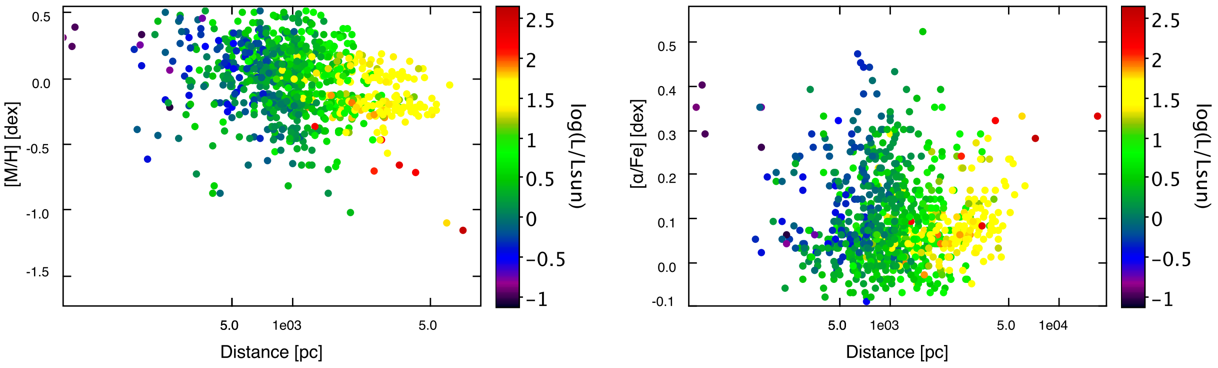

Fig. 2. Metallicity (left) and [α/Fe] (right) as a function of stellar distance from the Sun. This illustrates a possibility to study the metallicity Galactic gradient.

2.4 Adding kinematical information

When tracing the metallicity as a function of the stellar distance (Fig. 2 left), we see a correlation, probably linked to the Galactic metallicity gradient. This correlation does not appear that clearly for the [α/Fe] (Fig, 2 right).We matched the sample of stars with atmospheric parameters with the PPXML (Roeser et al. 2010) because these authors showed that the UCAC3 catalogue (Zacharias et al. 2010) has problems northern that $\delta = -20^\circ$. Besides, they argue that the proper motions they derived are as accurate or better than the UCAC2 catalogue (Zacharias et al. 2004). We found 1058 stars in common with errors around 0.4 arcsec per century.

---

[*] calculated from the absolute magnitude and choosing 4.83 for the absolute magnitude of the Sun

Combining these data with our $V_{\rm rad}$ and distance determination allowed us to measure the Galactic position and velocity components. We propagated the errors of every observational quantity either by deriving it analytically or using Monte-Carlo realisations. Galactic kinematics information allows to retrace stellar orbits of the stars and understand the structure and history, and link it to the chemistry of the Milky Way.

3 Conclusions and perspectives

We measured the atmospheric parameters and kinematical quantities for 1227 stars in the *CoRoT*/Exoplanet fields using the *MATISSE* algorithm (Gazzano et al. 2010a). We combined these results with isochrones and proper motions to estimate the absolute magnitude, distance, and Galactic kinematics of these stars (Gazzano et al. 2010b, in prep.; Kordopatis et al. 2010, in prep.). This opened the possibility to search for Galactic features such as the quantification of the Galactic metallicity gradient (Maciel & Costa 2010), Galactic population proportions from velocity components (Bensby et al. 2005) and take advantage of the [α/Fe] determination linked to Galactic kinematics. These points will be explored in a forthcoming paper (Gazzano et al. 2010b, in prep.). Finally, all these studies will be reproduced in other *CoRoT* fields and could be linked to the high quality *CoRoT* photometry.

We observed the spectra necessary for these studies at ESO/VLT. Computations have been done on the "Mesocentre SIGAMM" machine, hosted by Observatoire de la Côte d'Azur. We also thank C. Turon for her warnings about the proper motions from the UCAC3 catalogue, and V. Hill for our discussions.

References

Allende Prieto, C., Barklem, P. S., Lambert, D. L., & Cunha, K. 2004, A&A, 420, 183
Baglin, A., Auvergne, M., Boisnard, L., et al. 2006, in COSPAR, Plenary Meeting, Vol. 36,
Baglin, A., Auvergne, et al., 2007, Fifty Years of Romanian Astrophysics, 895, 201
Bagnulo, S., Jehin, E., Ledoux, C., et al. 2003, The Messenger, 114, 10
Baranne, A., et al. 1996, A&A, 119, 373
Bensby, T., Feltzing, S., Lundström, I., & Ilyin, I. 2005, A&A, 433, 185
Deleuil, M., et al. 2009, AJ, 138, 649
Demarque, P., Woo, J.-H., Kim, Y.-C., & Yi, S. K. 2004, ApJS, 155, 667
Fukugita, M., Ichikawa, T., Gunn, J. E., et al. 1996, AJ, 111, 1748
Gazzano, J.-C., de Laverny, P., Deleuil, M., et al. 2010, A&A, in press
Gazzano, J.-C., de Laverny, P., Recio-Blanco, A., et al. 2010, in preparation
González Hernández, J. I., & Bonifacio, P. 2009, A&A, 497, 497
Gustafsson, B., Edvardsson, B., Eriksson, K., et al. 2008,A&A, 486, 951
Hinkle, K., Wallace, L., Livingston, W., et al. 2003, in The Future of Cool-Star Astrophysics, Vol. 12, 851–856
Kordopatis, G. et al., A&A, in preparation
Lindegren, L., Babusiaux, C., Bailer-Jones, C., et al. 2008, in IAU Symposium, Vol. 248, 217–223
Maciel, W. J. & Costa, R. D. D. 2010, in IAU Symposium, Vol. 265, 317–324
Pepe, F., Mayor, M., Galland, F., Naef, D., Queloz, D., Santos, N. C., Udry, S., & Burnet, M. 2002, A&A, 388, 632
Prugniel, P., Soubiran, C., Koleva, M., & Le Borgne, D. 2007, ArXiv Astrophysics e-prints
Recio-Blanco, A., Bijaoui, A., & de Laverny, P. 2006, MNRAS, 370, 141
Robin, A. C., Reylé, C., Derrière, S., & Picaud, S. 2003, A&A, 409, 523
Robin, A. C., Reylé, C., Derrière, S., & Picaud, S. 2004, A&A, 416, 157
Roeser, S., Demleitner, M., & Schilbach, E. 2010, AJ, 139, 2440
Santos, N. C., Lovis, C., Pace, G., Melendez, J., & Naef, D. 2009, A&A, 493, 309
Udry, S., & Santos, N. C. 2007, ARA&A, 45, 397
Zacharias, N., Urban, S. E., et al. 2004, AJ, 127, 3043
Zacharias, N., Finch, C., Girard, T., et al. 2010, AJ, 139, 2184