PhD thesis

Archaeology of the Milky Way thick disc in the Gaia era.

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Galactic archaeology and the Gaia mission

The formation and evolution of disk galaxies like the Milky Way is one of the major problems of modern astrophysics. Our presently prevailing view of the Universe structure formation history relies on a hierarchical process driven by the gravitational forces of the large-scale distribution of cold, dark matter (ΛCDM). In this theoretical framework, large galaxies like the Milky Way are believed to form through the merging of many proto-galactic fragments (Abadi et al. 2003). However, although ΛCDM numerical simulations have had remarkable success in matching the observed largest structures in the Universe, they fail to reproduce the observed properties of structures on galactic and sub-galactic scales.

The oldest stars in our Milky Way Galaxy have different chemical compositions to younger ones. They are more primitive even than objects in the distant parts of the universe (at redshifts z = 3-5). The Galactic archaeology approach consists in deciphering the fossil information encoded in the stellar component of our Galaxy and its satellites, uncovering the different stages of formation and evolution of the Galaxy we live in (Freeman & Bland-Hawthorn, 2002).

In the near future, the ESA/Gaia mission will observe approximately a billion stars in the Galaxy. For this sample, Gaia will measure stellar distances to new precisions at milliarcsecond accuracies. Of the three instruments that Gaia carries, the Radial Velocity Spectrometer (RVS) will observe spectra at two different resolutions (R ~ 11500 and R ~ 7000) over the wavelength domain from 847 nm to 874 nm. This wavelength region includes several key spectral features which will be used to determine the stellar parameters and metallicities for at least 25 million stars. As a consequence, Gaia will have a major impact on our knowledge of the Milky Way history. The challenge will be to exploit this survey to acquire a global vision of the Milky Way system, how it is now, how it was built up.

In the framework of the Gaia mission preparation and scientific exploitation, the AMBRE project (Worley et al. 2010) consists in the analysis of the archived spectra of four European Southern Observatory (ESO) spectrographs under a contract between ESO and OCA. It offers a unique opportunity to test the performances of the Gaia analysis algorithms on large datasets of real spectra and to prepare the necessary scientific data interpretation methods. The AMBRE project is formally connected to the Gaia Data Processing and Analysis Consortium

Analysis and scientific exploitation of the AMBRE spectral database

The goal of this thesis is to prepare the scientific exploitation of the Gaia spectroscopic data. For that purpose, we propose to analyse, with different automated parametrization algorithms that we have developed for the treatment of the Gaia spectra, several tens of thousands of stellar spectra from the ESO archive to which we have a privileged access through the AMBRE project.

A total of 200 000 spectra are included in the AMBRE database. Among them, about 80 000 spectra have been collected with the VLT-FLAMES facility in its GIRAFFE/LR8 configuration, sharing the same wavelength domain and resolution as the Gaia Radial Velocity Spectrometer in its low resolution mode. The galactic locations of the targeted regions are presented in Fig. 1. The analysis of those spectra will enable rigorous testing on a large dataset of real Gaia-like spectra.

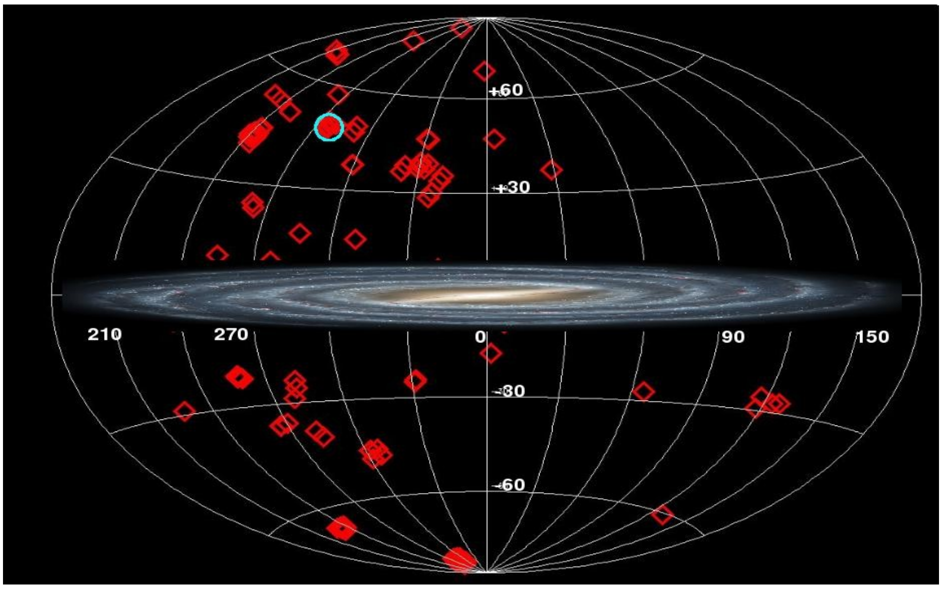

Fig. 1: *Galactic locations of the regions targeted by the ~80000 GIRAFFE/LR8 spectra of the AMBRE project. The blue circle is the field already analysed by our group (Kordopatis PhD thesis).*

In addition, our group is responsible for the parametrization of the Gaia RVS stellar data within the Gaia consortium. The detailed comparison of different stellar parametrization methods, based on an optimisation approach, projection algorithms or classification, will allow to build an optimal analysis pipeline dedicated to the Gaia data that will be integrated within the Gaia general data treatment pipeline at CNES.

In this context, one of the major challenges will be to develop new automated stellar parametrization methods allowing the determination of a important number of parameters, including the chemical abundances of individual elements at the stellar surface. The present project relies already on two methods developed by our group: MATISSE (Recio-Blanco et al. 2006, a local multilinear regression method) and DEGAS (Bijaoui et al. 2010, a classification algorithm based on an oblique decision tree). Both algorithms are already integrated into the Gaia general pipeline at CNES (c.f. Fig. 2).

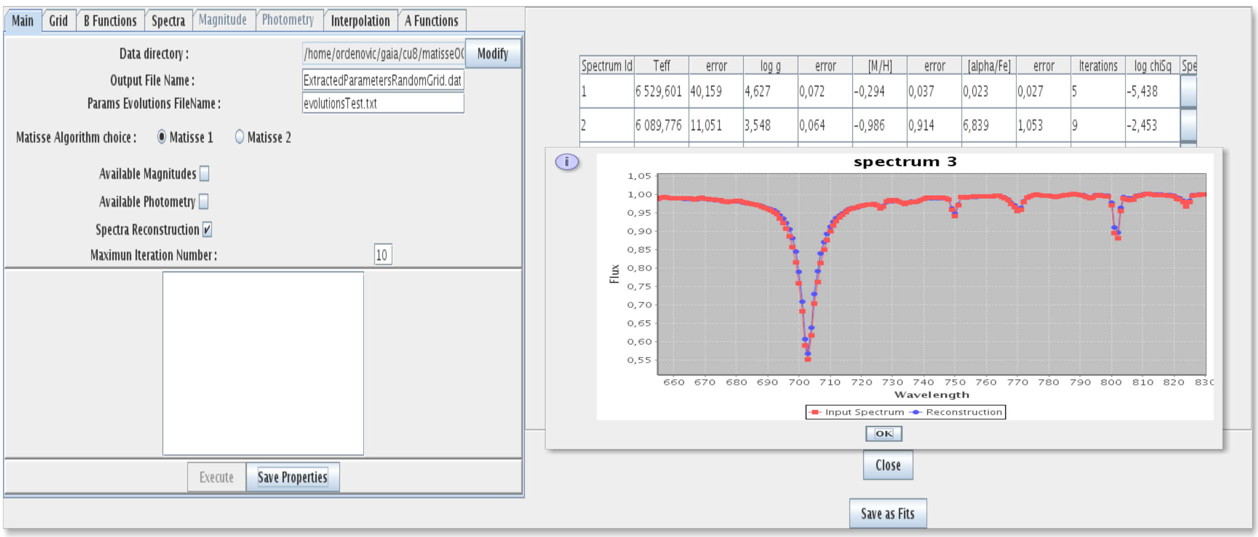

Fig.2 : *Graphic interface of the spectral analysis tool developed by our group and integrated at CNES within the general Gaia data treatment pipeline.*

The formation of the Galactic Thick Disc

The AMBRE GIRAFFE/LR8 database contains several thousands of Galactic stars collected as foreground/field targets of different programmes and remained unexploited up to now. This enormous quantity of data allows to sound the vertical and the radial structure of the Galactic Thick Disc and to give unprecedented constraints to Galactic models of formation and evolution.

Following the experience that our group has in this field (cf Fig. 3 and description here below of G. Kordopatis PhD thesis), we propose to exploit the extensive AMBRE database to disentangle and constrain unambiguously the possible origin of the Galactic Thick Disc: direct accretion of stars from disrupted satellites (Abadi et al. 2003), thickening of a pre-existing thin disc through a minor merger (Villalobos & Helmi, 2008), scattering or migration of stars by spiral arms (Shönrich & Binney, 2009) and in situ triggered star formation during/after gas-rich mergers (Brook et al. 2005).

We will particularly concentrate on two aspects: i) to establish the presently poorly constrained chemo-dynamical properties of the thick disc far from the solar neighbourhood at various heights from the galactic plane, by determining distances, kinematics, and whenever possible, angular momentum and eccentricities that will be analized in the light of the various scenarios. ii) to identify and characterise possible sub-structures within the thick disc.

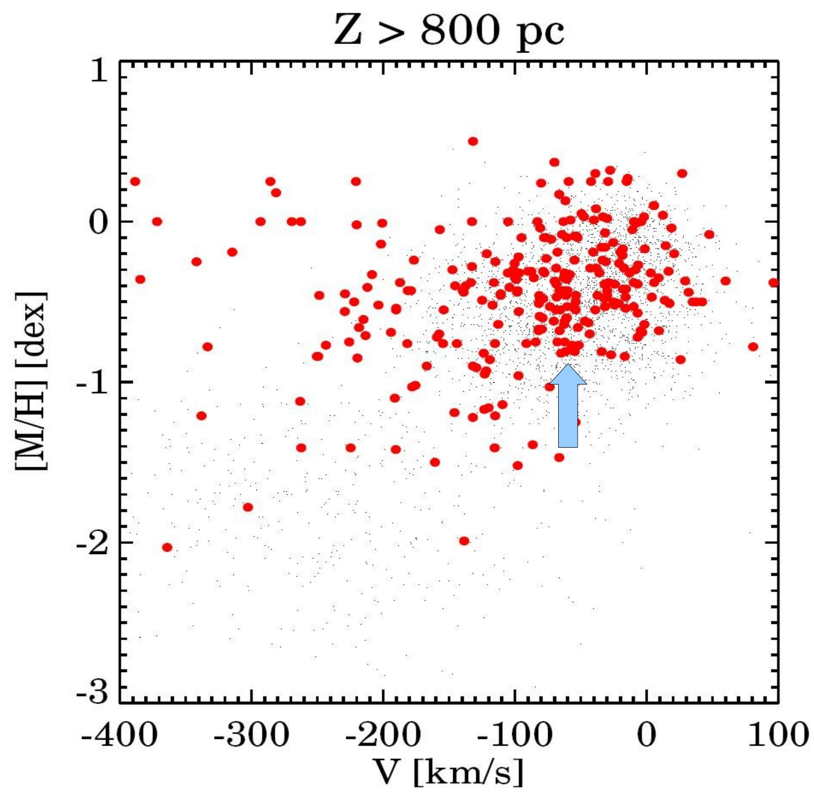

Fig 3. : *Global metallicity versus Galactic rotational V velocity of the stars far from the Galactic plane (above 800 pc), in the field studied by Kordopatis et al. 2011a & 2011b. The stars pointed out by the blue arrow correspond to a Thick disc population rotating slower around the Galactic centre than the canonical ones observed in the solar neighbourhood. This study has revealed that their*

abundances are in agreement with the general metallicity distribution of Thick Disc stars.

We have already started to answer to the previous questions thanks to the analysis of 700 stars in the Galactic direction l=277deg b=47deg, marked in Fig. 1 by the blue circle (Kordopatis et al. 2011a & 2011b). This has been the first extensive spectroscopic Thick Disc survey far from the solar neighbourhood, combining metallicity determinations with a complete dynamical analysis (c.f Fig. 3). This pencil bin survey has now to be extended to different Galactic directions. The AMBRE project, together with our experience on automated stellar parametrization, gives us a unique opportunity to perform a Thick Disc archaeology study by exploiting thousands of real Gaia-like spectra.

In addition, our group is deeply involved in the proposed Gaia-ESO Galactic Chemo-dynamical public survey. This project (starting date: octobre 2011) consists in 300 dedicated nights of VLT/GIRAFFE observations, targeting ~10^5 stars in all the major stellar components of our Milky Way. The proposed thesis will prepare the technical and scientific skills necessary for this survey by consistently analysing the kinematics and the chemical abundances of a statistically significant sample of stars. The student will be involved directly in the analysis of the Gaia-ESO survey as soon as the data will be available.

Summing up, the work of this thesis, combining extensive data to which we have a privileged access and appealing to the rigorous testing of the newest spectral analysis tools, will be a step towards the preparation of Gaia data scientific exploitation, by shedding new light on our knowledge of the Milky Way thick disc.

References:

Abadi et al. 2003, ApJ 591, 499

Bijaoui, A., Recio-Blanco, A., de Laverny, P., & Ordenovic, C. 2010, in ADA 6 - Sixth Conference on Astronomical Data Analysis

Brook et al. 2005, ApJ 630, 298

Freeman & Bland-Hawthorn, 2002, Annual Review of Astronomy and Astrophysics, Vol. 40, p. 487-537

Kordopatis et al. 2010, SF2A-2010: Proceedings of the Annual meeting of the French Society of Astronomy and Astrophysics. Eds.: S. Boissier, M. Heydari-Malayeri, R. Samadi and D. Valls-Gabaud, p.365

Kordopatis et al. 2011a & 2011b A&A, submitted

Recio-Blanco, Bijaoui & de Laverny, 2006, MNRAS, 370, 141

Schönrich & Binney, 2009, MNRAS, 399, 1145

Villalobos & Helmi, 2008, MNRAS, 391, 1806

Worley et al. 2010, SF2A-2010: Proceedings of the Annual meeting of the French Society of Astronomy and Astrophysics. Eds.: S. Boissier, M. Heydari-Malayeri, R. Samadi and D. Valls-Gabaud, p.399