Progetto tesi di dottorato in Fisica e Astronomia per XXXVIII Ciclo dell'Università di Firenze

How is it made?
Looking for the origins of the stellar populations that made up the Galactic disc

Supervisor: Laura Magrini

in collaboration with Germano Sacco and Lorenzo Spina

An assumption often made in studies of our Galaxy is that the chemical makeup of a star provides the fossil information on the environment where it was born. Under this premise, it would be possible to *tag* stars that formed from the same material through clustering in the chemical space. This methodology is known as "chemical tagging".

The chemical tagging technique makes the hypothesis that it is possible to use elemental abundances to `reconstruct' dispersed chemically homogeneous star clusters (Bland-Hawthorn et al. 2010). Regardless of the precision achievable in elemental abundances, the success of chemical tagging relies on the significance of two critical factors: the chemical diversity of the interstellar medium in space and time and the level of chemical homogeneity of stars formed from the same giant molecular cloud.

While the "strong" version of chemical tagging, i.e. based only on the chemical information, is likely to fail in the Galactic disc, due to its slow evolution and high density/mixing of its stellar populations, the addition of kinematic information and stellar ages seems to be very promising.

The aim of this project is to investigate the issue of chemical tagging with a multiple approach, following the next steps:

- ***Confirming the basis of chemical tagging, i.e. probing the level of homogeneity of star clusters:*** the PhD student will tackle this topic by obtaining precise differential abundances between members of stellar clusters (data from the Gaia-ESO survey and from the SPA project, already available and reduced), investigating the evolutionary and analysis effects which might produce differences among cluster members.

- ***Putting constraints on the intra-cluster differences:*** the PhD student will investigate the intra-cluster differences (related to the Galactocentric position and age), to exploit the potentially most interesting elements, i.e., the elements that contribute most to differentiate clusters from one another, such as the heavier elements (Y, Ba), and Fe, Mg, Si, and Na (see Blanco-Cuaresma et al. 2015, Garcia-Dias et al. 2019, Spina, Magrini et al.

submitted). She/he will exploit the final data release of **Gaia-ESO,** with the final releases of the GALAH and APOGEE surveys, which are providing high-resolution spectra for more than 300 clusters.

- ***Adding ages and kinematic properties:*** we aim at improving the detection of disrupted clusters in the field of large spectroscopic surveys, as Gaia-ESO, APOGEE and GALAH using the combination of chemical, dynamical and age properties of field stars, to put constraints on the scenarios of formation of evolution of our Galaxy.

- ***Chemical tagging in the era of Gaia DR3***: In June 2022, Gaia DR3 will be available to the whole astronomical community, and it will provide also stellar parameters abundances, together with exquisite astrometry and photometry. The data, combined with those from ground-based spectroscopic surveys, will be used to refine the chemical tagging technique, e.g. identifying kinematical substructures to be then chemically characterised (see Helmi et al. 2018).

During the three years of the PhD, she/he will learn some spectral analysis techniques to derive stellar parameters and chemical abundances. She/he will compare with stellar evolutionary models, including, e.g., mixing, extra-mixing and diffusion which might introduce abundance variations with time, to understand the level of homogeneity of the parent molecular cloud from which the cluster formed. Using machine learning techniques, she/he will detect the elements which are the best tracers of the uniqueness of each cluster. She/he will apply the best set of elements, together with ages and kinematical properties, to stars in the field of large spectroscopic surveys. The Project is valuable also in preparation of the science cases for new instruments, such as the High-resolution spectrograph for VLT (HRMOS) and the WST telescope.