Project title: Galactic Archaeology with neutron capture elements

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Present-day stellar chemical abundances, ages, and kinematics are fossil records of the chemical abundances of the interstellar medium (ISM) when the stars formed. These data are very rich in information and can be explored in different directions. Elements with Z > 30 are labelled neutron capture elements: they are mainly formed through multiple neutron captures, and not through fusion because charged particle reactions on elements beyond iron (Z = 26) are endothermic (omitting the proton captures, responsible for less than 1% of the heavy elements). The neutron capture process is split in the rapid process (r-process) or slow process (s-process) depending on whether the timescale for neutron capture is faster or slower than radioactive beta decay, according to the initial definition by Burbidge et al. (1957). Neutron capture elements have complex nucleosynthesis and they are not yet deep investigated as - for example - alpha elements.
Many studies have investigated the most striking signatures found in the vast realm of the Galactic halo stars. These stars are very old and when they were formed the ISM was still not enriched and their metallicity is typically a few thousandths of the Solar metallicity. The first chemical signature observed in halo stars was the **spread in the neutron capture elements** (McWilliam et al. 1998). Stars extremely rich in neutron capture elements were discovered, the so-called r-process rich stars, in which the Eu abundance is almost solar, compared to extremely low abundances of other elements.
The most recent investigation expanded the number of the stars at very low metallicity up to approximately thousand stars with high-resolution spectra and detailed chemistry of about 30 elements. More signatures appeared, such as **the spread of light (e.g. Sr, Y, and Zr) to heavy (e. g. Ba and La) neutron-capture elements**. Many questions are also raised from the **population of carbon-enhanced metal-poor stars (CEMP),** with about half of them present a very high abundance of barium, most likely the signature of binary interactions. In extremely small **dwarf spheroidal galaxies** (also called Ultra faint galaxies), only tiny amounts of neutron capture were found, until recent times, when Ji et al. (2016) discovered in Reticulum II several stars super-rich in neutron capture elements.
Present surveys, such as GALAH, APOGEE and WEAVE (due this year and delayed by pandemic) are producing an enormous amount of data for the stars of our Milky Way. There is also a strong and exciting connection between the rising field of gravitational waves and this project. Indeed the most promising sources of r-process material are the neutron star mergers, rare events that can explain the spread of neutron capture elements in halo stars.
The successful PhD candidate will work on this vast subject and the main aim of her/his project will be to perform a theoretical study to interpret one (or more) of the different chemical signatures highlighted here using chemical evolution models. In her/his project, the candidate will benefit not only of the experience in chemical modelling of the supervisors but also of their strong connections with renowned experts in stellar nucleosynthesis and measurements of chemical abundances in the stellar atmosphere. She/he can be also involved in the medium size observational survey MINCE (Measuring at Intermediate metallicity Neutron Capture Elements), led by Cescutti; MINCE aims to measure abundances of neutron capture elements in around 1000 halo stars, thanks to spectra of extreme quality in telescopes all around the world.