ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

DIPARTIMENTO DI FISICA E ASTRONOMIA
Department of Physics and Astronomy - DIFA

PhD project in ASTROPHYSICS

Title of the Project*:* Probing the early history of the Milky Way formation with the chemical DNA of Bulge stellar systems

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Scientific Case: While observations of the distant Universe show that bulges of spiral galaxies form through multiple mergers of massive clumps of gas and stars, and are subsequently enriched by accretion events, no direct evidence of these processes has been found so far in the Milky Way Bulge. Still, the Galactic Bulge is the sole spheroid where individual stars can be observed, allowing a unique exploration of the debris of those primordial clumps and accreted structures. Indeed, the discovery that Terzan5 (Ferraro et al., 2009, Nature,462, 483) and Liller1 (Ferraroet al, 2021, Nat. Astr., 5, 311), two Bulge systems with the appearance of globular clusters (GCs), host multi-age and multi-iron populations, and share the same "chemical DNA" of Bulge stars strongly suggest that they could be Bulge Fossil Fragments (BFFs), the remnants of the proto-Bulge formation process. Thus, a variety of relics tracing different phenomena are expected to populate the Bulge: BFFs, in-situ formed and externally-accreted GCs, and also nuclear star clusters of cannibalized structures. Each system could provide a piece of information about the Bulge formation and evolutionary history. The signatures of the different origins are imprinted in the kinematic, photometric, and chemical properties of these stellar systems, and can be read with different levels of accuracy.
Outline of the Project: In particular, the chemical tagging is a very powerful tool to unveil the true nature and origin of stellar systems, because specific abundance patterns provide authentic "chemical DNA tests" univocally tracing the enrichment process, hence the environment where the stellar population formed. In fact, the atmospheres of the stars that we observe today preserve memory of the chemical composition of the interstellar medium (ISM) from which they formed, and the chemical abundances of the ISM vary in time if more than one burst of star formation occurs, owing to the ejecta of each stellar generation. Thus, stars formed at different times and in environments with different star formation rates (SFRs) have different chemical compositions, and by analysing the chemistry of each stellar population one can univocally trace the enrichment process of the ISM. Different abundance patterns are expected depending on the stellar polluters, the enrichment timescale and the SFR, with a few specific abundance patterns being so distinctive that they can be used as "DNA tests" of the stellar population origin.
In this framework we are leading a Large Programme at the ESO-Very Large Telescope (VLT) which exploits the superb performances of the spectrograph operating in the near-IR CRIRES+ to perform an unprecedented chemical screening of a representative sample of Bulge stellar systems, with the aim to determine their chemical DNA and finally unveil their true origin. A total of 255 hours of observing time was assigned to this Large Programme (PI: Ferraro).

The student will be in charge of the spectroscopic analysis of the high-resolution CRIRES spectra to derive chemical abundances of several key elements. In particular, beyond the iron, the abundance of many iron-peak elements (like Zinc, Vanadium, etc) and alpha-elements (like Calcium, Silicon, Magnesium, Titanium) will be derived. These abundances will be used to construct powerful chemical DNA indicators as the 'classical" [α/Fe]–[Fe/H] diagram and to test the new-defined DNA test involving [V/Fe] and [Zn/Fe] ratios. The combination of these test will allow a solid distinction between in-situ formed and accreted GCs and the univocal identification of the environment in which the stellar systems formed.

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