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: *Cosmic-Lab: probing the physics of dense stellar systems*

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Scientific Case: The Universe we live in is dominated by darkness. Indeed, the vast majority of the matter (and possibly of the energy) in the Universe is dark, while only a few percent can be revealed through light signals. Fortunately the presence of dark matter (DM) leaves imprints in the kinematical properties of the luminous mass, revealing invisible structures as DM halos and super-massive black holes. This project is devoted to study the kinematics of sub-galactic stellar systems with the aim of unveiling and probing the existence of non-visible matter at the globular cluster (GC) scales. Finding DM halos in sub-galactic structures would be crucial to alleviate the cosmological "missing satellite problem". Identifying intermediate-mass (10^3-10^5 $M_\odot$) black holes (IMBHs) in GCs could shed new light on the formation processes of the SMBHs observed in galaxies and AGNs already at redshift z>6. Precisely determining the internal structure and kinematics of GCs would also fill our current lack of knowledge about the physics of these stellar systems, which are true astrophysical milestones.

Outline of the Project: To address these issues we propose to perform the most comprehensive study ever attempted to determine the internal structure and kinematics of GCs. Specifically, we are determining the projected density distribution, the velocity dispersion profile and the rotation curve, from the very center out to the tidal radius and through unbiased methodologies, for a sample of 36 Galactic GCs well representative of different structural parameters, dynamical stages and environmental conditions. The line-of-sight (LOS) kinematics will be determined from the spectra of several hundreds individual stars located along the entire extension of each GC, by exploiting state-of-the-art technology in a non-conventional way. The data needed to perform this part of the project are already acquired by means the ESO Multi-Instrument Kinematic Survey (MIKiS) that consists of 3 Large Programmes at the ESO-VLT (PI: Ferraro, for a total of 400 hours of observing time). We combine: *(i)* Adaptive Optics (AO) Integral Field Spectroscopy (IFS) in the innermost cluster regions (arcsecond scale), *(ii)* seeing-limited IFS for the intermediate radial range (tens of arcsecond scale), and *(iii)* wide-field multi-object spectroscopy for the most external regions (from one to tens arcminute scales).
A detailed presentation of the survey and results can be found in: Ferraro et al., 2018, ApJ, 860, 50; Ferraro et al.,2018, The Messenger, 172, 18; Lanzoni et al., 2018 ApJ, 865, 11; Lanzoni et al., 2018, 860, 95.

PROPER MOTIONS - Accurate proper motions (PMs) of individual stars in the center of each GC will be computed from multi-epoch HST images. This will provide us, for the first time, with the 3D kinematics of dozens of central stars, thus allowing us to reconstruct their orbits and recognize possible high-velocity objects accelerated by an IMBH. Moreover, we will properly sample the very central regions, where the most interesting dynamical processes are expected to occur (but where PMs of stars below the main sequence turnoff are not precisely measurable in most GCs because of crowding; see Watkins et al. 2015, ApJ 803, 29). This is crucial to detect possible central LOS velocity dispersion cusps. The PMs released by the GAIA space mission will complement this information in the external cluster regions, thus providing us with the 3D cluster kinematics along the entire radial extension.

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