PhD name: Silvia Leanza

PhD Cycle: XXXV

Tutor: Francesco Ferraro

Co-supervisors: Cristina Pallanca, Barbara Lanzoni

RESEARCH PROJECT: Exploring the kinematics of Globular Cluster cores

Astrophysical Context and Aim of the Project

The internal kinematics of Globular Clusters (GCs) is still largely unexplored because resolving individual stars in the overcrowded central regions of these dense stellar systems is very challenging. This is one of the main reasons why GCs are routinely described by means of oversimplified (spherical, isotropic, and non-rotating) models. However, recent results have shown signatures of systemic rotation (Vasiliev & Baumgardt+21, MNRAS, 505,5978; Sollima+19, MNRAS, 485, 1460, Ferraro+18b, ApJ, 860, 50; Lanzoni+18, ApJ, 861, 16) and significant deviations from the King velocity dispersion (VD) profile (Lanzoni+2018 ApJ, 865,11) in the outer regions of an increasing number of GCs. This already indicates that reality is much more complex than models and it suggests that even more surprising results may be found from the study of the central regions, which are known to be the most affected by internal dynamical processes. However, the kinematic exploration of GC cores is still at its dawn.

Within this context, my PhD project is aimed to explore the internal kinematics of the innermost regions of a large sample of Galactic GCs at sub-arcsecond spatial resolution, by using adaptive optics (AO) assisted integral-field spectroscopic observations (e.g., with MUSE/NFM and SINFONI). In particular, we aim to determine the VD profile and the rotation curve in the innermost ∼10'' to: (1) provide the very first determination of the inner kinematic structure, (2) detect unexpected kinematical features (as central VD drop or cusp) and (3) possibly, identify intermediate-mass (10^3 - 10^5 $M_\odot$) black holes (IMBHs) in the cores of these dense stellar clusters.

Second Year Activity and Results

During this year, my work was focused on the full investigation of the internal kinematics of NGC 1904. During my first year of PhD, I reduced and analyzed AO-MUSE/NFM and NOAO-MUSE/WFM observations of this GC. This year, I then worked on upgrading the method of analysis of the MUSE data cubes, improving the spectra extraction and adding a procedure able to quantify the level of contamination of the targets from neighboring sources (which can be significant in the central regions). In fact, this may affect the radial velocity (RV) measures and, hence, impact on the resulting VD and rotation profiles. I then complemented the MUSE data with FLAMES measurements for the most external regions of the system. The final sample consists of more than 1700 RVs of individual stars over the entire cluster extension, from 0.3'' to 770'' from the center. The main results obtained from the RV analysis are:

1) we detected a significant signature of systemic rotation, with a maximum amplitude of ∼1.5 km s^{-1} at ∼1 half-mass radius (∼70''), and a position angle of the rotation axis of 98°;
2) the velocity dispersion profile is well described by the same King model that best fits the projected density distribution, with no evidence of a central cusp or other significant deviations, and with a constant inner plateau at ∼6 km s^{-1}.

I also investigated the cluster rotation in the plane of the sky by taking advantage of the proper motions provided by the Gaia EDR3. This analysis has shown:

1) a component of rotation also in the plane of the sky, with a maximum amplitude of ∼2.0 km s^{-1} at ∼80'' from the cluster center;
2) no evidence of tangential or radial anisotropy in the velocity distribution.

As a final result, for a sub-sample of 130 stars, it was possible to analyze the three velocity components (RV and proper motions) together, confirming the presence of systemic rotation and providing an inclination angle of ∼40° for the rotation axis, with respect to the observer line-of-sight. All the details of the analysis and the discussion of the results are presented in Leanza et al. (2021), which has been just submitted to the ApJ.

Recently, I have started a similar analysis, based on MUSE/NFM and SINFONI data, for the massive GC NGC 6440. I am taking advantage of my visit to ESO (Garching), under the Marco Polo project, to explore improved methods and software tools for the extraction and analysis of MUSE spectra, in collaboration with Dr. Elena Valenti, who is one of the most experts in this instrument.

WORKSHOPS, CONFERENCES & MEETINGS

22 - 25 March 2021 – Northwestern University, Online event – "TRiple EvolutioN and DYnamics 3"

Seminar cycle by La Sapienza University, Online event, - "Quid ultra? Frontiers and controversies in astrophysics"

ESO Seminar series, Online event – "ESO Cosmic Duologues 2021"

ESO Seminar series, Online event – "Hypatia Colloquium"

PhD SCHOOLS

3 March 2021 – ESO Garching, Online event - LPO Users Workshop - Part II: "Optimising Phase 1 proposal planning and submission"

5 - 8 July 2021 – Online event – Science with MAVIS

INTERNAL COURSES

30 November - 2 December 2020 – Bologna, Online event, "The Interstellar Medium"

19 - 23 April 2021 – Bologna, Online event, "Gamma Ray Bursts: from observations to physical properties"

5 - 14 May 2021 – Bologna, "Writing, talking and presenting Science", organized by Dott. Roberto Decarli

ISA LECTURES

19 January 2021 – "Extreme events: how to describe and predict them using mathematical theories" by Sandro Vaienti

28 September 2021 – "How the Brain Controls Pain" by Mary Heinricher

RESEARCH PERIOD ABROAD

1 September - 30 November 2021 – Marco Polo mobility grant – Visiting student at the ESO, Garching, for a research collaboration with Dr. E. Valenti

COMPETITIVE TELESCOPE/COMPUTER TIME ALLOCATIONS

Co-I in the ESO-VLT proposal "Fast rotating Blue Stragglers prefer loose clusters: unveiling the affair",

PI: F. R. Ferraro, 20 h

Co-I in the ESO-VLT proposal "Unveiling the inner core kinematics of globular clusters at sub-arcsecond scale", PI: F. R. Ferraro, 16h

Co-I in the ESO-VLT Large Program "What is going on in globular cluster cores? Unveiling the core kinematics at sub-arcsec scale", PI: F. R. Ferraro, 142 h

OTHER RELEVANT ACTIVITIES

Co-relator of the Master's degree thesis “Esplorazione cinematica delle regioni centrali dell’ammasso globulare NGC 6441 alla ricerca di un buco di massa intermedia” presented by Camilla Perfetti

Python and Astropy course - by Luca Fini & Dr. Rossi Fabio (INAF)

October 2020 - January 2021 – CLA English Course, University of Bologna

March - June 2021 – CLA English Course, University of Bologna

PUBBLICATIONS

S. Leanza et al., 2021, “The ESO-VLT MIKiS survey reloaded: velocity dispersion profile and rotation curve of NGC 1904”, submitted to the ApJ

C. Pallanca et al. 2021 “A New Identity Card for the Bulge Globular Cluster NGC 6440 from Resolved Star Counts”, ApJ, 913, 137