PhD name: Bhavana Bhat
PhD Cycle: 35
Tutor: Barbara Lanzoni

RESEARCH PROJECT: Cosmic-Lab: globular clusters as cosmic laboratories for astro-archeology and multi-body dynamics

Globular Clusters(GCs) are unique astrophysical systems which undergo all the physical processes known in stellar dynamics within a timescale comparable to the age of the universe. In the Milky Way they are very old (10-12 Gyr) stellar systems, with high central density (up to a million stars per cubic parsec). They are collisional systems which progressively change their internal structure, and the radial distribution and content of objects with different masses: the most massive stars tend to transfer kinetic energy to lower mass objects (energy equipartition) and progressively sink toward the system center (dynamical friction and mass segregation).The continuous kinetic energy transfer from the core to the outskirts leads to a runaway contraction of the core itself, with a substantial increase of its density virtually toward infinity: the so-called “core-collapse” (CC). The contraction is thought to be halted by the formation and hardening of binary systems, and the post-CC phase is characterized by several episodes of central density increase, followed by stages during which the cluster rebounds toward a structure with lower density and more extended core (the so-called “gravothermal oscillations”). The long-term internal dynamical evolution tends to generate compact clusters, making large-core systems to naturally evolve toward objects with progressively smaller core radius. Concurrently, the radial distribution of stars with different masses progressively varies in time (the most massive objects migrating to the center). The characteristic timescales of these changes depend in a very complex way on cluster parameters like central density, binary fraction, the Galactic potential well, and so on. Hence, clusters with the same chronological age can be in very different dynamical stages (i.e., they can have different dynamical ages). The observational identification of the dynamical age of star clusters is challenging. Indeed, while the majority of Galactic GCs is expected to have already core collapsed (due to their short central relaxation times), observations indicate that this is the case for just a small fraction (15-20%) of the entire population. This result, however, only relies on the detection of a steep power-law cusp in the central portion of the cluster density profile, strongly deviating from the "classical" flat-core behavior of the King model that well reproduces the density profile of the large majority (80-85%) of GCs. This discrepancy could indicate that the density cusp may be significantly reduced/delayed due to other processes (e.g., gravothermal oscillations, binary fraction), and it calls for the identification of new parameters being able to more reliably distinguish GCs in early stages of dynamical evolution, from those that already suffered CC.

The aim of my PhD project is to search for alternative observational diagnostics of the
dynamical state of GCs, and to investigate their possible dependence on the cluster

properties (initial concentration, initial binary fraction, fraction of dark remnants and tidal effect of the host galaxy). Last year, by analyzing Monte Carlo simulations of a GC at various time intervals, I found that the normalized cumulative radial distribution (nCRD) of resolved stars included within one half-mass radius (rh) shows a clear sensitivity to the dynamical evolution of the system, thus indicating that the nCRD could be used as diagnostics of the dynamical state of the cluster. I thus performed an extensive exploration of new possible parameters that could be derived from the nCRD. During this year, I finalized the definition of three diagnostics: A5, which is the area subtended by the nCRD between the cluster centre and 0.05 rh; P5, which is the number of stars within 0.05 rh; and S2.5, which is the slope of the straight line tangent to the nCRD at 0.025 rh. The time evolution of these parameters enables us to clearly distinguish pre-CC clusters from post-CC clusters. We also tested the dependence of these parameters on the two main assumptions used in their construction i.e, the radius used to select the stars from which the nCRD is built (rh), and the magnitude cut adopted for the star sample selection. We found that the magnitude adopted cut, which dictates the mass range of the stars included in the construction of nCRD, affects the sensitivity of the parameters to dynamical evolution. This work is described in the paper Bhat et al. (2021) submitted to the ApJ. I am currently working on the second paper of this series (Bhat et al., 2021, in preparation) where I extend the same analysis and test the new diagnostics on simulations of GCs with different initial binary fractions. I'm also analysing two Monte Carlo simulations of GCs with different initial concentrations leading them to have CC at early and late times compared to the CC time of the first analysed simulation. I tested the new diagnostics on these two simulations and preliminary results show that they properly distinguish pre-CC and post-CC systems irrespective of their absolute CC time. The results will be presented in an additional paper in the early 2022.

WORKSHOPS, CONFERENCES & MEETINGS

28 June – 2 July 2021, online - conference: EAS 2021
5 July – 8 July 2021, online – Science with Mavis 2021

PhD SCHOOLS

12 July – 23 July 2021, Online – ISM Summer School
"Interstellar Medium of galaxies, from the epoch of reionization to the Milkyway"

INTERNAL COURSES

5 May -14 May 2021 Bologna, Italy – ”Writing, talking and presenting Science”
19 April- 23 April 2021 Bologna, Italy - “Gamma Ray Bursts: from the observations to physical properties”
30 November – 2 December 2020, Bologna, Italy - “The interstellar Medium”

ISA LECTURES

19 January 2021 - “Extreme events: how to describe them using mathematical theories”
26 January 2021 - “RNA:Biological functions and therapeutic potential”

RESEARCH PERIOD ABROAD

COMPETITIVE TELESCOPE/COMPUTER TIME ALLOCATIONS

CoI in ESO - Large program “What is going in globular clusters cores? Unveiling the core kinematics at sub-arcsec scale”, PI- F. R. Ferraro, 143.16 hr

CoI in ESO - “Fast rotating Blue Stragglers prefer loose clusters: unveiling the affair”, PI- F. R. Ferraro, 20hr

OTHER RELEVANT ACTIVITIES

28 June – 2 July 2021, online - EAS 2021- volunteered for the conference online

PUBLICATIONS

Bhat et al., 2021,"Searching for new observational signatures of the dynamical evolution of star clusters”

Pallanca et al., 2021,"New structural parameters of the bulge globular cluster NGC 6440
from Star Density Profile"