PhD student: Jianxing Chen

PhD Cycle: 35

Tutor: Francesco R. Ferraro

Co-supervisors: Mario Cadelano, Barbara Lanzoni

RESEARCH PROJECT: Exploring the white dwarf cooling sequence in Globular clusters

Context. White dwarfs (WDs) are the evolutionary endpoint of stars with mass below $8M_{\odot}$ (possibly up to $11M_{\odot}$), which correspond to the vast majority (98%) of stars in the Universe. Their study can bring a large amount of information about their progenitors and some physics under extreme conditions. In many previous studies, the evolution of WDs has been described as a pure cooling process, with no active thermonuclear reactions, and their cooling rate has been used as cosmic chronometer to constraint the age of stellar populations such as the Galactic disk, the halo, globular and open clusters. However, some recent theoretical computations suggested that the presence of a very thin residual hydrogen-rich shell around the dense core of the WD can provide some stable nuclear burning, able to supply a non-negligible source of energy that significantly slows down the cooling process. This is predicted to be more probable in low- than in high-metallicity, progenitors (I. Renedo et al. 2010; L. G. Althaus et al. 2015).

Globular clusters (GCs) are very old and metal-poor stellar systems in the Galaxy, and they provide large and homogeneous samples of WDs with relatively low-metallicity, compared to the Galactic field. Hence, they are the ideal laboratory where the properties of the WD cooling sequences (WDCSs) can be studied. My PhD project is devoted to a systematic investigation of the WD cooling sequence in a sample of GCs, based on high-quality data acquired with the Hubble Space Telescope (HST).

Progresses. As first step of this project, we selected two "twins GCs": M13 and M3. Indeed, they share many physical properties (as metallicity, mass, etc) but show quite different Horizontal Branch (HB) morphologies. After performing "UV-guided" PSF photometry of the available HST images, I obtained high-quality color-magnitude diagrams (CMDs) where the brightest portion of the WDCS is clearly visible. I carried out extensive artificial star experiments to assess the completeness of the observed WD samples. The detailed comparison of the WD luminosity functions of the two systems, after proper normalization to the overall respective cluster populations, shows a significant over-abundance of WDs in M13 with respect to M3 at the same level of magnitude (467 and 326 WDs, respectively). We suggested that it is due to a significant slowing down of the WD cooling process in M13, in agreement with its observed HB morphology. In fact, the blue extension of the HB in M13 is populated by stars that skip the last phase of the Asymptotic Giant Branch and therefore do not experience the third dredge-up event, during which most of the Hydrogen in the envelope is burned. This implies that the WD progeny of these stars presents a residual Hydrogen envelope thick enough to guarantee stable thermonuclear burning during the WD cooling evolution, with a significant increase of the cooling time. This is the first time that this effect has been observed, and the discovery deserved publication in *Nature Astronomy*.

We are now investigating the WDCS in NGC 6752, a GC with metallicity and HB morphology similar to those of M13. At odds with M13, this system is in an advanced stage of dynamical evolution (it is a core-collapsed cluster). Hence, in NGC 6752 we have the opportunity to also investigate the effects of the cluster internal dynamical evolution on the WD population, by comparing the WDCS properties at different distances from the cluster center. In fact, two main sets of data have been acquired in this cluster, one just at the center and one in the outer regions. In both fields the brightest portion of the WDCS is clearly sampled. I'm now performing artificial star experiments, studying the population ratios (N_agb/N_hb) and comparing the WDCS in the two fields. An intriguing feature is emerging from a first preliminary investigation of the WDCS morphology: a sub-sample of WDs define a sort of strip in the blue portion of the WDCS, near the beginning point of WD crystallization. I have checked each of them in the images and we confirmed that they are real stars. This feature is worth of further investigation.

In addition, we selected additional GCs with well-defined WDCSs and with different HB morphologies: NGC 2808 (HB blue tail), NGC 7089 (HB blue tail), and NGC 5904 (no HB blue tail). These will be the next targets of our investigation.

WORKSHOPS, CONFERENCES & MEETINGS

19-23 July 2021 Sagan Exoplanet Summer Virtual Workshop: Circumstellar Disks and Young Planets
29-30 Mar 2021 KITP Online Conference: White Dwarfs from Physics to Astrophysics

PhD SCHOOLS

18 July - 1 Aug 2021 China - Summer School in Planetary Sciences
12-16 July 2021 4th Spanish - Institute of Space Sciences Summer School: "Artificial Intelligence for Astronomy"

INTERNAL COURSES

5-7, 10, 12, 14 May 2021 Bologna, Italy - "Writing, talking and presenting Science"
19-23 April 2021 Bologna, Italy - "Gamma Ray Bursts: from observations to physical properties"
30 Nov - 2 Dec 2020 Bologna, Italy - "The Interstellar Medium"

ISA LECTURES

26/01/2021 - "RNA: Biological Functions and Therapeutic Potential"
19/01/2021 - "Extreme events: how to describe and predict them using mathematical theories"
15/12/2020 - "Translating texts which do not exist. Pseudo-originality, multistable figures, and Fortini's literary reception of Heine and Brecht"
27/10/2020 - "Scholarship and Art: Visual and Intellectual Encounters across the Mediterranean"

RESEARCH PERIOD ABROAD

I will go to Liverpool John Moores University (LJMU) through the "Marco Polo" Project from 1 Feb, to 30 April 2022

COMPETITIVE TELESCOPE/COMPUTER TIME ALLOCATIONS

OTHER RELEVANT ACTIVITIES

1 June 2021 QUID ULTRA - "The evolution of massive black holes through cosmic times"
18 May 2021 QUID ULTRA - "Quenching star formation in galaxies"
16 April 2021 QUID ULTRA - "The future of cosmology"
12 Feb 2021 Seminar Announcement: WHAT IS A MODEL? AN EVOLUTION PERSPECTIVE
5 Feb 2021 Seminar Announcement: HOW TO GIVE A SCIENTIFIC PRESENTATION

PUBBLICATIONS

1. *Slowly cooling white dwarfs in M13 from stable hydrogen burning*., Chen, J., Ferraro, F.R., Cadelano, M. et al., 2021, Nature Astronomy, https://doi.org/10.1038/s41550-021-01445-6.
2. *PSR J1641+3627F: A Low-mass He White Dwarf Orbiting a Possible High-mass Neutron Star in the Globular Cluster M13*, Cadelano M., Chen. J., Pallanca, C., et al., 2020, ApJ, 905,63
3. *The white dwarf cooling sequence of NGC 6752*., Chen, et al., 2021., in preparation.