Ph.D. Project

The stellar populations of dwarf galaxies through cosmic times

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Dwarf Galaxies are the most numerous and common type of galaxy at all cosmic times. They are among the first galaxies to form and this makes them of fundamental interest for several reasons. Firstly, they are the building blocks that, through continuous merger events, form more massive galaxies like our Milky Way. Secondly, they are responsible for the ionisation and chemical enrichment of the primordial gas, composed by neutral H and He only. In this so called Epoch of Reionization ($z \sim 6$) feedback processes involving complex baryonic physics (stellar radiation and winds, supernovae explosions) act, leading systems to a state of self-regulation and shaping the properties of first galaxies (Bromm & Yoshida 2011). Dwarf Galaxies, due to their small masses, are very sensitive to any kind of perturbation, thus they represent ideal laboratories in which to study feedback processes.
These systems have been extensively studied in the Local Group, where dozens of them are found as Milky Way's satellites. High-z observations are not yet available, but soon James Webb Space Telescope (JWST) will revolutionise the field allowing us to detect the most luminous ones at redshift $z > 5$.

I'm interested in studying dwarf galaxies at high redshift through high-resolution numerical simulations, since they could solve many unanswered questions: how does the build up of galaxies work? How are dwarf satellites influenced by environmental and feedback effects during reionization? Which one among them will we observe with JWST?

JWST will do a follow up of many Lyman Break Galaxies (LBG) known at high-z and we expect it to catch in its field of view the most luminous dwarf satellites that surround them. To make testable predictions, we need cosmological simulations of typical LBGs that have high spatial and mass resolution and feature detailed physical processes (e.g. Pallottini et al. 2017). In my Master's thesis I studied in great detail the stellar populations of all of the simulated satellite dwarf galaxies that surround the main massive one at $z = 6$. Deriving star formation and metal enrichment histories I investigated how the environment in which they formed impacted their evolution; through spatial distributions I inferred where stars with different age and metallicity are preferentially located; and modelling their spectral energy distributions I can make robust predictions for JWST.

The aim of my PhD work is to further deepen our knowledge of stellar populations in dwarf galaxies, studying how the presence of a near massive galaxy impact their evolution and developing my own simulations of dwarf galaxies down to $z = 0$ in order to make significant comparisons with data of small systems of the Local Group. These two points are detailed below:

1. The Role of the Environment. Small dwarf galaxies, with their low gravitational binding energy, are the structures that are affected the most by both environmental effects (gravitational interactions, ram pressure stripping) and stellar feedback (radiation and SN explosions). In order to get a better understanding of the interplay between these effects at high redshift, I would deepen the study of dwarfs' stellar populations taking advantage of an implemented version of the above mentioned high-z simulation that includes also radiative transfer (Pallottini et al. 2019). In particular, I would study the stellar properties (ages, metallicities, masses) of each satellite as a function of the distance from their massive host galaxy. An analysis of the velocities of these structures could also provide information about their kinematical history and show if and when these small systems are destined to merge with the main one.

2. Simulations of Dwarf Galaxies down to present-day. The study of dwarf galaxies within the Local Group have long captured the attention of both theorists and observers, since many Milky Way's and Andromeda's low-mass faint satellites can be interpreted as descendants of the first galaxies (e.g. Salvadori & Ferrara 2009). Observations of these objects have reached unprecedented accuracy, even with star by star measurements for many of them (e.g. Simon 2019). These studies show an interesting presence of extremely old and metal-poor stars in many of these dwarfs, indicating that these stars might have formed in a pristine environment billions of years ago and survived up to present days. I would be interested in developing my own set of simulations of dwarf galaxies using the zoom-in technique down to redshift $z = 0$ in order to make extremely accurate comparisons with local dwarfs. Such simulations should reach higher spatial and mass resolution, as to resolve even the less massive systems, and they should also follow star formation from a zero-metallicity gas. From the analysis of the obtained stellar populations, with particular attention on ages and metallicities, I could infer if observed faint dwarf galaxies are effectively the remnants of the first structures that formed in the Universe.