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Memorie della

Local Group

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Abstract. The Local Group is a unique site to investigate the properties of dwarf galaxies and to test the mass assembly that built giant systems. To introduce the "Local Group, Local Cosmology" Symposium, I will give a short, personal view of the most important discoveries of the latest years, and I will point out the crucial still open questions to be discussed in the next few years.

Key words. Local Group – Galaxies: dwarf – Galaxies: stellar content – (Cosmology:) early Universe –

1. Introduction

How did galaxies form and evolve? This is one of the fundamental open questions in modern astrophysics and cosmology. One way to approach the problem is to study nearby galaxies in the Local Group (LG), which can be largely resolved into their individual stars. This offers incomparable possibilities to characterize stellar systems in terms of star formation history (SFH), mass assembly, chemical evolution, abundance patterns, dynamics, and properties of the gas content. With this respect, the LG is a perfect "*cosmological laboratory*", as it is the only group that can be studied in such a level of detail, offering the strongest constraints to galaxy evolution models. The luminous mass of the LG is dominated by the two giant spirals, the Milky Way (MW) and M31, but these are outnumbered by a sizable sample of $\sim$ 70 dwarf systems. Since the formation of galaxies is believed to proceed via continuous merging of small halos, dwarf galaxies and globular clusters are crucial targets to identify the actual building blocks. For this reason, they have been the focus of a paramount effort, both observational (e.g., Gallart et al. 1996; Bellazzini et al. 2001; Dolphin et al. 2001; Cole et al. 2007; Monelli et al. 2010a,b; Battaglia et al. 2012) and theoretical (e.g., Mayer et al. 2001, 2006; Mayer 2010; Salvadori et al. 2008; Klimentowski et al. 2009; Sawala et al. 2010; Shen et al. 2013).

Since the nineties, new photometric capabilities have greatly impulsed the field. The introduction of wide-field CCD cameras (e.g., 2.2m/WFI, Blanco/MOSAIC-II, CFHT/12K) allowed a comprehensive view of the nearby satellites covering a large area in the sky. In parallel, the unprecedented high-resolution offered by the HST, especially by the ACS and WFC3 cameras, allowed the direct deep study of galaxies external to the MW system. Accurate photometry reaching well below the oldest main sequence turn-off is now feasible for most of the galaxies in the LG, out to $\sim$1.5 Mpc. This is a necessary requirement to perform precise dating of the oldest populations (Gallart et al. 2005), and in turn constraining the early evolution of galaxies and the physical mechanisms at play (internal feedback, cosmic reionization, interactions: Monelli et al. 2010b; Hidalgo et al. 2011).

Similarly, the advent of multi-object spectroscopic facilities on large telescopes (e.g., VLT: FLAMES, FORS, VIMOS; Keck: DEIMOS) has been a breakthrough, opening the possibility to simultaneously collect spectra for large number of stars in a given system. This allowed to reconstruct the chemical evolution of many satellites, disclosing fundamental differences in the chemical pattern of the α-elements of these galaxies when compared to the MW halo (Shetrone et al. 2001, 2003; Tolstoy et al. 2003). While this may pose a severe problem for their identification as representative building blocks of the halo, the surviving dwarfs have evolved as independent systems, subject to internal chemical evolution and interactions with other systems, contrary to the ones that were accreted onto the halo stars.

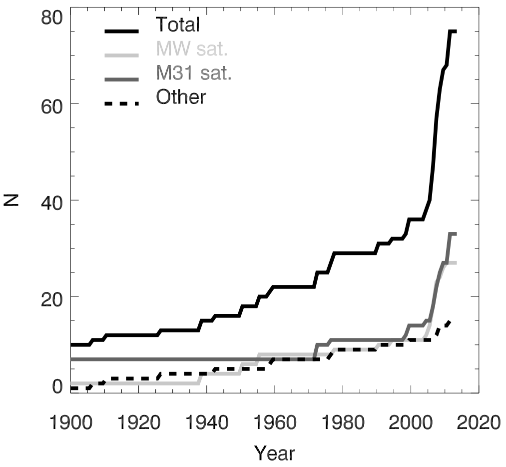

Fig. 1. Number of known LG galaxies (within 1.5 Mpc) as a function of time. We plot either the year corresponding to the discovery or the first paper available (the data are from McConnachie 2012). Note the sudden increase in the number of MW and M31 starting in 2005.

2. New discoveries...

During the last ten years there have been fundamental and somehow unexpected discoveries that have brought new insights and open issues. First of all, it was realized that the "chemical anomalies" in globular clusters (GCs), that is star-to-star variations of the light elements abundances known since the seventies (Osborn 1971; Kraft 1978), are not exceptions but the rule, and trace of the existence of multiple stellar populations. The anomalous red giant branch (RGB) first discovered in Omega Centauri (Pancino et al. 2000) was the first of a series (Bedin et al. 2004; Milone et al. 2010; Monelli et al. 2013). This has represented a fundamental change in the paradigm of GCs as the best approximation of simple stellar populations. Based on solid photometric and spectroscopic evidence, it is now accepted that most, if not all the Galactic GCs have undergone complex evolution, with two or more stellar generations of stars with distinct chemical properties. Most important, observations strongly support the idea that, to explain such a chemical evolution, newly formed GCs had to be significantly more massive than what we observe today (Carretta et al. 2009). Models suggest that GCs might have lost up to 90% of their initial mass (D'Ercole et al. 2008), and the evaporated stars would have accreted on the MW halo. Therefore, understanding the early evolution of GCs will have fundamental impact on our understanding of the MW itself.

A second boost was given by the sudden increase of a large amount of new dwarf galaxies around both the MW and M31. Figure 1 shows the number of known galaxies in the LG as a function of time. Light and dark solid lines show the MW and M31 satellites, respectively, while the dashed line indicates other more isolated systems within 1.5 Mpc. Note the sudden increase of new discoveries starting around a decade ago. This occurred mainly thanks to two projects. On the one hand, the quick raise of known M31 dwarfs was possible thanks to the efforts of the PaNDAS project (McConnachie et al. 2009). Interestingly, there appear to be systematic differences between the properties of the dwarf system of M31 and the MW, for example in terms of stellar populations (Da Costa et al. 1996, 2000) and size (McConnachie & Irwin 2006), possibly linked to the early evolution of the host system (Weisz et al. 2014).

Similarly, the analysis of SDSS data brought to the discovery of ultra-faint dwarf galaxies (UFD, Willman et al. 2006) which in less than ten years have more than doubled the number of known satellites of the MW. This new class of objects has somehow unexpectedly extended the range of properties of "classical" dwarfs spheroidals to significantly smaller size regime, given their extreme low-mass ($M_\star < 10^5 M_\odot$). In a sense, they have blurred the border between the definition of what is a dwarf galaxies and what is a star cluster. Moreover, they are characterized by purely old (> 10 Gyr) and metal-poor ([Fe/H] $\sim$ -2 dex) populations. Their low mass suggests that they are the best candidates to investigate the effect of re-ionization as global mecahnism to stop star formation in low-mass halos at early epochs (Brown et al. 2012, see also Brown et al., this conference proceedings). Therefore, UFDs are thought to be the closest examples of passively evolved relics of the pristine building blocks.

In parallel, the increasing number of extremely-metal poor stars is opening new windows to the early evolution of the Universe (Caffau et al. 2011; Keller et al. 2014). While it is unlikely to observe the first generation stars (Pop. III), because they were probably massive ($M > 10 M_\odot$, Hirano et al. 2014), it should be possible to identify the second generation stars formed from the yields of the first supernovae, thus having direct constrains on the Pop. III objects. Very metal-poor stars ([Fe/H] < -3) have been found not only in the halo, but also in satellite dSphs (Kirby et al. 2008; Starkenburg et al. 2010, 2013).

3. ...and open questions

The increasing amount of data have grown in parallel to the capability to develop models of galaxy evolution, also thanks to steadily improving computation facilities. However, many questions still remain unsolved.

- What are the building blocks of the MW?
- What drove the early evolution of dwarf galaxies (feedback, cosmic reionization, interaction)?
- What is the origin of the transformation from gas-rich to gas-poor systems, and of the morphological classification? Is there an evolutionary link between dIrr and dSph galaxies, or did they form with intrinsecally different properties?
- Where are the missing satellites?

During the last twenty years, an incredible amount of data has been accumulated for increasingly more distant objects in the LG. Furthermore, we are entering a new golden era in which large surveys will give a dominant contribution to the advances in the field. Current big projects such as RAVE, PANSTARR, GAIA, SEGUE, or future ones such as the LSST, will provide deep insight in all these open questions. On the one hand, in a few years new data of proper motion, kinematics, chemical composition, will pave new roads to our understanding of the formation of the MW and the LG. However, at the same time this unprecedented amount of data available to the community will require a fundamental change of perspective, requiring a new approach to handle the data storage, treatment, and reduction, and it will compel a novel way of analysing and solving problems.

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