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Isolated galaxies in the Local Group

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Abstract. Dwarf galaxies in the Local Group allow to study in great detail the physical mechanisms responsible for the formation and evolution of galaxies. In fact, their resolved stellar populations allow to unveil their star formation and chemical evolution histories back to the earliest epochs. In particular, they can be used to constrain the efficiency of both local (Supernovae, SN) and global (reionization) mechanisms. The most isolated galaxies are the particularly interesting because, not having suffered strong interactions with the giant galaxies, they are free from environmental effects and they are ideal probes to test the early evolution of dwarf systems. I summarize here some of the latest results concerning isolated galaxies in the Local Group, with particular enphasis on the result of the LCID project.

Key words. Galaxies: Local Group – Galaxies: dwarf – Galaxies: evolution – Galaxies: star formation – Galaxies: photometry

1. Introduction

The evolution of dwarf galaxies is expected to be heavily affected by both intrinsic and environmental processes. They are thus essential probes of the physical ingredients included in current galaxy formation and evolution models. Heating by the ultraviolet (UV) radiation arising from cosmic reionization, and blowout of the gas by feedback from SNe are two such mechanisms, able to dramatically affect the formation and evolution of dwarf-sized halos (Mac Low & Ferrara 1999; Bullock et al. 2001; Stoehr et al. 2002; Kravtsov et al. 2004; Ricotti & Gnedin 2005; Strigari et al. 2008; Stinson et al. 2009; Sawala et al. 2010). They are invoked, in particular, to solve the so-called missing satellites problem (Klypin et al. 1999; Moore et al. 1999).

Heating from the cosmic UV background is thought to prevent star formation in the smallest halos (ultra-faint dSph, $M_{TOT} \lesssim 7{\times}10^7 M_\odot$). For larger systems, after the onset of star formation, feedback from SNe becomes a crucial mechanism that can blow away all the residual gas, while UV background alone has almost no effect (Sawala et al. 2010). However, if feedback made the gas diffuse and reduced its radiative cooling efficiency before reionization, then the UV background is expected to have a strong effect, producing a sharp cut off in the star formation at the epoch of reionization. Finally, self-shielding is effective only in the inner regions of the halos, leading to population gradients as a function of radius that can be detected. This scenario can be further complicated by local effects if the galaxy is located in dense environments or close to a massive

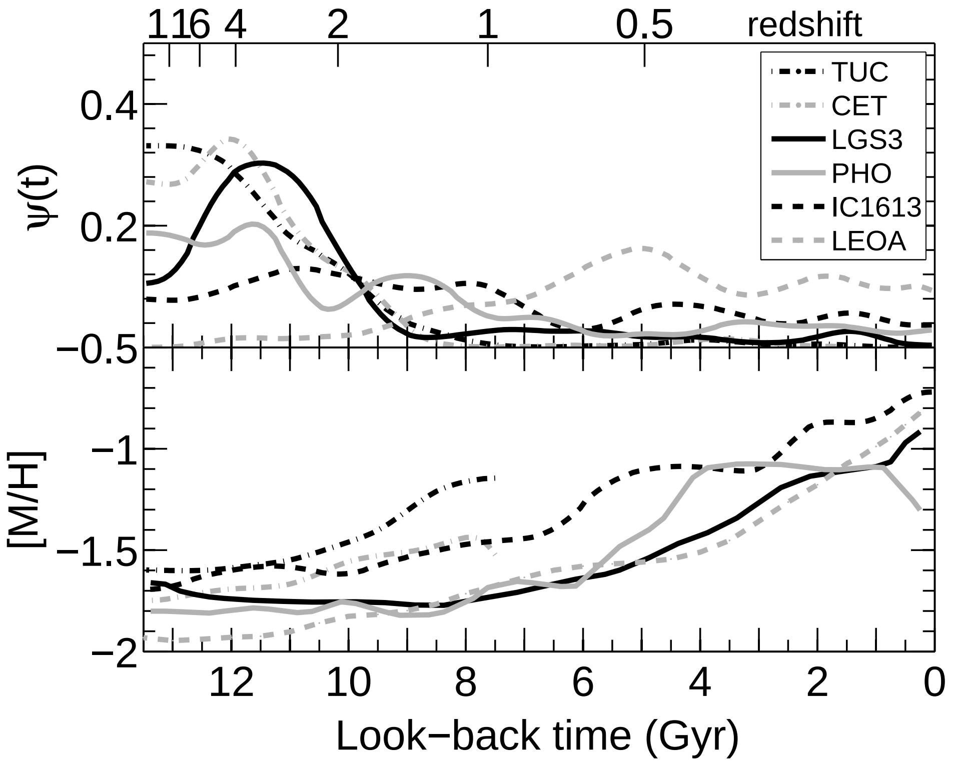

Fig. 1. Summary of the LCID project concerning the SFH of six galaxies. The star formation rate (top) and the age-metallicity relation are presented. Galaxies of diffrent morpological type are represented with different line style.

galaxy. Not only can the local UV flux be an order of magnitude larger due to nearby massive galaxies, but the gravitational interaction with other systems can also be extremely efficient to remove gas, stars, and dark matter from a gas-rich galaxy and transform it to a pressure-supported, gas-poor dSph (Mayer et al. 2006). Hence the importance of truly isolated galaxies to disentangle the contribution of environmental and intrinsic processes.

The most direct way to study the evolution of a galaxy is to quantitatively derive its full star formation history (SFH) from colour-magnitude diagrams (CMD) reaching the oldest main-sequence turnoffs (oMSTO). This provides both the star formation rate and the chemical enrichment as a function of time, bringing direct insights on the physical mechanisms involved, thus helping to discriminate between the different scenarios proposed so far. In this contribution I will summarize the current knowldege of the SFH of some of the most isolated galaxies in the Local Group (LG).

2. The LCID project

A sample of relatively isolated galaxies was studied by the LCID project (*LCID - Local Cosmology from Isolated Dwarfs*, including six galaxies within 900 kpc: Cetus and Tucana (dSph), LGS 3 and Phoenix (dIrr/dSph), Leo A and IC 1613 (dIrr). Cole et al. (2007); Monelli et al. (2010a,b) and Hidalgo et al. (2011). These results are summarized in Fig. 1, which shows the star formation rate (top) as a function of time and the age-metallicity relation

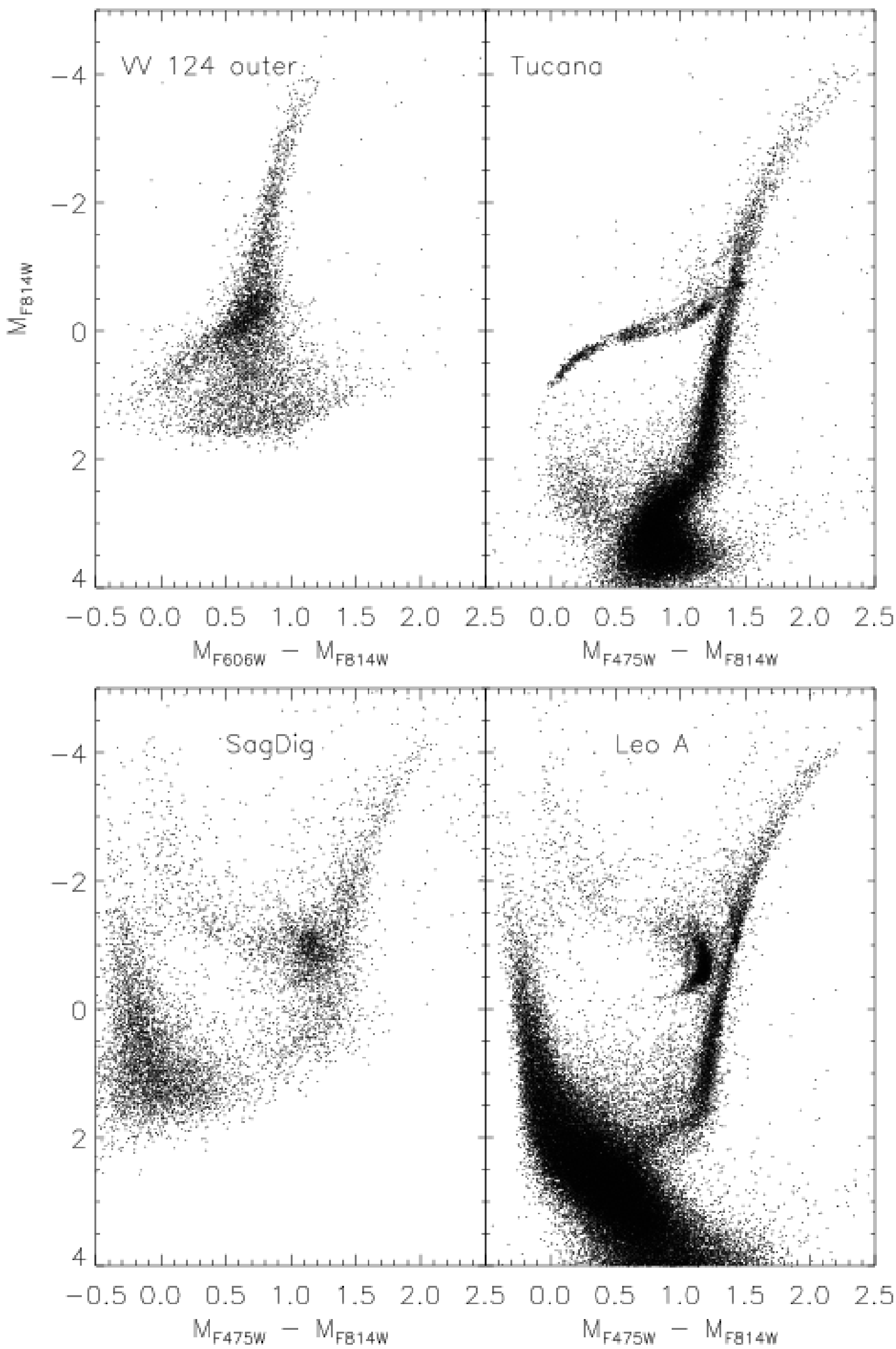

Fig. 2. Comparison between the CMD of LCID galaxies with that of more isolated systems. *Top:* The dSph Tucana is compared with the external regions of VV 124: due to the strong spatial gradient, only old populations are present in the outskirts of VV 124. Note the similarity in the HB morphology. *: Bottom:* Leo A is compared to SagDig. Note the intriguing similarity between the features of the two CMDs. Is SagDig analogous to Leo A, dominated by intermediate-age populations?

(bottom). Some of the most important results are the follows:

- An old population of stars (>12 Gyr) is ubiquitous in all the sample galaxies.
- Galaxies of different morphological type present different SFHs. The dSphs Cetus and Tucana are purely old systems, with no stars younger than 10 Gyr, in striking similarity with some Milky Way satellite such as Sculptor, Ursa Minor and Draco. This also means that they are outliers in the density-morphology relation, being purely old dSphs but not satellite of neither the Milky Way nor of M31. On the other extreme, dIrr have been forming stars at any epoch, with at least 50% of the mass formed in the last 8 Gyr. dIrr/dSph share properties with both previous types: the are dominated by old stars as dSphs, but were able to sustain a low level of star formation until the present day, similarly to dIrrs.
- This variety of different SFHs demonstrates that no galaxy experienced the sharp cut-off predicted by some model at the end of the reionization era. This indicates that the reionization alone was not able to completely stop the star formation. More mechanisms are required, such as the interplay of UV background and SN feedback (Sawala et al. 2010), and possibly interactions (Mayer et al. 2006).
- Leo A is the only clear example of a young galaxy (Cole et al. 2007): it produced 90% of its stars in the last 8 Gyr. The very low old star formation activity (in agreement with the small number of RR Lyrae stars), maybe the signature of reionization in the SFH, causing a strong delay in the peak of star formation (Kepner et al. 1997; Barkana & Loeb 1999).
- The chemical enrichement seems to be faster in dSph than in transition and dIrr galaxies (Hidalgo et al. 2013, submitted). In particular, in the dSph/dIrr a quck enrichment is observed at relatively recent epochs (<6 Gyr), when the star formation rate significantly decreased with respect of the main peak.

Despite the high degree of isolation, we cannot exclude that the LCID galaxies experienced some interaction with giant galaxies. For example, the radial velocity of Cetus and Tucana (Lewis et al. 2007; Fraternali et al. 2009), suggests that a close pericenter passage may have occurred at very early epochs, possibly inducing the stop in star formation. In particular, despite Tucana spent most of its life in isolation, it presents intriguing similarities with the close Milky Way satellite Sculptor. Both host two populations of old stars (>10 Gyr), with different chemical content and spatial distribution (Tolstoy et al. 2004; Bernard et al. 2008), also proved by the complex HB morphology and the occurrence of two red giant branch bumps (Majewski et al. 1999; Monelli et al. 2010c). On the other hand LGS 3 and Phoenix, which are less massive and much closer to M31 than Cetus and Tucana, were able to retain gas and form star until the present day. It is therefore possible that the environmental effect have played an important role in these relatively isolated galaxies. An question still to be investigated in details is therefore: given that the reionization alone was not enough to significantly affect the early evolution of dwarf systems, can the combined effect of UV background and SNe feedback in truly isolated systems explain their observed properties?

3. Isolated galaxies in the LG?

Only a handful of LG galaxies present a higher degree of isolation than the LCID ones: VV 124, SagDIG, and DDO210. They are all located at least at 1 Mpc from both the MW and M31 and, most importantly, their free-fall time into either spiral is longer than a Hubble time. This means that they have never been satellites of either of the dominant members of the LG (Karachentsev et al. 2009; McConnachie 2012) Their exceptional isolation implies that they are the only known galaxies in the LG for which we can be certain that their evolution has never been complicated by local environmental mechanisms. In addition, they are intrinsically small, and therefore more prone to be affected by the physical mechanisms we want to study.

Interestingly, the shallow photometry currently available reveals that VV 124 and SagDIG present quite diverse properties. To illustrate this, we show in Fig.2 the best CMDs for both galaxies, compared to some of the LCID targets.

VV 124: it is dominated by old populations (Jacobs et al. 2011; Bellazzini et al. 2011), which manifests with a prominent HB, very populated in a wide colour range, similar to that of Tucana. However, VV 124 also hosts, very centrally concentrated, a population as young as few tens of million years, thus making it similar to dIrr/dSph galaxies such as LGS 3 and Phoenix. Moreover, wide-field photometry (Bellazzini et al. 2011) shows the existence of an extended, flattened structure compatible with an edge-on disc. VV 124 could therefore be the unique case in the LG of an originally disc-like structure partially transformed into a spheroid.

SagDIG: it presents hints of an old population (Momany et al. 2005), but seems to be dominated by intermediate-age and young stars. Its CMD is strikingly similar to that of Leo A, hinting that the SFH of this galaxy could be a rarity, but not a unique case.

While these morphological similarities allow to guess analogous evolutions, no quantitative SFH based on deep photometry reaching the oMSTO are currently available.

4. Final remarks

Isolated galaxies in the LG are fundamental objects to understand the mechanisms that shaped the early evolution of dwarf systems, and therefore to constrain the models of galaxy evolution. While exquisite data exist for relatively isolated objects, mostly thanks to the LCID project, more distant galaxies like VV 124, SagDig and DDO 210 have been surveyed with shallow data only. Future observations of these systems might allow a comparison with the properties of the LCID and the Milky Way satellites.

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