Uncovering Early Galaxy Evolution in the ALMA and JWST Era
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The quest for relics: Massive compact galaxies in the local Universe

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Abstract. In the local Universe there exists a rare population of compact galaxies resembling the high-redshift quiescent population in mass and size. It has been found that some of these objects have survived largely unchanged since their formation at high-z. They are called relic galaxies. With the goal of finding relic galaxies, we searched the SDSS-MaNGA DR15 release for massive compact galaxies. We find that massive compact galaxies are mostly composed of old, metal-rich and alpha enhanced stellar populations. In terms of kinematics, massive compact galaxies show ordered rotation in their velocity fields and σ_* profiles rising towards the center. They are predominantly fast rotators and show increased rotational support when compared to a mass-matched control sample of average-sized early-type galaxies. These properties are consistent with these objects being relic galaxies. However, to confirm their relic status, we need to probe larger radii ($\gtrsim 3R_e$) than probed with the current data.

Keywords. galaxies: evolution, galaxies: kinematics and dynamics

1. Introduction

Massive quiescent galaxies in the early Universe are unlike their local counterparts. In particular, they are remarkably compact (typical half-light radius $R_e \simeq 1$–$2\,$kpc) and disk dominated (Buitrago *et al.* 2008; van der Wel *et al.* 2011). In the local Universe, there exists a rare population of compact galaxies resembling the high-redshift quiescent population in mass and size. Some of these local compact galaxies were found to be relic galaxies: objects which have survived largely unchanged since their formation at high-z (Yıldırım *et al.* 2017). The study of these relics opens a new window into early galaxy evolution.

2. Methodology

Sample selection: with the goal of finding relic galaxies, we searched the SDSS-MaNGA DR15 release for massive compact galaxies, defined as fulfilling these criteria: 1) $10^{10.5}\,M_\odot < M_* < 10^{11.5}\,M_\odot$; 2) The size of the semi-major axis of the half-light ellipse is at least $1\,\sigma$ smaller than the value predicted by the local mass-size relation for early-type galaxies. 87 galaxies satisfy these criteria.
Control sample: In order to assess if massive compact galaxies differ from average-sized quiescent galaxies in any other parameter than their size, we define two control samples: 1) a mass-matched quiescent galaxy sample and 2) a σ_e matched-control sample (where σ_e is the velocity dispersion measured inside an aperture of radius R_e). Each control sample contains 174 galaxies.
Stellar population synthesis and kinematics: To derive the stellar population properties for each spaxel in the datacubes we employed the STARLIGHT code together with

the E-MILES stellar population models (Vazdekis *et al.* 2016), fitting the stellar absorption features in 3800–7000 Å restframe wavelength range. We employed the pPXF code to measure the stellar kinematics.

3. Results

The stellar populations of massive compact galaxies: massive compact galaxies are divided into two groups: 1) old (mass-weighted age $\gtrsim 8$ Gyr), metal-rich ($Z_* \gtrsim Z_\odot$) and alpha enhanced galaxies (65% of the sample); 2) younger (mass-weighted age $\lesssim 6$ Gyr), metal rich ($Z_* \gtrsim Z_\odot$) galaxies (35%).

The rotational support of massive compact galaxies: a comparison of the V_{max}/σ_0 distribution of the massive compact galaxies sample with a mass-matched and a σ_e-matched control sample of average-sized galaxies shows that massive compact galaxies have an increased rotational support. Furthermore, massive compact galaxies are predominantly fast-rotators, in clear contrast to average-sized galaxies.

4. Conclusion

• **Clues on the formation of massive compact galaxies:** massive compact galaxies show ordered rotation in their velocity fields (except for 5 galaxies) and σ_* profiles rising towards the center. A strong anti-correlation between V_* and the Gauss-Hermite moment h_3 (which describes asymmetric deviations from a Gaussian) is observed in 80% of the sample. Simulations of major mergers with large gas fractions ($\gtrsim 30\%$) reproduce the observed kinematics, specifically this anti-correlation (Hoffman *et al.* 2009).

• **Clues on the evolution of massive compact galaxies:** for the bulk of the sample, it can be concluded that these galaxies suffered no dry major mergers, as they produce slowly rotating remnants with near-Gaussian line-of sight velocity distribution (i.e. no correlation between V_* and h_3). We can also constrain the growth of massive compact galaxies by dry minor mergers: minor mergers bring old, metal-poor and alpha-enhanced stars to the outskirts of galaxies, which is inconsistent with the high metallicities observed out to $\approx 2\,R_e$. Furthermore, frequent minor mergers decrease the rotational support of galaxies (Bournaud *et al.* 2007), which is inconsistent with the observed increased rotational support of massive compact galaxies. Thus, while we cannot a discard a modest growth through minor merging, a growth dominated by minor mergers is inconsistent with the observed properties of massive compact galaxies.

• **Are massive compact galaxies relics?** About 25% of the sample have properties consistent with a formation at $z \gtrsim 1$ and a subsequent passive evolution. However, to confirm the relic status of these objects we need to probe larger radii ($\gtrsim 3R_e$) than probed with the current data.

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