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 $\sigma_*$ 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 ($\geq 3R_e$) 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 $\sigma_e$ matched-control sample (where $\sigma_e$ 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 ($Z_*>Z_\odot$) 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 $V_{\text{max}}/\sigma_0$ distribution of the massive compact galaxies sample with a mass-matched and a $\sigma_e$-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 $\sigma_e$ 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 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 $z>1$ 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.

References