DRAFT VERSION SEPTEMBER 11, 2013
Preprint typeset using LaTeX style emulateapj v. 12/14/05

THE EVOLUTION OF THE NUMBER DENSITY OF COMPACT GALAXIES

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Draft version September 11, 2013

ABSTRACT

We compare the number density of compact (small size) massive galaxies at low and high redshift using our Padova Millennium Galaxy and Group Catalogue (PM2GC) at $z = 0.03-0.11$ and the CANDELS results from Barro et al. (2013) at $z = 1-2$. The number density of local compact galaxies with luminosity weighted (LW) ages compatible with being already passive at high redshift is compared with the density of compact passive galaxies observed at high-z. Our results place an upper limit of a factor ~ 2 to the evolution of the number density and are inconsistent with a significant size evolution for most of the compact galaxies observed at high-z. The evolution may be instead significant (up to a factor 5) for the most extreme, ultracompact galaxies. Considering *all* compact galaxies, regardless of LW age and star formation activity, a minority of local compact galaxies ($\leq 1/3$) might have formed at $z < 1$. Finally, we show that the secular decrease of the galaxy stellar mass due to simple stellar evolution may in some cases be a non-negligible factor in the context of the evolution of the mass-size relation, and we caution that passive evolution in mass should be taken into account when comparing samples at different redshifts.

Subject headings: galaxies: clusters: general — galaxies: evolution — galaxies: structure — galaxies: fundamental parameters

1. INTRODUCTION

The average size of passive and massive galaxies at $z = 1-2.5$ has been observed to be much smaller than that of galaxies of similar masses in the local Universe (Daddi et al. 2005, Trujillo et al. 2006, Cimatti et al. 2008, van Dokkum et al. 2008, Cassata et al. 2011, Damjanov et al. 2011, to name a few), usually adopting as comparison low-z galaxies with a Sersic index greater than 2.5 (Shen et al. 2003). These results have suggested that galaxies have undergone a strong evolution in size. Minor dry mergers have been proposed as the main mechanism driving such evolution (Naab et al. 2009, Oser et al. 2012).

At low redshift, compact massive galaxies are a small fraction of the overall population in the general field (Trujillo et al. 2009, Taylor et al. 2010, Poggianti et al. 2013, hereafter P13) but are much more common in galaxy clusters (Valentinuzzi et al. 2010, hereafter V10).

In P13, we have studied the population of compact massive galaxies in the local universe for the first time on a non-Sloan sample representative of the general field galaxy population, the Padova Millennium Galaxy and Group catalogue (PM2GC, Calvi et al. 2011). Compact PM2GC galaxies with radii and mass densities comparable to high-z massive and passive galaxies are mostly S0s with intermediate-to-old stellar populations, and have the characteristics to be likely little-evolved descendants of high-z compact galaxies (P13).

At a given mass, galaxies with older stellar populations are on average more compact (van der Wel et al. 2009, Saracco et al. 2009, V10, P13 and references therein). When high-z passive galaxies are compared with local galaxies *with old stellar populations*[1] (their most probable descendants), the average evolution in size at fixed mass between $z = 1-2.5$ and $z \sim 0$ turns out to be mild, a factor ~ 1.6, as half of the evolution observed for the overall passive galaxy population is driven by larger galaxies becoming passive at lower redshifts (P13, V10).

A crucial aspect for assessing the real evolution in size of individual galaxies is to evaluate how many of the distant galaxies have remained compact till today, comparing high- and low-z number densities. Cassata et al. (2011) and (2013) have studied the evolution of the number density of passive early-type galaxies and concluded this is driven by both the size growth of compact galaxies and, mostly, by the appearance of new early type galaxies with larger sizes. Similar conclusions are reached by Carollo et al. (2013), who find no change in the number density of compact quenched early-type galaxies of masses $< 10^{11} M_{\odot}$, and a 30% decrease at higher masses over the redshift interval $0.2 < z < 1$. Saracco et al. (2010), comparing their high-z morphologically-selected early-type sample with the cluster galaxies by V10, concluded that most of the compact early-types at high-z can be accounted for by their local counterparts. In contrast, Taylor et al. (2010) found a strong evolution in the number density of extremely compact galaxies using as local comparison disk-free red sequence SDSS galaxies.

Recently, new estimates for the number density of compact high-z galaxies have become available for the GOODS-S and UDS fields of CANDELS (Barro et al. 2013, hereafter B13). This sample is unprecedented for number of galaxies and quality, and relies on selection criteria that we can try to reproduce at low redshift. In this paper we compare the CANDELS results with our PM2GC local sample to establish the amount of evolution in the number density of compact galaxies. This directly constrains the number of galaxies that experienced a significant evolution in size.

We use (H_0, Ω_m, Ω_λ) = (70,0.3,0.7), and a Chabrier (2003) IMF, to be consistent with the high-z dataset.

2. DATA AND METHODOLOGY

Our aim is to compare our low redshift data with the high-z results from B13, who studied the structure of massive galaxies at $z = 1.4-3$ in the GOODS-S and UDS CANDELS

[1] Luminosity-weighted ages compatible with being already passive at high-z.

fields. We use the number densities obtained by B13 for all compact galaxies and for passive compact galaxies with masses above $10^{10}M_{\odot}$, for which their sample is 90% complete. B13 define passive ("quiescent") galaxies to have a specific star formation rate $< 10^{-0.5}\mathrm{Gyr}^{-1}$, corresponding to a star formation rate about 1/10 of that of typical star-forming galaxies at $z=2$ on the star formation rate-mass relation. Their circularized galaxy radii were obtained with GALFIT from $HST/WFC3$ H-band[2] images (van der Wel et al. 2012), and their masses with a spectrophotometric model based on Bruzual & Charlot (2003).

Our low-z analysis is based on the PM2GC, a spectroscopically complete sample of galaxies at $0.03 \leq z \leq 0.11$ brighter than $M_B < -18.7$. This sample is sourced from the Millennium Galaxy Catalogue (MGC, Liske et al. 2003, Driver et al. 2005), a B-band contiguous equatorial survey complemented by a 96% spectroscopically complete survey down to B=20. The PM2GC is similarly complete for masses $M_{\star} \geq 1.6 \times 10^{10}M_{\odot}$, and contains 1515 galaxies above this limit.

The image quality and the spectroscopic completeness of the PM2GC are superior to Sloan, and these qualities make it an interesting dataset to study galaxy sizes in a complete sample of galaxies at low-z, as outlined in P13. Effective-radii, axial ratios and Sersic indexes were measured on MGC B-band images with GASPHOT (Pignatelli & Fasano et al. 2006, Bindoni et al. in prep.), an automated tool which performs a simultaneous fit of the major and minor axis light growth curves with a 2D flattened Sersic-law, convolved by the appropriate, space-varying PSF. Details on the size measurements and a comparison with independent size estimates of PM2GC galaxies are given in P13. Galaxy stellar mass estimates were derived by Calvi et al. (2011) using the Bell & de Jong (2001) relation and are in good agreement with DR7[3] (Abazajian et al. 2009) masses, with no offset and a < 0.1dex scatter (P13).

2.1. *Sample selection: compactness criterion*

We stress that no morphological information is used in the galaxy selection, neither at high- nor at low-z.

B13 define compact those galaxies with

$$\log(\mathrm{M_{high-z}}/\mathrm{r_e^{1.5}}) \geq 10.3\,\mathrm{M_{\odot}kpc^{-1.5}} \quad (1)$$

where M_{high-z} is the stellar mass of high-z galaxies and r_e their effective radius.

The stellar mass of a system is defined as the sum of the mass in living stars + the mass of stellar remnants[4]. Assuming passive evolution, the stellar mass of a galaxy changes with time simply due to the evolution of its stars: as they progressively evolve and eventually die, they retain only part of their mass as remnant.

For a stellar generation of solar metallicity, a Chabrier IMF and the Bruzual & Charlot (2003) model, the fraction of initial stellar mass that remains is equal to 1 for ages less than 1.9×10^6 yr, while it can be approximated as $f(t) = 1.749 - 0.124 * log t$ at older ages, where t is the age of the stellar population in years.

[2] This corresponds to rest-frame wavelengths from B to R band. Galaxy sizes are larger at shorter wavelengths (P13), therefore by using local B-band sizes we obtain a conservative upper limit to the density evolution.

[3] http://www.mpa-garching.mpg.de/SDSS/DR7/Data/stellarmass.html

[4] The stellar mass in this paper and in general in the literature is described by equation (2) in Longhetti & Saracco (2009).

If a high-z galaxy is observed very soon after the end of the bulk of star formation, say 10^8 yr after, by $z \sim 0.1$ it retains only ~ 70% of its observed high-z mass. If star formation stopped 2 Gyr before the high-z observations (at z=4.8 for a z=2 observed galaxy), this fraction is ∼90%. We adopt an intermediate value of 80%, corresponding to a quenching of star formation occurred 0.6 Gyr before the high-z observations (at z=2.5 for a z=2 observed galaxy), in line with recent observations of recently quenched galaxies at $z = 1-2$ (Wuyts et al. 2010, Whitaker et al. 2012). Adapting eqn. 1, out compactness threshold at low redshift is

$$\log(\mathrm{M_{low-z}}/\mathrm{r_e^{1.5}}) = \log(0.8 \times \mathrm{M_{high-z}}/\mathrm{r_e^{1.5}}) = 10.2\,\mathrm{M_{\odot}kpc^{-1.5}} \quad (2)$$

It is worth noting that passive evolution in mass will also lead to larger sizes for adiabatic expansion (Hills 1980) if the mass returned by stars to the interstellar medium is lost by galaxies in a SN- and/or AGN-driven galactic wind, as indicated by X-ray data for early-type galaxies (Ciotti et al. 1991). Such mechanism is internally driven and may contribute to the evolution in size. The effects on galaxy sizes of rapid mass loss driven by quasar superwinds in massive galaxies and by supernova-driven winds in less massive galaxies have been discussed by Fan et al. 2008. One type of galaxies where there is unequivocal evidence for merger-driven evolution both in mass and in size are the Brightest Cluster Galaxies (eg. Lidman et al. 2012, Valentinuzzi et al. 2010b, but see also Stott et al. 2010). However, such galaxies may have a very different evolution from the rest of the massive galaxy population (P13).

Finally, if B13 used Maraston (2005) model instead of Bruzual & Charlot (2003), their high-z masses would be typically ∼0.15 dex smaller due to the different treatment of the TP-AGB stellar phase, which is important for stellar population ages typical of high-z galaxies, but is uninfluential on the masses at low-z. As a consequence, adopting Maraston's model, the compactness density threshold at low-z would shift to $\sim 10.05\,\mathrm{M_{\odot}kpc^{-1.5}}$. In the following we will use the compactness criterion based on Bruzual & Charlot, unless otherwise stated, but we will show that this is a major source of uncertainty in the comparison of high- and low-z samples. Above the PM2GC mass limit there are 141 compact galaxies according to the compactness criterion based on Bruzual & Charlot, and 294 using Maraston.

2.2. *Sample selection: LW ages*

All PM2GC galaxies have a spectrum from the SDSS, the 2dFGRS (Colless et al. 2001) or the MGCz (Driver et al. 2005). The galaxy stellar history was derived by fitting the spectra with the spectro-photometric model described in Fritz et al. (2007, 2011). All the main spectro-photometric features (continuum flux and shape, and emission and absorption lines) are reproduced by summing the theoretical spectra of Simple Stellar Populations (SSPs) of 12 different ages, from 3×10^6 to $\sim 14 \times 10^9$ years (P13). From the spectral analysis, it is possible to derive an estimate of the average age of the stars in a galaxy weighted by the light we observe. The LW age was computed by weighing the age of each SSP composing the integrated spectrum with its bolometric flux. For passive galaxies, this reflects to a first approximation the epoch of the last star formation episode.

The model age determination can be quite uncertain, especially at the old ages considered here, and it is necessary to

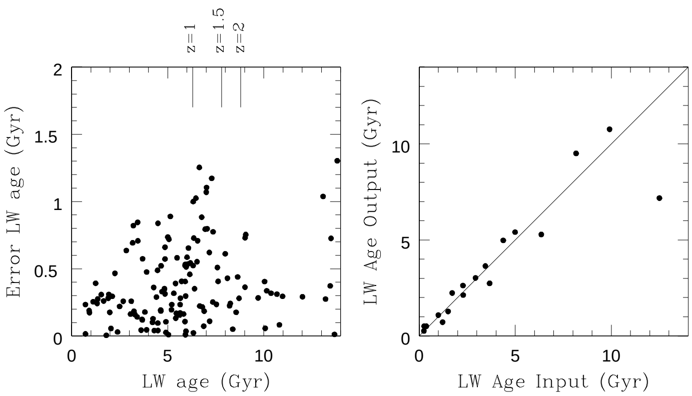

FIG. 1.— **Left.** Error on LW age for all compact PM2GC galaxies estimated as explained in §2.2.1. **Right.** Comparison between the LW age of simulated templates of different star formation histories ("input") and the LW age recovered for them from the model fitting ("output"). The templates include a wide range of star formation histories, from those mimicking the histories of galaxies of different morphological types (ellipticals to late spirals), to post-starbursts, to constant star formation rates truncated at different times.

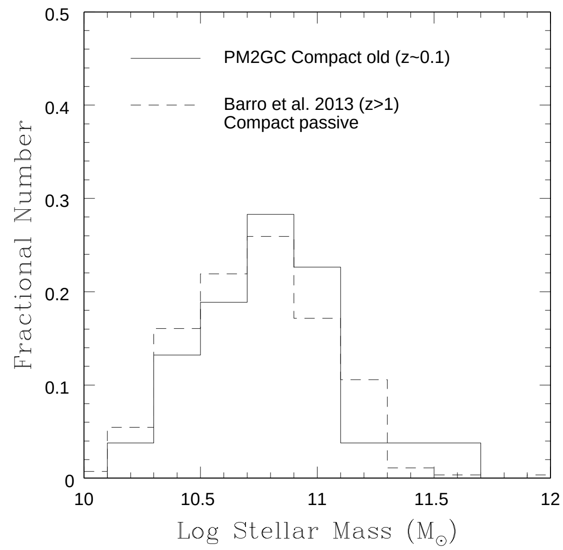

FIG. 2.— Stellar mass distributions of PM2GC compact and old galaxies (solid histogram, LW ages $\geq$ than the lookback time to $z = 1$) and of B13 high-z compact passive galaxies (dashed histogram).

evaluate how these uncertainties affect the number density estimates.

The spectrophotometric model obtains the best fit star formation history, and consequent LW age, by performing a random exploration of the parameter space, searching for the combination of star formation rate and extinction values of the various single stellar populations that minimizes the differences between the synthetic and the observed spectra.

As explained in Fritz et al. (2007), the internal error on the LW age is estimated by exploiting the characteristics of the optimization routine. The path towards the best fit parameters depends on their initial value, and so does the final solution (star formation history and, consequently, LW age). We perform 11 simulations for each metallicity, and explore three metallicities, changing both the initial parameters and the seed of the random number generator, sampling the entire space of solutions. The LW age error is taken to be half the difference between the highest and lowest values of LW age among all simulations. Such error is less than 1 Gyr for all compact PM2GC galaxies except for a few cases, with a median of 0.3 Gyr (see left panel of Fig. 1).

To further test the age uncertainty, we used synthetic spectra of galaxy templates with different star formation histories, mimicking the histories of galaxies of different morphological types (ellipticals to late spirals), post-starbursts and constant star formation rates truncated at different times, as was done in Fritz et al. (2007). The "true" (input) LW age of such templates are compared to the LW age recovered by the spectral fitting in the right panel of Fig. 1. Generally, the model is able to recover the input LW age with a good approximation, except for our oldest template for which it underestimates it. For our purposes, it is important that the model does not show a tendency to *overestimate* the LW ages, thereby assigning old ages to young galaxies.

In this paper we want to compare the number density of compact passive galaxies at high-z with that of equally compact low-z galaxies whose LW age testifies that they were already passive at high-z, and therefore should comply with the B13 criterion for passivity. To do this, we select galaxies at $z \sim 0.1$ with a LW age equal to or greater than the time elapsed between three high redshift values ($z = 1, 1.5$ and 2, corresponding to lookback times 6.3, 7.8 and 8.8 Gyr, respectively) and $z \sim 0.1$.

Visually inspecting the spectra of all 39 (59 for Maraston) compact PM2GC galaxies with LW ages $\geq$ 6.3 Gyr (z=1), their passivity at the time they are observed is confirmed by the lack of emission lines: only 5 (7 for Maraston) galaxies have weak (equivalent width [OII] $<$ 5 Å) emission with line ratios consistent with a weak AGN.

Figure 2 shows that the stellar mass distribution of compact passive high-z galaxies is similar to the mass distribution of PM2GC compact and old (LW age corresponding to $z > 1$) galaxies, and a KS-test is unable to prove there are significant differences (P=0.1). This is consistent with the hypothesis that PM2GC compact and old galaxies are local counterparts of the high-z compact and passive population.

Matching progenitors and descendants is one major problem in trying to assess the number density evolution of any type of high-z galaxies, including compact galaxies. Different methods have been proposed to obtain a meaningful comparison, and none of them is free from problems. For example, a morphological selection of early-type galaxies both at high- and low-z does not take into account the fact that a large number of high-z late-type galaxies turn into early-type galaxies by z=0, while using a fixed number density is prone to partial contamination and relies on semi-analytic models that do not reproduce the galaxy stellar mass function at redshifts above zero (Leja et al. 2013).

Our approach based on LW ages is not free from problems either, because it relies on the assumption that compact passive galaxies at high-*z* have not been "rejuvenated" by star formation at subsequent times. Indeed, while it is reasonable to assume that all local compact galaxies with old LW ages must have been compact and passive at high-*z*, not all compact passive galaxies at high-*z* necessarily have old LW ages today. There might be some of their local counterparts that are still compact, but have not remained always passive throughout their evolution, as at later times they may have experienced some episode of star formation such to disqualify them from being "old" in the local sample. Though not optimal, our method links the high-*z* population with at least some of their low-*z* counterparts, thus providing an upper limit to the evolution of the number density of compact passive galaxies, i.e., to the difference between the high-*z* and low-*z* number of such galaxies.

2.3. *Number densities*

The high-z number densities for passive, star-forming and all galaxies are taken directly from B13. They are for a mass limit $10^{10} M_{\odot}$, which is slightly lower than the $1.6 \times 10^{10} M_{\odot}$ PM2GC limit. This difference should have little effect on the number densities, as most of the high-z compact galaxies are well above the PM2GC limit (Guillermo Barro 2013, private communication). The different limit in mass will, again, result in underestimating the number density of local compacts relative to that of high-z compacts.

For the PM2GC we compute the number density of compact galaxies of different LW ages as described above, as well as the total number density of all low-z compact galaxies, regardless of their age. The number of galaxies is divided by the comoving volume of the PM2GC survey, that extends over an effective area of 30.88deg^2 on the sky between $z = 0.03$ and $z = 0.11$. No volume correction is needed, as the survey is complete down to our mass limit at $z = 0.11$. Our number densities for both Bruzual & Charlot and Maraston high-z models are given in Table 1.

3. RESULTS

Figure 3 shows the mass-size diagram of all PM2GC galaxies above our mass limit. The solid and dashed lines represent the compactness threshold of B13 with and without the mass evolution effect, respectively. The compactness criterion isolates galaxies approximately 2σ away from the median PM2GC mass-size relation, as the plot shows. This compactness criterion is slightly less strict than the limit for superdense galaxies adopted in P13 (see green points in Fig. 3).

Our main result is presented in Fig. 4, where the number density of low redshift compact galaxies is compared with the high redshift values. Selecting only PM2GC compact galaxies with LW ages at least as old as the lookback time between $z \sim 0.1$ and $z = 1, 1.5$ and 2 we plot their number density values as red circles at the corresponding redshifts in the left panel.

The largest uncertainty in the PM2GC number densities arises from the precision of the LW age estimate obtained by the spectrophotometric model. The number density error bars in Fig. 4 take into account the change in number density varying the LW age corresponding to each redshift by ± 1 Gyr. As

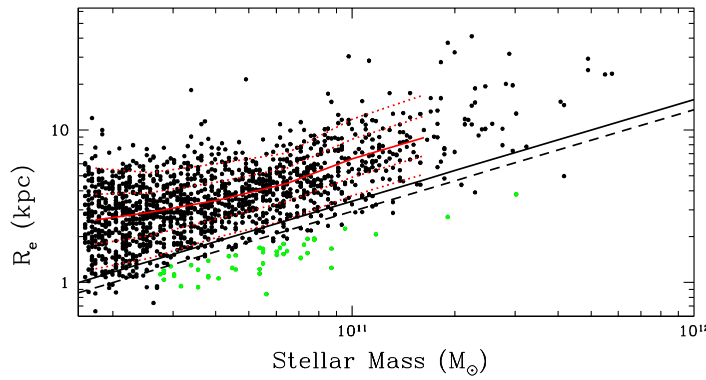

FIG. 3.— Circularized effective radius as a function of stellar mass for all galaxies in the PM2GC mass-limited sample (all points, 1515 galaxies). The solid and dashed black lines represent the Barro's compactness criterion limit taking into account and ignoring the effect of mass evolution, respectively (see text). The red solid line, with dotted 1σ and 2σ lines, is the PM2GC median. Green points represent superdense galaxies according to the compactness criterion adopted in P13.

discussed in §2.2.1, this corresponds to the upper envelope of the internal age uncertainty, and we have no reason to believe there should be any systematic overestimation of ages in the modeling. Such error dominates over the poissonian error. The X-axis error bar shows the ± 1 Gyr intervals in redshift.

From Fig. 4, the number ratio of high- to low-z densities is ~ 1 at $z = 1$ (no evolution) and only ~ 2.3 at $z = 2$. The low-z estimates are within 1-1.5 σ of the high-z estimates.

The red squares in the plot show the PM2GC number densities obtained adopting Maraston (2005) model at high-z, hence shifting the high-z masses and consequent compactness threshold by 0.15 dex. In this case, high- and low-z number density values are even closer, their ratio being = 1.6 at $z = 2$.

We stress once again that, in deriving the number density at low-z, only compact galaxies that have remained passive since high-z are counted. Some high-z compact quiescent galaxies might have remained compact till today but have experienced star formation after they were observed at high-z, and these are not considered in our low-z compact galaxy census. Our number of old compact galaxies at low-z is therefore potentially a lower limit to the number of compact quiescent galaxies that have remained compact. Consequently, the difference between the high-z and low-z values in Fig. 4 provides an upper limit to the number density evolution.

Although an exact estimate of the evolution is hampered by the various uncertainties involved, clearly a strong evolution in the number density of compact galaxies, such as the factor 10 sometimes quoted from simulations (Hopkins et al. 2009), is not supported by our analysis. Our results are consistent with a small or even negligible evolution in the number density of compact galaxies, suggesting that at most ~half of the high-z compact galaxies have evolved in size by $z = 0$.

At low-z, the total number density of compact galaxies in the PM2GC, regardless of their LW age, is $4.7 \times 10^{-4}\,\mathrm{Mpc}^{-3}$. This value is compared in the right panel of Fig. 4 with the total number density of compact passive + star-forming galaxies in CANDELS, which reaches a maximum value $2.9 \times 10^{-4}\,\mathrm{Mpc}^{-3}$ at $z = 1.6$. This comparison suggests that the bulk of the compact galaxies have formed their structure and their mass by $z \sim 1-1.5$, and that an additional minority of them, up to about 1/3 of today's compact galaxies, might have formed at lower redshifts.

This comparison also shows that the total number density of PM2GC compact galaxies of any age is significantly higher than the number density of passive compact galaxies at high-z. Relaxing the restrictive assumption of no subsequent star formation, the whole population of high-z compact passive galaxies could evolve into the local compact population.

The mild number density evolution of compact passive galaxies we find in this paper is in good agreement with the results from Cassata et al. (2011) who found that the number density of compact (at least 1σ below the local mass-size relation) early-type passive galaxies decreases only by a factor of two from $z \geq 1$ to $z = 0$.

3.1. *The most extreme compact galaxies*

The compactness criterion and the mass range adopted in this paper are dictated by the B13 high-z sample (to which we aim to compare). It would be desirable to assess the number density evolution of galaxies of different masses and degree of compactness, as soon as such detailed information will become available at high-z, to investigate whether the evolution varies with galaxy mass and compactness.

As we have shown above, the B13 criterion corresponds to about 2σ below the low-z median mass-size relation, which is similar to what most previous works used to define compact galaxies. This is the typical degree of compactness of high-z massive and passive galaxies found in other studies as well, except for the extremely compact galaxies in the sample at $z \geq 2$ of van Dokkum et al. (2008), that are outliers in the stellar densities and radii distributions (see P13 for a discussion).

We can attempt to compare our results to the work of Cassata et al. (2011), who considered separately the evolution of "ultra-compact" *early-type* (morphologically selected) passive galaxies, defined to have sizes at least 0.4 dex below the local *early-type* mass-size relation and representing about 20-30% of their sample at $z \geq 1$. If we consider PM2GC early-type galaxies (ellipticals+S0s, Calvi et al. 2012) that are old in LW age ($z = 1$) and lie at least 0.4 dex below the PM2GC median mass-size relation for early-type galaxies (Table 1 in P13), taking into account a 0.1 dex mass evolution as before, we obtain a number density $0.4 \times 10^{-4}\,\mathrm{Mpc}^{-3}$ and $0.9 \times 10^{-4}\,\mathrm{Mpc}^{-3}$ for Bruzual & Charlot and Maraston high-z models, respectively, again under the assumption of no star formation activity at redshifts below 1. For reference, the ultracompact densities in Cassata et al. (2011) are $\sim 2.2 \times 10^{-4}\,\mathrm{Mpc}^{-3}$ at $z = 1-1.2$.

This seems to suggest that the density evolution of the ultra-compact population has been stronger than that of the whole compact population, up to a factor between 2.5 and 5. Again, these are upper limits to the evolution, assuming no star formation at later times. This is based on a morphologically selected sample, and it would be useful to repeat the comparison with large high-z samples of ultracompact galaxies of all morphological types as was done in the rest of the paper.

It is also worth noticing that the most extreme compact galaxies at high redshifts mostly lie at $z > 2$ (Cassata et al. 2011, Cimatti et al. 2012, P13 Fig. 4), and are likely observed soon after the end of their star formation activity. Under these conditions, the passive evolution in mass we discussed in §.2.1 can be very strong on a short timescale. A galaxy forming the bulk of its stars at $z = 2.5$, between $z = 2-2.2$ and today will have lost 19-23% of its $z = 2-2.2$ observed mass. Already at $z = 1$, such galaxy will have lost 13-17% of its $z = 2-2.2$ mass. The effect could be much larger for galaxies that stopped forming stars just before being observed as passive at high redshift, as suggested by the B13 results. In general, passive mass evolution affects the comparison of high- and low-z samples. A stellar generation evolving passively since high-z, by $z = 0$ will have lost almost 50% of its initial mass.

The exact amount of mass evolution depends on the IMF assumed, on the epoch of major star formation and detailed star formation history, therefore is highly uncertain. The effect will become more and more prominent as observations approach the epoch when star formation stopped.

We suggest that the extreme compactness of $z > 2$ galaxies and the very strong evolution between $z = 2$ and $z = 1$ might be at least partially due to a fast passive evolution in *mass* between $z = 2$ and $z = 1$.

4. CONCLUSION

We place an upper limit to the evolution in the number density of passively evolving, compact galaxies from high redshift to the nearby Universe. We conclude that at most half, and possibly an even smaller fraction, of the high-z population has appreciably evolved in size. A more precise estimate of the amount of size evolution is hindered mainly by the uncertainty in high-z galaxy mass estimates, and by the difficulty to match exactly progenitors and descendants on the basis of luminosity-weighted ages. However, even under conservative assumptions, our results do not demand a major evolution in size for most of the compact high-z galaxies. On the other hand, we find that the amount of evolution may be stronger (upper limits between 2 and 5) for the most extreme, ultra-compact galaxies, which represent a minority of the massive and passive population at high-z. A detailed comparison as a function of galaxy mass and degree of compactness will be feasible when the corresponding information becomes available for high-z samples.

We gratefully acknowledge useful discussions and the datapoints provided by Guillermo Barro, and support from the WINGS team. We thank Joe Liske, Simon Driver and the whole MGC team for making their valuable dataset public and easily accessible. We acknowledge financial support from the PRIN-MIUR 2009 and PRIN-INAF 2010.

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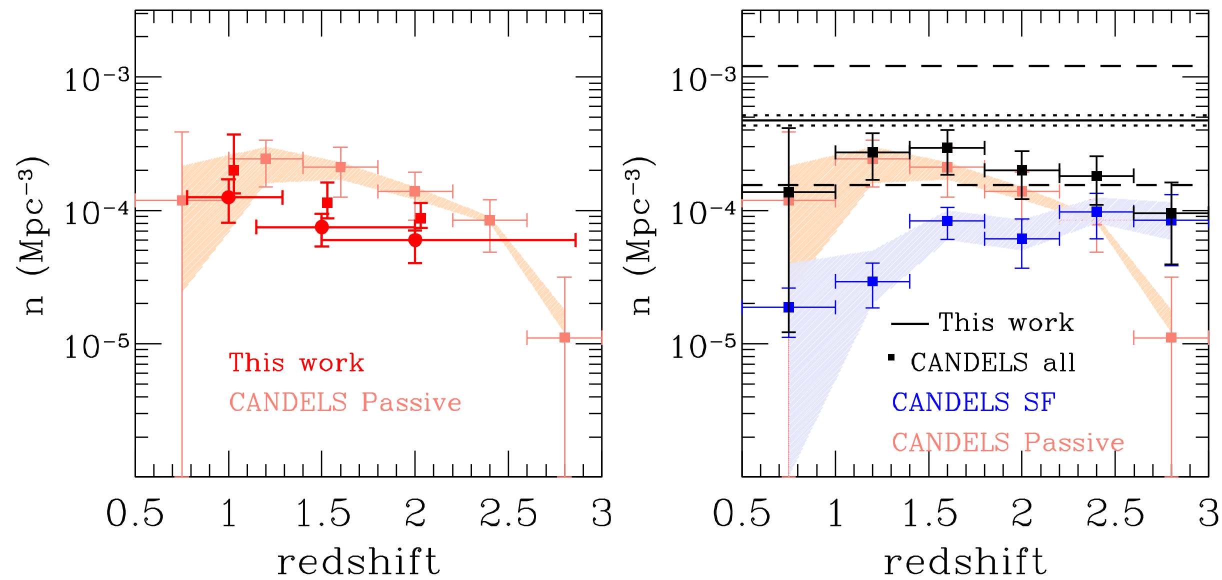

FIG. 4.— Comparison of the number density of compact galaxies at high and low redshift. **Left.** The number densities of *local* (z=0.03-0.11) PM2GC compact galaxies with LW ages compatible with being passive at $z = 1, 1.5$ and 2 are shown as red circles, and plotted at the redshift corresponding to their LW age. Red rectangles show the values for local compact galaxies adopting the conversion to Maraston's masses at high-z and have been slightly shifted in redshift for clarity. Error bars on the Y axis reproduce the values obtained for LW ages = LW age$_{z=1,1.5,2}$ ±1 Gyr. Error bars on the X axis are the ±1Gyr intervals around each redshift. Pink points are the number densities of CANDELS compact passive galaxies observed at high redshift. The shaded region encompasses the CANDELS number densities when their selection thresholds in specific star formation and compactness limits are modified by ±0.2 dex, as given in B13. **Right.** The number density of *all* compact galaxies in the local Universe, regardless of their LW age, is compared with the same quantity observed by CANDELS at high redshift. The PM2GC value is shown by the horizontal solid black line, with Poissonian errors (dotted lines) and upper and lower values obtained modifying the compactness criterion by ±0.2 dex (dashed lines). The CANDELS number density of all compact galaxies (black points) is obtained as the sum of compact passive (pink) and compact star-forming (blue) galaxies. The meaning of shaded areas is like in the left panel.

TABLE 1
NUMBER DENSITY OF LOW-Z COMPACT GALAXIES

	$LWage_{z=1}$	$LWage_{z=1.5}$ 10^{-4}Mpc^{-3}	$LWage_{z=2}$
Compact (Bruzual&Charlot) ($\log(M_{low-z}/r_e^{1.5}) \geq 10.2\,M_\odot\,kpc^{-1.5}$)	$1.3^{1.7}_{0.8}$	$0.8^{0.9}_{0.5}$	$0.6^{0.7}_{0.4}$
Compact (Maraston) ($\log(M_{low-z}/r_e^{1.5}) \geq 10.05\,M_\odot\,kpc^{-1.5}$)	$2.0^{3.7}_{1.3}$	$1.1^{1.6}_{0.9}$	$0.8^{1.1}_{0.7}$

TABLE 2
*

PM2GC number density values of compact galaxies at low redshifts with LW ages $\geq$ than the lookback time to the corresponding redshift (see text). Values are given both adopting the B13 compactness criterion that uses Bruzual & Charlot models at high-z, and converting the high-z masses to Maraston's models. The lower and upper values at each redshift were obtained varying the LW age by ±1 Gyr.

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