Bias Corrected Size-Stellar Mass Relations of Massive Galaxies at z~ 0.5-3 in the GOODS-N Region by *HST/WFC3*

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Abstract

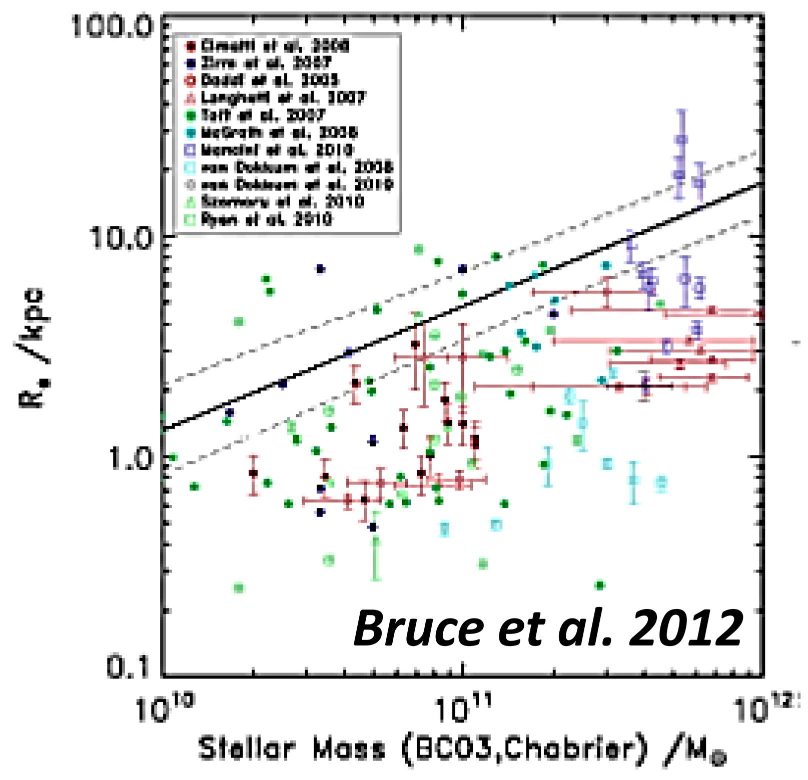
We analyze the recent released *HST/WFC3 IR* images and derive the size-stellar mass relations for massive galaxies at z~ 0.5-3. As done by many previous works we use GALFIT to derive the morphological parameters, although we make use of 6,000 artificial galaxies (*AGs*) simulation. According to the simulation, GALFIT returns biased results, mainly depending on the source magnitude. With careful concerns and our bias correct method, we analyze massive galaxies in the GOODS-North region, and find that they evolve passively during the epoch, independently of their stellar mass and redshift. In addition to these analysis, we reanalyze the previously found compact galaxies, which are believed to have surprisingly small radius compared to those of the local galaxies with similar stellar mass, and we find that they have larger size than expected, which suggests the galaxies at z~ 3 didn't need the violent evolution to the local size.

§1.Introduction

The study of the high-redshift early-type galaxies (ETGs) provides us the understanding of the formation and evolution to massive galaxies in the local Universe. Their star-formation activity is believed to be peaked during the cosmological epoch $1<z<3$ (e.g. Kajisawa & Yamada 2006), and morphologies have changed dramatically.

At a fixed stellar mass, spheroidal galaxies were significantly compact at high redshift and evolved with rapid increase of the effective radius by a factor of 4 or even larger from z ~ 3 and by a factor of 2 from z~ 1.

Although the recent infrared observations with the HST are very deep and have high spatial resolution, it has been argued that they have smaller effective radii not only because of the low signal-to-noise ratio (S/N) observations, but also because of the systematical errors. In this work, we examine those errors of GALFIT, which is one of the most frequently used 2D fitting code for galaxies, and derive robust results by correcting them for each magnitude bins.



§2.Data

2.1 *HST/WFC3*

We use the NIR data taken with *HST/WFC3* as part of the CANDELS survey. At present, the CANDELS survey in the GOODS-N has not completed, so we use the available data of 1-5 orbit observations with H_{160}. The images are reducted and drizzled to a pixel size of $0.06\ arcsec$.

2.2 MOIRCS Deep Survey (*MODS*)

We make use of the K_S-band selected catalogue of the *MODS* in the GOODS-N region (Kajisawa et al. 2009), which are based on our imaging observations in J, H, K_S bands with *MOIRCS* (Suzuki et al. 2008) installed on the Subaru telescope. The stellar mass of *MODS* samples was obtained by SED fitting of multi-band photometry with GALAXEV templates. Based on *MODS* catalogue, we choose 1,058 massive galaxies in the GOODS-N with $M_* > 10^{10}\ M_\odot$ at 0.5 <z< 3.

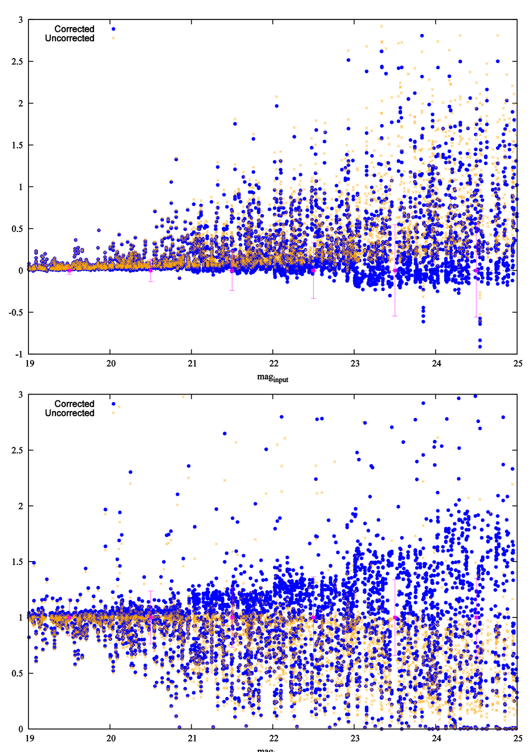


Fig.3a (top): magnitude, 3b (bottom) : r_e for 6,000 AGs.

§3.Analysis

3.1 GALFIT Simulation (Fig.3a,b)

GALFIT is a widely used 2D Sérsic (Surface Brightness Profile) fitting code which calculates χ^2 for the model of galaxy and finds the minimum- χ^2 parameter set. The Sérsic profile is,

$$\Sigma(r) = \Sigma_e exp\left[-b(n)\left(\left(\frac{r}{r_e}\right)^{\frac{1}{n}} - 1\right)\right].$$

To see the bias and uncertainties of the results by GALFIT, we make *AGs* and fit them by GALFIT. After this test, we estimate average error and scatter of the output mag and r_e for each input mag, and correct those results. n is not corrected to prevent complexity.

§4.Results

4.1 GOODS-N galaxies (Fig.4a)

We fit the galaxies in the GOODS-N in the process of GALFIT in §3 and correct the result mag and r_e, based on its output mag. By using *MODS* catalogue, we mark quiescent galaxies (*QGs*, purple circle).

The straight lines in the figure are the size-Mass relation for the local galaxies by Shen et al. (2003, *S03*) and Guo et al. (2009, *G09*).

-> Compared to the local relations, there are several massive galaxies with small radius (*Compact galaxies*).

-> *QGs* are smaller at a given mass, whereas starforming galaxies (*SFGs*, blue triangle) have slightly larger size.

4.2 Bias Correction (Fig.4b)

In contradiction to the result of Fig.4a, there are few compact galaxies after our bias correction.

To check our method, we reanalyze the compact galaxies that were done by previous works (green and orange symbols). The results are consistent with those of the GOODS-N galaxies, and their size become larger. Some of them have comparable size to the local size.

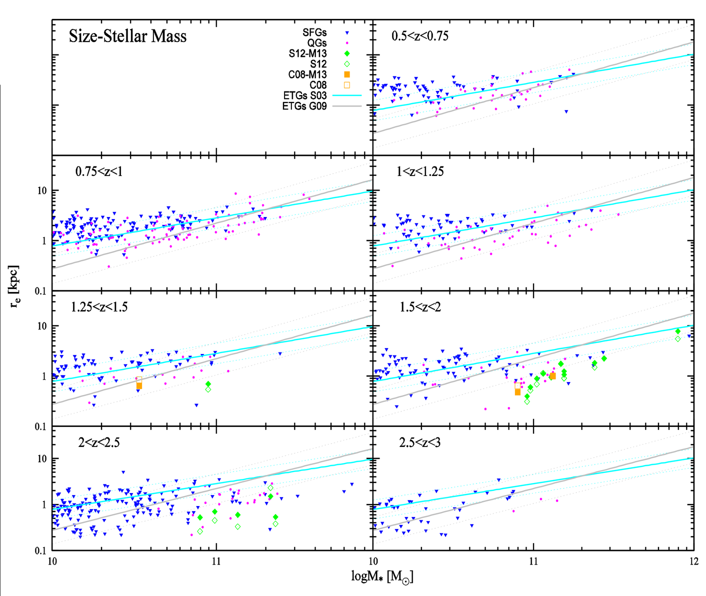
4.3 The evolution of size-mass relation (Fig.4c)

As we derive the corrected size-mass relations, we look their trend with redshift. For each redshift bin, we obtain the least square fit between the size and mass of the galaxies with a linear regression,

$$logR_e = a\log(M_*/M_c) + b,$$

where M_c is set to $10^{11} M_\odot$.

As shown in Fig.4c, there is no significant evolution for *a*, which is consistent with Ichikawa et al.(2012).



Uncorrected(Left;Fig.4a) and Corrected (Below;Fig.4b) Size-mass relations.

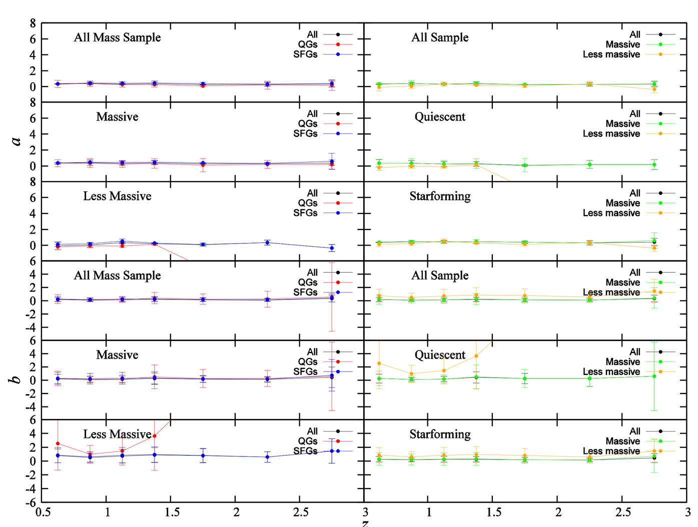
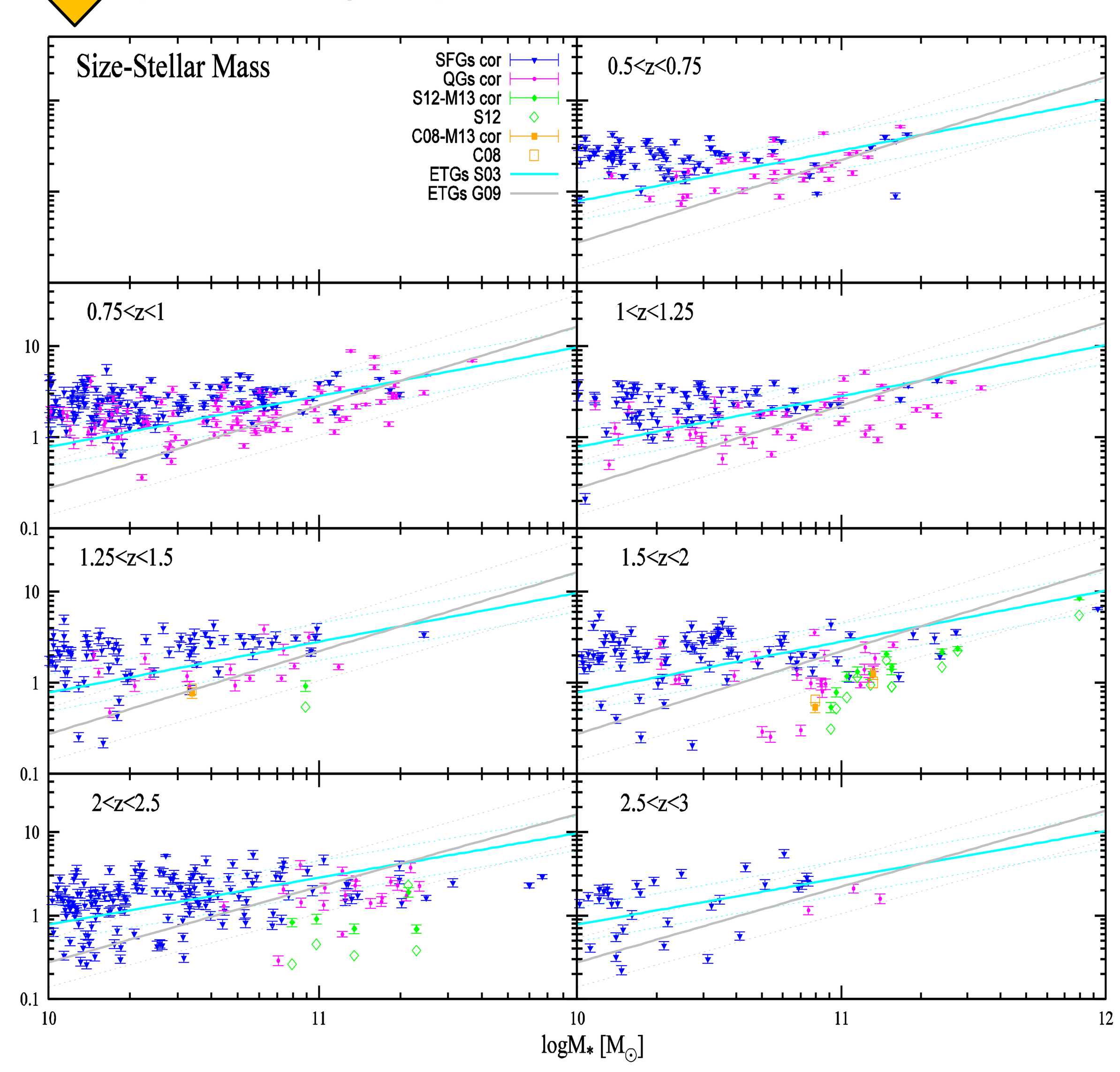


Fig.4c : Evolution of the Size-mass relations



§5.Summary

As shown above, we derived the size of the galaxies in the GOODS-N region by using GALFIT and corrected their r_e based on the *AG* simulation. According to our analysis, the size of galaxies at high-z are not so small as suggested before, but underestimated because of the lack of *S/N* and the systematic error.

Their size-mass relation remain unchanged from z~ 3 to z~ 0.5, and we expect the passive evolution scenario for them during the epoch independently of its stellar mass.