Uncertainties and Systematic Effects on the estimate of stellar masses in high z galaxies.

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Abstract. We discuss the uncertainties and the systematic effects that exist in the estimates of the stellar masses of high redshift galaxies, using broad band photometry, and how they affect the deduced galaxy stellar mass function. We use at this purpose the latest version of the GOODS-MUSIC catalog. In particular, we discuss the impact of different synthetic models, of the assumed initial mass function and of the selection band. Using Charlot & Bruzual 2007 and Maraston 2005 models we find masses lower than those obtained from Bruzual & Charlot 2003 models. In addition, we find a slight trend as a function of the mass itself comparing these two mass determinations with that from Bruzual & Charlot 2003 models. As consequence, the derived galaxy stellar mass functions show diverse shapes, and their slope depends on the assumed models. Despite these differences, the overall results and scenario remains unchanged. The masses obtained with the assumption of the Chabrier initial mass function are in average 0.24 dex lower than those from the Salpeter assumption, at all redshifts, causing a shift of galaxy stellar mass function of the same amount. Finally, using a 4.5 µm-selected sample instead of a Ks-selected one, we add a new population of highly absorbed, dusty galaxies at \( z \approx 2 - 3 \) of relatively low masses, yielding stronger constraints on the slope of the galaxy stellar mass function at lower masses.

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INTRODUCTION

Galaxy stellar mass (GSM) and galaxy stellar mass function (GSMF) has been the main topics of numerous works in recent years [e.g., 1, 2, 3, 4]. So far a downsizing scenario has emerged: most massive galaxies (\( M > 10^{11} M_{\odot} \)) had faster evolution at high redshift, with about 50% of their mass already assembled at \( z \approx 1 \); instead, the mass assembly in less massive galaxies continues up to low redshift [e.g. 1]. These analysis use multicolor catalogs, and the GSM estimates are inferred from the comparison between spectral energy distribution (SED) and libraries of synthetic spectra. Assumptions and systematics affect these estimates and the derived GSMF. Among the others, systematics originate from the assumed ingredients in the building of the library of synthetic spectra (e.g. stellar population models, initial mass function (IMF), SFR histories, reddening). Furthermore, as the \( M/L \) ratio depends from the spectral type, the selection band could affect the GSMF determination (for a detailed description of this problem see the related section and 5, 1).

To discuss the impact of these uncertainties, we use the latest version of the GOODS-MUSIC multi-wavelength catalog, covering 14 bands from U to 8\( \mu m \) band (Santini et al. submitted). We show how the assumptions on the stellar population models and IMF
affect the results. Using a 4.5µm-selected sample ($4.5\mu m \sim 23.1$), we also show a comparison between GSMFs obtained using different selection bands ($Ks$ and $4.5\mu m$).

**DIFFERENT RECIPES FOR STELLAR MASS ESTIMATES**

The procedure adopted to obtain the GSMs is described in detail in [5, 1]. In this section we show how the inferred masses change adopting the same initial conditions (Salpeter IMF [7], metallicity and age grids, etc...) but different simple stellar population tracks. In Fig. 1 we show the comparison between masses obtained using the Bruzual & Charlot 2003, Maraston 2005 [8, 9] and Charlot & Bruzual 2007 [10, 11] models (elsewhere BC03, MR05 and CB07). The continuos lines of different colors indicate isodensity contours (0.01,0.1,0.3,0.7 of the maximal density). As expected, the masses obtained with MR05 and CB07 are on average lower than those obtained with BC03 [10, 11, 12]. However, as it is shown in the redshift bin 0.4-0.8, the ratio between CB07 and BC03 shows a dependence with the mass itself. Masses obtained from BC03 models are higher than the CB07 ones of 0.3 dex at $M < 9.5M_\odot$, and of 0.05 dex at...
Instead, the MR05 model gives masses in average lower than those from BC03 of a constant amount (~0.2 dex) with the exception of a small group of objects at $M > 10^{11} M_\odot$. In the higher redshift bins the mass range covered is smaller, and this makes the effect described above less evident. These systematic in the mass estimates cause different shapes in GSMFs and affect their slopes, as shown in Fig. 2. The result is a shallower GSMF for the CB07 models and a steeper one for MR05 with respect to the determination obtained using the BC03 models. However, the general trend of fast evolution at high redshift for the most massive galaxies ($M > 10^{11} M_\odot$) is observed, as shown in Fig. 2.

We also tested how the GSMF changes under different assumptions of the IMF. In particular we adopt the Chabrier [13] and the Salpeter IMFs, the former being steeper at low stellar masses than the latter. This different shape causes a systematic in the GSMs as shown in Fig. 3. Here, in the upper panels, we compare masses obtained with our standard recipes and CB07 libraries, but with the two different choice of IMF. The masses obtained using a Chabrier IMF are in average 0.24 dex lower than those obtained adopting a Salpeter IMF, and this effect is totally independent from the range of redshift and mass probed. As a consequence the GSMFs have the same shape, but the one obtained with a Chabrier IMF is shifted at lower masses of the same amount above mentioned, as is shown in the bottom panel of Fig. 3.
FIGURE 3. Top: comparison between masses obtained with a Chabrier IMF and with a Salpeter one, the curves are the same of Fig. 1. Bottom: comparison of the GSMF obtained with a Chabrier IMF (blue continuous curve and points) and with a Salpeter one (red dashed line and points).

MASS FUNCTION WITH A 4.5 µm -SELECTED SAMPLE

The effects described in the previous section depend on different assumptions of the library ingredients. Here, we focus on the selection effects of our sample. The use of a magnitude limited sample does not translate into a well defined, sharp limit in stellar mass, as the M/L ratio depends from the galaxy spectral type. In the case of a $Ks$-magnitude limited catalog, the sample can be complete for early type galaxies and moderately obscured star-forming ones, while it could miss very dusty star-forming galaxies, as widely discussed in [1]. As result, the $Ks$-selected GOODS–MUSIC sample could be affected by this kind of incompleteness over redshift $\sim 2$ [see Fig. 3 in [1]]. This problem could be alleviated by a 4.5 µm-selection, which probes longer wavelengths less affected by dust extinction at these redshifts. Adding the objects selected in the 4.5µm band, but fainter in $K$, we find a population of highly absorbed, dusty galaxies at $z \approx 2$ – 3 of relatively low masses. The effect on GSMF is shown in Fig. 4 showing the comparison of the GSMF obtained from $Ks$ (blue dotted-lines and empty circle points) and 4.5 µm (red dashed-lines and empty triangular points) sample. We find that this new selection does not increase the GSMF at higher masses and that very dusty galaxies do not give a relevant contribution to the amount of stellar mass at all redshift considered here. At lower masses, in the redshift bins between 1.6 and 3, it improves the statistics, and although it does not change the results, it helps given a more solid constraint to the determination of $\alpha$ parameter of the Schechter function. This contribution becomes
FIGURE 4. GSMFs obtained with different magnitude-selected samples. Red dashed line from a 4.5\(\mu\)m-selected sample, and the blue one from a \(K_s\)-selected sample.

essential in the determination of the \(\alpha\) parameter in the higher redshift bin.

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