Stellar populations of LBGs at z~5 I: The stellar masses, ages, color excesses, and star formation rates

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Abstract

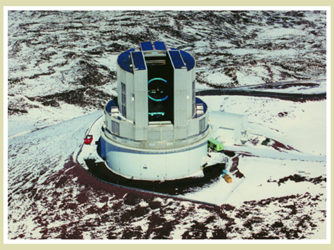
We present the results of SED fitting analysis for Lyman Break Galaxies at z~5 in the GOODS-N and its flanking fields. With the IRAC images in the GOODS-N, which are publicly available, and the IRAC images that we observed in the flanking fields, we constructed the rest-frame UV-optical SEDs for our large sample that is selected robustly. For this sample, we fit the observed SEDs with population synthesis models. The comparisons of the distributions of the parameters for our sample with those for the z=2-3 samples show the increase of the stellar mass from z~5 to z=2-3 and that the z~5 galaxies are relatively younger than for the z=2-3 galaxies. We also found that the star formation rate is higher than that in z=2-3 galaxies.

1. Objective

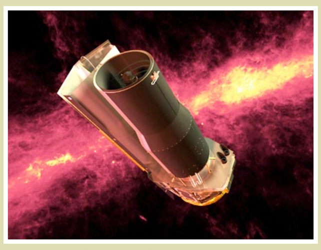
Recent studies show the gradual increase of the stellar mass density with time. However, the studies on the stellar mass of galaxies at z>5 are restricted because the lack of sufficiently deep mid-IR data. With the advent of Spitzer, we can access the rest-frame optical wavelength, and thus, the stellar mass of galaxies at z~5. In this presentation, we explore the properties, especially stellar mass, of Lyman Break Galaxies (LBGs) at z~5 using Subaru/S-Cam and Spitzer/IRAC imaging data.

2. Sample Selection

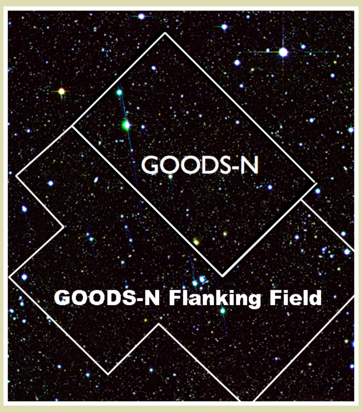
We use the LBG sample of Iwata et al.(2007), which consists of ~600 objects in/around the GOODS-N. Among them, we select objects which appear to be isolated and not contaminated by neighboring objects in IRAC images. With the public IRAC images in the GOODS-N and the IRAC images we observed in the GOODS-FF, we constructed observed SEDs for the large sample selected robustly, which consists of ~100 objects.



Subaru/Suprime-Cam
Effective area: ~500 arcmin^2
Magnitude limit (1.2"Φ, 5σ):
V:28.2, Ic:26.9, z':26.6

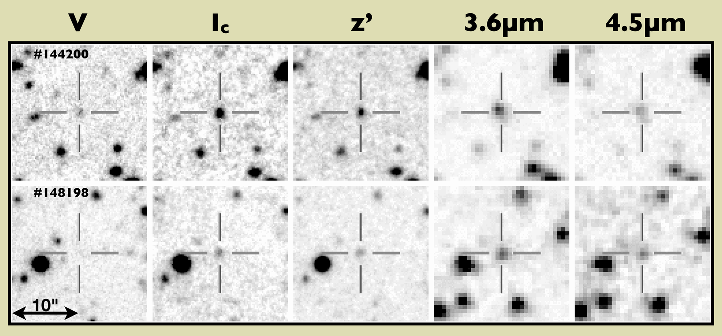


Spitzer/IRAC
Effective area: ~400 arcmin^2
Magnitude limit (2.4"Φ, 3σ):
3.6μm:25.9, 4.5μm: 25.6 (GOODS-N)
3.6μm:24.8, 4.5μm: 24.1 (GOODS-FF)



Area covered by IRAC is presented on the Subaru/Suprime-Cam area. Almost 80% of the optical images is covered by the mid-Infrared images.

In the bottom figure, two example images of our sample are shown. These objects are selected robustly to make reliable photometry.



The postage stamps of objects in 5 passbands. The LBG candidate is indicated by a cross in each panel.

3. Population Synthesis Modeling

population synthesis modeling is handled as follows:

- Bruzual & Charlot 2003
- Salpeter IMF (0.1 - 100 M_{sun})
- Constant Star Formation History
- 0.2 Z_{sun} model
- Calzetti extinction law
- Including Hα emission
- Redshift of all objects is fixed to be z=4.8

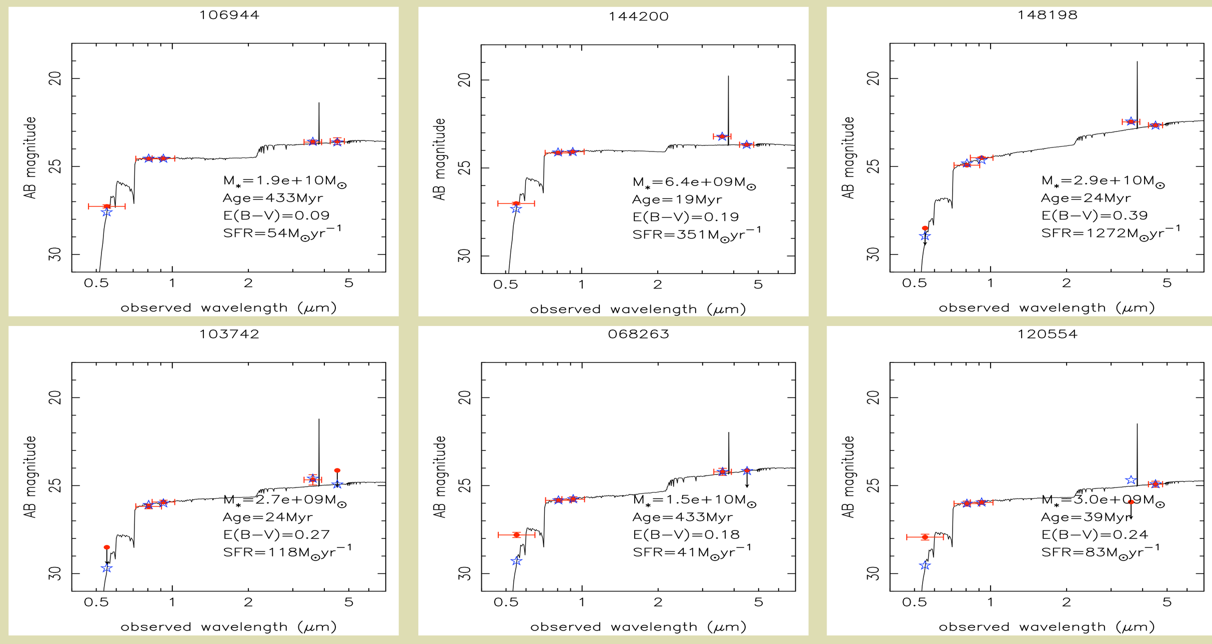
Note:
• Hα emission line is included in the model spectrum with Kennicutt law.
• We examine the effects of these model assumptions (choice of star formation history, metallicity, extinction law) on the stellar mass and found the effects is ~0.3dex at most.

4. Results

Comparing the observed SEDs with model SEDs, we infer the stellar properties of galaxies at z~5. In the right figure, examples of our fitting results are presented with the output parameters.

Sample best-fitted parameters

M_*^{median} = 4.1x10^9 M_{sun}
Age^{median} = 25 Myr
E(B-V)^{median} = 0.22 mag
SFR^{median} = 141 $M_{sun}yr^{-1}$



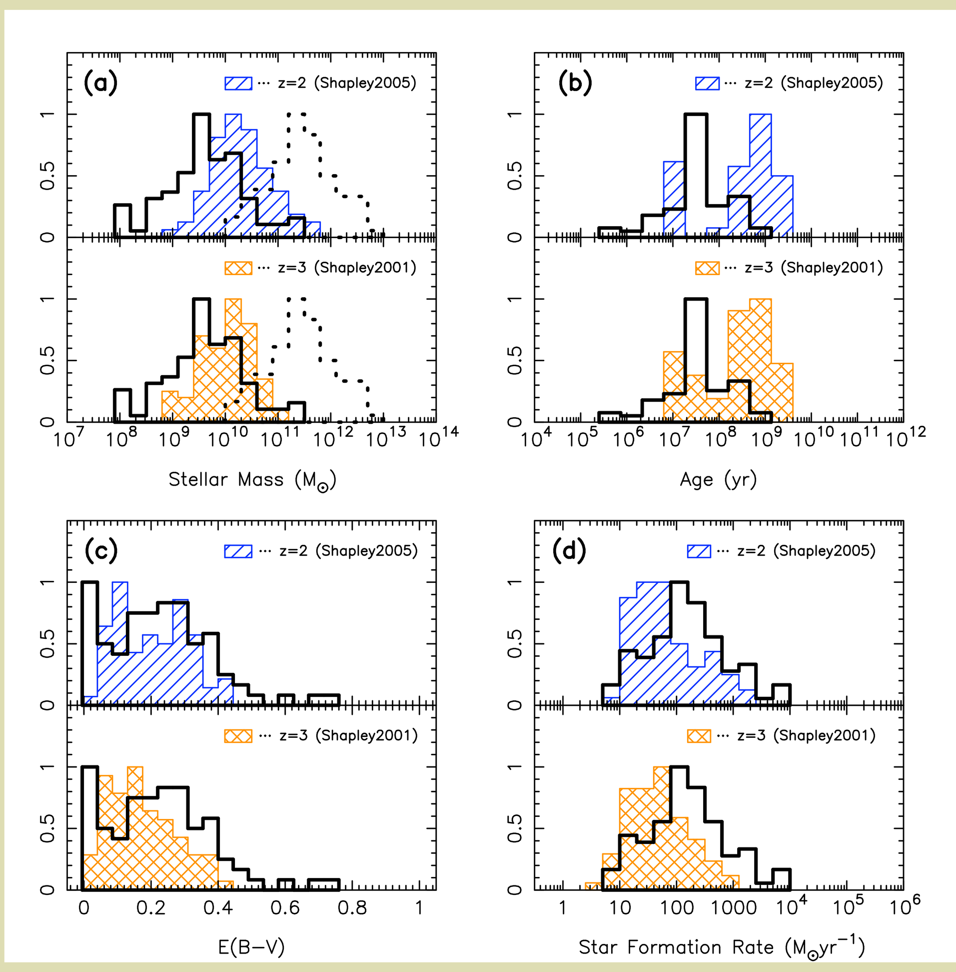
Best-fitted 0.2Z_{sun}, CSF models. The observed SEDs and the model SEDs are indicated by red points and blue points, respectively. The best-fitted parameters are also shown.

5. Comparison with the results of z=2-3 galaxies

The distributions of the output parameters from the fitting of our sample is compared with those of z=2-3 sample in the right figure, where the histogram is normalized so that its peak value equals unity for comparison. For sample galaxies at z=2 and 3, we use Shapley et al. (2001) and Shapley et al. (2005), respectively.

Although the detailed algorithm of SED fitting procedure is different from us, both samples are fitted using models of Bruzual & Charlot (2003) with a Salpeter IMF, constant star formation history, and the Calzetti et al. (2001) extinction law. For the fair comparison, we use the samples whose the rest-frame UV absolute magnitudes are brighter than -19.7 mag.

The stellar mass of z~5 galaxies is smaller than that of z=2-3 galaxies by a factor of ~4 and the age of z~5 galaxies is relatively younger than that of z=2-3 galaxies. The star formation rate is higher than in z=2-3.



Distributions of best-fitted parameters for z~5 sample with that for z=3 sample from Shapley et al.(2001) and z=2 sample from Shapley et al.(2005). For comparison, peaks of the distribution are normalized to unity.

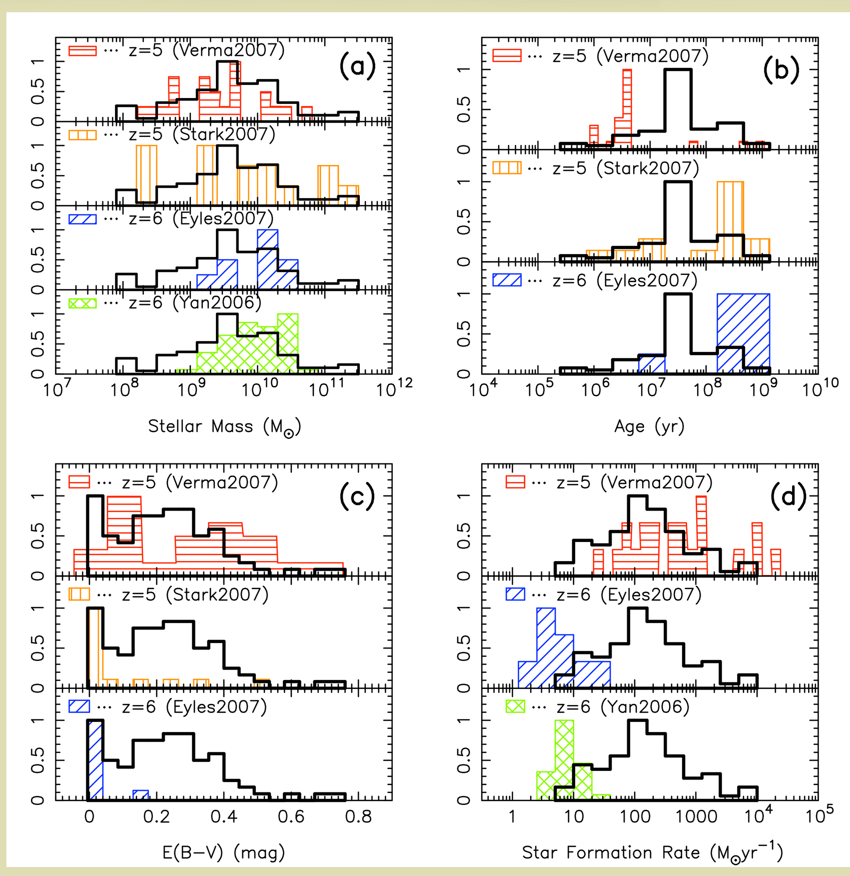
In the upper left panel of the upper right figure, the dotted line indicates the distribution of stellar mass at z=2 assuming that each galaxy of our sample continues the star formation at the rate derived from the SED fit until z=2. As a whole, the distribution shifts toward larger mass than observed at z=2. This implies that star formation may decrease from z~5 to z=2.

6. Comparison with the results of z=5-6 galaxies

The distribution of the output parameters from the fitting of our sample is compared with those of other z=5-6 samples. For sample galaxies at z=5, we use Stark et al. (2007) and Verma et al. (2007), for z=6 samples, we use Yan et al.(2006) and Eyles et al.(2007). The ranges of the rest-frame UV and optical luminosity for these samples are almost the same.

As illustrated in the left figure, the range of the inferred stellar mass for our sample is broadly consistent with other observations: the masses are widely distributed from M_* = $10^8 M_{sun}$ to $10^{11} M_{sun}$. However, while the median of the stellar mass of our sample is consistent with Verma et al.(2007) and Stark et al. (2007), it is marginally smaller by a factor of 3-4 than that for z=6 objects of Yan et al.(2006) and Eyles et al.(2007).

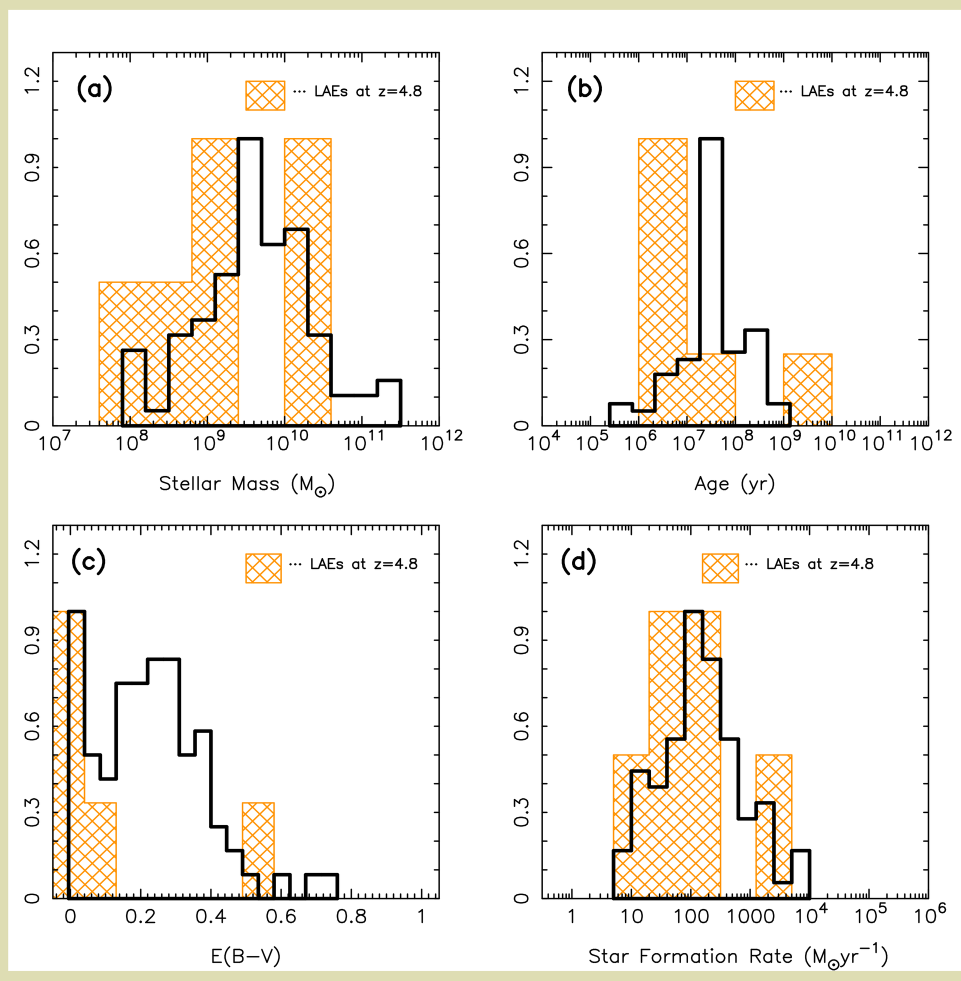
This may be partly due to the insufficient number of the z=6 sample for considering the statistical properties. It is noteworthy that the models used in the SED fitting for the z=6 sample are slightly different from those we used. Thus, the difference of the distribution of stellar mass between z=5 and z=6 samples may not be significant.



Distributions of best-fitted parameters for z~5 sample with that for samples of Stark et al.(2006), Verma et al.(2007), Yan et al.(2006), and Eyles et al.(2007). For comparison, peaks of the distribution are normalized to unity.

7. Comparison with the results of LAEs at z=4.8

The distributions of the output parameters from the fitting of our LBG sample are compared with those of 6 Lyman Alpha Emitters (LAEs) which are detected in IRAC at z=4.8 (the same redshift as our LBG sample) in the GOODS-N (Yuma et al., in prep.). The SED fitting procedure is the same as that for z~5 LBGs



Distributions of best-fitted parameters for z~5 sample with that for z=4.8 LAEs. The parameters are derived by using the same SED fitting procedure as for LBGs. For comparison, peaks of the distributions are normalized to unity.

The median stellar mass of the LAEs is 1.0×10^9 M_{sun}, which is smaller than that of LBGs by a factor of 3-4. The median stellar age of the LAEs is 4.6 Myr, which is ~5 times smaller than that of LBGs. The median color excess of the LAEs is 0.07, which is ~3 times smaller than LBGs and the median star formation rate is 87 M_{sun} yr^{-1}, which is smaller than that of LBGs by a factor of ~1.6.

These suggest that LAEs are relatively young and less massive galaxies comparing to LBGs at the same redshift. Also, LAEs are less dusty and the star formation rate is comparable or smaller than that of LBGs. However, we should note that the number of the sample LAEs is considerably small.