Galaxy Evolution across the Hubble Time
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Evolution of the rest-frame UV LF from $z \sim 8$ to $z \sim 4$

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Abstract. We have assembled large samples of galaxies at redshift $z \sim 4$, 5 and 6 (totalling >4300 objects, >1000 objects, >500 objects, respectively) from all the deep HST ACS and NICMOS data taken to date (over 2000 orbits of data). From these we have derived rest-frame *UV* luminosity functions, luminosity densities, and star formation rates in a very robust and consistent way to very faint luminosities ($0.01L*$ to $0.04L^*$). The faint-end slopes α of these luminosity functions are remarkably uniform and steep ($\alpha \sim -1.7$), indicating very little evolution from $z \sim 6$ to $z \sim 4$. The characteristic luminosity L^* brightens considerably (by ∼1 mag) over this period, but the overall change in the luminosity function is such as to lead to little change in the luminosity density and star formation rate over this time. We also have detected galaxies at $z \sim 7-8$ and set strong limits at $z \sim 10$ directly from deep HST NICMOS observations. Spitzer observations of these $z \sim 7$ galaxies have been used to estimate masses and ages, suggesting substantial formation at $z \sim 10$ or earlier. These results show that this hierachical build-up continues into the reionization epoch.

Keywords. galaxies: evolution, galaxies: formation, galaxies: high-redshift

1. Introduction/Results

Over the past few years, there has been significant progress in understanding the evolution of the rest-frame UV LF across cosmic time. At lower redshift, deep far-UV data from the Galaxy Evolution Explorer (GALEX: Martin *et al.* 2005) have allowed us to select large samples Lyman break galaxies at $z \lesssim 1.5$ (Arnouts *et al.* 2005; Schiminovich *et al.* 2005) in the same way galaxies were first selected at z ∼3–4 (Madau *et al.* 1996; Steidel *et al.* 1999). At the same time, there has been increasing amounts of very deep, wide-area optical data available from ground and space to select large dropout samples at z ∼4–6 (e.g., Giavalisco *et al.* 2004; Bouwens *et al.* 2006; Yoshida *et al.* 2006).

Of particular utility in all these LF studies has been the high-quality imaging data available from the Hubble Space Telescope. These data reach both very deep ($\gtrsim$29 AB mag in the Hubble Ultra Deep Field) and very wide ($\gtrsim$300 arcmin^2 over the GOODS fields), making it possible for us to select thousands of galaxies at $z \sim 4$–6 over a wide range in luminosity (stretching from $\sim 4L^*$ to $\sim 0.01L^*$).

Our group has taken advantage of these data to construct significant samples of >4300 $z \sim 4$ *B*-dropouts, >1000 $z \sim 5$ *V*-dropouts, and >500 $z \sim 6$ *i*-dropouts (Bouwens *et al.* 2006; Bouwens *et al.* 2006, in preparation). After carefully modelling the contamination levels, completeness, selection functions, and flux properties of our selections, we derived rest-frame *UV* LFs, luminosity densities, and star-formation rate densities at $z \sim 4$–6 to very faint luminosities (i.e., $0.01L^*_{z=3}$ at $z \sim 4$). Remarkably, we found that the faint-end slopes α of our luminosity functions are consistently steep ($\alpha \sim -1.7$) at $z \sim 4$–6. The characteristic luminosity L^* brightens considerably over this time, while the normalization ϕ^* shows no significant evolution.

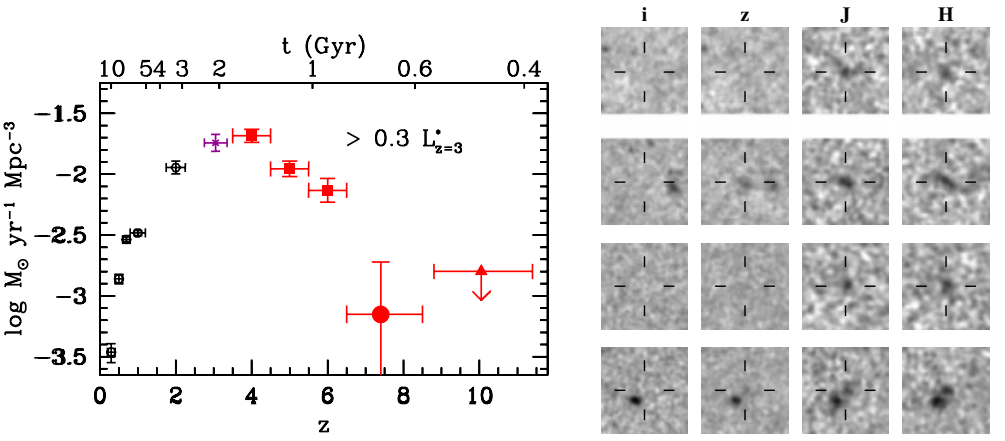

Figure 1. *(left)* Star Formation History of the Universe (uncorrected for extinction and integrated down to $0.3L^*_{z=3}$). Shown are our determinations at $z \sim 4$–6 (large red squares: Bouwens *et al.* 2006 and Bouwens *et al.* 2006, in preparation), our recent determination at $z \sim 7.4$ (large red circle: Bouwens & Illingworth 2006), and upper limits at $z \sim 10$ (red triangle: Bouwens *et al.* 2005). Included are also determinations at $z \sim 0$–2 (Schiminovich *et al.* 2005) and $z \sim 3$ (Steidel *et al.* 1999). The star formation rate density is observed to increase rather dramatically from $z \sim 8$ to $z \sim 4$. *(right)* Optical and near-infrared images of four candidate star-forming galaxies at $z \sim 7$–8. These galaxies were found in deep NICMOS imaging available over the Ultra Deep Field and GOODS fields (Bouwens & Illingworth 2006).

To see if these trends held at even early times, our group conducted a search for star-forming galaxies at $z \sim 7$–8 by applying a z-dropout selection to all of the publically available NICMOS data ($\sim$19 arcmin^2) coincident with deep optical data (Bouwens & Illingworth 2006). What we found is only one z-dropout in our most conservative selection, and four z-dropouts in a less conservative selection. Since these numbers were substantially less less than we expected assuming no evolution from $z \sim 6$, this indicated to us that the rest-frame UV LF had evolved significantly over this interval. Noting that we had already observed a significant brightening of L^* from $z \sim 6$ to $z \sim 4$, the simplest interpretation of this result was that the characteristic luminosity of galaxies at $z \sim 7$–8 is even fainter than at $z \sim 6$ (by $\sim$1 mag).

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Discussion

ANONYMOUS: Is the UVLF for z =4-6 results by S. Beckwith consistent with yours?

RYCHARD BOUWENS: It is too early to make official comments, but it would be consistent.

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