The Astrophysical Journal, 630:L137–L140, 2005 September 10

UV CONTINUUM SPECTROSCOPY OF A $6L_*$ $z = 5.5$ STARBURST GALAXY[1,2,3]

C. C. Dow-Hygelund,[4] B. P. Holden,[5] R. J. Bouwens,[5] A. van der Wel,[6] G. D. Illingworth,[5] A. Zirm,[6] M. Franx,[6] P. Rosati,[7] H. Ford,[8] P. G. van Dokkum,[9] S. A. Stanford,[10] P. Eisenhardt,[11] and G. G. Fazio[12]
Received 2005 June 13; accepted 2005 July 29; published 2005 August 24

ABSTRACT

We have obtained a high S/N (22.3 hr integration) UV continuum VLT FORS2 spectrum of an extremely bright ($z_{850} = 24.3$) $z = 5.515 \pm 0.003$ star-forming galaxy (BD38) in the field of the $z = 1.24$ cluster RDCS 1252.9−2927. From *HST* Advanced Camera for Surveys imaging, this object was selected as a potential $z \sim 6$ Lyman break galaxy (LBG) based on its red $i_{775} - z_{850} = 1.5$ color. This object shows substantial continuum (0.41 ± 0.02 μJy at 1300 Å) and low-ionization interstellar absorption features typical of LBGs at lower redshift ($z \sim 3$); this is the highest redshift LBG confirmed via metal-absorption spectral features. The equivalent widths of the absorption features are similar to $z \sim 3$ strong Lyα absorbers. No noticeable Lyα emission was detected ($F \leq 1.4 \times 10^{-18}$ ergs cm^{-2} s^{-1}, 3 σ). This object is at most amplified 0.3 mag from gravitational lensing by the foreground cluster. The delensed half-light radius of this object is 1.6 kpc (0″.25), and the star formation rate derived from the rest-frame UV luminosity is SFR$_{\rm UV}$ = 38 $h_{0.7}^{-2}$ $M_\odot$ yr^{-1} (142 $h_{0.7}^{-2}$ $M_\odot$ yr^{-1} corrected for dust extinction). In terms of recent determinations of the $z \sim 6$ UV luminosity function, this object appears to be $6L_*$. The *Spitzer* IRAC fluxes for this object are 23.3 and 23.2 AB mag (delensed) in the 3.6 and 4.5 μm channels, respectively, implying a mass of (1–6) $\times$ 10^{10} $M_\odot$ from population synthesis models. This galaxy is brighter than any confirmed $z \sim 6$ *i*-dropout to date in the z_{850} band, and in the 3.6 and 4.5 μm channels, and is the most massive starbursting galaxy known at $z > 5$.

Subject headings: galaxies: high-redshift — galaxies: individual (J1252-5224-4599) — galaxies: starburst

1. INTRODUCTION

Despite the large samples of photometrically selected $z \sim 6$ Lyman break galaxies (LBGs; Bouwens et al. 2003, 2005), spectroscopic confirmation has been difficult, because of the faint flux levels required. Ground-based follow-up programs have had success rates of ∼25%, by identifying redshifts through Lyα emission (Stanway et al. 2004a, 2004b; C. Dow-Hygelund et al. 2005, in preparation). Malhotra et al. (2005) have verified 23 $z \sim 6$ i_{775}-dropout galaxies via the presence of strong Lyman continuum breaks using low-resolution Advanced Camera for Surveys (ACS) grism observations. However, none of these very low resolution spectra can be used to identify the absorption features necessary to measure metal abundances or to characterize the interstellar medium. To do this, we need to observe anomalously bright objects in order to obtain a high continuum signal-to-noise ratio (S/N). The best example of this remains the strongly gravitationally lensed (30 ×) $z \sim 3$ galaxy MS 1512-cB58 (Pettini et al. 2000).

In this Letter, we report on the spectroscopic confirmation of a particularly bright $z_{850} = 24.3$ (Bouwens et al. 2003) $z \sim 6$ *i*-dropout candidate: object 1252-5224-4599, hereafter BD38, in the RDCS 1252.9−2927 field (Cl 1252; Rosati et al. 1998). We show that this large ($r_{\rm hl}$ = 0″.29) starbursting galaxy has a Lyman continuum break and interstellar absorption features at a redshift of $z = 5.515$, but lacks Lyα emission. Throughout we adopt ($\Omega_{\rm tot}$, Ω_M, Ω_Λ) = (1.0, 0.3, 0.7) and $H_0 = 70$ km s^{-1} Mpc^{-1}. All magnitudes are given in the AB system (Oke & Gunn 1983).

2. OBSERVATIONS, REDUCTION, AND ANALYSIS

The *Hubble Space Telescope* ACS observations of BD38 ($\alpha_{2000} = 12^{\rm h}52^{\rm m}56^{\rm s}.888$, $\delta_{2000} = -29°25'55''.50$) involved three orbits of F775W (i_{775}) and five orbits of F850LP (z_{850}). Very Large Telescope (VLT) Infrared Spectrometer and Array Camera (ISAAC; 6.0 hr for J_s and 5.7 hr for K_s) and *Spitzer* Infrared Array Camera (IRAC; 1000 s for both 3.6 and 4.5 μm) imaging were also obtained. For details see Bouwens et al. (2003), Lidman et al. (2004), and Fazio et al. (2004).

We measured the $i_{775} - z_{850}$ color in 0″.6 apertures, and the total z_{850} magnitude was measured in a 1″.1 aperture. For measuring the $z_{850} - J_s$ and $z_{850} - K_s$ colors, we smoothed the z_{850} image to match the J_s- and K_s-band point-spread function, and we used 1″.0 apertures. The difference between the 1″.1 and 0″.6 z_{850} magnitudes was then added to the i_{775}, J_s, and K_s magnitudes.

Using the z_{850} image as a model for the IRAC data, every object in the z_{850} image within 20″ of BD38 was smoothed

[1] Based on observations made with the NASA/ESA *Hubble Space Telescope*, which is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS 5-26555. These observations are associated with programs 7817, 9270, 9301, and 9583.

[2] Based on observations collected at the European Southern Observatory, Paranal, Chile (LP166.A-0701 and 169.A-0458).

[3] Based in part on observations made with the *Spitzer Space Telescope*, which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under NASA contract 1407.

[4] Physics Department, University of California, 211 Interdisciplinary Sciences Building, 1156 High Street, Santa Cruz, CA 96064; cdow@scipp.ucsc.edu.

[5] Astronomy Department, University of California, Santa Cruz, CA 96062; holden@ucolick.org, bouwens@ucolick.org, gdi@ucolick.org.

[6] Leiden Observatory, P.O. Box 9513, J. H. Oort Building, Niels Bohrweg 2, NL-2300 RA Leiden, Netherlands; vdwel@strw.leidenuniv.nl, azirm@strw.leidenuniv.nl, franx@strw.leidenuniv.nl.

[7] European Southern Observatory, Karl-Schwarzschild-Strasse 2, D-85748 Garching, Germany; prosati@eso.org.

[8] Department of Physics and Astronomy, Johns Hopkins University, 3400 North Charles Street, Baltimore, MD 21218-2686; ford@pha.jhu.edu.

[9] Department of Astronomy, Yale University, P.O. Box 208101, New Haven, CT 06520-8101; dokkum@astro.yale.edu.

[10] Department of Physics, University of California at Davis, 1 Shields Avenue, Davis, CA 95616-8677.

[11] Jet Propulsion Laboratory, California Institute of Technology, MS 169-327, 4800 Oak Grove Drive, Pasadena, CA 91109.

[12] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, MS 65, Cambridge, MA 02138.

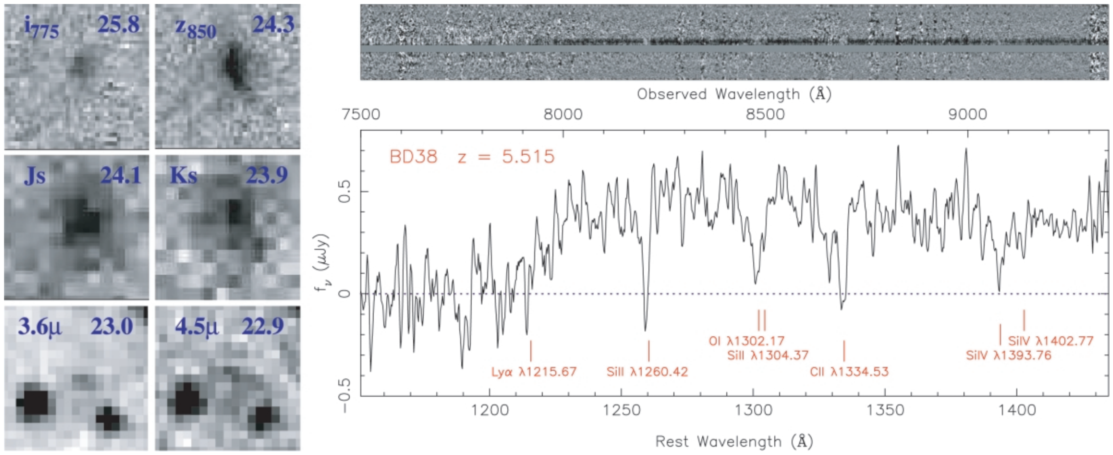

FIG. 1.—*Left*: ACS, ISAAC, and IRAC imaging of BD38. The i_{775}, z_{850}, J_s, and K_s thumbnails are 1″.5 on a side. The 3.6 and 4.5 μm thumbnails are 15″.0 on a side. The disturbed morphology of BD38 is apparent and, together with the spectroscopic data, suggests vigorous star formation. Furthermore, the relatively red $z - J_s$ and $z - K_s$ colors coupled with the strong LIS lines (see below) suggests that BD38 is a relatively dust-enriched and chemically evolved galaxy. The object is extended toward the lower right (northwest) direction by ≈0″.26 and toward the upward (east) by 0″.22. These "plumes" could be the product of a recent merger. *Right*: Two-dimensional and extracted one-dimensional FORS2 spectra of BD38. The total integrated time was 22.3 hr. The gray smooth rectangular region of the two-dimensional spectrum covers a cluster member spectrum that occupied the slit. The one-dimensional spectrum has been smoothed with a 5 pixel boxcar filter. Strong LIS absorption features are marked, and the blue dotted line denotes zero flux. The equivalent widths of these lines are very similar to those found by Shapley et al. (2003) for 198 $z \sim 3$ LBGs that are strong Lyα absorbers (see Table 1). Utilizing these features yields a systematic redshift of $z = 5.515 \pm 0.003$.

with a kernel to match the ACS and IRAC data. The normalization of this kernel was varied individually for every object until the χ^2 between the model image and the IRAC data was minimized.

The resulting ACS, ISAAC, and IRAC images are shown in Figure 1. BD38's observed magnitudes are $i_{775} = 25.76 \pm 0.15$, $z_{850} = 24.25 \pm 0.05$, $J_s = 24.1 \pm 0.1$, $K_s = 23.8 \pm 0.1$, 3.6 μm $= 23.0 \pm 0.3$, and 4.5 μm $= 22.9 \pm 0.4$. Clearly evident is the strong $i_{775} - z_{850}$ flux decrement. Furthermore, the object is increasing in luminosity toward longer wavelengths. Assuming the rest-frame UV continuum of BD38 satisfies the form $f_\lambda \propto \lambda^\beta$, we are able to derive a spectral slope of $\beta = -1.5 \pm 0.2$ over rest-frame 1400–3000 Å, from the z_{850}, J_s, and K_s fluxes.

We spectroscopically observed BD38 using the FOcal Reducer/low dispersion Spectrograph 2 (FORS2) on the 8.2 m VLT Yepun unit telescope. We used the 600*z* grism with the OG590 blocking filter, yielding a resolution of 1.64 Å pixel^{-1}. The slit width was 1″.0. A total of 80 exposures were taken to acquire a 22.3 hr integrated spectrum. BD38 and three other *i*-dropouts were targeted serendipitously as part of a larger fundamental plane study. For details see van der Wel et al. (2005).

TABLE 1
STRONG BD38 INTERSTELLAR ABSORPTION FEATURES

$\lambda_{\rm lab}$[a] (Å)	Ion	$\lambda_{\rm obs}$[b] (Å)	$z_{\rm ion}$[b]	W_o[c] (Å)	$W_{o,\,z\sim3}$[d] (Å)
1260.42	Si II	8205.77	5.510	3.18 ± 0.15	1.85 ± 0.16
1302.17	O I	8485.38	5.516	3.05 ± 0.10	3.24 ± 0.16
1304.37	Si II	8498.43	5.515	...	...
1334.53	C II	8699.72	5.518	2.88 ± 0.13	2.34 ± 0.16
1393.76	Si IV	9079.21	5.514	1.92 ± 0.25	1.83 ± 0.23
1402.77	Si IV	9140.84	5.516	1.14 ± 0.07	1.01 ± 0.17
Mean			5.515		

NOTE.—For ion O I, W_o and $W_{o,\,z\sim3}$ contain O I λ1302.17 + Si II λ1304.37.
[a] Vacuum wavelengths.
[b] Observed wavelengths (heliocentric).
[c] Rest-frame equivalent width and 1 σ error.
[d] Rest-frame equivalent width for G1 of the Shapley et al. (2003) $z \sim 3$ LBG sample.

The 22.3 hr integrated FORS2 absorption spectra are shown in Figure 1. A precipitous continuum break is clearly seen at ≈7900 Å, reducing the continuum from 0.41 ± 0.02 to 0 ± 0.02 μJy. Six clear absorption features are indicated in the figure.

The continuum break is due to the Lyα forest, while the absorption features are the low-ionization interstellar (LIS) lines typically seen in LBGs at $z \sim 3$ (Shapley et al. 2003) and

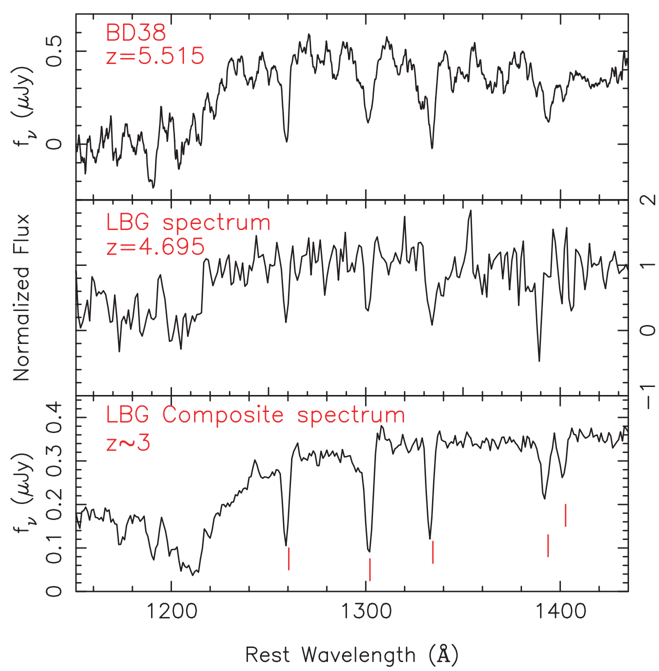

FIG. 2.—Spectral comparison between BD38, a $z = 4.695$ LBG spectrum from Ando et al. (2004), and a $z \sim 3$ composite LBG spectrum from Shapley et al. (2003). BD38's spectrum has been smoothed with a 13 pixel boxcar filter. The continuum break and marked absorption features show a strong match with BD38 and the LBG spectra, indicating that this object is a starbursting LBG.

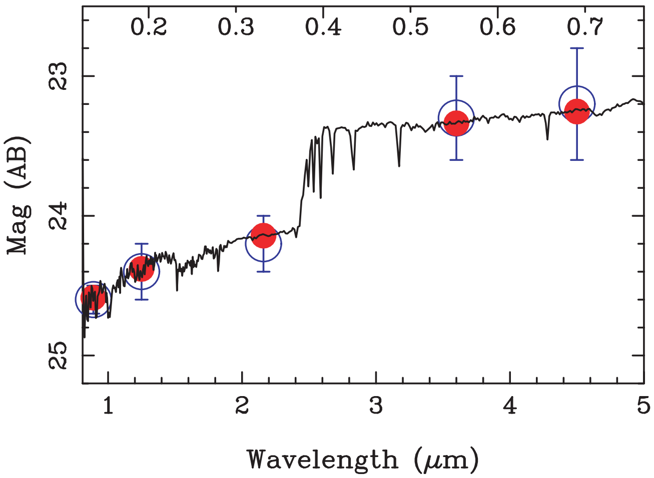

FIG. 3.—Best-fit Bruzual & Charlot (2003) SED for BD38. The open circles with error bars denote the measured magnitudes, and the filled red circles represent the model SED magnitudes in each bandpass and channel. The upper and lower axes are the rest-frame and observed wavelengths, respectively. Model parameters are $\tau = 100$ Myr, $Z_\odot$, age $= 227^{+27}_{-35}$ Myr, $E(B-V) = 0.10^{+0.10}_{-0.10}$, and a mass $= (43 \pm 13) \times 10^9\ M_\odot$ The magnitudes have been dimmed by 0.3 mag to account for weak lensing by the cluster potential (§ 3.1). The clear rest-frame 0.4 μm Balmer break suggests a dominant stellar population of at least 100 Myr.

the UV spectra of local starbursts (e.g., Heckman et al. 1998). Table 1 lists the observed LIS absorption lines, their corresponding vacuum wavelengths (λ_{lab}), observed wavelengths (λ_{obs}), redshifts, and measured equivalent widths (W_o). In Figure 2 we show BD38's spectrum, along with the composite spectrum of 198 $z \sim 3$ LBGs that lack Lyα emission (Shapley et al. 2003), and object 2 ($z = 4.687$ LBG) of Ando et al. (2004). There is a strong similarity in each spectrum's continuum break and absorption features. This demonstrates that BD38 is an LBG at $z = 5.515 \pm 0.003$.

There appears to be some weak emission at 7920 ± 1 Å, which would be the expected position of the Lyα emission line. However, the S/N for this feature is poor. We determine a 3 σ upper limit of 1.4×10^{-18} ergs cm^{-2} s^{-1} on this features. This is an order of magnitude smaller than is seen for $z \sim 6$ LBGs with strong Lyα emission (Stanway et al. 2004b; C. Dow-Hygelund et al. 2005, in preparation).

3. A ~6L_* STARBURST GALAXY

3.1. *Luminosity*

BD38 is 1.3 mag (z_{850}) brighter than any other *i*-dropout found in its host field, Cl 1252 (Bouwens et al. 2003), and is 0.4 mag brighter than any other verified $z \sim 6$ LBG to date (Bunker et al. 2003; Malhotra et al. 2005; C. Dow-Hygelund et al. 2005, in preparation). Two common explanations for anomalously bright galaxies are (1) they are powered by an active galactic nucleus (AGN) or (2) they are gravitationally lensed. We consider each hypothesis in turn.

The AGN interpretation of the high luminosity is unlikely. First, Lyα λ1215.67 emission and N v λ1240 emission, typical of AGNs (Osterbrock 1989), were not detected. Second, BD38 was undetected in *Chandra* and *XMM-Newton* Cl 1252 surveys, with upper luminosity limits of $L_X = 1.6 \times 10^{43}$ and 6.5×10^{43} ergs s^{-1} in the 0.5–2 and 2–7 keV bands, respectively (Rosati et al. 2004). This excludes BD38 being a type 1 AGN (QSO), and the absence of high-ionization spectral lines is inconsistent with this object being a low-luminosity type 2 AGN. Finally, the object is very extended, lacks a point source, and has LIS features similar to lower redshift starburst spectra.

Gravitational amplification can only account for a small portion of BD38's high luminosity. BD38 is 88″ from the Cl 1252 cluster center, and using the results of Lombardi et al. (2005) we estimate the gravitational magnification due to the cluster potential to be at most 1.3× or 0.3 mag. Lensing by any obvious nearby galaxy has been calculated to be less than 3%. Therefore, we believe BD38 to be intrinsically very luminous.

BD38 is an extremely luminous ($z_{850} = 24.6$ mag delensed) galaxy for this epoch. If no evolution is assumed in the UV luminosity function from $z \sim 3$ to $z \sim 6$ for L_*, BD38 is a 4L_* object. However, using the observed evolution in L_*, this object is an even more extreme 6L_* (Bouwens et al. 2005). The surface density of such objects is estimated to be only one per 400 arcmin^2. In fact, only one similarly bright (SBM object 3 [Stanway et al. 2003]; $z_{850} = 24.7$) *i*-dropout has been found over the entire 320 arcmin^2 ACS footprint of the two GOODS fields (Bunker et al. 2003). Furthermore, BD38 is brighter than all the *i*-dropout objects discovered in the 767 arcmin^2 Subaru Deep Field (Shimasaku et al. 2005). In addition, BD38's 3.6 μm = 23.3 and 4.5 μm = 23.2 mag fluxes (delensed) are the largest found in any *i*-dropout object to date (Eyles et al. 2005), and they are 0.6 mag brighter than SBM object 3 in the 3.6 μm channel.

The UV magnitudes imply an 1500 Å continuum luminosity of $2.7 \times 10^{29}\ h_{0.7}^{-2}$ ergs s^{-1} Hz^{-1}. This yields a star formation rate (SFR$_{UV}$) of 38 $h_{0.7}^{-2}\ M_\odot$ yr^{-1} (Madau et al. 1998). The $\beta = -1.5$ suggests that BD38 suffers from dust obscuration, and utilizing equation (11) of Meurer et al. (1999) yields a UV dust extinction value of $A_{1600} = 1.45$ mag. This increases SFR$_{UV}$ by a factor of 3.78–142 $h_{0.7}^{-2}\ M_\odot$ yr^{-1}.

3.2. *Morphology and Color*

BD38 has a delensed half-light radius of $r_{hl} = 0\farcs25$ (z_{850}), implying a physical half-light radius of $r_{hl} = 1.6\ h_{0.7}$ kpc. This object is among the largest *i*-dropouts at $z \sim 6$. This r_{hl} corresponds to the size of luminous blue compact galaxies in the local universe (Koo et al. 1994), although the SFR of BD38 is a factor of ≈6 times higher.

Alhough BD38 is unusually bright, its A_{1600}, SFR$_{UV}$, and r_{hl} resemble $z \sim 3$ LBGs and compact ultraviolet luminous galaxies (UVLGs) populating the local universe (Heckman et al. 2005). Averaging the equivalent width values of Si II (λ1260), O I (λ1302)/Si II (λ1304), and Ci II (λ1335) yields −3.0 Å, similar to −2.5 Å for group 1 (G1) and −2.8 Å for seven $z \sim 5$ LBGs (Ando et al. 2004), and those found for UVLGs. These lines are saturated; therefore, they are not useful for measuring metal abundances (see Shapley et al. 2003). However, this similarity in the LIS equivalent widths suggests that BD38's combination of neutral gas covering fraction and velocity dispersion is similar to lower redshift starbursts.

3.3. *Population Synthesis Modeling*

Using the z_{850}, J_s, K_s, and *Spitzer* IRAC 3.6 and 4.5 μm data, we fit Bruzual & Charlot (2003) stellar synthesis models to BD38 using a similar methodology as Papovich et al. (2001) and Eyles et al. (2005). We use the dust models from Calzetti et al. (2000), and assume metallicities of 0.4 or 1.0 $Z_\odot$.

We examined three sets of models for the spectral energy distribution (SED) of BD38: a (1) simple stellar population (SSP), (2) a constant, and (3) exponentially declining star formation. All models are poorly constrained because they only have five independent photometric measurements and large errors on the IRAC fluxes. The best-fitting SSP (minimum mass and age model) is a 0.4 $Z_\odot$, $6.0^{+2.6}_{-0.4}$ Myr population with $E(B-V) = 0.26^{+0.04}_{-0.04}$ and a mass of $(7.0 \pm 2.1) \times 10^9\ M_\odot$. Assuming a constant star formation rate yields a 1 $Z_\odot$, 720^{+470}_{-300} Myr population with $E(B-V) = 0.13^{+0.07}_{-0.05}$ and a mass of $(64 \pm 20) \times 10^9\ M_\odot$. The lowest χ^2 model, shown in Figure 3, has an exponentially decaying star formation rate with $\tau = 100$ Myr, a 1 $Z_\odot$, 227^{+27}_{-35} Myr population with $E(B-V) = 0.10^{+0.10}_{-0.10}$, and a mass of $(43 \pm 13) \times 10^9\ M_\odot$. All errors are formal 68% confidence limits for the input model. We emphasize that all of these models have competitive χ^2 values and that there are as many parameters [τ, Z, age, $E(B-V)$, and mass] as there are data points. It is striking that the most reasonable models (i.e., those with ongoing star formation) all imply large masses, with mass-to-light ratios typical of $z \sim 3$ galaxies (e.g., Labbé et al. 2005).

Using the same assumptions as Eyles et al. (2005), BD38 is at least 2–3 times more massive than the comparably bright ($z_{850} = 24.7$) $z = 5.78$ galaxy SBM object 3, although the stellar ages derived are similar. Hence, BD38 is likely the most massive $z \sim 6$ i-dropout LBG to date. Interestingly, SBM object 3 possesses strong Lyα emission (unlike BD38), is compact (unlike BD38), and is 0.6 mag fainter in the 3.6 μm channel than BD38.

This object is unique, representing the tip of the $z \sim 6$ mass function. BD38 is likely a dusty [$E(B-V) \sim 0.1$], massive LBG composed of a large current burst of star formation ($\mathrm{SFR_{UV}} = 40$–$142\ h^{-2}_{0.7}\ M_\odot\ \mathrm{yr}^{-1}$) together with a slightly older population (6–700 Myr) of $(1–6) \times 10^{10}\ M_\odot$ stars. These results are dependent on the very shallow IRAC imaging; much longer integration times are necessary to confirm this interpretation. Mid-IR imaging would give much stronger constraints on possible SEDs.

Although this is only one object, its similarities to other luminous $z \sim 3$ LBGs provide us with insights into evolution over the interval $3 \leq z \leq 6$. This object (1) has no noticeable Lyα emission and (2) is more dust-reddened than typical $z \sim 6$ objects (Stanway et al. 2005; Bouwens et al. 2005). These traits are typical of the more luminous high $\mathrm{SFR_{UV}}$ $z \sim 3$ LBGs (Shapley et al. 2003). Therefore, even though the universe was only half as old at $z = 5.5$ (1 Gyr) than at $z \sim 3$ (2 Gyr), the composition and star-forming properties of extremely luminous objects appear to be essentially unchanged.

This research has been supported by NASA grant NAG 5-7697. We thank our anonymous referee for helpful comments that improved this Letter. We are extremely grateful to M. Ando, A. Shapley, and collaborators for the generous use of their data and to Dan Magee for his adept computer assistance.

REFERENCES

Ando, M., Ohta, K., Iwata, I., Watanabe, C., Tamura, N., Akiyama, M., & Aoki, K. 2004, ApJ, 610, 635
Bouwens, R., Illingworth, G., Blakeslee, J., & Franx, M. 2005, ApJ, submitted
Bouwens, R. J., et al. 2003, ApJ, 595, 589
Bruzual, G., & Charlot, S. 2003, MNRAS, 344, 1000
Bunker, A. J., Stanway, E. R., Ellis, R. S., McMahon, R. G., & McCarthy, P. J. 2003, MNRAS, 342, L47
Calzetti, D., Armus, L., Bohlin, R. C., Kinney, A. L., Koornneef, J., & Storchi-Bergmann, T. 2000, ApJ, 533, 682
Eyles, L., Bunker, A., Stanway, E., Lacy, M., Ellis, R., & Doherty, M. 2005, MNRAS, in press (astro-ph/0502385)
Fazio, G. G., et al. 2004, ApJS, 154, 10
Heckman, T. M., Robert, C., Leitherer, C., Garnett, D. R., & van der Rydt, F. 1998, ApJ, 503, 646
Heckman, T. M., et al. 2005, ApJ, 619, L35
Koo, D. C., Bershady, M. A., Wirth, G. D., Stanford, S. A., & Majewski, S. R. 1994, ApJ, 427, L9
Labbé, I., et al. 2005, ApJ, 624, L81
Lidman, C., Rosati, P., Demarco, R., Nonino, M., Mainieri, V., Stanford, S. A., & Toft, S. 2004, A&A, 416, 829
Lombardi, M., et al. 2005, ApJ, 623, 42
Madau, P., Pozzetti, L., & Dickinson, M. 1998, ApJ, 498, 106
Malhotra, S., et al. 2005, ApJ, 626, 666
Meurer, G. R., Heckman, T. M., & Calzetti, D. 1999, ApJ, 521, 64
Oke, J. B., & Gunn, J. E. 1983, ApJ, 266, 713
Osterbrock, D. E. 1989, Astrophysics of Gaseous Nebulae and Active Galactic Nuclei (Mill Valley: University Science Books)
Papovich, C., Dickinson, M., & Ferguson, H. C. 2001, ApJ, 559, 620
Pettini, M., Steidel, C. C., Adelberger, K. L., Dickinson, M., & Giavalisco, M. 2000, ApJ, 528, 96
Rosati, P., della Ceca, R., Norman, C., & Giacconi, R. 1998, ApJ, 492, L21
Rosati, P., et al. 2004, AJ, 127, 230
Shapley, A. E., Steidel, C. C., Pettini, M., & Adelberger, K. L. 2003, ApJ, 588, 65
Shimasaku, K., Ouchi, M., Furusawa, H., Yoshida, M., Kashikawa, N., & Okamura, S. 2005, PASJ, 57, 447
Stanway, E. R., Bunker, A. J., & McMahon, R. G. 2003, MNRAS, 342, 439
Stanway, E. R., Bunker, A. J., McMahon, R. G., Ellis, R. S., Treu, T., & McCarthy, P. J. 2004a, ApJ, 607, 704
Stanway, E., McMahon, R., & Bunker, A. 2005, MNRAS, 359, 1184
Stanway, E. R., et al. 2004b, ApJ, 604, L13
van der Wel, A., Franx, M., van Dokkum, P. G., Rix, H.-W., Illingworth, G. D., & Rosati, P. 2005, ApJ, in press (astro-ph/0502228)