SF2A 2014
J. Ballet, F. Bournaud, F. Martins, R. Monier and C. Reylé (eds)

THE FIRST HST FRONTIER FIELDS CLUSTER : SEARCH FOR Z >7.5 GALAXIES

N. Laporte[1], F. E. Bauer[1, 2], S.Kim[1], R. Pelló[3], I. Pérez-Fournon[6, 4], D. Schaerer[5] and A. Streblyanska[4, 6]

Abstract. At the end of 2013, HST has started its most recent flagship program : the "Frontier Fields", aiming to observe 6 galaxies clusters. These images will reach a depth comparable to the HUDF but in a cluster field. The first release of Abell 2744, the first Frontier Fields target, has been made public on December 17 2013. We have used this dataset combined with Spitzer images to search for Lyman Break galaxy (LBG) at z >6.5 in the 4.9 arcmin^2 field of view, bright enough to be observed by current spectrographs. The brightest high-z object is found at z∼8 with a modest amplification factor (μ∼1.5). Its SED shows an optical break between ACS and WFC3 data and another one between the two first channels of IRAC/Spitzer. This "break" at 4.5 microns can be explained by strong [OIII] and Hβ lines at z ∼8. Its properties deduced by SED-fitting are the following : SFR of 8-60 $M_{\odot}$/yr, stellar mass of (2.5-10)$\times 10^9 M_{\odot}$ and a size of r =0.35±0.15 kpc. Its brightness makes it one of the brightest z∼8 objects to date, and it could be observed by current NIR-spectrographs installed on 8-10m class telescopes in a reasonable amount of time.

Keywords: Galaxies: distances and redshifts, Galaxies: evolution, Galaxies: formation, Galaxies: high-redshift, Galaxies: photometry, Galaxies: star formation

1 Introduction

Observations probing the edges of the Universe is one of the most intriguing challenges of the coming decade, particularly with respect to detecting the first population III stars (e.g. O'Shea & Norman 2007) and the first galaxies at z>12 (Bromm & Yoshida 2011). Several telescopes and instruments are under development and have put these topics in their key objectives. Ten years ago, only a dozen objects at z> 6 had been discovered (Kneib et al. 2004), with none above z>7.5. Nowadays, the number of z∼6, z∼7, and $z\geq$8 galaxies selected in deep surveys count in the 1000s (e.g. Le Fevre et al. 2014), several 100s (e.g. Bouwens et al. 2011) and ∼300 (e.g. Labbé et al. 2013), respectively. Thanks to these huge numbers of objects, the evolution and properties of galaxies is relatively well-constrained up to z∼6, with many secure spectroscopic confirmations (Jiang et al. 2013). Beyond z ∼6, however, spectroscopic follow-up remains extremely challenging due to the decreasing mean brightness of these objects (Finkelstein et al. 2013) and the fact that several $z\geq$8 candidates have been finally identified as mid-z interlopers (e.g. Hayes et al. 2012). Several theoretical studies have demonstrated the interest of combining lensing fields and large deep blank fields to search for high-z galaxies over a large range of luminosities (Maizy et al. 2010). This has been confirmed by most of the current surveys, such as the *Hubble Ultra Deep Field* (Beckwith et al. 2006) and *CLASH* (Postman et al. 2012) carried out with HST.

[1] Instituto de Astrofísica, Facultad de Física, Pontificia Universidad Catlica de Chile, 306, Santiago 22, Chile
[2] Space Science Institute, 4750 Walnut Street, Suite 205, Boulder, Colorado 80301
[3] IRAP, CNRS - 14 Avenue Edouard Belin - F-31400 Toulouse, France
[4] Departemento de Astrofisica, Universidad de La Laguna (ULL), E-38205 La Laguna, Tenerife, Spain
[5] Observatoire de Genéve - 51 Chemin des Maillettes - CH-1290 Sauverny - Switzerland
[6] Instituto de Astrofísica de Canarias (IAC), E-38200 La Laguna, Tenerife, Spain

Cluster Name	RA [J2000]	DEC [J2000]	z	Observations
Abell 2744	00:14:21.2	-30:23:50.1	0.308	Oct. 2013 - Jul. 2014
MACS0416.1-2403	04:16:08.9	-24:04:28.7	0.396	Jan. 2014 - Sep. 2014
MACS0717.5+3745	07:17:34.0	+37:44:49.0	0.545	Aug. 2014 - Apr. 2015
MACS1149.5+3745	11:49:36.3	+22:23:58.1	0.543	Nov. 2014 - Jun. 2015
Abell S1063	22:48:44.4	-41:31:48.5	0.348	2016 *(to be approved)*
Abell 370	02:39:52.9	-01:34:36.5	0.375	2016*(to be approved)*

Table 1. *HST* Frontier Fields observation schedule

2 The HST Frontier Fields

The new flagship program of HST, the Frontier Fields (hereafter, HFFs) started at the end of 2013, leveraging deep ACS and WFC3 observations combined with gravitational lensing to observe six massive galaxy clusters along with six deep blank fields (see Table 1). Thanks to the huge depth of *HST* images, ultra faint galaxies at very high-z (m_{F160W} ~31-32 AB) will be detected in HFF data (Richard et al. 2014). Several studies have already demonstrated that the number of $z \geq 8$ objects expected in the full Frontier Fields survey is ≥ 130 (Coe et al. 2014). Six teams have provided lensing models for each cluster (Bradač et al. 2009, Richard et al. 2014, Merten et al. 2011, Zitrin et al. 2013, Johnson et al. 2014 and Mohammed et al. 2014), and derived amplification maps at several redshift.

We combined the first full HFF dataset behind Abell 2744 (140 orbits in total - ID : 13386, 13495 - PI : S. Rodney, J. Lotz) with *Spitzer* Frontier Fields observations (50h on source - PI : T. Soifer and P. Capak) and HAWKI/VLT K_s image (27h - ID : 092.A-0472 - PI : G. Brammer) to search for bright $z \geq 7.5$ objects. The properties of data we used in this study are presented on table 2.

3 Lyman Break Galaxies behind Abell 2744

We applied the Lyman Break Galaxy technique (Steidel et al. 1999) combining non-detections in F435W, F606W, F814W and detections in F125W, F140W, as well as color criteria on Abell 2744 images. After visual inspection, 2 sources, well detected in F125W, F140W and F160W, appear as excellent z ~8 candidates with $m_{H_{160}}$=26.2±0.1 AB. Moreover these two galaxies are located in a clean region of the data making the photometry free of contamination by neighboring objects. These objects have been selected independently and confirmed in several recent studies (Atek et al. 2014, Coe et al. 2014 and Zheng et al. 2014). In the following we will focus on Abell2744_Y1, which is not detected at 3.6μm, but is clearly detected at 4.5μm (Figure 1), suggesting contribution of strong [OIII]+Hβ at $z \geq 7.5$ (Labbé et al. 2013, Smit et al. 2014, Finkelstein et al. 2013).

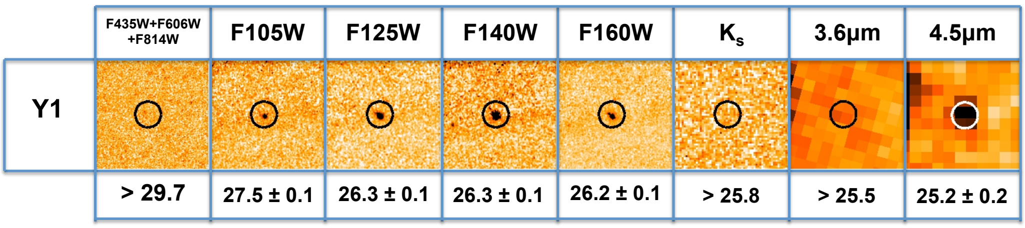

Fig. 1. Thumbnail images of the brightest z~8 candidate selected behind Abell 2744. The size of each stamp is 4"×4" and the position of Abell2744_Y1 is displayed by a black 0.4" radius circle (white circle at 4.5μm for clarity purpose)

4 Properties of the brightest z~8 candidate

We computed the photometric redshift of Abell2744_Y1 using an adapted version of *Hyperz* (Bolzonella et al. 2000) and templates including nebular emissions. The best SED-fit is found at $z \approx 8$, with the 1σ confidence

Filter	$\lambda_{central}$ [μm]	$\Delta\lambda$ [μm]	t_{exp} [ks]	m(5σ) [AB]	Instrument
F435W	0.431	0.073	16.16	28.5	ACS
F606W	0.589	0.156	13.25	28.7	ACS
F814W	0.811	0.166	13.25	28.7	ACS
F105W	1.050	0.300	46.52	29.1	WFC3
F125W	1.250	0.300	16.32	28.7	WFC3
F140W	1.400	0.400	22.43	28.8	WFC3
F160W	1.545	0.290	46.57	28.8	WFC3
K_s	2.146	0.324	97.4	25.5	HAWKI
3.6	3.550	0.750	90.9	25.5	IRAC
4.5	4.493	1.015	90.9	25.0	IRAC

Table 2. Properties of *HST*, *VLT* and *Spitzer* data on Abell 2744. - ACS limiting magnitudes are deeper than those published in Laporte et al. (2014) because in that proceeding we use the full dataset.

interval spanning z~7.5 - 8.5, and no low-z solution in the redshift probability distribution. The best solution is always found at high-z no matter which library templates we used or what the Spitzer non-detection limits we assumed at 3.6μm (2 or 3σ). If we force a low-z solution by limiting the redshift range to 0-3, a value of z~2 is found (although with poor χ^2). For instance, the Spitzer detections are incompatible with this solution (Laporte et al. 2014). We estimated an amplification factor of $\mu\approx$1.5 using the public lensing model provided by the CATS group (Richard et al. 2014). This factor is consistent with those found using other public lensing models produced by Merten (μ=1.50), Sharon (μ=1.91), Williams (μ=1.16) and Zitrin (μ=1.33-2.11), suggesting a moderate amplification regime.

The Star Formation Rate (SFR) estimated from the best SED-fit ranges from 8 to 60 $M_\odot$/yr depending on the adopted metallicity and minimum age imposed, its stellar mass $M_\star\sim(2.5\text{-}10)\times10^9$ $M_\odot$ and the specific SFR deduced is sSFR~1Gyr^{-1}. We derived its size following two methods: SExtractor half light radius (Bertin & Arnouts 1996) corrected for PSF broadening and GALFIT modeling (Peng et al. 2002) assuming a Sersic profile. The results are similar suggesting $r\sim0.3\pm0.1$ kpc after correction for magnification, that is consistent with values published in recent studies (e.g. Ono et al. 2013)

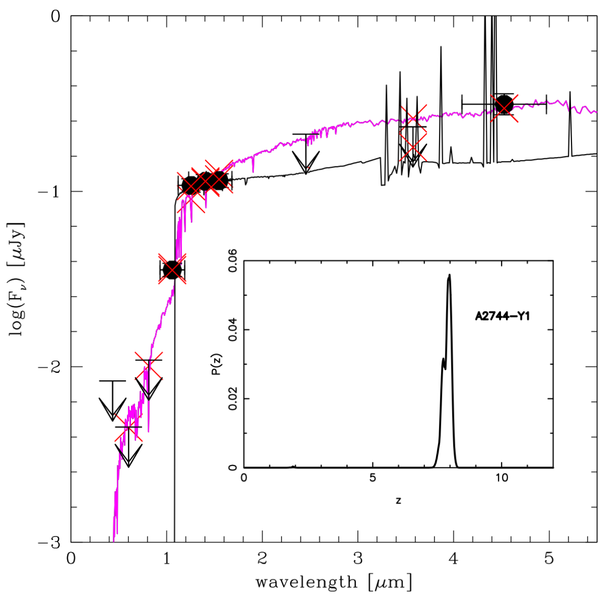

Fig. 2. Best SED-fit of the brightest z~8 candidate selected in the first HFF dataset. The black line displays the best fit without any constraints on the redshift, the magenta line shows the best fit assuming a low-z solution ($z\leq3$). Upper limits are plotted at 1σ, 5σ and 3σ for ACS, HAWKI and IRAC data respectively. The P(z) is over-plotted.

5 Discussion and Conclusions

The SED of Abell2744_Y1 is comparable to the recent $z \sim 7.5$ LBG confirmed by spectroscopy (Finkelstein et al. 2013) regarding its spectral break between optical and NIR data (F125W-F606W > 2mag) and the detection at 4.5μm in conjunction with a non-detection at 3.6μm with similar depth. Furthermore the H_{160}-[3.6] <0.5 and J_{125} - H_{160} are in good agreement with the trend observed by (Labbé et al. 2013) (cf. figure 2 of that paper) for $z \sim 8$ objects. The colors of these 2 objects fulfill the color criteria defined by Oesch et al. (2012) and Lorenzoni et al. (2011) and their *intrinsic* SEDs are similar to the $z \sim 8$ candidates selected in the CANDELS survey (Grogin et al. 2011).

The brightness of this $z \sim 8$ object makes it observable by most of the current spectrographs installed on 8-10m class telescopes. Spectroscopic follow-up with MMIRS/Magellan (McLeod et al. 2012) is on-going and should reveal the nature and properties of this object at short term.

We acknowledge support from CONICYT-Chile grants Basal-CATA PFB-06/2007 (NL, FEB, SK), Gemini-CONICYT #32120003 (NL), "EMBIGGEN" Anillo ACT1101 (FEB), FONDECYT 1141218 (FEB), and Project IC120009 "Millennium Institute of Astrophysics (MAS)" of the Iniciativa Científica Milenio del Ministerio de Economía, Fomento y Turismo (FEB), the Spanish Ministry of Economy and Competitiveness (MINECO) under the 2011 Severo Ochoa Program MINECO SEV-2011-0187 (AS), the French Agence Nationale de la Recherche bearing the reference ANR-09-BLAN-0234 (RP).

References

Atek, H., Richard, J., Kneib, J.-P., et al. 2014, ApJ, 786, 60
Beckwith, S. V. W., Stiavelli, M., Koekemoer, A. M., et al. 2006, AJ, 132, 1729
Bertin, E. & Arnouts, S. 1996, A&AS, 117, 393
Bolzonella, M., Miralles, J.-M., & Pelló, R. 2000, A&A, 363, 476
Bouwens, R. J., Illingworth, G. D., Oesch, P. A., et al. 2011, ApJ, 737, 90
Bradač, M., Treu, T., Applegate, D., et al. 2009, ApJ, 706, 1201
Bromm, V. & Yoshida, N. 2011, ARA&A, 49, 373
Coe, D., Bradley, L., & Zitrin, A. 2014, ArXiv e-prints
Finkelstein, S. L., Papovich, C., Dickinson, M., et al. 2013, Nature, 502, 524
Grogin, N. A., Kocevski, D. D., Faber, S. M., et al. 2011, ApJS, 197, 35
Hayes, M., Laporte, N., Pelló, R., Schaerer, D., & Le Borgne, J.-F. 2012, MNRAS, 425, L19
Jiang, L., Egami, E., Mechtley, M., et al. 2013, ApJ, 772, 99
Johnson, T. L., Sharon, K., Bayliss, M. B., et al. 2014, ArXiv e-prints
Kneib, J.-P., Ellis, R. S., Santos, M. R., & Richard, J. 2004, ApJ, 607, 697
Labbé, I., Oesch, P. A., Bouwens, R. J., et al. 2013, ApJ, 777, L19
Laporte, N., Streblyanska, A., Clement, B., et al. 2014, A&A, 562, L8
Le Fevre, O., Tasca, L. A. M., Cassata, P., et al. 2014, ArXiv e-prints
Lorenzoni, S., Bunker, A. J., Wilkins, S. M., et al. 2011, MNRAS, 414, 1455
Maizy, A., Richard, J., de Leo, M. A., Pelló, R., & Kneib, J. P. 2010, A&A, 509, A105
McLeod, B., Fabricant, D., Nystrom, G., et al. 2012, PASP, 124, 1318
Merten, J., Coe, D., Dupke, R., et al. 2011, MNRAS, 417, 333
Mohammed, I., Liesenborgs, J., Saha, P., & Williams, L. L. R. 2014, MNRAS, 439, 2651
Oesch, P. A., Bouwens, R. J., Illingworth, G. D., et al. 2012, ApJ, 759, 135
Ono, Y., Ouchi, M., Curtis-Lake, E., et al. 2013, ApJ, 777, 155
O'Shea, B. W. & Norman, M. L. 2007, ApJ, 654, 66
Peng, C. Y., Ho, L. C., Impey, C. D., & Rix, H.-W. 2002, AJ, 124, 266
Postman, M., Coe, D., Benítez, N., et al. 2012, ApJS, 199, 25
Richard, J., Jauzac, M., Limousin, M., et al. 2014, MNRAS, 444, 268
Smit, R., Bouwens, R. J., Labbé, I., et al. 2014, ApJ, 784, 58
Steidel, C. C., Adelberger, K. L., Giavalisco, M., Dickinson, M., & Pettini, M. 1999, ApJ, 519, 1
Zheng, W., Shu, X., Moustakas, J., et al. 2014, ArXiv e-prints
Zitrin, A., Meneghetti, M., Umetsu, K., et al. 2013, ApJ, 762, L30