Belén Alcalde Pampliega, Doctorado en Astrofísica

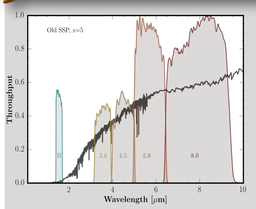
UCM, PhDay Físicas 2017

Extremely Red massive Galaxies in the early Universe: mid-IR bright sources at z>3

1. Abstract

The process of galaxy evolution and mass assembly in the early universe is still controversial and the 3<z<6 epoch is a key period for the build-up of galaxies.
State-of-the-art surveys such as CANDELS or GOODS, with superb depth, spatial and wavelength coverage, have already revealed many galaxies at those redshift.
The bulk of those distant sources, however, are LBGs, i.e., they have been selected by means of the Lyman break techniques. Therefore, our sample of galaxies at z=3-6 are biased towards blue objects. However, some galaxies, and specially massive ones, can be quite red and faint at rest-frame UV wavelengths, thus being elusive to those LBG selection.
In this work, we combine the deepest CANDELS and IRAC surveys on the sky (those in the two GOODS fields), to undertake a thorough search and detailed analysis of IRAC-detected galaxies with no CANDELS counterpart, i.e., H>27-28, [3.6]~23-24. These sources are identified with red galaxies at z>3 with abrupt Balmer/D4000 breaks.

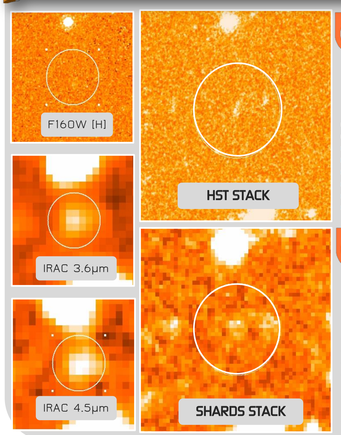
2. H-band dropouts



In the past years, large samples of high redshift galaxies have been gathered, most of them, using various color-criteria techniques , which utilize strong spectra breaks prevalent in massive galaxies, such as the Lyman break dropout technique (Madau et al. 1996, or emission line galaxies (mainly LAEs). They select UV bright sources and may be biased against of extremely red optically faint galaxies as illustrated in Huang et al. (2011) and Caputi et al. (2012) and Wang et al. (2016)

Our **H-band dropouts sample**, has been built searching for extremely red objects that are bright in the 3.6 and 4.5μm IRAC bands yet undetected in deep WFC3/HST H-band over ~100 arcsec² of the GOODS fields.

Counterparts & Stacking

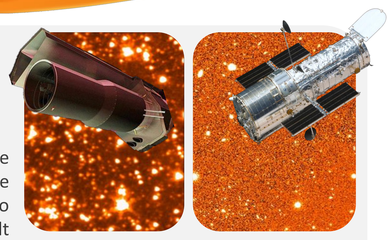


70% To increase the limiting depth, we stacked the 24 medium-band SHARDS images and we also combined data obtained with CANDELS/HST (WFC3 F105W, F125W & F160W: and ACS F435W, F606W, F775W and F814).

65% 23/34 (70%) sources are clearly detected in the HST Stack and 11/17 (65%) are also detected in the SHARDS stack. Only 4 of our sources are exclusively detected in IRAC Channels.

3. Selection

Our **H-band dropouts sample**, have been built searching bright sources in the *Spitzer* 3.6 and 4.5μm IRAC images that are not detected in the *HST* H-band in GOODS fields.



TFIT The mIR images have very different and lower angular resolution (~2") than that obtained with the HST WFC3 H band (~0.2").
A software package called TFIT (Laidder et al. 2007) is specially design to perform photometry given a high resolution and a low resolution image by using the spatial positions and morphologies of objects in the high resolution image to construct object templates, which are then fitted to the lower resolution image.

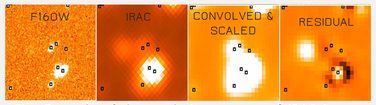
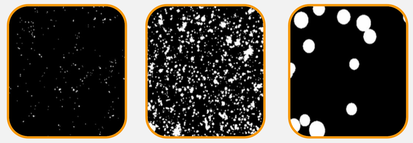


Fig. *Example of deconvolution process of IRAC images from HST reference image.*

MASKS First, we create a mask for pixels above a threshold flux, then another mask around the brightest (m<20) stars in the field with a circular radio function of its magnitude and finally we mask fault pixels that appeared in the image during the convolution process.

All these masks are applied to the residual image and replaced by the median background with a gaussian noise.



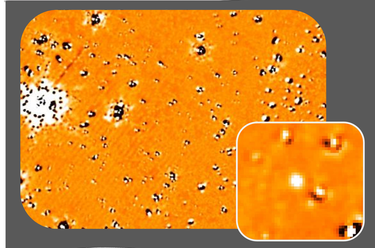
Masks applied to the residual IRAC images. From left to right: pixel faults, bright H-band sources cores, and stars with m<20.

WINGS Although most of the flux was deleted after masking the images, there was some flux leftover in the wings and avoiding false detections was required. For that purpose, we applied a mathematical morphology method around H-bright sources. We have iteratively generated one-pixel-width outlines, subtracted the median flux in each contour and added the median background value in the surrounding.

Deconvolution & flux scale → Residual image

Mask bright sources → masked image

Avoid wings → Final image



34 bona fide H-Band DROPouts

Visual inspection

To avoid spurious sources, we **cross-correlate** the catalogues and discard sources not detected in both .

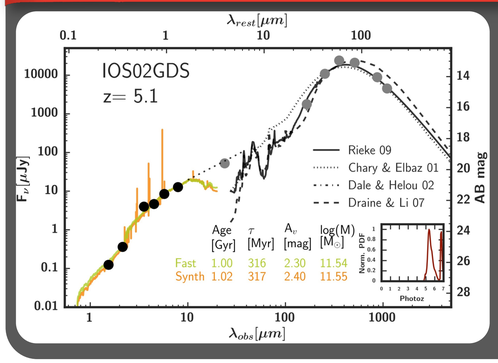
Finally, we **visually inspect** the final images to remove any false source from our sample.

Cross -correlation

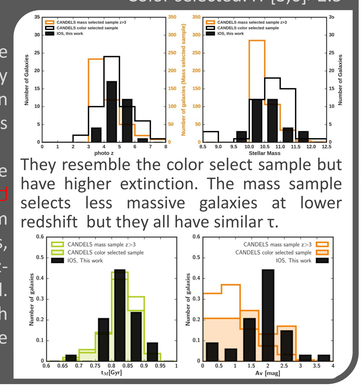
As we have followed the same procedure separately in 3.6 and 4.5μm we obtained **two catalogues using SEXTRACTOR** in the two final images.

4. SED fitting & stellar properties

We built 2 comparison samples:
Mass selected @ z>3
Color selected: H-[3,6]>2.5



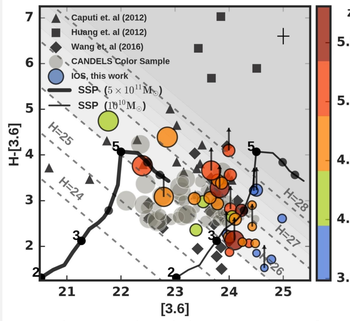
To estimate photometric redshifts, we fitted the observed UV-to-NIR photometry of each galaxy to templates based on stellar population synthesis (SPS) models using two codes.
Once we fixed the photoz, we characterized the optical-to-NIR and MID/FIR-to-submm SEDs by fitting them to SPS and dust emission models, respectively with synthesizer (Pérez-González et al. 2008) and fast (Kriek et al. 2009) software. The combination of both fits provided us with estimates of the stellar masses, SFRs & stellar properties.

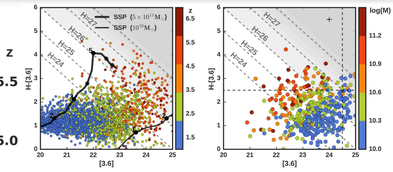


They resemble the color select sample but have higher extinction. The mass sample selects less massive galaxies at lower redshift but they all have similar τ.

5. What are those sources?

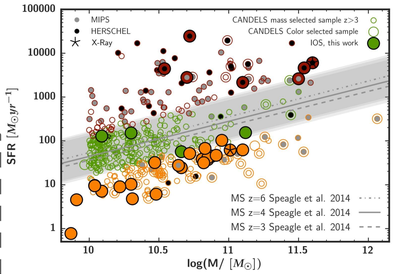
Red, massive ...

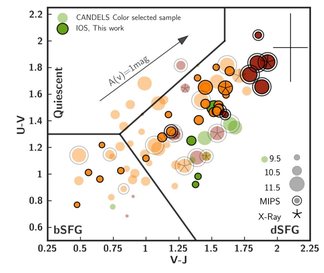




Color diagnostic diagrams are very useful to understand and compare our sources . Left panel shows the position of the CANDELS color sample and already detected red z>3 H-undetected samples from the literature. **Our galaxies are color coded by redshift and sized by mass.**

We have analyzed the properties of our sources divided in 3 subsamples as funcion of their position in the SFR vs Mass Plane: Starbust, Main sequence and sub-main sequence galaxies.

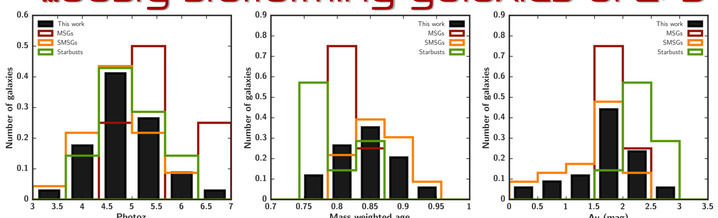




~25% of our sources are mid/far IR emitters detected at λ>24μm. All but one correspond to starbust galaxies.

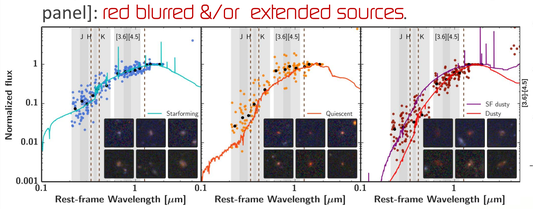
~85% dusty starforming galaxies [dSFG]
~15% blue starforming galaxies [bSFG]
No Quiescent galaxies found

...dusty starforming galaxies at z>3

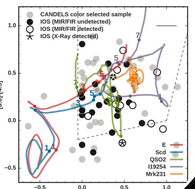


Morphology?

They are expected to be similar to CANDELS dSFGs [right panel]: red blurred &/or extended sources.



AGNs?



Acknowledgements

Funded by Spanish MINECO grant AYA2012-31277

SHARDS

Rainbow Database