Lyman Break Galaxies in ALHAMBRA, J-PLUS, and J-PAS Surveys

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Abstract

We are carrying out a systematic search for Lyman Break Galaxies (LBGs) in the ALHAMBRA Survey data. With the ALHAMBRA filter set, we can detect the Lyman forest, permitting a LBG identification, for galaxies at redshifts z ≥ 2 and up to z~5 for the brightest objects. Our LBG candidate selection bases on spectral fitting of template spectra on the very low resolution spectra derived from the 20 intermediate optical band and three infrared broad band ALHAMBRA filters.

The spatial coverage of ALHAMBRA survey (4 deg^2) is bigger than in any of the previous LBG surveys. The surface density of LBGs decreases with brightness so that we especially expect to contribute on better sampling of the bright end of the LBG luminosity function.

Once the shallower, but much more extended (8000 deg^2) JPLUS and JPAS survey data are available, we will adopt our LBG search method to these surveys. Thanks to the huge area covered by these new surveys, we expect to achieve significant information on the bright LBGs at z~2-3 (JPLUS) and z~2-4 (JPAS).

Introduction

A Large Area Multimedium-Band Optical and Near-Infrared Photometric Survey (ALHAMBRA, Moles, M. et al., 2008, AJ, 136, 1325) maps 4 deg^2 of the Northern sky with 20 contiguous, equal width (310 Å FWHM), medium band optical filters from 3500 Å to 9700 Å, plus the three standard broad bands, JHK, in the NIR (see Fig. 1). The photometric system in the optical is optimized to get (for a fixed amount of total observing time) the maximum number of objects with accurate classification and redshift and to be sensitive to relatively faint emission features in the spectrum. The observations were carried out with the Calar Alto 3.5m telescope using two wide field cameras: LAICA in the optical, and OMEGA-2000 in the NIR. The integration time per pointing is 100 ks leading to 5 σ limiting magnitude AB ~ 25 from blue to 8300 Å, AB ~ 24.7-23.4 for the redder optical filters, and J ~ 23.3, H ~ 22.7, K ~ 21.9 in the NIR. The observations were started in August 2004 and are now completed leading to a photometric catalogue of 450 000 objects.

The ultraviolet bright star-forming galaxies at high redshift are called Lyman Break Galaxies (LBGs, for a review, see Giavalisco, M., 2002, ARA&A, 40, 579). Their identification is mainly based on two ultraviolet spectral features: the Lyman break at 912 Å and the Lyman forest between 912 Å and 1216 Å, and can thus be detected from the Earth only at redshifts z≳2. In addition to allowing the classification of the objects, these features allow their redshifts to be determined. This, in turn, makes it possible to study the cosmic evolution of these early star-forming galaxies.

Traditionally, LBGs are discovered based on their broad-band colors measuring the drop in brightness due to the Lyman break and/or Lyman forest. Our method to search for LBGs is based on the photo-spectra obtained from the ALHAMBRA data, and χ^2 spectral fitting of model templates, including theoretical and empirical LBG spectra, and spectra of other types of galaxies and stars. Our approach aims at both cleaner and more complete candidate selection as compared to the broad band selection. In addition, our LBG search is unique thanks to the larger covered volume than in any of the previous LBG surveys. This expectedly leads to a greater number of candidates discovered than in the earlier studies, and especially we contribute in sampling the bright-end of the LBG luminosity function as the surface density of LBGs decreases with their increasing brightness.

In the future, we are planning to extend the LBG search to J-PLUS and J-PAS survey data. J-PLUS (Javalambre Photometric Local Universe Survey) and J-PAS (Javalambre-PAU Optical Survey) are photometric surveys of 8000 deg^2. J-PLUS will be carried out in 8 intermediate-narrow band filters, and 4 SDSS filters (g,r,i,z), see Fig. 2, and J-PAS in 54 narrow-band contiguous filters spanning the range ~3700–9200 Å plus 2 broad-band filters at the blue and red end, see Fig. 3. The surveys will be carried out with T80Cam (J-PLUS) and JPCam (J-PAS), panoramic cameras mounted, respectively, on the 80cm telescope recently arrived to the Observatorio Astrofísico de Javalambre (OAJ)*, Teruel, Spain, and the 2.5m OAJ telescope still under construction. Starting in 2013, J-PLUS will be completed in 2 years, allowing to study stellar spectral types and luminosity classes and stellar populations in nearby galaxies up to limiting magnitude M(AB)~22. J-PAS will be completed in 4-5 years, starting in 2014, allowing to determine redshifts and SEDs for ~200 hundred million galaxies up to the limiting magnitude M(AB)~22.5 – 23.5.

The candidate selection

To select LBGs from the ALHAMBRA catalog, the steps below are followed. In the future it will be adopted to J-PLUS and J-PAS data sets.

- Remove spurious detections (in the borders, overlapping/saturated objects, etc.).
- As a first step, require detection at least in 5 filters around the presumed Lyα break, i.e. sampling both the Lyman forest and the UV continuum redwards the break. If detection in the Lyman forest is not required (next step), fainter/more distant objects can be discovered but the candidate reliability decreases.
- Separate point-like and extended objects using the ALHAMBRA photometric stellarity parameter.
- Create a spectral library consisting of template spectra of LBGs, other types of galaxies and stars.
- Carry out χ^2-fitting and find the best fits, fitting stellar spectra only for point-like objects.
- For objects fitting well a LBG spectrum check the other possible solutions and the absolute UV magnitude to check the reliability of the LBG candidates.

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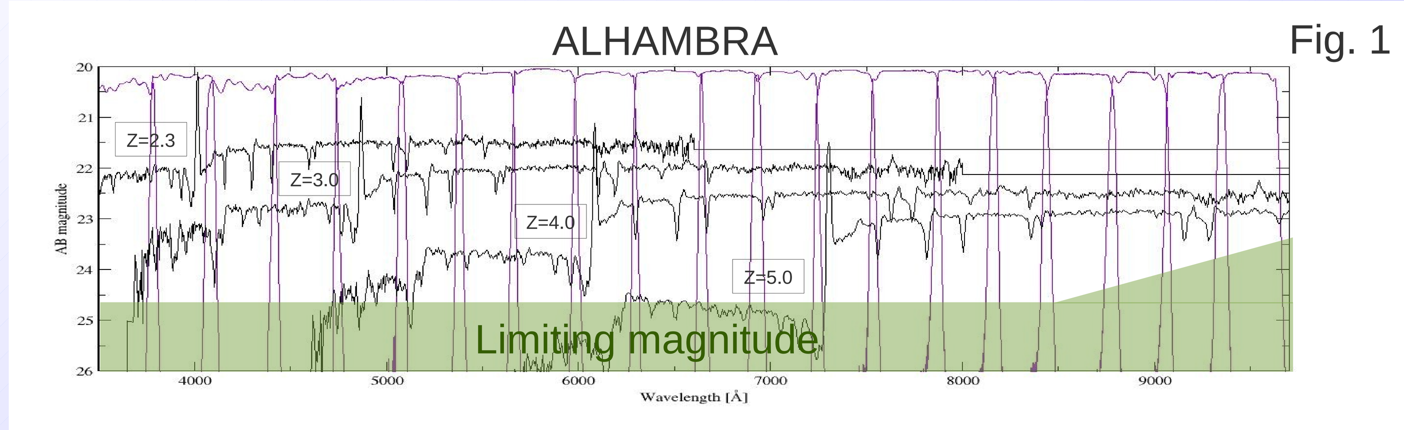
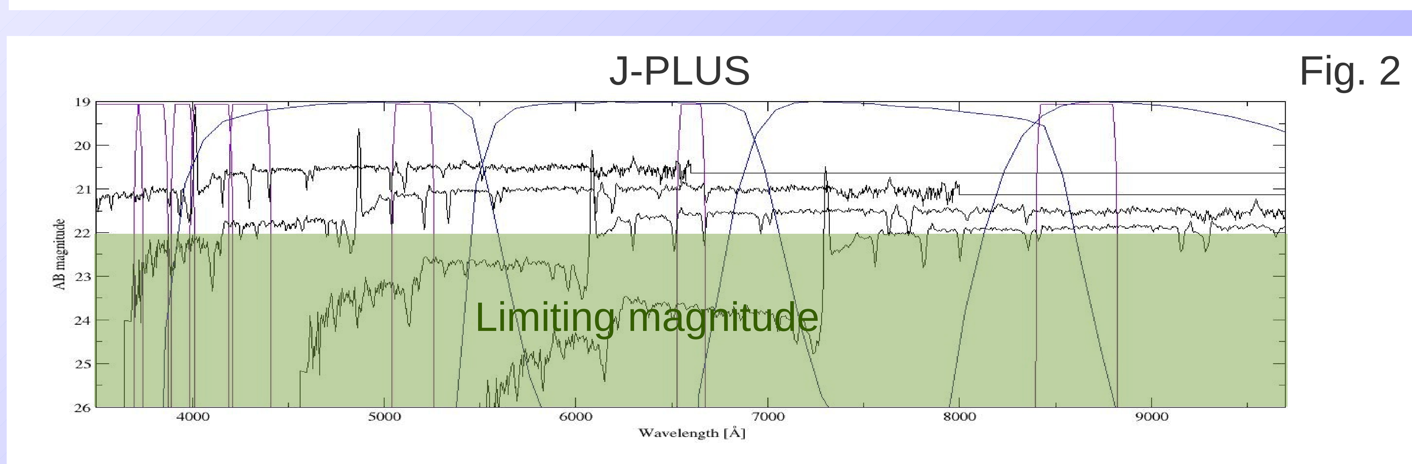
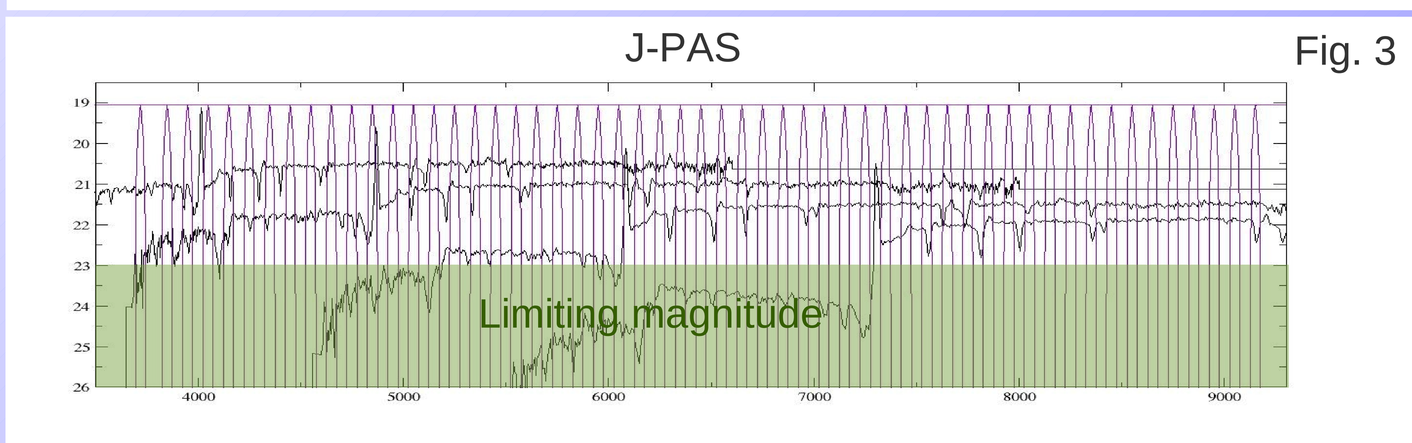
A LBG spectrum and ALHAMBRA, J-PLUS, and J-PAS filters

An average spectrum of 811 LBGs at z~3 (Shapley et al. 2003) as seen at different redshifts (redshift dependence of the Lyman forest considered according to Madau 1995). Overplotted are the ALHAMBRA (Fig. 1), J-PLUS (Fig. 2) and J-PAS (Fig. 3) filter transmission curves:

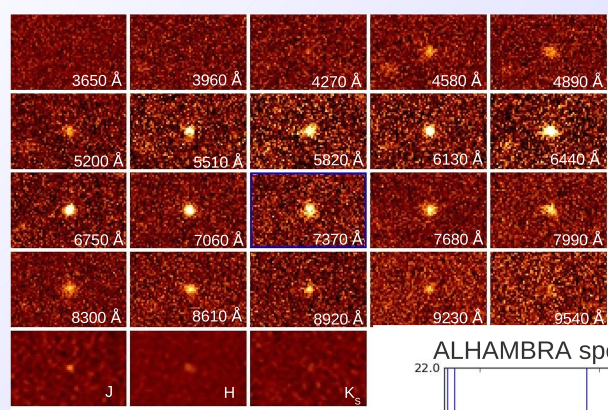






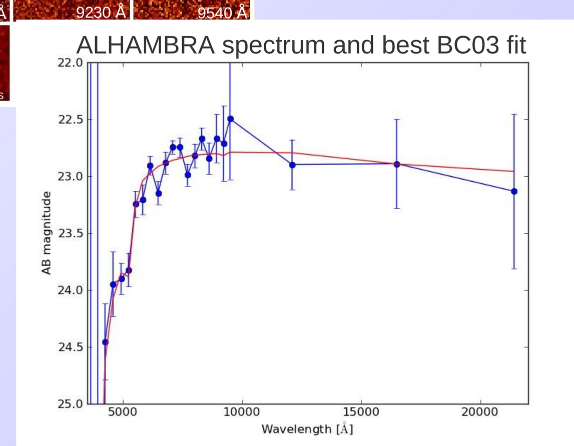
Examples: a LBG and an elliptical galaxy candidate

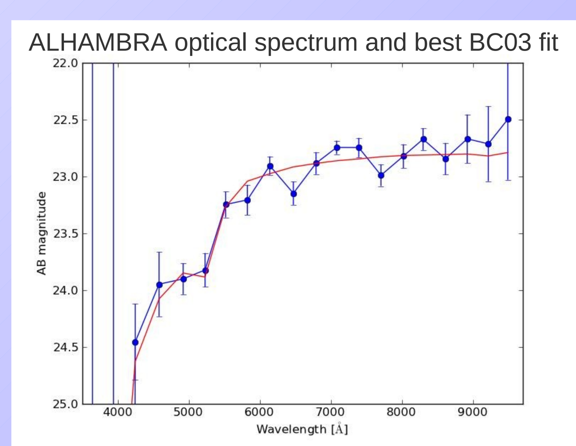
ALHAMBRA images:



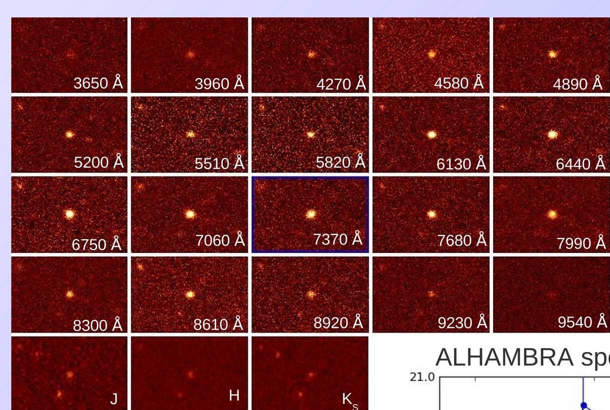
LBG candidate at z=3.45

Best fitting BC03 (Bruzual & Charlot 2003, MNRAS, 344, 1000) model: [Fe/H]=-2.249, age= 1Myr, E(B-V)=0.3, z=3.45



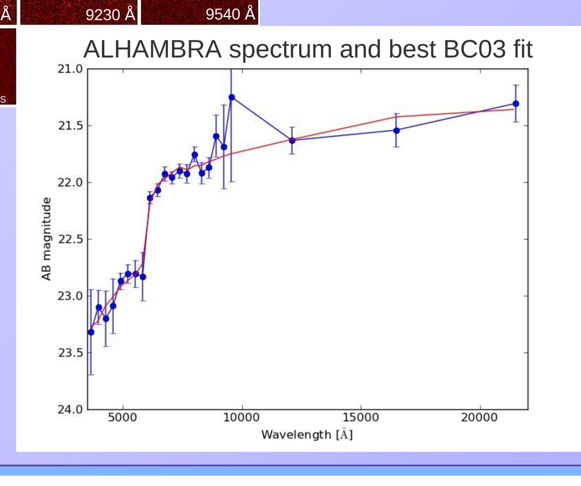


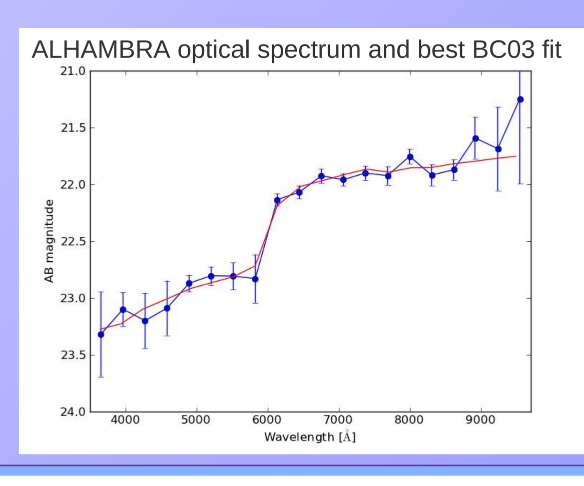
ALHAMBRA images:



Elliptical galaxy candidate at z=0.59

Best fitting BC03 model: [Fe/H]=-0.33, age= 63Myr, E(B-V)=0.2, z=0.59





Future prospects

Our new LBGs (ALHAMBRA, J-PLUS, J-PAS) will improve the sampling of the bright end of the LBG luminosity function at the redshift interval z~ 2-5. From the luminosity functions the UV luminosity density at different redshifts can be derived. This quantity can be then converted into star formation rate (SFR) density (Kennicutt 1998, ARA&A, 36, 189). The earlier studies of LBGs at the redshift range z=3-6 (see Ly et al. 2009, ApJ, 697,1410, and references therein) indicate that the SFR density was 10 or more times higher in the past than at z=0. We aim at testing this result based on our new LBG sample. The advantage of our study as compared to the earlier ones is the homogenuity; the data at all redshifts and along the whole spatial extent are observed by the same surveys, avoiding any possible biases which could be related to observational issues.

Finally, we aim to study the clustering of the selected LBG candidates at different redshifts and its dependence on the galaxy UV colours. LBGs have been found to have a relatively strong spatial clustering, comparable to that of present-day bright spiral galaxies (Giavalisco et al. 1998, ApJ, 503, 543; Porciani et al. 2002, ApJ, 565, 24; Adelberger et al. 2005, ApJ, 619, 697). In addition, the strength of the spatial clustering of LBGs is found to be a function of their UV luminosity, with brighter galaxies having larger correlation length (see, e.g., Allen et al. 2005, MNRAS, 360, 1244). Measuring clustering strength requires a large galaxy sample from a wide sky coverage. Our new samples of LBGs fulfills these criteria better than any of the earlier samples used for LBG clustering studies.