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Star-forming clumps in Lyman break analogs

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Abstract. In this work we analize a sample of near galaxies (z ∼ 0.2) with behavior analogous to the distant galaxies. The study of clumps in this galaxies, provides information on structures, radial velocity mapping and deviations from the star formation law for main-sequence star-forming galaxies. In addition, we investigate the physical processes that regulate star formation in this galaxies these galaxies and extrapolate the results to nearby and distant starbursts galaxies. We describe the clump identification process, the parameters that characterize them and present some results, such as: clumps are dominated by the velocity dispersion, presenting a small velocity shear; the star formation rate within clumps is more efficient than the surrounding interstellar medium by a factor of 2, and approximately 50% of the clump virial mass is composed of molecular gas.

Resumo. Neste trabalho analisamos uma amostra de galáxias próximas (z ∼ 0,2) com comportamento análogo a galáxias no Universo distante. O estudo dos nódulos (*clumps*) dessas galáxias fornece informações sobre estruturas, mapeamento de velocidade radial e desvios da lei de formação estelar para galáxias da sequência principal. Além disso, buscamos compreender os processos físicos que regulam a formação de estrelas nessas galáxias e na tentativa de extrapolar os resultados para as galáxias *Starbursts*, próximas e distantes. Neste trabalho descrevemos o processo de identificação dos *clumps*, os parâmetros que os caracterizam e apresentamos alguns resultados, tais como: os aglomerados são dominados pela dispersão de velocidade, apresentando um pequeno gradiente de velocidades; a taxa de formação estelar dentro dos *clumps* é mais eficiente do que o meio interestelar ao redor por um fator 2 e estimamos que aproximadamente 50% da massa virial é composta de gás molecular.

Keywords. galaxies: formation — galaxies: ISM — galaxies: starburst

1. Motivation

We know today that there is a significant increase in the density of star formation at large redshifts (z ∼ 2) relative to that observed in the local universe (Madau & Dickson 2014). However, due to the low spatial resolution obtained with the observations, the intrinsic properties of the distant objects are still not fully understood. This galaxies show irregular morphologies (Law et al. 2007) and clump structures (Bournaud et al. 2015). Usually, in the Local Universe, this clumps are observed in irregular dwarf galaxies, however, at high redshift, they are commonly found in disk galaxies. The most plausible alternative for the study of distant main sequence galaxies are the so-called Lyman-break analogs (LBAs). These objects, with the median redshift of z ∼ 0.2 were initially selected by ultraviolet luminosity ($L_{FUV} > 10^{10.3} L_\odot$) and surface brightness ($L_{UFV} > 10^9 L_\odot kpc^{-2}$) using the Galaxy Evolution Explorer (GALEX). They present characteristics very similar to the high redshift star-forming, such as their masses, SFR, metallicity, (Heckman et al. 2005, Hoopes et al. 2007), morphology (Overzier et al. 2009, 2010), kinematics (Gonçalves et al. 2010) and molecular gas reservoirs (Gonçalves et al. 2014). In addition, observations in the ultraviolet and optical also show typical characteristics of high resdhift star-forming galaxies, such as massive star formation clumps, evidences for outflows, mergers and interactions . There for, LBAs are the best laboratories to study the physical processes associated with star formation in the early universe, with the advantage of higher spatial resolution and signal-to-noise ratios. The standard cosmological model, with $H_0 = 70 kms^{-1}Mpc^{-1}, \Omega_m = 0.30$ and $\Omega_\Delta = 0.70$, was adopted for all analyses and calculations in this work.

2. Sample

Our sample consists of 17 LBA observed with the OSIRIS integral field unit, attached to the Keck II telescope (Larkin 2006), using adaptive optics, resulting in an angular resolution of approximately 50 mas, corresponding to structures with physical dimension of 200 pc for these distances. The spectral resolution is R ∼ 3800. The observations were centered on the Paschen-α (Paα) emission line (rest wavelength 1875.1 nm). A more detailed description of the observations, as well as the discussion of the properties of objects in our sample, can be found in Hoopes et al.(2007), Overzier et al.(2009, 2010) and Gonçalves et al.(2010, 2014).

3. Clump properties

In this work, we apply the FellWalker method of the CUPID package found in Starlink's astronomical analysis and processing software (Currie 2013) to select the clumps in each Pa-α image. We also obtain the velocity dispersion (σ) distribution and compare the velocity shear (v_c) and dispersion between host galaxies and clumps. In our sample the typical value for our clumps is ∼ 70 km s^{-1} (Figure 1).

Using the velocity dispersion and clump dimensions, and assuming clumps are virialized, we infer virial masses for each one.

We obtain a relation between the star formation rate and the gas mass for the host galaxies and the clumps, to estimate the depletion time of these objects.

The relation for clumps is given by:

$$\log \frac{SFR}{[M_\odot \mathrm{yr}^{-1}]} = 1.16 \log \frac{M_{\mathrm{gas}}}{[M_\odot]} - 8.96 \quad (1)$$

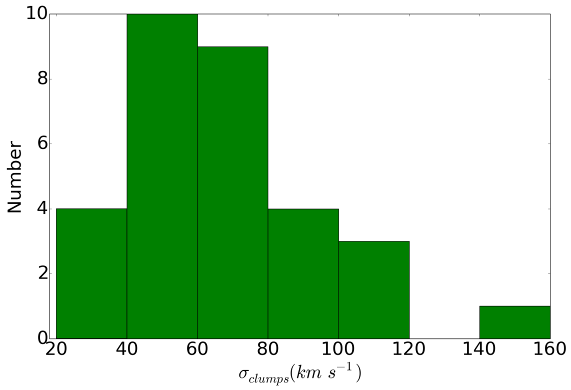

Figure 1. Distribution of the velocity dispersion of the 31 clumps. The typical value for our clumps is ~ 70 km s^{-1}

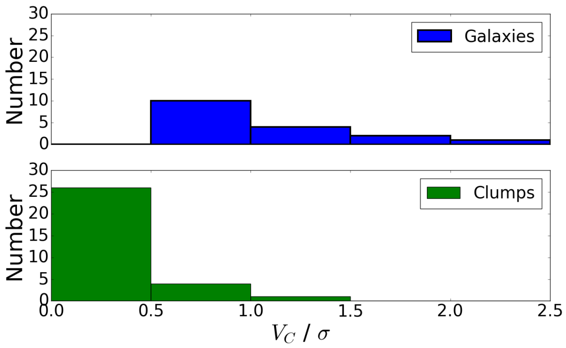

Figure 2. Distribution of v_c/σ for host galaxies and clumps. The clumps are dispersion dominated, showing little velocity shear and a strong random component;

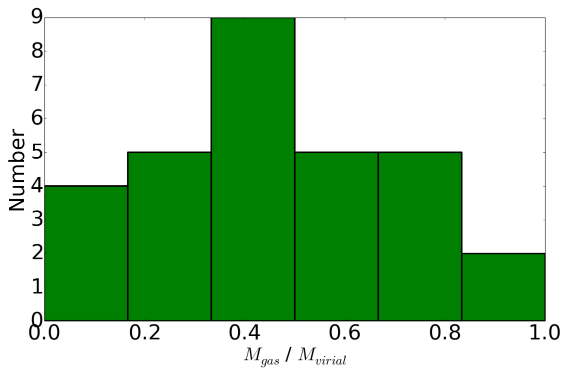

Figure 3. Distribution of the ratio between the circular velocity and the velocity dispersion, for host galaxies and clumps. We estimate that approximately 50 % of the viral mass in clumps is composed by molecular gas. The remaining is probably dominated by stars.

Using a Schmidt-Kennicut equation, Genzel et al. (2010) found a relation for the molecular gas with almost the same angular coefficient value (1.17). Time calculated was 0.3 Gyr for galaxies and 0.23 Gyr for clumps.

4. Results

Star formation within the clumps is more efficient than in the surrounding interstellar medium by a factor of 1.3. The clumps are dominated by velocity dispersion with a little velocity shear. Assuming these clumps are in dynamic equilibrium, we estimated that approximately 50 % of the virial mass in clumps is composed by gas. The remaining is probably dominated by stars. We intend to examine the stellar mass distribution in these galaxies in order to verify this hypothesis.

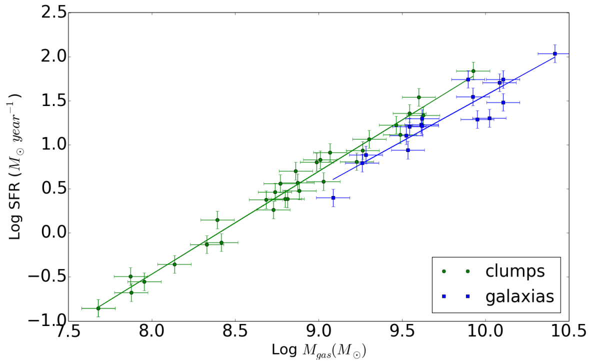

Figure 4. Main sequence of galaxies and clumps. The star formation rate on clumps is higher than the environment around them.

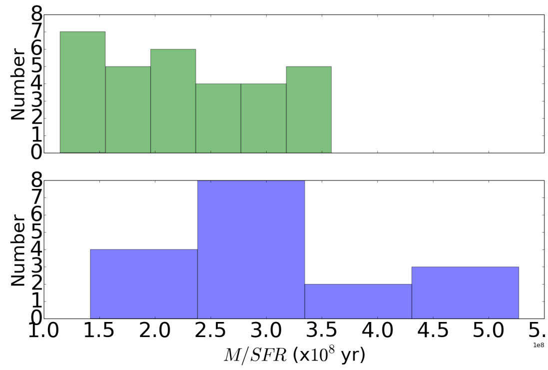

Figure 5. Distribution of depletion time of galaxies (blue) and clumps (green). The star formation rate is more efficient in clumps than the insterstellar medium by a factor of 1.3.

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