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Galaxy Zoo: Star Formation Histories in the COSMOS Survey

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ABSTRACT

Key words: keyword1 – keyword2 – keyword3

1 INTRODUCTION

Becky's group environment paper Smethurst et al. (2017).

2 DATA

2.1 Multi-wavelength data

In this study we used the K_s-selected catalog of the COSMOS/UltraVISTA field from Muzzin et al. (2013). The catalog contains PSF-matched photometry in 30 photometric bands covering the wavelength range $0.15\mu m \rightarrow 24\mu m$ and includes the available *GALEX* (Martin et al. 2005), CFHT/Subaru (Capak et al. 2007), UltraVISTA (McCracken et al. 2012), S-COSMOS (Sanders et al. 2007), and zCOSMOS (Lilly et al. 2009) datasets.

We required the rest-frame U - V and V - J colours which were calculated using the EAZY code (Brammer et al. 2008). EAZY determines rest-frame colors by integrating the best-fit SED through the redshifted filter curves over the appropriate wavelength range.For the U and V filters the Johnson response curves calculated in Maíz Apellániz (2006) were used. The J filter used the 2MASS response curve from Skrutskie et al. (2006).

2.2 Environment data

A continuous environmental deisity estimate (δ) for each galaxy was obtained from Darvish et al. (2015). The method used to estimate environment was weighted Voronoi Tessellation (WVT) which is an iteration on the simple Voronoi Tessellation technique (Ebeling & Wiedenmann 1993; Bernardeau & van de Weygaert 1996). In simple Voroni Tesselation, galaxies are divided into redshift planes to estimate local density. WVT uses a Monte-Carlo acceptance-rejection process to incorporate a weighted contribution from each galaxy in the density estimate. The weight assigned to each galaxy corresponds to the likelihood of it residing in the particular redshift slice being examined. Weighting the contributions aims to reduce the impact of redshift uncertainties on the density estimates.

Darvish et al. (2015) showed that WVT outperforms several other density estimation methods when evaluated against known surface density profiles. Moreover, unlike other density estimators (nearest neighbor methods) WVT makes no underlying assumptions about the geometry and morphology of the structures in the density field. (Hovever it is noted that Veronoi Tessellation can not be used to assign density estimates to galaxies near the edge of the field.) Overall Darvish et al. (2015) concludes that WVT is a robust density estimator.

The WVT algorithm and a comparison between several density estimation methods can be found in Sections 4.3 and 6 of Darvish et al. (2015) respectively. In this study galaxies were binned into low ($\log(1+\delta) \leq -0.25$), intermediate ($-0.25 < \log(1+\delta) < 0.25$), and high ($\log(1+\delta) \geq 0.25$) desnity groups.

2.3 Galaxy Zoo Hubble Morphological classifications

Morphological classifications of galaxies were obtained from the Galaxy Zoo Hubble[1] (GZH) citizen science project (Willett et al. 2017). GZH allowed several independent visual classifications of each galaxy image by volunteers, the question flowchart for each image is shown in Figure 4 of Willett et al. (2017). Volunteers were shown colour-composite images of real and simulated *Hubble Space Telescope* galaxies to correct for classification redshift bais.

Follwing Smethurst et al. (2015) we exploit the continous nature of GZH vote fractions (see Section 3 of Willett et al. (2017)) to investingate the role morphology has in populations of galaxies. This is acheived by weighting each galaxies contribition to the analysis of a population by one

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[1] https://hubble.galaxyzoo.org

of its morphological vote fractions. An example of a galaxy with assoiciated vote franctions of disc (p_d) and smooth (p_s) is shown in the top right of figure [FIG].

The GZH project provides detailed classifications of 119,849 galaxies from publicly-released *Hubble Space Telescope Legacy* programs conducted with the Advanced Camera for Surveys. In this study we used a subset of the total GZH sample corresponding to 84,954 galaxies found in the COSMOS Survey (Scoville et al. 2007; Koekemoer et al. 2007).

3 METHODS

3.1 Modelling Star Formation History

We used the publically available, Markov Chain Monte Carlo based (Foreman-Mackey et al. 2013), STARPY[2] code to infer the star formation history (SFH) of each galaxy in our sample. Inputs of redshift and of rest-frame U - V and V - J colours, combined with the stellar population model of Bruzual & Charlot (2003), a solar metallicity, and a Chabrier IMF Chabrier (2003) produces a SFH for each galaxy. These models do not account for intrinsic dust. An explanation of how STARPY works can be found in Section 3

The SFH model used is parameterised by t_q and τ [Gyrs], where t_q is the onset time of quenching and τ characterises the rate of quenching. Increaing τ represents an exponetially slower quench. Assuming that all galaxies formed at $t = 0$ [Gyrs] with an initial burst of constant SFR (SFR_0), we write the SFH over cosmic time ($0 \le t$ [Gyrs] ≤ 13.8) as:

$$\mathrm{SFR}(t) = \begin{cases} \mathrm{SFR}_0(t_q) & t \le t_q \\ \mathrm{SFR}_0(t_q)\exp\left[-\frac{(t-t_q)}{\tau}\right] & t > t_q \end{cases} \tag{1}$$

$$P(\theta_k) = \begin{cases} 1 & 0 \le t_q \text{ [Gyr] } \le 13.8 \text{ and } 0 \le \tau \text{ [Gyr] } \le 4 \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

4 CONCLUSIONS

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[2] http://github.com/zooniverse/starpy/