A Bayesian's perspective of quenching via bulge evolution

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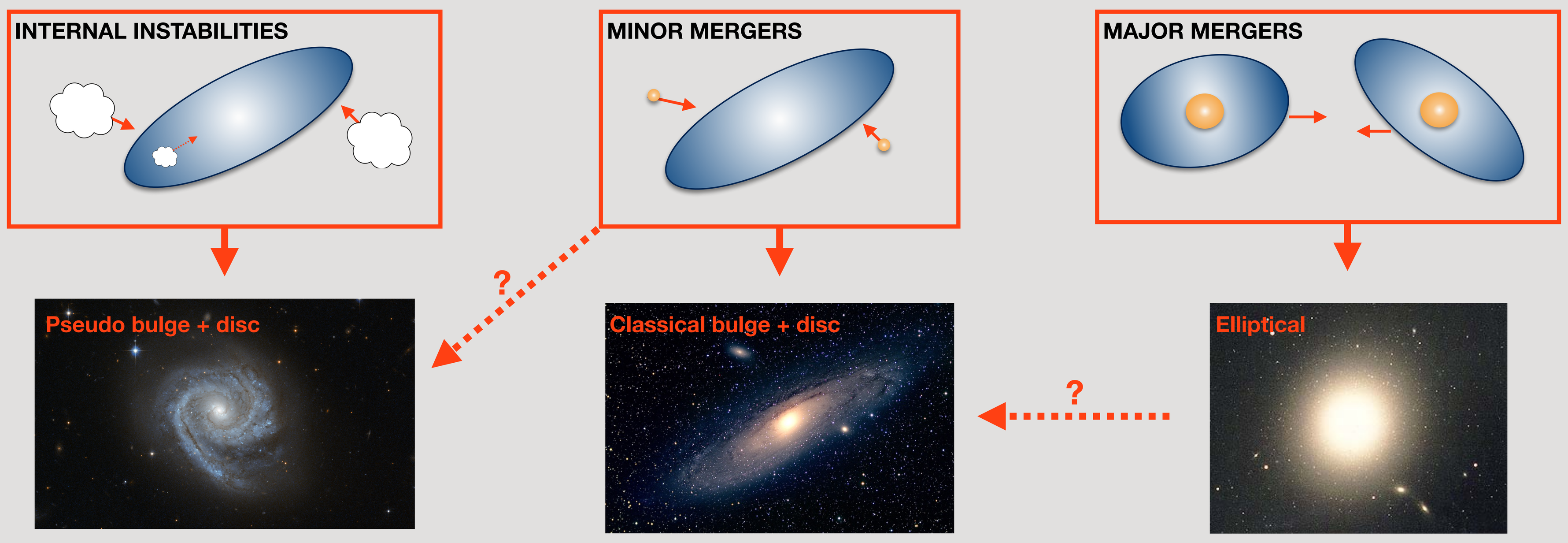
1. INTRODUCTION

The morphological transformation of spirals into elliptical galaxies has been widely acknowledged to be accompanied by a quenching of their star formation which is fundamentally driven by its morphology (see Martig et. al. 2009). We investigate the relation between the structure of galaxy bulges and the stellar populations of their hosts for a mass-selected sample of 970 galaxies above 10^{10} M⊙, spanning 0. ≤ z ≤ 0.85.



A schematic of our current ideas of galaxy evolution. The scenarios can be summarised into roughly three mechanisms; internal instabilities, minor mergers & major mergers.

- *Elliptical galaxies are thought to be the result of a merger of two equal sized progenitor galaxies or major merger.*
- *Disc + bulge galaxies with a classical bulge are thought to be the result of hierarchical clustering via minor mergers. However it has been suggested that after a major merger, gas can be re-accreted onto a spheroid forming a disc.*
- *Disc perturbations from chaotic gas accretion can send gas and stars to the centre of a galaxy forming a disc-like bulge or pseudo bulge.*

2. SAMPLE

We utilised the sample chosen by Gadotti 2009 which were suitable for structural analysis based on an image decomposition and presented a fair representation of the galaxy population in the local universe along with a sample chosen from COSMOS.

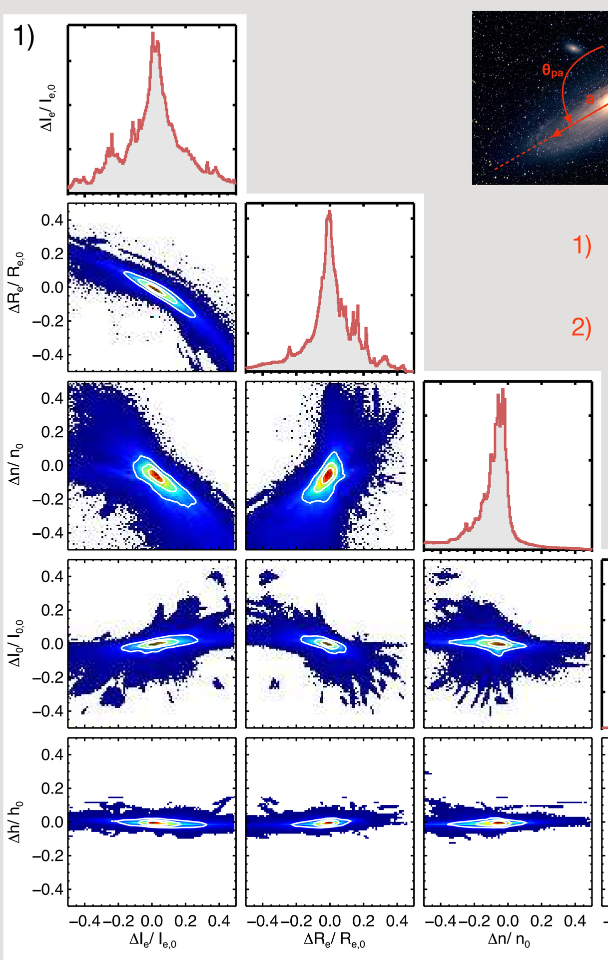
In particular they have the following characteristics:

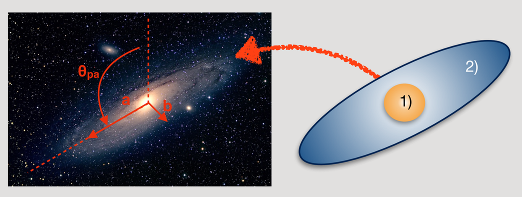
- Spectroscopically classified catalogue in the SDSS.
- Low redshift range 0.02 ≤ z ≤ 0.07; High redshift range 0.5 ≤ z ≤ 0.85.
- Galaxy mass > 10^{10} M⊙.
- Axial ratio *b/a ≥ 0.7.*
- Total number of galaxies: 380 from SDSS and 350 from COSMOS.

We use the catalogs given by Brinchmann et al 2004 for the global stellar mass and star formation rates in SDSS and the 3D-HST data products for COSMOS (Skelton et al 2014).

3. METHOD

Testing the method





1) $$I(R) = I_e \exp\left\{-b\left[\left(\frac{R}{R_e}\right)^{1/n} - 1\right]\right\}$$

2) $$I(R) = I_0 \exp\left(-\frac{R}{h}\right)$$

$$\epsilon = 1 - \frac{b}{a}\ ;\ \theta_{pa} = \text{position angle}$$

A new MCMC algorithm was created in order to directly compute the probability of the model parameters in the 2D photometric decomposition process.

We created a sample of mock galaxy images based on the results of Gadotti 2009 to quantify the accuracy and precision of the new MCMC algorithm. The galaxies were created using a two-component model *i.e.* Sérsic + exponential profiles (equations 1 & 2).

Figure 1. Joint probability distributions of the mock galaxies stacked as a bias i.e. (x_0 - x)/x_0 where x_0 is the true value and x are the values after the fit. The white contours show the 1, 2, and 3 sigma confidence levels.

Classification

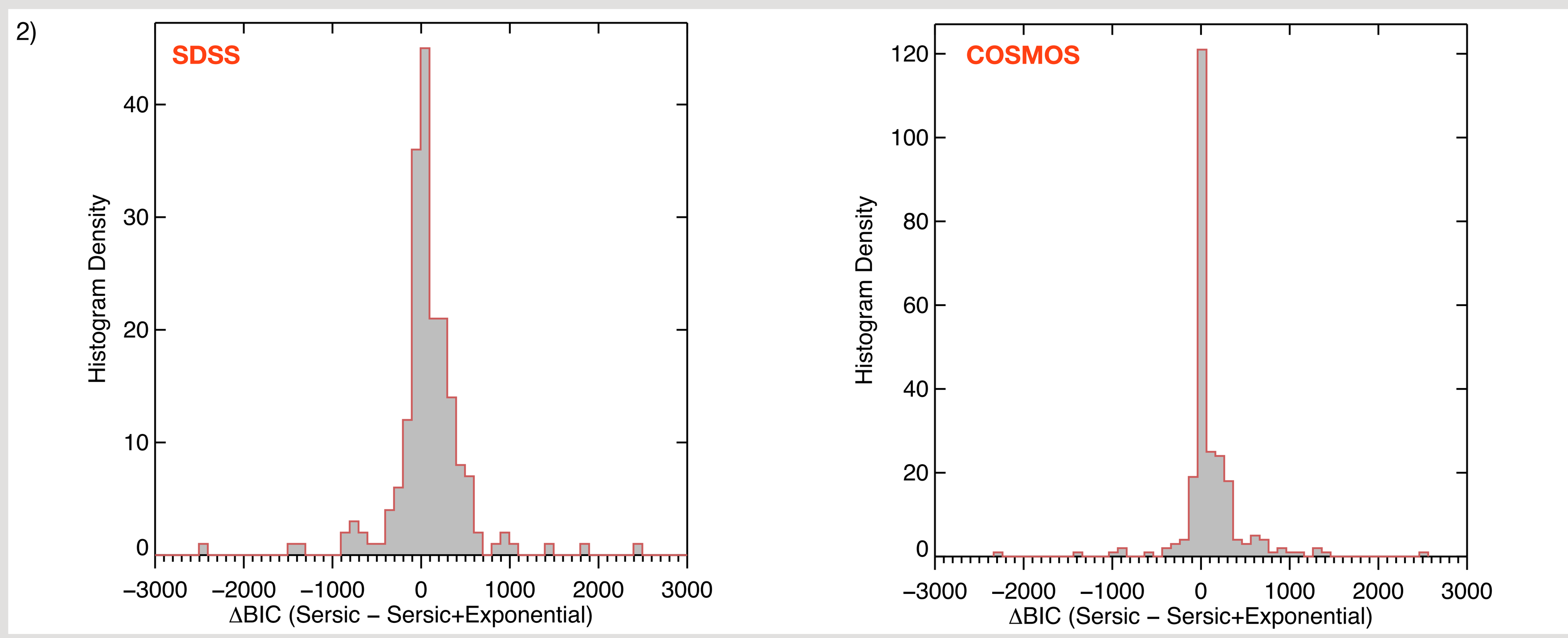


Figure 2. We fit each galaxy in our sample with both a single component i.e. a single Sérsic profile as well a two component model i.e. Sérsic + exponential. We then use the Bayesian Information Criterion (Kass and Raftery 1995) to identify the more likely model for a galaxy. Here, the more positive ΔBIC gets, the greater the probability a galaxy has of having a bulge and a disc.

4. RESULTS

The following figures utilise each fit from the sample and combines all the posterior probability distributions. This, for the first time, gives us a unique look into both the errors on each of the parameters as well as their covariances and correlations.

Bulge size (Re) vs. Total stellar mass

Low-z (z ~ 0.05) | High-z (0.5 < z < 0.85)

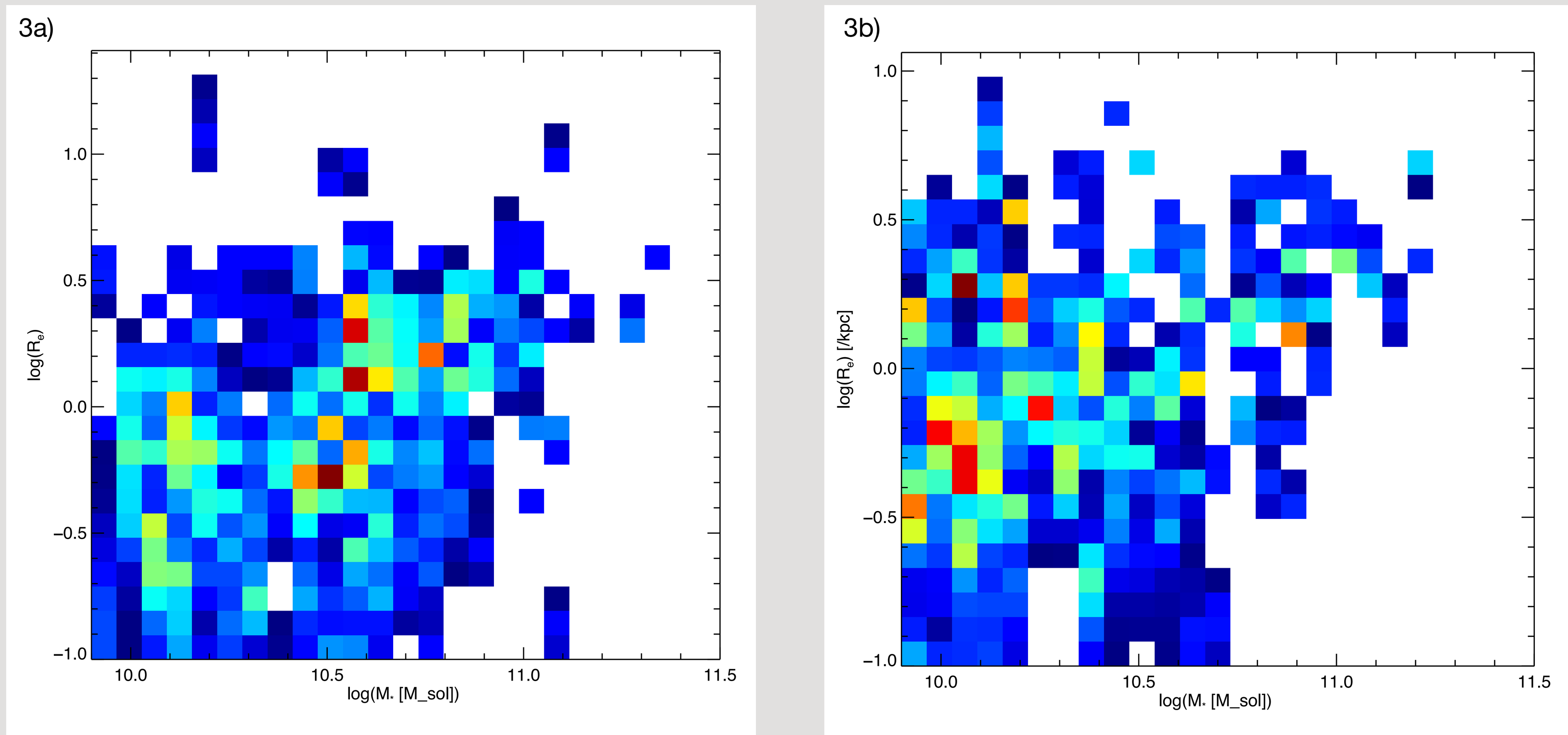


Figure 3. We now show the size-mass relations plotted with the marginalised posterior probability of the logarithm of the bulge effective radius plotted against the logarithm of the stellar mass. These size-mass plots do not immediately display a clear deviation between bulge populations, but instead reveal the size-mass scaling of galaxies between the two redshift bins.

Sérsic index vs. specific star-formation rate

Low-z (z ~ 0.05) | High-z (0.5 < z < 0.85)

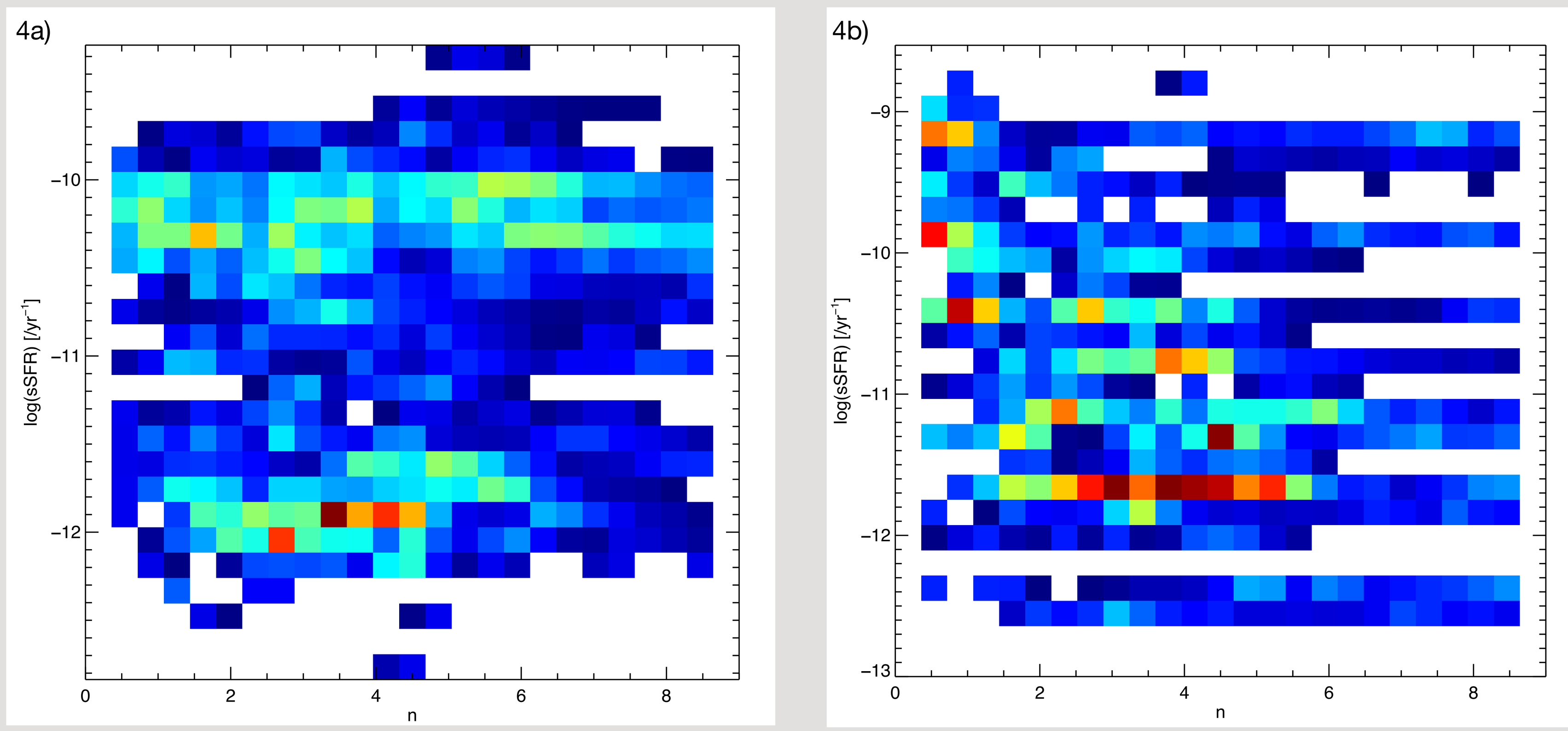


Figure 4. The distribution of observed galaxies in the sSFR-n plane in the redshift bins z~0.05 and 0.5 ≤ z ≤ 0.85. The colours shown are similar to figure 3 in that they represent the marginslised posterior probability for the Sérsic index of each galaxy plotted against the sSFR. Brennan et al 2015 interpret this plot as a way to interpret different physical processes. Different populations of bulges appear vary over the redshift range.

5. CONCLUSIONS

- A new Bayesian algorithm to perform the photometric decomposition of galaxies has been developed.
- We applied this new method to a sample of 380 galaxies in the local universe extracted from SDSS and 350 at a redshift range 0.5 ≤ z ≤ 0.85 from COSMOS.
- We have studied the coevolution of SFR and morphology from z~0.85 to the present by examining the build-up of different bulge populations using the sSFR versus Sérsic index plane.
- We also investigated the size-mass relations between our bulges and the total stellar mass of the host galaxies.
- Our Bayesian perspective of galaxy structures opens up a new way to understand the physical process driving the formation and evolution of galaxies.

7. REFFERENCES

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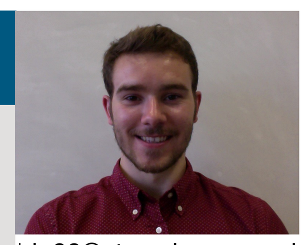

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