Bivariate mass-size distribution by Galaxy Zoo 2 morphologies

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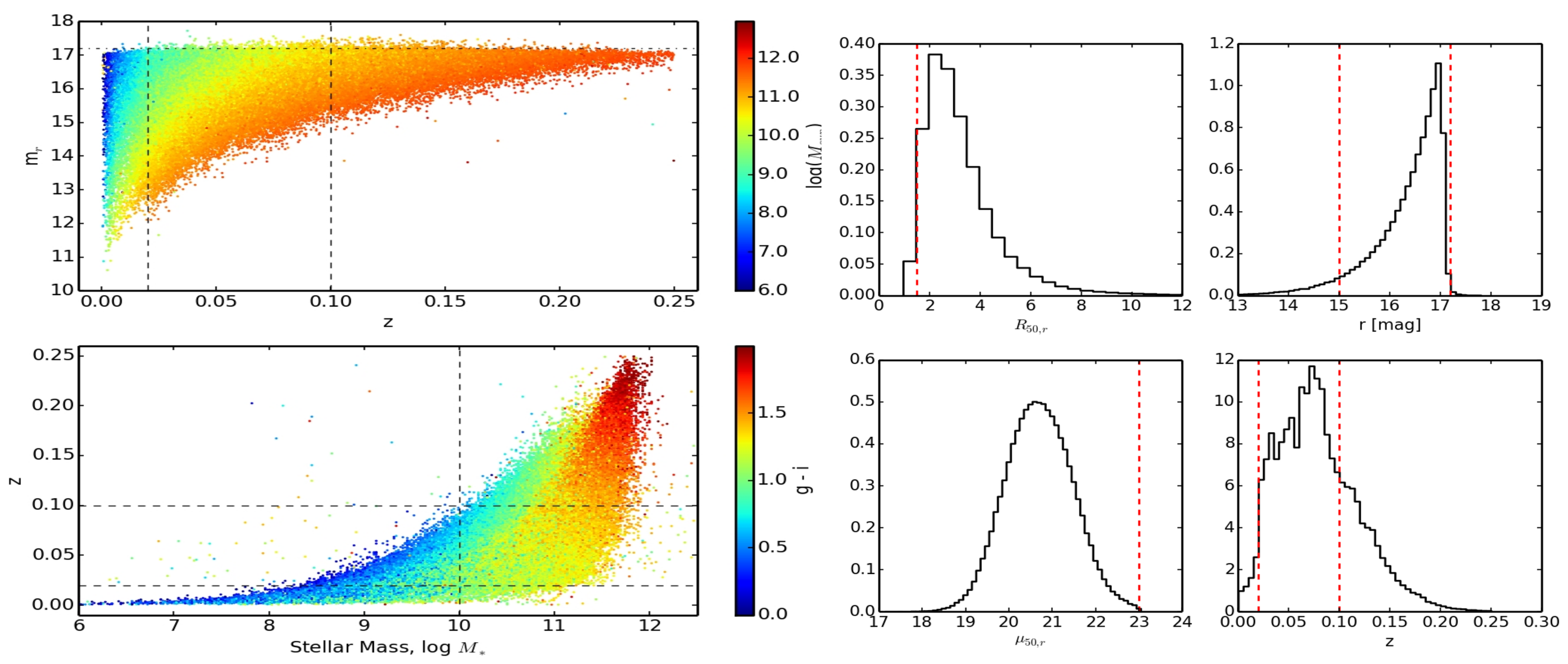
Abstract

It is well known that the mass-size distribution evolves as a function of cosmic time and that this evolution is different between passive and star-forming galaxy populations. However, the devil is in the details and the precise evolution is still a matter of debate since this requires careful comparison of the number densities of similar galaxy populations over cosmic time while properly selecting representative and consistent morphological samples.

Here we present the first step in an ambitious undertaking to calculate the bivariate mass-size distribution as a function of time and morphology by considering galaxies visually classified by citizen scientists during Galaxy Zoo 2. We quantify the mass-size distribution using the well-known parametric Maximum Likelihood estimator

Sample Selection



Left: dashed lines demonstrate cuts on redshift, magnitude and mass.

Right: distribution of various properties of the GZ2 sample. Red dashed lines demonstrate cuts on size, magnitude, surface brightness and redshift.

With these cuts we are relatively complete in mass down to 10 M_sun.

Morphological Subdivisions

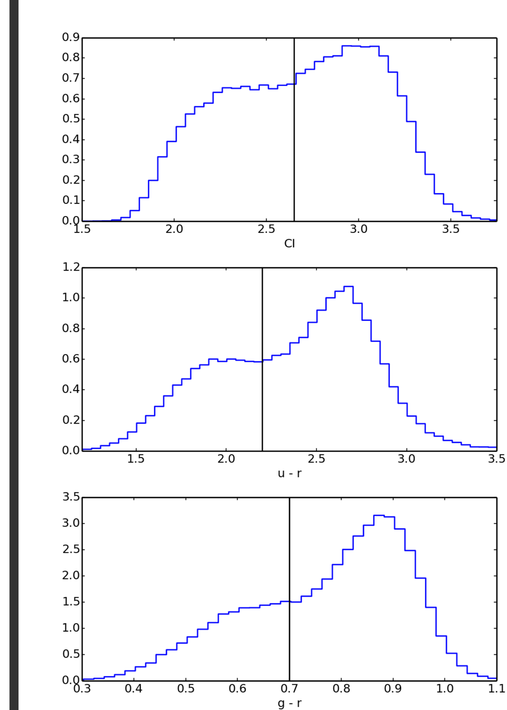


Fig. X Histograms of various broad standard morpholigcal indicators typically used to separate late- and early-type galaxies. Top: Concentration Index (CI) defined as CI = R90 / R50. Middle: u – r color. Bottom: g – r color.

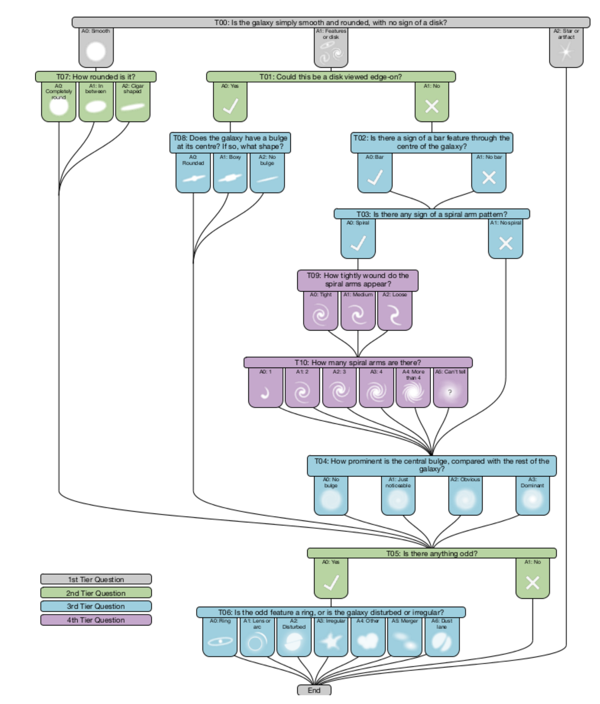


Fig. X Decision tree shown to users on galaxyzoo.org. In our analysis we begin by isolating galaxies after the first question. 'Smooth' galaxies are found to roughly correlate with late-types while 'Featured' objects include disks, edge on galaxies, and mergers.

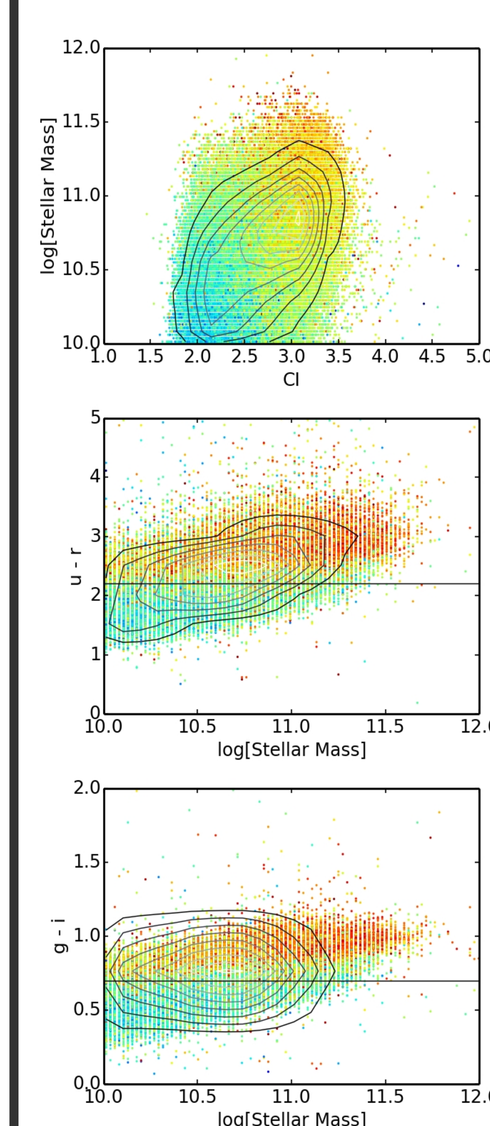


Fig. X: Multi-dimensional look at the dataset. Top: Mass vs CI with color as a function of u – r. Middle: u – r vs Mass with color as a function of CI. Bottom: g – r color vs Mass with color as a function of CI. Dasked lines demonstrate the cuts from Fig. X.

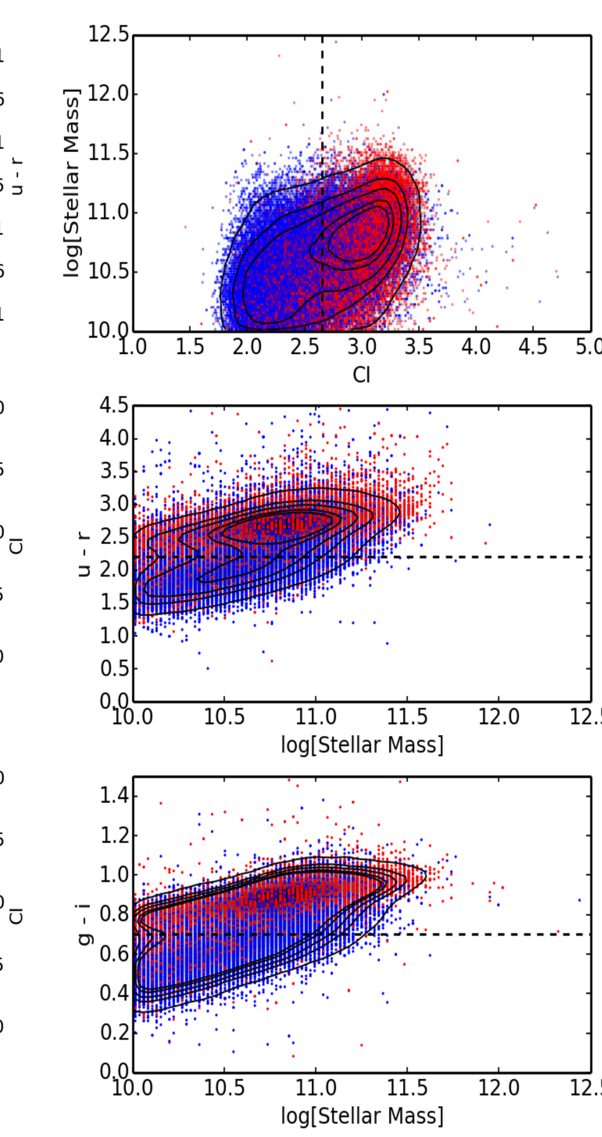


Fig. X: Same as Fig. X but now colored by visual morphologies from Galaxy Zoo 2. Red denotes galaxies labeled as "Smooth" which roughly correlates with late-types whereas blue denotes "Featured" which is heavily dominated by disk galaxies.

Parametrization of Model and Fitting Method

We adopt the Schecter function as our model mass function as is customary. The volume number density of galaxies within the mass range (M, M+dM) is described by:

$$\Psi(\mathrm{M})d\mathrm{M} = \phi^* \left(\frac{\mathrm{M}}{\mathrm{M}^*}\right)^{\alpha} \exp\left(-\frac{\mathrm{M}}{\mathrm{M}^*}\right)\frac{d\mathrm{M}}{\mathrm{M}^*}$$

For the size distribution we adopt a log-normal distrubution where the probability density that a galaxy at M has efective half-light radius between (Re, Re + dRe) is given by:

$$p(\mathrm{R_e})d\mathrm{R_e} = \frac{1}{\sigma_{\ln \mathrm{R_e}}\sqrt{2\pi}} \exp\left(-\frac{\ln^2(\mathrm{R_e}/\bar{\mathrm{R}}_\mathrm{e})}{2\sigma^2_{\ln \mathrm{R_e}}}\right)\frac{d\mathrm{R_e}}{\mathrm{R_e}}$$

We connect the above equations by adopting a power-law relation which connects the mass and the peak of the size distribution, R:

$$\bar{\mathrm{R}}_\mathrm{e}(\mathrm{M}) = \mathrm{M}_0\left(\frac{\mathrm{M}}{\mathrm{M}_0}\right)^{\beta}$$

The full bivariate distribution is then characterized by five free parameters:

$$\mathbf{P} = [\alpha, \mathrm{M}^*, \beta, \mathrm{R}_0, \sigma_{\ln \mathrm{R_e}}]$$

We use the maximum likelihood estimator (MLE) to recover the best fit parameters

we use the STY parametric maximum likelihood estimator (MLE), modified to account for uncertainties in the measurements of the line luminosity, as explained in Section 5.2. One of the major advantages of the MLE is that it allows us to fit the data without binning. Particularly for small samples, this technique reduces the biases introduced by the choice of bin-size or bin-center as well as any effects due to changing completeness and effective volume within the bin

Results

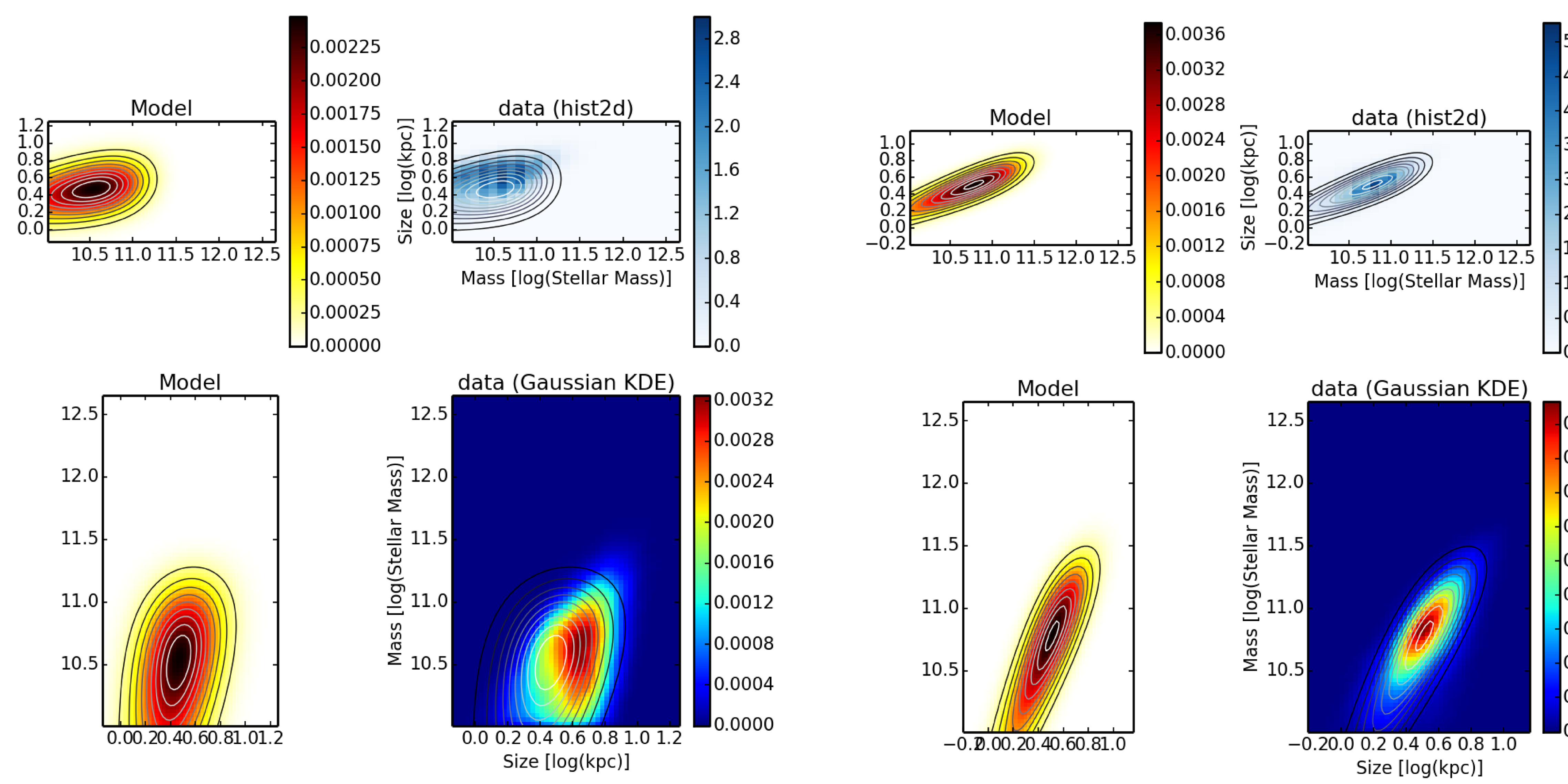


Fig. X PLACEHOLDER