On the stability of morphological parameters measurements with redshift

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Introduction

To understand how galaxies were formed and evolved, we need to measure their properties at different redshifts. Traditional morphological and structural parameters (e.g. Sérsic intensity, effective radius and index, concentration, asymmetry, Petrosian Radius, Gini coefficient) may be dependent on the image sampling, PSF and SNR. So in order to measure how the morphology of these objects evolve with time, we need to know how robust our measurements are at different redshifts. In this way, we used the FERENGI application to simulate the effect of observing the same galaxy at different redshifts. We applied the procedure to the FREI database to artificially redshift local galaxies up to 1.5 Gpc ($z \approx 0.4$) and then used the FOTOMETRIKA package to measure several morphological and structural parameters. In this way we were able to check how the measurements behave as the spatial resolution and the SNR decreases. Those parameters that depend on the distance can be corrected for and compared with other measurements, given that we have a Cosmology model. Other parameters, such as asymmetry (both traditional and an improved version), are found to be present stable measurements with redshift.

Cosmological model

In order to understand how the redshift affects the measurements, we need a cosmological model that describe the universe expansion. In our case, the FRWL metric and the Friedmann's equation are the mathematical description necessary. Thus, the distance in the line of sight in this case is

$$D = D_H \int_0^z \frac{dz'}{(\Omega_M(1+z)^3 + \Omega_k(1+z)^2 + \Omega_\Lambda)^{\frac{1}{2}}}$$

where Ω_M, Ω_k and Ω_Λ are the energy density parameters, which is dependent from the cosmological model and D_H is the Hubble distance defined as

$$D_H = \frac{c}{H_0}$$

for a flat $\Lambda - CDM$ universe, $\Omega_k \approx 0$. In FERENGI, the numerical values for Ω_M and Ω_Λ are 0.3 and 0.7 respectively. H_0 is parameterized as follows

$$H_0 = \mathrm{h}\ (100\ \mathrm{km\ s^{-1}\ Mpc^{-1}})\ ,\ \mathrm{h} = 0.7$$

MORFOMETRYKA measurements

MORFOMETRYKA (Ferrari 2014) was used to measure the structural and morphological parameters from the galaxies. It takes each galaxy image, subtracts sky background, locates the object, measures the center, axes lengths and position angle; performs aperture photometry and fits a Sérsic law to the light profile (Sérsic 1968); measures Petrosian radius (Petrosian 1976), concentration, asymmetry, smoothness and Gini coefficient (Abraham 1994), (Conselice 2000) & (Lotz 2004). MORFOMETRYKA also presents a new asymmetry index (A_3) based on Spearman correlation coefficient.

FERENGI

FERENGI simulates the redshifting of an object to a given distance. It applies the correct cosmological corrections for size, surface brightness and bandpass shifting. Barden et al. 2008 calls this process "artificial redshifiting". In our case, we wrapped FERENGI's code to produce images of the selected nearby galaxy into several redshifts in a given interval of 50 Mpc, from 0.1 Gpc to 1.5 Gpc.

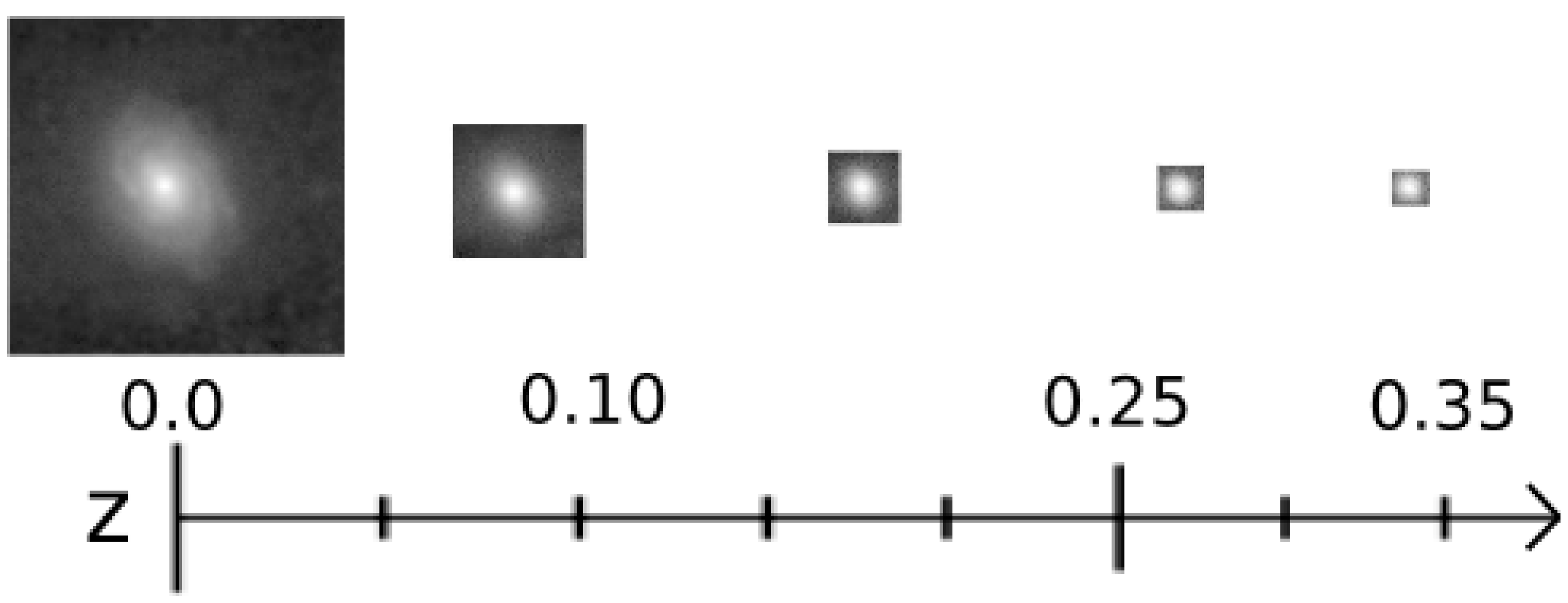

Figure: Diagram of the artificial redshifiting of NGC 4030 galaxy

Acknowledgements

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FREI database

FREI galaxy database is a well known collection of images from nearby galaxies collected through the Palomar and the Lowell observatories. In the case of our study, all the images used are taken with two filters, J (450 nm) and R (650 nm). These images are good to work with because they are well documented, including the PSF information necessary.

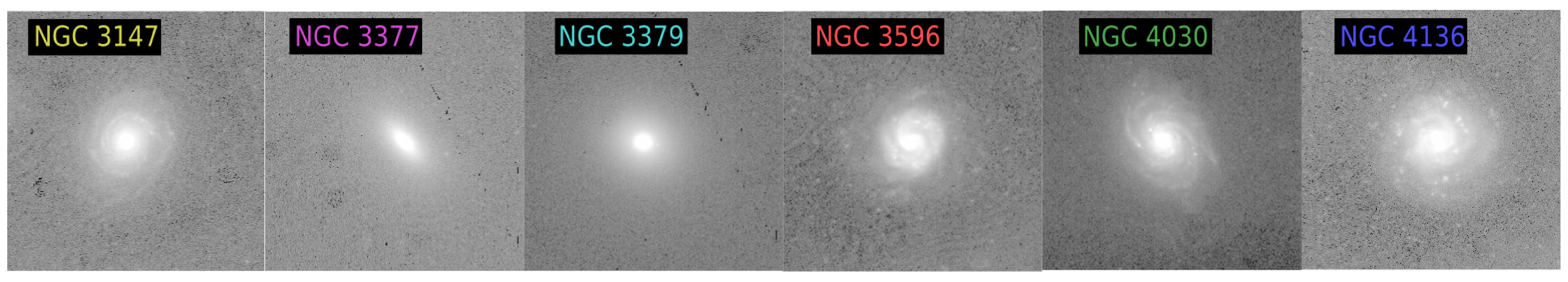


Figure: Example of FREI galaxies used in this study.

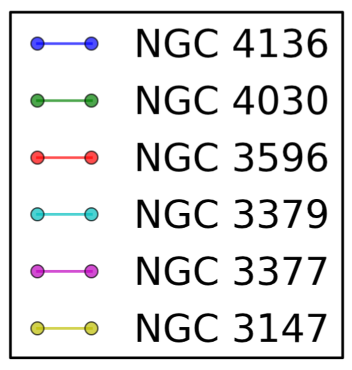
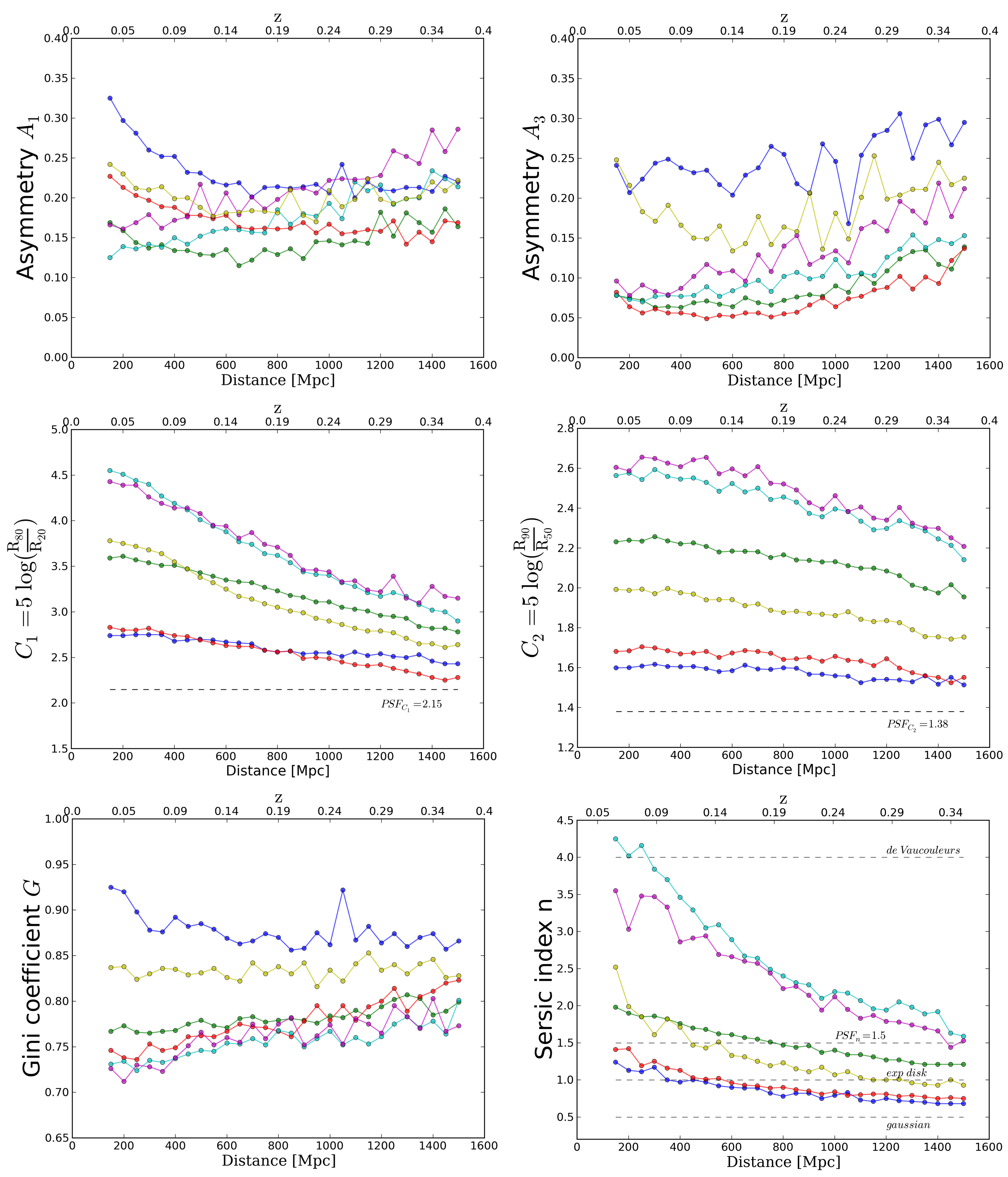


Figure: Color codes

Measurements with redshift



Conclusions

- Concentration, Asymmetry, Gini and Sérsic parameters can be measured reliably by MORFOMETRYKA.
- A_3 asymmetry index (this work) **discriminates** better than traditional index A_1.
- C_2 (outer) concentration **discriminates** better than C_1 (inner).
- **Image sampling** is crucial for morphometry measurements. General advice is

$$\text{pixel size} < \frac{R_n}{10}$$

- Measurements converge to the PSF values with increasing redshift. **Reliable measurements** are limited to distances where

$$R_n > 2\ \mathrm{PSF_{FWHM}}$$

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