Discerning Structural Multicomponents in Galaxies with Light Concentration

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1 Abstract

Galaxy classification is a powerful tool to the understand the evolution of structures in the universe. Galaxy formation and evolution is imprinted in their current morphology. Today's data volume is, however, beyond human processing capabilities and visual classification is not viable anymore. We have to appeal to objective and algorithmic ways to characterize galaxy morphology. One approach is to use **galaxy morphometry**. One of our main goals of the present work is to investigate the presence of **multicomponent in galaxies** (e.g. bulges and disks). We address the problem by considering a powerful diagnostic tool for this purpose which is to measure the **galaxy light concentration**. The light concentration $C_{k\ell}$ is a measure of how concentrated the light distribution with respect to to the galaxy center. $C_{k\ell}$ is obtained computing the ratio of radii R_k and R_ℓ that contains some fraction k and ℓ of the total light L_T of the galaxy. To measure R_k we use the Morfometryka algorithm and our approach is to compare how these observables compare to numerical models.

2 Theory

One start point on morphometry is to compute the ratio of radii that contains some fraction of the total light L_T of the galaxy . This is a **robust measure of concentration** which can be applied even at moderate redshifts, where standard photometry techniques is unstable. Concentration is closely related to the Sérsic function index n defined by (Sérsic, 1968).

The concentration is defined in terms of two radius R_k and R_ℓ that contains some fraction k and ℓ of the total galaxy light (Kent, 1985; Conselice, 2003; Ferrari et al., 2015)

$$C_{k\ell} = \frac{R_k}{R_\ell} \tag{1}$$

in other words

$$L(R_k) = k\, L_T. \tag{2}$$

Concentration is one of the main morphometric parameters that **contains information about the formation and evolution of galaxies** and thus can be used to trace the evolutionary stage of galaxies at different redshifts. **Concentration** is also crucial for classifying galaxies, for it has a large variation between spiral and elliptical galaxies.

3 Missing Light in L_T

By definition $L_T = L(\infty)$ but in practice we cannot measure beyond some finite radius R'. Since the signal-to-noise at high cosmological distances are very low, R' changes with redshift and thus our estimated value for L_T. If we want to **reliably measure** R_k we need a good estimate of L_T. Usually, R' is taken to be two times the Petrosian radius R_p, $R' = 2R_p$, but, a significant portion of light will be lost, as we see in Fig. 1.

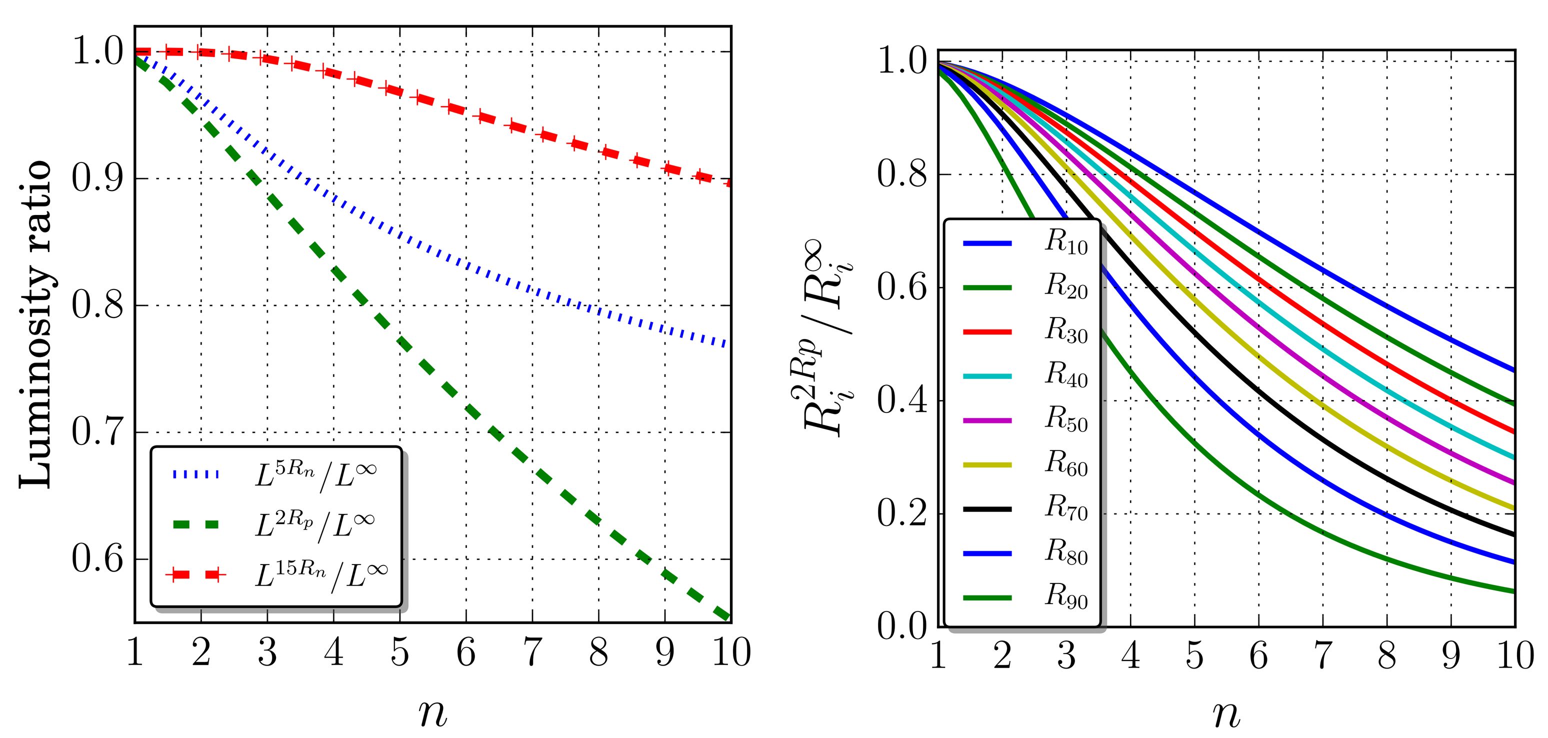

Figure 1: Fraction of luminosity integrated until some finite points (see legend) and the total luminosity for Sérsic models as function of the Sérsic index n.

4 Methodology

Our approach to **unravel multicomponent in galaxies** is to compare how the set of radii measurements compare to that of models. Galaxies with have more than one component, bulge+disk (BD) for example, will have in principle a distinct set of $\{R_{10}, R_{20}, ..., R_{90}\}_{\rm BD}$ in relation to an image composed by one component, i.e. a single elliptical or a pure bulge with $\{R_{10}, R_{20}, ..., R_{90}\}_{\rm E}$, see Fig.2. To measure all R_i we use the **automated** Morfometryka **algorithm** (Ferrari et al., 2015). Calibration of the measurements is done in two steps: a set of B+D mock images are generated utilizing Python and after are processed with the algorithm. The results are compared with the exact numerical solution of eq. (2).

This is a **calibration procedure** for $\{R_k\}$ and once it will be concluded, our main goal is test and understand **how concentration index change according to the morphology** and the efficiency it has to **distinguish components**.

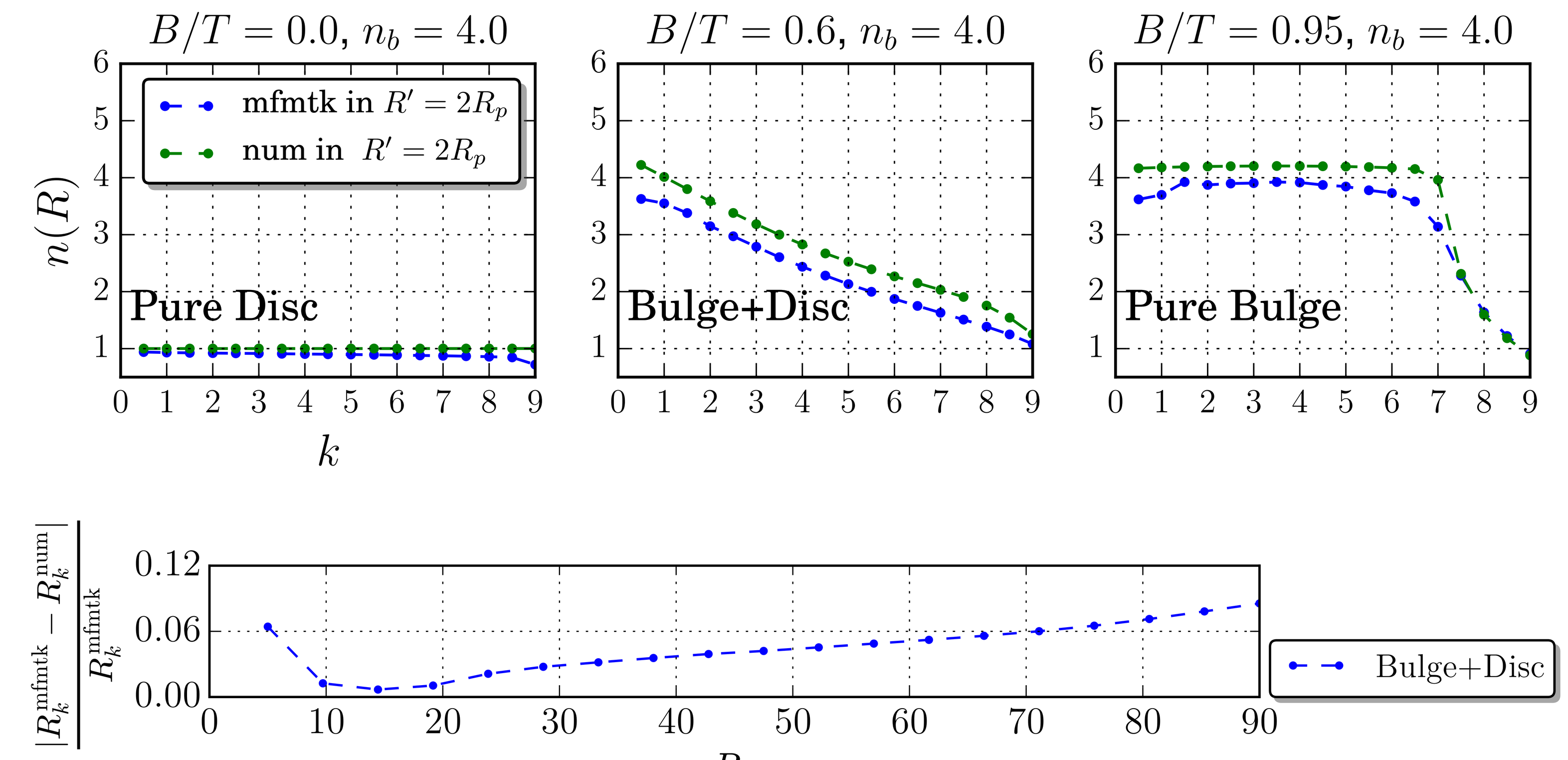

Figure 2: Top panel: comparing $\{R_k\}$ with $\{R_k^{\rm num}\}(n)$, the Sérsic index is determined in each position R_k - the $n(R)$ curve. Therefore bulge and disc are identified: (left) pure disc, $n \approx 1$; (center) B+D composition, $n \approx 4 \to n \approx 1$; (right) pure bulge $n \approx 4$. Bottom panel: fractional error in relation to the exact value of $\{R_k^{\rm num}\}$ and that obtained by mfmtk.

5 Examples & Discussion

The approach introduced previously, using the morphometric set $\{R_k\}$, was able to identify a B+D composition in our models of images, as we can see in Fig.2. Further, we show an example of the same procedure applied to three observed galaxies in Fig.3, from EFIGI catalog r-band (Baillard et al., 2011). The indexes $\{R_k\}$ revealed the distinct morphologies of these galaxies. This shows that the **concentration radii** R_k are **good morphometric indexes** to characterize the morphology of a galaxy. Therefore our next step is to study all possible **groups of concentration indexes** $C_{k\ell}$, obtained by combination of several ratios R_k/R_ℓ.

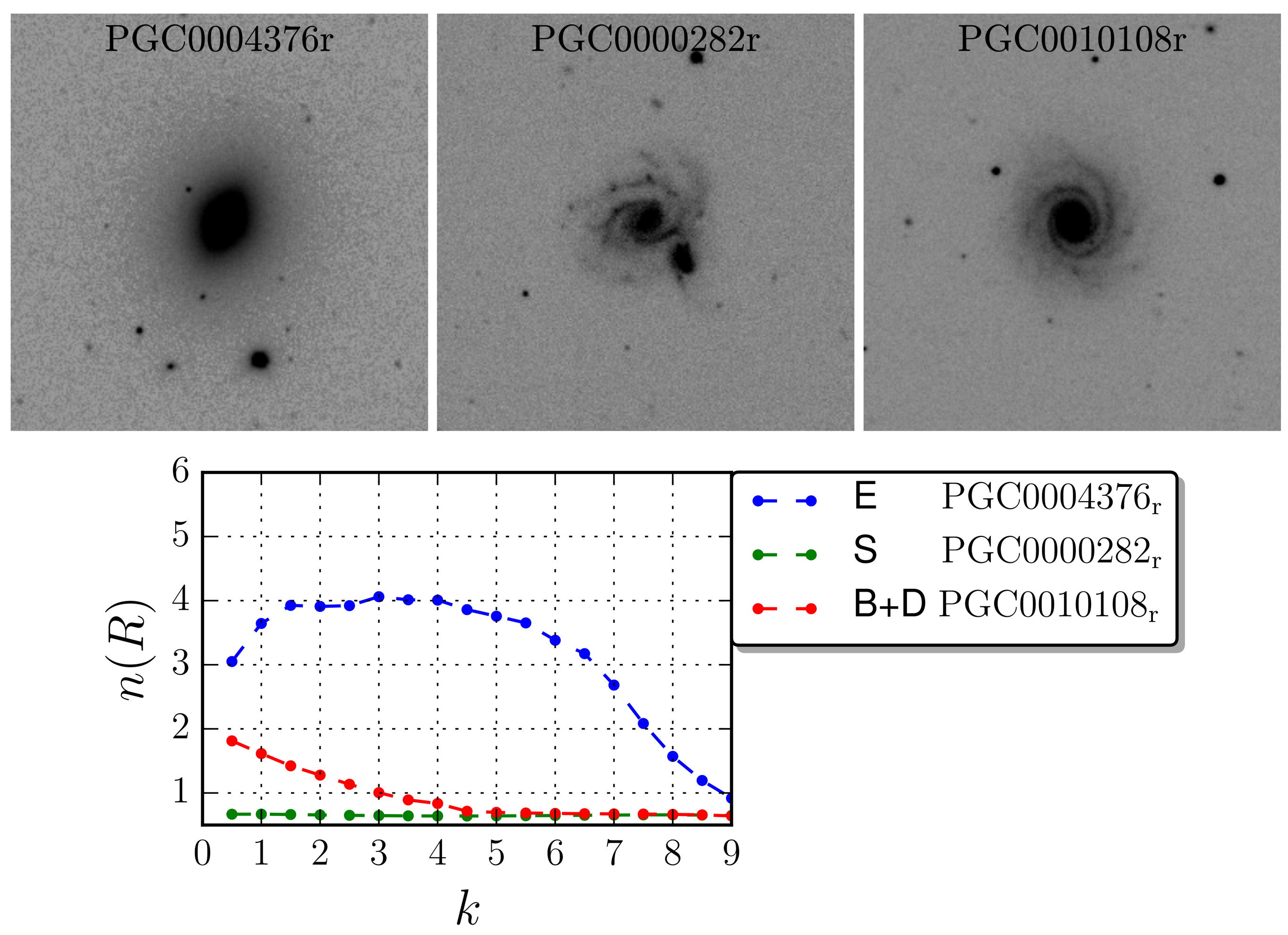

Figure 3: Example of identification of morphologies using R_k. Top panel: (left) elliptical; (center) spiral without bulge; (right) spiral with bulge. This is suggested by the plots in the bottom panel, showing n measured with mfmtk in each position R_k.

6 Conclusion

With the creation of mock images and the numerical solution of eq.(2), we can **calibrate** the Morfometryka algorithm and therefore the measurements of R_k and **concentration**. Consequently we are capable to test and improve our approach to **unravel multicomponent in galaxies**. These are the initial tools to apply an **analysis to real data** in subsequent works.

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