Structure and evolution of nearby galaxies

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Using GAMA photometric and morphology data, we studied the structure and evolution of galaxies in redshift $z < 0.5$. Based on $u - r$ rest-frame colour versus the Sérsic index plane, galaxies were divided into early- and late-type populations. The analysis show evolution of the $u - r$ colour and Sérsic index and the strong correlation between these parameters indicating that the galaxy mergers are the main driving mechanism transforming disk-like galaxies into ellipticals.

1 Introduction

The standard classification of galaxies (Hubble, 1926) divides them into two main populations: the elliptical and spiral galaxies. The elliptical galaxies appear in oval shape almost without visible structure. Their luminosity profiles are smooth, nearly featureless and very well fitted by the Sérsic (1963) law (with index $n \approx 4$ for nearby galaxies). The observed red colour of these objects originates from the populations of old, mostly low mass, stars. The gas and dust contents in these objects and the star formation activity are small.

The dominant element of the spiral galaxies is a flat, rotating disk. The contents of gas and dust are much higher than in elliptical galaxies. Clearly visible arms and bars of these objects are places of ongoing star formation. The blue colour of these objects is coming from the population of young stars. The central region of the spiral galaxies is dominated by evolutionary advanced stars, so their colour is moving into red. Disky galaxies have a lower light concentration in the center than elliptical galaxies and their brightness profile is well described with the Sérsic index $n \approx 1$. The current model of galaxy evolution assumes that transformation of disk-like galaxies into elliptical galaxies occurs as a result of their collisions and mergers (e.g. Toomre & Toomre, 1972; De Lucia et al., 2006; Cox et al., 2008).

2 Analysis and Results

In this study, we used the physical parameters of nearby galaxies coming from the GAMA project (Galaxy And Mass Assembly: Liske et al., 2015). This survey covers an area of $\sim 360\,\mathrm{deg}^2$ on the sky and collects physical parameters of about 375,000 galaxies with redshift range from $z = 0$ to 0.5. From the GAMA public database the absolute magnitues and morphological parameters of galaxies were extracted. In presented analysis we used the Sérsic (1963) profile given by the equation

$$I(r) = I_\mathrm{e} \exp\left\{-b_\mathrm{n}\left[(r/r_\mathrm{e})^{1/n} - 1\right]\right\}, \quad (1)$$

where: r_e is the half-light radiuss of the galaxy, parameter b is a normalization factor dependenting on the Sérsic index n, and I_0 is the brightness of the central region of the galaxy.

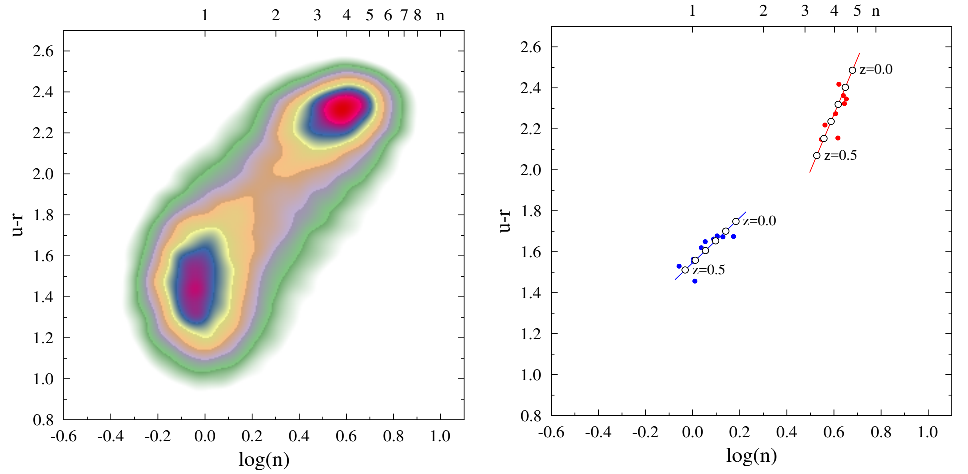

Fig. 1: Left: GAMA galaxy surface density map of $u-r$ rest-frame colour vs. the Sérsic index n distribution. Right: Coevolution of the $u-r$ colour and the Sérsic index n of elliptical (red symbols) and disk-like (blue symbols) galaxies. Approximated linear relationships are presented with lines whereas the white circles mark redshifts.

The $u-r$ rest-frame colour versus the Sérsic index n plane presented in the left panel of Fig. 1 was the starting point of our research. The plot shows that the surface density distribution of all studied objects is bimodal with clearly separated peaks corresponding to the early- (upper right corner) and late-type (lower left corner) galaxies (e.g Driver et al., 2006; Krywult et al., 2017).

Detailed analysis carried out in eight equally spaced redshift bins from $z = 0$ up to 0.5, shows that the maxima positions of late- and early-type galaxy populations, marked as blue and red dots in the right panel of Fig.1, depend on redshift. The linear fit of the $u-r$ rest-frame colour and the Sérsic index n dependance on redshift z for galaxies of both morphological types is given by the equations: disk-like: $\log(n) = 0.19 - 0.43\,z$, $u-r = 1.75 - 0.47\,z$; elliptical: $\log(n) = 0.68 - 0.30\,z$, $u-r = 2.49 - 0.83\,z$. The obtained functions are presented as blue (disk-like) and red (elliptical) straight lines in the right panel of Fig. 1, and show different evolutional tracks of the late- and early-type galaxies. The slope of the $u-r$=f($\log(n)$) relation for the disk-like galaxies is equal to 1.1, whereas for elliptical galaxies it is significantly steeper and is equal to 2.7.

We found that in the redshift range from $z = 0.5$ to 0, the $u-r$ rest-frame colour of the elliptical galaxies changes in the range $\Delta(u-r) = 0.42$ mag, mainly driven by the population of old stars. The rest-frame $u-r$ colours of the disk-like galaxies become redder, $\Delta(u-r) = 0.24$ mag from $z = 0.5$ to present day, indicating older mean ages and larger dust contents of galaxies. However, the colour change is less than in the elliptical galaxies due to ongoing star formation activity.

Our results show that in the redshift range from $z = 0.5$ to 0 the Sérsic index value of disk-like galaxies increases from $n = 0.9$ to 1.5 whereas for the elliptical galaxies its value changes from $n = 3.4$ to 4.8. To compare the galaxy shape evolution of different types of galaxies we assumed the same value of the half-light radius $r_{\mathrm{e}} = 2.5$ kpc. The black line presented in the left panel of Fig. 2 shows that central,

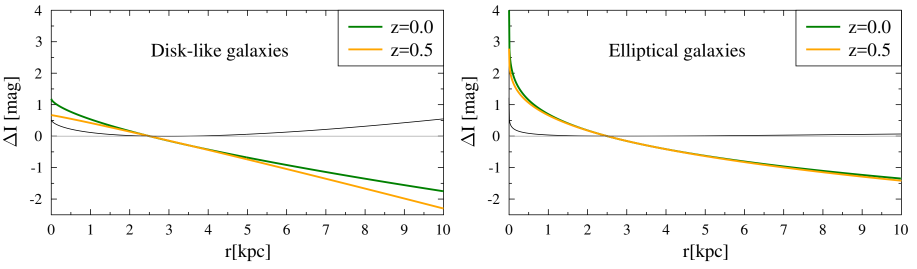

Fig. 2: Sérsic profiles of the disk-like (left panel) and elliptical (right panel) galaxies for redshift $z = 0.0$ (green line) and 0.5 (yellow line). The black solid line presented in each panel shows the difference between galaxy light profiles at redshifts $z = 0$ and $z = 0.5$.

$r < r_e$, brightness of the disk-like galaxies increases in the examined redshift range by about 0.5 mag. Moreover, the galaxy bulge, $r < 0.2\,r_e$, is three times brighter, ~ 1.2 mag, for nearby objects and indicates a matter migration towards galaxy centre. The brightness of the external part of the nearby objects decreases slower than the distant galaxies which indicates the star-forming activity in the disk-like galaxy. Fig. 2 shows that the central luminosity of elliptical galaxies increases with time by ~ 1.5 mag. Whereas, the luminosity of the external regions of the distant elliptical galaxies decreases in very similar way to the nearby objects.

3 Conclusion

Using GAMA photometric and morphology data, we studied the structure and evolution of nearby galaxies. The data showed evolution of the $u - r$ colour and Sérsic index and the strong correlation between these parameters. The different colour–shape coevolutional tracks of the disk-like and elliptical galaxies indicate that the galaxy mergers are the main driving mechanism transforming late-type galaxies into early-type objects.

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