arXiv:2014.07743

The origin of bulges and discs in the CALIFA survey: I. Morphological evolution.

J. Méndez-Abreu,[1,2,3,4]★ A. de Lorenzo-Cáceres, [1,2,5,6]S. F. Sánchez[3]

ABSTRACT

This series of papers aims at understanding the formation and evolution of non-barred disc galaxies. We use the new spectro-photometric decomposition code, c2D, to separate the spectral information of bulges and discs of a statistically representative sample of galaxies from the CALIFA survey. Then, we study their stellar population properties analising the structure-independent datacubes with the PIPE3D algorithm. We find a correlation between the bulge-to-total (B/T) luminosity (and mass) ratio and galaxy stellar mass. The B/T mass ratio has only a mild evolution with redshift, but the bulge-to-disc (B/D) mass ratio shows a clear increase of the disc component since redshift $z < 1$ for massive galaxies. The mass-size relation for both bulges and discs describes an upturn at high galaxy stellar masses ($\log(M_\star/M_\odot) > 10.5$). The relation holds for bulges but not for discs when using their individual stellar masses. We find a negligible evolution of the mass-size relation for both the most massive ($\log(M_{\star,\mathrm{b,d}}/M_\odot) > 10$) bulges and discs. For lower masses, discs show a larger variation than bulges. We also find a correlation between the Sérsic index of bulges and both galaxy and bulge stellar mass, which does not hold for the disc mass. Our results support an inside-out formation of nearby non-barred galaxies, and they suggest that i) bulges formed early-on and ii) they have not evolved much through cosmic time. However, we find that the early properties of bulges drive the future evolution of the galaxy as a whole, and particularly the properties of the discs that eventually form around them.

sample

CALIFA(近傍銀河の面分光;677個の銀河を含む)から

- **Bulge-to-disc:58個**
- **Bulge-to-disc+broken exponential:40個**
- **Early type:32個**

を抽出(barred galaxyは除いてある)

⇨C2D+PIPE3Dで解析
⇨photometric propertyと質量の関係を見る

Result

Fig.7

- **B/T mass ratioが銀河全体の質量と正の相関**
- **z~1でmassive galaxyが大きくdisc成長**

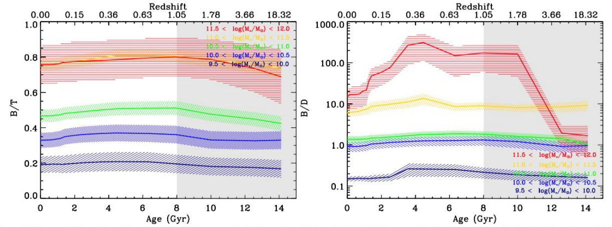

Figure 7. Time evolution of the bulge-to-total (B/T) mass ratio (left panel) and bulge-to-disc (B/D) mass ratio (right panel) for galaxies in different mass bins (see colors in the legend). The mass of every component has been computed using the stellar population analysis. The redshift is shown in the upper x-axis. The shaded area represents stellar ages (or redshifts) which are not well resolved in our stellar population analysis (see text for details).

Fig.8

- **disc,bulgeともに$\log(M_\star/M_\odot) > 10.5$で有効半径がupturn**
- **横軸をbulge質量で書いた時も同じ傾向**
- **横軸をdisc質量にするとその傾向は消える**

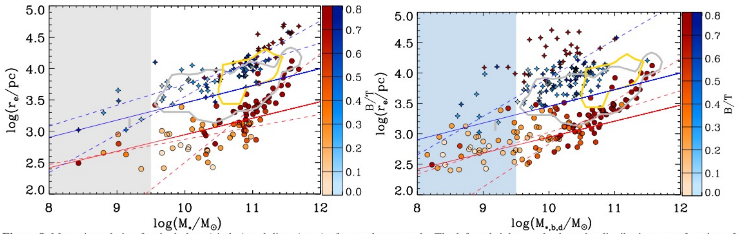

Figure 8. Mass-size relation for the bulges (circles) and discs (stars) of our galaxy sample. The left and right panels show the distributions as a function of the global galaxy mass and the mass of each component, respectively. All stellar masses are derived from our stellar population analysis. The effective radii of both bulges and discs (1.678×h) are obtained from the r-band photometric decompositions of Méndez-Abreu et al. (2017). Grey isocontours represent the mass-size relation of our galaxy sample without separating their structures. Golden isocontours show the mass-size relation of the photometrically defined *pure* ellipticals in the CALIFA sample (see Méndez-Abreu et al. 2018, for details). The B/T luminosity ratio for each galaxy is coloured in reddish (bulge) and bluish (disc) colors according to the colorbars. The blue and red solid lines show the best-fit obtained by Lange et al. (2016) for their sample of discs and spheroids, respectively. The blue and red dotted lines represent the best-fits (see Table 3) obtained for our sample of discs and bulges, respectively. To perform our fit to the mass-size relation we divided the sample into two mass bins: $8 < \log(M_\star/M_\odot) < 10.5$ and $10.5 < \log(M_\star/M_\odot) < 12$ to capture the clearly appreciated change in the slope. The grey and blue shaded areas show the global and disc stellar mass range where our sample is incomplete, respectively.

Fig.9

- **バルジについてはz~2以降mass-size relationに大きな変化なし**
- **ディスクについてはlow-mass discが大きく質量成長している(2倍以上)が、high-mass discはそれほど質量成長なし**

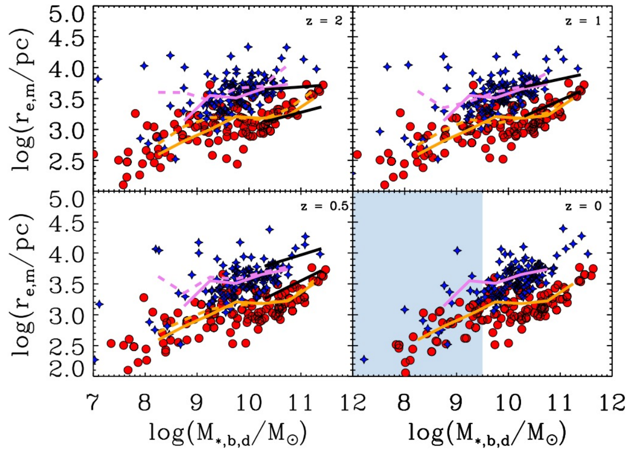

Figure 9. Mass-size relation for the bulges (circles) and discs (stars) of our sample galaxies at different redshifts ($z = 2$, upper left; $z = 1$, upper right; $z = 0.5$, bottom left; $z = 0$, bottom right). The stellar mass and effective radius correspond to the one for each component. At $z > 0$, different panels show the mass of each component at the corresponding redshift as computed from the fossil record method. The effective radii are computed using the reconstructed mass surface density at different ages (redshift) from their stellar populations, therefore they are half mass radii ($r_{\mathrm{e,m}}$) The orange and violet solid lines in all panels show the mean values of the $z = 0$ relation computed in bins of 0.5 magnitude for bulges and discs (only bins with more than 5 galaxies are shown), respectively. The dashed lines show the mean values at the corresponding redshift. Black lines show the best fit obtained from Dimauro et al. (2019) to their sample of $\log(M_\star/M_\odot) > 10.3$ bulges and discs at high redshift.The blue shaded area shows the disc stellar mass range where our sample is incomplete.

Fig.10

Sersic indexは

- **銀河全体とbulgeの質量と正の相関**
- **discの質量とは相関がない**

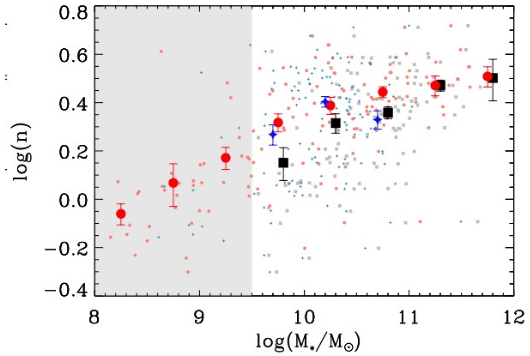

Figure 10. Distribution of the bulge Sérsic index as a function of the global galaxy mass (grey small squares), bulge mass (small salmon circles), and disc mass (small cyan stars) for our sample galaxies. Large black squares, red circles, and blue stars represent the mean values in global galaxy, bulge, and disc masses, respectively. The mean values are only represented for bins where our sample is statistically representative (see Sect. 4.2). Blue stars and black squares have been slightly shifted from the center of the bin for visualization purposes. The grey shaded area shows the global stellar mass range where our sample is incomplete.

Conclusion

discのpropertyは銀河やbulgeのpropertyに大きく依存しているが、discのpropertyは銀河やbulgeのpropertyに影響を与えない
⇨元々あったbulgeからdiscが成長したことを示唆

考えられるプロセス

- **massive high-redshift quiescent compact galaxy(or red nugget)がz~0のdisc galaxyのbulgeになった(Graham&Scott(2013);de la Rosa et al.(2016))**
  ⇨ Costantin et al.(2020)によると、この描像はlow-massにも拡張可能かもしれない

⇨少なくともmassiveな銀河についてはdiscの成長をz~1以降経験して、早期型から晩期型へと進化したか?(inside-outな形成シナリオ)