Low Surface Brightness Galaxies in IllustrisTNG

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Abstract.

We explore the nature of low surface brightness galaxies (LSBGs) in the hydrodynamic cosmological simulation TNG100 of the IllustrisTNG project, selecting a sample of LSBGs at $z = 0$ over a wide range of stellar masses ($M_{*} = 10^{9}$–10^{12} $M_{\odot}$). We show that the specific star formation rates of LSBGs are not significantly different from those of high surface brightness galaxies (HSBGs), but that LSBGs are systematically less massive and more extended than HSBGs, and tend to display spiral-like morphologies according to a kinematic criterion. At fixed stellar mass, we observe no systematic differences in their dark matter halo masses, but we find that the haloes hosting LSBGs have a higher baryonic fraction. We finally find that LSBGs have higher stellar specific angular momentum and halo spin parameter values compared to HSBGs, as suggested by previous works. We track the evolution of these quantities back in time, finding that the spin parameters of the haloes hosting LSBGs and HSBGs exhibit a clear bifurcation at $z \sim 2$, which causes a similar separation in the evolutionary tracks of other properties such as galactic angular momentum and effective radius, ultimately resulting in the values observed at $z = 0$. The higher values of specific stellar angular momentum and halo spin in LSBGs seem to be responsible for their extended nature, preventing material from collapsing into the central regions of the galaxies, also causing LSBGs to host less massive black holes at their centres.

Introduction.

LSBGs are intrinsically faint objects, characterized by a central surface brightness μr > 22.0 mag arcsec^{-2}, and constitute about 50% of the extragalactic population. They are objects tipically with late-type morphologies (extended spirals with weak bars/bulges) being gravitationally dominated by a massive DM halo at all radii, formed within halos with high spin parameter λ, which determine properties such as size an stellar density.

There are several works employing cosmological simulations to study the formation of LSBGs, in order to provide a feascibe scenario. It seems that both, LSBGs and HSBGs are born from similar kind of objects, evolving towards different population by several mechanisms such as secular evolution, mergers, and accretion. However these mechanisms have a different impact depending on the stellar mass of the galaxy and the local environment in which these galaxies reside.

Main Goals.

We use TNG100 to make an extensive study of the main properties of LSBGs at z=0 such as morphology, SFR, angular momentum and spin parameter. We attempt to build synthetic samples in order to study some important mechanisms related with their evolution, such as mergers, star formation history and accretion mechanisms, in order to provide a feasable scenario to the formation of LSBGs.

Sample Construction.

We built a sample of galaxies with $M_* > 10^9 M_\odot$ using TNG100 at its highest resolution level as follows:

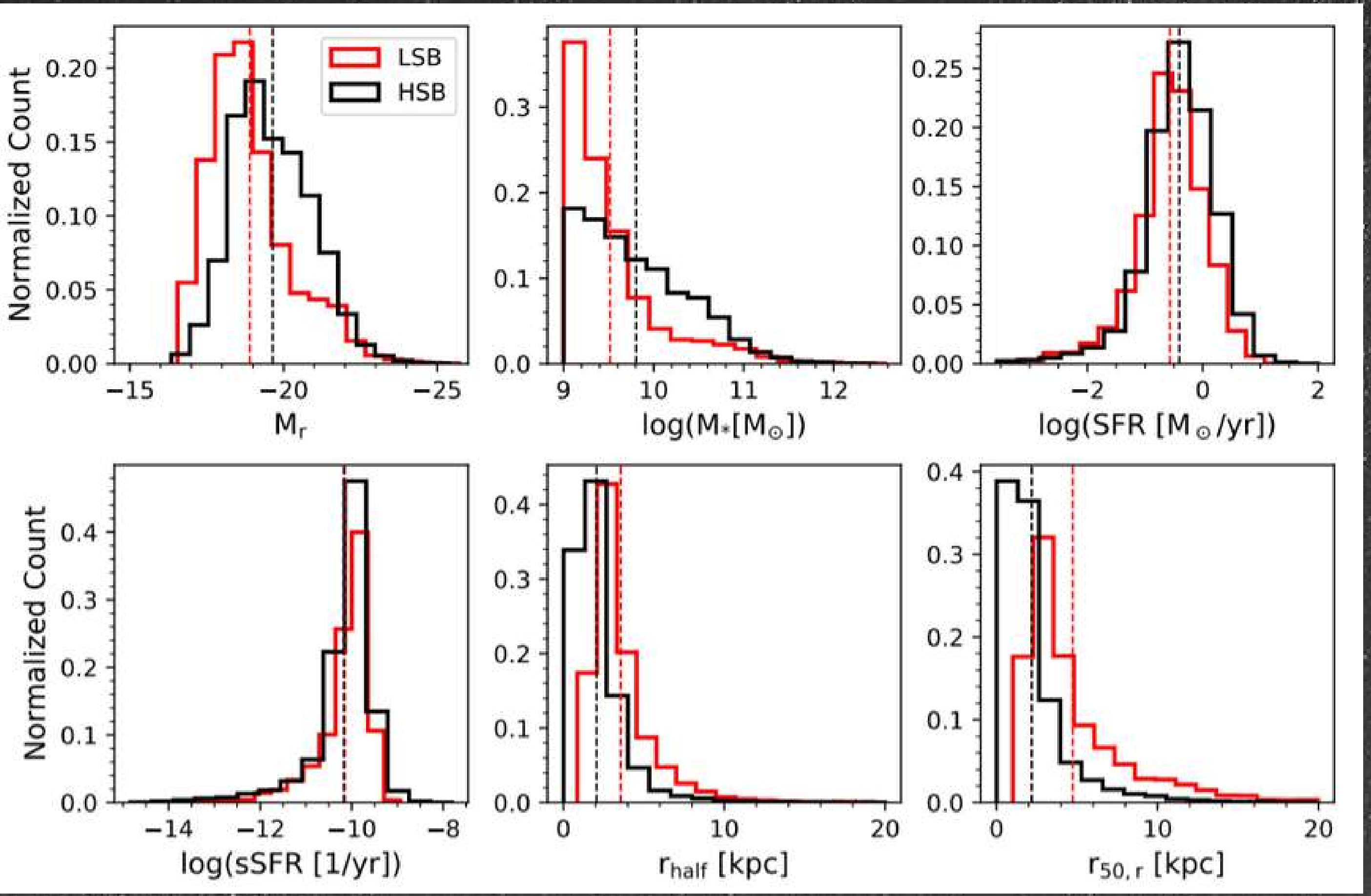
1. Obtain the specifica angular momentum to orientate the galaxies as face-on.
2. Calculate the effective radius R50 containing half of the total luminosity in the r-band.
3. Calculate the apparent magnitude considering the flux of all the particles within R50.
4. Obtain the surface brightness as:

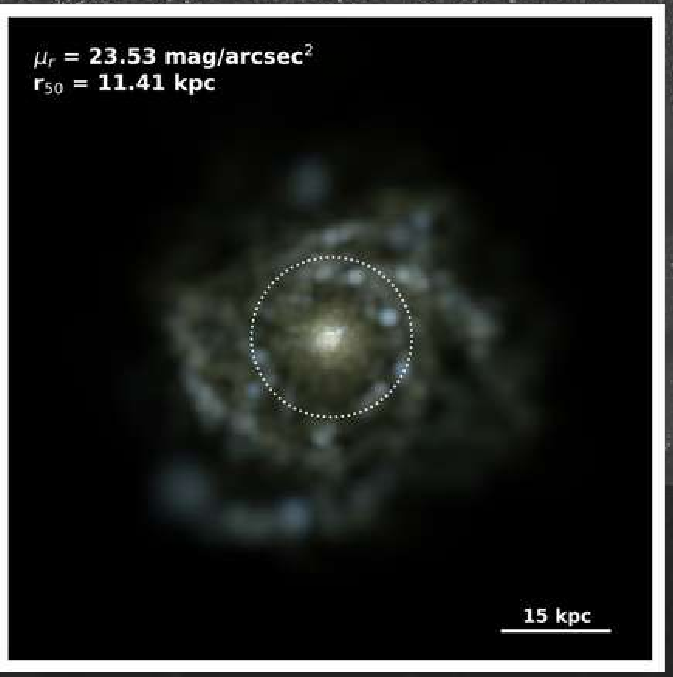
We classify as LSBGs those galaxies with μr > 22.0 mag arcsec^{-2}.

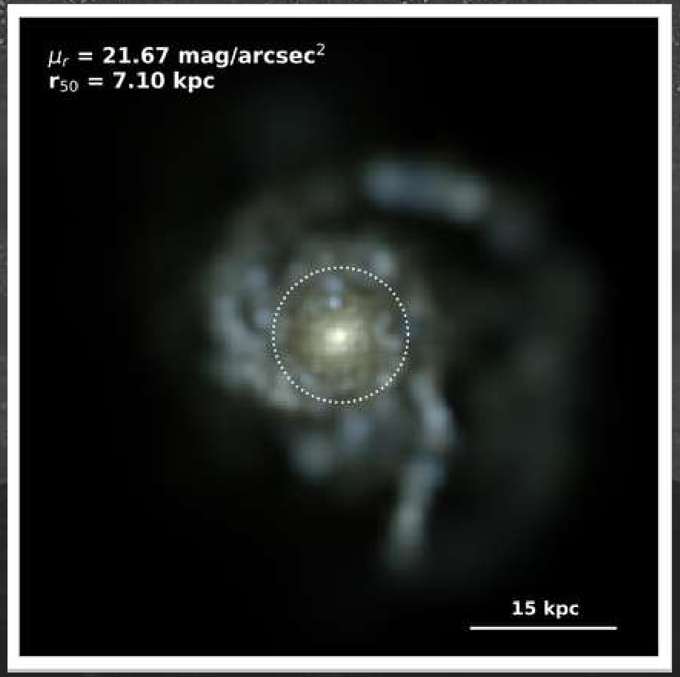
The full sample consists on 36,516 galaxies
- 13,899 LSBGs
- 22,617 HSBGs

Results: Global Statistics.

LSBGs at z=0 are found to be fainter, less massive and extended compared with HSBGs.

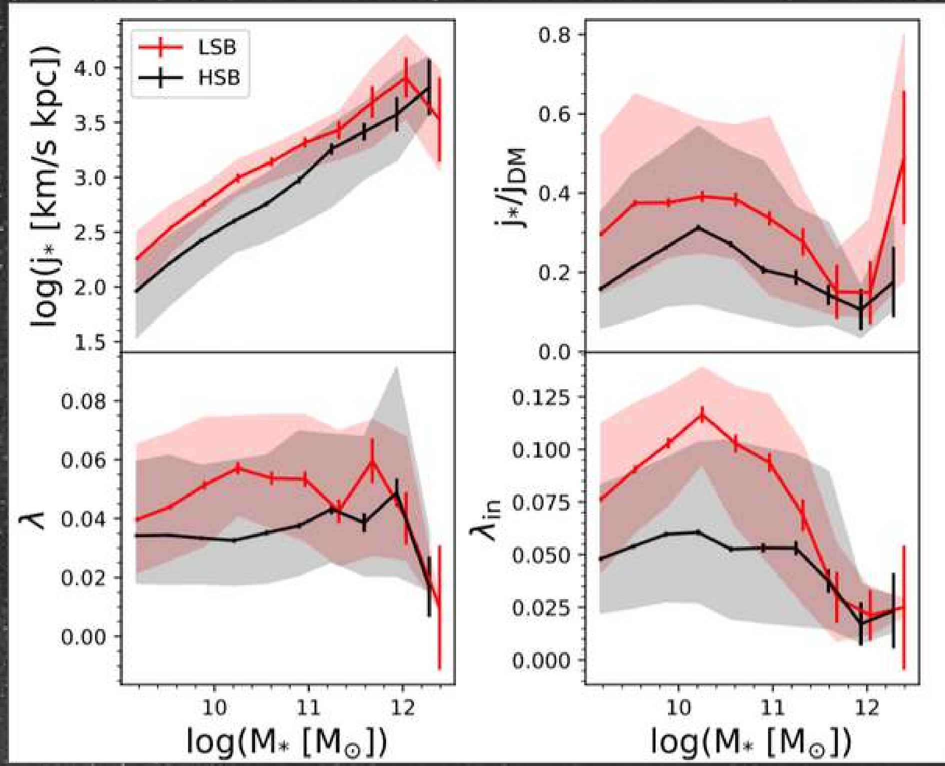






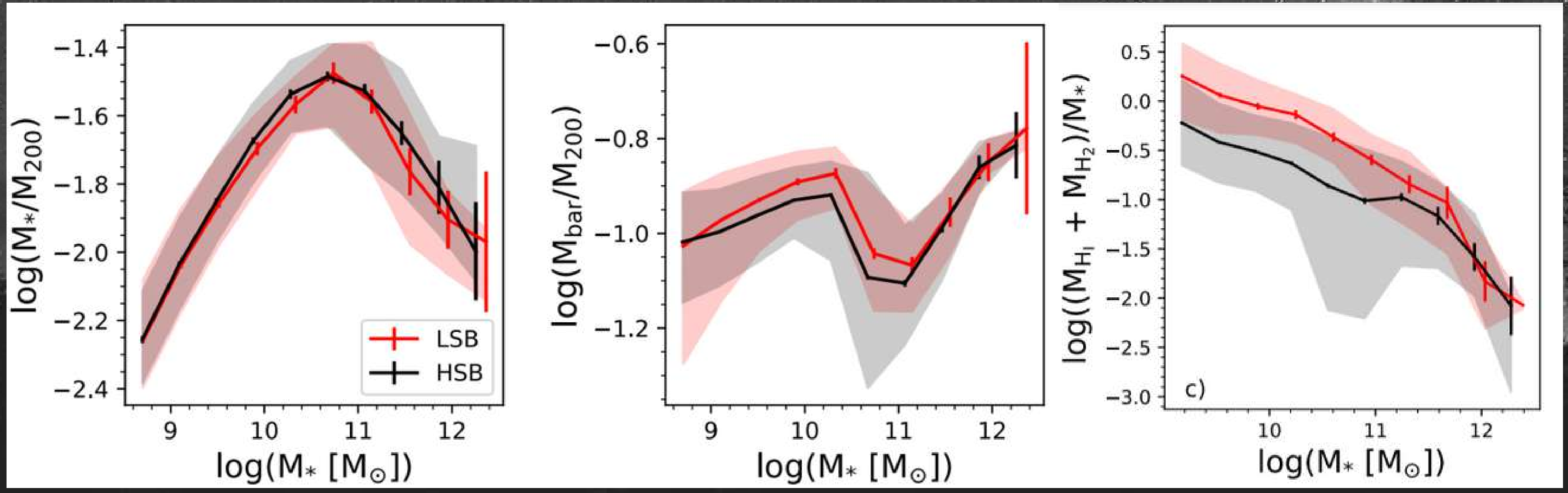
Results: Angular Momentum.

At fixed stellar mas, LSBGs present systematically higher values of their spin parameter λ, and higher retention factors. This favours a scenario in which both result in higher stellar angular momentum in LSBGs



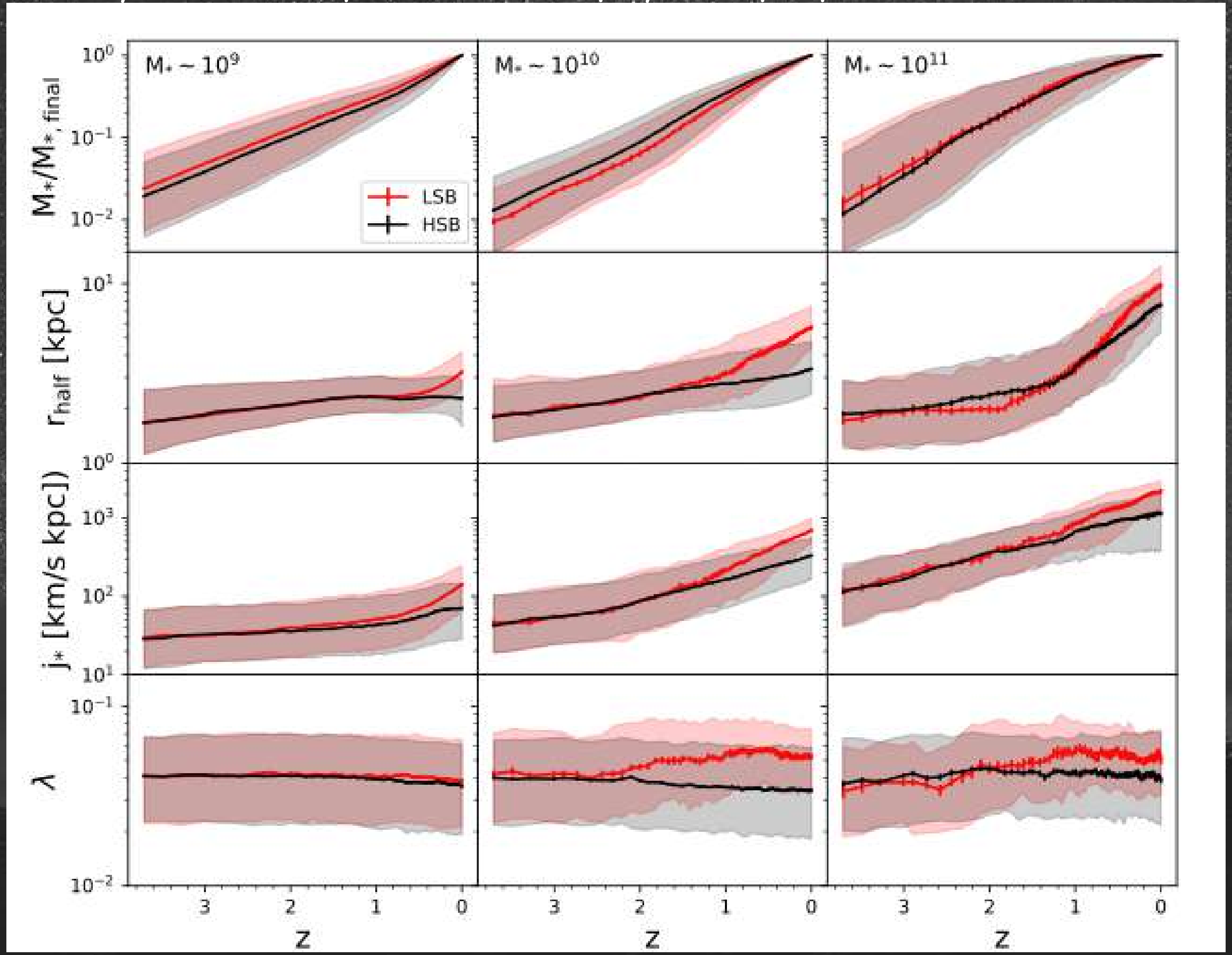
Results: Baryonic Content.

LSBGs present marginally smaller stellar-to-halo mass fraction compared with HSBGs, but higher baryonic-to-halo mass. Given tha LSBGs are formed within halos with similar mass at fixed stellar mass, the excess in the baryonic budget must consist of gas.

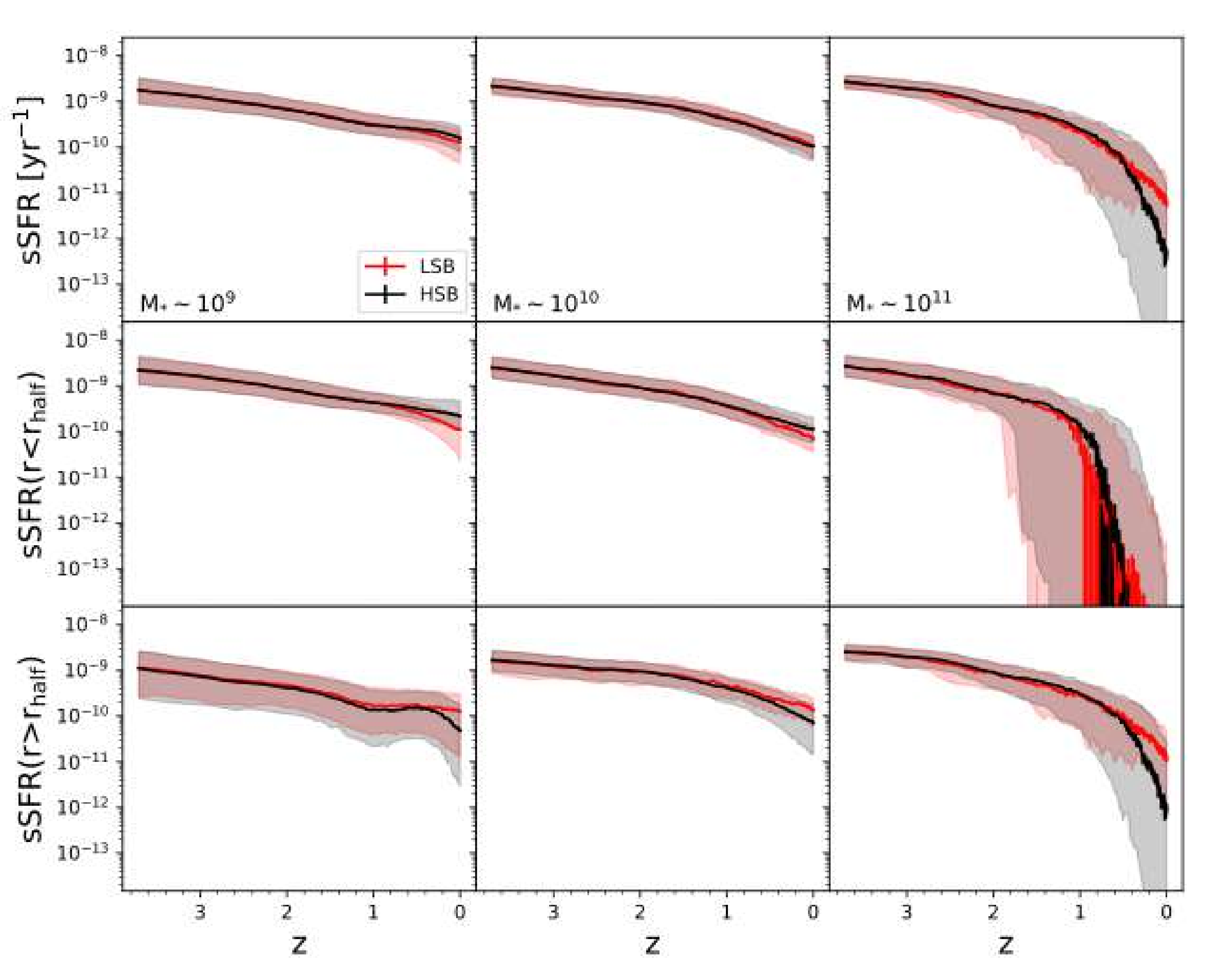


Results: Redshift Evolution

There is no significant difference in the stellar mass assembly between LSBGs and HSBGs. The redshift evolution shows a bifurcation of rhalf and j_* at z~0.5-1.5. The evolution of λ in the parent haloes of LSBGs and HSBGs exhibit a divergence of nearly a factor of 2 at a slightly earlier redshift, suggesting that the increase in λ may have an impact on other physical properties of the LSBGs



The central sSFR is less intense for LSBGs than for HSBGs at low redshift (z <1.5). The contrary is observed when we look at the sSFR at r > rhalf, indicating a more intense star formation in the outer regions of LSBGs when compared with HSBGs. These results are in agreement with previous studies in which LSBGs are produced through the accretion of high angular momentum material that promotes star formation at larger radii.



Summary and Conclusions.

- We built our simple according to the central surface brightness on the r-band, considering the flux of these stellar particles within the radius that contains half of the total luminosity.
- LSBGs are found to be fainter, less massive, gas-rich and more extended than their HSBGs counterparts.
- At fixed stellar mass, LSBGs consistently exhibit higher spin parameters and angular momentum ‘retention factors tan HSBGs. The combination of both result in the higher stellar angular momentum observed.
- LSBGs and HSBGs with similar mass are formed within DM halos of similar mass, but with LSBGs having larger amounts of baryonic content, mainly in the form of non-star-forming gas.
- Tracking the redshift evolution, the values of λ and j^* diverge at z~2-1.5 and as a consequence, the stellar component seems to be affected.
- Around z~1-0.5, LSBGs and HSBGs have similar star formation histories, but then both populations diverge when we compare the star formation activity in the inner and outer regions, being LSBGs the ones with most of their star formation activity in the outer regions.

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