Giant Low Surface Brightness Galaxies in TNG100

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INTRODUCTION

What are GLSBGs?

1. Low Surface Brightness Galaxies (LSBGs) are those galaxies characterized by a surface brightness fainter than the one of the night sky.

2. First reported by Freeman (1970) as a very "unique" population of spiral galaxies with surface brightness $\mu_0 < 21.65$ mag/arcsec^2.

3. After the discovery of Malin 1 (Bothun et al. 1987; Impey & Bothun 1989), it has been found that this galaxy contains an extended stellar disk five times larger than the MW (Boissier 2016).

4. Such extended and massive sources are genuinely rare, and are part of the so-called 'Giant' Low Surface Brightness Galaxies (GLSBGs).

5. They present large neutral hydrogen masses, the most massive HI systems.

INTRODUCTION

How do GLSBGs are formed?

Up to 2020, about 83 GLSBGs have been reported in the literature.

A number of mechanisms have been proposed over the years to explain the formation of GLSBs:

i) Extreme late-type galaxies consuming gas at slower rate than normal galaxies.

ii) Formed from rare density peaks (3σ) within low density environments.

iii) Formed in high spin DM halos.

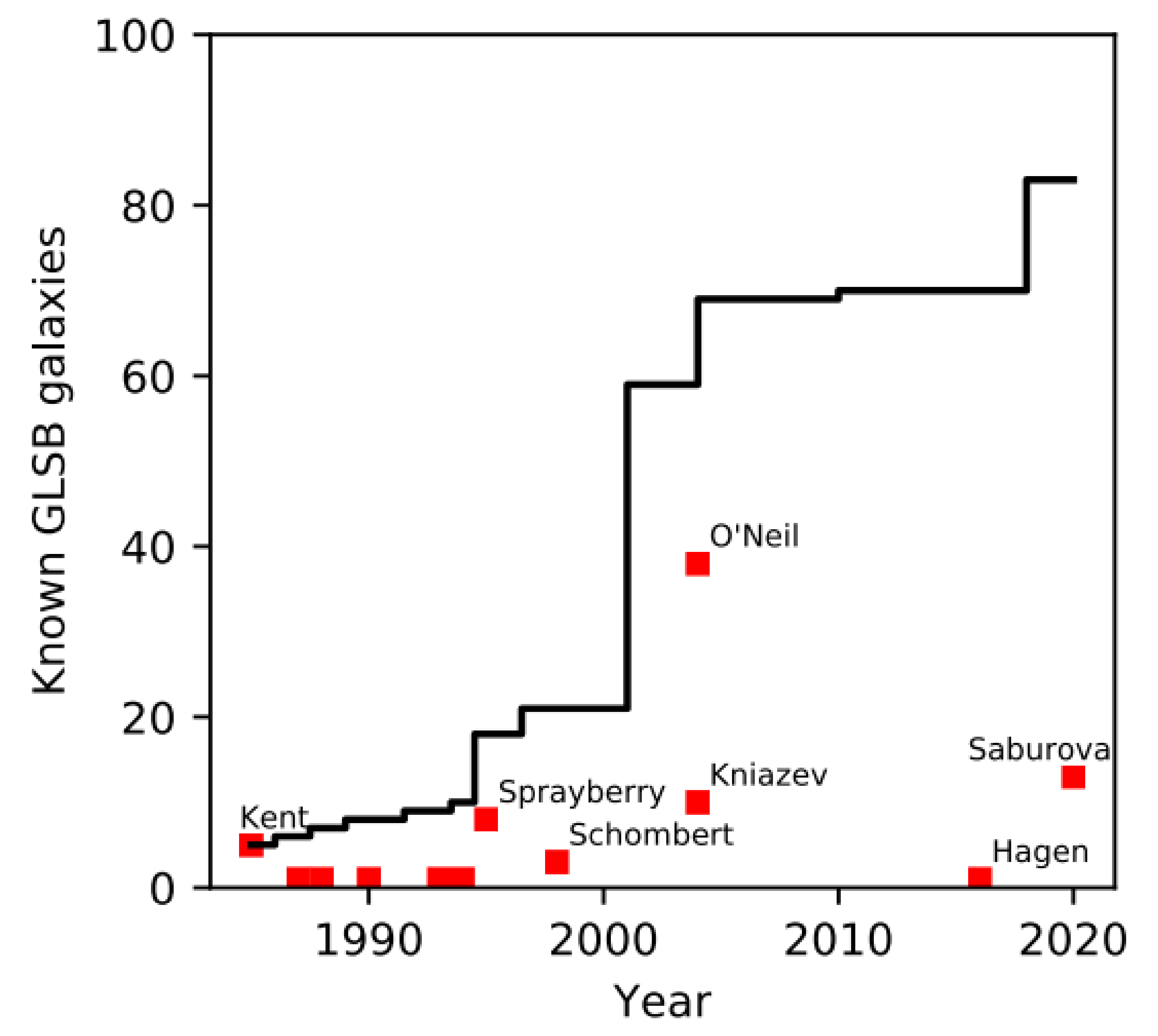
iv) Disk instabilities causing material to migrate outwards

v) Accretion of satellite galaxies.

vi) They are the result of head-on collisions.

vii) GLSBs form in massive and rarefied dark matter halos, hence shallower gravitational potential wells than normal galaxies

Zhu et al. (submitted)



A summary of GLSB galaxy discoveries since 1985.

THE SAMPLE

GLSBGs in the IllustrisTNG 100 cosmological simulation

We employed the TNG100 run of the IllutrisTNG project among sumplementary galaxy catalogs which include the halo spin parameters (Zjupa & Springel 2017), as well as galaxy merger histories (Rodriguez-Gomez 2015).

GLSBGs candidates are selected based on their HI distribution, such that $R_{HI} > 50$kpc, where R_{HI} is measured where the surface mass density drops below $1\,M_{\odot}\,pc^{-2}$.

Due to the HI size-mass relation, this naturally implies a large total HI mass, above $10^{10}\,M_{\odot}$

From visual inspection, galaxies with wraped features (those with undergoing mergers) are removed from the GLSBGs candidates.

The total number of GLSBGs candidates is 203

THE SAMPLE

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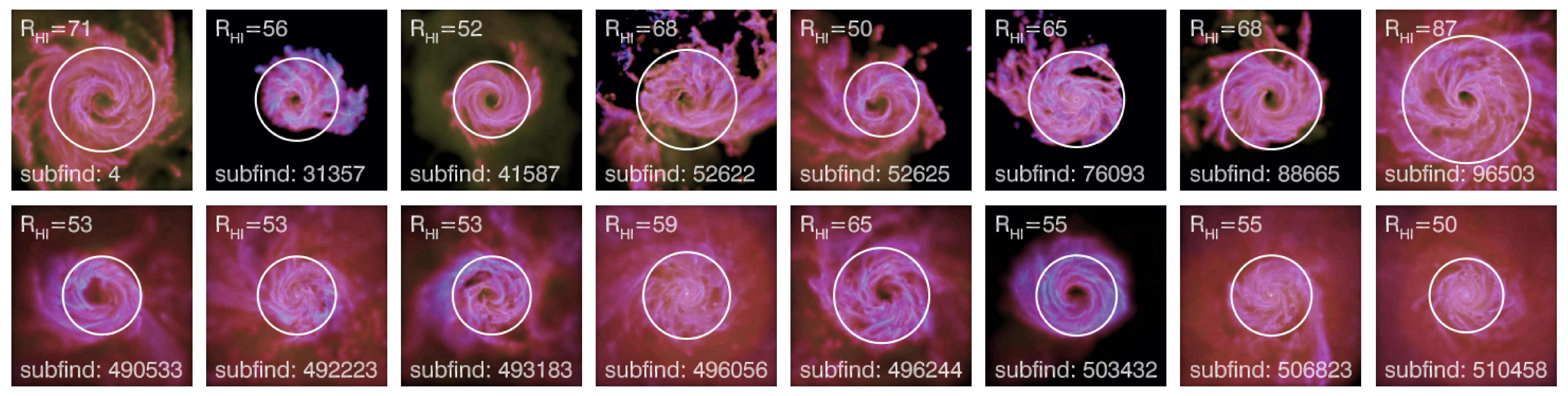
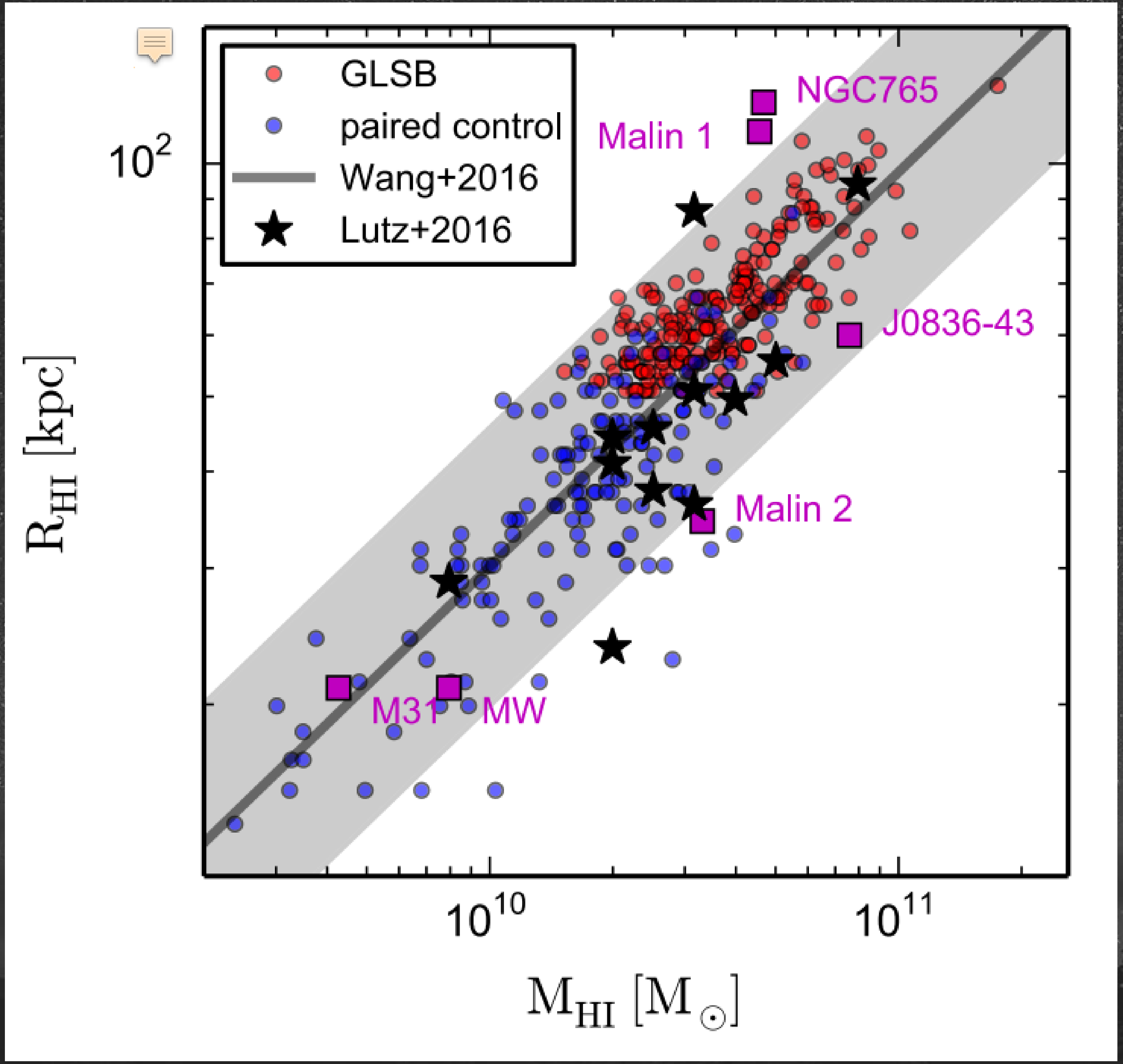


Face-on view of extended cold H i disks in GLSB candidates selected from TNG100. Only 16 out of 203 candidates are displayed here. The side length for each panel is 250 kpc.

The Sample

"Paired" Control Samples and "Normal" Galaxies



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We constructed two sets of Control Samples for statistical purposes for comparison:

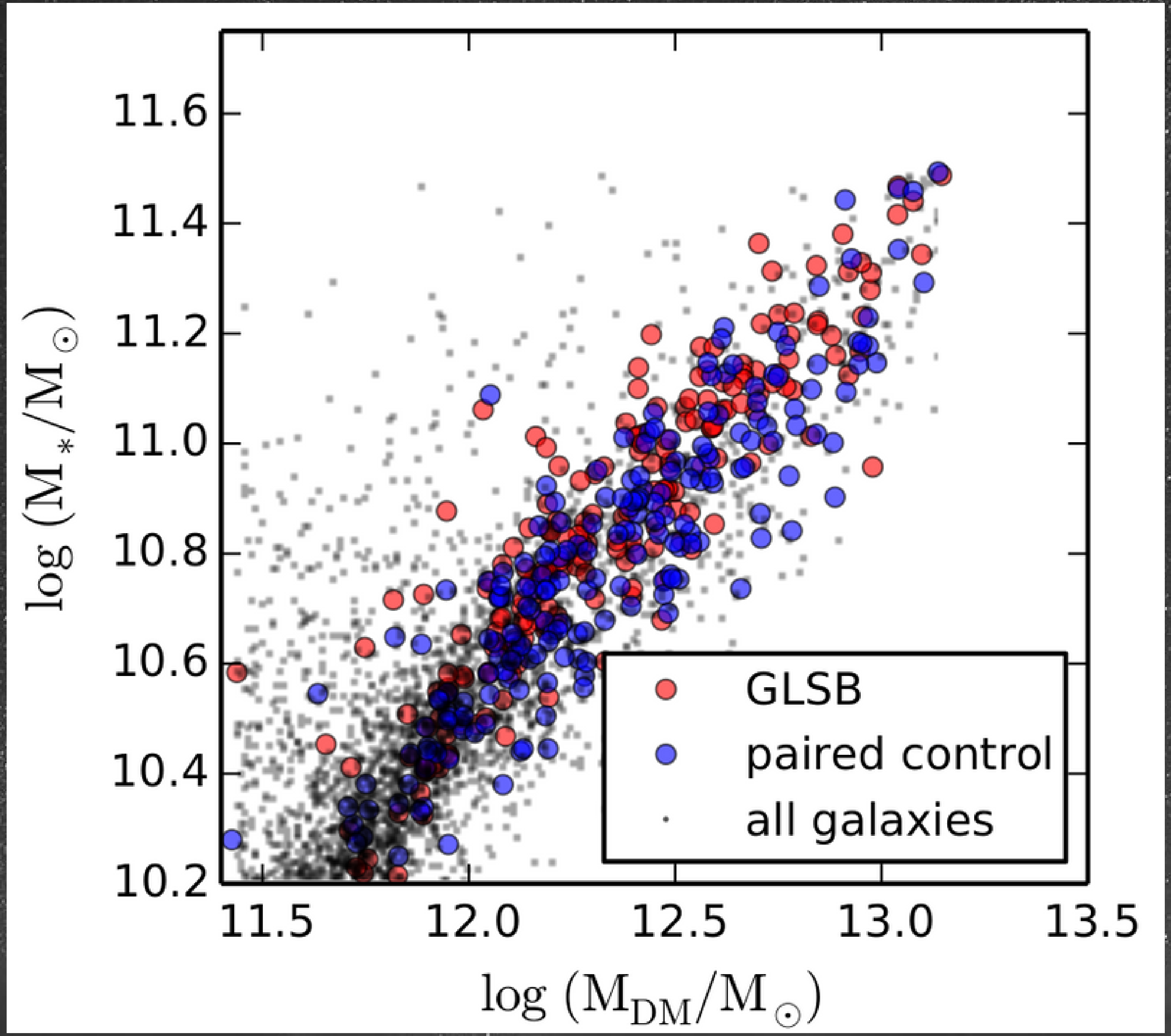
i) A Paired Control Sample: For a given GLSBG, we search the closest neighbour in the M_*-M_{DM}-M_{HI} plane.

ii) Normal Galaxies: Consisting in all the galaxies in TNG100 within the stellar mass range of the GLSBG sample ($10.2 < \log(M_*) < 11.6$).

The mass-size relation in these GLSBGs is consistent with observations, and is well fitted by the Wang et al. (2016) regression.

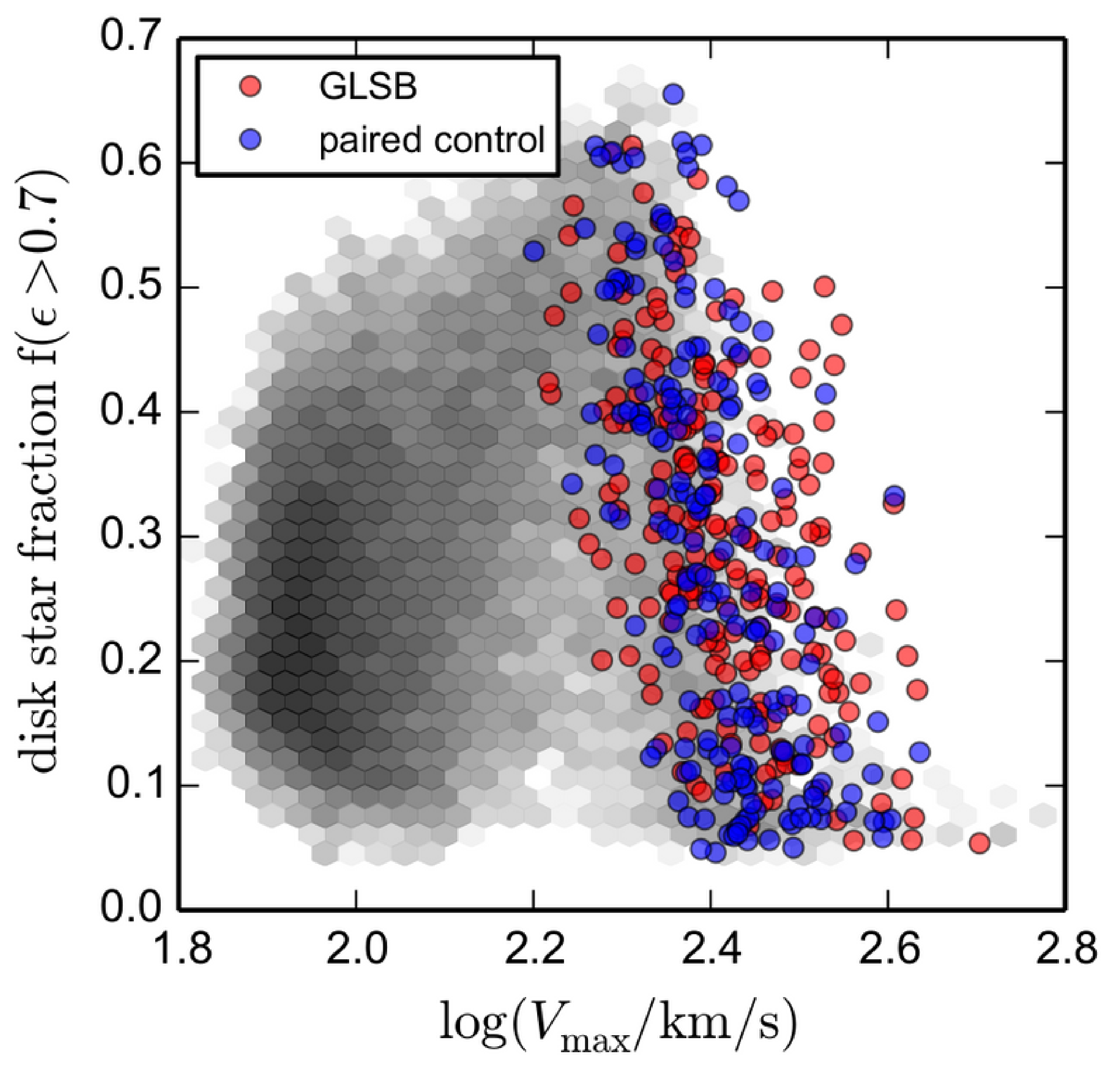
RESULTS

Main galaxy properties



GLSBs are mostly massive systems with total dark matter mass above $10^{12} M_\odot$ and stellar mass above $10^{10} M_\odot$

$f_{e>0.7}$... The fraction of stars with circularity e>0.7



$f_{e>0.7}$ peaks at Vmax = 200 km/s and drops towards both, higher and lower Vmax. The drop of $f_{e>0.7}$ with Vmax > 200 km/s reflects a transition from early type to late-type galaxies.

Zhu et al. (submitted)

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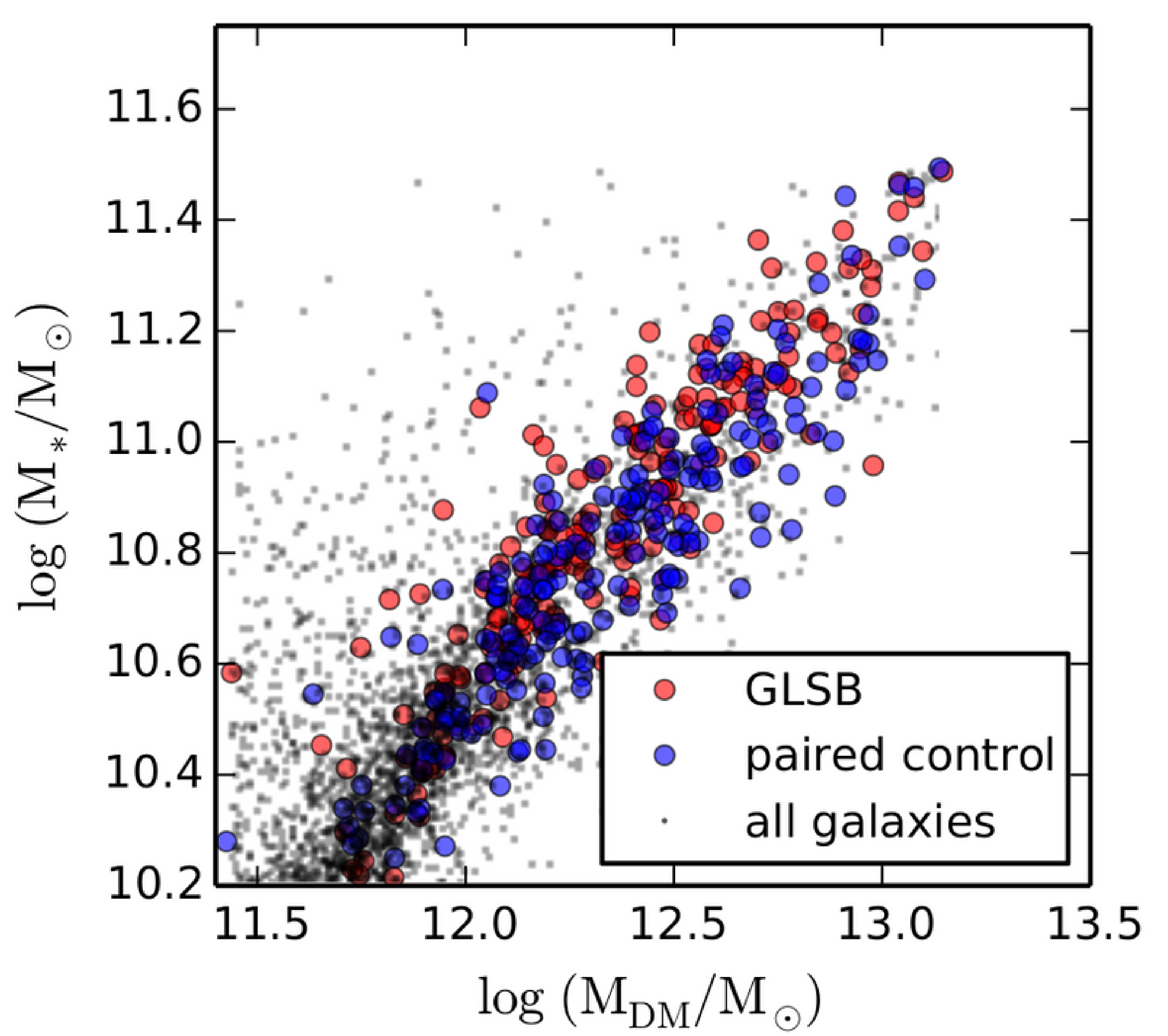

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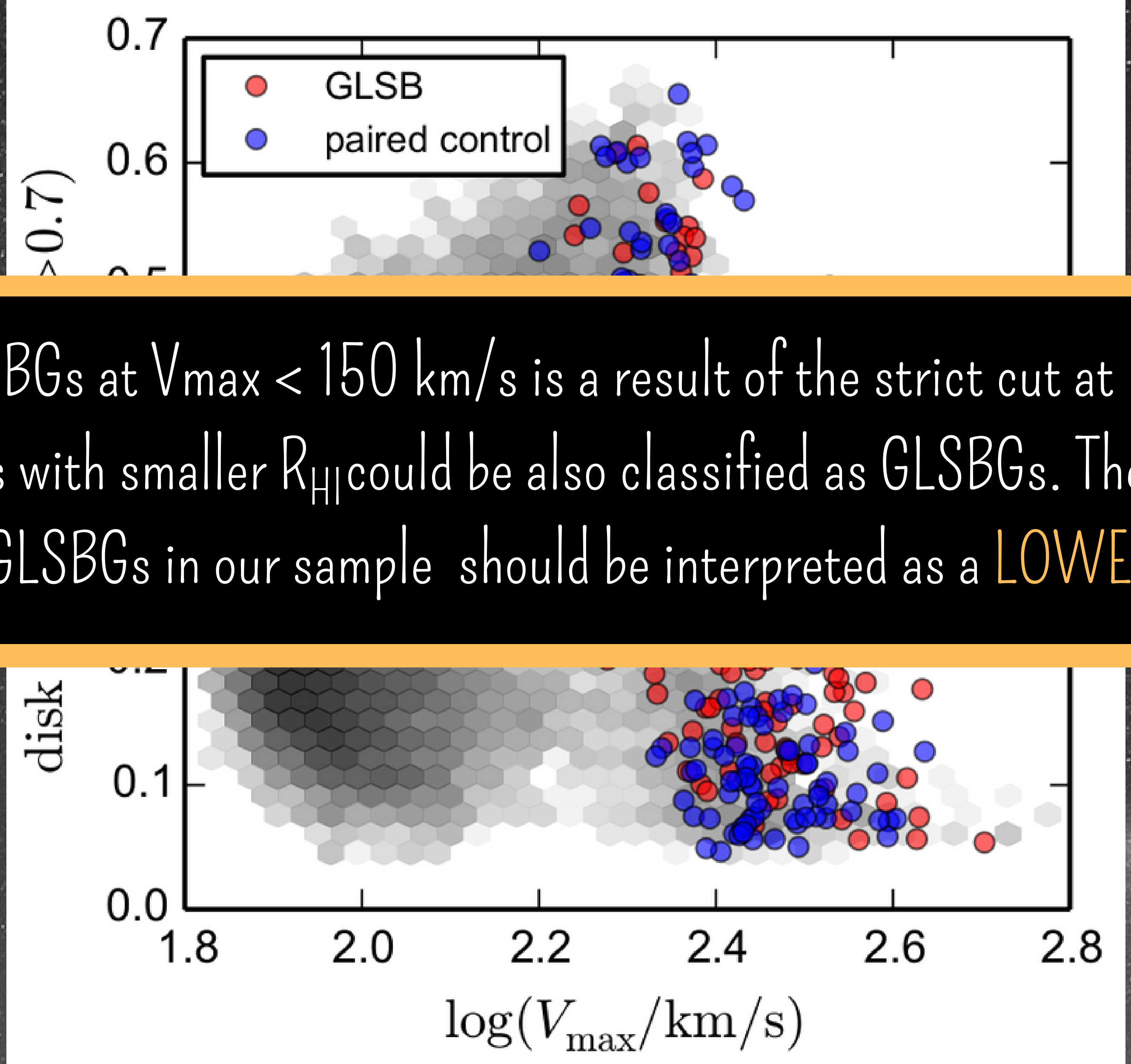

The lack of GLSBGs at Vmax < 150 km/s is a result of the strict cut at R_{HI} = 50 kpc. Some galaxies with smaller R_{HI} could be also classified as GLSBGs. Therefore, the number of GLSBGs in our sample should be interpreted as a LOWER LIMIT.

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Zhu et al. (submitted)

RESULTS

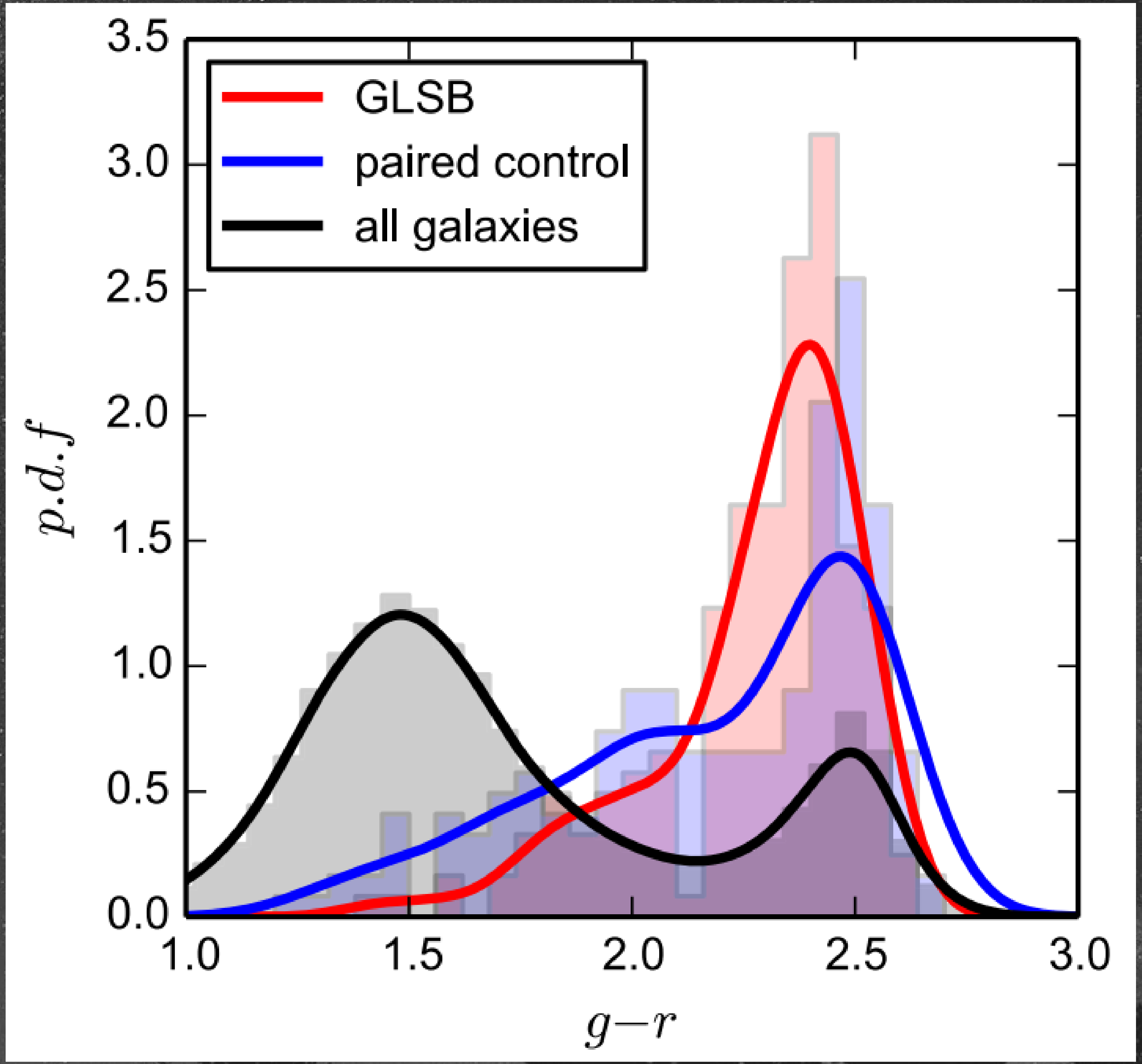
Color-magnitude diagram and Star Formation.

GLSB galaxies often contain high surface brightness inner components.

Diffuse UV emission has been detected in a number of GLSBGs, which is a sign of current star formation activity (O'Neil et al. 2007, Boissier et al. 2008,2016).

The color bimodality separates the all TNG100 galaxies into two well-defined peaks. For GLSBs, the peak for blue galaxies is absent.

Zhu et al. (submitted)



Galaxy u − r distributions for GLSB, control and all TNG100 galaxies at z = 0.

RESULTS

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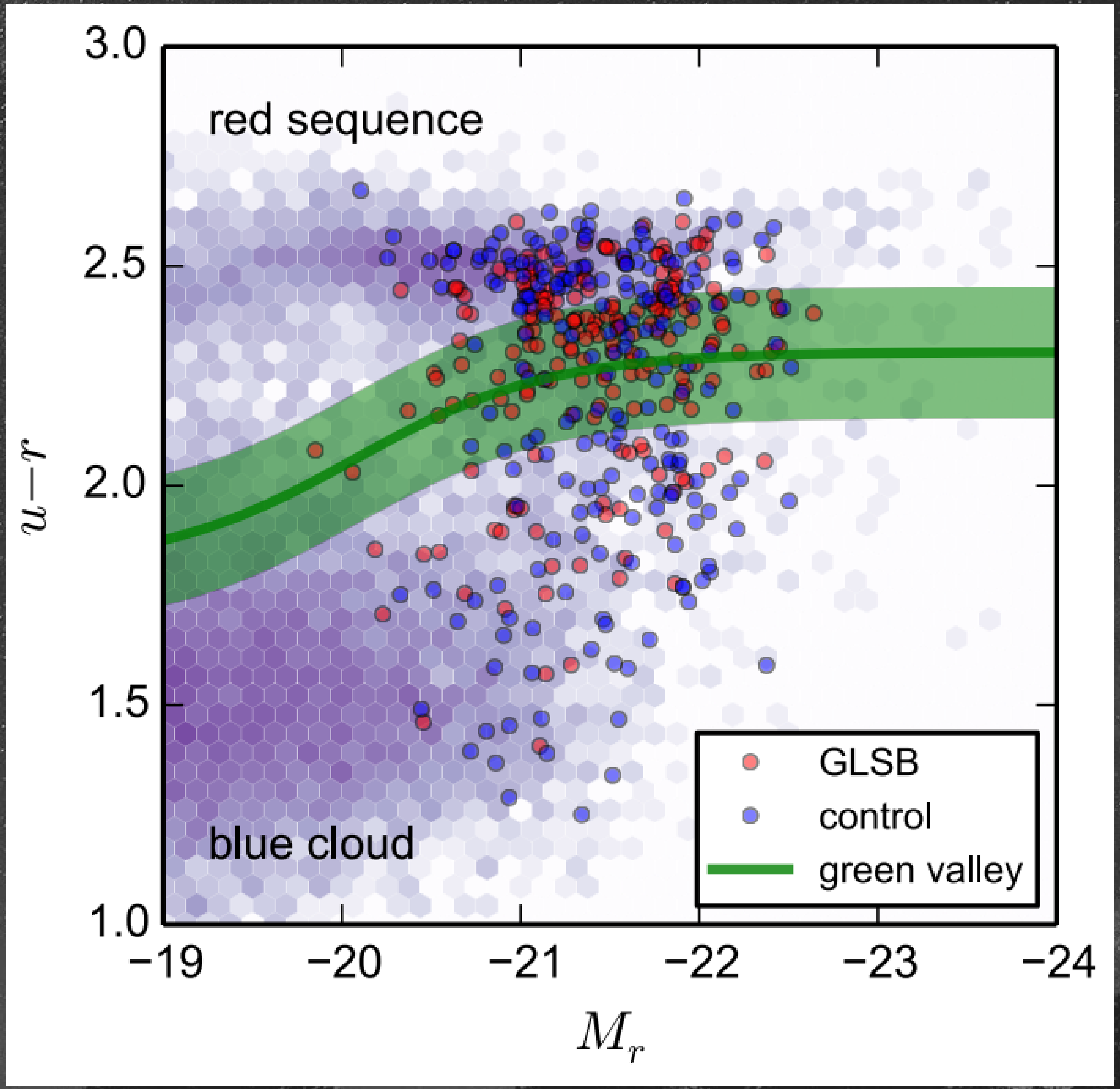

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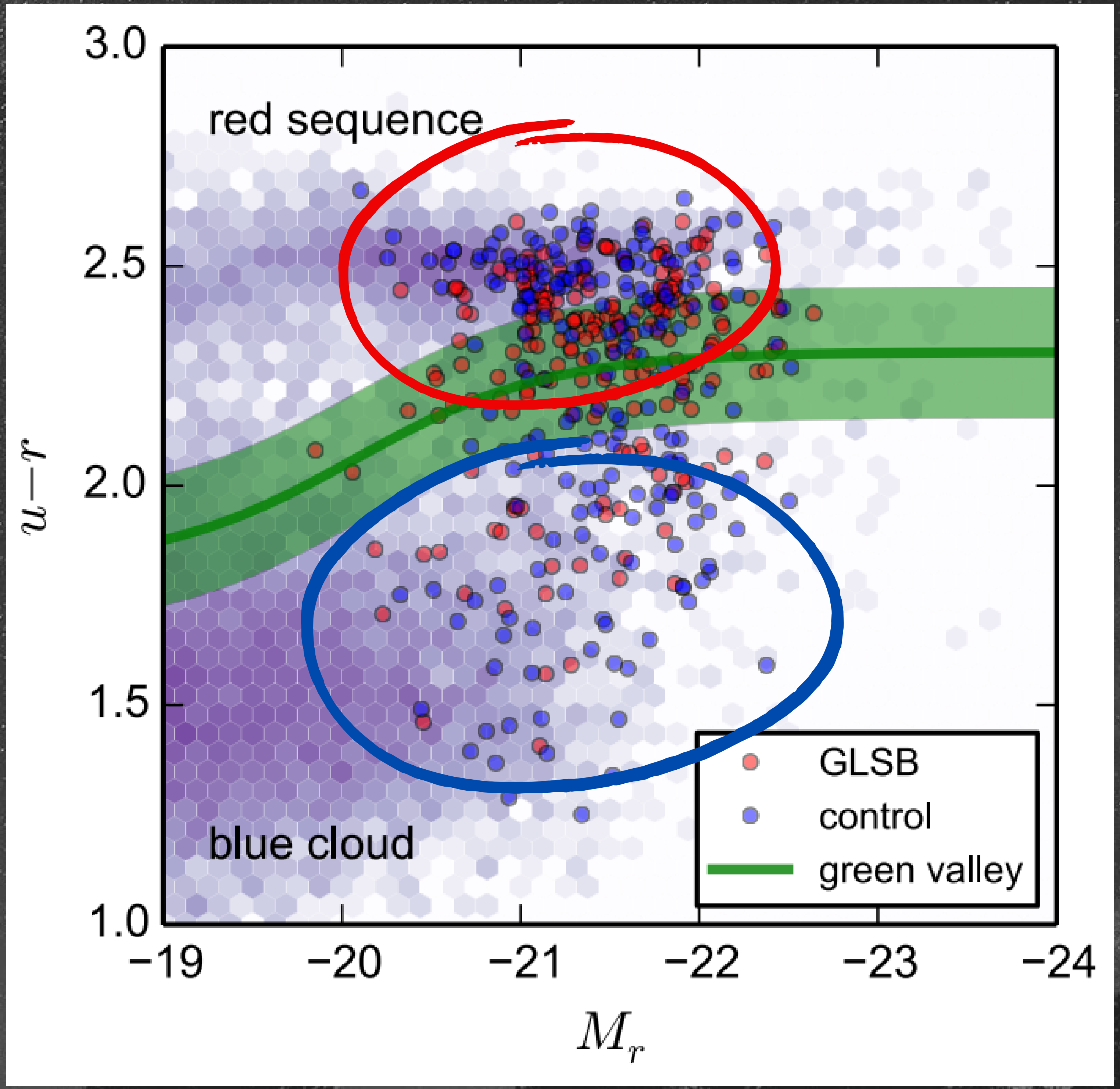
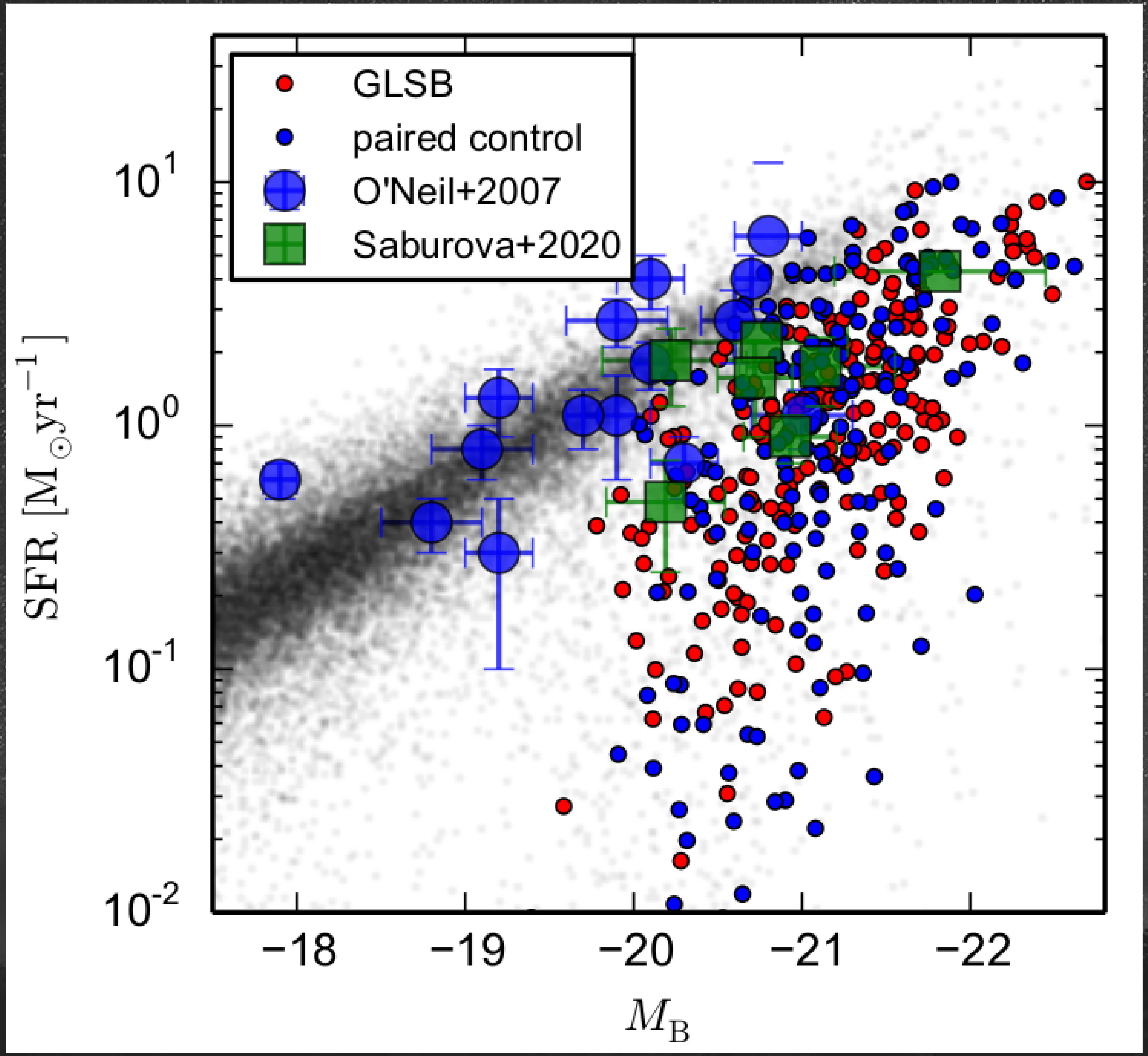


Many GLSB galaxies around the green valley are in transition
between the blue and red galaxies, often still with ongoing star formation activities.

RESULTS

Color-magnitude diagram and Star Formation.



Zhu et al. (submitted)

It can be observed that a good fraction of the GLSBGs sample is characterized by SFR $< 1M_\odot/yr$.

This is consistent with that most of the galaxies are located between de green valley and the red sequence .

Although GLSBGs generally contain more gas, as long as it remains diffuse, no significant higher level of star formation activity is seen.

A comparison of total star formation rate (SFR) vs. the total B-band magnitudes for GLSBGs, compared with observational meassurements.

RESULTS

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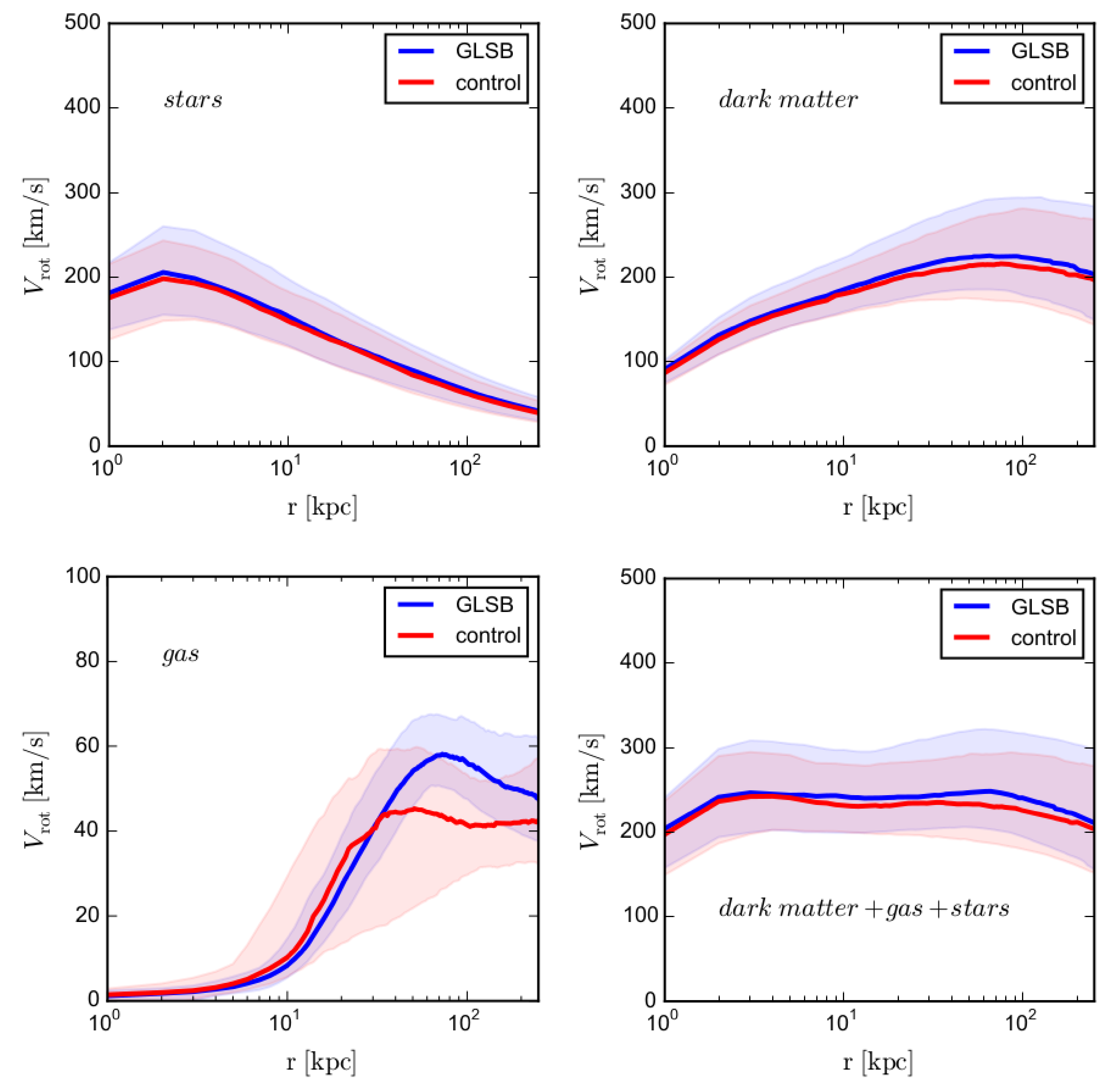
Mass distribution

For the total mass distribution, the solid curve shows a flat rotation curve, with a median value of 240 km/s, consistent with observations (Kasparova et al. 2014, Mishra et al. 2017, Saburova et al. 2021, end more...).

It is only in the gas distribution that we find differences in the mass distribution, where the GLSB sample contains larger gas masses

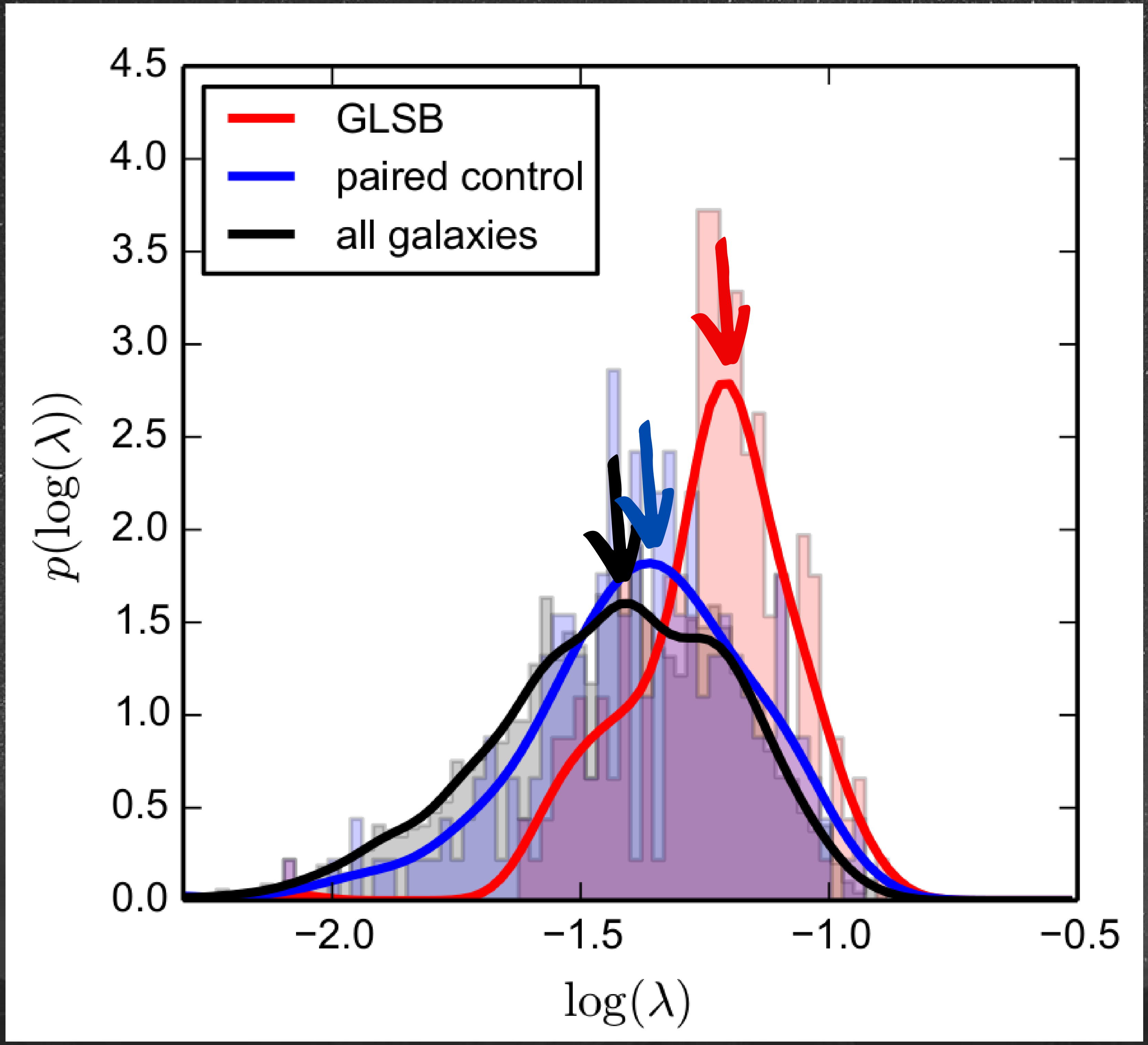


The rotation curves, in the form of enclosed mass

$V^2_{rot} = GM_{en}/r$

RESULTS

Spin Parameter



Zhu et al. (submitted)

$$\lambda = \frac{J_{\rm tot}}{M_{\rm tot}} \frac{E_{\rm tot}^{1/2}}{G M_{\rm tot}^{3/2}}$$

The median values for the spin parameter are 0.038 and 0.043 for the two control samples. For GLSBGs is 0.060, ~40% larger, in a good agreement with previous studies employing simulations (Kulier et al. 2020, Pérez-Montaño et al. 2022)

RESULTS

Merger History

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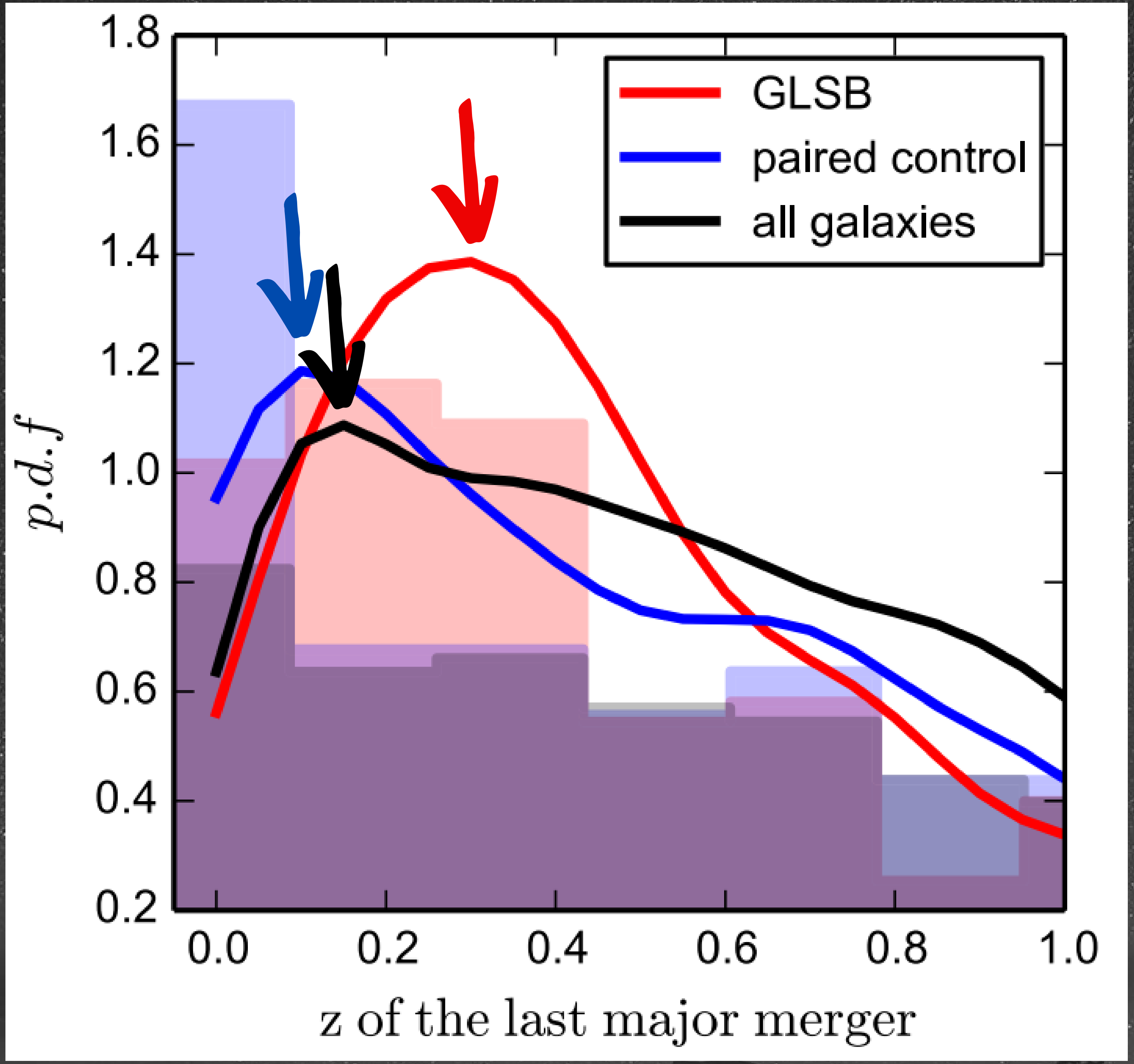
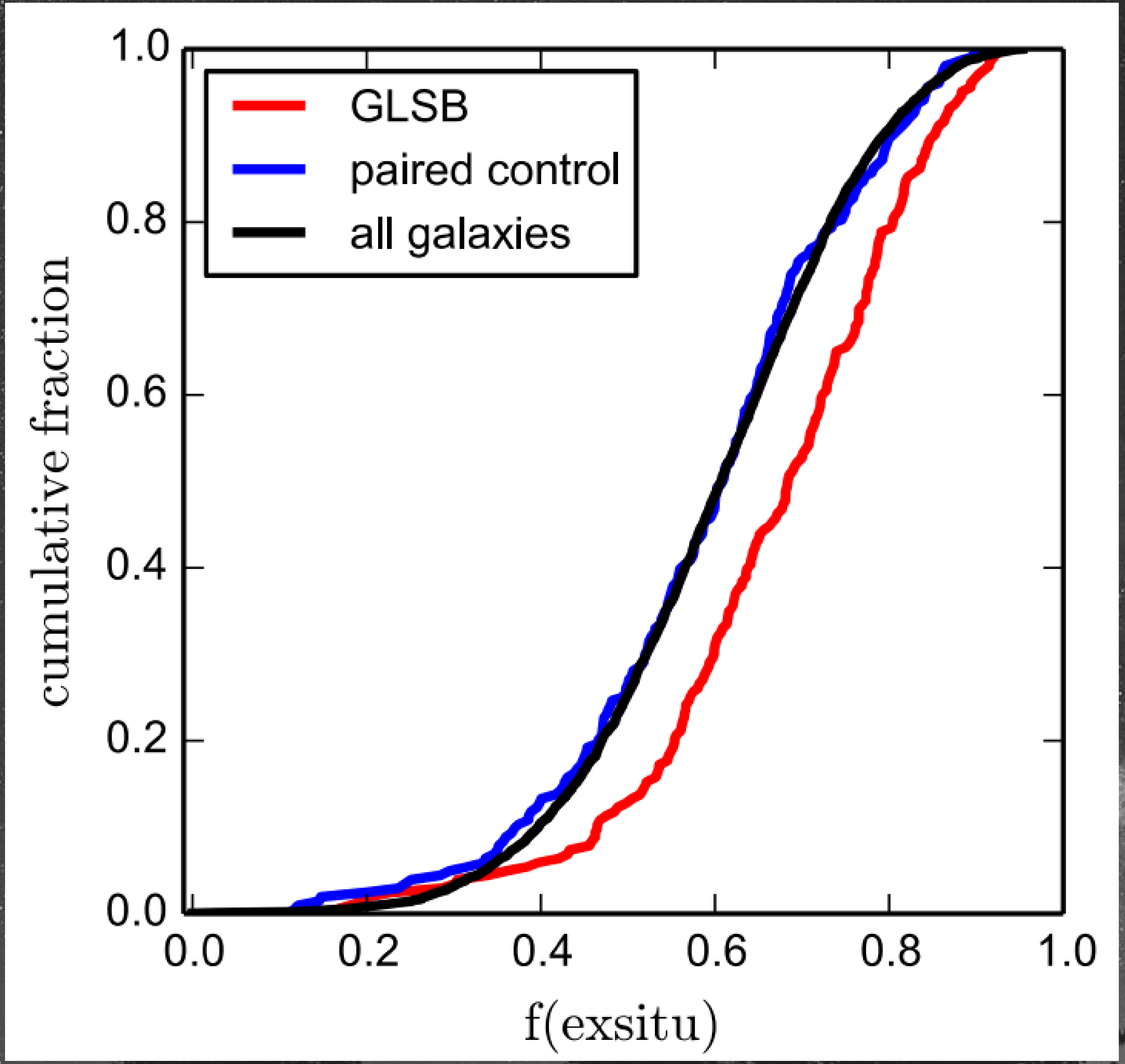


The GLSBGs sample contains a large number of galaxies with major mergers completed 2-4 Gyr ago. Galaxies in control samples, by contrast,have very recent mergers.



GLSB galaxies consistently show a larger f(exsitu), mostly driven by mergers, similar to Pérez-Montaño et al. (2022)

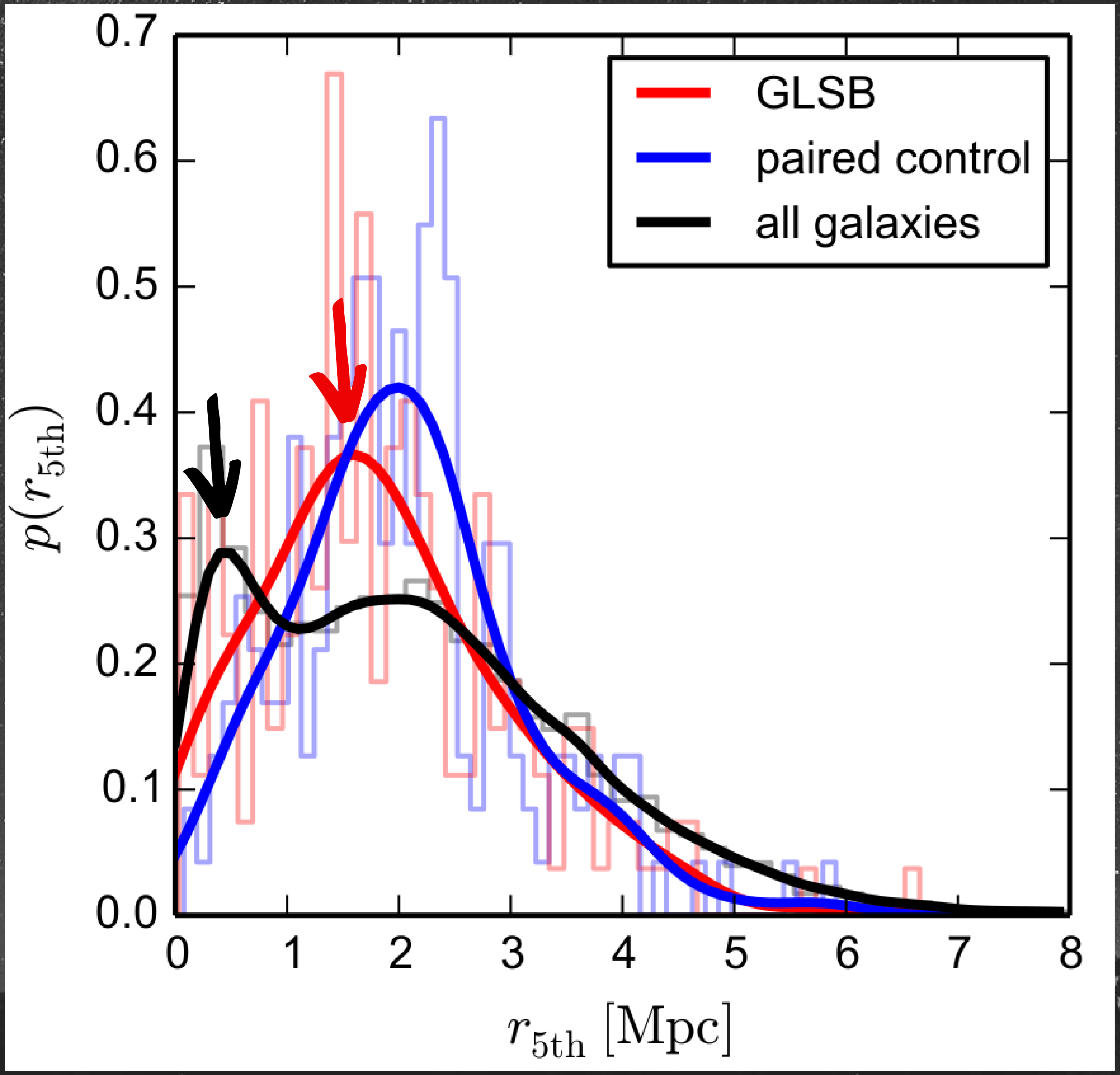
RESULTS

Environment

In general, LSBGs are most likely to be found within more isolated environments (Bothun et al. 1993, Rosenbaum et al. 2009, Reshetnikov et al 2010, Pérez-Montaño & Cervantes Sodi 2019).

GLSBGs are found to be further away from their 5th closest neighbor when compared with "all" TNG galaxies, reflecting a relatively isolated nature.

Zhu et al. (submitted)



DISCUSSION

How do GLSBGs form?

🤔 i) Extreme late-type galaxies consuming gas at slower rate than normal galaxies.

Relative isolattion leds to the survival of large disks already present, however, some galaxies experienced major mergers that disrupt the gas.

✗ ii) Formed from rare (3σ) density peaks within low density environments.

Both control and GLSBGs are located in more isolated environments than "all" TNG100 galaxies, but they are rarely found in voids.

✓ iii) Formed in high spin DM halos.

We found that massive GLSBGs would naturally form in massive halos with large spin parameter

✗ iv) Disk instabilities causing material to migrate outwards

Galaxies in our sample contains both early/late type galaxies (as in Kulier et al. 2020). The built-up of gas disks from galaxy mergers is observed directly form animations.

DISCUSSION

How do GLSBGs form?

✓ i) Accretion of satellite galaxies.

Given that GLSBGs are among the most HI massive systems, an additional chanel of cold gas supply is needed, such an external galaxy falling into host galaxies.

✗ ii) They are the result of head-on collisions.

The timing of the last major merger is significantly different (2-4 Gyr ago). Recent collisions (< 1 Gyr) are expected from previous studies (Mapelli et al. 2008). Moreover, a preferential in-spiral orbit is observed, which results in a well aligned gas-stellar components.

✗ iii) GLSBs form in massive and rarefied dark matter halos, hence shallower gravitational potential wells than normal galaxies

No significant difference is found in the dark matter mass distribution.

Thank you

Questions?