Feedback from intermediate-mass black holes on dwarf galaxy morphology at z = 2

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Motivation: Why Study IMBHs in Dwarf Galaxies?

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- Dwarf Galaxies: Shallow potential wells make them ideal testbeds.
- Simulations: Large-box models lack resolution for low-mass dwarfs.

Methodology

- GIZMO (Hopkins 2017), Plank Collaboration et al. (2016) ΛCDM model
- Zoom-in cosmological simulations
- Identical mass halos $M_{vir} \sim 10^{10}\, M_{\odot}$, high/low spin
- Resolution: ~ 74 pc (gas) and 118 pc (stars) at z=2
- Cooling and heating: KROME (Grassi et al. 2014), including photoheating, H2 UV pumping, Compton cooling, photoelectric heating, atomic cooling, H2 cooling, and both chemical heating and cooling.
- Star formation: a turbulence-driven approach as described by Lupi et al. (2018).
- Black hole:
  - "sub-grid" torques-driven accretion model (Hopkins & Quataert 2011)
  - Using minimum halo mass for BH seeding ($M_{HaloMin}$)
  - AGN wind feedback characterized by two parameters: the mass loading β and the wind velocity v

Simulation sets

Model no.	z_f	$\log M_{vir}$ [$M_\odot$]	λ	v_{wind} [$km\ s^{-1}$]	M_{seed} [$M_\odot$]	$M_{HaloMin}$ [$M_\odot$]	BH present
NoBHL	2	~10	~0.035	N/A	N/A	N/A	No
BHs4hl6v2L	2	~10	~0.035	2000	5×10^4	10^6	Yes
BHs4hl7v2L	2	~10	~0.035	2000	5×10^4	10^7	Yes
BHs4hl6v10L	2	~10	~0.035	10 000	5×10^4	10^6	Yes
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NoBHH	2	~10	~0.1	N/A	N/A	N/A	No
BHs4hl6v2H	2	~10	~0.1	2000	5×10^4	10^6	Yes
BHs4hl7v2H	2	~10	~0.1	2000	5×10^4	10^7	Yes
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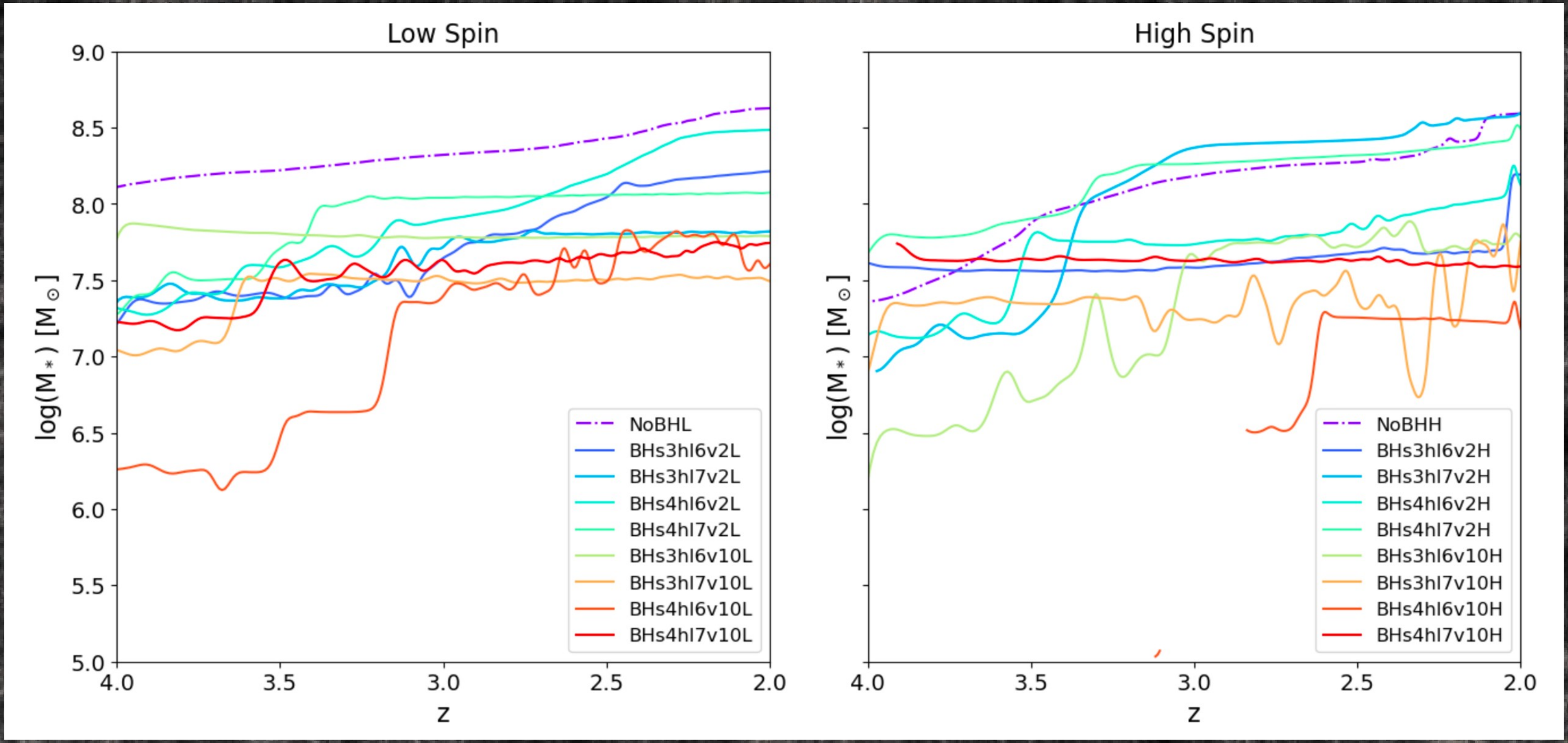
Results: Galaxy General

[* z=4-2, 1.8Gyr]



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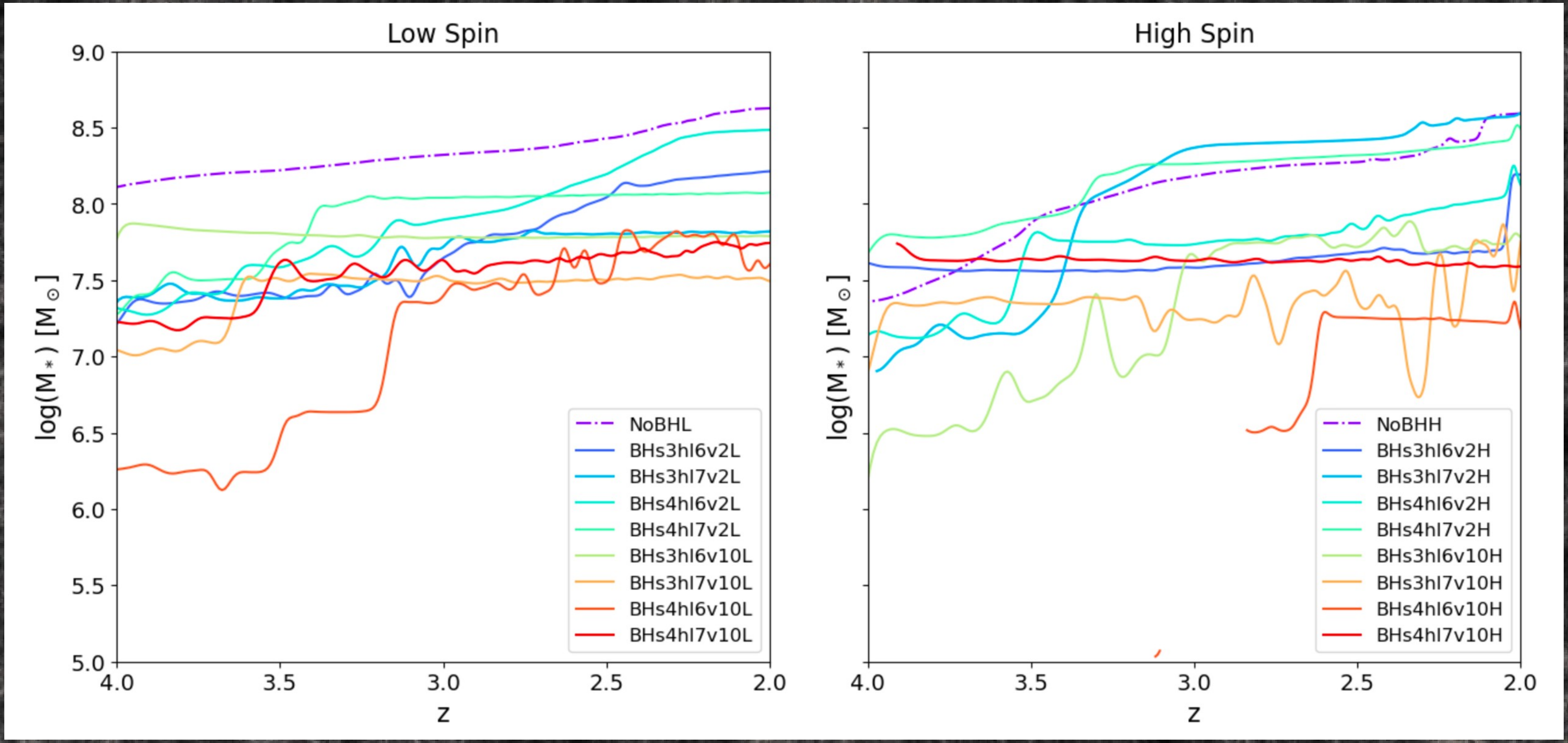
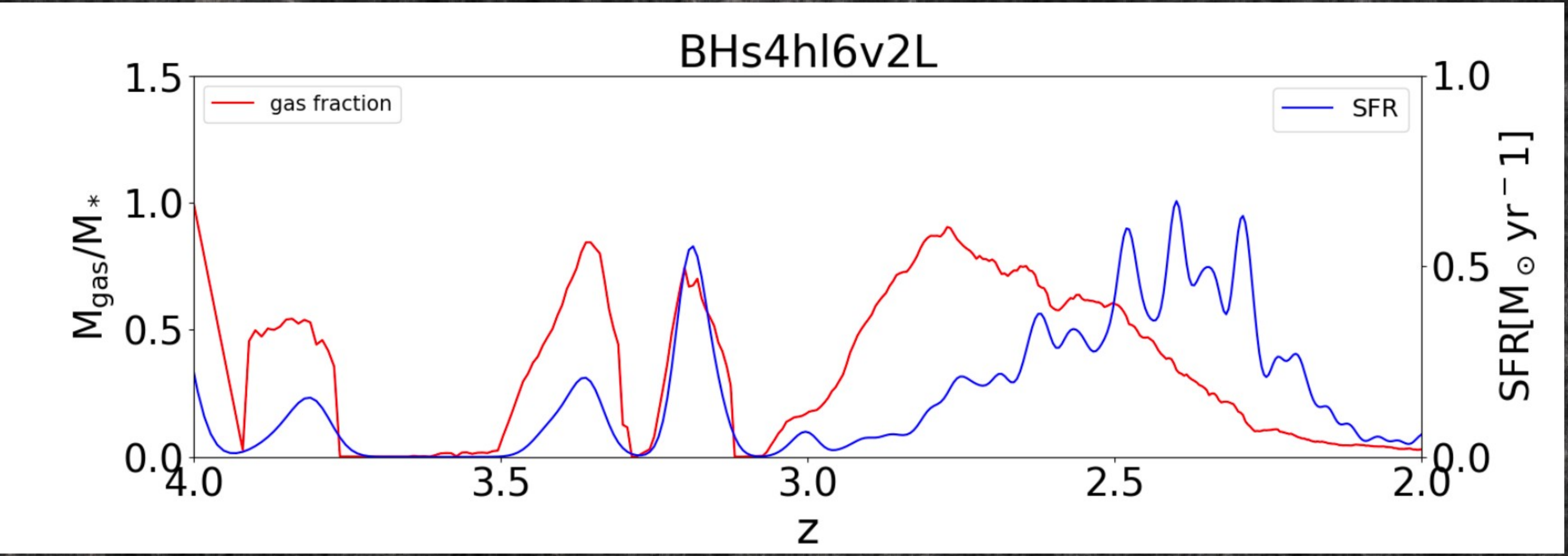


- The final stellar mass of galaxies exhibits no significant dependence on the halo spin parameter λ, yet shows a strong correlation with the BH models.

Example: BHs4hl6v2L



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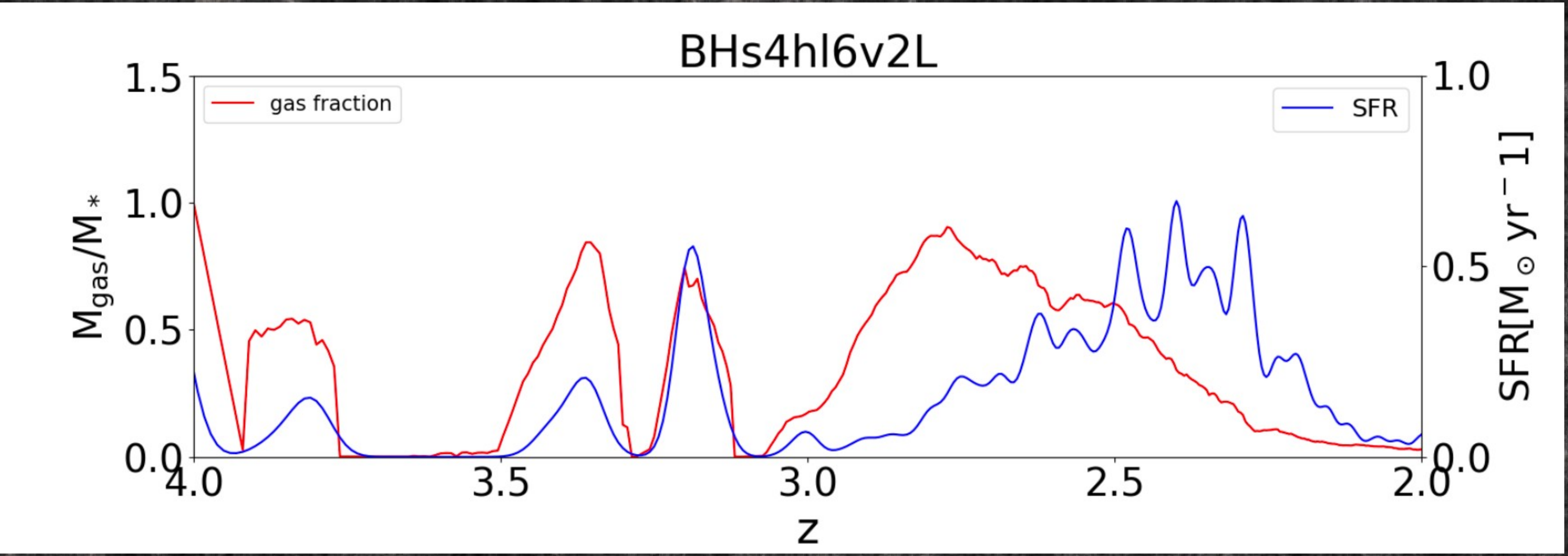

Correlation between SFR (blue) and gas fraction (red): galaxy experience frequent starbursts, a phenomenon associated with galaxy quenching.

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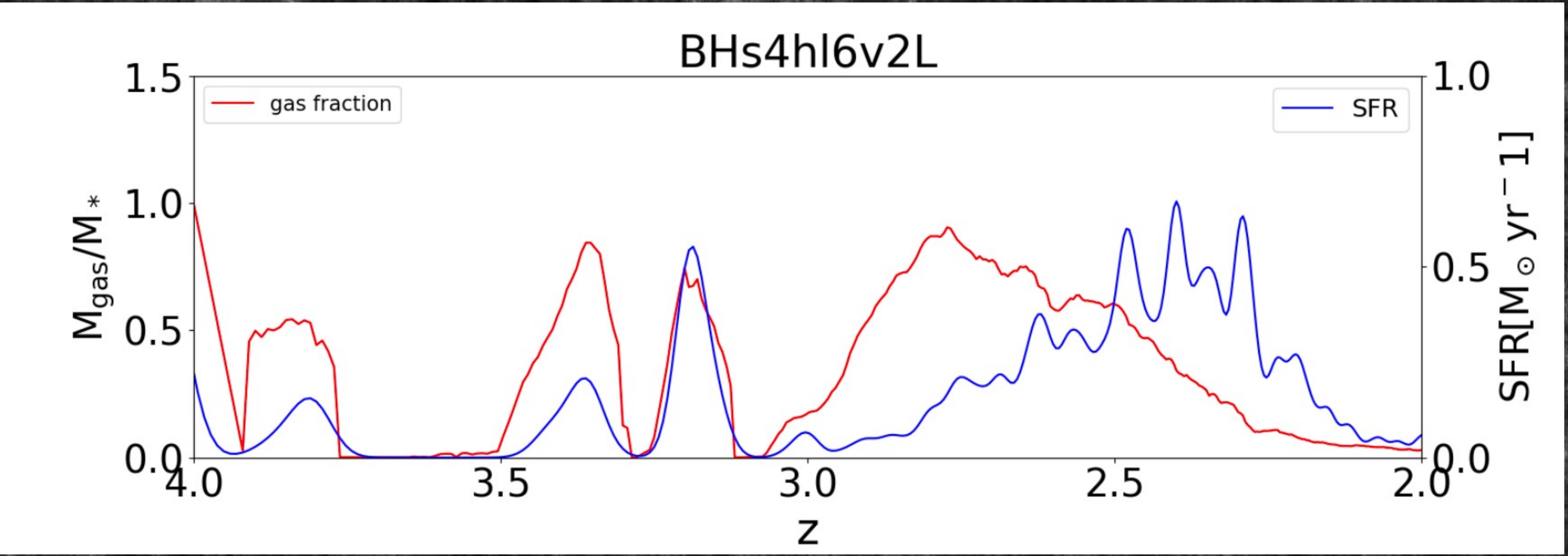

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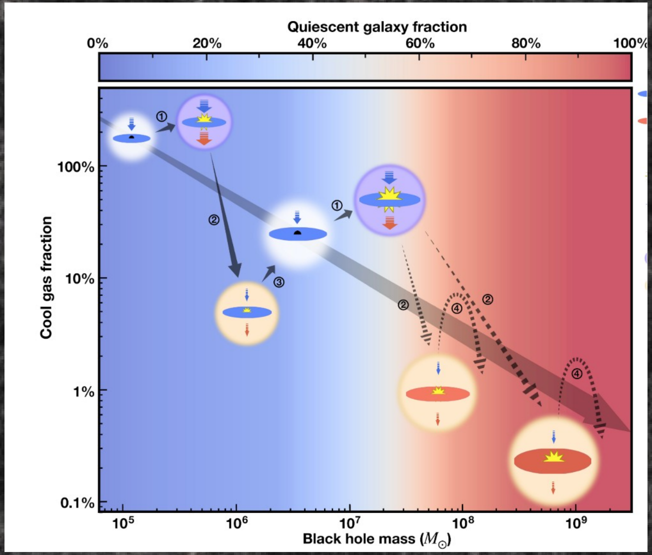
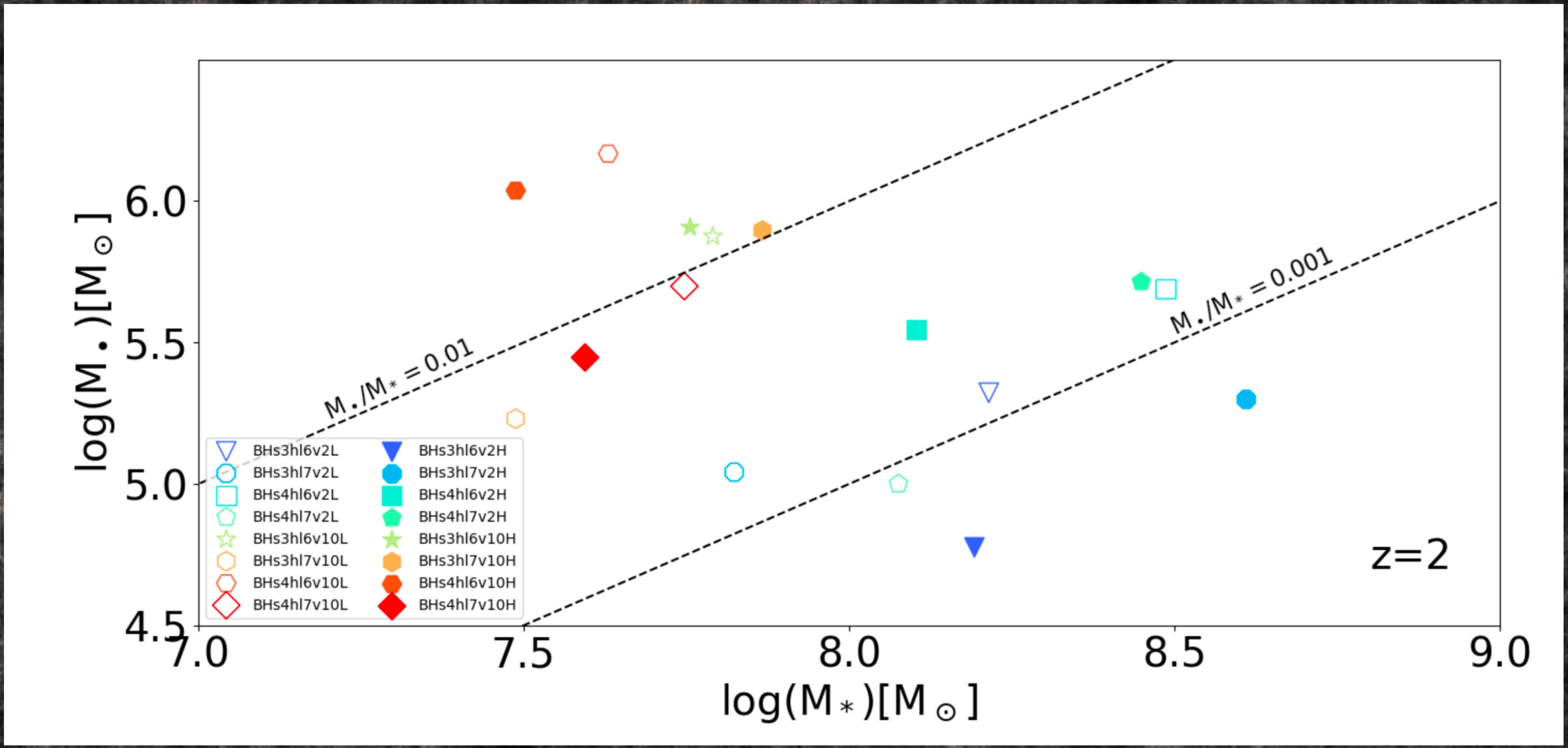


(Wang et al. 2020)

Results: $M_\bullet - M_\star$



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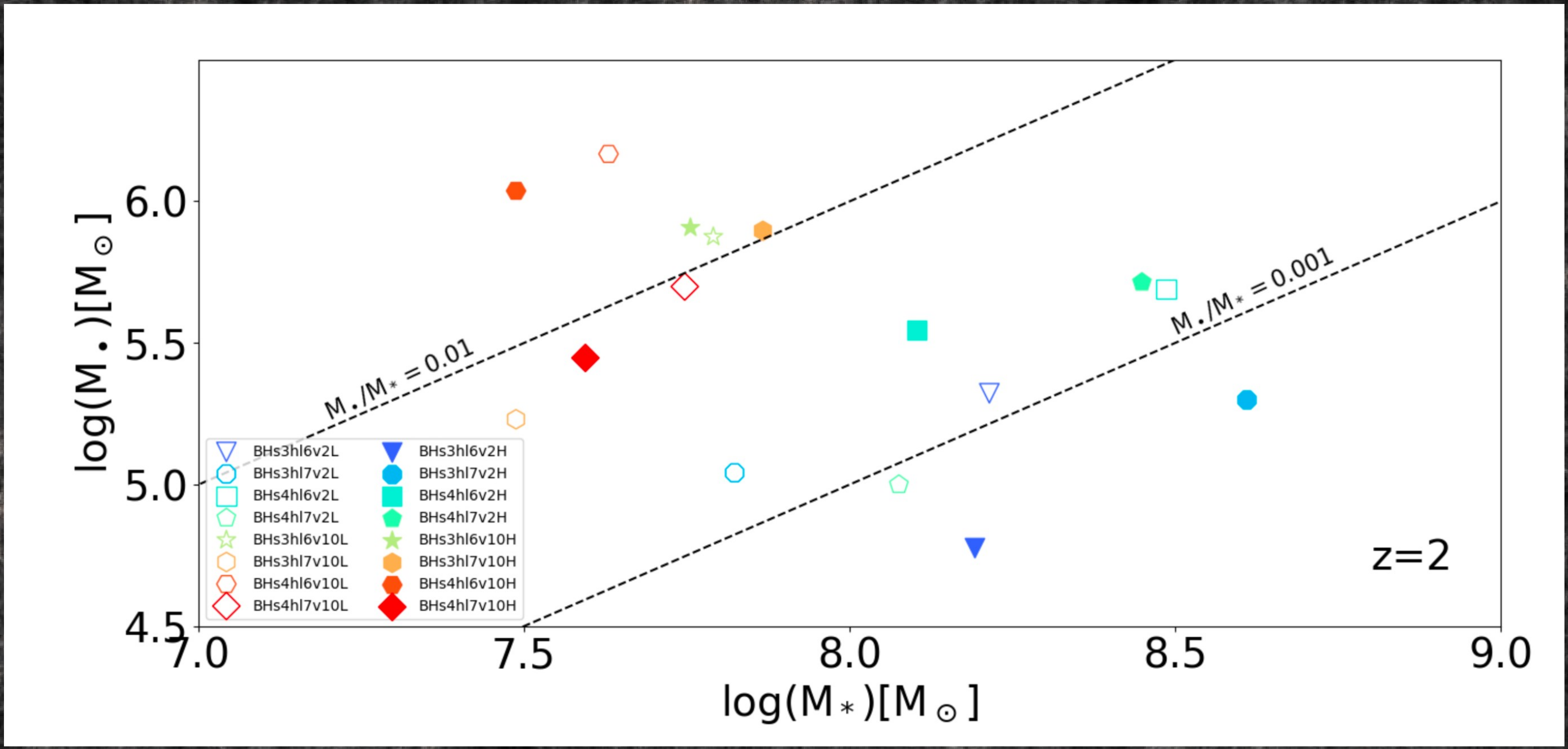

- $M_\bullet - M_\star$ range overlap with JWST spectroscopic data from Harikane et al. (2023), Yue et al. (2024), Ding et al. (2023) and Maiolino et al. (2024).

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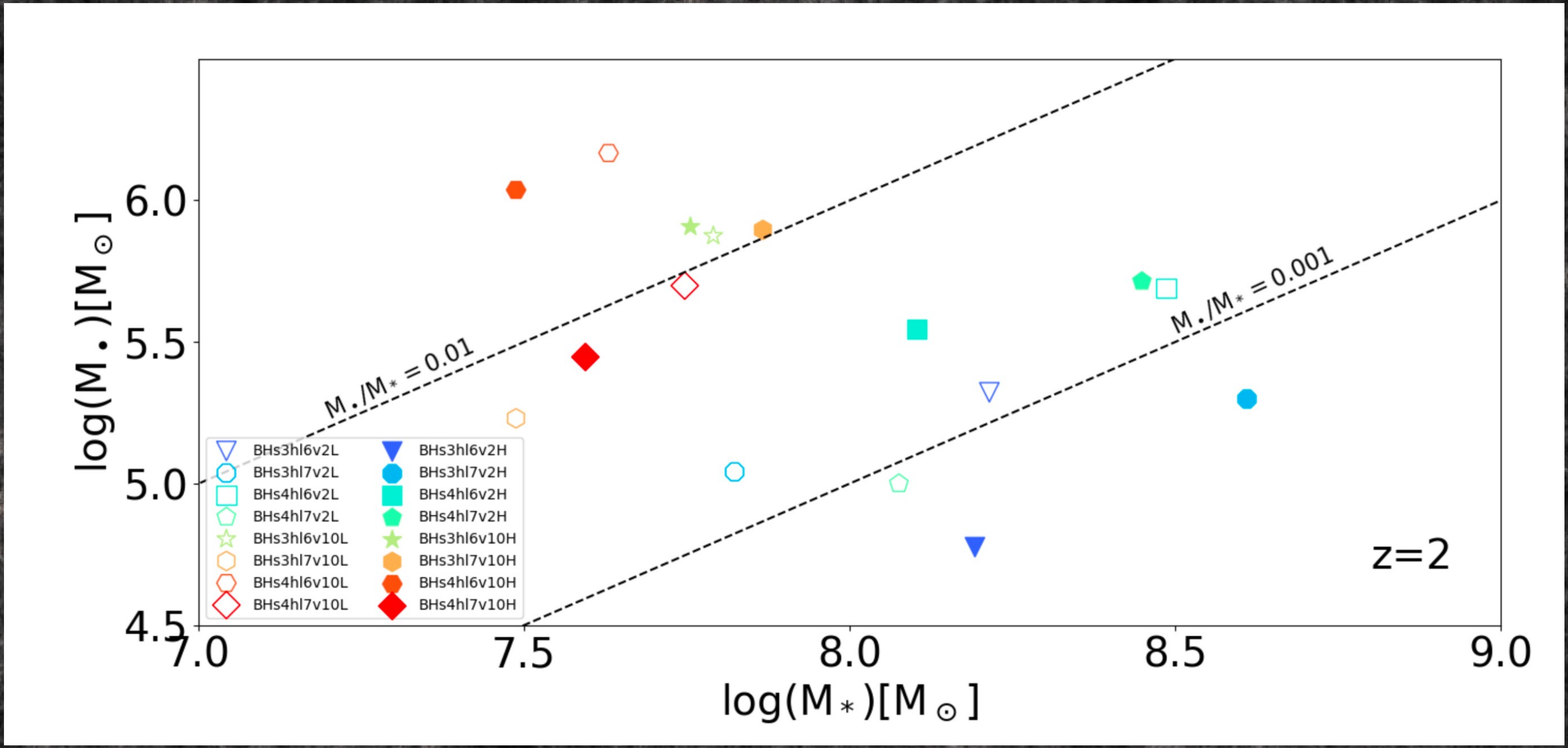

- $M_\bullet - M_\star$ range overlap with JWST spectroscopic data from Harikane et al. (2023), Yue et al. (2024), Ding et al. (2023) and Maiolino et al. (2024).
- Two distinct branches: high/low AGN wind velocities

Results: Gini/M_{20} coefficient

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- Classification criteria based on the HST Survey of the Extended Groth Strip (EGS) from 0.2<z<1.2 (Lotz et al. 2008):

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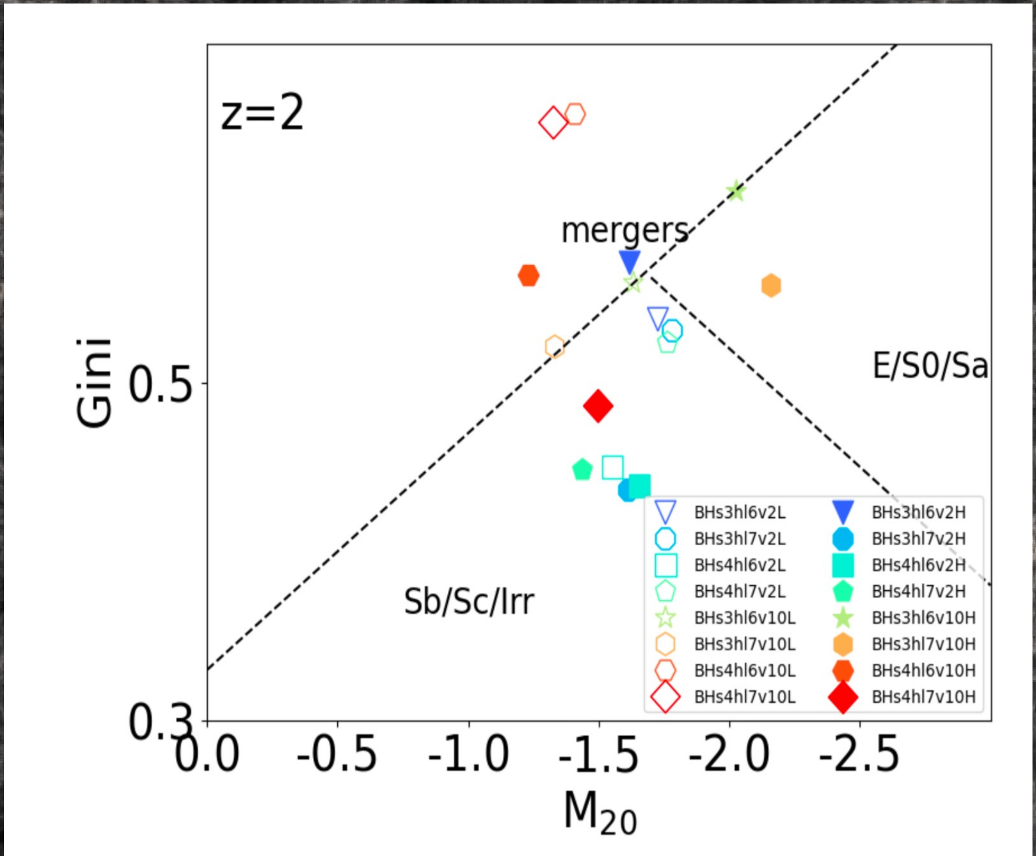

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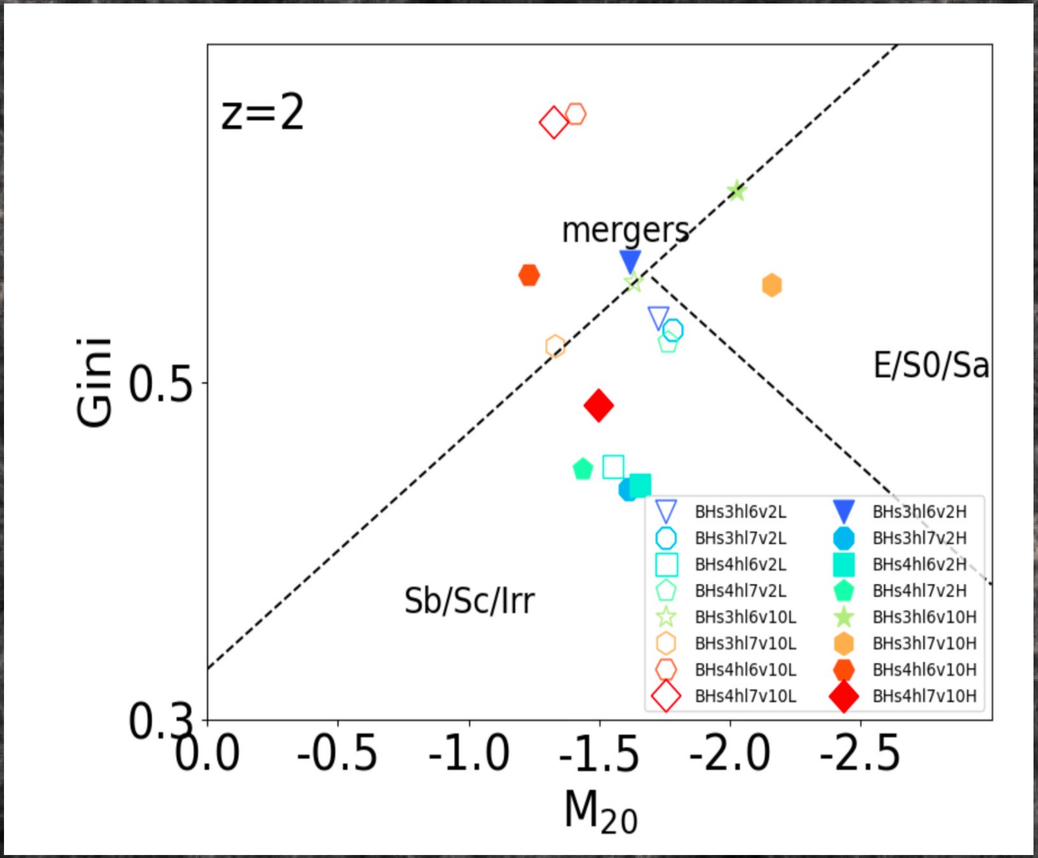

- we chcek mereger by examining actual nearby galaxies within a radius of 10 kpc/h through 2<z<4.

Model no.	Artificial merger ratio	Model no.	Artificial merger ratio
NoBHL	0.00	NoBHH	0.71
BHs4hl6v2L	0.91	BHs4hl6v2H	0.16
BHs4hl7v2L	0.04	BHs4hl7v2H	0.78
BHs4hl6v10L	0.03	BHs4hl6v10H	0.18
BHs4hl7v10L	0.09	BHs4hl7v10H	0.67
BHs3hl6v2L	0.40	BHs3hl6v2H	0.90
BHs3hl7v2L	0.22	BHs3hl7v2H	0.33
BHs3hl6v10L	0.85	BHs3hl6v10H	0.01
BHs3hl7v10L	0.58	BHs3hl7v10H	0.00

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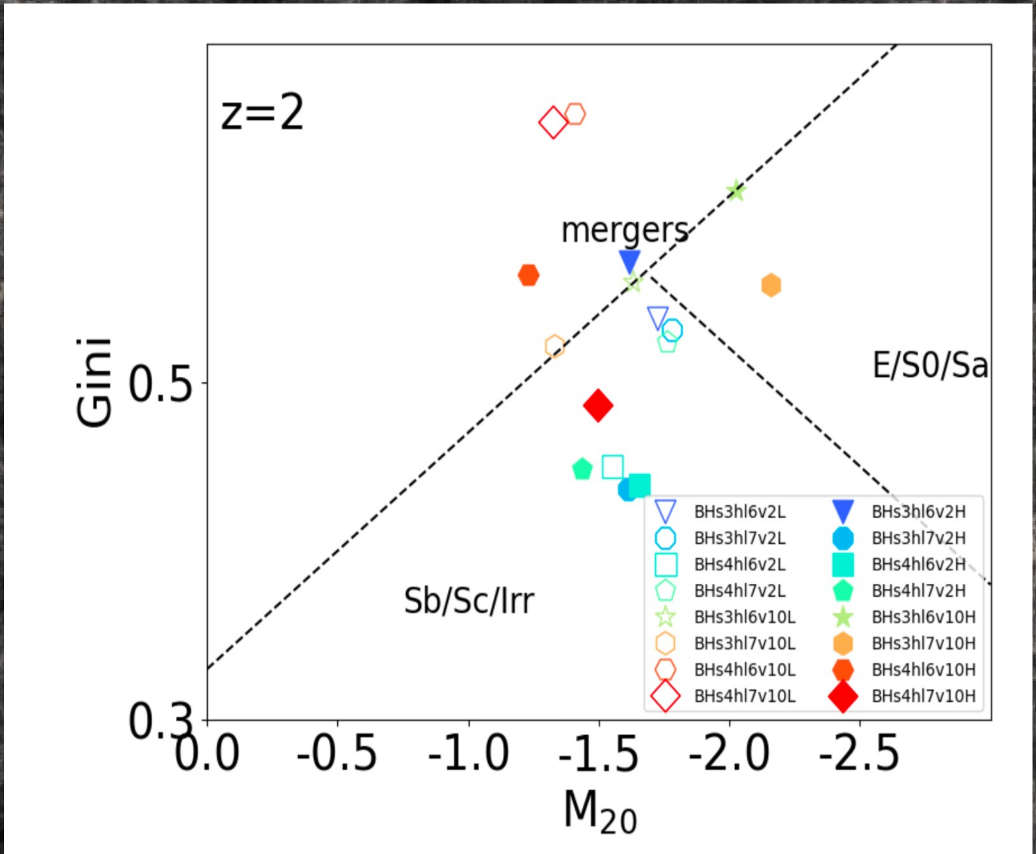

- we chcek mereger by examining actual nearby galaxies within a radius of 10 kpc/h through $2<z<4$.
- Compared to typical low redshift galaxies, our high redshift galaxies $(z > 2)$ tend to be more concentrated and many exhibit flattened bright centers.

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Results: CAS statistics

- CAS system:
  - Concentration (C)
  - Asymmetry (A),
  - Smoothness/Clumpiness (S)

  — another set of non-parametric galaxy morphology statisticsBershady et al. (2000)

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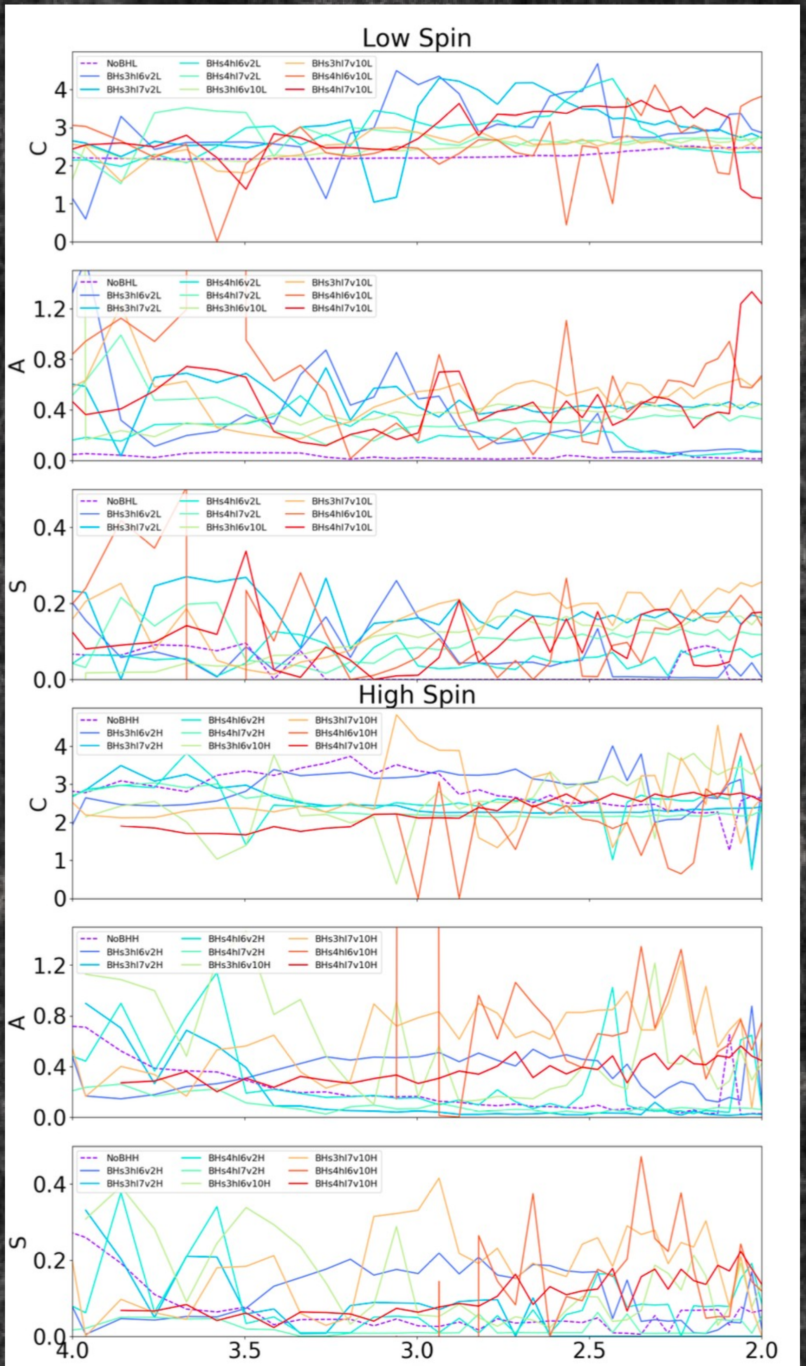
- For concentration, all galaxies are located within a narrow range of $1 < C < 4$



Results: Sersic fitting & Rotational support

- 1D Sersic (1963) Profile fitting
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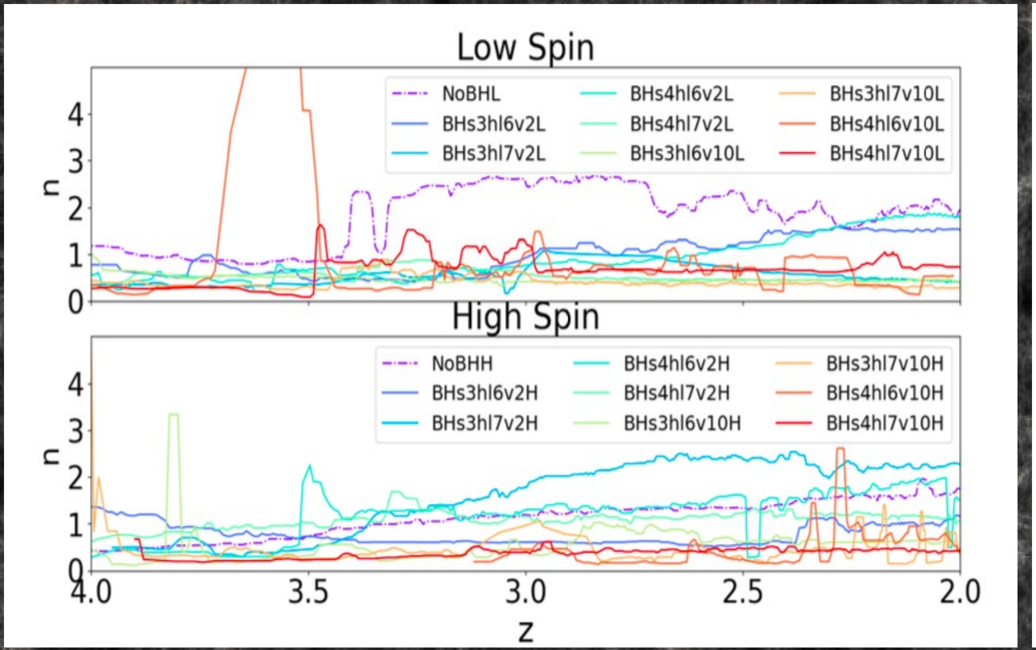
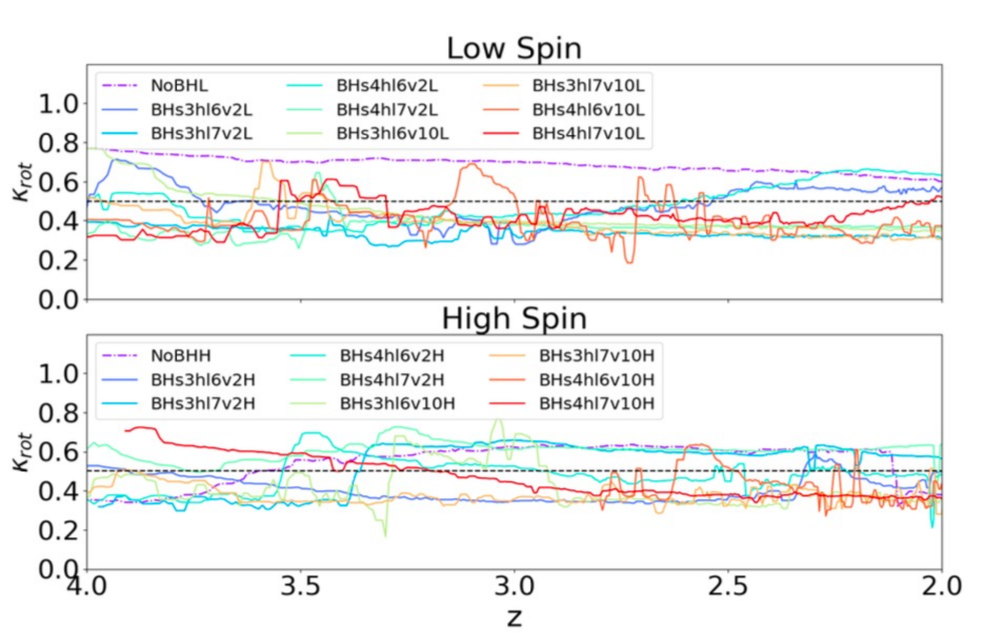
  fraction of the stellar kinetic energy that is in ordered rotation
- Models with BH: low Sersic indices ($n < 2$), and intermediate rotational support (κrot between 0.3 and 0.6).





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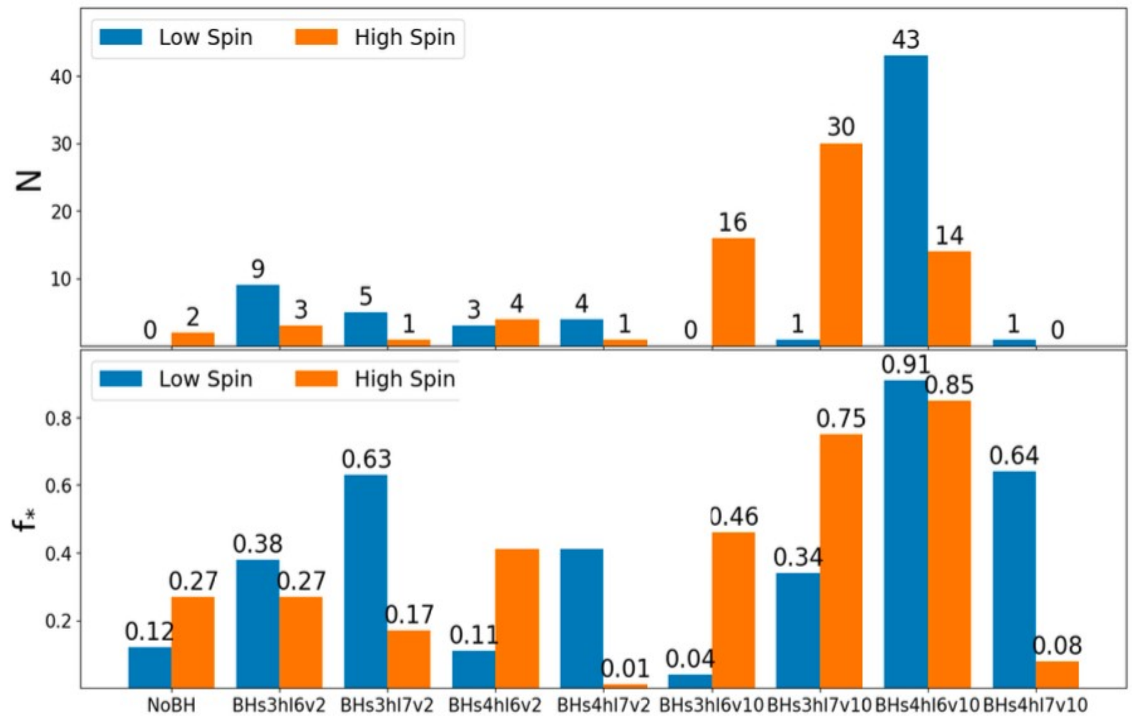

Merger statistics. Top panel – major merger counts for all models from $2 \lesssim z \lesssim 4$. Bottom panel – stellar mass contribution from mergers since galaxies reach 10% of their final mass.

Results:Surface photometry and morphology

- We post-processed the galaxies with the 3D radiative transfer code SKIRT (Baes et al. 2003), applied redshifting and pixelization, and generated synthetic images using the JWST F200W filter.

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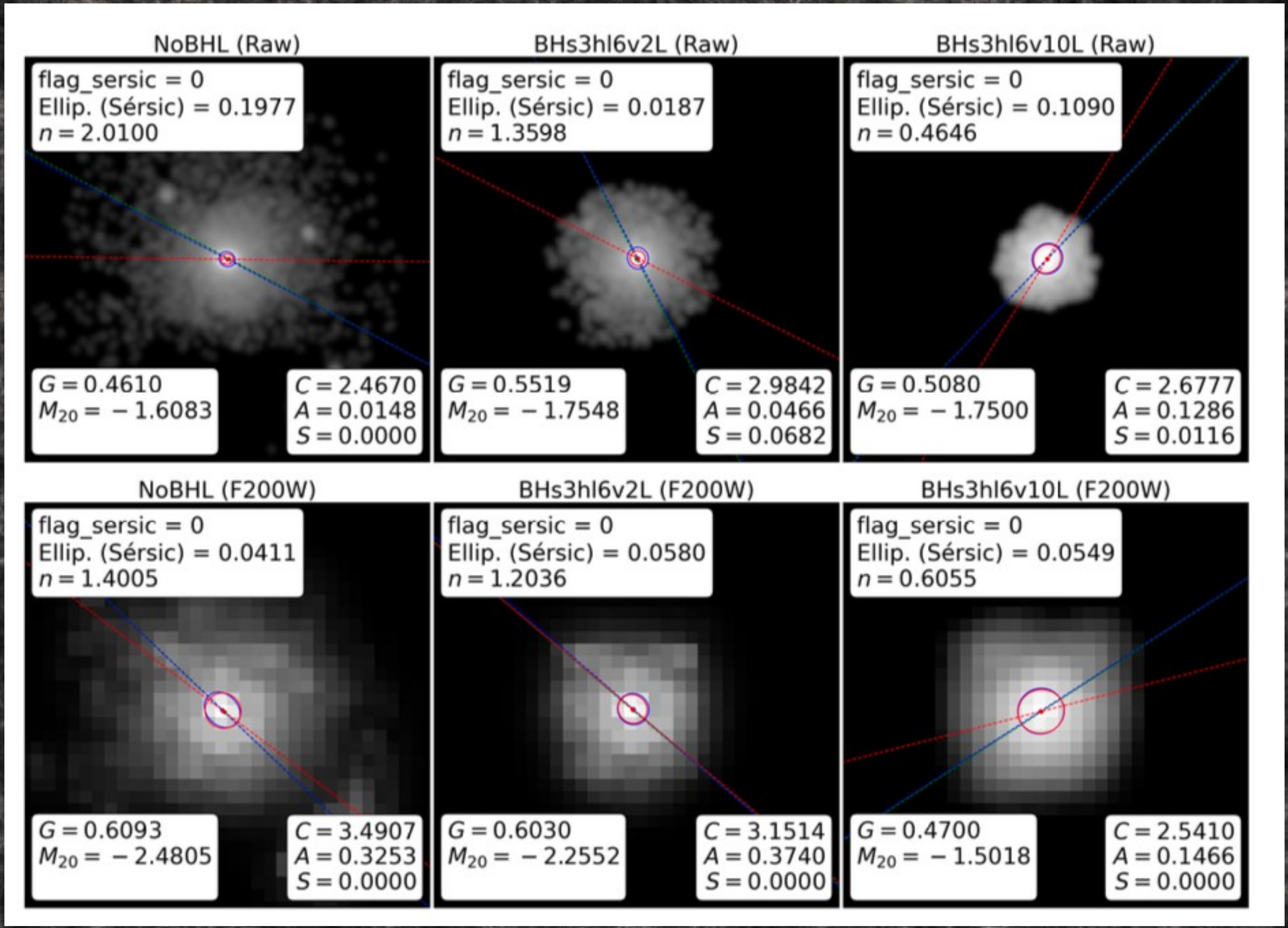

Smearing effects due to the limitations imposed by instrument pixel size and PSF convolution.

↓

nearly all of our galaxies exhibit larger half-light radii in luminosity images compared to density images

Conclusion

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- Morphological Impact: Stronger feedback → flatter galaxies, lower stellar masses, and distinct central concentrations (low Sérsic index, intermediate rotation).
- Caution in Interpretation: Low-redshift diagnostics may misrepresent high-redshift systems.
- Observational Limits: Pixelation and convolution can exaggerate galaxy sizes and concentrations.

Thank You!

Questions welcome