Exploring the high-redshift Size-Mass Relation in SPHINX

RUM 2026

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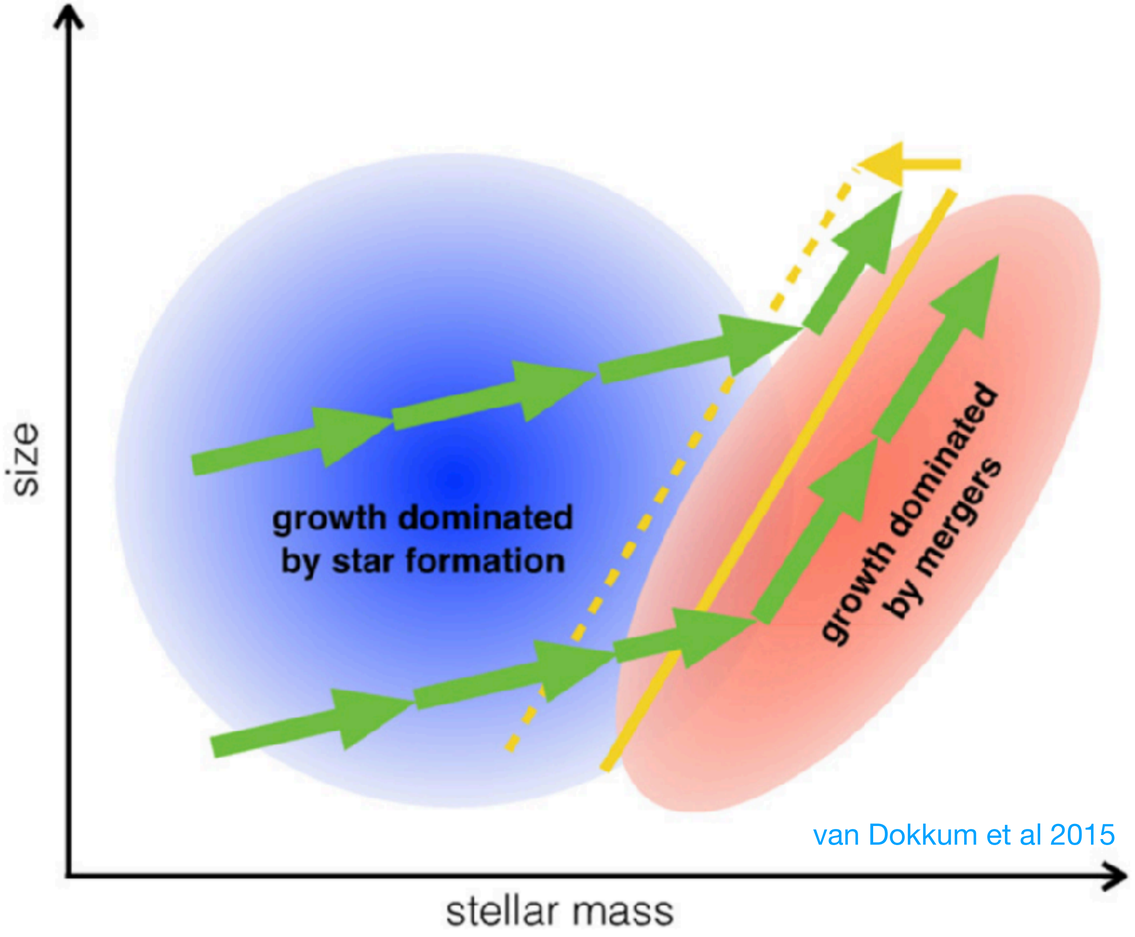
Size-Mass Relation

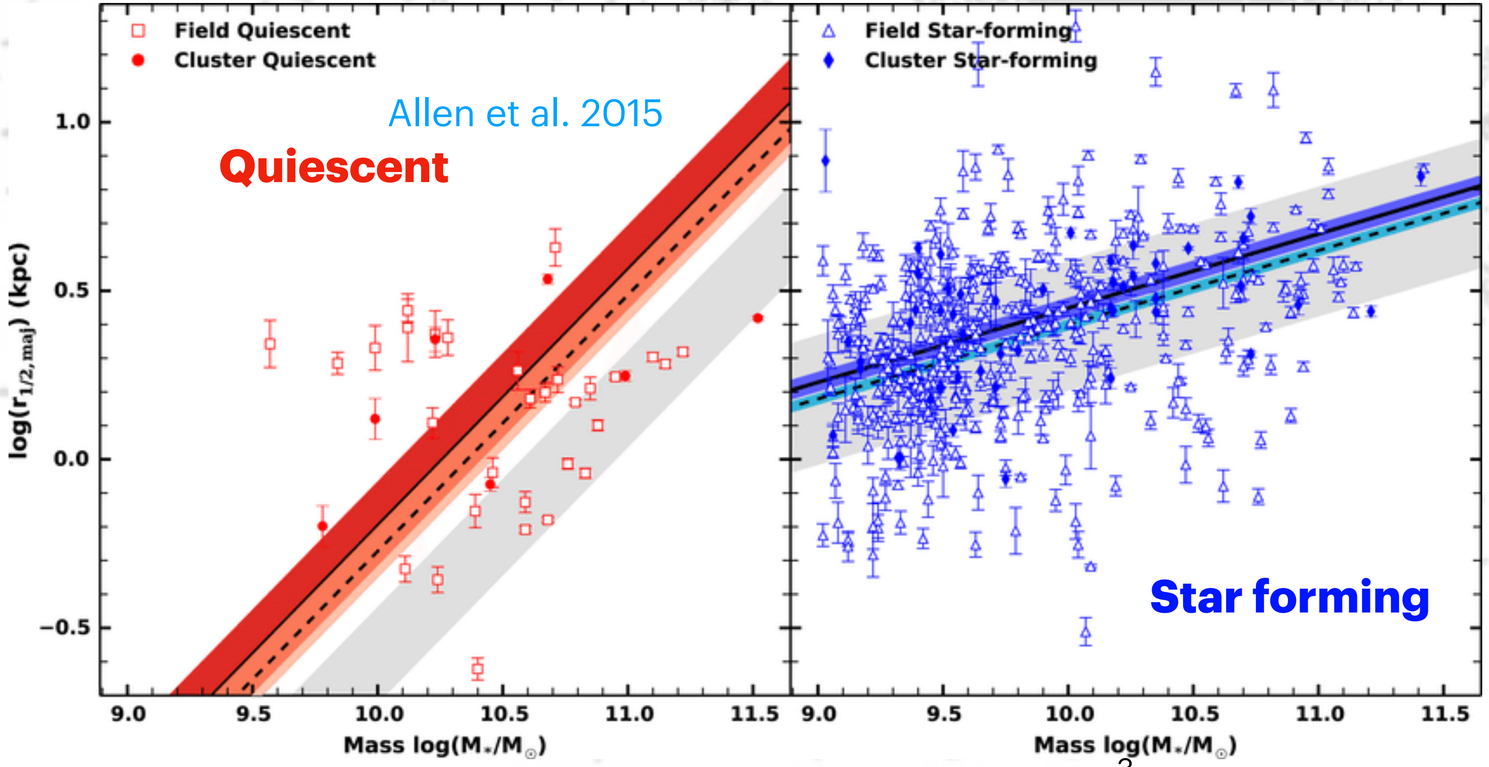
- Diagnostic of structural evolution of galaxies
  - Investigate inside-out growth
  - Quenching pathways
  - Quiescent growth through mergers
  - Roles of stellar and AGN feedback



van Dokkum et al 2015

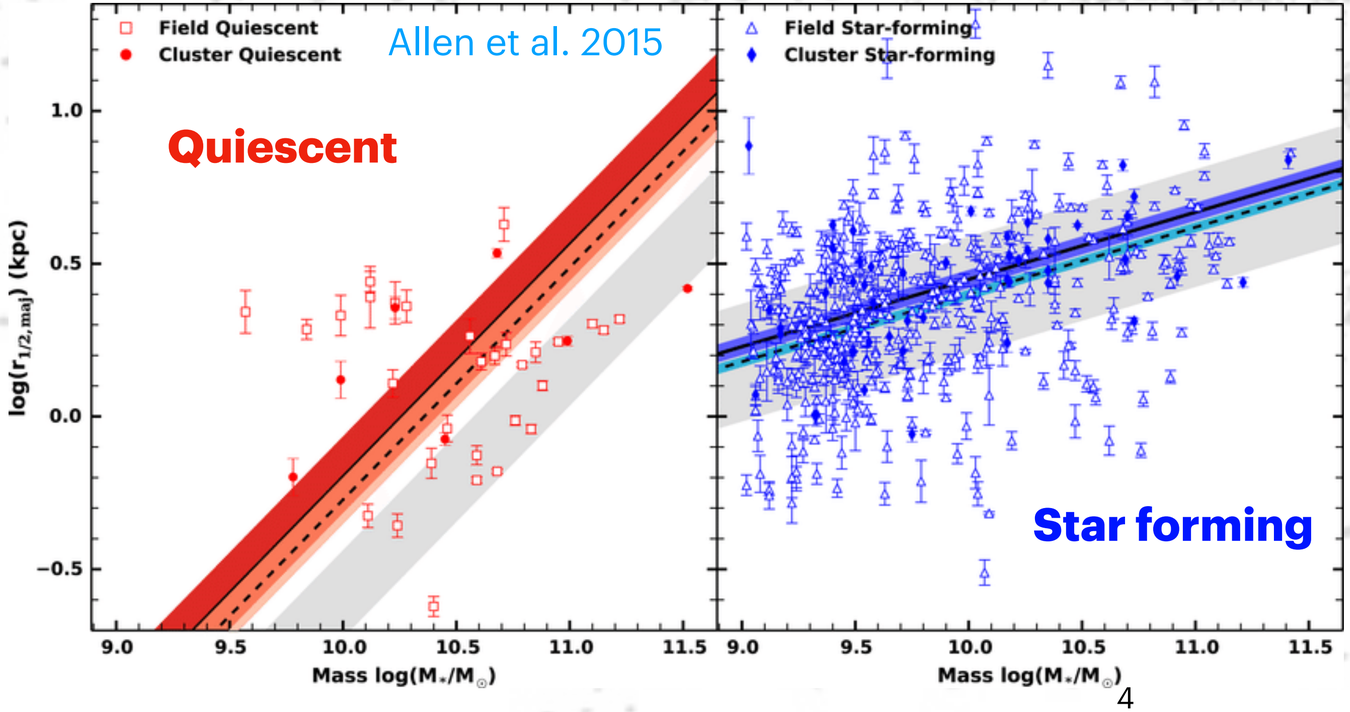
SMR at low z

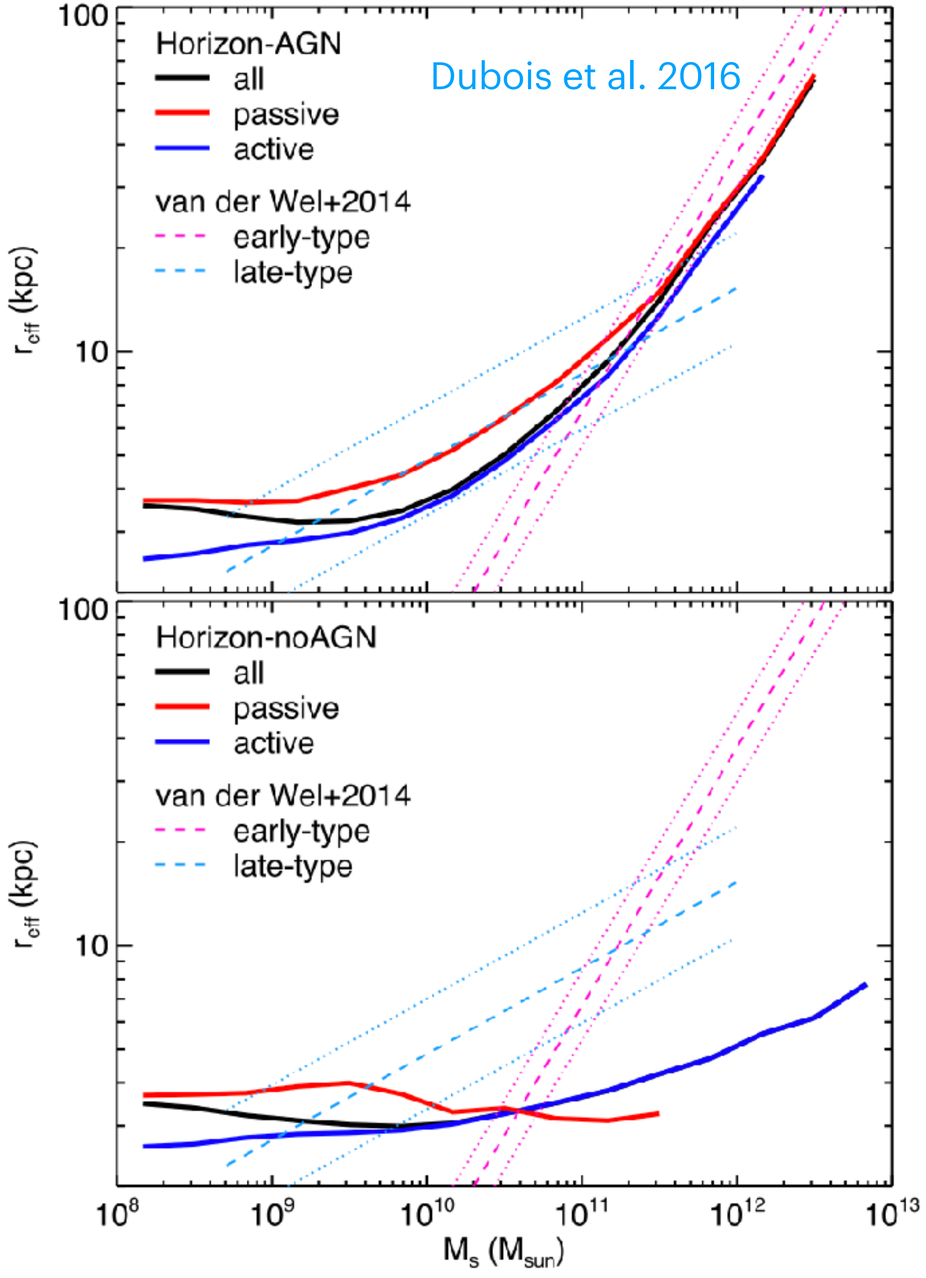
- **Observations:** Star forming galaxies larger with shallower slope than quiescent galaxies
- **Positive slope**, modeled either with single or double power law
  - Mirrors relation between stellar and halo mass



SMR at low z

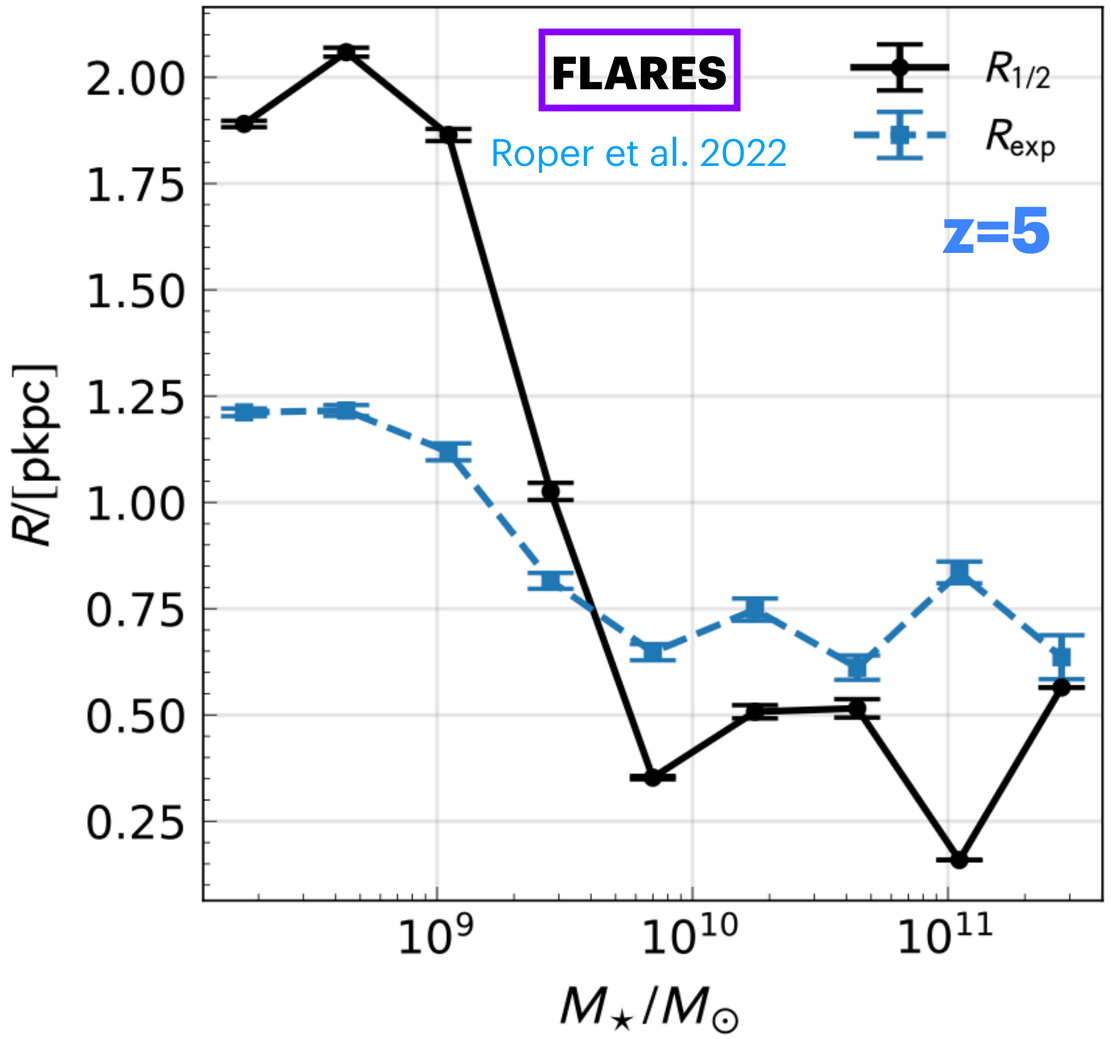
- **Simulations:** highlight importance of **AGN feedback** in regulating size in the **high-mass** regime
- Often calibrated to reproduce SMR at z=0





SMR at high z

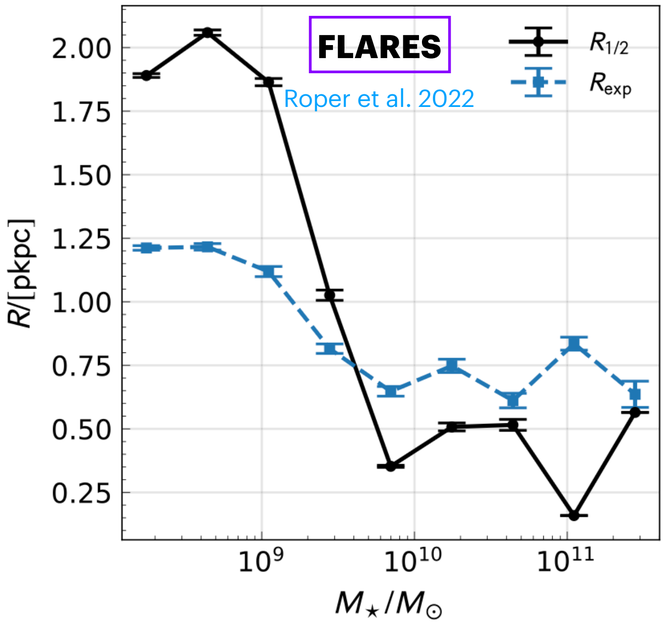
Large volume Simulations



- Hydrodynamic simulation using EAGLE model
- Same resolution at EAGLE 100 cMpc model

SMR at high z

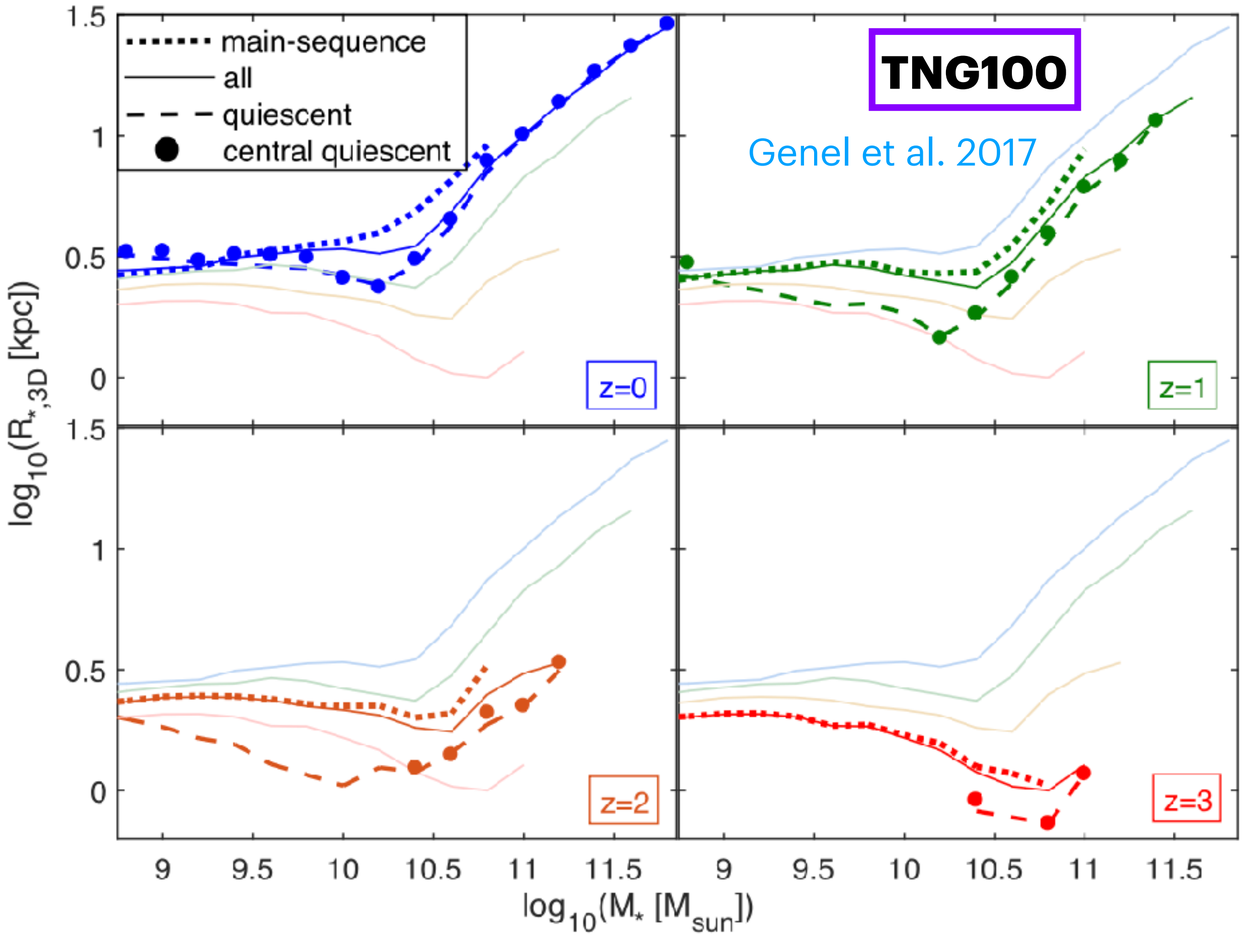
Large volume Simulations



110 Mpc box length

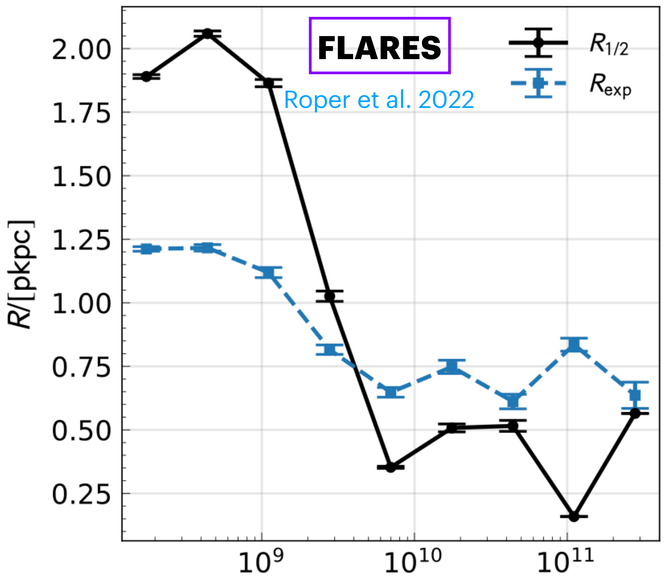
$1.4 \times 10^6 M_\odot$

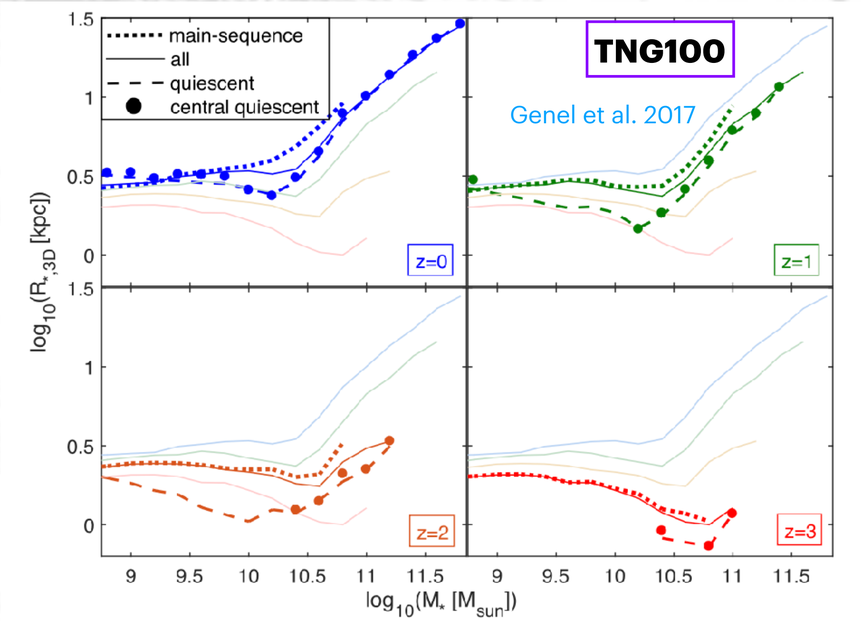
baryonic resolution



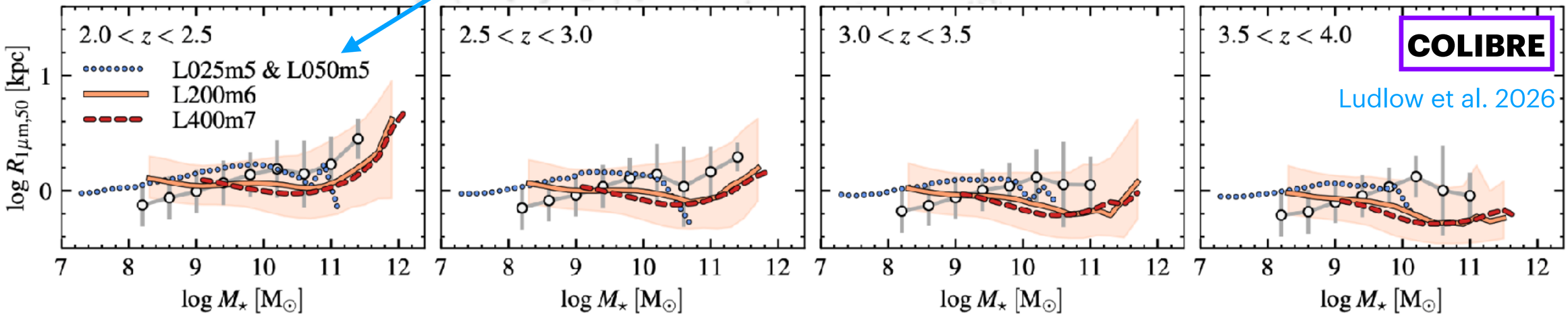
SMR at high z

Large volume Simulations





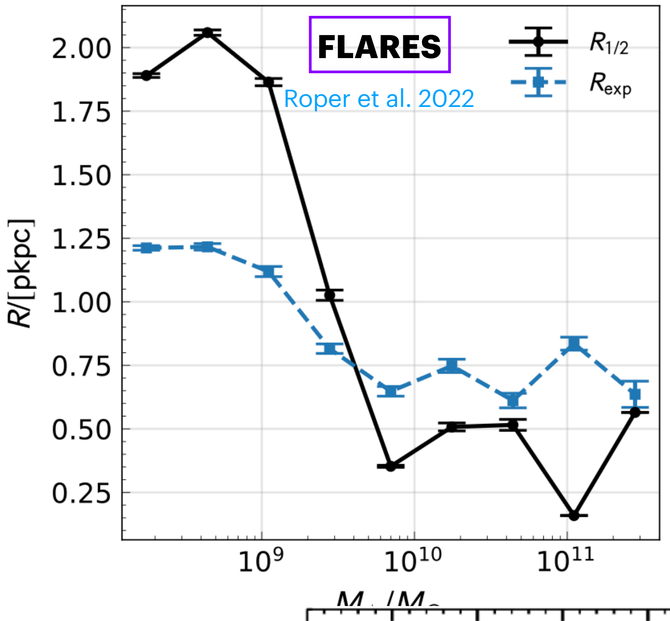
Different box sizes/ resolutions

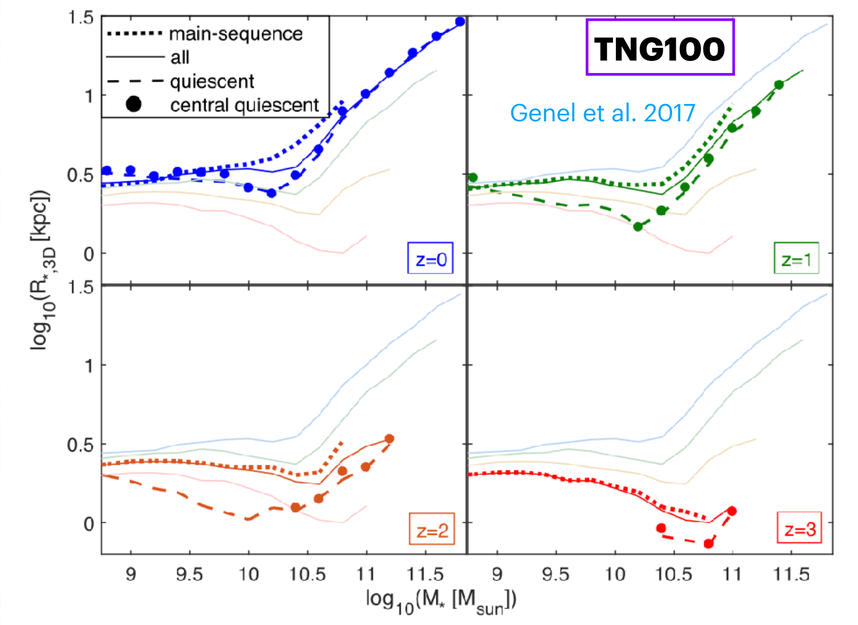


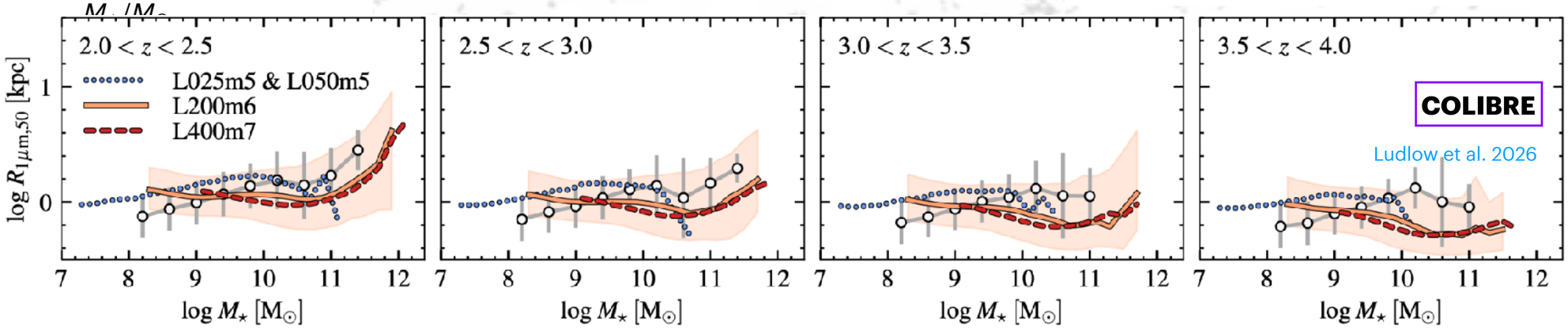
SMR at high z

Large volume Simulations

Flattening/ downturn for intermediate mass galaxies at increasing redshift





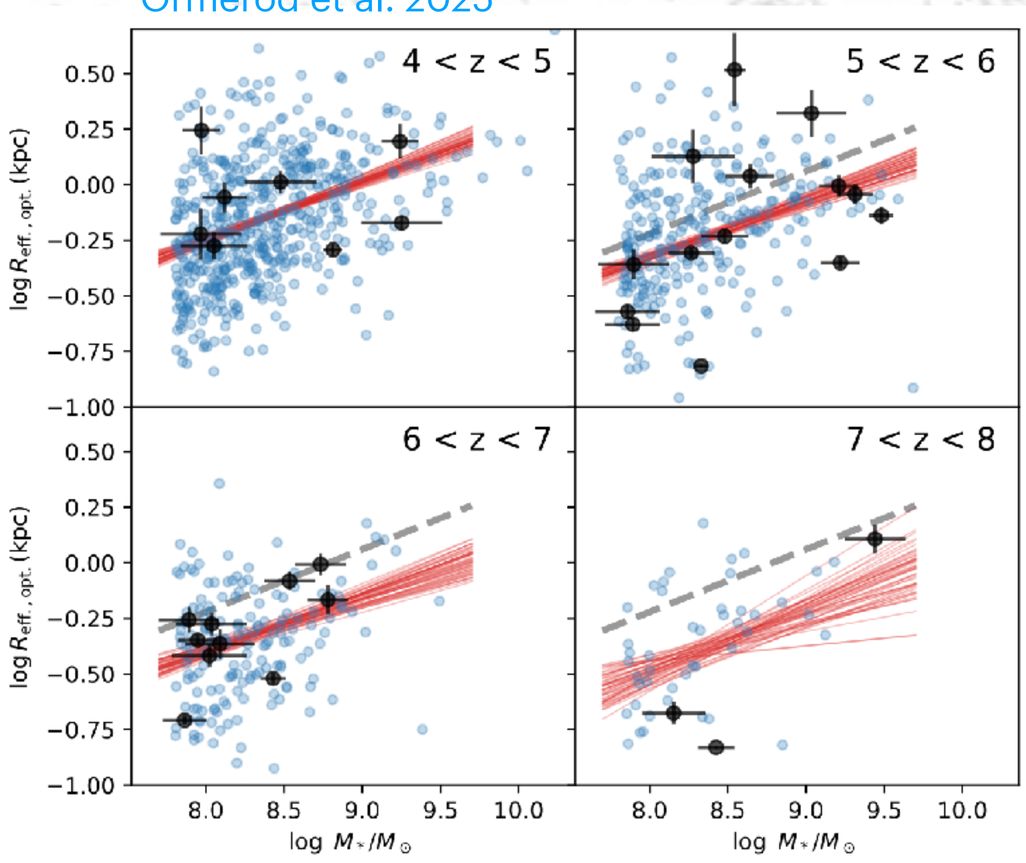


SMR at high z- Observations

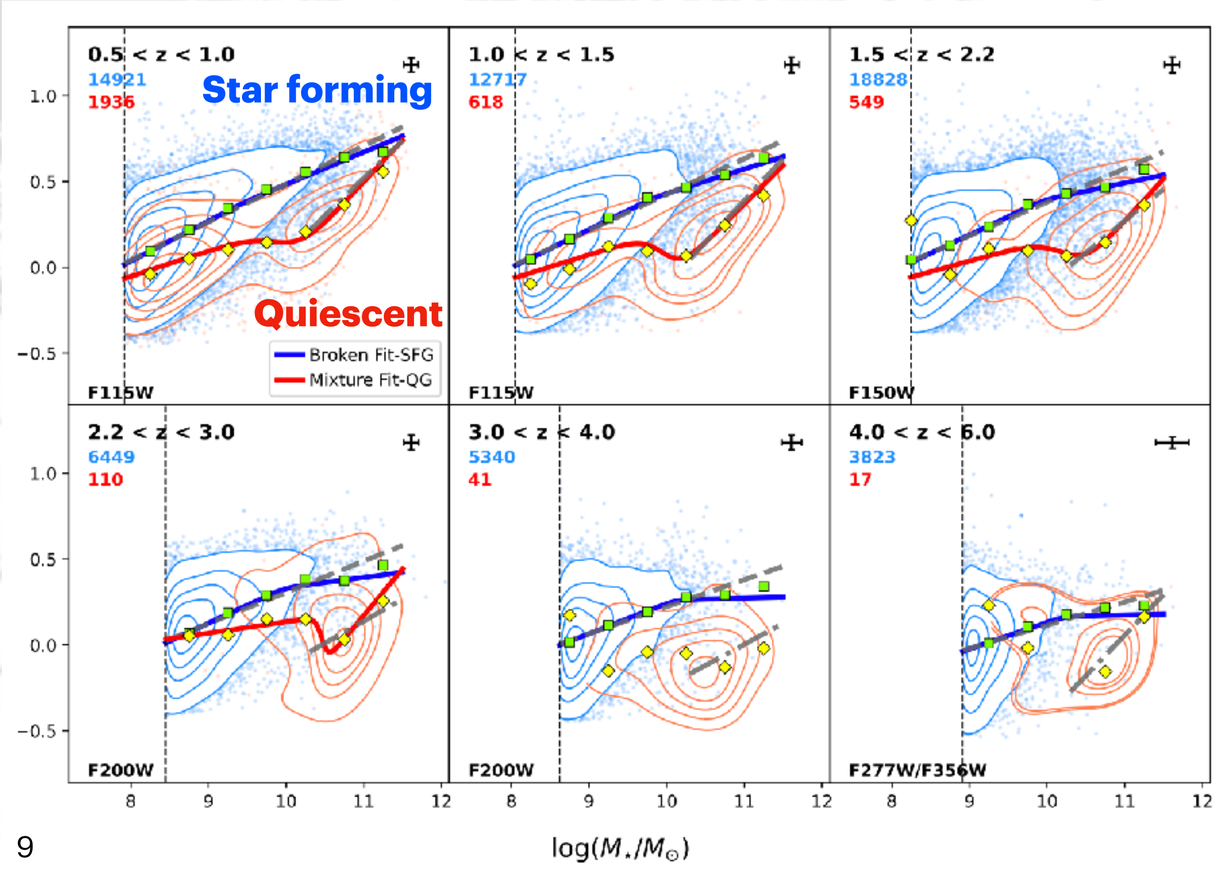
With JWST we can explore SMR at high redshift

Current results point to a positive slope, **disagreeing with simulations**

Ormerod et al. 2025



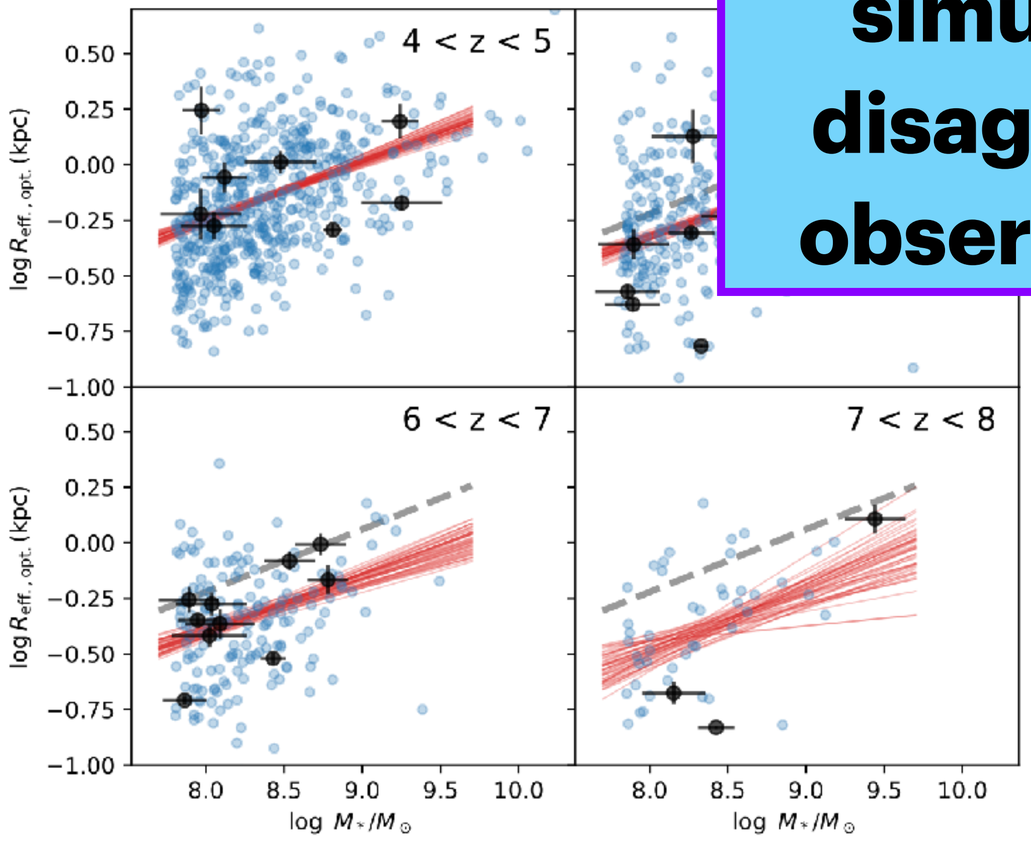
Chen et al. 2026



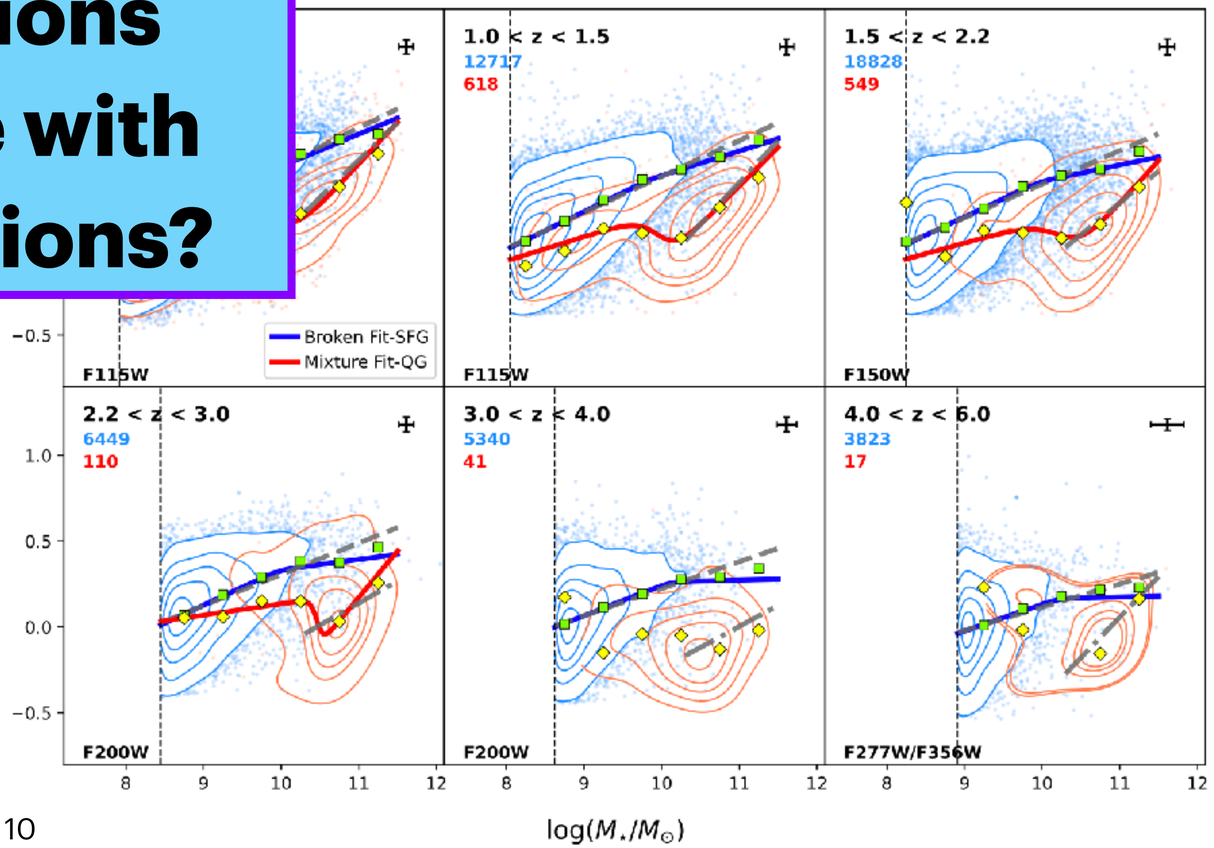
SMR at high z- Observations

Why do simulations disagree with observations?

Ormerod et al. 2025



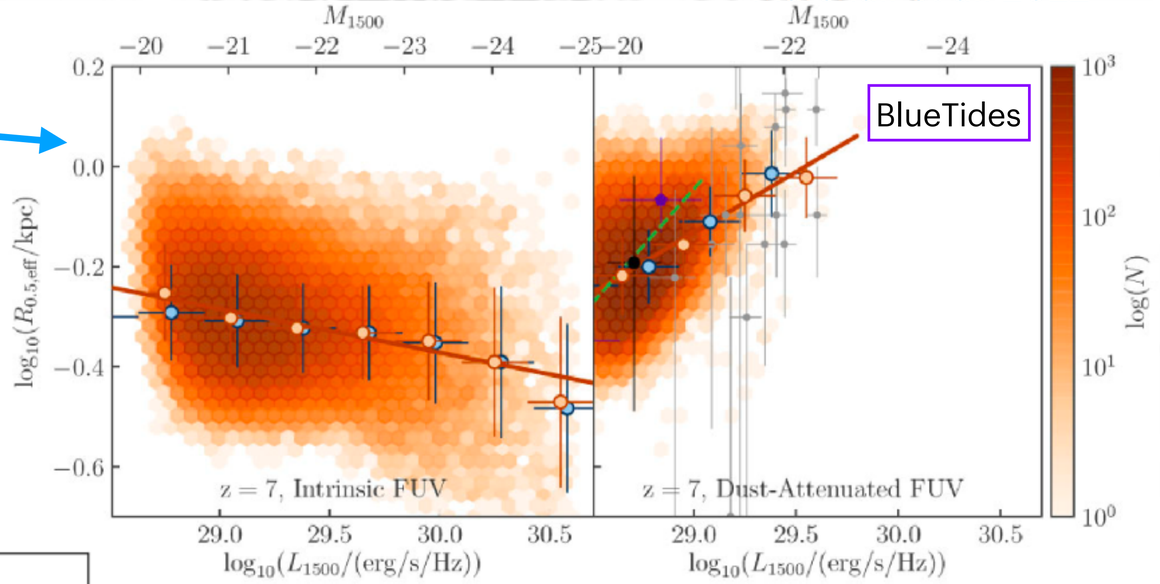
Chen et al. 2026



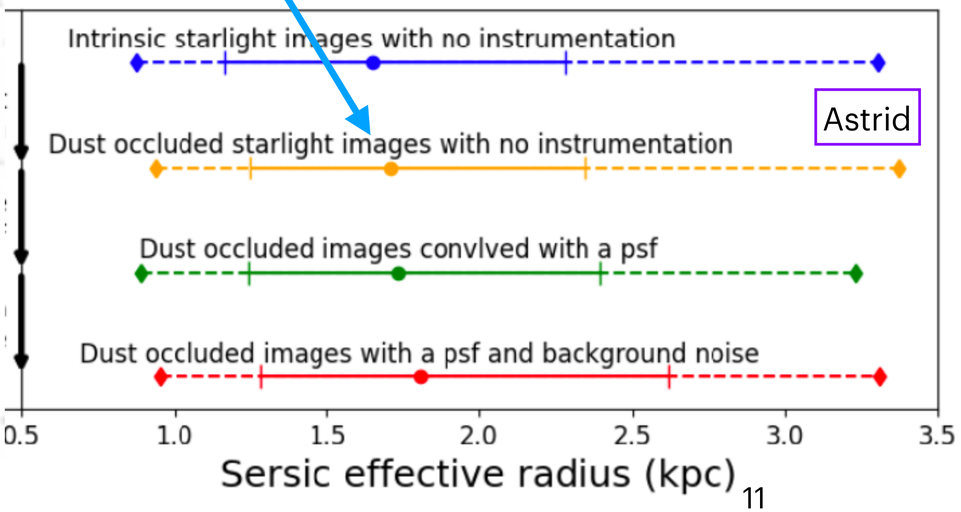
Effects of dust?

- Many simulations can recover positive slope when including **dust attenuation**
  - Particularly increases observed UV sizes
- Other studies find **only minor size difference** with dust

Marshall et al. 2022



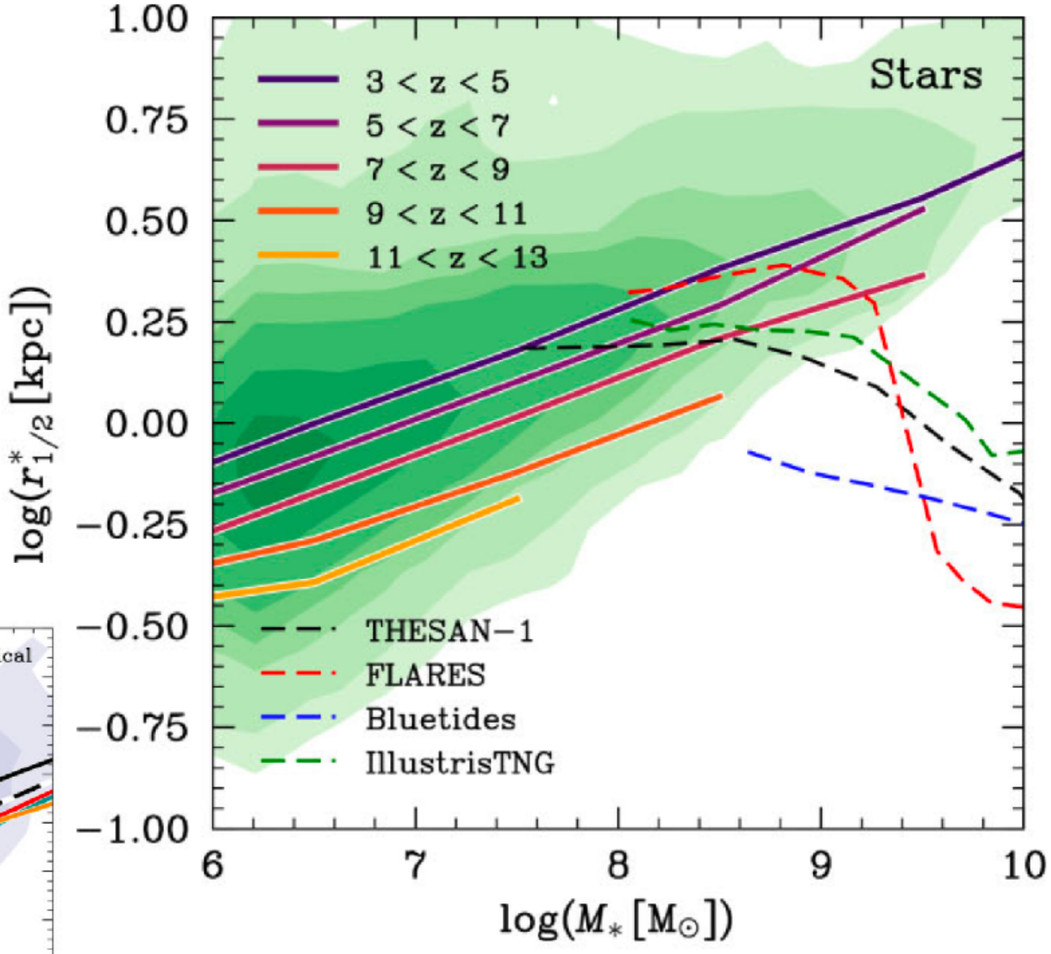
LaChance et al 2025

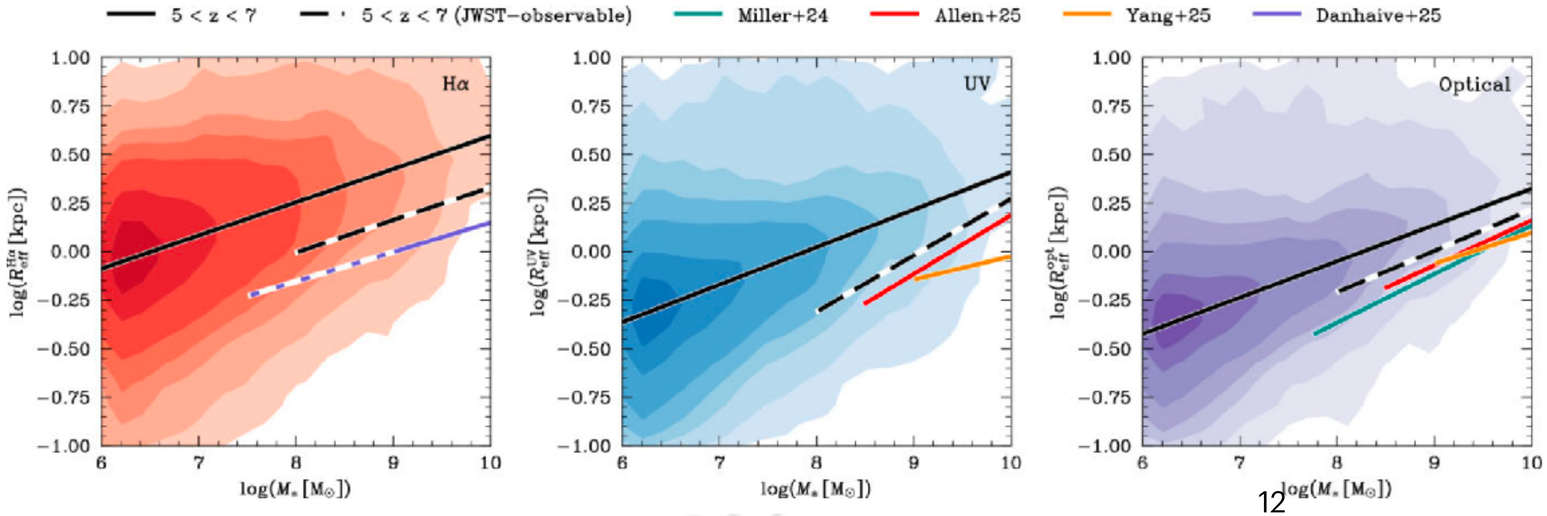


Unresolved star formation and feedback?

McClymont et al 2025

- THESAN Zoom: more resolved star formation lead to intrinsic positive slope across all masses and redshifts
- More closely matches observations without invoking dust attenuation





Motivation

- **Why do simulations predict a negative slope but observations are positive?**
- Theories:
  - **Dust attenuation?**: high redshift galaxies intrinsically more compact, but dust increases observed sizes
    - extent of this effect in simulations is unclear
  - **Unresolved SF?**: regulating galaxy sizes in the early universe may depend strongly on bursty star formation and feedback, which is not properly resolved in large simulations

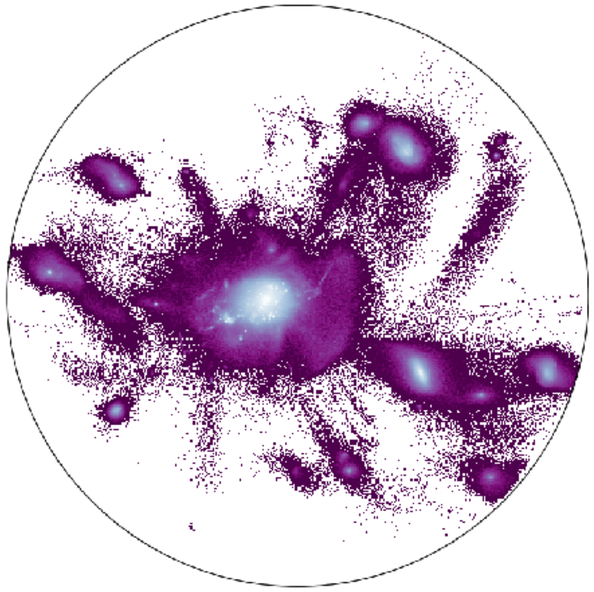
SPHINX simulation

- 20 co-moving Mpc box sides, minimum cell width~11pc at z=6
  - -> can resolve low mass galaxies
  - Contains thousands of low and intermediate mass galaxies, allowing us to explore the regime of the turnover with higher resolution than larger volume simulations

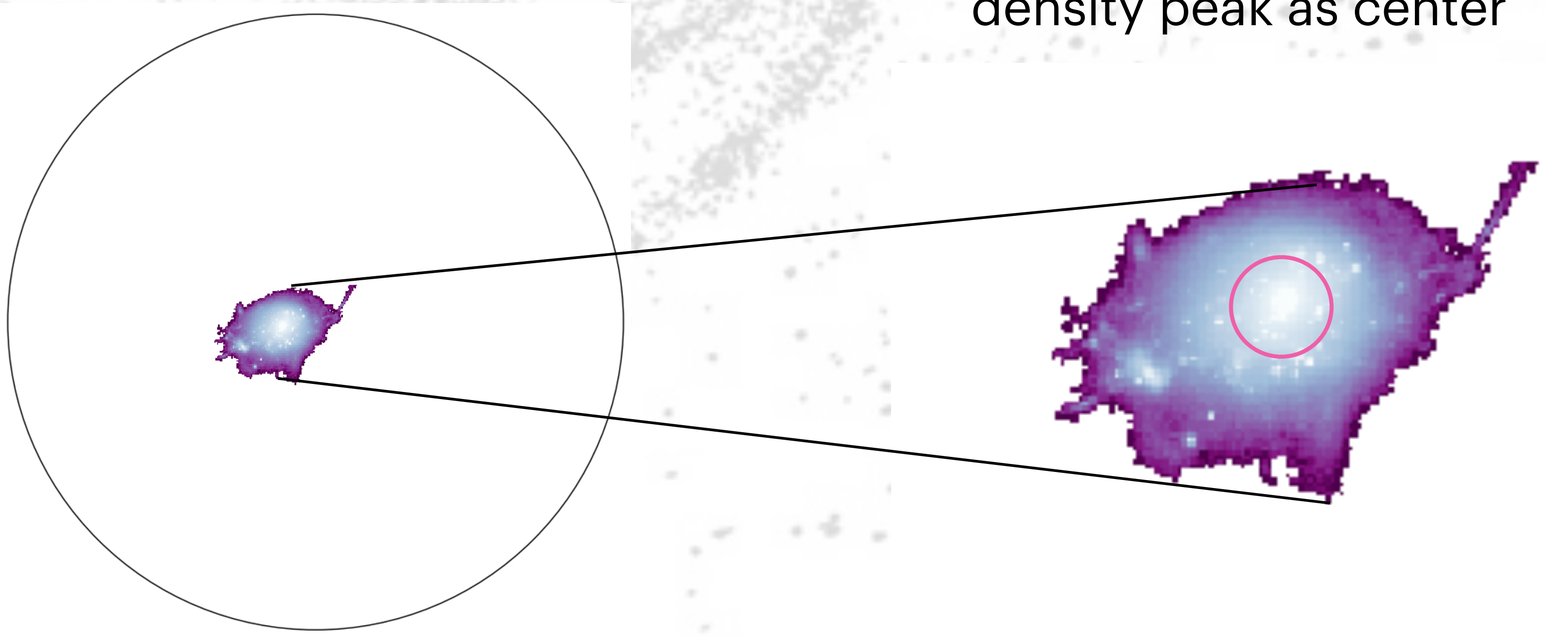
Intrinsic Size Measurement

Galaxy Catalog with HaloFinder HOP (preliminary version)

1. Read stars within galaxy's viral radius



2. Mask stars not associated with main galaxy



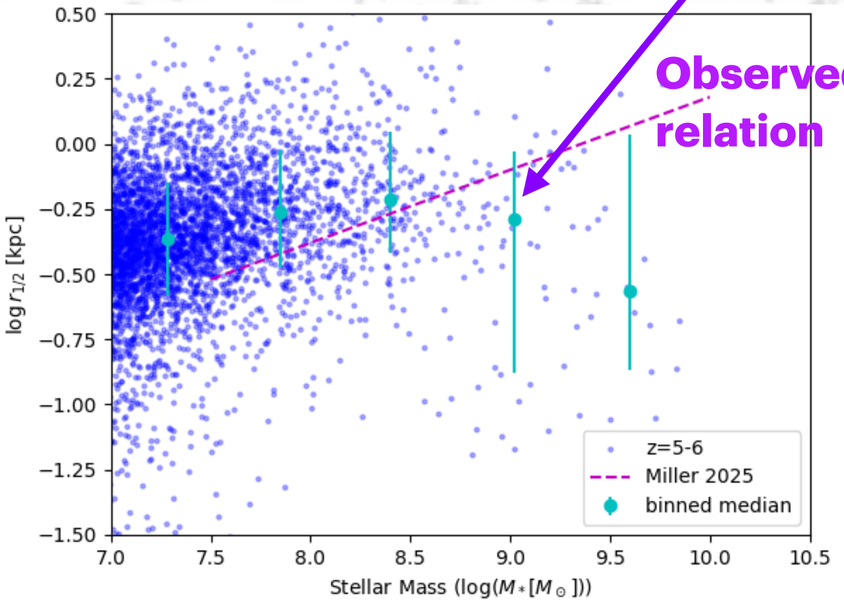
3. Measure half-mass radius with mass surface density peak as center

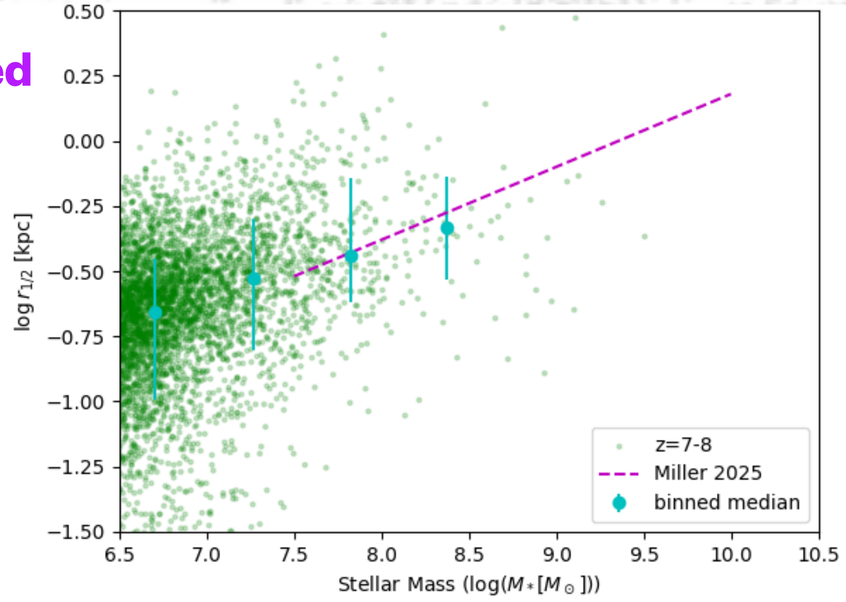
Intrinsic SMR in SPHINX

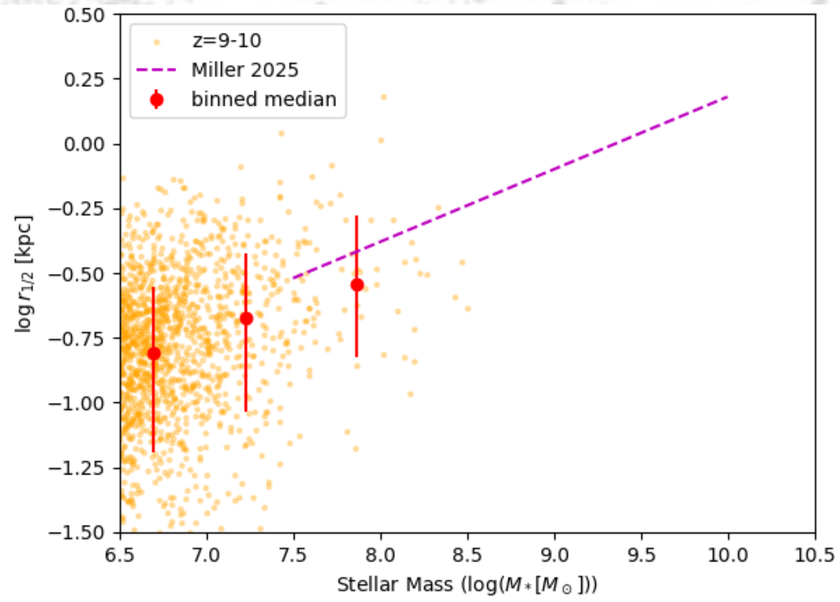
Downturn around log(M*/Msun)=9

Observed relation

At higher redshifts: only low mass galaxies -> linear slope





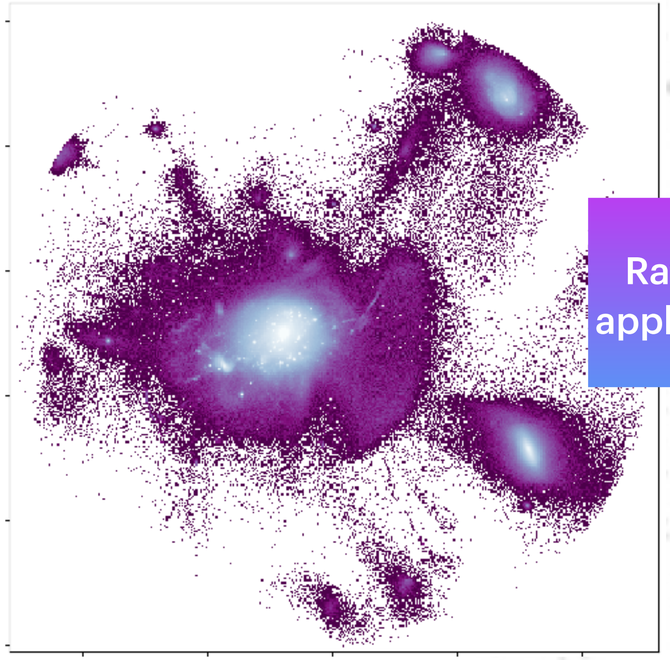


Mock observations and GLIMPSE

- **How will this relation change when observing?**
- Effects of PSF, dust, noise?
- How are complex systems (mergers, satellites etc.) differentiated in observations?
- How can this help us interpret observations from the GLIMPSE survey?

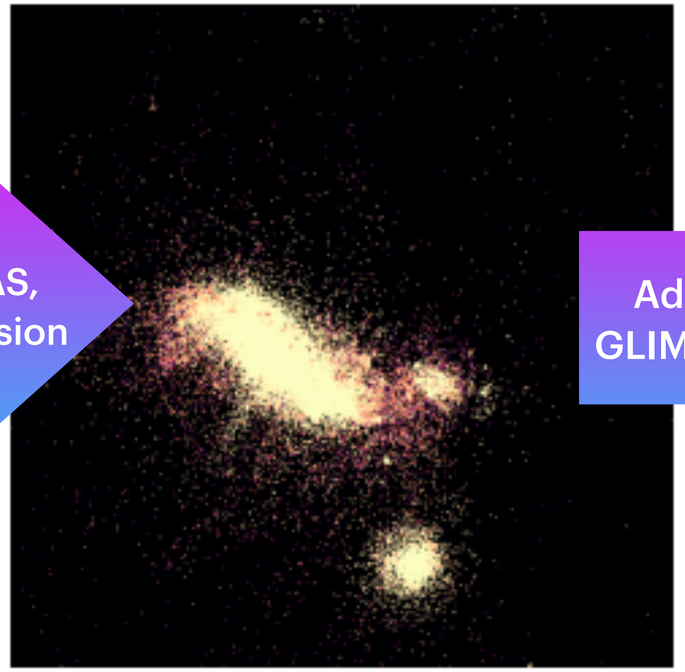
Making Mocks

Stars/gas from SPHINX



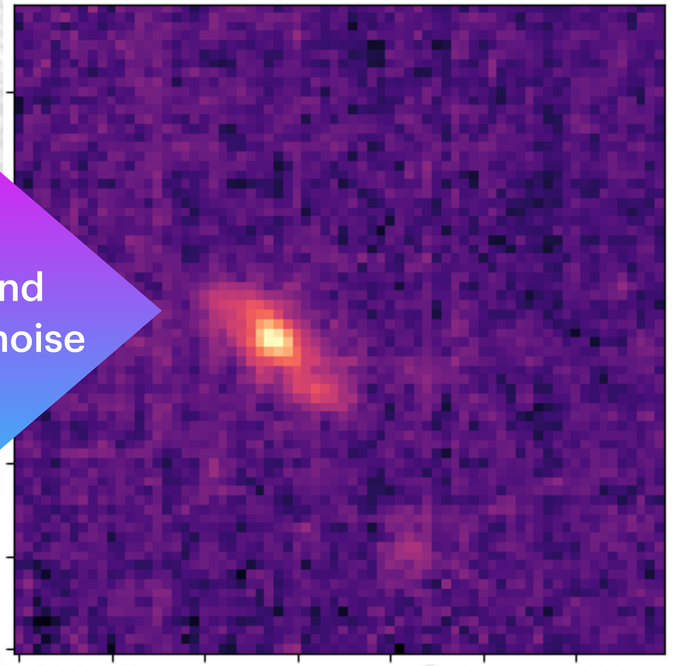
Raytrace in RASCAS, apply filter transmission

F444W



Add filter PSF and GLIMPSE survey noise

F444W (PSF+noise)

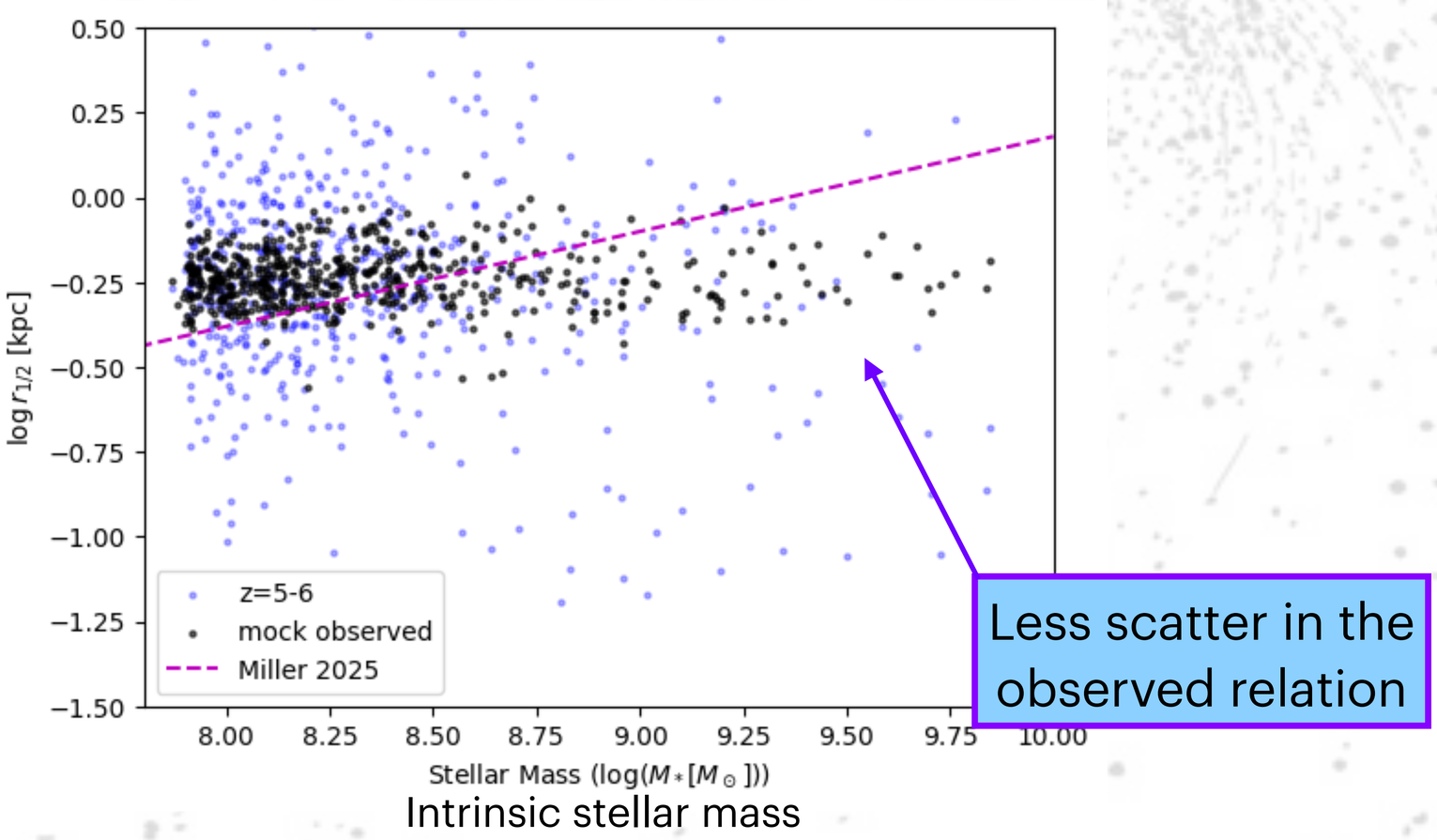


Images produced in all JWST filters in multiple directions

SMR from mocks

⚠Early stages of analysis

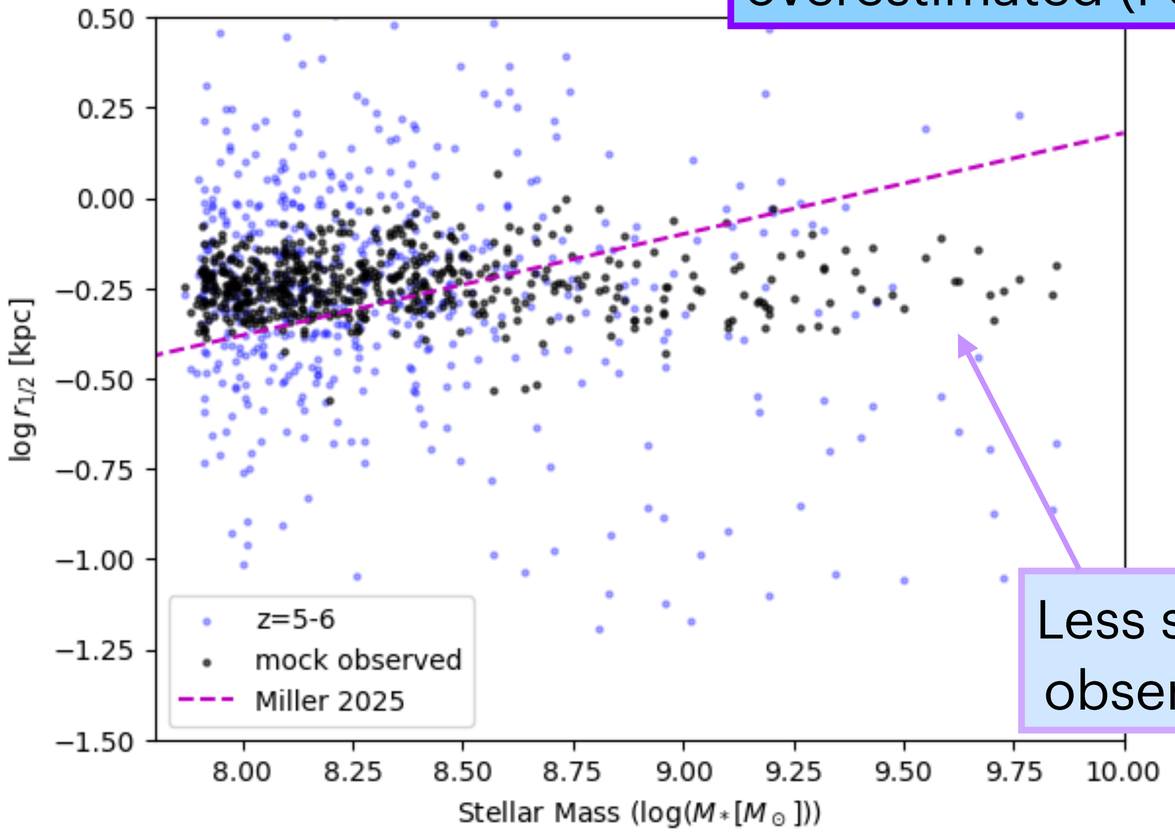
- Use SourceExtractor to identify galaxy
- Mask background
- Measure half-light radius
- Here: half-light radii in rest-optical (F444W filter)



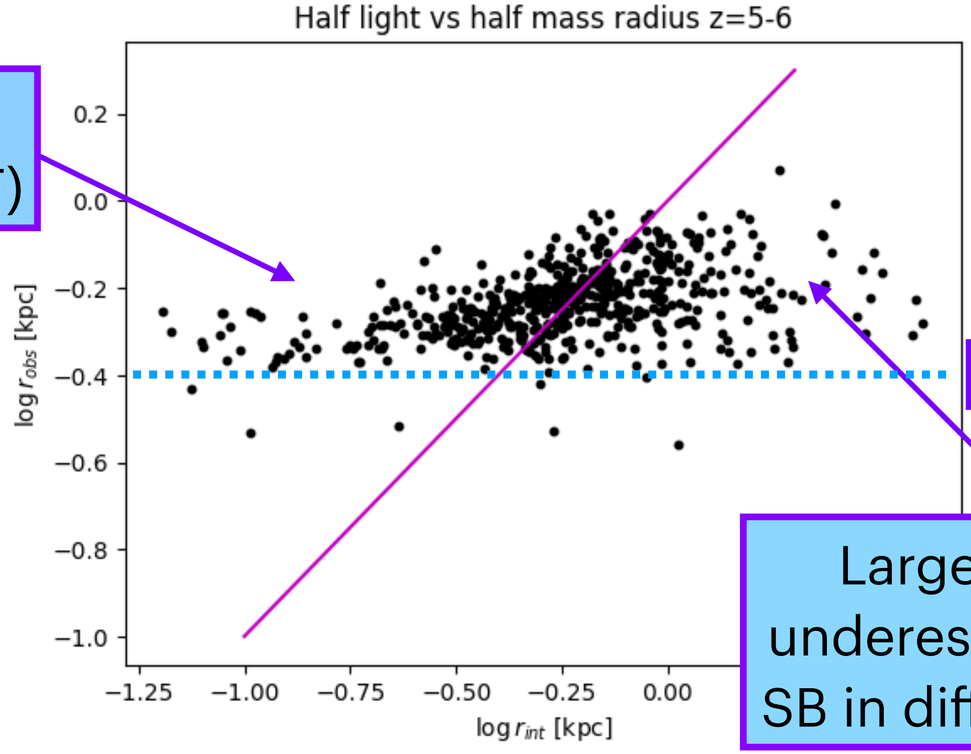
Intrinsic stellar mass

SMR from mocks

⚠Early stages of analysis



Small galaxies: overestimated (PSF)



Pixel size at z=6

Large galaxies: underestimated (low SB in diffuse regions)

Less scatter in the observed relation

Summary and Next steps

- Despite the higher resolution in SPHINX, **intermediate mass galaxies are too compact** compared to observational trends
- More detailed analysis to come...
  - Add **lensing effects**- most of the galaxies in this mass range will be undetected/ PSF limited without lensing
  - **SED fitting** to get observed mass
  - Explore the **impacts of dust**- painted-on models versus a dusty SPHINX run