THE PREVALENCE OF MASSIVE QUIESCENT DISKS IN THE EARLY UNIVERSE

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With the CANDELS team and Colby undergrads including:

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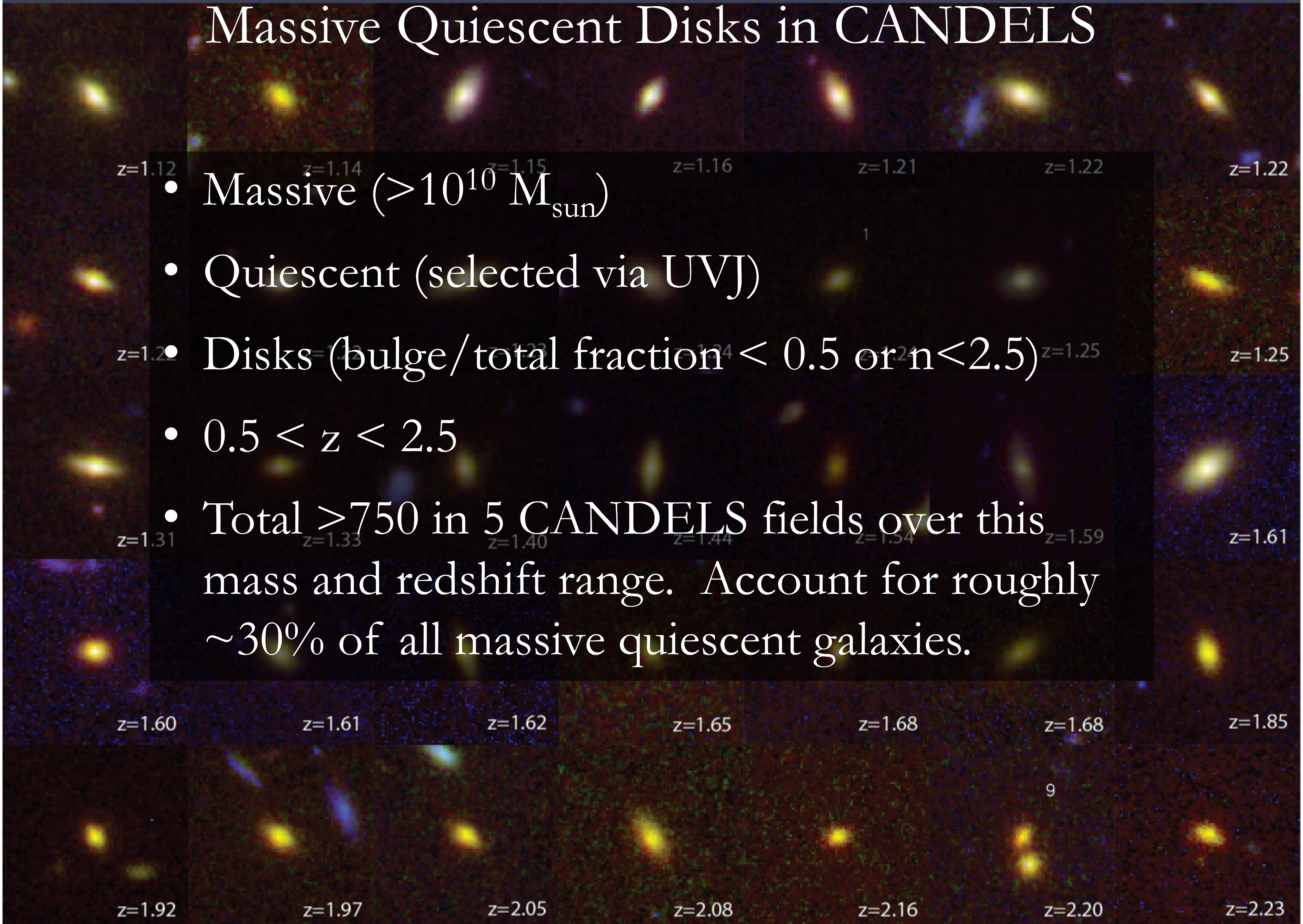
CANDELS 2017

Massive Quiescent Disks in CANDELS

- Massive (>10^{10} M_{sun})
- Quiescent (selected via UVJ)
- Disks (bulge/total fraction < 0.5 or n<2.5)
- 0.5 < z < 2.5
- Total >750 in 5 CANDELS fields over this mass and redshift range. Account for roughly ~30% of all massive quiescent galaxies.



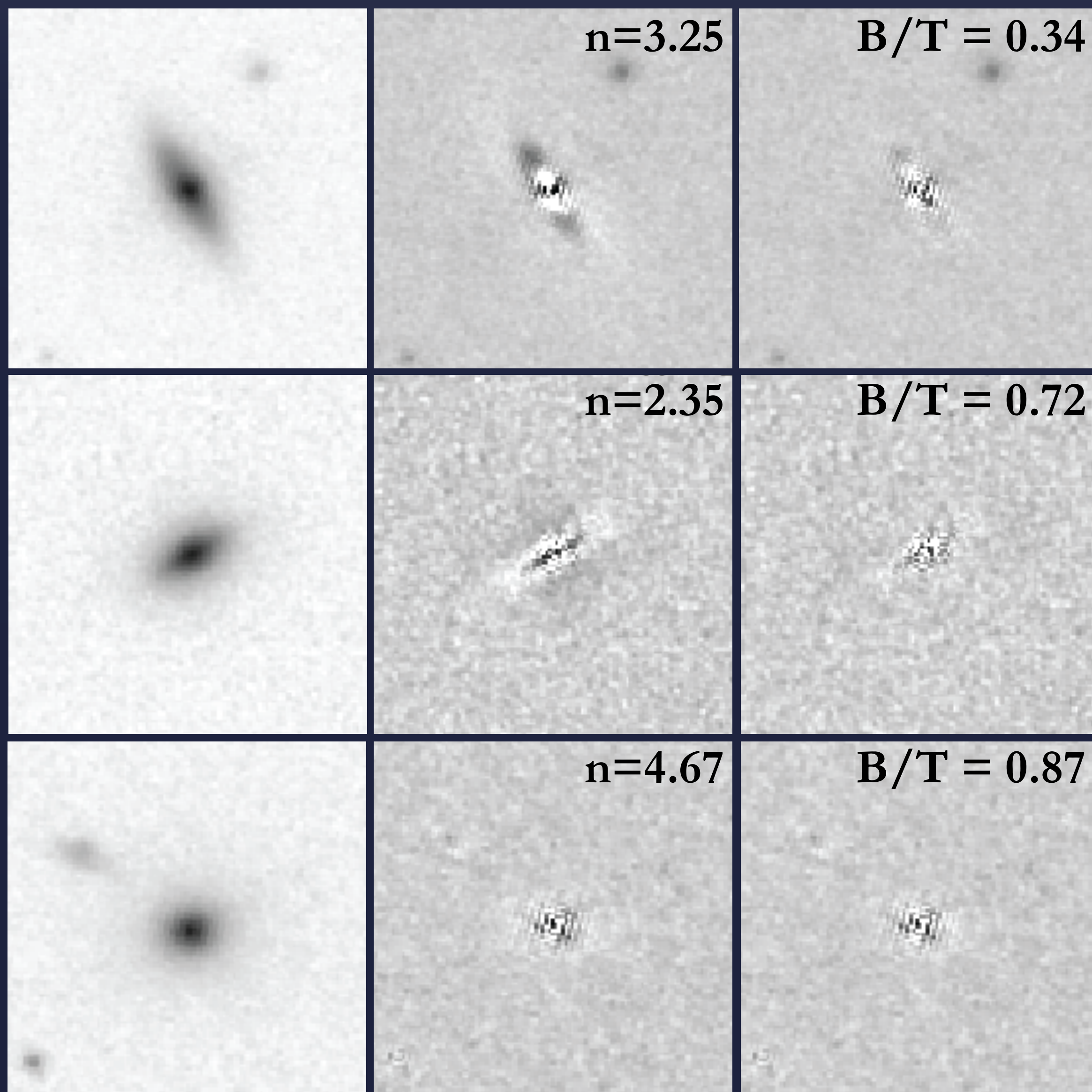
DETAILED MORPHOLOGY STUDIES

- Most galaxies aren’t as simple as pure disks or pure ellipticals.
- By convention, Sersic
  $n<2.5$ = disk-like
  $n>2.5$ = spheroidal
- With good data we can decompose an image of a galaxy into its subcomponents

TWO-COMPONENT FITTING

1-component residual

2-component residual



disk-dominated (2 components)

bulge-dominated (2 components)

spheroid (1 component)

TWO-COMPONENT FITTING

Residual Flux Fraction:

$$\mathrm{RFF} = \frac{\sum_{i,j\in A} \left| I_{i,j} - I_{i,j}^{\mathrm{model}} \right| - 0.8 \times \sum_{i,j\in A} \sigma_{i,j}^{bkg}}{\sum_{i,j\in A} I_{i,j}}$$

(Hoyos et al. 2011)

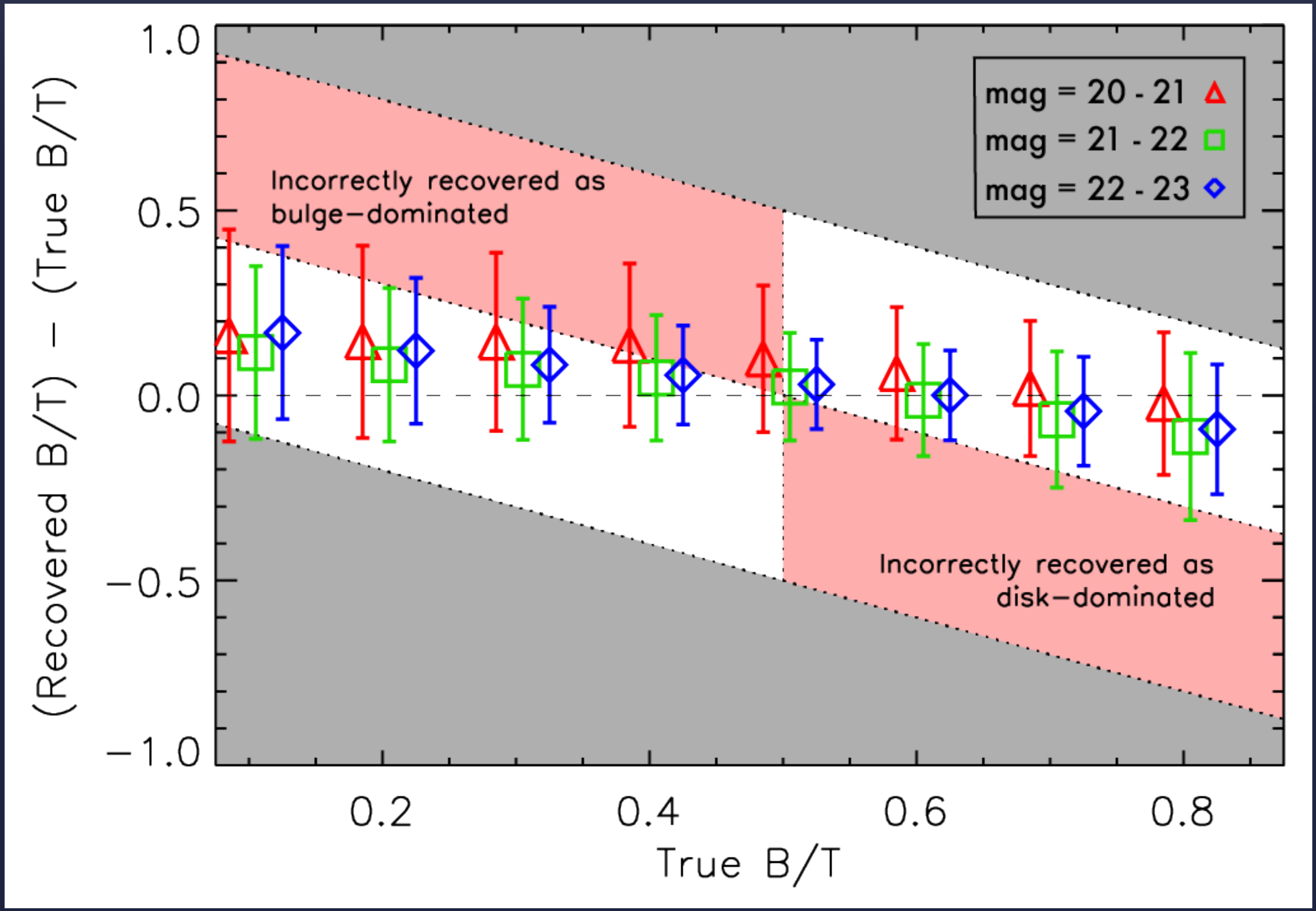
Compare RFF for 1 and 2-component models to determine whether 2-components are required to sufficiently fit the data.

We require (RFF1 – RFF2)/RFF1 > 0.5 to favor the 2-component model.

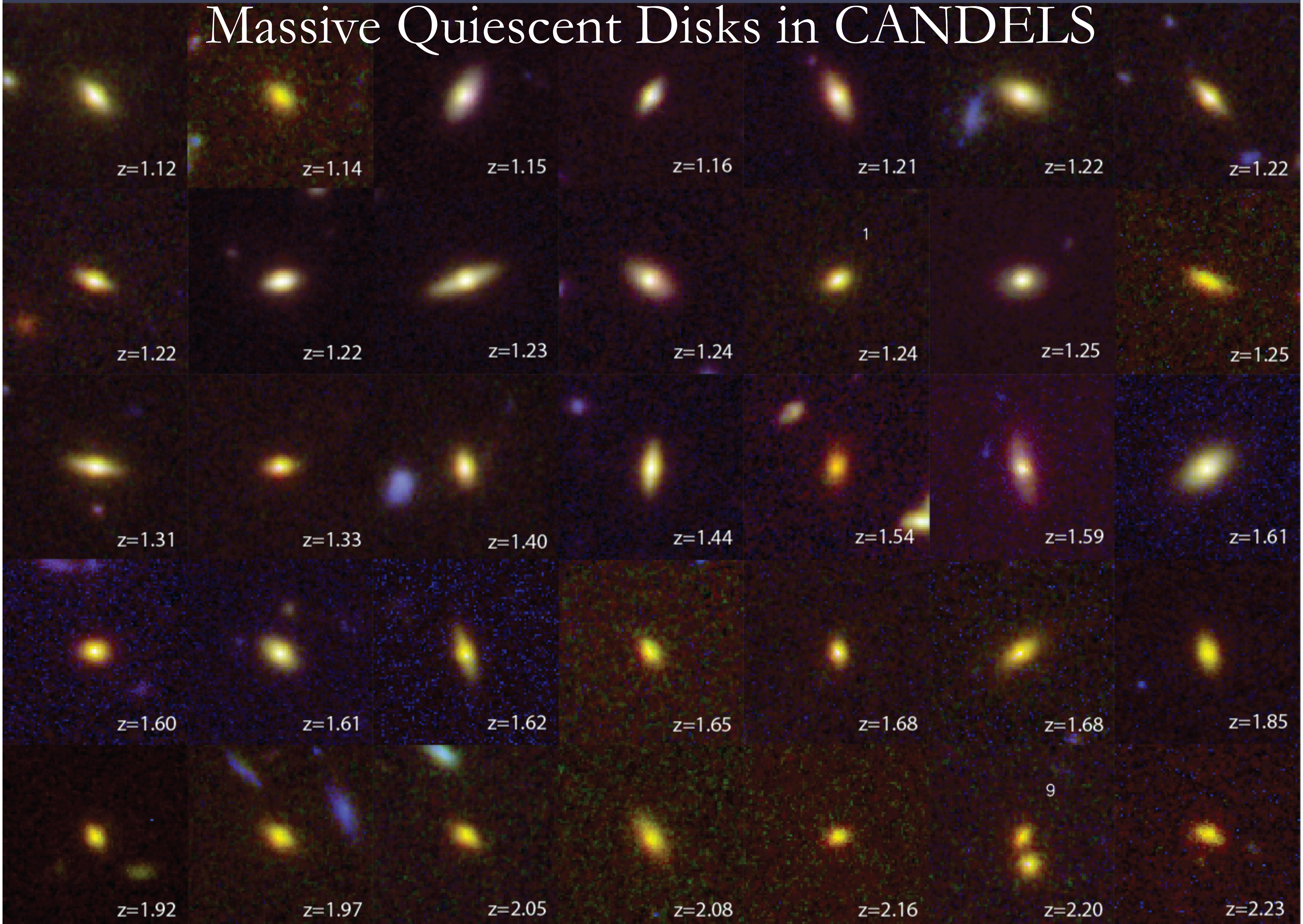
SIMULATED B/T RECOVERY

- ~500,000 mock galaxies created with galfit, spanning the parameter space of observed high-z galaxies.
- PSF + noise added to replicate CANDELS-like data
- range of magnitudes and B/T ratios
- recover morphologies with galfit and compare to truth

SIMULATED B/T RECOVERY



Massive Quiescent Disks in CANDELS



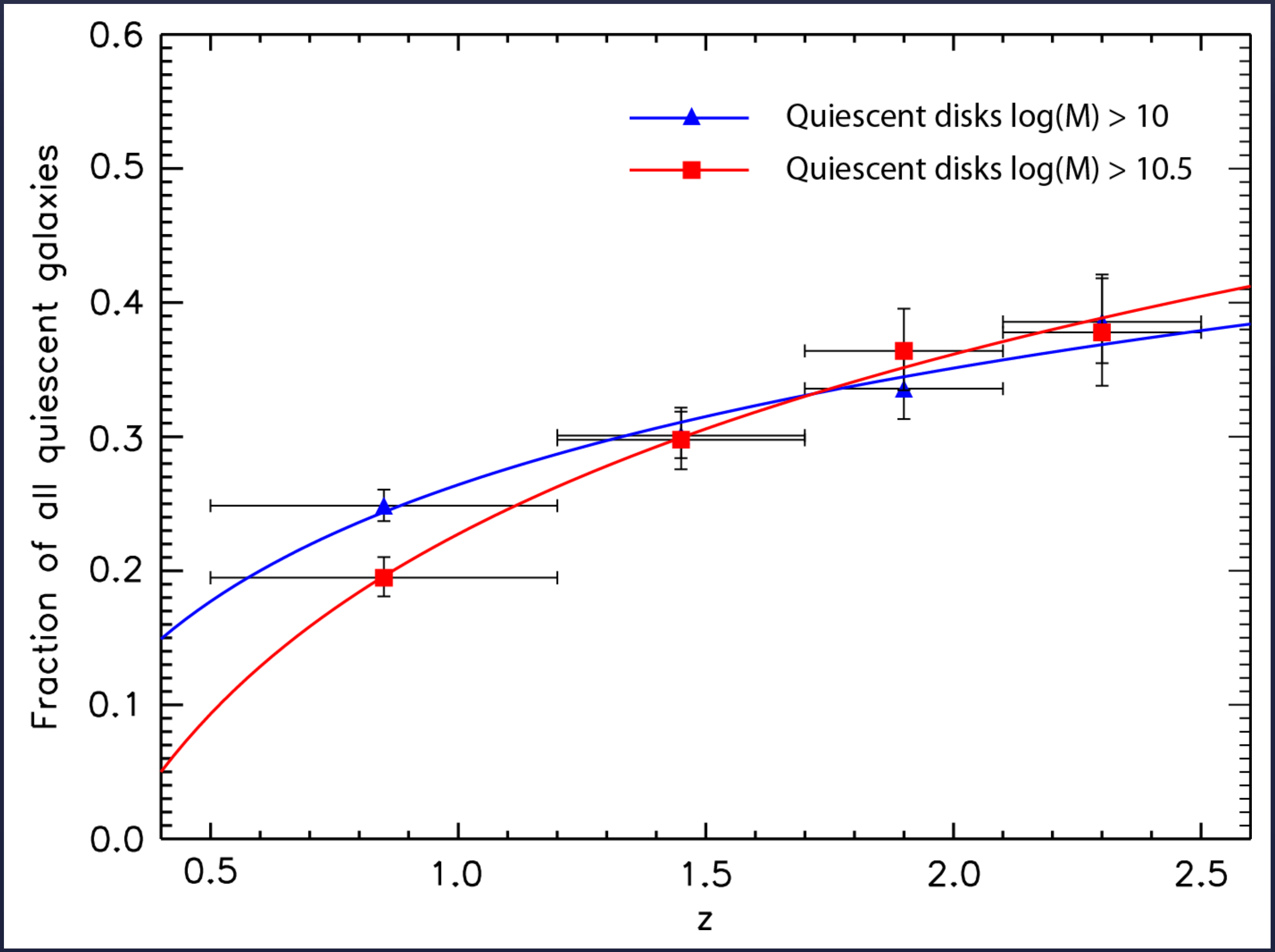
REDSHIFT EVOLUTION IN QUIESCENT DISK FRACTION

Statistics using all 5 CANDELS fields:

Significant fraction (>35%) of quiescent disks at high-z.

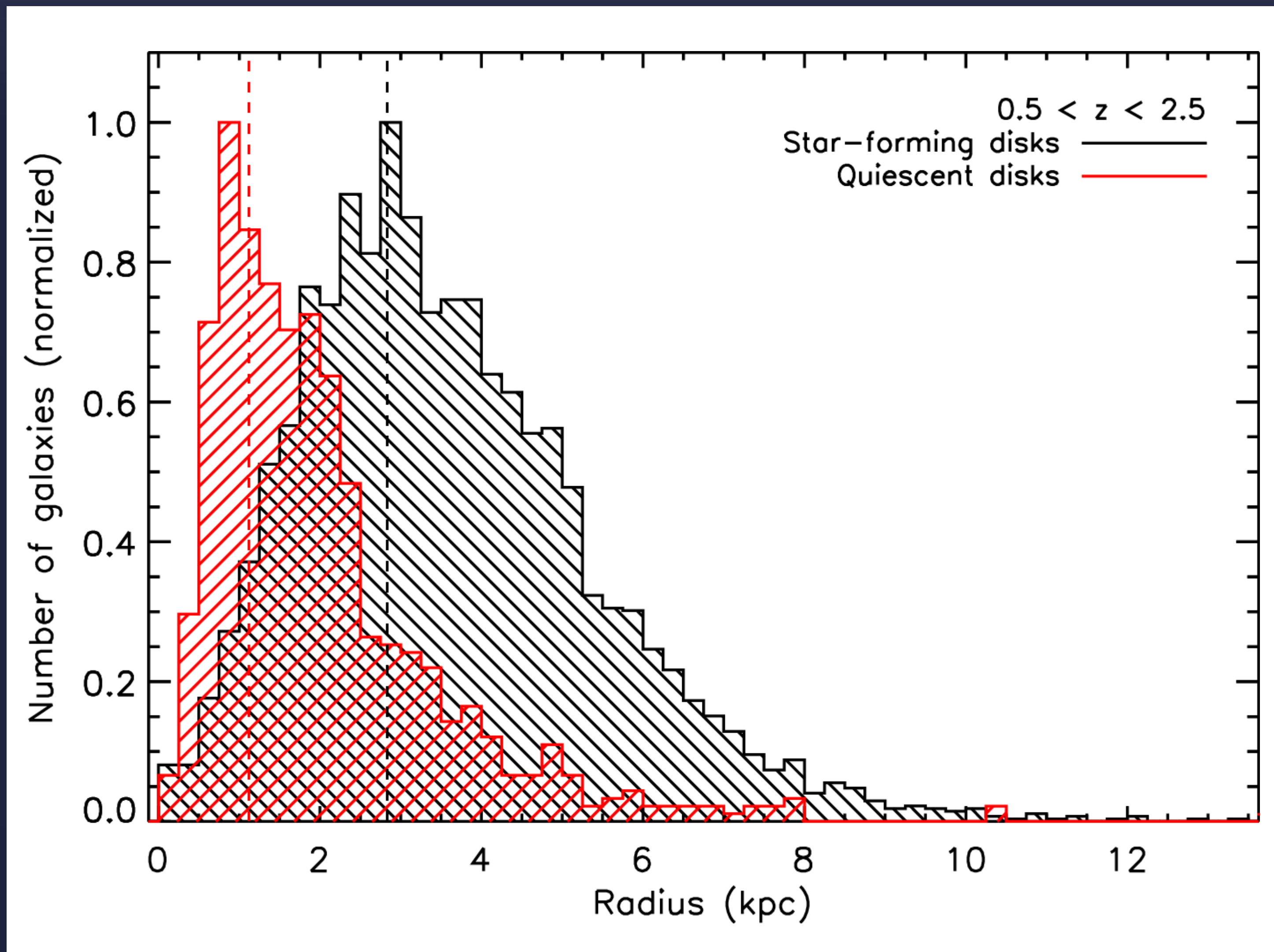
Trend even more prominent among the most massive galaxies.

Note: QDs defined to have B/T < 0.5 or n<2.5



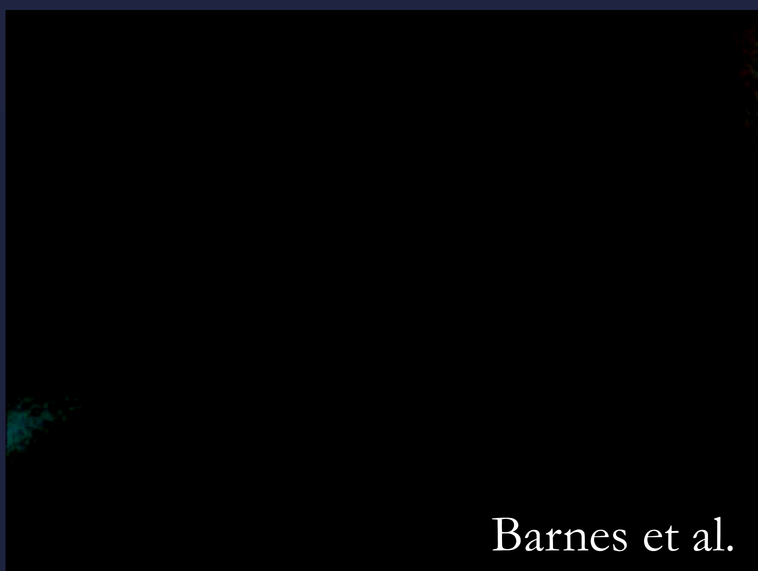
COMPACTNESS

Like their quiescent spheroid counterparts, quiescent disks are significantly more compact than star-forming galaxies at the same redshift and mass.



THE IMPORTANCE OF QUIESCENT DISKS

- <u>Disks quenched before transforming to spheroids.</u>
- Compaction?
- How to assemble ~ 10^{11} M_{sun} into a disk at early times?



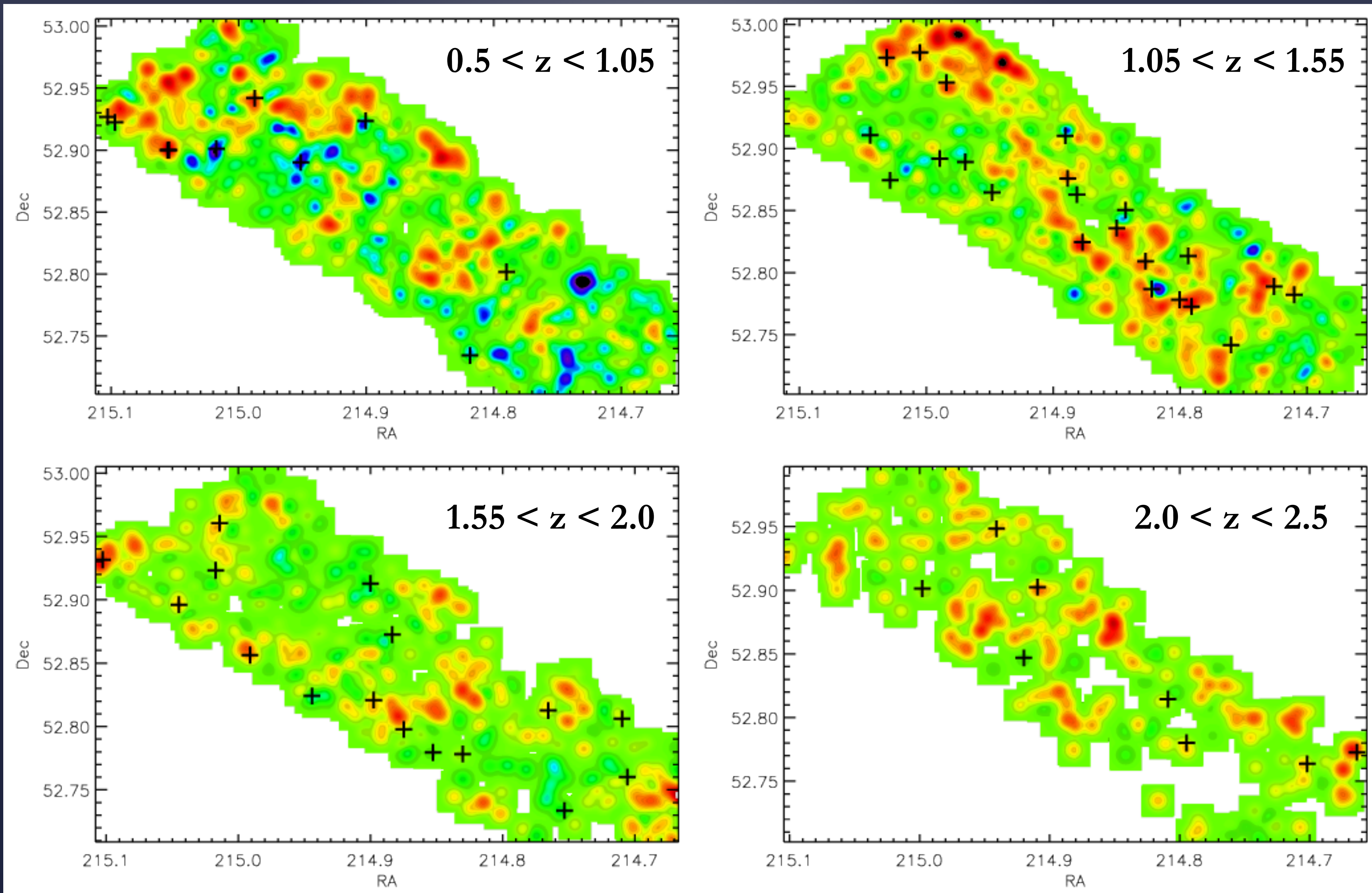
Major mergers: requires extremely gas-rich progenitors, and even then, difficult to form low bulge fraction disks.

Cold mode accretion: can build up angular momentum. VDI efficient at forming compact objects.

THE IMPORTANCE OF QUIESCENT DISKS

- Disks quenched before transforming to spheroids.
- Compactification?
- How to assemble ~ 10^{11} M_{sun} into a disk at early times?
- How to shut down SF?
  - AGN? – need a source of fuel (mergers, VDI, etc.).
  - Halo/ environmental quenching?

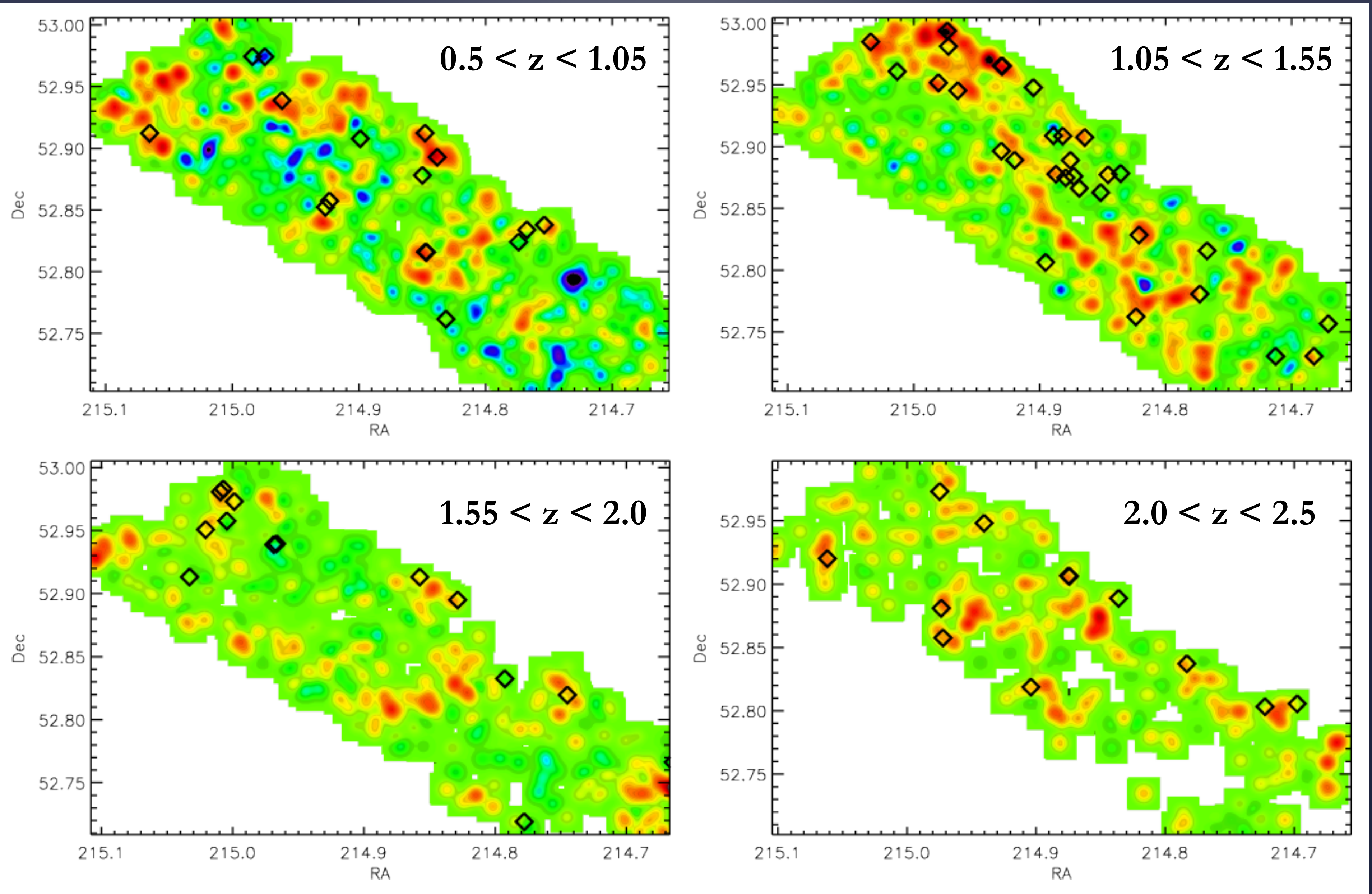
ENVIRONMENTS



+ Quiescent disks

overdensity data from Fossati et. al (2017)

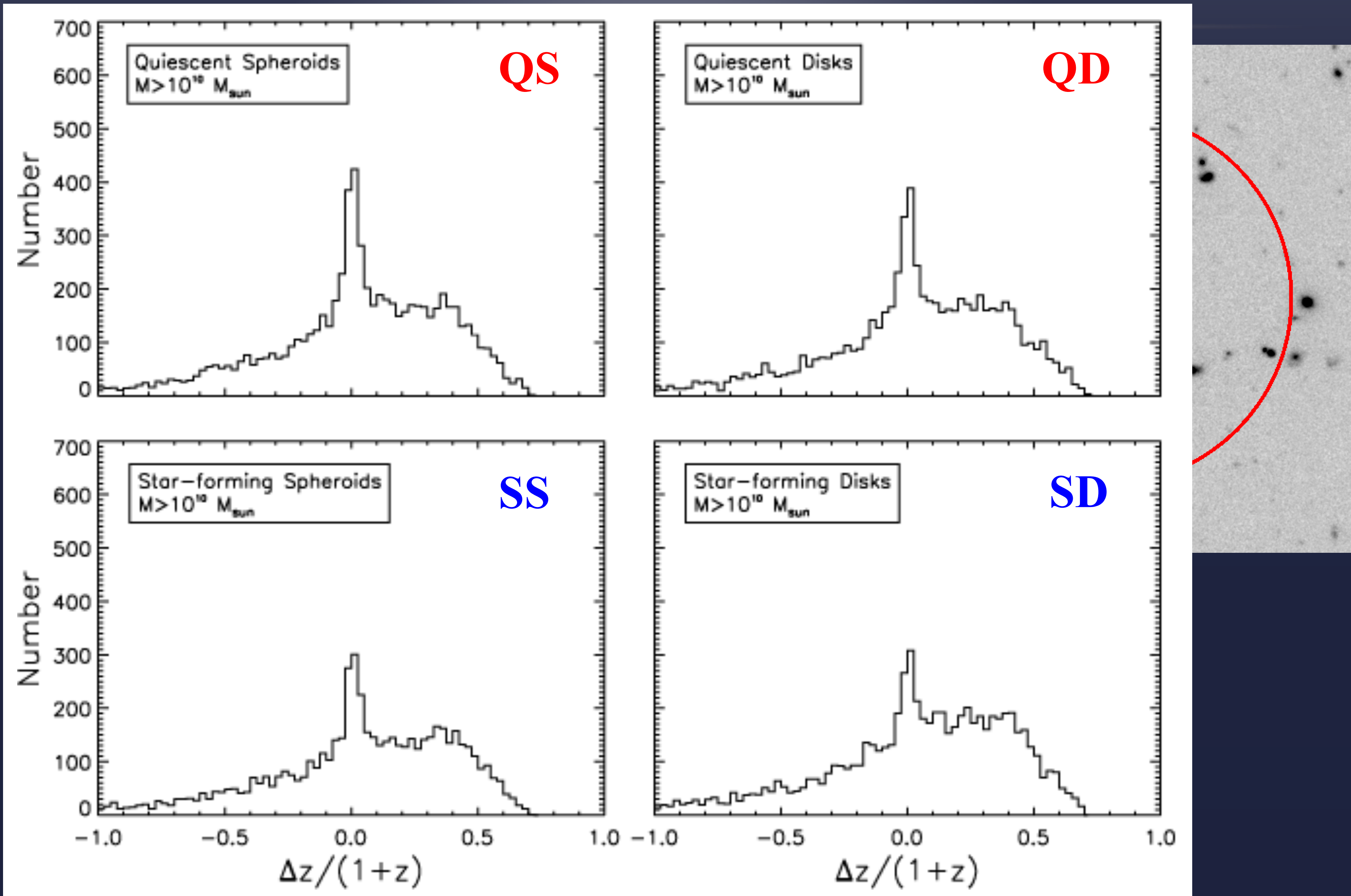
ENVIRONMENTS



◇ Quiescent spheroids

overdensity data from Fossati et. al (2017)

ENVIRONMENTS



THE IMPORTANCE OF QUIESCENT DISKS

- Disks quenched before transforming to spheroids.
- Compactification?
- How to assemble $\sim 10^{11}$ M_{sun} into a disk at early times?
- How to shut down SF?
  - AGN? – need a source of fuel (mergers, VDI, etc.).
  - Halo/ environmental quenching? – needs further study, but indications they live in overdense environments. Possible timescale problems.
  - Other processes: morphological quenching. May take too long to be viable for massive quiescent disks at z~2.

THE FIRST GENERATION OF S0 GALAXIES?

- Similar characteristics (mass, B/T) to local S0s, but much more compact.
- Inside-out growth via minor dry mergers to increase size?
- May provide an important link to the formation mystery of S0s today.

SUMMARY

- Massive quiescent disks are common at high-z.
- Mechanism to build up early massive disks? Cold gas accretion followed by compaction.
- Need a mechanism to shut down star formation.
  - Possibilities include: AGN (but how to feed the black hole?), rapid gas consumption followed by halo quenching (environments are overdense), morphological quenching (timescales probably too long).
- Mergers important later in "puffing-up" dense galaxies to place them on local size-mass scaling relations and in converting disks to spheroids.