If you want to understand function,

All in One Basket

Francis Crick

Discovery (1988)'

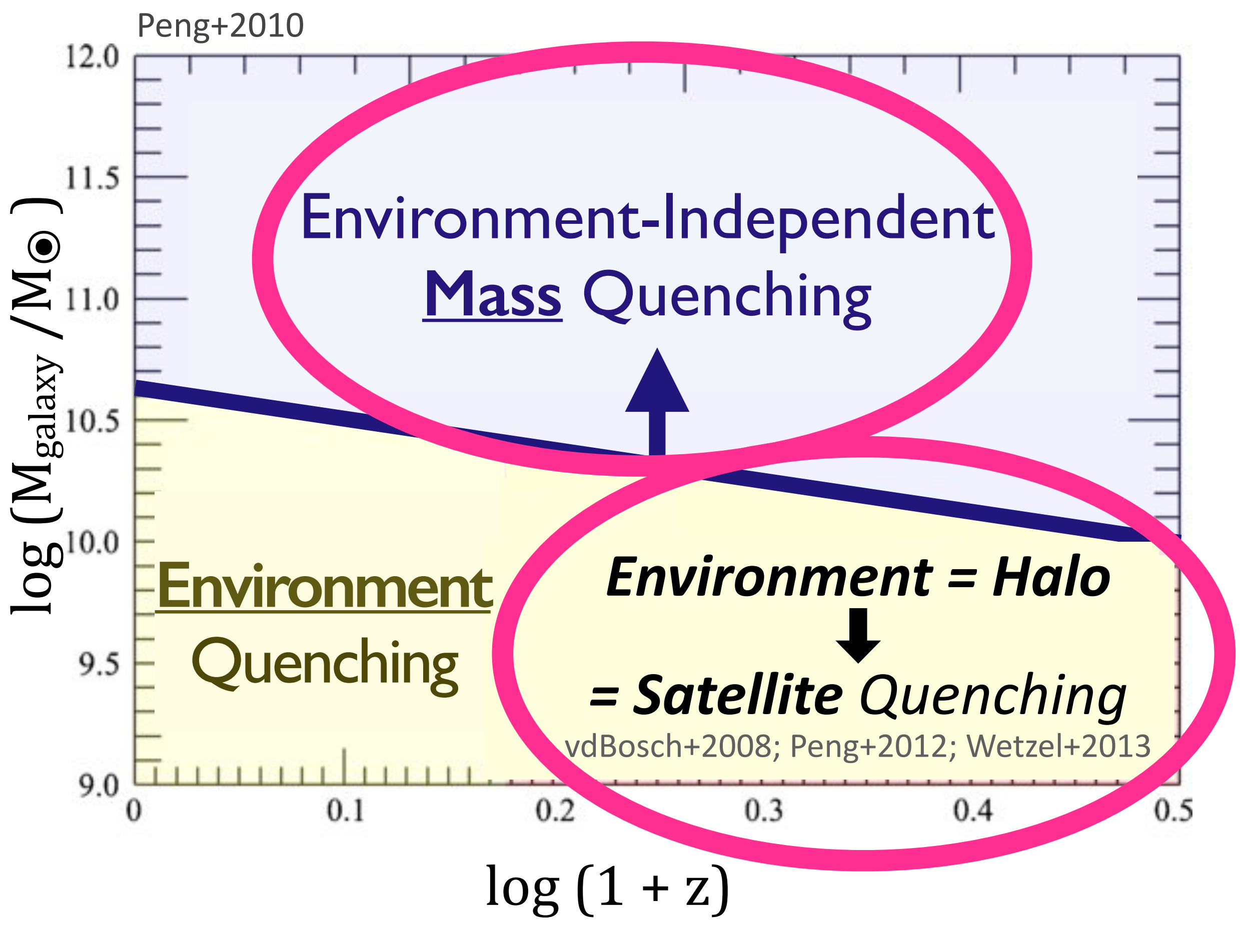
Quenching

Morphological Transformations

Environmental Effects

Size Growth of Quenched Galaxies

When Galaxies Switch Off



(One or another)
AGN Feedback ?
Dave'+, Hopkins+,....

Halo Quenching ?
Dekel+,.....

Morphological
(Gravitational)
Quenching ?
Martig+, Genzel+,....

Strip

Im

Larson+,Kaw

ng?

Separability of Quenched Fraction
with galaxy mass and environment
Peng+2010

QUENCHING ↔ MORPHOLOGY :

HOW TO MAKE ~M* SPHEROIDS?

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Impact of Mass and Environment on Quenching and Morphologies

Focus on Satellites in Nearby Group Halos

ZENS: z~0 Groups Sample

Carollo, **Cibinel** et al 2013, ZENS I, ApJ 776, 71
Cibinel, Carollo et al 2013a, ZENS II, ApJ 776, 72
Cibinel, Carollo et al 2013b, ZENS III, ApJ 777, 113

The overall quenched *satellite* fraction increases towards group centers.
(see also eg vdBosch+2008, Peng+2012, Wetzel+2012, Woo+2013,….)

The fraction of quenched satellites *with an early-type morphology* is constant with halo-centric.

All analyses at constant halo R
stellar mass M $\geq 10^{10}$ M$_\odot$

- Either both quenching channels produce *same morphological mix*, or
- Neither is associated with a morphological transformation.

The morphological mix of quenched galaxies at a given mass is decoupled from the overall quenched fraction

Consistent with picture of two quenching channels, one that acts on all galaxies and is independent of the environment, and another one that acts only on satellites and depends on halo-centric radius

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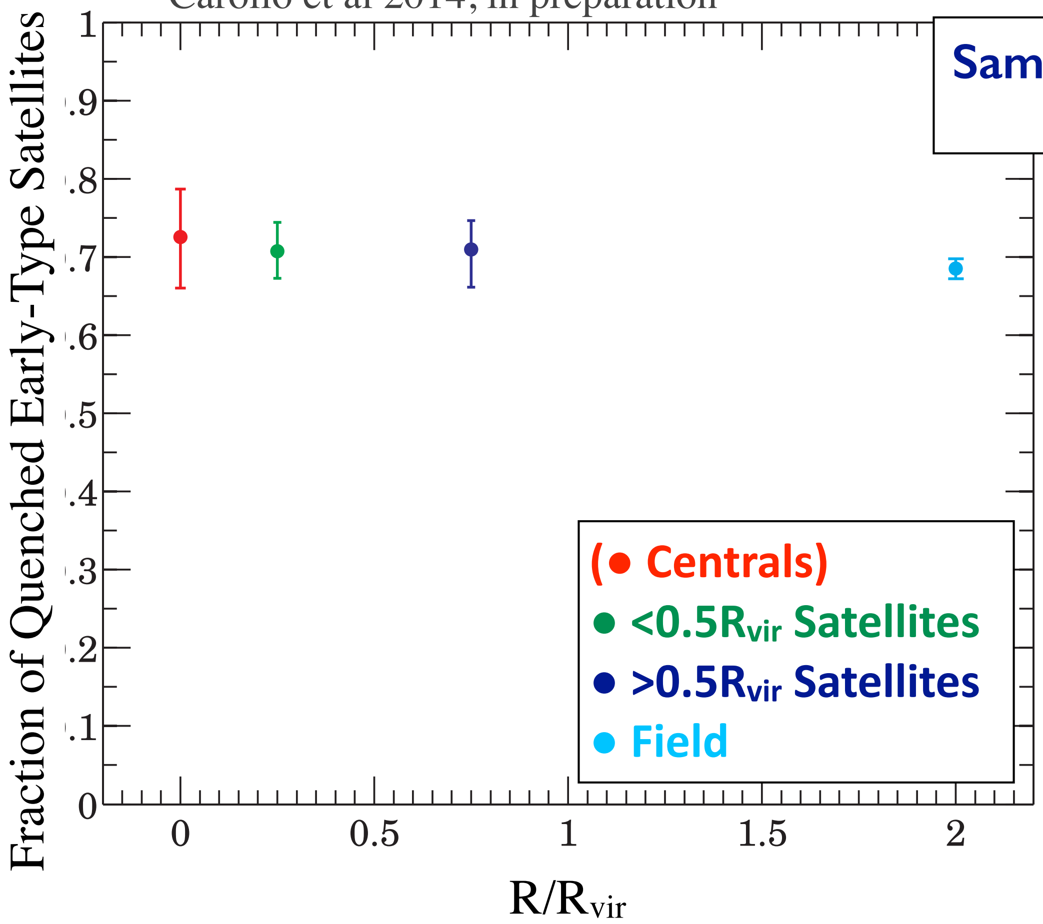
Flat Morphological Mix of *Quenched-Satellites* with $R_{halo\text{-}centric}$ out to z~0.8

Carollo et al 2014, in preparation



Same in COSMOS with zCOSMOS Groups Sample
(Knobel et al 2012)

$0.2 < z < 0.8$
$10^{10.25} < M_{galaxy}/M_{\odot} < 10^{11.75}$
$M_{halo} > 10^{12.5} M_{\odot}$

(result independent of M and z-binning)

The morphology-density relation results from the increasing *fraction* of quenched galaxies, *not* from changes in the morphological mix towards the centres of halos

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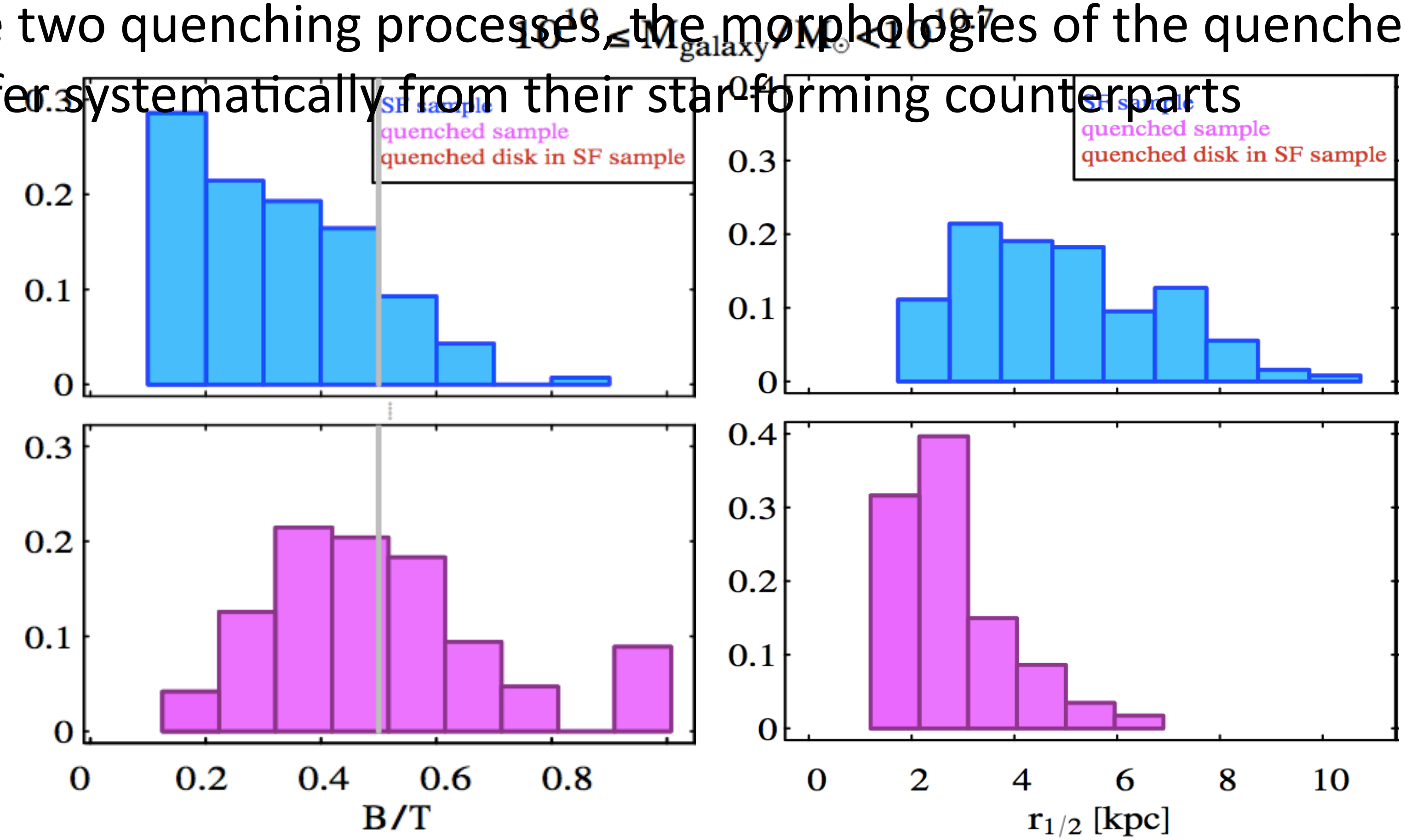
Comparison of Morphologies between Quenched and Star-Forming Satellites

ZENS IV. Carollo+ 2014 arXiv 1402.1172

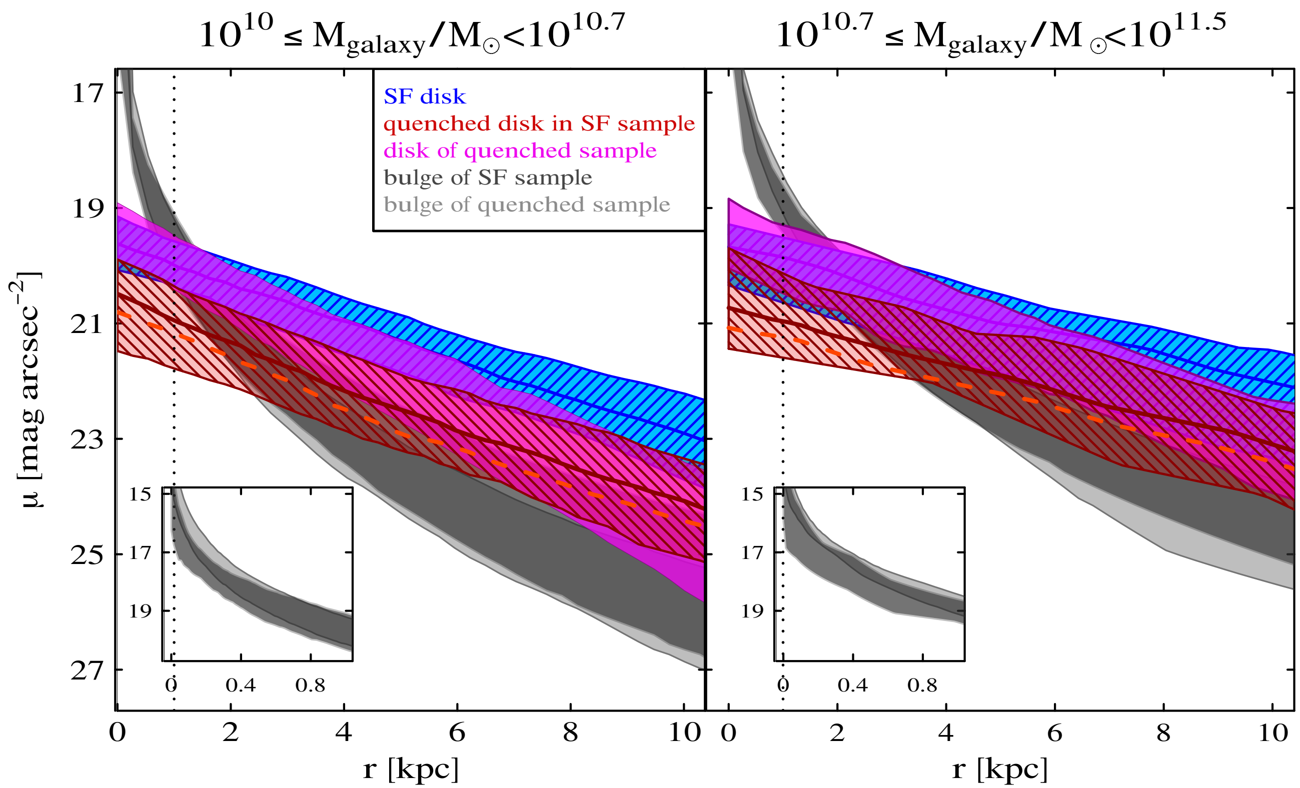
- Despite no difference in the morphological outcomes of the two quenching processes, the morphologies of the quenched satellites differ systematically from their star-forming counterparts



- Quenched satellites have larger B/T and smaller half-light radii than star-forming satellites

Comparison of Bulges and Disks between Quenched and Star-Forming Satellites

ZENS IV. Carollo+ 2014 arXiv 1402.1172

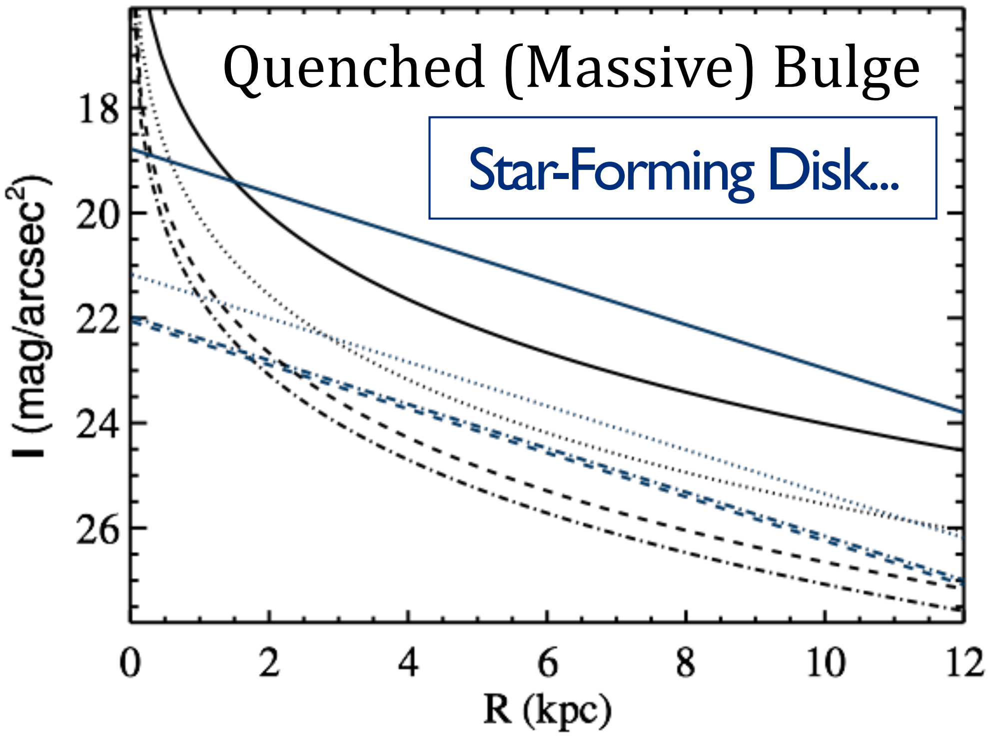


- The bulges in quenched and star-forming satellites have very similar luminosities and surface brightness profiles

The differences in B/T and in half-light radii are mostly due to differences in the disks, which have lower luminosities in the quenched galaxies

- Any mass growth of the bulges associated with quenching cannot greatly change these quantities

Star Formation in Disks ⇒ Quenching = *Disk* Quenching



Apparent Morphological Transformation Through Disk Fading

$\xi = D_Q/D_{SF} < 1$

$$(B/T)_{SF} = \frac{B}{B + D_{SF}}$$

$$(B/T)_Q = \frac{B}{B + D_Q} = \frac{(B/T)_{SF}}{\xi + (1-\xi)(B/T)_{SF}}$$

Disk fading after quenching
increases the morphological B/T — and decreases the half-light radii,
even if there are ***no underlying structural changes in the stellar mass distributions***

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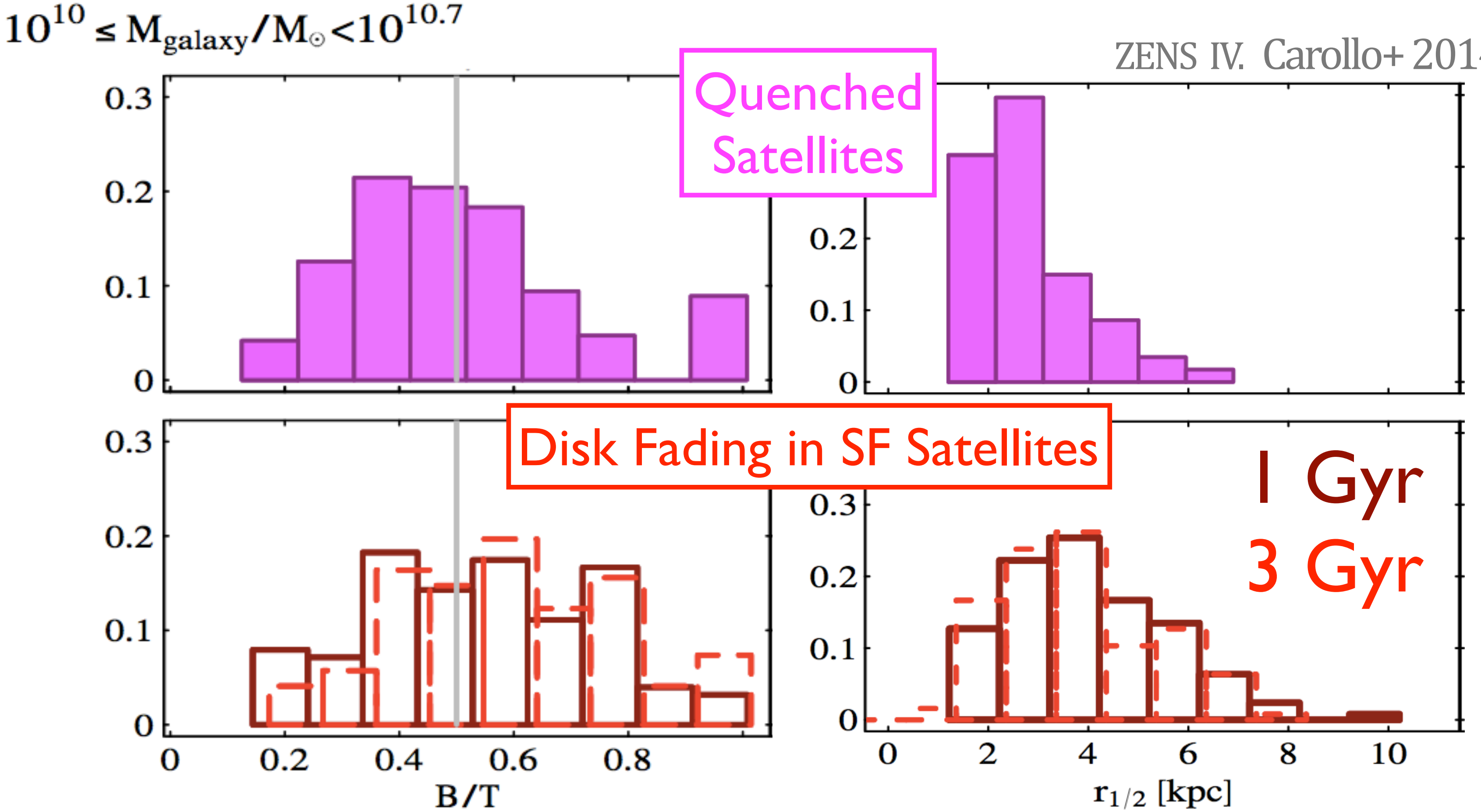
Simulated B/T and $r_{1/2}$ of *Uniform* Disk Fading after Disk Quenching

ZENS IV. Carollo+ 2014 arXiv 1402.1172



- Disk fading after quenching quantitatively explains the morphological difference in B/T between star-forming and quenched satellites
- The difference in galaxy half-light radii between quenched and star-forming satellites remains larger than can be explained by *uniform* fading of the disks following quenching

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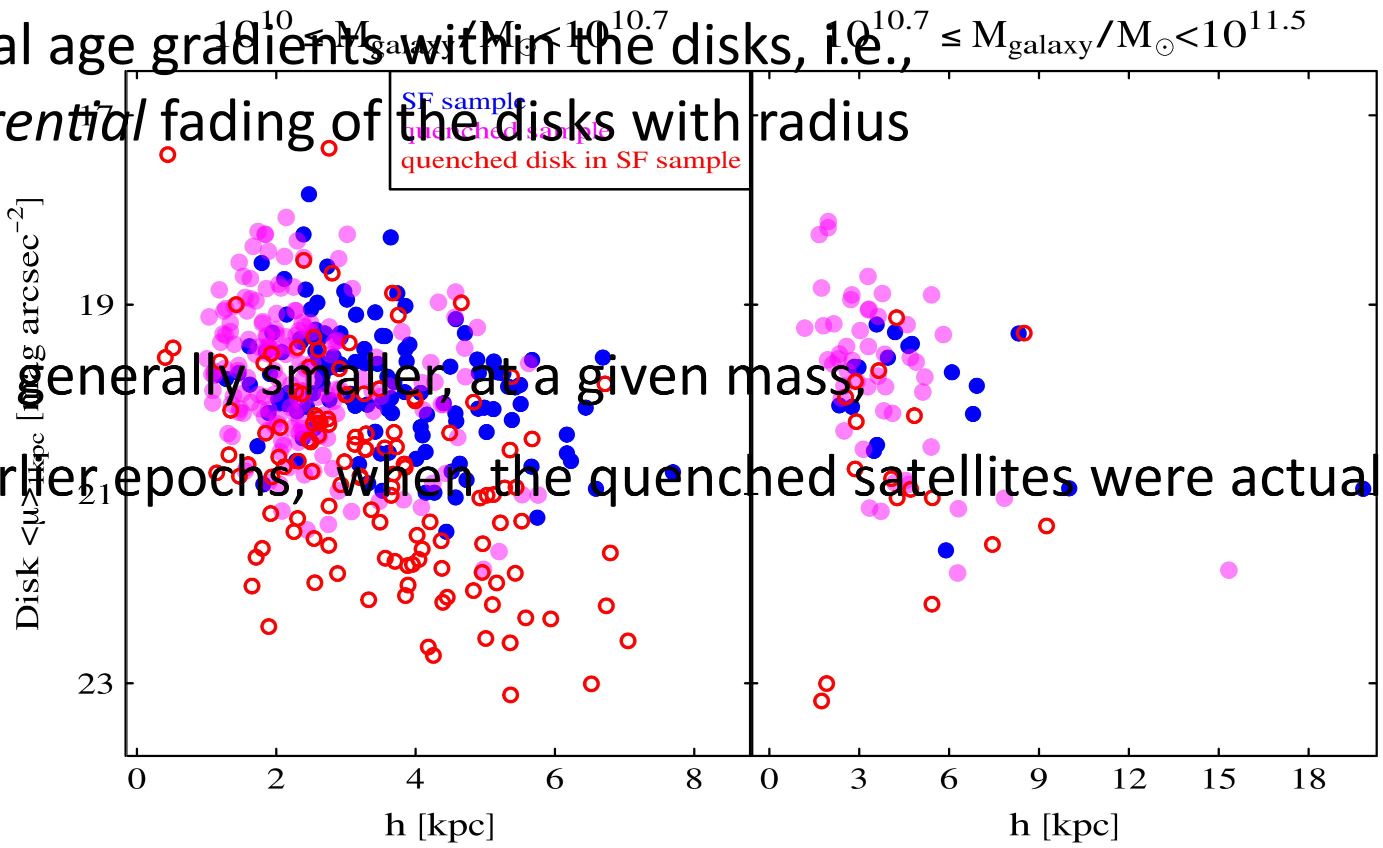
Another Failure of *Uniform* Disk Fading: Disk Scale Lengths

Expectations from inside-out growth of disks

ZENS IV. Carollo+ 2014 arXiv 1402.1172

➡ Radial age gradients within the disks, i.e., *differential* fading of the disks with radius

➡ disks generally smaller, at a given mass, at earlier epochs, when the quenched satellites were actually quenched



▸The quenched disks have smaller scale lengths than in star-forming satellites

Quantifying Differential Fading

$$h_{fade} = \frac{h_{SF} h_Q}{h_{SF} - h_Q} = (h_Q^{-1} - h_{SF}^{-1})^{-1}.$$

With:

$$\mu_{SF}(r) = \mu_{SF,0} + 1.085 r h_{SF}^{-1}$$

and

$$\mu_Q(r) = \mu_{Q,0} + 1.085 r h_Q^{-1},$$

the fading $\Delta\mu(r)_{fade}$ at different radii will be given by:

$$\Delta\mu(r)_{fade} = (\mu_{Q,0} - \mu_{SF,0}) + 1.085 r (h_Q^{-1} - h_{SF}^{-1}).$$

With $h_Q \sim 0.5 h_{SF}$:

➜ $h_{fade} \sim h_{SF}$

➜ $\mu_{Q,0} - \mu_{SF,0} \sim 0$

➜ $\Delta\mu(h_{SF})_{fade} = 1$ mag

Consistent with ~1-3 Gyr of passive evolution; fully explains the smaller sizes of quenched satellites relative to star-forming satellites

Three Points so far

1. Simple fading of the disks after star-formation ceases can explain the change in the *observed (light-defined) B/T* and in the *mean half-light radii*, that are seen in quenched galaxies relative to a plausible set of star-forming progenitors, without the need for any substantial mass growth or other changes in the bulge components.

2. This supports the idea that neither mass-quenching nor satellite-quenching produce a significant structural change in the stellar mass distribution of satellite galaxies.

3. Mass- and satellite quenching: apparently two quenching channels, but a single physical process.

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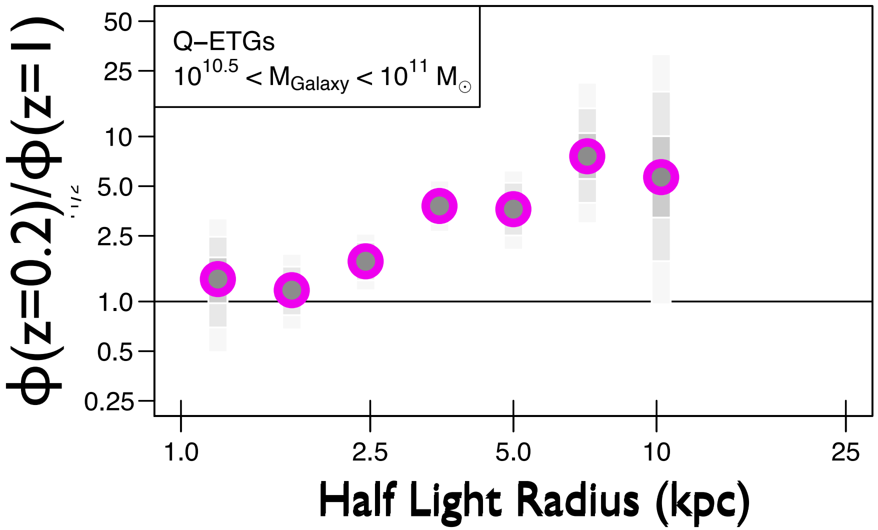
The evolution of the SIZE Function of ~M* Quenched ETGs since z=1 / The ratio of the z=0.2 and z=1 SIZE Functions of ~M* Quenched-ETGs

Carollo+ 2013, ApJ 773, 112

I_{AB}<24 COSMOS Sample

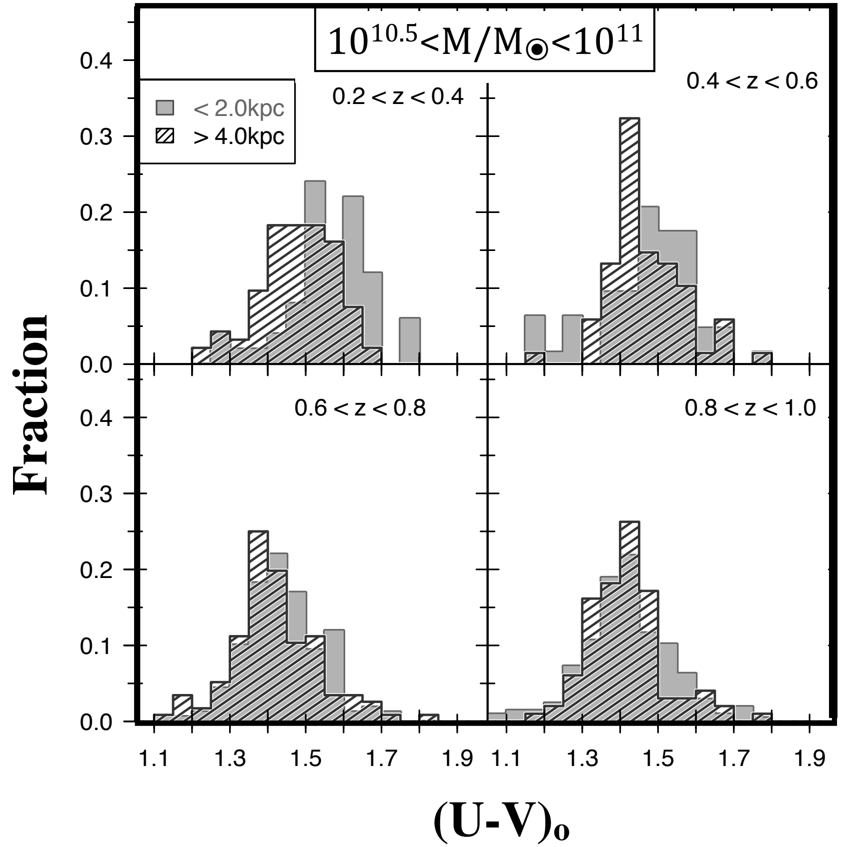


At ~M*,
no change in the comoving #-density
of *compact* Q-ETGs ($r_{1/2}$ < 2kpc)

Most of the growth
in the comoving #-densities of Q-ETGs
is observed at *LARGE* galaxy sizes

Stellar Populations of Compact & Large M* Q-ETGs

Carollo+ 2013, ApJ 773, 112



- **Compact Q-ETGs** become systematically redder towards later epochs
- U−V color difference consistent with a passive evolution of their stellar populations

➡ **Stable population that does not appreciably evolve in size**

- **Larger Q-ETGs** have average rest-frame U-V colors **bluer than compact Q-ETGs**

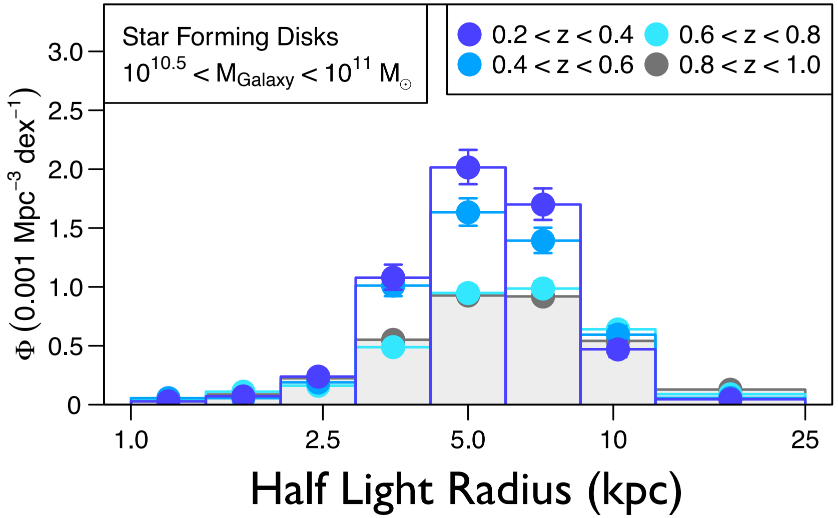
➡ **At any z<1, larger Q-ETGs younger than compact Q-ETGs**

Increase with z→0 of the *median* size of Q-ETGs primarily caused by the addition at later epochs of larger and more diffuse Q-ETGs

The evolution of the SIZE-Function of ~M* *Star-Forming* G's since z=1

Carollo+ 2013, ApJ 773, 112

I_{AB}<24 COSMOS Sample



SFGs:
At these high stellar masses,
very dense, bulge-dominated disks

Assume direct quenching of SF galaxies from their Main Sequence

Predictions for Quenched Fractions from Φ_{SFGs}

Peng+2010

Production rate f_Q of quenched objects at any time *t*:

$$f_Q(t) = \frac{\Phi_{SF}(t) \times rsSFR(M_{Galaxy}, t) \times \frac{M_{Galaxy}}{M^*}}{\Phi_{SF}(t)}$$

Fractions $f_{Q,i}$ of newly-quenched galaxies in each redshift bin *i*:

$$f_{Q,i} = f_Q \Big|_{t(z_{high,i})}^{t(z_{low,i})} = \frac{M_{Galaxy}}{M^*} \int_{t(z_{high,i})}^{t(z_{low,i})} \mathrm{rsSFR}(\mathrm{M_{Galaxy}}, \mathrm{t})\, dt$$

Predicted size-function of newly-quenched galaxies ➡

$$\Phi_Q(r_{1/2}) = \sum_{i=1} f_{Q,i} \times \Phi_{SF,i}(r_{1/2})$$

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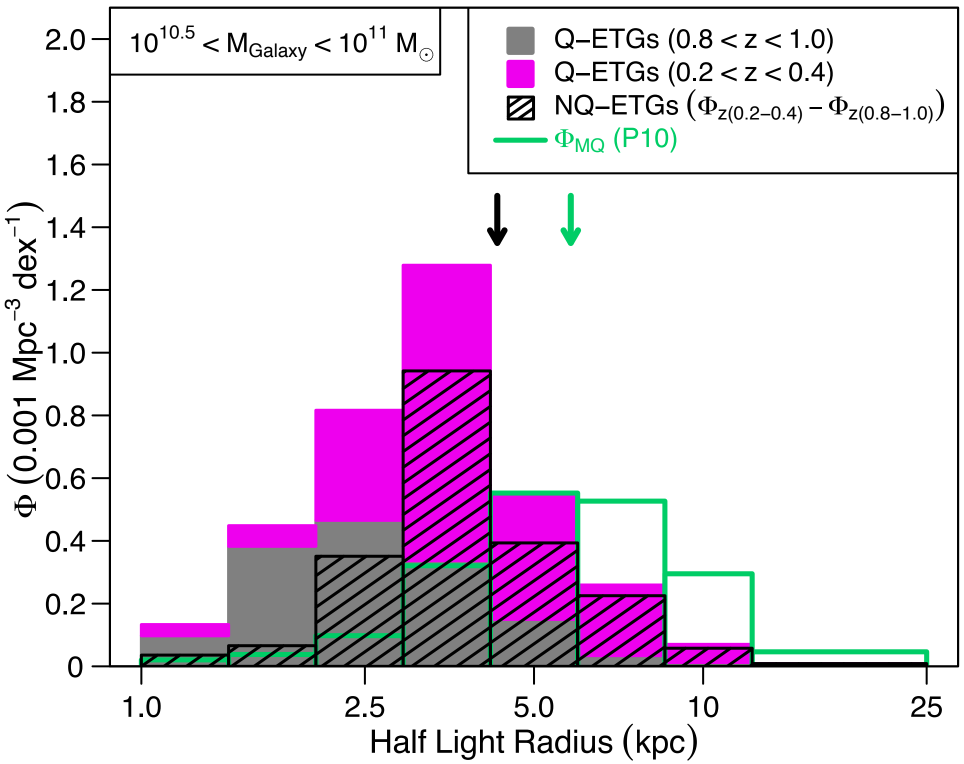
Comparison of Observed and Predicted Size Functions of Quenched G's

Carollo+ 2013, ApJ 773, 112



Predicted Quenched SFGs

Observed Newly-Quenched ETGs

**At ~M*,
observed newly-quenched ETGs
are ~30% smaller than progenitor SFGs.**

**Production of M* spheroids since z~1
fully consistent with direct quenching of galaxies out of the SF Main Sequence
and subsequent fading of their quenched disk components.**

Summary

At $M > 10^{10} M_{\odot}$ *and* redshifts $z \lesssim 1$

1.

**Conclusions valid at high galaxy mass and recent epochs.
They may *not* hold at lower galaxy masses and
for quenching occurring at much earlier times.
(e.g., Joanna Woo & Sandro Tacchella's Talks !)**

2. **Analysis of bulge and disk profiles of quenched and star-forming satellites shows that *neither mass- nor satellite-quenching are likely to change the mass-defined B/T*, which is thus probably set by other processes operating prior to the onset of quenching.**

3. **(Differential) *fading of quenched disks* is fully consistent *apparent* increase of (light-defined) B/T.**

4. **Compact Q-ETGs: stable in number density and passively-evolve since z~1.
Larger galaxies are quenched at later epochs.
Sizes of *newly-quenched* early-type galaxies consistent with fading of quenched disks.**

Satellite-and mass-quenching: Two different manifestations of the same physical process.
E.g., satellite quenching a process linked to the parent halo mass (@Avishai).
**The mass-independence of satellite-quenching arising from
the independence of the satellite mass function on group halo mass (@Peng+2012).**