Decomposing the sizes of bulge-disk systems at $1<z<3$

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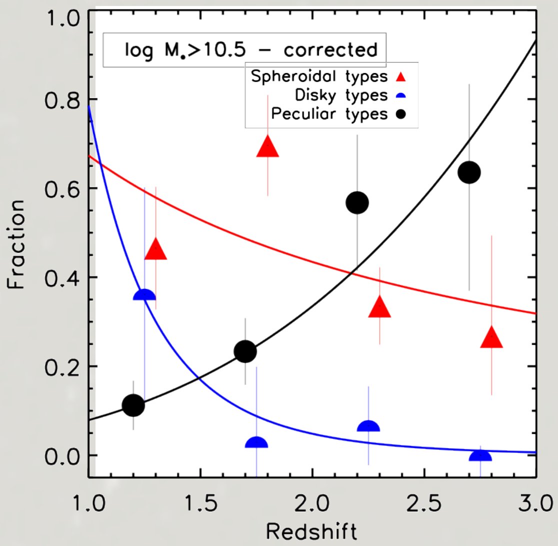
& members of the CANDELS team

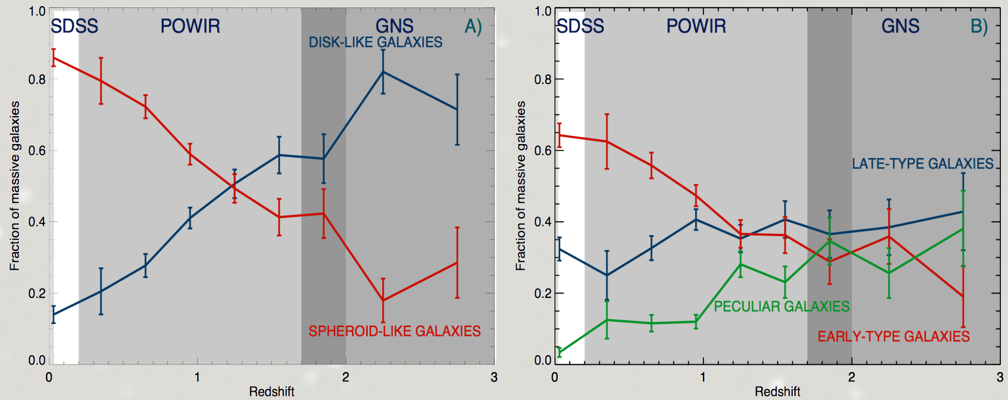
Galaxy Morphological Evolution Over 1<z<3

visual classifications



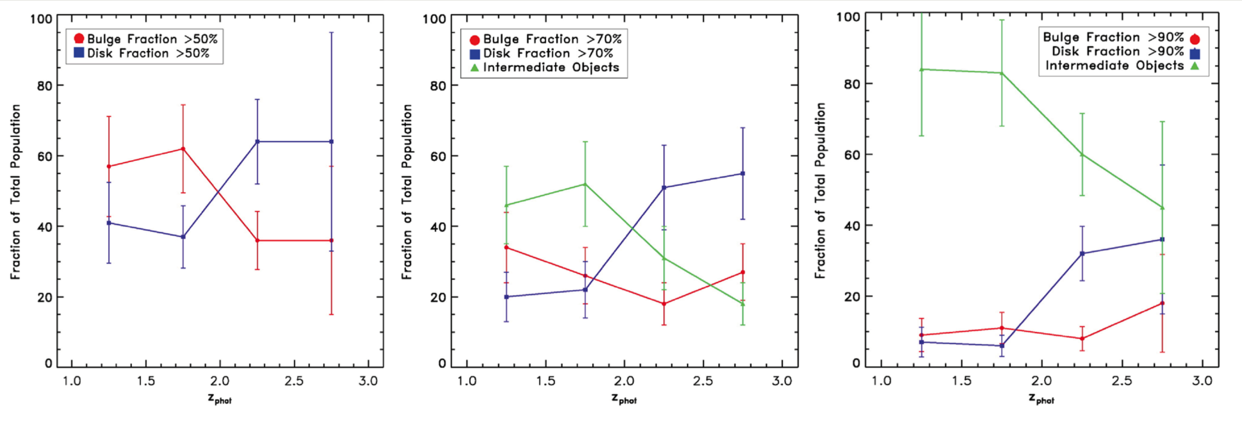
Mortlock et al. 2013

single Sérsic fits



Buitrago et al. 2013

decomposed light fractions



Bruce et al. 2012

What do decomposed fits really tell us ?

Bulge+Disk Decompositions

CANDELS: WFC3/IR F160W, F125W + ACS F814W, F606W
-wide (GOODS-N, GOODS-S) 5-σ (pt. source) depth 27.7 [AB] over ~65 sq. arcmin
- deep (UDS, COSMOS, EGS) 5-σ (pt. source) depth 27.0 [AB] over ~187 sq. arcmin

CANDELS sample of ~400 galaxies at $M_* > 10^{11} M_\odot$ at $1<z<3$ in UDS and COSMOS

Define 3 components : disk n=1, bulge n=4, PSF

Models:

- bulge only
- disk only
- bulge + PSF
- disk + PSF
- bulge + disk
- bulge + disk + PSF

Likelihood ratio test:

Adopt simplest model, unless a model with more free parameters has:
$X^2_{complex} < X^2_{simpler} - \Delta X^2(d.o.f_{complex} - d.o.f_{simpler})$
at the 3σ level.

similar results using BIC

Bulge+Disk Recoverability

Grid of 9216 objects with total mag 21.8 [AB] with the following set-up:

B/T Light Fraction	0.99, 0.95 ,0.9, 0.75, 0.5, 0.25, 0.1, 0.05	Axial Ratio	0.1, 0.3, 0.6, 1.0
Effective Radii	1, 5, 10, 20 pixels	Relative Position Angle	0, 30, 60, 90

light fractions

- B/T fractions recovered to within 10%, in 80% of cases
  - no systematic offsets

sizes

<u>Disks</u>

- Random uncertainty:5-10%
- Systematic offset: 1-5% under-estimate for pure disk or bulge+disk systems

<u>Bulges</u>

- Random uncertainty: pure bulges 5-10%, mixed systems 10-20%
- Systematic offset: pure bulges 1-5%, mixed systems 1-10%

PSF Recoverability

PSF/T Light Fraction	0.05, 0.1, 0.15, 0.2, 0.33, 0.5	Axial Ratio	0.1, 0.3, 0.6, 1.0
Effective Radii	1, 5, 10, 20 pixels	Relative Position Angle	0

PSF false positives

Fitting a PSF to a bulge, disk or bulge+disk model only

- fit=single Sérsic +PSF false positive rate **5%**, **0.5%** if all component sizes>1 pixel
- fit=B+D+PSF false positive rate **3.5%**, **0.3%** if all component sizes>1 pixel

PSF recovery

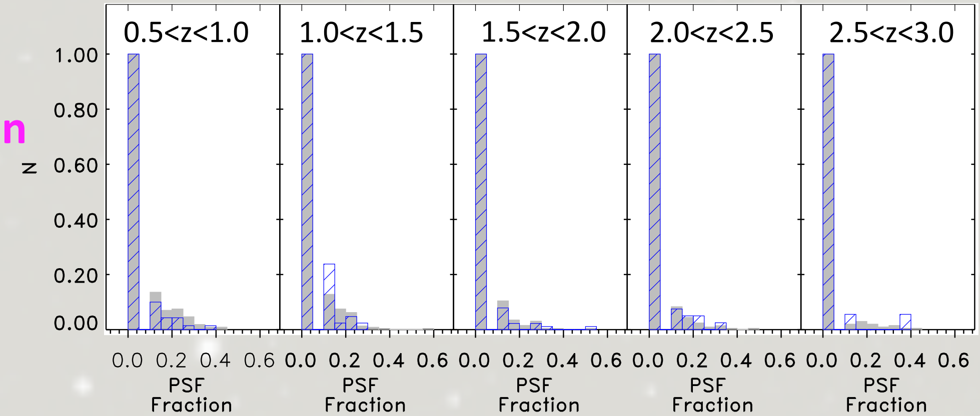
Fitting a PSF to a bulge+PSF, or disk+PSF model

- model=bulge+PSF recovery rate **40%**
- model=disk+PSF recovery rate **66%**

PSF Connection with AGN (Bruce et al., in prep)

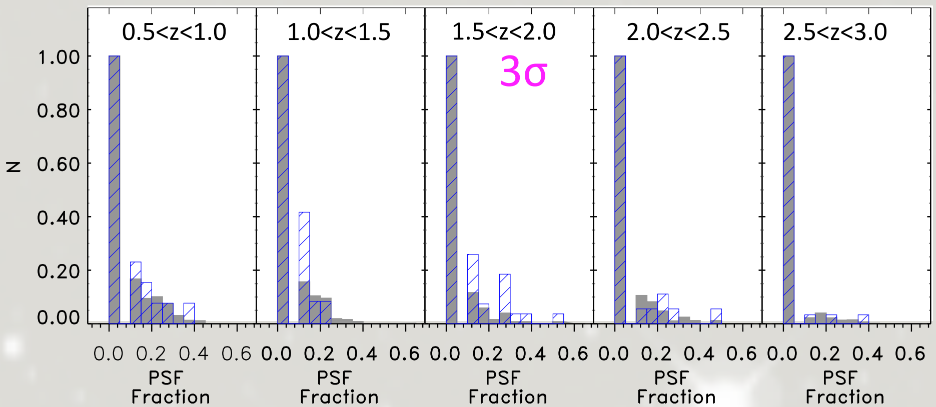
- Sample: 1600 $M>10^{10}M_{solar}$ galaxies at 0.5<z<3 in CANDELS GOODSS mass-matched to the 170 AGN candidates from the Kocevski 2012 (internal CANDELS catalogue)

24μm Connection

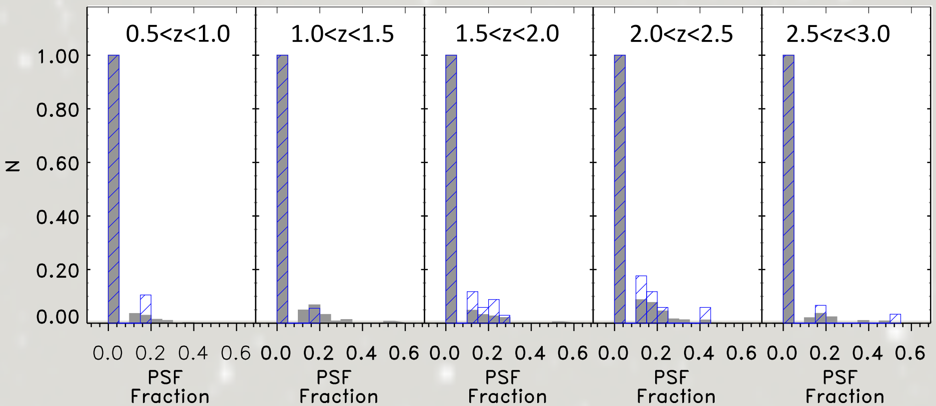


No evidence that a PSF component correlates with the presence of an AGN.

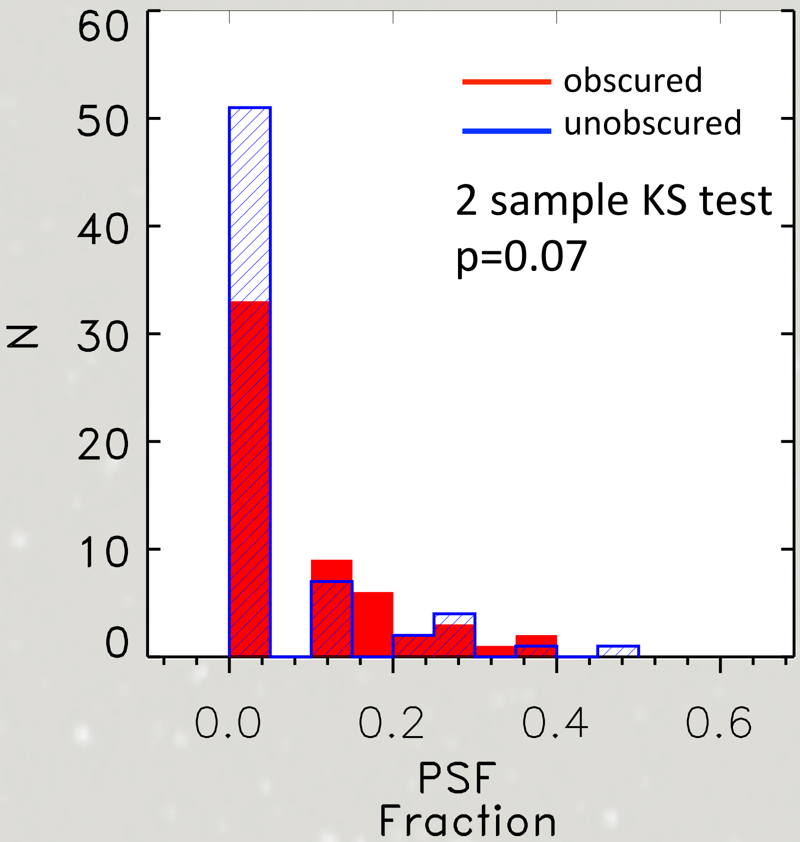
single Sérsic + PSF



bulge+disk+ PSF



PSF Fractions



Szokoly et al. 2004 FORS/FORS2 follow-up of X-ray detections in the 942 ks CDFS catalogue

PSF fraction =0.51, QSO, type 1, strong emission lines in optical indicating AGN

PSF Connection with AGN (Bruce et al., in prep 2015)

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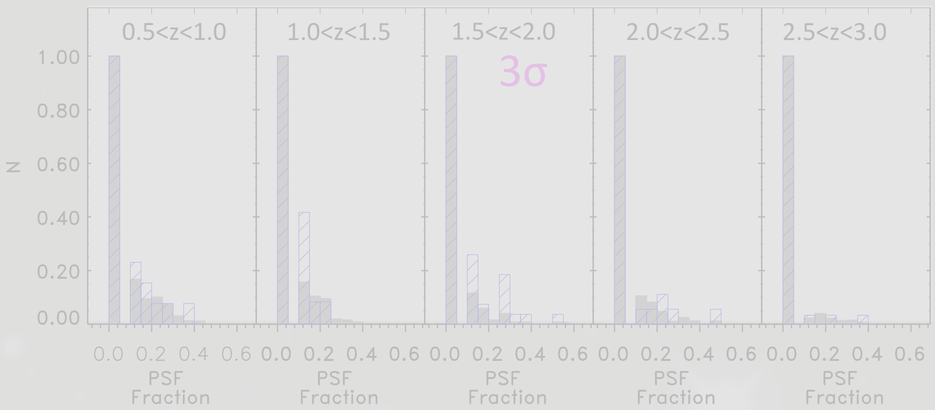
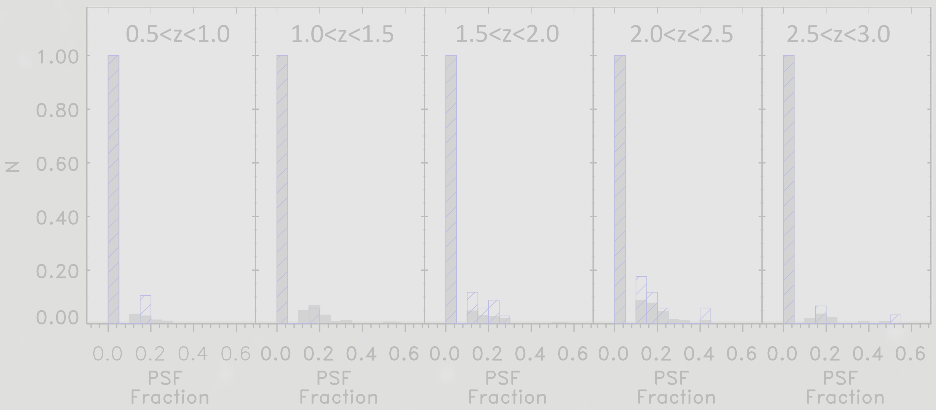
24μm Connecti

Work in progress !

Also testing :

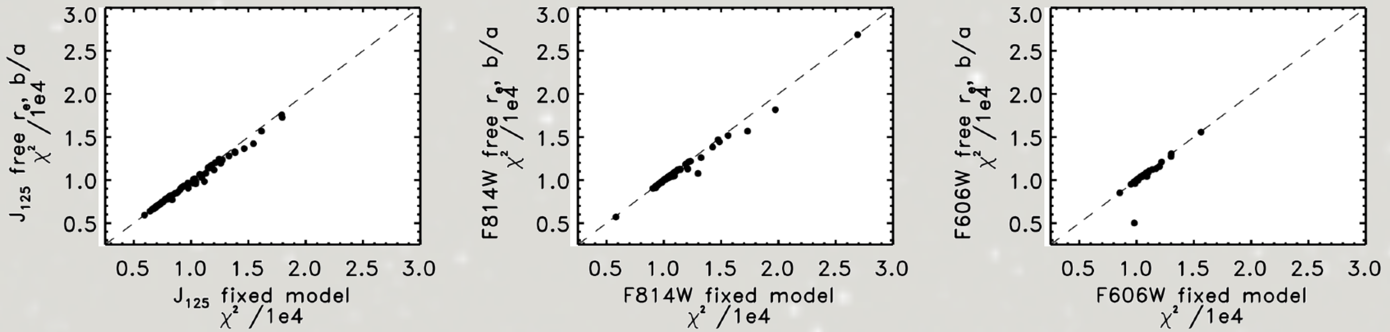
- PSF fraction against $L_{X\text{-}ray}$
- Prevalence of Type I AGN in PSF fits
- General trends in obscured vs unobscured fractions





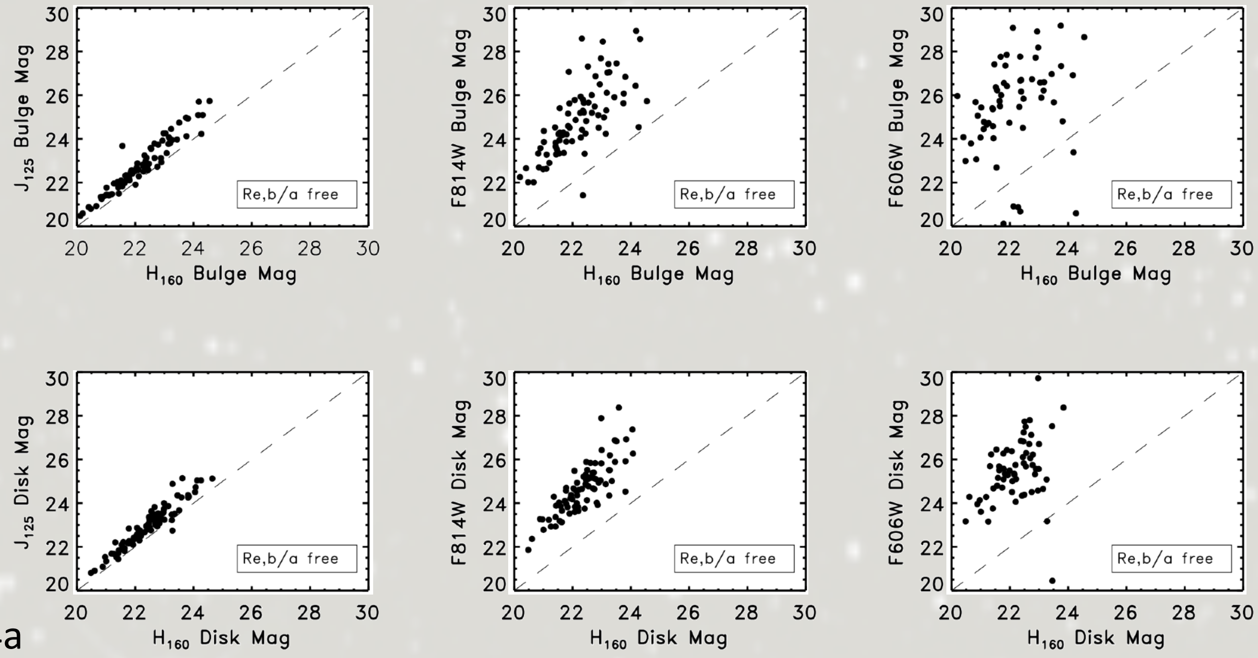
Extending Morphological Decompositions

Fix all morphological parameters at the H-band fits



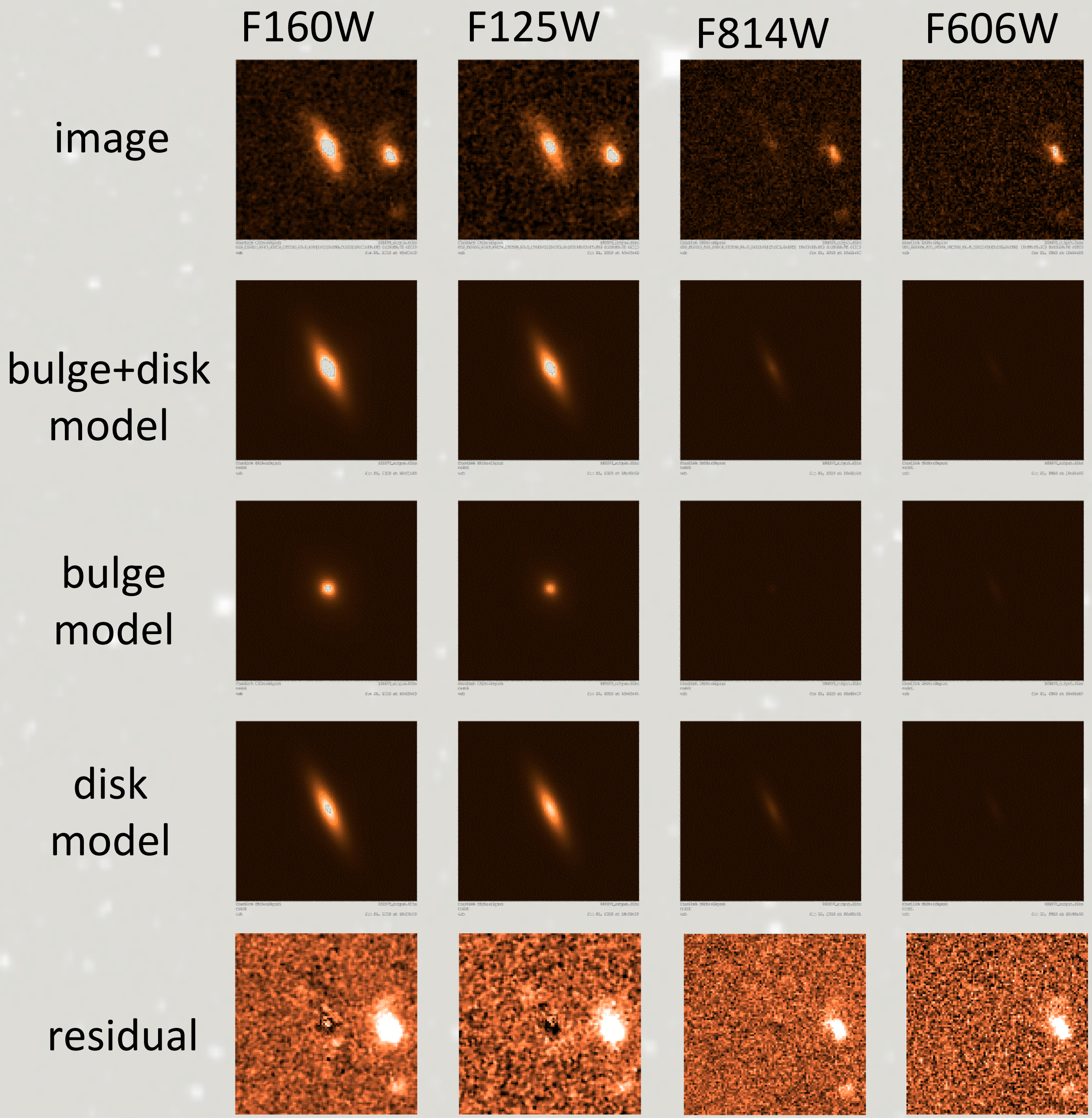
Free parameters give little improvement in the goodness of fit

And introduce biases which are hard to understand



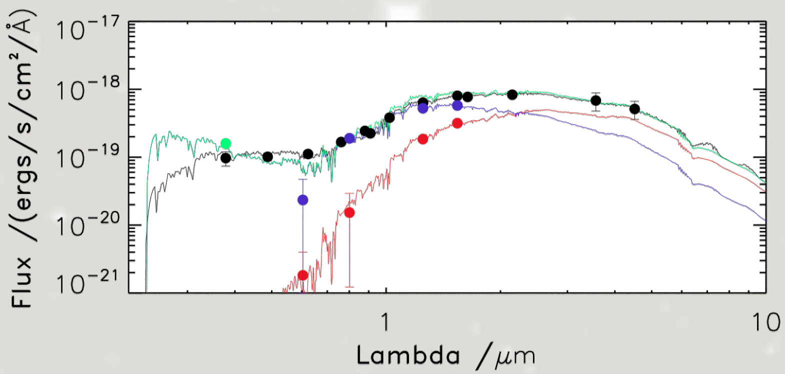
Bruce et al. 2014a

Example Morphological Decomposition

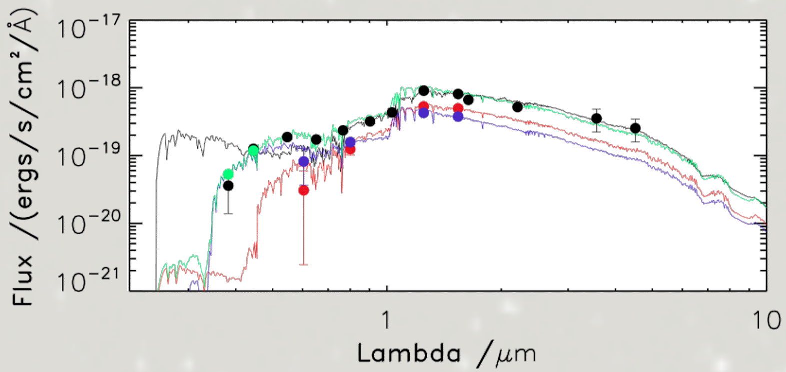


Example SED Fitting

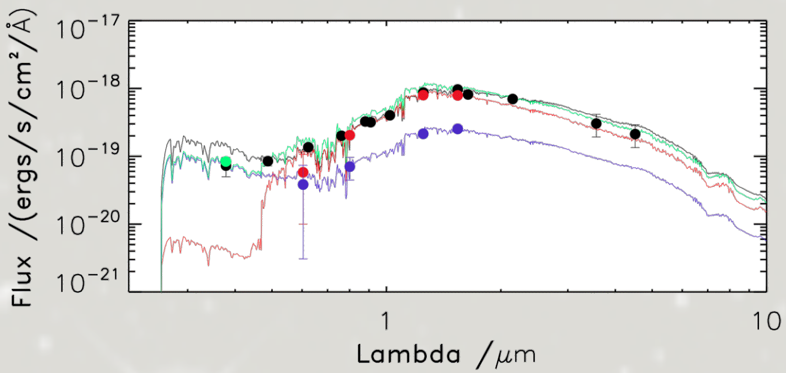
B/T<0.5



B/T=0.5



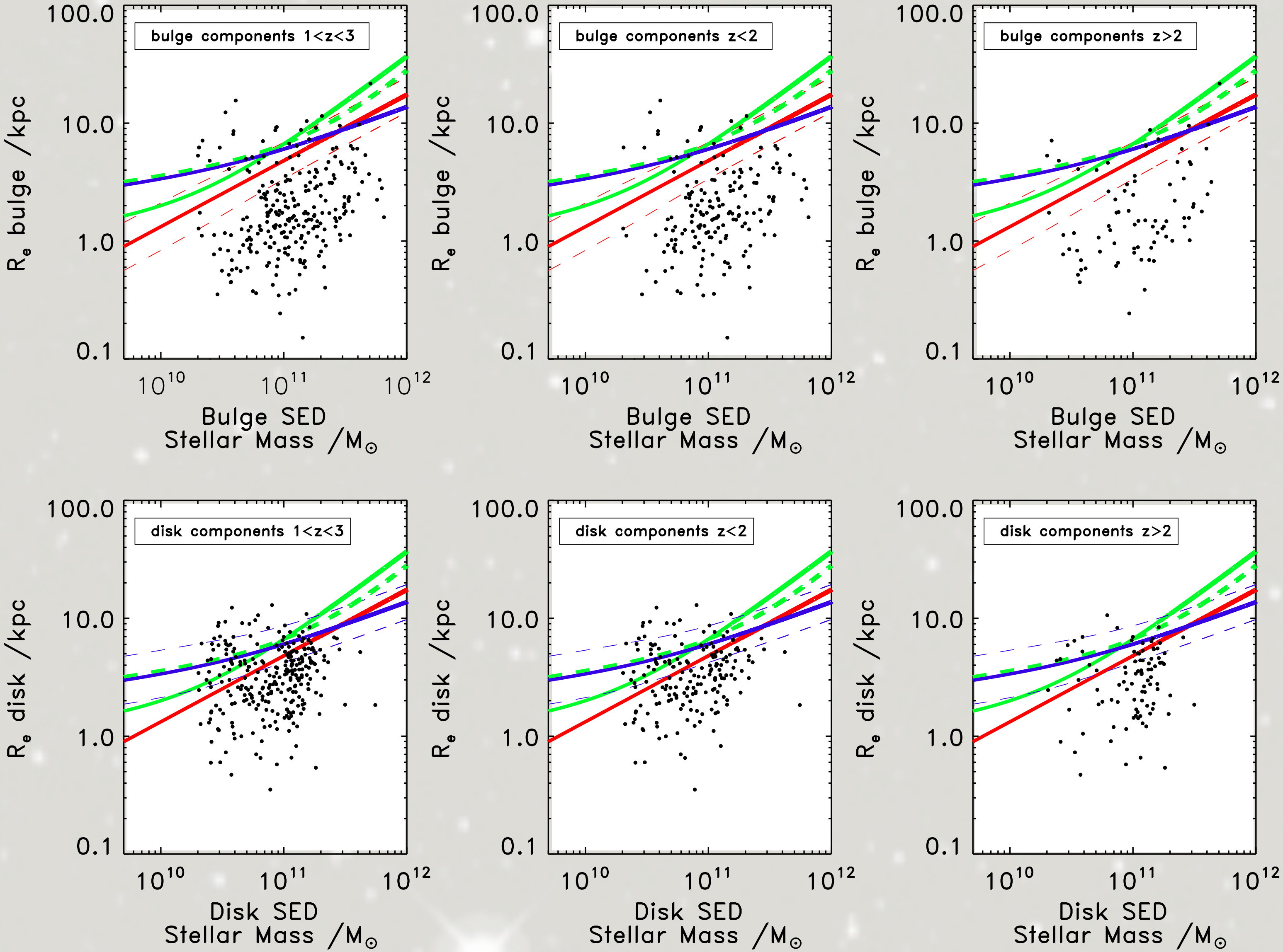
B/T>0.5



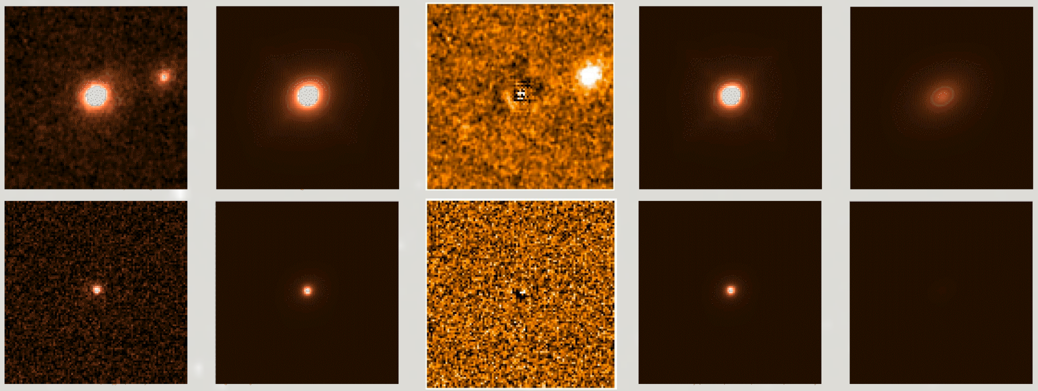
Bruce et al. 2014a

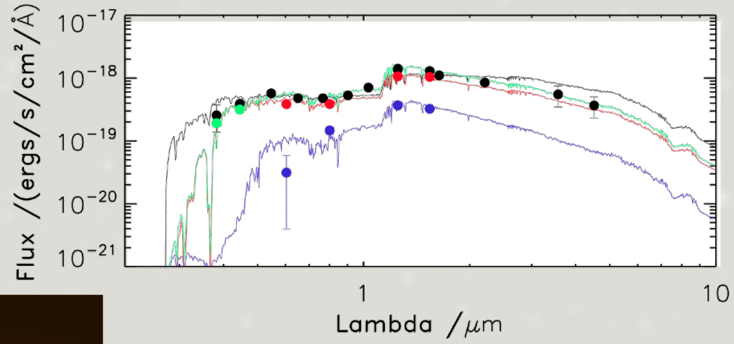
Decomposed Size-Mass Relations

Bruce et al. 2014b – updated with Lange et al. 2015 visual classifications



Star-forming Bulges

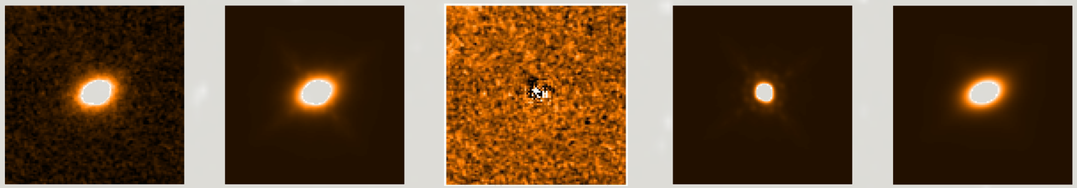


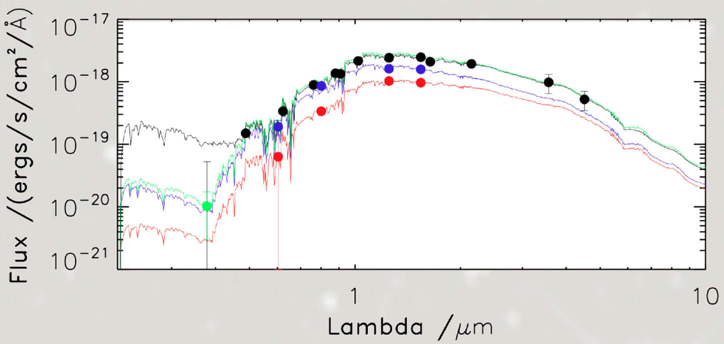


11±4%

18±5%

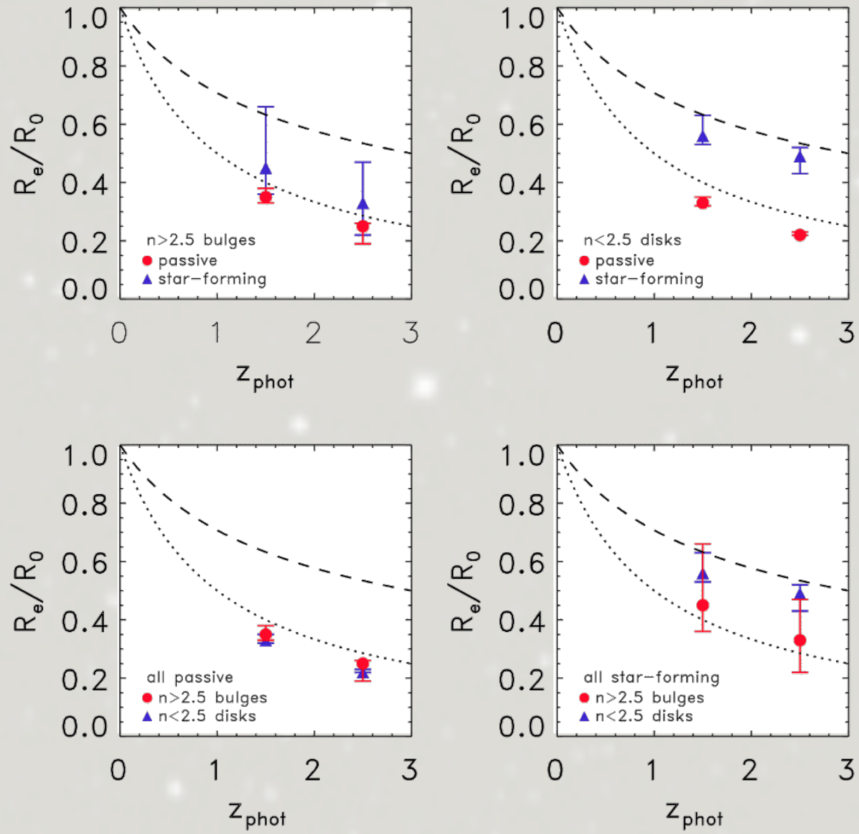
Passive Disks



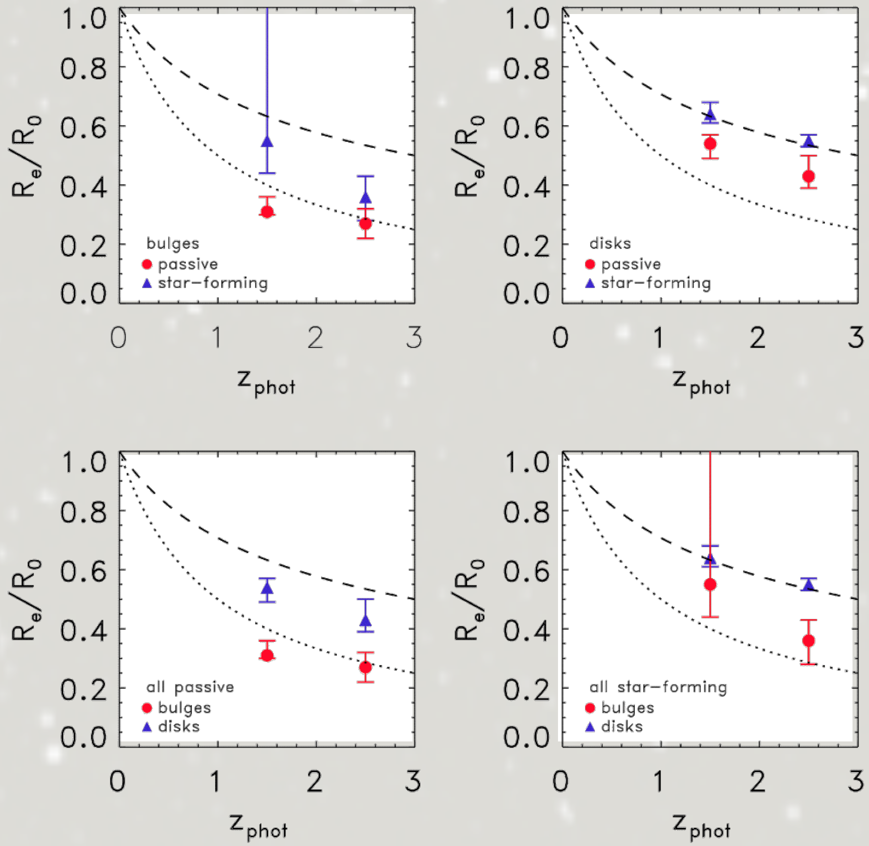


Fully Decomposed Size Evolution

single Sérsic fits using n=2.5



all bulge and disk components



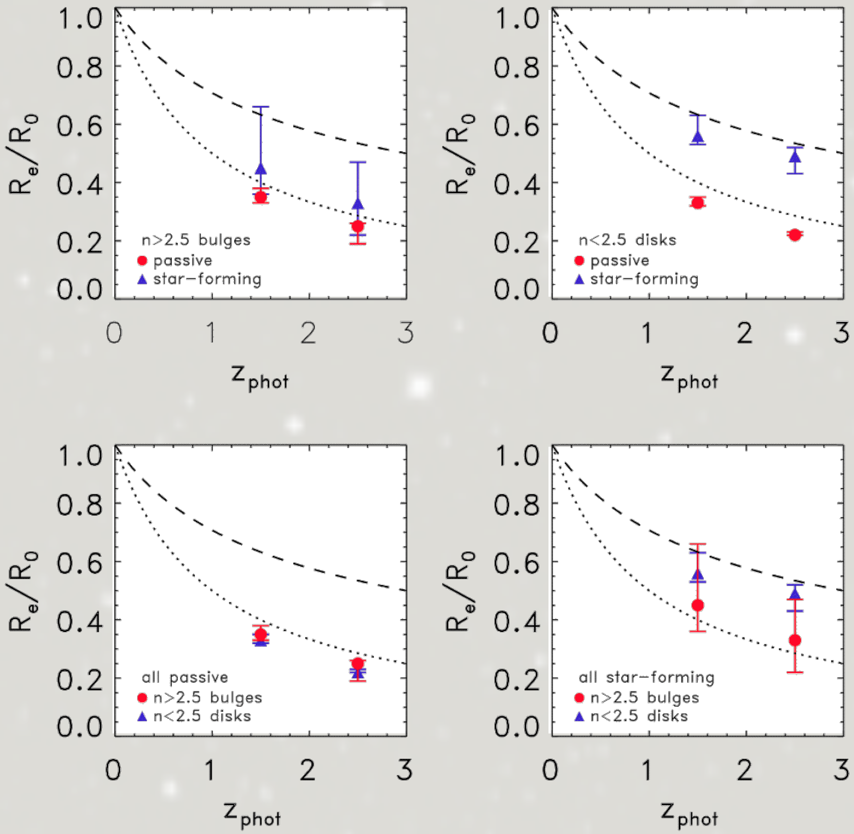
………… $R_e(z)/R_0 \propto (1+z)^{-1}$ for ETG's (van der Wel et al. 2008)

– – – – $R_e(z)/R_0 \propto (1+z)^{-0.5}$ for star-forming disks

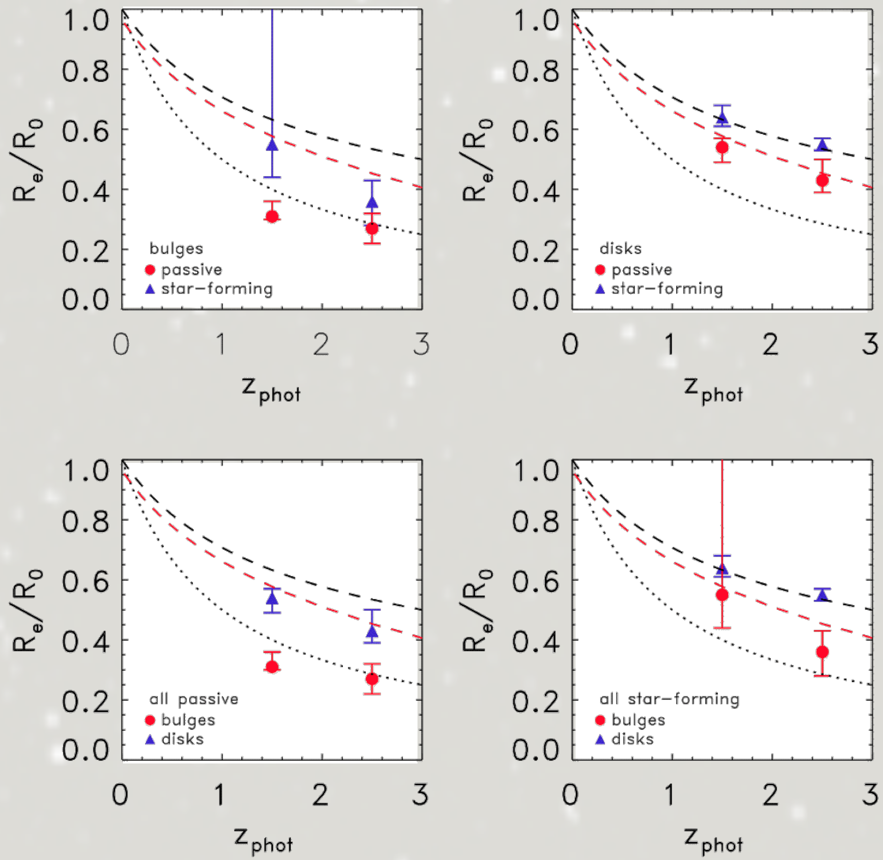
Bruce et al. 2014b

Fully Decomposed Size Evolution

single Sérsic fits using n=2.5



all bulge and disk components



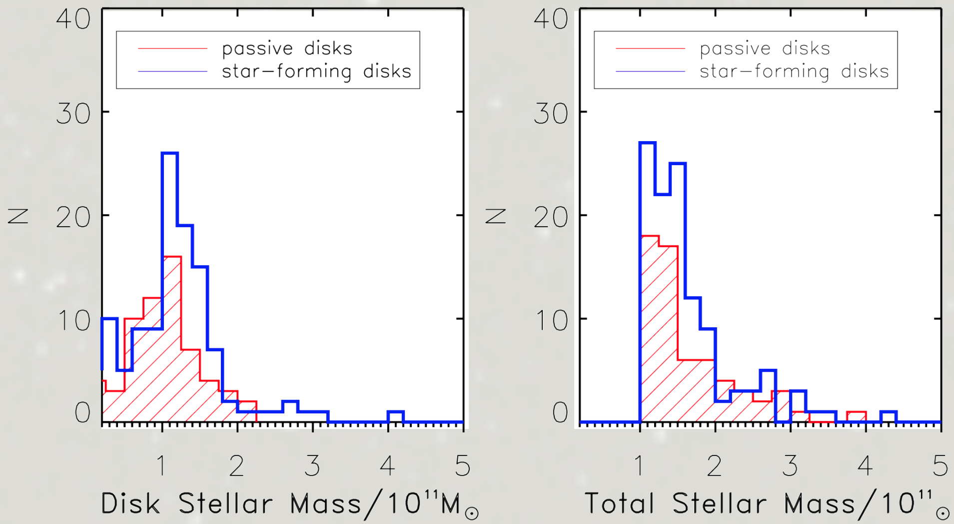
.... $R_e(z)/R_0$ α $(1+z)^{-1}$ for ETG's (van der Wel et al. 2008)

– – – – $R_e(z)/R_0$ α $(1+z)^{-0.5}$ for star-forming disks

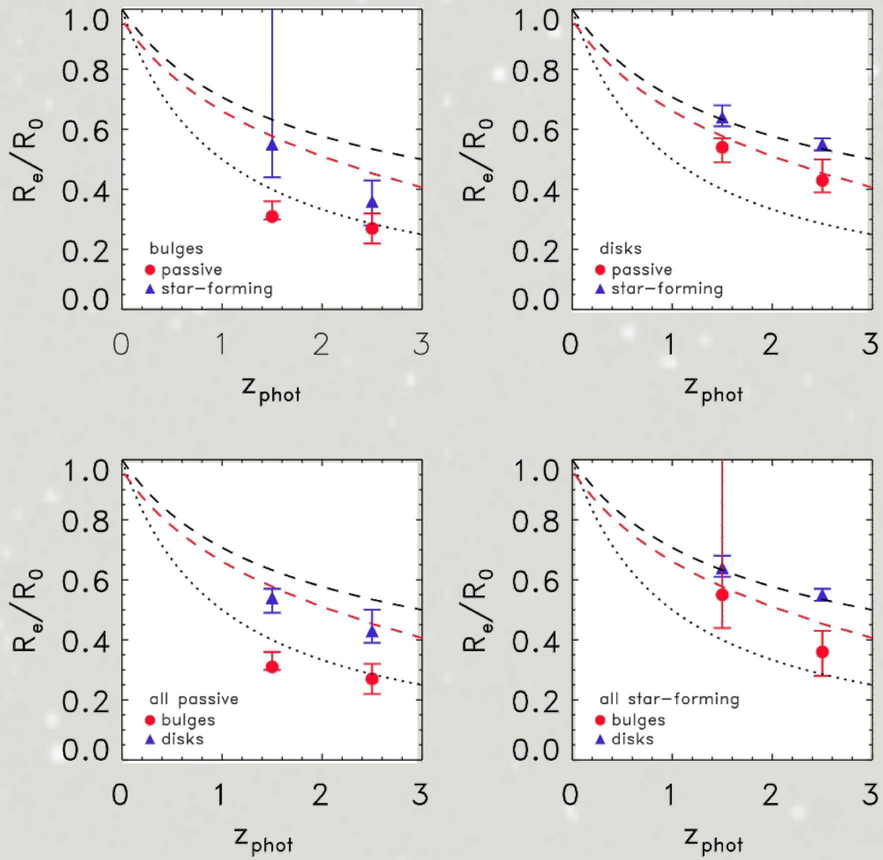
– – – – 1Gyr earlier star-forming disk relation for the progenitors of passive disks

Fully Decomposed Size Evolution

disk mass evolution



all bulge and disk components



1Gyr earlier star-forming disk relation for the progenitors of passive disks

passive disk components display:

- sizes comparable to their star-forming progenitors

and

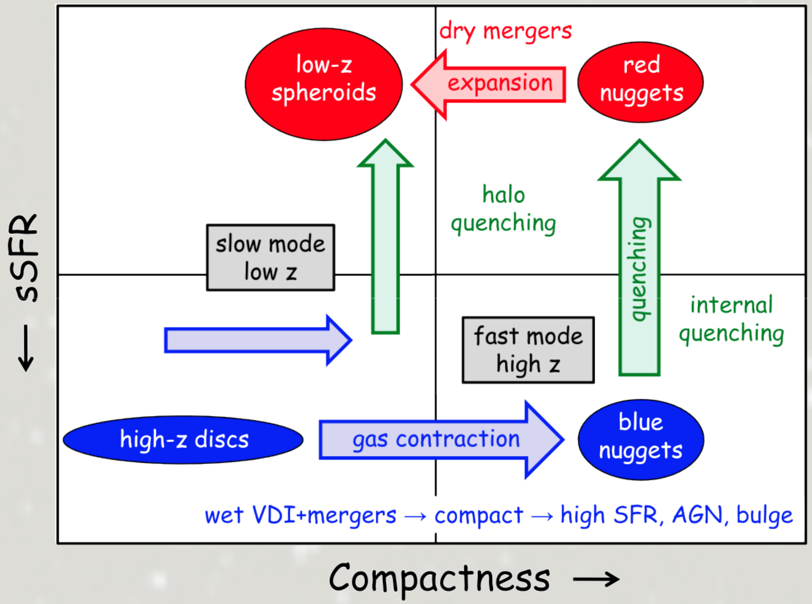
- mass evolution consistent with models which transfer mass to a central bulge over time.

Comparisons with Models

- The size of newly-quenched, younger, galaxies scales with the average density of the Universe at the epoch when they quenched.

Valentinuzzi et al. 2010b, Cassata et al. 2011, Poggianti et al. 2013a,b, Cassata et al. 2013, Carollo et al. 2013, Krogager et al. 2013

- Formation and evolution of compact galaxies.



Dekel & Burkert 2014

(also Barro et al. 2013a,b, Barro et al. 2014)

Conclusions

- Decompositions the morphologies, stellar-masses and star-formation rates of massive galaxies can provide valuable additional insight

Highlighted Results:

★ A significant fraction of passive galaxies are disks (18±5%) and star-forming galaxies are bulges (11±4%). How compatible is this with current evolution models such as VDI ?

★ Intermediate sizes of passive disks, which are comparable in size to their 1Gyr earlier star-forming disk progenitors.

★ The accompanying disk stellar-mass evolution, which appears to be in line with a transfer of mass out of the disk into a central bulge component.

Questions:

- How much do VDI models help us ?
- What are the timescale arguments for these processes ?
- What will we learn from a direct comparison to local decompositions ?