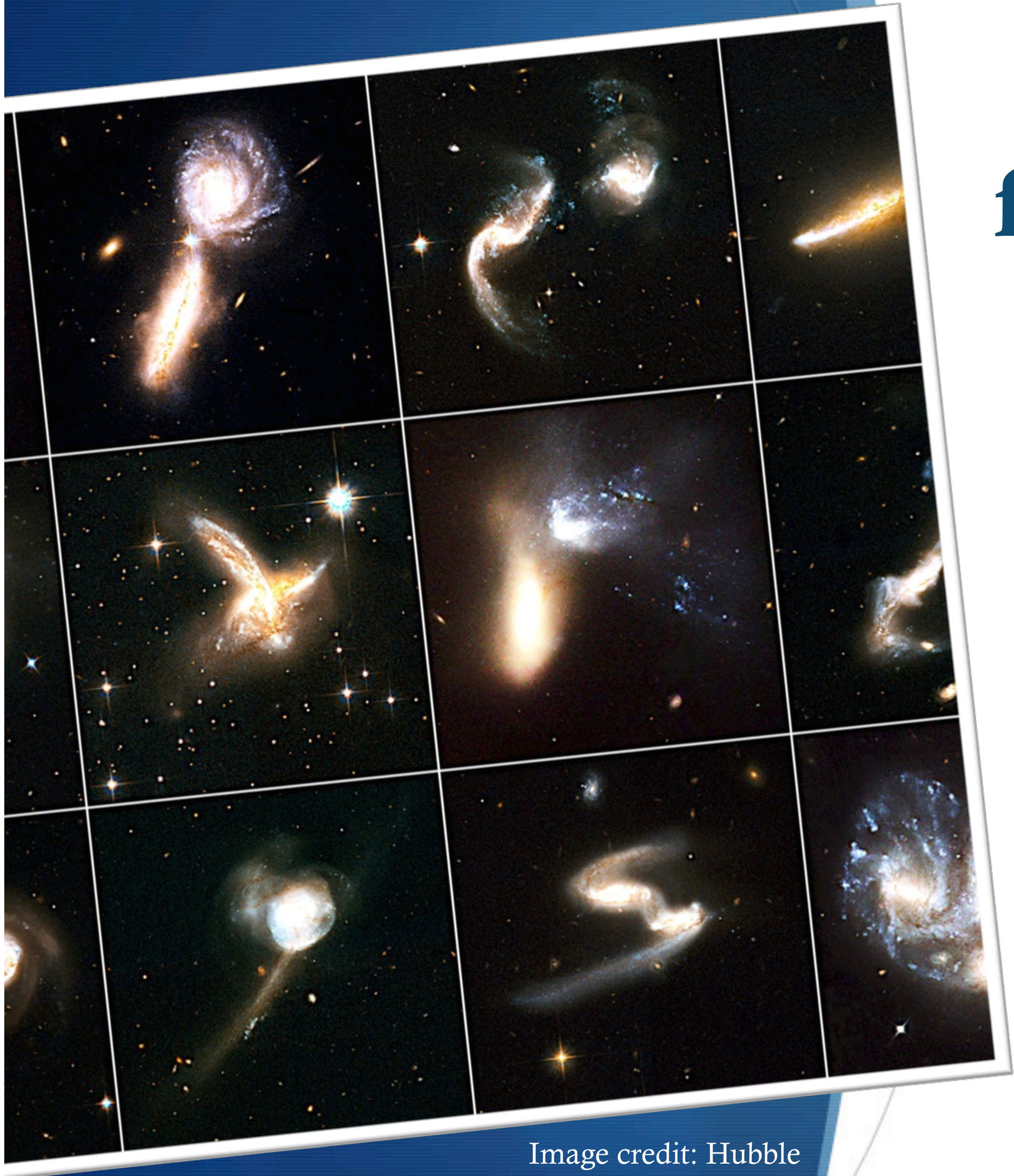


Image credit: Hubble

Galaxy merger fractions at z=0-3: Resolving the discrepancy in observations

Allison Man

Dark Cosmology Centre

Uni. Copenhagen, Denmark

+ Sune Toft, Andrew Zirm

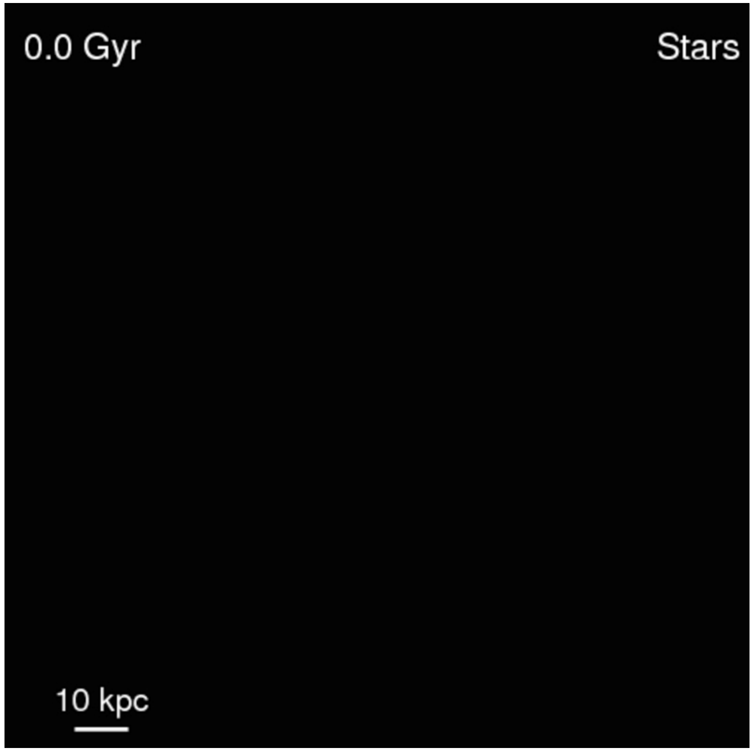
ApJ submitted

Bologna, 19th September 2014

Why do we care about galaxy mergers?

Mergers can…

- Transform galaxy morphologies
  - Disk ➔ spheroids, bulge formation
    (Toomre & Toomre 72; Barnes & Hernquist 96; Hopkins+10)
  - If gas poor: Puff up galaxies
    (Khochfar & Silk 06; Bezanson+09; Naab+09, +12; Nipoti+09; Hilz+12,+13)
- Trigger activity in galaxies if gas-rich
  - Enhance star formation / starbursts
    (de Propris+05; Engel+10; Kartaltepe+10; Patton+11, +13)
  - Trigger black hole accretion (AGN)
    (Treister+12; Ellison+13)
- Accrete stellar mass
  (Bundy+04; Oser+10; Ferreras+13)



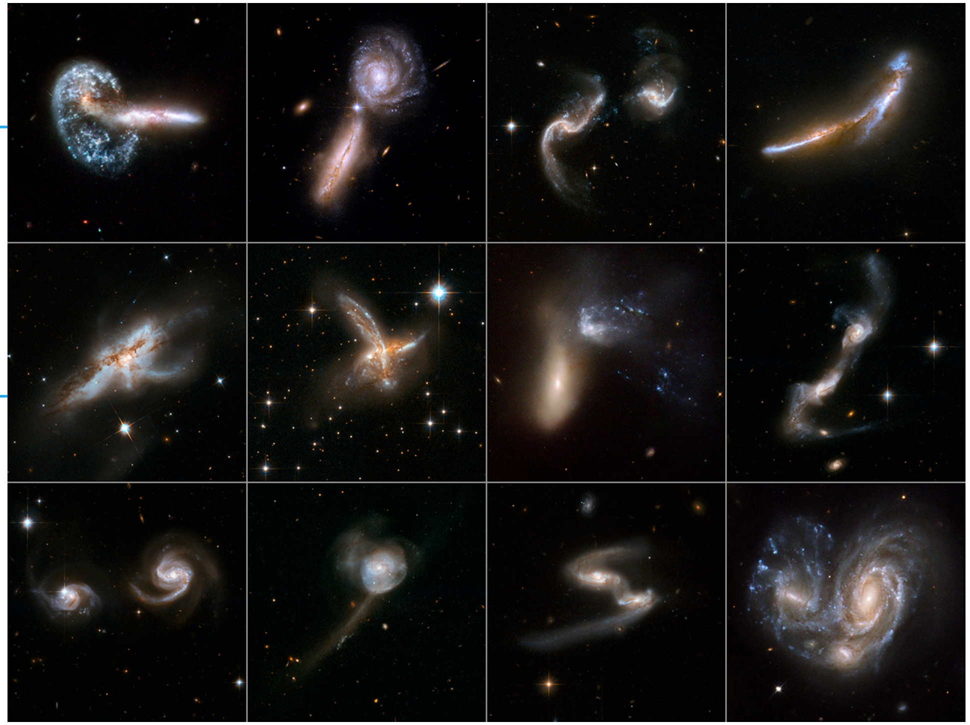
Milky Way-like gas poor merger simulation from [Philip Hopkins]

Measuring galaxy merger rates

Given a galaxy catalogue (with RA, Decl, redshift, magnitude / stellar mass)

1) Identify galaxy mergers

- Morphology
- Close galaxy pairs

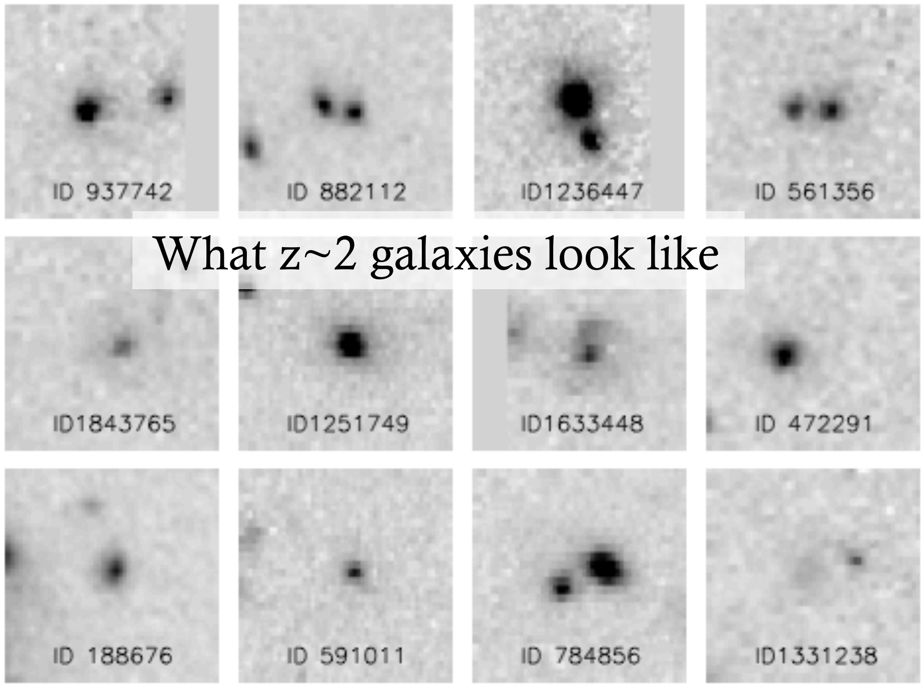


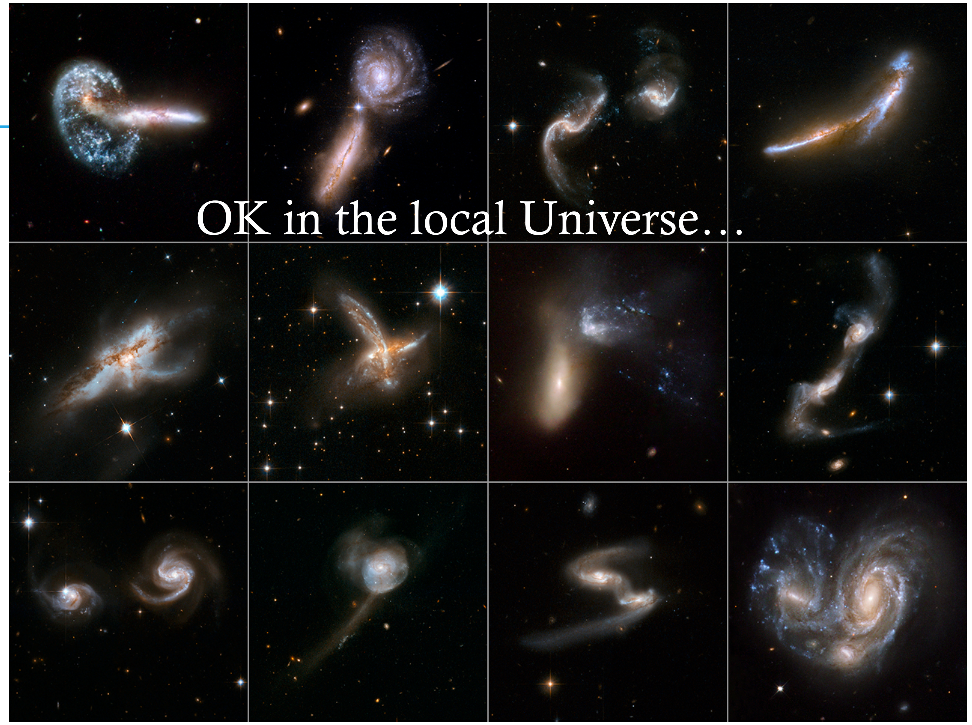
Zepf & Koo 89; Le Fevre+00, Patton+00, 08; Lin+04, 08; de Propris+05, Kartaltepe+07; Ryan+08; Bluck+09; Bundy+09; de Ravel +09; Robaina+10; Williams+11; Xu+12; Lopez-Sanjuan+11, +12, +13; Man+12, +14; Newman+12; Xu+12; Tasca+14 and more

Measuring galaxy merger rates

Given a galaxy catalogue (with RA, Decl, redshift, magnitude / stellar mass)

1) Identify galaxy mergers





ɔris+05, Kartaltepe+07; Ryan+08; Bluck+09; Bundy+09; de Ravel
ˀ, +13; Man+12, +14; Newman+12; Xu+12; Tasca+14 and more

Measuring galaxy merger rates

Given a galaxy catalogue (with RA, Decl, redshift, magnitude / stellar mass)

1) Identify galaxy mergers

- Galaxy pairs – with projected separation of 10-30kpc/h, matching redshifts
- Major merger : Mass ratio 1:1 – 1:4
- Minor merger : Mass ratio 1:4 – 1:10

2) Calculate merger fraction (X % of galaxies are merging)

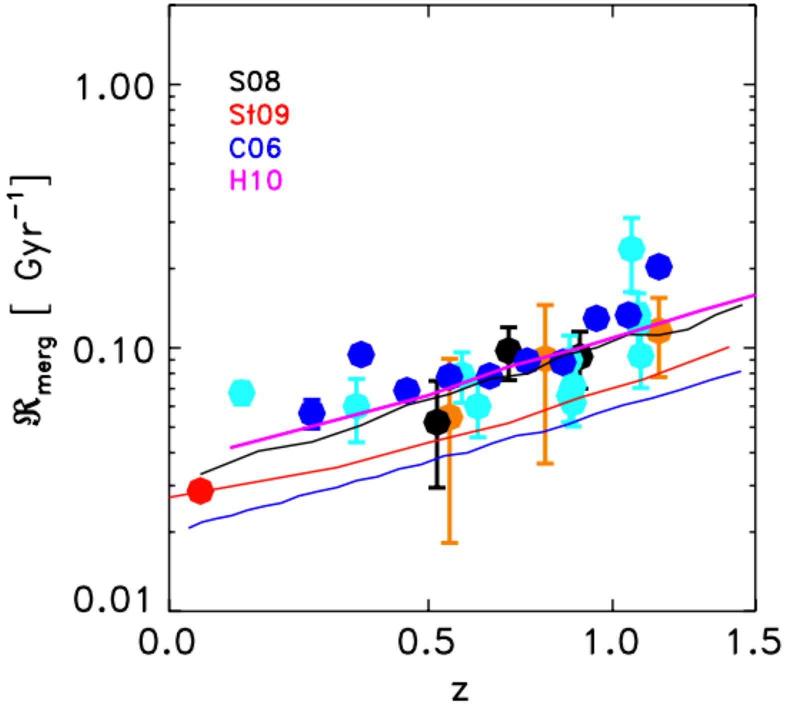
3) Convert merger **fraction** to **rate** using timescale

- Merger observability timescale, e.g. 0.4 - 1 Gyr for 10-30 kpc/h pairs (Lotz+10)
- Merger rate = N mergers / galaxy / unit time

Zepf & Koo 89; Le Fevre+00, Patton+00, 08; Lin+04, 08; de Propris+05, Kartaltepe+07; Ryan+08; Bluck+09; Bundy+09; de Ravel +09; Robaina+10; Williams+11; Xu+12; Lopez-Sanjuan+11, +12, +13; Man+12, +14; Newman+12; Xu+12; Tasca+14 and more

Consistent merger rates at z<1.5

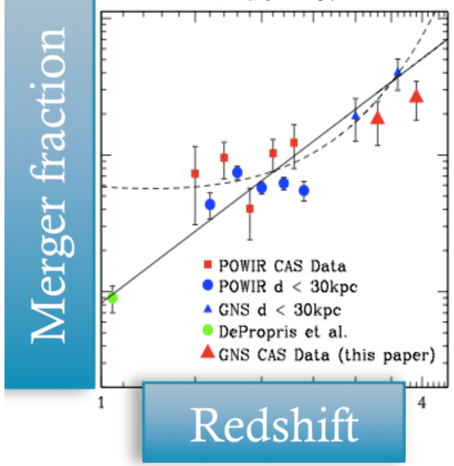
- Lotz+11 find consistency across observations & theoretical predictions up to z=1.5 if samples are selected the same way



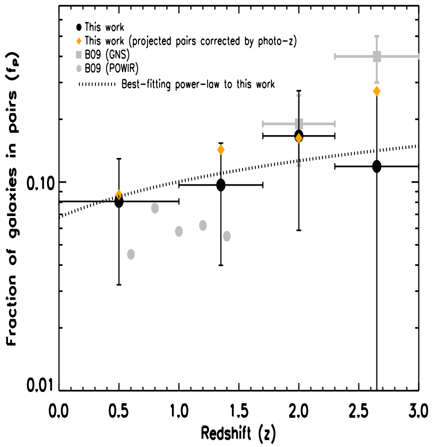
Major merger rate (Lotz+11)
••• Observations
--- Theoretical predictions

Discrepant merger fractions at z~2

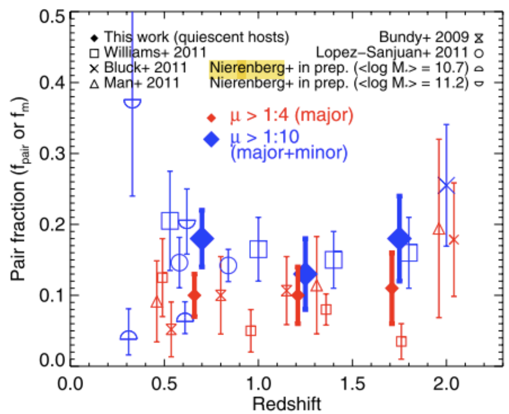
Bluck+09



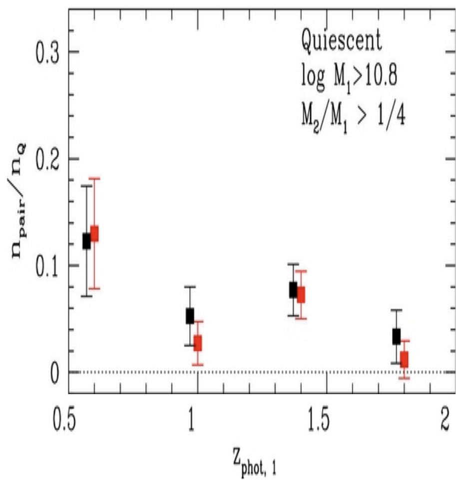
Man+12



Newman+12



Williams+11



Increase strongly w/ z

No evolution with z

Decrease with z

Based on different data (*HST* vs ground-based)
& selection (*H*-band flux ratio vs stellar mass ratio)

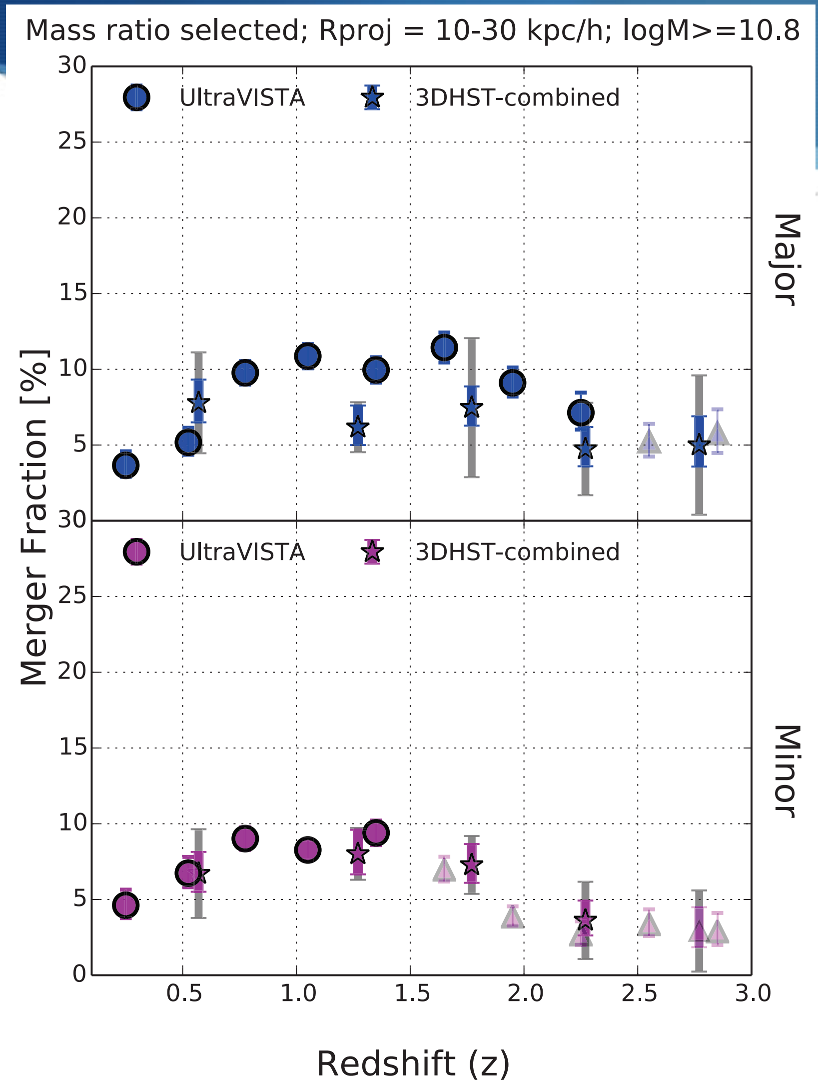
Galaxy merger fractions

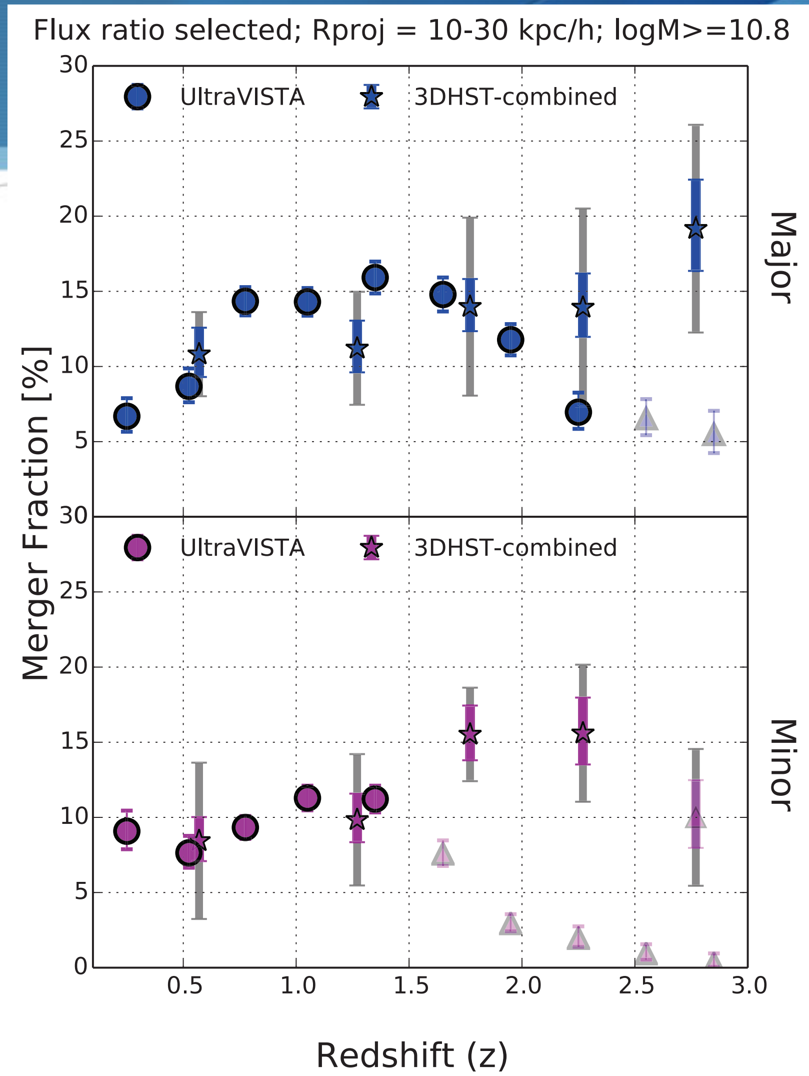
- Largest sample of photometrically selected mergers at z>1

Survey	Ref	Area [deg^2]	Depth (5σ)	FWHM
UltraVISTA / COSMOS	Muzzin+13	1.62	K=23.8	0.75”
3DHST + CANDELS	Skelton+14	0.25	H=26.9	0.18”

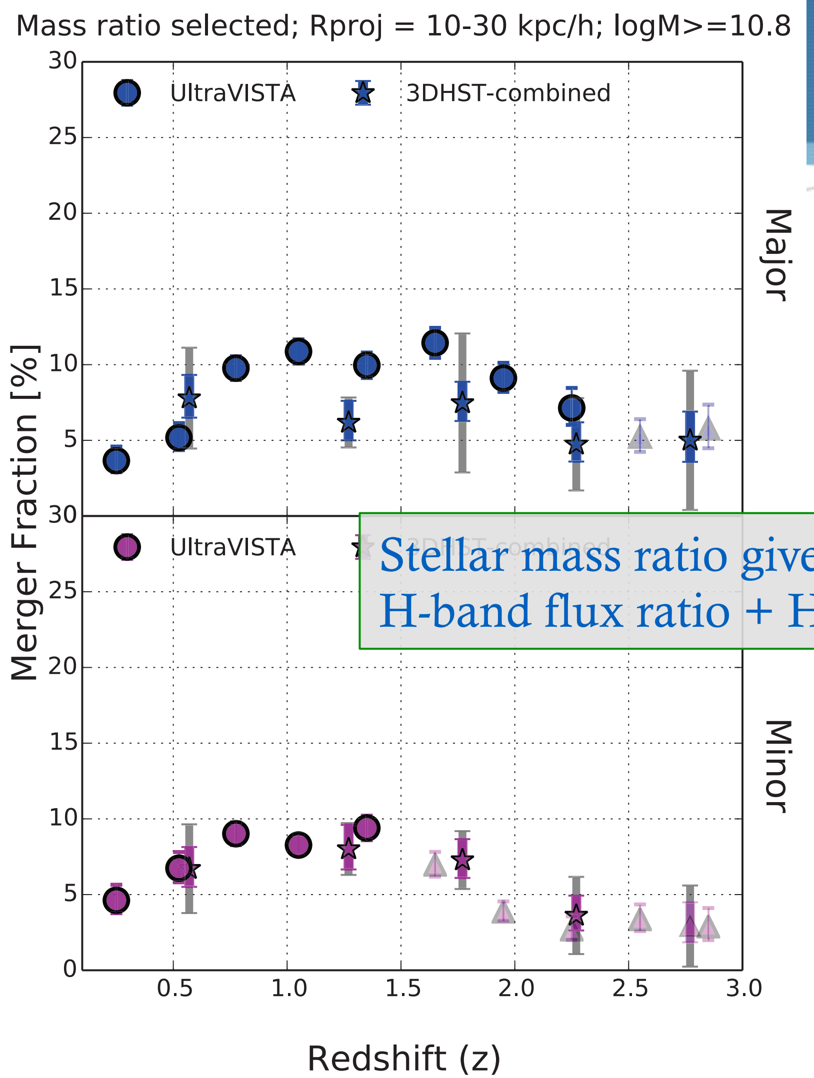
- Merging massive (logM≥10.8) galaxies are identified by pairs:
  - Projected separations 10-30 kpc/h
  - Photo-z's overlap within 1σ uncertainties
  - **Stellar mass or H-band flux ratio**
    - 1:1 – 1:4 (major)
    - 1:4 – 1:10 (minor)

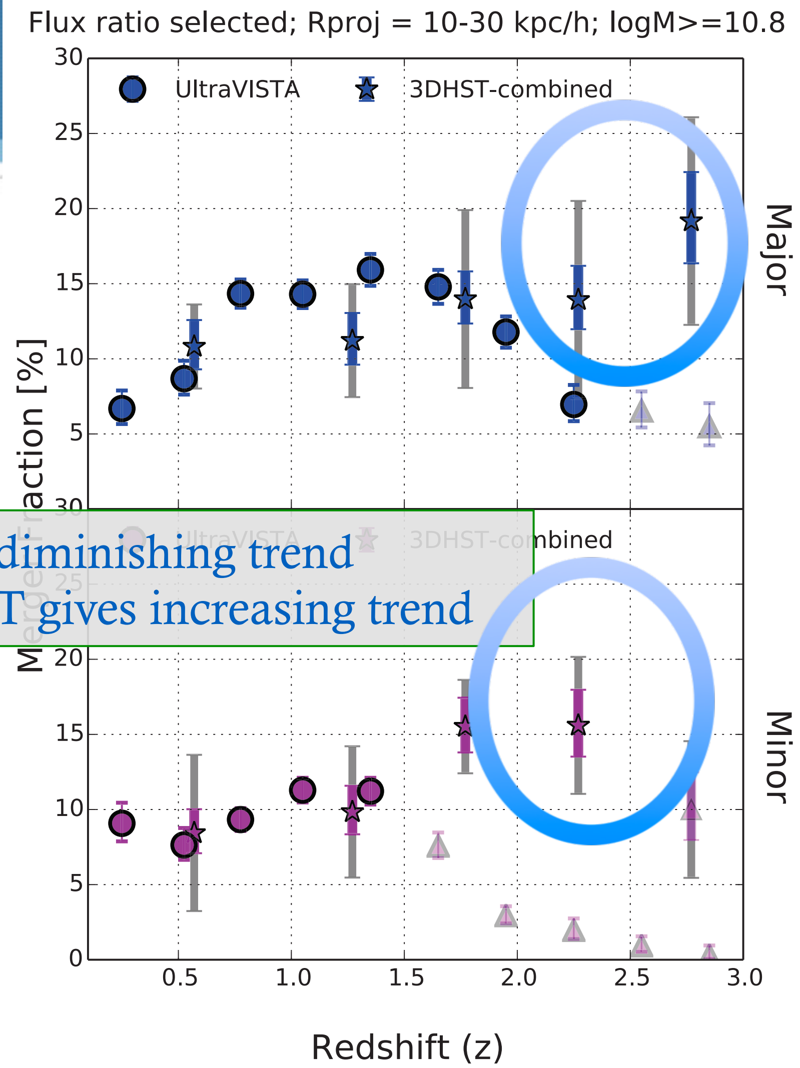
Galaxy merger fractions





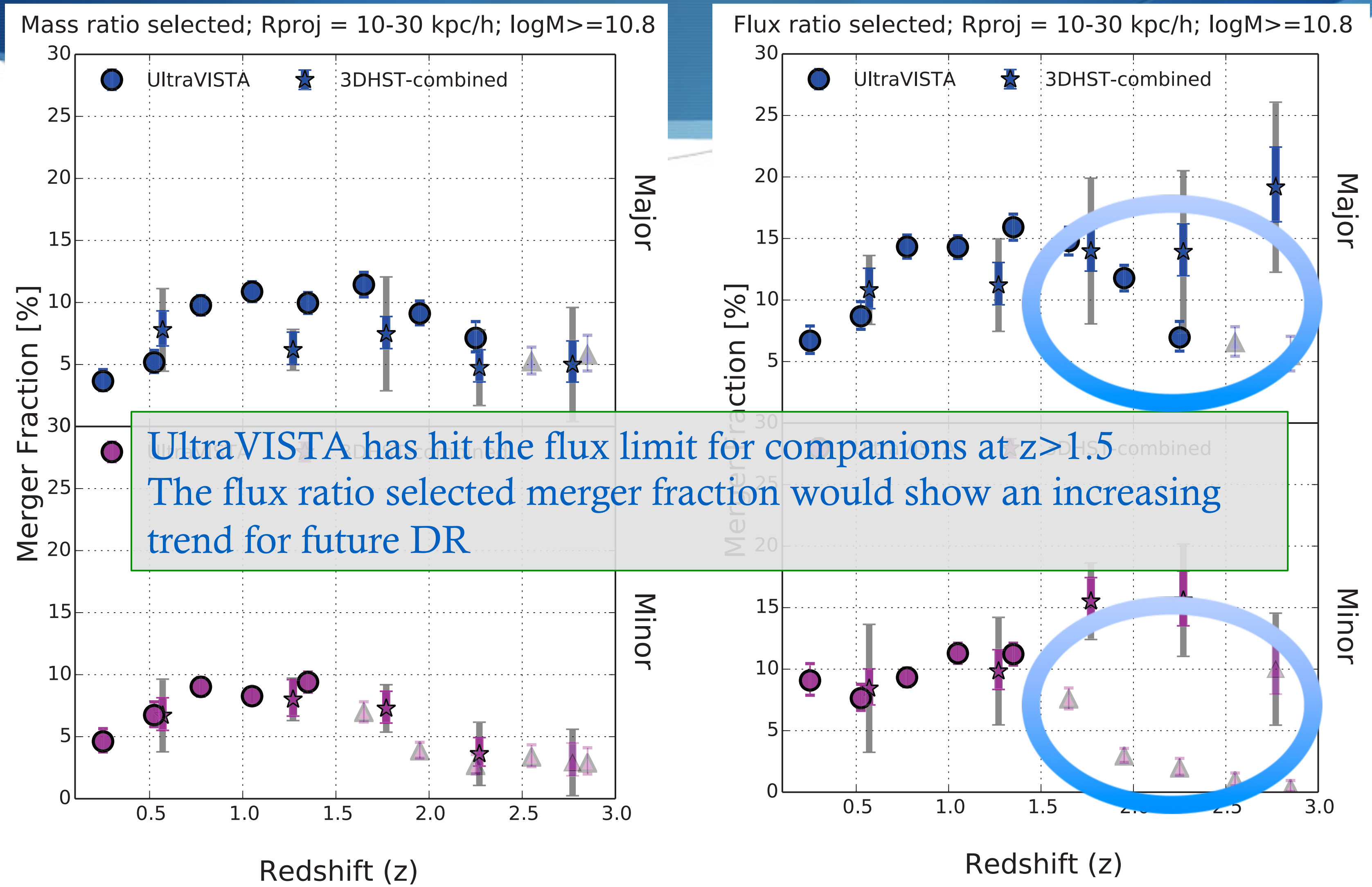
Galaxy merger fractions





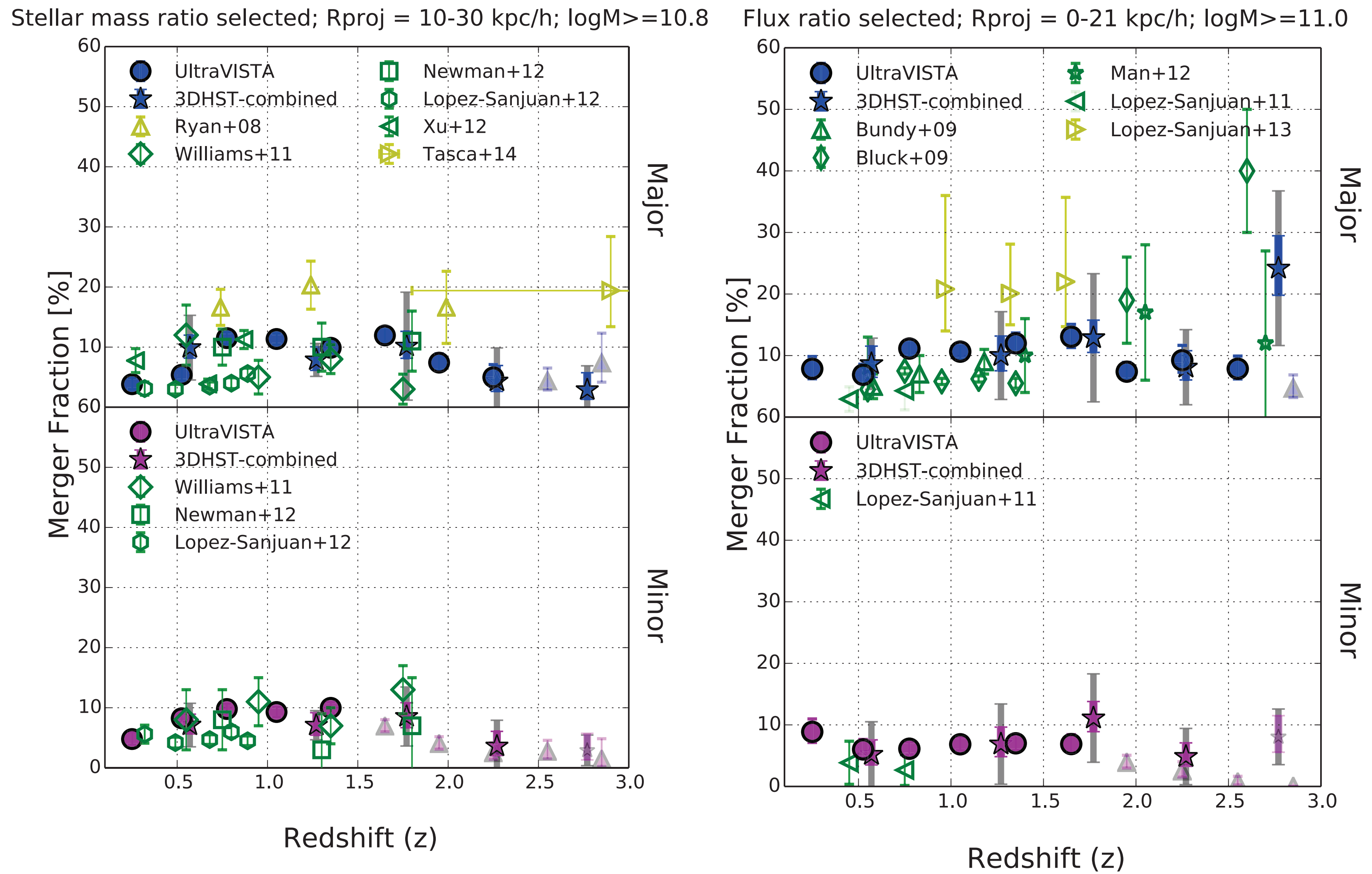
Stellar mass ratio gives diminishing trend
H-band flux ratio + HST gives increasing trend

Galaxy merger fractions



UltraVISTA has hit the flux limit for companions at z>1.5
The flux ratio selected merger fraction would show an increasing trend for future DR

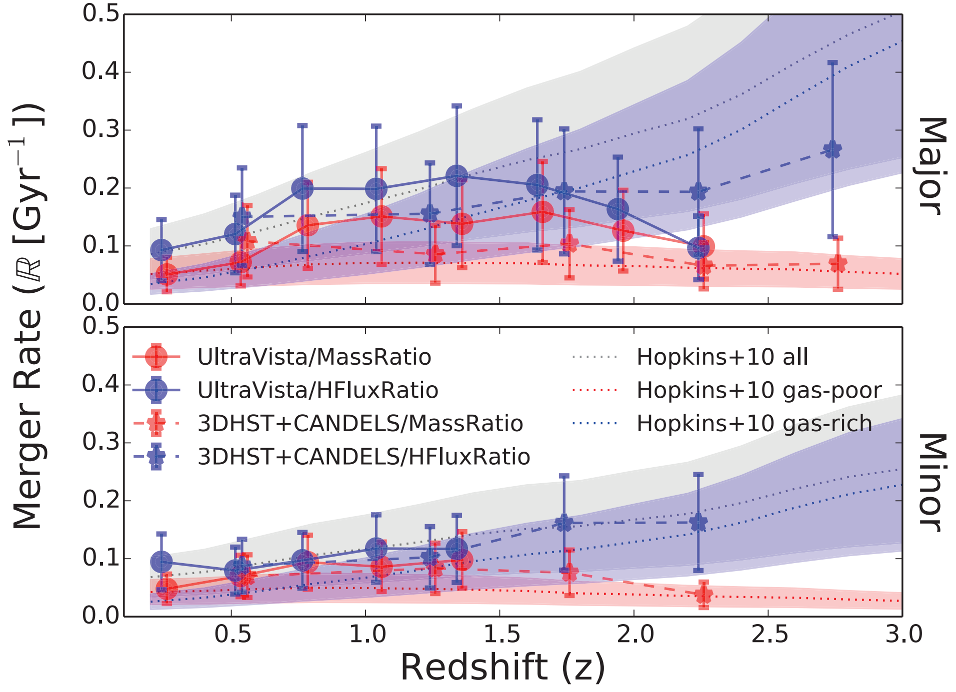
Merger fractions - literature



Inferred merger rate & evolution

z=0.1-2.5	Stellar mass ratio selected	Flux ratio selected
Major merger	1	1.5
Minor merger	0.7	1

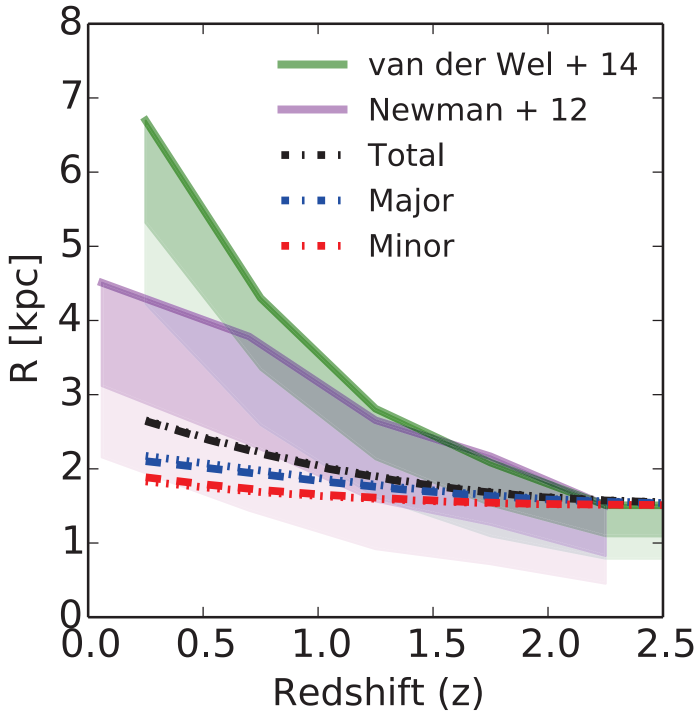
A massive galaxy doubles its stellar mass from z~2.5 to 0.1 by accreting stars via major & minor mergers



Insufficient merging to explain size evolution of quiescent galaxies

- Average sizes of quiescent galaxies increase their sizes ~3-5 times
  (Newman+12, and ref therein)
  - Disappearance of compact galaxies by merging
    (Belli et al. 2014a; van der Wel et al. 2014; van Dokkum et al. 2014)
  - Addition of larger, later quenched galaxies
    (Carollo+13; Poggianti+13; Krogager+14)

Assuming all mergers are dry, major + minor mergers can increase the sizes by a factor of 2 from z~2.5 to 0.



Merger-driven size evolution models based on Naab+09; Hilz+13

Conclusions

- Discrepant merger fraction at z~2:
  - Stellar mass ratio ➔ bias against gas-rich satellites ➔ diminishing merger fraction
  - Observed H-band flux ratio ➔ bias towards gas-rich satellites ➔ increasing merger fraction
- Which ratio to used? Depends on science questions.
- Merging is enough to explain the stellar mass assembly of the most massive galaxies at z~0-2.5, but additional mechanisms are needed to explain the rapid average size evolution of quiescent galaxies