The State of CANDELS

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4 August 2017

Productivity

- 102 Papers published by the team* (10 in past year)
  - 6421 citations
- ~112 papers using CANDELS by other groups+
  - 4475 citations
- 10896 citations for CANDELS in title or abstract
- h-index = 56
- 157 published blog articles (inactive)

* CANDELS in abstract; Author contains at least one of the various builders

+ CANDELS in abstract; Author does not include any of the various builders

Data products

Product	Team	World
WFC3/IR, ACS images	12345	12345
WFC3/UV images	5	1 5
Photometry, photz, SED fitting, rest-frame photometry	12345	12345
Galfit sersic fits (F160W)	12345	12345
CAS/Gini/M20/MID	12345	
CANDELS Visual classifications	123	1
GalaxyZoo classifications	123	
Mock catalogs from Semi-analytical models	12345	
Photo-z probability distributions	12345	
Bulge/disk decompositions	12345	
Clump Catalogs	1	
Mock data from hydro simulations		

5 – GOODS-N
4 – EGS
3 – COSMOS
2 – UDS
1 – GOODS-S

Science Goals: Supernovae

Supernovae	Obtain a direct, explosion-model-independent measure of the evolution of Type Ia supernovae as distance indicators at z > 1.5, independent of dark energy.
Supernovae	Refine the only constraints we have on the time variation of the cosmic-equation of state parameter *w*, on a path to more than doubling the strength of this crucial test of a cosmological constant by the end of HST's life.
Supernovae	Provide the first measurement of the SN Ia rate at z ≈ 2 to distinguish between prompt and delayed SN Ia production and their corresponding progenitor models.

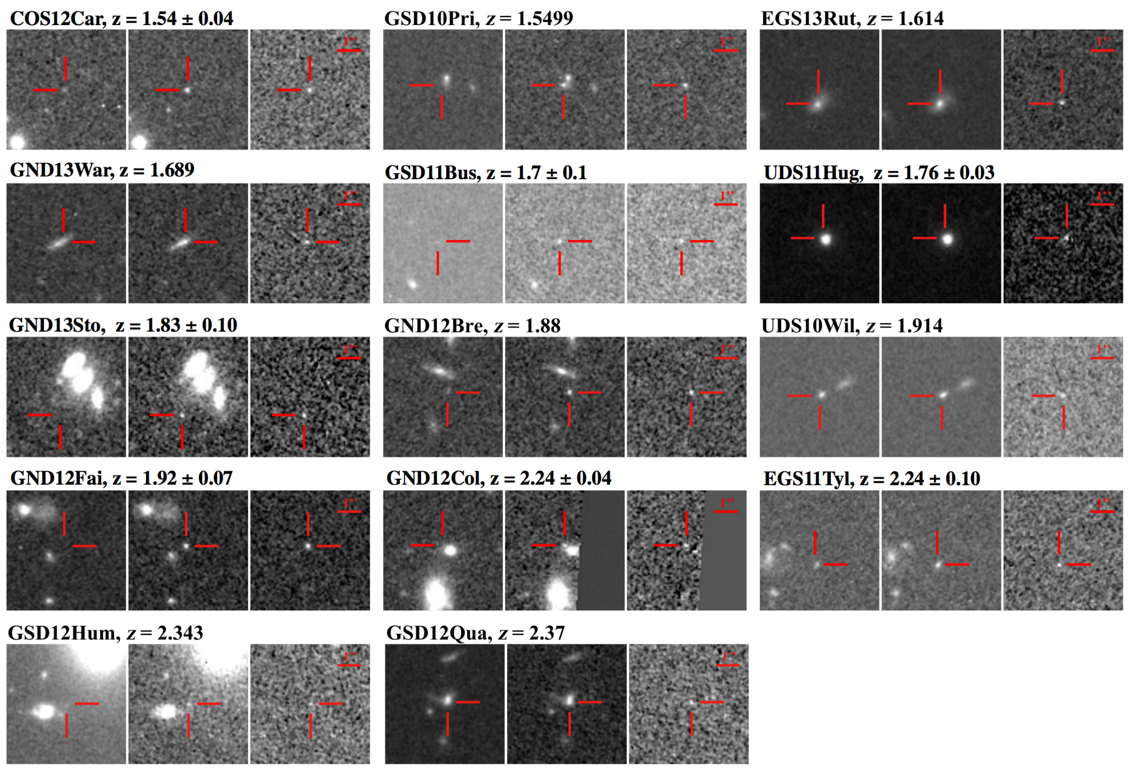
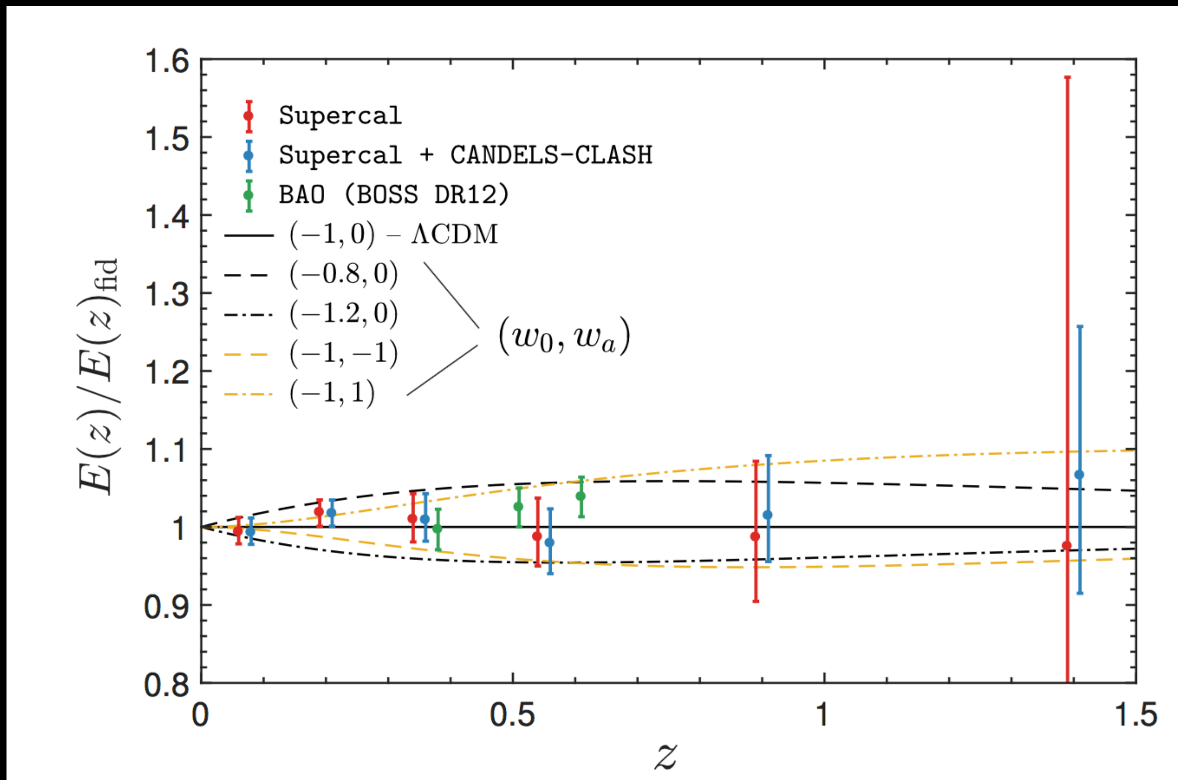


Figure 2. Detection images for 14 SN from the CANDELS fields with redshifts $z > 1.5$. Each image triplet shows H band (F160W) images with the template image on the left, the discovery epoch image in the middle, and the difference image on the right. All images have a width of about 6 arcsec, with north up and east to the left. The position of the SN is marked by (red) crosshairs in every frame. Discovery images for the other 51 SN with $z < 1.5$ are provided in Appendix B.

Building the Modern SN Ia Hubble Diagram; to the limit



Riess+ (in preparation)

Established: SNe Ia to z=2.1, dw/dz~0 +/-1 still tracking model, but SN Ia at z~2 are rare→long progenitor fuse

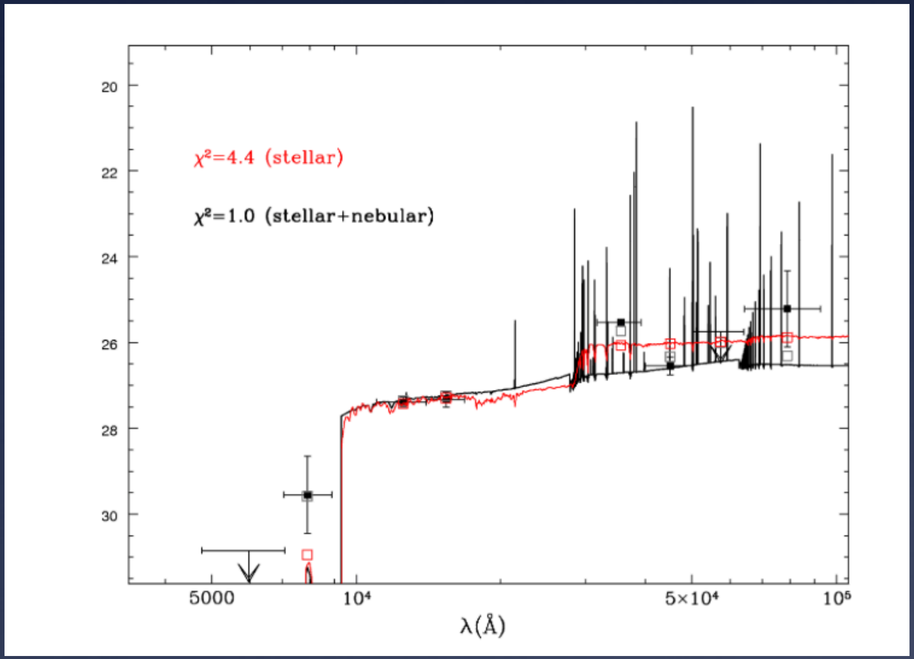
Science Goals: Cosmic Dawn

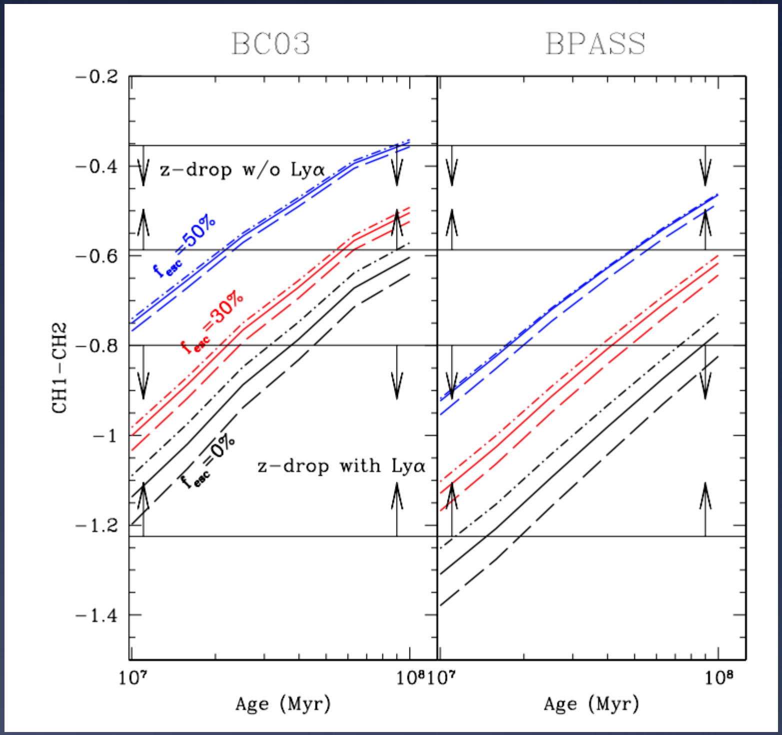
Cosmic Dawn	Constrain star-formation rates, ages, metallicities, stellar-masses, and dust content of galaxies at the end of the reionization era z ~ 6 – 10.
Cosmic Dawn	Improve the constraints on the bright end of the luminosity function at z ~ 7 and 8, and make z ~ 6 measurements robust using proper 2-color Lyman break selection.
Cosmic Dawn	Measure fluctuations in the near-IR background light, at sensitivities sufficiently faint and angular scales sufficiently large to constrain reionization models.
Cosmic Dawn	Greatly improve the estimates of the evolution of stellar mass, dust and metallicity at z = 4 – 8 by combining WFC3 data with very deep Spitzer IRAC photometry.
Cosmic Dawn	Identify very high-redshift AGN by cross-correlating optical dropouts with deep Chandra observations. Constrain fainter AGN contributions via X-ray stacking.
Cosmic Dawn	Use clustering statistics to estimate the dark-halo masses of high-redshift galaxies with triple the area and double the maximum lag of prior HST surveys.

Finkelstein+ 12a,b,13,15a,b, Duncan+14, Grazian+12,15
Yan+12, Curtis-Lake+13,14, Tilvi+13,14, Rogers+14
Salmon+15, Nayyeri+14, Castellano+14, Caputi+12
Mitchell-Wynne+15,Giallongo+15
Song+16,Salmon+16, White+….in preparation

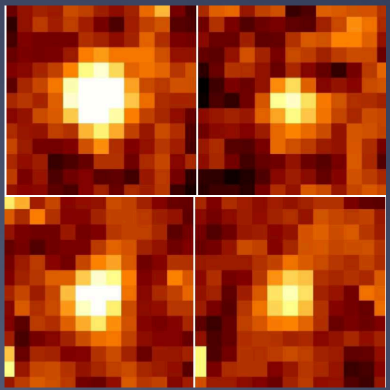
Emission lines

Castellano+17



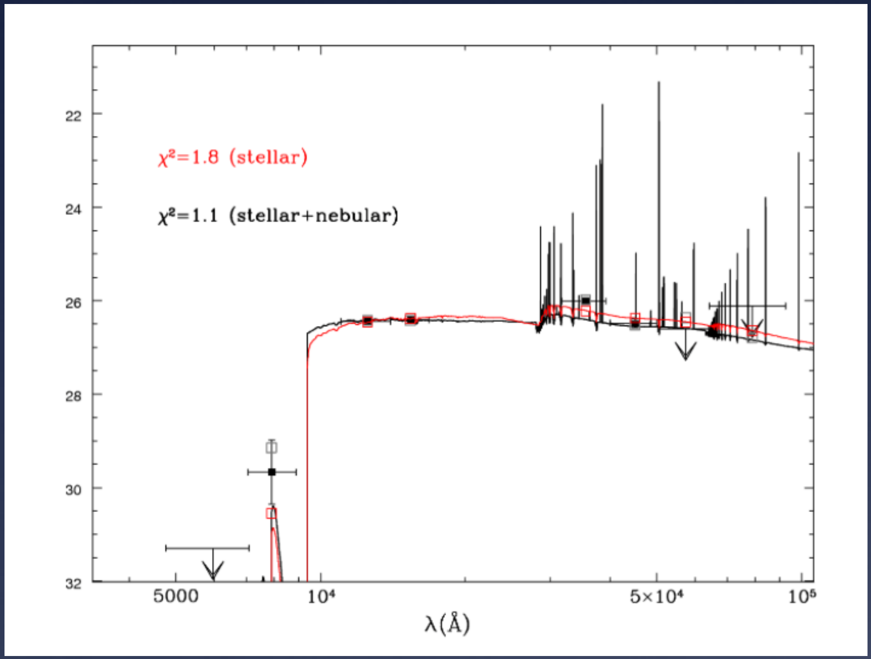


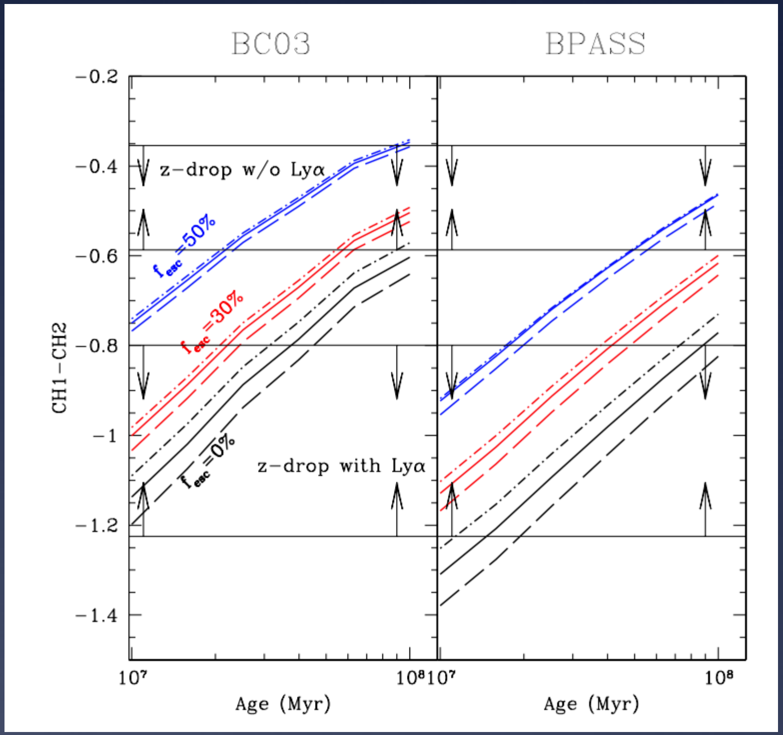
- $Z \sim 6.8$ Lyα and non-Lyα emitters
- Evidence for strong [OIII]
- f_{esc} likely to be low in Lyα emitters



Emission lines

Castellano+17





- Z~6.8 Lyα and non-Lyα emitters
- Evidence for strong [OIII]
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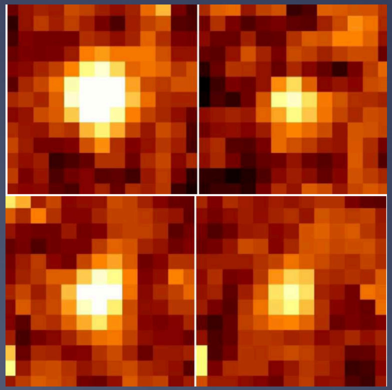
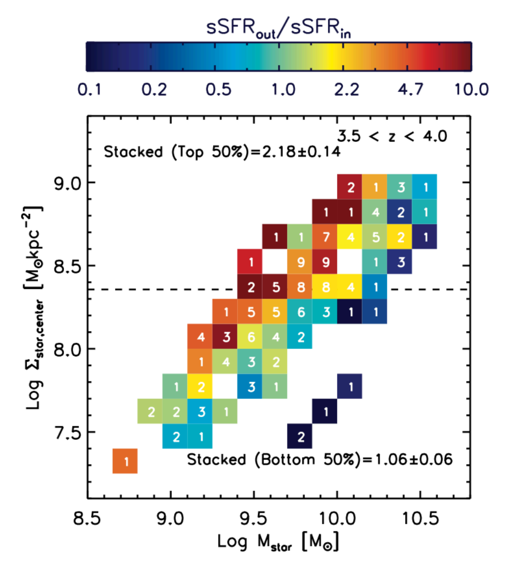
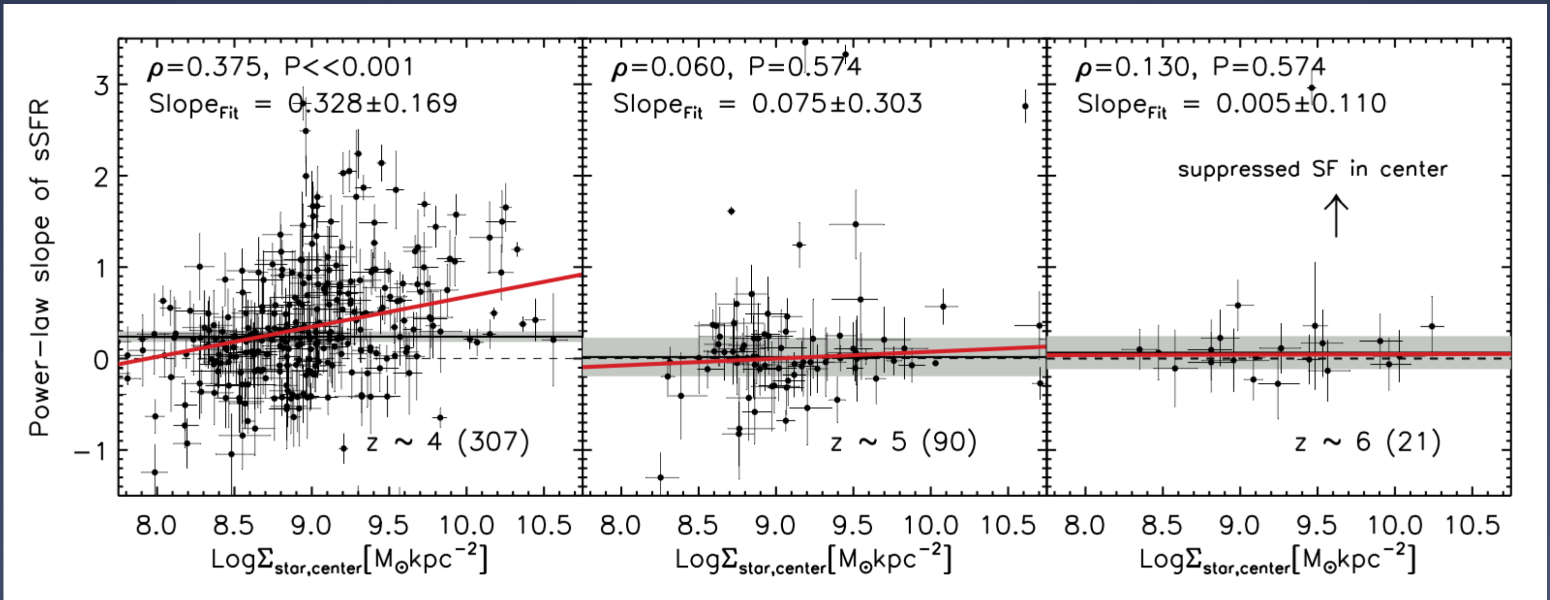


Radial stellar-population gradients

At z=4 there is evidence that high-mass galaxies are quenching in their centers

Jung+17

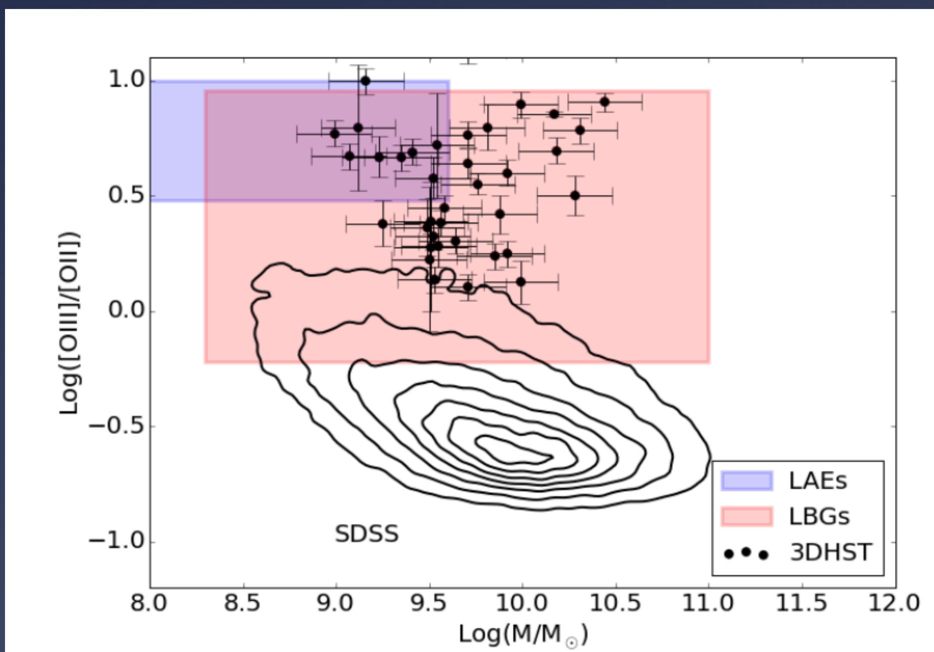




Science Goals: Ultraviolet campaign

UV	Constrain the Lyman-continuum escape-fraction for galaxies at $z \sim 2.5$.
UV	Identify Lyman-break galaxies at $z \sim 2.5$ and compare their properties to higher-z LBG samples.
UV	Estimate the star-formation rate in dwarf galaxies to $z > 1$ to test whether dwarf galaxies are "turning on" as the UV background declines at low redshift.

Relatively low f_{esc} even for strong [OIII] emitters at z~2.5



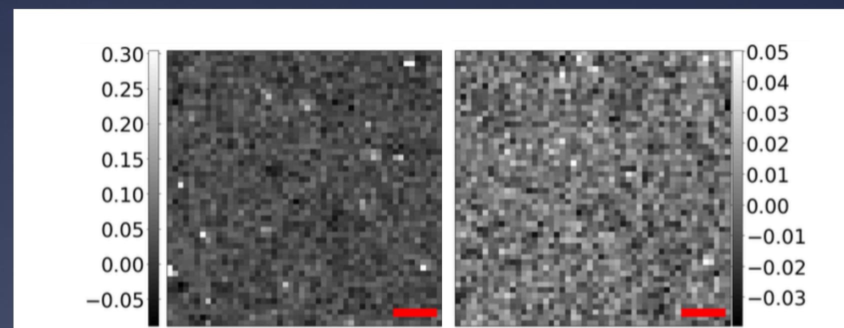


Figure 3. The stacked rest-frame LyC images for the (a) [OII] and (b) strong (O_{32}>5) emitters. A linear greyscale

Selection	N_{objs}	f_{esc}^{LyC}
[OII]	208	<5.6%
All O_{32}	41	<6.7%
O_{32}> 5	13	<14.0%

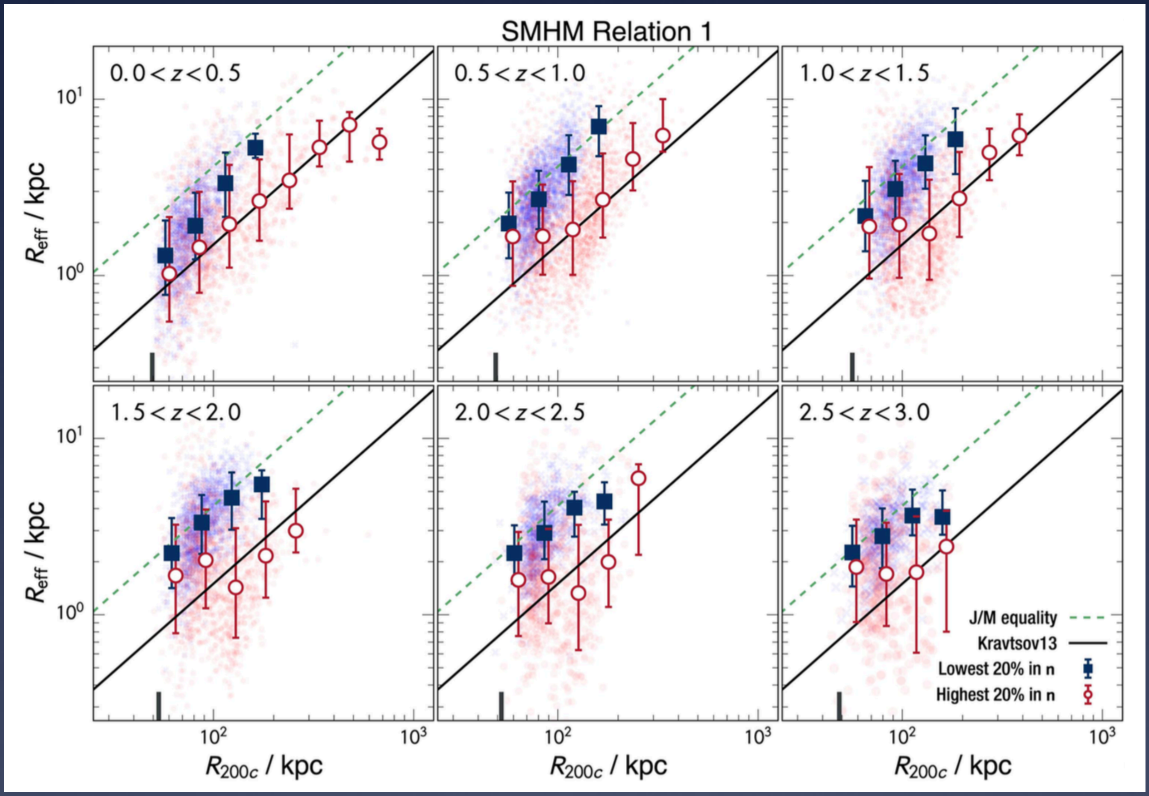
Rutkowski+17

Science Goals: Cosmic "High Noon"

Cosmic Noon	Improve by an order of magnitude the census of passively-evolving galaxies at 1.5 $< z <4$. Measure mass functions and size distributions in the rest-frame optical, measure the trend in clustering with luminosity, and quantify evolution with redshift.
Cosmic Noon	Use rest-frame optical observations at $1 < z < 3$ to provide solid estimates of bulge and disk growth, and the evolution spiral arms, bars, and disk instabilities.
Cosmic Noon	Test models for the co-evolution of black holes and bulges via the most detailed HST census of interacting pairs, mergers, AGN, and bulges, aided by the most complete and unbiased census of AGN from Herschel, improved Chandra observations, and optical variability.
Cosmic Noon	Detect individual galaxy subclumps and measure their stellar mass, constraining the timescale for their dynamical-friction migration to the center leading to bulge formation.
Cosmic Noon	Measure the effective radius and Sersic index in the rest-frame optical of passive galaxies up to $z \sim 2$ and beyond and combine with ACS data to quantify envelope growth and UV-optical color (age) gradients.
Cosmic Noon	Determine the rest-frame optical structure of AGN hosts at $z \sim 2$.
Cosmic Noon	Identify Compton-thick, optically obscured AGN at $z \sim 2$ and determine their structure.

Too many papers to list here…

Galaxy sizes track halo sizes

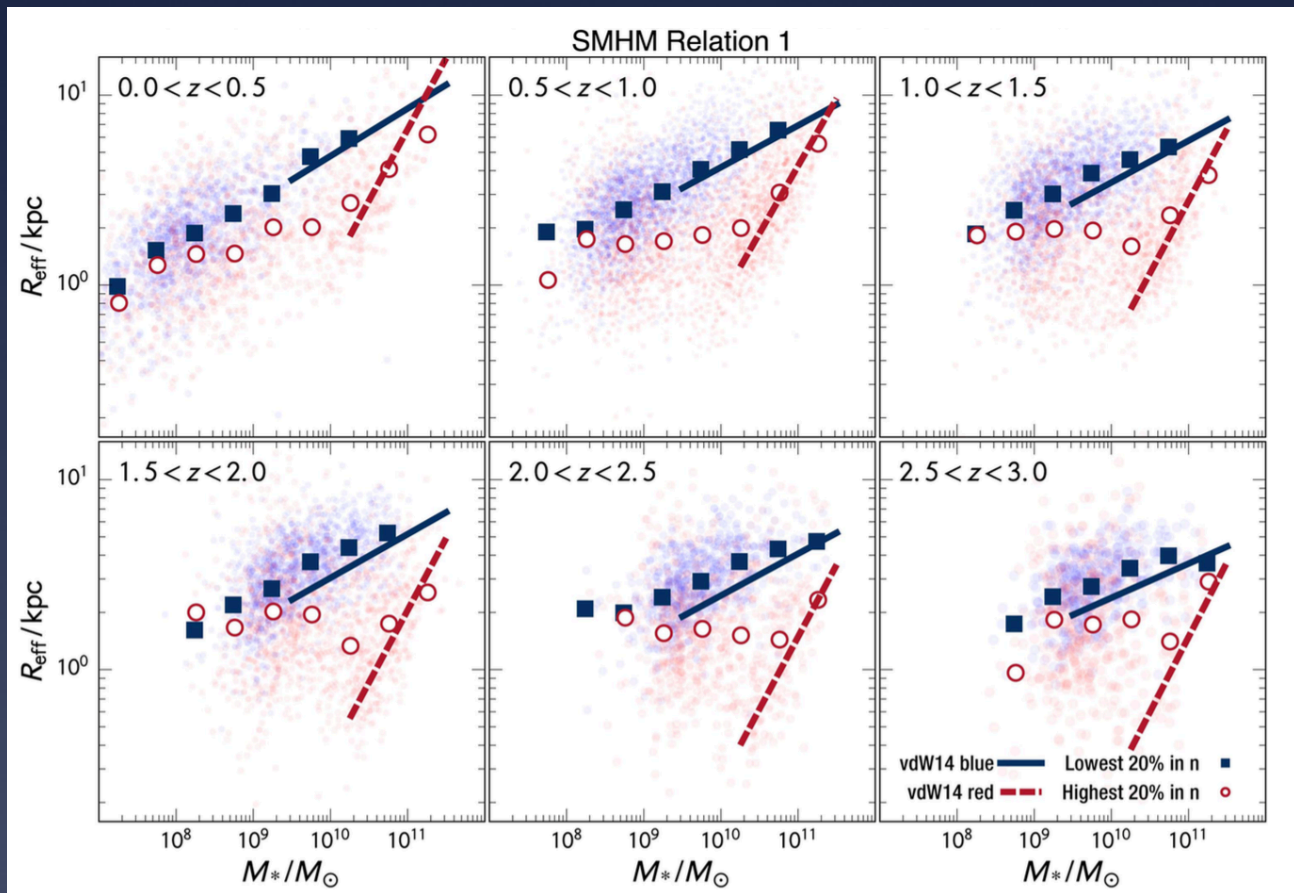


Huang+17

Galaxies track halo size growth out to z=3

- Mild evolution for late-types at z<1
- Roughly constant offset for early types

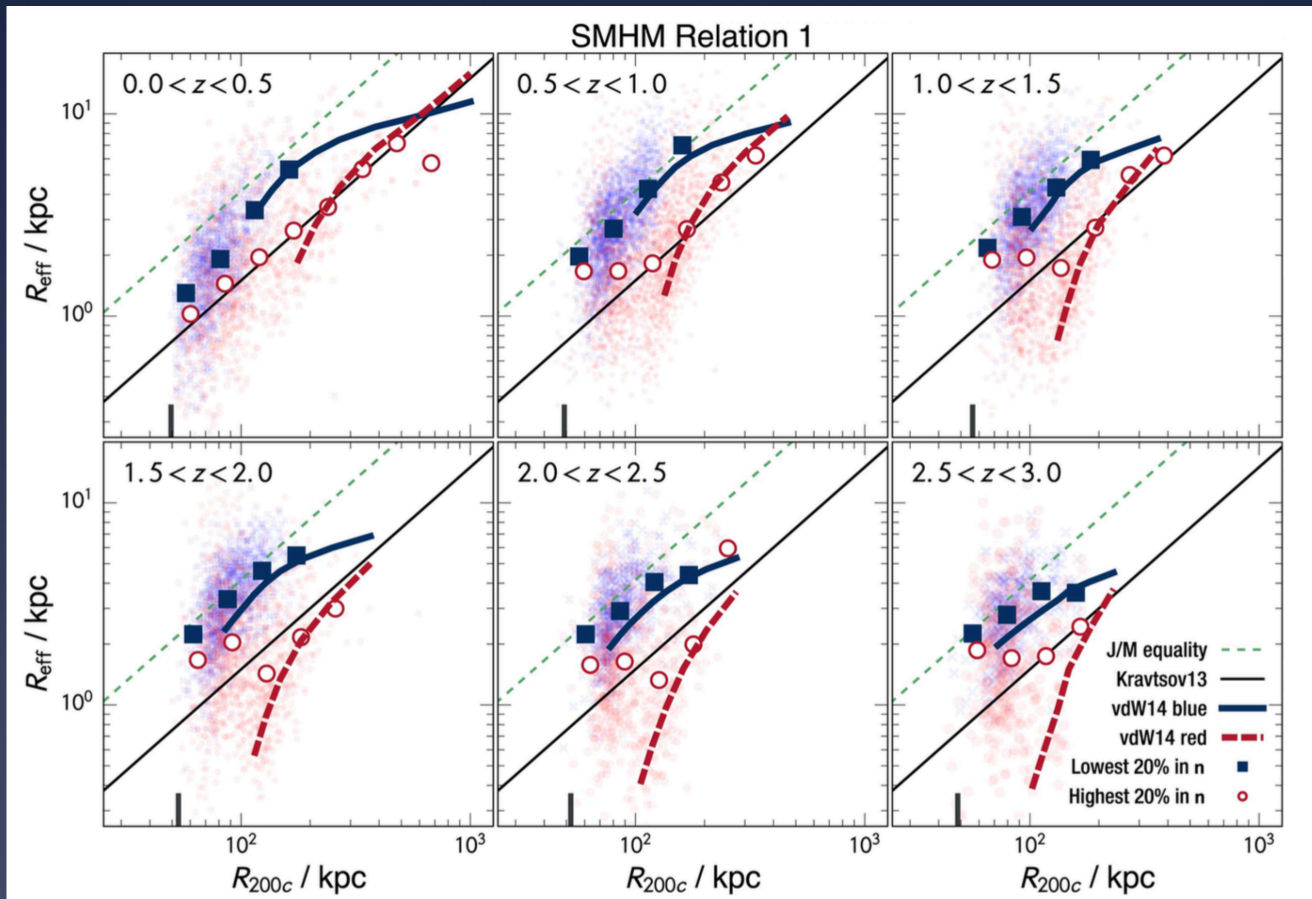
Radius vs. stellar mass



Huang+17

A bit unclear whether r-M* or r-Mh is more linear

Radius vs. stellar mass



Huang+17

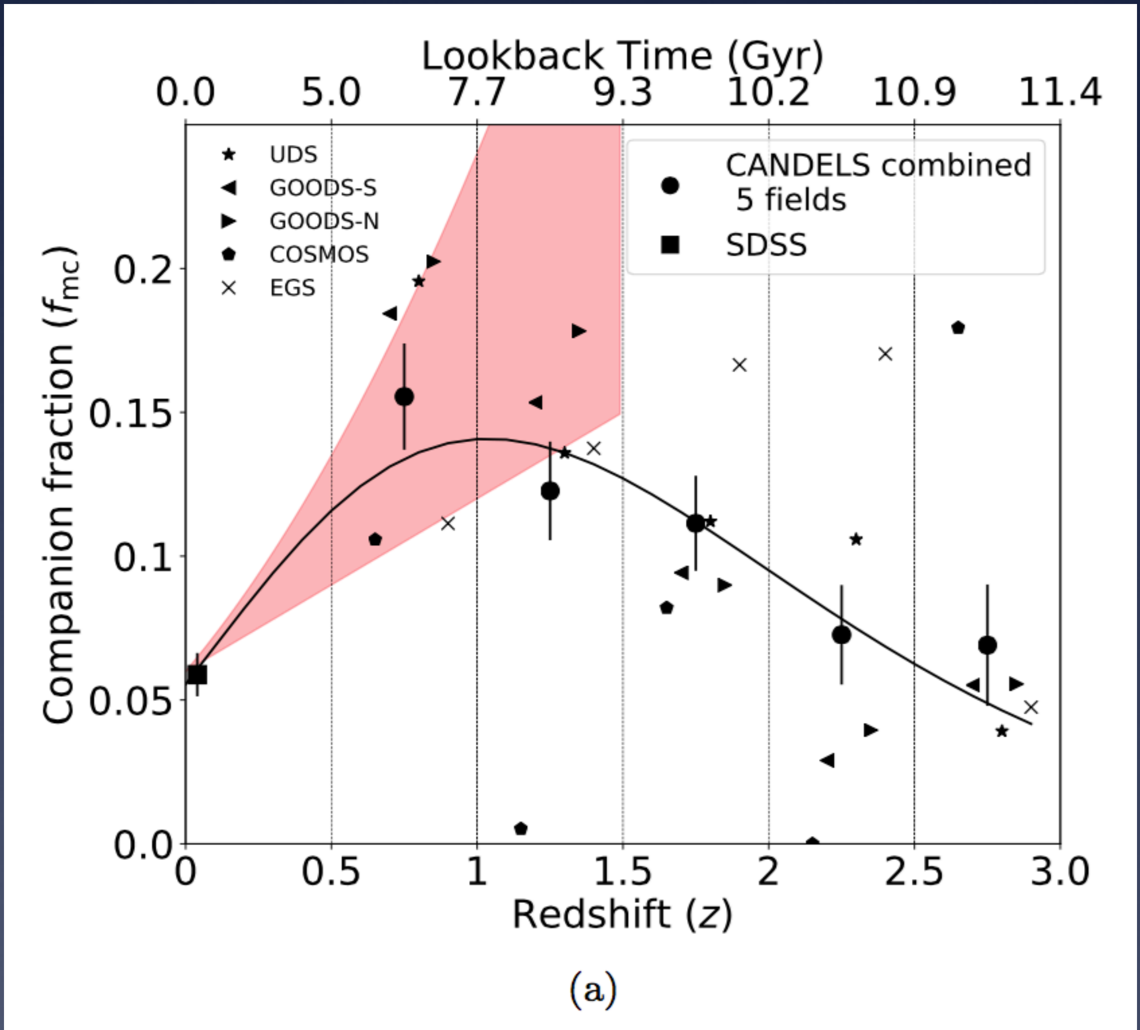
A bit unclear whether r-M* or r-Mh is more linear

Merger rate evolution

Pair counts favor a declining merger rate at z>1

Departs from simple power-law evolution seen at lower redshift

Details are sensitive to how you select pairs

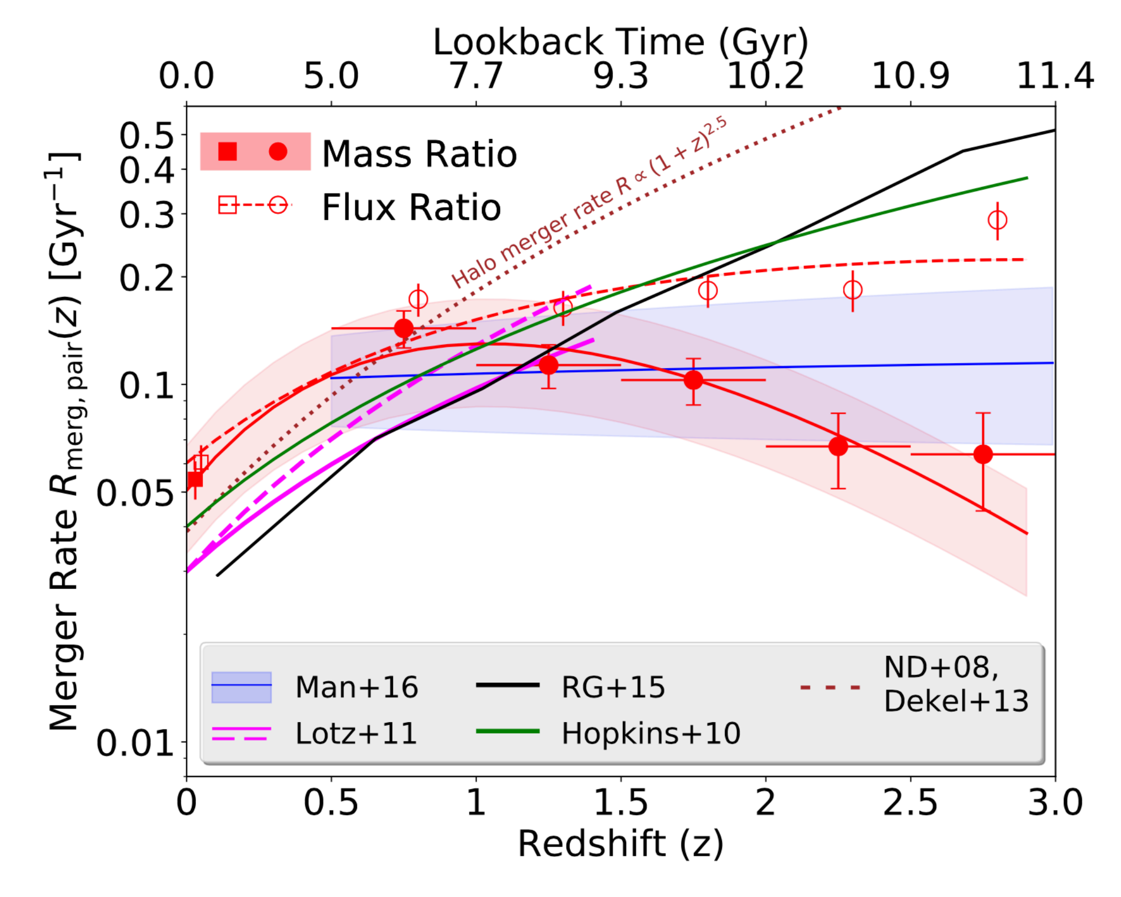


Mantha+17

Merger rate evolution

Tension with theoretical expectations:

⇒ Revisions to pair observability predictions during the pre-merger phase?



Mantha+17

AGN prefer compact star-forming hosts

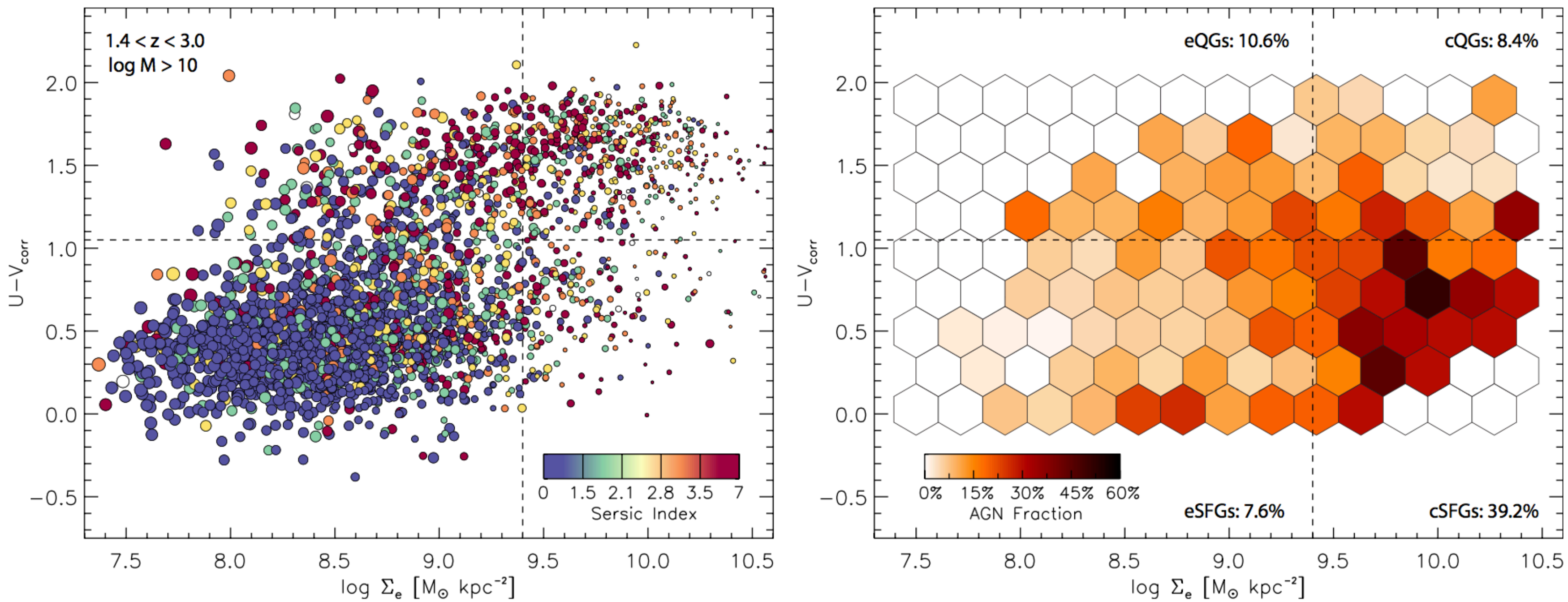
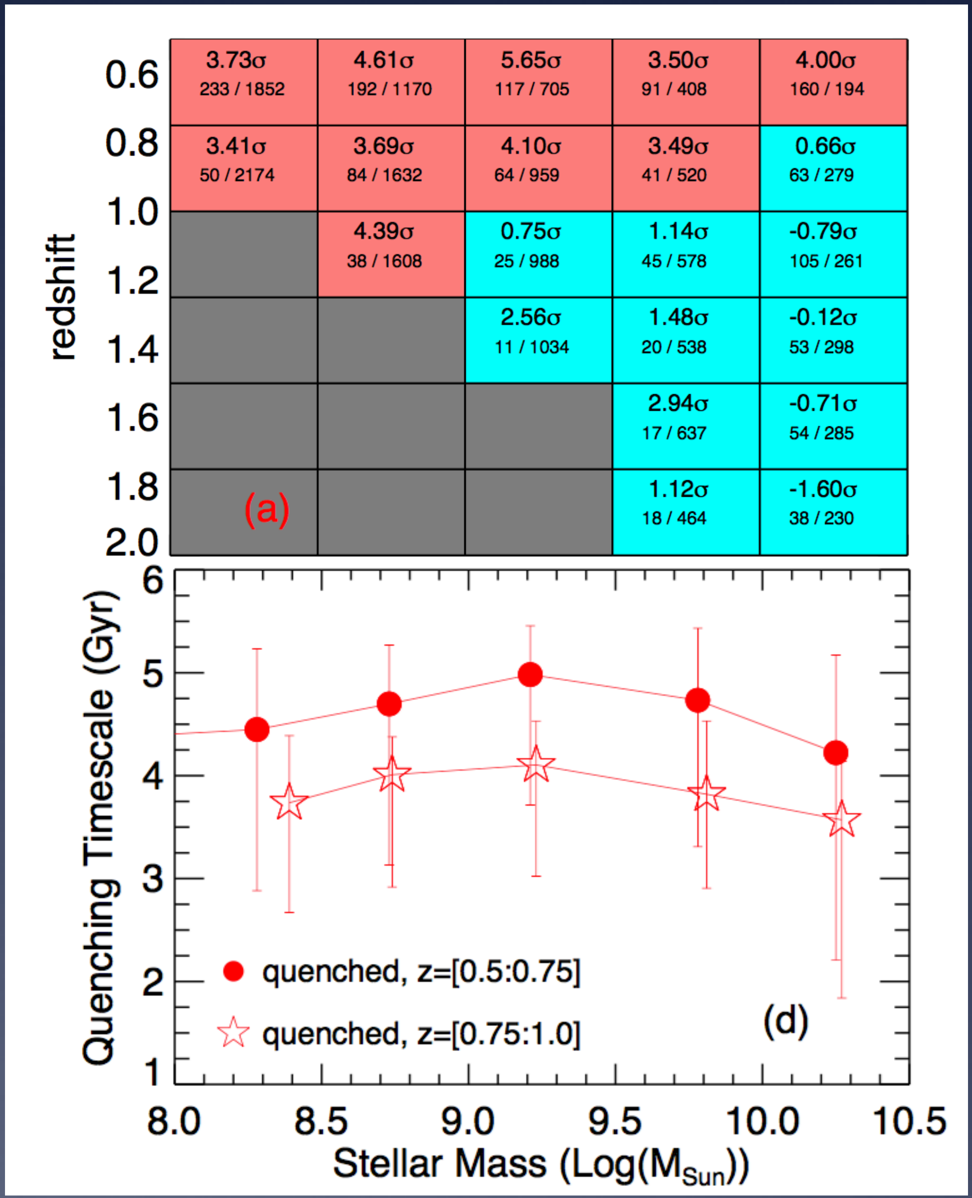


FIG. 5.— (*left*) Surface mass density (Σ_e) versus rest-frame color for galaxies with $M_* > 10^{10}\ M_\odot$ in the redshift range $1.4 < z < 3.0$. Points are color coded by their best-fit Sersic index and symbol sizes are scaled to the physical size of each galaxy. (*right*) AGN fraction in regions of Σ_e-color space. We find the AGN fraction peaks among the compact, star-forming population.

Kocevski+17

Environmental Quenching

- Spatial distributions relative to a massive neighbor differ for quenched & star-forming galaxies
- Constrains environmental-quenching timescales



Guo+17

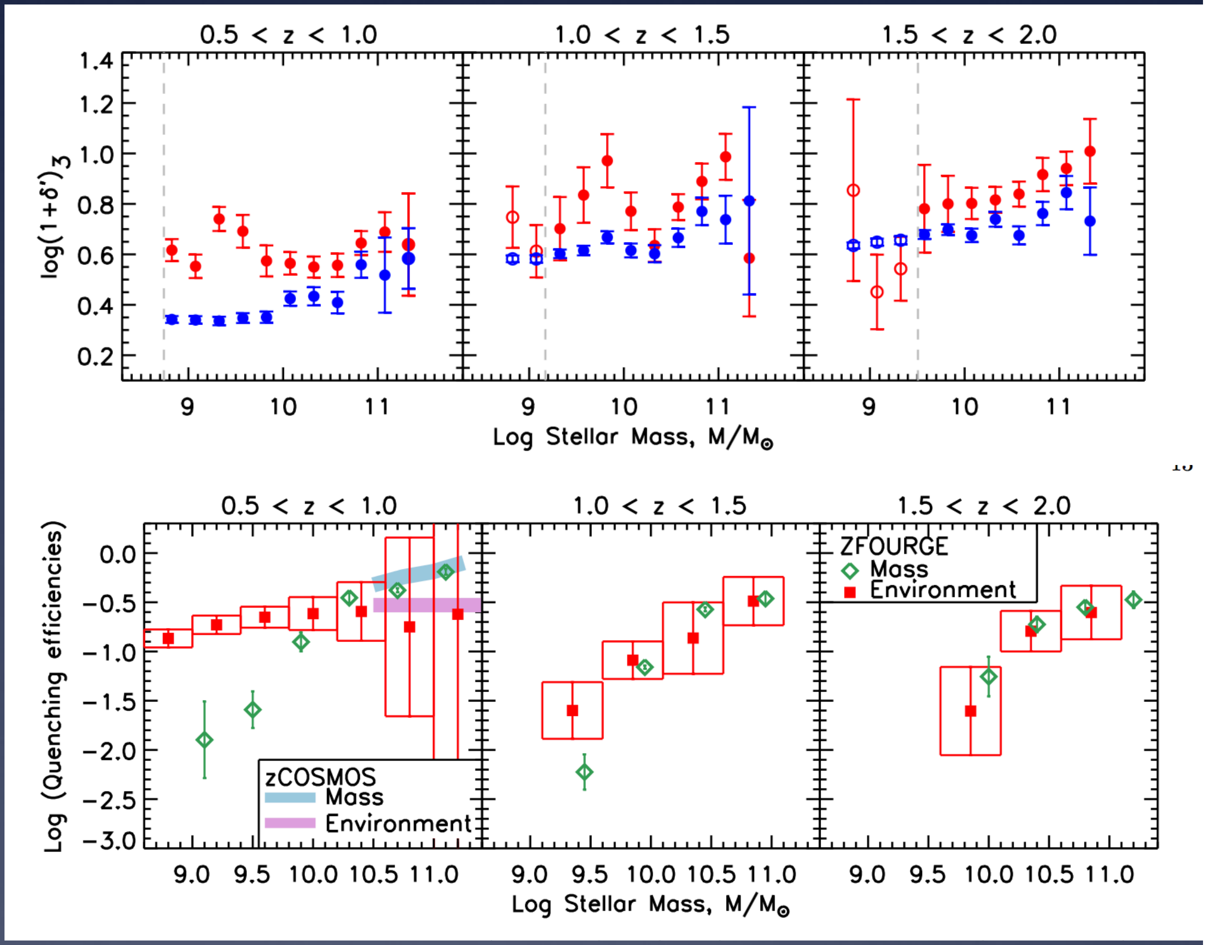
Environmental quenching

LogM* > 10.5:

- Mass & environmental quenching efficiencies comparable at all z

Lower mass:

- Environmental quenching kicks in at z<1

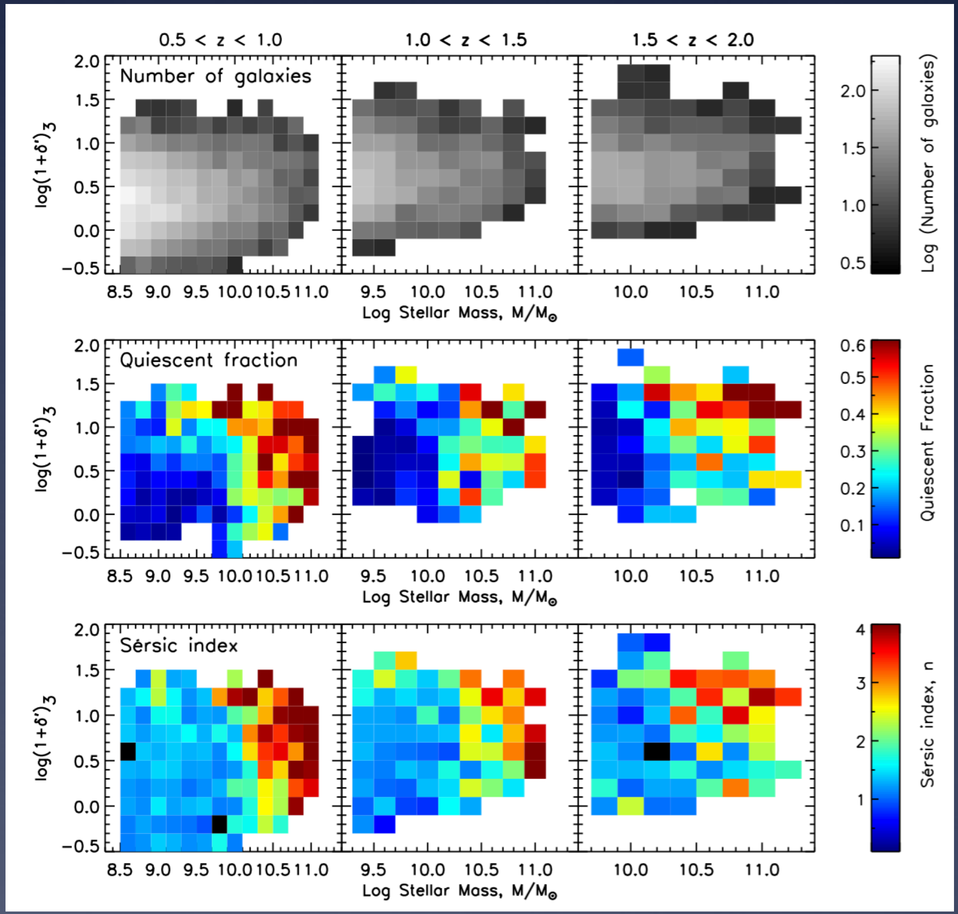


Kawinwanichakij+17

Quenched galaxy morphologies vs. environment

Morphologies of lower-mass quiescent galaxies are inconsistent with simply shutting off star-formation

Process that transforms morphology must be concurrent

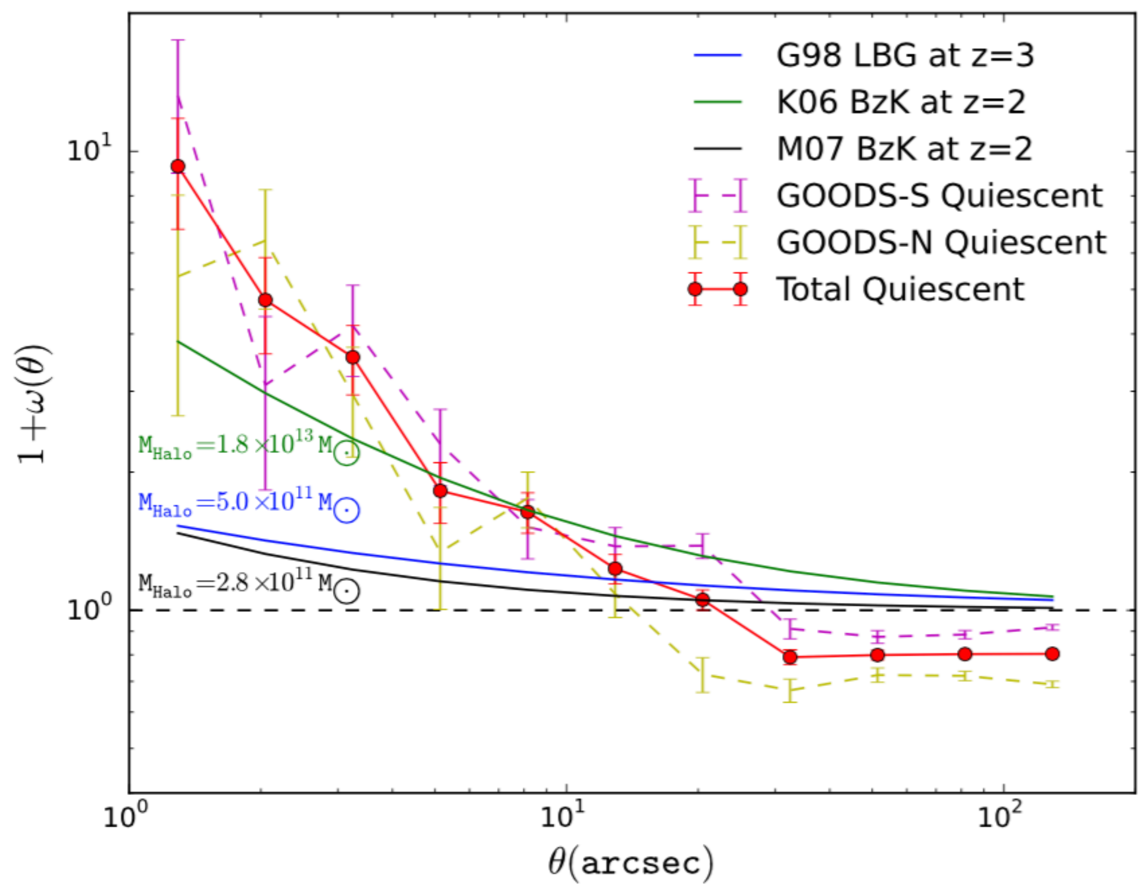


Kawinwanichakij+17

Environmental quenching z=2

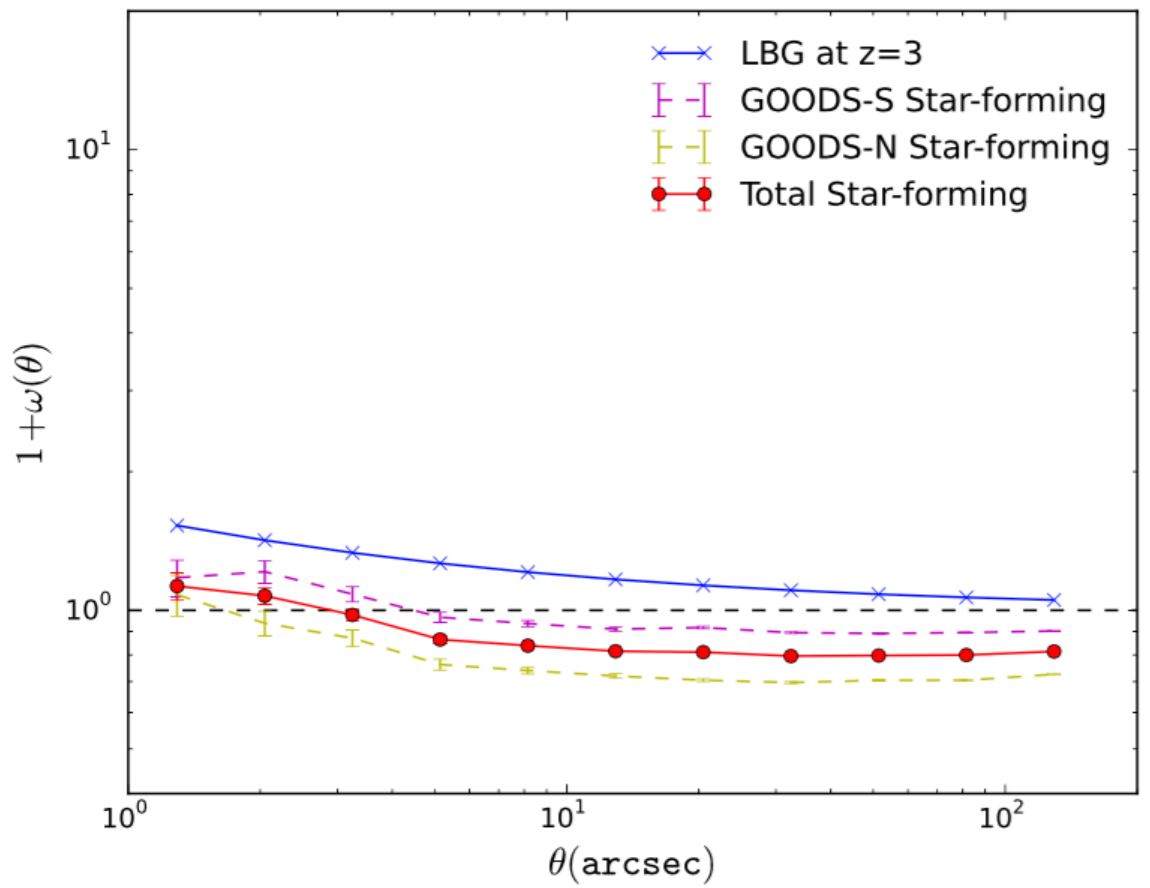
Quiescent galaxies prefer quiescent neighbors

Ji+17



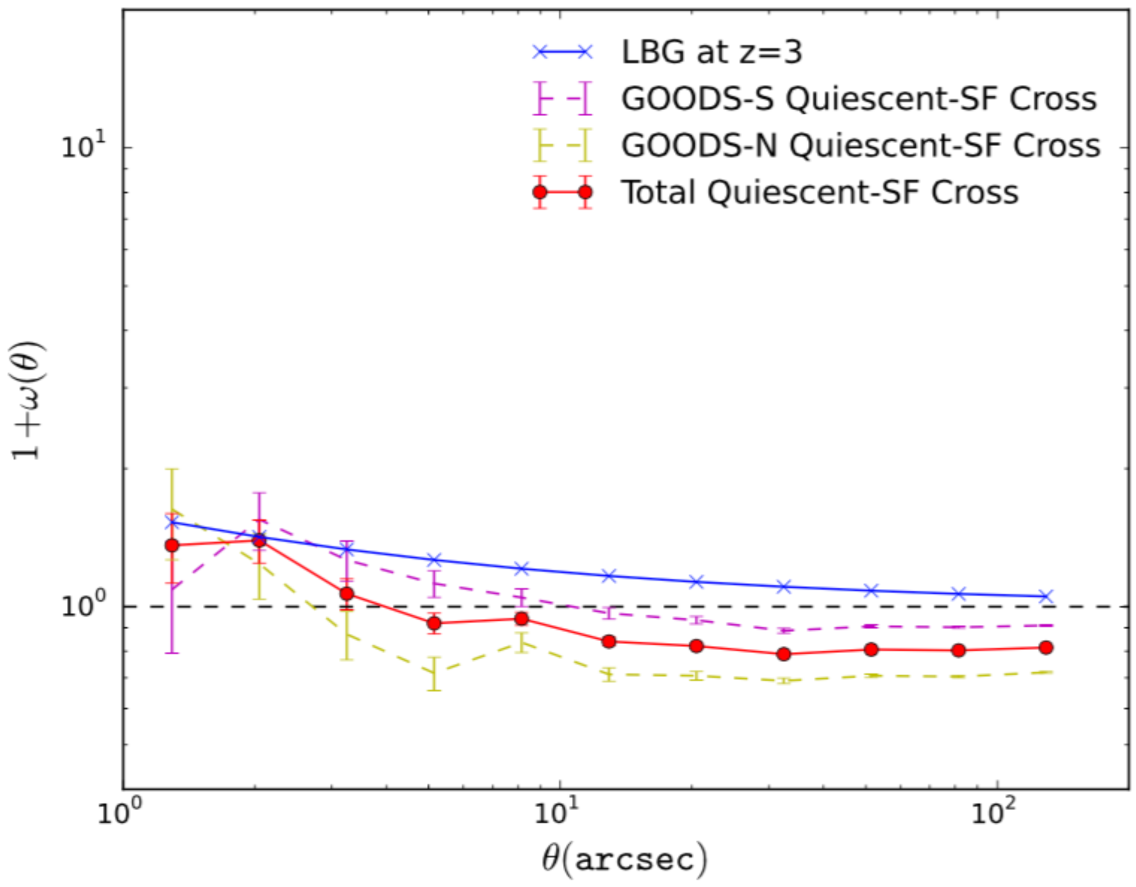
(a)

Environmental quenching z=2



(b)

Environmental quenching z=2

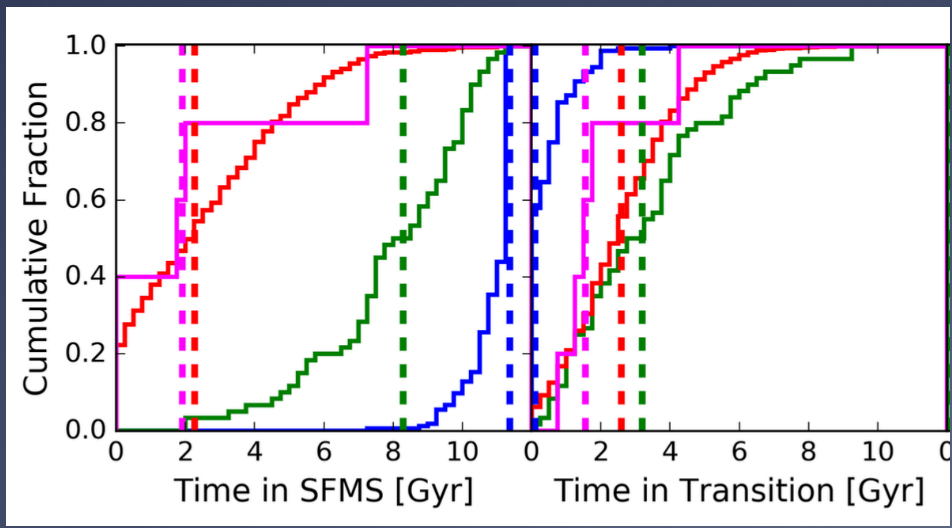


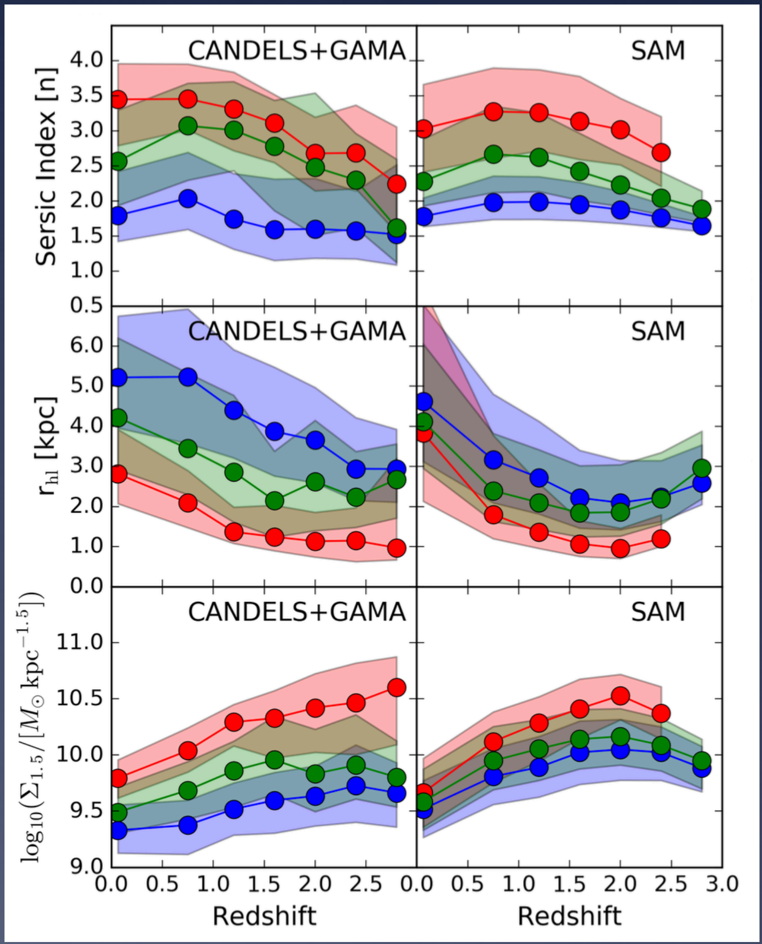
(c)

Transition galaxies are transition in most properties

Models suggest a mix of processes

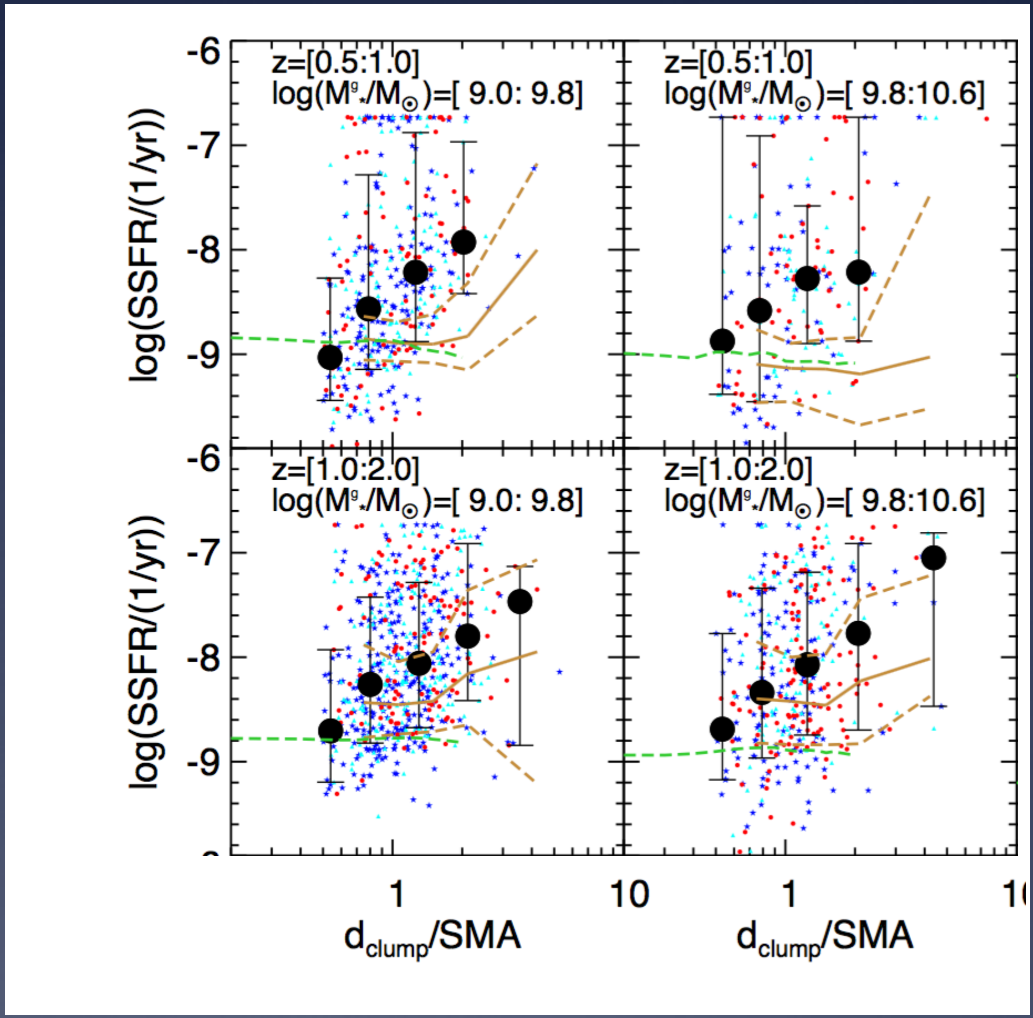
Relatively long transition times





Pandya+17

Clumps near galaxy centers are less vigorously forming stars



Guo+17

Conclusions…

- CANDELS is well established as one of the most productive science programs in the history of *Hubble*.
- But…there is still a lot of work to do!