How WFIRST can help us constrain the physics of galaxy formation

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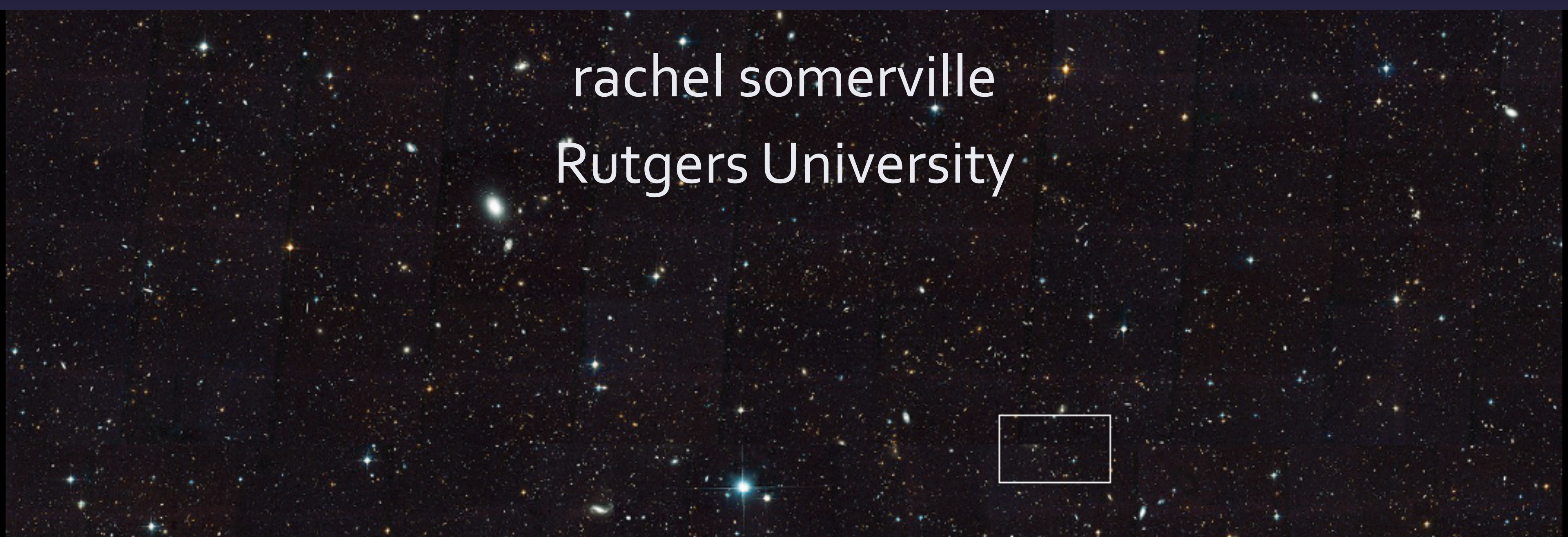


- diversity of galaxy morphology, structure, and stellar populations
- scaling relations between global and structural & kinematic properties (e.g. m_*, B/T, r, V, M_{BH}); evolve over cosmic time in interesting ways
- strong correlation between stellar populations (SF history) and morphology – in place since z~2

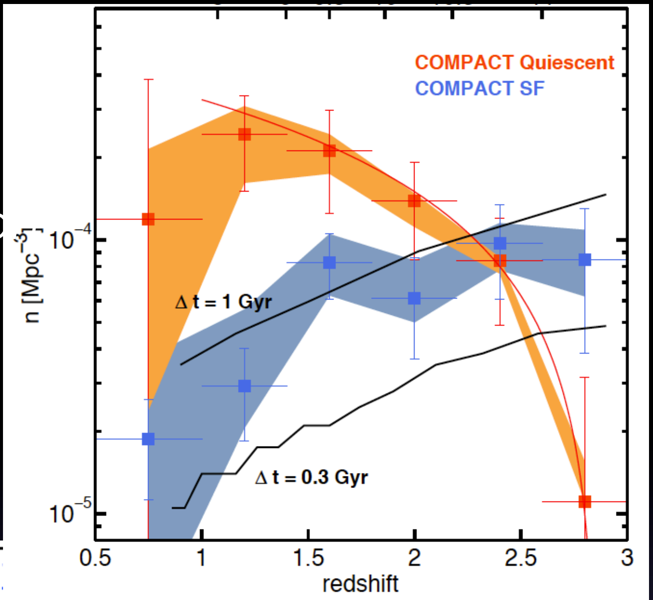
CANDELS
Cosmic Assembly Near-infrared Deep Extragalactic Legacy Survey

PIs: S. Faber
& H. Ferguson

e.g. Hubble Deep Fields, GOODS, GEMS, STAGES, AEGIS, COSMOS, Hubble Ultra-deep Fields, CANDELS, 3D-HST

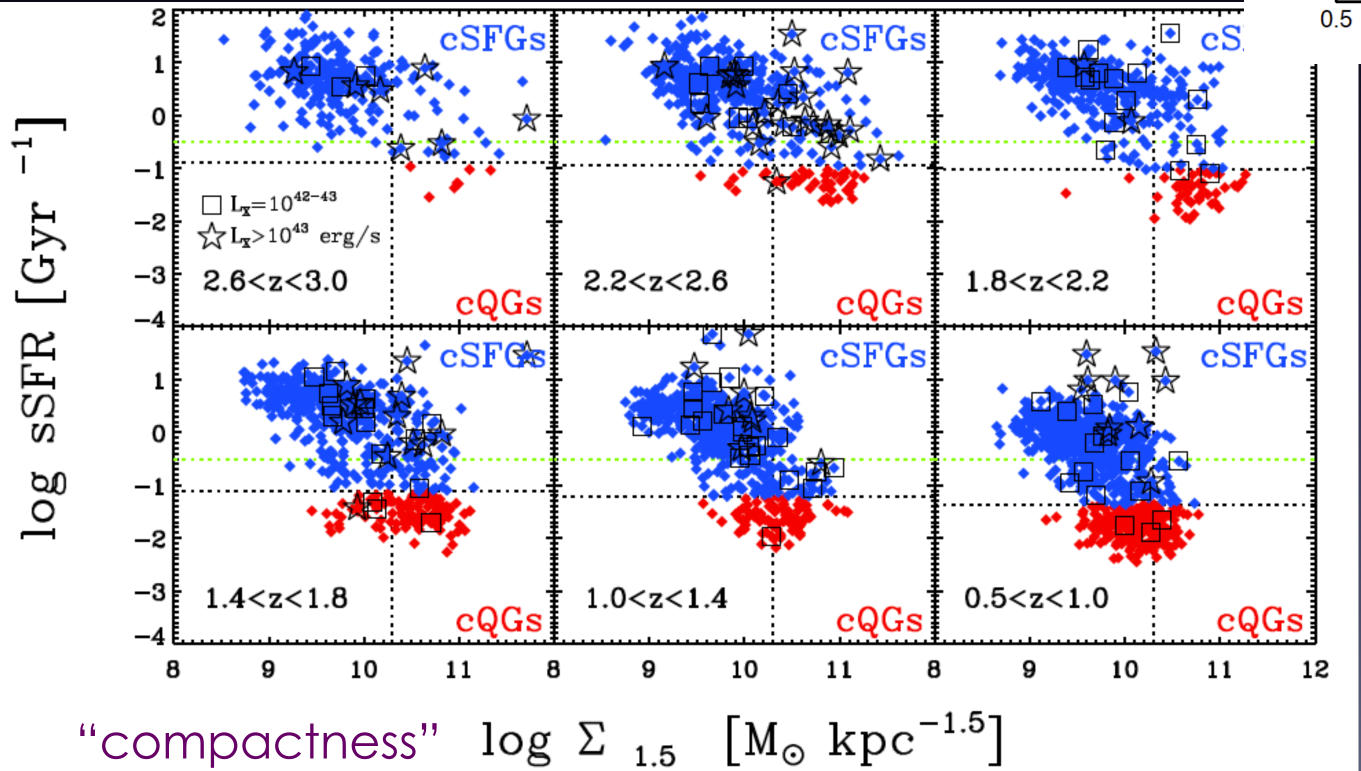
the connection between quenching and structural evolution

- *quenching, size, and morphological transformation are all occurring, but at different rates (slow track, fast track)*
- *strongest predictor of quenching at every epoch seems to be central (<~1kpc) density or B/T*



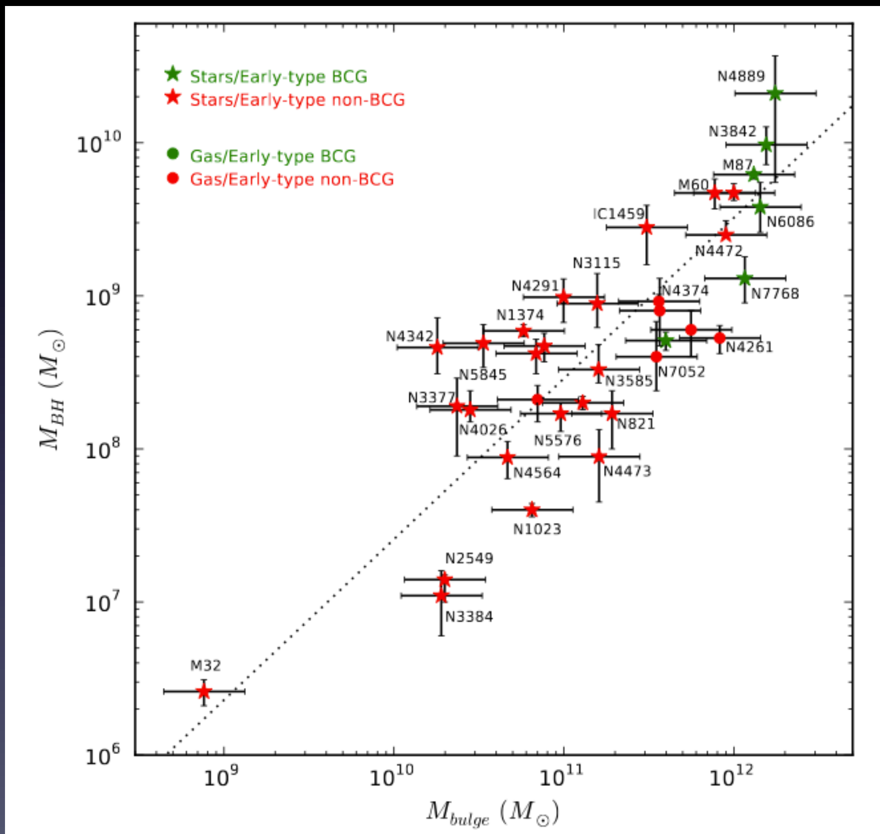
E. Choi et al. in prep.

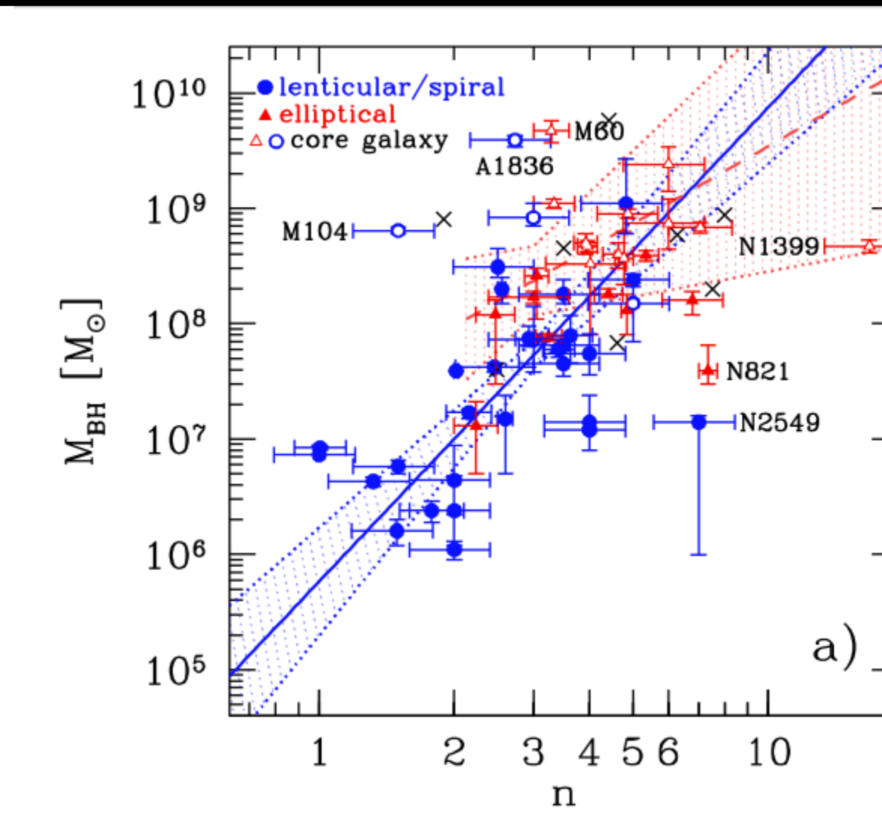
see also Bell et al. 2008, 2012; Cheung+'12; Fang+'13; Wuyts+11; Lang+14; Barro+ in prep



CANDELS analysis by Viraj Pandya after Barro et al. 2013 bulge mass and light profile (Sersic index) correlated with the mass of the supermassive black hole harbored by the host galaxy (in nearby galaxies)

black hole mass



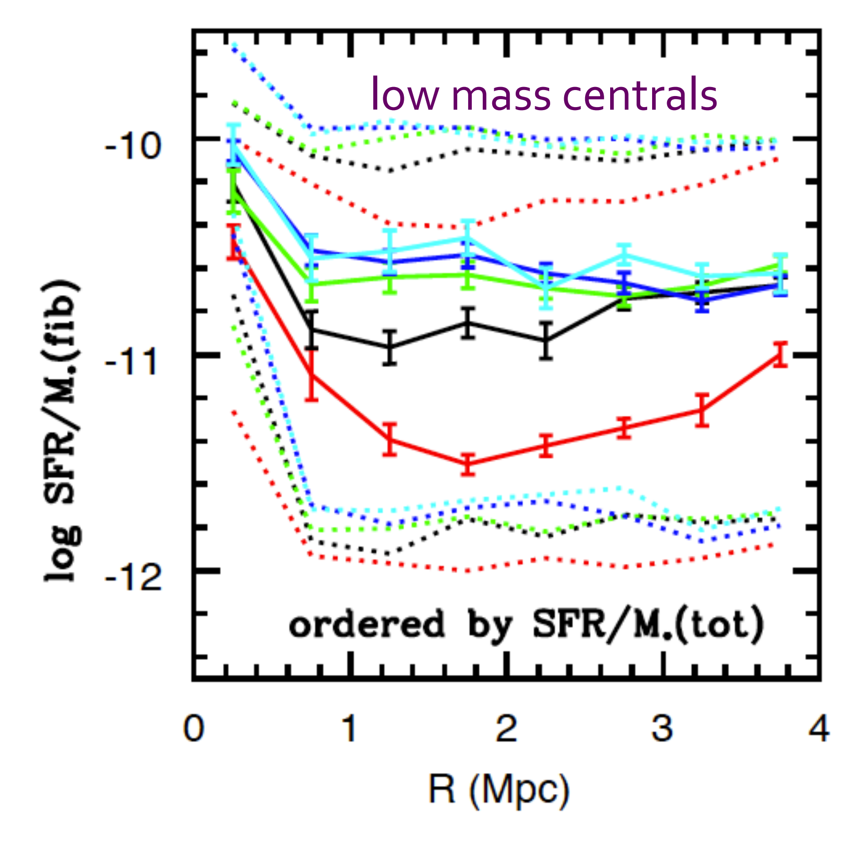


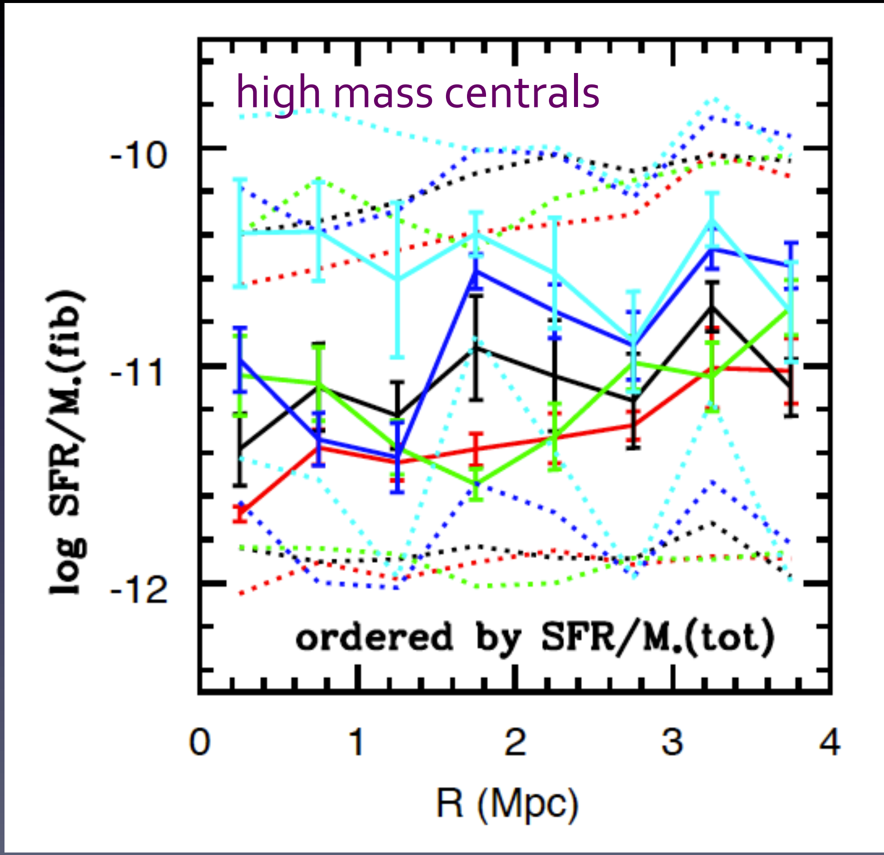
bulge mass McConnell & Ma 2013 Sersic index Savorgnan et al. 2013

Galaxy Conformity

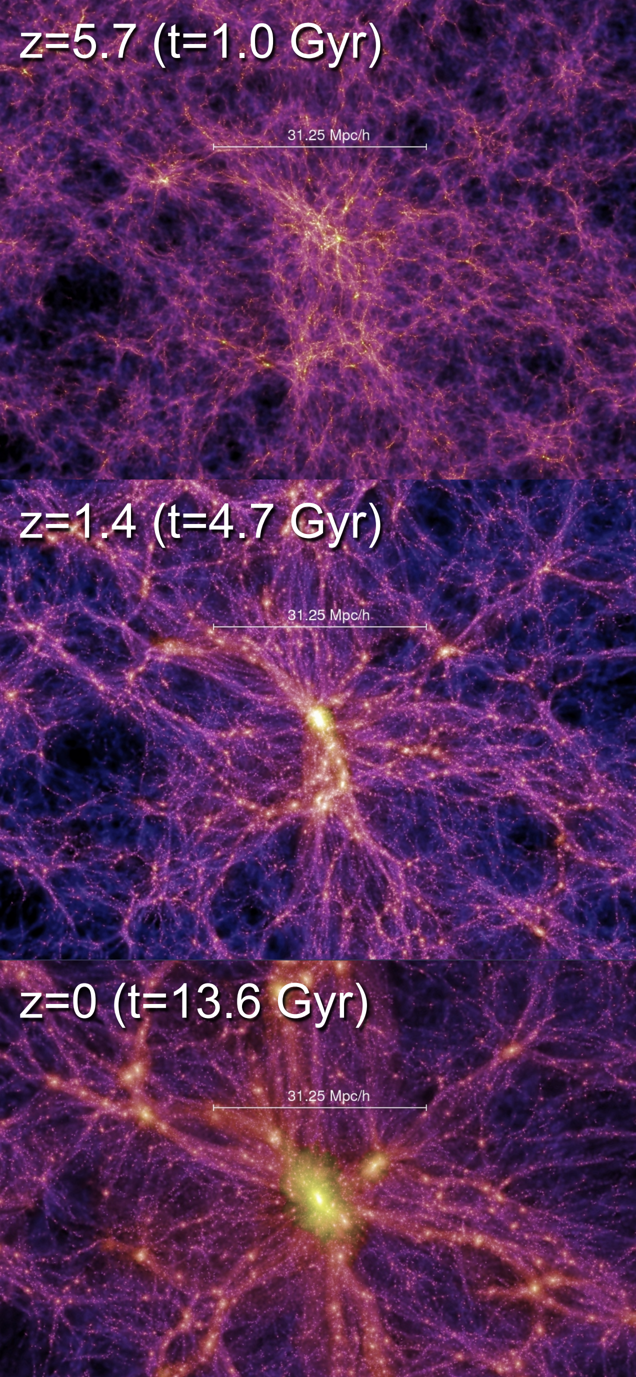
galaxies seem to "know about" the properties of their neighbors out to large distances

cyan: highest 90% centrals; blue 1st quartile, green: 2nd quartile, black: 3rd quartile, red: 4th



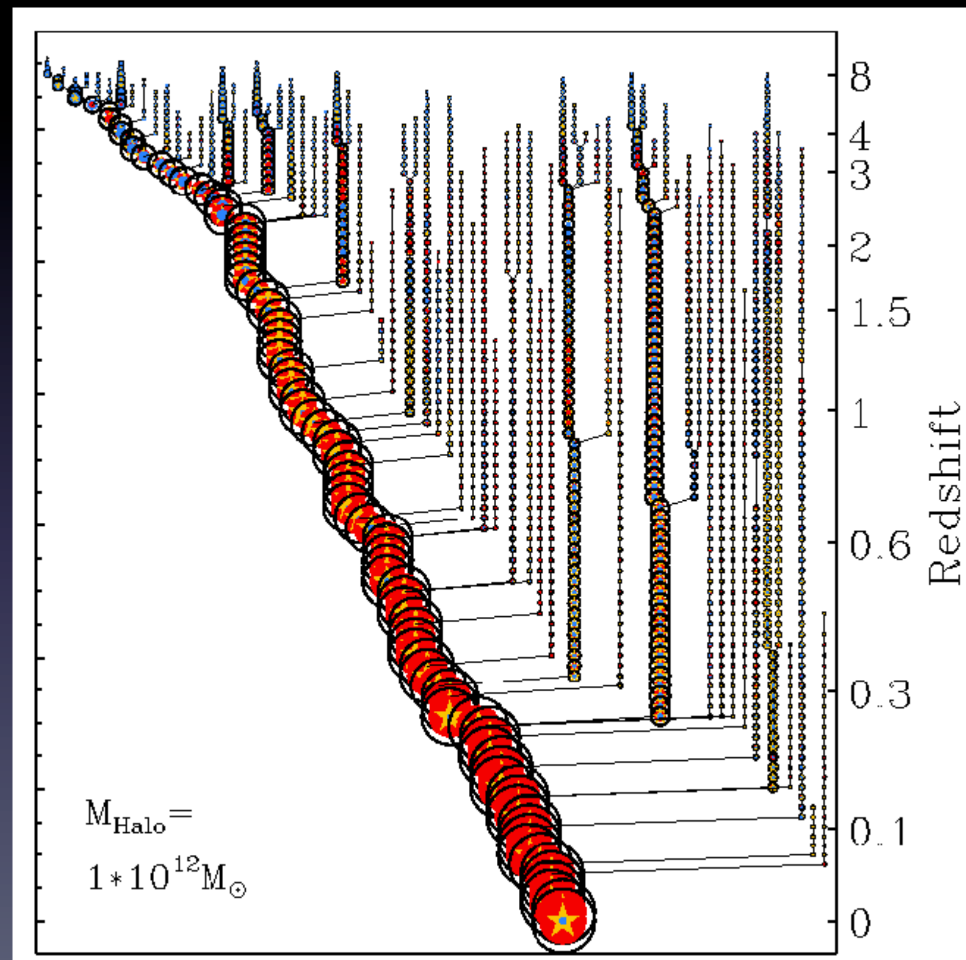


Kauffmann et al. 2013; Weinmann et al. 2006 – based on SDSS nearby galaxy sample

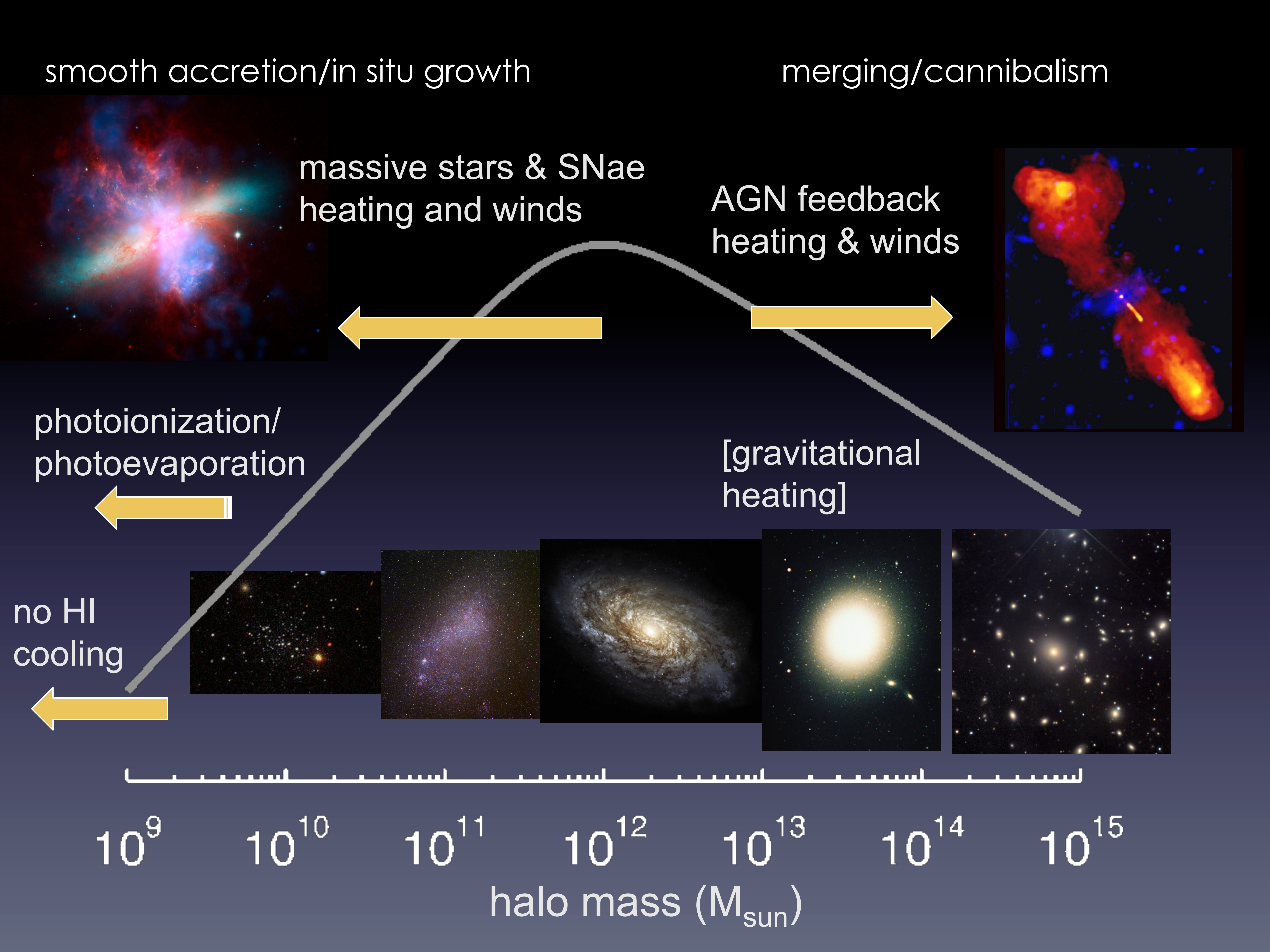


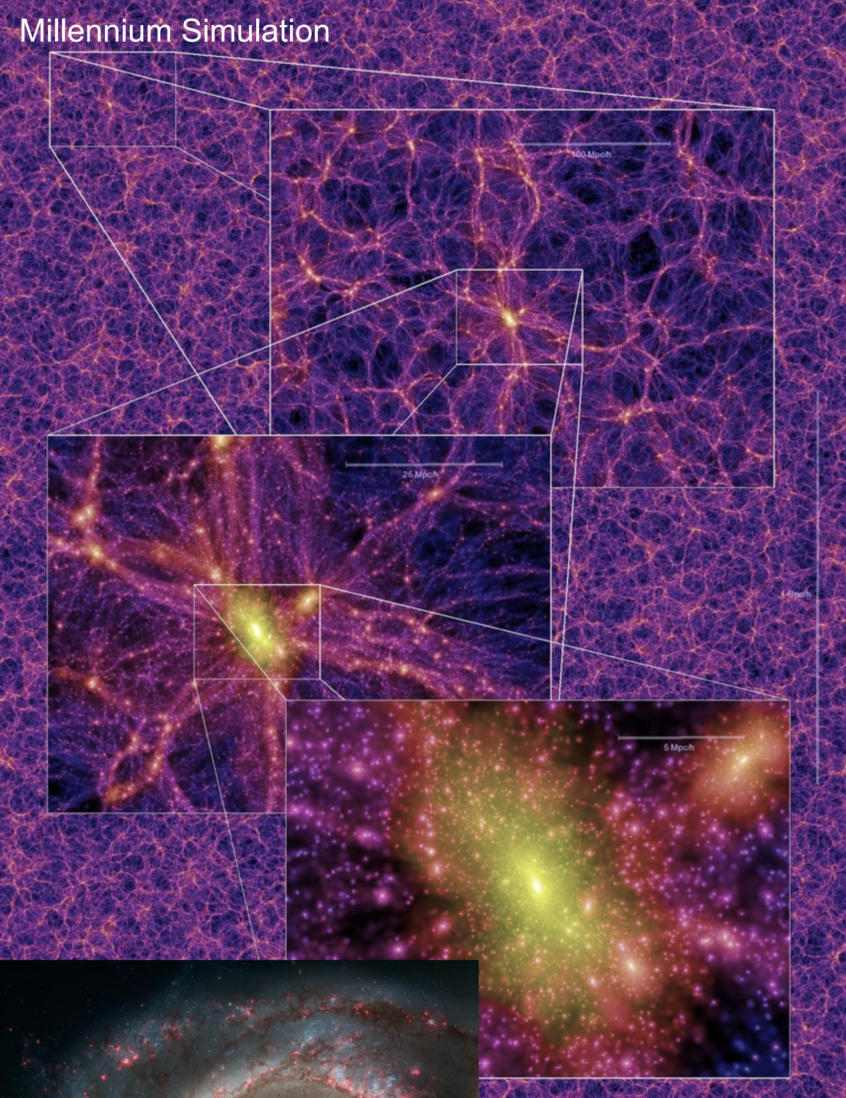
Millennium Simulation

The ΛCDM (dark energy + cold dark matter) paradigm provides us with a rich and predictive framework within which to calculate dark matter halos grow over time

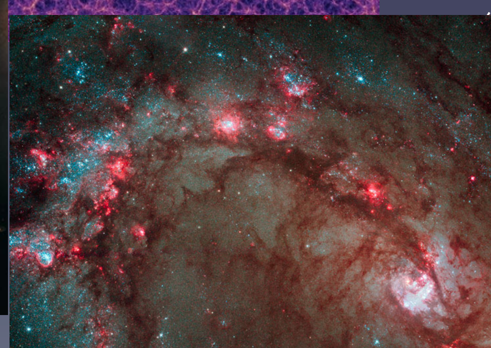


Hirschmann et al. 2012


smooth accretion/in situ growth
merging/cannibalism
massive stars & SNae
heating and winds
AGN feedback
heating & winds
photoionization/
photoevaporation
[gravitational
heating]
no HI
cooling
10^9
10^10
10^11
10^12
10^13
10^14
10^15
halo mass (M_sun)

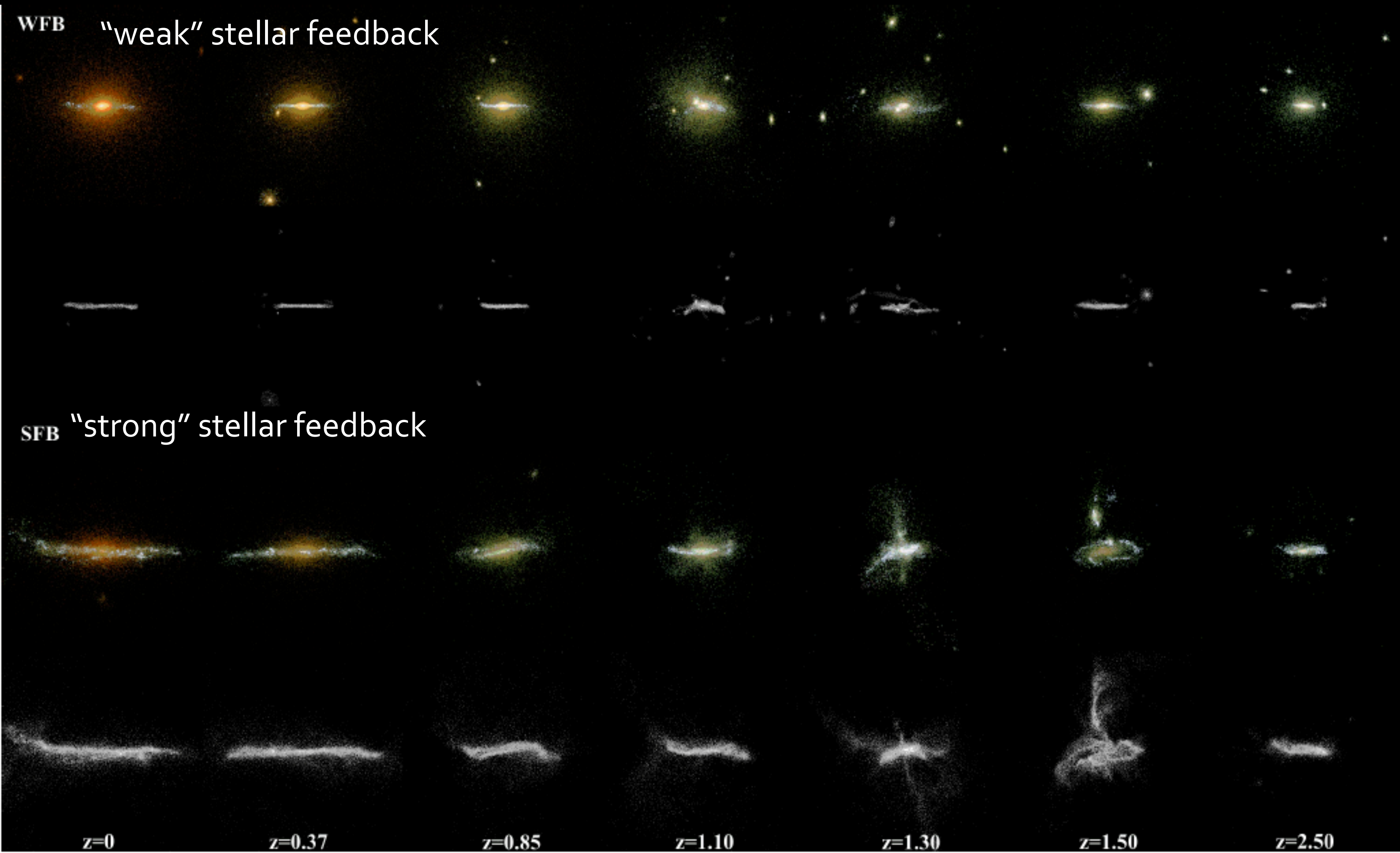


- large-scale structure: 100's of Mpc
- galaxy environment: ~1-3 Mpc
- galaxy internal structure ~0.1-1 kpc
- Giant Molecular clouds: ~10's of pc
- star clusters/SNae: pc/sub-pc
- structures associated with supermassive BH: pc/AU

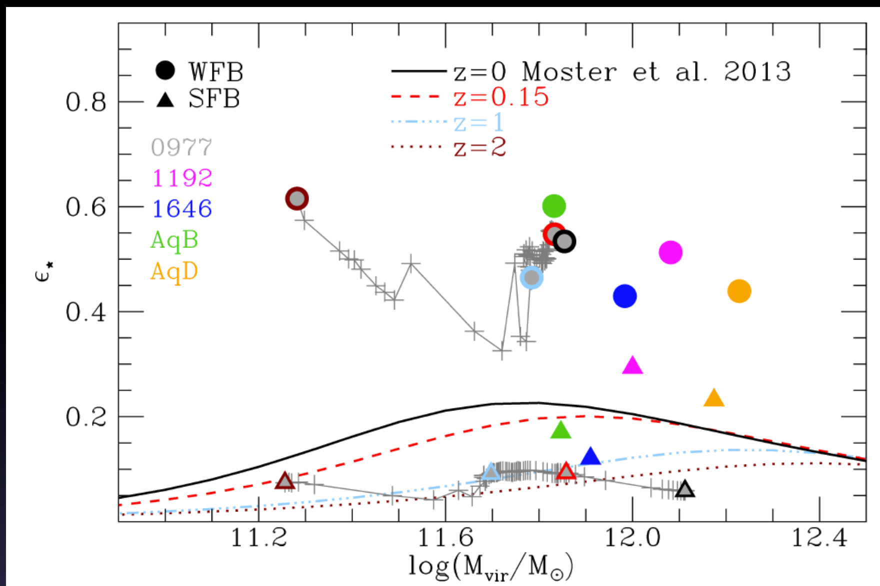


impact of stellar feedback on disk structure

Übler et al. 2014

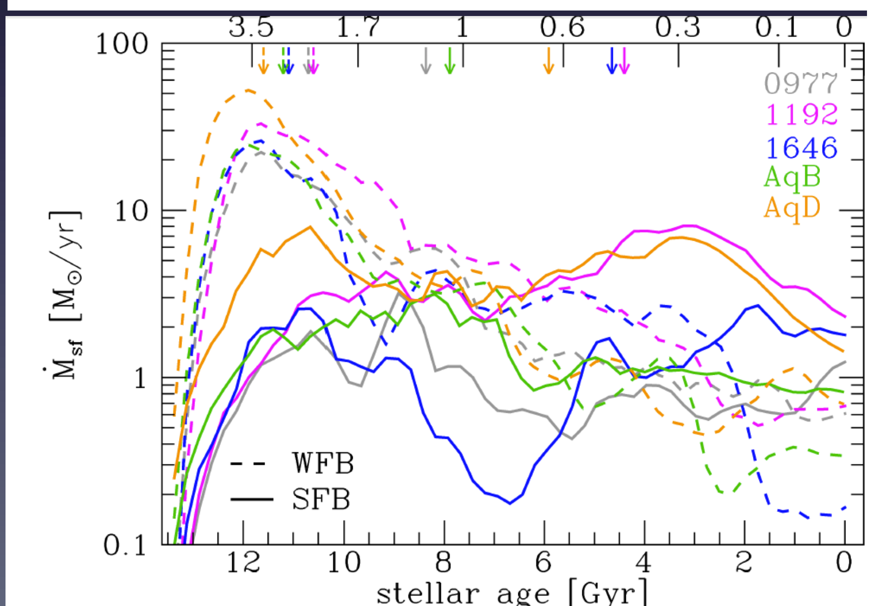


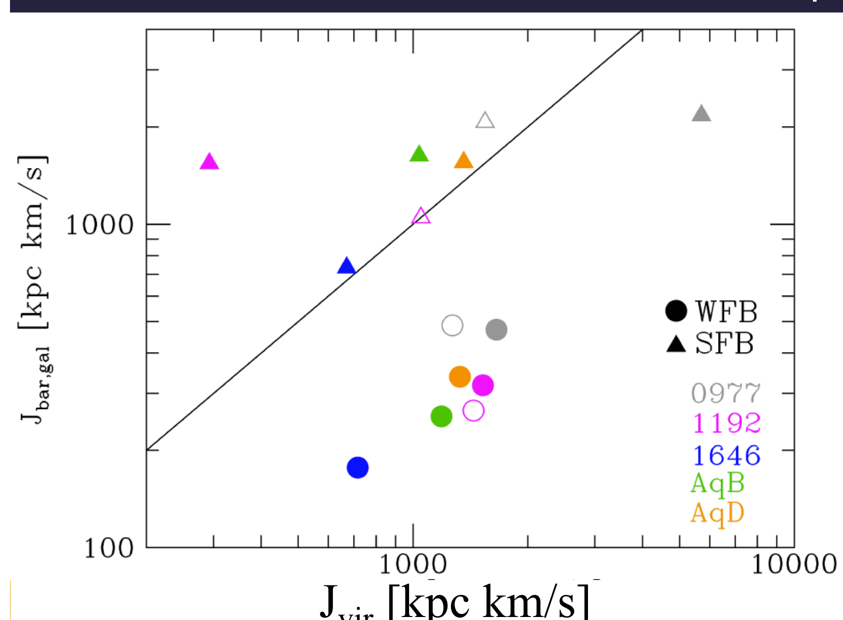
efficient stellar-driven winds: the key to formation of realistic galactic disks



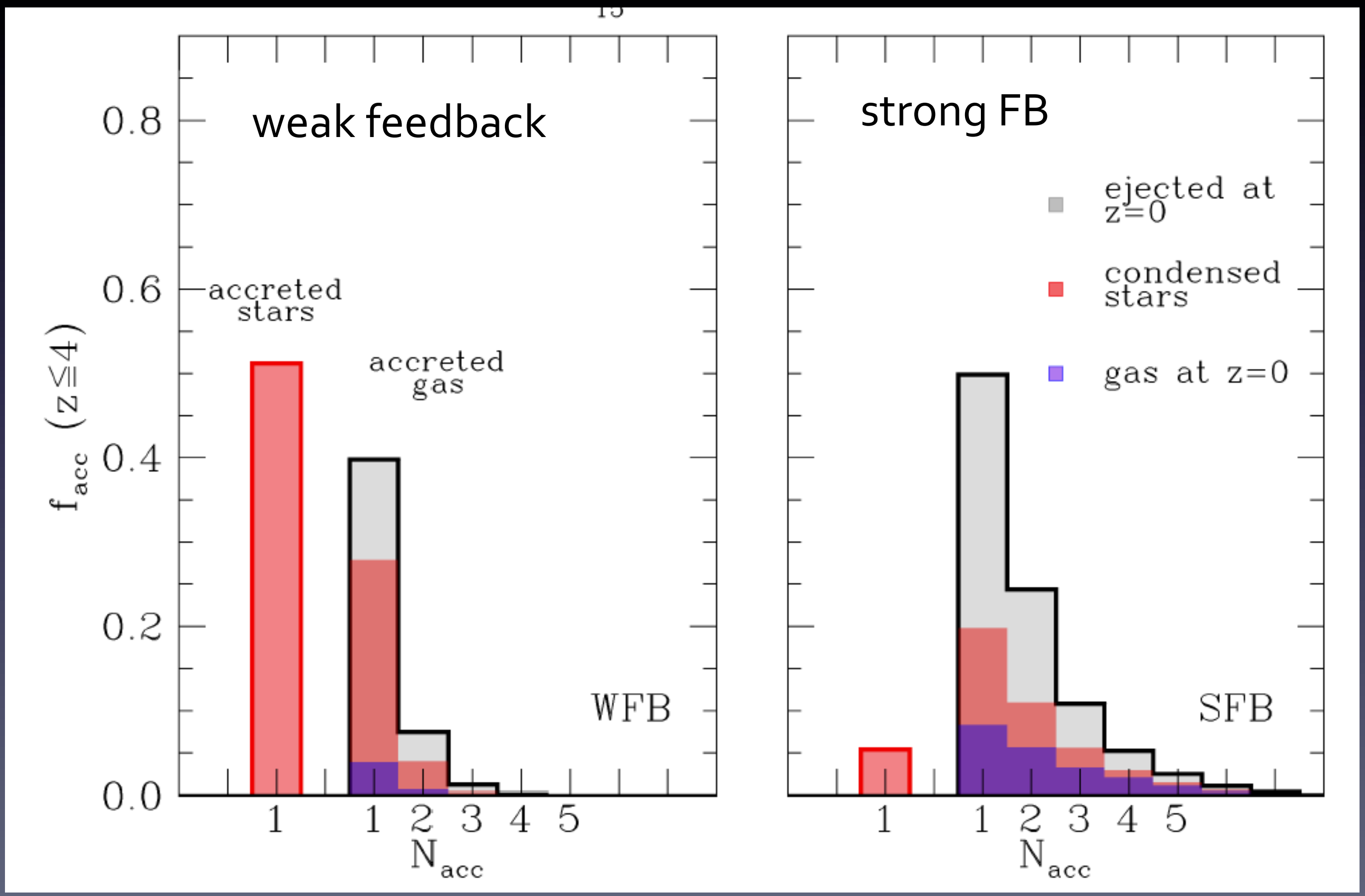
1. reduces stellar fractions
2. reduces early star formation
3. increases angular momentum

Übler et al. 2014





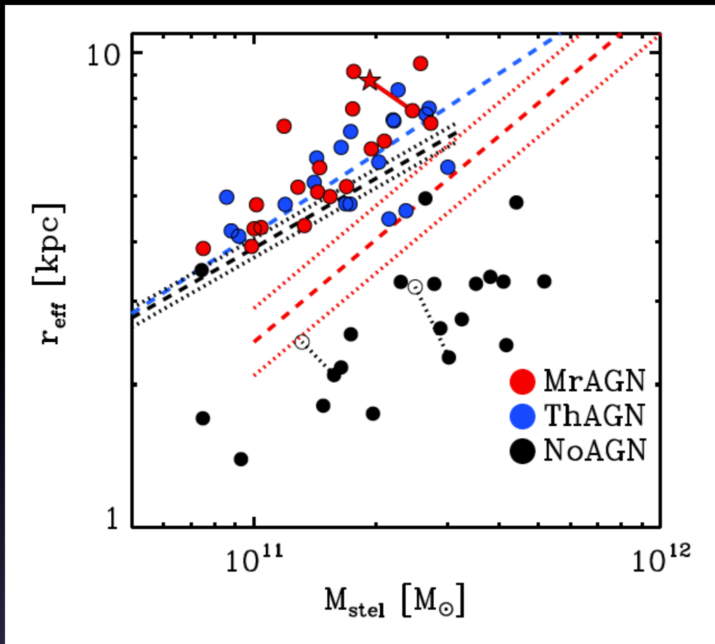
4. reduces fraction of stars acquired via mergers/accretion (relative to 'in situ' formation)
5. increases gas fraction and amount of gas accreted/ejected/accreted multiple times

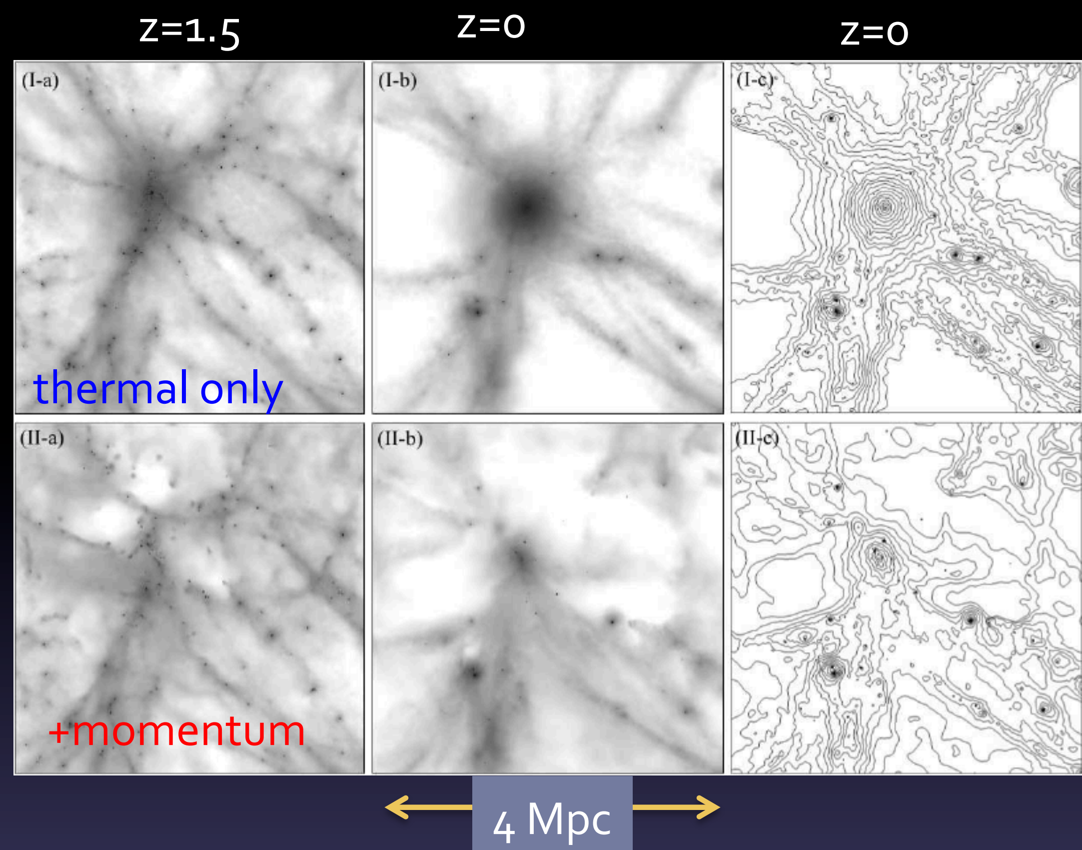


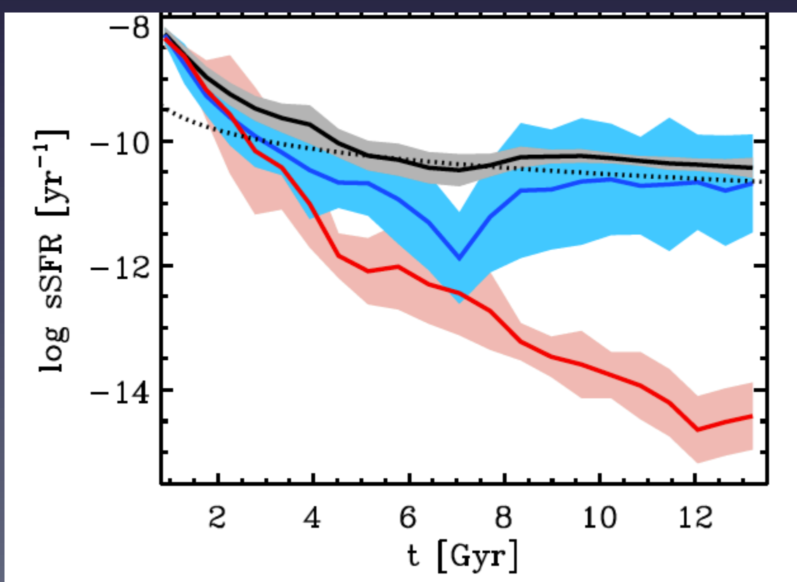
see also
Brook et al. 2011, 2012
Guedes et al. 2011
Scannapieco et al. 2011
Agertz et al. 2011
Christensen et al. 2012

Übler et al. 2014

AGN feedback







- size-mass scaling relations
- size evolution
- fraction of accreted/in situ
- quenching

very sensitive to AGN feedback!

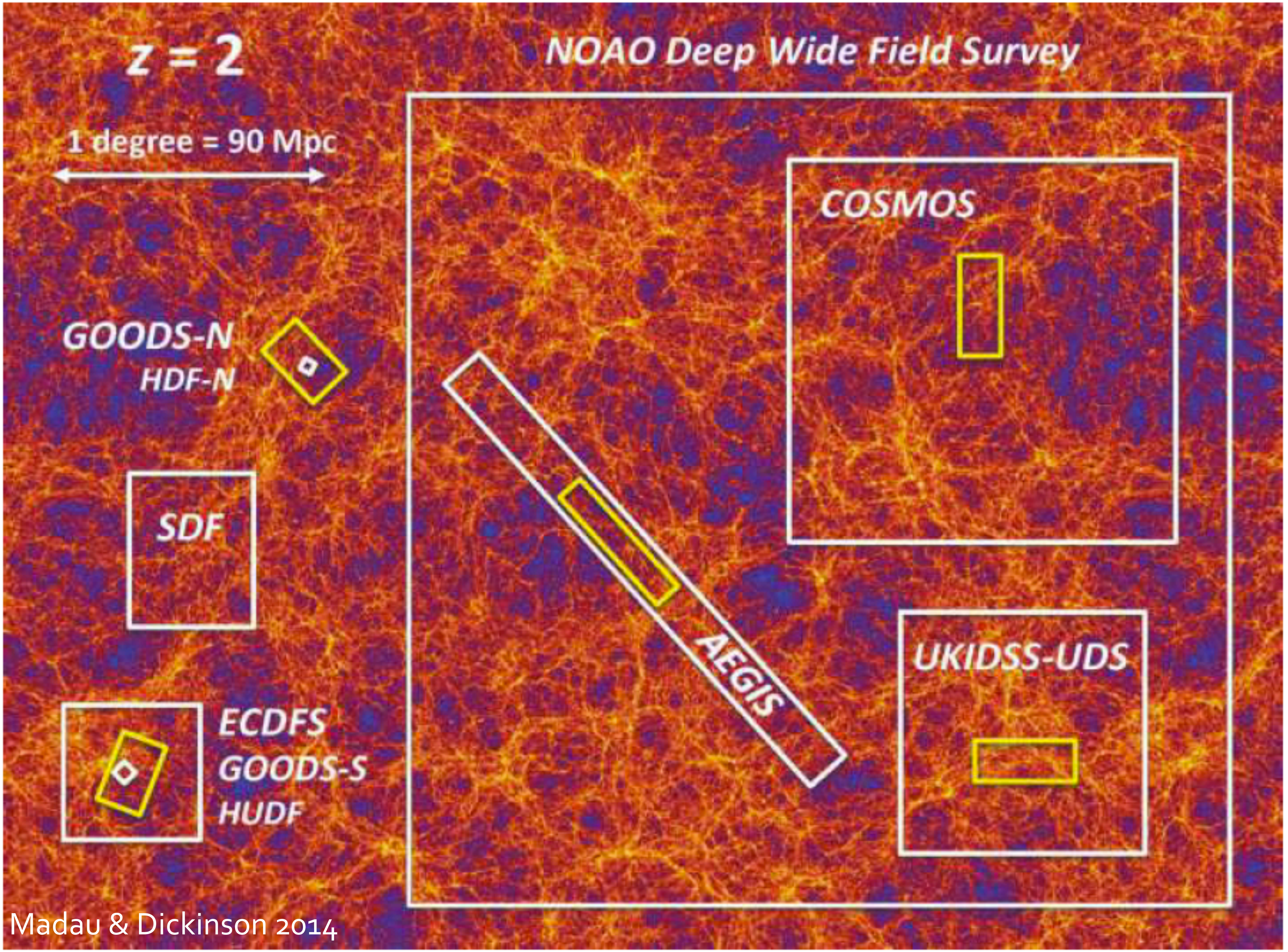
Choi et al. 2014; Choi et al. in prep
w/ J. Ostriker, T. Naab, L. Oser, R. Brennan

project

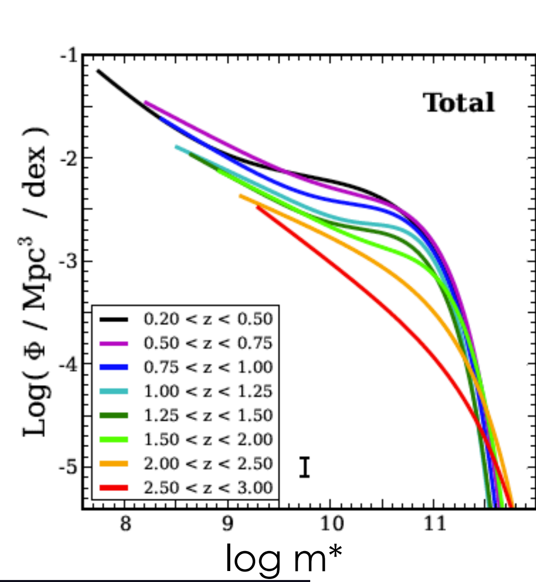
- measure m_*, sSFR, B/T, Σ(1kpc), good redshifts over about 10 deg^2
- divide into stellar mass and redshift bins and study correlations between structural & SF properties across scales from kpc to several Mpc
- use DM maps from lensing and X-ray follow-up to better understand environments
- get cold gas masses from ALMA/SKA, etc
- study CGM with absorption lines

summary

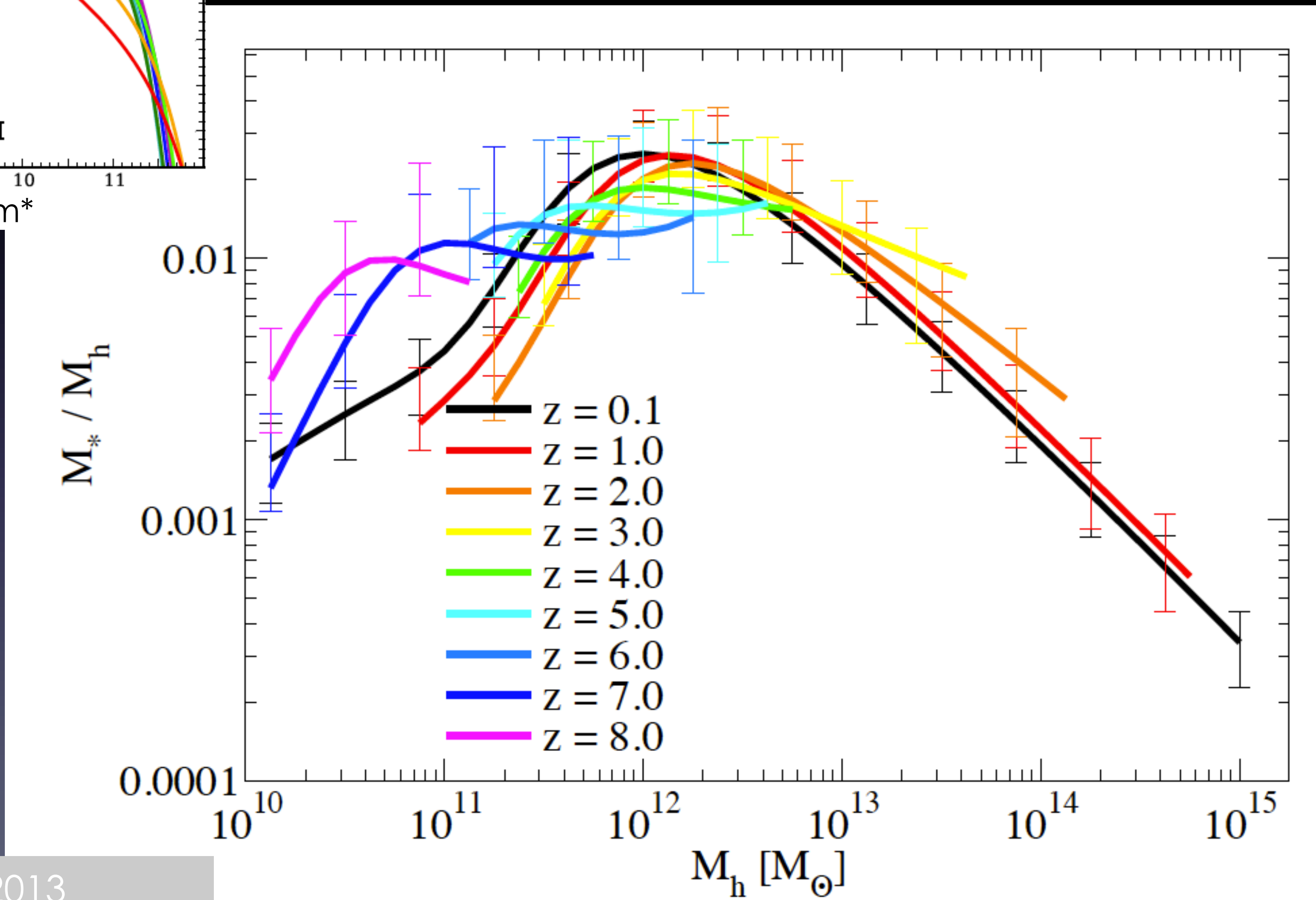
- understanding the details of “feedback processes” connected with stars, SNae and AGN is the greatest open challenge for galaxy formation models
- studying the correlations between galaxies’ global properties, stellar populations, and structural scaling relations and their evolution over time is a powerful way to constrain these processes
- galaxy properties are correlated over a surprisingly large range of scales – poorly understood – important if we want to use emission line selected samples to study dark energy/cosmology!
- *only* WFIRST will be able to collect high resolution imaging over large enough fields to answer these questions



Madau & Dickinson 2014



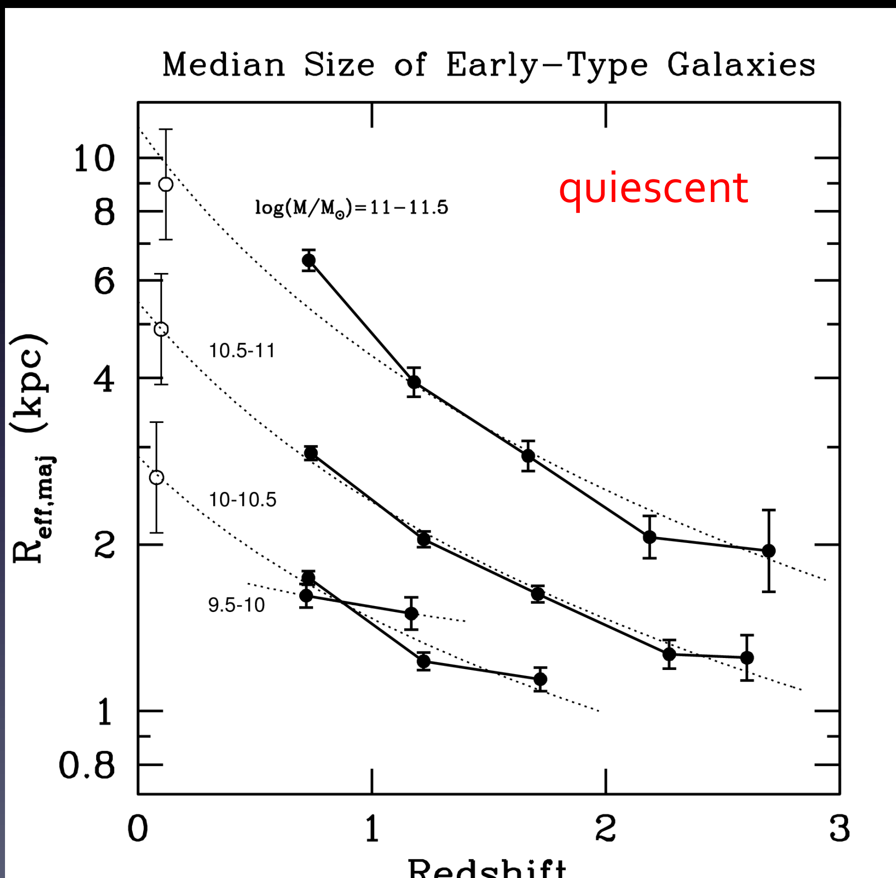
- 'staged' assembly: massive galaxies form earlier and more rapidly
- Abundance matching (SHAM) constraints on stellar fractions to z~4

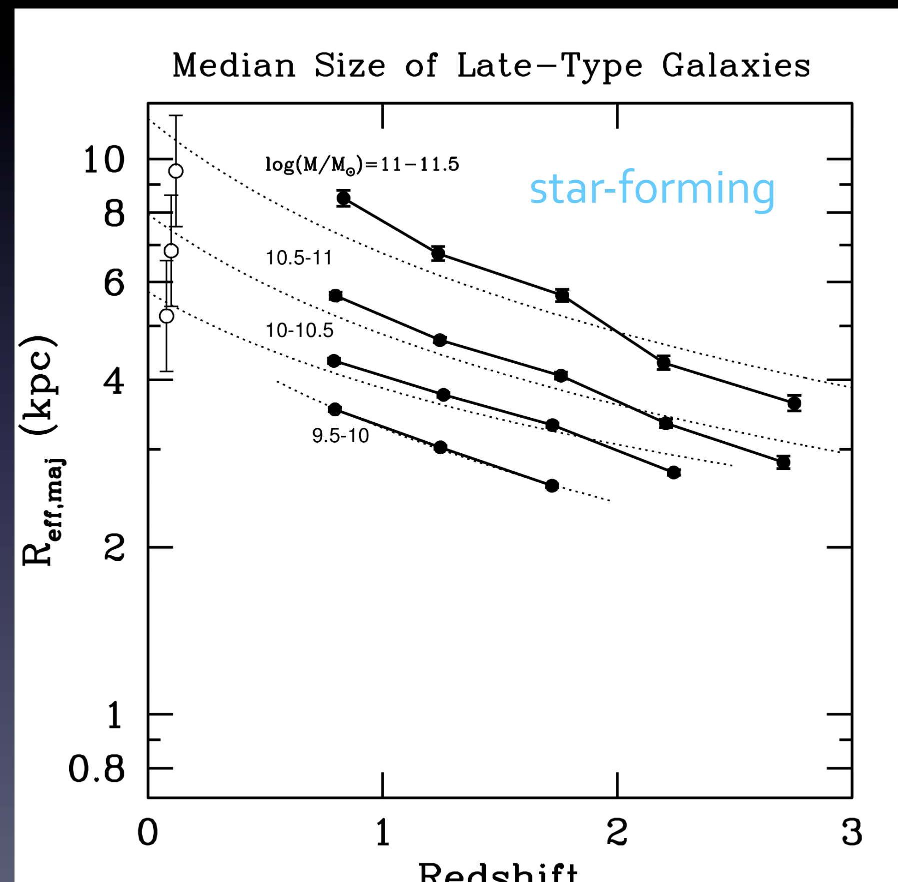


Behroozi et al. 2013
see also Moster et al. 2013

- quiescent galaxies more compact
- sizes evolve more rapidly
- mass-dependent size evolution (structural downsizing)

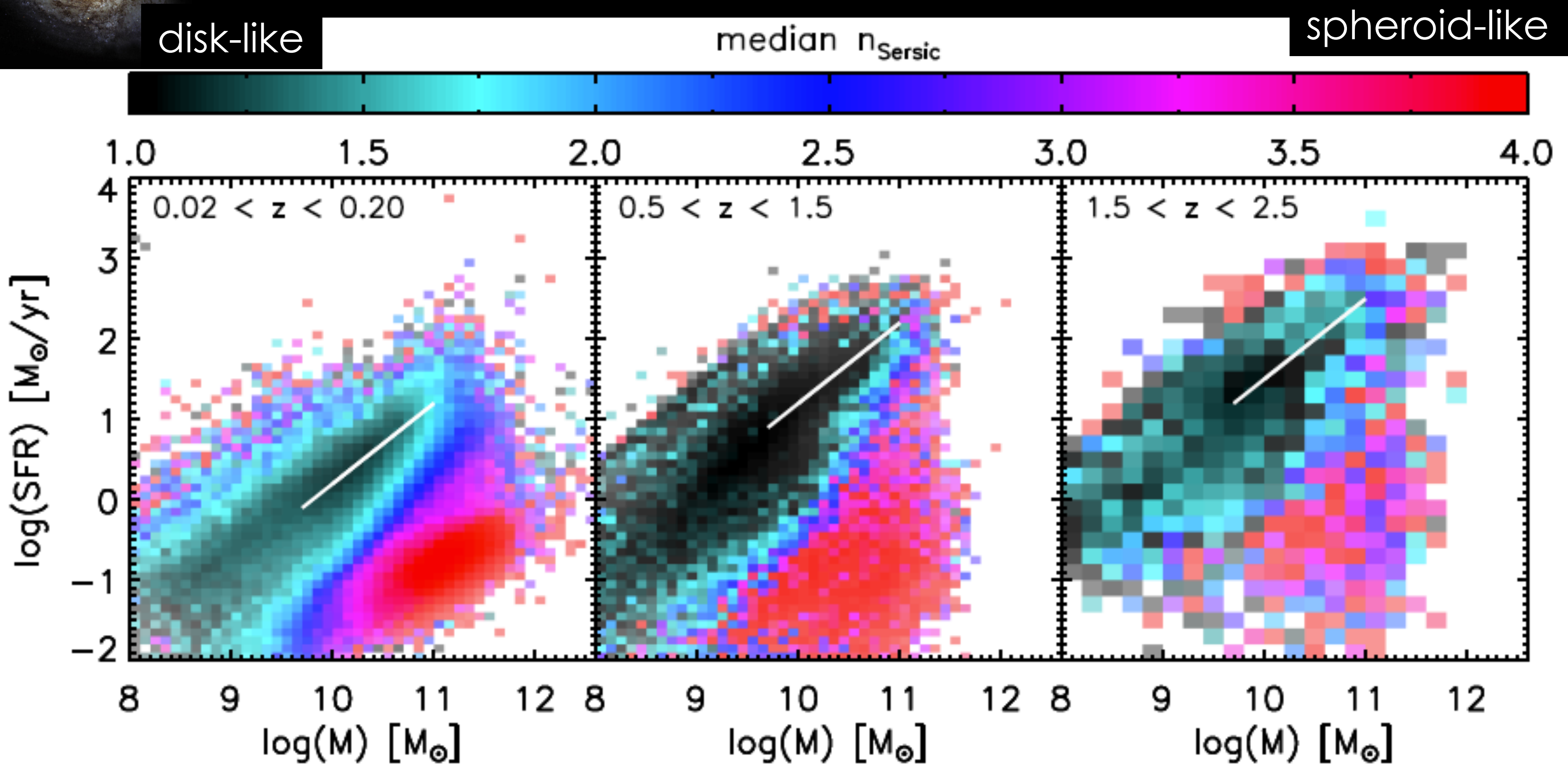
- SF galaxies more extended
- sizes evolve slowly
- self-similar size evolution





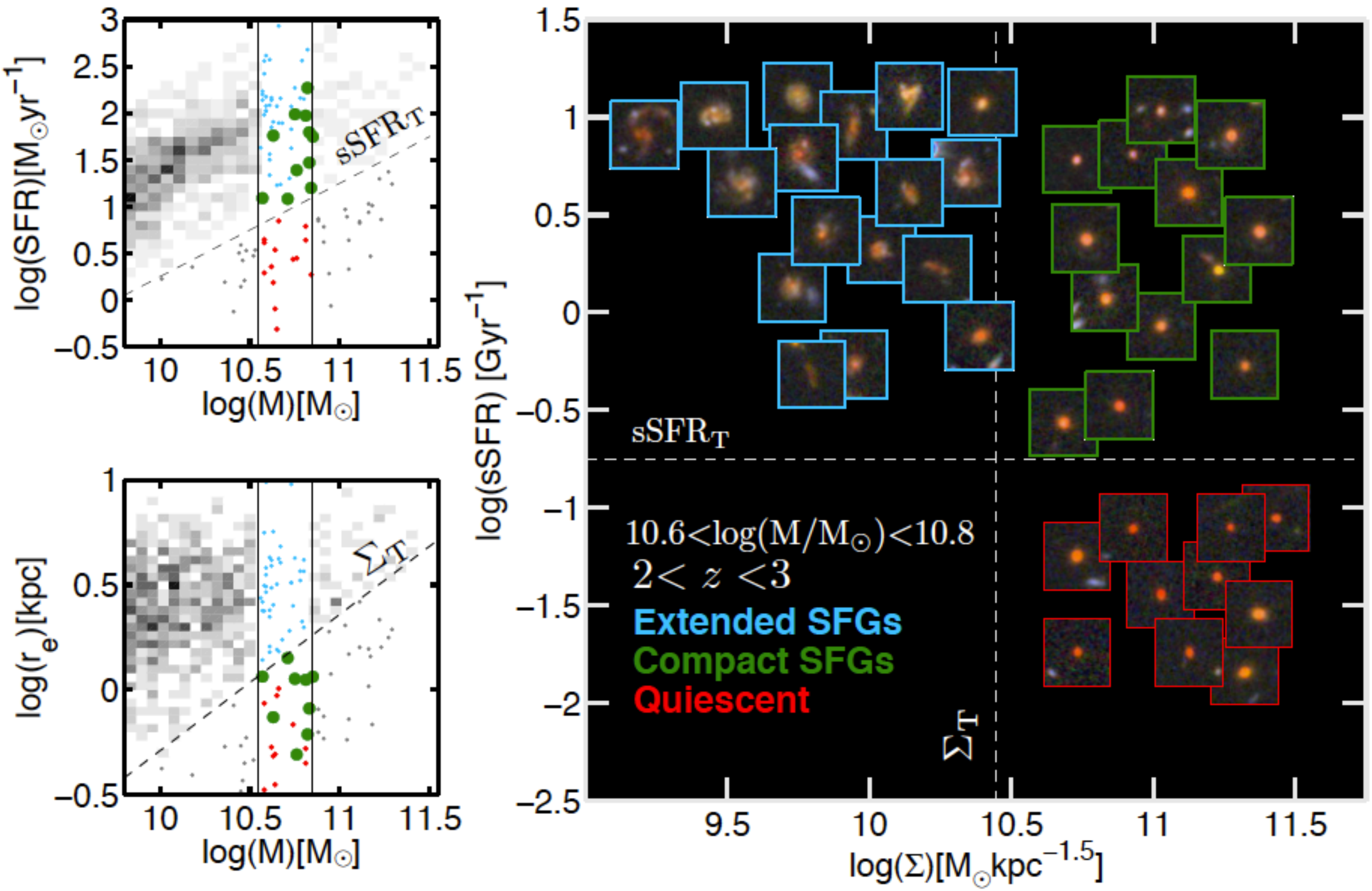
van der Wel et CANDELS+3D-HST 2014

- galaxy structure and location wrt the SF sequence are linked
- strong observed correlation between quiescent fraction and bulge mass, morphology, central density

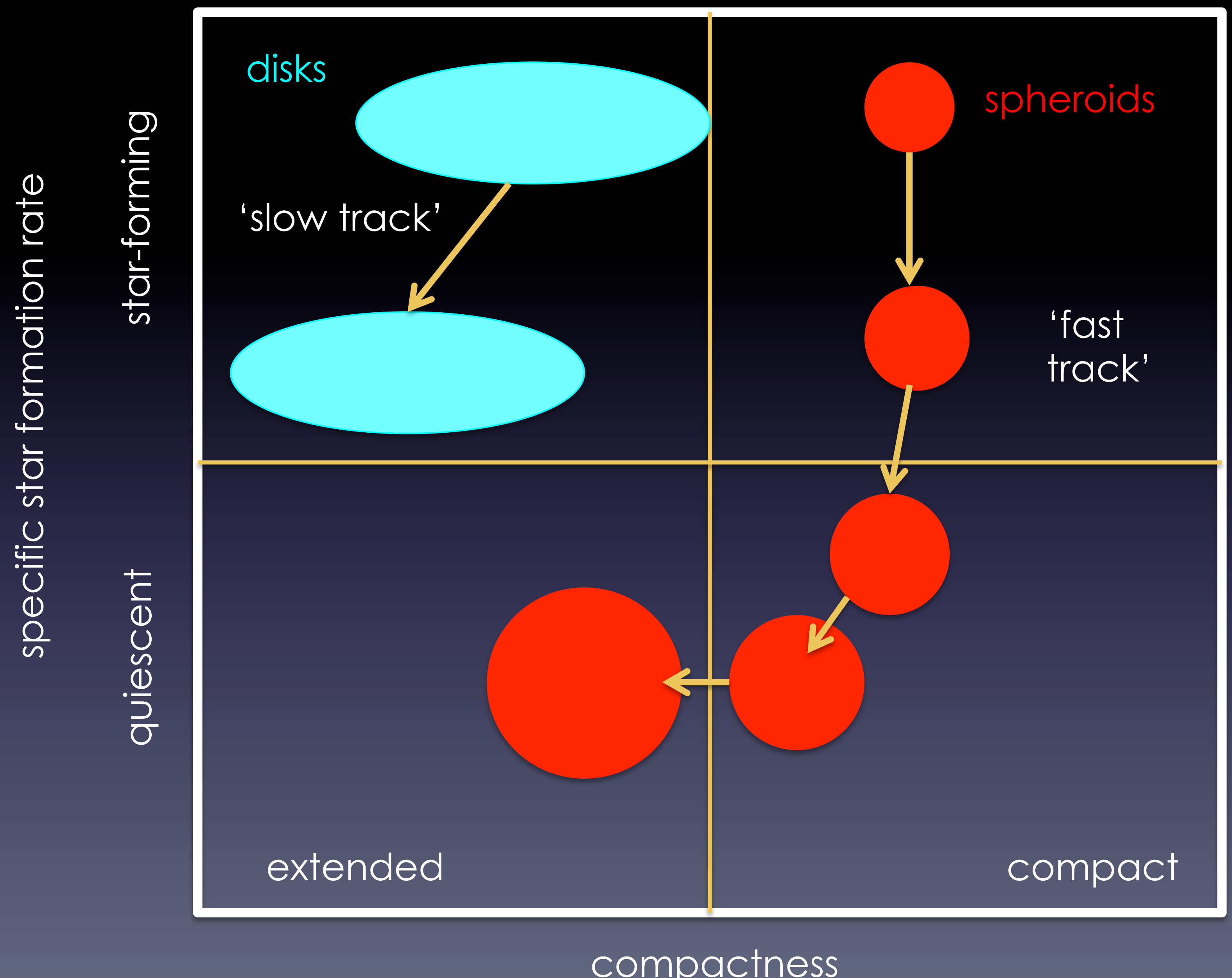


see also Bell et al. 2008, 2012; Cheung+'12; Fang+'13

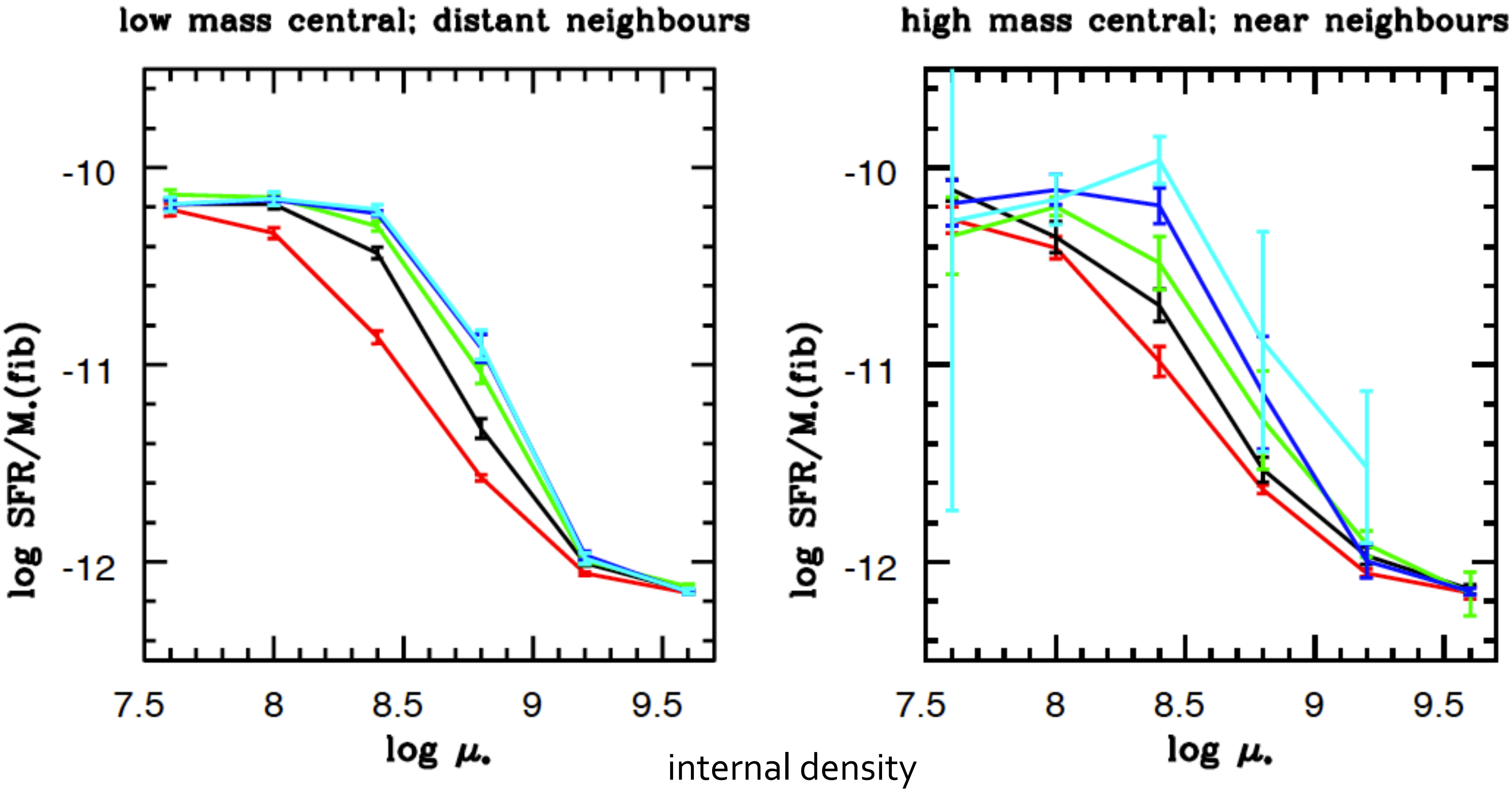
Wuyts et al. 2011



Barro et al. 2013 'compactness'


disks
spheroids
'slow track'
'fast track'
extended
compact
compactness
specific star formation rate
star-forming
quiescent

correlation between internal structure and sSFR
"knows about" properties of central galaxy even Mpc away!



Kauffmann et al. 2013