Morphologies and building blocks of galaxies at high redshift

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TMT
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国立天文台
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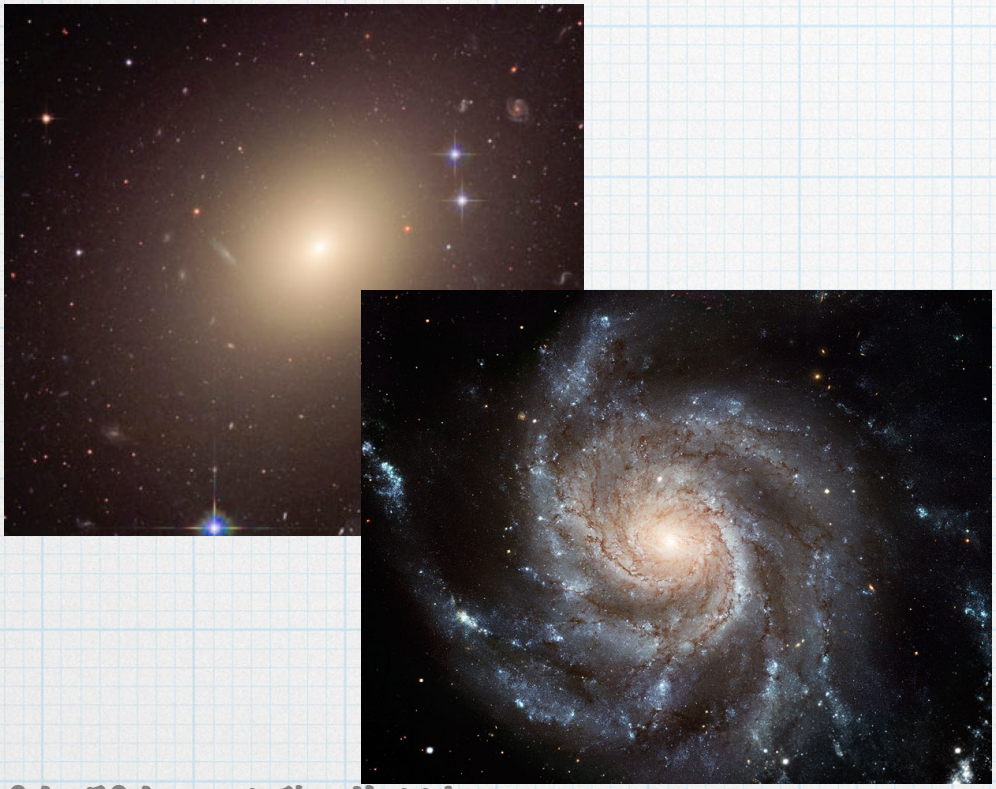
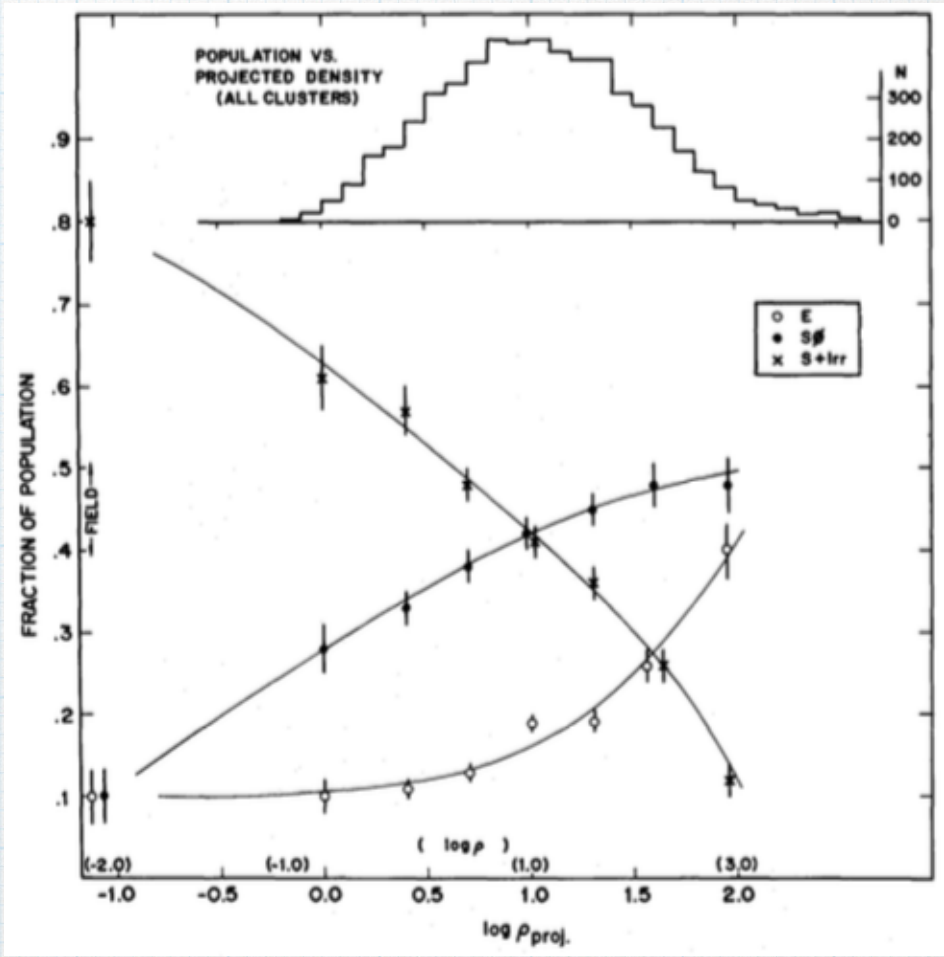
National Astronomical Observatory of Japan

Galaxies in the current Universe

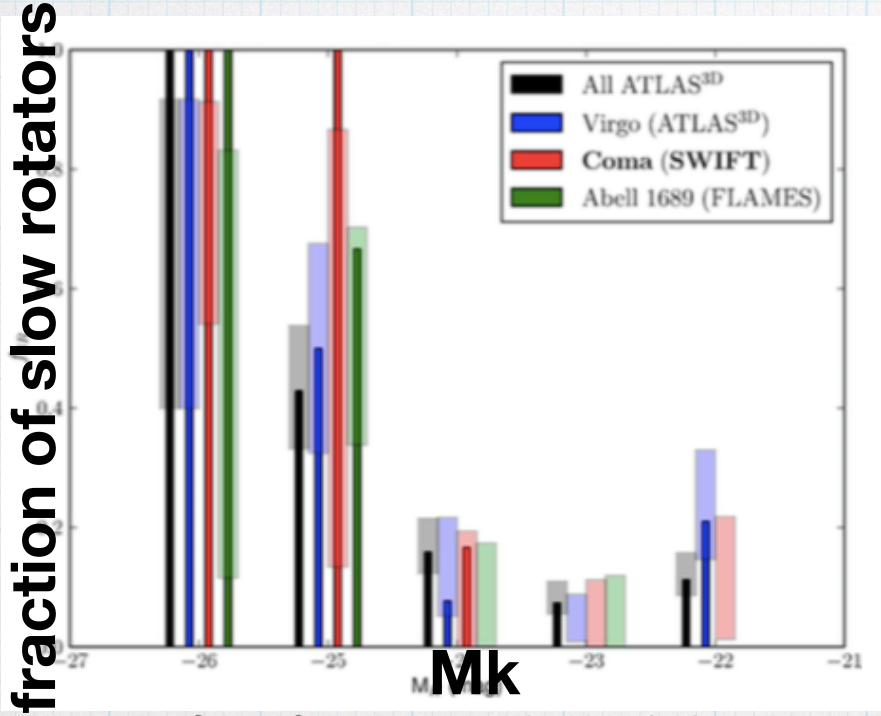


NASA, ESA, and The Hubble Heritage Team (STScI/AURA)

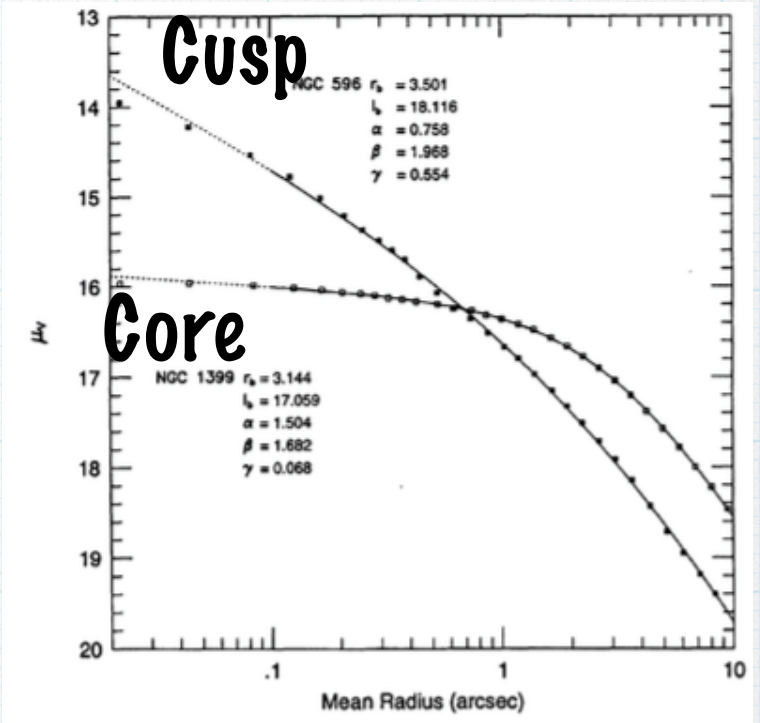


Morphology density relation (Dressler et al. 1980)

Elliptical-Elliptical dichotomy



Houghton et al. 2013

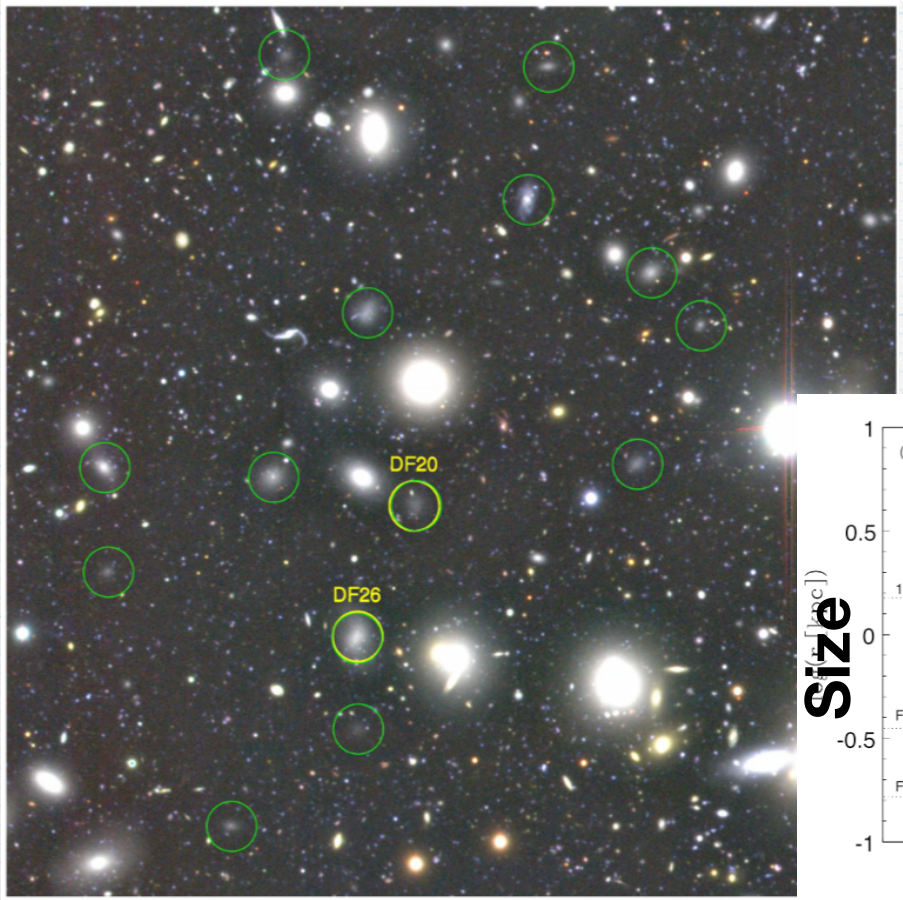


Lauer et al. 1995

Giant ellipticals
- boxy, core, anisotropic, triaxial, slow rotator, formed earlier instantly

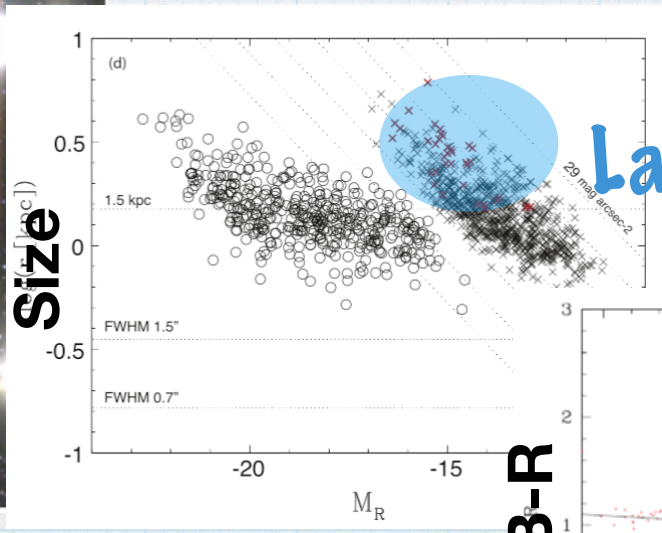
Lower mass ellipticals
- disky, cuspy, isotropic, fast rotators, younger

How were ultra diffuse galaxies in the current clusters lost their baryon?

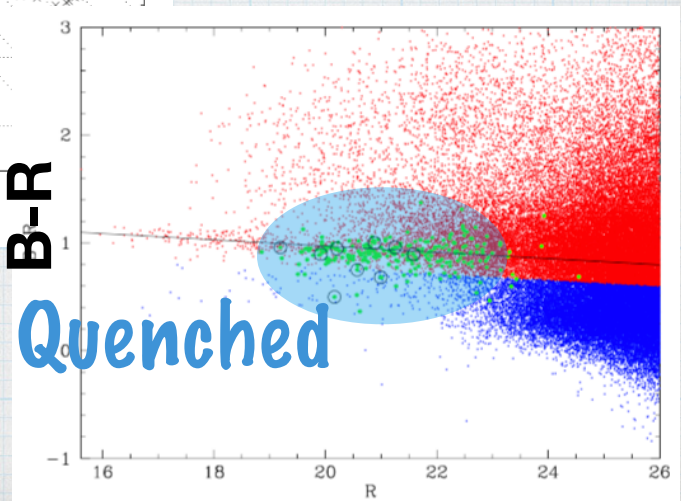


UDGs in the Coma cluster (Koda et al. 2015)

feedback at high-z or ram-pressure stripping etc..., when they infall into the cluster core

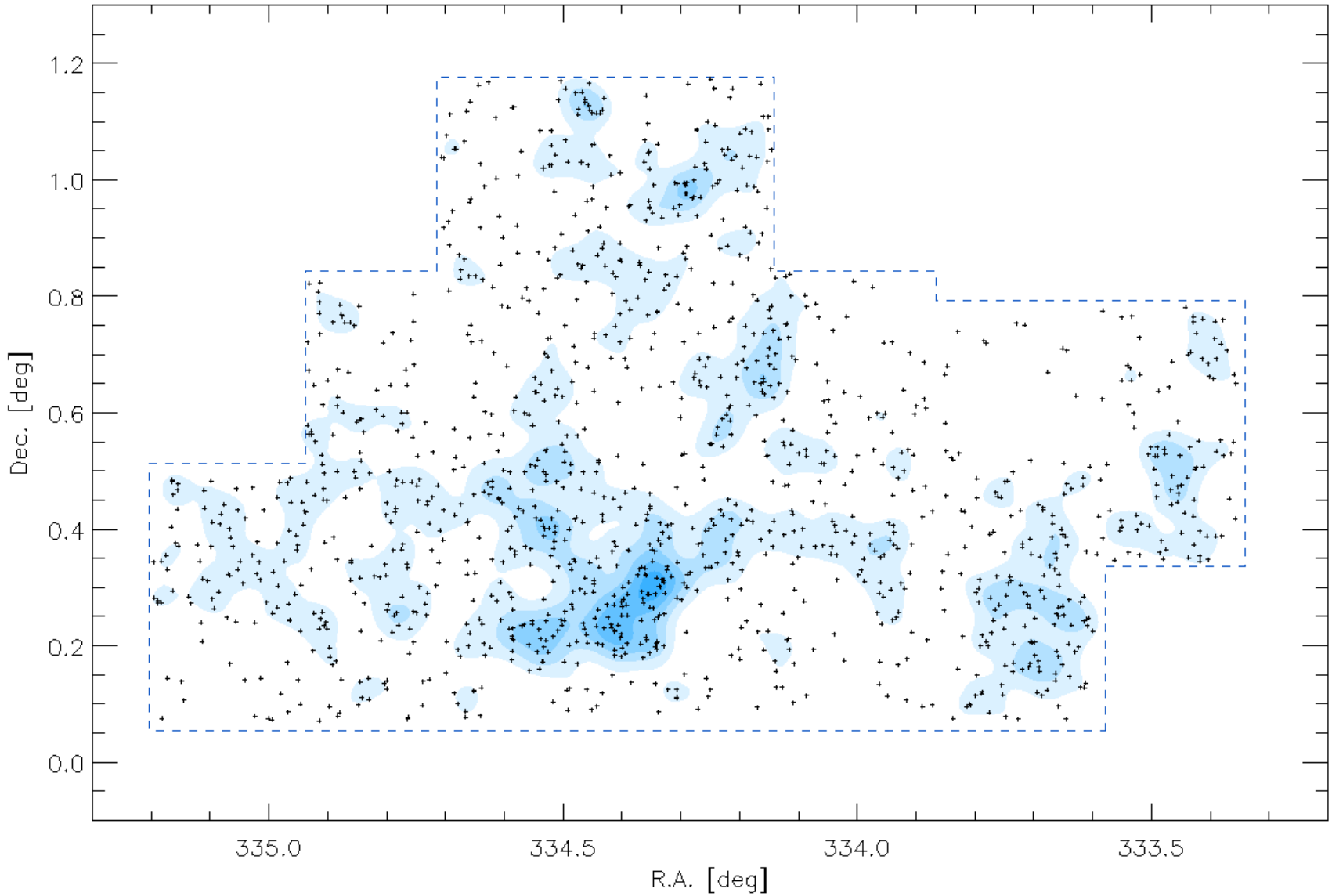


Large



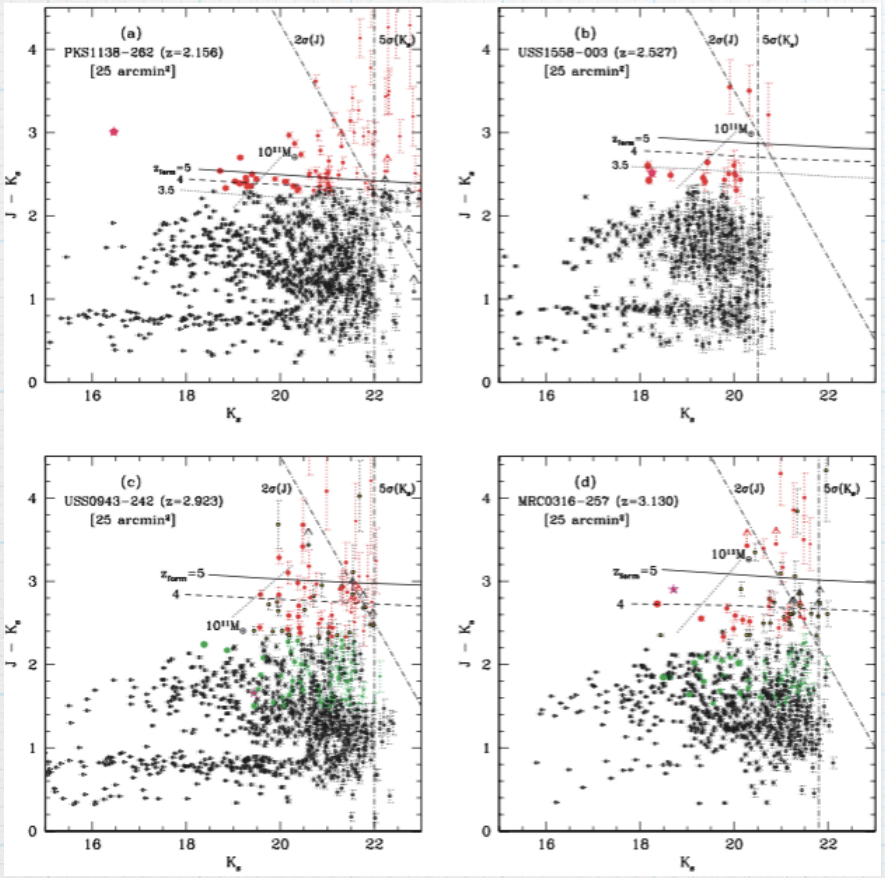
Old, Quenched

At high-z ... Protoclusters = important laboratories for studying how morphology density relation developed



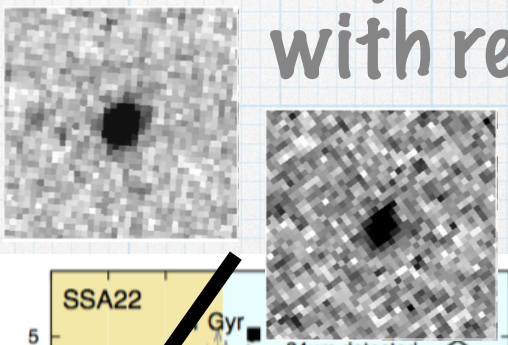
SSA22 superstructure at z=3.09 (Yamada et al. 2012)

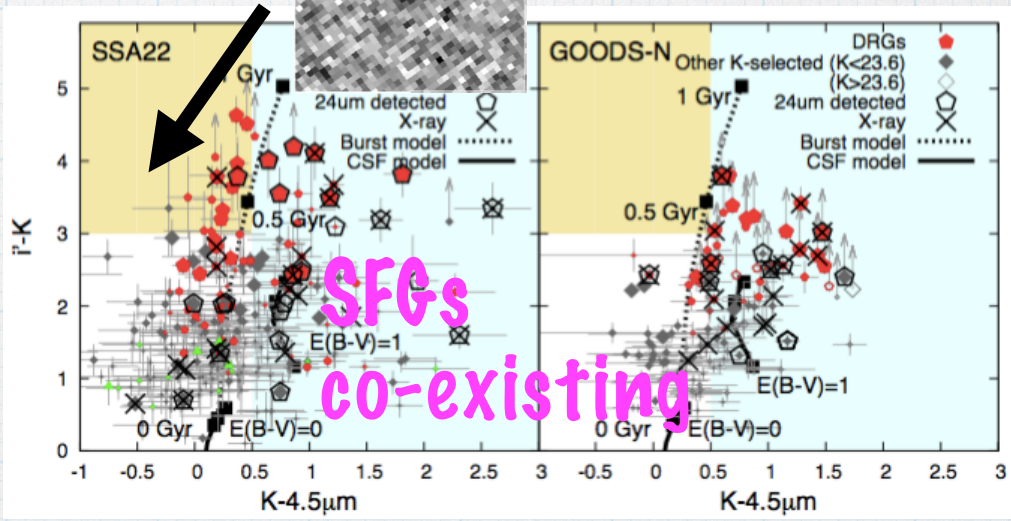
Appearance of red sequence at z>2



z=2-3 protoclusters
Kodama et al. 2007

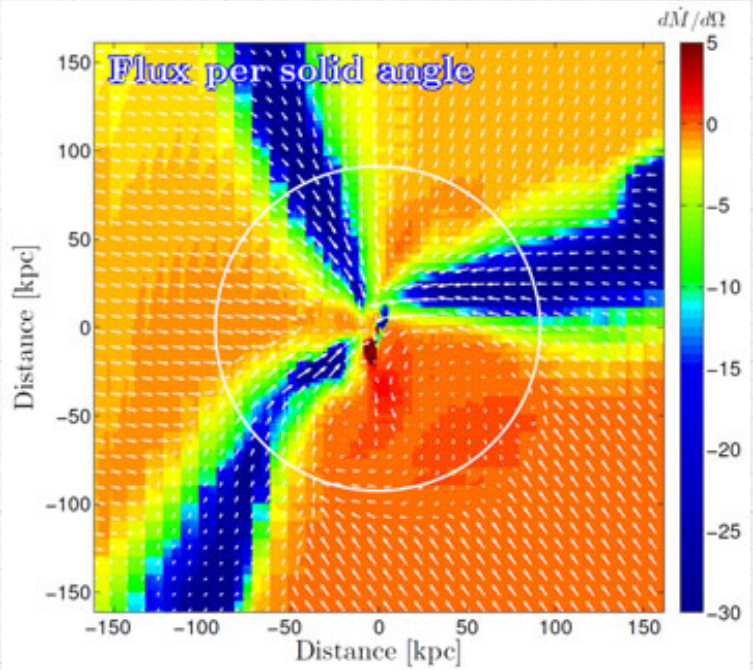
Massive compact ellipticals with re~1 kpc



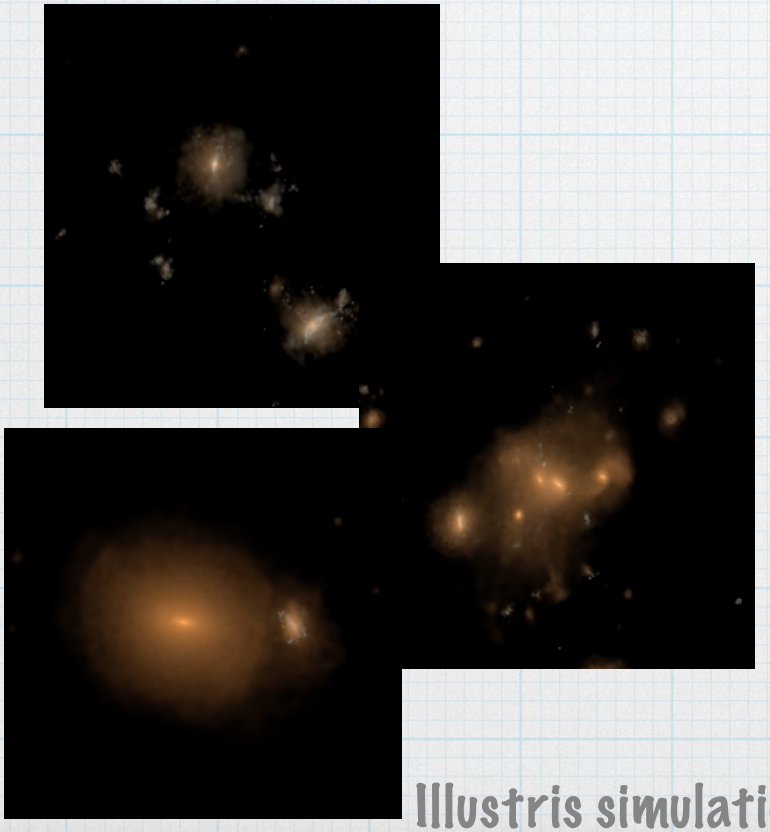


z=3.09 protocluster
(Kubo et al. 2013)

* Cold accretion
  * form massive galaxies at z>2
  * clumpy disk -> clump migration -> bulge
  * fast rotators are preferentially formed



Dekel et al. 2009

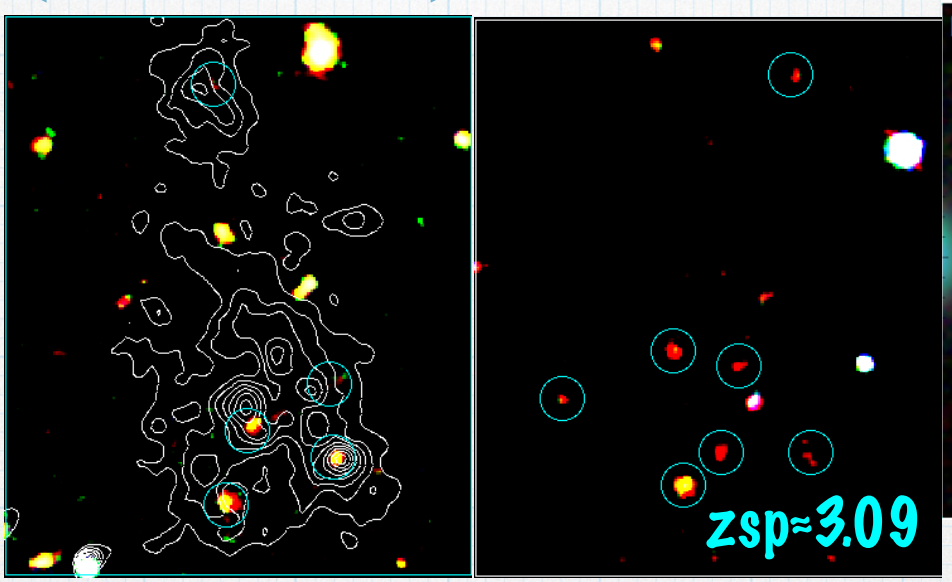


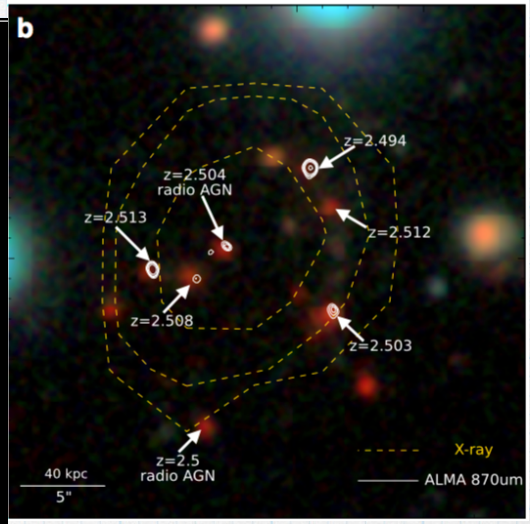
Illustris simulation

* Hierarchical mergers
  * multiple mergers of massive galaxies -> slow rotators
  * maybe with SMBH mergers forming core profiles
  * minor mergers for strong size growth

~150kpc in physical

Spiderweb at z=2.16
(Miley et al. 2006)





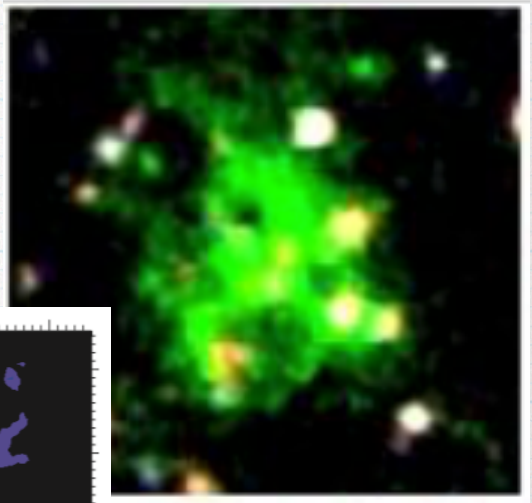
cluster core at z=2.5
Wang et al. 2016

"Many" multiple galaxies at the core of the SSA22 superstructure at z=3.09 (Kubo et al. 2016)

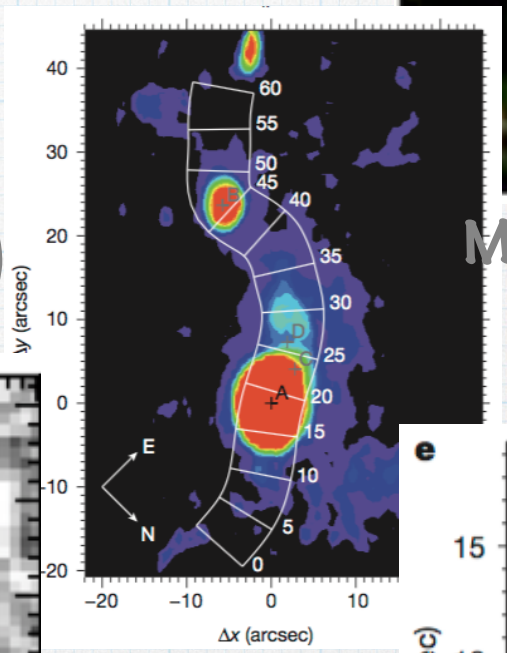
The plausible hierarchical multiple merger phases of the most massive galaxies (BCGs?) in the protoclusters' cores at z>2
Requiring deep NIR imaging and spectroscopy with 8-10 m Telescopes ... $M^*>10^{10}\sim10^{10.5}$ $M_\odot$

* Cold accretion= one of the plausible origin of giant Lyα nebulae (LABs)
* Rotational disk with > 100 kpc diameter (Martin+15) = cold flow disk?
* Very huge SMG (Umehata+15)

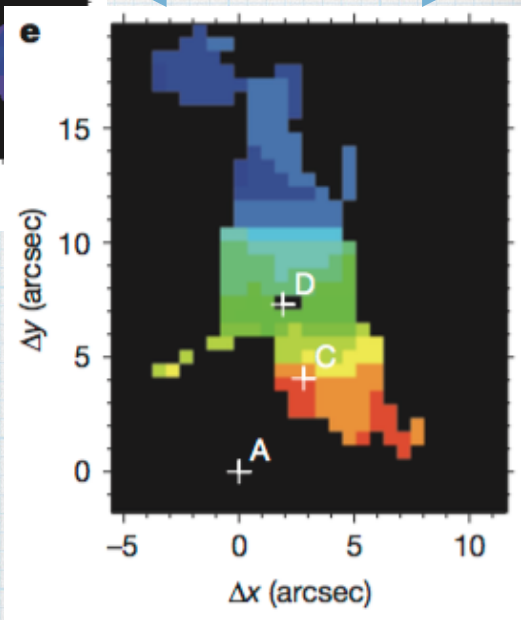
~180kpc



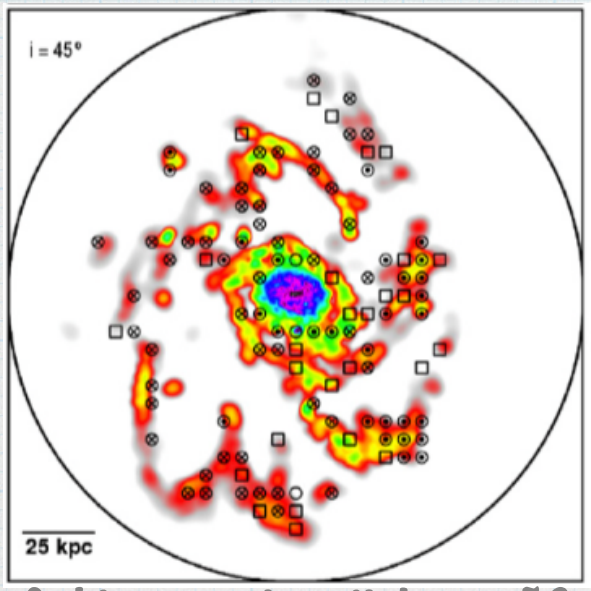
Matsuda et al. 2006



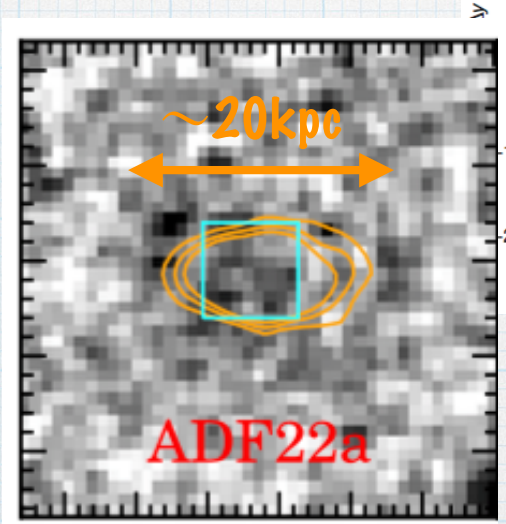
~120kpc



Martin et al. 2015



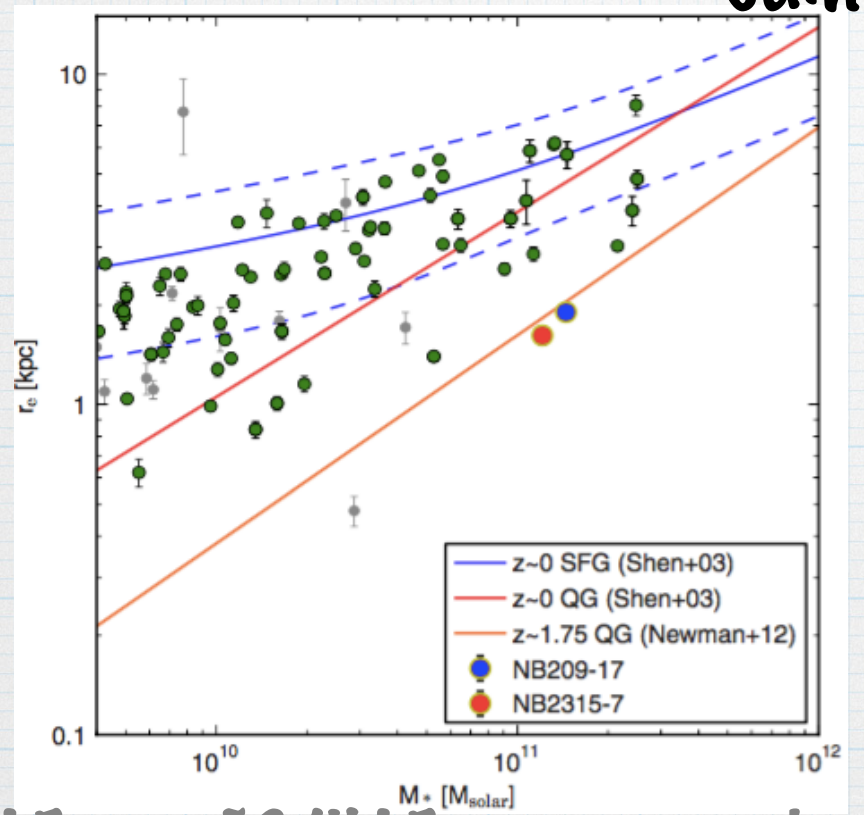
Cold accretion disk at z~2 (Stewart et al. 2011)



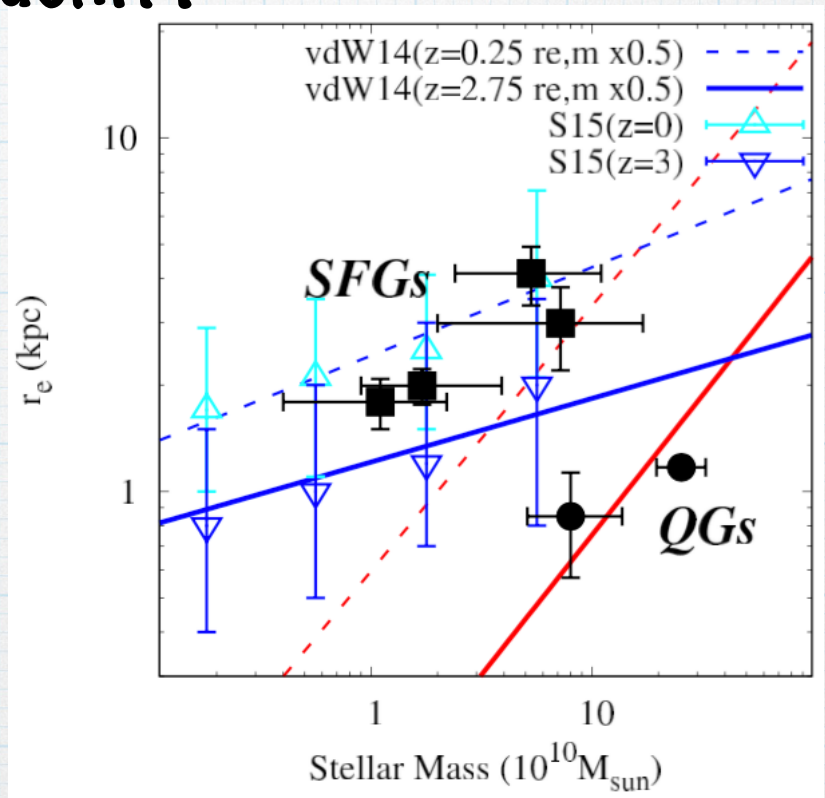
Bright and huge SMG in the SSA22 protocluster (Umehata et al. 2015)

Environment and morphology at z>2

Protocluster massive SFGs are on average larger than the field massive SFGs at the same redshift



HAEs at z~2 (HAEs are strongly clustered) (Tadaki et al. 2014)



proto-BCG group in the z=3.09 protocluster (Kubo et al. in prep)

Environment and morphology at z>2

* Massive quiescent galaxies in the protoclusters are massive compact ellipticals, requiring strong size evolution
* Large SFGs (also plausible progenitors of massive early-type) are preferentially formed
  * Enhanced merger rate?
  * Large unstable disks formed by cold gas accretion?
  * Feedback on their building blocks -> the descendants with large velocity dispersion -> large disks?

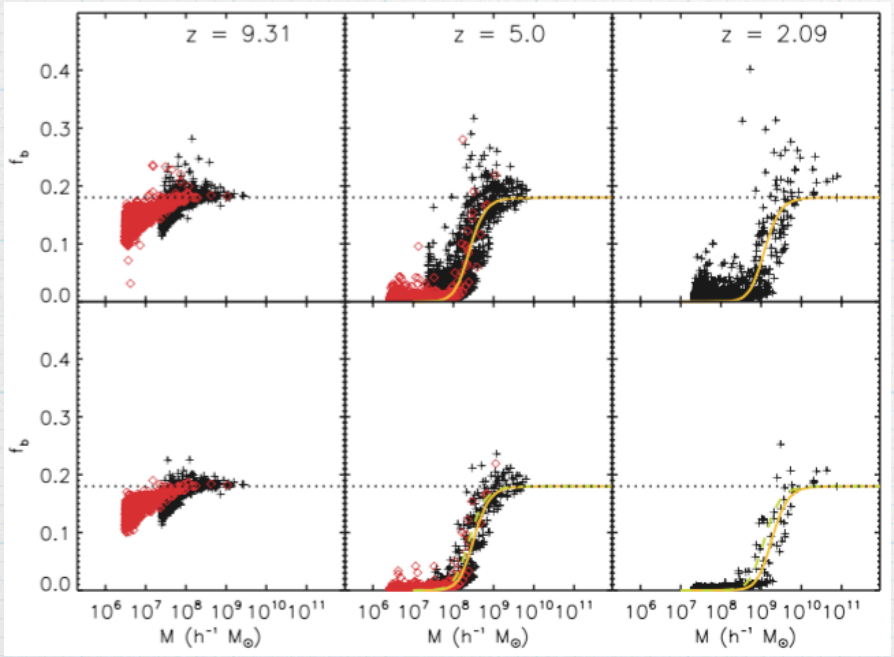
Much high resolutions and sensitivity are required

Resolved morphology and kinematics of z=2-3 galaxies with the TMT

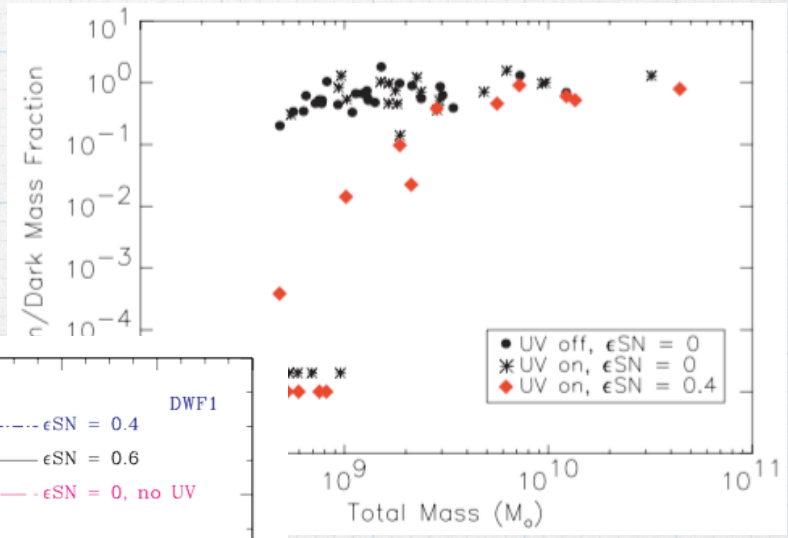
* SFGs in the protoclusters
  * identify the cold stream
  * resolve the kinematics of large SFGs: mergers and/or large clumpy disks
  * feedback in satellites: cut-off at certain mass of satellites and/or diffuse satellites
* QGs in the protoclusters
  * two-phase formation? : cold accretion (fast) -> mergers (slow rotators)
  * cusp -> core by SMBHs mergers

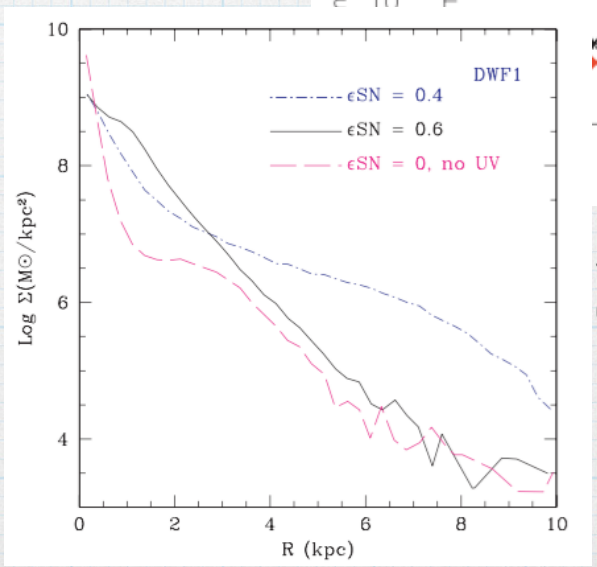
Building blocks of building blocks of ...

Reionization and/or SNe feedback can affect the radial profiles of and/or reduce formation of low mass galaxies ($M_H < 10^{10}\ M_\odot$ ($M^* < 10^{8.5}\ M_\odot$) at $z \sim 2$)



Reionization (Okamoto et al. 2008)





SNe feedback
Governato et al. 2007

Study morphologies with ULTIMATE-SUBARU

* With ULTIMATE-SUBARU
  * Detect the possible SMBH mergers
  * Evolution of kinematics and morphologies of cluster galaxies (K_{tot} <22~23)

    Powerful for statistics and rare objects
* With TMT
  * Cold gas filament
  * Diffuse (and faint) galaxies and outskirt
  * Clump migration
  * Formation of the cores

Summary

* In the protoclusters at z=2-3, SFGs with large sizes are preferentially formed. They would be the key for morphology density relation
* To clarify their origin, resolving morphology and kinematics with the TMT is necessary, e.g., cold accretion, behaviors of small satellites, SMBH mergers at z=2-3
* Synergy with ULTIMATE-SUBARU is also important.

Five-story pagoda of To-ji: h=55m →
~ the TMT Dome height = 56m