Early universe, galaxy formation and IGM (High-z)

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Martin, Crystal L.	UCSB	UC	
Cooray, Asantha	UCI	UC	
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Convener & Group co-leader
Group leader

37 members
USA: 22
Japan: 6
Canada: 3
China: 3
India: 3

DSC-2007 structure (High-z)

26 pages

Some issues:

Dramatic progresses since 2007: IFU of z~2 galaxies and spectroscopy of z>7 galaxies

Lower-z science (z<1) was largely missing

Some non-scientific section titles (instrument driven instead)

Need involvement of wider communities and international partners,
which will form the basis of future international key programs on TMT!

DSC-2014 structure (High-z)

Too much volume
~60 pages !
should be reduced by 50%

4 The early Universe (G1) Dickinson, Ouchi, et al.

4.1 Overview

4.2 Early source and cosmic reionization

4.3 Characterizing the first galaxies and their influence on IGM

4.4 Angular sizes…

5 Galaxy formation and the intergalactic medium

5.1 Overview

5.2 The peak era of galaxy assembly (G2) Reddy, Giavalisco, Kodama, et al.

5.2.1 TMT and galaxy formation

5.2.2 How does the distribution of dark matter relate to the luminous stars and gas we see?

5.2.3 The growth of stars: star-formation histories, dust, and chemical evolution

5.2.4 The formation of passive galaxies and the birth of the Hubble Sequence

5.2.5 The census of baryons and the baryon cycle

5.2.6 Spatial dissection of forming galaxies

5.3 The age of maturity and quiescence (G3) Cooper, Pierce, et al.

5.3.1 Morphological and kinematic growth of galaxies

5.3.2 Feedback and the physics of galaxy quenching

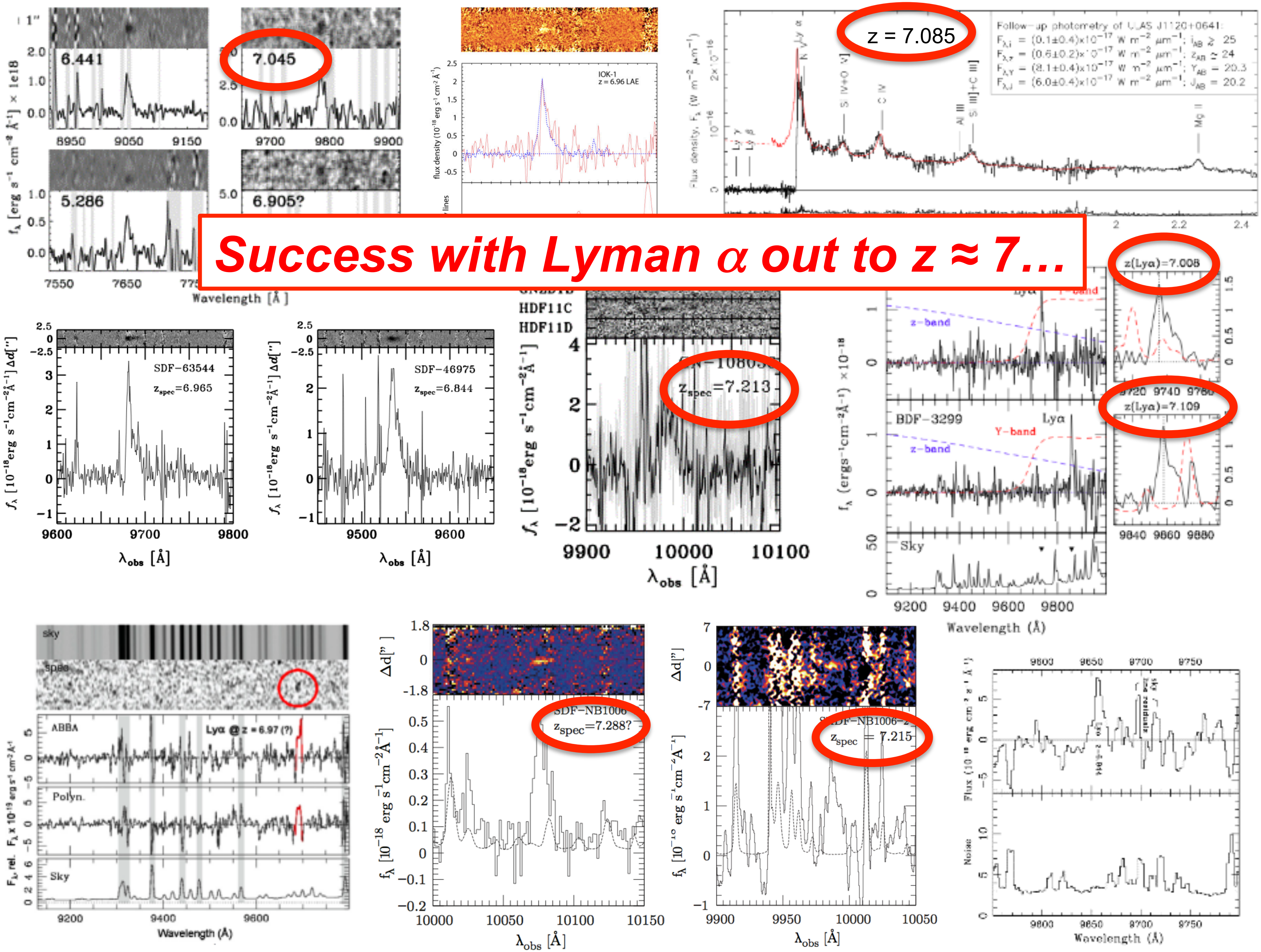
5.4 The intergalactic medium (G4) Prochaska, Fang, et al.

5.4.1 Background

5.4.2 TMT and the IGM

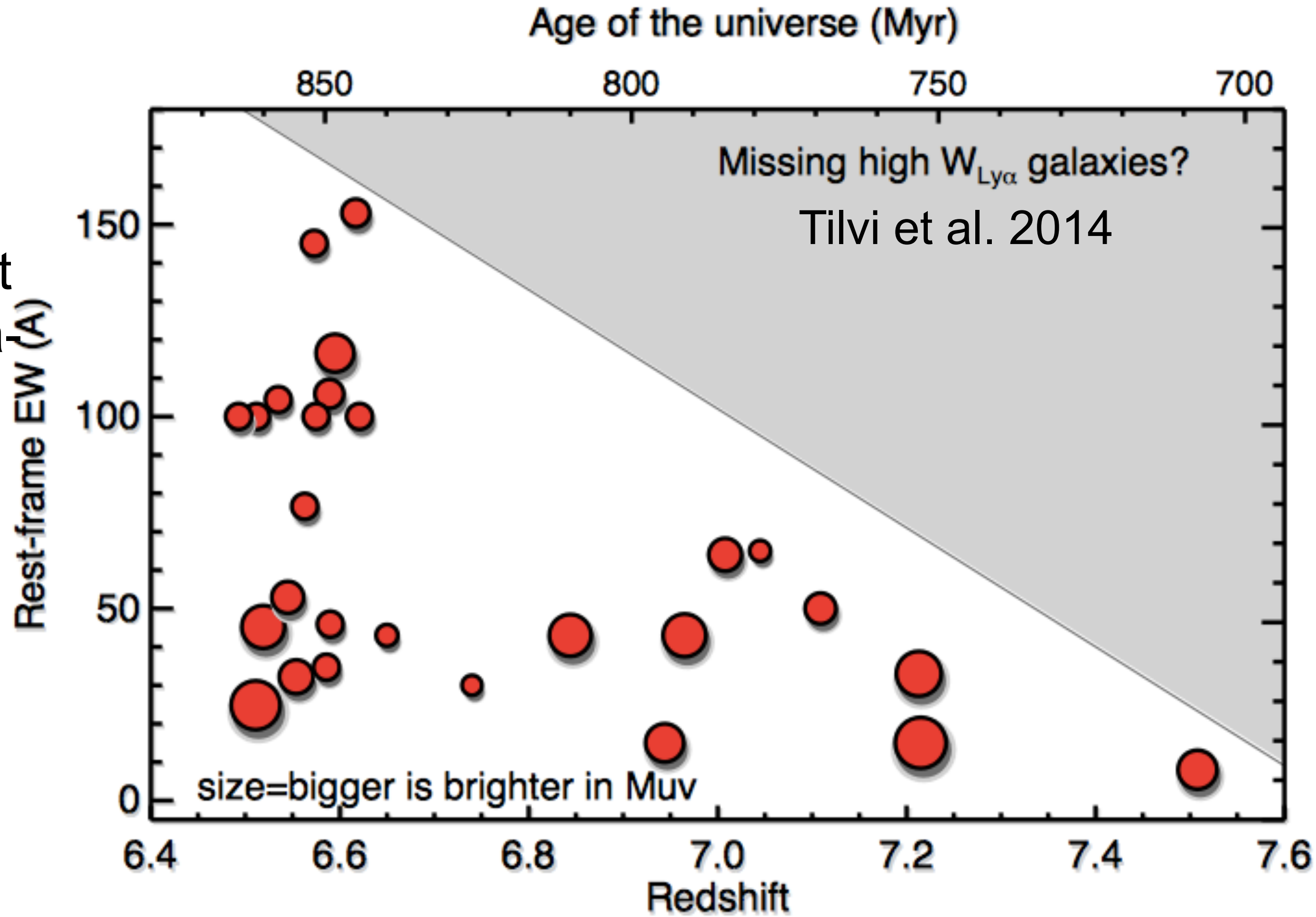
5.4.3 TMT and the CGM

Success with Lyman α out to $z \approx 7$…



…but is Lyα disappearing at z > 6.5?

High-EW Lyα emission lines seem to be disappearing at z > 7, even with ultra-deep spectroscopy

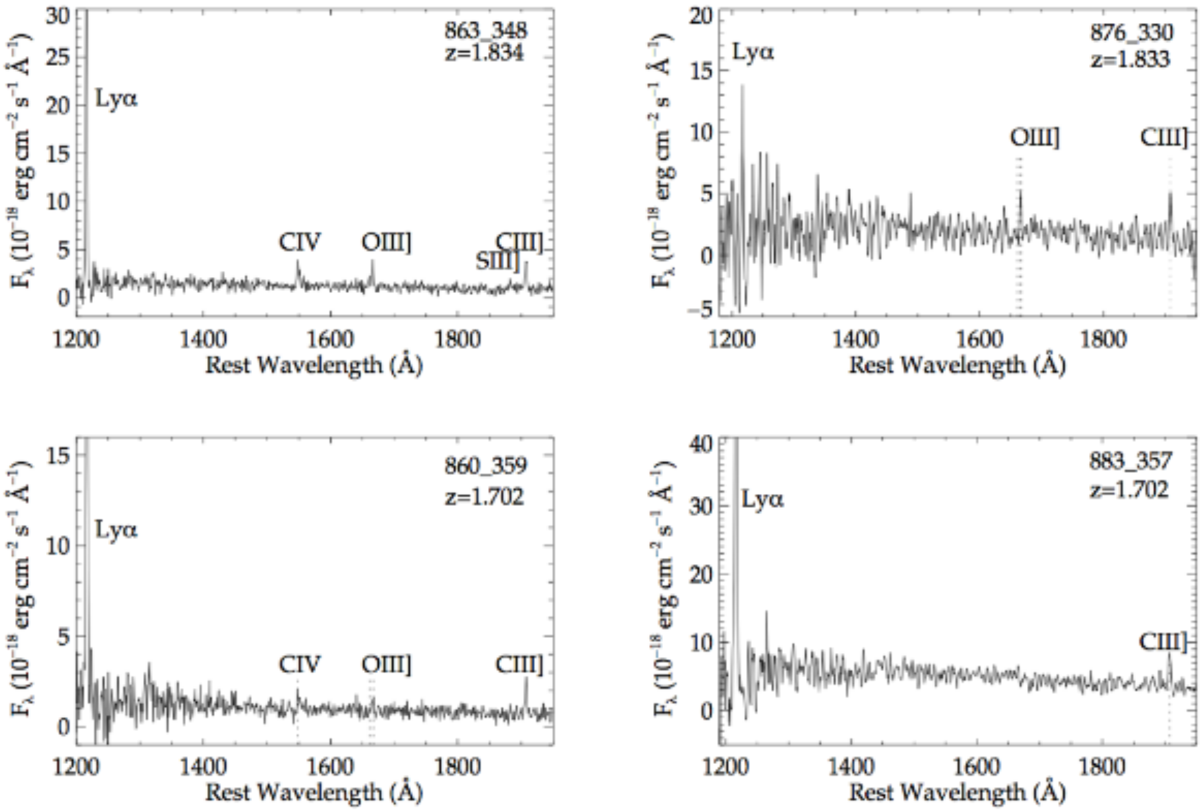


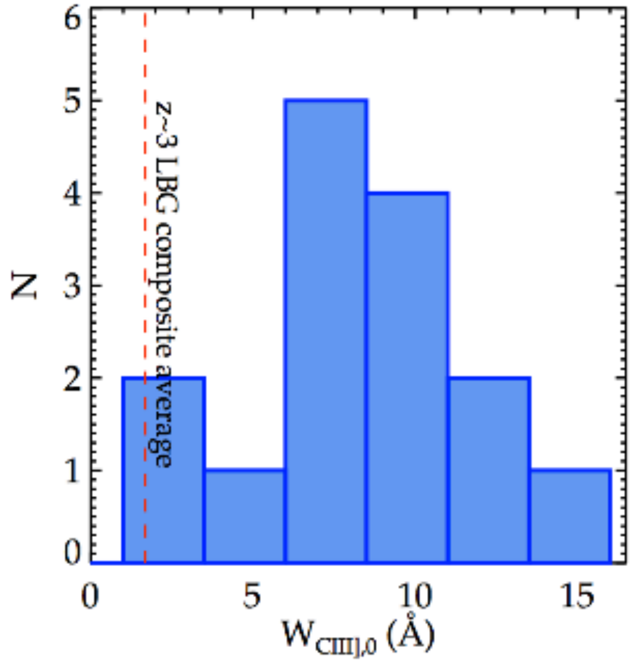
Pentericci et al. 2011; Ono et al. 2012; Schenker et al. 2012; Treu et al. 2013, Tilvi et al. 2014, Vanzella et al. 2014…

Weak high-excitation UV lines to the rescue?!

Stark et al. 2014: 10 hr optical spectra from Keck+VLT
Strongly lensed dwarf gals at z ≈ 2 – analogs to z > 7 low-mass, low-metallicity gals?

CIII]1909 is OIII]1663 are *rare* in bright LBGs at z ≈ 2-3, but *common* in these dwarfs.
Detectable out to z ≈ 12+ with TMT. Not resonance lines – can be used for kinematics.





Figures courtesy Dan Stark

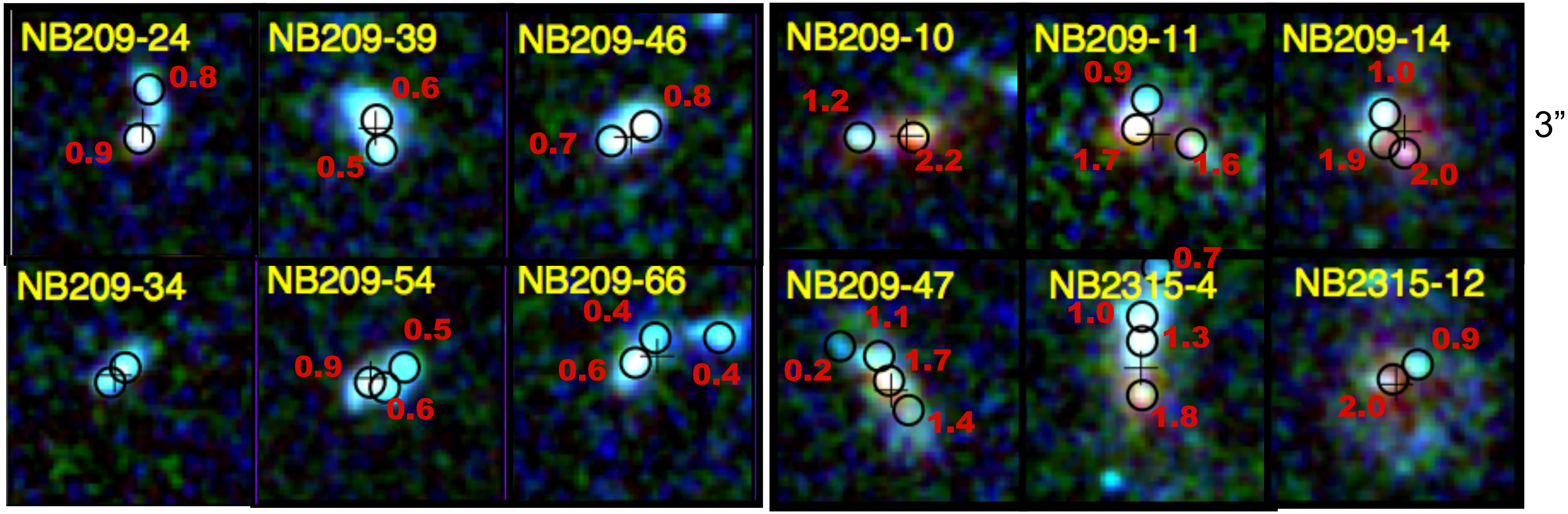
Clumpy structures are common (~40%) in SFGs at z~2

HST images (V_{606},I_{814},H_{160}) of NB-selected Hα emitters at z~2 in UDS-CANDELS field

less massive clumpy galaxies (**M_{star}<$10^{10}$$M_{\odot}$**)

massive clumpy galaxies (**M_{star}=$10^{10-11}$$M_{\odot}$**)

3” (~25kpc)



colours (I_{814}-H_{160}) of individual clumps are shown with red numbers

Tadaki et al. (2013b)

The red clumps (often seen in massive dusty galaxies) may be the site of central dusty starburst to form a bulge as a result of clump migration and mergers!
We need to spatially resolve clumps, star forming activities and kinematics within the galaxies with AO-assisted observations with TMT (0.1kpc resolution!)

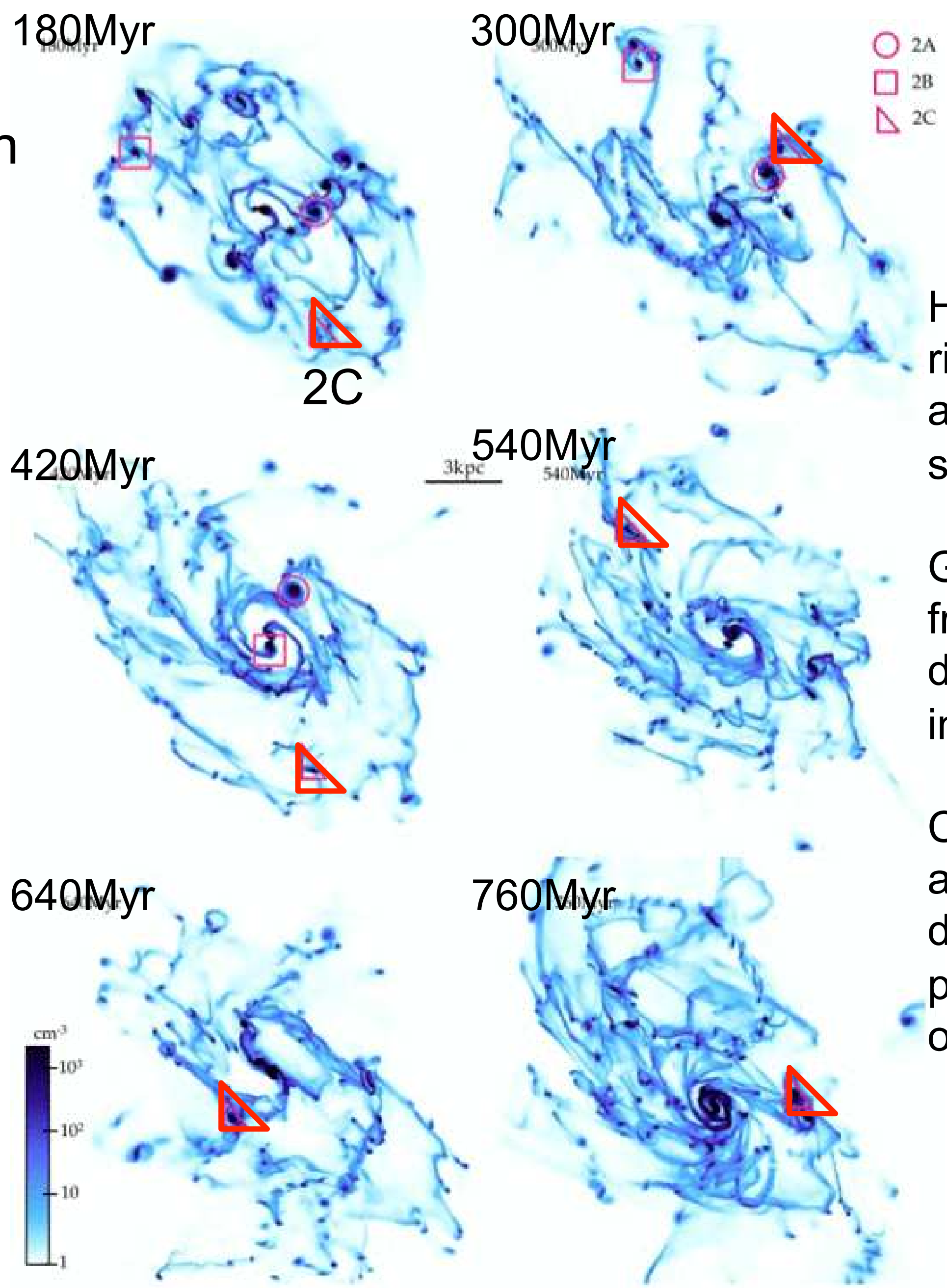
Numerical simulation of clumpy galaxies (N-body + SPH)

Bournaud et al. (2013)

Stellar feedback (photo-ionization, radiation pressure, and supernova) are fully considered.

Medium-mass galaxy

$M_{dyn} = 3.5 \times 10^{10} M_{\odot}$



High-z galaxies are gas rich due to massive gas accretion through cold streams.

Gas rich disks are fragmented to clumps due to gravitational instability.

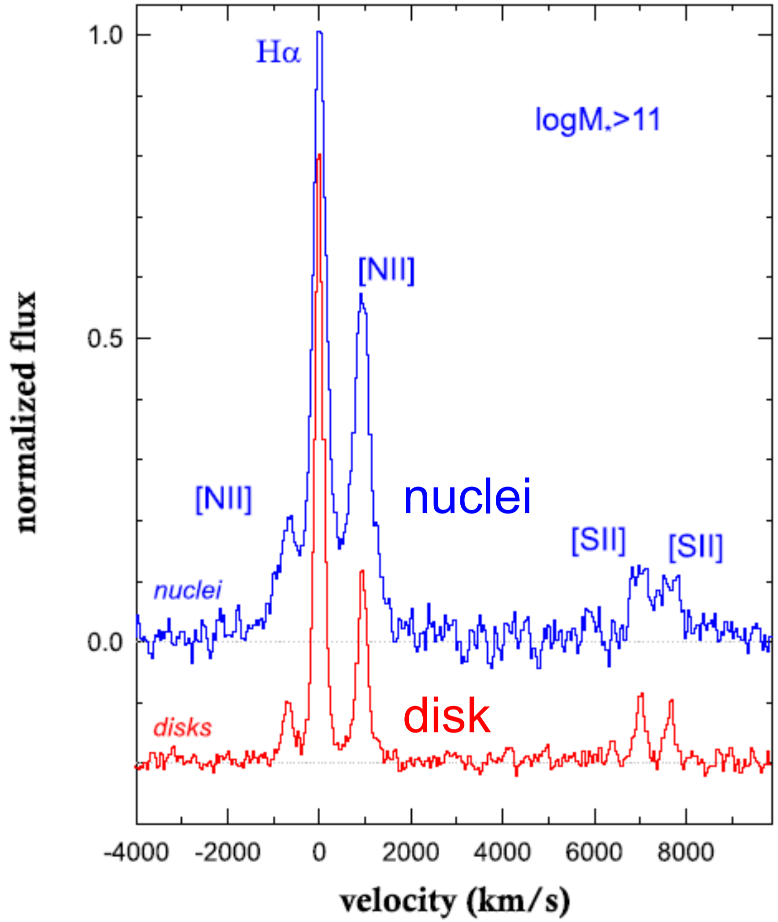
Clumps migrate towards a galactic center due to dynamical friction and probably make a bulge of a disk galaxy.

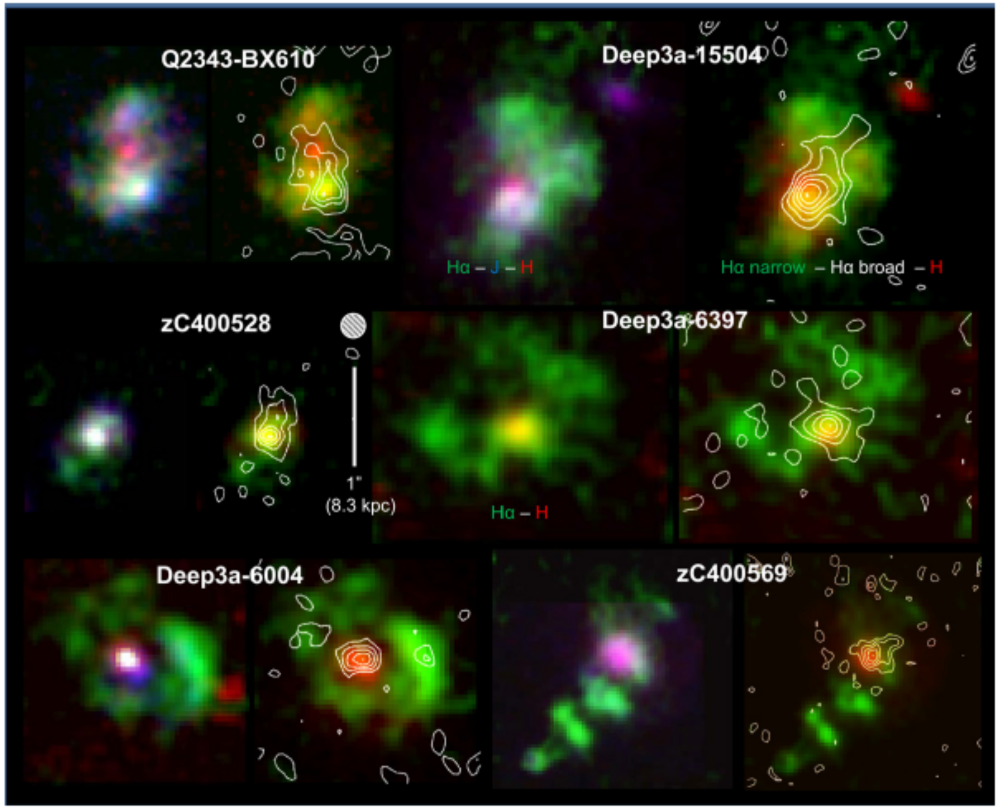
Bulge formation in disk galaxies through clump migration and merger at the center?

→ Necessity for spatially resolved studies of star forming activities and kinematics

Stacked Hα spectrum of massive SFGs at z=1-3

8 galaxies with log M_*>11





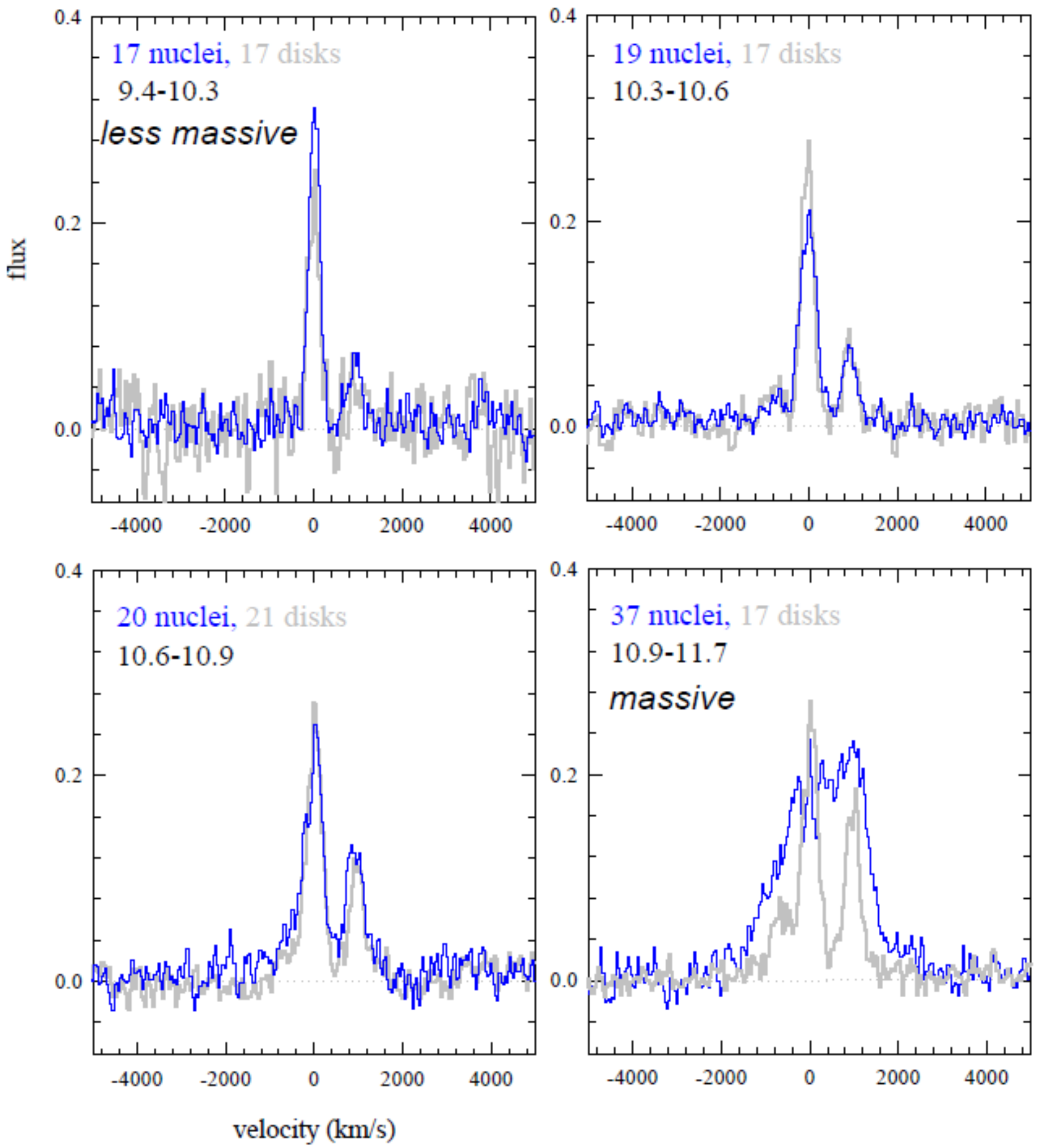
the spectra in the central region show a broad component

which is a signature of gaseous outflows.

Genzel et al. (2014)

Stellar mass dependence

Genzel et al. (2014)



2-20 hrs integration on VLT

- log M*=9.4-10.9
SF-driven outflow (Δv_{broad}~300km/s)?

different physical process

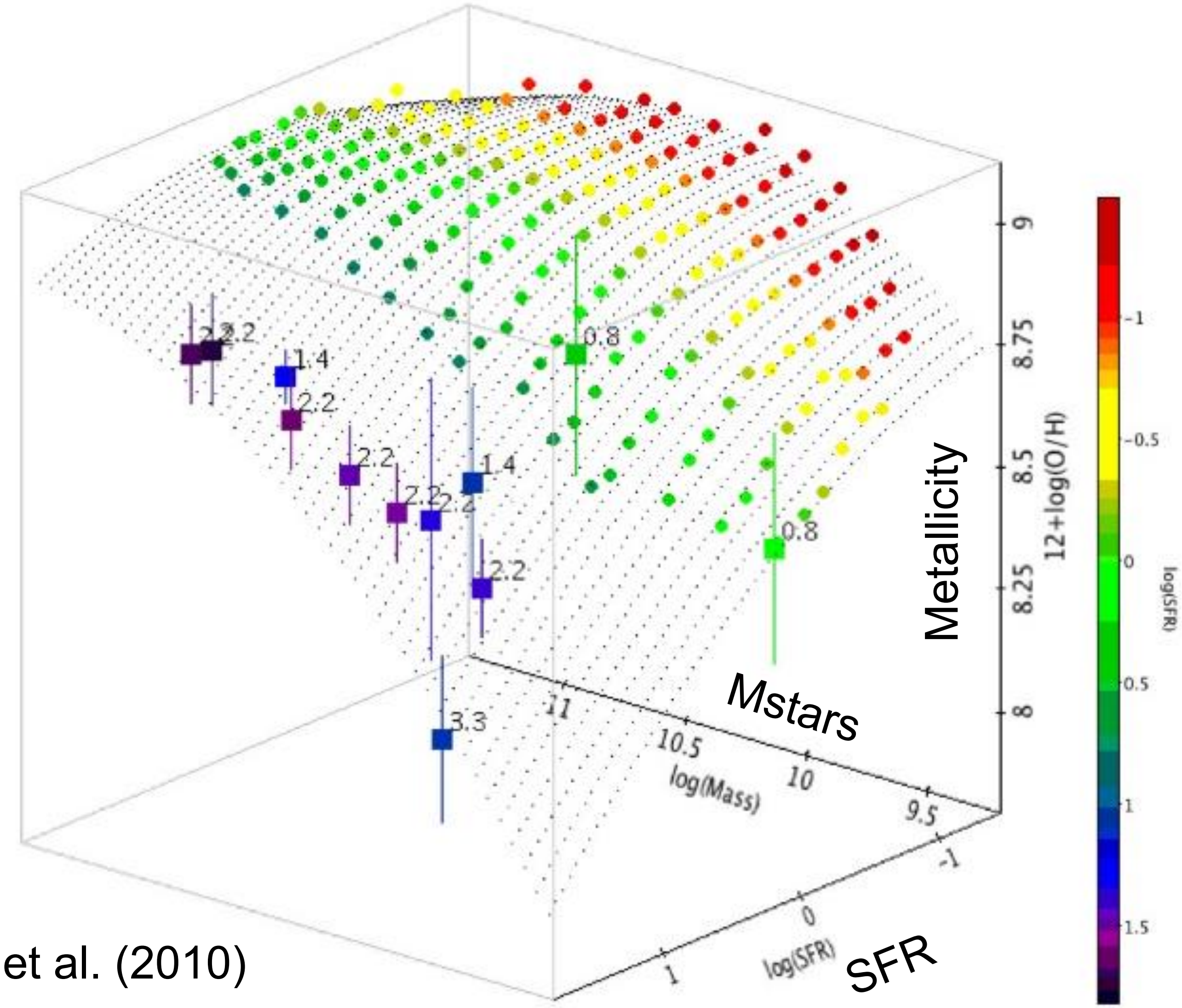
- log M*>10.9
AGN-driven outflow?

Massive galaxies tend to show AGN driven outflows (AGN feedback)

TMT will spatially/kinematically resolve broad AGN-driven outflow component with 100pc resolution, and will also identify AGN contribution from spatially resolved line diagnostic.

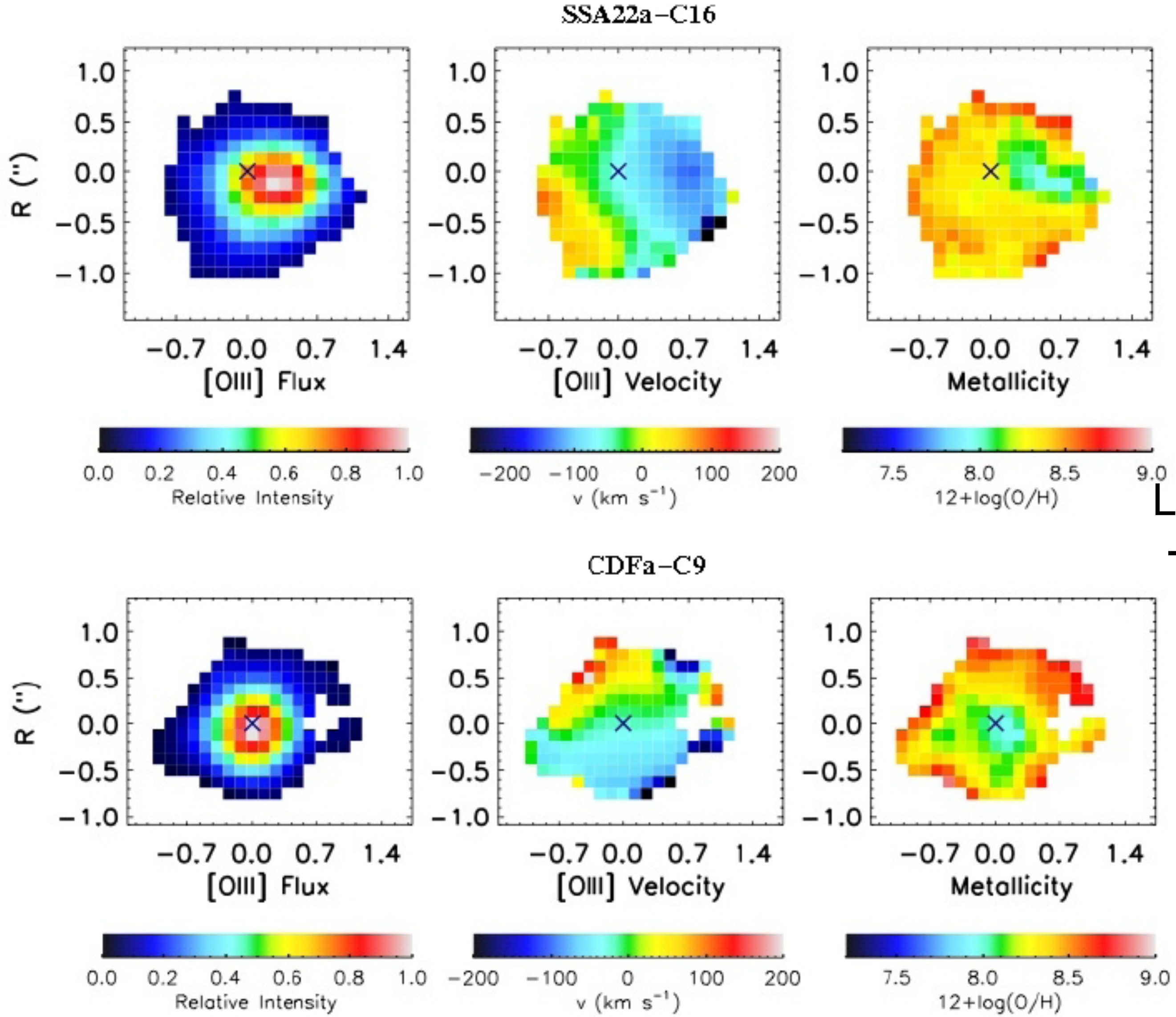
Fundamental Metallicity Relation

Gaseous metallicity is a good tracer of past SFH and gas inflows/outflows, and it can be measured by line ratios such as [NII]/Hα and ([OII]+[OIII])/Hβ.



Mannucci et al. (2010)

Resolved Gas-Phase Chemical Evolution: Clues to SF propagation and gas inflow/outflows



VLT/SINFONI

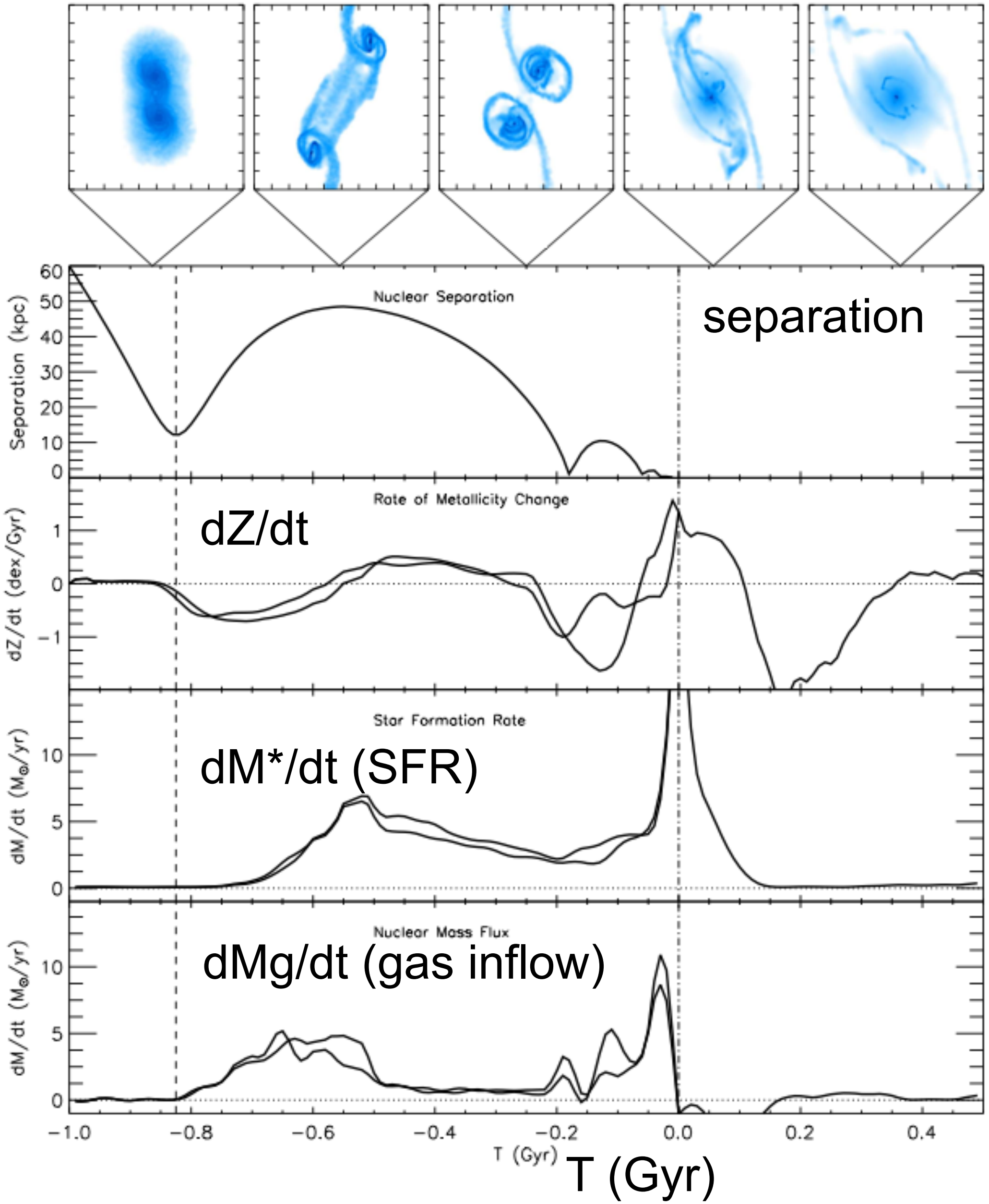
Cresci et al. (2010)

2D map of line ratios will provide metallicity distributions within galaxies

Lower metallicity at the center → Dilution of metals by inflow of outer metal poor gas?

TMT will break the degeneracy between metallicity and ionizing states with multiple line ratio measurements, including week lines.

Chemical Evolution in Merging Galaxies



N-body/SPH (GADGET-2) Simulation

Torrey et al. (2011)

Two competing effects:

Dilution of metals initially by the inflow of metal poor gas to the center due to loss of its angular momentum during mergers.

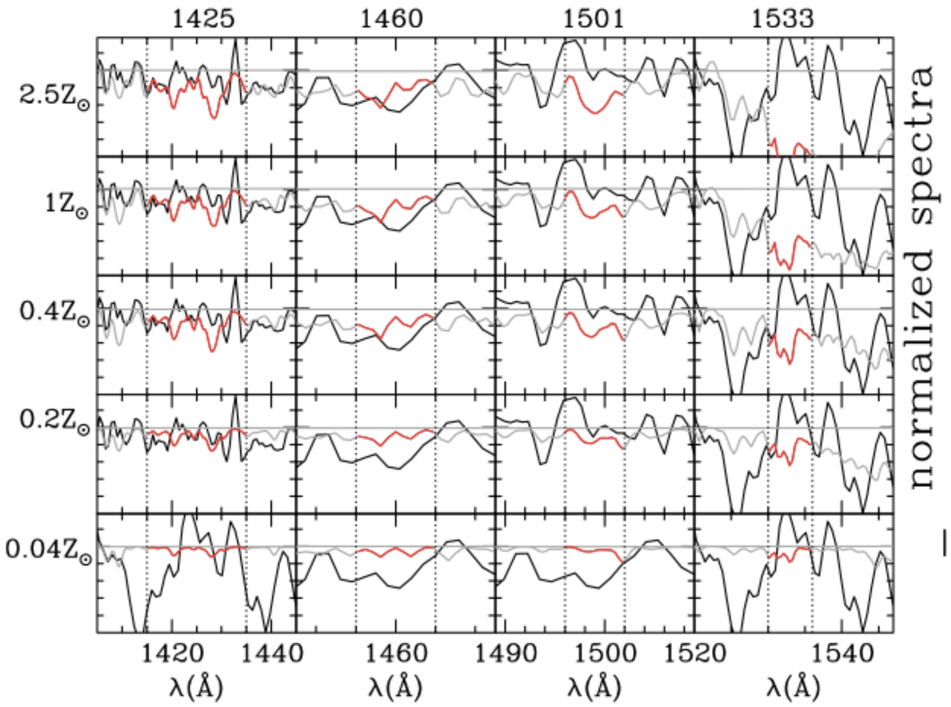
Enrichment of metals then follows by successive starbursts

Stellar metallicities from UV absorption lines

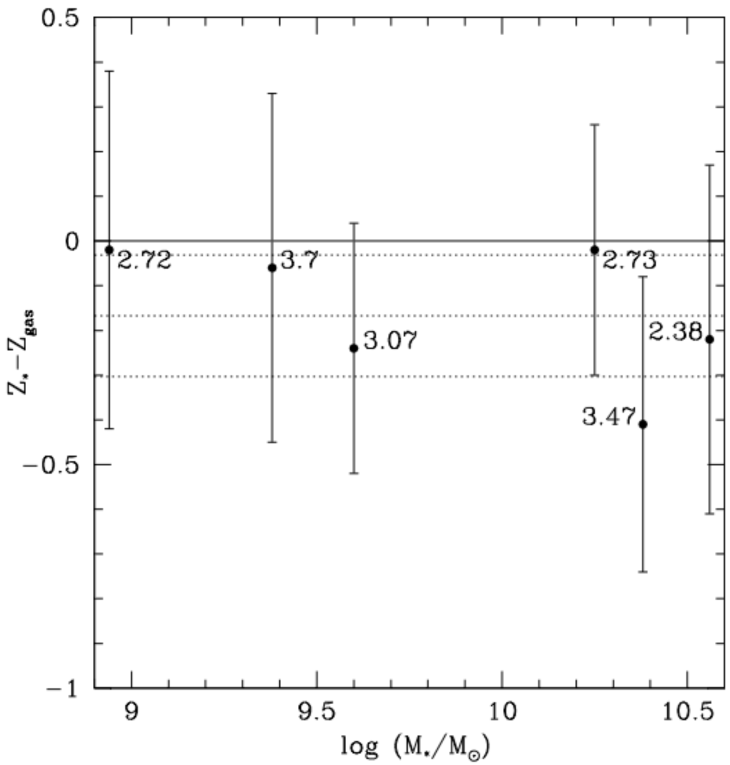
A new frontier at high-z: Metallicity-sensitive FUV stellar features, 1360-2020 A

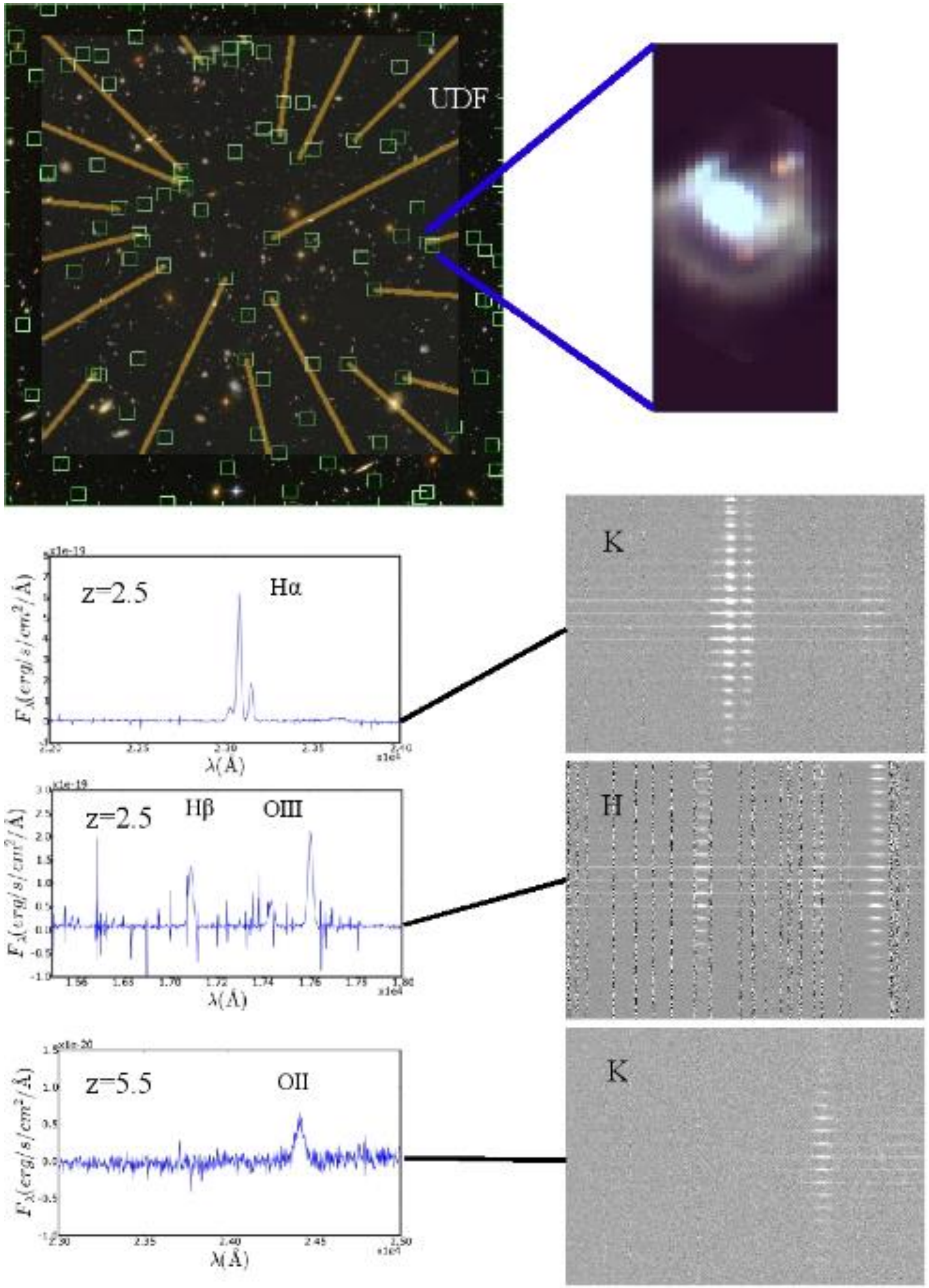
Very expensive today: 37h spectra with VLT/FORS2, galaxies m(R) = 23.4 – 25.0

MOBIE @ z <≈ 5.5 – 6; IRMS and IRIS at higher redshifts



Sommariva et al. 2012





Figures – Simulated IRMOS observations of Lyman-break galaxies.
Courtesy: IRMOS-UF/HIA team.

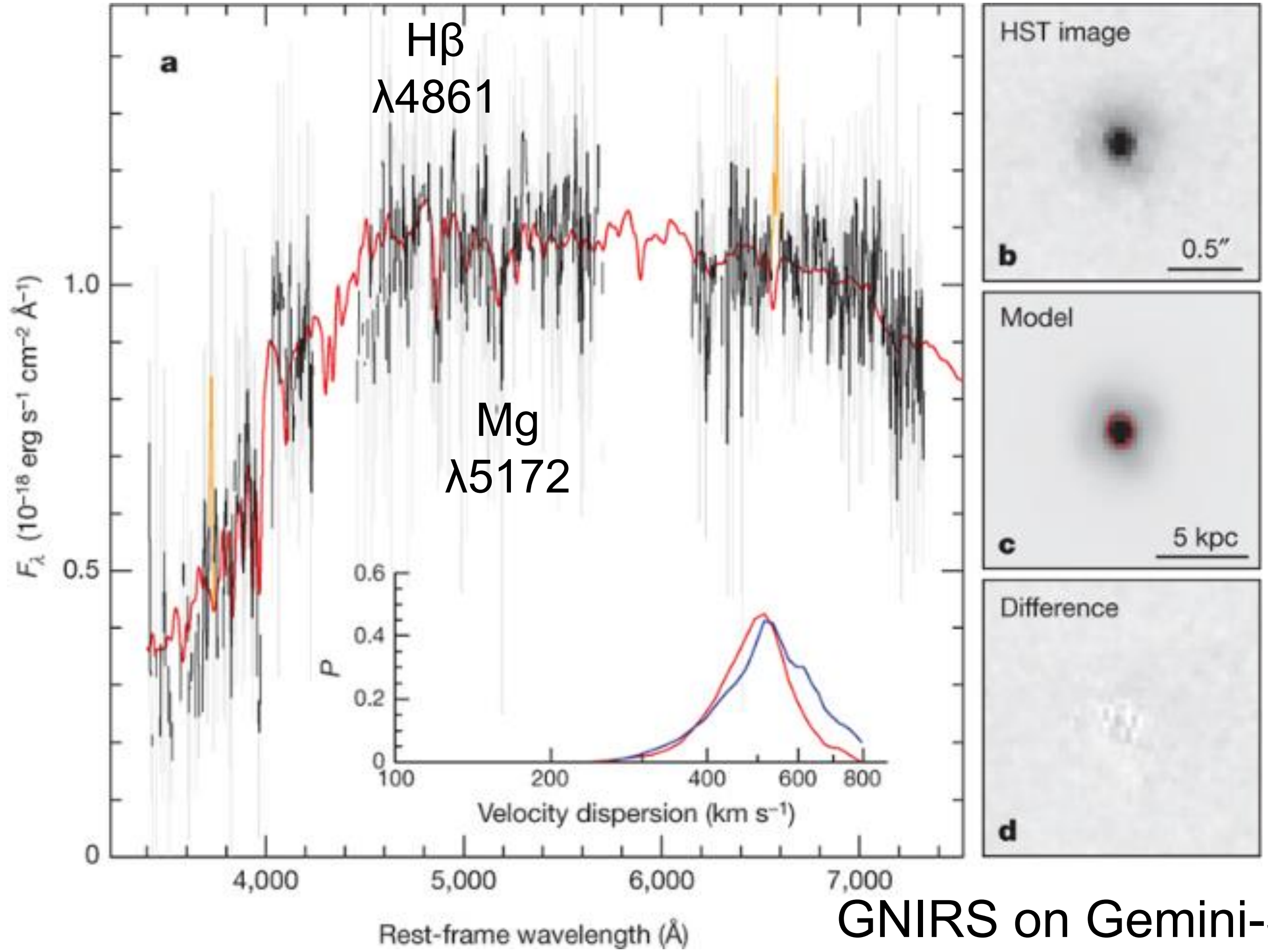
Multiple-IFU with MOAO will be really unique with TMT.

The multiplicity of IFU will be best utilized with sufficient number densities of available targets at the depth we can reach with TMT!

What is the optimal multiplicity and the field of view of MOAO from science requirements?

Continuum, absorption lines of red galaxies at z~2

We can estimate stellar ages and metallicities of individual galaxies.



GNIRS on Gemini-S, 29 hrs

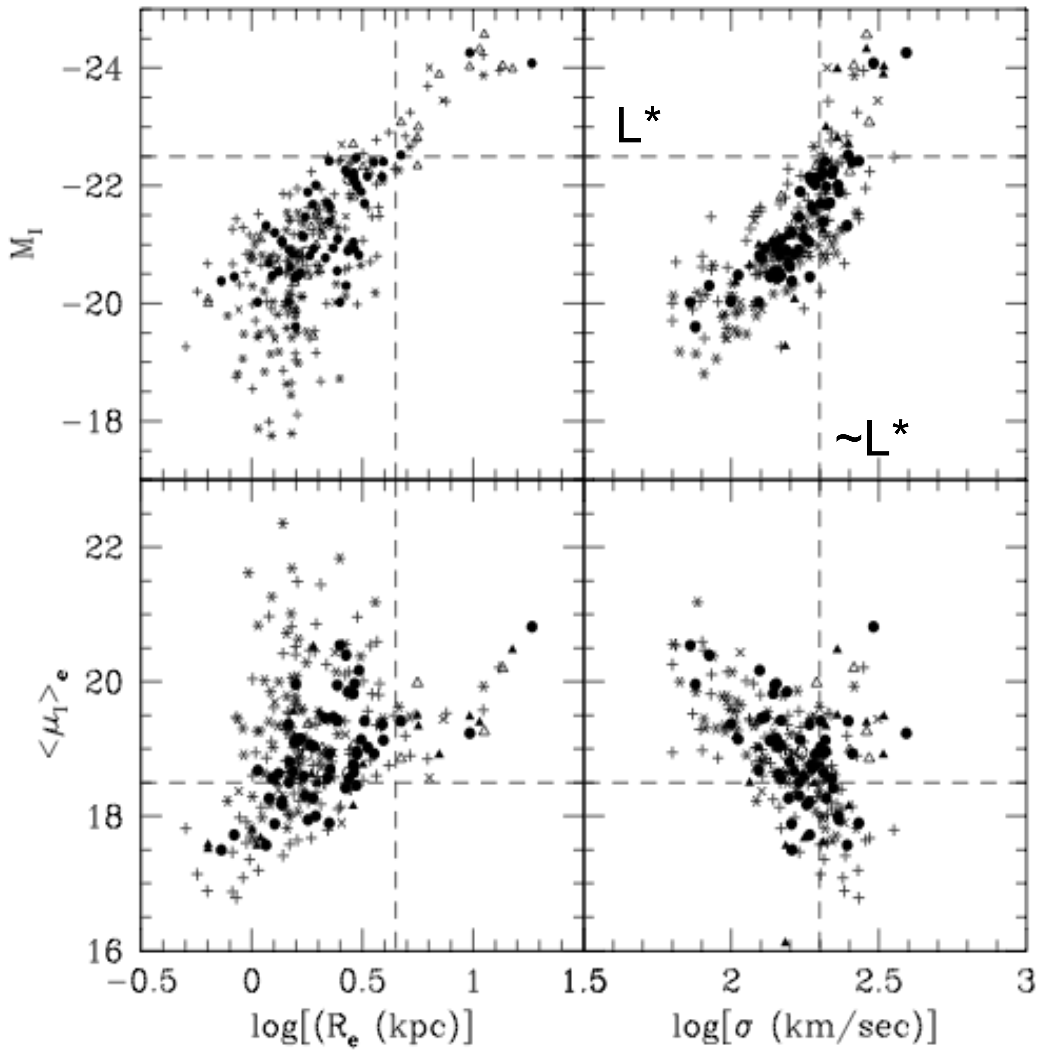
Spectrum and HST images of 1255-0 at z = 2.186.
van Dokkum *et al*. *Nature* **460**, 717-719 (2009)

K=19.26 (Vega)

$M^{*}=2\times10^{11}M_\odot$

→ 2hrs exposure with TMT !

Fundamental plane of cluster galaxies



Low-z galaxy clusters

Pierce & Berrington (2014)

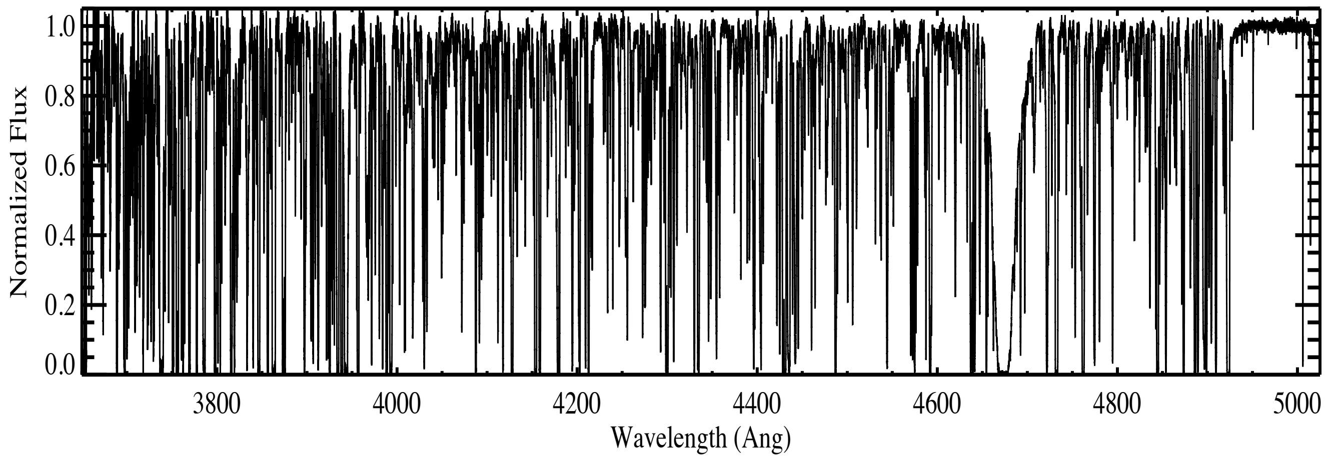
At z~2, accurate measurements of σ will require S/N ~ 50 spectroscopy at R ~ 3000 with WFOS/IRMS.
To sample 2-3 magnitudes below *L** will require exposure times of about 6 hours with TMT.

Figure — Various projects of the fundamental plane for four clusters. The dashed lines are drawn at $L \sim L^*$ to illustrate that the $L > L^*$ systems populate a distinct region within the FP (see lower right panel). The differences between the $L > L^*$ galaxies and those with $L < L^*$ are readily apparent.

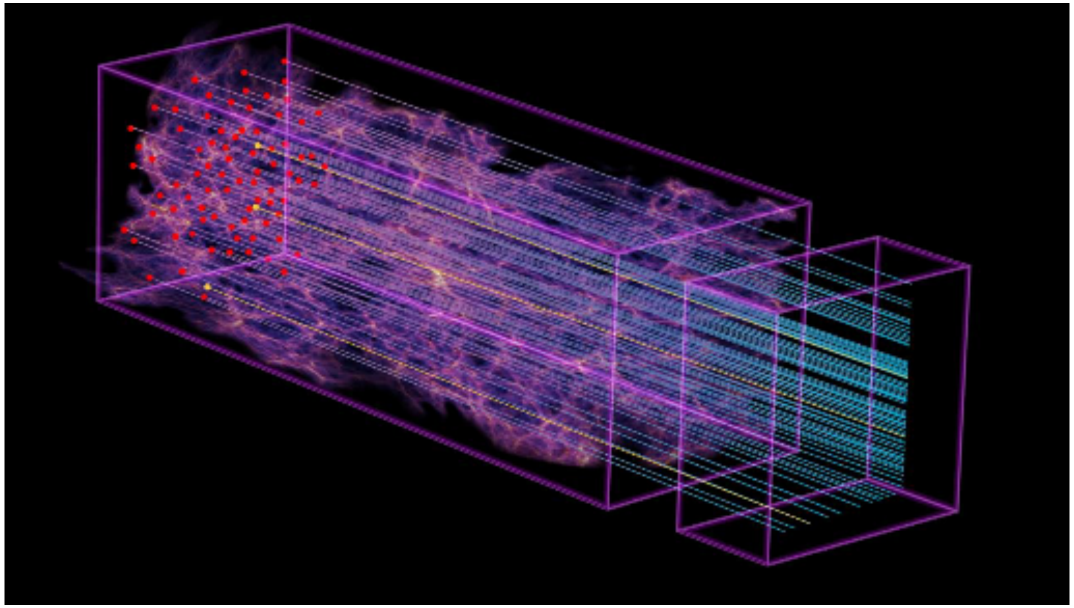
IGM tomography with optical, high-R, multi-object spectroscopy

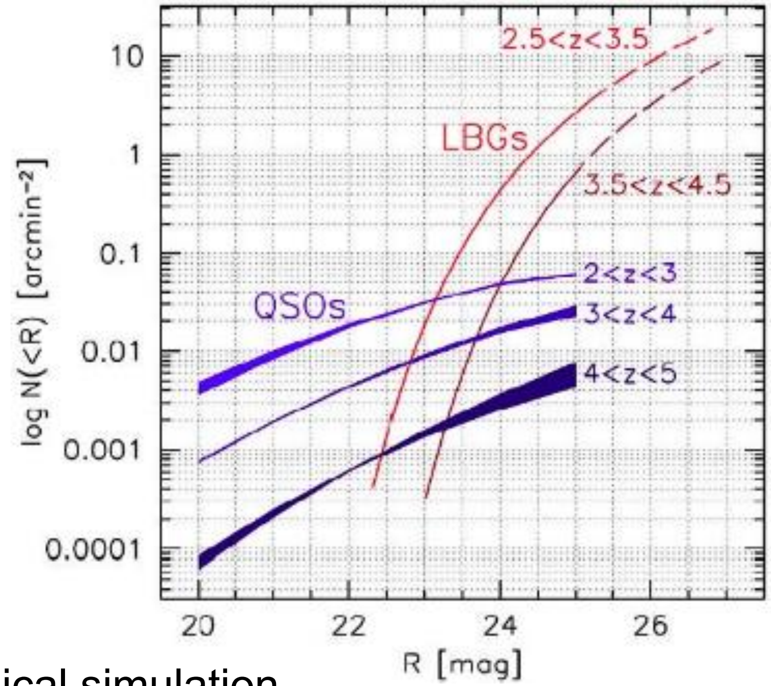
What is the optimal spectral resolution from science requirements?

R>5000?



UV-bright galaxies can be used as background Illuminators at the depth of TMT!





The “cosmic web” of the baryon distribution in a cosmological simulation

Potential key programs

- Spectroscopic follow-up campaign of z>7 candidates (LSST, HSC, VISTA, Cluster lensing, WISH, WFIRST, JWST…) using Lyα, HeII1640, CIII]1909, OIII]1663.
- 0.1 kpc-scale anatomy (morphology/kinematics/ in-/outflows), and multi-line diagnostics of high-z galaxies (down to sub-L* at z<4).
- Continuum/absorption-line NIR spectroscopy of high-z galaxies (passive/dusty).
- IGM/CGM tomography with optical, high resolution, absorption-line spectroscopy.

More…from the breakout session

- **Mass-limited, high-completeness, ultra-deep spectroscopic survey (at both optical and NIR) which will cover a vast range of science (e.g. redshifts, kinematics, stellar populations, IGM tomography…)**

- 3D kinematics of Coma cluster from proper motion measurements over >10yrs.

- High spatial resolution, narrow-line ratio survey of ~1000 lensed QSOs to probe halo substructures

- Spectroscopic follow-up of core-collapse SNe at z~2

Summary

- High-z ISDT has 37 members (the largest group!)
- Split into 4 subgroups (G1,G2,G3, and G4)
- Many thanks to the actual contributors!
- DSC update is however not yet completed.
- And it needs to be shortened by a factor of 2!
- We should complete our DSC by the end of Aug, and send it to the TMT-SAC for further edition.
- Some potential key programs have been discussed. We will continue discussion on them by telecon/wiki/etc and in sub-working groups.