Tomograpy of the Intergalactic and Circumgalactic Medium with the E-ELT

Martin Haehnelt

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Merriam-Webster

to·mog·ra·phy *noun* \tō-ˈmä-grə-fē\

Definition of TOMOGRAPHY

: a method of producing a three-dimensional image of the internal structures of a solid object (as the human body or the earth) by the observation and recording of the differences in the effects on the passage of waves of energy impinging on those structures — compare COMPUTED TOMOGRAPHY

— **to·mo·graph·ic** *adjective*

Origin of TOMOGRAPHY

Greek *tomos* section + International Scientific Vocabulary -*graphy* — more at TOME

First Known Use: 1935

Figures prominently in the TMT and GMT science cases.

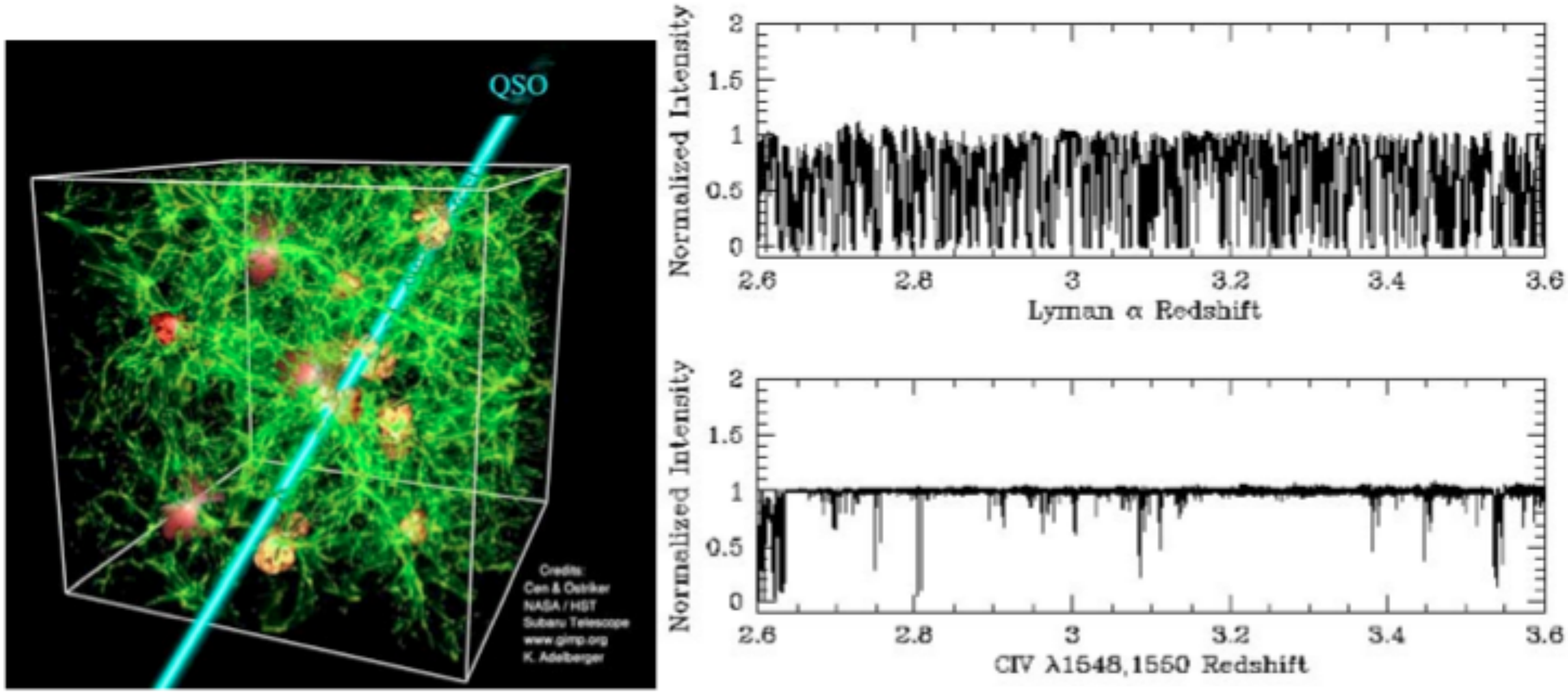
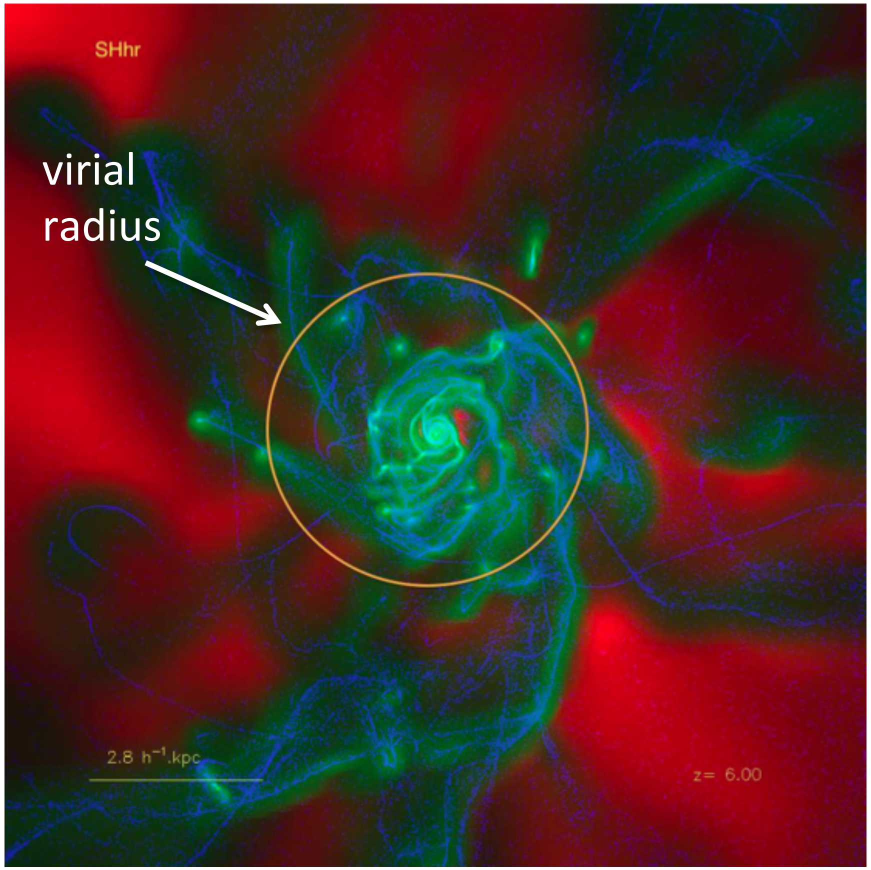


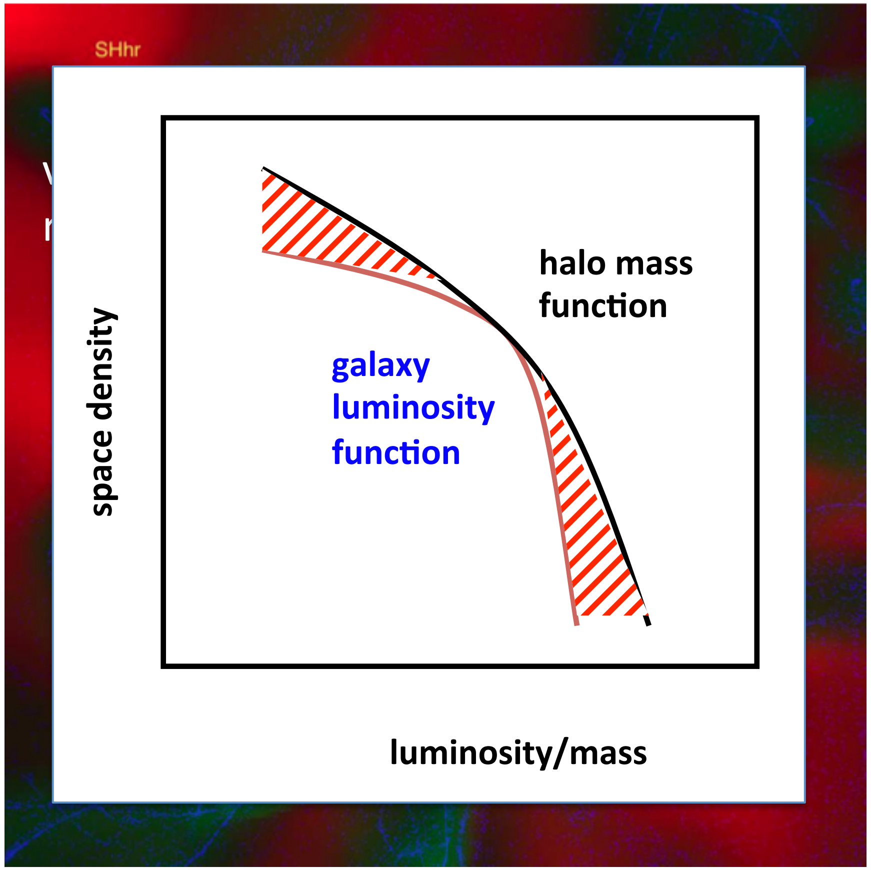
Figure 5-11. The "cosmic web" of the baryon distribution in a cosmological simulation. Here, HI in the IGM traces the dark matter distribution even in regions with low density contrast. A line of sight through the volume yields a one-dimensional map of both the HI and metallic species along the line of sight, as shown in the right-hand panel. Regions disturbed by galaxy formation processes are schematically indicated. In such regions, sightline probes will reveal the extent to which galaxies alter the physical state of the IGM: their sphere of influence, mass outflow, ionization effects, deposition of mechanical energy, etc. Densely sampled sightlines through a survey volume, together with detailed maps of the galaxy distribution, will provide unprecedented views of the distribution of baryons in the Universe, and their relation to the sites of galaxy formation.

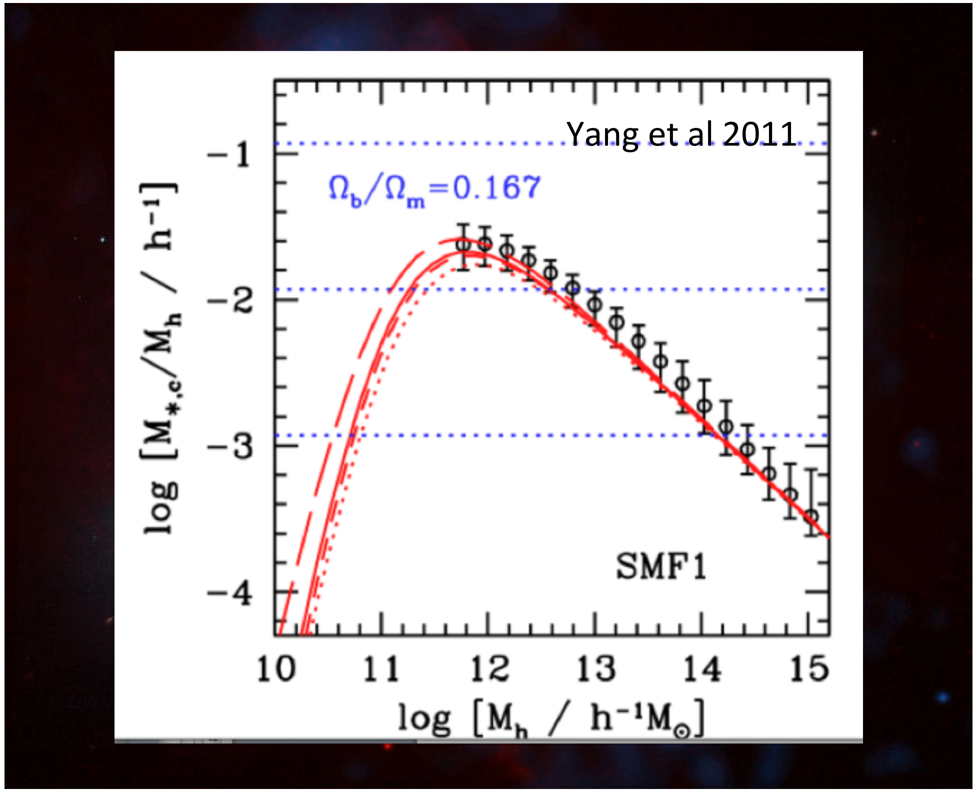
The baryonic lifecycle of galaxies: Inflows vs Outflows



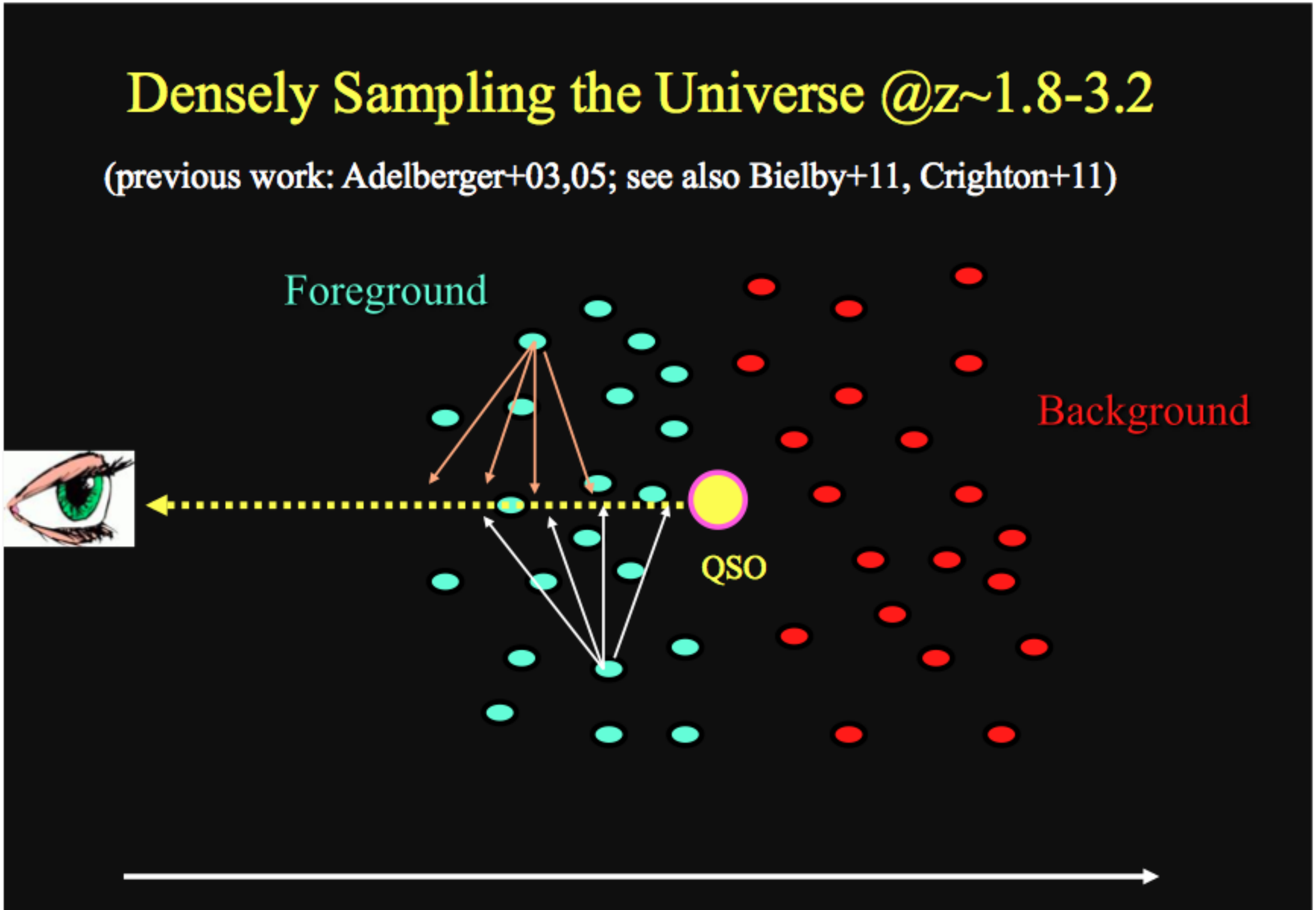
Cold flows. Galactic Winds. Metal Enrichment.

The baryonic lifecycle of galaxies: Inflows vs Outflows



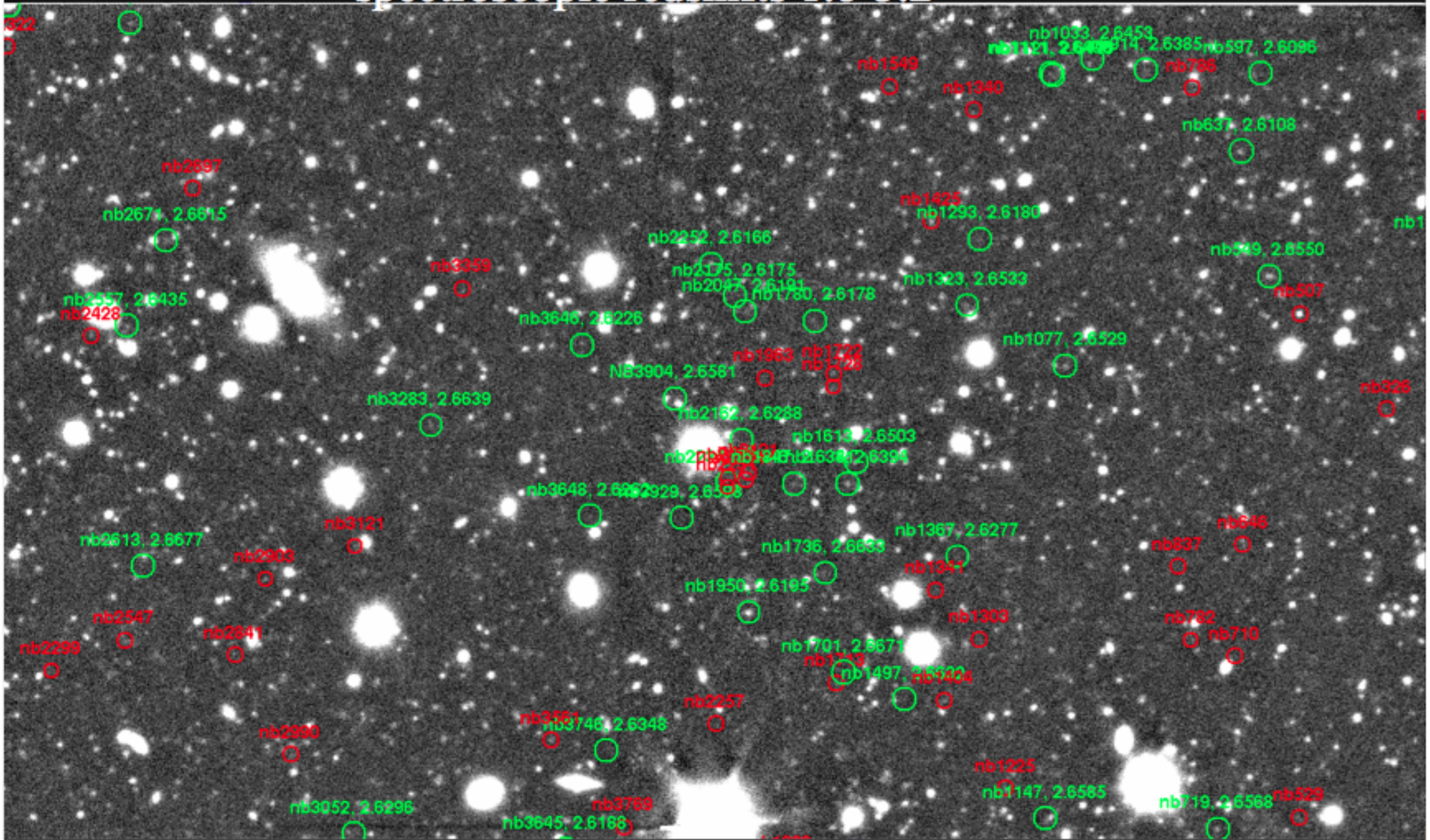


Cold flows. Galactic Winds. Metal Enrichment.



From Chuc Steidel’s talk at 2011 Durham conference

Typical Field, 5' x 7', ~150 spectroscopic redshifts 1.8-3.2



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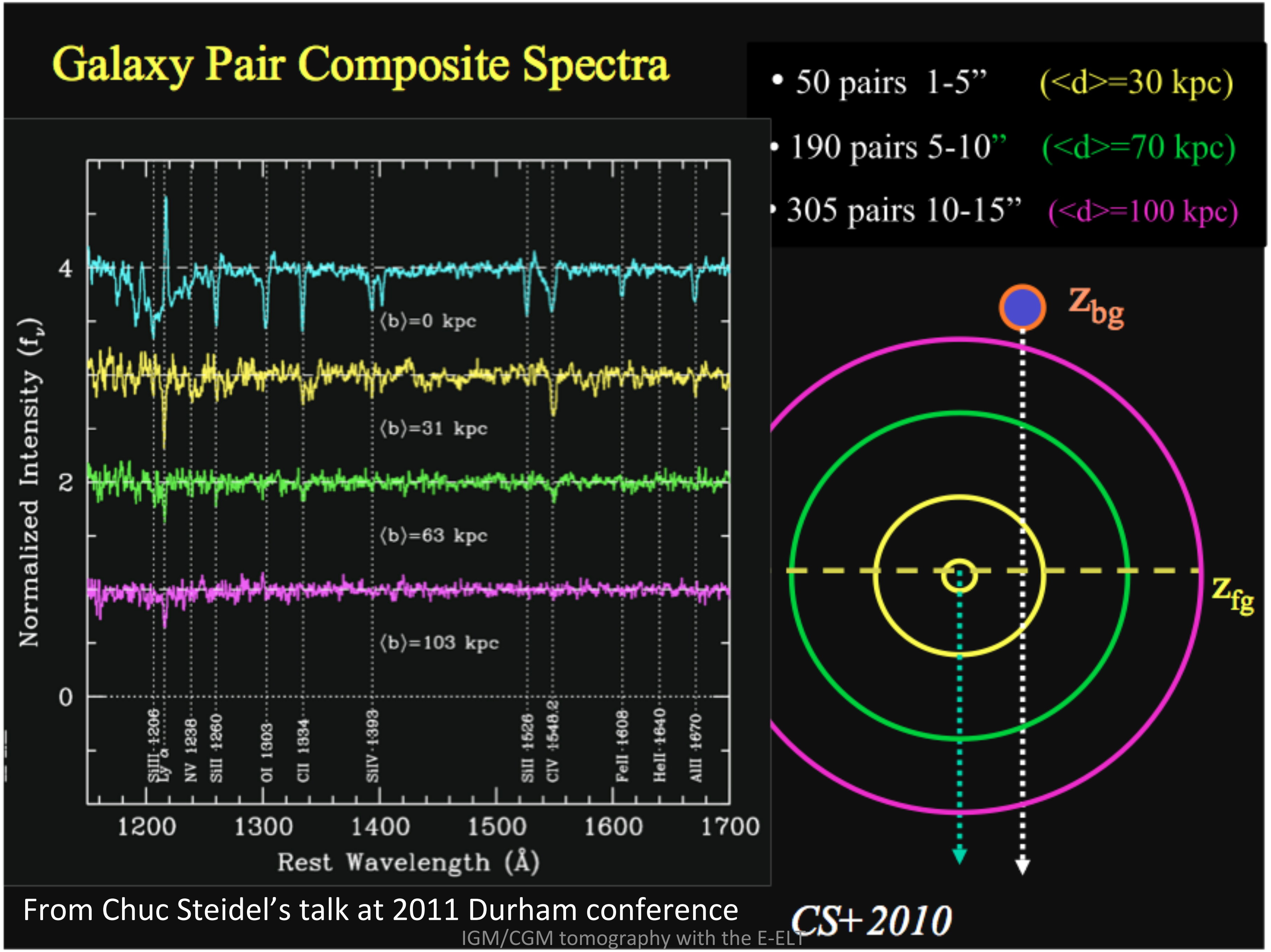
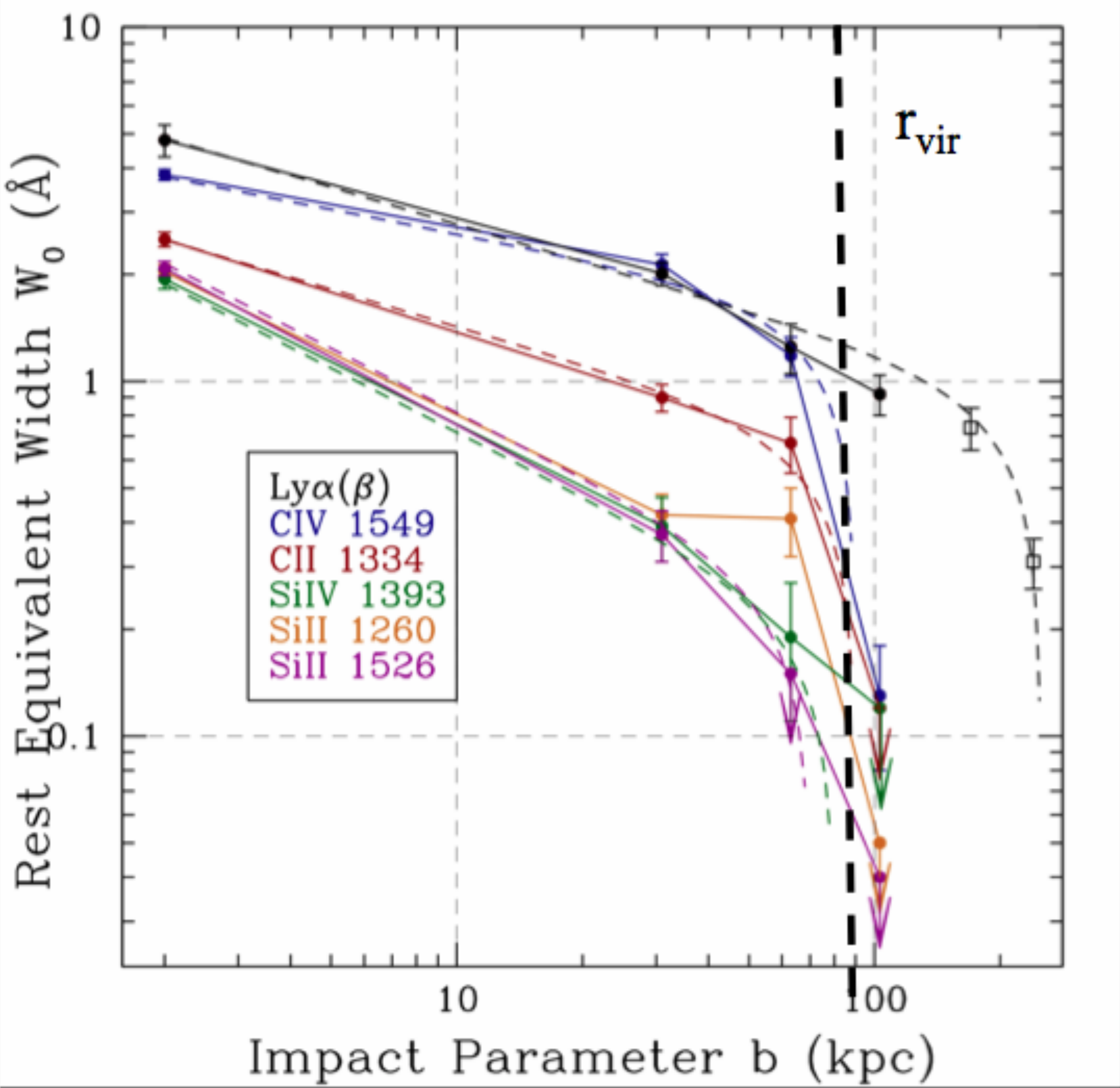


Galaxy Pair Composite Spectra
• 50 pairs 1-5" (<d>=30 kpc)
• 190 pairs 5-10" (<d>=70 kpc)
• 305 pairs 10-15" (<d>=100 kpc)
Normalized Intensity (fν)
⟨b⟩=0 kpc
⟨b⟩=31 kpc
⟨b⟩=63 kpc
⟨b⟩=103 kpc
SiIII 1206
Ly α
NV 1238
SiII 1260
OI 1303
CII 1334
SiIV 1393
SiII 1526
CIV 1548.2
FeII 1608
HeII 1640
AlII 1670
1200 1300 1400 1500 1600 1700
Rest Wavelength (Å)
z_{bg}
z_{fg}
CS+2010
From Chuc Steidel's talk at 2011 Durham conference

W_0 vs. Galaxy Impact Parameter, z~2-3 LBGs



Models:

TABLE 5
W_0 VS. b MODEL PARAMETERS[a]

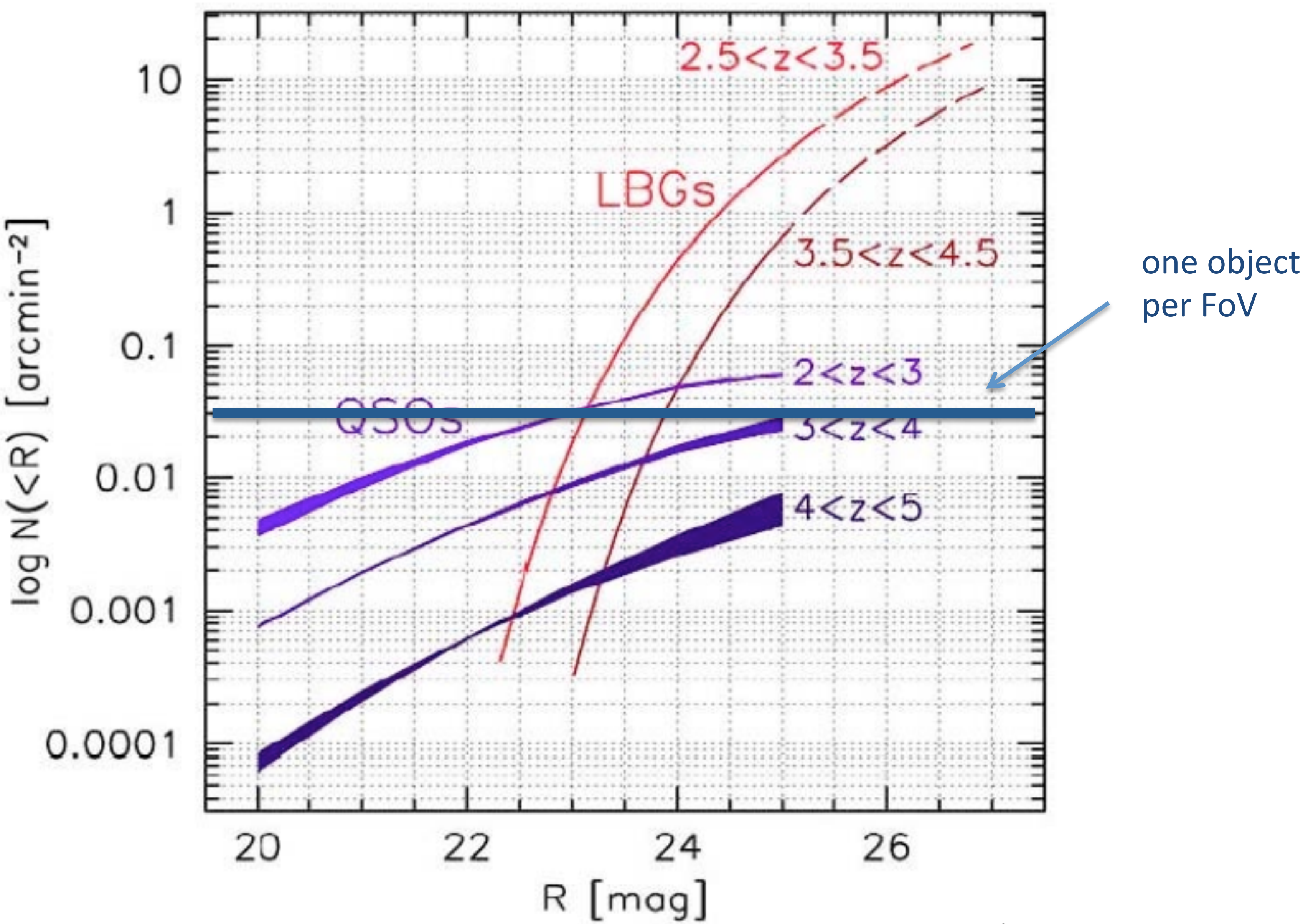
Line	γ[b]	$R_{\rm eff}$ (kpc)	$v_{\rm out}$	$f_{c,max}$[c]
Lyα(1216)	0.37	250	820	0.80
C IV(1549)	0.23	80	800	0.35/0.25[d]
C II(1334)	0.35	90	650	0.52
Si II(1526)	0.60	70	750	0.40
Si IV(1393)	0.60	80	820	0.33

[a] Parameters used to produce the model curves shown in Fig. 20
[b] Power law exponent in the expression $f_c(r) = f_{c,max} r^{-\gamma}$
[c] Maximum value of the covering fraction for each transition, measured from the composite spectrum (see Fig. 7)
[d] Includes contributions from C IV λ1548 and C IV λ1550 of 0.35 and 0.25, respectively.

$$f_c(r) \sim r^{-\gamma}$$

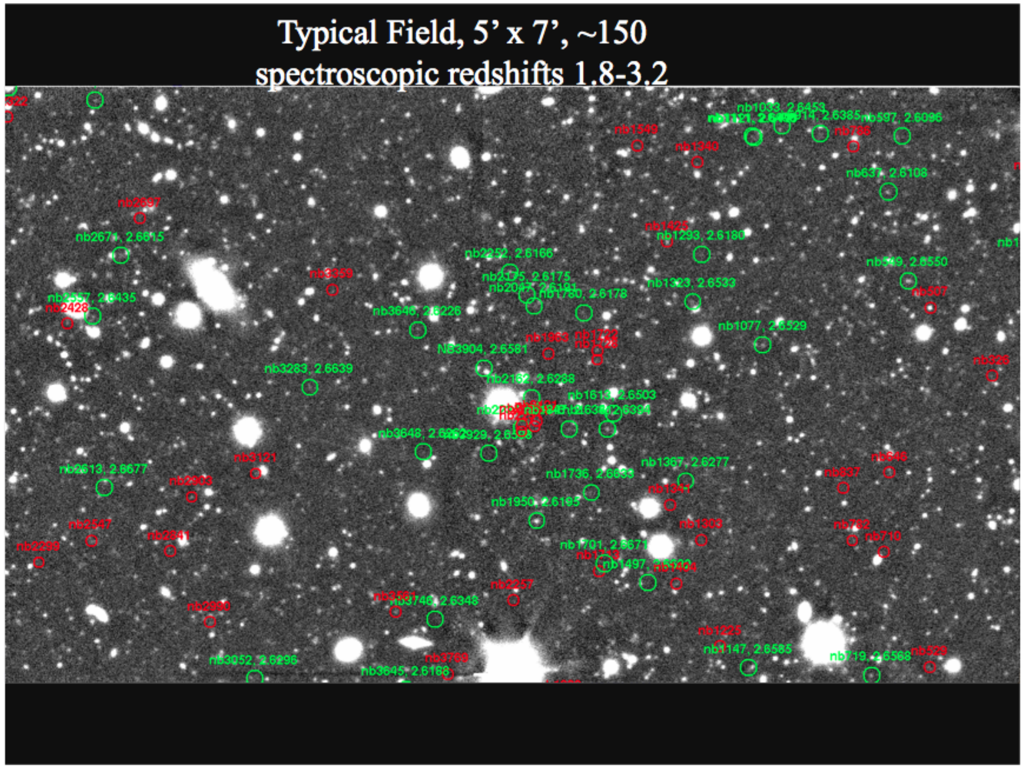
From Chuc Steidel's talk at 2011 Durham conference

CS et al 2010

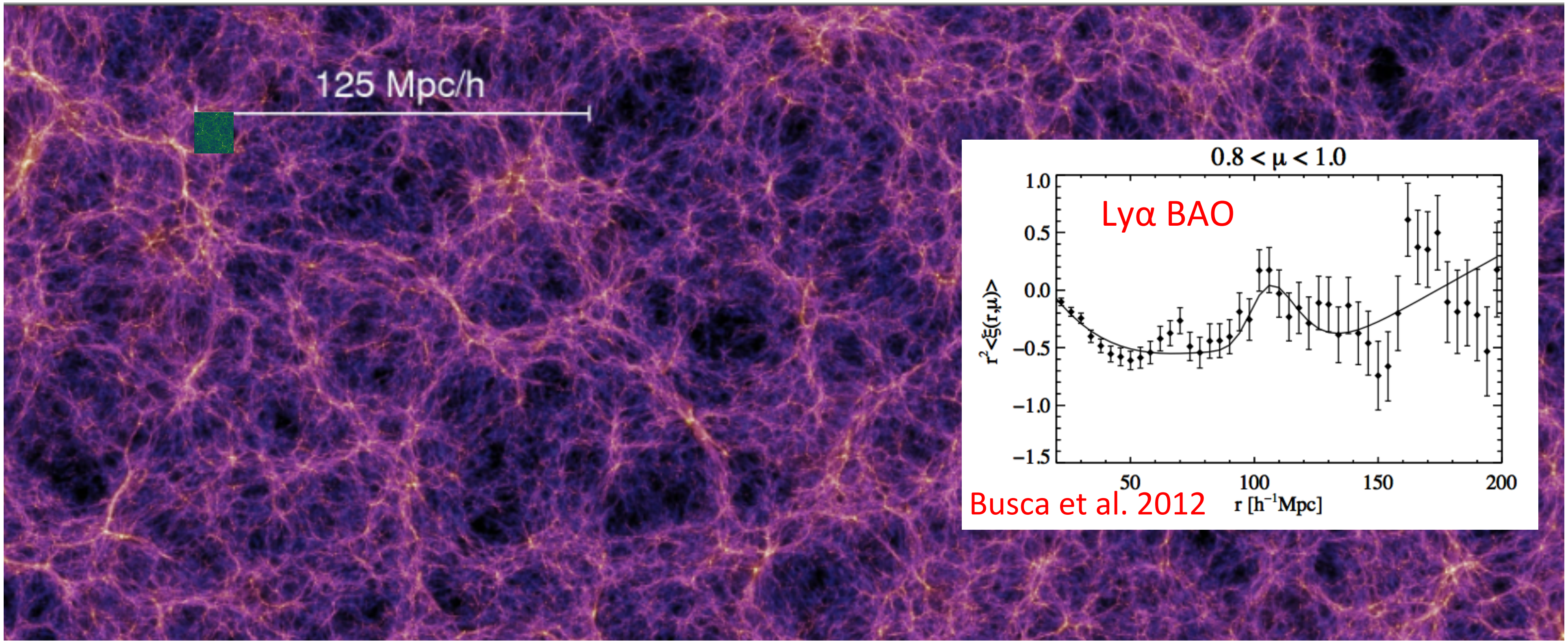


from TMT science case

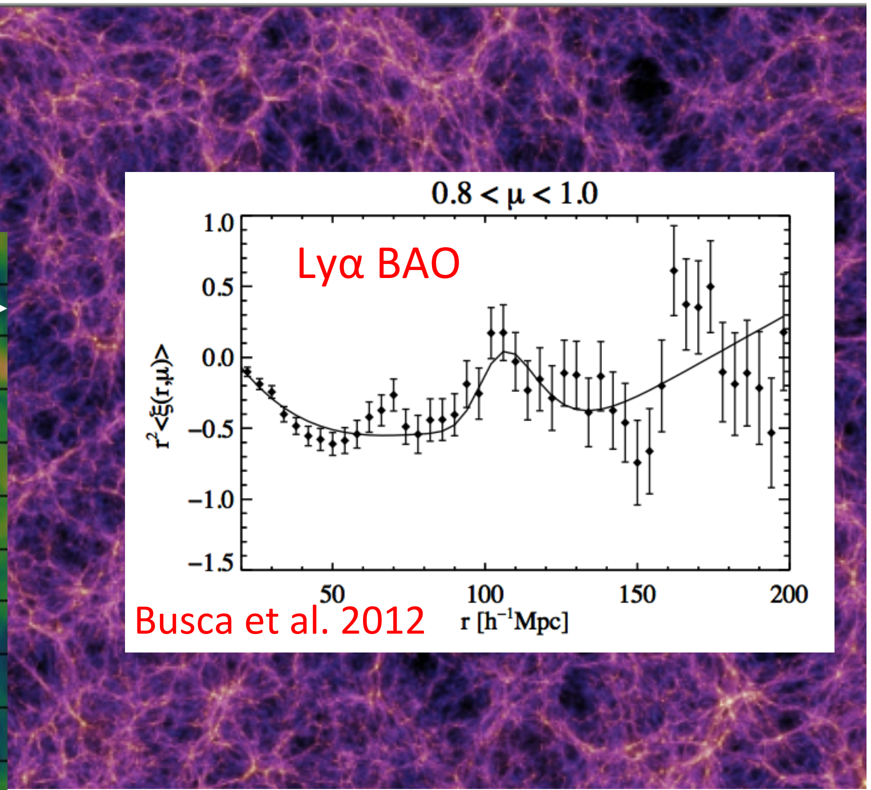
Tomography of the Circumgalactic Medium with the E-ELT

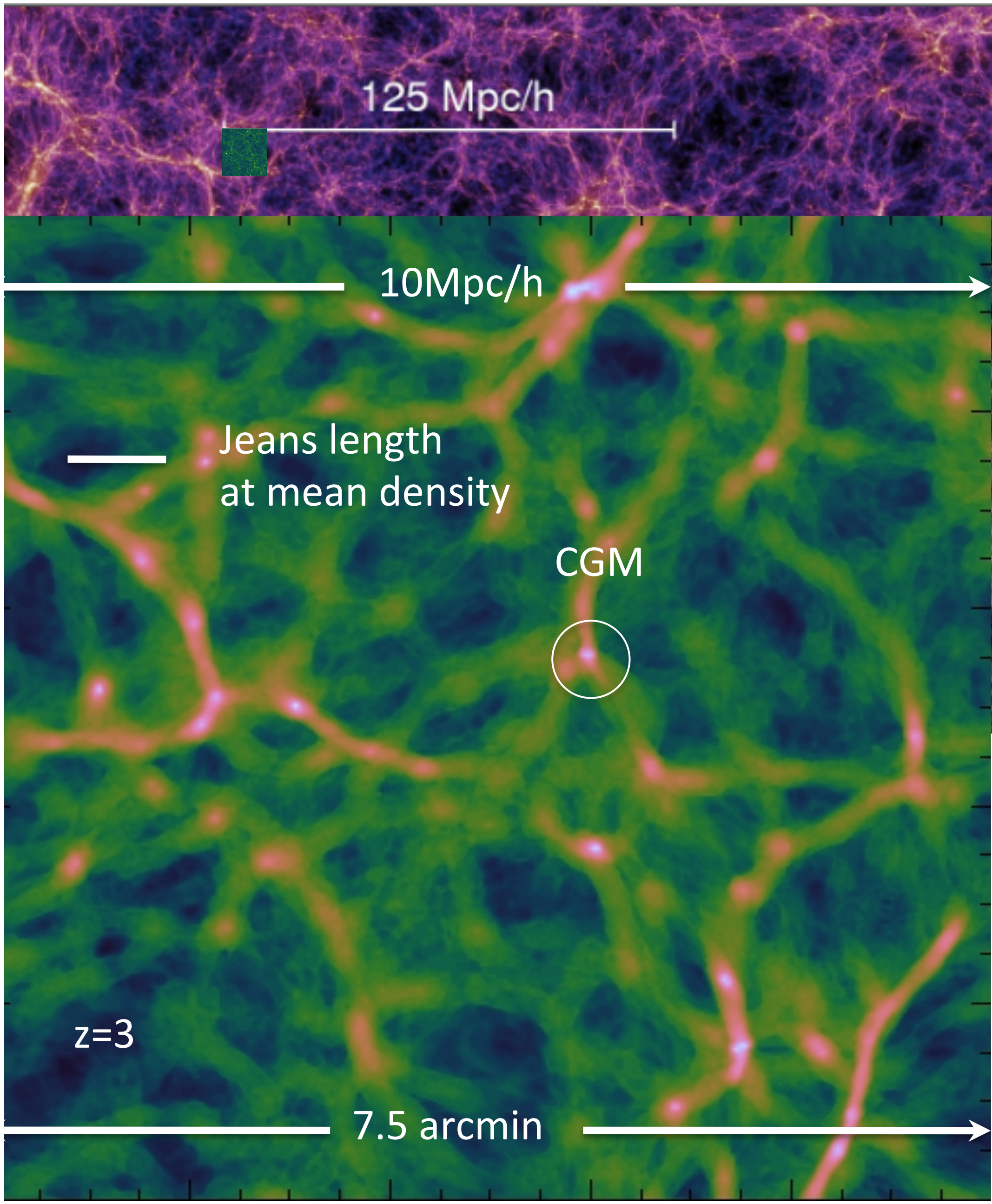


- can do this in a single night
- can go three too four magnitudes deeper
- for E-ELT FoV multiplex >100 and resolution R≤5000 match very well



Simulation pictures from Volker Springel and James Bolton.

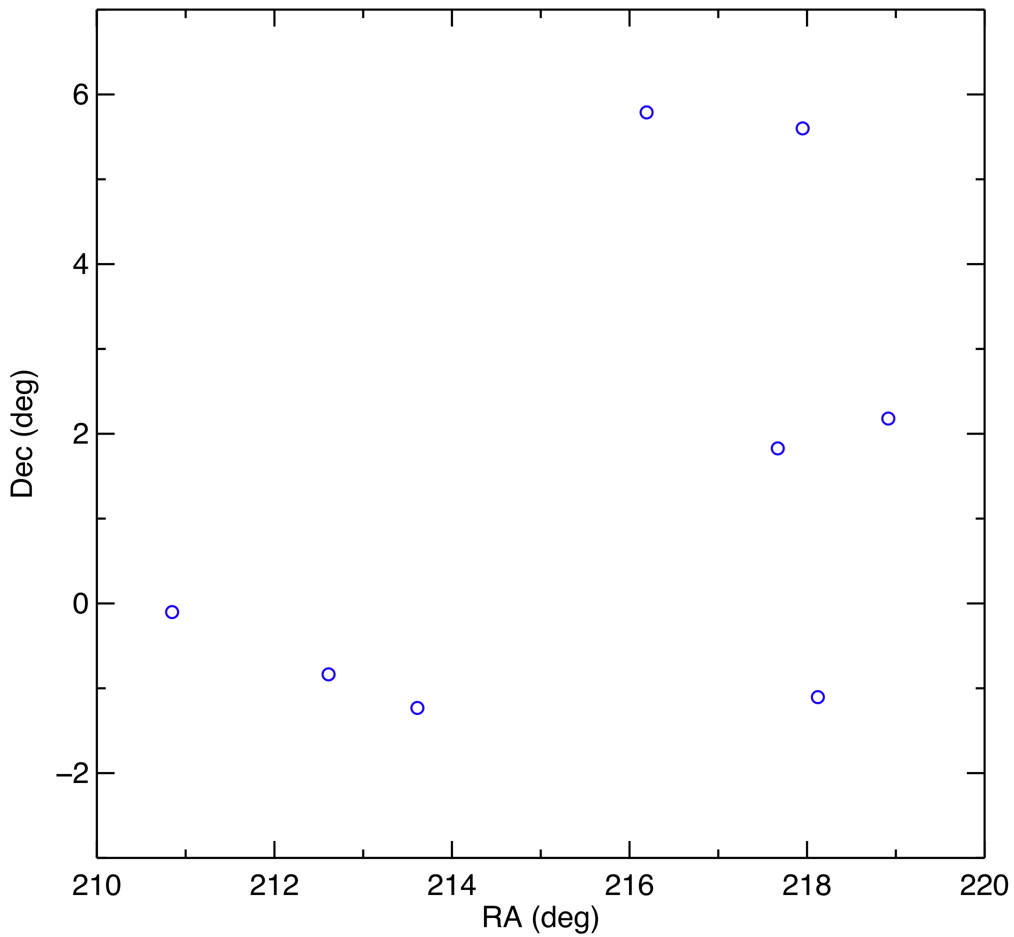




There is a long way to go for tomography in terms of scales.

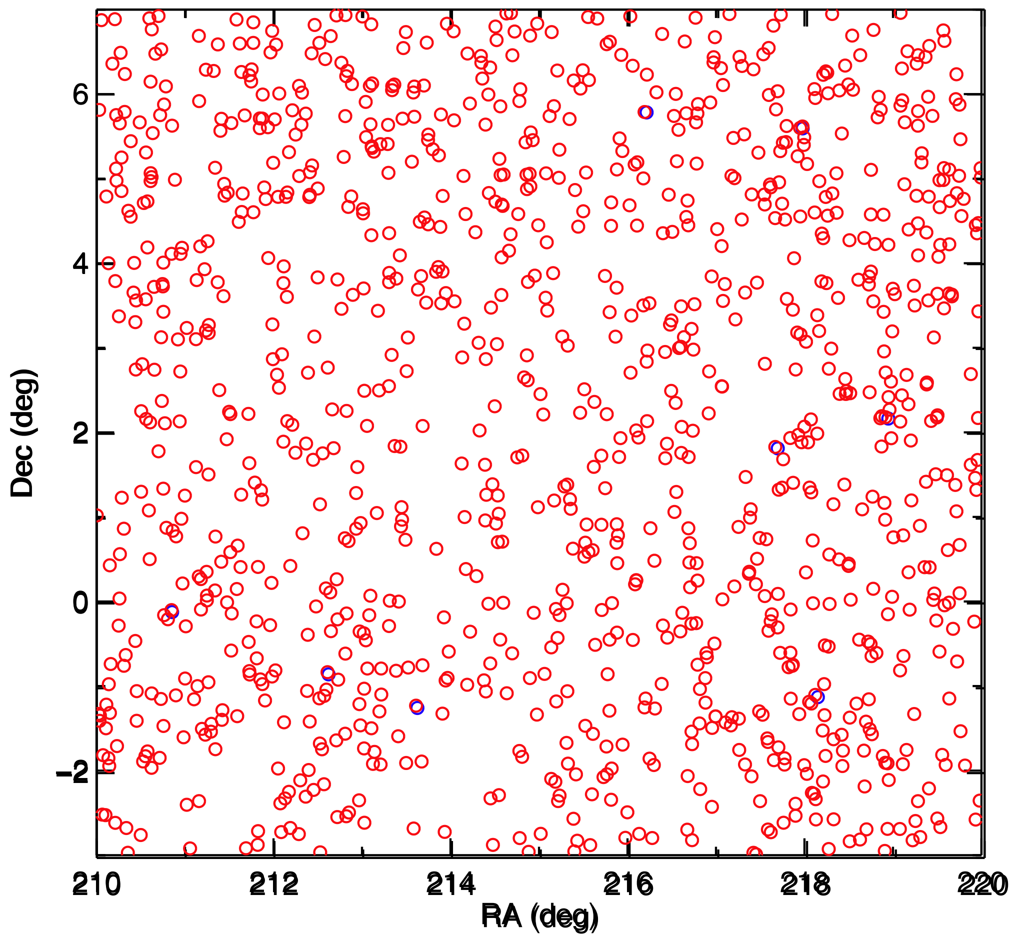
Simulation pictures from Volker Springel and James Bolton.

High-resolution spectroscopy of QSOs



courtesy of George Becker

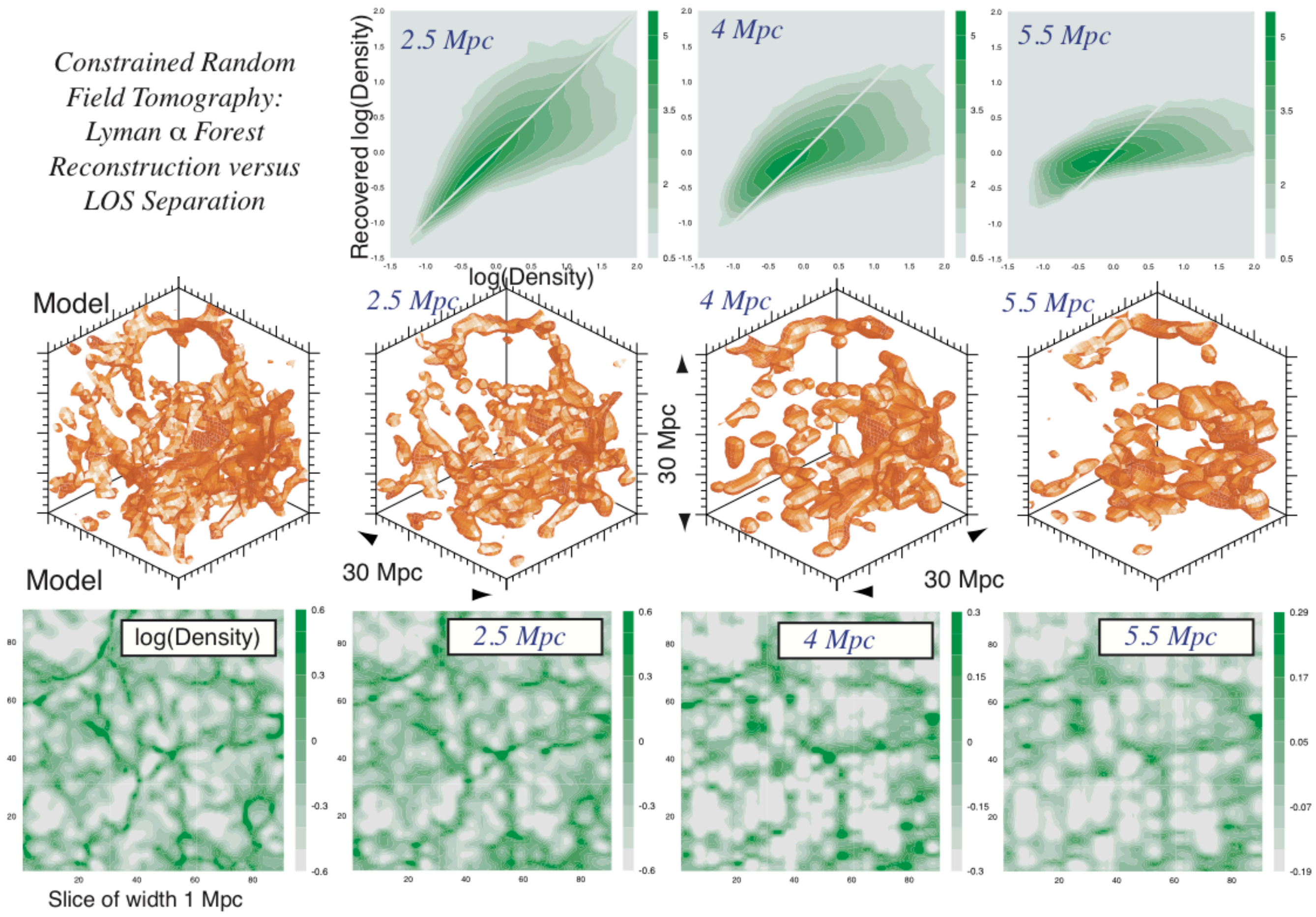
High-resolution spectroscopy of QSOs



This is what moving from 18th to 21st magnitude buys you.

courtesy of George Becker

Pichon et al. 2001

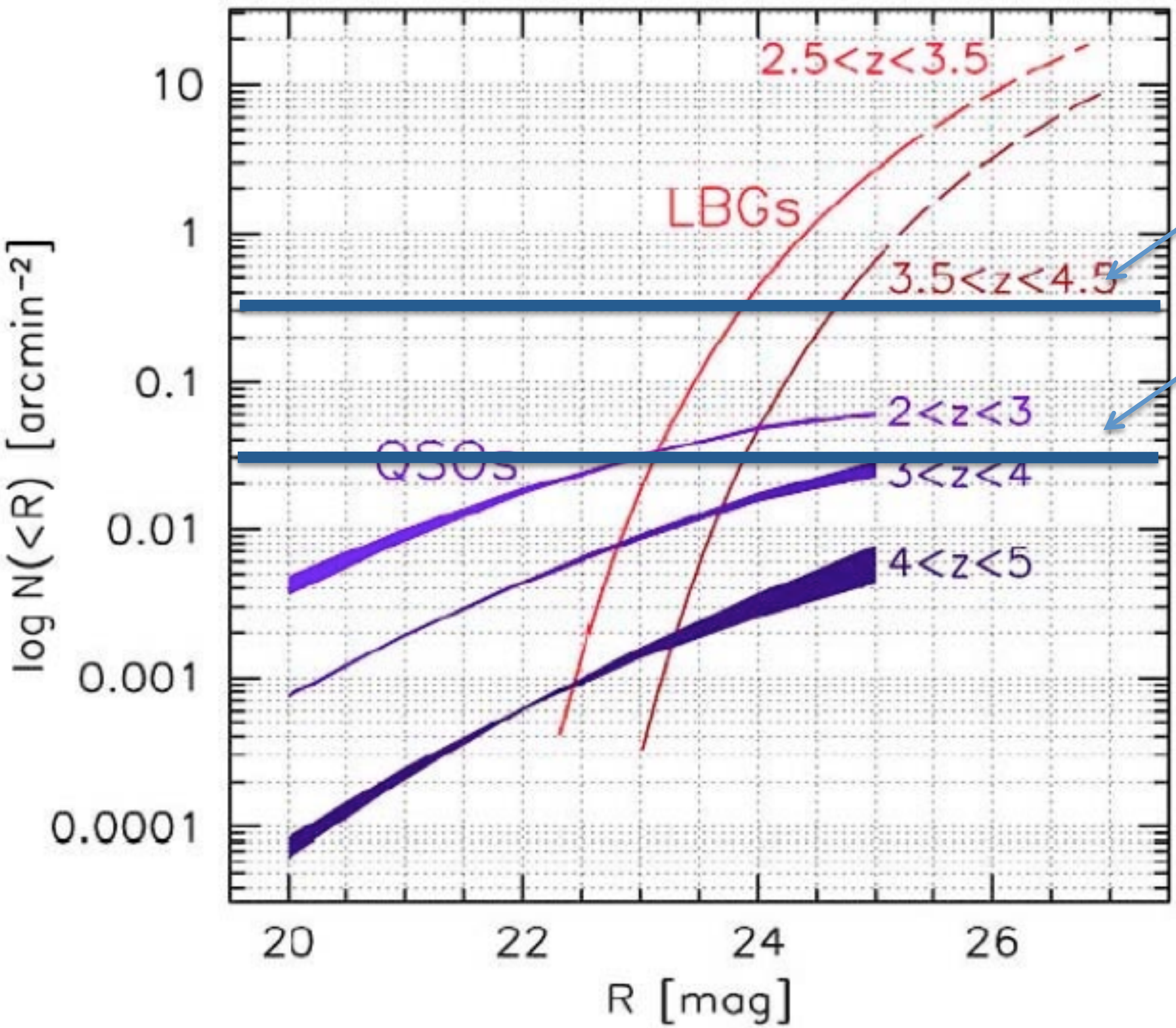


900 400 150 /sqdeg

QSOs -> 100 / sqdeg not enough

With LBGs => Density field will be recovered

from Patrick Petitjean's talk at Cambridge EELT-HIRES meeting



1000/sqdeg

one object
per FoV≈

Lyα-Tomography of the Intergalactic Medium with the E-ELT

Resolution:

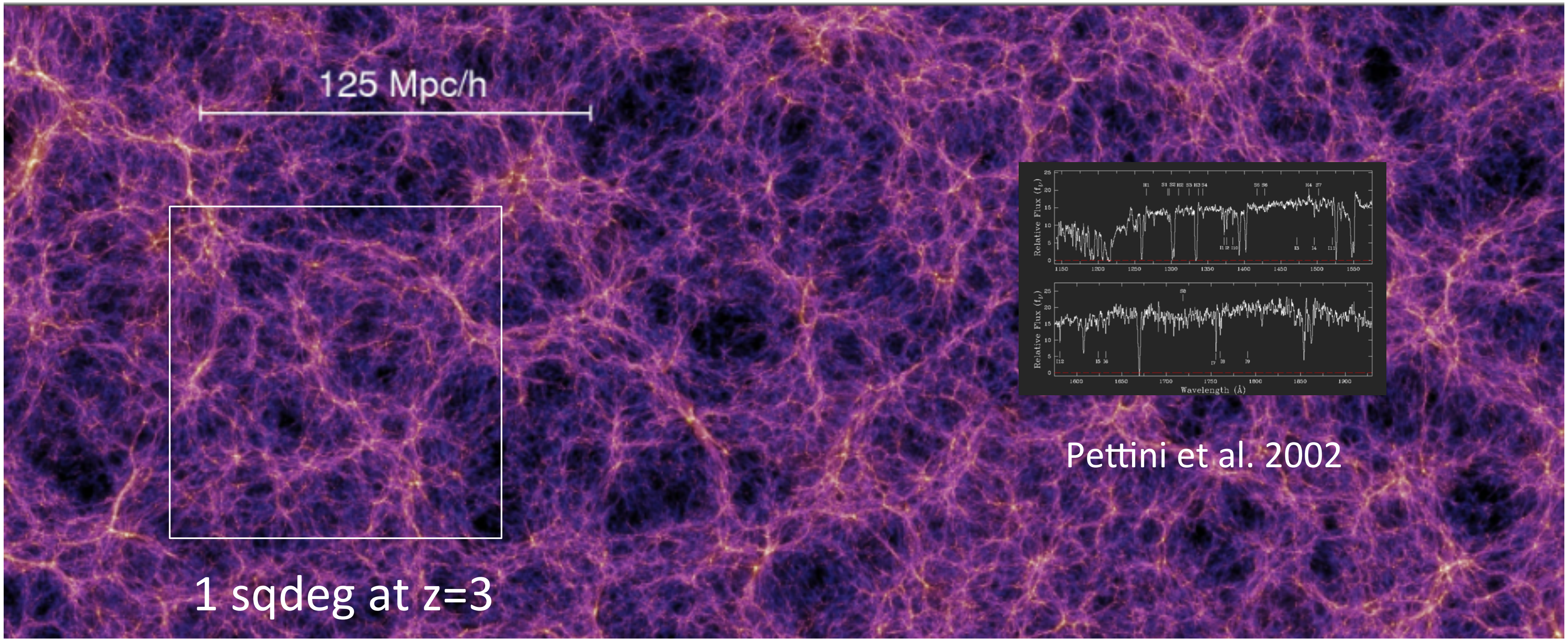
Compromise of resolving the Jeans mass along the line-of-sight and mapping a large enough aera (1sqdeg, or more partially covered along filaments) with a reasonable amount of observing time (300-500h). R≥10000 appears optimal.

Multiplex:

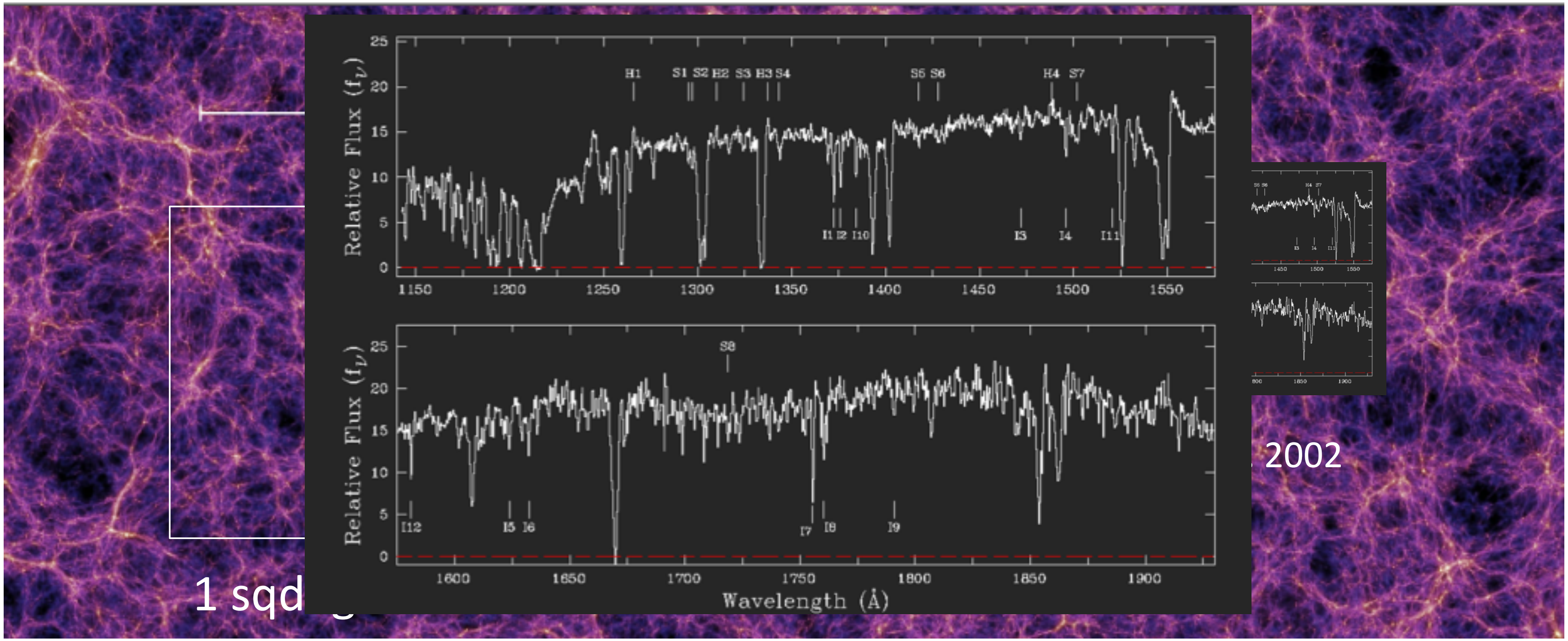
Compromise of marginally resolving the Jeans mass perpendicular to the line-of-sight and to map a large enough aerea. Multiplex of 10-20 to capture LBGs down to R= 24 appears optimal.

Wavelength:

Blue sensitivity helps to push to low redshift. For tomography of large-scale distribution of metals , extension to the near-IR is essential.



A square degree sampled with 1000 spectra of the quality of that of CB58



A square degree sampled with 1000 spectra of the quality of that of CB58

Summary

- Tomography of the IGM/CGM will allow us to properly understand the baryonic life cycle of galaxies and will be the tool of choice for unraveling how stellar and AGN feedback regulates galaxy formation. Exploitation of this science case will be very competitive.

- Tomography of the circum-galactic medium with the E-ELT requires high multiplex (> hundred) and will enable a detailed characterisation of inflows and outflows in individual galaxies.

- Tomography of the IGM with a proper reconstruction of the filamentary structure of the cosmcic web to study how the eco-cycle of galaxies relates to the large scale distribution of matter requires moderate multiplex (10-20) and intermediate, but still reasonably high resolution (> 10000).

- Combining the two will be particularly powerful.