Building Massive Galaxies Through Cosmic Time

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The BOSS Team

IPMU, December 2010

Outline

1. IPMU Preamble. Galaxies and fundamental physics.
2. Measuring galaxy growth in BOSS.
3. Merger histories of individual galaxies.
4. Summary and prospects.

Preamble: Physics and Mathematics of the Universe

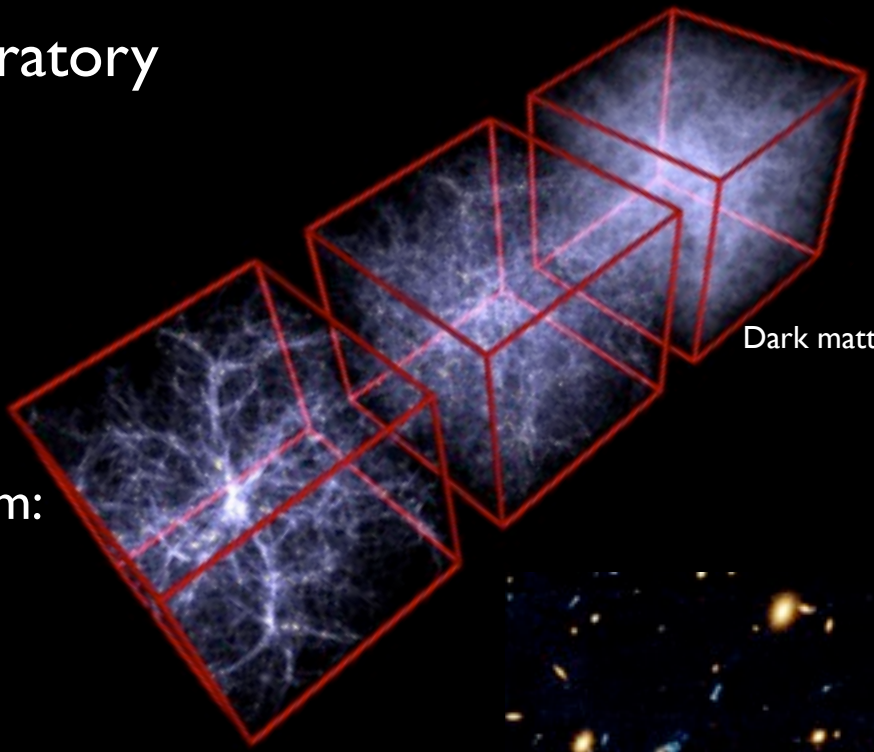
Observations?

CERN / LHC

Subaru

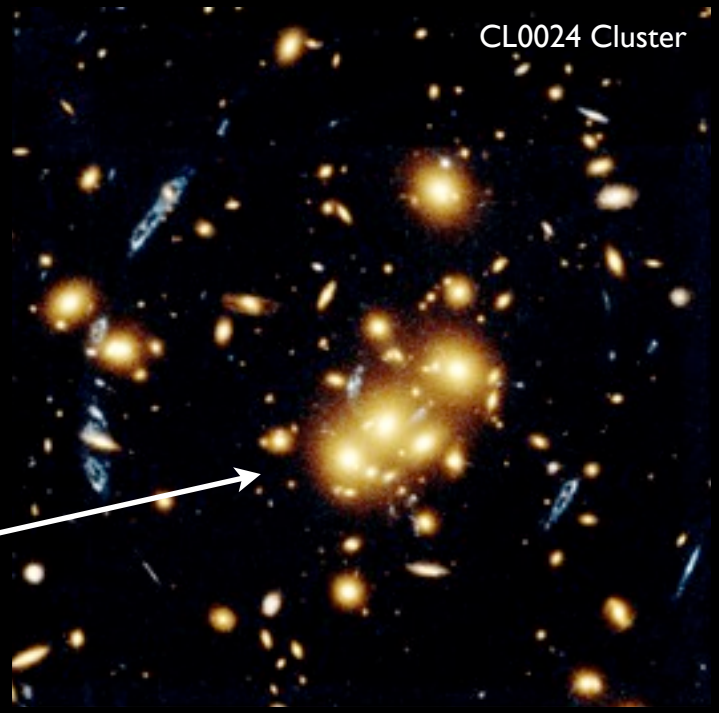
The Universe as laboratory

Subaru



Dark matter simulation

Fundamental physics from:
- expansion history
- growth of structure
- probes of the metric



CL0024 Cluster

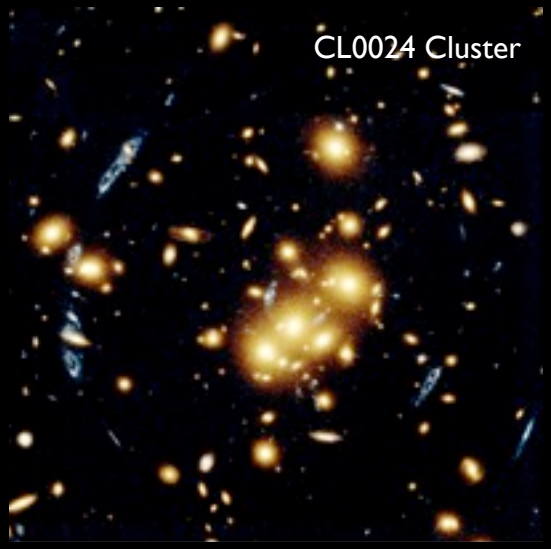
Galaxies are the observable:
- trace density field
- mass probes

Messy!

Galaxy physics will dominate systematics.

Current problems in galaxy evolution...

since z~1.5, about 9 Gyr ago



Current problems in galaxy evolution...

since z~1.5, about 9 Gyr ago

- growth and assembly through time
- relation to dark matter (bias)
- fueling of star formation (inflows)
- quenching of star formation
- star formation history (bursty? smooth?)
- morphology and morphological evolution
- role of galaxy-galaxy mergers
- role of active nuclei
- role of environment and local density
- outflows of gas

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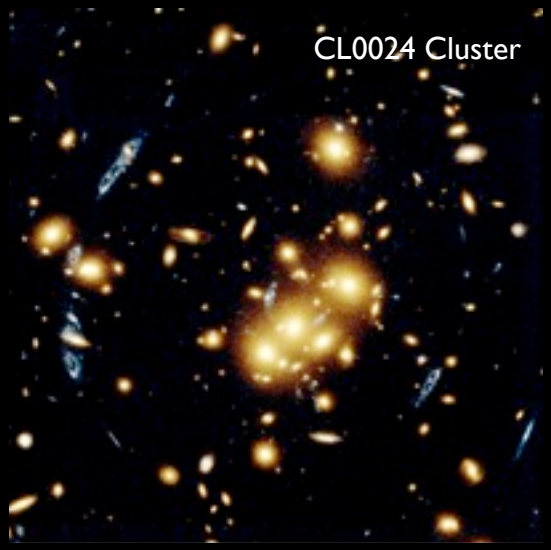

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See: weak lensing GR & cosmology to follow

How are massive galaxies built through cosmic time?

1) Do they grow hierarchically and at what rate?

Following LCDM and dark matter?

2) What processes drive or inhibit growth?

The most massive galaxies are centrals

Mergers, feedback, environment...

How are massive galaxies built through cosmic time?

strategy

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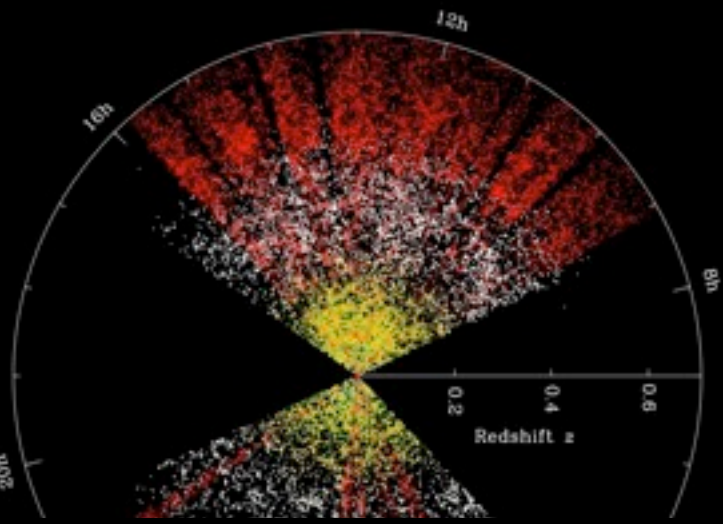
large surveys →



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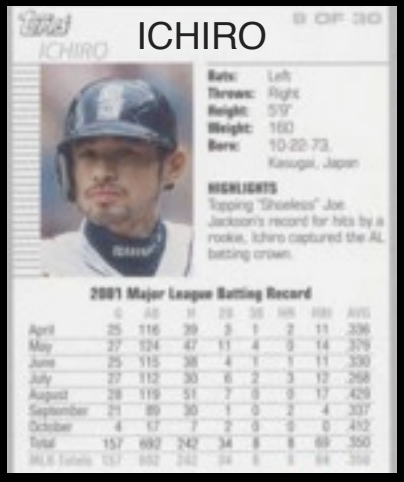

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Hierarchical LCDM dark matter assembly

Note: comoving (expanding) coordinates

Millennium, Springel et al. 2005

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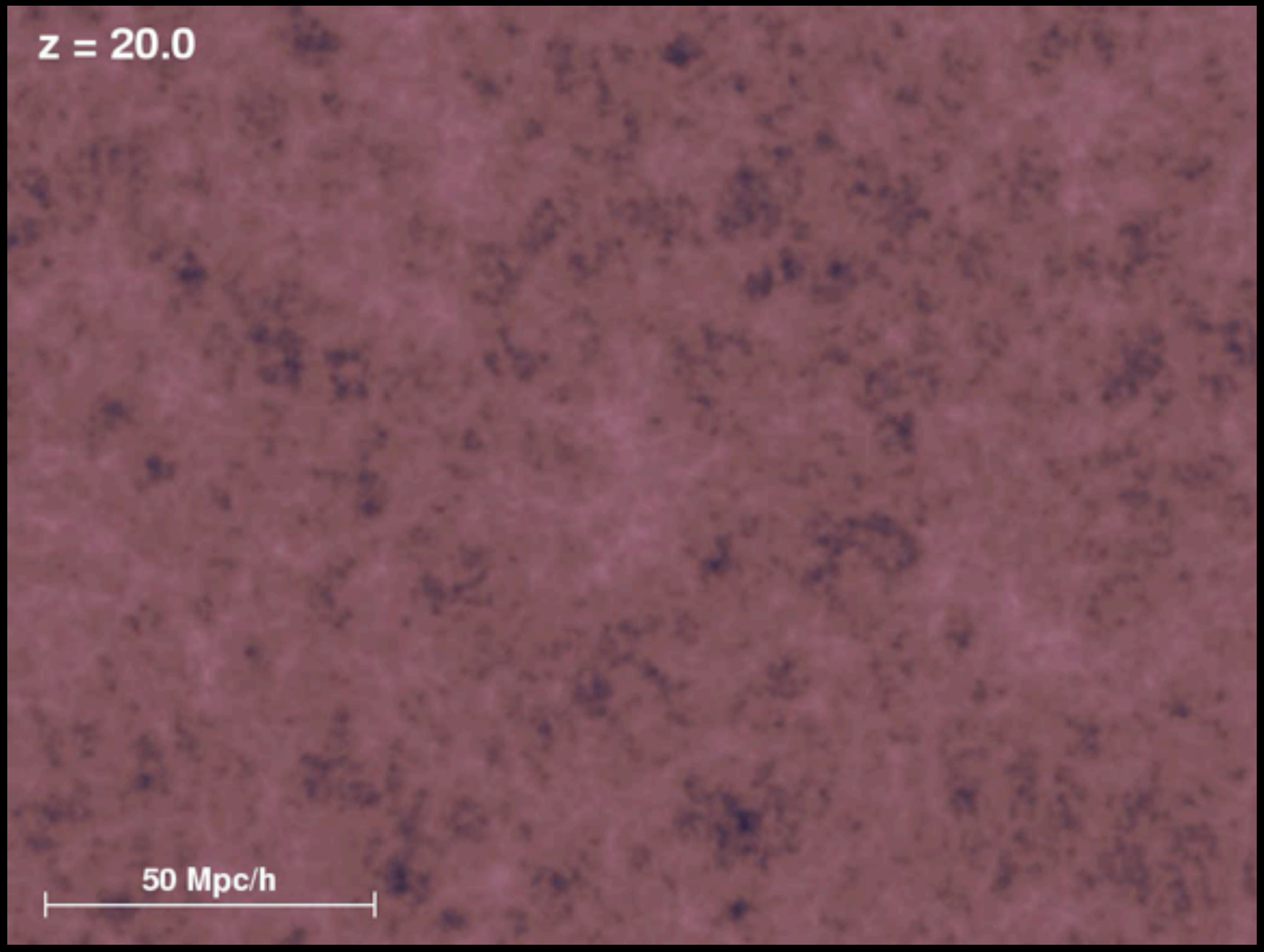

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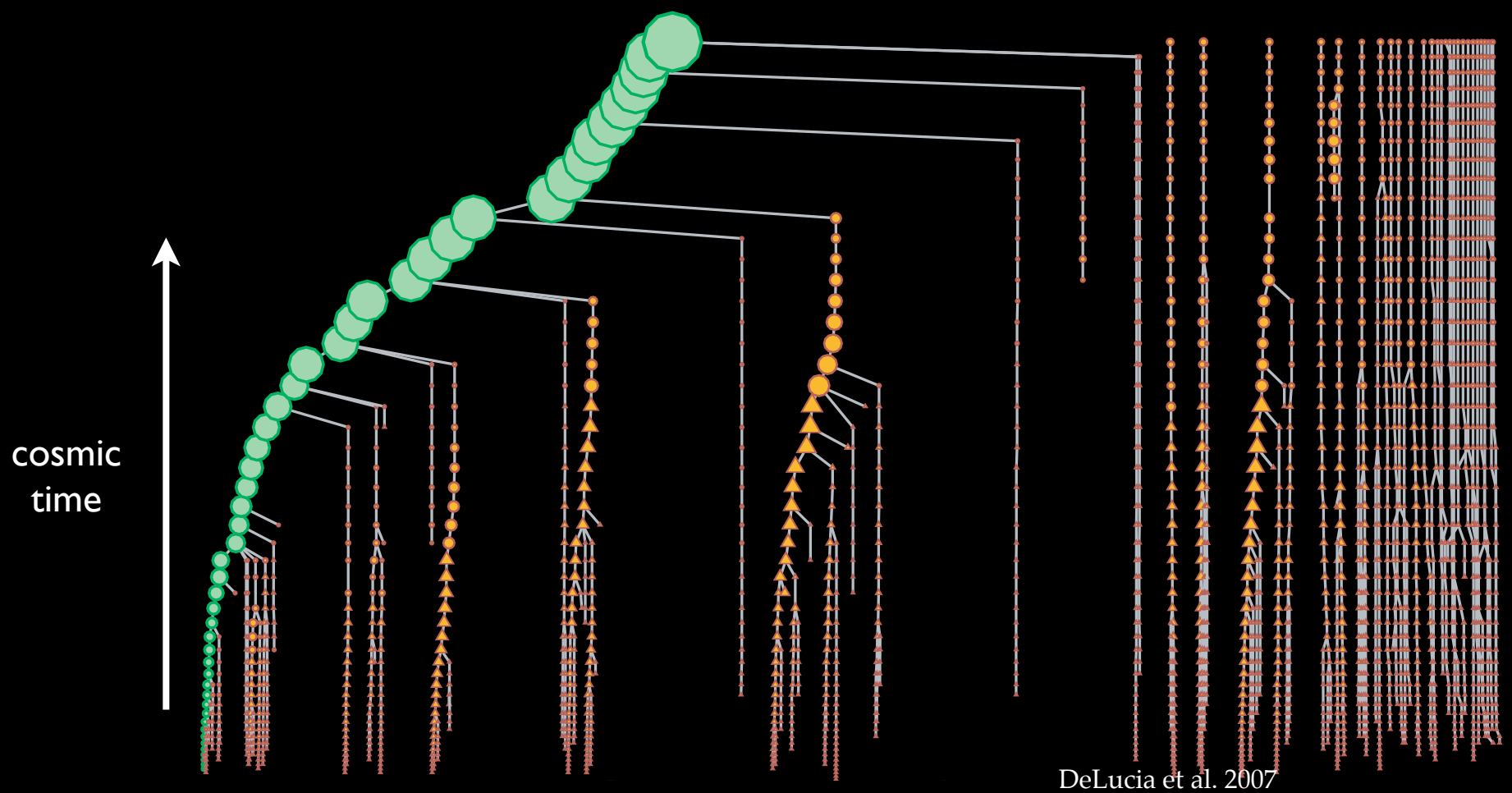
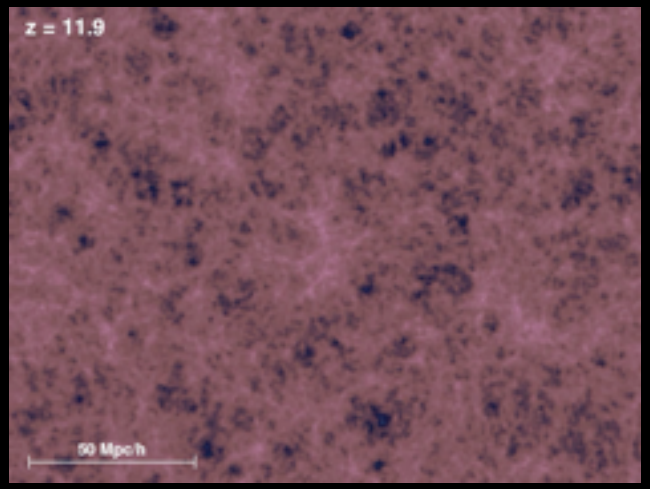
Assembling dark matter halos

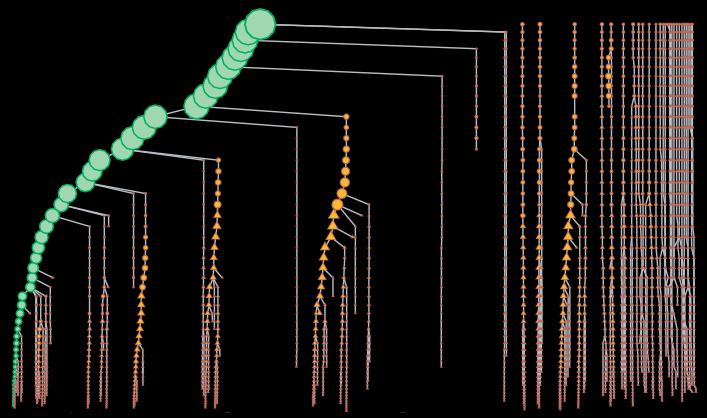




Assembling dark matter halos

cosmic time

DeLucia et al. 2007



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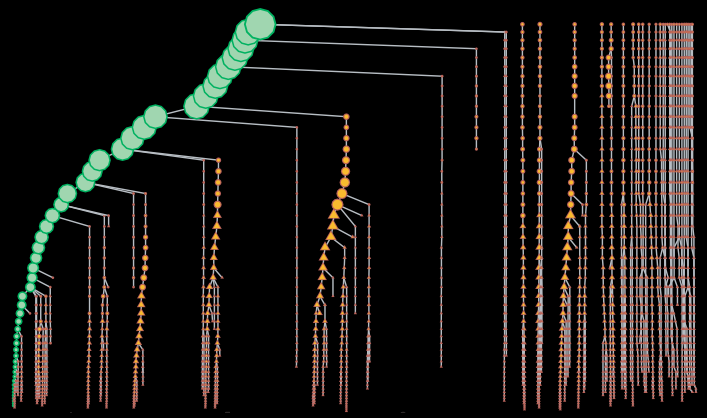
... drive the assembly of galaxies



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Example triple merger
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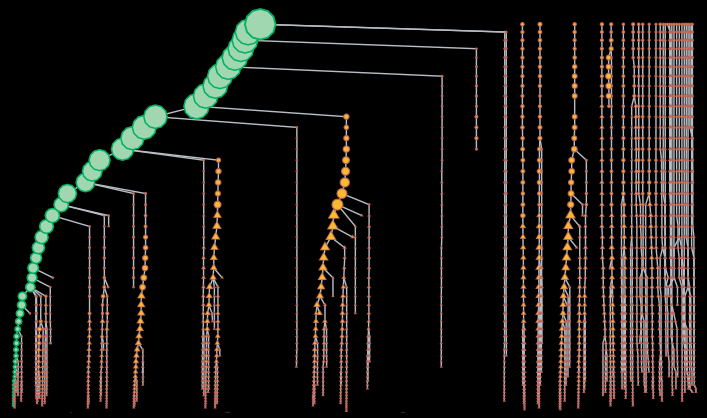

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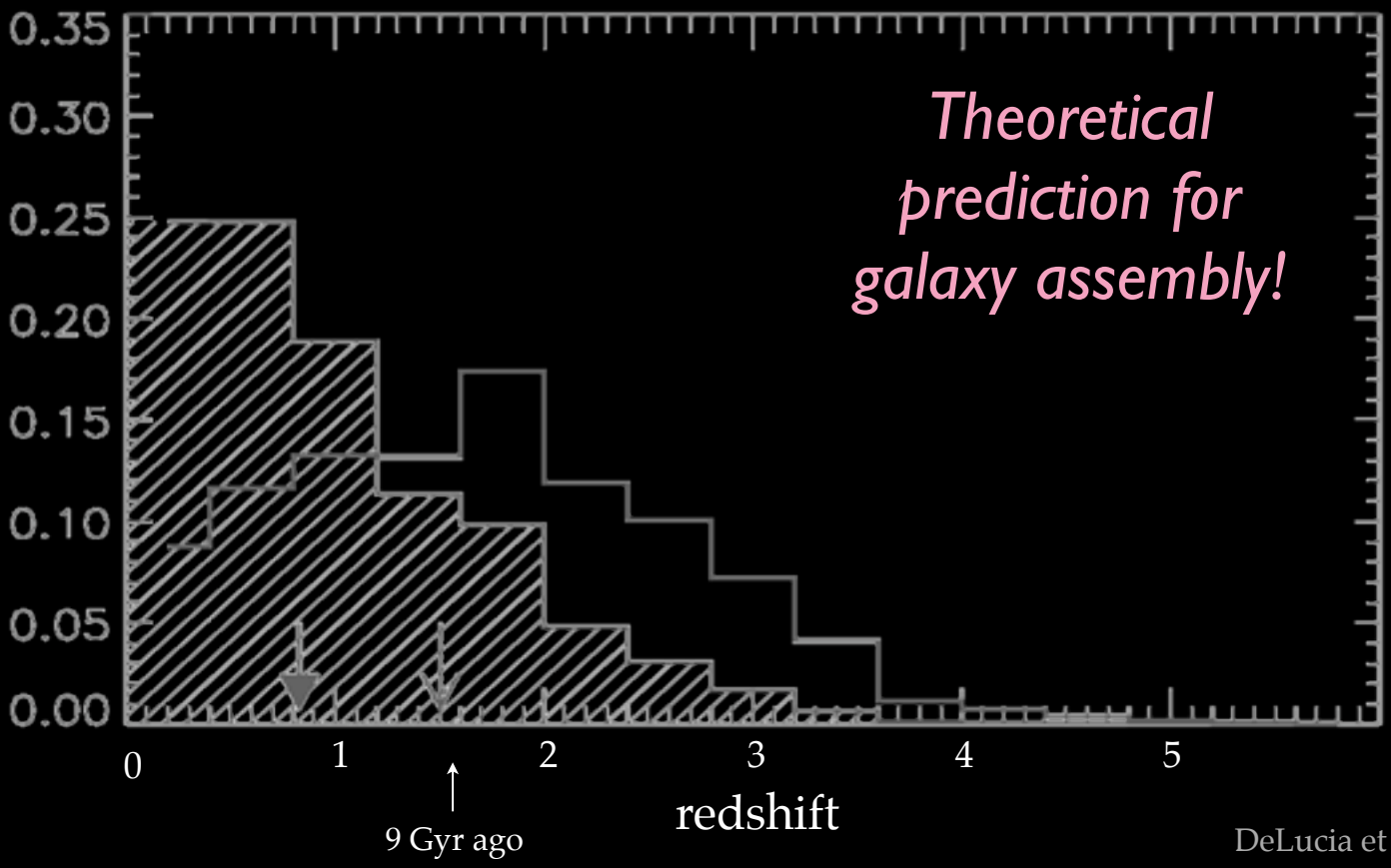
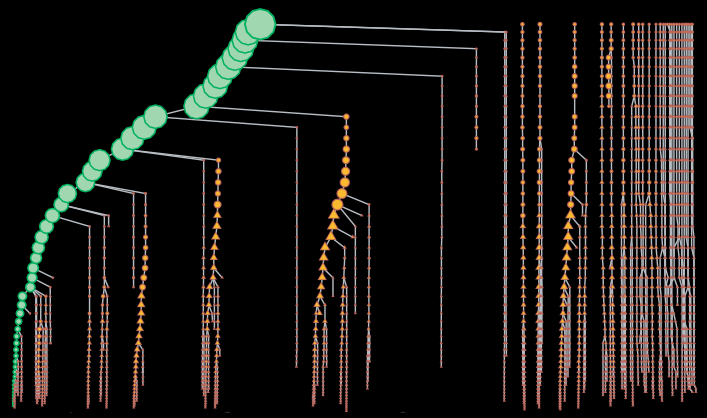


Theoretical prediction for galaxy assembly!

DeLucia et al. 2007



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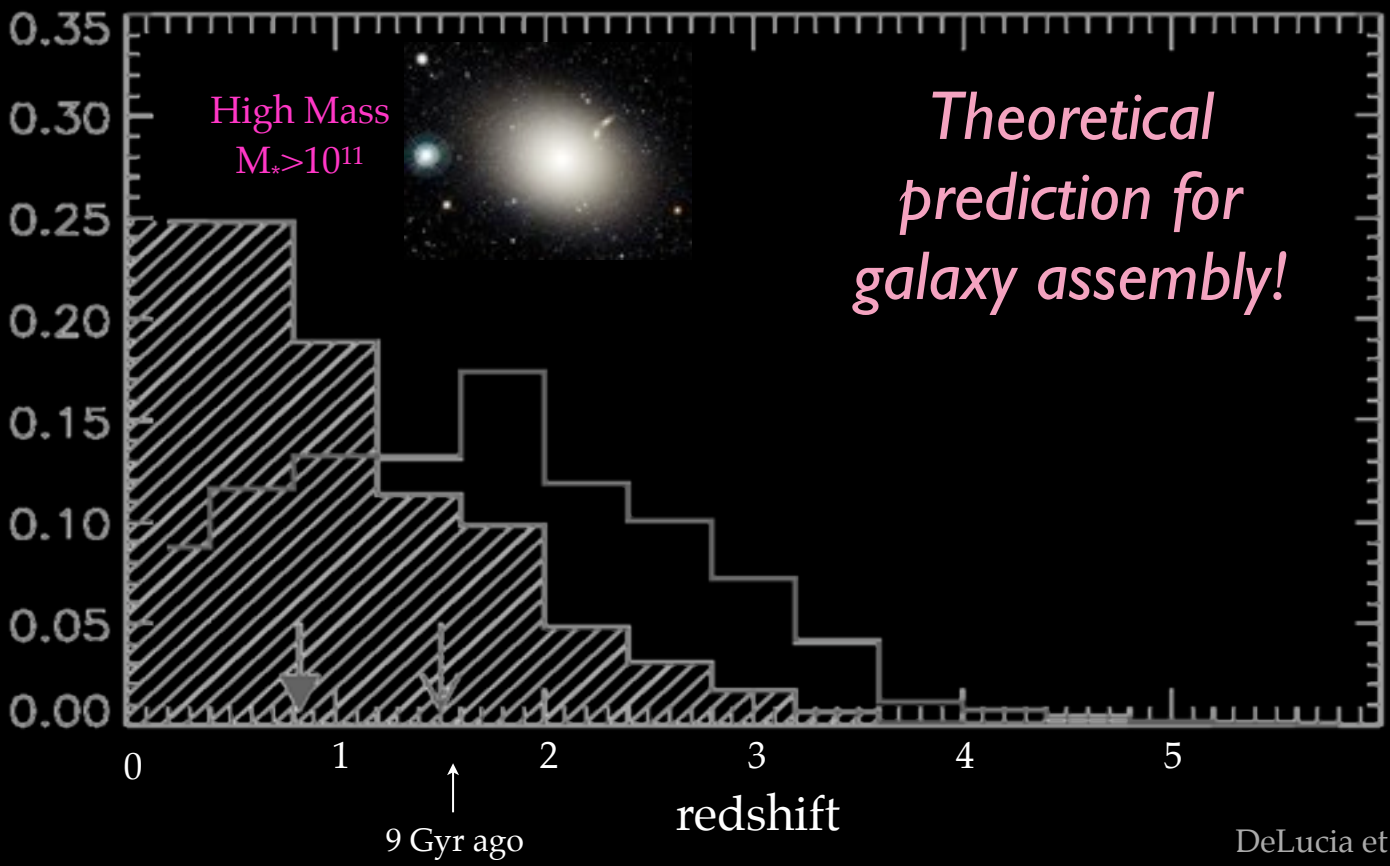

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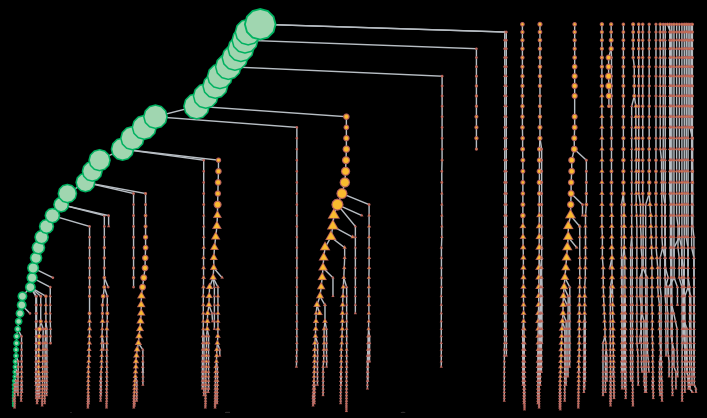

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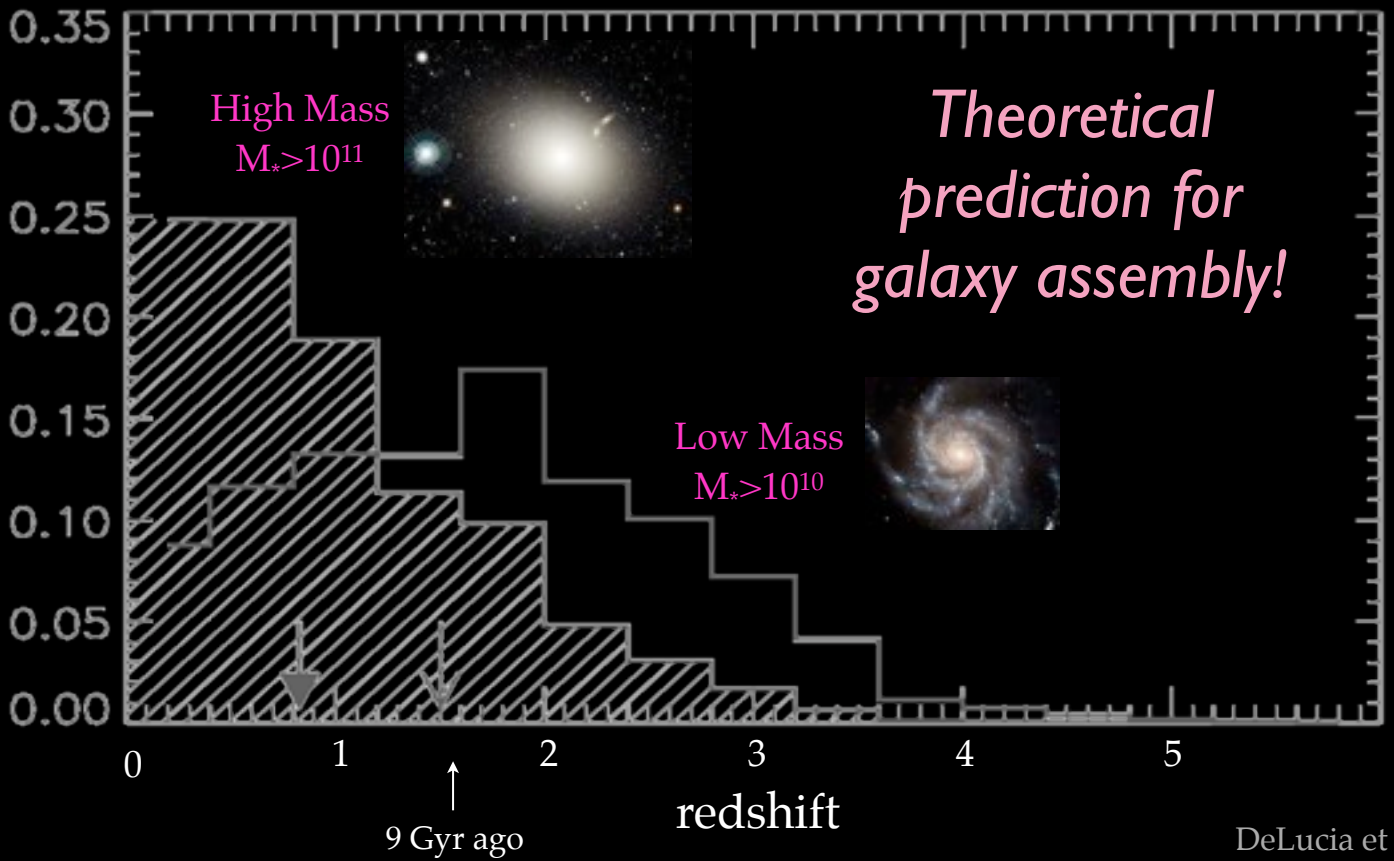

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How can we observe, test, and measure this growth?

- How do we measure mass?
- How do we measure assembly?

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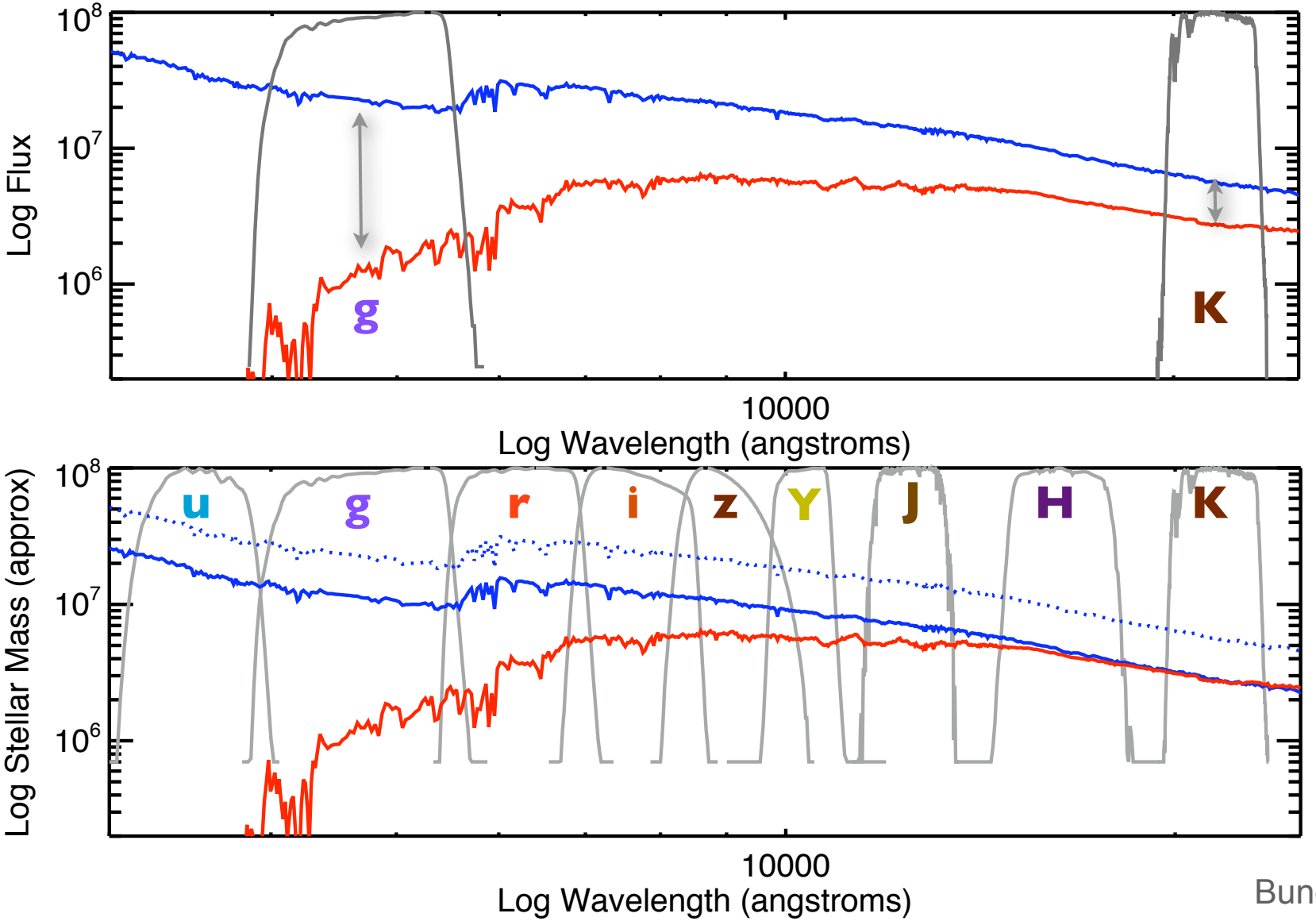
Stellar Mass Estimates



Bundy+05

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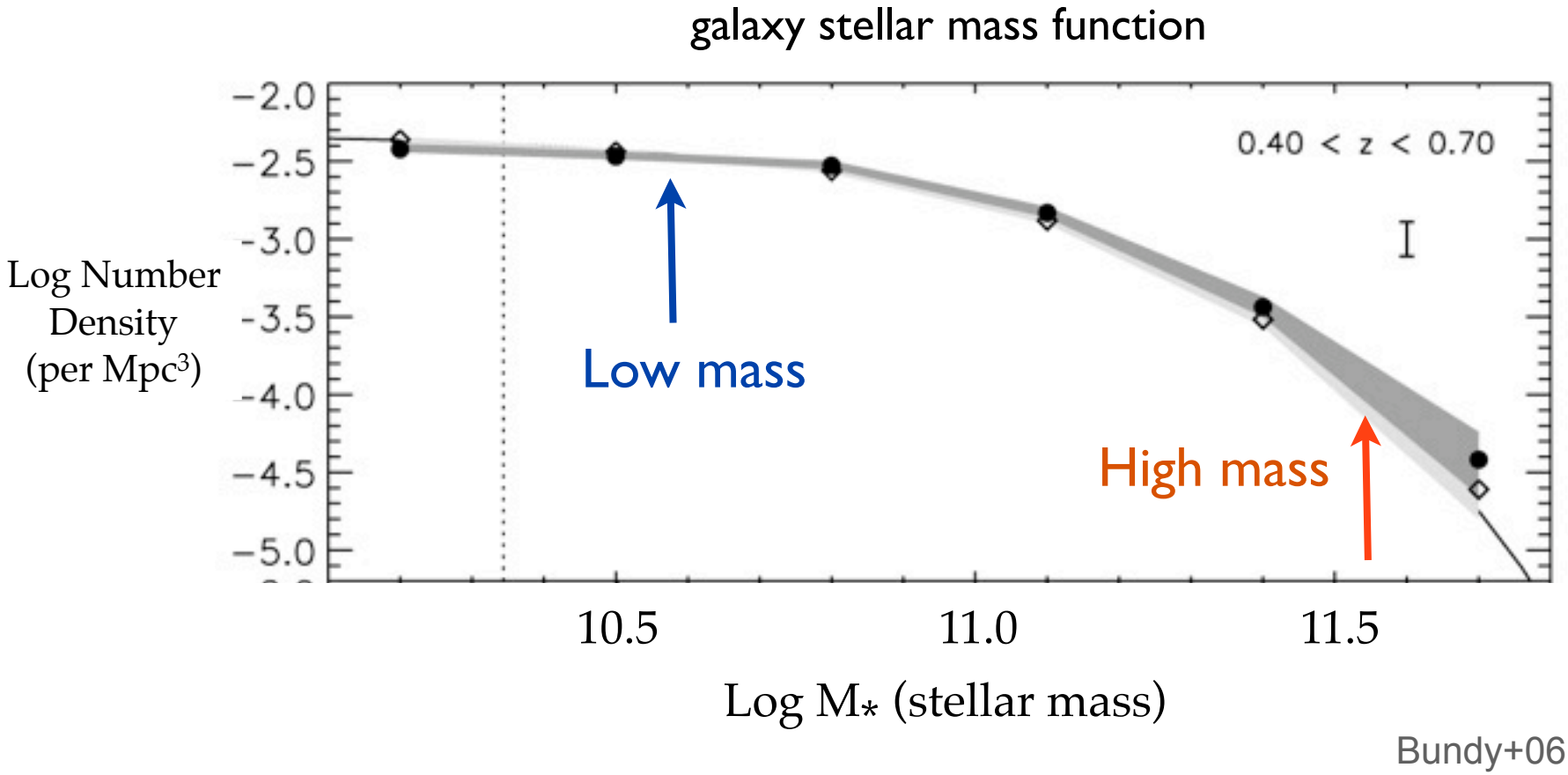

Bundy+06

Palomar/DEEP2, 1.5 deg²

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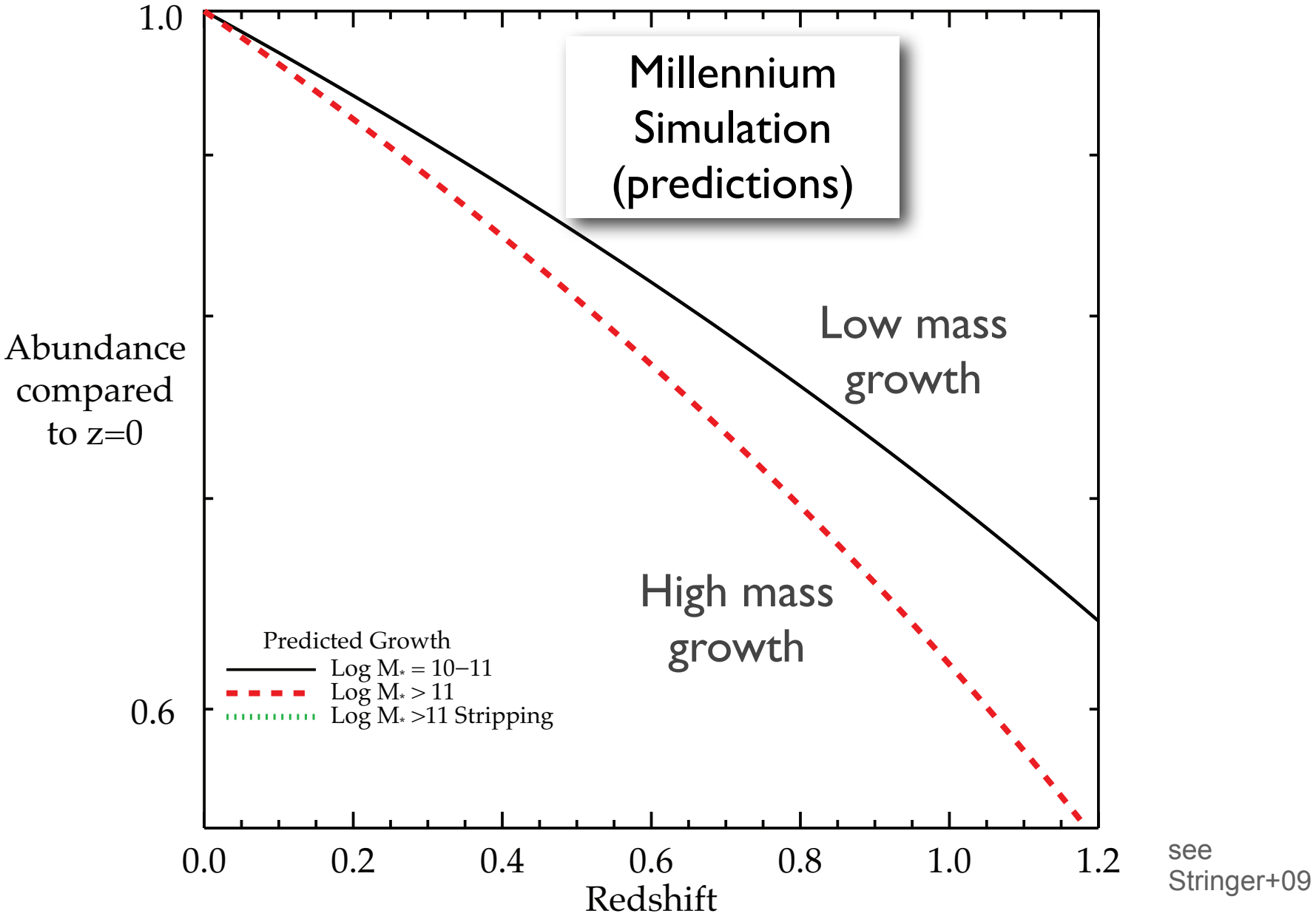

see Stringer+09

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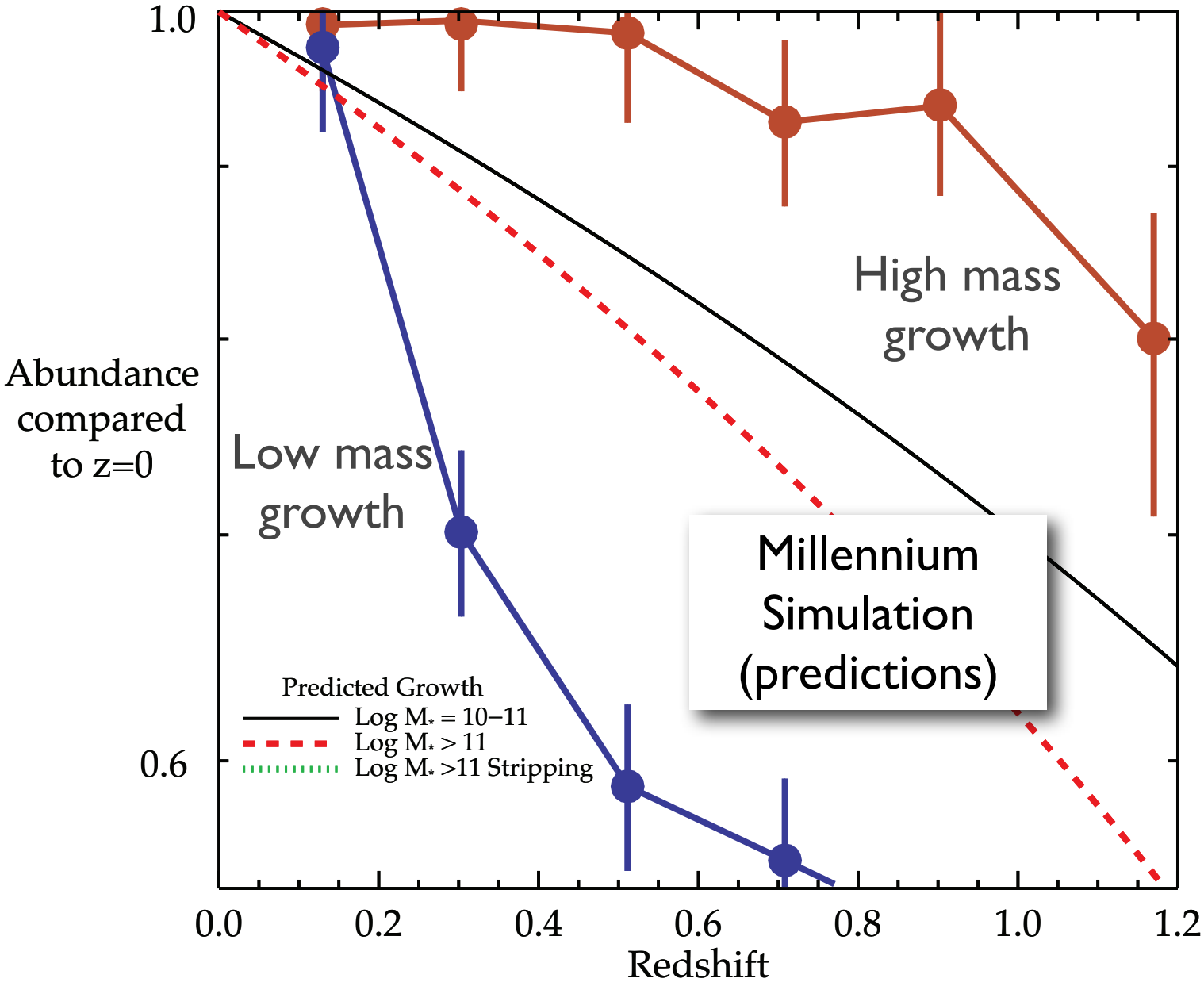

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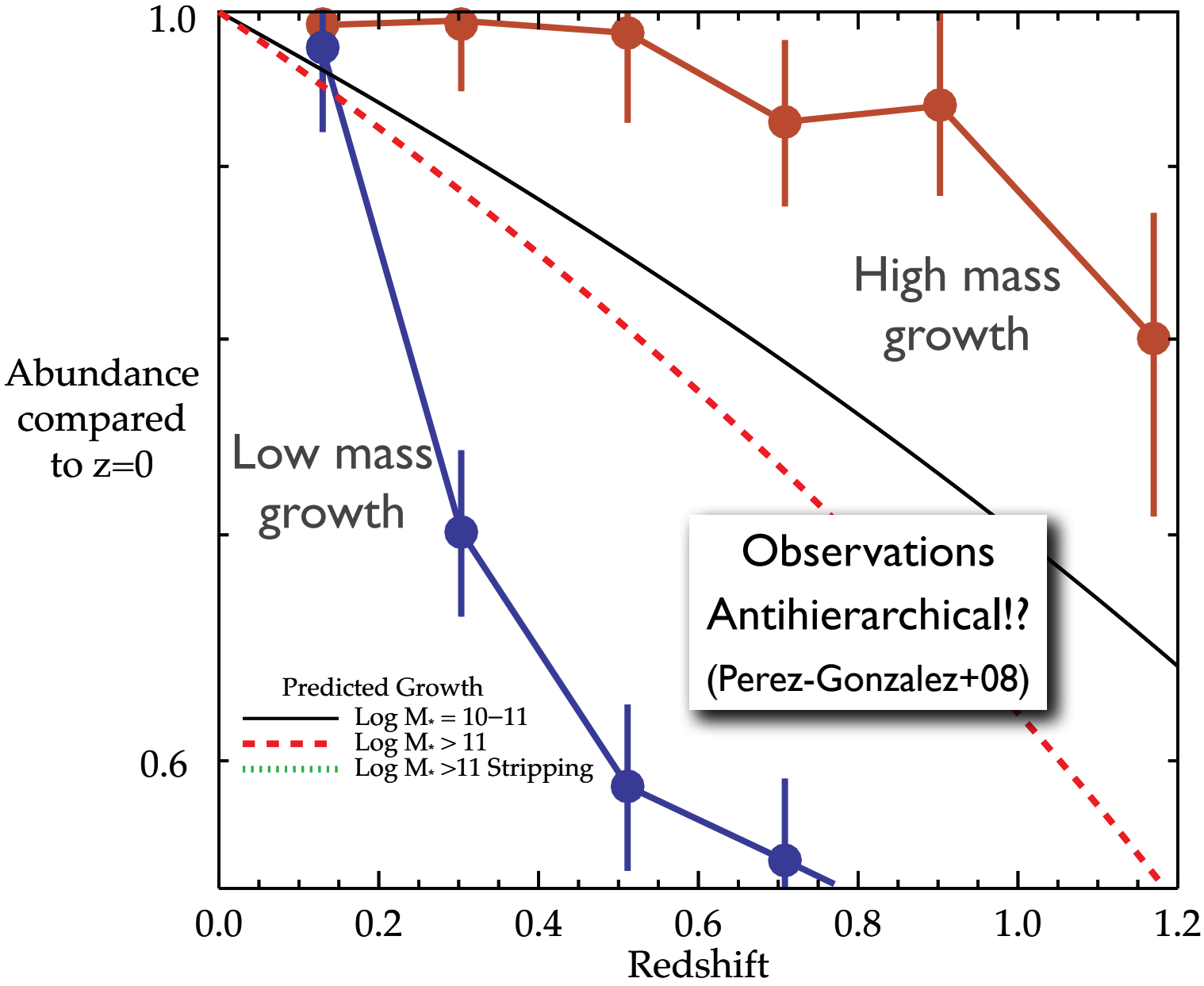

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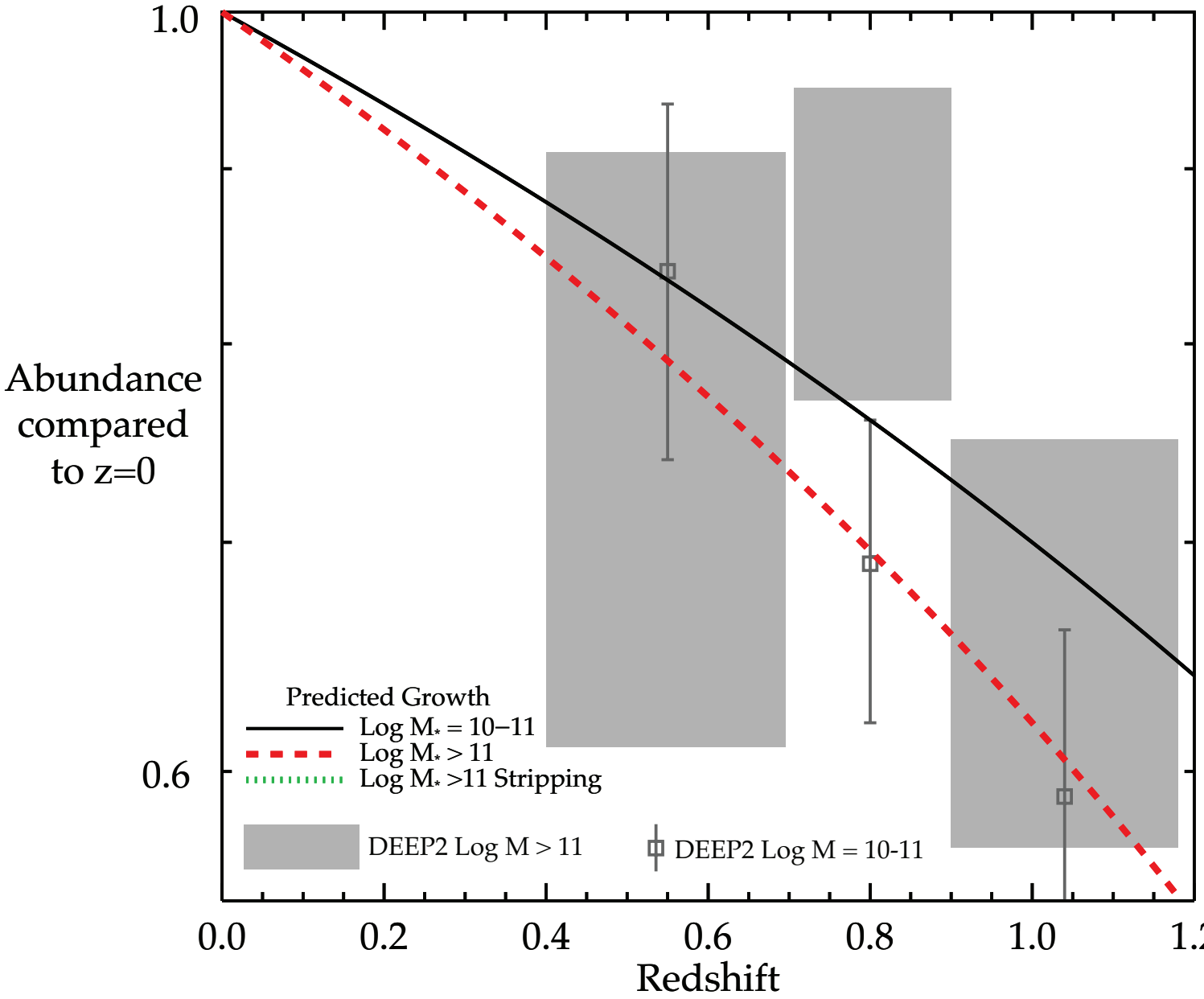

Errors now include cosmic variance from 20 mock lightcones

see Stringer+09

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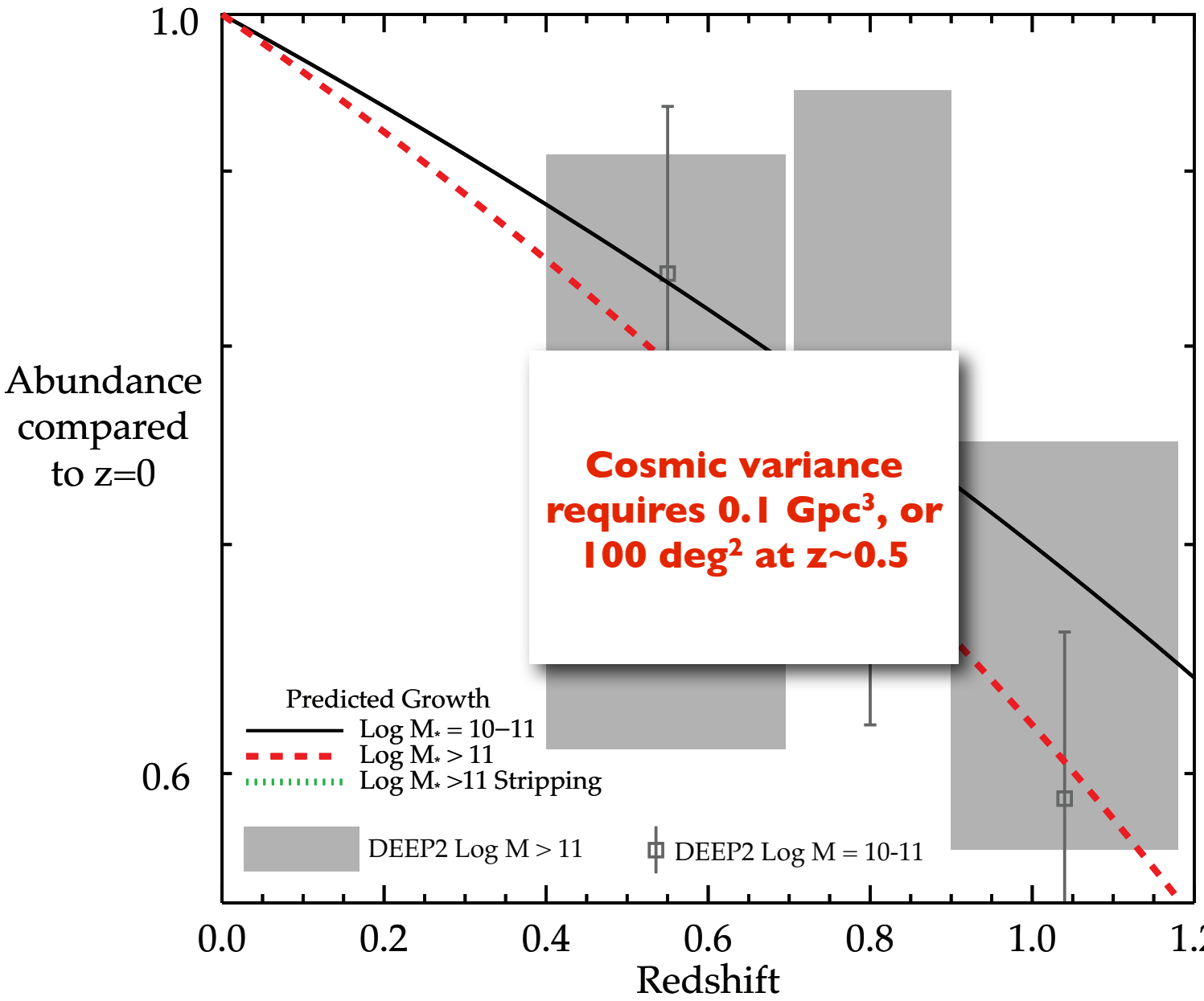

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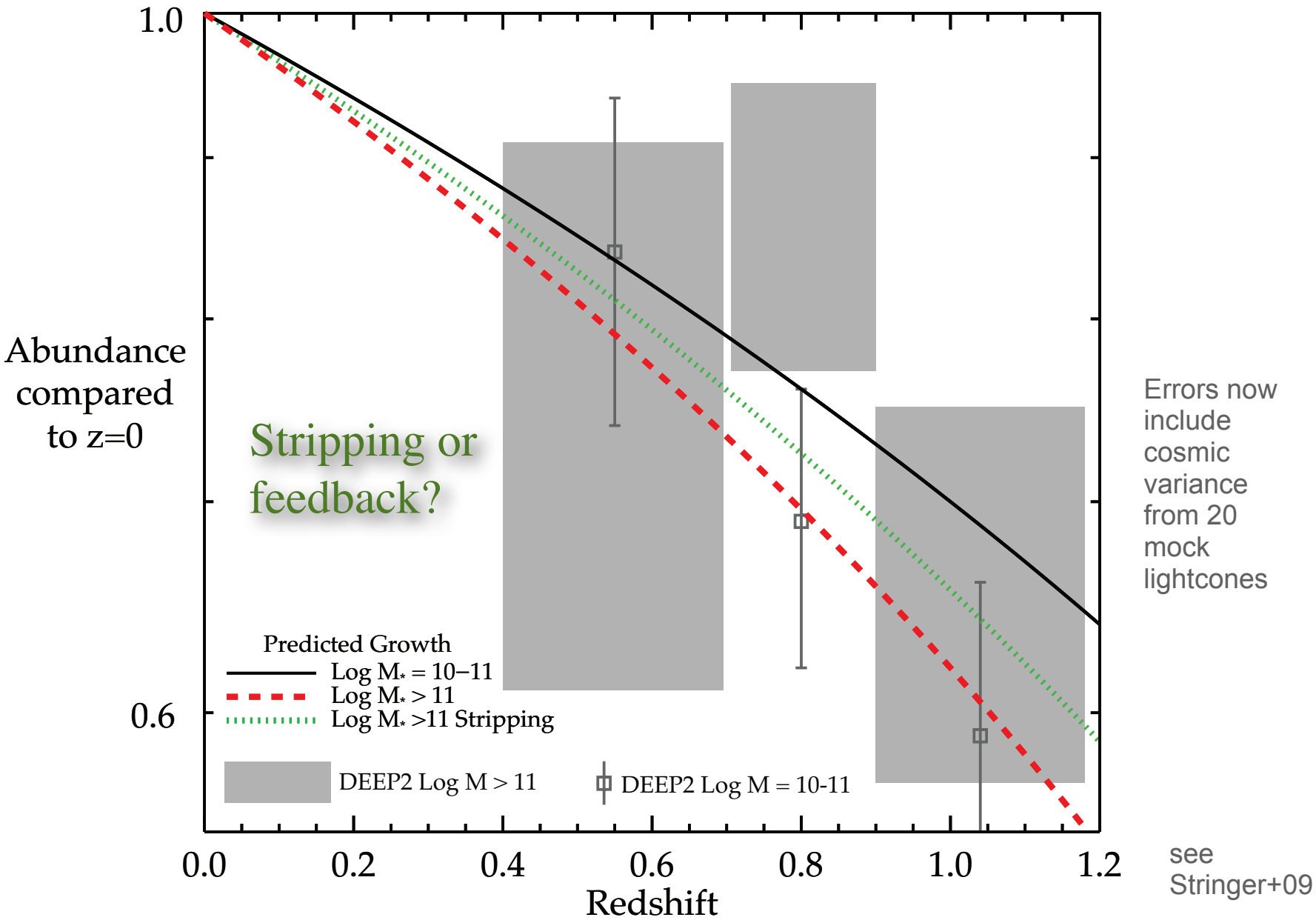

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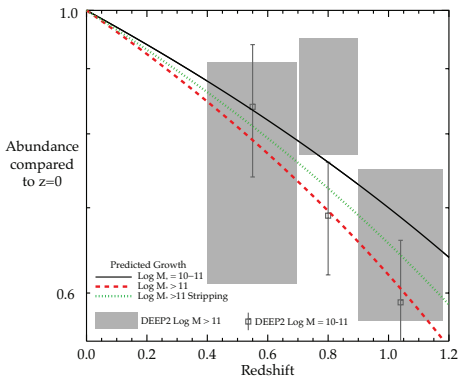
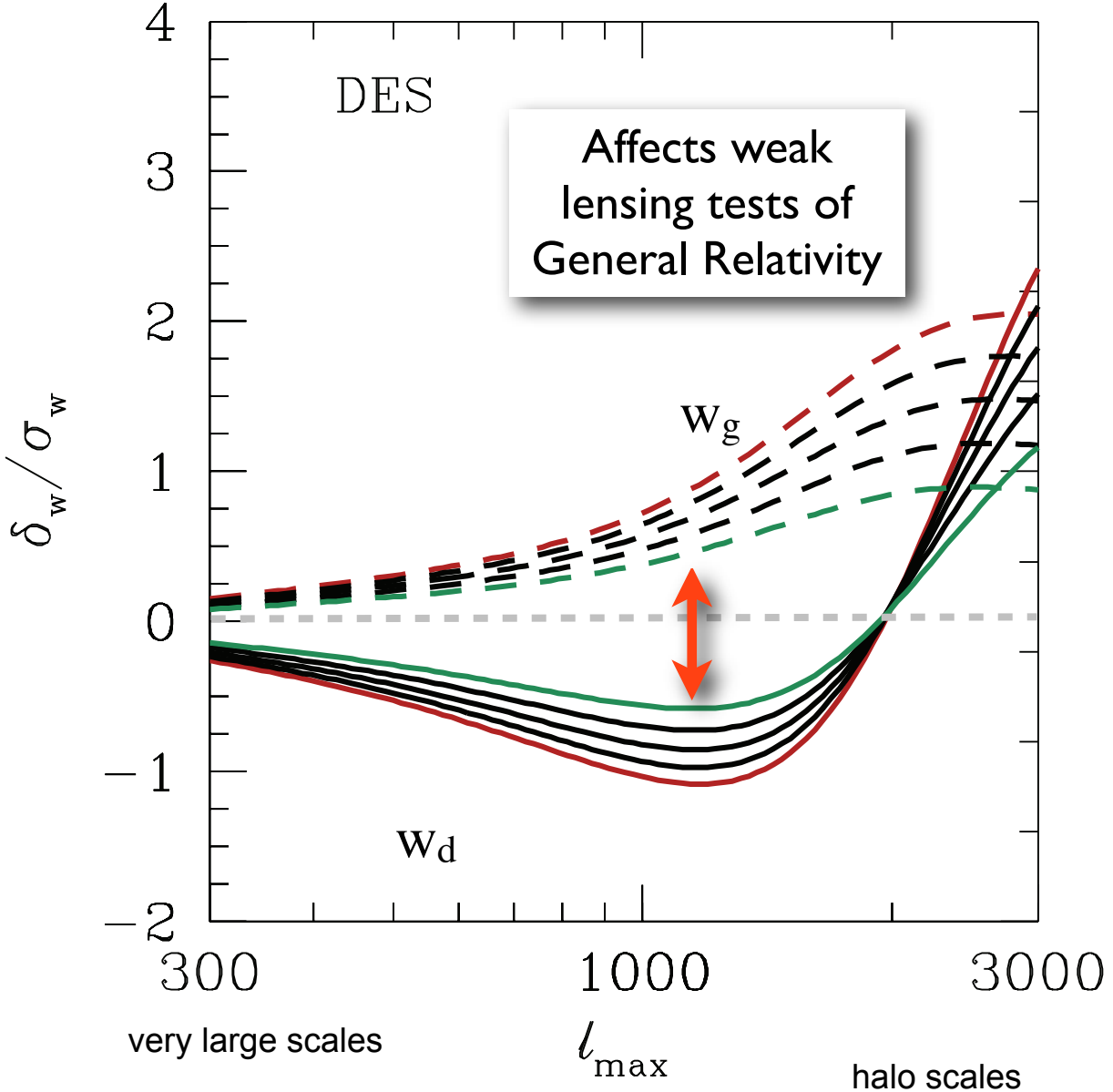
Connection to fundamental physics probes



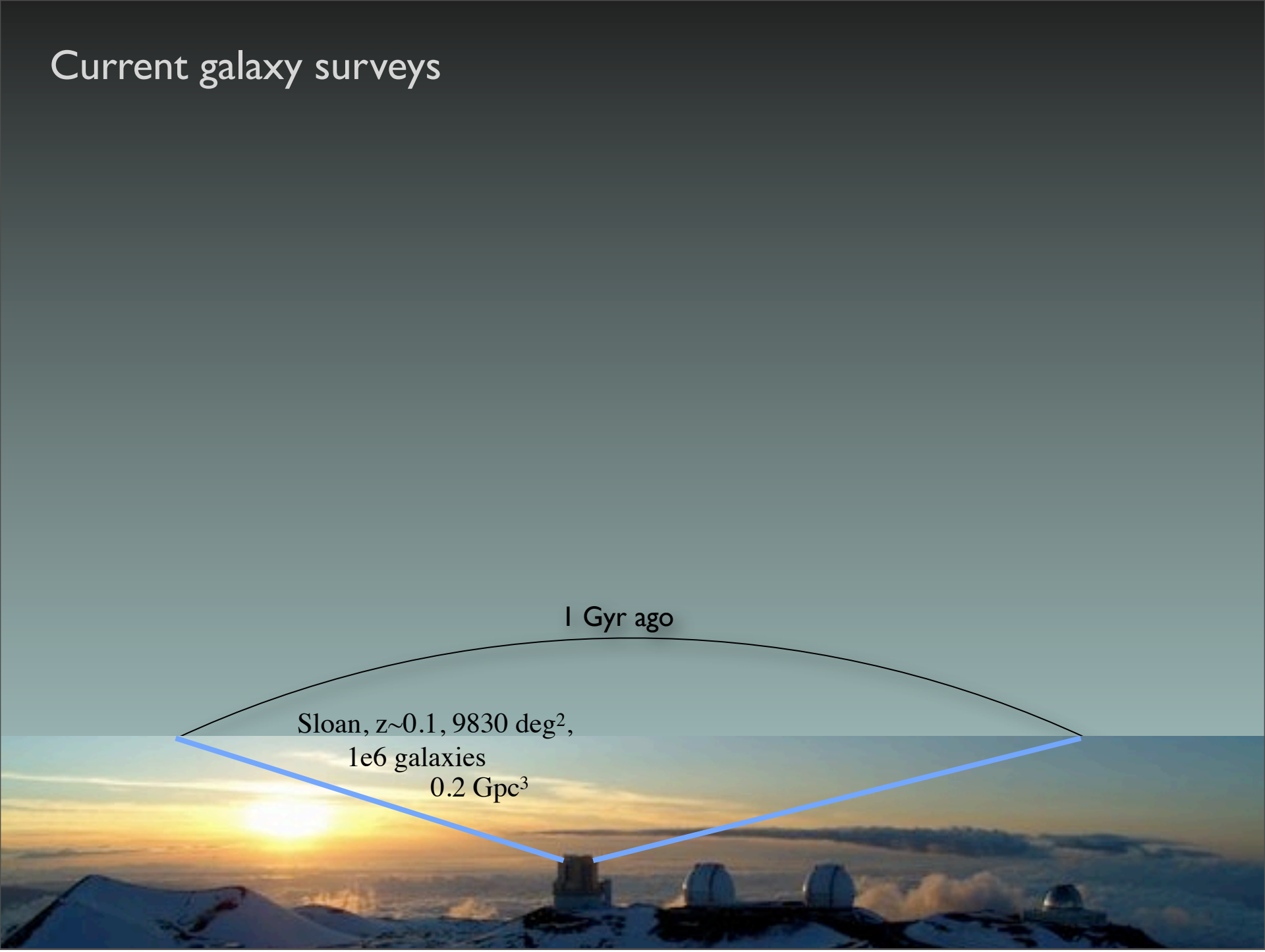
growth = merging (stripping)
+ SFR + feedback

These processes adjust total mass profiles and bias weak lensing probes of fundamental physics.



Hearin & Zentner 2009

Current galaxy surveys



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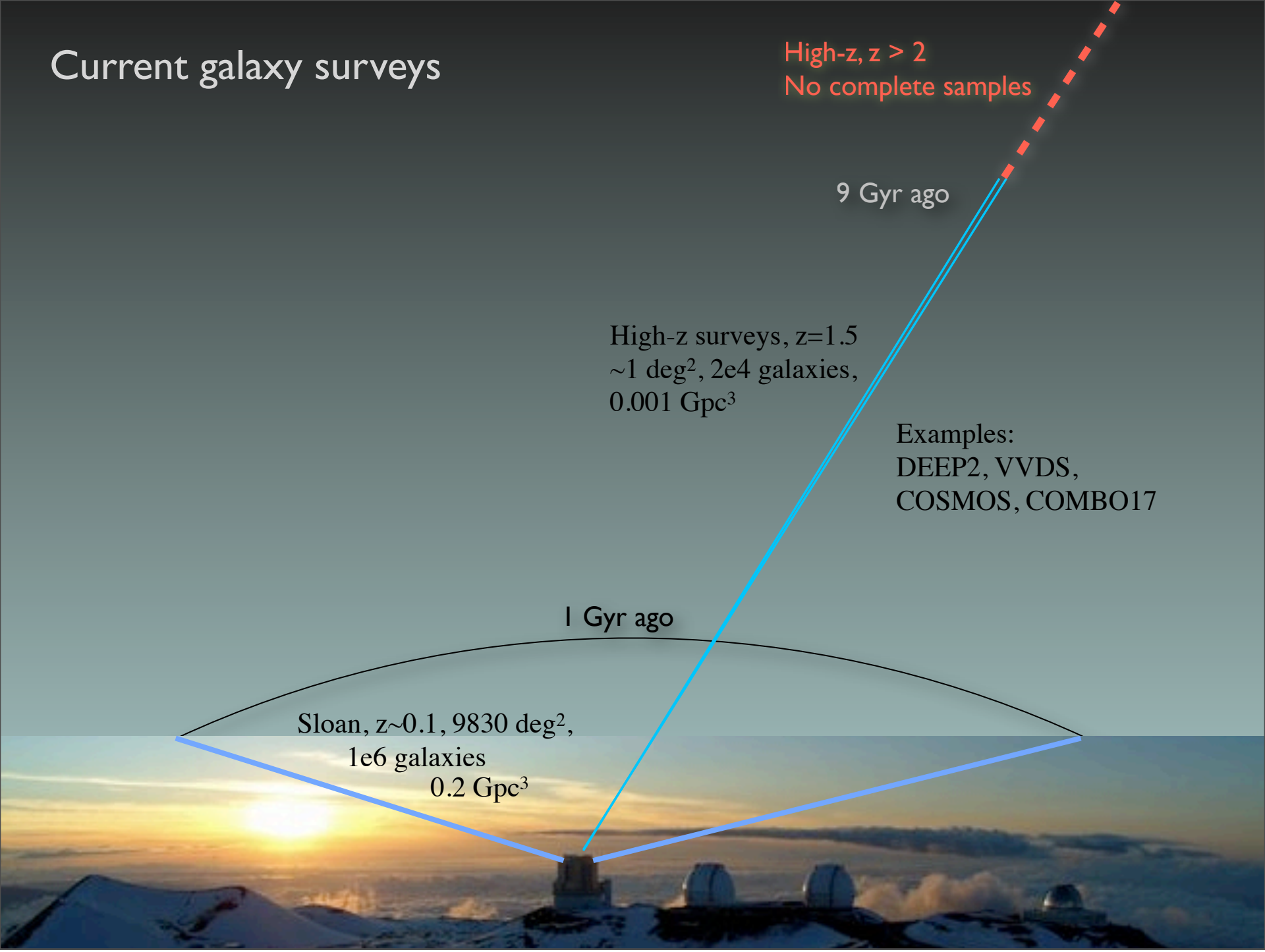


Planned surveys

LSST: construction 2016?

SuMIRe, 2011-2020?

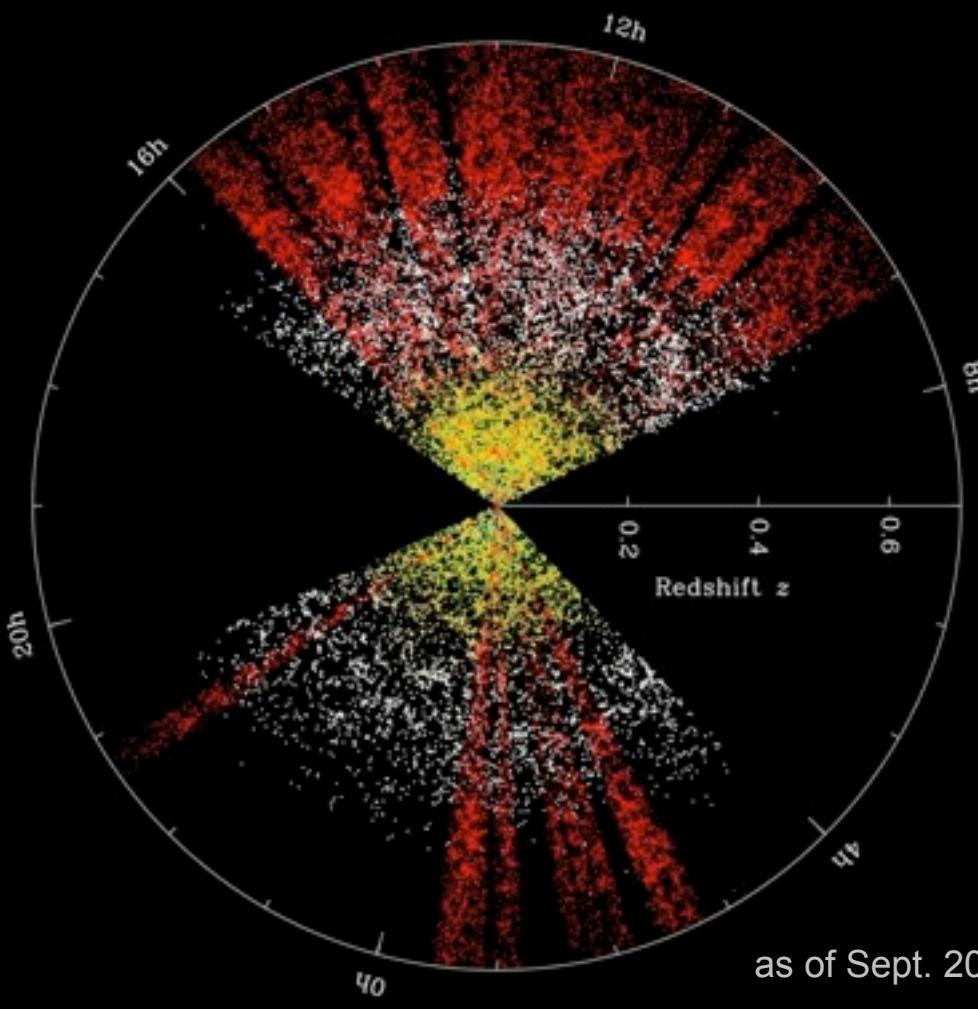
BOSS: Baryon Oscillation Spectroscopic Survey (Working NOW!)

PI: David Schlegel

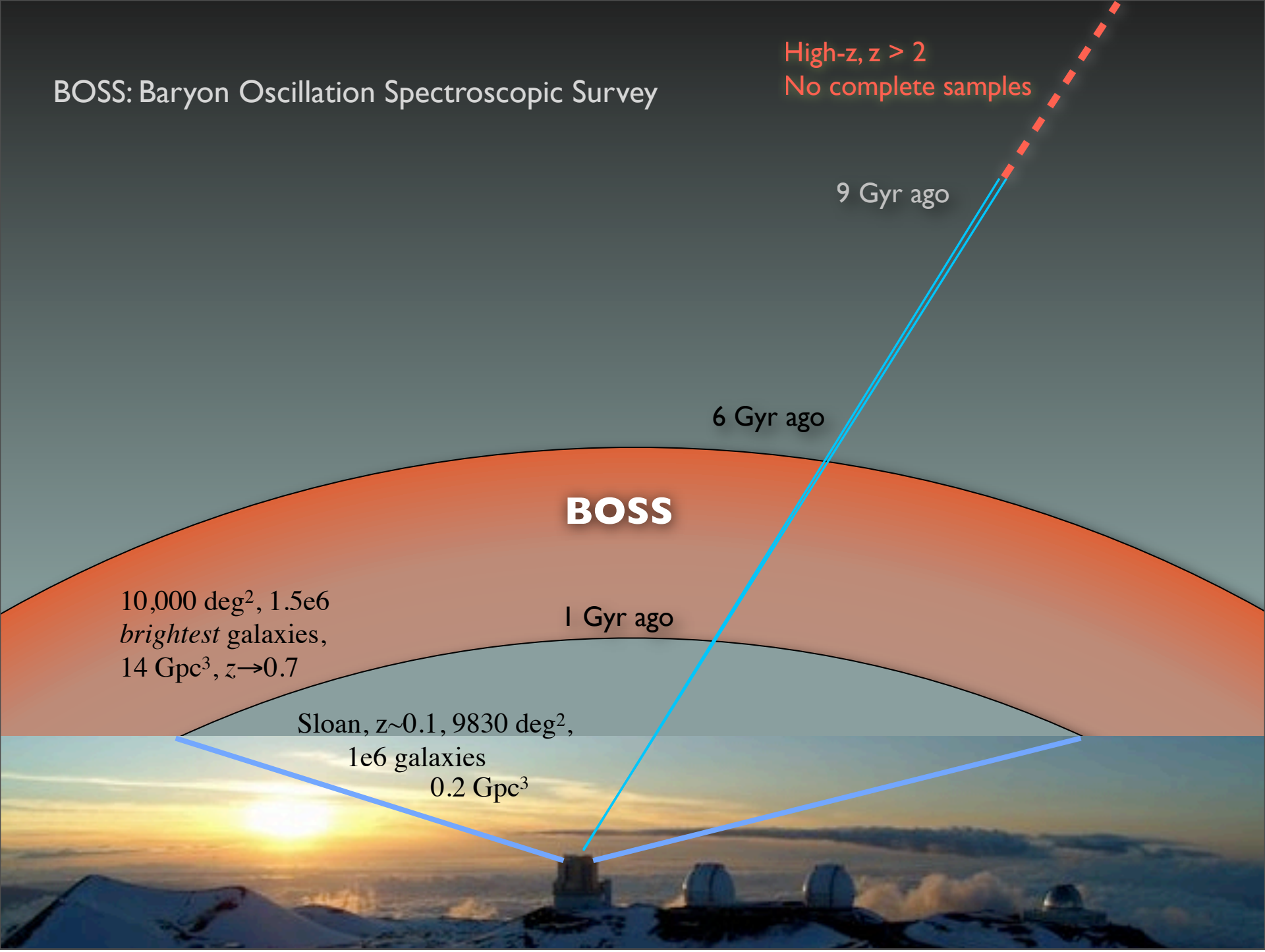
The BOSS

- SDSS-III program, better spectrographs
- 5 deg^2 plates, 1000 fibers
- 10,000 deg^2, 1.5e6 massive galaxies to z~0.7

(2.5m telescope!)



as of Sept. 2010


BOSS: Baryon Oscillation Spectroscopic Survey
High-z, z > 2
No complete samples
9 Gyr ago
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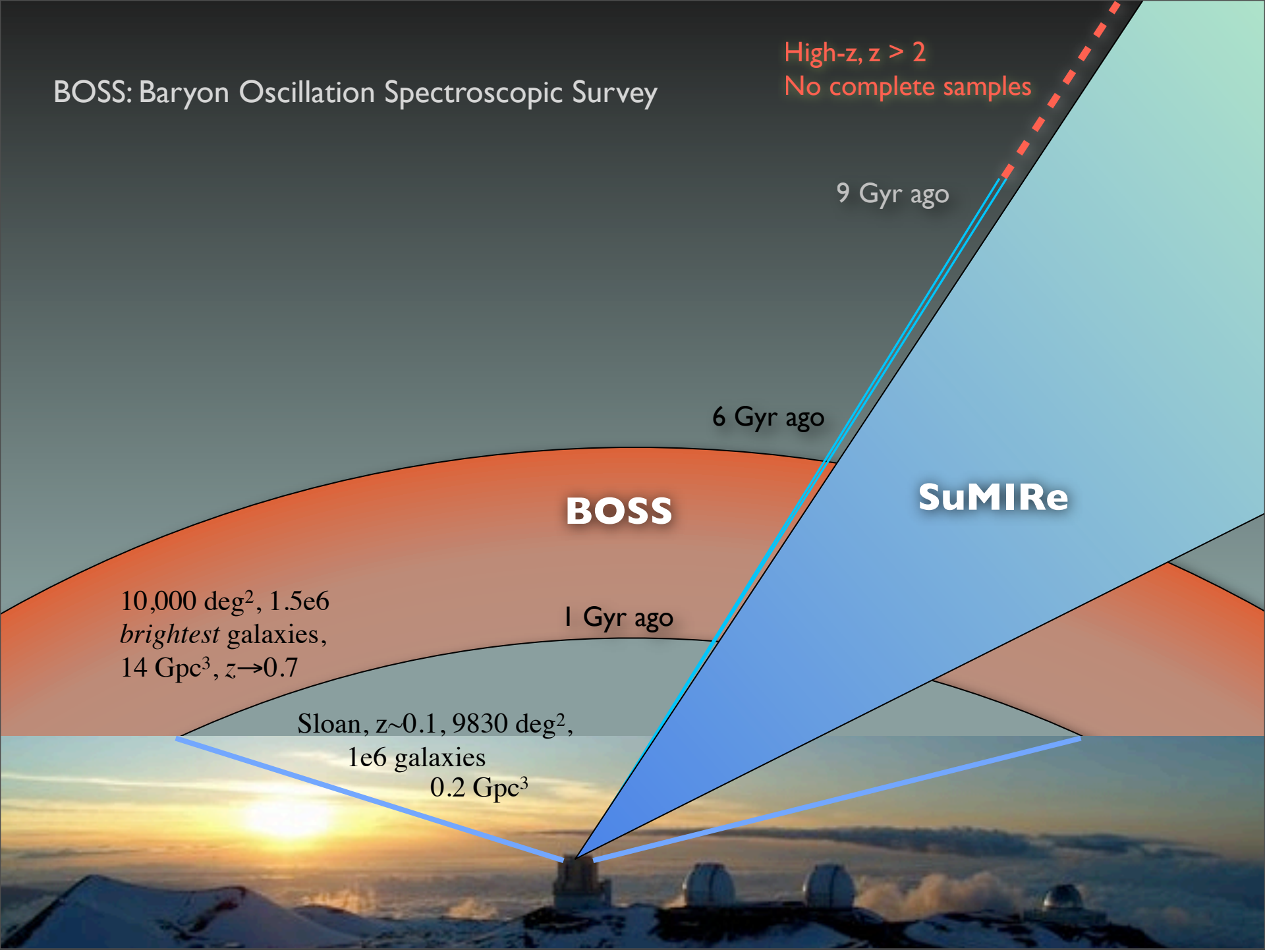
BOSS
10,000 deg², 1.5e6
brightest galaxies,
14 Gpc³, z→0.7
1 Gyr ago
Sloan, z~0.1, 9830 deg²,
1e6 galaxies
0.2 Gpc³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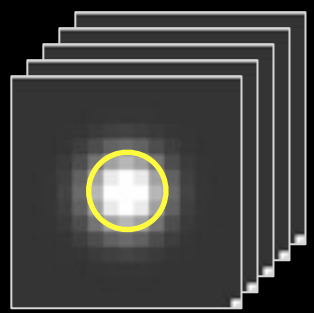
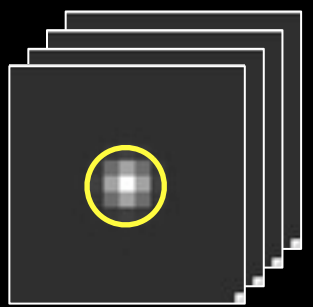
The problem: IR for reliable stellar mass estimates



BOSS
ugriz

Photometry matching

UKIDSS
YJHK



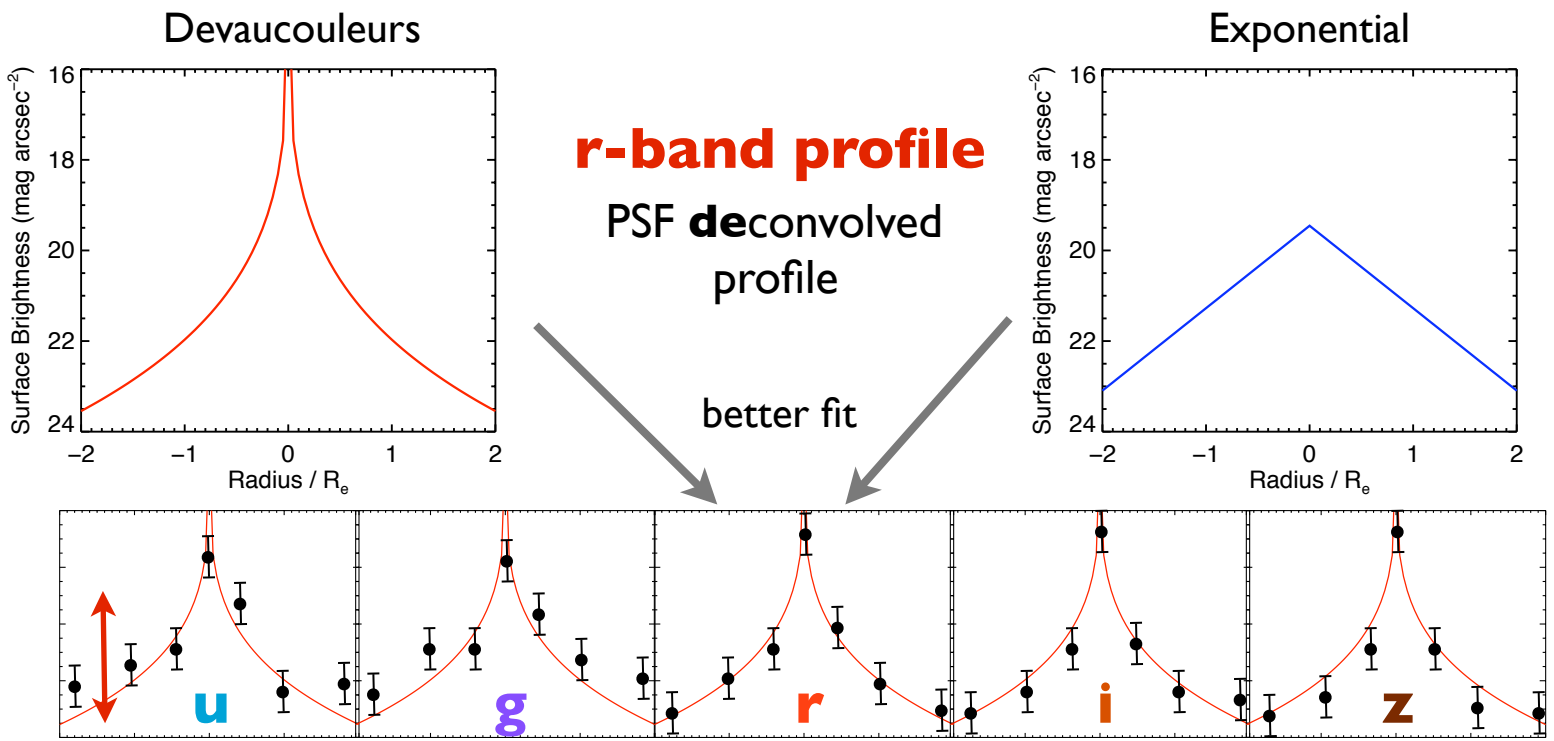
1000-2000 deg^2 overlap ➟ catalog level matching

Differences

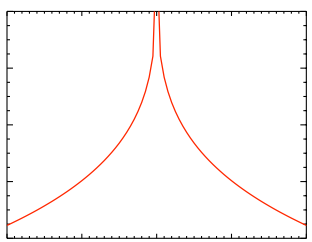
- Magnitude system (AB vs. Vega)
- Spatially varying PSFs
- Photometry techniques / apertures available
- Pixel scales (UKIDSS is 0.4”)
- Magnitude limits
- Coverage by band (non-detection vs non-observation)

Recurring problems for the future of large surveys

BOSS+UKIDSS: "Synthetic Aperture" Matched Photometry



scaled to each band, each PSF convolved



SDSS, r-band profile

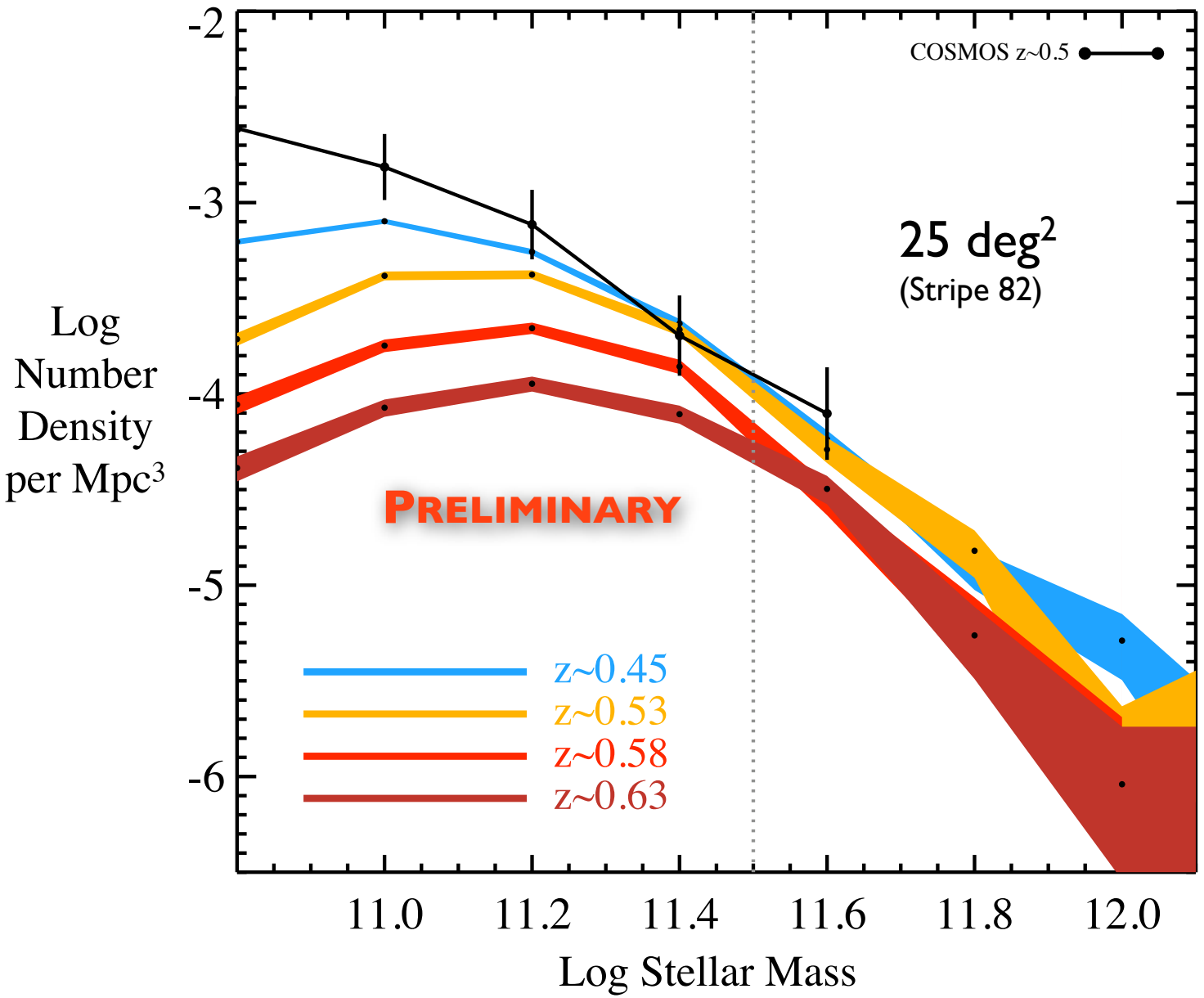
→ ⊗ UKIDSS PSF in best band (H-band) →

Matched photometry in UKIDSS apertures (e.g., diam = 2.8")

$u_{SYN} = r_{SYN} + (u-r)$
$g_{SYN} = r_{SYN} + (g-r)$
$r_{SYN} = r_{SYN}$
$i_{SYN} = r_{SYN} + (i-r)$
$z_{SYN} = r_{SYN} + (z-r)$

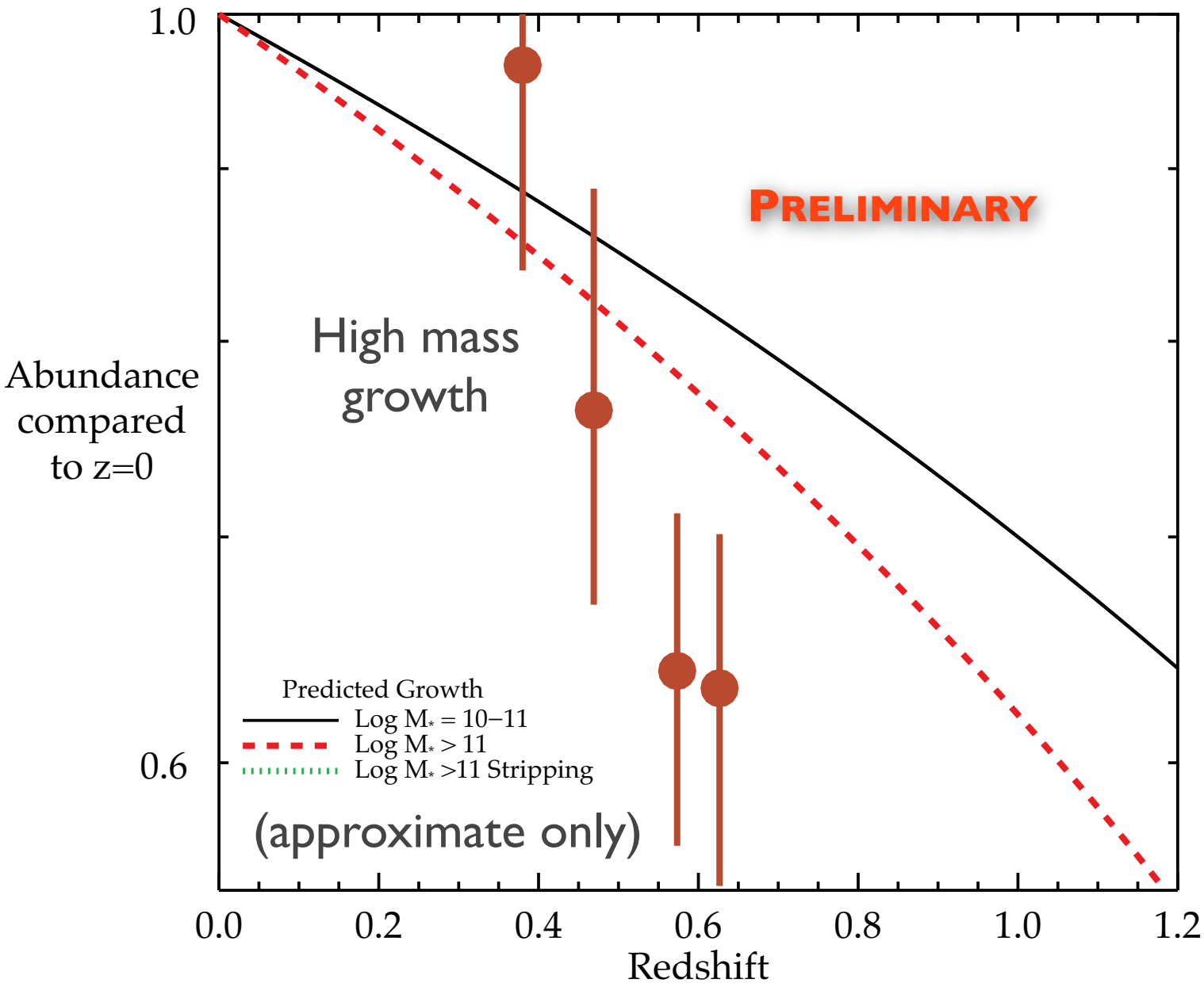
$Y_{AperMag} = Y_{AperMag} + (Y-H)_{PSF}$
$J_{AperMag} = J_{AperMag} + (J-H)_{PSF}$
$H_{AperMag} = H_{AperMag}$
$K_{AperMag} = K_{AperMag} + (K-H)_{PSF}$

First Look! Galaxy Stellar Mass Function



see also Matsuoka & Kawara 2010

Preliminary results so far...



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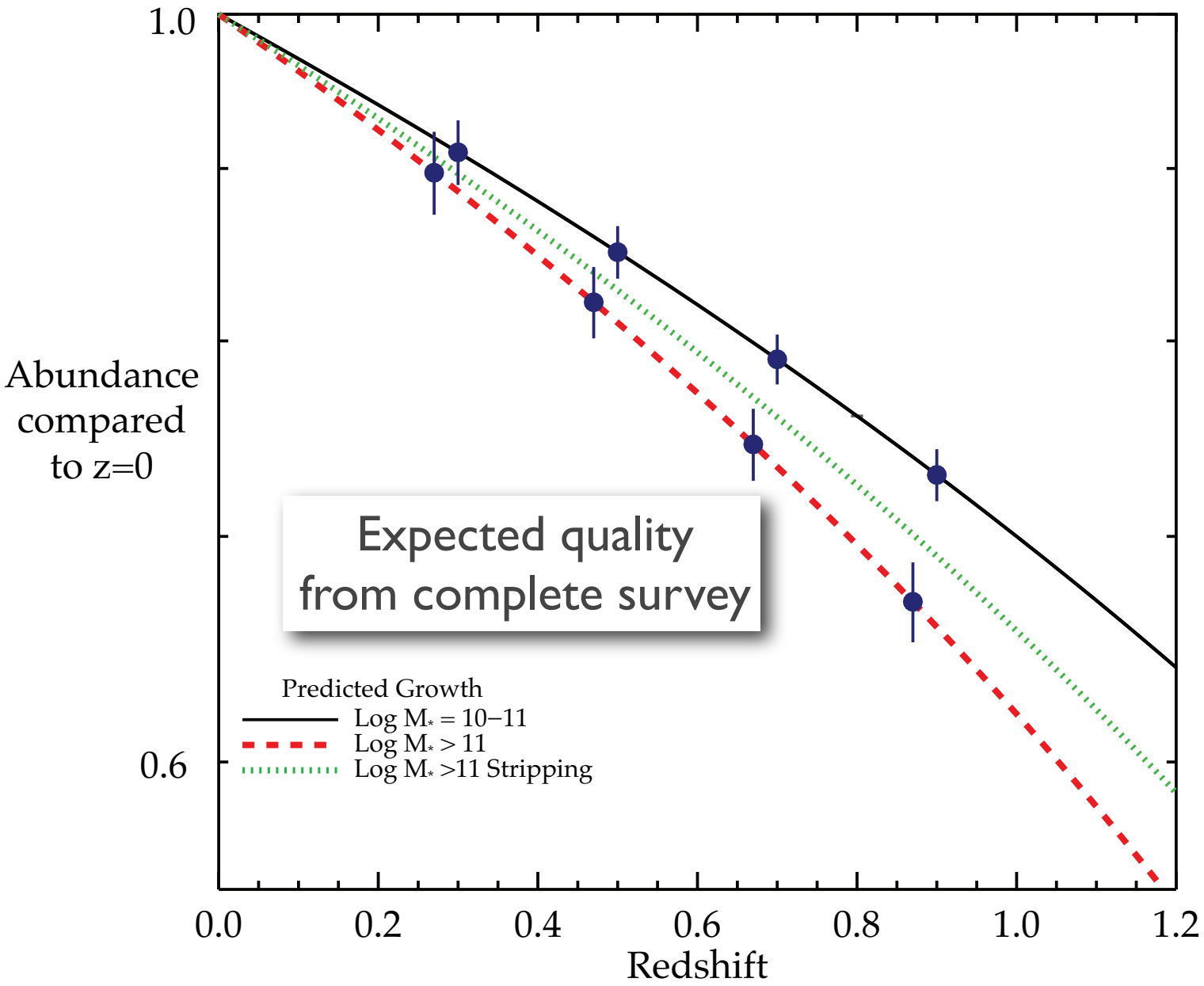

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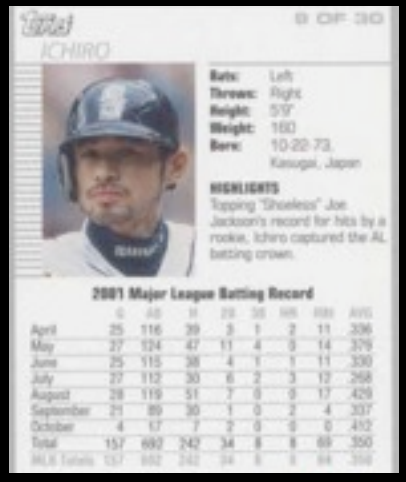

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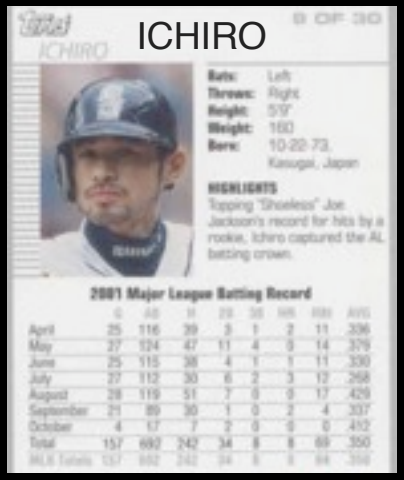

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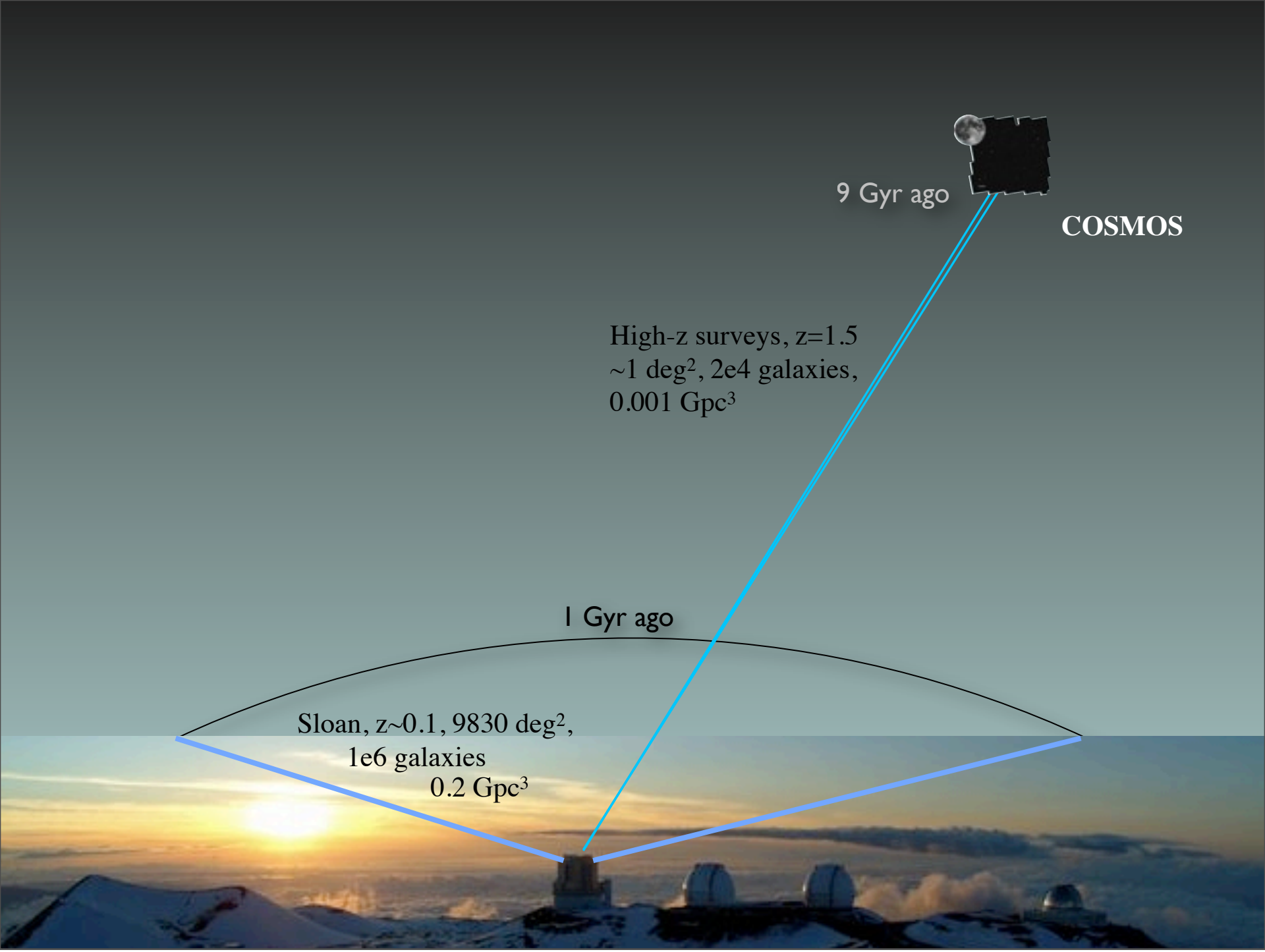
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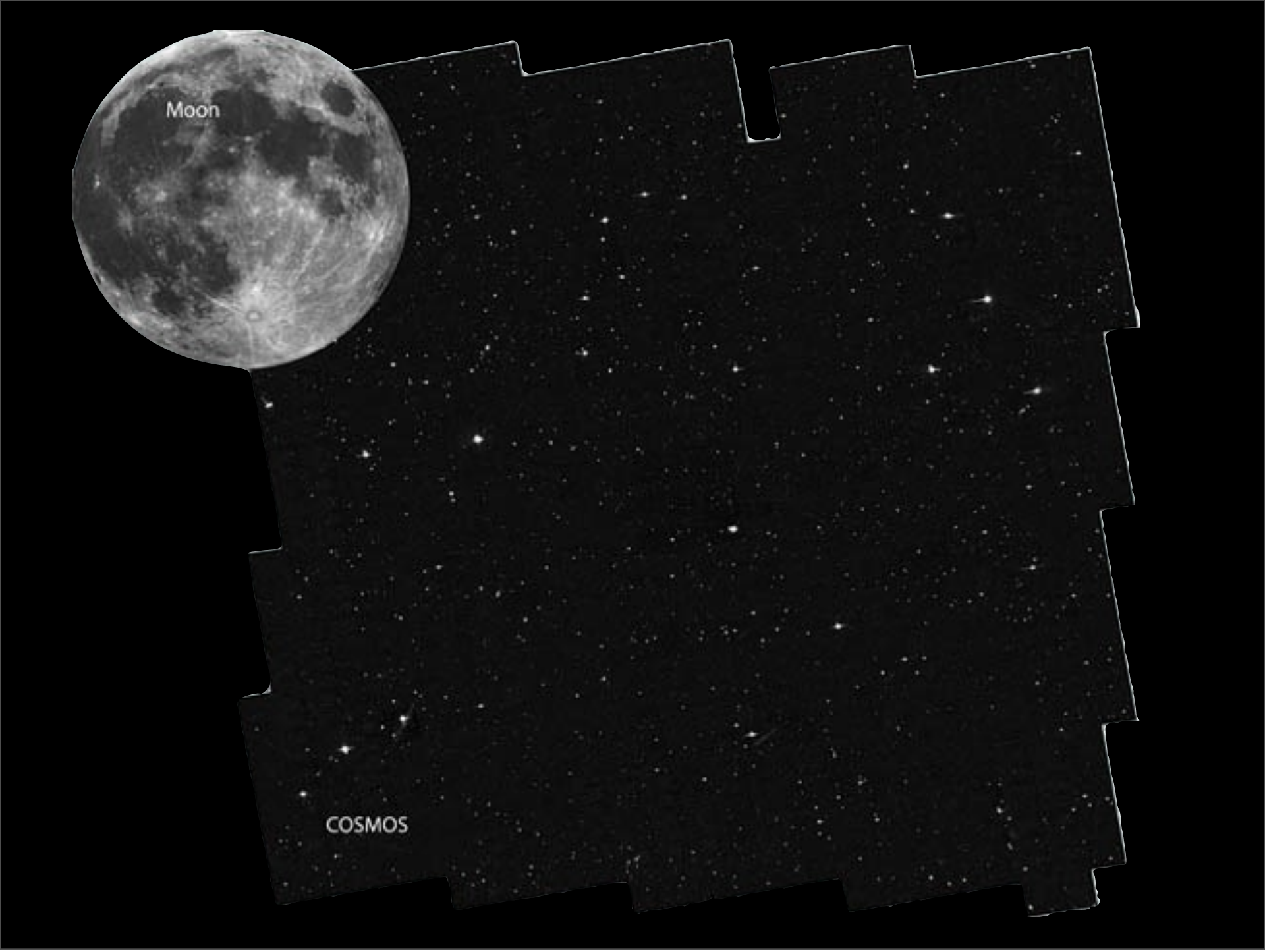
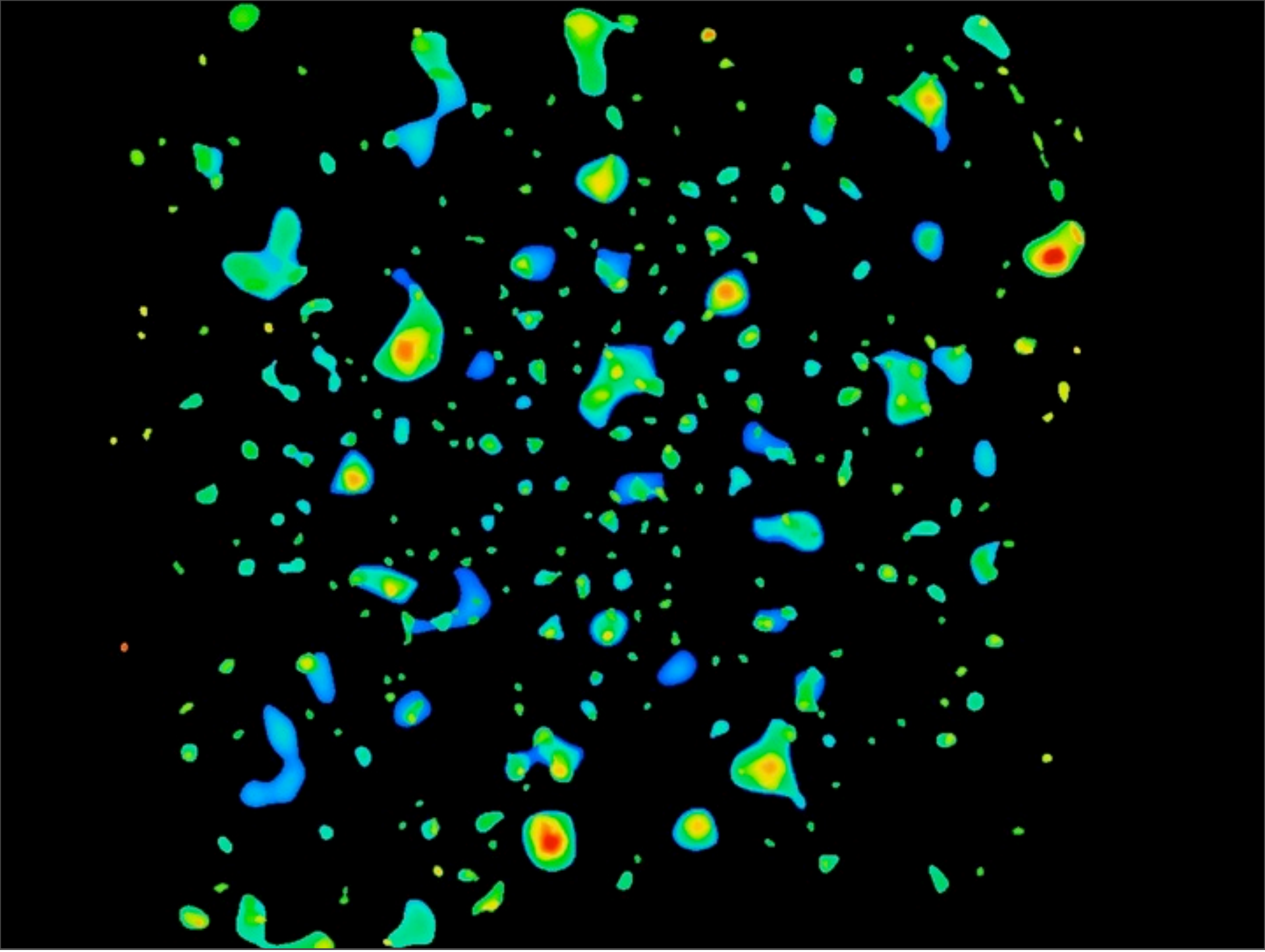
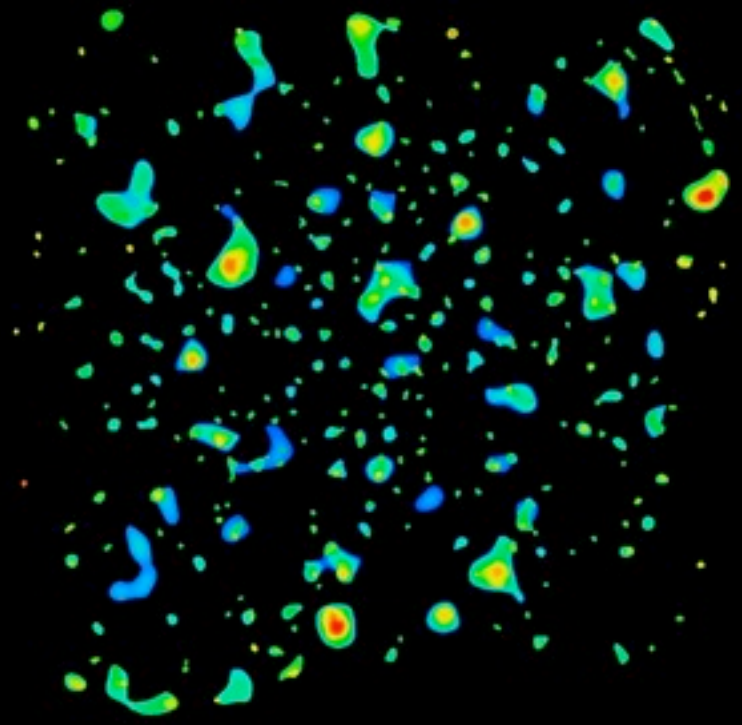

Moon
COSMOS



2010年12月9日木曜日

COSMOS Groups



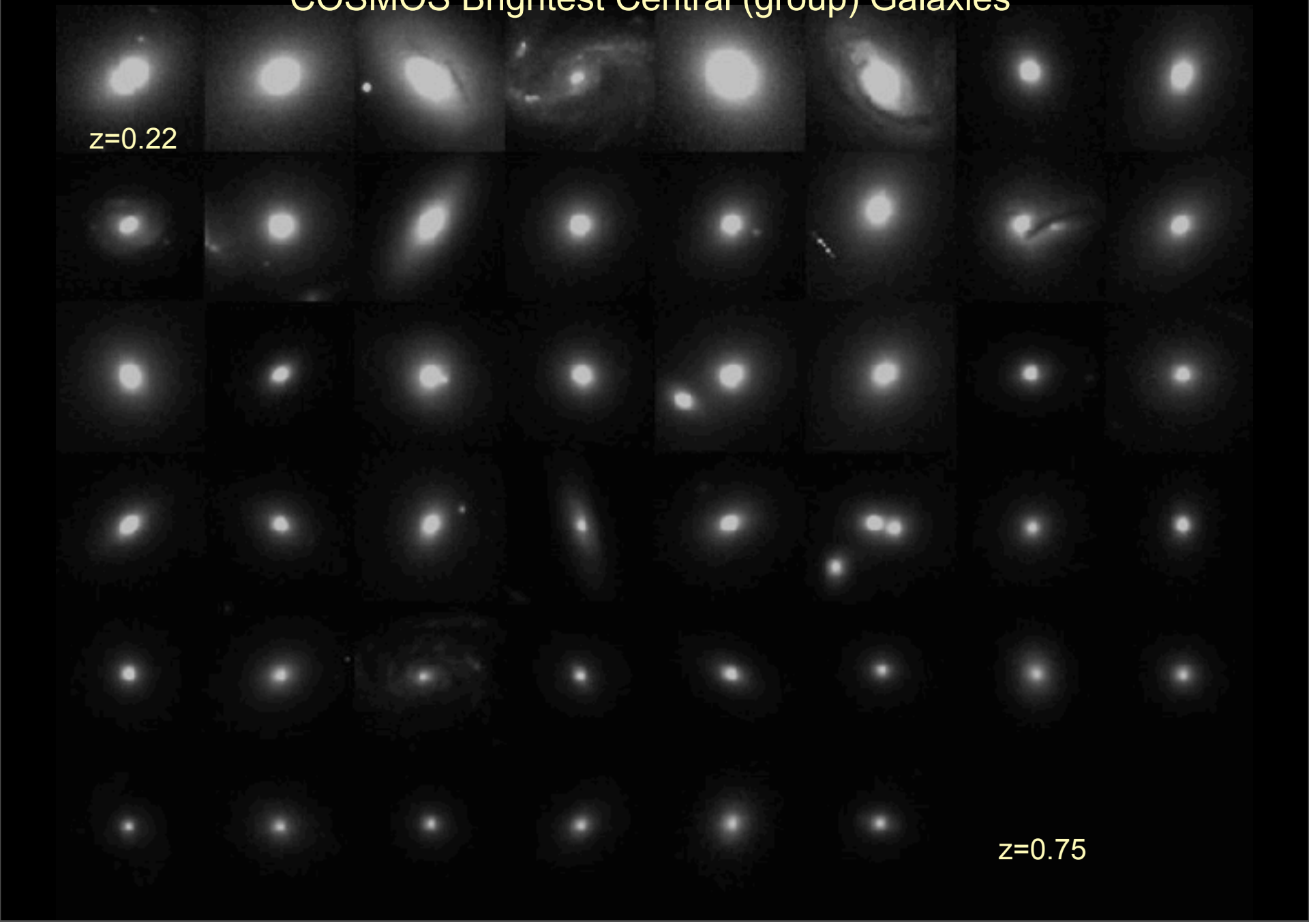
- HST/ACS over 1.6 deg^2
- 30 bands to AB ~ 25
- Photo-z accuracy of ~0.02

Scoville+07, Capak+07, Ilbert+09

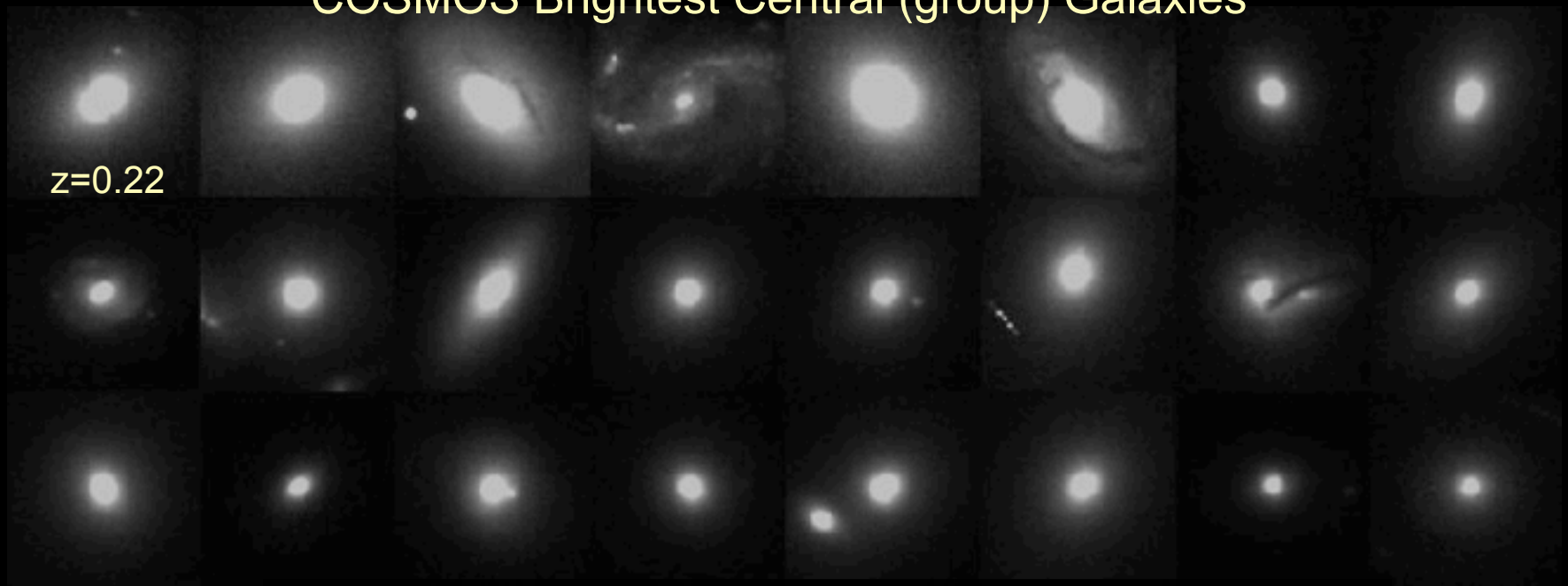
- ~150 groups X-ray selected groups using Chandra + XMM
- weak lensing calibrated halo masses M_{200}~5 x 10^{13} $M_\odot$
- 0.2 < z < 1.2
- Unique in M_{200}, z, completeness

Finoguenov+07, Leauthaud+10

COSMOS Brightest Central (group) Galaxies



COSMOS Brightest Central (group) Galaxies



Why study galaxy growth using BCGs?

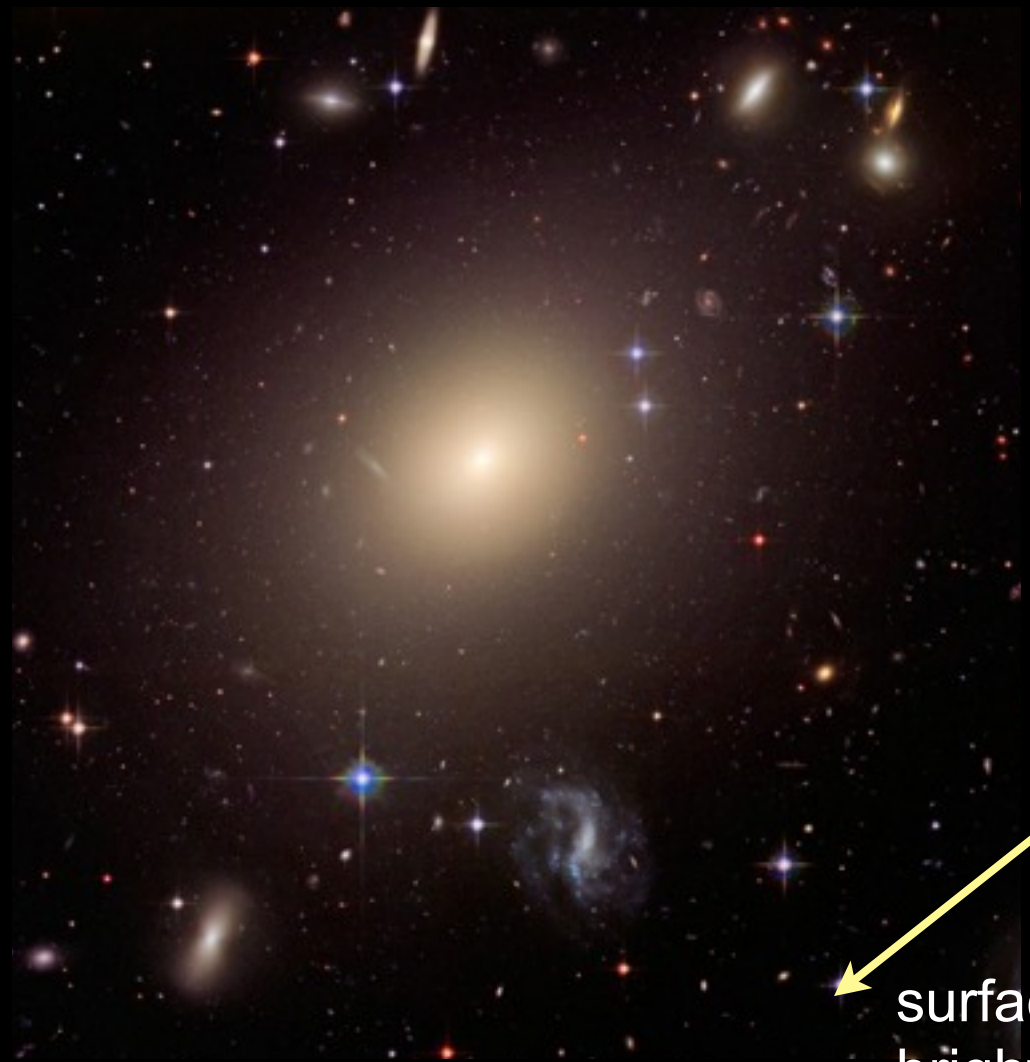
1. They are the most massive galaxies in the universe.

2. They live in a special place, allowing tests of specific physical processes.

3. They are (usually) ellipticals and follow scaling relations.

z=0.75

Internal structure of ellipticals

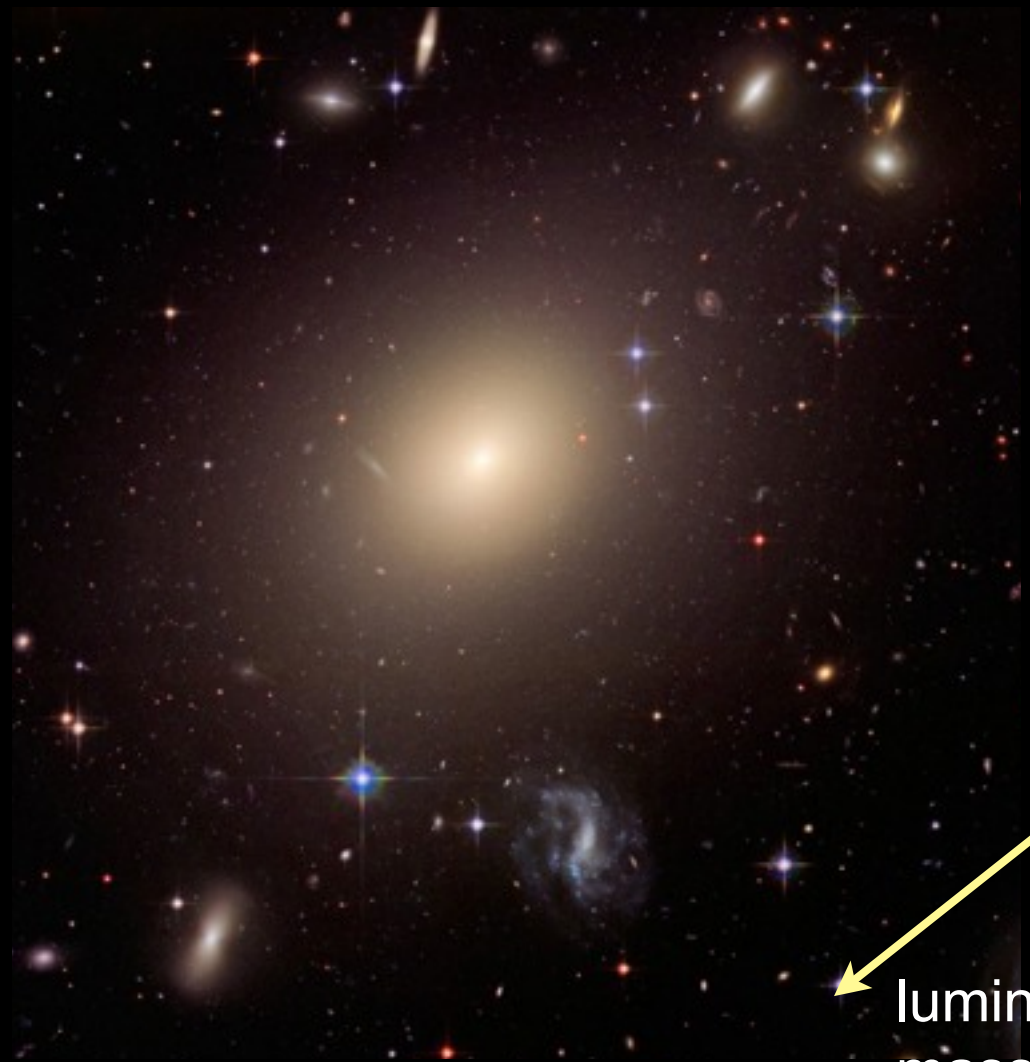


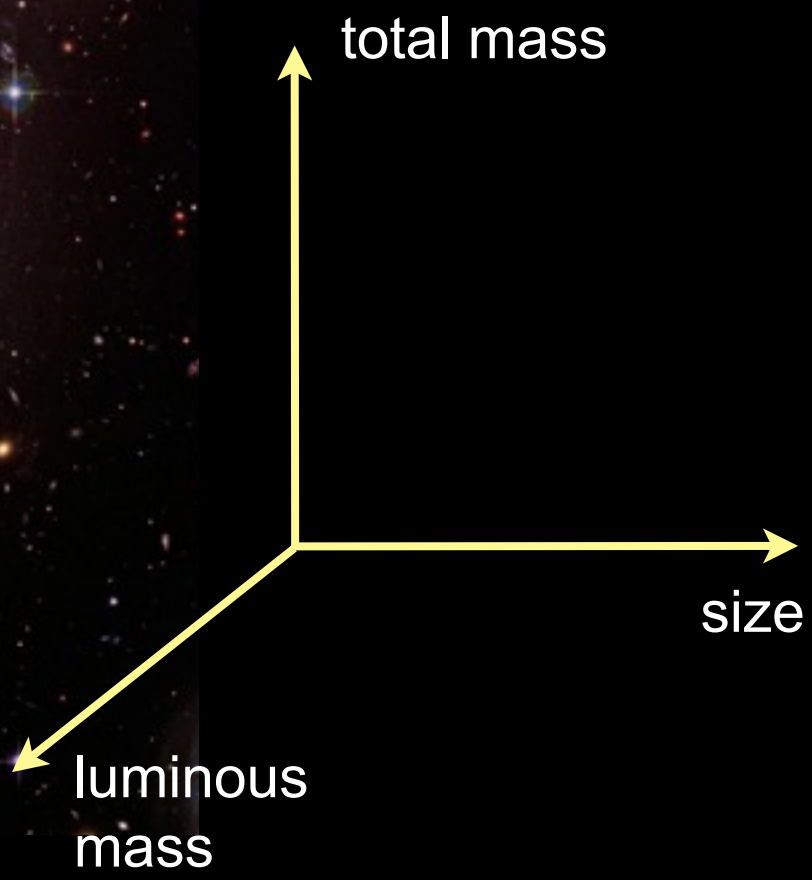
velocity dispersion
(spectroscopy)

size
(high resolution)

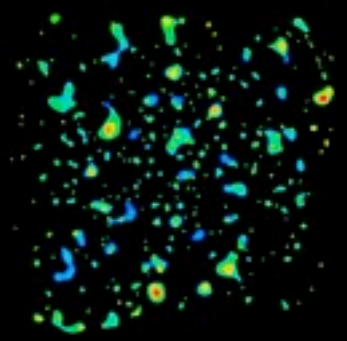
surface brightness
(ideally $M_\star$)

Internal structure of ellipticals





COSMOS Groups and BCGs



VLT Followup with FORS2

Increase spec-z membership (to z=1),
Stellar velocity dispersions of BCGs and field ellipticals,
Spec-z merging pairs of group members

- 4 perfect nights in February 2010
- ~1hr exposures, R~2000
- First pass reduction: 537 redshifts, 47 BCG velocity dispersions
- Second pass will increase samples by 50%

Projects

1. Weak-lensing vs. L_X scaling relations.

   Alexie Leauthaud (Leauthaud+10)

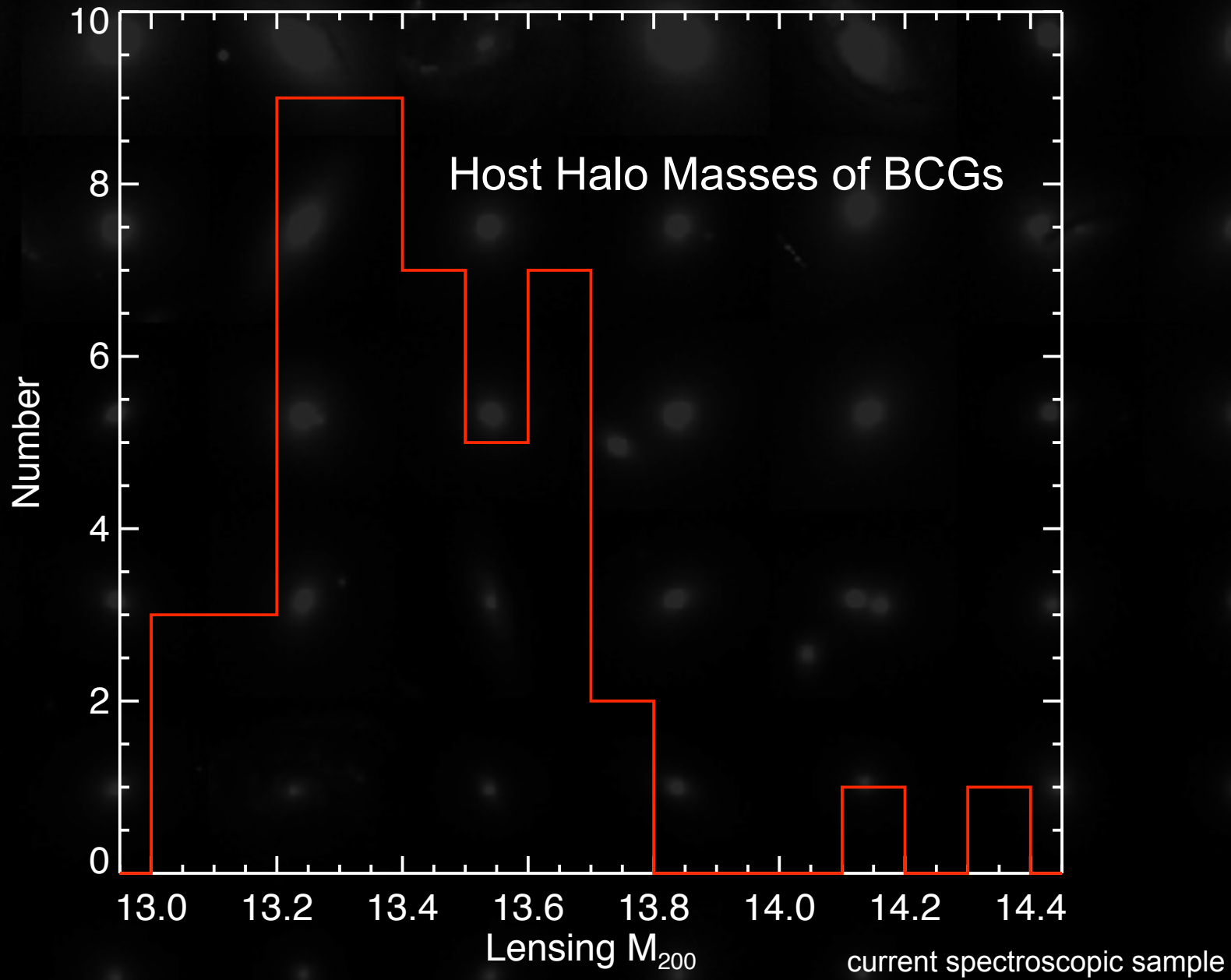
2. Lensing constraints on halo centers and group member assignment. Matt George et al. (in prep)

3. HOD constraints. Jeremy Tinker et al. (in prep)

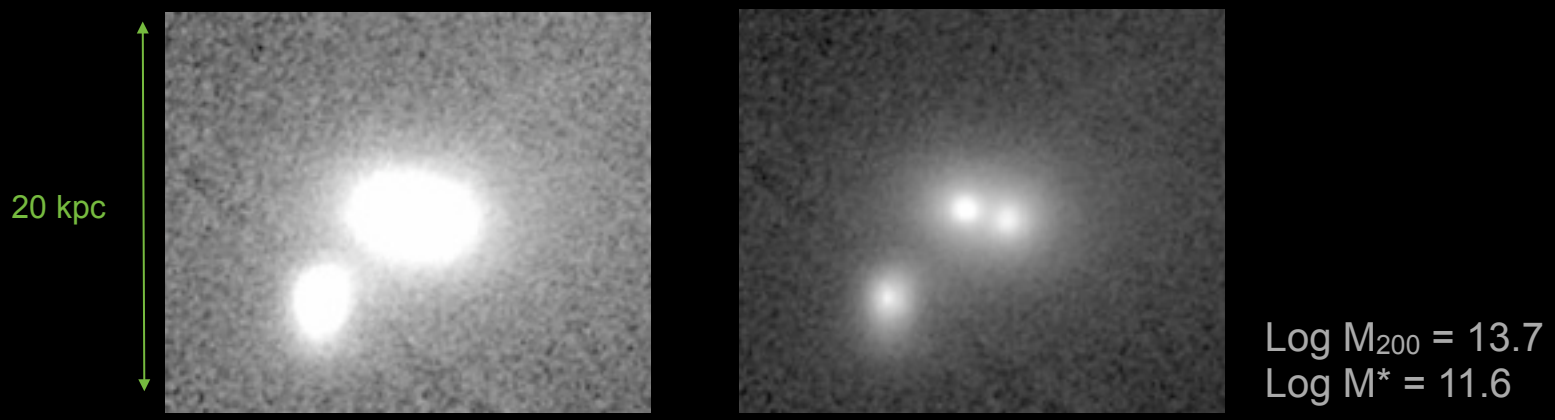
4. Statistical nature of BCGs. Melody Wolk et al. (in prep)

5. Assembly history of groups and BCGs.

See later slides!


Host Halo Masses of BCGs
Number
0
2
4
6
8
10
13.0
13.2
13.4
13.6
13.8
14.0
14.2
14.4
Lensing M200
current spectroscopic sample

BCG Mergers...



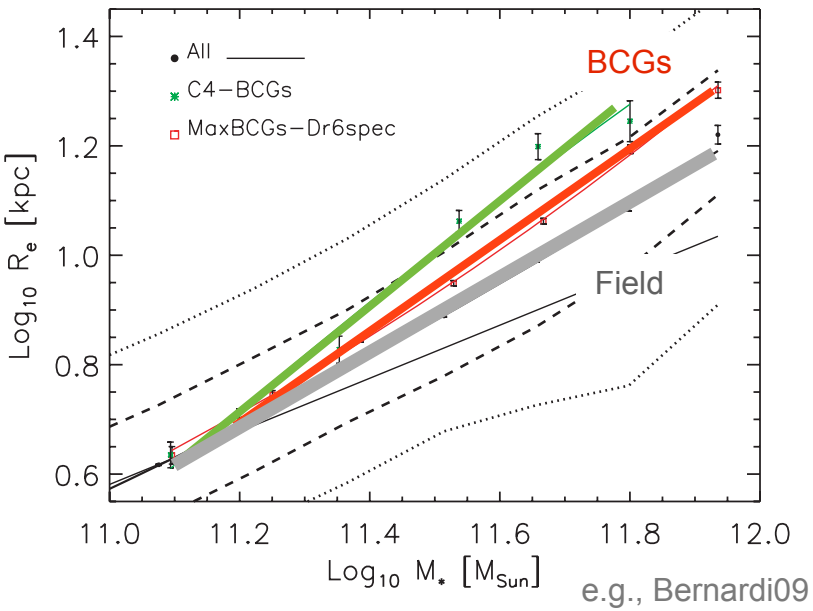
BCG triple merger at z=0.49 revealed!

PRELIMINARY

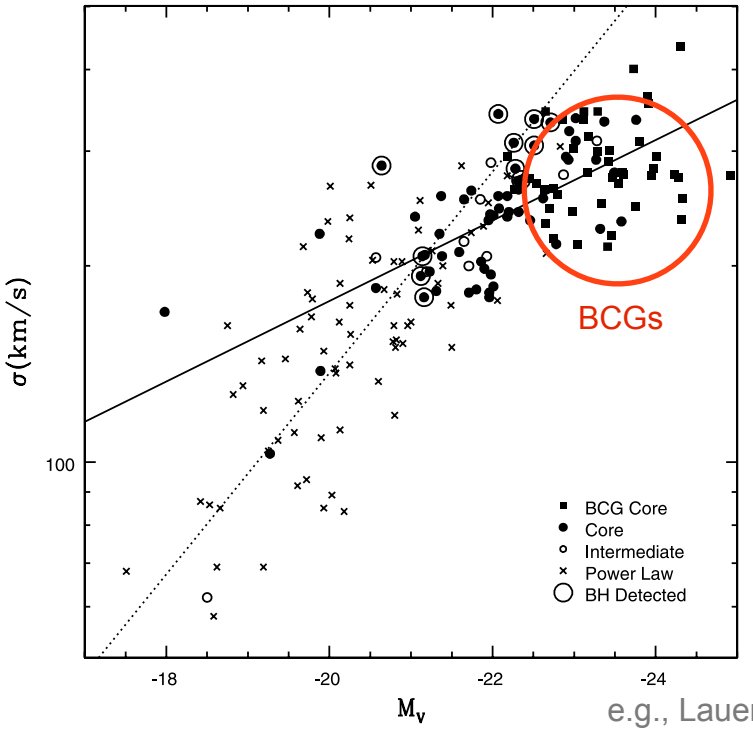
- Major BCG pairs ~10%
- Substructure and tidal features ~50%
- Late time BCG assembly in action?
  Growth to be quantified..

e.g., Tran+08 but see Wiley+08

The dynamical evolution of BCGs



e.g., Bernardi09



e.g., Lauer+07

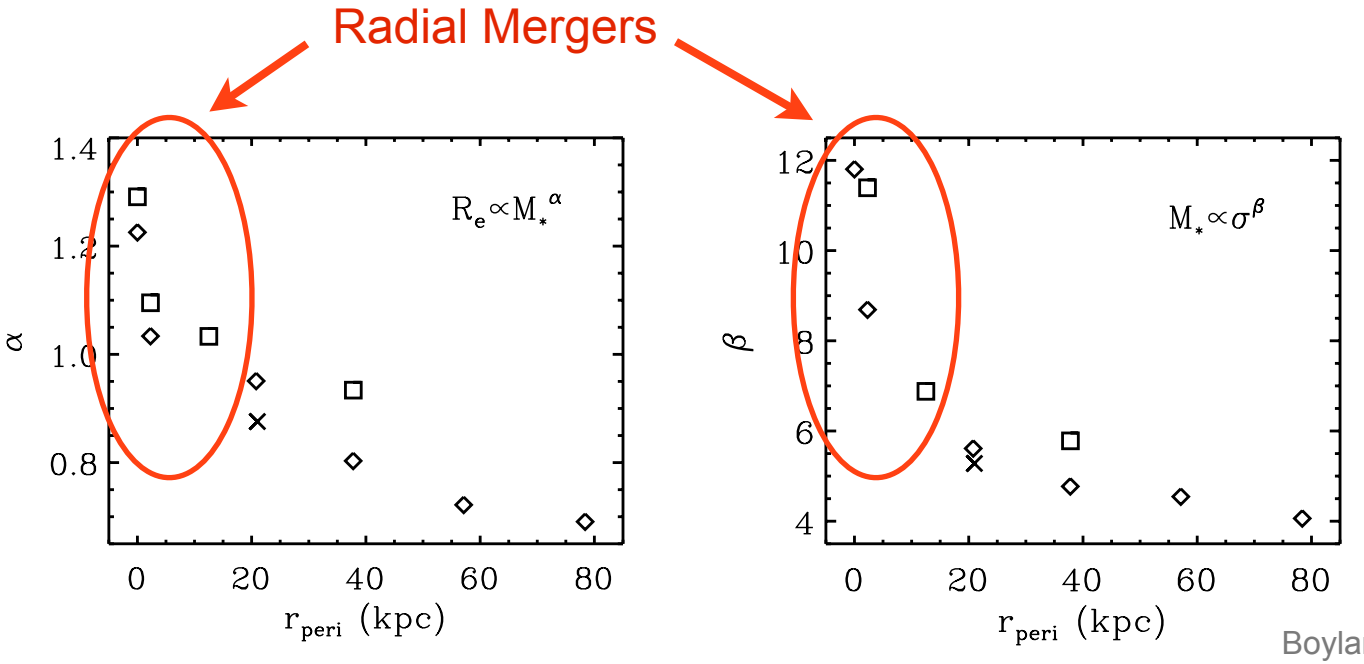
Local cluster BCGs are larger...

with lower velocity dispersions.

But do lie on the Fundamental Plane

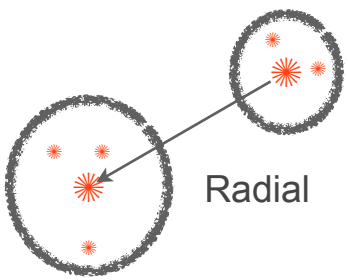
The dynamical evolution of BCGs

Expected evolution in FP projections as seen in radial merger simulations

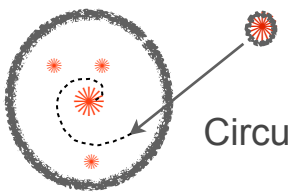


Boylan-Kolchin+06

Do radial BCG mergers may signify major *halo* mergers?
Major galaxy mergers?

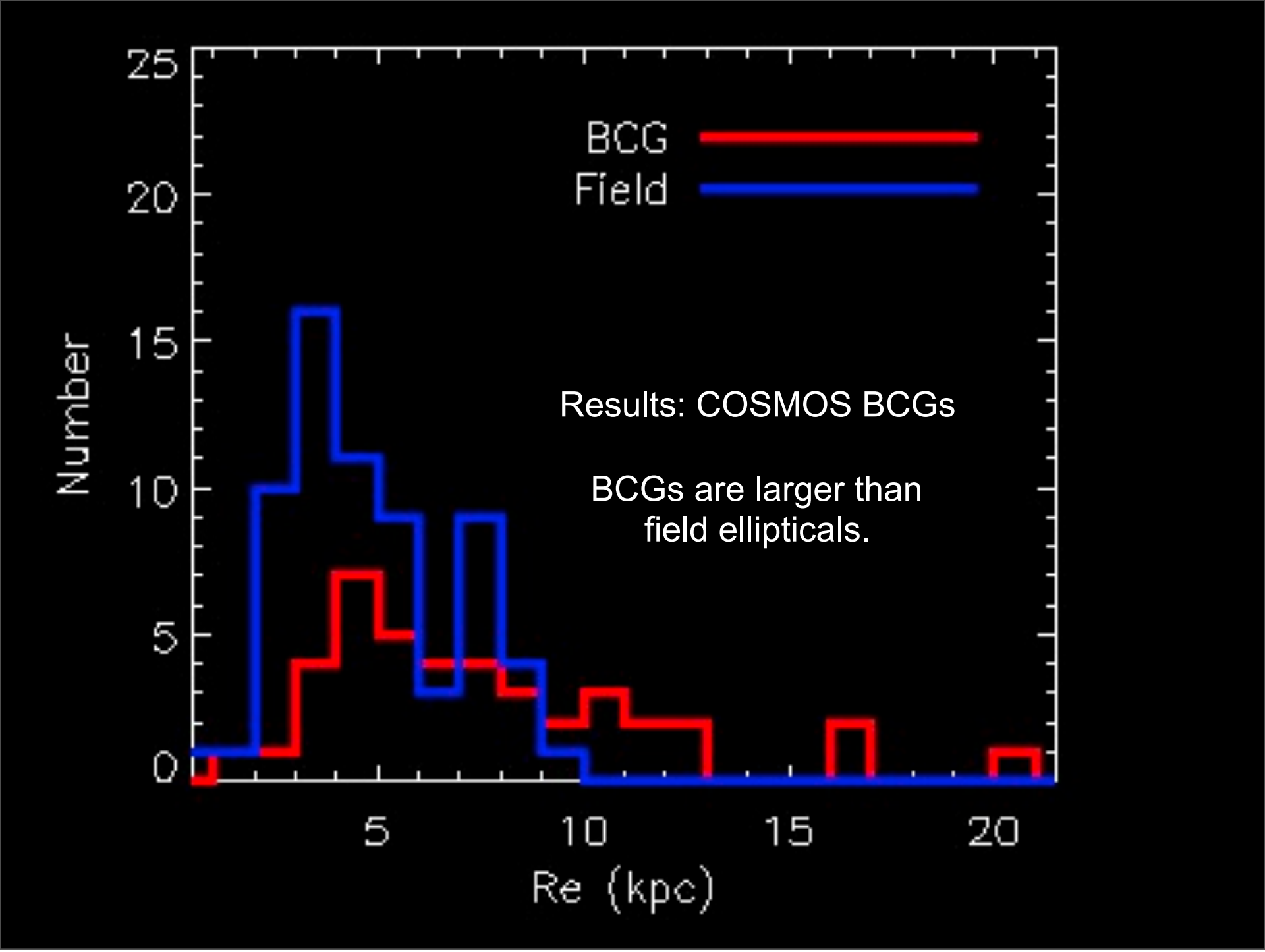


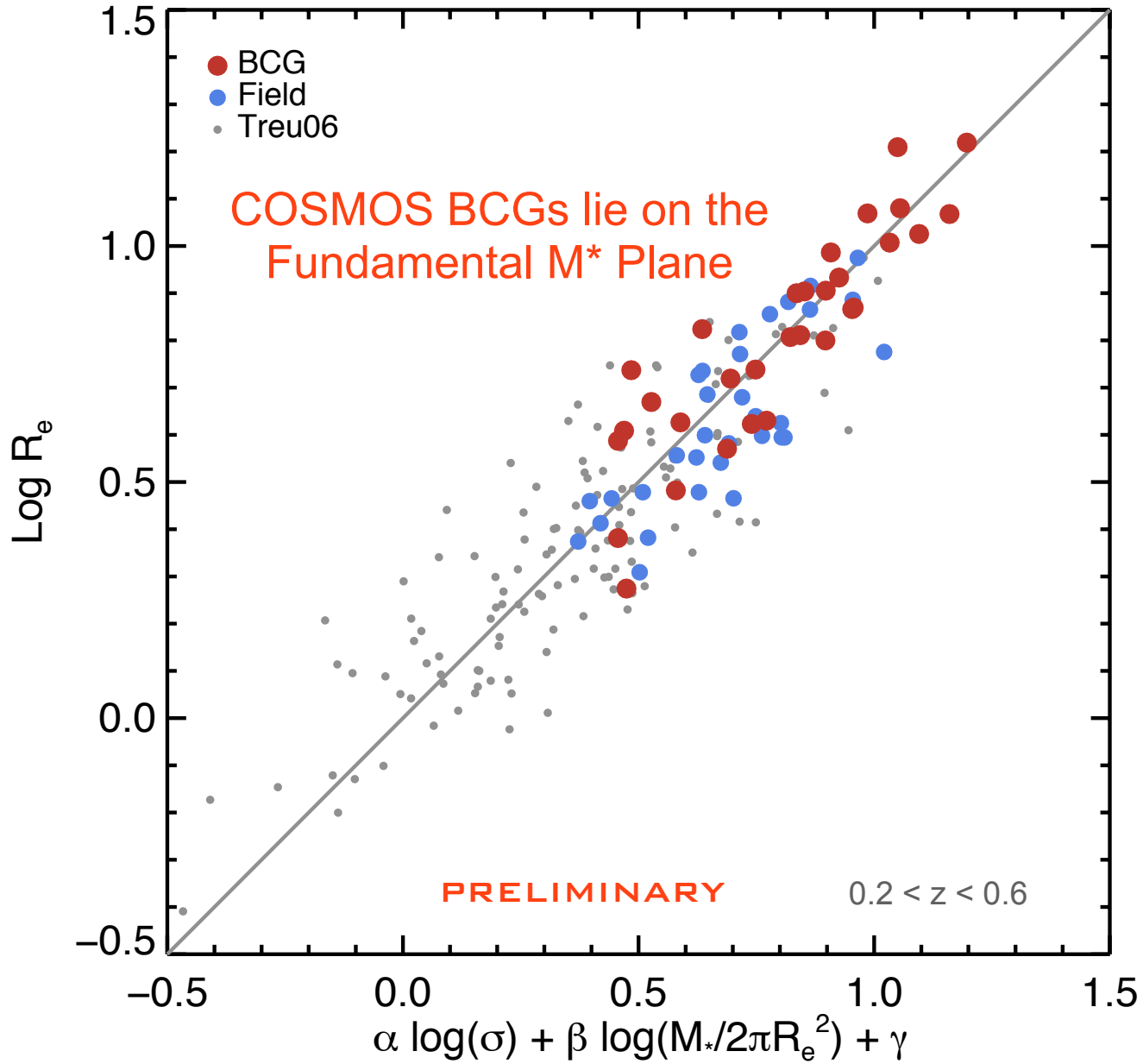
Major halo / Major stellar

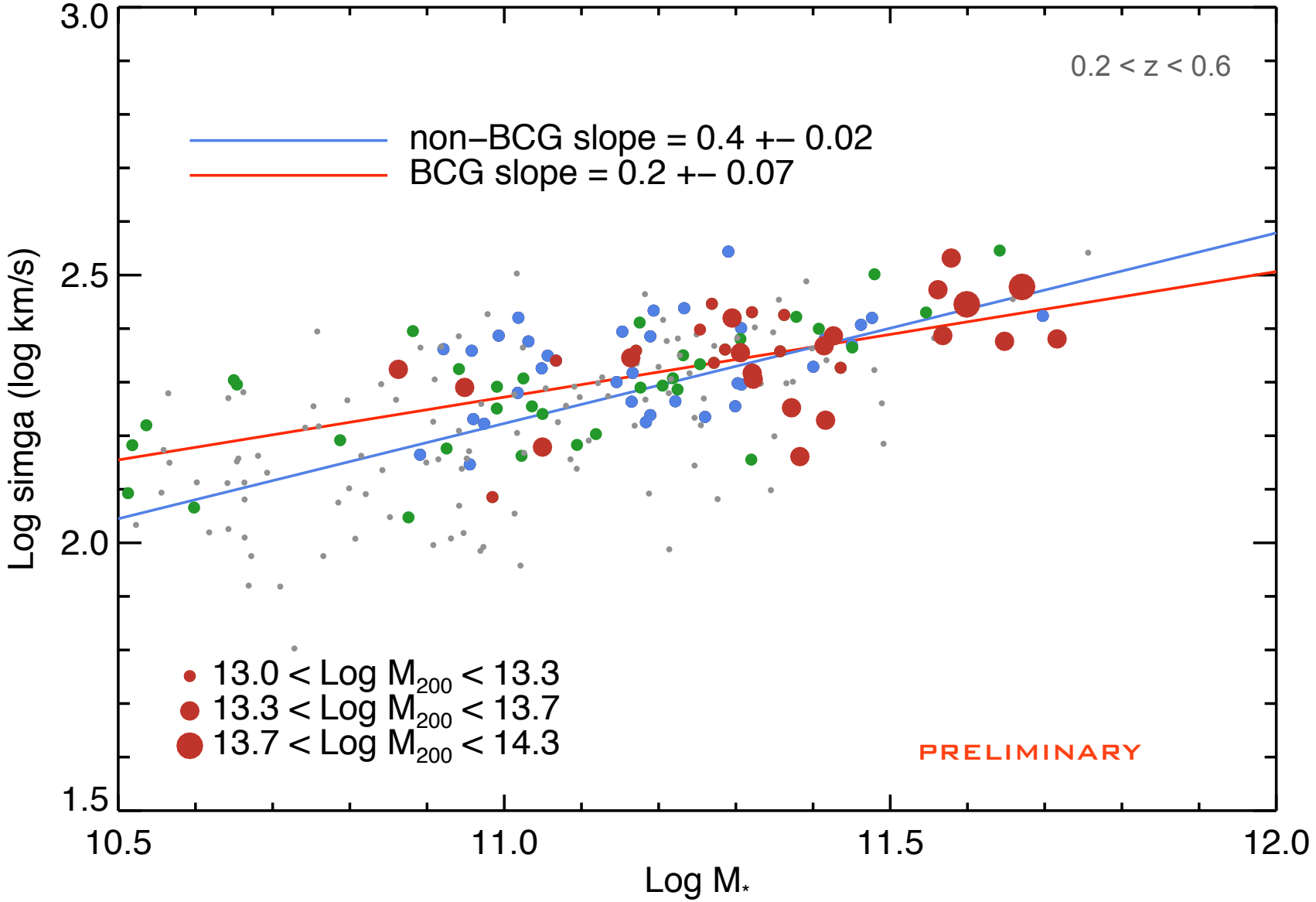


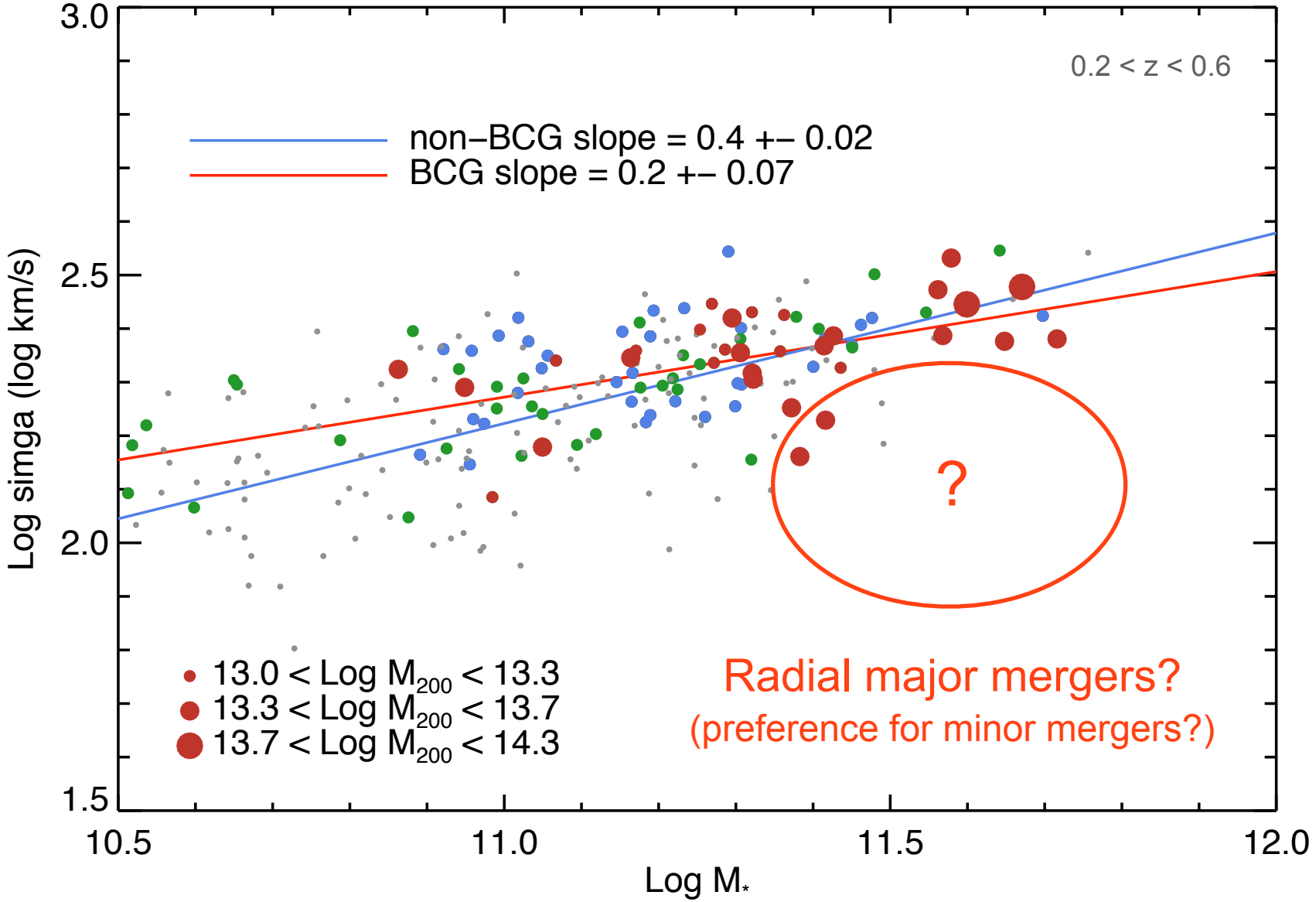
Minor halo / Major stellar

New sub-halo studies needed.
Still unclear see e.g., Wetzel 2010, Faltenbacher 2010

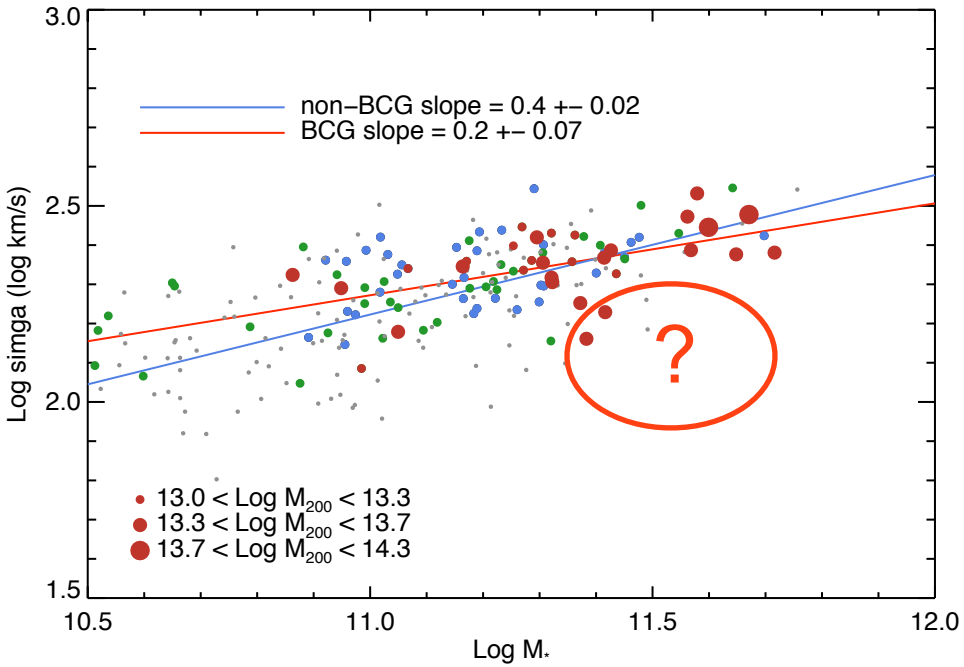

BCG
Field
Results: COSMOS BCGs
BCGs are larger than
field ellipticals.
Number
Re (kpc)
0
5
10
15
20
25

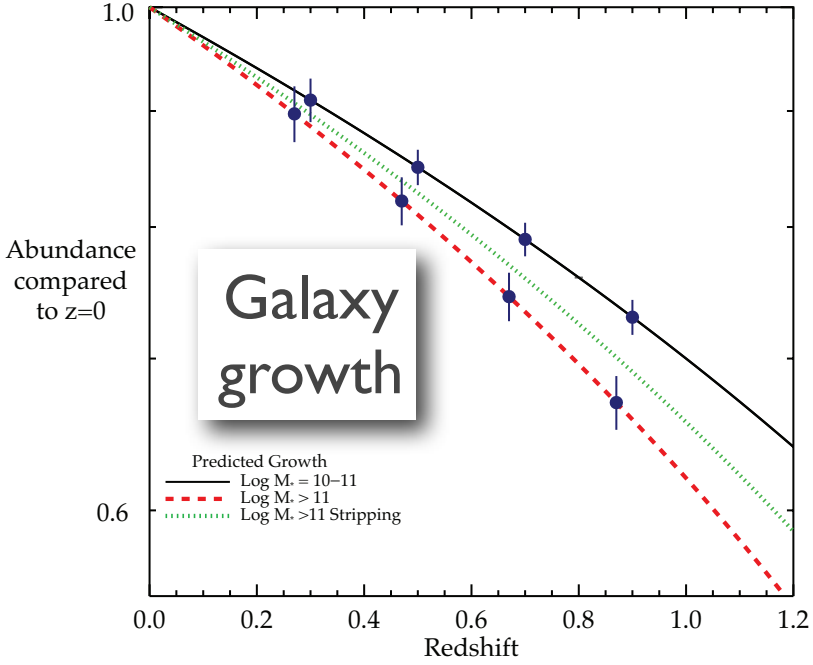

BCG
Field
Treu06
COSMOS BCGs lie on the
Fundamental M* Plane
PRELIMINARY
0.2 < z < 0.6
Log R_e
$\alpha \log(\sigma) + \beta \log(M_*/2\pi R_e^2) + \gamma$
1.5
1.0
0.5
0.0
−0.5
−0.5
0.0
0.5
1.0
1.5


0.2 < z < 0.6
non−BCG slope = 0.4 +− 0.02
BCG slope = 0.2 +− 0.07
13.0 < Log M200 < 13.3
13.3 < Log M200 < 13.7
13.7 < Log M200 < 14.3
PRELIMINARY
Log simga (log km/s)
Log M*
3.0
2.5
2.0
1.5
10.5
11.0
11.5
12.0

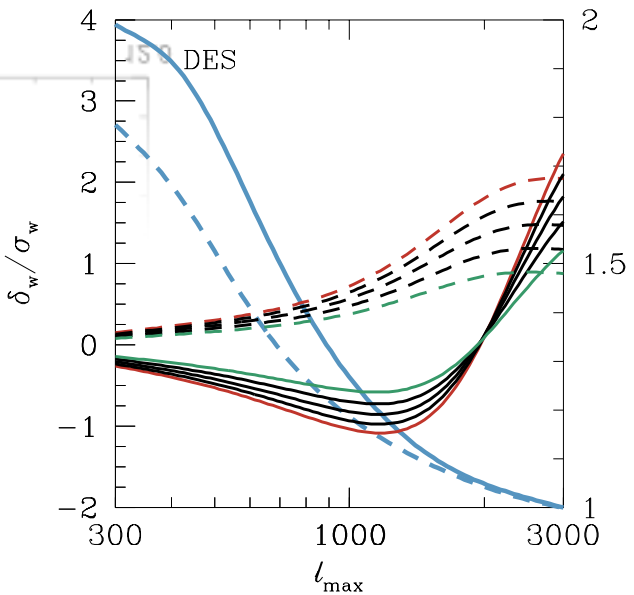

3.0
2.5
2.0
1.5
10.5
11.0
11.5
12.0
Log simga (log km/s)
Log M*
0.2 < z < 0.6
non−BCG slope = 0.4 +− 0.02
BCG slope = 0.2 +− 0.07
?
13.0 < Log M200 < 13.3
13.3 < Log M200 < 13.7
13.7 < Log M200 < 14.3
Radial major mergers?
(preference for minor mergers?)

Future





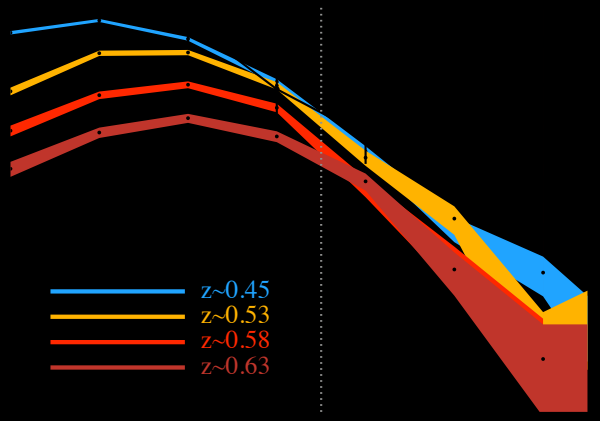
Model constraints



Summary:
The Growth of Massive Galaxies

Combining the statistical power of new large surveys with detailed tests of physical mechanisms.

- **BOSS**: First robust measures of galaxy growth and detection of hierarchical galaxy assembly in the next few months.



- **BCGs Mergers**: COSMOS BCGs show frequent signs of minor merging. But their dynamics show little sign of significant mergers. Evidence for stripping and suppression?