B03

Cosmology with Galaxy Redshift Survey

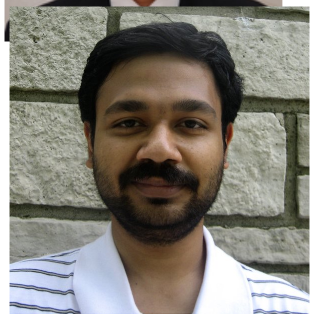
Masahiro Takada
(Kavli IPMU)

KAVLI IPMU INSTITUTE FOR THE PHYSICS AND MATHEMATICS OF THE UNIVERSE
東京大学 THE UNIVERSITY OF TOKYO
wpi

"Cosmic Acceleration" kickoff meeting @Kavli IPMU, Sep, 2015







B03 Our Team




- PI: Masahiro Takada (IPMU)
- Co-I's
  - N. Tamura (IPMU): PFS ⇒ *see next talk*
  - I. Iwata (Subaru): PFS at Subaru
  - R. Takahashi (Hirosaki): numerical cosmology
- Collaborators
  - N. Yasuda (IPMU): HSC/PFS software
  - S. More (IPMU): method/analysis/model
  - A. Leauthaud (IPMU): method/analysis/model
  - N. Suzuki (IPMU): data analysis/software
  - K. Bundy (IPMU): data analysis
  - Y. Minowa (Subaru): PFS at Subaru
- +PDs, students

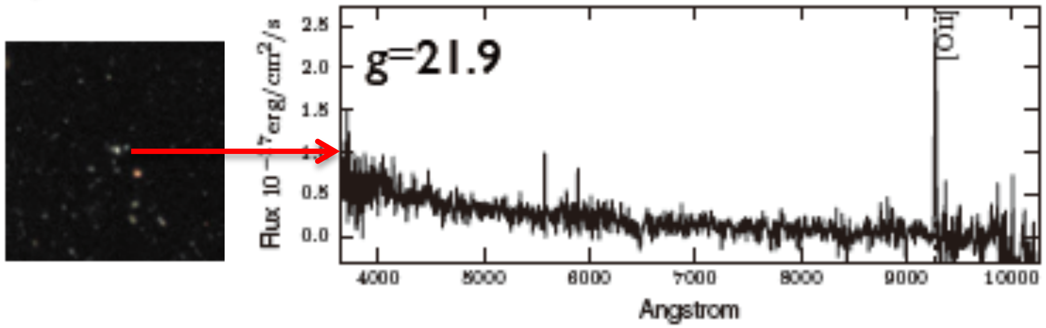
Galaxy survey; imaging vs. spectroscopy

Imaging

- Find objects
  - Stars, galaxies, galaxy clusters
- Measure the image shape of each object → *weak gravitational lensing*
- For cosmology purpose
  - *Pros*: many galaxies, a reconstruction of dark matter distribution
  - *Cons*: 2D information, limited redshift info. (photo-z at best)

Spectroscopy

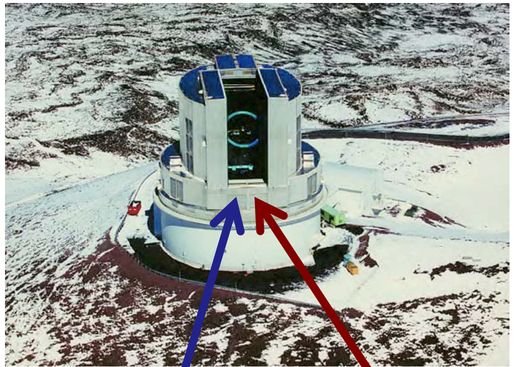
- Measure the photon-energy spectrum of *target* object
- Distance to the object can be known → *3D clustering analysis*
- For cosmology
  - *Pros*: more fluctuation modes in 3D than in 2D
  - *Cons*: need the pre-imaging data for targeting; observationally more expensive (or less galaxies)



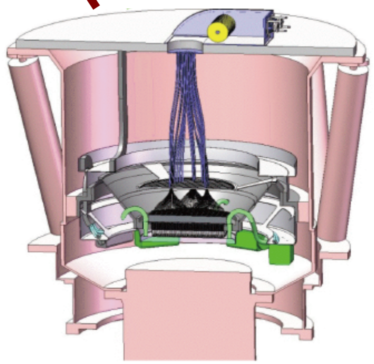
SuMIRe = Subaru Measurement of Images and Redshifts

H. Murayama (Kavli IPMU Director)

- IPMU director Hitoshi Murayama funded (~$32M) by the Cabinet in Mar 2009, as one of the stimulus package programs
- Build *wide-field* camera (Hyper Suprime-Cam) and *wide-field* multi-object spectrograph (Prime Focus Spectrograph) for the Subaru Telescope (8.2m)
- Explore the fate of our Universe: dark matter, dark energy
- Keep the Subaru Telescope a world-leading telescope in the TMT era
- Precise images of 1B galaxies
- Measure distances of ~4M galaxies
- **Do SDSS-like survey at z>1**

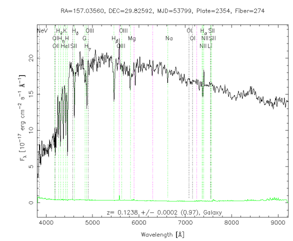


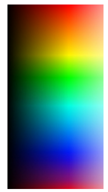
Subaru (NAOJ)



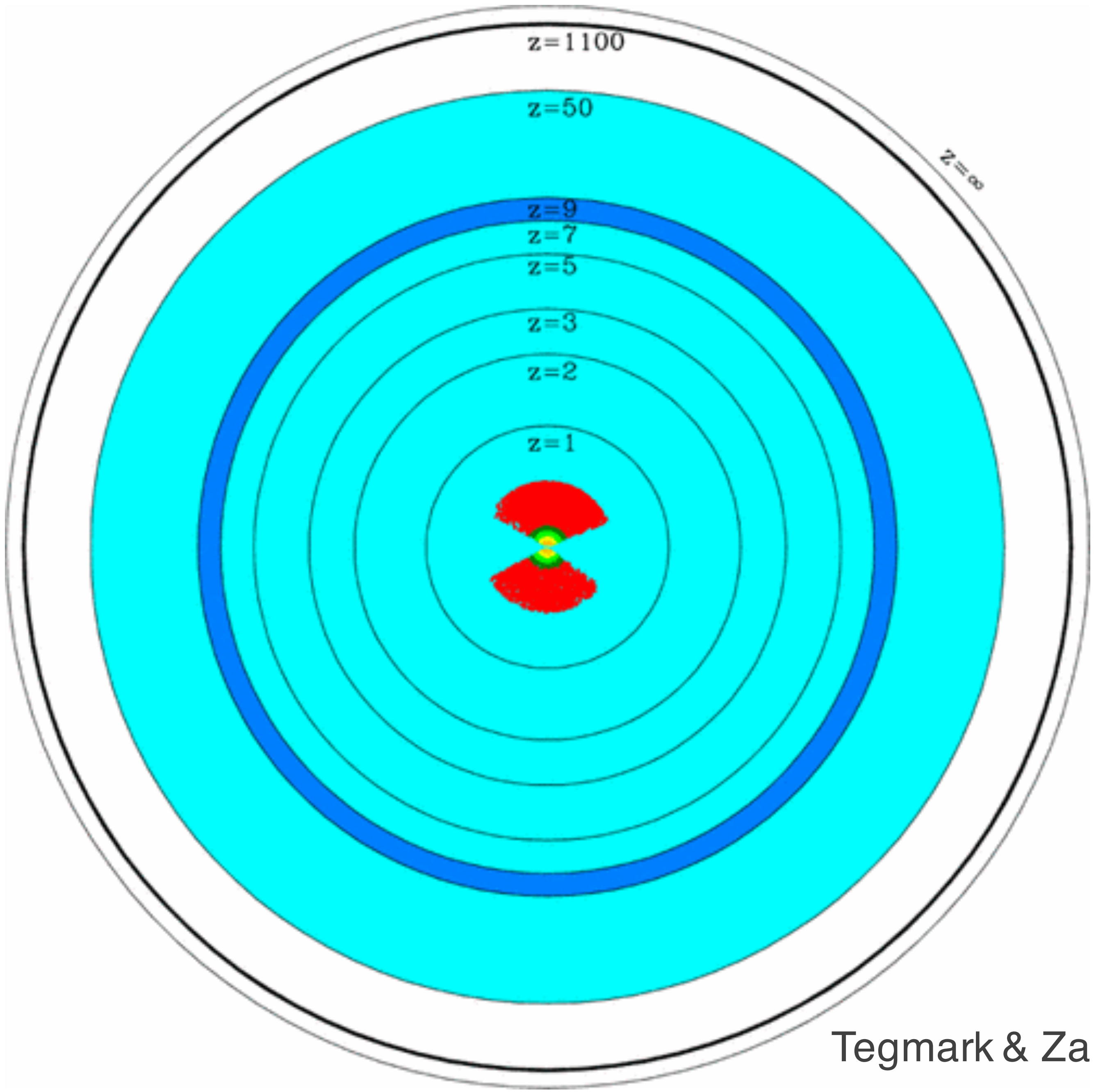
PFS

HSC





Cosmology with "3D" Galaxy Survey



- Wide-are galaxy surveys
- CMB=a 2D snapshot of the universe at z~1000
- Galaxy survey carries 3D information
- 3D≫2D
- Can be very powerful

Tegmark & Zaldarriaga 09

Cosmological Collider Physics

Nima Arkani-Hamed (IAS)

Cosmological Collider Physics

Nima Arkani-Hamed and Juan Maldacena

Institute for Advanced Study, Princeton, NJ 08540, USA

- Complementary to CMB & LHC
- A new approach

Abstract

We study the imprint of new particles on the primordial cosmological fluctuations. New particles with masses comparable to the Hubble scale produce a distinctive signature on the non-gaussianities. This feature arises in the squeezed limit of the correlation functions of primordial fluctuations. It consists of particular power law, or oscillatory, behavior that contains information about the masses of new particles. There is an angular dependence that
have a relative phase that crucially de
the fluctuations and can be viewed as

also see http://physics.princeton.edu/cmb50

Can we use (messy) galaxy survey data for the fundamental physics?

Super-Sample Signal

Yin Li,[1,2] Wayne Hu,[2] and Masahiro Takada[3]

[1] *Department of Physics, University of Chicago, Chicago, Illinois 60637,*
[2] *Kavli Institute for Cosmological Physics, Department of Astronomy & Astr*
Enrico Fermi Institute, University of Chicago, Chicago, Illinois 60637,
[3] *Kavli Institute for the Physics and Mathematics of the Universe (W*

The Lagrangian-space Effective Field Theory of Large Scale Structures

Rafael A. Porto[1,2], Leonardo Senatore[3,4,5] and Matias Zaldarriaga[1]

[1] *School of Natural Sciences, Institute for Advanced Study, Olden Lane, Princeton, NJ 08540, USA*

[2] *Deutsches Elektronen-Synchrotron DESY, Theory Group, D-22603 Hamburg, Germany*

[3] *Stanford Institute for Theoretical Physics, Stanford University, Stanford, CA 94306*

[4] *Kavli Institute for Particle Astrophysics and Cosmology, Stanford University and SLAC, Menlo Park, CA 94025*

4 May 2014

Testing Inflation with Large Scale Structure: Connecting Hopes with Reality

Conveners: Olivier Doré and Daniel Green

Marcelo Alvarez[1], Tobias Baldauf[2], J. Richard Bond[1,3], Neal Dalal[4], Roland de Putter[5,6], Olivier Doré[5,6], Daniel Green[1,3], Chris Hirata[7], Zhiqi Huang[1], Dragan Huterer[8], Donghui Jeong[9], Matthew C. Johnson[10,11], Elisabeth Krause[12], Marilena Loverde[13], Joel Meyers[1], Daniel Meerburg[1], Leonardo Senatore[12], Sarah Shandera[9], Eva Silverstein[12], Anže Slosar[1] Kendrick Smith[11], Matias Zaldarriaga[1], Valentin Assassi[15], Jonathan Braden[1], Amir Hajian[1], Takeshi Kobayashi[1,11], George Stein[1], Alexander van Engelen[1]

Dec 2014

The Effective Field Theory of Large Scale Structures at Two Loops

John Joseph M. Carrasco[1], Simon Foreman[1,2], Daniel Green[1,2], and Leonardo Senatore[1,2,3]

Stanford Institute for Theoretical Physics and Department of Physics, Stanford University, Stanford, CA 94306

[2] *Kavli Institute for Particle Astrophysics and Cosmology, Stanford University and SLAC, Menlo Park, CA 94025*

[3] *CERN, Theory Division, 1211 Geneva 23, Switzerland*

ucture surveys promise to be the next leading probe of cosmological information. It ucial to reliably predict their observables. The Effective Field Theory of Large Scale TofLSS) provides a manifestly convergent perturbation theory for the weakly non-linear

Geometrical Constraint on Curvature with BAO experiments

Masahiro Takada[1] and Olivier Doré[2,3]

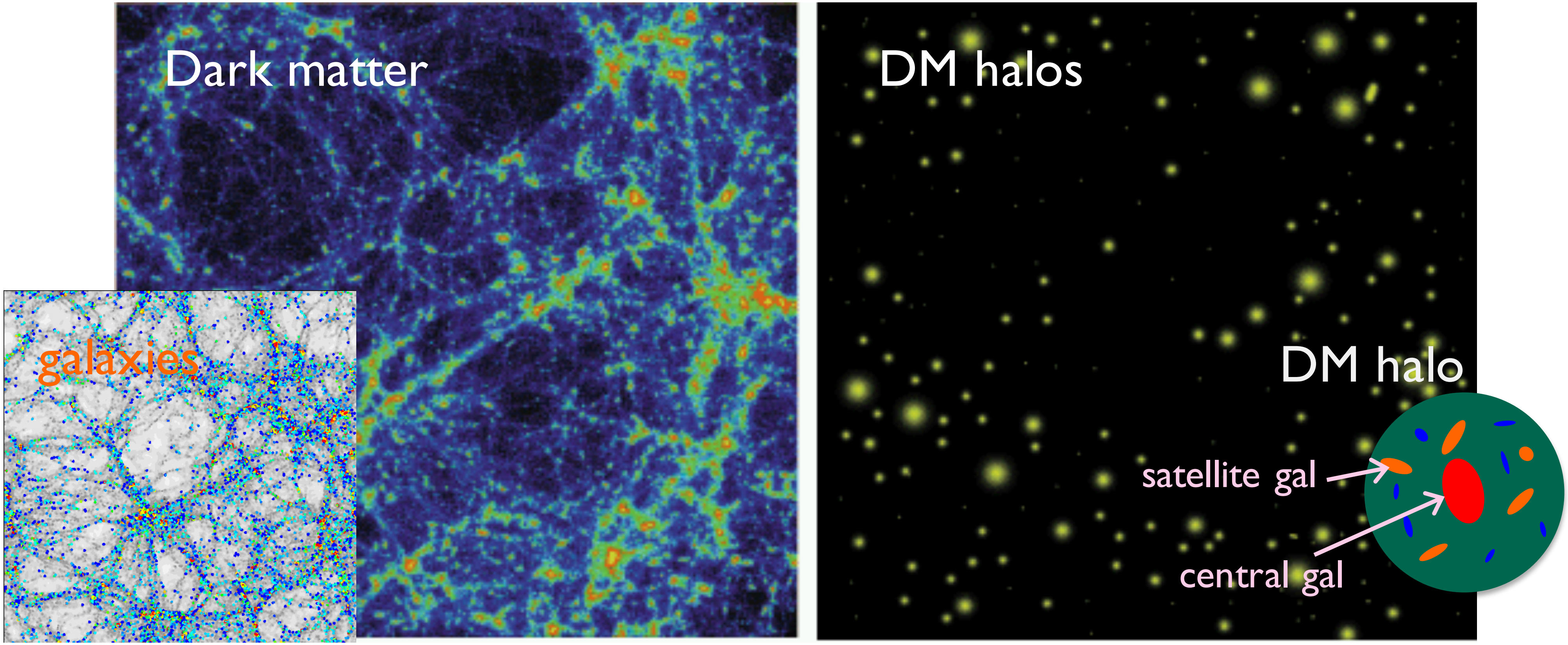
[1] *Kavli Institute for the Physics and Mathematics of the Universe (Kavli IPMU), The University of Tokyo Institutes for Advanced Study, The University of Tokyo, Chiba 277-8583, Japan*
[2] *Caltech M/C 350-17, Pasadena, CA 91125, USA*
[3] *Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, California, U.S.A.*

The spatial curvature (K or Ω_K) is one of the most fundamental parameters of isotropic and homogeneous universe and has a close link to the physics of early universe. Combining the radial and angular diameter distances measured via the baryon acoustic oscillation (BAO) experiments allows us to unambiguously constrain the curvature. The method is primarily based on the metric theory, but not much on the theory of structure formation other than the existence of BAO scale and is free of any model of dark energy. In this paper, we estimate a best-achievable accuracy of constraining the curvature with the BAO experiments. We show that an all-sky, cosmic-variance-limited galaxy survey covering the universe up to $z \gtrsim 4$ enables a precise determination of the

2015

Challenges: Galaxy Bias

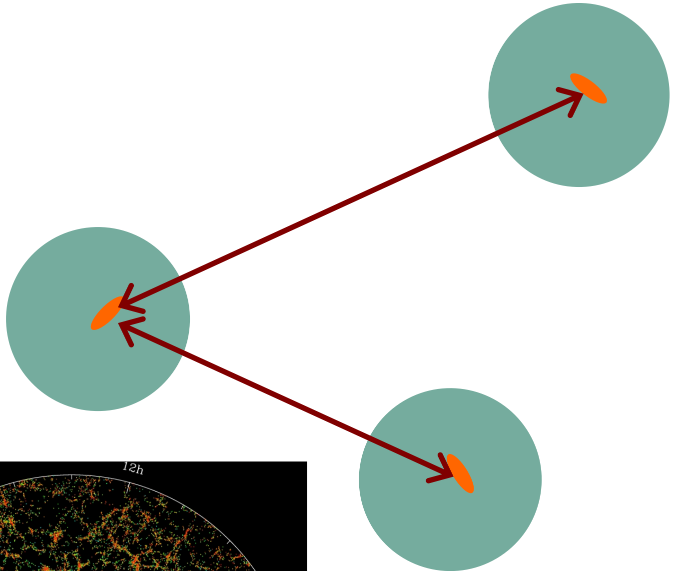
A possible, practical route: galaxy-halo connection

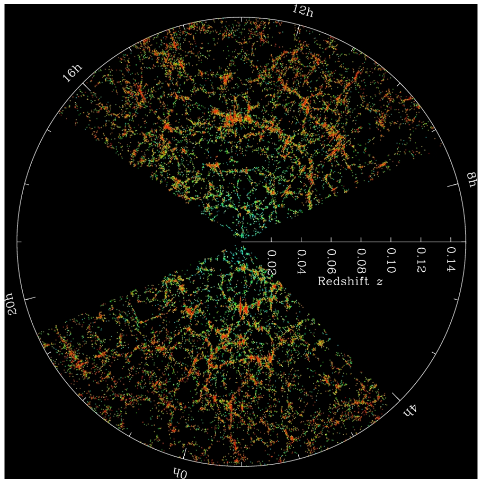


- Still impossible to accurately model galaxy formation from first principles
- Galaxies reside in dark matter halos
- Clustering of dark matter halos are relatively easy to model based on simulations and/or analytical models

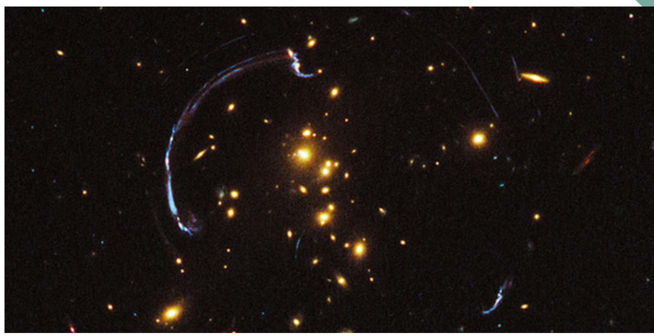
Combined probes: Clustering + Lensing

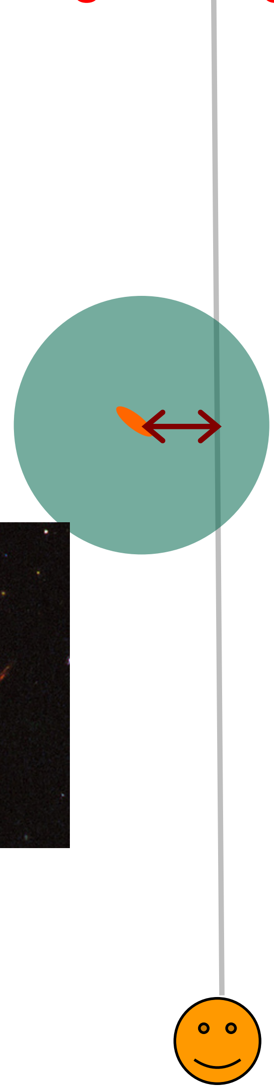
- Clustering analysis (3D galaxy distribution)





- Correlation of 3D galaxy positions with background galaxy shapes





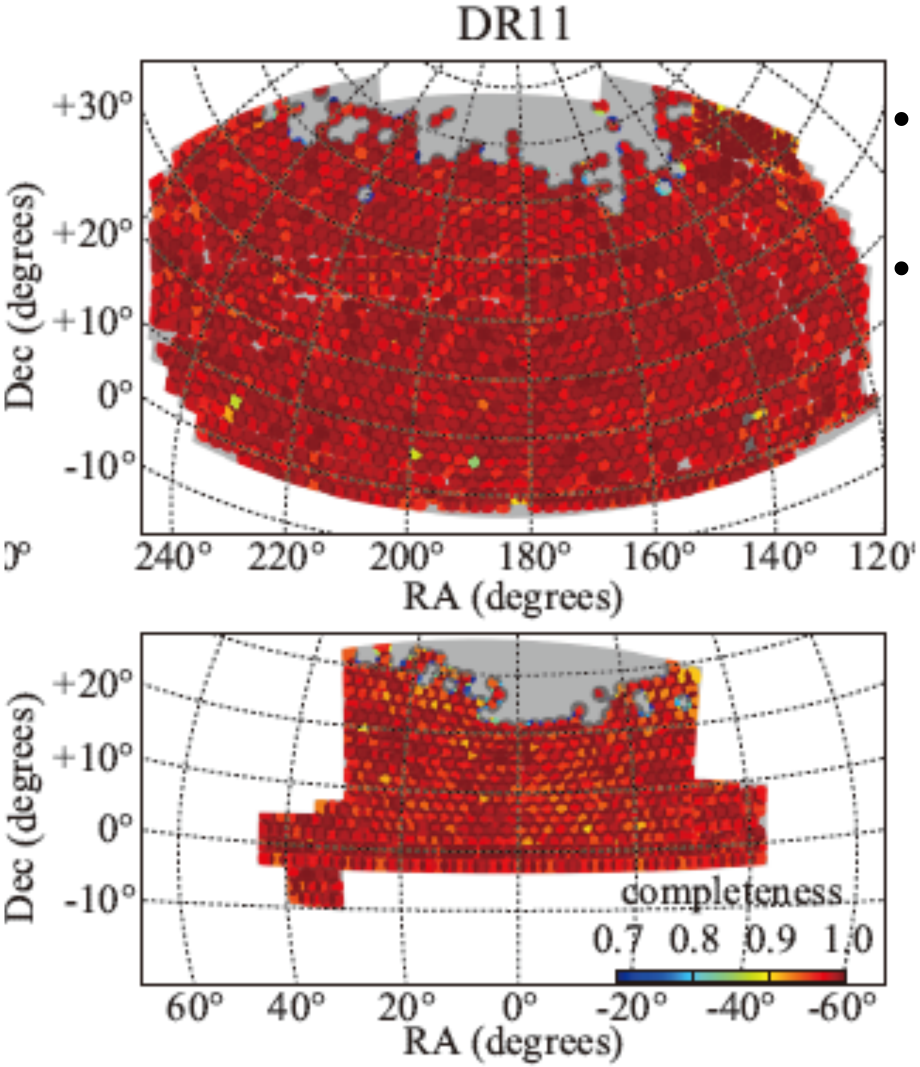
Synergy of imaging and spec-z BOSS-CFHT example

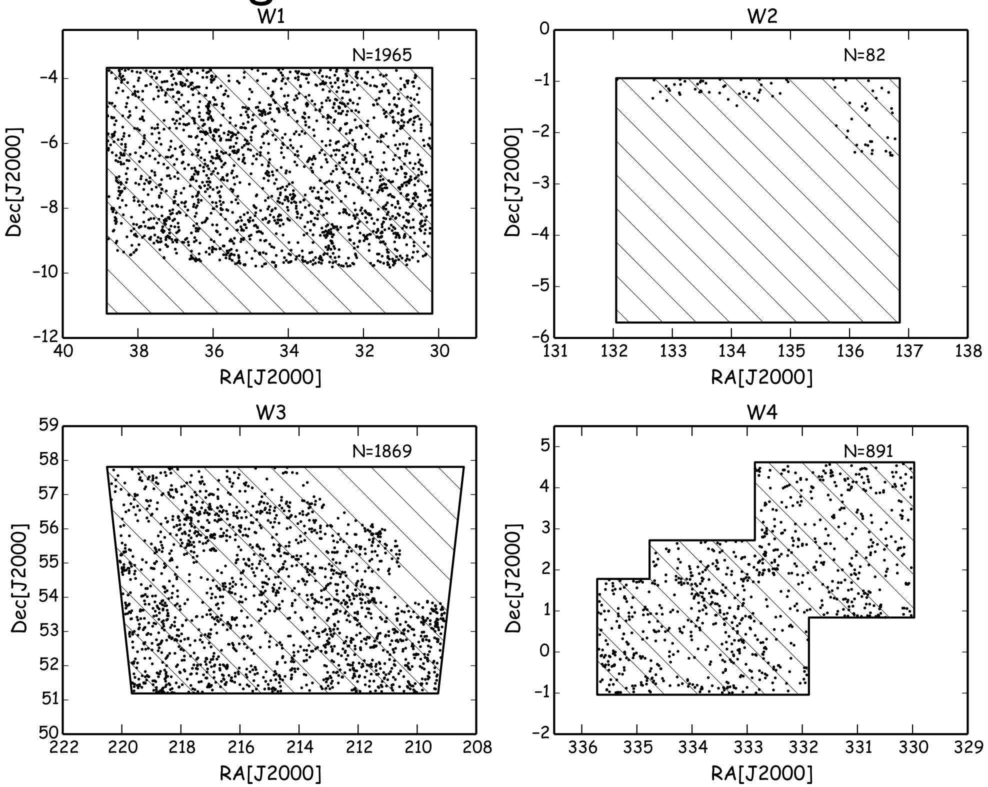
Miyatake, More, Mandelbaum, MT, Spergel+15
More, Miyatake+15


H. Miyatake


S. More

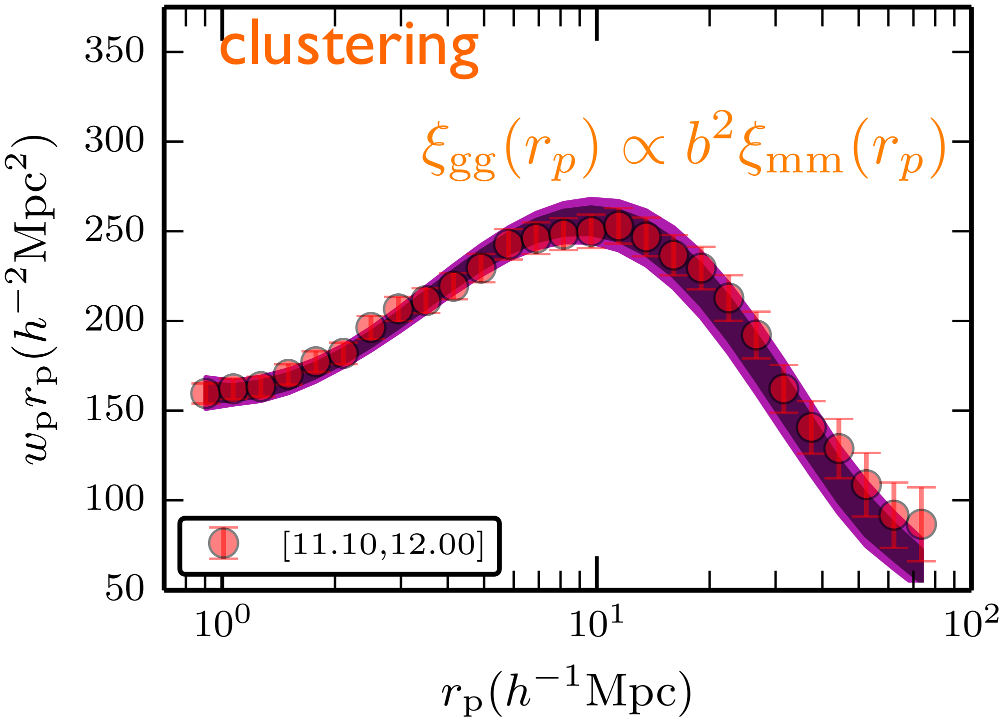
- BOSS DR11: ~0.8M CMASS gals (fsky~0.25), and the lensing studies not yet done
- CFHTLenS: the overlapping region is ~120 sq. degs, ~4800 CMASS gals, <z_s>~0.7
- Also Hikage+13

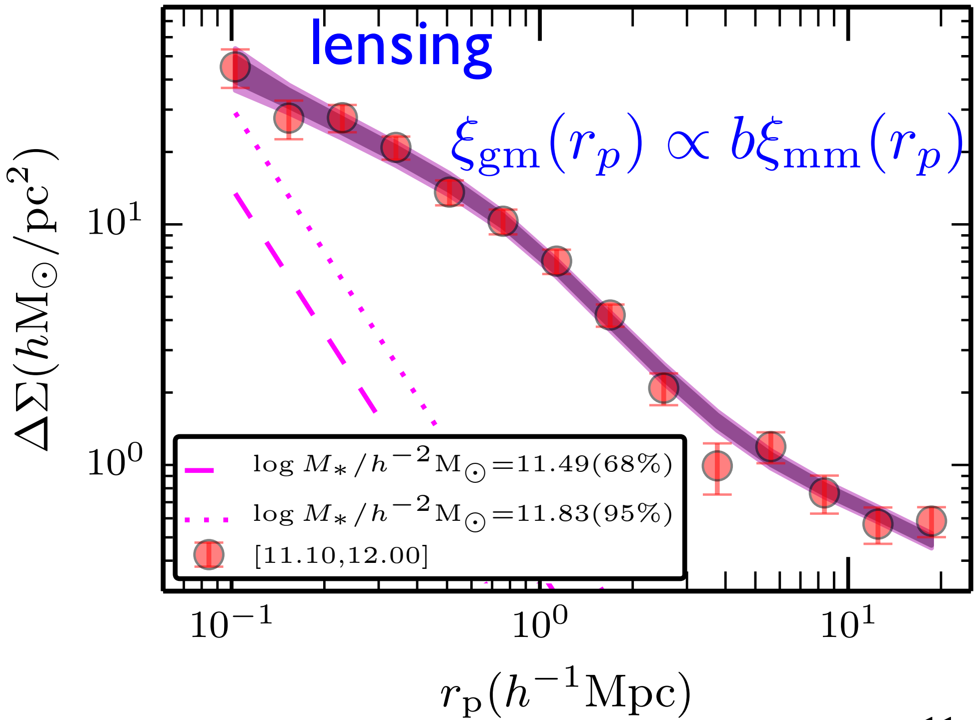


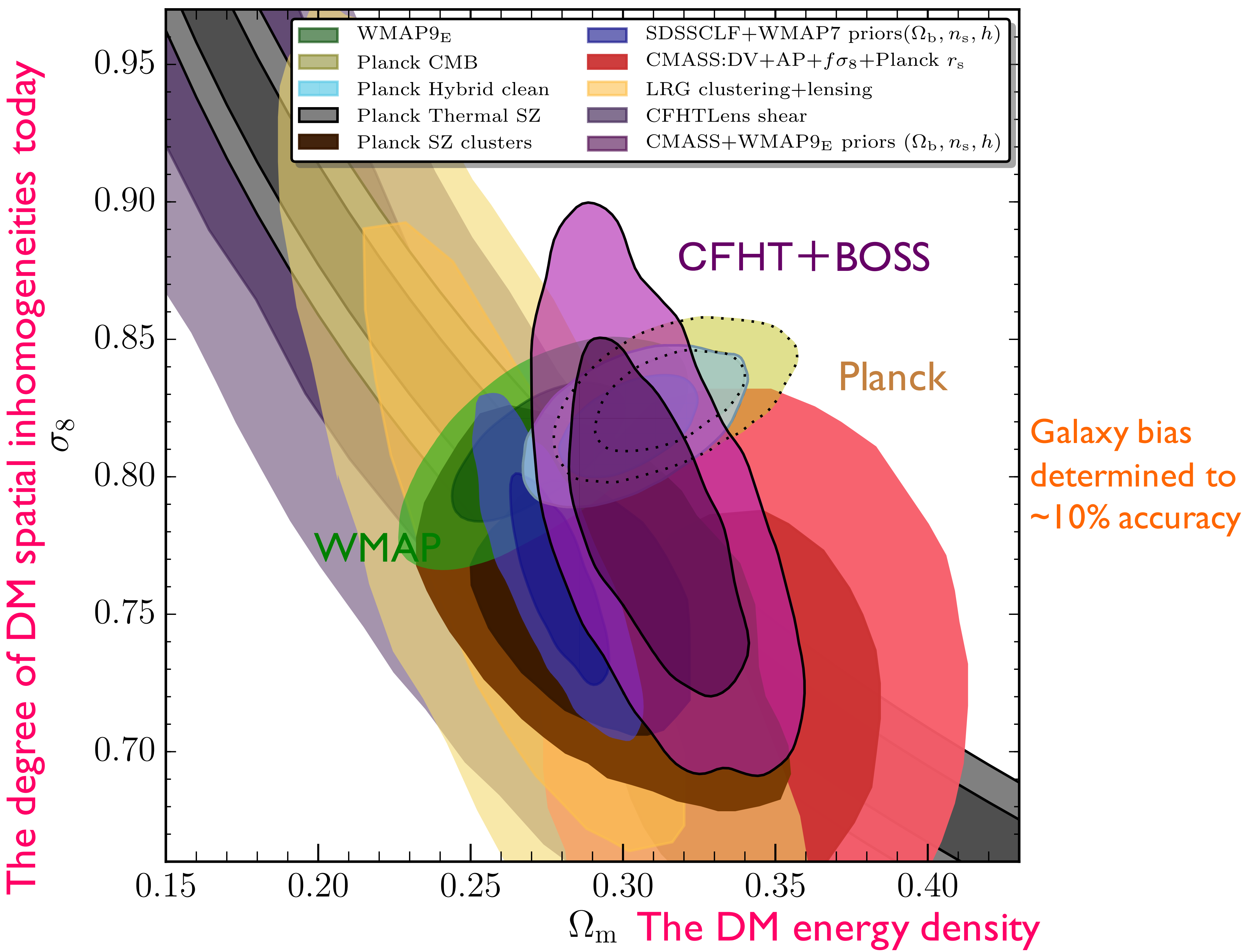


Combined probes: Lensing (imaging) + Clustering (spec-z)

- Lensing: directly measure the DM distribution (but projected)
- Clustering: 3D mapping of galaxy distribution; a much higher S/N, but galaxy bias uncertainty
- CFHTLenS (3.6m imaging, *only ~120 sq. deg,* n_g*(z>0.5)~8 arcmin*$^{-2}$) + BOSS (2.5m spec-z, 8,400 sq. deg, 0.47<z<0.59)







WMAP9$_E$
Planck CMB
Planck Hybrid clean
Planck Thermal SZ
Planck SZ clusters
SDSSCLF+WMAP7 priors(Ω_b, n_s, h)
CMASS:DV+AP+$f\sigma_8$+Planck r_s
LRG clustering+lensing
CFHTLens shear
CMASS+WMAP9$_E$ priors (Ω_b, n_s, h)
CFHT+BOSS
Planck
WMAP
Galaxy bias determined to ~10% accuracy
The degree of DM spatial inhomogeneities today
σ_8
0.95
0.90
0.85
0.80
0.75
0.70
0.15
0.20
0.25
0.30
0.35
0.40
Ω_m
The DM energy density

Imaging + Spectroscopy (+CMB lensing)

ASPEN CENTER FOR PHYSICS

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July 20 - August 10
Combining Probes in Cosmological Surve
Organizers:
Sarah Bridle, University of Manchester
Scott Dodelson, Fermi National Laborat
Masahiro Takada, Kavli Institute fc
Mathematics of the Universe

The Lambda-dominated Cold Dark
successfully explains a broad rang
observations including the recent Planck measurement of
cosmic microwave background anisotropies. However, the success is only phenomenological in that the model requires introducing new unknown physics in the form of inflation, dark matter and dark energy or modified gravity. Understanding the nature of this new physics is arguably the most tantalizing problem in cosmology today. Cosmological observations, such as galaxy surveys and cosmic microwave background experiments, offer the most promising way of making progress on these problems. The workshop will focus on learning even more about the new physics by combining the many probes made possible by these observations.

2014 Aspen Summer WS "Combining Probes in Cosmology Surveys", S. Dodelson, S. Bridle, MT: had WL, galaxy clustering, CMB, …

August 3 - August 31
Model Building in the LHC Era

Miyatake, More et al. 2015


H. Miyatake


S. More

Almost accepted in PRL

Evidence of Halo Assembly Bias in Massive Clusters

Evidence of Halo Assembly Bias in Massive Clusters

Hironao Miyatake,[1,2,*] Surhud More,[2] Masahiro Takada,[2] David N. Spergel,[1,2] Rachel Mandelbaum,[3] Eli S. Rykoff,[4,5] and Eduardo Rozo[6]

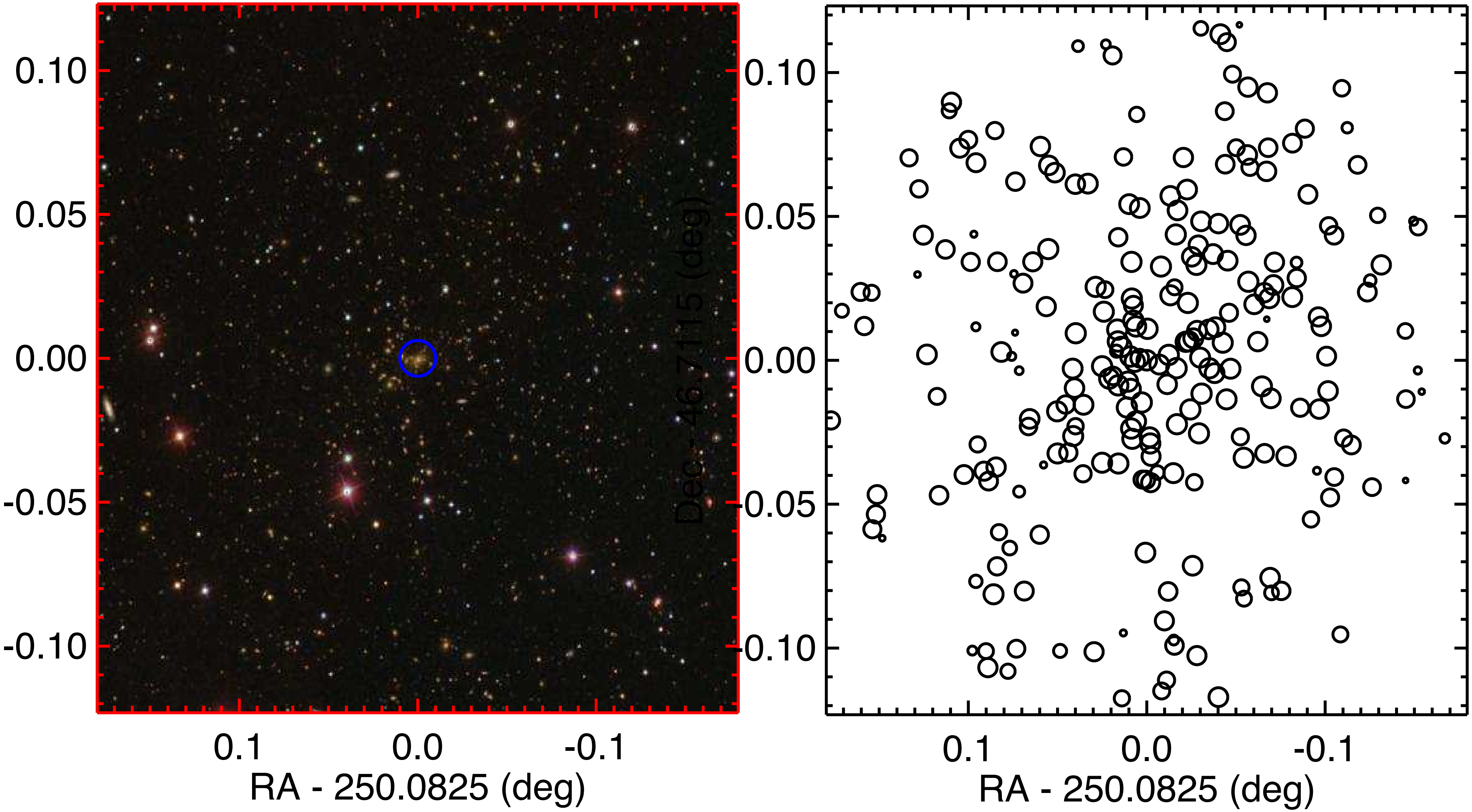
[1]*Department of Astrophysical Sciences, Princeton University, Peyton Hall, Princeton NJ 08544, USA*
[2]*Kavli Institute for the Physics and Mathematics of the Universe (WPI), UTIAS, The University of Tokyo, Chiba, 277-8583, Japan*
[3]*McWilliams Center for Cosmology, Department of Physics, Carnegie Mellon University, Pittsburgh, PA 15213, USA*
[4]*Kavli Institute for Particle Astrophysics & Cosmology, P. O. Box 2450, Stanford University, Stanford, CA 94305, USA*
[5]*SLAC National Accelerator Laboratory, Menlo Park, CA 94025, USA*
[6]*Department of Physics, University of Arizona, 1118 E 4th St, Tucson, AZ 85721, USA*

(Dated: July 1, 2015)

We present significant evidence of halo assembly bias for redMaPPer galaxy clusters in the redshift range [0.1, 0.33]. By dividing the 8,648 clusters into two subsamples based on the average member galaxy separation from the cluster center, we first show that the two subsamples have very similar halo mass of $M_{200\mathrm{m}} \simeq 1.9 \times 10^{14}\ h^{-1} M_\odot$ based on the weak lensing signals at small radii $R \lesssim 10\ h^{-1}$Mpc. However, their halo bias inferred from both the large-scale weak lensing and the projected auto-correlation functions differs by a factor of ~1.5, which is a signature of assembly bias. The same bias hypothesis for the two subsamples is excluded at 2.5σ in the weak lensing and 4.6σ in the auto-correlation data, respectively. This result could bring a significant impact on both galaxy evolution and precision cosmology.

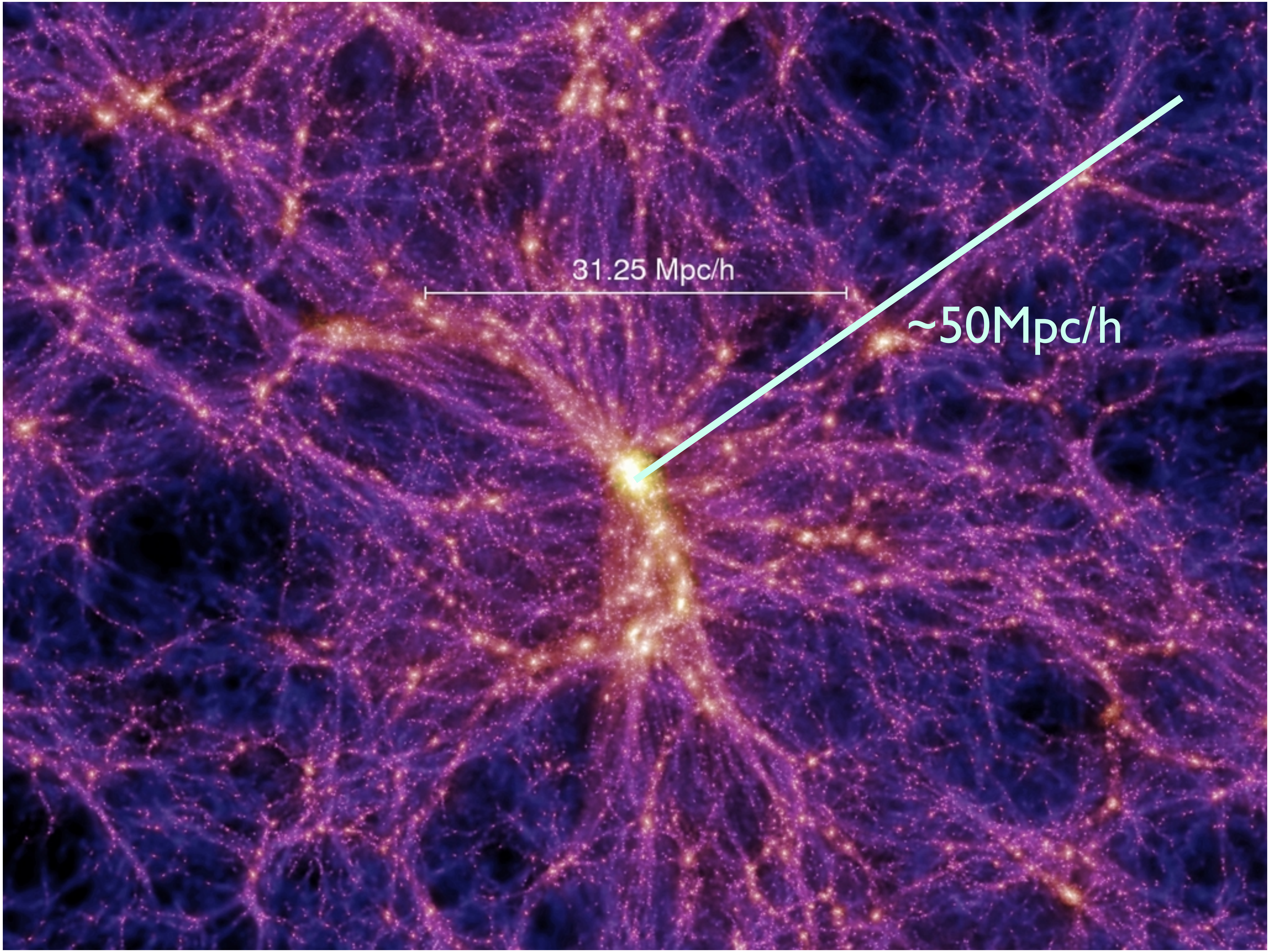
Since massive cluster-sized halos of cold dark matter ... catalog contains an optical richness estimate λ, a photo-

Clusters = Most massive self-grav. system



Clusters easy to find…

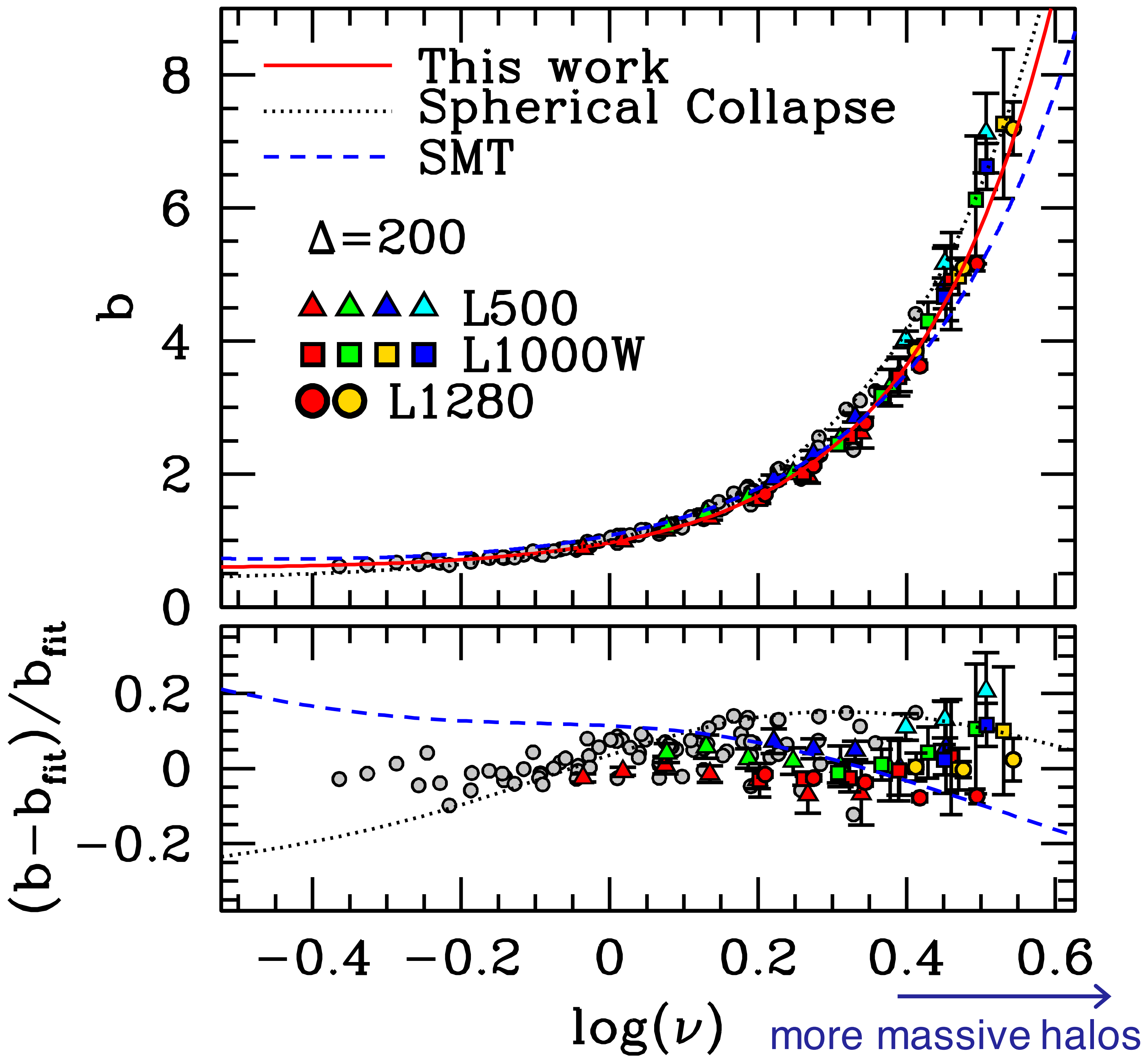
Rykoff, Rozo+ 2014


31.25 Mpc/h
~50Mpc/h

Halo bias

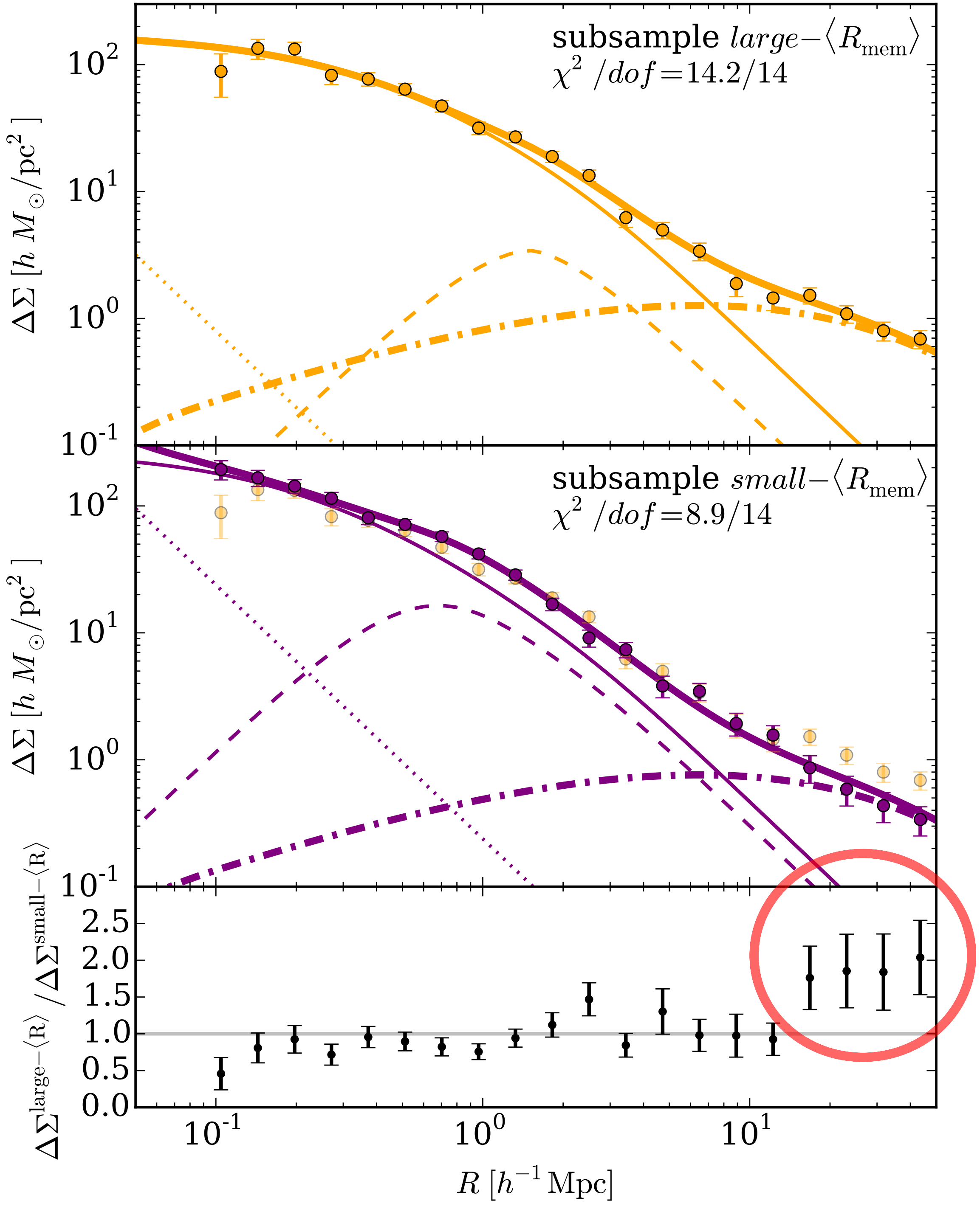
Mo+96
Sheth+ 99, 01
Tinker+10

$b(M)$



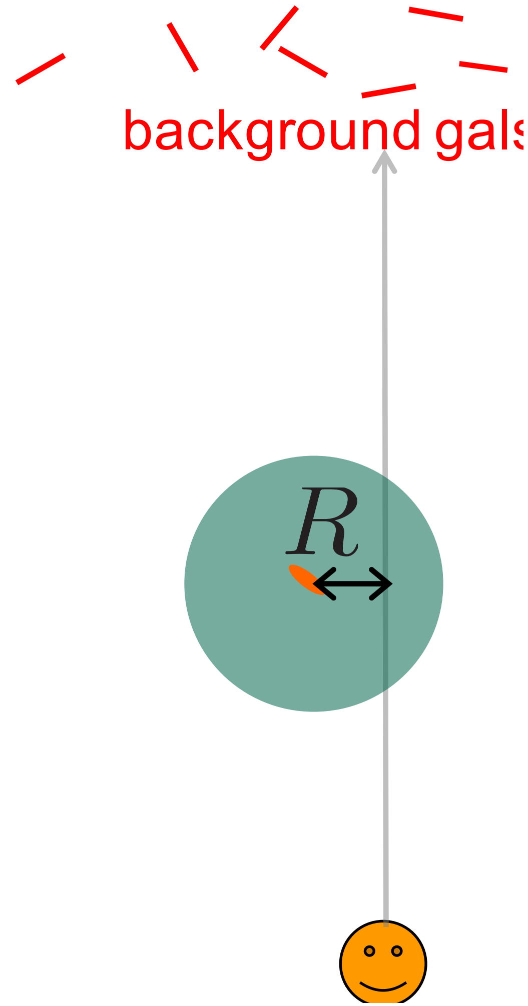
$b(M, p_\alpha)$?

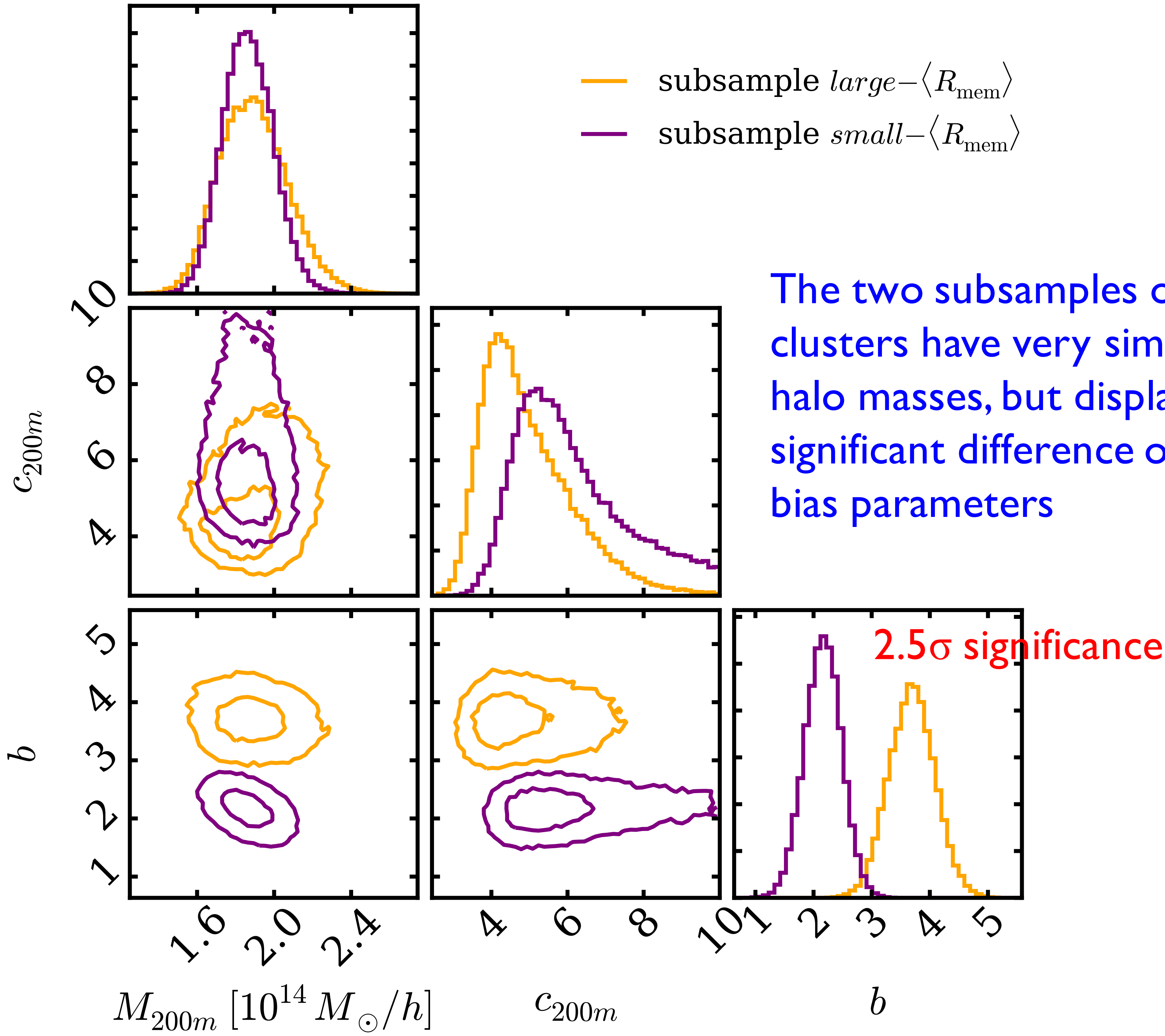
Weak lensing signal



Proxy of halo assembly history for each cluster

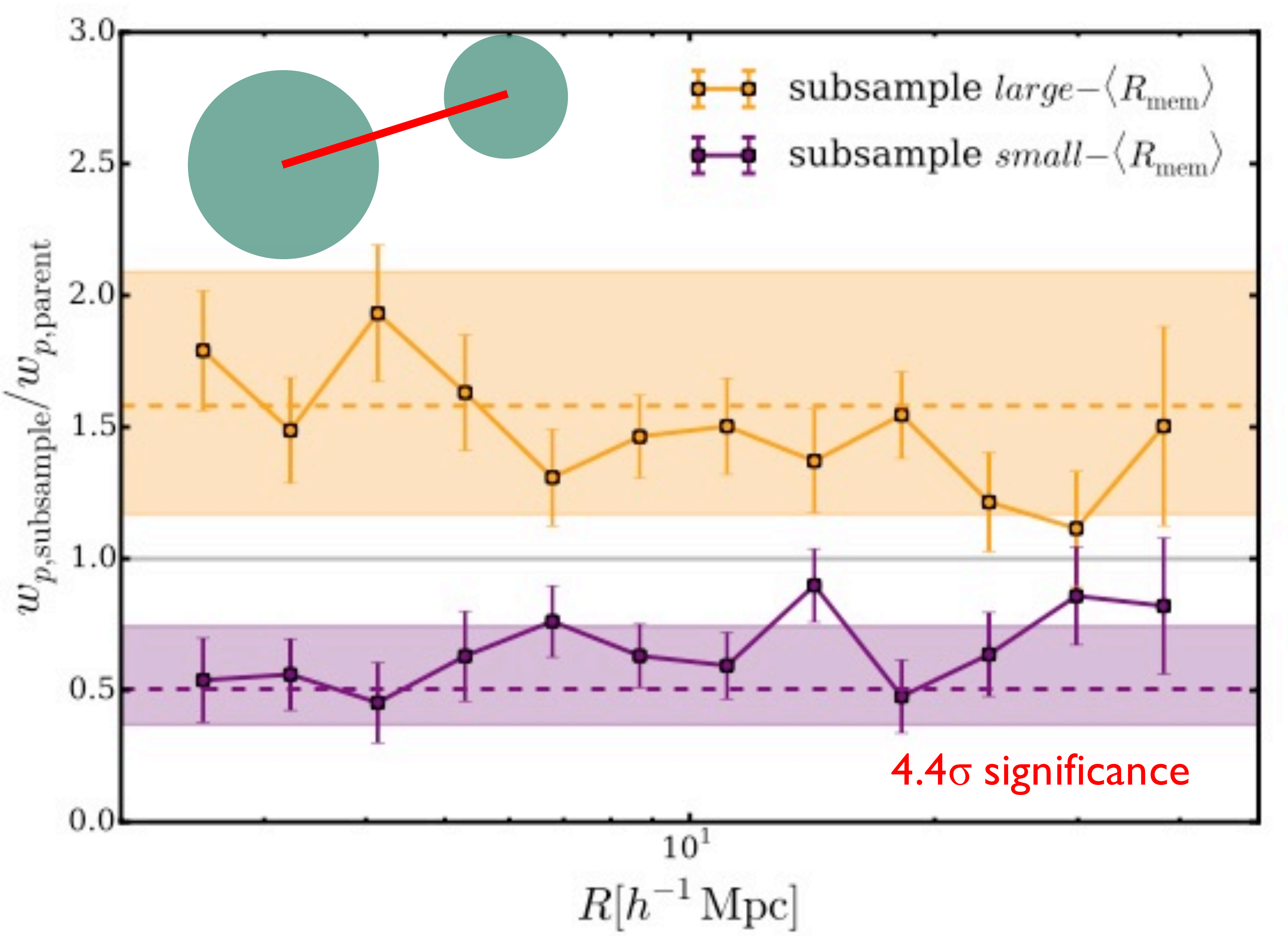
$$\langle R_{\rm mem}\rangle \equiv \frac{\sum_i p_{{\rm mem},i} R_{{\rm mem},i}}{\sum_i p_{{\rm mem},i}}$$

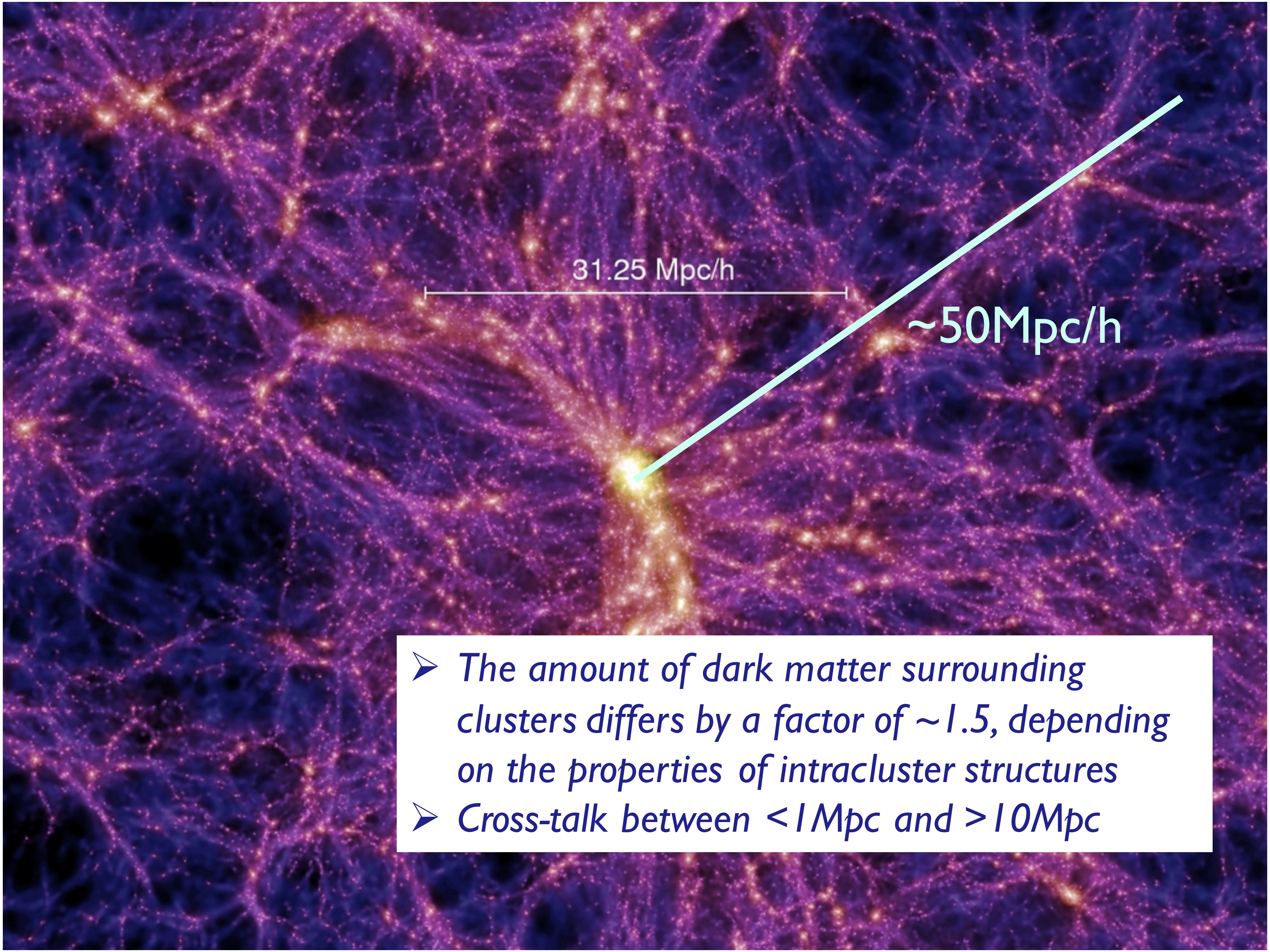




The two subsamples of clusters have very similar halo masses, but display a significant difference of their bias parameters

Auto-correlation functions of the two subsamples

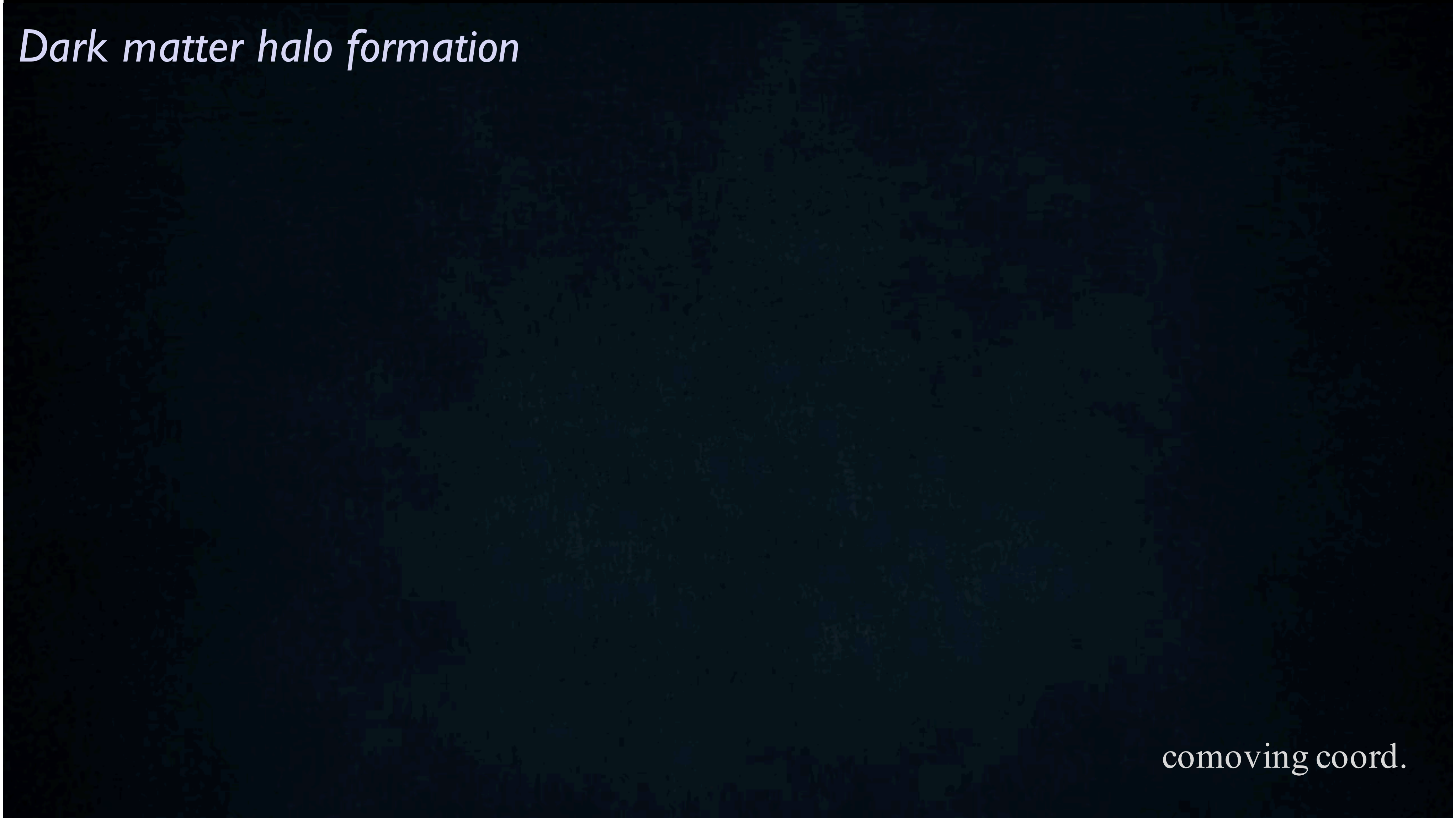




- *The amount of dark matter surrounding clusters differs by a factor of ~1.5, depending on the properties of intracluster structures*
- *Cross-talk between <1Mpc and >10Mpc*

What is the origin of the assembly bias?

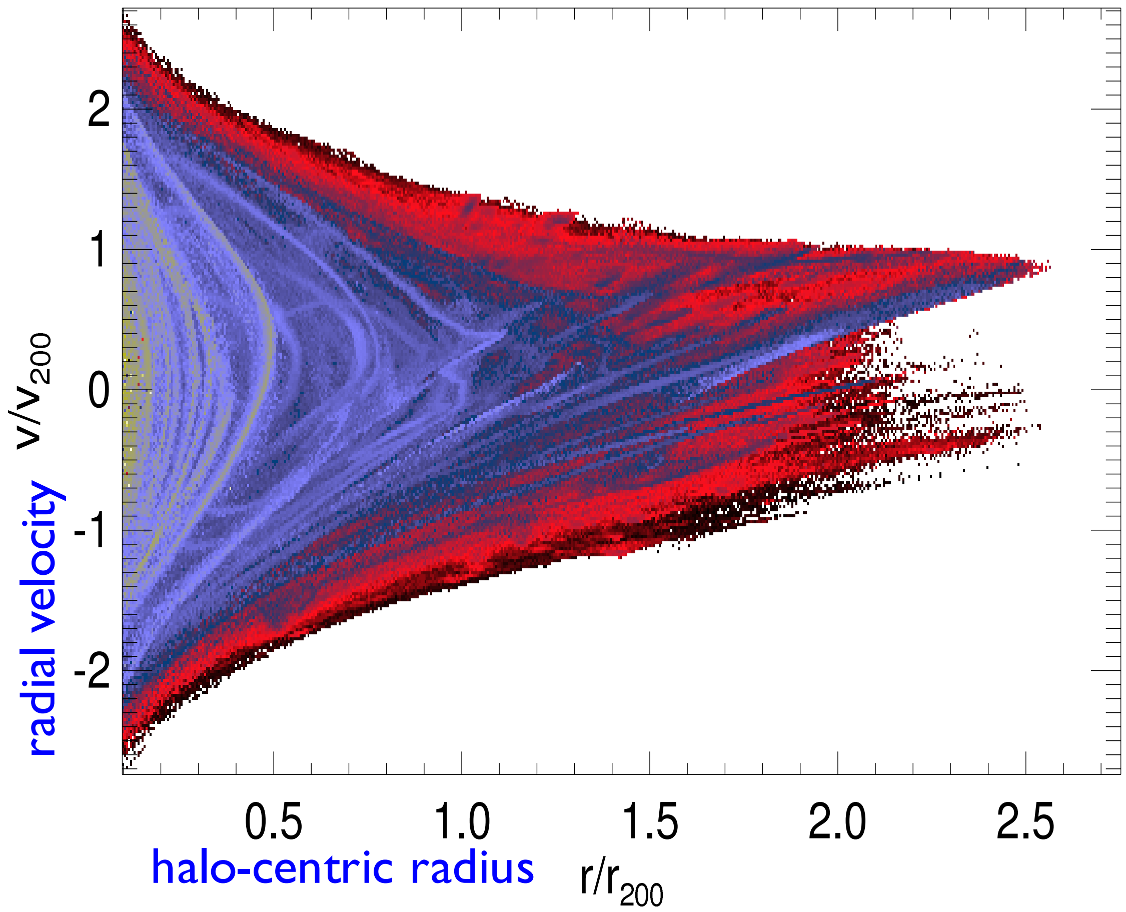
Dark matter halo formation



Continuous mergers/mass accretion

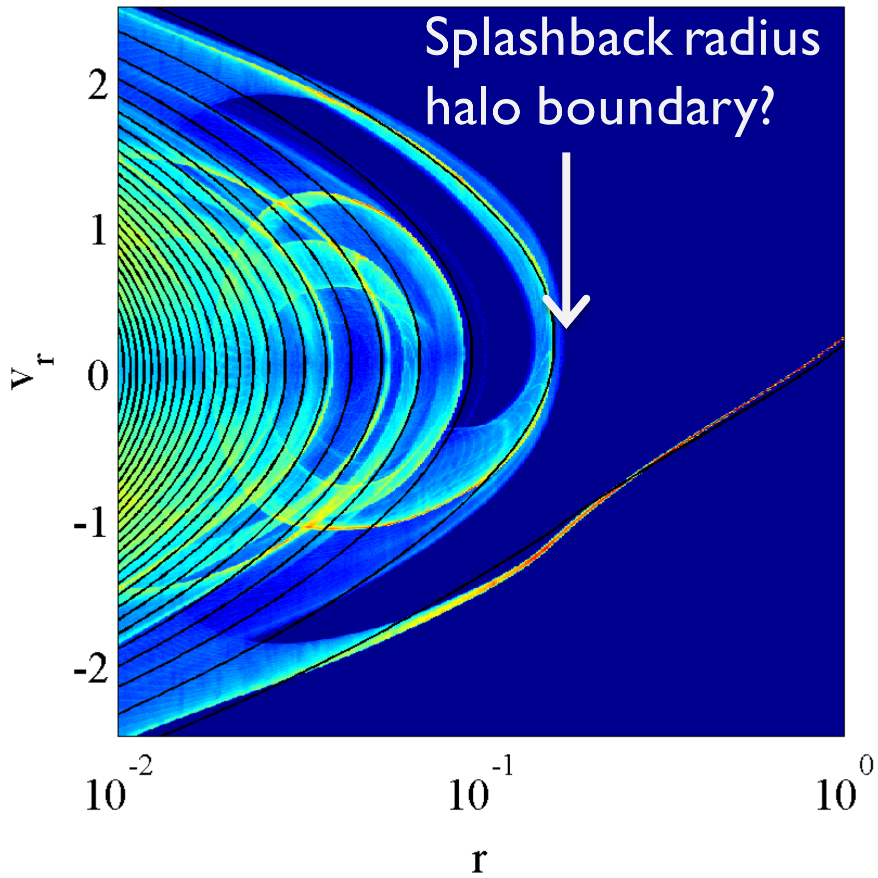
Phase-space structure of DM halo: caustics and streams

Vogelsberger & White 11



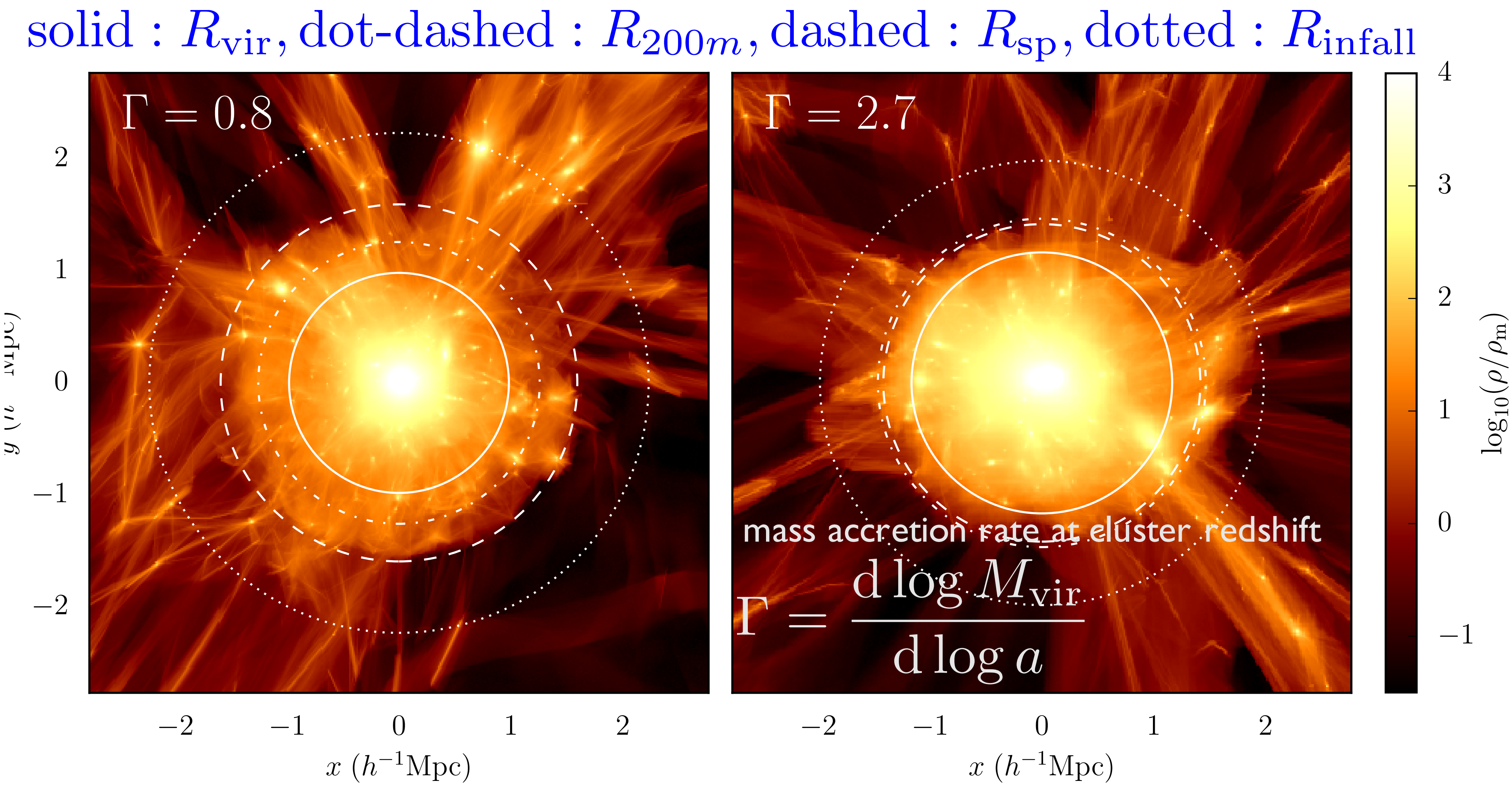
Phase-space structure of DM particles (subhalos removed)

Adhikari & Dalal 14

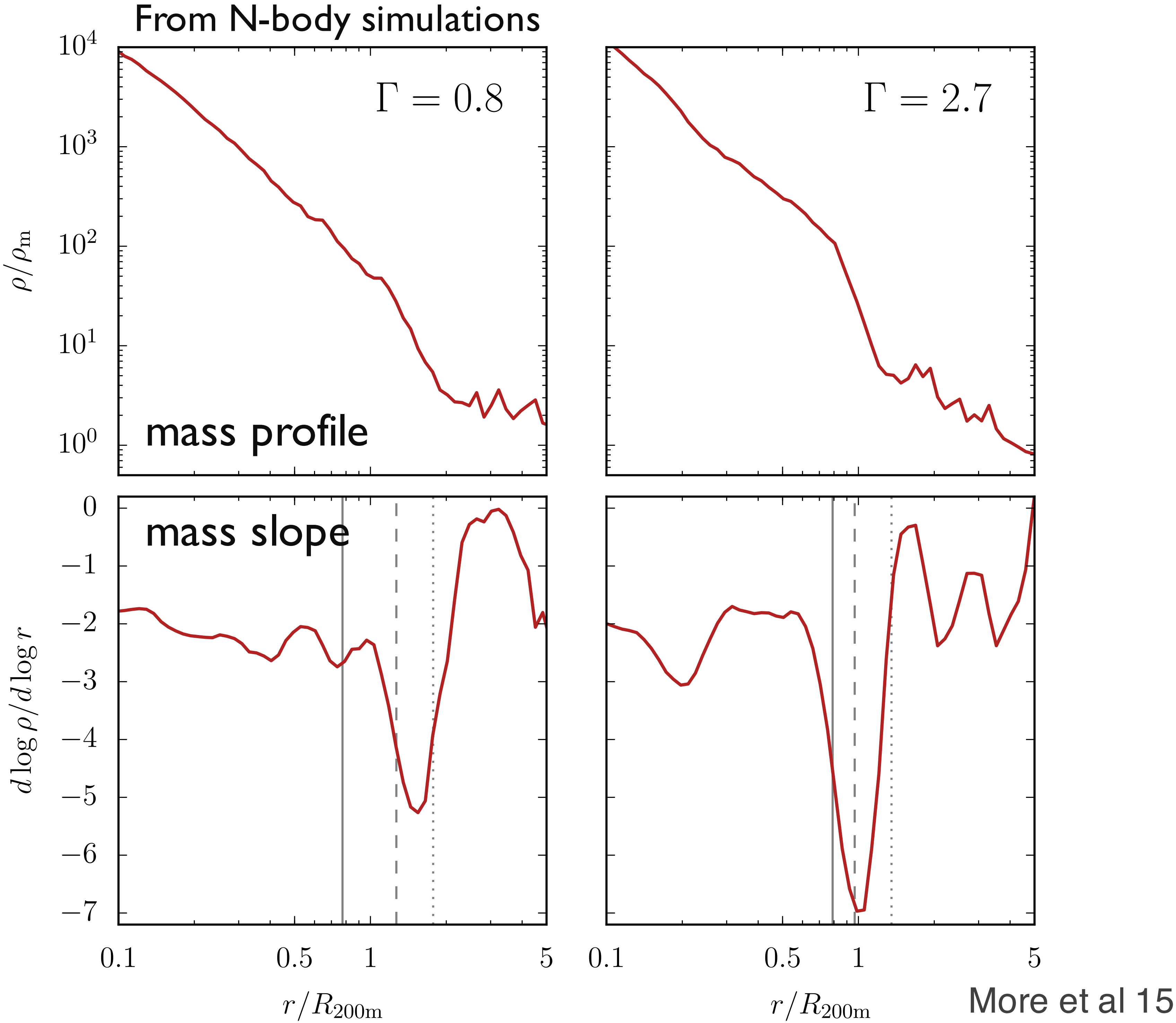


Analytical model:
Secondary infall model of spherical collapse

Halo boundary: splashback radius

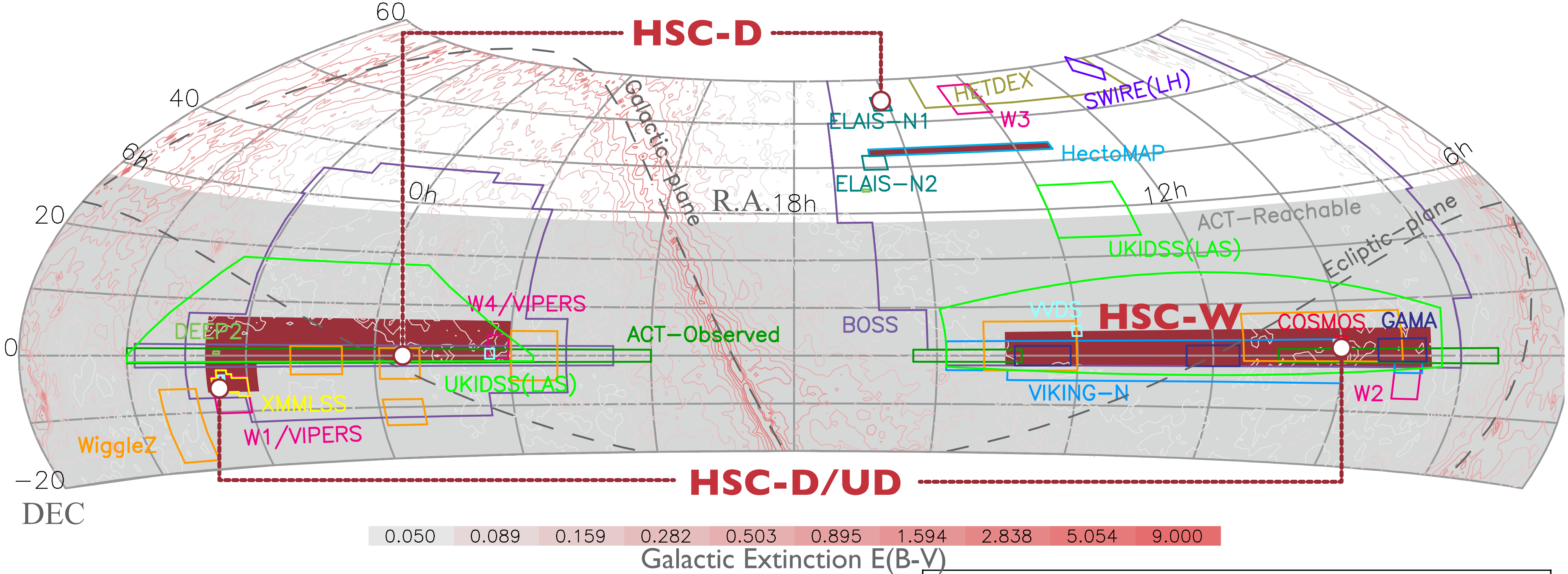


Splashback radius is a more physically-motivated halo boundary?
Most of gravitationally bound particles are enclosed inside

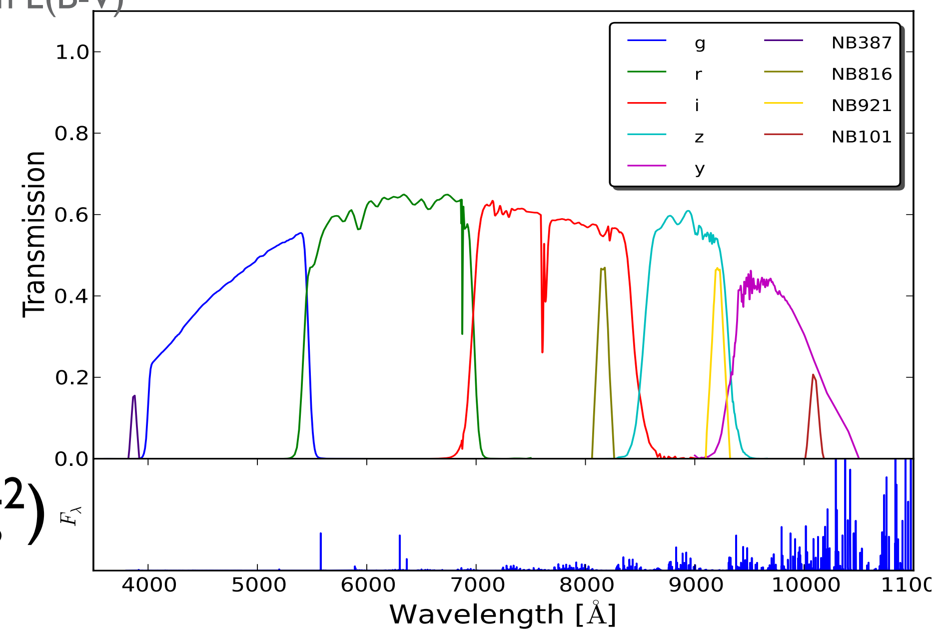


From N-body simulations
$\Gamma = 0.8$
$\Gamma = 2.7$
mass profile
mass slope
ρ/ρ_{m}
$d\log\rho/d\log r$
$r/R_{200\mathrm{m}}$
$r/R_{200\mathrm{m}}$
More et al 15

HSC Survey: 300nights granted (PI: Satoshi Miyazaki)

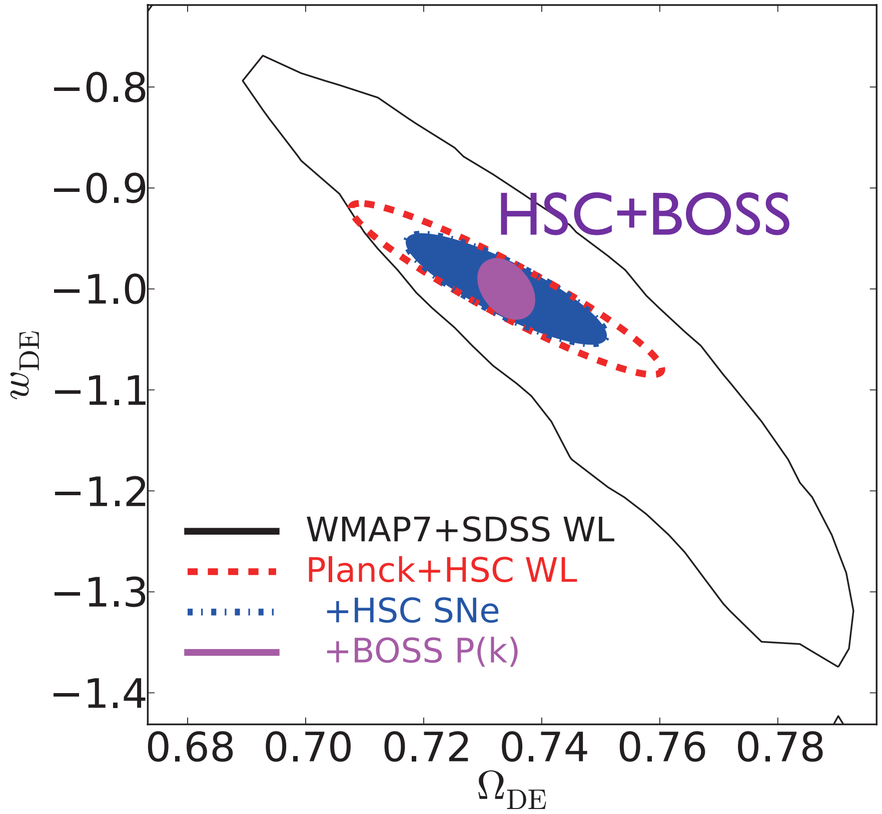


- 2014 – 2019 (so far 21 nights)
- Three survey layers
  - Wide (i~26, grizy, 1400 deg^2)
  - Deep (i~27, grizy+NBs, 28 deg^2)
  - Ultra-D (i~28, grizy+NBs, 3.5 deg^2)



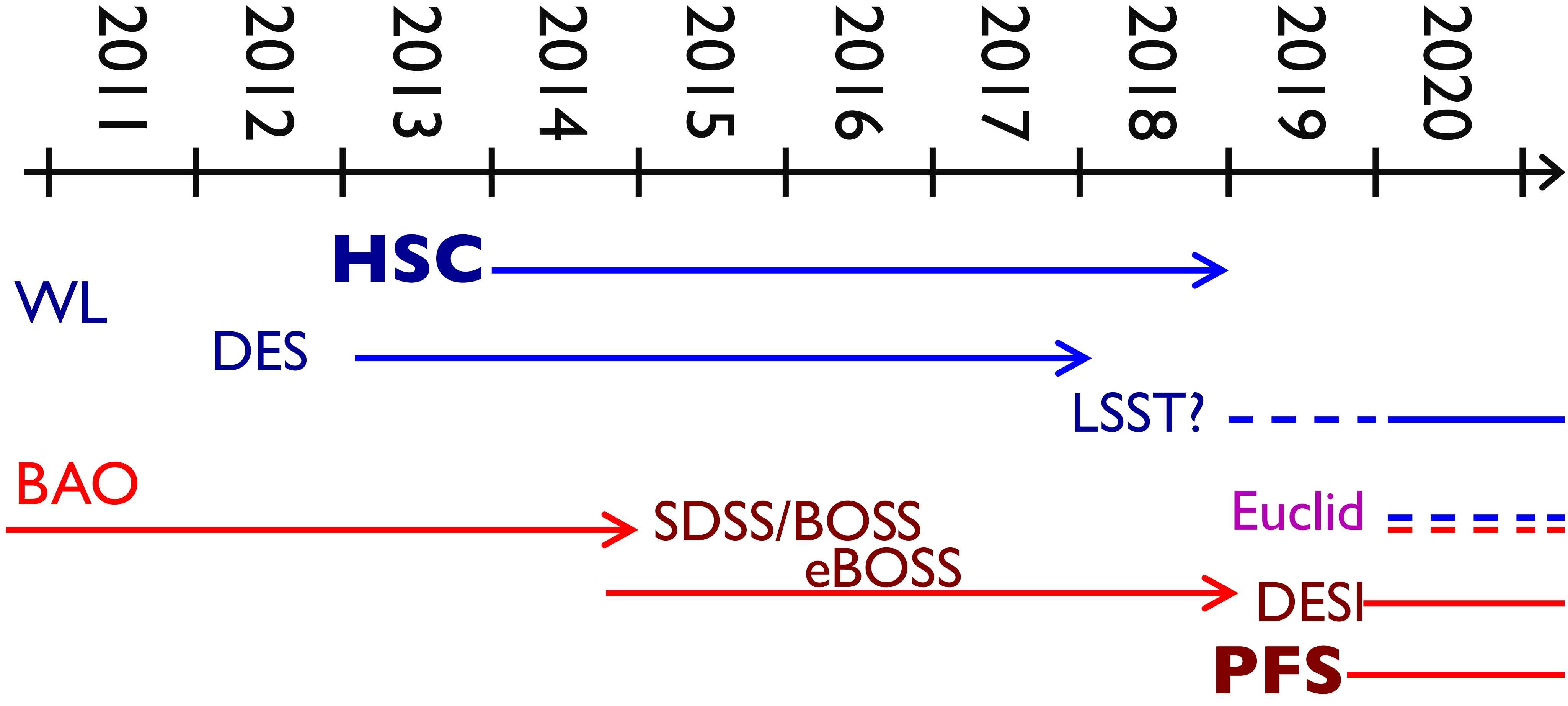
HSC-expected cosmological constraints

Data	w_{pivot}	w_a	FoM	γ_g	$m_{\nu,\text{tot}}$[eV]	f_{NL}	n_s	α_s
BOSS-*BAO*	0.064	1.04	15	–	–	–	0.018	0.0057
HSC(WL)-*B* (baseline)	0.080	0.86	15	0.15	0.16	30	0.014	0.0041
HSC(WL)-*O* (optimistic)	0.068	0.66	22	0.083	0.082	18	0.013	0.0040
HSC(WL+SN)-*B*	0.043	0.60	39	0.15	0.16	30	0.014	0.0041
HSC(WL+SN)-*O*	0.041	0.45	54	0.081	0.081	18	0.013	0.0040
HSC-*O*+[BOSS-$P(k)$]	0.028	0.36	99	0.038	0.076	17	0.011	0.0029
HSC-*O*+[BOSS+PFS]	0.027	0.19	196	0.035	0.07	17	0.009	0.0022



- The HSC promises a significant improvement in our understanding of the universe (dark energy, neutrino mass, other cosmological parameters)

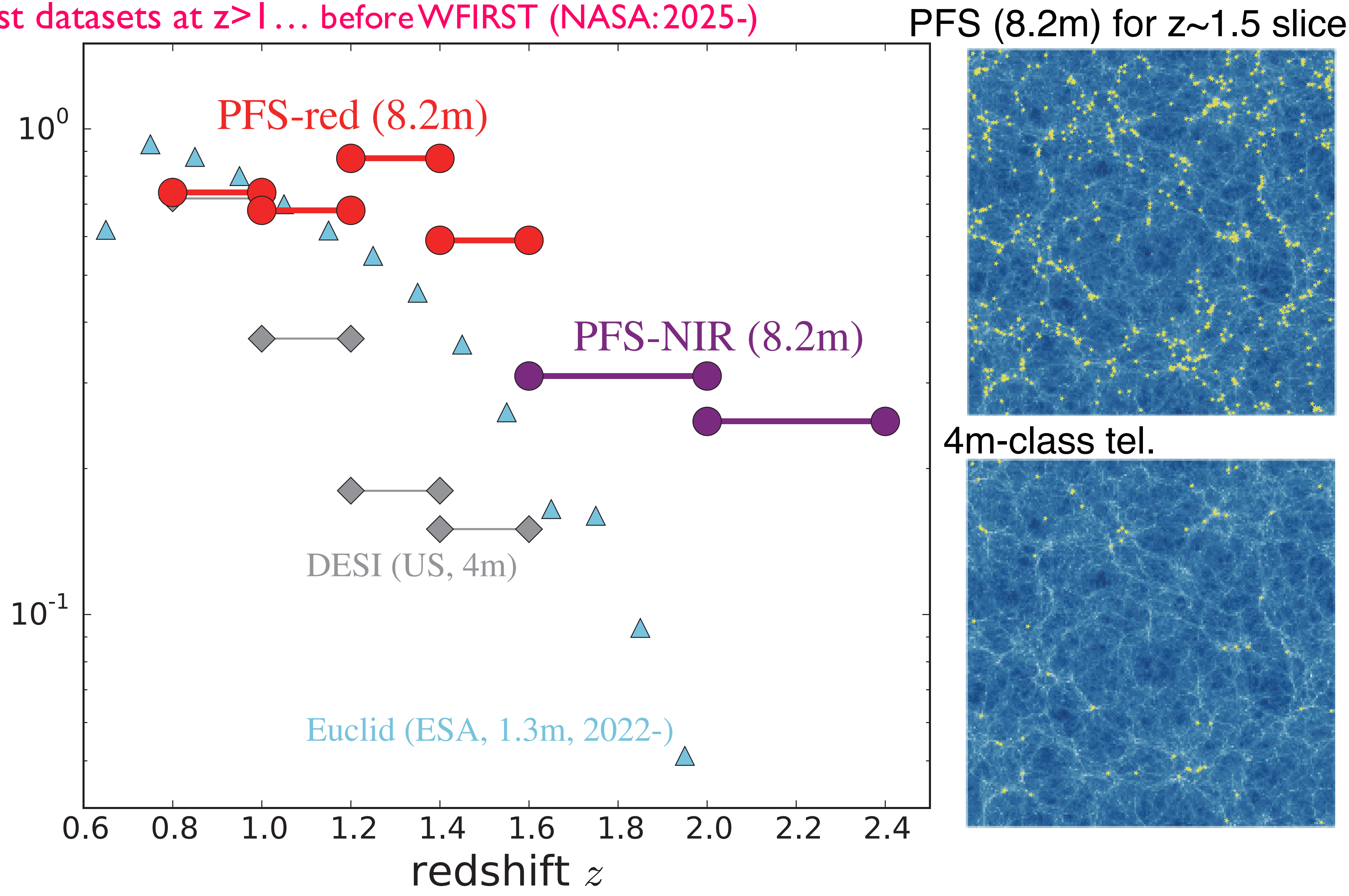
Competition

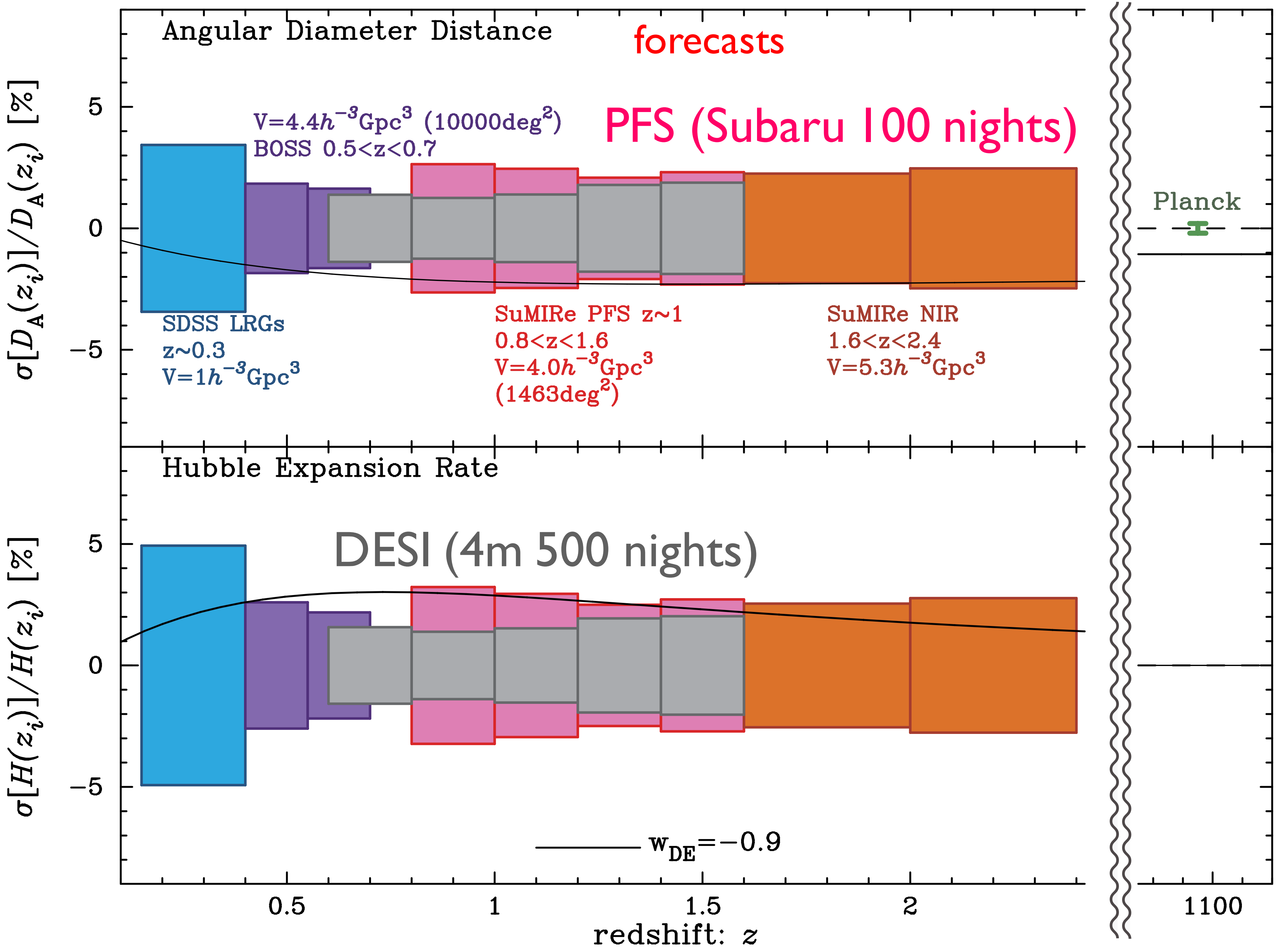


We are in a good position! and will lead survey cosmology/astronomy in 2020 era

Power of PFS

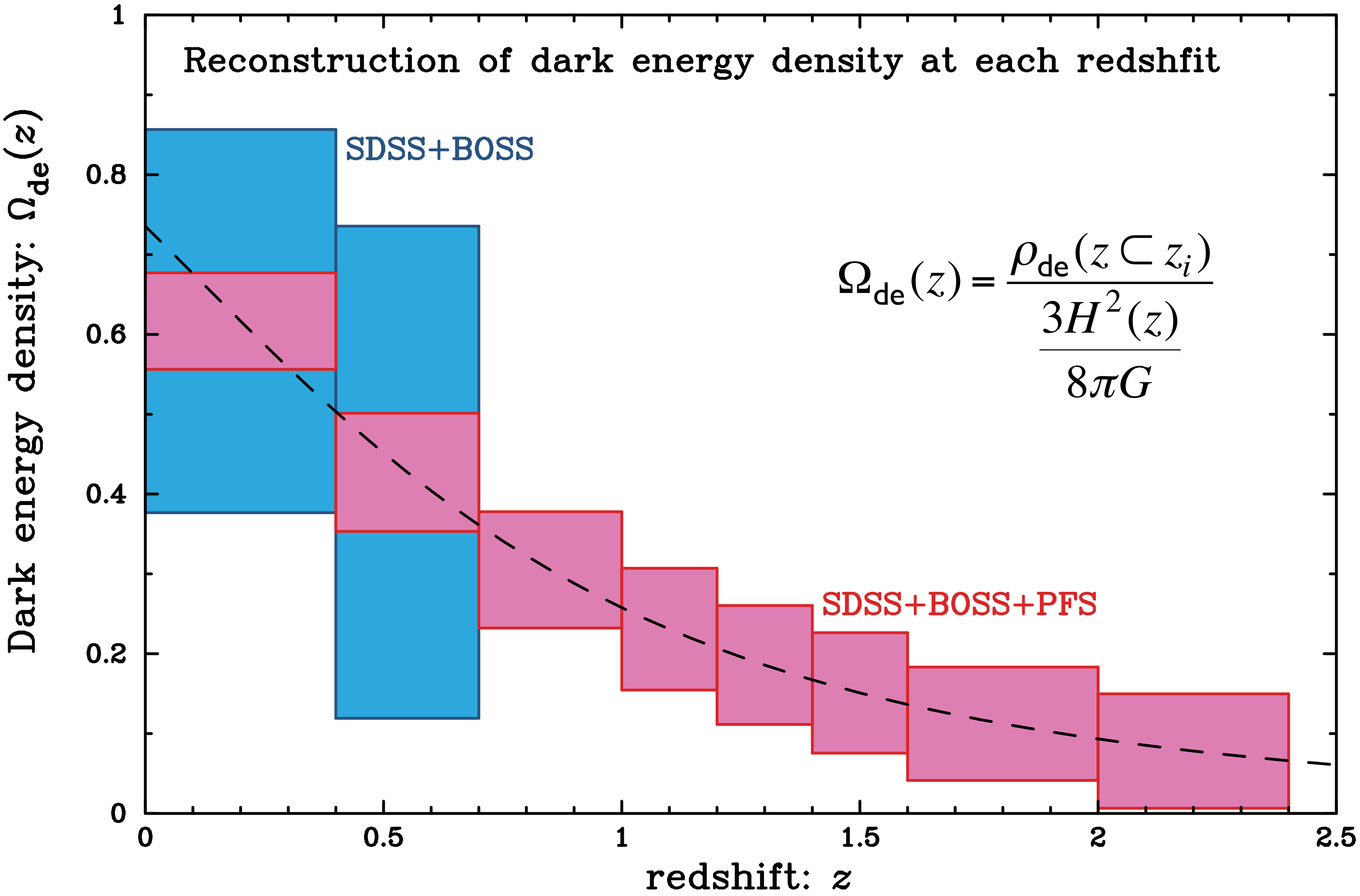
Best datasets at z>1… before WFIRST (NASA: 2025-)



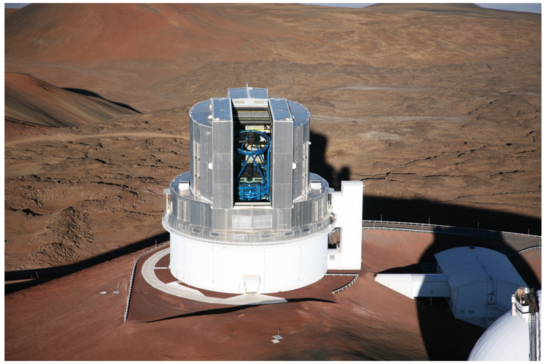


Angular Diameter Distance
forecasts
PFS (Subaru 100 nights)
V=4.4h^-3Gpc^3 (10000deg^2)
BOSS 0.5<z<0.7
SDSS LRGs
z~0.3
V=1h^-3Gpc^3
SuMIRe PFS z~1
0.8<z<1.6
V=4.0h^-3Gpc^3
(1463deg^2)
SuMIRe NIR
1.6<z<2.4
V=5.3h^-3Gpc^3
Planck
σ[D_A(z_i)]/D_A(z_i) [%]
Hubble Expansion Rate
DESI (4m 500 nights)
w_DE=−0.9
σ[H(z_i)]/H(z_i) [%]
5
0
−5
0.5
1
1.5
2
1100
redshift: z

Model-independent DE reconstruction



The 6th PFS collaboration meeting, Dec 2015 @ Taipei



The Goals of B03

- Imaging and spectroscopic surveys, or lensing and clustering, are so complementary
- Challenges: how observationally we can calibrate the galaxy bias uncertainty, DM: lensing and galaxy: spec-z
- B03 aims at developing a method of combined cosmological probes
  - HSC + BOSS (the first results: ~2017)
  - HSC + eBOSS (until about 2019)
  - Eventually HSC + PFS (2019 -)