

DARK ENERGY SURVEY GALAXY CLUSTER SCIENCE RESULTS

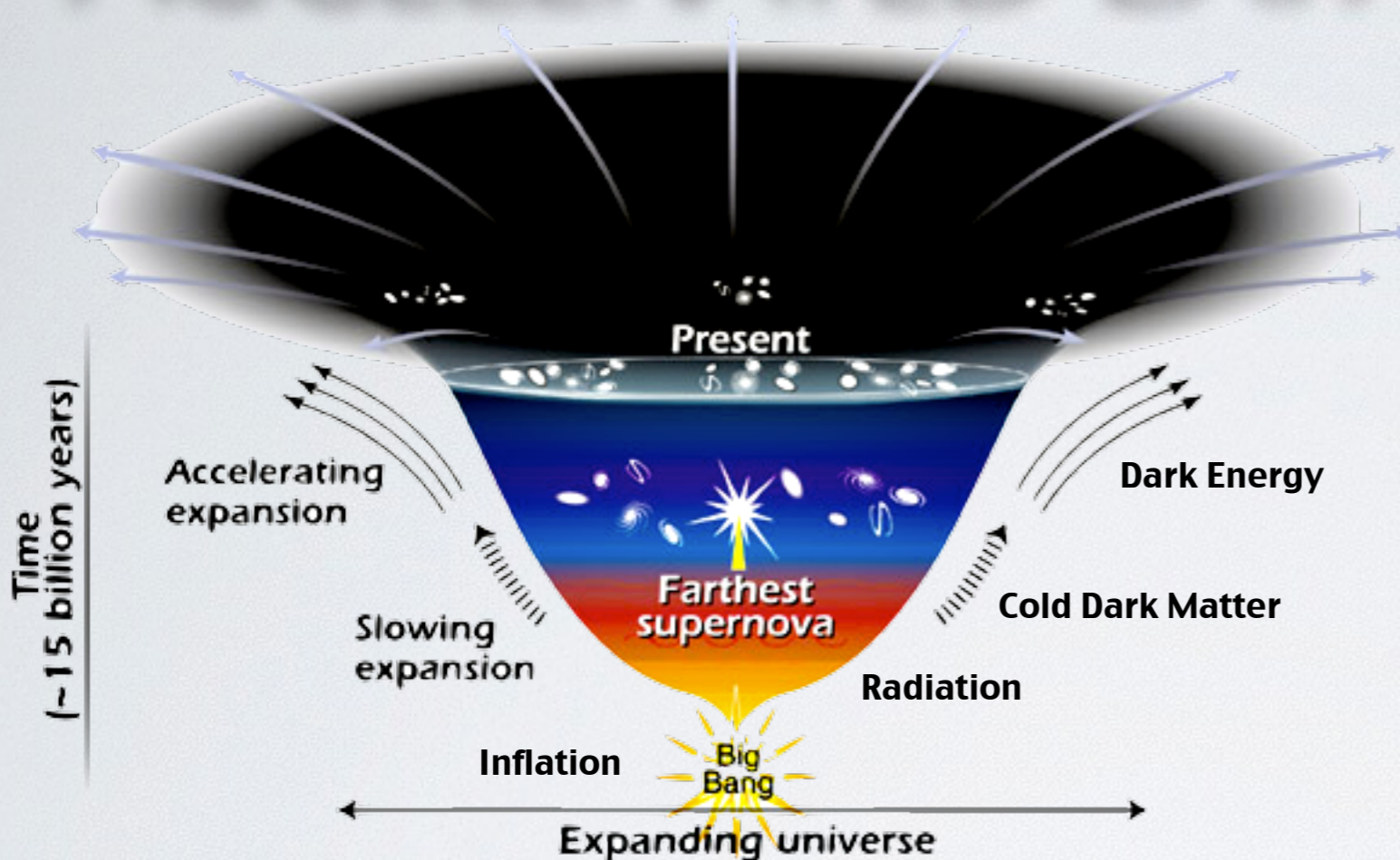
Marcelle Soares-Santos

 Fermilab

COSMO 2014 ♦ Chicago ♦ August 27, 2014

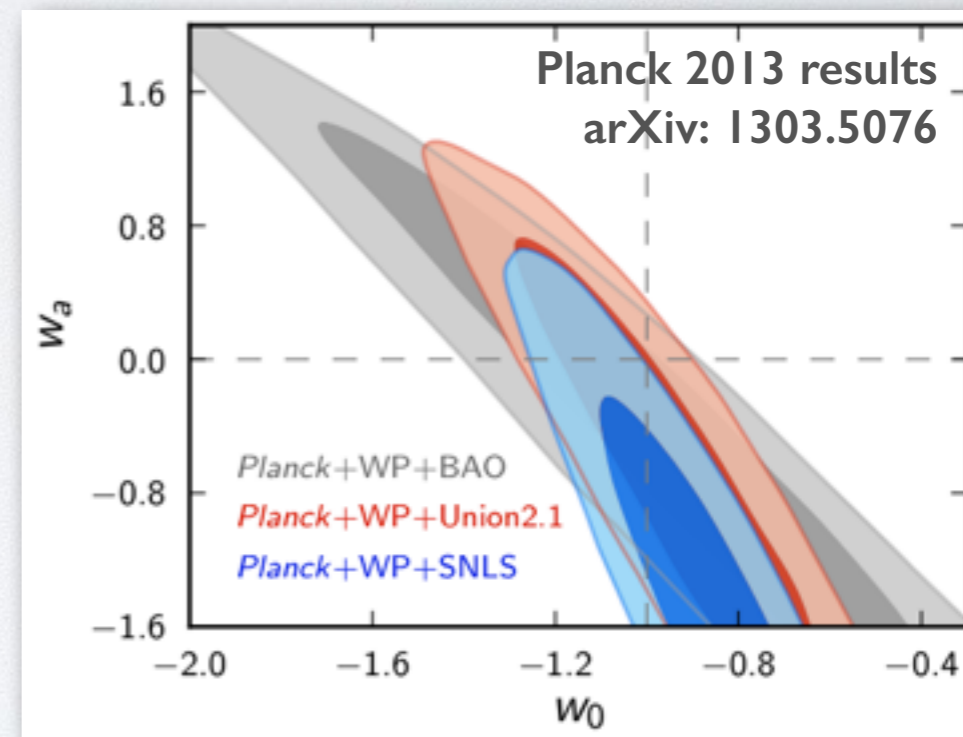


DARK ENERGY & ACCELERATED EXPANSION



Dark Energy candidate:
Cosmological Constant (Λ)

$$w = -1$$



$$\frac{\ddot{a}}{a} = -\left(3p + \rho\right)$$

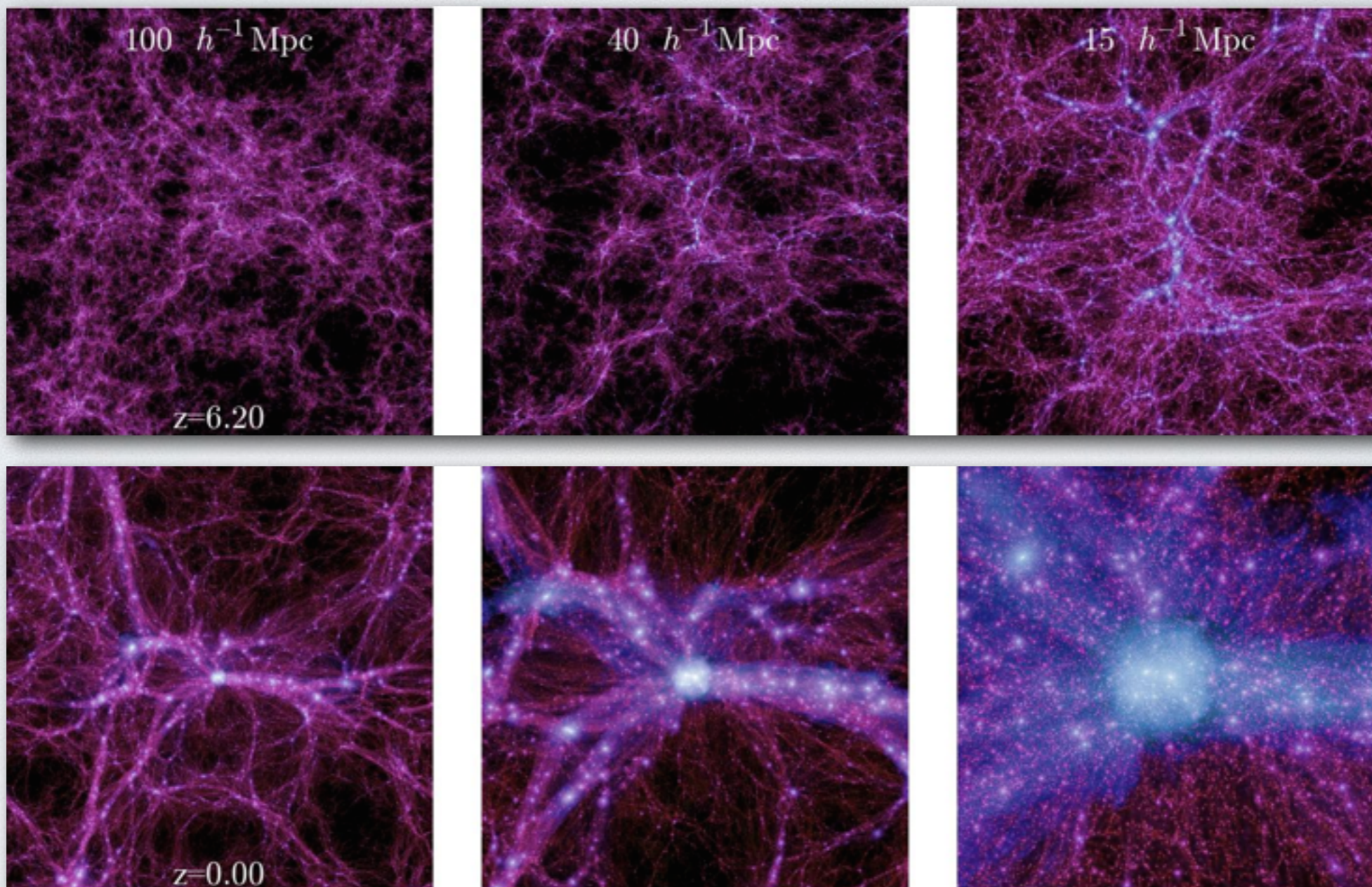
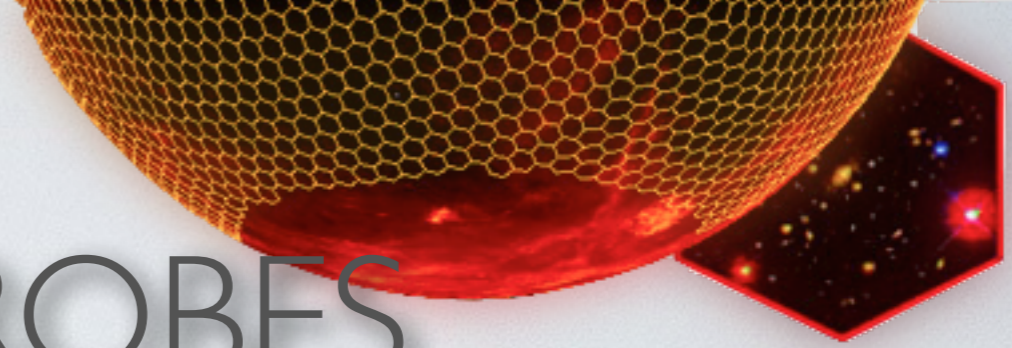
spacetime geometry (scale factor) energy content (equation of state)

$$p = w(a)\rho$$

$$w(a) = w_0 + w_a(1 - a) + \dots$$



GALAXY CLUSTERS AS DARK ENERGY PROBES



12 Gyr ago

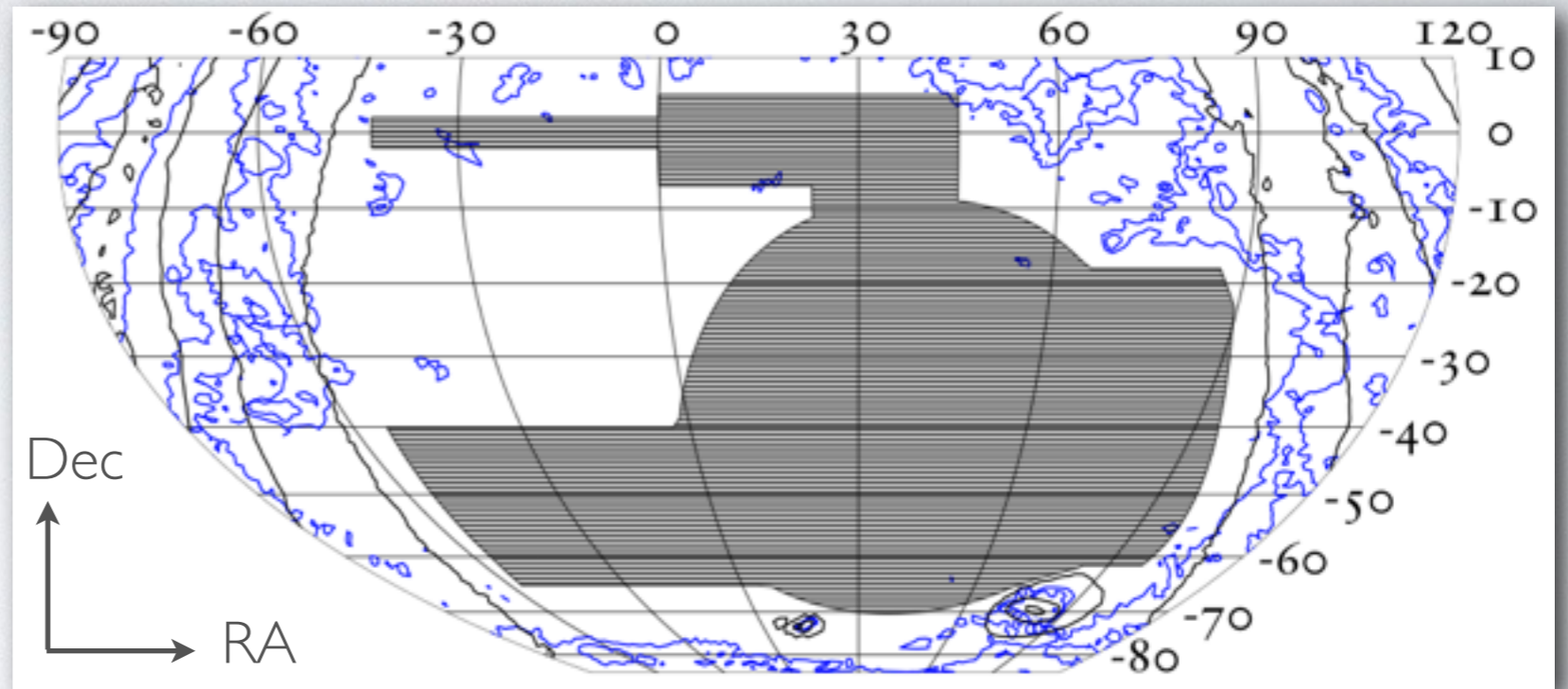
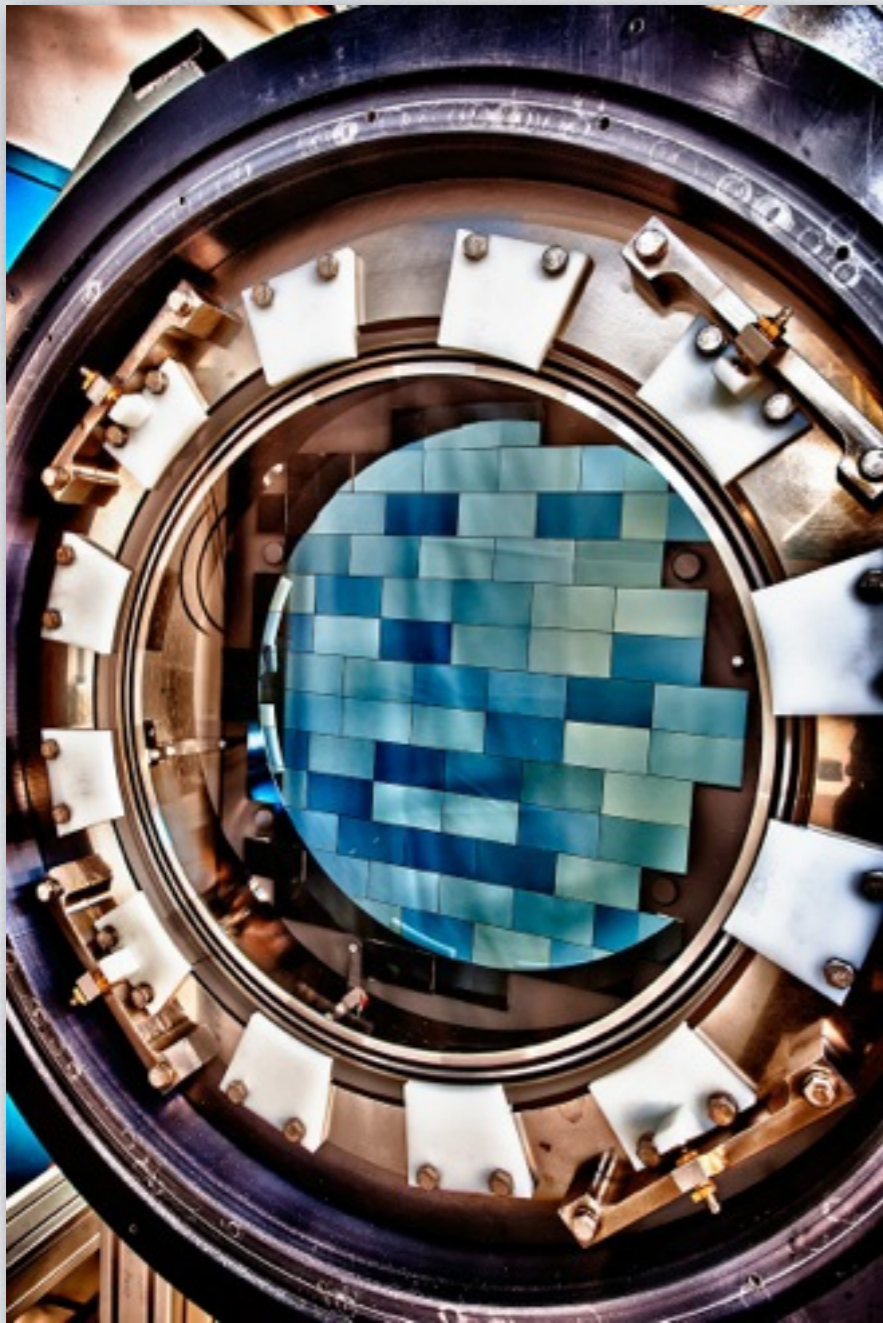
present

Growth of structure in the Universe (by the Millennium Simulation Team)

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DARK ENERGY SURVEY



DECam

3 sq deg FOV, 570 Mpix
optical CCD camera

Facility instrument at
CTIO Blanco 4-m
telescope in Chile

First light: Sep 2012

Survey

5000 sq deg grizY to 24th mag
overlapping with SPT and VISTA

30 sq deg SNe survey
0.9 arcseconds seeing

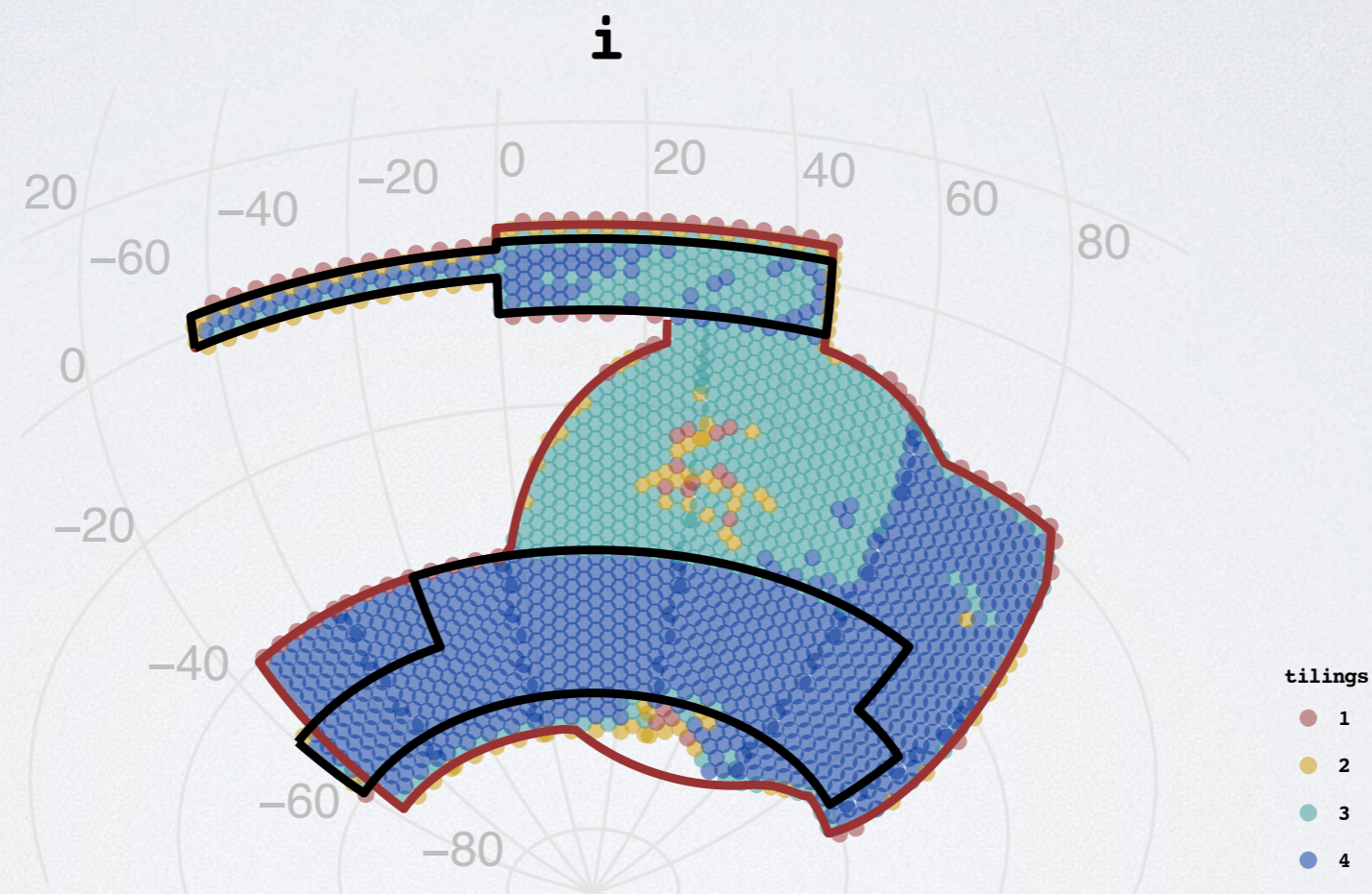
525 nights: 2013-2018



OBSERVATIONS

2nd DES season: Aug 15, 2014 – Feb 2015

~5000 sq-deg, up to 4 tilings in grizY (only i-band shown here)



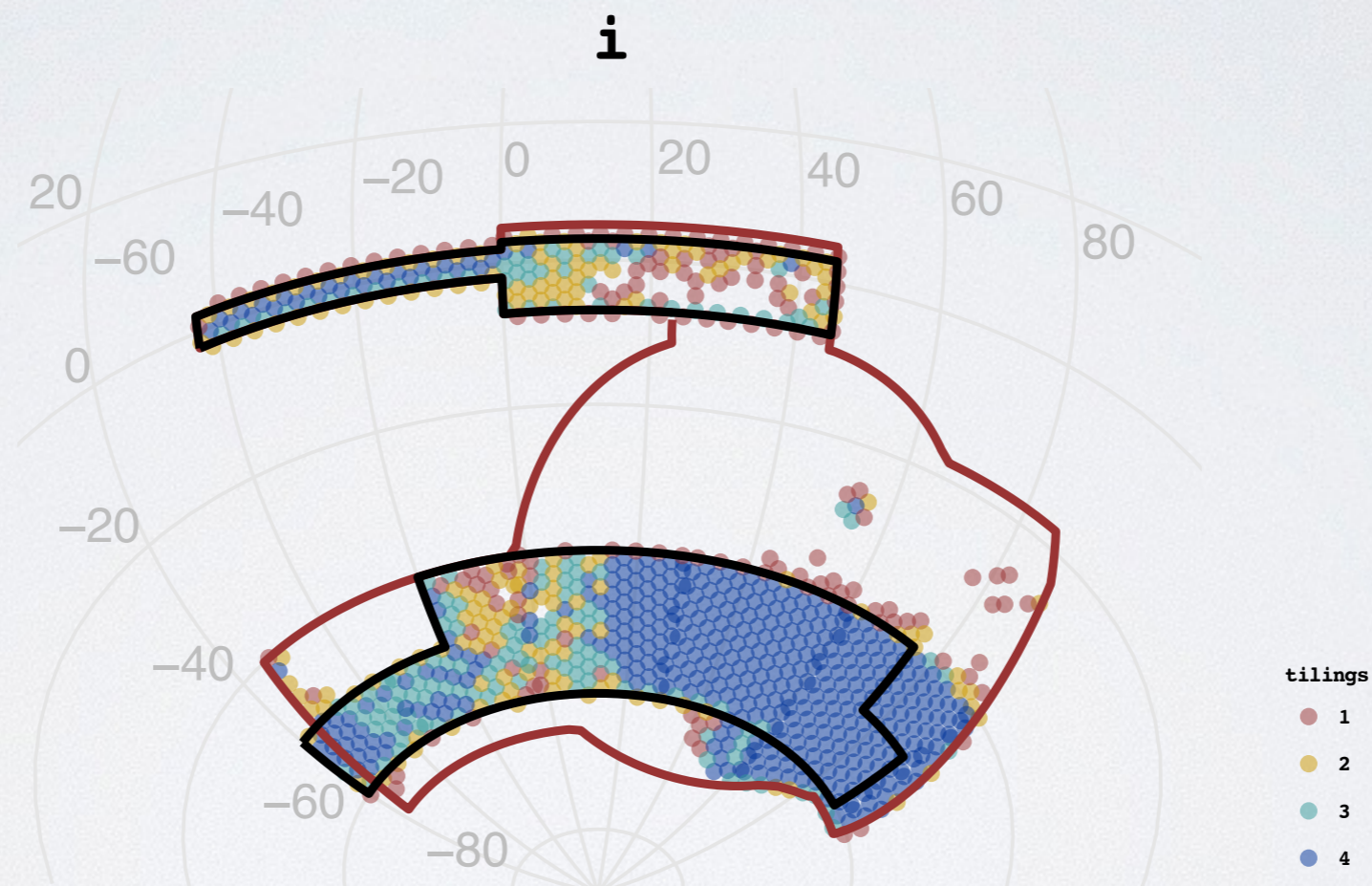
DES Year-2 (expected)



OBSERVATIONS

1st DES season: Aug 31, 2013 – Feb 9, 2014

~2000 sq-deg, up to 4 tilings in grizY (only i-band shown here)



DES Year-1 (observed)

OBSERVATIONS

SV (Nov 1, 2012 — Feb 23, 2013)

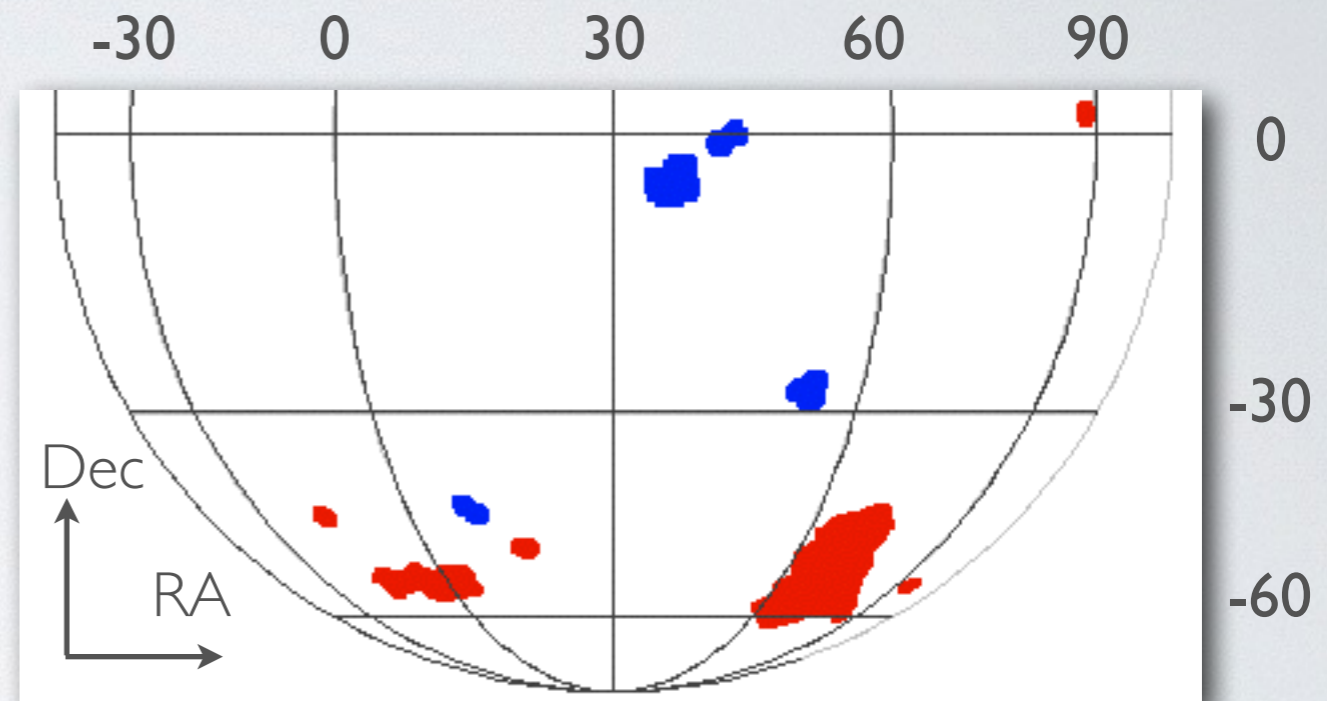
34,266 exposures

SNe survey, Mini-survey areas observed

Covered ~300 sq-deg to full depth

Smooth operations, new observers trained

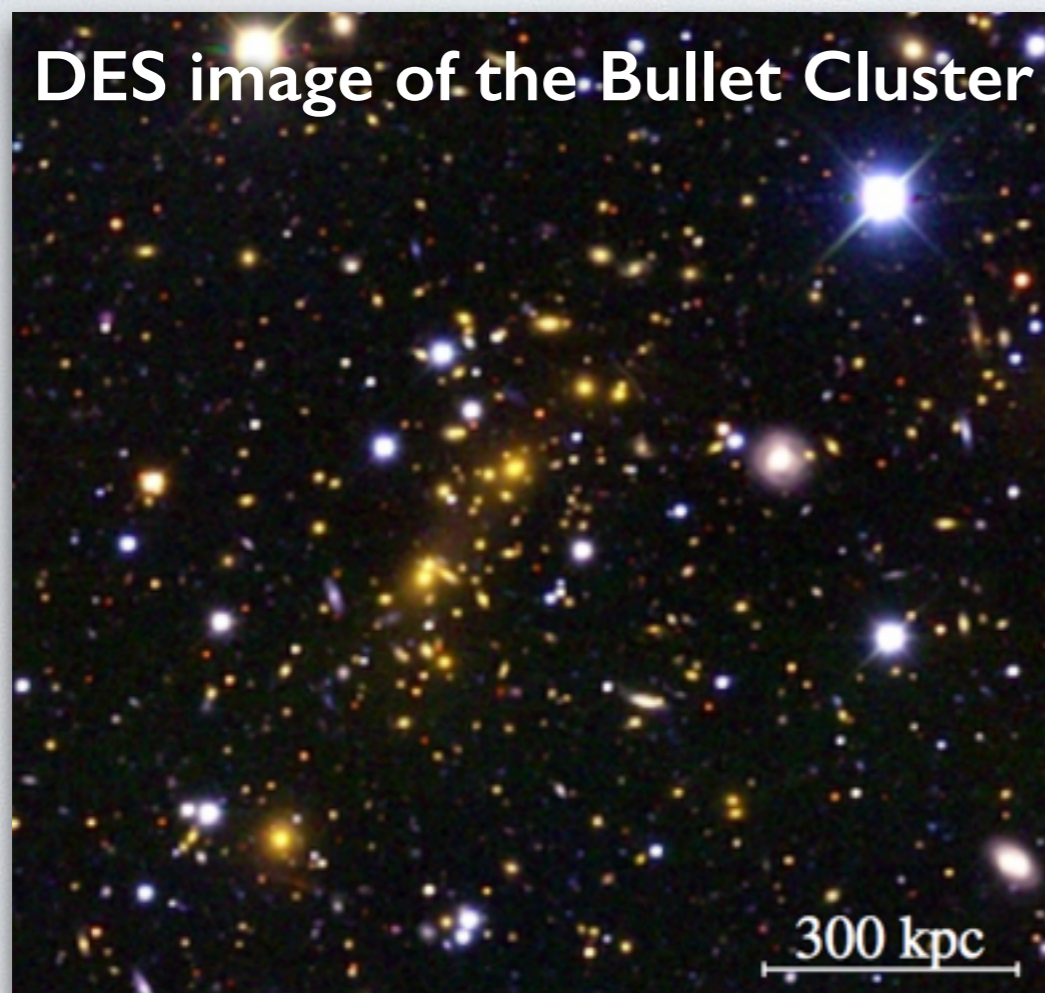
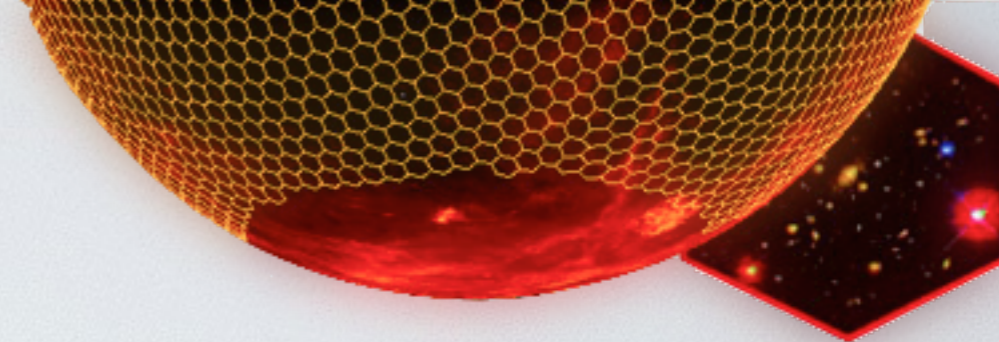
Processing pipeline (DESDM) checked
SNe processing time < 24h
coadds done
object catalogs produced (SVAI)
photometric redshifts calculated



DES SV (observed)



CLUSTERS IN DES



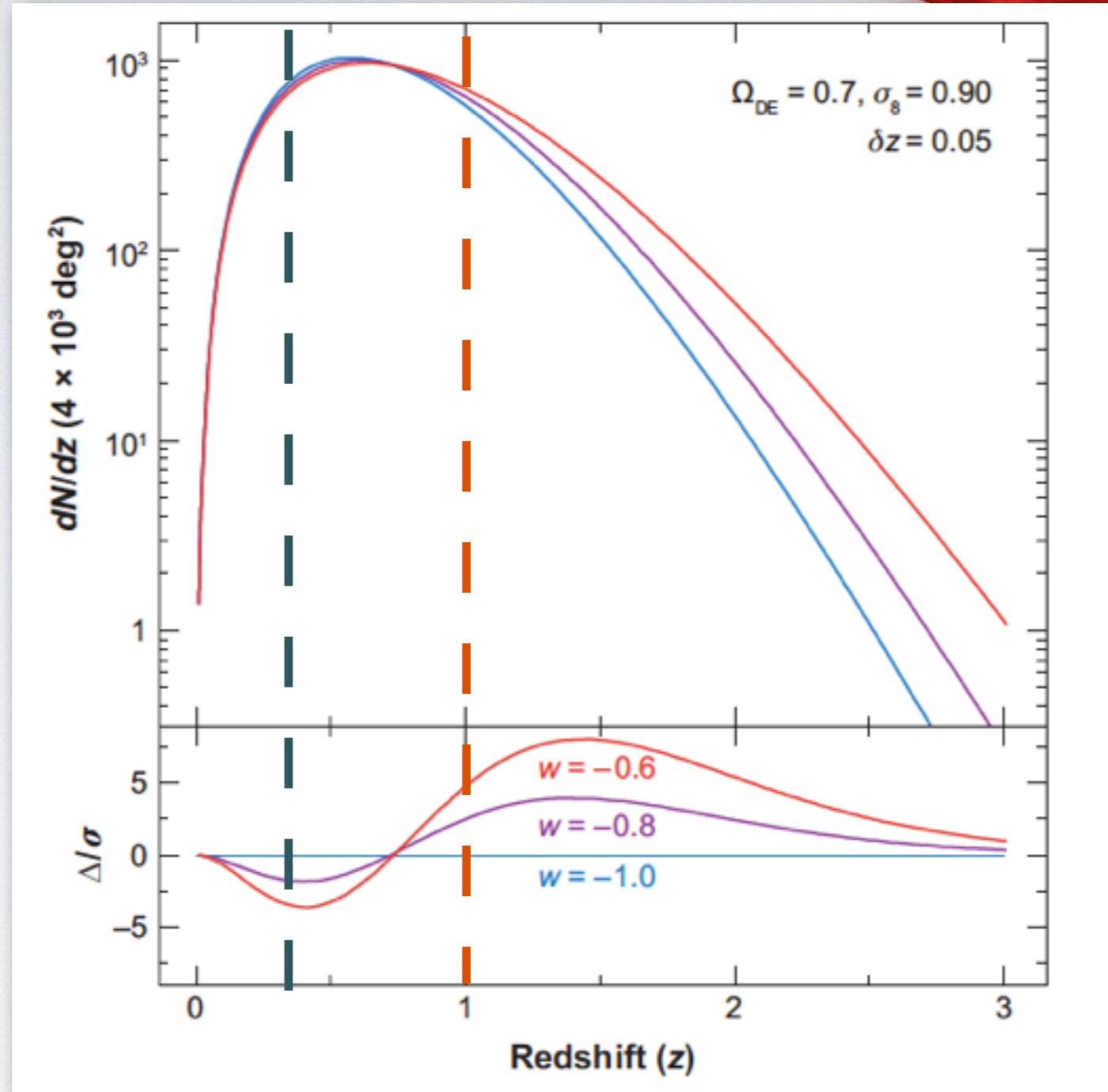
arXiv:1405.4285



NUMBER COUNTS

SDSS MaxBCG sample:
up to $z \sim 0.3$

DES samples:
up to $z \sim 1$



Number of clusters above $10^{14.5}$ solar masses as a function of z , for a 4000 sq-deg survey in 3 different cosmologies.



CLUSTERS FOR COSMOLOGY PROGRAM



Cluster finder algorithms, typically selected using criteria such as:

- significant over-densities (ex: **Voronoi Tessellation** method)
- colors of galaxy cluster members (ex: **redmapper** method)
- luminosity function of galaxies in clusters

To be useful for cosmology, cluster sample must have:

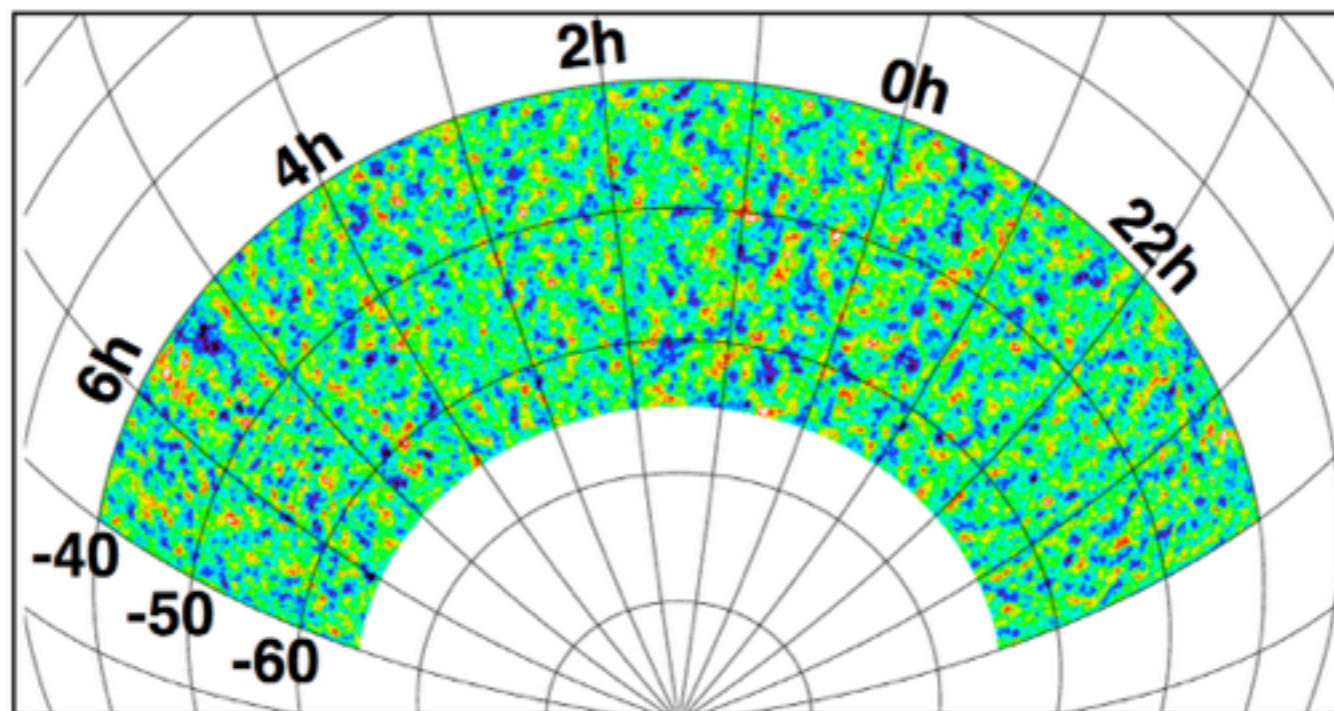
- cluster coords (RA, Dec, z)
- observable quantity that relates to mass (ex: “**richness**”)
 - observable-mass calibration function, with scatter
- selection function as a function of z and mass



SPT AND DES

SZ signal can be used for calibration of DES mass-richness relation

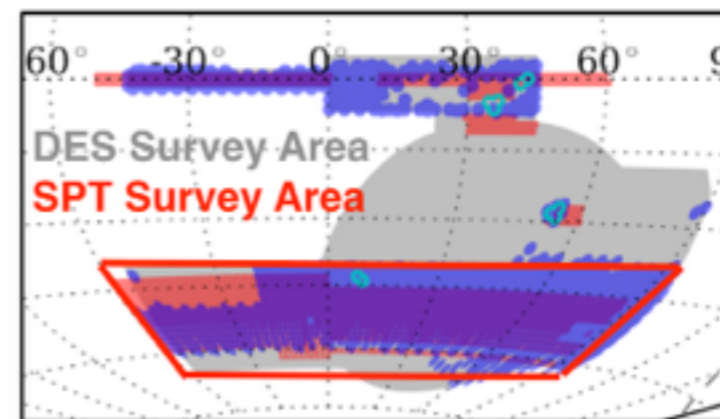
The 2500 deg² SPT-SZ Survey (2007-2011):



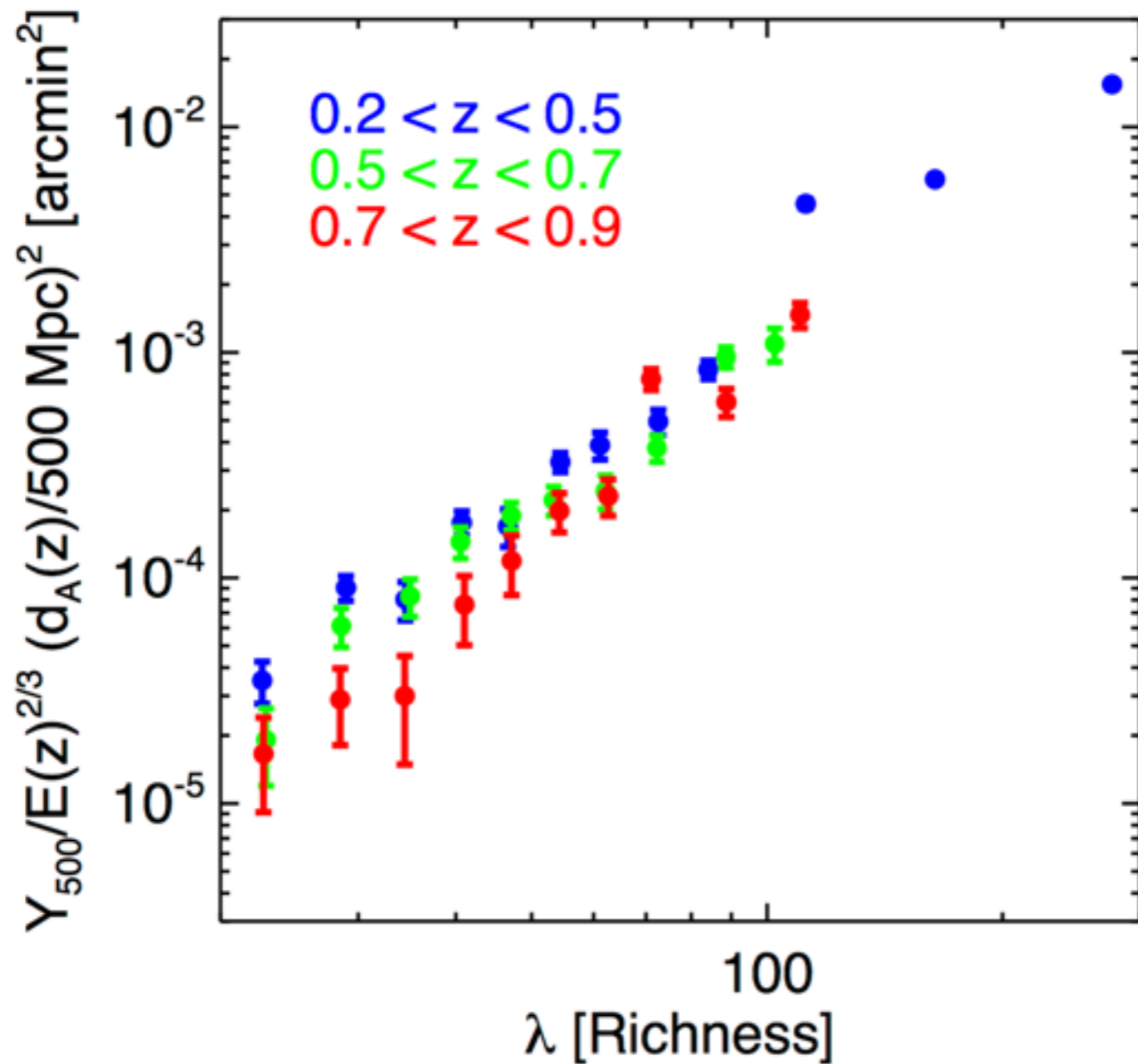
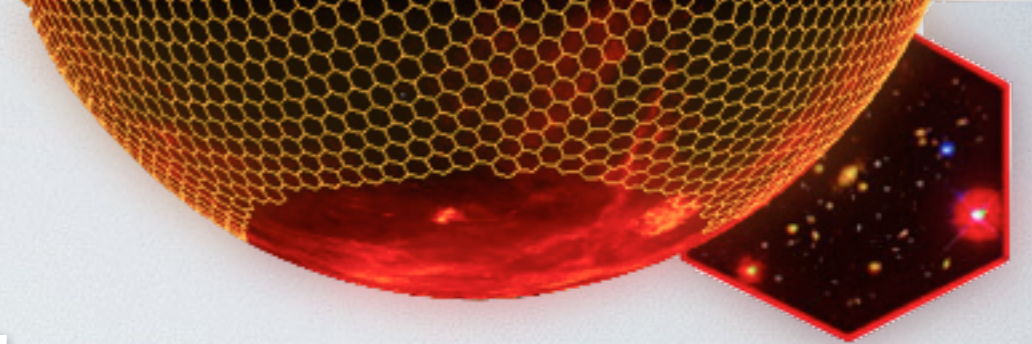
Final survey depths of:

- **90 GHz:** 40 $\mu\text{K}_{\text{CMB-arcmin}}$
- **150 GHz:** 17 $\mu\text{K}_{\text{CMB-arcmin}}$
- **220 GHz:** 80 $\mu\text{K}_{\text{CMB-arcmin}}$

Complete overlap with DES survey



SPT AND DES



Stack of SPT-SZ data on ~ 600 optically selected clusters from first 150 deg² of DES-SV data

Strong correlation in multiple richness and redshift bins from $0.2 < z < 0.9$

Used as an early calibration of DES optical richness for cluster mass $> 10^{14}$ solar masses

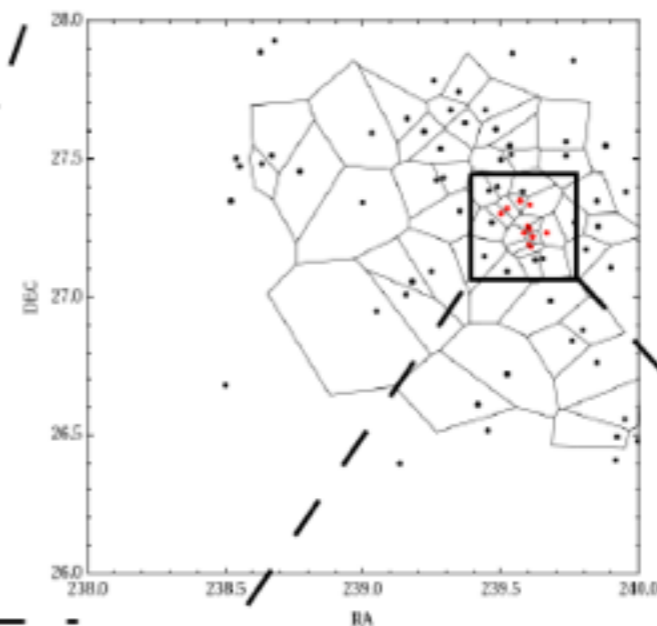
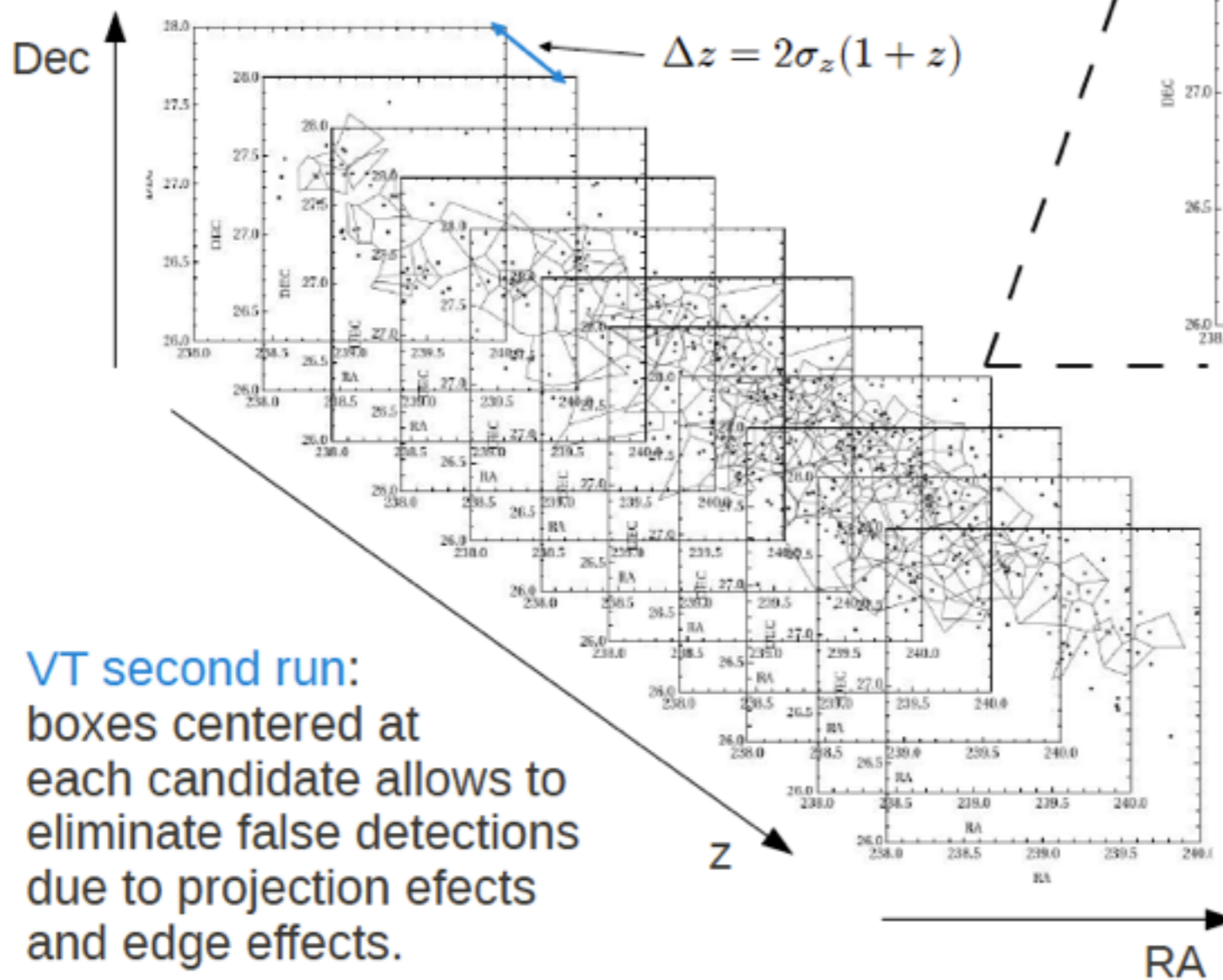
Clusters found with the **redmapper** cluster finder technique.



VORONOI TESSELLATION

VT cluster finder in 2+1D

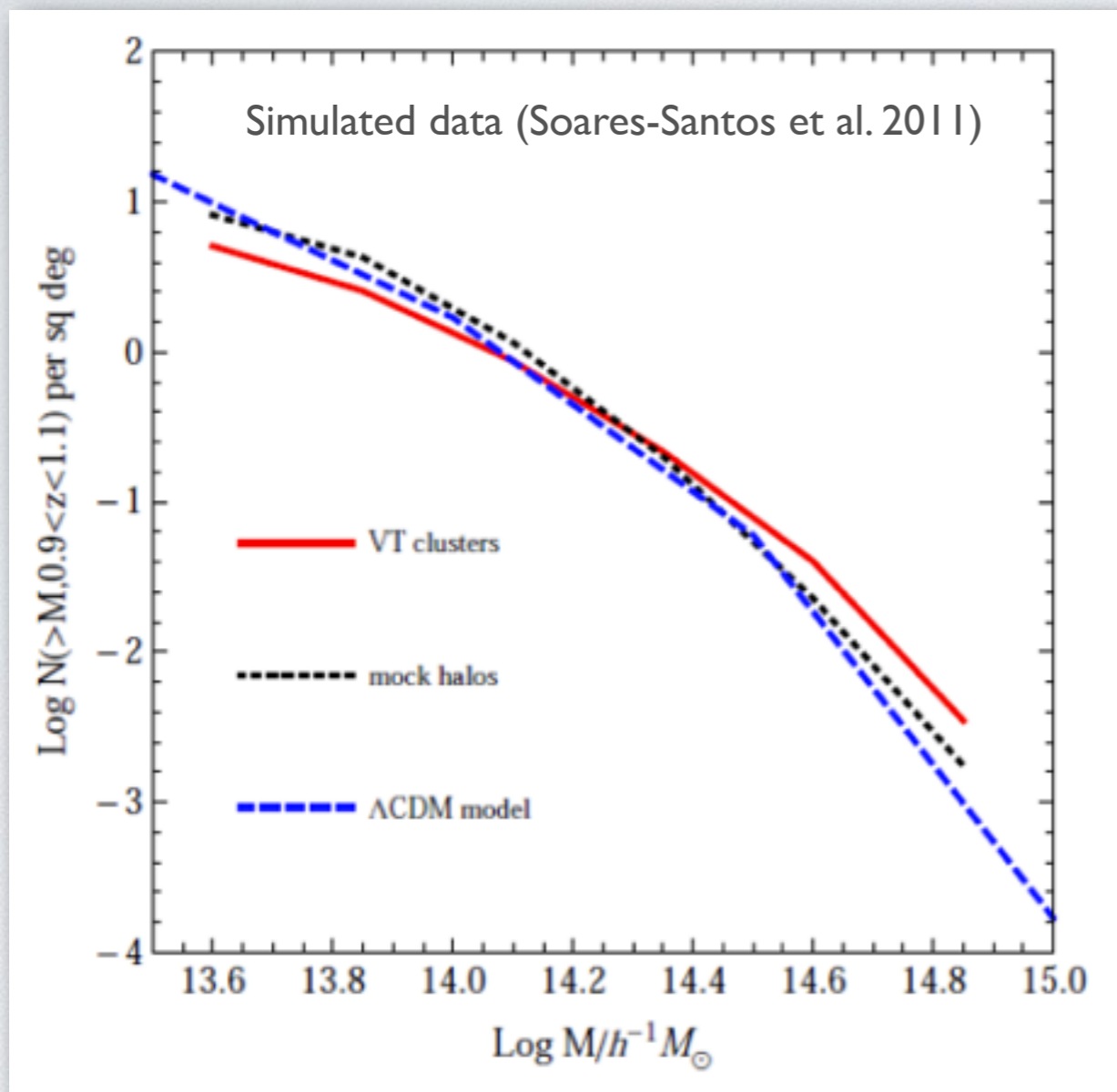
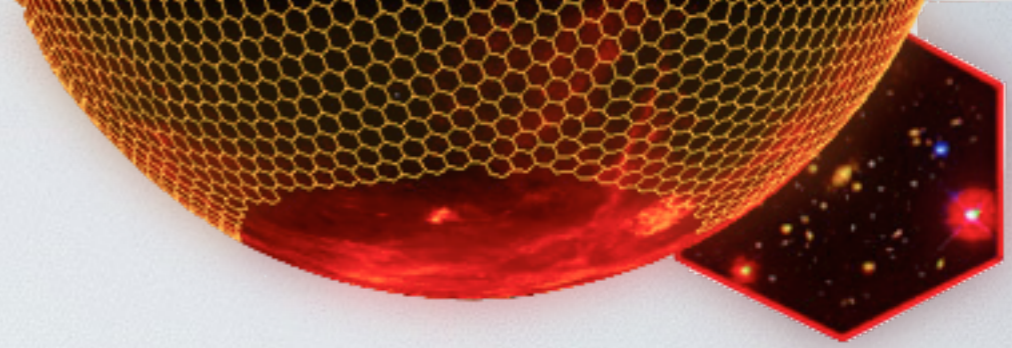
VT first run: cluster candidates detected in photo-z shells



VT second run: boxes centered at each candidate allows to eliminate false detections due to projection effects and edge effects.



CLUSTER MASS FUNCTION

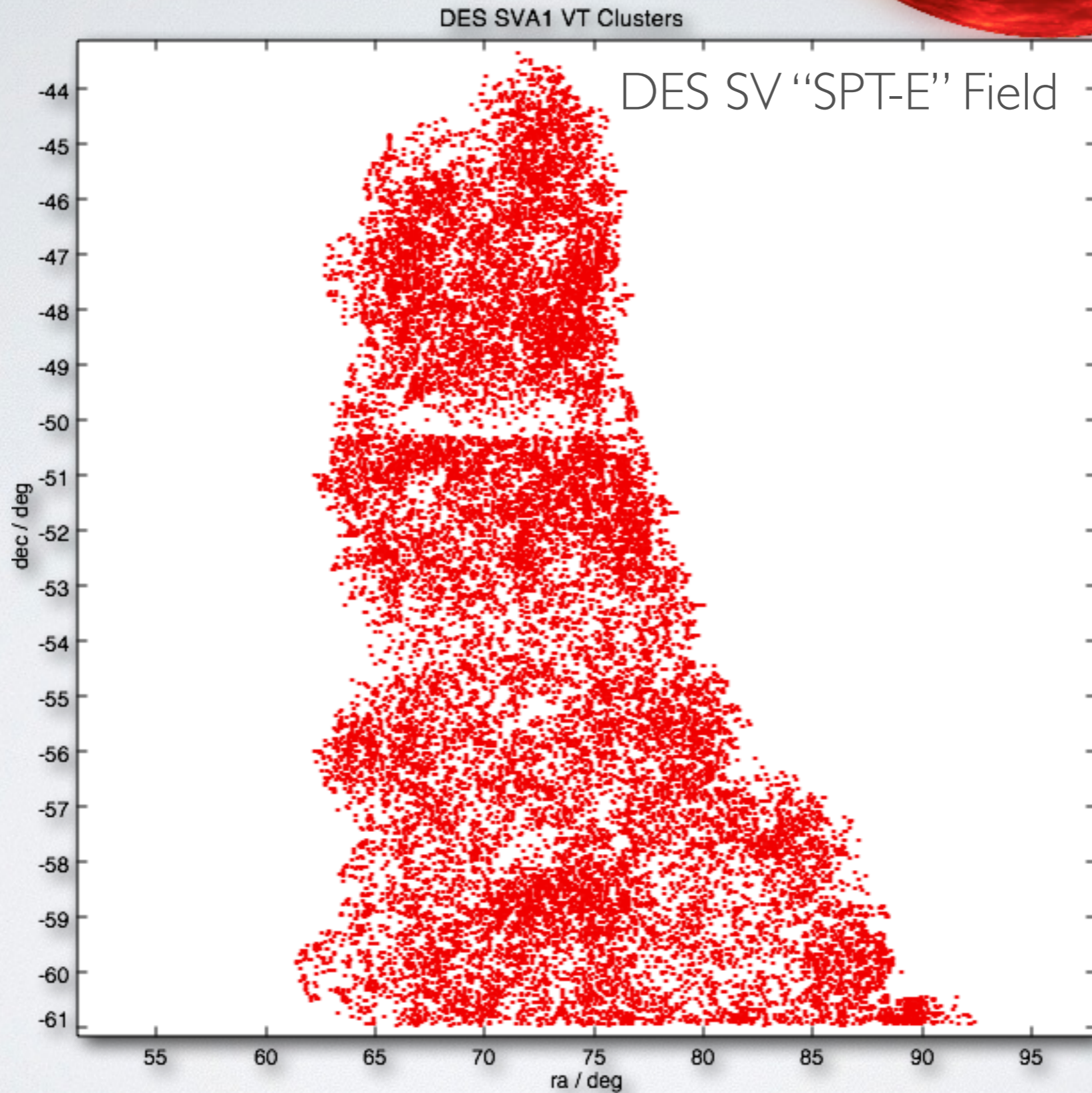


By applying the VT cluster finder on mock catalogs, we can **measure the selection function** for our cluster catalog.

We apply that selection function back to the cluster number counts to obtain the **mass function**.

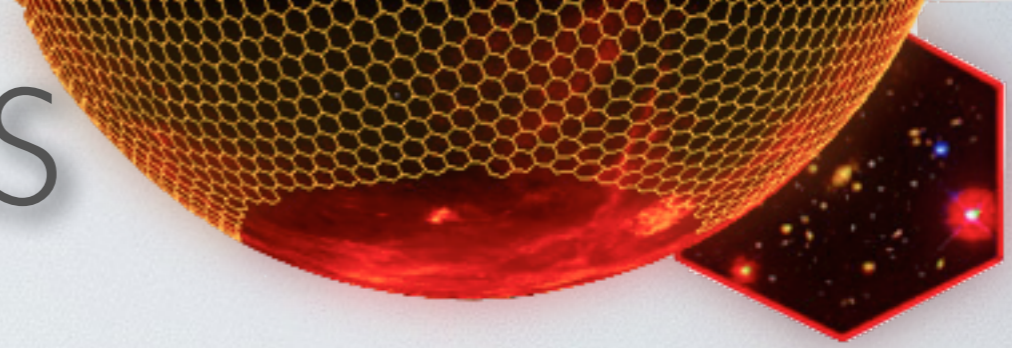


DES SV: VT CLUSTERS

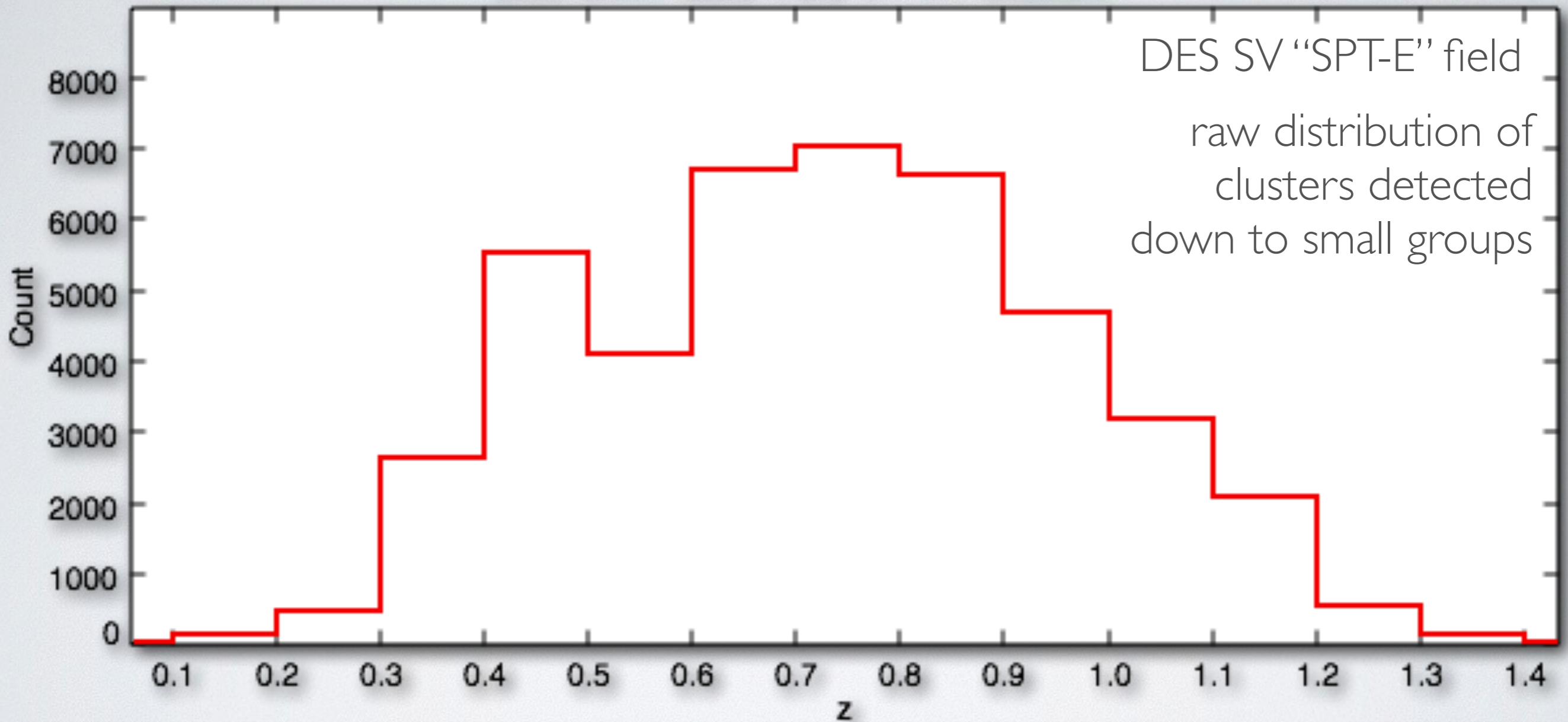


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DES SV: VT CLUSTERS

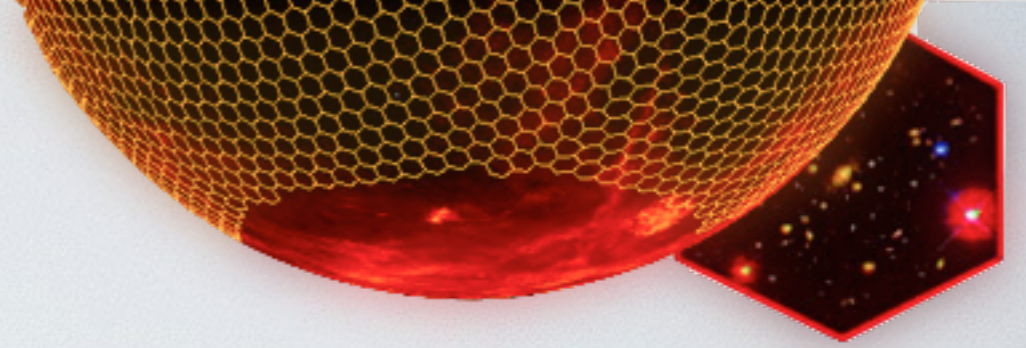


DES SVA1 Gold-1.0.2 VT-1.1 Clusters

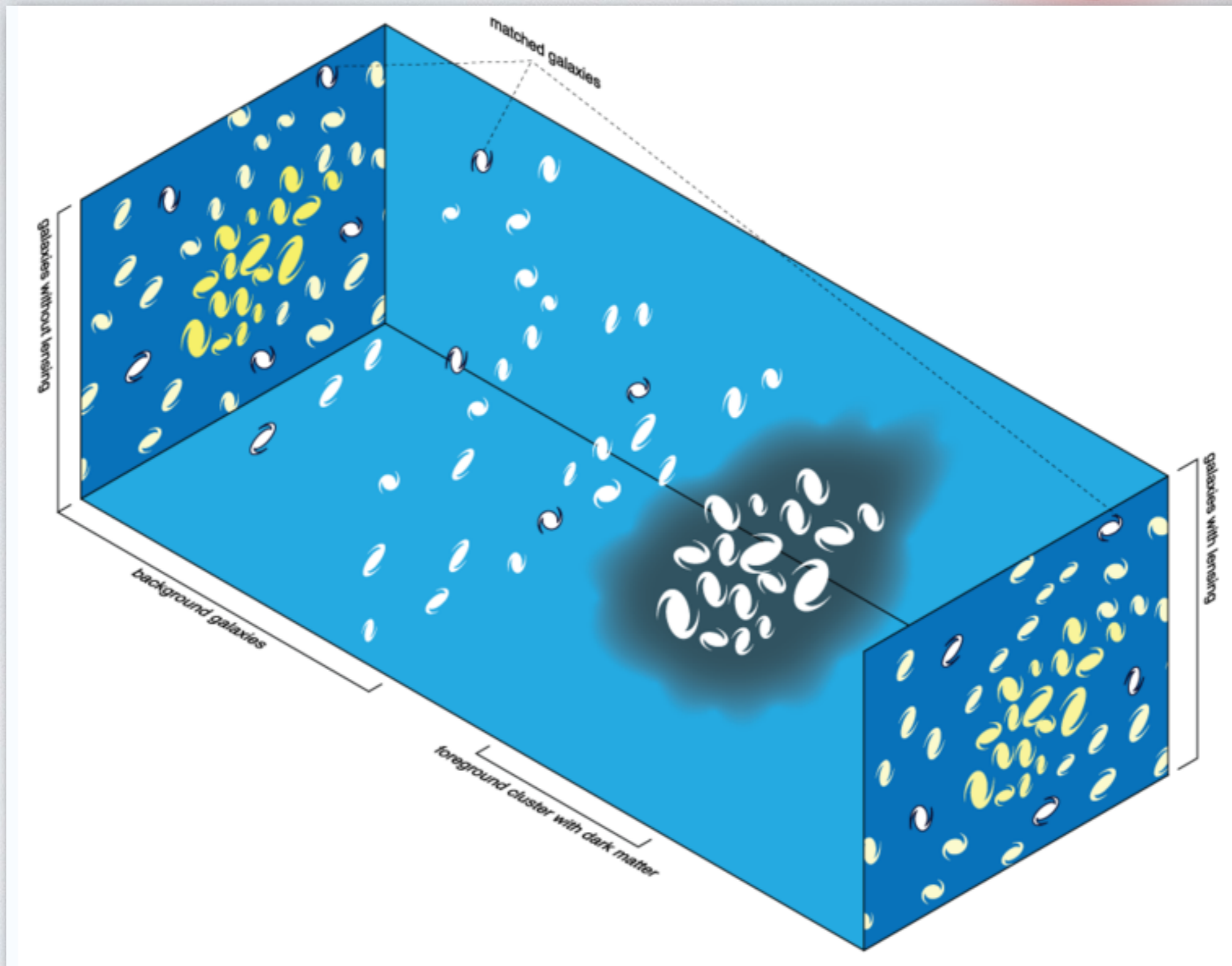


NEXT STEPS FOR VT CLUSTERS

- Mass-richness calibration
 - Using the Weak Lensing signal behind clusters stacking in bins of richness
 - Determine mean relation, scatter
 - Next: include SZ info, control of systematics
- Selection function



CLUSTERS LENSING



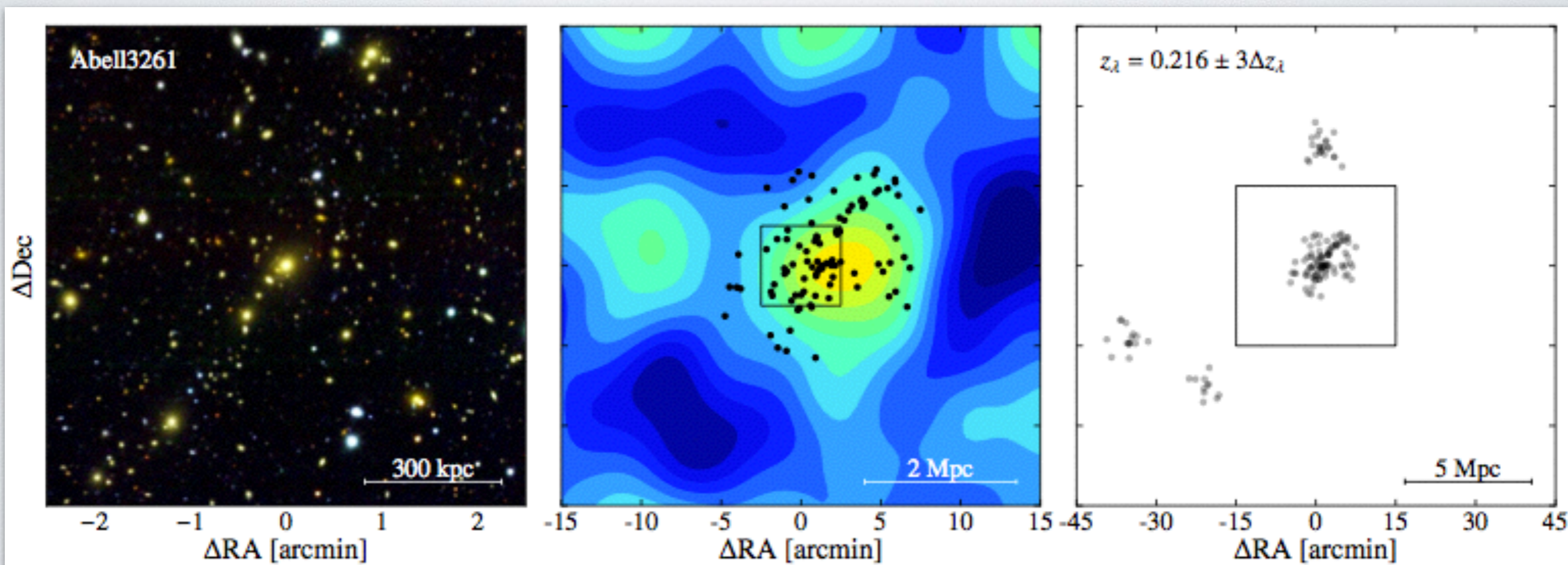
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INDIVIDUAL CLUSTER MASSES

arXiv:1405.4285

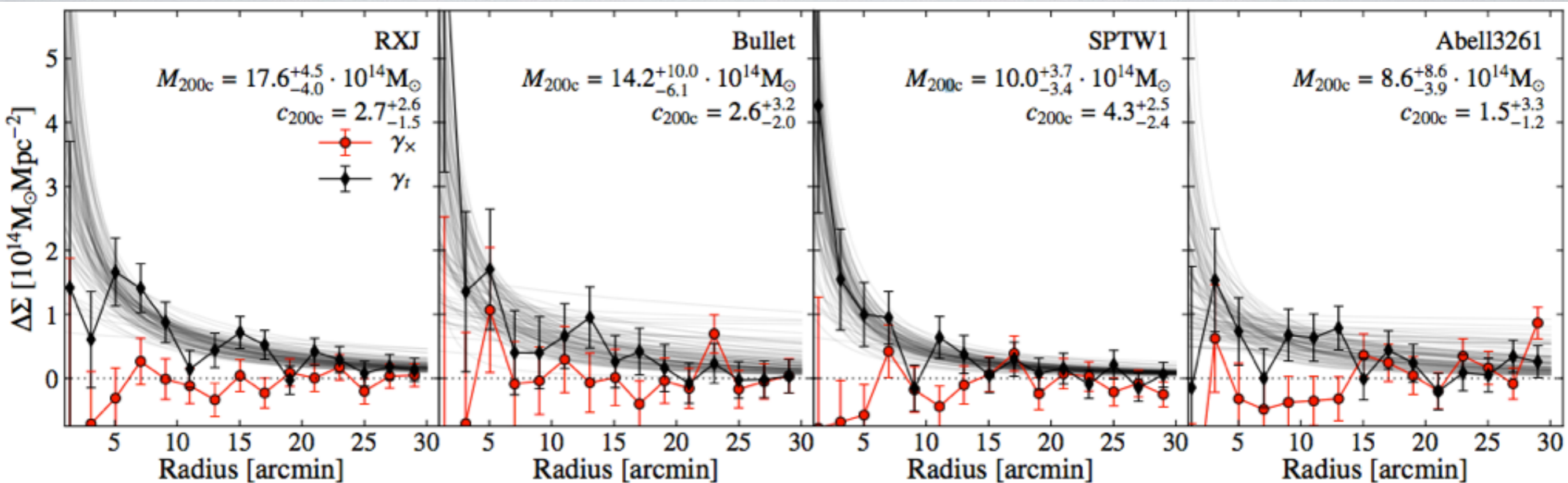
Shown here: 1 of 4 known massive clusters at $z \sim 0.2-0.4$



INDIVIDUAL CLUSTER MASSES

arXiv:1405.4285

4 known massive clusters at $z \sim 0.2-0.4$



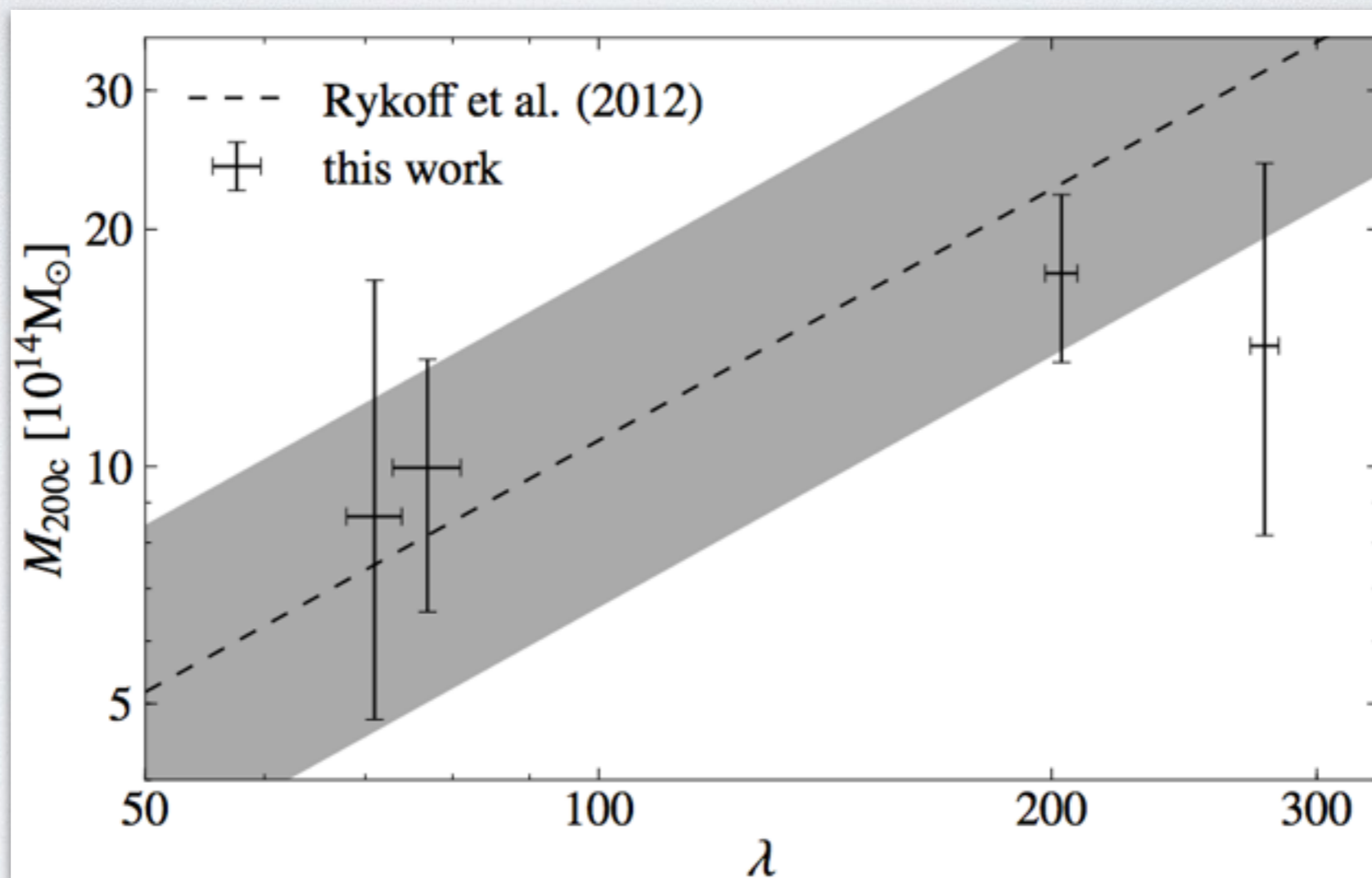
Black: WL signal; Red: B-mode cross check; Gray: monte-carlo



INDIVIDUAL CLUSTER MASSES

arXiv:1405.4285

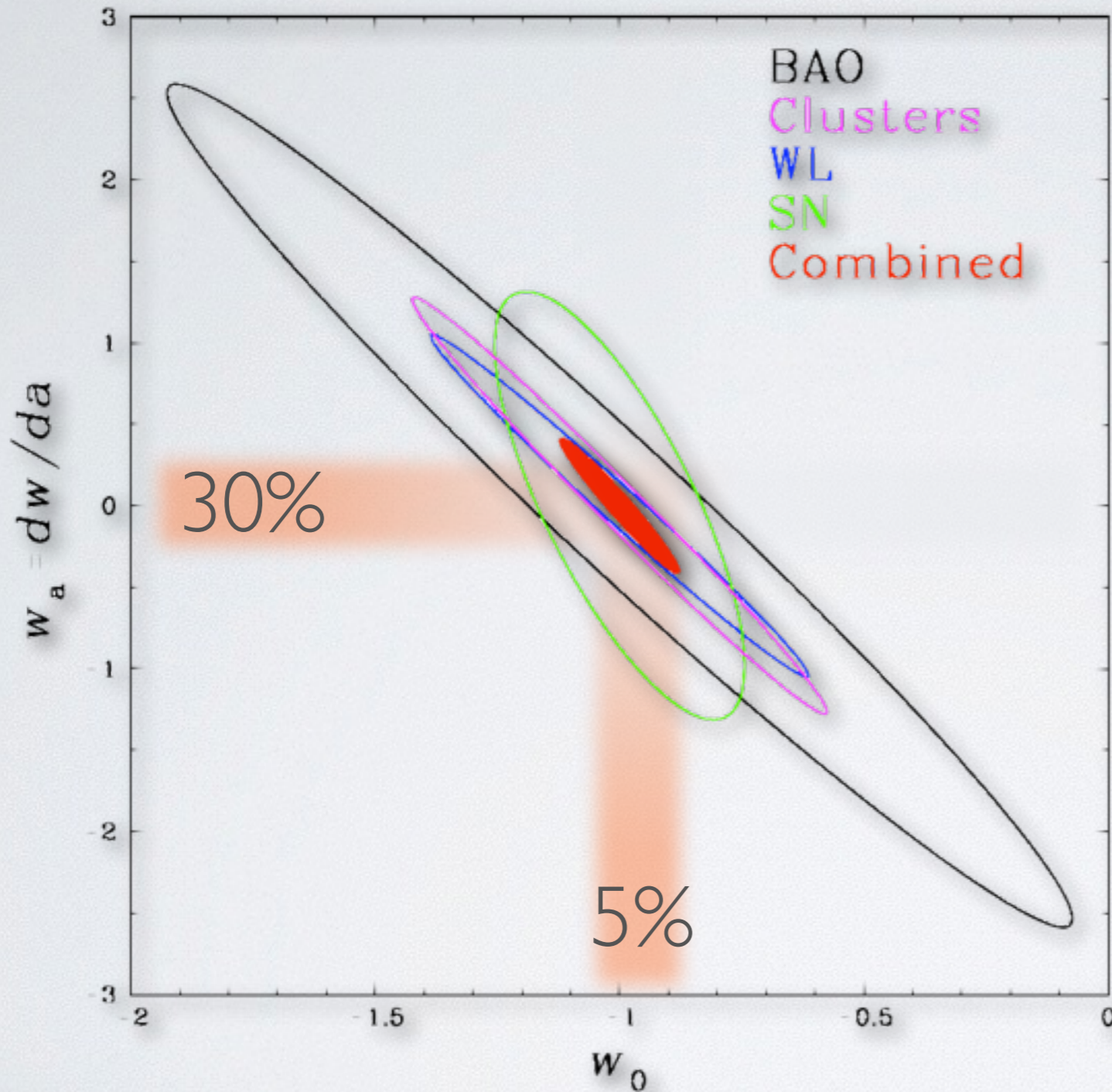
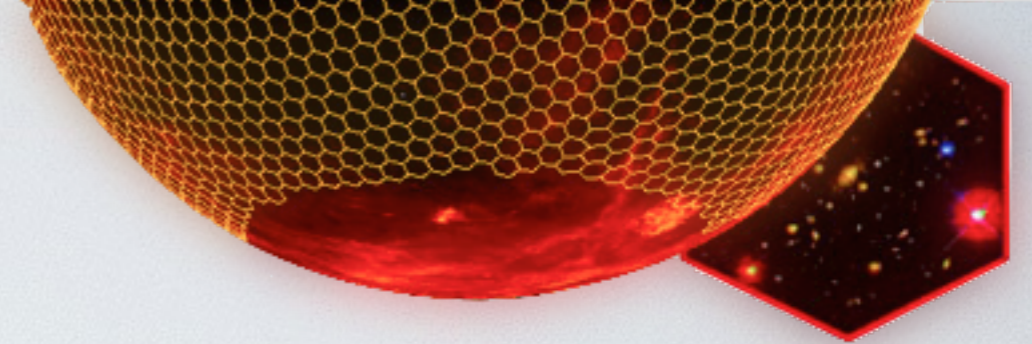
4 known massive clusters at $z \sim 0.2-0.4$



Mass-richness
relation



DES PROJECTIONS



5000 deg², 0.9'' seeing,
24th mag (redshift~1.4)

300M galaxies, shapes,
100K clusters, 4K SNe Ia

4 combined probes

3-5x improved Dark
Energy measurement



SUMMARY

These are exciting times for galaxy cluster science in DES!

Multiple analyses ongoing. Highlighted in this talk:

- SPT SZ measurements for DES clusters selected with the redmapper method
- Cluster Cosmology program with VT algorithm
- Individual mass measurements for 4 clusters (arXiv: 1405.4285)

Stay tuned for more results including Year-1 and Year-2 data soon!

