The Dark Energy Survey (DES): status, first results, and mocks.

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THE DARK ENERGY SURVEY

OUTLINE

- The Dark Energy Survey
- First Results
- Mock Galaxy Catalogues

THE DARK ENERGY SURVEY

# DES Science Summary

Betoule et al. 2014

4 Probes of Dark Energy:

Galaxy Clusters (distance & structure growth)
Tens of thousands of clusters to z~1
Synergy with SPT, VHS

Weak Lensing (distance and structure growth)
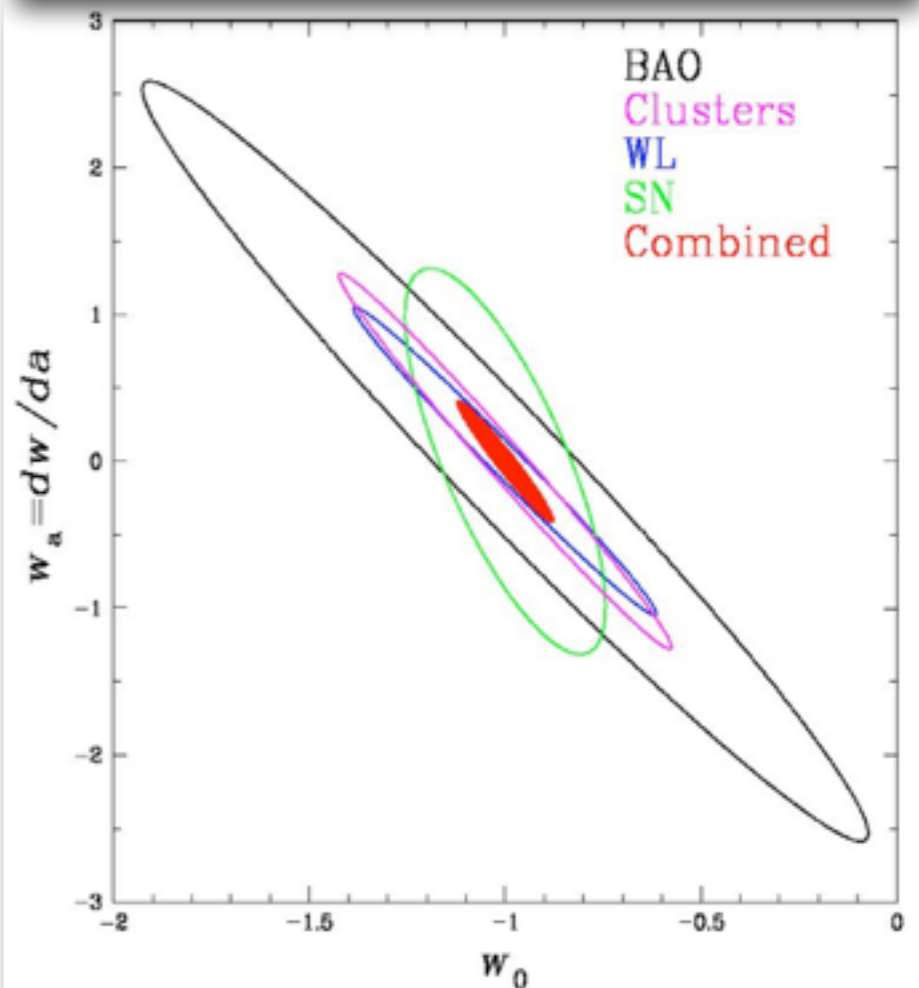Shape and magnification measurements of 200 million galaxies

Baryon Acoustic Oscillations (distance)
300 million galaxies to z~1.4 and i<24

Supernovae (distance)
3500 well-sampled SNe Ia to z~1

Now:
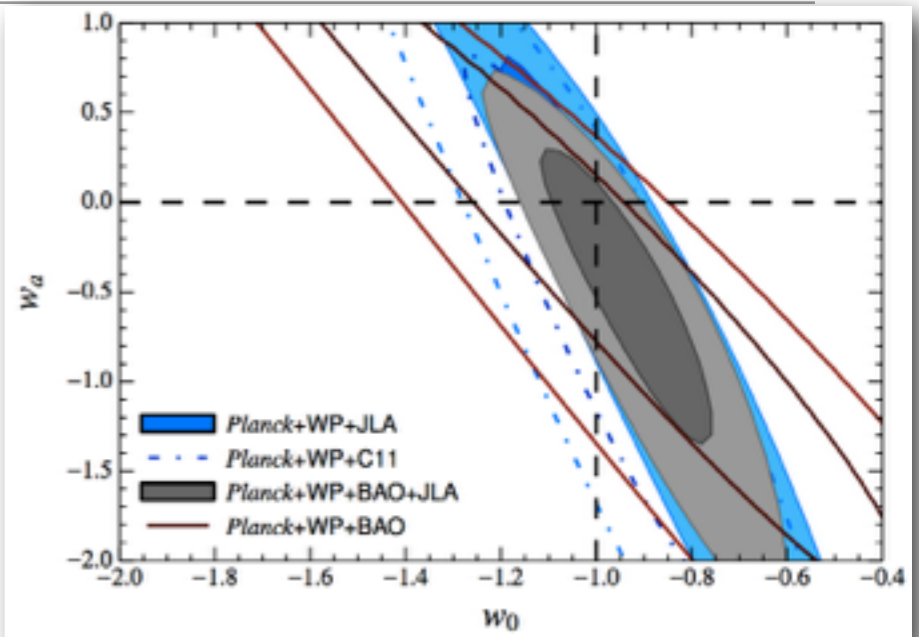
DES:

DES Collaboration:
~300 scientists from 28 institutions

facebook.com/darkenergysurvey
http://darkenergysurvey.org

USA: Fermilab, UIUC/NCSA, University of Chicago, LBNL, NOAO, University of Michigan, University of pennsylvania, Argonne National Laboratory, Ohio State University, Santa Cruz/SLAC Consortium, Texas A&M University , CTIO (in Chile)
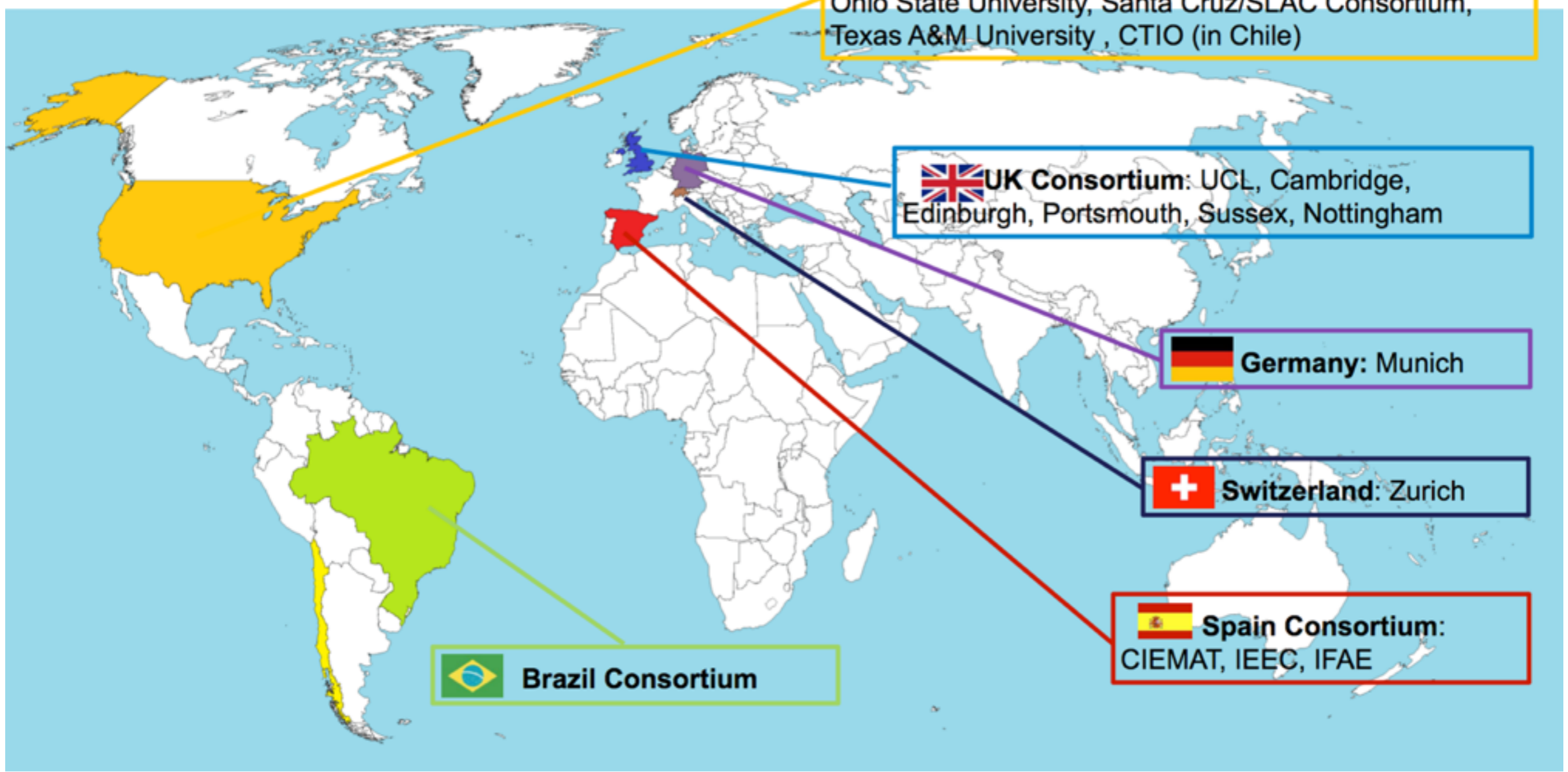
UK Consortium: UCL, Cambridge, Edinburgh, Portsmouth, Sussex, Nottingham

Germany: Munich

Switzerland: Zurich

Spain Consortium: CIEMAT, IEEC, IFAE

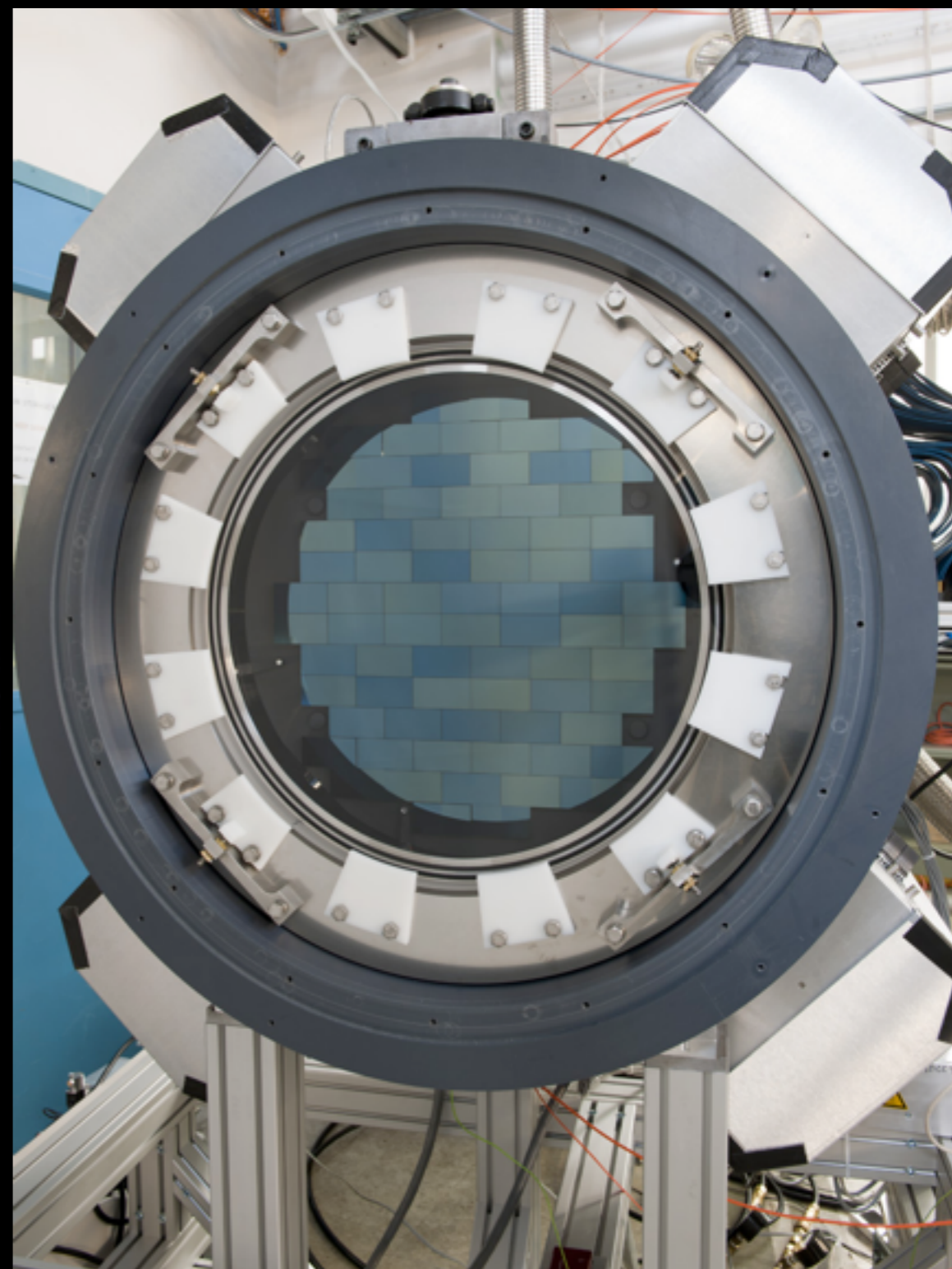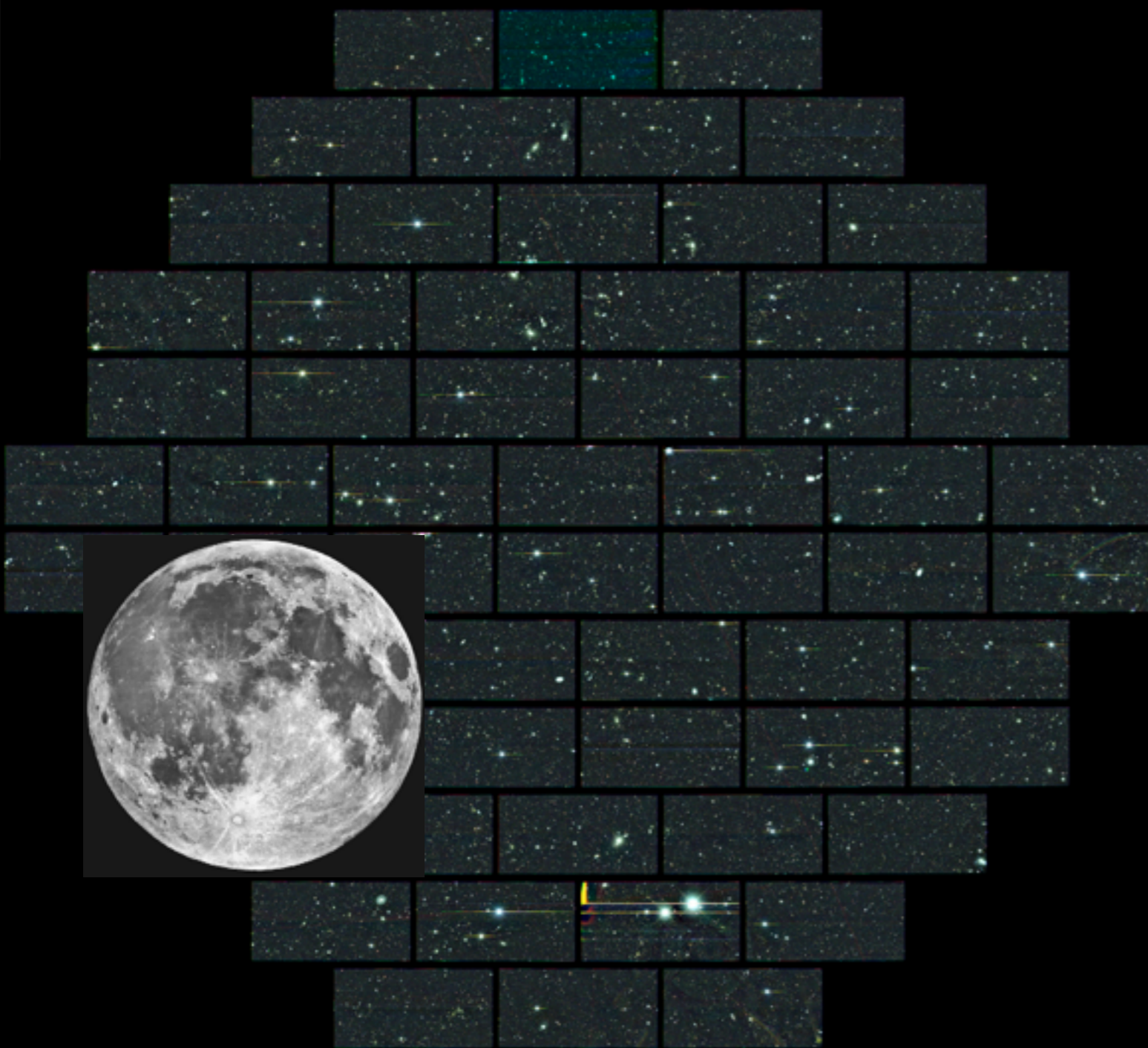**Brazil Consortium**

DARK ENERGY SURVEY

The Dark Energy Survey

- Cerro Tololo Inter-American Observatory Blanco 4-meter telescope

- First light Sept. 12, 2012

- Survey 2013-2018, 525 nights

- DECam: 570 Mpix, 3 deg^2 FOV, griZY filters

- 5000 deg^2 survey footprint, to mag 24 (redshift ~1.5) + 30 deg^2 deep SN fields

DES Field of View & Focal Plane

DES Early Data
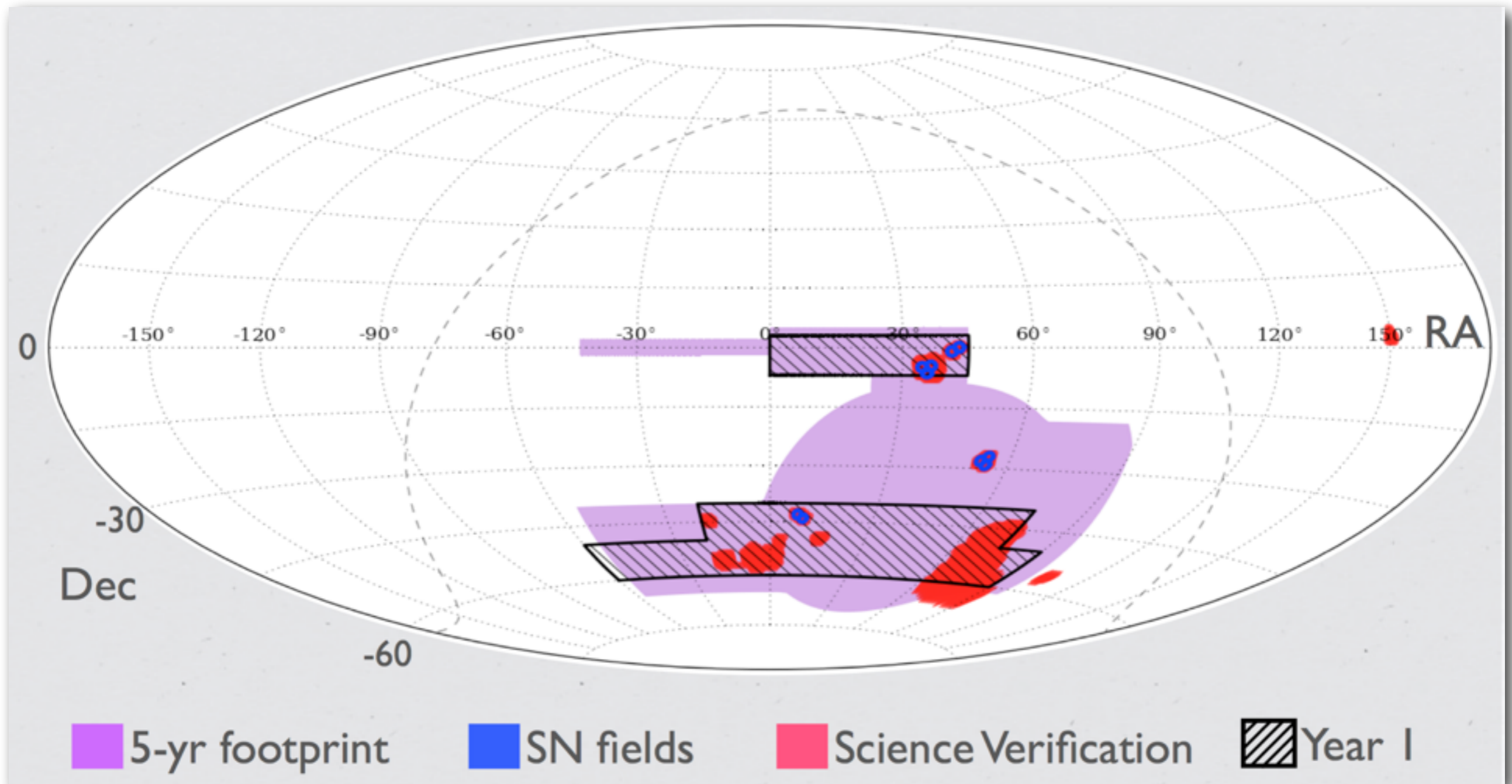
...moment of zen...

DES Survey Footprint

Science Verification: ~250 sq. deg. to ~full depth; 45 M objects
Year 1: ~1500 sq. deg. overlap SPT, SDSS: 4/10 tilings; 140 M objects

OUTLINE

- The Dark Energy Survey
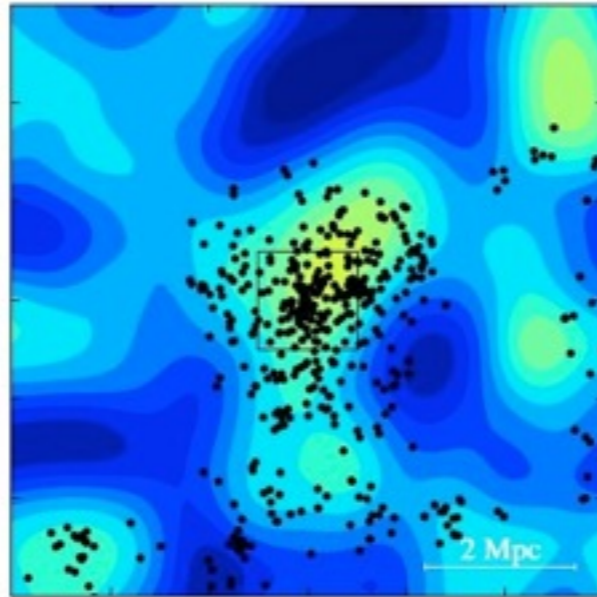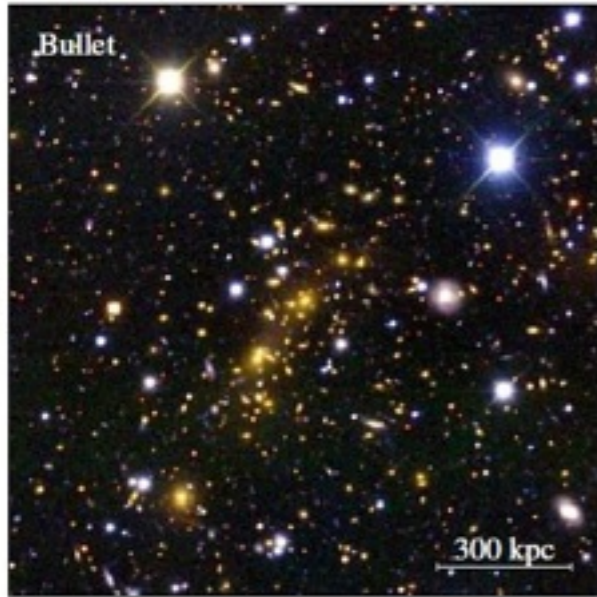- First Results
- Mock Galaxy Catalogues

THE DARK ENERGY SURVEY

Testing Weak Lensing: Masses of 4 galaxy clusters
(Melchior et al. arXiv:1405.4285)

Multi-color image of the inner 5 arcmin

Map of WL aperture mass significance overlaid with gals inner 30 arcmin

- Measure the masses and redshifts of four known massive galaxy clusters
- Background galaxies identified using photo-z
- Cluster member galaxies identified using photo-z and RedMaPPer
- Weak lensing analysis using im3shape code

Results in very good agreement with previously known measurements

Table 4. Weak lensing masses M_{200c} in units of $10^{14} M_{\odot}$ (with a flat prior on c_{200c}), redMaPPer richness λ and redshift estimate z_λ, and their statistical errors (see Section 3.2 and Section 5.1 for details). The literature mass estimates are derived from weak lensing, galaxy dynamics (D) or optical richness (R).

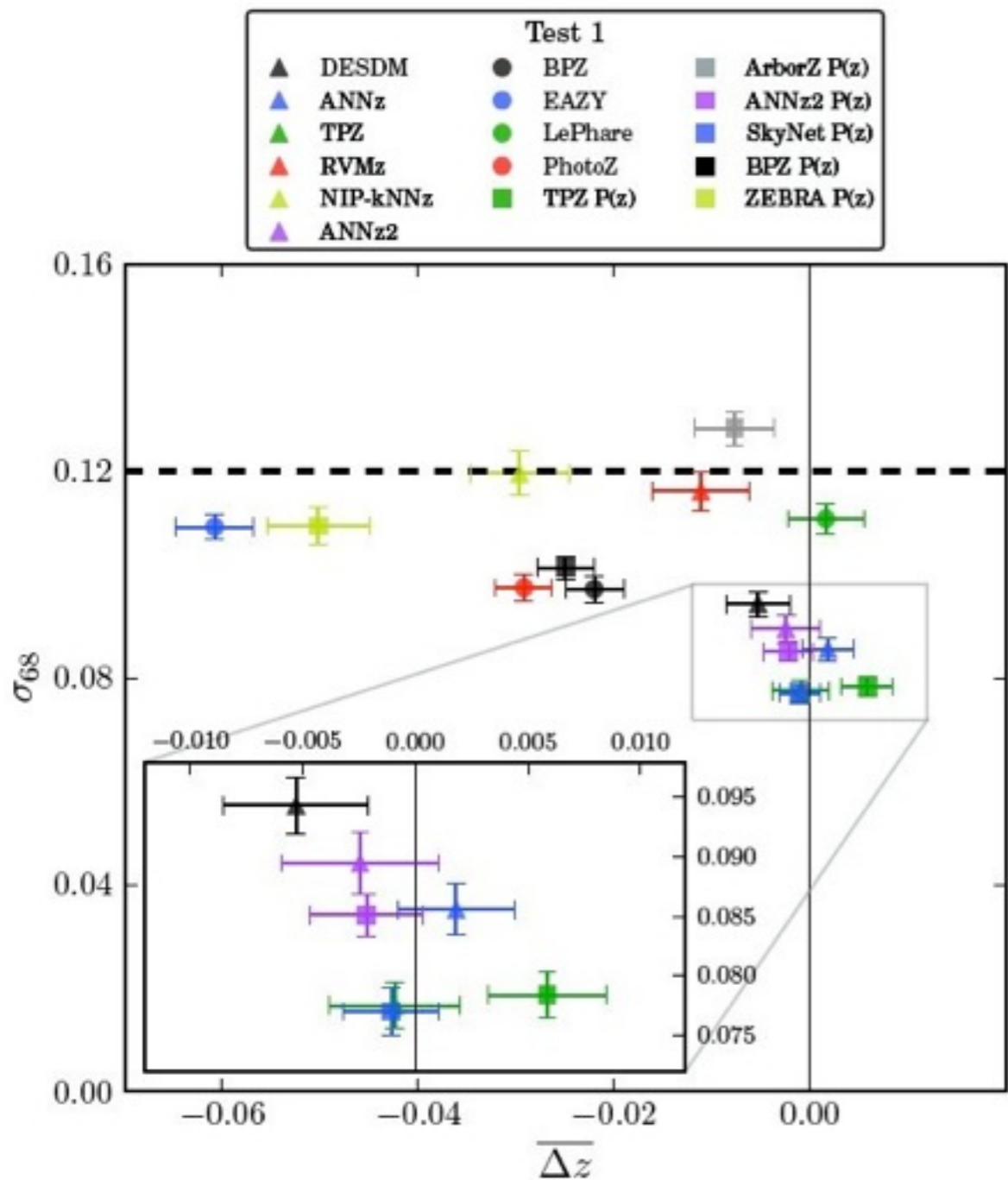| Cluster name	M_{200c}	λ	z_λ	Literature value M_{200c}
RXC J2248.7-4431	$17.6^{+4.5}_{-4.0}$	203 ± 5	0.346 ± 0.004	$22.8^{+6.6}_{-4.7}$ (Gruen et al. 2013b), 20.3 ± 6.7 (Umetsu et al. 2014), 16.6 ± 1.7 (Merten et al. 2014)
1E 0657-56	$14.2^{+10.0}_{-6.1}$	277 ± 6	0.304 ± 0.004	17.5 (Clowe et al. 2004)[i], 12.4 (Barrena et al. 2002, D)
SCSO J233227-535827	$10.0^{+3.7}_{-3.4}$	77 ± 4	0.391 ± 0.008	$11.2^{+3.0}_{-2.7}$ (Gruen et al. 2013a), $4.9 \pm 3.3 \pm 1.4$ (High et al. 2010, R)
Abell 3261	$8.6^{+8.6}_{-3.9}$	71 ± 3	0.216 ± 0.003	—

[i] We converted the measured r_{200c} from Clowe et al. (2004), which lacks an error estimate, to M_{200c} using the critical density in our adopted cosmology.

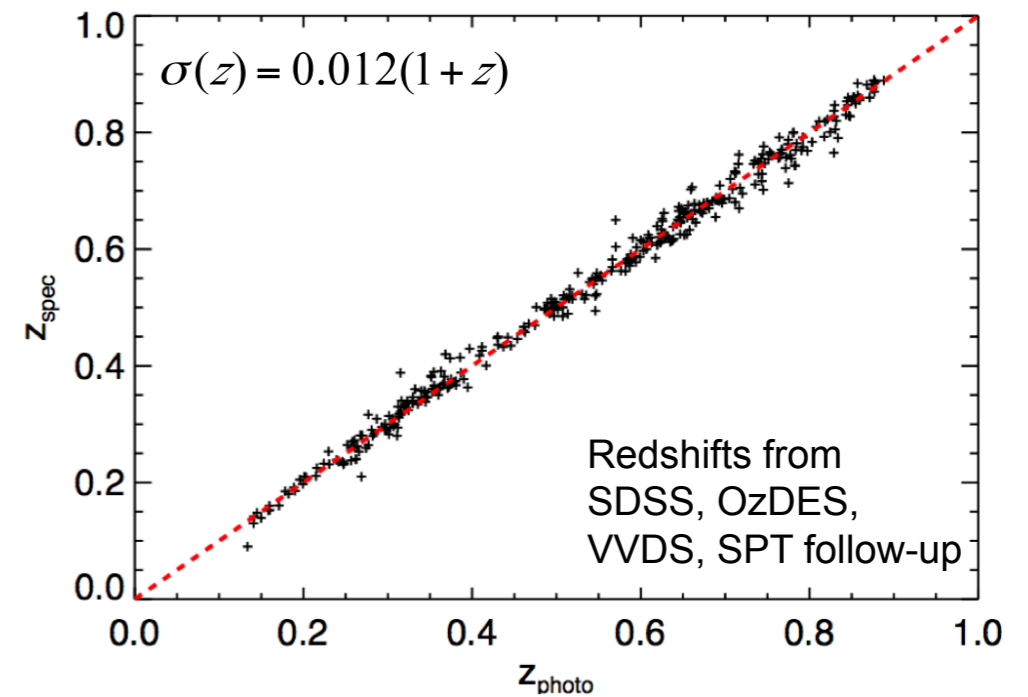**DES can measure galaxy shapes, even in the SV preliminary data set**

Preliminary Results from Science Verification Data: Photometric Redshifts
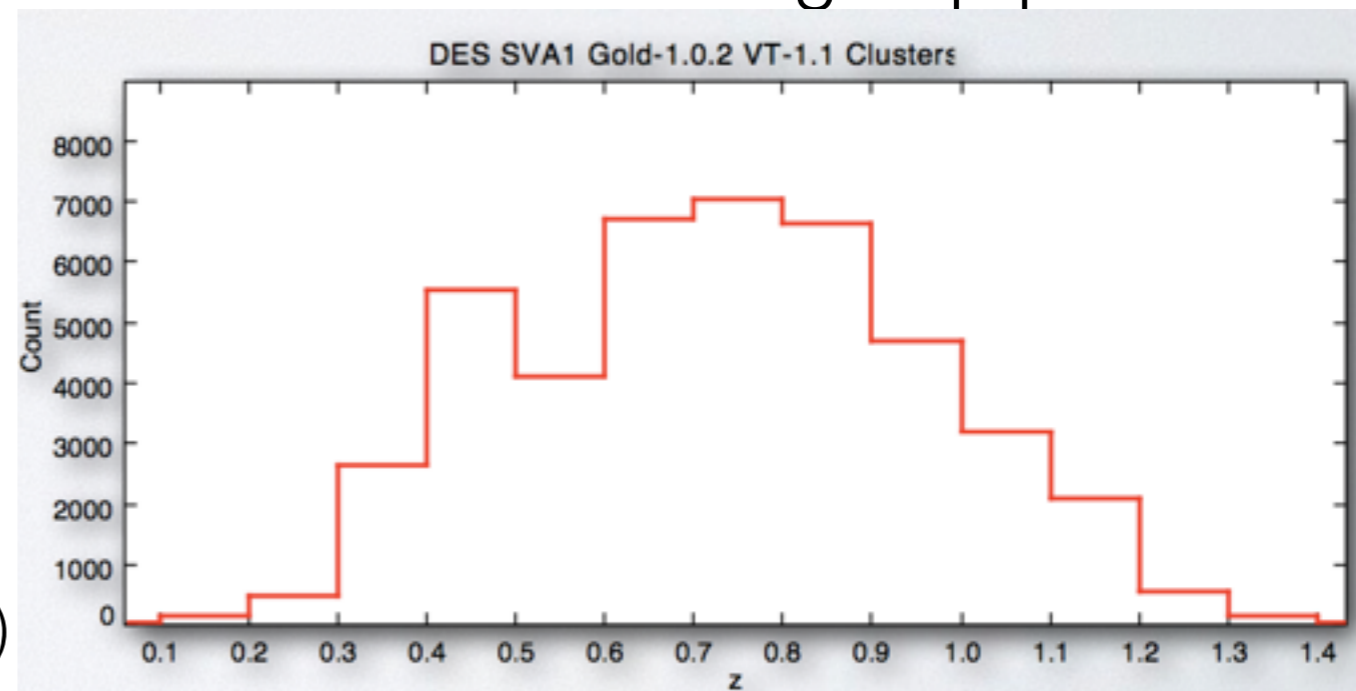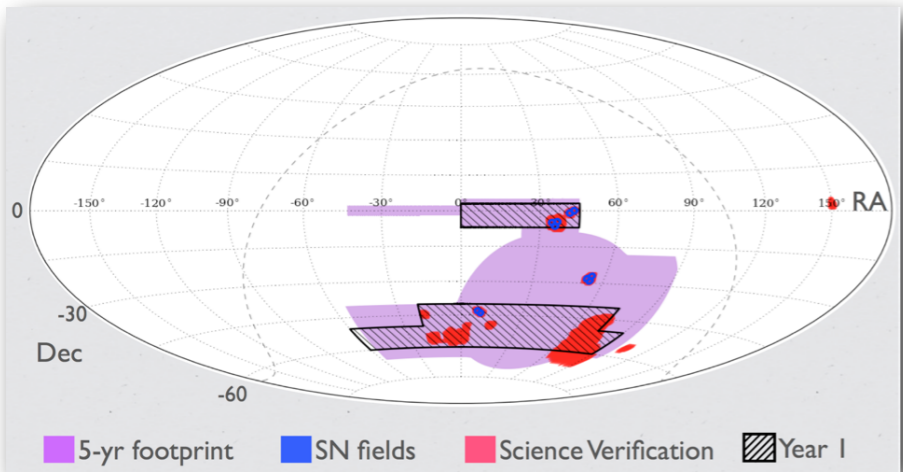
Many codes already meet requirements

Redmapper photo-zs

$$\sigma(z) = 0.012(1+z)$$

Redshifts from SDSS, OzDES, VVDS, SPT follow-up

Voronoi cluster & group photo-zs

Carles Sanchez et al., MNRAS 445 1482 (2014)

Dark Energy Survey Synergy
with the South Pole Telescope

(covering 2500 deg² ~ 6% of sky)

2h 0h
4h
22h
6h
-40
-50
-60

Final survey depths of:
- 90 GHz: 40 uK$_{CMB}$-arcmin
- 150 GHz: 18 uK$_{CMB}$-arcmin
- 220 GHz: 80 uK$_{CMB}$-arcmin

WMAP lower resolution full sky map with SPT area marked

RA
0
-150° -120° -90° -60° -30° 0° 30° 60° 90° 120° 150°
-30
Dec
-60

■ 5-yr footprint   ■ SN fields   ■ Science Verification   ▨ Year 1
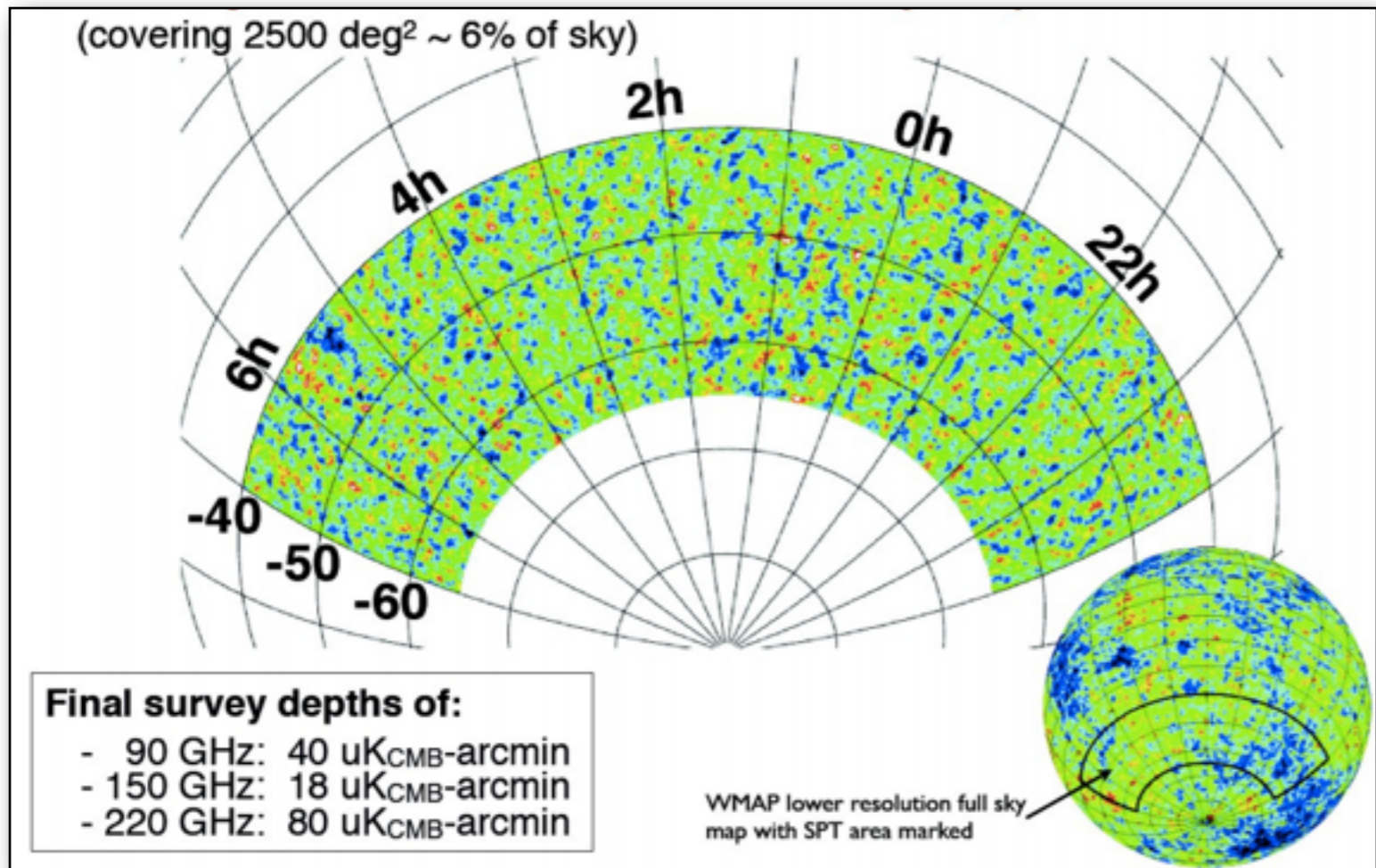
DES survey area encompasses SPT Sunyaev-Zel'dovich Cluster Survey (2500 deg²)

Preliminary   DES x CMB
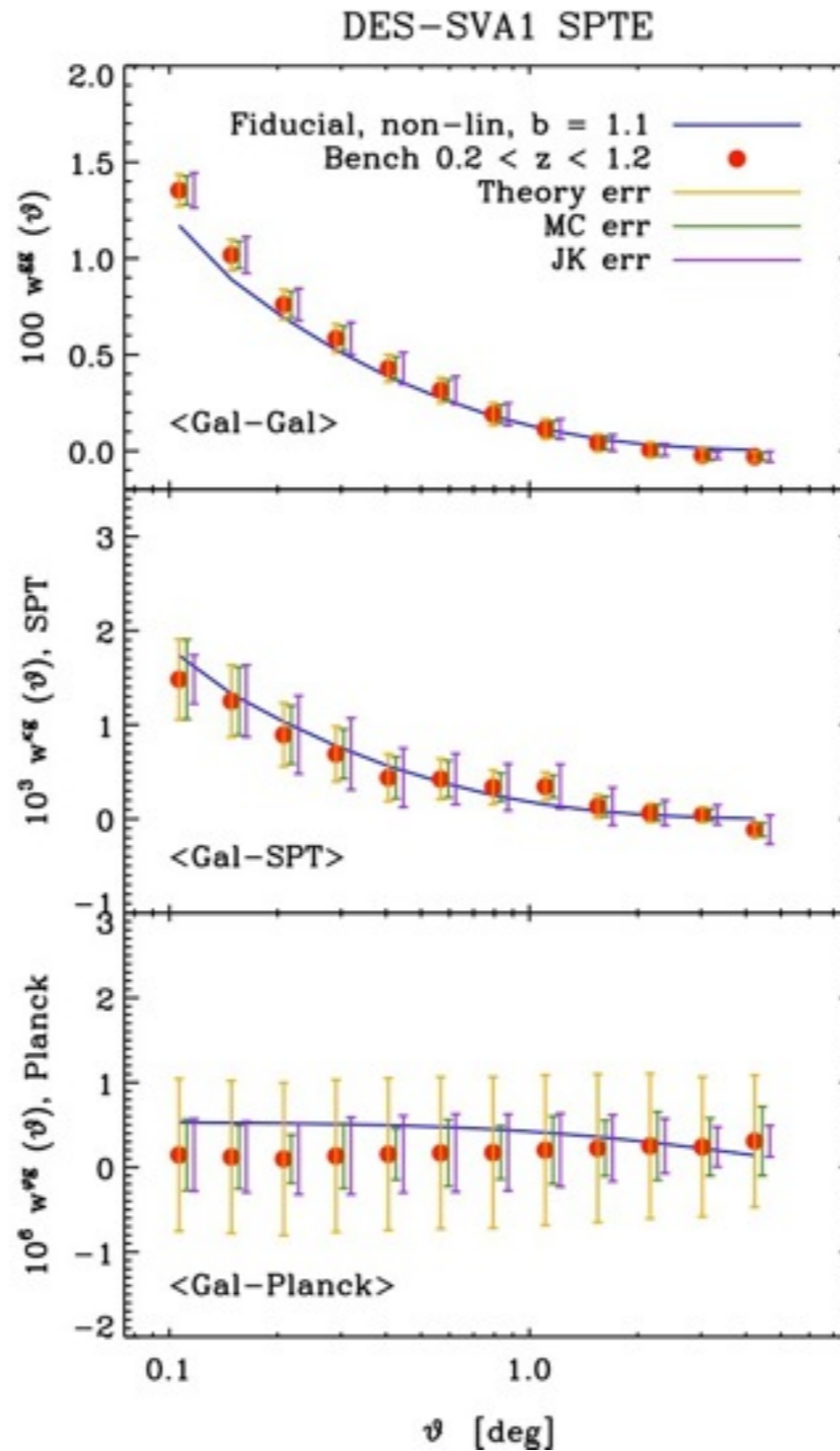
About 5 sigma detection of positive cross-correlation currently with SV data

Giannantonio et al. 2015 (in prep)

Results from Science Verification Data: SuperLuminous SuperNova

DES13S2cmm

E

N

host

45″
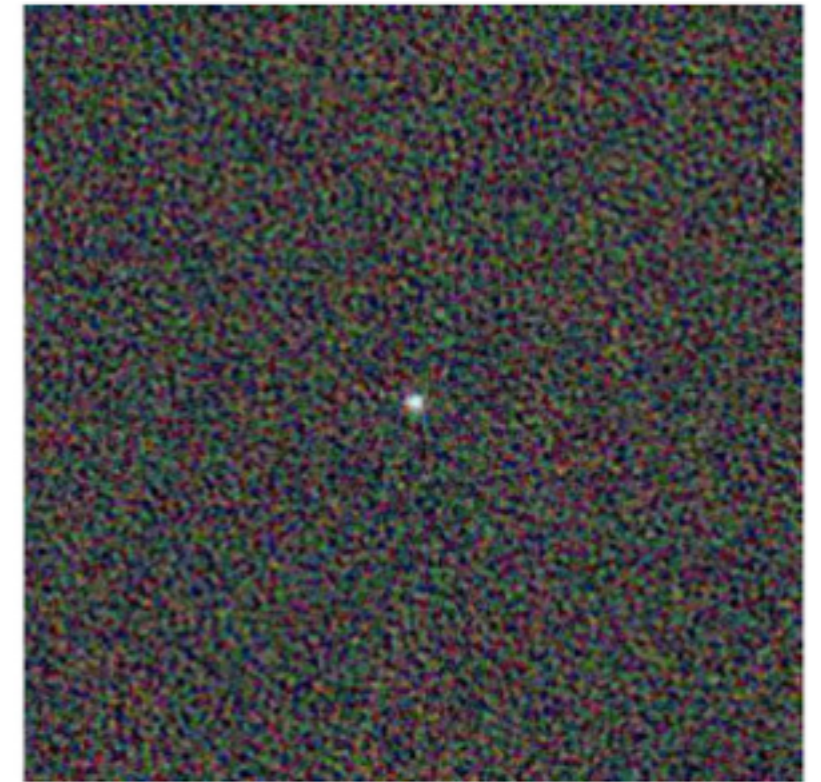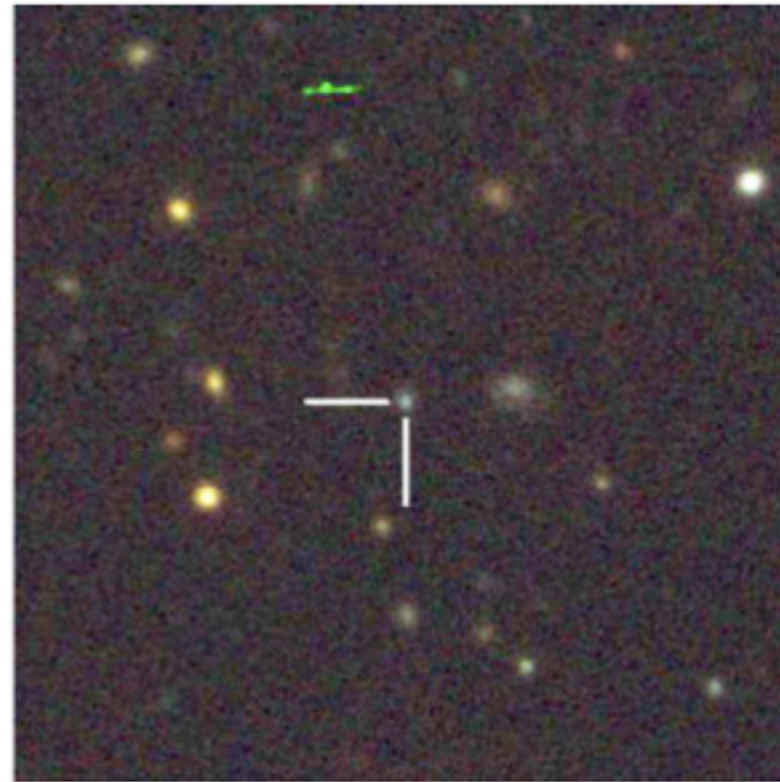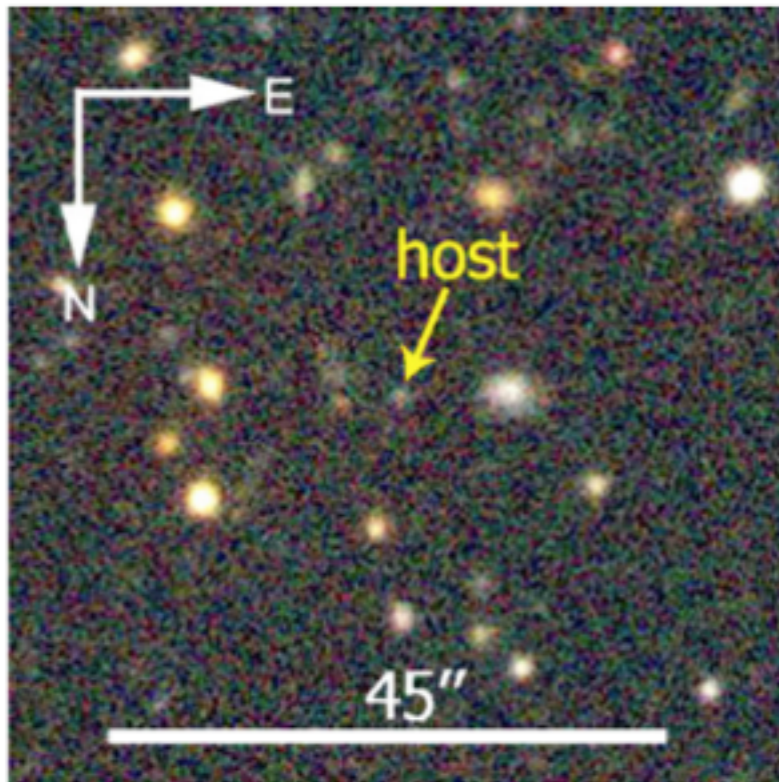
- SLSN are 50 times brighter than typical SN.
- SLSN are rare objects. Only 14 are observed as well as this one.
- Spectroscopically confirmed SLSN with $z = 0.663 \pm 0.001$
- Located in a faint, low metallicity, low stellar-mass host galaxy.

Preliminary DES Results:
Eight Milky Way dwarf galaxy satellite candidates
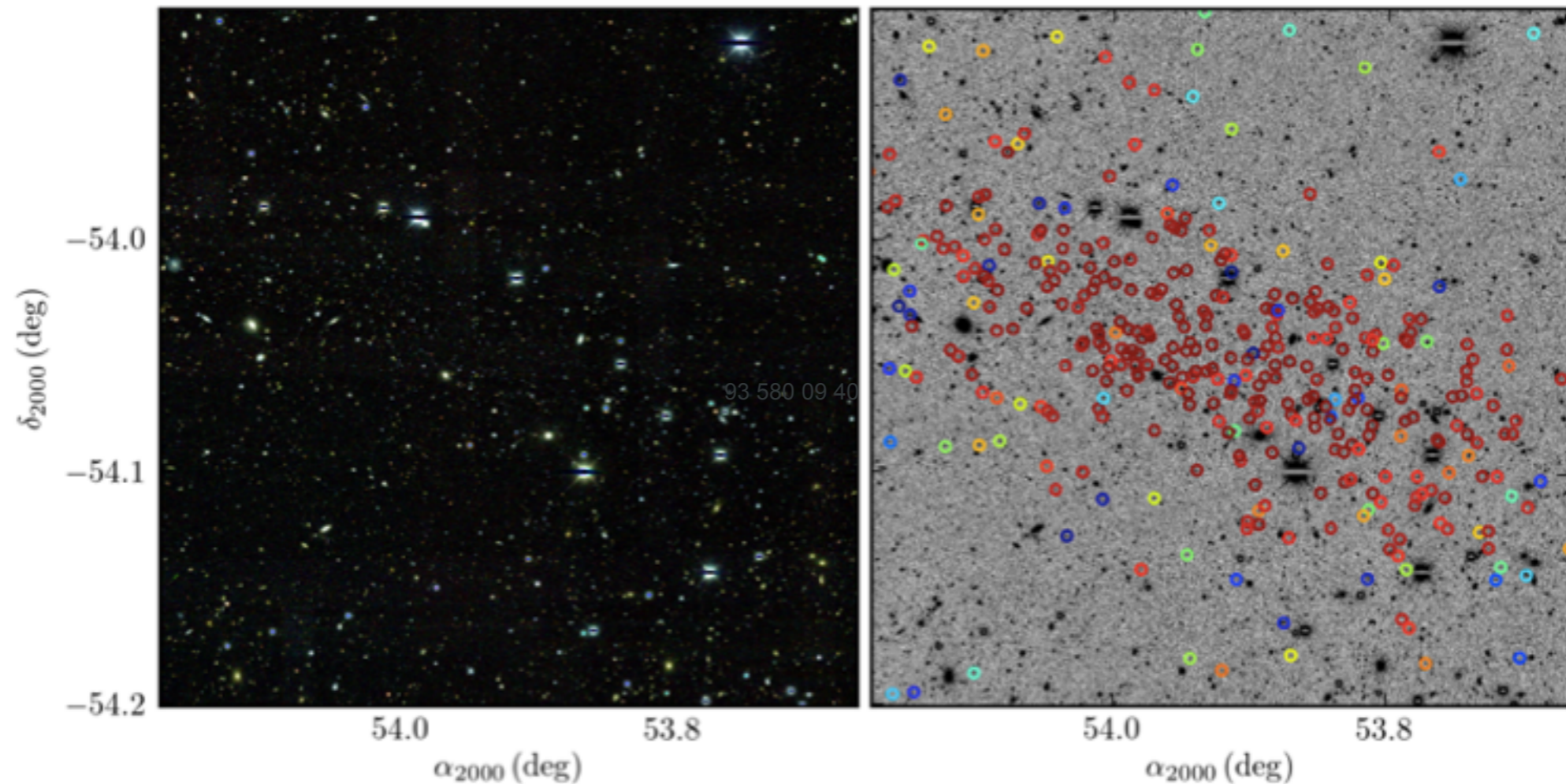
- From 1,800 deg² of optical imaging data (DES 1st year)
- Identified as statistically significant overdensity of stars

Bechtol et al. 2015 (arXiv:1503.02584)

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THE DARK ENERGY SURVEY

Mock Catalogues

- *Testing your pipelines*
- *Understanding Errors*
- *Computing covariances*

- *You know what has been included in the mocks, so one can work out what are the best estimators, and test systematics.*
- *As pipelines become complex they are more difficult to capture by theoretical modelling, and mocks are needed.*
- *Covariance matrix require a large number of realisations, the production of fast mock galaxy catalogues may provide them*
- *Large number of mocks allows for exploration of the parameter space.*

Mock Catalogues

slow ← → **fast**

ROUTE A

ROUTE B

N-Body simulations
+ high resolution
+ baryons
+ galaxy formation semi-analytical models

Move dark matter particles analytically

Run PM simulations with fewer time steps

all scales

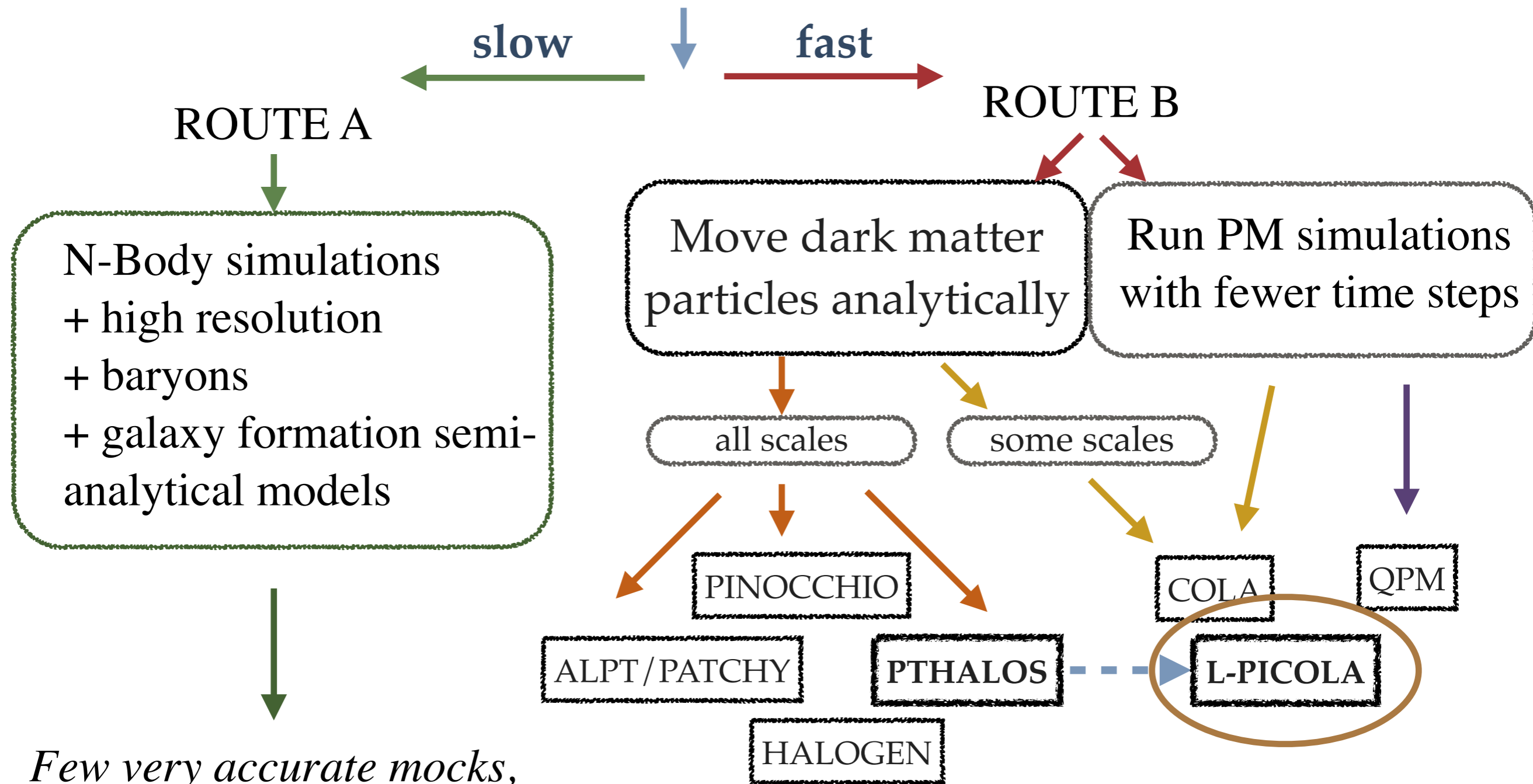some scales

PINOCCHIO

COLA

QPM

ALPT/PATCHY

PTHALOS - - → L-PICOLA

HALOGEN
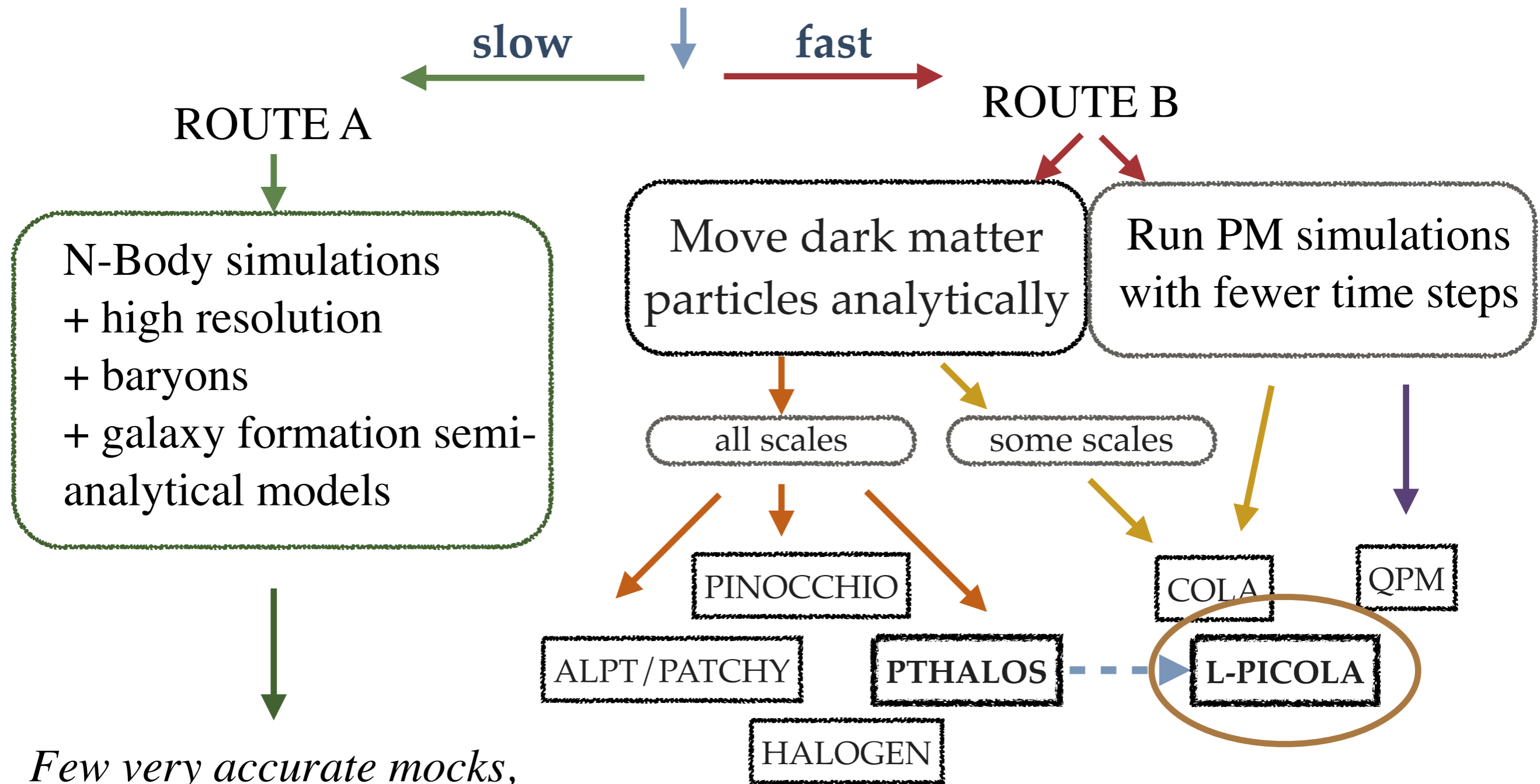
Few very accurate mocks, but computationally very expensive.

♣ *2-3 orders of magnitude faster than N-body runs*

♣ *decide how to define halos and populate galaxies*

Mock Catalogues

slow ← | → fast

ROUTE A

ROUTE B

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Run PM simulations with fewer time steps

all scales   some scales

PINOCCHIO   COLA   QPM

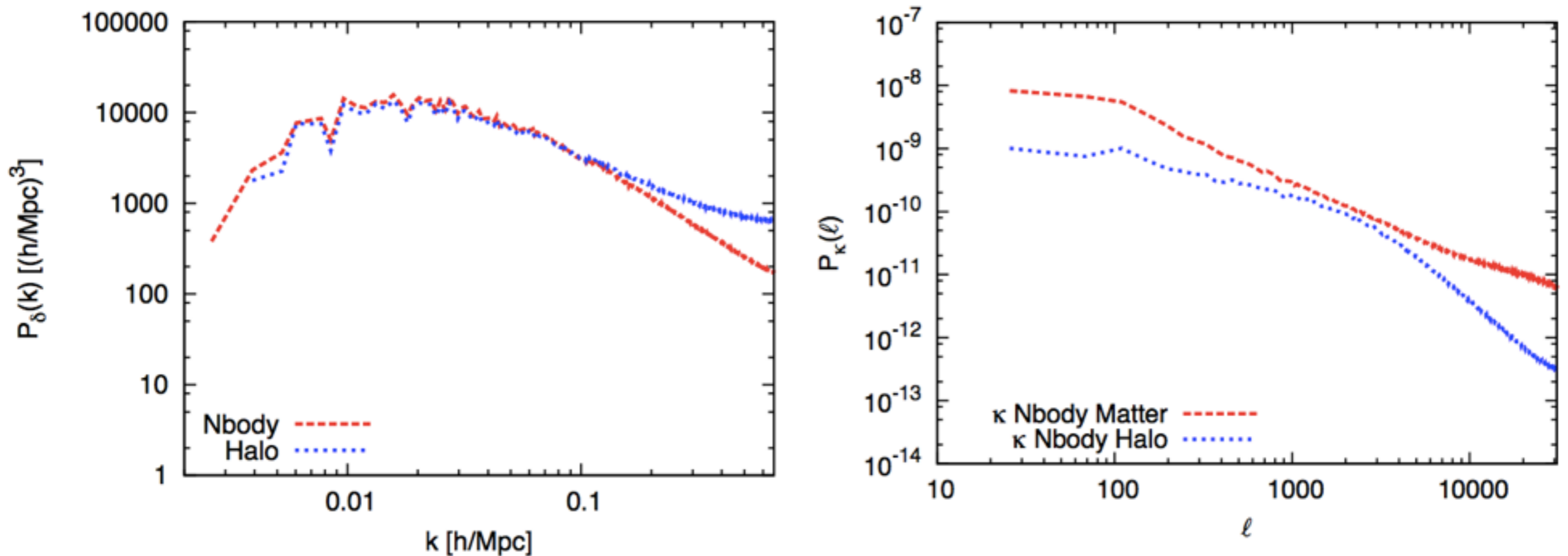ALPT/PATCHY   PTHALOS ⇢ L-PICOLA

HALOGEN

Few very accurate mocks, but computationally very expensive.

L-PICOLA fast mocks: Cullan, MM & Percival 2015

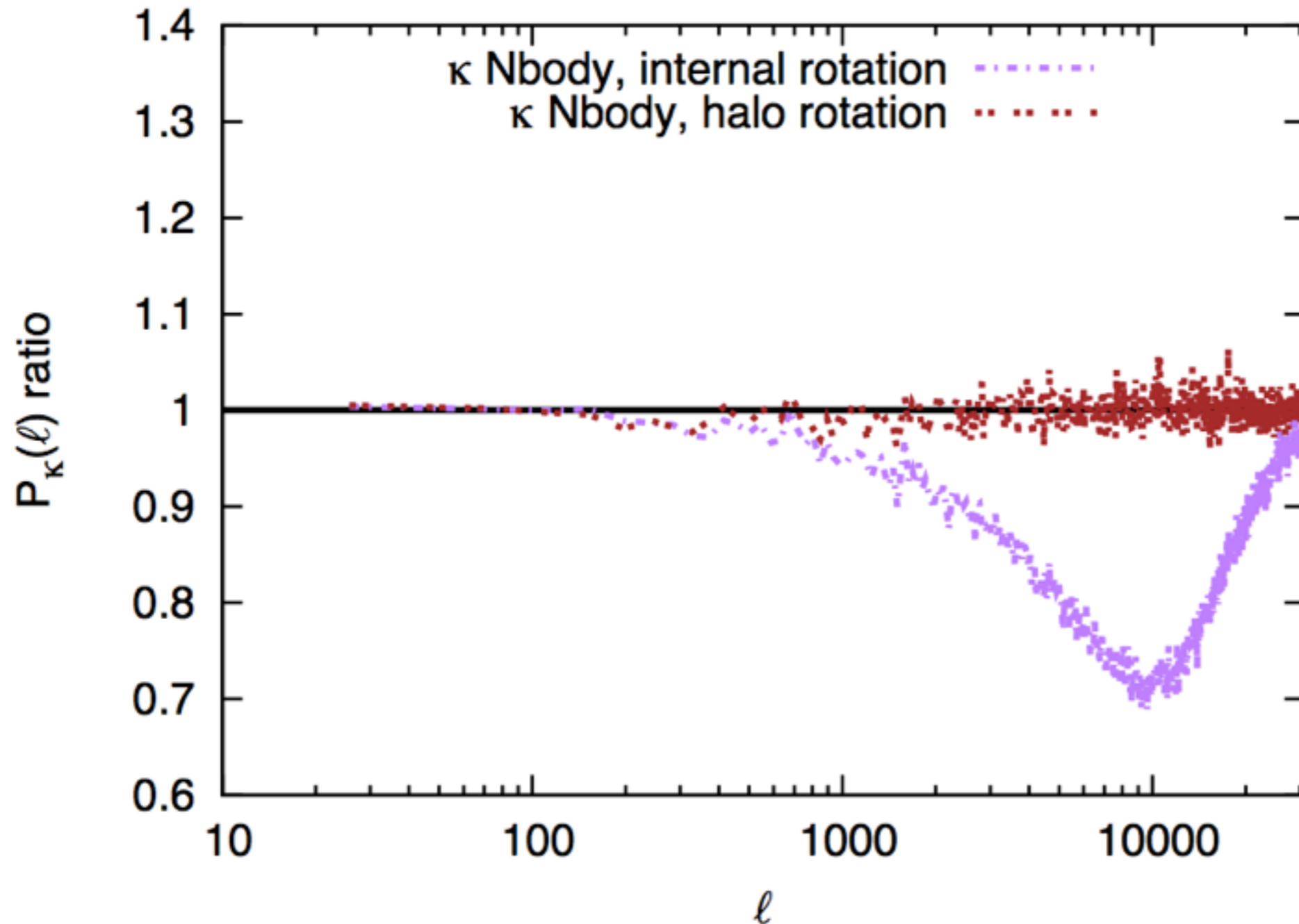Fast Images on n-body: UFIS, Chang et al. 2015

Mock Catalogues: cosmic web

The importance of cosmic web on the power spectrum

The cosmic web contributes significantly to the convergence power spectrum.
Obtaining $P\kappa$ only from halos misses power.

Mock Catalogues: substructures

Summary

- Initial Science Verification data already yielding high-quality results; photoz codes already comply with science requirements, and images are good for lensing.

- First results include: lensing of four massive clusters, discovery of eight candidates for Milky Way dwarf galaxy satellites and a superluminous supernova.

- MUCH work ongoing within DES. Second year of observations just ended! First dark energy results and cosmology expected from Year 1 & 2 data.

- Mock galaxy catalogues are essential for the analysis of galaxy clustering. Fast mocks can be done using L-PICOLA.