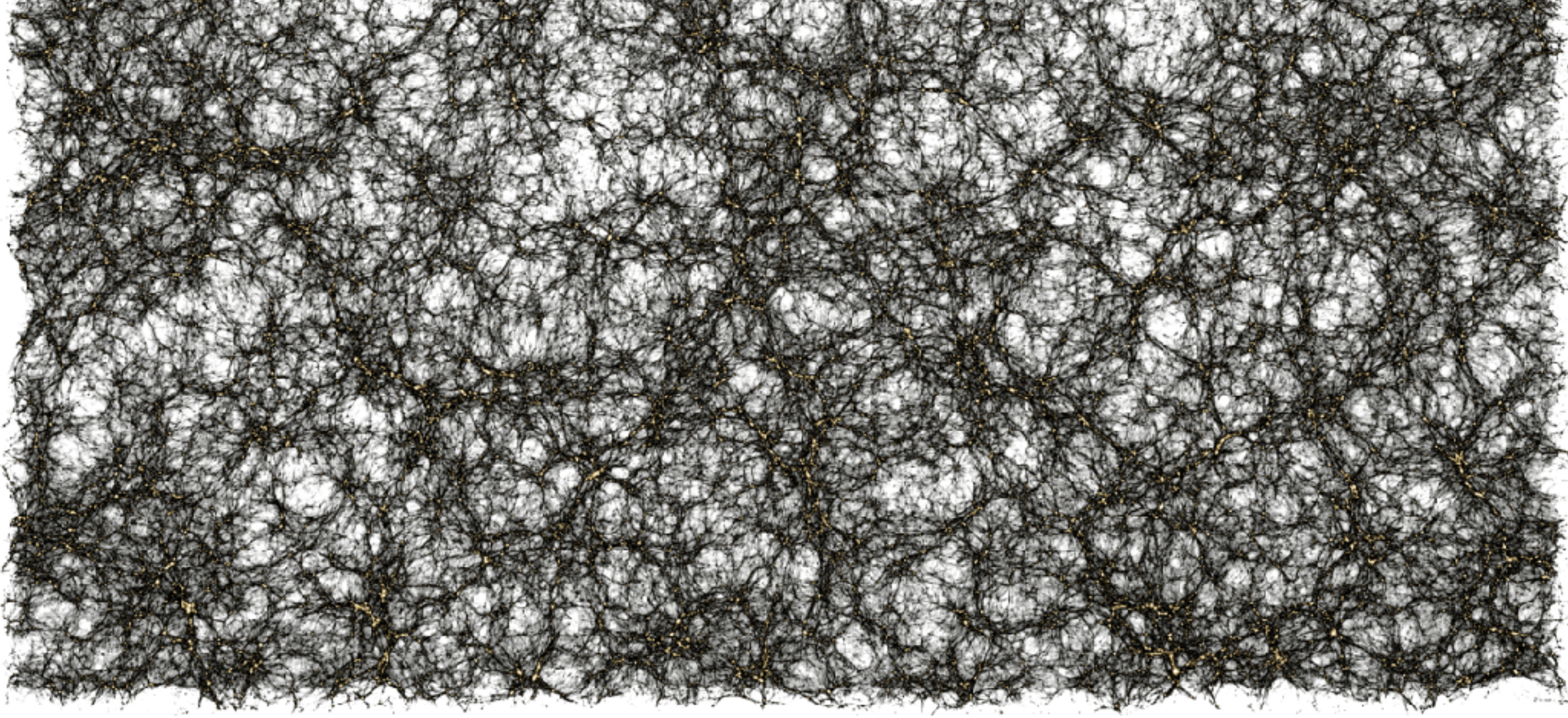


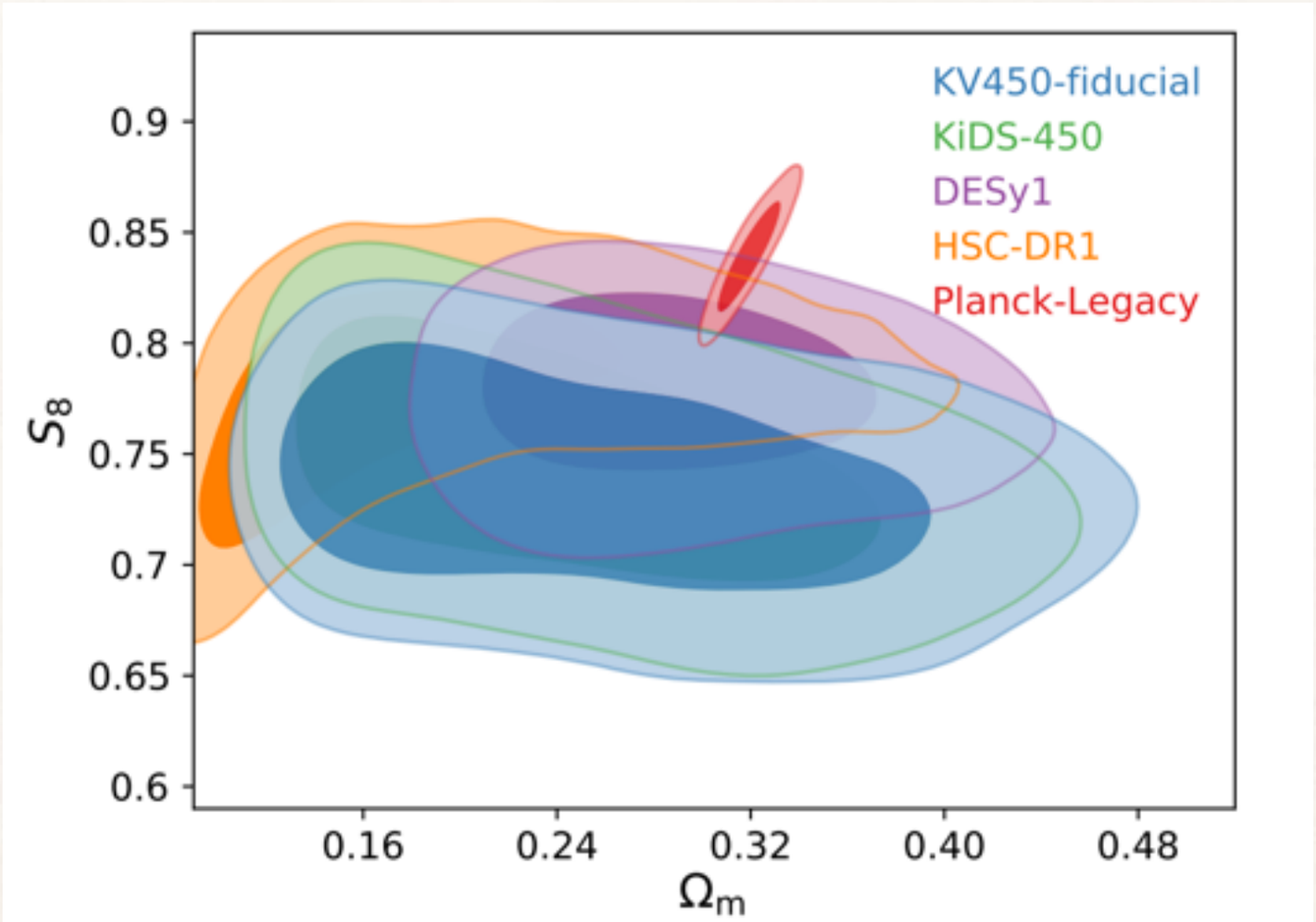
The Buzzard Flock: Synthetic Sky Catalogs for Precision Cosmology

Joe DeRose (UC Santa Cruz & UC Berkeley)

5/6/20 — GCCL Seminar

Low Redshift Universe Tests of LCDM

Hildebrandt et al. 2018



Stage III and Stage IV galaxy surveys will put LCDM to the test, but only if we can understand our systematics.

Role of Cosmological Simulations in Modern Surveys

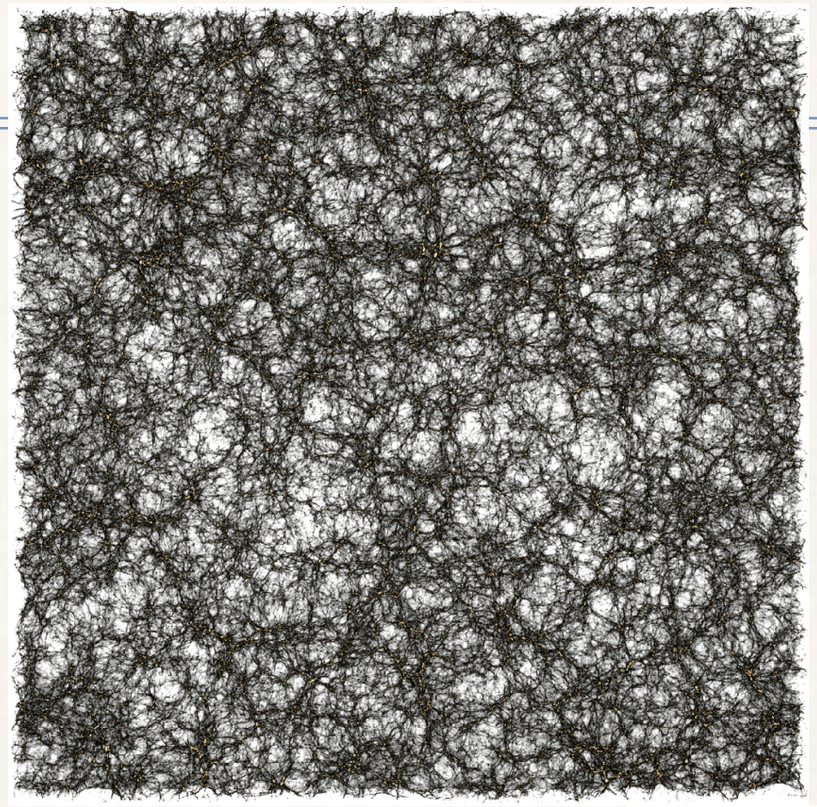
- The Mock as the Test
  - Pipeline and algorithm development
  - Systematics estimation and tests of marginalization schemes
  - Case study - the Dark Energy Survey

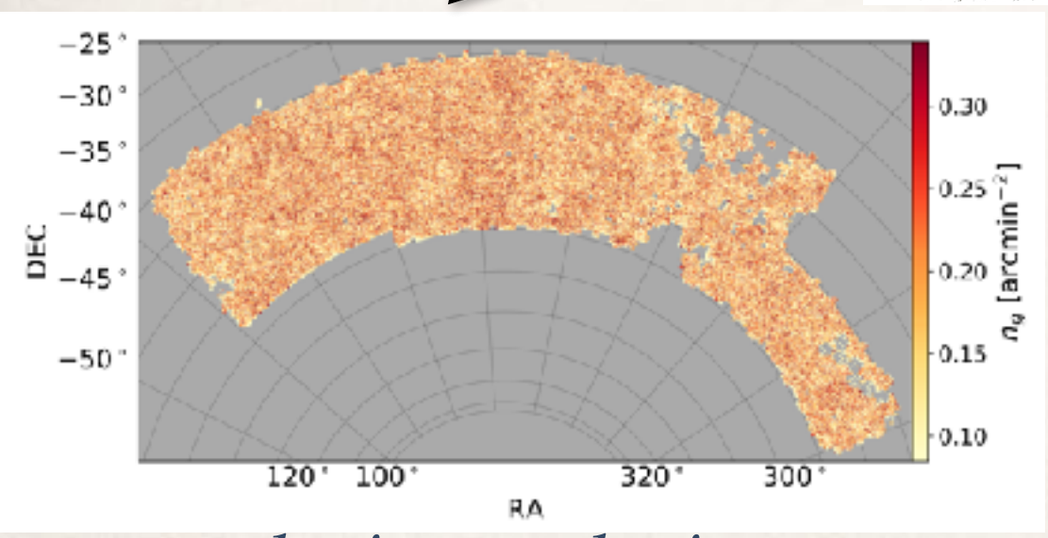
- The Mock as the Model *(not in this talk, but I also work on this)*
  - Accurate predictions for non-linear observables
  - Covariances

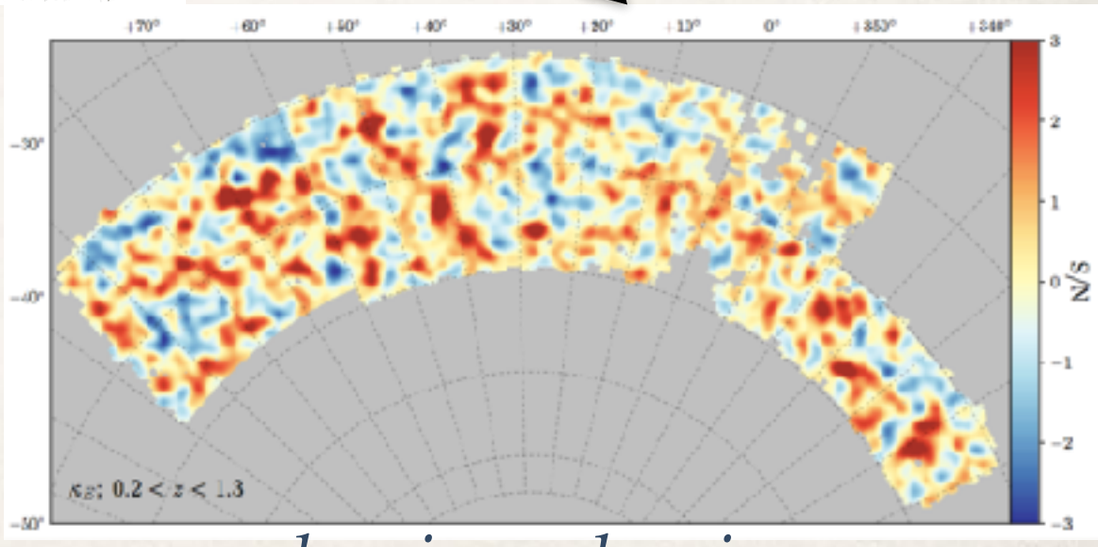
The Dark Energy Survey

- Imaging survey of the southern sky
  - ~5000 sq. degrees
  - 4m Blanco Telescope on Cerro Tololo, Chile
  - 5 bands: *grizy*
- Done taking 6 years of data, results published for first year (Y1) and working on analyzing first 3 years (Y3)

DES Year 1 Cosmology: 3x2-point







galaxies x *galaxies*
angular clustering

galaxies x *lensing*
galaxy-galaxy lensing

lensing x *lensing*
cosmic shear

Testing 3x2-point with Mocks

- Is my pipeline accurate enough for the statistical precision of my data?
  - Robustness to modeling assumptions/observational systematics
    - galaxy bias, redshift distributions, intrinsic alignments, baryons, shear calibration, etc.

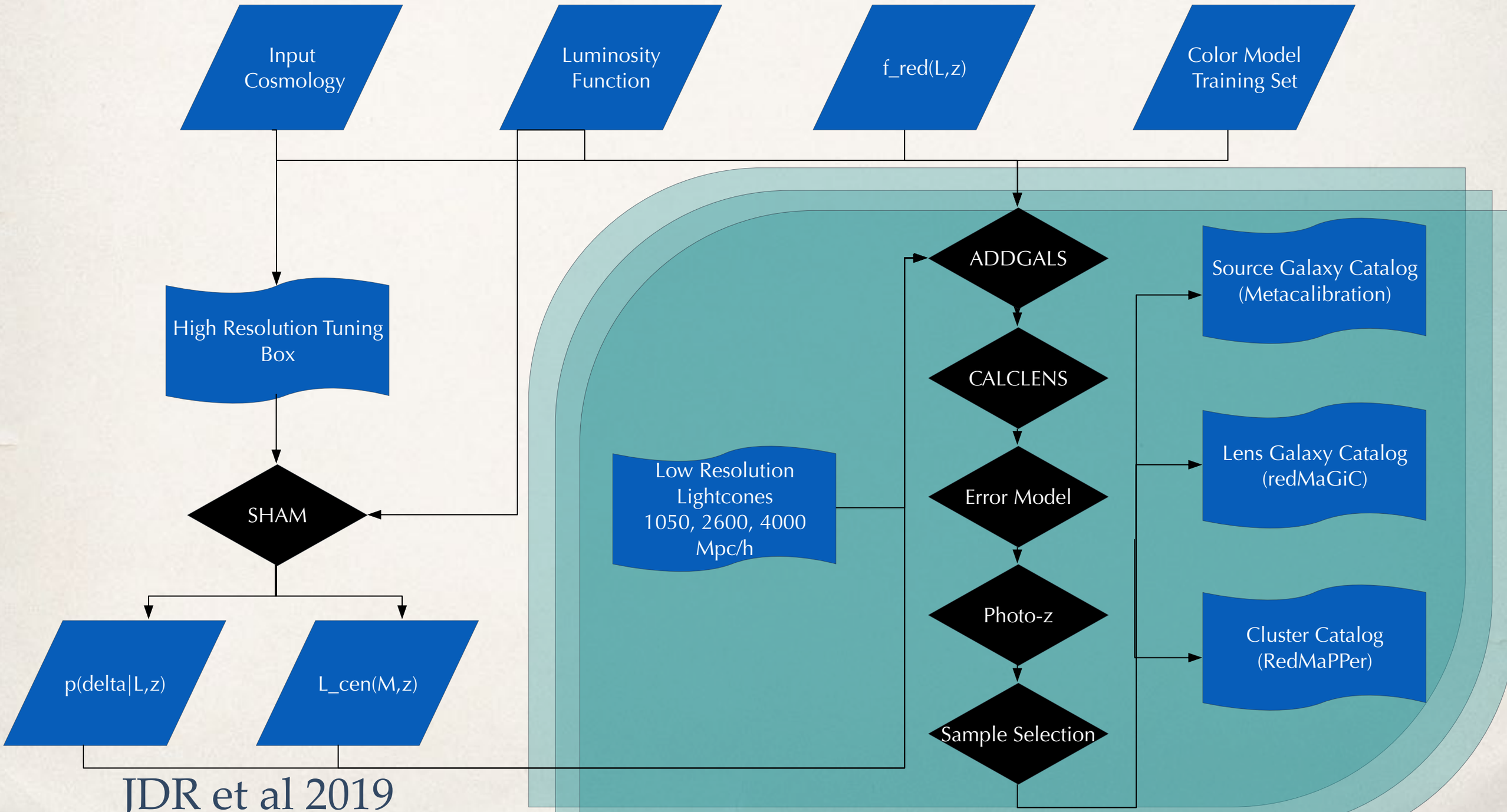
Testing 3x2-point with Mocks

- Is my pipeline accurate enough for the statistical precision of my data?
  - Robustness to modeling assumptions/observational systematics
    - **galaxy bias, redshift distributions**, intrinsic alignments, baryons, shear calibration, etc.

Testing 3x2-point with Mocks

- Is my pipeline accurate enough for the statistical precision of my data?
  - Robustness to modeling assumptions/observational systematics
    - **galaxy bias, redshift distributions**, intrinsic alignments, baryons, shear calibration, etc.
- Requirements
  - High enough resolution to model all measurements accurately, e.g. clustering and lensing
  - Flexible enough to model many samples and their cross-correlations
  - Many times the volume of the survey (must be inexpensive)

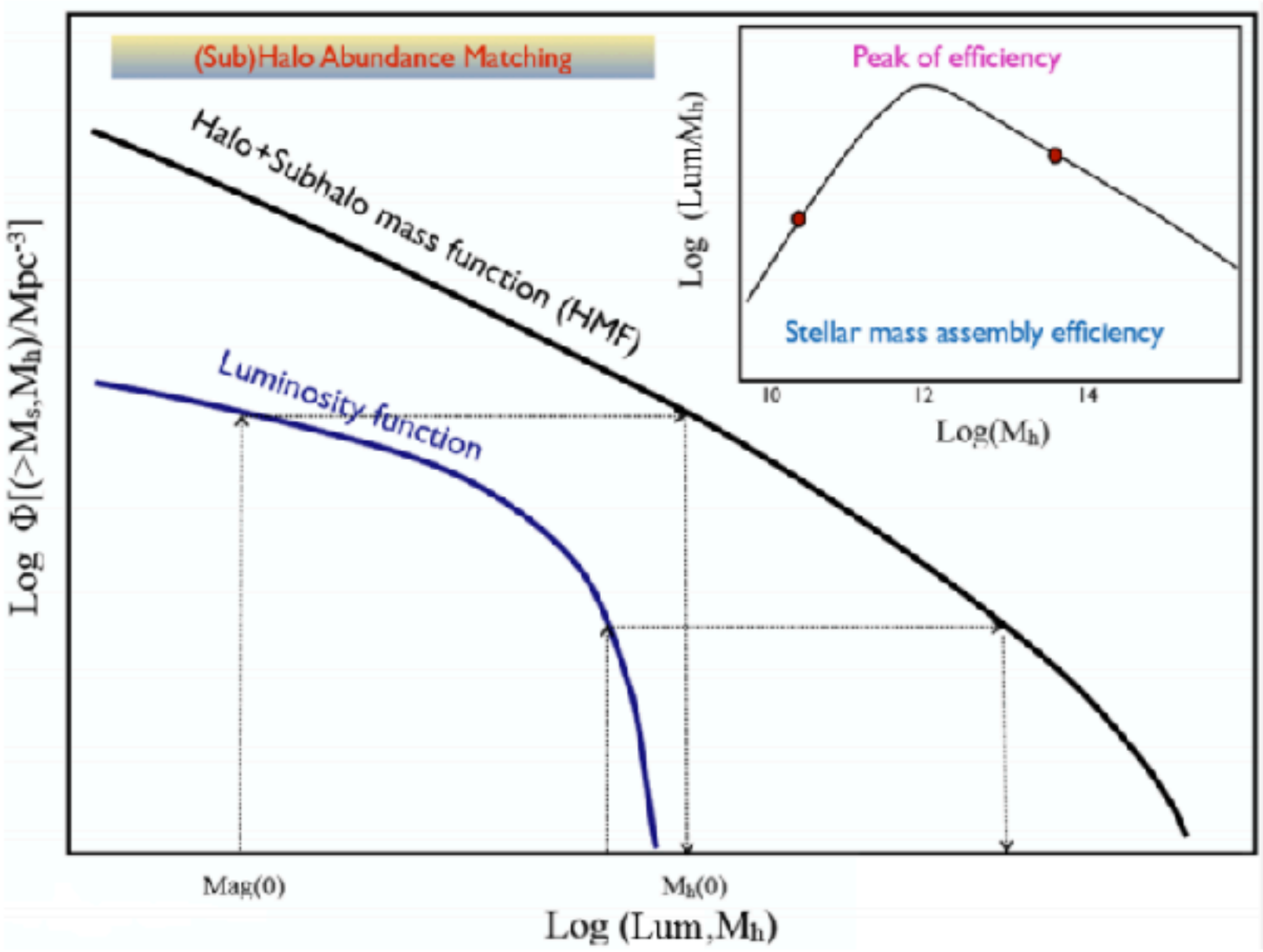
Our Solution: The Buzzard Flock



JDR et al 2019

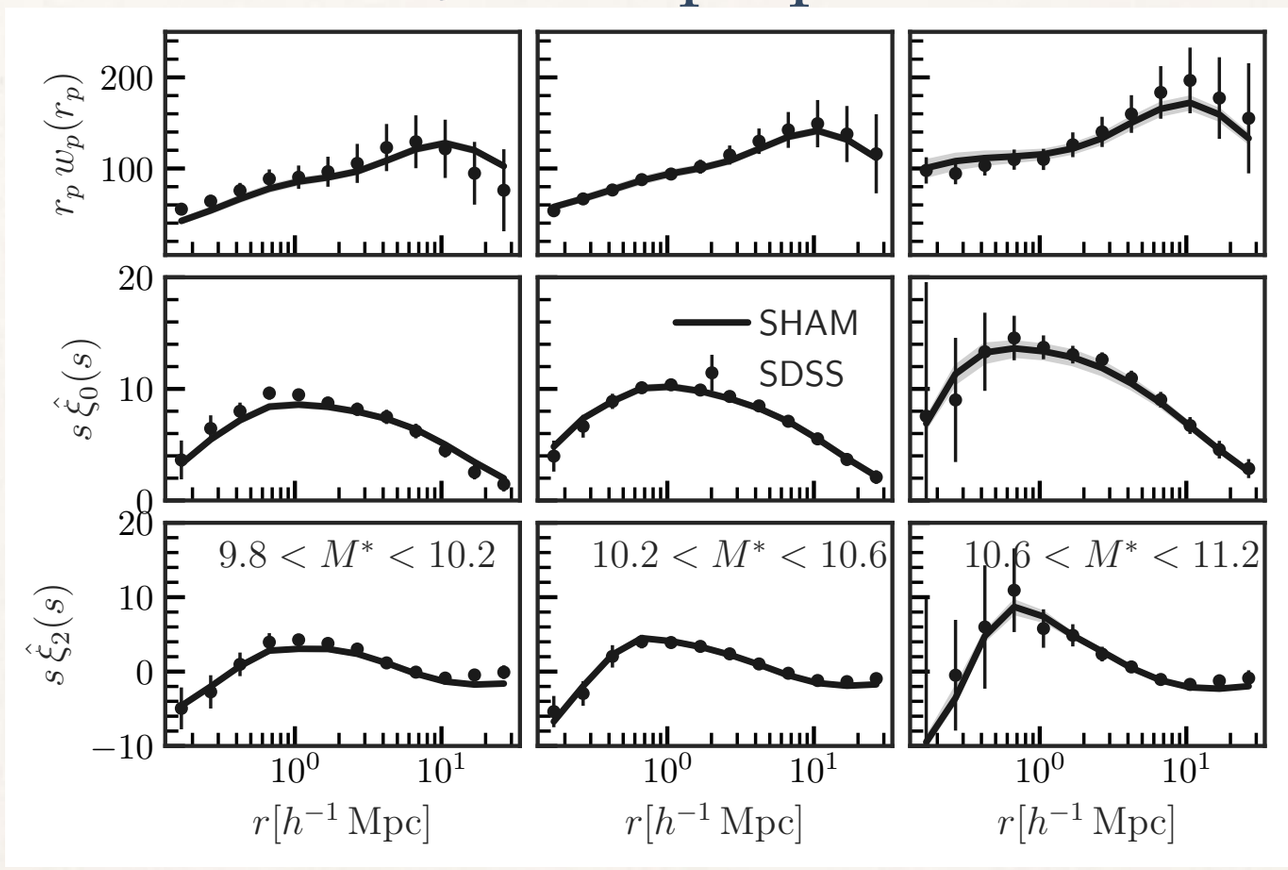
Sub-halo Abundance Matching

- Simple 1-to-1 matching between (sub)halos in simulation and galaxies via rank order in cumulative abundance
- Traditionally 1 free parameter: scatter in galaxy property at fixed halo property



AM Can Model a Diversity of Clustering Statistics

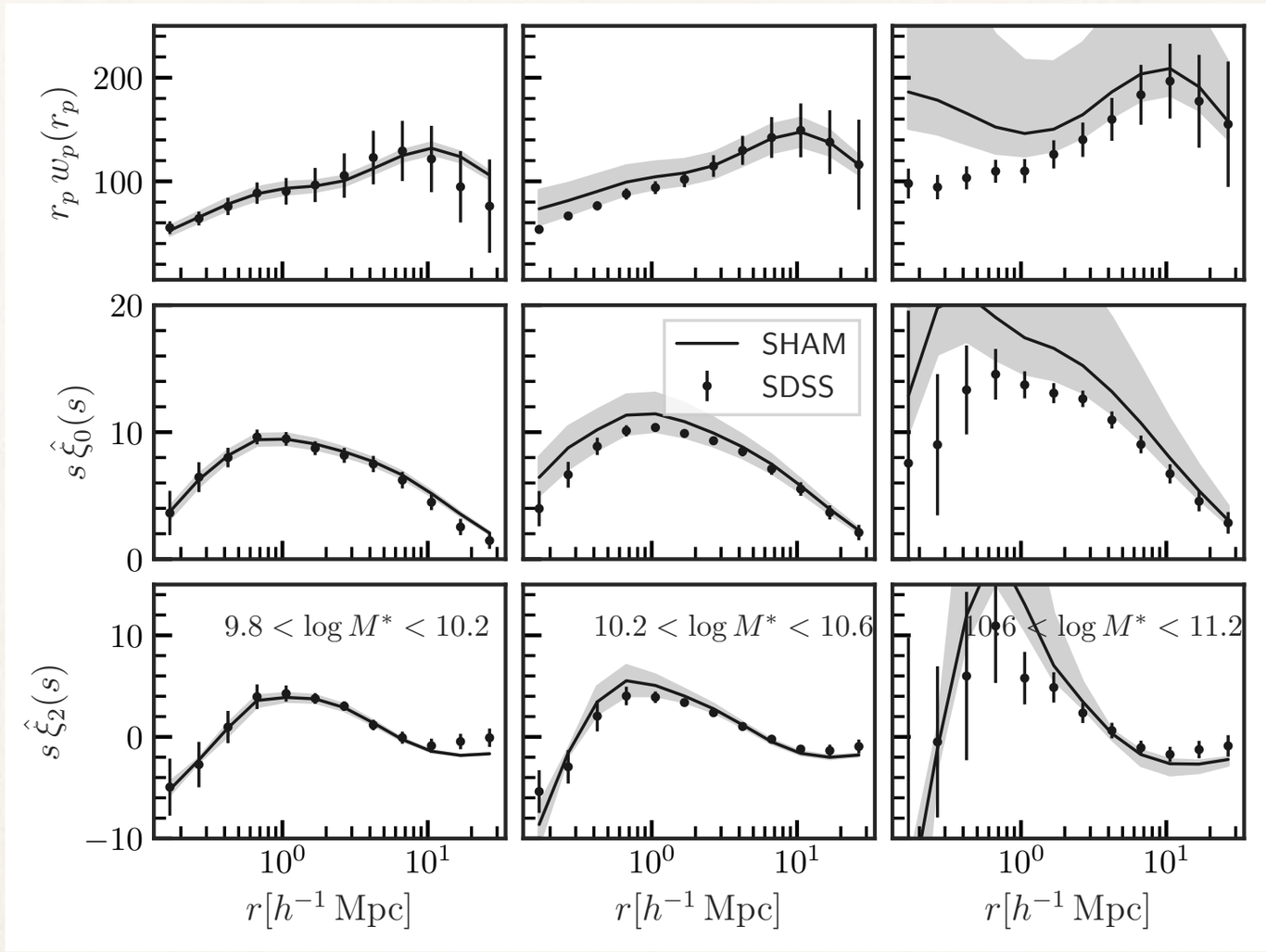
JDR in prep.



Use different proxy, $v_\alpha = v_{\rm vir}\left(\frac{v_{\rm peak}}{v_{\rm vir}}\right)^\alpha$, where α is a free param yields good fits to all statistics other than in lowest mass sample.

AM Can Model a Diversity of Clustering Statistics

JDR in prep.

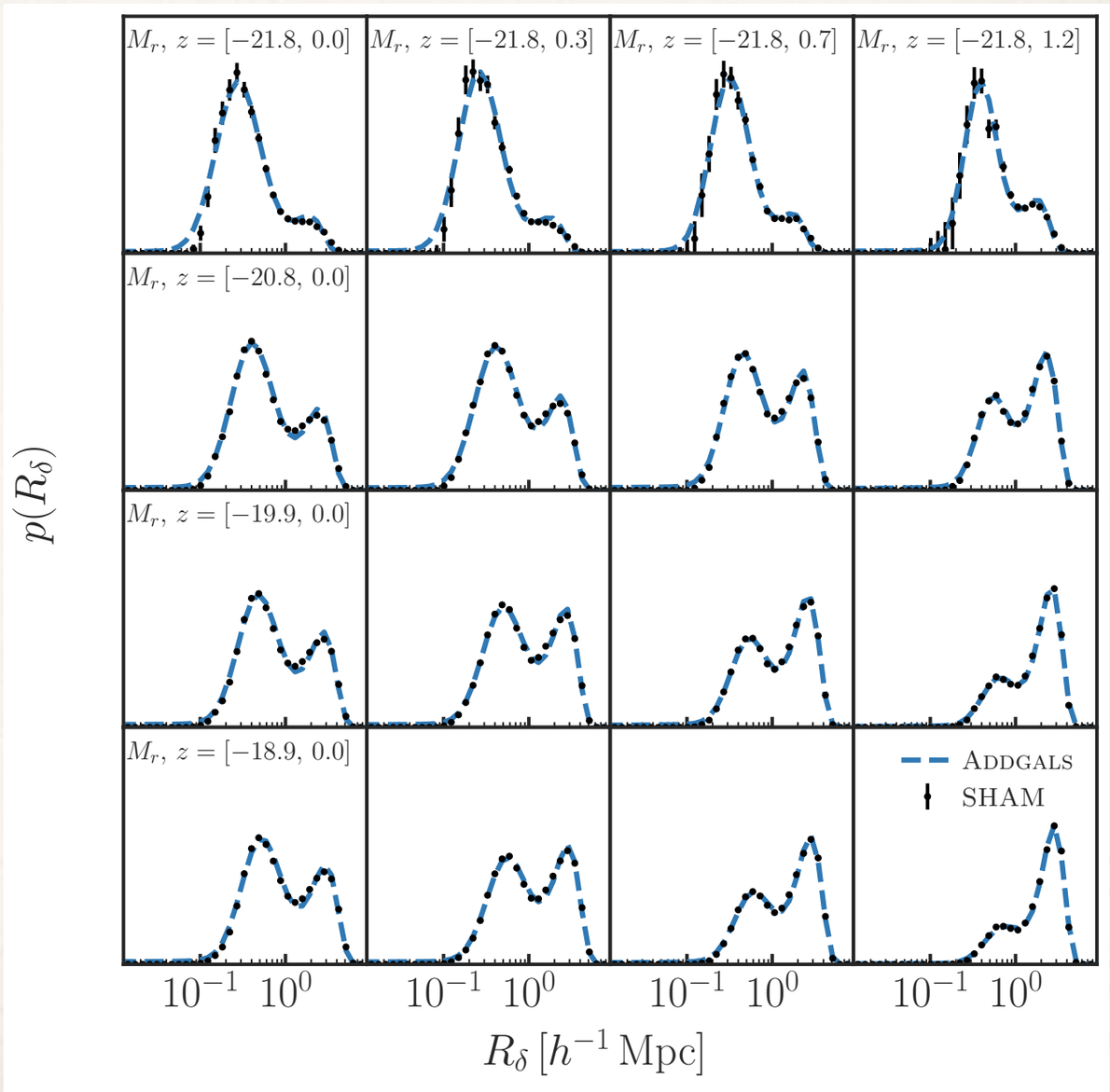


Can fit lowest stellar mass bin with orphan model, but inconsistent with more massive samples. A persistent problem!

ADDGALS

Adding Density Determined Galaxies to Lightcone Simulations

- Run subhalo abundance matching model on high resolution simulation, measure $p(\delta \,|\, L, z)$

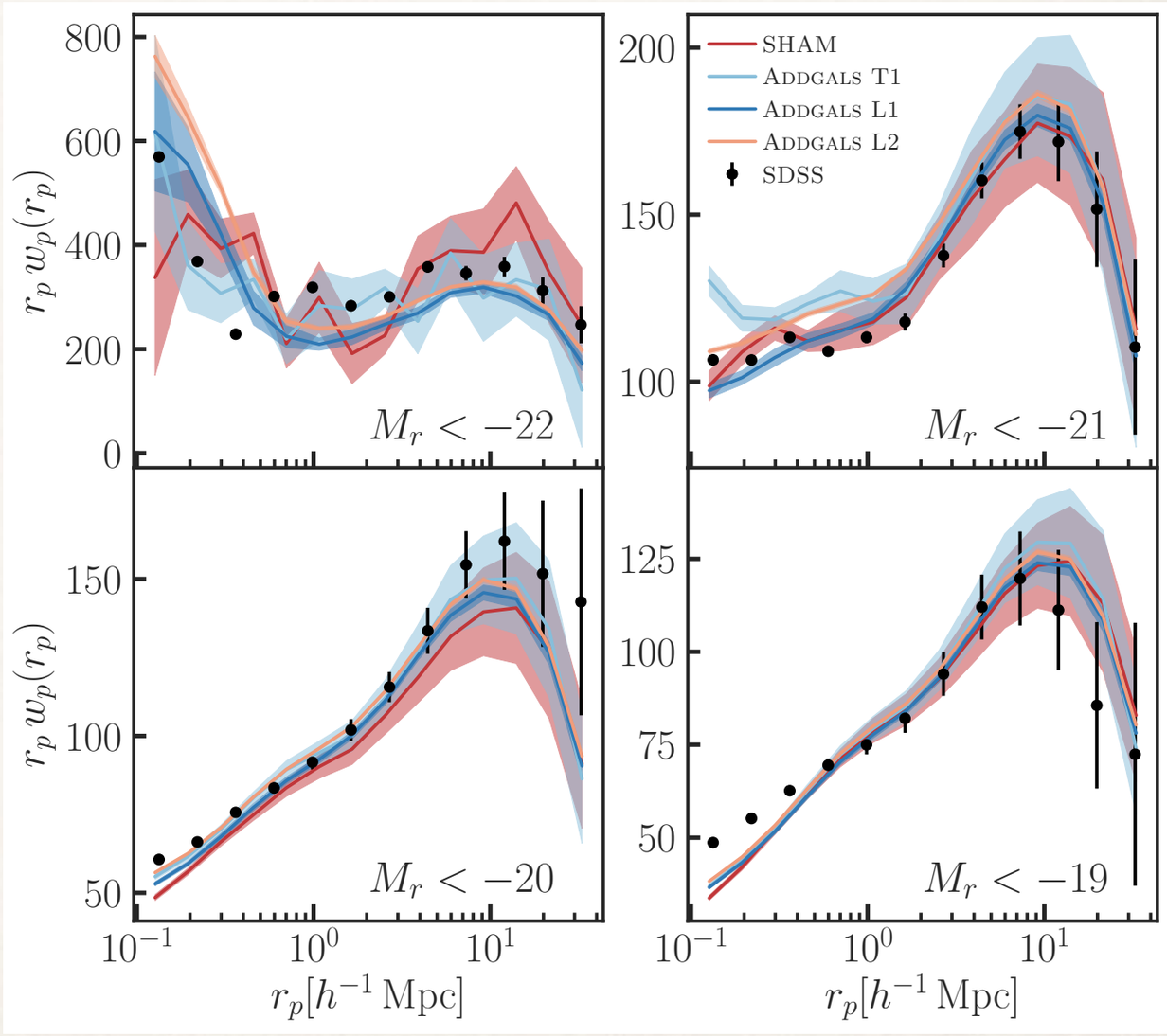


Wechsler, JDR in prep.

ADDGALS

Adding Density Determined Galaxies to Lightcone Simulations

- Run subhalo abundance matching model on high resolution simulation, measure $p(\delta \,|\, L, z)$
- Sample from this distribution to populate low-res light cones

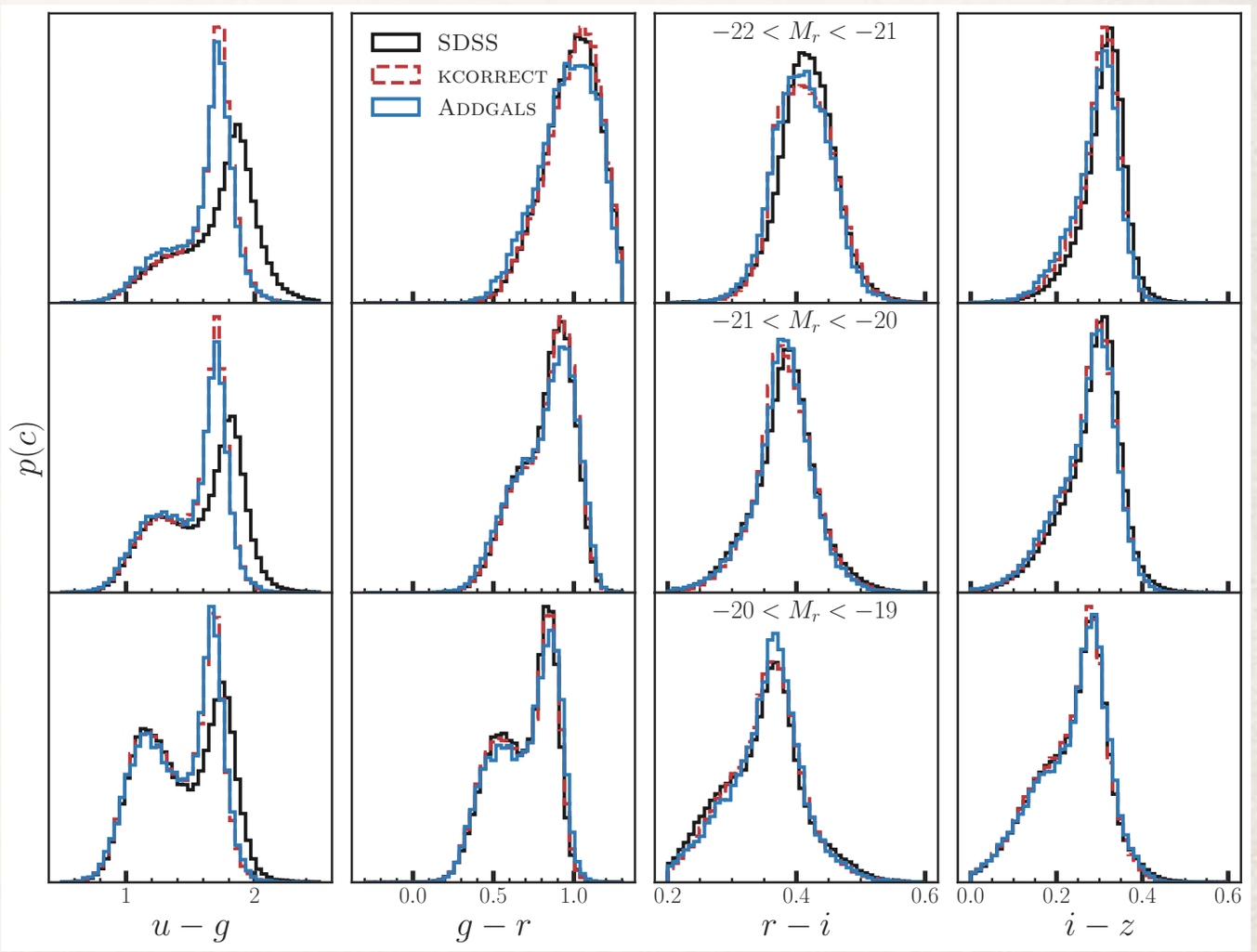


Wechsler, JDR in prep.

SEDs & Colors

Paste SED template fits from SDSS as a function of M_r, z

- Templates not constrained to bluer than rest frame g.
- Can generate any optical, NIR, NUV photometry by integrating SEDs over relevant bandpasses



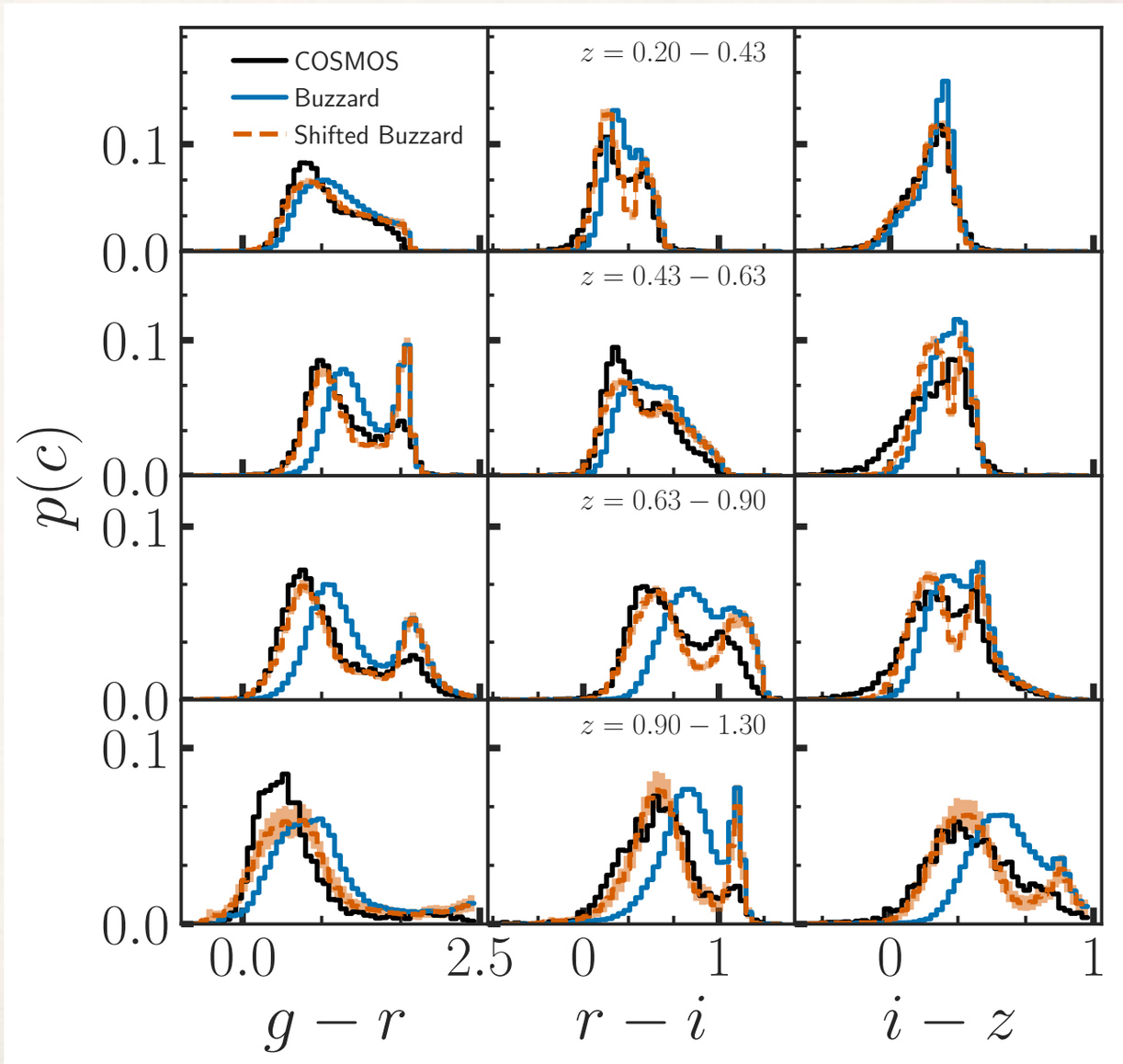
Wechsler, JDR in prep.

SEDs & Colors

Paste SED template fits from SDSS as a function of M_r, z:

Not perfect at higher redshifts:

- Red sequence well modeled, but blue cloud off by redshift dependent shift.
- Provides something reasonably complex for algorithm testing

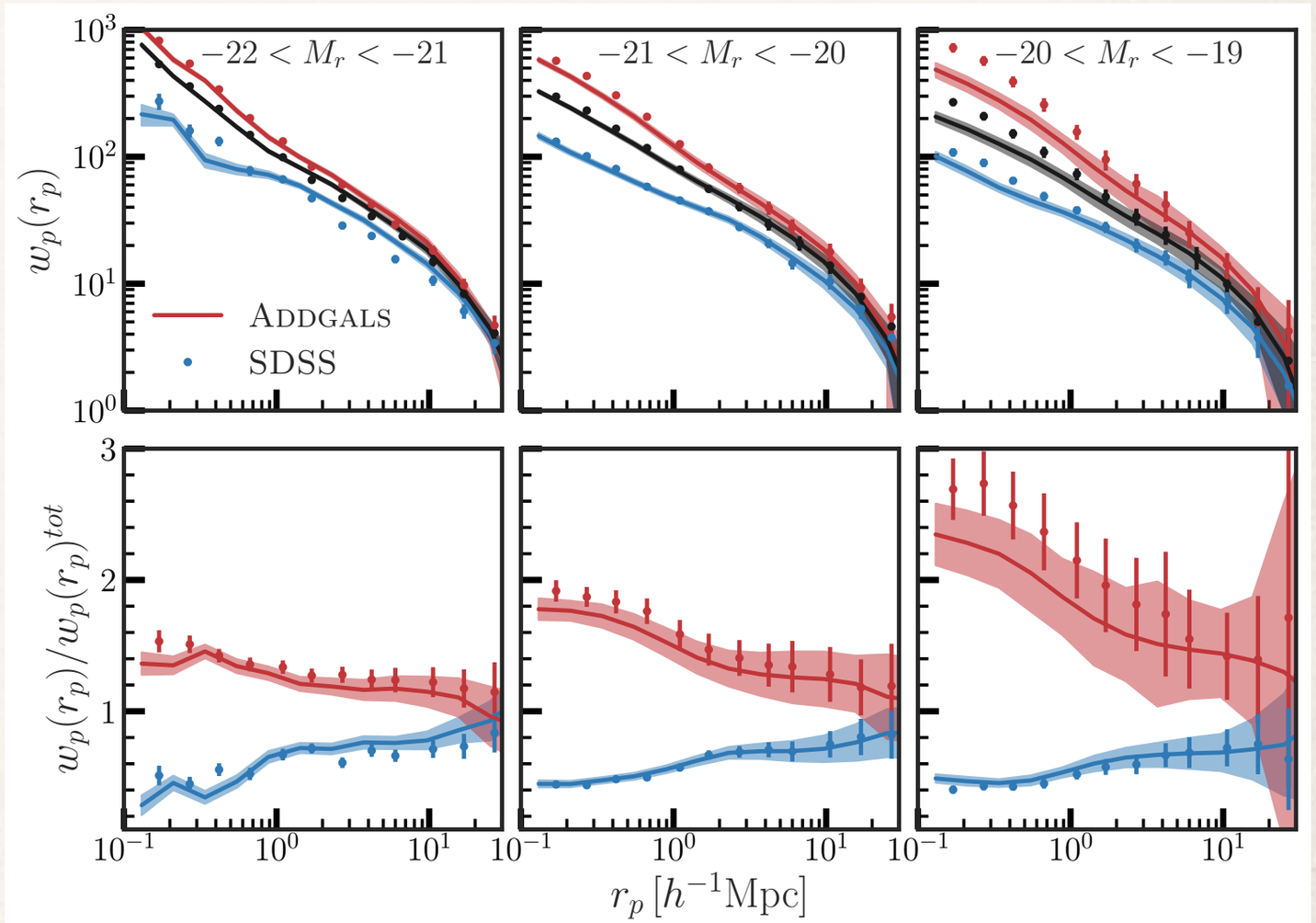


JDR et al 2019

Color-dependent clustering

Impart color dependence to clustering signal by conditional abundance matching SEDs to galaxies

- Rank SEDs by g-r color at fixed M_r
- Rank simulated galaxies by distance to nearest massive halo at fixed M_r

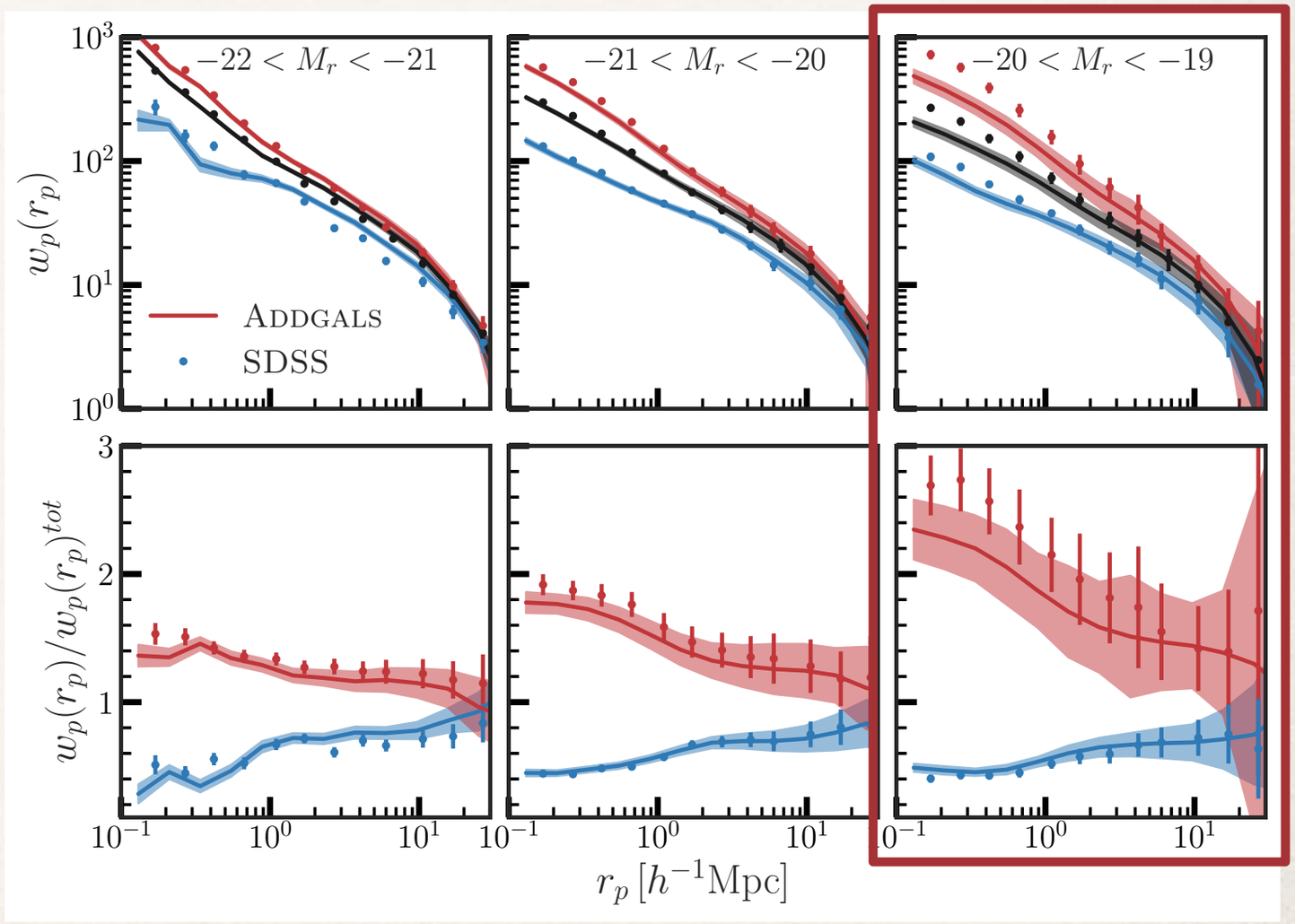


Wechsler, JDR in prep.

Color-dependent clustering

Impart color dependence to clustering signal by conditional abundance matching SEDs to galaxies

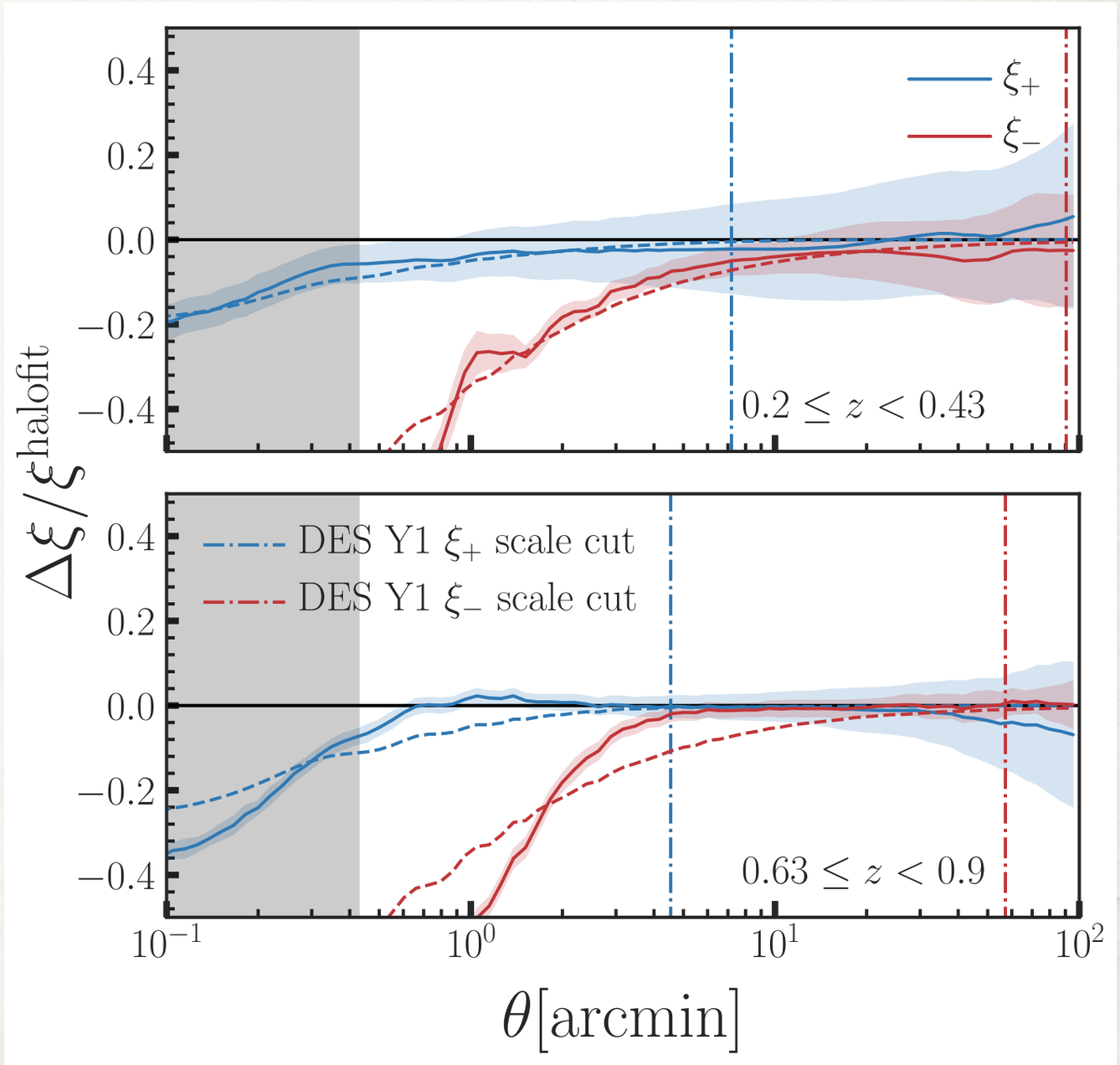
- Successfully matches quenched fraction as function of r
- Residual issues due to lack of orphans in SHAM



Wechsler, JDR in prep.

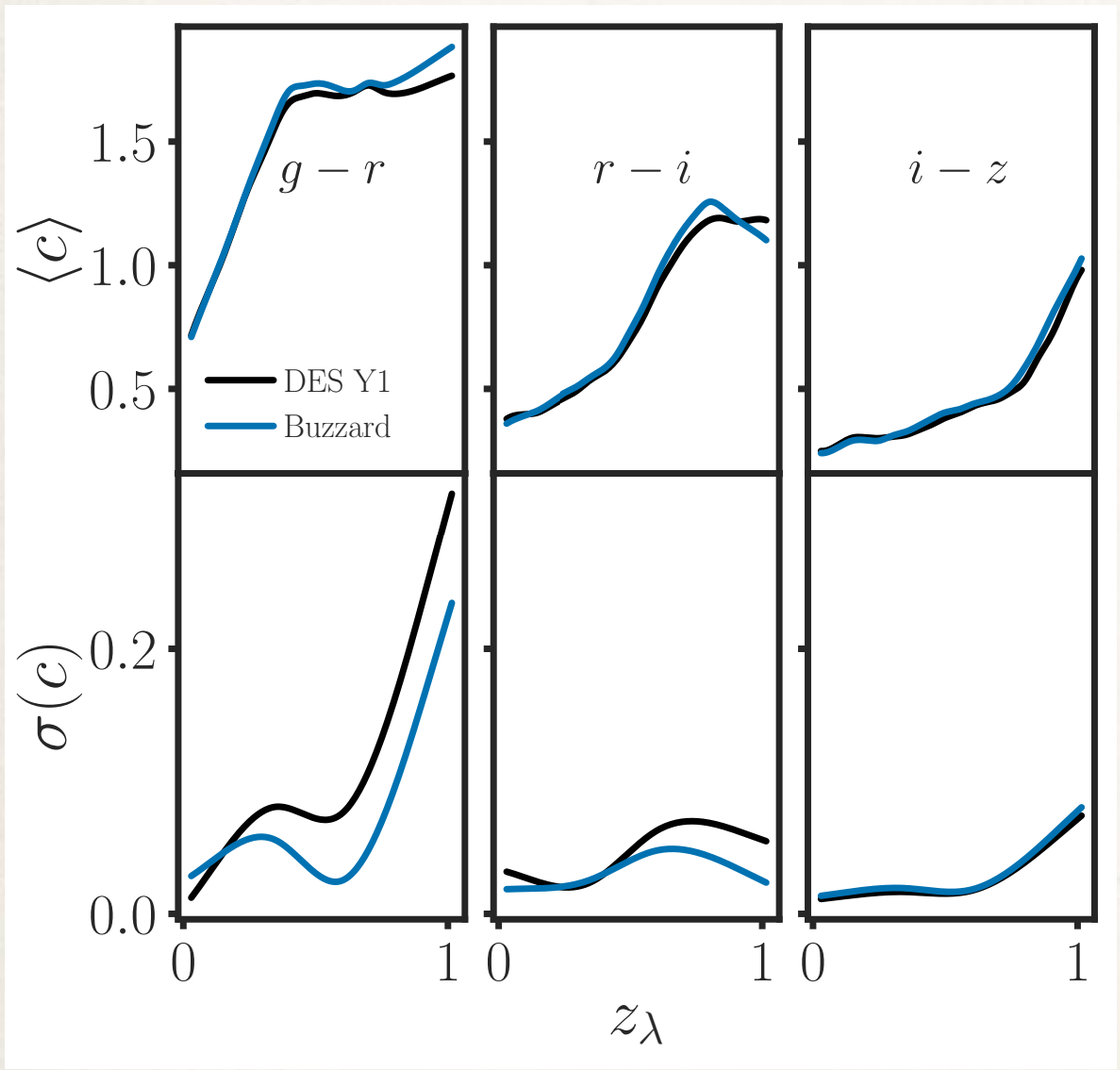
CALCLENS

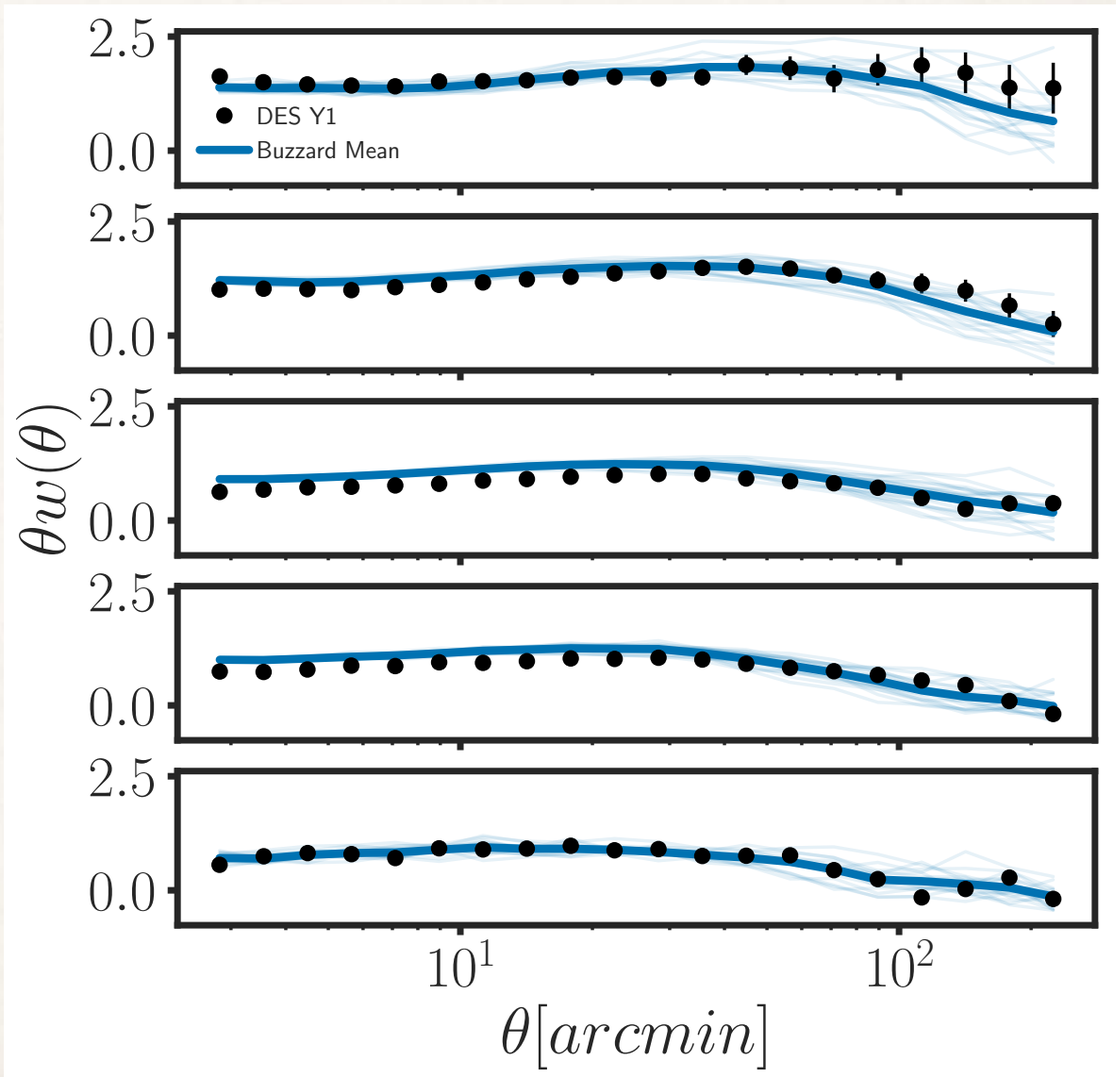
- Spherical harmonic transform Poisson solver (Becker 2013)
- Ray-tracing on nside=8192 healpix grid
- Calculate shear, convergence for all galaxies



JDR et al 2019

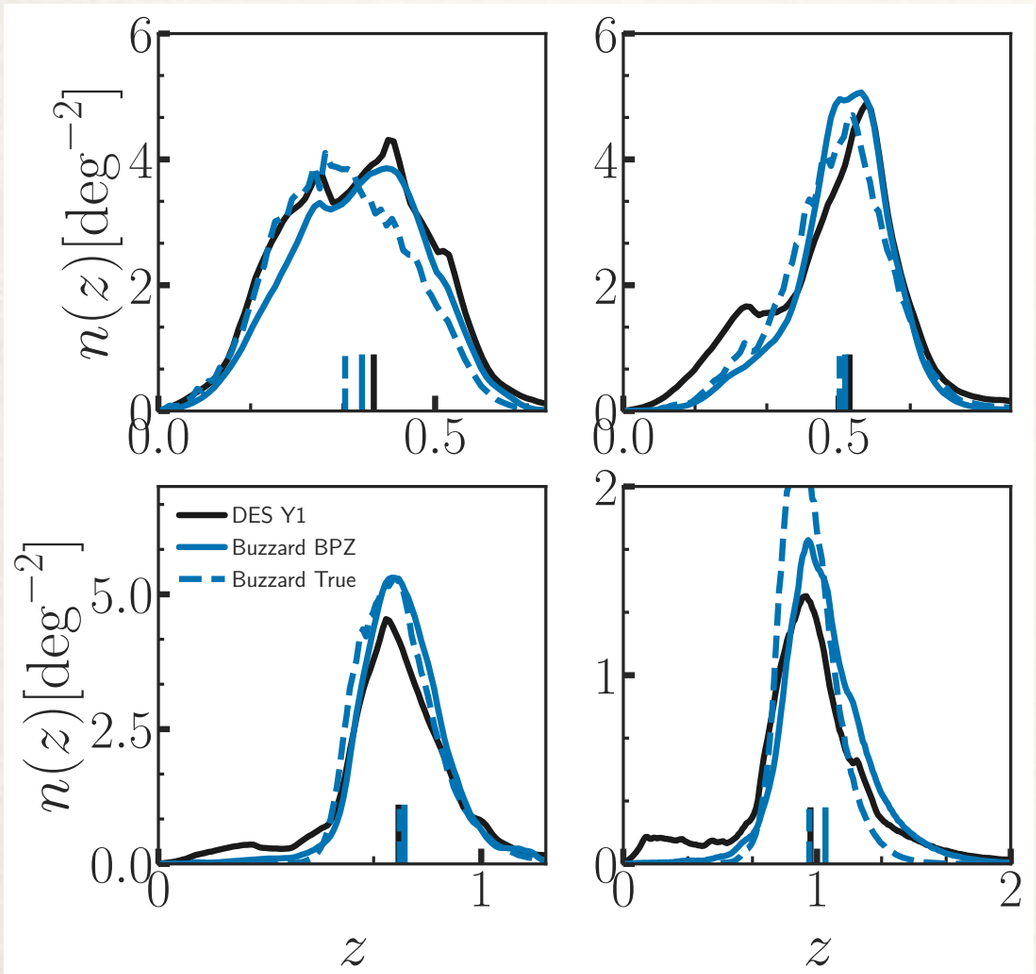
Realistic Observables: Lens Galaxies

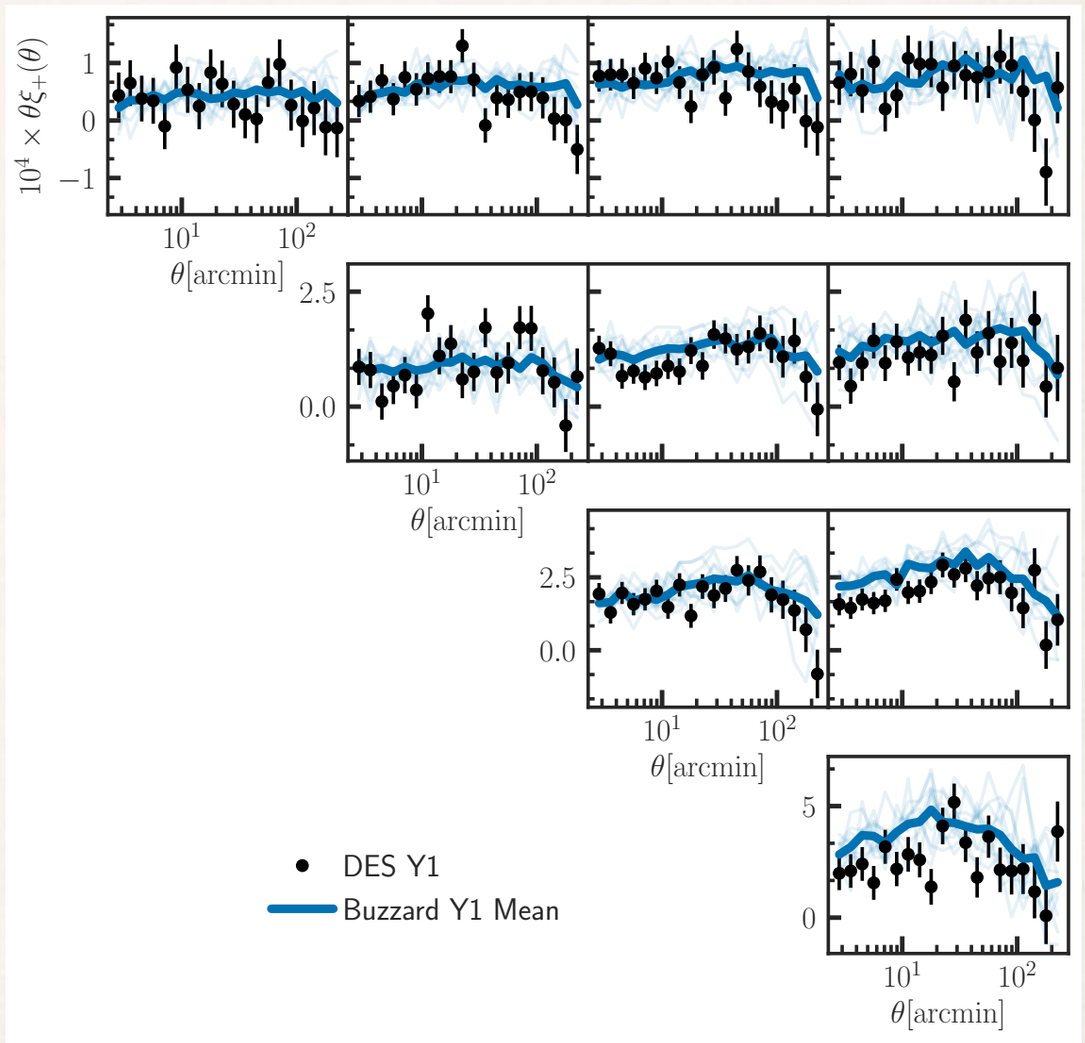




Robust red-sequence allows high fidelity redMaGiC sample selection

Realistic Observables: Source Galaxies

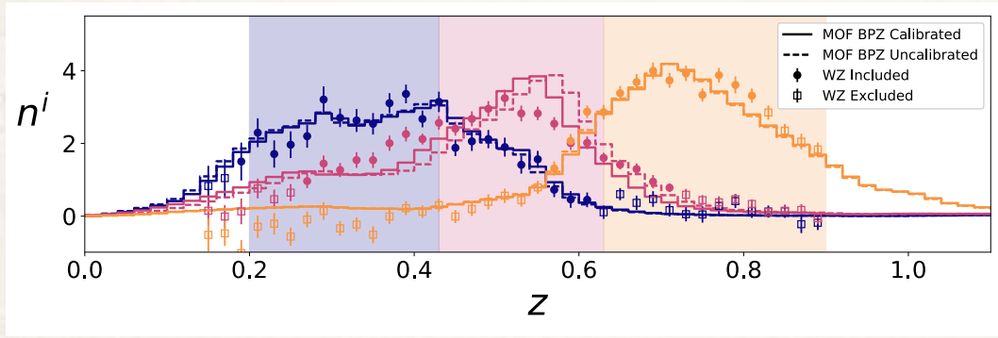




Metacalibration like sample selected with similar S/N properties as data.
BPZ run on fluxes with Y1 like photometric errors.

Buzzard sims used in a 11/14 of "DES Y1 Results"

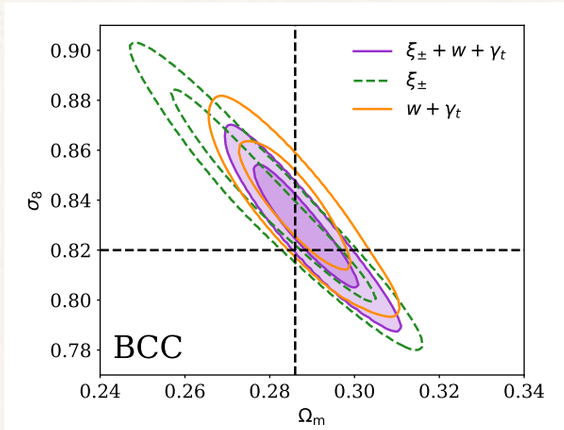
Redshift Estimation



Gatti, Vielzeuf et al.

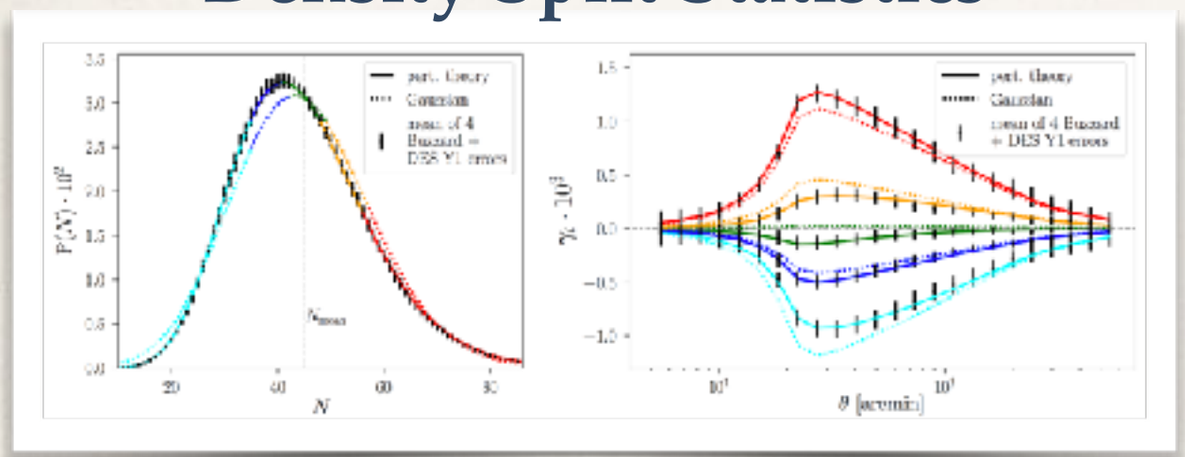
Hoyle et al.

3x2pt Parameter Inference



MacCrann, JDR et al. 2018

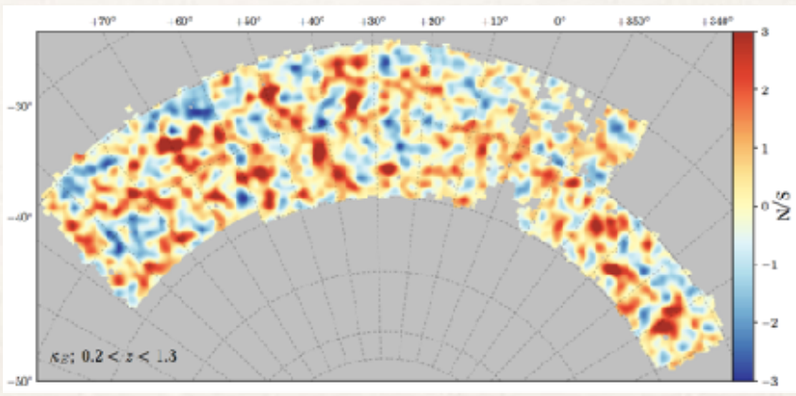
Density Split Statistics



Gruen, Friedrich, Krause, JDR et al.

Friedrich, Gruen, JDR, Krause et al.

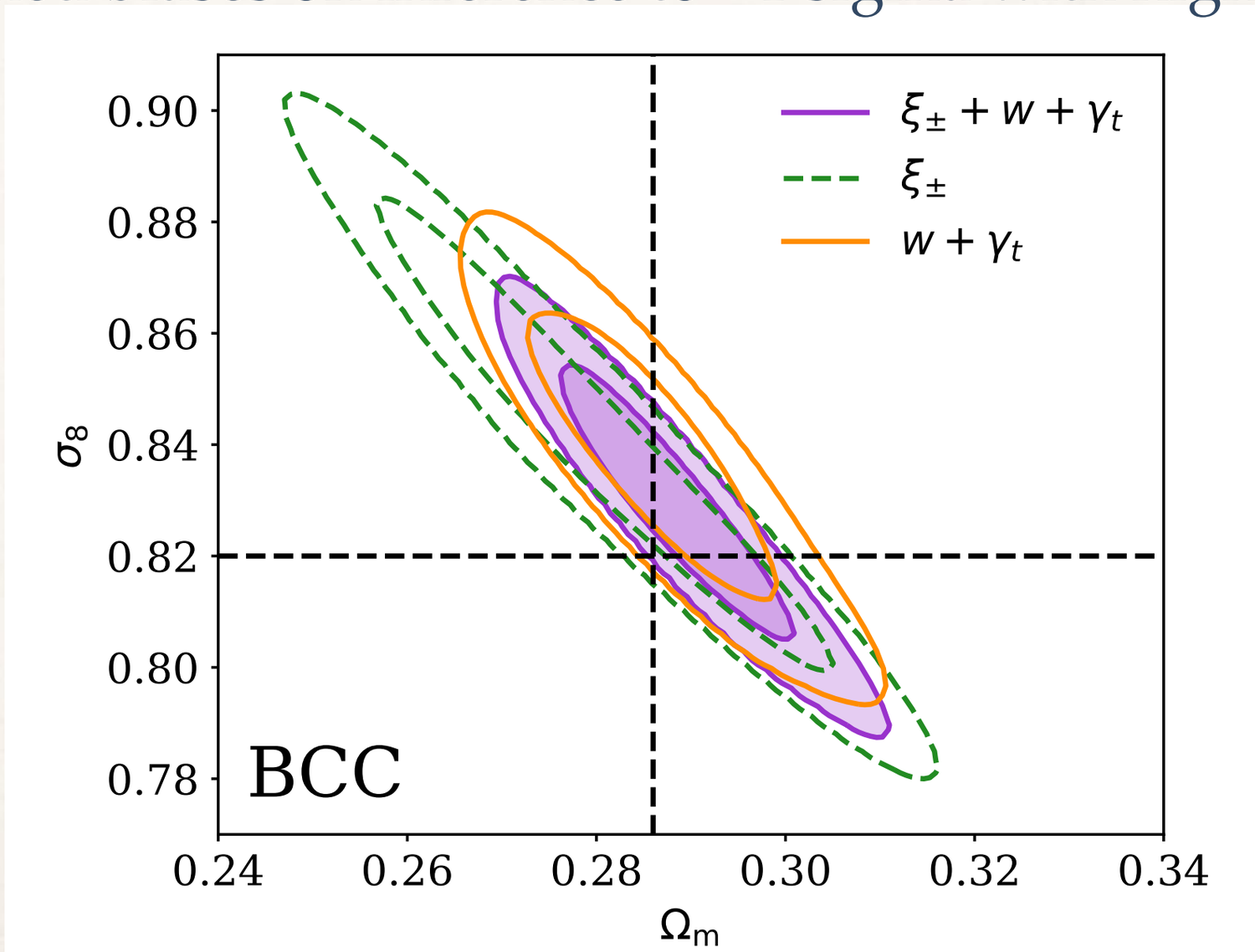
Mass Mapping



Chang et al. 2018

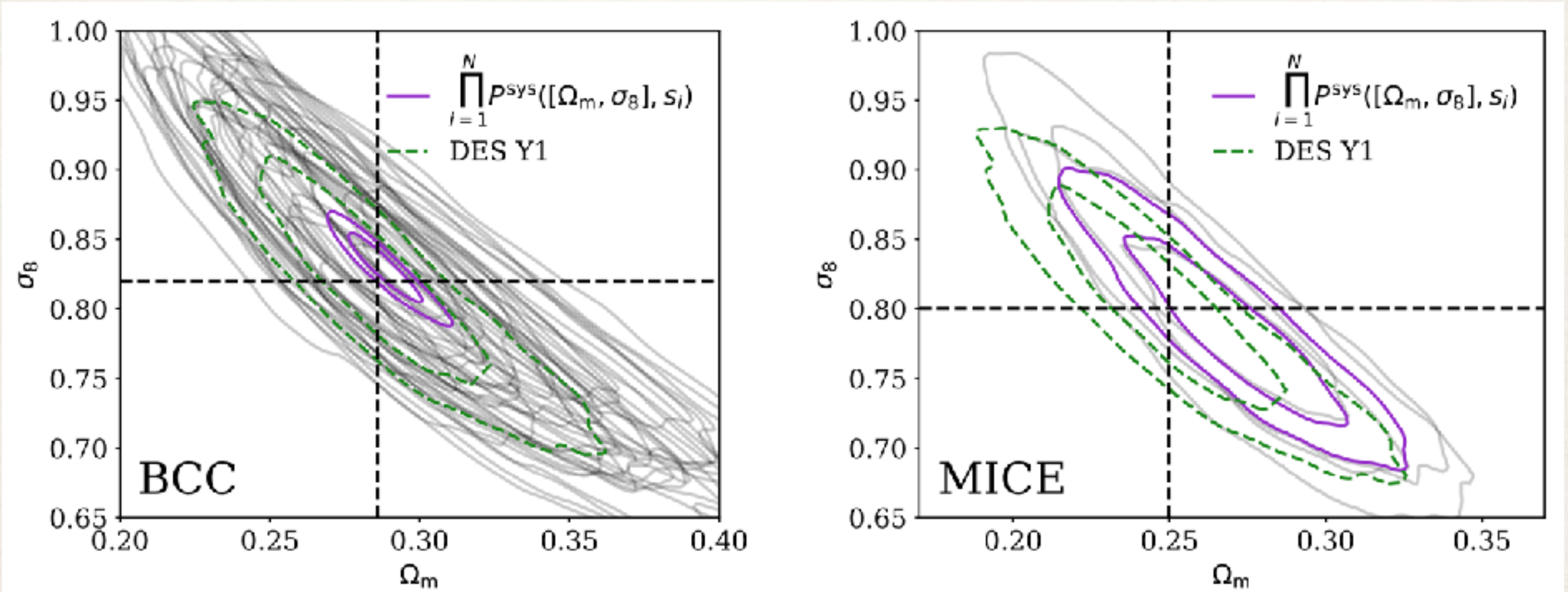
Highlight: Validating the 3x2pt Pipeline

Constrained biases on inference to <1 sigma with high confidence



MacCrann, JDR et al. 2018

Highlight: Validating the 3x2pt Pipeline



Results corroborated from an independent simulation.

MacCrann, JDR et al. 2018

Ongoing/Future Work

DES Y3

Many new things coming for DES Y3 3x2pt:

- Source redshift calibration using self-organizing maps with a combination of many band photo-zs and spectroscopy
- Shear-ratio and clustering redshift information
- Higher order bias modeling
- Higher order IA modeling
- Small scale GGL non-locality mitigation
- Lens magnification modeling
- Multiple lens samples

DES Y3

Many new things coming for DES Y3 3x2pt:

- **Source redshift calibration using self-organizing maps with a combination of many band photo-zs and spectroscopy**
- **Shear-ratio and clustering redshift information**
- **Higher order bias models to mitigate scale dependent bias effects**
- Higher order IA models
- **Small scale GGL non-locality mitigation**
- **Lens magnification modeling**
- **Multiple lens samples**

Currently being tested using updated suite of 70 Buzzard simulations
(DeRose + DES Collab. in prep.)

DESI Lensing Mock Challenge

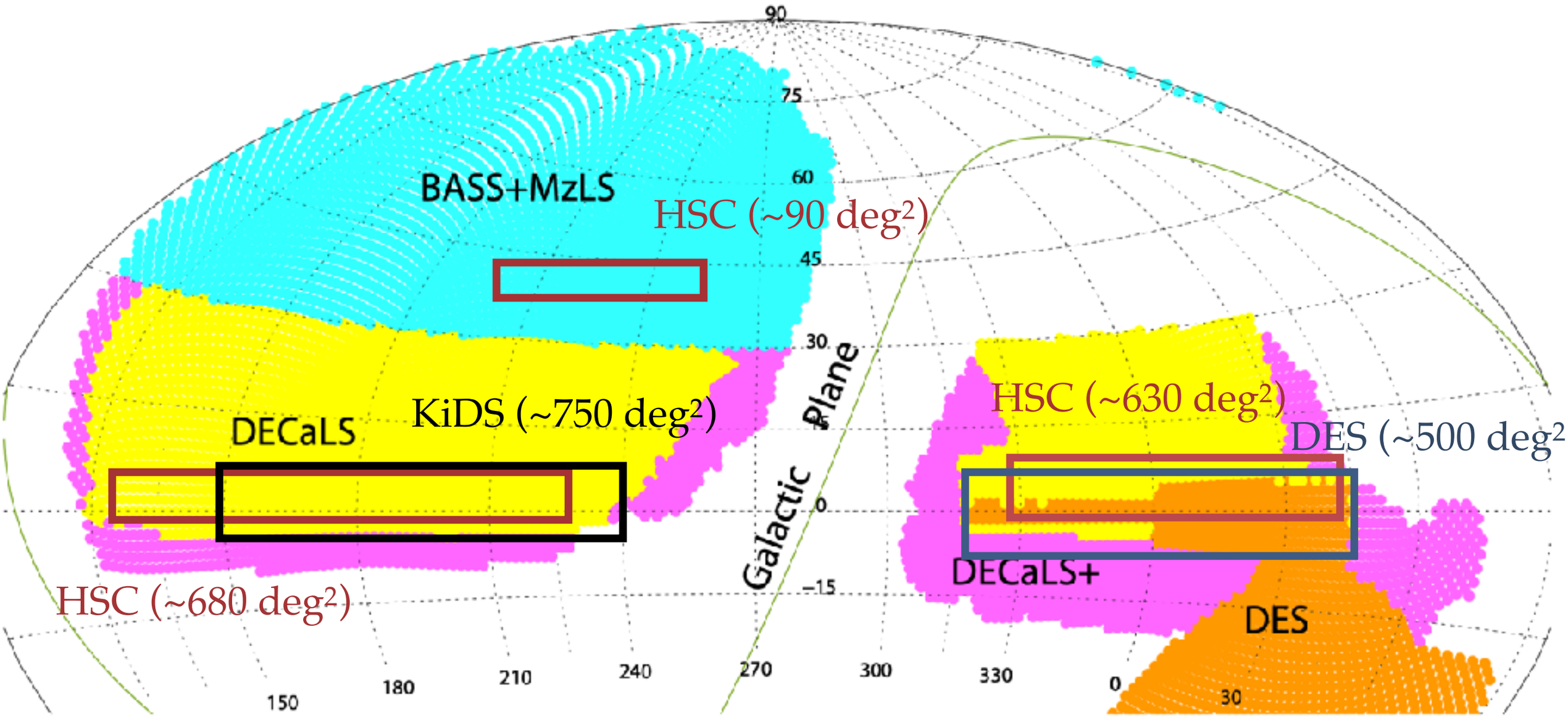


Figure from 1611.00036 w/ additions by C. Blake

DESI Lensing Mock Challenge

- **Stage 0**: DESI lenses and generic source catalogues (e.g.compare measurement codes, photo-z dilution corrections for \Delta\Sigma)

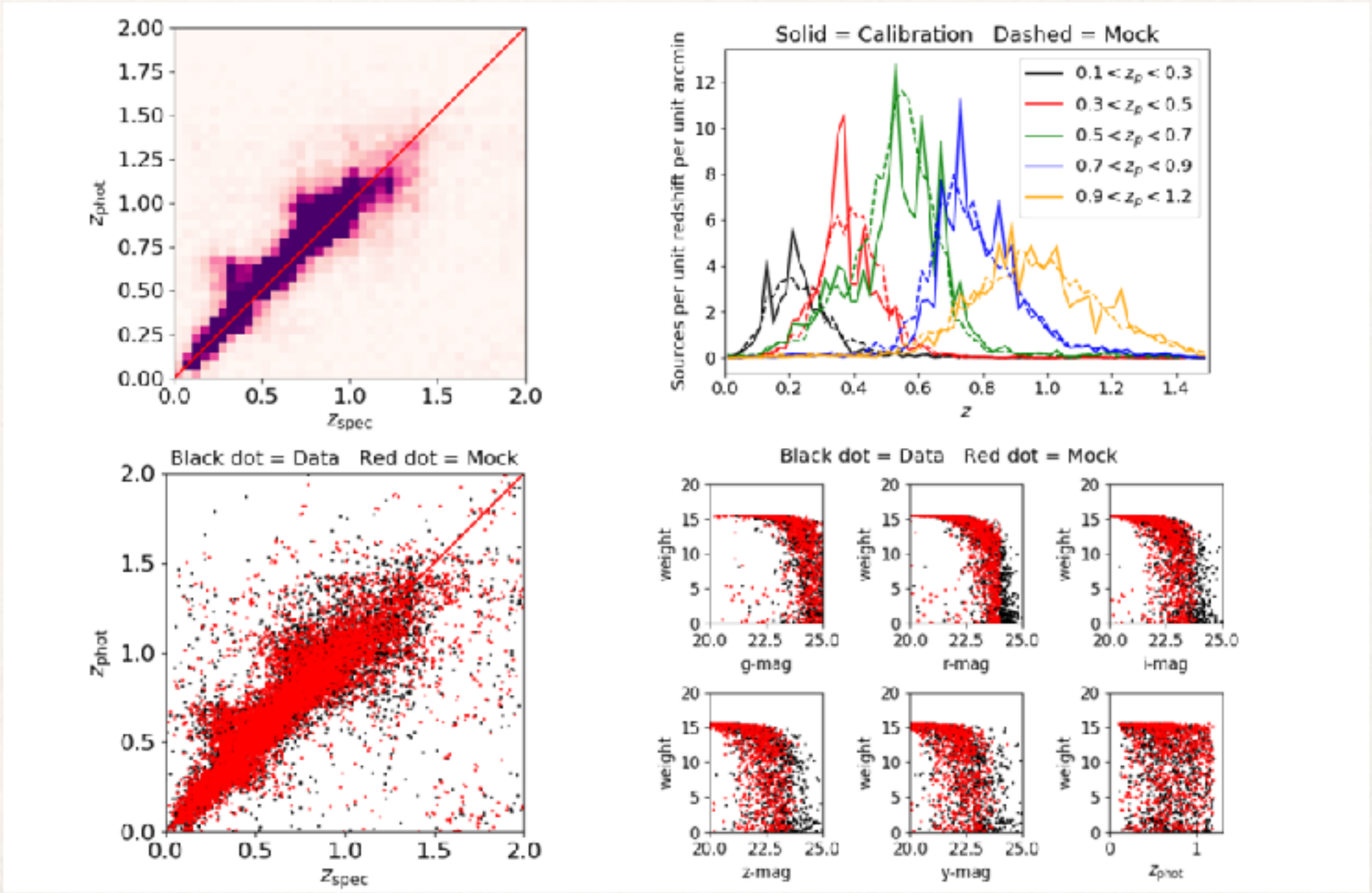
- **Stage 1**: DESI lenses and source catalogues tailored to specific lensing surveys (HSC, KiDS, DES), for tests of systematics related to sources (e.g. photo-z dilution, “boost” correction, multiplicative shape calibration) (**We are here)**

- **Stage 2**: Tests of systematics related to lenses (e.g. optimal lens weights, fibre collisions redshift incompleteness, inhomogeneity in lens catalogues, lens systematic weights)

- **Stage 3**: Test cosmological fitting pipeline (e.g. combined-probe covariance, modelling)

Ongoing work by Chris Blake, JDR, Johannes Lange, Alexie Leauthaud, Suhkdeep Singh, Ji Yao, and more

e.g. KiDS-like Mock



Figs. from C. Blake

Summary

- Cosmological Simulations are essential for testing nearly all facets of current galaxy surveys
- We have designed an algorithm that allows us to produce realistic suites of galaxy catalogs including:
  - Non-linear bias
  - Lensing
  - Photometric errors
  - Photo-zs
- We have used these in DES to test our Y1 3x2pt analysis and ongoing Y3 analyses
- These will also be used for lensing work in DESI

Thanks!