Synthetic Galaxy Catalogues From A Galaxy Formation Model

Alex Merson
University College London

Carlton Baugh, John Helly, Violeta Gonzalez-Perez, Jo Woodward,
Peder Norberg, Shaun Cole, Carlos Frenk

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Outline

- Lightcone catalogues

  - the GALFORM model

  - construction process

- Applications

  - group-finding

  - future surveys e.g. EUCLID

  - colour selection

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Why Build Mock Catalogues?

Mock catalogue: synthetic dataset emulating a real data sample

Broad range of applications...

PREDICTION

- Relate observational results to theoretical predictions
  → put theory into "observational framework"

- Predictive power -- higher redshift predictions compared to empirical methods (e.g. Halo Occupation Distributions)

CALIBRATION

- Calibrate (statistical) estimators
  → already know "correct" answer, e.g.

  - group-finding algorithms

  - photo-z estimators

  - error estimation

- Assessment/removal of systematics

- Synthetic training sets

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Lightcone Galaxy Catalogues

- Galaxies positioned according to epoch at which cross past lightcone of observer

- Incorporate galaxy evolution with redshift

- Construction: halo merger trees from N-body simulation (**Millennium Simulation**, Springel *et al.* 2005) and semi-analytic model of galaxy formation (**GALFORM**, Cole *et al.* 2000)

- Advantages of using semi-analytic models:

  - model star-formation history to high redshift

  - low computational cost (c.f. hydrodynamical simulations)

  - multi-wavelength predictions (X-ray, UV, optical, IR, radio)

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COSMOLOGICAL MODEL

DARK MATTER HALO MERGER TREES
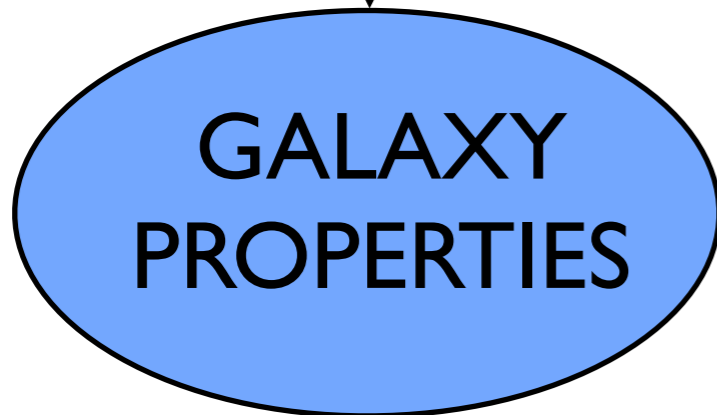
- Gas cooling -- disk formation
- Star formation & feedback (SN + AGN)
- Galaxy mergers -- spheroids, starbursts
- Chemical evolution & enrichment
- Dust extinction

Galform

e.g. luminosity function (K-band, 60µm), HI mass function, gas metallicity, disk radii, morphological fraction
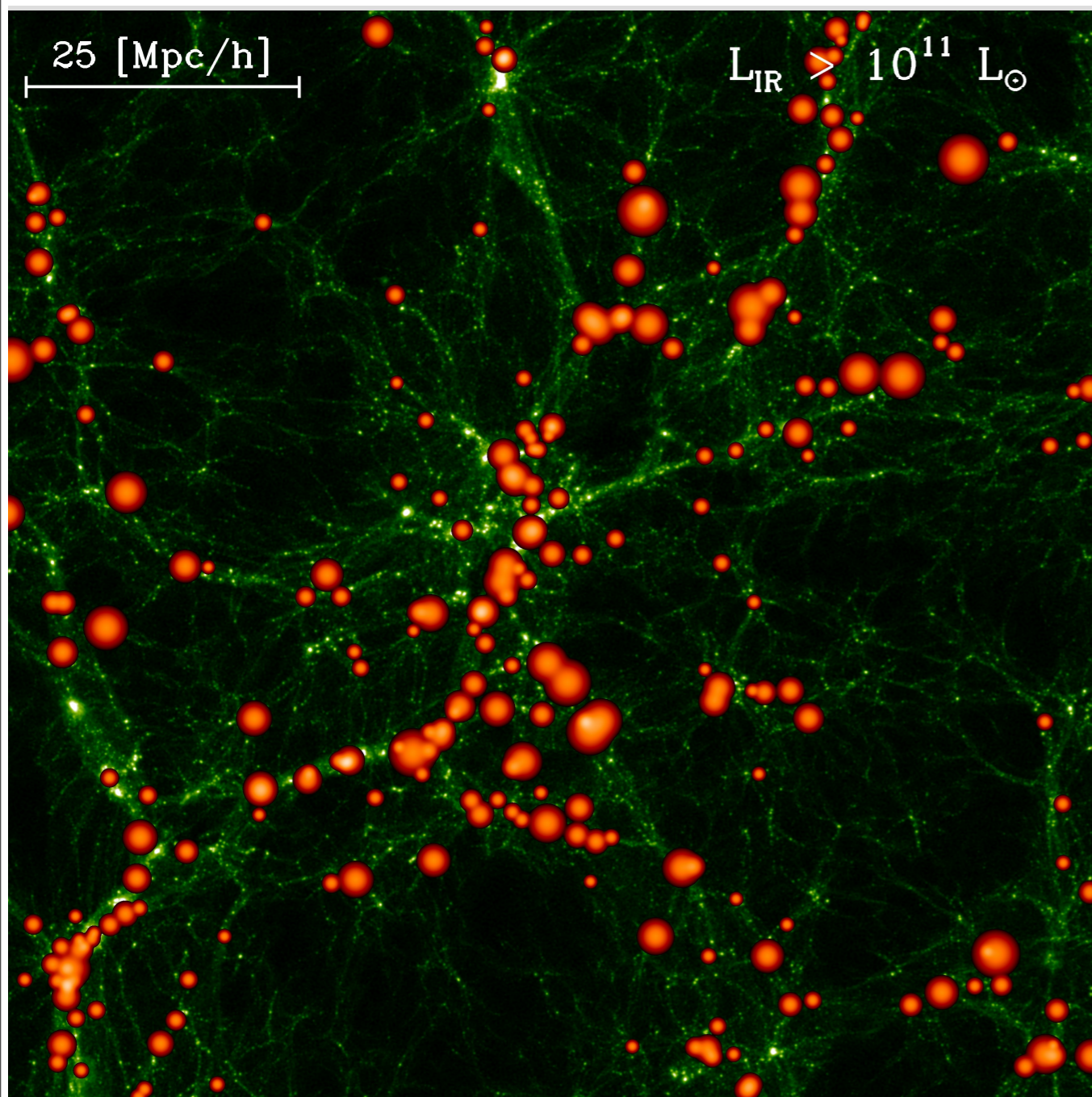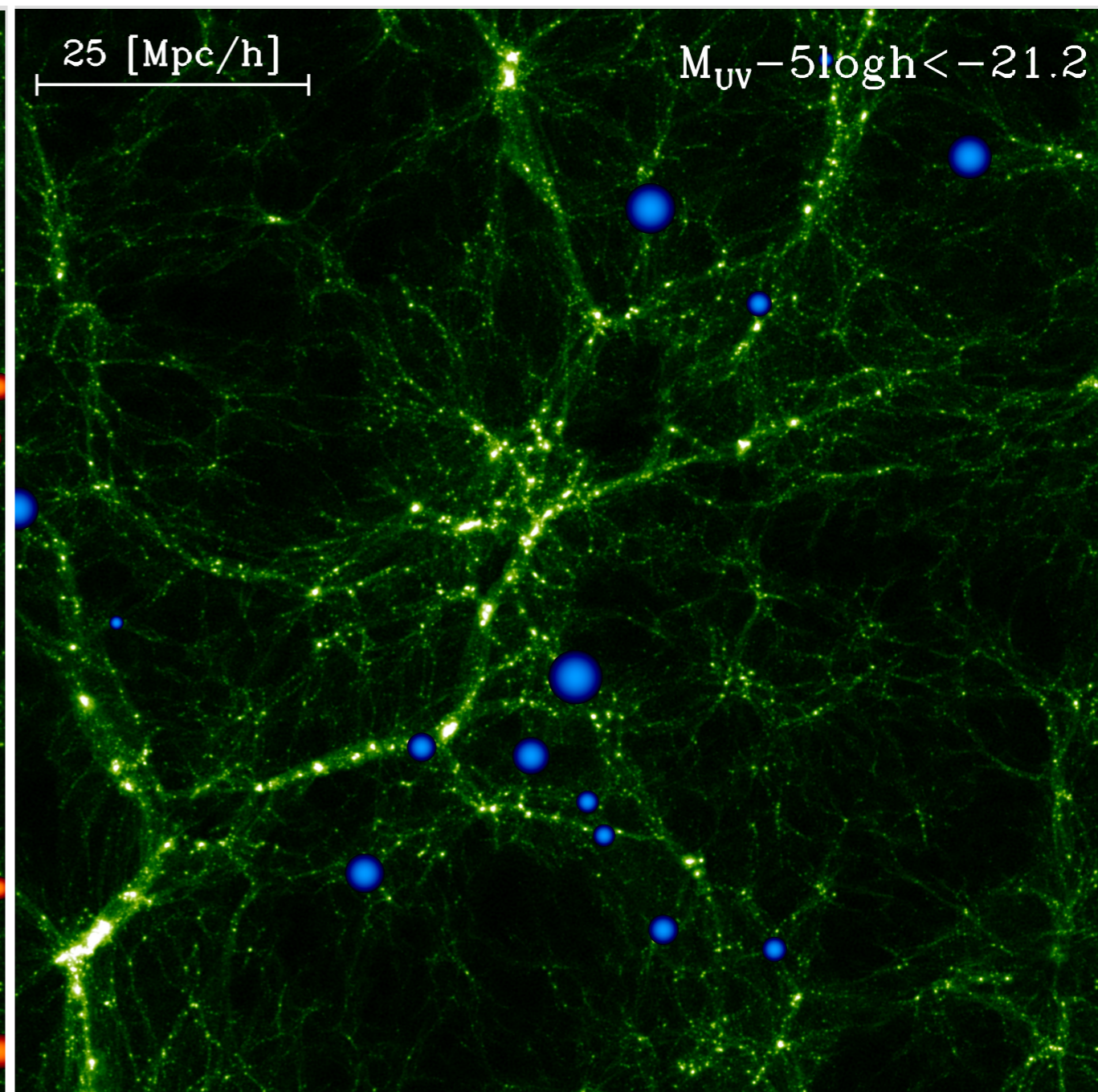
GALAXY PROPERTIES

FIT OBS. AT z ~ 0?

NO

YES

OUTPUT MODEL

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Multi-wavelength Predictions

Far-IR

Far-UV

Lacey *et al.* (2010)

Lightcone Construction

Merson *et al.* (2013)
astro-ph-1206.4049

redshift

$z = 5.7$

$z = 1.4$

$z = 0.0$
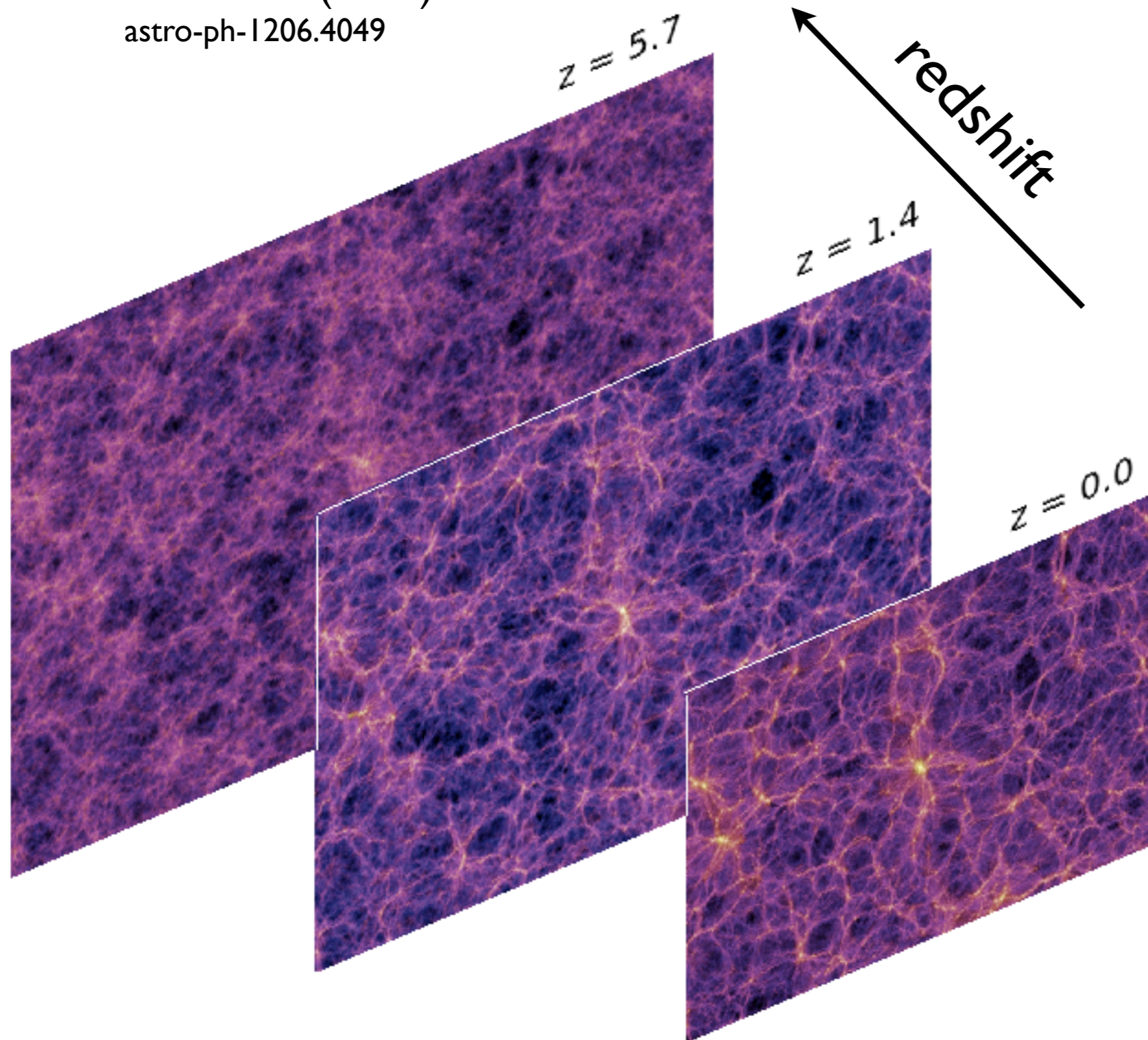
- Run GALFORM on N-body snapshots of cosmological simulation (Millennium Simulation)

- Place observer

- Generate cosmological volume (replicate box)

- Determine when each galaxy enters past lightcone of observer -- interpolate galaxy positions and velocities.

Lightcone Construction
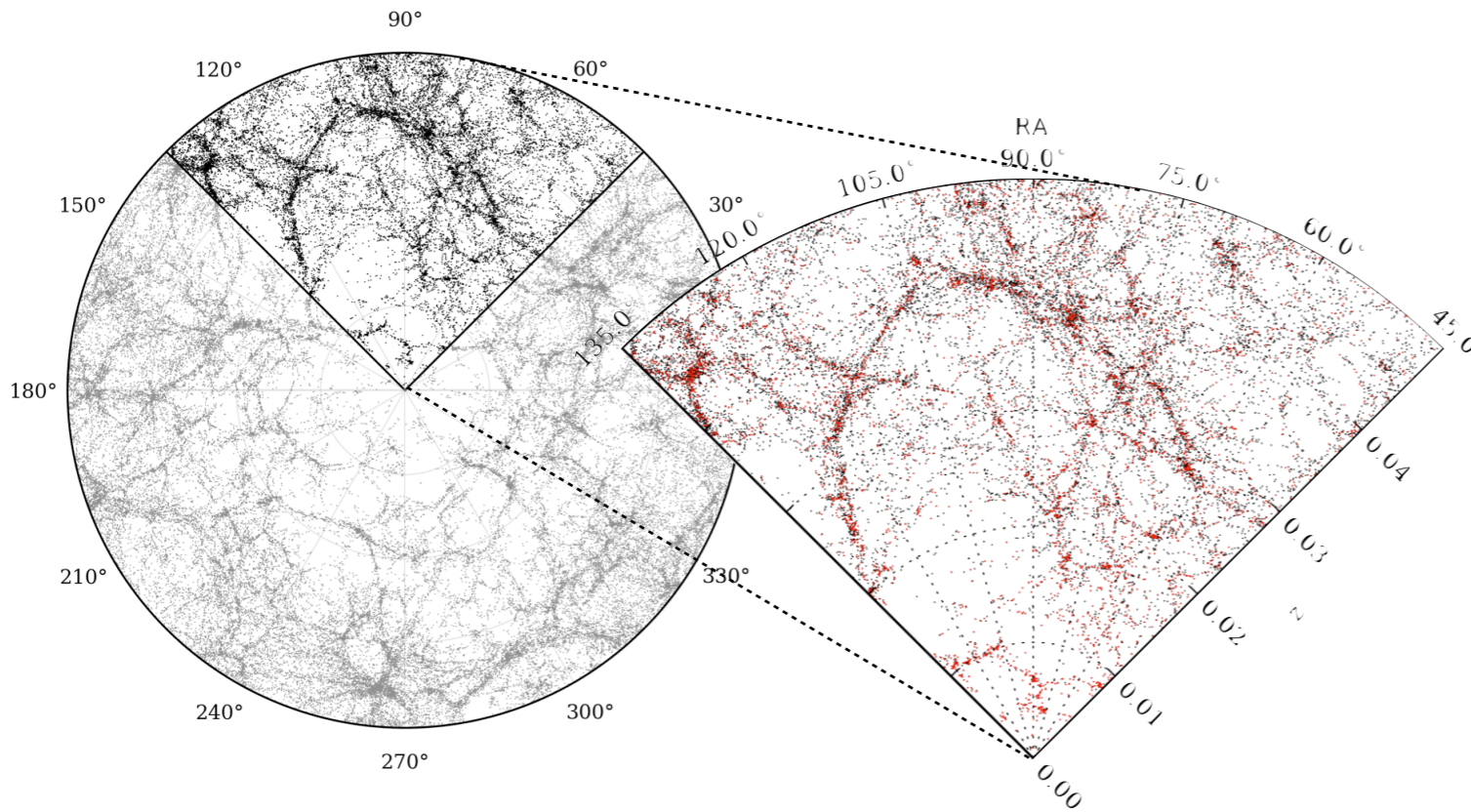
- Apply angular mask (select solid angle)

- Apply radial selection (e.g. flux limits)
  -- can select by multiple properties simultaneously (AND/OR selections)
  -- magnitudes, dust fluxes, cold gas mass, ...

- Post-processing (e.g. images, completeness mask, photo-zs)

without k-correction interpolation

with k-correction interpolation

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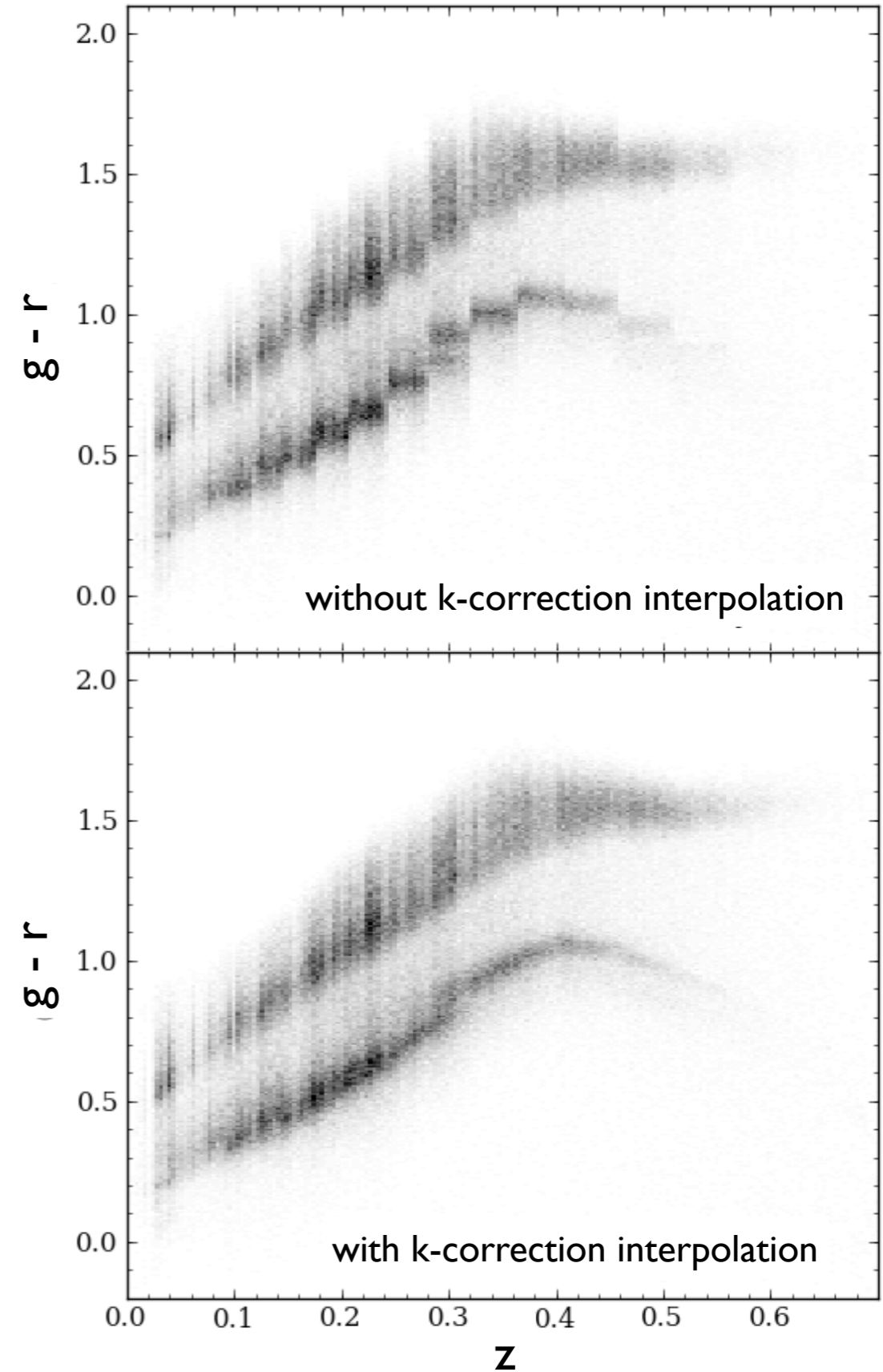
Mock Images
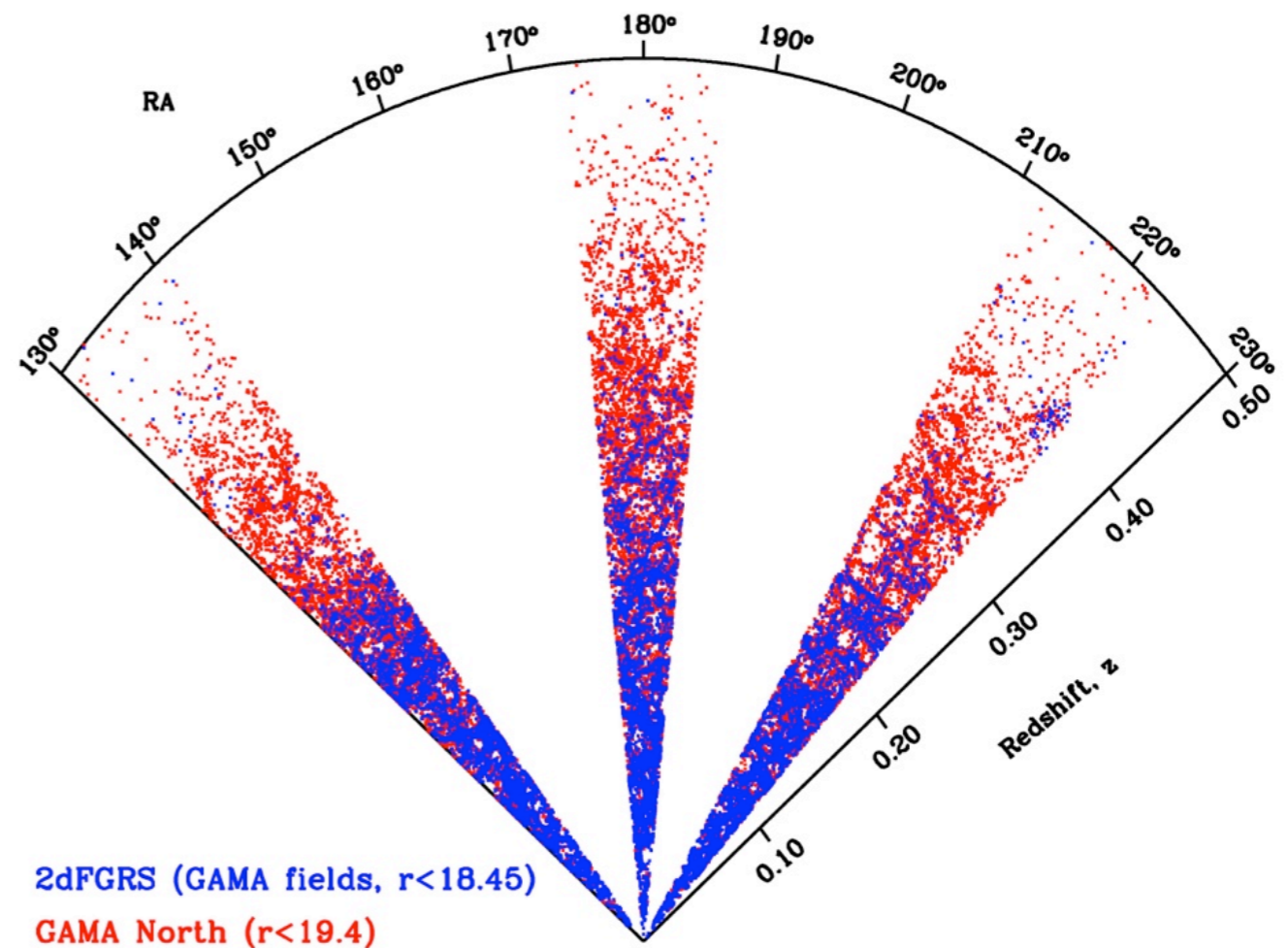
Daniel Farrow (Durham)

PanSTARRS gri image

Group Finder Calibration

- Mocks used to calibrate group-finding algorithms for galaxy surveys e.g. 2dFGRS (Eke *et al.* 2004)

- Properties of mock groups already known -- adjust group finding parameters until mock groups recovered
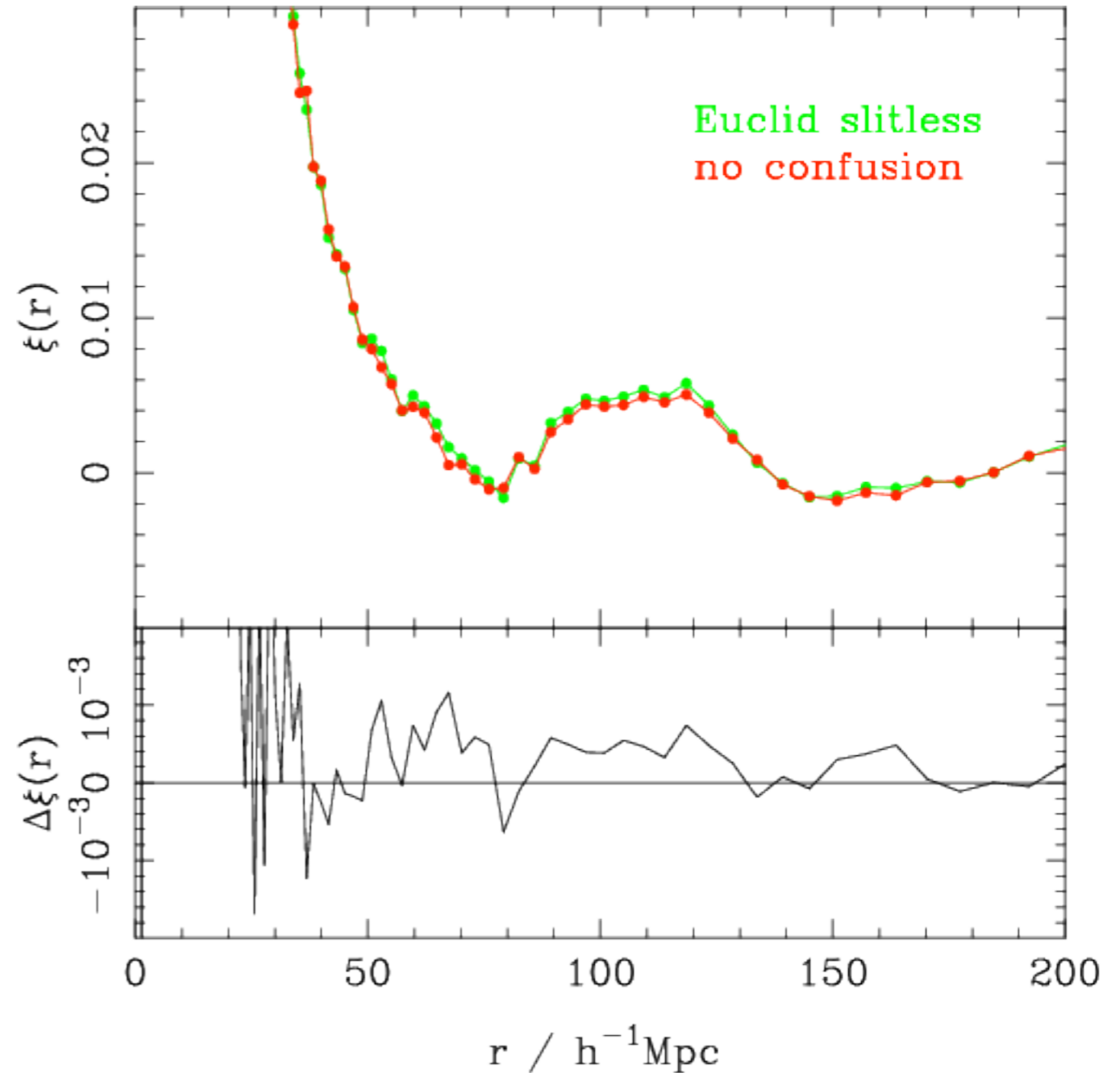
<u>Durham Lightcones</u>

- PanSTARRS-1 (Murphy et al. 2011)

- GAMA (Robotham et al. 2011)

- 6dFGS (Merson et al., in prep.)

- Dark Energy Survey (Santos et al., in prep.)

Future Galaxy Surveys: EUCLID

10 [Mpc/h]

Orsi *et al.* (2010)

Euclid slitless
no confusion

$\xi(r)$

$\Delta\xi(r)$

$r \, / \, h^{-1}Mpc$
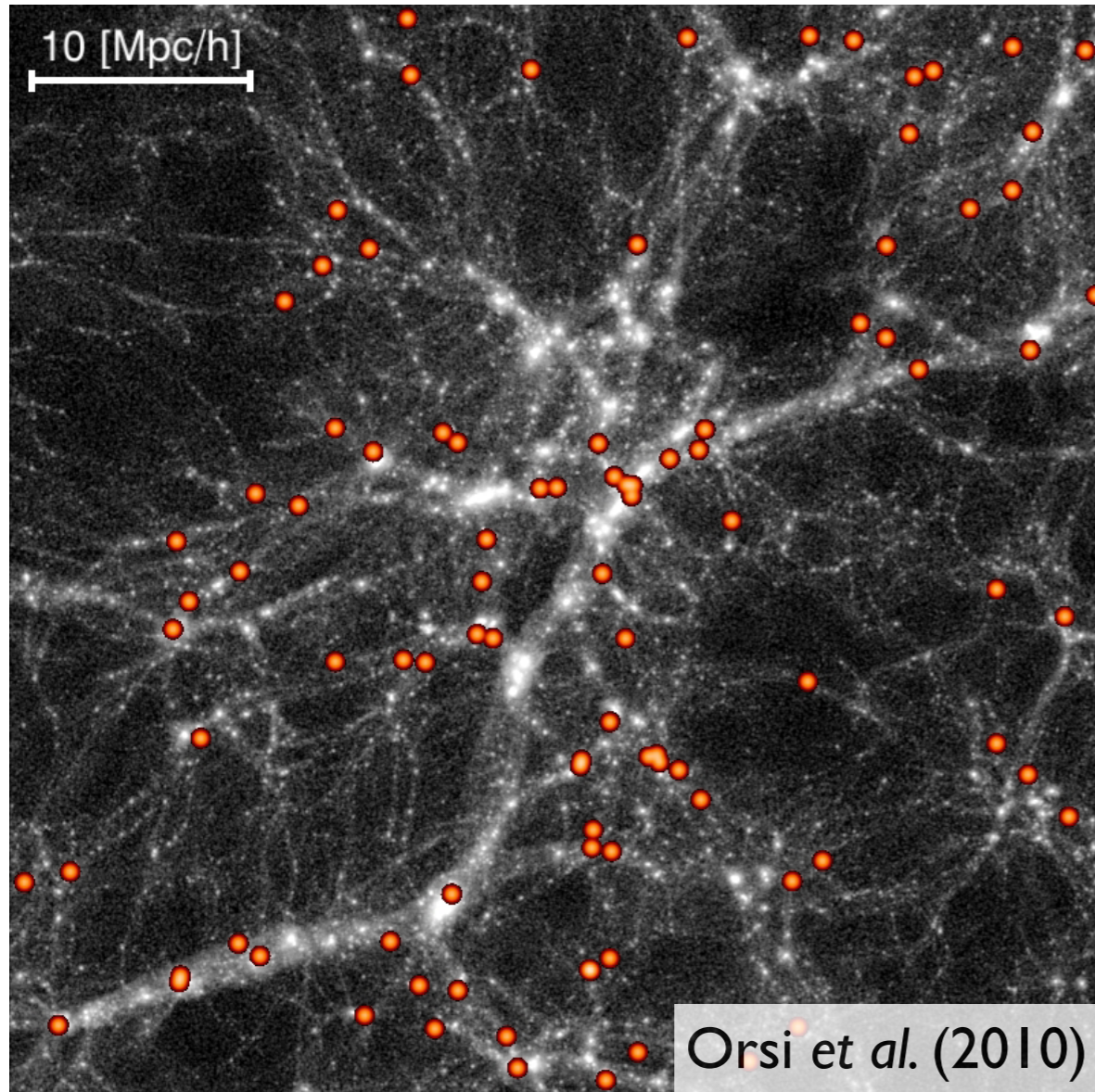
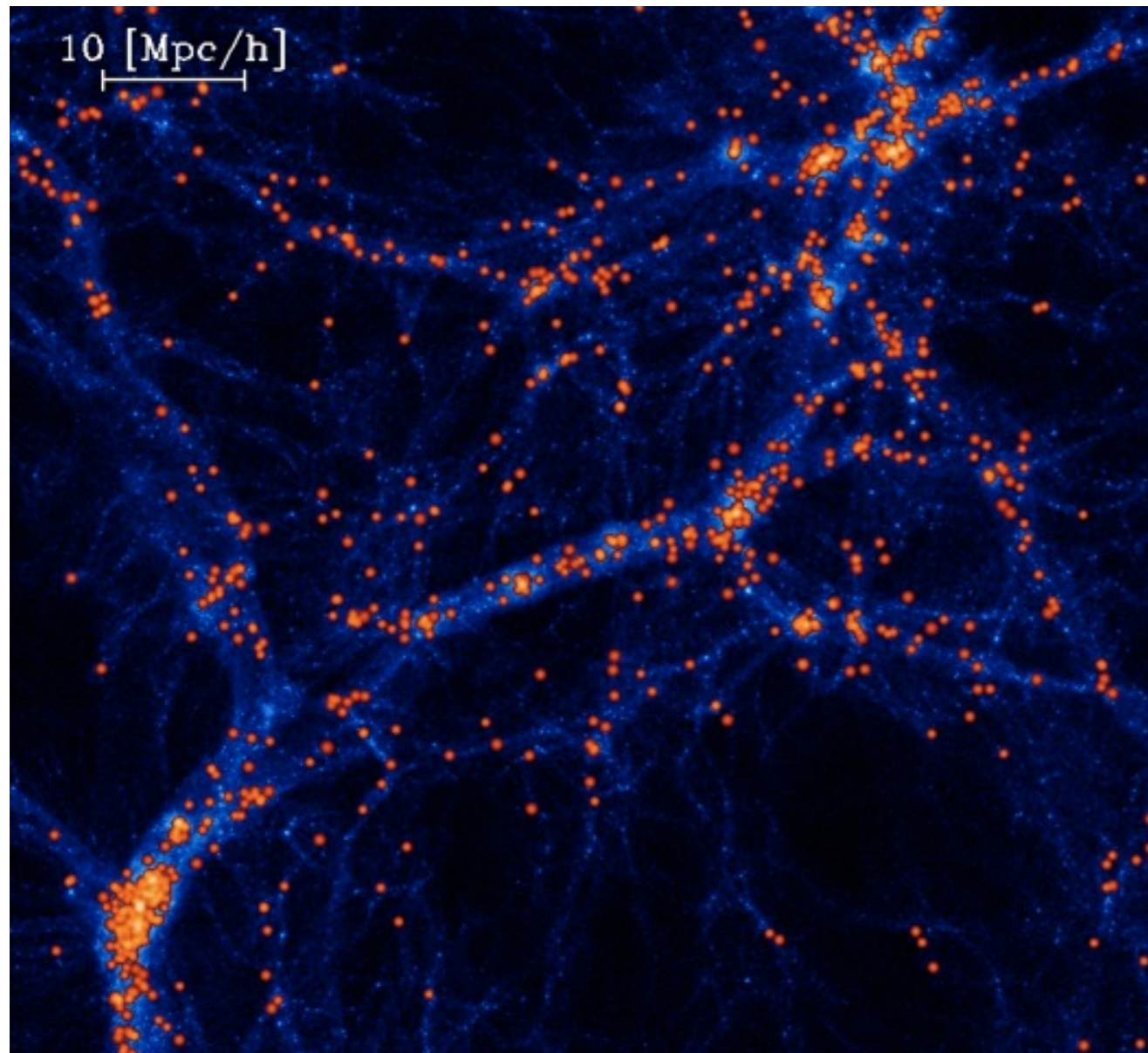- GALFORM galaxies: Hα, H-band selection
- EUCLID JHK filters (also PanSTARRS, DES, LSST)
➡ pipeline calibration, legacy science, ...

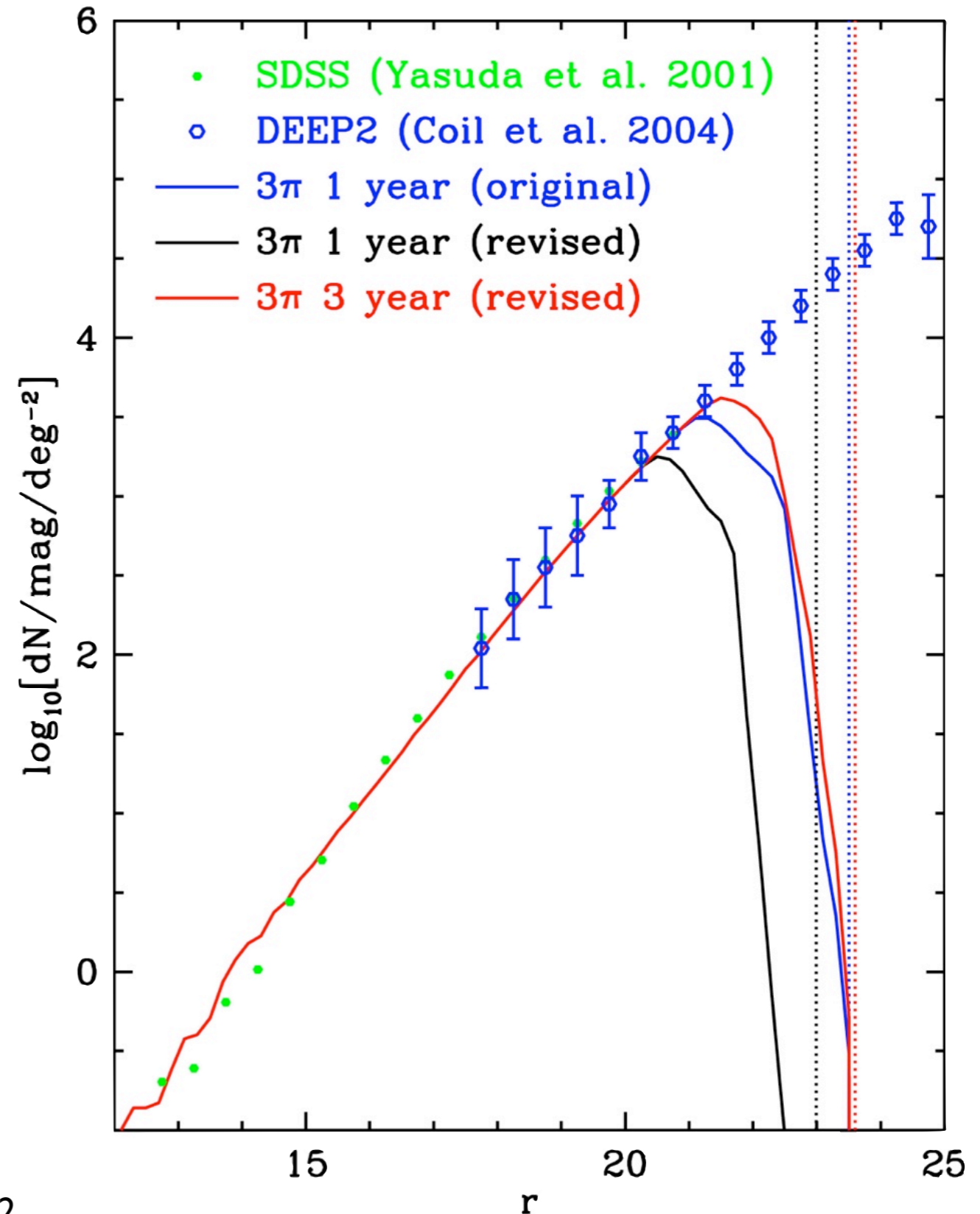Laureijs *et al.* (2011)

EUCLID red book,

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Lightcones For Photometric Surveys

1000 deg^2 lightcone
grizy selection

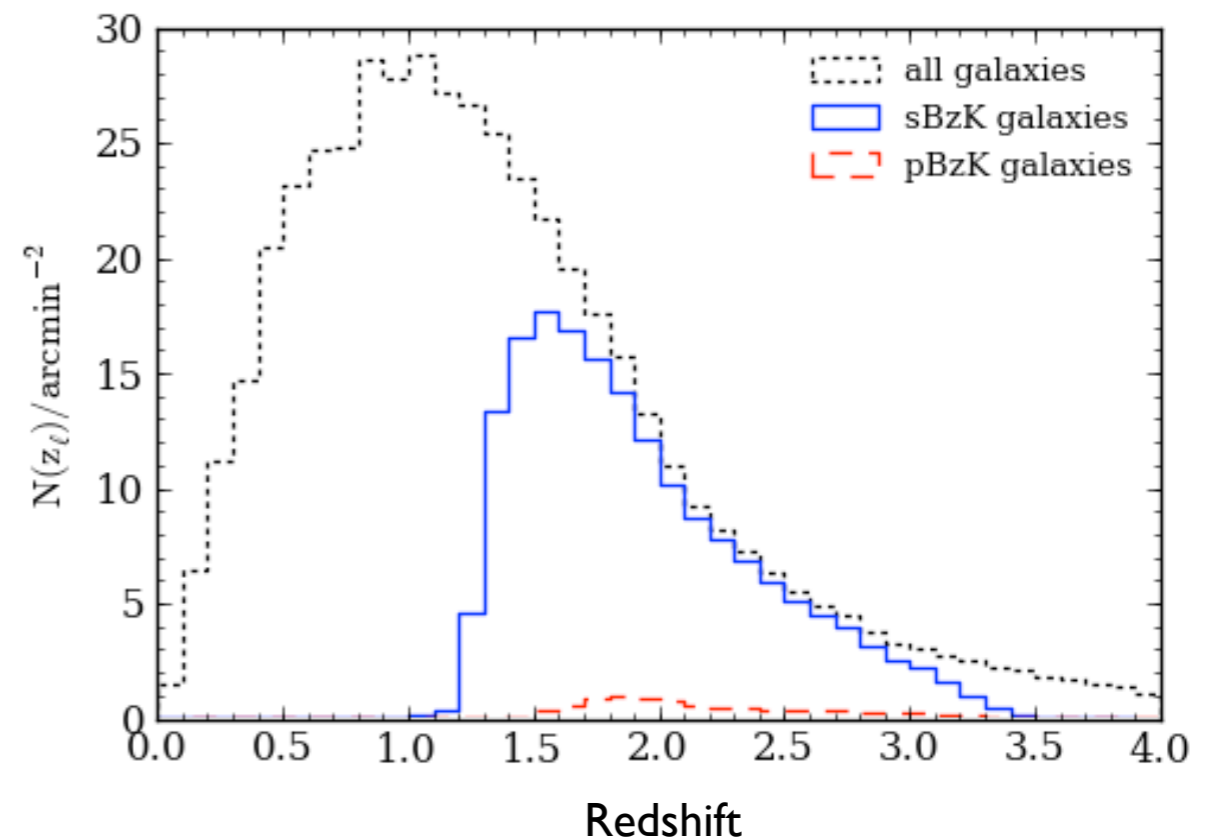SDSS (Yasuda et al. 2001)
DEEP2 (Coil et al. 2004)
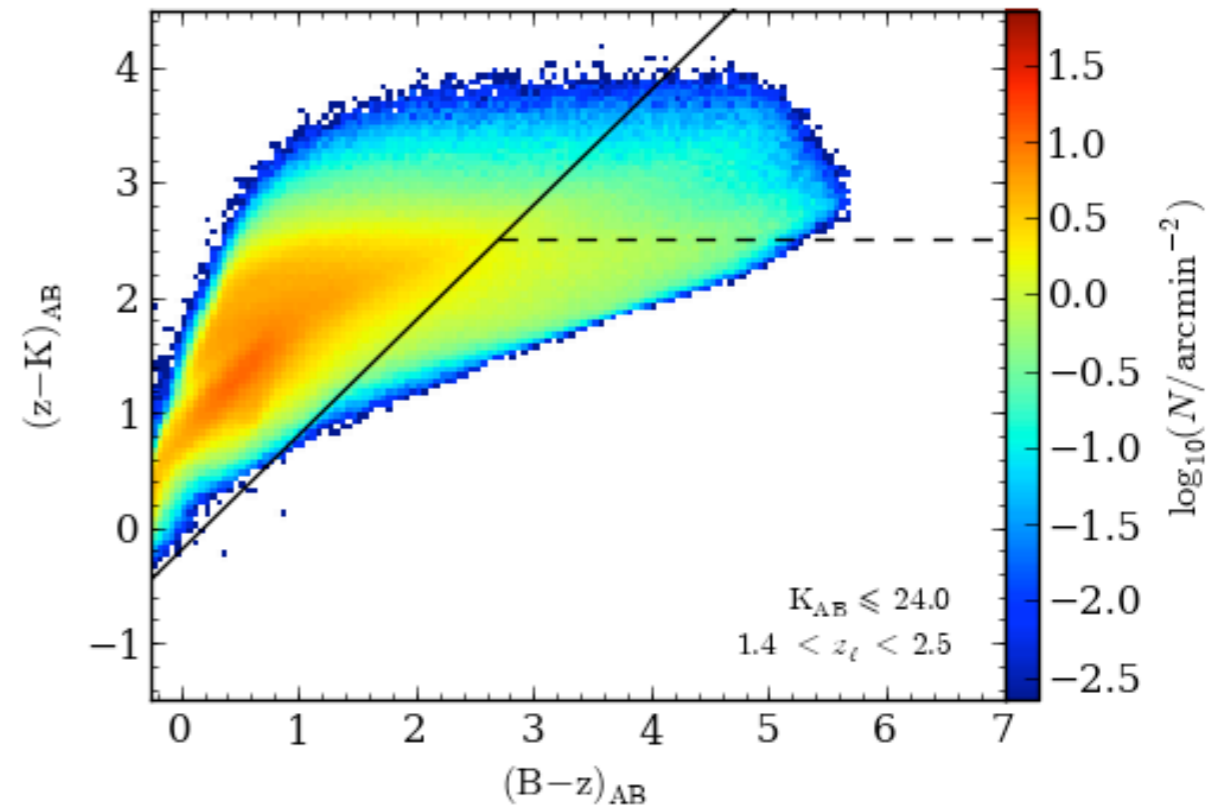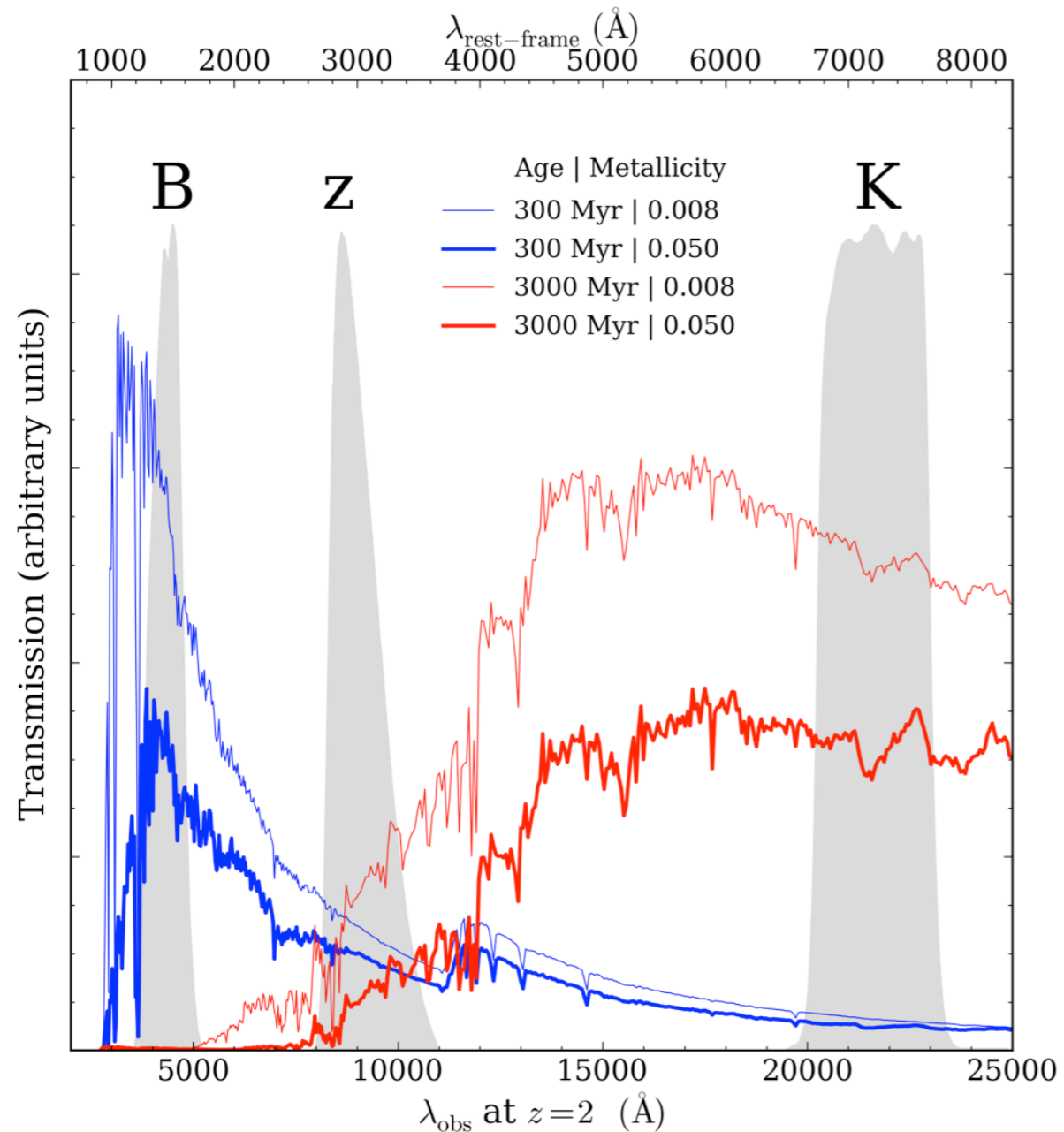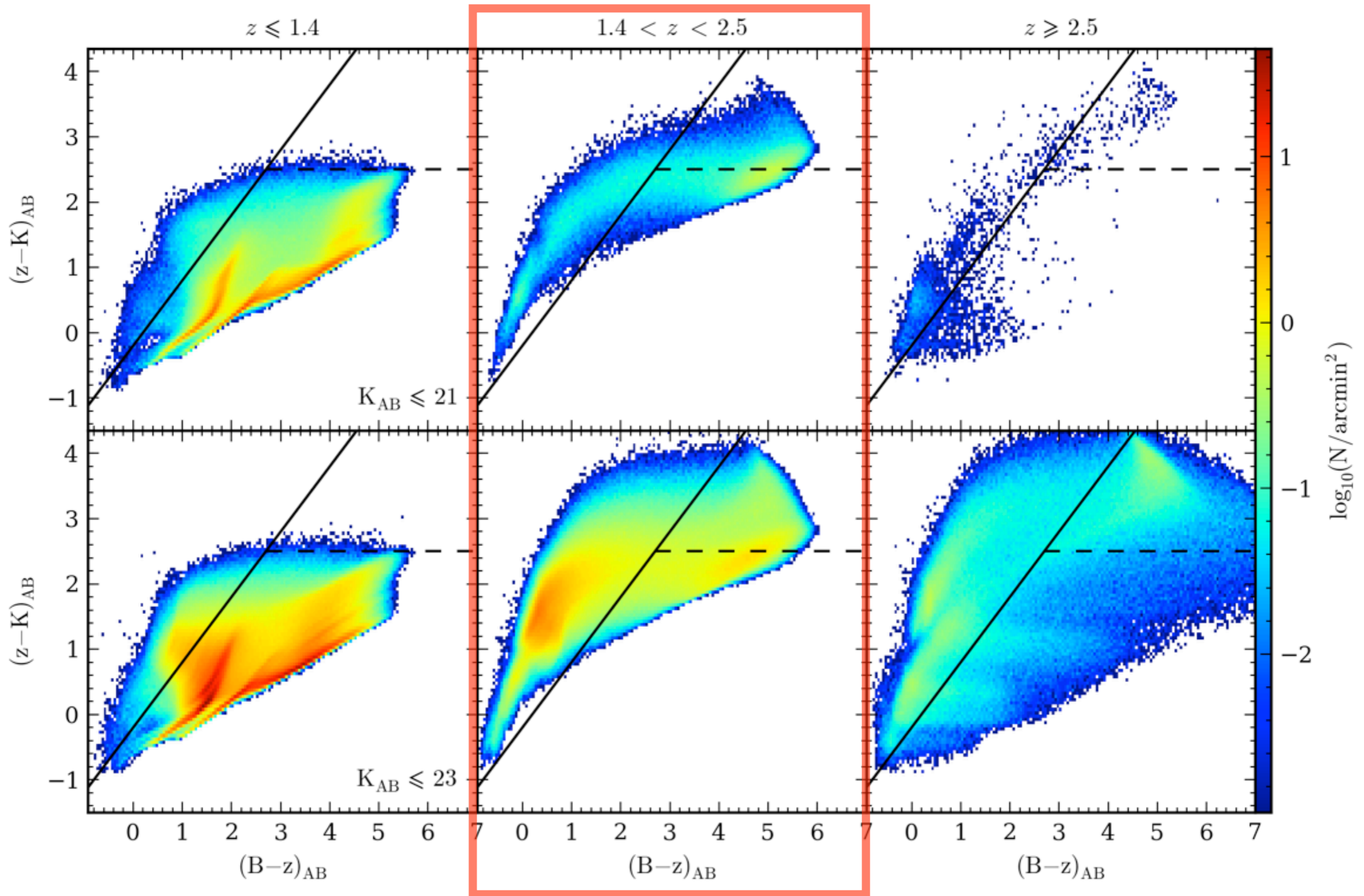3π 1 year (original)
3π 1 year (revised)
3π 3 year (revised)
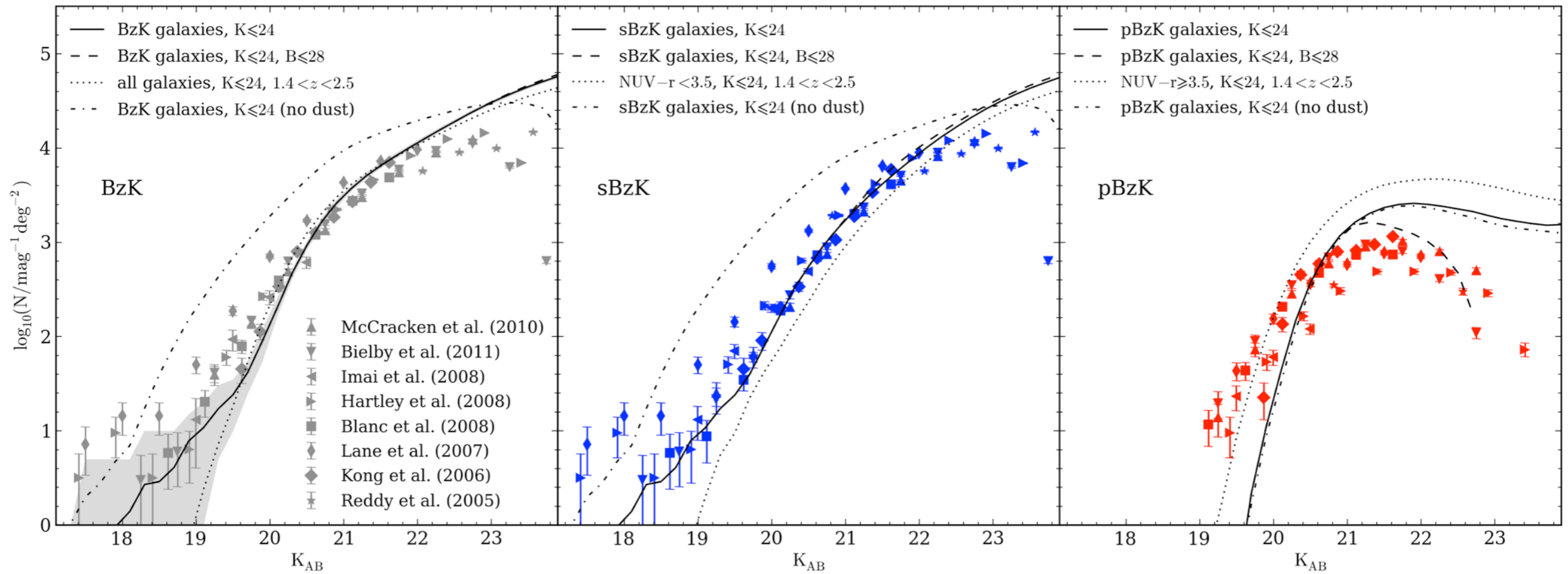
Galaxy Colour Selections

- BzK selection (Daddi *et al.* 2004)
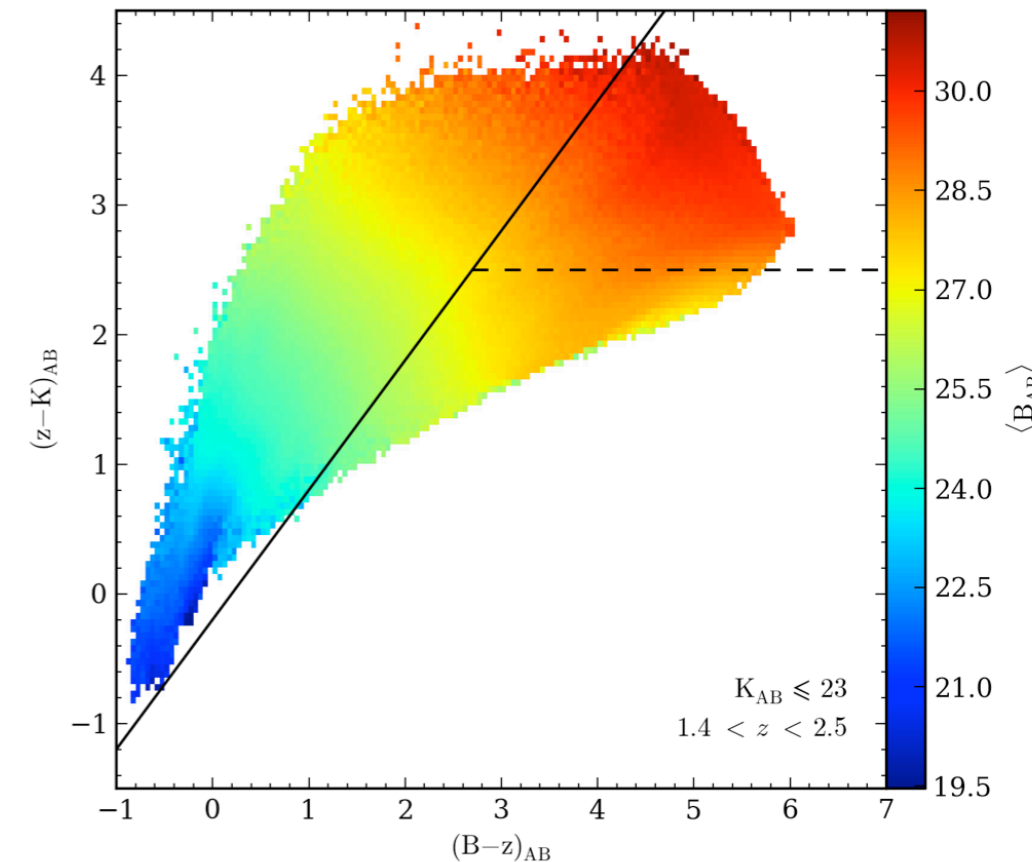- select star-forming & passive galaxies at 1.4 < z < 2.5

Completeness & Contamination

BzK Number Counts

- Good agreement in counts of BzK and sBzK galaxies
- Poorer agreement in pBzK counts - unable to match turnover
- Possibly due to insufficient B-band depth:
- Assign B-band magnitude equal to detection limit
    - (B-z) colour too blue
   - Confuse passive and star-forming galaxies

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Durham Lightcones

- Lightcones currently available:

  - Galaxy And Mass Assembly (r, K-band selection)

  - Herschel ATLAS (60, 100, 160, 250 500μm selection)

  - PanSTARRS PS1 (grizy selection)

  - WALLABY, TAIPAN (HI selection)

  - EUCLID (Hα, H-band selection)

  - Dark Energy Survey (grizy selection)

  - ALHAMBRA (various narrow band selection)

- Formats: ASCII, HDF5, (FITS)

- Simulations: Millennium, Millennium 2, MillGas, (Millennium XXL)

- Post-processing: images, (lensing, spectra, photometric redshifts) ...

- Can also produce interpolated snapshots

- Distribution: gzipped tar files, (SQL database)

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Extra Material

Need For Interpolation
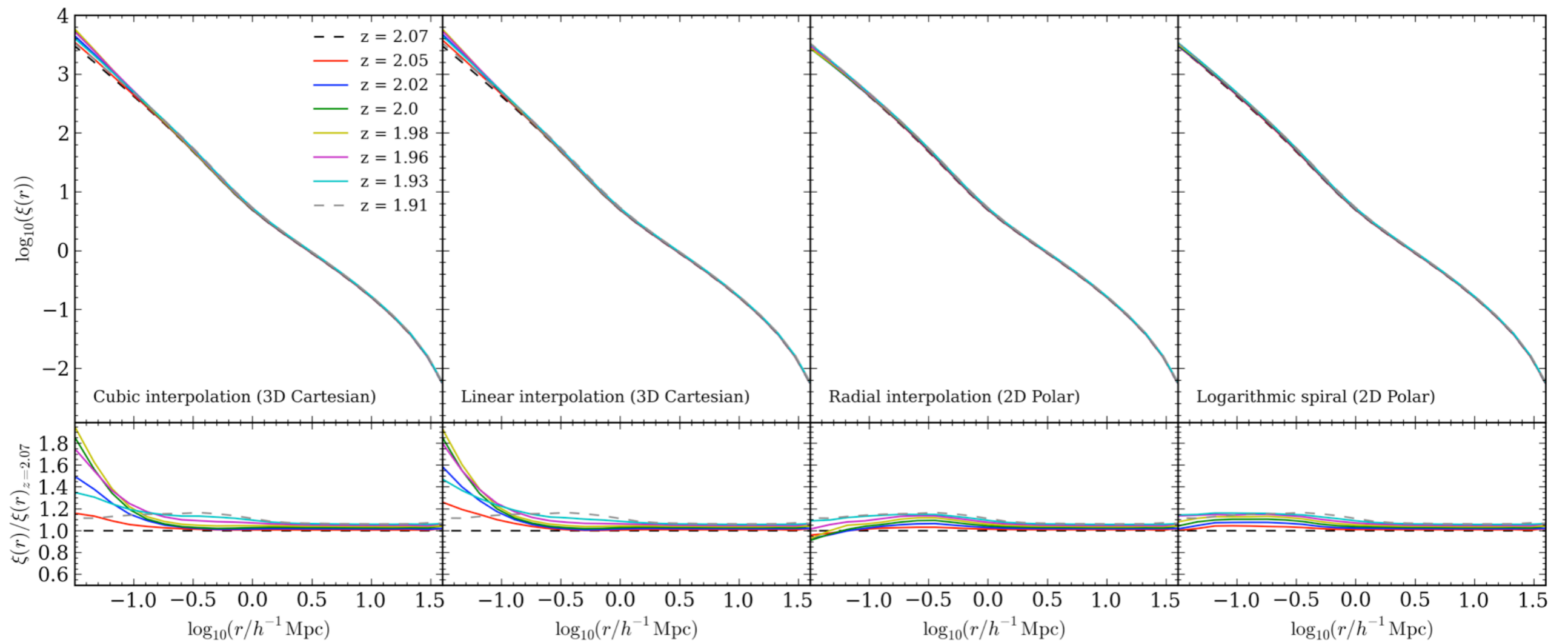
- Between z = 1.91 and z = 2.07 have ~ 20% change in amplitude of ξ(r)

- At intermediate redshift z ~ 2, with NO INTERPOLATION have ~ 10% uncertainty on ξ(r)