Euclid photo-z calibration plan

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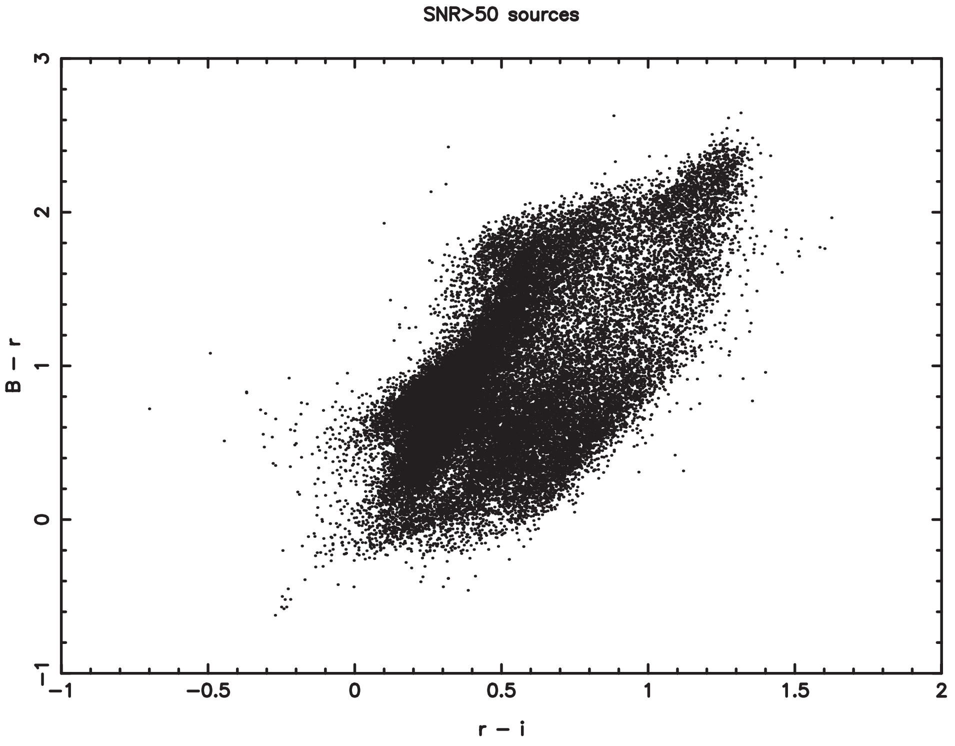
Philosophy

- If W_o=-0.95+/-0.01 how do we convince the community the error bar is correct?
  - Need multiple equally powerful methods to calibrate
  - Need set of tertiary calibrators to triple check systematics
- Two methods identified as primary calibrators
  - Color-Redshift manifold calibration (e.g. Masters et al. 2015)
  - Clustering-cross correlations (e.g. Newman et al. 2015, Menard et al. 2013)
  - Should be viewed as interchangeable with same final result
- Tertiary methods to validate binning and co-variance
  - Photo-z/Photo-z clustering cross-correlation
  - Density field re-construction?

Why Do Photometric Redshifts Work?

- Galaxies are very similar in many ways
  - Same physics
  - Cluster in color space
- Photo-z is a map of the color space manifold to redshift
  - High dimensionality
  - Complex manifold
  - Lots of ways to do this mapping
- Error distributions and systematics are important



Why cosmology photo-z is different

- For cosmology we do not need all objects
  - Only using the lensing sample, not all galaxies
  - Need a method to define objects with well constrained redshift distributions
    - Reject the rest
    - Forget those faint red galaxies at z~2 we are not using them for cosmology because they are rare and hard to get redshifts to
- Need an accurate redshift distribution for samples of objects
  - Individual objects don't matter
  - Should be selecting objects from color space rather than photo-z space
    - Think of this as an optimal binning problem
  - Still have estimates of P(z) for each object

Mapping the Color-Redshift relation (Masters et al. 2015)

- We adopt a widely-used technique known as the Self-Organizing Map (SOM), or Kohonen Map
- Easy to visualize
- Easy to understand

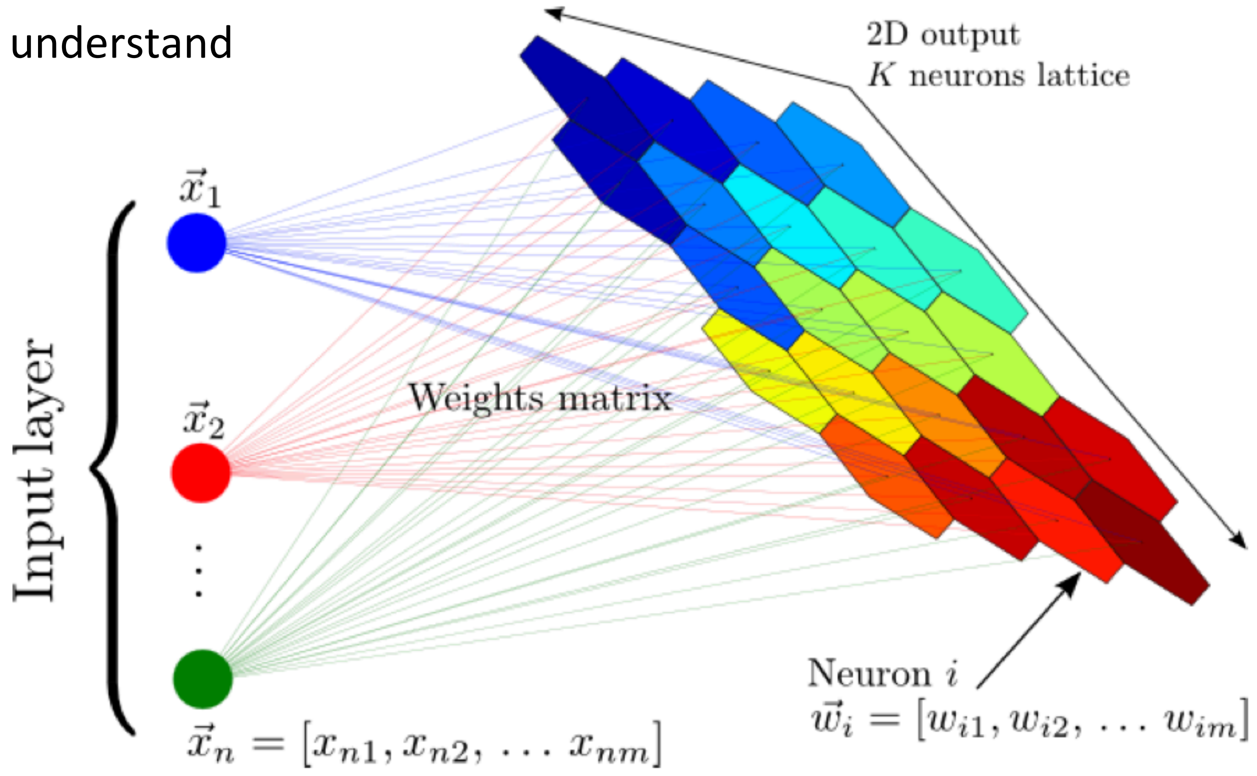
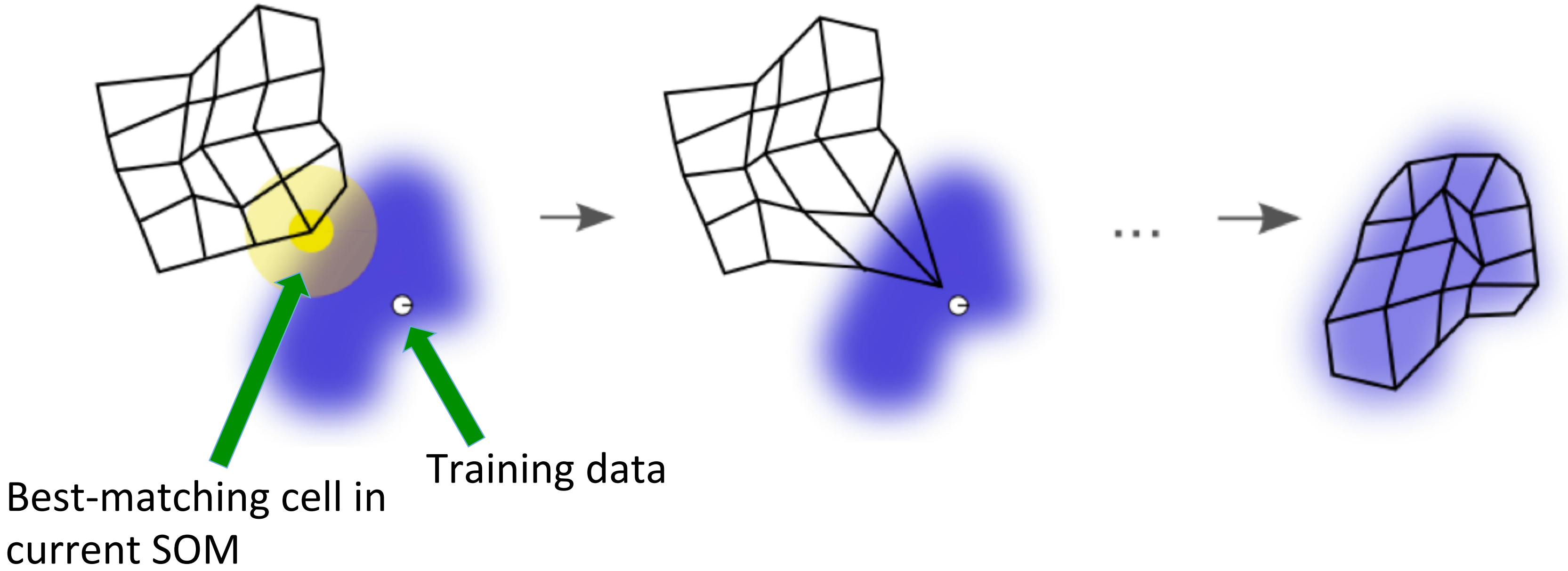


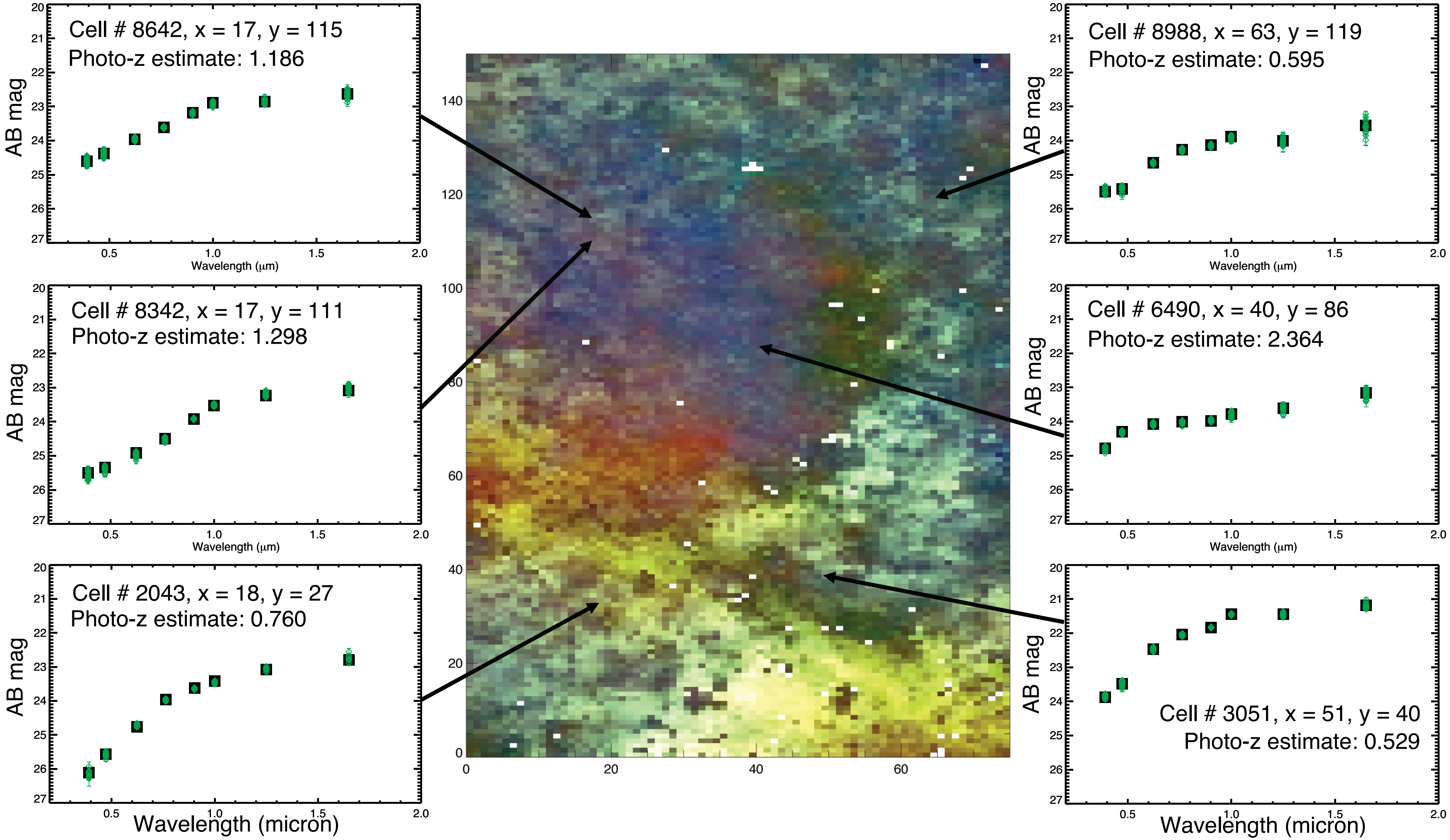
Illustration of the SOM (From Carrasco Kind & Brunner 2014)

Mapping the Color-Redshift relation (Masters et al. 2015)



1. Initialized map is presented with training data, i.e. the colors of one galaxy from the overall sample.
2. Map moves towards training data, with the closest cells being most affected.
3. Process repeats many times with samples drawn from training set until the map approximates the data distribution well.

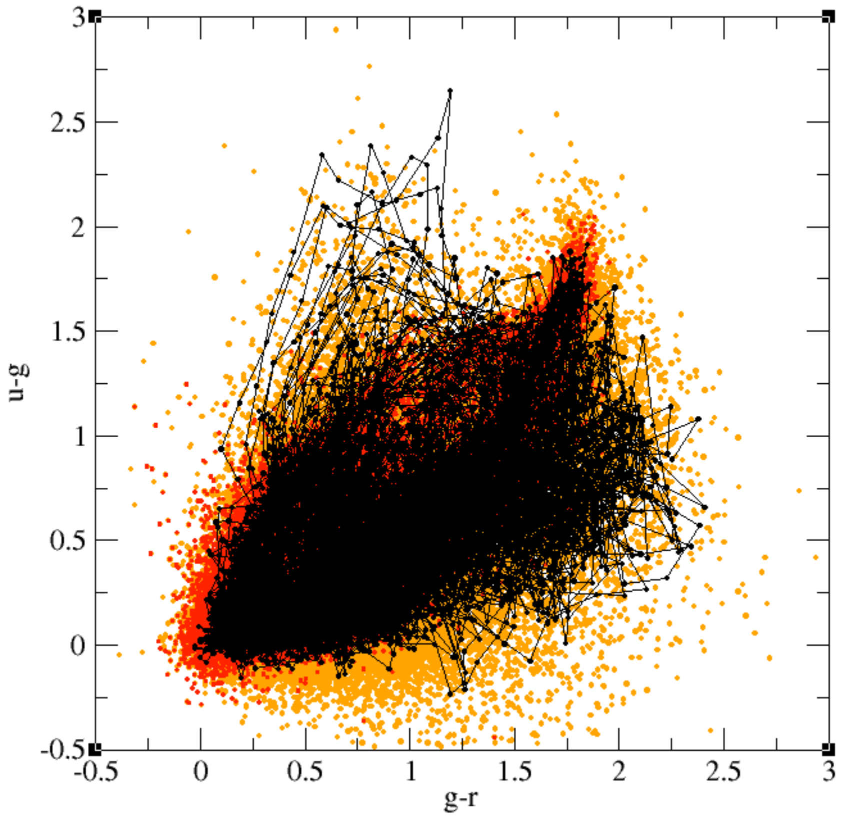
Mapping the Color-Redshift relation

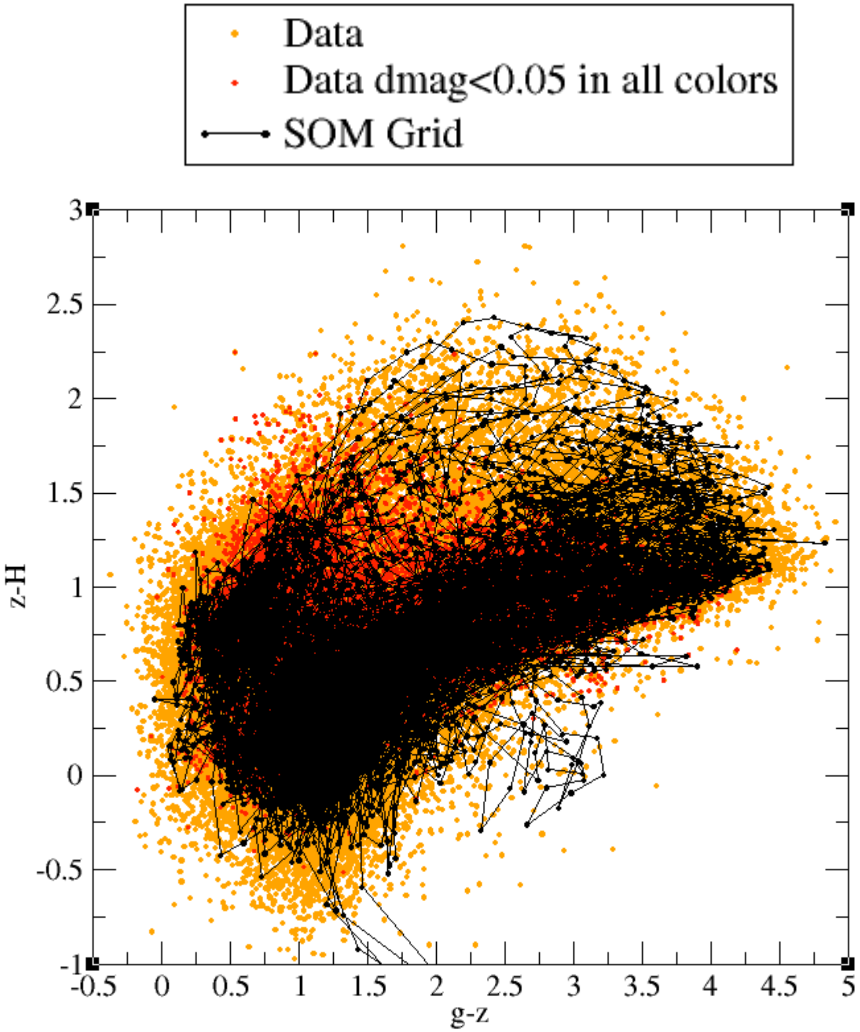


Masters et al. 2015

Mapping the Color-Redshift relation

The SOM grid in color-color plots

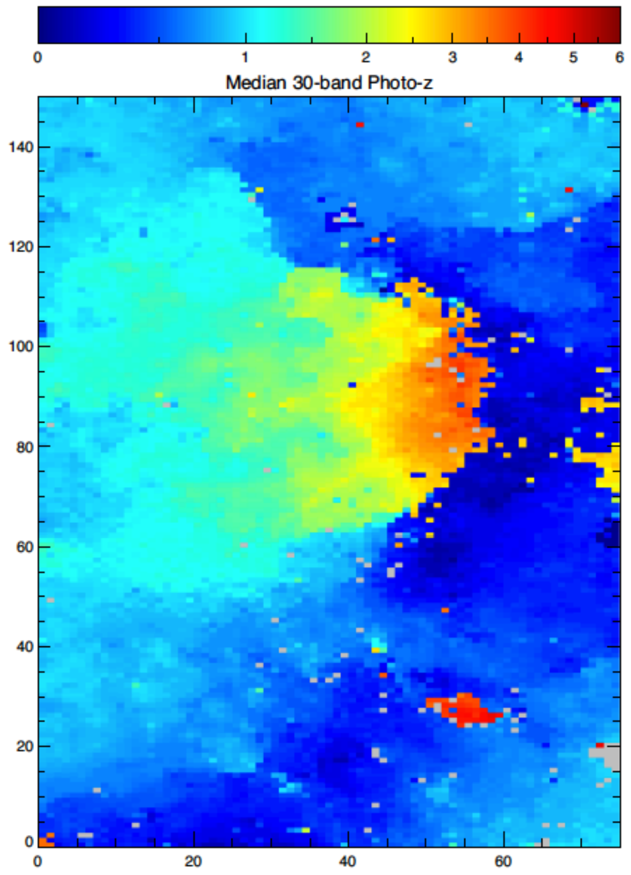




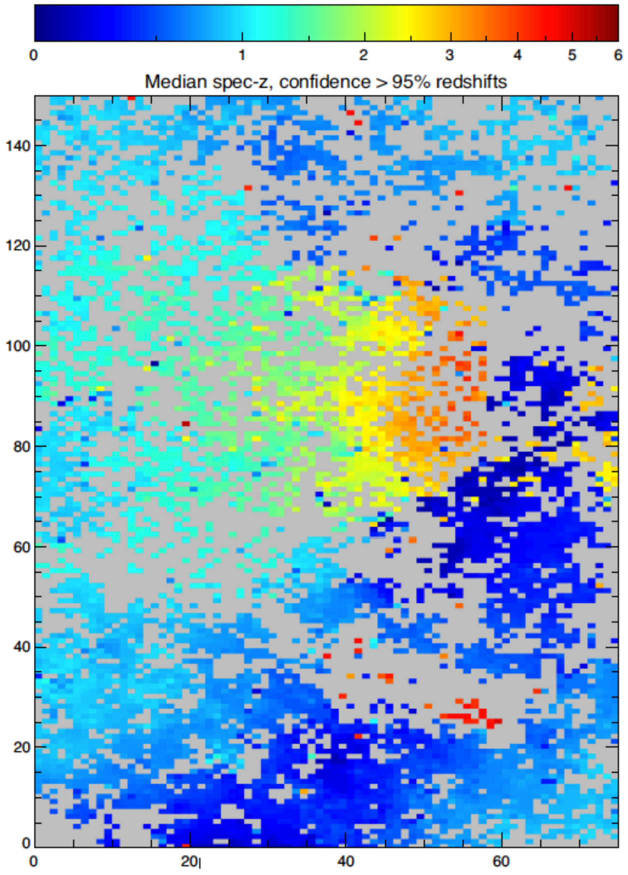
Mapping the Color-Redshift relation

- Can visualize the 7-dimentional color data
- Test if the analytic model fits
- Test where the data driven model is valid
- Target grey areas with spectroscopy

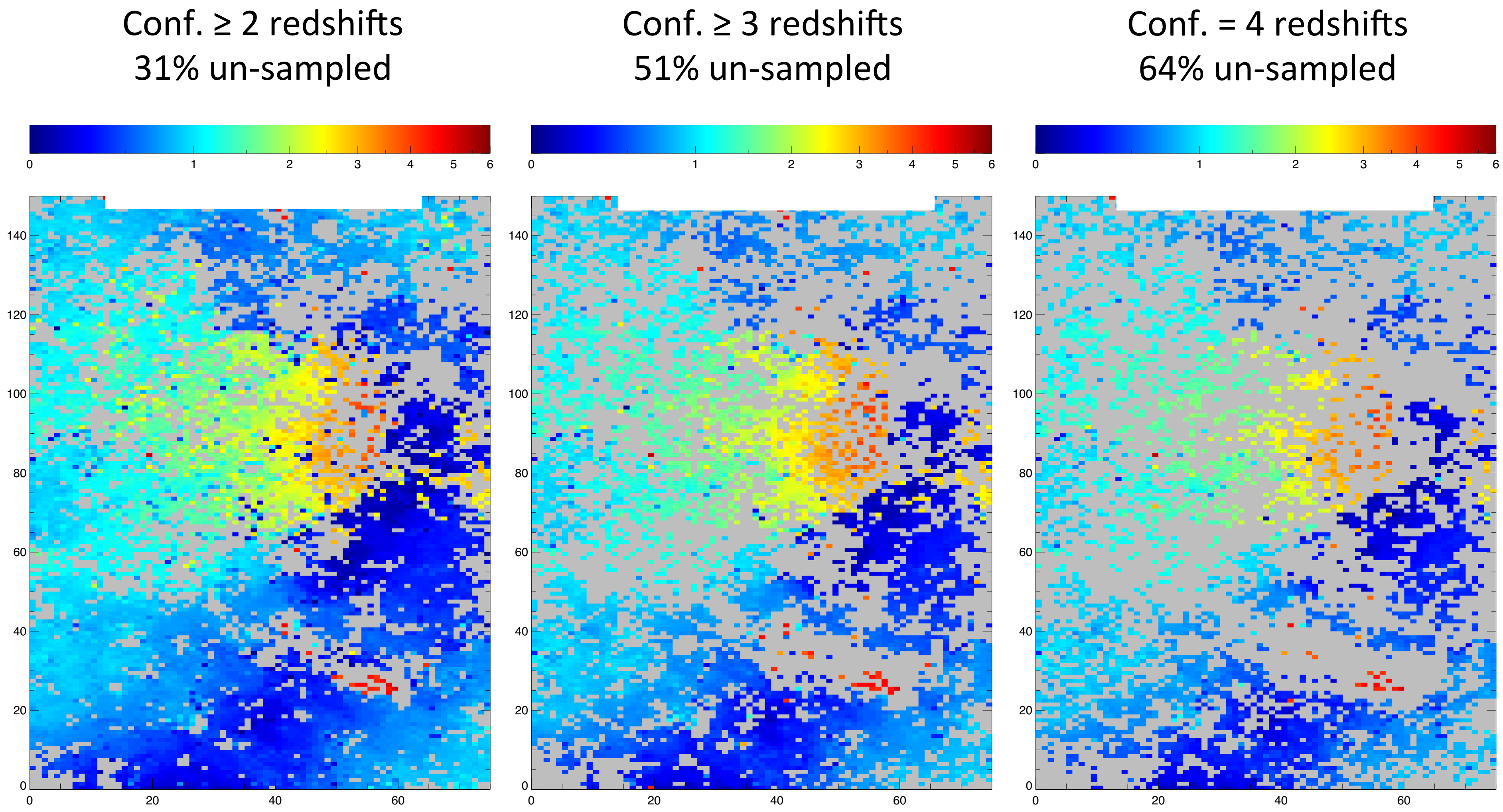
Analytic (Template) Model



Data (spectra) Driven Model



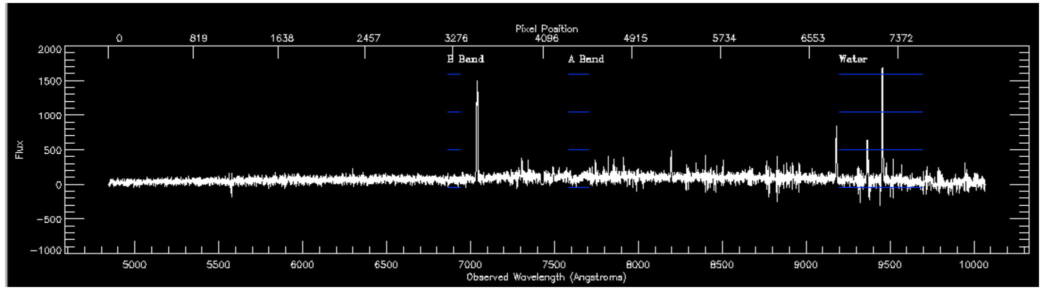
Spec-z's across the shallower *Euclid* map at different confidence levels

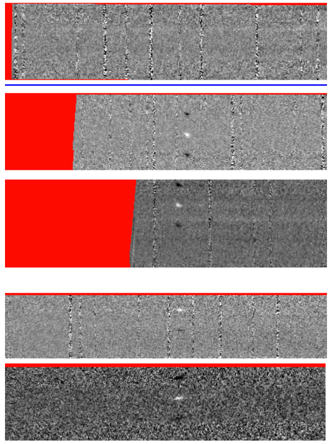


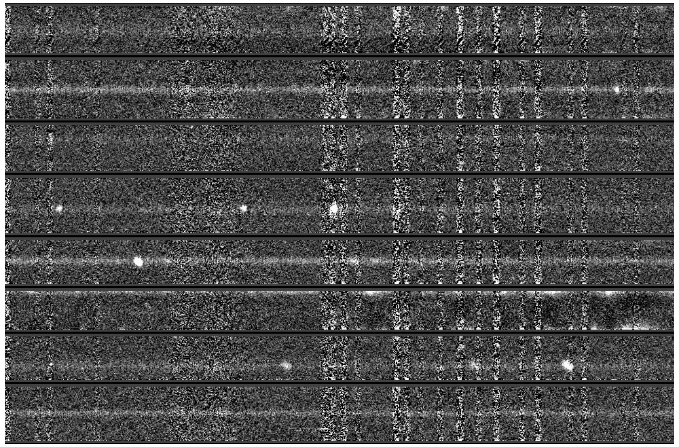
At low confidence there appear to be very few Unknown-Unknowns. Main problem is getting high-confidence redshifts.

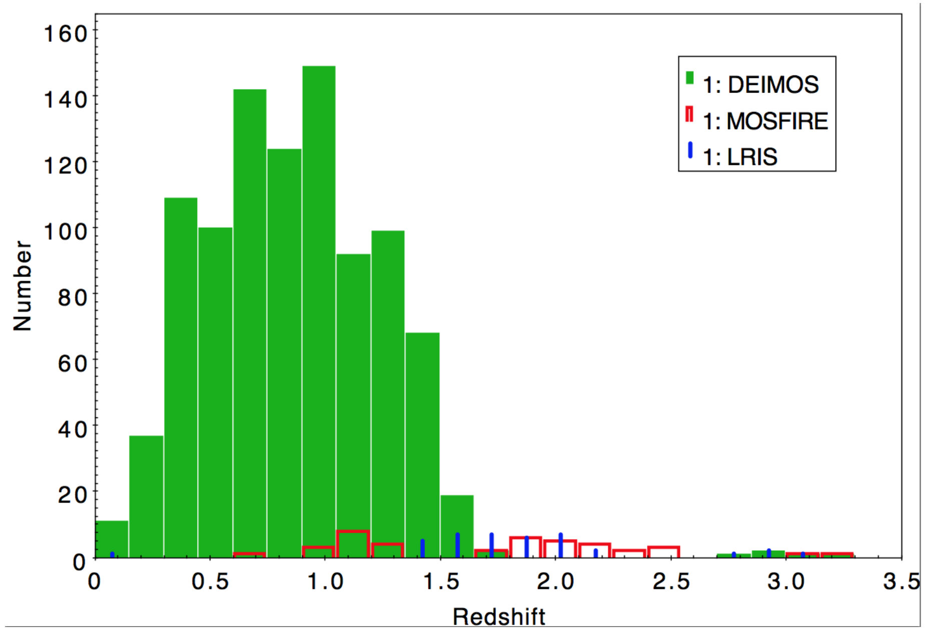
C3R2

- Aim to fill in the color-redshift map for Euclid
- Not a typical redshift survey
  - Have an expectation of what we are looking for
  - Multiple instruments, variable exposure times
  - Keep going until we have a redshift
- ~40 nights on Keck with multiple instruments
- Will go a long way to measuring the LSST/WFIRST mapping



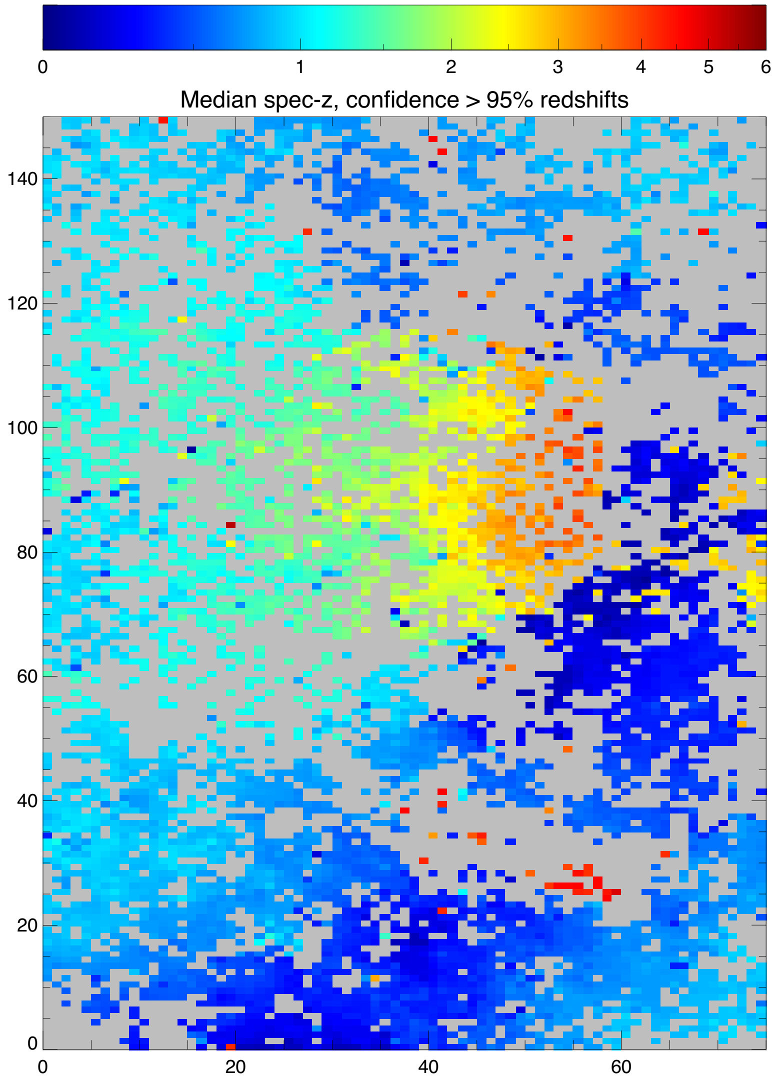






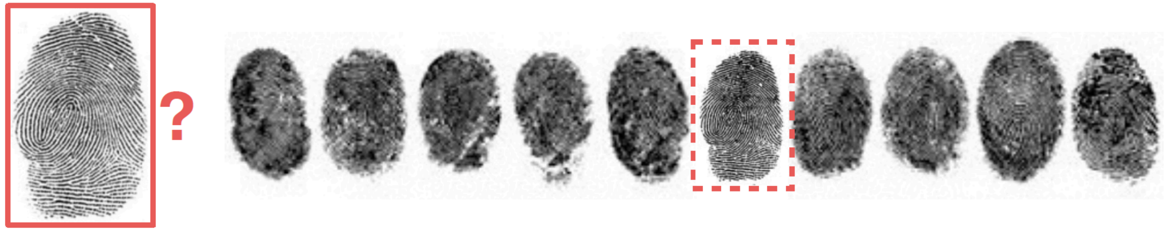
Increased coverage from 3 DEIMOS nights

- 3 DEIMOS nights, ~680 new high-confidence redshifts in COSMOS



Clustering (Astrometric) redshifts

- Use spatial distribution on sky to match spectroscopic and photometric samples
- Works like finger-print matching



Probability for two different fingerprints to match ~ 1/68 billion

Galton (1892)

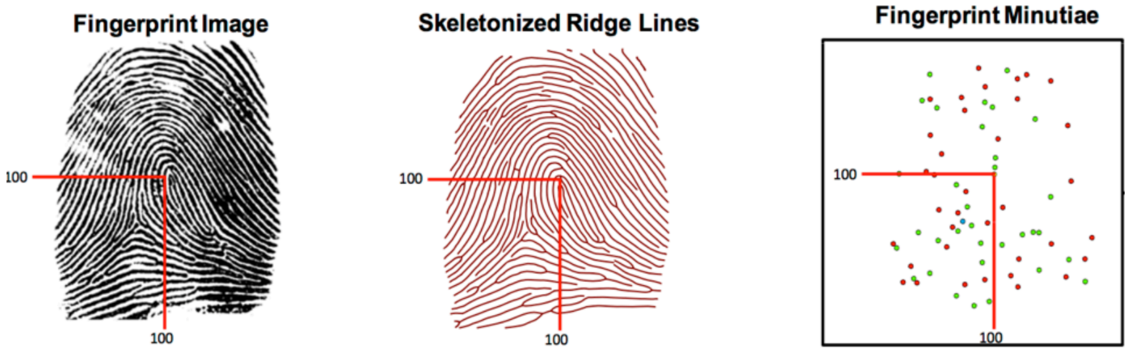
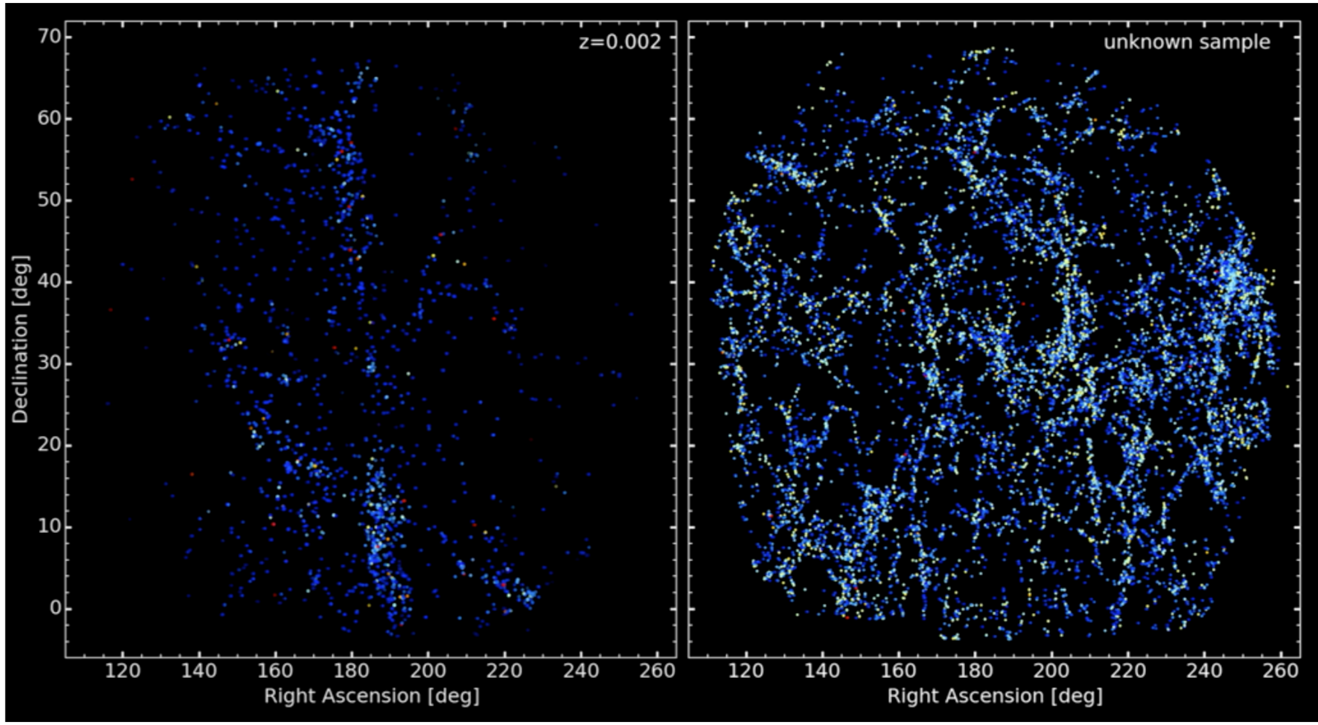


Image credits: Taylor, Dutton, Aldrich & Dutton

Credit: Menard, Mendez, Rahman

Clustering (Astrometric) redshifts

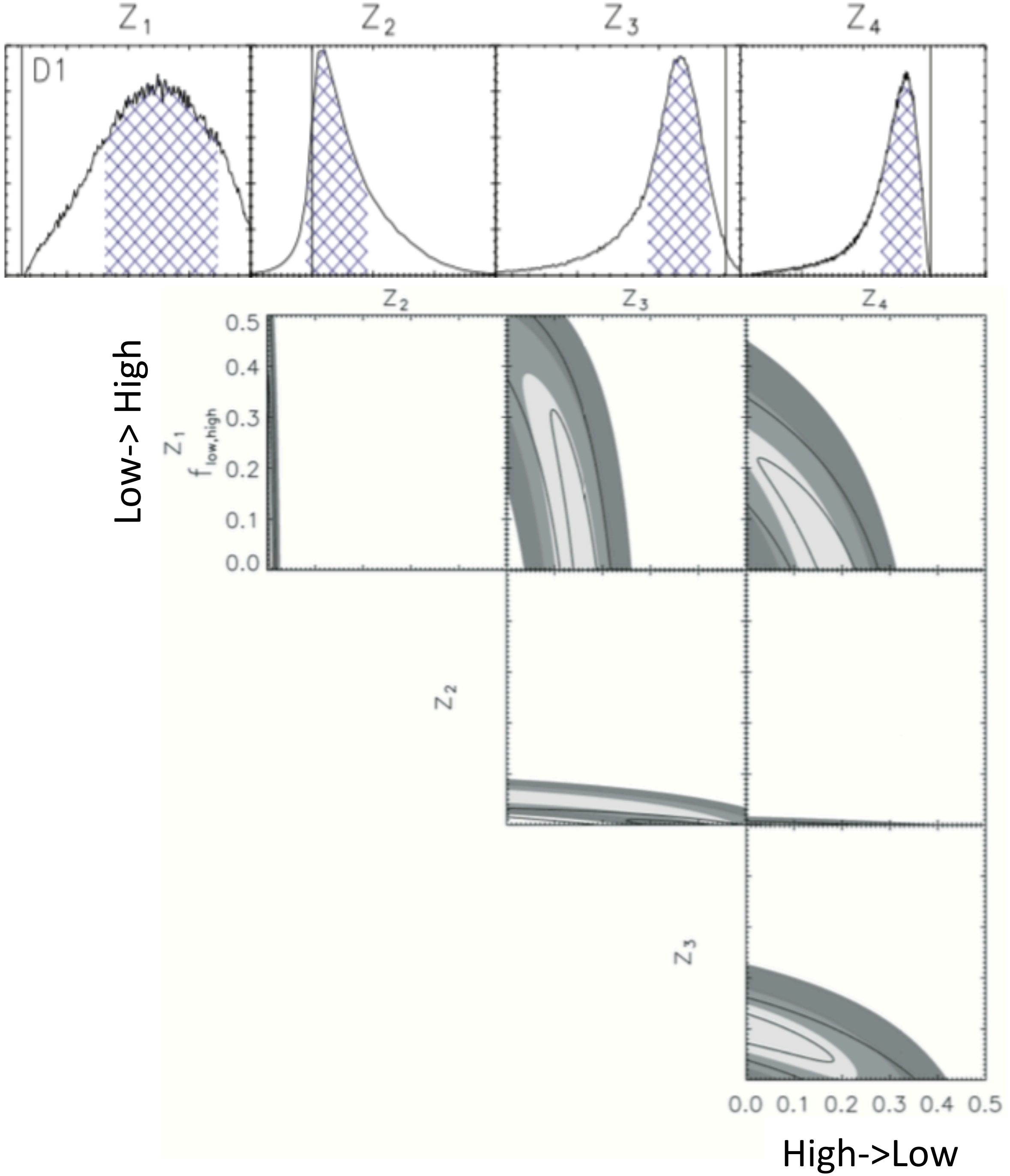
- Can use small scale (1-halo, Menard et al.) and/or large scale (2-halo, Newman et al.) clustering
- Spectroscopy can be very incomplete
- But needs to be reliable and overlap in redshift



Credit: Menard, Mendez, Rahman

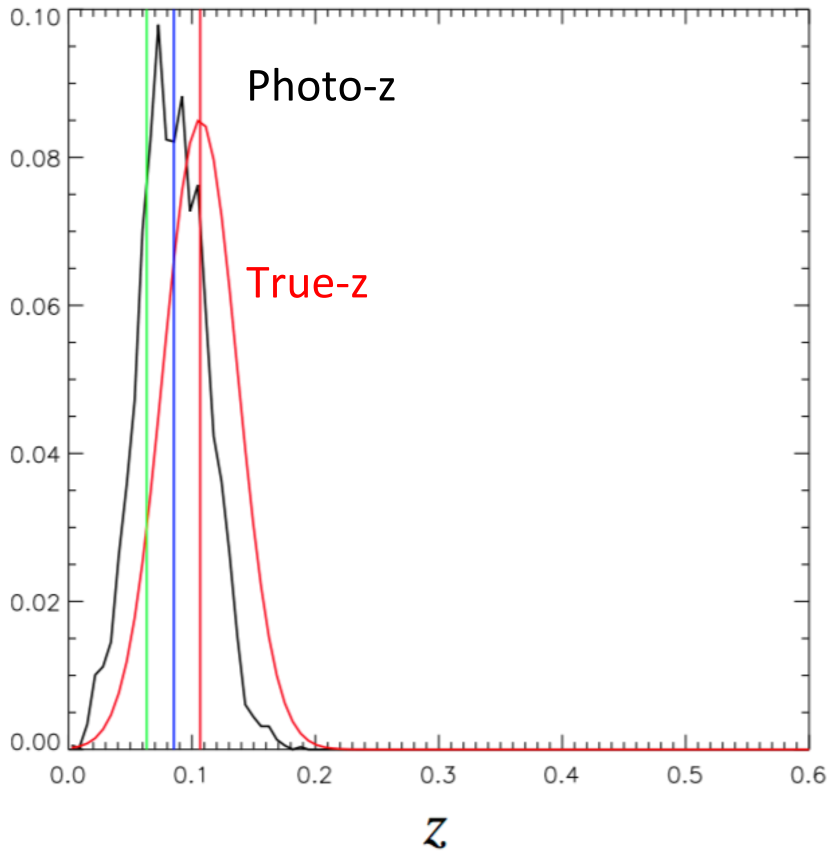
Tertiary Calibrators

- Photo-z/Photo-z cross correlation
  - Benjamin et al. 2010
- Look for angular cross power between photo-z bins
- Can verify expected cross correlation between bins
- Sensitive to outliers



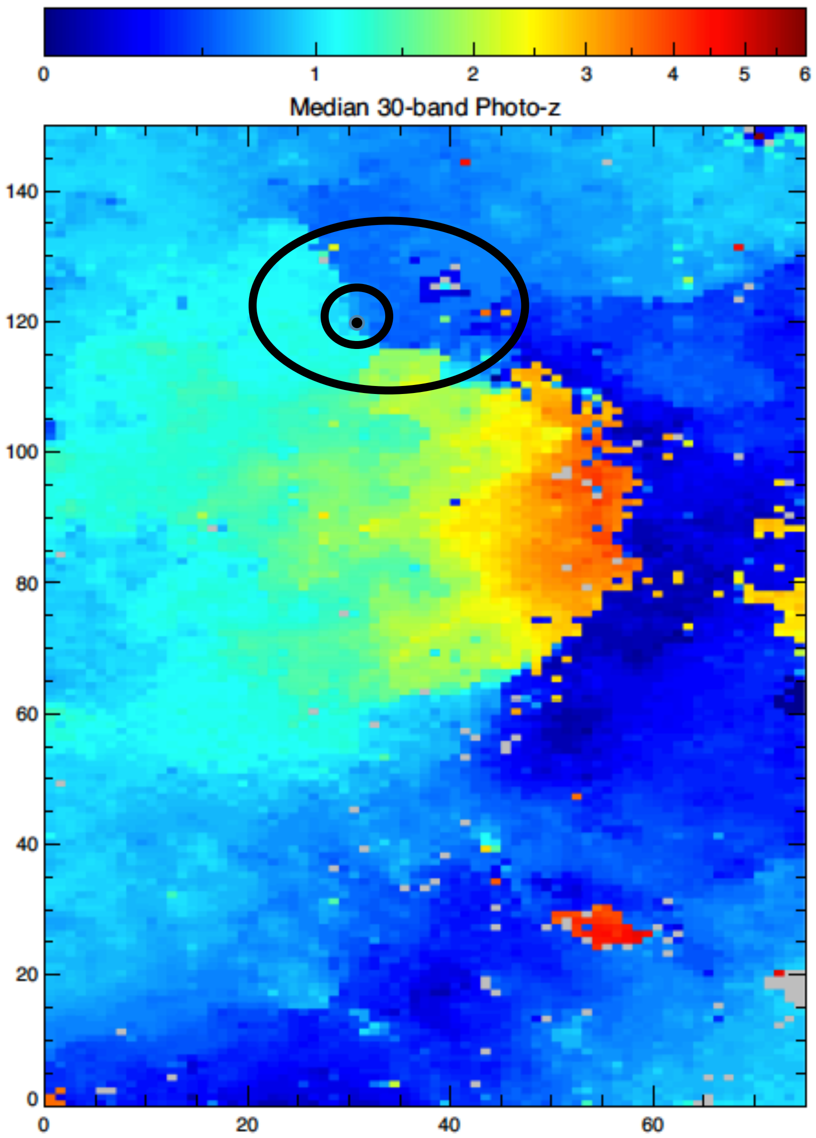
Tertiary Calibrators

- Large Scale Structure re-construction
  - Jasche & Wandelt (2012)
- Compare structures measured with spec-z and photo-z
  - Look for offsets
- Can be done statistically for the whole range of structures
  - Verifies bias estimates



Requirements for all methods

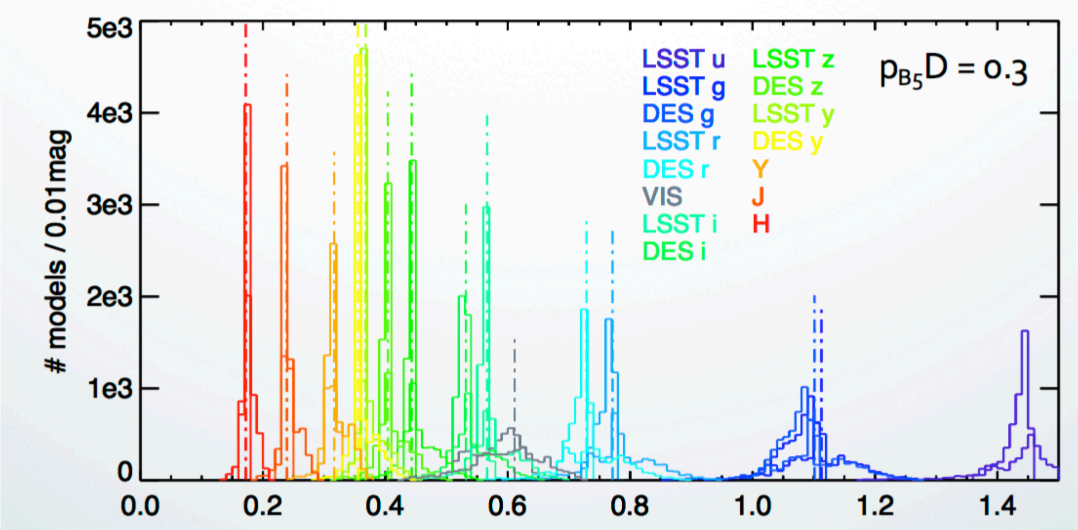
- Need an empirical determination of photometry errors
  - Deep/repeated fields to measure error distributions
    - Taken under range of conditions for ground based data
    - Tails of error distribution matter
  - Verified with simulations
    - Know effects of blending/de-blending
- Need deep photometry data in Spectral calibration field
  - Special photo-z calibration fields
- Good photometric mask



Requirements for all methods

- Map of galactic extinction
  - Method to correct for galactic extinction with errors
  - In detail both the normalization and correction of the extinction depend on the intrinsic colors of the object
- Spectroscopy good to $dz/(1+z)<0.001$ (better than bias requirement
  - Or more spectra to make up for lower accuracy
  - Details matter
    - Doppler shift from motion of earth
    - CMB dipole
- Spectroscopy needs to be very reliable (>99.5%)
  - Can mask samples that are un-reliable
  - Spectroscopic failures need to be tracked

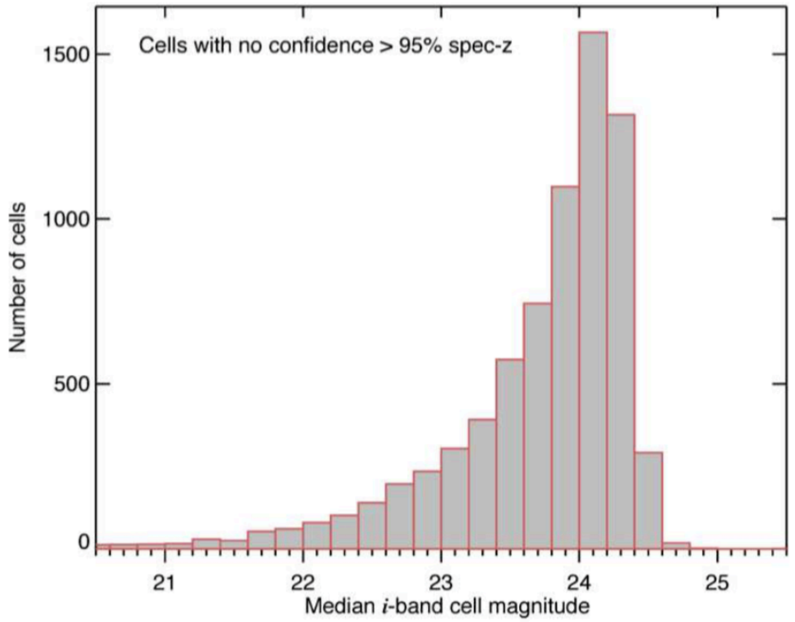
Difference between correction and single dust correction for different SED types

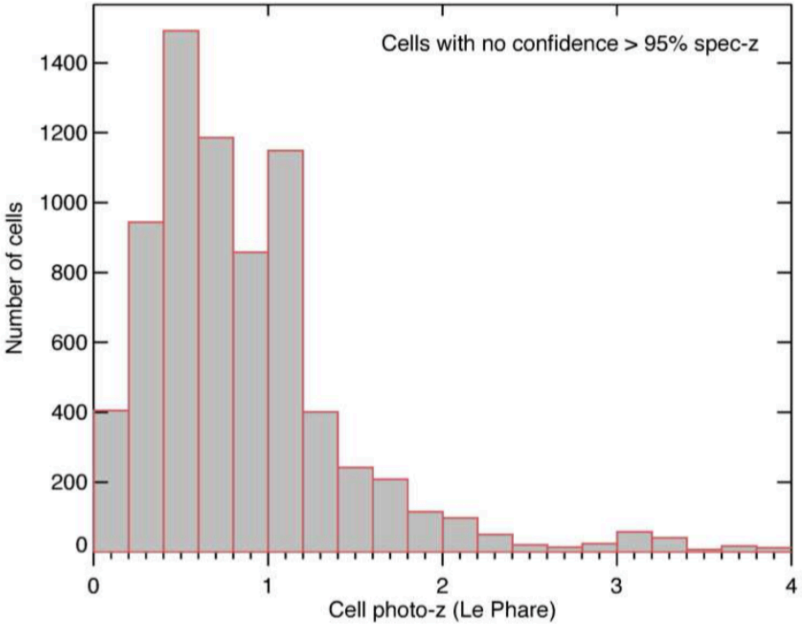


A. Galametz accepted

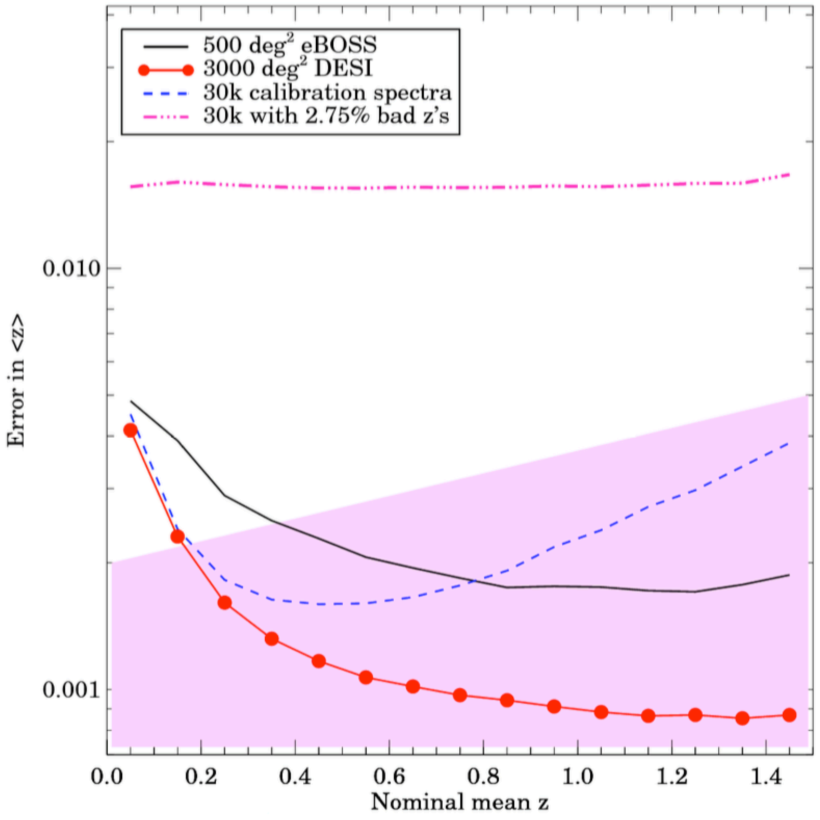
Color-Redshift Requirements

- Photometry deep fields
  - SNR > 5x wide survey
  - Ground + Euclid
  - All bands used for photo-z
  - 4-6 widely spaced fields needed
  - Multiple realizations of photometry in these fields
- >10k high-quality spectra
  - Fully representative in color space
  - Spread between the fields





Requirements for clustering cross correlation



- Spectroscopic redshifts covering full redshift range
  - Need to be very, >99.5%, pure
  - Grism Spectra not good enoug
- Minimum of 100k redshifts over widely spaced fields
- ~Evenly spaced in redshift, need ~50k at z>1.5
- Need one set of spectra for each external data set used
  - SDSS+BOSS in north?
  - 4MOST in south?
- Larger areas better, can use large scale clustering
- Still need a way to bin the data into tomographic bins
  - Need to control systematics
- Probably something like the SOM
  - Could use photo-z code
  - Could use color-cuts

Conclusions

- Need multiple methods to measure and verify the redshift distribution of the tomographic bins and the errors
  - Color redshift and clustering methods most promising
  - Different requirements on spectroscopy
- Spectroscopy hard but not impossible for lensing
  - Does not need to sample entire galaxy population, just lensing sample
  - Needs to be well thought out
  - Not blind targeting like previous redshift surveys
- Need deep imaging in the calibration fields
  - Characterize the sample
  - Reduce need for spectroscopy