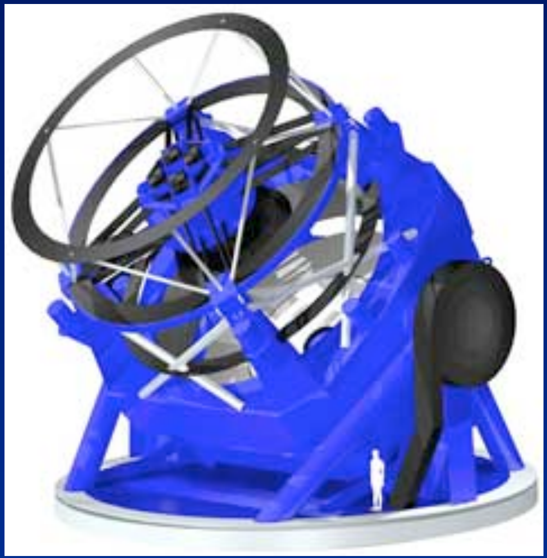
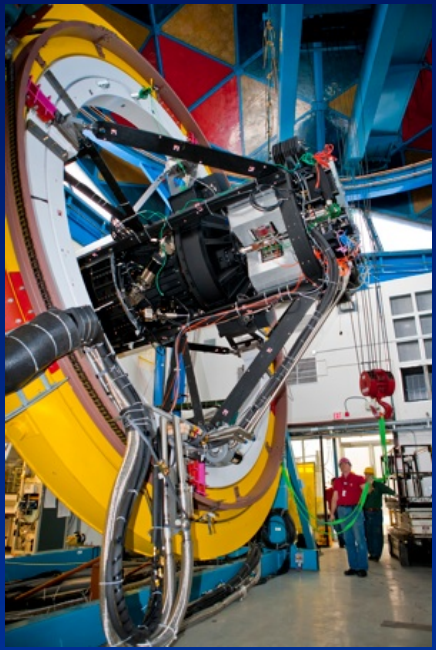
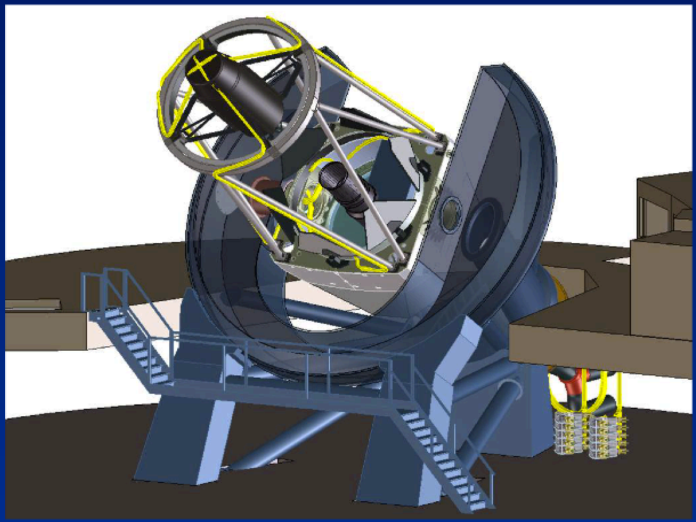
Photometric Redshift Calibration with Wide-Area Surveys







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Outline

I. Photo-*z* calibration lessons learned from existing deep spectroscopic surveys

- Expected error rates of "secure" redshifts exceed calibration requirements

- Existing samples to *i*~22.5-23 are systematically incomplete at the 30-70% level

II. Required exposure time to get ~90% completeness to *i*~23: ~32 hours with Keck, ~25 nights with DESpec.

- 6x longer to reach DES limit (*i*~24)

III. A promising alternative: wide-area spectroscopic surveys utilizing cross-correlation techniques

Calibrating photo-*z*'s is a difficult problem

- Requirement for training set/machine-learning/weighting techniques: a large spectroscopic sample with well-understood sampling of the full range of properties of photo-*z* targets

- For template-based approaches, need spectroscopic training samples that span full range of real galaxy SEDs. Still need to go faint (smaller galaxies begin star formation later).

- Problem for Stage IV experiments: planned targets are too dim to get spectroscopic redshifts for *en masse*

- Problem for Stage III experiments: Existing deep spectroscopic survey samples from 8-10m telescopes are **far** from complete, and have unacceptably high error rates even for "secure" *z*'s

Redshift error rates that are acceptable for galaxy evolution studies are not for DE

VVDS, zCOSMOS, and DEEP2 all use 'flag' or 'Q' =3 to indicate redshifts with >95% confidence, flag/Q=4 for >99.5% (actual failure rates shouldn't match confidences exactly)

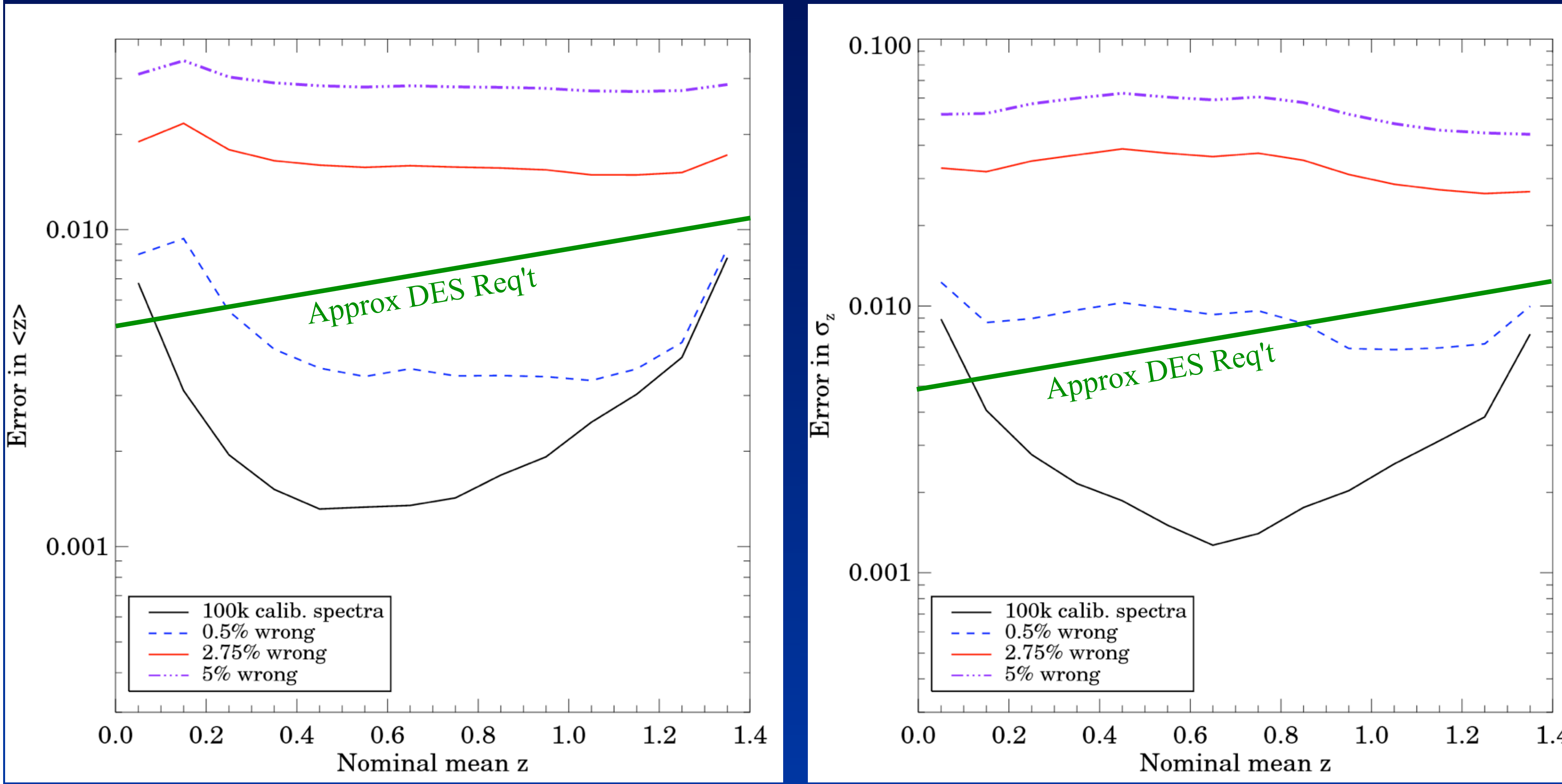
Flag = 3 redshifts are ~50% of VVDS/zCOSMOS "secure" measurements (17% for DEEP2).

What impact will incorrect/outlier redshifts have on photo-z calibration errors?

- Consider an ideal calibration sample: a 100% complete set of redshifts of 100k galaxies, perfectly tracing the redshift/property distributions of the photometric sample (here: DES)

- Model: incorrect redshifts are off by a number drawn from a skew Gaussian with mode=0.5 and sigma = 0.5

Even with 100% complete samples, current false-z rates would compromise DE inference



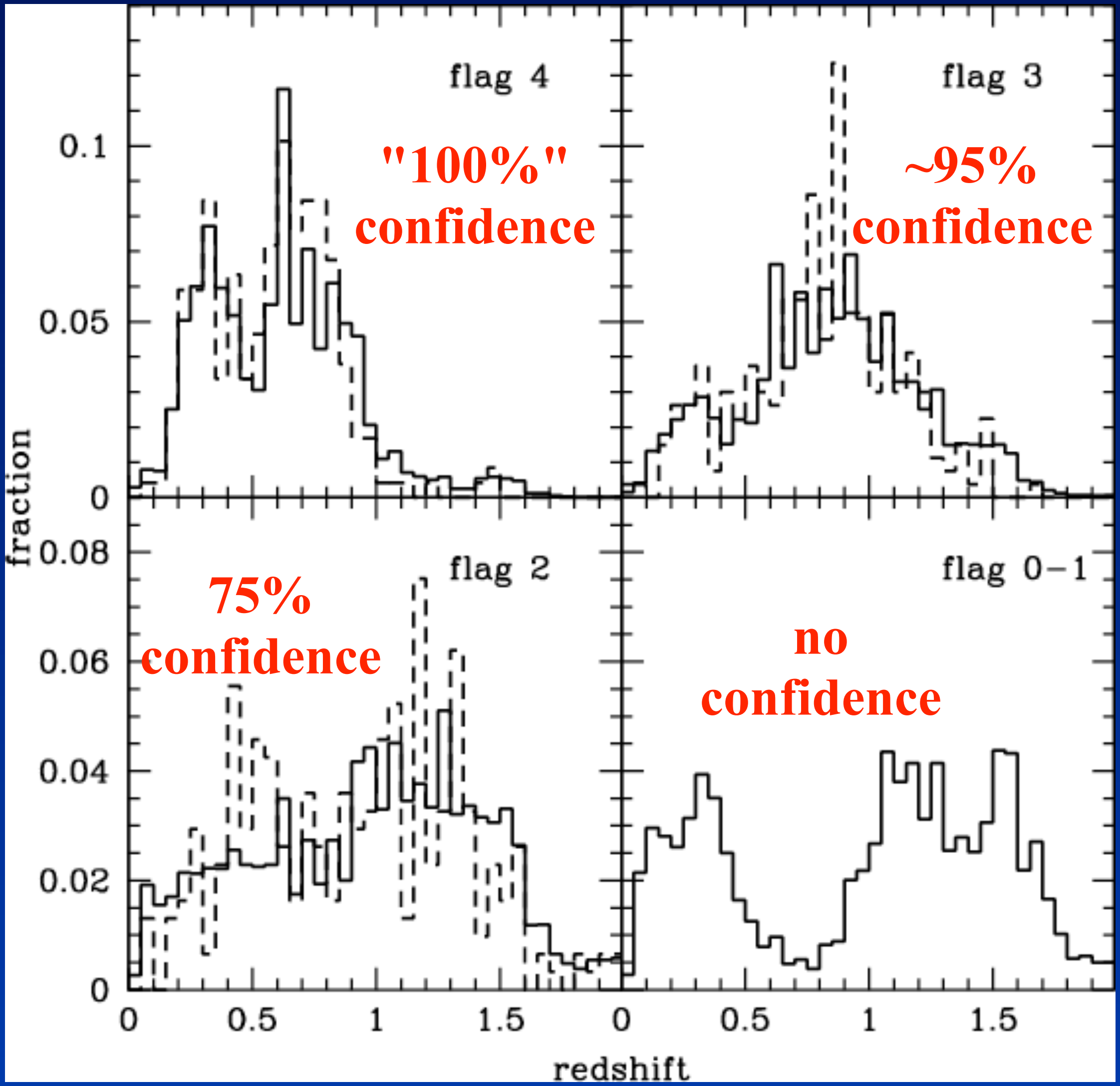
Based on actual redshift distributions for ANNz-defined DES bins in mock catalog from Huan Lin, UCL & U Chicago, provided by Jim Annis

Existing redshift surveys are highly and systematically incomplete; e.g. VVDS...

VVDS-wide: i<22.5 survey at VLT

- Almost all galaxies at z>1 have lower-confidence redshifts.

- Success rate is a function of photo-z; success rate is 21% if flag 4 is required, 42% if flag 3 (~95% correct) are acceptable



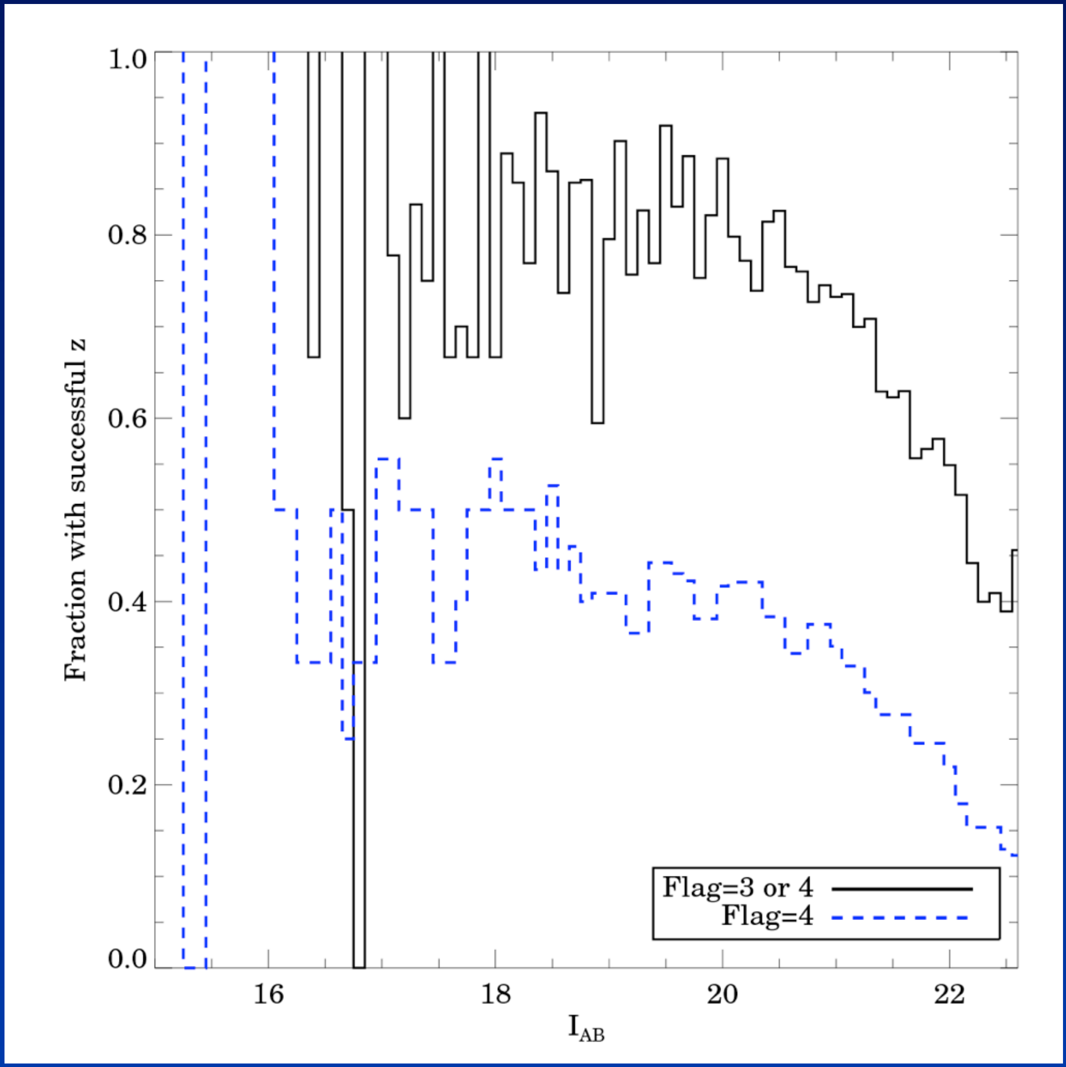
zCOSMOS does somewhat better, but *z* success falls off past *i*=20

zCOSMOS-bright: ***i*<22.5 survey at VLT**

- Redshift success is a strong function of magnitude.

- 59% redshift success rate for galaxies if count flag 3+4 (>95% confidence), 26% if require flag 4 (>99.5% confidence).

- Very few secure redshifts at *z*>1



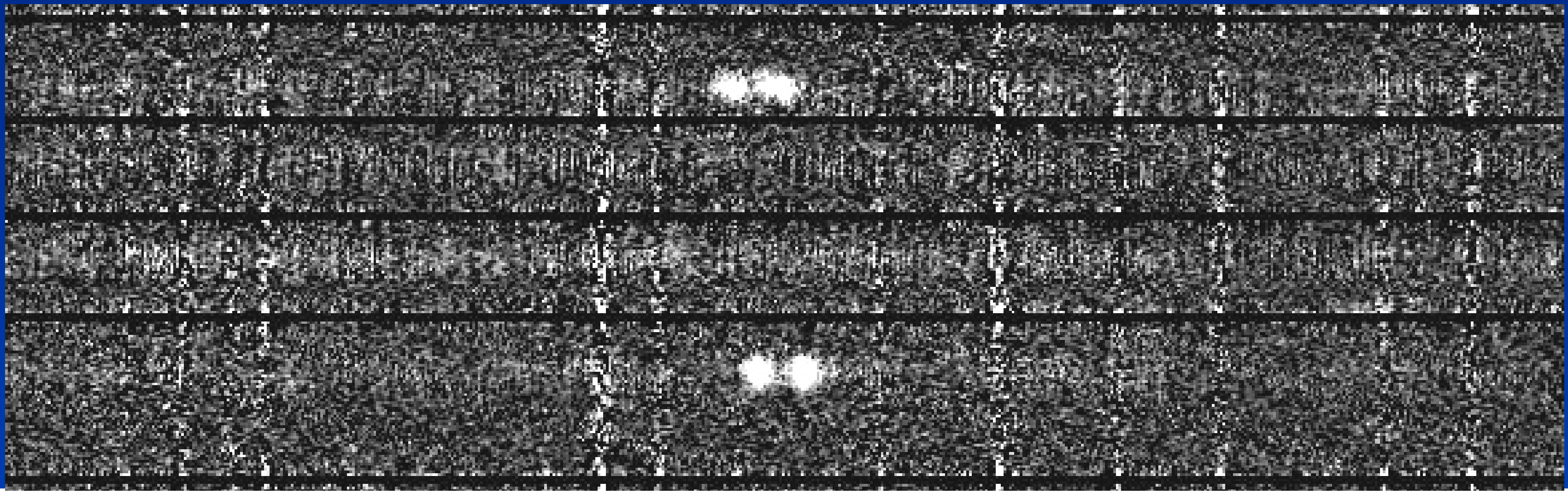
DEEP2 obtained the highest redshift success rate amongst the large deep surveys: 73%

DEEP2: R_{AB}<24.1 survey at Keck, focused on 0.7<z<1.4

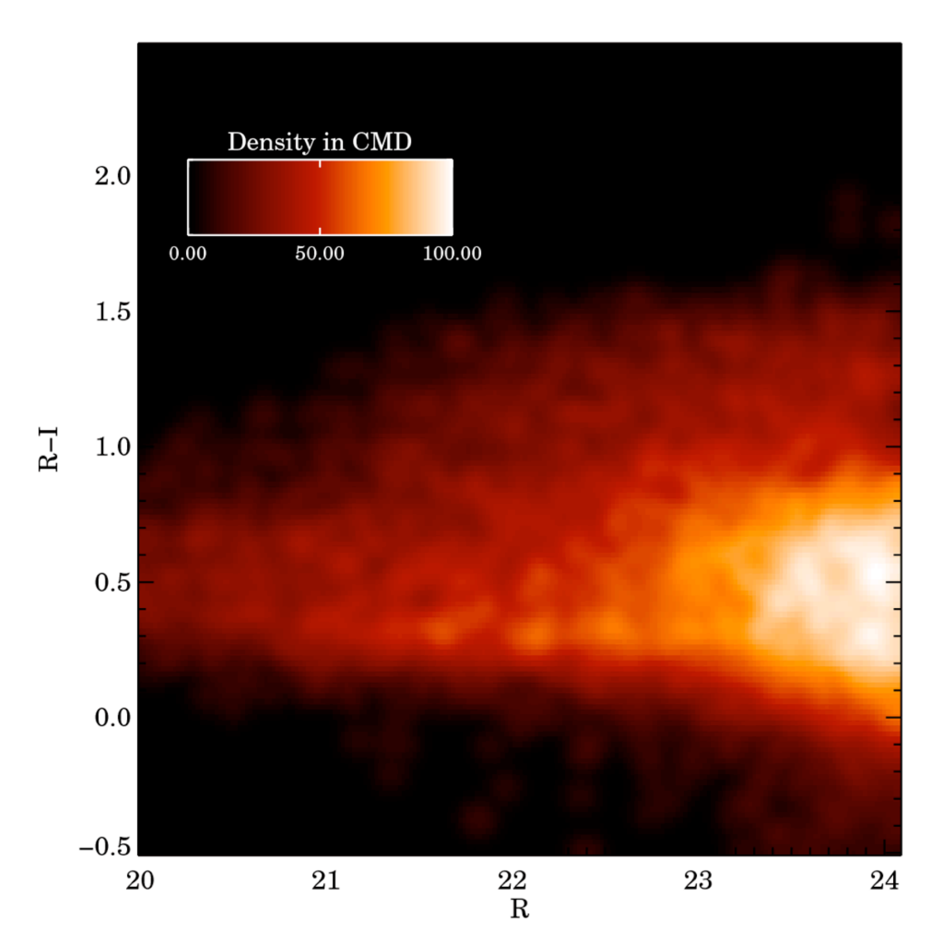
DEEP2 has 2 categories of redshift quality considered successful (totalling ~73% of targeted galaxies):

Q = 3: 17% of successes; >98.4% correct (based on 2614 objects with repeated observations)

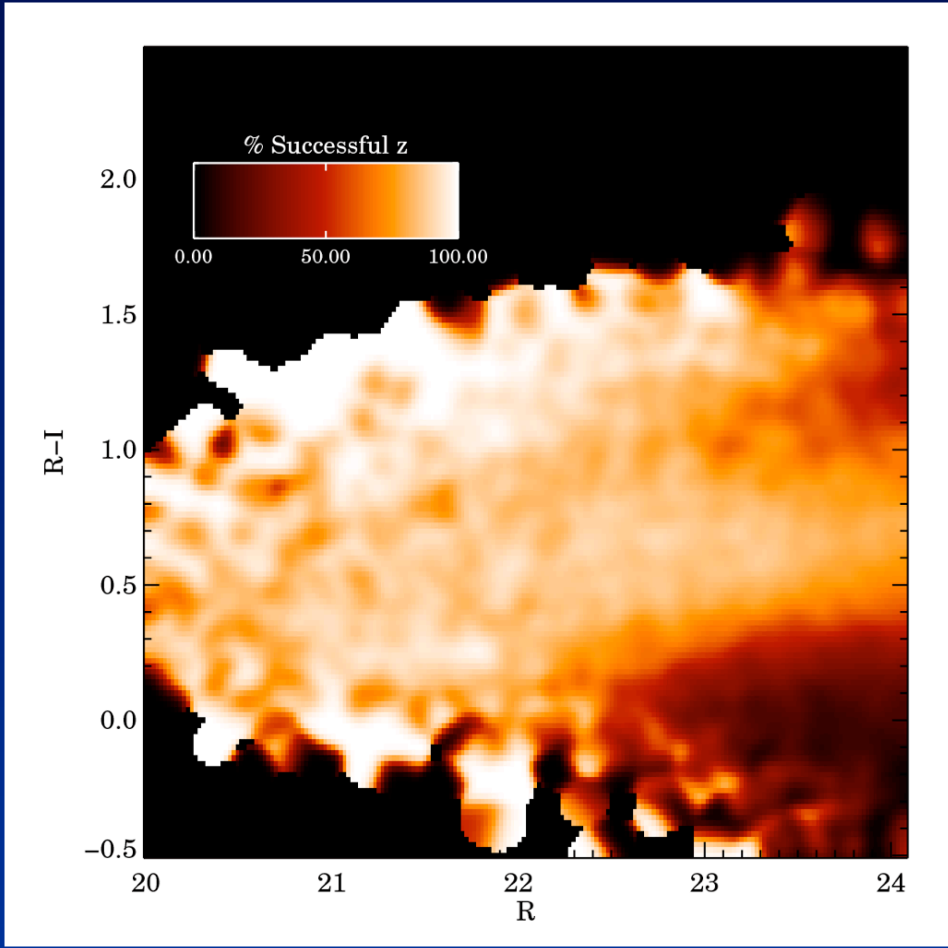
Q = 4: 83% of successes; >99.7% correct (ditto)



Redshift success rate depends on both color and magnitude



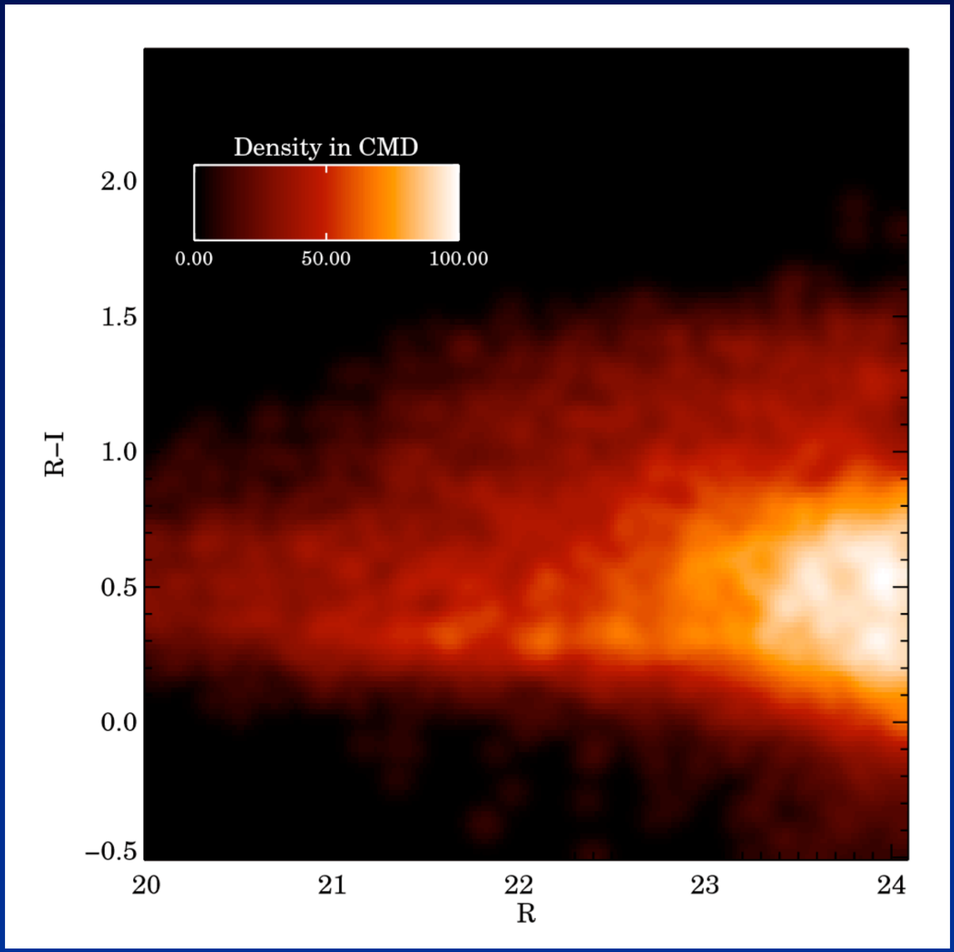
Observed Color-Magnitude diagram for DEEP2 targets (in EGS, so no color cut)

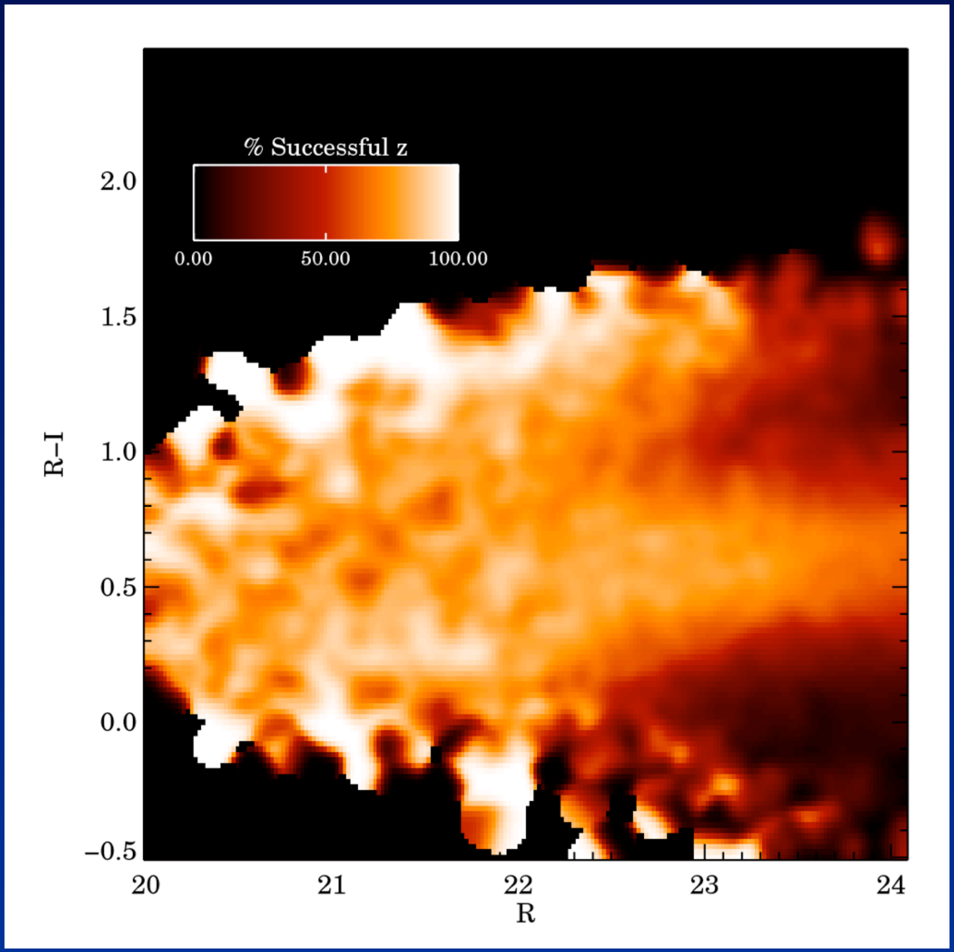


Redshift success (Q=3 or 4) rate

Newman et al. 2012

Redshift success rate depends on both color and magnitude



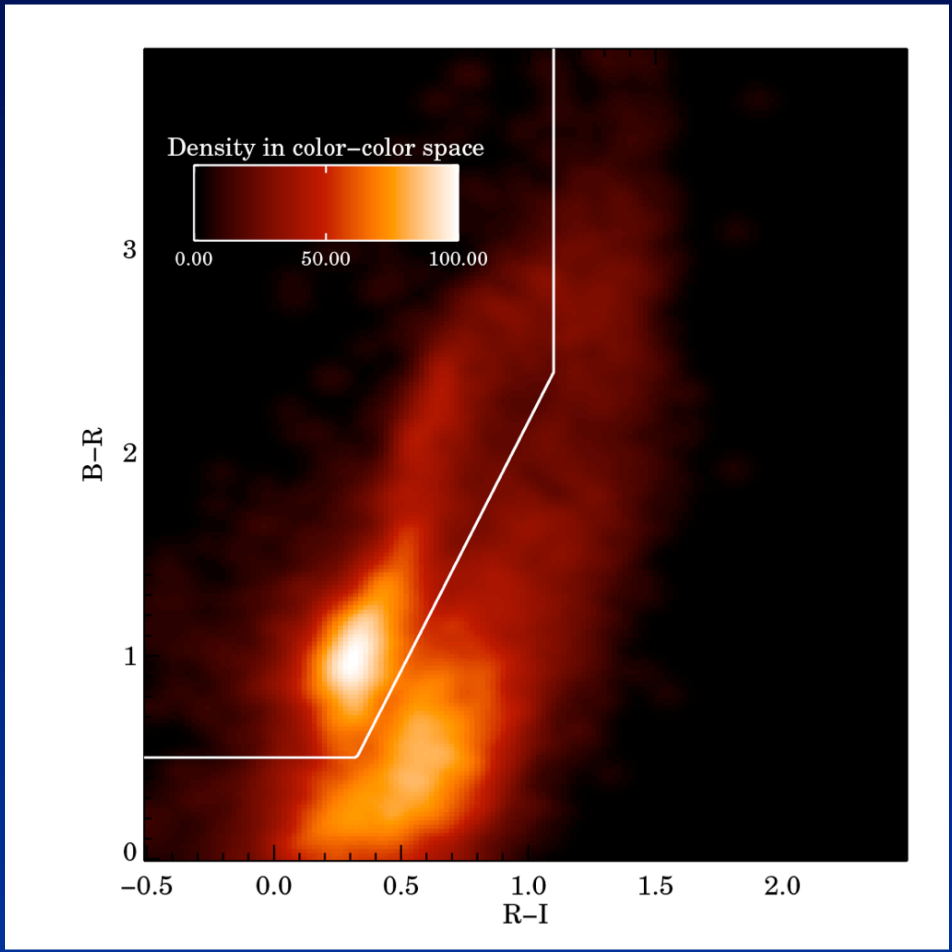


Observed Color-Magnitude diagram for DEEP2 targets (in EGS, so no color cut)

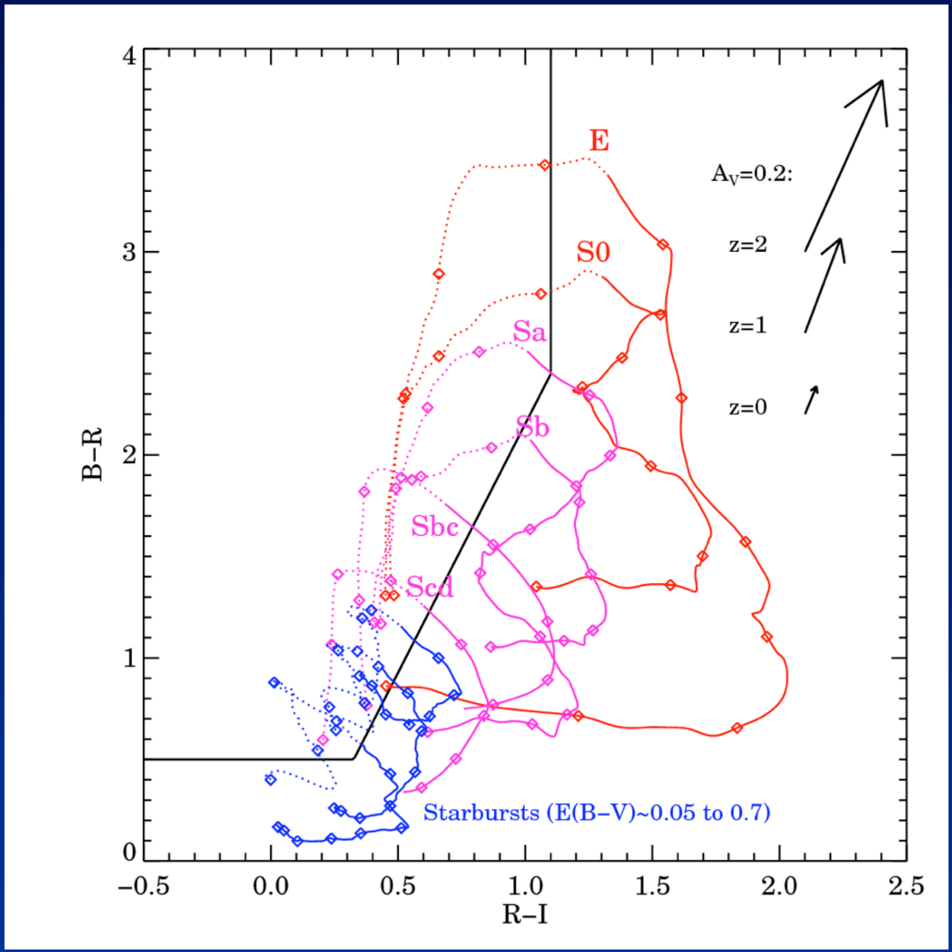
Redshift success (Q=4 ONLY) rate

Newman et al. 2012

Redshift Success in DEEP2 color-color diagrams

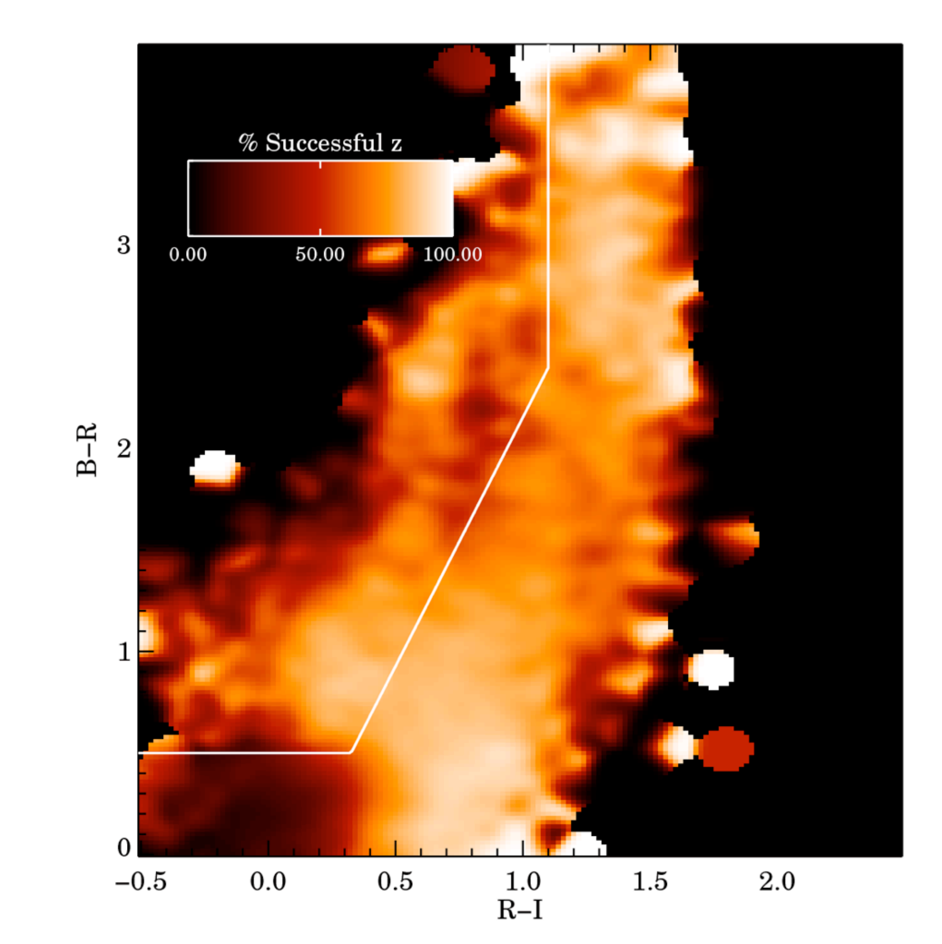


Observed color-color diagram for DEEP2 targets (in EGS, so no color cut)

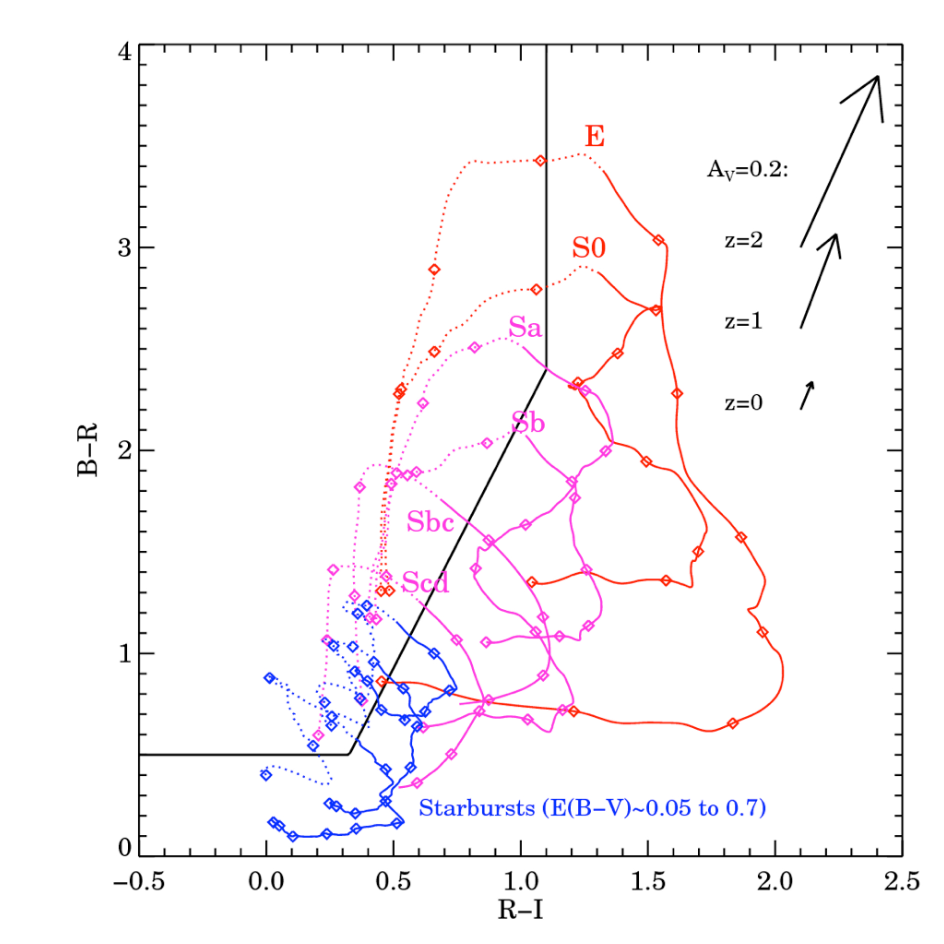


CWW tracks through CMD (dot-solid transition at z=0.7, diamonds every 0.2 in *z*)

Redshift Success in DEEP2 color-color diagrams



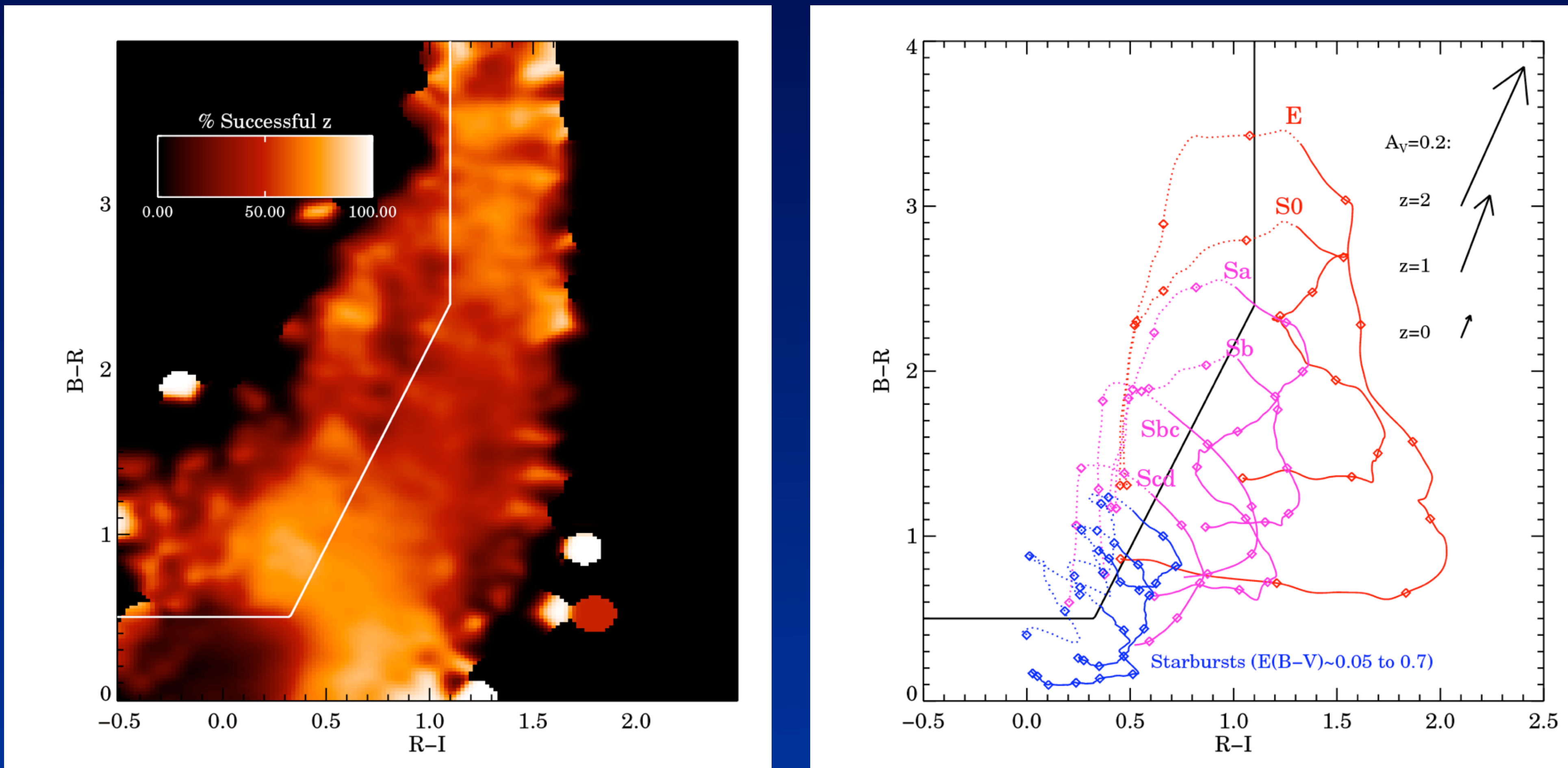
Success (Q=3 or 4) rate for DEEP2; <90% in best regions



CWW tracks through CMD

Newman et al. 2012

Redshift Success in DEEP2 color-color diagrams

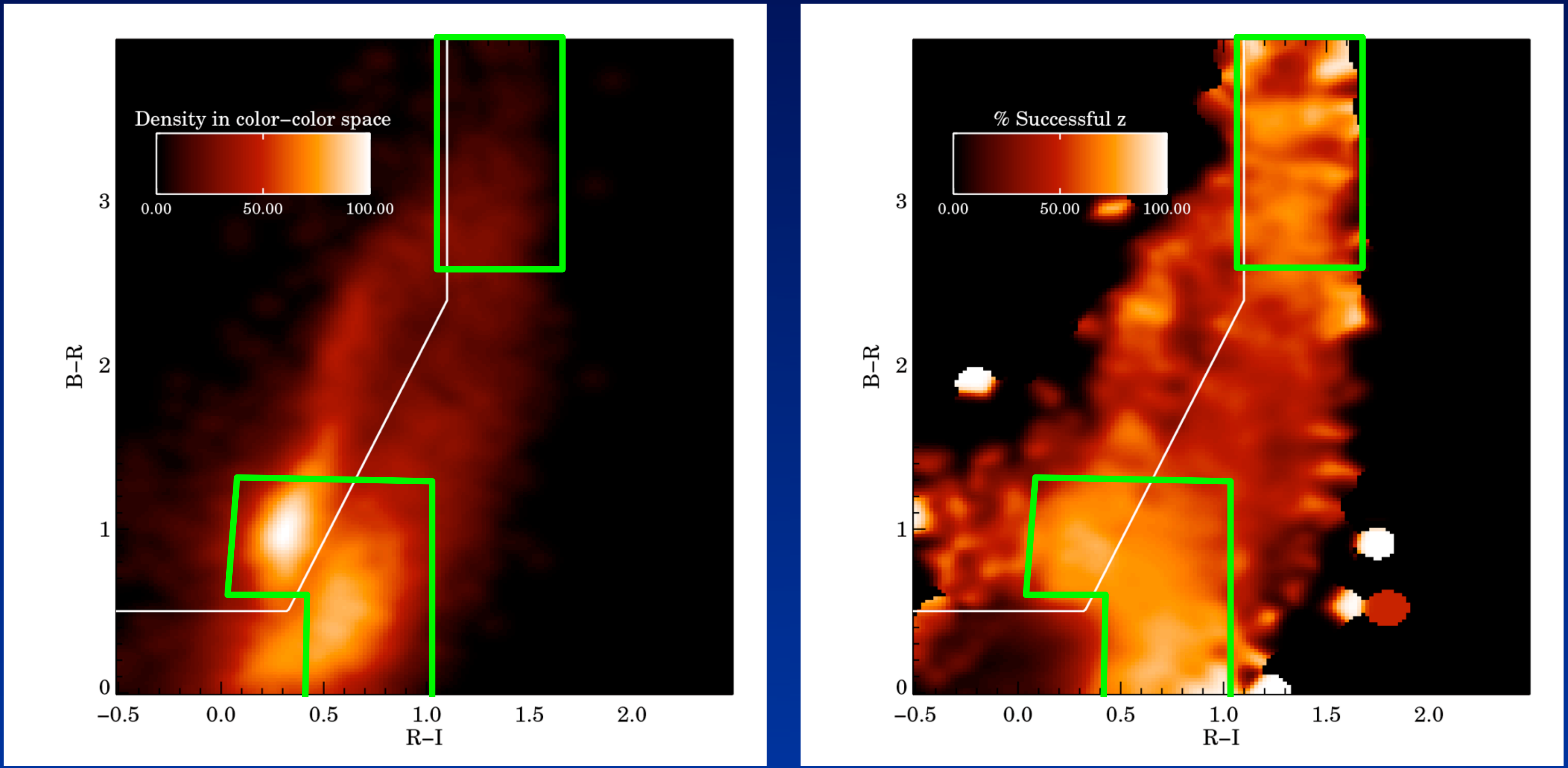


Success (Q=4 ONLY) rate for DEEP2; <80% in best regions

CWW tracks through CMD

Newman et al. 2012

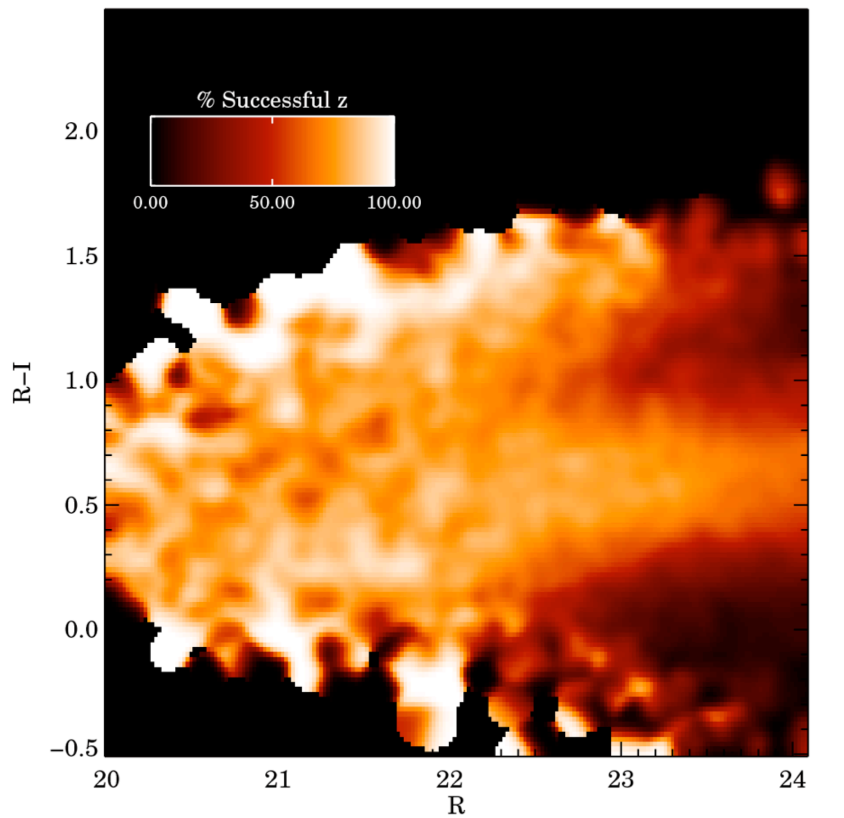
Restricting to 'good' parts of color space bears significant cost - and still has substantial failure rate

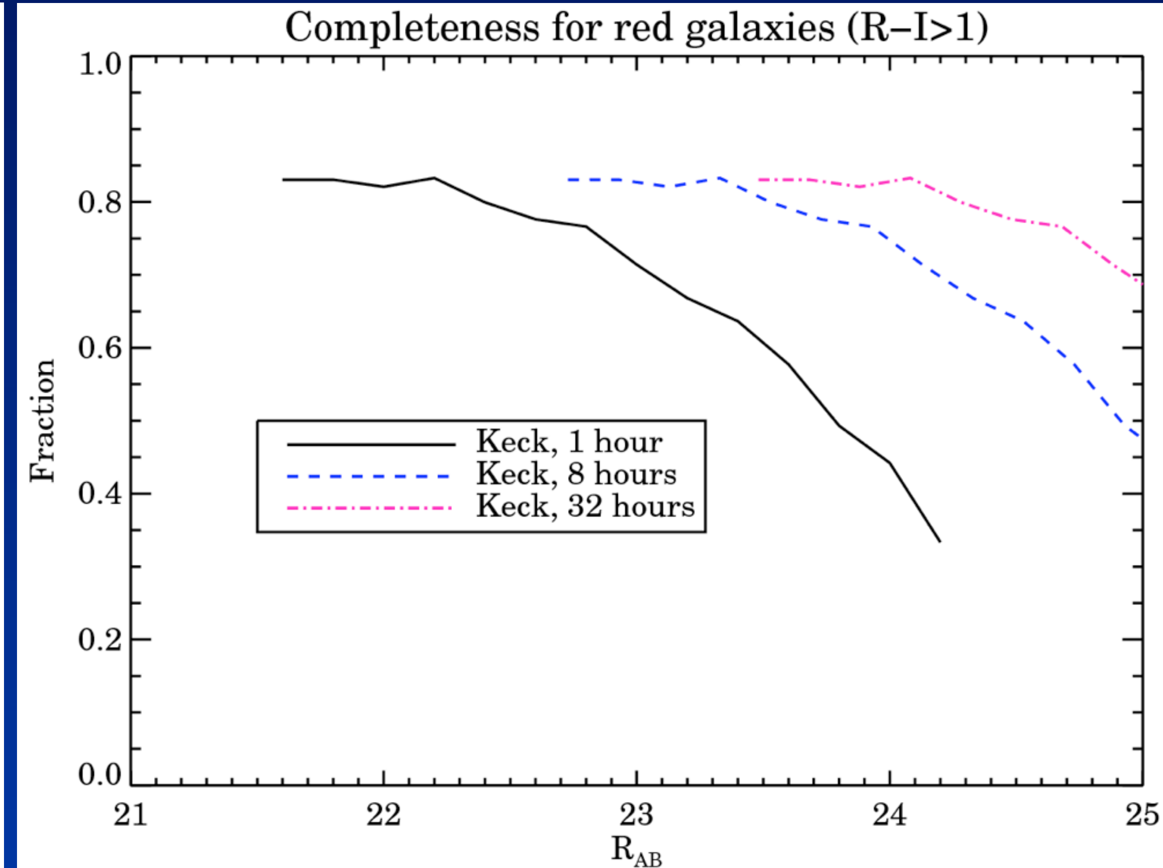


The regions with 'good' redshift success contain ~60% of R_{AB} < 24.1 objects.

32 Keck hours/spectrum is required to get good completeness for red galaxies to *r*=24.1 (*i*~23)

- ≈ **25 NIGHTS** with DESpec
- Achieving that completeness to *i*=24 would take >6x longer!

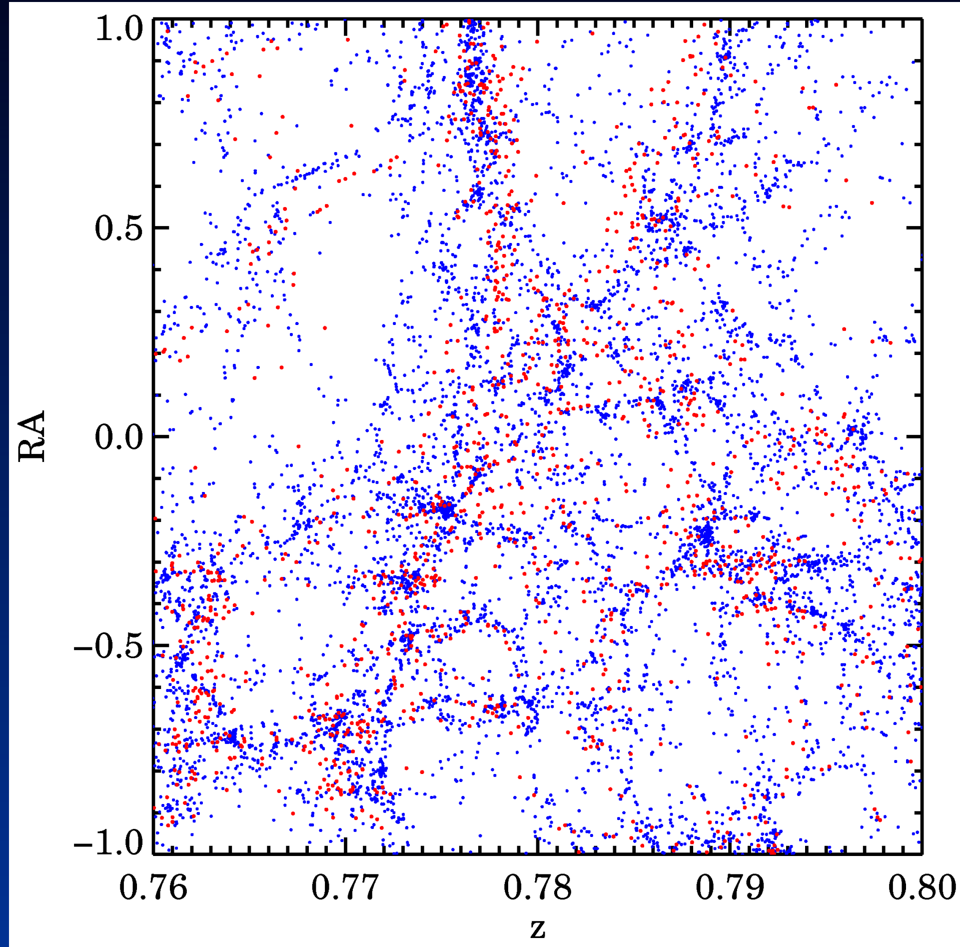




DES should not assume that full training sets will be available for machine-learning/weighting photo-z methods !!!

Cross-correlation methods: exploiting redshift information from galaxy clustering

- **Galaxies of all types cluster together: trace same dark matter distribution**
- **Galaxies at significantly different redshifts do not cluster together**
- **From observed clustering of objects in one sample with another (as well as information from their autocorrelations), can determine fraction of objects in overlapping redshift range**

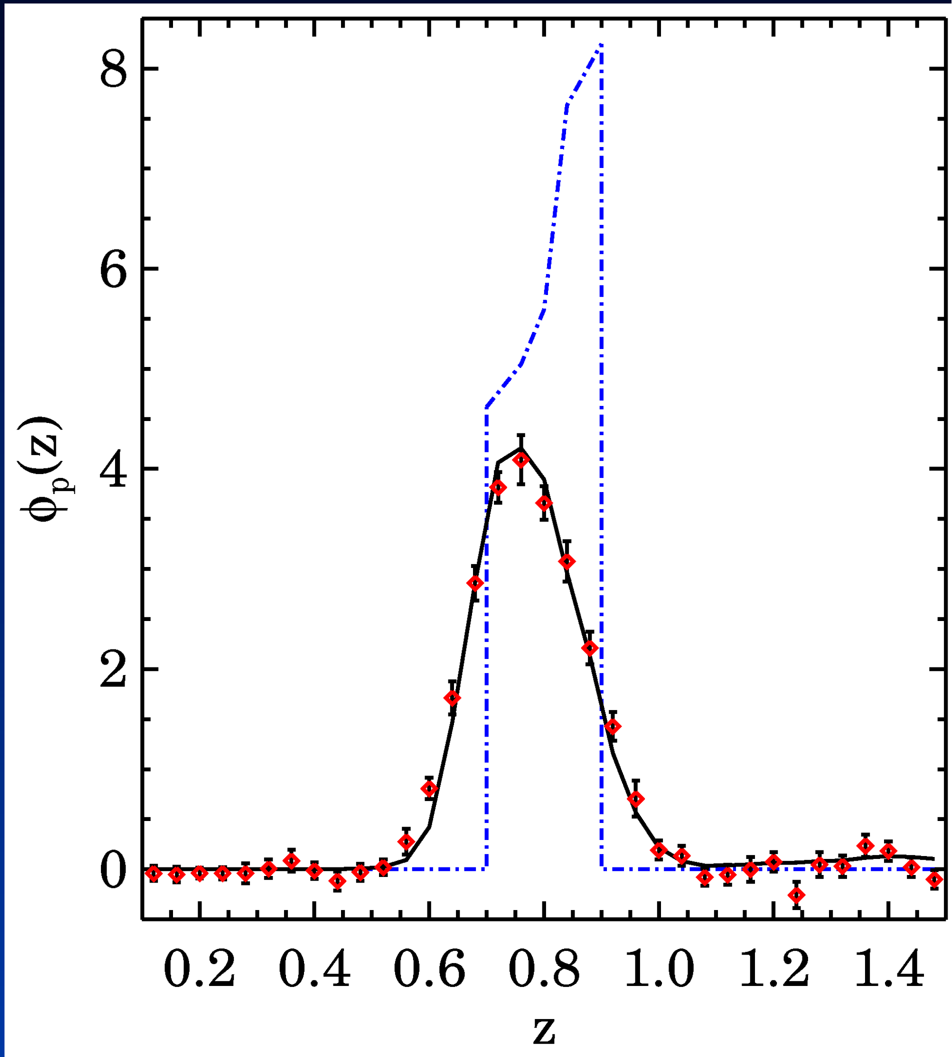


Photometric sample (e.g. DES)

Spectroscopic sample (e.g. DEEP2)

Detailed redshift distribution can be obtained by cross-correlating with spectroscopic samples

- **Key advantage: spectroscopic sample can be systematically incomplete and include only bright galaxies**
- **See: Newman 2008, Ho et al. 2008, Matthews & Newman 2010, 2012**

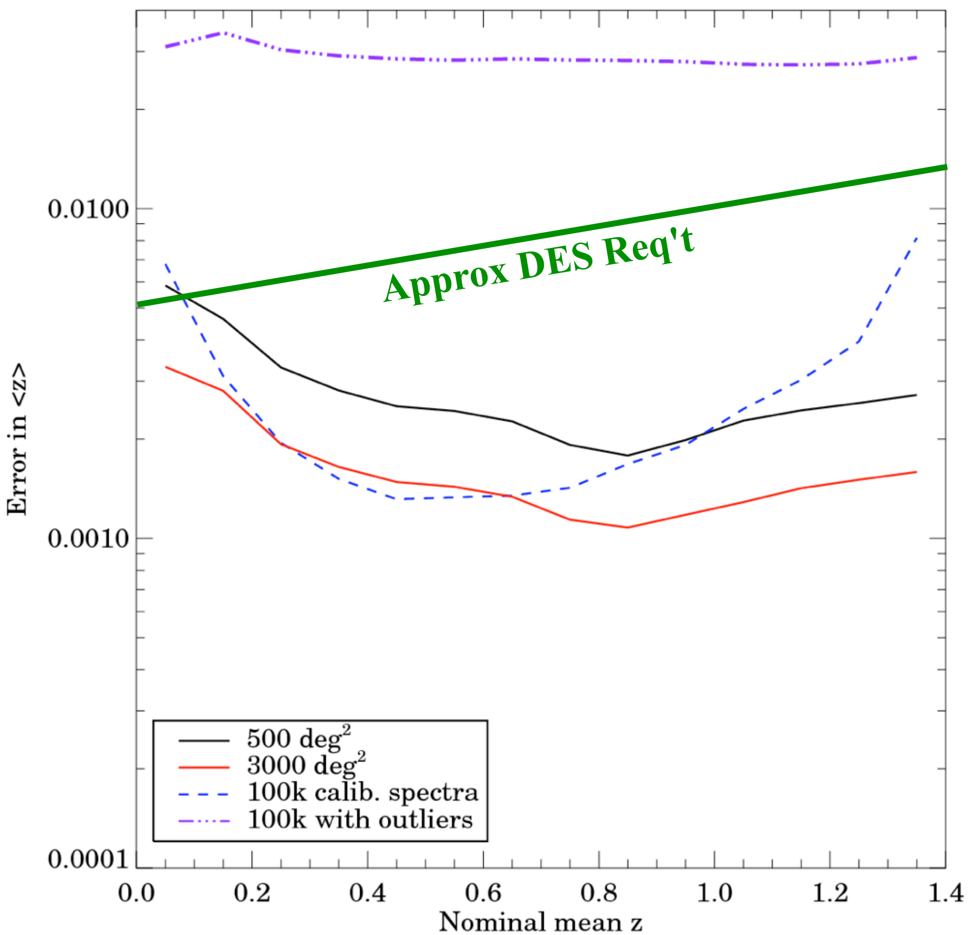


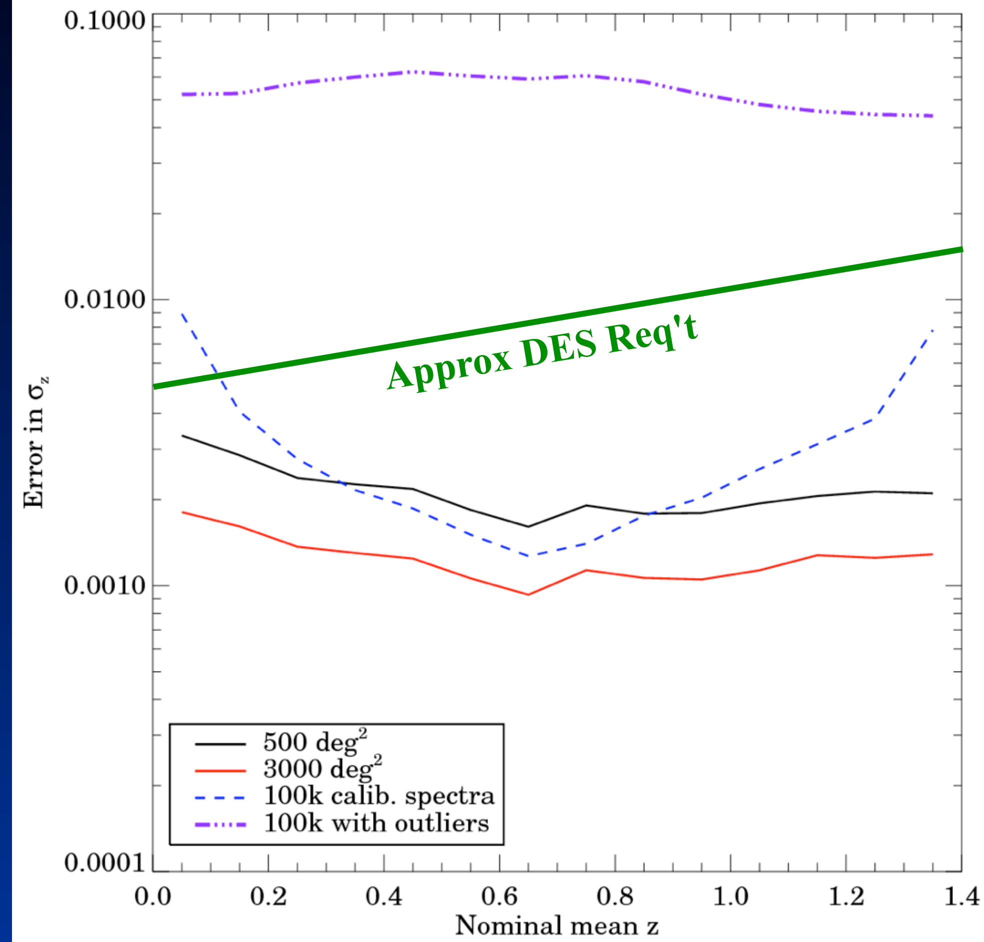
Blue: z_{phot} distribution of objects with $0.7 < z_{phot} < 0.9$

Black: True z distribution of sample, spanning 24 widely-separated fields

Red: Cross-correlation reconstruction with only a R<24, 4 deg^2 survey

Cross-correlation methods can outperform even ideal conventional calibration samples

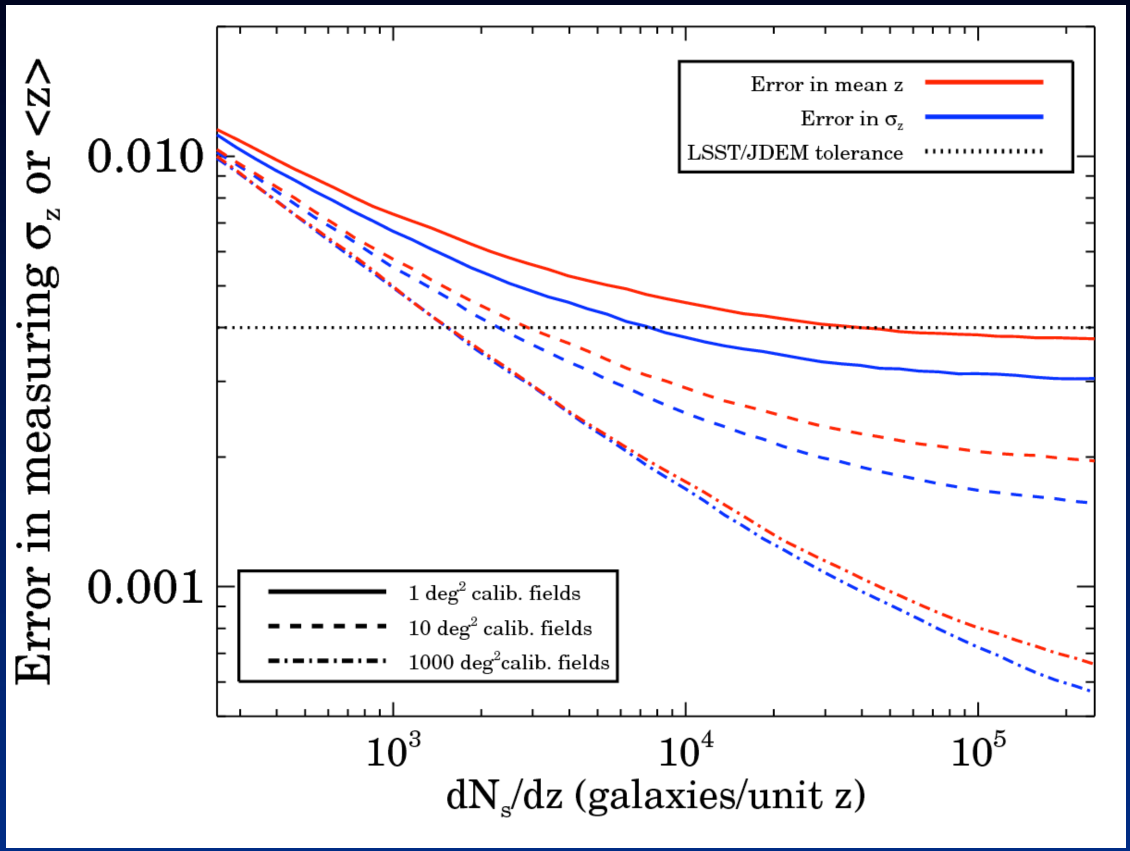




Plots from BigBOSS-DES WG report (Weinberg et al. 2012). 500 or 3000 deg^2 of BigBOSS overlap vs. 100% complete sample of 100k spectra following DES z distribution

Spectroscopic requirements for cross-correlation methods

- Error model tested with Millennium mock catalogs
- Example: spectra are obtained in 4 fields, and used to characterize a photo-z bin at z=1 with $\sigma_z = 0.05$ and Σ =10 objects/arcmin^2 (errors scale roughly as $\sigma_z^{1.4}\ \Sigma^{-0.5}$)



- For areas > few deg^2, few tens of thousands of spectra per unit *z* are required to calibrate LSST
- Wider surveys with more spectra will allow us to do even better (e.g. characterize z distribution for smaller samples)

Conclusions

- Current/ongoing deep data sets are not sufficient to calibrate Stage III/IV programs with conventional techniques:
    - Failure rates 10% at best, >50% at fainter end of DES
    - Incorrect "successful" z's cause unacceptable calibration errors
    - Extremely long exposures needed to get ~10% failure rate at *i*=24
    - These are especially large problems for training-set/machine-learning based photo-z methods!
- Using cross-correlation techniques, reasonably-sized, “easy”-to-obtain spectroscopic datasets can determine redshift distributions for photometric samples with precision sufficient for DES or LSST. For DES, ~1000 deg^2 overlap with eBOSS may be sufficient.
- Larger samples covering wider areas are especially valuable - DESpec or BigBOSS!
- See Newman 2008 and Matthews & Newman 2010, 2012 for details and recipes; DEEP2 DR4 at http://deep.berkeley.edu/DR4

DEEP2 Redshift Quality vs. magnitude