Dark Energy Science Collaboration Photometric Redshift Plans

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DESC Photo-z Plans

Multi-pronged approach to characterizing/improving photo-z methods and results

- **Series of three simulations/Data Challenges leading up to data from ComCam, used as testbed for pipeline development**
- **Determination/storage of p(z), p(z,[x]) for analysis groups**
- **Develop/test cross-correlation calibration method**
- **Investigate mitigation of blending/foreground systematic effects, inclusion of NIR data**
- **Obtaining the necessary training/calibration data sets**

We have made it a point of emphasis to include the analysis working groups from the beginning to make sure that what we are producing is actually what they need

DESC Photo-z Plans

LSST Project scope does not include photo-z algorithm development. That task has been taken on by the DESC Photo-z working group.

Many science cases require extremely well-calibrated redshift distributions.

Accurate probability distributions, and in many cases p(z, [α]), will enable DESC and other LSST Science Collaborations to *optimize* their science.

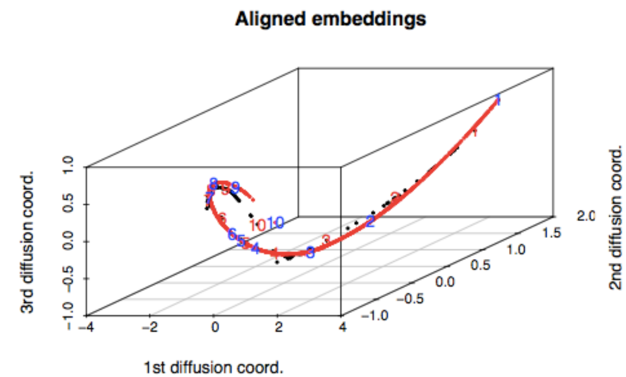
The DESC Photo-z working group is developing the infrastructure to meet all these demands.

Simulations/Data Challenges

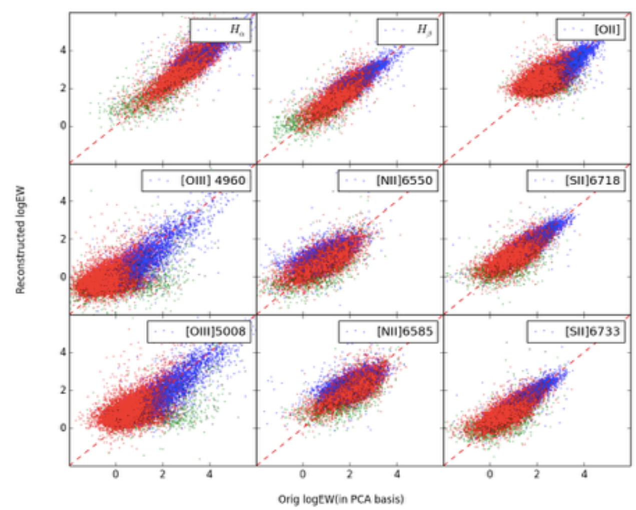
Three data challenges with increasingly sophisticated and realistic data sets. ugrizy (+NIR) photometry for input to photo-z codes.

- **DC1: Idealized data (simple error model, no foregrounds, no blending). For DC1 tests we need perfect knowledge of templates/training sets, so we map SEDs to continuous version of Brown empirical spectra. Add emission lines with model based on Beck et al. (2016). 2nd Sim: Buzzard simulations with empirical SEDs from SDSS.**

- **Key deliverables: Tests of accuracy of p(z) as a PDF with perfect template knowledge; develop p(z) storage methods; basic forecasts of best-case performance**



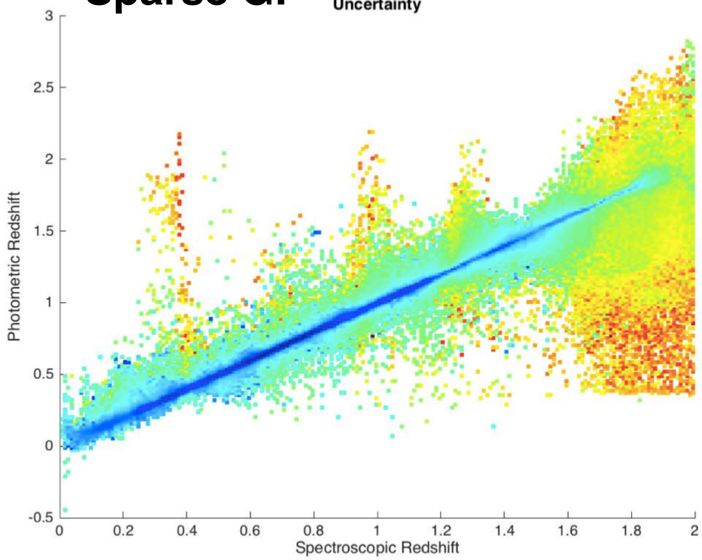
Shin, Lee, Freeman, in prep



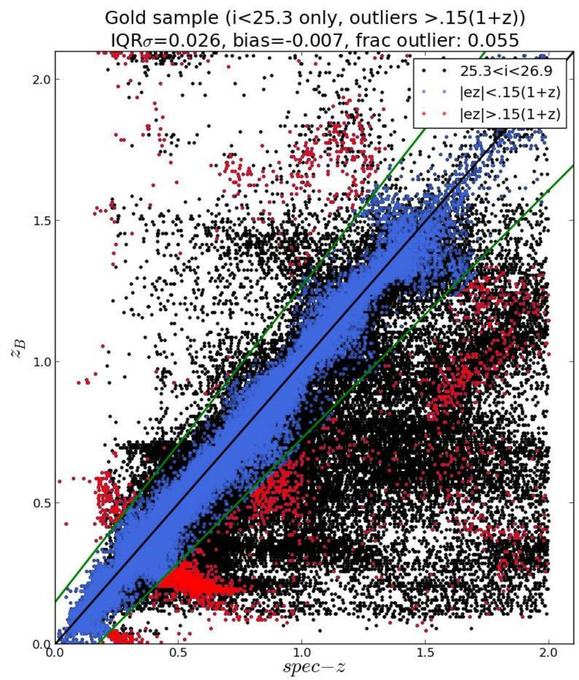
Liu, Schafer, et al., in prep

DC1 Preliminary Results

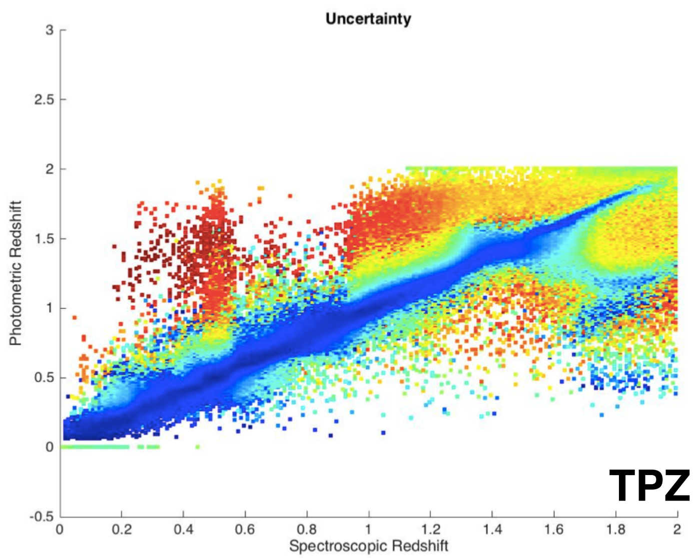
Sparse GP



BPZ w/default prior

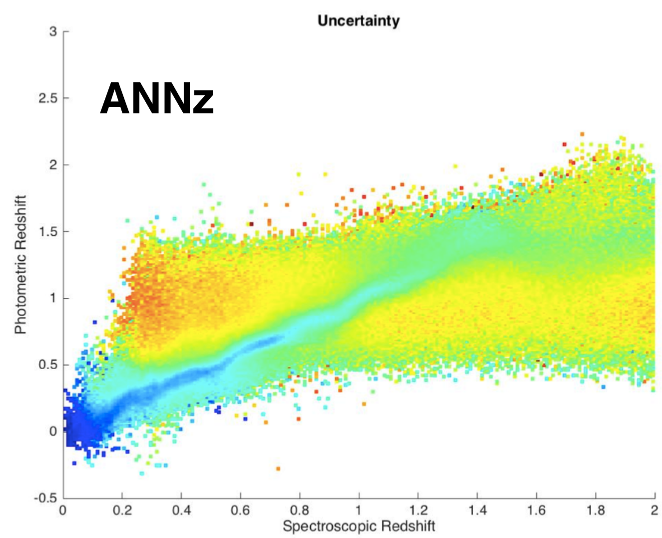


10^6 Buzzard galaxies with i<27.0 z<2.0



TPZ

ANNz



Simulations/Data Challenges

- **DC2: Add imperfections: systematic photometric errors, incompleteness in spectroscopic training sets (e.g. model failures based on emission lines, stellar mass, restframe color, sSFR), some foreground effects**

- **Key deliverables: Tests of cross-correlation calibration method; investigations of methods of mitigating incompleteness and blending effects; improved p(z) estimates for analysis groups**

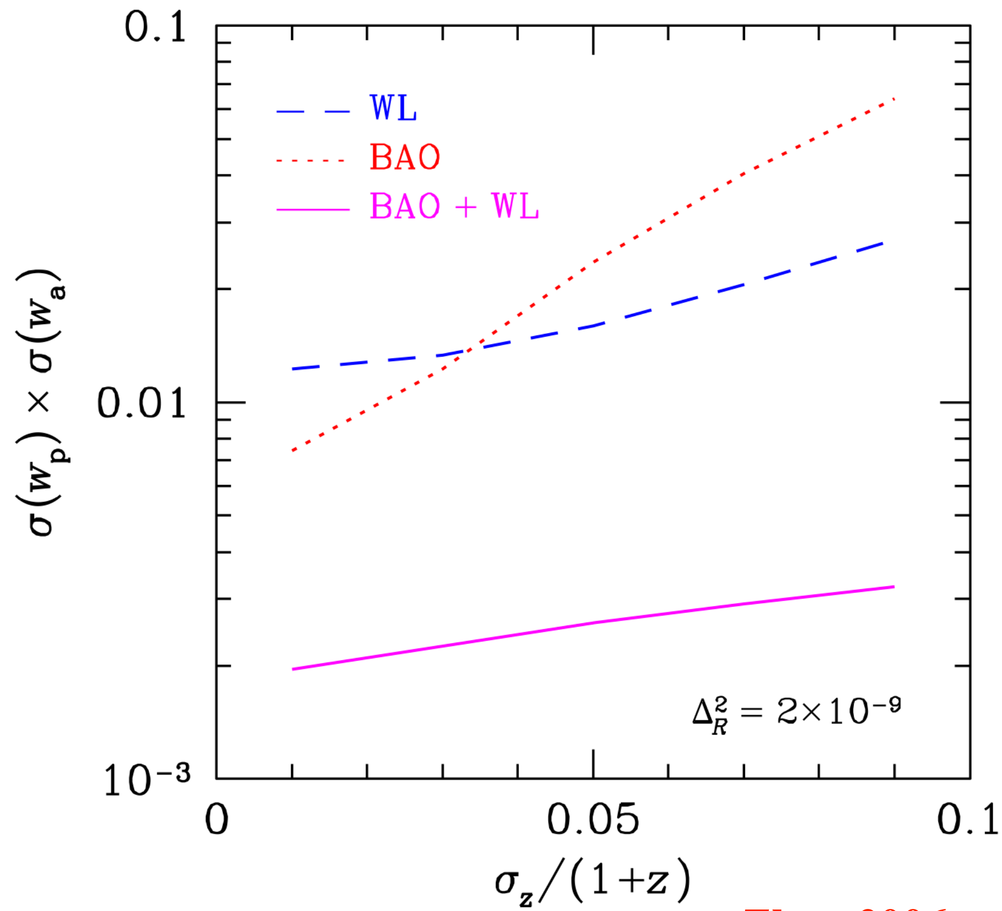
Simulations/Data Challenges

- **DC3: Full image based simulation, including blending, magnification, foregrounds, improved SEDs**

- **Key deliverables: End-to-end pipeline for photo-z computation with improved algorithms; first proposals for spec-z training samples; develop p(z) and p(z,[α]) storage methods; prepare to run on ComCam data**

Two ways we use spectroscopy: training and calibration

- **Training**: Reducing errors in *individual object* photo-z's by improved templates (i.e. knowledge of SED-redshift relation) or larger set of training data with z's
- Better-trained algorithms yield smaller RMS errors: improves DE constraints, esp. for BAO and clusters

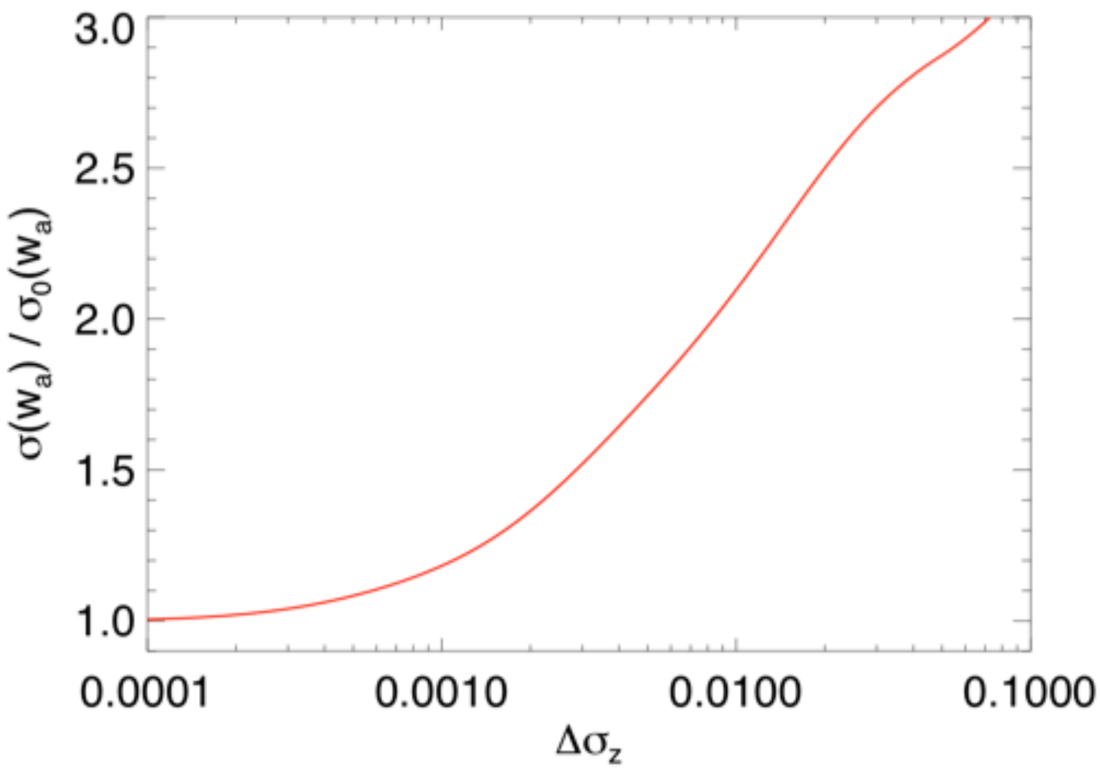


Zhan 2006

– Training datasets can contribute to calibration of photo-z's. ~Perfect training sets (systematic failure rates <~0.1-1%) would solve calibration needs; this is the primary *WFIRST* photo-z calibration strategy (use clean portions of color space only).

Two ways we use spectroscopy: training and calibration

- For weak lensing and supernovae, individual-object photo-*z*'s do <u>not</u> necessarily need high precision, but their calibration must be accurate - i.e., overall bias and errors (or redshift distributions) need to be extremely well-understood



Newman et al. 2013

– *uncertainty in* bias, $\sigma(\delta_z) = \sigma(\langle z_p - z_s \rangle)$, and *uncertainty in* scatter, $\sigma(\sigma_z) = \sigma(\mathrm{RMS}(z_p - z_s))$, must both be <~0.002(1+*z*) for Stage IV surveys

Minimum requirements for training spectroscopy: cf. Newman et al. 2015 for details

- Sensitive spectroscopy of >~30,000 faint objects (to *i*=25.3)
  - Based on estimates from a variety of theory papers
  - Needs a combination of large aperture, long exposure times, and high multiplexing
- Coverage of full ground-based spectral window
  - Ideally, from below 4000 Å to ~1.3μm
- Significant resolution ($R=\lambda/\Delta\lambda>\sim4000$) at red end
  - Allows secure redshifts from [OII] 3727 Å line at z>1
- Field diameters > ~20 arcmin
  - Need to span several correlation lengths for accurate clustering
- Many fields, >~15, to mitigate sample/cosmic variance
  - 15 0.1 deg^2 fields have ~same variance as six 1 deg^2 fields.
- If all of these are achieved, AND highly-secure redshifts are measured for >99+% of targets, the training set can also calibrate LSST at the needed accuracy.

Summary of (some!) potential instruments

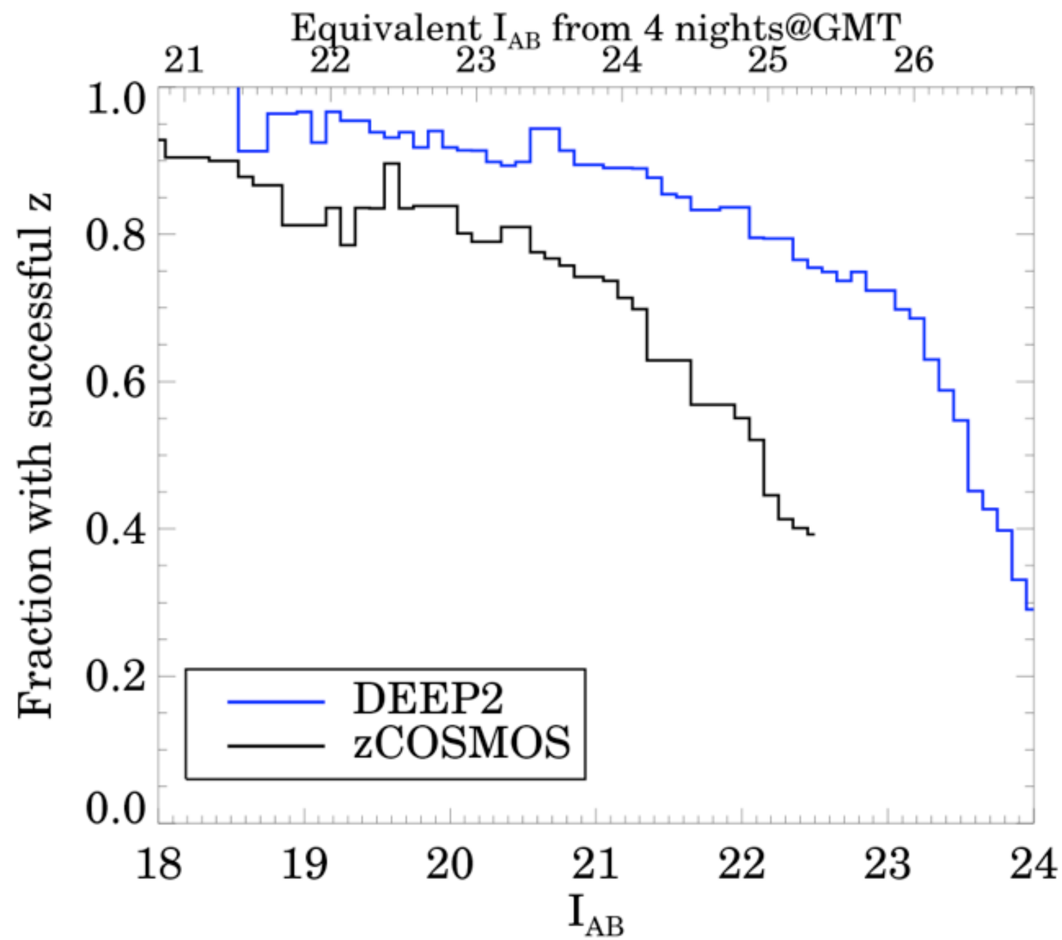
Telescope / Instrument	**Collecting Area (m^2)**	**Field area ($arcmin^2$)**	**Multiplex**	**Limiting factor**
Keck / DEIMOS	76	54.25	150	Multiplexing
VLT / MOONS	58	500	500	Multiplexing
Subaru / PFS	53	4800	2400	# of fields
Mayall 4m / DESI	11.4	25500	5000	# of fields
WHT / WEAVE	13	11300	1000	Multiplexing
VISTA / 4MOST	10.7	14400	1400	Multiplexing
GMT/MANIFEST+GMACS	368	314	420-760	Multiplexing
TMT / WFOS	655	40	100	Multiplexing
E-ELT / MOSAIC	978	39-46	160-240	Multiplexing
Keck / FOBOS	76	314	500	Multiplexing
MSE	98	6360	3200	# of fields
Magellan / MAPS	32	6360	5000	# of fields

Time required for each instrument (in years of dark+grey time)

Telescope / Instrument	Total time(y), DES / 75% complete	Total time(y), LSST / 75% complete	Total time(y), DES / 90% complete	Total time(y), LSST / 90% complete
Keck / DEIMOS	0.51	10.2	3.2	64
VLT / MOONS	0.20	4.0	1.3	25
Subaru / PFS	0.05	1.1	0.34	6.9
Mayall 4m / DESI	0.26	5.1	1.6	32
WHT / WEAVE	0.45	9.0	2.8	56
VISTA / 4MOST	0.39	7.8	2.4	48
GMT/MANIFEST+GMACS	0.02 - 0.04	0.42 - 0.75	0.13 - 0.24	2.6 - 4.7
TMT / WFOS	0.09	1.8	0.56	11
E-ELT / MOSAIC	0.02 - 0.04	0.50 - 0.74	0.16 – 0.23	3.1 - 4.7
Keck / FOBOS	0.12	2.3	0.72	14
MSE	0.03	0.60	0.19	3.7
Magellan / MAPS	0.09	1.8	0.56	11

DESC plans do not assume that training set will necessarily enable accurate calibration

- In current deep redshift surveys (to i~22.5/R~24), 25-60% of targets fail to yield secure (>95% confidence) redshifts
- Redshift success rate depends on galaxy properties - losses are systematic, not random
- Estimated need 99-99.9% completeness to prevent systematic errors in direct calibration
- Incorrect-z rates also need to be <1%



Data from DEEP2 (Newman et al. 2013) and zCOSMOS (Lilly et al. 2009)

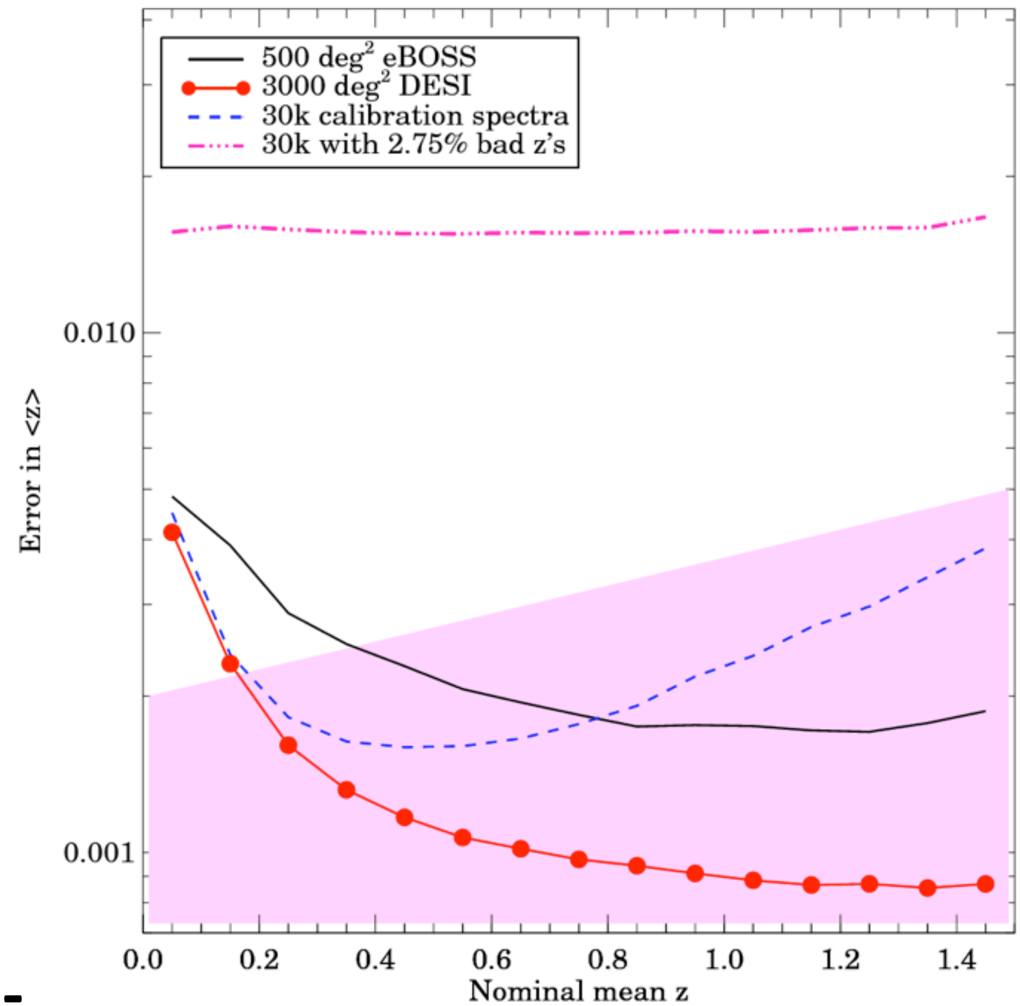
Instead, expectation is that we will need to utilize cross-correlation calibration methods

- Galaxies of all types cluster together: trace same dark matter distribution

- Enables reconstruction of *z* distributions via spectroscopic/ photometric cross-correlations (Newman 2008)

- For LSST calibration, require >100k objects over >100 deg^2, spanning full z range

- >500 degrees of overlap with DESI-like survey would meet LSST science requirements (>4000 sq deg of overlap expected)



Snowmass white paper: *Spectroscopic Needs for Imaging DE Experiments* (Newman et al. 2015, http://arxiv.org/abs/1309.5388)

Key Challenges

- Testing that p(z), p(z,α) are accurate
- Combining photo-z's from multiple algorithms and/or developing a "definitive" photo-z algorithm
- Optimizing spectroscopic samples & dealing with spectroscopic incompleteness
- Methods for training algorithms that are robust to false "secure" redshifts
- Storage of multidimensional redshift PDF info
- Joint processing of LSST/WFIRST data for photo-z's is non-trivial

Some Questions for Discussion

- How can we best take advantage of/combine the efforts from LSST + *WFIRST* groups working on simulation tools? Photo-z methods?

- What are the requirements for LSST + *WFIRST* photo-z performance? Or, conversely, what information on photo-z performance do analysis groups need in order to forecast their cosmology constraints and develop pipelines?

- How do we work together to maximize utility/ minimize duplication in spectroscopic samples?

Bonus slides

LSST & WFIRST Weak Lensing DETF FoM will be >1.6x larger if can train at z>2 with WFIRST IFC

A bigger issue for WFIRST WL: J or H-limited sample skews to higher z!

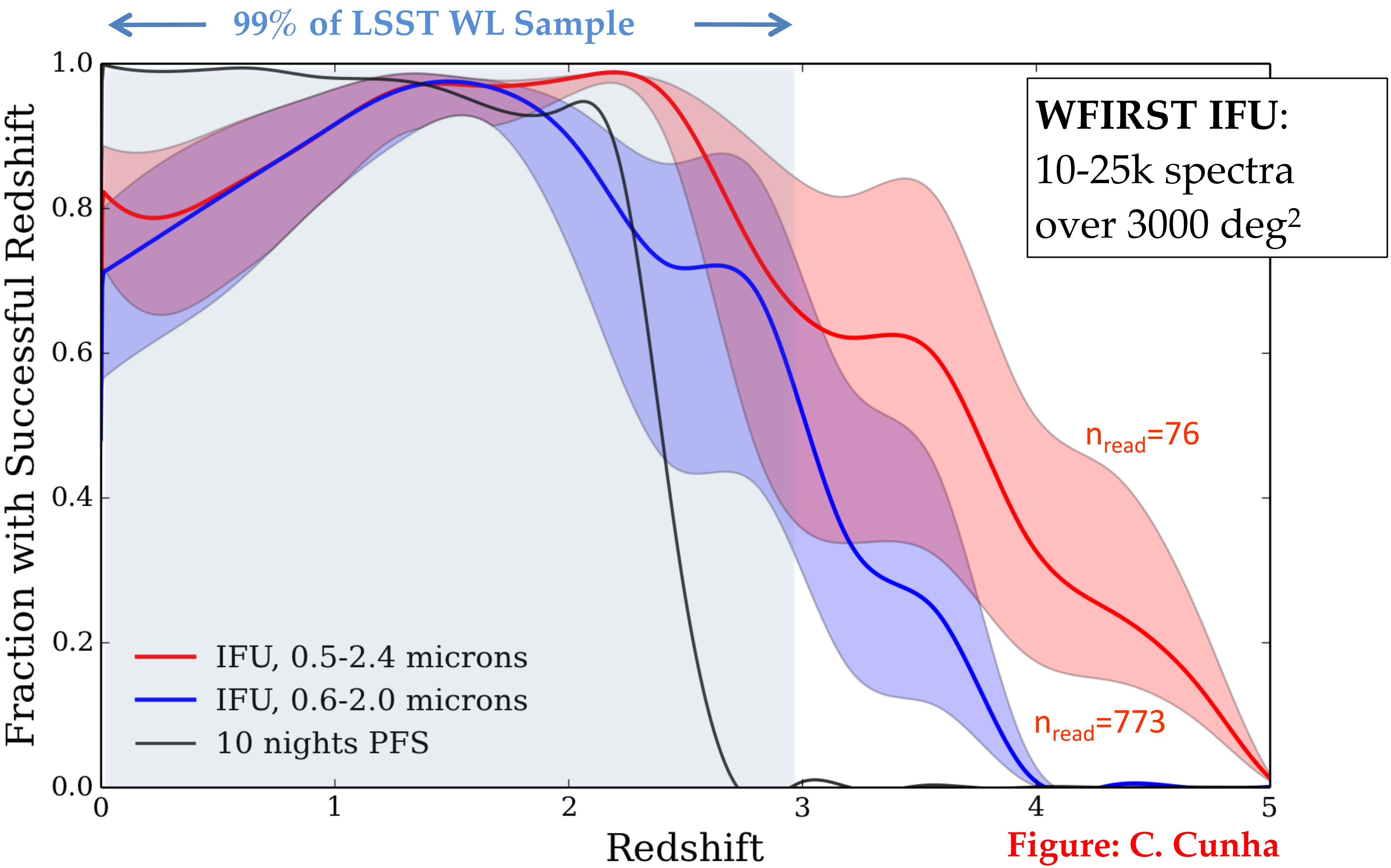
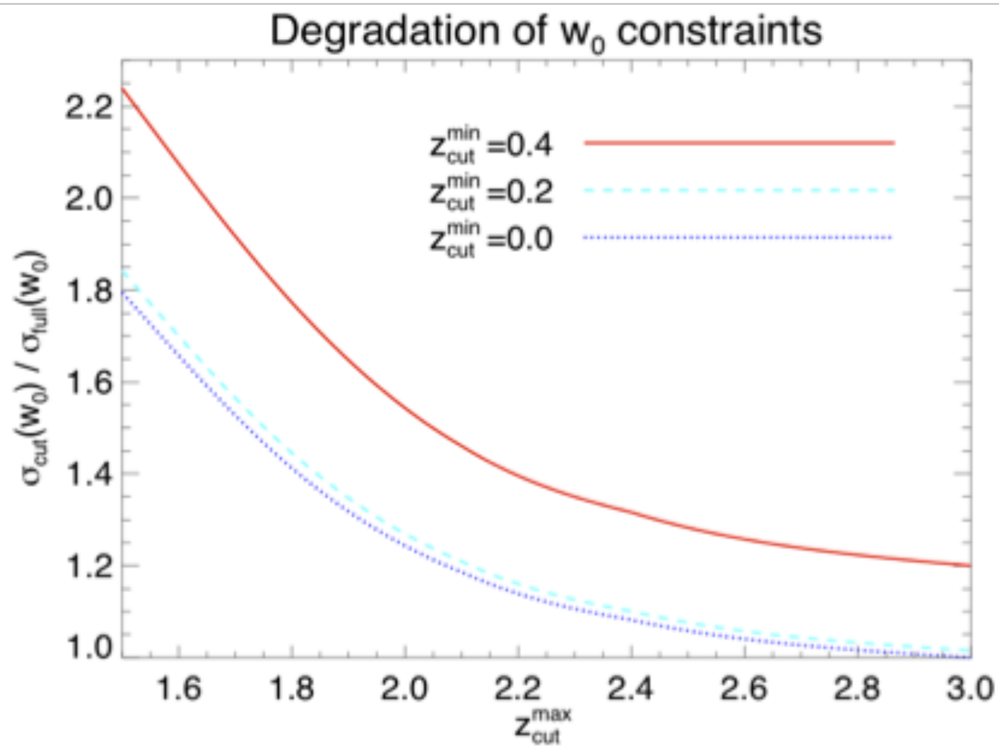


Figure: C. Cunha

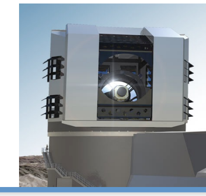
WFIRST IFC can enable dark energy constraints from the high-redshift tail of the *z* distribution

- For LSST, DE FoM is ~40% worse if have to throw out z>2, ~20% worse if only cover z<2.5
- WFIRST skewed to higher z: 40%/20% FoM degradation for training to z=2.6/2.9
- >70% lower FoM if WFIRST cannot work at z>2
- Expect ~20" dither freedom in each direction: can choose amongst ~5 objects in WFIRST or LSST weak lensing sample per HLS pointing for spectroscopy



Hearin et al. 2012
(LSST-like scenario)

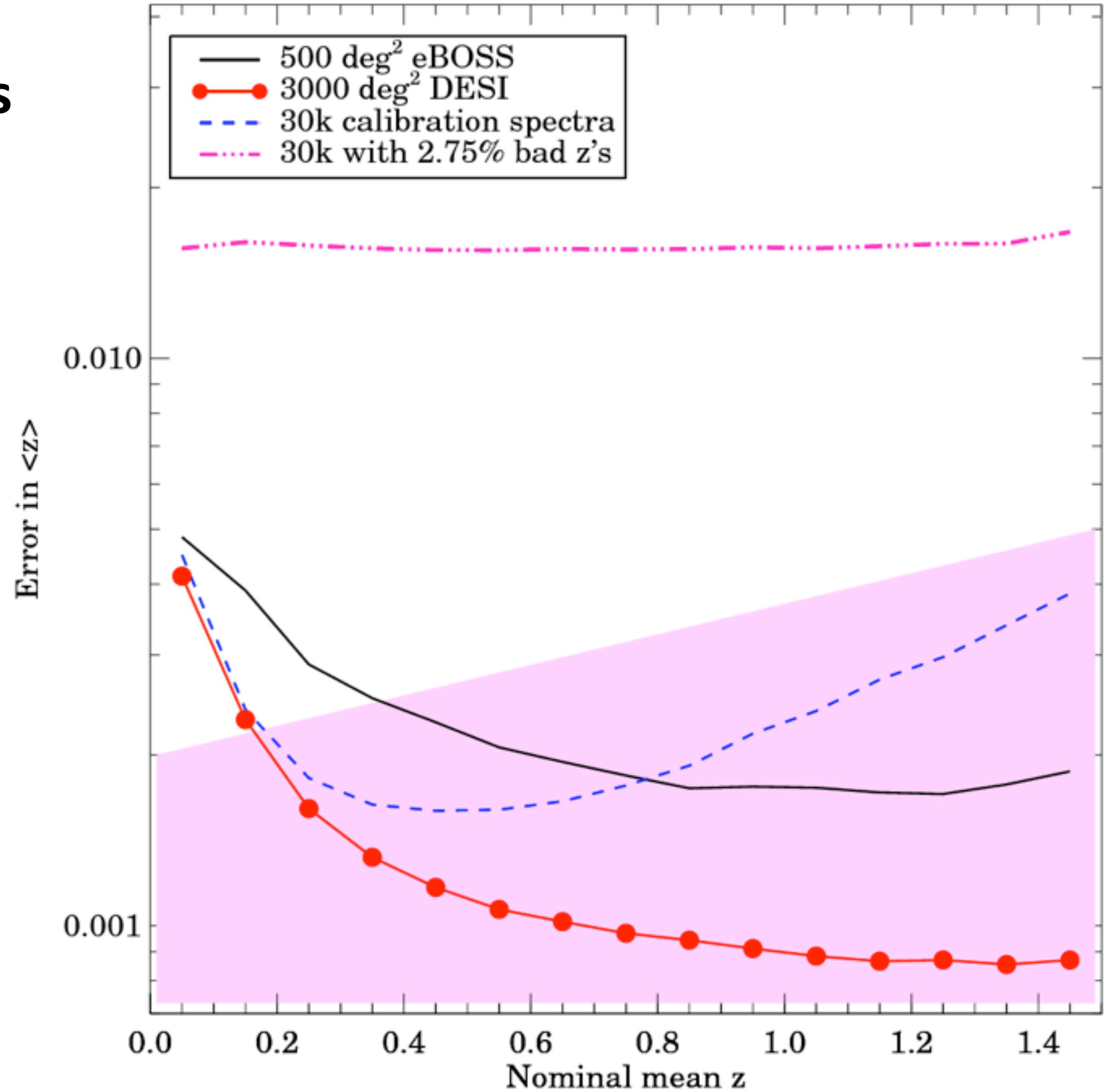
Grism spectroscopy should contribute to cross-correlation analyses



- To reach LSST calibration requirements, require >100k objects over >100 sq. degrees, spanning z range of sample (cf. Matthews & Newman 2010)

- >500 square degrees of overlap with DESI-like survey enables cross-correlation calibrations to meet Stage IV requirements

- **WFIRST grism redshifts should only be better for this than DESI QSOs at z~1.5-3.** Redshift range will be limited by need for multiple emission lines for secure z's, however. Broader wavelength range is better.



Snowmass White Paper: Spectroscopic Need
for Imaging DE Experiments