DARK ENERGY SURVEY

The Impact of Spectroscopic Incompleteness for Weak Lensing Surveys

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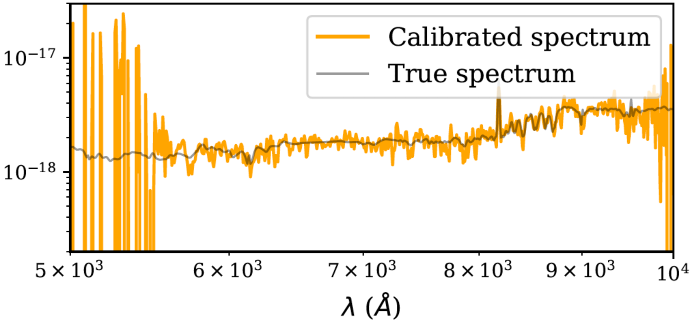
with **Chihway Chang** (KICP), **Soniya Samani** (QMU, Oxford)

and the Dark Energy Survey



https://arxiv.org/abs/2003.10454v1

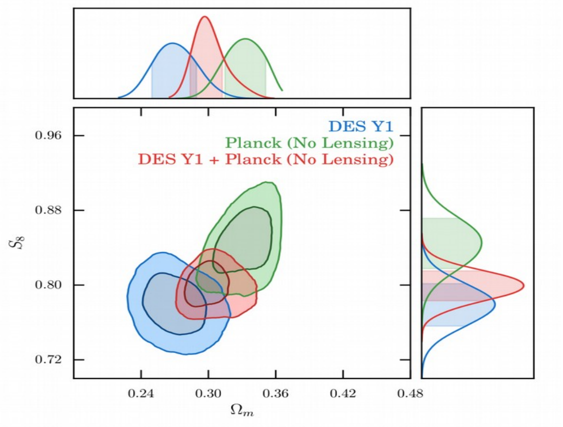
GCCL seminar, May 8th 2020

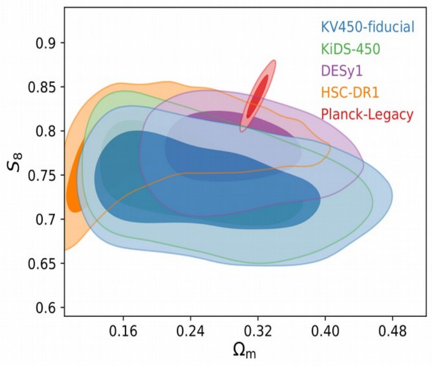
Cosmology is done*

(* Not really)

- ΛCDM model is an exceptional fit to measurements of the CMB!
- But tells us little about Dark Energy, if it evolves with time.
- Model is phenomenological: we don't know what dark matter or dark energy are!
- Late time probes of cosmological parameters agree *marginally* with Planck ΛCDM - or perhaps not!
- Tantalising possibility of missing physics, but a lot of hard work before we get an answer.

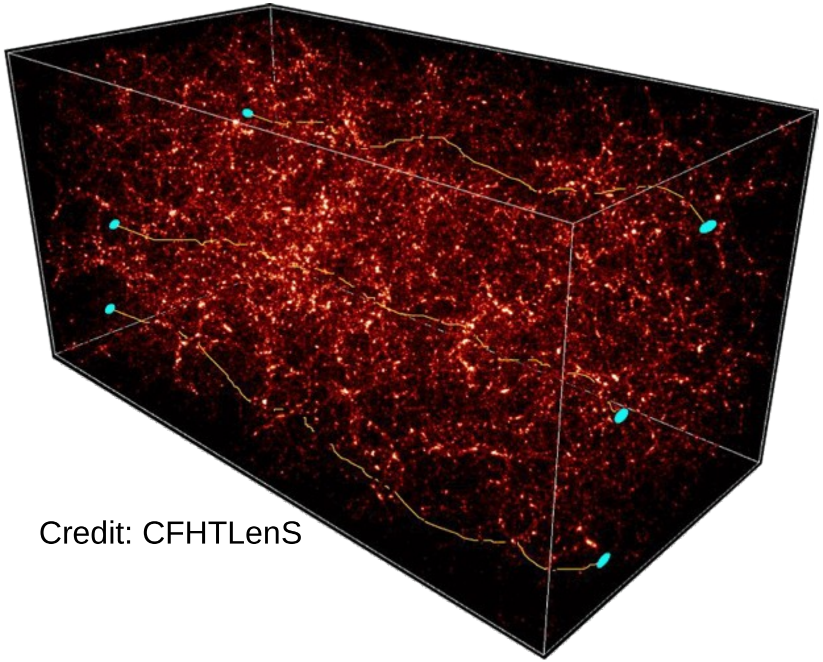
Dark Energy Survey et al. (2018)





Hildebrandt et al. (2019)

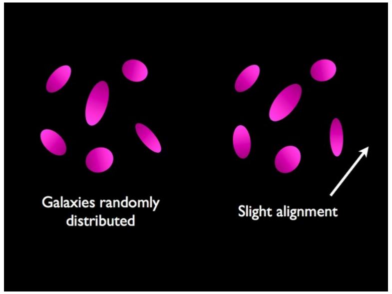
Cosmology from cosmic shear



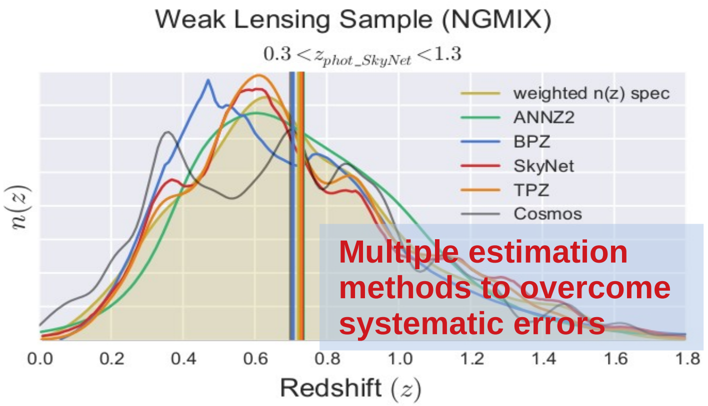
Credit: CFHTLenS

Two ingredients:

1) Shear correlation function



2) Redshift distribution(s)

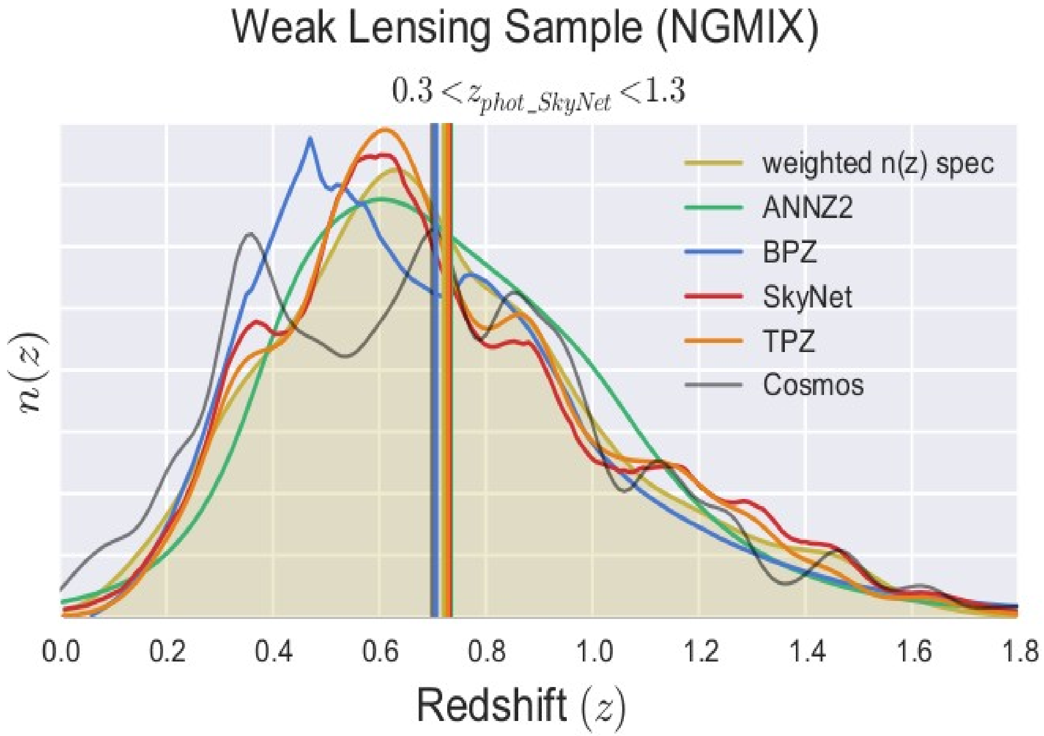


Bonnett, Troxel, Hartley, Amara & DES (2016)

DES Science Verification analysis – photo-z methods

- Machine learning (TPZ, SkyNet, ANNz2)
- Template fitting (BPZ + sim. calibration)
- Lima-like spectroscopic re-weighting
- Cosmos-30 band photo-z (Ilbert+ 2009)
- Each method contains systematic uncertainties.

  → mean-z accurate to ~0.05 * (1+z) per bin.



Bonnett, Troxel, Hartley, Amara & DES (2016)

The Dark Energy Survey – Y1 analysis

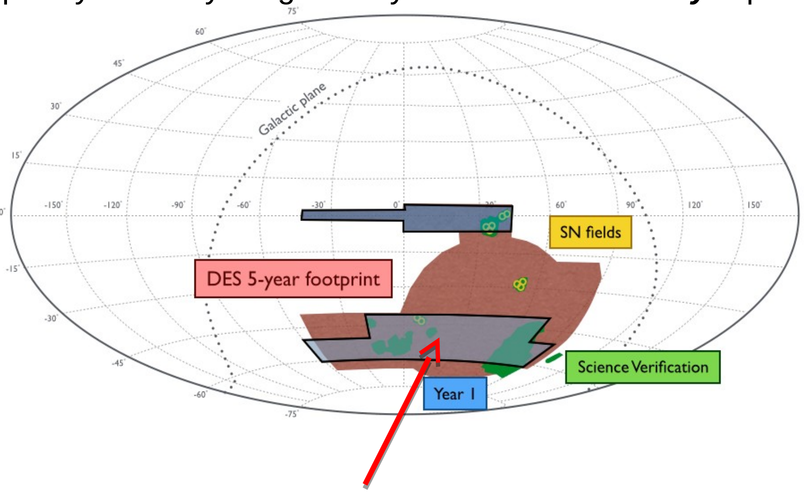
Wide-Field Survey (c. 5000 sq deg):
- 90 sec exposures in *griz*;
- 45 sec exposures in *Y*

Typically 2 survey tilings/filter/year

Supernova Survey (c. 30 sq deg):
- 150-200 sec exp's in *griz* (shallow)
- 200-400 sec exp's in *griz* (deep)

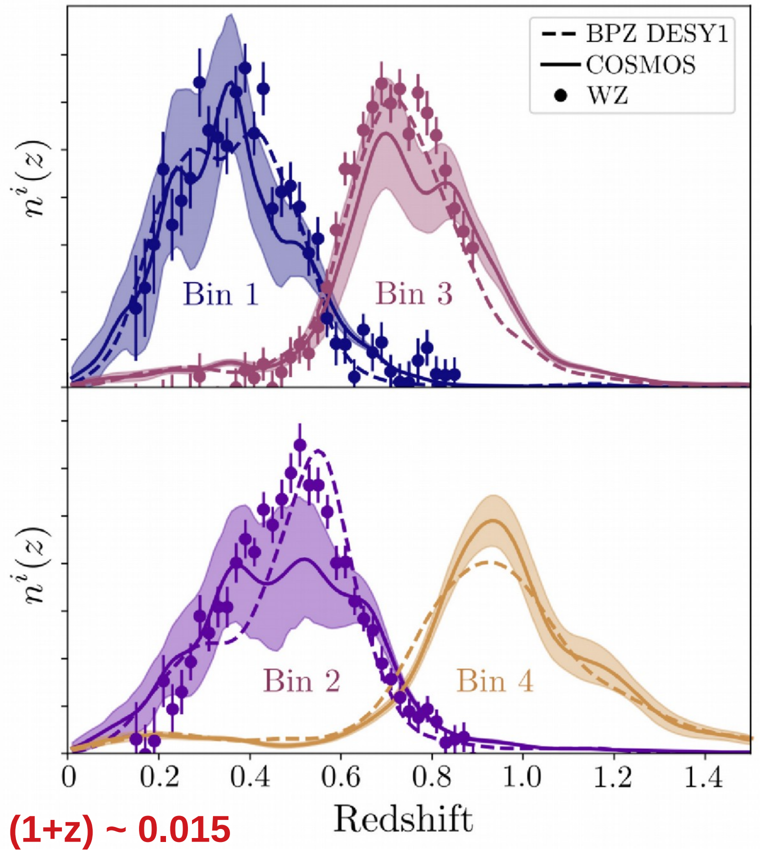
Many repeat observations

Credit: A. Merson



Overlap with the South Pole Telescope Survey (SPT)

Hoyle et al. (2018)

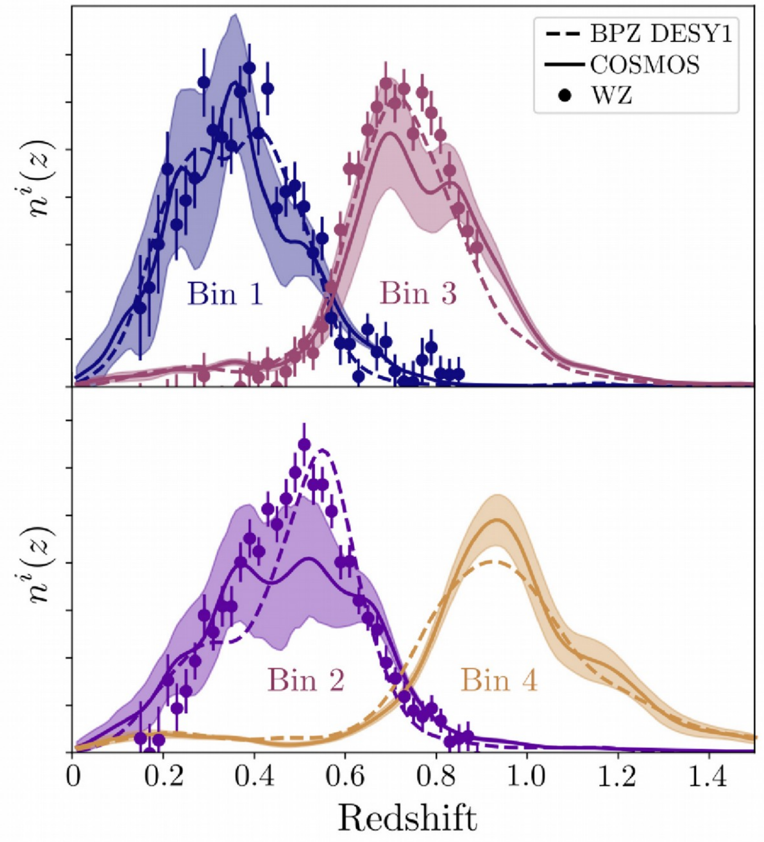


Redshifts calibrated to Δz / (1+z) ~ 0.015

The Dark Energy Survey – Y1 photo-z methods

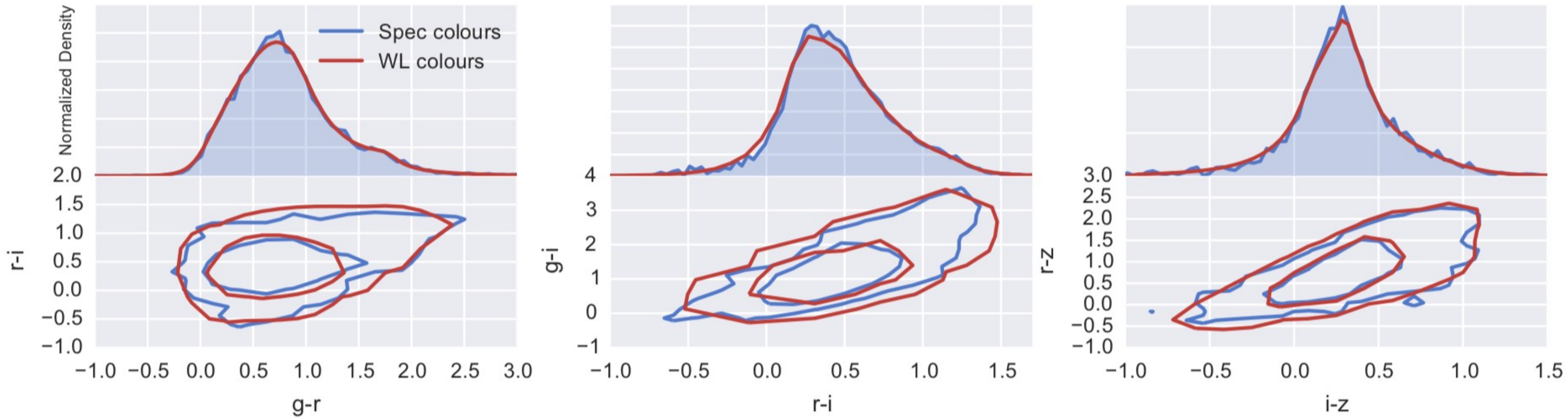
	SV	Y1
Dir. Spectr. calibration	compilation in SN fields	Not used
Template fitting	BPZ + sim. calibration	BPZ + empirical template calibration
Machine learning	3 methods	(1 method)
Cosmos calibration	via sample cuts	via chi-sq.
Clustering	Not used	redMaGiC

Hoyle et al. (2018)



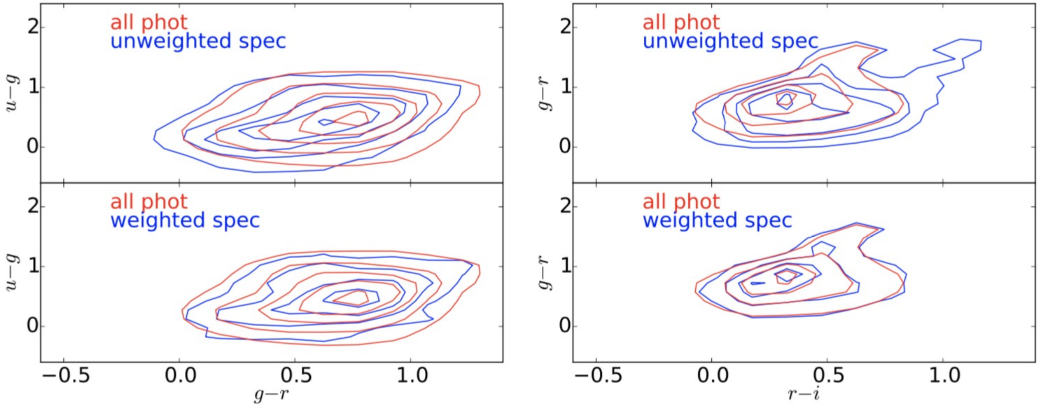
Direct calibration of redshift distributions

Bonnett, Troxel, Hartley+, DES (2015)

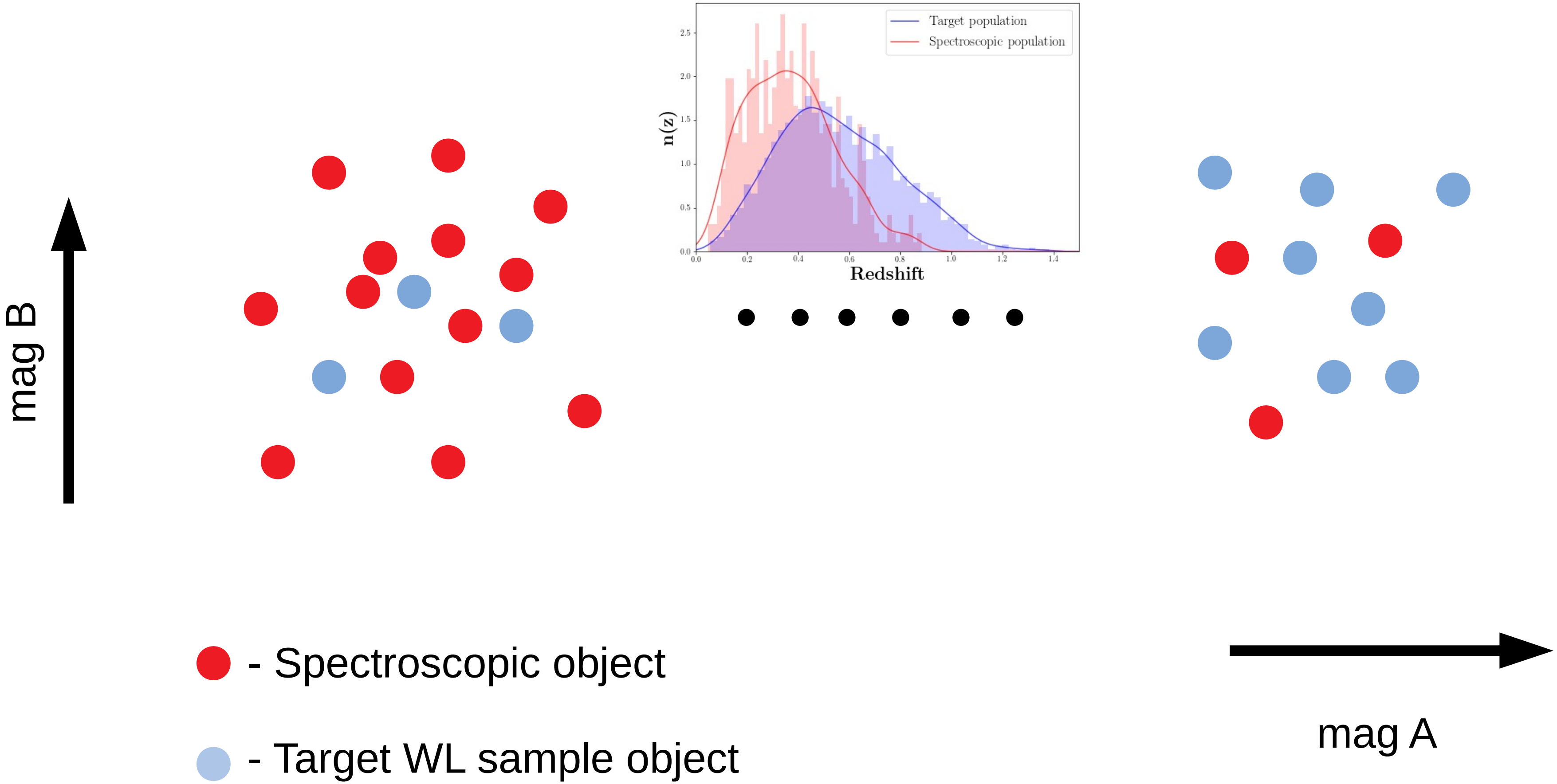


Hildebrandt+, KiDS (2017)

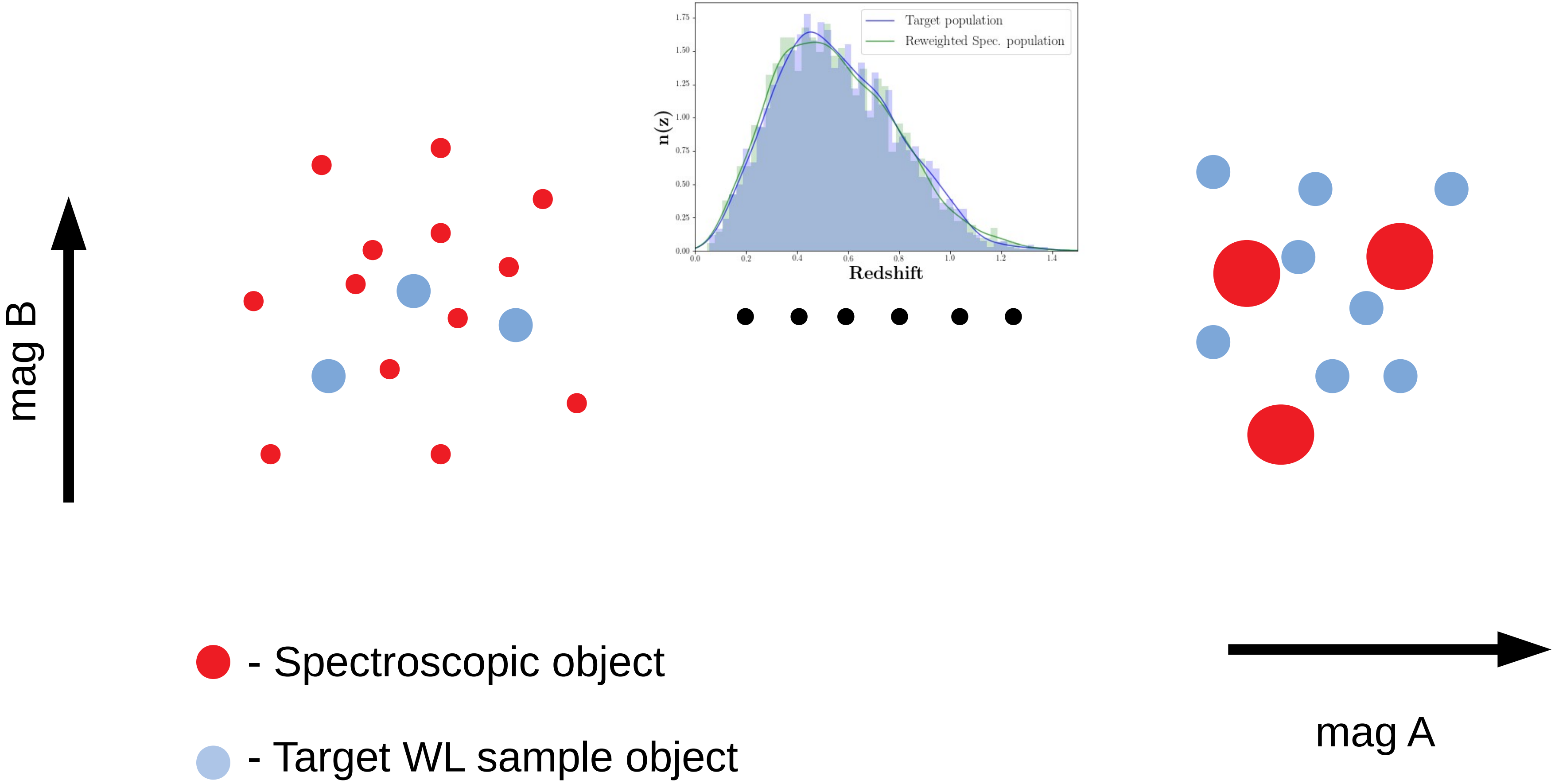
Based on Lima+ (2008): reweight the the galaxies in the spectroscopic sample so that their photometric (color, mag) distribution matches the target sample → the redshift distribution of the reweighted spectroscopic sample will also match the true redshift distribution of the target sample



Direct calibration of redshift distributions



Direct calibration of redshift distributions



Assumptions in the Lima et al. method

- The spectroscopic redshifts of the sample being weighted are all correct.
- The uncertainties in the photometry of the spectroscopic sample are representative of the target sample.
- At any given locale in photometric space, the **available** spectroscopic redshifts are equivalent to a random draw from the true redshift.

The underlying assumption of the Lima method is that all the selections that are involved in **compiling the spectroscopic sample** can be recovered using the colors **available to the target sample**.

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Goal of this work:

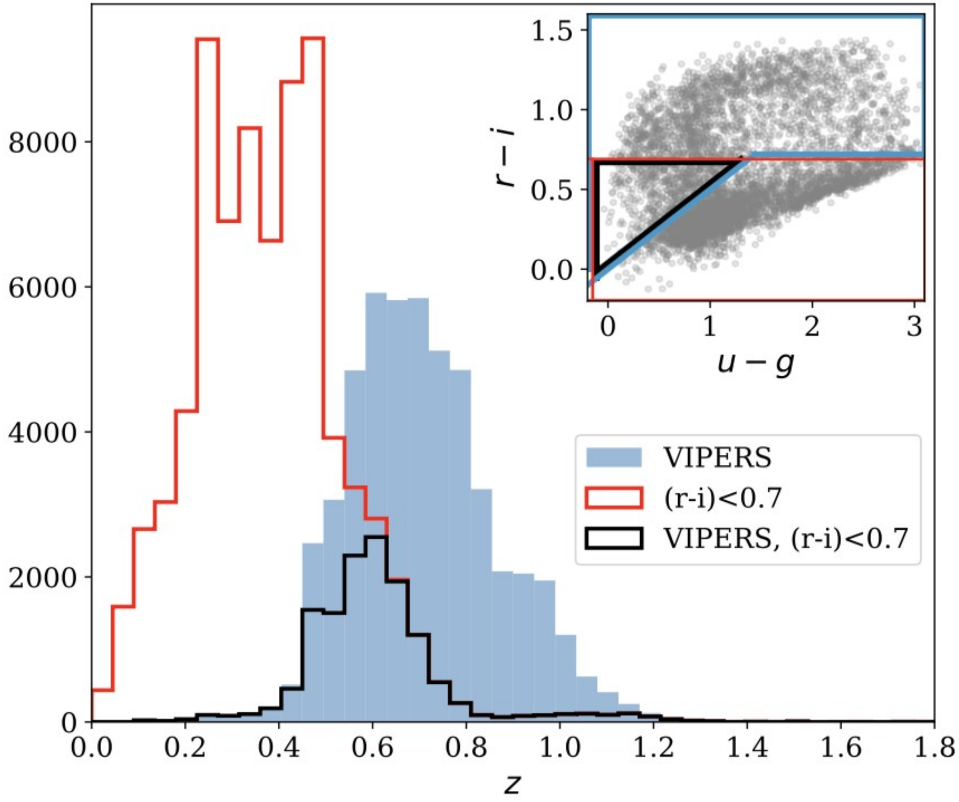
- Quantitatively examine the validity of the last point above.
- Explain the choice of not using this method for redshift calibration in DES Y1.
- Figure out what this implies for future DES analyses and Euclid / LSST (also, KiDS).

Obvious examples where the assumptions are not true

Hartley & Chang et al. (subm)

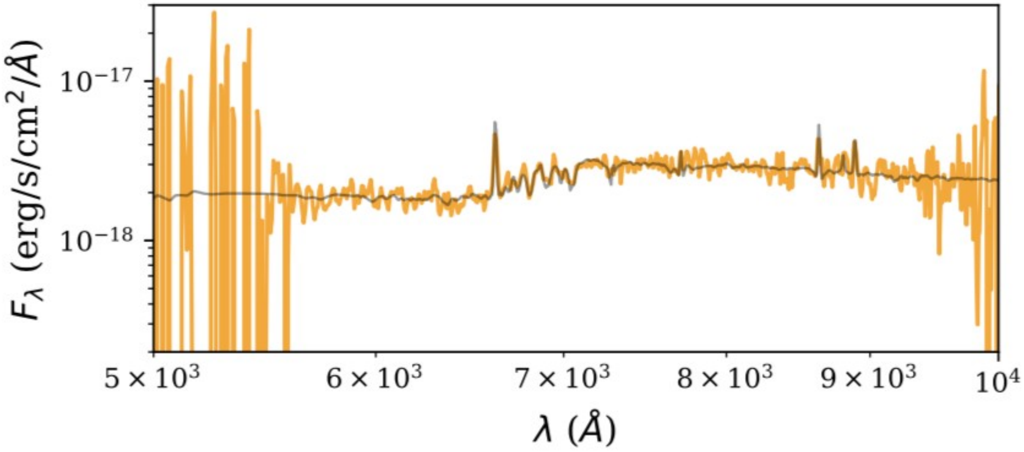
- **PRIMUS:** redshifts obtained by fitting low resolution spectra and any matched photometry to an empirical library of spectra, hard cut at z=1.2
- **VIPERS:** selection uses u-band, which is not accessible by DES
- **DEEP2:** selection uses B-band, which is not accessible by DES

→ An equal mix of VIPERS and VVDS Wide spectroscopic targets introduces a bias of ~1%, **due to targetting alone,** in the DES photometric space.

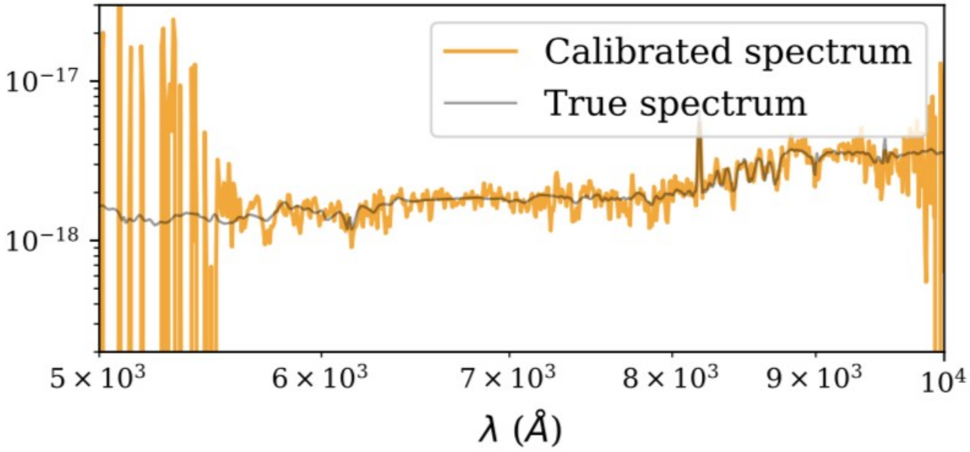


Less obvious examples

i=22, z=0.77



i=22.3, z=1.19



Good spectra → Flag=4

Not-so-good spectra → Flag=2

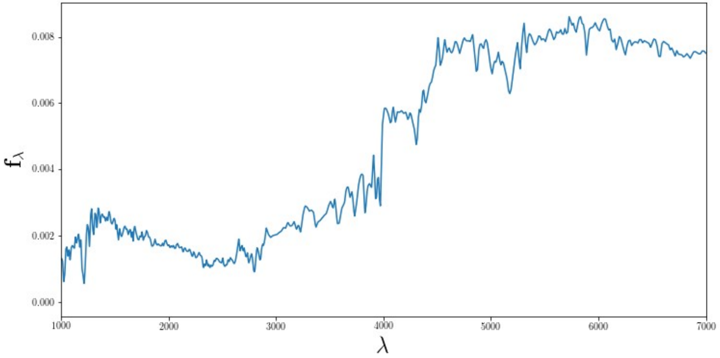
Typically, **Flag>=3** is used to select reliable redshifts in spectroscopic samples, where the Flags are given by experienced redshifters that use a combination of features in the spectra to determine the Flag and redshift.

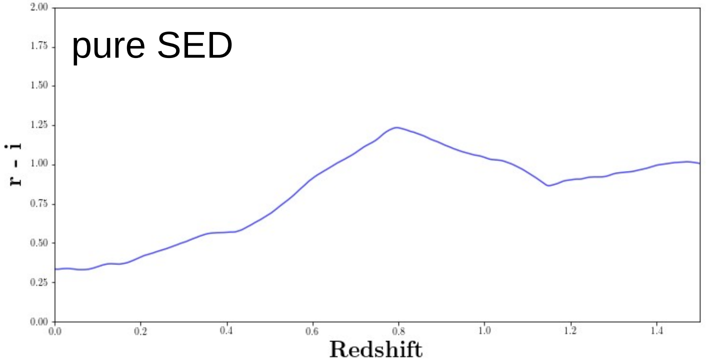
Why not use the Lima (DIR) method?

Spectroscopic samples are assembled using knowledge that is not accessible to the target sample's photometric space. Is this a problem?

Illustration:

- Take one SED (Sb type galaxy)
- Relation exists between redshift and apparent colour → photometric redshift.





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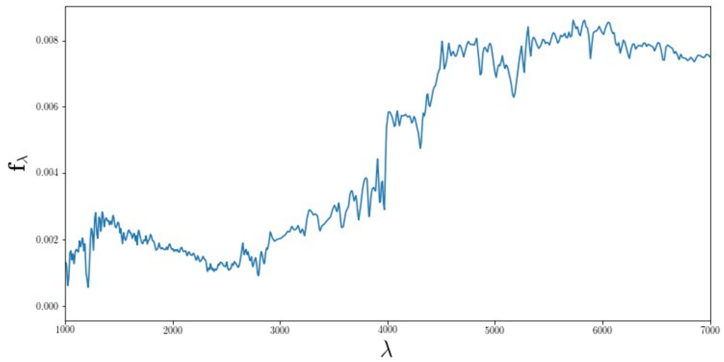

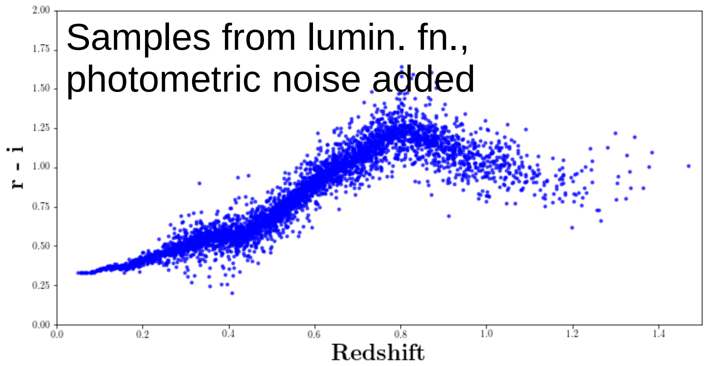

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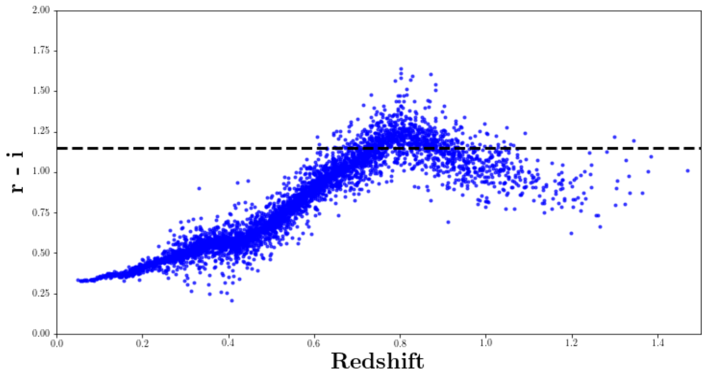
- Take a colour locale, e.g. r – i = 1.15.
- → infer a redshift distribution from spec. objects.



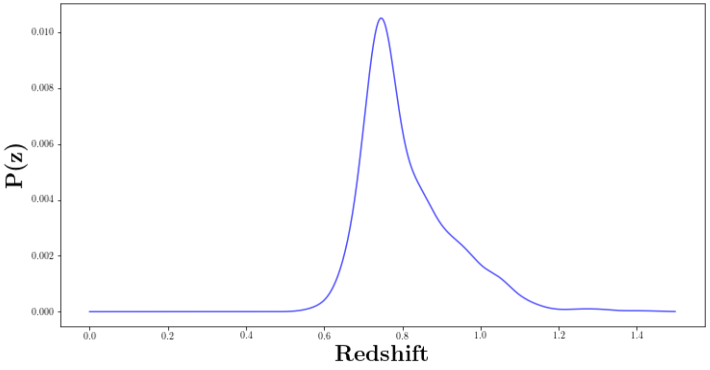


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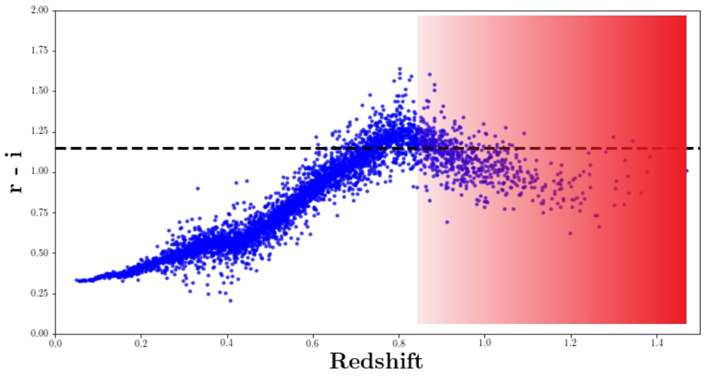
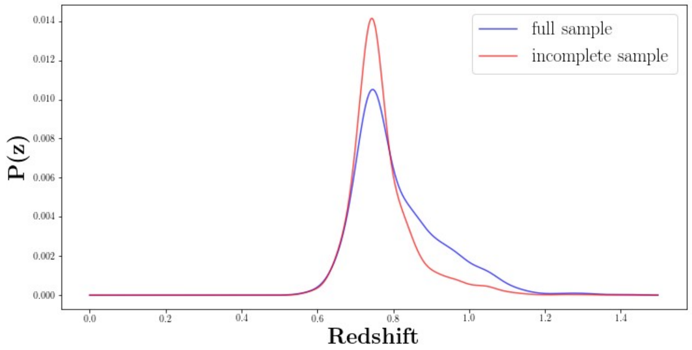
Illustration:

- Take one SED (Sb type galaxy)
- Relation exists between redshift and apparent colour → photometric redshift.
- Take an r – i colour for some subset of target galaxies, r – i = 1.15.
- → infer a redshift distribution from spec. objects.
- For VIMOS, it becomes increasingly difficult to obtain secure redshifts at high redshift. ([OII] lost in noise, or drops out of the spectroscopic window.)
- **At constant colour and magnitude** → introduces a small redshift bias.





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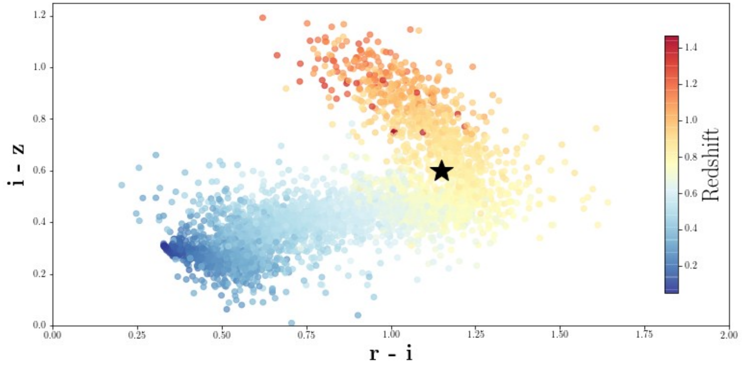
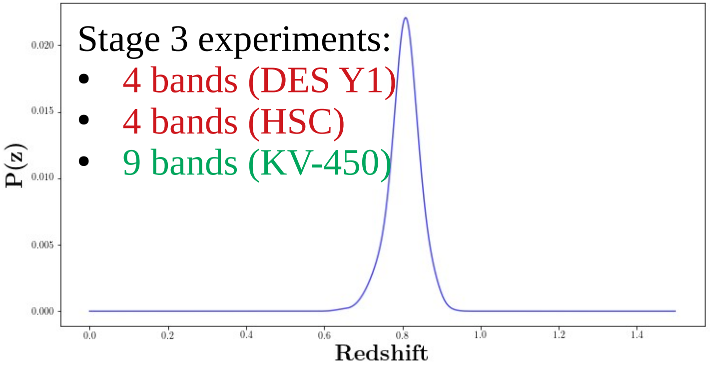
- **At constant colour and magnitude** → introduces a small redshift bias.
- Higher dimensions mean narrower intrinsic redshift distributions, and so smaller biases. But high-z, blue galaxies will, in general, have broad n(z).



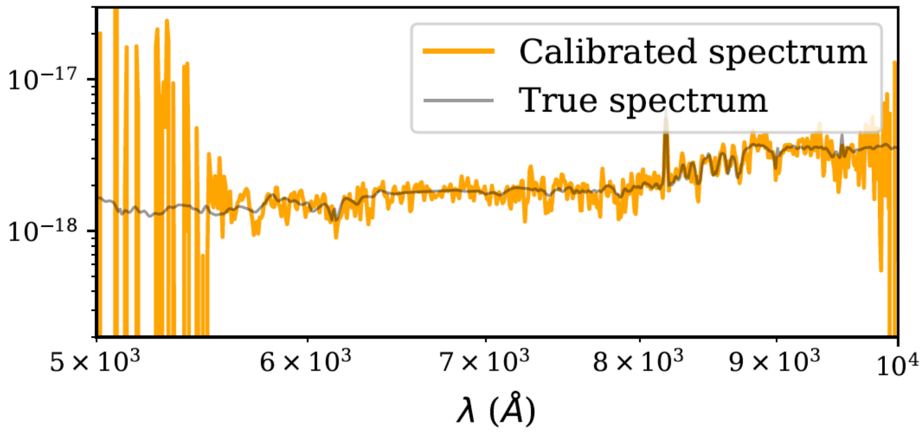


Simulating Spectroscopic incompleteness

Do the small biases in incomplete spectroscopic samples result in a significant bias in target sample mean redshift?

→ Model the process of obtaining spec samples, via “realistic” simulations of spectra.

→ Began in early 2016!



Steps

- Simulate spectra coming from the 4 main VIMOS samples used in DES Y1: VVDS Deep/Wide, VIPERS, zCOSMOS [Poisson noise, otherwise pretty idealized].
- Recruit DES/OzDES colleagues to redshift the spectra and assign Flags.
- Use random forest (RF) to enlarge sample.
- Apply Lima et al. method where target sample approximates the DES Y1 WL sample.
- Evaluate the resulting bias in the mean redshift for each tomographic bin as a function of minimum Flag used for spec sample.

Simulating spectra

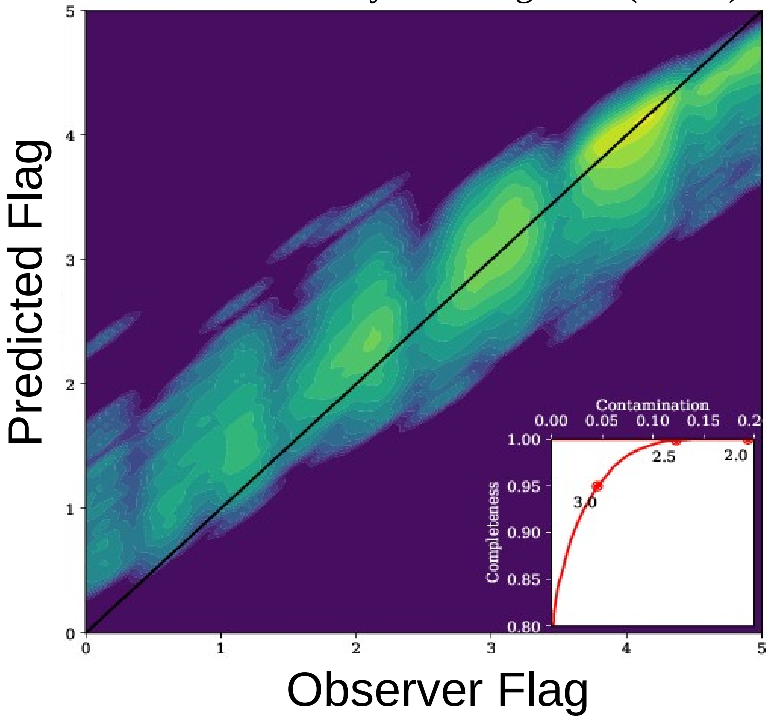
- Based on BCC-Buzzard + ADDGALS (Wechsler+) - galaxies assigned to halos, following colour-density relation.
- Galaxy SEDs parameterised by 5 PCA components from k-correct.
- Apply spec survey selection functions to patches of BCC sky, separated by appropriate angles.
- SEDs redshifted, sky added, telescope + instrument transmission applied → Poisson sampled.
- Sky subtracted, corrected for instrument response.
- Spectra packaged into bundles of 200 for Human inspection (~10% of total sample), with a random 10% of spectra in each bundle found in at least one other bundle.
- Redshifted and quality flags assigned by observers, using Marz tool.
- Quality flags standardised, using the spectra that were viewed more than once.
- Spectral features extracted and a random forest used to assign confidence flags to the full sample.

Obtaining confidence flags

Random Forest features:

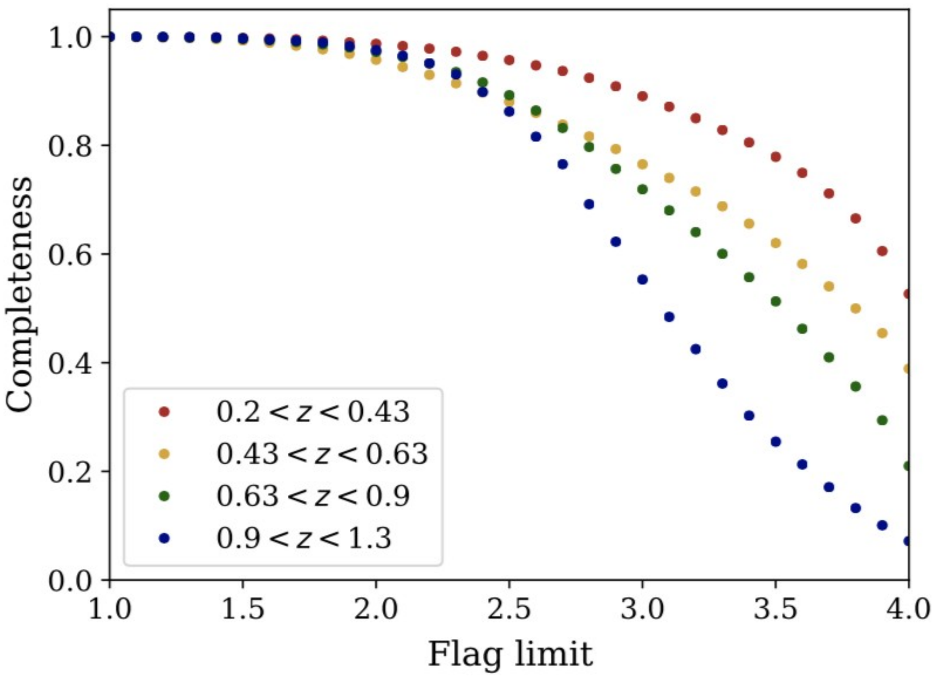
Wavelength (Å)	Feature
1215.7	Lyα
240.0	NV
1303.0	OI
1334.5	CII
1397.0	SiIV1393+OIV1402
1549.0	CIV1548
1640.0	HeII
1909.0	CIII]
2142.0	NII]
2626.0	FeII
2799.0	MgII
2852.0	MgI
2964.0	FeII
3727.5	[OII]
3933.7	CaK
3968.5	CaH
4101.7	Hδ
4304.4	Gband
4340.4	Hγ
4861.3	Hβ
4958.9	[OIIIa]
5006.8	[OIIIb]
5175.0	MgI
5269.0	CaFe
5711.0	MgI
6562.8	Hα
6725.0	[SII]6717.0+6731.3
4000 Å	break strength.

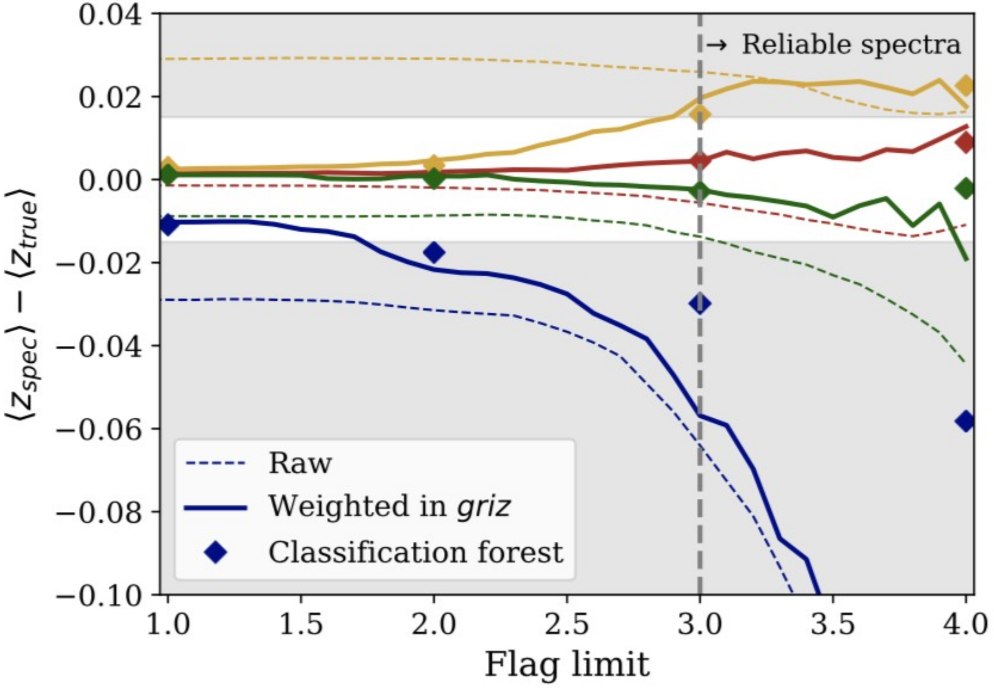
Hartley & Chang et al. (subm.)



Results

Hartley & Chang et al. (subm.)

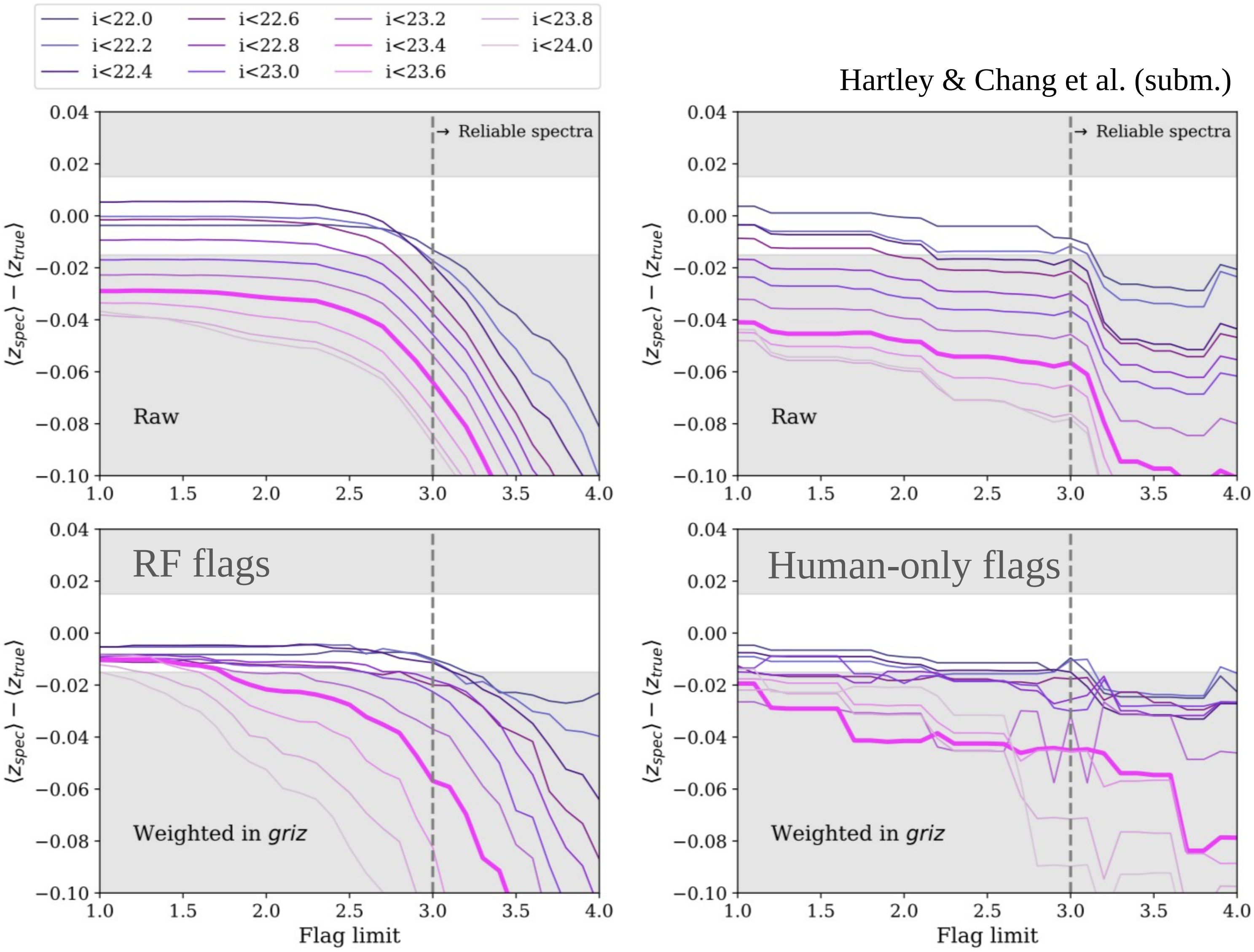




NB: more bands = better, but need to check the exact level

Results

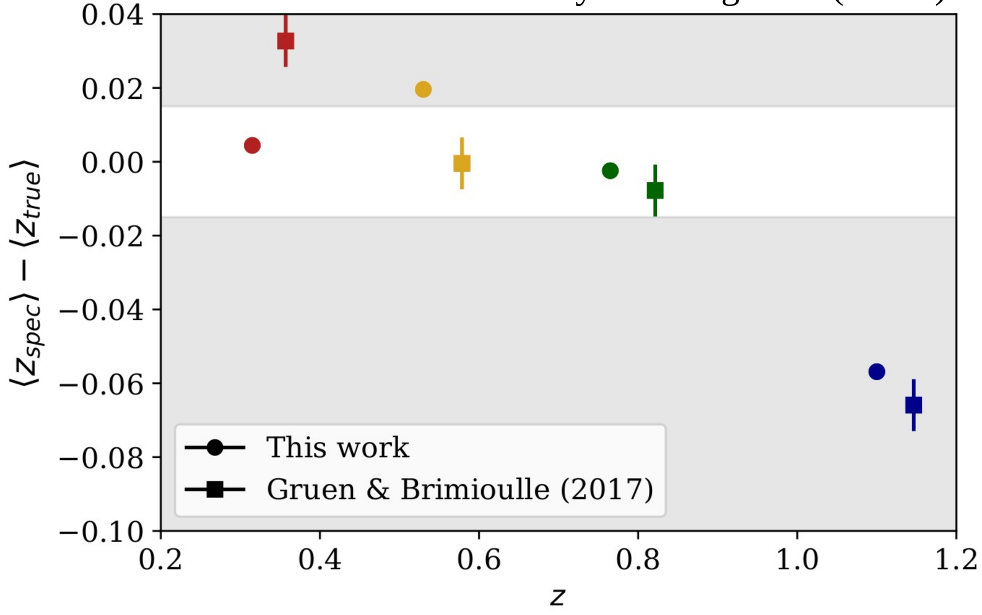
Hartley & Chang et al. (subm.)



Results

Also reasonable agreement with comparisons between incomplete spectroscopic samples and 8-band photometric redshifts.

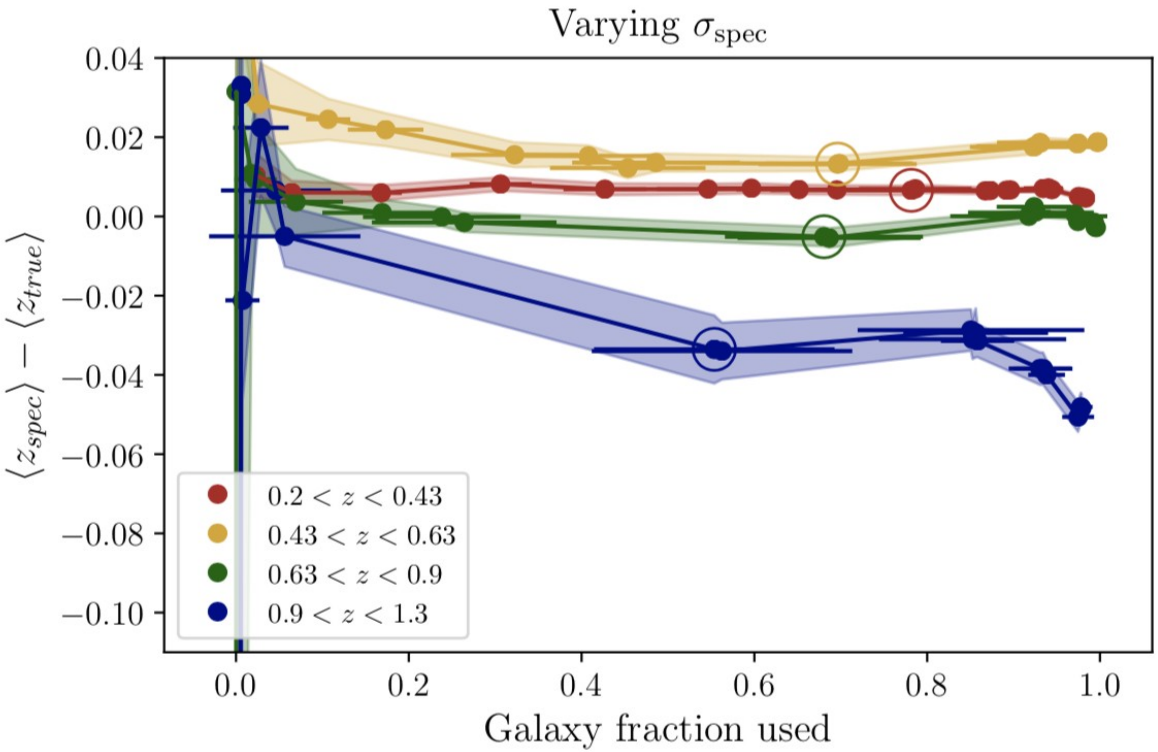
Hartley & Chang et al. (subm.)



Potential mitigation approach?

- Use lower Flags
- Remove uncertain SOM cells
- Calibrate via simulations

Neither seem super promising at the first pass… but clearly more work needs to go into this.



Hartley & Chang et al. (subm.)

Summary

- Our spectroscopic samples are constructed via **selections that may not be recoverable via color cuts available to the photometric surveys**.
- Using simulations, we examined the effect of such spectroscopic incompleteness on the resulting redshift estimate for a DES Y1-like sample.
- We find that for DES Y1, direct calibration introduces biases on the mean redshift at a level that **exceeds the other calibration methods**.
- Going forward, more work needs to go into understanding the selection in our spectroscopic selection, not only for direct calibration. This needs to be taken into account in on-going spectroscopic targetting (e.g. C3R2).
- In principle impacts all similar experiments, though will vary with spec samples used and number of photometric bands available.