The role of DESI in Photo-*z* Calibration for LSST, Euclid, and future cosmological surveys

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On behalf of the DESI Collaboration and the DC3R2 team

APS Spring Meeting
DESI Special Session
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Advised by Daniel Gruen, Aaron Roodman, and Alex Amon

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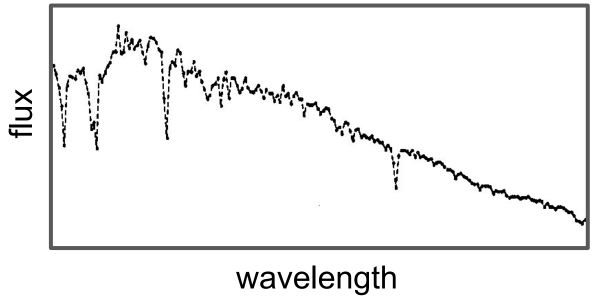
Photometric Redshifts, (Photo-zs)

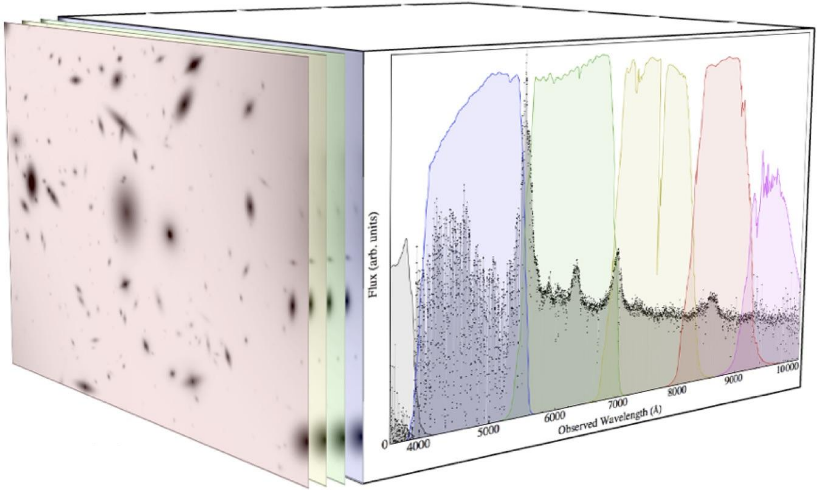
Weak lensing surveys require an understanding of the **distance distributions** of lensed objects as well as their lenses to gain insight into cosmology.

- *Redshift, z* ∝ Distance
- The redshift can be known to high confidence from the full **spectral energy distribution** (SED) of a galaxy if it has emission or absorption features
- Most galaxies only have **fluxes** in a few filters



Agenda

I. The State of Photo-z Calibration
II. DESI as a Contributor
III. Spectroscopic Biases: Brightness
IV. Photometric Scatter
V. Conclusions



Galaxy survey imaging, e.g. Vera Rubin Observatory

Image credit: David Kirkby

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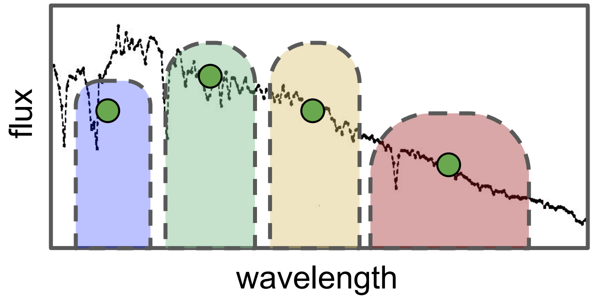

Fluxes + **Galaxy Models/Data** → **Photo-z Estimates**

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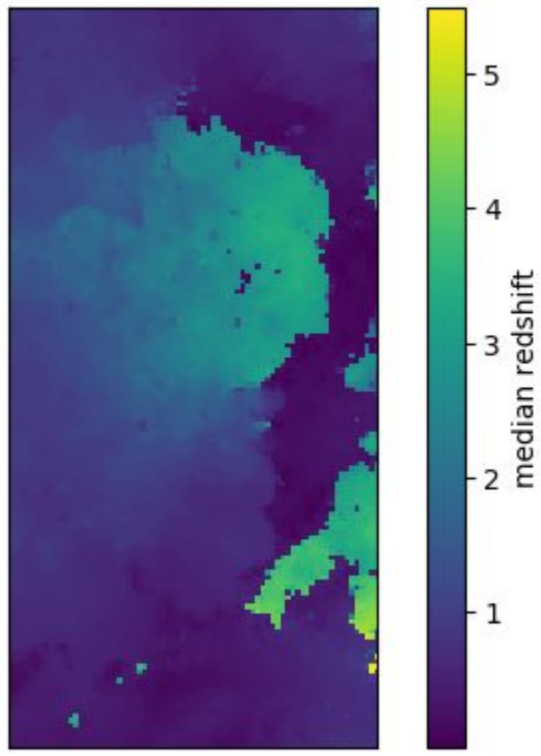
The Color Space

***ugrizYJHK* photometry** breaks degeneracies in similar galaxy SEDs

➔ 8-band color space can be discretized using **self organizing maps** (SOMs).

Weak lensing surveys like DES (*Myles+2021*) and KiDS (*Hildebrandt+2020*) associate galaxy spectra with known *z* with similarly colored wide field galaxies.

Masters+2015 built a SOM using this deep photometry that approximates the color space that will be visible to LSST and Euclid and informs spec-*z* searches.



Masters+2015 SOM,
trained on COSMOS photo-zs

The Color Space

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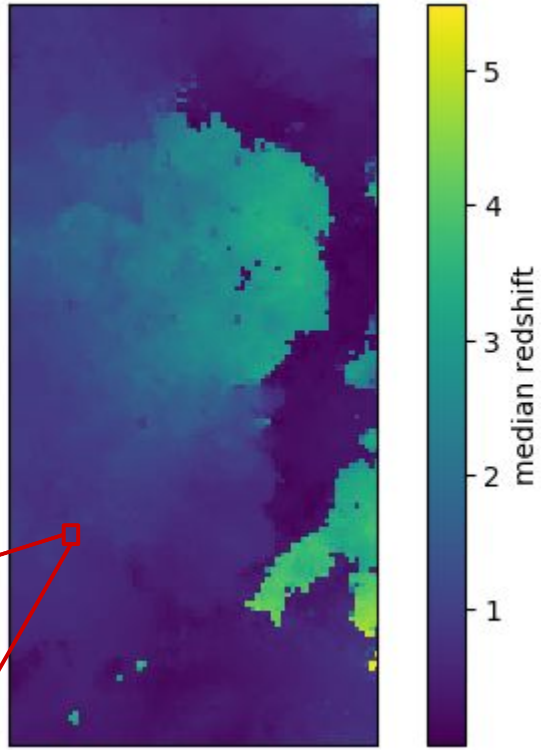
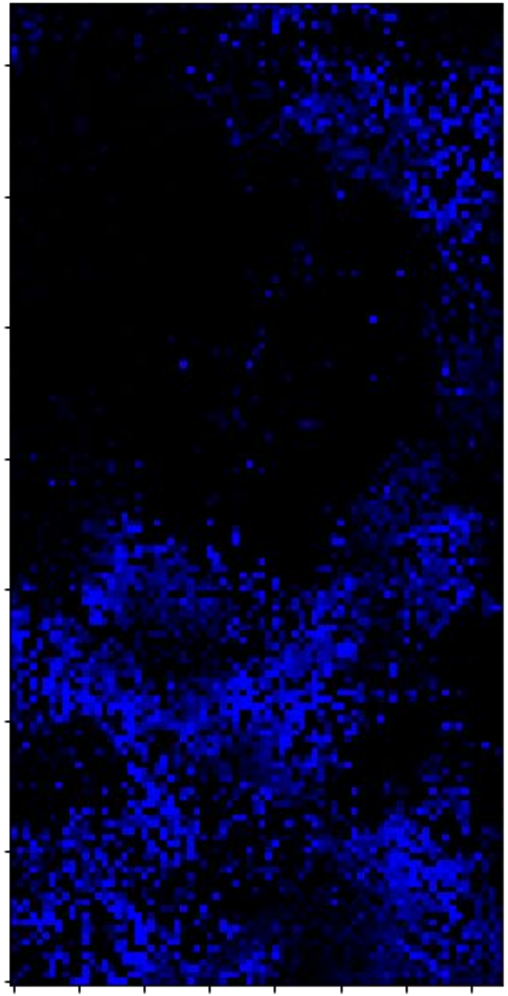
Each 'cell' is a selection of ugrizYJHK colors that we want to populate with spectroscopic galaxies.



Masters+2015 SOM, trained on COSMOS photo-zs

Where do DESI galaxies live?

DESI **C**omplete **C**alibration of the **C**olor **R**edshift **R**elationship (DC3R2) [secondary target program]



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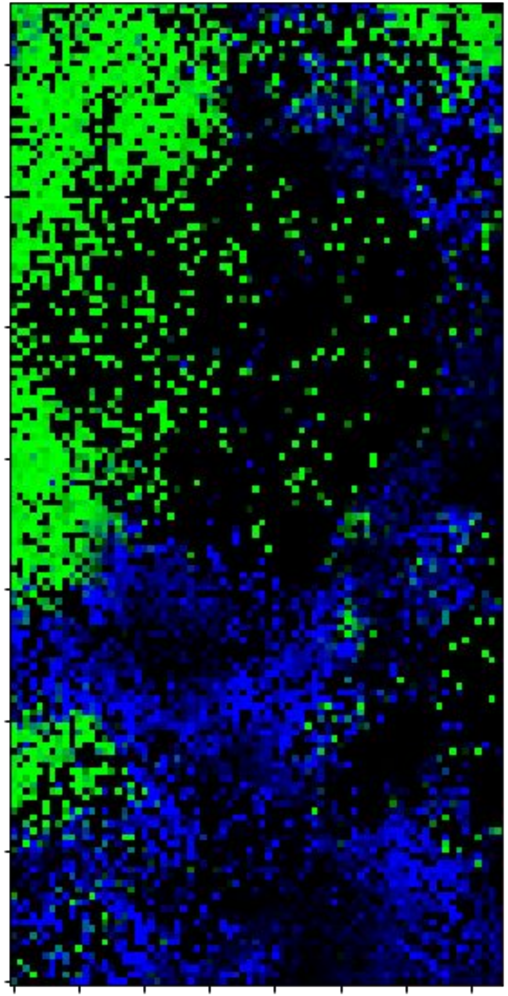

Emission **L**ine **G**alaxies (ELGs)
DESI **C**omplete **C**alibration of the **C**olor **R**edshift **R**elationship (DC3R2) [secondary target program]

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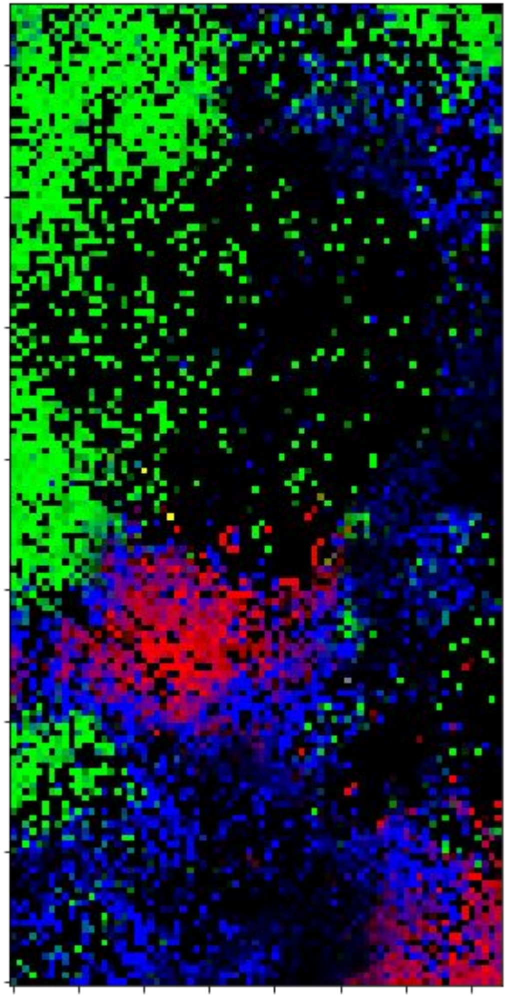
Where do DESI galaxies live?

Luminous **R**ed **G**alaxies (LRGs)

Emission **L**ine **G**alaxies (ELGs)

DESI **C**omplete **C**alibration of the **C**olor **R**edshift **R**elationship (DC3R2) [secondary target program]



Color Coverage: How it changes with survey

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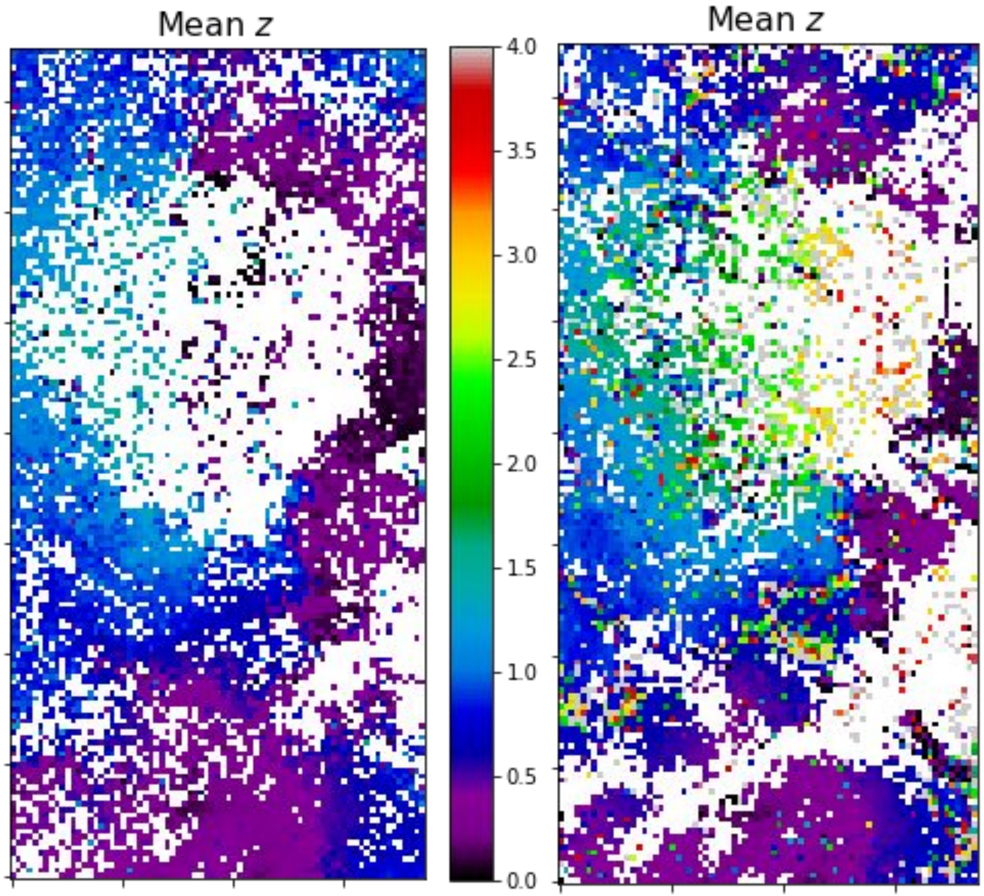
Regular DESI Ops + DC3R2

- ~57% cells covered
- 241k galaxies
- SV + partial Y1, DESI Operations
- 4h Additional Dedicated Tiles



COSMOS Field Spectroscopy,
C3R2 + zCOSMOS + Others

- 64.5% cells covered
- 27k galaxies
- > 1200 hrs of exposure on Keck/ VLT/Gemini S/ Subaru

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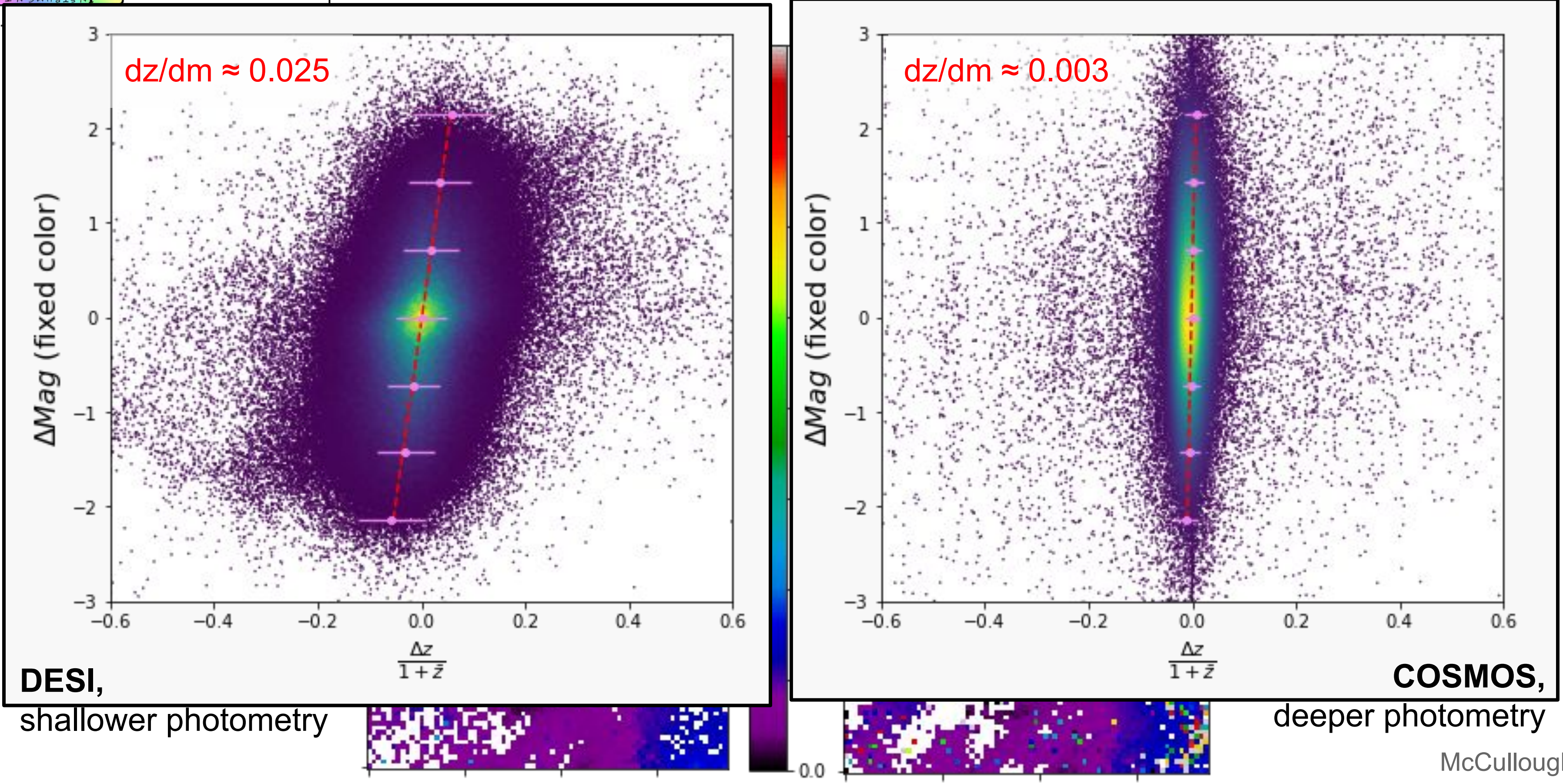
Color Coverage: How it changes with survey



DESI,
shallower photometry

COSMOS,
deeper photometry

Magnitude and Redshift

Spectroscopic galaxies are biased to brighter samples than ‘wide’ field galaxies that they calibrate. For **fixed colors** (e.g. a galaxy phenotype), we want to constrain **the magnitude dependence of redshift.**

Our SOM method relies on a null hypothesis (*dz/dm≈0*) that could be corrected easily to first order if false.

- Preliminary studies find this effect is **linear** and **small** (*Masters+2019*), *dz/dm*
- The photo-*z* requirement for DESC is on the mean redshift per tomographic bin
  - All uncertainties that contribute to *dz/dm* have to similarly be known to

$$\frac{\Delta z}{(1+\bar{z})} \approx \Delta(dz/dm) \times (\bar{m}_{wide} - \bar{m}_{spec}) \approx 0.001 \text{ (DESC Y10)}$$

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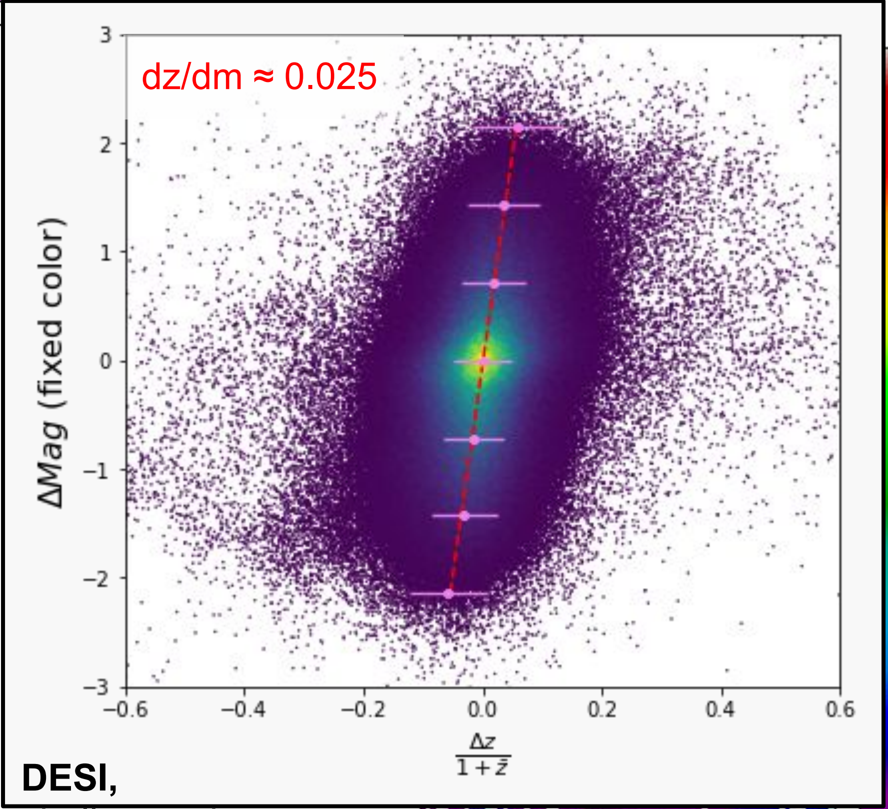
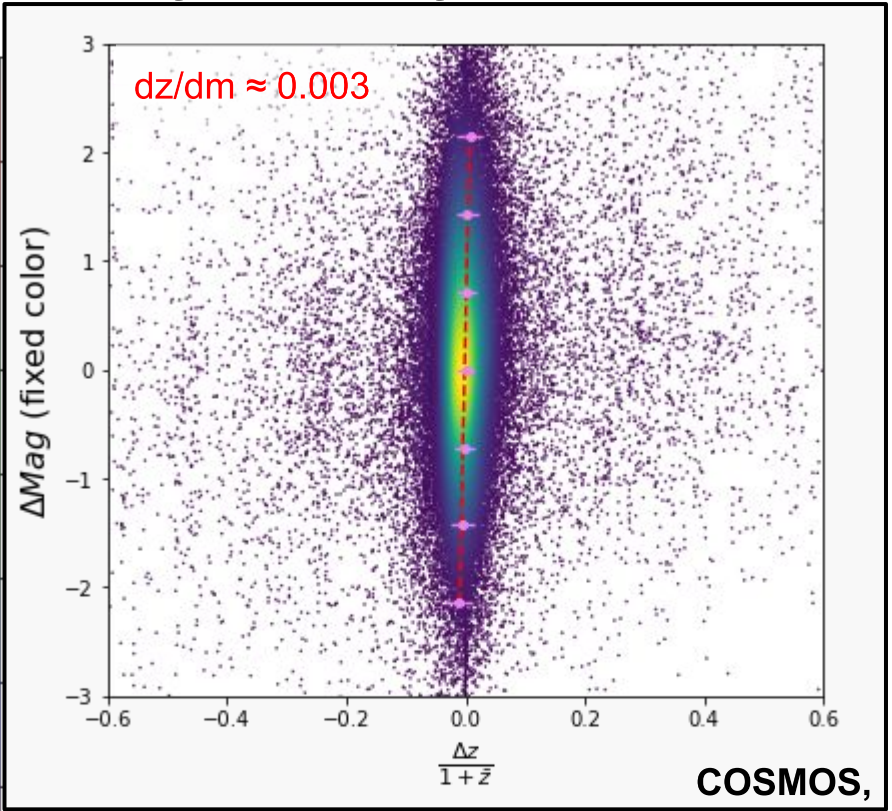
If we used DESI spectra alone, we have to know the systematics to:

$$\boxed{\Delta(dz/dm) \leq 0.0005}$$

DESI v. COSMOS: Why do they differ?

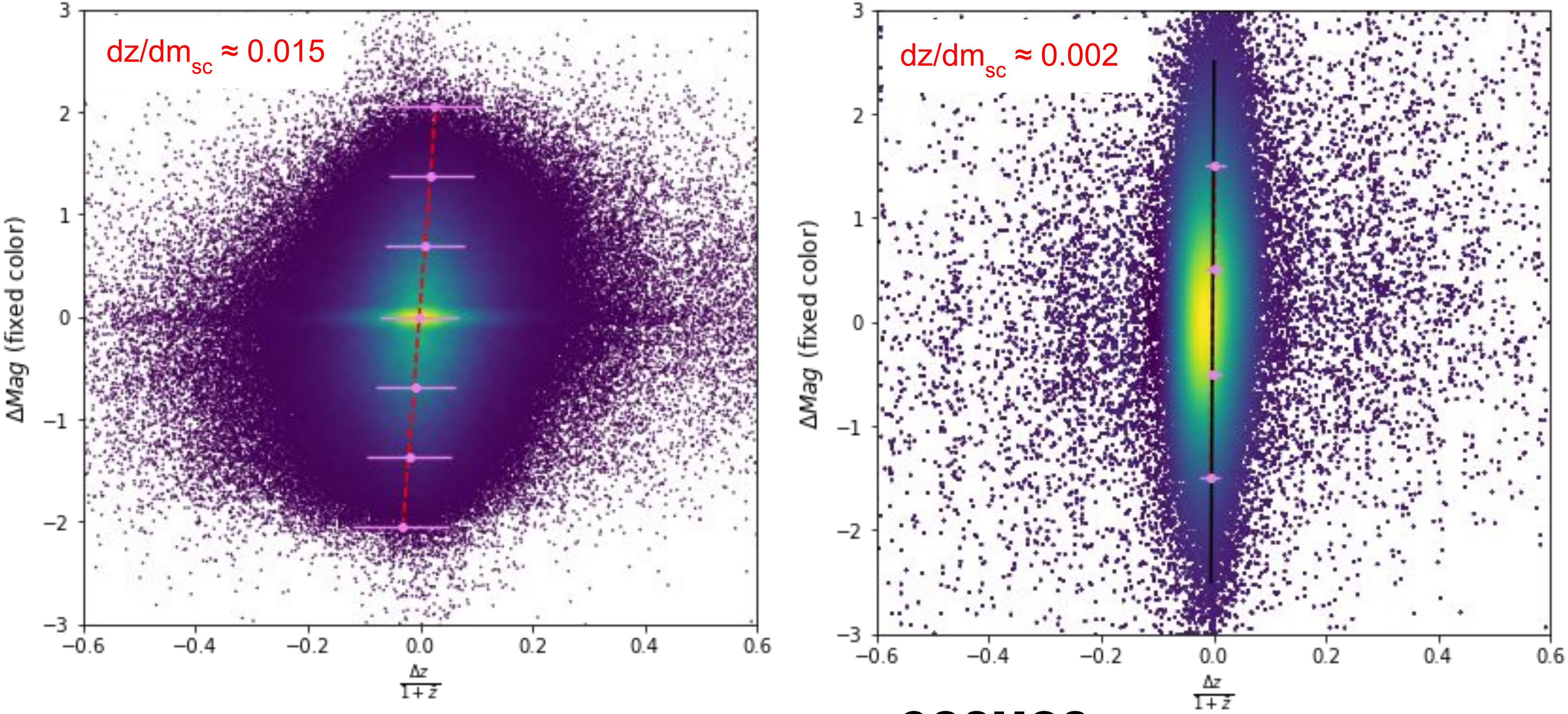


DESI,
shallower photometry



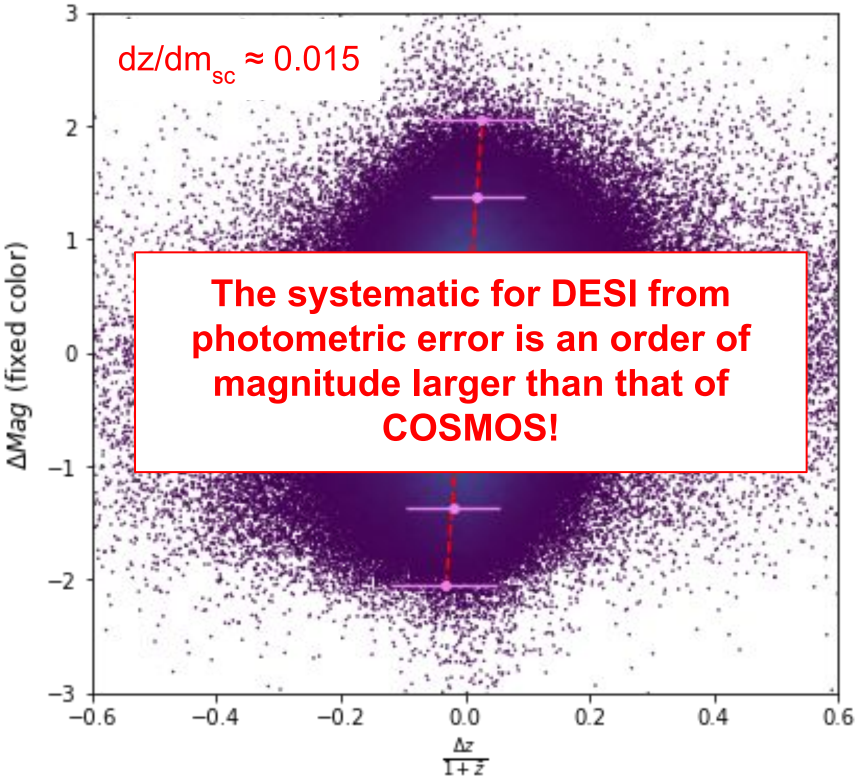
COSMOS,
deeper photometry

Photometric Scatter as a Systematic

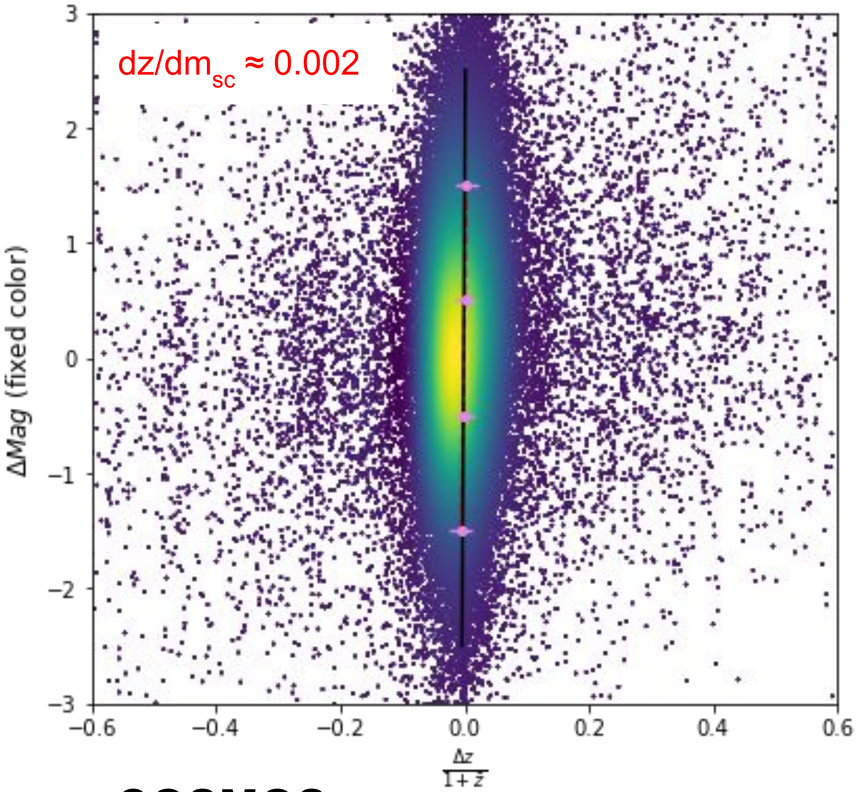


DESI *(McCullough+ 2022, in prep)* **COSMOS**

Photometric Scatter as a Systematic

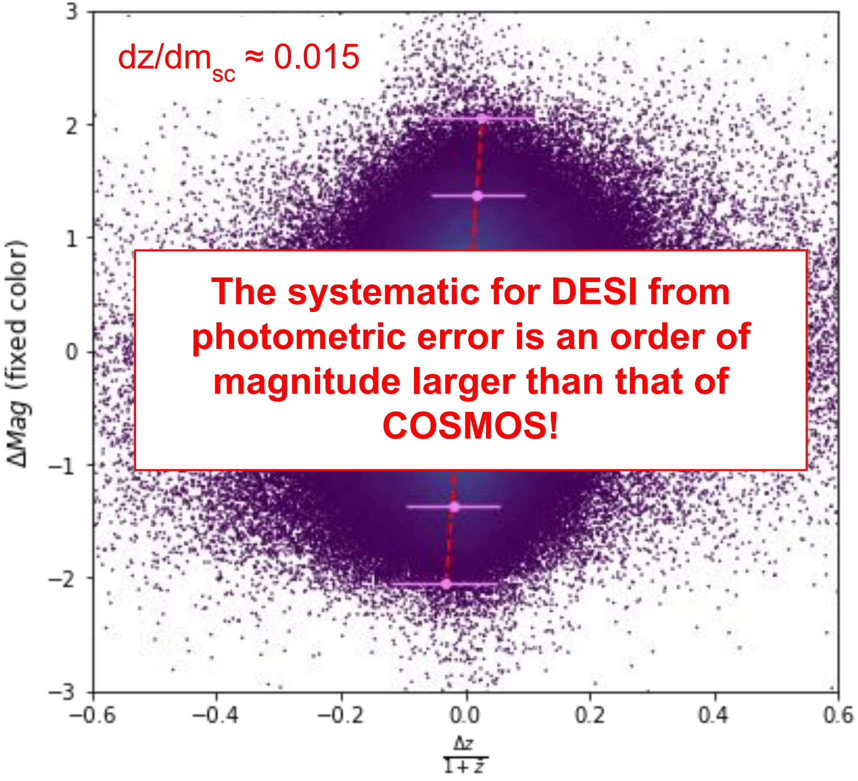


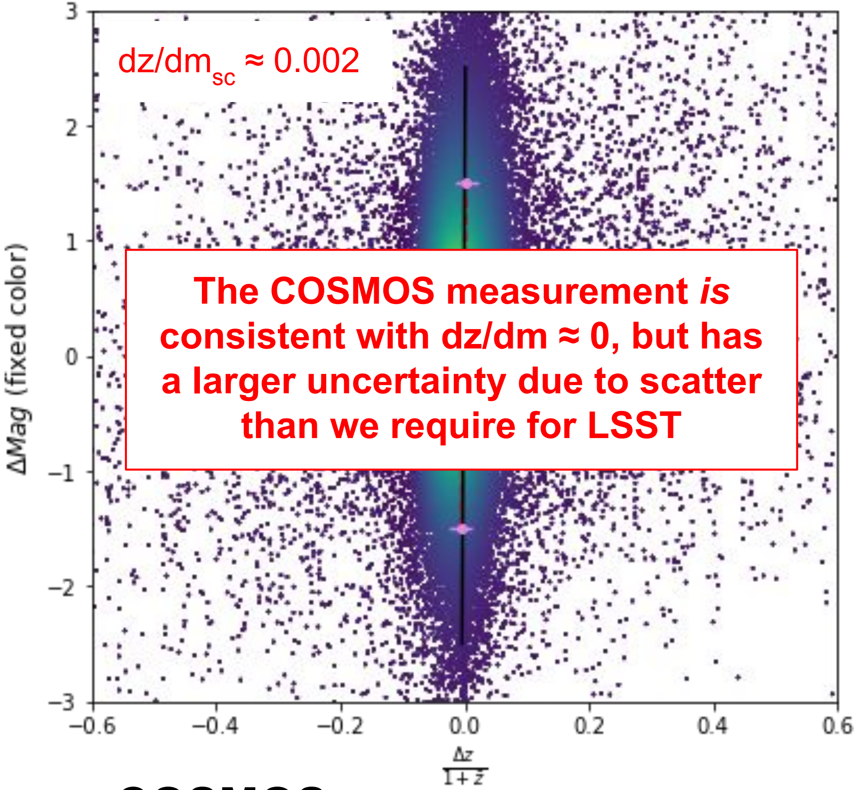
DESI *(McCullough+ 2022, in prep)*



COSMOS

Photometric Scatter as a Systematic





DESI *(McCullough+ 2022, in prep)* **COSMOS**

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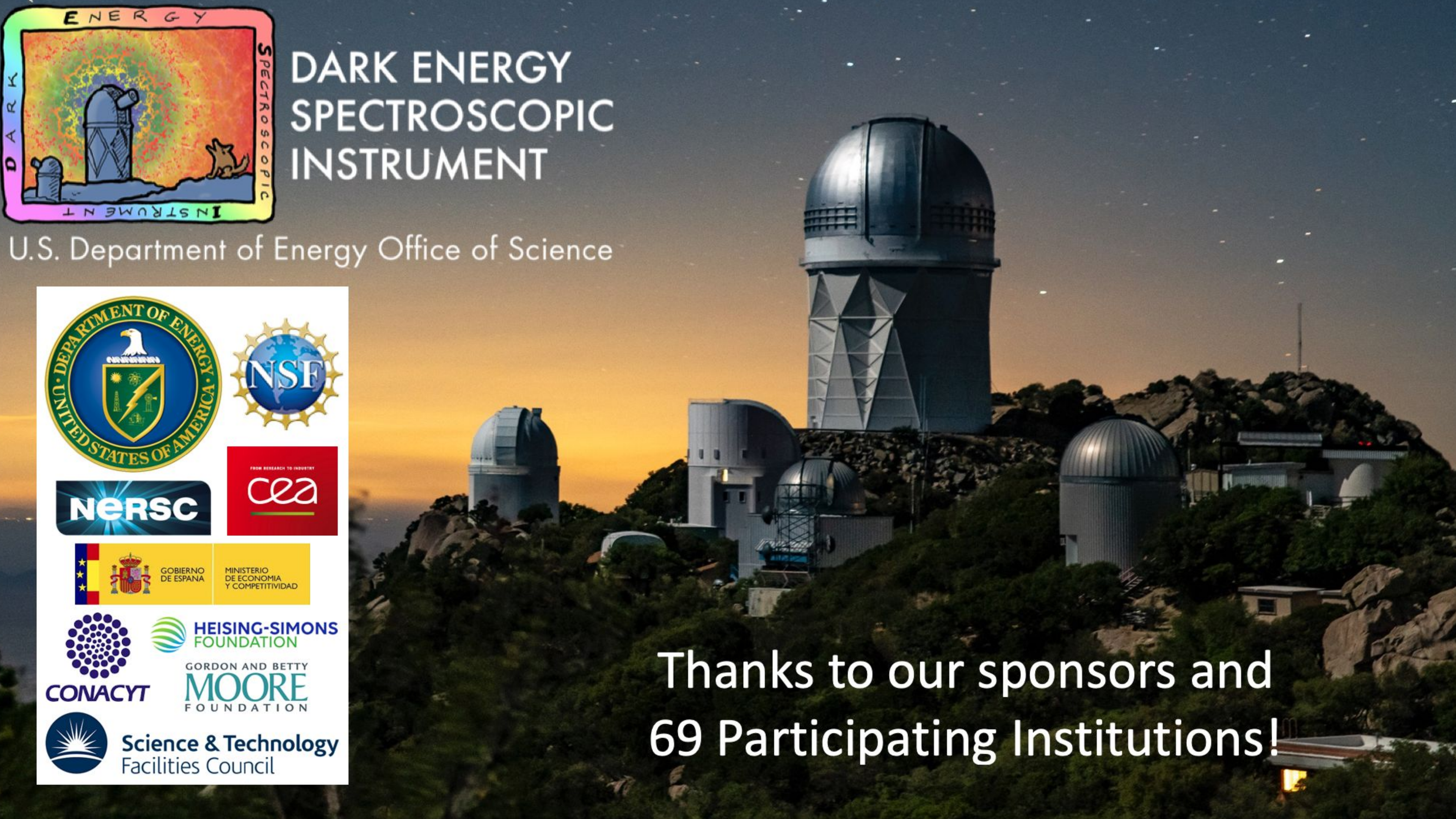
Summary

- DESI will provide millions of spectra, and *has already* served to calibrate **~54% of the color space visible to Euclid/LSST** with areas with high multiplicity.
- Future DESI efforts and other spec surveys like 4MOST will massively increase spectroscopic coverage.
- **Selection effects** on spectroscopic redshifts **must be well understood**, especially when they will be significantly brighter than wide field galaxies they are meant to calibrate (*dz/dm*).
- **Deep drilling photometric survey follow ups or good survey simulation** can increase our ability to calibrate for the effect of photometric scatter on this measurement and will be required to meet future photo-*z* requirements.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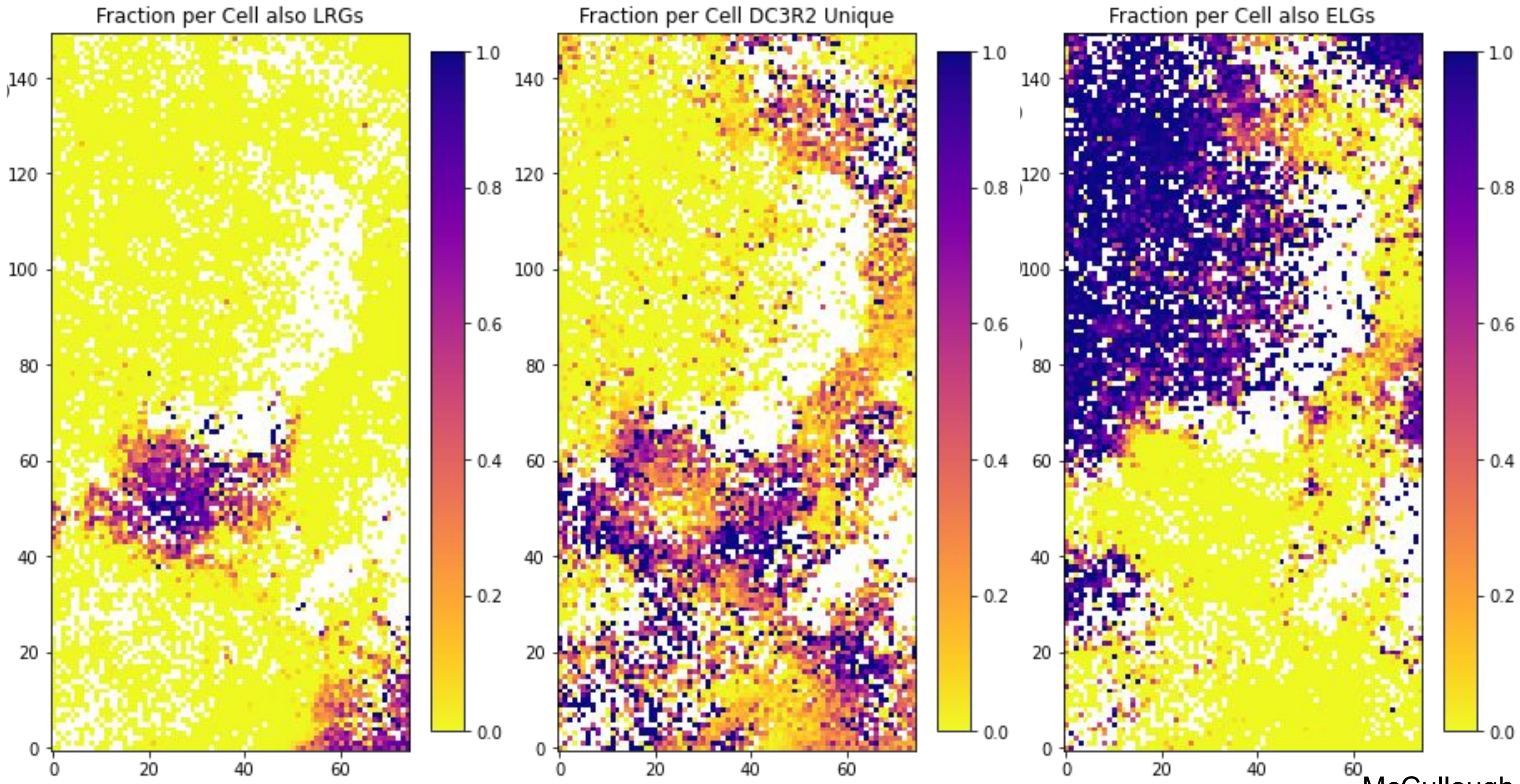
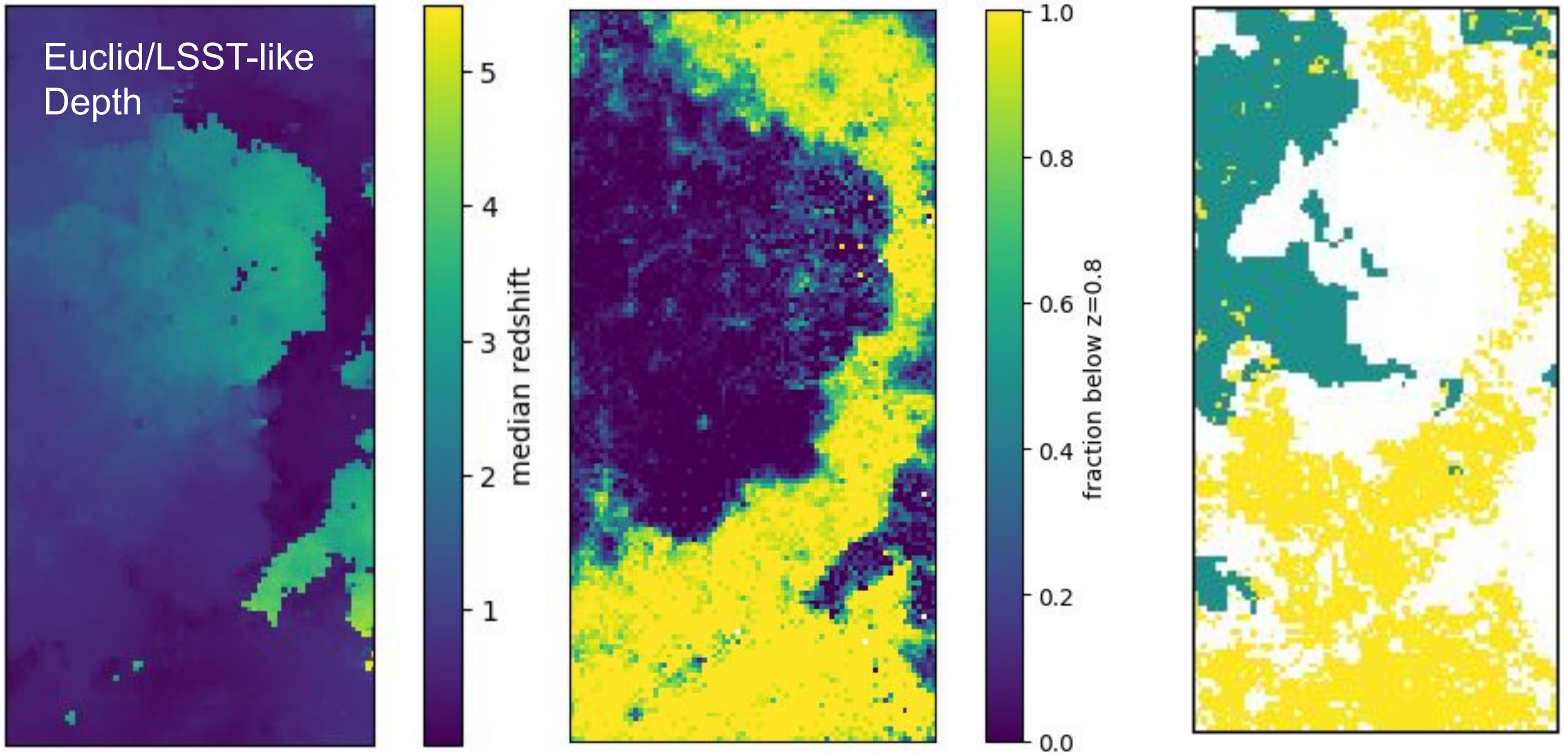
Backup

What types of galaxies live in this color space?



The DESI Effort to Calibrate the Color Redshift Relation



Masters+2015
SOM

Looking at low redshift z<0.8
structure in the SOM

DESI ELG Estimated Selection
DC3R2 Selection Envelope

Spectroscopic Completeness

Entire, unweighted DESI coverage of C3R2 SOM

~ 60% coverage of the color-space!

(with uniform redshift completeness cuts: $\Delta\chi^2$ > 25 defining "good spectra")