

# Photo-z estimates for LSST

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and LSST DESC PZ WG

- Vast majority of cosmology and extra-galactic science that will be done with LSST will rely on photometric redshifts (photo-z), including all primary probes of Dark Energy.
- Also important for some transient science (e.g. GW counterparts).
- Particularly challenging for Weak Lensing cosmology (DESC): error in  $w_a \sim 5x$  error in mean redshift – implies  $\langle z \rangle$  must be known to **0.2%** accuracy.
- LSST project have a commitment to provide photo-z – **will probably adopt recommendation from DESC.**
- DESC will produce for each galaxy in the “gold” sample ( $i < 25$ ):
  - Precise single-value “best” redshifts (2% accuracy);
  - Accurate redshift probability distribution functions (PDF),  $p(z)$ ;
  - Multi-variate PDFs in mass and galaxy type,  $p(z, M^*)$ ,  $p(z, T)$ .

# Photo-z methods and requirements

Three classes of photo-z method:

- Modelling galaxy SEDs (+ morph)
- Empirical mapping flux (+ morph)  $\rightarrow$  redshift
- Cross-correlation with tracers of LSS (e.g. spec-z samples)

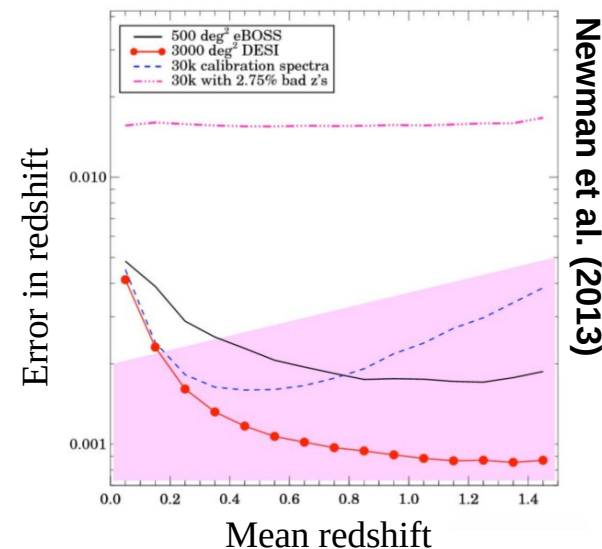
Two major tasks:

- Deriving precise individual redshifts with accurate  $p(z)$ .
- Calibrating the redshift distribution of a sample.
- (Validating the final distributions)

Requirements currently under review.  $\sigma_{\langle z \rangle} < 0.2\%$  per bin under simplistic assumptions.

Statistical precision is not a worry – systematic errors are.

$\rightarrow$  **Explore via series of data challenges.**



# Data Challenge 1 (Oct 15 – Jun 18)

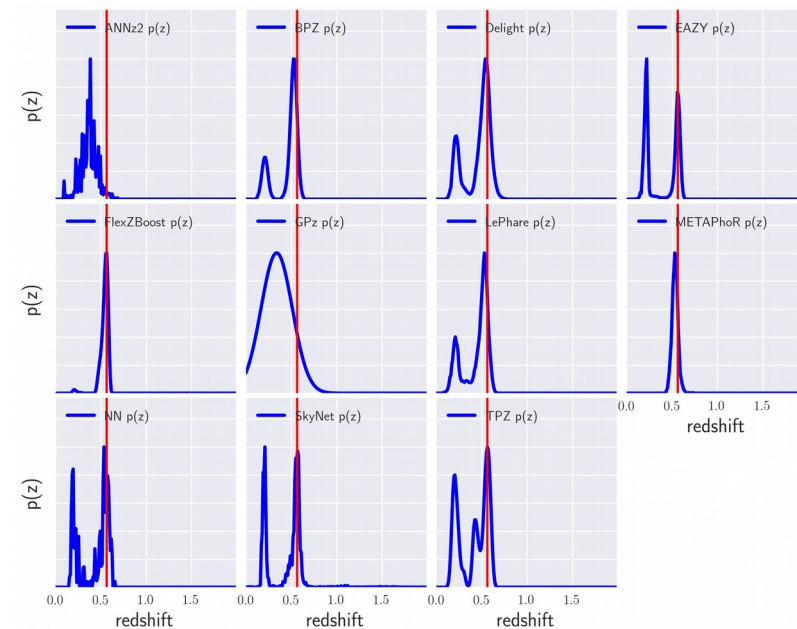
Perfect set-up over 8 sq. deg.:

- Same templates used to generate photometry as are used in photo-z codes.
- Training sample complete and representative to full depth (~44,000 objects).
- No stars.
- No AGN contribution.
- $0 < z < 2$ .
- Each participant was asked to return the  $p(z)$  for every galaxy in the test set.

- Aim to understand the impact of method on the interim redshift posterior by removing errors associated with training, templates and prior.

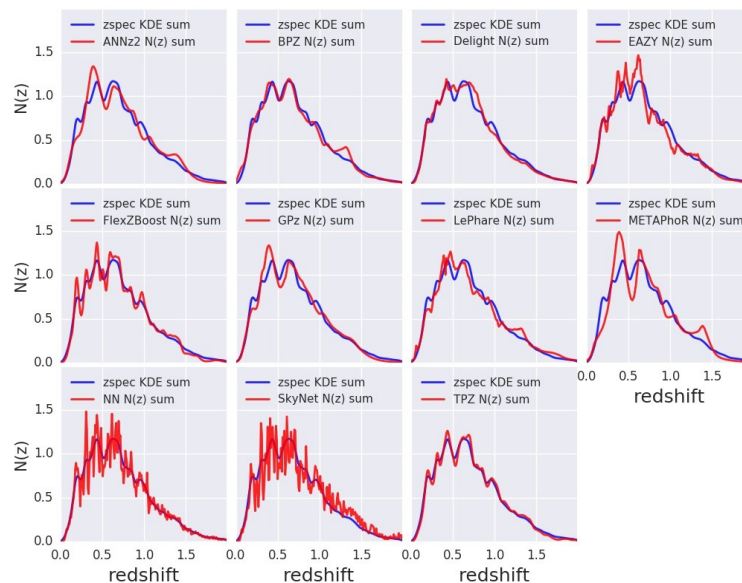
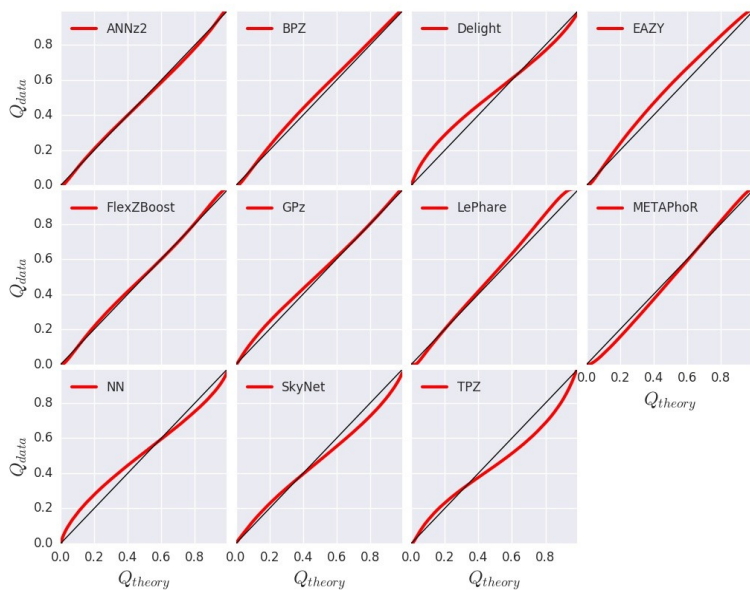
- Test ability to recover known distribution, and accuracy of individual  $p(z)$ .

Schmidt, Malz et al. (in prep.)



# Data Challenge 1 (Oct 15 – Jun 18)

Current redshift codes contain implicit priors, which mean we do not get the true answer, even with complete information.



Schmidt, Malz et al. (in prep.)

# Data Challenge 2 (Jul 18\* - present)



- Comprises simulated catalogue products (5000 sq. deg.), full image simulations (~10s sq. deg.).
- For PZ it includes development of three major pipelines:
  - **PZ\_PDF** (lead: Sam Schmidt – UC Davis) – Produce and store  $p(z)$  for each galaxy. Includes, training machine learning methods, calibrating priors and combining output from different codes.
  - **PZ\_Calibrate** (lead: Chris Morrison – U. Washington) – Create “DESI-like” spec-z sample, estimate redshift distribution via cross-correlation; development of magnification and bias evolution mitigation algorithms.
  - **PZ\_Incomplete** (lead: Will Hartley – UCL) – Simulate spectra of current and future spectroscopic surveys and produce “realistically incomplete” spec-z train / test sets.
- (Interface with wider DESC pipelines, e.g. TXPipe)

\* preparation for DC2 began Oct 16

# Data Challenge 3



Simulation area TBD. Aim is to have complete pipelines for Science Verification / Year 1 data by the end of DC3.

Additional features / systematics:

- $p(z, M^*)$ ,  $p(z, T)$
- Impact of blended sources
- AGN contribution
- Incompleteness / systematics in DESI (+ other calibration samples)
- Solving issues uncovered during DC1 / DC2

# DESC Science Roadmap



## PZ Products and Projects:

<b>PZ Key Product (DC1 &amp; DC2 &amp; DC3): Photometric Redshifts Pipeline PZPDF (PZ5)</b>	123
Deliverable: “Metrics pipeline for evaluation and comparison of photometric redshift codes”	123
Deliverable: “Validation of metrics pipeline”	123
Deliverable: “ComputePrior analysis stage for PZPDF”	124
Deliverable: “One-dimensional $p(z)$ routines (PZMainAlgorithms) for PZPDF”	124
Deliverable: “CombineResults for one-dimensional $p(z)$ for PZPDF”	124
Deliverable: “PZStorage1D for one-dimensional $p(z)$ for PZPDF”	124
Deliverable: “ $p(z)$ for DC2 using PZPDF”	125
Deliverable: “Validation of $p(z)$ for DC2 using PZPDF”	125
Deliverable: “Needs assessment for two-dimensional $p(z, \alpha)$ for PZPDF”	125
Deliverable: “Accounting for spectroscopic incompleteness in PZPDF”	125
Deliverable: “Two-dimensional $p(z, \alpha)$ implementation for PZPDF”	125
Deliverable: “Validation of $p(z, \alpha)$ for PZPDF on DC3”	126

Blue: done

Black: in progress

Green: planned

<b>PZ Key Product (DC2 &amp; DC3): Photometric Redshifts Pipeline PZCALIBRATE (PZCALIBRATE)</b>	126
Deliverable: “WGTomographicSelector for PZCALIBRATE”	126
Deliverable: “PZBiasEvolutionEstimator for PZCALIBRATE”	126
Deliverable: “MagnificationCorrection for PZCALIBRATE”	127
Deliverable: “PZClusterz for PZCALIBRATE”	127
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<b>PZ Key Product (DC2): Photometric Redshifts Pipeline PZIncomplete (PZIncomplete)</b>	128
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Deliverable: “Validation and testing of PZIncomplete using DC2 simulations”	129
Deliverable: “PZ Requirements for and development of DC1 simulations”	146
Deliverable: “PZ Requirements for Incompleteness”	148
Deliverable: “PZ Requirements for Cross-correlation Method”	148

LSST:UK All-hands meeting

Cardiff, 13-15<sup>th</sup> May, 2019



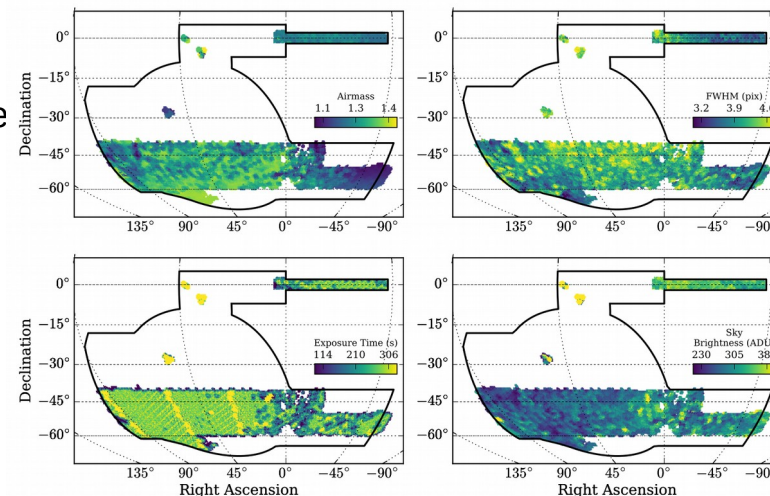


# Phase B proposal

(Cut from final submission)



- 1) ANNz2 development** – to meet required standard given perfect training.  
*Progress: on-going for other codes, incl. in UK: GPz (Oxford), BPZ (UCL).*
- 2) Sample redshift distribution framework** – Module to correctly propagate  $p(z)$  uncertainties into redshift distributions and cosmological inference.  
*Progress: on-going alongside requirements work (NYU, Carnegie Mellon).*
- 3) Impact of spatially varying systematics** – Development of methods to overcome impact of survey characteristics on calibration of  $n(z)$ .  
*Progress: no current effort and not (explicitly) in SRM, but still required.*
- 4) Covariance models** – Update covariance modelling to account for non-Gaussian effects and varying survey characteristics.  
*Progress: no current effort within PZ.*
- 5) Stress test on real data** – Testing end-to-end pipeline on real data.  
*Progress: no current effort, but still required (in future).*



Drlica-Wagner et al. (2018)

# PZ leadership and resources



PZ WG Convenor:

Ofer Lahav (UCL)

Chris Morrison (Washington), 0.2 FTE

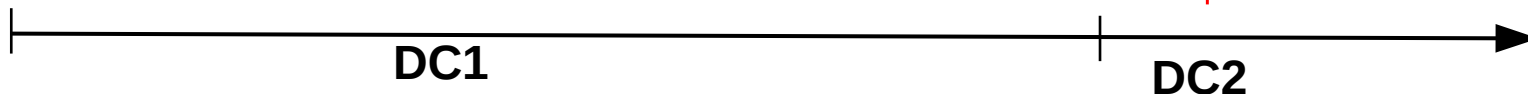
PZ WG Convenor:

Sam Schmidt (UC Davis)

Will Hartley (UCL), 0.2 FTE from Nov 18

Pipeline scientist:

Sam Schmidt (UC Davis), 0.5 FTE



Approximate FTE required for pipeline completion:

- **DC2** - ~ 5 FTE
- **DC3** - ~ 4.5 FTE (+ contingencies)

Current active membership of PZ:

- ~ 2 dozen regulars on telecons
- ~ 6 members working on direct PZ infrastructure for at least part of their time (mostly hack days).

**➡ Severe shortfall in current effort, but opportunity for continued UK leadership!**