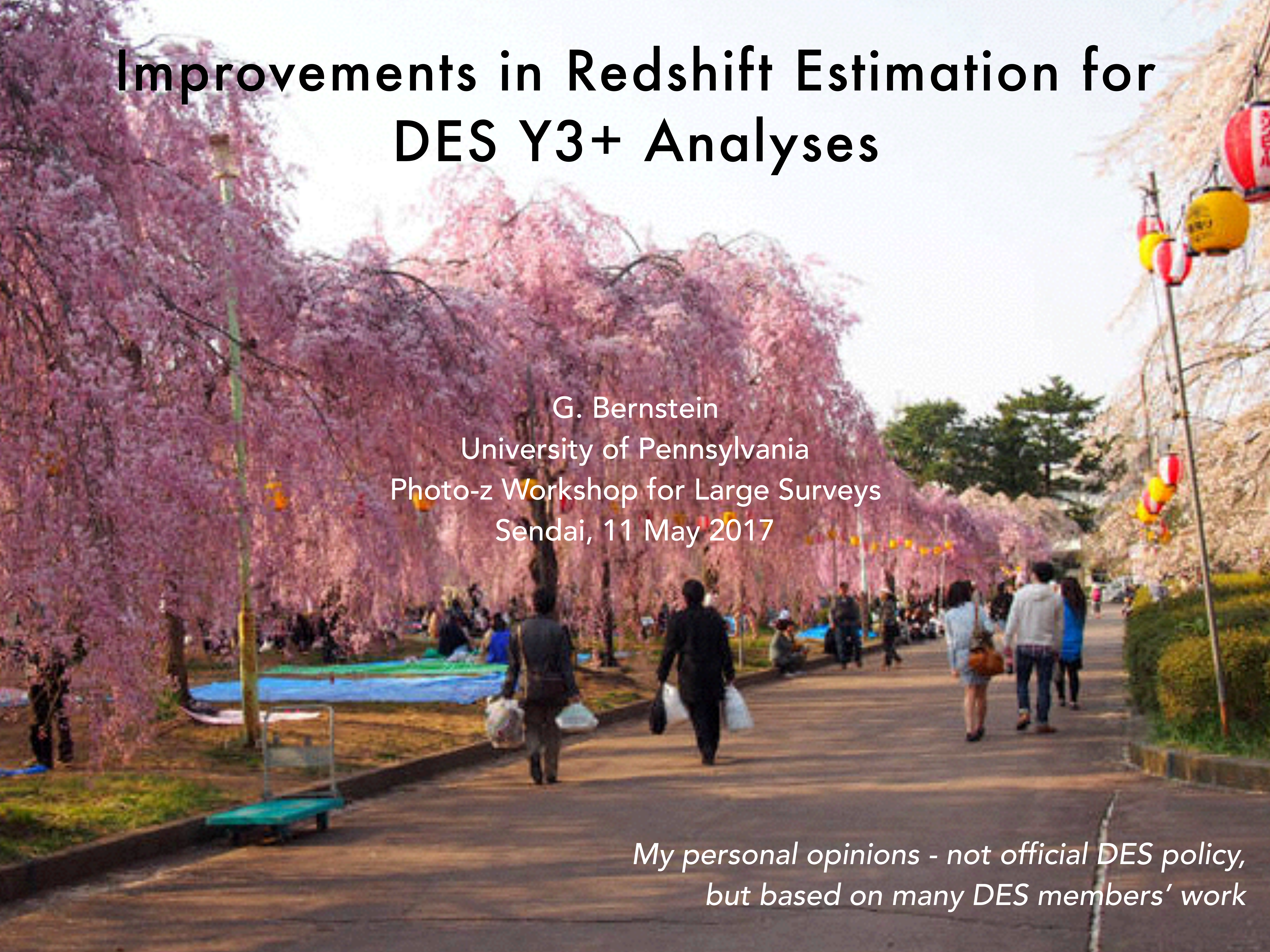
Improvements in Redshift Estimation for DES Y3+ Analyses



G. Bernstein
University of Pennsylvania
Photo-z Workshop for Large Surveys
Sendai, 11 May 2017

My personal opinions - not official DES policy, but based on many DES members' work

DES Y1 recap

SV: 150 deg^2, published
Y1: 1500 deg^2, nearly done, summer 2017
Y3: 5000 deg^2, serious analysis starting now

- BPZ w/refined templates yields $n_{PZ}(z)$ for bins selected by BPZ max.
- Cosmology analysis assumes $n(z) = n_{PZ}(z+\Delta z)$ with free parameter Δz per bin
- Prior on Δz is assigned by value from reweighted 30-band COSMOS PZ's
- Independent prior on Δz from clustering wrt red sequence catalog $0.15<z<0.8$
- *[Numerical tests show that shape of n(z) does not affect cosmology inference by more than Y1 stat errors]*

Known issues after Y1 analysis

A. Spectroscopic surveys are too incomplete even for Y1 analysis

B. Cosmic variance from direct (DIR) calibration with COSMOS narrow-band PZ would dominate Y3+ error budgets

C. Correlation redshifts (WZ) add significant information but are incomplete solution (bias degeneracy, limited z range)

D. dn/dz from PZ estimators does not agree sufficiently well with DIR, WZ for Y3+ accuracy

E. Selection criteria for weak lensing (WL), PZ can be in conflict.

A reductive view of redshift estimation

$$P(z|f) \propto \sum_T \mathcal{L}\left[f|f_T(z)\right] n_T(z)$$

f=fluxes
T=types

Rev. Bayes then guarantees that the population satisfies

$$\frac{dn}{dz} \propto \sum_i P(z_i|f_i)$$

This is what we need!
Point estimates not so useful...

What could possibly go wrong with that?

- We do not properly know the density of types $n_T(z)$ or the noiseless fluxes $f_T(z)$
- We do not properly know the measurement flux noise likelihood *L*
- *This equation is incorrect in the (unavoidable) presence of any selection effect, including redshift binning!*

Improving the prior n_T, f_T

- **Synthetic template** offer no information on $n_T(z)$. Also does not exactly reproduce observed colors f_T.
- **Color map** techniques (eg SOM): often incomplete knowledge of $n_T(z)$, but a good knowledge of $f_T(z)$.
  - Leistedt Mortlock Peiris: Bayesian hierarchical model (BHM) with $n_T(z)$ and all individual z's as free parameters. Still reliant on priors where colors are fully ambiguous / uninformative on T,z.
- Ideally: generate n_T, f_T by **sampling the real population**, where truth z is known.
  - *"BFD" method does this "sampled prior" for estimating weak lensing shear - part per thousand accuracy!*
  - What sampling density is sufficient? Can "fuzz" each template by using spectral synthesis to generate template "clones" in a small range of z (Speagle et al)
  - DES is maximizing DECam coverage of multi-/narrow-band photo-z survey fields.

Getting the right noise distribution

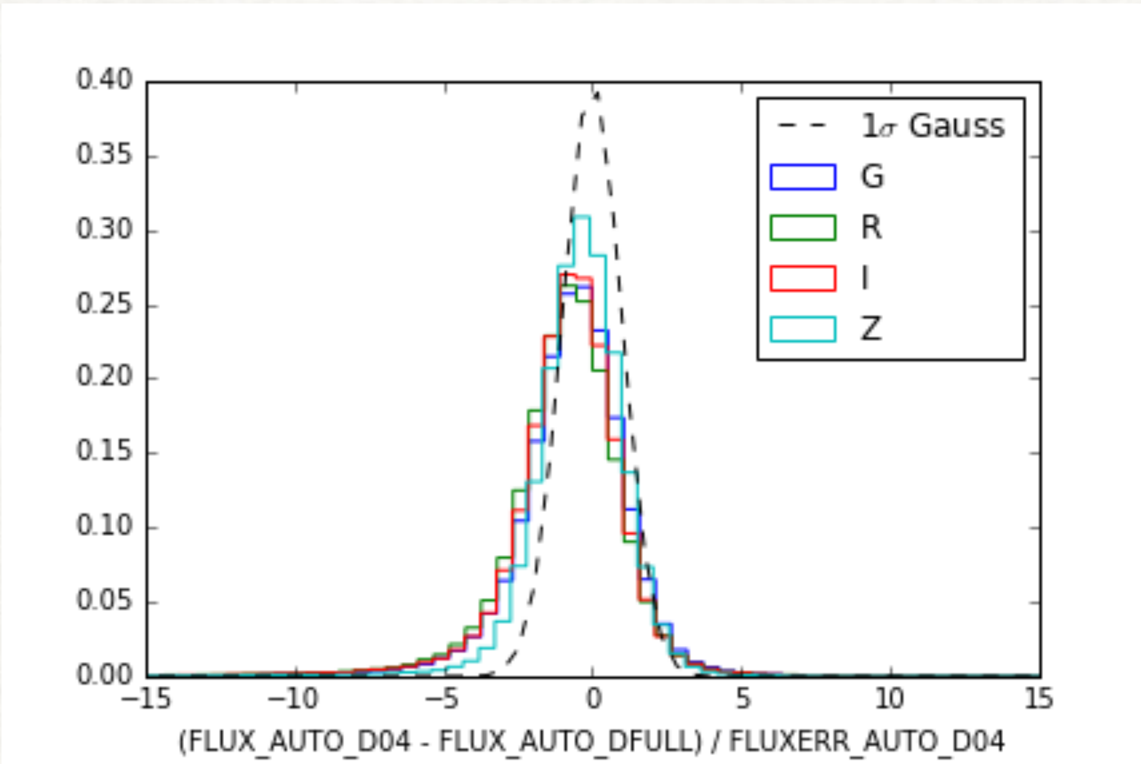
$$P(z|f) \propto \sum_T \mathcal{L}\left[f|f_T(z)\right] n_T(z)$$

- How much attention has been paid the flux likelihood in other surveys (e.g. DES *Balrog*, HSC *SynPipe*)?
- Complex fitting, iterative aperture photometry yield obscure error distributions. Better off with fixed-aperture, PSF-corrected fluxes (GaaP, BFD)?

$$\begin{Bmatrix} M_I \\ M_r \\ M_+ \\ M_\times \end{Bmatrix} = \int d^2k \, \frac{\tilde{I}^o(\boldsymbol{k})}{\tilde{T}(\boldsymbol{k})} W(|\boldsymbol{k}^2|) \begin{Bmatrix} 1 \\ k_x^2 + k_y^2 \\ k_x^2 - k_y^2 \\ 2k_x k_y \end{Bmatrix}.$$

- An example from work of Christina Krawiec (UPenn) on probabilistic identification of high-z galaxies

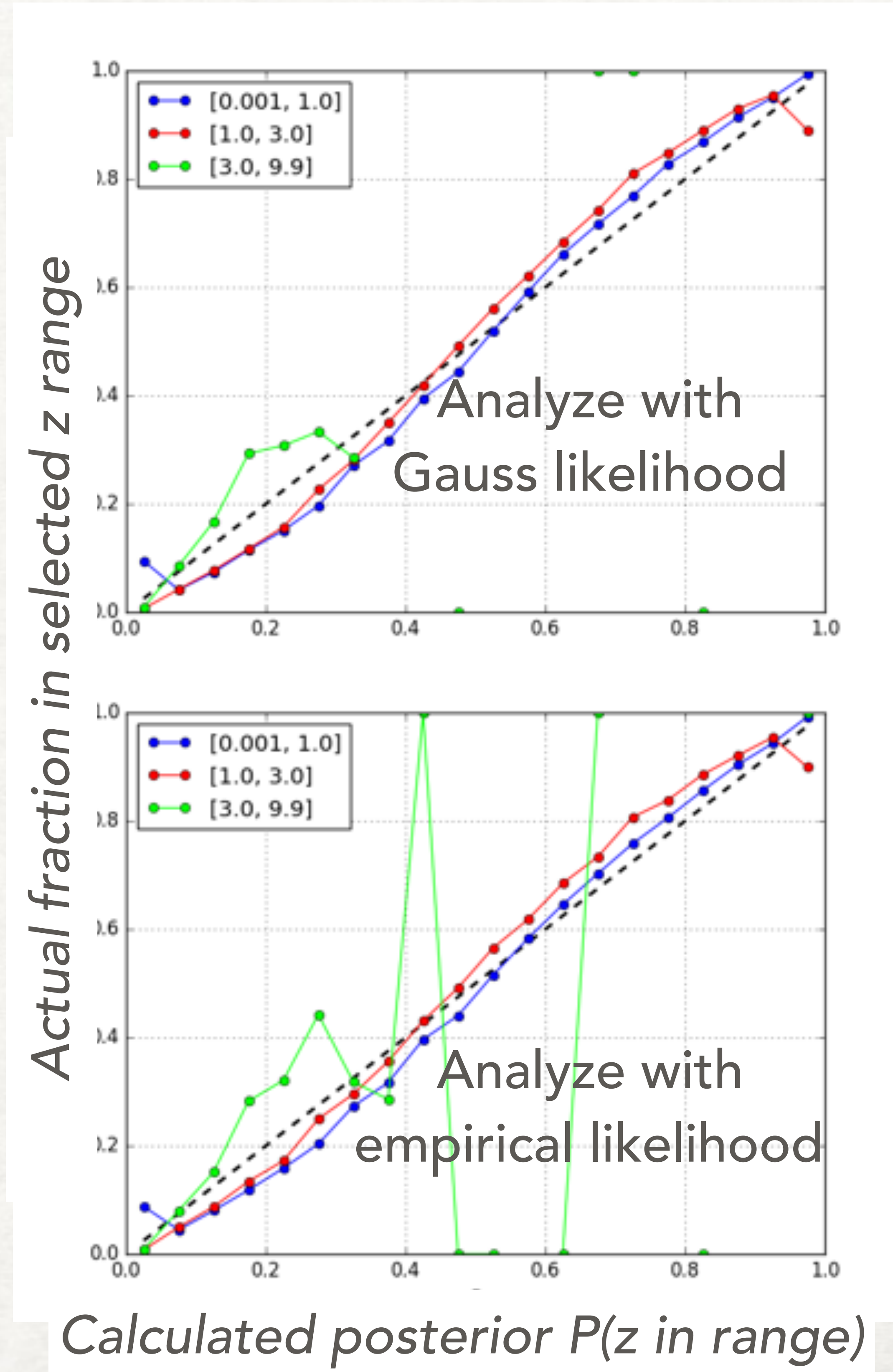
Demonstration of effect of error mis-estimation



Compare MAG_AUTO in deep image to normal-noise photometry, plot in units of claimed MAGERR_AUTO.

Done on COSMOS field where multi-band PZ's are available.

Research by Christina Krawiec at Penn.



Conceptual errors in standard BPZ

$$P(z|f) \propto \sum_T \mathcal{L}\left[f|f_T(z)\right] n_T(z)$$

$$\frac{dn}{dz} \propto \sum_i P(z_i|f_i)$$

- As Alex Malz has emphasized, latter statement is correct only when $n_T(z)$ starts off correct…
- A deeper flaw: *selection is not included. We only use selected galaxies, so the correct formula is*

$$P(z|s,f) \propto \sum_T \mathcal{L}(f|s,T,z)P(s|T,z)n_T(z)$$

Censored flux likelihood: depends on galaxy morphology too

Selection prob (depends on observing conditions!)

Selection functions

- Like it or not, you have one, and it is noisy.
- Bin assignment is a particularly difficult selection function to quantify, e.g. selection function that depends on the *P(z|f)!*
- *P(s)* via simulated data (& ML training): need to repeat this for all different observing conditions /depths in the survey.
- WL measurement codes also have selection functions /weights - and we know they cause "large" (~1%) errors in shear if not corrected. ***PZ and WL cannot make independent selections, each must know the total selection function to avoid biases!!***
  - *BFD method can calculate the selection function analytically for the fixed-aperture moments when selection is made on the basis of these moments, e.g. a flux cut.*
  - *Metacal method corrects selection by repeating entire measurement process with slightly sheared version of input image, including re-running PZ codes. But per-bin BPZ posteriors still not formally correct.*
- DES Y3 will need to confront this head-on.

Conceptual errors in standard BPZ

$$P(z|s,f) \propto \sum_T \mathcal{L}(f|s,T,z)P(s|T,z)n_T(z)$$

This term is wrong too!

$$P(z|s,f) \propto \sum_T \mathcal{L}(f|s,T,z)P(s|T,z)\bar{n}_T(z)\left[1 + b_T\delta_m(\Omega,z)\right]$$

- Down this route lies the technique of full BHM sampling of the survey (mass/galaxy density fields, redshift assignment, cosmology)
- Also yields (I think) a natural method for combining clustering and photometric redshift information
- And joint selection criteria.
- …but that is not likely to be implemented for DES Y3 reductions this year.