On the joint forward modeling of WFIRST-AFTA and LSST imaging

Wide-field Infrared Surveys: Science and Techniques, Dark Energy parallel session 1

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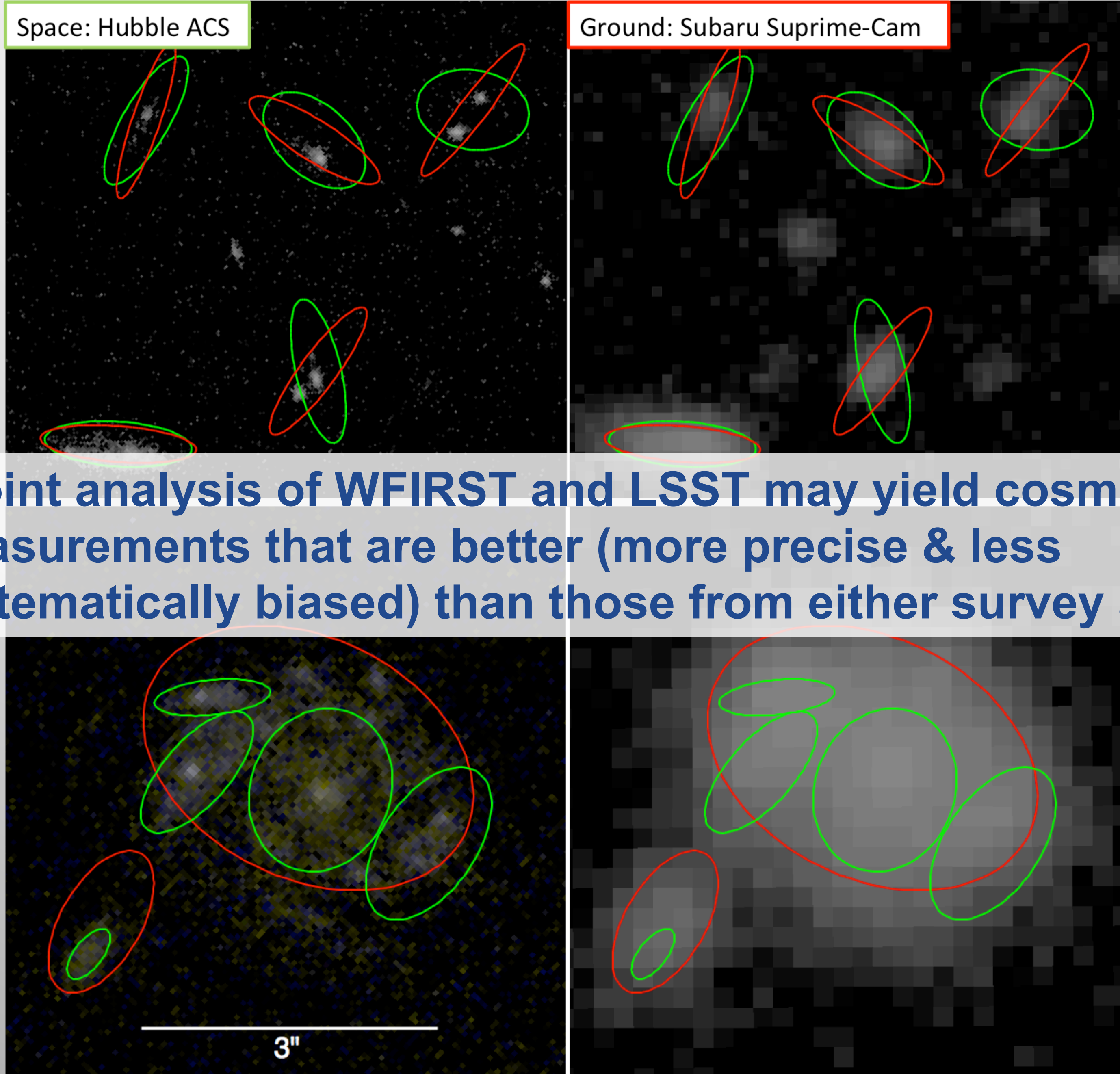


A joint analysis of WFIRST and LSST may yield cosmic shear measurements that are better (more precise & less systematically biased) than those from either survey alone.

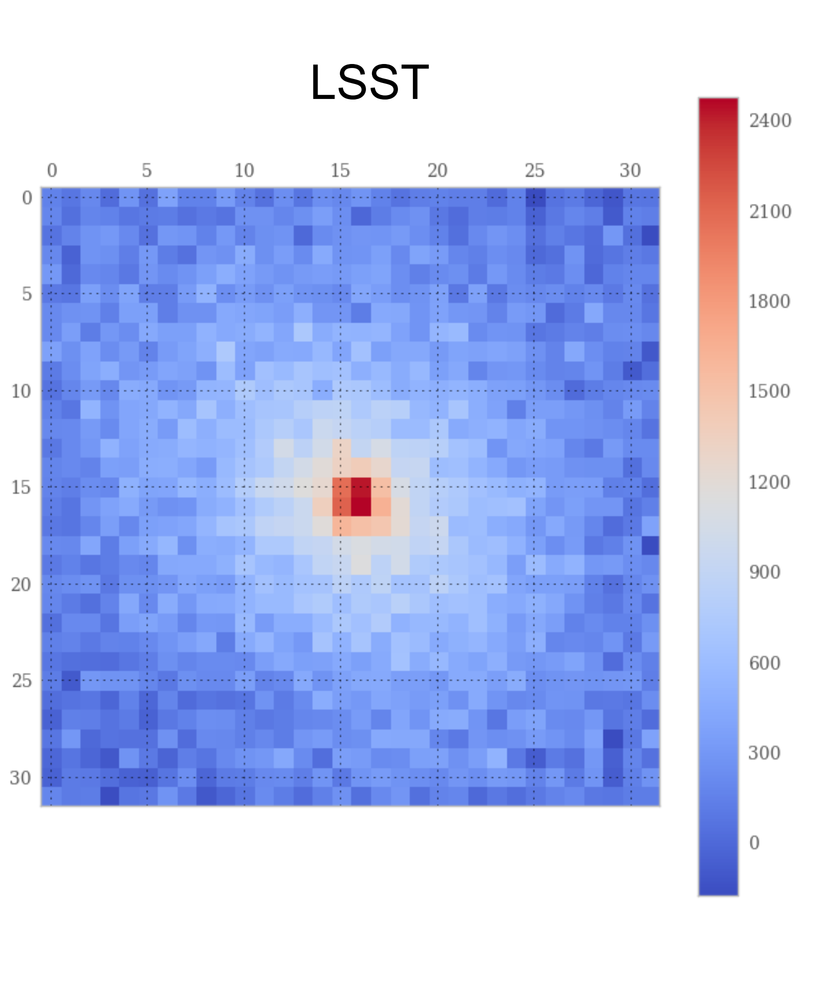
We expect different shear measurements from different surveys because,

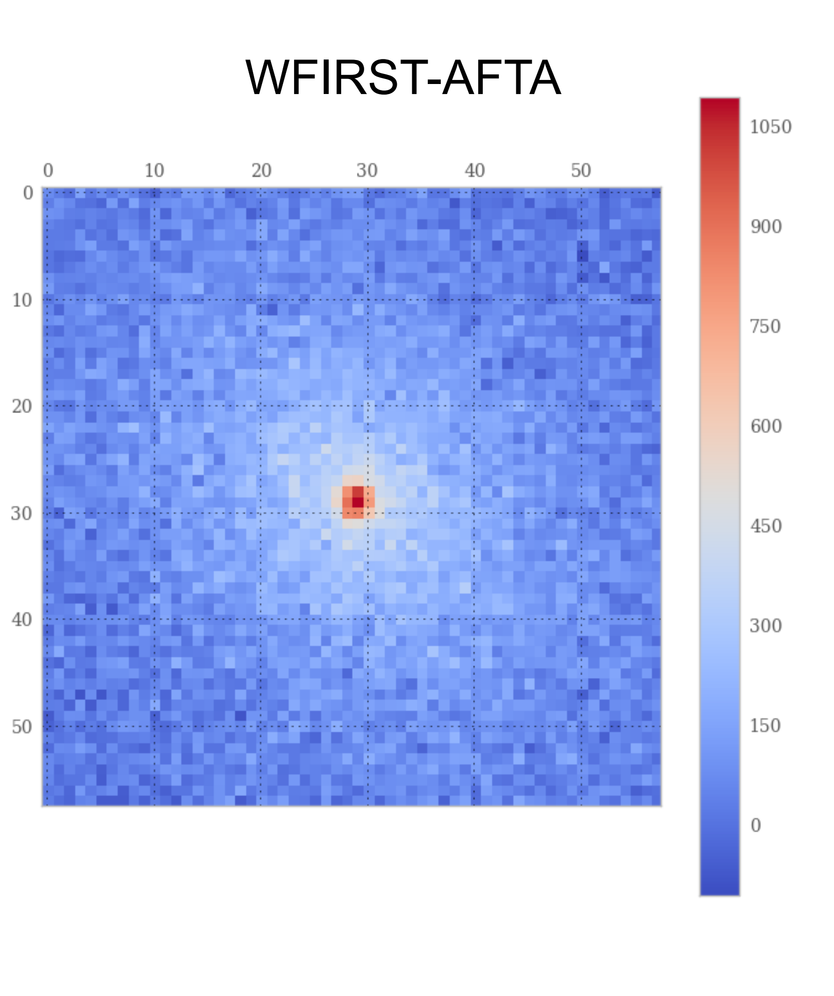
1. Different PSFs and pixel scales let us see different parts of a galaxy.

2. Galaxy morphologies change with wavelength.
   - Some galaxies may only be detectable in one survey.

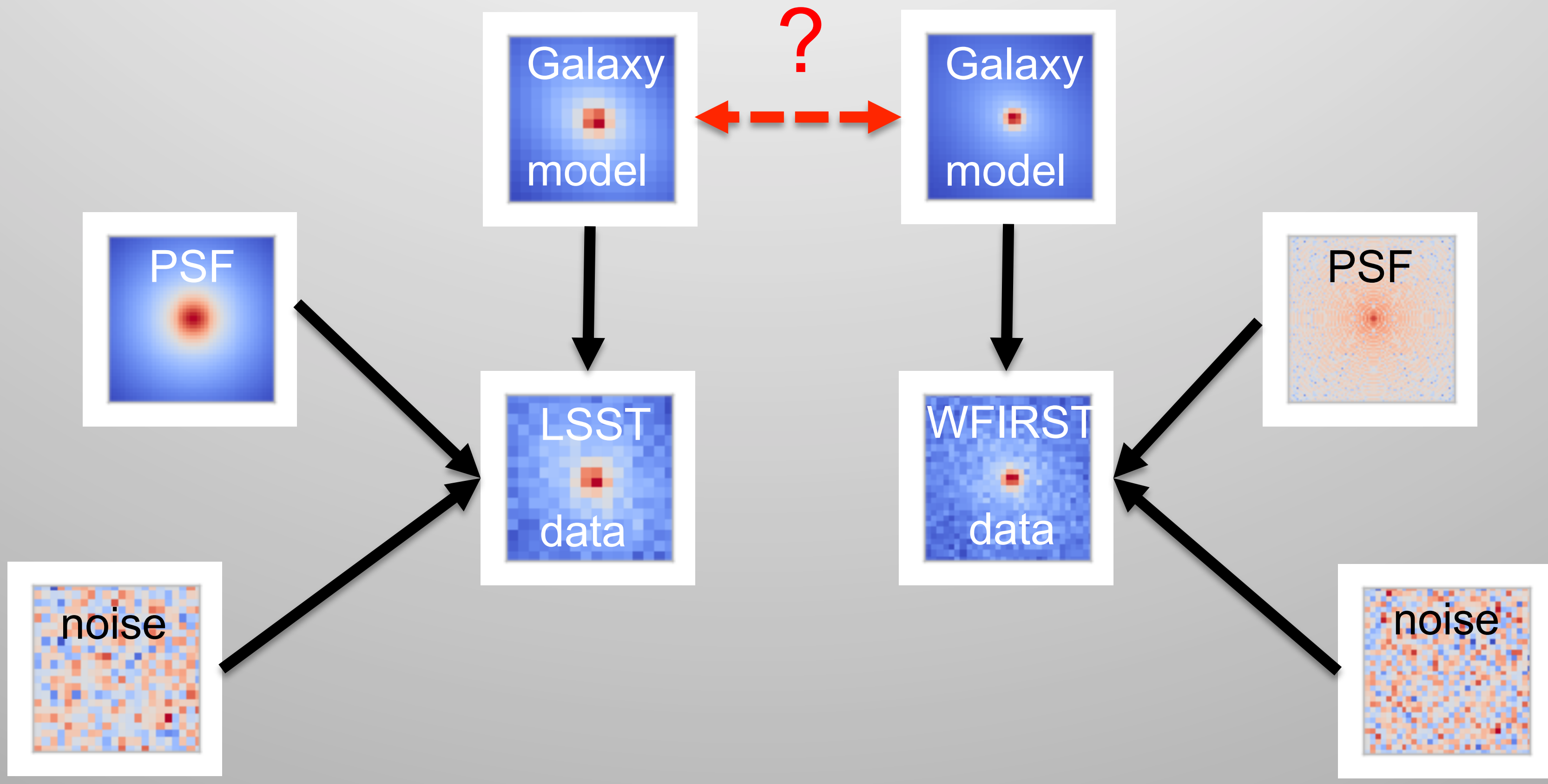
3. Objects can be blended (or shredded) as seen with different PSFs.

How do ellipticity measurements compare for an isolated, high-SNR galaxy?





Measuring galaxy ellipticity (and other properties) from different surveys



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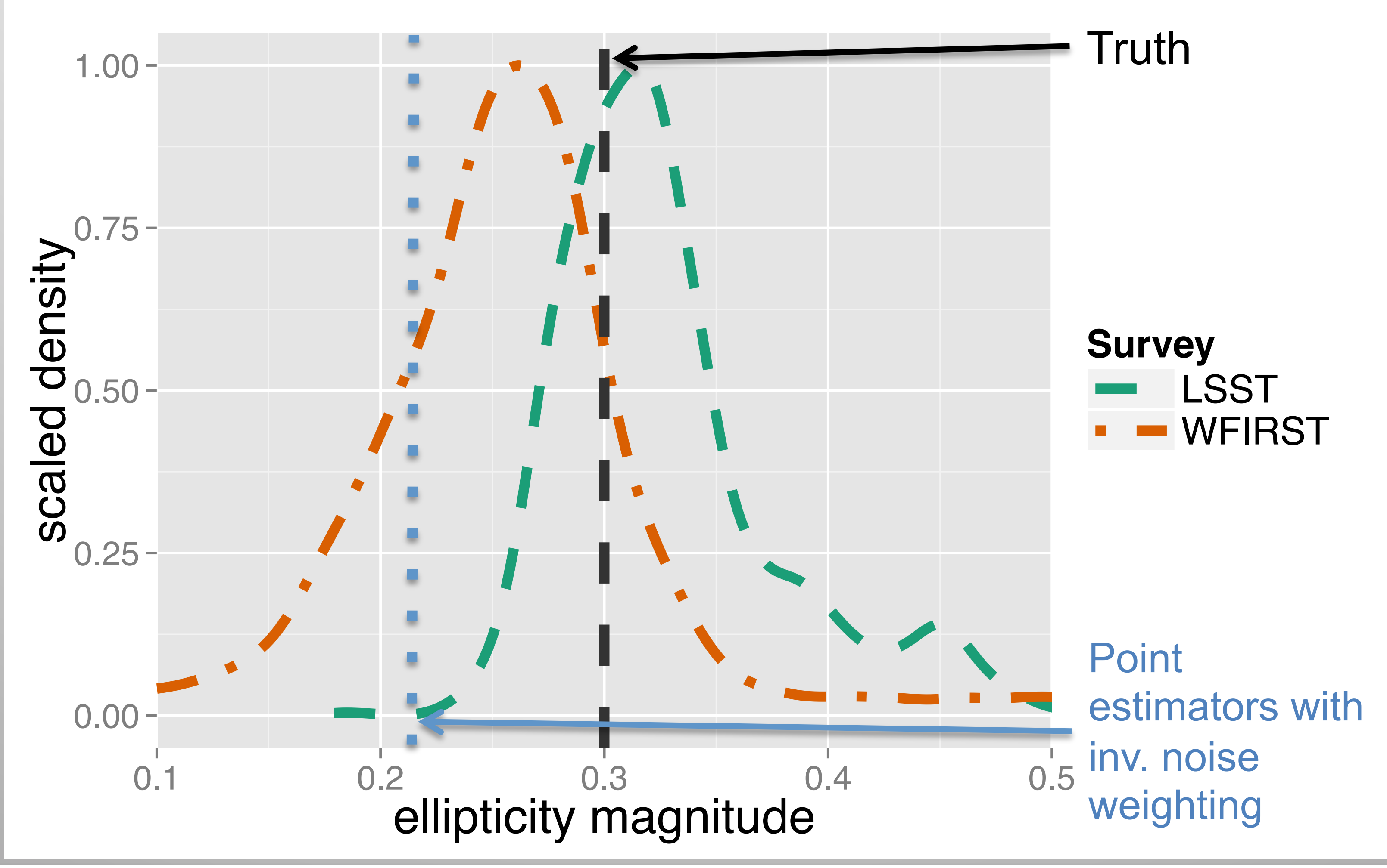
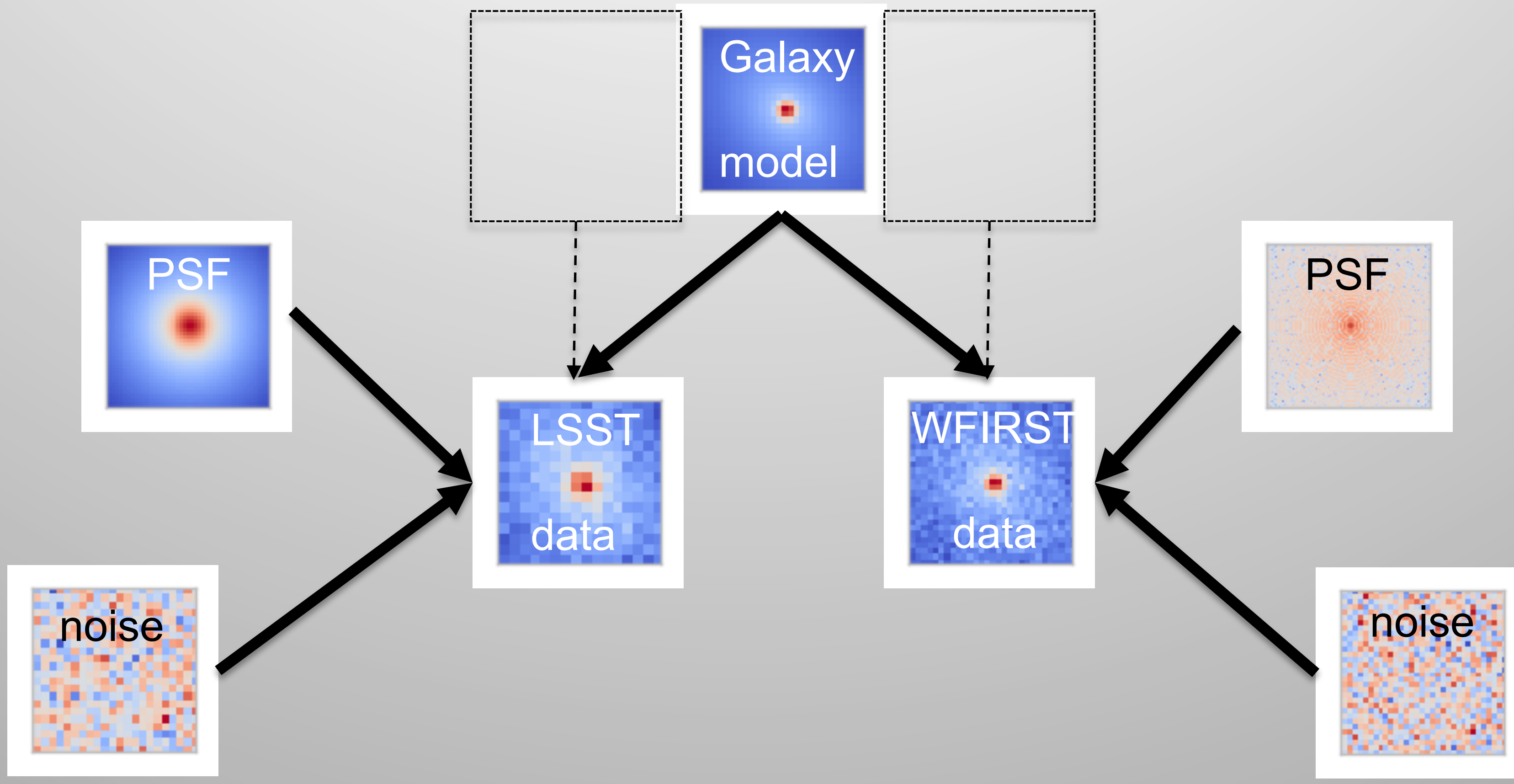


Measuring galaxy ellipticity (and other properties) from combined survey data

Analyze pixels from both surveys assuming same galaxy model.
Analogous to forced photometry.



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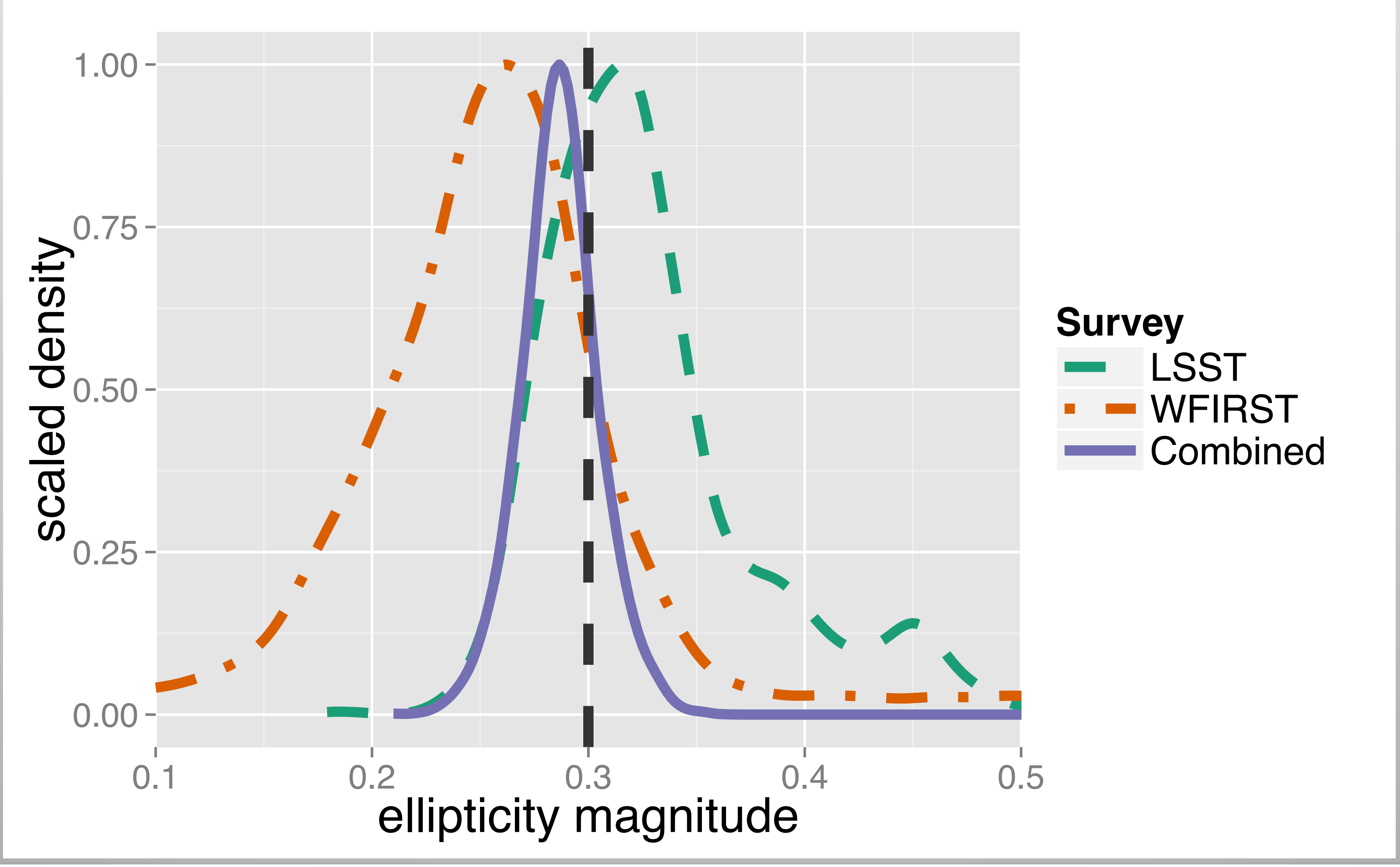
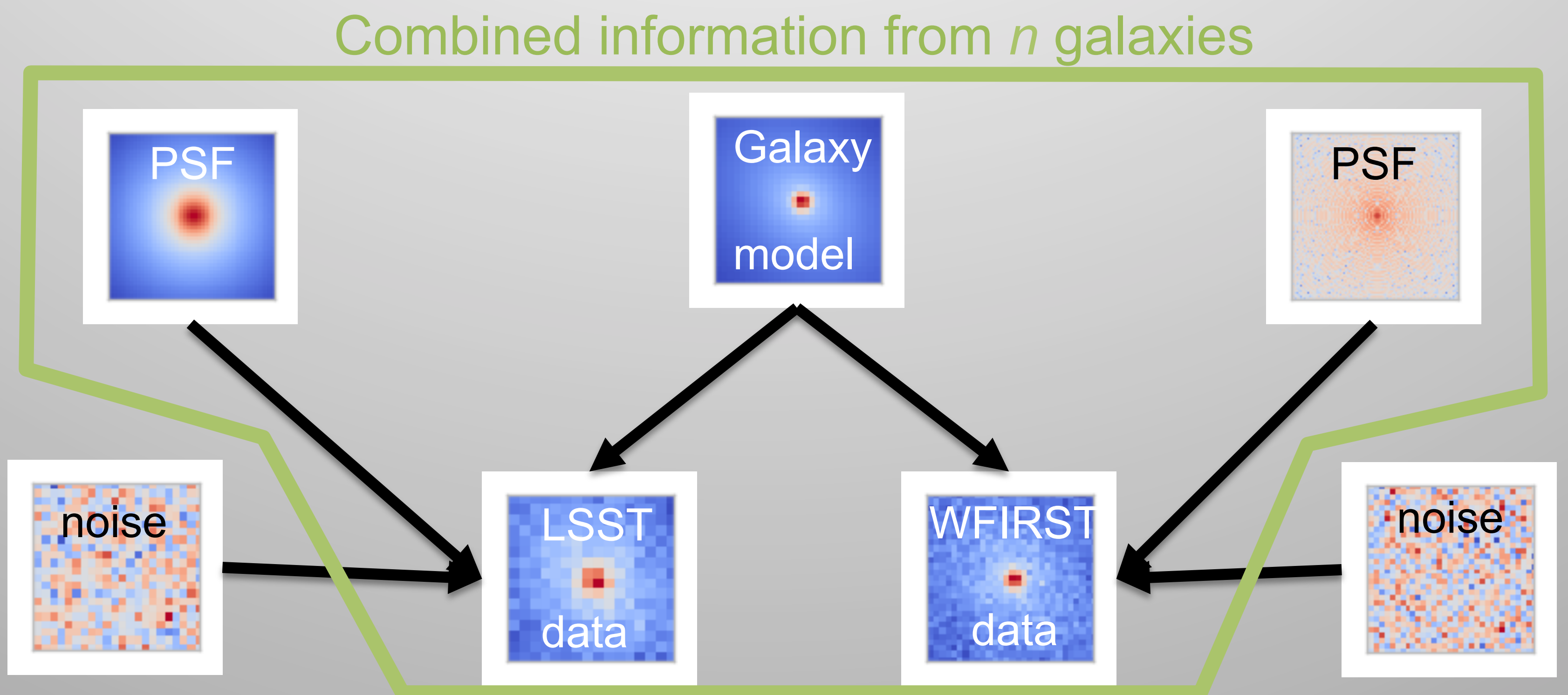
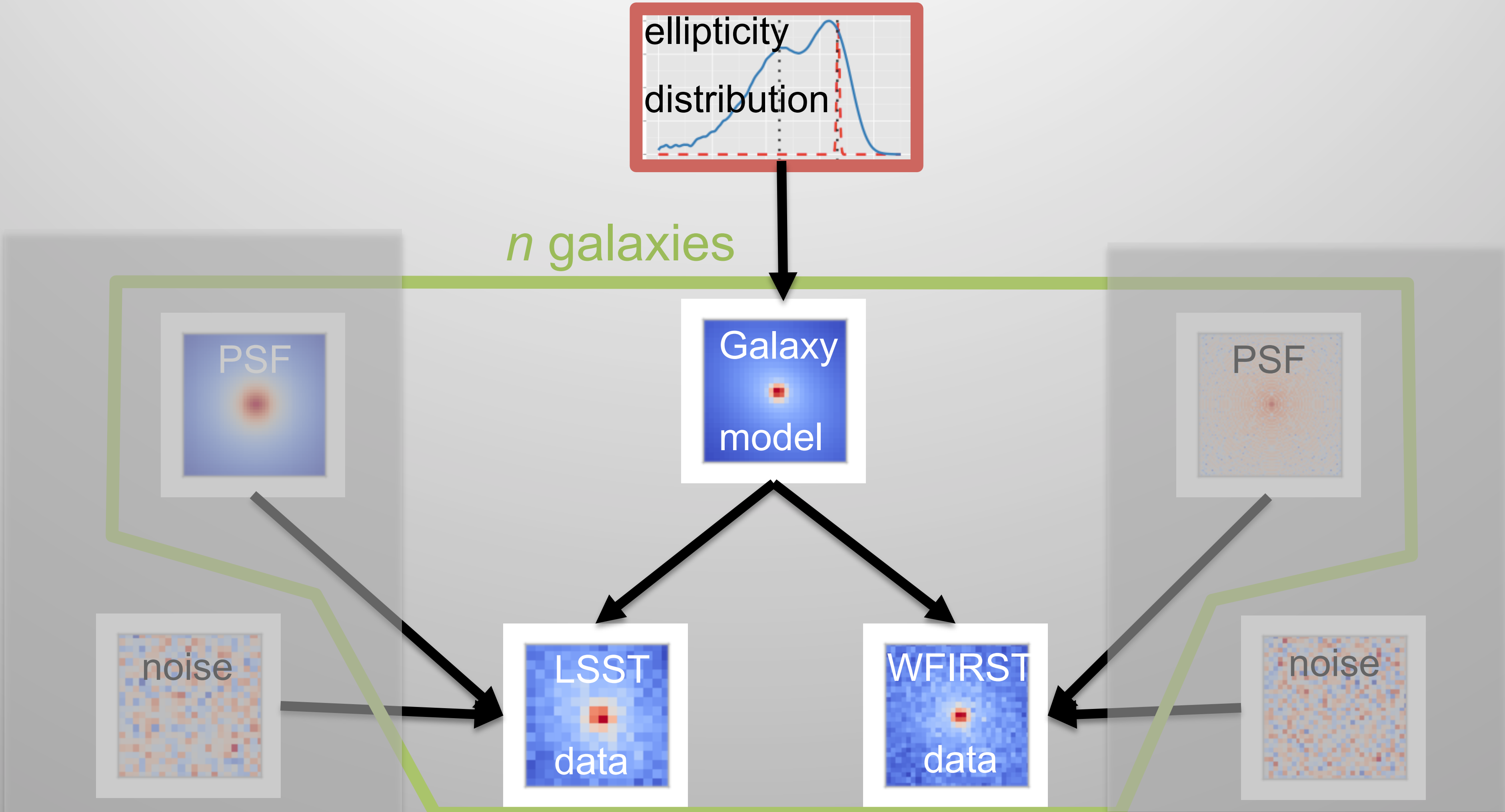


Combining information from different galaxies…

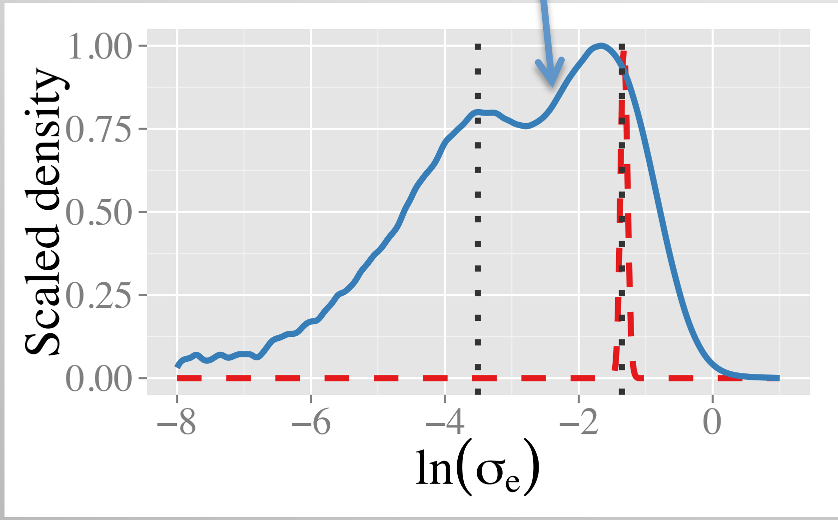


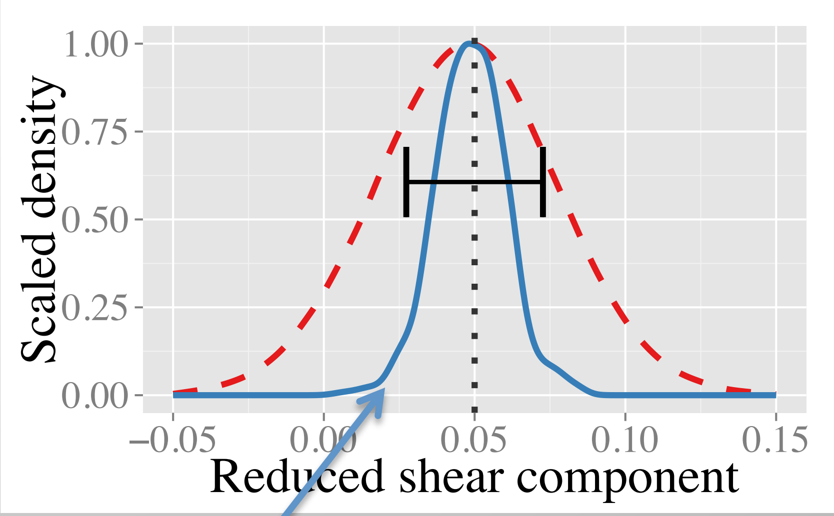
Combining information from different galaxies requires a hierarchical model



Learn responsivity to shear

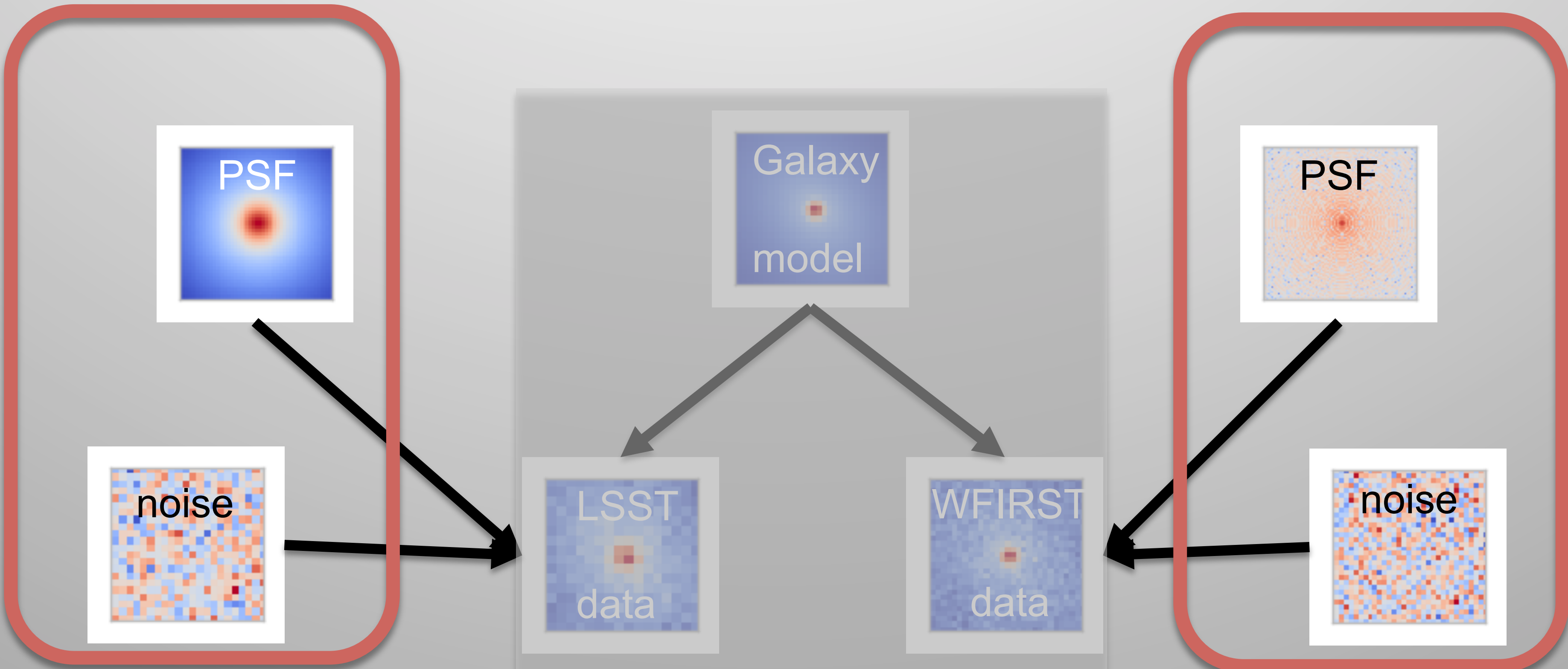
Galaxy intrinsic ellipticity distribution is bi-modal.



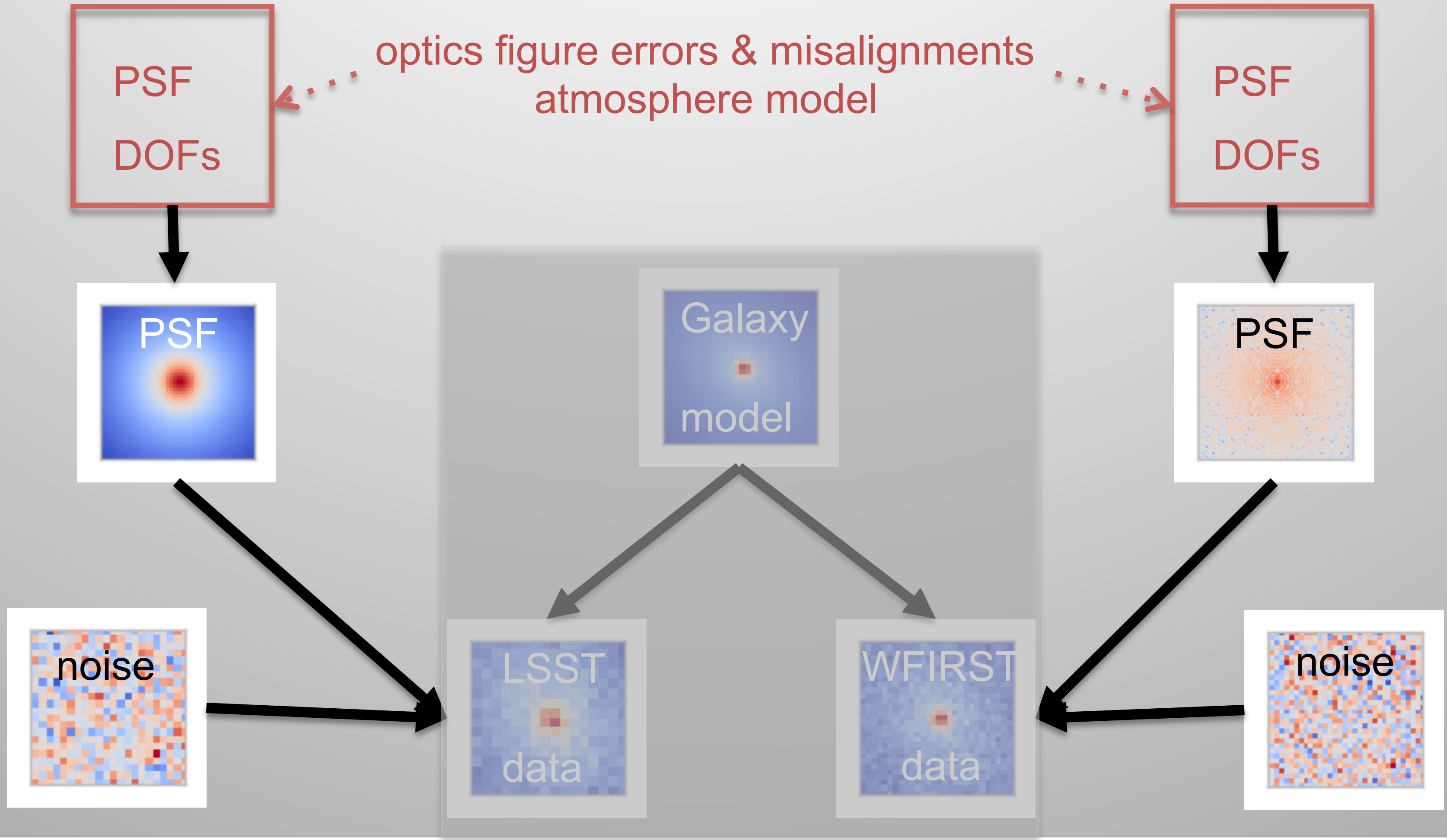


Knowledge of rounder sub-population improves shear inference.

Unbiased inference of galaxy properties requires marginalization of PSFs (and noise models)



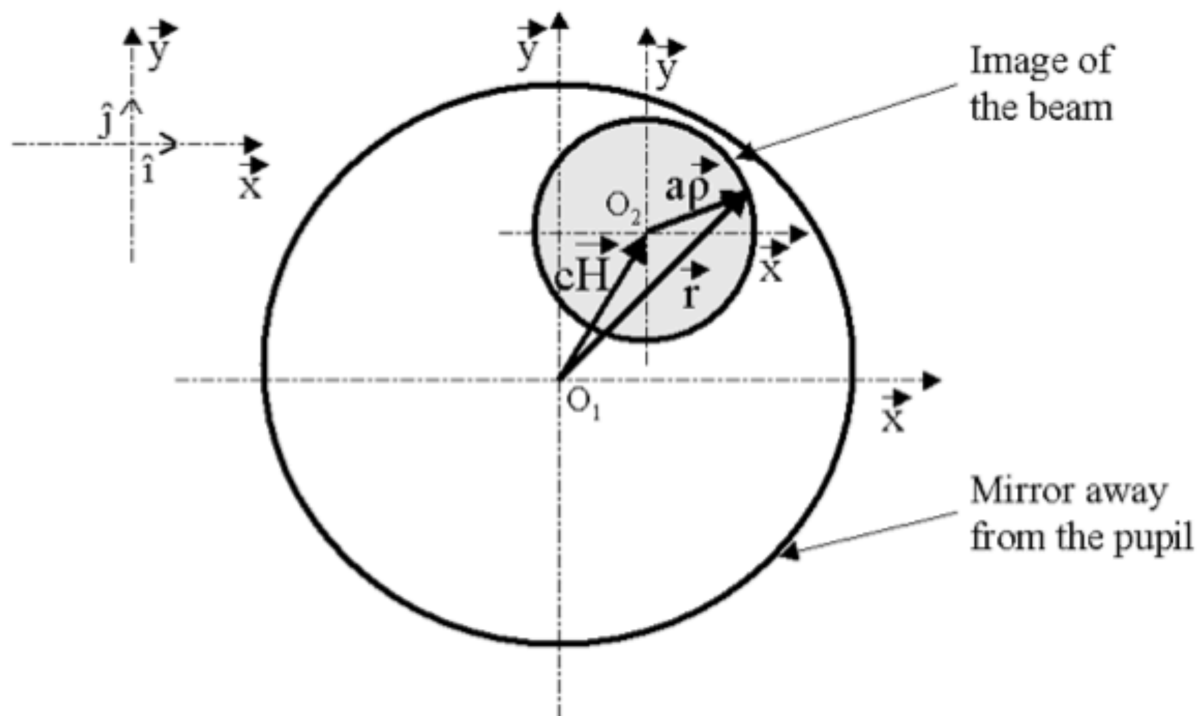
Marginalize PSF uncertainties with a consistent model for all objects in a field



Fast parameterized model for the aberrated optics PSF

Goal: Map figure errors and tilts/decenters to exit pupil wavefront perturbations as a function of field location.

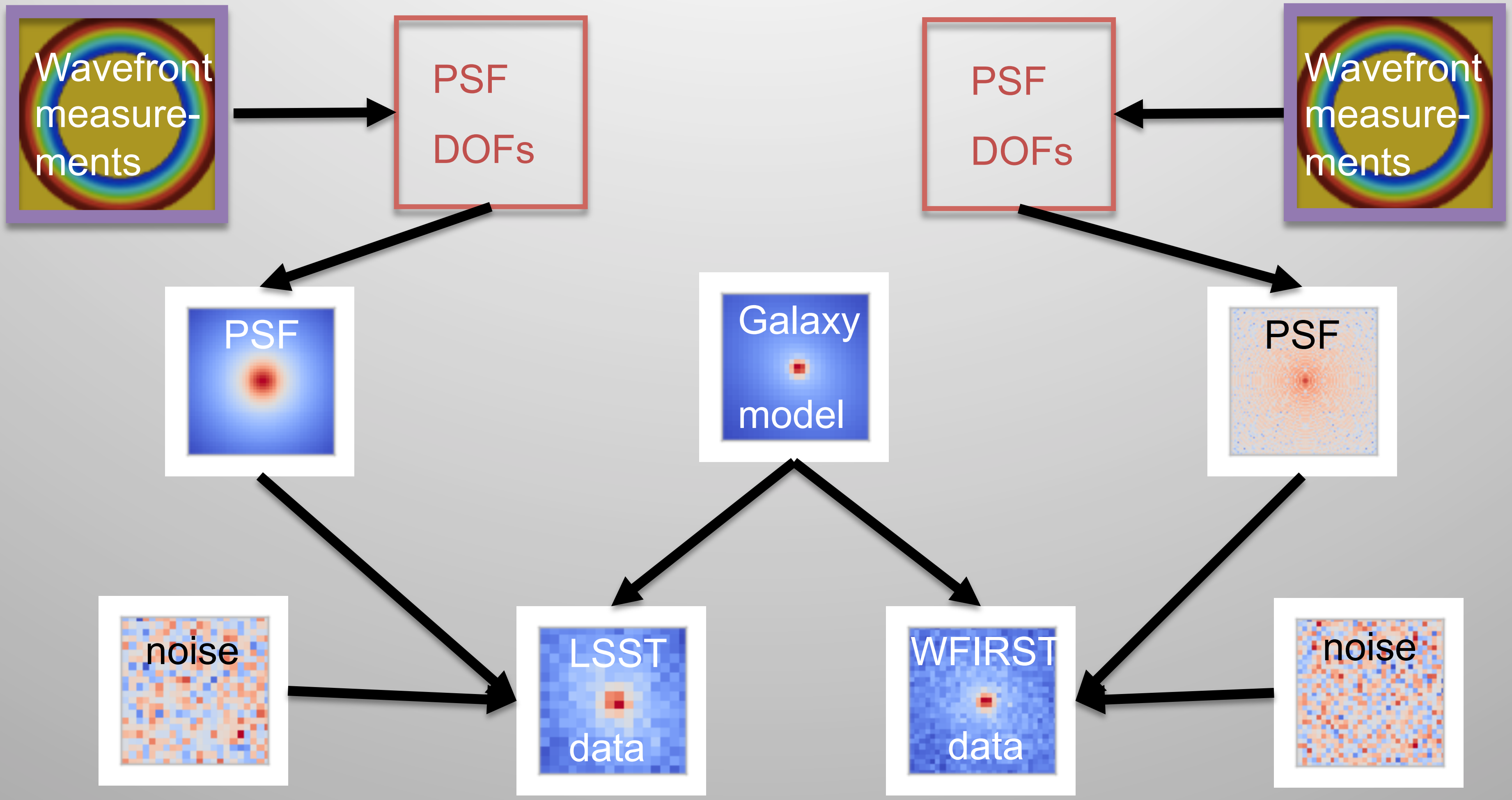
Geometry for mapping bending modes on mirrors to basis functions in the exit pupil.



Tessieres & Burge (2004)

- Thompson (1980, 2005)
- Tessieres & Burge (2004)
- Manuel (2009)
- Schechter & Levinson (2011)

Include external constraints on PSF uncertainties from stars or direct wavefront measurements



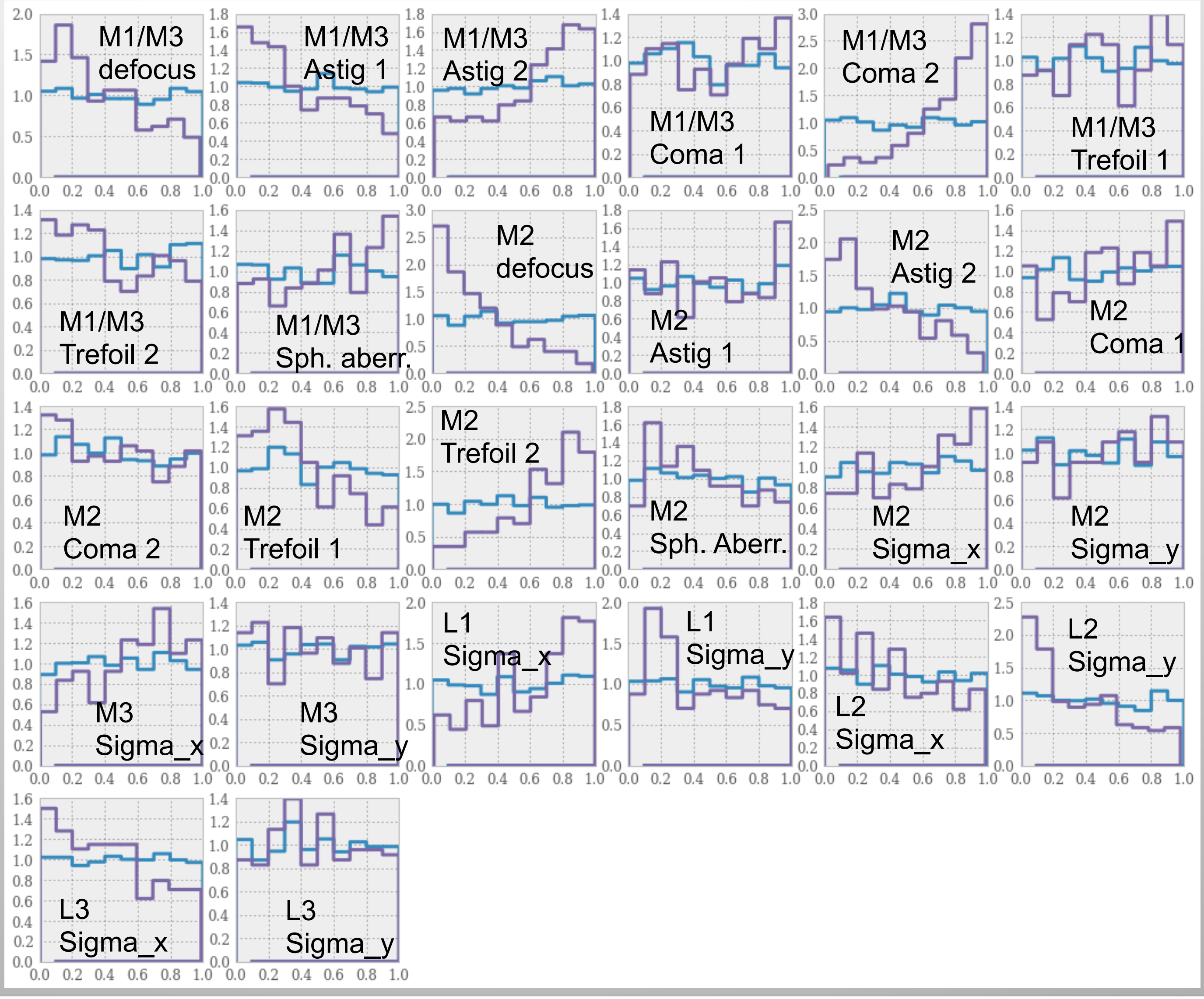
Including external constraints on PSF uncertainties

LSST optical design

26 optics perturbation parameters

Blue: no bound on AO merit function

Purple: AO merit function < 0.01



Methods for combining survey data

1. Catalog comparison
2. Interim samples from 1 survey + pixel-level analysis in 2nd survey
   - Need many samples
3. Interim samples from both surveys
   - Need many samples + binning of model parameters
4. Joint analysis of pixel data

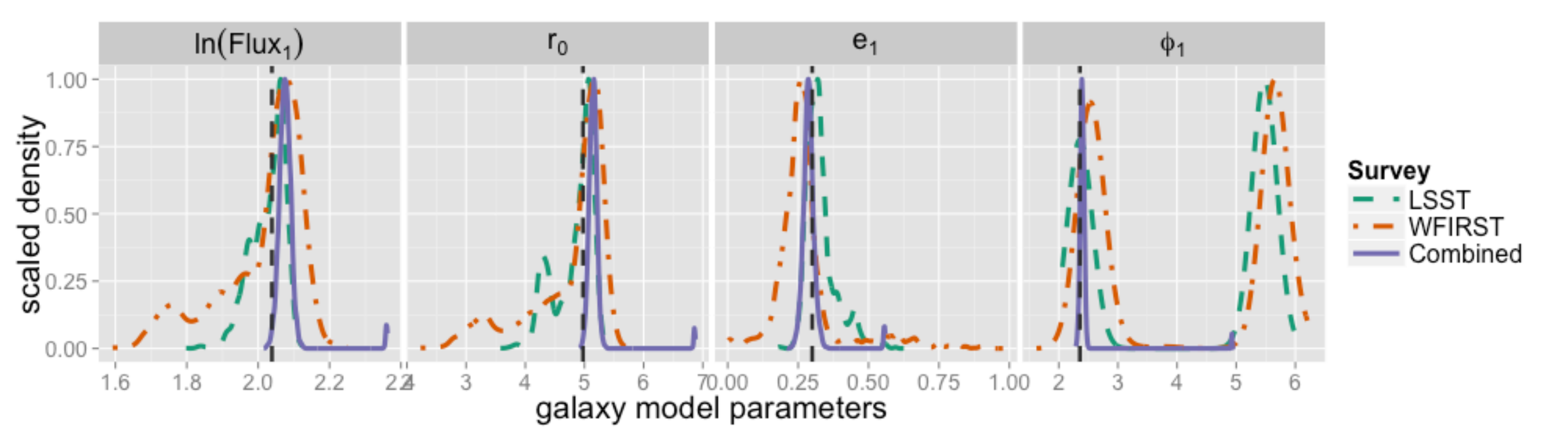
Challenge: methods 2 - 4 often require re-analyzing pixel data

Summary recommendations

1. Don't combine catalogs -- Instead combine random samples of model parameters.
2. Prioritize models (of galaxies, telescope, detector) that are fast to evaluate.
3. Plan for computing resources for Monte Carlo sampling (incl. reanalysis of surveys).
4. Move PSF analysis from the image to the pupil plane.

Statistical framework described in arXiv:1411.2608

Marginal densities of galaxy model parameters



Codes for MCMC of galaxy models

- GalSim can predict pixel data with a parameterized model for a galaxy.
- But, it's slow if we need to recompute for every step in an MCMC chain.
- Josh Meyers (Stanford) benchmarked:

PSF	Galaxy	Time per step (sec)
Moffat	Exponential	0.03
Moffat	de Vaucouleurs	0.54
Kolmogorov + aberrated optics	Exponential	0.58
Kolmogorov + aberrated optics	de Vaucouleurs	1.1