Photometric Calibration of DES

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What is Photometric Calibration?

- DES measures fluxes of stars, galaxies, supernovae, etc as counts of photoelectrons on CCDs
- Converting those counts to physical fluxes and magnitudes is the purpose of calibration
- Major effort from the calibration working group in DES.

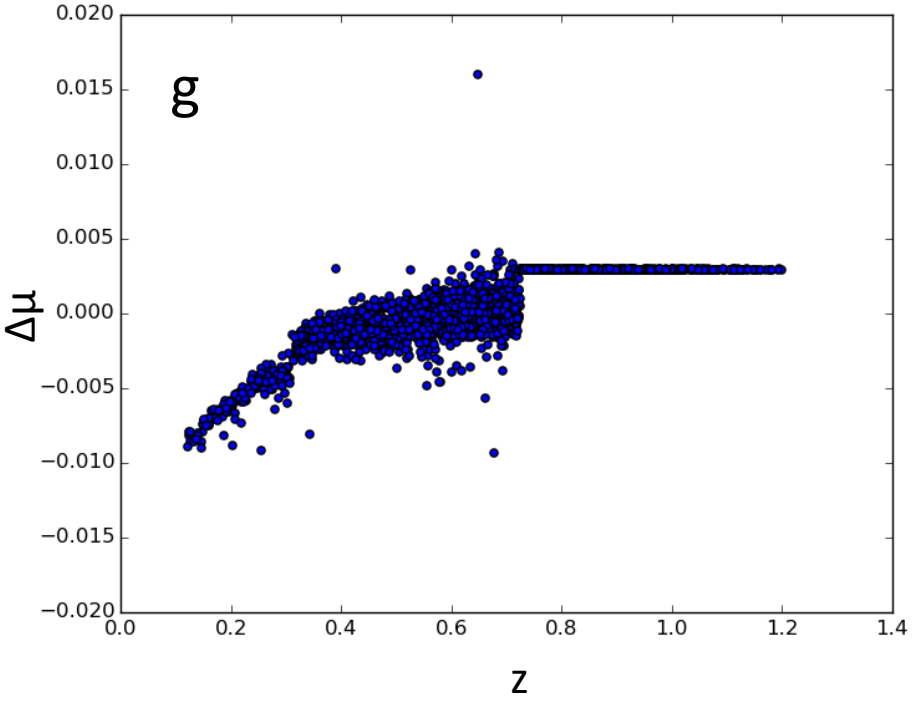
Photometric Calibration is the largest systematic error in Supernova Cosmology

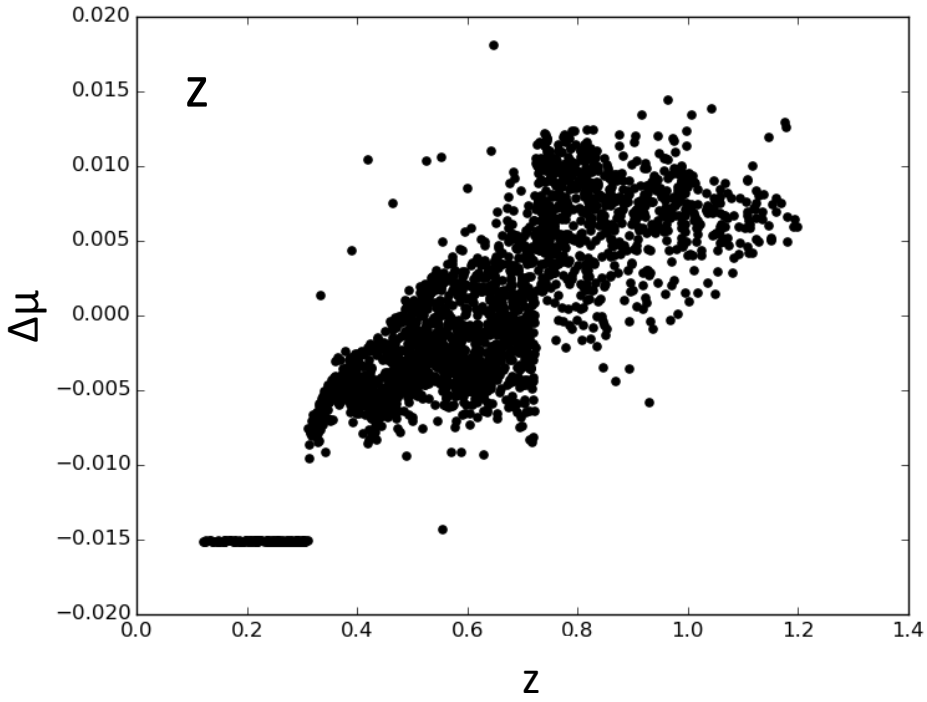
Pan-STARRS Supernova Survey Systematic Error Budget

Systematic Error Source	Contribution to dw
Photometric Calibration	**0.045**
SN Color Model	0.023
Host Galaxy Dependence	0.015
MW Extinction	0.013
Selection Bias	0.012
Coherent Flow	0.007

Scolnic D, Rest A, Riess A, Huber ME, Foley RJ, Brout D, Chornock R, Narayan G, Tonry JL, Berger E, et al. (2014) Systematic uncertainties associated with the Cosmological Analysis of the First Pan-STARRS1 Type Ia Supernova Sample. APJ 795:45

A 1% calibration uncertainty causes light curve fitter to add systematic bias in Distance Modulus with redshift as well as introducing scatter



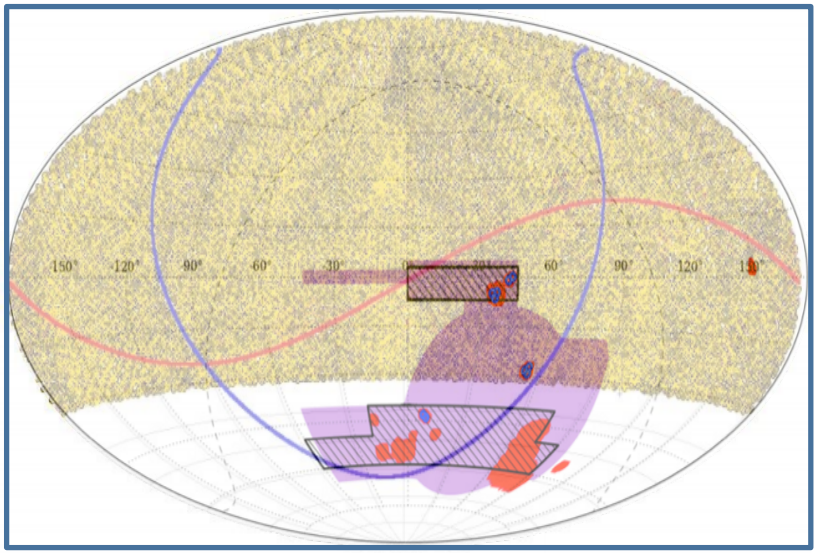


DES has several paths attacking the photometric calibration

- Observations of standard stars (CalSpec and Other independently calibrated stars)
- **Cross-checking the Calibration with previous well-calibrated surveys like Pan-STARRS**

FGCM Calibration is cross-checked by prior surveys

- Largest and best-calibrated survey, Pan-STARRS (PS1) overlaps with 8 DES Supernova Fields
- PS1 is calibrated to 5 mmag across 3π of the sky



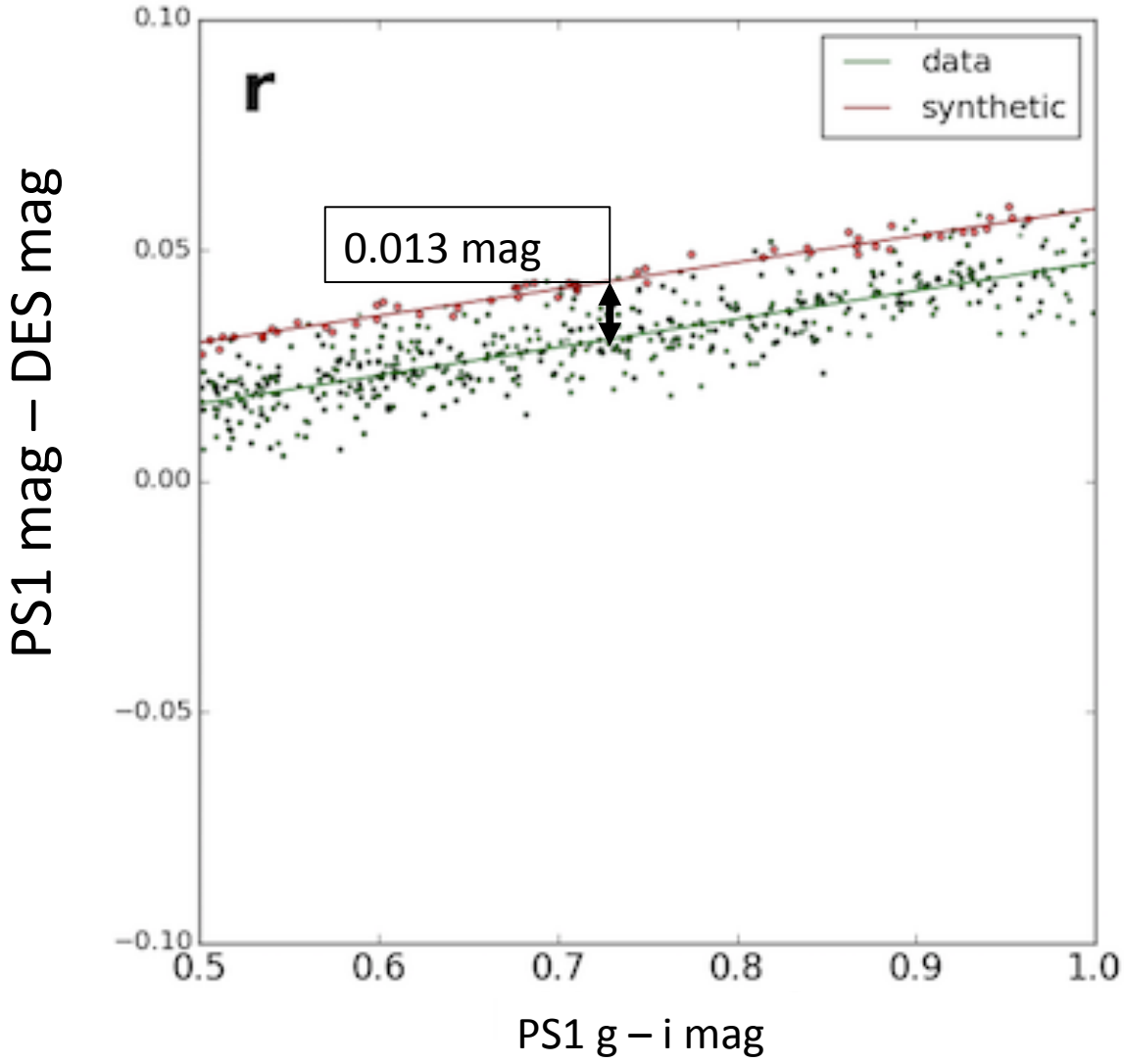
Yellow and black = PS1
Purple = DES wide field
Blue = DES supernova fields

Scolnic, D., S. Casertano, A. Riess, A. Rest, E. Schlafly, R. J. Foley, D. Finkbeiner, et al. 2015. "Supercal: Cross-Calibration of Multiple Photometric Systems to Improve Cosmological Measurements with Type Ia Supernovae." The Astrophysical Journal 815 (2) (December 16): 117. doi:10.1088/0004-637x/815/2/117.

The cross-calibration of DES and PS1

- Using the measured filter transmission functions of DES + PS1, we calculate synthetic magnitudes for a library of standard stars
- Then compute the expected magnitude difference between the two surveys as a function of color.
- Compare the expected difference with the observed difference

The cross calibration of DES and PS1



This plot is using the stars in DES field C1

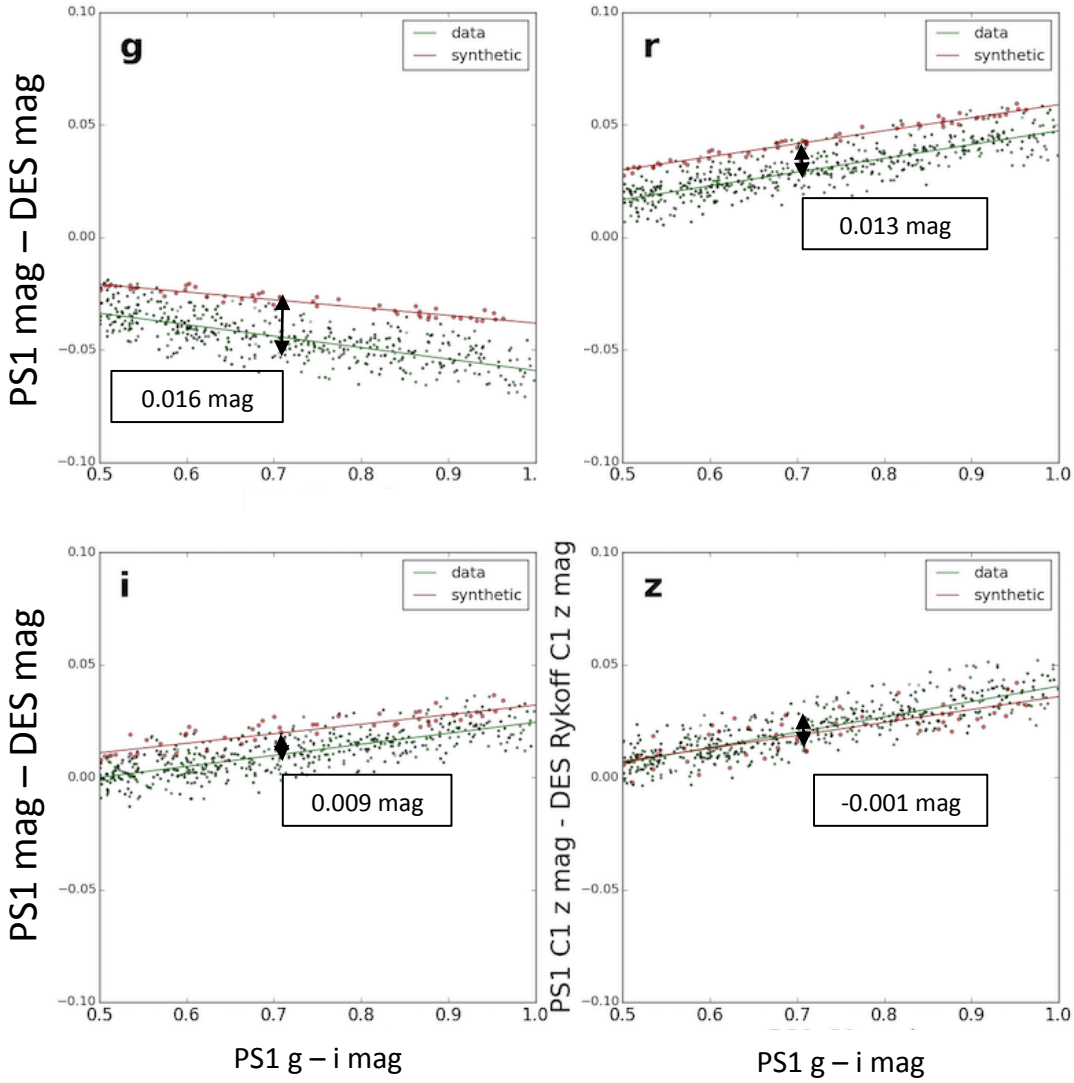
Ideally, slopes are identical and the offset is zero.

Slopes here are very close to identical, but the offset is 13 mmag.

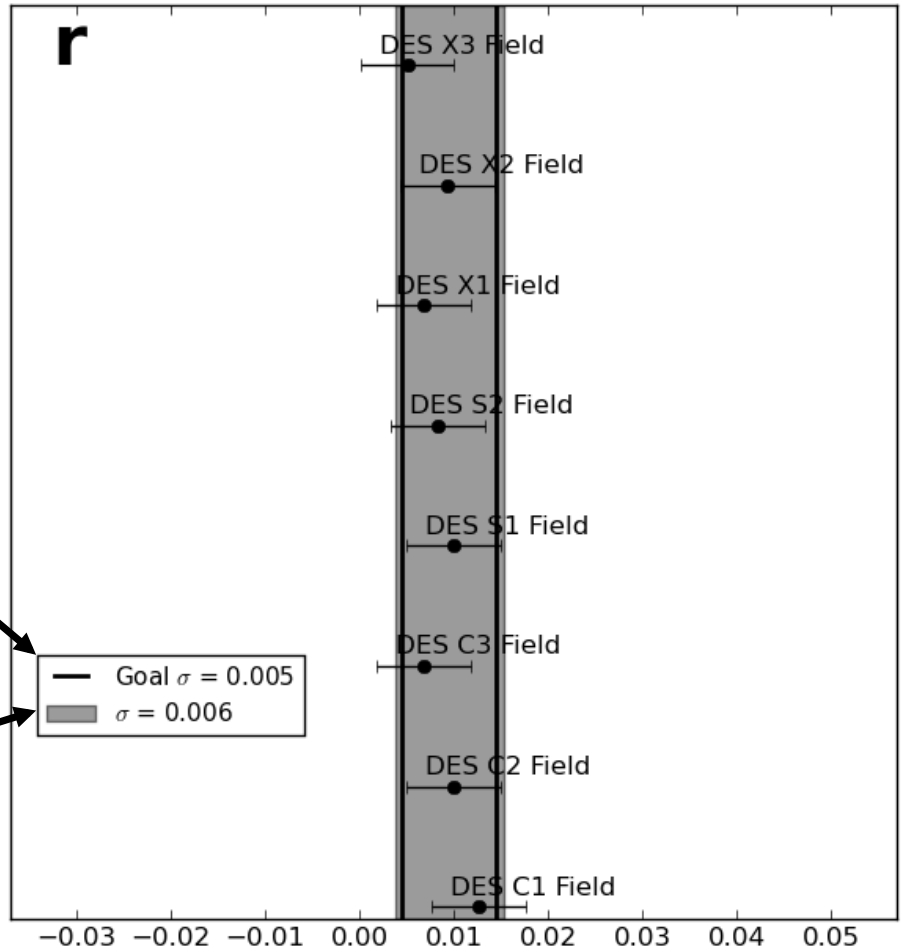
For individual fields this offset can vary by a few mmag from zero, but this is too much.

However, there are still unapplied corrections.

The cross calibration of DES and PS1



Field to Field Relative Calibration of DES and PS1

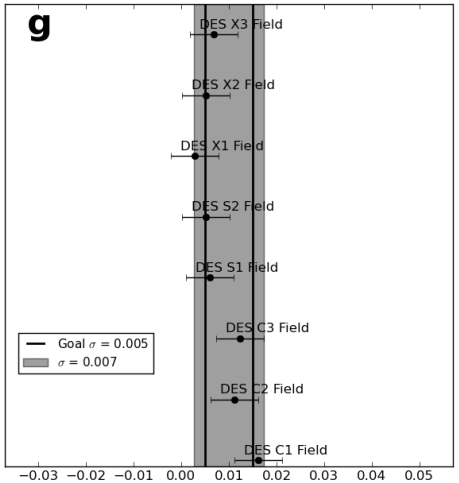


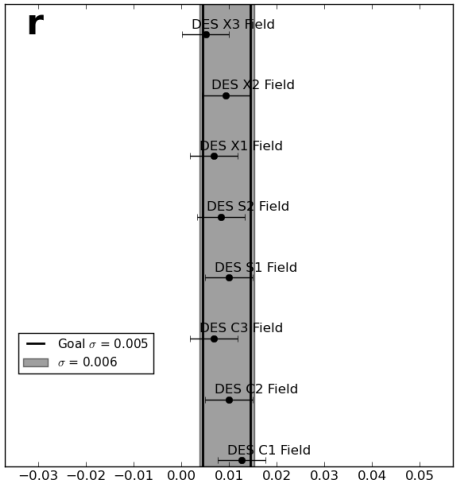
Calibration uncertainty goal is 0.5 % (5 mmag)

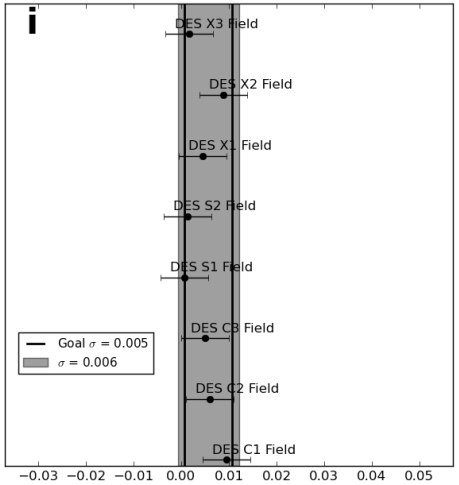
Shaded area indicates current uncertainty.

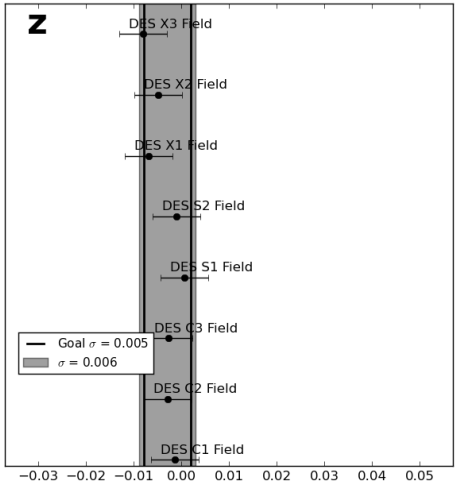
The arrows on the previous slide ⟷

Field to Field Relative Calibration of DES and PS1









Conclusions

- Difference Imaging only requires ~2% calibration
- Current Calibration is ~1% (includes errors from standard stars not shown here)
- In order to reduce Calibration systematic to be subdominant to statistics, need 0.5%
- Still working to improve both mean and scatter using chromatic corrections from SN SEDs, atmospheric models, and CCD-by-CCD transmission functions.

Li, T. S., DePoy, D. L., Marshall, J. L., Tucker, D. L., Bernstein, G. M., et al., "Assessment of Systematic Chromatic Errors that Impact Sub-1% Photometric Precision in Large-Area Sky Surveys", 2016, AJ, 151,157