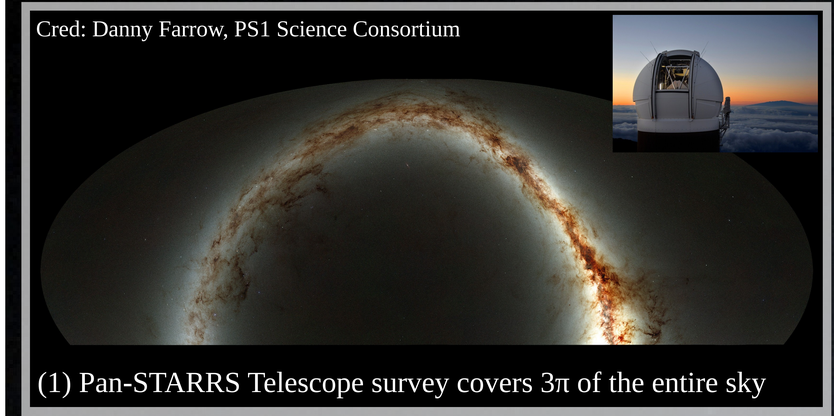
Photometric Calibration of the Pan-STARRS Survey to Improve Cosmological Measurements with Type Ia Supernovae

Joseph Manuel[1], Daniel Scolnic[2]

[1]Department of Astrophysics and Planetary Science, Villanova University

[2]Department of Physics, Duke University



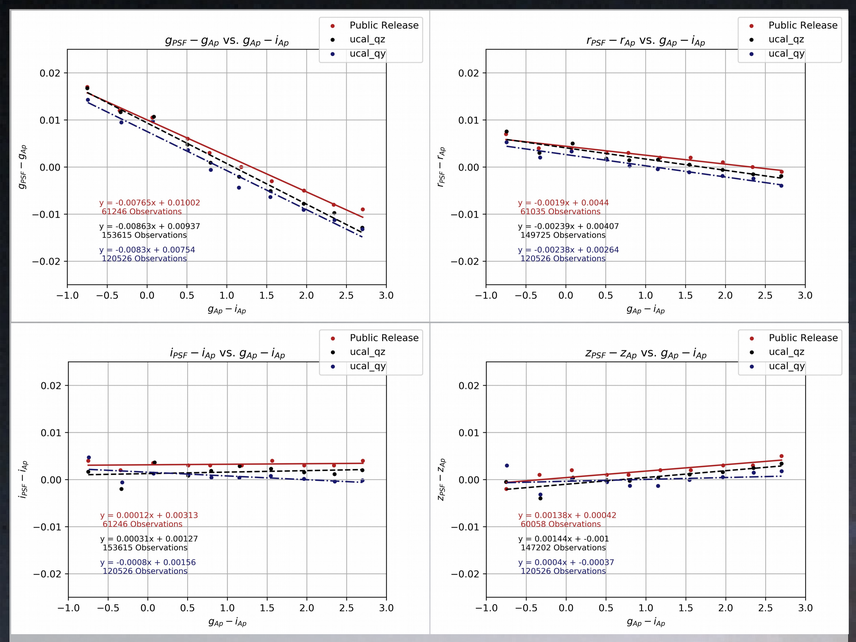
(1) Pan-STARRS Telescope survey covers 3π of the entire sky

Abstract

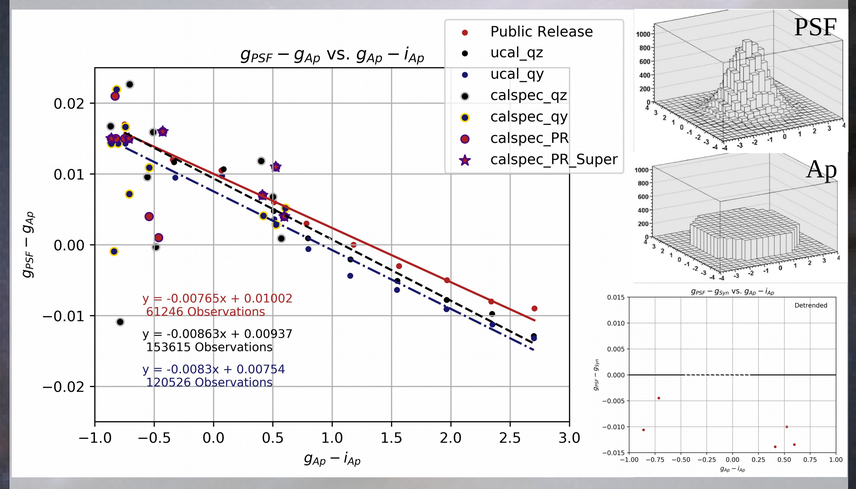
Photometric calibration is the dominant systematic uncertainty in the analysis of type Ia supernovae (SNIa) for precision cosmology (Scolnic et al. 2018). Recent studies have shown that 1% level uncertainties in the calibration can propagate to up to 5% level systematic uncertainties in measurements of the equation-of-state of dark energy. The Pan-STARRS survey (PS1) is critical in this pursuit as it has discovered and measured a large fraction of the SNIa used to measure dark energy, and the PS1 calibration has been used to re-calibrate almost every other SN survey. Here, we revisit the calibration of PS1 to address percent-level discrepancies in measurements between the Point-Spread Function (PSF) versus aperture photometry of calibration stars. We find a significant discrepancy in *g* passband, likely due to the PSF-shape dependence on color. We correct for this affect by changing the effective passband, and then redetermine the absolute calibration of the PS1 survey. We measure the calibration of each filter to 3 mmag, paving the path to next best measurements of dark energy with even bigger samples of SNe in the future.

Method

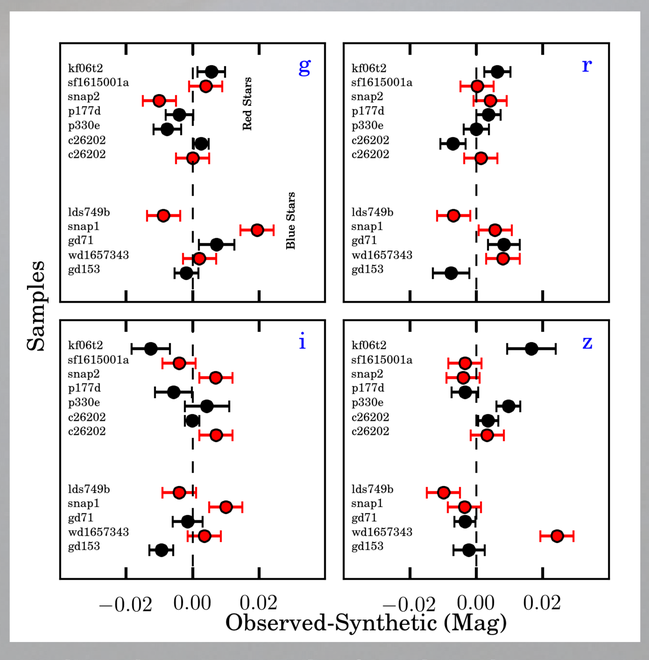
In our initial results from sampling the Pan-STARRS data across several versions, we find that there is a significant discrepancy occurring between the PSF and Aperture magnitudes such that a dependency is occurring with respect to the color index, primarily in the *g* passband (2). We are reasonably convinced that the PSF magnitudes are primarily affected over the Ap magnitudes because of scattering susceptibility for bluer light. Additionally, because the bluest band in the sample is *g*, high-*z* SN observations measure much bluer rest-frame wavelengths than the low-z observations



(2) PSF-Ap Magnitudes in the *g*,*r*,*i*,*z* passbands binned against color, displaying significant discrepancy in the *g* passband



(3) Overplotting matched Calspec and Supercal photometric standards in the PS1 survey for the *g* passband | bottom right panel displays the detrended, matched PS1 PSF-Supercal objects



(4) Observed-Synthetic magnitudes for select photometric standard samples compared between Calspec (red) and PS1 (black)

(Scolnic et al. 2018). A shift in a single passband can also bias SN color measurements which further requires this phenomena to be addressed (Jones et al. 2018). To properly calibrate this effect, we match photometric standards on the Calspec system from the Hubble Space Telescope and the Supercal system, provided by D. Scolnic (2015) to their respective Pan-STARRS measurements (3). We see that this color dependency is also present in the photometric standards, so from here, we then detrend the matched Pan-STARRS measurements. This is done by comparing their respective Synthetic magnitudes produced by the Supercal system and eliminating the color dependency as displayed in the bottom right panel (3).

Results / Future Work

In our analysis, we are able to identify, in the *g* filter, a color dependency in the prior calibration of the Pan-STARRS data contributing to a systematic uncertainty of about 1%. In the calculation of the equation-of-state parameter for dark energy, this propagates to an approximate systematic uncertainty of 5% which we have now been able to account for and eliminate. A comparison of sample Calspec and PS1 measurements between their observed and synthetic magnitudes show greater agreement as a result of this correction (4). Future analysis will look at possible sky dependency for this blue band phenomena, as differing observation coordinates may yield varying susceptibility. Work will be done to account for this dependency in the Pan-STARRS calibration system if it is present which will contribute to the next best measurements of dark energy in the future.

Acknowledgments

The authors gratefully acknowledge support for this project through the Kavli Institute for Cosmological Physics at the University of Chicago.

References

Conley, A., Guy, J., Sullivan, M., et al (2011). Astrophysical Journal, Supplement Series, 192(1).

Jones, D. O., Scolnic, D., Foley, R. J., Rest, A., Kessler, R., et al (2018). arXiv:1811.09286.

Scolnic, D., Casertano, S., Riess, A., Rest, A., Schlafly, E., Foley, R. J., et al (2015). Astrophysical Journal, 815(2).

Scolnic, D., Rest, A., Riess, A., Huber, M. E., Foley, R. J., et al (2014). The Astrophysical Journal, 795(1), 45.

Scolnic, D., Jones, D. O., Rest, A., Pan, Y. C., Chornock, R., et al (2018). Astrophysical Journal, 859, 101.