# Absolute Photometric Calibration in Rubin Data Preview 1 with HST CalSpec Standard Star C26202

Christina Adair (SLAC), Douglas Tucker (Fermilab)

Abstract: The LSSTComCam commissioning observations of the Extended Chandra Deep Field South (ECDFS) included the HST CalSpec standard star C26202, which is faint enough to avoid saturation in LSSTComCam science images. This standard star was previously used for the absolute AB calibration of the Dark Energy Survey Data Release 2 (DES DR2). Two analyses were conducted using the LSSTComCam observations of C26202: (1) determination of AB magnitude offsets for the *ugrizy* bandpasses, and (2) measurement of the absolute system throughput for these bandpasses. AB offsets were derived by comparing calibrated LSSTComCam AB magnitudes with synthetic magnitudes. The absolute system throughput analysis involved computing expected counts for C26202 across a range of airmasses and comparing them with observed counts. Results show good agreement between measured and predicted values. This paper presents results from the final Data Preview 1 (DP1) processing.

## Introduction

The Extended Chandra Deep Field South (ECDFS) was observed with LSSTComCam during commissioning and includes an HST CalSpec* standard star, C26202 (Figure 1), which is faint enough to avoid saturation in LSSTComCam science exposures. This star has previously served as the absolute AB flux calibrator for the Dark Energy Survey Data Release 2 (DES DR2; Abbott et al. 2021).

Using the LSSTComCam observations of C26202, two complementary analyses were performed:

1. **AB Magnitude Offsets** — quantifying the deviation of the initial absolute photometric calibration from the AB magnitude system for each of the *ugrizy* bandpasses.
2. **Absolute System Throughput** — measuring the total system throughput of LSSTComCam across the *ugrizy* bandpasses.

*https://www.stsci.edu/hst/instrumentation/reference-data-for-calibration-and-tools/astronomical-catalogs/calspec

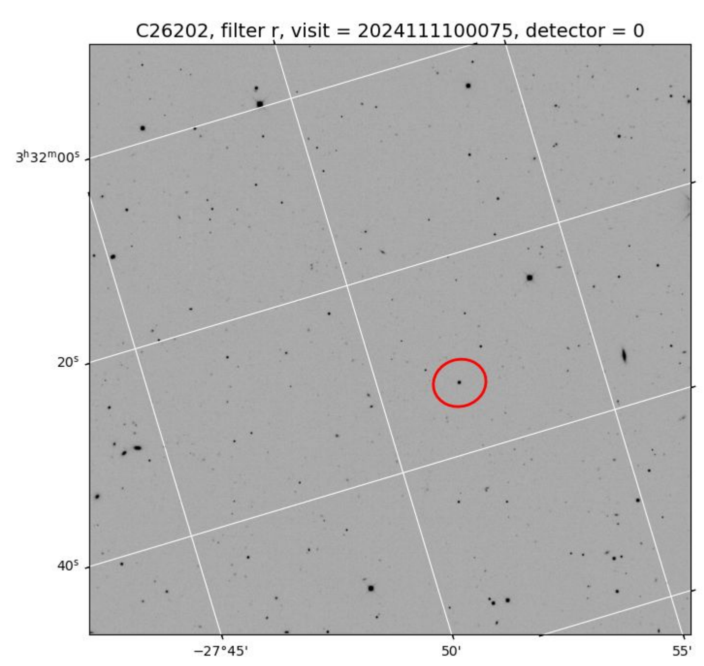


**Figure 1 - LSSTComCam image of HST CalSpec Standard Star, C26202**

## Synthetic Magnitudes

Synthetic AB magnitudes were computed using tools from the **`rubin_sim.PhotUtils`** package (https://rubin-sim.lsst.io/introduction.html) that integrated the product of the C26202 spectral energy distribution (SED) and the LSSTComCam total system throughput curves for each *ugrizy* bandpass (see Figure 2) and converted the resulting integrated fluxes into AB magnitudes. Essentially, Equation 7 of Fukugita et al. (1996), which defines the calculation of broadband AB magnitudes, was used.

The SEDs were obtained from the HST CalSpec database. The system throughput curves – which include filter transmission, optical transmission and reflectivity, detector efficiency, and the atmospheric transmission at Cerro Pachon) were obtained from the LSST **`syseng_throughputs`** GitHub repository (https://github.com/lsst-pst/syseng_throughputs). For the detector response, the average quantum efficiency of an LSSTCam ITL CCD was employed.

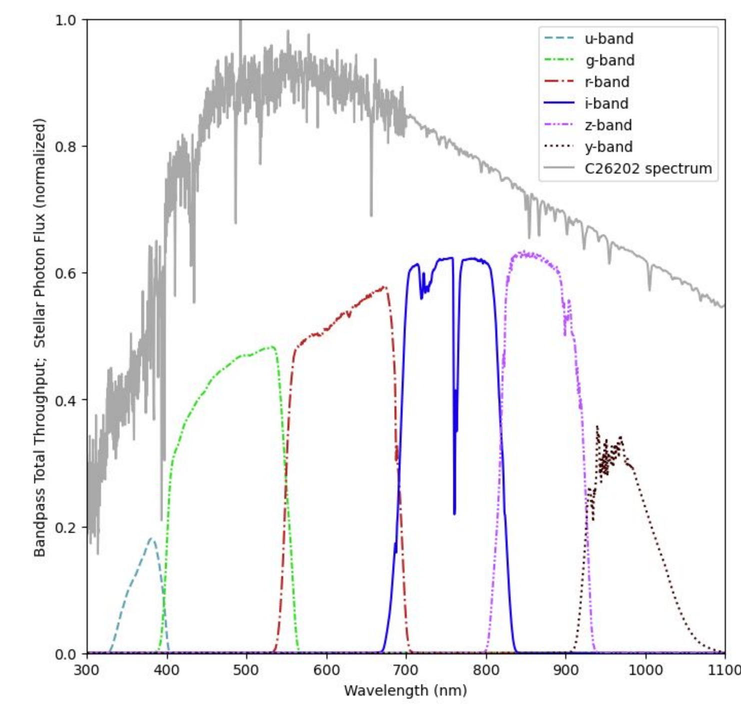


**Figure 2 - HST CalSpec SED, `C26202_stiswfcnic_007.fits`, plotted with the total throughputs of the LSSTComCam standard filter bandpasses**

## AB Offsets

The C26202 AB magnitude offsets represent the differences between the calibrated observed LSSTComCam AB magnitudes and the synthetic AB magnitudes for the LSSTComCam *ugrizy* filter bandpasses.

The calibrated AB magnitudes were derived from the DP1 **`calibFlux`** values (in nanojanskys) using the standard conversion:

$$\mathrm{mag_{ab}} = -2.5\log_{10}(\mathrm{calibFlux}) + 31.4$$

Two HST CalSpec spectral energy distributions (SEDs), **`c26202_stiswfcnic_007.fits`** and **`c26202_mod_008.fits`**, were used as spectrophotometric reference spectra for C26202. Synthetic magnitudes for these 2 SEDs were calculated as described in the previous section (**"Synthetic Magnitudes"**). For the atmospheric transmission, an atmospheric model for Cerro Pachon at an airmass of X=1.2 from the LSST **`syseng_throughputs`** GitHub repository was used.

The resulting AB magnitude offsets are summarized in Table 1. These results demonstrate excellent agreement: for all filters except *u*, the AB offsets are well below 0.01 mag (~1%) for both SEDs. Even in the *u*-band — known for its calibration challenges — the offsets remain within ~0.05 mag (~5%).

Details can be found in the rendered Jupyter notebook, **`ABoffsets_LSSTobs_calspec.ipynb`**: https://github.com/lsst-sitcom/sciunit_photocalib/blob/tickets/SP-1736/notebooks/AbsCalib/ABoffsets_LSSTobs_calspec.ipynb

**Table 1: Comparison of LSSTComCam observed magnitudes with synthetic magnitudes calculated from HST CalSpec C26202_mod_008 and C26202_stiswfcnic_007 using LSSTComCam passbands**

| band | n_band | median_mag_obs | stiswfcnic_007 | mod_008 | offset_stiswfcnic_007 | offset_mod_008 |
|---|---|---|---|---|---|---|
| u | 30 | 17.622860 | 17.572800 | 17.586964 | 0.050060 | 0.035896 |
| g | 165 | 16.699335 | 16.691931 | 16.692687 | 0.007404 | 0.006648 |
| r | 188 | 16.363117 | 16.362017 | 16.361654 | 0.001100 | 0.001463 |
| i | 126 | 16.260426 | 16.260196 | 16.259542 | 0.000230 | 0.000884 |
| z | 122 | 16.243525 | 16.243679 | 16.243690 | -0.000154 | -0.000165 |
| y | 26 | 16.245932 | 16.238847 | 16.238887 | 0.007084 | 0.007045 |

## Absolute System Throughput Measurements

For the absolute system throughput analysis, the expected total counts (in electrons) for C26202 were computed across each LSSTComCam bandpass. Here, the HST CalSpec spectral energy distribution (SED) file, **`c26202_stiswfcnic_007.fits`**, served as the spectrophotometric reference for C26202. As with the synthetic magnitudes, to model the detector response, the average quantum efficiency of an LSSTCam ITL CCD — sourced from the Rubin LSST **`syseng_throughputs`** GitHub repository was used.

Expected counts were calculated over a range of airmasses (1.0 < X < 2.5) in 0.1 increments to span the full range of observing conditions for the DP1 LSSTComCam data.

Subsequently, the post-instrumental-system-response (post-ISR) counts for C26202 were retrieved from the DP1 observations using the Butler at the USDF. The **`psfFlux`** measurement was used, with an aperture correction applied to convert from PSF to total flux, using the 12.0-pixel-radius **`base_CircularApertureFlux_12_0_instFlux`** as a proxy for the total instrumental flux.

Finally, for each of the *ugrizy* filters, the ratio of observed to expected (synthetic) total flux was computed and plotted (see Figure 3). The observed and predicted counts agree to within ~5% across most bands, with the exception of *g* and *y*, which show deviations of ~10%.

Details can be found in the rendered Jupyter notebook, **`Throughputs_LSSTComCam_C26202.ipynb`**: https://usdf-rsp.slac.stanford.edu/nb/user/dltucker/lab/workspaces/auto-5/tree/WORK/GitHub/SP-1736/sciunit_photocalib/notebooks/AbsCalib/Throughputs_LSSTComCam_C26202.ipynb

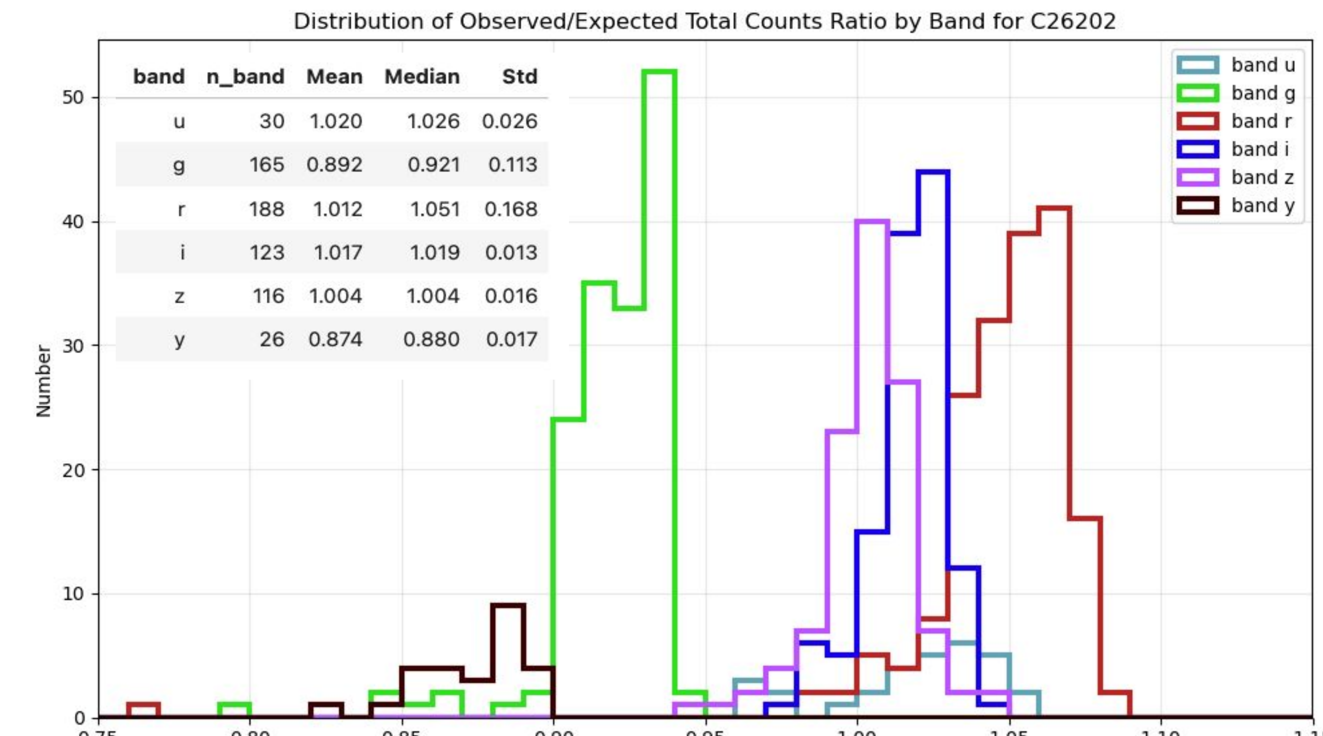


**Figure 3 - Distribution of Observed/Expected Total Counts Ratio**

## Acknowledgements

This material is based upon work supported in part by the National Science Foundation through Cooperative Agreements AST-1258333 and AST-2241526 and Cooperative Support Agreements AST-1202910 and 2211468 managed by the Association of Universities for Research in Astronomy (AURA), and the Department of Energy under Contract No. DE-AC02-76SF00515 with the SLAC National Accelerator Laboratory managed by Stanford University. Additional Rubin Observatory funding comes from private donations, grants to universities, and in-kind support from LSST-DA Institutional Members.

Portions of this work were assisted by AI-based language tools, including Microsoft Copilot (powered by OpenAI's GPT-4), which was used to help refine text and improve clarity.

Software development was assisted by Claude-Sonnet-3.5 (Anthropic, 2024), a large language model, as well as other AI-based tools.

## References

- Abbott, T.M.C., Adamow, M., Aguena, M., et al. 2021, "The Dark Energy Survey Data Release 2," ApJS, 255, 20
- An Interim Report on the ComCam On-Sky Campaign - SITCOMTN-149, Section 9.2
- NSF-DOE Vera C. Rubin Observatory (2025); The Vera C. Rubin Observatory Data Preview 1 DOI Logo https://doi.org/10.71929/rubin/2570536.
- SLAC National Accelerator Laboratory and NSF-DOE Vera C. Rubin Observatory (2024); LSST Commissioning Camera DOI Logo https://doi.org/10.71929/rubin/2561361
- NSF-DOE Vera C. Rubin Observatory (2025); Legacy Survey of Space and Time Data Preview 1 DOI Logo https://doi.org/10.71929/rubin/2570308
- Fukugita, M. et al. 1996, "The Sloan Digital Sky Survey Photometric System," AJ, 111, 1748, https://ui.adsabs.harvard.edu/abs/1996AJ....111.1748F/abstract

Rubin Observatory is a joint initiative of the National Science Foundation (NSF) and the Department of Energy (DOE). Its primary mission is to carry out the Legacy Survey of Space and Time, providing an unprecedented data set for scientific research supported by both agencies. Rubin is operated jointly by NSF's NOIRLab and SLAC National Accelerator Laboratory (SLAC). NOIRLab is managed for NSF by the Association of Universities for Research in Astronomy (AURA) and SLAC is operated for DOE by Stanford University.