CCDs in Living Color: Understanding the LSST Camera Focal Plane's visual color via Quantum Efficiency measurements

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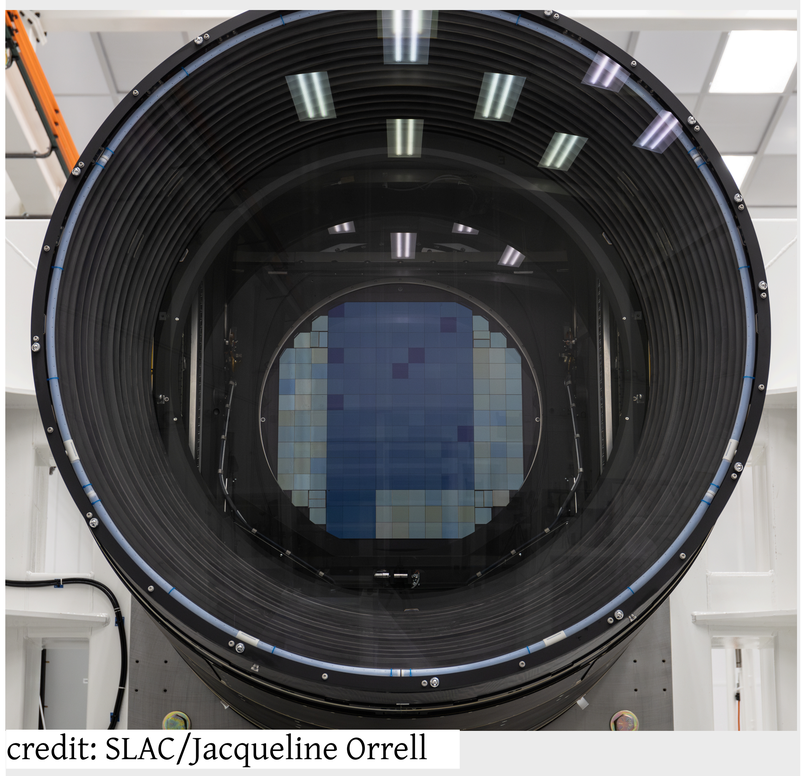
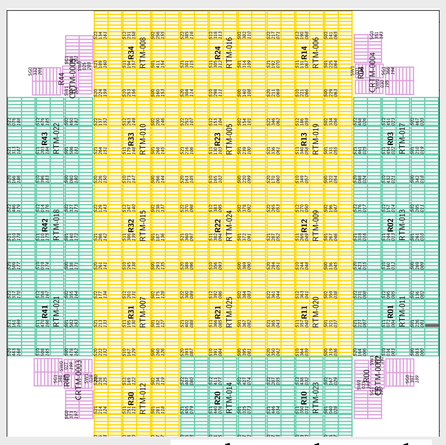
Abstract

The LSST Camera focal plane, the largest ever constructed, consists of 201 16-MegaPixel CCDs from two manufacturers. Viewed in room light the CCDs are blue colored, with one vendor's sensors a consistent dark blue while the other ranges from light blue to very light greenish-blue. We interpret the visual appearance as due to the amount of light reflected, or 1 - QE, as a function of wavelength and compare these colors against those expected from our laboratory measurements of Quantum Efficiency. Visually the comparison between digital photographs of the focal plane and the QE-based model is excellent. Finally, we use our photograph of the focal plane in room light to compare with measurements of the CCD to CCD absolute level of QE in visual wavelengths and comment on the utility of this room-light photographic method.

LSST Camera



credit: SLAC/Jacqueline Orrell

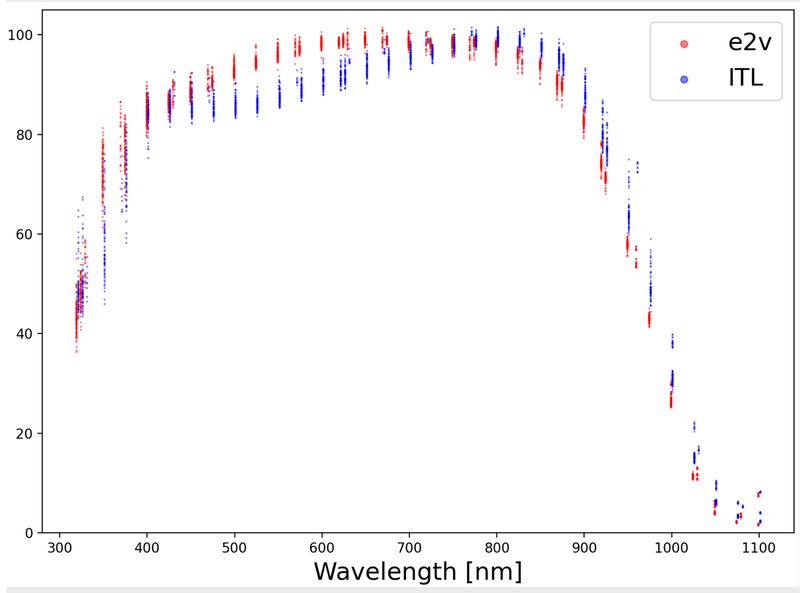


credit: Seth Digel

CCDs from e2v are placed in the center of the Focal Plane and appear Dark Blue, while those from ITL placed on the sides and bottom of the Focal Plane appear Light Blue to Tan

Quantum Efficiency

Quantum Efficiency (QE) of the CCDs were measured for each Raft (3x3 CCD sub-assembly) in a dedicated cryostat and test stand [O'Connor SPIE 2016, Lopez SPIE 2018]



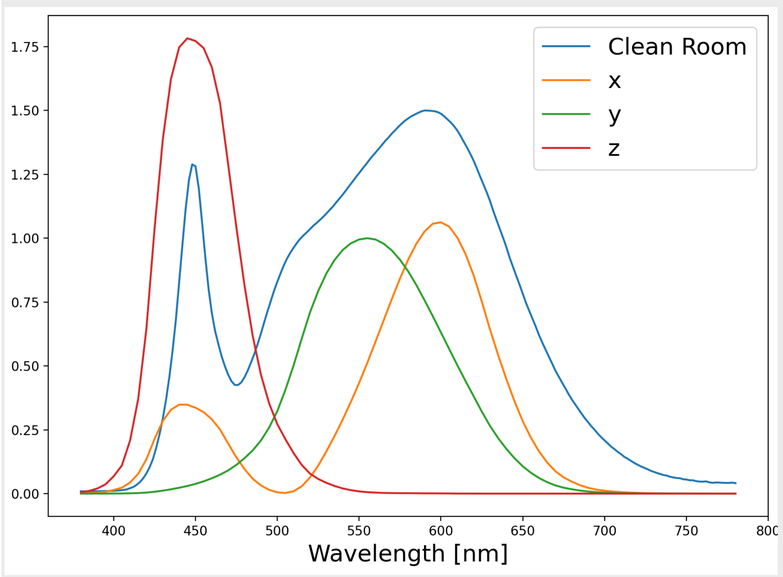
XYZ and RGB Color

To model the visual color appearance of the Focal Plane, we evaluate the RGB color of the 1-QE spectrum. To find RGB colors we first find colors in the CIE 1931 XYZ color space, according to:

$$X = \int_\lambda S(\lambda) I(\lambda) \bar{x}(\lambda) d\lambda$$

$$Y = \int_\lambda S(\lambda) I(\lambda) \bar{y}(\lambda) d\lambda$$

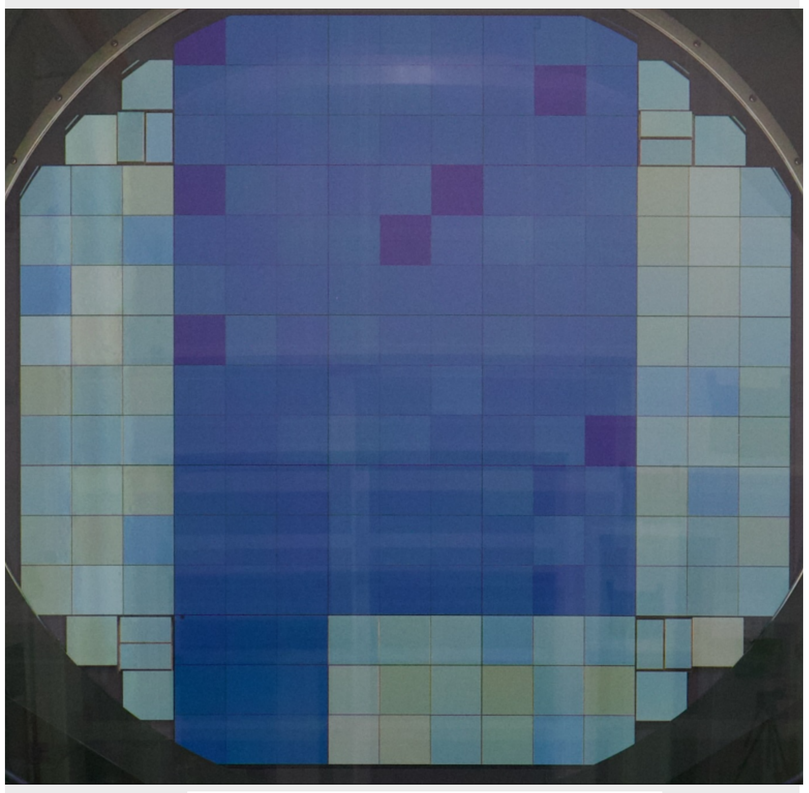
$$Z = \int_\lambda S(\lambda) I(\lambda) \bar{z}(\lambda) d\lambda$$



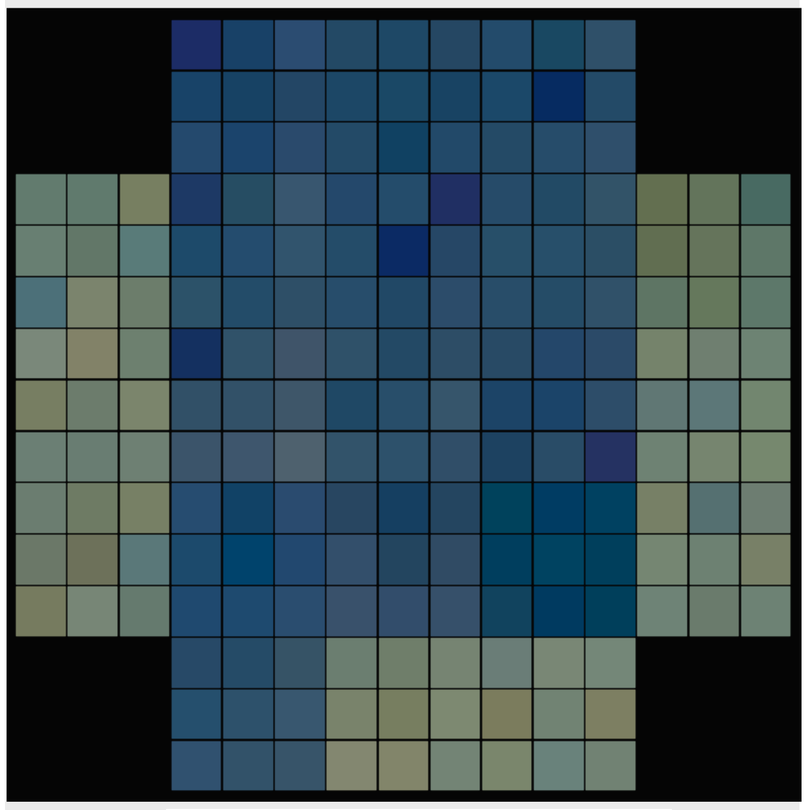
Where S(λ) is taken from the 1-QE spectrum and I(λ) is the Clean Room illumination, measured in the LSST Camera clean room with a PR-670 spectra-radiometer [J. Farrell].

We convert from XYZ color space to the sRGB color system, using a D50 Illuminant, with code from the text *Learning Scientific Programming with Python.* We chose sRGB to better match the Luminance distribution of the photograph.

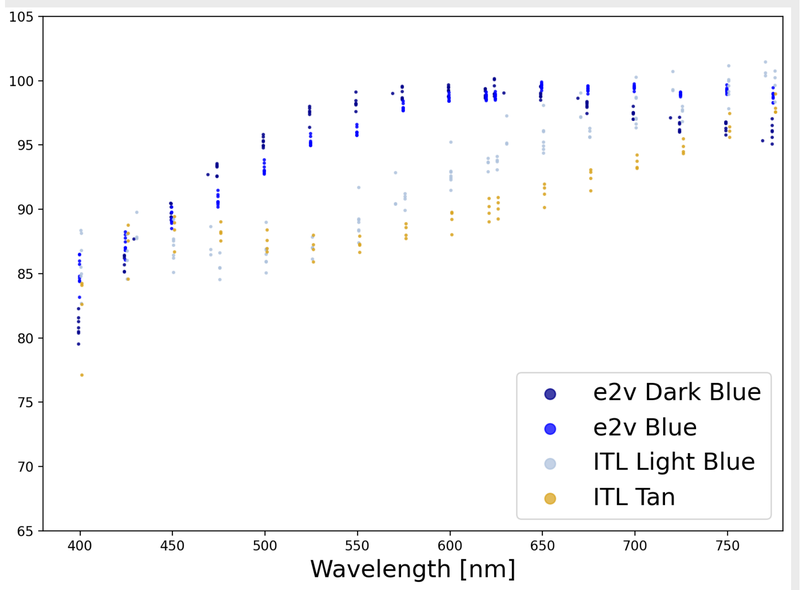
Focal Plane Color



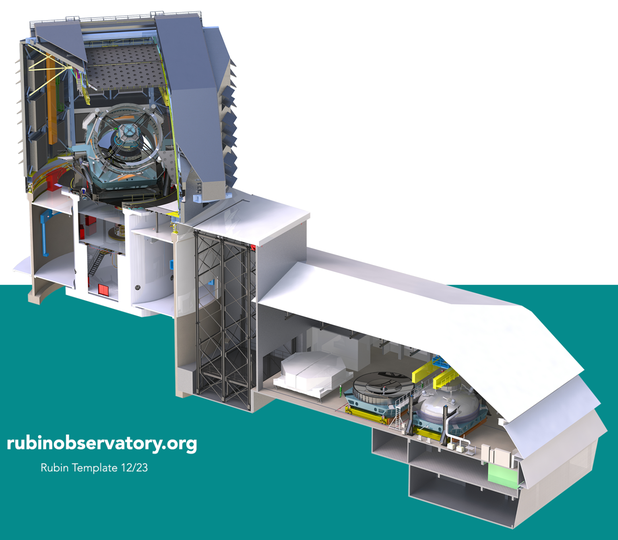
Photograph of the Focal Plane



Color Model of the Focal Plane



Systematic QE variation between and among each type of CCD, in the range 450-700nm, is producing the wide range of visual color.



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This material is based upon work supported by the National Science Foundation under Cooperative Agreement 1258333 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. Additional funding for Rubin Observatory comes from private donations, grants to universities, and in-kind support from LSSTC Institutional Members.