DECal Calibration System

Analysis of the Spectrophotometric Flat Field System for the DECam Instrument in support of the Dark Energy Survey at the CTIO Blanco 4m Telescope

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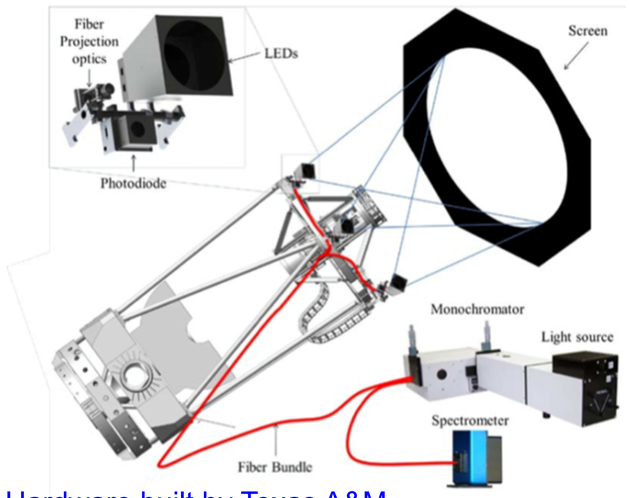
ABSTRACT

Data from the DECal spectrophotometric flat field system installed at the CTIO Blanco 4m telescope have been acquired throughout the first calendar year of operations of the DECam instrument. An initial analysis has been performed that allows for the measurement of the total system throughput (less atmosphere) – the response of the instrument as a function of wavelength, focal plane position, and time. The DECal hardware also includes an LED-based system for acquiring daily flat fields.

REQUIREMENTS

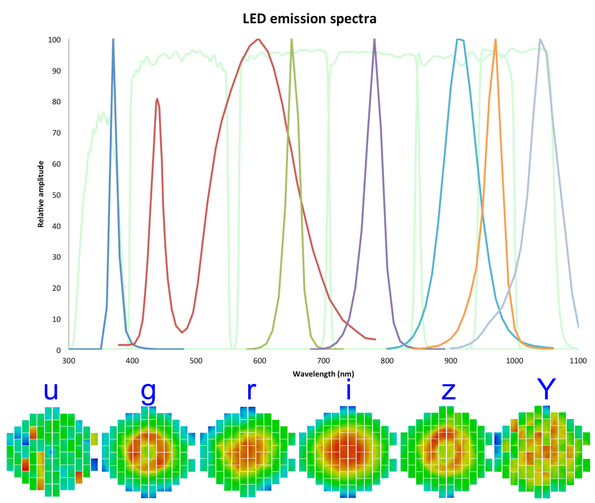
- Science requirements
  - Photometric calibrations: R10: spatially varying magnitude systematics < 2%, with a goal of < 1% for grizY and R11: < 0.5% on color zeropoints (1% for z-Y)
  - R13: Synthesized grizY magnitudes agree with measurements to within 2%
- Specifications and Technical Requirements constrain optical corrector, filters, CCDs
  - TG12: Flat fielding procedure accurate to RMS < 0.5%
  - TO5: optical corrector optimized in performance approx. over 400-1000 nm
  - TO8: exit pupil ghosts < 3% gradient over 0.3 deg
  - TO15: Filter transmission > 85% in griz and TO16: < 10% peak-to-peak variation
  - TO20: Transmission shall fall within envelopes given in the Filter Specifications Document
  - TD1: CCD nonlinearity < 1% with TD7: (g,r,i,z) CCD QE (60%, 75%, 75%, 65%)
- The DECal system is meant to help ensure and quantify the degree to which these specifications and requirements are met

HARDWARE



Hardware built by Texas A&M

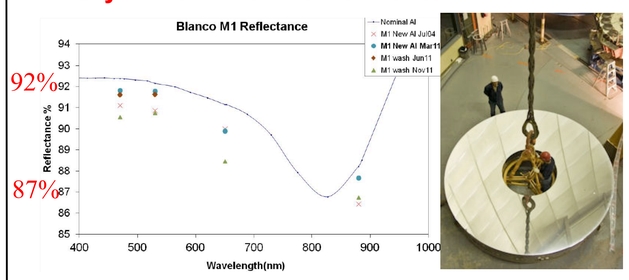
LEDs for Daily Flat Fields



Flats have illumination and pupil ghosts effects

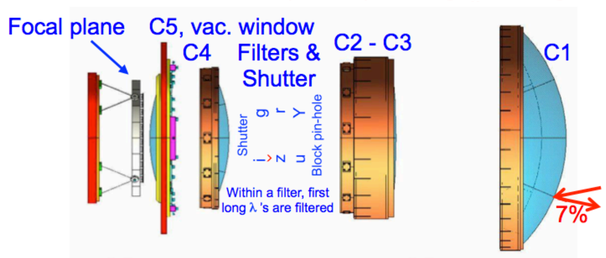
SYSTEM THROUGHPUT

Primary Mirror – aluminum and dust



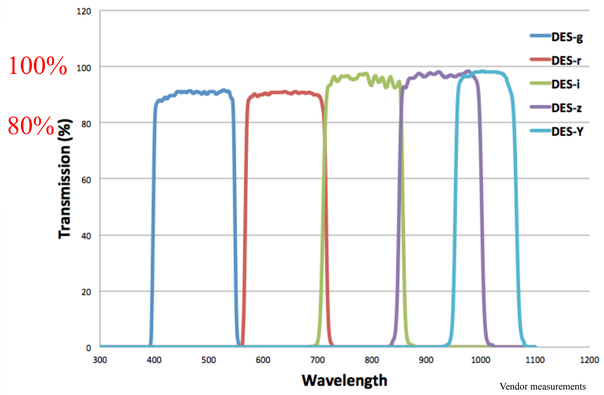
www.ctio.noao.edu/DocDB/0004/000402/001/Blanco_R%25-log-file.pdf

Corrector – fused silica (n=1.46) and MgF_x coatings



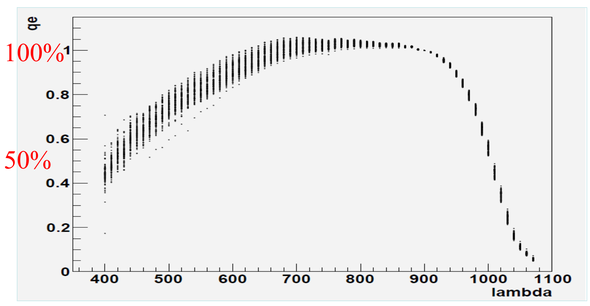
Vendor measurements, DocDB 5066

Filter – multi-layer coatings



Vendor measurements

CCD – poly-Si and ITO/SiO2 anti-reflective coating



Laboratory Measurements

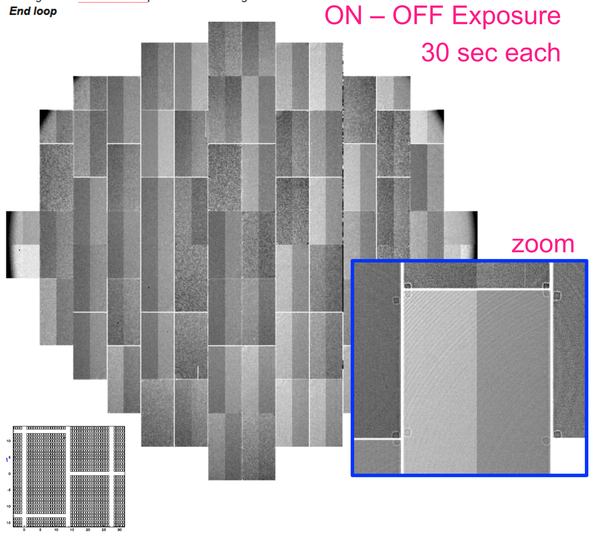
The total system throughput is the product of all the wavelength-dependent effects shown.

RAW DATA PRODUCTS

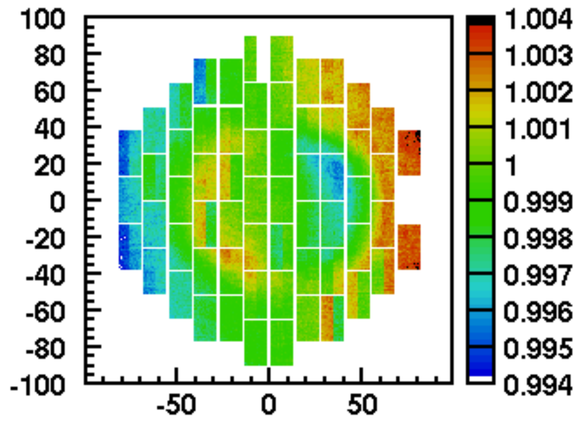
Typical scanning sequence

Point telescope at the flat field screen
Start loop
Set monochromator wavelength
Turn on monochromator output to illuminate screen
Begin taking photodiode "light" data
Take DECam image
Simultaneously take spectrum with spectrometer
Reduce spectrometer output in real time and record median wavelength and reduced spectrum to disk
Turn off monochromator output
Begin taking photodiode "dark" data
Take DECam dark image (if necessary)
Change monochromator output to next wavelength
End loop

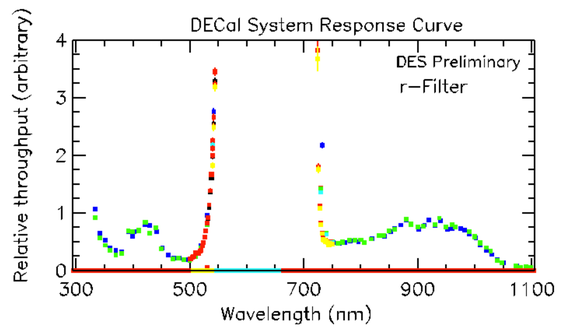
ON – OFF Exposure
30 sec each



Compute truncated averages in “super-pixels”



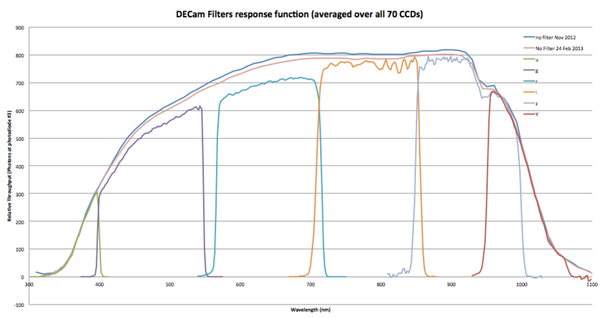
r-Filter response relative to none Jun/Feb double ratio demonstrating precision to better than 0.2%



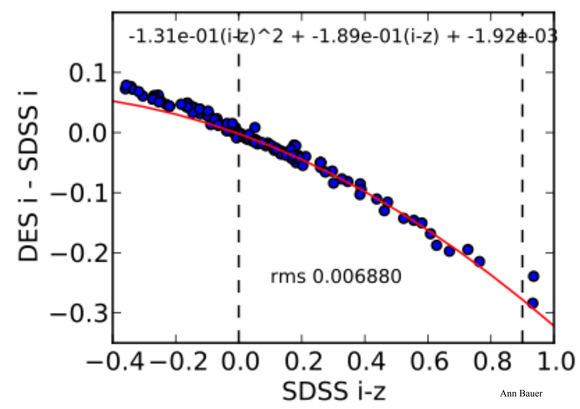
Color represent one of eight different r-Filter scans obtained throughout the first DES year demonstrating repeatability and highlighting the rising and falling throughput edges and the out-of-bandpass light.

DERIVED DATA PRODUCTS

System throughput



Transformation equations



Ann Bauer

SOME ISSUES

- Use of the DECal measurements requires care
  - Illumination and Pupil Ghost effects are present. These are currently corrected in the DES data by using star flats
  - A handful of amplifiers show some non-linearities at low light levels. In principle, each pixel could have it’s own throughput … what degree of segmentation is useful
- Full integration into a coadded image is complex with multiple epochs from overlapping exposures

CONCLUSIONS

Data from the DECal spectrophotometric flat field system are being collected and analyzed to verify technical specifications and requirements are being met at a level necessary for meeting the science requirements.

The system throughput is being measured and monitored as a function of wavelength, focal plane position, and time.