DARK ENERGY SURVEY

System Throughput with the DECal Spectrophotometric Calibration System

System Throughput
System Monitoring
Some aspects of DES CCDs
Transmission Curves, Transfer functions, etc.

W. Wester – Fermilab
DECal team includes folks at Texas A&M including J.P. Rheault, Jen Marshall, Ting Li, and Darren DePoy plus David James at CTIO

System throughput

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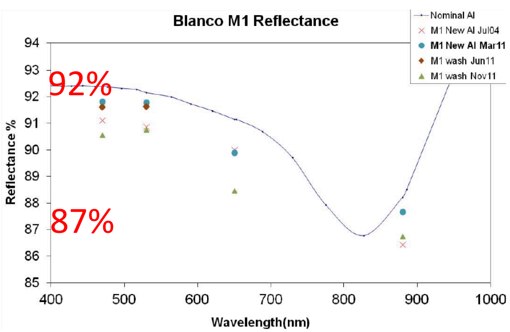
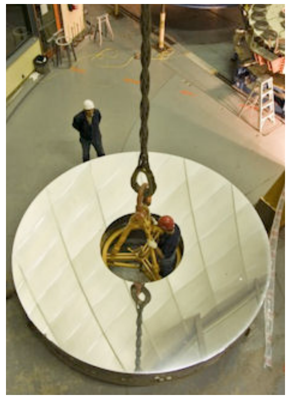
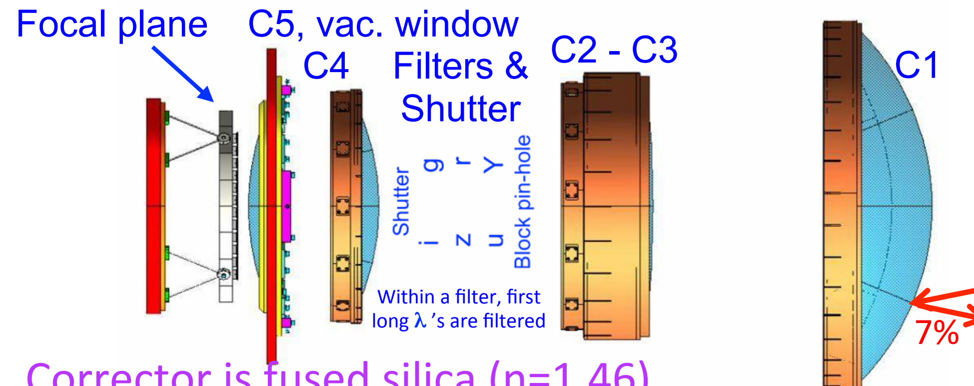
Primary mirror is Al + dust



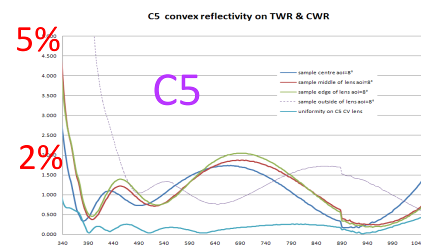
www.ctio.noao.edu/DocDB/0004/000402/001/Blanco_R%25-log-file.pdf

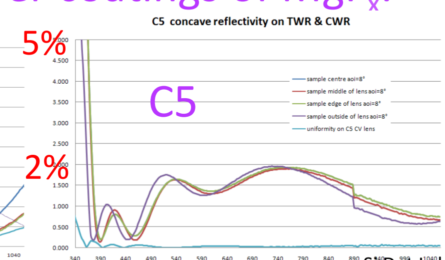




Corrector is fused silica (n=1.46).

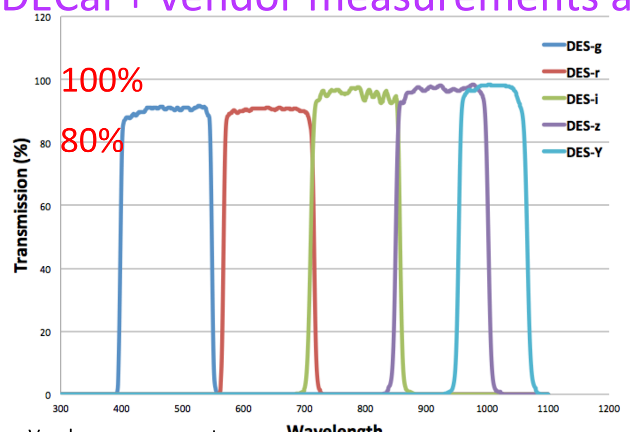
C2-C5 have multi-layer coatings of MgF_x.





DocDB: 5066

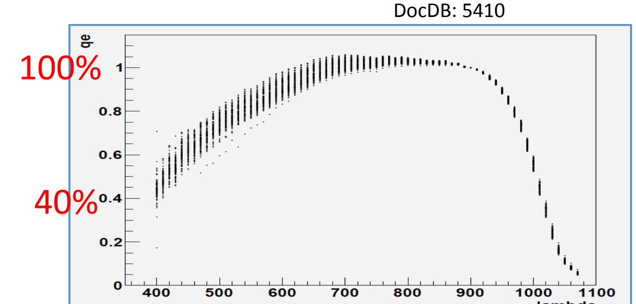
Filters engineered to provide bandpasses with multilayered coatings, DECal + vendor measurements agree.



Vendor measurements

CCDs QE optimized for red until bandgap (~1100nm) – poly-Si + AR reflectance ITO/SiO_2 cuts short λ's (~350nm)

Si Det Lab Measurements
DocDB: 5410



+ Atmosphere (we have aTmCAM and GPS devices)

DECal

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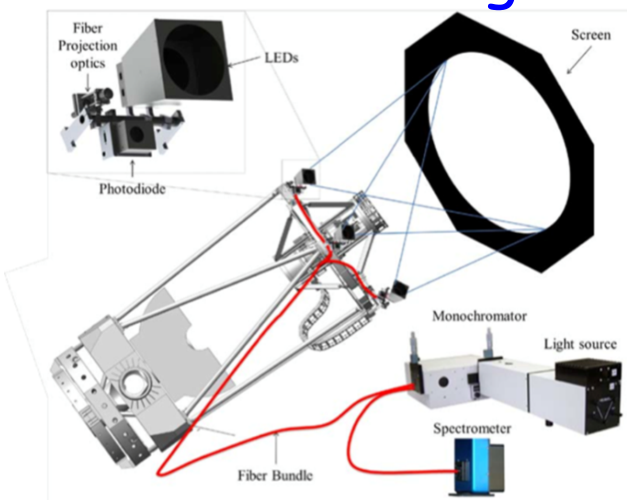
- The DECal flat field system is capable of generating system response maps by scanning projected light of known wavelength and intensity onto a flat screen



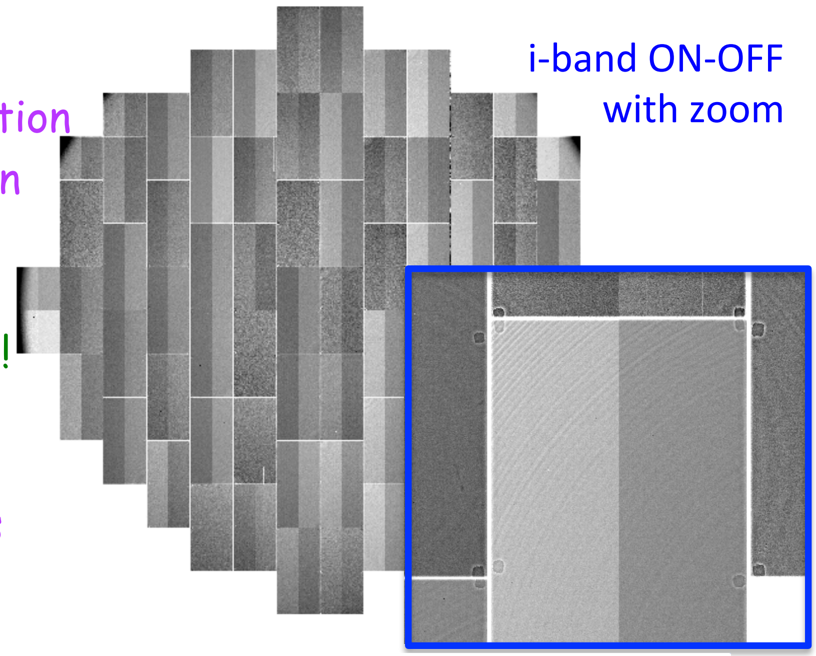
Hardware built by Texas A&M.

1) Daily flat field illumination using LEDs
2) Periodic scans using monochrometer light carried up by fibers

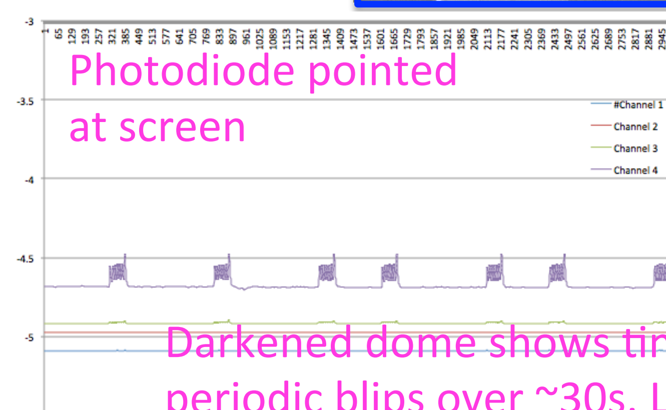
- Scans taken 2012: Oct, Nov 2013: Feb Jun, July, Sept, Oct, Nov and 2014: May, July, Aug, Sept, Oct 2015: Jan
- (1) Monitor changes in <u>relative</u> throughput (SDSS observed effects)
- (2) <u>Relative</u> system response curves vs function of focal plane position

DECal raw data products

- Images
  - "ON": 30 sec exposure during fiber illumination
  - "OFF": 30 sec exposure, no fiber illumination
    - Typically every 5th exposure is an OFF
    - Bkgd light is small (but non-zero) inside the darkened dome – watch for twilight!
  - Overscan correction removes occasional small (few counts) jumps
  - Can apply individual gain and QE corrections (+/- 10%) or a correction that matches edges of the CCDs (effective gain x QE)
- Data from spectrophotometric system
  - Measured wavelength of the output of a fiber
  - Intensity of light on the screen with NIST calibrated photodiodes
  - Settings, temperature readings, time stamps, etc.



i-band ON-OFF with zoom



Photodiode pointed at screen

Darkened dome shows tiny periodic blips over ~30s. LED in the enclosure?

Throughput vs wavelength

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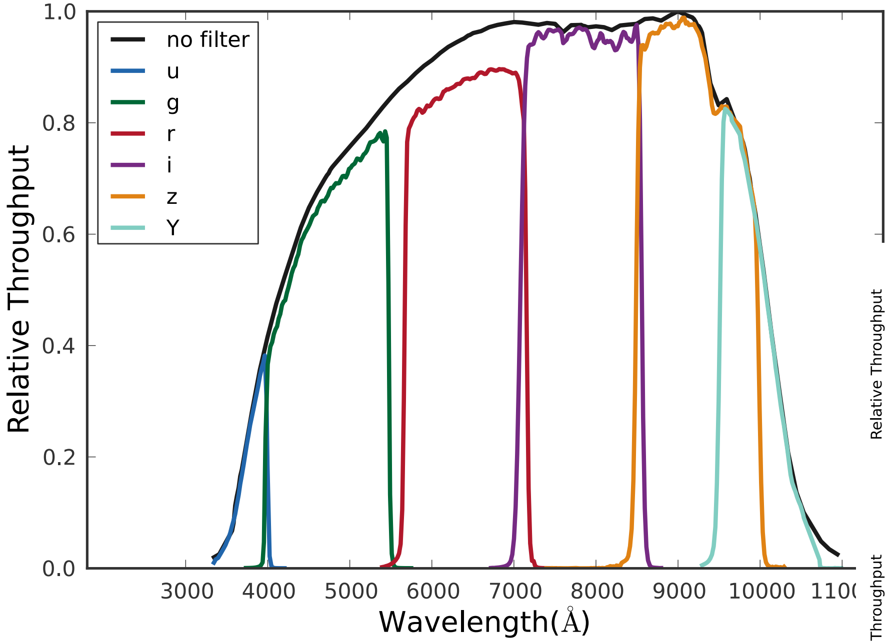
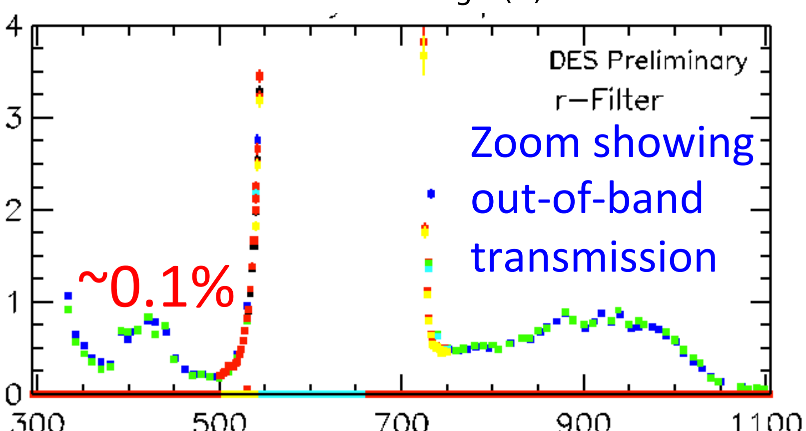
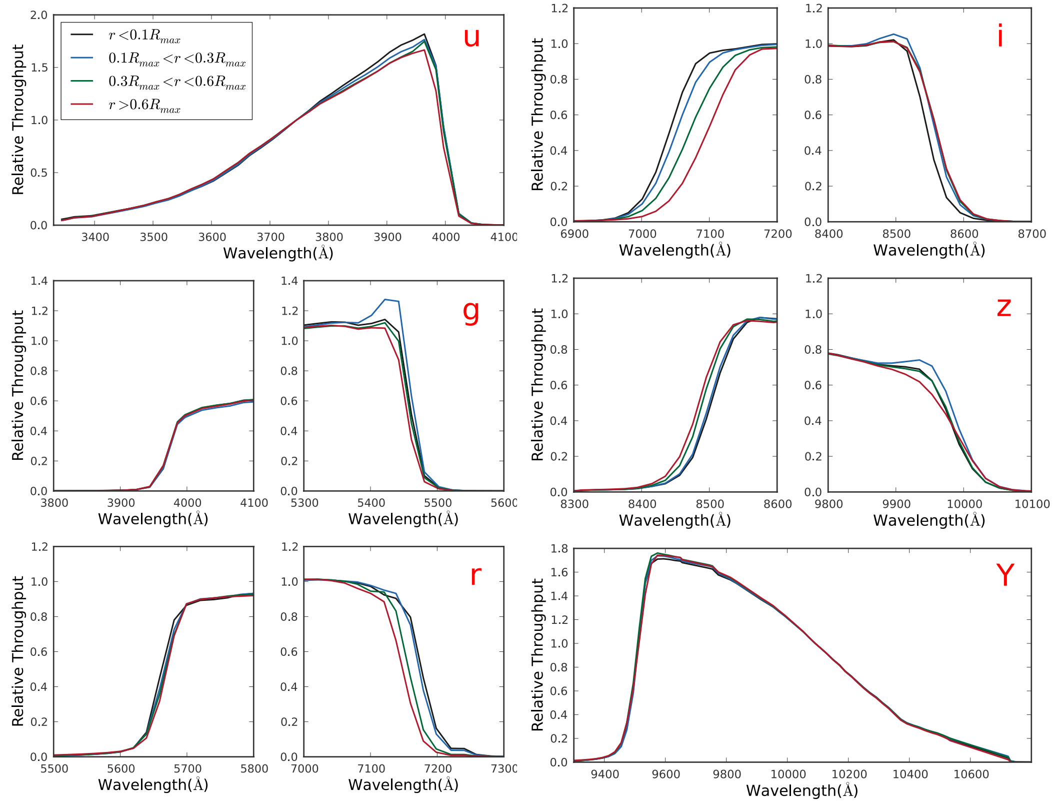


System throughput vs wavelength is measured by DECal, is monitored through periodic scans with some attention to the blue and red filter edges. Data product of the average response is provided.





Update in progress!

Throughput vs focal plane position

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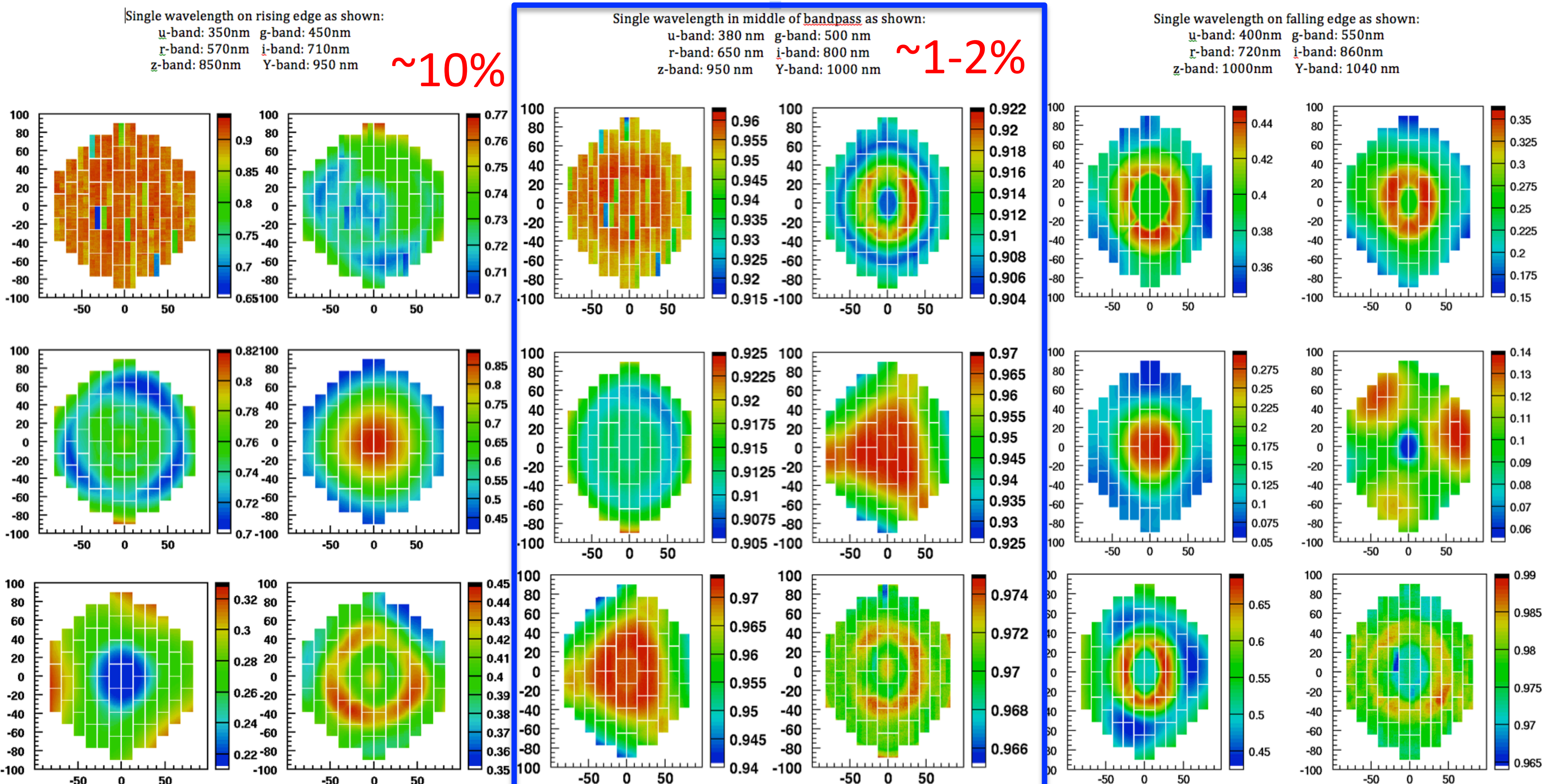
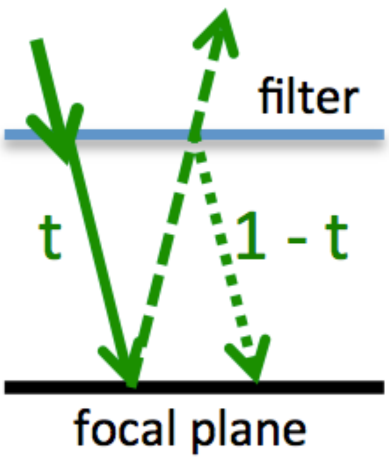
Truncated average response ON-OFF (overscan, gain, intensity corrections)

Normalized to the response with noFilter. Illumination effects, ghosts, filter variation contribute.



Caveats

There are a number of additional caveats in using the system response curves. In particular, separating pupil ghost effects from illumination effects and radial dependence.



Note also that the detrending of DES images include dividing by the LED flat field (which has its own spectral illumination) and then removing pupil ghost effects via star flats

DECal is for relative response. There is a program to collect DA white dwarf spectra to set both "absolute color" and with other data, also set absolute magnitude scales.

Full throughput (system + atmosphere)

https://cdcvs.fnal.gov/redmine/projects/descalibration/wiki

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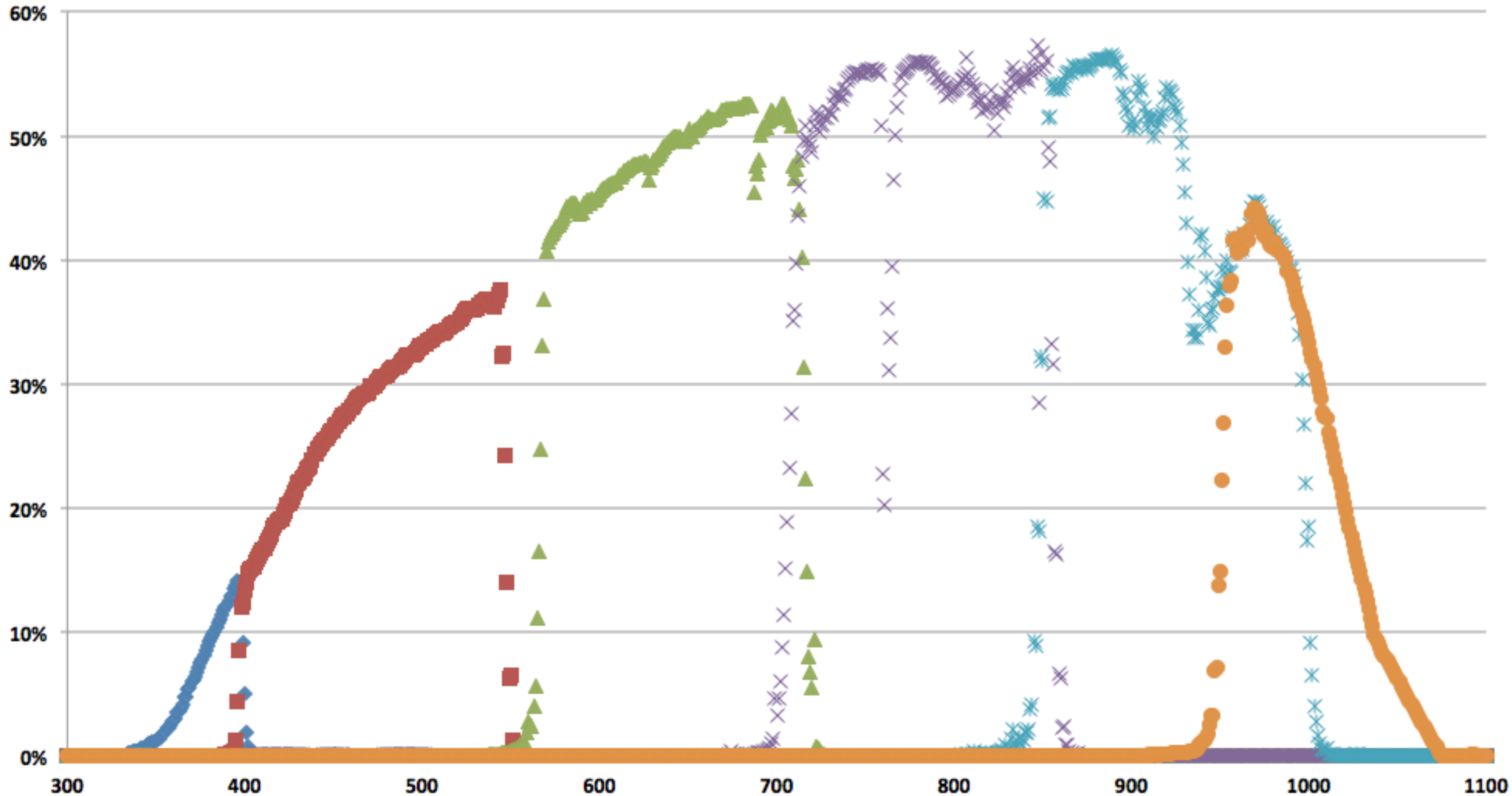

Atmosphere effects from MOTRAN models (aerosols and H_20 vapor). An aTmCam is installed at CTIO and provides monitoring (+ a separate GPS based system)

Transfer functions and absolute scale

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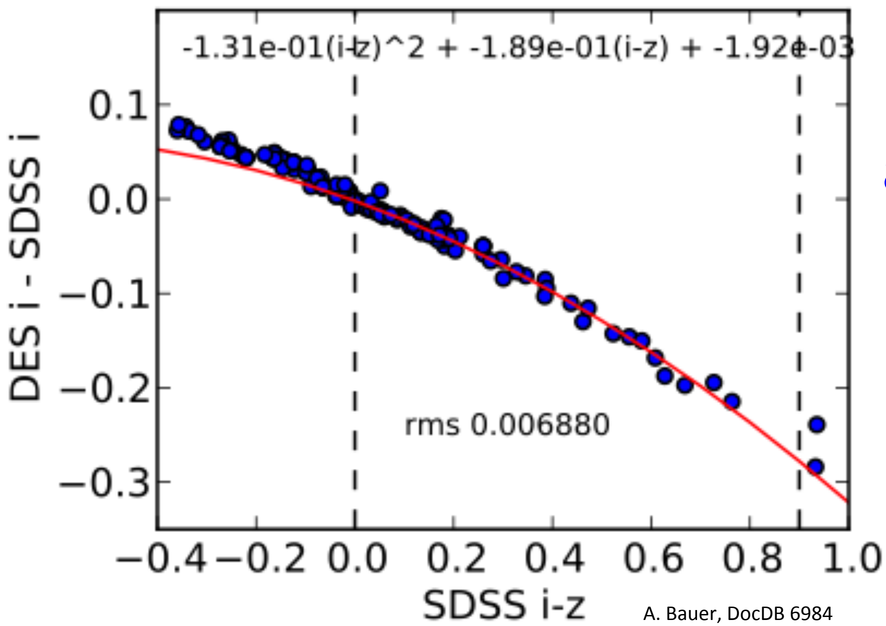


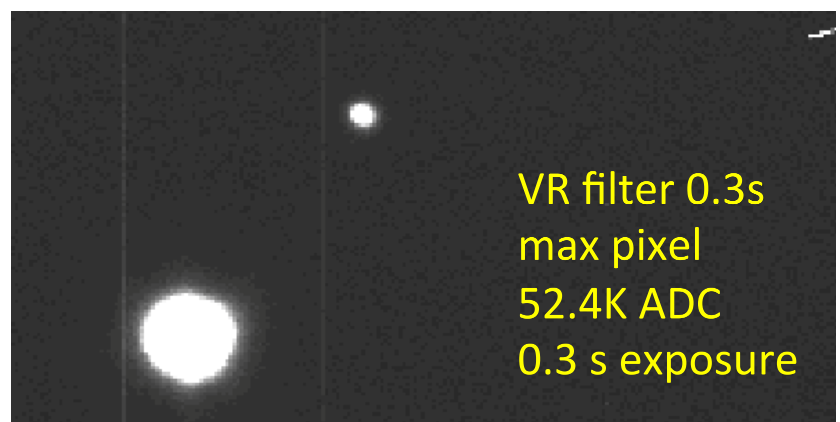
A. Bauer, DocDB 6984

Initial setting of absolute scale done using stars from with known SEDs and magnitudes.

$$N_* = A\,t \int \frac{\lambda}{hc}\, f_\lambda\, S_\lambda\, d\lambda$$

Current program utilizes a set of calspec standards such as BD+17 and DA white dwarfs

Transfer functions derived from the system response maps to determine the DES to SDSS transformation in magnitudes and color for a catalog of stellar spectral types.



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Conclusions

- DECal system functions to monitor and determine the system throughput as a function of wavelength and position on the focal plane
- Analysis of DECal data is performed on unprocessed raw images – need to monitor
- There are tricky effects to sort out such as illumination and pupil ghosts into a processing system that relies on biases, daily flats, and star flats → what's the "recipe"
- Despite these issues, DECam is on track towards demonstrating percent-scale photometric precision.

Extra slides

Study OFF data

Point to the Flat Field Screen in the darkened dome and take exposures

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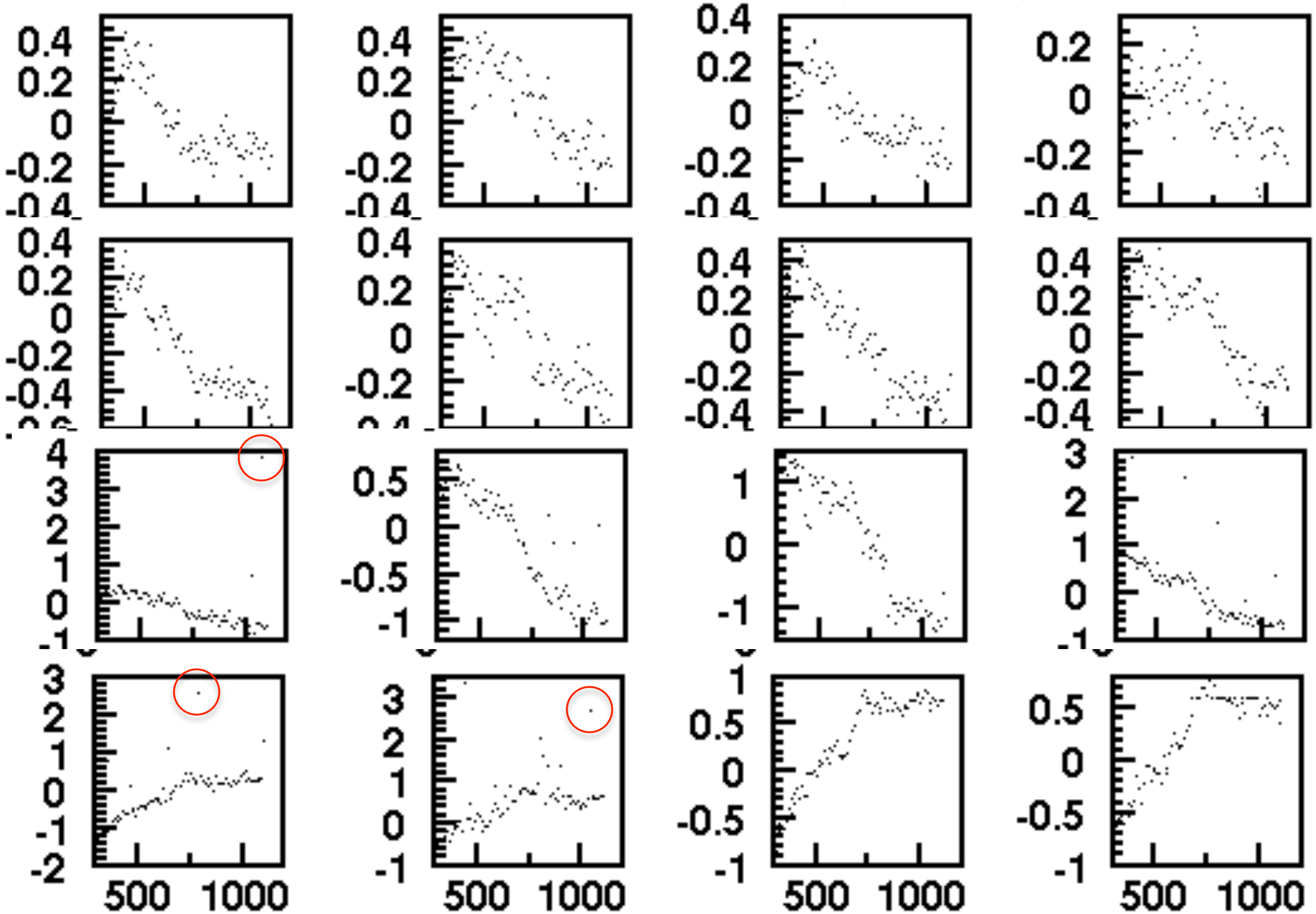
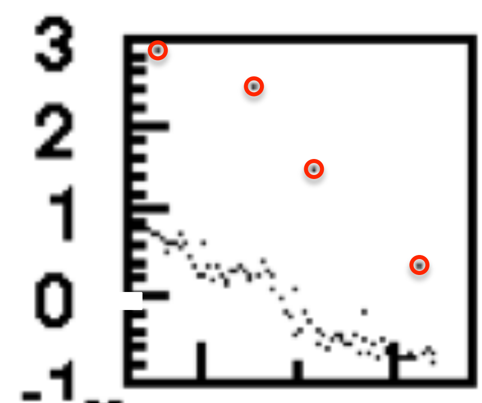
Selected CCDs (amp1/amp2)
1, 2, 11, 15, 25, 35, 45, 55

At each wavelength, compute the average of 288 super-pixels/amplifier and subtract from global average.



Average usually stable to +/- 0.5cnts with an occasional outlier of +/- 3cnts. These outliers are removed by sub-tracting the overscan then, fluctuations vs time over an hour are <0.1 cnt.



W. Wester, FNAL DES ChicagoLand Mtg, Feb 23 2015

A look at bias exposures

Keep the shutter closed, just take 0s exposures

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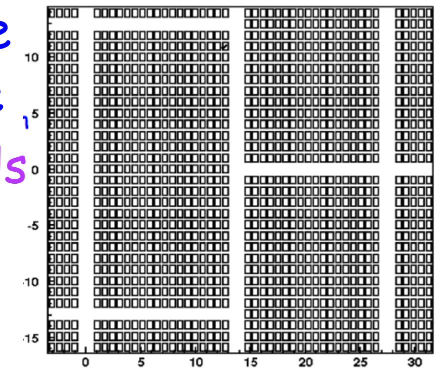
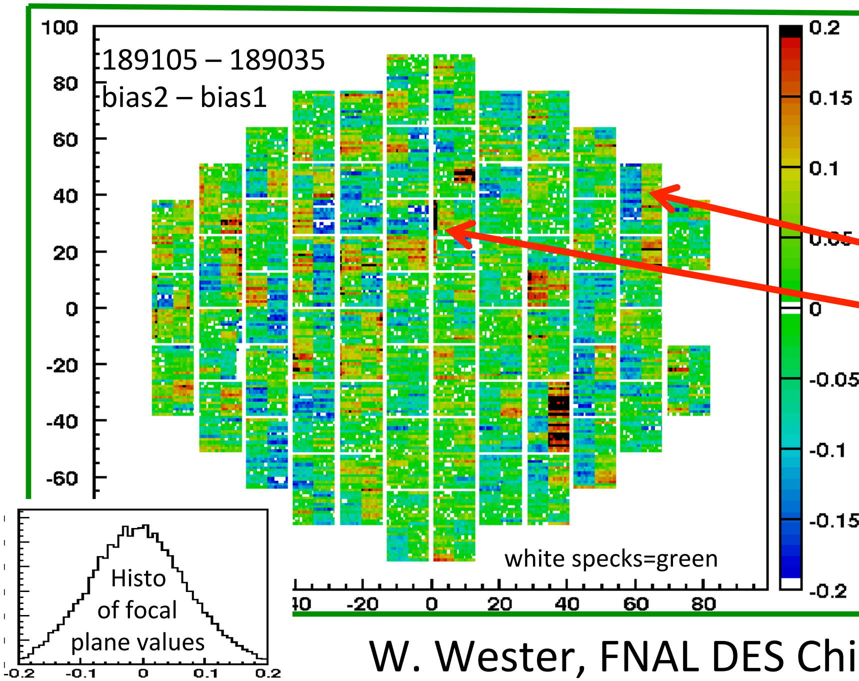
- Analyze as DECal exposures (ON-OFF) where ON is the exposure of interest and OFF is a earlier bias exposure
- Compute (middle 68%) average in a little box of 110x162 pixels where each CCD has 18 x 25 boxes (removes edge pixels)
  - griz note: divide the average by a single "edge matching" number per amp



- Study the 11 bias exposures after LED flat field sequence
  - Note: each of the biases has an earlier single bias exposure subtracted from it.



Difference of two bias exposures

Note: differences are typically < 0.2 cnts.

Other observations:

- Collection of rows have correlated shifts.
- An occasional discrepant column.

Small observation:
1st of 11 bias exposures has between 0.5-1.6 ADC counts difference per pixel as shown – other exposures <0.2 cnts.