PreCam, the Precursor to the Dark Energy Camera: Instrumentation and Preliminary Results

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Calibration and Standardization of Large Surveys and Missions in Astronomy and Astrophysics

Fermilab
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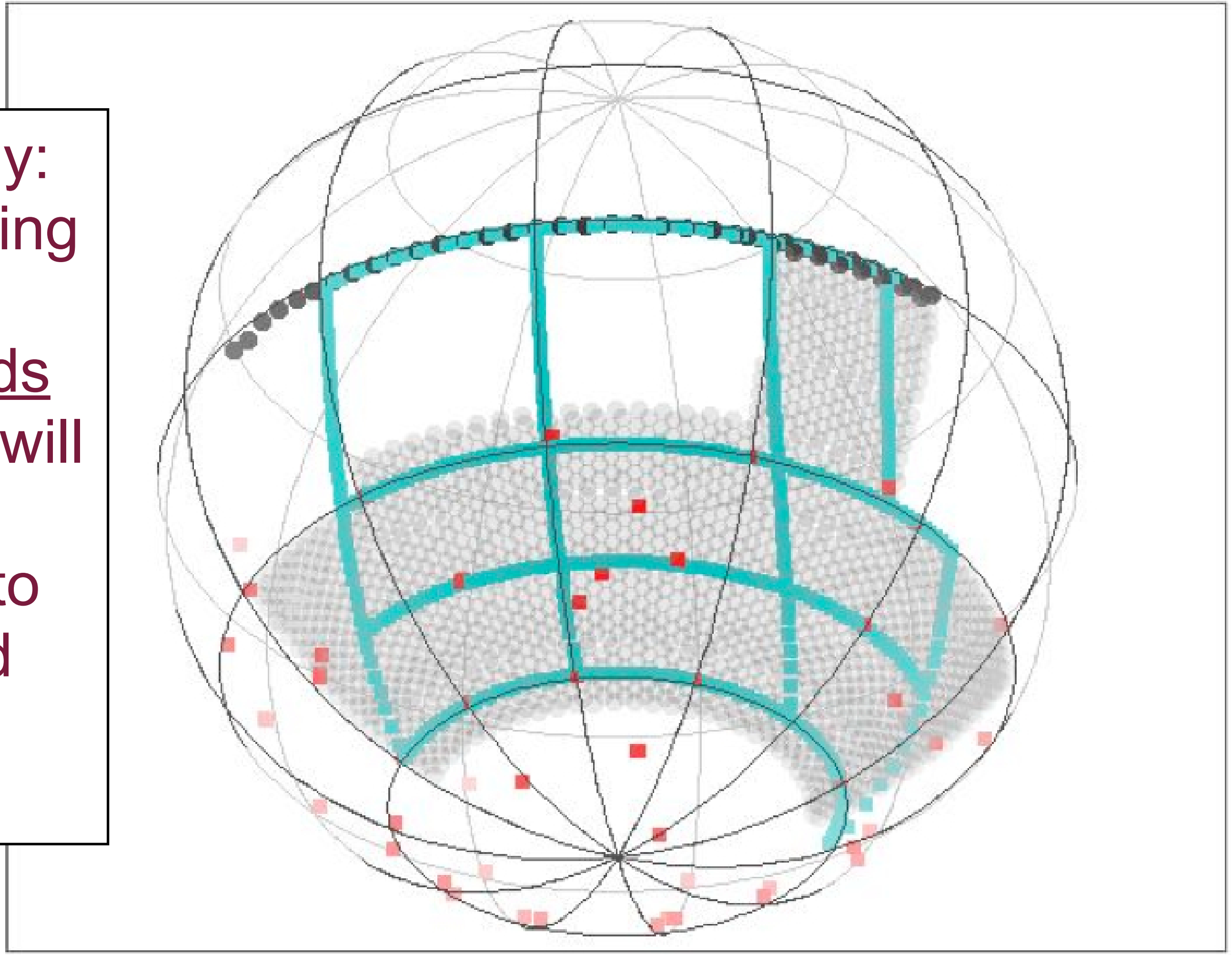
Outline

- Calibrating the Dark Energy Survey
- The PreCam Instrument: Design and Construction
- Bench Tests
- Installation and Commissioning
- Observations, Data Processing, and Analysis
- Preliminary Results: Single-Epoch Photometry, Image Stacking
- See also S. Allam's talk (next) for more detailed results

Calibrating the DES: PreCam Grid & DES Footprint

Rib & Keel Strategy:
Every ~20 min during the DES, a field containing hundreds of calibrated stars will be observed.
These will be tied to SDSS, USNO, and Southern u'g'r'i'z' Standard Stars.



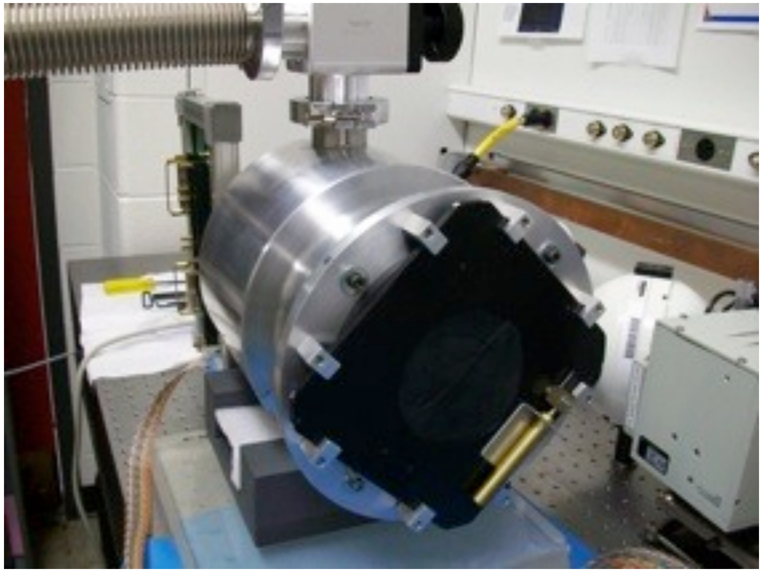
PreCam Goals and Timeline

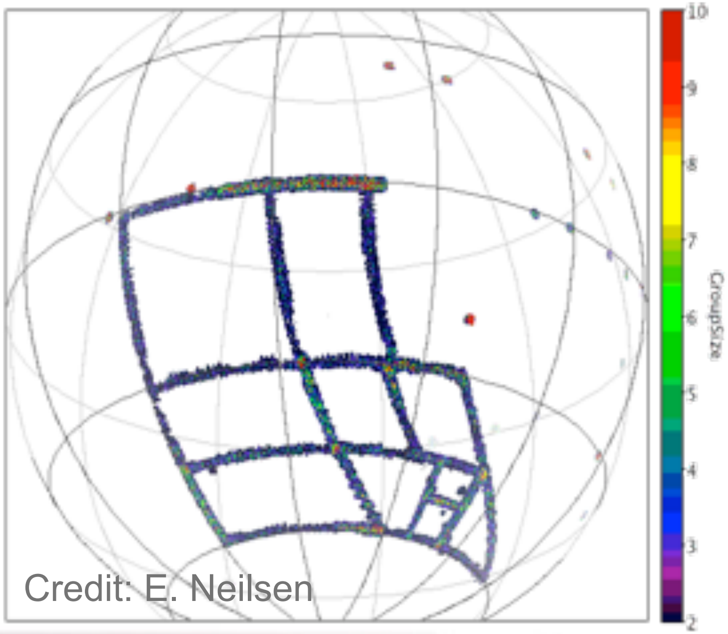
PreCam is a scaled down (2 CCD) version of the DECam that was used (in part) for development and testing of DECam hardware and software.

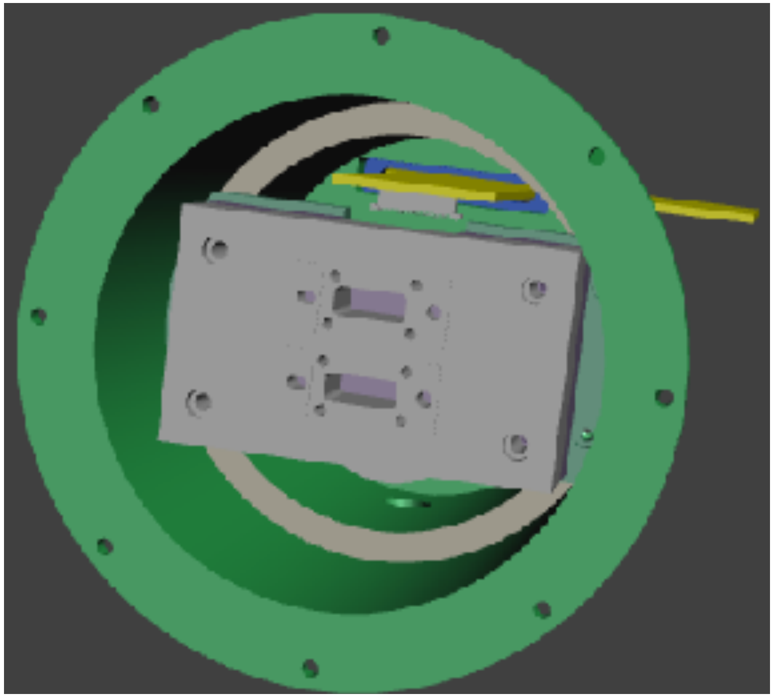
PreCam's primary goal was to observe a sparse grid of southern hemisphere standard stars ahead of the DES (especially in Y).

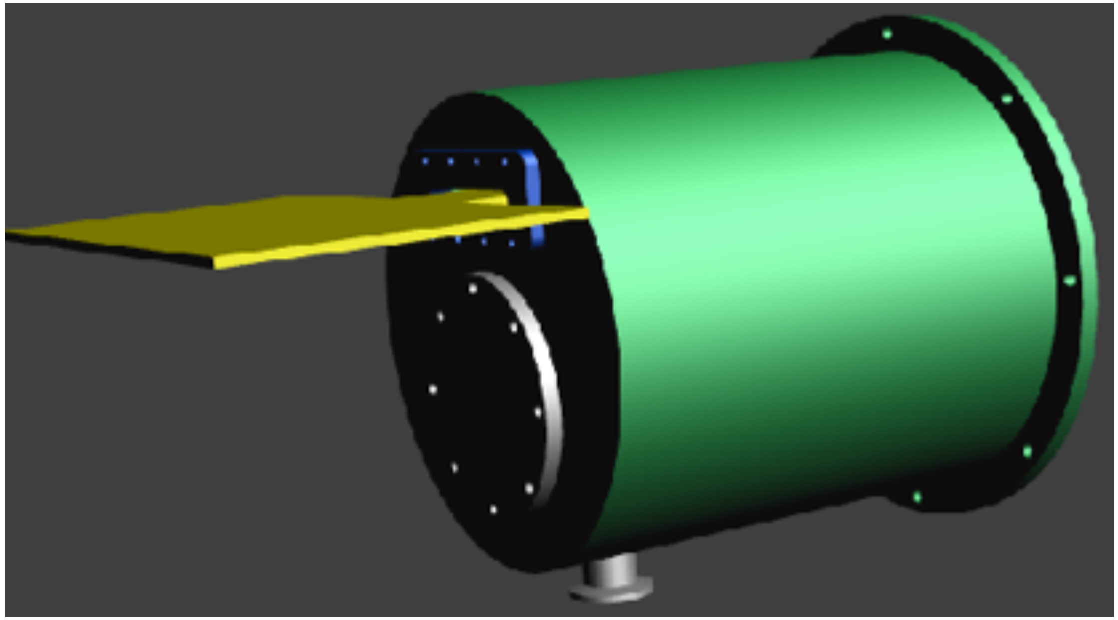
It was designed and constructed in less than one year. First orders for parts were placed in January 2010 and it achieved first light that August.

Precursor observations will allow DES to begin with photometric standards and save up to 10% of the DES observing time that would otherwise be devoted to calibration efforts.









PreCam Vessel

Focal Plane Support Plate

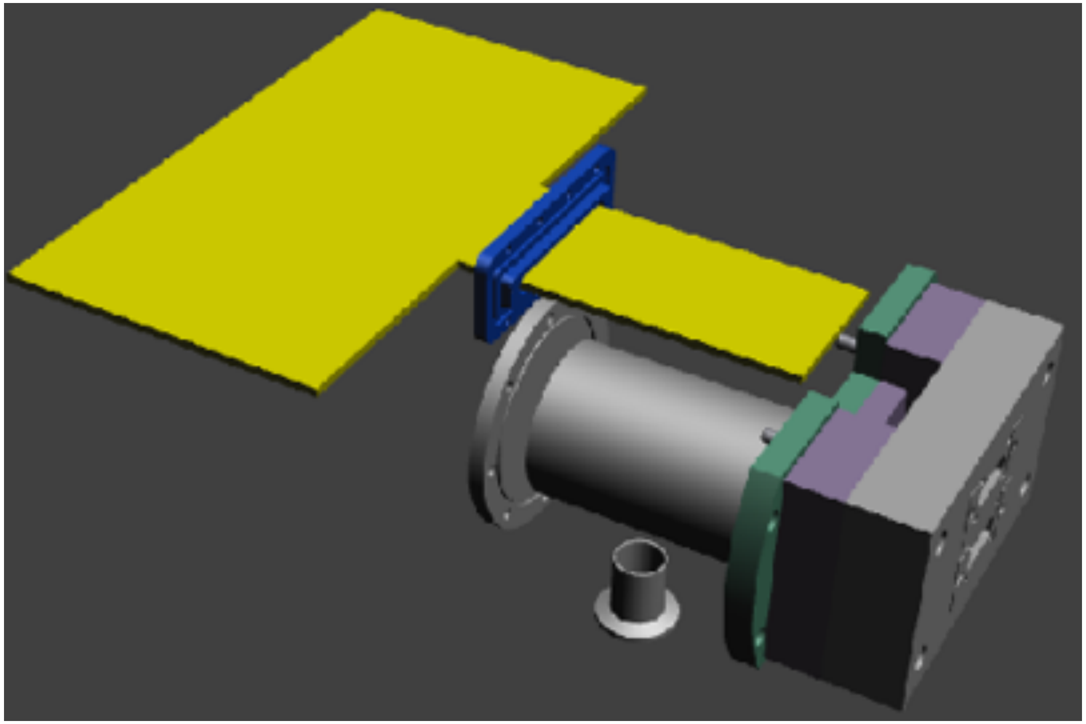
Thermal Transfer (Cu) Block

G-10 Mounting Block

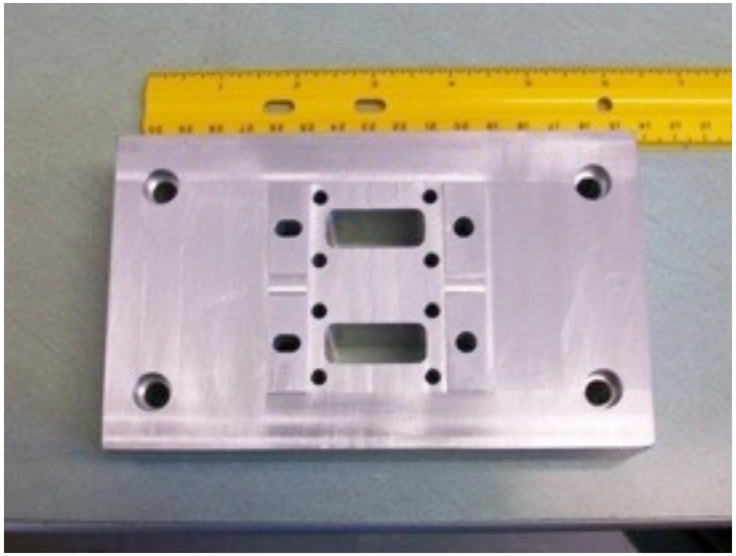
CryoTiger

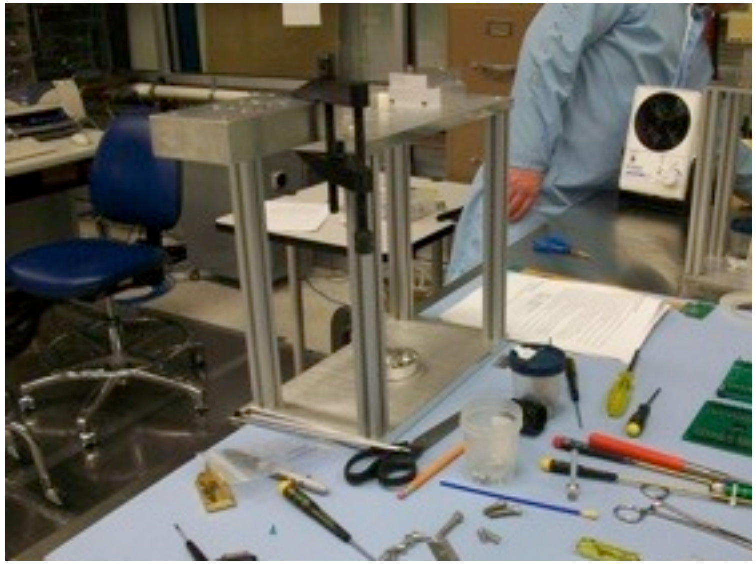
Vacuum Interface Board

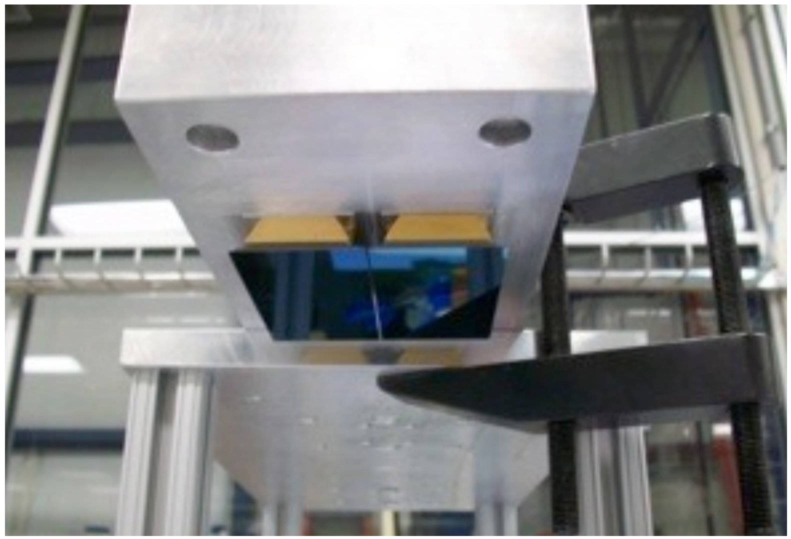
Dewar



Focal Plane Support Plate & CCD Installation

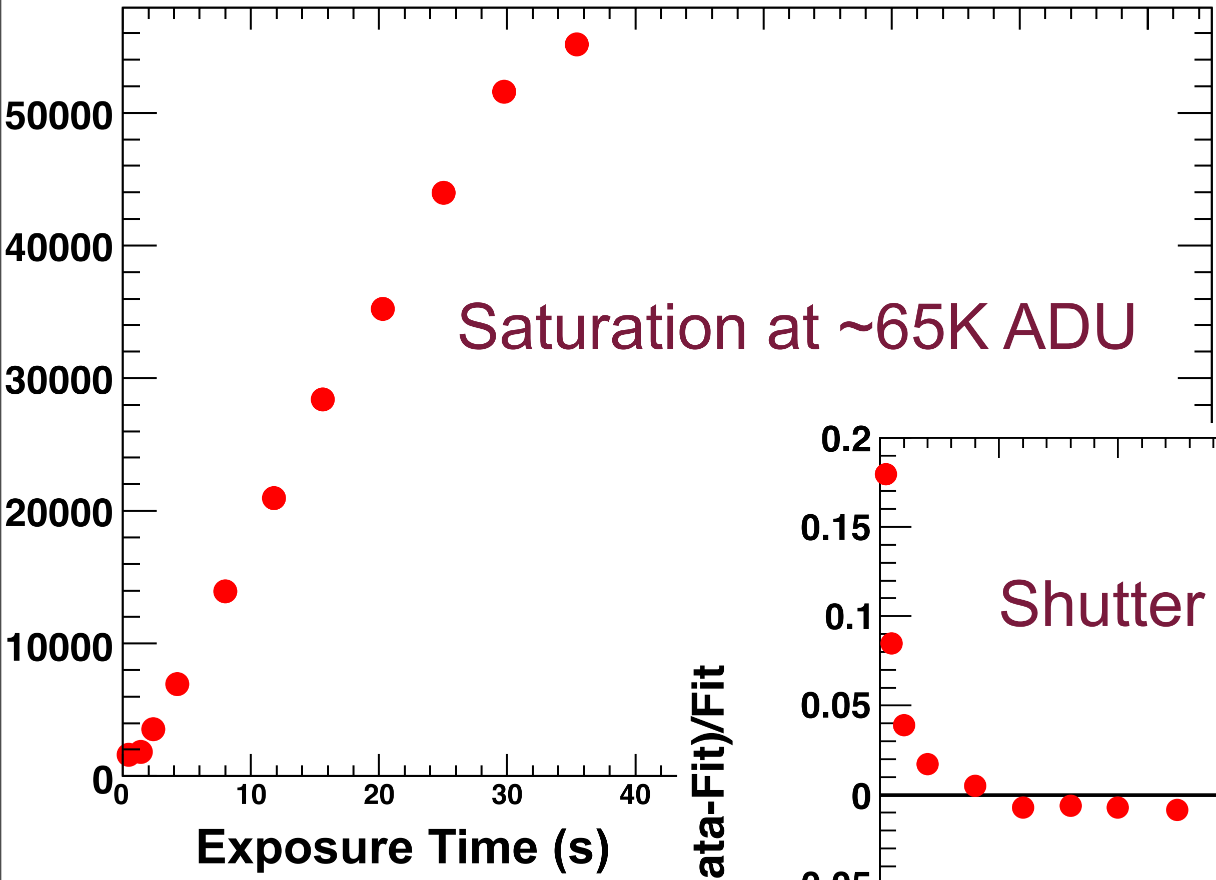


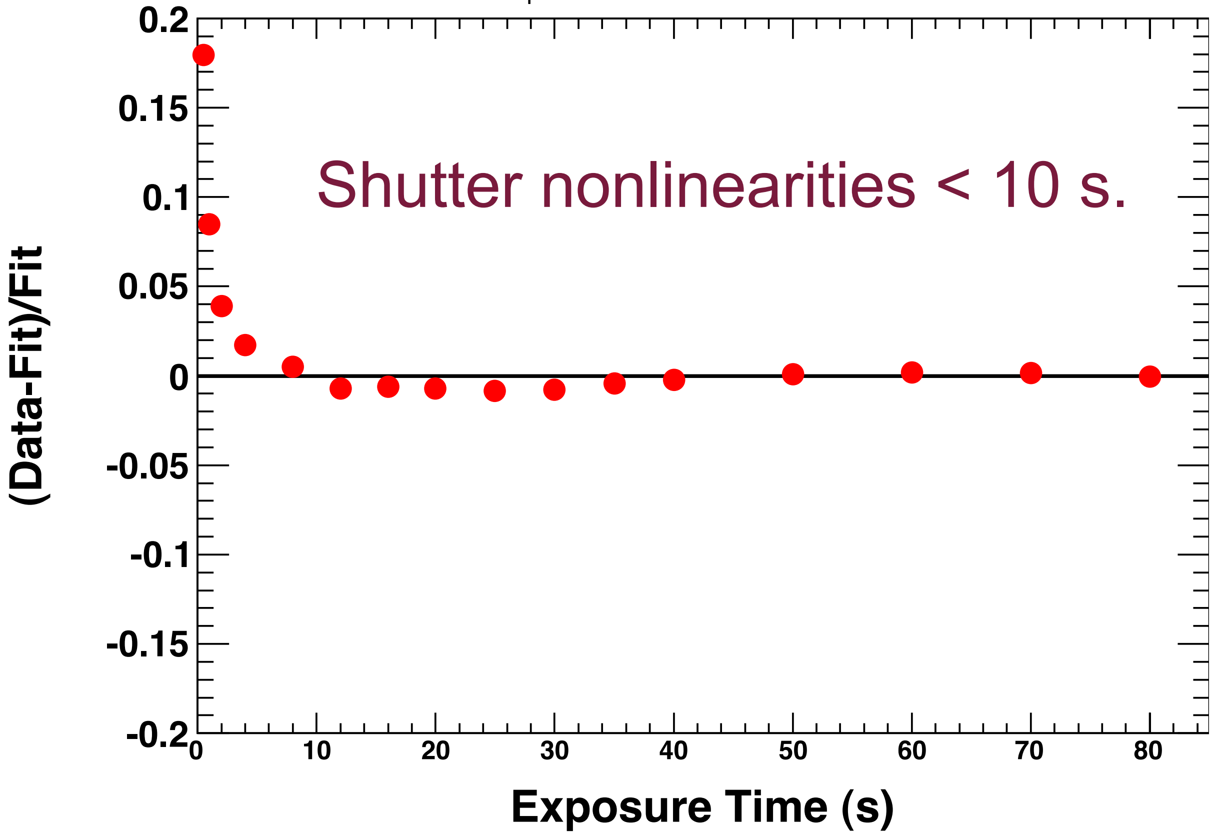




Bench Tests I: Laboratory Setup

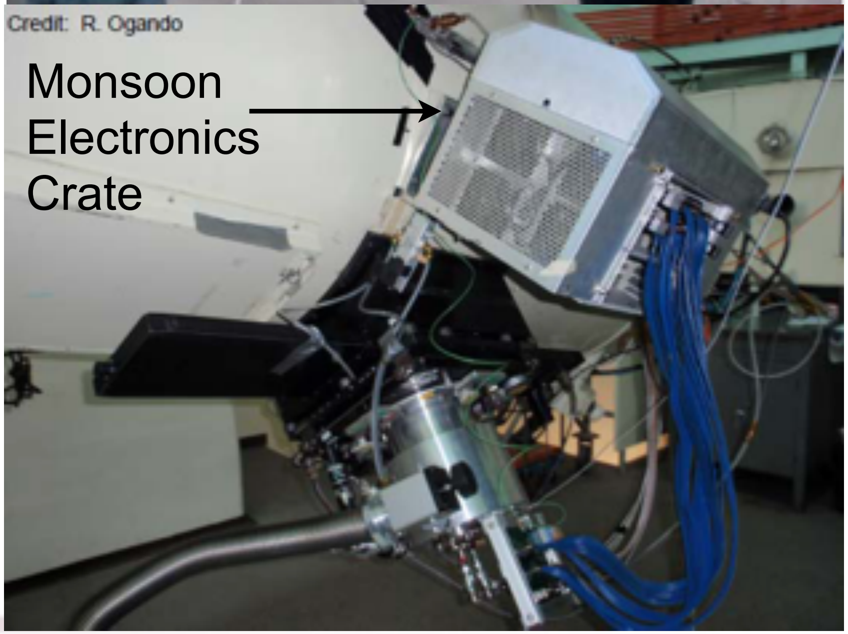
Bench Tests II: Linearity, Full Well



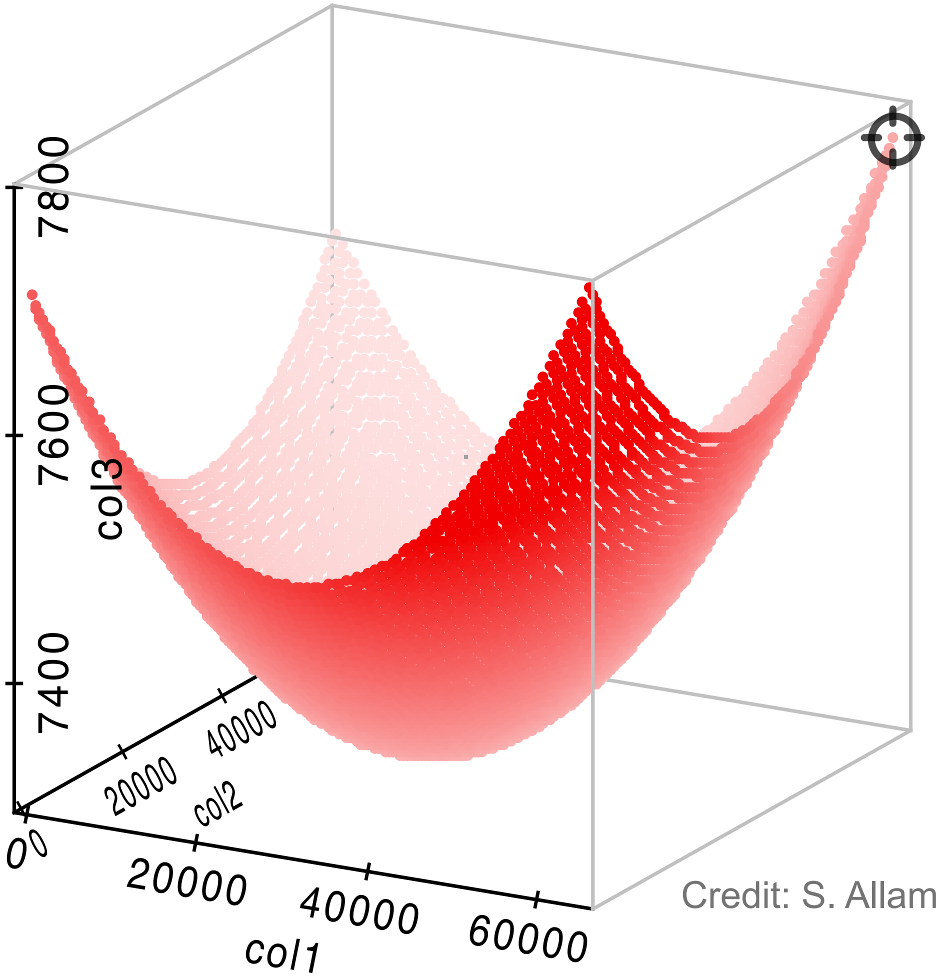


Installation on the Curtis-Schmidt Telescope at CTIO

Credit: UofM Astronomy

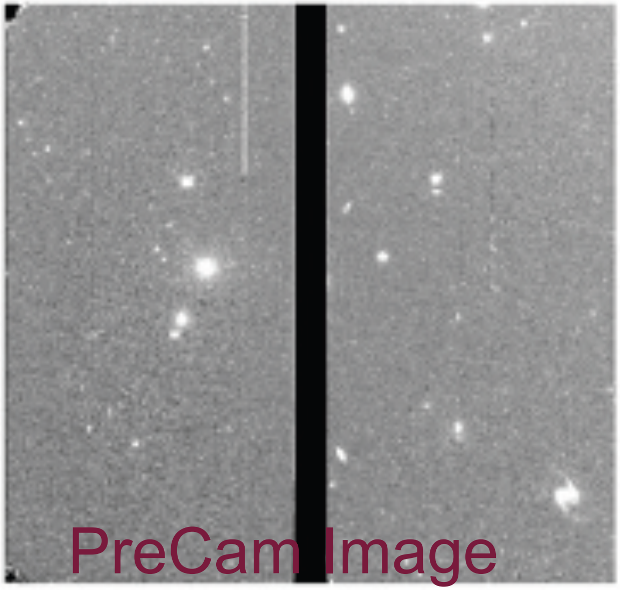


Commissioning I: Best Focus Surface, Early Images

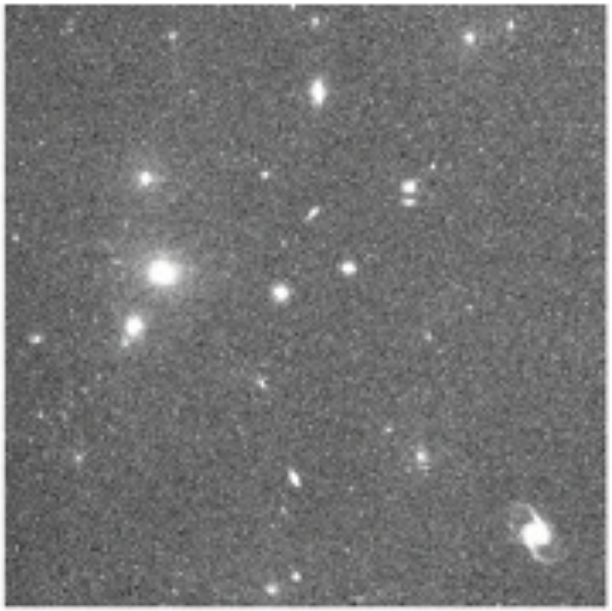


Credit: S. Allam

Note curved focus surface due to lack of field flattener



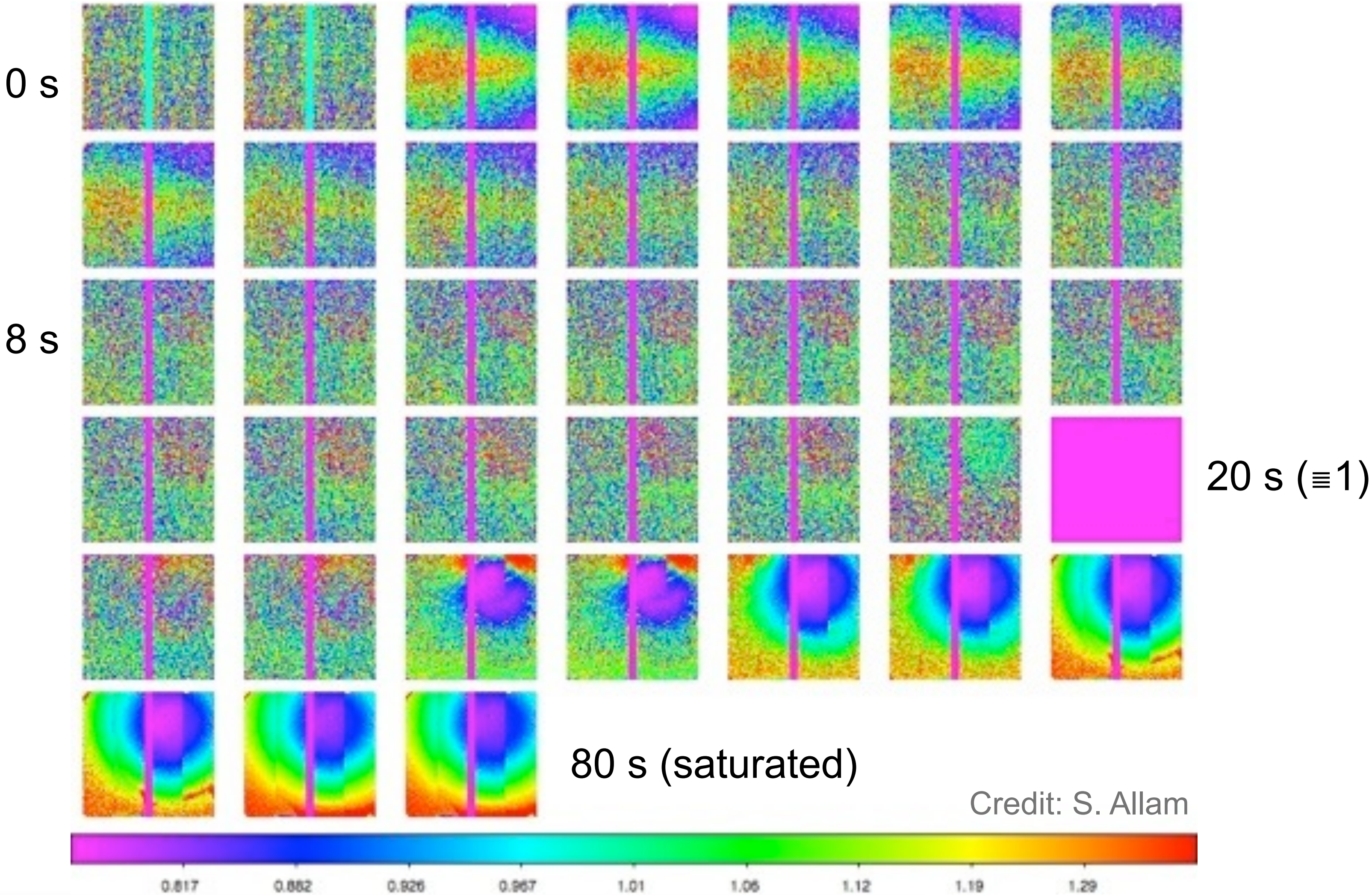
PreCam Image



Prior Sky Survey Image

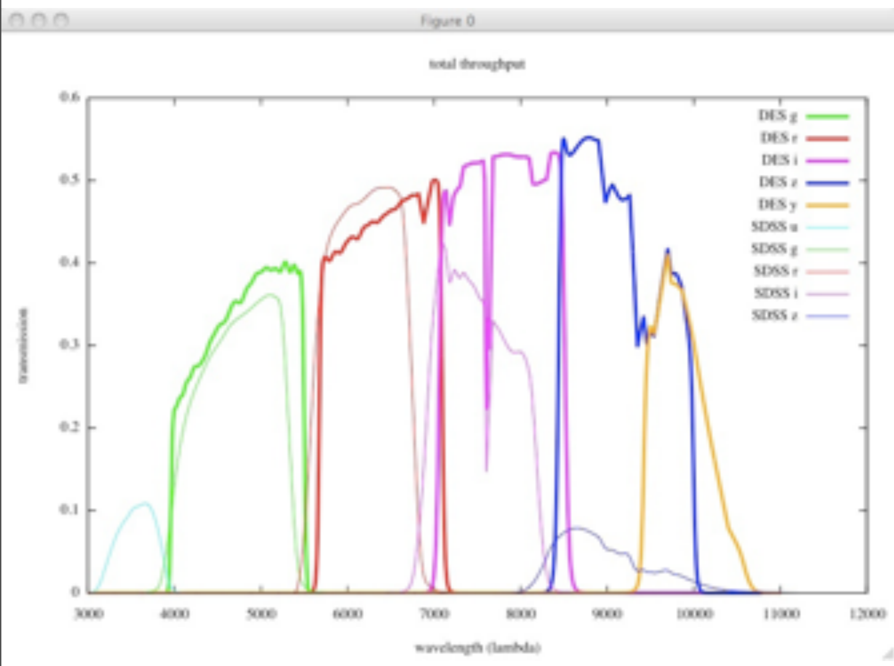
Commissioning II: Shutter Timing from On-Sky Data

nonzero shutter actuation time effects are negligible beyond ~8s, <u>confirming results</u> of bench tests

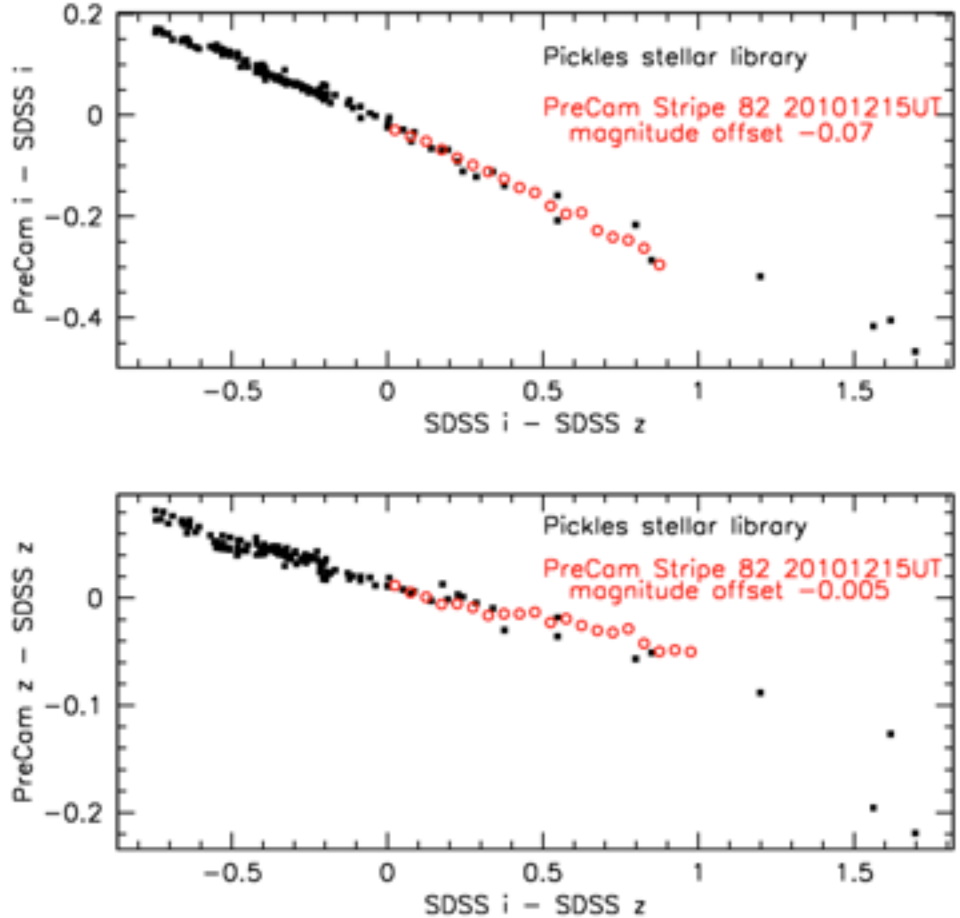


Commissioning III: Filter Performance

Transmission vs. Wavelength: DES Filters vs. Sloan Filters



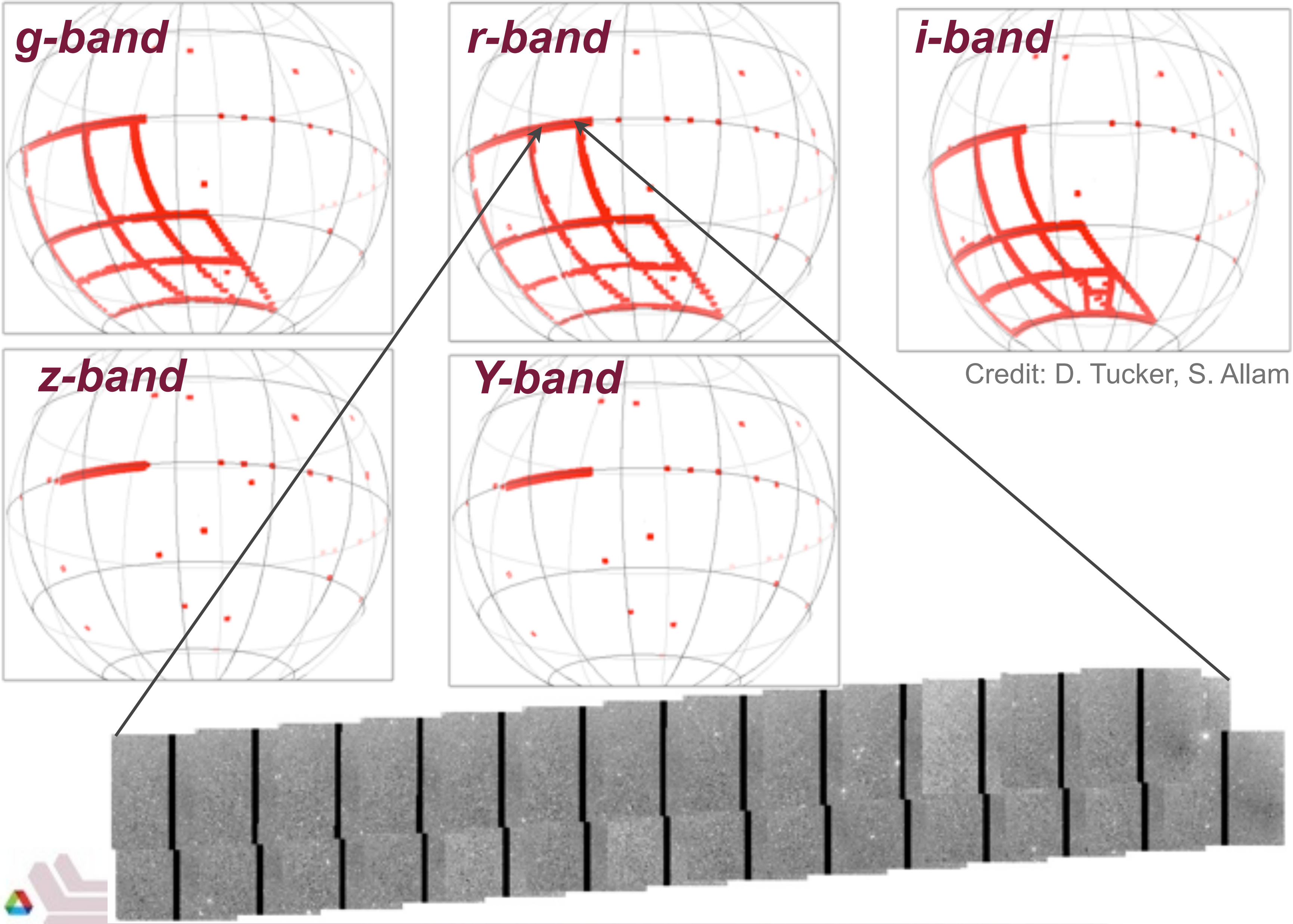
DES/PreCam Color Response



Credit: D. Tucker

PreCam Observations by Filter

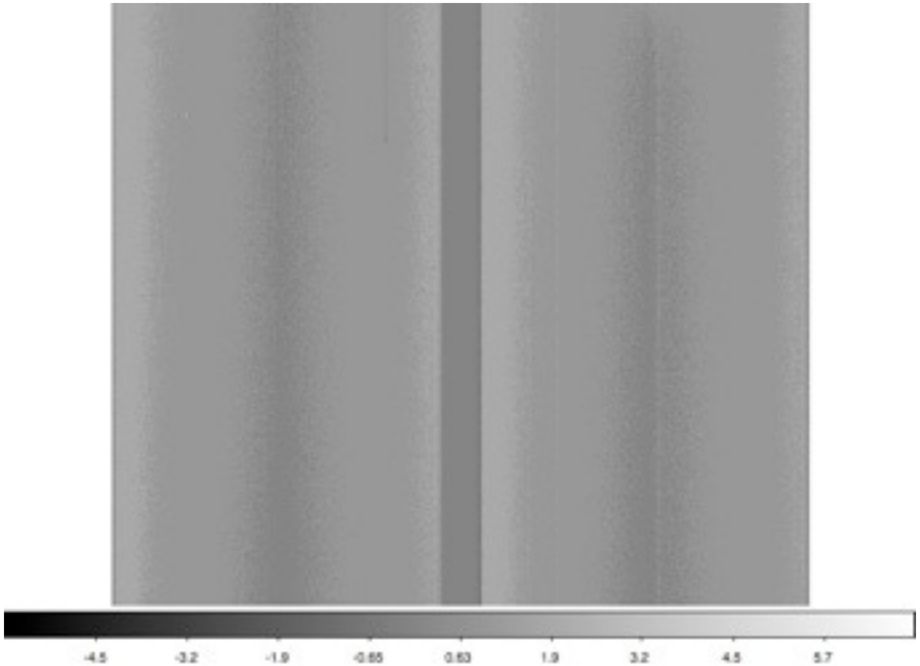
Steps to the PreCam Southern Hemisphere Standard Star Catalog



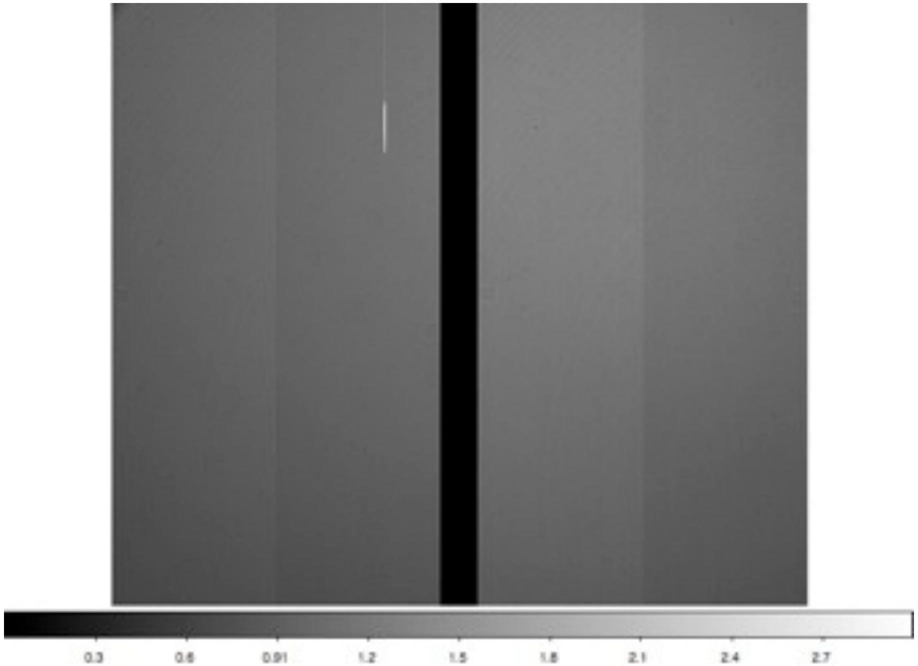
Credit: D. Tucker, S. Allam

Data Processing at FNAL (v1,v2,v3,v4) & ANL (v3+)

- Fermilab developed processing pipeline consisting primarily of shell/py scripts for bias subtraction, flat-field corrections, etc.
- Each iteration added functionality--crucial improvements include banding/streaking removal, astrometry
- Further processing/analysis scripts developed in parallel at ANL



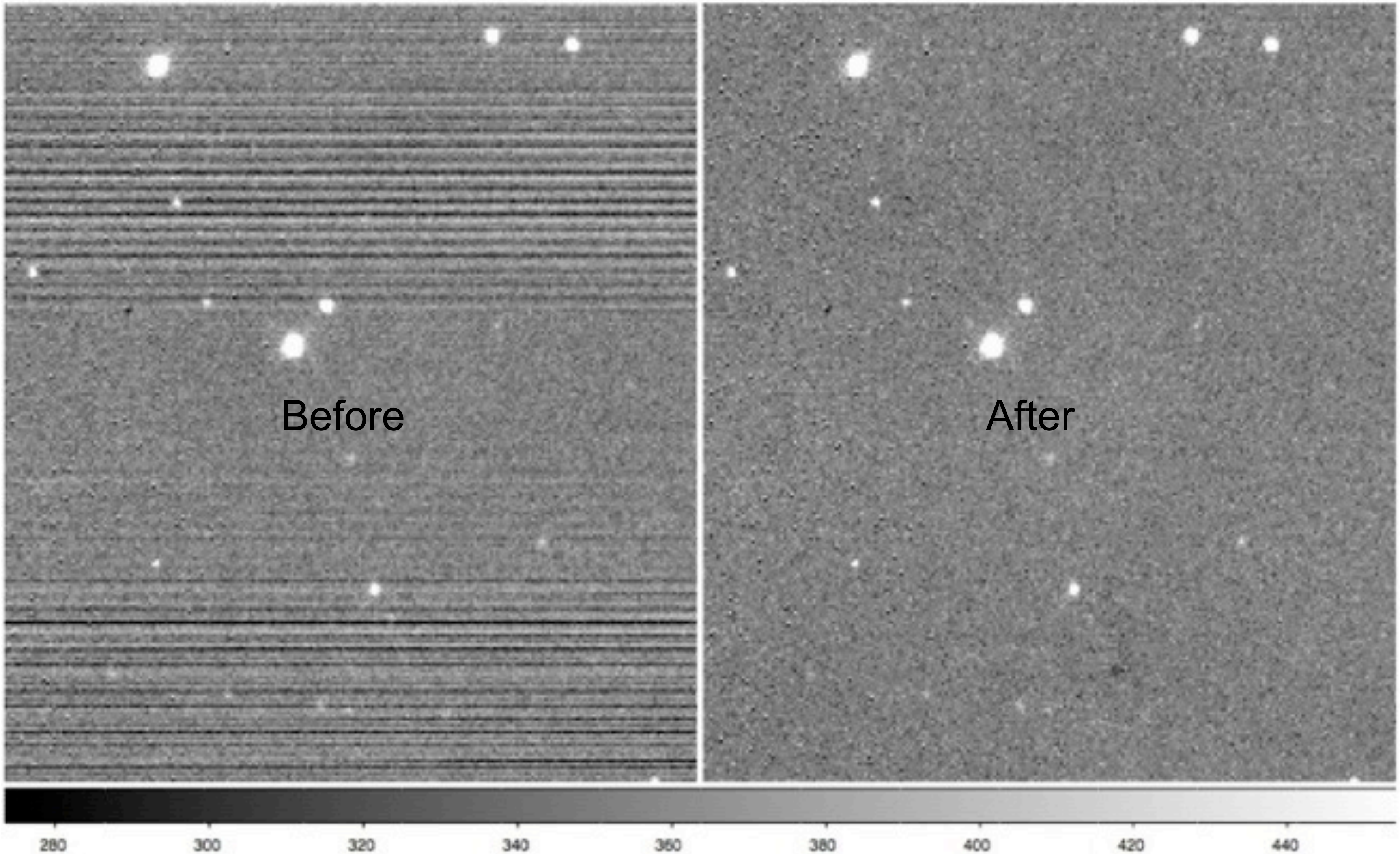
Bias



Flat

Tuesday, April 17, 2012

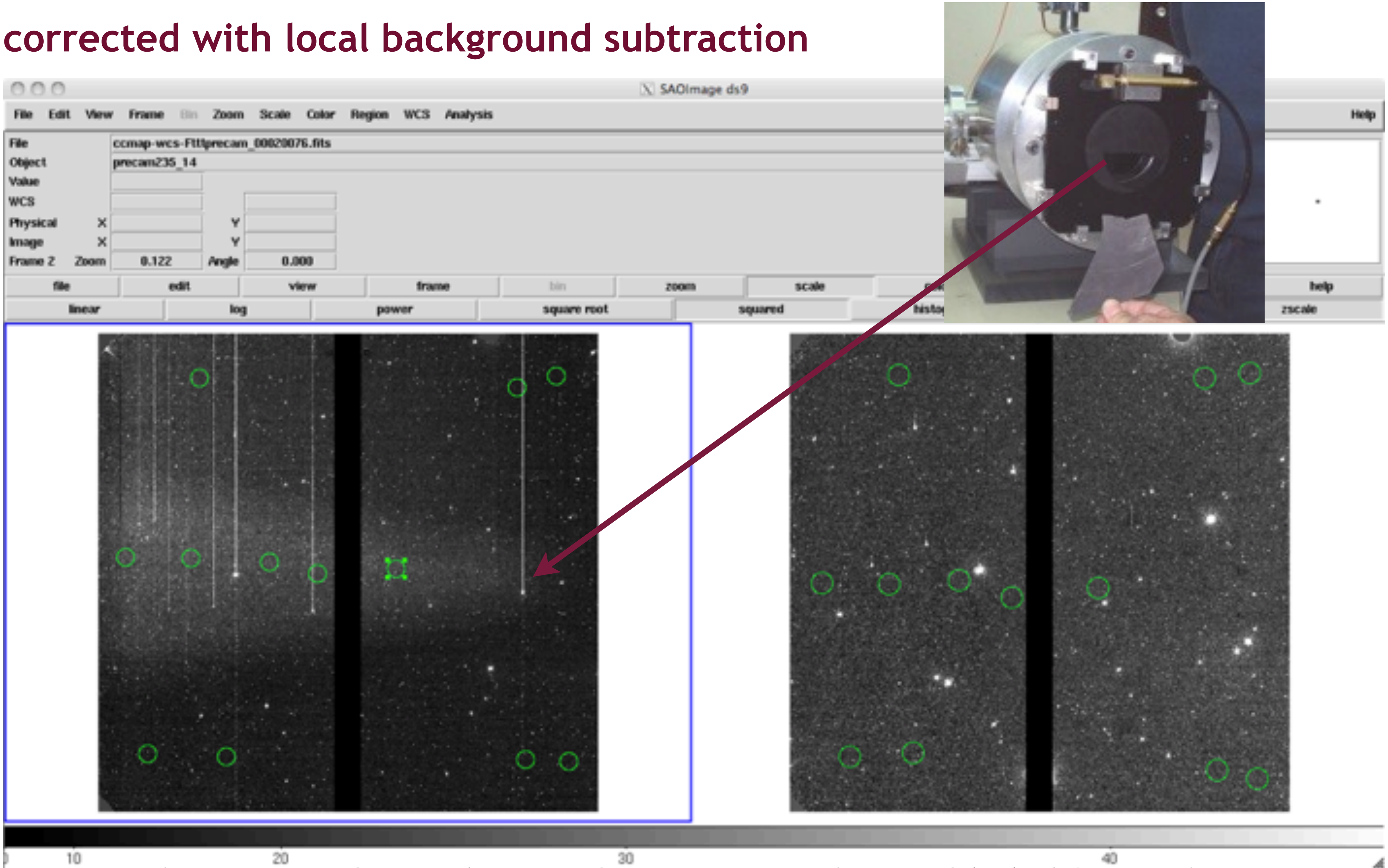
Data Processing II: Streaking/Banding & Software Corrections



Hardware Fix: Repaired VIB Cables, Strain Relief & Cable Trays

Data Processing III: Identifying Problematic Shutter Images

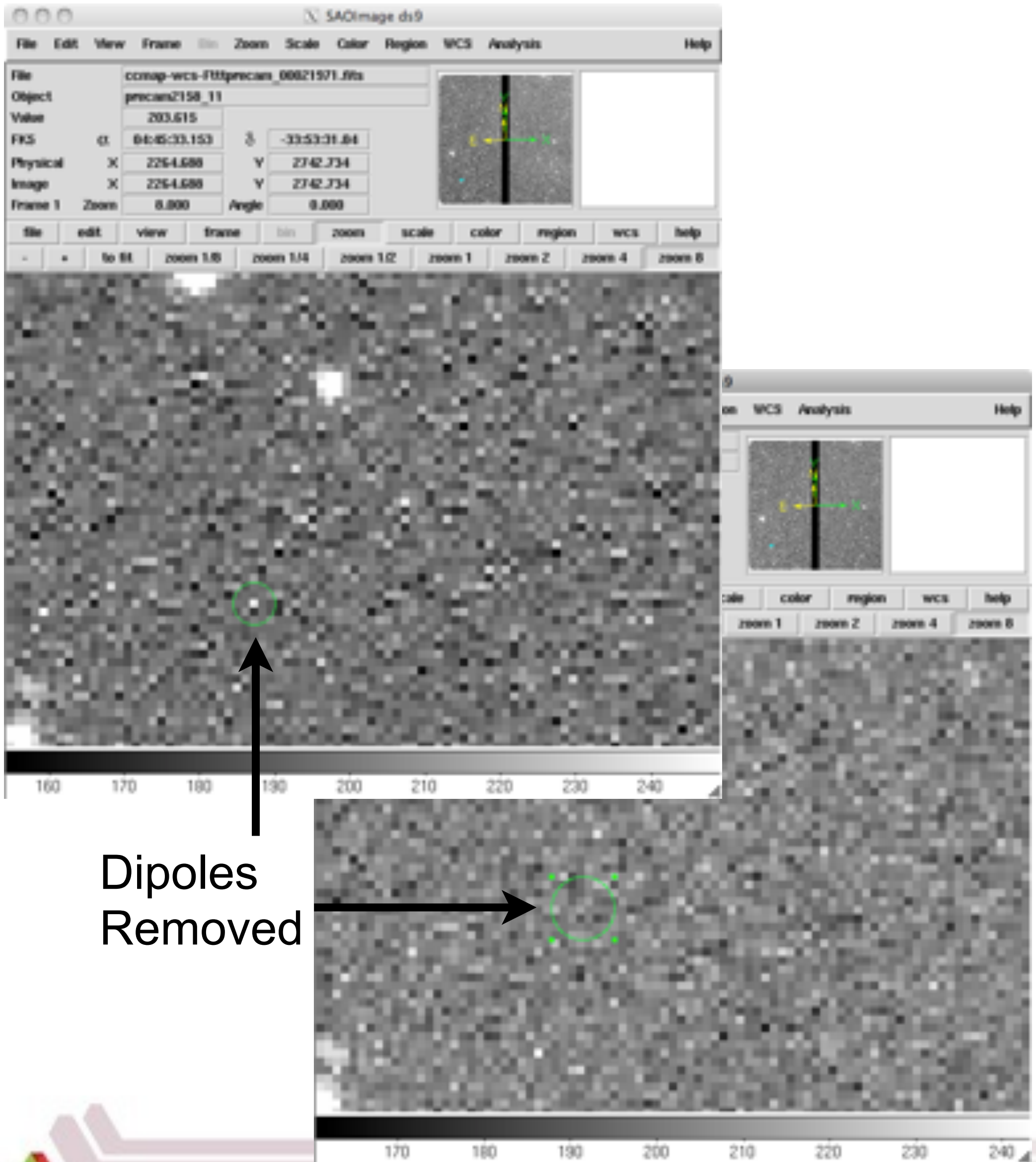
corrected with local background subtraction

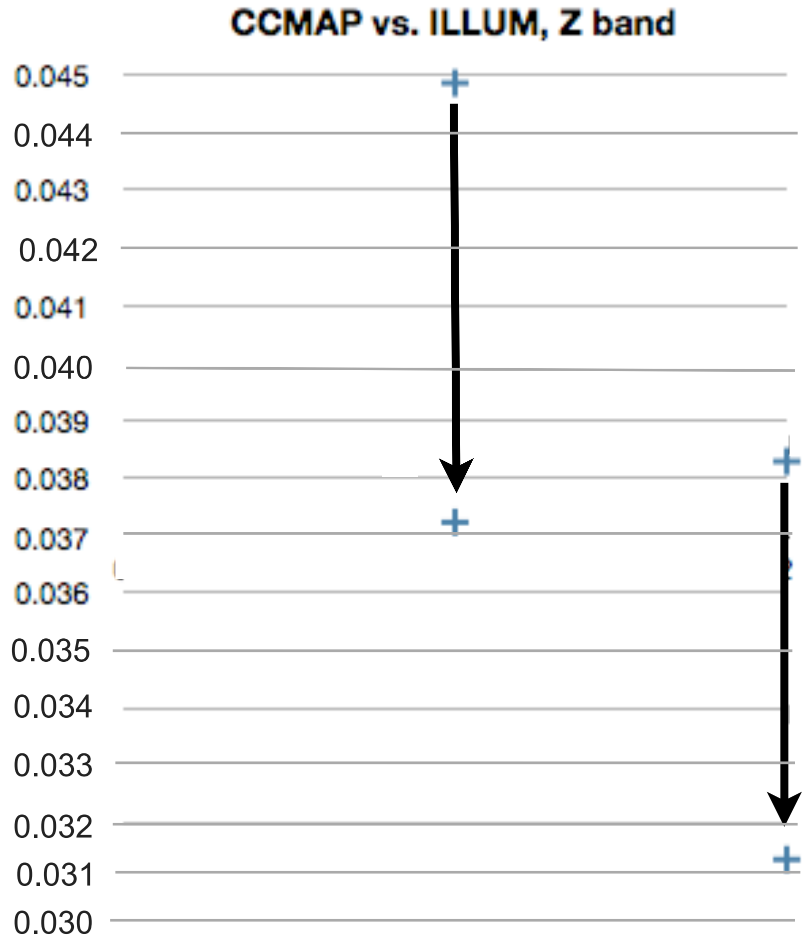


Hardware Fix: Slow-Release Valve <u>increases shutter blade lifetime</u> by ~3x

Data Processing IV: Illumination Correction

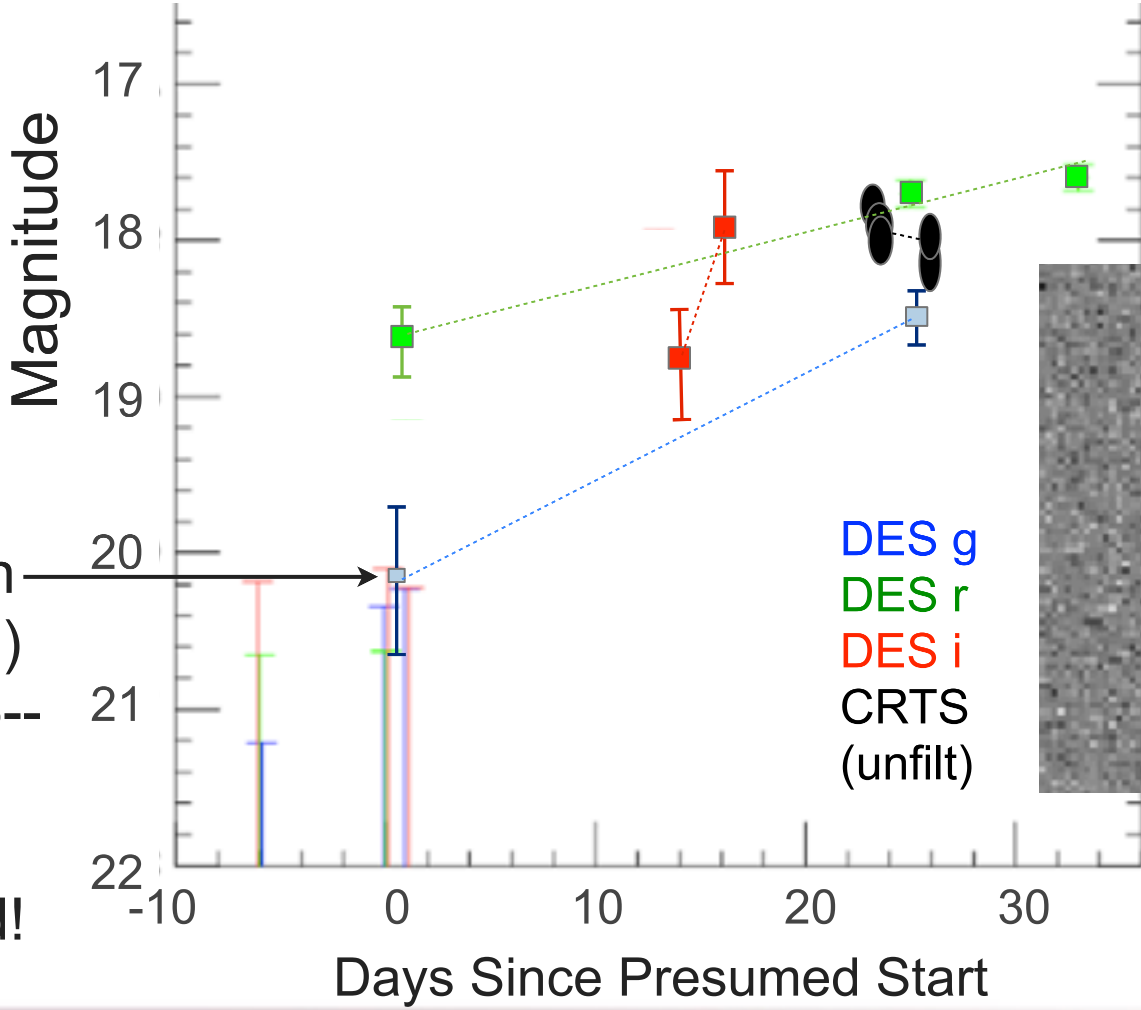
0.7% improvement to z band photometry, other effects negligible





Data Quality Checks/DES Proof-of-Concept

PreCam gri observations from 11/29/2010 to 01/01/11 of SN2010lr, a spectroscopically confirmed SNIa associated with host galaxy 2MASX J00023401-3044061 at z ~ 0.062 (Drake et al., Prieto et al.)



Detection (S/N_{pix}<2) on Dec 5-- below standard threshold!

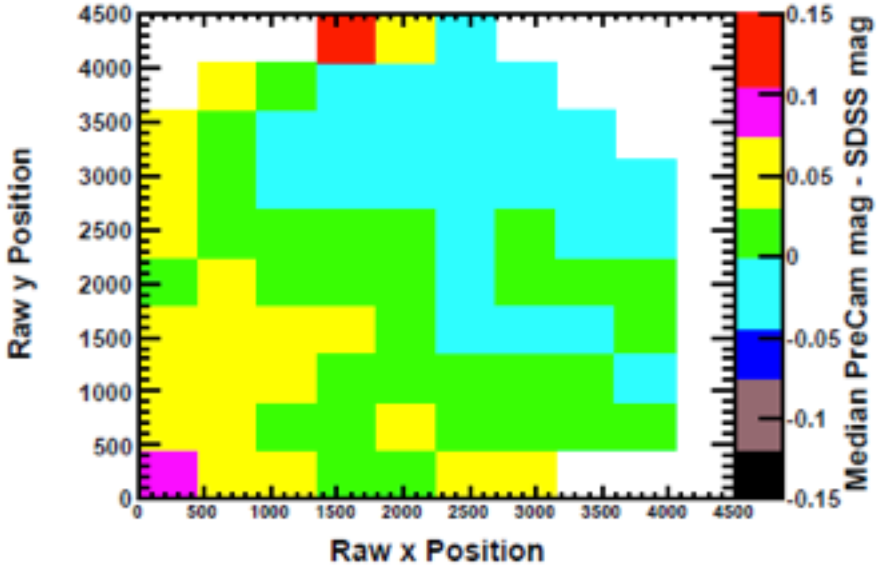
CCD edge = poor focus?

Date	Zero-Point Offset (USNO)	Standard Deviation (USNO)	Zero-Point Offset (Southern Standards)	Standard Deviation (Southern Standards)	Zero-Point Offset (SDSS)- RA40to50	Standard Deviation (SDSS)- mag<15	Standard Deviation (SDSS)-NoMagCut
20101215			g: 2.3372 r: 2.1269 i: 2.2864 z: 2.5072	g: .05323 r: .05176 i: .05021 z: .06227	g: 2.17425 r: 1.95941 i: 2.12993 z: 2.32859	g: .05258 r: .04194 i: .0581 z: .05982	g: .08925 r: .09445 i: .1065 z: .08172
20110107	g: 2.08978 r: 1.899857 i: 2.05227 z: 2.247	g: .02374 r: .03213 i: .03222 z: .02319	g: 2.0802 r: 1.91872 i: 2.05298 z: 2.263	g: .02843 r: .04228 i: .02944 z: .04915	g: 2.0645 r: 1.9346 i: 2.07891 z: 2.2993	g: .04711 r: .04305 i: .05134 z: .05304	g: .09277 r: .09258 i: .09468 z: .08514
20110108	g: 2.1784 r: 1.98041 i: 2.1281 z: 2.3587	g: .07305 r: .06301 i: .05031 z: .05476	g: 2.12746 r: 1.93154 i: 2.24 z: 2.3044	g: .03003 r: .04221 i: .04874 z: .03008	g: 2.1617 r: 1.94502 i: 2.10669 z: 2.3456	g: .05267 r: .03744 i: .05214 z: .05843	g: .1057 r: .09614 i: .1025 z: .07865
20110112	g: 2.1035 r: 1.932 i: 2.0765 z: 2.248	g: .03165 r: .05489 i: .04316 z: .04514	g: 2.07424 r: 1.905615 i: 2.06179 z: 2.21012	g: .02947 r: .03518 i: .03624 z: .03695	g: 2.11098 r: 1.92643 i: 2.07017 z: 2.25469	g: .04387 r: .03939 i: .04554 z: .05621	g: .08868 r: .08243 i: .102 z: .08538
20110113	g: 2.08618 r: 1.90392 i: 2.05038 z: 2.21058	g: .02186 r: .02544 i: .02691 z: .02033	g: 2.07 r: 1.89748 i: 2.06527 z: 2.20684	g: .03127 r: .03662 i: .04353 z: .03638	g: 2.143606 r: 1.9298 i: z: 2.26745	g: .02575 r: .04268 i: z: .06571	g: .09088 r: .08401 i: z: .0936

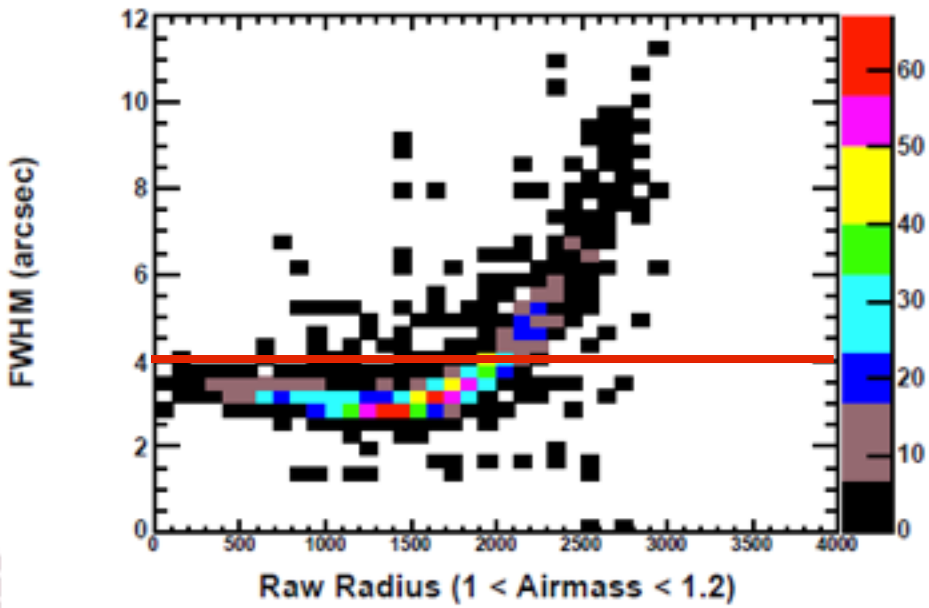
Final Data Analysis Steps: Star Flats + Data Quality Cuts

added "flat field" to remove final CCD response gradient prior to analysis

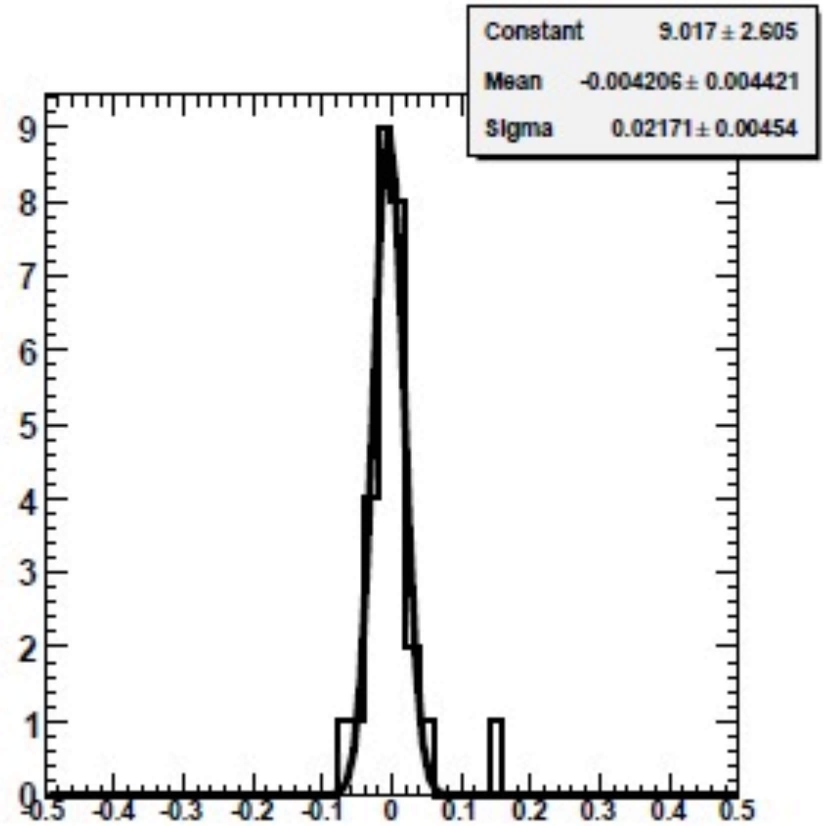
- FNAL v3 production + ANL ROOT scripts
- USNO, Southern u'g'r'i'z', and SDSS standards
- SDSS airmass correction and Star Flat correction applied
- magerr<.01 for all bands
- FWHM < 4.0, Class_Star > 0.95



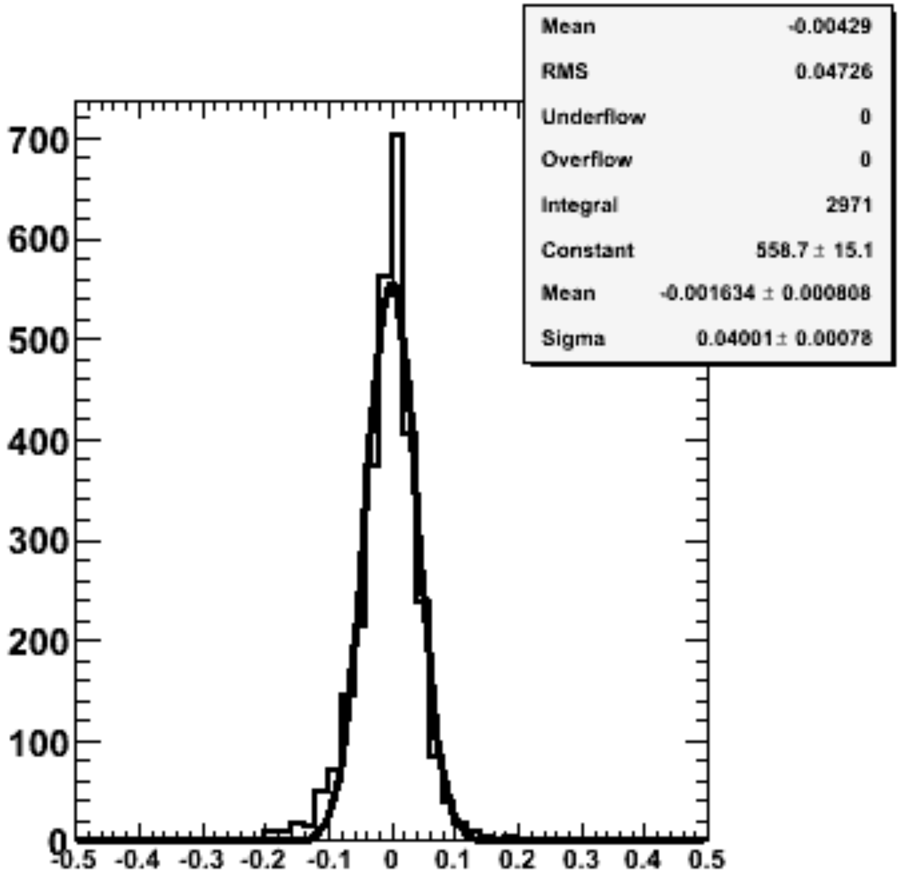
v3aper12	.06871
v3aper12, stellarity > .95	.04901
v3aper10, stellarity > .95	.048496
v3aper10, stellarity > .95, fwhm < 4.	.048434
v3aper10, stellarity > .95, fwhm < 4. , pixels cut	.048447
v3aper10, stellarity > .95, fwhm < 4. , pixels cut, starflats	.040106
v3aper10, stellarity > .95, fwhm < 4. , pixels cut, starflats, mag < 17.	.03838



Preliminary Results I: Single-Epoch Photometry



PreCam z - USNO z Bright



PreCam r - SDSS r

Preliminary Single-Image Photometric Accuracy:
4.0% (SDSS r,i); 3.2% (SDSS z); or 2.2% (USNO z, mag<14)

Preliminary Results II: Stacking Images

- Matches on (RA,DEC) ±3” using STILTS for 2011-01-07

- Preliminary photometric comparison for selected stars: Mag(i) - Mag(j) = ΔMag (if ≥3 measurements of star exist)

- Best ΔMag: 0.0026 (Precise repeatability, if not accuracy)
- Worst ΔMag: 0.2042 (But not all corrections/cuts applied...)

- 0.0 < Median ΔMag < 0.17 (There is room for improvement!)

- Explored only 3 stacked images from one night (out of 51 total); systematic studies of possible improvements underway

- Goal: 4%→2% photometric accuracy over full PreCam grid...

Conclusions

- The Precursor to the Dark Energy Camera (PreCam) has been successfully built and deployed at Cerro Tololo Interamerican Observatory

- Individual component and system-level tests have been performed on analogs of DES hardware/software

- PreCam observed a significant fraction of its total planned footprint; a second season of observations is being explored

- Preliminary results show single-epoch photometric accuracy of 3-4%, with accuracy better than 2% for brighter (<14th mag) stars. Refined processing + source stacking show promise for improved photometric accuracy.

- Beyond its primary goal of identifying calibration standards, PreCam is already proving the capabilities of DES science!