DECam

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- DECam
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  - Mosaic Comparison
- Blanco Improvements
- DECam Calibration System (Darren DePoy)

Overview

NOAO Large Science Projects

- LSP Objectives: maximize scientific return of NOAO facilities by
  - Providing new, large-scale, state-of-the-art instrumentation for the U.S. O/IR System
  - Attacking a significant science problem with a survey that has significant value for future community use
- LSP #1: DECam/DES on the CTIO Blanco 4m telescope
  - Open Announcement of Opportunity (AO) for Blanco in 2003
  - Proposal by DES Consortium, led by Fermilab
  - External Review Panel Recommendation: DECam will represent "*an asset to the National Observing system", and together will the DES archive, "will enable an enormous amount of science over a broad spectrum of interests in the NOAO community.*"

DECam+DES Key Points

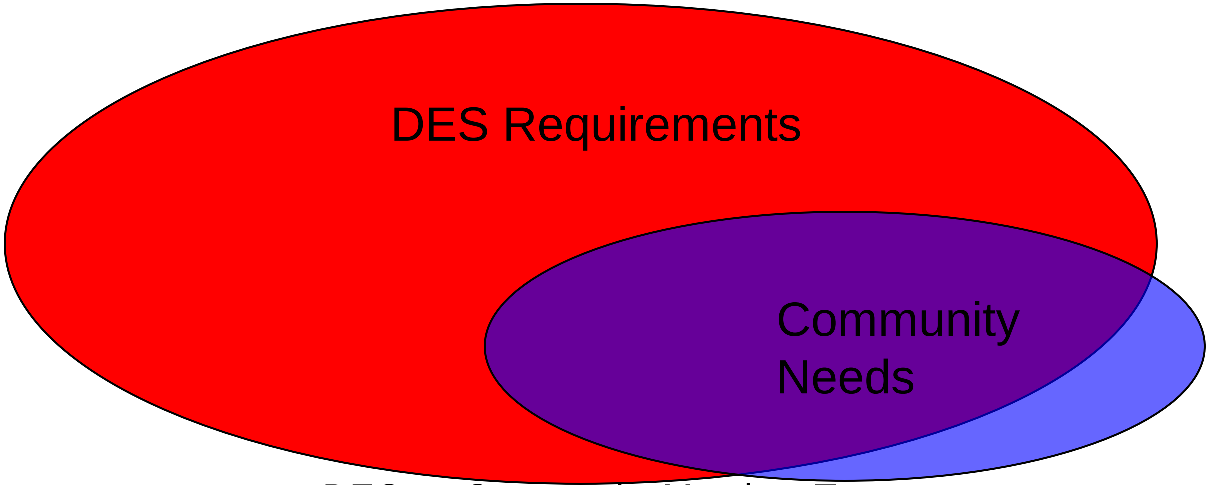
- The NOAO Community gets
  - The **Dark Energy Camera, DECam,** a *facility-class* wide-field optical imager system for the Blanco 4m
  - A **Community Pipeline** to provide basic reduced data
  - Delivery of the **Dark Energy Survey archive**, a resource covering a significant portion of the southern skies
- The DES Consortium gets
  - 525 nights over 5 years to carry out the Dark Energy Survey

DECam: a Facility Instrument

- What does *facility-class* instrument mean?
  - Use by visiting astronomers
    - From <1 night runs to longer-term surveys
  - Use in a variety of “well-defined” observing modes
    - Point & Stare, Dithers (fill in the gaps), Survey (DES-style)
  - Well documented for visiting users
  - Consistent with Observatory standards
  - Well integrated into NOAO operations & user support
    - CTIO mountain operations and visiting astronomer support
    - Data management operations, PI and Archive user support

Developing DECam Requirements

- Requirements are combination of
  - Survey driven: high quality systems specifically for DES
  - Community driven: broader use cases, general interfaces, different modes of observing
- DES requirements are, in general, very stringent and there is a high degree of overlap between DES requirements and community needs



NOAO User Community Use of DECam

Document – *Community Needs for the Dark Energy Camera & Data Management System*

Highlights –

- DECam should be useable over all optical wavelengths 320-1100 nm (an Atmospheric Dispersion Corrector is not a requirement)
- Filter mechanism design should both minimize filter swaps, and allow such swaps to be carried out safely in a reasonable time
- F/8 mirror easily available
- Observing protocols and operation modes are listed
- Data format and metadata are listed
- DMS must support use both by the DES and the community

NOAO User Community Use of DECam

The User Community has two routes to DECam data:

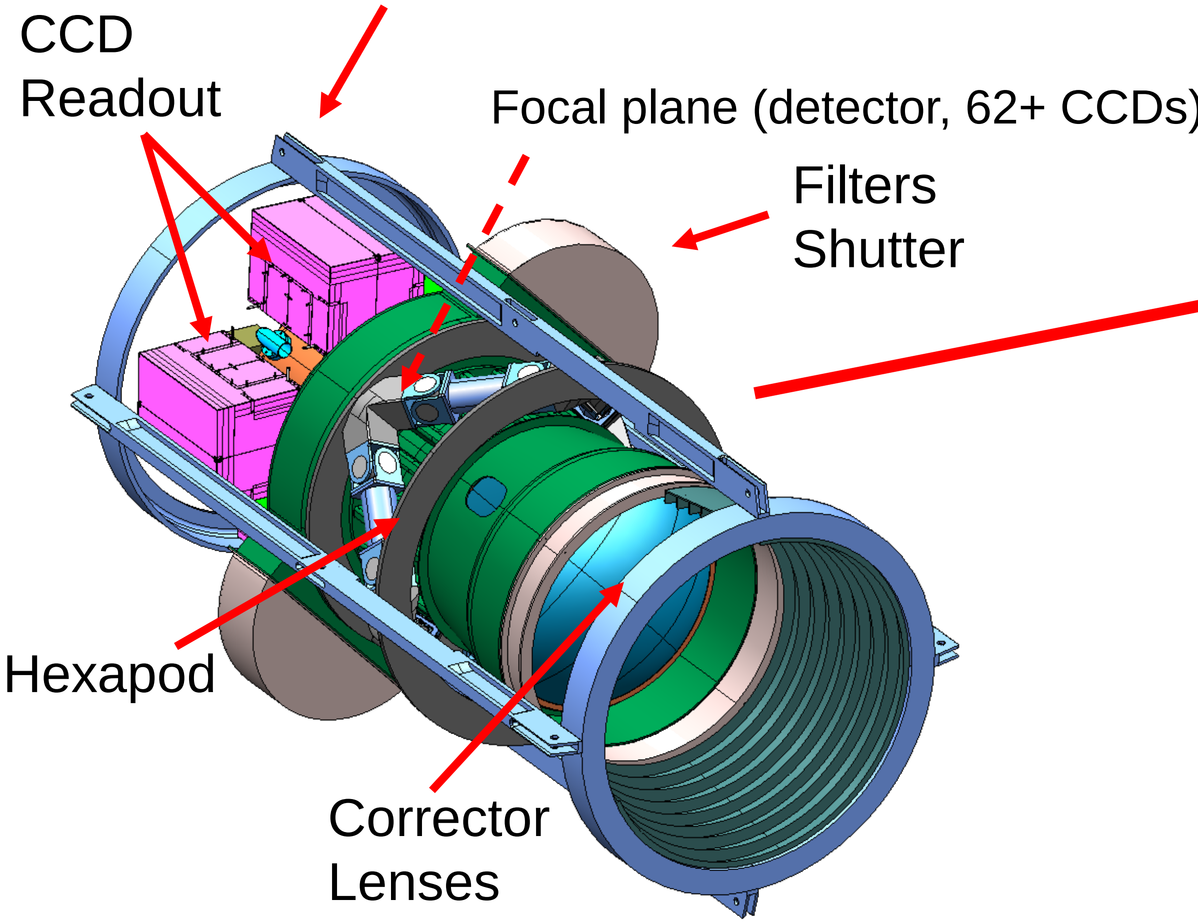
- The DES itself (Josh Friedman talk), which has a 12 month proprietary period
- By proposing to NOAO for P.I, or Survey Proposals (Dara Norman & David James talk)

DECam

DECam Construction Project

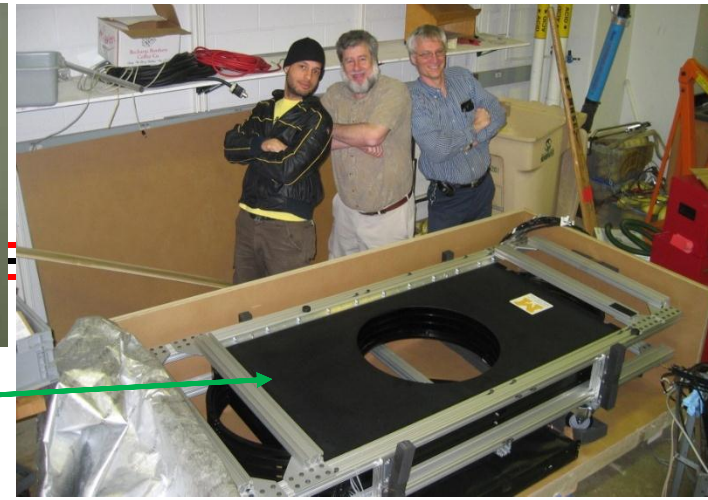
- DECam Imager   (lead Fermilab)
- Data Management (lead NCSA at UIUC)
- Blanco Telescope Improvements (lead CTIO)

DECam – at prime focus

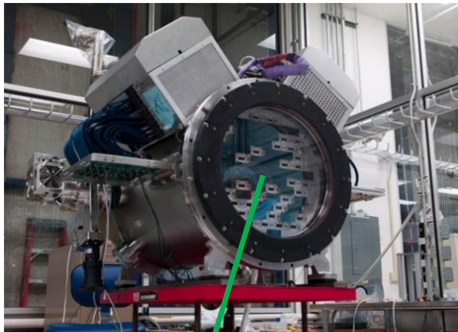


DECam Systems

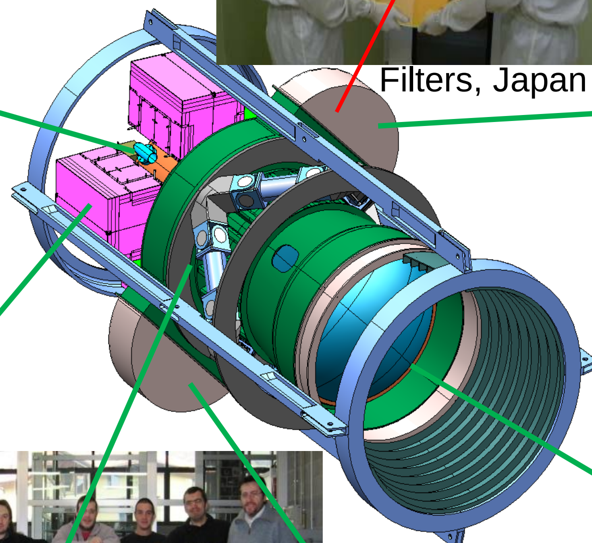
Filters, Japan

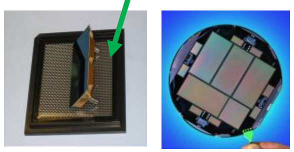


Filter changer, Univ. of Michigan

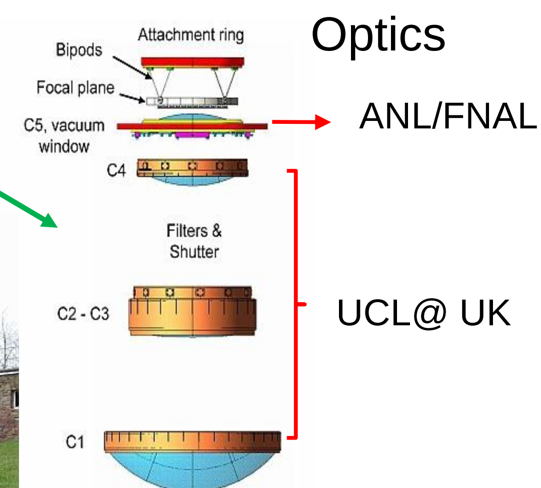


Imager, FNAL





CCDs, wafer from LBNL, packaged at FNAL



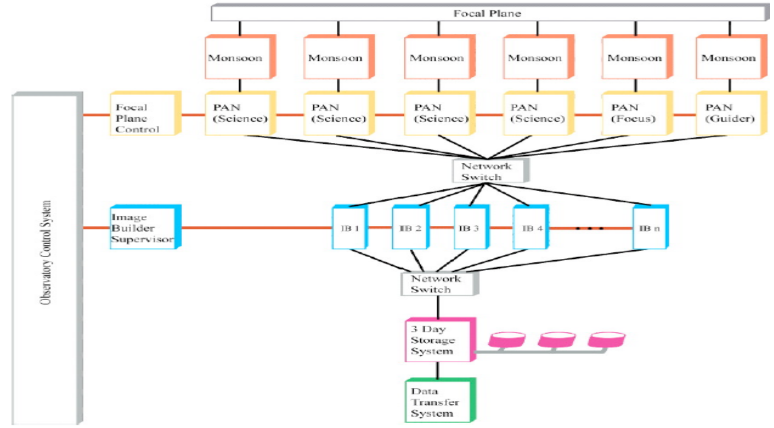
Hexapod, Italy

Electronics, Spain and FNAL

Shutter, Germany

DECam Supporting Systems

Cooling and Vacuum system, FNAL,
Keep CCDs at 173K, 10^{-6} Torr

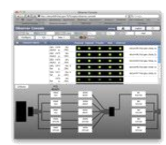


THE DARK ENERGY SURVEY

SISPI GUI Interfaces

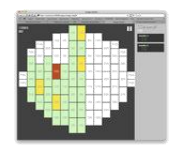
Apps

Observer Console



Comfort Display

Image Health



Architect Console

Variable Viewer

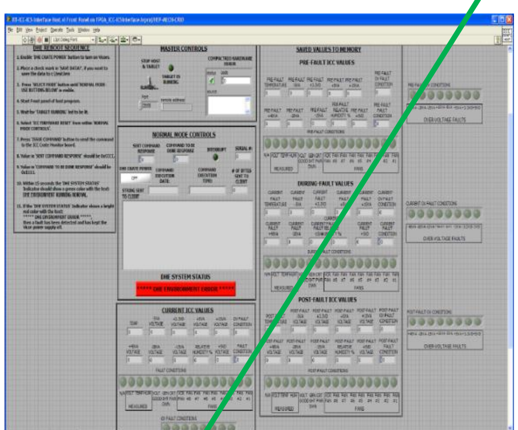
Exposure Table

image coming soon

Alarm Viewer

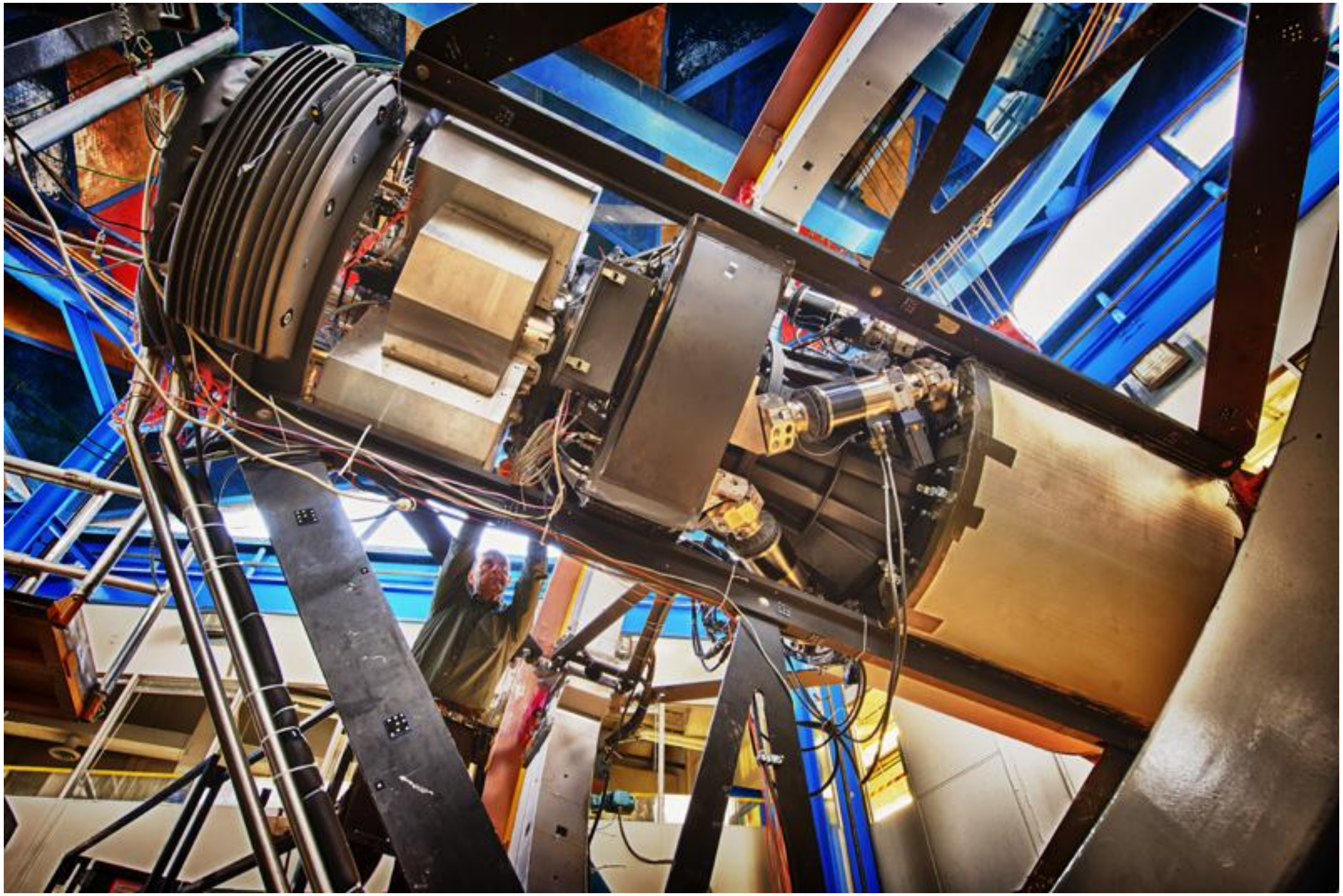
image coming soon

DAQ / Controls / Monitoring System
OSU, UIUC, FNAL



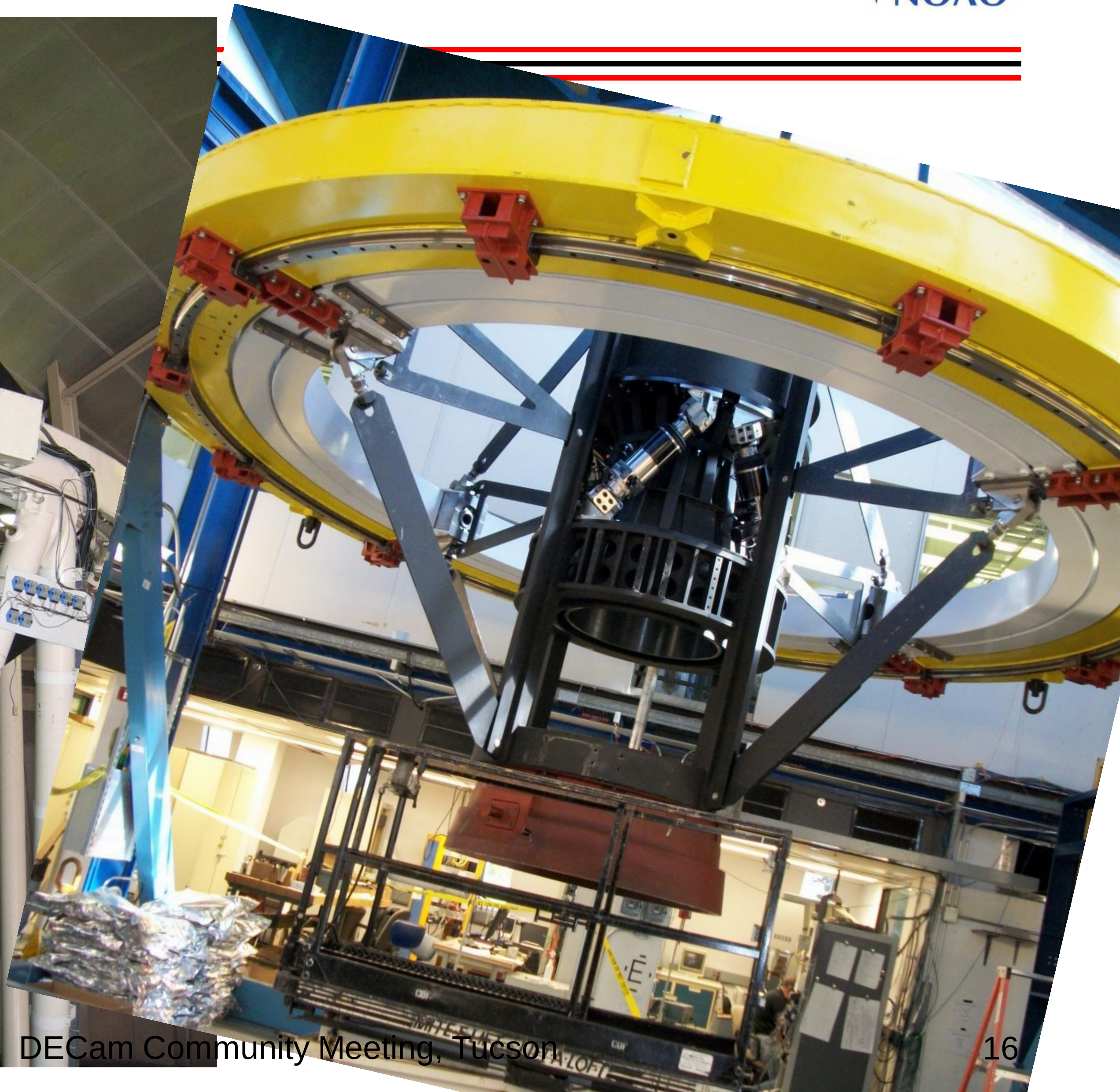
Instrument Control System, ANL, FNAL

A telescope simulator was built to hold DECam and perform integration tests



The Blanco Telescope

Fermilab



Full size prototype used for testing

DECam Details

Optics

Optics Facts

- Corrector design by Rebecca Bernstein (UCSC) following concepts by Mike Gladders (U Chicago)
- Five elements, all fused silica
- Lens mounts design by Peter Doel (UCL)
- Low distortion design (pixels at field edge have 1.5% greater area than those at the center. Scale ~ 0.27 arcsec/pixel
- There is no ADC
- Not achromatic – but pretty much so to the red of 600 nm
- Image quality budget 0.32 arcsec (0.27 arcsec in the optical design)
- For comparison, CCD diffusion contributes 0.31 arcsec, the primary 0.16 arcsec, grand total 0.49 arcsec

C1 Lens Fabrication

Steve Kent inspecting the C1 Blank (980mm diameter) at Corning Jan. 2008

C1 polishing complete Jan. 2011
C4 coating complete May 2011

Mechanical Requirements

- Minimize overall size
  - largest lens diameter should be <1m
  - Fit within existing prime focus cage
- Provide a workable filter location
  - 4 locations, 8 filter capacity
  - Smaller angles better (uniformity with angle)
  - 13 mm thick, 620mm diameter
- Provide a workable shutter location
  - C3 and C4 (along with filters)

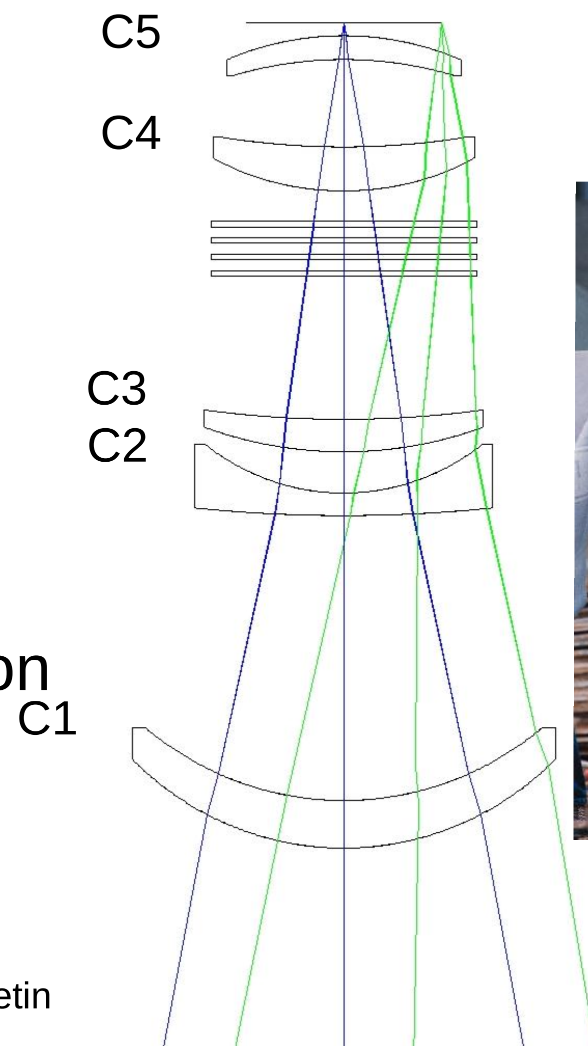
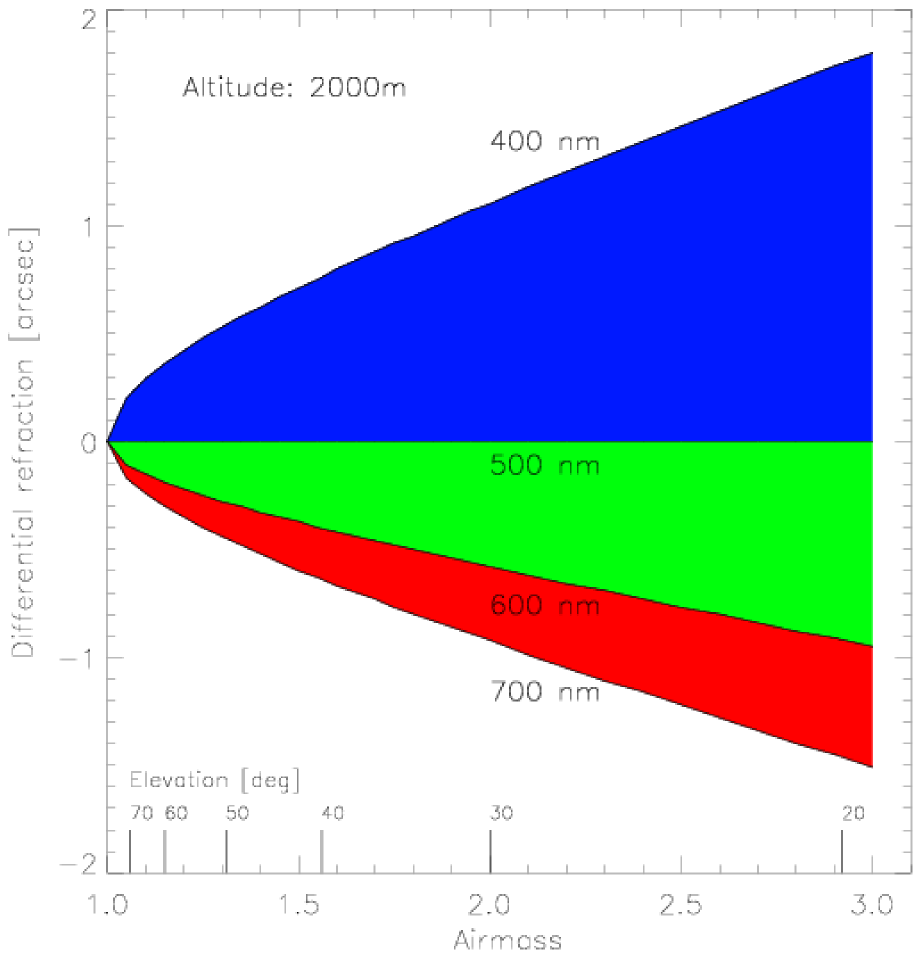


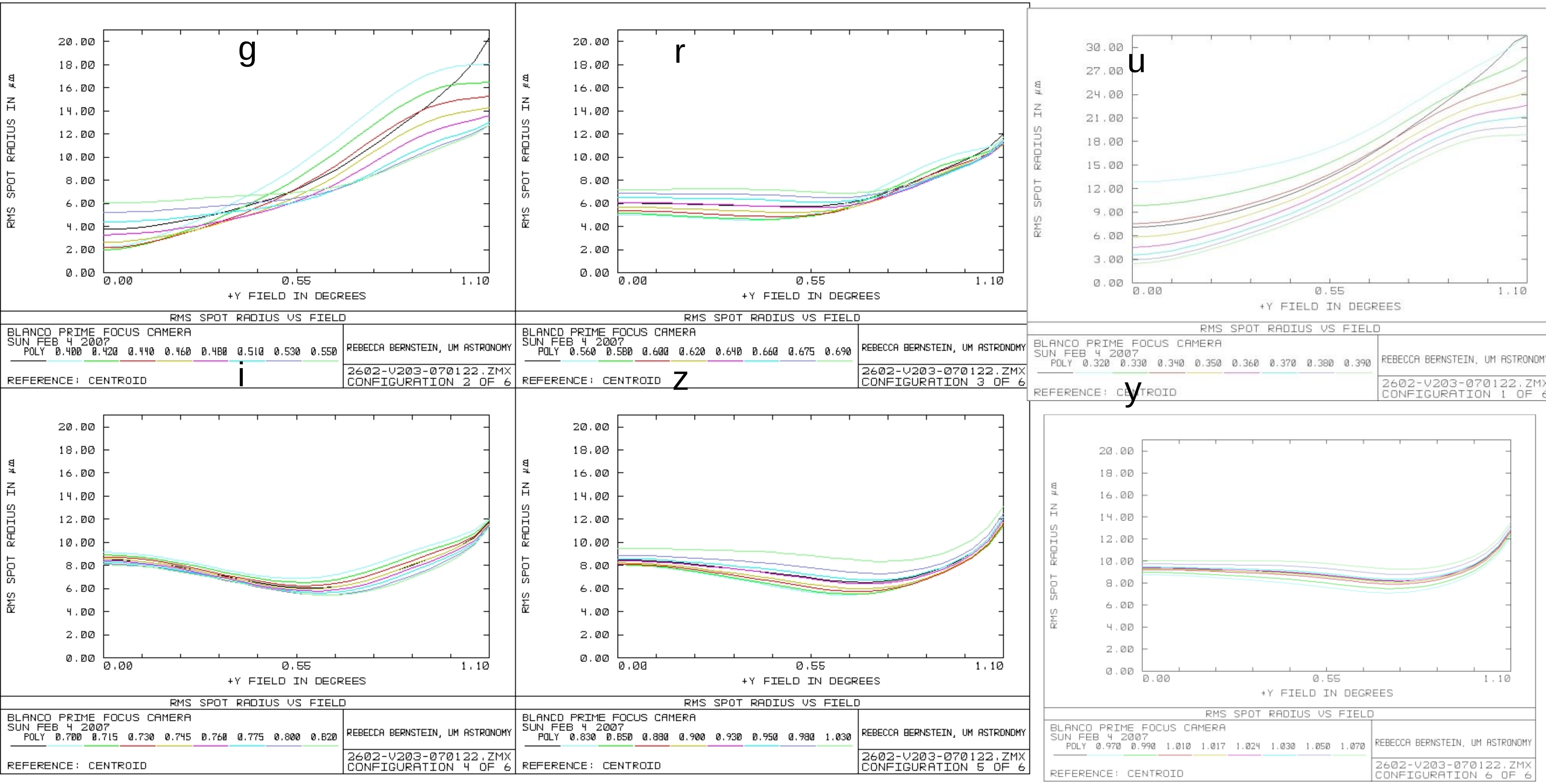
Image Quality Issues

- The new corrector
  - Five elements, C5 is the dewar window
  - C2 and C4 each have one aspheric surface
  - C1 is not coated, others are BBAR
- What does no ADC mean?
  - Plan to observe blue passbands at reasonable (e.g. ~ <1.5) airmass
  - The plus side is that the psf will be stable
  - Reference: A. Filippenko, PASP 1982, 94, 715
- Focus and Alignment
  - We have the ability to automatically focus on a frame by frame basis
  - We also have the ability to tweak xshift and yshift, tip and tilt.
  - And even tweak the primary mirror axial supports
- Guiding
  - There are four dedicated 2Kx2K guide CCDs on the focal plane

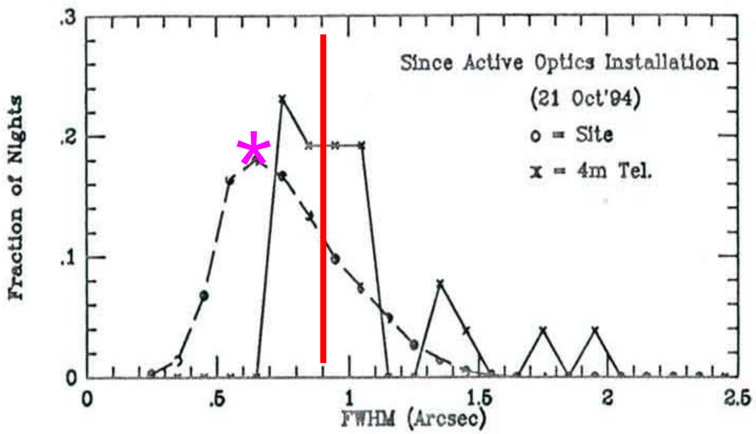
Differential Refraction



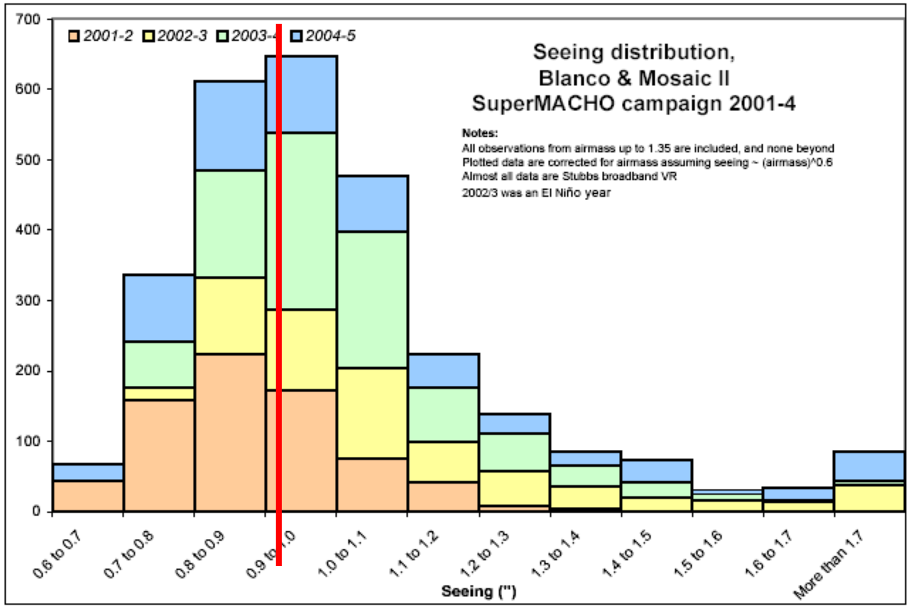
Radial image quality



[Expected image quality … Blanco + CTIO]



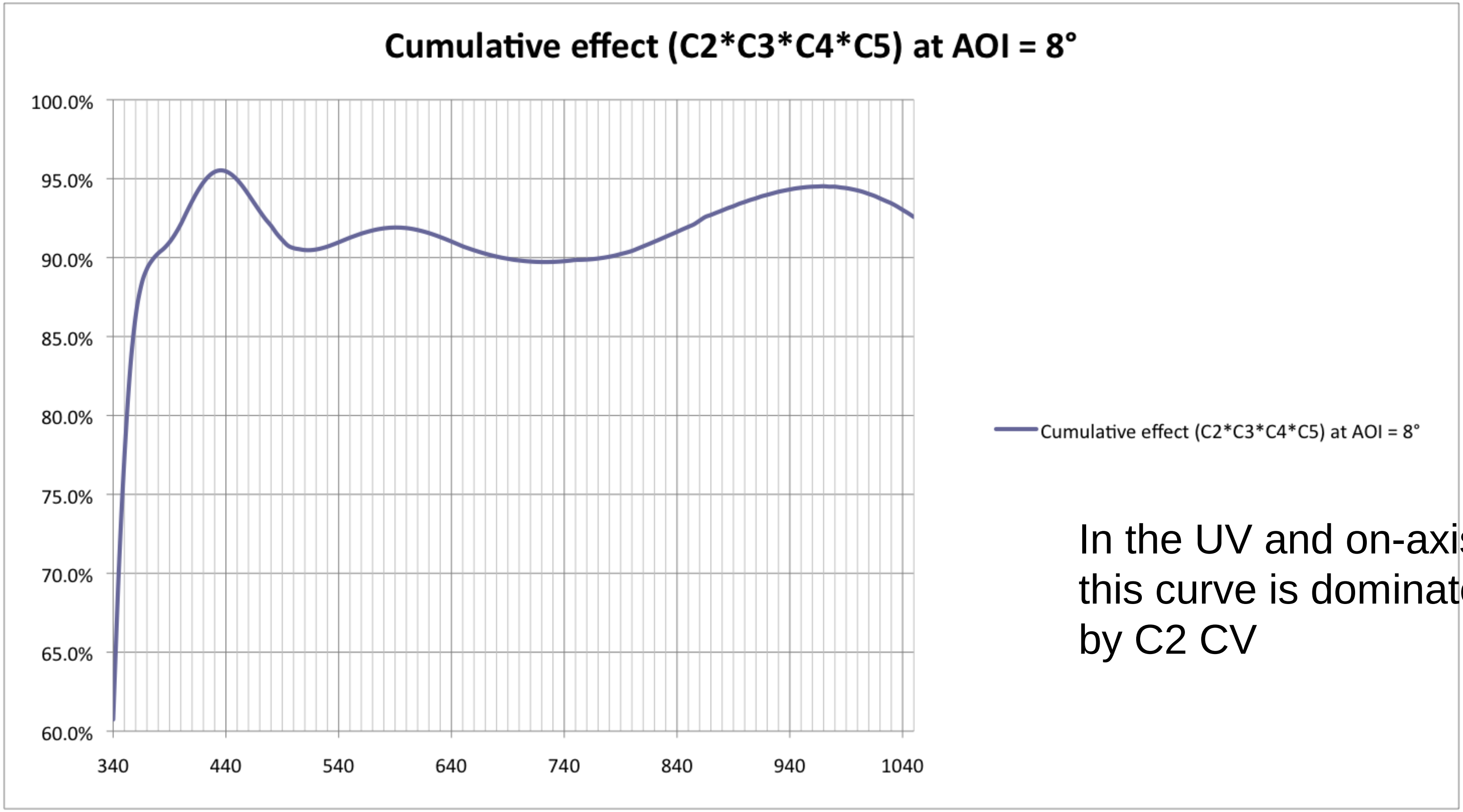
* Site seeing



Telescope and site performance stable… measured multiple ways.

Median V band zenith image size ~0.9” fwhw

Corrector Transmission



In the UV and on-axis this curve is dominated by C2 CV

Optics Summary

	DESIGN	Requirements
Field of view:	2.2 deg	2.2 deg
Pixel scale, F/#:	58.0 (f/3.0)	56-58 (f/2.9-3.0)
Image quality:	fwhm=0.25” (R_{rms}~8.5µm)	fwhm < 0.27”
Wavelength:	g,r,i,z (U acceptable)	g,r,i,z (U not specified)
Pupil ghost	peak ~3%, grad ~0.05% /mm	peak < 3% grad < 0.05% /mm
Image ghost	~25.1 mag/asec^2	< 25 mag/asec^2 for 6 mag star
Aspheric surfaces:		
configuration	c4-cvx, c2-ccv	2 single aspheres
MAD max slope	~1mm/50mm	1mm/50mm
Spaces for filters/shutter	Good.	50mm shutter, 250 mm filters
C1 diameter, overall length.	~950 mm, ~1.8m	minimized, as possible

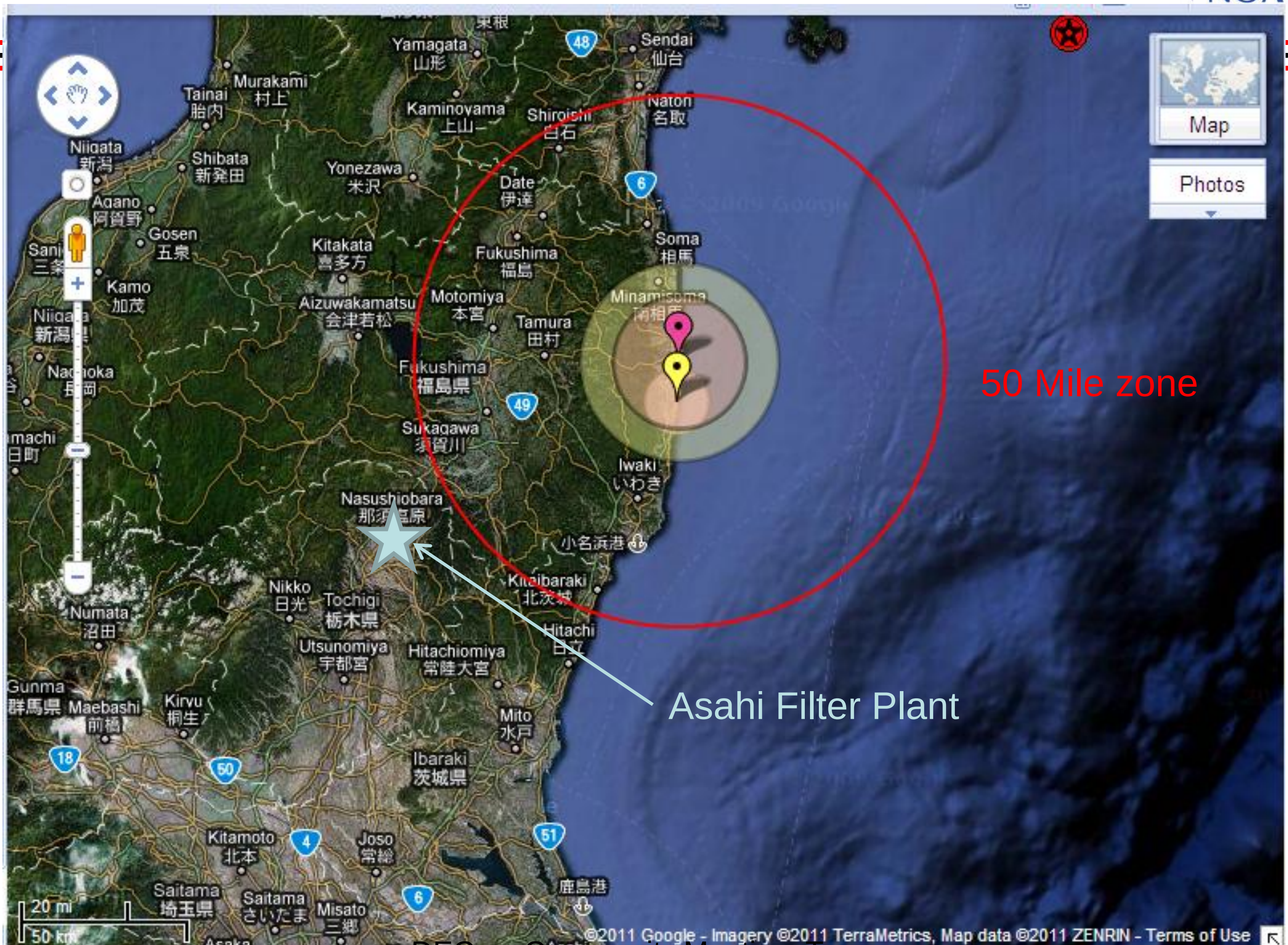
Shutter, Filters

Shutter

- Bonn University made the DECam Shutter
- Opening is ~ 600mm diameter
- The DECam Shutter is the largest astro shutter(so far)

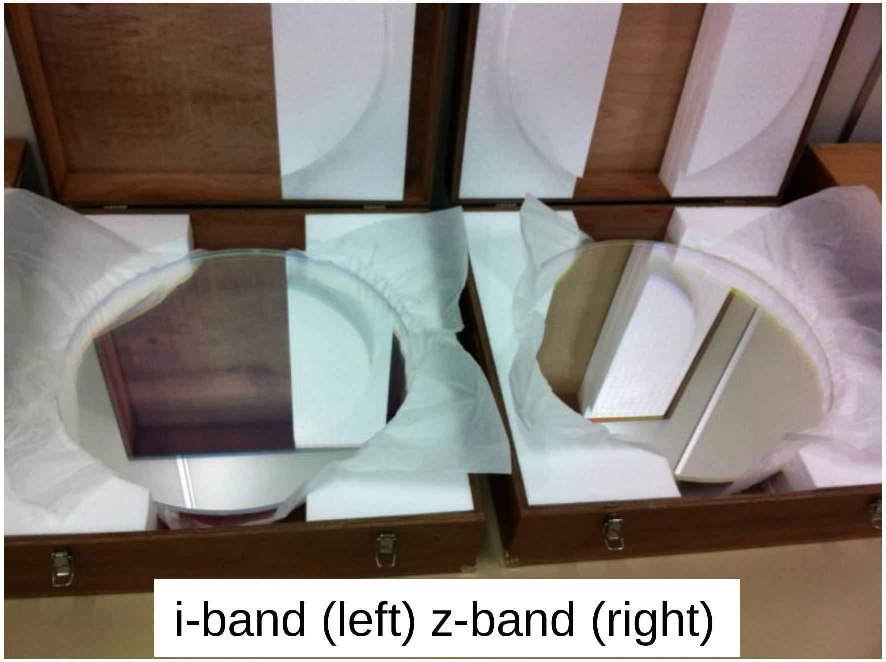
CERRO TOLOLO INTER-AMERICAN OBSERVATORY
NOAO

Filters



Filters

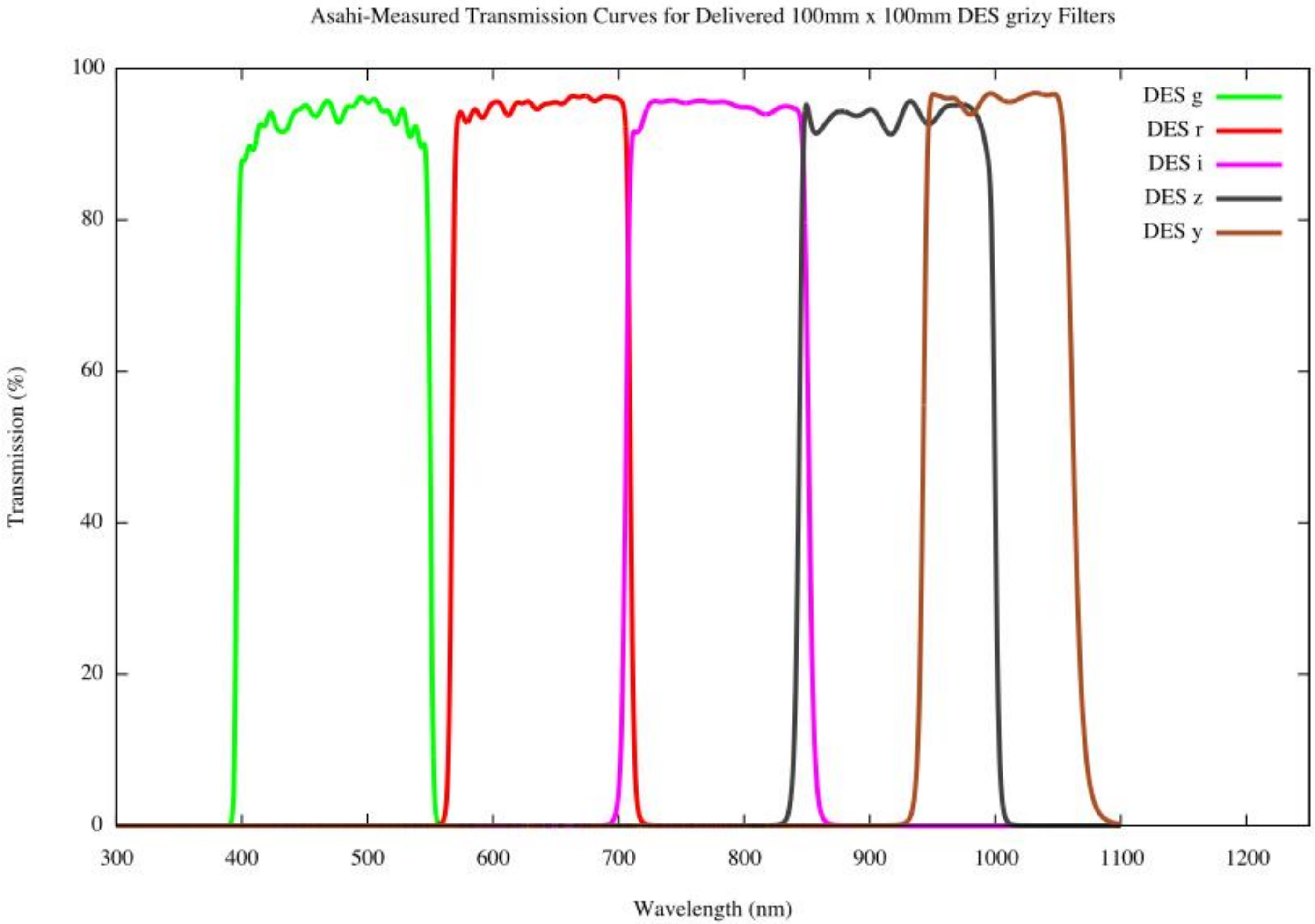
- 620mm substrate, 600mm clear aperture, largest ever!
- Asahi built and commissioned a huge coating chamber as well as custom cleaning, polishing and testing equip.
- Struggled to get repeatable results, by Feb 2011, 3 sides of 3 filters complete
- May 2011: Chamber modifications to reduce outgassing (Installed just before the earthquake!) made a huge difference*: i, z, y and r filters are complete and delivered*
- Now working on *g*



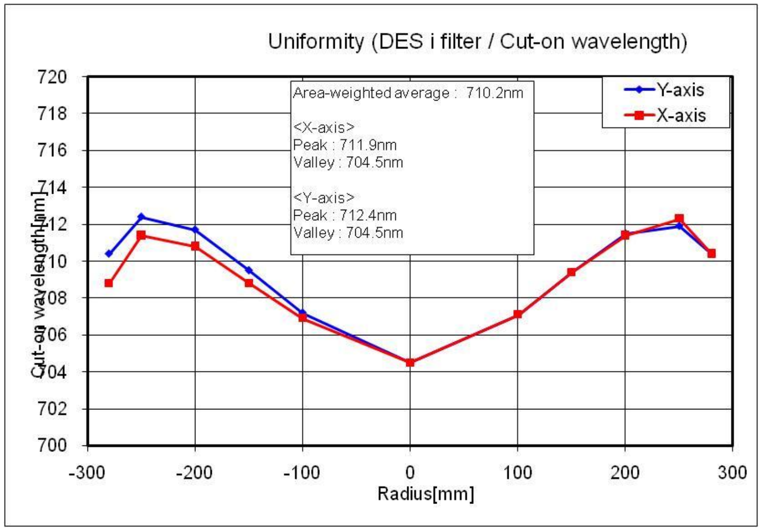
i-band (left) z-band (right)

Guard posted to watch DECam filters

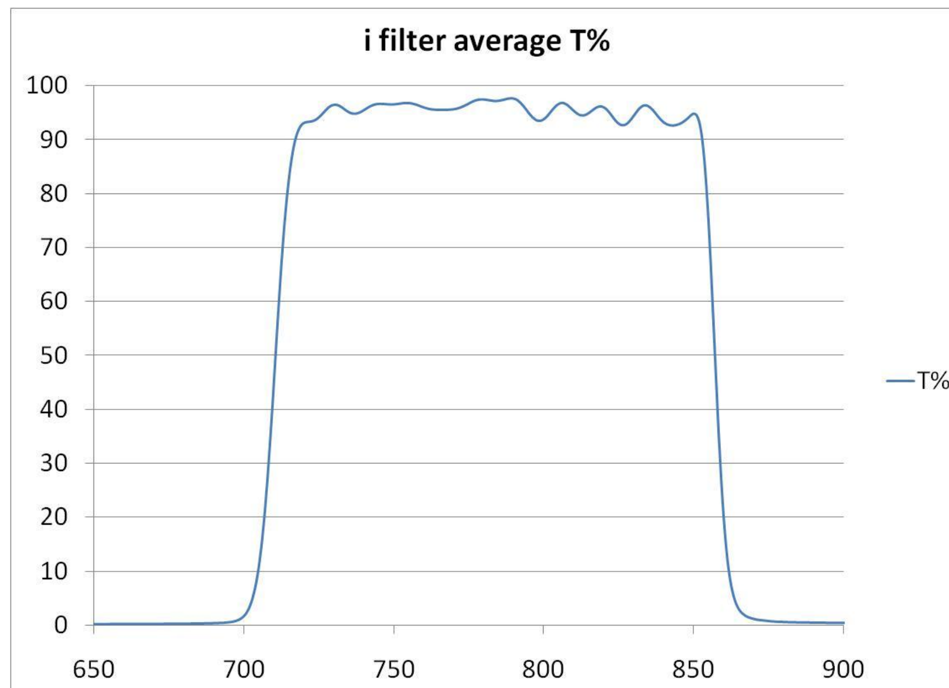
Passbands

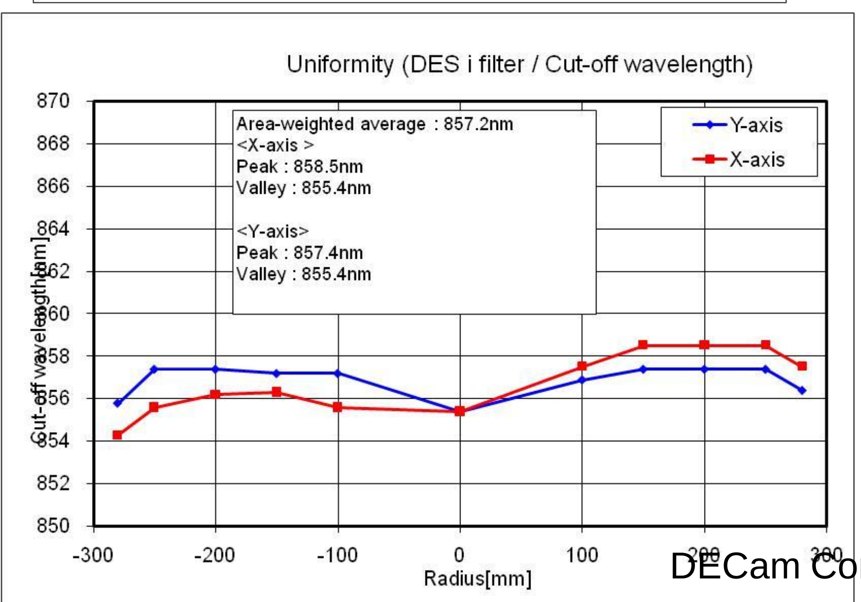

Asahi-Measured Transmission Curves for Delivered 100mm x 100mm DES grizy Filters
Transmission (%)
Wavelength (nm)
0
20
40
60
80
100
300
400
500
600
700
800
900
1000
1100
1200
DES g
DES r
DES i
DES z
DES y

i filter uniformity



Specs	Measured
• +-3nm cut-on	• +-4nm cut-on
• +-4nm cut-off	• +-3nm cut-off
• > 85% trans	• ~ 96% trans!!

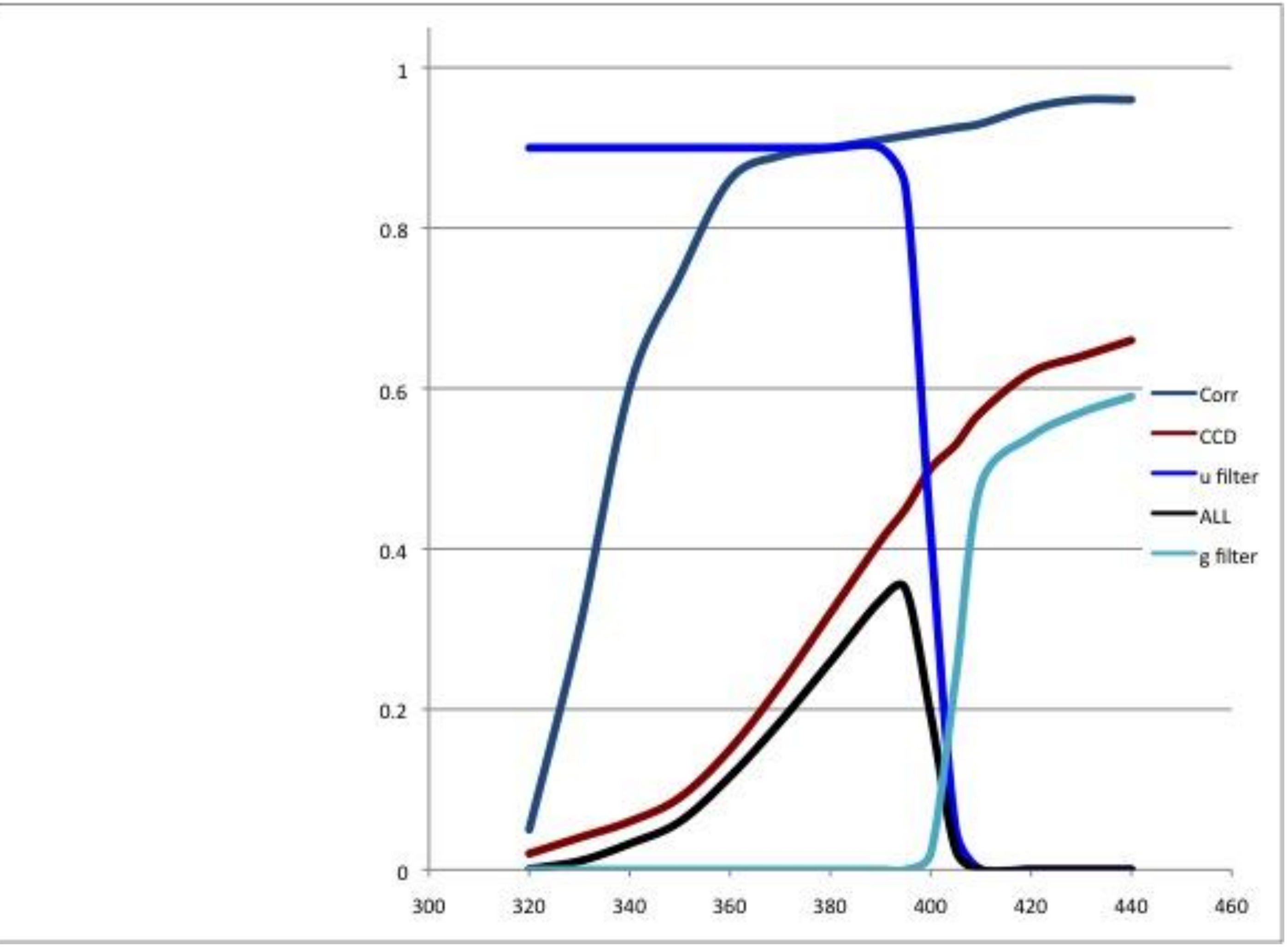




More filters

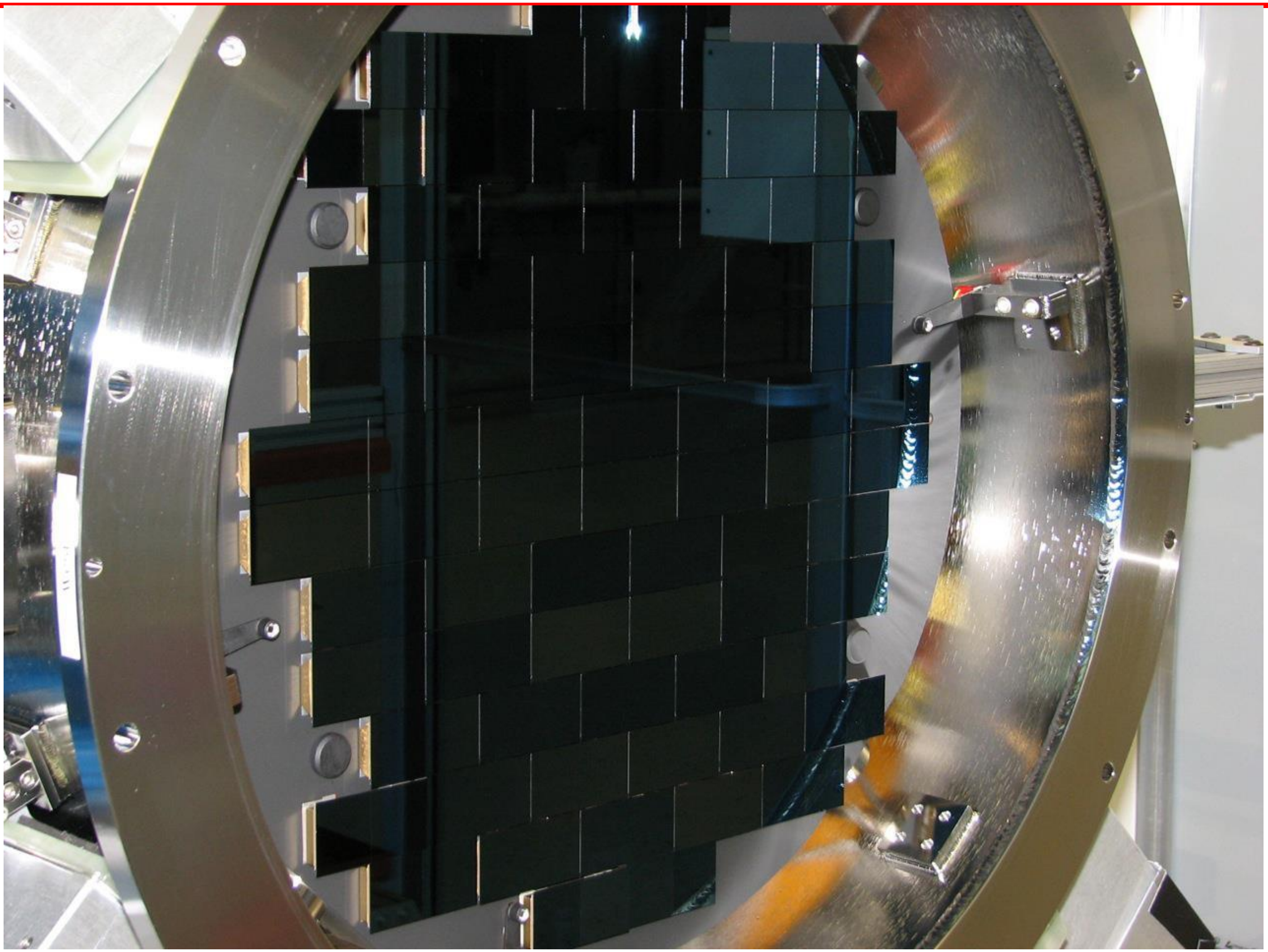
- Community input, expert committee recommendations gave a list
  - SDSS u ------ merely hard to make
  - Johnson B,V ------ cannot match passbands
  - Washington C ------ merely hard to make
  - Narrow band ------ beyond SOTA, + field issues
  - Very broad-band e.g. V+R ------ OK beyond ~ 600 nm
- First priority: SDSS u.
- Asahi have agreed to do a test-of-concept after completing DECam g and HSC g,z,Y (December +)
- We would then be in the construction queue following the Korean (KZT) filters

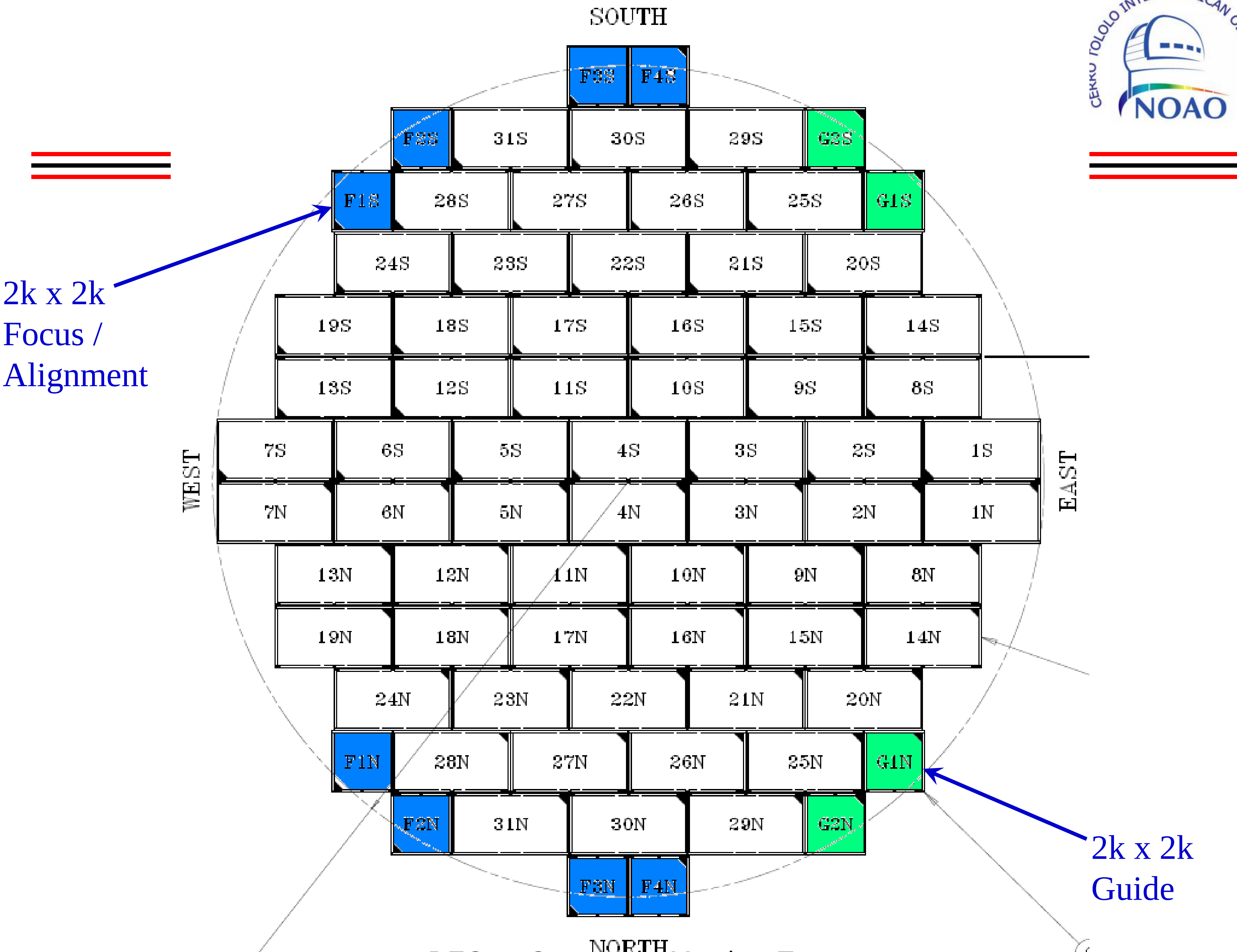
Is there any u response?



CCDs

The science-grade CCDs installed…




SOUTH
F3S
F4S
F2S
31S
30S
29S
G2S
F1S
28S
27S
26S
25S
G1S
24S
23S
22S
21S
20S
19S
18S
17S
16S
15S
14S
13S
12S
11S
10S
9S
8S
7S
6S
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4S
3S
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13N
12N
11N
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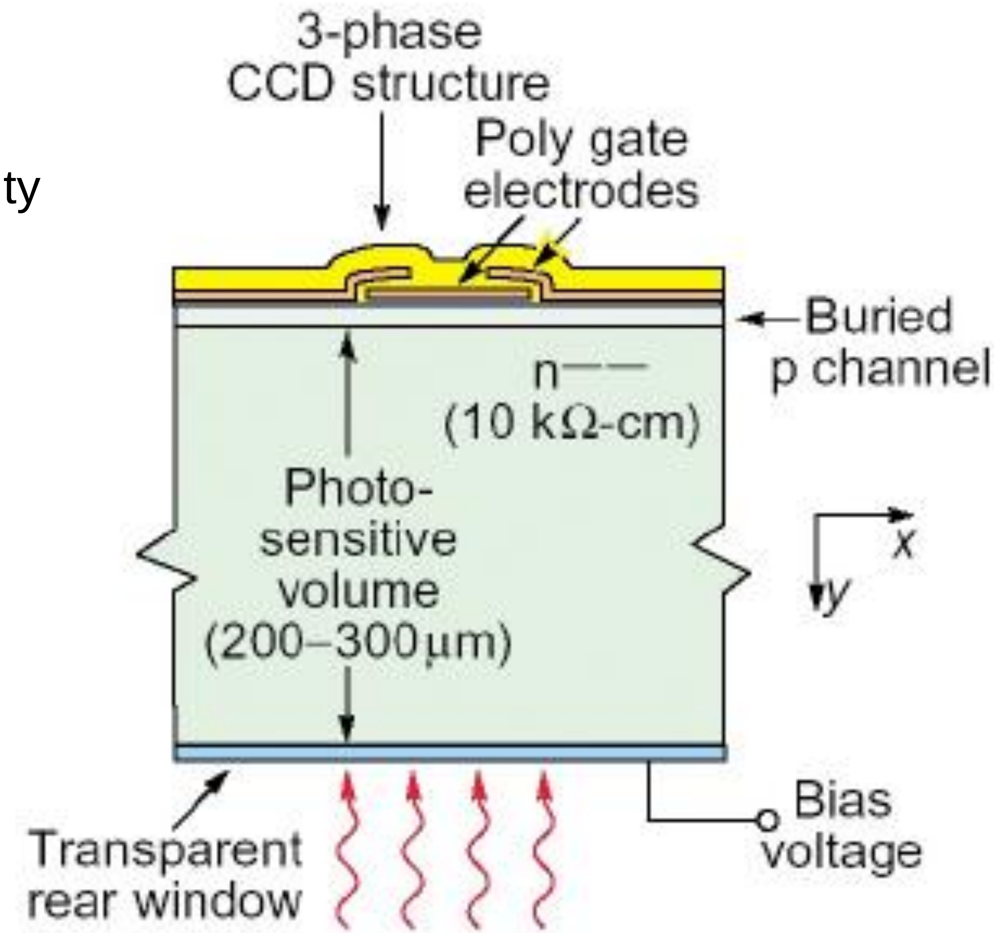
16N
15N
14N
24N
23N
22N
21N
20N
F1N
28N
27N
26N
25N
G1N
F2N
31N
30N
29N
G2N
F3N
F4N
NORTH
WEST
EAST
2k x 2k
Focus /
Alignment
2k x 2k
Guide

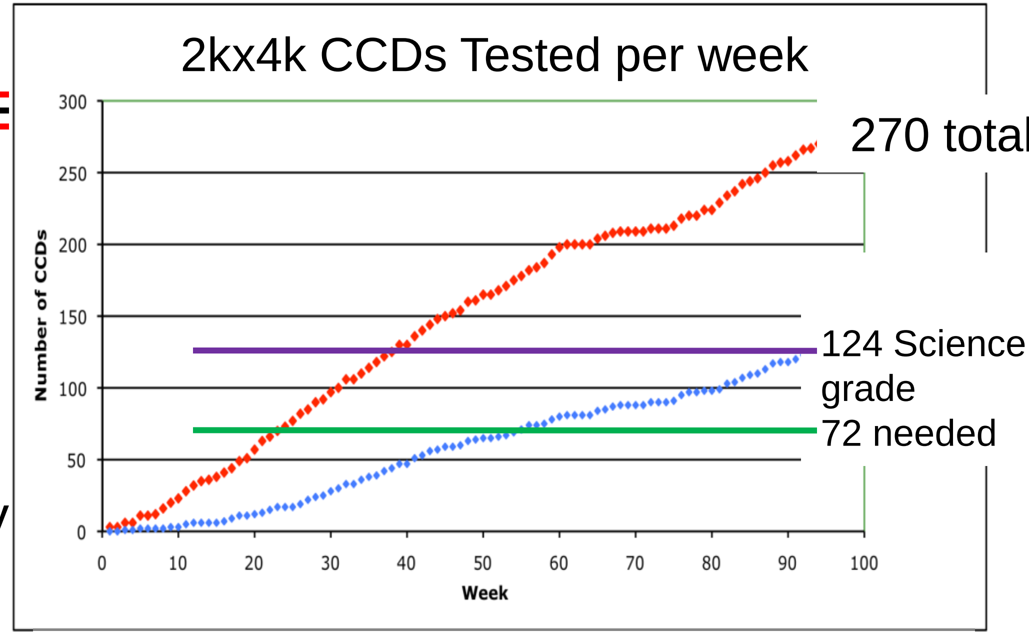
DECam CCD structure

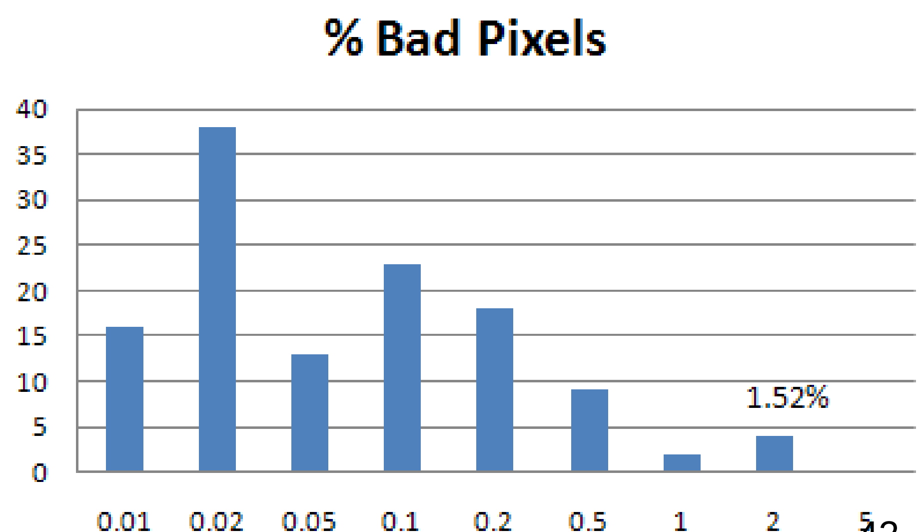
- 4-side buttable
- High Red sensitivity
- Almost no fringing



CCD Production is complete

- Packaging and testing started Nov. 2008, finished Oct. 2010
  - 270 2kx4k CCDs packaged and tested
  - 124 are Science Grade ready for the focal plane
  - 62 + 10 spares are required
  - 26 science grade 2kx2k (need 12 plus spares, for guide and focus)
  - Mean #bad pix = 0.12%

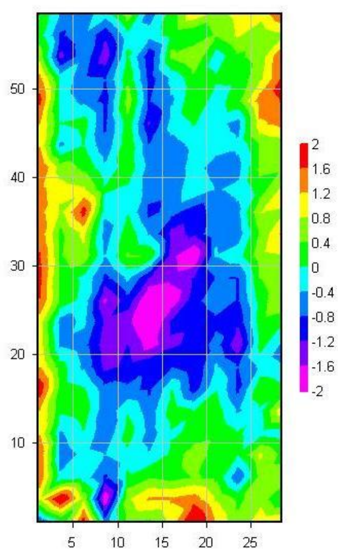




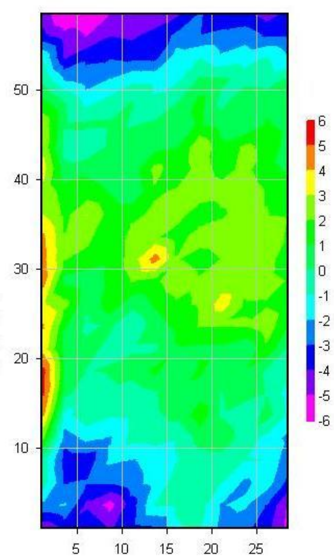
CCD Package Flatness

- The CCD package is flat so that whole surface is in focus at the same time.
- Specs. Control overall shape & “bumpiness”.
- Scan 7200 points at room and operating temperature (T = 173 K).

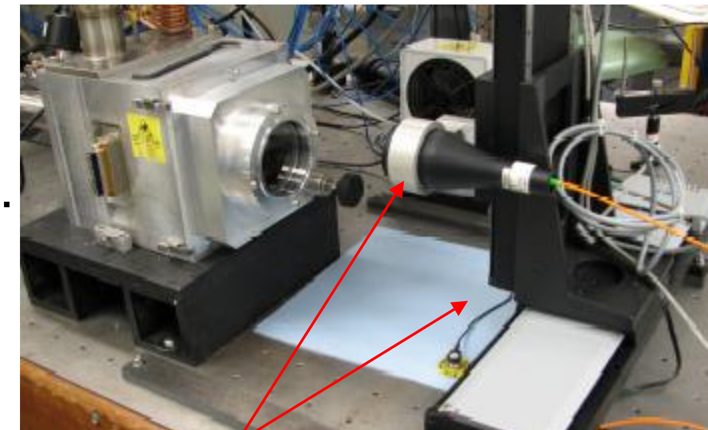
CCD is ~31mm x 62 mm



T=293K
Full Scale is
-2 +2 μm



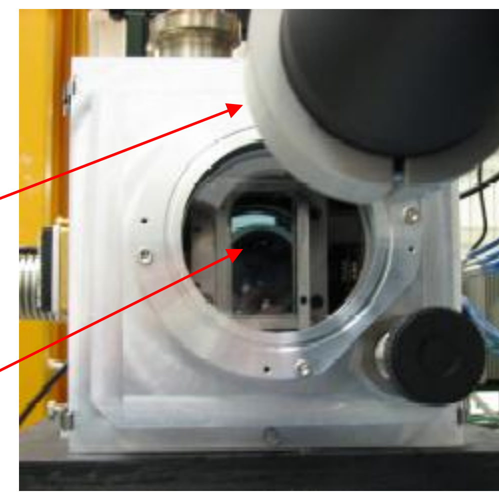
T=173K
Full Scale is
-6 +6 μm



X and Y precision stages (+- 1 μm)

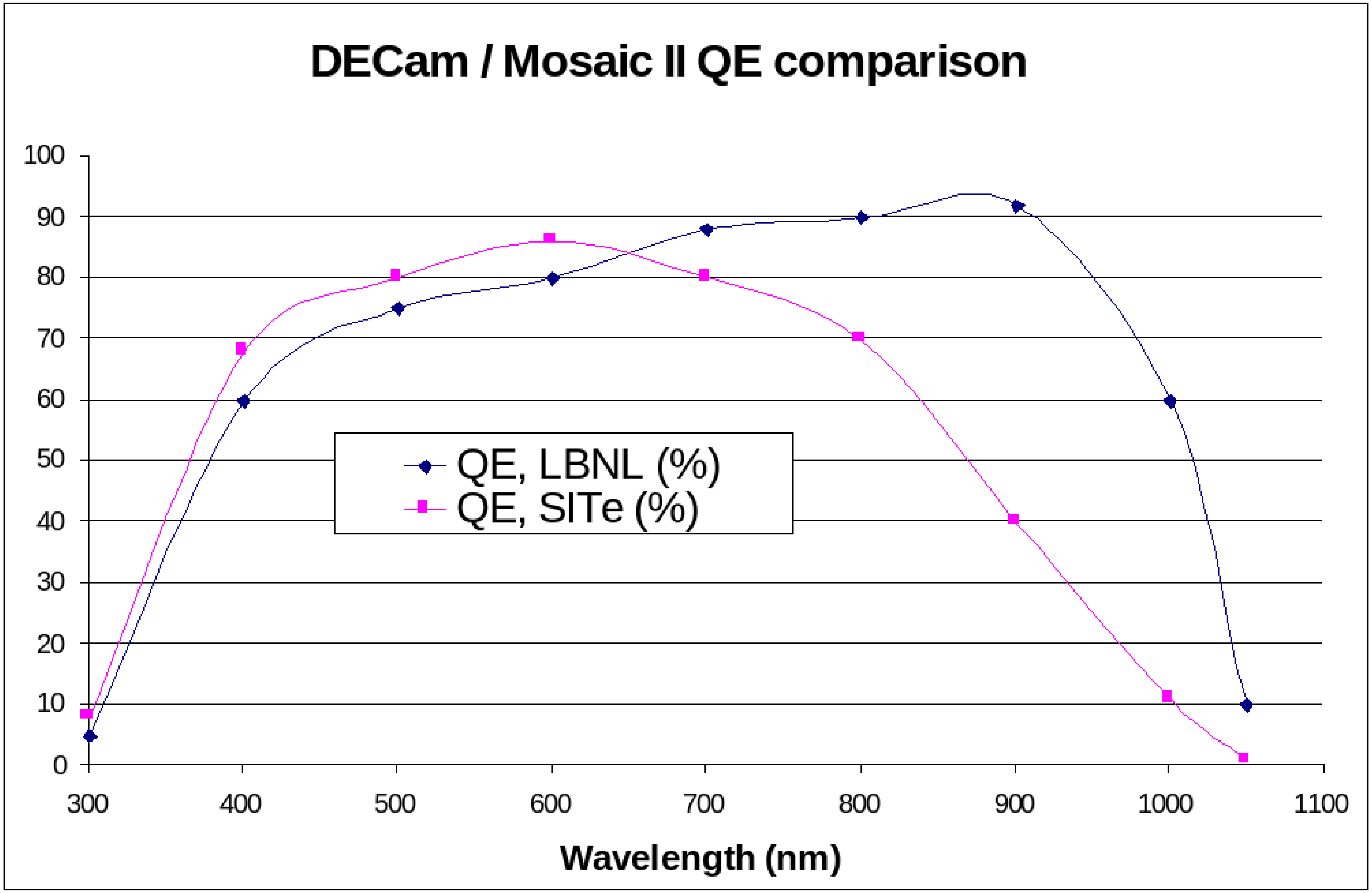
Micro-Epsilon confocal imager

CCD



Micro-Epsilon Opto-NCDT 2400

Quantum Efficiency



QE Uniformity

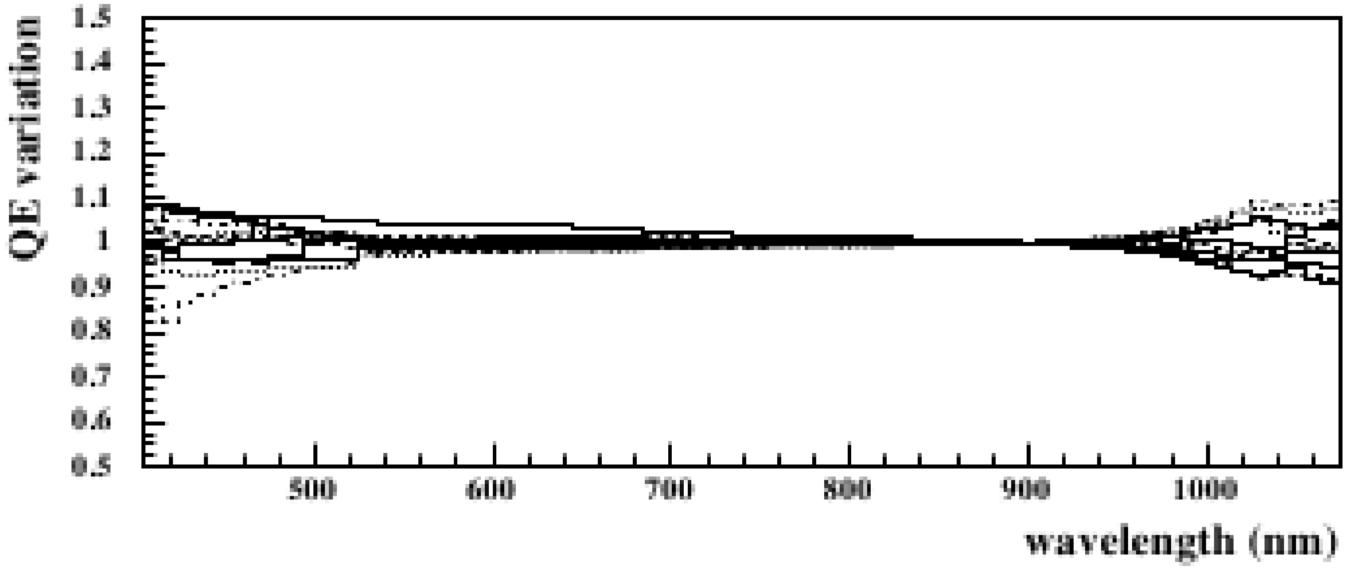
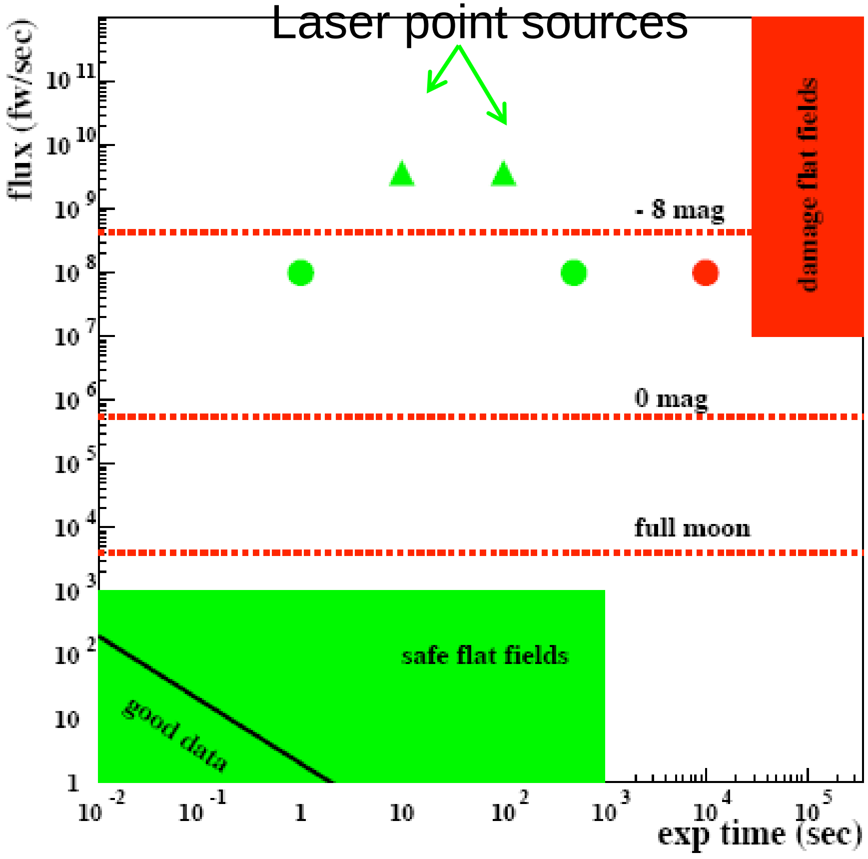


Figure 6. Quantum efficiency relative variations observed in a group of 12 representative DECam CCDs.

Extensive testing at Fermilab uncovered an unappreciated risk to the CCDs

- Full Well of CCDs can be reduced by extreme exposures to light while CCDs are biased
  - Reduced from ~ 200ke to ~ 130 ke
- Discovered in 2009
  - First thought it was due to power spikes, or uncontrolled clock voltages at power on/off
- In 2010 discovered large flat light sources could cause this damage
  - CCD voltages not always off when we took the cover off !
- March 2011 – Workshop with external CCD experts
  - Confirmed flux light over the whole detector for long periods of time is the source of the damage



Photodiode interlock installed in imager will kill power if excessive light is detected

Software

- Klaus Honscheid talk this afternoon

Calibration (DECal)

- Talk by Darren DePoy in a few minutes
- There will be a new flat field screen, which is close to Lambertian in its behavior, even in the u band.
- The spectral response, pixel by pixel, will be accurately measured on a regular basis using a scanning spectrophotometric system.

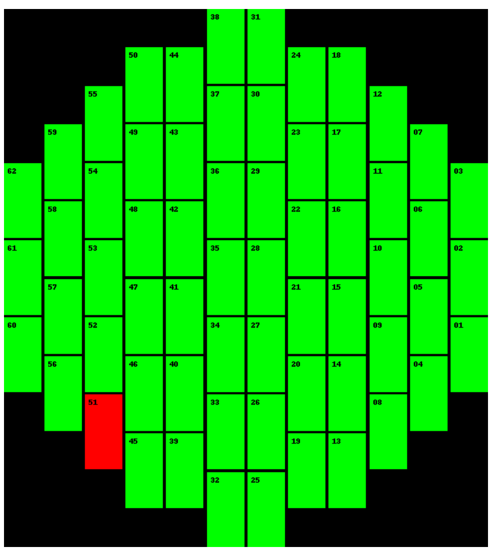
The Data

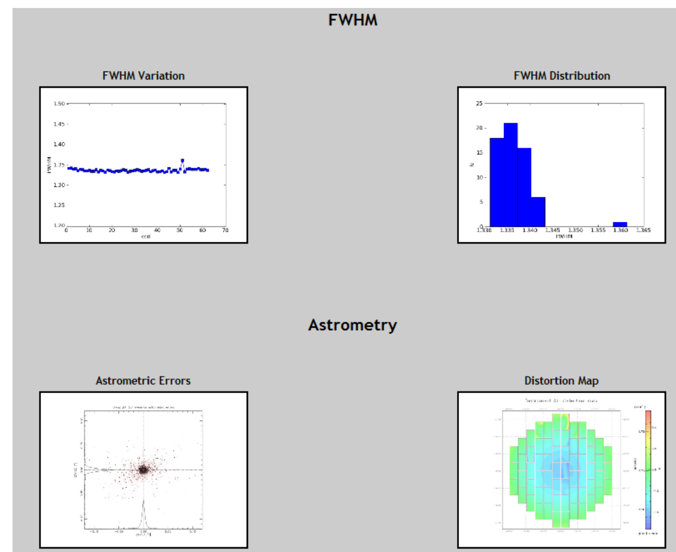
- DECam data will be hosted and served from the NOAO Science Archive. It gets there via the Data Transfer System (DTS). 1 Gb/s shared line from La Serena to US.
- There will be a reduction “community” pipeline (CP)
- The CP is being developed at NCSA in a collaboration with the SDM group at NOAO. It will run at NOAO. *Talk by Frank Valdes.*

- How does one deal with 1 GB raw images?
  - Linux box $3,500: 2 processor 12 core machine with 24 GB memory, 2 x 1 TB disk, fast video card etc
  - DS9 loads full raw image in 10 seconds
  - Need 64 bit IRAF
  - We went from 400x400 to 4096x4096 in 6 years Factor 100. Then another factor 4 in 2 years. Don’t panic!!! Disks are cheap.

Quick Reduce (DES Brazil)

- Process a sample of DECam images with astronomy codes (similar to DM quality)
- Sampling rate depends on available processing power, average exposure time etc.
- Initial setup includes 2 multi-core machines at CTIO. Installation (almost) complete
- Web based user interface: sample screen shots





Mosaic vs. DECam

Parameter	Mosaic II	DECam
No. of CCDs	8	62 + 12(F&A, guiding)
CCD Format	2Kx4K, 15μ pixels	2Kx4K, 15μ pixels
CCD Type	Standard, BBAR	Depleted, red optimized
Full well	60K	130K
Image size	128 MB	1040 MB
RON	6-12 e- rms	15 e- rms
Read time	100s	17s
Overheads	10s	3s
Guiding	separate	Focal plane
Filters	many	g r i z Y
ADC	yes	no

Efficiency Comparison

- Shallow Survey in the red (e.g. DES, 80s exposures): DECam covers area 30 times faster than Mosaic *(area, QE, readtime)*

- Deep exposures on a "small" target (i.e. globular cluster, 12 x 300s blue + 30 x 150s red). This is a 4 hour program on Mosaic, 2 hours on DECam *(QE, readtime)*

- Standard stars. It is almost as quick to put the central stars of SA98 on 62 DECam CCDs one after the other as it is to put it on the 8 CCDs of Mosaic. *(readtime)*

- Standard stars. Five ~few second exposures takes 2 minutes rather than 12 minutes. *(readtime)*

Telescope & Facility Improvements

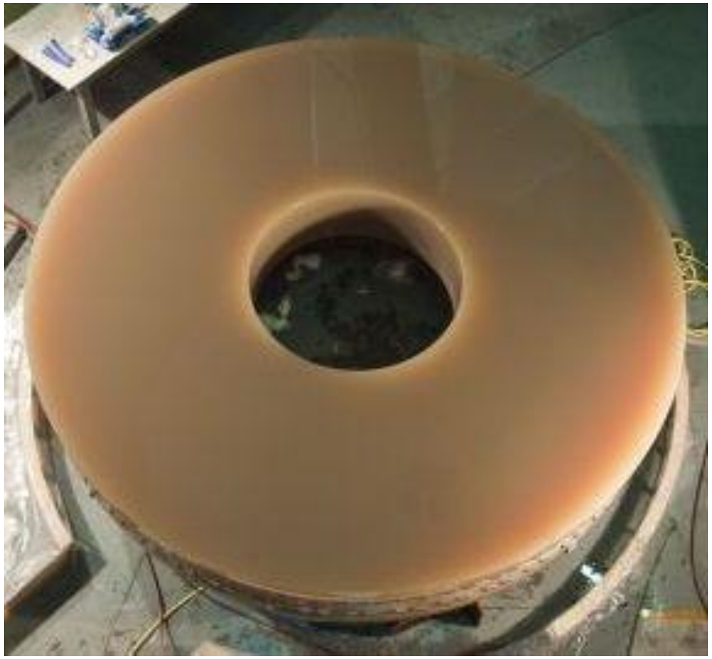
Telescope Improvements

- New telescope control system
  - Tape encoders
  - Computer hardware and software
  - A development of the SOAR TCS
  - 2 degree track to track offset < 17 seconds
  - Improved tracking performance

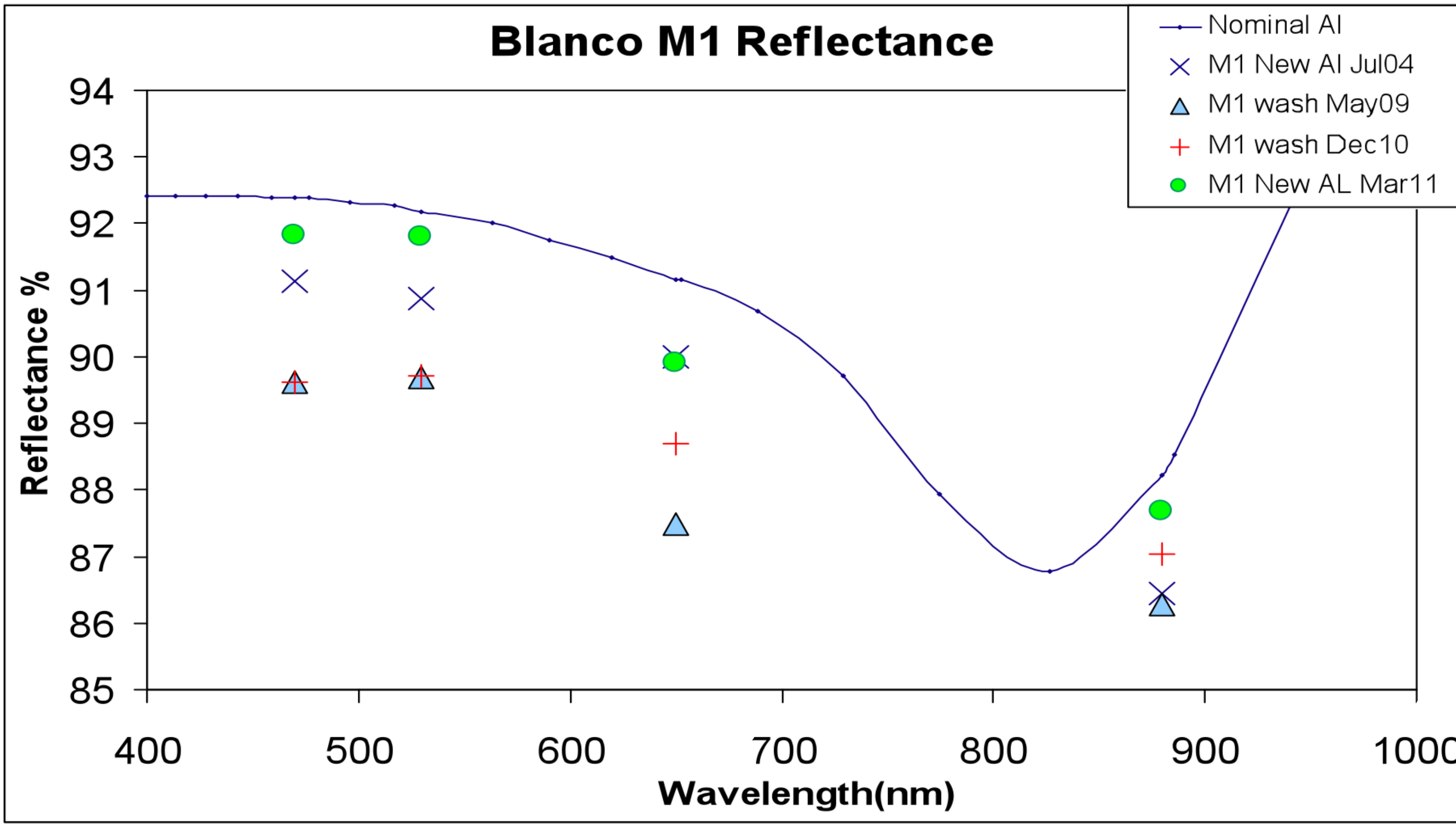
- Improved telescope environment
  - Re-install primary air extraction/cooling system
  - New control software
  - Note - DECam itself beings improvements

Status – Facility Improvements

- Blanco primary radial supports
  - No breakages after 2 years!
- Primary mirror successfully realuminzed



Re-Aluminization of M1



Computer room upgrade: BEFORE

Computer room upgrade: AFTER!!

Console room upgrade: BEFORE

Console room upgrade: AFTER!!

Blanco Improvements

- Instrument Maintenance Facility (ex Coudé room) on telescope Main Floor
- Contains a Clean Room

The End

Use at the Telescope

- Observing Console
  - Usual controls supporting different observing modes
  - Basic instrument and data systems health monitors
- Quick Look Display
  - Showing data as it comes in
- Quick Reduce Pipeline
  - Provide quick-look reductions of data to varying degrees
  - User-definable reduction level, depending on data rates

Post-observing Support

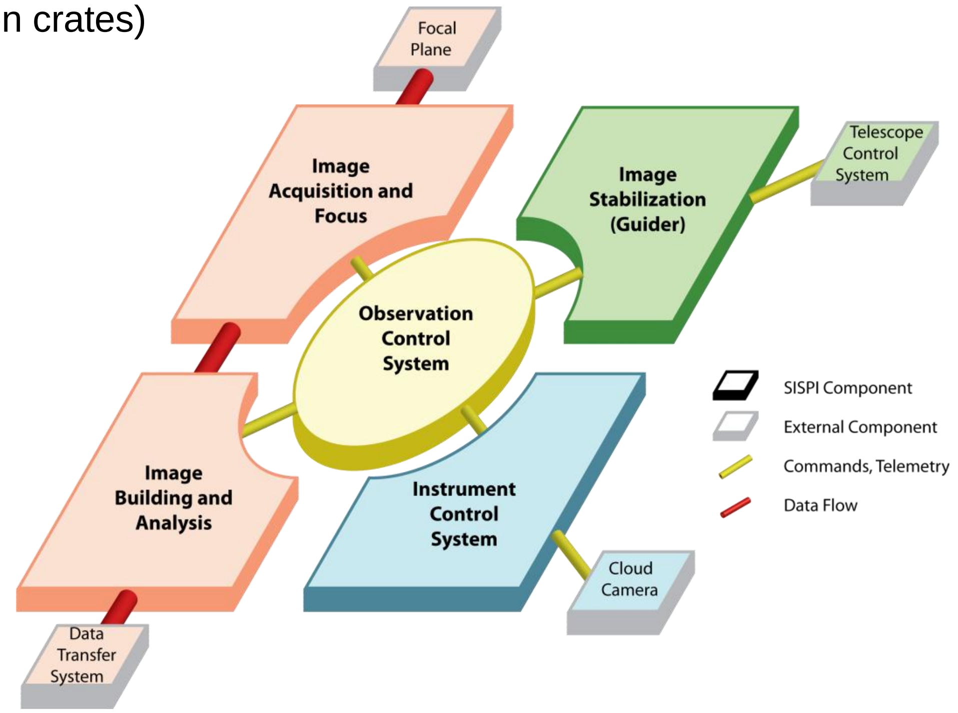
- Raw data available through NOAO Science Archive
  - Standard proprietary period
- Data automatically processed by “Community Pipeline”
  - made available to PI through the NOAO Science Archive
- Community Pipeline…
  - Removes instrumental signatures
  - Provides astrometric solution
  - Provides rough photometric solution
  - Provides basic image stacking (support for dither sequences)

  Roughly same services as current MOSAIC pipeline

SISPI Overview

SISPI is the DECam data acquisition and control system

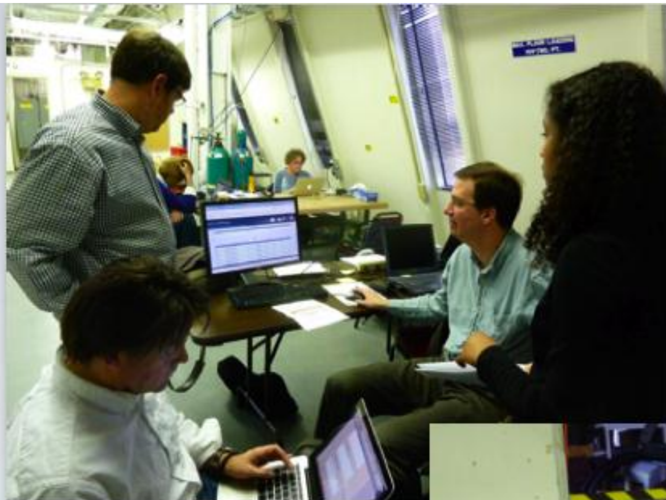
- Data Flow
  - Image acquisition (Panview, 6 Monsoon crates)
  - Image Builder (multiple instances)
    - FITS formatting
    - Image Health
    - Compression (tile/rice)
  - Submit to NOAO DTS
  - > 50,000 test images
- Observation Control
  - OCS (pipelined architecture)
  - obstac
- Instrument Control
  - Internal (Shutter, Hexapod, Filter)
  - External (Cooling, Temperatures, ICC)
- Guider & Focus
- Interfaces to TCS and Cloud Camera



The Observing Environment

- The User Interface is web-based. The top-level observer's GUI's are being developed
- Scripting (chaining together of observations) will be possible
- Instrument Health, Image Health for every image
- Quality Assurance automatically run on a subset of images
- The incoming images will be Tee'd off to an observer's machine with lots of disk space and memory, for interaction.

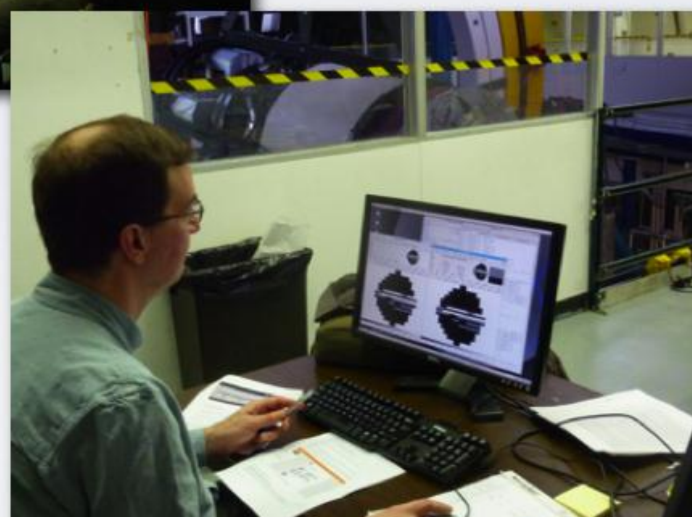
4 night 'observation' was performed at FNAL with simulated stars.



4 **mock nights** on Feb. 14-18
8 **observers** (2 per night)
10 **experts** providing support
400 **images** taken

valuable **feedback** from observers

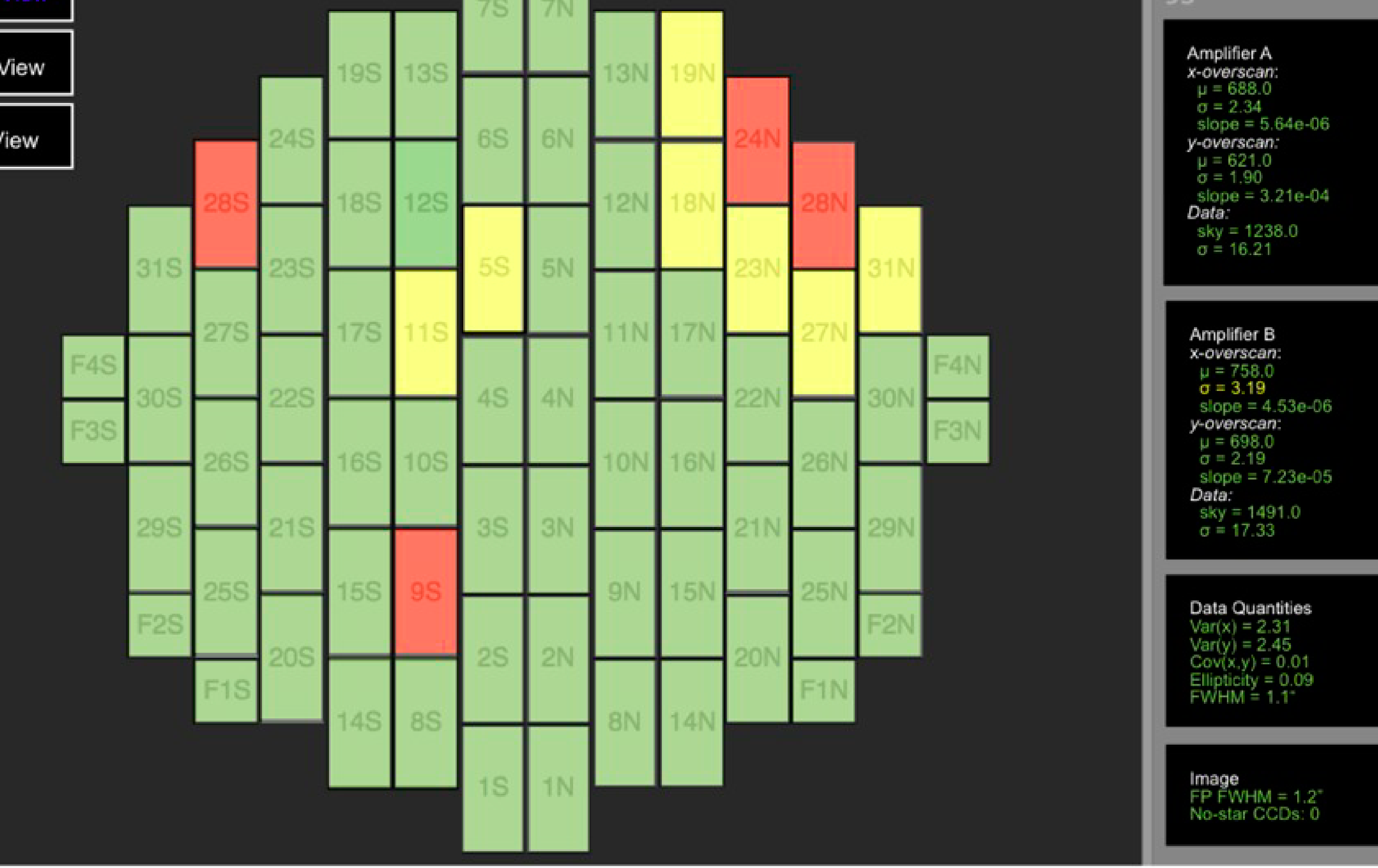
improvements implemented **in real time**



main survey and **supernova** modes exercised

auto-pilot software tested

Credit : M.Soares-Santos


View
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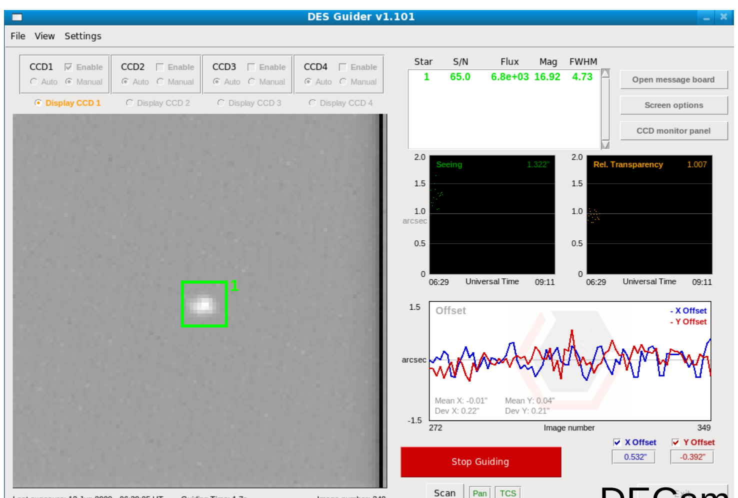
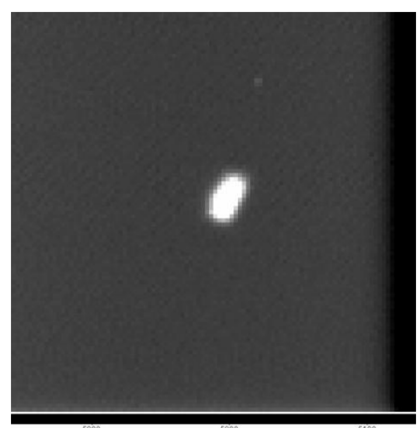
F2S
F2N
20S
2S
2N
20N
F1S
F1N
14S
8S
8N
14N
1S
1N
Amplifier A
x-overscan:
μ = 688.0
σ = 2.34
slope = 5.64e-06
y-overscan:
μ = 621.0
σ = 1.90
slope = 3.21e-04
Data:
sky = 1238.0
σ = 16.21
Amplifier B
x-overscan:
μ = 758.0
σ = 3.19
slope = 4.53e-06
y-overscan:
μ = 698.0
σ = 2.19
slope = 7.23e-05
Data:
sky = 1491.0
σ = 17.33
Data Quantities
Var(x) = 2.31
Var(y) = 2.45
Cov(x,y) = 0.01
Ellipticity = 0.09
FWHM = 1.1"
Image
FP FWHM = 1.2"
No-star CCDs: 0

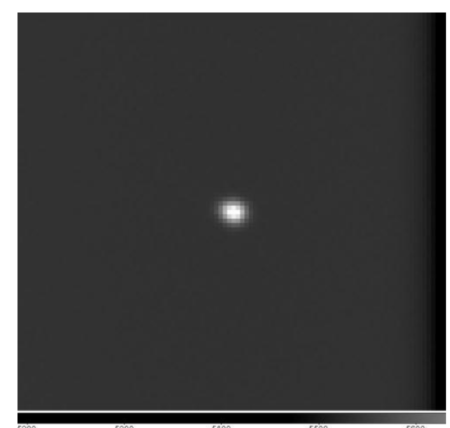
DES Guider Summary / Status

- AutoGuiding algorithm [Tested @ CTIO 1m telescope]
- Region Of Interest mode [Tested @ CTIO 1m telescope]
- Communication with PanVIEW & TCS [Tested @ CTIO 1m telescope]
- 4 CCDs guiding mode [implemented]
- SISPI system code integration [completed for mock observing test]
- GUI standardization [in progress...]





no guide



DES guide