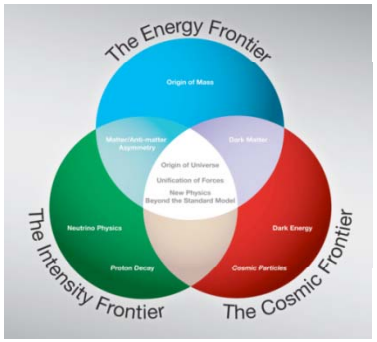
The Dark Energy Survey (DES) & Camera (DECam)

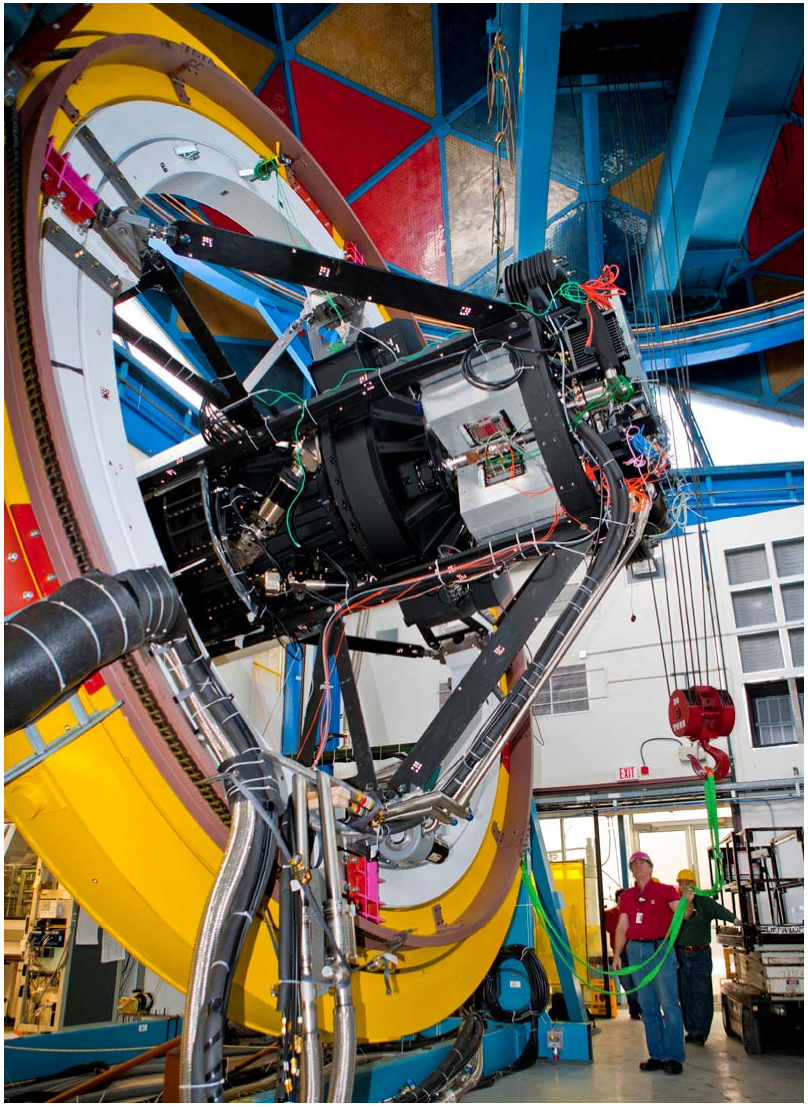
DARK ENERGY SURVEY

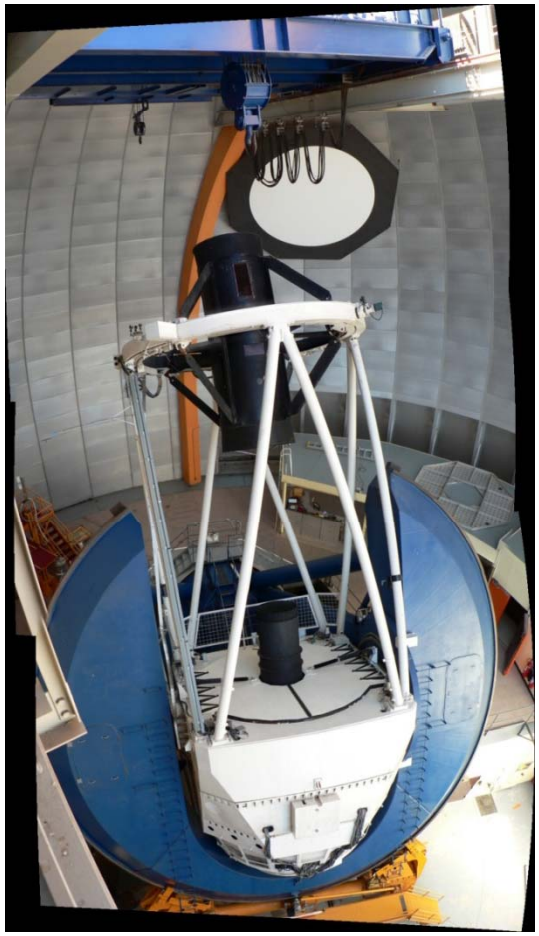


Tom Diehl

Fermi National Accelerator Laboratory

AAS January 2012, Austin TX



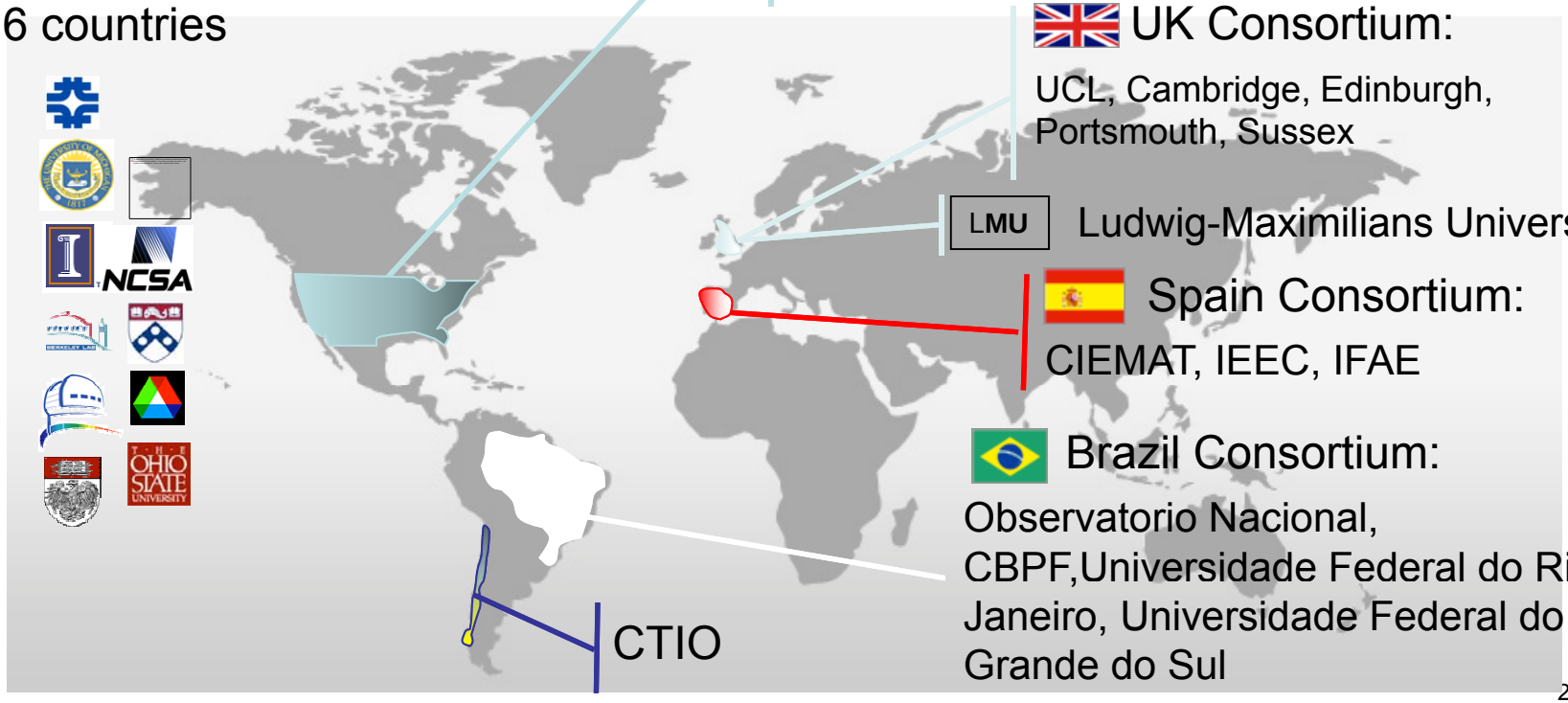


DES Collaboration

DARK ENERGY SURVEY

… is an international collaboration
Of astronomers, astrophysicists, and particle physicists
119+ scientists
12+ institutions
6 countries

Fermilab, UIUC/NCSA, University of Chicago, LBNL, NOAO, University of Michigan, University of Pennsylvania, Argonne National Laboratory, Ohio State University, Santa-Cruz/SLAC Consortium, Texas A&M



UK Consortium:

UCL, Cambridge, Edinburgh, Portsmouth, Sussex

LMU Ludwig-Maximilians Universität

Spain Consortium:

CIEMAT, IEEC, IFAE

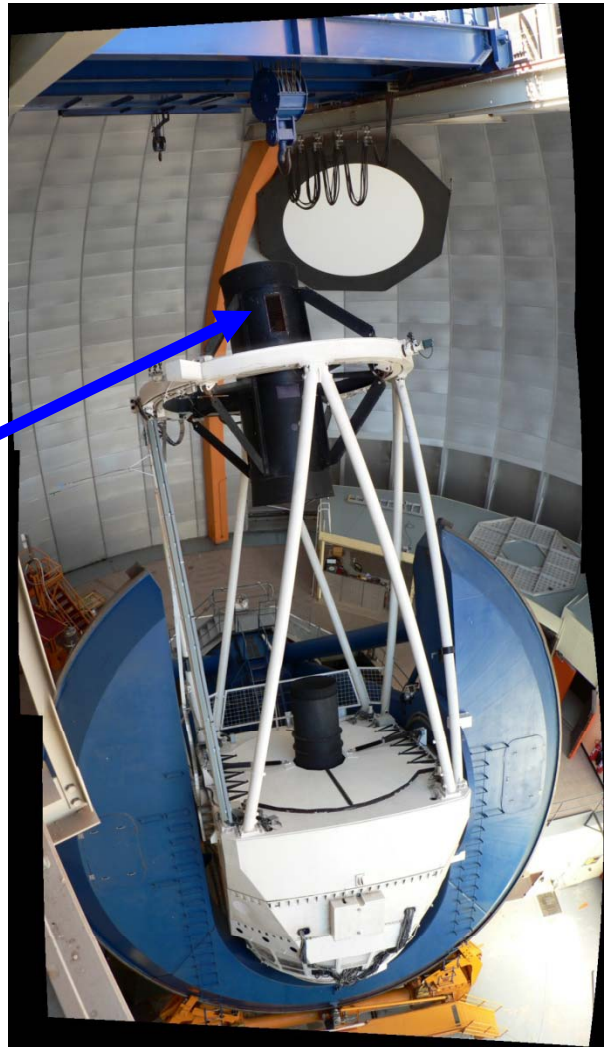
Brazil Consortium:

Observatorio Nacional, CBPF,Universidade Federal do Rio de Janeiro, Universidade Federal do Rio Grande do Sul

The Dark Energy Survey (DES)

DARK ENERGY SURVEY

- The DES Science:
  - Measure dark energy equation of state with 4 complementary techniques BAO, Galaxy Cluster statistics, Weak Gravitational lensing and SN1a.
  - Perform a 5000 sq. deg. survey of the southern galactic cap + 30 sq. deg. SN1A survey
- New Instrument:
  - Replace this PF imager with a new 2.2 FOV, 570 Mega pixel CCD camera + corrector.
- In this talk I describe the status of the camera and outline the testing that we've performed both before and after delivery to CTIO.



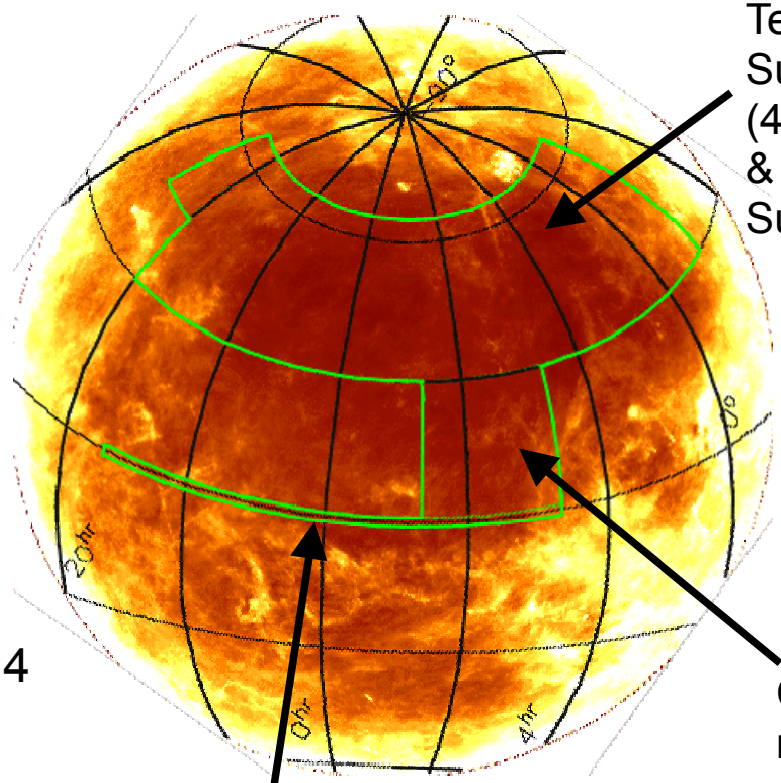
Use the Blanco 4M Telescope at the Cerro-Tololo Inter-American Observatory (CTIO)

Survey Parameters

DARK ENERGY SURVEY

- The Wide-field survey is 5000 sq-deg of the Southern Galactic Cap. The whole sky (4π) has 41253 sq-deg.
  - 300M Galaxies: 10σ *grizY* = 24.6, 24.2, 24.4, 23.8, 21.5
  - 2% photometric precision
  - 0.9” FWHM i-band seeing
- A 30 sq-deg Supernova Survey
  - Imaging during non-photometric conditions or when the “seeing” is poor. Repeat fields at least every 4 nights.
  - Discover ~4000 SN1A $0 < z < 1.2$
- 525 nights from Sept. to Feb. 2012 to 2017.

Survey Footprint
(preliminary)



Overlap with South Pole Telescope Survey (4000 sq deg) & Vista VHS Survey

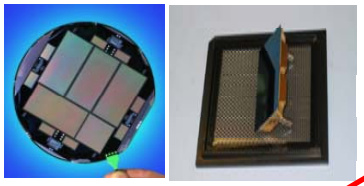
Connector region (800 sq deg)

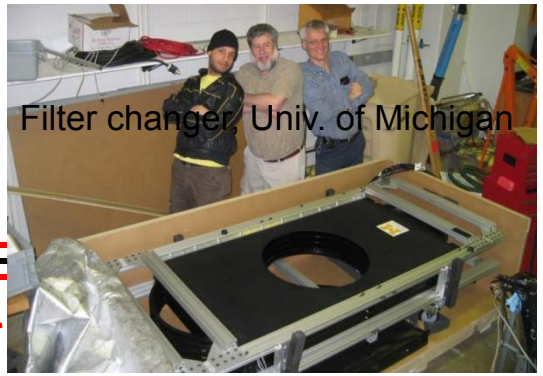
Overlap with SDSS equatorial Stripe 82 for calibration (200 sq deg)

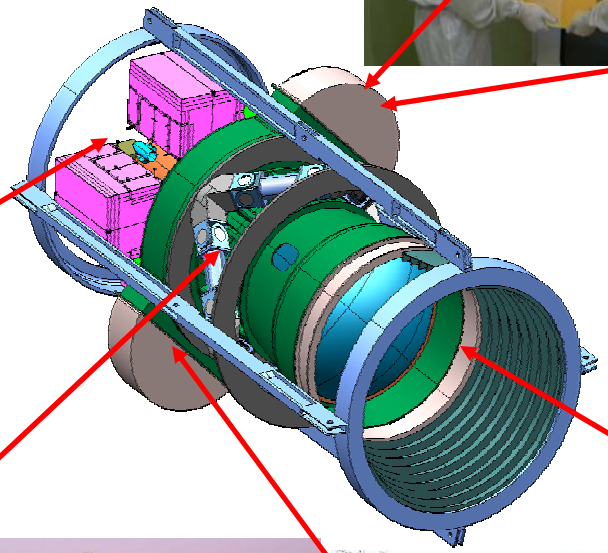
DECam SubSystems

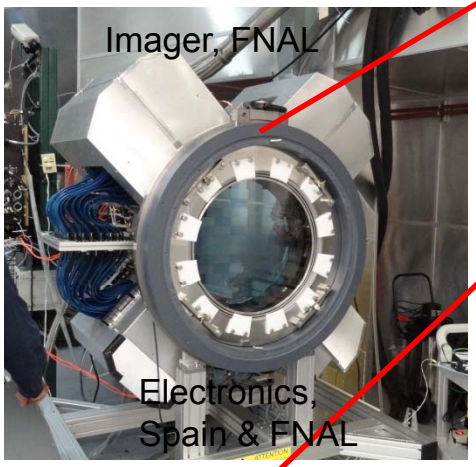
DARK ENERGY SURVEY

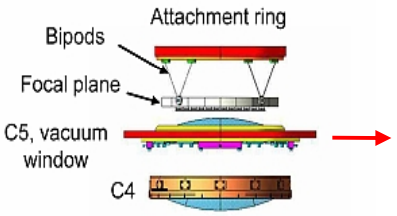
CCDs, wafer from LBNL, packaged and tested at FNAL.



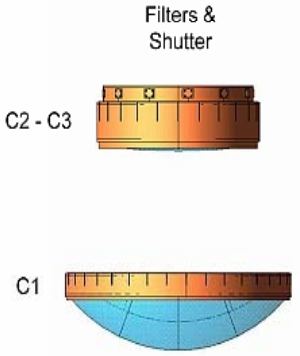








ANL/FNAL

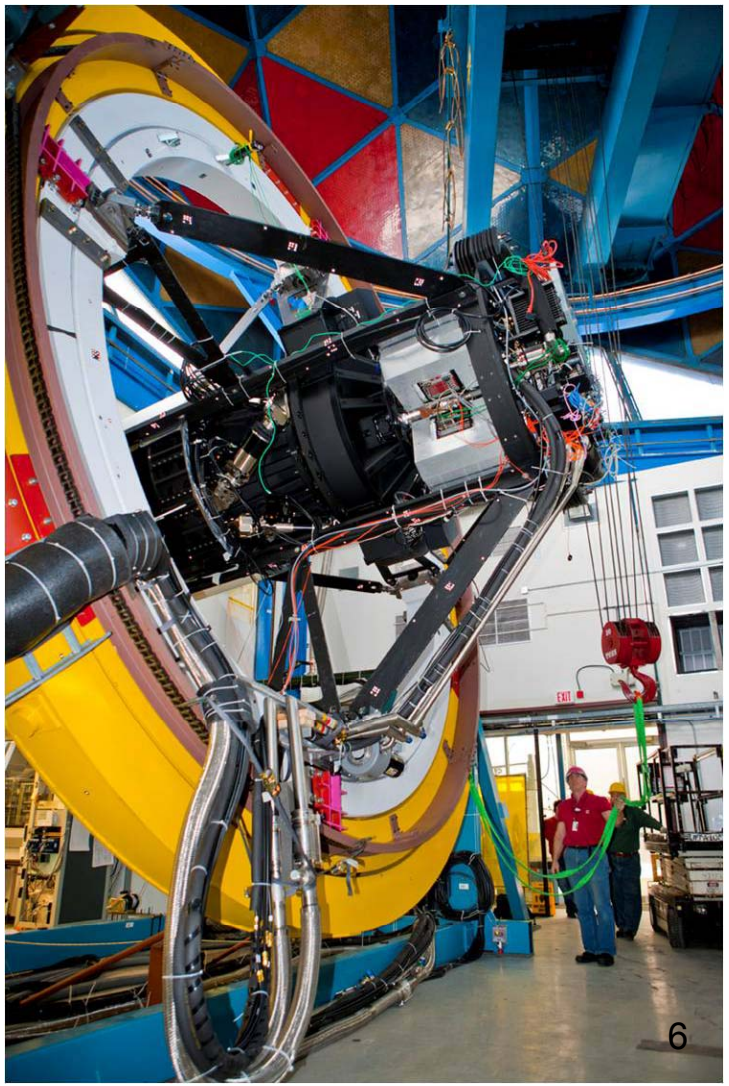


UCL @ UK

Testing DECam @ FNAL on a "Telescope Simulator"

DARK ENERGY SURVEY

- We built a copy of the telescope upper rings (white rings to right) and spider, supported in a "telescope simulator"
- Procedures for installation and removal of the Prime Focus Cage, f/8 (secondary mirror), and camera at CTIO were developed and tested by mid-2010.
- We performed integration and testing of DECam and all it's systems (except optics). Tested the DAQ software "SISPI" in mock observing runs where we read out engineering grade CCDs Shipped all, except imager and optics, to Chile by July 2011.
- Final CCD selection, installation and retesting in the Imager & then shipped to Chile in November 2011.



Testing DECam Optics

DARK ENERGY SURVEY

- Filters are being produced by Asahi Spectra (Japan)
- The r, i ,z, & Y-band filters are finished and have arrived at CTIO.
- The g-band will be finished before end of February 2012.

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

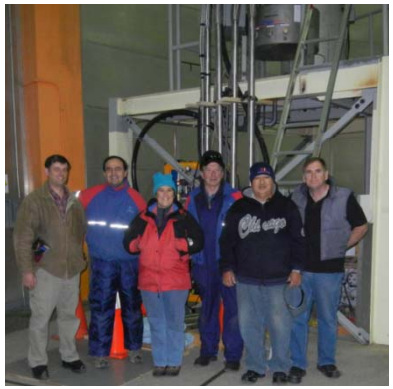
- The 5-element optical corrector is at UCL where the …
- Lenses were installed into cells and the cells into the barrel . The alignment was tested on a rotary table (see photo above). Shipped in December.
- The Corrector and rotary table arrived in Chile 12/16/2011.

Installation and Testing in Chile [1]

in collaboration with the CTIO Staff

DARK ENERGY SURVEY

- CTIO & DECam Infrastructure
  - Rebuilt the control room
  - New f/8 handling system
  - LN2 imager cooling system for operations on/off the telescope
  - RASICAM
  - Installed a new cleanroom in the Coude Room for Newfirm and DECam
  - Prime Focus Cage Ass'y practice
  - Numerous infrastructure additions and upgrades.



Installation and Testing in Chile [2]

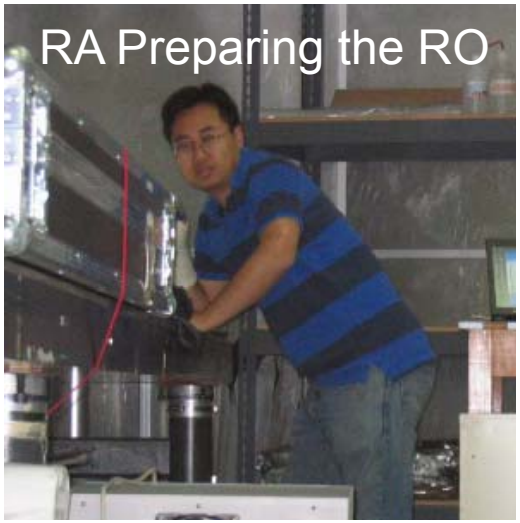
in collaboration with the CTIO Staff

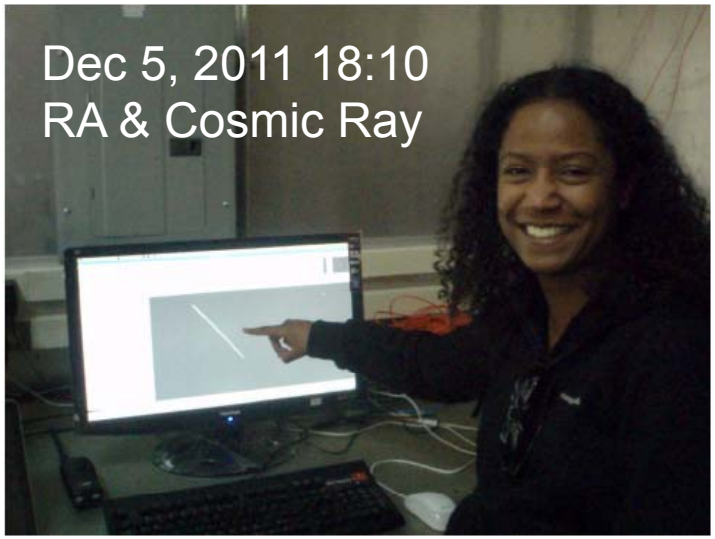
DARK ENERGY SURVEY

- We retested all sub-systems in Chile in July to Dec.
  - Ensure they are all still working
  - Familiarize the CTIO staff with the equipment operation
  - Improve documentation and procedures (as necessary)
- The Imager was unpacked in December and is at present being operated at in the Coude Room (Main floor) of the telescope.
- Optics internal alignment is being retested right now.

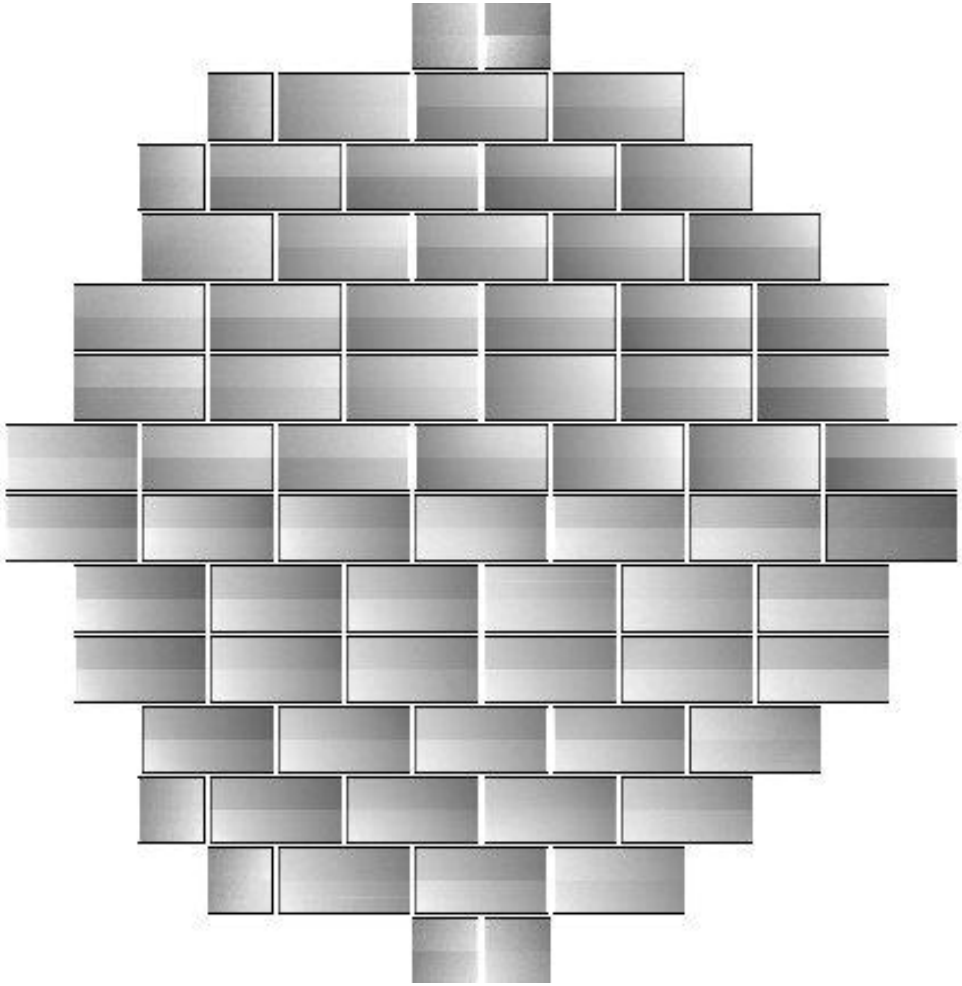
Imager Cooled Down & Reading Out!

DARK ENERGY SURVEY





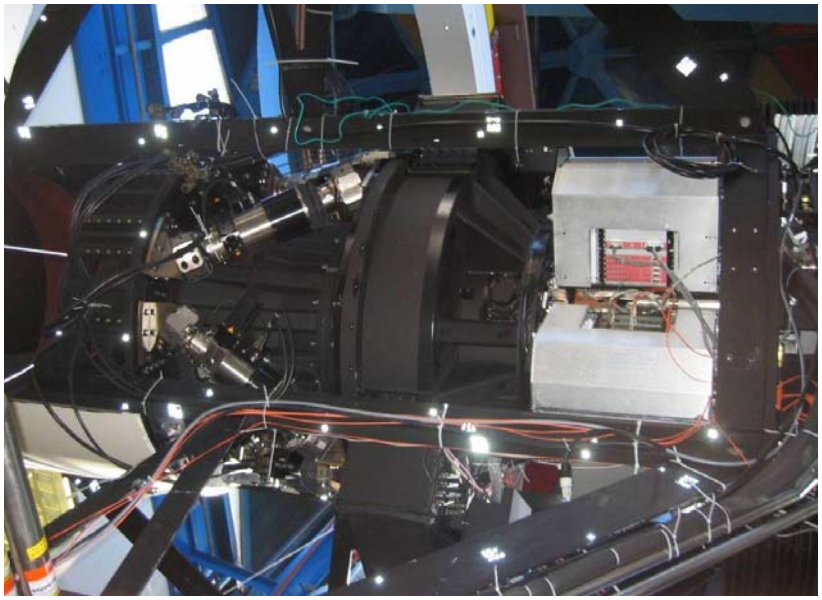
Dec. 6: Beautiful flat field Image verified that the CCDs remain functional after shipping.



Summary & Plan Outline

DARK ENERGY SURVEY

- DECam is in Chile. Testing shows “all systems are go”.
- CTIO will take the telescope out of service in February.
- The New Prime Focus Cage and all DECam components (except imager) will be installed
- New f/8 alignment and controls commissioning interleaved with imager installation.
- DECam will see 1st light in June.
- External user “Science Verification” period
- The Dark Energy Survey will start its 5-yr run in September.
- Thank-you to CTIO Staff from DES



DARK ENERGY
SURVEY

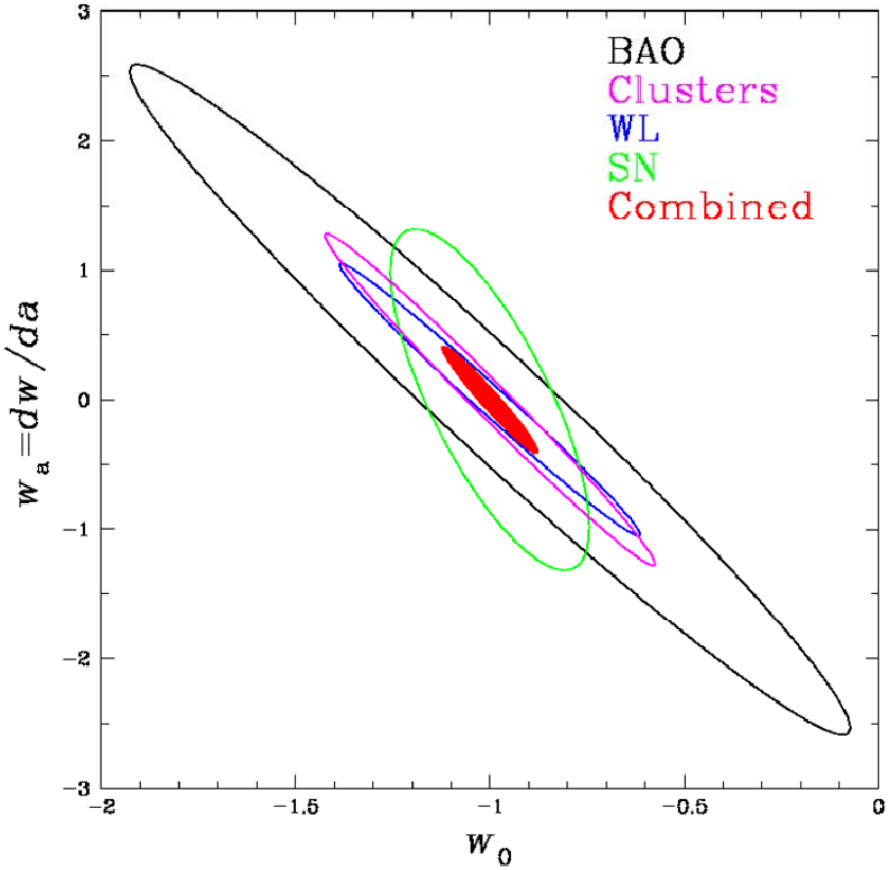
Extra Slides

The Dark Energy Survey

DARK ENERGY SURVEY

- Science goal : Measure the time dependence of the dark energy equation of state, improving the figure of merit defined by the Dark Energy Task Force by a factor of 4-5 compared to present knowledge.
- Combined Methods
  - BAO, SN1A, Galaxy Cluster Statistics, Weak Gravitational Lensing
  - Permits an understanding of systematic unc'ys

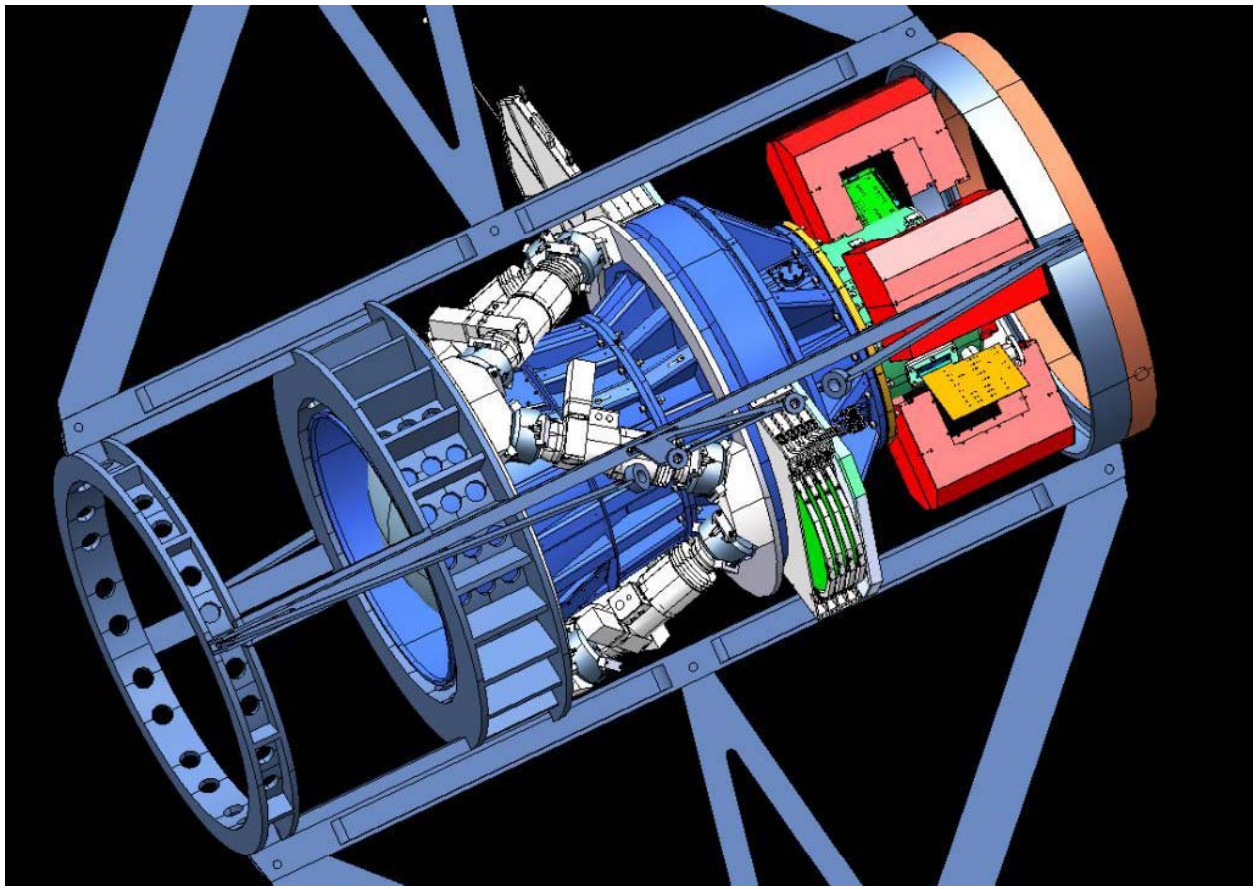
Forecast Limits on w, w_a



DARK ENERGY SURVEY

DECam Overview

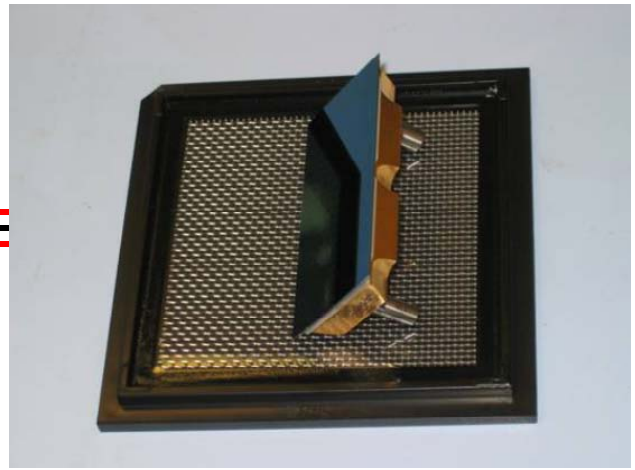
- Optics:Lenses
- CCDs
- Electronics
- Optics:Filters
- Shutter
- Barrel
- Spider/Cage
- Hexapods
- Controls

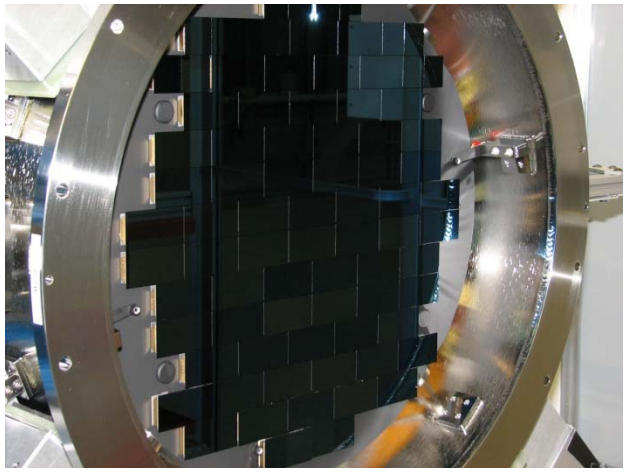


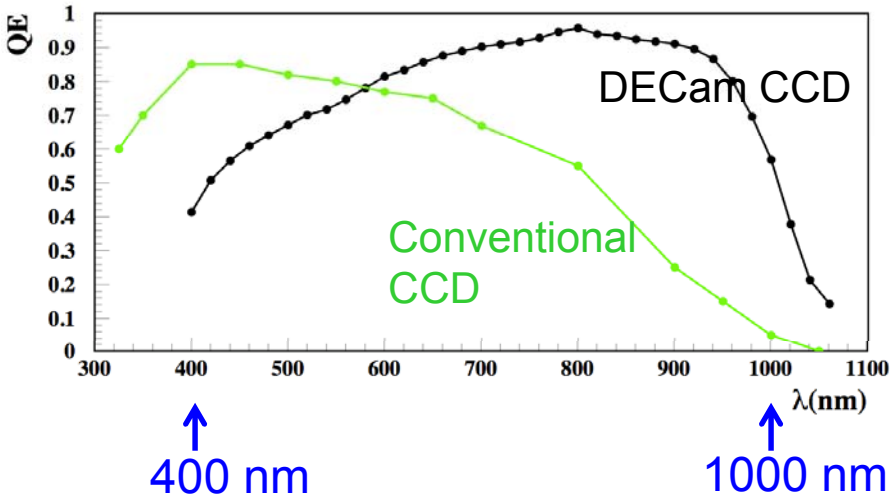
Science Grade CCDs

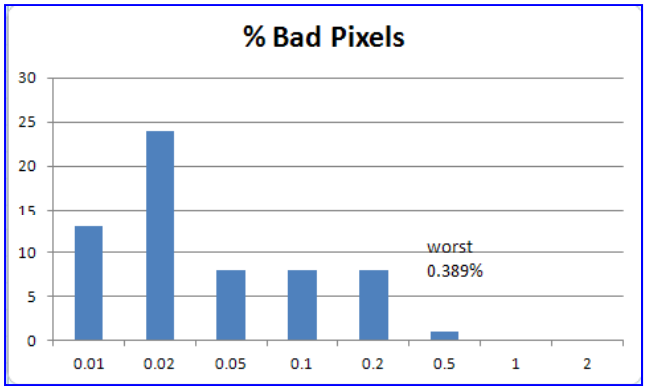
DARK ENERGY SURVEY

- Thick, back-illuminated, fully-depleted CCDs have high QE in near-IR. Manufactured at Dalsa and LBNL and packaged and tested at Fermilab
- ***124*** 2kx4k & ***24*** 2kx2k Science Grade CCDs (passed all technical requirements)
  - We choose the best 62 among those CCDs very selectively based on cosmetics, full well, & QE.









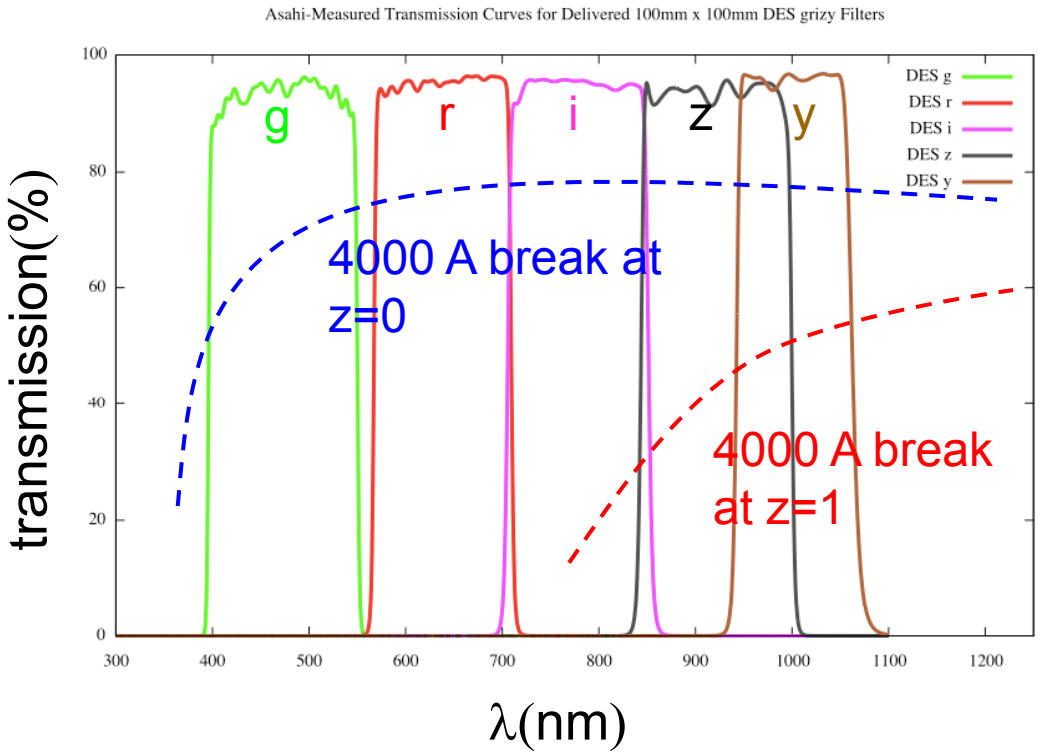
DES Filters & Photometric Z's

DARK ENERGY SURVEY

- Measure relative flux in *grizY filters* and track the "4000 Angstrom break"
- Estimate individual galaxy redshifts with accuracy $\sigma(z) < 0.1$ (~0.02 for clusters)
- Filters are being produced by Asahi Spectra (Japan)
- 4 are finished, g-band soon.

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

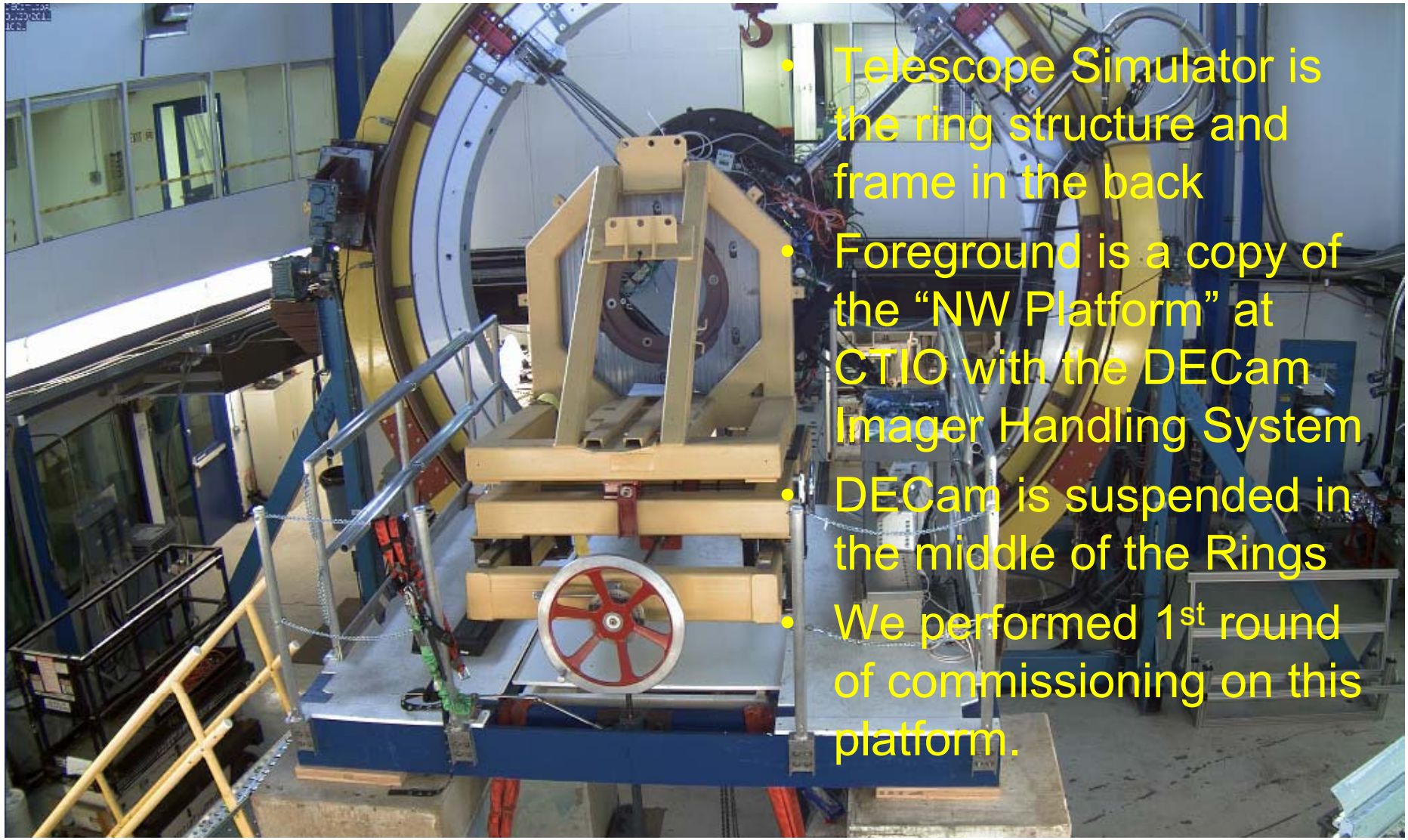
Elliptical galaxy spectrum



World's biggest astronomical filters (60 cm)

Commissioning on a "Telescope Simulator" at FNAL

DARK ENERGY SURVEY



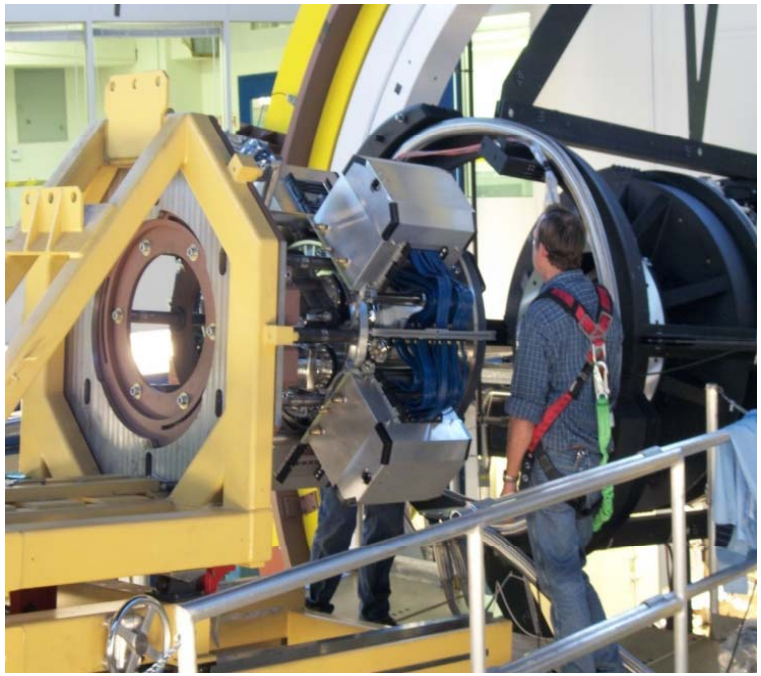
- Telescope Simulator is the ring structure and frame in the back
- Foreground is a copy of the "NW Platform" at CTIO with the DECam Imager Handling System
- DECam is suspended in the middle of the Rings
- We performed 1st round of commissioning on this platform.

Commissioning & Mechanical Infrastructure

DARK ENERGY SURVEY

- Secondary Mirror (f/8) Handling System, tested at FNAL, is now installed at CTIO

- DECam Imager Handling System being used to install the imager into the Cage



Commissioning the Instrument & Mock Observing at FNAL

DARK ENERGY SURVEY

- Commissioned all hardware components except final optics.
- We used engineering-grade CCDs.

- Performed real observing of a fake star field using DECam online software.

THE DARK ENERGY SURVEY

SISPI GUI Interfaces

Apps

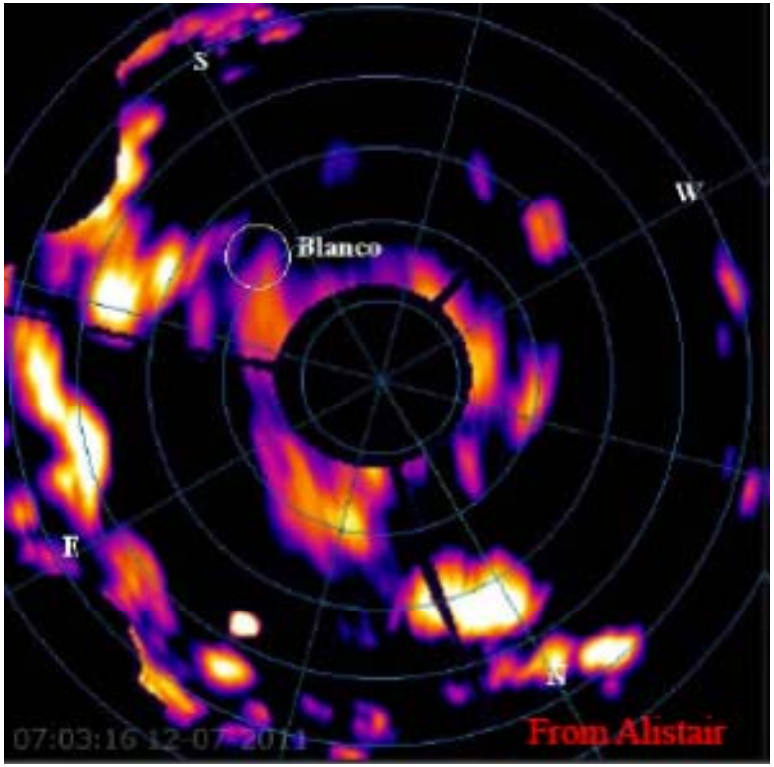
Observer Console | Comfort Display | Image Health | Architect Console

Variable Viewer | Exposure Table | Alarm Viewer | Telemetry

RASICAM at CTIO

DARK ENERGY SURVEY

- A new IR cloud camera provided by the DES Collaboration is operating at CTIO



DARK ENERGY SURVEY

Biggest Camera?

	Blanco DECam	CFHT MegaCam	WIYN O.D.I.?	Subaru HyS.C.	PanStarrs *1	LSST	Yerkes
Year	2011	2003	2012+	2011+	2009	2018+	1909
Filters	62 cm diameter	30 x 30 cm	42 x 42 cm	60 cm diameter		75 cm diameter	
Shutter	60 cm diameter		45 x 45 cm	58 cm diameter?	48 x 48 cm		
Primary Mirror	3.9m	3.6m	3.5m	8.2m	1.8m	6.5m	40” lenses 300 lbs
1st Lens Corrector	0.98 m 176 kg	0.8m	0.59m 36 kg	0.82 m	0.6 m	1.55 m	
Focal Plane	45 cm	25 x 25 cm	40.5 x 41.5 cm	48 cm diameter	40 cm	60 cm diameter	6 in.
Pixels	520 M	340 M	971 M	1.0 B	1.4 B	3.2 B	Plates
F.O.V.	3 deg^2	1 deg^2	1 deg^2	1.8 deg^2	7 deg^2	9.5 deg^2	100 deg^2
Etendue AΩ	~32	~8	~8	95	~12	~340	~200
Time to “do a DECam”	1	~10	~10	0.5	~4	~0.1	~1000

DARK ENERGY SURVEY

Biggest Camera?

	Blanco DECam	CFHT MegaCam	WIYN O.D.I.?	Subaru HyS.C.	PanStarrs *1	LSST	Yerkes
Year	2011	2003	2012+	2011+	2009	2018+	1909
Total weight	11 tons	1325 kgs	2500 lbs			2800 kgs	
Readout time	17s						
1st Lens Corrector	0.98 m 173 kg	0.8m	0.59m 36 kg	0.82 m	0.6 m	1.55 m	
Focal Plane	45 cm	25 x 25 cm	40.5 x 41.5 cm	48 cm diameter	40 cm	60 cm diameter	6 in.
Pixels	520 M	340 M	971 M	1.0 B	1.4 B	3.2 B	Plates
Coverage	3 deg^2	1 deg^2	1 deg^2	1.8 deg^2	7 deg^2	9.5 deg^2	100 deg^2
Etendue $A\Omega$	~32	~8	~8	95	~12	~340	~200