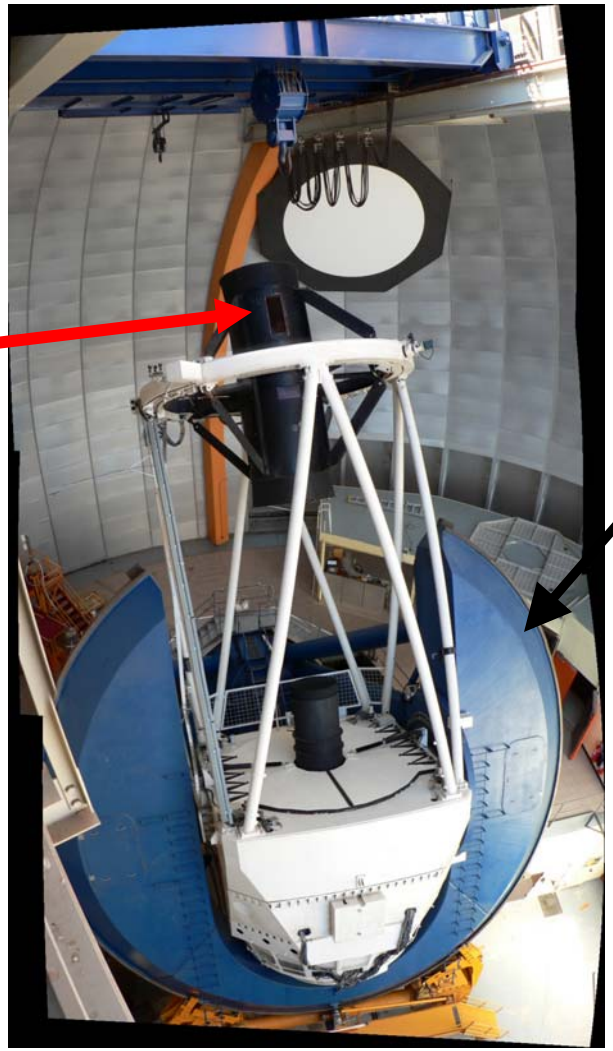
The Dark Energy Survey (DES)

DARK ENERGY SURVEY

- Plan:
  - Perform a 5000 sq. deg. survey of the southern galactic cap
  - Measure dark energy with 4 complementary techniques
- New Instrument:
  - Replace the PF cage with a new 2.2° FOV, 520 Mega pixel optical CCD camera + corrector
- Time scale:
  - Instrument Construction 2008-2011
- Survey:
  - 525 nights during Oct.–Feb. 2011-2016
  - Area overlap with SPT SZ survey and VISTA VHS survey



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

DES Participating Institutions

DARK ENERGY SURVEY

- **Fermilab**
- **University of Illinois at Urbana-Champaign**
- **University of Chicago**
- **Lawrence Berkeley National Laboratory**
- **University of Michigan**
- **NOAO/CTIO**
- **Spain-DES Collaboration:**
  Institut d'Estudis Espacials de Catalunya (IEEC/ICE), Institut de Fisica d'Altes Energies (IFAE), CIEMAT-Madrid:
- **United Kingdom-DES Collaboration:**
  University College London, University of Cambridge, University of Edinburgh, University of Portsmouth, University of Sussex
- **The University of Pennsylvania**
- **Brazil-DES Consortium**
- **The Ohio State University**
- **Argonne National Laboratory**

12 participating institutions and >100 participants

DES Funding from DOE, NSF, STFC (UK), Ministry of Education and Science (Spain), FINEP (Brazil), and the Collaborating Institutions

Dark Energy Survey in the context of the DETF report

DARK ENERGY SURVEY

The Dark Energy Task Force (DETF):

- DETF report sent to AAAC and HEPAP in 2006
- Emphasized importance of multiple probes
- Envisioned staged approach based on Figure of Merit (FoM) and scale:
  - Stage III: near-term, intermediate scale; FoM~3-5x increase over Stage II
  - Stage IV: longer-term, large-scale; FoM~5-10x over Stage II
- Recommended immediate start of Stage III projects

DES is a Stage III project:

near-term: survey 2011 – 2016

intermediate scale: build a new camera and data management system for an existing telescope

projected improvement in the DETF FoM is a factor of 4.6

Dark Energy Survey Science Program

DARK ENERGY SURVEY

Basic DES data set: 300 million galaxies, z > 1, photo-z meas

DES will use Four Probes of Dark Energy

- Galaxy Cluster Counting: N(M,z)
  - Red shifts and masses of ~100,000 clusters to z>1
    - Of which ~10,000 will have SZE measurements from SPT
  - Sensitive to growth of structure and expansion
- Weak Lensing
  - Shape measurements of 300 million galaxies
  - Sensitive to growth of structure and expansion
- Baryon Oscillations
  - 300 million galaxies to z = 1 and beyond
  - Sensitive to expansion
- Supernovae
  - >9 sq deg SN 1a survey
  - 1000-1400 SN 1a to z ~1
  - Sensitive to expansion

The four probes are complementary and will provide insight into the systematic uncertainties

Basic Survey Parameters

DARK ENERGY SURVEY

Sensitivity

Galaxies: 10σ *grizY* = 24.6, 24.2, 24.4, 23.8, 21.5 (galaxies)

Point sources: 5σ *grizY* = 26.0, 25.5, 25.7, 25.2, 22.8 (stars)

Area

~5000 degree^2

Repeated area of ~10 degree^2

Image quality

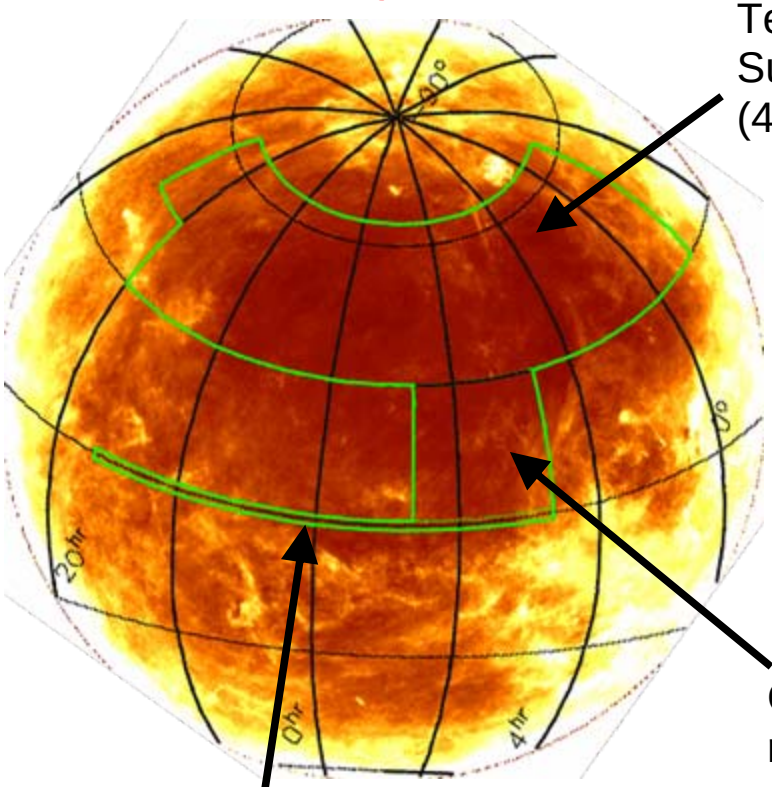
<0.9 arcsec FWHM

Stable across full field-of-view

Photometric precision

<2% absolute

Survey Area



Overlap with South Pole Telescope Survey (4000 sq deg)

Connector region (800 sq deg)

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

Galaxy Photo-z Simulations

DARK ENERGY SURVEY

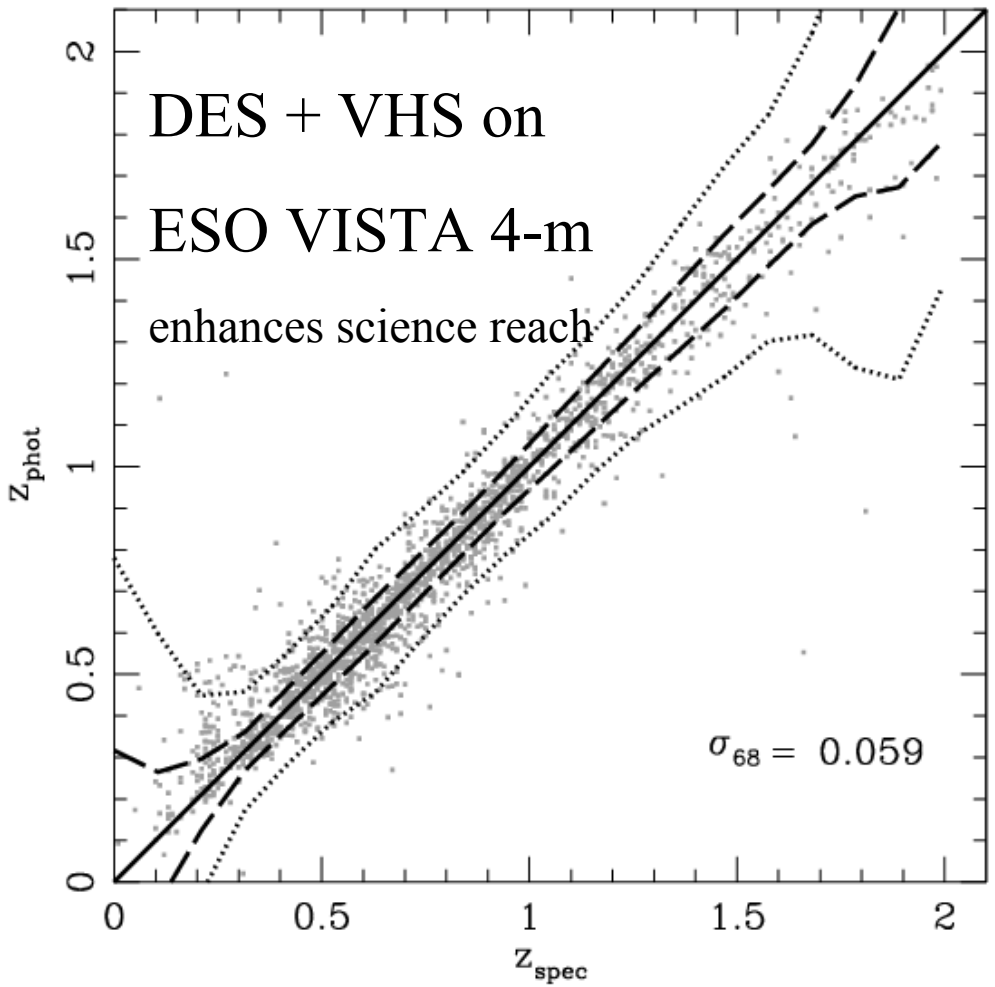
DES +VISTA VHS griz filters + J, K, H

10σ Limiting Magnitudes

g	24.6
r	24.1
i	24.0
z	23.9

+2% photometric calibration error added in quadrature

Key: Photo-z systematic errors under control using *existing* spectroscopic training sets to DES photometric depth



Cunha, etal

Improved Photo-z & Error Estimates and robust methods of outlier rejection

DES Forecasts: Power of Multiple Techniques

DARK ENERGY SURVEY

$w(z) = w_0 + w_a(1-a)$

Assumptions:

Clusters:

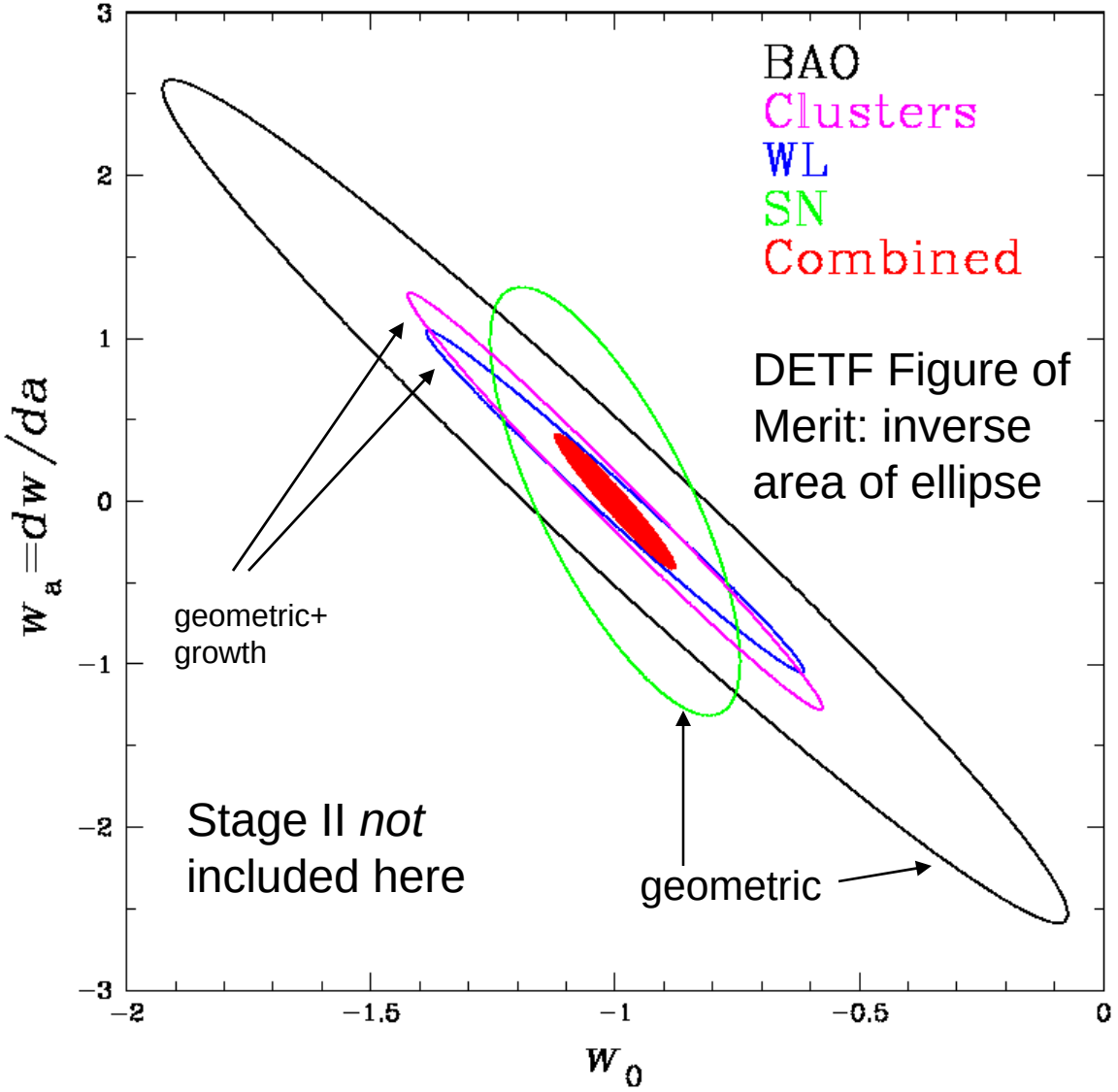
σ_8=0.75, z_{max}=1.5,
WL mass calibration

BAO: ℓ_{max}=300
WL: ℓ_{max}=1000

Statistical+photo-z systematic errors only

Spatial curvature, galaxy bias marginalized, Planck CMB prior

Factor 4.6 relative to Stage II

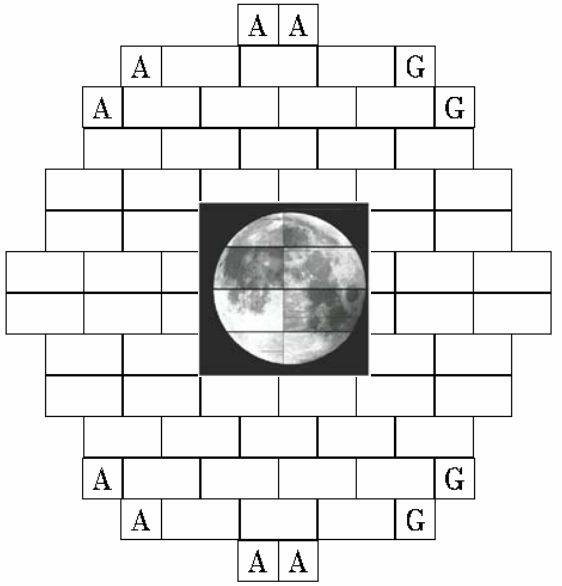


The DES Instrument: DECam

DARK ENERGY SURVEY

- To meet the DES science requirements, within the allocated time period DECam must have:
  - 3 sq. deg. field of view
  - excellent image quality
  - red sensitive CCDs
  - g,r,i,z,Y filters
- The DECam R&D program is nearly complete
- Final Design and Construction are about to begin

DECam Focal Plane

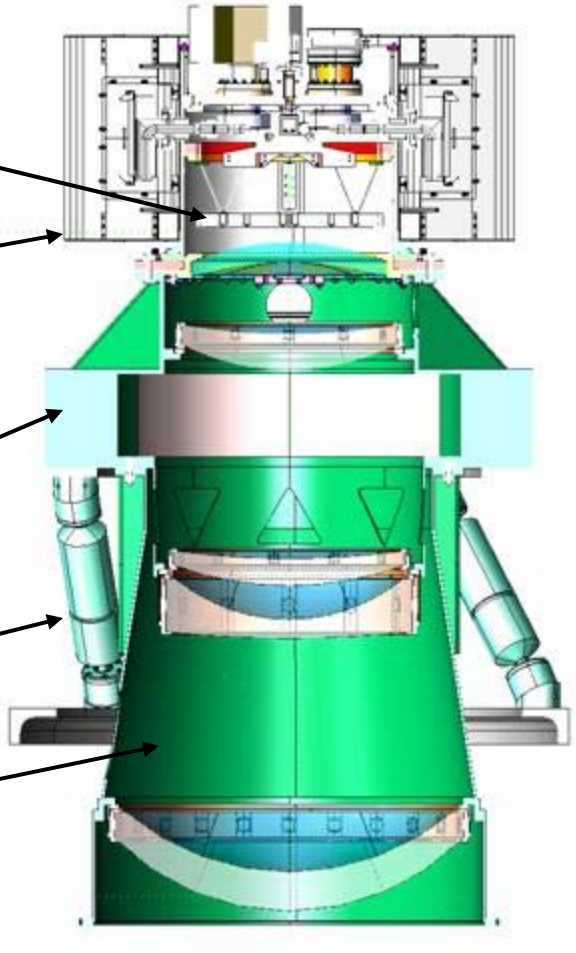


62 2kx4k Image CCDs: 520 MPix
8 2kx2k Alignment/focus CCDs
4 2kx2k Guide CCDs

DECam overview

DARK ENERGY SURVEY

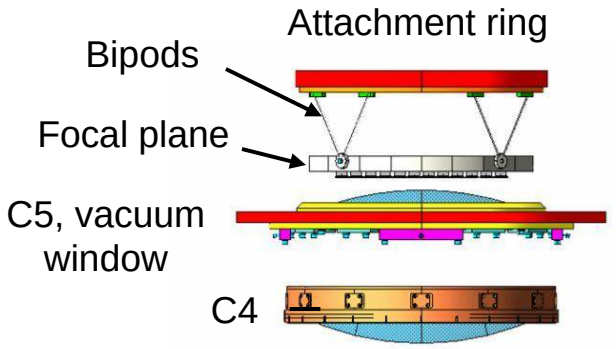
- CCD focal plane is housed in a vacuum vessel (the imager) which is supported by the barrel
- CCD readout electronic crates are mounted to the outside of the Imager and are actively cooled.
- Filter changer (8 filter capacity) and shutter form one mechanical unit.
- Hexapod provides focus and lateral alignment capability for the corrector-imager system
- Barrel supports the lenses and imager



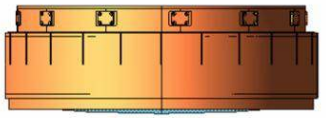
Optics

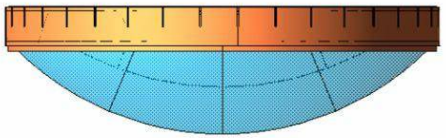
DARK ENERGY SURVEY

- Five element fused silica corrector
- Two aspheric surfaces
- Last element is window of CCD vessel
- Blanks are complete, and are now at the polishing vendor

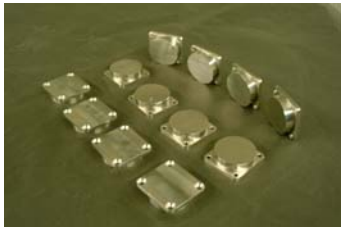


Filters & Shutter



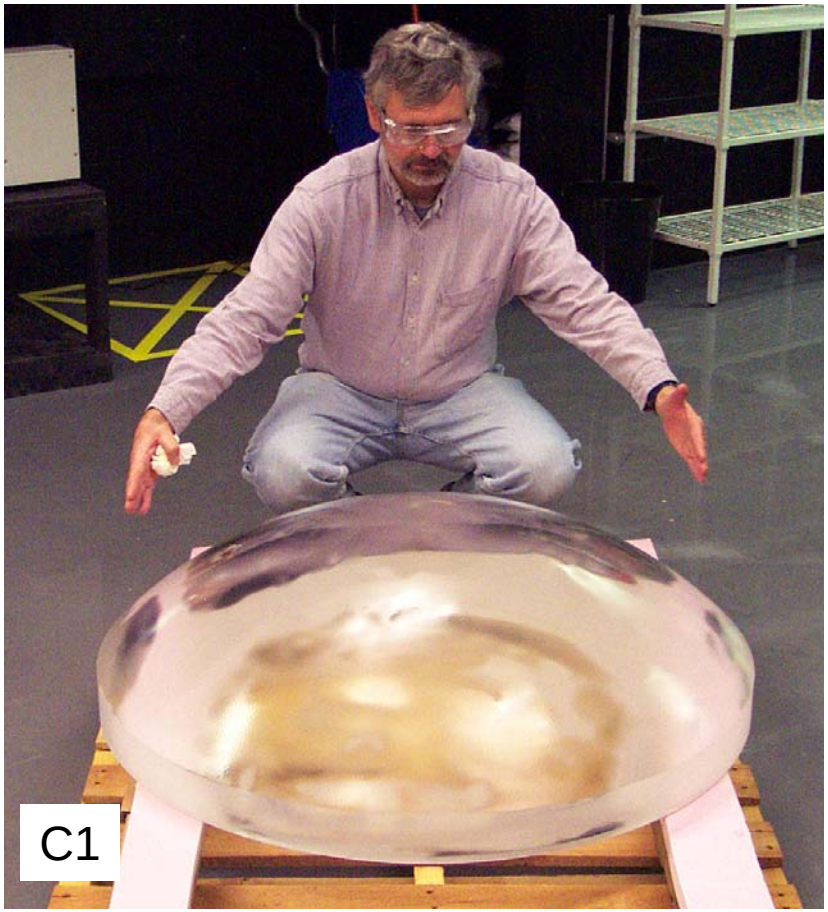


Prototype Cell and Pad covers



Blank inspection at Corning

DARK ENERGY SURVEY

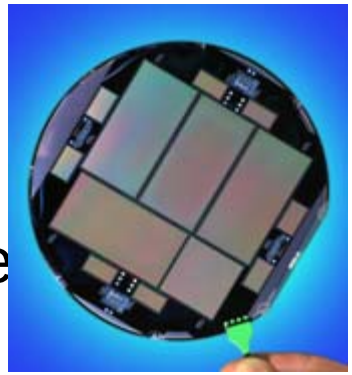


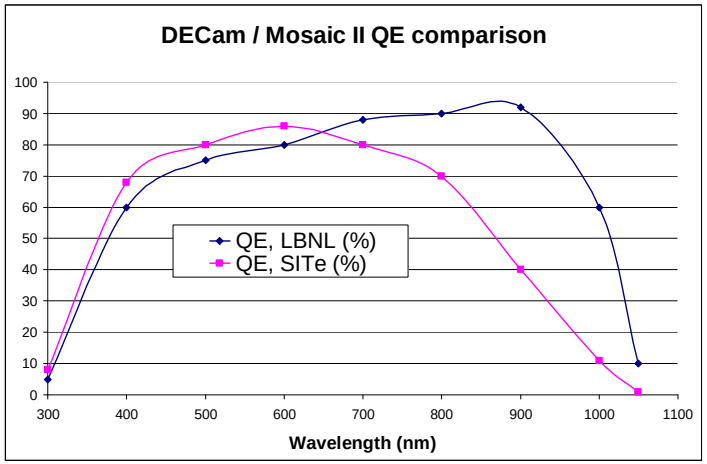
The next step, polishing, will remove only ~ 1 mm per side

DECam CCDs

DARK ENERGY SURVEY

- Red Sensitive CCDs developed by LBNL:
  - QE> 50% at 1000 nm
  - 250 microns thick
  - 2 RO channels/device
  - readout time ~17sec





- Three stage fabrication:
  - Wafers fabricated at Dalsa
  - Final processing steps at LBNL
  - Packaging at Fermilab

- 34 of the 2k x 4k CCDs delivered to Fermilab are potential science grade

Multi-CCD Test Vessel / Imager Prototype

DARK ENERGY SURVEY

- 10 prototype CCD packages installed in Multi-CCD Test Vessel
- Prototype high density boards derived from the NOAO Monsoon system meet the readout specifications (<10 e noise @ 250kpix/sec).
- Testing program with telescope simulator to demonstrate performance of cooling system, hexapod, electronics

DARK ENERGY SURVEY

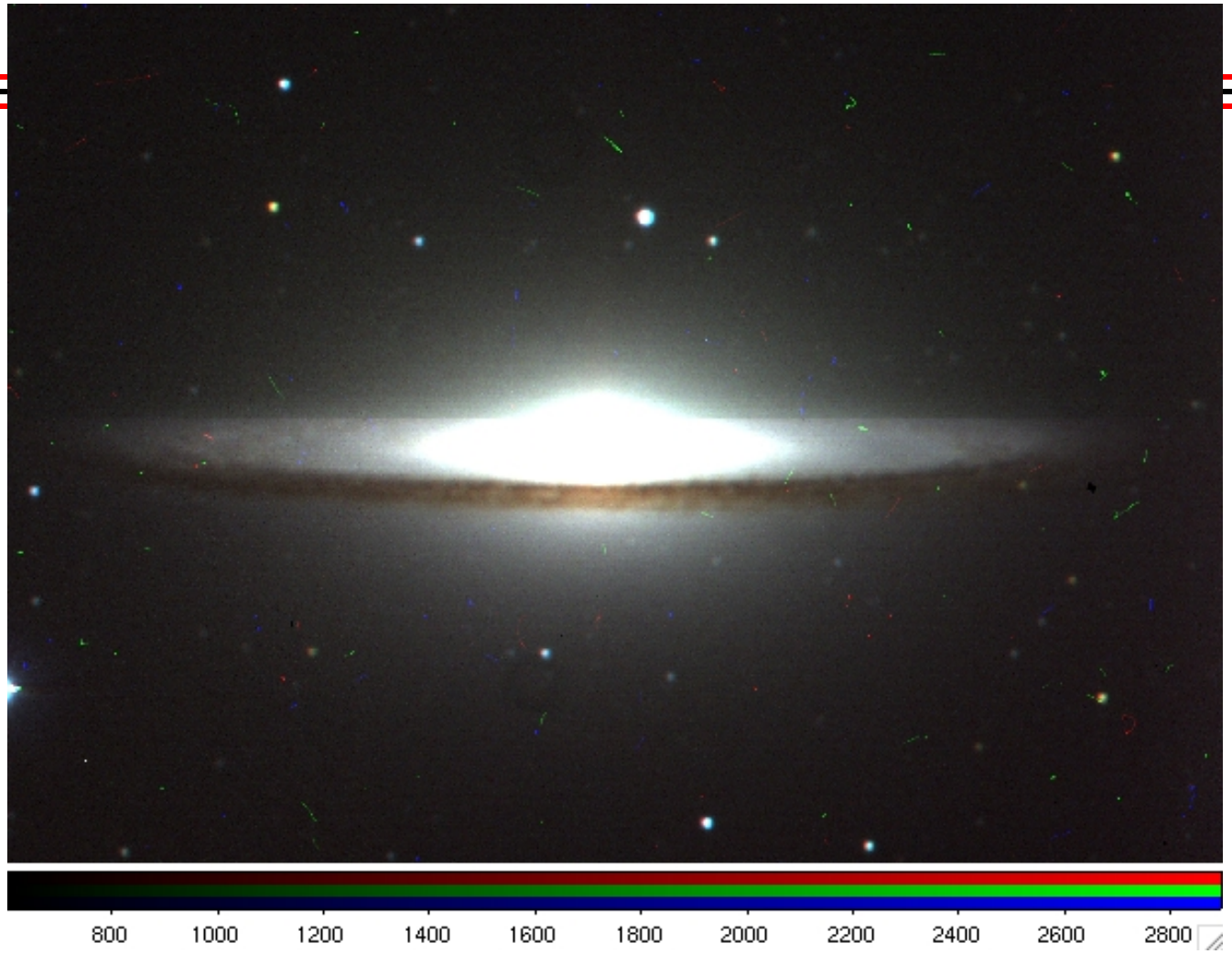
April 2008

1 DECam CCD

with Monsoon electronics

in a small test dewar

on the CTIO 1m (next to the Blanco)



Goal April 2011: 62 DECam CCDs in a new camera on the Blanco 4m

Conclusions

DARK ENERGY SURVEY

- DES will measure Dark Energy using multiple complementary probes: constraints are robust to systematics in a single probe

- DOE Approval process and R&D for the DES Instrument, DECam, are both nearly complete
  - CD-0 approval in Nov. 2005
  - CD-1 approval in Oct. 2007
  - CD-2 approval & CD-3a approval in May 2008
  - Currently seeking CD-3b approval releasing remaining construction funds

- We are looking forward to taking DECam to CTIO in Dec. 2010 and to beginning the Dark Energy Survey in Oct. 2011

DARK ENERGY
SURVEY

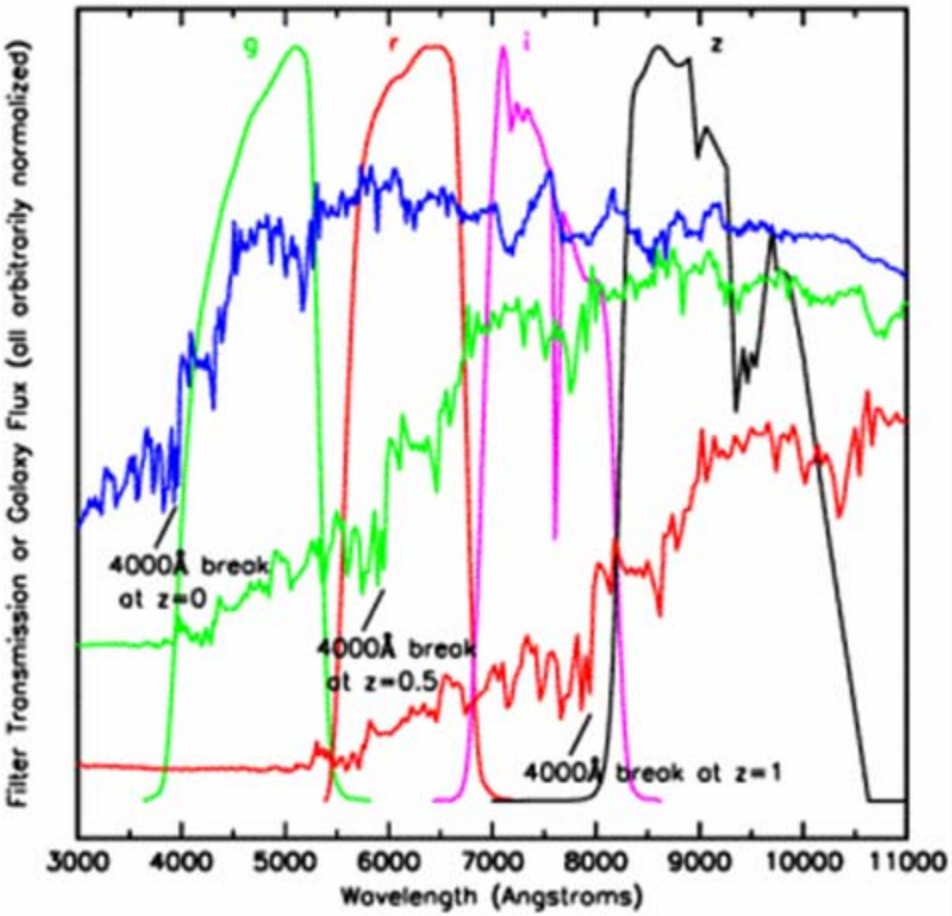
Extras

DES Photometric Redshifts

DARK ENERGY SURVEY

- Measure relative flux in *grizY filters* and track the 4000 A break
- Estimate individual galaxy redshifts with accuracy $\sigma(z) < 0.1$ (~0.02 for clusters)
- Good detector response in *z* band filter needed to reach z~1.5

Elliptical galaxy spectrum



Forecast Constraints

DARK ENERGY SURVEY

DETF FoM

Method	$\sigma(\Omega_{DE})$	$\sigma(w_0)$	$\sigma(w_a)$	z_p	$\sigma(w_p)$	$[\sigma(w_a)\sigma(w_p)]^{-1}$
BAO	0.010	0.097	0.408	0.29	0.034	72.8
Clusters	0.006	0.083	0.287	0.38	0.023	152.4
Weak Lensing	0.007	0.077	0.252	0.40	0.025	155.8
Supernovae	0.008	0.094	0.401	0.29	0.023	107.5
Combined DES	0.004	0.061	0.217	0.37	0.018	263.7
DETF Stage II Combined	0.012	0.112	0.498	0.27	0.035	57.9

Table 1: 68% CL marginalized forecast errorbars for the 4 DES probes on the dark energy density and equation of state parameters, in each case including Planck priors *and* the DETF Stage II constraints. The last column is the DETF FoM; z_p is the pivot redshift. Stage II constraints used here agree with those in the DETF report to better than 10%.

- DES+Stage II combined = Factor 4.6 improvement over Stage II combined
- Large uncertainties in systematics remain, but FoM is robust to uncertainties in any one probe, and we haven't made use of all the information.
- Further detail of these forecasts is contained in the Dark Energy Science Program.