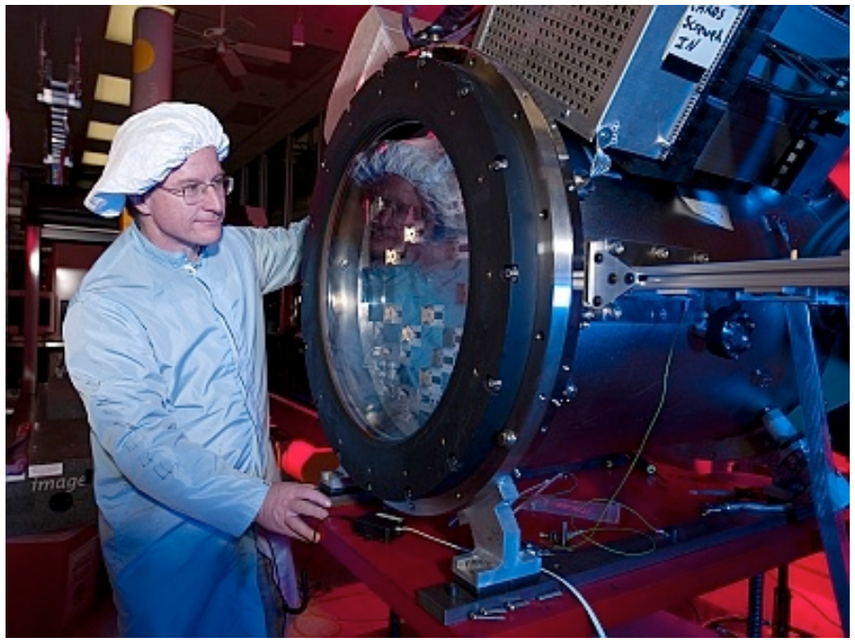
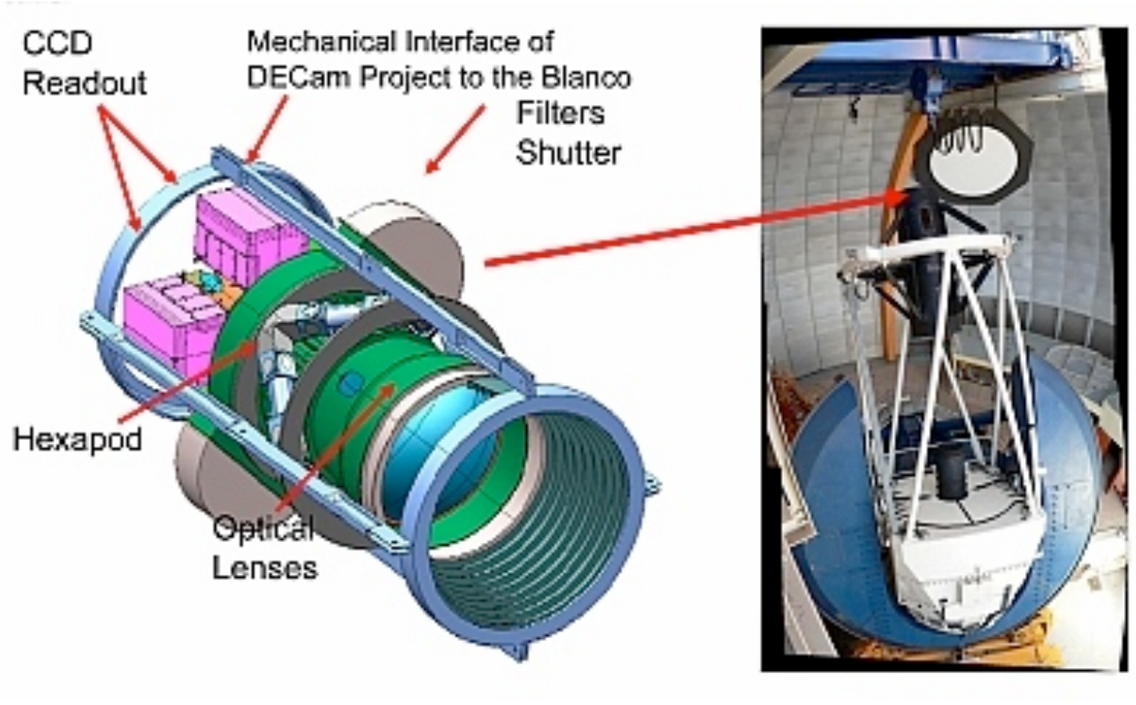
The Dark Energy Survey: Status and Science Goals

Kyler Kuehn
Argonne National Laboratory

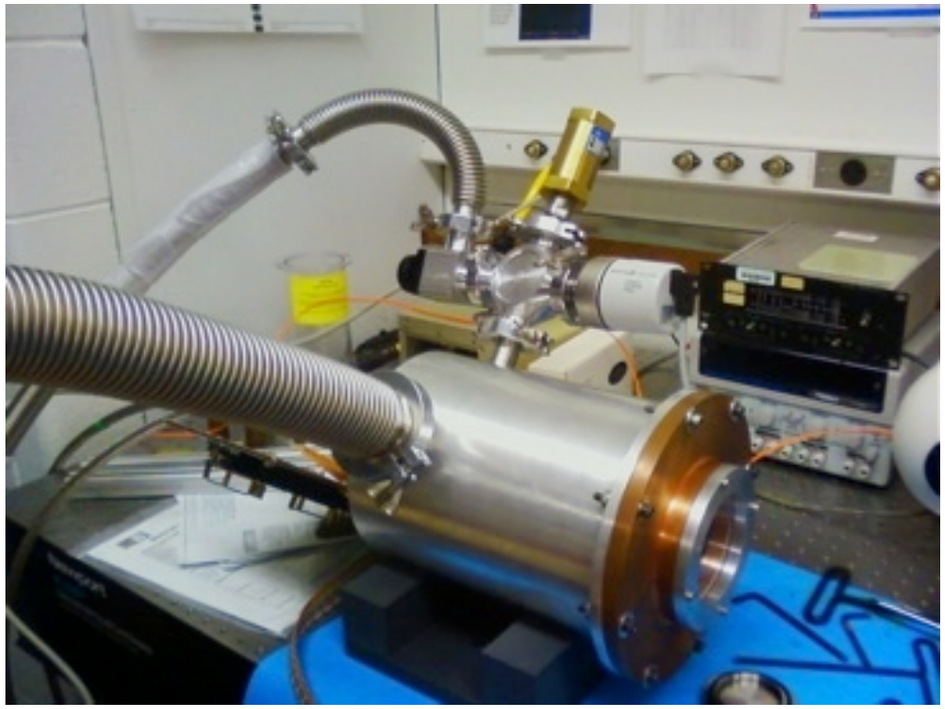
Canada-America-Mexico Physics Graduate Student Conference
Washington, DC
2011-09-29

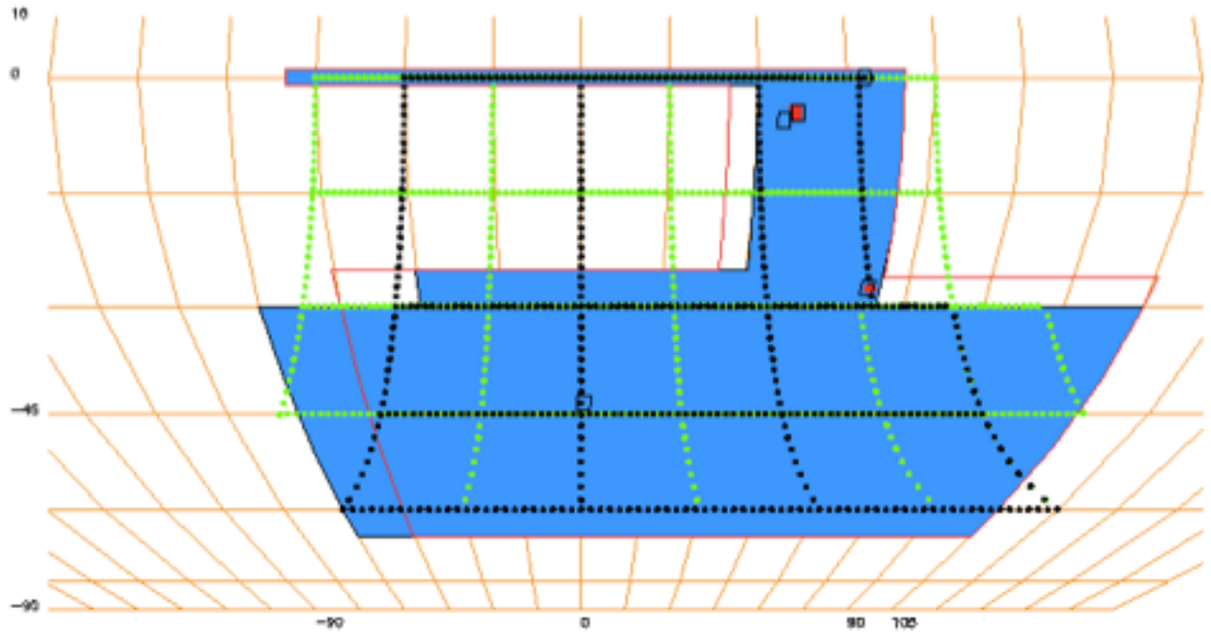
Most Important Results: Detector Capabilities, Hardware Status

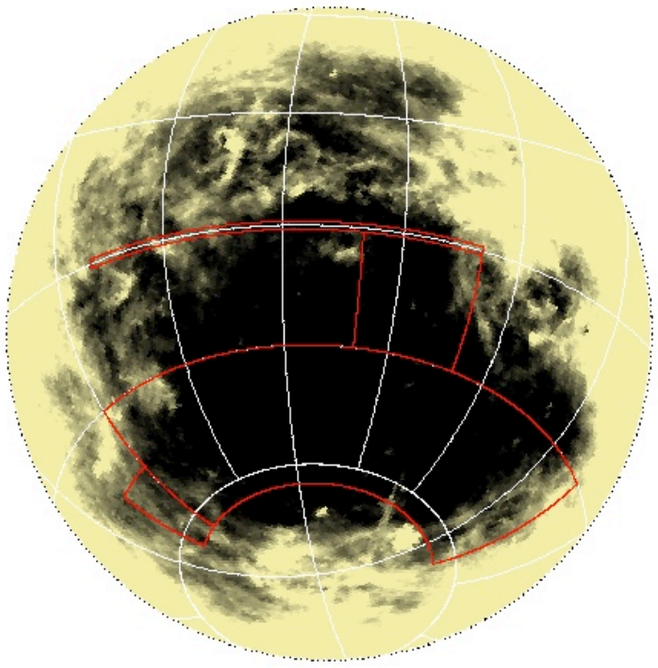


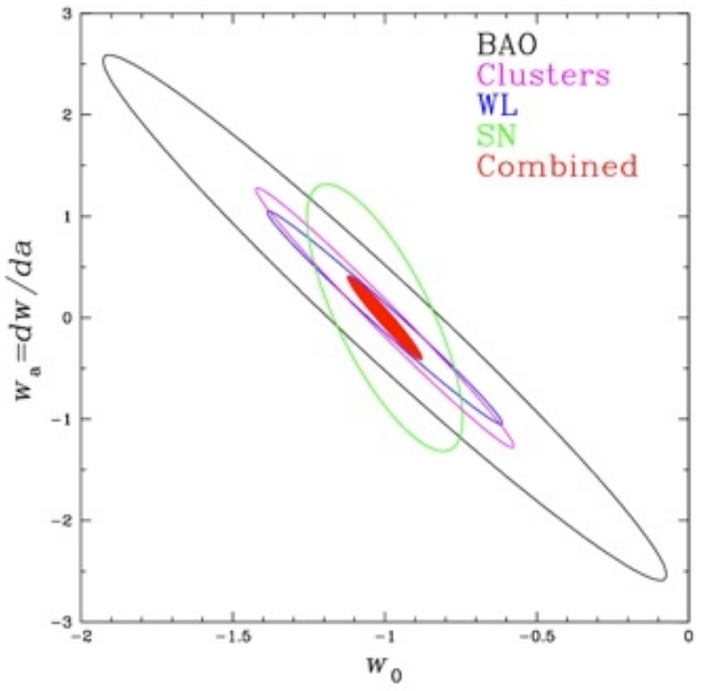


Most Important Results II: Preliminary Science, Survey Goals









The Dark Energy Survey Collaboration

More than 200 scientists and engineers from...

Fermilab — The Fermi National Accelerator Laboratory

UIUC/NCSA — The University of Illinois at Urbana-Champaign

Chicago — The University of Chicago

LBNL — The Lawrence Berkeley National Laboratory

NOAO — The National Optical Astronomy Observatory

United Kingdom DES Collaboration

- UCL - University College London
- Cambridge - University of Cambridge
- Edinburgh - University of Edinburgh
- Portsmouth - University of Portsmouth
- Sussex - University of Sussex
- Nottingham - University of Nottingham

Spain DES Collaboration

- IEEC/CSIC - Instituto de Ciencias del Espacio,
- IFAE - Institut de Fisica d'Altes Energies
- CIEMAT - Centro de Investigaciones Energeticas, Medioambientales y Tecnologicas

Michigan — The University of Michigan

DES-Brazil Consortium

- ON - Observatorio Nacional
- CBPF - Centro Brasileiro de Pesquisas Fisicas

UFRGS - Universidade Federal do Rio Grande do Sul

Pennsylvania — The University of Pennsylvania

ANL — Argonne National Laboratory

OSU — The Ohio State University

TAMU — Texas A&M University

Santa Cruz-SLAC-Stanford DES Consortium

- Santa Cruz - University of California Santa Cruz
- SLAC - SLAC National Accelerator Laboratory
- Stanford - Stanford University

Munich—Universitäts-Sternwarte München

- Ludwig-Maximilians Universität
- Excellence Cluster Universe

The Era of Observational Cosmology

Two (competing!) observations of supernovae showed that the cosmos is dominated by a mysterious "Dark Energy" that drives the accelerated expansion of the universe, and subsequent observations utilizing different probes (e.g. CMB) have confirmed this result.

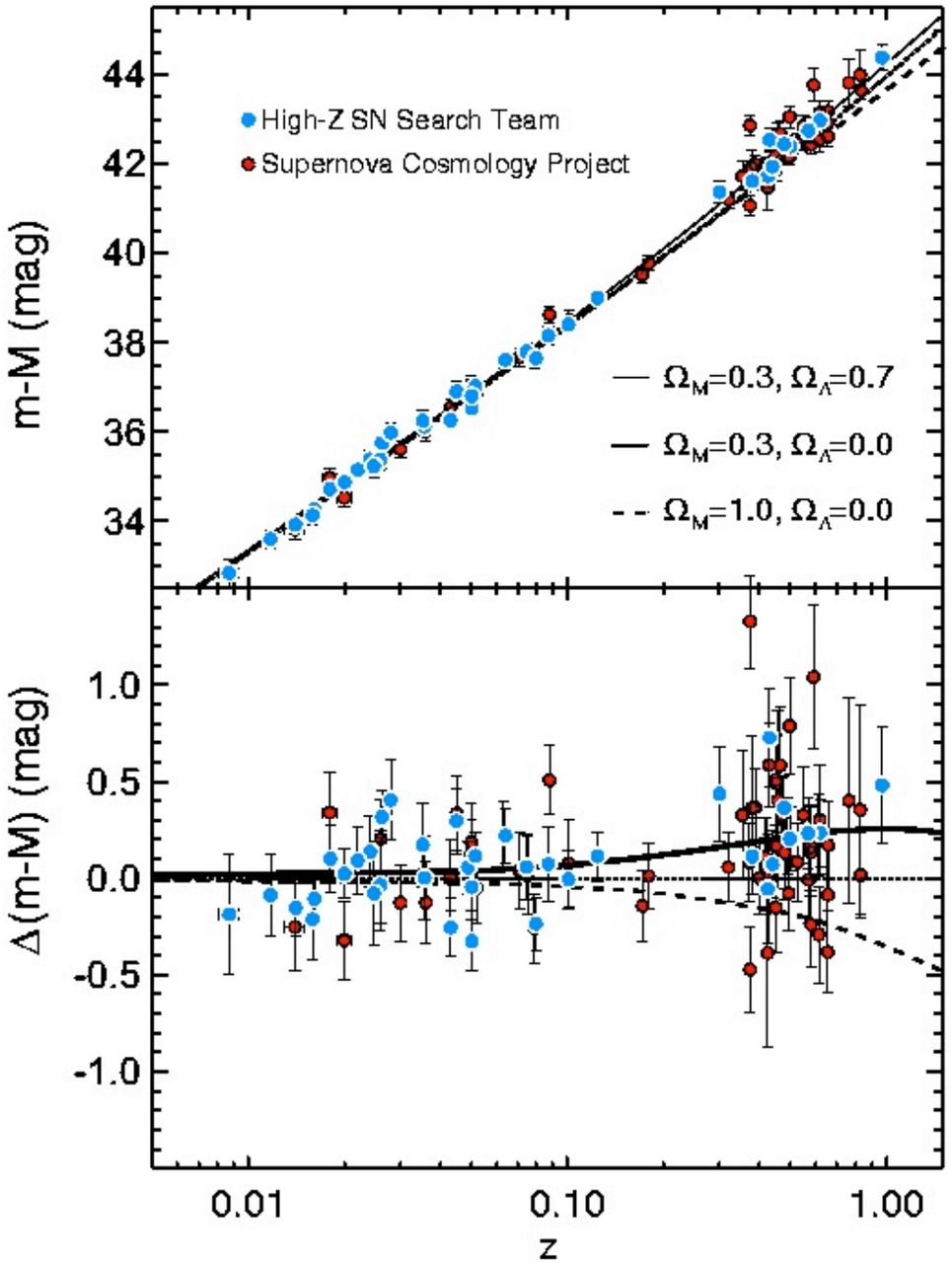
The properties of Dark Energy can be expressed in terms of its Equation of State at different redshifts:

$w(z) = p/\rho$

We parameterize w(z) as follows:

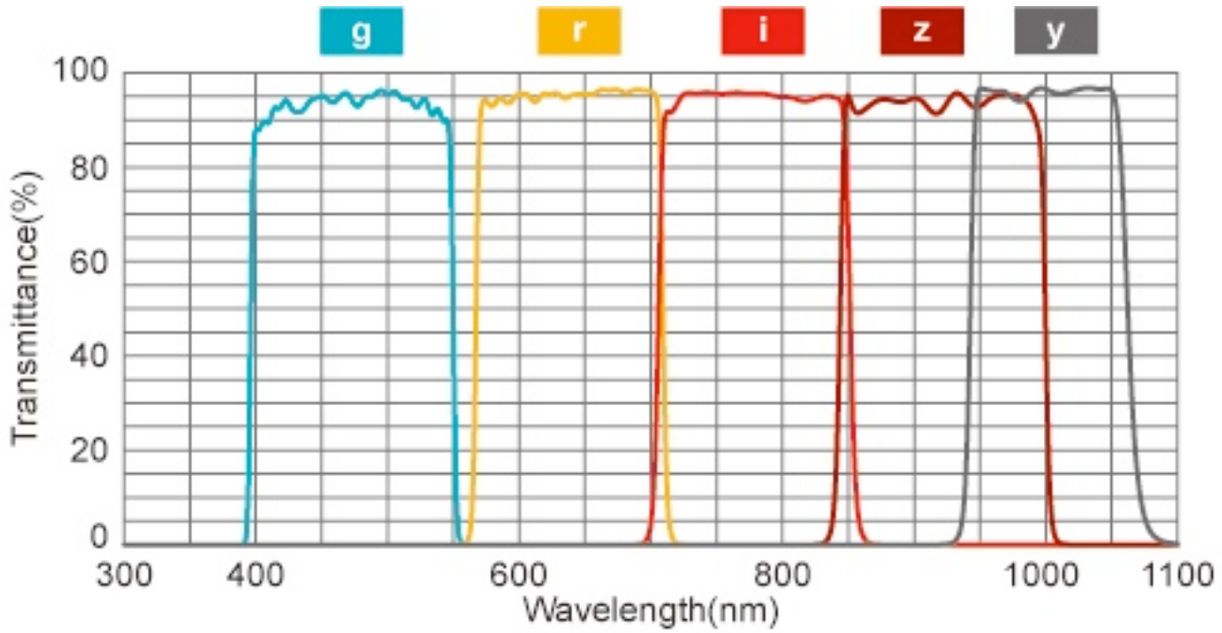
$w(z) = w_0 + w_a(1-a)$, where **$a=(1+z)^{-1}$**

$w_0 = w_\Lambda$ (i.e. the cosmological constant) if $w_a = 0$.



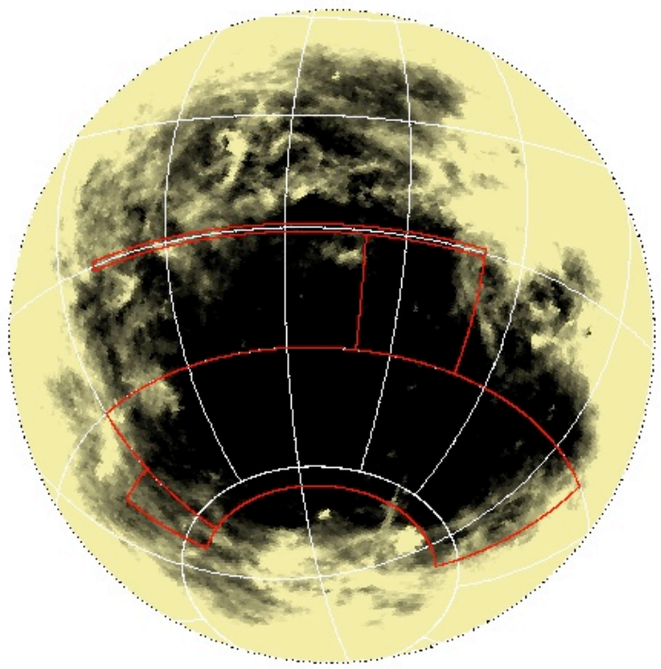
The Dark Energy Survey

Starting in 2012, DES will observe 5000 deg^2 of the southern sky over 525 nights with (SDSS-like) grizY filters. The DES "footprint" overlaps with VISTA Hemisphere Survey (DES Y-band data ⟷ VHS JHK data), as well as SDSS, SPT, and Skymapper.



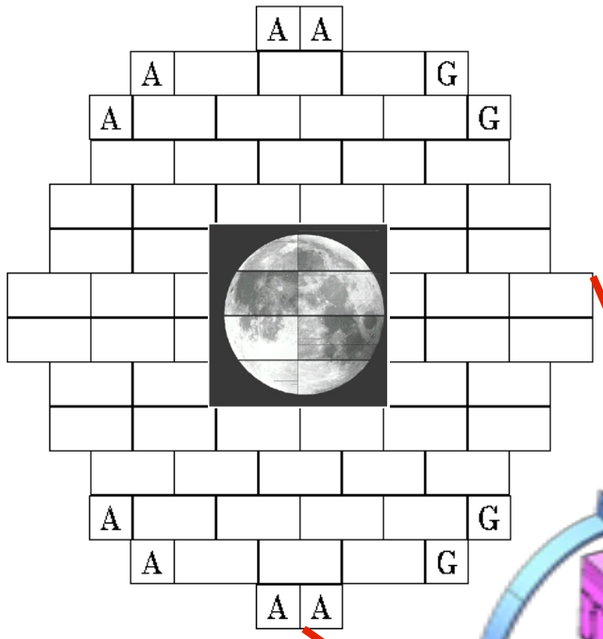
DES uses four complementary methods to constrain the Dark Energy Equation of State:

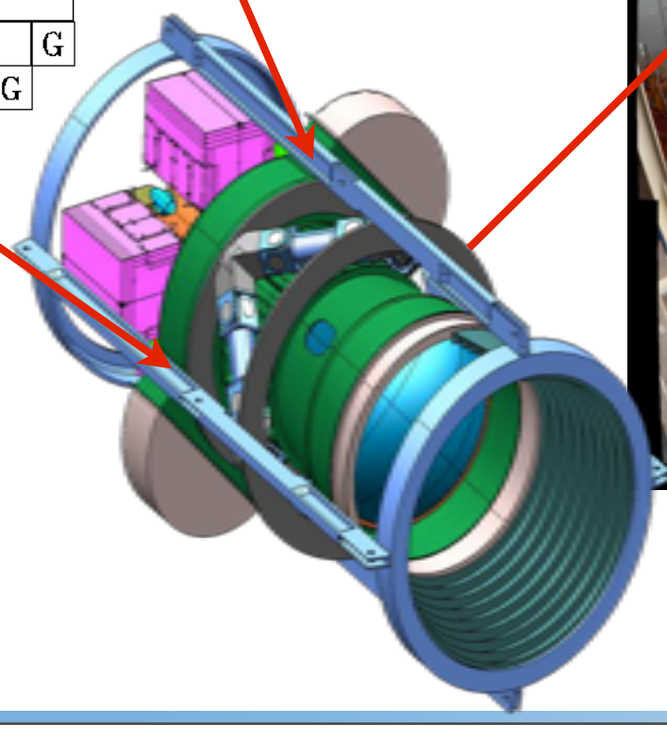
- Supernovae
- Galaxy Clusters
- Weak Lensing
- Large Scale Structure

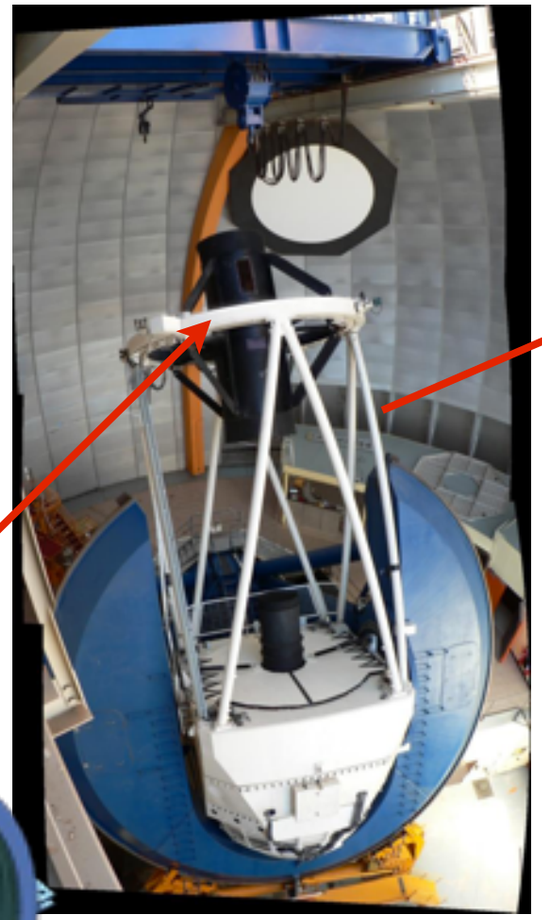


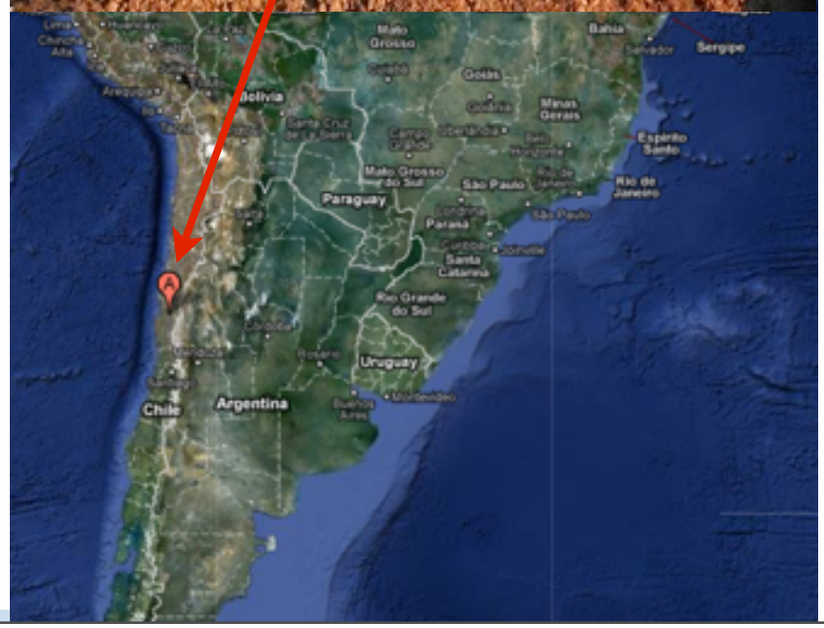
The DES Instrument: DECam

The newly-constructed Dark Energy Camera will be installed at the prime focus of the 4m. Blanco Telescope at Cerro Tololo Inter-American Observatory in Chile. DECam consist of 62 2k x 4k extremely red-sensitive (QE > 50% at 1000nm) CCDs, plus associated guide/focus CCDs, with a field of view of approximately 3 square degrees.

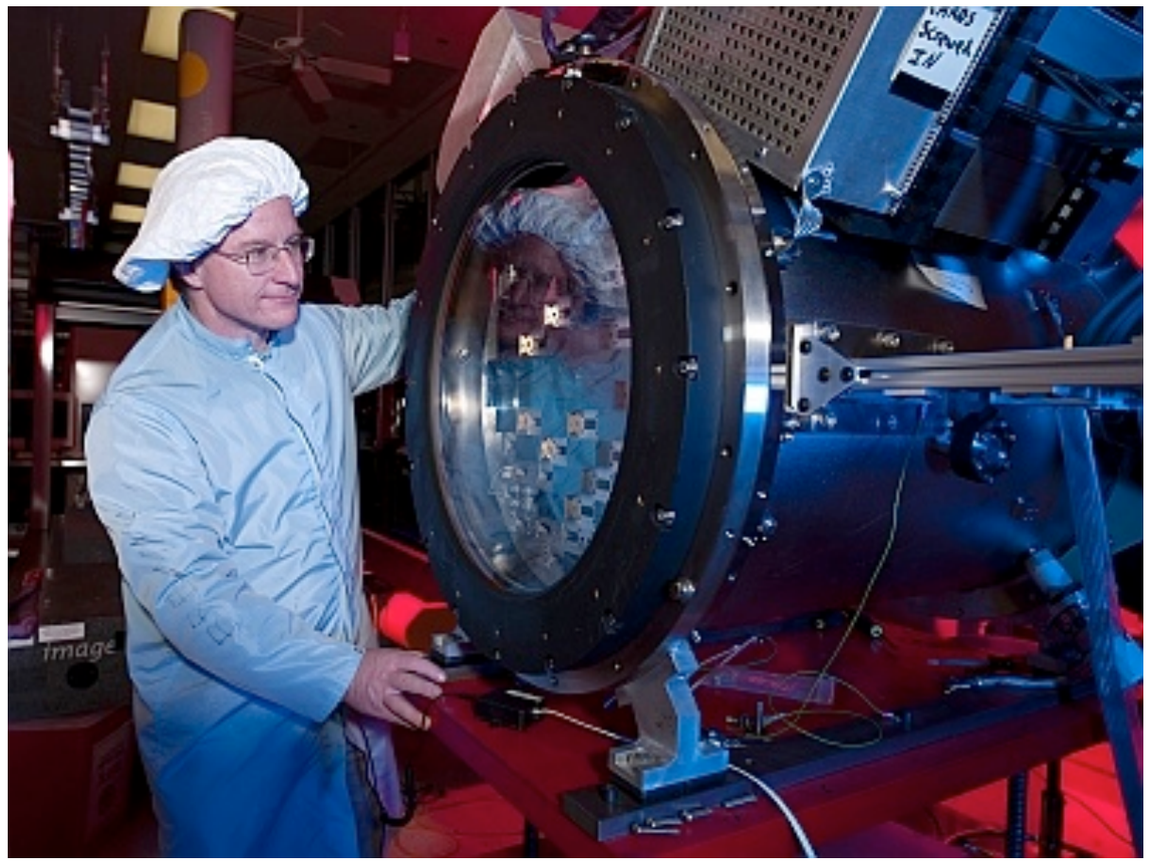








DES/DECam Components



Camera: Science CCDs, Guide/Focus CCDs, Focal Plane, Pressure Vessel

Optics, Filters: 5 lenses >1m. in diameter + grizY filters

Shutter: fast (>0.1 s) control, large enough for ~1m. diameter focal plane.

DAQ Electronics: Vacuum Interface Boards to Monsoon Crates

Cryogenics/Heating: 200L of LN2, vessel controlled to within 0.25K

Pressure Control: ~1m^3 held to P<10^{-4} torr

Hexapod: mm-level positioning of a multi-ton instrument

f/8 Handling System: for other Blanco instruments

Software: Instrument, Infrastructure, and Image Control--SISPI; ObsTac

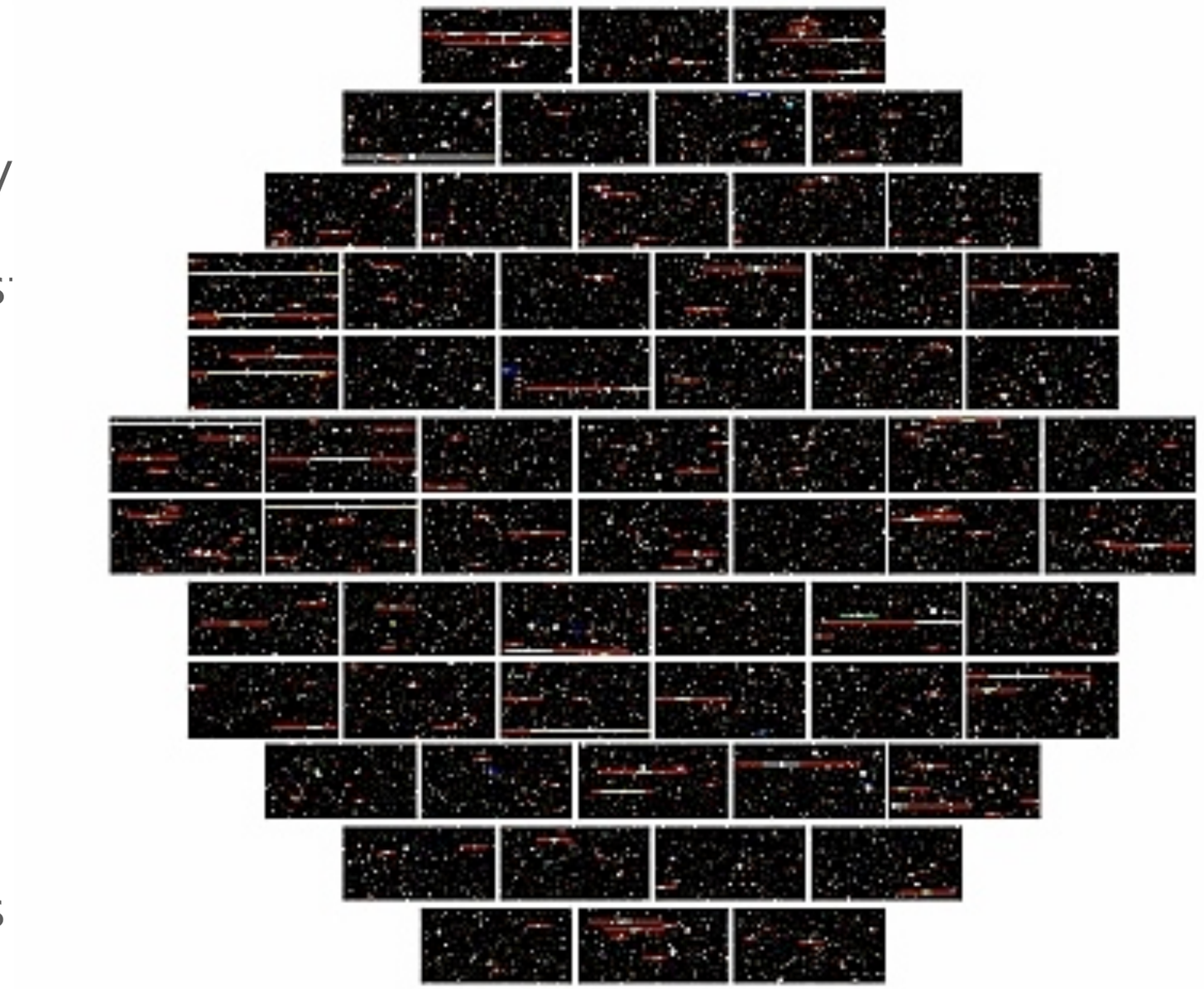
Simulations: Image-level (pixels) and Catalog-level

DESDM: Data Management of all data products

Science Analysis Tools: SN, WL, Clusters, BAO, “non-key” science

DES Simulations

Simulations must be accurate enough to test processing and analysis pipeline for most stringent requirements (usually set by Weak Lensing). Star-galaxy separation is the biggest challenge.



Each new (~annual) DR incorporates additional image effects. Includes both large-area simulations (~200 deg^2), as well as smaller (~20 deg^2) "Golden Standard" nights with significantly improved detail.

Each simulation requires ~days of Fermi Grid computing time (Particle-physics like datasets).

DES Image Acquisition/Processing Software

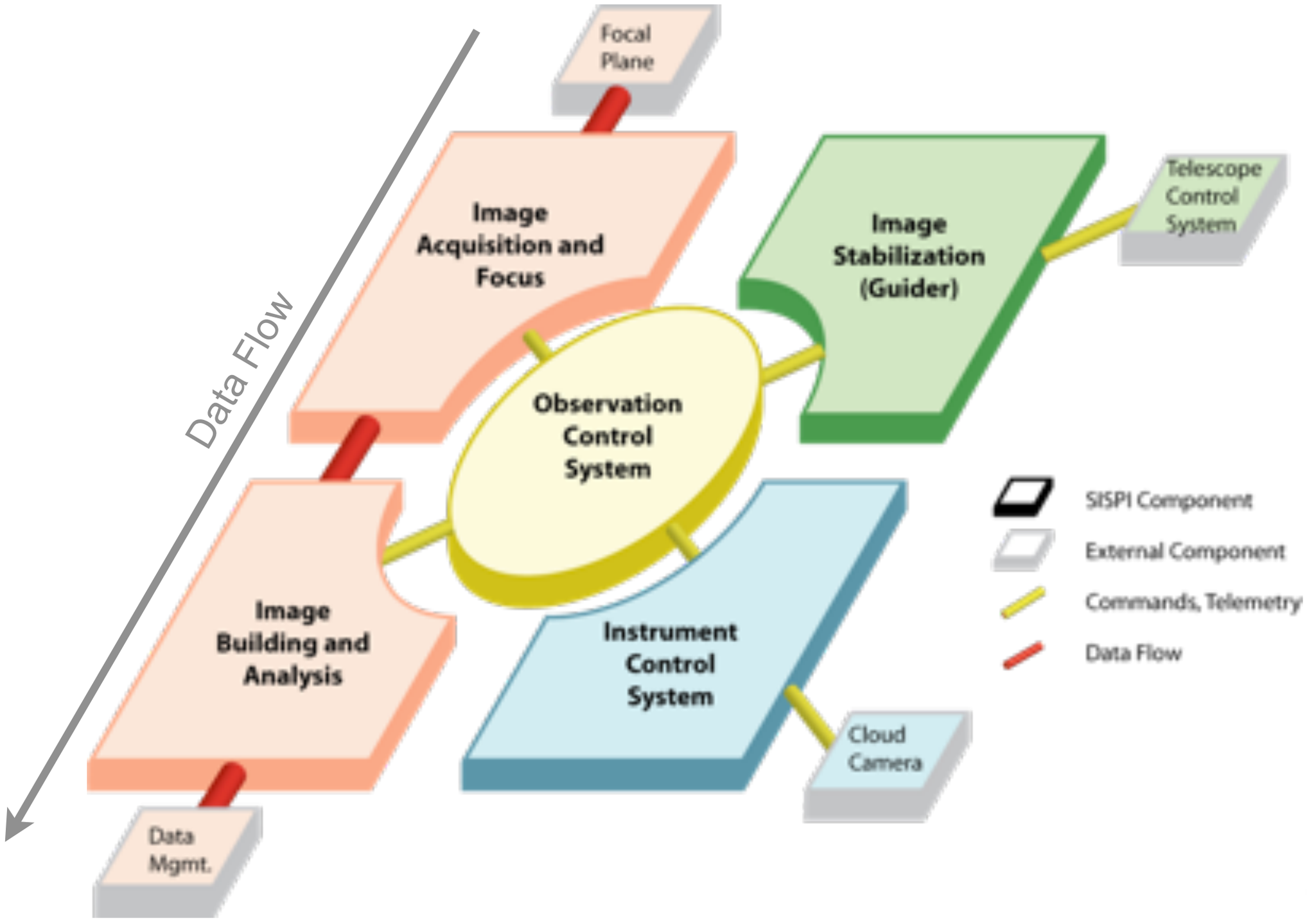
DES will acquire ~1GB images every ~2 minutes for ~8 hours every night. With associated metadata, DES will generate >1PB of data!

These images need to be minimally processed and viewable in (near-) real-time for quality assurance purposes.

A few components include:

- Observation Control System includes GUI interfaces for control
- Instrument Control System includes filter/shutter control
- Focus Control provides feedback during (and between) exposures
- "Image Display" down-samples 1GB image to ~10MB in <2 seconds.
- "Image Health" calculates characteristics of each CCD (background, dead/hot pixels, sample object size and ellipticity) in < 10 seconds.
- DESDM--data transmission, storage, and analysis:
  - "Brazil" Portal for online image processing (dark subtraction, flat-fielding, co-addition, initial science)
  - CTIO 3-Day Storage and Data Transport System for local image cache and transmission to NOAO-Tucson/NCSA/Fermilab, respectively.

Survey Image System Process Integration (SISPI)



DES Image Calibration

Requirement:

- Hundreds of Southern Hemisphere standard stars per square degree
- Y-Band standards particularly needed

Purpose:

- Extinction standards and (nightly) photometric solutions
- Facilitate transformation to previous standard systems (e.g. SDSS)
- Requirement of 2% photometry, Goal of 1% photometry

Problems:

- Most current standard stars would saturate DECam
- This could take up to 10% of the survey observing time...

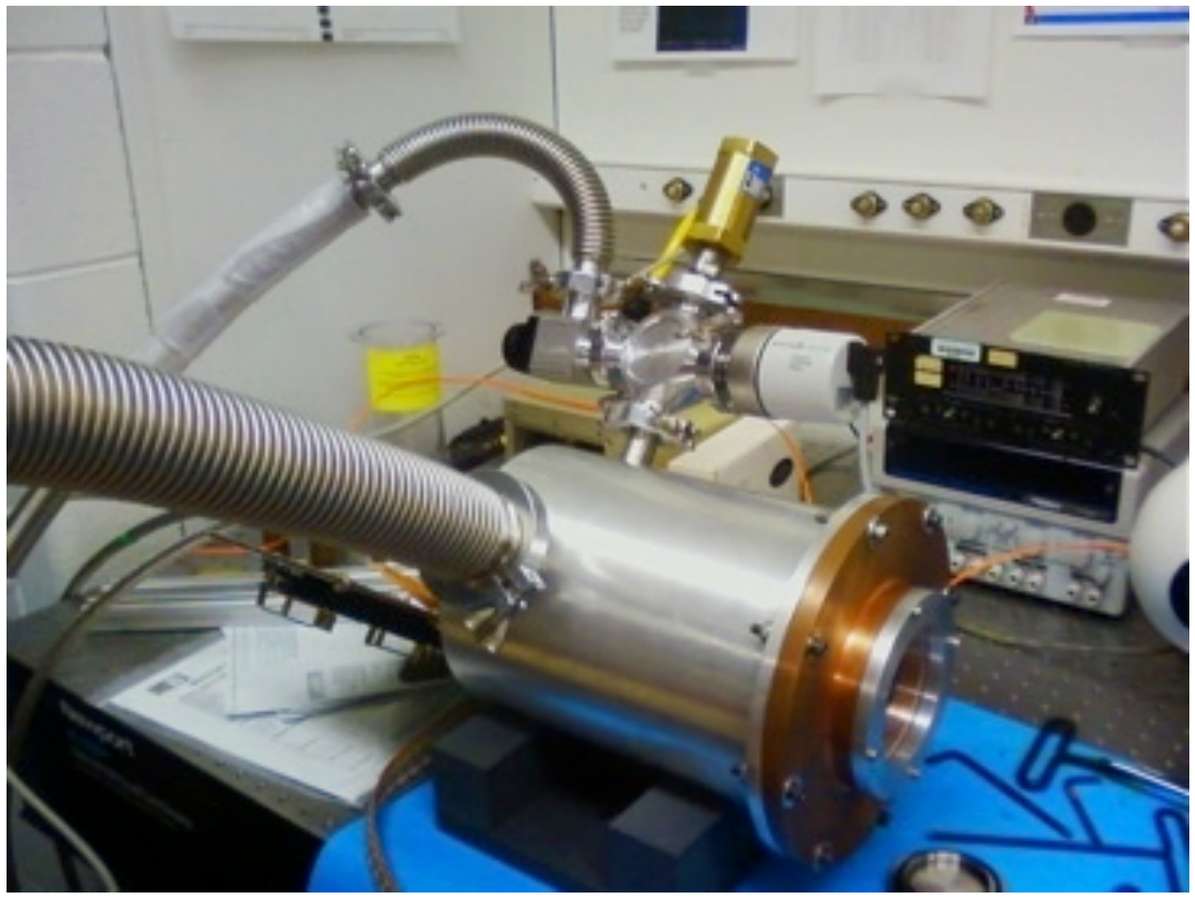
The Solution:

Precursor observations in the DES footprint prior to the start of the Survey, with a smaller (but similar) system...PreCam

PreCam

PreCam was constructed at Argonne, and consists of two 2k x 4k CCDs identical to those that will be used in the Dark Energy Survey, along with a pressure control system, cryogenics, and other hardware functionally similar to DES.

PreCam also provides a test of DES-style filters, readout electronics, and software infrastructure for instrument control, telemetry feedback, and survey strategy.

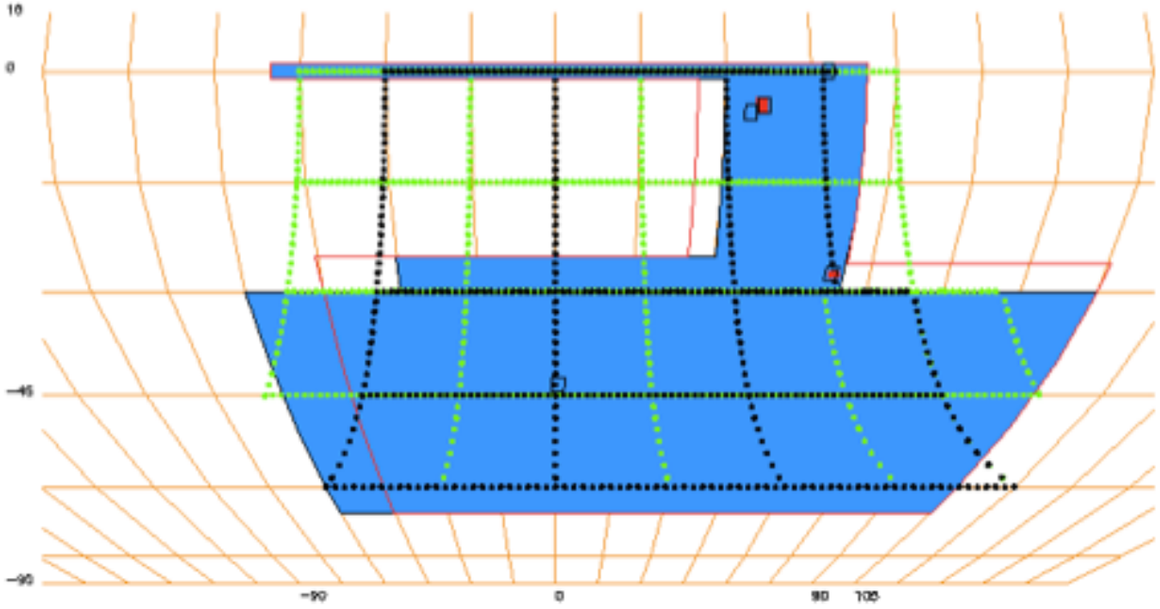


PreCam II

PreCam received 100 nights of observing time in 2010-2011 on the University of Michigan Curtis-Schmidt telescope at CTIO. Approximately 2/3 of that time was scheduled for science observing.

The larger pixel scale afforded by the Curtis-Schmidt allowed PreCam to observe nearly the same FoV as DECam, but to brighter magnitudes more suitable for standard stars.

Possible continuation of observations being discussed...

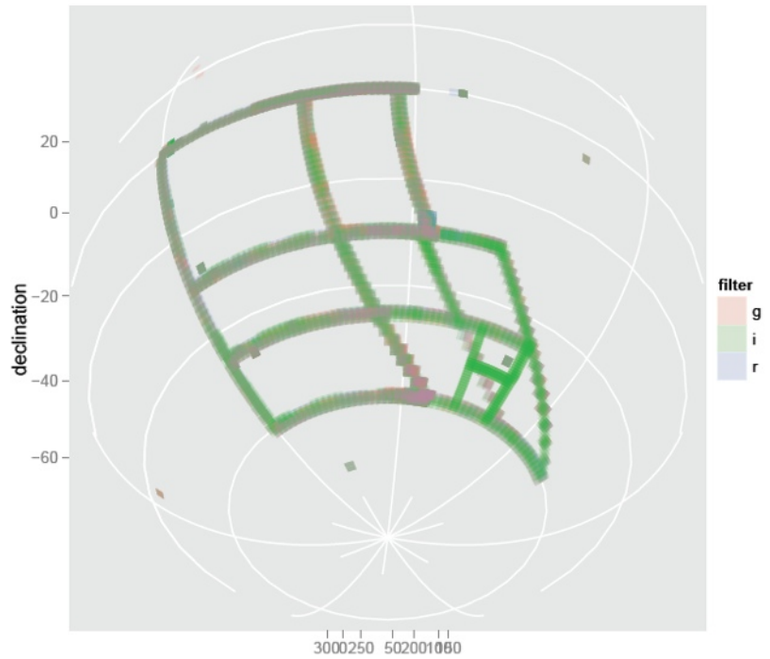


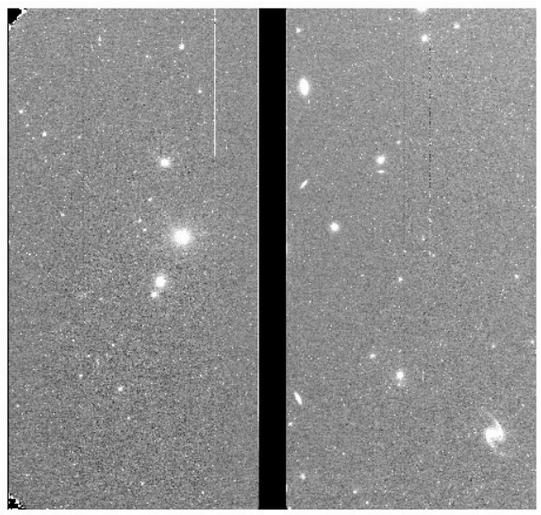
= DES footprint = PreCam "Sparse Grid"

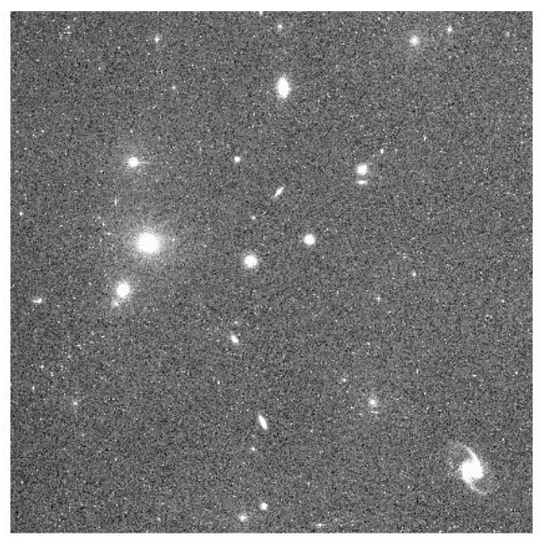
Band	PreCam Exposure Time [seconds]	PreCam saturation limit	DES saturation limit (100s exposure)	PreCam mag limit (S/N=50)	PreCam detection limit (S/N=5)	# Stars per sq deg, DES sat to PreCam S/N=50
(1)	(2)	(3)	(4)	(5)	(6)	(7)
g	36	12.8	16.3	17.8	20.9	186
r	51	13.2	16.3	17.8	20.7	265
i	65	13.4	16.2	17.7	20.5	344
z	162	14.1	16.0	17.5	20.1	317
y	73	11.6	14.3	15.8	18.5	150

PreCam Preliminary Results

PreCam acquired ~25000 images in a “sparse grid” observing pattern over the DES footprint, including 25 passes over SDSS Stripe 82 in grizY filters, and multiple passes in gri filters over the remainder of the footprint.

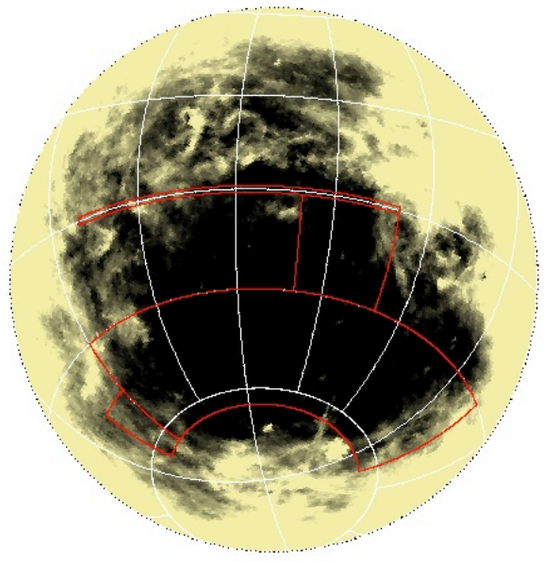






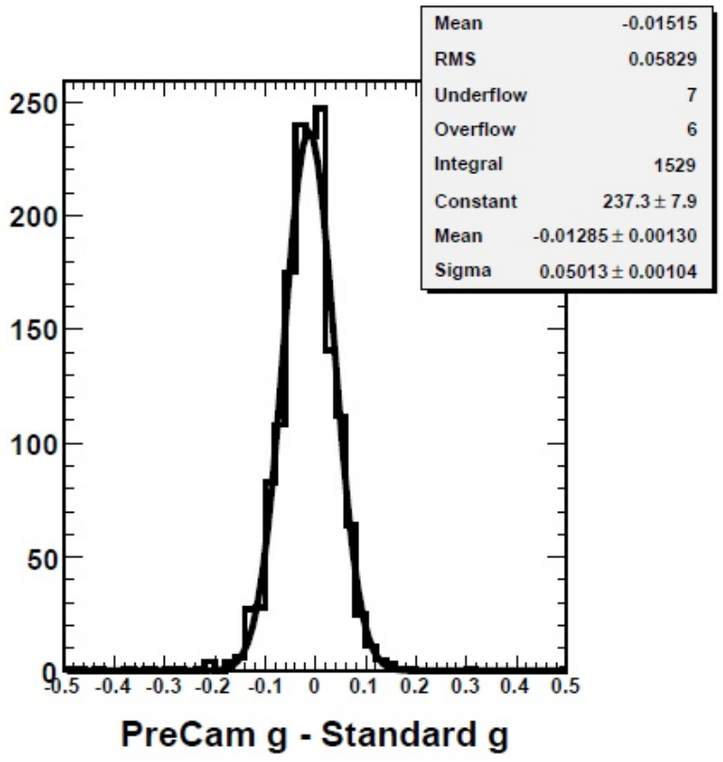
Previous Digital Sky Survey

Analysis of calibration and science data has begun at at Brazil, Fermilab, and Argonne. Goal is to define catalogs for astrometry and photometry, as well as to understand and mitigate any hardware, software, or other problems which could impact DES...



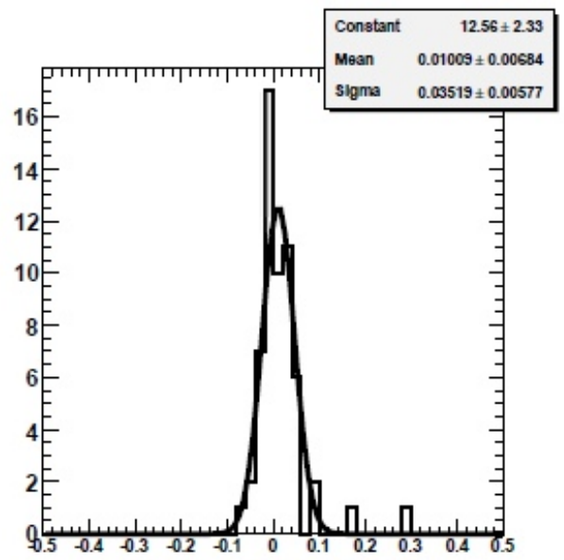
PreCam Preliminary Results II

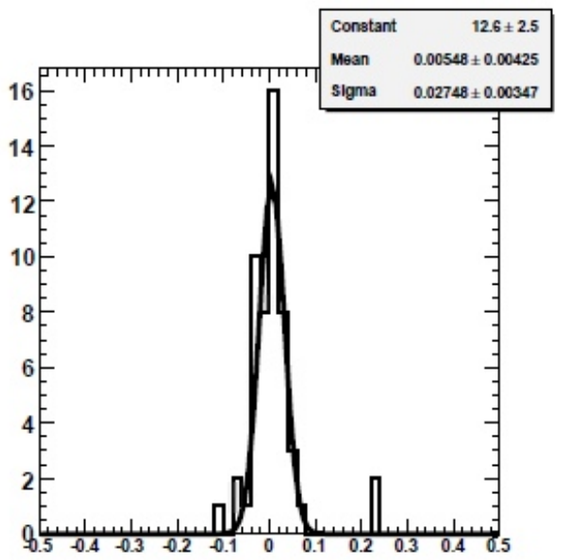
PreCam compared to SDSS Standards (Mag<16)

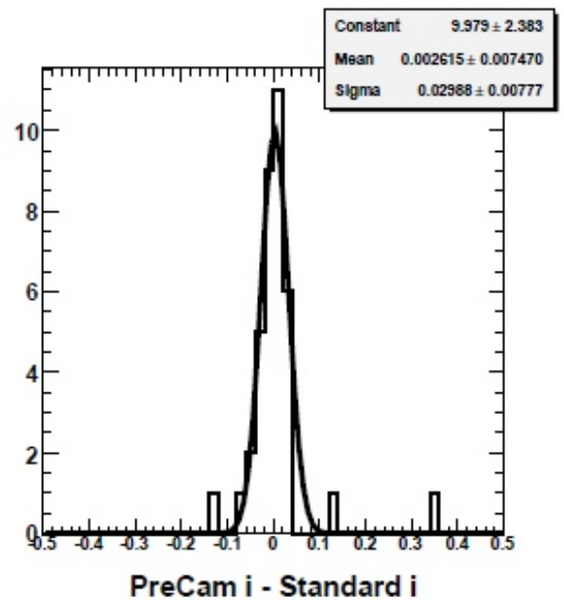


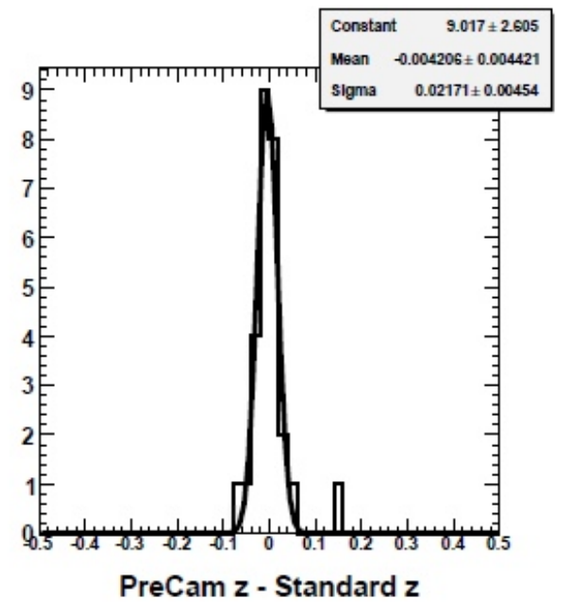
5% Sigma (4.8% with Illumination Correction)

PreCam compared to South Standards (Mag<14)









2-3.5% Sigma

Current DECam Status

DECam is currently (during the last week of September) being shipped from Fermilab to Cerro Tololo Inter-American Observatory. All camera hardware (with the exception of the optics) was previously assembled at Fermilab, and all control software is in functional form.

The Future of DECam and DES

Currently shipping; some components (e.g. f/8 handling system) already in place on the Blanco Telescope at Cerro Tololo

Installation of DECam components on Blanco from January 2011 to May 2012 (Shutdown of telescope starting in January 2012)

Commissioning of DECam May 2012 to July 2012

Preliminary observations (prior to Community Use) in August 2012

Survey officially begins in September 2012 (data proprietary for one year)

First year data release in late 2013/early 2014

3-year and 5-year (full) data releases follow

Expect a wealth of non-DE science for both DES and Community Users!

Final (expected) constraints on DE EoS of <10% for w_0 and of order 20% for w_a

The Goal:
From Survey Data to Dark Energy Constraints