Dark Energy Survey (DES)

Fermilab, University of Chicago, University of Illinois at Urbana-Champaign, Berkeley Lab, NOAO/CTIO, Spanish Consortium (IEEC, IFAE, CIEMAT), United Kingdom Consortium (University College London, University of Cambridge, University of Edinburgh, The University of Portsmouth Institute of Cosmology and Gravitation, University of Sussex), University of Michigan

The Dark Energy Survey (DES) Collaboration is an international project with the goal of carrying out a survey to determine the dark energy and dark matter densities and the dark-energy properties, parameterized with its equation of state, *w*, with great statistical precision (5%) through four independent techniques: redshift distribution and evolution of galaxy clusters, weak gravitational lensing on large scales, evolution of galaxy clustering, and type-Ia supernova distances. The four methods are sensitive to different combinations of cosmological parameters and are subject to different systematical uncertainties. Furthermore, combining these four techniques, it will be possible to separate the effect of dark energy on the geometry of the universe from the effect on the growth of structure, resulting in a robust and improved determination of the properties of the dark energy. The survey will image 5000 sq. deg in the southern sky and collect 300 million galaxies, 30000 galaxy clusters, and 2000 type-Ia supernovae. It will be carried out over a 5 year period using a new 3 sq. deg mosaic camera (DECam) mounted at the prime focus of the 4m Blanco telescope at CTIO in Chile.

SCIENCE PROGRAM

Dark Energy

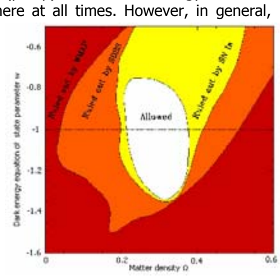
In 1998 observational evidence surfaced that the expansion of the universe is accelerating, even if gravitational attraction among ordinary matter restrains the expansion. The conclusion is that a mysterious form of energy, dubbed "dark energy," whose properties are basically unknown, is the dominant component of the universe at the current time, with about 70-75% of all mass-energy.

The main scientific aim of the collaboration is to determine the properties of the dark energy, by measuring the *w* parameter of its equation of state ($p=w\rho$). If the dark energy turns out to be Einstein's cosmological constant, then $w=-1$ everywhere at all times. However, in general, *w* will depend on cosmic time, or equivalently on redshift z:

$$w(z) = w_0 + w_a(1-a) = w_0 + w_a\frac{z}{1+z}$$

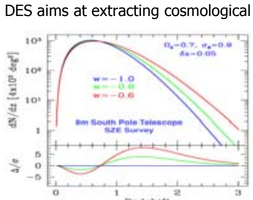
DES will measure three parameters:

- w_0 , the equation of state now
- w_a , which measures the rate of change of w
- Ω_Λ , the dark energy density normalized to the critical density



Techniques

DES aims at extracting cosmological information on dark energy from four cosmological probes:

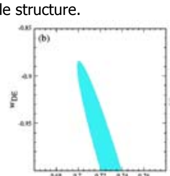


1) Galaxy cluster counting and spatial distribution of clusters to z=1.3.

DES will make a detailed optical measurement of galaxy clusters, including photometric redshifts, in conjunction with the South Pole Telescope (SPT) survey that will detect clusters through the Sunyaev-Zel'dovich effect.

2) Weak gravitational lensing

DES will measure shapes and photometric redshifts for 300 million galaxies and enable accurate measurement of lensing by large-scale structure.



3) Galaxy angular clustering

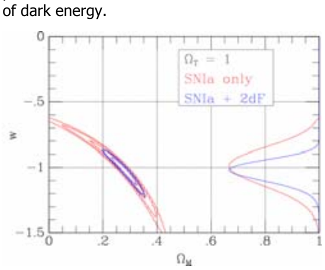
DES will measure the angular clustering of galaxies in photometric redshift shells out to z~1.1. This will provide cosmological information from the shape of the power spectrum transfer function and the distance to each redshift shell.

4) Hubble diagram for type-Ia SNe

Type-Ia SNe can be turned into cosmological standard candles through the relationship between their duration and luminosity. From ground-based telescopes, type-Ia SNe can provide luminosity distances up to redshifts around 1, with about 7% precision. The Hubble diagram (distance vs. redshift) measures the history of the expansion rate of the universe, which depends on the dark energy properties.

Type-Ia Supernova

In 1998, usage of low- and high-redshift type-Ia supernovae (SNe) as precision distance indicators provided the first direct evidence for the accelerating expansion of the Universe, and the existence of dark energy.



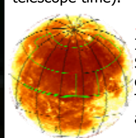
DES will use 10% of its allocated time to discover and measure well-sampled *r*, *i* and *z* light curves for about 2000 type-Ia supernovae in the redshift range 0.3<z<0.75 through repeat imaging of a 40 sq. deg. region. These SNe will provide relative distance estimates to constrain the properties of the dark energy

Assuming flat cosmology, plot of projected constraints from the DES sample of 1900 SNe Ia at redshifts from z=0.25 to 0.75 (red) and combined with current galaxy power spectrum measurements (blue). Right-hand curves marginalize over Ω_M. Follow-up spectroscopy assumed for a portion of the SN sample.

INSTRUMENT DESIGN

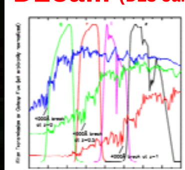
Instrument

DECam will be placed in the Blanco 4-meter telescope at Cerro Tololo Inter-American Observatory (CTIO) in Chile. The DES collaboration will use this instrument as a survey instrument during 525 nights between Oct. and Feb. during the years 2010 to 2014 (30% of the telescope time).

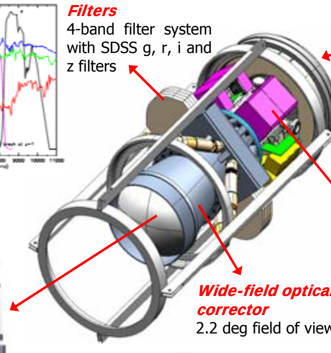


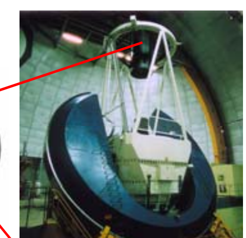
Survey
It will cover 5000 sq. deg. of the South Galactic Cap. 4000 sq. deg. overlapping with the South Pole Telescope Sunyaev-Zel'dovich survey and 200 sq. deg. with SDSS Stripe 82.

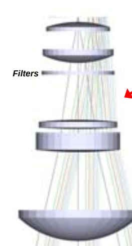
DECam (DES Camera)



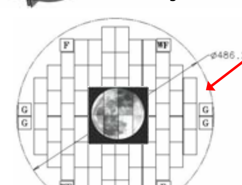
Filters
4-band filter system with SDSS g, r, i and z filters

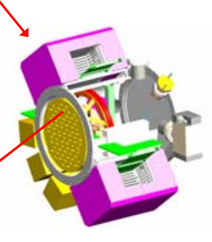






Wide-field optical corrector
2.2 deg field of view





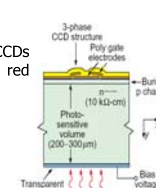
Focal plane
- 62 2Kx4K Image CCDs (0.27"/pixel)
- 8 2Kx2K CCDs for guiding, focus and lateral alignment

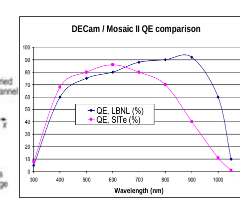
DES CCD vessel
- 520 Mpixel optical CCD camera (3 sq. deg.)
- Low-noise CCD readout (<10 e-)
- Cryogenic cooling system (160 K)
- data acquisition and control system to connect to the Blanco observatory infrastructure.

CCDs

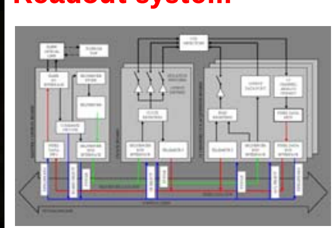
A key component of the project are the CCDs developed by LBNL, more sensitive to red light.

QE> 50% in z-band (825-1100 nm)
250 μm thick, fully depleted
15μm pixels, 0.27"/pixel
2 readout channels/device
readout time ~17sec (<10e- readout noise)





Readout system



- Based on Monsoon system developed by NOAO
- Consists of 3 Boards:
  - Master Control Board (MCB)
  - Clock & Bias Board (CBB)
  - Data Acquisition Board (ACQ)
- DES modifications include high-density ACQ (12 channels) and a simplified CBB
- Will be housed in three thermally controlled crates
  - Constant interior temperature for stable electrical performance
  - Ambient temperature will be tracked during night to avoid thermal plumes

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http://www.darkenergysurvey.org