



The Dark Energy Survey

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Evidence for dark energy is two-fold

- 1. Accelerated expansion of the Universe, measured from supernovae type Ia (SN Cosmology Project, High-z SN project).
- 2. Universe is ~= flat (CMB) but matter content is ~27% (LSS).



Credit : Perlmutter 2003

Credit :NASA / WMAP



There are several ways to explain dark energy

- 1. Additional unknown stress-energy component with *negative* pressure.
- 2. Break-down of general relativity at large distances.
- 3. Assumptions not valid (homogeneity)

$$R_{\mu\nu} - \frac{1}{2}g_{\mu\nu} R + g_{\mu\nu}\Lambda = \frac{8\pi G}{c^4}T_{\mu\nu}$$

Early 2000's **INVESTIGATE NATURE** (w=const? w≠-1) Dark Energy Task Force: four preferred observation types



The inevitable collaboration slide

Dark Energy Survey

 (\mathbf{E})

A M

120+ scientists

20+ institutions

... is an international project to measure the dark energy equation of state (nature). This effort is led by Joshua Frieman (Fermilab). Fermilab, UIUC/NCSA, University of Chicago, LBNL, NOAO, University of Michigan, University of Pennsylvania, Argonne National Laboratory, Ohio State University, Santa-Cruz/SLAC/ Stanford Consortium, Texas A&M University

K Consortium:

UCL, Cambridge, Edinburgh, Portsmouth, Sussex, Nottingham Universitäts-Sternwarte München

Spain Consortium: CIEMAT, ICE (IEEC/CSIC), IFAE

Brazil Consortium:

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

CTIO





DES in a nutshell

- Survey project using 4 complementary techniques:
 - I. Cluster Counts
 - II. Weak Lensing
 - III. Large-scale Structure
 - IV. Supernovae
- Two multiband (photometric) surveys:
 5000 deg² grizY to 24th mag AB griz
 10 deg² repeat (Sne)
- Build new 3 deg² FOV multi-CCD camera, Data management system, improve Blanco facilities





Survey strategy combines calibration, overlaps, SN regions in 5 filters for 5 years





Ciemot **DECam** is the instrument to carry out the survey from the primary focus



7/23



The detector system consists of a 520 Mpixel camera with 62+ red-sensitive CCDs



DECam with science-grade CCDs installed



DECam CCD's quantum efficiency (in blue)





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



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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

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The path to first light



Mini-survey/science acceptance: 4/2012 – Survey : 9/2012





Current status of DECam at CTIO



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Data management of O(PB) data will be carried out by NCSA





Pipeline is tested through the data challenge process as in a particle physics project



Produce cosmological simulations

Process through atmosphere, detectors, include 'nasty' stuff





Science Working Groups study the quality of data through these Data Challenges (~200 sq.deg.)





Science Working Groups study the quality of their analysis pipelines through Blind Cosmology Challenges (~5000 sq.deg.).



(new simulations with more DES-like systematics coming up by Stanford team)

EPS-HEP2011 DES I.Sevilla

22/07/2011



DES Science: 4 probes of Dark Energy

Supernovae la



Baryon Acoustic Oscillations



Cluster density



Weak lensing



Much more!: galaxy evolution, strong lensing, QSOs...

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Supernovae la



'Mature', photometric id and redshifts

Strategy: geometry probe

- Obtain light curves + calibrate: shape in different bands relates to luminosity.
- Luminosity + app. magnitude + redshift,

$$\chi^2 = \sum_{objects} \frac{(\mu - 5\log(d_L(z;\theta,w))/10pc)^2}{\sigma^2}$$

• Measure reapetedly same area, photometry for id and redshift

DES:

• Measure ~1200 SN photometrically, up to z=~1 (assuming deep survey)

• 10+% of the survey time will be devoted to SN search revisiting an area of 10 sq.deg. (assuming deep survey)

• Photometric errors will be addressed w/ onsite measurements of photometry, spectroscopic follow-ups.

Systematics: dust, evolution, calibration...

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Cluster density

Strategy: structure and geometry probe

• Obtain number count of galaxy clusters per unit volume.

• Combine counts with cluster mass predictions (theory) + selection function + observable-mass relationship.

DES:

- Measure ~1.7e5 rich clusters w/ M>5e13M_sun up to z~1.5
- Mass using partnership with South Polar Telescope (using Sunyaev-Zeldovich effect)

Systematics: observable-mass relation, completeness and purity of cluster sample



Very sensitive, mass uncertainty, untested for cosmology

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Weak lensing





Strategy: structure and geometry probe

• Statistical measurement of distortions of background objects created by intervening matter (shear-shear) in redshift shells.

- Foreground galaxy cross-correlations with shear (galaxy-shear).
- It means measuring shapes and redshifts.

DES:

- Shapes of ~3e8 galaxies.
- PSF < 0.9" FWHM

Systematics: photo-z's, PSF anisotropy, shear calibration

Theoretically well-founded, instrumental systematics





Baryon Acoustic Oscillations

Strategy: distance probe

- CMB provides scale of acoustic peak.
- Search for this peak in angular two-point correlation function of galaxies in redshift shells.
- This gives an estimation of the expansion history.
- Measure a huge amount of galaxies in a large area and volume.

DES:

- Correlation function of ~3e8 galaxies up to z~1.5.
- Probe larger volume and redshift range than current state-of-the-art

Systematics: photo-z's, projection effects, non-linear evolution, galaxy-mass relationship (bias).



Robust, weakest constraints

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Expected performance

Assumptions:

- statistical+photo-z systematic errors only
- spatial curvature, galaxy bias marginalized
- Planck CMB prior
- Factor 4.6 improvement over Stage II
- Deep systematics study









• The **Dark Energy Survey** is an international project to characterize the dark energy equation state ($\sigma(w_0)=6\%$ and $\sigma(w_a)=21\%$).

• This is will be done building a **wide field imaging camera at the Blanco telescope** to simultaneously use the four probes recommended by the DETF: **supernovae; cluster density; weak lensing tomography; baryon acoustic oscillations**.

• A big effort is going into **understanding the systematics** from astrophysical effects.

- Huge legacy value, valuable facility instrument for the community.
- Survey to start scientific operations in September 2012, for five years, but camera will be installed and **first scientific data will be produced in the next few months**.

www.darkenegysurvey.org





Backup slides





The survey uses 5 large filters covering the 400 – 1000 nm range







The survey uses 5 large filters covering the 400 – 1000 nm range + 3 IR filters





The survey will be conducted in tilings: 2/year/filter

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105 nights/year in Sep-Apr; rest of the time is a facility instrument Filters -> photo-z = 0.05(1+z) precision





Forecast from white paper

Table 1: Example forecast marginalized 68% CL statistical DES constraints on constant equation of state parameter w.

Method/Prior	Uniform	WMAP	Planck
Clusters:			
abundance	0.13	0.10	0.04
w/ WL mass calibration	0.09	0.08	0.02
Weak Lensing:			
Shear-shear (S-S)	0.15	0.05	0.04
Galaxy-shear(G-S)+G-G	0.08	0.05	0.03
S-S+G-S+G-G	0.03	0.03	0.02
S-S+bispectrum	0.07	0.03	0.03
Galaxy angular clustering	0.36	0.20	0.11
Supernovae Ia	0.34	0.15	0.04

Assuming CDM, negligible neutrino masses, adiabatic Gaussian primordial perturbations w/ power law spectrum, flat Universe.





Syst. errors from white paper

Table 2: Dominant sources of systematic error and methods for controlling them; see text.

Method	Dominant Systematic Errors	Primary Controls	
Clusters	Sample selection	SZE + optical cluster selection; simulations	
	Mass-observable relation	Self-calibration; statistical WL masses	
	Multiplicative shear	Measurement algorithm; shear vs. gal. size	
	Additive shear	PCA; active focus; wave-front sensing &	
Weak Lensing		alignment control	
	Photo-z biases	Spectroscopic calibration sets	
	Small-scale power spectrum	Null small-scale power; high-res. simulations	
Angular clustering	Bias prescription errors	Angular bispectrum; clustering by type	
	Large-scale photometric	Calibration strategy; clustering by color;	
	calibration errors	angular sub samples	
	Photo-z biases	Spectroscopic calibration sets	
Supernovae Ia	SN evolution	Low and high z SNe comparison	
	Photometric errors	Calibration strategy; artificial SNe	
	Extinction	SN color and host galaxy information	
	Photo-z errors & biases	SN spectroscopic calib. sub sample	







Chosen to maximize:

- visibility from DES site
- past observation history
- visibility from, e.g., Hawaii

Chandra Deep Field – South Sloan Stripe 82 SN Legacy Survey (SNLS) D1 XMM-Newton LSS ELAIS S1

From a study by Peter Nugent





DES Science organization

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- Ofer Lahav chairs the DES Science Committee
- DES Science Working groups
 - Large scale Structure (Enrique Gaztañaga and Will Percival)
 - Clusters (Joe Mohr and Chris Miller)
 - Weak Lensing (Sarah Bridle and Bhuv Jain)
 - Supernovae (Masao Sako and Bob Nichol)
 - Simulations (Gus Evrard and Andrey Kravtsov)
 - Photoz (Francisco Castander and Huan Lin)
- Ancillary (not aimed at DE) science study groups
 - Galaxy Formation & Evolution
 - Strong Gravitational Lensing
 - QSOs
 - Galactic (Milky Way) Archeology
 - Combined Probes & Theory





PreCam uses 2 scientific grade CCDs as a testbed for DECam and calibration purposes



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Mini-survey for two weeks for camera and data management validation: first science!

Perform full-depth observations in 100 sq.deg.

Area is off main survey

Overlap existing datasets when possible

Run acceptance tests on data