The Dark Energy Survey

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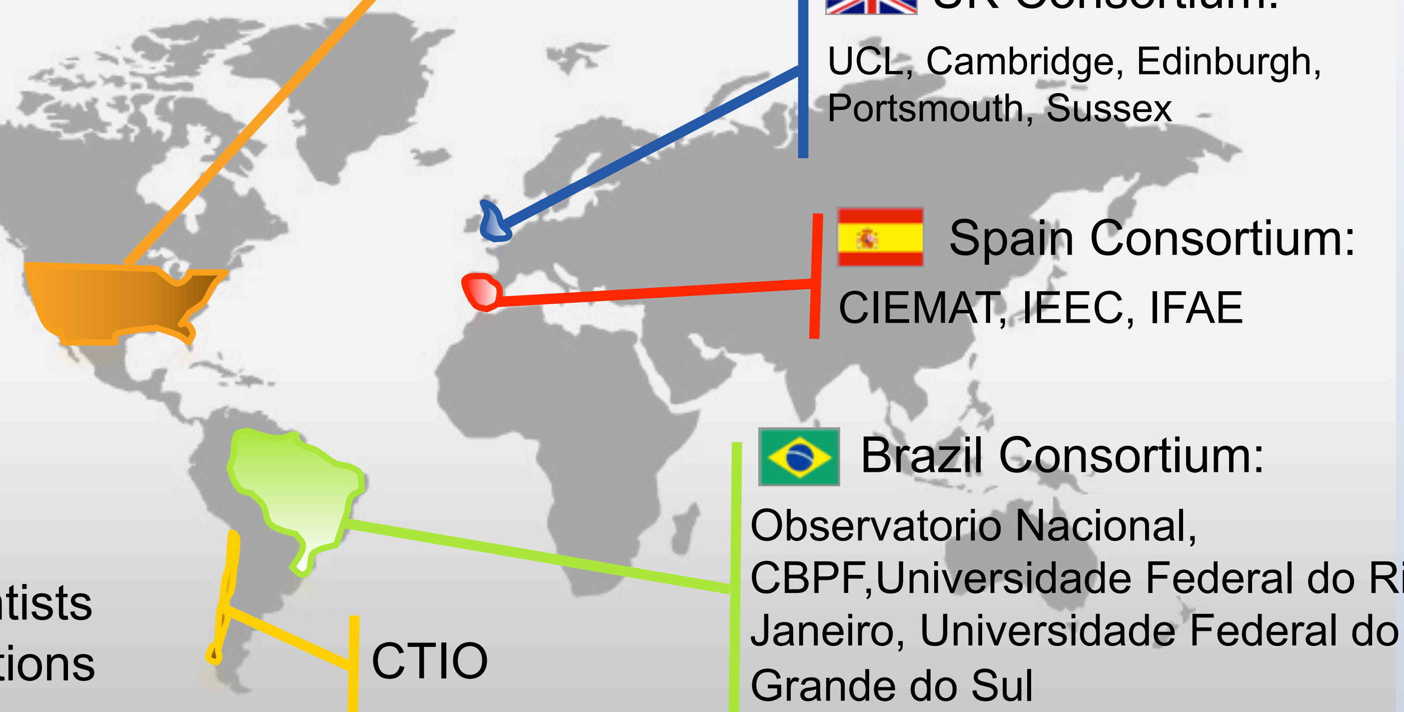
CIEMAT
on behalf of the DES Collaboration

The inevitable collaboration slide

Dark Energy Survey

… is an international project to narrow down the dark energy equation of state (nature). This effort is led by John Peoples (Fermilab).

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



UK Consortium:

UCL, Cambridge, Edinburgh, Portsmouth, Sussex

Spain Consortium:

CIEMAT, IEEC, IFAE

Brazil Consortium:

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

100+ scientists
12+ institutions

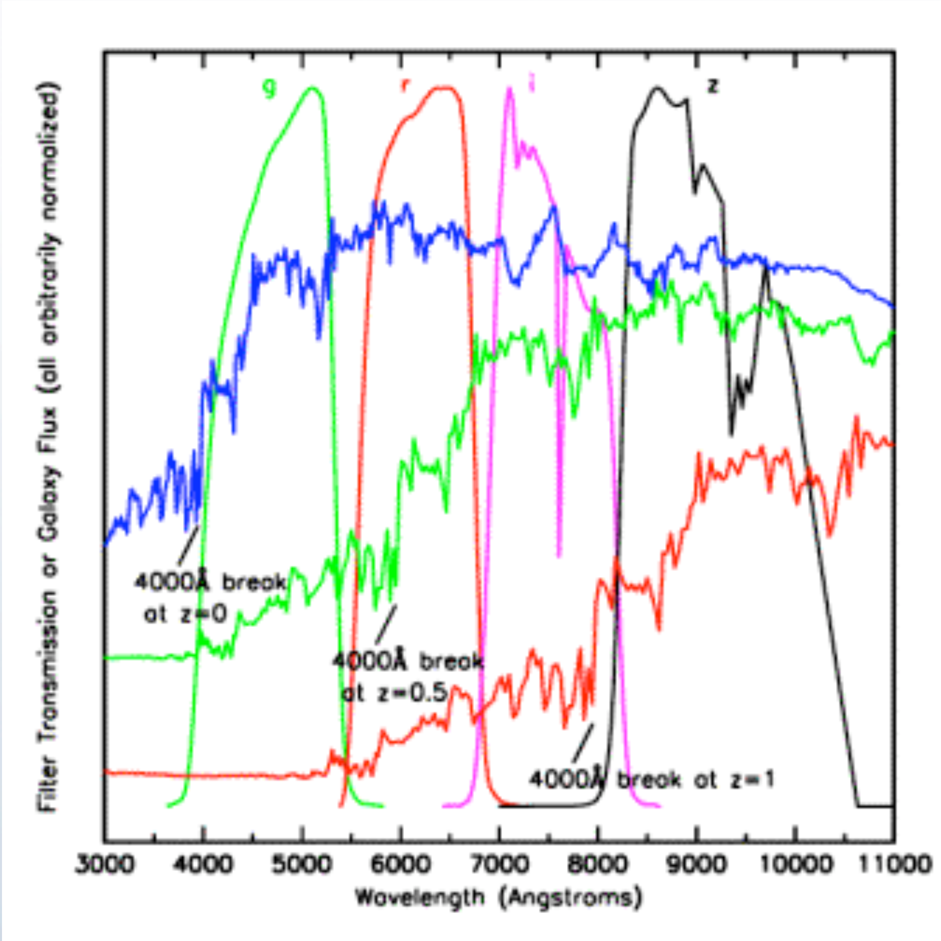
CTIO

Introduction

Dark Energy Survey

… is a project to narrow down the nature of dark energy.

… How? Building an **imaging wide-field camera** and conducting a multi-bandpass **photometric survey** of the southern sky (DETF four probes)



62-CCD mosaic image simulation

The scientific case

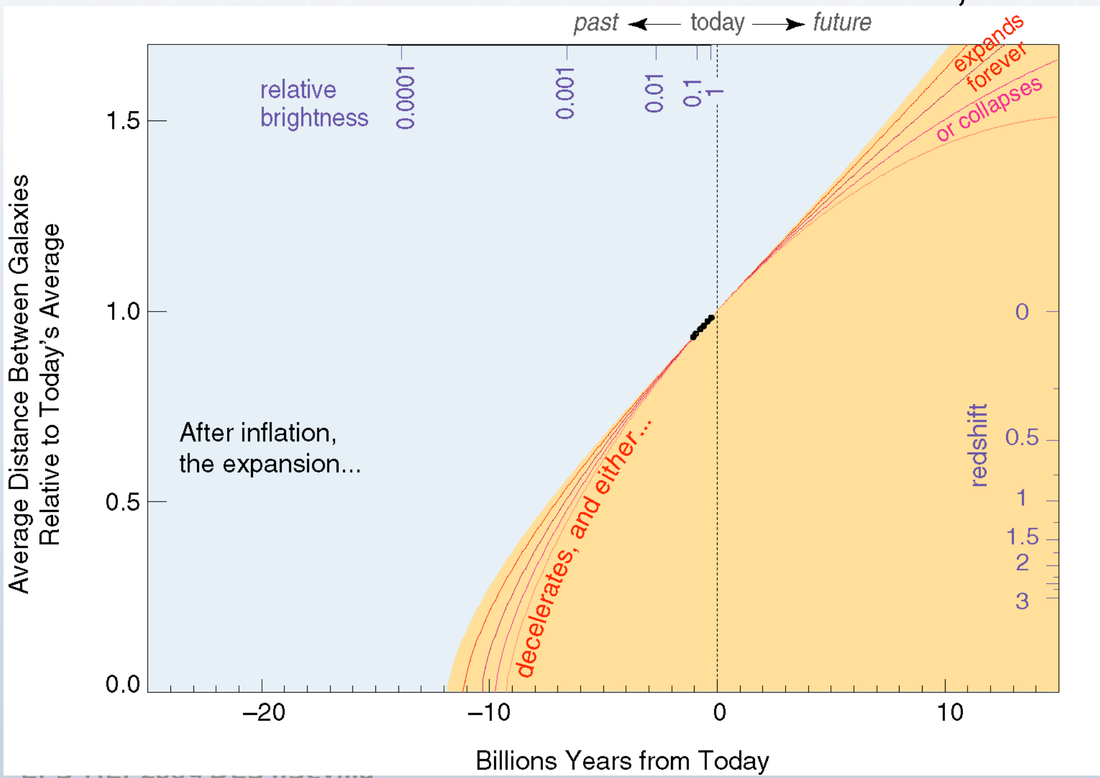
Evidence for dark energy is two-fold:

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).

This leads to two possibilities:

1. Additional unknown stress energy component with *negative* pressure.
2. Break-down of general relativity at large distances.

Perlmutter, 2003



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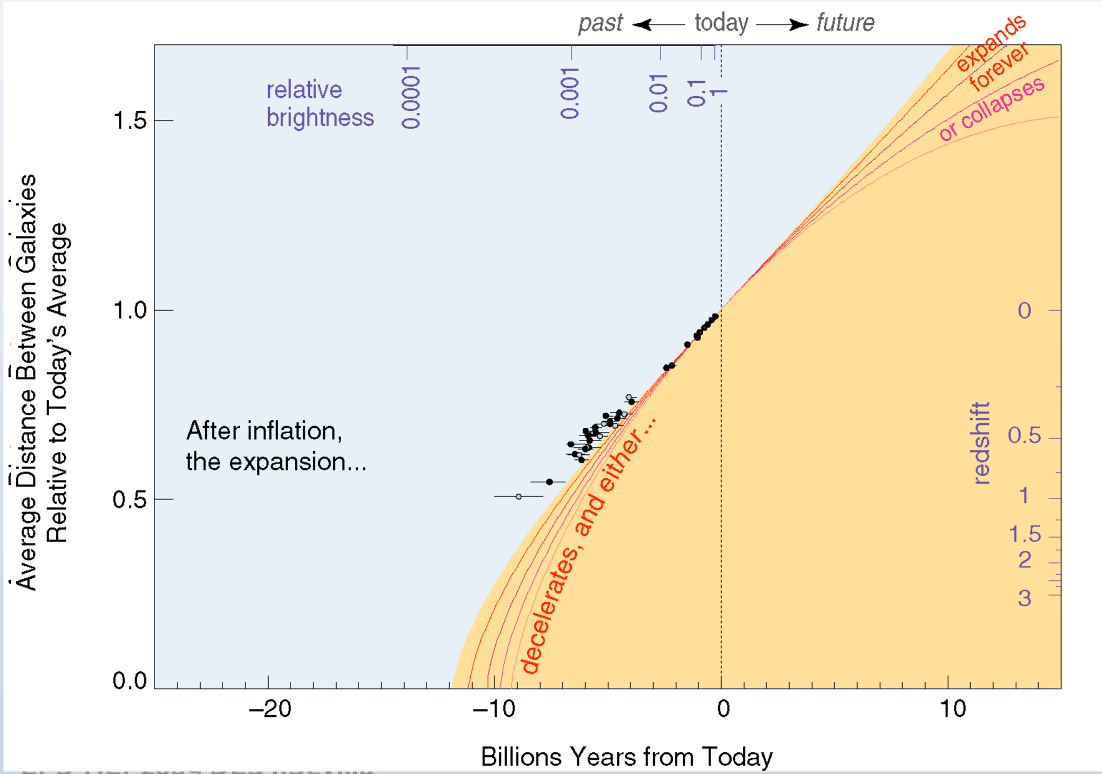

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Describing Dark Energy

A phenomenological way to parametrize dark energy properties:

Equation of state: w = p/ρ (Turner,White 1997)

Linder 2003 parametrization: $w = w_0 + w_a z/(1+z)$

Main features to be tested: is w=-1? dw/dz=0?.

$\omega_X = p_X/\rho_X$

From M. Turner astro-ph/010810[illegible]

Candidate	ω	$d\omega/dz$
Cosmological Constant	-1	0
Rolling Scalar Field (Quintessence)	$-1 \to 1$	$\frac{1/2\dot{\phi}^2 - V(\phi)}{1/2\dot{\phi}^2 + V(\phi)}$
False Vacuum State	-1	~ 0
Topological Defects (N=1 strings...)	-N/3	~ 0
Others	?	?

Many proposals for its nature: progress will likely come from improvement in observational constraints using different probes.

Currently: **σ(w) ~ 0.07 all experiments <u>combined</u>**; $w < -0.85$ (95%) (assuming ct. w)

DETF has identified four probes as most promising if used in combination. These require large, deep surveys.

The instrument

525 nights available during 5 years, at CTIO Blanco 4m (Chile)

5000 sq.deg coverage (1/8 celestial sphere) in grizY filters.

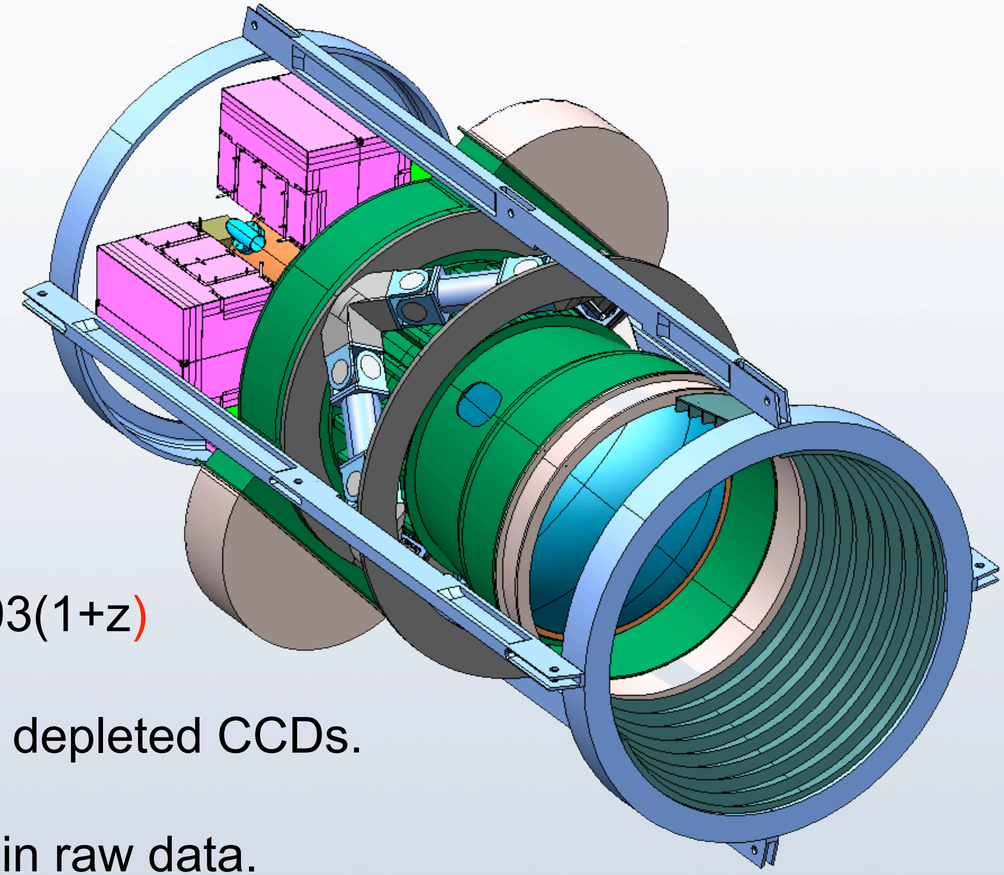
Magnitude limit is ~24 in each of the bands (10σ detections)

Photometric redshift error: $\sigma(z) = 0.03(1+z)$

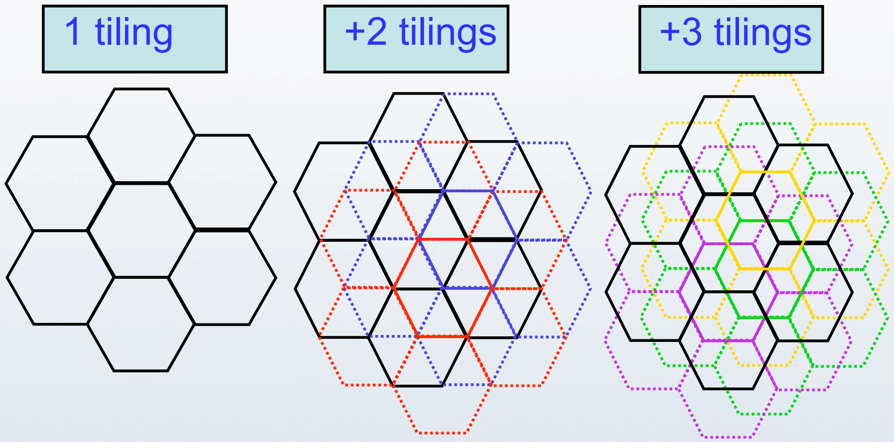
Camera uses 520 Mpixel, thick, fully depleted CCDs.

Total DES Survey will be O(PBytes) in raw data.

Four probes: Supernovae, cluster counts, weak lensing tomography, galaxy power spectrum.

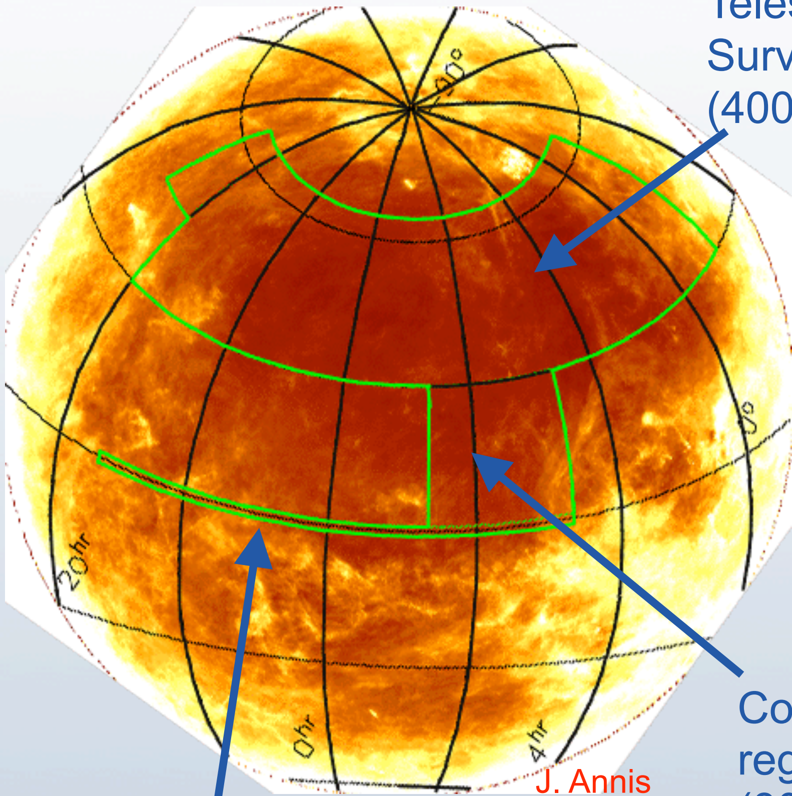


The survey



- DES “tiles” 5000 deg^2 of sky at a rate of 2 times per year in each of 4 filters, constraints on DE possible after two years

Survey Area

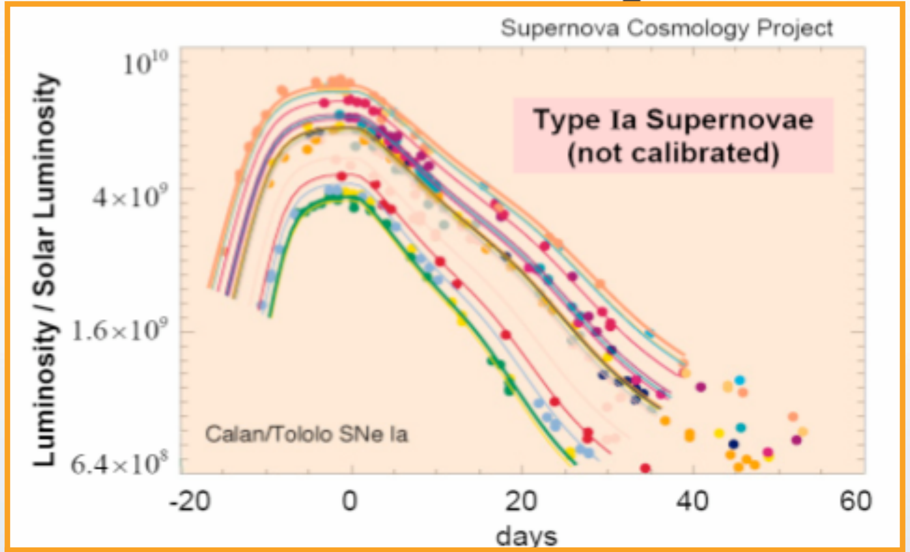


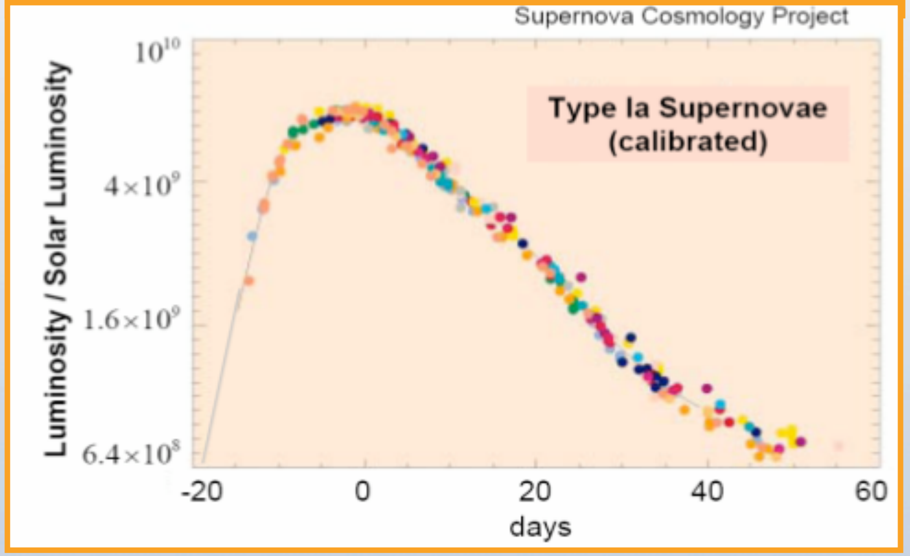
Overlap with South Pole Telescope Survey (4000 sq deg)

Connector region (800 sq deg)

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

Supernovae Ia





Strategy: distance probe

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

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

DES:

- Measure ~2000 SN photometrically, up to z=~1.
- Large sample and improved z-band response
- 10% of the survey time will be devoted to SN search revisiting an area of 40 sq.deg.
- Photometric errors will be addressed w/ on-site measurements of photometry, spectroscopic follow-ups.

Systematics: dust, evolution, calibration…

Very 'mature', photometric redshifts

Cluster density

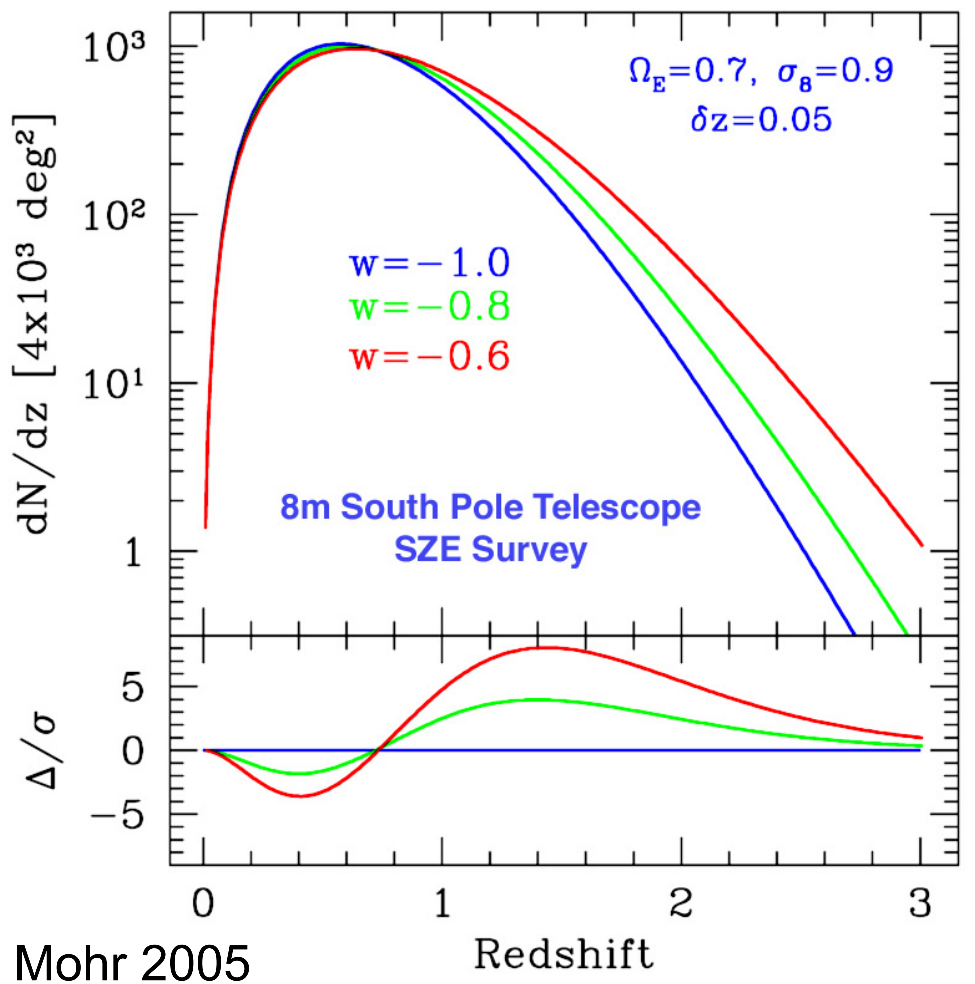
Strategy: structure probe

• Obtain number count of galaxy clusters per unit volume.
• counts + cluster mass predictions + redshift:

$$\frac{d^2N}{dz d\Omega} = \frac{c}{H(z;\theta,w)} D_A^2 (1+z)^2 \int_0^\infty f(O,z)dO \int_0^\infty p(O \mid M,z) \frac{dn}{dM}(z;\theta)dM$$

DES:
• Measure ~20000 clusters up to z~1.3
• Identification using partnership with South Polar Telescope (using Sunyaev-Zeldovich effect).

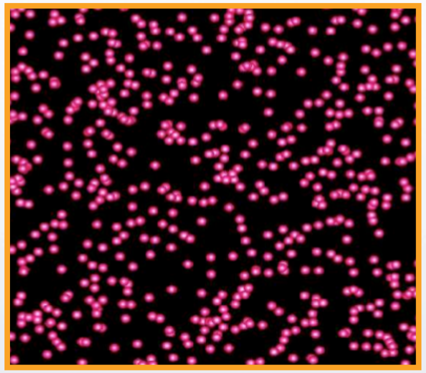
Systematics: observable-mass relation, photometric redshift, completeness and purity of cluster sample…

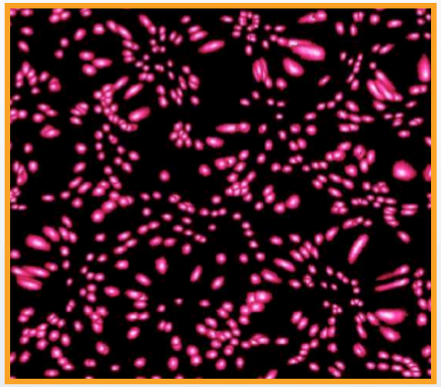


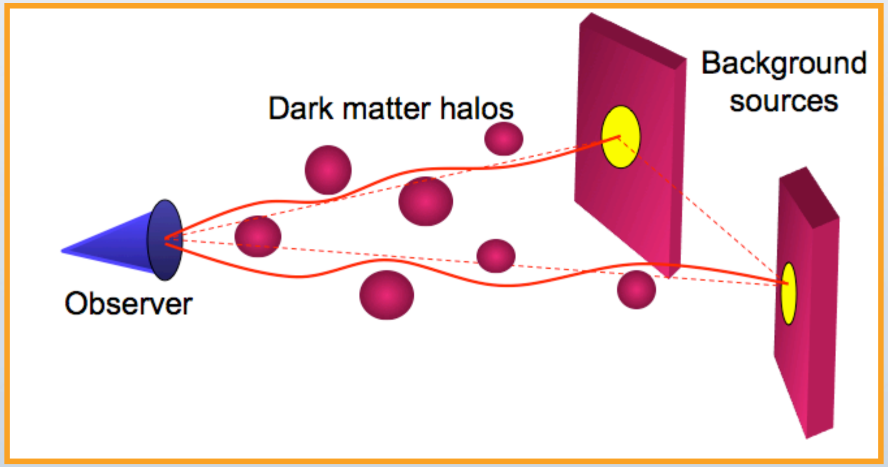
Mohr 2005

Very sensitive, systematics, untested

Weak lensing







Strategy: structure probe

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

• Foreground galaxy cross-correlations with shear (galaxy-shear).

•Shear angular power spectrum as function of redshift:

$$P_l(z_s) = \int_0^{z_s} \frac{H(z)}{D_A^2(z)} \left|W(z,z_s)\right| P(k;z)\,dz$$

• 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, untested

Galaxy angular clustering

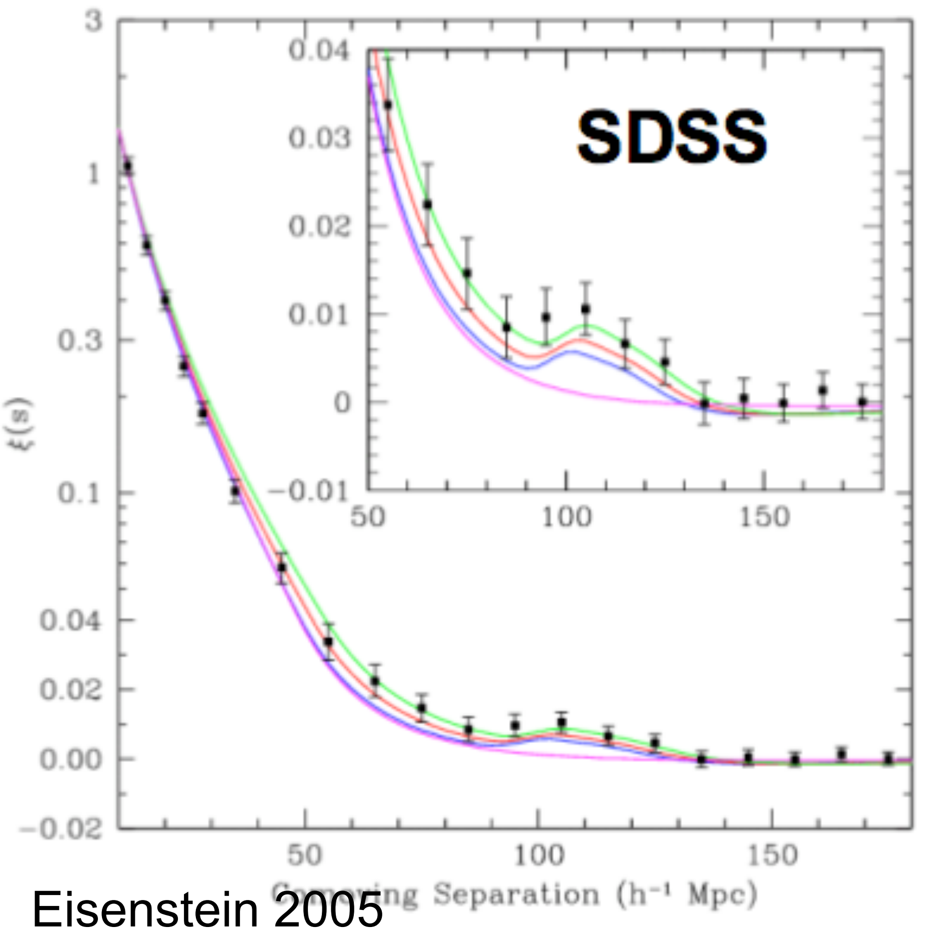
Strategy: distance probe

• CMB provides scale of acoustic peak.
• Search for this peak in angular two-point correlation function of galaxies (of a certain type) in redshift shells.
• This gives an estimation of the expansion history.

DES:
• Power spectrum of ~3e8 galaxies up to z~1.5.
• Probe larger volume and redshift range than current state-of-the-art (SDSS)

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

Simple, weakest constraints



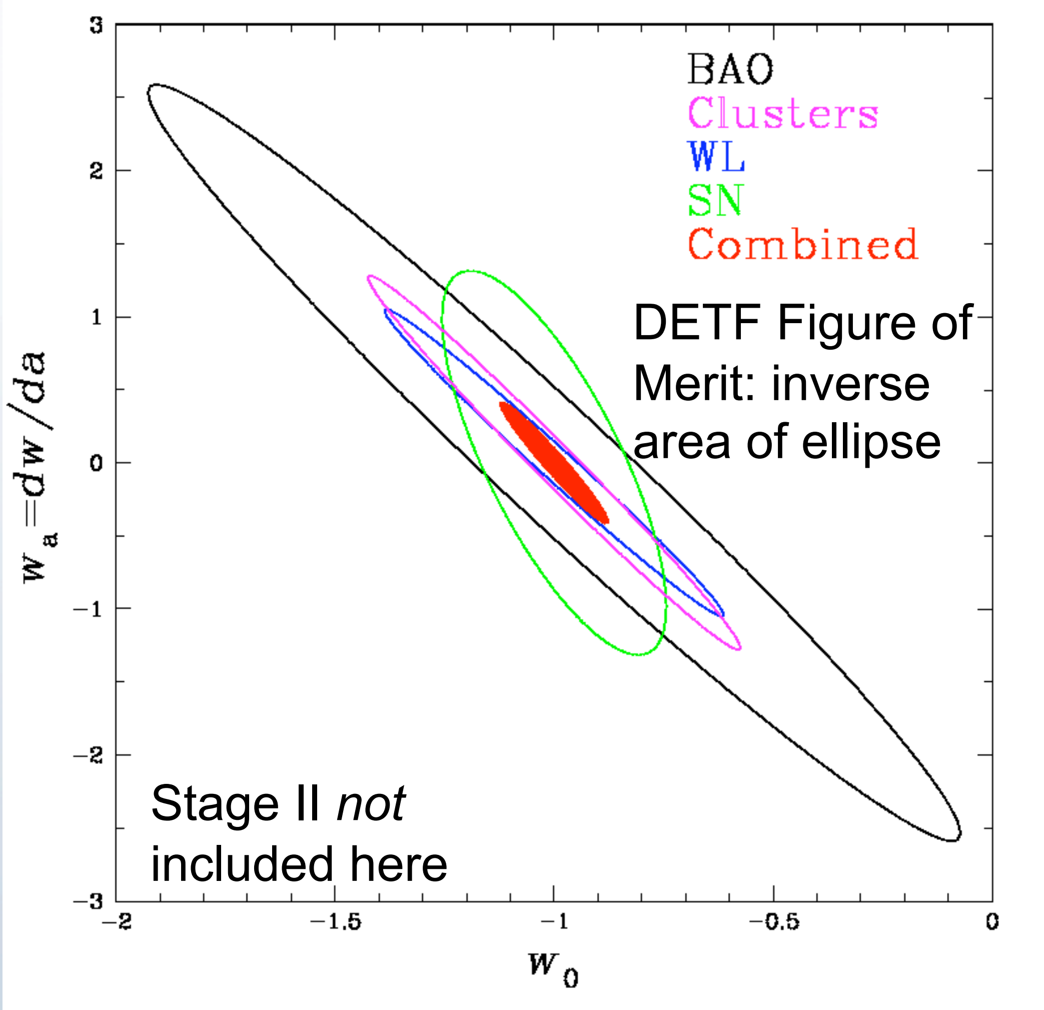
Eisenstein 2005

Expected performance

Assumptions:

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

$w(z) = w_0 + w_a(1-a)$ 68% CL



Summary

- The **Dark Energy Survey** has been constituted as a short-term project to tackle the problem of the **nature of dark energy**, before other larger efforts farther into the future.

- This is will be done building a **wide field camera** to simultaneously use the four probes recommended by the DETF: **supernovae; cluster counting; weak lensing tomography; angular power spectrum of galaxies**. This allows for intrumental systematics control.

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

- The expected errors, considering statistical and photometric redshift errors only, $\sigma(z)=5\%$ and $\sigma(dw/dz)=15\%$.

- Survey on-schedule to start scientific operations in September 2011, for five years.

Backup slides

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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.

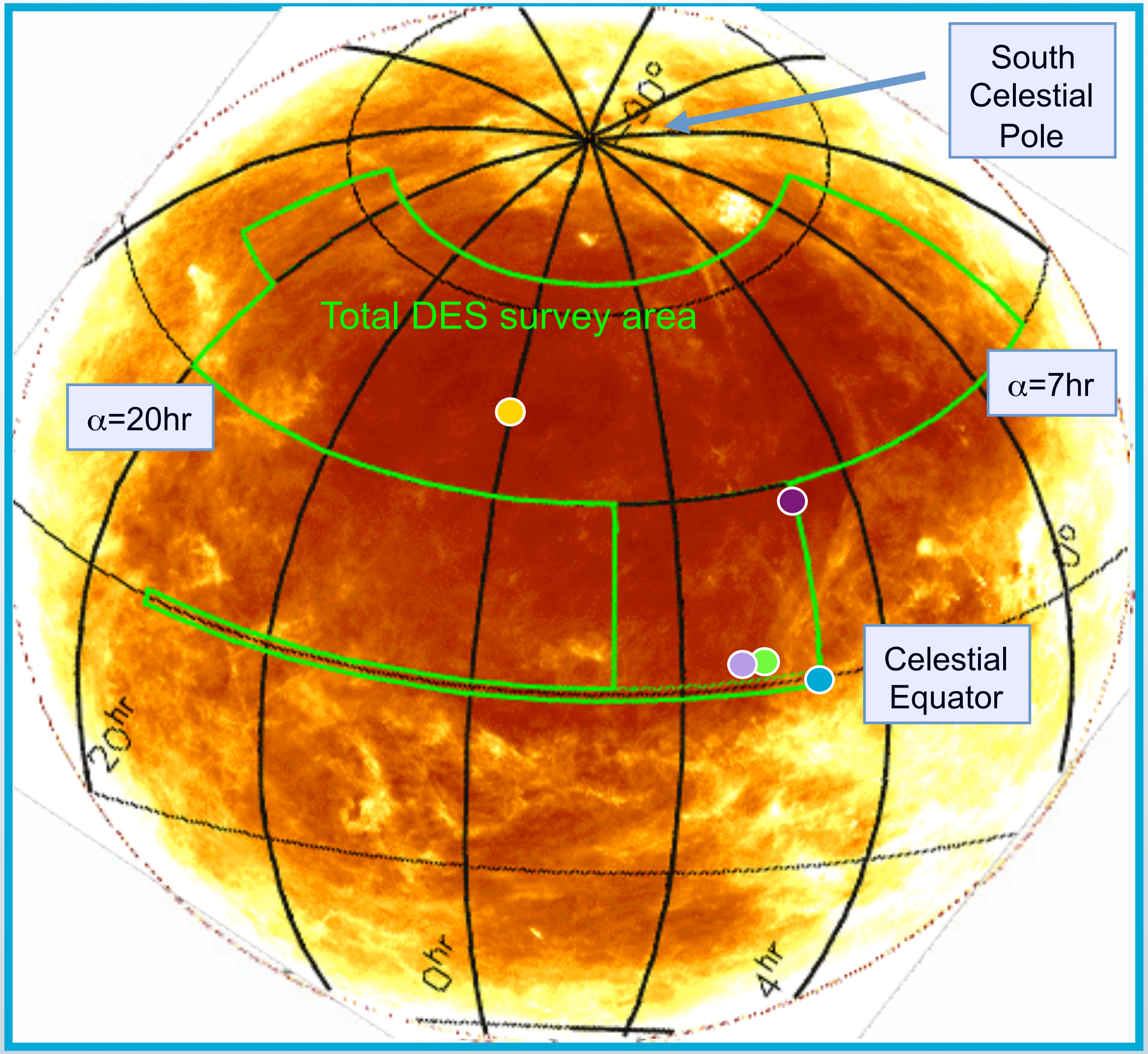
Method	Dominant Systematic Errors	Primary Controls
Clusters	Sample selection Mass-observable relation	SZE + optical cluster selection; simulations Self-calibration; statistical WL masses
Weak Lensing	Multiplicative shear Additive shear Photo-z biases Small-scale power spectrum	Measurement algorithm;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

Currently Favored DES-SN Fields

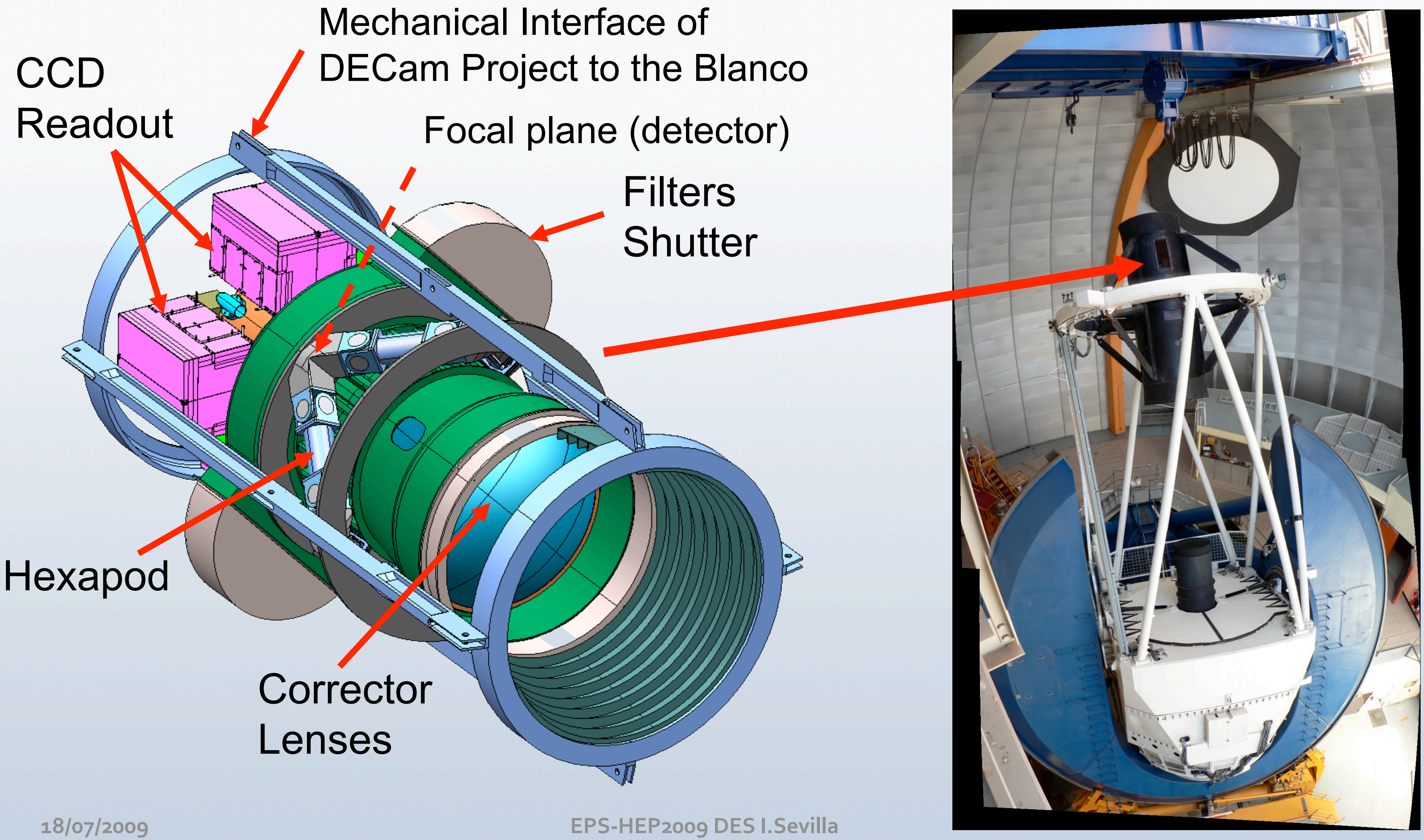
- Chosen to maximize:
  - visibility from DES site
  - past observation history
  - visibility from, e.g., Hawaii

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

From a study by Peter Nugent



The camera: DECam



DES Science organization

- Josh Frieman and Ofer Lahav chair the DES Science Committee

- DES Science Working groups
  - Large scale Structure (Enrique Gaztanaga and Will Percival)
  - Clusters (Joe Mohr and Tim McKay)
  - Weak Lensing (Sarah Bridle and Bhuv Jain)
  - Supernovae (John Marriner and Bob Nichol)
  - Simulations (Gus Evrard and Andrey Kravtsov)
  - Photoz (Francisco Castander and Huan Lin)

- Ancillary (not aimed at DE) science study groups (formation in progress)
  - Galaxy Formation & Evolution
  - Strong Gravitational Lensing
  - QSOs
  - Galactic (Milky Way) Archeology
  - Combined Probes & Theory

What the future holds for DES…

End of 2009: most of the elements are finalizing fabrication.

1st half 2010: last CCDs are selected.

During 2010: All camera elements are sent to FNAL to be integrated and tested in the telescope simulator.

Early 2011: Camera at CTIO: installation.

Summer 2011: Commissioning.

Fall 2011: Ready to go!