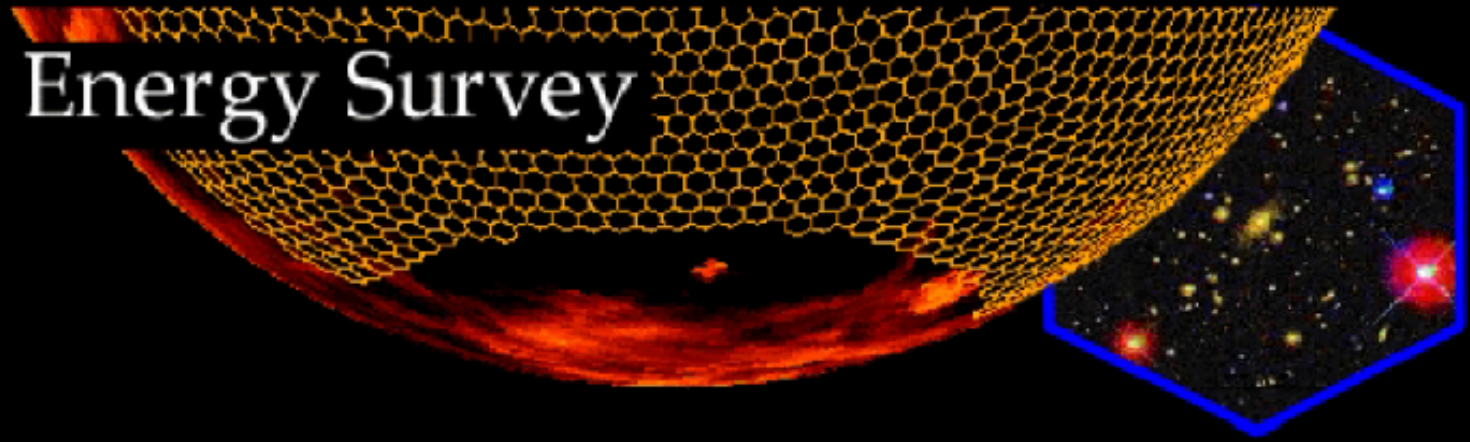


The Dark Energy Survey



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on behalf of the DES Collaboration



- ◆ **The Dark Energy**
 - ▶ Accelerated Expansion
 - ▶ What is known about Dark Energy
 - ▶ Dark Energy Probes
 - ▶ Cosmological Observations

- ◆ **The Dark Energy Survey**
 - ▶ Science Goals
 - ▶ The Instrument
 - ▶ The Survey
 - ▶ The DES Collaboration
 - ▶ Timetable

- ◆ **Status and perspectives**

The Dark Energy: Accelerated Expansion and the New Cosmology



The high quality data of the last decade have brought a revolution in cosmology and a new standard model.

The discovery of the accelerated expansion implies that the dominant component of the matter-energy content of the universe is DARK ENERGY

Besides...

Matter density is dominated by COLD DARK MATTER

Perturbations arise from inflation

Baryon asymmetry arises in the GUT or ElectroWeak transition.

Dark Energy is both a cosmological and a particle physics issue



The Dark Energy: What do we know about Dark Energy?

- 1) It emits no electromagnetic radiation
- 2) It has large, negative pressure ($p = w \rho$, with $w \sim -1$)
- 3) It is approximately homogeneous (more precisely, does not cluster significantly with matter on scales at least as large as clusters of galaxies)
- 4) In order to grow the structure observed today, $w < -1/2$

Because its pressure is comparable in magnitude to its energy density it is more "energy-like" than "matter-like" (matter being characterized by $p \ll \rho$).

Dark energy is qualitatively very different from Dark Matter.



The Dark Energy: Parametrization and Study

Identify the nature of the Dark Energy is one of the most important problems of Physics

For the moment, parametrize the Dark energy through the equation of state:

$$\omega_X = p_X / \rho_X$$

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

As Dark Energy is a diffuse, very weakly interacting with matter and low-energy phenomenon, it will be hard to produce in accelerators. As it isn't found in galaxies and clusters, the Universe is the natural lab (perhaps the only one) to study Dark Energy



The Dark Energy: Probes of Dark Energy

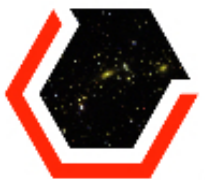
- ▶ **Luminosity Distance .vs. z** : SNIa
- ▶ **Angular Diameter Distance .vs. z** : BAO, Alcock-Paczynski
- ▶ **Comoving Volume*Number Density .vs. z** : Galaxy/Cluster counts, SZ, X-rays
- ▶ **Shear Convergence** : Weak Lensing
- ▶ **Other Tests** : CMB, probes of non-minimal or anomalous couplings

Cosmological observations can address:

- ◆ *Measure if $w=-1$ or not*
- ◆ *dw/dz non-zero would indicate the presence of something new*
- ◆ *Understand systematics!!!!!!*
- ◆ *Precise measurements!!! (It's hard to distinguish among different models)*

Several observations with

- ◆ **Different systematics**
- ◆ **Different cosmological parameters degeneracies**
- ◆ **Different redshift sensitivities**



Next generation sky survey aimed directly at understanding the mystery of dark energy

4 Science Goals:

- ◆ *Cluster counting and spatial distribution of clusters at $0.1 < z < 1.5$*
- ◆ *Shifting of the galaxy spatial angular power spectra with redshift*
- ◆ *Weak lensing measurement on several redshift shells to $z \sim 1$*
- ◆ *2000 snla at $0.3 < z < 0.8$*

Impact (20000 clusters, 300 million galaxies, 2000 snla):

- **5-15% measurement of w in each technique**
- **30% measurement of dw/dz in each technique**

Combined, they provide **STRONGER CONSTRAINTS**
and **CHECK ON SYSTEMATIC ERRORS**

The Dark Energy Survey: Cluster Counting



DARK ENERGY
SURVEY

Measure: Clusters redshift distribution, cluster observable distribution at each redshift (mass function)

DES will have ~ 20000 clusters

Sensitivity: Volume/distance-redshift relation, growth rate of cosmic structure, power spectrum shape (transfer function)

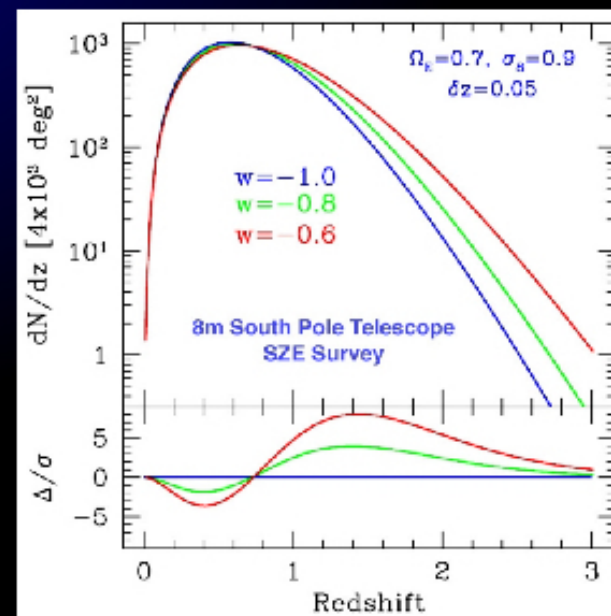
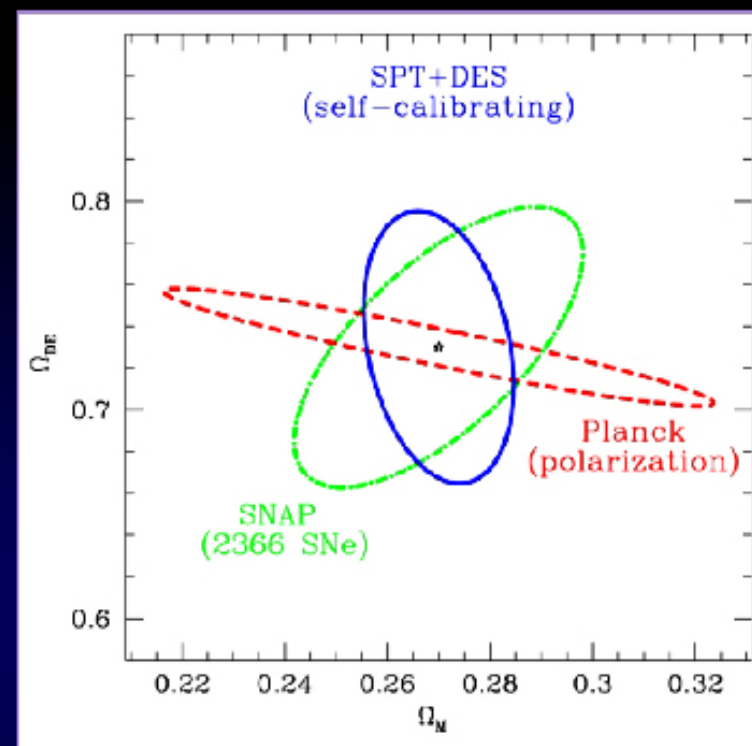
Use SZ effect (SPT Telescope), WL and X-ray to select clusters and measure masses

Systematics:

- Sample selection
- Statistical mass-observable calibration
- Sources contamination
- Photometric redshift

Need:

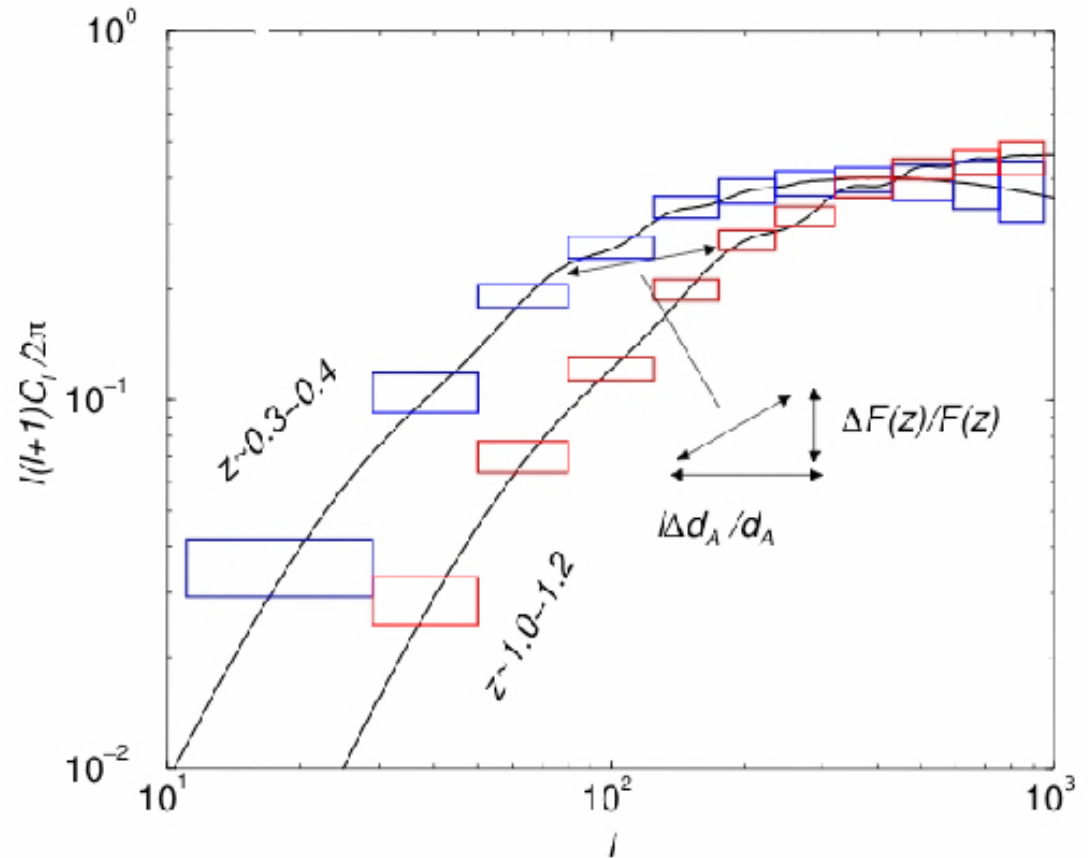
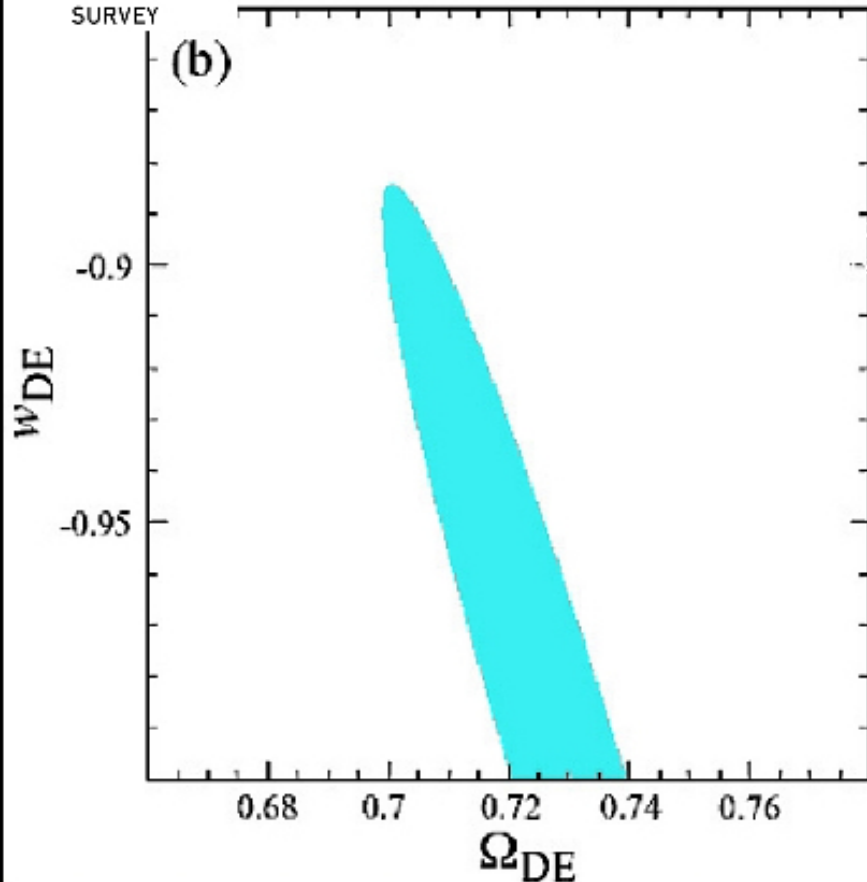
- Understanding of the formation of dark matter halos
- Clean way of selecting a large number of clusters
- Redshift for each cluster
- Observables that can be used as mass estimators





The Dark Energy Survey: Galaxy and Cluster Angular Power Spectrum

DARK ENERGY SURVEY



~300 million galaxies up to $z \sim 1.5$. Peak and BAO provide a ruler

Measure spatial clustering of galaxies as a function of redshift

Theory predicts how the shape of the power spectrum depends on redshift

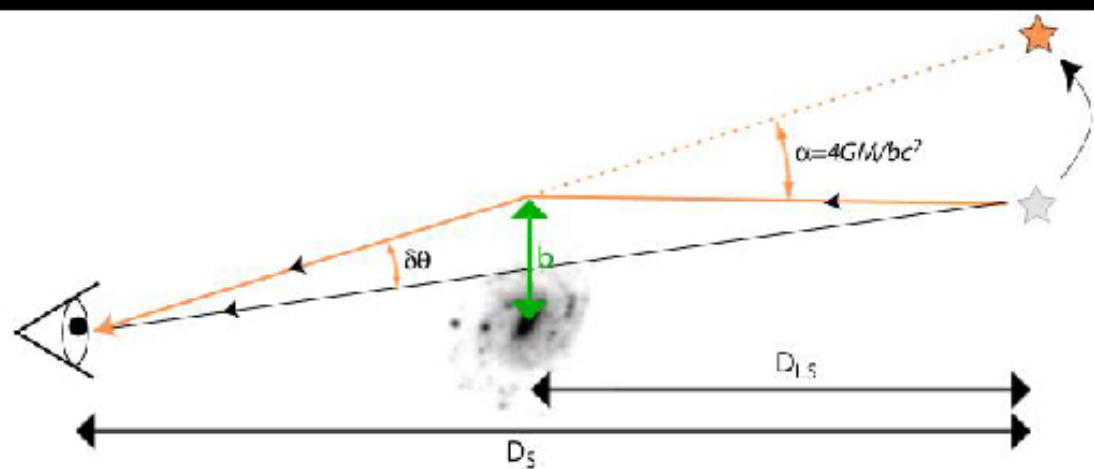
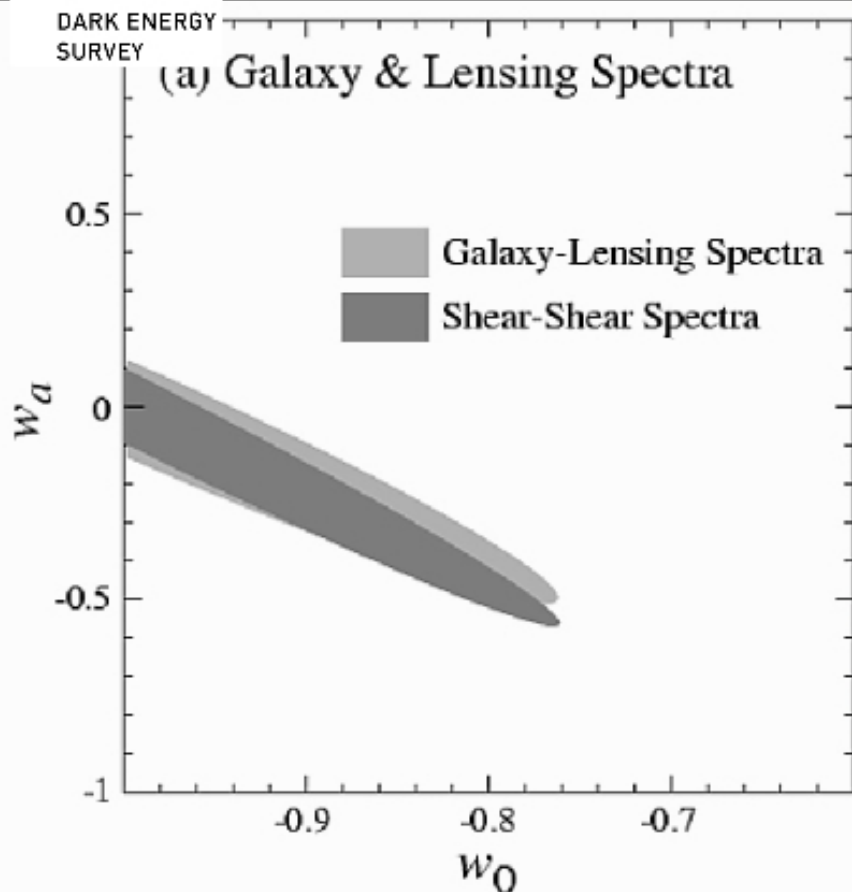
Systematics:

Bias prescription error,

calibration and biases in photo- z



The Dark Energy Survey: Weak Lensing

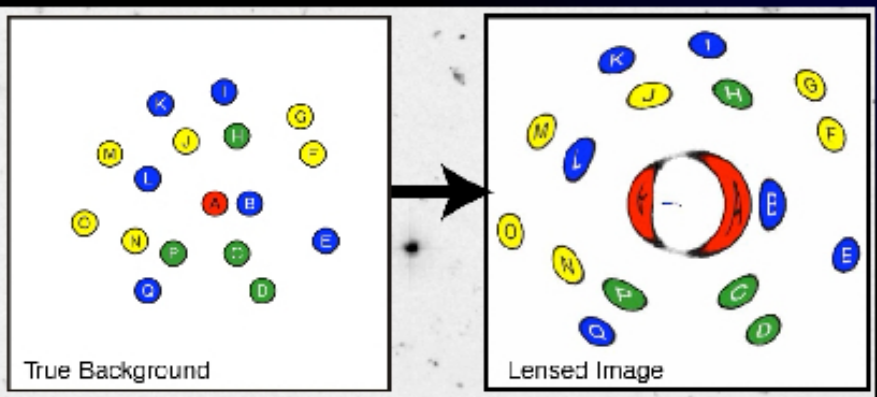


$$\delta\theta = \frac{4GM}{bc^2} \frac{D_{LS}}{D_s}$$

We observe this deflection angle (more precisely, gradients of the deflection angle).

Cosmology changes growth rate of mass structures in the Universe.

Cosmology changes the geometric distance factors.



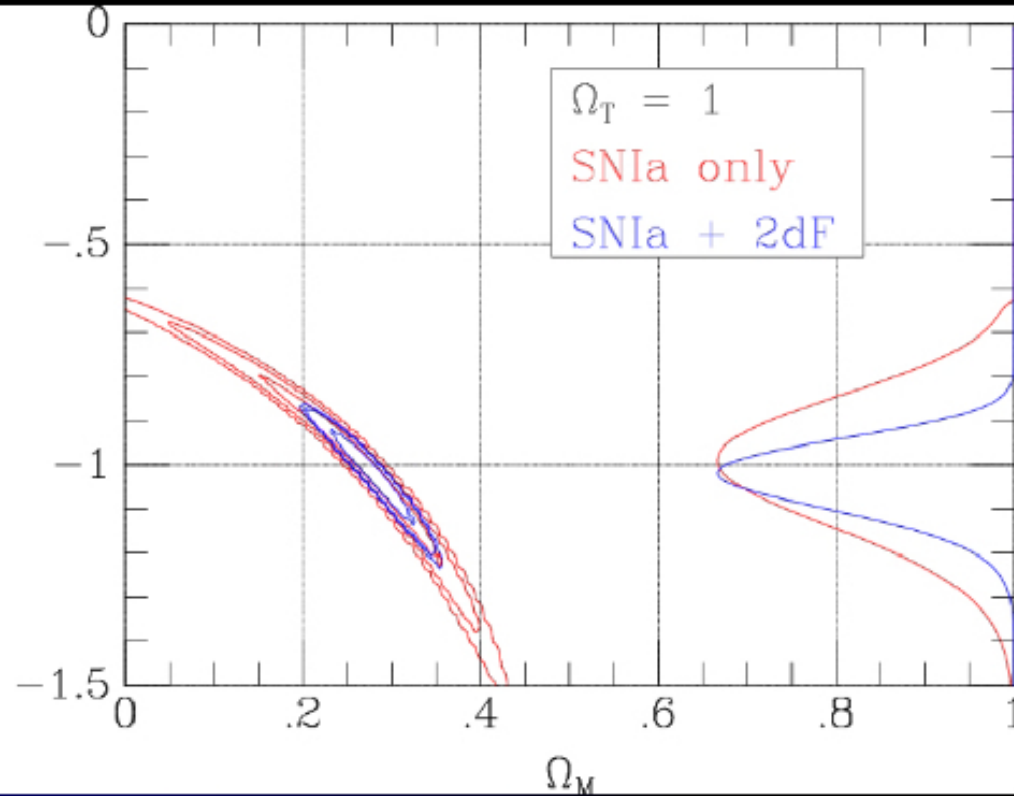
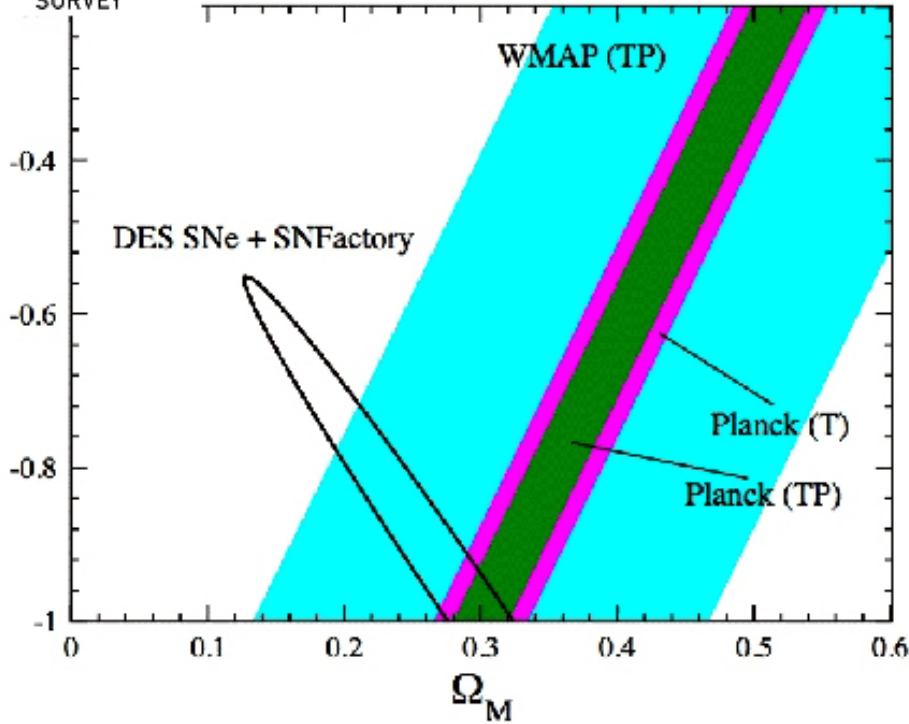
Measure shapes for ~300 million source galaxies with $\langle z \rangle = 0.7$
 shear-shear & galaxy-shear correlations
 Probe distances and growth rate of perturbations
 Shear as a function of redshift. Intensity is different for different source galaxies for the same cluster lens.

Systematics: calibration and false detections shear, photo-z biases, small scale power spectrum



The Dark Energy Survey: Supernovae

DARK ENERGY SURVEY



Repeat observations of 40 sq-degrees, 10% of survey time

~2000 well-measured griz snla light curves $0.2 < z < 0.8$

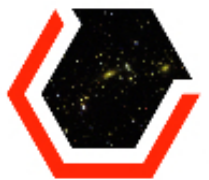
Larger sample and improved z-band response compared to other experiments

Identify supernovae type 1a using photometric and color methods

Systematics:

SN evolution, extinction

photometric errors and biases



DARK ENERGY
SURVEY

The Dark Energy Survey: The Instrument

**Survey 5000 sq-degrees in the
South Galactic Cap**

- 30% of the time for DES
- 70% of public use

**Use 4m Blanco Telescope at CTIO;
an existing and working telescope**

**DES will replace the entire cage
of the prime focus**

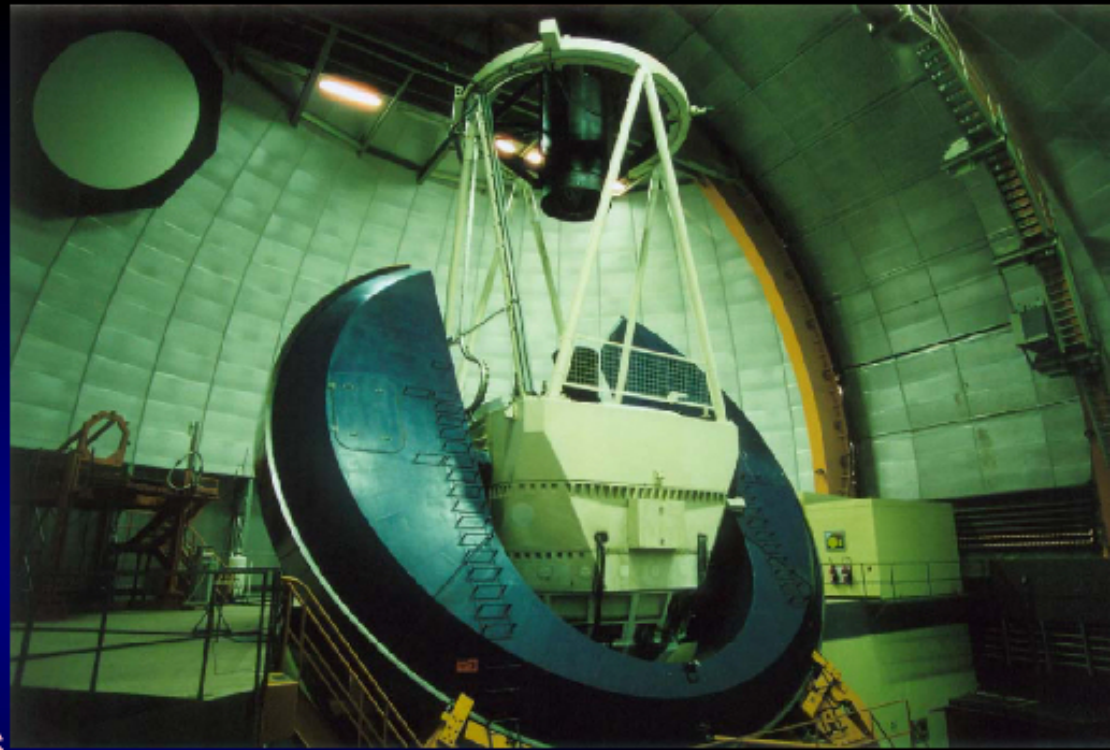
Install a new camera and new optics

SDSS g, r, i, z filters covering visible and infrared

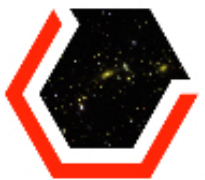
Each Image (3 sq-degrees):

- ~20 galaxy clusters
- ~20000 galaxies

Each Night: ~300 GB Image Data



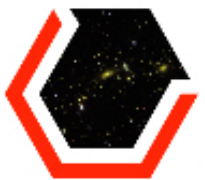
The Dark Energy Survey: The Instrument



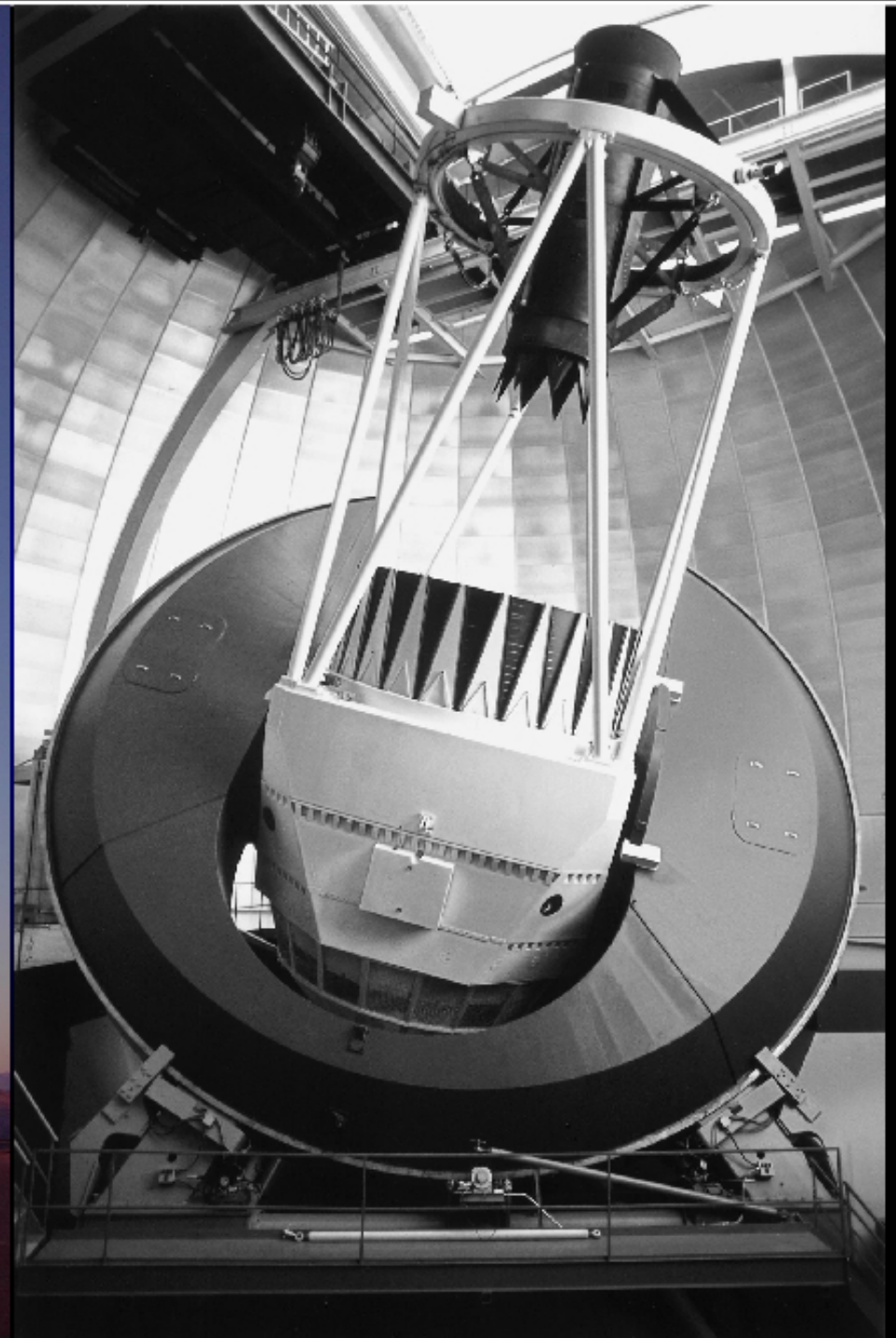
DARK ENERGY
SURVEY

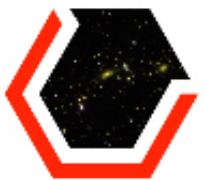


The Dark Energy Survey: The Instrument



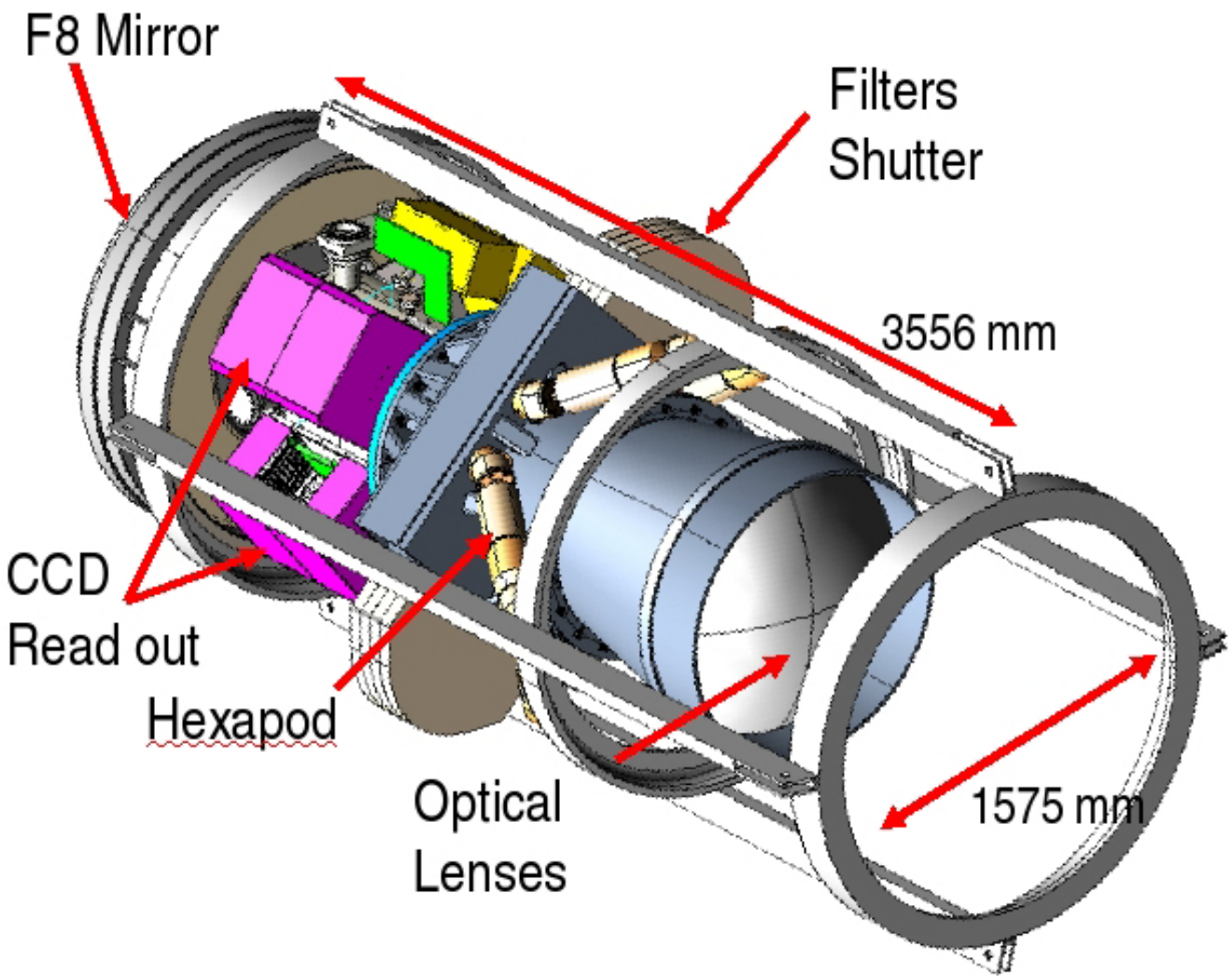
DARK ENERGY
SURVEY





DARK ENERGY
SURVEY

The Dark Energy Survey: The Camera



DES is building a new camera for Blanco: DECam

500 Million pixels

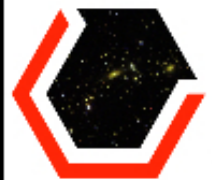
Sensitive to visible and near IR

DES is building also the associated optics

DECam will be installed at the prime focus.

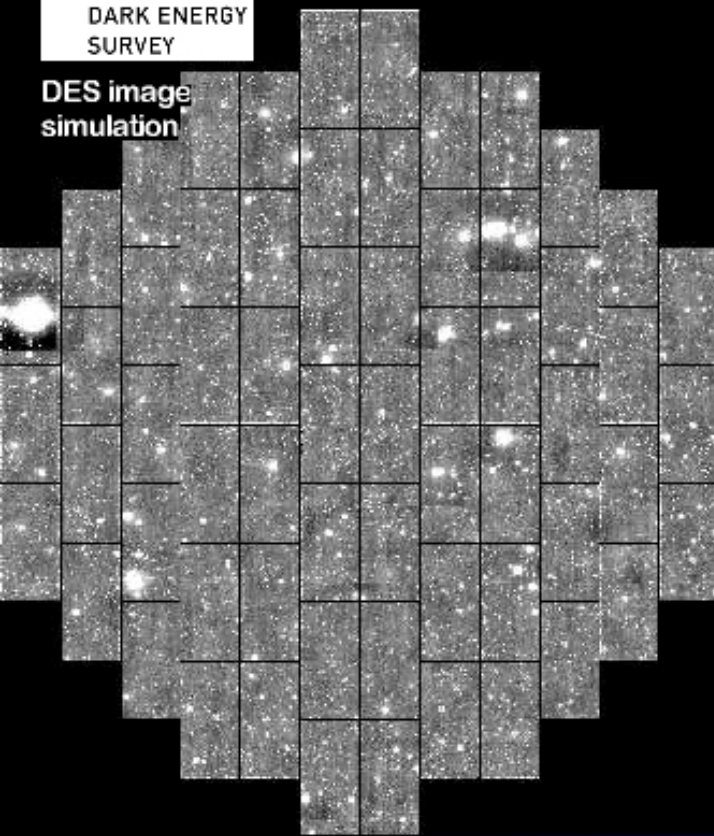
It is a mobile piece, can be rotated to use a mirror at the back

The Dark Energy Survey: The Camera



DARK ENERGY
SURVEY

DES image
simulation



62 2k x 4k image CCDs
+ guide and focus CCDs

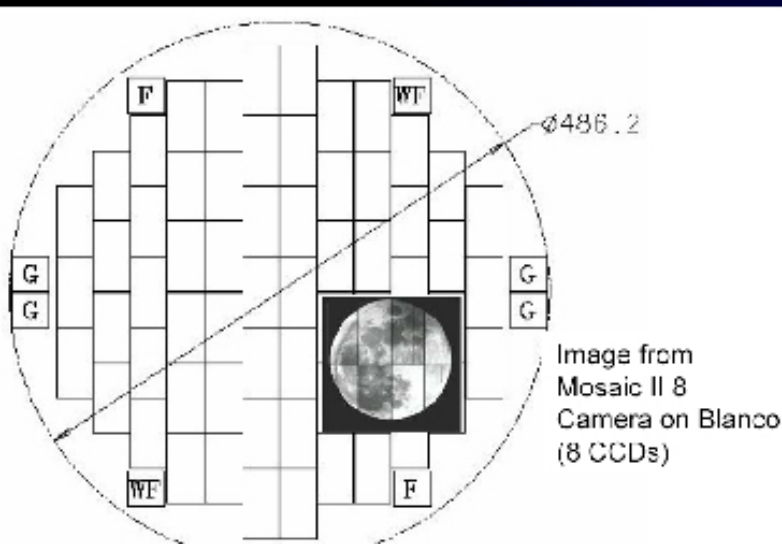
0.27"/pixel

Scroll shutter: < 3 sec
open-close

4 filters (g, r, i, z) < 10 sec
exchange

5 elements optical corrector

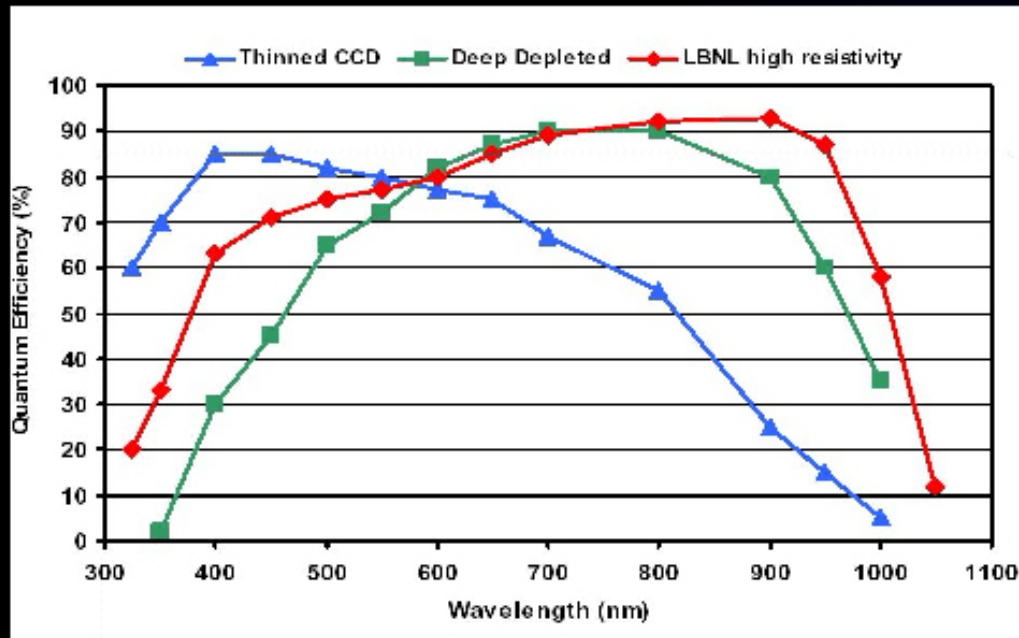
Approximately hexagonal





DARK ENERGY SURVEY

The Dark Energy Survey: CCDs



Pixel size: 15x15 microns

Readout time: 17 sec.

Noise: 5e at 250 kpix/sec

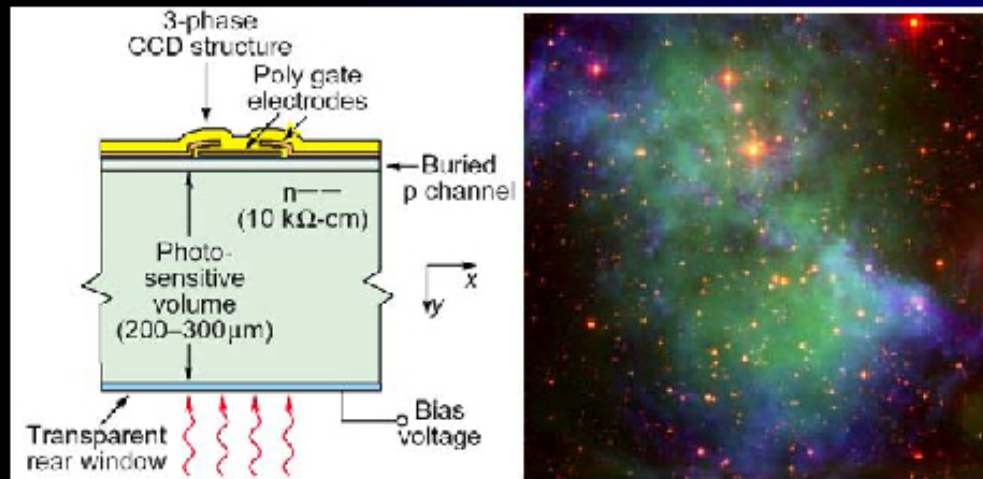
Quantum Efficiency > 50% at 1000 nm

250 microns thick

2 Read Out Channels device

Developed by LBNL for SNAP

DES CCDs have already been used on telescopes in small numbers

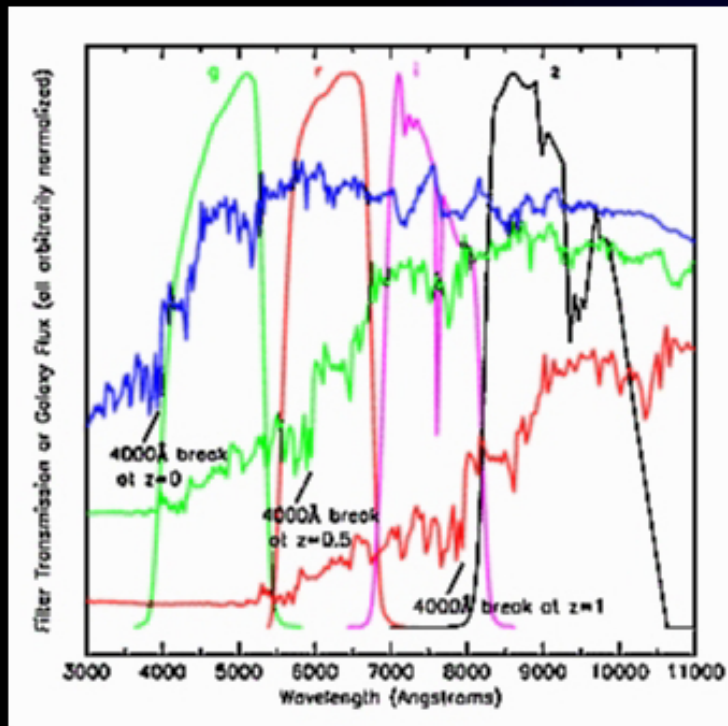




DARK ENERGY
SURVEY

The Dark Energy Survey: Photometric Redshifts

**4 SDSS filters: g, r, i, z. From
~3500 to ~10500 Å**



Target red galaxy spectra at $z = 0, 0.5, 1$

The 4000 Å break in brightness of an object seen through the different filters gives a measurement of the redshift

At $z=1$, only the z filter gets much light

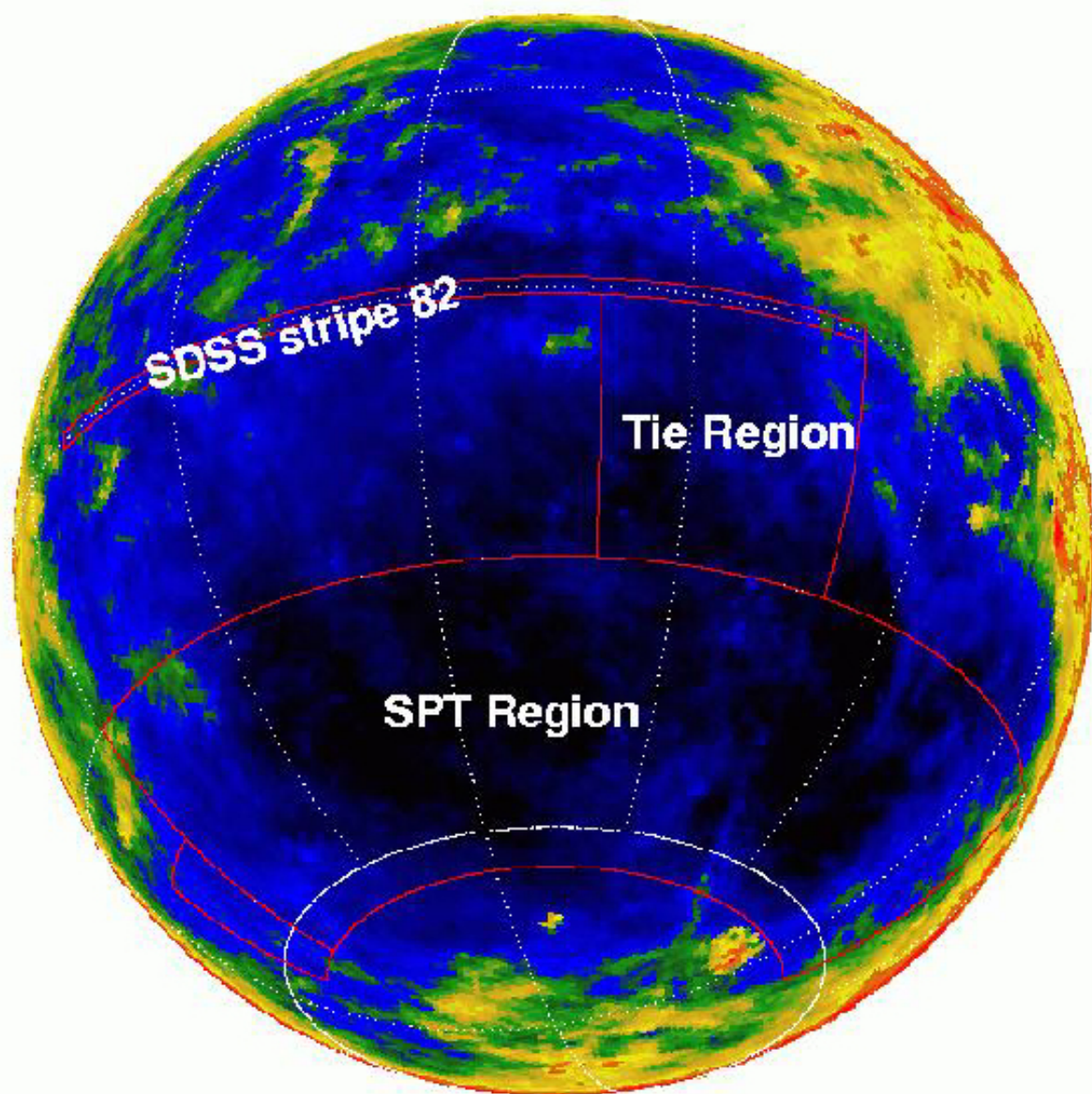
This is not as precise as a full spectrum but it is MUCH FASTER and can go FAINTER

45 min for spectra; 55 sec for photo-z

The Dark Energy Survey: The Survey



DARK ENERGY
SURVEY



*Area covered:
5000 sq-degrees*

*Overlap with SPT
SZ survey:
SPT masses +
DES redshifts*

*SDSS stripe 82
provides photo-z
calibration
spectra*

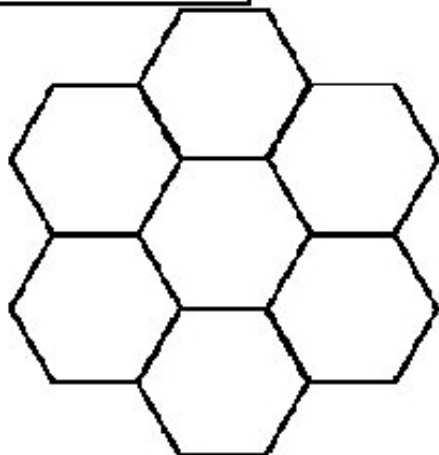
*Tie region connects
the two*

The Dark Energy Survey: The Survey

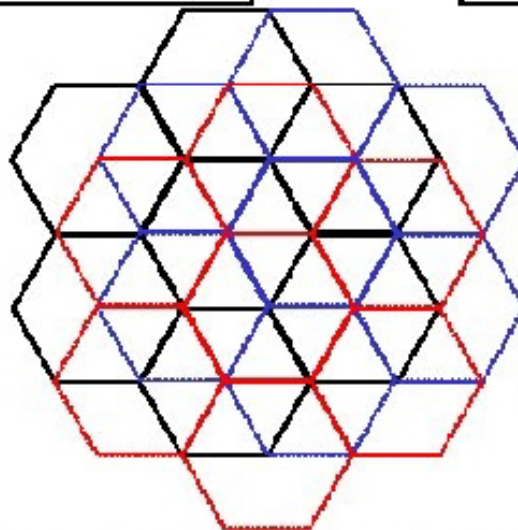


DARK ENERGY
SURVEY

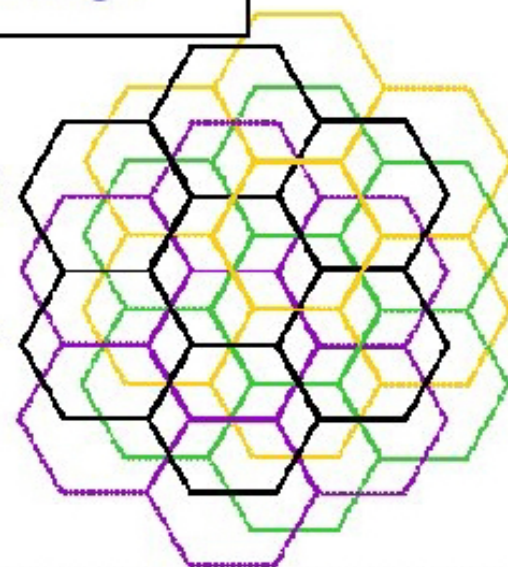
1 tiling



2 tilings



3 tilings



2 tilings of the full area per year per filter.

Calibration will be driven by the large number of overlapping observations

Use overlapping images of known stars to place all images on the same relative system

- ◆ **Thousands of stars per overlap**
- ◆ **Precision only limited by systematics**
- ◆ **Overlapping tilings will allow reduction of systematics**

Images will be 100 sec long

- ◆ **Telescope slew time is 35 sec, but hopefully will come down to 20 sec.**



The Dark Energy Survey: Data Management

GOALS:

Support acquisition and reliably transfer 300 GB/night produced on 500 nights over 5 years from CTIO (Chile) to NCSA (Illinois, USA)

Process data at NCSA, provide to DES team at their sites and provide to community

Maintain DES archive over the long term

STRATEGY:

Require automatic data process and quality assurance

Expect to reprocess the data yearly

Build coadds with science catalogs after each observing season

Public data access supported

Single pointing images released ~1 year after acquisition

Science products released twice, at the midway point and at the end of the survey

The Dark Energy Survey: The Collaboration



DARK ENERGY
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Fermilab

U. Illinois at Urbana-Champaign

U. Chicago

LBNL

U. Michigan

NOAO/CTIO

UK Consortium:

U. College London

U. Cambridge

U. Edimburgh

U. Portsmouth

U. Sussex

SPANISH CONSORTIUM:

CIEMAT

IEEC

IFAE

14 Institutes

77 scientists

(+ technical staff

+ students)

SPOKESPERSON:

John Peoples (Fermilab)



The Dark Energy Survey: Timetable

2005-2007: Design and R&D

CCDs: Testing and packing. Develop characterization procedure

OPTICS: Define final cost. Order material in 2006, polish in 2007.

ELECTRONICS: High speed readout at very low noise. Build crates for prime focus

2008-2009: Construction

Final production of CCDs, packing and test

JUNE 2008: Start tests of full camera

End optics

JUNE 2009: Transport full instrument to Chile

SEPTEMBER 2009: START DATA TAKING

2009-2014: Survey



The Dark Energy Survey: Status and perspectives

The "Dark Energy Task Force" (chair: R. Kolb) gives DES the status of Stage III.

"If executed in combination, Stage-III projects would increase the DETF figure of merit by a factor in the range of approximately three to five with the large degree of uncertain forecast of systematic errors."

And one of the strong points of DES is the control of systematics errors using different approaches to the measurement...



The Dark Energy Survey: Conclusions

DES is a next generation sky survey aimed to study the dark energy which will start in 2009

The goal is to measure w at 5% precision and dw/dz at 15% precision with 4 techniques:

- **Cluster counting**
- **Cluster/Galaxy angular power spectrum**
- **Weak Lensing**
- **Supernovae Ia**

It will cover 5000 sq-degrees in the southern hemisphere and will overlap with SPT SZ survey

New experiment in astronomical standards: Large collaboration, almost dedicate telescope and large volume of data.