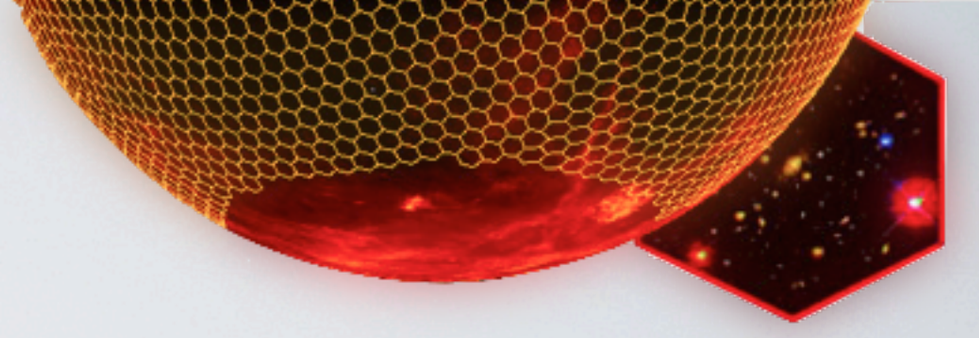
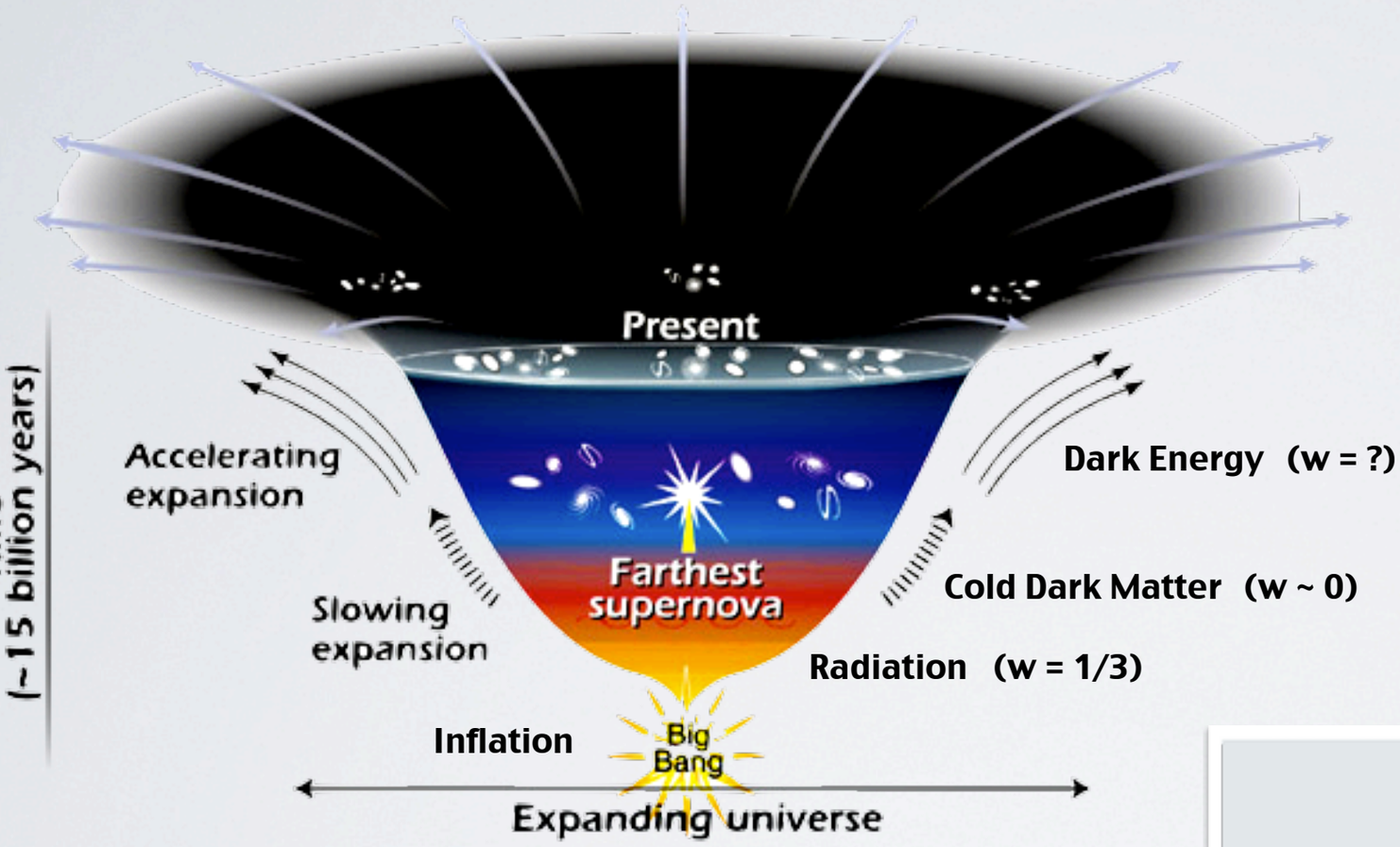


THE DARK ENERGY SURVEY STATUS & SCIENCE PROSPECTS

Marcelle Soares-Santos
Fermilab

ICHEP 2012 ◆ Melbourne, July 6 2012

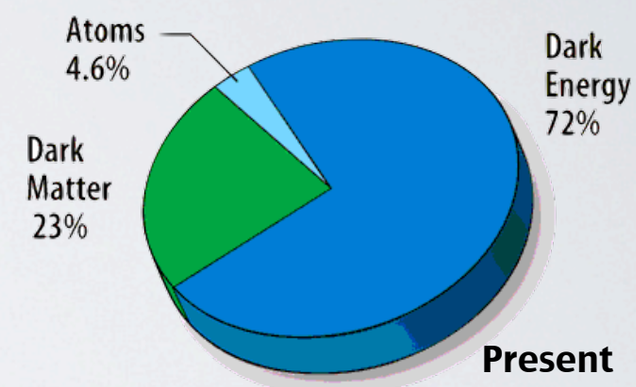
DARK ENERGY & ACCELERATED EXPANSION



equation of state parameter

$$p = w(a)\rho$$

$$w(a) = w_0 + w_a(1-a) + \cdots$$



$$\ddot{a}/a = -(3p + \rho)$$

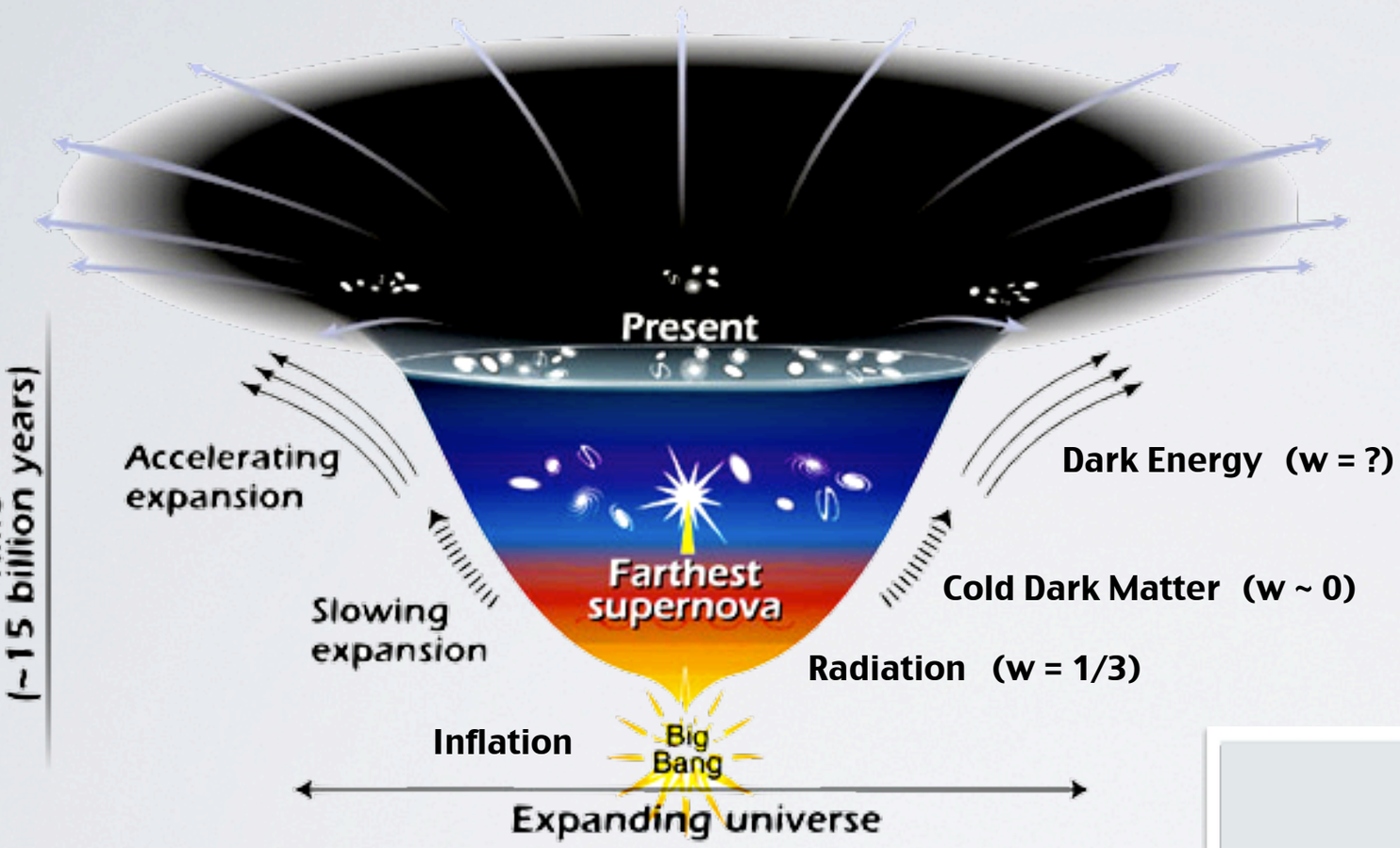
spacetime geometry (scale factor)

energy content (equation of state)

This is how well we know Dark Energy ➤➤ parameters today. (Komatsu et al. 2010)

$$w_0 = -0.93 \pm 0.12$$
$$w_1 = +0.38 \pm 0.65$$
$$\Omega_\Lambda = 0.72 \pm 0.02$$

DARK ENERGY & ACCELERATED EXPANSION



equation of state parameter

$$p = w(a)\rho$$

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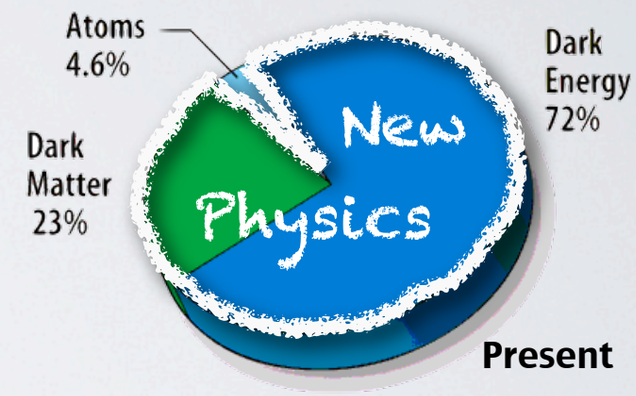

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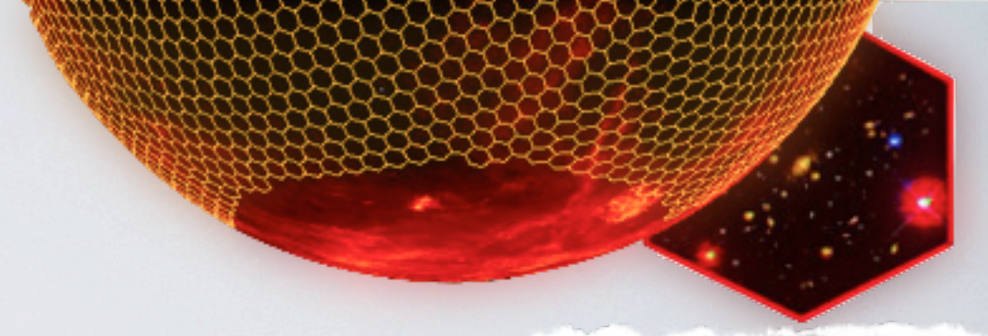
ASTROPHYSICAL OBSERVABLES



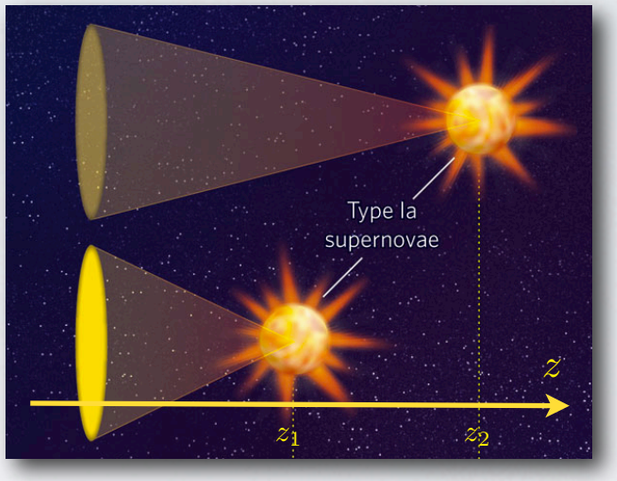
redshift & scale factor

$$a = \frac{1}{1+z}$$

$$z = \Delta\lambda/\lambda$$

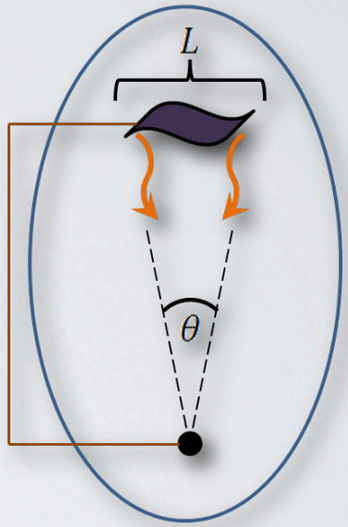
$D_L(z)$ Luminosity distance: **standard candle**

1. supernovae (SNe)



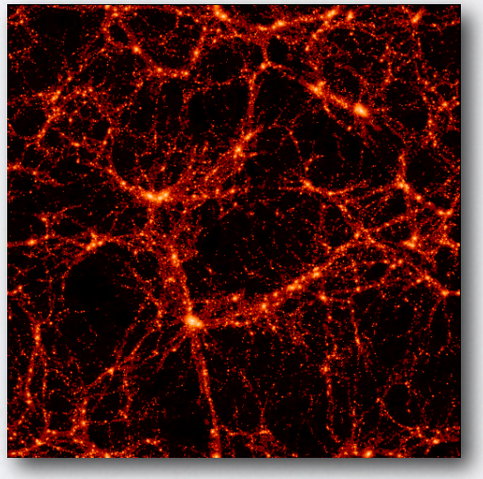
$D_A(z)$ Angular diameter distance: **standard ruler**

2. baryon acoustic oscillations (BAO) , cosmic microwave background (CMB)



$G(\rho, z)$ Growth of structure: **galaxy clustering**

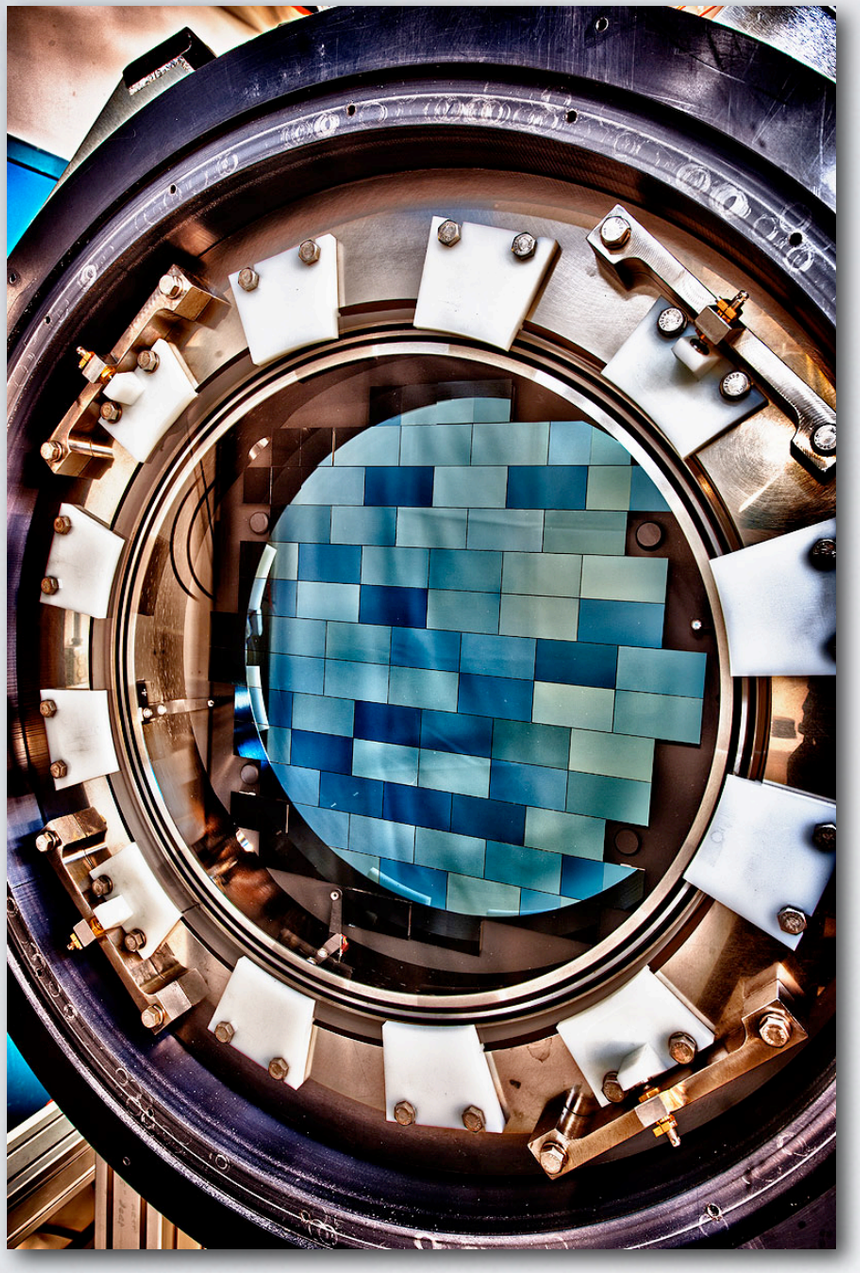
3. weak gravitational lensing (WL)
4. galaxy cluster abundance (Clusters)

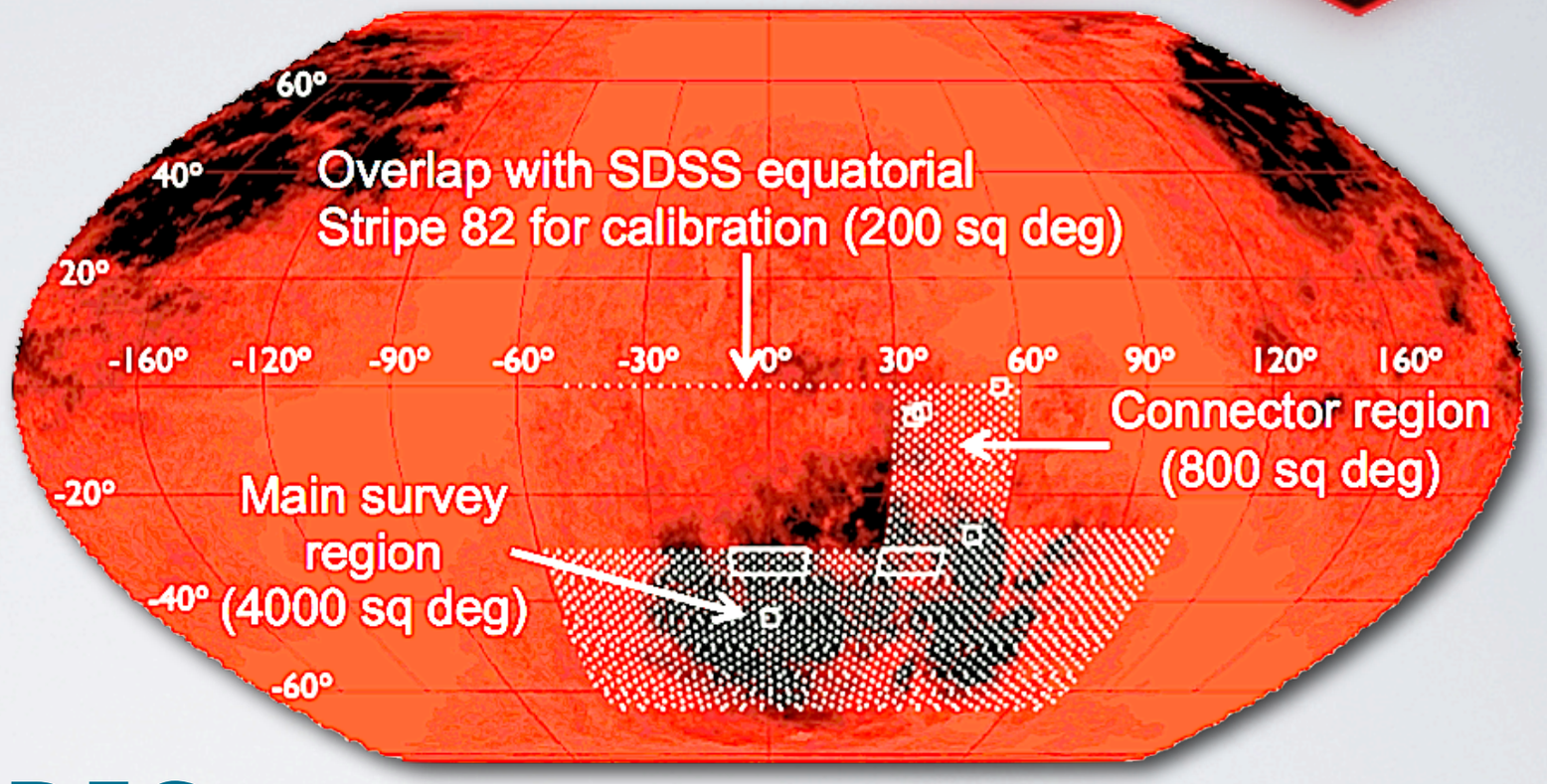


DES is sensitive to Dark Energy via 4 probes.

Planck results will be used in DES analyses.

DARK ENERGY SURVEY





DECam

3 sq deg FOV, **570 Mpix** optical CCD camera

Facility instrument for **CTIO Blanco 4-m telescope in Chile**

First light: Oct 2012

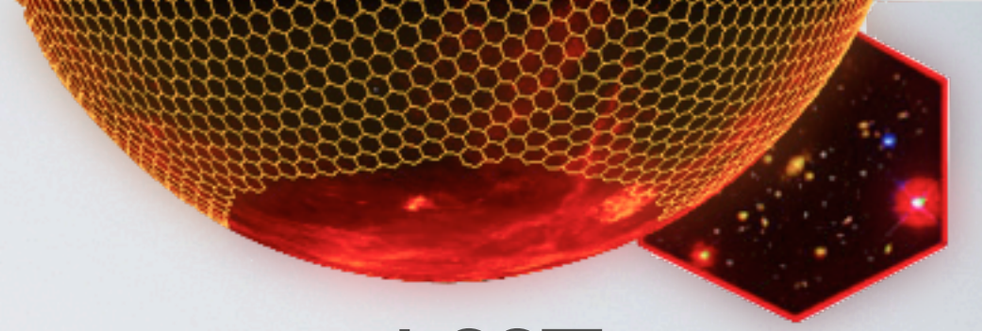
Survey

5000 sq deg grizY to **24th mag** at **0.9 arcseconds seeing** overlapping with: **SPT, VISTA**

30 sq deg repeat (SNe)

525 nights: 2012-2017

SKY SURVEYS



SDSS	DES	LSST
2001-2014	2012-2017	2021-20??
imaging and spectroscopy	imaging (with plans for spectroscopic follow up)	imaging
10,000 deg^2 up to z ~ 0.4	5,000 deg^2 up to z ~ 1.4	20,000 deg^2 up to z ~ 2
1 galaxy/sq-arcmin	10 galaxies/sq-arcmin	30 galaxies/sq-arcmin
2.5-m telescope	**4-m telescope**	8.4-m telescope
120 Mpix camera	**570 Mpix camera**	3000 Mpix camera

Our field is experiencing a transition similar to the Tevatron–LHC transition seen in the collider world.

COLLABORATION

150 scientists,
25 institutions

US: Fermilab, UChicago, LBNL, UIUC/NCSA, Michigan, ANL, TAMU, OSU, UPenn, UCSB, SLAC, Stanford

Brazil: UFRGS, ON, CBPF

UK: UCL, Sussex, Portsmouth, Cambridge, Edinburgh, Nottingham

Germany: LMU

Spain: CIEMAT, IFAE, IEEC/CSIC

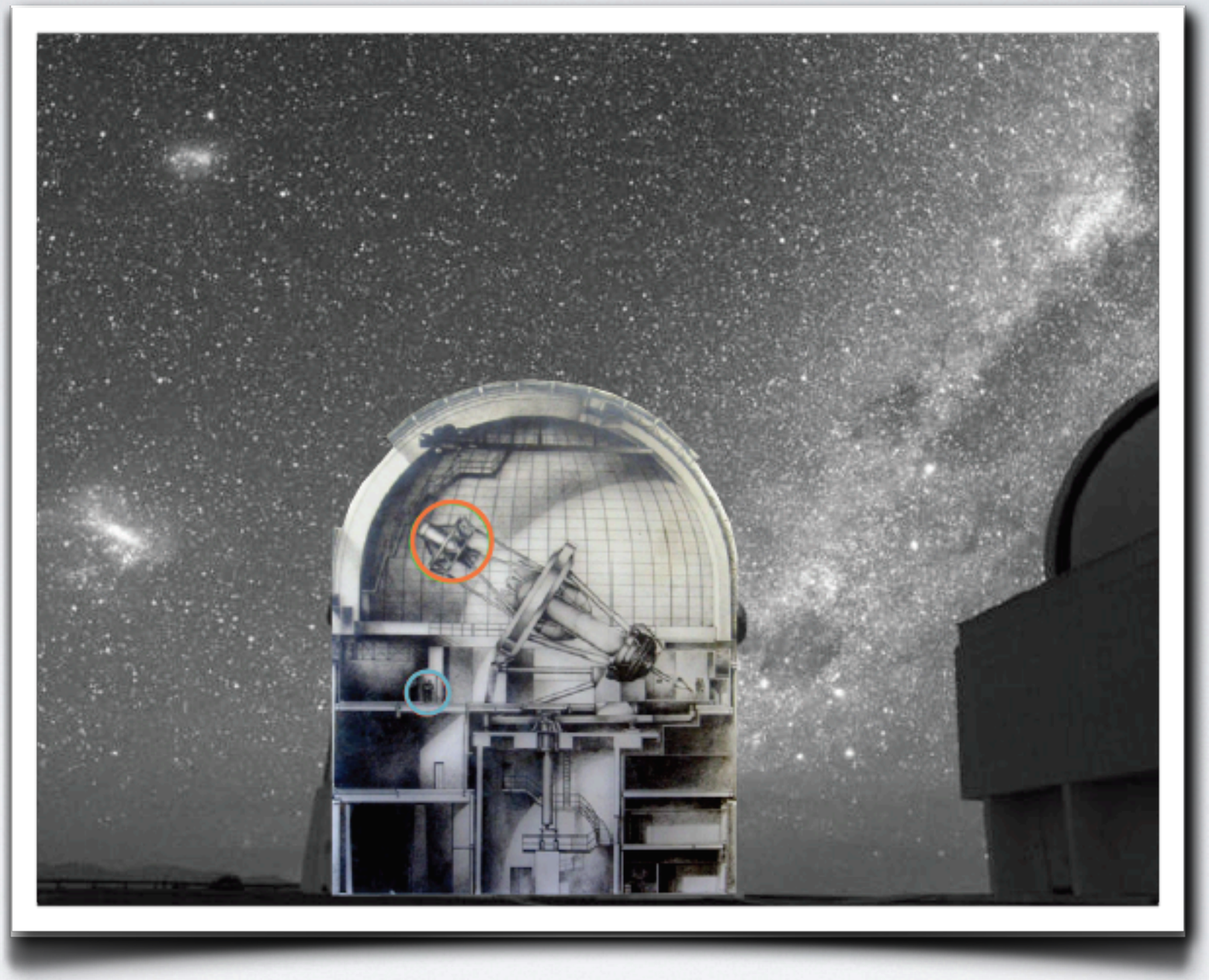
Switzerland: ETH Zurich

darkenergysurvey.org
facebook.com/darkenergysurvey

BLANCO TELESCOPE

DECam replaces the old Mosaic camera on the CTIO 4-m telescope in Chile.

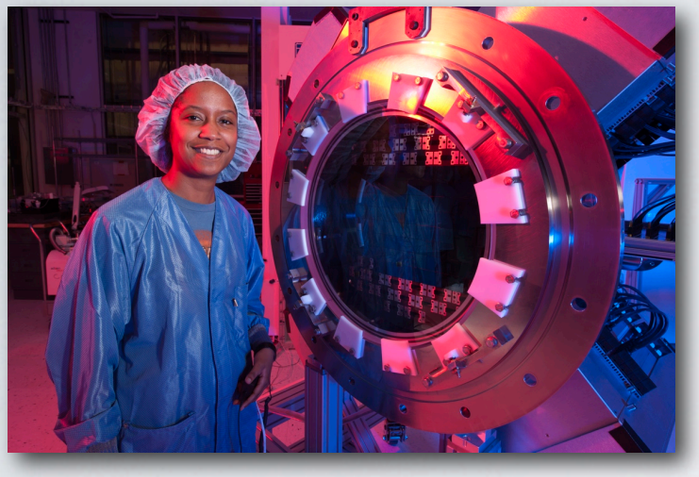
BLANCO TELESCOPE



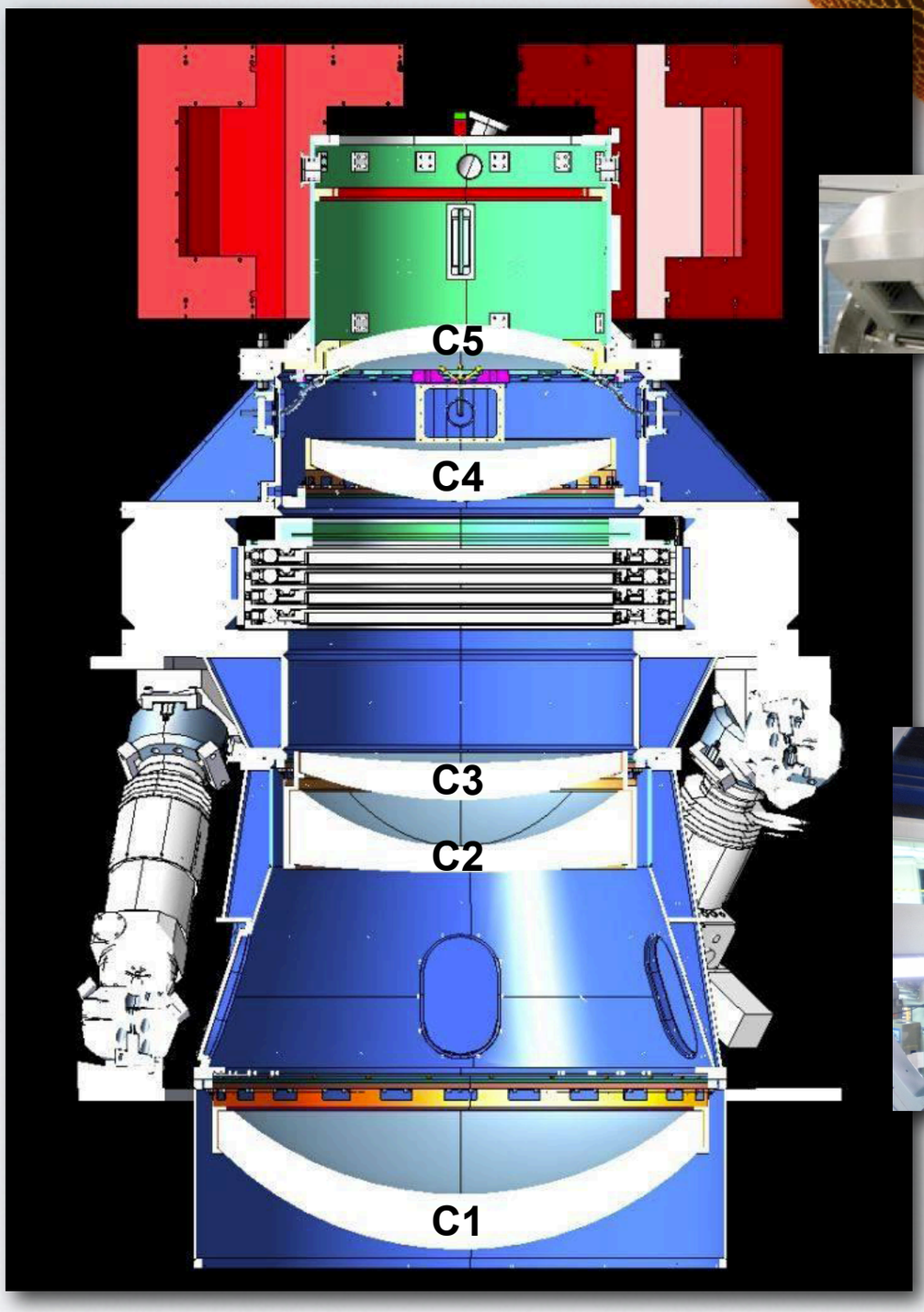
DECam replaces the old Mosaic camera on the CTIO 4-m telescope in Chile.

DECAM

CCD focal plane is housed in a vacuum vessel (**the imager**)

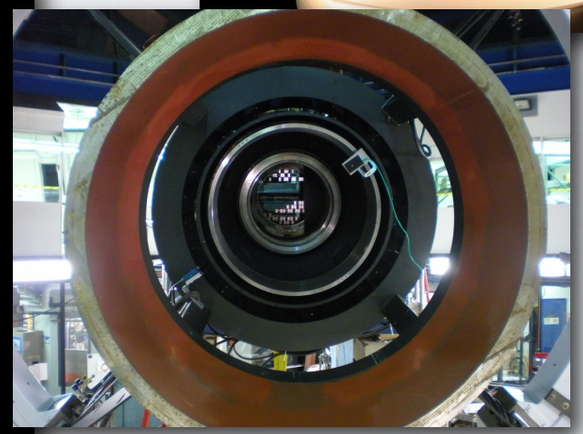


Hexapod provides focus and lateral alignment capability for the corrector-imager system



Barrel supports the **5 lenses** and imager

CCD readout electronic crates are actively cooled to eliminate thermal plumes



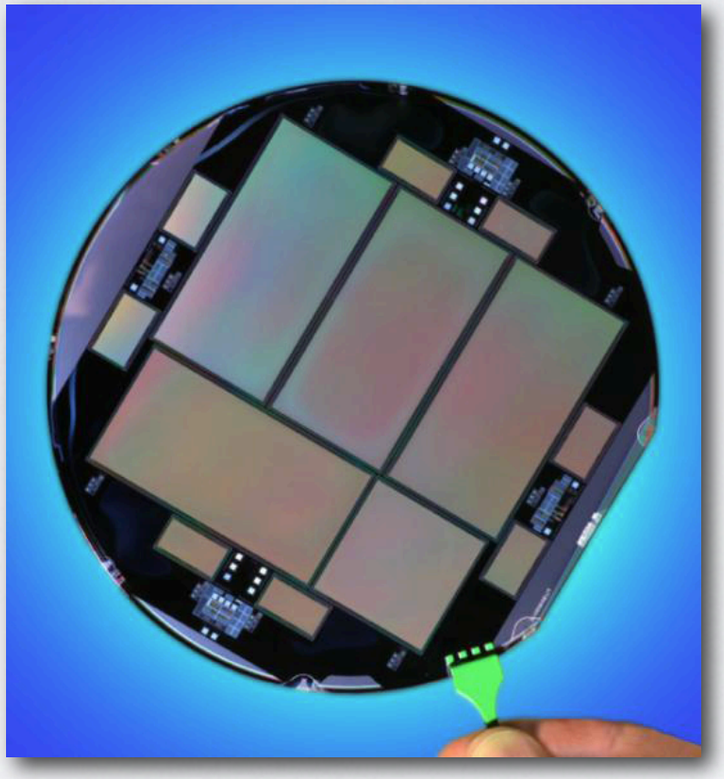
Filter changer with 8 filter capacity and **shutter** fit between lenses **C3** and **C4**

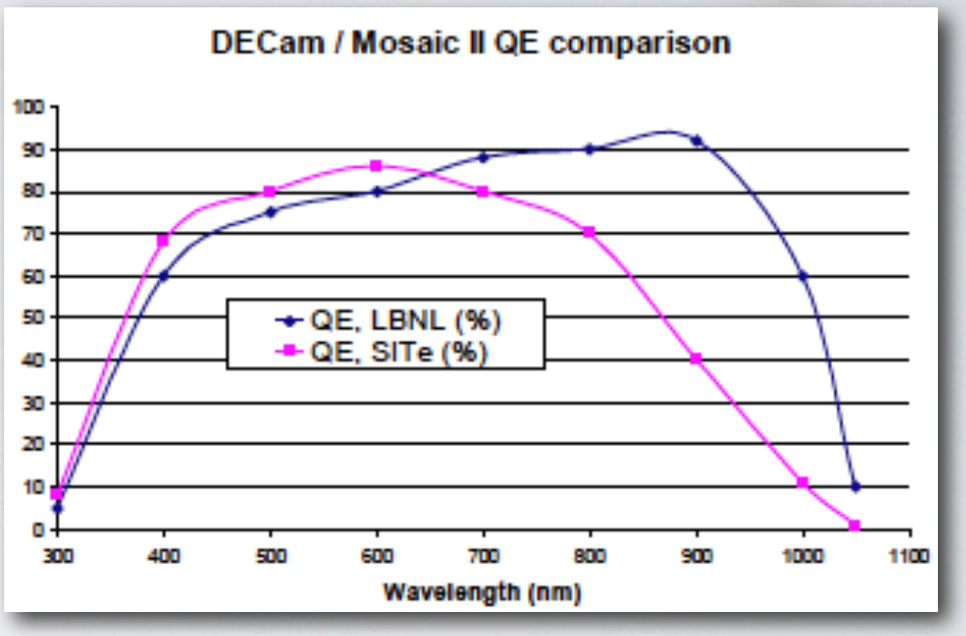
LN2 is pumped from the telescope floor to a heat exchanger in the imager: cools the CCDs to -100 C

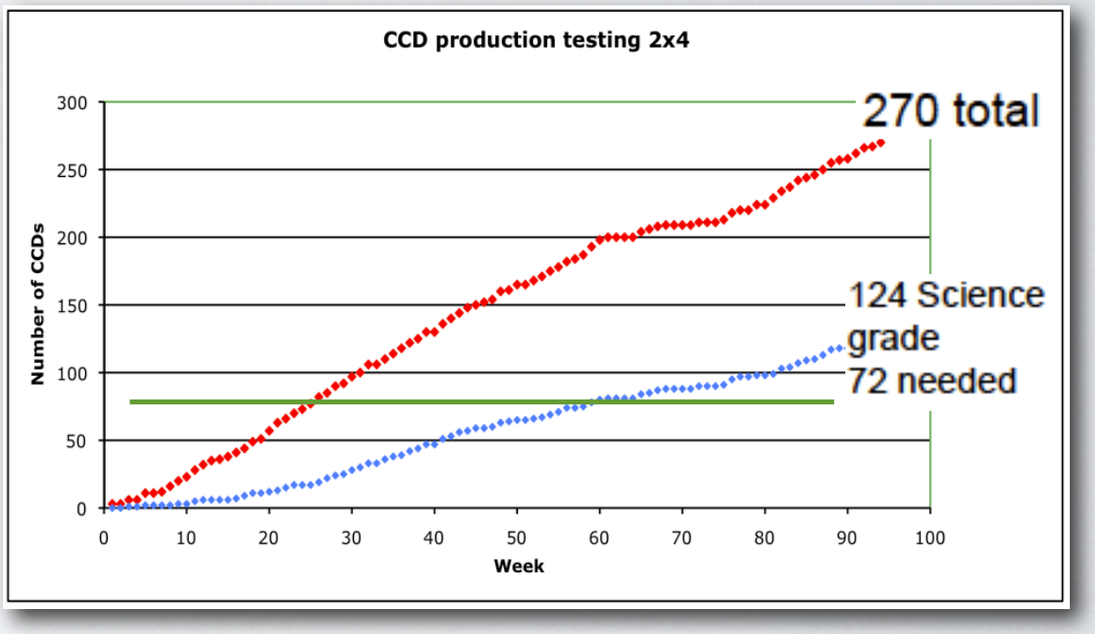
DECAM CCDS

Red Sensitive CCD wafers, designed by LBNL, processed at DALSA and LBNL:

- QE> 50% at 1000 nm
- 250 microns thick
- readout 250 kpix/sec
- 2 RO channels/device
- readout time ~17sec

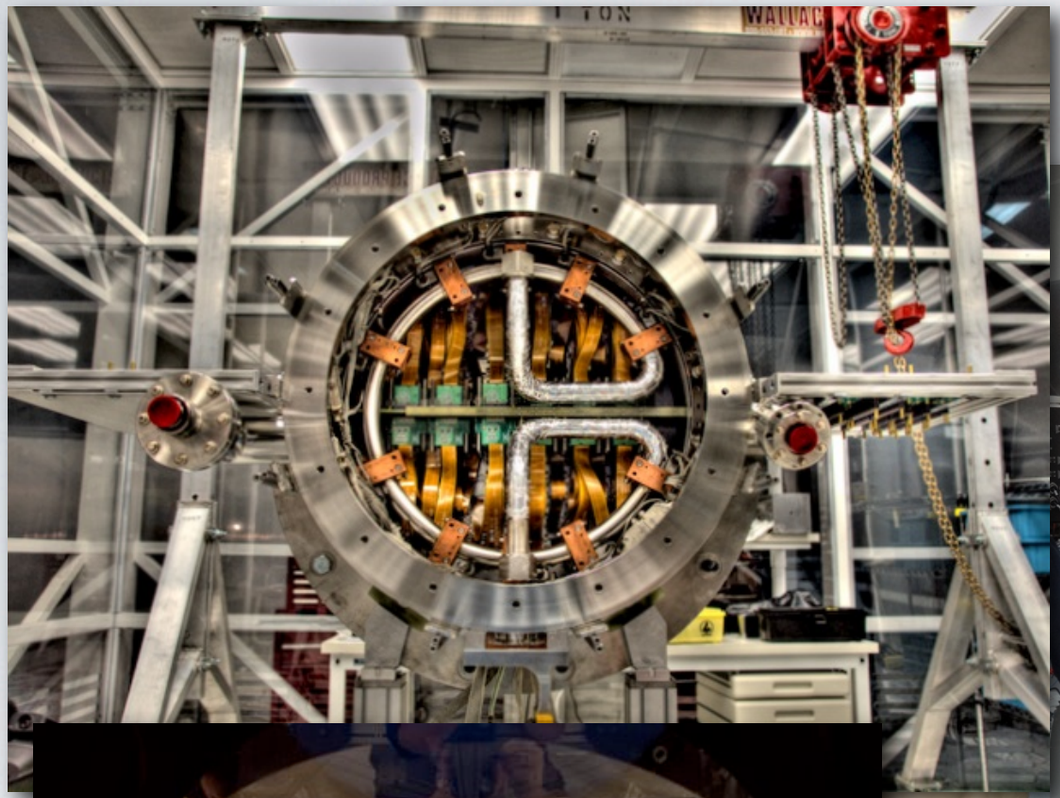


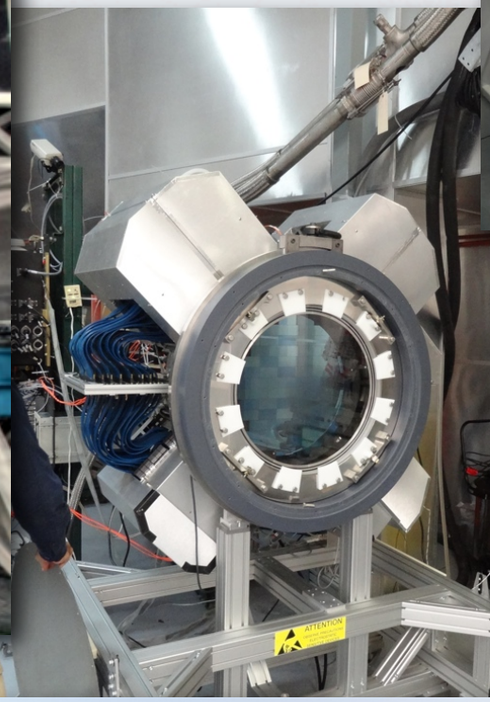




CCDs are packaged and tested at Fermilab.

DECAM IN CHILE

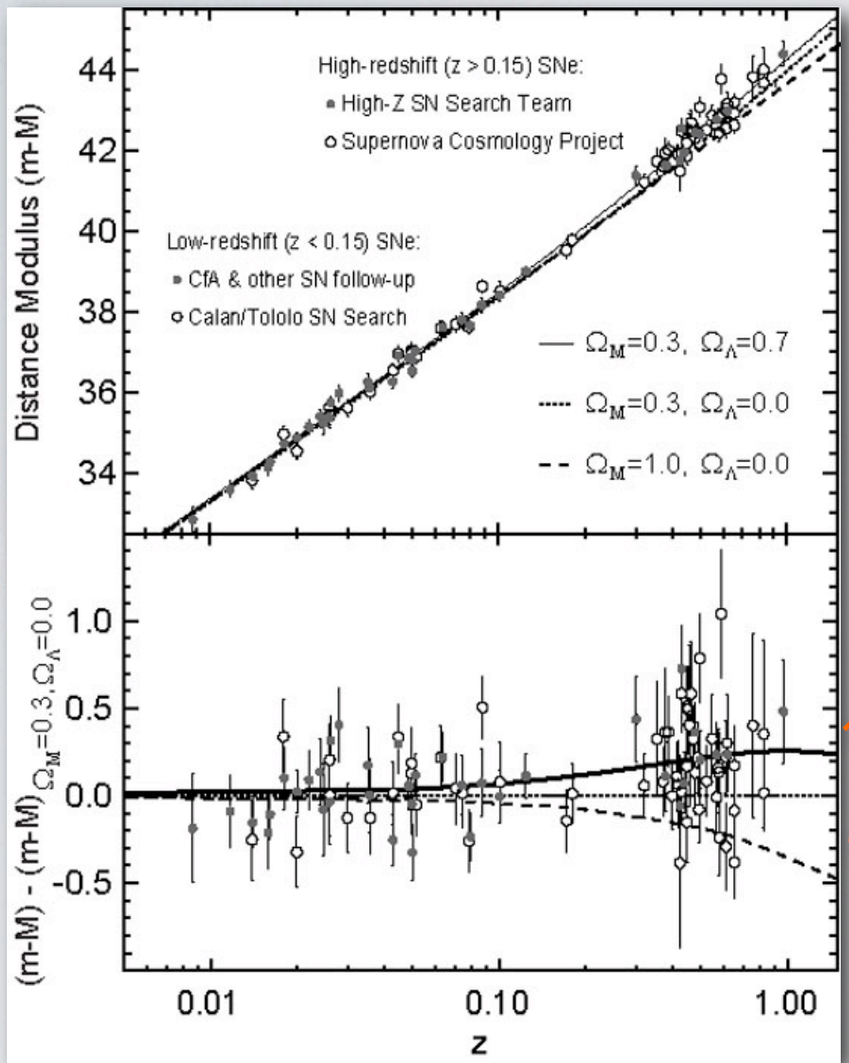




From
Dec 2011
to
Jan 2012

We checked out the imager at CTIO!

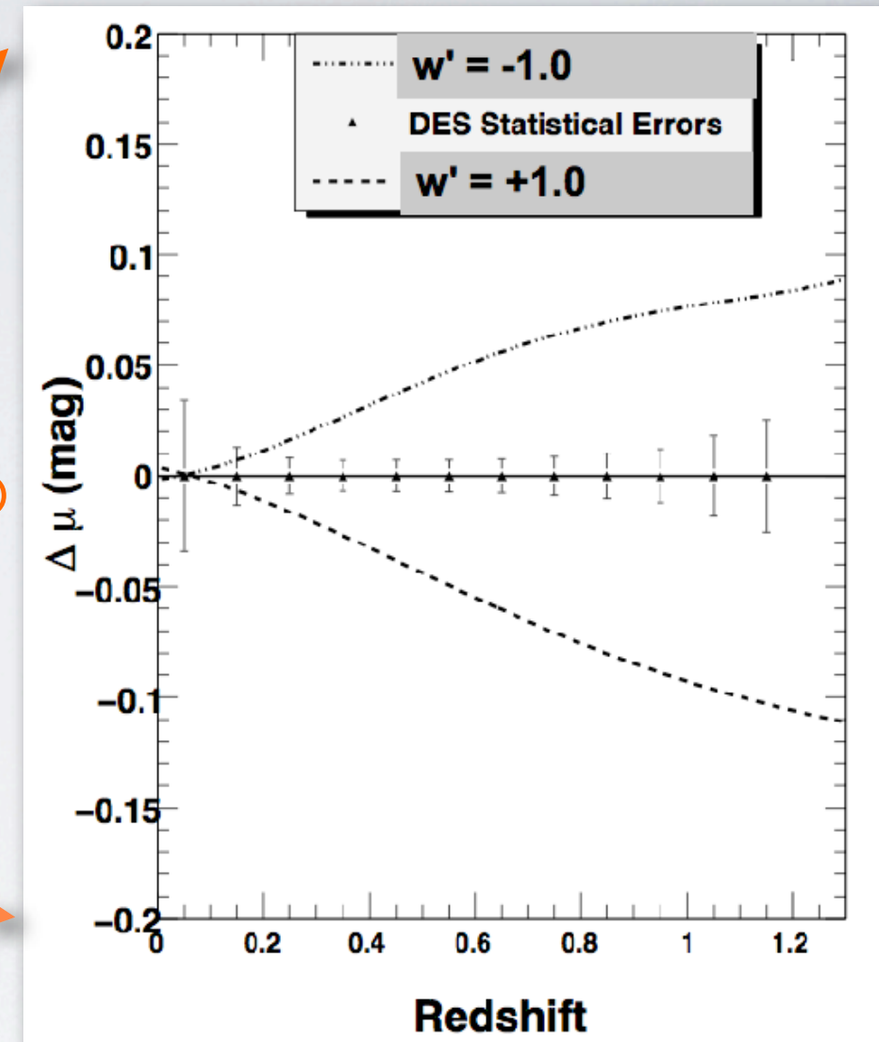
DES SCIENCE: SN



First results: ~ 100 SNe. Measured w.
(Riess et al. 1998, Perlmutter et al. 1999).

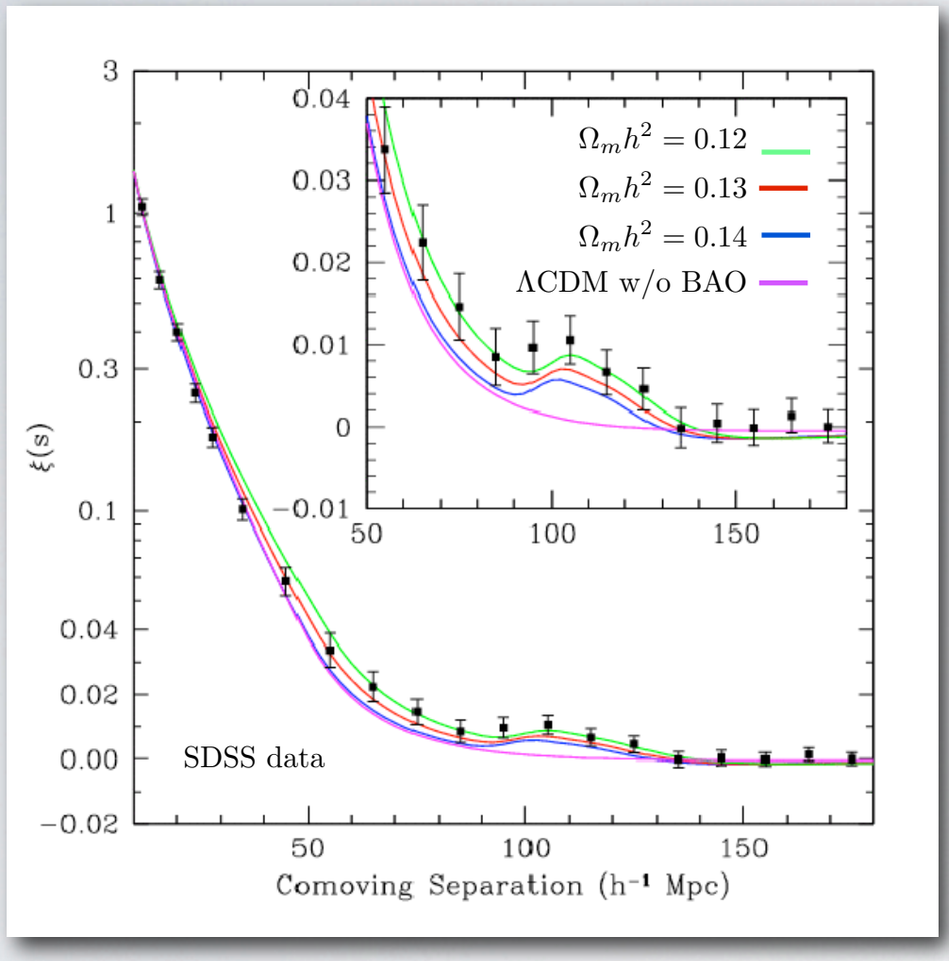
4000
SNe up to
z ~ 1.2

30 sq deg



DES expected sensitivity. Large and deep sample for measurement of w(a).

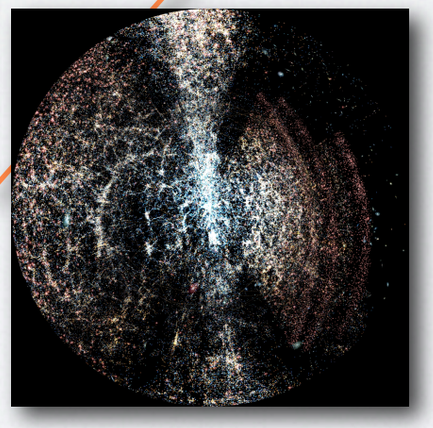
DES SCIENCE: BAO

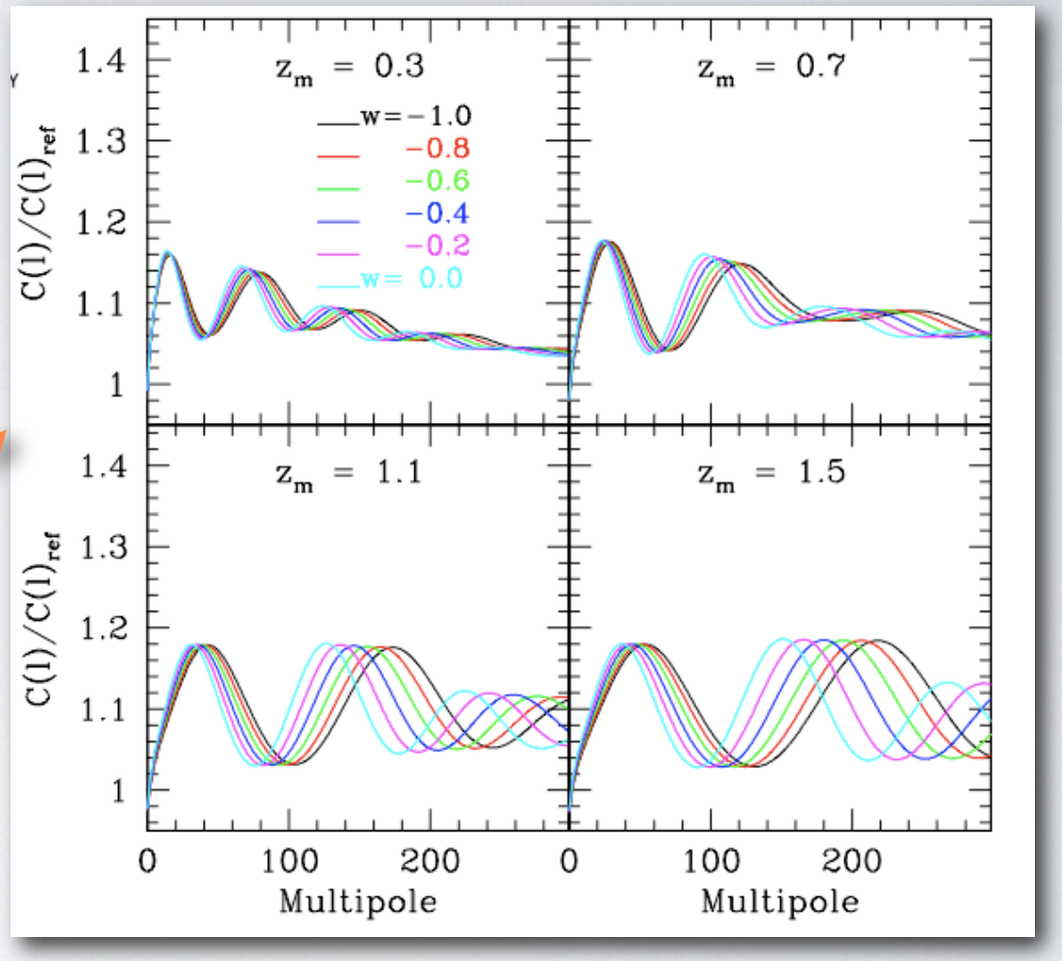


First results: mean spectroscopic redshift ~ 0.35. Measured Ω_m (Eisenstein et al. 2005)

mean photometric redshift~0.7

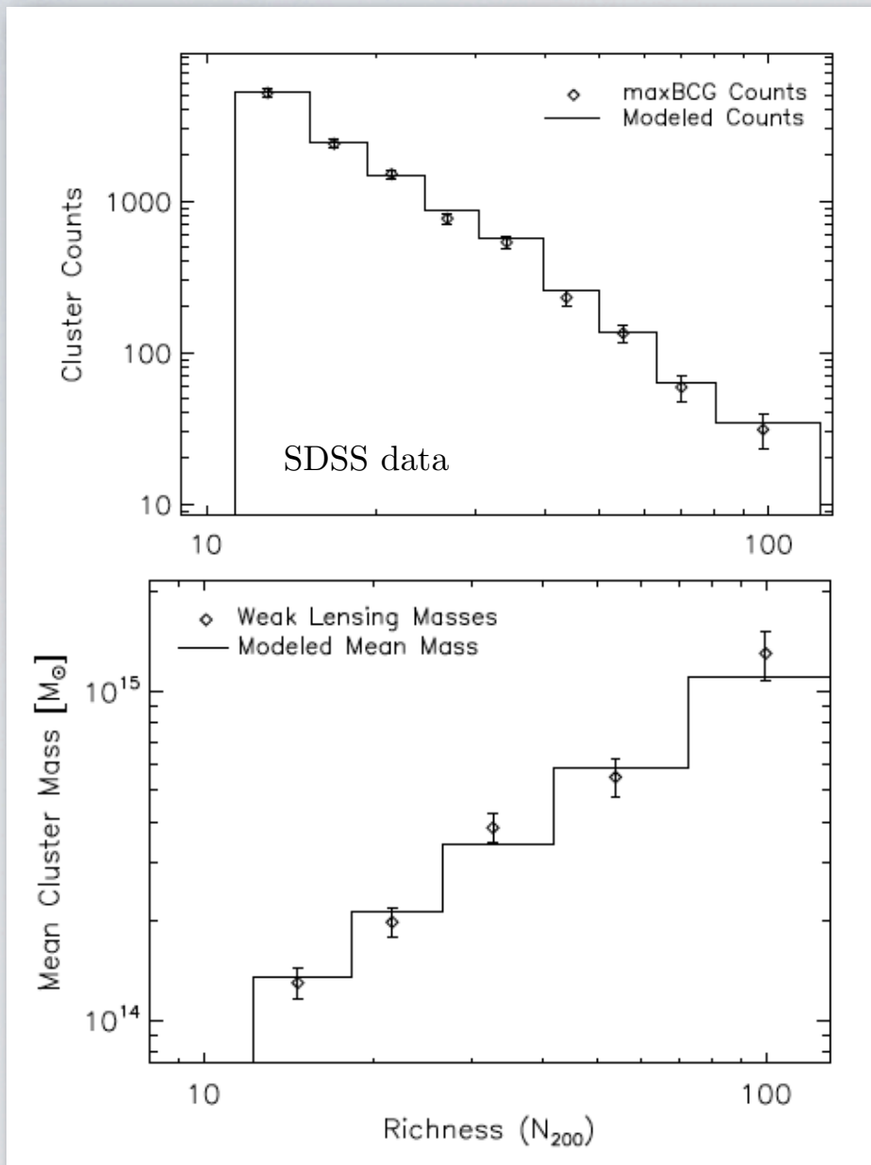
300M glxs



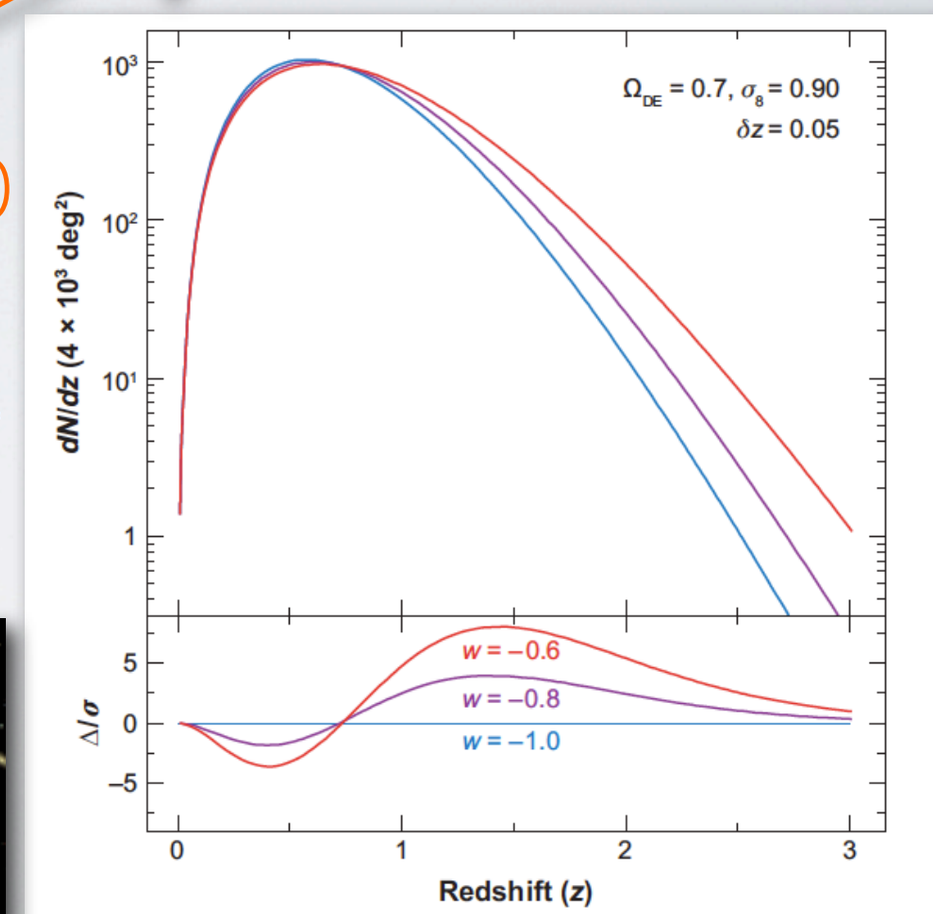


DES expected sensitivity. Can measure w by probing deeper.

DES SCIENCE: CLUSTERS



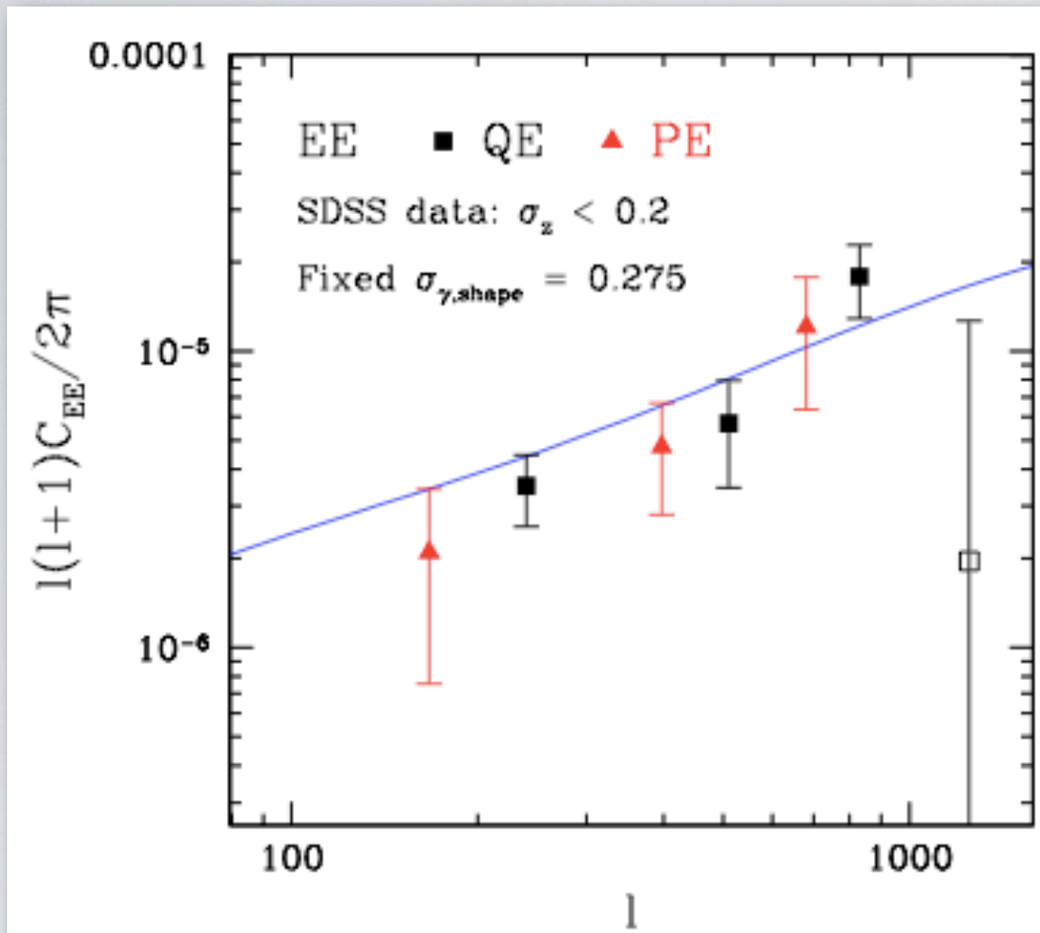
100,000 galaxy clusters z ~ 1



Current results: 6000 clusters, z ~0.35
Measured Ω_m (Rozo et al. 2010)

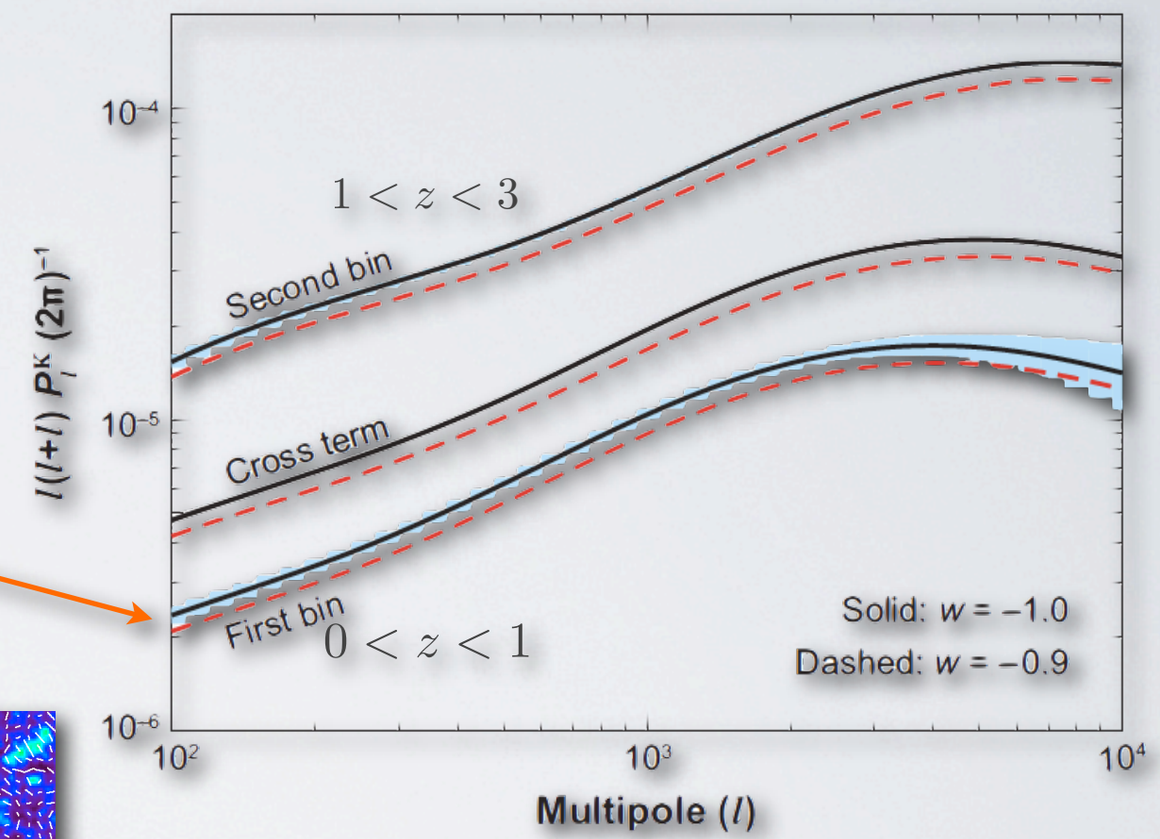
DES expected sensitivity. Measure w with deep & wide survey.

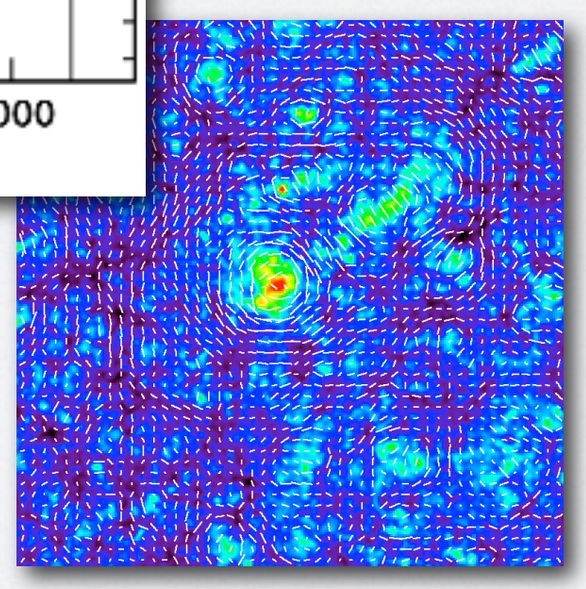
DES SCIENCE: WL



5000 sq deg

300M glxs

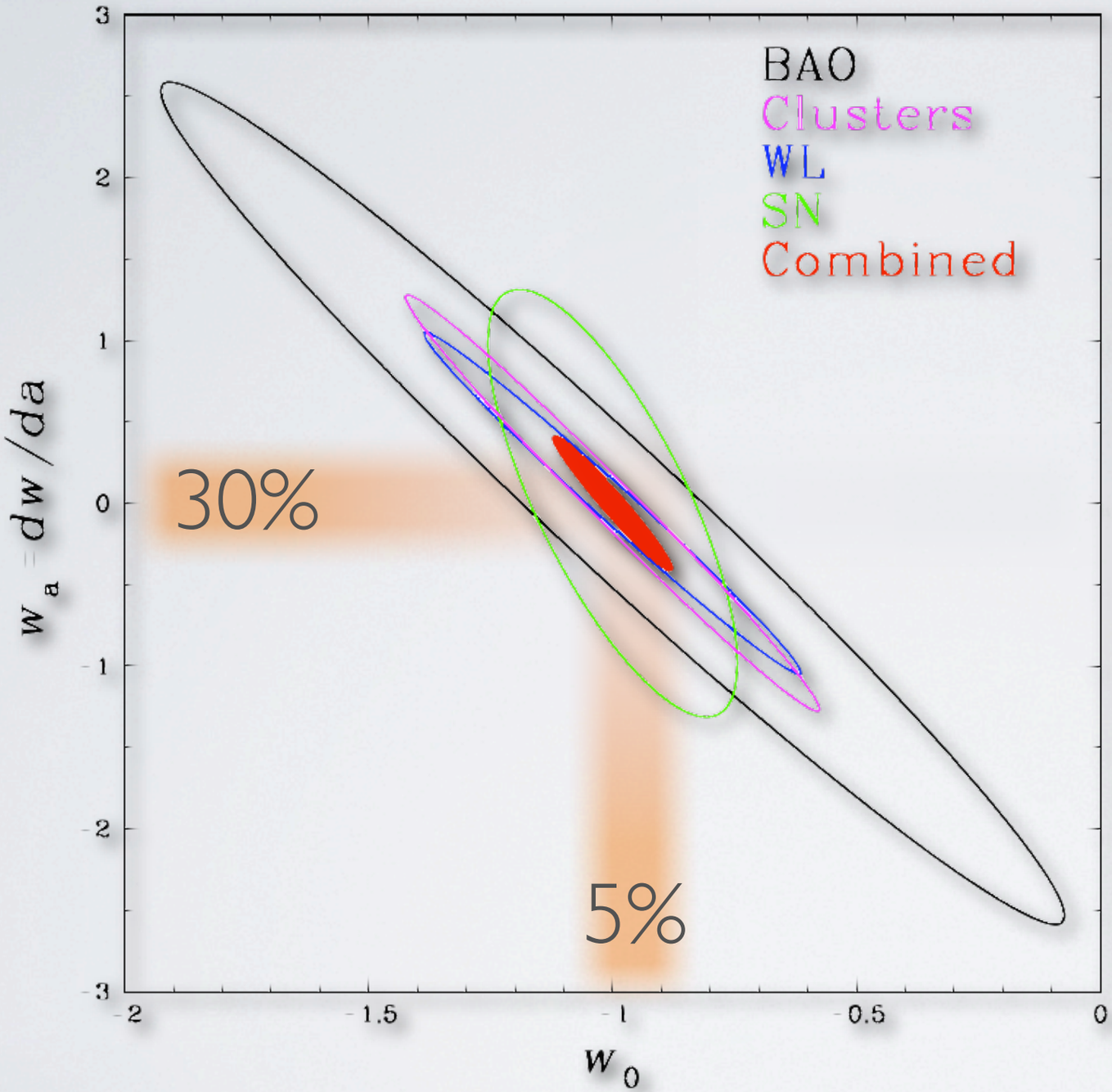




Current results: 275 sq deg, 24th magnitude. Measured Ω_m . (Lin et al. 2011)

DES expected sensitivity. Source galaxies in first bin only. Can measure w by going wider.

DES PROJECTED LIMITS



5000 deg^2, 0.9'' seeing, 24th mag (redshift~1.4)

300M galaxies, shapes, 100K clusters, 4K SNe

4 combined probes

3-5x improved Dark Energy measurement

TIMELINE

DECam

Oct 2010 - Feb 2011: tests on telescope simulator at ➤➤ Fermilab

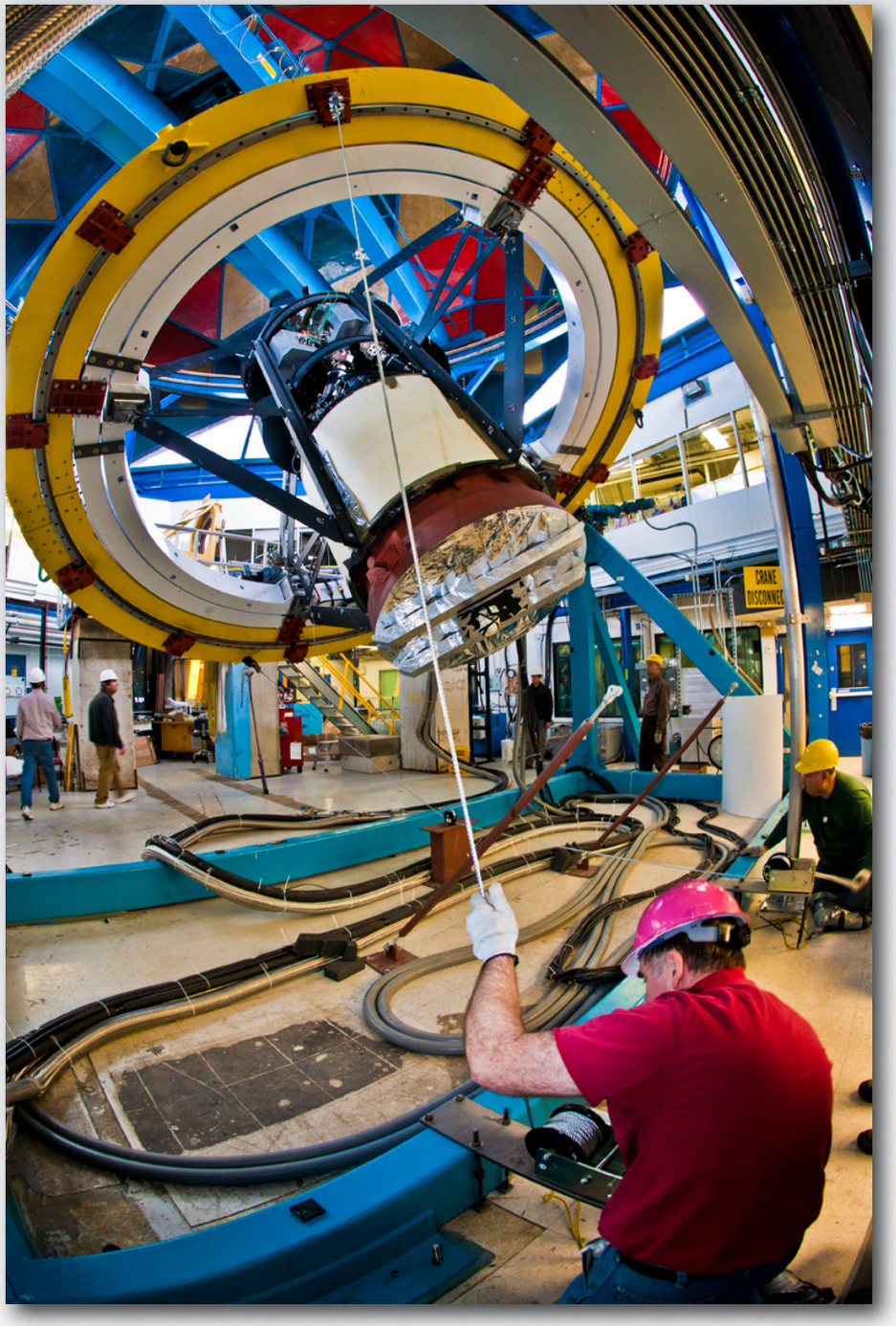
Mar-Dec 2011: integration and shipping to Chile

Jan-Sep 2012: installation and commissioning

late 2012 onward: available for DES and community

DESpec

2012: Concept for a wide-field spectrograph to follow up DES



Survey

Fall 2010: PRECam survey collected calibration data

2011-2012: Data pipeline development, survey strategy design

2012-2017: science data taking

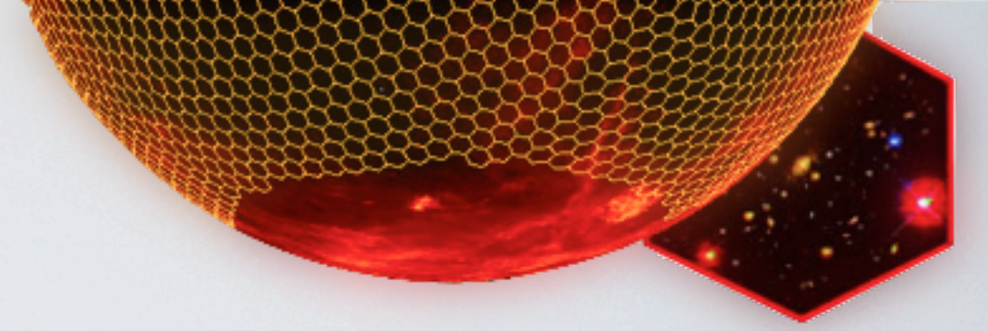
Science

2012: Blind Cosmology Challenge on simulated data

2013: Analyses start

2014: First results

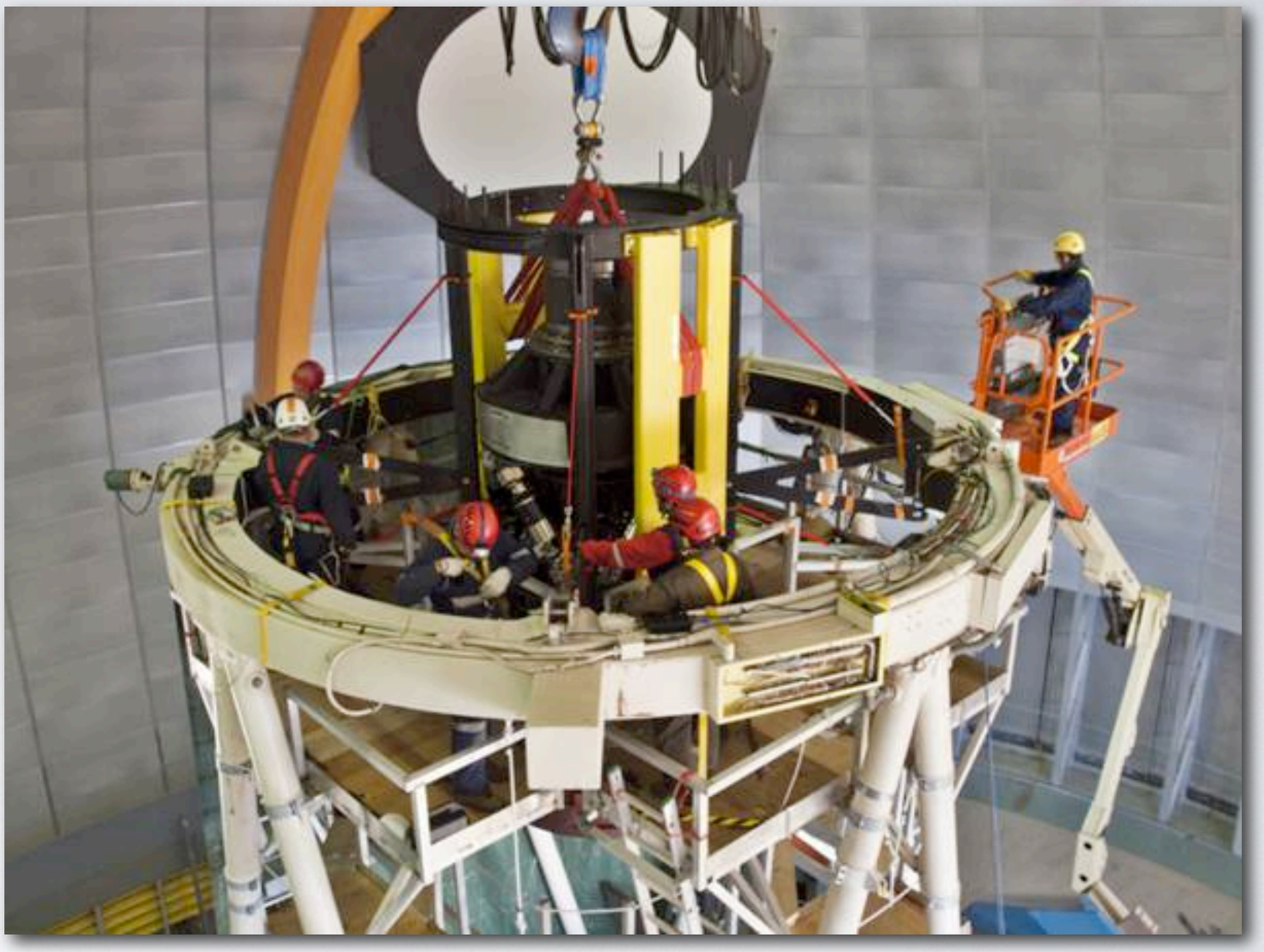
CONCLUSIONS



DES is a galaxy survey designed to study dark energy.

Data taking will start in 2012 and is planned for 5 years.

We expect to **improve current measurements by a factor of 3-5** and **shed some light on dark energy**.



DECam installation in Chile (June 2012)

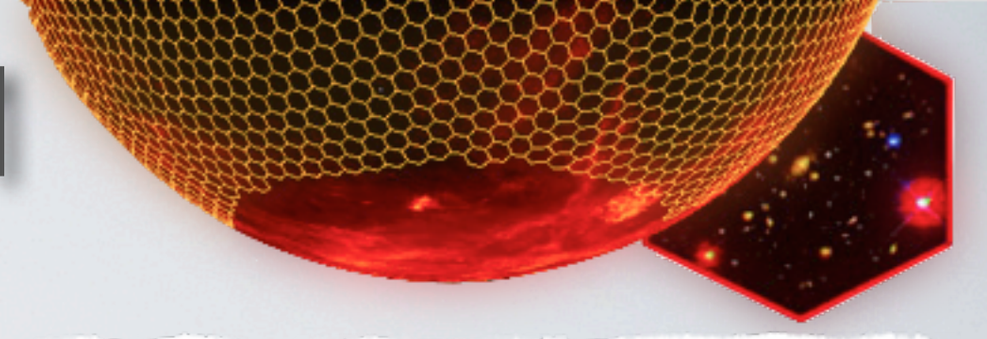
BACKUP SLIDES

DECAM IN CHILE

And picked up a few new collaborators

(some cuter than others)

QUANTUM VACUUM & DARK ENERGY



fractional energy densities

$$\Omega_\Lambda = 1 - \Omega_m - \Omega_k$$

Ω_m Matter energy density

Ω_k Geometrical curvature

Ω_Λ Dark energy density, if vacuum, $w_0 = w = -1, \; w_a = 0$

cosmological constant (Λ)

This is how well we know Dark Energy today. Combining **multiple probes** (Komatsu et al. 2010). ➤➤

$$w_0 = -0.93 \pm 0.12$$
$$w_1 = +0.38 \pm 0.65$$
$$\Omega_\Lambda = 0.72 \pm 0.02$$

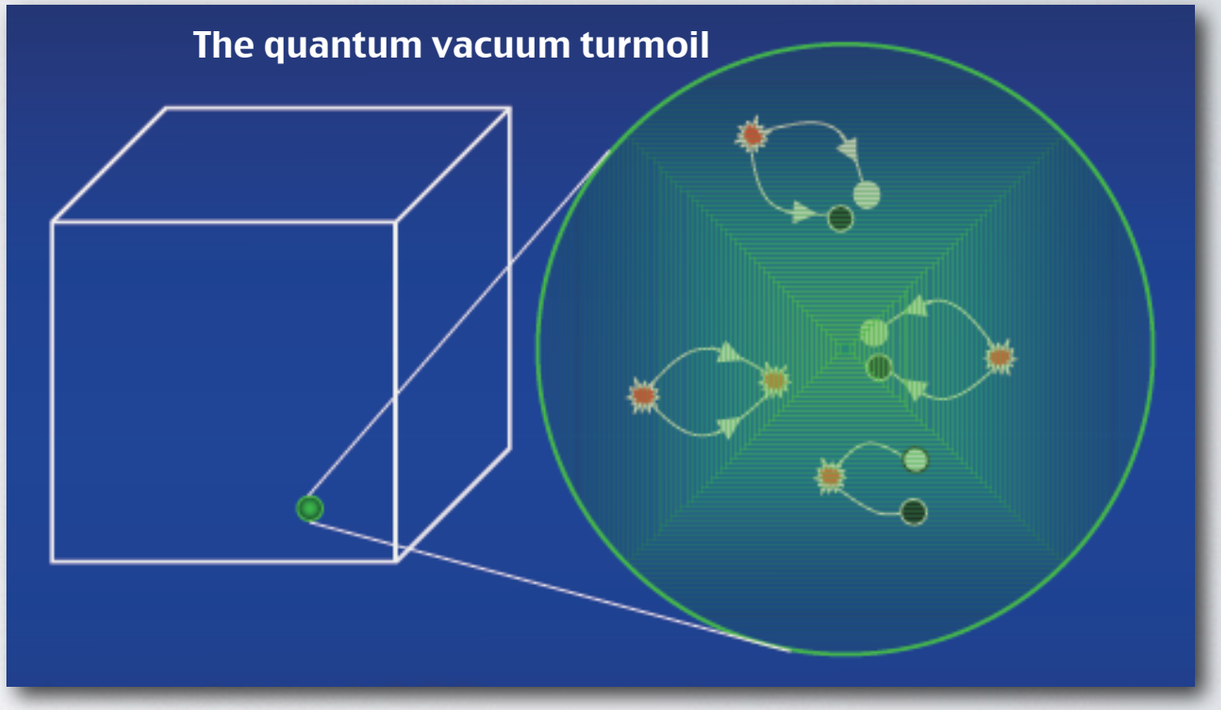
Equation of state consistent with ➤➤ **cosmological constant** !

What about the energy density? **Ask a theorist...**

COSMOLOGICAL CONSTANT PROBLEM

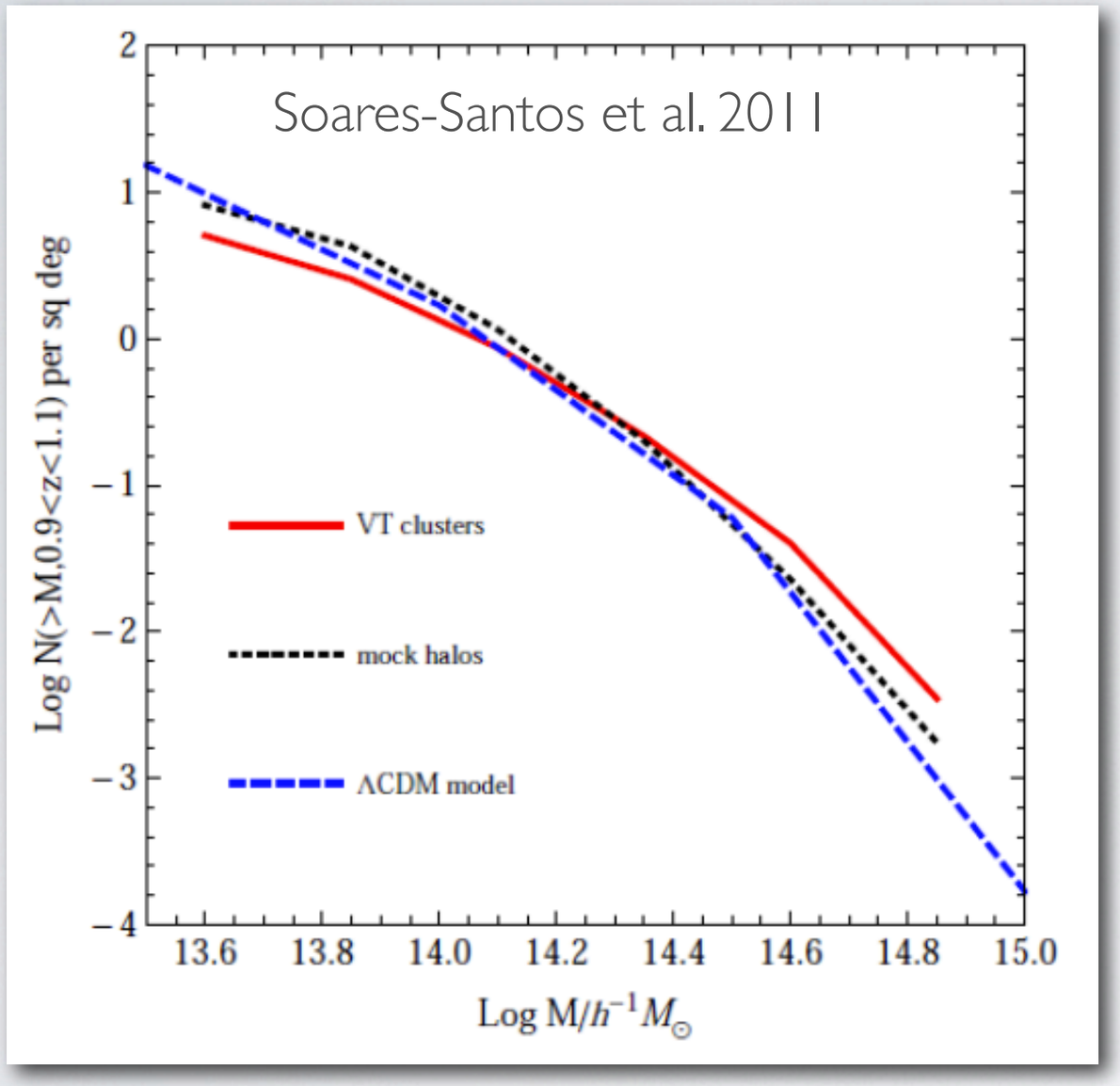
Simple calculation: $\Omega_\Lambda = 10^{120}$
Well, that can't be right.

Through some not yet understood mechanism (symmetry?) the vacuum energy is cancelled and Ω_Λ is identically zero.



➤➤ **Well, that can't be right either...**
We have measured ➤➤ $\Omega_\Lambda \simeq 0.7$

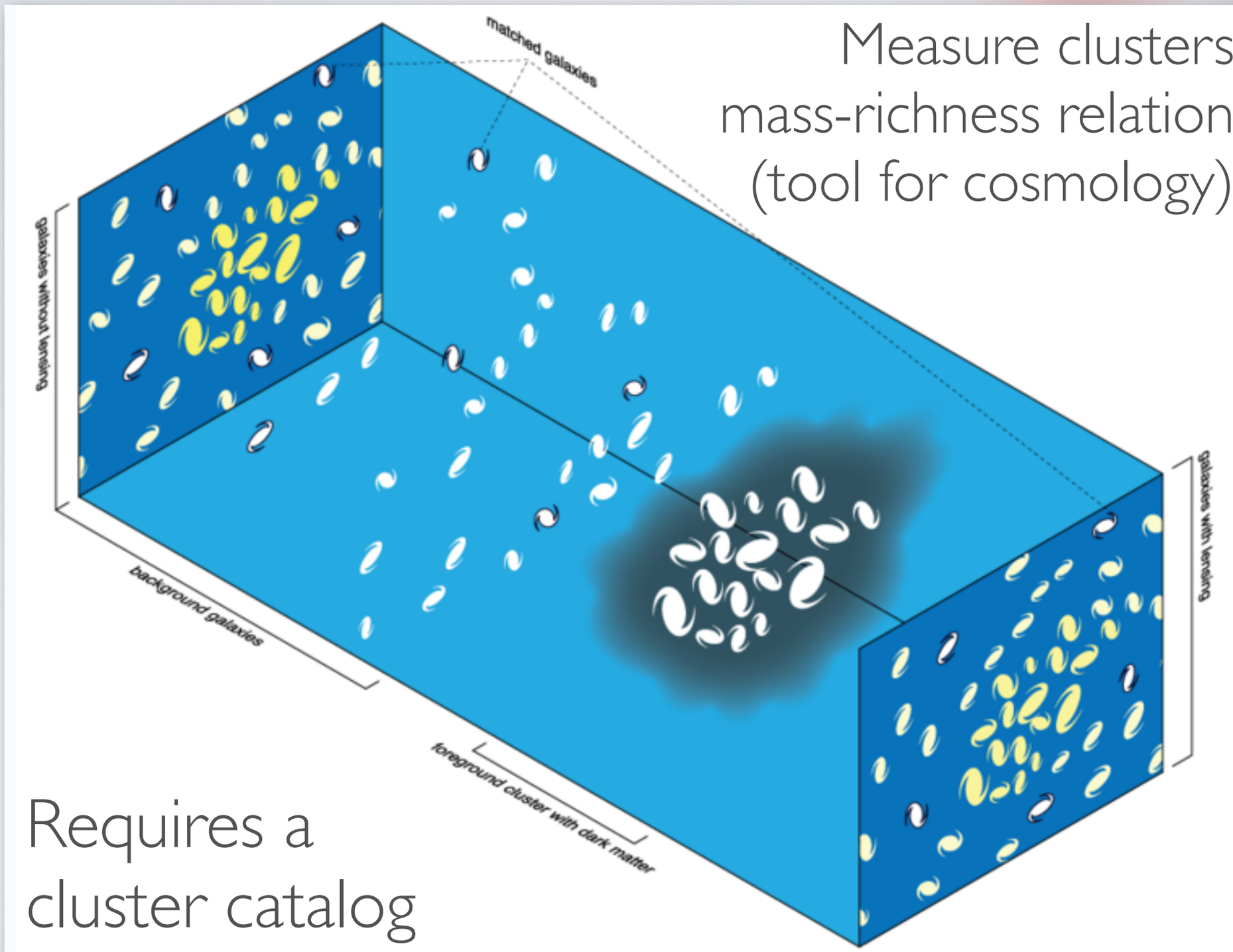
CLUSTER MASS FUNCTION



By applying the VT cluster finder on mock catalogs, we can measure the selection function for our cluster catalog.

We apply that selection function back to the cluster number counts to obtain the mass function.

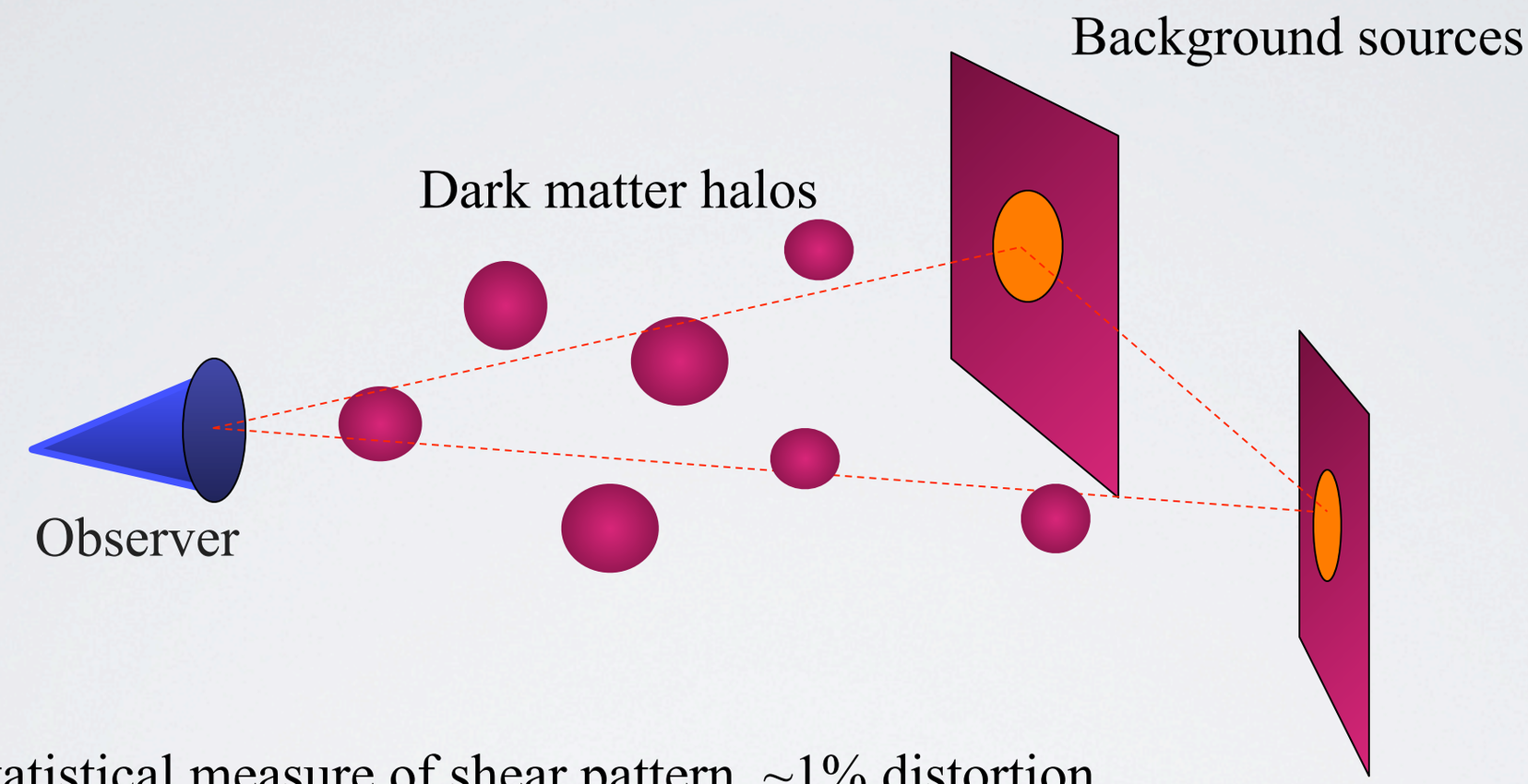
CLUSTERS LENSING



Measure clusters mass-richness relation (tool for cosmology)

Requires a cluster catalog

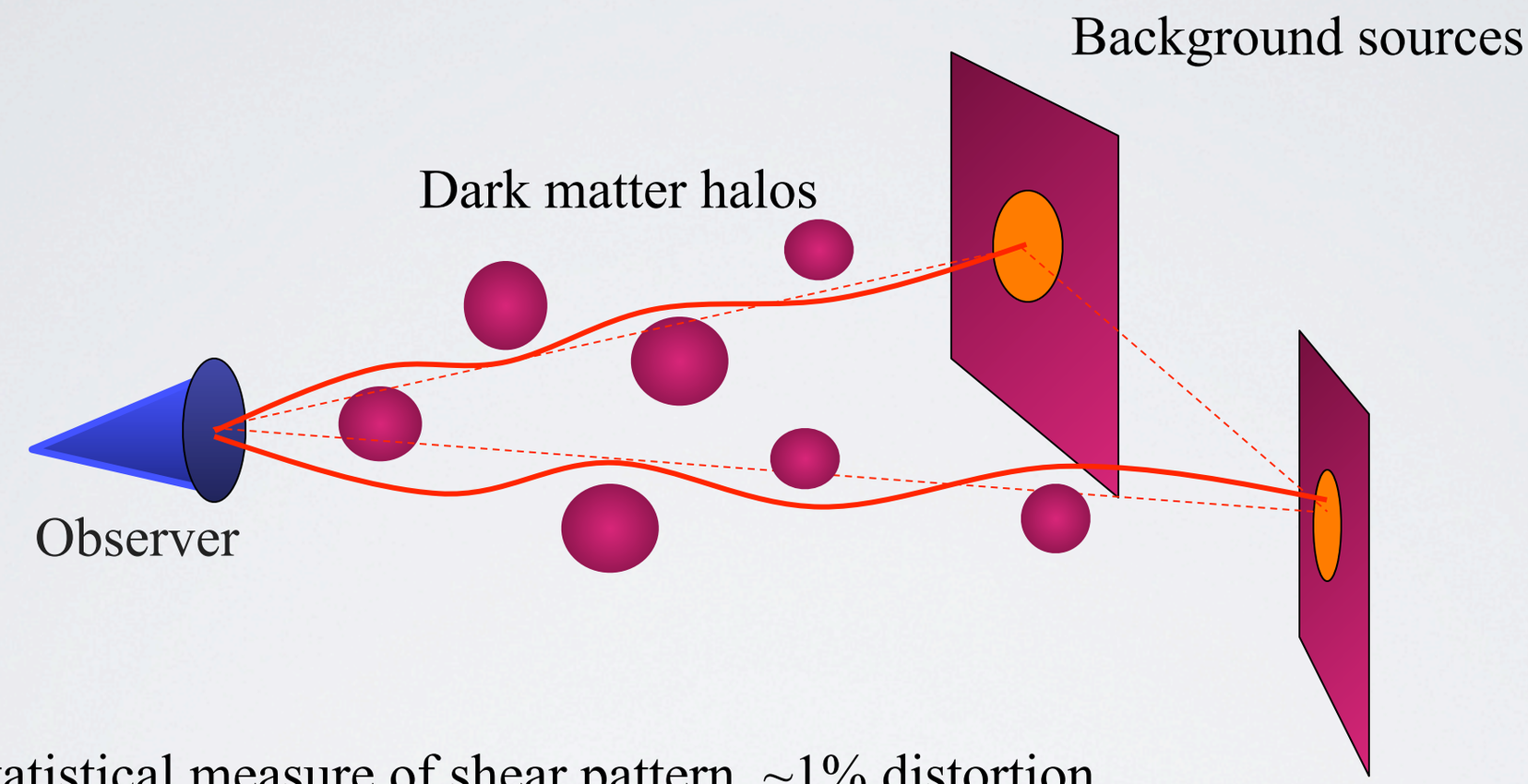
COSMIC SHEAR



- Statistical measure of shear pattern, ~1% distortion
- Radial distances depend on ***geometry*** of Universe
- Foreground mass distribution depends on ***growth*** of structure

Slide from J. Frieman

COSMIC SHEAR



- Statistical measure of shear pattern, ~1% distortion
- Radial distances depend on ***geometry*** of Universe
- Foreground mass distribution depends on ***growth*** of structure

Slide from J. Frieman

COSMIC SHEAR AND COSMOLOGY

$$\xi_\pm(\theta) \equiv \xi_{tt}(\theta) \pm \xi_{\times\times}(\theta) = \frac{1}{2\pi}\int_0^\infty d\ell\, \ell\, P_\kappa(\ell) J_{0,4}(\ell\theta),$$

correlation functions

convergence power spectrum: matter fluctuations after projection along line of sight

$$P_\kappa(\ell) = \frac{9}{4}\Omega_m^2\left(\frac{H_0}{c}\right)^4 \int_0^{\chi_{lim}} \frac{d\chi}{a^2(\chi)} P_\delta\left(\frac{\ell}{f_K(\chi)};\chi\right) \times \left[\int_\chi^{\chi_{lim}} d\chi' n(\chi') \frac{f_K(\chi'-\chi)}{f_K(\chi')}\right]^2,$$

power spectrum: 3D matter fluctuations growth of structure

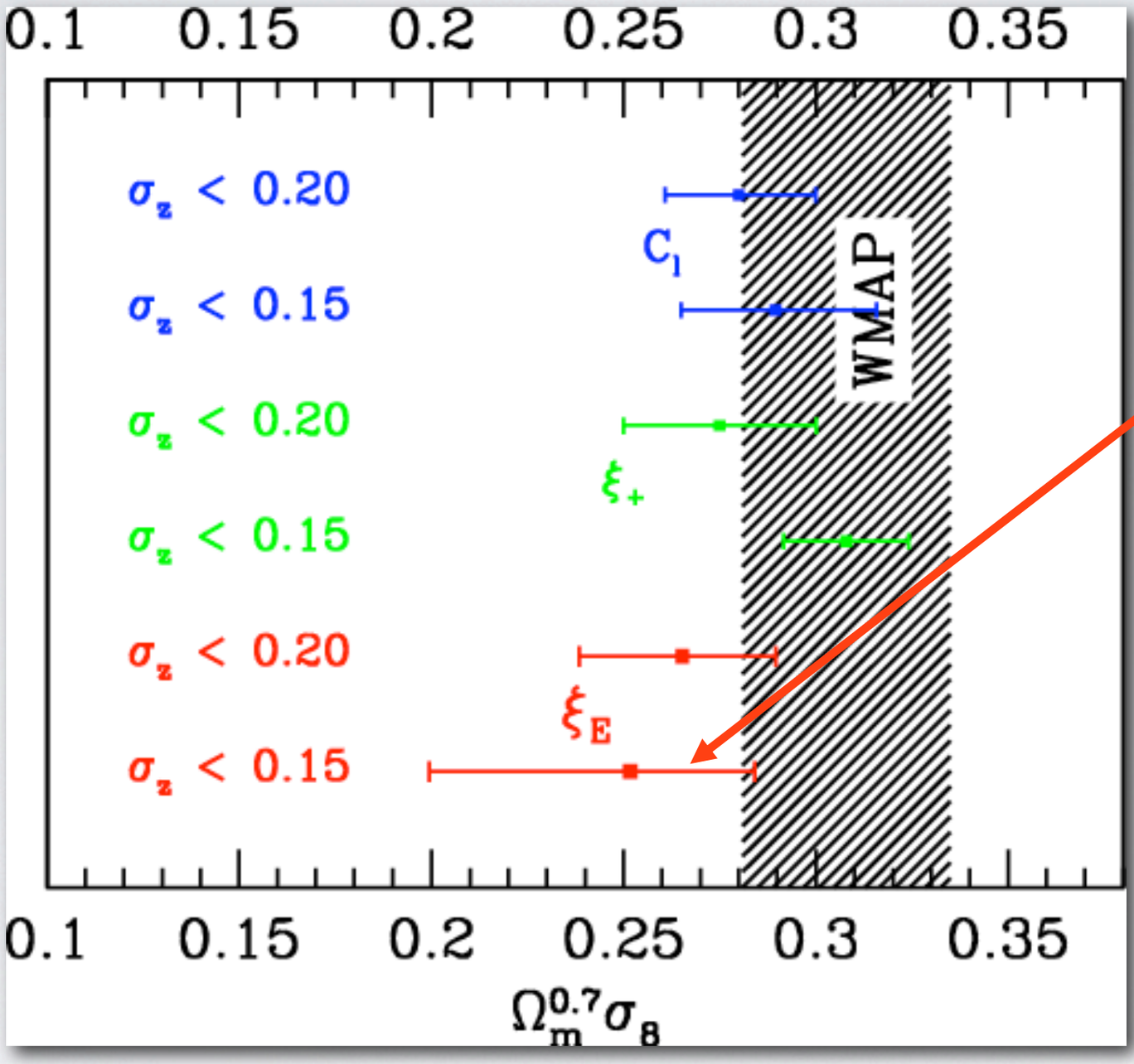
COSMOLOGY PARAMETERS

Galaxy redshift distribution

distances geometry

Slide from H. Lin

COSMOLOGY CONSTRAINTS



Power spectrum

ξ_+ correlation function

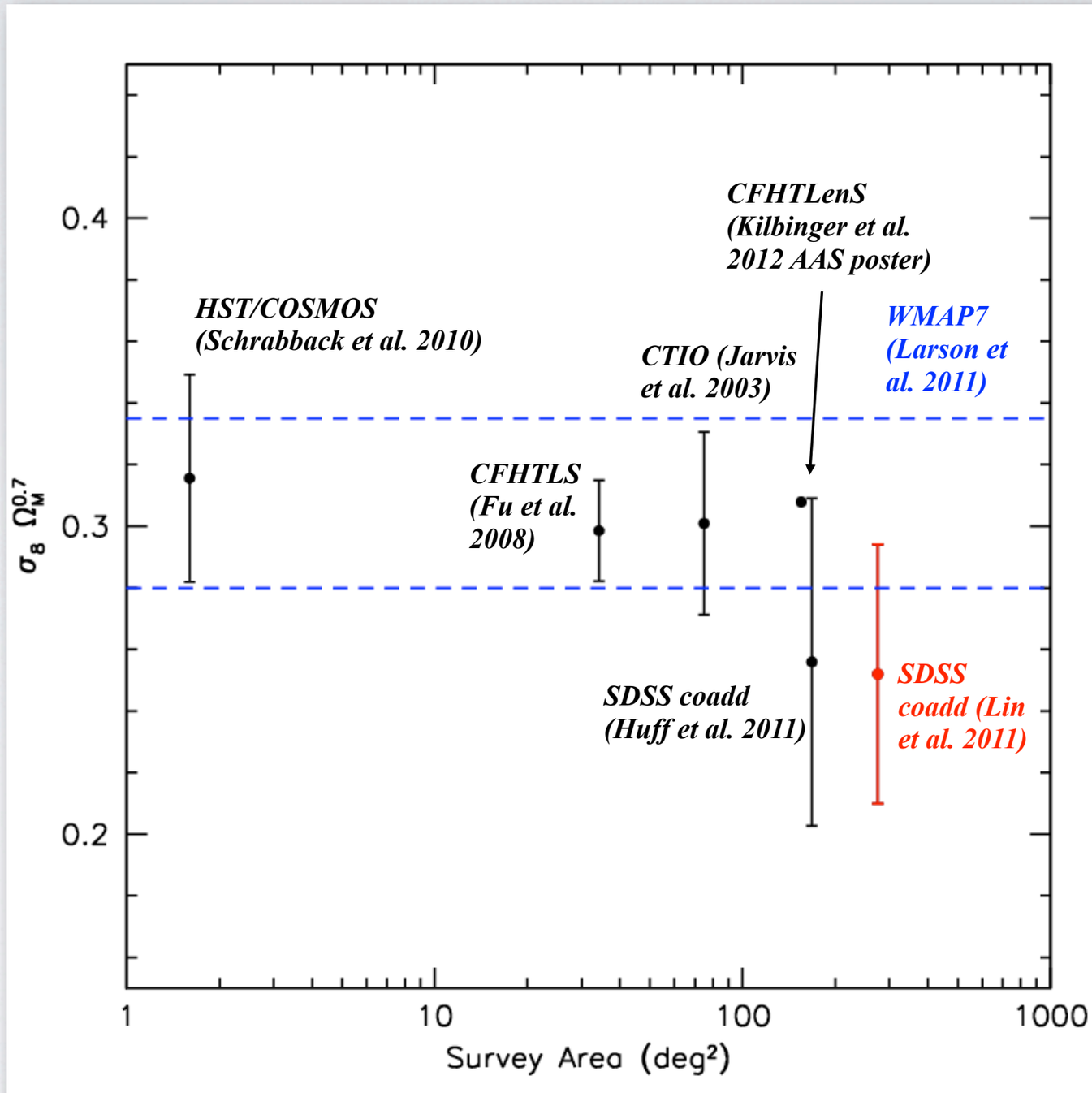
ξ_E E-mode correlation function

Final result uses our most conservative method/sample(in terms of error bar, photo-z errors, and B-modes):

$$\Omega_m^{0.7}\sigma_8 = 0.252^{+0.032}_{-0.052}$$

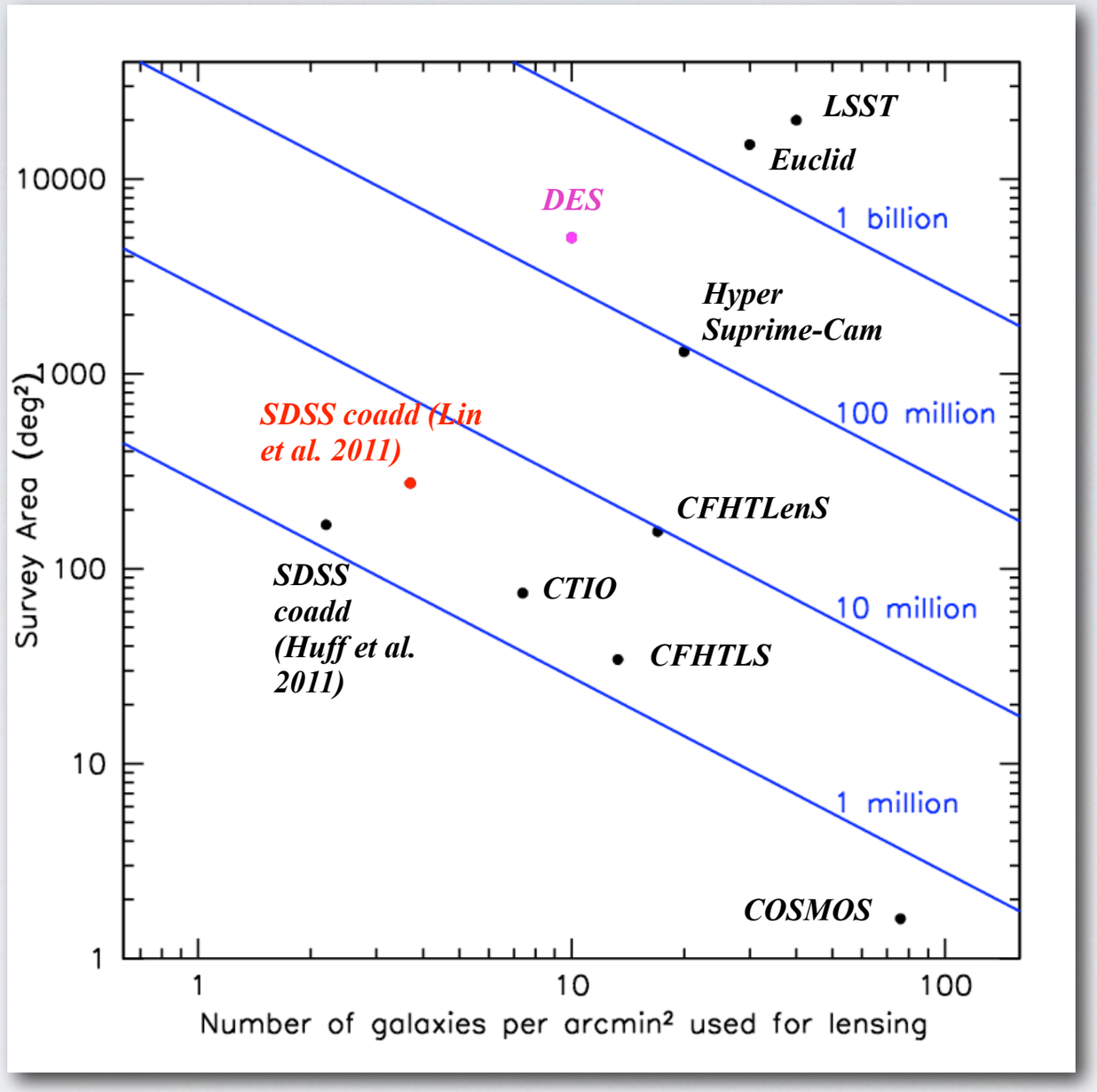
CONSTRAINTS VS. SURVEY AREA

$\sigma_8\ \Omega_M^{0.7}$ *evaluated at WMAP value* $\Omega_M = 0.266$



At 275 deg², we are the largest area survey used for cosmic shear detection so far

CONSTRAINT VS. NUMBER OF GALAXIES



Blue lines indicate constant numbers of galaxies