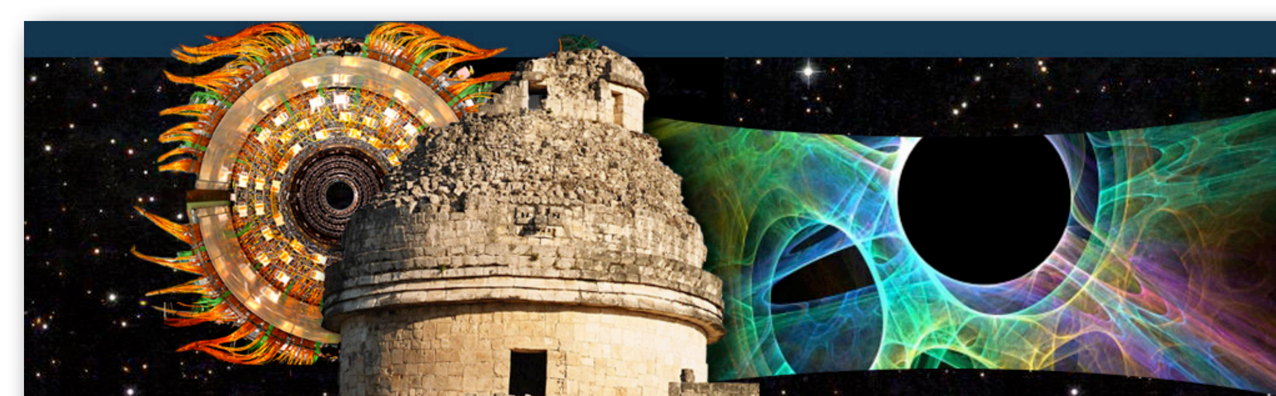
The Dark Energy Survey Project

Science Prospects and Current Status

Brian Nord
[University of Michigan]

for the Dark Energy Survey Collaboration



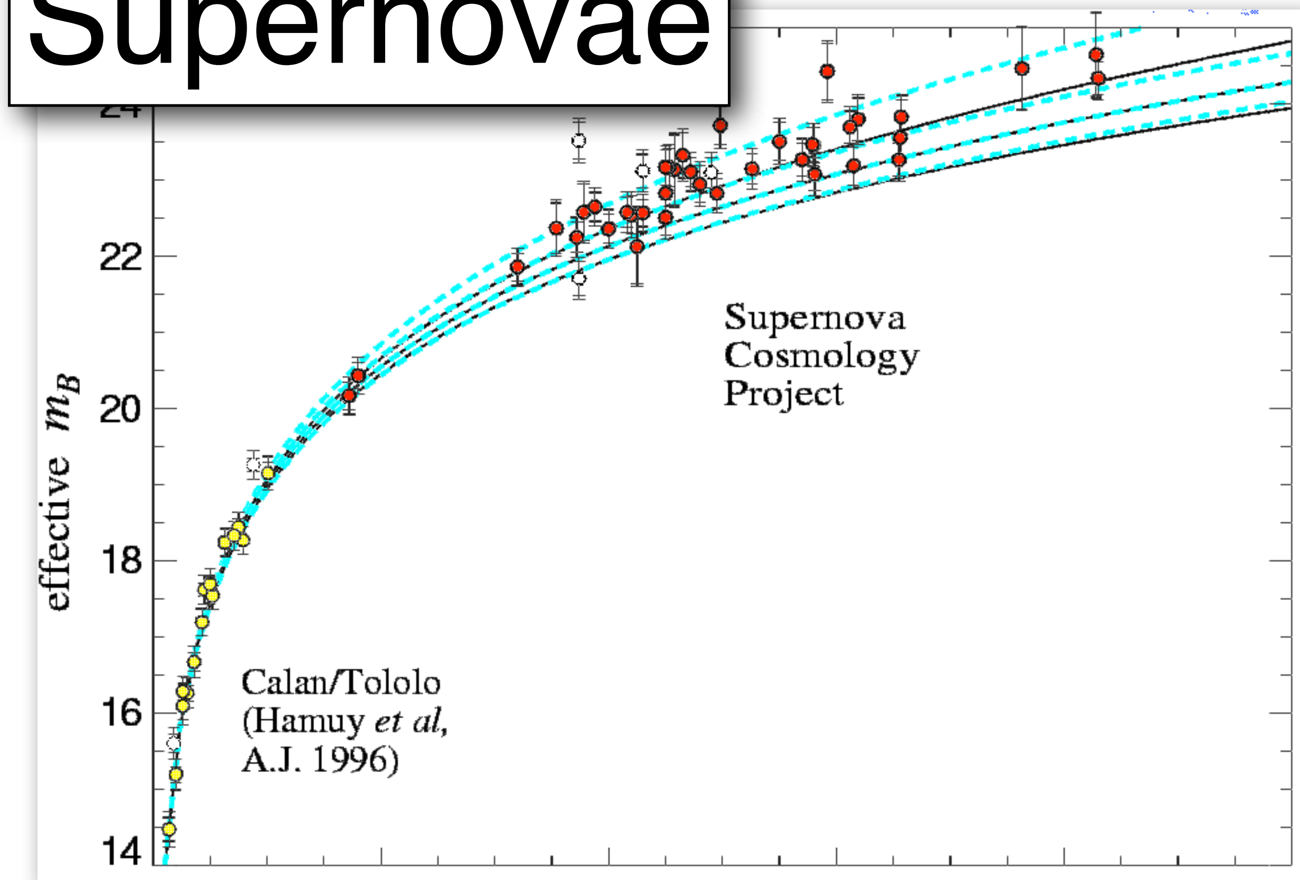
at PASCOS 2012
03. 06 . 2012
Merida, Mexico

Overview: the Dark Energy Survey (DES)

- DE Task Force and broader context
- DES at a glance
- The components of DES
  - Observations and Hardware
  - Simulations
  - Theory
- DES in context with other surveys
- Timeline and Status

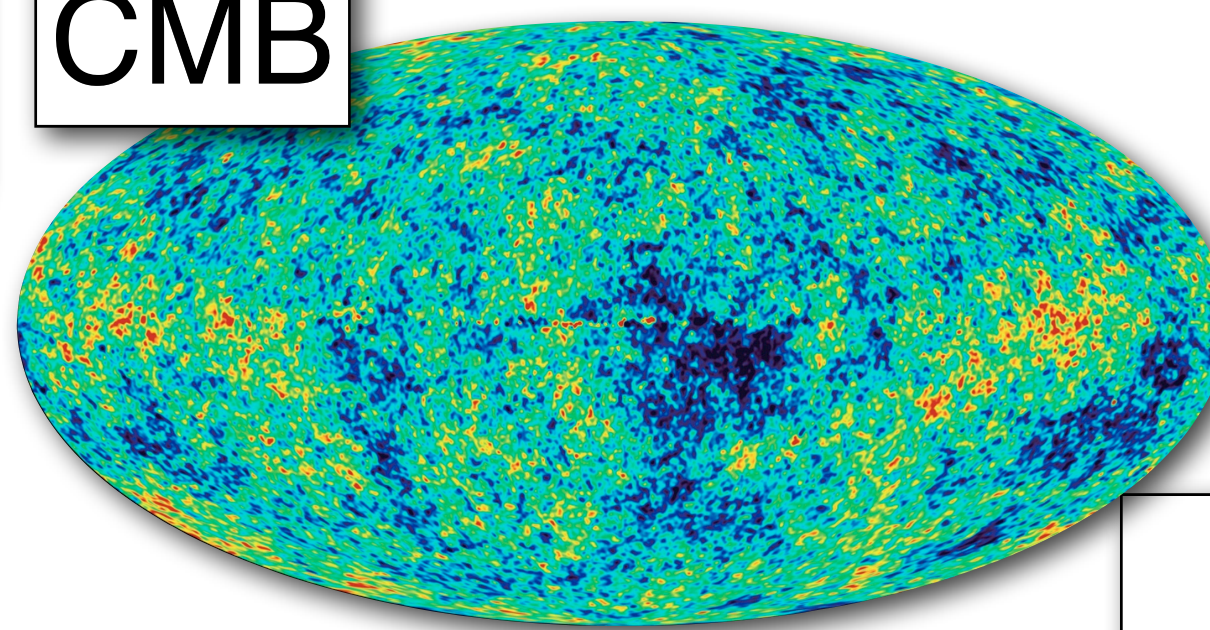
Dark Energy: the discovery

Supernovae

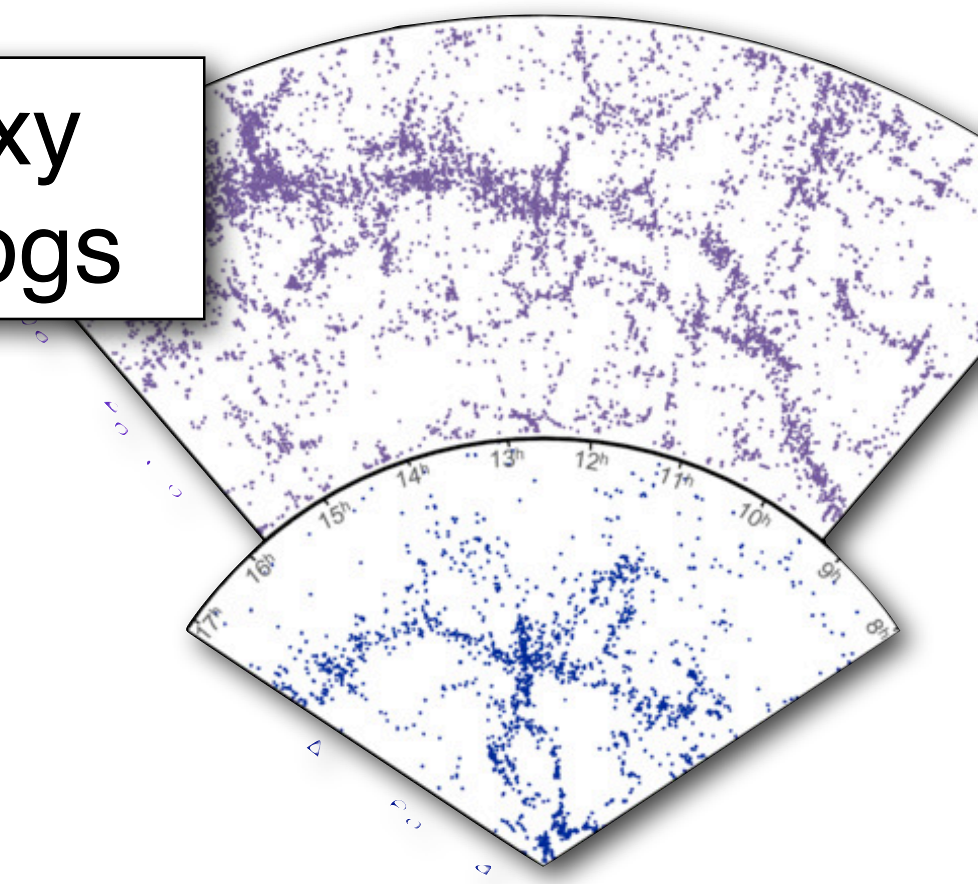


Assumptions:
- GR with Vacuum Energy
- Homogeneity/Isotropy

CMB

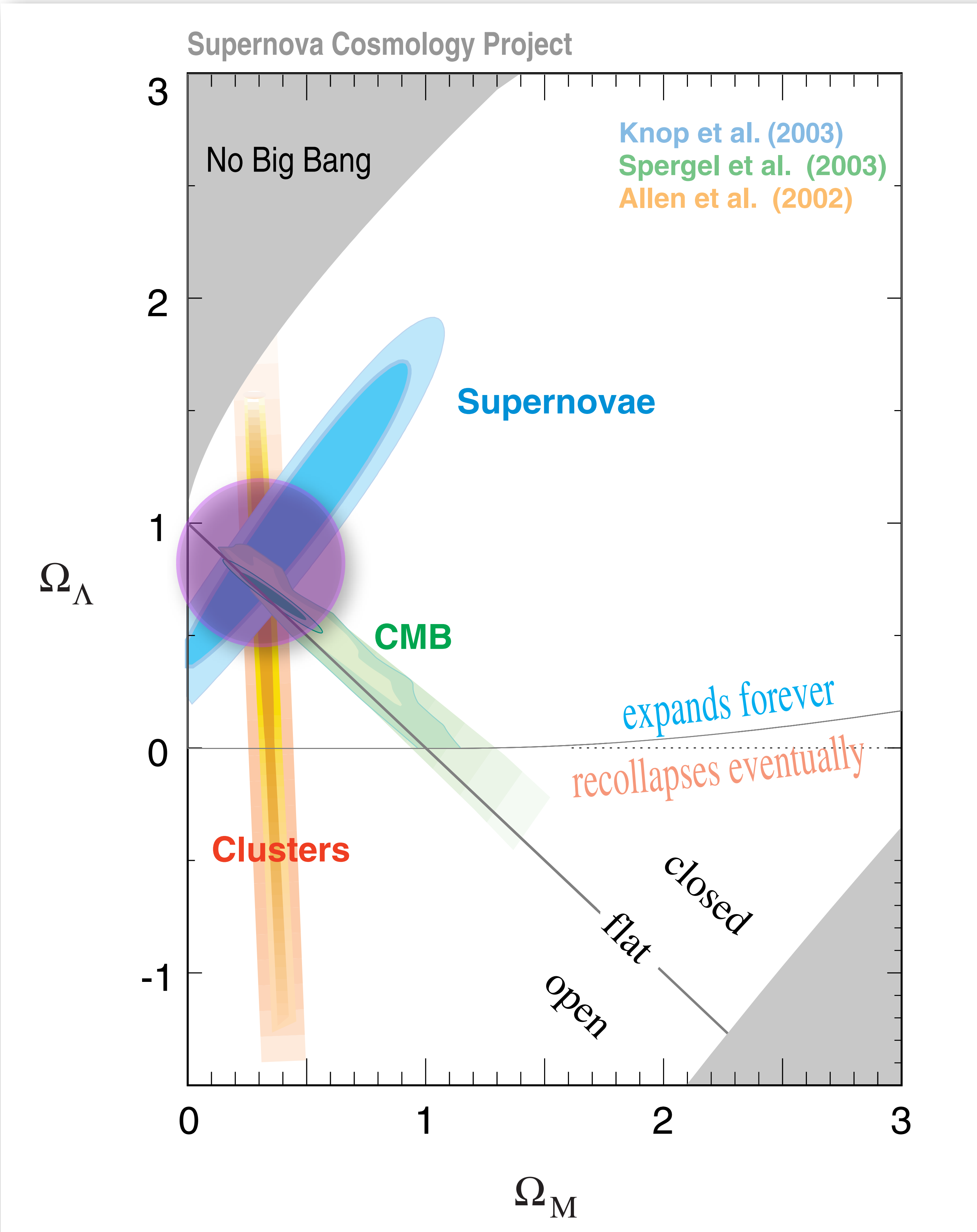


Galaxy Catalogs



Results:
- SN1e are further away than expected.
- The geometry of space-time is flat.
- The universe is matter under-dense.

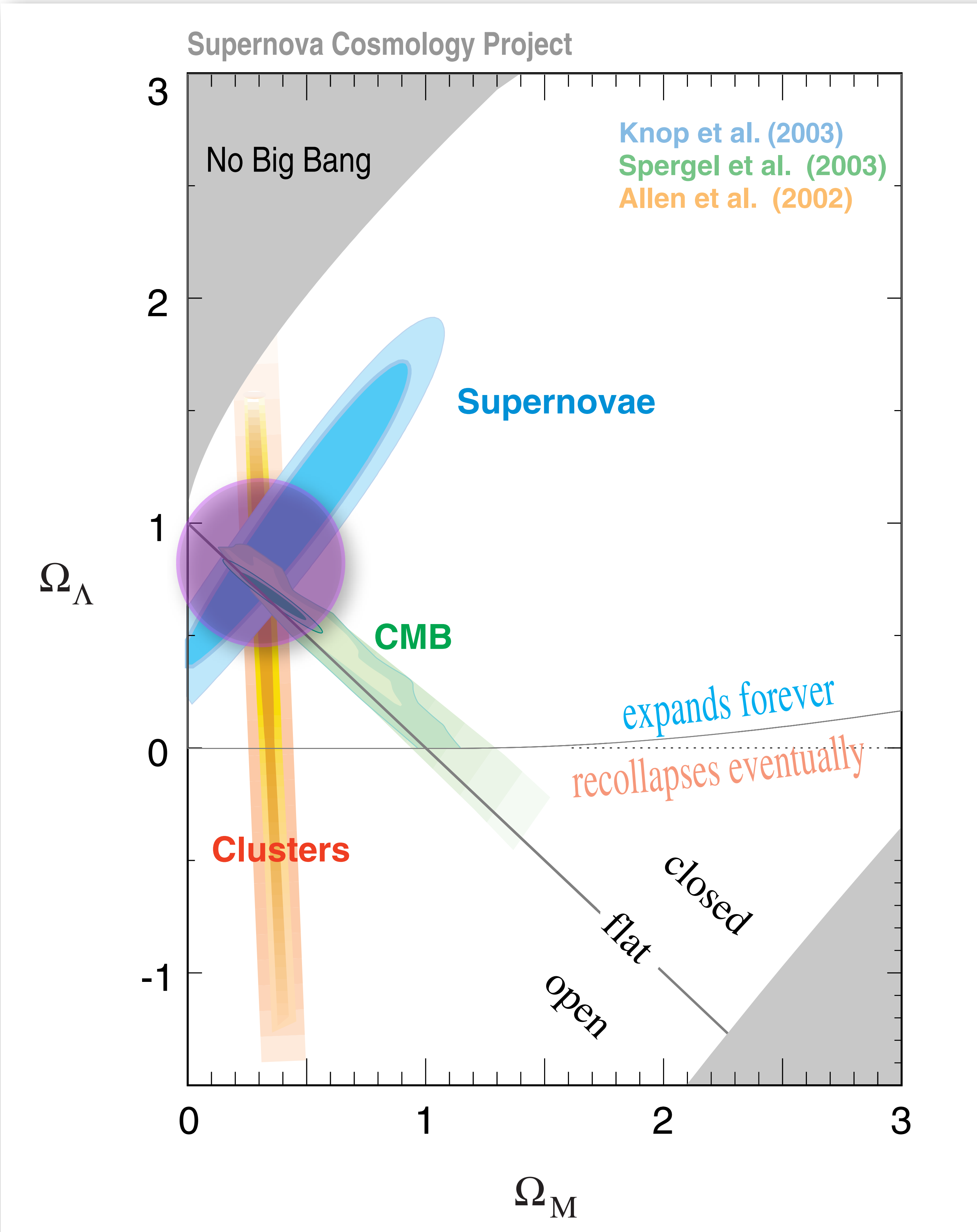
Dark Energy: implications



Implications:

- The universe's expansion is accelerating.
- Our descendants will live in island-universe mega-galaxies.

Dark Energy: implications



Implications:

- The universe's expansion is accelerating.
- Our descendants will live in island-universe mega-galaxies.
- Nobel Prize (2011)

Dark Energy: the strategy for cosmological surveys

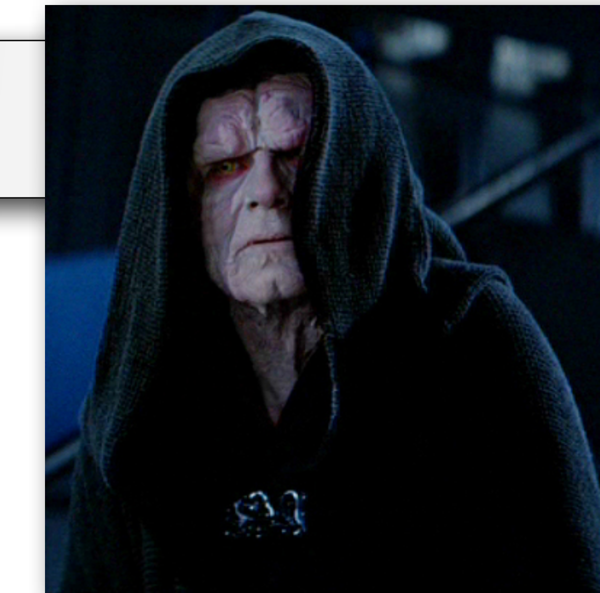
Test the underpinnings:

Search for deviations
from General Relativity.

Discern the basic nature of DE:

Cosmological Constant or
evolving equation of state?

Dark Energy: the goal



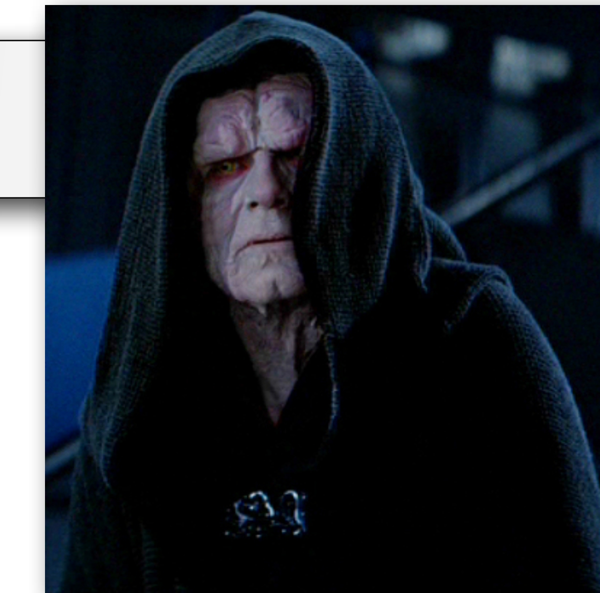
Dark Energy Task Force

[June 2005]

Eqn. of State: $w(a) = P(a)/\rho(a)$

Parametrization: $w(a) = w_0 + (1-a)w_a$

Dark Energy: the goal



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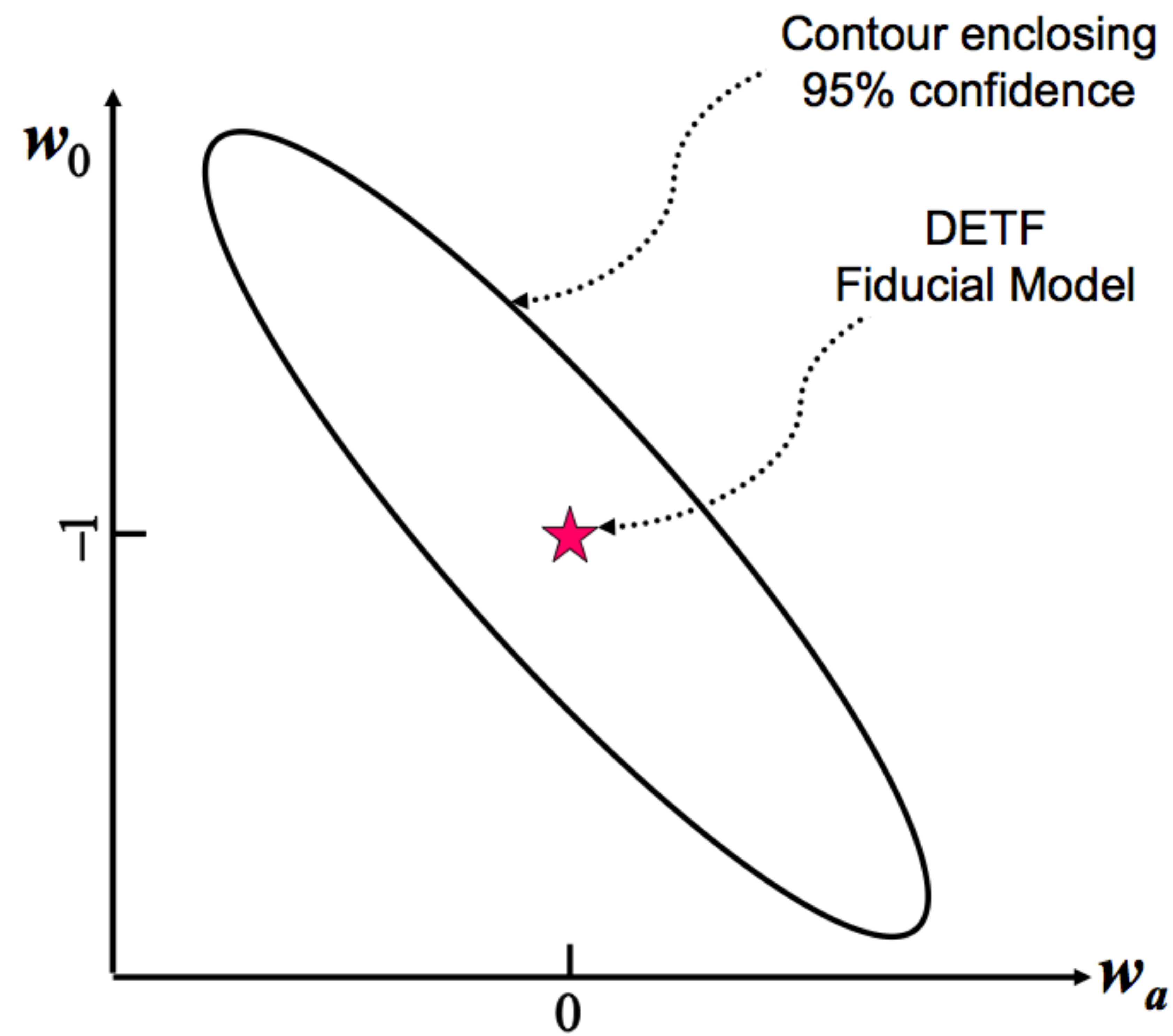

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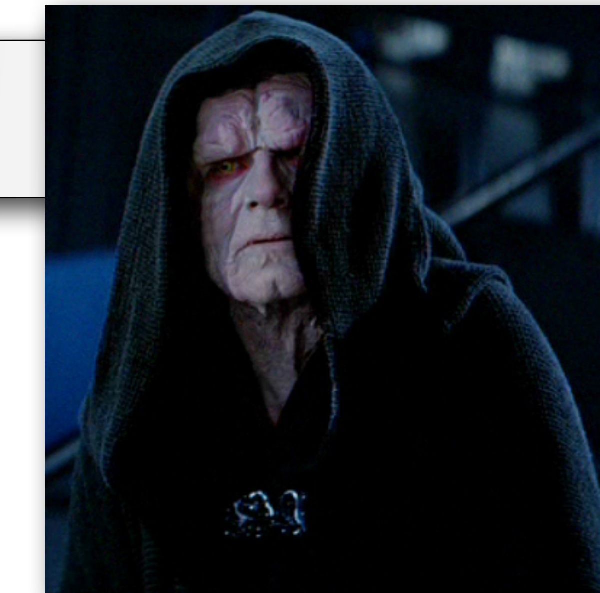

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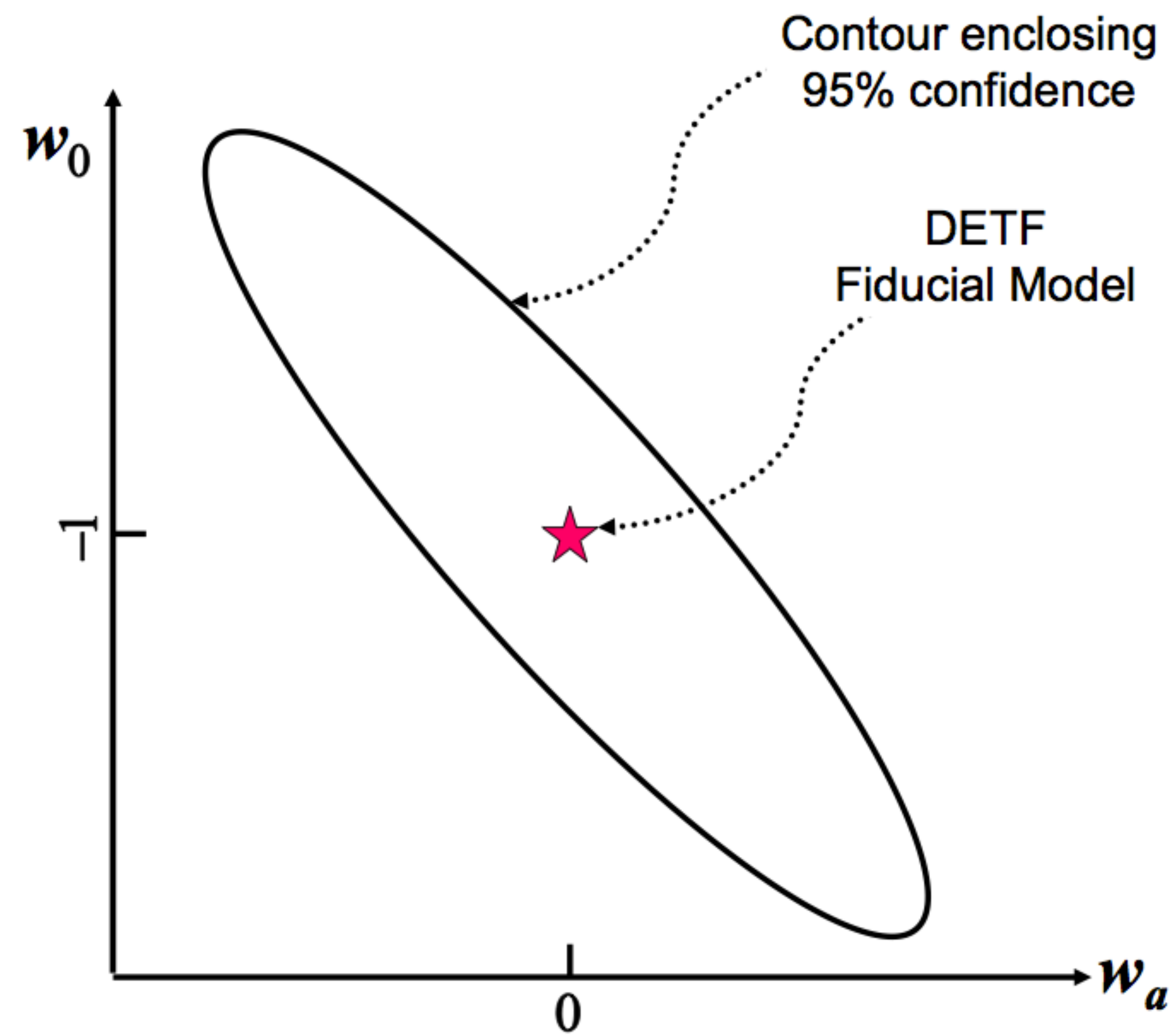
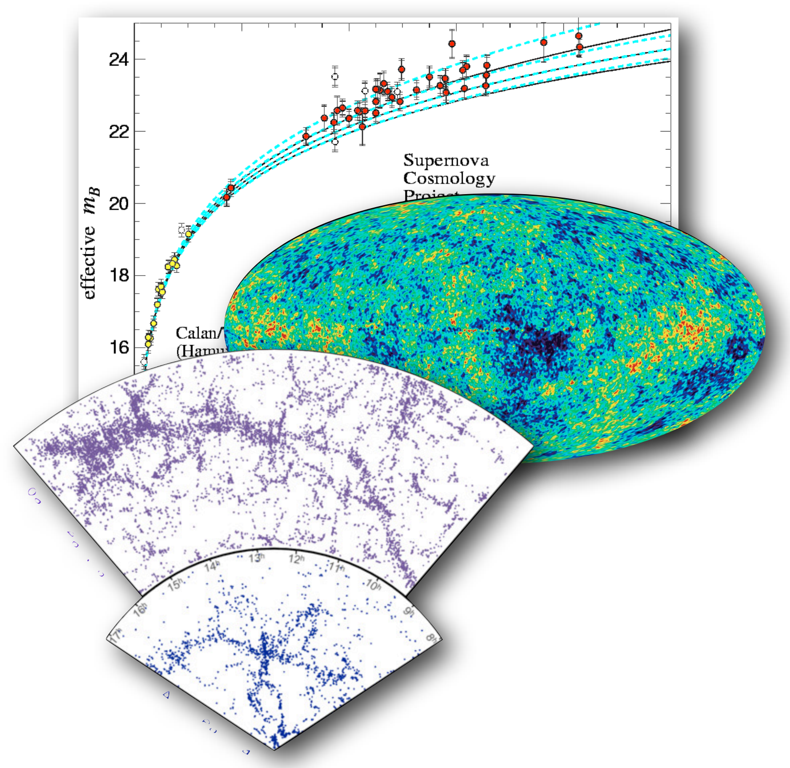
Figure of Merit:
Reciprocal of the error ellipse enclosing 95% confidence limit in the $\mathbf{w_0}$-$\mathbf{w_a}$ plane.

$$\mathrm{FOM} \propto [\sigma(w_0)\sigma(w_a)]^{-1}$$



Dark energy: the multi-stage survey approach

	Stage I	Stage II	Stage III	Stage IV
Timing	2005			
Example Experiments/ Data				
Knowledge about dark energy	Exists!			

Dark energy: the multi-stage survey approach

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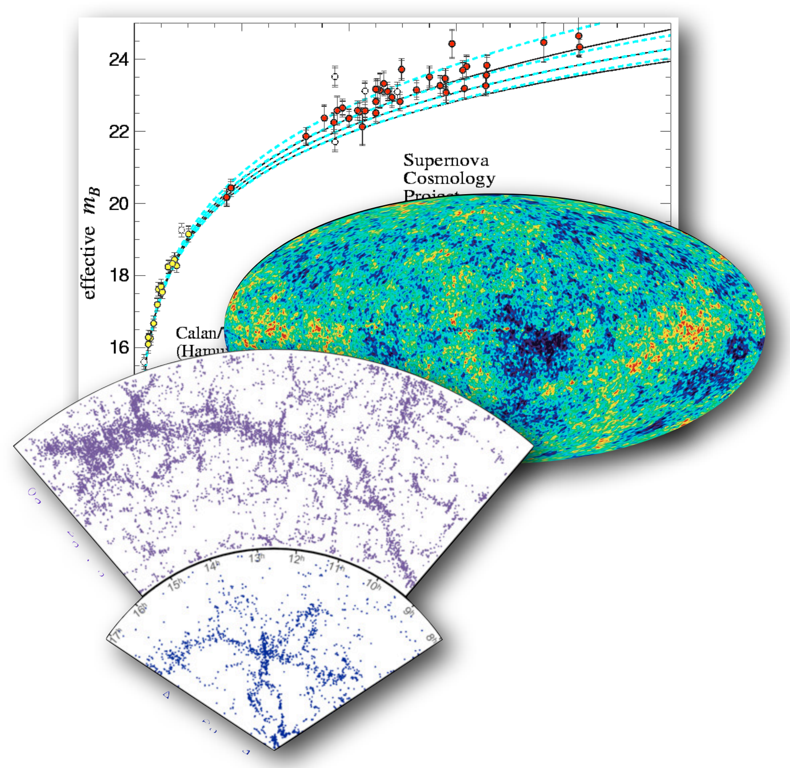
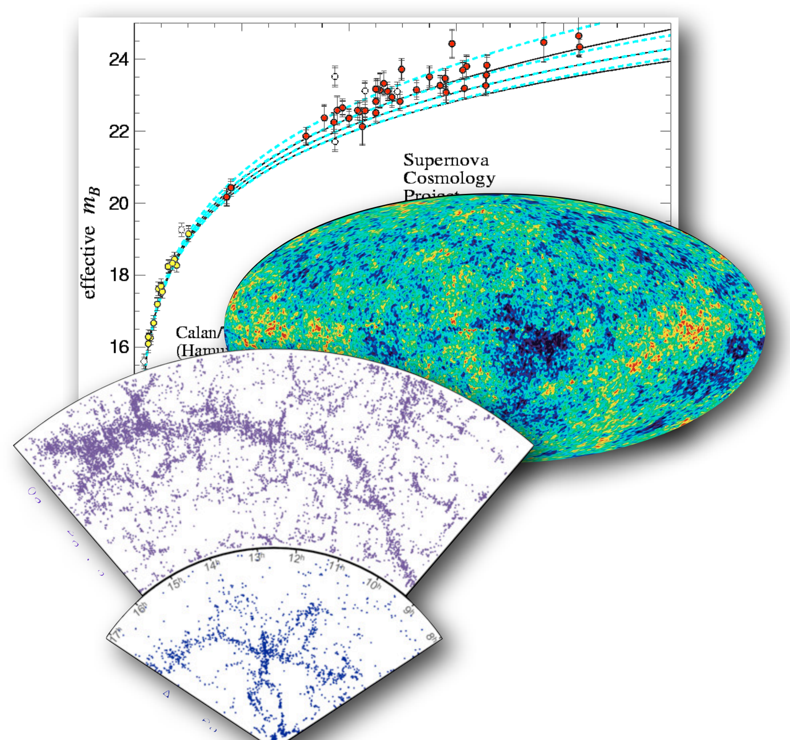
Example Experiments/ Data		SDSS South Pole Telescope		
Knowledge about dark energy	Exists!	Baseline FOM		

Dark energy: the multi-stage survey approach

	Stage I	Stage II	Stage III	Stage IV
Timing	2005	2010	Near-term, medium-cost projects [+5yrs]	Far-term, large-scale projects [+10yrs]
Example Experiments/ Data		SDSS	Dark Energy Survey	LSST
		South Pole Telescope	Planck	SKA
Knowledge about dark energy	Exists!	Baseline FOM	*3-5* over baseline	*9-18* over baseline

The Dark Energy Survey (DES) Project at a glance

Who is DES?

Fermi National Accelerator Laboratory
U. of Chicago
The National Optical Astronomy Observatory
United Kingdom
Brazil
Ohio State U.
Texas A&M U.
University Observatory Munich
The University of Illinois at Urbana-Champaign
National Center for Supercomputing Applications
Lawrence Berkeley National Laboratory
Spain
U. Michigan
U. Pennsylvania
Argonne National Laboratory
Santa Cruz, SLAC, Stanford
Associate Members:
Brookhaven National Lab, U. North Dakota, Paris, Taiwan

130+ individual members, plus post-docs and students

Principal Funding

U.S.: DOE, NSF
UK: STFC, SRIF
Spain: Ministry of Science
Brazil: FINEP, Ministry of Science, FAPERJ; Germany: Excellence Cluster
All collaborating institutions

~$45M

What will DES deliver?

Photometric/Imaging galaxy survey
+
Supernovae time-domain survey

technical and methodological infrastructure to inform next-gen/Stage IV surveys.

Constrain ...
- dark energy equation of state to 6% and
- its evolution to 20%.

What will DES do?

Expose the tug of war:

growth vs. expansion
+
rulers vs. candles

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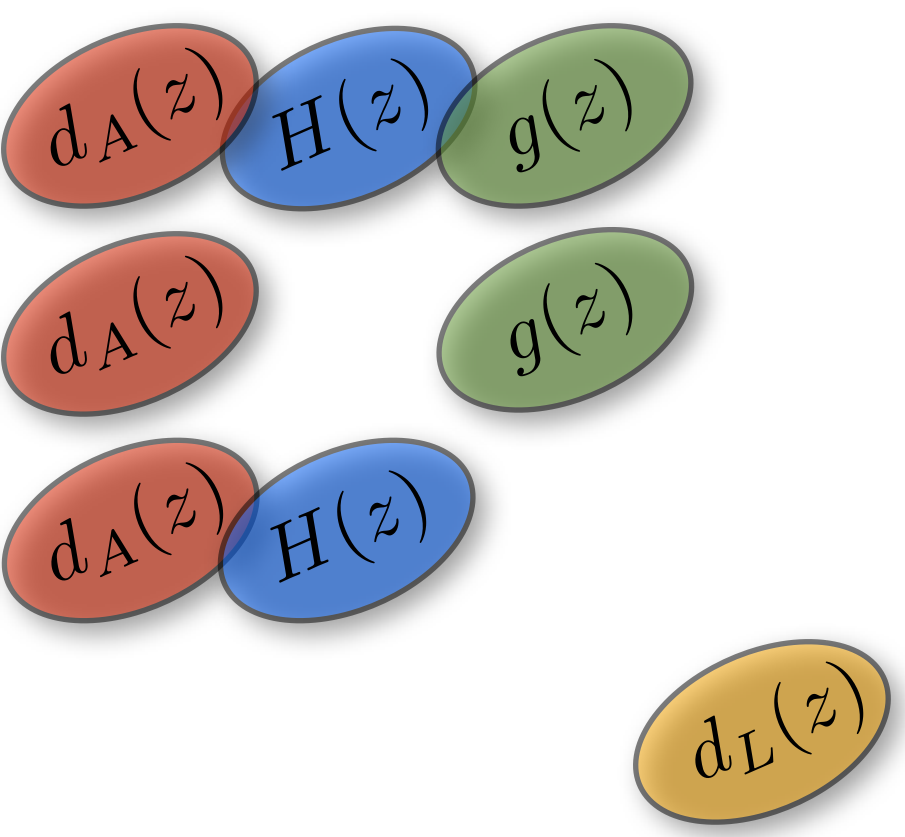
Tracer models



Four Probes

Galaxy Clusters
- ~100,000 clusters to z>1

Weak Lensing
- Shape measurements of 300 M gals

Baryon Acoustic Oscillations
- 300M gals to z>1

Supernovae
- 30 sq. deg. time-domain survey
- ~4000 well-sampled SNe Ia to z ~1

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growth vs. expansion
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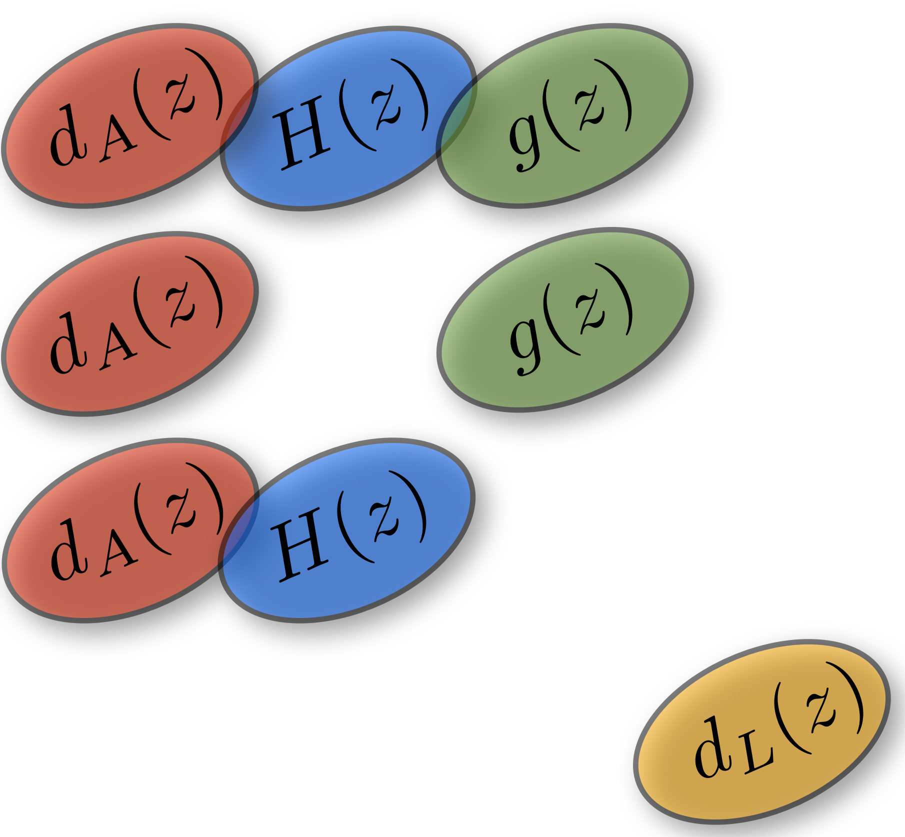

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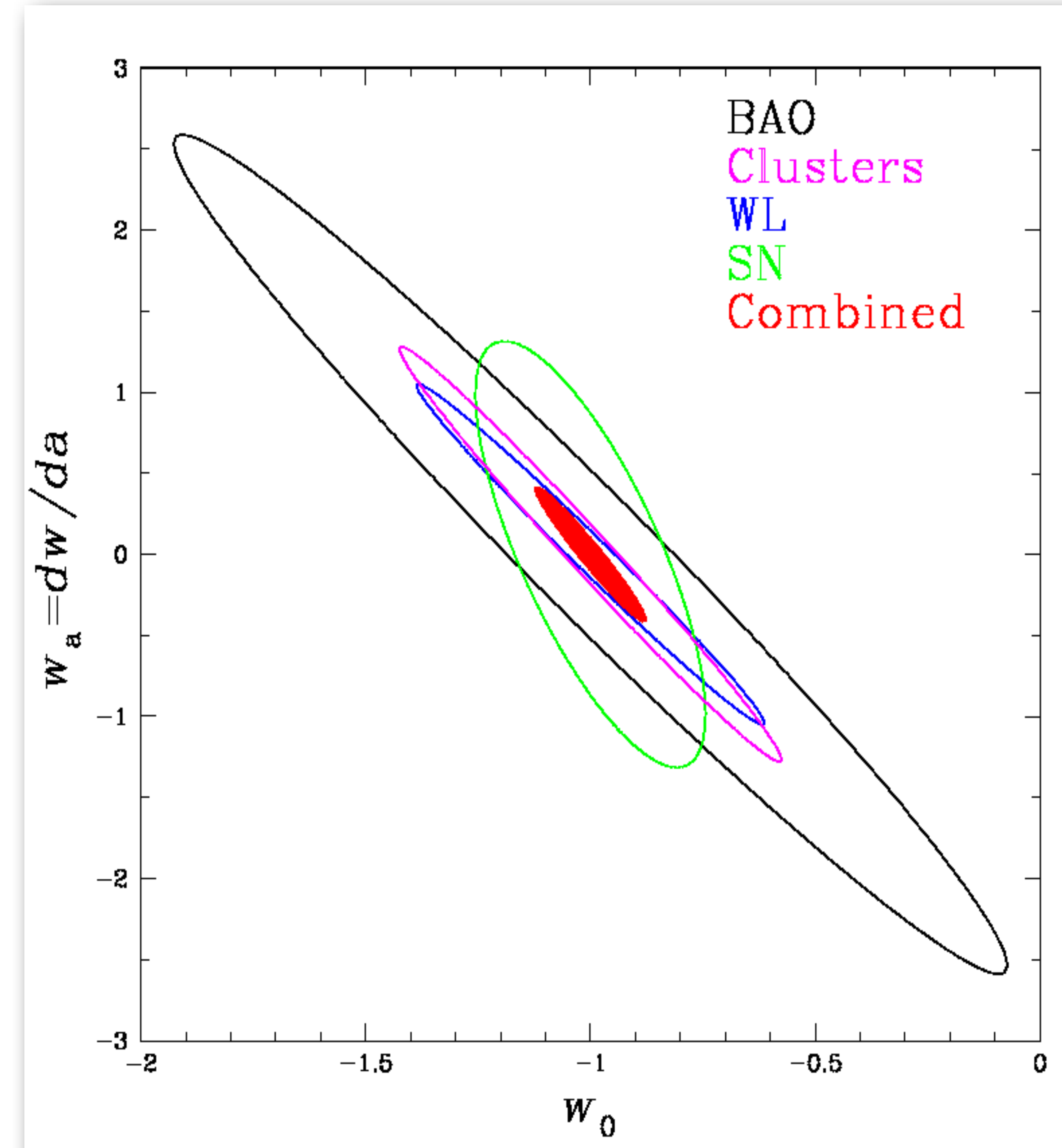
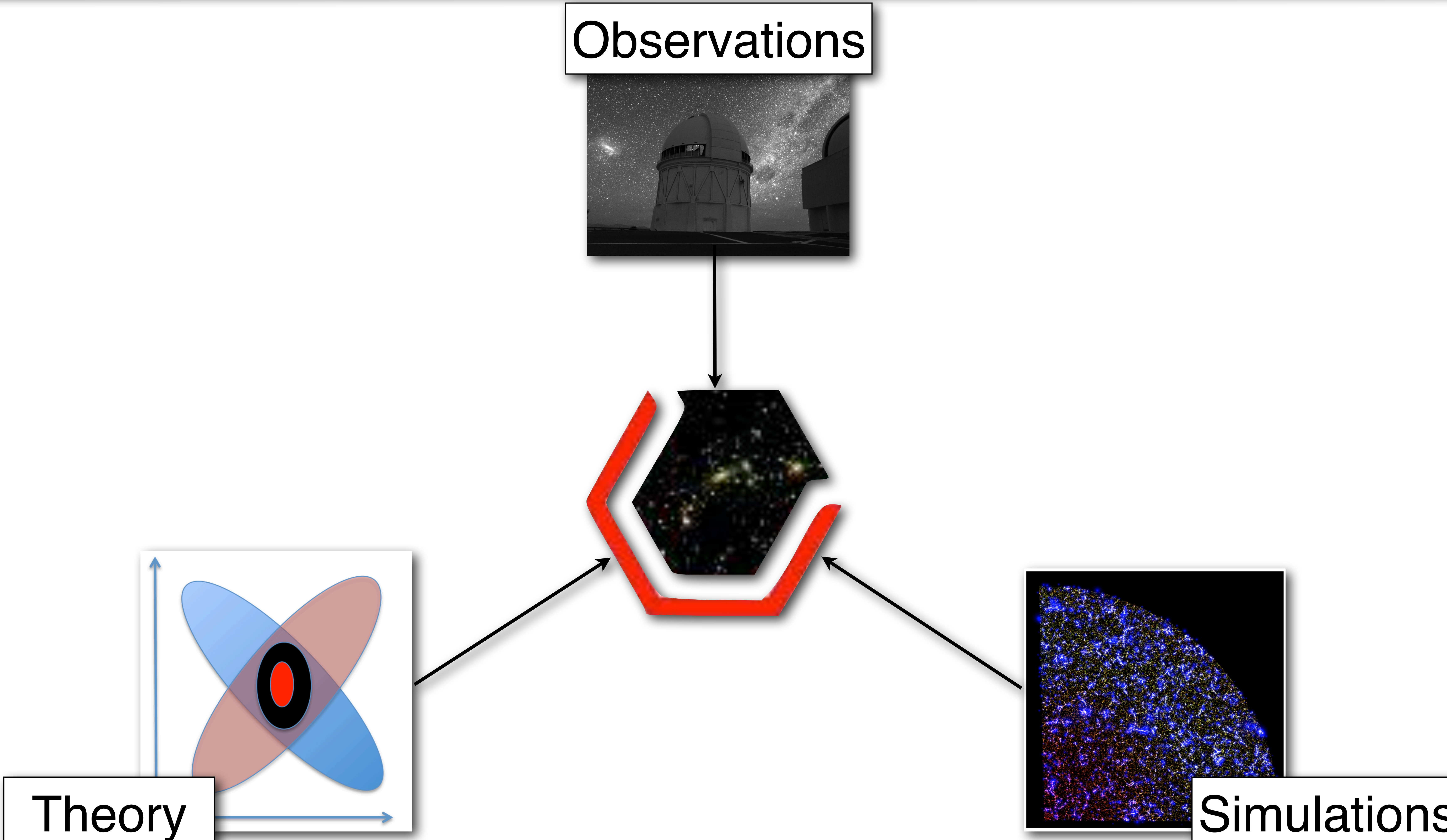


Factor **3-5** improvement over Stage II Figure of Merit.

DES: the components

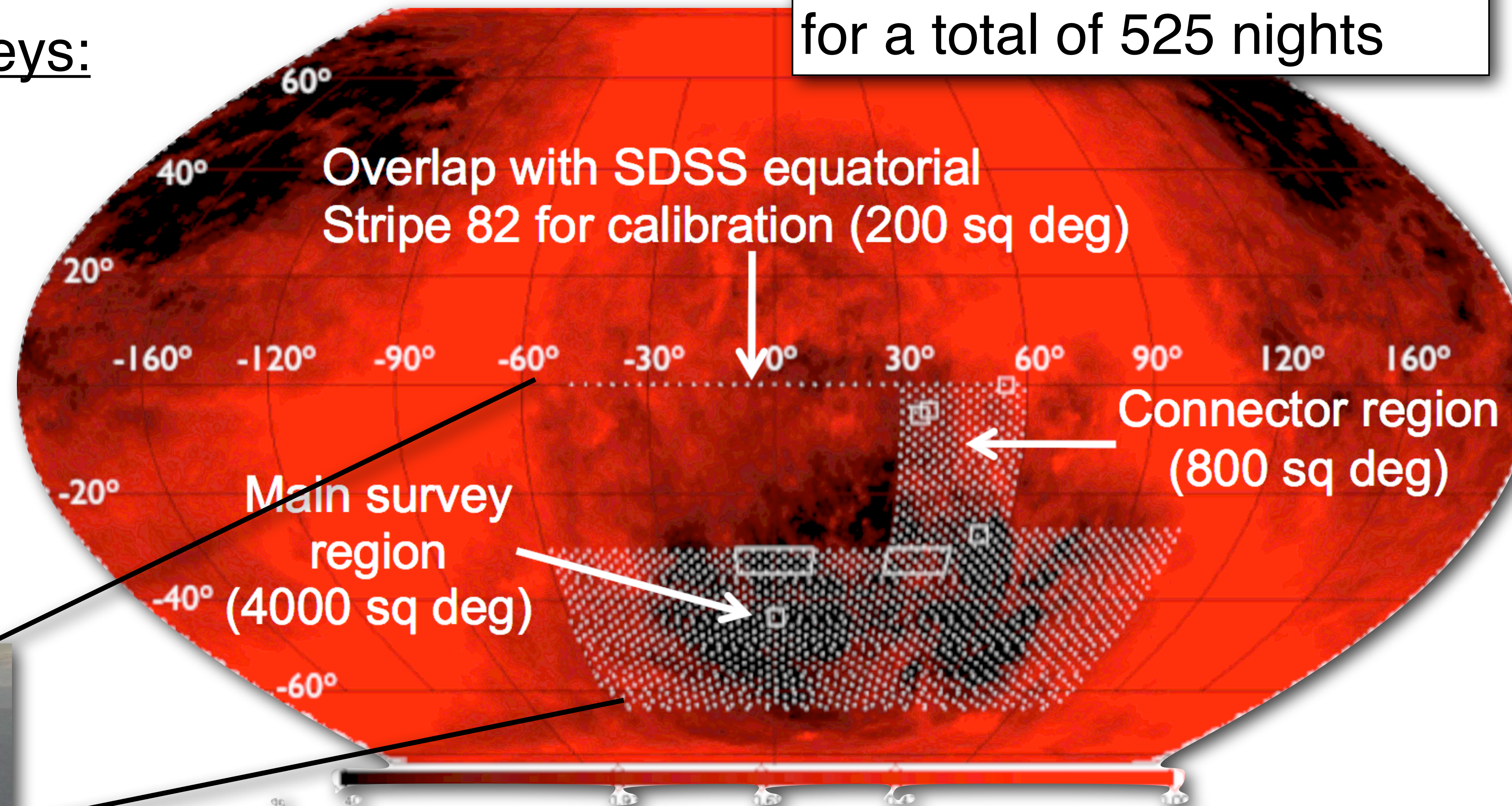


Observing Strategy

Survey during 2012-2017
for a total of 525 nights

Two concurrent multiband surveys:

- *galaxies*: 5000 deg^2 in *grizY*
  to mag 25-21
- *SNe*: 30 deg^2 for light curves.



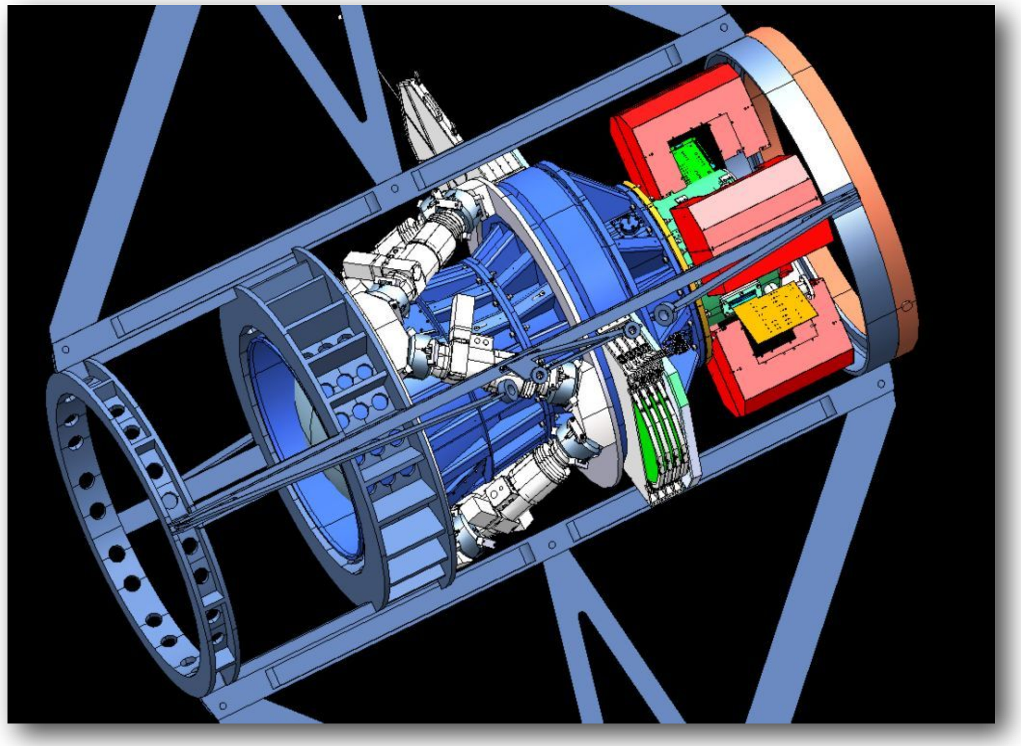
Cerro Telolo Int'l Observatory

New infrastructure and technical deliverables

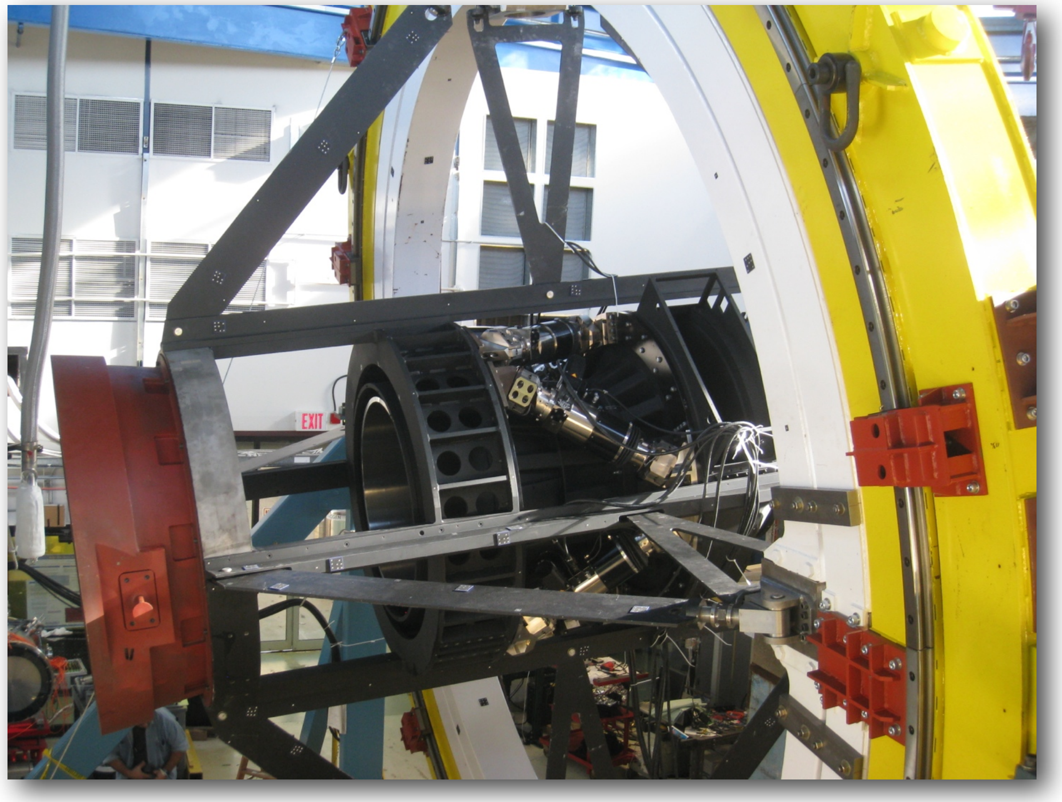
- 3 sq. deg. FOV camera
- Telescope improvements
- Data management system

The Dark Energy Camera (DECam)

Design [2003]



Testing [2010]



[Full-scale simulator at FNAL]

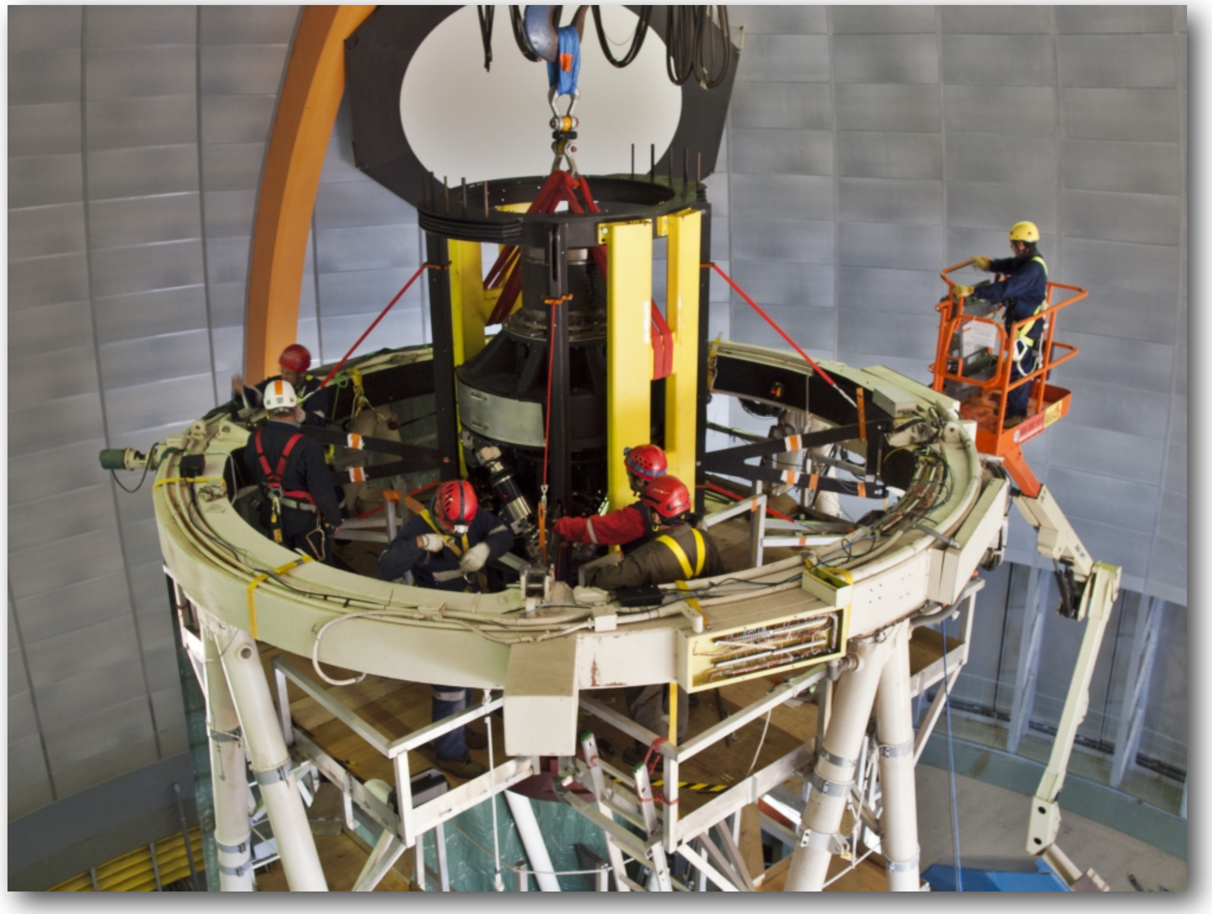
Data Management

- 300 Gb/night
- NCSA pipeline process real and sims
- coadd multi-epoch data

CCDs:

- 62 @ 2kx4k pixels
- 12 2kx2k for guide/ focus
- 520 Megapixels
- 250 micron thick
- 15-micron (0.27”) pixel size
- Excellent red sensitivity

Installation [2012]



Galaxy Simulations

from cosmology ...

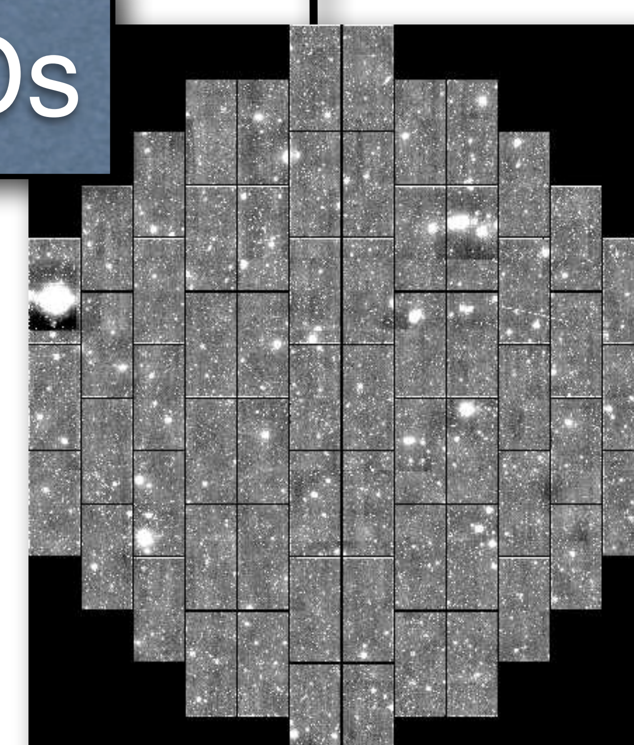
Dark Matter Light cone

Assign galaxies

Lens galaxies

Photometric noise

CCDs



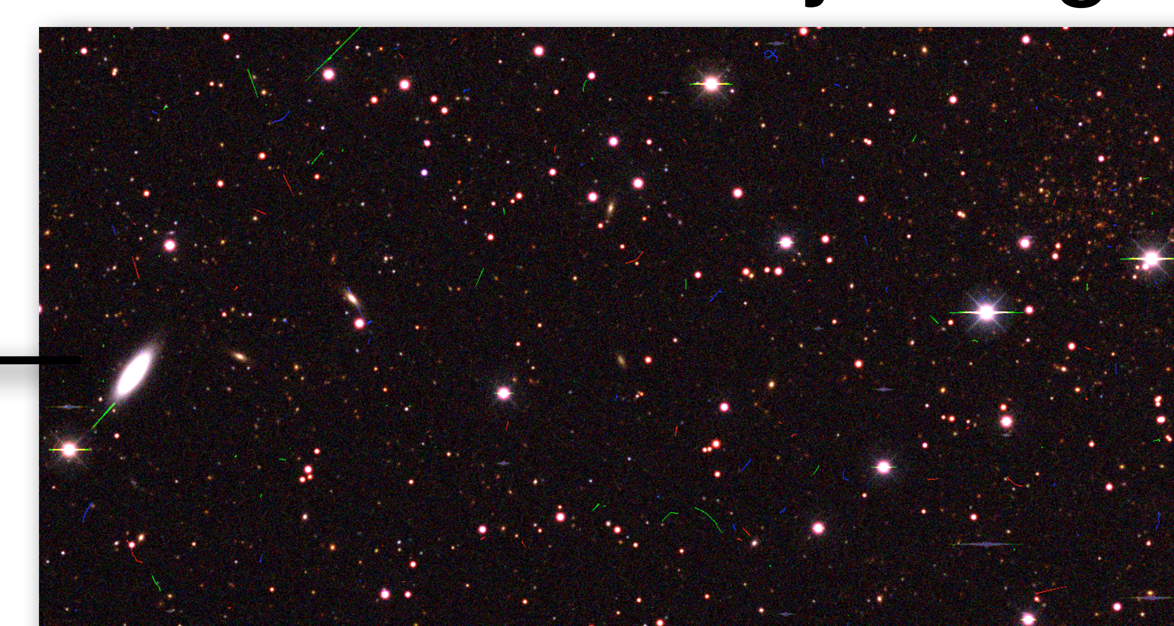
Simulation Properties:

- N-body lightcone to z~6
- ~10^{12} particles
- full DES footprint (5k sq. deg.)
- run on US national computing resources (Xsede)

Galaxy properties:

photometry, lensing, shapes, masking, stellar contamination, galaxy deblending, and more

... to sky image

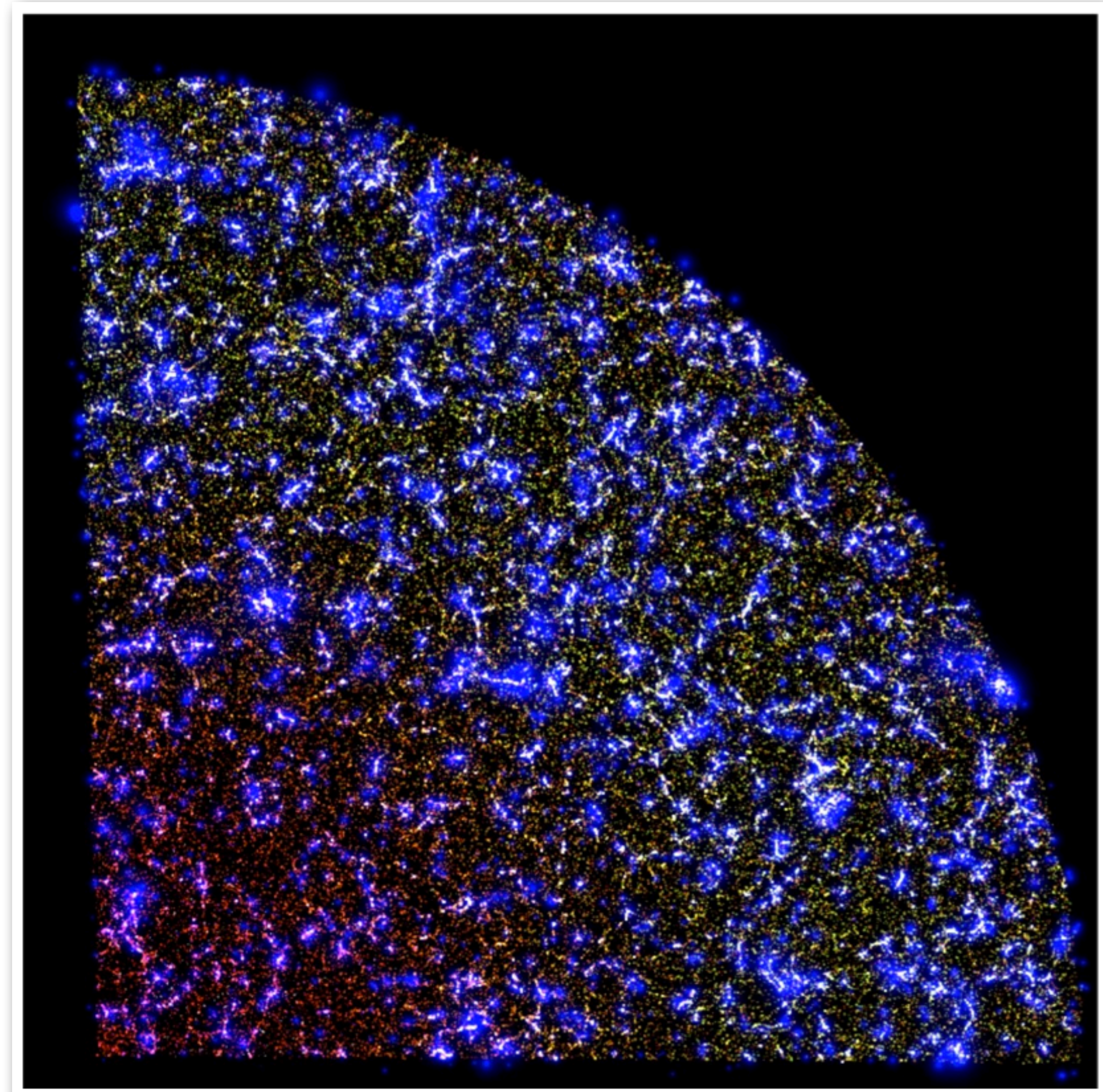


Blind Cosmology Challenge (BCC)

Science working groups [one for each probe] will compete to recover cosmological parameters.

Limited assumptions:
WMAP7-consistent, LCDM cosmology

Simulation Properties
- Full DES Sky coverage to z ~2
- 500M Galaxies to full depth
- Will eventually have 50-100 cosmologies.

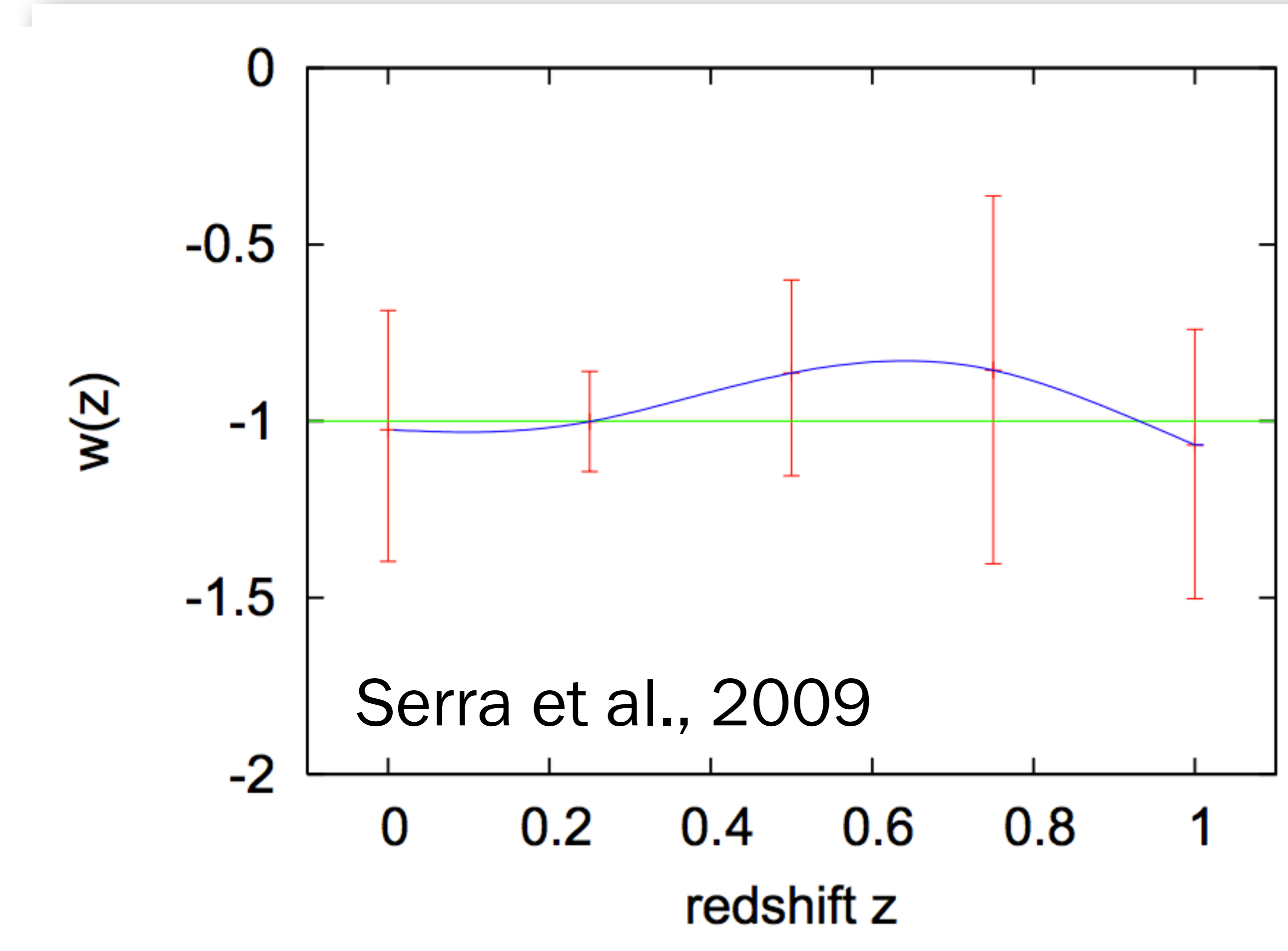


Theory Group

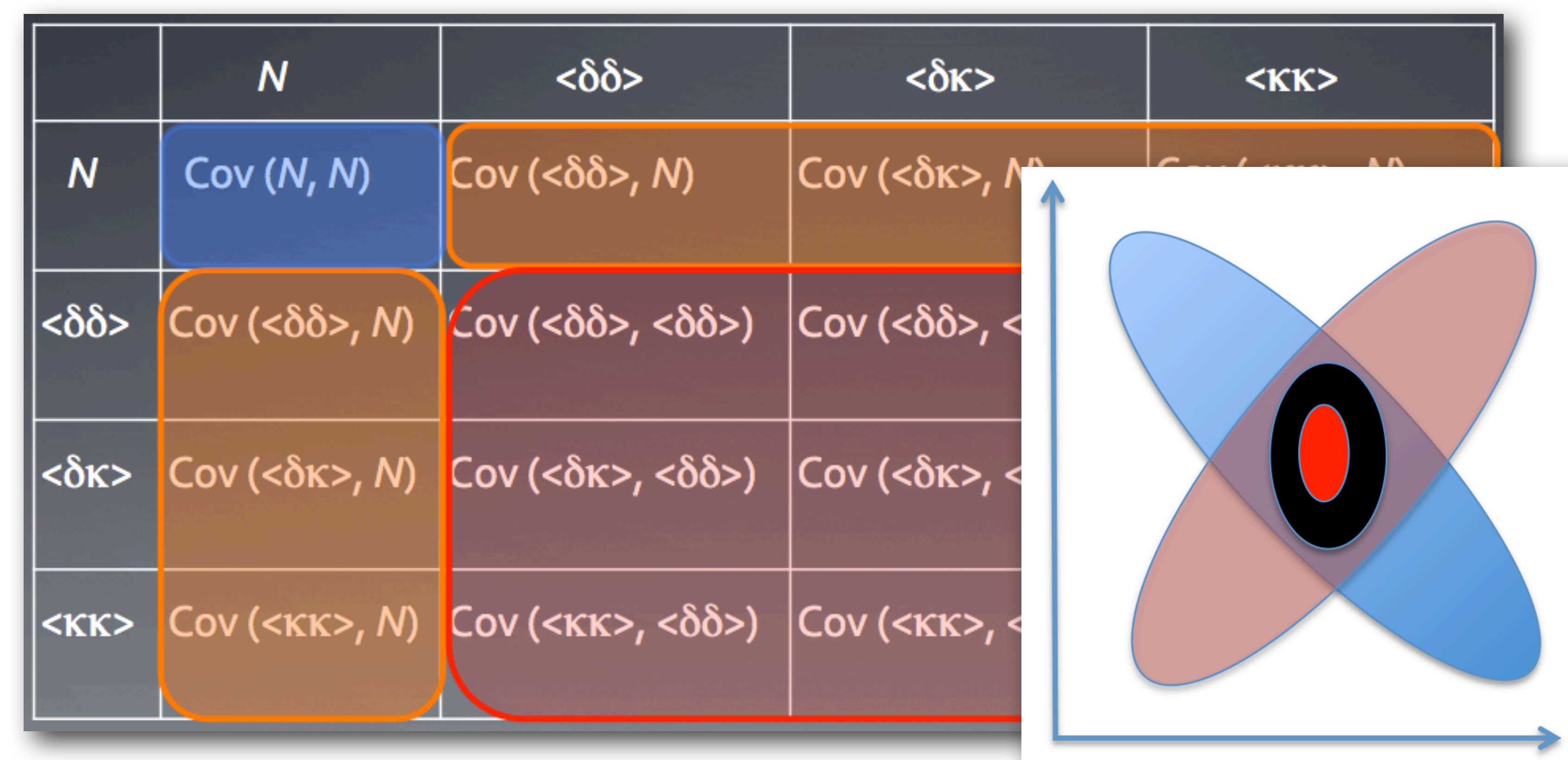
Principle Tasks

- develop models and reconstruct eqn of state w(z)
- Test modified gravity
- Combine probes
  - cross-correlation
  - general covariance matrix
- Other
  - inhomogeneity
  - non-Gaussianity
  - DE clustering, ISW

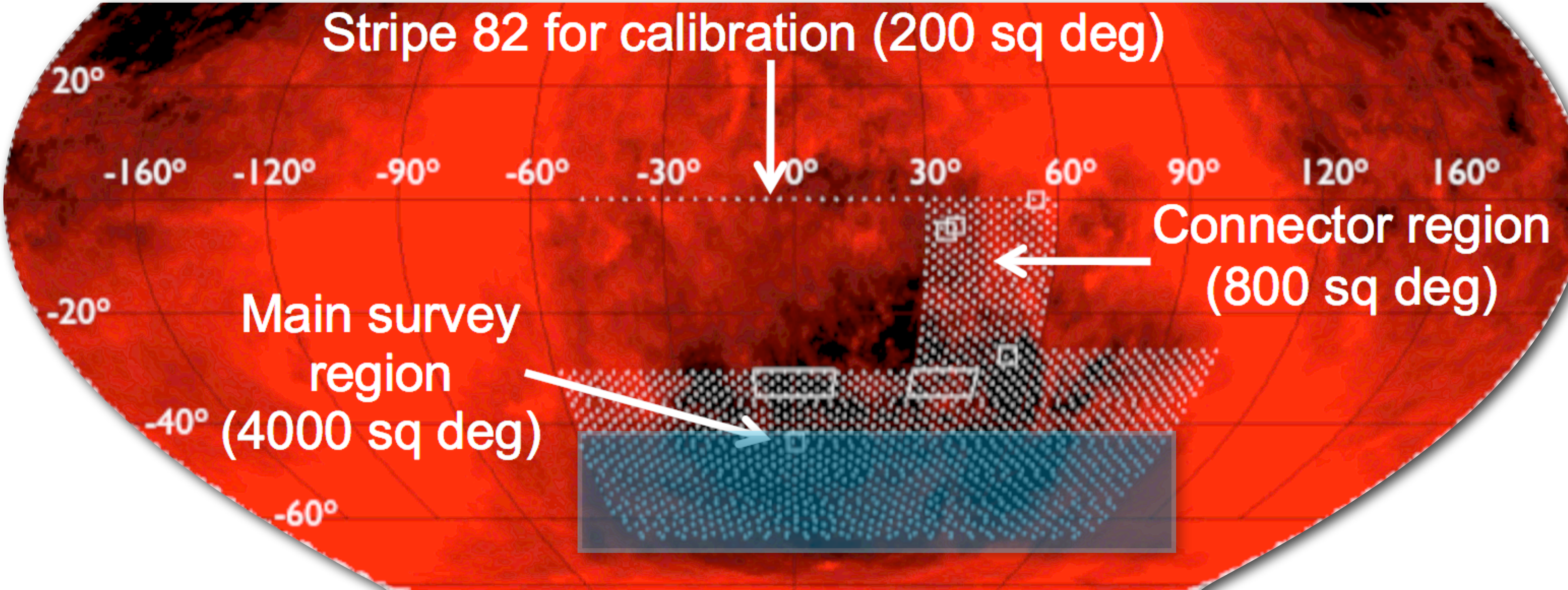
Current Global Constraints on w(z)



Covariance among probes



DES in context: surveys in multiple wavebands



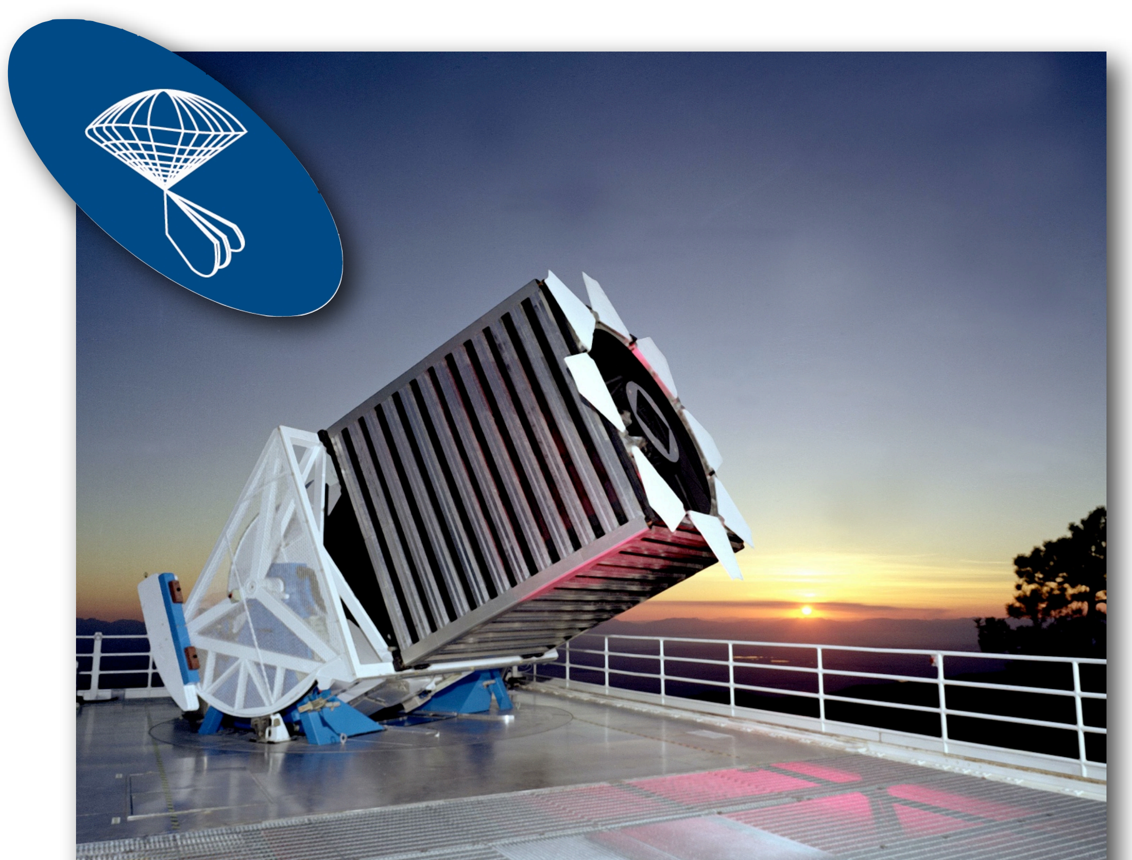
DES has substantial overlap with many past and future surveys.

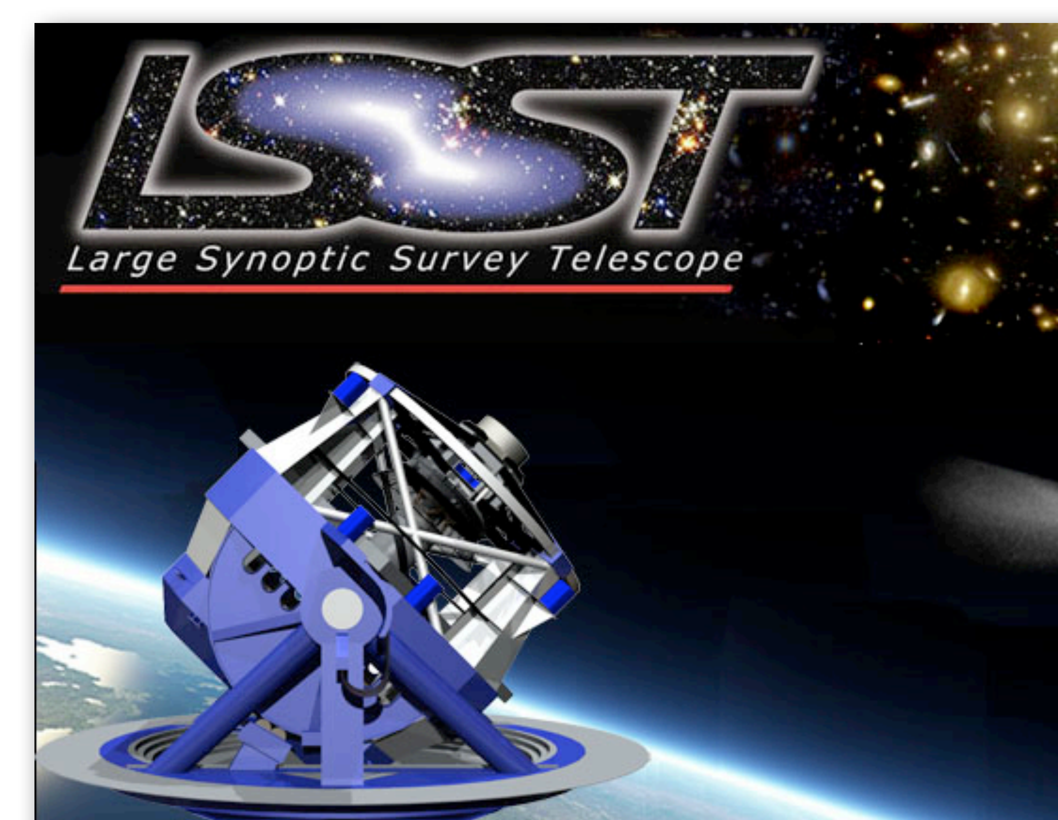
South Pole Telescope; SZ (radio) [2k sq. deg.]:
Cluster mass calibration

Vista Hemisphere Survey; deep and high-redshift [all-sky]:
Clusters, BAO, weak lensing

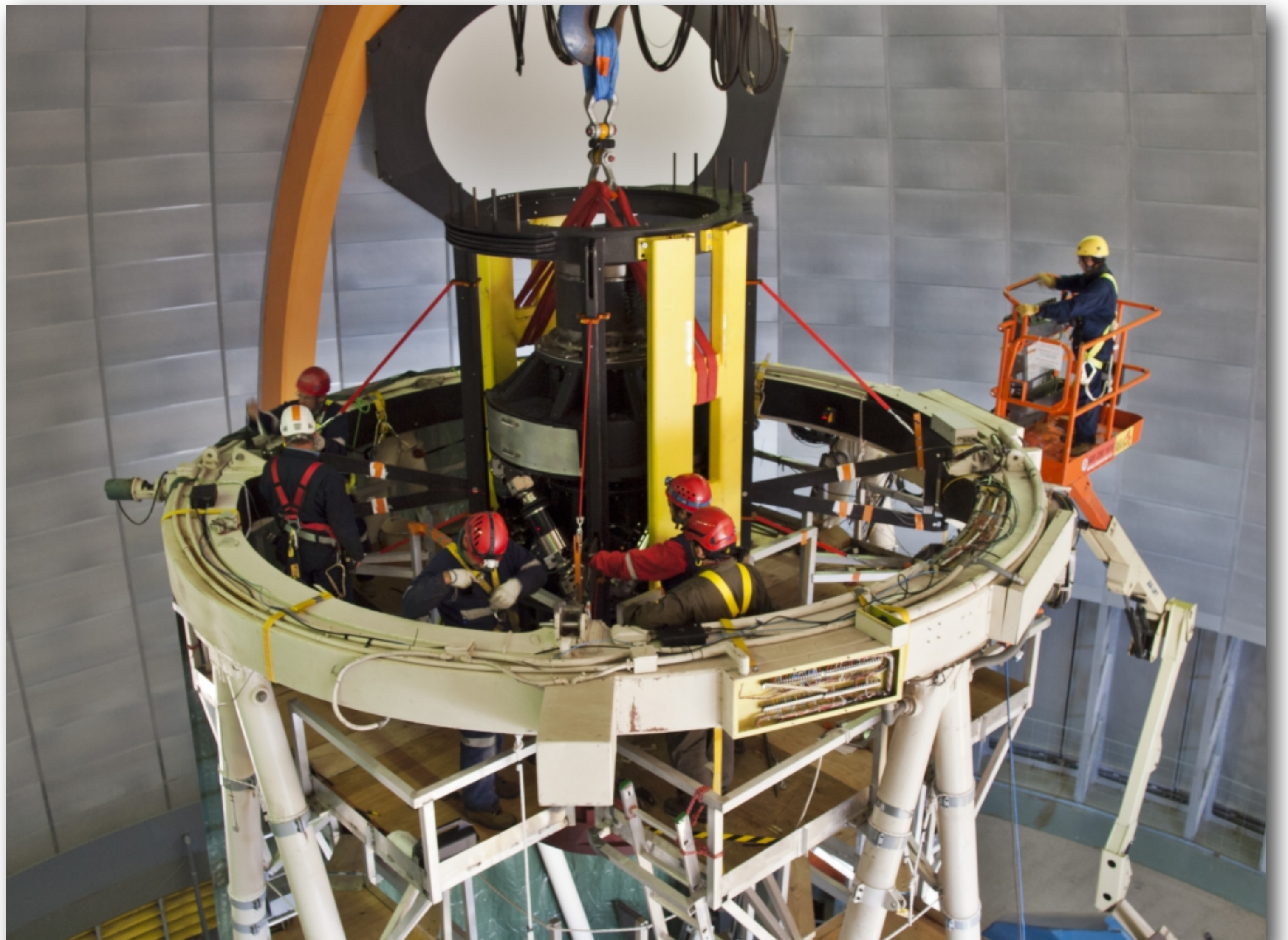
DES in context: past, current and future optical surveys

SDSS	DES	LSST
[Stage I/II]	[Stage III]	[Stage IV]
op.'s: 2000-2008	2012-2017	2017-2027
cost: $85M	$45M	$500M
Northern Hemisphere	Southern	Southern
2.5-meter mirror	4-meter	8.4 -meter
1M Galaxies	100M Galaxies	10,000M Galaxies
8.5K sq. deg. sky area	5k sq. deg.	30K sq. deg.
data rate: 200Gb/Night	500 Gb/Night	1,500 Gb/Night





Timeline: Operations and Science Analysis



[on-site installation nearly complete]

***Project initiated 2003
DECam R&D 2004-9
Instrument construction 2008-11
Final testing, integration now on-going
Ship components to Chile: Sept. 2010-Sept. 2011
Installation: Jan.-July. 2011-12
Imager first light on telescope: Sept. 2012
Commissioning/Sci Verification: Sept.-Nov 2012
Survey Starts: Nov. 2012
raw/reduced data released to public after 1 year

DES is poised to take the next step in understanding the nature of dark energy, with installation, commissioning, and survey operations commencing in the coming months.