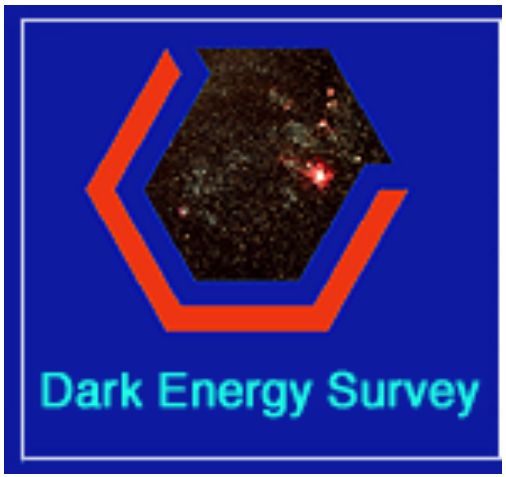
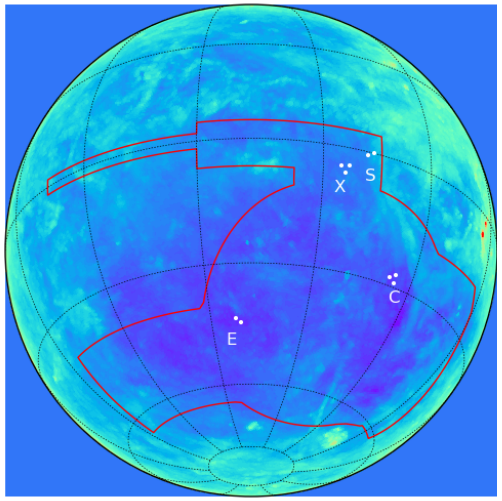
Some Early Results from the **Dark Energy Survey**

R. Kessler
University of Chicago
Fermilab Users Meeting
June 11, 2015





Dynamics

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3}\sum_i \left(\rho_i + \frac{3p_i}{c^2}\right)$$

Friedman Equation for grad students

Where i =

- **Matter** ($\ddot{a} < 0$)
- **Radiation** ($\ddot{a} < 0$)
- **dark energy** ($\ddot{a} > 0$ → expansion)

Dynamics

$$\frac{\ddot{a}}{a} = -\sum_i$$ **Stuff in the universe**

Friedman Equation for kids

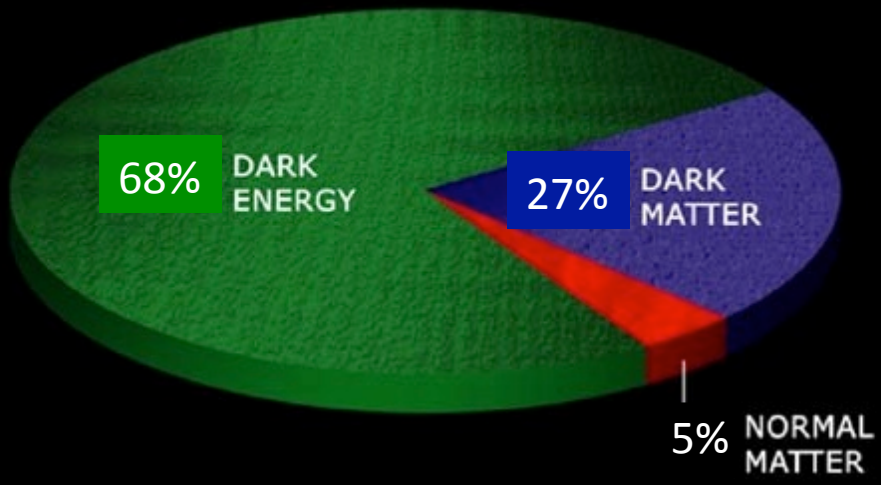
Where i =

- **Matter** ($\ddot{a} < 0$)
- **Radiation** ($\ddot{a} < 0$)
- **dark energy** ($\ddot{a} > 0$ → expansion)

DARK ENERGY SURVEY

Dark Energy

- What is the physical cause of cosmic acceleration?
  - Dark Energy or modification of General Relativity?



If w = −1 (cosmological constant)

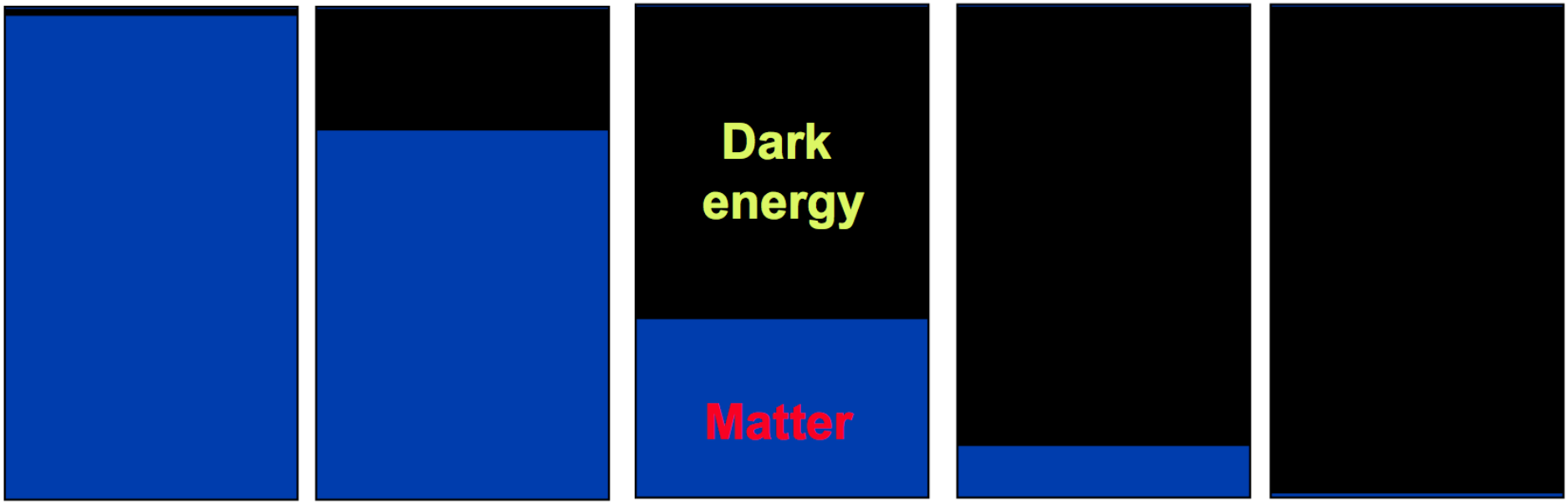
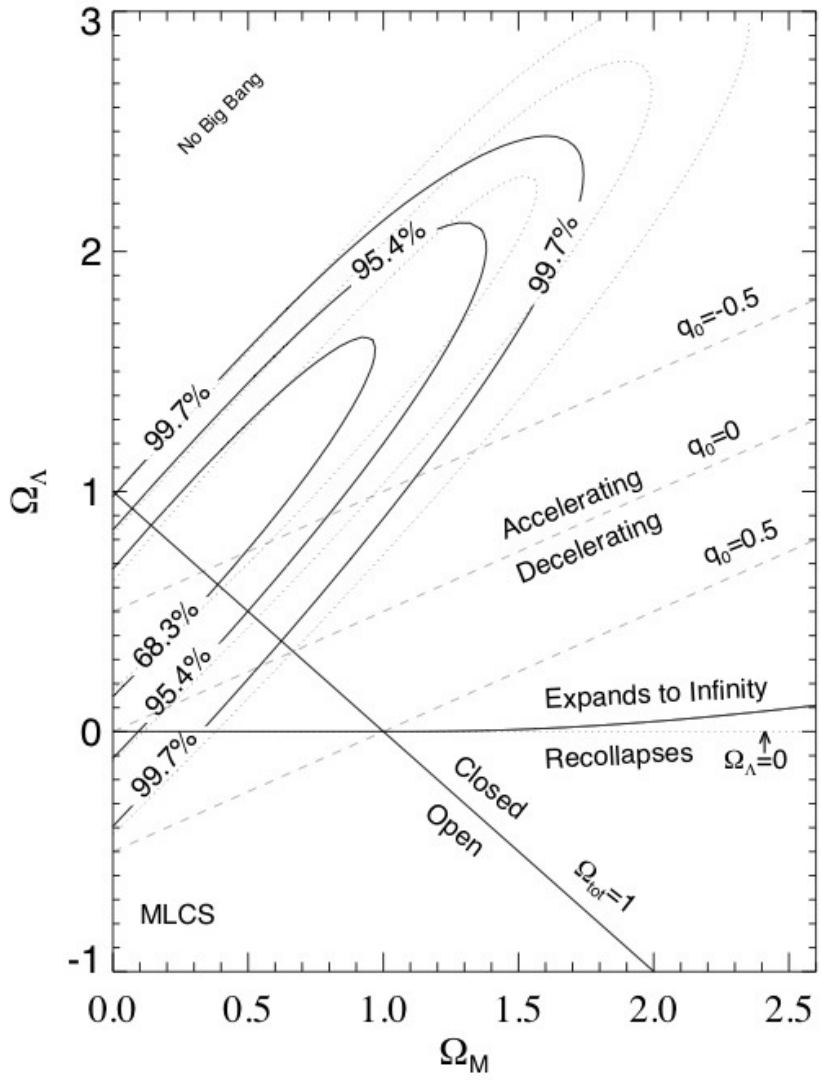
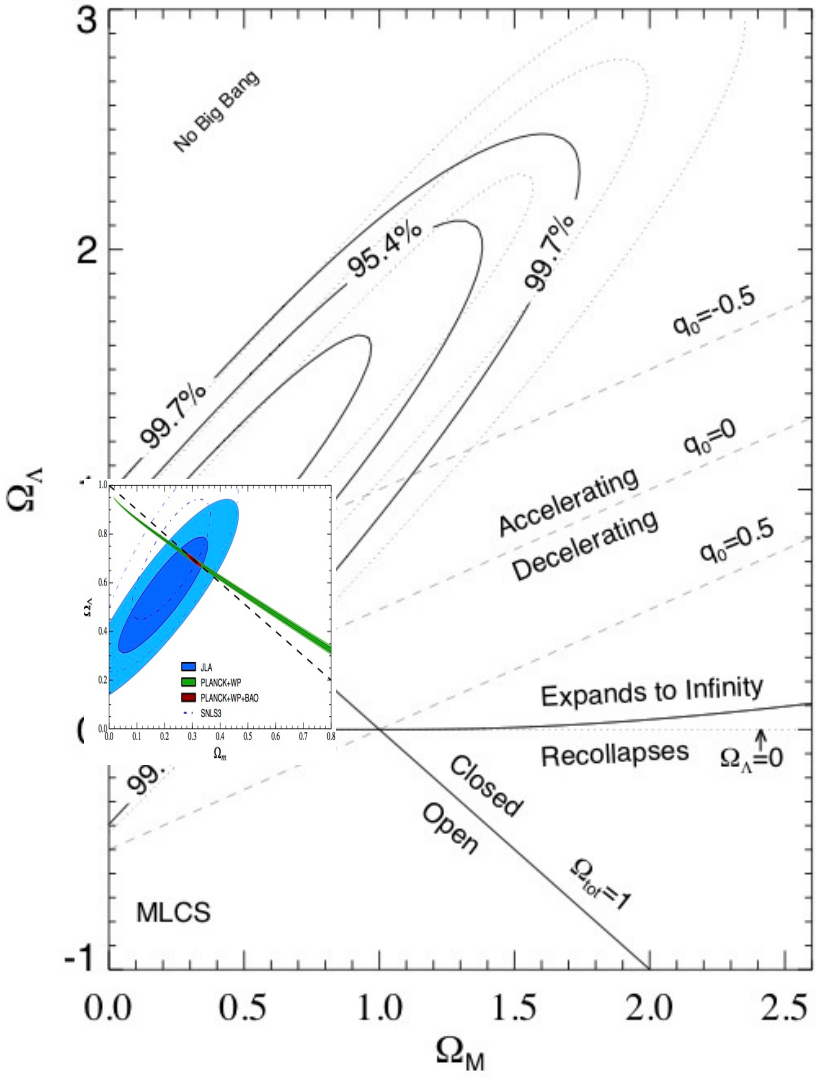


Chart from E. Linder

Then (Riess et al., 1998)



Then (Riess et al., 1998)
and now (Betoule et al., 2014)



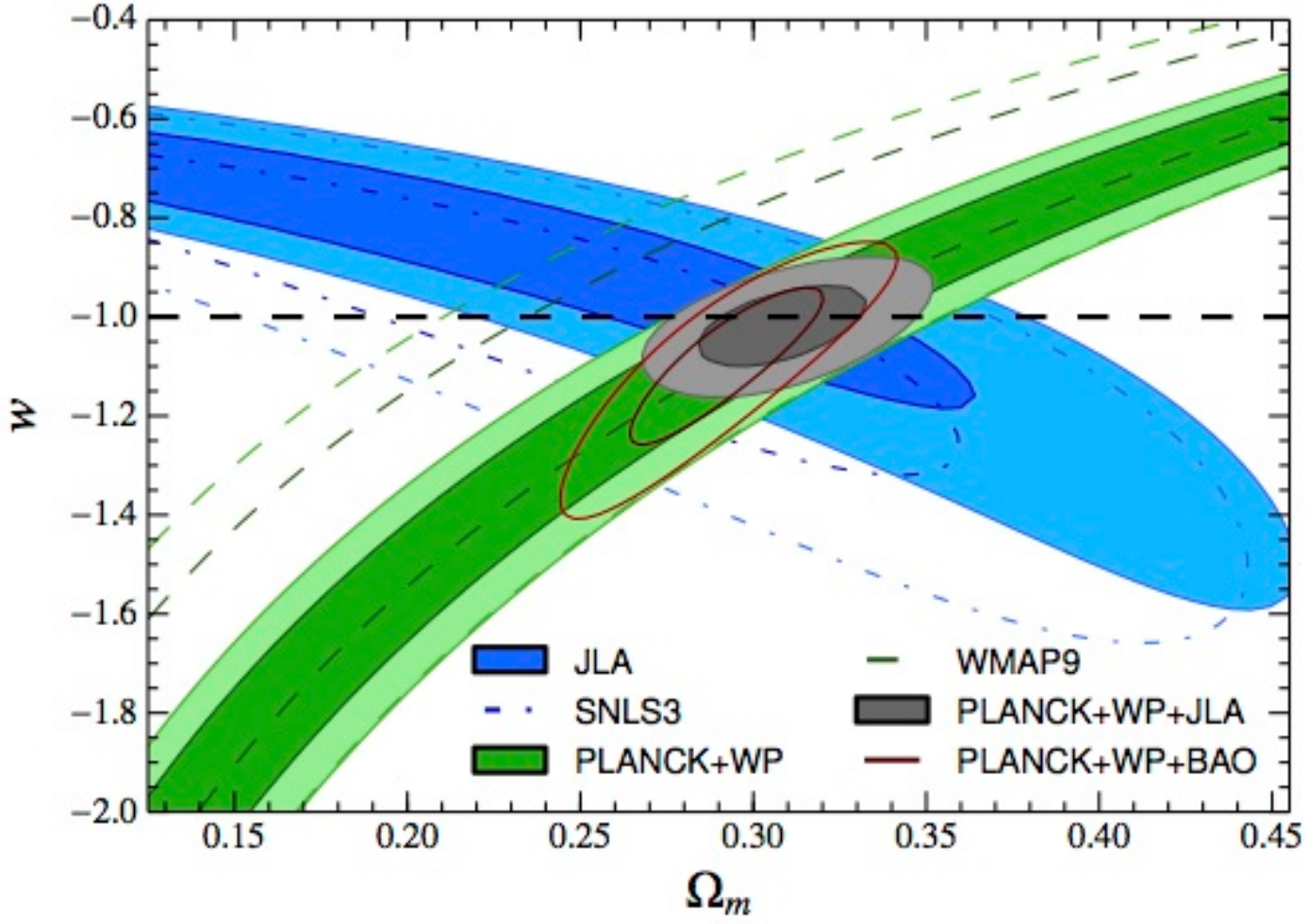
740 SNe Ia (nearby+SDSS+SNLS)

CMB (Planck+WMAP)

SNIa + CMB + BAO

Recent Results on w

(joint SDSS+SNLS analysis, 2014)



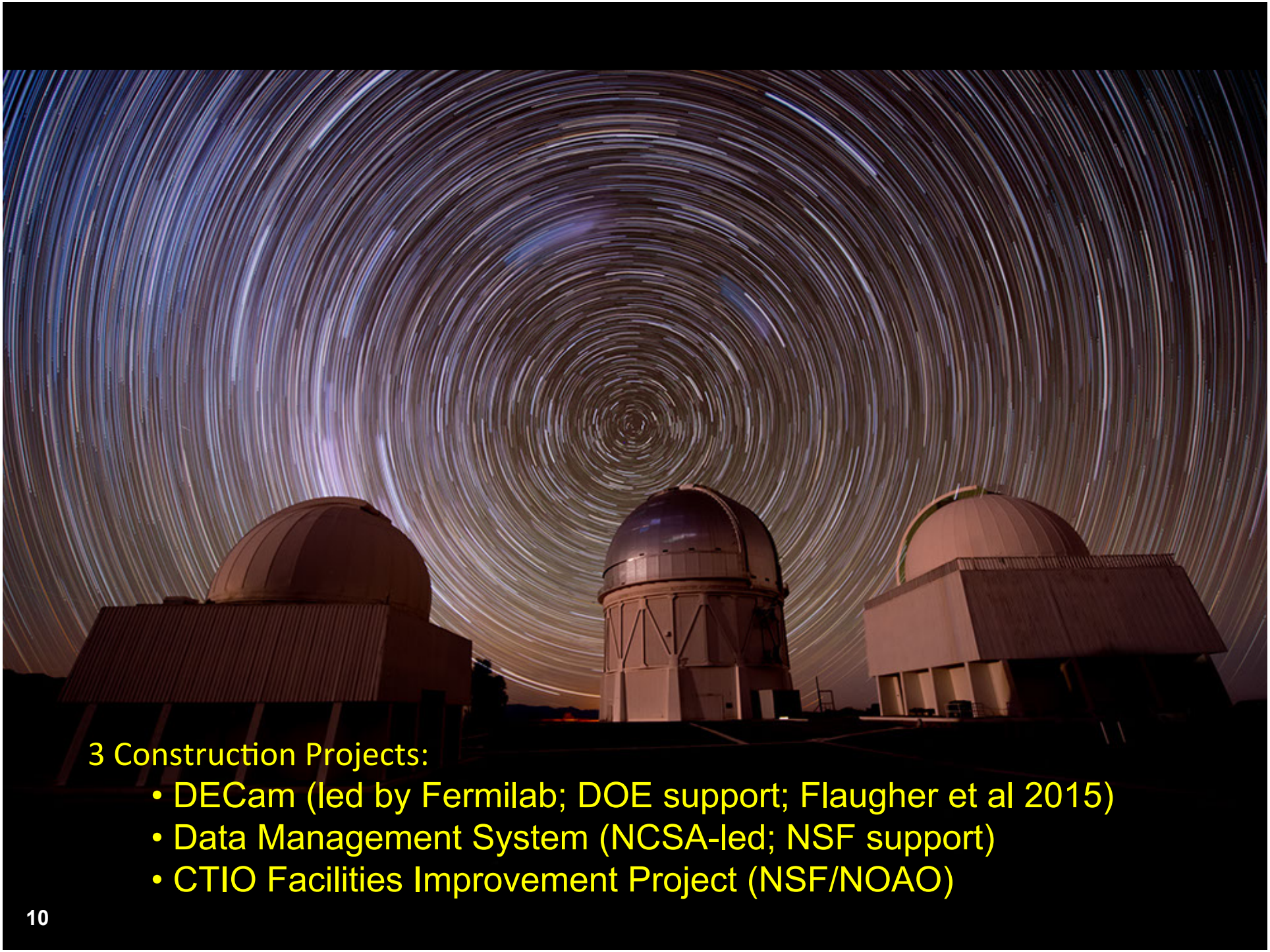
Combined with priors from CMB & BAO:

$w = -1.028 \pm 0.055$ (stat+syst)

What does DES probe?

"Distances" and "Growth" to disentangle
Dark Energy (new stuff)
from
Modified Gravity (new physics)

• Weak Lensing cosmic shear	Distances+growth
• Supernovae	Distances
• Baryon Acoustic Oscillations	Distances and H(z)
• Cluster counting	Distances+growth



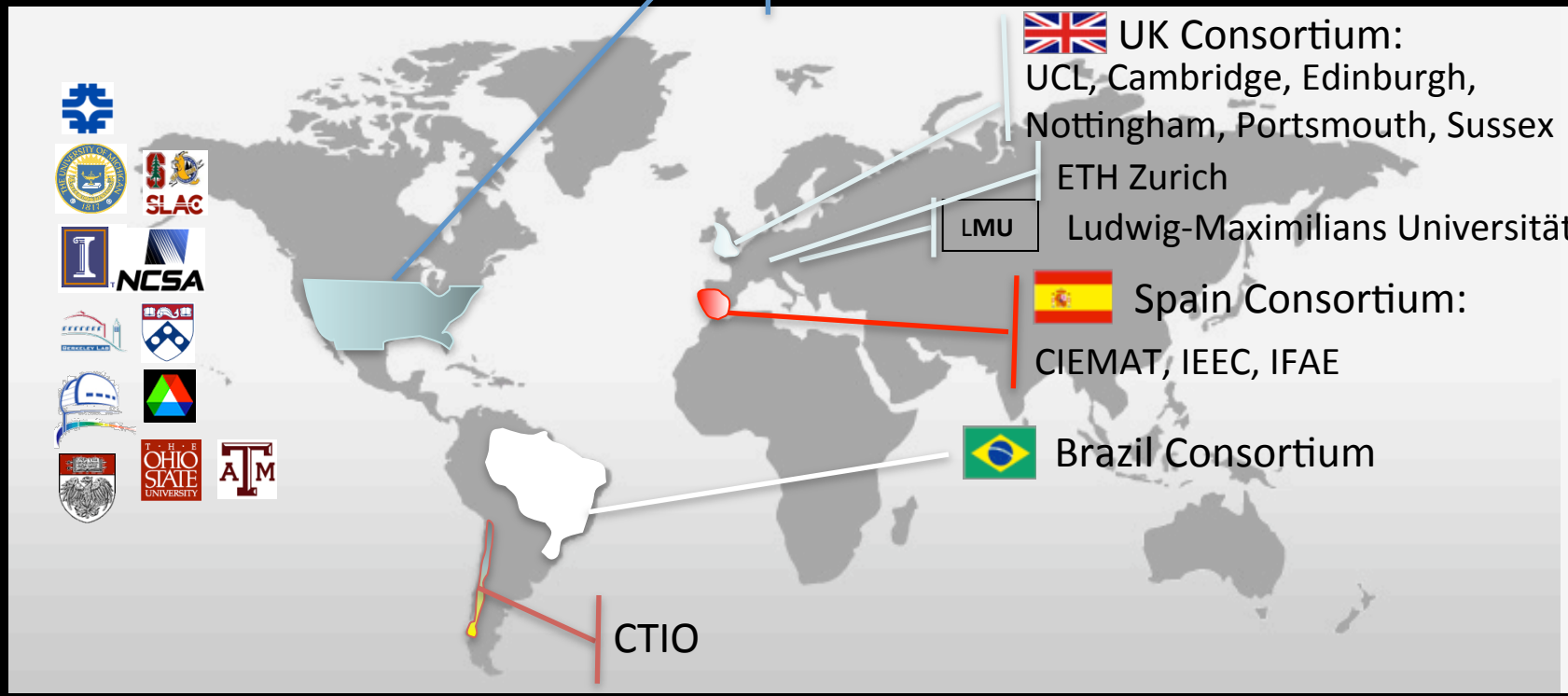
3 Construction Projects:

- DECam (led by Fermilab; DOE support; Flaugher et al 2015)
- Data Management System (NCSA-led; NSF support)
- CTIO Facilities Improvement Project (NSF/NOAO)

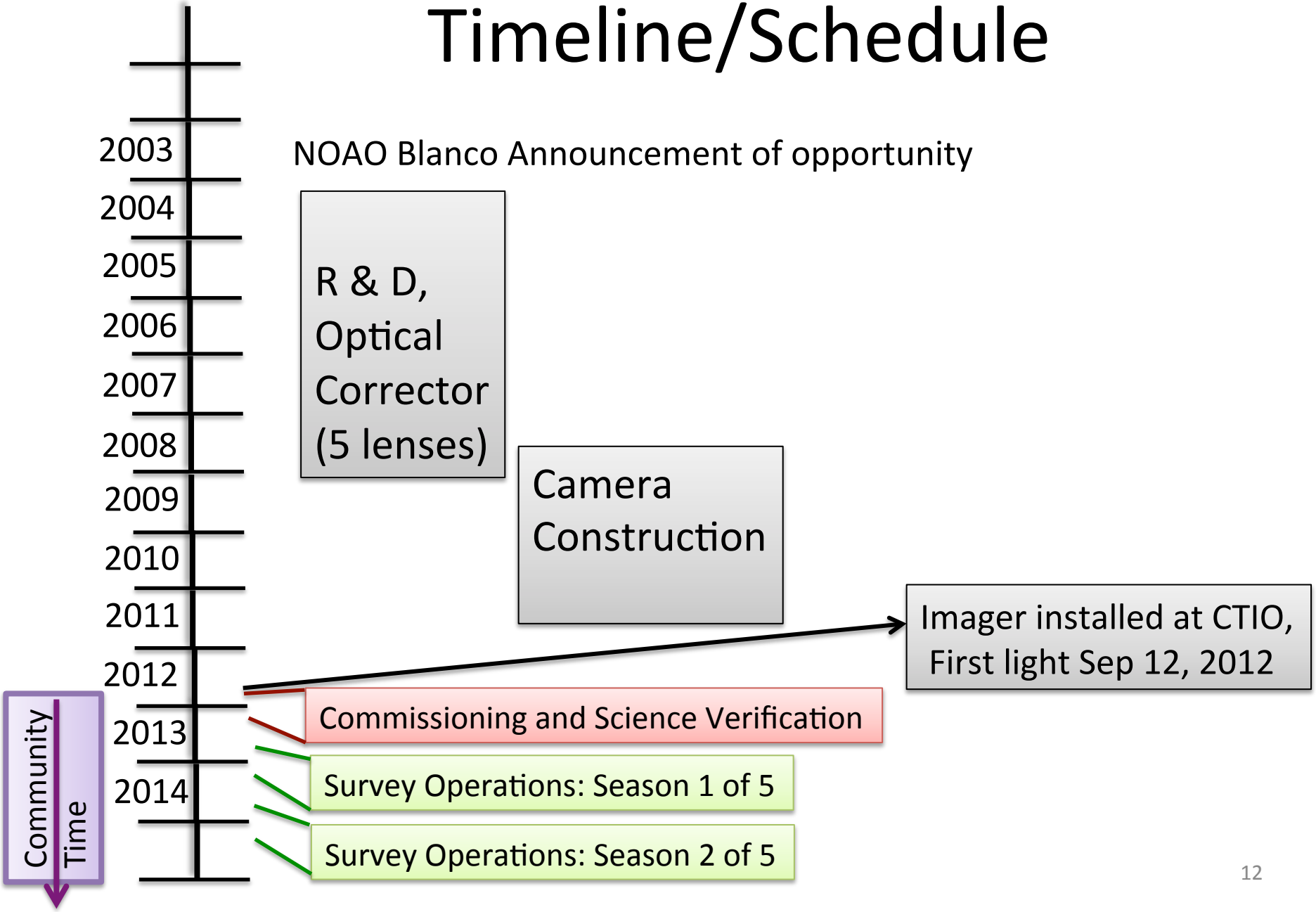
Dark Energy Survey Collaboration

~300 scientists
US support from DOE+NSF

Fermilab, UIUC/NCSA, University of Chicago, LBNL, NOAO, University of Michigan, University of Pennsylvania, Argonne National Lab, Ohio State University, Santa-Cruz/SLAC/Stanford, Texas A&M



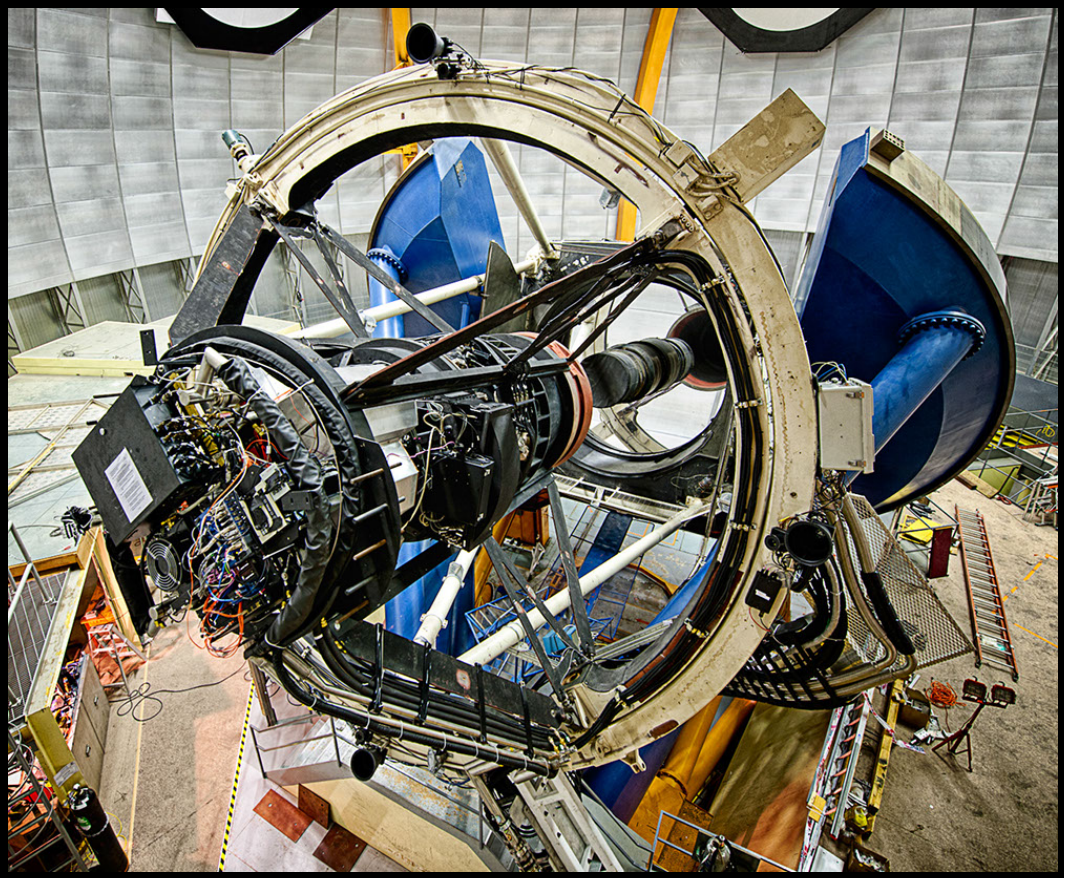
Timeline/Schedule



The Dark Energy Survey

- Probe origin of Cosmic Acceleration:
  - Distance vs. redshift
  - Growth of Structure
- Two multicolor surveys:
  - 300 M galaxies over 5000 s.d; grizY to 24th mag
  - 3000 SNe Ia (30 sq deg)
- New camera for CTIO Blanco 4m telescope
  Facility instrument
- Five-year Survey started Aug. 31, 2013
  525 nights (Sept.-Feb.)

DECam on the CTIO Blanco 4m

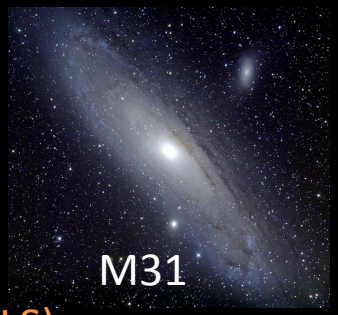


www.darkenergysurvey.org
www.darkenergydetectives.org

DARK ENERGY SURVEY

Fields of View

HST

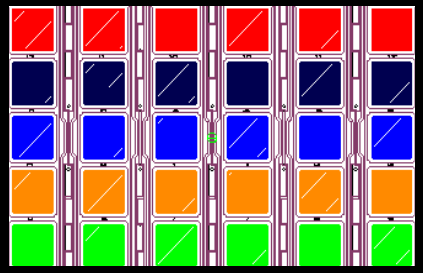


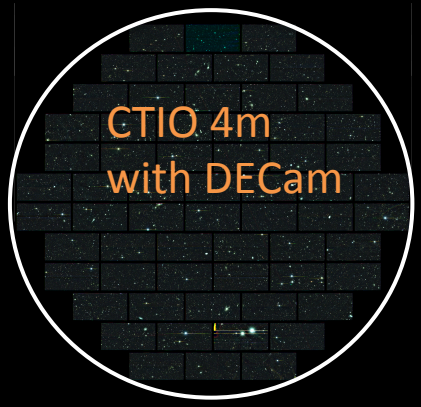
LSST 8m

CTIO 4m
before DECam

CFHT 4m (SNLS)

SDSS 2.5m
(1/2 area in gaps)



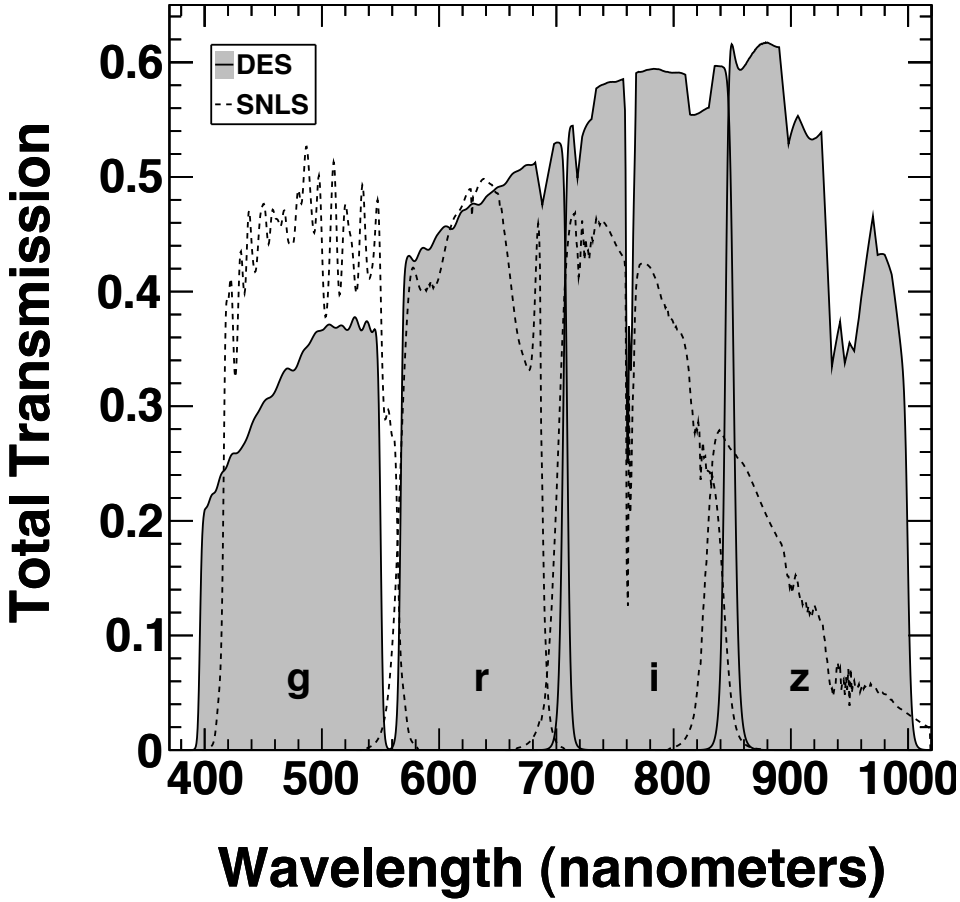


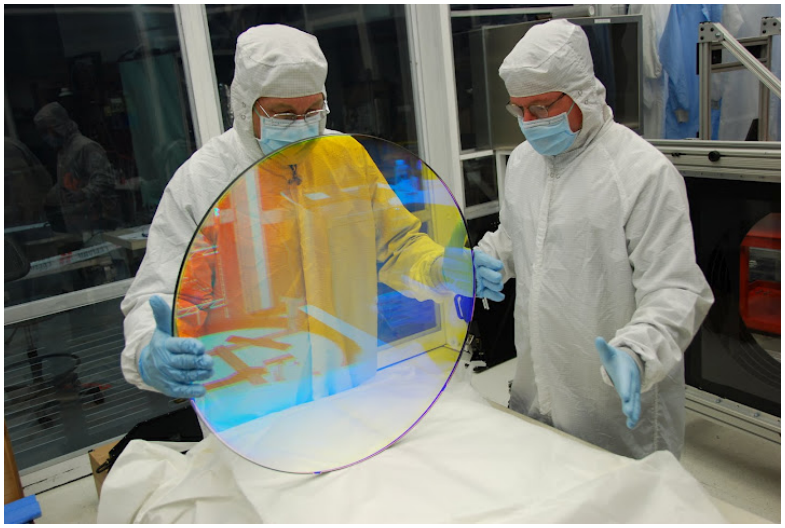
Pan Starrs 1.8m

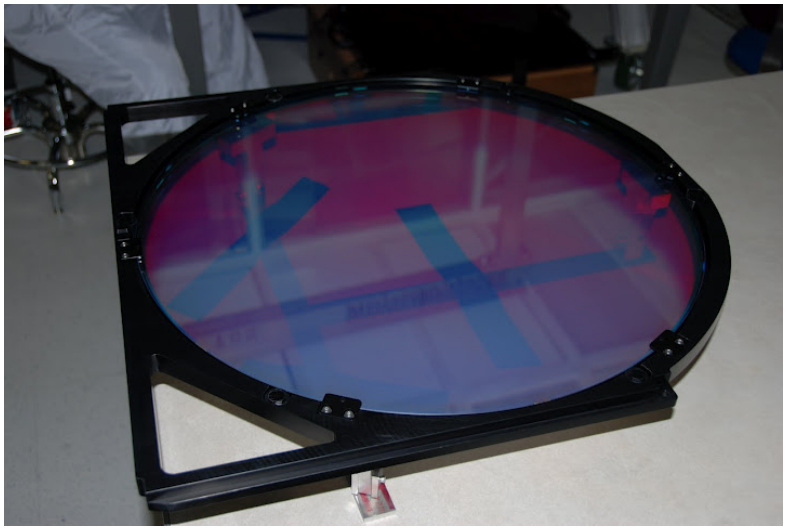
DES

THE DARK ENERGY SURVEY

New red-sensitive camera (DECAM) on CTIO 4m







Snapshot of Early DES Results

- **8** published papers
- **+ 17** submitted papers
- **+ lots** under internal review
- No DE results here, but will show a few important “stepping-stone” results.

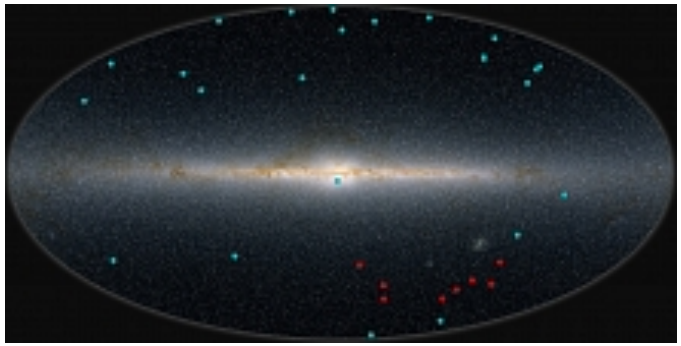
8 New Milky-Way Companions

Bechtol et al, 2015 (1503.02584)

- 27 known prior to DES
- Expect hundreds from N-body sims

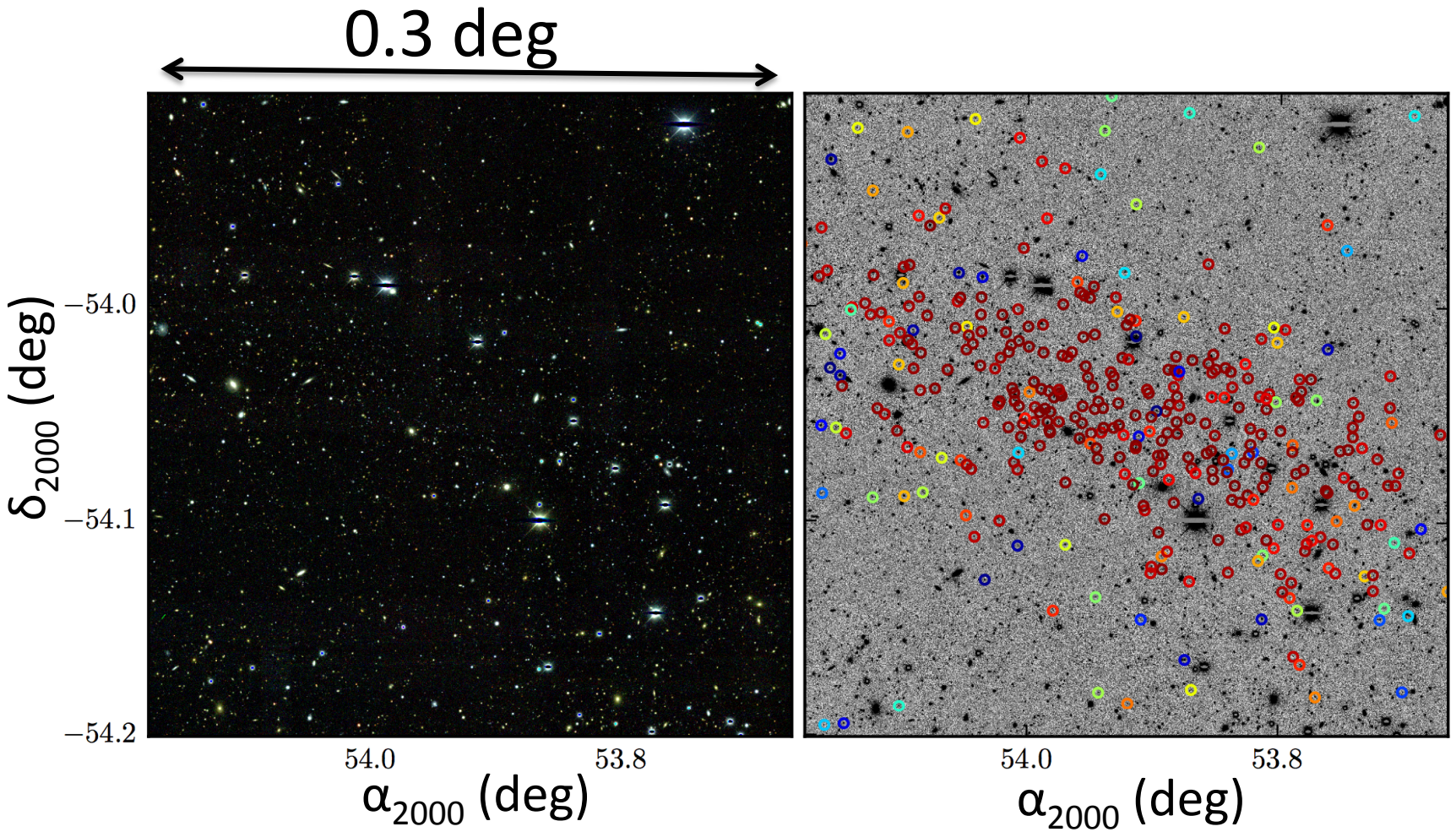
  (missing satellite problem)
- 8 new is significant

  (≈ ⅓ DES area, 1 of 5 seasons)



- Potential Dark Matter signal from annihilation chain to γ-rays -> Fermi-LAT: no γ-signal (Drlica-Wagner et al, 1503.02632)

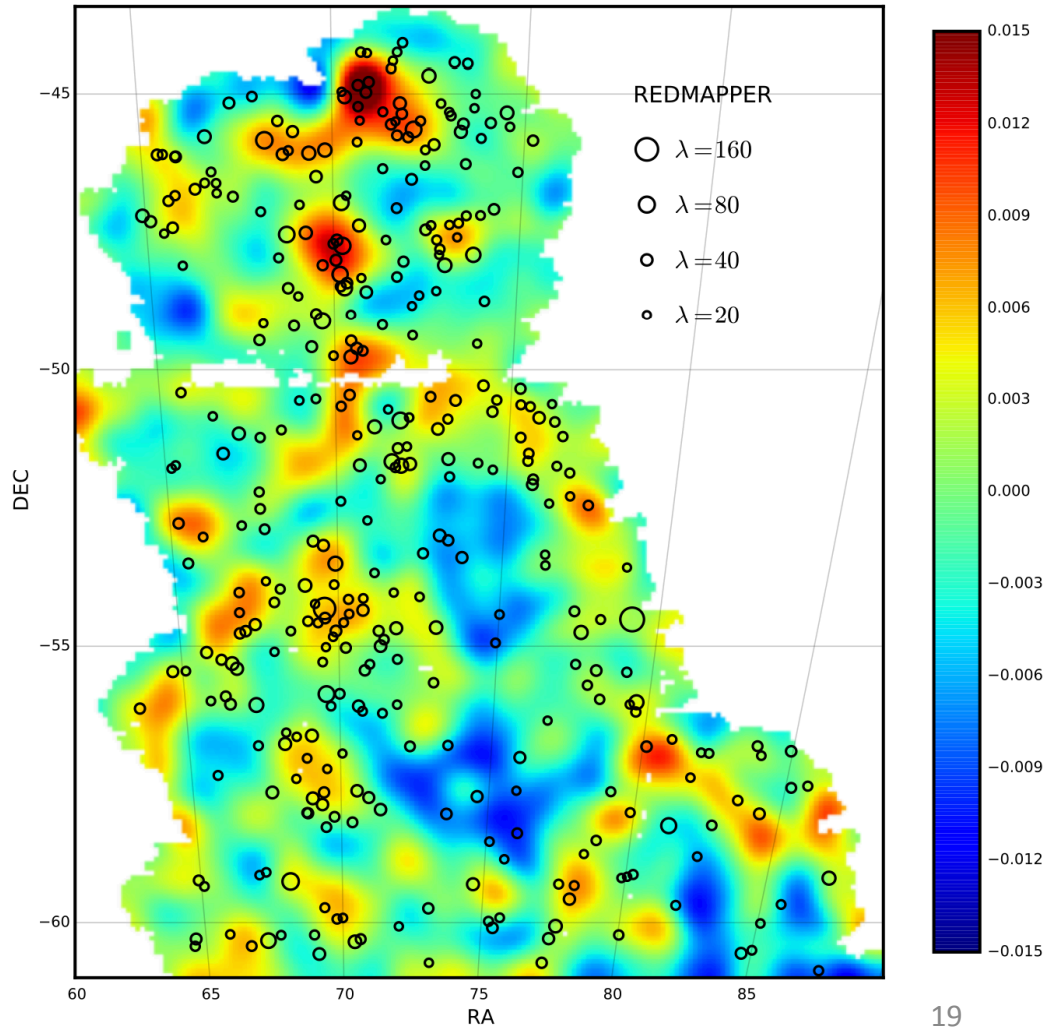
Example: Milky-Way Companion
DES J0335.6-5403



Weak Lensing Mass Map (SV)

Vikram et al, 2015 (1504.03002)

- Sensitive to growth of structure
- 139 deg^2 (3% of DES area)
- WL-cluster cross-corr seen at 6.8σ
- Systematics & stat errors comparable



Automated Scanning for Transients

Goldstein et al, 2015 (1504.02936)

Transient Science:

- SNIa for cosmology & SN-astrophysics
- Core collapse SNe
- Super-luminous SNe (Papadopoulos 2015)
- Kuiper Belt objects (Gerdes 2015, in prep)
- Active Galactic Nuclei
- Possible Tidal Disruption Event (Foley 2015)

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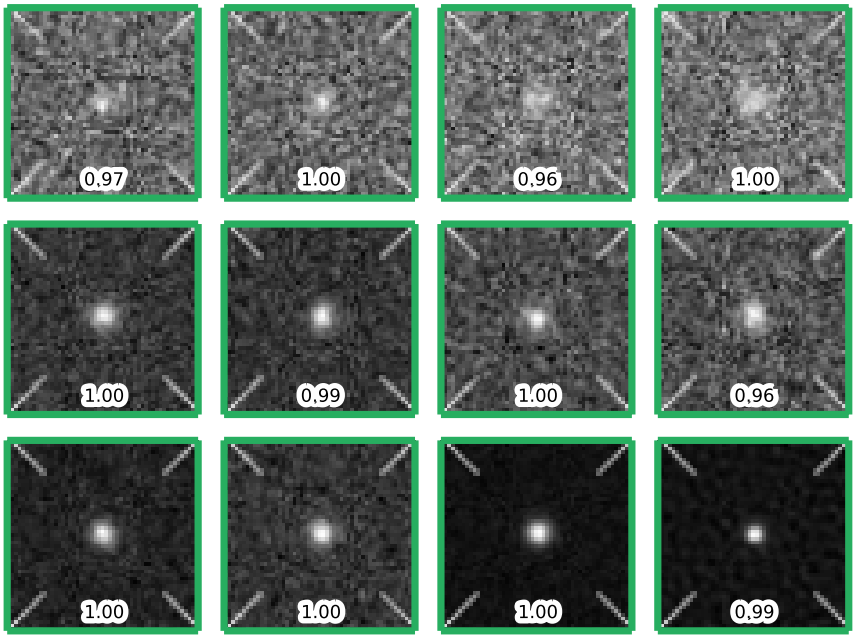

Genuine Astrophysical Sources

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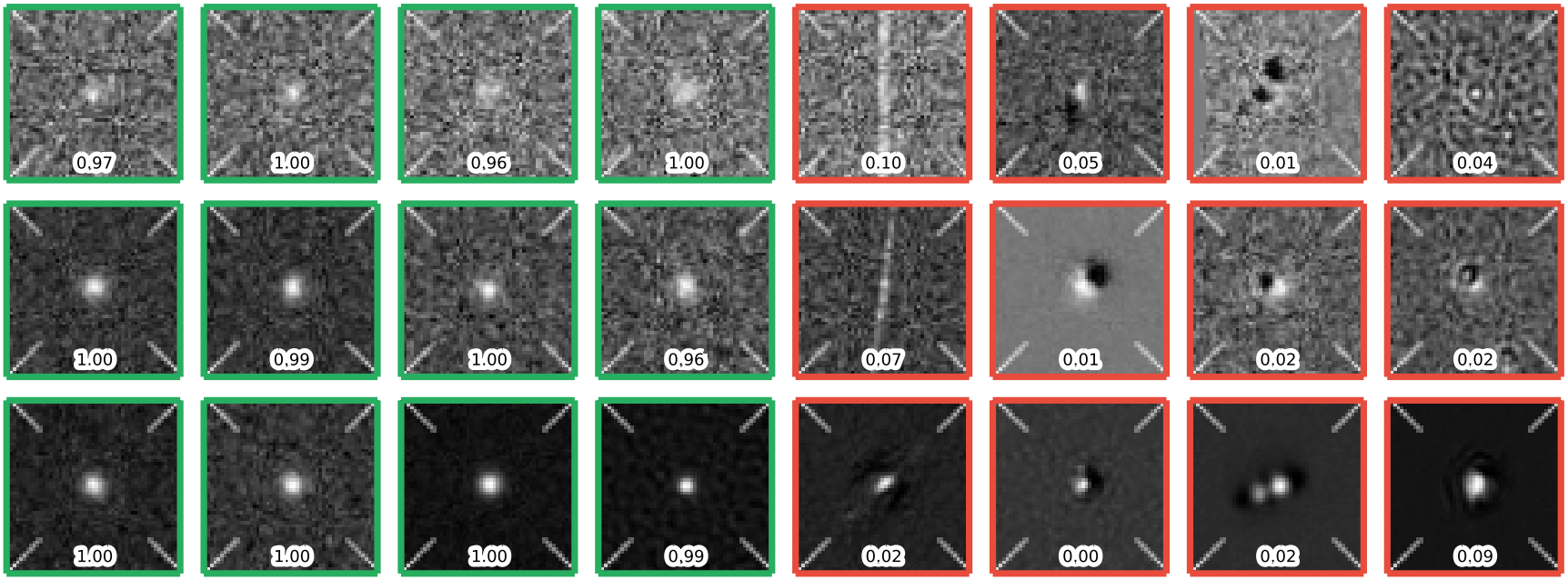

Genuine Astrophysical Sources, 7%

Subtraction artifact, 93% (few million per season)

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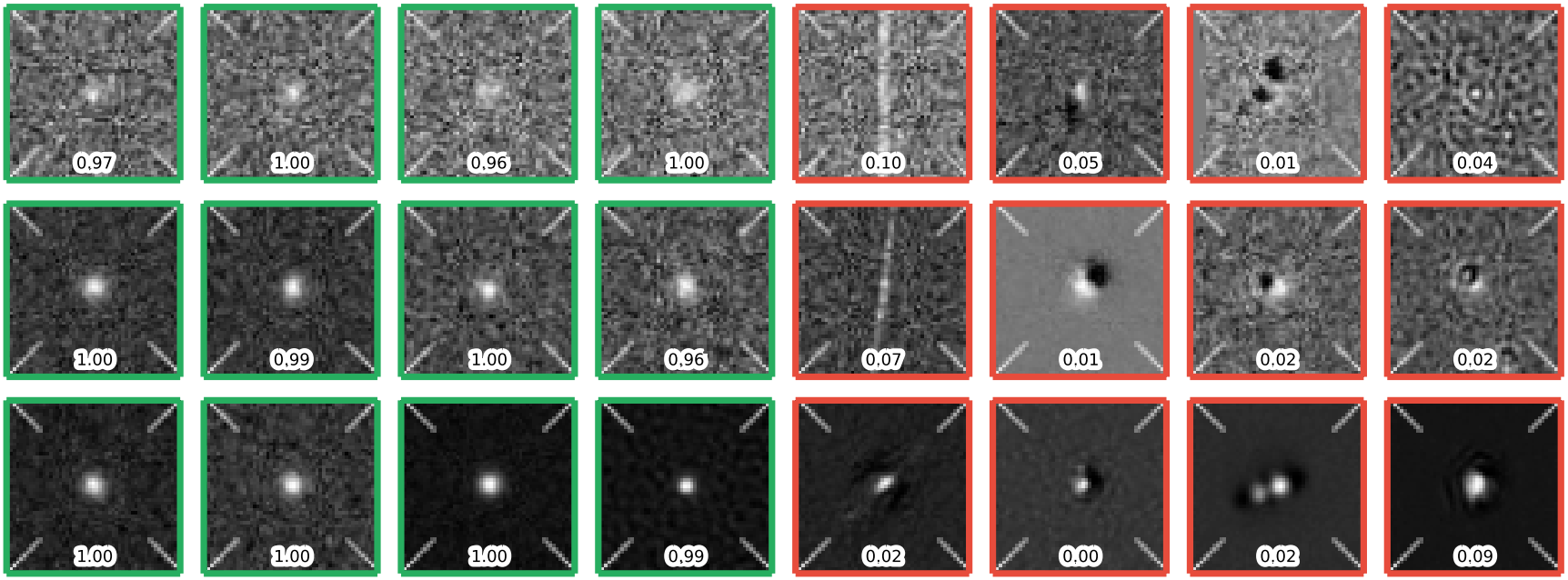


Genuine Astrophysical Sources, 7%

Subtraction artifact, 93% (few million per season)

After auto-scan on Y1:
75% genuine, 25% artifact, fake-SN loss only 1%

Galaxy Photometric Redshifts (SV)

C. Sanches et al., 2014 (1406.4407)

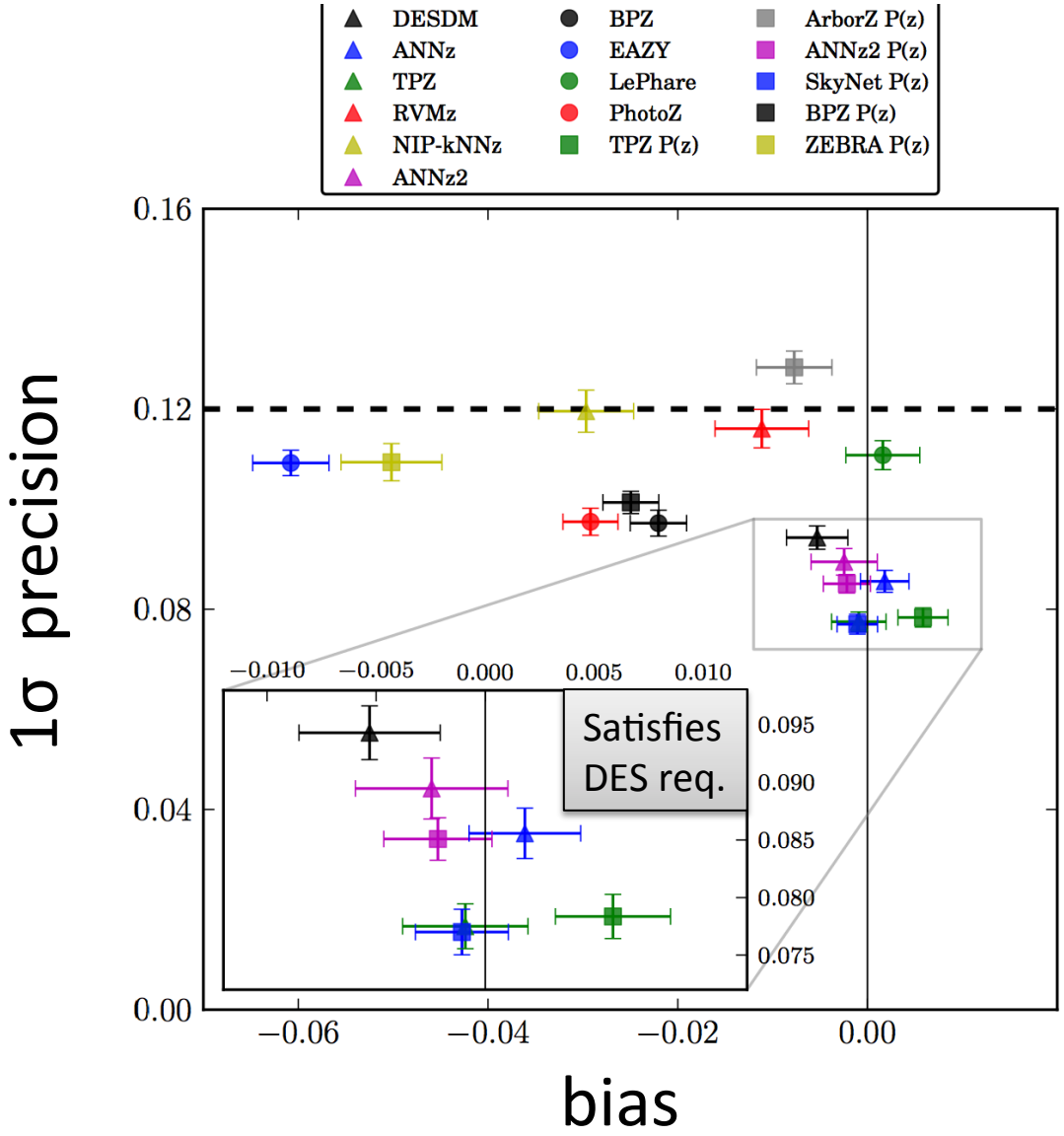
Science needing photo-z

- BAO with 300 million galaxies
- Weak Lensing
- Clusters
- Spec-targeting for transients

Large OzDES program to collect spec-z for training

(Yuan et al, 2015: 1504.03039)

Galaxy Photometric Redshifts (SV)



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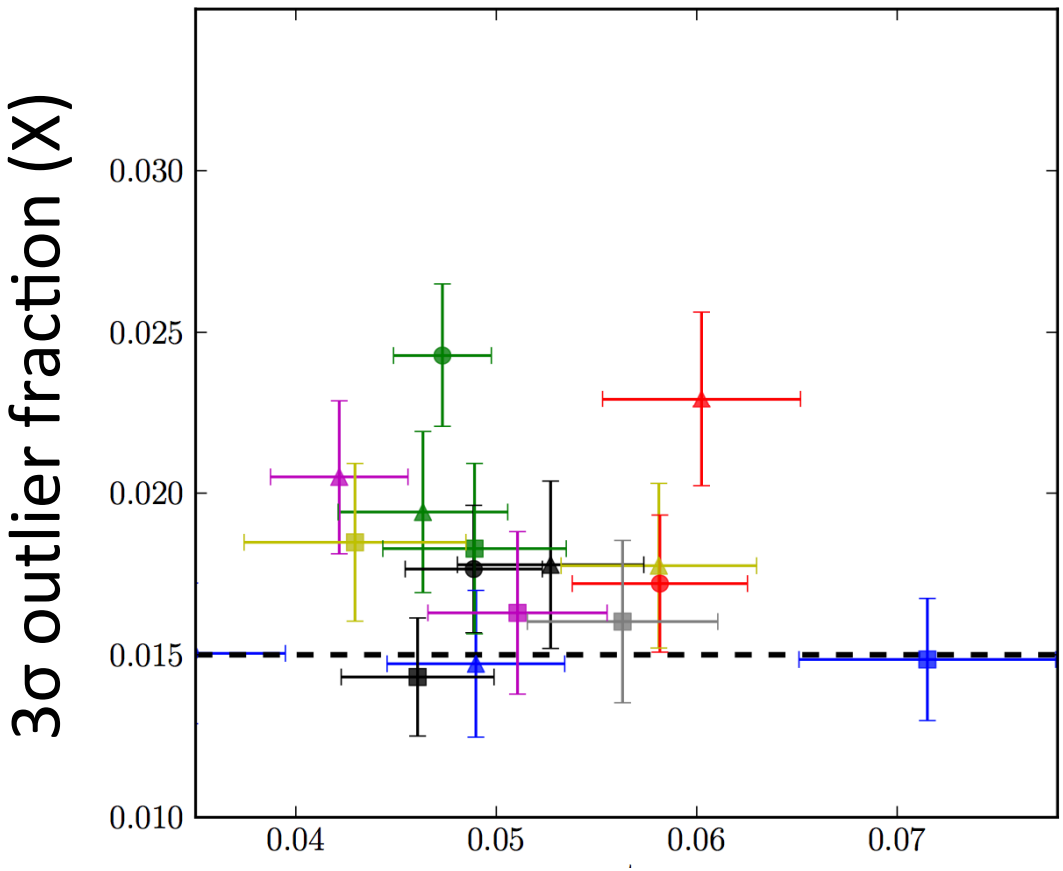
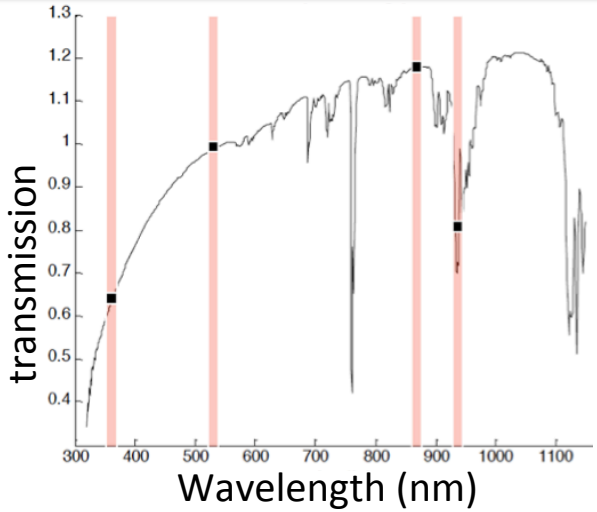


PRELIMINARY

Precision Calibration

(Li et al, in prep)

Use 4-band "**aTmCam**" to measure atmosphere transmission every 30 minutes



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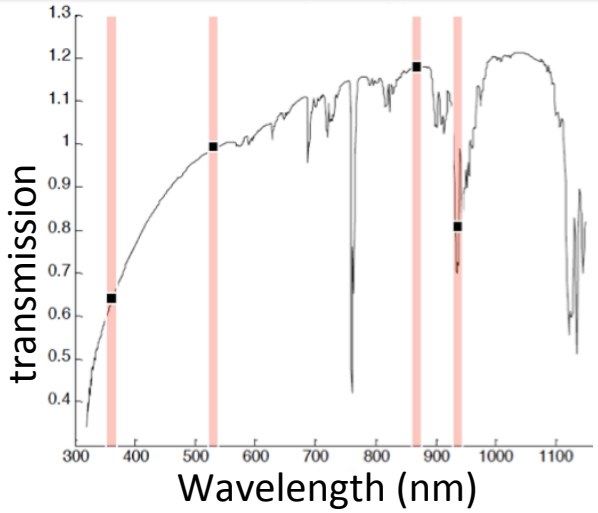
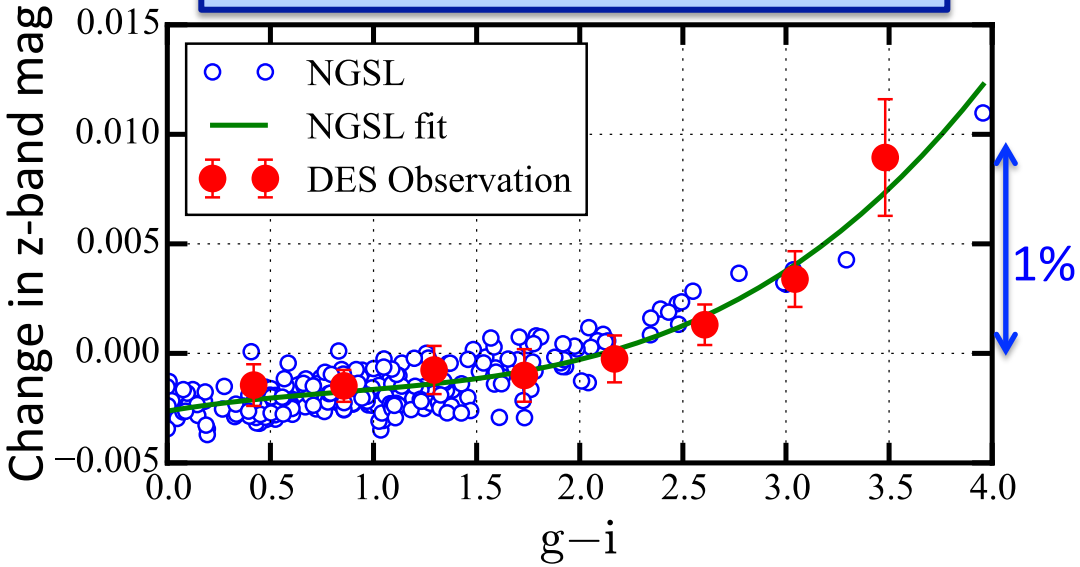


Affect of Water Vapor Variation:
3 mm vs. 13 mm



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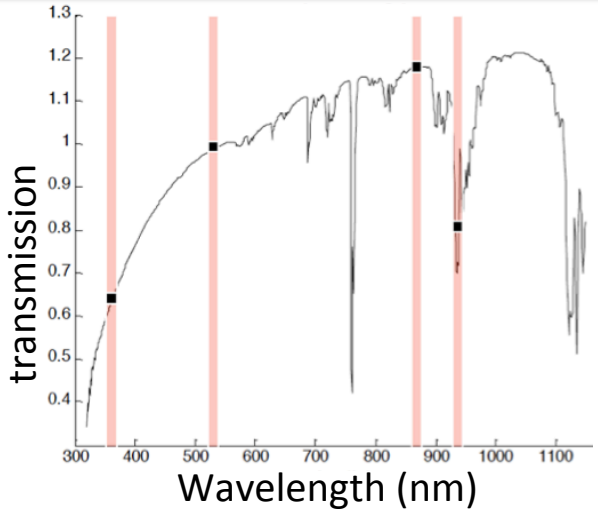

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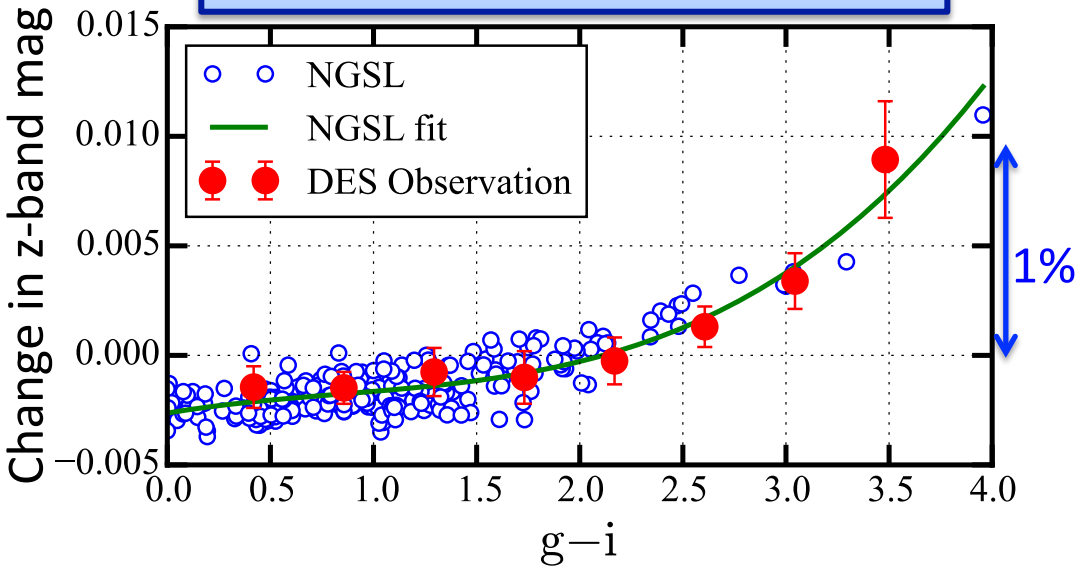

And also:
DECal system (Marshall et al, in prep) to measure
DECam+telescope efficiency vs. λ and focal plane position

Survey Status after 2 seasons

- Overall, survey going very well
- Excellent data quality
- About 10% behind on area (mostly weather)

Summary of Science with DES
(list keeps growing)

- For Cosmology :
  - Weak Lensing
  - Strong lensing
  - Baryon Acoustic Oscillations
  - Cluster counts & profiles
  - SNIa Hubble Diagram
  - Lensed supernovae
  - Superluminous supernovae
  - Reverberation mapping of black holes
  - photometric galaxy redshifts
  - photometric SN identification

- Astronomy & Astrophysics:
  - Superluminous supernovae
  - First quasars
  - Objects in the outer solar system
  - Galaxy evolution
  - Gamma Ray Bursts
  - Gravitational Waves
  - Magellanic Clouds