



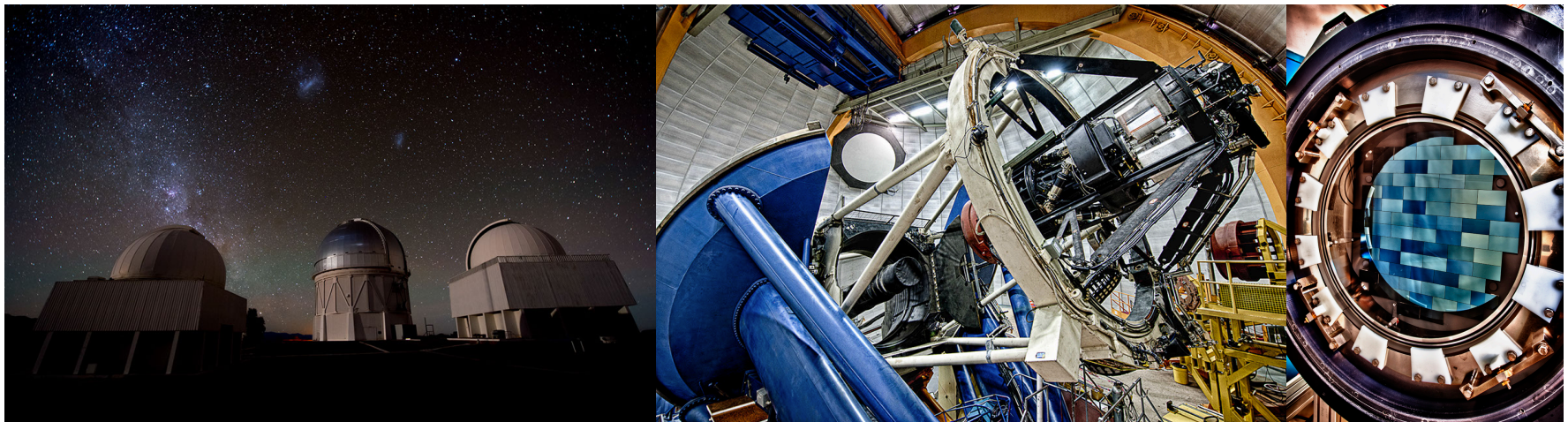
DARK ENERGY
SURVEY



The Dark Energy Survey: Status and Results

Tesla Jeltema
University of California, Santa Cruz

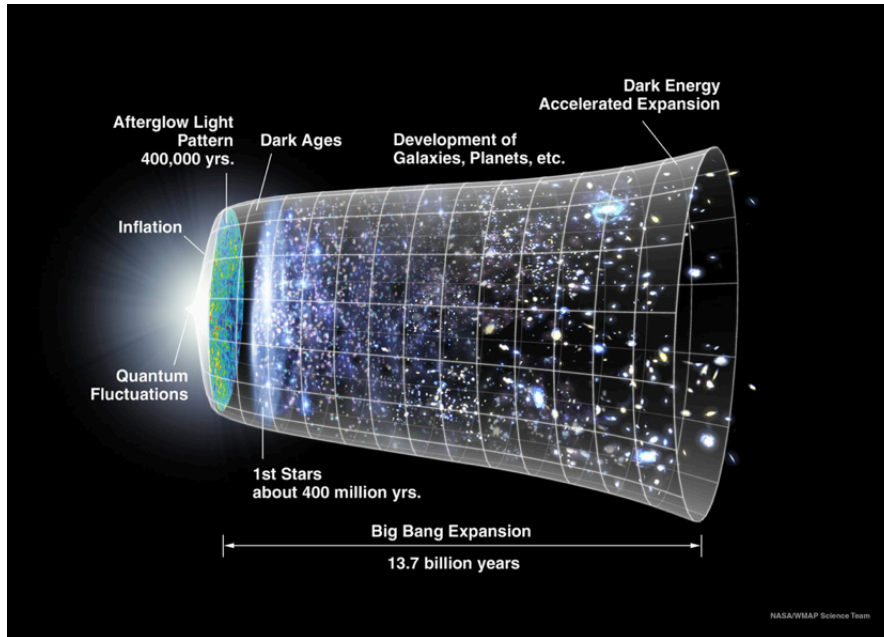
on behalf of the Dark Energy Survey Collaboration





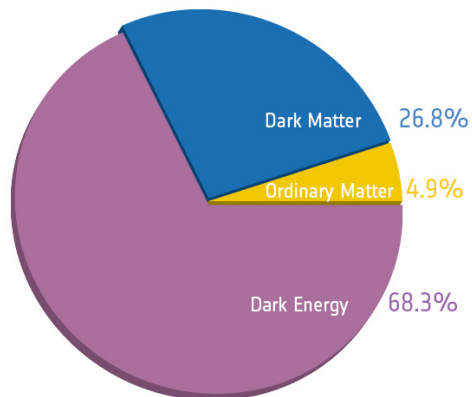
Dark Energy

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What is the cause of the observed cosmic acceleration?

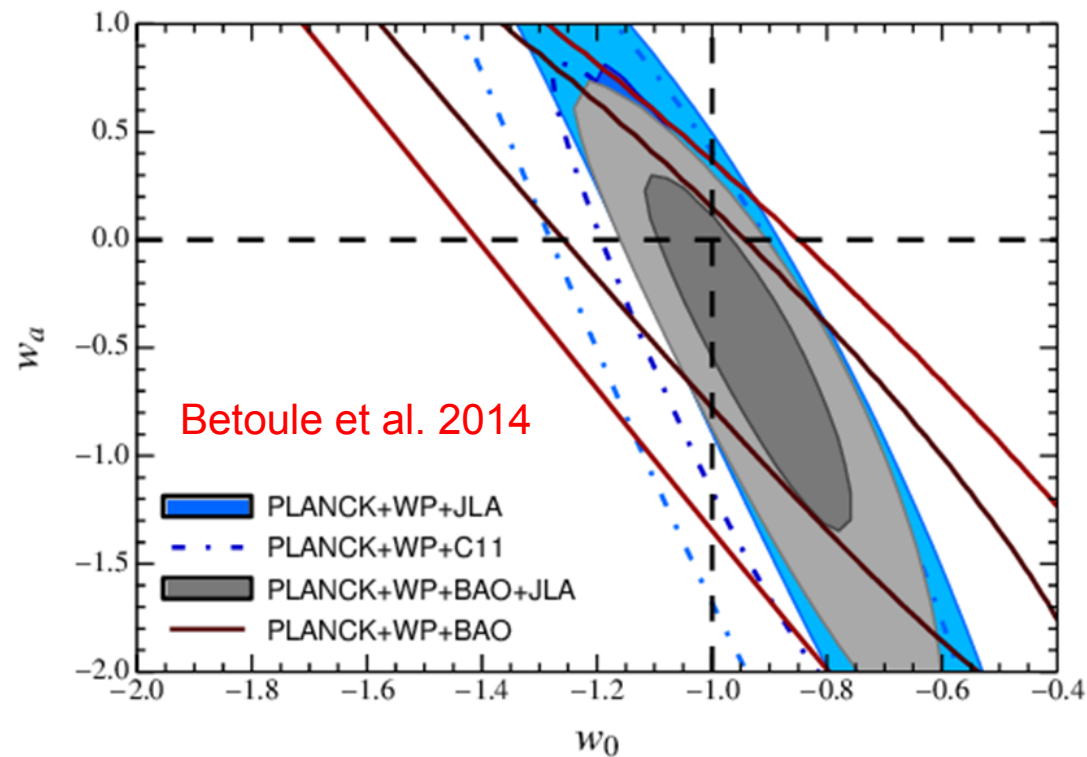
- Is it dark energy or a modification of general relativity?
- If it is dark energy, is it constant (Λ) or evolving; what is the DE equation of state?





Dark Energy

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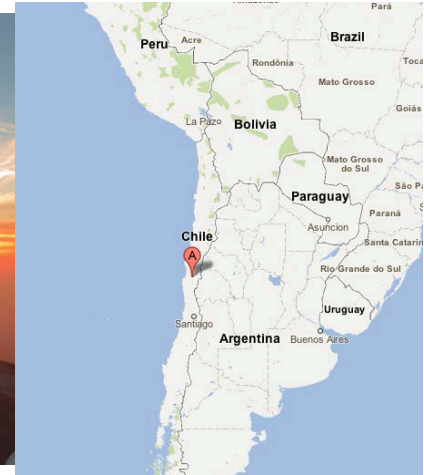
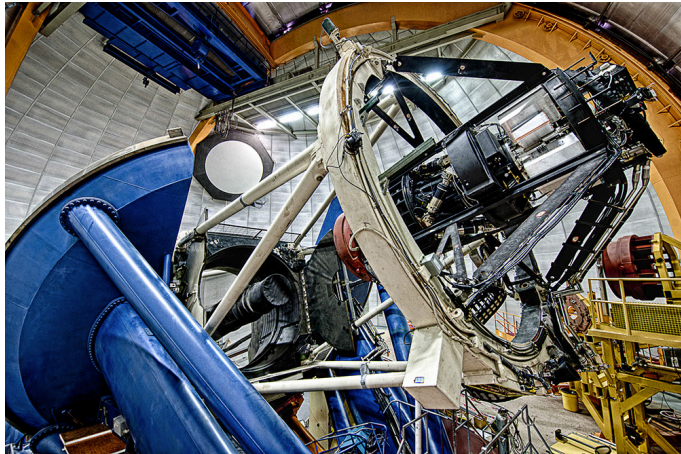


- Current measurements compatible with dark energy being the cosmological constant
- Not very sensitive yet to time variation of the equation of state



The Dark Energy Survey

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SURVEY



DECam on the Blanco 4m at CTIO

- Optical imaging survey with 4-m Blanco telescope at CTIO in Chile
- 5000 deg² (1/8 of the full sky) in grizY bands
- 30 deg² SNe fields revisited
- DECam: 570 Megapixel Camera with 3 deg² FOV
- Runs 2013-2018, 525 nights

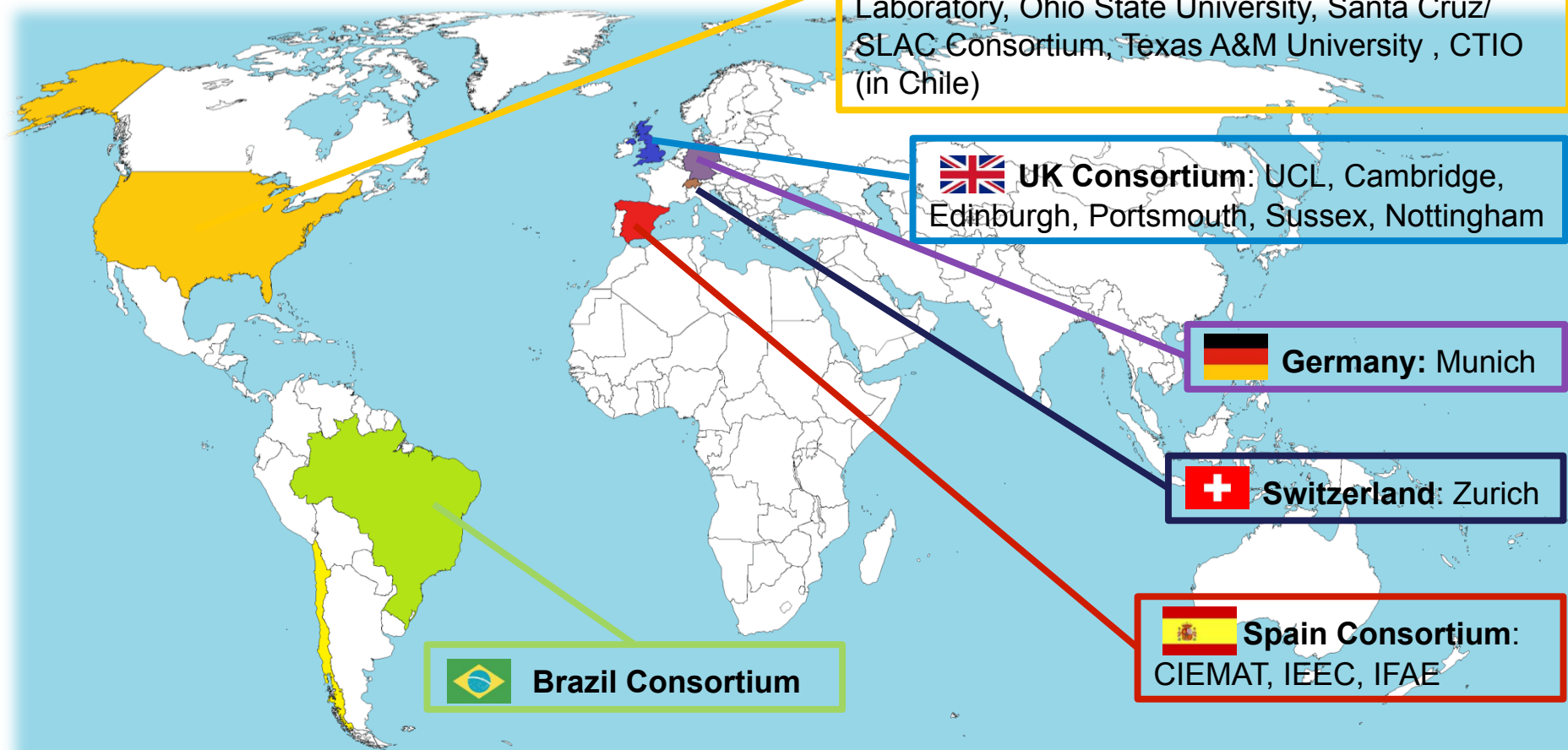


DES Collaboration:

~300 scientists from 28 institutions from around the world

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facebook.com/darkenergysurvey
<http://darkenergysurvey.org>





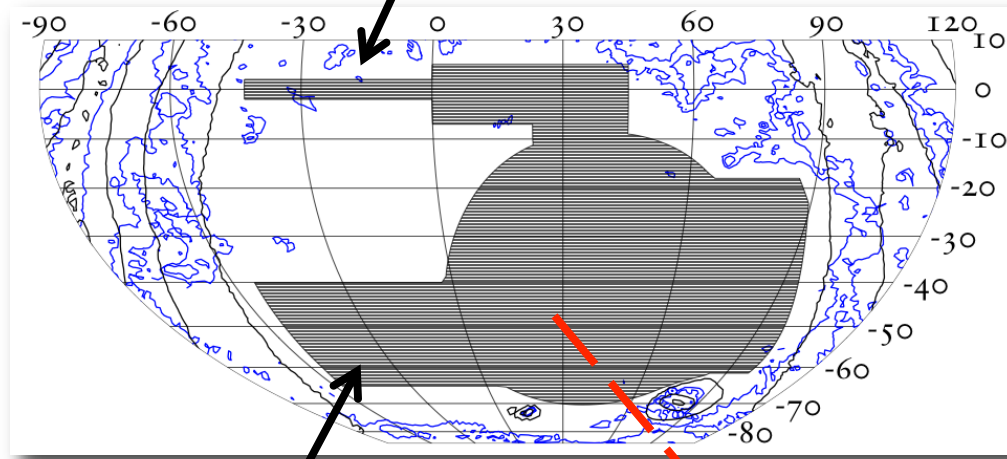
DES Survey Footprint

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SDSS Stripe 82 for calibration

Overlap with as many
surveys as possible:

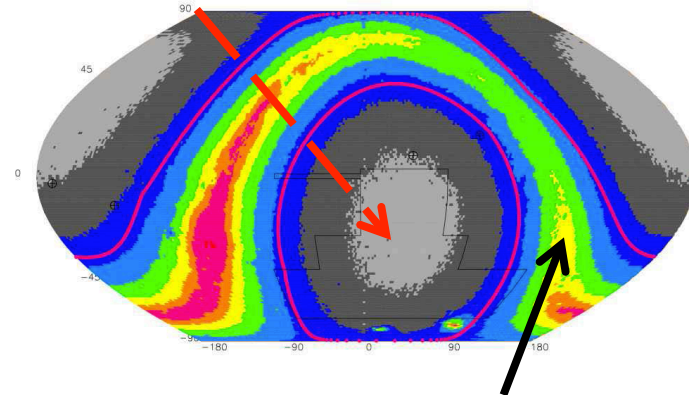
Stripe82, GAMA,
VVDS, eRosita,
BOSS, DEEP2,
PRIMUS, ...



2500 deg²
overlap with SPT

Visible from Cerro Tololo September –
February

DECam available for community use
when DES not observing



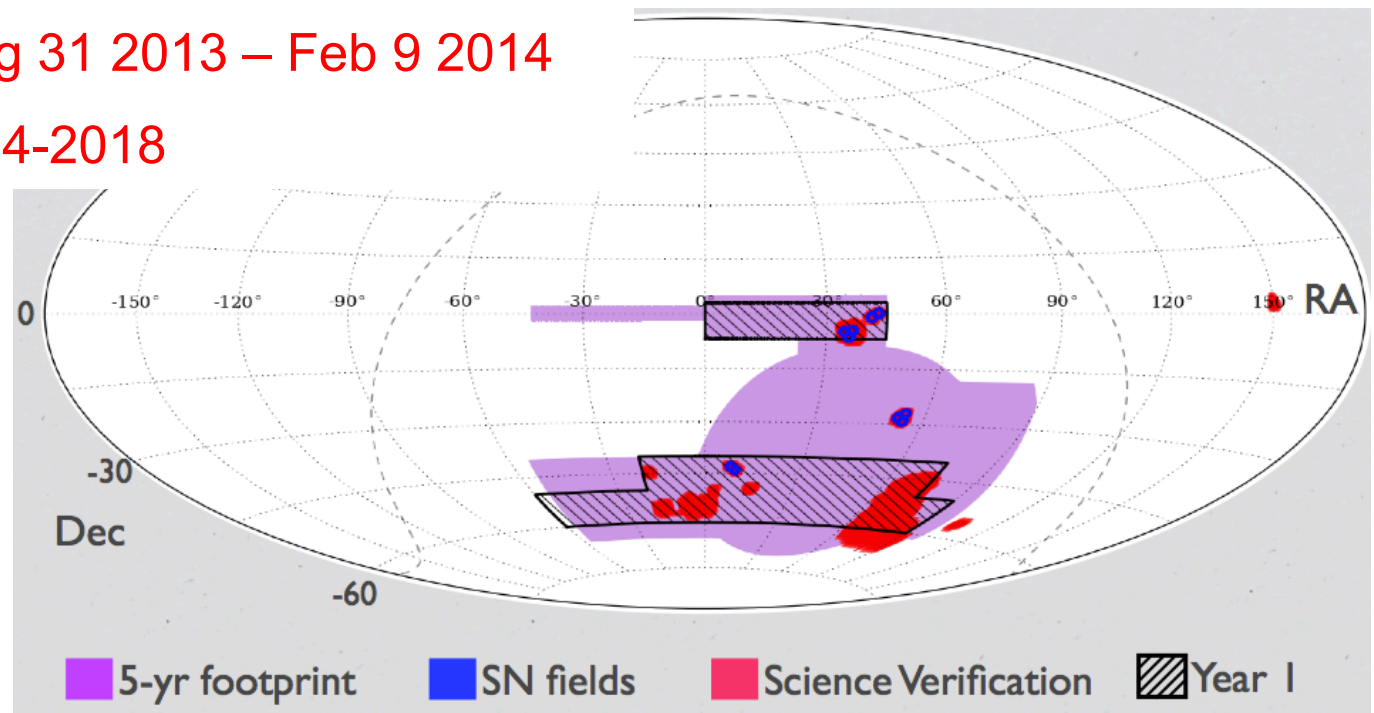
Milky Way, equatorial projection



DES Status

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- Imager installation: **Aug 30, 2012**
- First light: **Sept 12, 2012**
- Commissioning: **Sept - Oct 2012**
- Science Verification: **Nov 2012 – Feb 2013**
- First season: **Aug 31 2013 – Feb 9 2014**
- Season 2-5: **2014-2018**





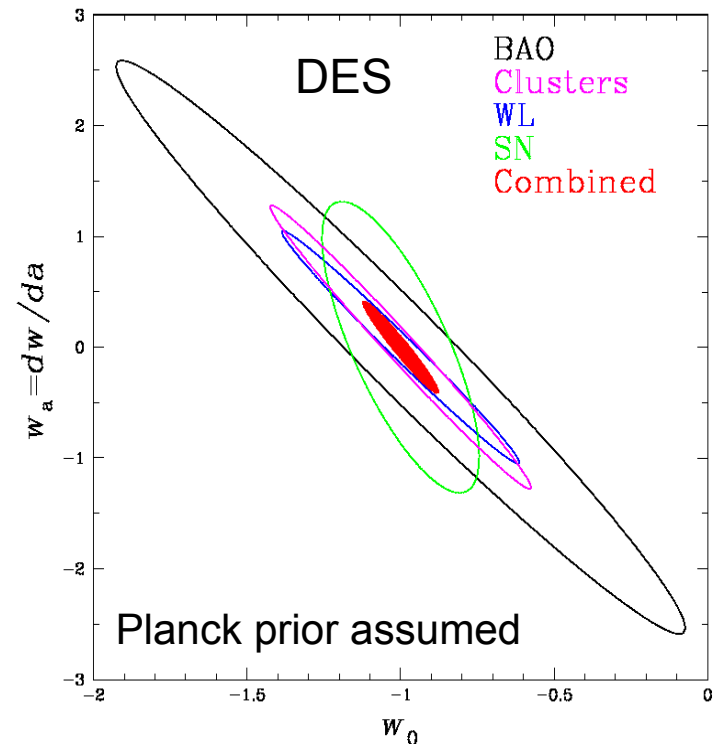
DES Science Overview

DARK ENERGY
SURVEY

Four Probes of Dark Energy

- **Galaxy Clusters**
 - ~100,000 clusters to $z > 1$
 - Synergy with SPT, VHS
 - *growth of structure and geometry*
- **Weak Lensing**
 - Shape measurements of 200 million galaxies
 - *growth of structure and geometry*
- **Baryon Acoustic Oscillations**
 - 300 million galaxies to $z = 1$ and beyond
 - *Sensitive to geometry*
- **Supernovae**
 - 30 sq deg time-domain survey
 - 3500 well-sampled SNe Ia to $z \sim 1$
 - *Sensitive to geometry*

Forecast Constraints on DE Equation of State

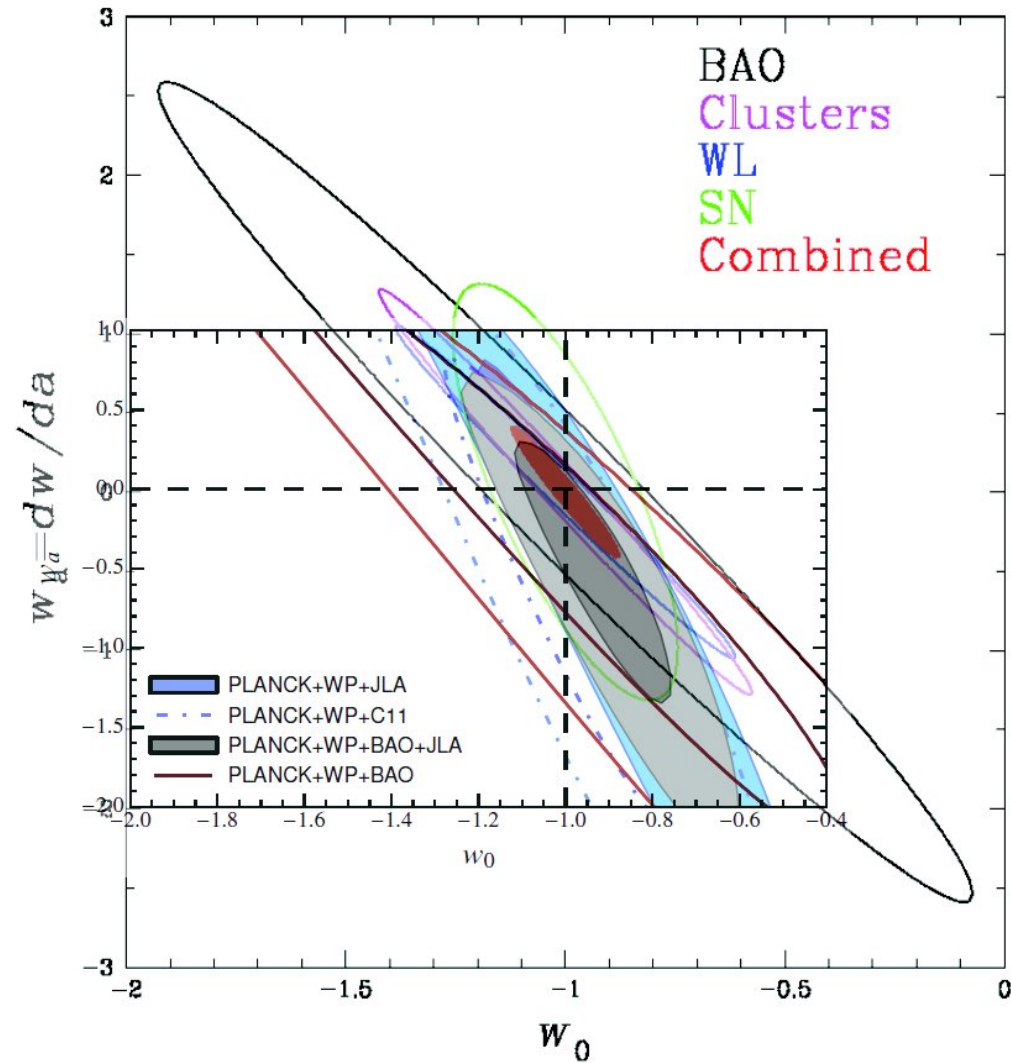


Factor 3-5 improvement over
Stage II DETF Figure of Merit



DES Science Overview

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Cluster Abundance

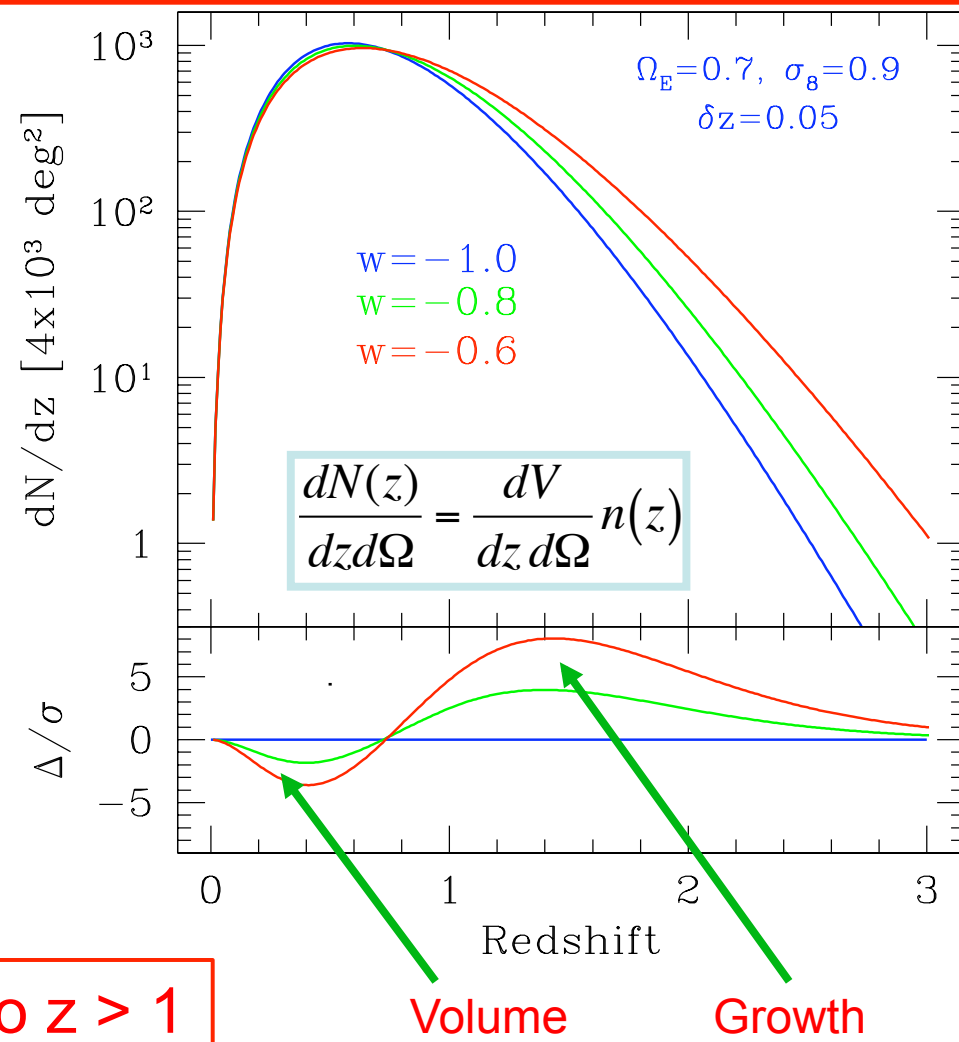
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Number of clusters above
a mass threshold per
redshift per solid angle

Depends on:

- volume surveyed
- density of cluster

** Models are normalized to
produce same cluster
abundance at low redshifts

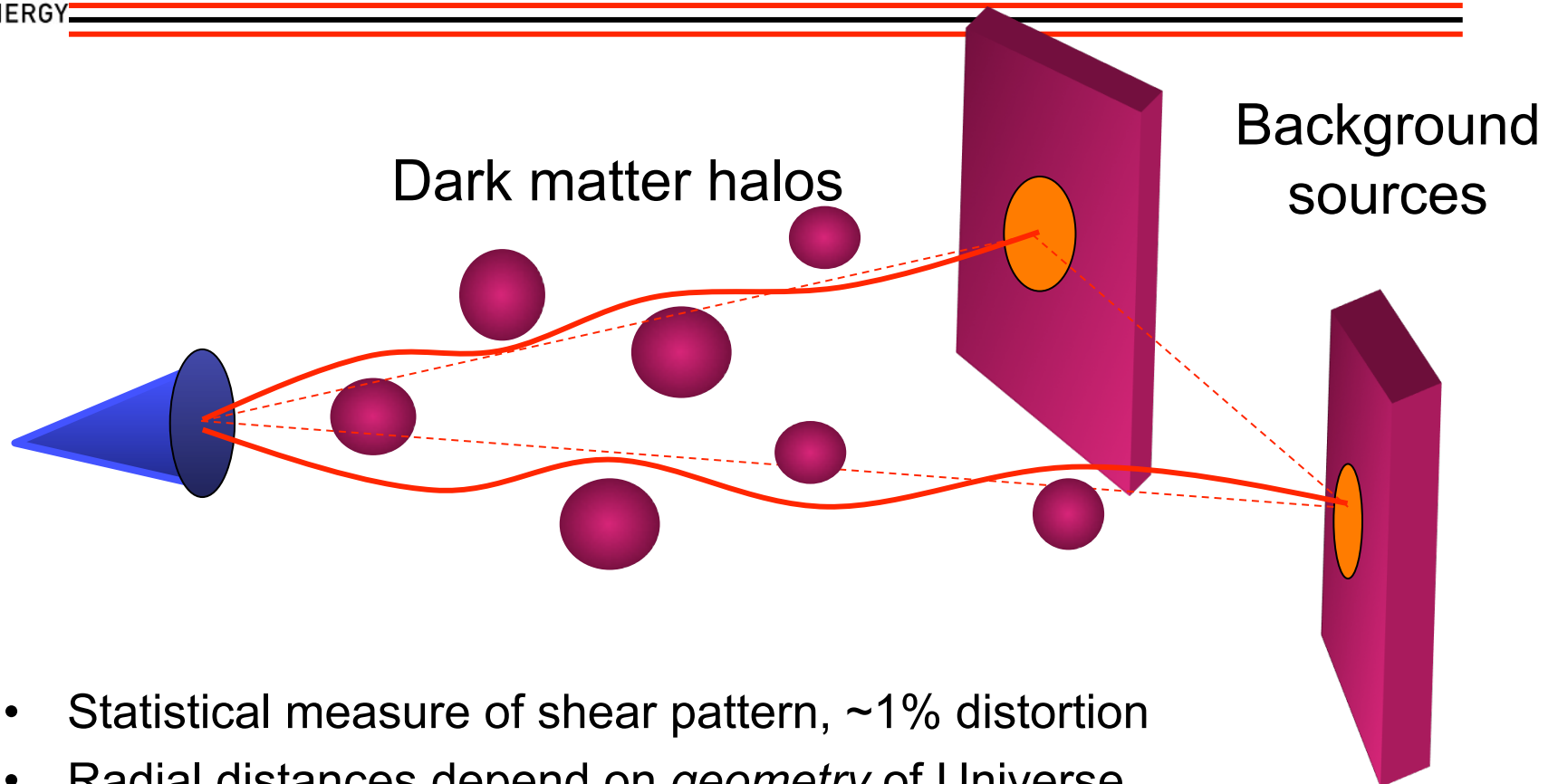


DES ~100,000 clusters to $z > 1$



Weak Lensing Cosmic Shear

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

DES shape measurements of 200 million galaxies



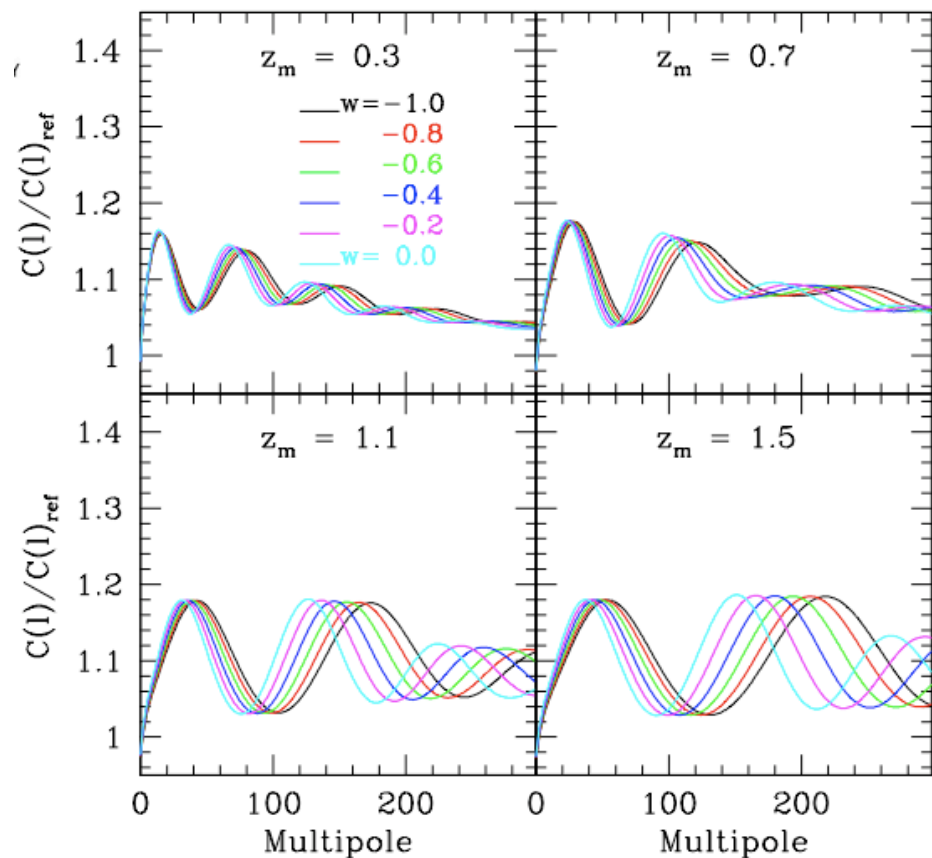
Baryon Acoustic Oscillations

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- Acoustic scale provides standard ruler. Scale set by last-scattering surface.
- Probe deeper than SDSS redshift survey (x10 increase in volume)

**DES 300 million galaxies
to $z > 1$**

Galaxy angular power spectrum in photo-z bins
(relative to model without BAO)

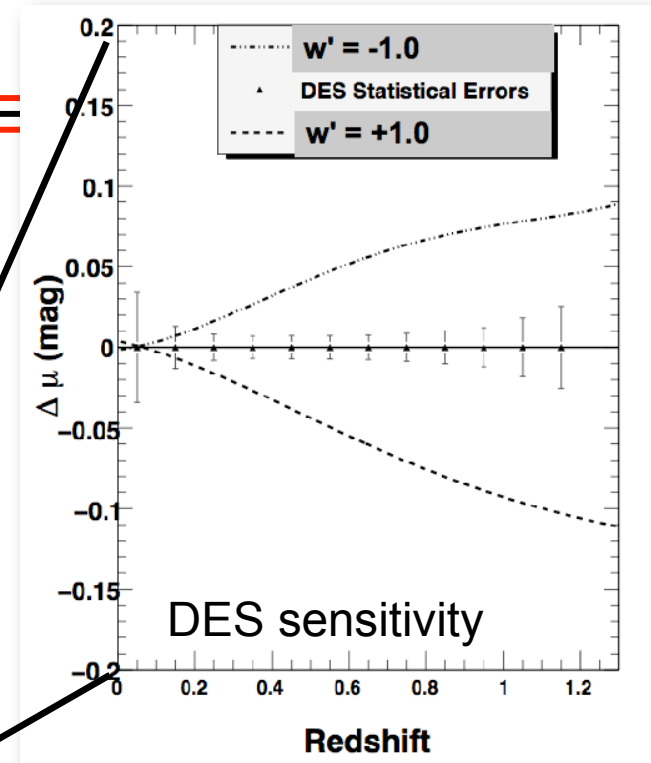
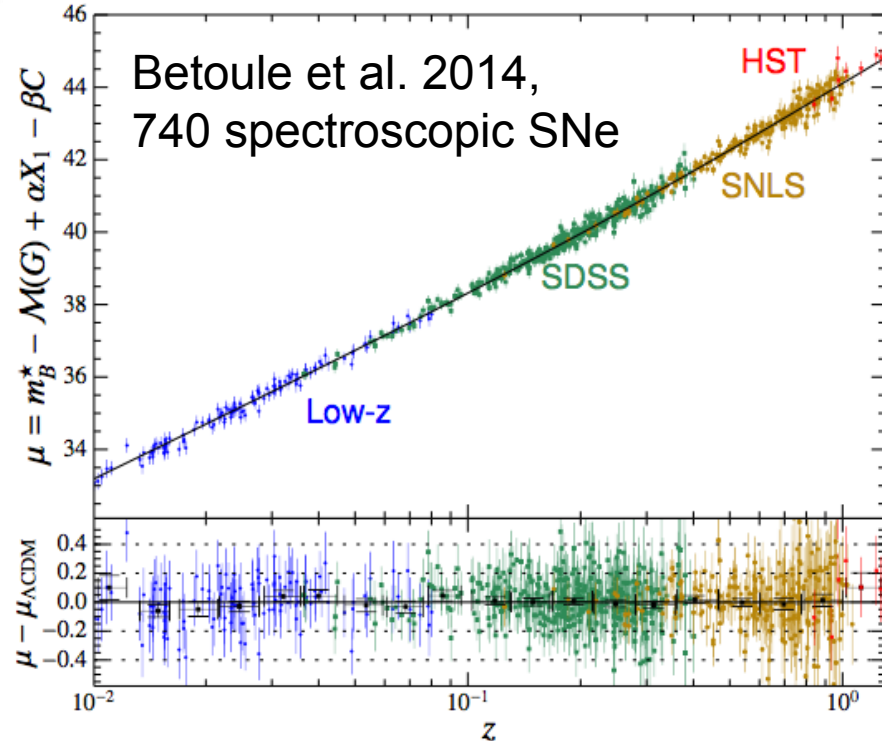


Fosalba & Gaztanaga



Supernovae

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- Standard candles
- Probe geometry

DES ~3500 well-sampled SNe Ia to $z \sim 1$

30 deg² with ~5 day cadence. Redshifts from spectroscopic follow-up, SNe and galaxy photo-zs

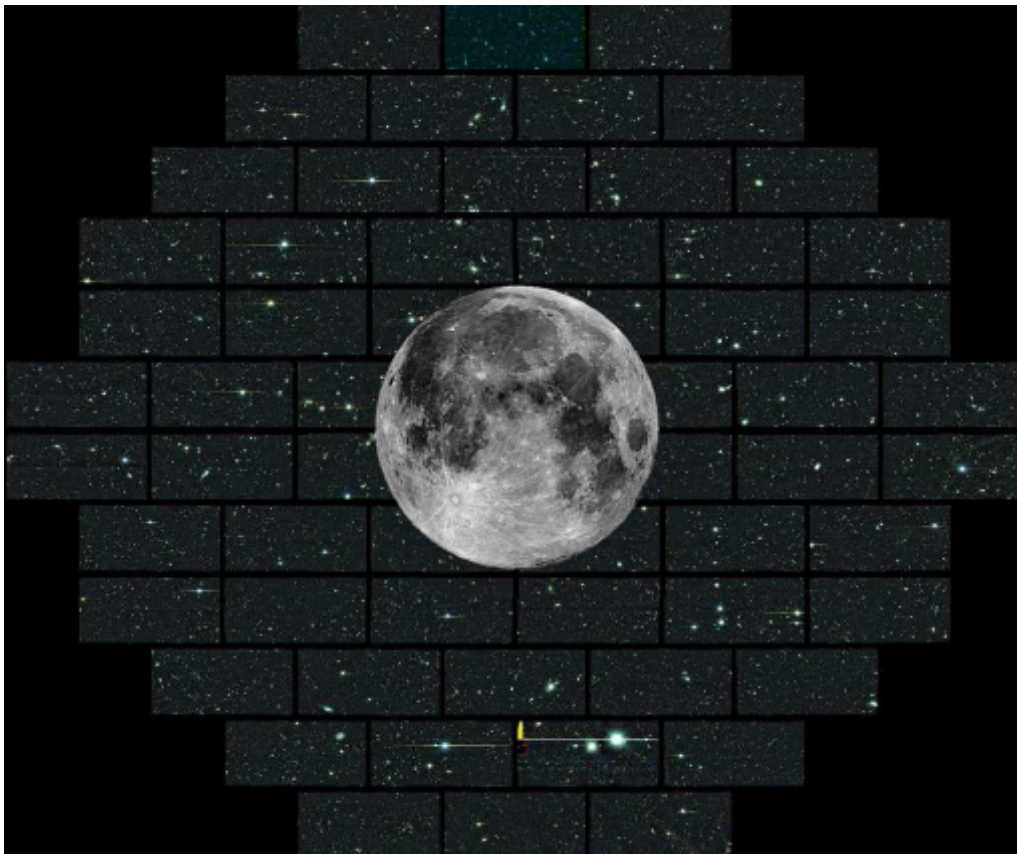


DES Survey Status

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- Early science using $\sim 250 \text{ deg}^2$ covered in Science Verification
- DECam performance has been extremely good!

One of the SNe fields



DECam image of
NGC1398 in Fornax cluster

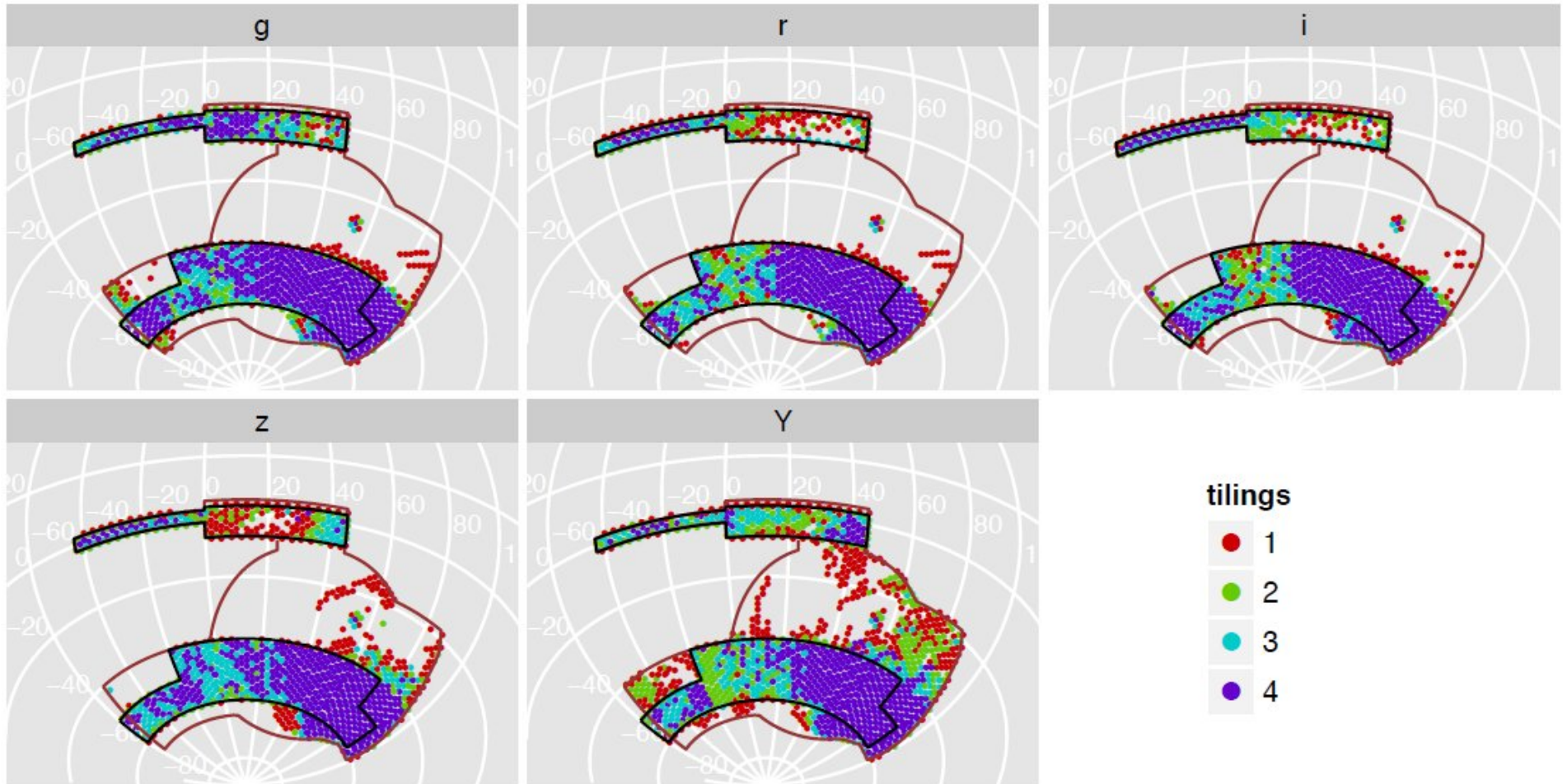




Survey Progress in Year 1

2000 deg² in 4 tilings (2/5 of the final depth)

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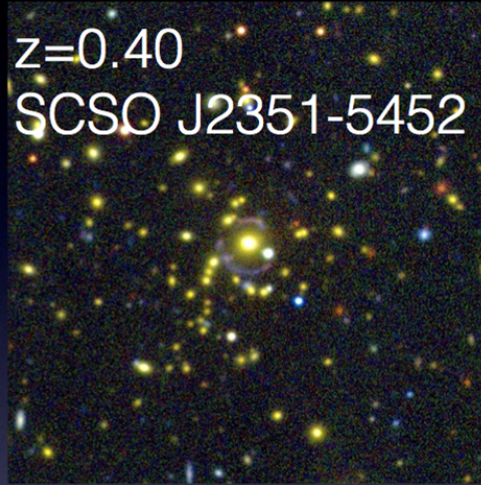
Early Results: Clusters

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$z=0.30$
Bullet Cluster



$z=0.40$
SCSO J2351-5452



$z=0.87$
"El Gordo"



$z=0.53$
SCSO J2336-5352



$z=0.76$
DES J0449-5909



$z=0.83$
DES J0250+0008

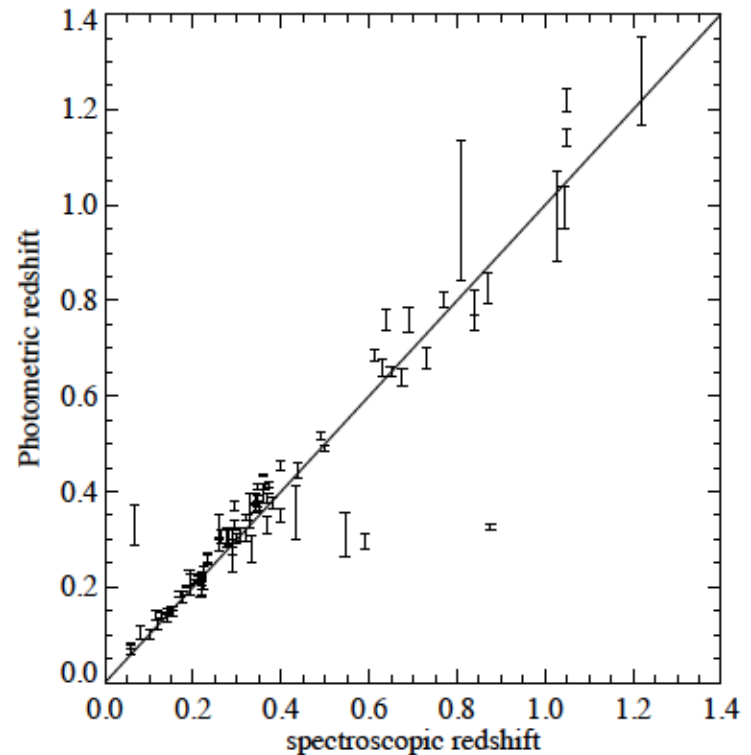




Early Results: Clusters

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- **20,000 clusters** identified by redMaPPer in DES SV
(redMaPPer is one of several cluster finders which will be used by DES, Rykoff et al. 2013)
- Photometric redshift performance is very good
- Cluster richness from redMaPPer performs well as a mass estimator



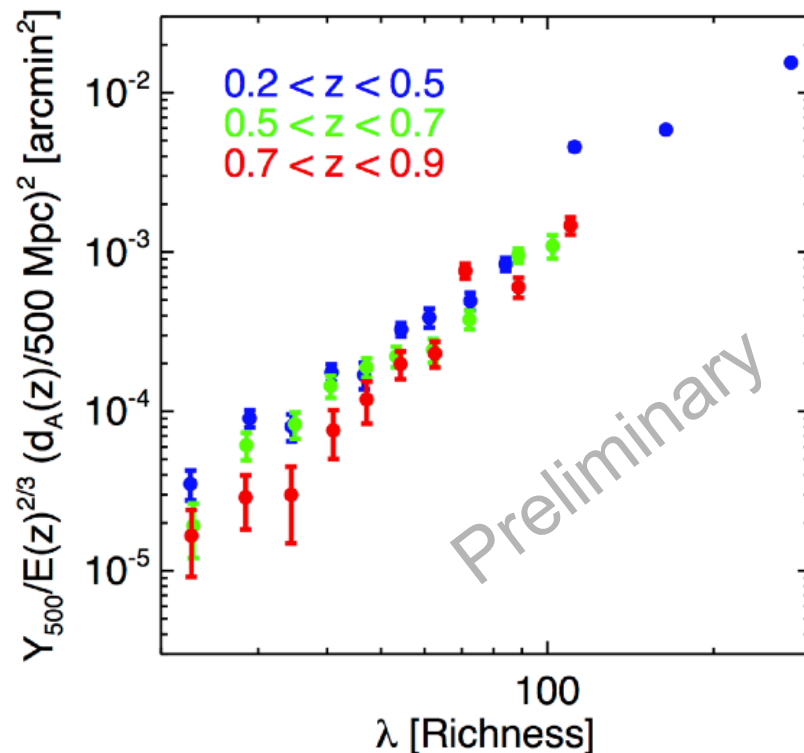
Plot courtesy of Chris Miller



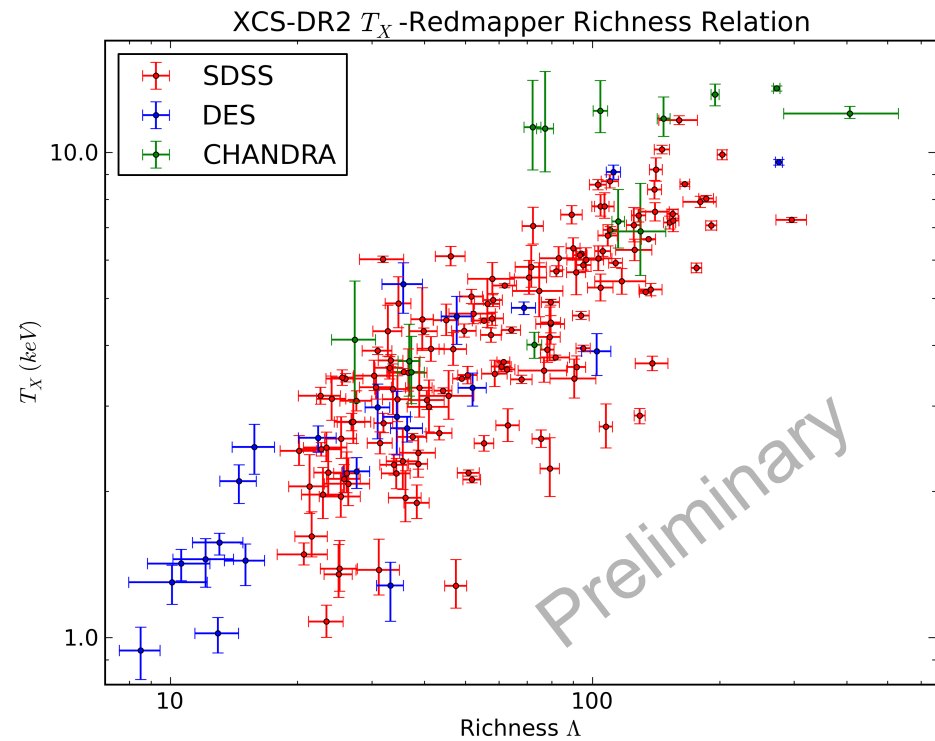
Early Results: Clusters

DARK ENERGY
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Richness correlates strongly with SZ and X-ray observables.



Plot courtesy of Alex Saro, Brad Benson and the SPT collaboration

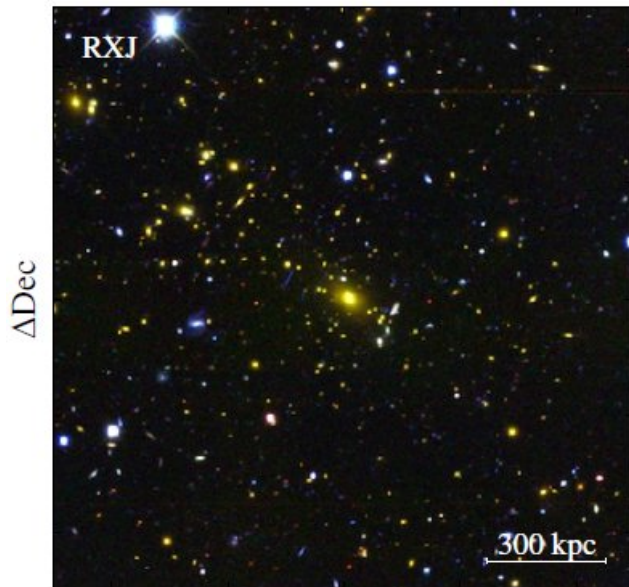


Plot courtesy of P Rooney, A Bermeo, D Hollowood, and the XCS collaboration

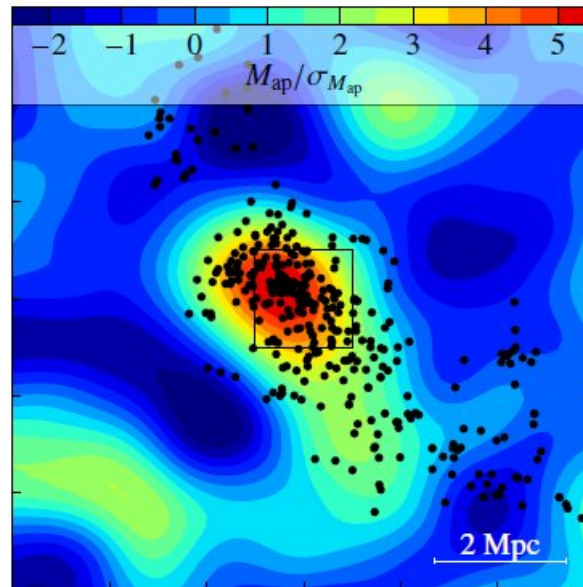


Early Results: Cluster Weak Lensing

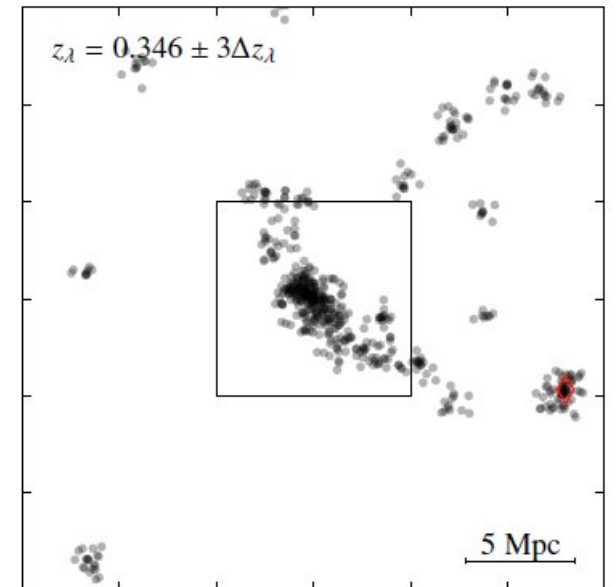
DARK ENERGY SURVEY



DES image (5 arcmin)



Weak lensing aperture mass map with galaxy positions (30 arcmin)



Galaxy positions (90 arcmin)

[arXiv:1405.4285:](https://arxiv.org/abs/1405.4285)

Weak lensing masses for four clusters in SV



Early Results: Supernovae

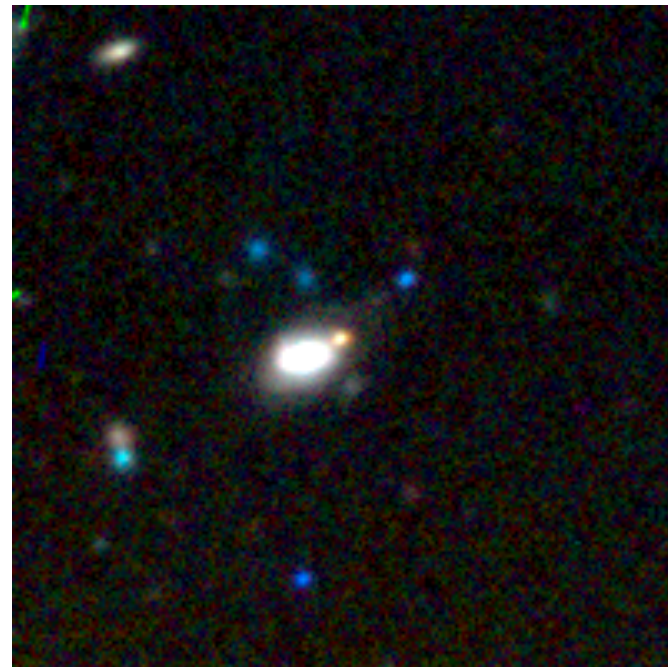
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Status from Science Verification:

- 7 Type Ia spectroscopically confirmed
- 427 photometrically classified Type Ia



Nov. 7



Dec. 15

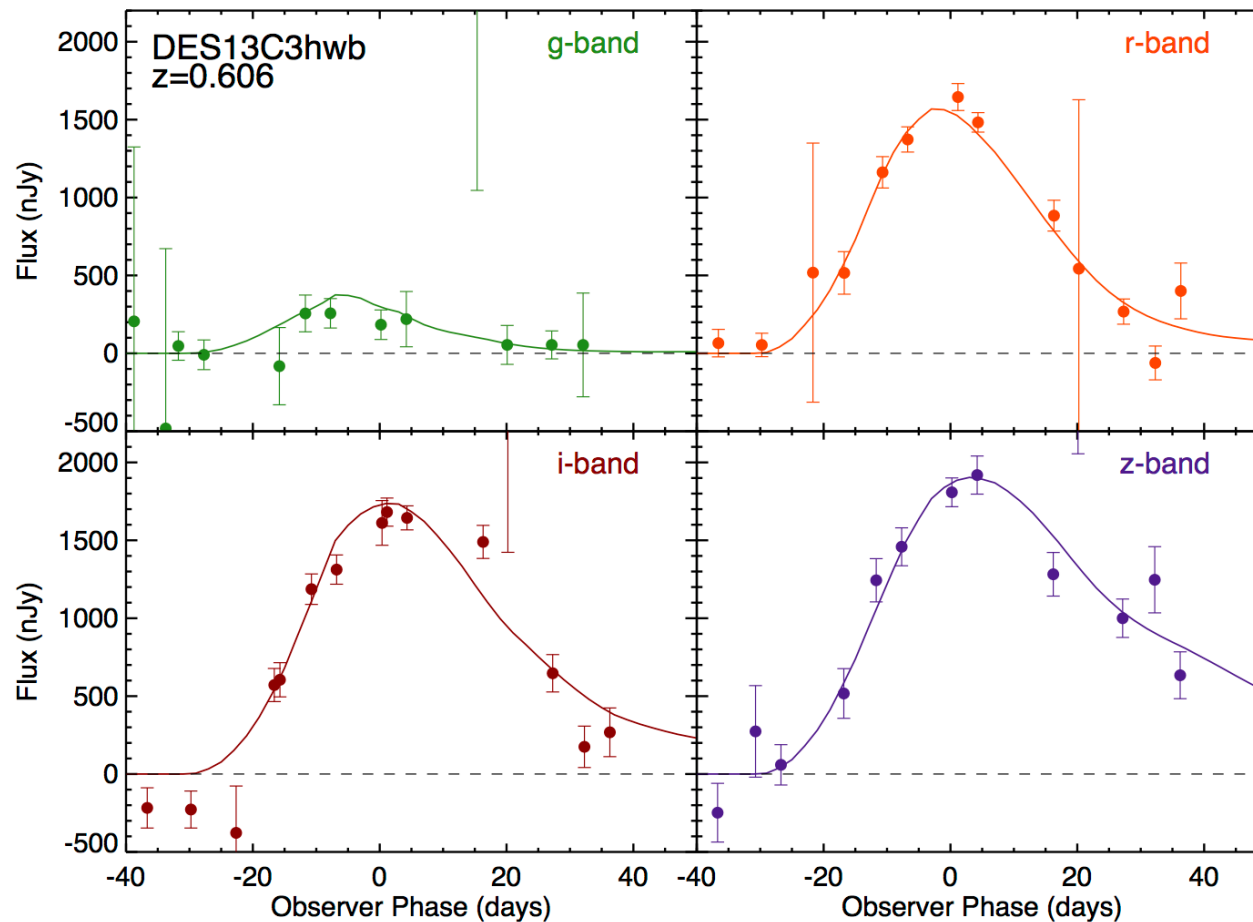
First confirmed SNe: SN Ia at $z=0.2$ confirmed at AAO



Early Results: Supernovae

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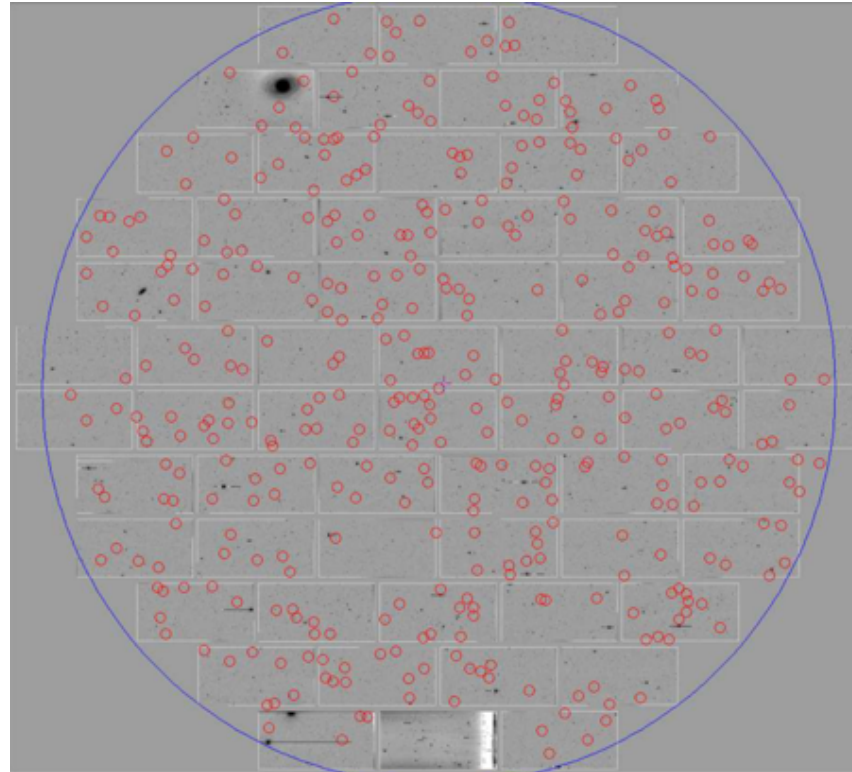
Example light curve: DES13C3hwb, SN-Ia at $z=0.606$





Spectroscopic Follow-up: OzDES

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- AAOmega/2dF on AAT: near-perfect overlap with DECAM FoV
- SN host galaxies targeted repeatedly
- 100 nights over 5 years



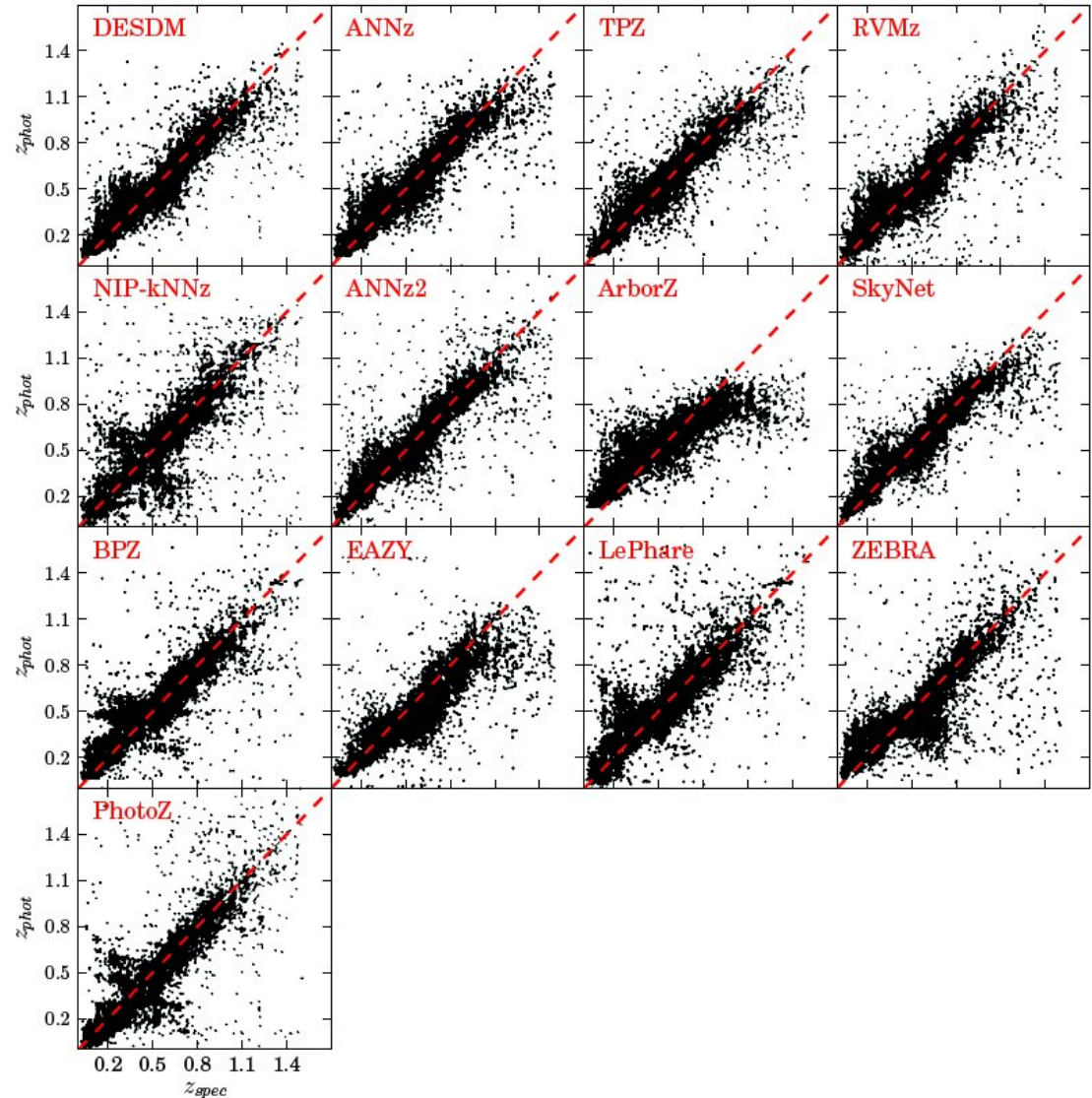
Photometric redshift performance

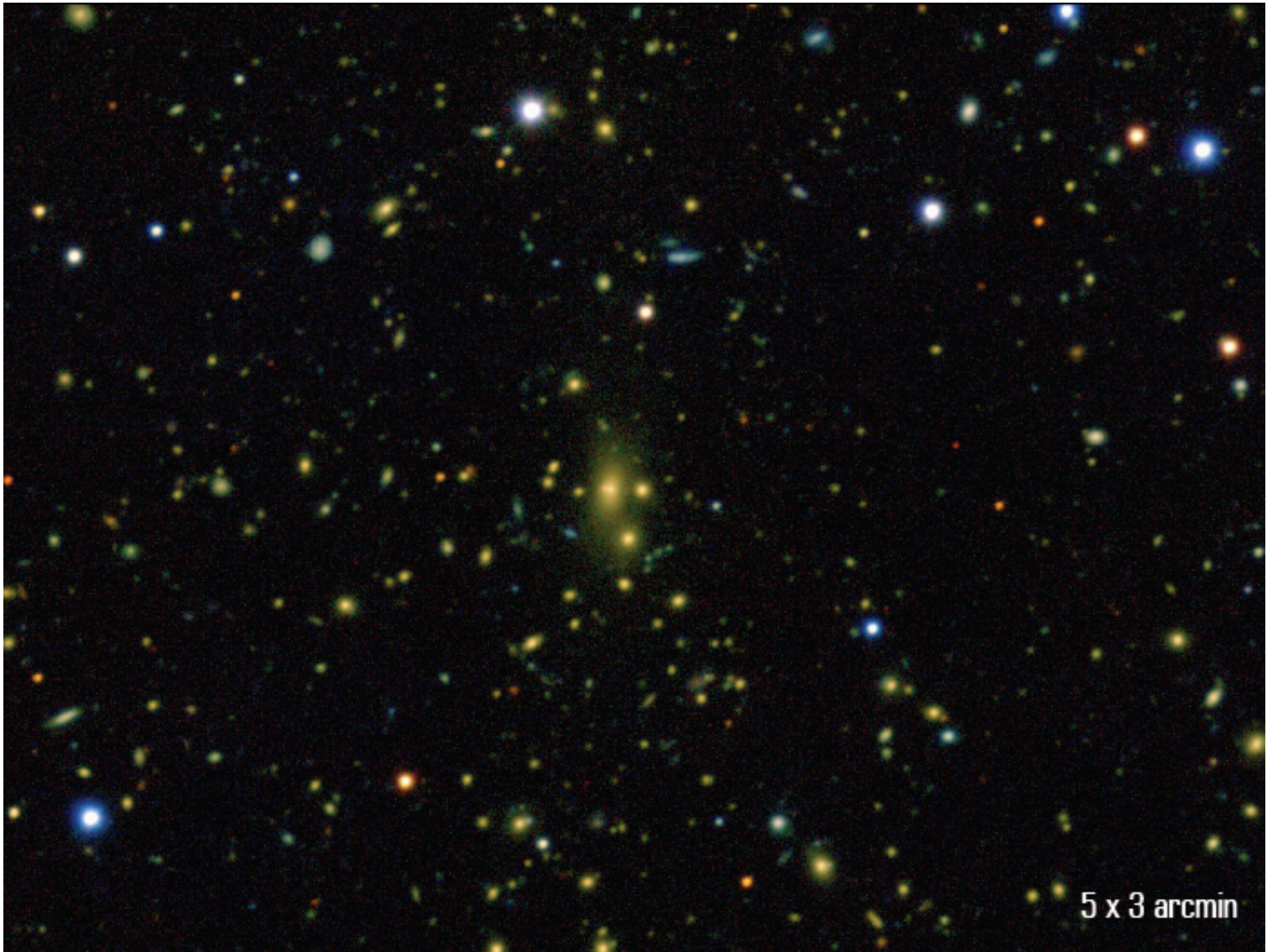
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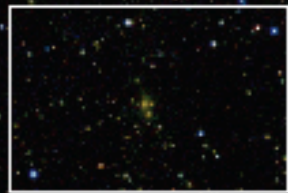
Use 15000 galaxies from
previous spectroscopic
surveys to test and calibrate
photometric redshifts

**DES photometric redshifts
are good.**

[arXiv:1406.4407](https://arxiv.org/abs/1406.4407)

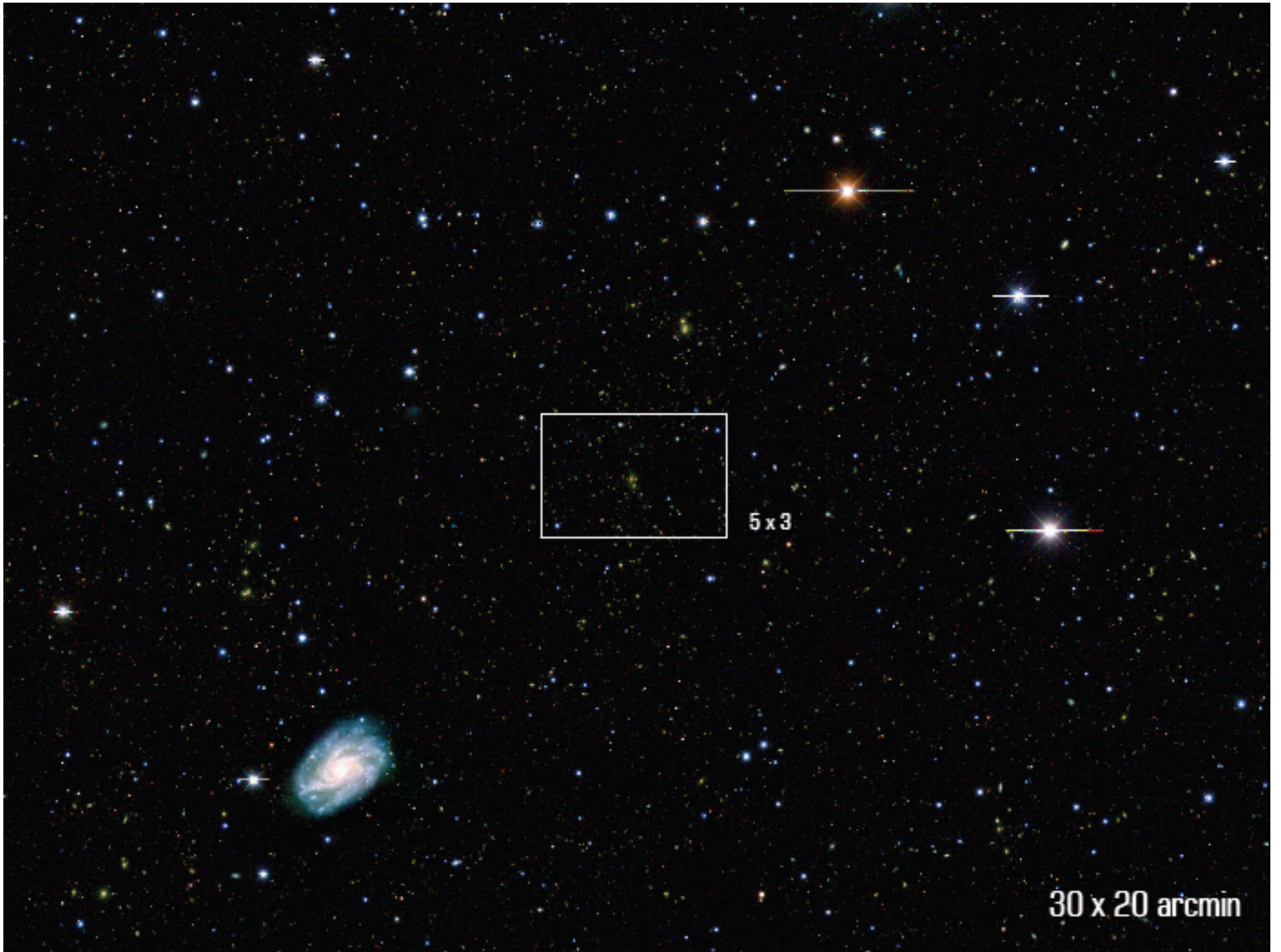






5 x 3

30 x 20 arcmin



50,000 galaxies in this image!



30 x 20

90 x 60 arcmin



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Summary

- **DES is underway and has recently finished its first season covering 2000 deg² at 40% depth.**
- Early science and DES performance testing using data taken in Science Verification (~5% of survey area)
- **DES is performing well** even at this early stage!
 - Required photoz precision attained
 - Supernova are being discovered at expected rate
 - Galaxy shape, cluster mass measurement demonstrated
- Early results include the discovery of new high-redshift clusters, new SNe Ia, and weak lensing mass measurements for SV clusters.



DARK ENERGY
SURVEY

