The Dark Energy Survey
Status and First Results

E. Sánchez (CIEMAT)
On behalf of the DES Collaboration
1. Dark Energy
2. The DES Project
3. Current Status
4. First Scientific Results
5. Conclusions
The Dark Energy

What is the physics behind the acceleration of the expansion of the Universe?
Cosmological constant?
Any new dynamical field?
Modifications to General Relativity?

Studies of dark energy from:
Expansion rate of the Universe
Growth of structure

Can be measured from Galaxy Surveys

ICHEP 2014

E. Sanchez
The Dark Energy

Huge progress over the last 15 years

However, there is still a very large room for improvement.
The Dark Energy

Current measurement compatible with dark energy being the cosmological constant

But not very sensitive yet to the time variation of the equation of state

Betoule et al. 2014
The Dark Energy Survey

Optical/IR imaging survey with the Blanco 4m telescope at Cerro Tololo Inter-American Observatory (CTIO) in Chile

5000 sq-deg (1/8 of the sky) in grizY bands (2500 sq-deg overlapping with SPT survey) + 30 sq-deg time-domain griz (SNe)

New 570 Mpx camera with 3 sq-deg FoV, DECam

Up to 24th magnitude (z~1.5)
DECam
The Dark Energy Camera

CCDs, wafer from LBNL, packaged at FNAL

Hexapod, Italy

Optics, UK

Shutter, Germany

Optomechanics, FNAL

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DECam: 570 Mpixel camera
Installed on Blanco since august 2012
DECam

74 CCD chips (570 Mpx/image) (62 2kx4k image, 8 2kx2k alignment/focus, 4 2kx2k guiding)

Red Sensitive CCDs
QE>50% @ 1000 nm
250 microns thick

3 sq-deg FoV
Excellent image quality
0.27˝/pixel

u,g,r,i,z,Y filters for photoz

Low noise electronics (<15 e @ 250 kpx/s)

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Collect light from galaxies in several broad-band filters in optical and NIR:

grizY (DES) + JK (VHS)

Use the flux in each filter to determine:
Type (Star/galaxy/QSO…)
Galaxy Type (spiral, elliptical…)
Photometric Redshift

Also position on the sky and shape information

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4 Probes of Dark Energy

**Galaxy Clusters** (dist & struct)
Tens of thousands of clusters to z~1
Synergy with SPT, VHS

**Weak Lensing** (dist & struct)
Shape and magnification measurements of 200 million galaxies

**Baryon Acoustic Oscillations** (dist)
300 million galaxies to z~1.4

**Supernovae** (dist)
3500 well-sampled Sne Ia to z~1
4 Probes of Dark Energy

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DES Collaboration:
~300 scientists from 28 institutions from around the world

USA: Fermilab, UIUC/NCSA, University of Chicago, LBNL, NOAO, University of Michigan, University of Pennsylvania, Argonne National Laboratory, Ohio State University, Santa Cruz/SLAC Consortium, Texas A&M University, CTIO (in Chile)

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

Germany: Munich

Switzerland: Zurich

Spain Consortium: CIEMAT, IEEC, IFAE

Brazil Consortium

facebook.com/darkenergysurvey
http://darkenergysurvey.org
DES Timeline

2003
Project start

2004-8
R&D

2008-11
DECam construction

2012 [Sept]
Installation and first light

2012 [Sept-Oct]
Commissioning

Nov 2012 - Feb 2013
Science Verification

Aug 31 2013 - 9 Feb 2014
First Season (Year 1)

2014-2018
Second-Fifth Seasons
First Light: 12 September 2012

Formax galaxy cluster

NGC 1365
DES Footprint
DES Current Status

- **DES (Year 1)**
- **DES (SN fields)**
- **DES (5V fields)**
- **DES (round-13)**
First Results: DECam performance has been extremely good

The next scientific results are based on these data (~157 sq-deg)

Main Goals: Exercise downstream analyses (DESDM) and determine whether quantities derived from image data are meeting DES requirements
Year 1 wide survey progress
2000 sq-deg in 4 tilings (2/5 of the final depth)
DES SV DATA

DECam 1x1 deg (1/3 of DECam FoV) grizY co-add image of SPT cluster at $z=0.32$

Around 50000 galaxies in this image

DES will be an unprecedented sample of galaxies going out to high redshifts
Galaxy clusters from DES: New clusters at high redshift (z>0.7!)

- 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

Slide from E. Rykoff
DES clusters correlate with X-ray data

z = 0.43

XMMXCSJ234231.5-562106.8

z = 0.47

XMMXCSJ234155.3-550745.5

Courtesy Phil Rooney and Eli Rykoff
Supernova DES13C3hwb, SN-Ia at z=0.606
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Supernova DES13C3hwb, SN-Ia at $z=0.606$
Supernova DES13C3hwb, SN-Ia at z=0.606 (Light Curves)
Strong Gravitational Lenses

Bullet

RXC J2248.7-4431

El Gordo

BCS J2352-5452

SPT-CLJ 0330-5228

SPT-CLJ 0502-6113
Use 15000 galaxies with spectroscopic determination of the redshift (from several previous surveys) for testing and calibrating photoz.

Most of the codes meet the DES science requirements, already at this early stage.

This paper proves that DES can measure photometric redshifts.
Photometric redshift performance
(arXiv:1406.4407)

Multi-color image of the inner 5 arcmin

Weak lensing aperture mass significance map of the inner 30 arcmin, overlaid with galaxies

The same galaxies, but for the entire useable field of view of 90 arcmin
Testing Weak Lensing: Masses of 4 galaxy clusters

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Measure the masses and redshifts of four known massive galaxy clusters
Background galaxies identified using photo-z
Cluster member galaxies identified using photo-z and RedMaPPer
Weak lensing analysis using im3shape code

Results in very good agreement with previously known measurements

<table>
<thead>
<tr>
<th>Cluster name</th>
<th>$M_{200c}$</th>
<th>$\lambda$</th>
<th>$z_{\lambda}$</th>
<th>Literature value $M_{200c}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>RXC J2248.7-4431</td>
<td>17.6$^{+4.5}_{-4.0}$</td>
<td>203 ± 5</td>
<td>0.346 ± 0.004</td>
<td>22.8$^{+6.6}_{-4.7}$ (Gruen et al. 2013b), 20.3 ± 6.7 (Umetsu et al. 2014), 16.6 ± 1.7 (Merten et al. 2014)</td>
</tr>
<tr>
<td>1E 0657-56</td>
<td>14.2$^{+10.0}_{-6.1}$</td>
<td>277 ± 6</td>
<td>0.304 ± 0.004</td>
<td>17.5 (Clowe et al. 2004), 12.4 (Barrena et al. 2002, D)</td>
</tr>
<tr>
<td>SCSO J233227-535827</td>
<td>10.0$^{+3.7}_{-3.4}$</td>
<td>77 ± 4</td>
<td>0.391 ± 0.008</td>
<td>11.2$^{+3.0}_{-2.7}$ (Gruen et al. 2013a), 4.9 ± 3</td>
</tr>
<tr>
<td>Abell 3261</td>
<td>8.6$^{+8.6}_{-3.9}$</td>
<td>71 ± 3</td>
<td>0.216 ± 0.003</td>
<td>—</td>
</tr>
</tbody>
</table>

\[\text{i} \] We converted the measured $r_{200c}$ from Clowe et al. (2004), which lacks an error estimate, to $M_{200c}$ using the critical density in our adopted cosmology.

This paper proves that DES can measure galaxy shapes, even in the Science Verification preliminary data set
Many other interesting results in the pipeline, that will be published soon:

- Galaxy clustering and validation against CFHTLS
- DES SV galaxies cross-correlated with CMB lensing
- SPT-SZE signatures of DES SV RedMaPPer clusters
- Joint Optical and near infrared photometry from DES and VHS
- Galaxy populations within SPT selected clusters
- DES/XCS: X-ray properties of galaxy clusters in DES SV
- The DES SV shear catalogue: Pipeline and tests
- Calibrated ultra fast image simulations for DES
- DES13S2cmm: The first super-luminous supernova from DES
- The DES supernova survey: Search strategy and algorithm
- Wide-field mass mapping with the DES SV data
Summary

DES started survey operations in August 2013.
SV data are of high quality, are currently being analyzed, and first papers have been already submitted.

*Photoz required precision reached*
*DES is able to measure galaxy shapes*
*Many results in the pipeline…*

The data quality and quantity for DES as a whole will be a major step beyond this.
First season data are being processed.
First Dark energy results expected from 2 first seasons of data. STAY TUNED!!!