The Dark Energy Survey: New Results

Ofer Lahav (UCL)
on behalf of the DES collaboration

LSS@Munich – 21 July 2015
Outline

• DES: status of observations
• The challenges: photo-z and galaxy shapes
• Low and high hanging fruit: batch of 10 papers in April, 12 new papers on the arXiv today
• DM and DE from DES
• Non-DE science from DES
• Nuisance parameters: systematics vs. new physics
So what is Dark Energy?

• Systematics mimic DE?
• Lambda-CDM, EoS $w = -1.00$?
• Dynamical scalar field $w(z)$?
• Signatures of modified gravity?
• Inhomogeneous Universe?
• Multi-verse?
• Something else unpredictable??

LCDM: “an almost perfect universe”
or “a simple but strange universe”?

$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$

DES artwork by Marie Kaus
12 DES-SV papers (*) on today’s arXiv1507

- Shear pipeline (Jarvis et al., 05603)
- Photo-z for WL (Bonnett et al.) – talk
- 2pt WL CF (Becker et al., 05598)
- Cosmology from 2pt WL CF (The DES Collaboration, 05552)
- WL around troughs (Gruen et al., 05090) - poster
- RedMagic galaxies (Rozo et al., 05460) - talk
- Galaxy clustering (Crocce et al., 05360)
- Combining probes (Park et al., 05353)
- DES x CMB (Giannantonio et al., 05551) – talk
- Systematic maps (Leistedt et al.,) – talk by Peiris
- SN pipeline (Kessler et al., 05137)
- Solar system: Neptune Trojan objects (Gerdes et al., 05177)

+ talks by Fosalba & Wechsler including DES simulations  + Posters
THE DES COLLABORATION
(~400 scientists from 6 countries)

Director: Josh Frieman
Instrumentation lead: Brenna Flaugher
DES Science Committee

- SC co-chairs: G. Bernstein & O. Lahav
- Large Scale Structure: E. Gaztanaga & A. Ross
- Weak Lensing: S. Bridle & B. Jain
- Clusters: J. Mohr & C. Miller
- SN Ia: M. Sako & B. Nichol
- Photo-z: F. Castander & H. Lin
- Simulations: K. Heitmann & R. Wechsler
- Galaxy Evolution: D. Thomas & M. Banerji
- QSO: P. Martini & R. McMahon
- Strong Lensing: L. Buckley-Geer & A. Amara
- Milky Way: B. Santiago & B. Yanny
- Theory & Combined Probes: S. Dodelson & J. Weller
- Spectroscopy: F. Abdalla & C. D’Andrea

- Analysis teams & Task Forces
The Dark Energy Survey

- **Multi-probe approach**
  - **Wide field:** Cluster Counts, Weak Lensing, Large Scale Structure
  - **Time domain:** Supernovae

- **Survey strategy**
  - 300 million photometric redshifts (grizY) over 5000 deg$^2$
  - + 2500 SN Ia (over 30 deg$^2$ fields)
  - overlap with VHS + SPT + OzDES + ...

- **Science Verification (SV):** 140 sq deg to full depth
- **Y1:** approx 2000 sq deg 40% of depth.
  - Median seeing FWHM approx 0.9"
  - (as required for WL in riz)
- **Y2:** approx remaining 3000 sq deg same depth
- **Y3** will start in Aug 2015 - 3 more seasons to go!
Some milestones since 2004...

- Assembling the DECam optical corrector at UCL...

- Filters made in Japan (months after the Tsunami...)

- ...and first light image of NGC 1365

![Image of people assembling scientific equipment](image1)

![Map showing location of Japan](image2)
Thanks to collaborators

UCL’s cosmologists

DES scientists
DES Footprint

Overlapping Imaging Surveys

Overlapping Spectroscopic Surveys

Credit: Alex Merson  (UCL)
Photo-z: DES SV data

Sanchez et al.

* Bonnett et al.
(incl. new ANNz2, Sadeh, Abdalla & OL, 1507.00490)
WL convergence: $\kappa_{\text{gal}}, \kappa_{E}, \kappa_{B}$

SV area 139 sq deg (only 3% of final DES)
Cross correlation signal: 5-7 sigma

Chang, Vikram, Jain et al. (PRL)

Vikram, Chang, Jain et al. (PRD)

1M Background sources @ z ~0.8
1M Foreground lenses @ z ~ 0.3
WL 2pt function from DES-SV: Measurement and Cosmology

Cosmological parameters
*The DES collaboration
(Bridle, McCrann, Zunz et al.)

2pt $\xi$ (+-) from two shear pipelines
* Becker et al.
* Jarvis et al.
DE EoS $w$ vs. fluctuation amplitude

- Possibly (first) signature of DE in DES-SV data alone
- $S_8$ is not sensitive to $w$
- $S_8$ from DES is in between Planck and CFHTLenS values

*The DES collaboration

WL image distortion: 1% effect, to be measured to 1%, to get $w$ to 1%
Weak lensing by troughs in the galaxy distribution

Measurement
- DES SV: ~150 sq. deg., full DES depth
- tracers: Rykoff/Rozo redMaGiC galaxies, 0.2<z<0.5, L>0.5L*, 1/(1000 Mpc³)
- troughs = lower 20% percentile
- sources: ~2x10⁶ at z>0.6
- significance ~ 15σ

Measurement: under/overdensity

*Gruen et al.*
Cross correlation of DES galaxies and mass fluctuations derived from the CMB

DES Gal-Gal
(0.2<z<1.2)
(cf. Crocce et al)

DES Gal – SPT mass
(6-sigma)

DES Gal – Planck mass
(4-sigma)

*Giannantonio et al
Weak Lensing mass vs. stellar mass:
Cluster RXJ 2248

Melchior et al (2014)
Palmase, Banerji, Jouvel, OL et al. (in prep)
$z > 0.9$ Type Ia Supernovae

Using OzDES spectra (plot from C. D’Andrea)
Nuisance Parameters

- Theoretical (the cosmological model & parameters, e.g. w/out neutrino mass)
- Astrophysical (e.g. galaxy biasing in LSS, dust in SN, intrinsic alignments in WL)
- Instrumental (e.g. image quality, photo-z)

Potentially hundreds of nuisance parameters (while the whole universe is fitted by 6 parameters!)
DES – more than Dark Energy

- Solar system objects
- MW, dwarf satellites, LMC
- Galaxy evolution (including biasing and intrinsic alignments)
- Strong lensing
- QSOs (+ lensed QSOs)
- Super-luminous SN
The tale of 8 MW dwarf satellites from Y1 (in red): strong evidence for Dark Matter, but no evidence for what it is!

Drlica-Wagner et al.
Bechtol et al.

+ Independent papers by a Cambridge team (Koposov et al.)

From Ret 2's spectroscopy (Simon et al.)
\[ M/L = 470 \, (M/L)_{\odot} \]

Search for more dwarfs in Y2
Summary

• Both photo-z and cosmic shear can be measured reliably.
• Many Cosmology and Astrophysics results from early DES data, many studies led by ECS.
• DES does see DM, an good correlations between DM and galaxies.
• On the path to DE results from Y1&Y2 (…Y5) from LSS, WL, Clusters and SN Ia (+ cross correlations)

• What are the prospects for a new paradigm shift, beyond LCDM?
Extra slides
# The DES surveys

<table>
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<th>Area</th>
<th>Exposure time (s) (per visit for SNe)</th>
<th>Specified median PSF FWHM (arcsec)</th>
<th>Dithering</th>
<th>Cadence</th>
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<td></td>
<td>g</td>
<td>r</td>
<td>i</td>
<td>z</td>
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<td>10x90 0.9&quot;</td>
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<td>3x200 -</td>
<td>3x400 -</td>
<td>5x360 -</td>
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