Dark Energy Progress Report

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Carnegie Mellon University
WFIRS2014 conference, Pasadena, 2014
Outline

• Brief revisit to Models of Dark Energy
• What each of the following probe have told us:
  – Lensing
  – Cluster
  – CMB
  – SN
  – BAO

Image: Robert Lupton & SDSS
Dark Energy Models

- LCDM
- Equation of State
- Dark Energy density
- Dark Energy interacting with Dark Matter
- Decaying Dark Energy
Dark Energy Models

What do we know about these models?

BOSS collaboration 2014
Outline

• Brief revisit to Models of Dark Energy

• What each of the following probe have told us:
  – Cluster
  – Lensing
  – CMB
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Image: Robert Lupton & SDSS
Dark Energy Progress

• Cluster

Vikhlinin et al. 2008

36 clusters from Chandra
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- Gravitational Lensing

SDSS-DR7 lensing + WMAP7 + SDSS clustering

Mandelbaum et al. 2012
Figure 4. Hubble diagram for the Union2.1 compilation. The solid line represents the best-fit cosmology for a flat $\Lambda$CDM Universe for supernovae alone. SN SCP06L4 falls outside the allowed $\sigma_1$ range and is excluded from the current analysis. When fit with a newer version of SALT2, this supernova passes the cut and would be included, so we plot it on the Hubble diagram, but with a red triangle symbol.
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- Supernova

Suzuki et al. 2012

SN+
WMAP7+
BAO (SDSSI/II+2dF)
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• CMB

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- Planck +
- WMAP polarization+
- BOSS 1st year data
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- BAO
- BOSS DR11 (near final)
- Same Acoustic Oscillations as in CMB

BOSS galaxy clustering WG + BOSS collaboration 2013
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• BAO
• BOSS DR11 (near final)
• Distance measurement at
  of 1% at $z=0.57$ and
  2.1% at $z=0.32$

BOSS galaxy clustering WG +
BOSS collaboration 2013
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- BAO constraints on Dark Energy

![Graph showing BAO constraints on Dark Energy]

BOSS galaxy clustering WG+
BOSS collaboration 2013
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• Combining all BAO measurements

Lines are Planck LCDM model predictions

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- BOSS galaxy BAO

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- Other BAO results: including Lyman-alpha forest

BOSS Lya and Lya X QSO

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- Combined constraints:
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• Dark Energy Density as a function of $z$:
  Positive Dark Energy component at $z<1$.
  Slightly negative ones at $z>1.6$, due to Lya data.

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We will display various dark energy models we have considered, and how each of the measurement contributed to the chi-square of the best fit model.

CMB chisq contributions are not shown.
More general forms of dark energy models gives constraints that are consistent with LCDM
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Alternative models

CMB contributions are not shown
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CMB contributions are not shown

WFIRST T-AFTA
Wide-Field Infrared Survey Telescope
The End
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• CMB

Fig. 35. 2D marginalized posterior distribution for $w_0$ and $w_a$ for Planck+WP+BAO data. The contours are 68% and 95%, and the samples are colour-coded according to the value of $H_0$. Independent flat priors of $-3 < w_0 < -0.3$ and $-2 < w_a < 2$ are assumed. Dashed grey lines show the cosmological constant solution $w_0 = -1$ and $w_a = 0$. 

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<th>$\Omega_A$</th>
<th>0.6817</th>
<th>0.685$^{+0.018}_{-0.016}$</th>
<th>0.6830</th>
<th>0.685$^{+0.017}_{-0.016}$</th>
<th>0.6939</th>
<th>0.693 $\pm$ 0.013</th>
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<td>$\sigma_8$</td>
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<td>0.829 $\pm$ 0.012</td>
<td>0.8322</td>
<td>0.828 $\pm$ 0.012</td>
<td>0.8271</td>
<td>0.8233 $\pm$ 0.0097</td>
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<td>$\omega_m$</td>
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<td>$H_0$</td>
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Dark Energy Progress

- Gravitational Lensing

Heymans et al. 2013
Dark Energy Progress

- Cluster

Spergel, Flauger & Hlozek 2013
Dark Energy Progress

- CMB

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<th>Parameter</th>
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Wide-Field Infrared Survey Telescope

WFIRST-T-AFTA
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- SN or
- BAO (BOSS 1st year)
- + Planck
- + WMAP Polarization

Planck Collaboration 2013

**Fig. 36.** 2D marginalized posterior distributions for $w_0$ and $w_a$, for the data combinations *Planck*+WP+BAO (grey), *Planck*+WP+Union2.1 (red) and *Planck*+WP+SNLS (blue). The contours are 68% and 95%, and dashed grey lines show the cosmological constant solution.