DESpec Science : Prospects & Challenges

- The landscape of spectroscopic surveys
- Improving DE FoM with DESpec+DES: from DETF Stage III to Stage IV experiment
- The importance of Same Sky for imaging & spectroscopy, target selection
- DE vs. Modified Gravity with DESpec+DES
- Other science: Neutrino Mass, Non-Guassianity etc.
- Challenges ahead



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The Landscape of Surveys

(some under construction, some proposed)

Photometric surveys: DES, VISTA, Pan-STARRS, HSC, Skymapper, PAU, LSST, ...

Spetroscopic surveys: WiggleZ, BOSS, e-BOSS, BigBOSS, DESpec, HETDEX, Sumire, 4MOST, SKA, ...

Space Missions: Euclid vs. WFIRST

New Results - BOSS



w = -1.03 + -0.07

Sanchez et al. 2012

Redshift Distortion as a test of Dark Energy vs. Modified Gravity



$$\delta_g\left(\mathsf{k}
ight)$$
 = (b + f μ^2) $\delta_m(\mathsf{k})$
f = Ω^γ



Blake et al. 2011



The Dark Energy Survey First Light in September 2012

4-probe approach

Cluster Counts Weak Lensing Large Scale Structure Supernovae la

• 8-band imaging

5000 deg² grizY 300 million photometric redshifts + JHK from VHS (1300 sq deg covered at half exposure time) +SPT SZ (550 clusters observed over 2500 sq deg)















DESpec: Spectroscopic follow up of DES

- Proposed Dark Energy Spectrometer (DESpec)
- 4000–fibre \$40M (?) instrument for the 4m Blanco telescope in Chile, using DES optics and spare CCDs
- 7 million galaxy spectra, target list from DES, powerful synergy of imaging and spectroscopy, starting 2017-18
- Spectral range approx 600 to 1000nm, R=3300 (red end)
- DES+DESpec can improve DE FoM by 3-6, making it DETF Stage IV experiment
- DES+DESpec can distinguish DE from ModGrav
- Participants: current international DES collaboration
 - + new teams

DESpec Instrumentation

- Build on DECam corrector
- 2 new lenses: C5 and C6
- Atmospheric Dispersion Corrector (ADC) - tbd
- 4000 fibres, FoV 3.8 sq deg
- Fibre positioners: e.g. JPL's Cobra or AAO's Echidna
- Spectrograph design based on Hetdex VIRUS
- Spare DEcam CCDs at hand
- Most of the DESpec optics already exists from DEcam
- Low cost, low risk experiment



Based on work by T. Diehl and S. Kent

DESpec activities



- DESpec White Paper (Frieman, Diehl et al.)
- UCL & Portsmouth hosted meetings in 2011; Munich 2012
- DESpec-related grants: STFC for R&D (£160k); Advanced ERC (OL, 2.4M Euro)
- Ongoing design studies for both science and instrumentation

DESpec: benefits per probe

- Photo-z/spec: better photo-z calibration (also via crosscorrelation)
- LSS: RSD and radial BAO, FoM improved by several (3-6)
- Clusters: better redshifts and velocity dispersions, FoM up by several
- WL: little improvement for FoM (as projected mass), but helps with intrinsic alignments
- WL+LSS: offers a lot for both DE and for ModGrav
- SN Ia: spectra of host galaxies and for photo-z training, improving FoM by 2
- Galaxy Evolution: galaxy properties and star-formation history
- Strong Lensing: improved cluster mass models

Recent relevant studies

- DESpec White Paper
- BB-DES JWG report (Weinberg et al.)
- Bernstein & Cai (2 papers)
- Gaztanaga et al.
- Kirk, OL & Bridle (in prep) LSS&WL FoM
- Jouvel, Abdalla et al. (in prep) target selection
- Helsby, Lin et al. (in prep) photoz/spec crosscorrelations

Improved FoM for clusters



Sarah Hansen & Clusters WG

LSS improvement with DESpec

Assume for 10 million spectra over 0.2<z<1.7 (sample 1)

FoM (DESpec+DES4+II+Planck) / FoM(DES4+II+Planck) = 3 - 6



Same Sky: How Important?



Gaztanaga et al.

The benefits of same Sky

- DES imaging provides natural target list for DESpec
- WL & LSS from same sky could constrain better biasing (both r and b), leading to muck higher FoMs (Gaztanaga, Cai & Bernstein, Kirk et al, BB-DES report)
- Reducing cosmic variance (MacDonald& Seljak, Bernstein & Cai)

Biasing prior is critical



Gaztanaga et al.

DES(WL) + DESpec(LSS)



10M spectra with uniform density over 0.2 < z < 1.7

300M galaxies for WL

Note:

- Here biasing assumed as known perfectly!
- Results sensitive to assumed priors

Kirk, OL & Bridle, in prep

Identifying Non-linear Stochastic Biasing from LSS&WL (within the Halo Model)



Non-Linear Stochastic Galaxy Biasing 5

Combining LSS & WL



Jullo et al. 2012





Jouvel, Abdalla et al.

Deviations from standard GR? $ds^{2} = -a^{2}(\tau) \{ d\tau^{2}[1 + 2\psi(\mathbf{x}, \tau)] + d\mathbf{x}^{2}[1 - 2\phi(\mathbf{x}, t)] \}$

Lensing is sensitive to the sum of potentials, while velocities respond to the temporal potential

$$\gamma(k,a) \equiv \frac{\ln(\delta_c/\mathcal{H}\delta_c)}{\ln\Omega_m(a)}, \quad \eta(k,a) \equiv \frac{\phi(k,a)}{\psi(k,a)},$$

Reyes et al. (Nature, 2010) Argue GR is "confirmed" from lensing and galaxy velocities – it illustrates the power of combining imaging and spectroscopy



Total Neutrino Mass DES+Planck vs. KATRIN $M_v < 0.1 \text{ eV}$ $M_v < 0.6 \text{ eV}$



OL, Kiakotou, Abdalla and Blake (2010) 0910.4714

Expect DESpec+DES+Planck can reach the lower limit from Physics experiments (0.05 eV), i.e detection of neutrino mass

Imprints of primordial non-Gaussianity on halo bias

$$\Phi_{\mathrm{NG}}(x) = \phi(x) + f_{\mathrm{NL}}(\phi^2(x) - \langle \phi^2 \rangle).$$

 $\delta_h = b_L (\delta + 2f_{\rm NL}\phi_p \delta_c).$

$$\Delta b(k) = 2(b-1)f_{\rm NL}\delta_c \frac{3\Omega_m}{2a\,g(a)r_H^2k^2}$$

Dalal et al. 2008

Note:

- Guassian initial conditions also generate Non-G (e.g $S_3 = 34/7$)
- Systematics challenging
- Ideally, test for inflation models

Ongoing R&D studies for DESpec+DES

- Standard DE FoM with careful attention to k-range, systematics and to priors, including Planck
- Modified Gravity vs. DE (new metrics needed, neutrino mass, non-Gaussianity
- Impact of spectral range and resolution on the probes
- Optimal survey strategy and target selection
- Quantify the benefits of same sky (phase correlations) for DES and DESpec: control galaxy biasing and cosmic variance
- Design of optics, spectrograph and fibre positioner
- Impact of DESpec on future surveys (e.g. LSST and Euclid)

Questions for Discussion:

- How does DESpec fit into the NOAO/DOE/STFC/ etc roadmaps?
- How cheap could DESpec be made?
- What will be the status of other spectroscopic surveys in 2017?
- What will be the level of interest in DE/ModGrav in 2017?
- What alternative science can be done with DES +DESpec?
- How to form a DESpec collaboration?
- How to time-share DESpec R&D with DES commissioning?

End

Questions presented to DES WGs

- How significant it is to have the spectroscopic follow up for your probe?
- How would the DE FoM be improved for your probe?
- What other analyses can be done with spectroscopy (eg redshift distortion, removing of intrinsic alignments for WL, galaxy properties, etc.)
- What magnitude and colour cuts, survey area and spectral resolution would be ideal for your science?
- Any other clever ideas for utilizing specroscopy?

Possible DESpec survey strategies

- (A) 100% spectroscopic completeness of the DES galaxies to r=21 mag, with redshift precision of 50 km/sec
- (B) The above plus 50% completeness to r=22.5 mag evenly distributed over all redshifts bins (using photo-z information to distribute the target selection in redshift)
- (C) Redshift precision of ~300km/s with 100% completeness to r=22 mag

The case for "Vanilla systematics"

- We model the whole universe with 6-12 parameters.
- How many parameters should we allow as "nuisance parameters" for unknown astrophysics – 10, 100, 1000?
- Great to have the technical ability to add as many parameters as we like, however...
- There is some knowledge from theory and simulations on galaxy biasing (and e.g. intrinsic alignments).
- A small number of physically motivated free parameters are easier for comparison with other analyses.
- These can be useful to test the1000-parameter setup (or their PCA-compressed version).

DESpec and BigBOSS

- In an ideal world, both should be built, esp covering north and south (cf. benefits of parallel projects - 2dF and SDSS, or the two SNIa teams)
- They have comparable area+depth per unit time;
 DESpec with higher fibre density, BigBOSS with larger FoV and larger optics
- Both subject to NSF review of NOAO portfolio (incl telescopes), and to the DOE process (cf. DES).
- Shared R&D process is beneficial (e.g. UCL is involved in optics for both) cooperation rather than competition.

EUCLID

ESA Cosmic Vision planned launch 2019

The key original ideas: weak lensing from space and photo-z, from the ground (DUNE) + spectroscopy (SPACE)

The new Euclid: 15000 sq deg 1B galaxy images + 50M spectra (+ground based projects, e.g. PS, DES, LSST,...)

Euclid

Mapping the geometry of the dark Universe

