Studying Cosmic acceleration and neutrino masses with DES.

http://www.darkenergysurvey.org

Outline

- DES: what is it and update + probes used
- Dark energy from DES.
- Neutrino masses from DES

Filipe Batoni Abdalla
Future Dark Energy Surveys

The Dark Energy Survey

EUCLID

SuMIRe Project

FIRST - 最先端研究開発支援プログラム -

WFIRST
The Dark Energy Survey (DES)

Proposal:
- Perform a 5000 sq. deg. survey of the southern galactic cap
- Measure dark energy with 4 complementary techniques

New Instrument:
- Replace the PF cage with a new 2.2 FOV, 520 Mega pixel optical CCD camera + corrector

Time scale:
- Instrument Construction 2008-2011

Survey:
- Area overlap with SPT SZ survey and VISTA VHS

Use the Blanco 4m Telescope at the Cerro Tololo Inter-American Observatory (CTIO)
The DES Collaboration

an international collaboration of ~100 scientists from ~20 institutions

US: Fermilab, UIUC/NCSA, University of Chicago, LBNL, NOAO, University of Michigan, University of Pennsylvania, Argonne National Laboratory, Ohio State University, Santa-Cruz/SLAC Consortium

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

Spain Consortium:
CIEMAT, IEEC, IFAE

Brazil Consortium:
Observatorio Nacional, CBPF, Universidade Federal do Rio de Janeiro, Universidade Federal do Rio Grande do Sul
Standard model of cosmology: Dark energy & dark matter exists, No budget for neutrino mass:

Observational data

- Type Ia Supernovae
- Galaxy Clusters
- Cosmic Microwave Background
- Large Scale Structure

Physical effects:

- Geometry
- Growth of Structure

\[ H(z) = H_0 \left[ \Omega_m (1 + z)^3 + (1 - \Omega_m) \exp \left( 3 \int_0^z \frac{1 + w}{1 + z} \, dz \right) \right]^{1/2}, \]

\[ \ddot{\delta}_m + \frac{3}{2} a^{-1} \left[ 1 - w(a) \left( 1 - \Omega_m(a) \right) \right] \dot{\delta}_m - \frac{3}{2} a^{-2} \Omega_m(a) \delta_m = 0, \]
Very Brief Overview on explaining the accelerated expansion

Dark Energy
- Cosmological constant
- Quintessence
  - $w = w(t)$
- Dark Energy:
  - Equation-of-state parameter $w$

modification of Einstein's gravity

String theory

$w = p_{DE}/\rho_{DE}$.
Assumptions:

Clusters:
\( \sigma_8 = 0.75, z_{\text{max}} = 1.5, \)
WL mass calibration

BAO: \( I_{\text{max}} = 300 \)
WL: \( I_{\text{max}} = 1000 \)
(no bispectrum)

Statistical+photo-z
systematic errors only

Spatial curvature, galaxy bias
marginalized,
Planck CMB prior
Neutrino oscillations indicate they have mass!

But not on the absolute scale of mass…

- Beta-decay kinematics
- Neutrinoless double beta-decay
- Cosmology!

KATRIN nemo Thomas, Abdalla Lahav (2009)

For example…

Not just interesting physics but, an integral part of the cosmological model…

Age of precision Cosmology

Neutrino mass…a test of LCDM
DES will also constrain the neutrino mass

- We have made simulations for this with Des photometric redshifts
- We have also measured this from the current SDSS survey.
- I will go through the assumptions and present the results from SDSS + forecasts for DES.
Tools: Photometric Redshifts

- Photometric redshifts (photo-z’s) are determined from the fluxes of galaxies through a set of filters
  - May be thought of as low-resolution spectroscopy

- Photo-z signal comes primarily from strong galaxy spectral features, like the 4000 Å break, as they redshift through the filter bandpasses

- Photo-z calibrations is optimized using spectra.

Galaxy spectrum at 2 different redshifts, overlaid on griz and IR bandpasses
Cosmology with LRG’s

I - Photo-z’s and Neural networks:

- **Collister & Lahav 2004**
  http://www.star.ucl.ac.uk/~lahav/annz.html

- Has an architecture: defined by a number of inputs/outputs and nodes in hidden layers
- Internally values range from 0 to 1 roughly
Looking at techniques in real data: The 2SLAQ & MegazLRG.

- 2SLAQ galaxies selected from the SDSS.
- Red galaxies $z=0.4-0.7$.
- Good photo-z for LRG given large 4000A break.
- 13000 galaxies from 2SLAQ. ~8000 for training ~5000 to calibrate the histogram.
- MegaZ-LRG DR7: 3.3 Gpc$^3$ in volume (largest photo-z survey), > 700000 galaxies used.
- Also use neural networks to separate stars from galaxies to better than 1% contamination of stars...

Abdalla et al 08
Galaxy Photo-z Simulations

DES + VHS

10σ Limiting Magnitudes

- g 24.6
- r 24.1
- i 24.0
- Z 23.8
- Y 21.6

+2% photometric calibration error added in quadrature

+ Developed improved Photo-z & Error Estimation and robust methods of outlier rejection

Cunha, Lima, Frieman, Lin and Abdalla, Banerji, Lahav

VISTA Hemisphere Survey

J 20.3
H 19.4
Ks 18.3

ANNz; low depth survey: training sets in place
Neutrino Physics - CMB

- CMB is affected by neutrino physics
- However degeneracies are large
- CMB insensitive to neutrino masses smaller than 1eV as they become non-relativistic after the CMB is set up.
- Does not consider the deflection spectrum

\[ \rho_r = \rho_\gamma + \rho_\nu = \left[ 1 + \frac{7}{8} \left( \frac{4}{11} \right)^{4/3} N_{\text{eff}} \right] \rho_\gamma \]
Neutrinos as Dark Matter

- Neutrinos are natural DM candidates
  \[ \Omega h^2 = \frac{\sum m_i}{93.2} \]
- They stream freely until non-relativistic (collisionless phase mixing)

Neutrino Free Streaming

\[ \nu \rightarrow \Phi \]

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Measuring the clustering with Photo-z

$$C_{l,m}^{\text{psky}} = \frac{|A_{l,m} - \frac{N}{\Delta\Omega} I_{l,m}|^2}{J_{l,m}} - \frac{\Delta\Omega}{N}$$

$$A_{l,m} = \sum_{i=1}^{N} Y_{l,m}^*(\theta_i, \phi_i).$$

$$I_{l,m} = \int_{\Delta\Omega} Y_{l,m}^* d\Omega \quad J_{l,m} = \int_{\Delta\Omega} |Y_{l,m}|^2 d\Omega$$
Probes of Cosmology

Luminous Red Galaxies (LRGS)

Sloan Digital Sky Survey (SDSS)

Luminous Red Galaxies (LRGS)

4 bins: 0.45 < z < 0.65

CMB + SN + BAO + SDSS LRGs + HST: < 0.28 eV (95% CL)

Thomas et al. [arXiv:0911.5291]

MegaZ DR7

12 Parameters:

\( \Omega_h^2; \Omega_c^2; \Omega_k^2; \tau; n_s; \ln(10^{10} A_s); \sum m_{\nu}; A_{SZ}; b_1; b_2; b_3; b_4 \)

\( \Sigma \mathrm{m}_\nu \)

12 Parameters:

\( \Omega_h^2; \Omega_c^2; \Omega_k^2; \tau; n_s; \ln(10^{10} A_s); \sum m_{\nu}; A_{SZ}; b_1; b_2; b_3; b_4 \)

\( \Sigma \mathrm{m}_\nu \)

Thomas et al. [arXiv:0911.5291]
MegaZ DR7
Angular Power Spectra: Systematics - code comparison and training set extrapolation

DR6 catalogues - various codes

Bigger difference between template procedures than between template-training set

(1) Extrapolation seems valid  (2) No bias from ANNz  (3) No change in excess power
‘Systematics and Limitations’

Cosmology = check of systematics

However

Galaxy Bias
Non-linearities

Parameter Degeneracies

Model underlying matter power spectrum but measure the galaxy power spectrum
Scale dependence...mimic...?

Bias result or lose data
Perturbation theory/ N-body simulations

E.g. Saito et al 09
Brandbyge & Hannestad 09

\[ L_{\text{max}} = 300 \Rightarrow 0.28 \text{ eV} \]
\[ L_{\text{max}} = 200 \Rightarrow 0.34 \text{ eV} \]

Although we want tighter neutrino constraints
We also want trustworthy neutrino constraints.

Quoted results assume cosmological constant cosmology

Degeneracy with \( w \) increases error bar

Linear bias is a good fit, so more parameters cannot be justified.
Future surveys will be able to say something more here...

Bounds reduced by \(~10\%\) if more params...
In the Future...

Forecast for Galaxy Clustering + Planck: $< 0.12$ eV

E.g. Lahav, Kiakotou, Abdalla and Blake - arXiv: 0910.4714

This combination will be 5 times more constraining than the WMAP + MegaZ equivalent
Total Neutrino Mass

**DES vs. KATRIN**

$M_{\nu} < 0.1 \text{ eV}$

$M_{\nu} < 0.6 \text{ eV}$

Goal: 0.05 eV but most importantly we might put the cosmological model to the test OR have a good stab at measuring the nu_mass! Other cosmological probes of the neutrino mass: weak lensing, CMB lensing, etc…
Conclusions

- DES under construction:
  - Lenses being polished
  - CCD’s being tested
  - Should have first light late next year.

- Science predicts an increase in our knowledge in the $w_0-w_a$ plane.

- Also increase in our knowledge in the neutrino mass:
  - Same experiment done on SDSS LRG’s $m_{\nu} < 0.28\text{eV}$
  - For DES $m_{\nu} < 0.12\text{eV}$ with Planck only.
  - All these have to be taken with a pinch of salt... but... hopefully we will either pin down the neutrino mass or put the cosmological model to strain.