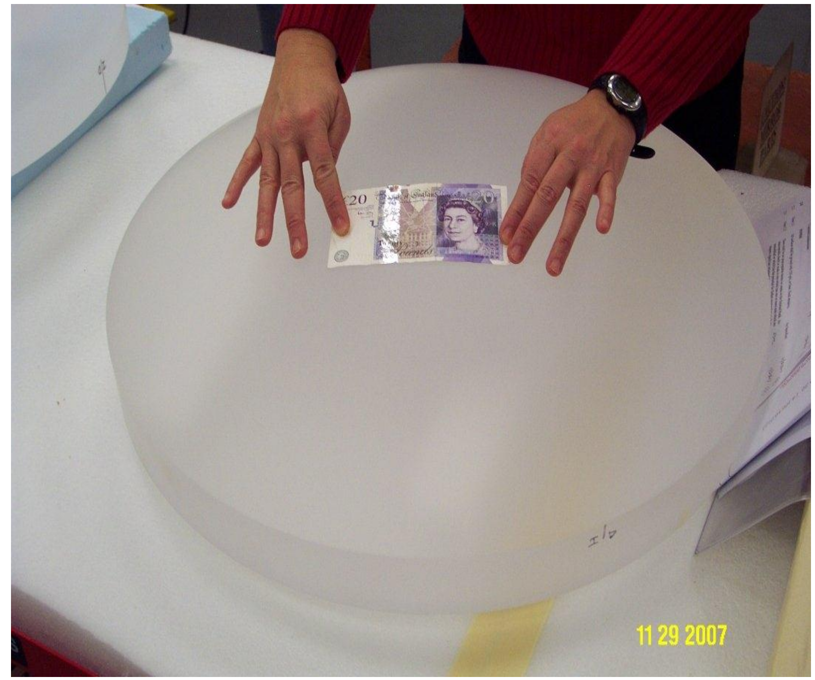
Studying Cosmic acceleration and neutrino masses with DES.

http://www.darkenergysurvey.org



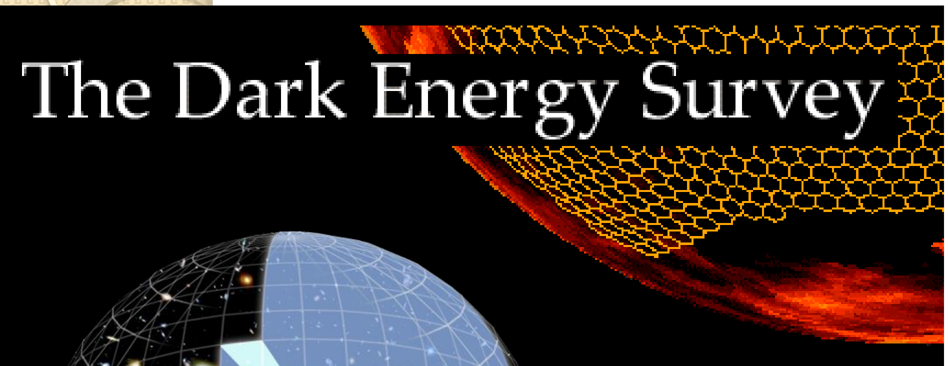
Outline

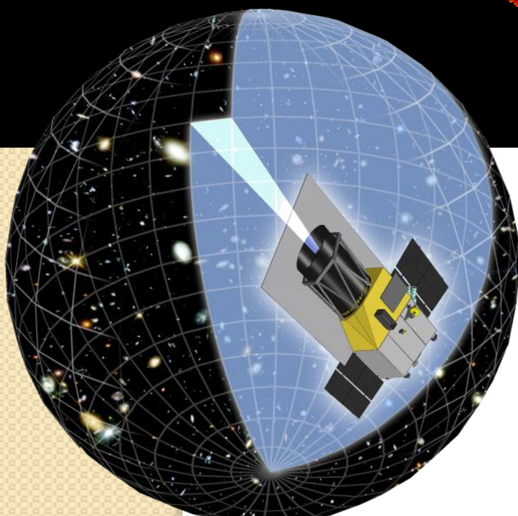
- DES: what is it and update + probes used
- Dark energy from DES.
- Neutrino masses from DES

Filipe Batoni Abdalla

UCL

Future Dark Energy Surveys





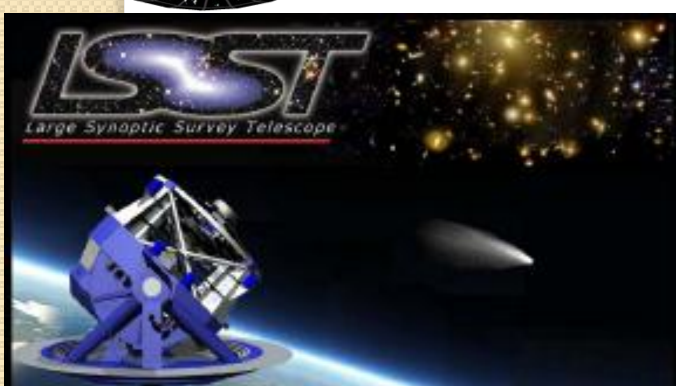
EUCLID

SuMIRe Project

Subaru Measurement of Images and Redshifts

FIRST -最先端研究開発支援プログラム-

WFIRST



SKA
SQUARE KILOMETRE ARRAY

The Dark Energy Survey (DES)

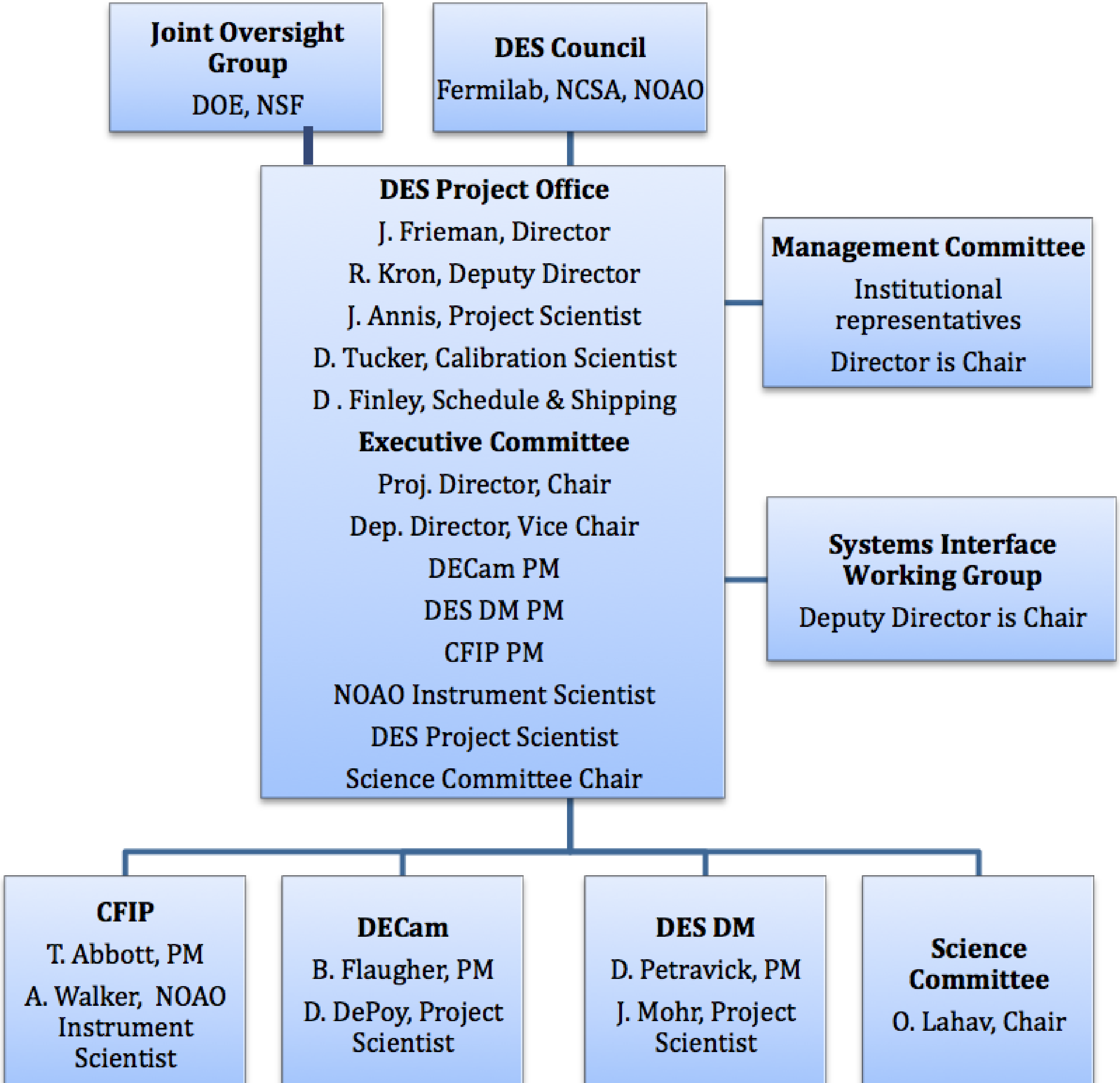
- Proposal:
  - Perform a 5000 sq. deg. survey of the southern galactic cap
  - Measure dark energy with 4 complementary techniques
- New Instrument:
  - Replace the PF cage with a new 2.2 FOV, 520 Mega pixel optical CCD camera + corrector
- Time scale:
  - Instrument Construction 2008-2011
- Survey:
  - 525 nights during Oct.–Feb. 2011-2016
  - Area overlap with SPT SZ survey and VISTA VHS

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

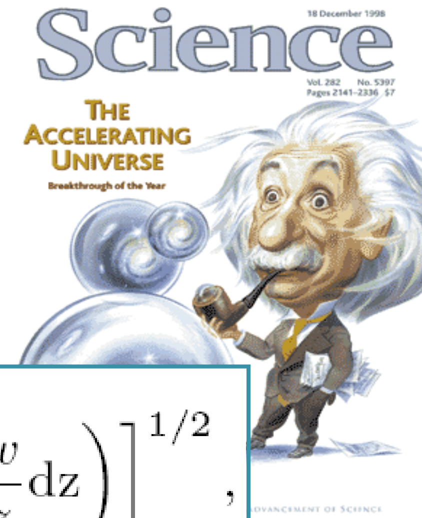
The DES Collaboration

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


Joint Oversight Group
DOE, NSF
DES Council
Fermilab, NCSA, NOAO
DES Project Office
J. Frieman, Director
R. Kron, Deputy Director
J. Annis, Project Scientist
D. Tucker, Calibration Scientist
D . Finley, Schedule & Shipping
Executive Committee
Proj. Director, Chair
Dep. Director, Vice Chair
DECam PM
DES DM PM
CFIP PM
NOAO Instrument Scientist
DES Project Scientist
Science Committee Chair
Management Committee
Institutional representatives
Director is Chair
Systems Interface Working Group
Deputy Director is Chair
CFIP
T. Abbott, PM
A. Walker, NOAO Instrument Scientist
DECam
B. Flaugher, PM
D. DePoy, Project Scientist
DES DM
D. Petravick, PM
J. Mohr, Project Scientist
Science Committee
O. Lahav, Chair

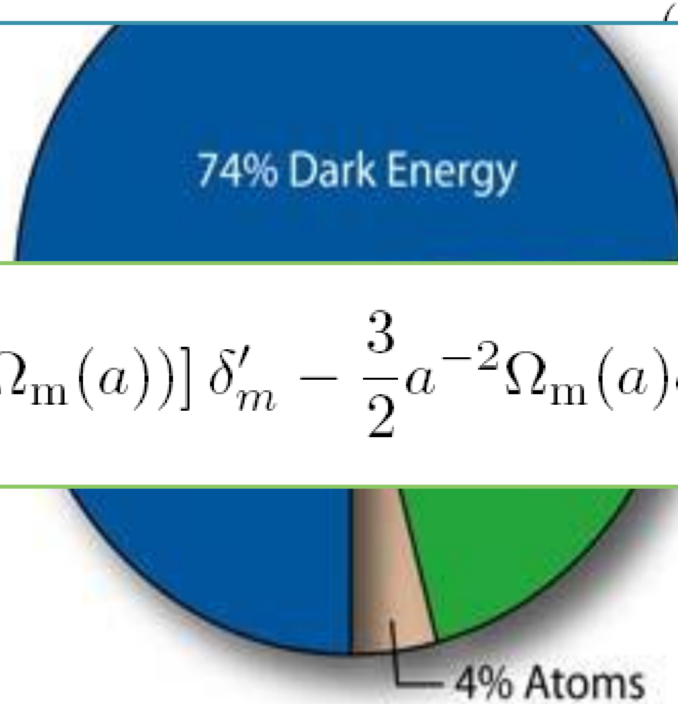
Standard model of cosmology:
Dark energy & dark matter exists,
No budget for **neutrino mass**:



Observational data

- Typ
- Gal
- Cosmic Microwave Background
- Large Scale Structure

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



$$\delta_m'' + \frac{3}{2} a^{-1} \left[1 - w(a) \left(1 - \Omega_{\rm m}(a) \right) \right] \delta_m' - \frac{3}{2} a^{-2} \Omega_{\rm m}(a) \delta_m = 0 \, ,$$

Physical effects:

- Geometry
- Growth of Structure

Very Brief Overview on explaining the accelerated expansion

Dark Energy

- Cosmological constant → W=-1
- Quintessence → w=w(time)
- ⋮

modification of Einstein's gravity

String theory

⋮

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

Dark Energy： equation-of-state parameter *w*

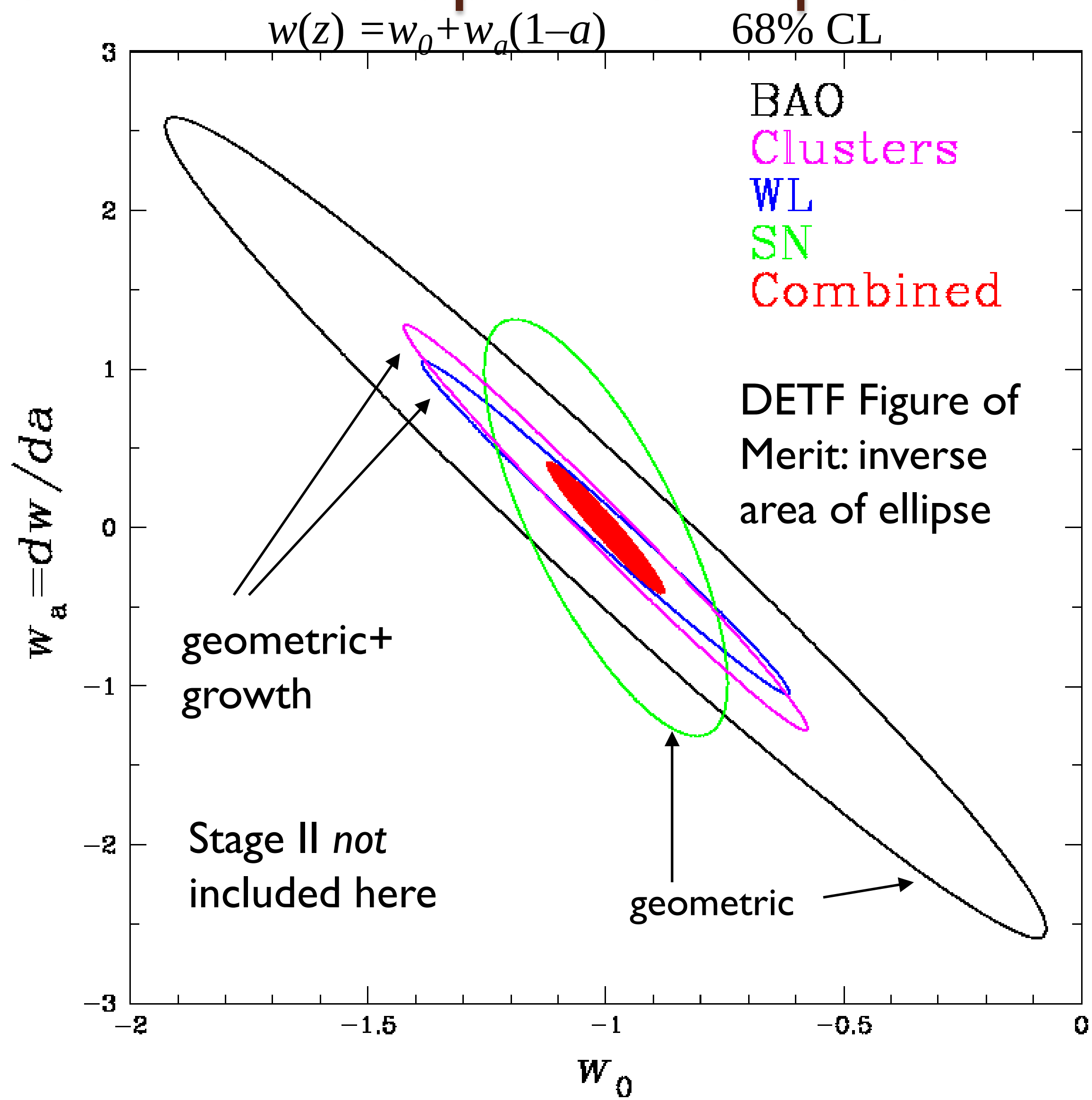
DES Forecasts: Power of Multiple Techniques

Assumptions:
Clusters:
σ_8=0.75, z_{max}=1.5,
WL mass calibration

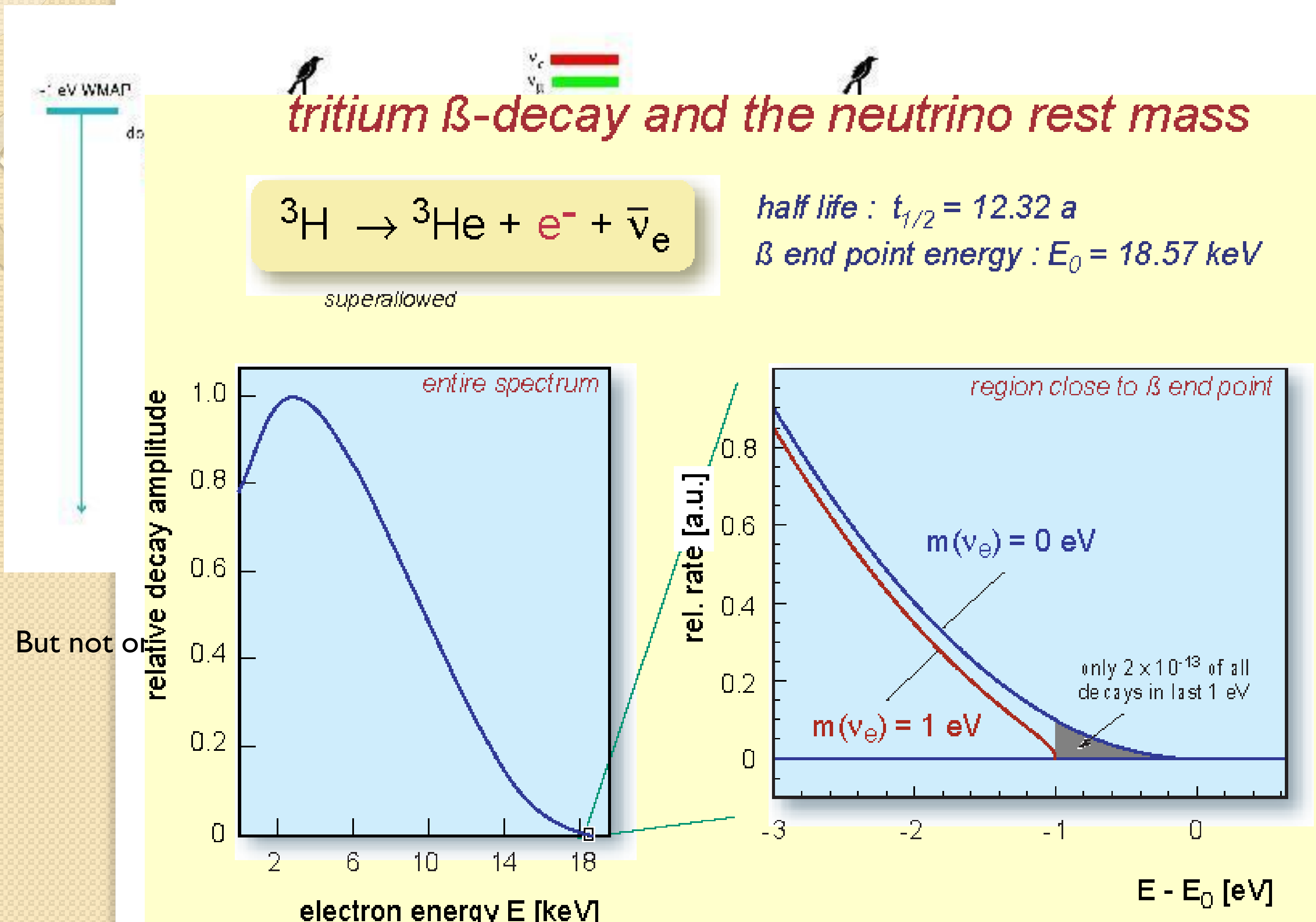
BAO: ℓ_{max}=300
WL: ℓ_{max}=1000
(no bispectrum)

Statistical+photo-z
systematic errors only

Spatial curvature, galaxy bias
marginalized,
Planck CMB prior



Neutrino oscillations indicate they have mass!



But not or

2009)

Age of precision Cosmology → Not just interesting physics but, an integral part of the *cosmological model…*

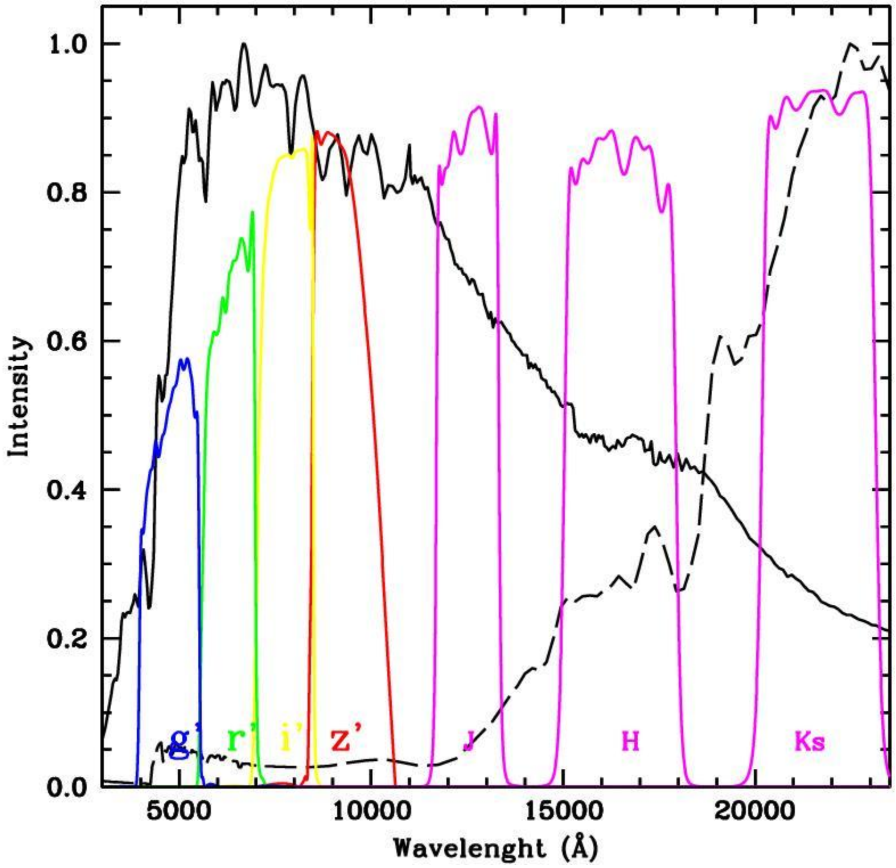
Neutrino mass…a test of LCDM

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.

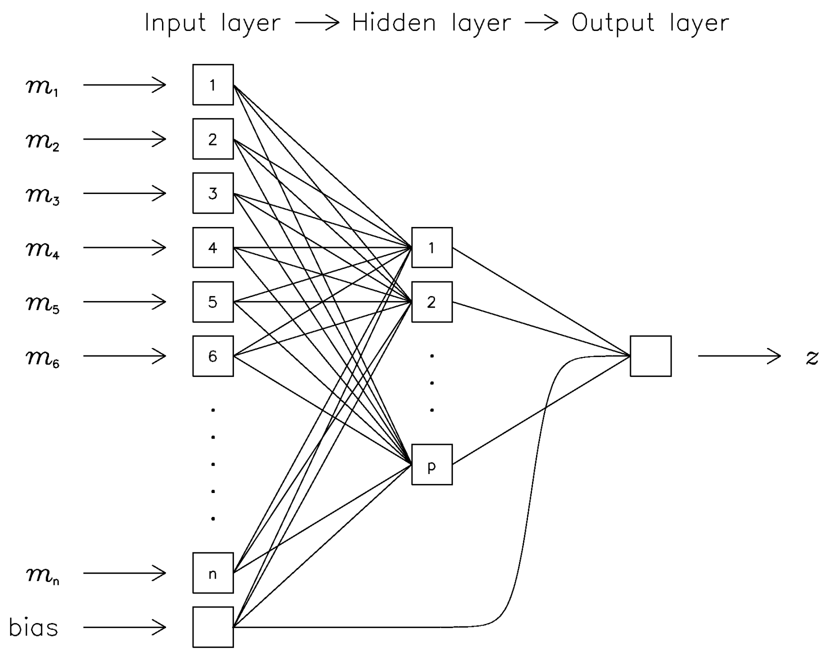
Tools: Photometric Redshifts

- 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.



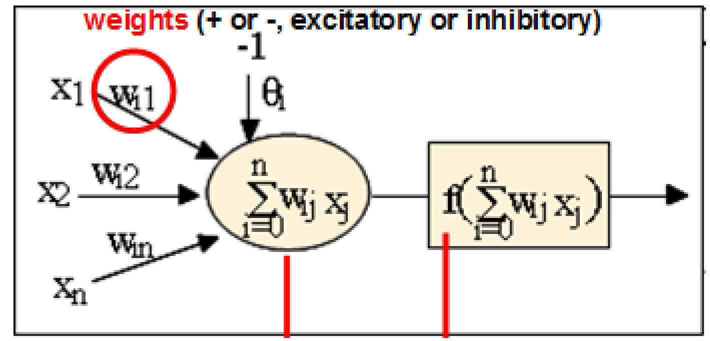
Galaxy spectrum at 2 different redshifts, overlaid on griz and IR bandpasses

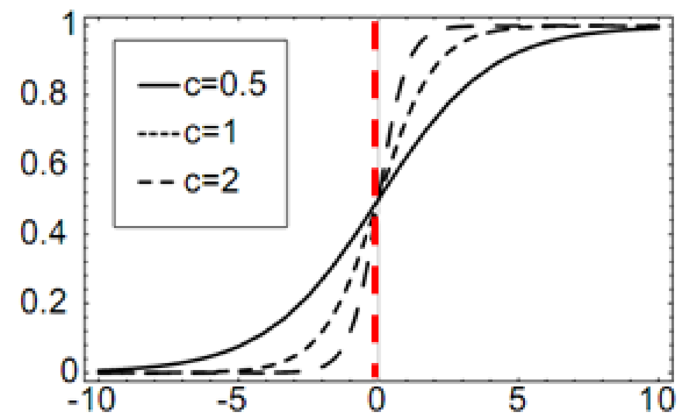
Cosmology with LRG's
I- Photo-z's and Neural networks:

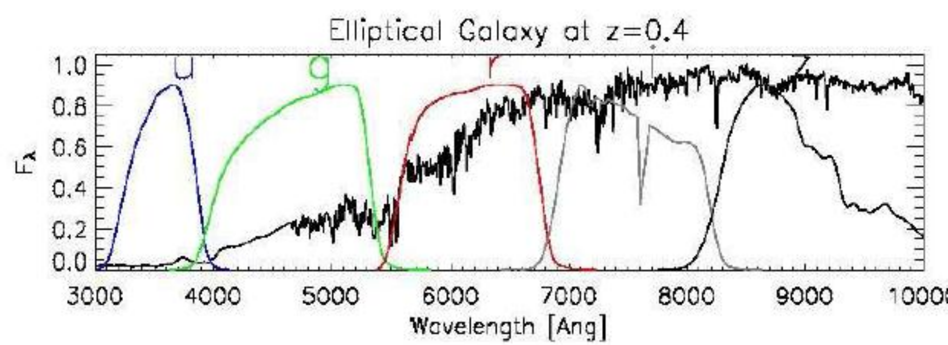


Collister & Lahav 2004

http://www.star.ucl.ac.uk/~lahav/annz.html





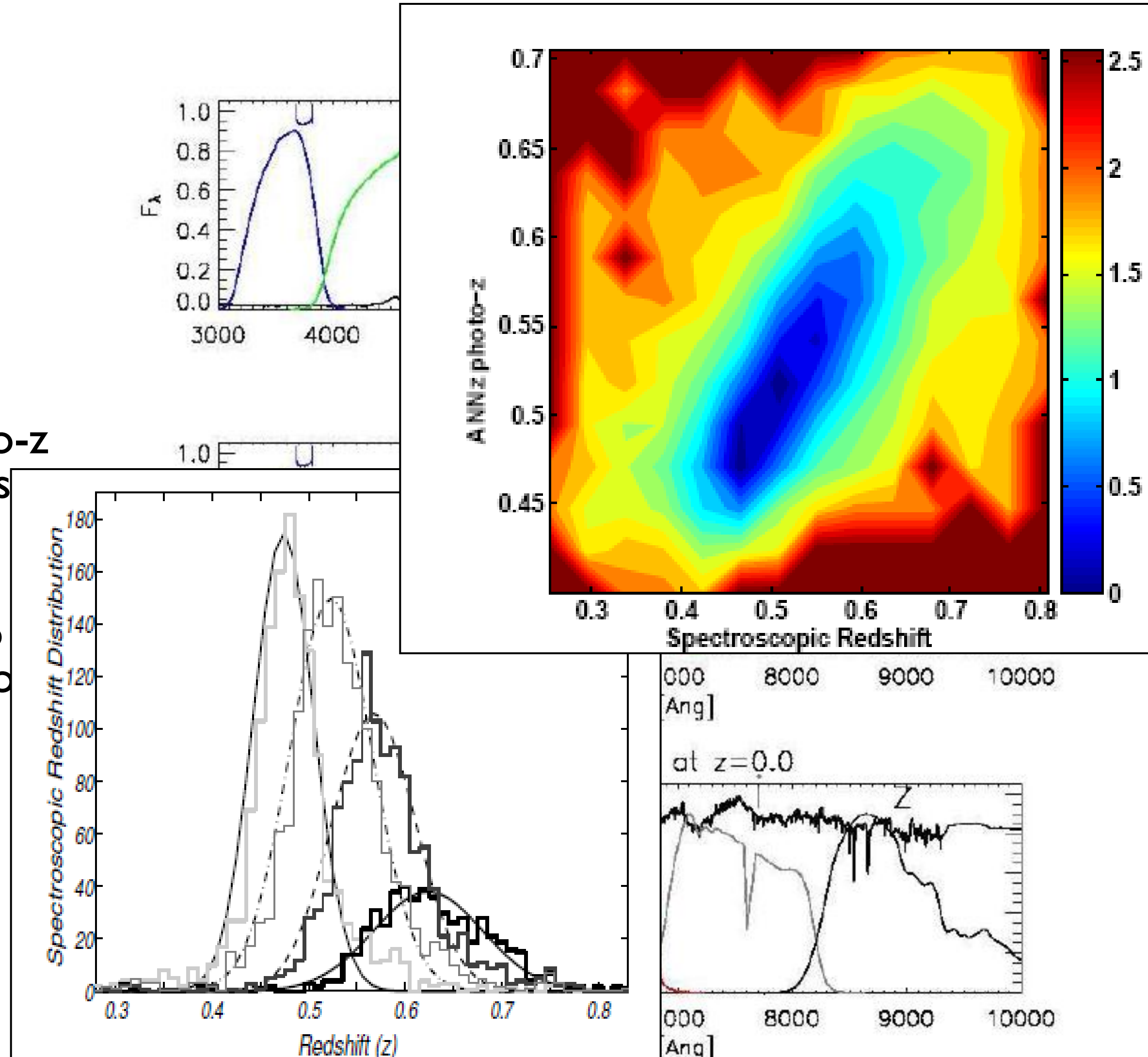


- Has an architecture: defined by a number of inputs/ outputs and nodes in hidden layers
- Internally values range from 0 to 1 roughly

Looking at techniques in real data: The 2SLAQ & MegazLRG.

Abdalla et al 08

- 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 o stars…



Galaxy Photo-z Simulations

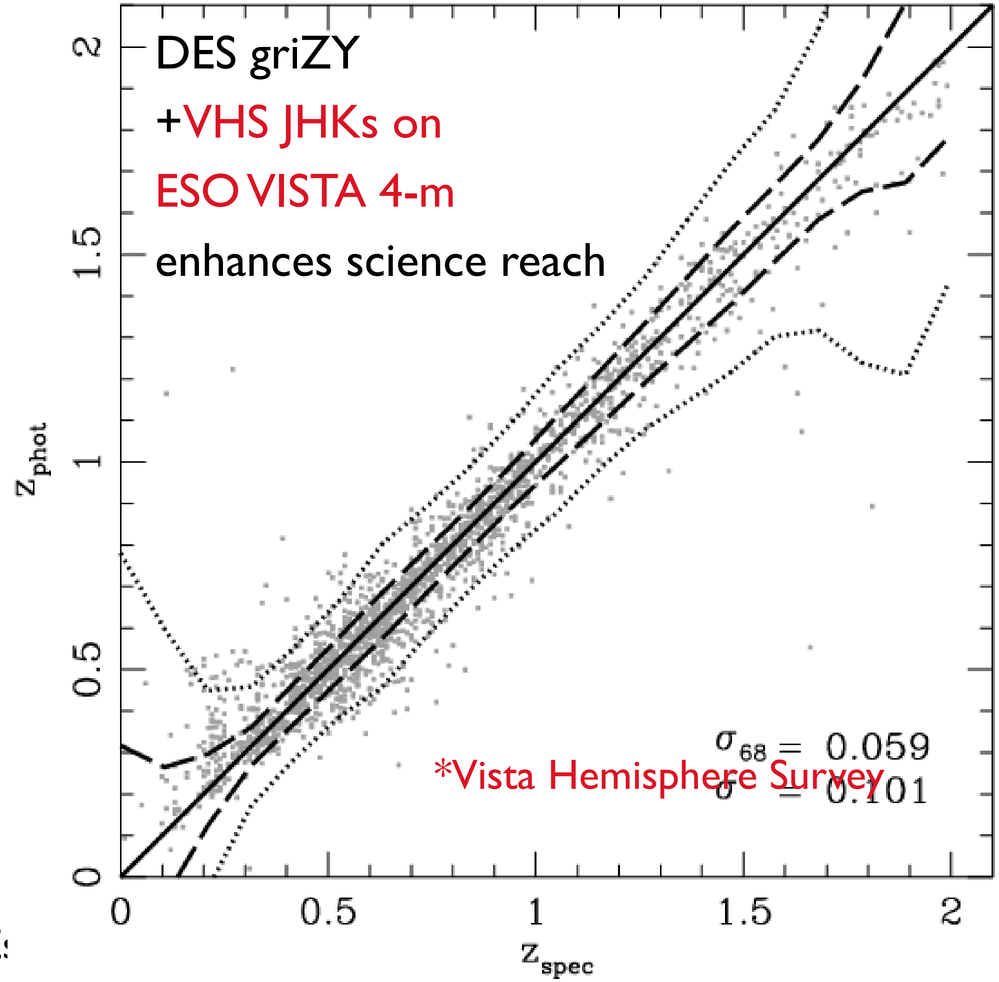
DES +VHS

10σ Limiting Magnitudes

g	24.6
r	24.1
i	24.0
Z	23.8
Y	21.6

J	20.3
H	19.4
Ks	18.3

+2% photometric calibration error added in quadrature



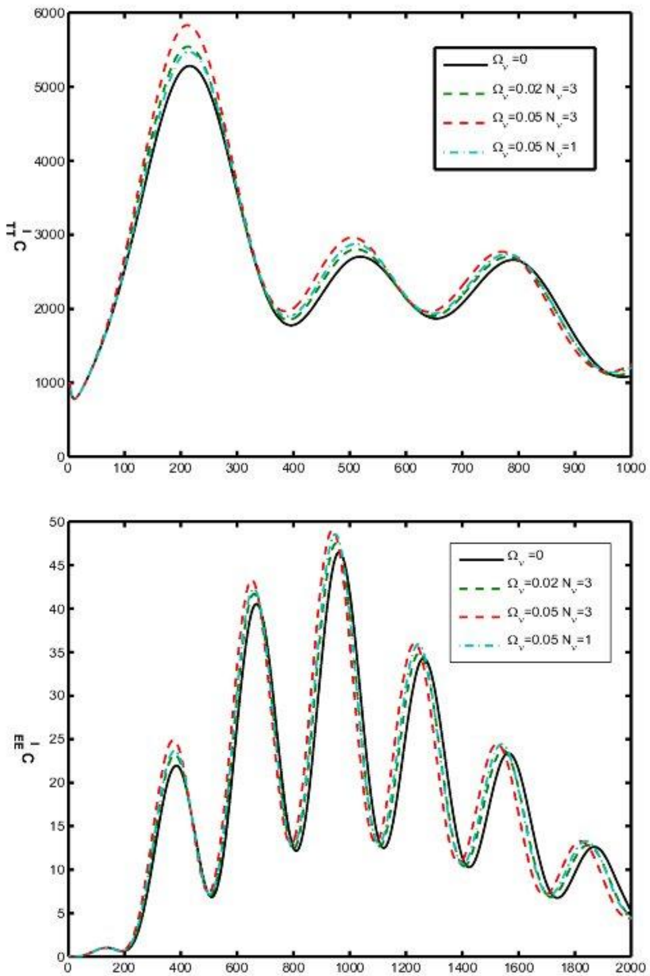
*Vista Hemisphere Survey

+Developed improved Photo-z & Error E:

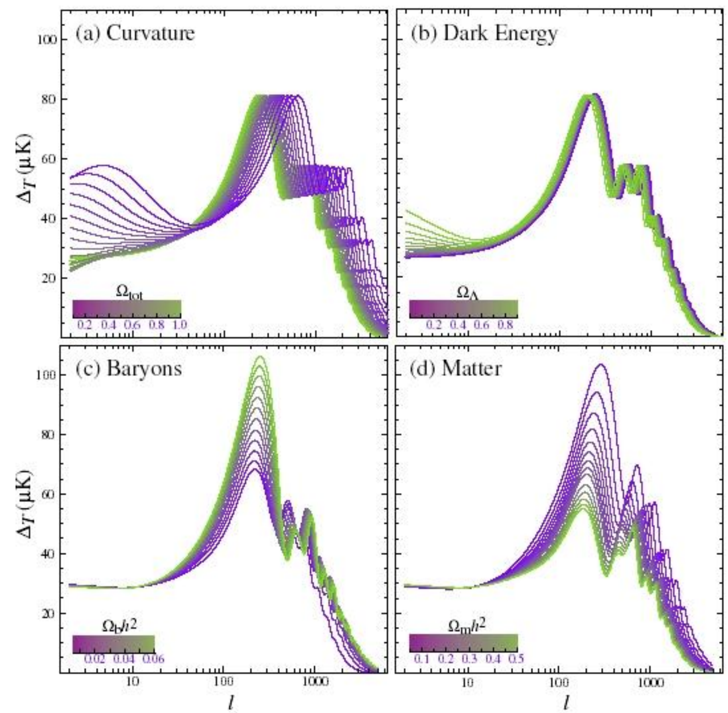
Cunha, Lima, Frieman, Lin and Abdalla, Banerji. Lahav

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



$$\rho_{\rm r} = \rho_\gamma + \rho_\nu = \left[1 + \frac{7}{8}\left(\frac{4}{11}\right)^{4/3} N_{\rm eff}\right] \rho_\gamma$$

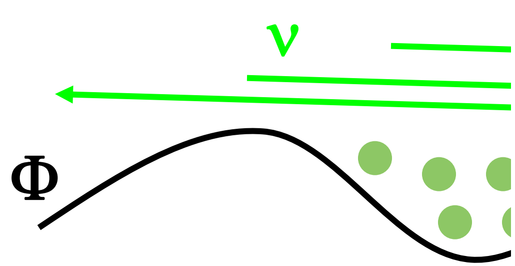
Neutrinos as Dark Matter

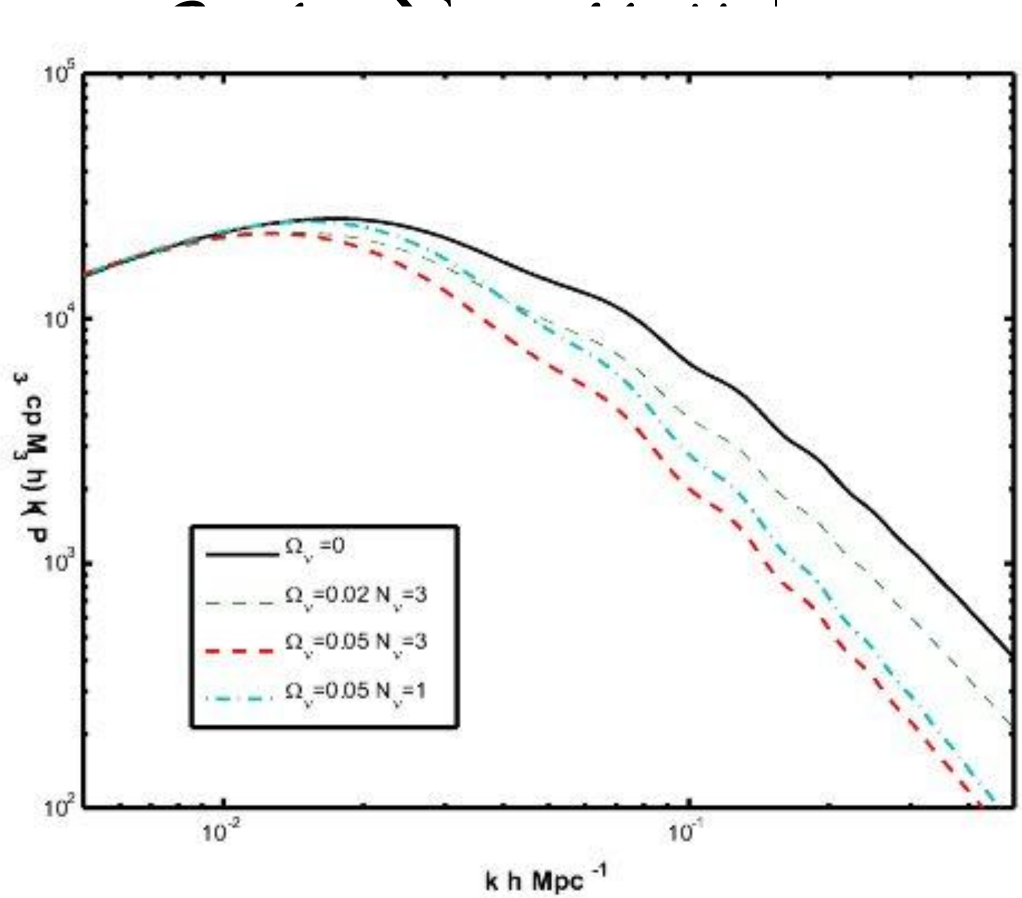
- Neutrinos are natural DM candidates

$$\Omega_\nu h^2 = \frac{\sum_i m_i}{93.2}$$

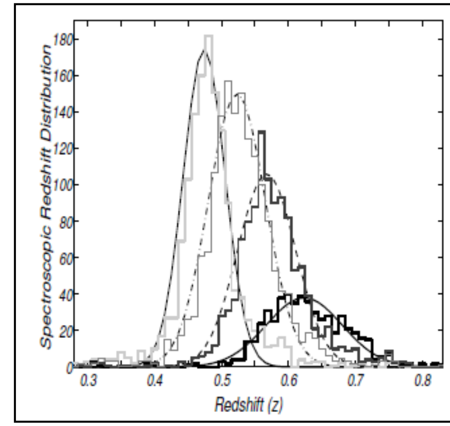
- They stream fre
phase mixing)

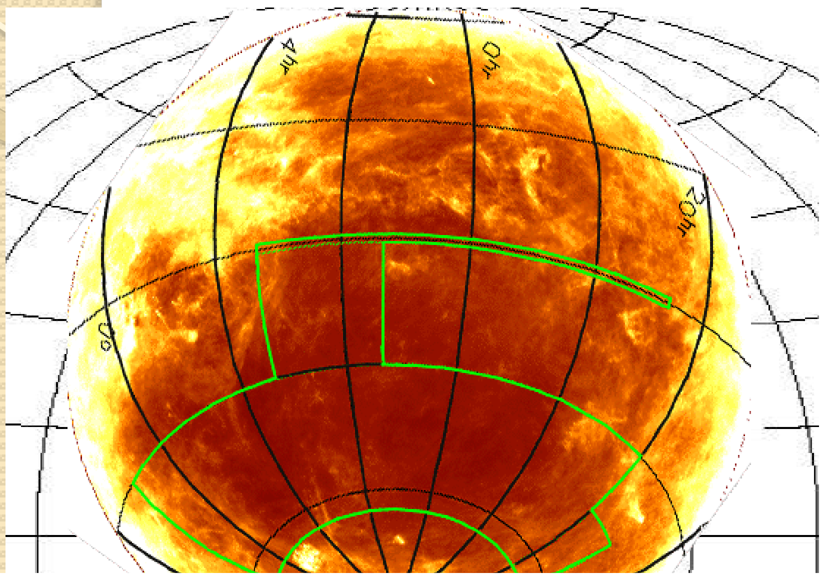
Neutrino Free Strea





Measuring the clustering with Photo-z

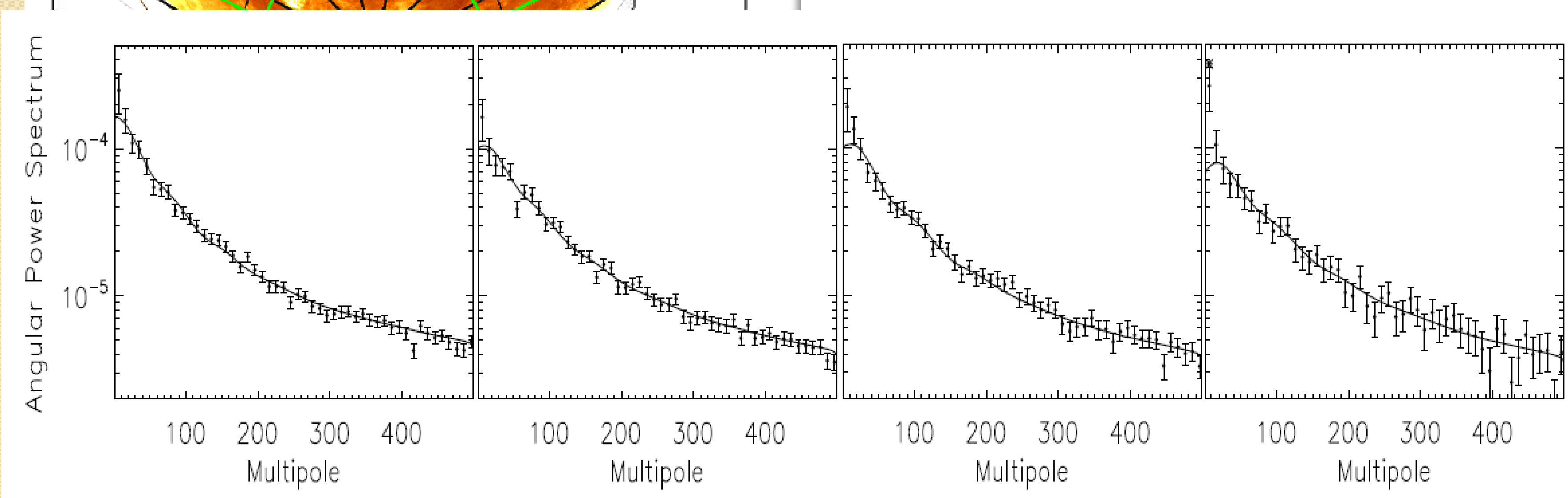




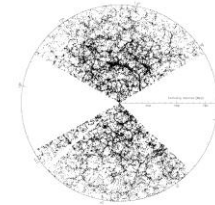
$$C^{\rm psky}_{l,m} = \frac{|A_{l,m} - \frac{N}{\Delta\Omega} I_{l,m}|^2}{J_{l,m}} - \frac{\Delta\Omega}{N}$$

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

$$I_{l,m} = \int_{\Delta\Omega} Y^*_{l,m}\, \mathrm{d}\Omega \qquad J_{l,m} = \int_{\Delta\Omega} |Y_{l,m}|^2\, \mathrm{d}\Omega$$

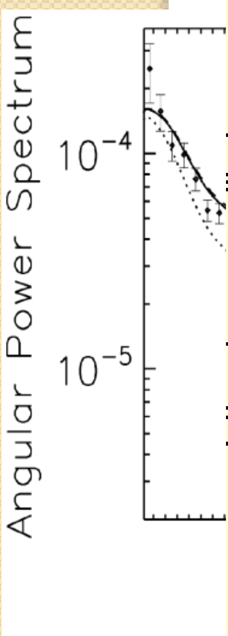


Probes of Cosmology



Luminous Red Galaxies (LRGS)

MegaZ DR7



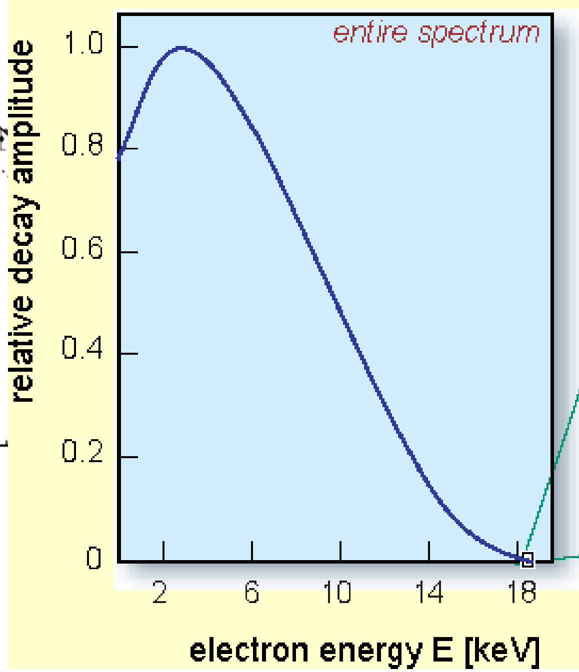
tritium ß-decay and the neutrino rest mass

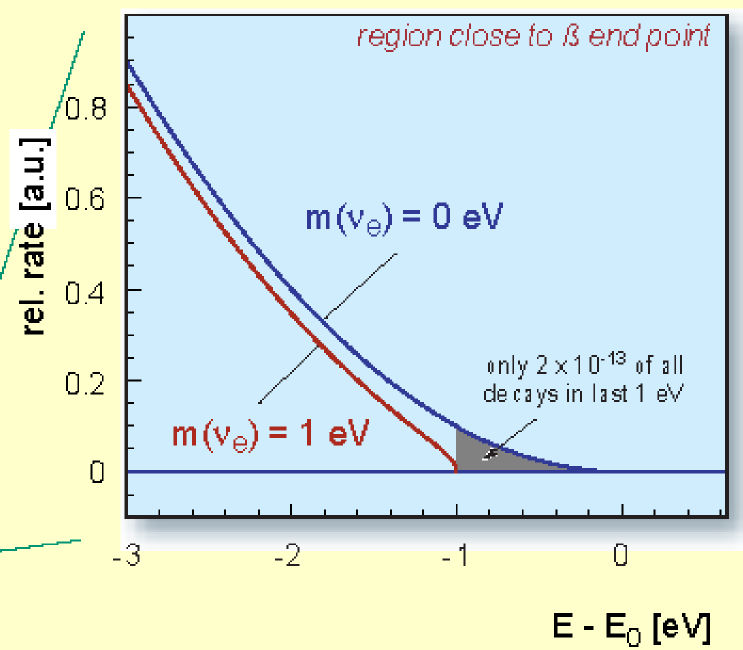
$^3H \rightarrow {}^3He + e^- + \bar{\nu}_e$

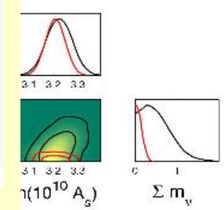
superallowed

half life : $t_{1/2}$ = 12.32 a

ß end point energy : E_0 = 18.57 keV







12 Parameters:

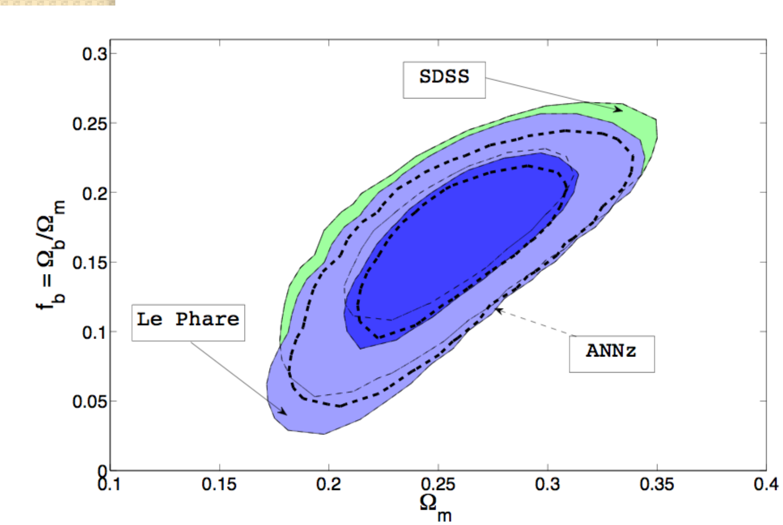
$$\Omega_b h^2;\Omega_c h^2;\Omega_\Lambda;\tau;n_s;\ln(10^{10}A_s);\sum m_\upsilon;A_{SZ};b_1;b_2;b_3;b_4$$

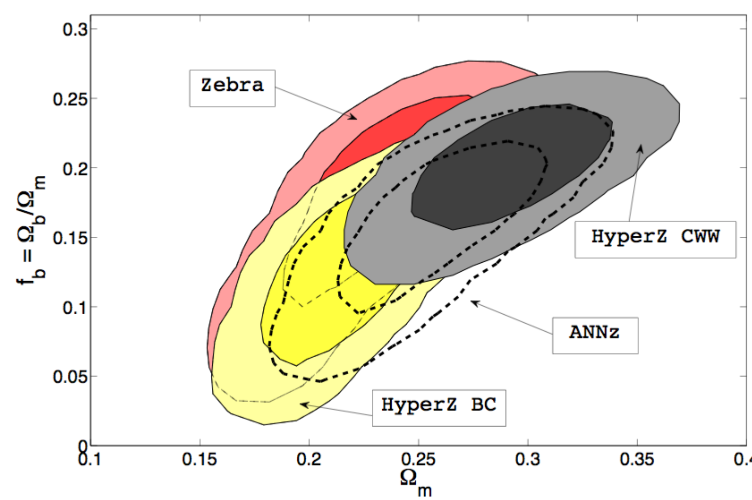
Thomas et al. [arXiv:0911.5291]

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

<u>However</u>

Although we want <u>tighter</u> neutrino constraints
We also want <u>trustworthy</u> neutrino constraints.

Galaxy Bias

<u>Model</u> underlying matter power spectrum but <u>measure</u> the galaxy power spectrum

Scale dependence…mimic…?

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

Non-linearities

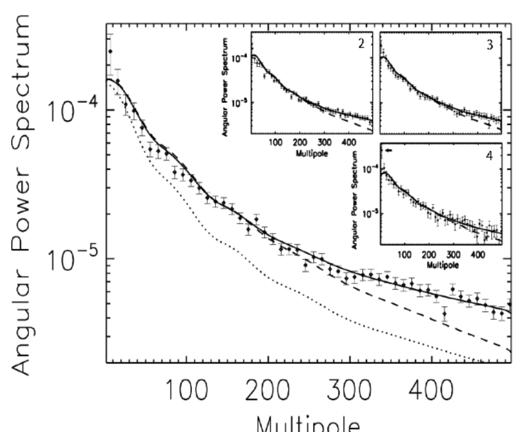
Bias result or lose data

Perturbation theory/ N-body simulations

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

L_max = 300 => 0.28 eV

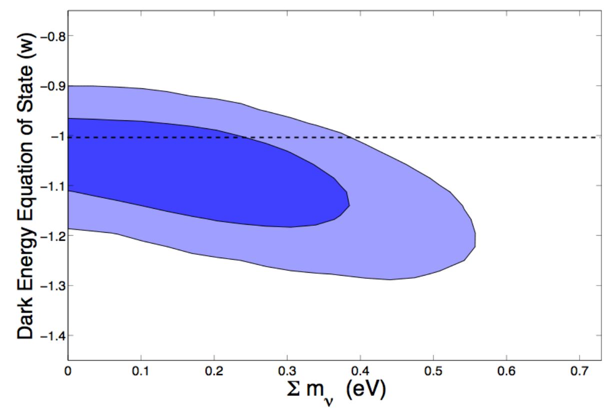
L_max = 200 => 0.34 eV



Parameter Degeneracies

Quoted results *assume* cosmological constant cosmology

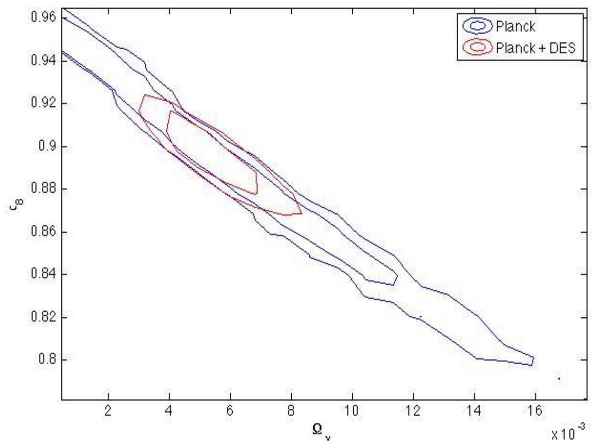
Degeneracy with w increases error bar



Bounds reduced by ~10% if more params…

In the Future…

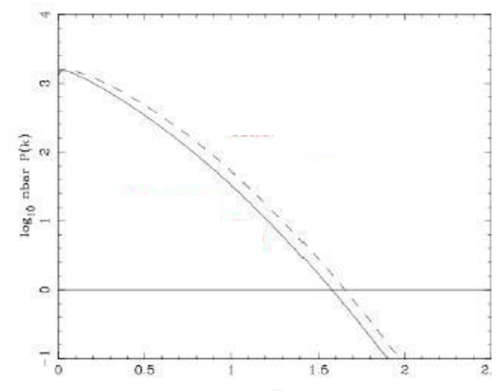
DARK ENERGY SURVEY



Galaxy Bias

Non-linearities **Better modelling!**

Parameter Degeneracies



Forecast for Galaxy Clustering + Planck: < 0.12 eV

$$\sigma_{ln\,P} = \frac{2\pi}{(Vk^2\Delta k)^{1/2}}\left(\frac{1+nP}{nP}\right)$$

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

$M_\nu < 0.1$ eV

$M_\nu < 0.6$ 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 a increase in our knowledge in w0-wa plane.
- Also increase in our knowledge in the neutrino mass:
  - Same experiment done on SDSS LRG's m_nu < 0.28eV
  - For DES m_nu < 0.12eV 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.