The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

2419-7

Workshop on Large Scale Structure

30 July - 2 August, 2012

The WiggleZ Dark Energy Survey - Final Results (almost!)

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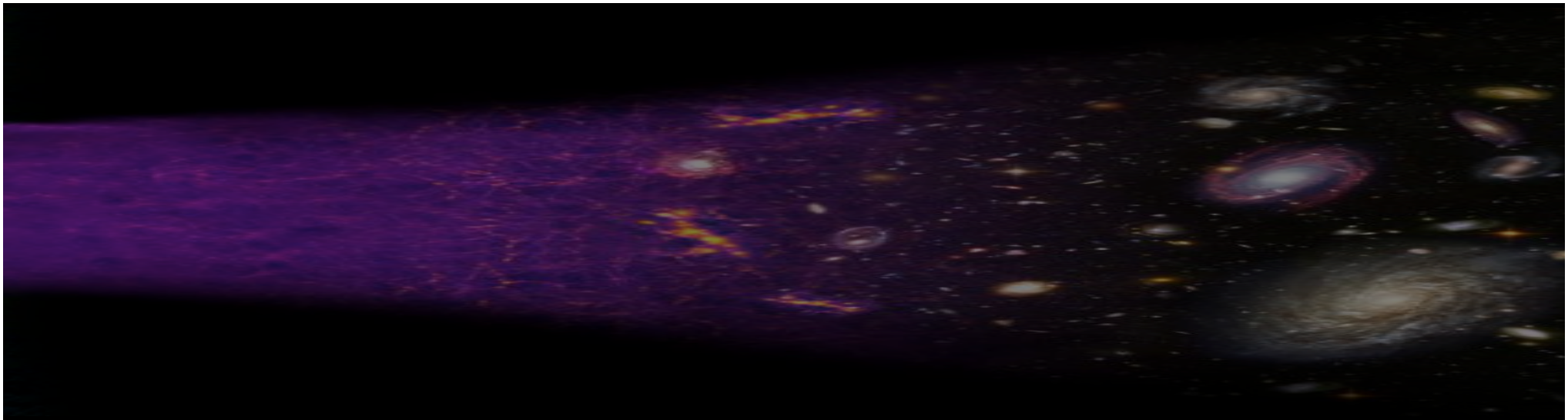

WiggleZ Final Results (almost!)

Tamara Davis
University of Queensland
and the whole WiggleZ team

Overview

What is WiggleZ?

Cosmology Results I'll talk about

Distances using BAO

Paper 1: z = 0.6
Paper 2: z=0.44, 0.6, 0.73

Homogeneity

Growth at high-z

Neutrinos

Paper 1: mass
Paper 2: N_{eff}

H(z) using Alcock-Paczynski

Paper 1: +SNe
Paper 2: +BAO

Full P(k) analysis
Data Release
CosmoMC

Results I'll skip

2D BAO

Reconstruction

Non-Gaussianity with Higher-order clustering

Genus/Topology

Non-standard cosmologies

Variations in G

WiggleZ papers

Paper	Lead authors	Title: "The WiggleZ Dark Energy Survey:"	arXiv
BAO's at z=0.6	Blake, Davis, Poole, Parkinson et al., 2011	testing the cosmological model with baryon acoustic oscillations at z= 0.6	1105.2862
BAO's in 3 redshift bins	Blake, Kazin, Beutler, Davis, Parkinson, et al. 2011	mapping the distance-redshift relation with baryon acoustic oscillations	1108.2635
Growth in 4 redshift bins	Blake, et al. 2011	the growth rate of cosmic structure since redshift z=0.9	1104.2948
Alcock-Paczynscki + SNe	Blake, Glazebrook, Davis, et al. 2011	measuring the cosmic expansion history using the Alcock-Paczynski test & distant Se	1108.2637
Alcock-Paczynscki + BAO	Blake, et al. 2012	joint measurements of the expansion and growth history at z < 1	1204.3674
Homogeneity	Scrimgeour, Davis, Blake, James, Poole, Staveley-Smith et al. 2012	the transition to large-scale cosmic homogeneity	1205.6812
Neutrino mass	Riemer-Sørensen, Blake, Parkinson, Davis, et al. 2012	Cosmological neutrino mass constraint from blue high-redshift galaxies	1112.4940
Small-scale clustering	Blake, Jurek, et al. 2009	small-scale clustering of Lyman-break galaxies at z < 1	0901.2587
WiggleZ overview	Drinkwater, ++ et al. 2010	survey design and first data release	0911.4246
Blue galaxy intrinsic alignments	Mandelbum et al. 2011	direct constraints on blue galaxy intrinsic alignments at intermediate redshifts	0911.5347
Selection function	Blake et al. 2011	the selection function and z = 0.6 galaxy power spectrum	1003.5721
Kinematics of luminous star-forming galaxies	Wisnioski, Glazebrook, Blake, Wyder, Martin, Poole, Sharp, Couch, Kacprzak, et al.	high-resolution kinematics of luminous star-forming galaxies	1107.3338
Galaxy evolution	Li, Yee, et al. 2012	Galaxy Evolution at 0.25 < z < 0.75 Using the Second Red-Sequence Cluster Survey	1201.1013

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In preparation	Nominal lead authors
Final data release and cosmology results	Parkinson, Riemer-Sørensen, Blake, Poole, Davis, et al.
Number of neutrinos	Riemer-Sørensen, Parkinson, Davis, et al.
BAO theory	Davis, Beutler, Blake, Parkinson, Scrimgeour et al.
2D BAO's	Davis, Kazin, Blake, et al.
Higher-order correlations	Marin et al.
Growth – beyond standard cosmologies	Parkinson et al.
Distances – beyond standard cosmologies	Peet, Davis, et al.
Reconstruction	Kazin et al.

The WiggleZ Dark Energy Survey
Five-year (final) results

High-z galaxy survey
$0.2 < z < 1.0$

238,000 blue galaxies

1 GPc^3

Observations finished 2011

Advantages:
Low-bias
High-redshift

THE TEAM:

UQ: Michael Drinkwater, Tamara Davis, David Parkinson, Signe Riemer-Sorensen, Russell Jurek (now at ATNF)

Swinburne: Warrick Couch, Chris Blake, Karl Glazebrook, Greg Poole, Darren Croton, Eyal Kazin, Felipe Marin

AAO: Matthew Colless, Rob Sharp, Sarah Brough

Sydney: Scott Croom, Ben Jellife

ANU: Mike Pracy

UBC: David Woods

Caltech: Chris Martin, Ted Wyder

Carnegie: Barry Madore

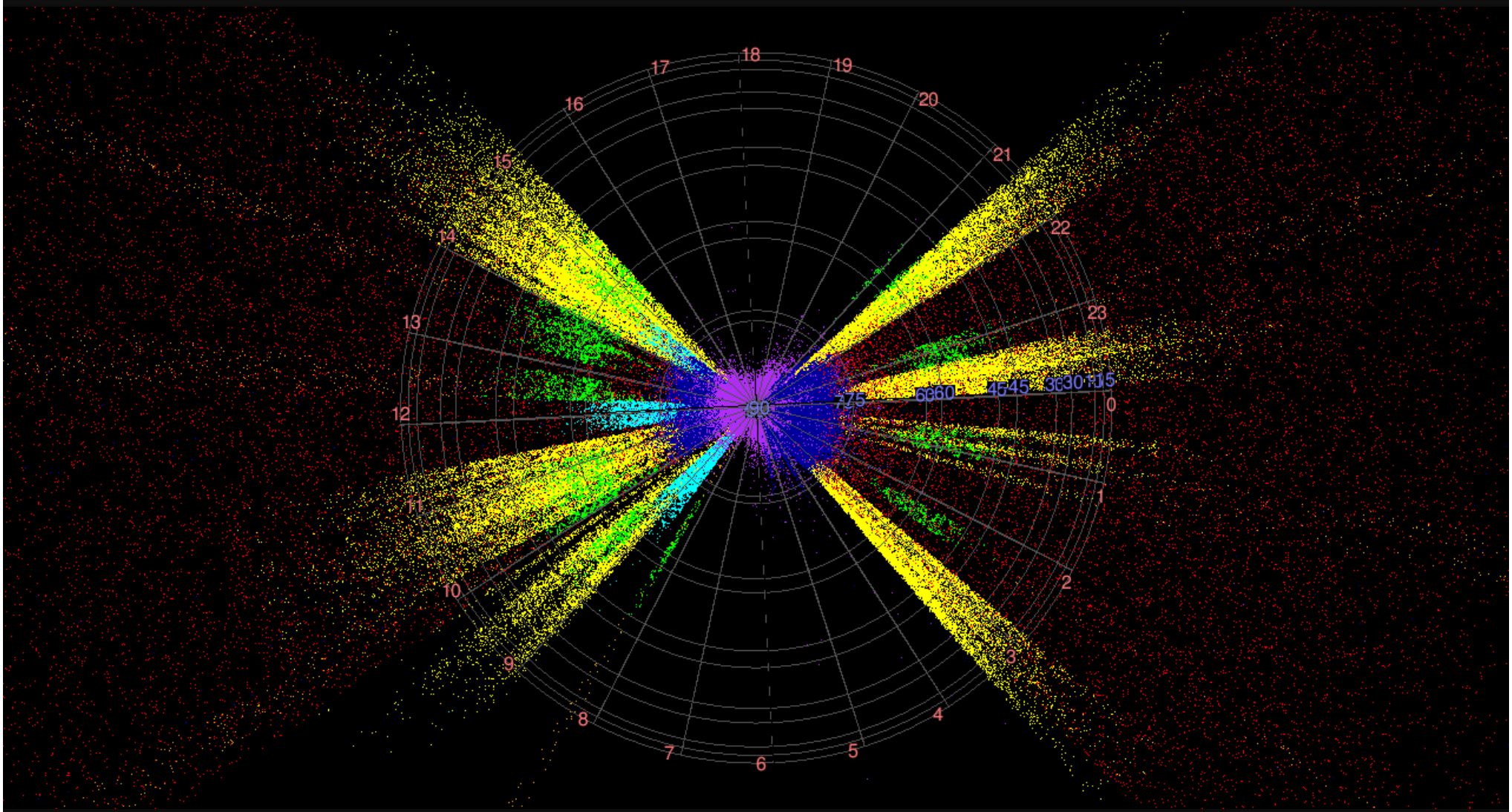
Plus students and associate members

WiggleZ survey fields
(compared to other AAT surveys)

7 equatorial fields, each 100-200 deg^2

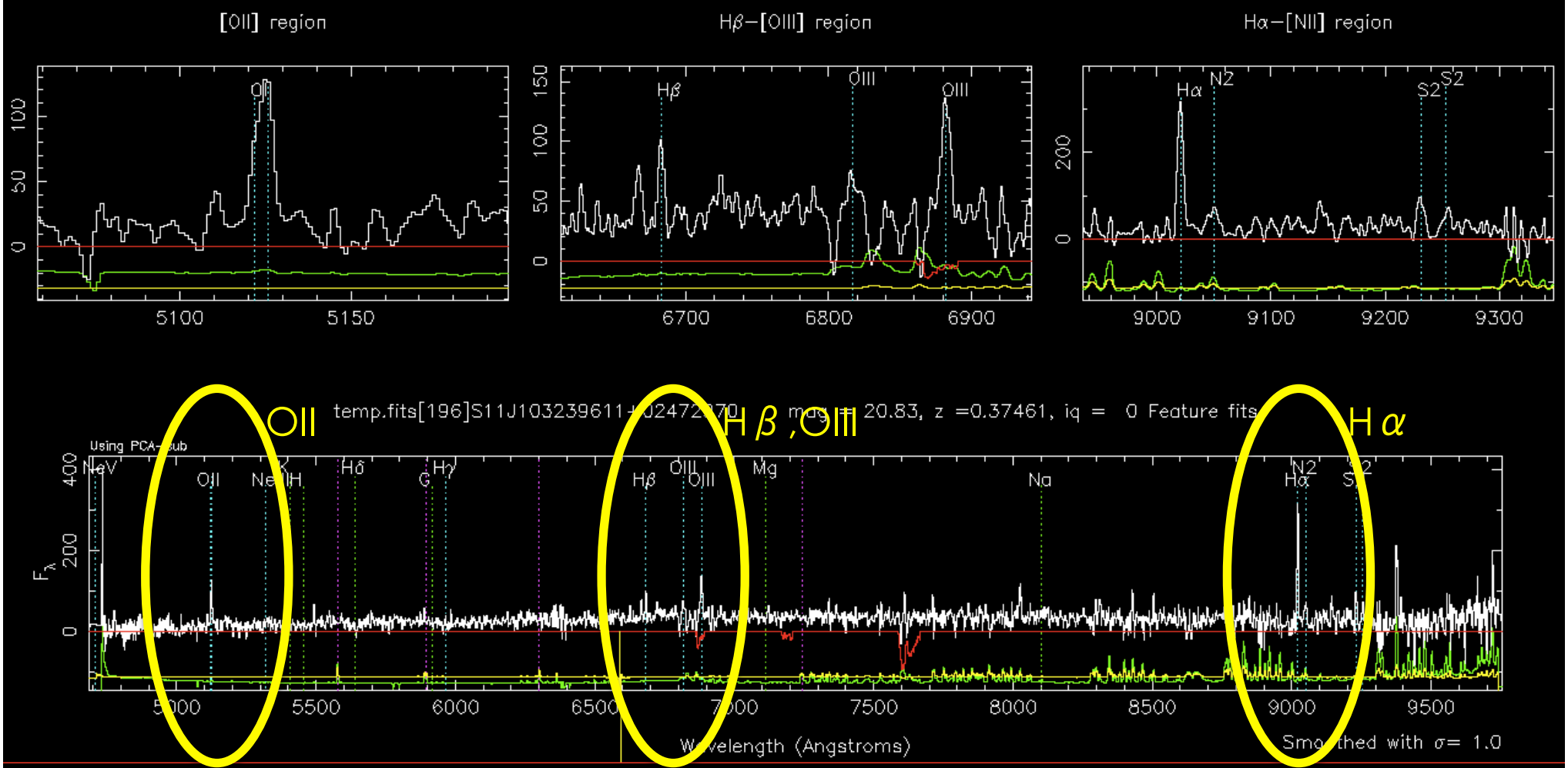
>9° on side, ~3 x BAO scale at $z > 0.5$

Physical size ~ 1300 x 500 x 500 Mpc/h

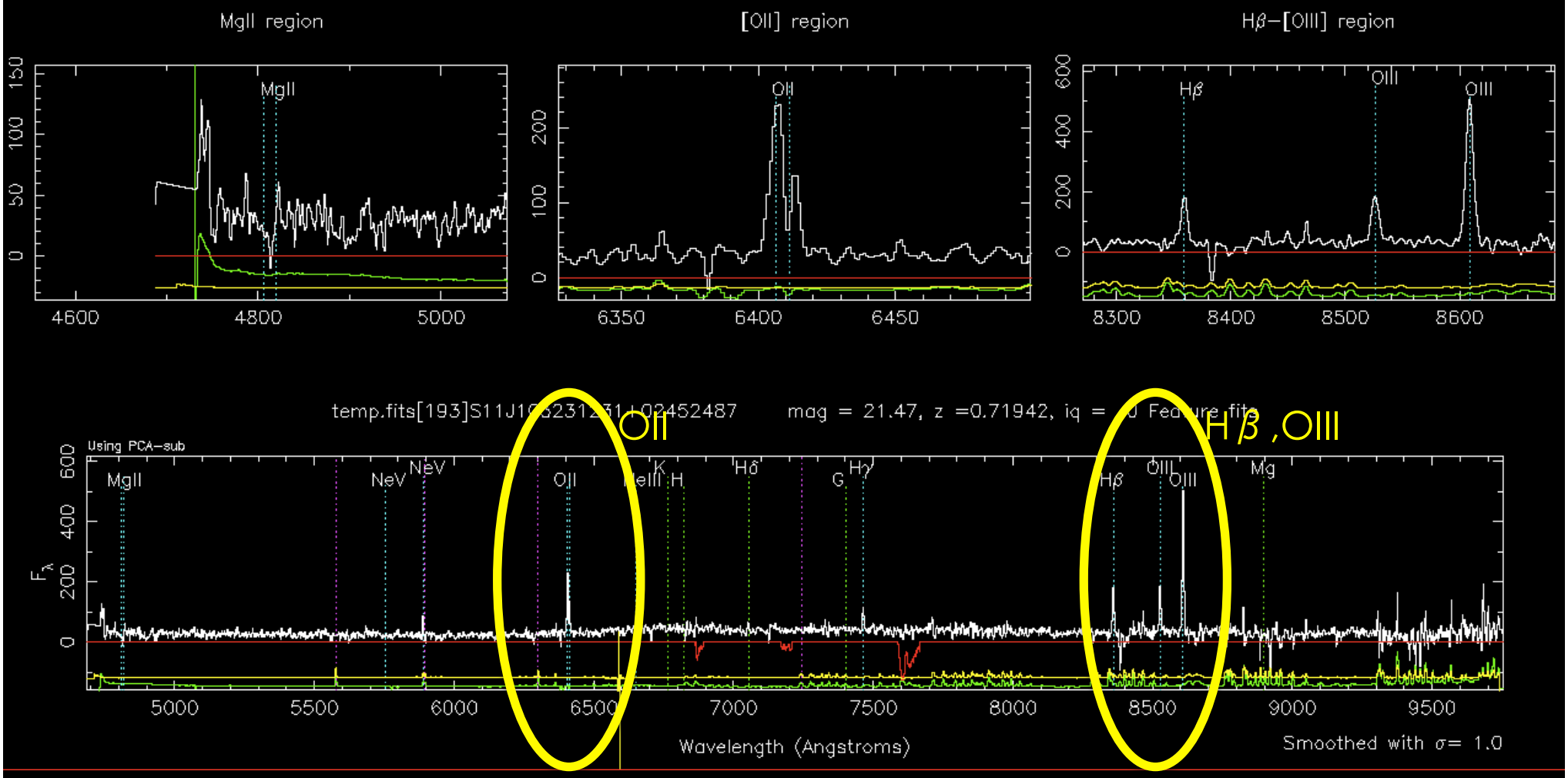


6dFGS (purple), 2dFGRS (blue), MGC (navy), GAMA (cyan), 2SLAQ-LRG (green), WiggleZ (yellow), 2SLAQ-QSO (orange), 2QZ (red); the celestial sphere is at z=1.

Example spectrum: z=0.37

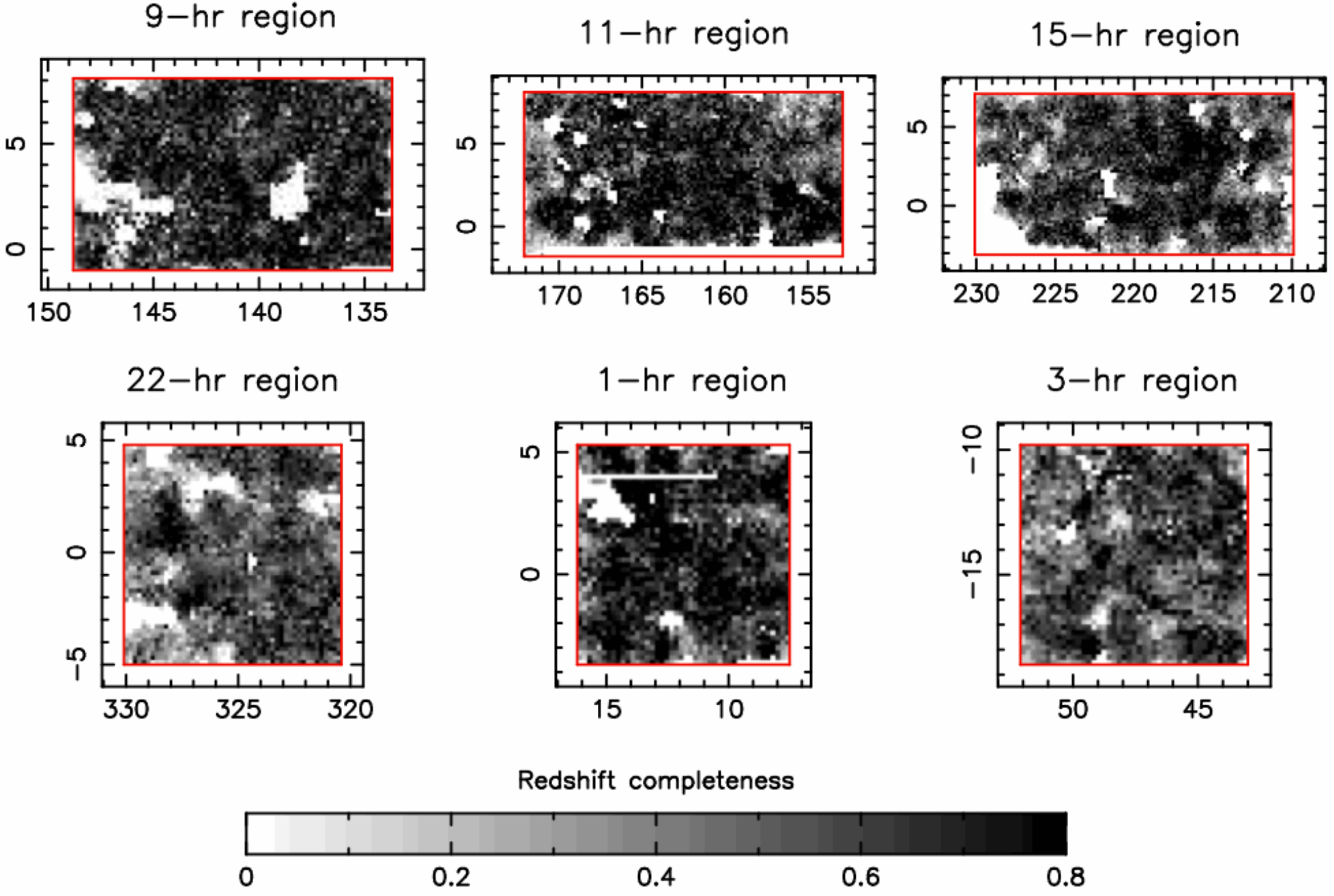


Example spectrum: z=0.72

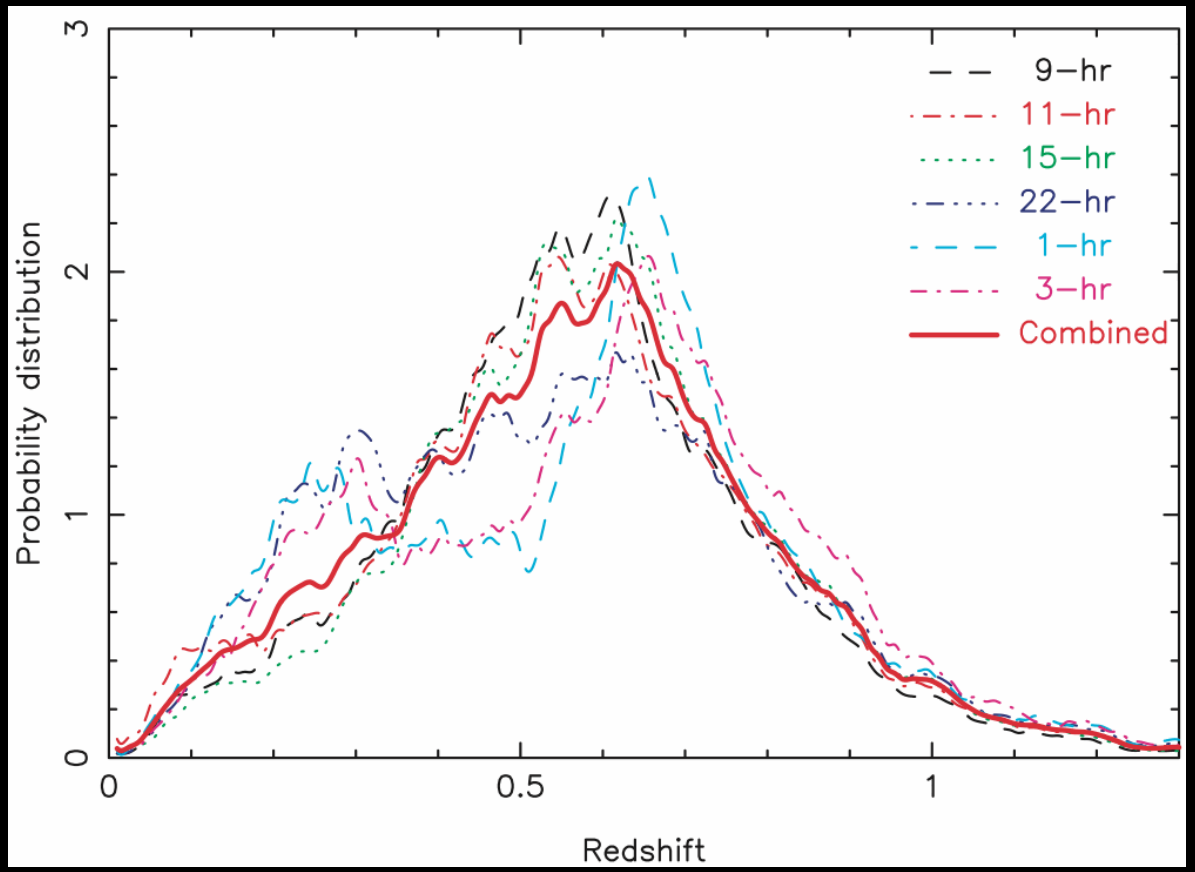


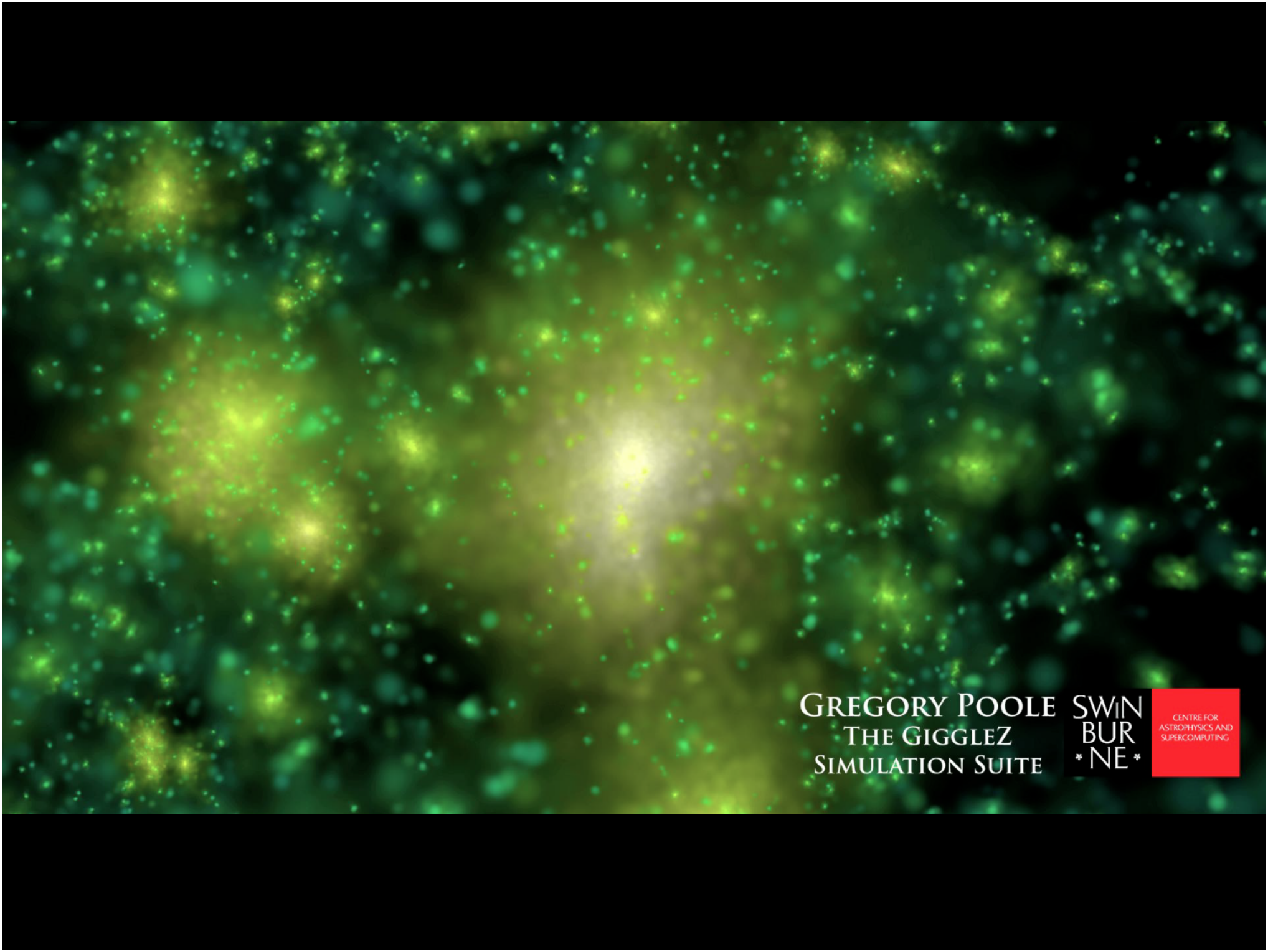
Redshifts become less certain above $z \sim 1$ because we lose $H\beta$

WiggleZ regions



WiggleZ regions




Gregory Poole
The GiggleZ
Simulation Suite
SWiN
BUR
NE
CENTRE FOR
ASTROPHYSICS AND
SUPERCOMPUTING

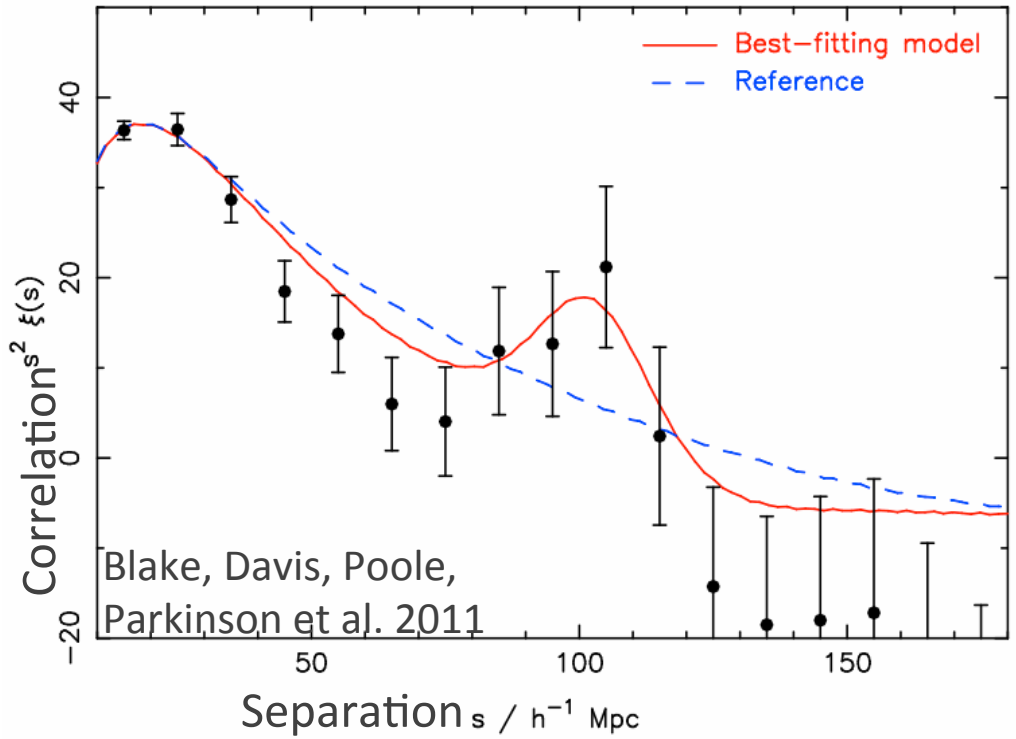
Blake, Davis, Poole, Parkinson et al. 2011

Blake, Kazin, Beutler, Davis, Parkinson et al. 2011

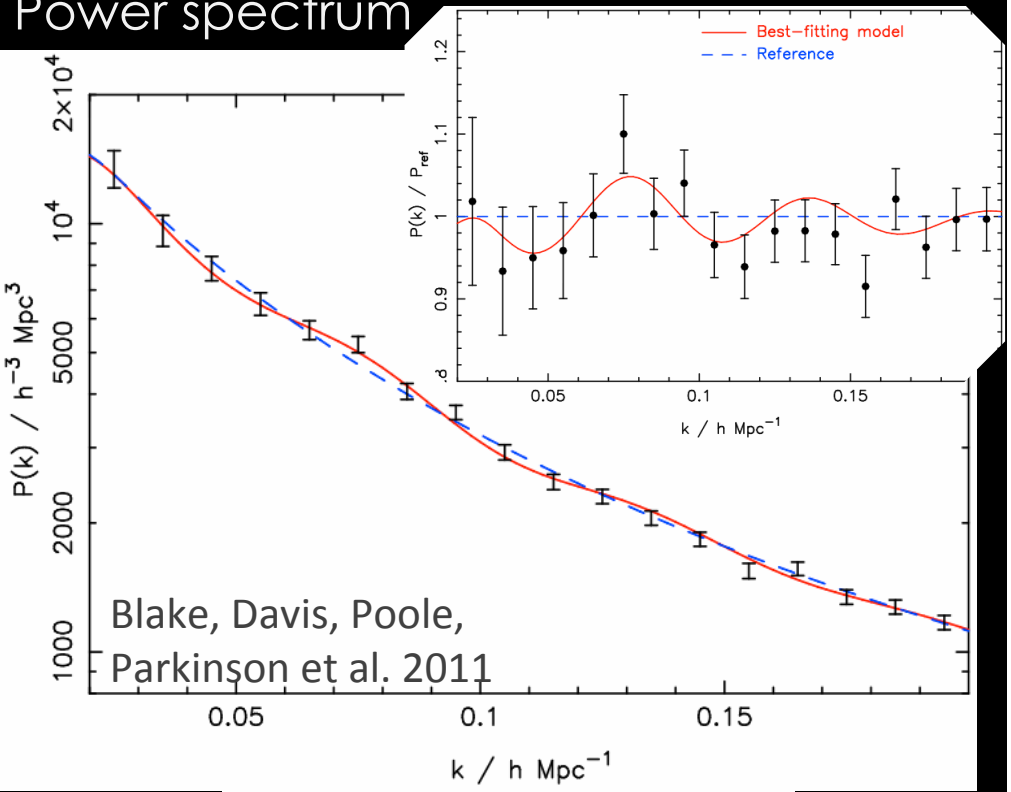
1. BARYON ACOUSTIC OSCILLATIONS

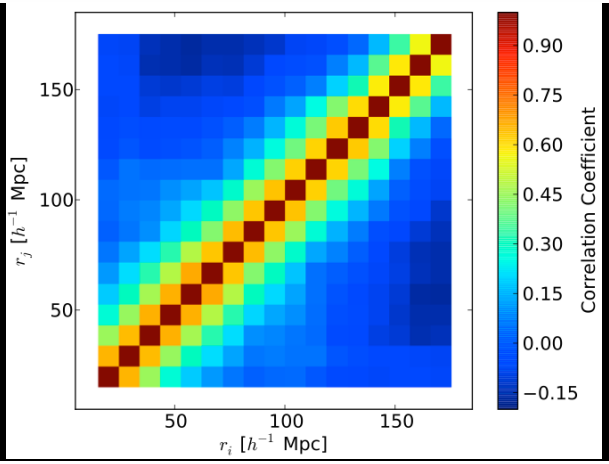
BAO-1: Single redshift bin

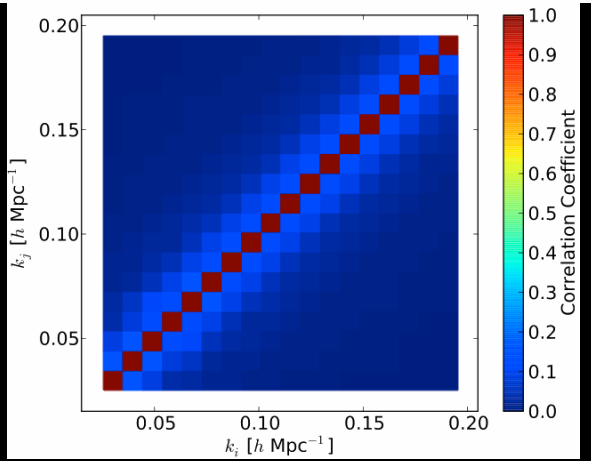
Correlation Function



Power spectrum







Measuring the distance scale

Two Tangential One Radial

$$D_V(z) = \left[(1+z)^2 D_A(z)^2 \frac{cz}{H(z)} \right]^{1/3}$$

BAO

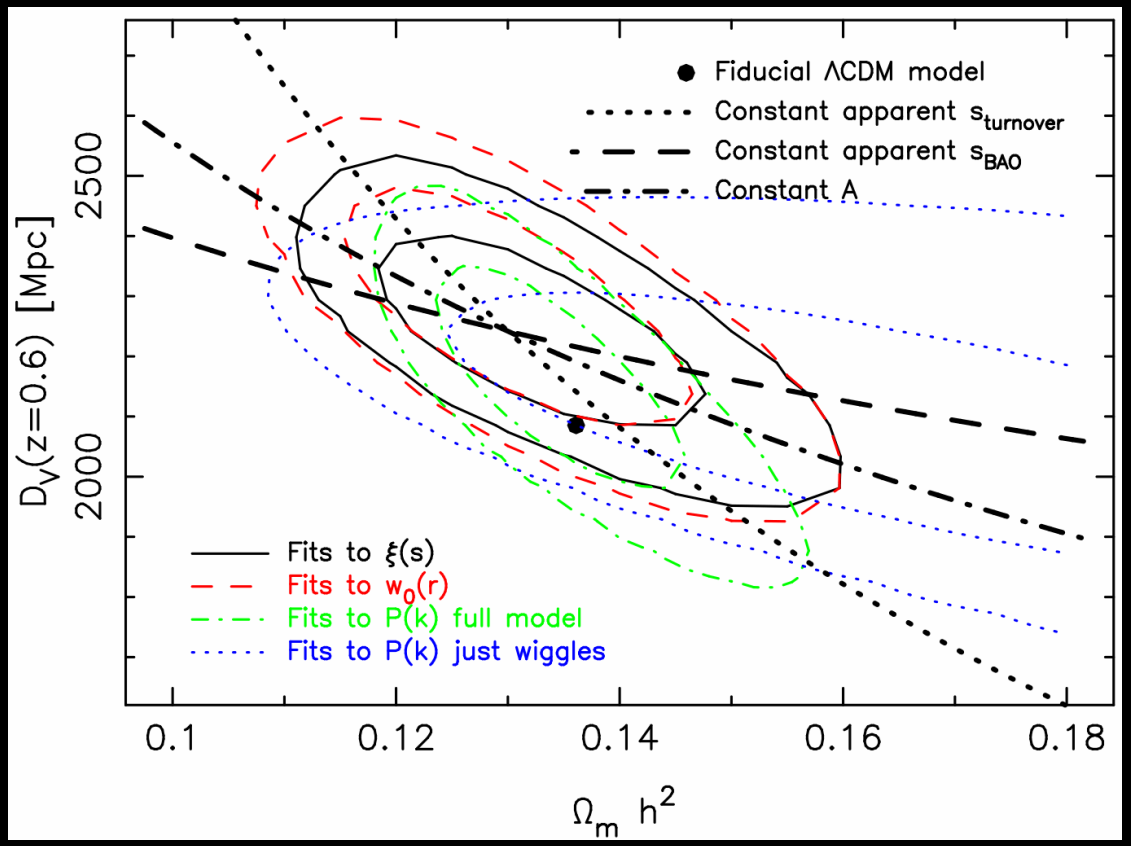
$$d_z \equiv \frac{r_s(z_d)}{D_V(z)}$$

$$A(z) = \frac{\sqrt{\Omega_m H_0^2}}{cz} D_V(z)$$

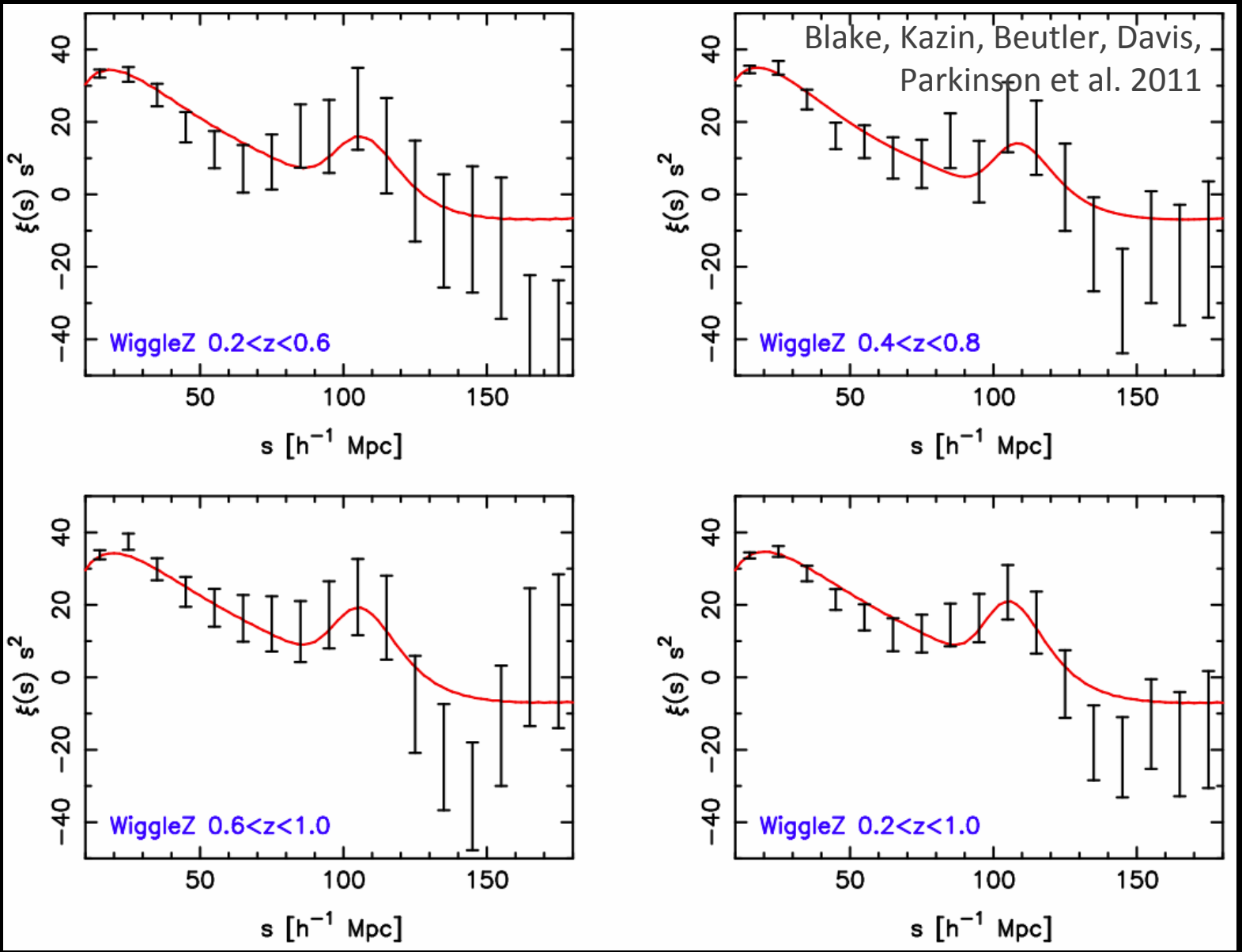
CMB

$$\theta_A \equiv \frac{r_s(z_*)}{d_A(z_*)}$$

$$\mathcal{R}(z_*) = \sqrt{\Omega_m h^2}\, d_A(z_*)$$

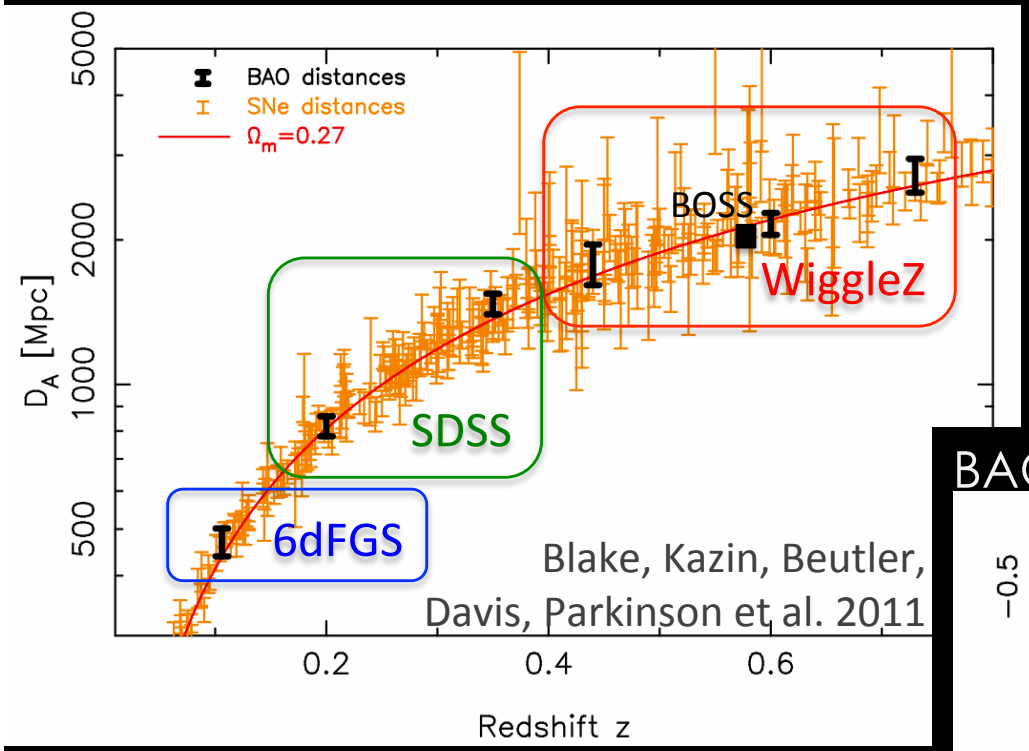


BAO-2: Three redshift bins



WiggleZ – Baryon Acoustic Oscillations

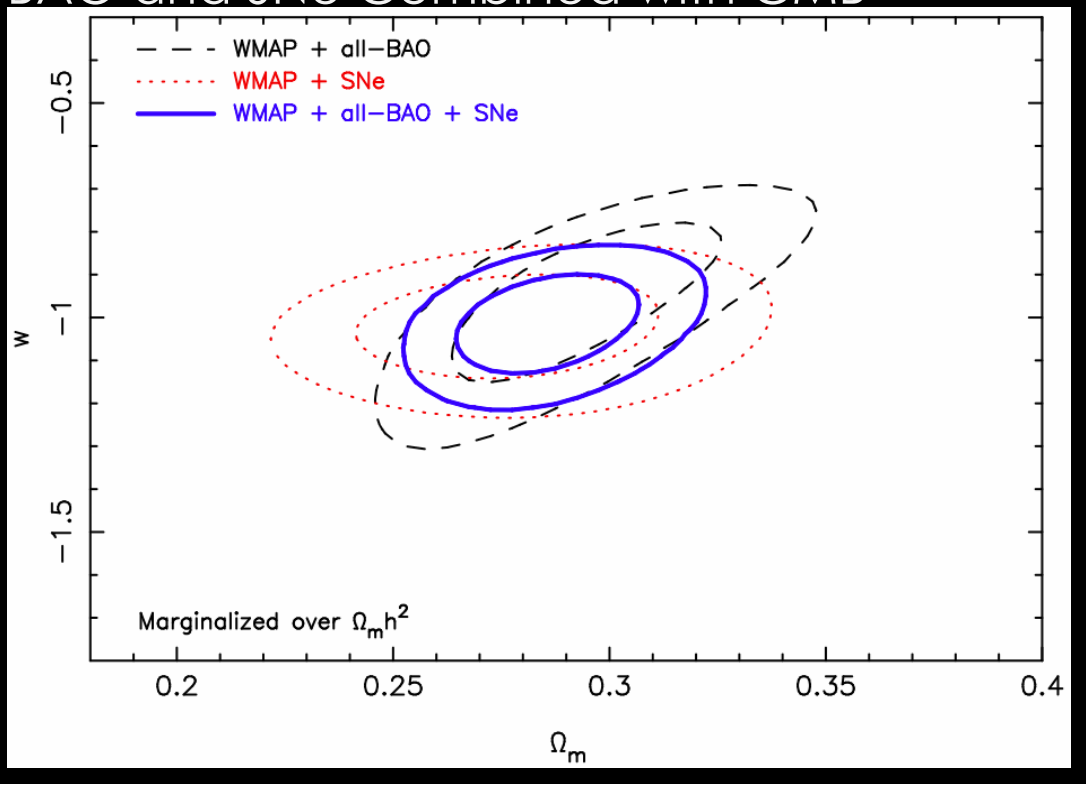
Compared to supernovae



No longer need SNe!

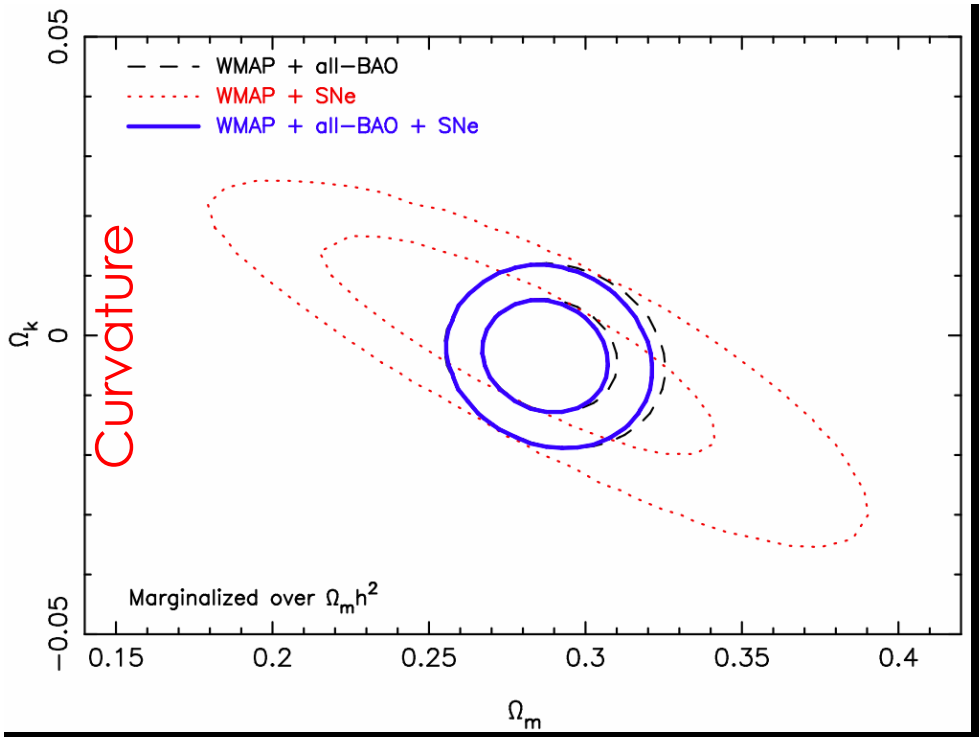
BAO distances alone now require acceleration!

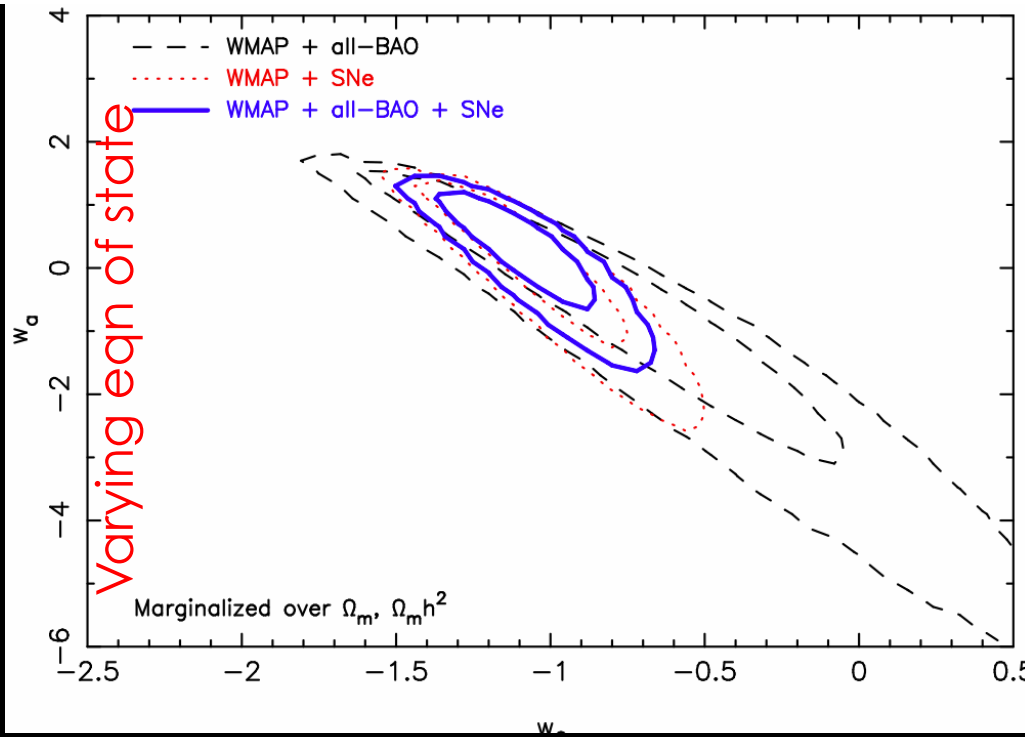
BAO and SNe Combined with CMB



We don't know what is causing the acceleration

(And the leading candidate, vacuum energy, is 10^{120} too large)





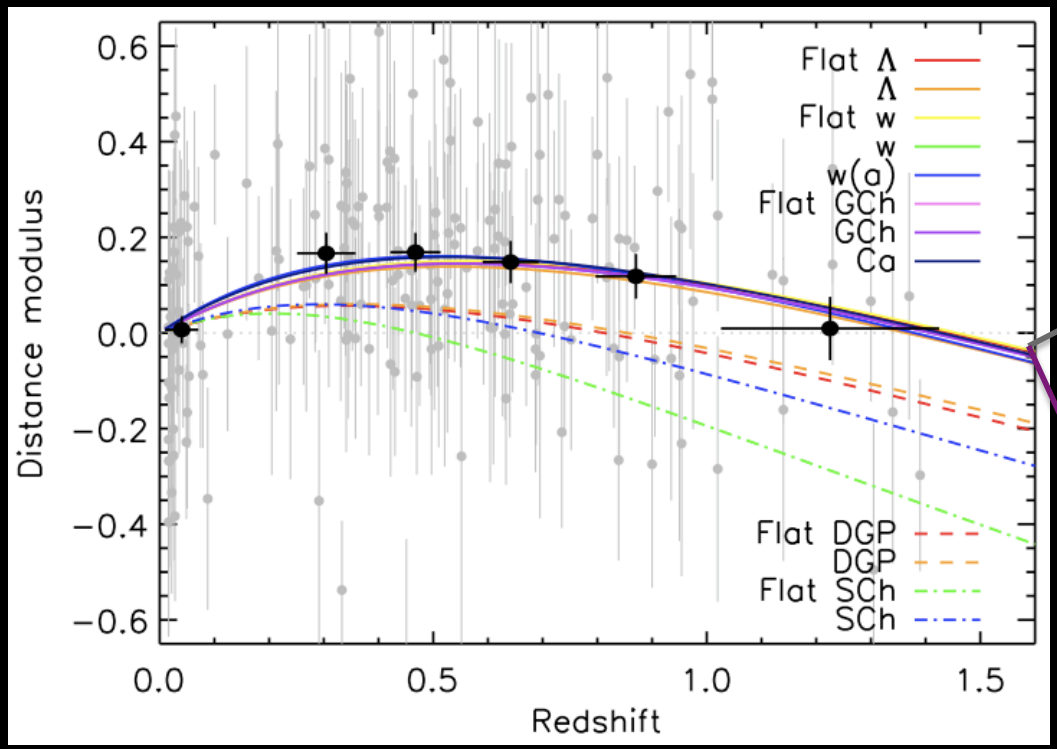
Final combined results

Model	χ^2	d.o.f.	Ω_m	$\Omega_m h^2$	h	Ω_k	w_0	w_a
Flat ΛCDM	533.1	564	0.290 ± 0.014	0.1382 ± 0.0029	0.690 ± 0.009	–	–	–
Flat wCDM	532.9	563	0.289 ± 0.015	0.1395 ± 0.0043	0.696 ± 0.017	–	-1.034 ± 0.080	–
Curved ΛCDM	532.7	563	0.292 ± 0.014	0.1354 ± 0.0054	0.681 ± 0.017	-0.0040 ± 0.0062	–	–
Curved wCDM	531.9	562	0.289 ± 0.015	0.1361 ± 0.0055	0.687 ± 0.019	-0.0061 ± 0.0070	-1.063 ± 0.094	–
Flat $w(a)$CDM	531.9	562	0.288 ± 0.016	0.1386 ± 0.0053	0.695 ± 0.017	–	-1.094 ± 0.171	0.194 ± 0.687

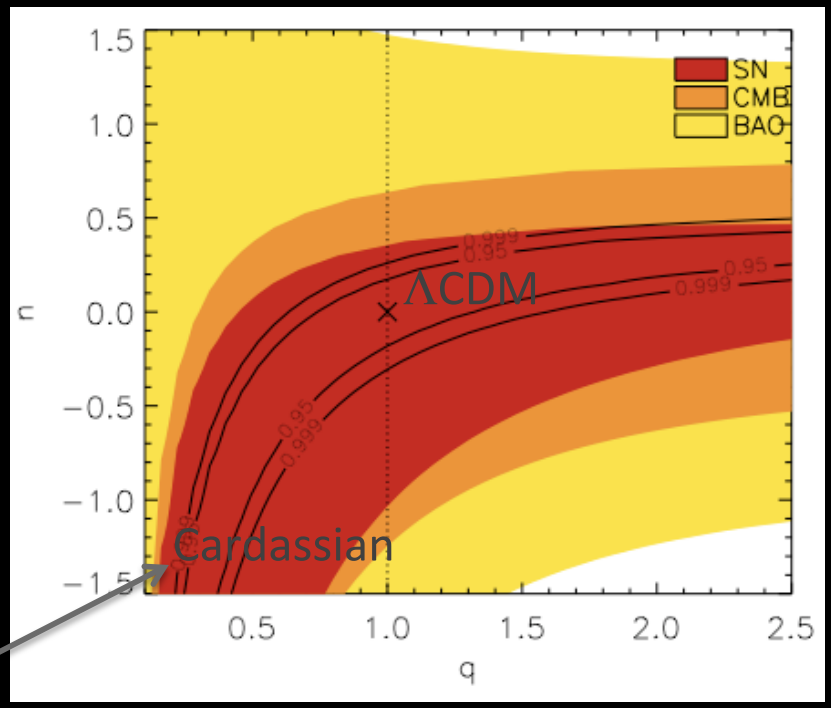
Blake et al. 2011

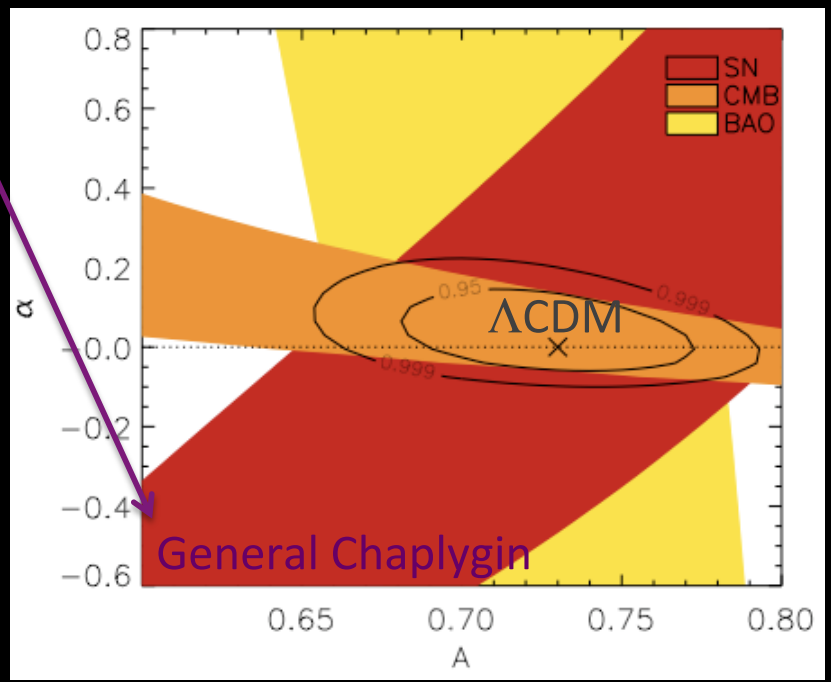
2. GROWTH OF STRUCTURE

Some models can't be distinguished



Davis et al. 2007





Other types of measurements needed

- Growth

overdensity

$$f = \frac{d(\ln \delta)}{d(\ln a)} \sim \Omega_M(z)^{\gamma}$$

γ = 6/11 in ΛCDM
γ = 6/10 in CDM
γ = 11/16 in DGP

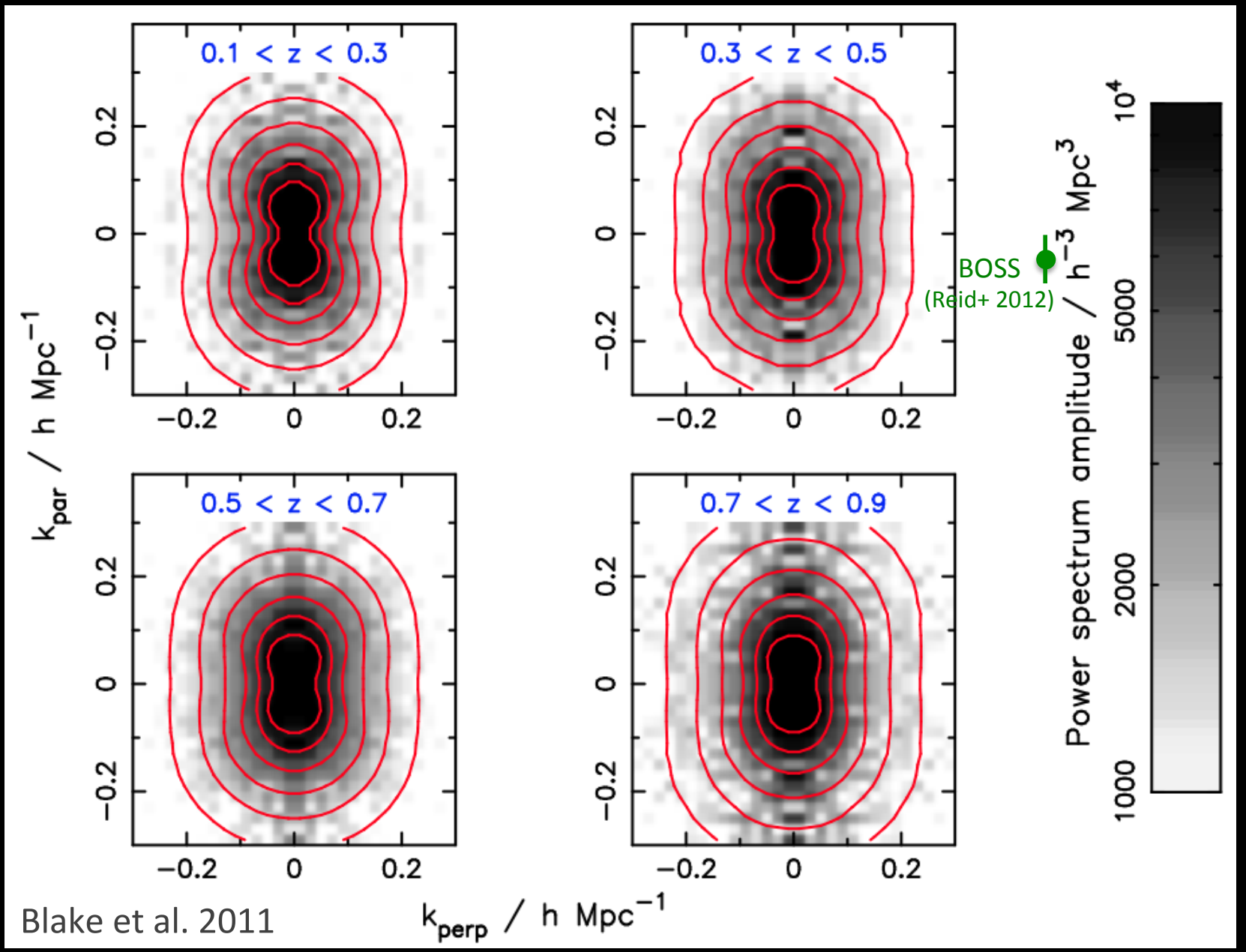
γ is different in different models

- Amplitude of density fluctuations at present day

$$\sigma_8$$

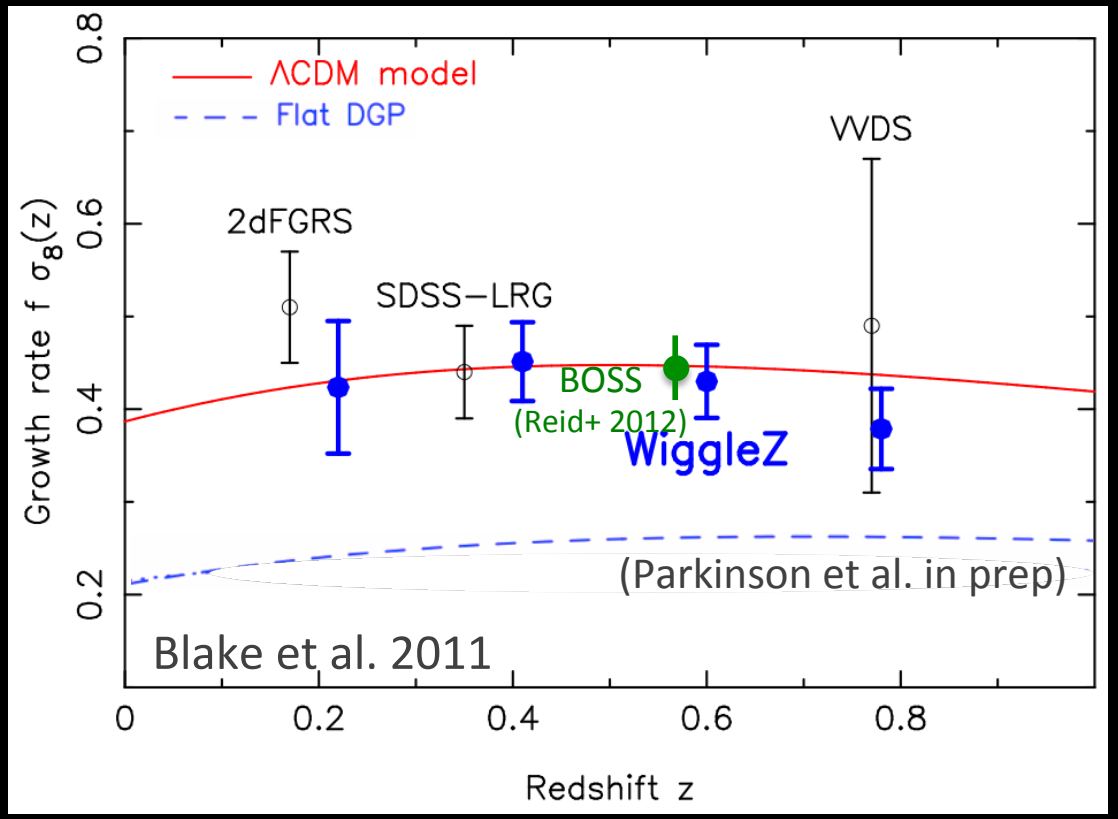
1. measure density in spheres 8 Mpc in radius
2. calculate the dispersion

WiggleZ – Growth of Structure



Blake et al. 2011

WiggleZ – Growth of Structure

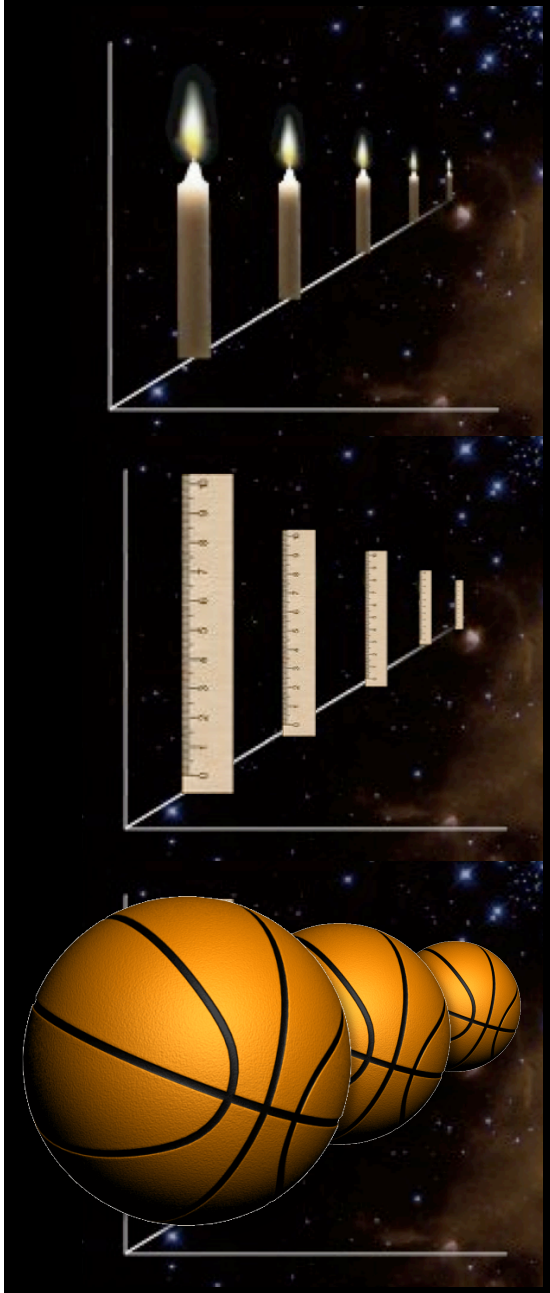


Blake et al. 2011

Blake, Glazebrook, Davis et al. 2011

3A. H(Z) ALCOCK-PACZYNSKI + SN

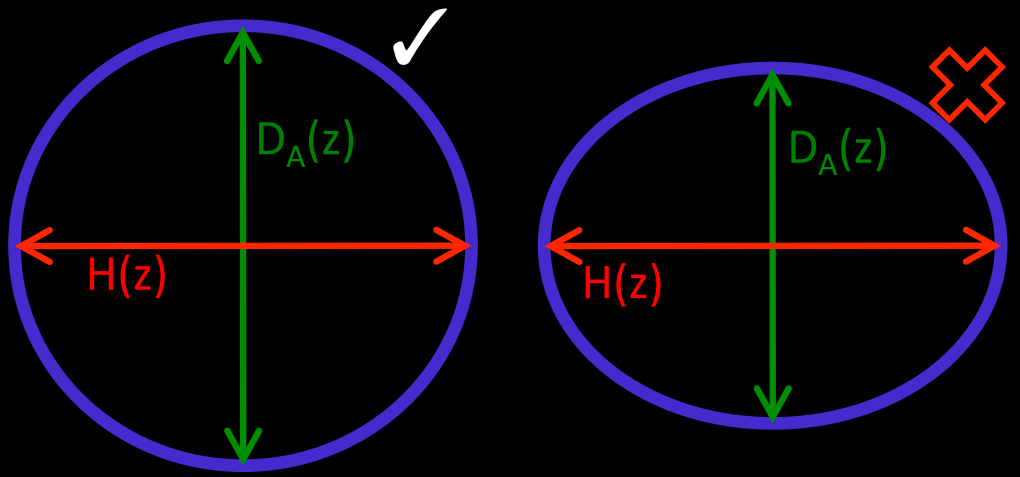
BAO – a standard sphere



- SNe = radial info (line of sight)
- CMB = tangential info (surface of sphere)

- BAO can be applied radially to give H(z) AND tangentially to give $D_A(z)$

Alcock-Paczynski test:



WiggleZ – Measurement of H(z)

WiggleZ measures

$$(1+z)D_A(z)H(z)/c$$

Supernovae measure

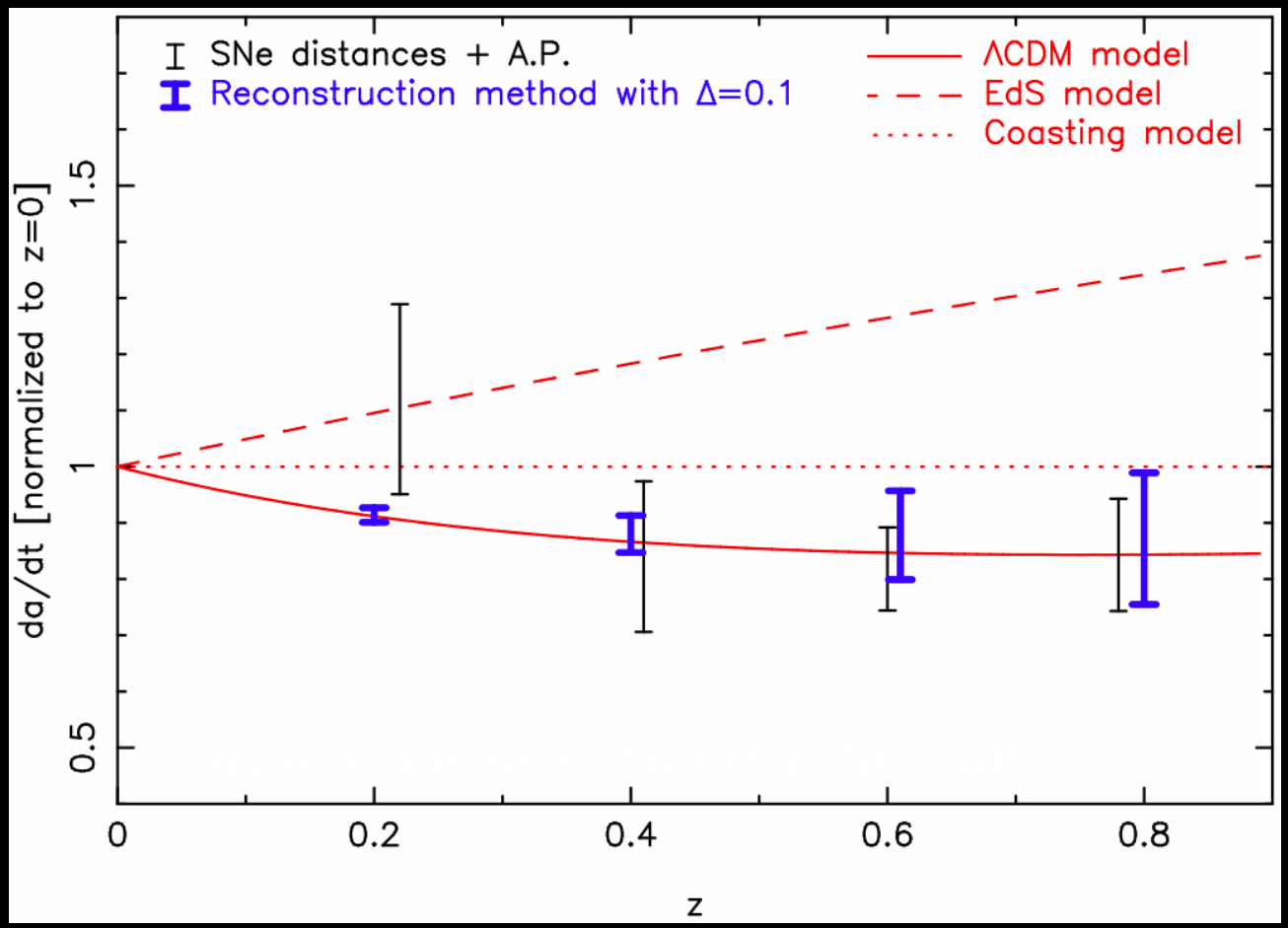
$$D_L(z)\,H_0/c$$

Distances are related by

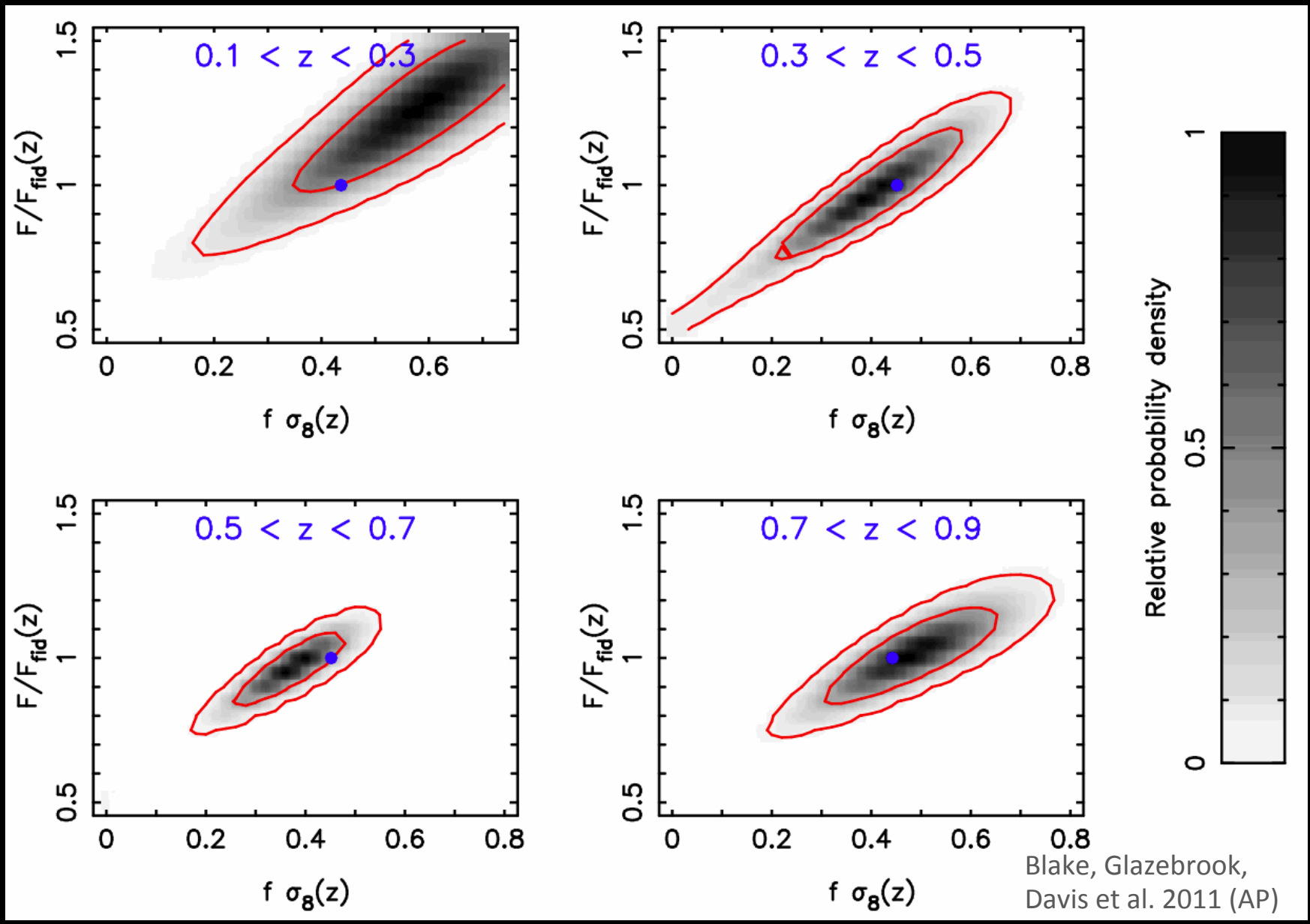
$$D_L(z) = D_A(z)\,(1+z)^2$$

So the ratio gives

$$H(z)/H_0$$

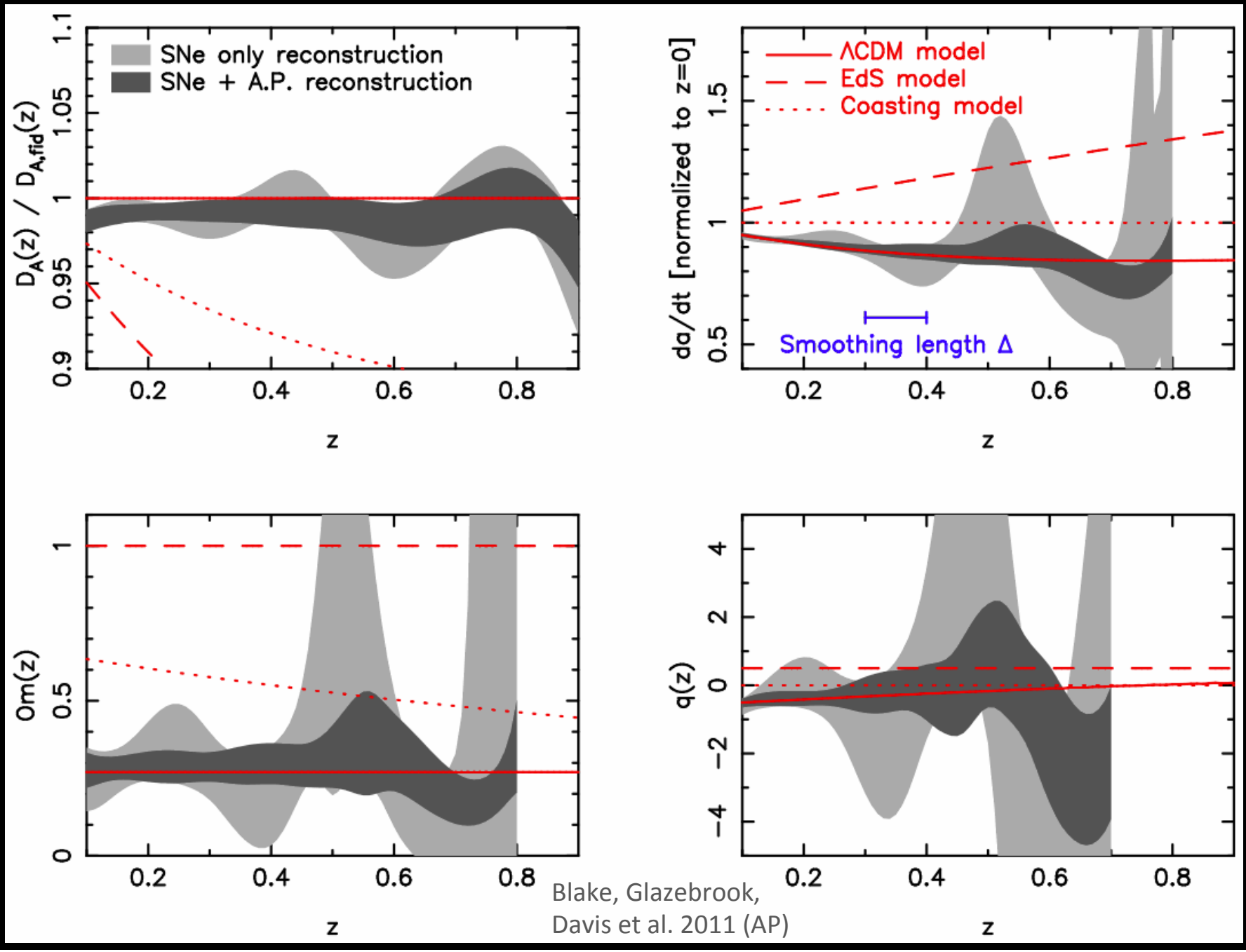


Alcock-Paczynski / z-space distortions



Blake, Glazebrook, Davis et al. 2011 (AP)

Reconstructions



Blake, Glazebrook, Davis et al. 2011 (AP)

Blake et al. 2012

3B. H(Z) ALCOCK-PACZYNSKI + BAO

WiggleZ growth + AP + BAO

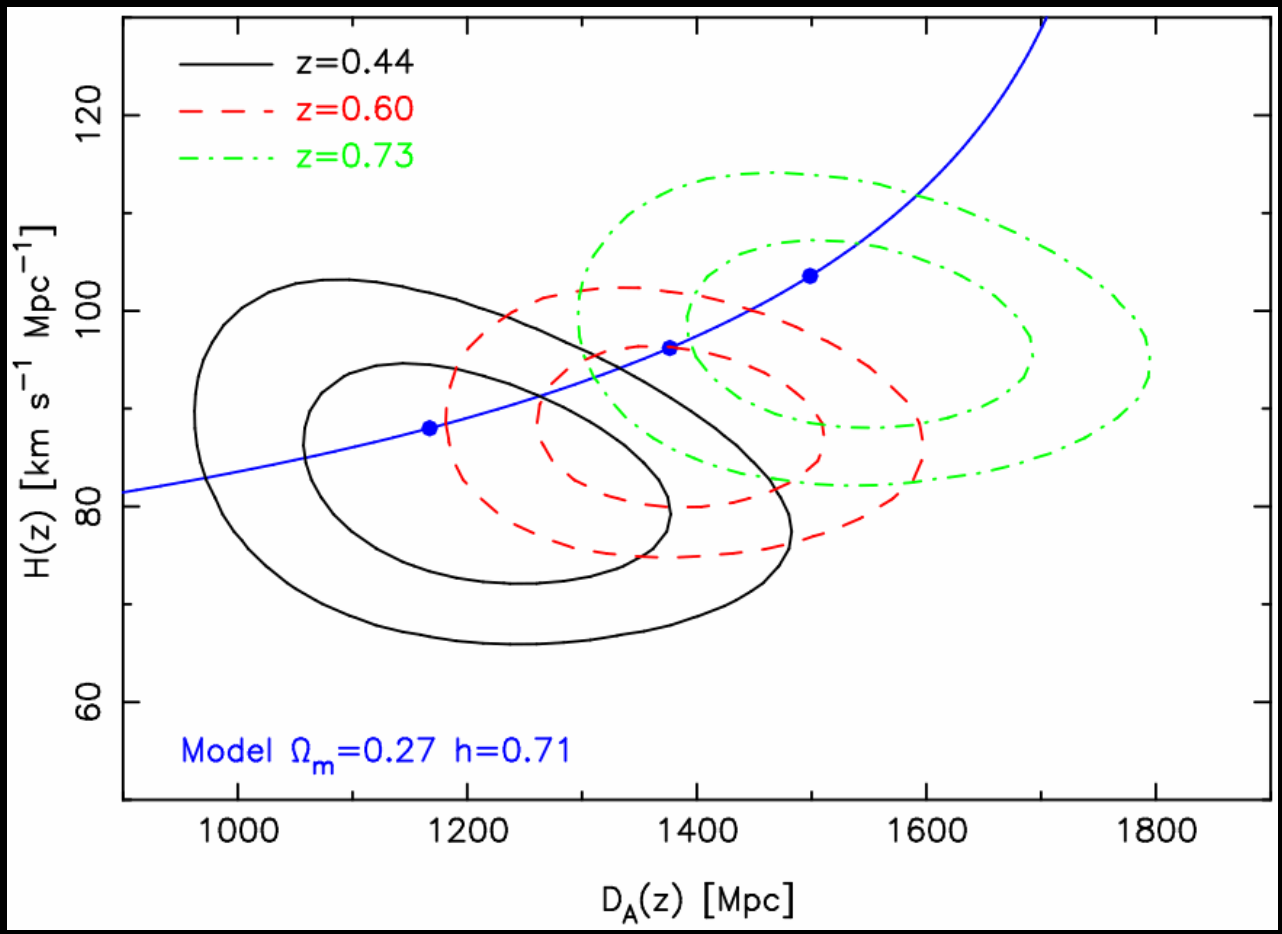
WiggleZ AP measures

$$F \propto D_A H$$

WiggleZ BAO measures

$$A \propto (D_A^2/H)^{1/3}$$

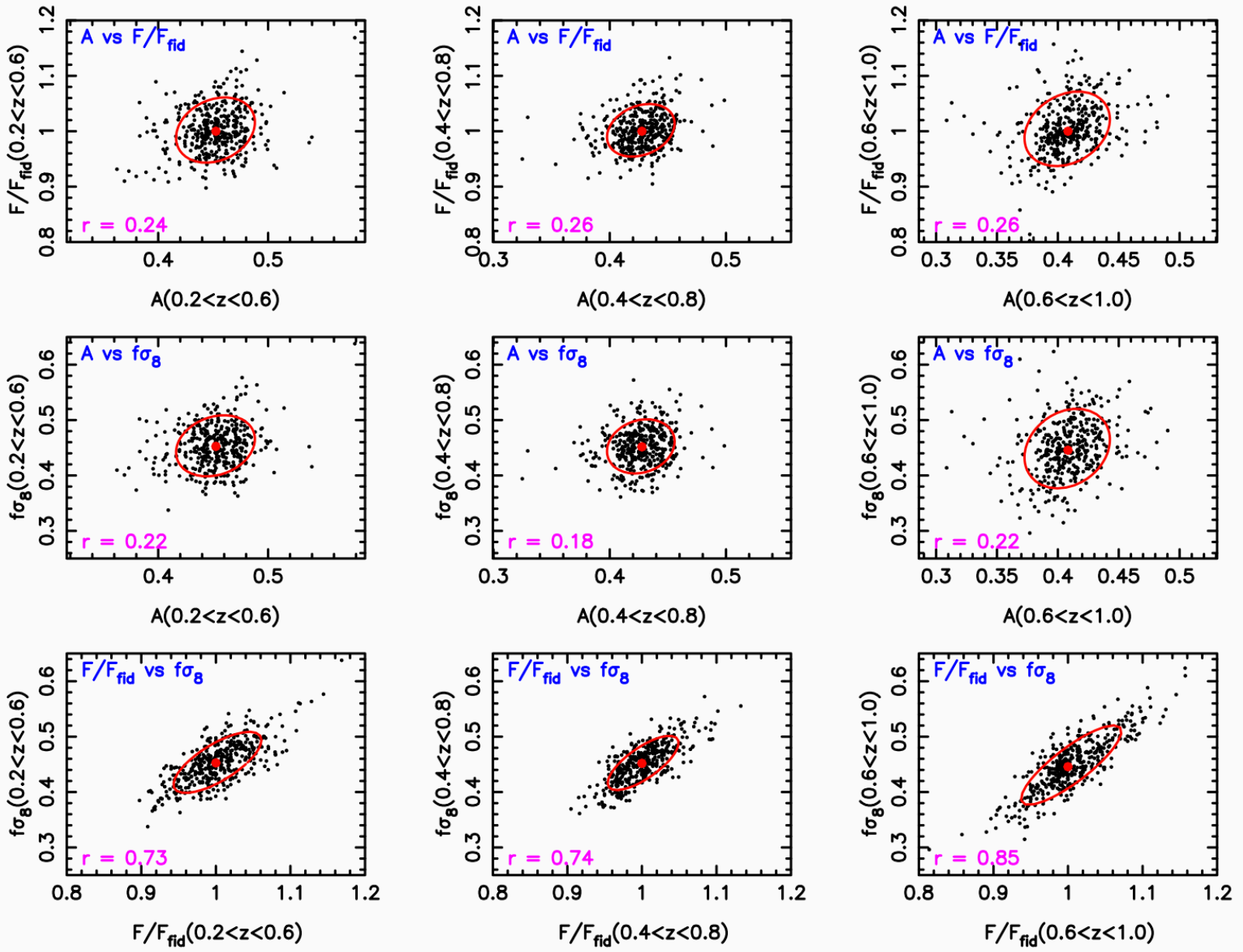
So the combination allows us to measure distance and expansion rate separately



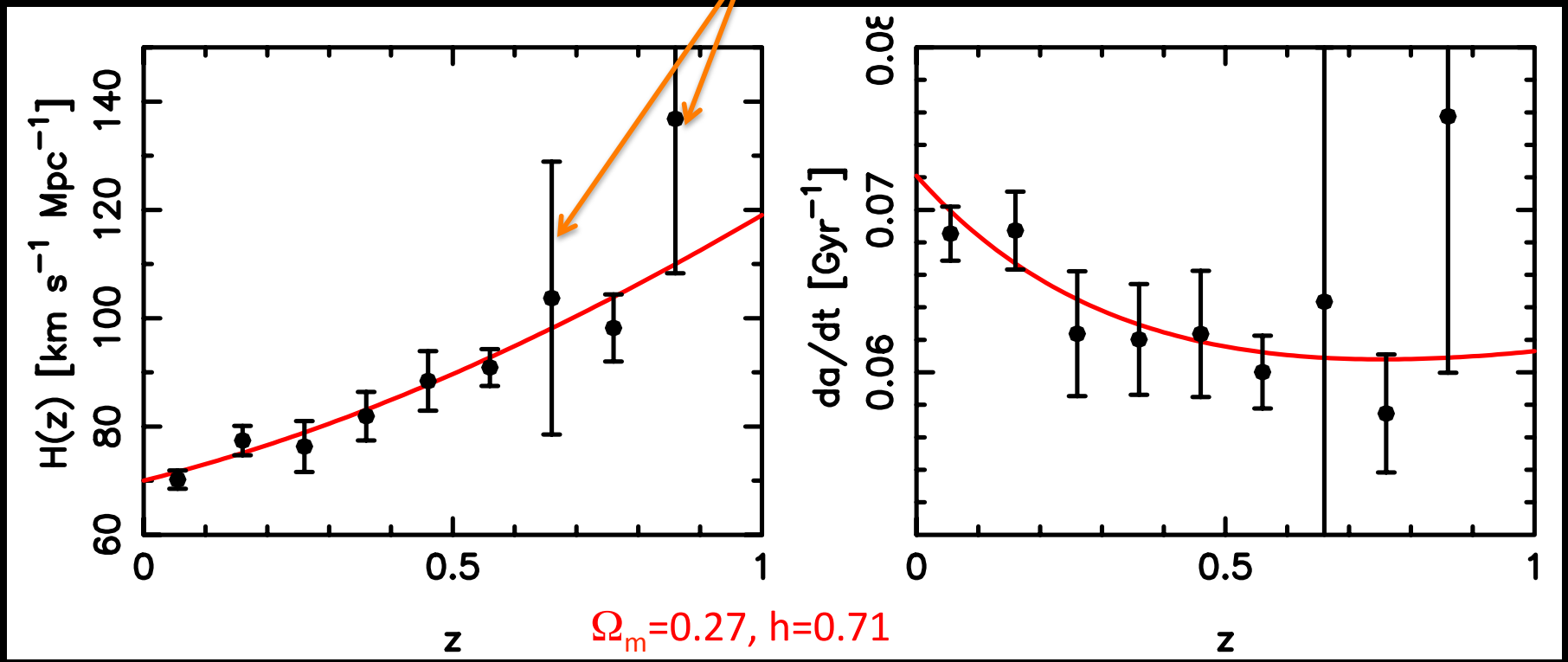
Marginalized over $\Omega_m h^2$, with CMB prior (Komatsu et al. 2009) of 0.1345±0.0055

Covariances

400 lognormal realizations per WiggleZ field and per z-slice (7200 total)



Combined with other BAO, SNe, and $\Omega_m h^2$



WiggleZ and BOSS (AP+BAO)
6dFGS and SDSS BAO
SNe (Union)
WMAP $\Omega_m h^2$ (not distances)

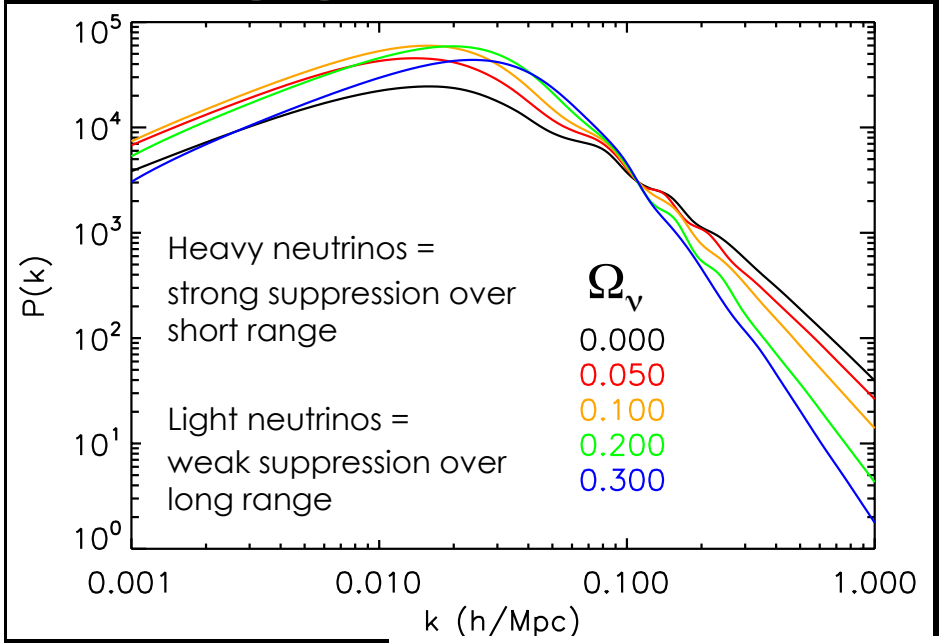
Riemer-Sørensen et al. 2012

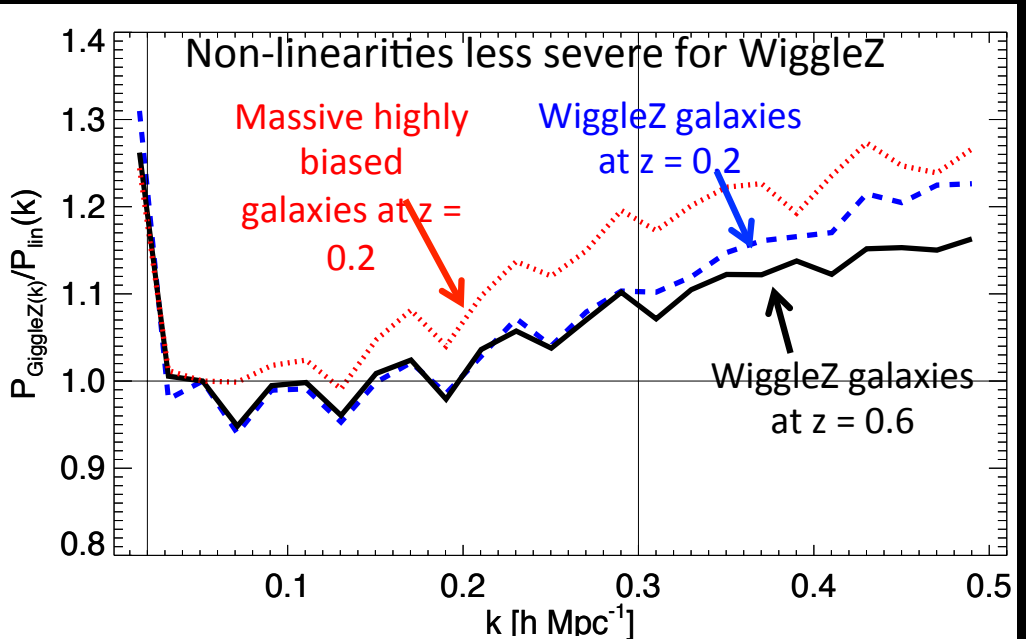
Riemer-Sørensen et al. 2012 (in prep)

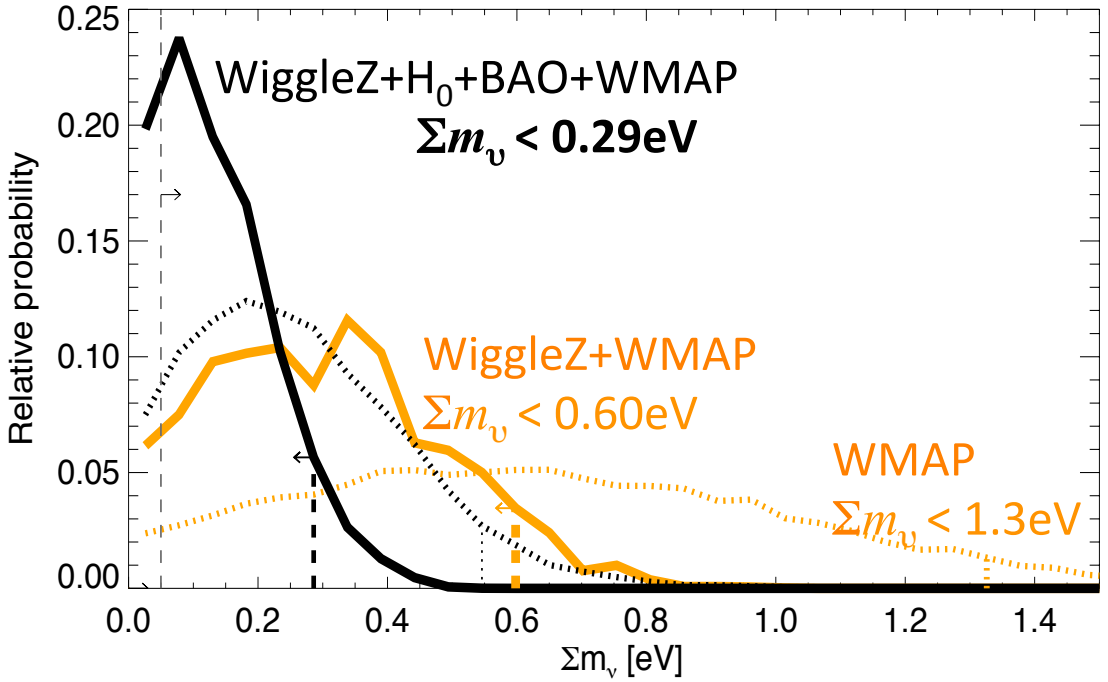
4. NEUTRINO MASS AND N_{EFF}

WiggleZ: Neutrino mass

Riemer-Sørensen et al. 2012





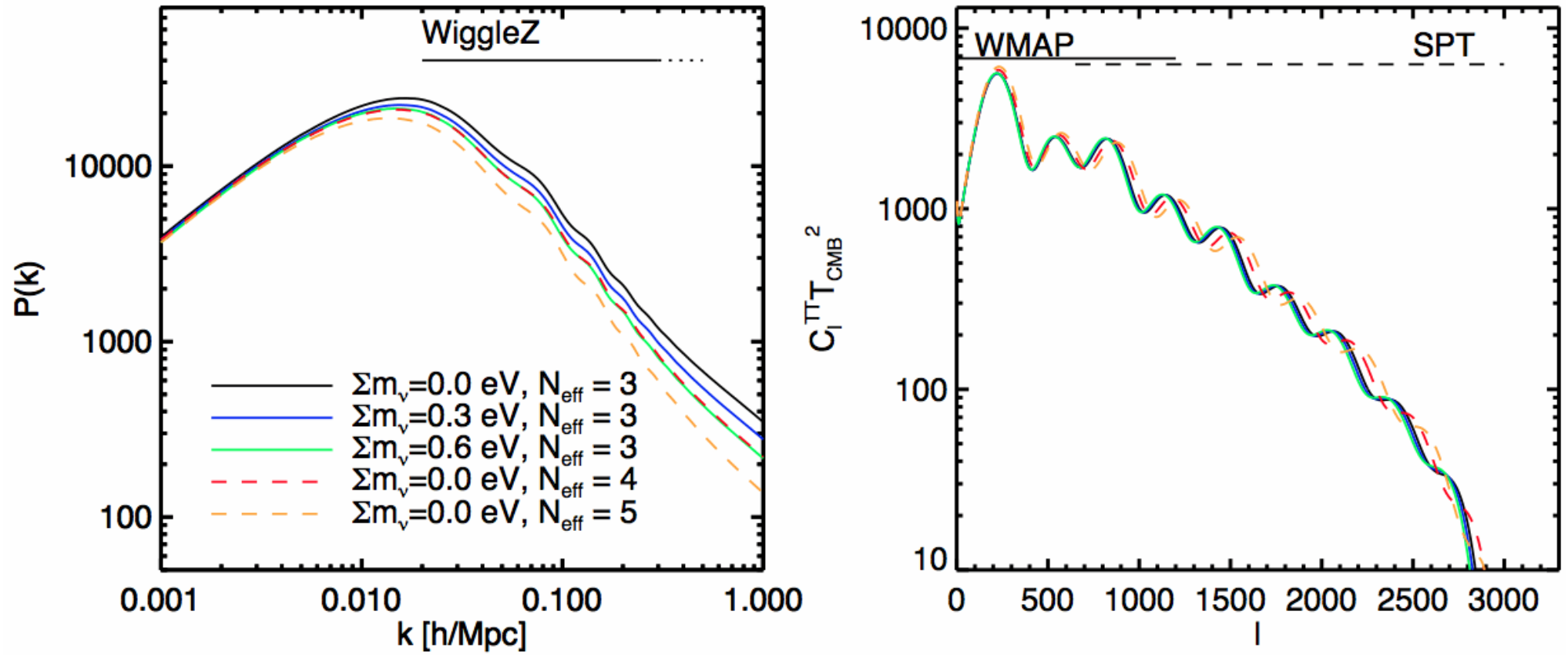


h=0.742±0.036
Reiss et al. 09

SDSS (Reid et al. 10)
Σm_υ < 0.62eV
Photo (dePutter 12)
Σm_υ < 0.28eV
Ly-α (Seljak et al. 06)
Σm_υ < 0.17eV

To k=0.3;
To k=0.1 we get
Σm_υ < 0.39eV

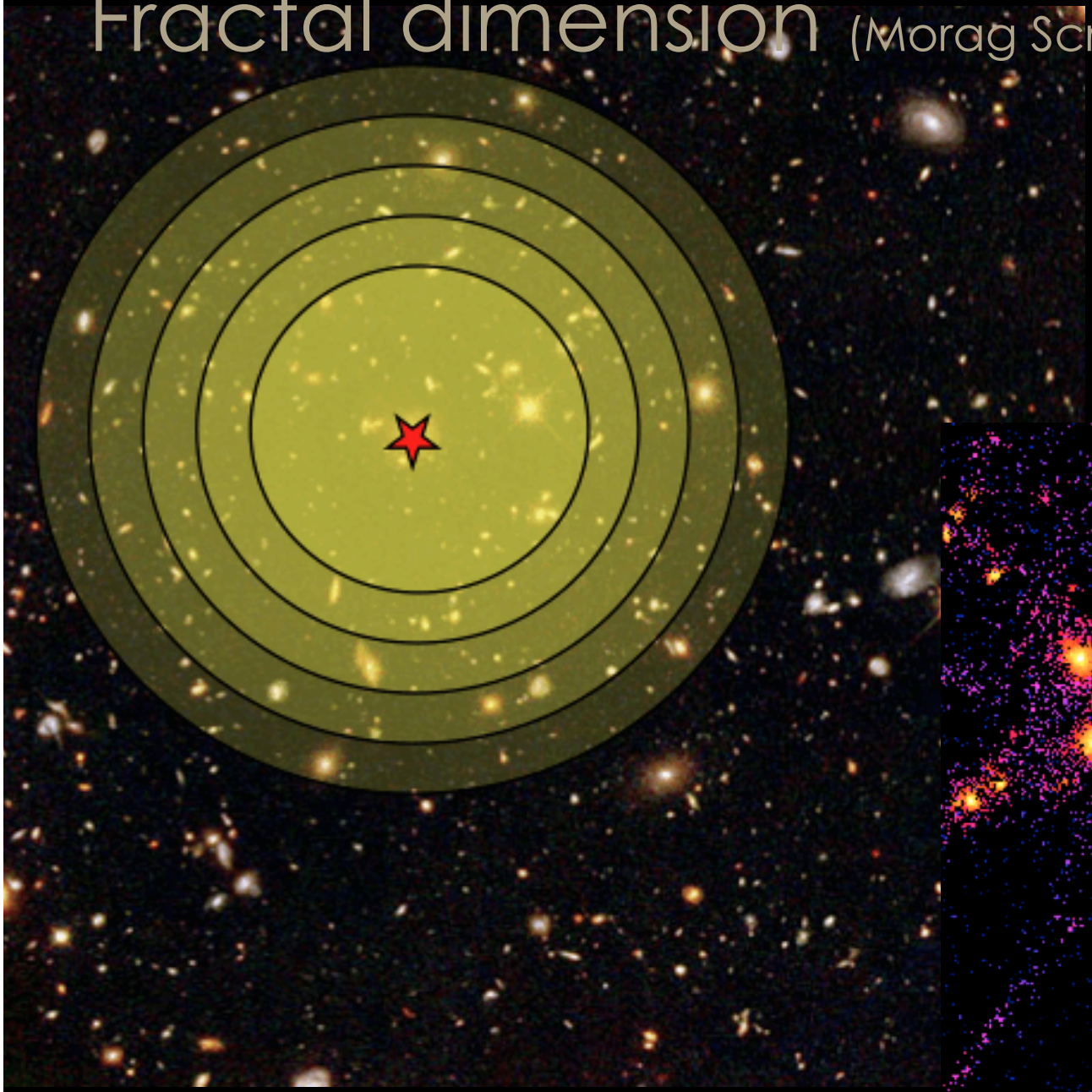
Paper 2: Neutrino mass + number

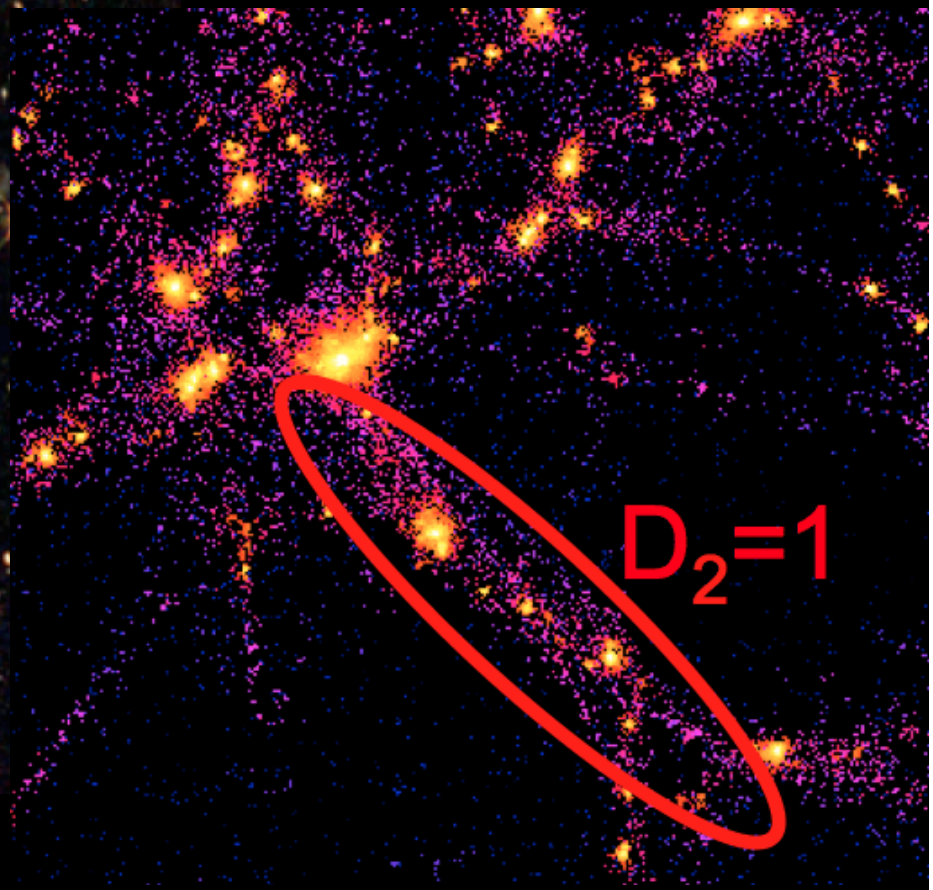


Scrimgeour, Davis, Blake et al. 2012

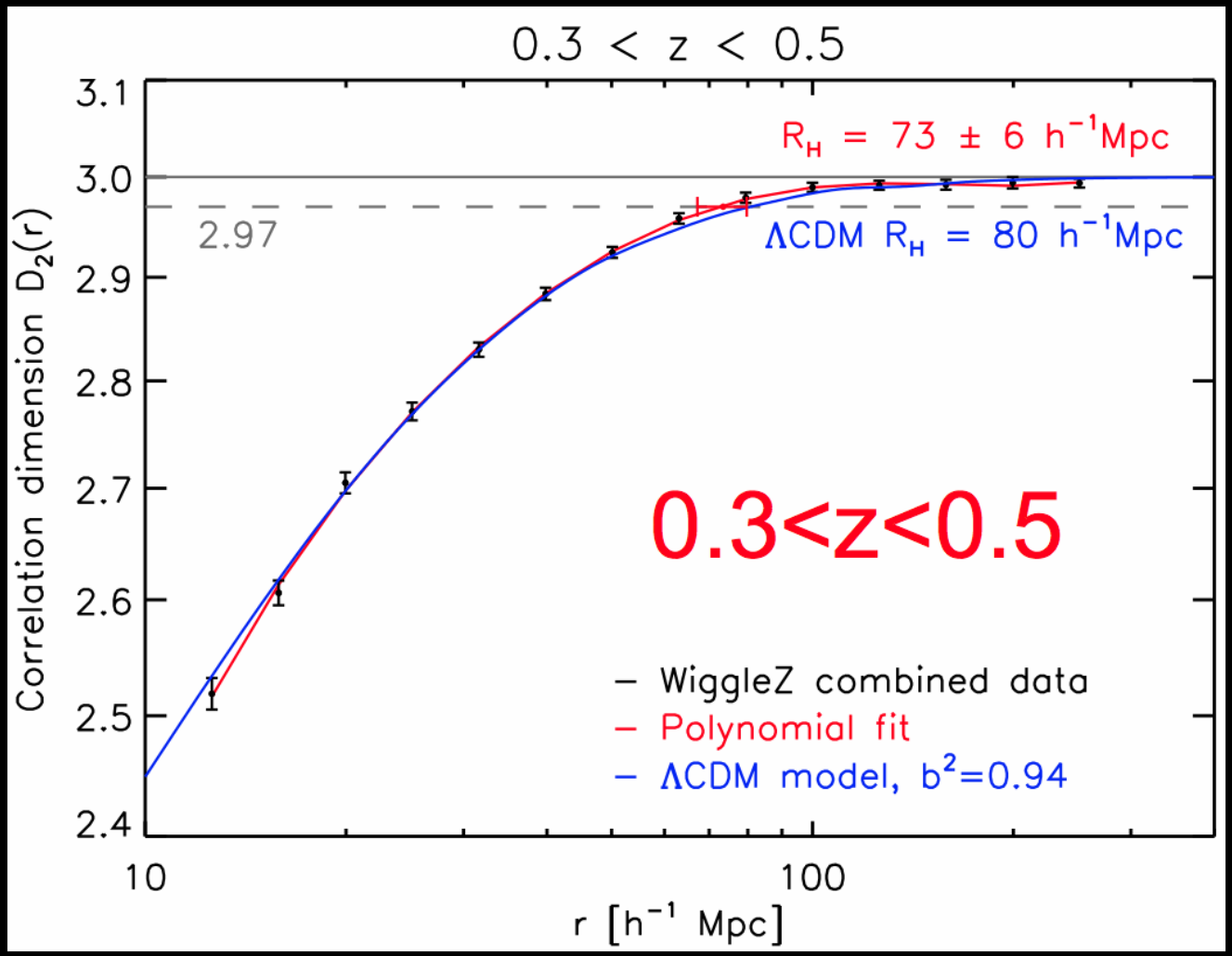
5. HOMOGENEITY

Fractal dimension (Morag Scrimgeour, ICRAR)





$$N(<r) \propto r^{D_2}$$



Parkinson, Riemer-Sørensen, Blake, Poole, Davis, et al. in prep

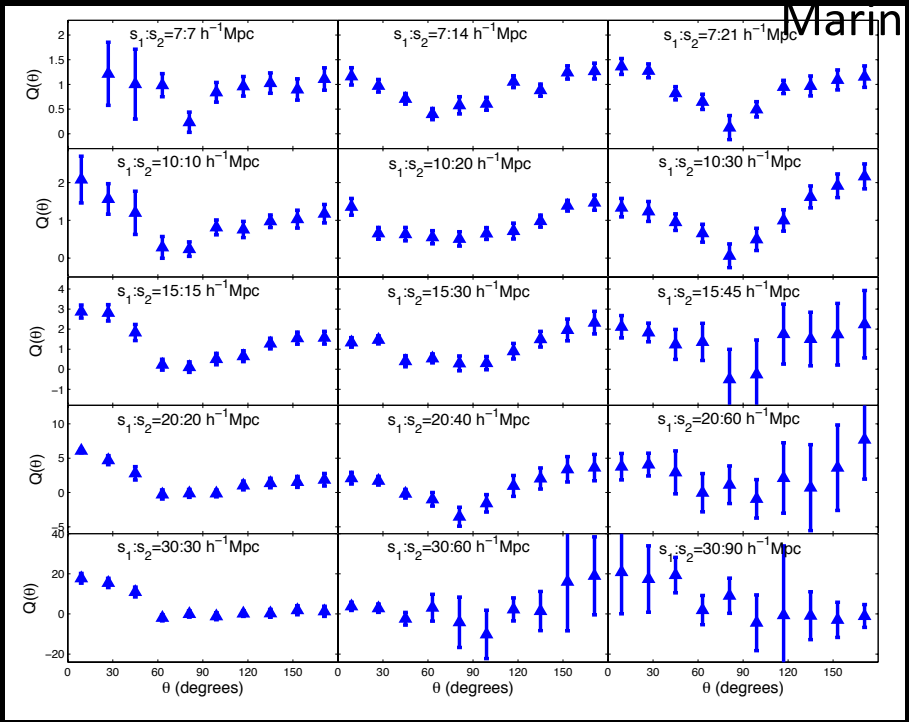
6. FULL POWER SPECTRUM DATA RELEASE + COSMOMC

Watch this space.

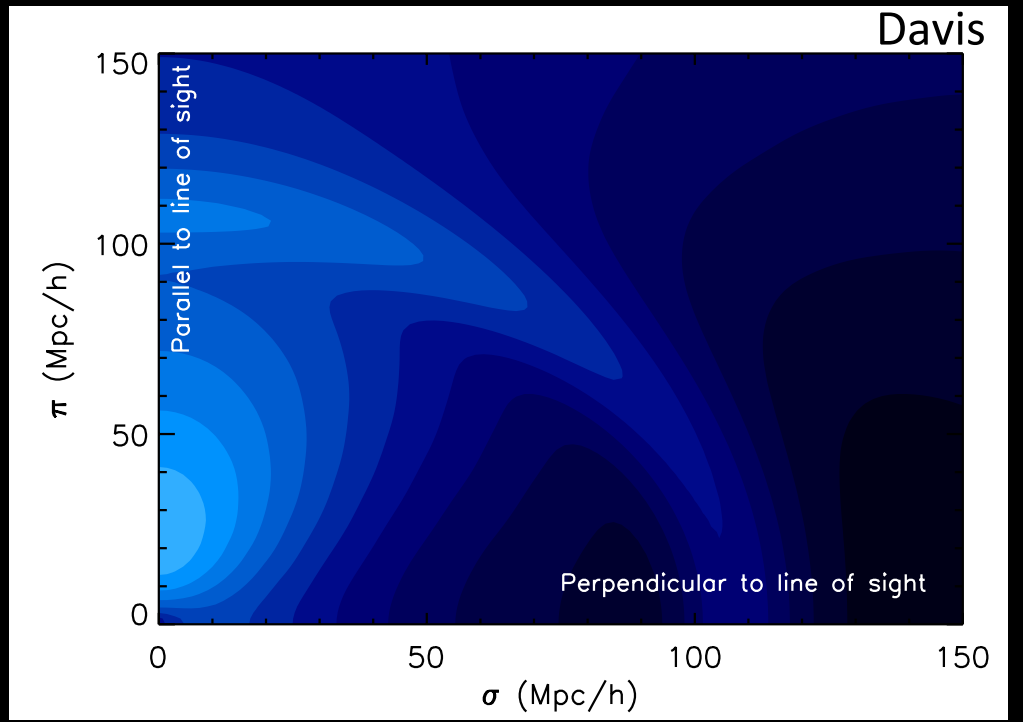
(ΛCDM wins)

Other Upcoming Results (with WigglerZ at this conference)

Higher-order statistics (see Felipe Marin)



2D BAO and reconstruction (see Eyal Kazin)



Summary

WiggleZ is a great data set, with many interesting cosmology results

We're about to release our data and CosmoMC module

We hope you would like to use it and are happy to work with you to help