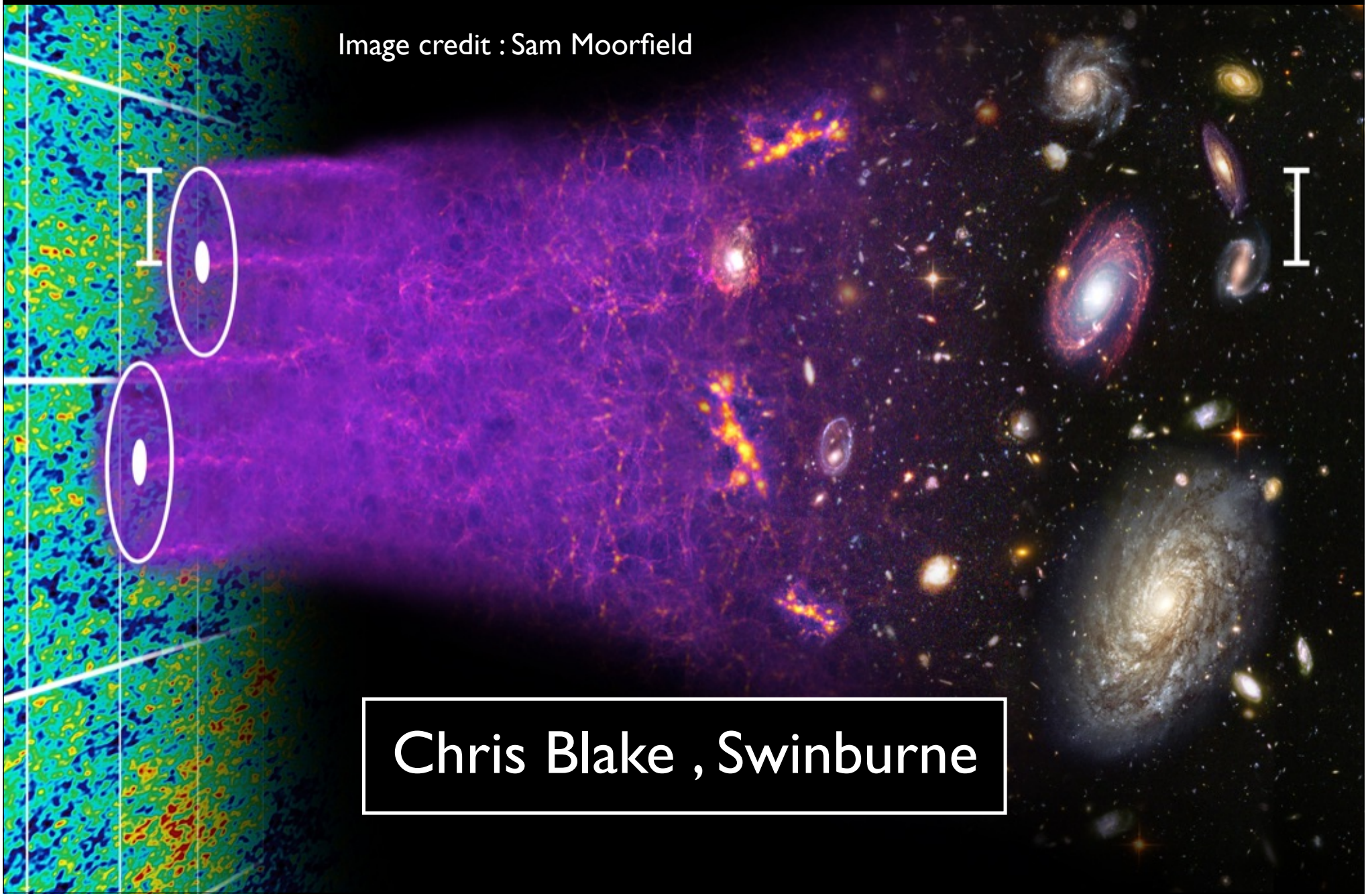
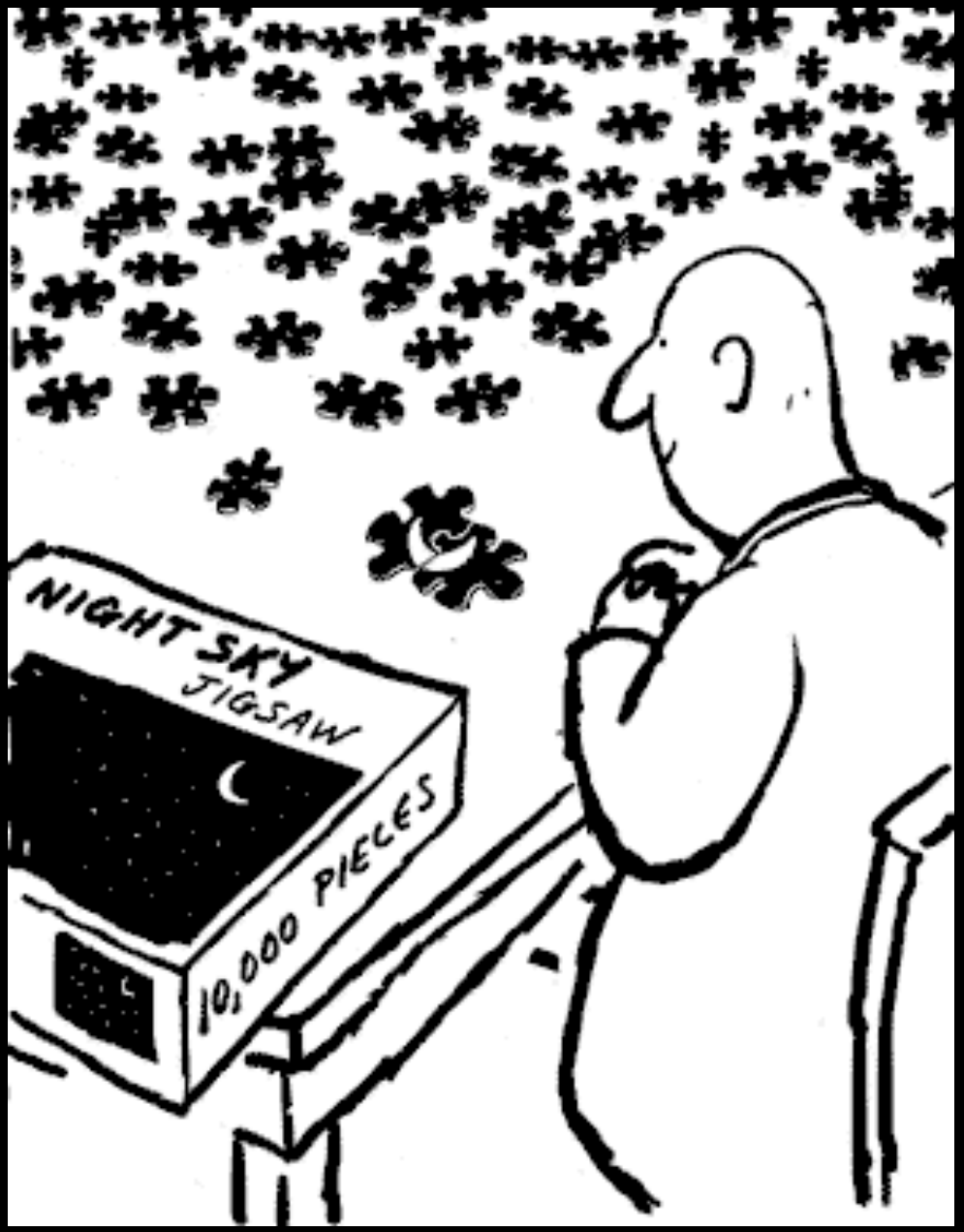
Measuring dark energy with WiggleZ



Chris Blake , Swinburne

The dark energy puzzle



What is "dark energy" ?

1) new, missing matter-energy component

2) failure of the laws of gravity

3) failure of the laws of quantum theory

4) systematic errors in our observations?

The WiggleZ Dark Energy Survey

- Large-scale structure survey covering SDSS-like volumes over a range of higher redshifts to z=1
- Test the cosmological model in three ways :
- (1) Use the baryon acoustic peak as a standard ruler to measure cosmic distances to z=1
- (2) Map the growth rate of structure to z=1
- (3) Use Alcock-Paczynski distortions to measure a non-parametric expansion history
- Cross-check evidence for dark energy from SNe

WiggleZ survey basics

The WiggleZ Survey (observational) Team

Swinburne : Chris Blake , Carlos Contreras , Warrick Couch , Darren Croton , Karl Glazebrook , Tornado Li , Greg Poole , Emily Wisnioski

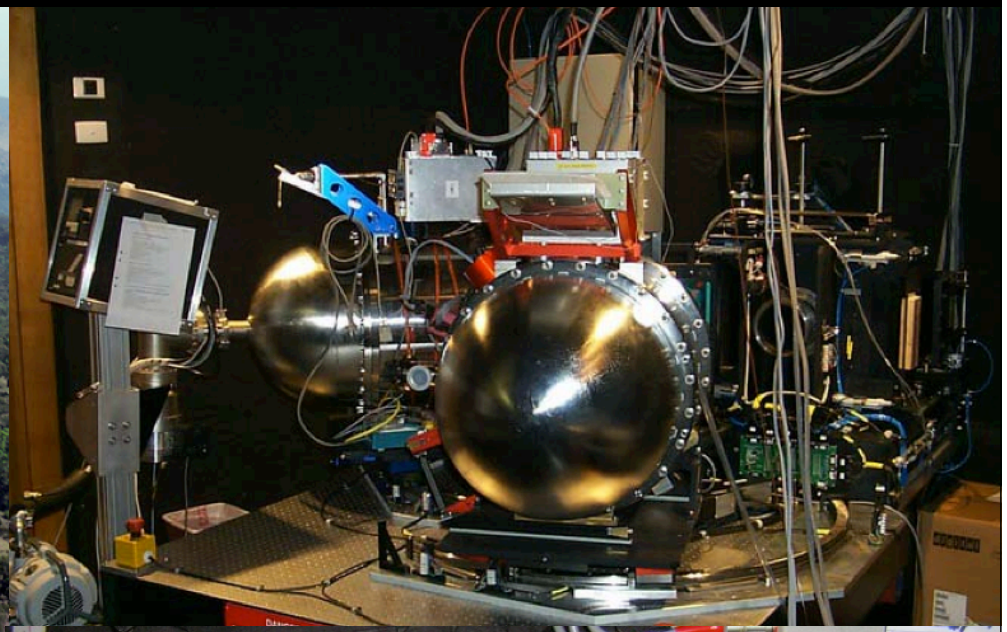
University of Queensland : Tamara Davis , Michael Drinkwater

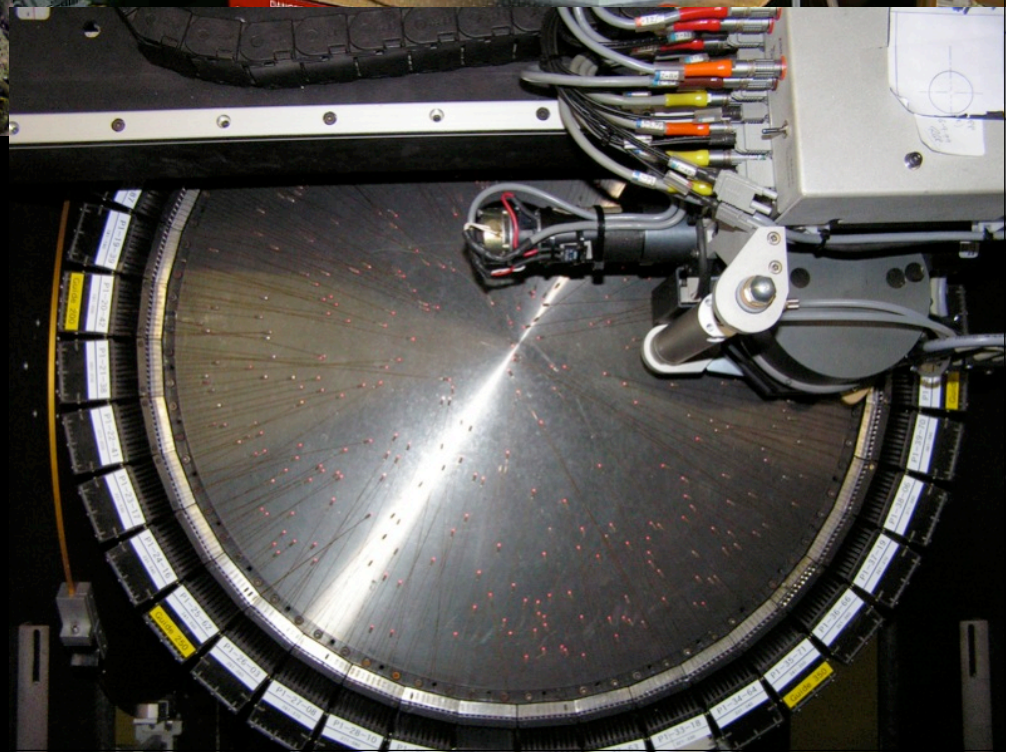
Sarah Brough (AAO) , Matthew Colless (AAO) , Scott Croom (U.Syd.) , Ben Jelliffe (U.Syd.) , Russell Jurek (ATNF) , Kevin Pimbblet (Monash) , Mike Pracy (UNSW) , Rob Sharp (ANU) , David Woods (UBC)

GALEX team : Karl Forster , Barry Madore , Chris Martin , Ted Wyder

RCS2 team : David Gilbank , Mike Gladders , Howard Yee

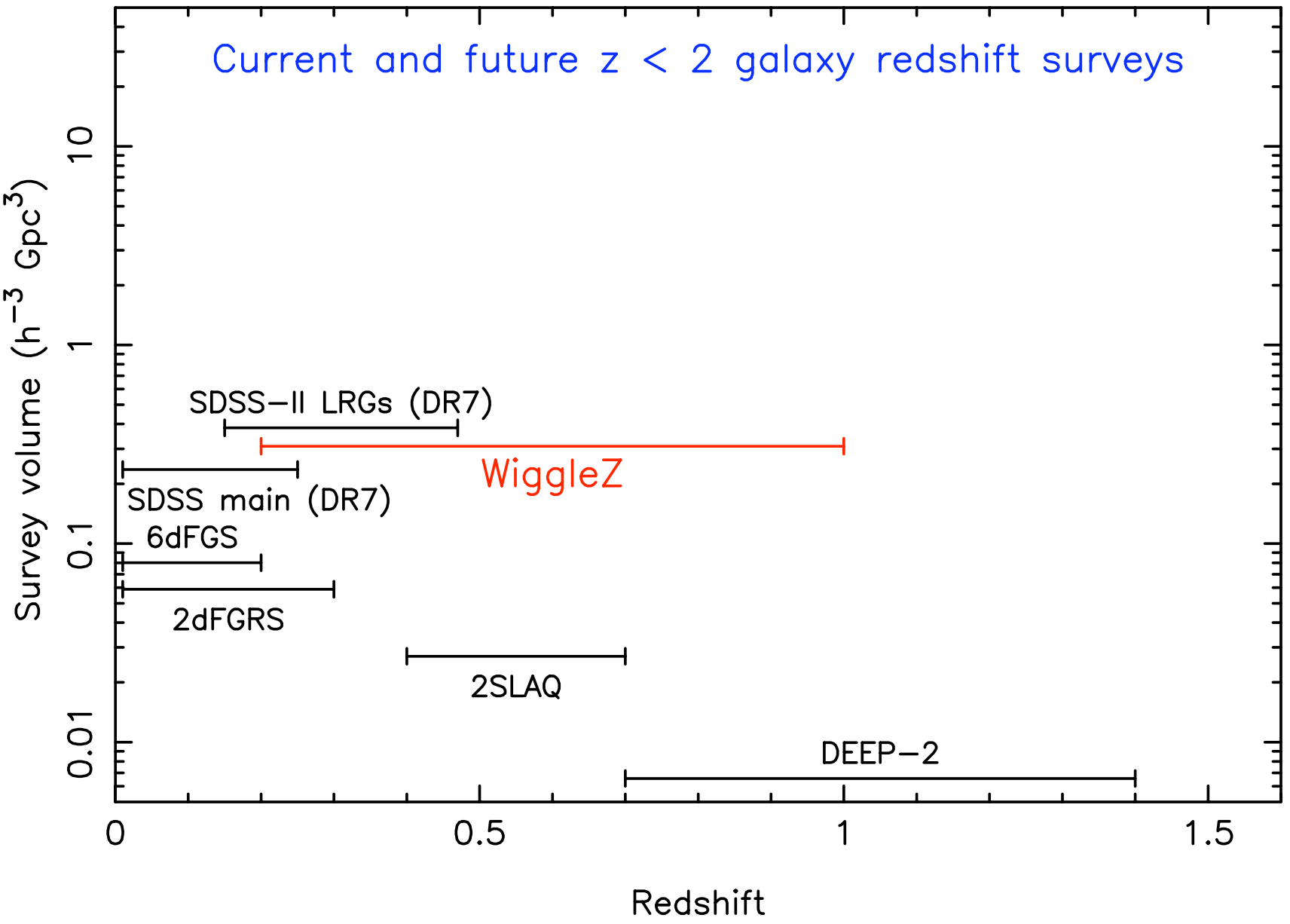
The WiggleZ Dark Energy Survey



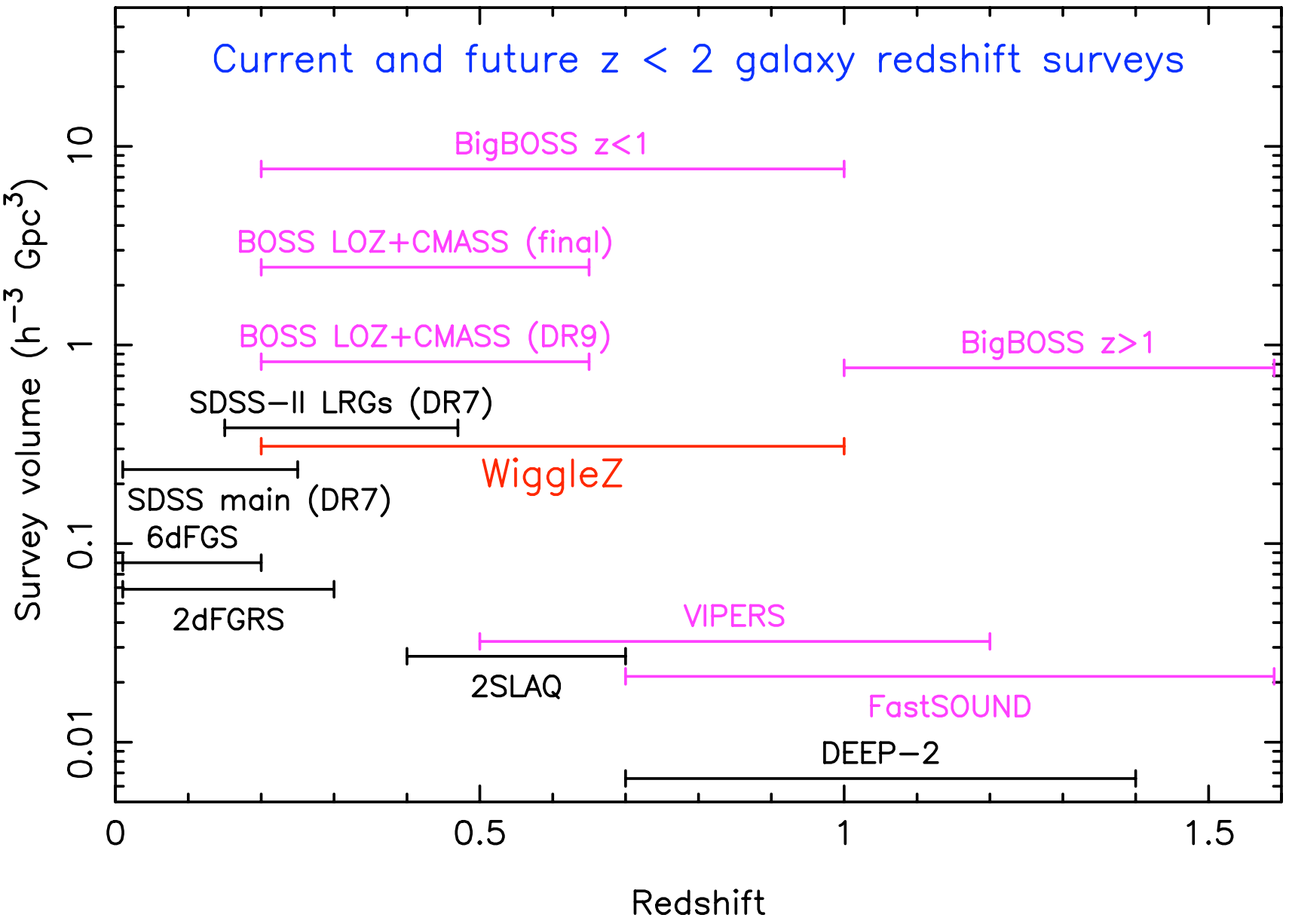


- 1000 sq deg , $0.2 < z < 1.0$
- 200,000 redshifts
- blue star-forming galaxies
- Aug 2006 - Jan 2011

Survey comparison

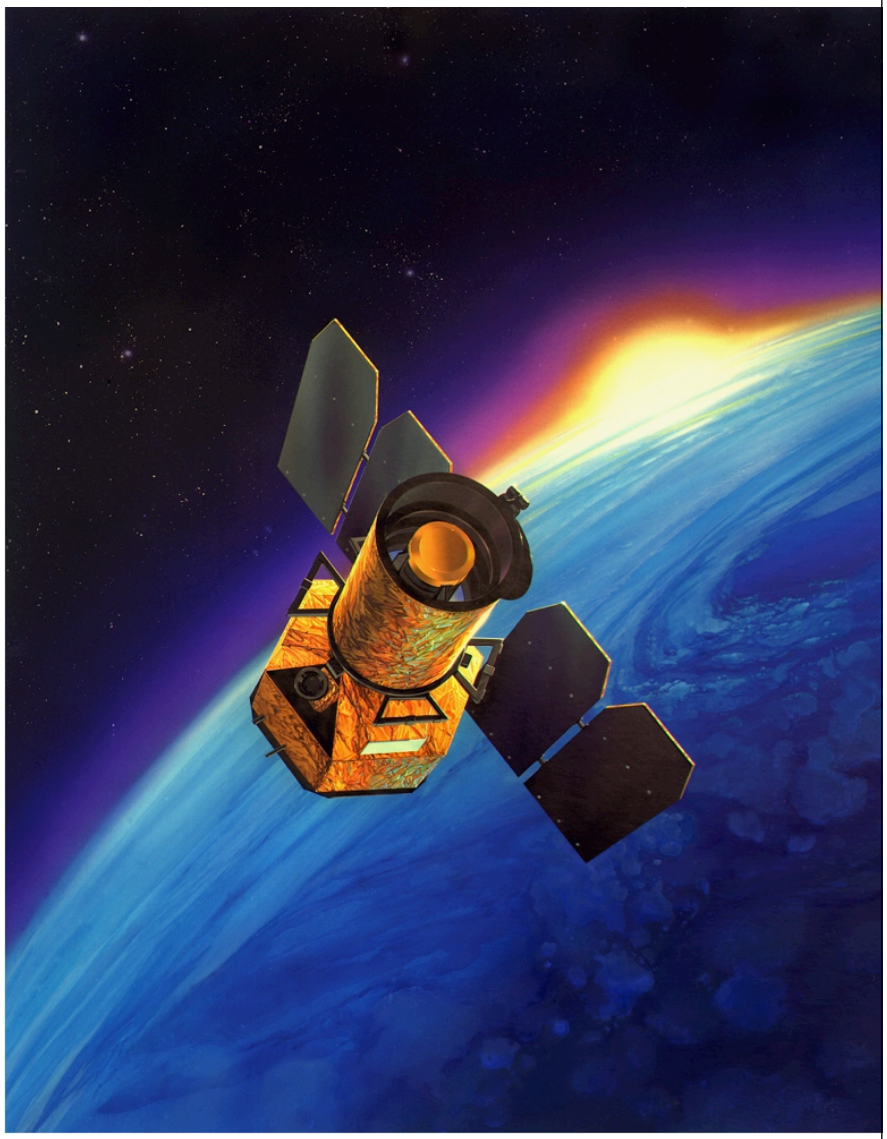


Survey comparison

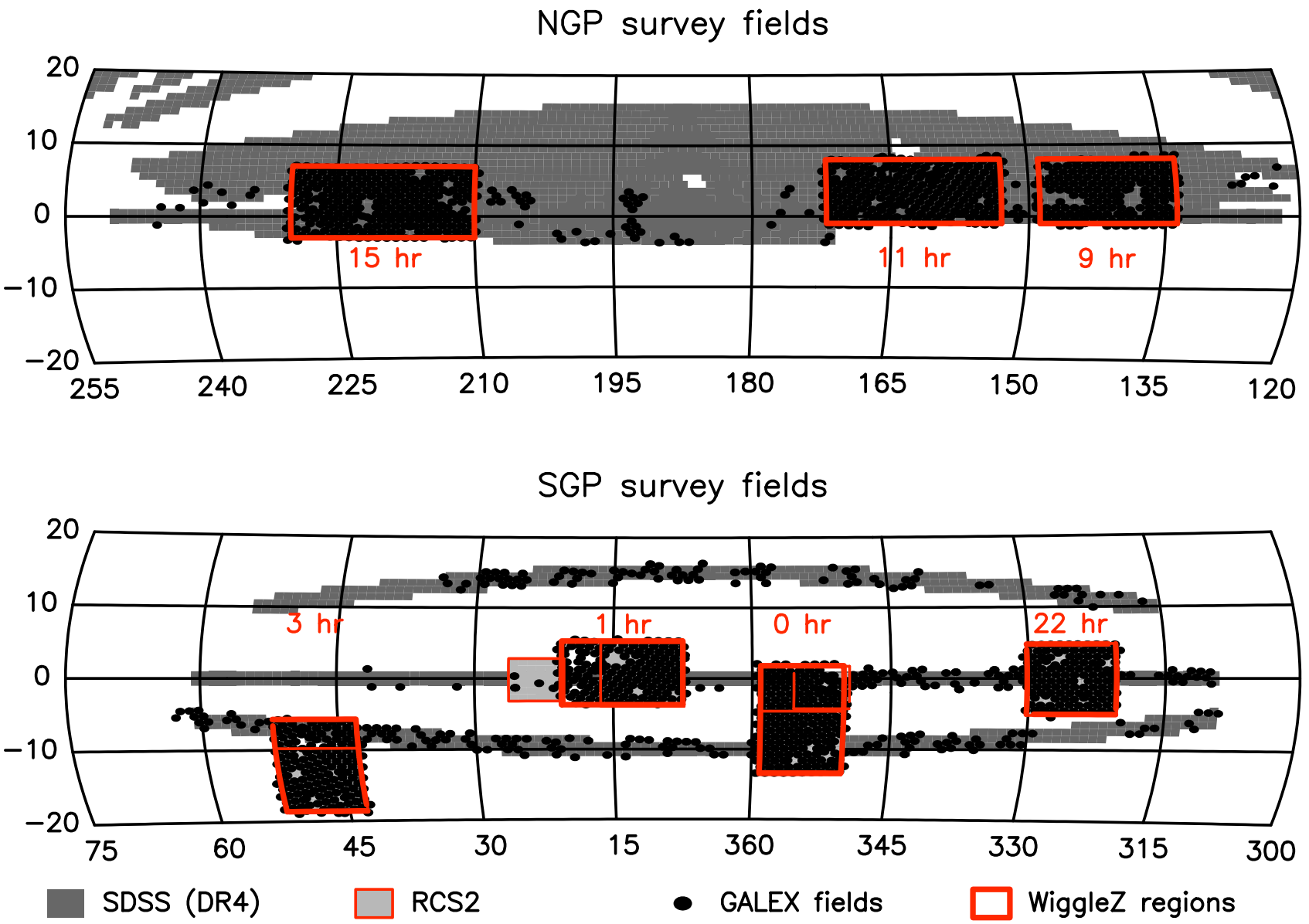


Survey design

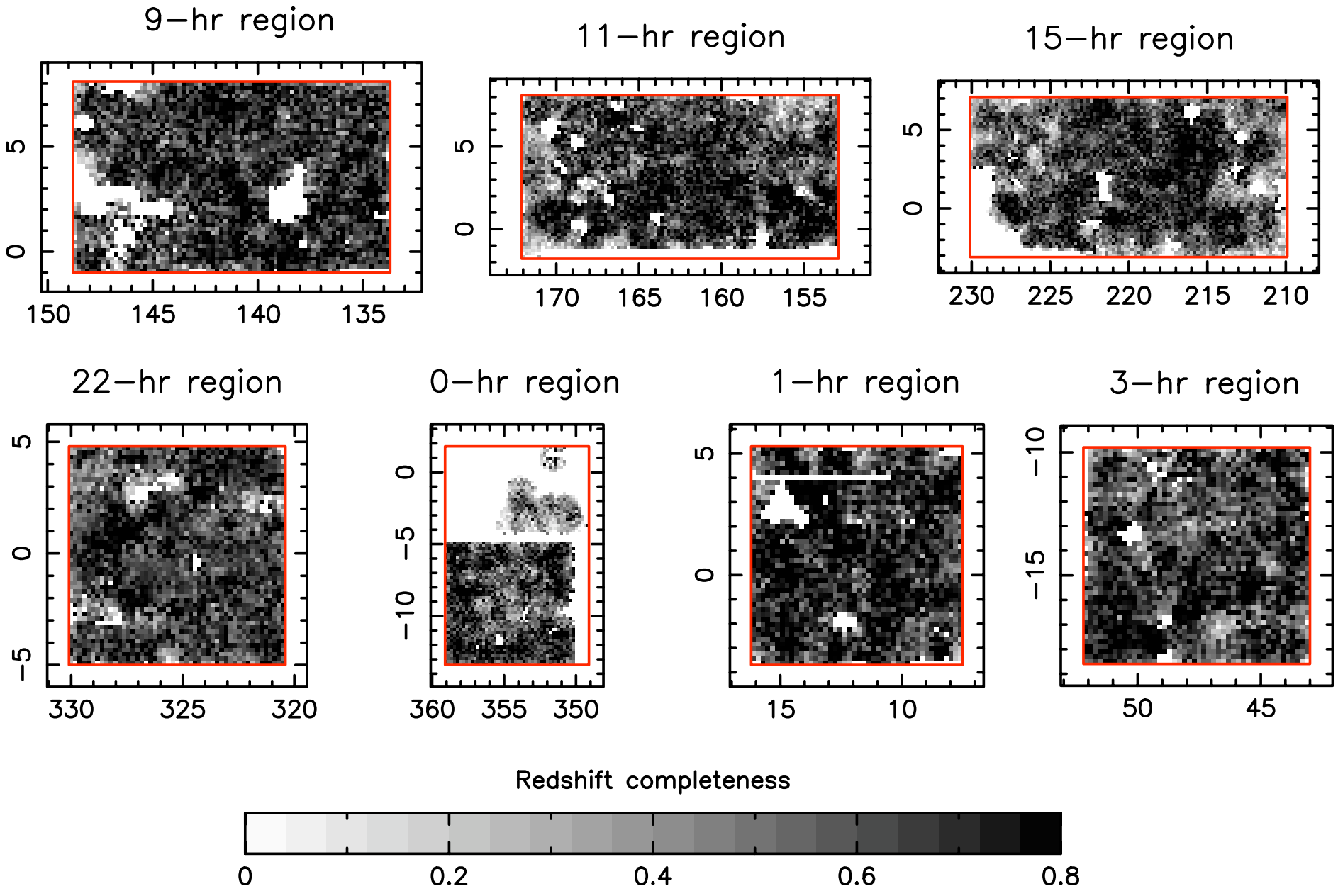
- Follow up UV-selected sources from GALEX imaging
- Colour cuts select high-redshift galaxies
- Star-forming galaxies : redshifts from emission lines, SFR 10-100 solar masses per year
- Short 1-hr exposures - maximize numbers with 70% redshift completeness



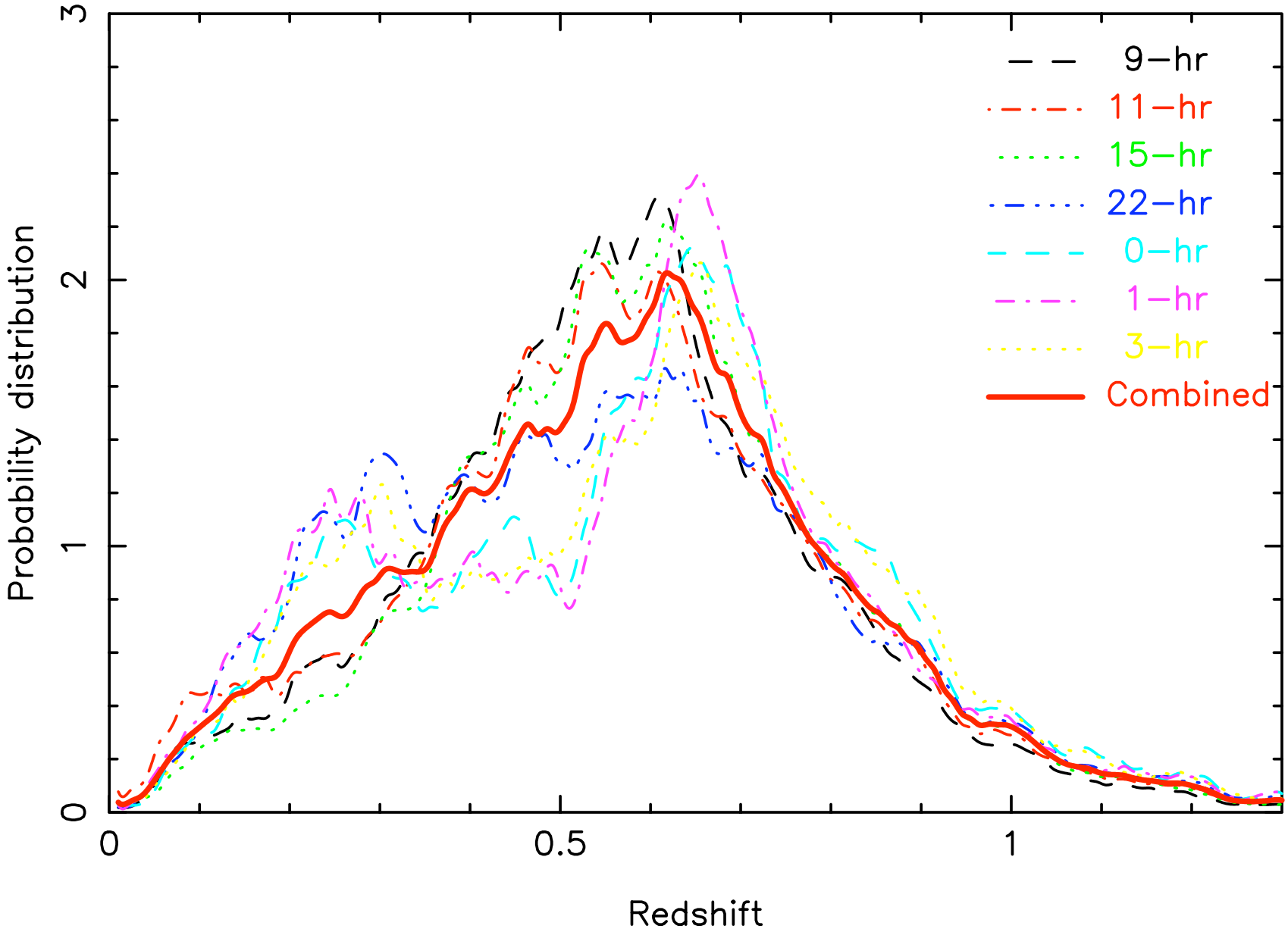
Survey design



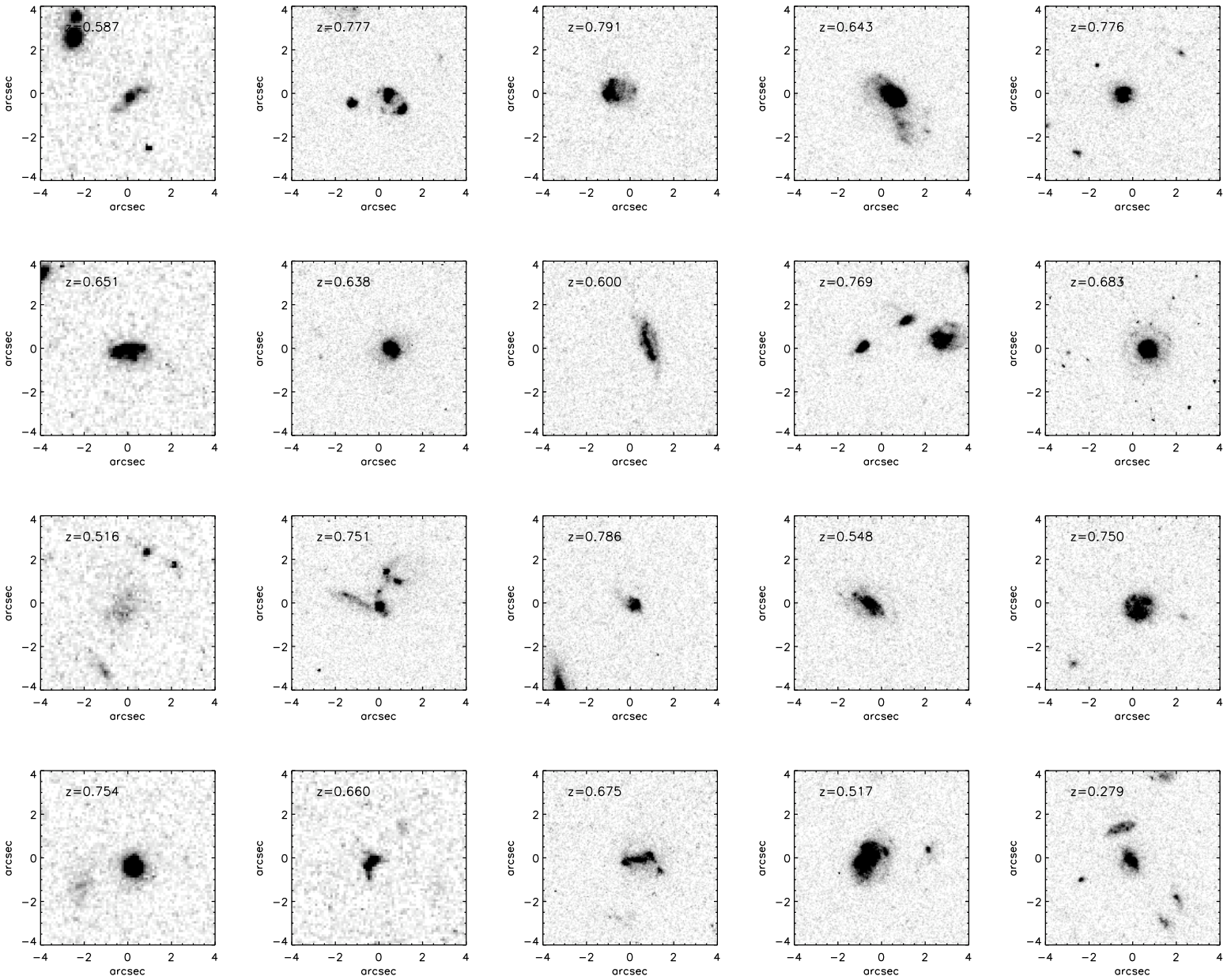
Survey design



Redshift distribution



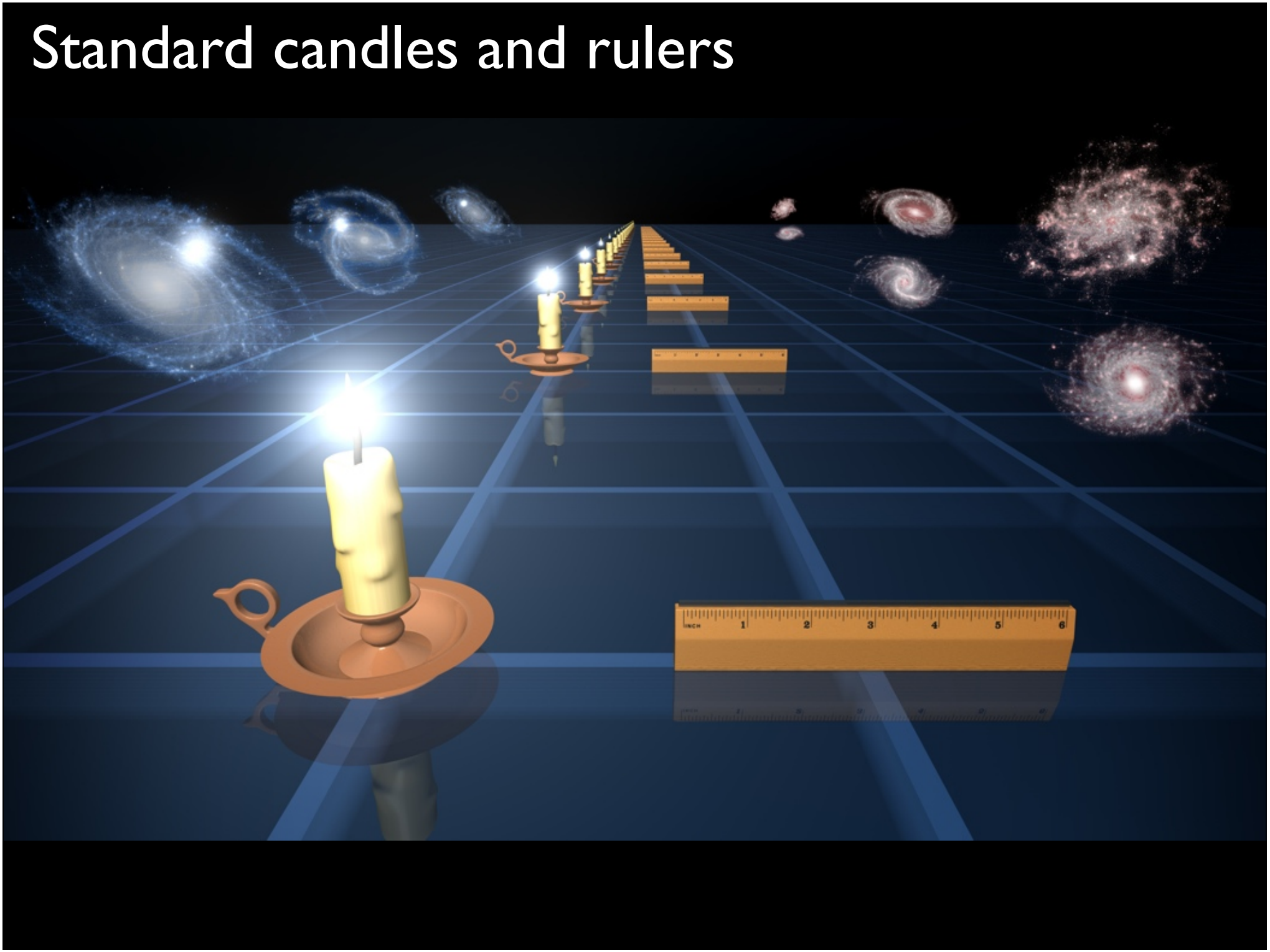
Galaxy targets



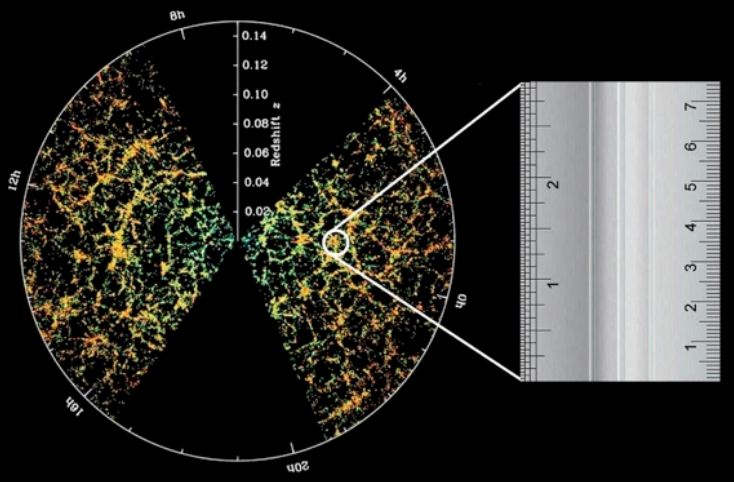
(Credit: Mike Pracy)

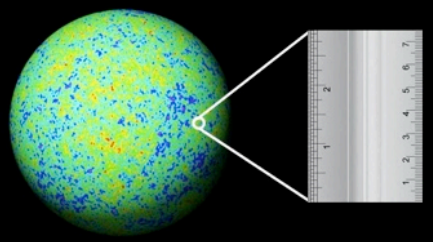
Measurement of the distance-redshift relation

Standard candles and rulers

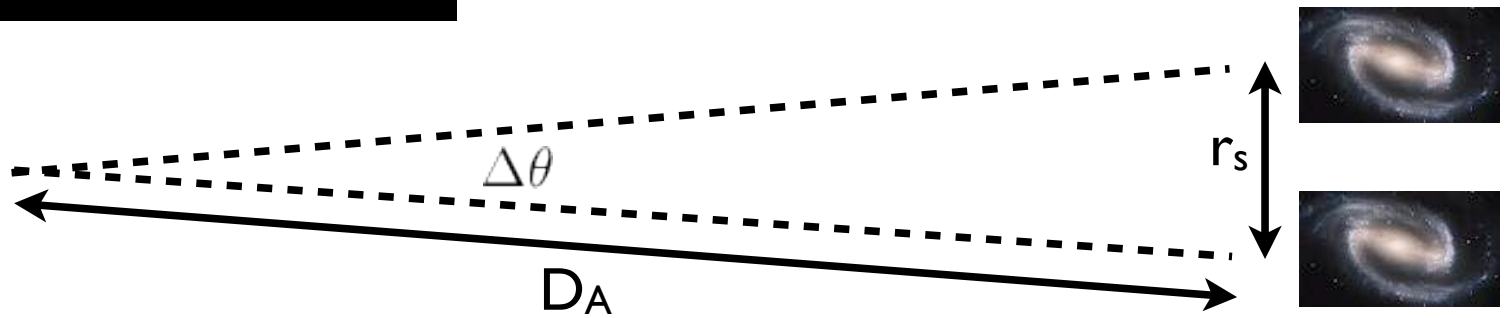


Standard ruler : baryon acoustic peak

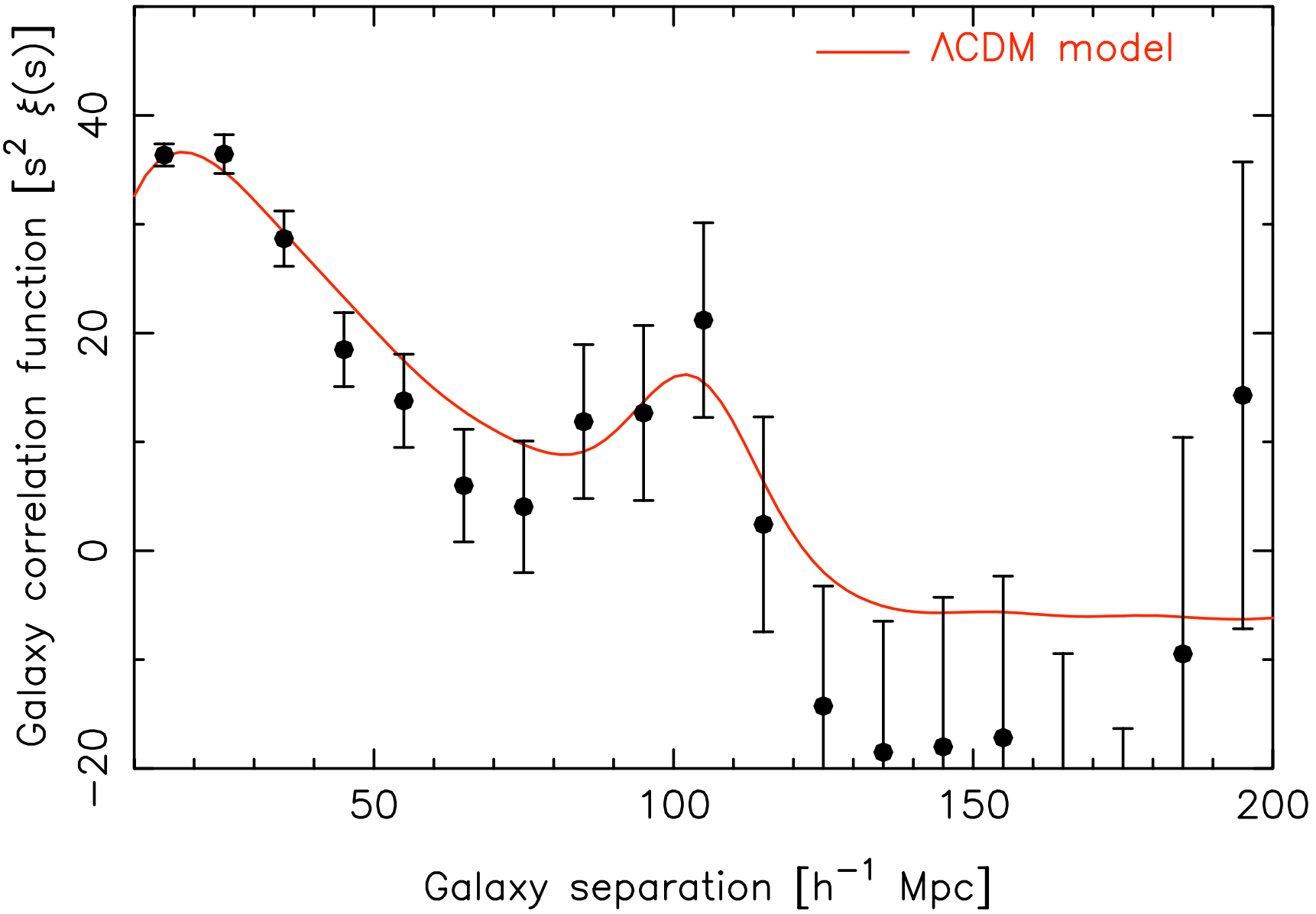




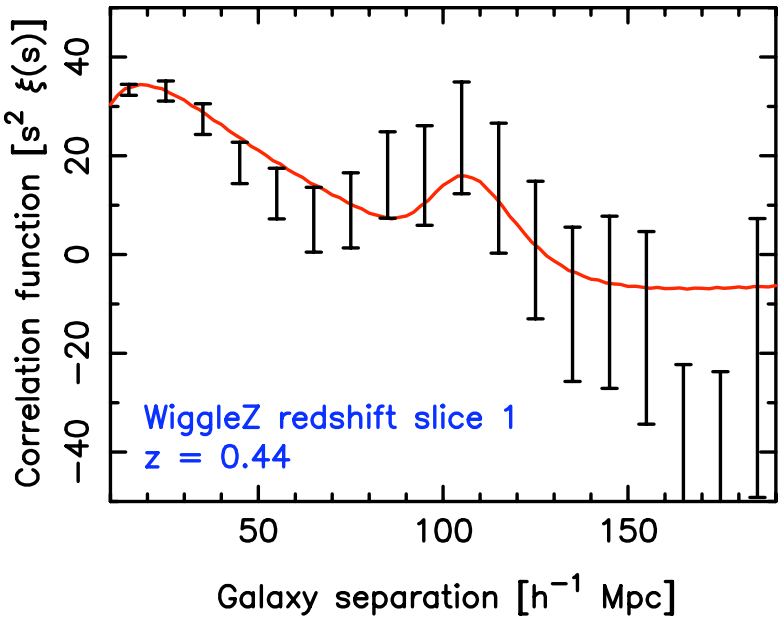
- Preferred co-moving separation of 105 h^{-1} Mpc between clumps imprinted at recombination
- We observe a preferred angular separation between galaxies at some redshift
- Allows distance determination by simple geometry

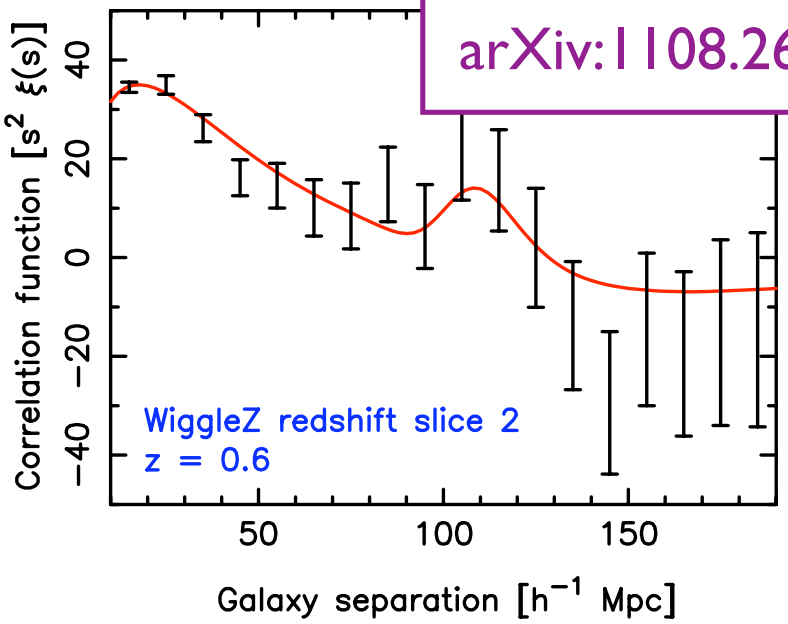


The baryon acoustic peak in WiggleZ

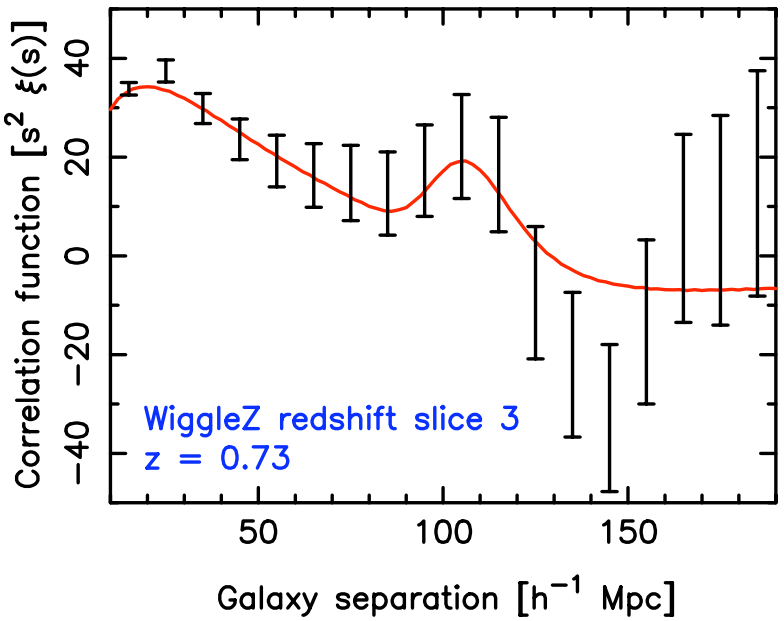


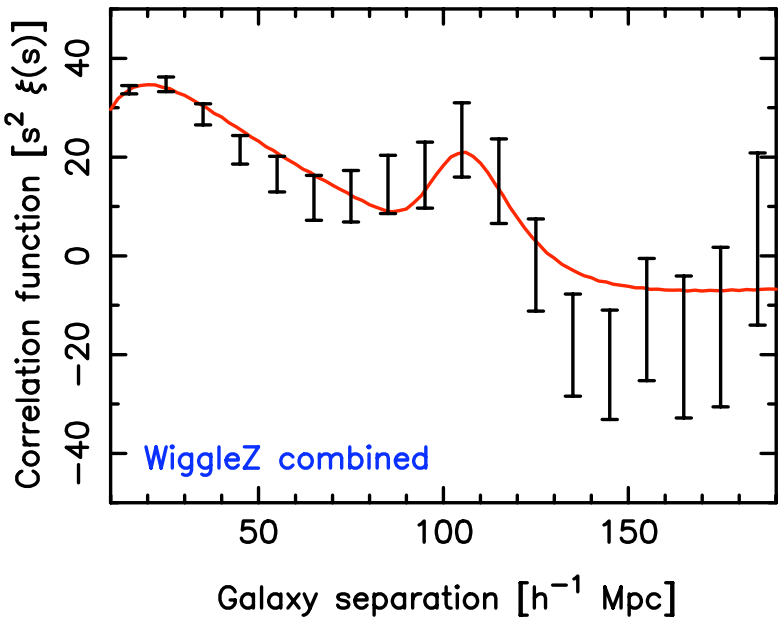
The baryon acoustic peak in WiggleZ



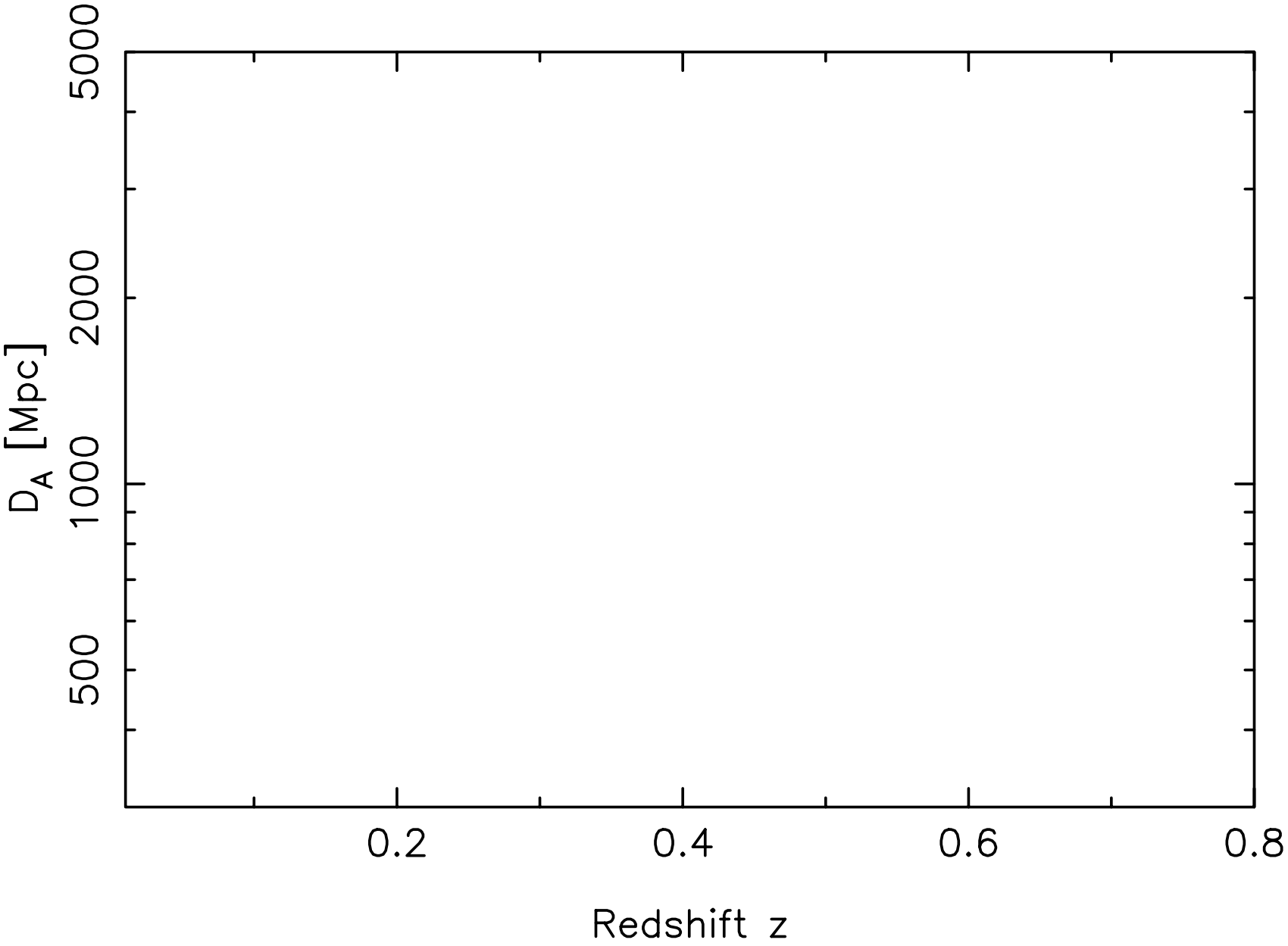


arXiv:1108.2635

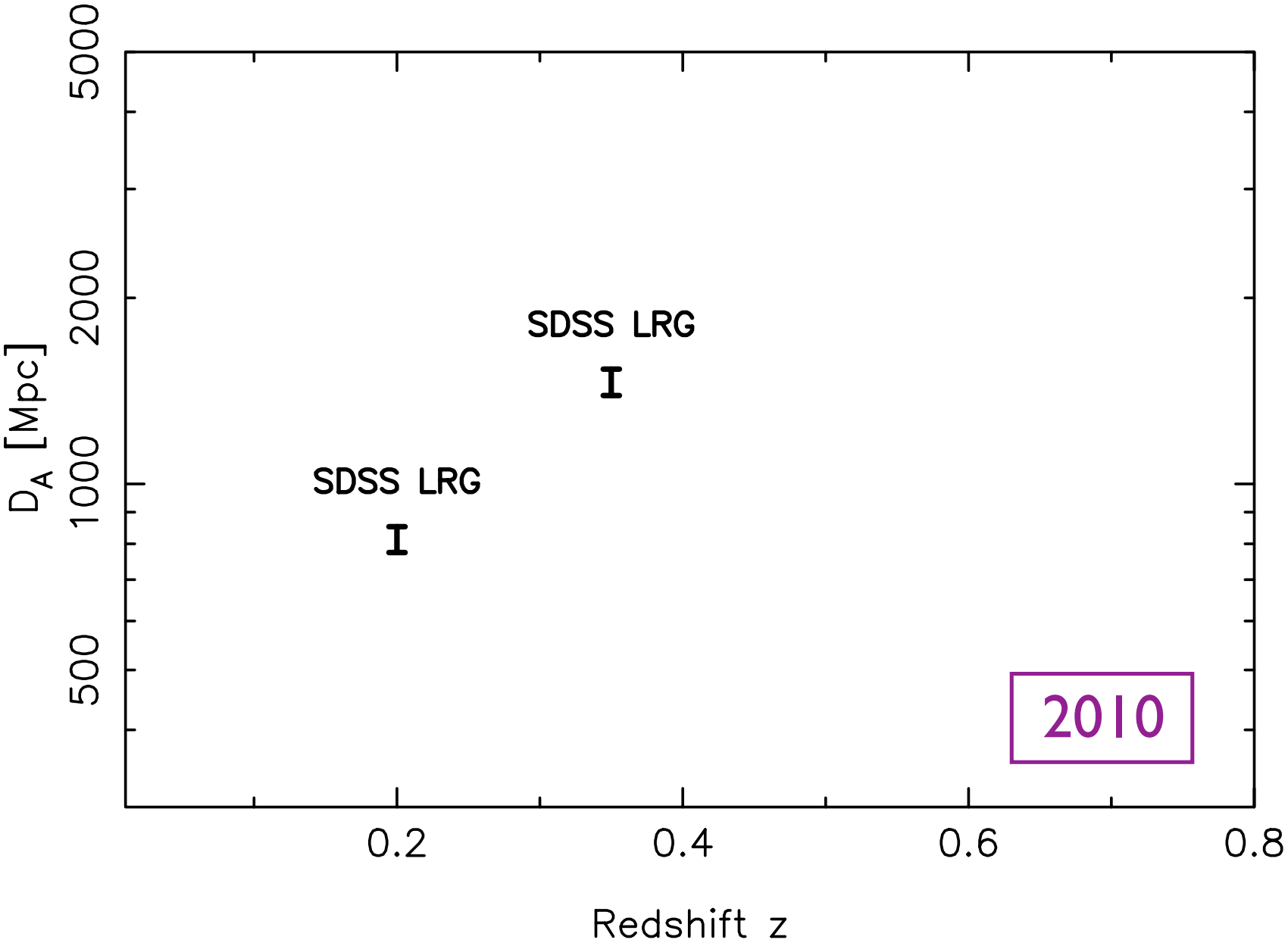




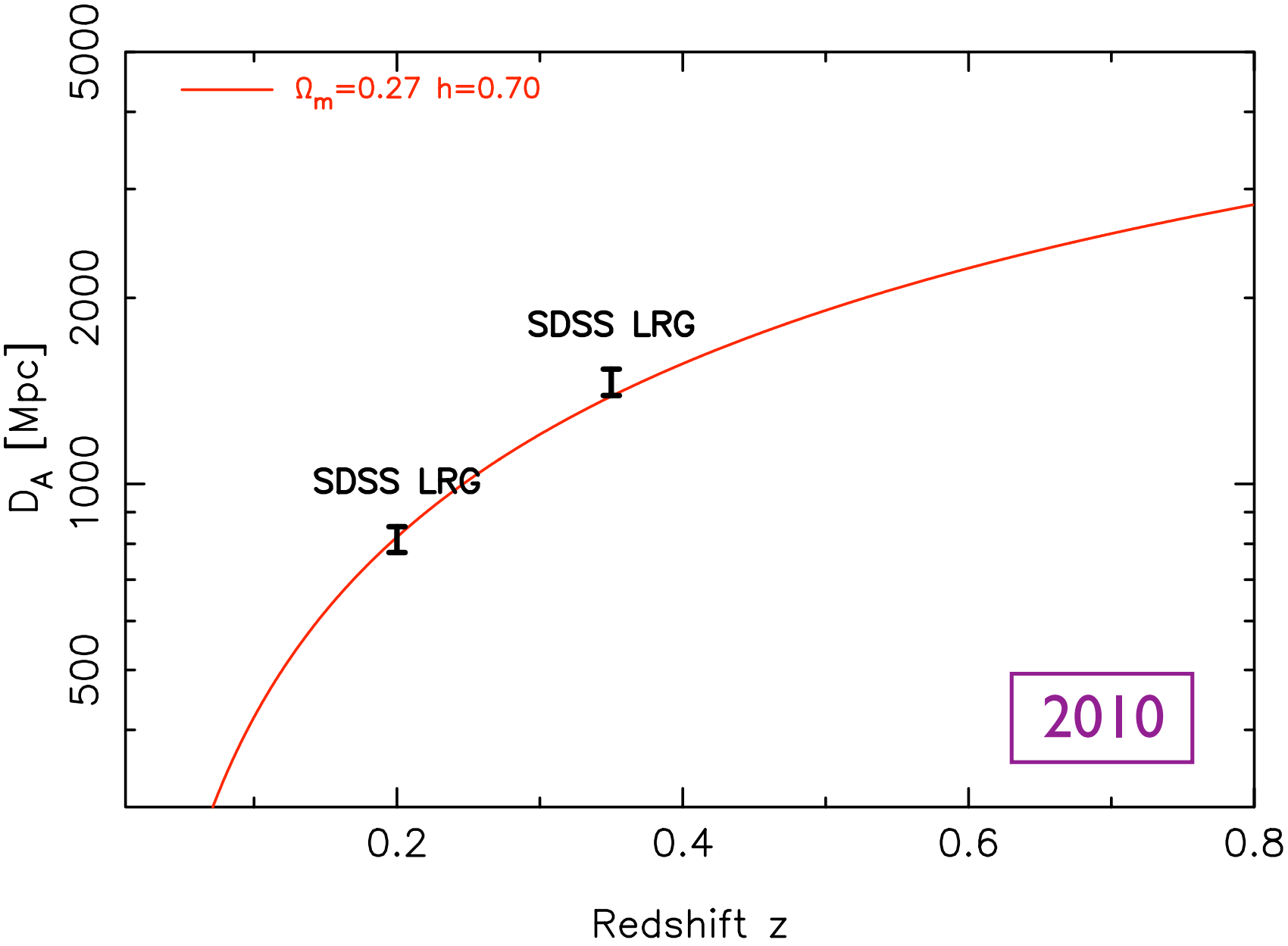
BAO Hubble diagram



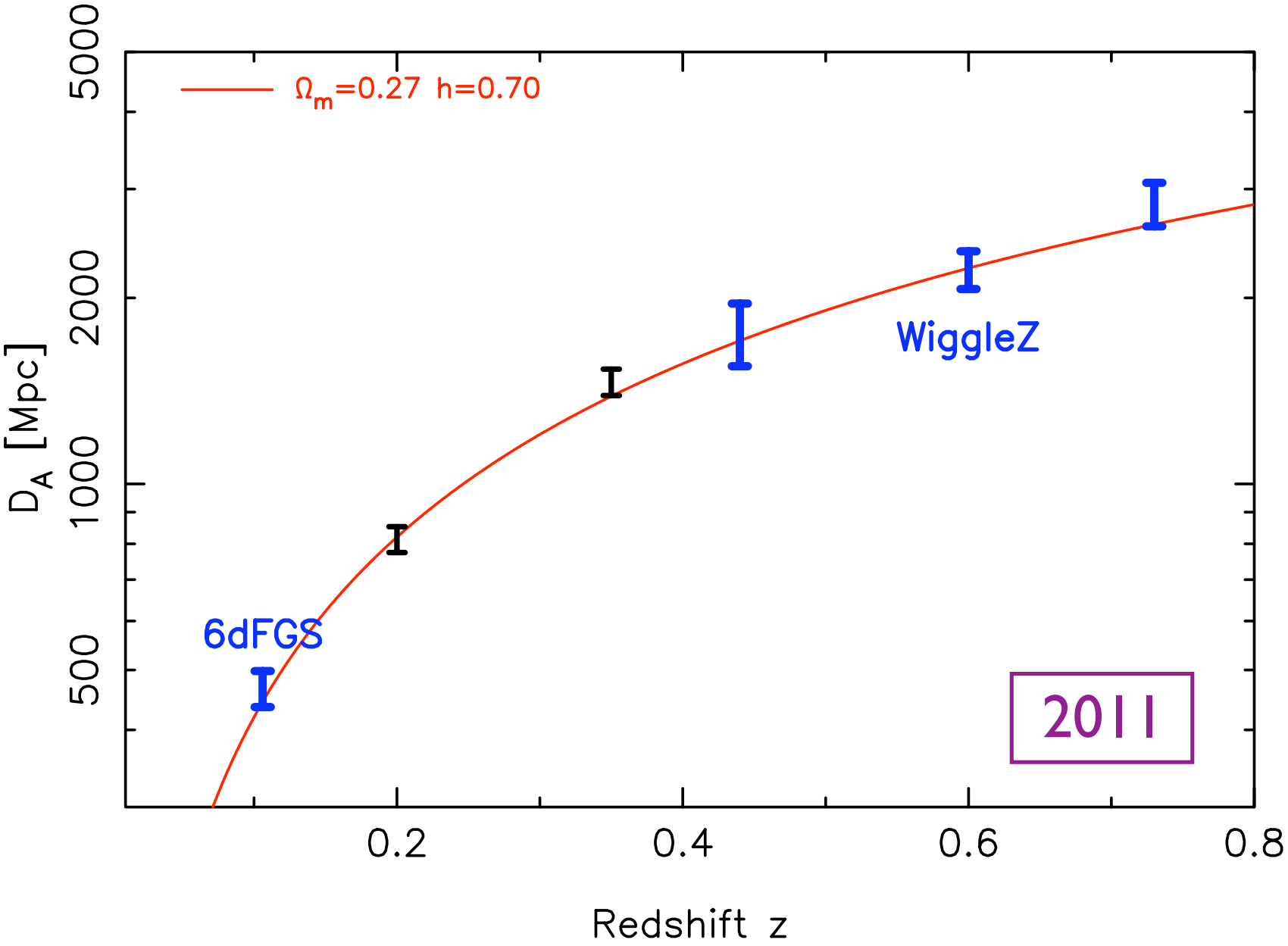
BAO Hubble diagram



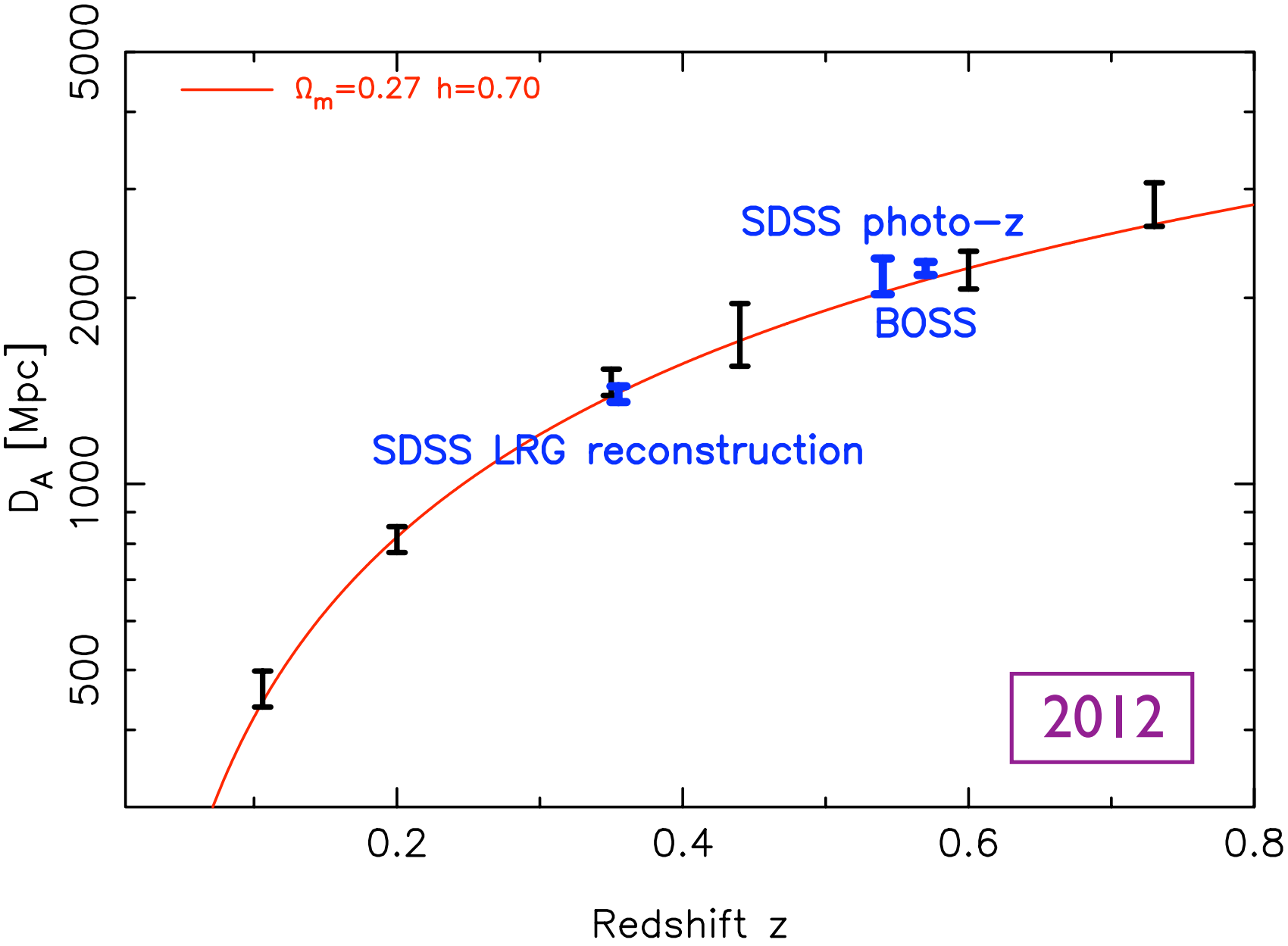
BAO Hubble diagram



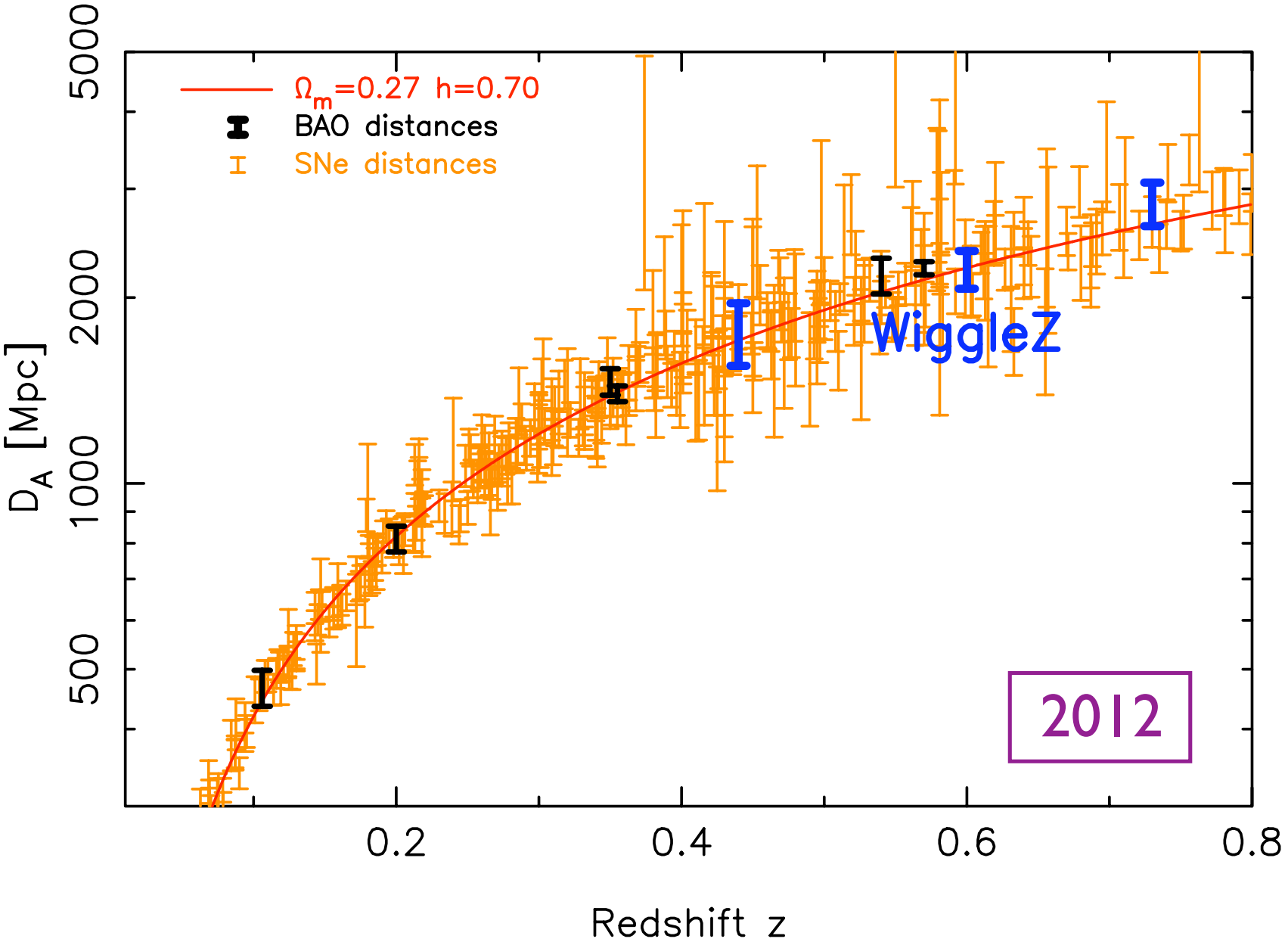
BAO Hubble diagram



BAO Hubble diagram



BAO Hubble diagram

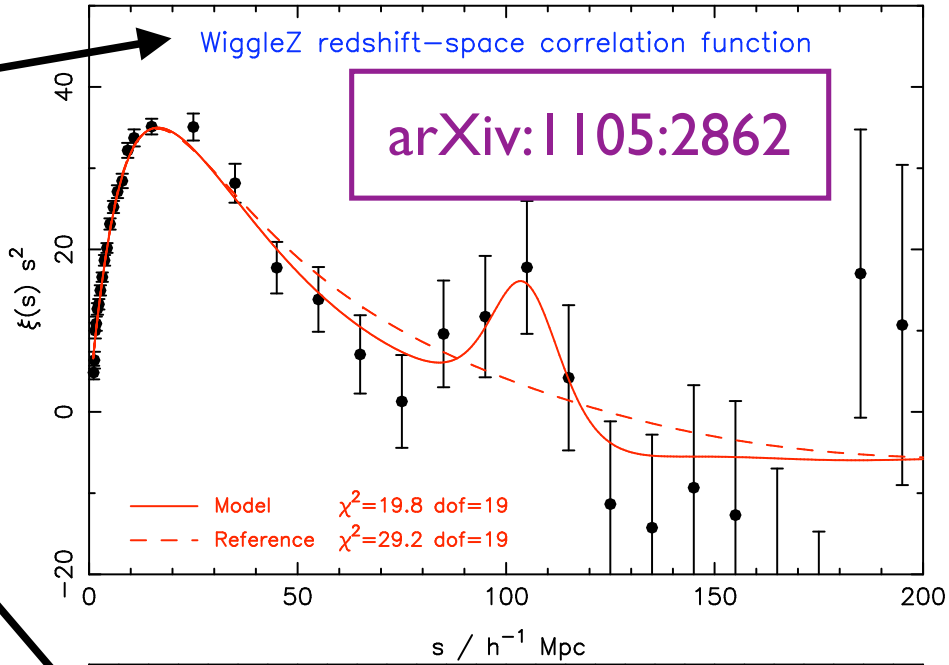


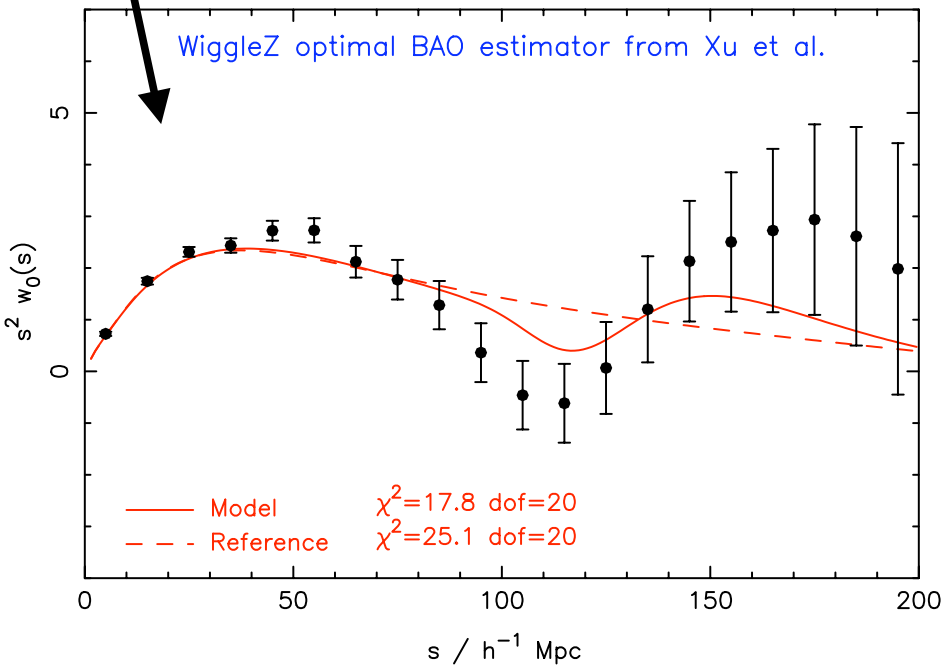
Comparison of BAO statistics in WiggleZ

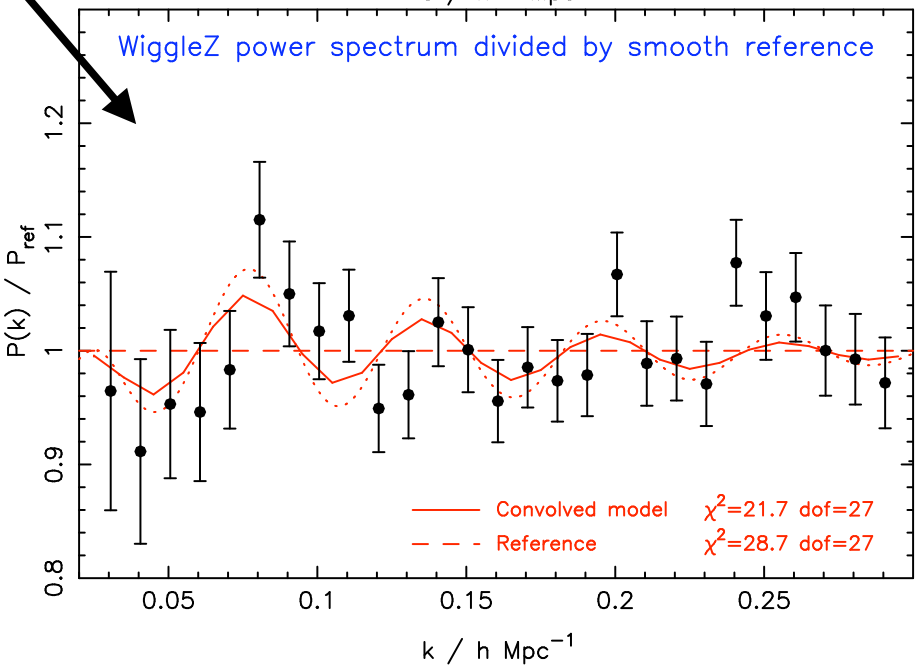
Correlation function

Power spectrum

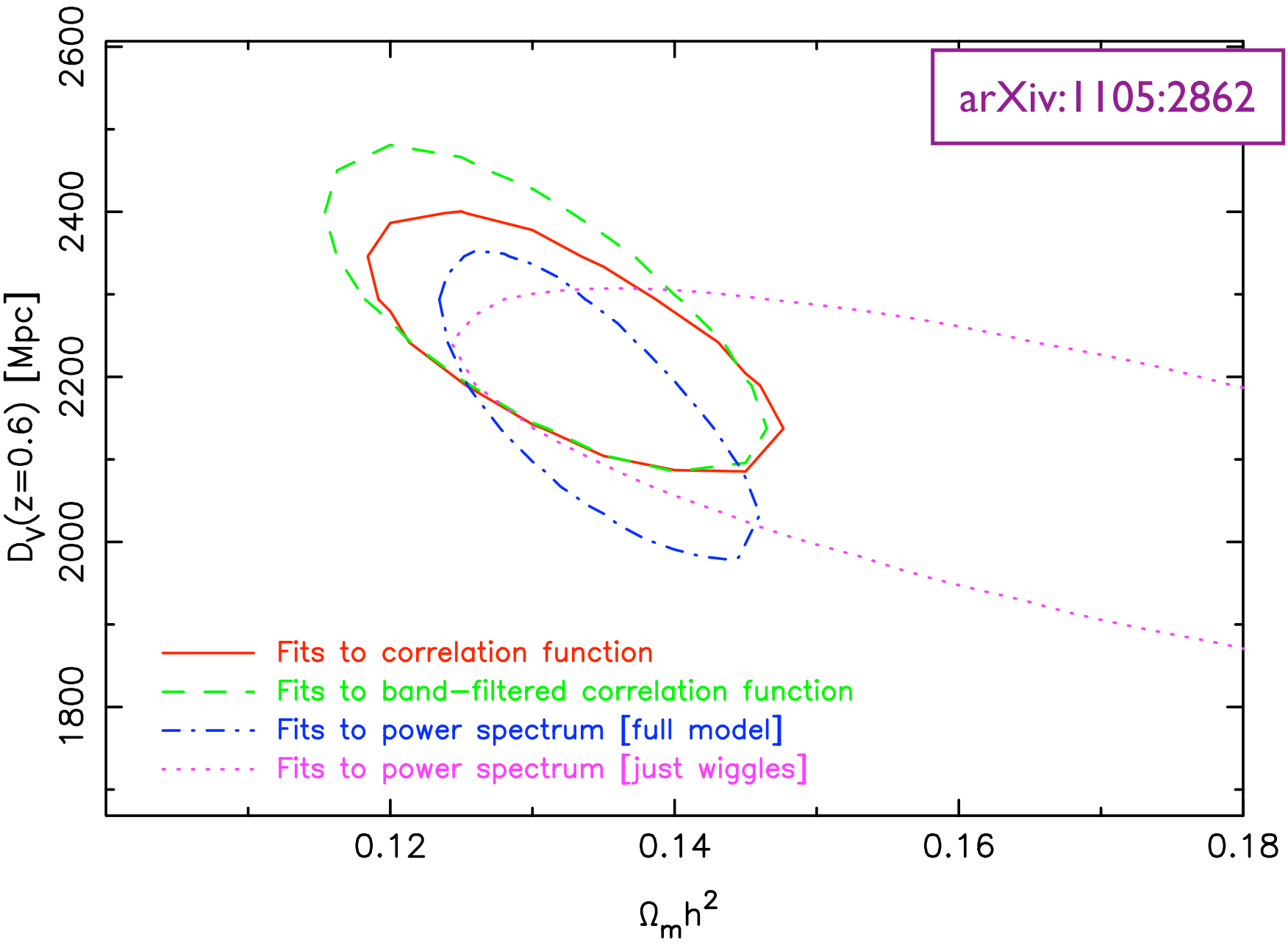
Band-filtered correlation function





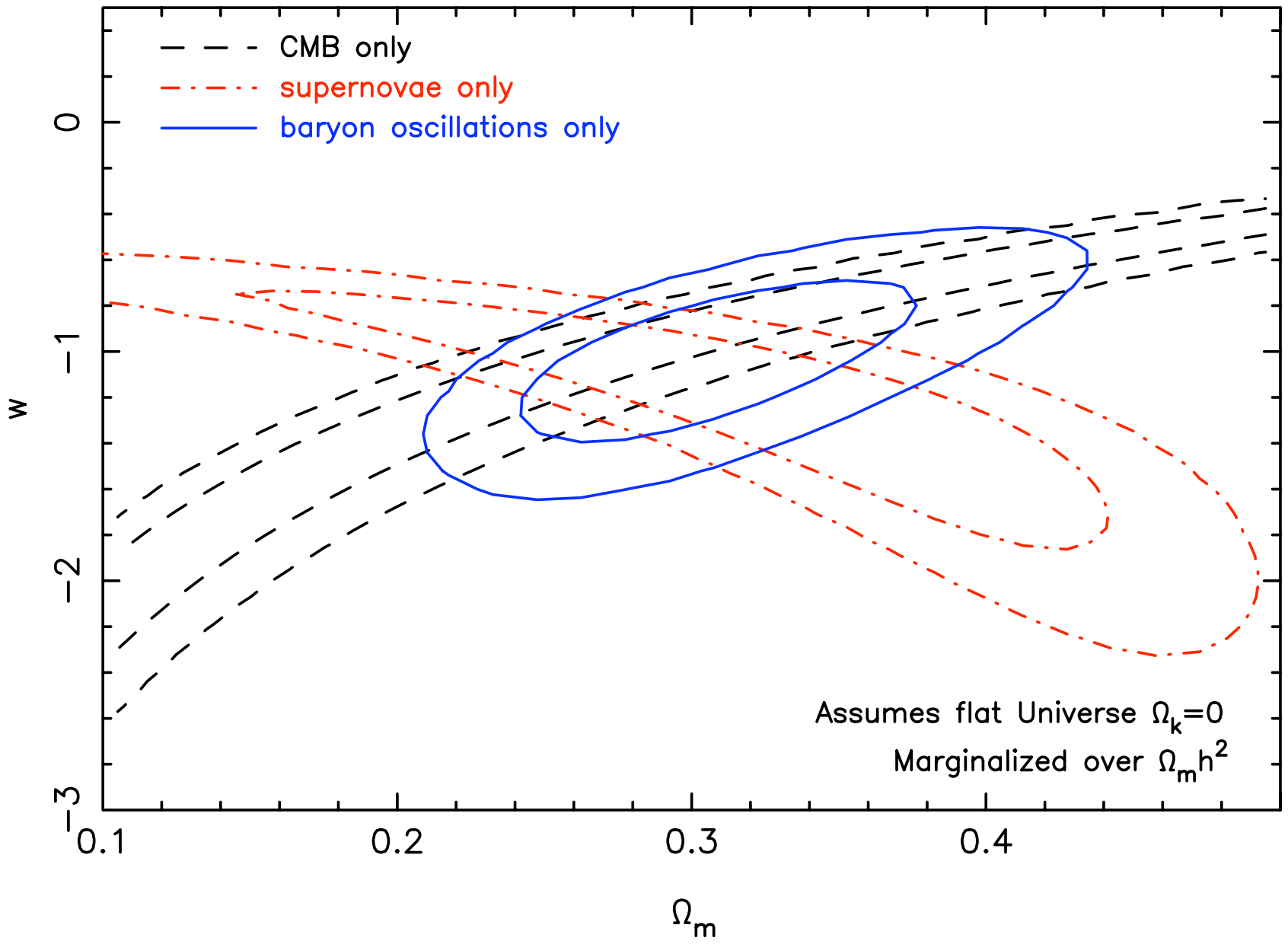


Comparison of BAO fitting techniques

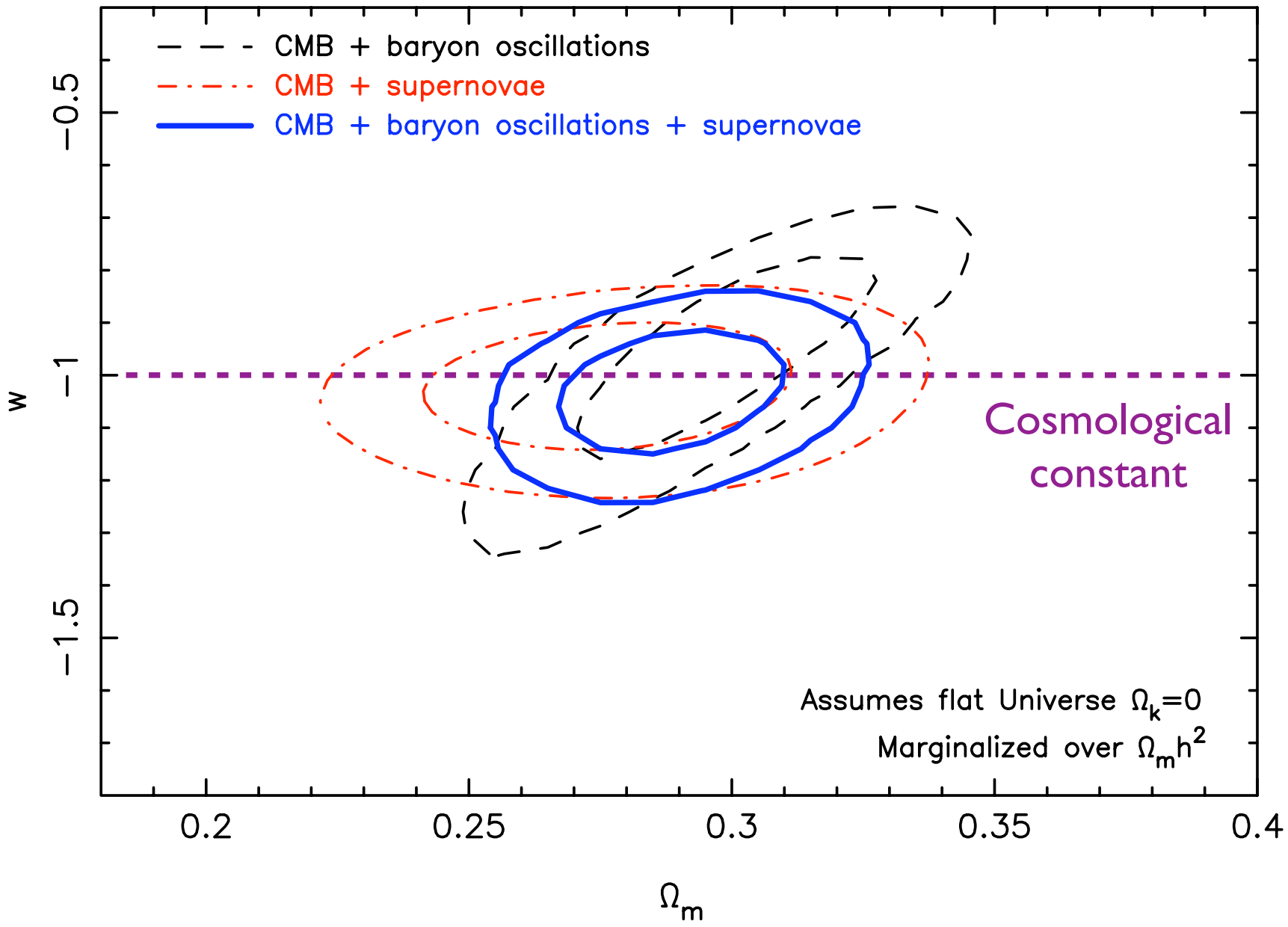


Measurement of the dark energy equation-of-state

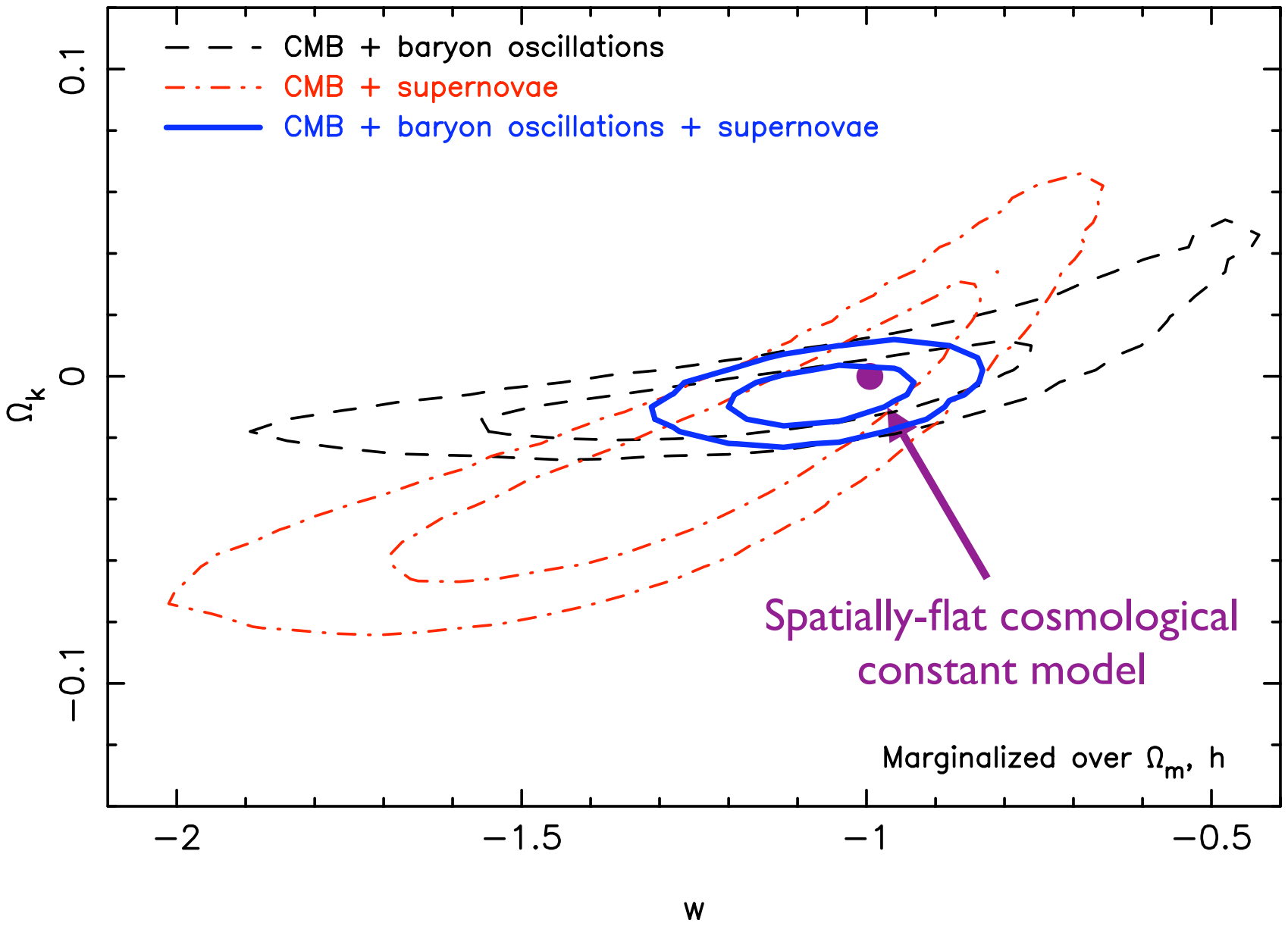
Cosmological parameter fits



Cosmological parameter fits



Cosmological parameter fits

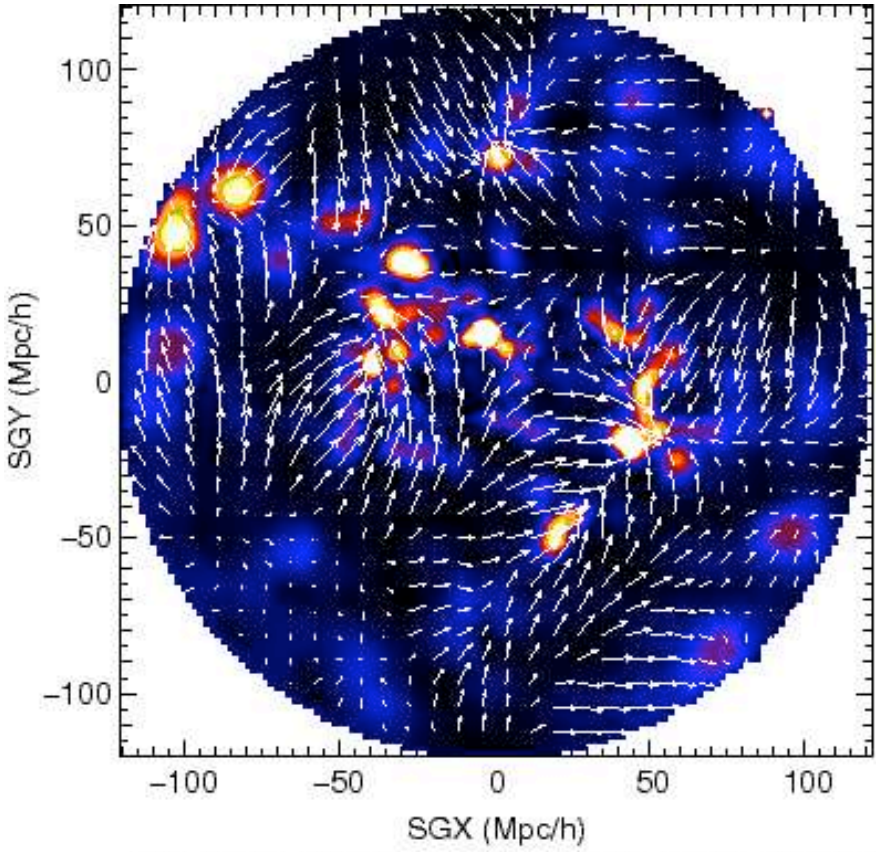


Measurement of the growth of structure

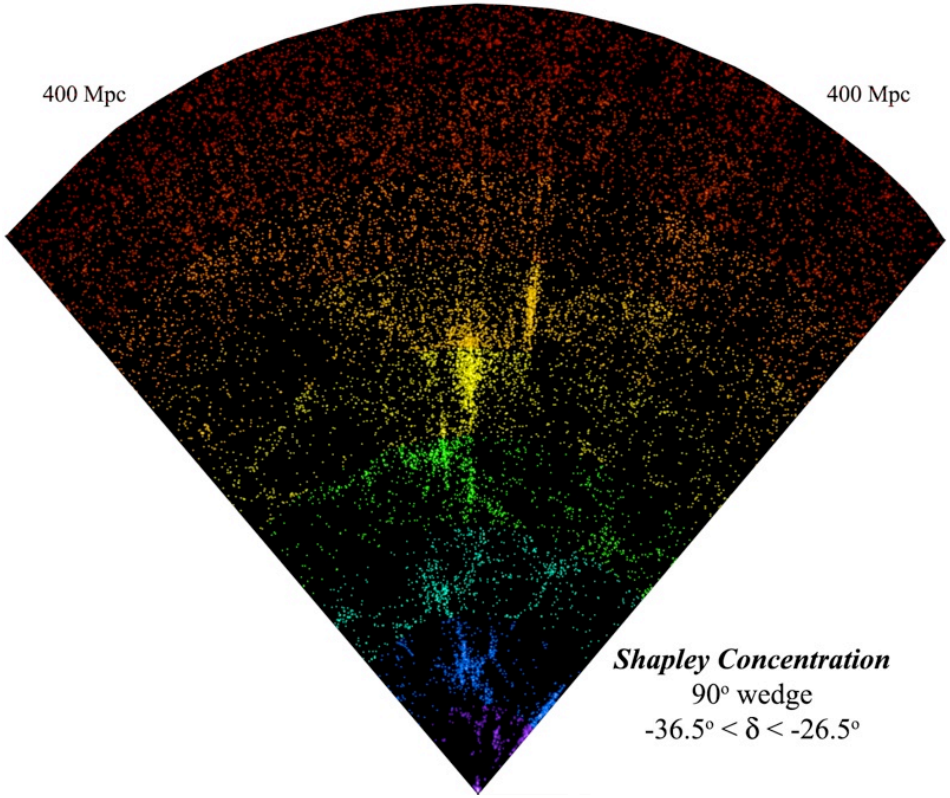
Redshift-space distortions

- Does a cosmological model produce self-consistent cosmic growth and expansion histories?

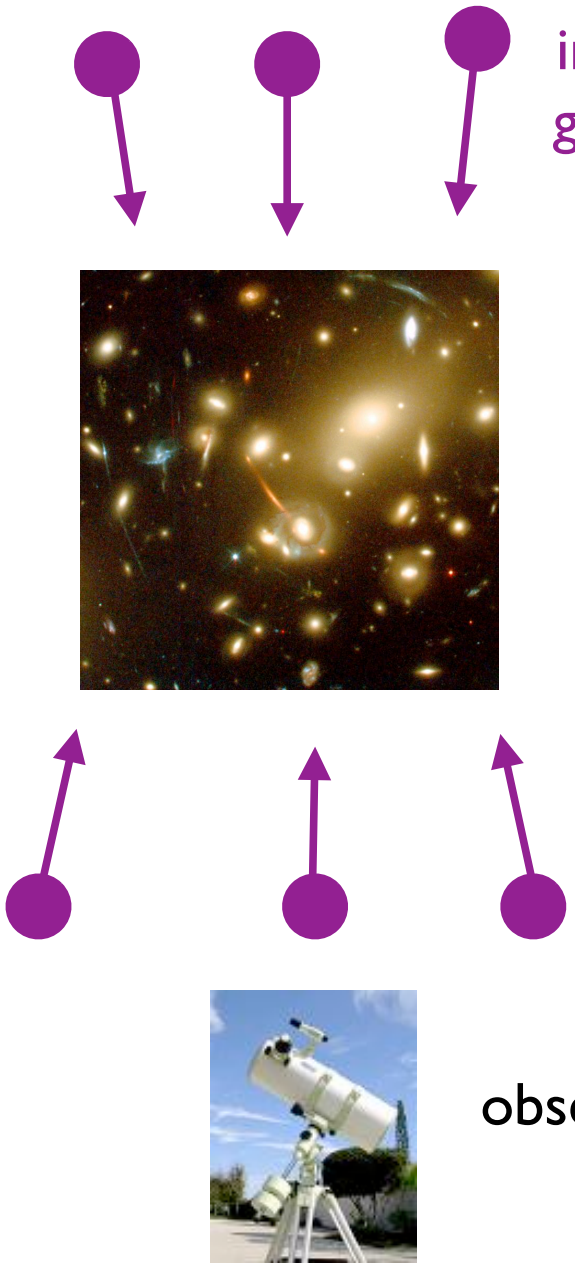
coherent flows

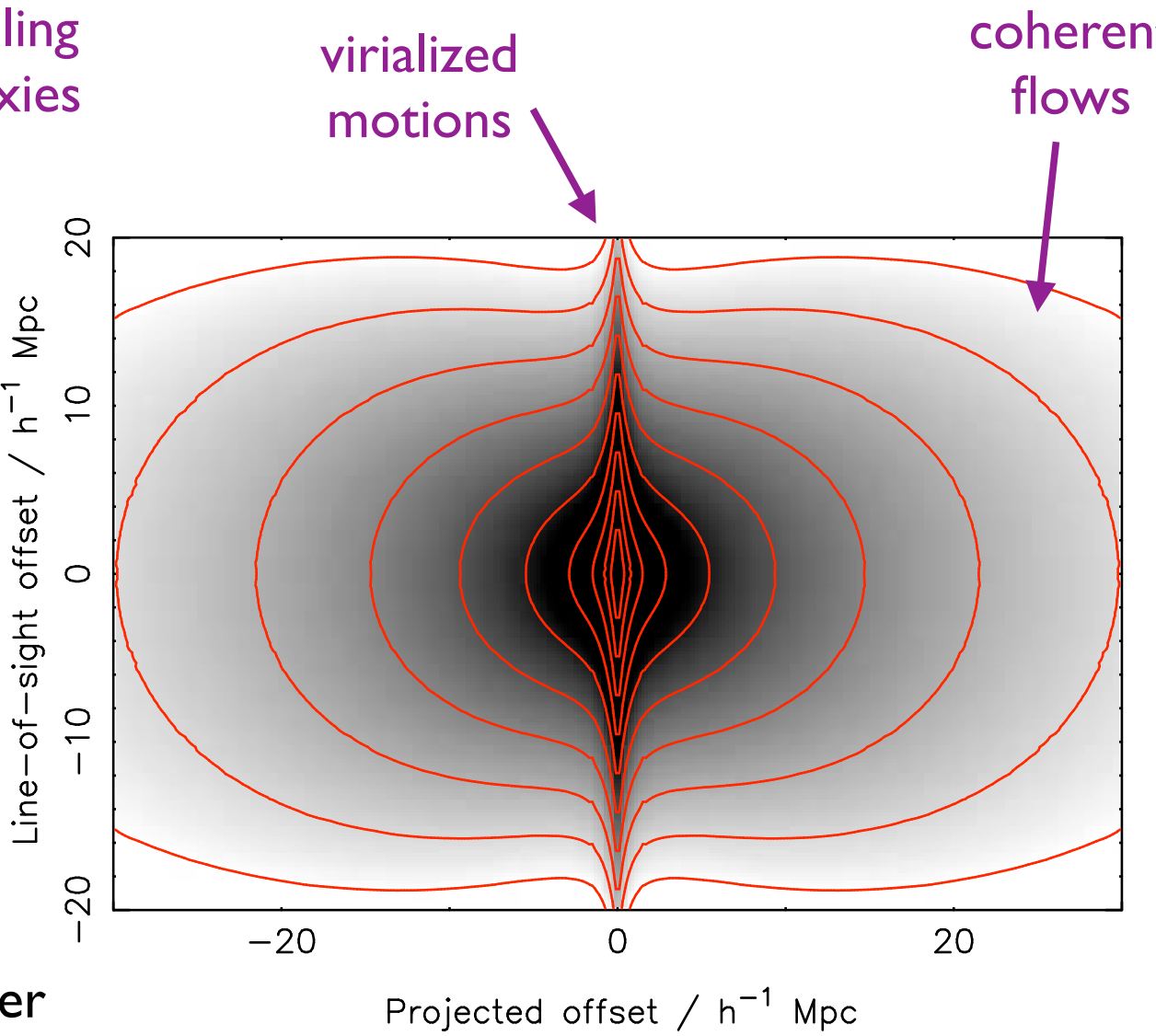


virialized motions

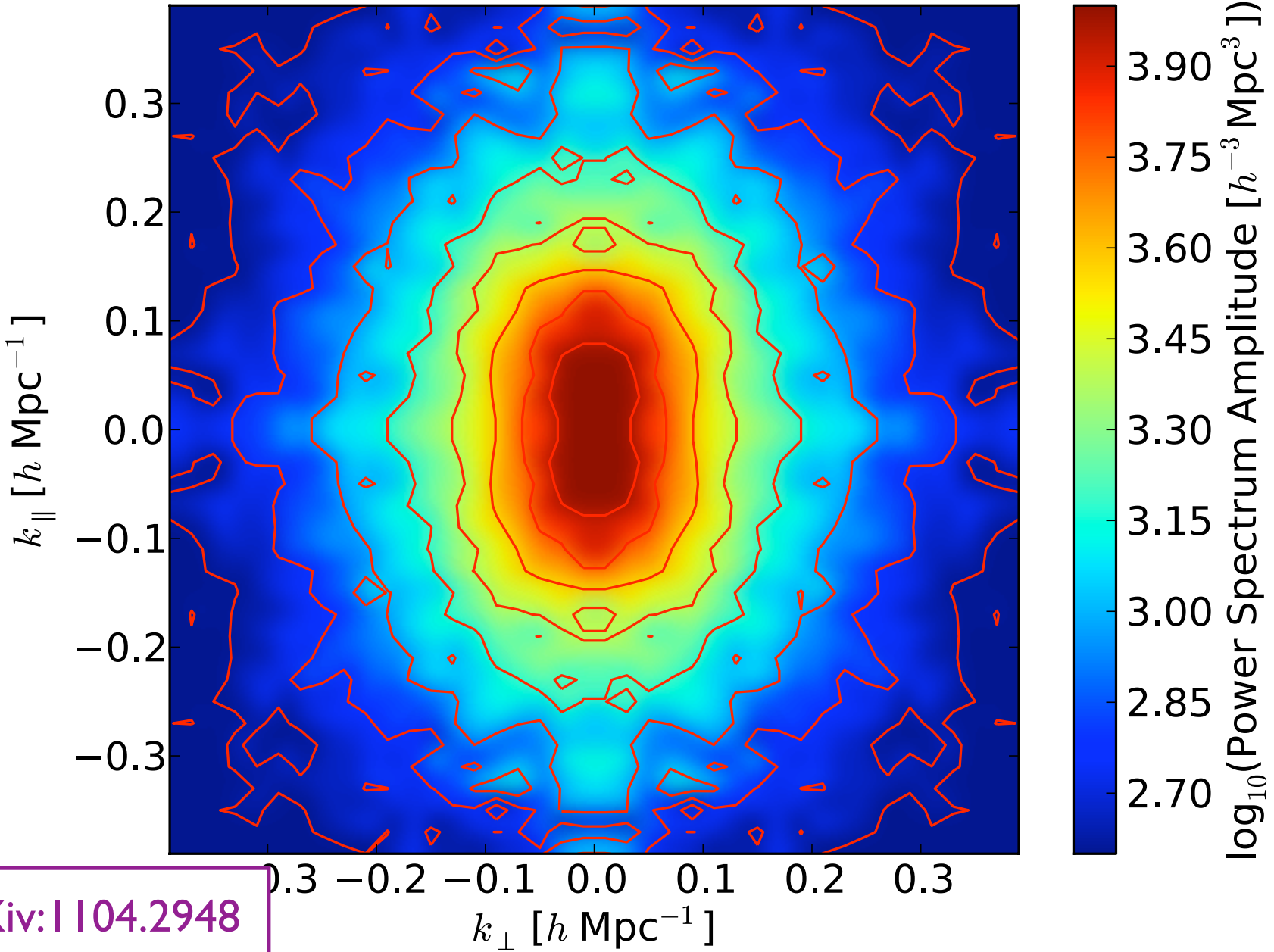


Redshift-space distortions



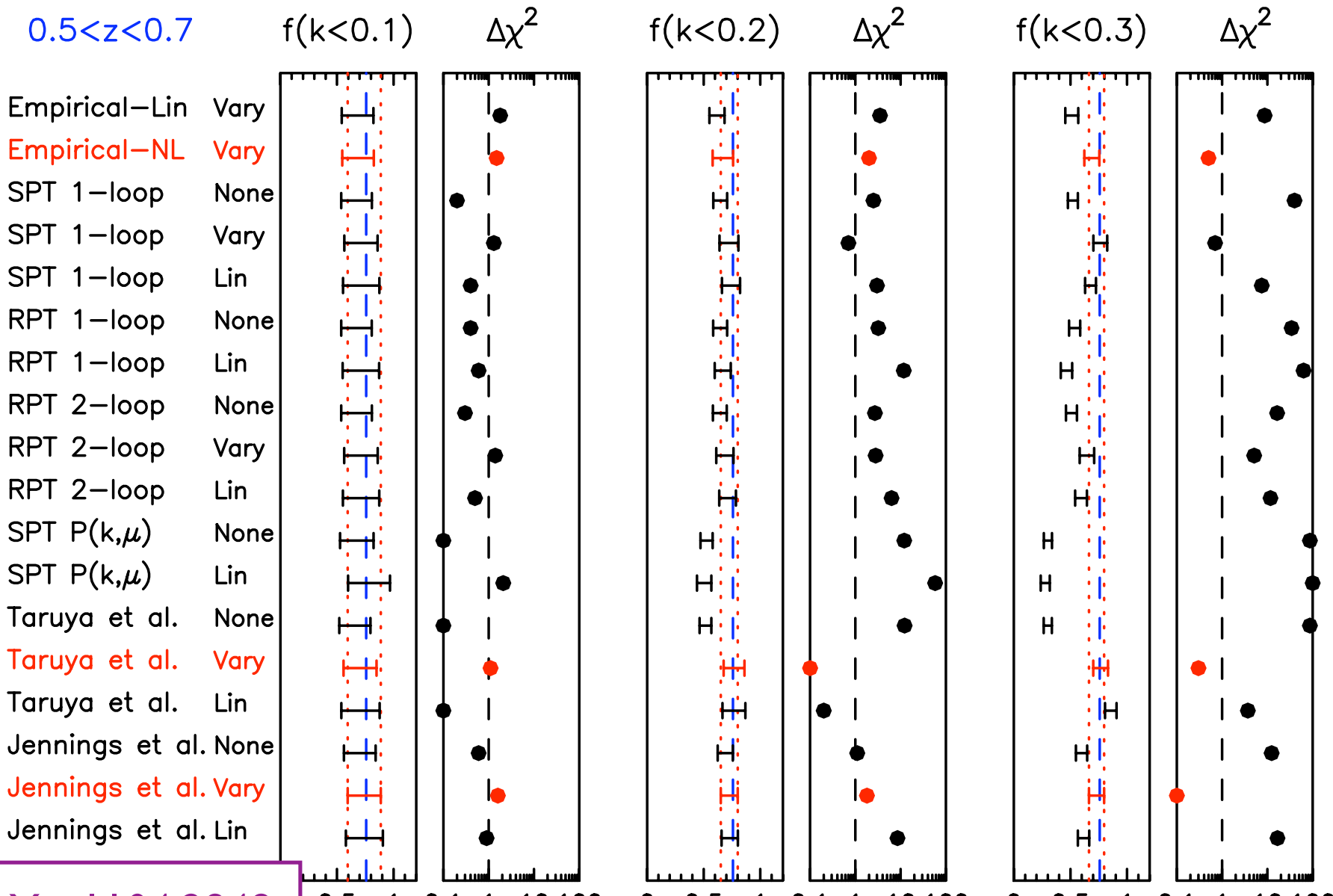


Redshift-space distortions in WiggleZ



arXiv:1104.2948

Growth rate measurements from WiggleZ



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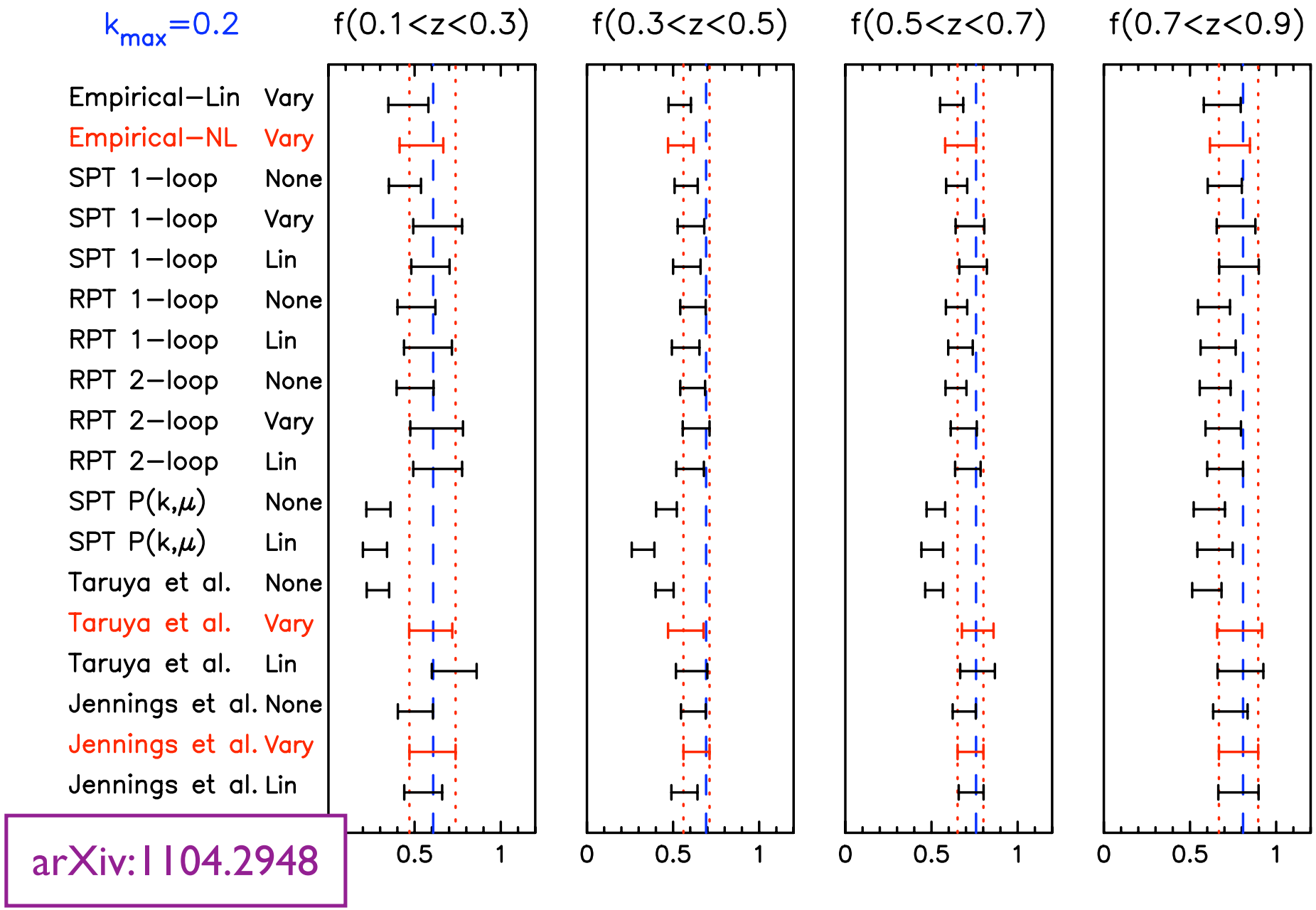

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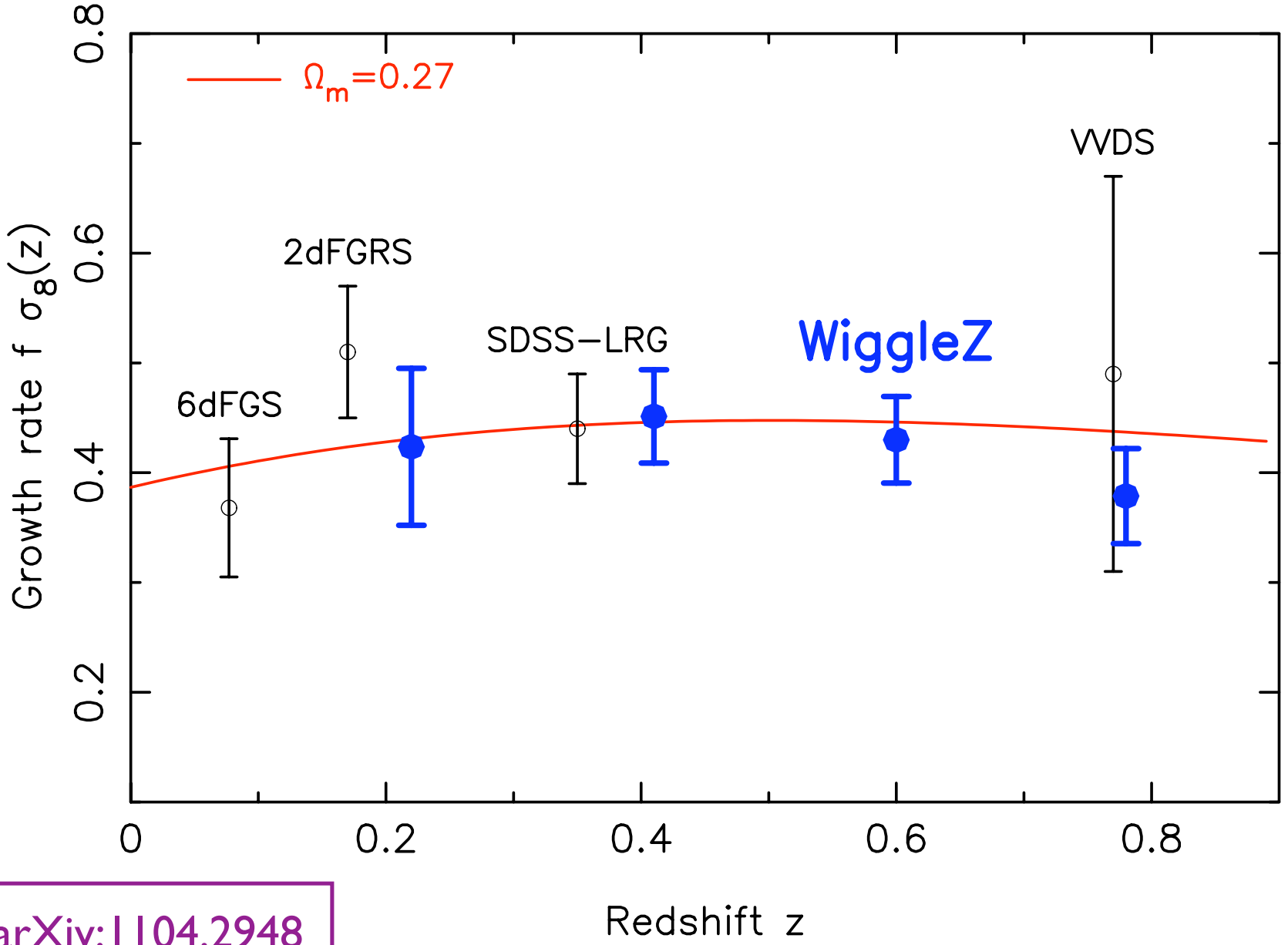


arXiv:1104.2948

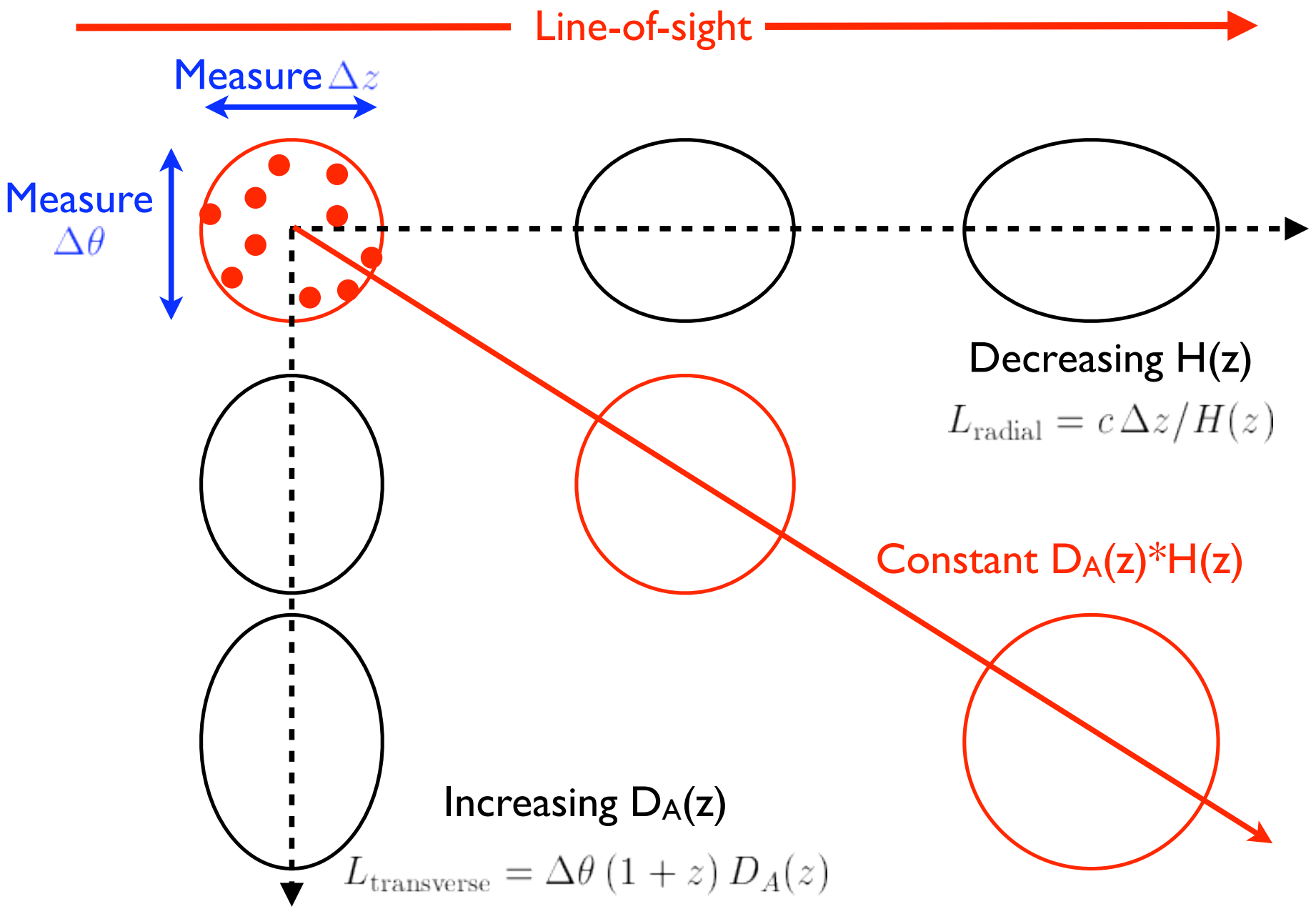
Measurement of the cosmic expansion rate

Model-independent cosmic acceleration

- With current data, the accelerating expansion can only be established by assuming a cosmological model
- But, the importance of dark energy lies in the fact that we don't know what this model should be!
- Can we demonstrate the acceleration model-independently or non-parametrically?
- Need to measure the Hubble parameter as a function of redshift :

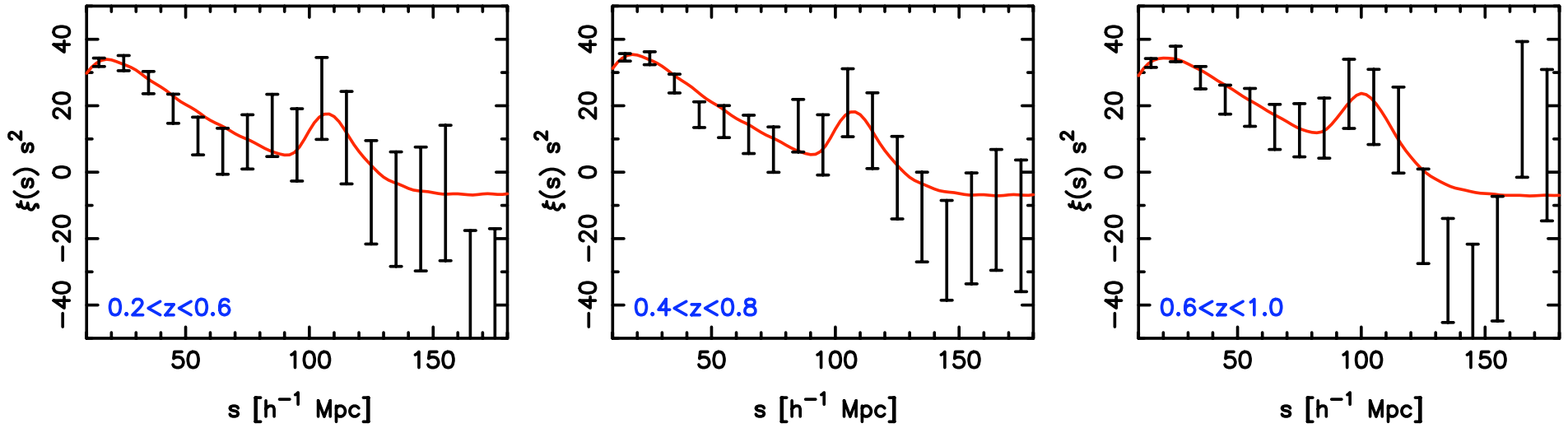
$$\dot{a} = \frac{H(z)}{1+z}$$

Alcock-Paczynski measurement

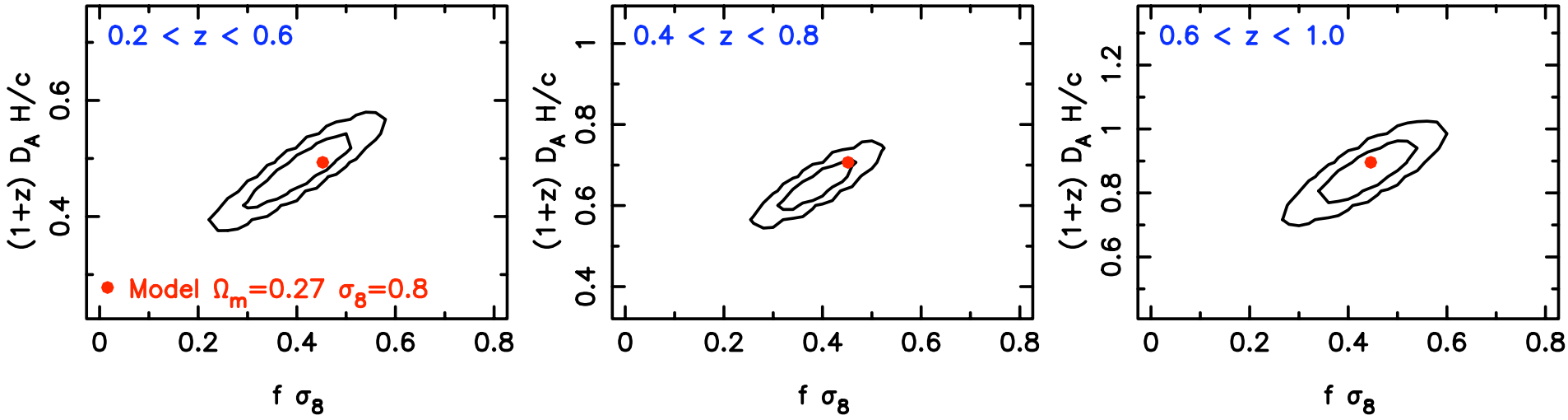


Alcock-Paczynski measurement in WiggleZ

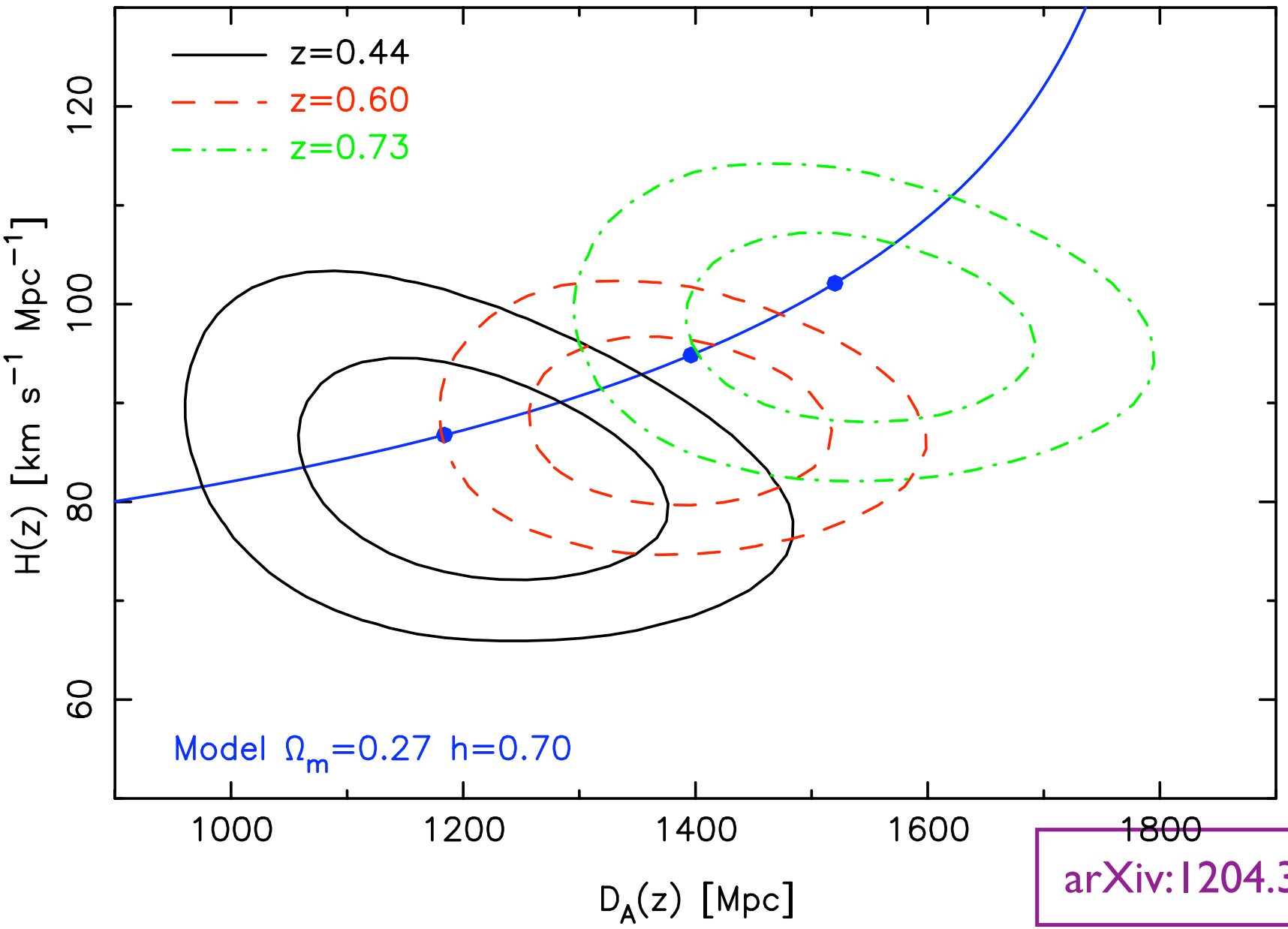
BAO determines D_A^2/H



AP effect determines D_A H

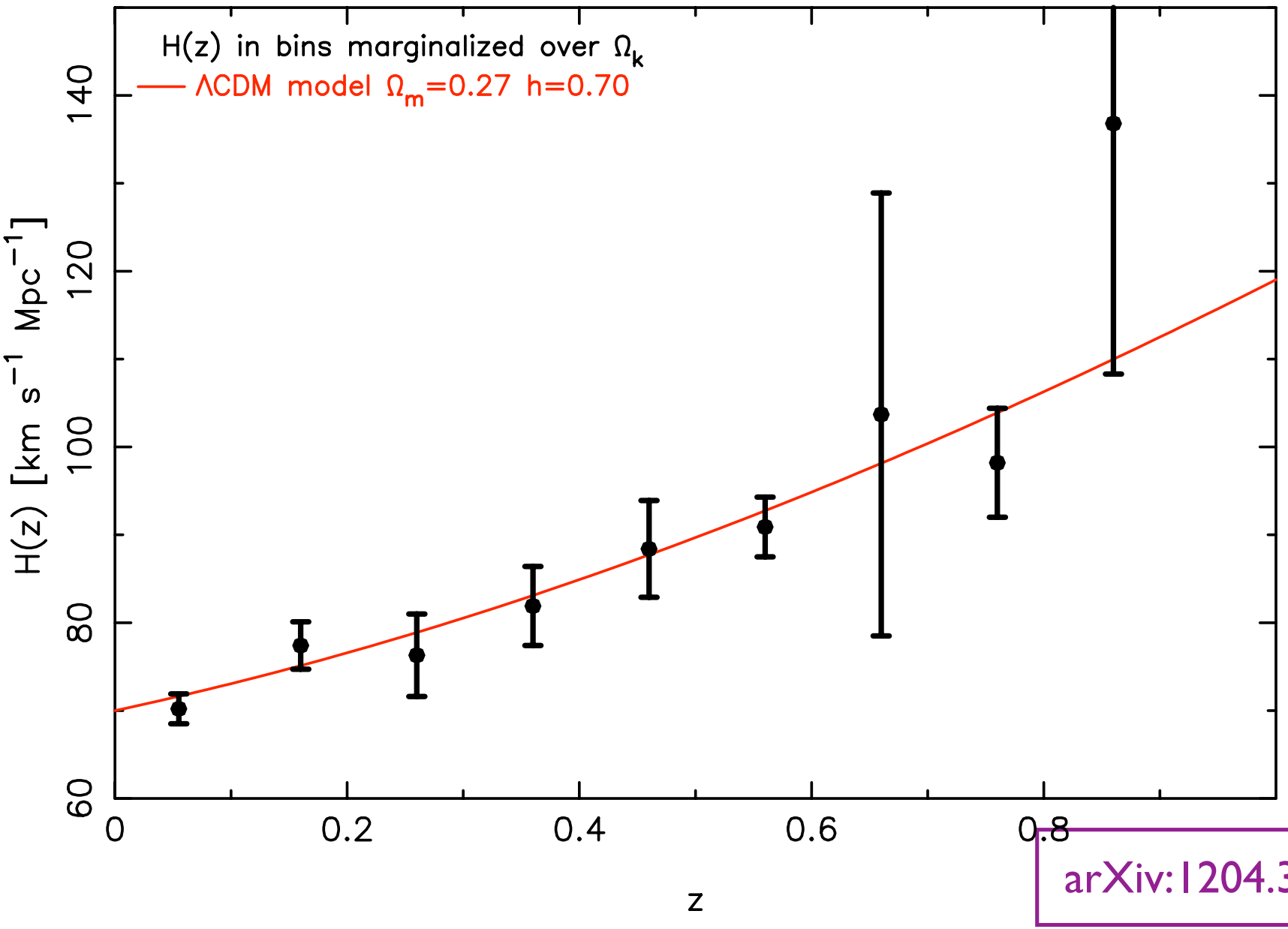


WiggleZ measurements of $D_A(z)$ and $H(z)$



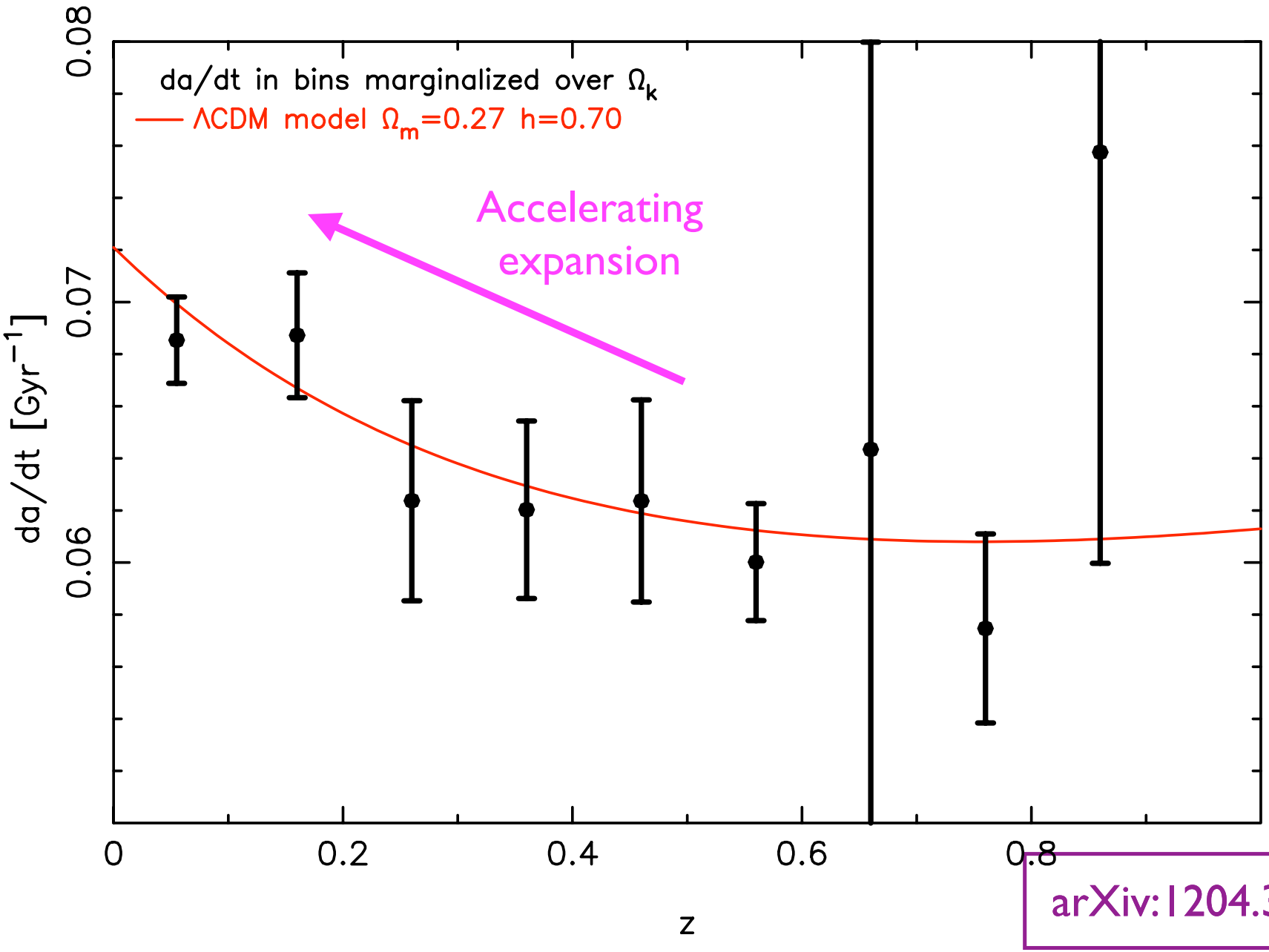
arXiv:1204.3674

H(z) measurements



arXiv:1204.3674

da/dt measurements



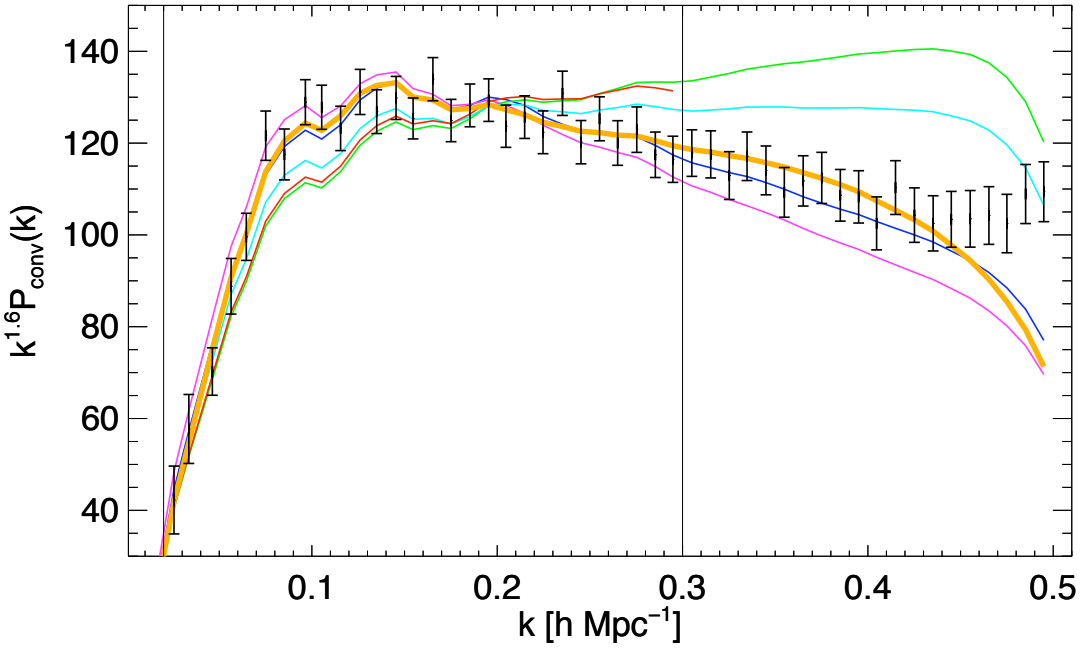
arXiv:1204.3674

A feast of other science

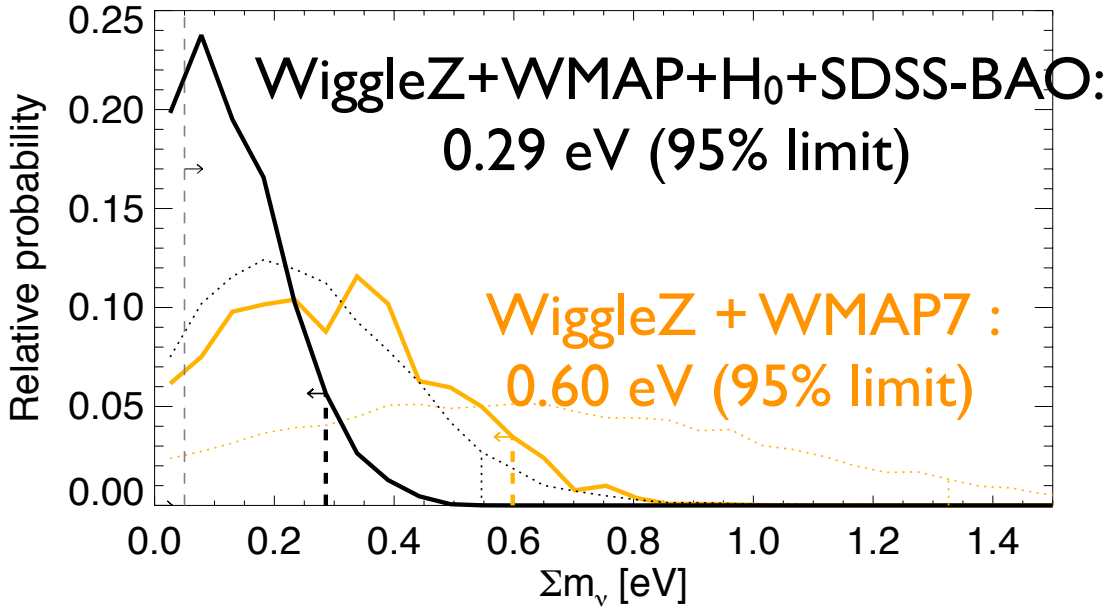
Neutrino mass limit from WiggleZ P(k)

Riemer-Sorensen et al.
arXiv:1112.4940

Combined WiggleZ power spectrum dataset compared to various models :



Probability histogram for the sum of neutrino masses :



Other analyses in progress ...

- Cosmo-MC module for P(k) and data release
- Limits on modified gravity theories
- Higher-order clustering (non-Gaussianity , skewness)
- BAO reconstruction and 2D fitting for $D_A(z)$ / $H(z)$
- Clusters and voids
- Cosmic topology (genus)
- Turnover in power spectrum (early-universe physics)

Summary of results from WiggleZ

- Baryon acoustic oscillations measure cosmic distances to z=0.8 and provide cross-check with supernovae
- Alcock-Paczynski effect allows direct measurement of the cosmic expansion [H(z)] at high redshift
- Redshift-space distortions provide accurate measurement of growth of structure to high redshift
- General Relativity + cosmological constant models have been tested in a new way and remain a good fit
- If dark energy behaves as Lambda, what is its physics?

Thank you!