Large scale structure analysis with the 6dF Galaxy Survey
LBNL, Berkeley, January 2012

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International Centre for Radio Astronomy Research

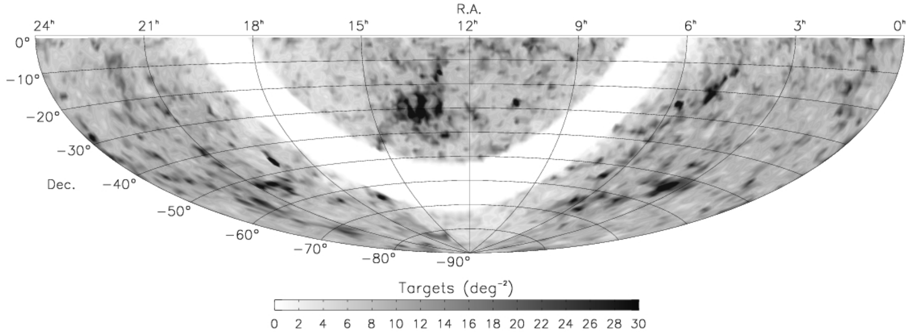
Outline of the talk

Big picture: What is the nature of dark energy?

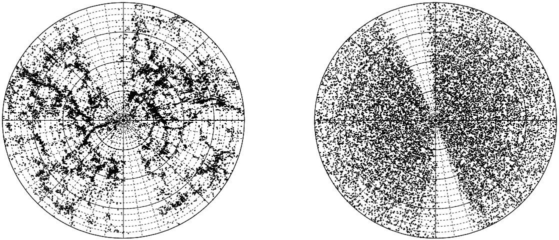
1. Testing the expansion history of the Universe (dark energy EoS): Baryon Acoustic Oscillations (BAO)
2. Testing General Relativity: Redshift space distortions

What is 6dFGS?

- Spectroscopic survey of southern sky (17,000 deg^2).
- Primary sample from 2MASS with $K_{tot} < 12.75$; also secondary samples with $H < 13.0$, $J < 13.75$, $r < 15.6$, $b < 16.75$.
- Median redshift $z \approx 0.05$ ($\approx$ 220 Mpc).
- Effective volume $\approx 8x10^7 h^{-3}$ Mpc^3 (about as big as 2dFGRS).
- 125.000 redshifts (137.000 spectra).



What is a correlation function?



The correlation function is defined via the excess probability of finding a galaxy pair at separation s:

$$dP = \overline{n}^2 \left[1 + \xi(s)\right] dV_1 dV_2$$

A correlation function measures the degree of clustering on different scales.
We have to count the galaxies at different separations s and calculate the correlation function via

$$\xi(s) = \frac{DD(s)}{RR(s)} - 1$$

(In my analysis I used the Landy & Salay estimator)

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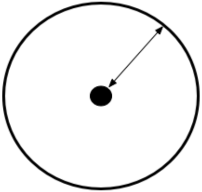

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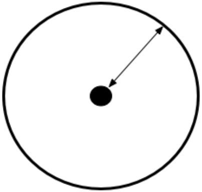

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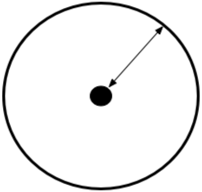

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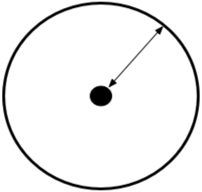

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- The radius of the sphere is a preferred distance scale -> standard ruler.
- First detections in 2dFGRS and SDSS, Cole et al. (2005), Eisenstein et al. (2005).

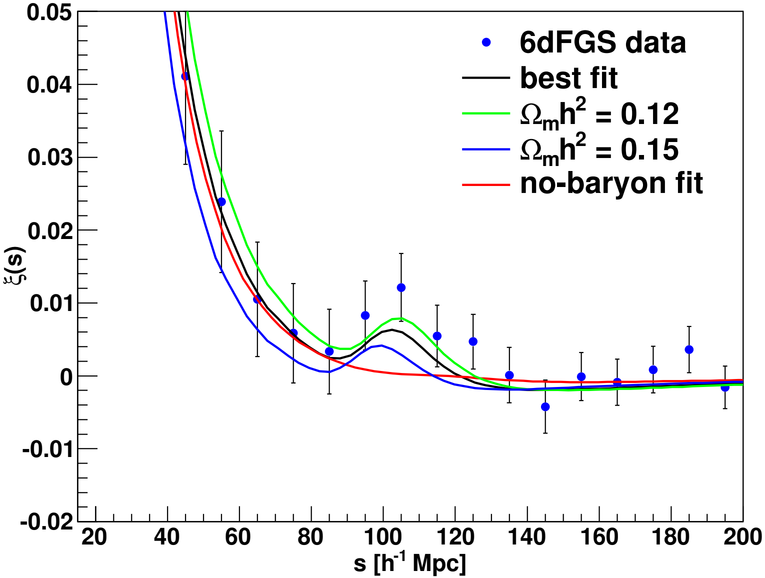
Motivation

1. The sound horizon scale is set by the physical matter- and baryon density, $\Omega_m h^2$ and $\Omega_b h^2$.
2. We can get these two values from the CMB $\rightarrow$ the BAO scale in the galaxy survey turns into a standard ruler.
3. A standard ruler enables a distance measurement. The ultimate cosmology tool!
4. This enables us to measure the Friedmann eq., $H(z)$

$$H(z) = H_0 \left[\Omega_m a^{-3} + \Omega_\Lambda a^{-3(1+w)}\right]^{1/2}.$$

5. At low redshift, $a \approx 1$, a distance measurement constrains only H_0 (similar to the distance ladder technique).

Results



6dFGS data
best fit
$\Omega_m h^2 = 0.12$
$\Omega_m h^2 = 0.15$
no-baryon fit
ξ(s)
s [h^{-1} Mpc]
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
20
40
60
80
100
120
140
160
180
200

Results

$$\xi_{\mathrm{model}}(s) = B(s)b^2\left[\xi(s) * G(r) + \xi_1^1(r)\frac{\partial\xi(s)}{\partial s}\right]$$

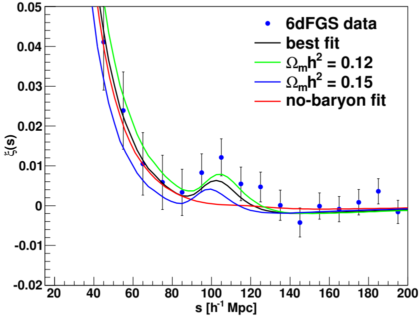
$$\xi_1^1(r) = \frac{1}{2\pi^2}\int_0^\infty dk\ kP_{\mathrm{lin}}(k)j_1(rk)$$

$$\xi(r) = \frac{1}{2\pi^2}\int_0^\infty dk\ k^2P_{\mathrm{lin}}(k)j_0(rk)$$

$$\tilde{G}(k) = \exp\left[-(k/k_*)^2\right]$$

Crocce & Scoccimarro (2008), Sanchez et al. (2008),

Eisenstein et al. (2007), Eisenstein, Seo & White (2007)



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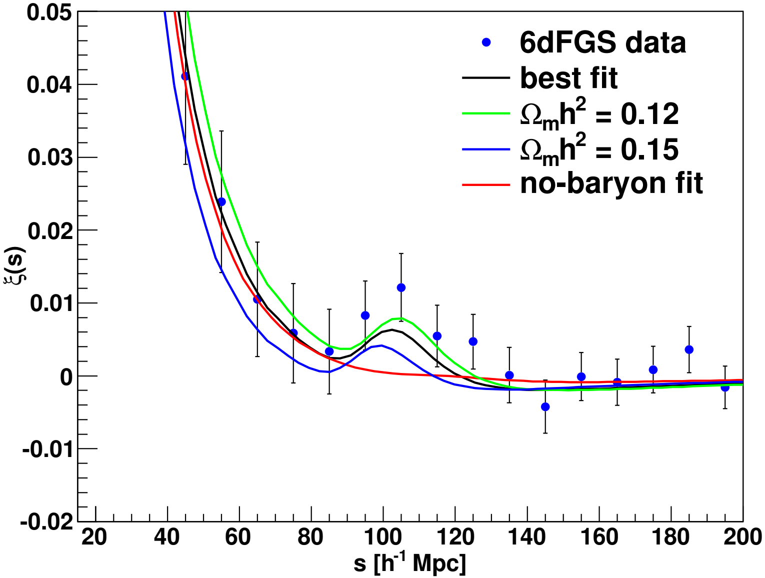

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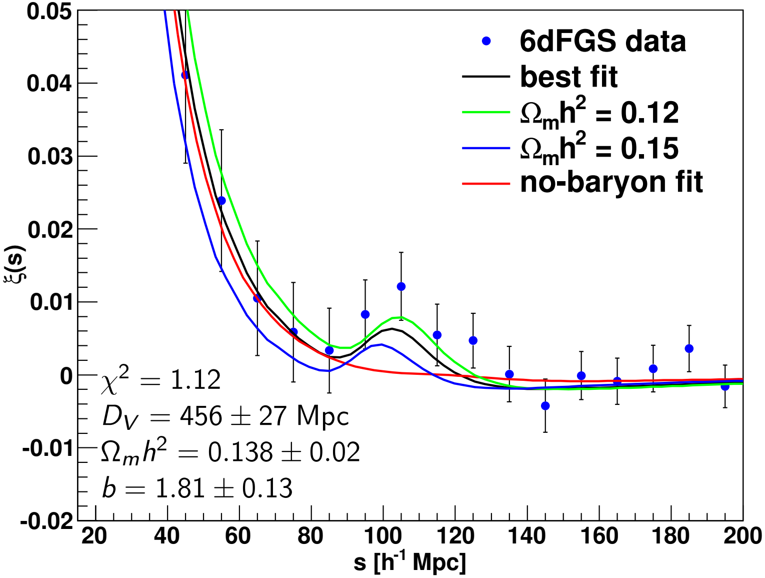

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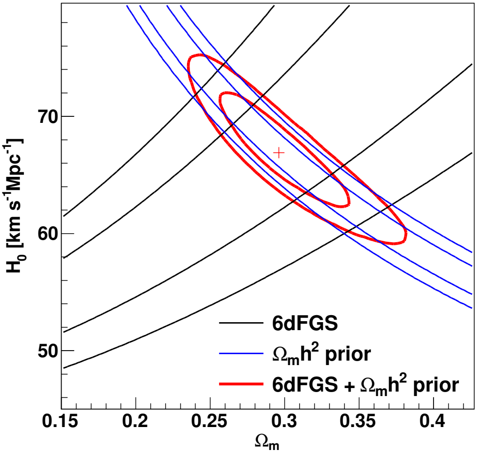
no-baryon fit
$\chi^2 = 1.12$
$D_V = 456 \pm 27$ Mpc
$\Omega_m h^2 = 0.138 \pm 0.02$
$b = 1.81 \pm 0.13$
$\xi(s)$
s [h^{-1} Mpc]
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
20
40
60
80
100
120
140
160
180
200

Cosmological implications



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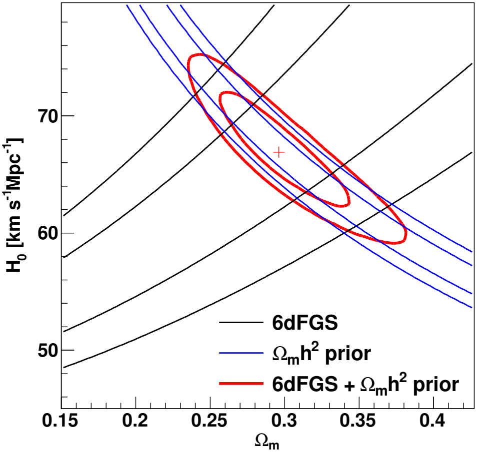

6dFGS: $H_0 = 67 \pm 3.2\,\mathrm{km/s/Mpc}$

SH0ES project: $H_0 = 73.8 \pm 2.4\,\mathrm{km/s/Mpc}$ (Riess et al. 2011)

WMAP7: $H_0 = 70.3 \pm 2.5\,\mathrm{km/s/Mpc}$ (Komatsu et al. 2010)

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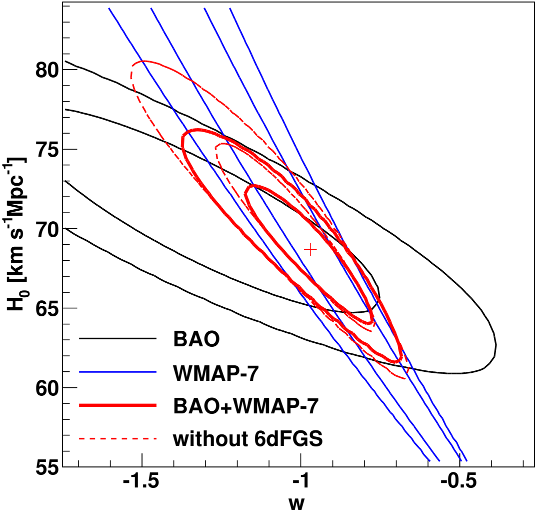

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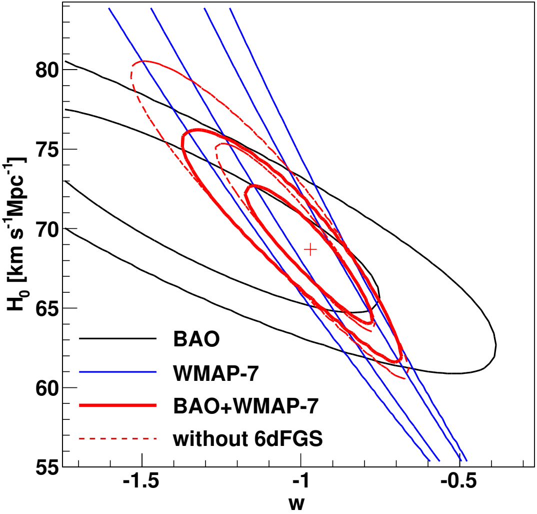

In a wCDM universe we find $w = -0.97 \pm 0.13$.

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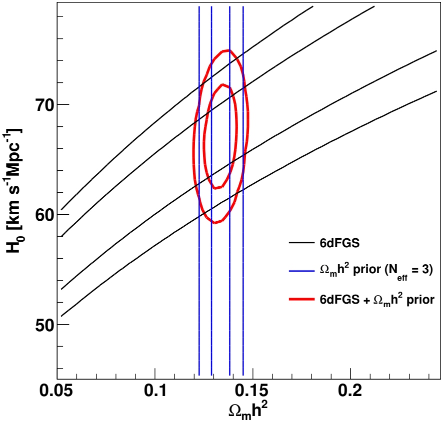

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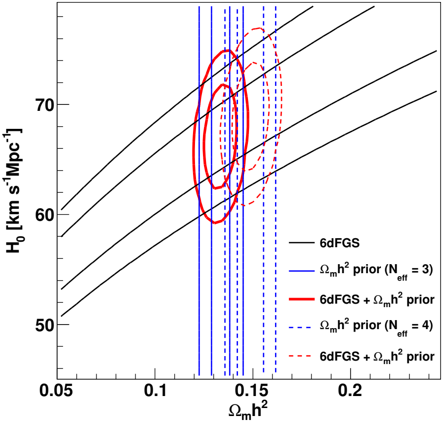

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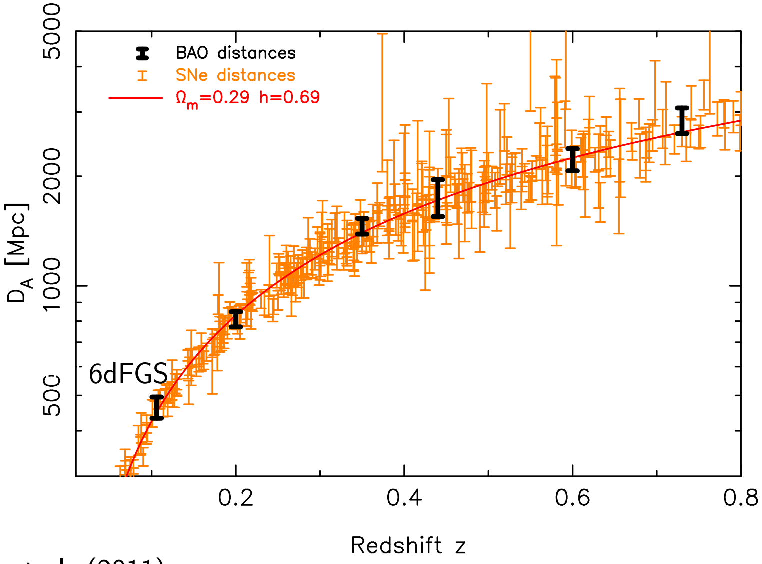

Blake et al. (2011)

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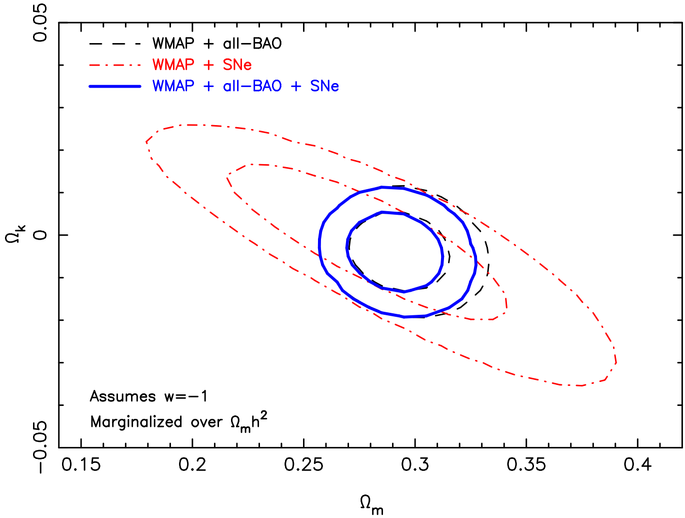

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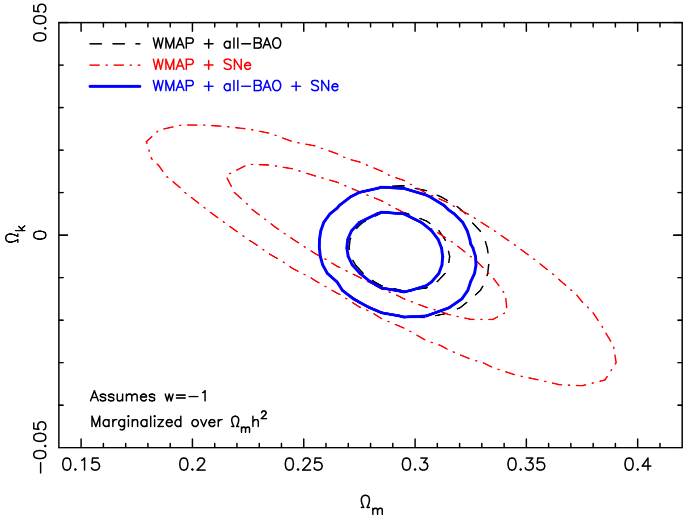

Blake et al. (2011) $(\Omega_k = -0.004 \pm 0.0062)$

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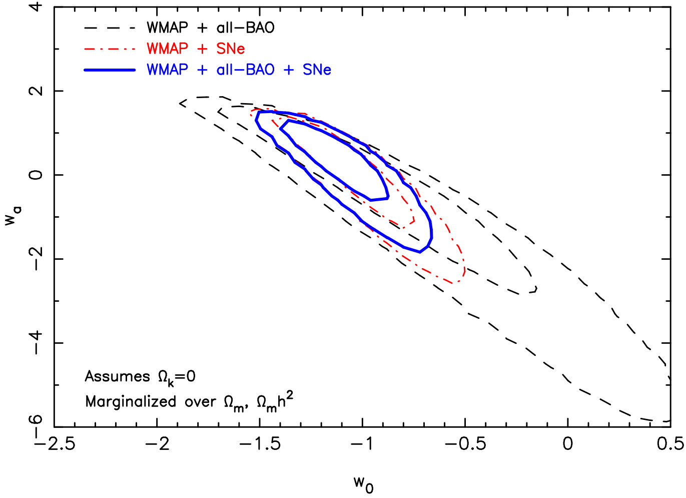
$w(a) = w_0 + (1 - a)w_a$



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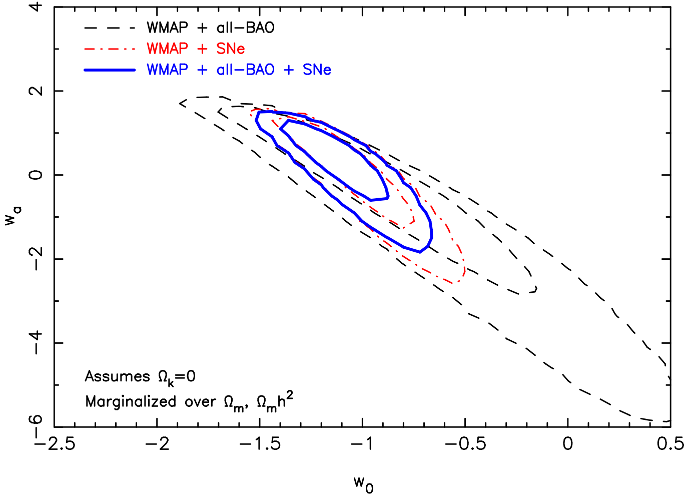
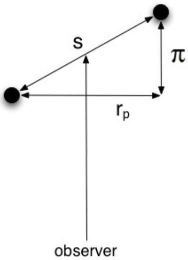
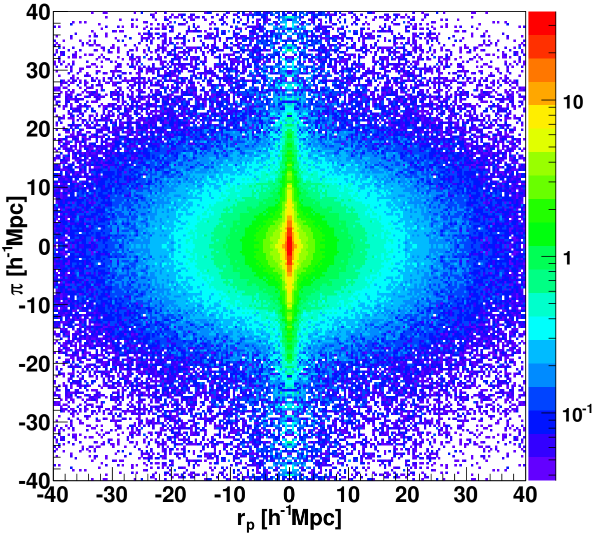


Blake et al. (2011) $(w_0 = -1.094 \pm 0.171,\ w_a = 0.194 \pm 0.687)$

Redshift space distortion analysis

6dFGS 2D correlation function





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$$\boxed{f(z) = \beta b = \Omega_m^\gamma(z)}$$

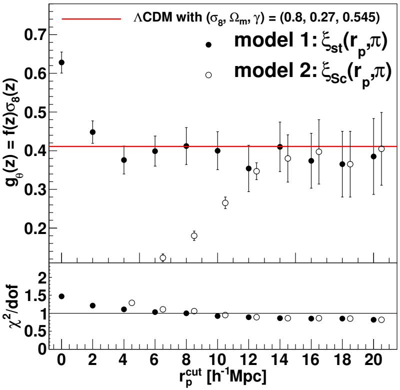
f = growth rate, b = linear bias, $\Omega_m = \frac{\rho_m}{\rho_0}$
Theoretical predictions: $\gamma^{\Lambda CDM} = 0.55$, $\gamma^{\mathrm{DGP}} = 0.69$
$\rightarrow$ At low redshift we have no uncertainties because of the Alcock-Paczynski effect.

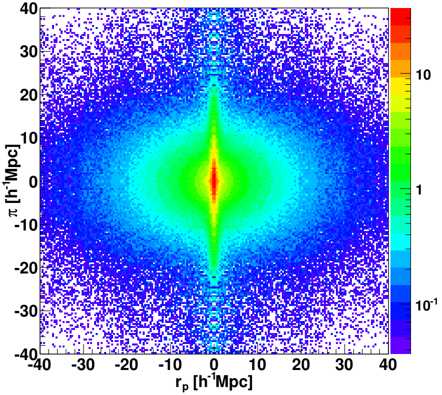
Data modelling

model1: $P(k,\mu) = \left(b + f\mu^2\right)^2 P_{\delta\delta}(k) \dfrac{1}{1 + k^2\mu^2\sigma_p^2/2}$ Kaiser (1987), Peacock & Dodds (1996)

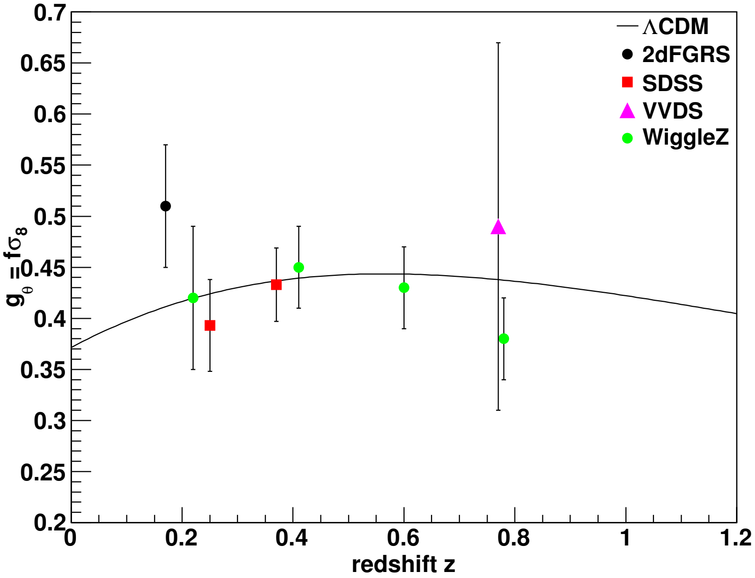
model2: $P(k,\mu) = e^{-(k\mu\sigma_v)^2} \left[b^2 P_{\delta\delta}(k) + 2\mu^2 bfP_{\delta\theta}(k) + \mu^4 f^2 P_{\theta\theta}(k)\right]$

Scoccimarro (2004)





Testing General Relativity



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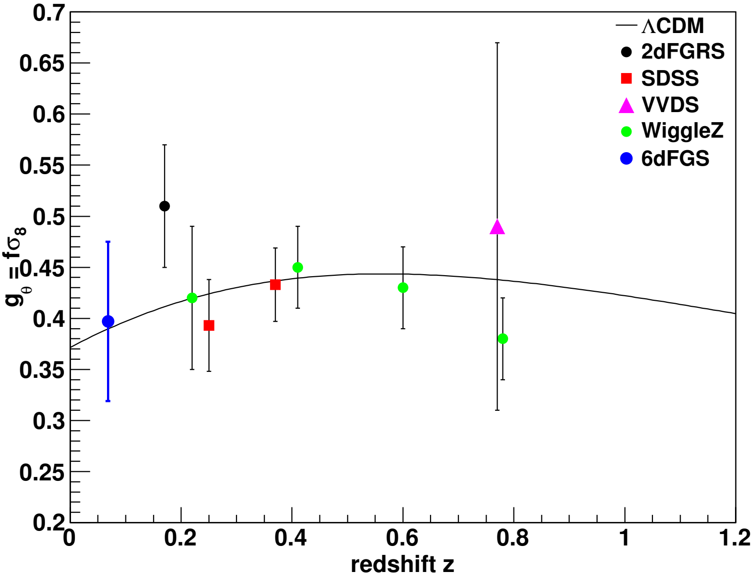

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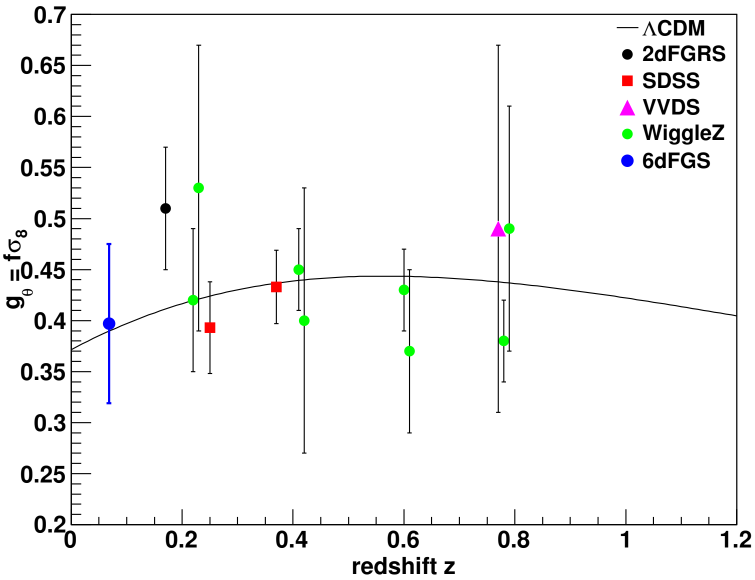

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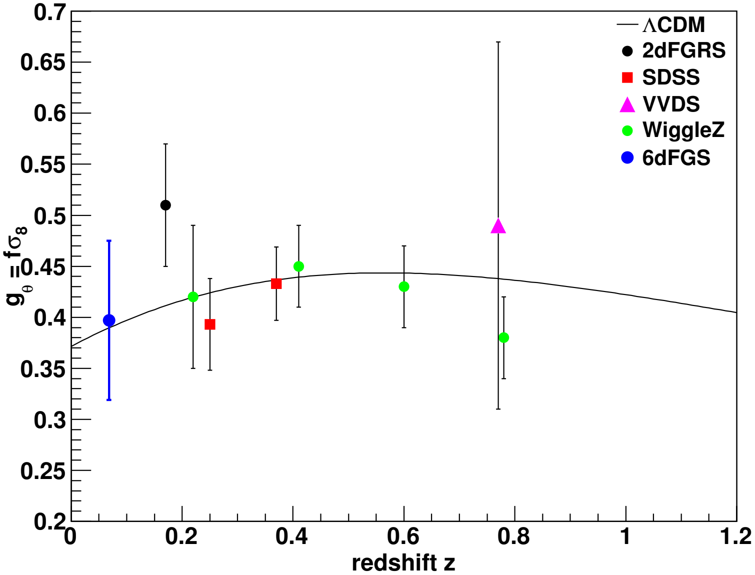

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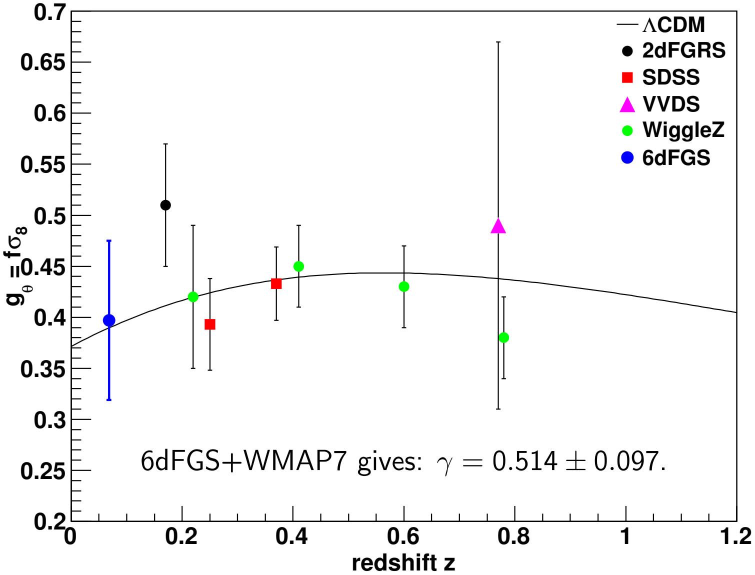

What would be the best redshift space distortion survey?

- The error of the power spectrum is prop. to its amplitude

$$\sigma_{P(k)} \propto (b + f\mu^2)^2 P(k) + < N >$$

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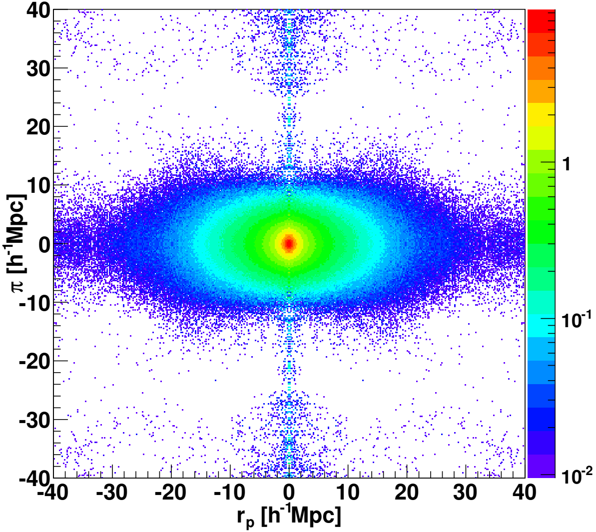
- At low redshift we don't have to deal with the degeneracy between the Alcock-Paczynski effect and redshift space distortions.

The WALLABY galaxy survey

- Radio galaxy survey conducted on the ASKAP radio telescope, a precursor of the Square Kilometre Array (SKA). The telescope is located in the West Australian desert.
- timeline: 2014-2018
- $\sim 600\,000$ galaxies
- $V_{\mathrm{eff}} \approx 0.12 h^{-3}\,\mathrm{Gpc}^3$
- galaxy bias ~ 0.7 (Basilakos et al. 2007)
- $z \approx 0.04$

WALLABY forecast



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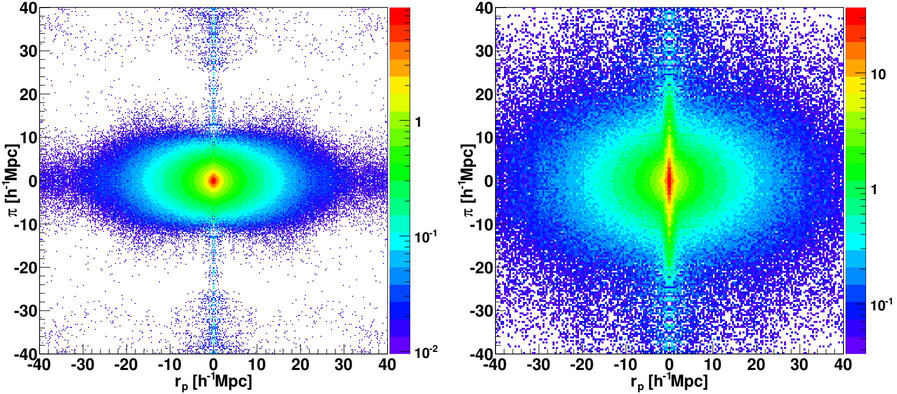
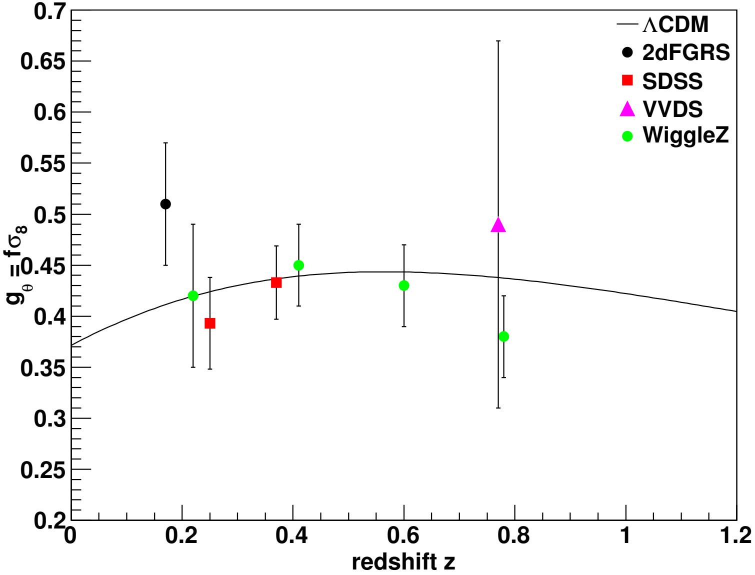


Future survey forecasts



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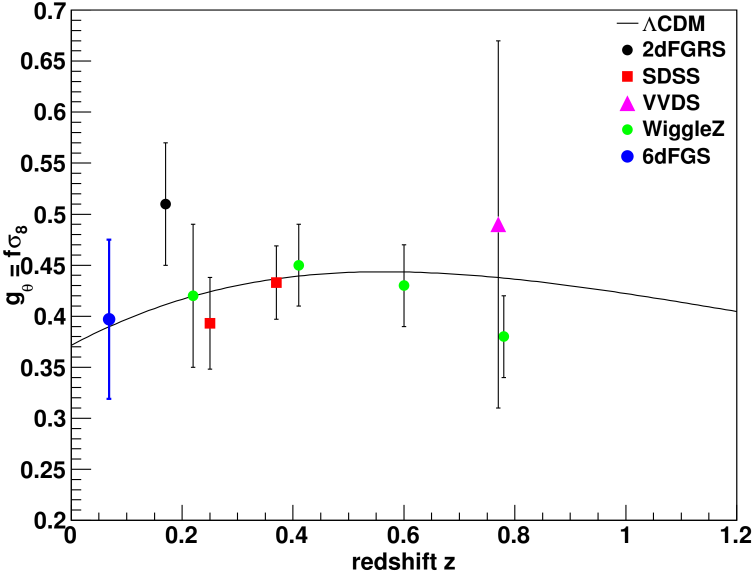

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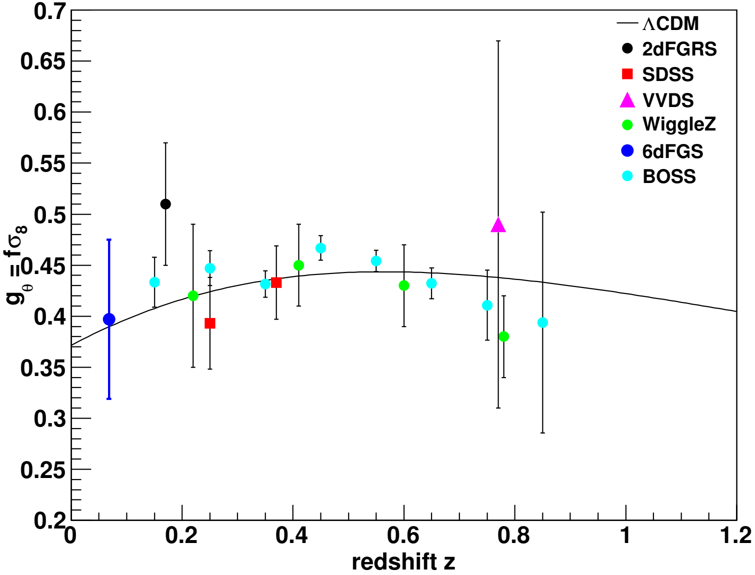

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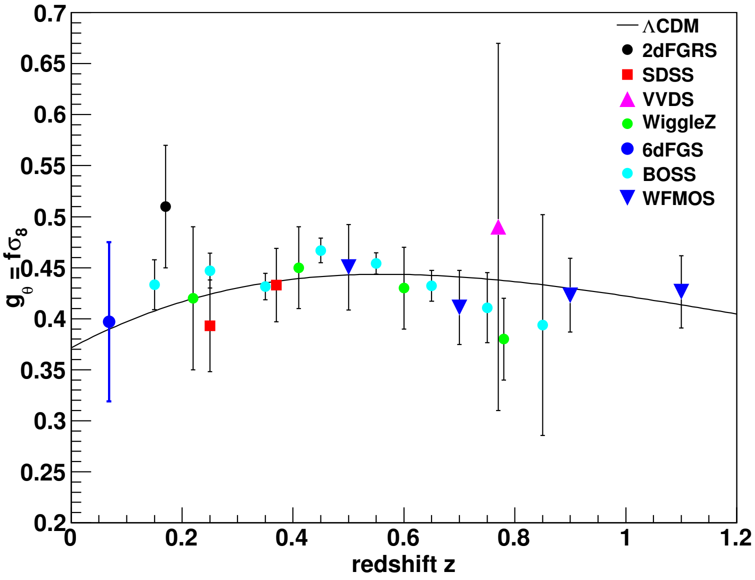

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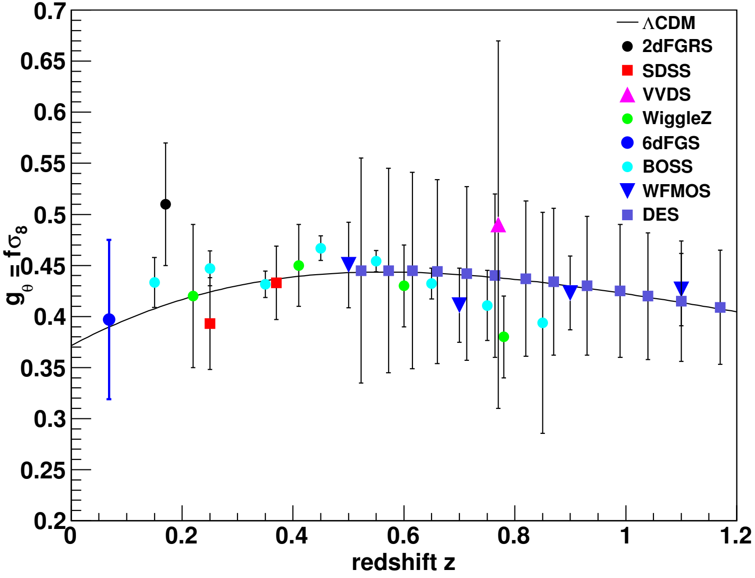

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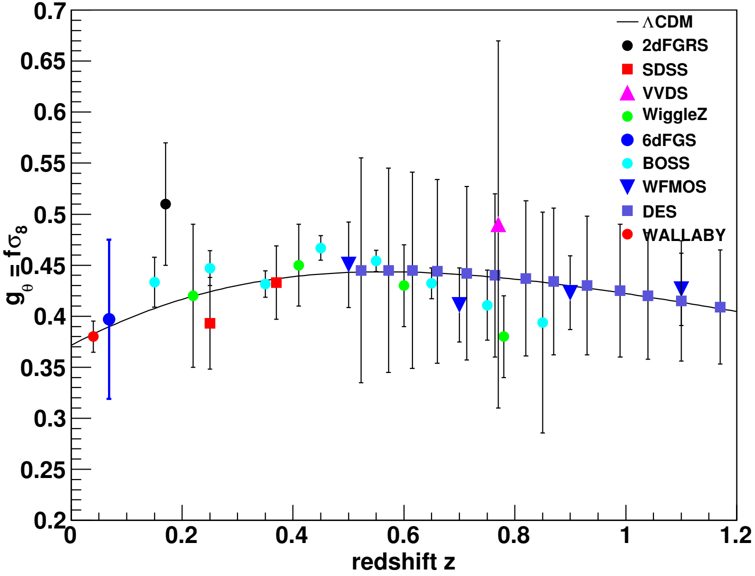

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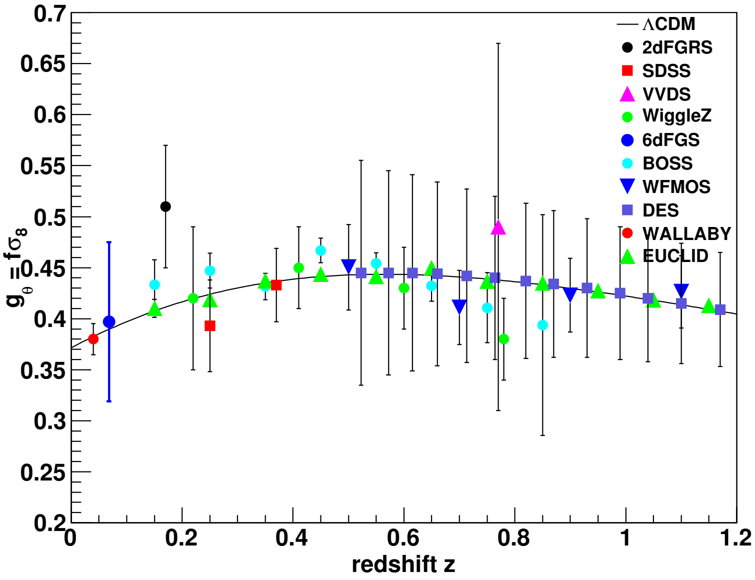
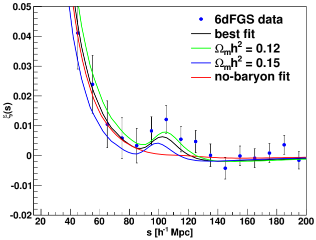


Summary



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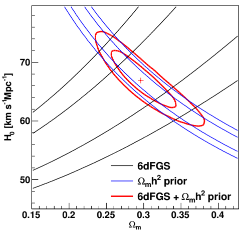
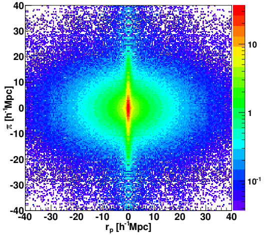
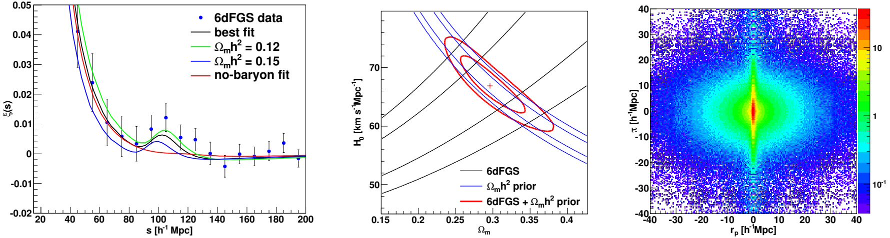


6dFGS
$\Omega_m h^2$ prior
6dFGS + $\Omega_m h^2$ prior
H_0 [km s^{-1}Mpc^{-1}]
Ω_m



π [h^{-1}Mpc]
r_p [h^{-1}Mpc]

Summary



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$$H_0 = 67 \pm 3.2\ \mathrm{km/s/Mpc}$$

(Riess et al. (2011) found 73.8 ± 2.4 km/s/Mpc)

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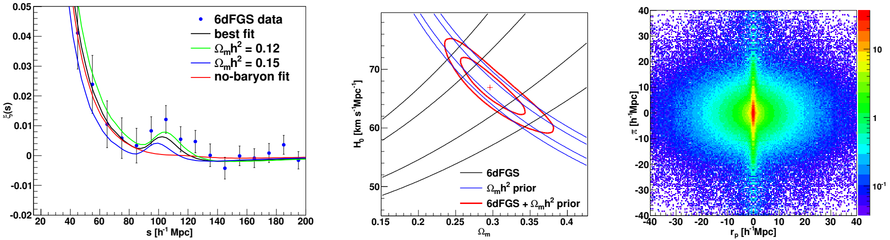

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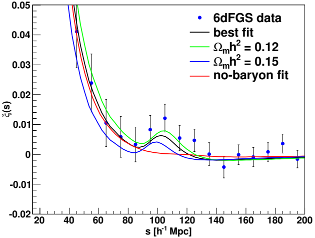

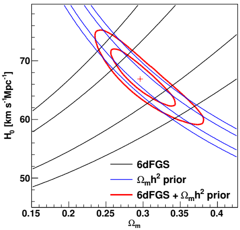

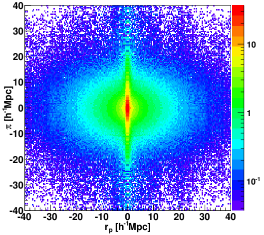

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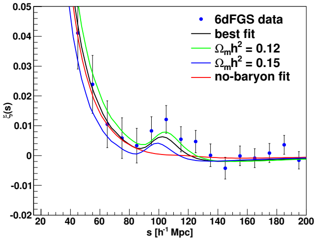

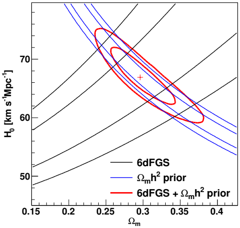

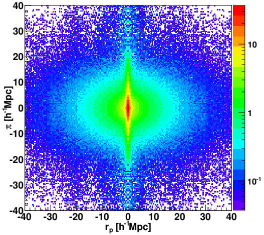

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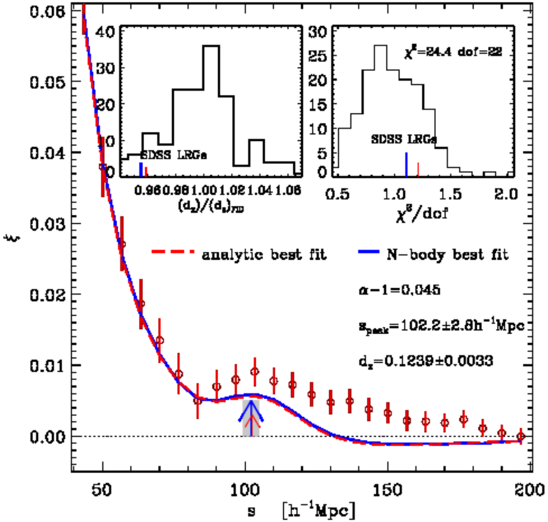
$\rightarrow$ Currently we don't have any signs for a cosmology beyond ΛCDM.

Thank you very much

Cosmological implications



Blake et al. (2011)

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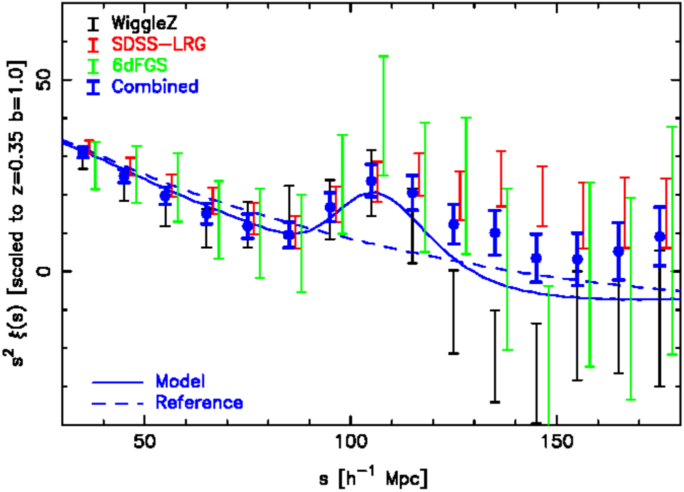

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