# Cosmology with TAIPAN : optimizing the survey design

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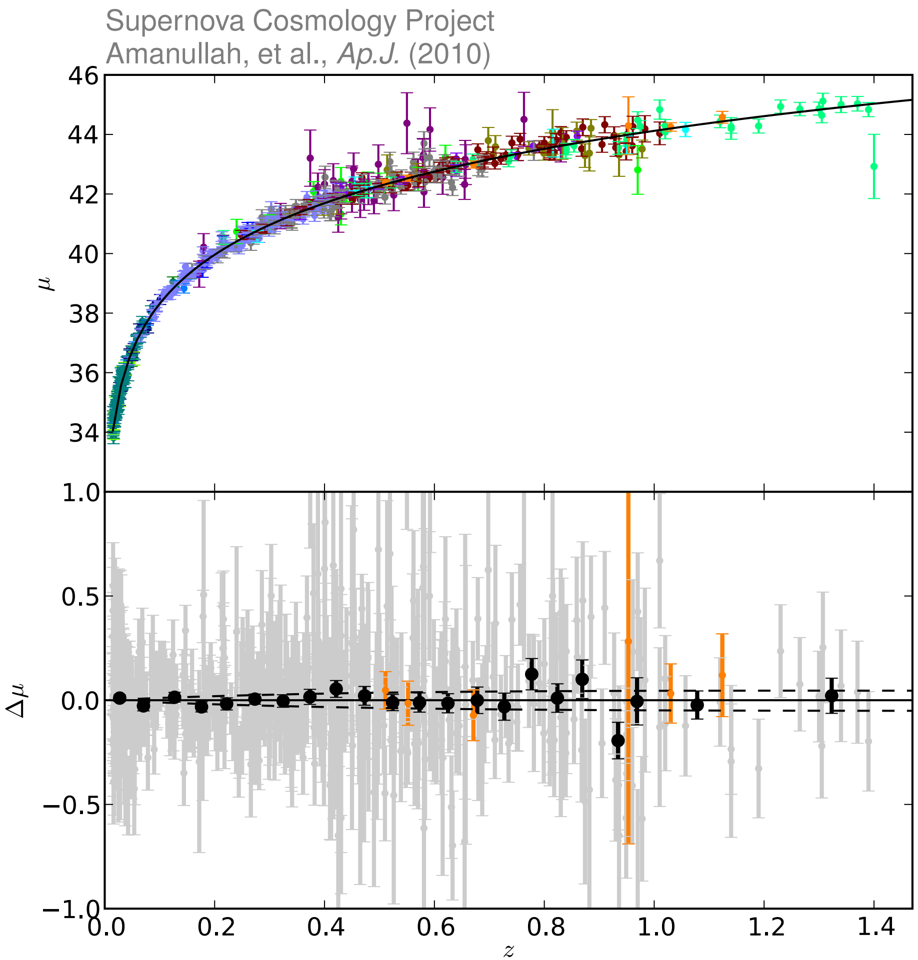
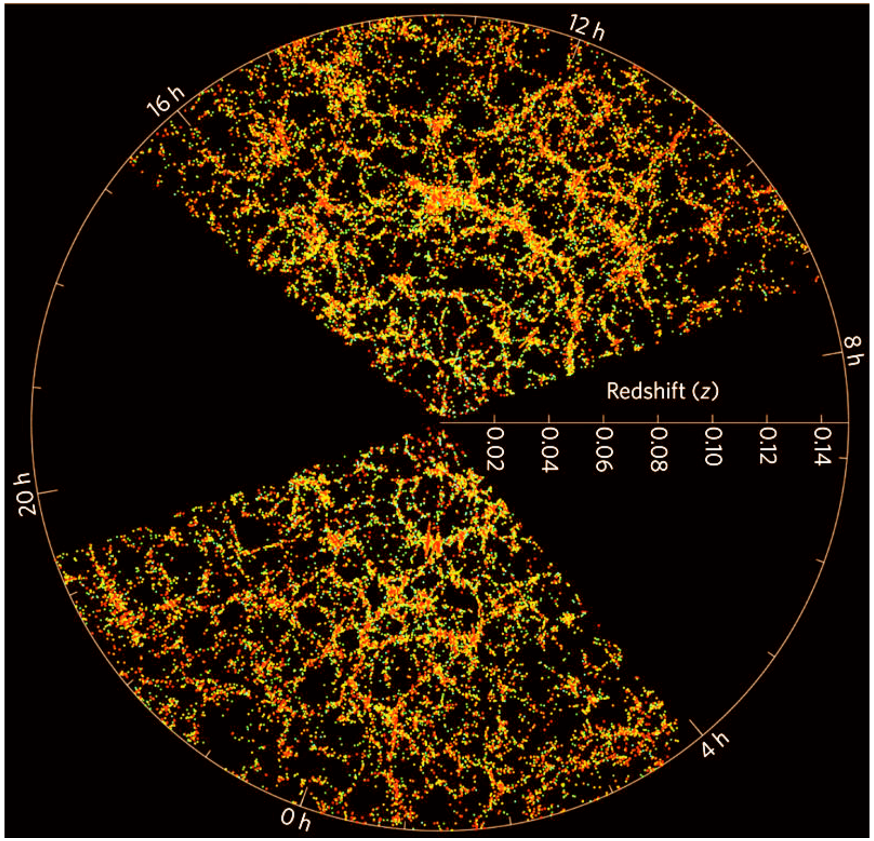
# Probes of the cosmological model

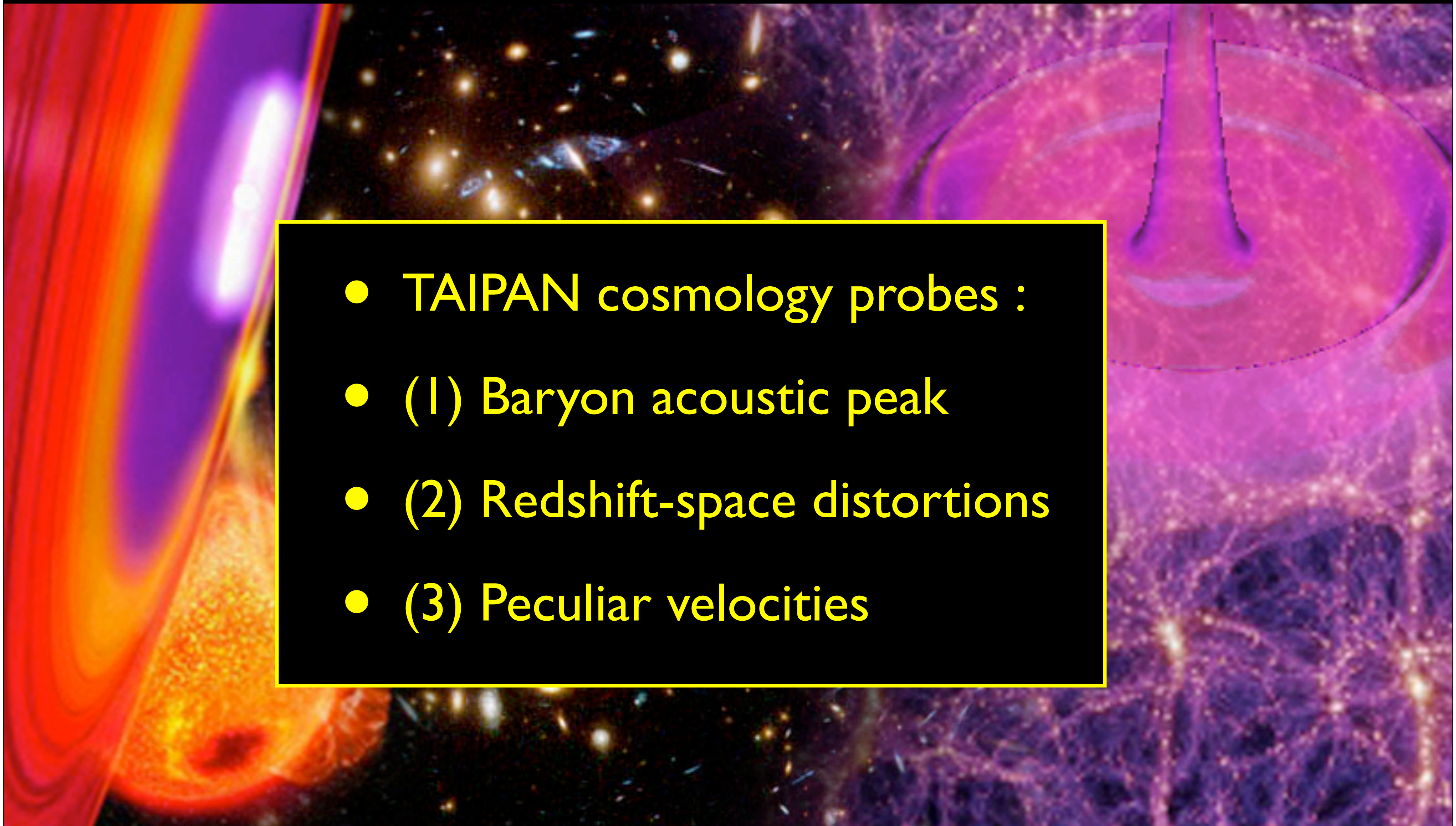
How fast is the Universe expanding with time?

How fast are structures growing within it?



# Probes of the cosmological model

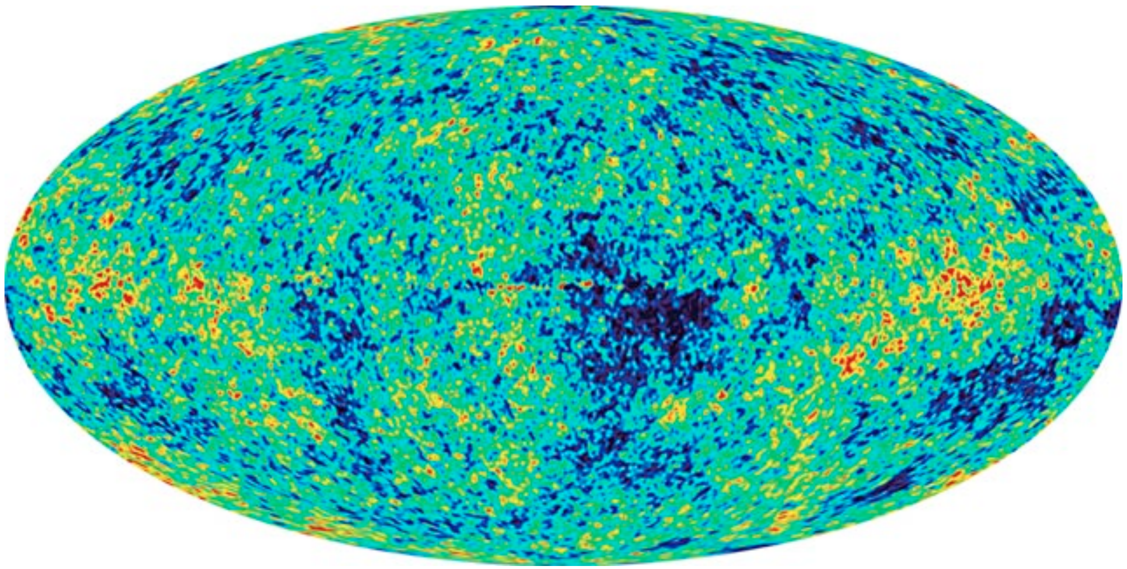


- TAIPAN cosmology probes :
- (1) Baryon acoustic peak
- (2) Redshift-space distortions
- (3) Peculiar velocities

# Baryon acoustic peak

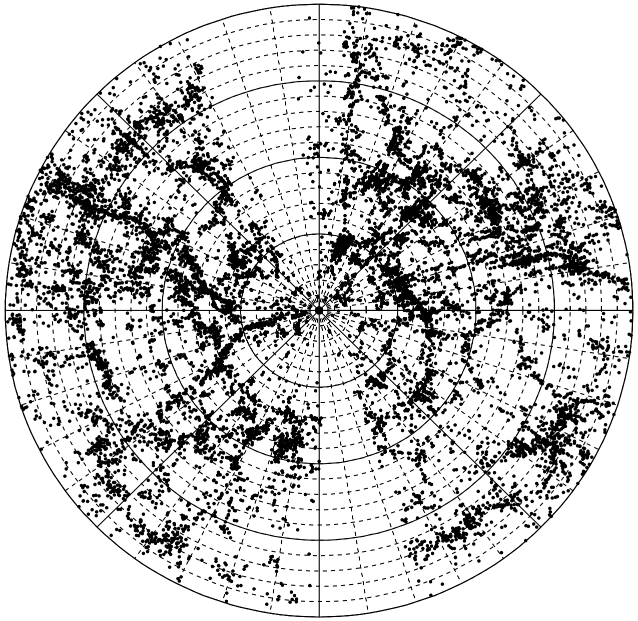
- Standard ruler in galaxy clustering pattern which allows the mapping out of cosmic distances

- Calibrated in units of Mpc using CMB physics with accuracy of 1.1% [WMAP] , 0.3% [Planck]



- Application to a low-z survey measures $H_0$

# Existing low redshift measurement!

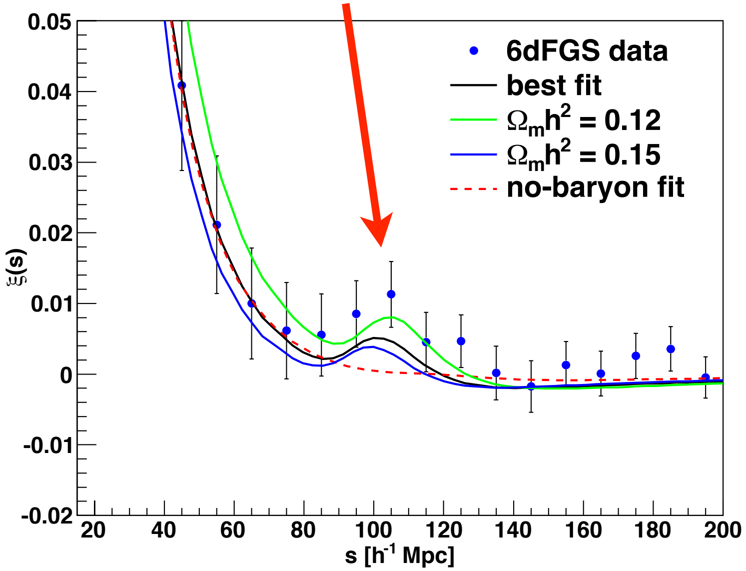


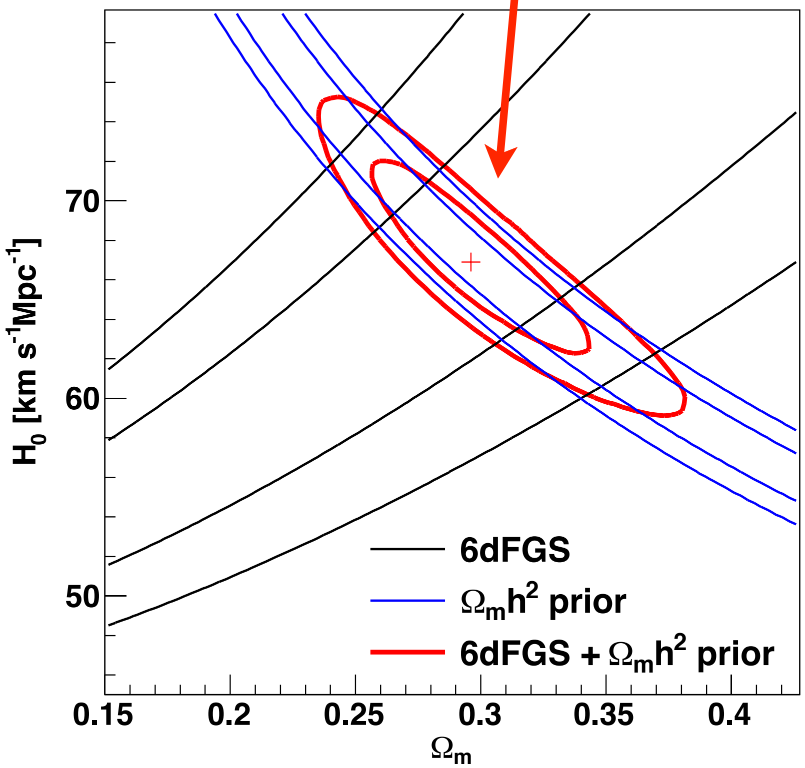
## 6dF Galaxy Survey

Beutler et al. (2011)

$H_0 = 67.0$ +/- 3.2 km $s^{-1}$ $Mpc^{-1}$

D(z=0.1) = 456 +/- 27 Mpc



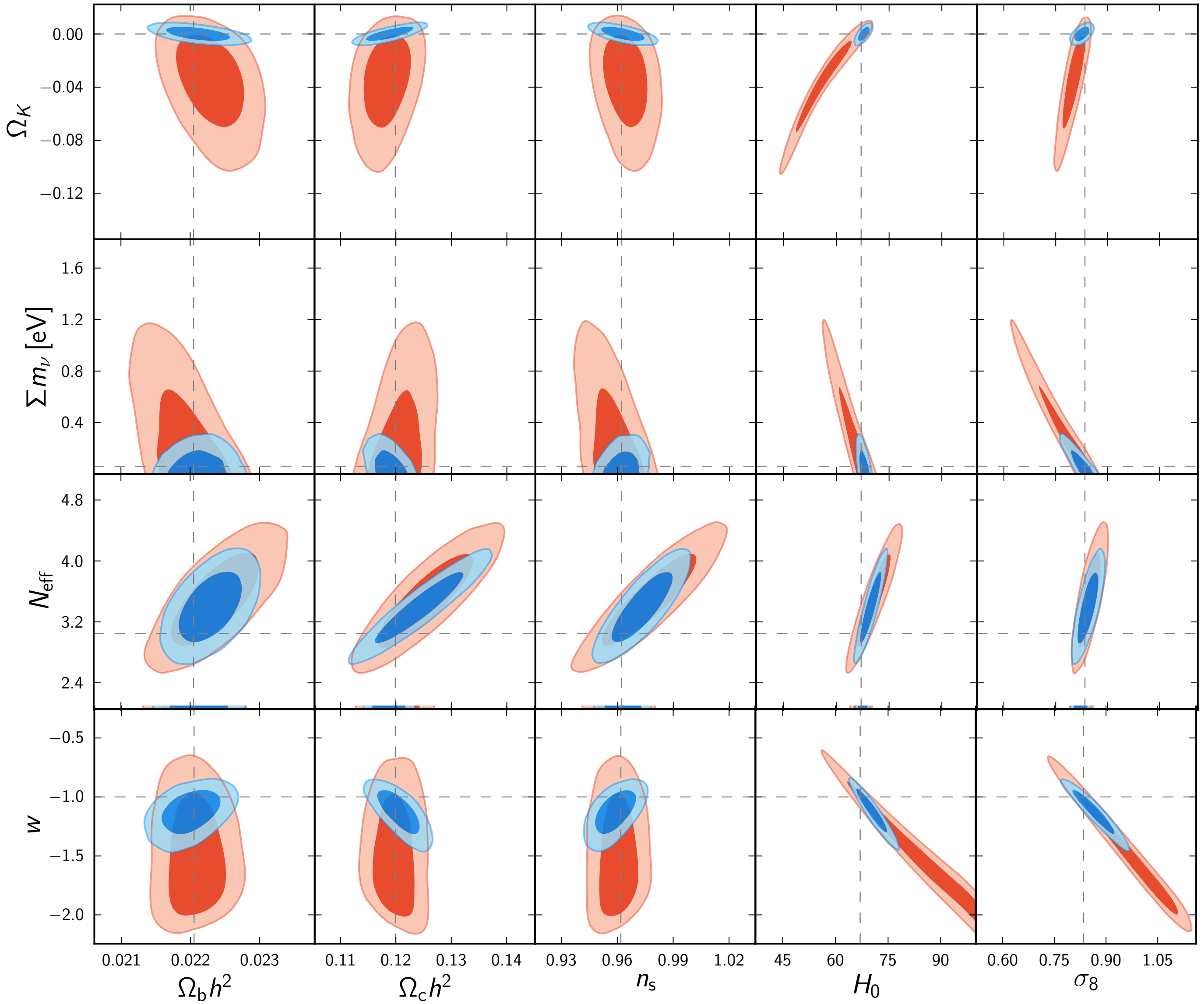



# Why measure $H_0$?

- TAIPAN will make 1% $H_0$ measurement
- Local expansion rate is a fundamental cosmic parameter (e.g. important for determining the age of the Universe)
- Assuming flat LCDM, Planck CMB constrains $H_0$ to ~1.8%, but this is a model-dependent result
- Independent determination of $H_0$ can improve the measurement of other parameters (e.g. dark energy, neutrino numbers/masses)
- There are systematic discrepancies between CMB and local $H_0$ measurements (Cepheids, masers, supernovae)

# Why measure $H_0$?

- Planck determination of $H_0$ is model-dependent




Planck results

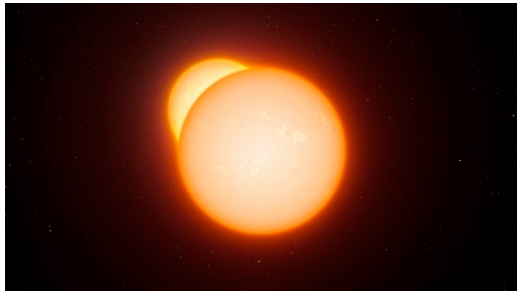
Red : CMB only

Blue : CMB+BAO

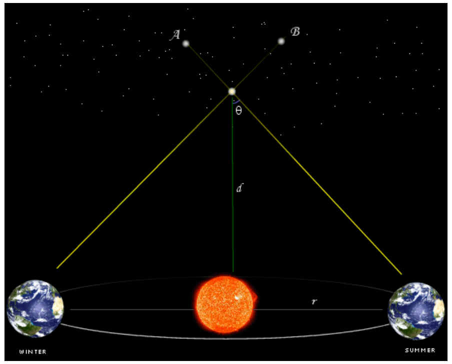
# Why measure $H_0$?

- Local determinations of $H_0$

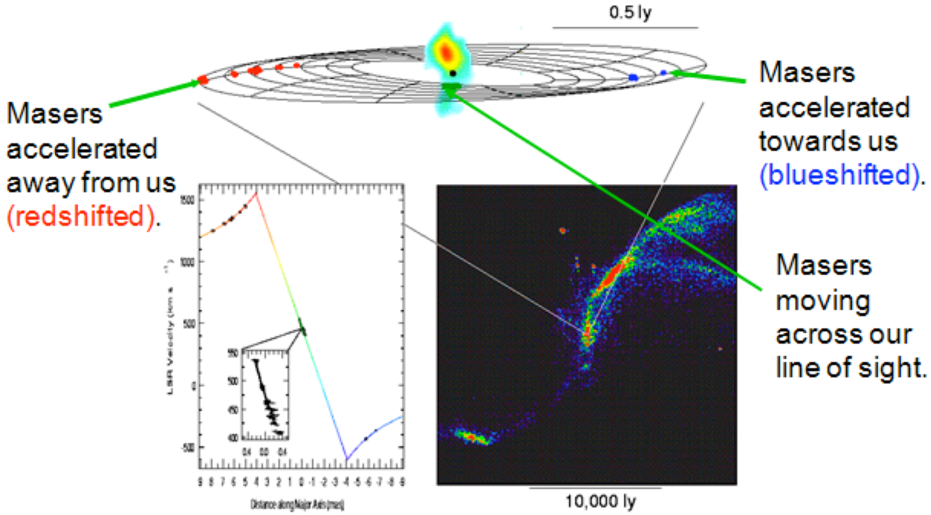
Eclipsing binaries
(in LMC, 50 kpc)



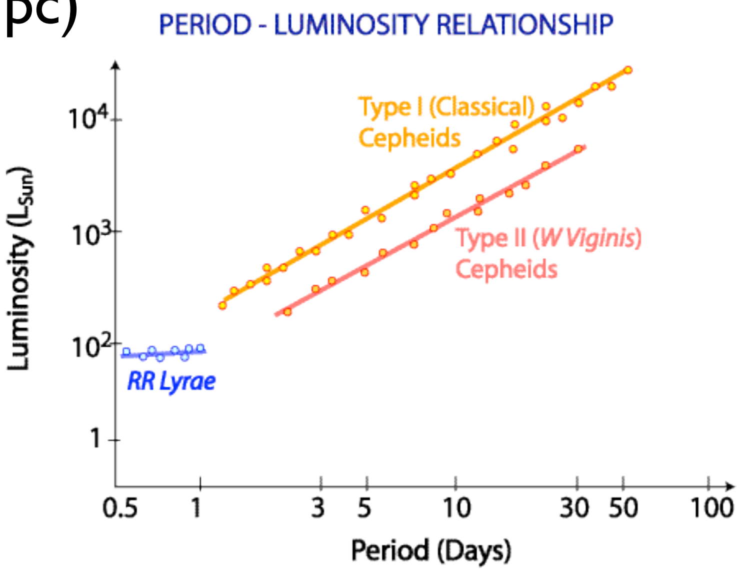
Parallax (< 1 kpc)



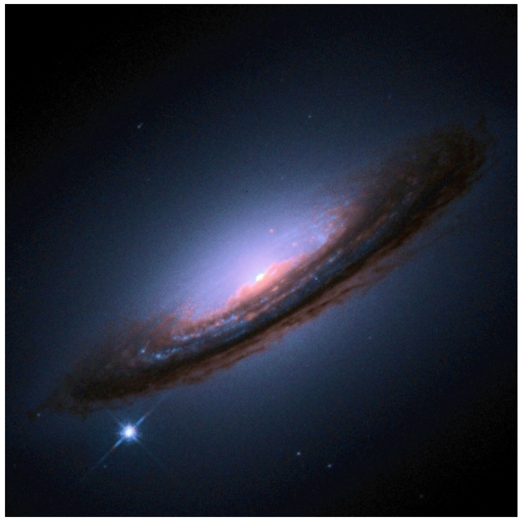
Masers (NGC4258 at 7.6 Mpc)




Cepheids
(< 30 Mpc)

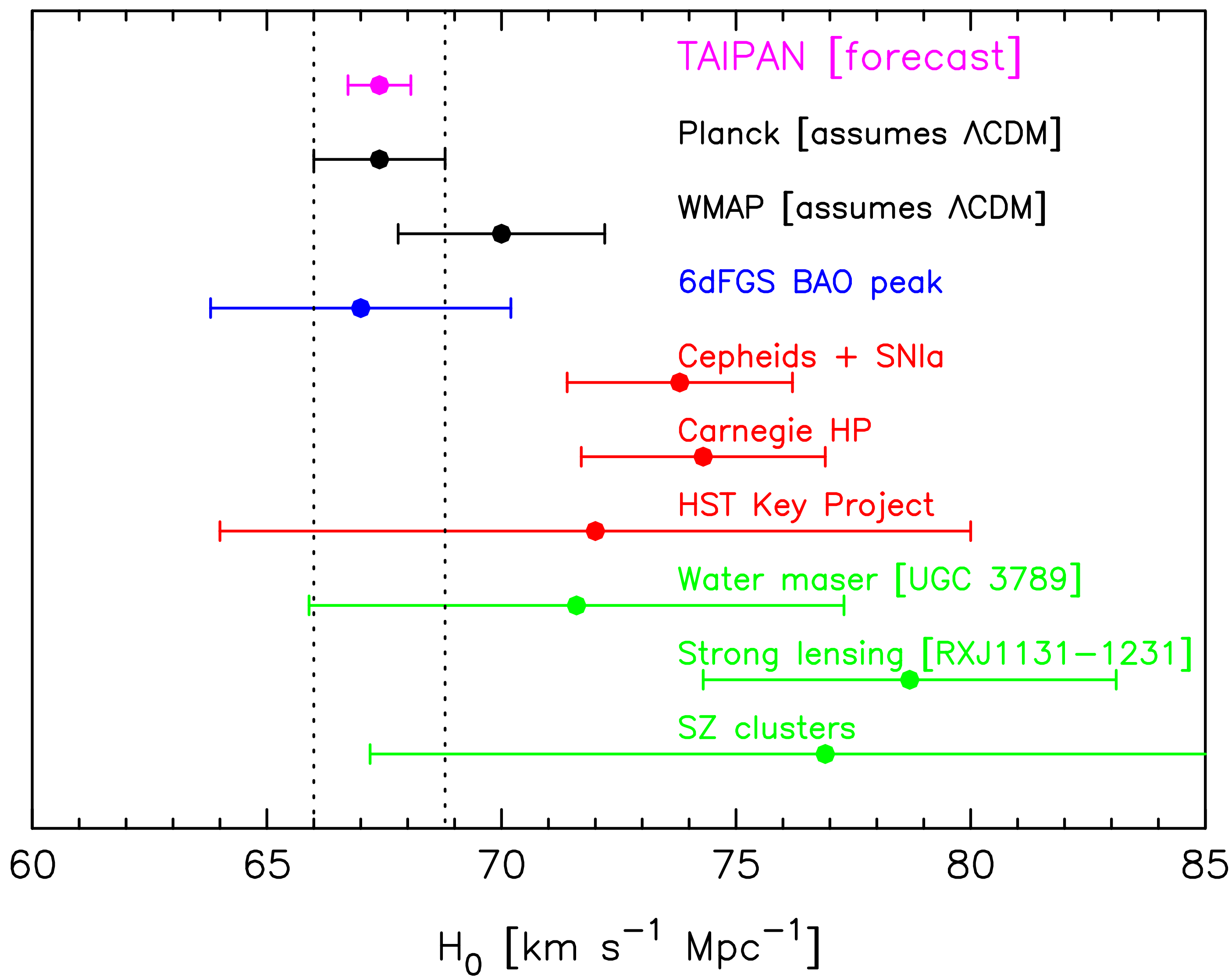



Supernovae
(z < 0.1)



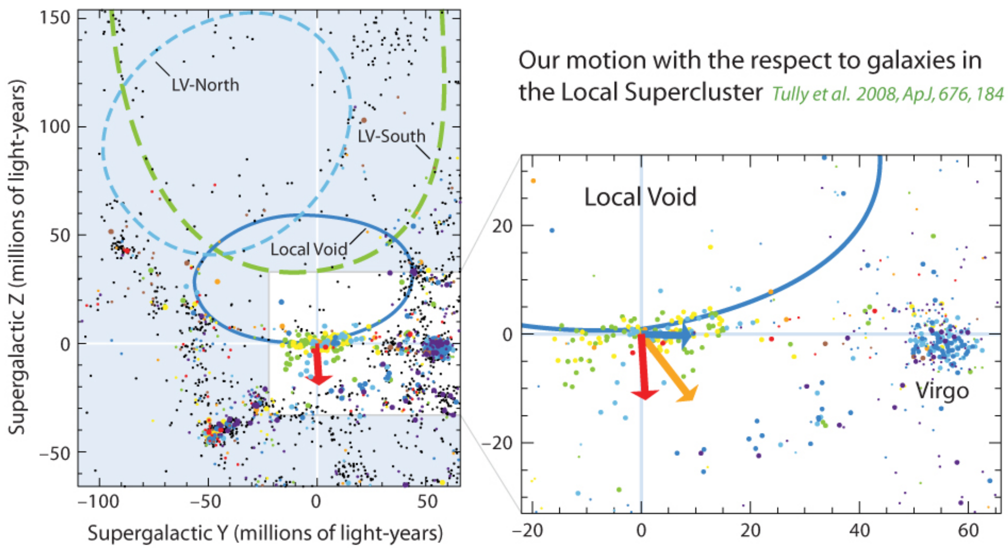
# Why measure $H_0$?

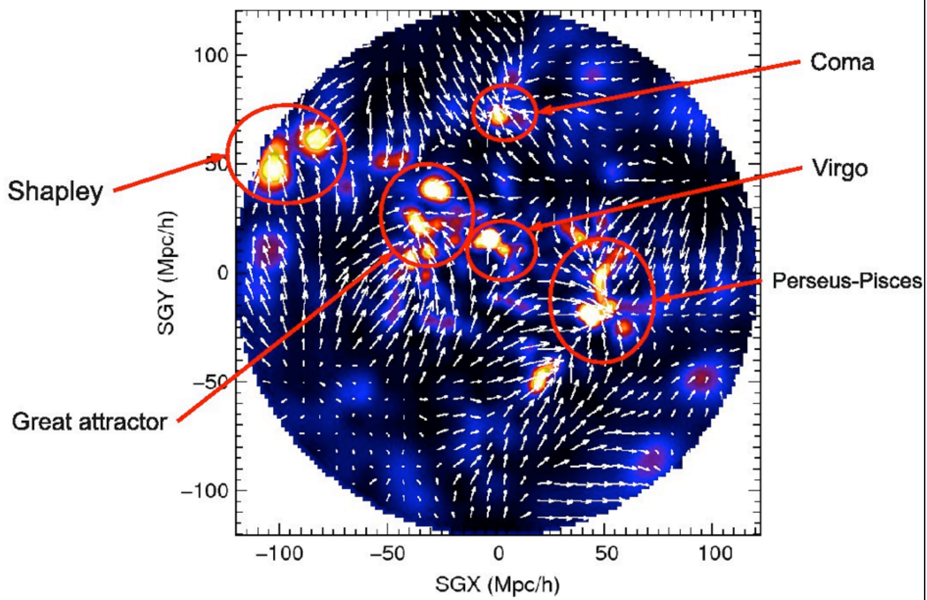
- Discrepancies between Planck and local measurements



# Why measure $H_0$?

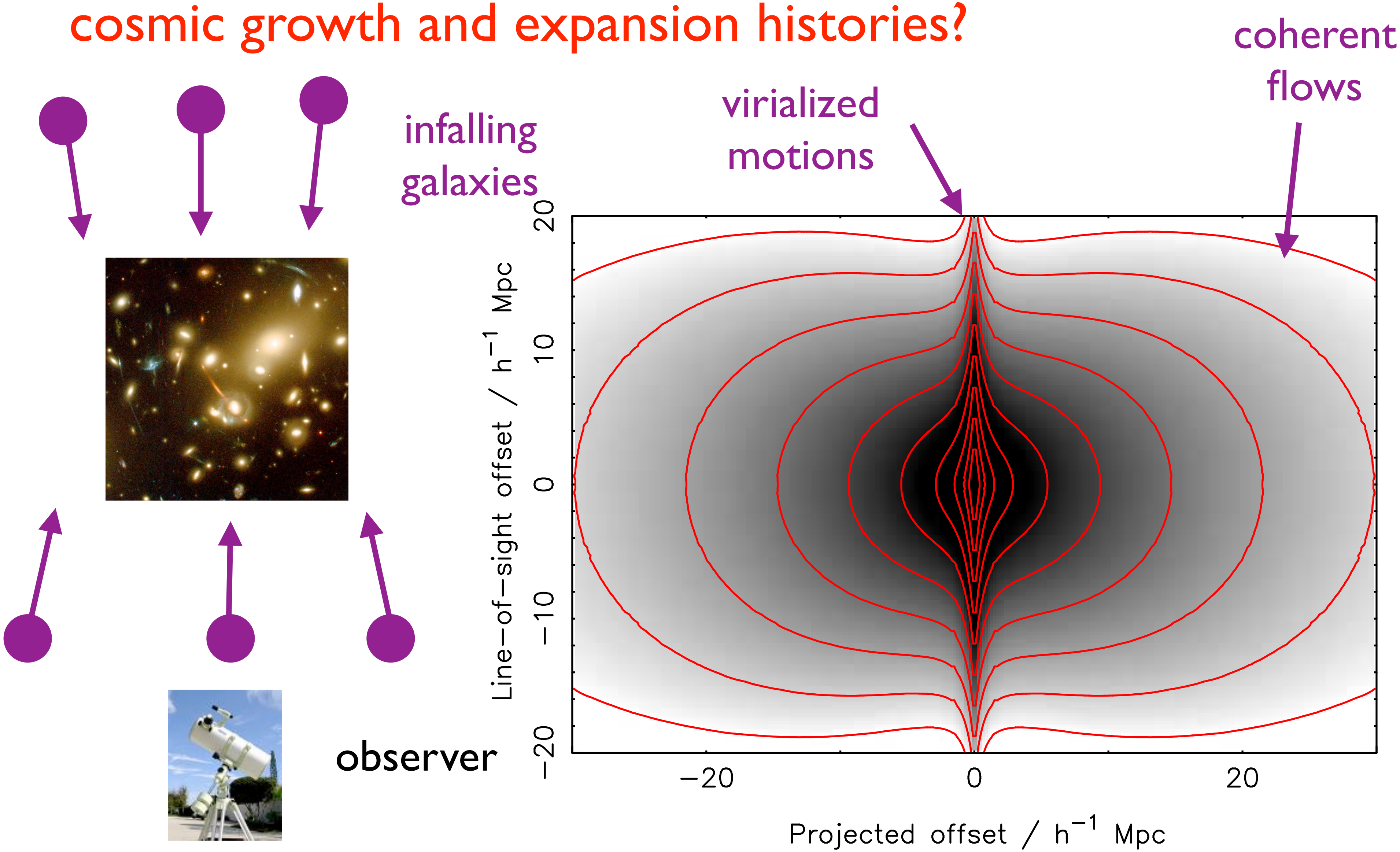
- Discrepancies could be systematic errors ...?
- ... or signatures of non-LCDM physics?
- ... or signature of gravitational physics driven by inhomogeneity / backreaction ?



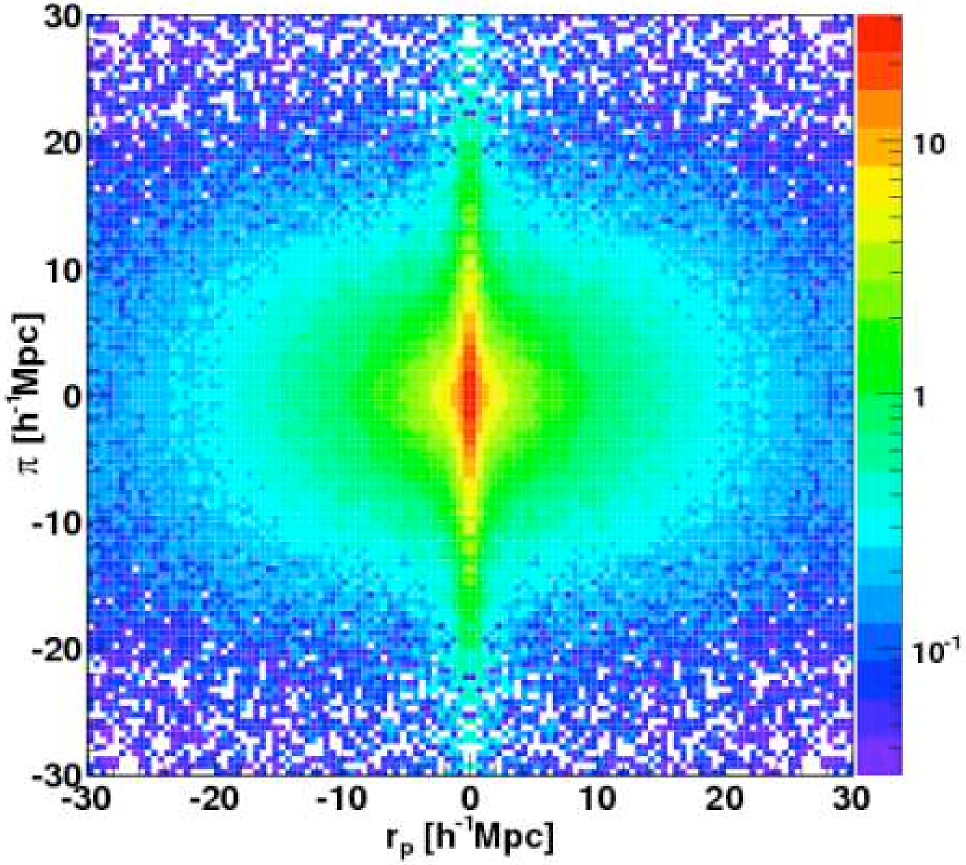
# Redshift-space distortions

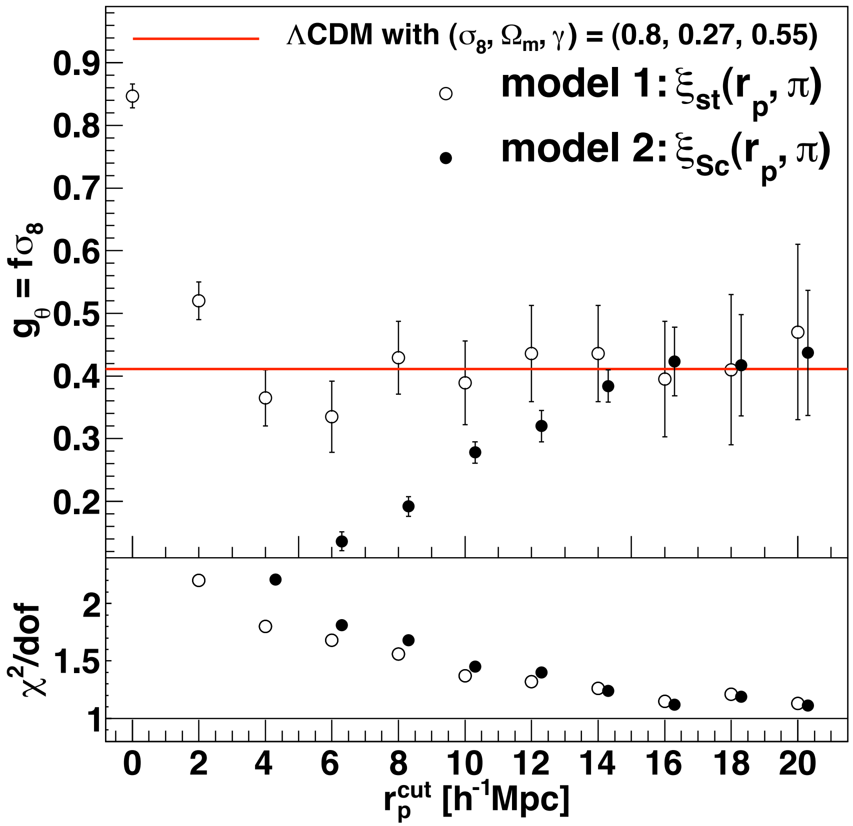
- Does a cosmological model produce self-consistent cosmic growth and expansion histories?



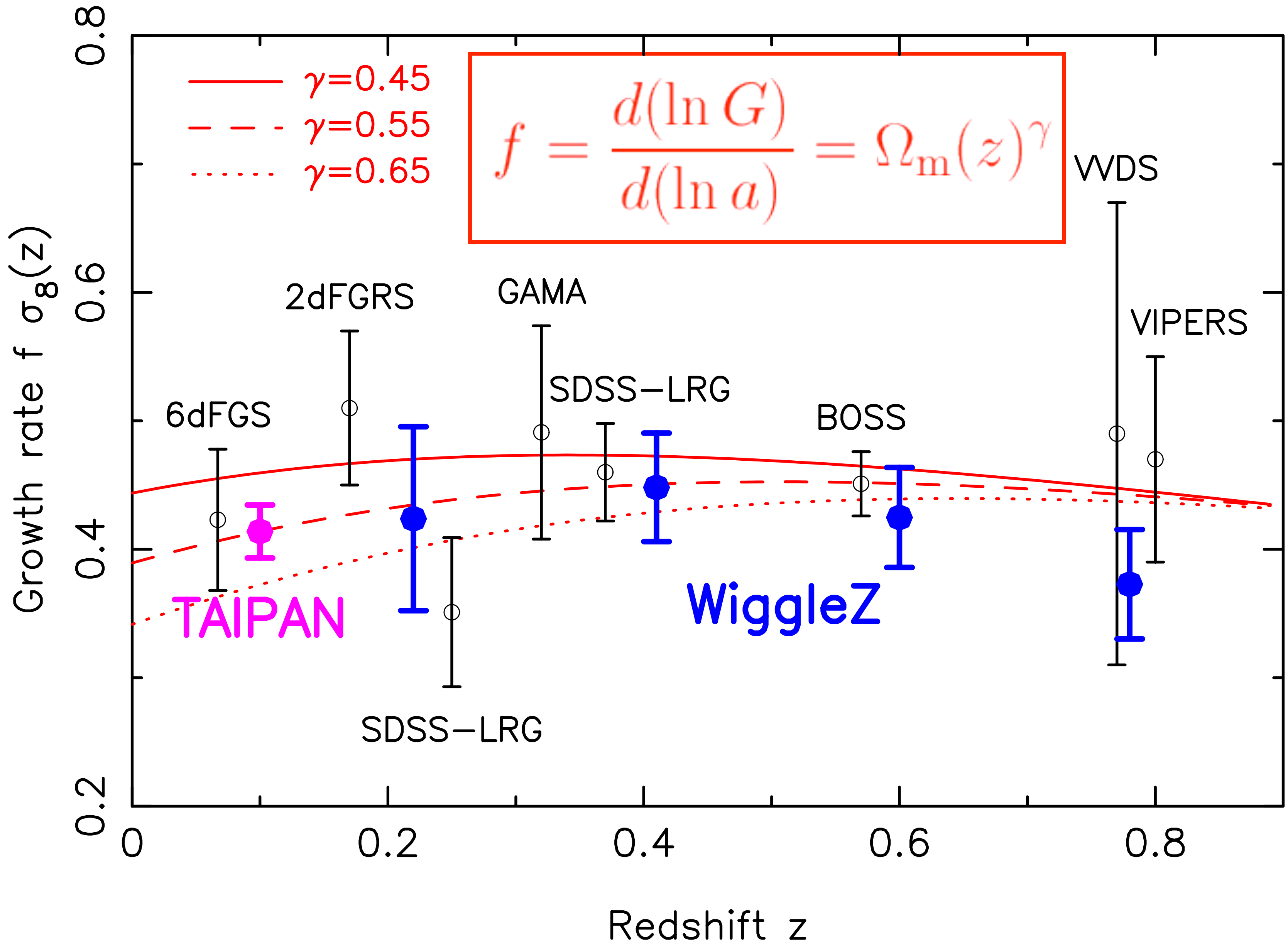
# Redshift-space distortions

- 6dFGS measurement from Beutler et al. (2012)



# Redshift-space distortions



# Why measure RSD at low redshift?

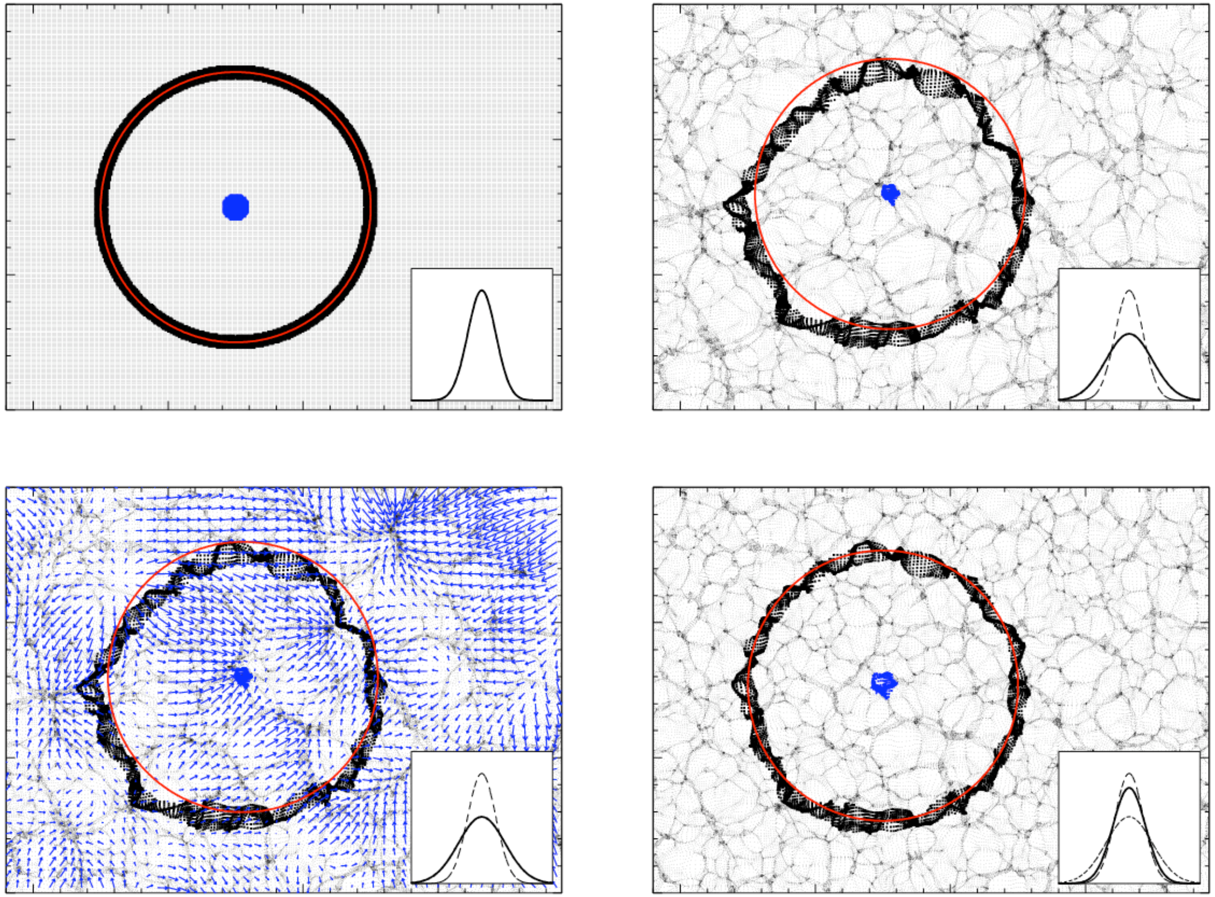
- TAIPAN will make 5% growth rate measurement
- Advantage : local growth rate is very sensitive to dark energy or modified gravity model
- Advantage : high number density of galaxies may be observed, allowing multiple-tracer techniques
- Disadvantage : structure becomes "non-linear" at low redshift and difficult to model
- Disadvantage : is difficult to cover a sizable volume

# Analysis techniques

- Two approaches for optimizing these measurements

- We can select galaxies to fill space more uniformly [e.g. photo-z]
- We can use "reconstruction" of the acoustic peak

Padmanabhan et al. (2012)



# Survey simulations

- Use Fisher matrix techniques to predict $H_0$ and growth measurements given survey n(z) and area

astro-ph/0701079

IMPROVED FORECASTS FOR THE BARYON ACOUSTIC OSCILLATIONS AND COSMOLOGICAL DISTANCE SCALE

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**ABSTRACT**

We present the cosmological distance errors achievable using the baryon acoustic oscillations as a standard ruler. We begin from a Fisher matrix formalism that is upgraded from Seo & Eisenstein (2003). We isolate the information from the baryonic peaks by excluding distance information from other less robust sources. Meanwhile we accommodate the Lagrangian

# Survey simulations

- Luminosity functions

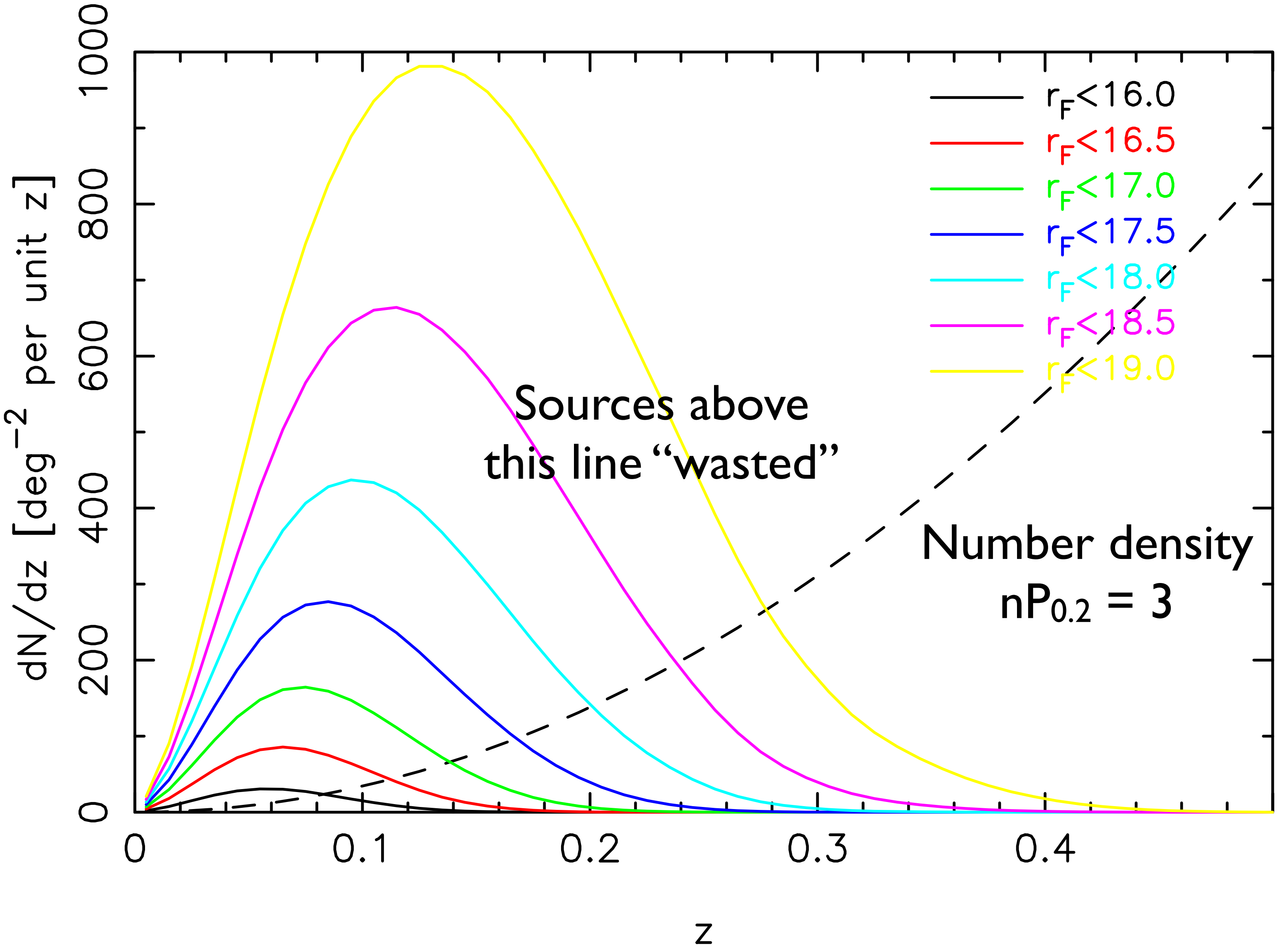
| | |
|---|---|
| Selection band | $r_F$ |
| Luminosity function | Jones et al. (2006) 6dFGS $r_F$-band |
| K-corrections | Poggianti (1997) for E galaxies |
| Conversion to AB mags | $r_{AB} = r_F + 0.36$ (Fukugita 1995) |
| Bias of sources | b=2 |

- Surveys

| | |
|---|---|
| Maximum survey area | 20,000 $deg^2$ |
| Survey duration | 5 years |
| Time fraction | 0.5(dark) x 0.66(weather) |
| Hours observed/night | 8 |

# Survey simulations

- Redshift distributions



# Survey simulations

- Telescope/instrument assumptions

| | |
|---|---|
| Mirror diameter | 1.2 m |
| Efficiency (instrument) | 0.2 |
| Efficiency (atmosphere) | 0.9 |
| Field-of-view diameter | 6 deg |
| Number of fibres | 150 |
| Fibre diameter | 3 arcsec |
| Read noise | 3 electrons |
| Dark current | 0.003 elec/s/pix |
| Number of pixels extracted | 4 (2x2) |
| Configuration time | 300 s |
| Maximum exposure time | 1800 s |

# Survey simulations

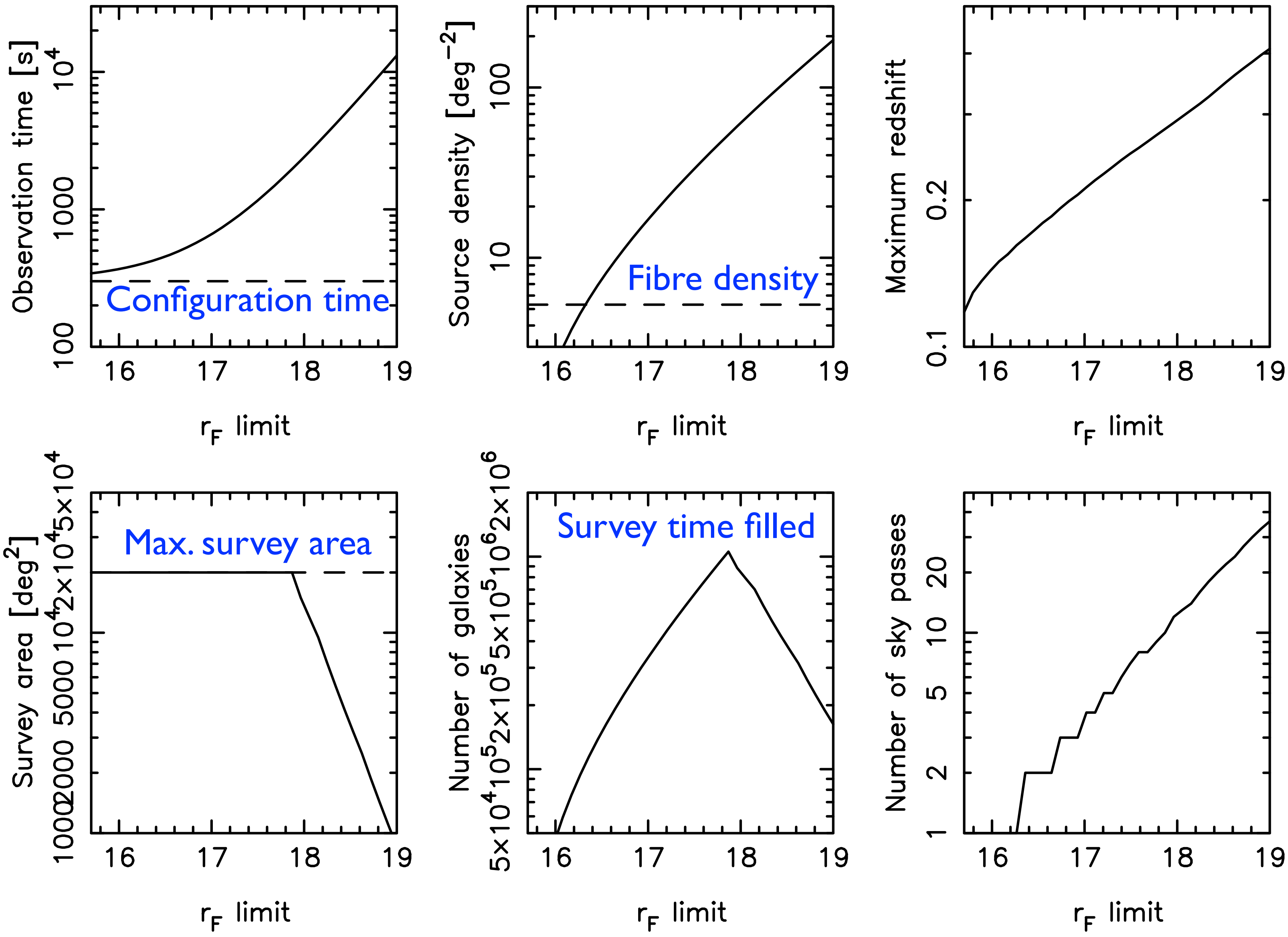
- Exposure time assumptions

| | |
|---|---|
| Wavelength to evaluate S/N | 5483 A |
| Size of SRE | 2.384 A |
| Sky background (AB mags) | 20.8 |
| Required S/N per SRE | 1.0 |
| Half-light radius of sources | 5 arcsec |
| Seeing | 1.5 arcsec |
| Aperture light loss | (fibre area)/(source area) |
| Redshift completeness | 0.7 |

# Survey simulations

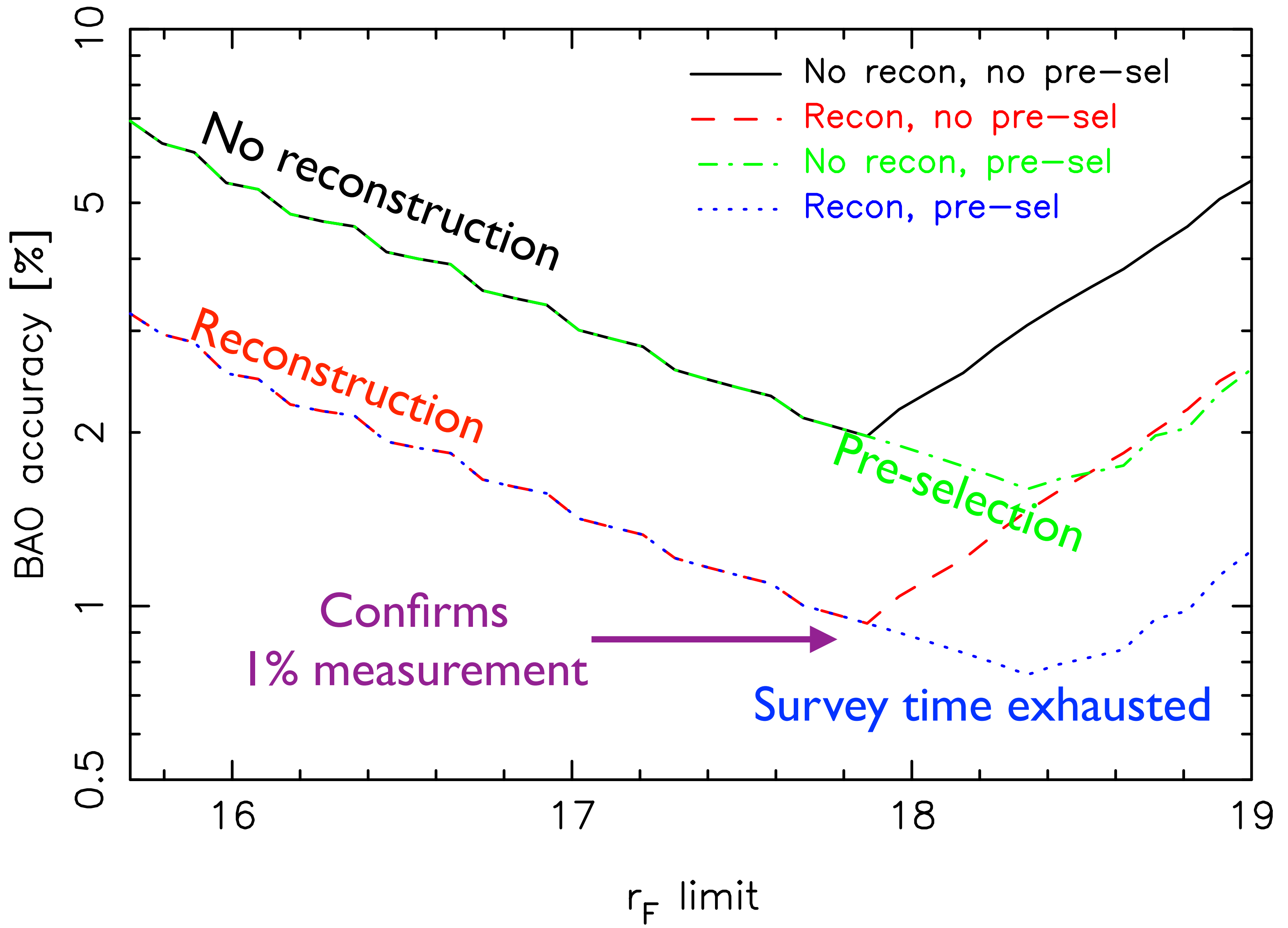
- Vary magnitude threshold in range $16 < r_F < 19$ with bright limit $r_F = 15.6$ (6dFGS)
- Use $r_F$ to determine source density and N(z)
- Use source and fibre density to determine number of passes of sky required to complete survey
- Use $r_F$ and S/N goal to determine exposure time
- Use exposure time, survey duration, number of passes and FoV to determine survey area (max. 20,000 $deg^2$)
- Use N(z) and area to forecast BAO and growth errors

# Survey simulations



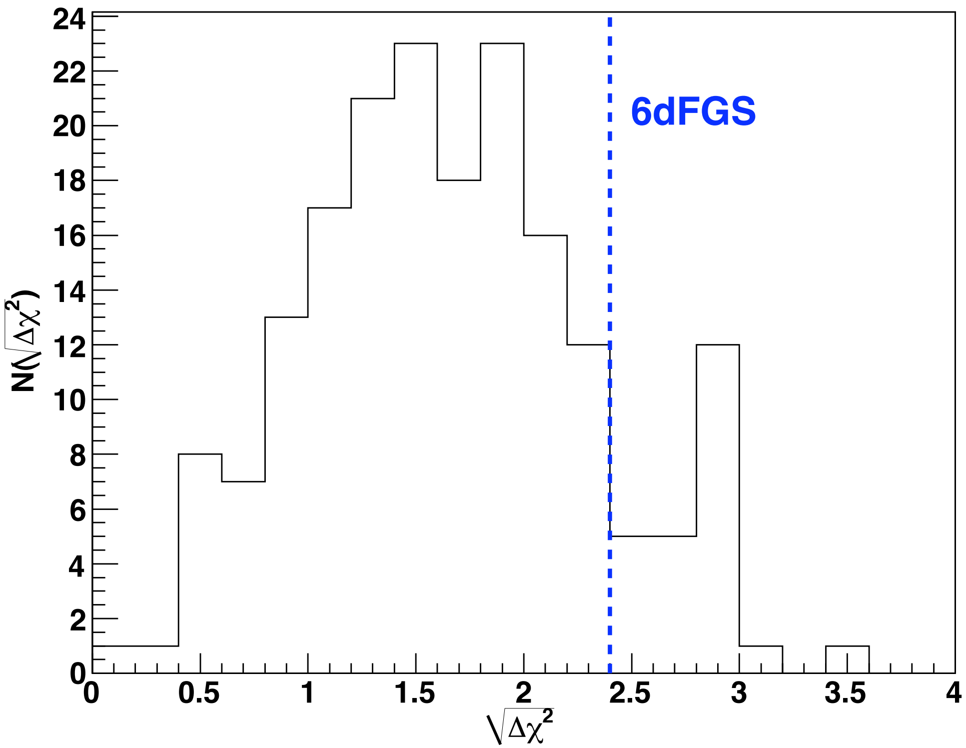
# Survey simulations

- BAO accuracy



# Survey simulations

- Cosmic variance

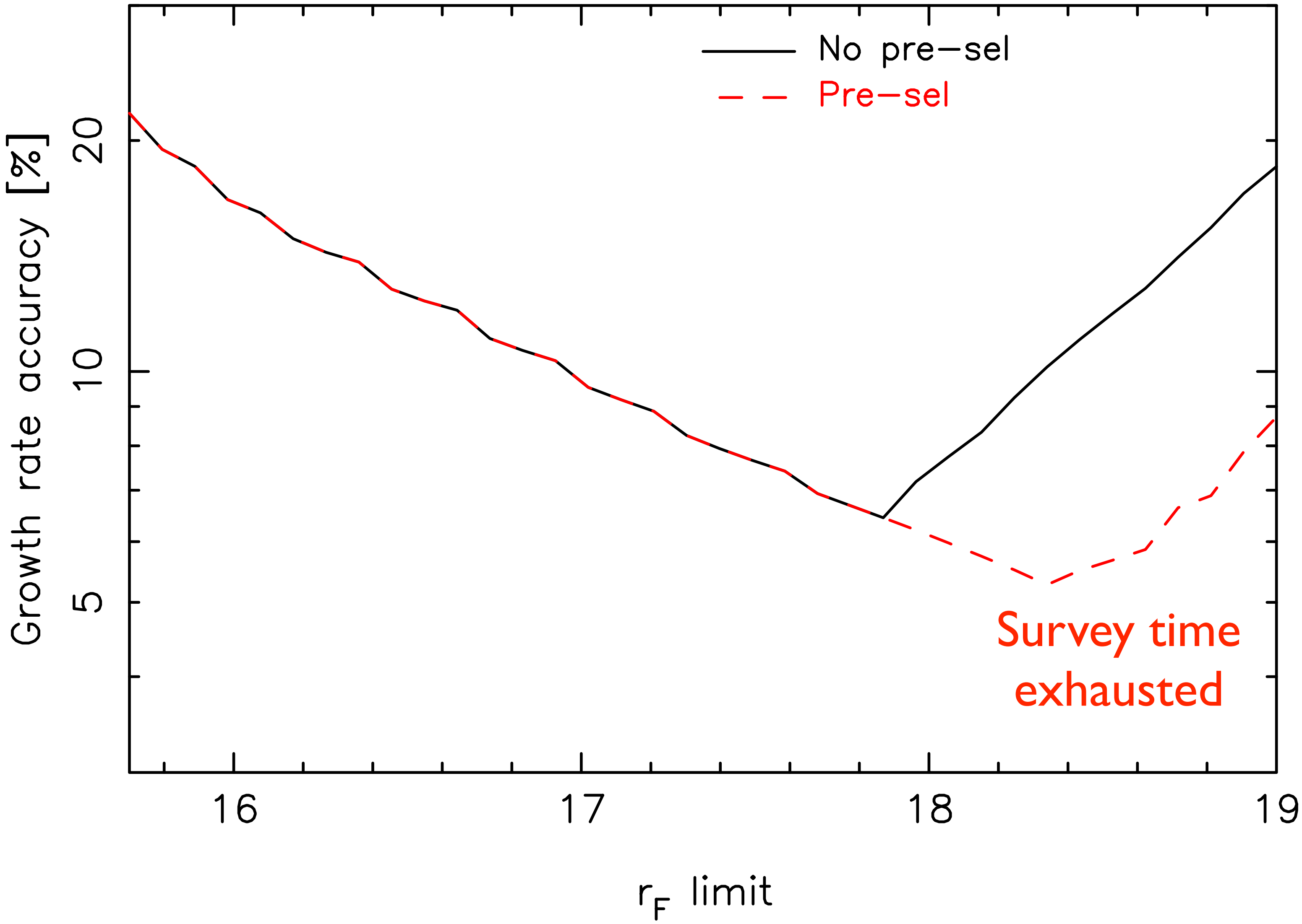



Beutler et al. (2011)

**Figure 8.** The number of log-normal realisations found with a certain $\sqrt{\Delta\chi^2}$, where the $\Delta\chi^2$ is obtained by comparing a fit using a ΛCDM correlation function model with a no-baryon model. The blue line indicates the 6dFGS result.

# Survey simulations

- Growth accuracy



# Conclusions

- TAIPAN can provide 1% measurement of $H_0$ cross-checking CMB vs. local measurement discrepancy
- TAIPAN can improve the $z=0$ growth rate by a factor of 2, resulting in stronger tests of GR
- Survey simulation suggests $r_F<17.8$ is optimal for 5-year flux-limited survey [depends on design choices!]
- Optimal pre-selection allows 0.5 mag fainter limit and ~30% improvements in parameters