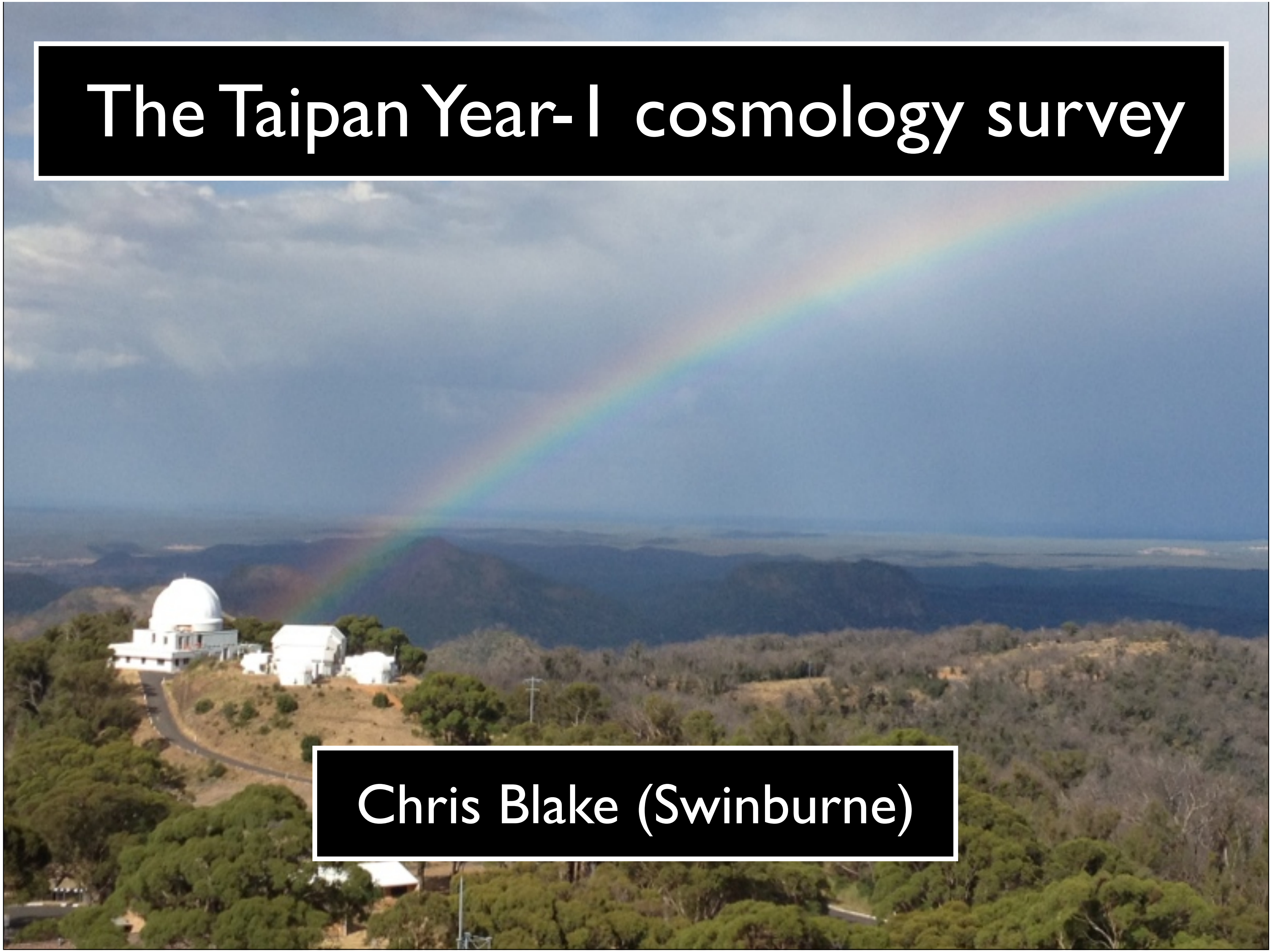
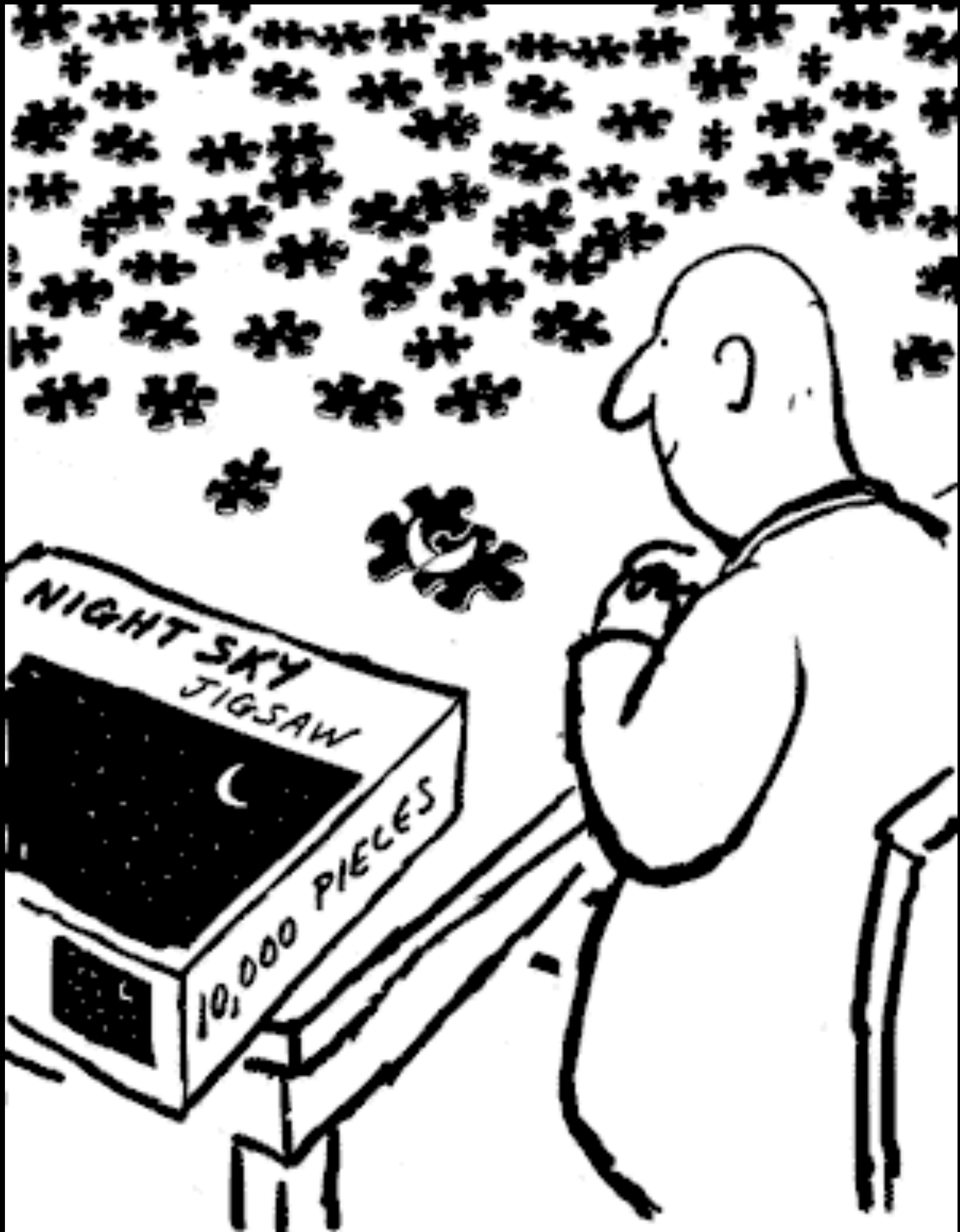
The Taipan Year-1 cosmology survey

Chris Blake (Swinburne)



Cosmological physics



What is “dark energy” ?

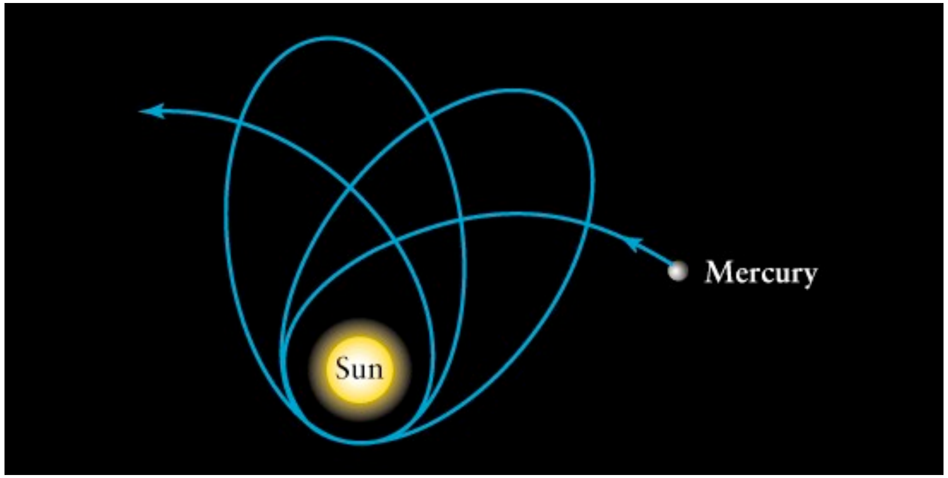
1) new, missing matter-energy component

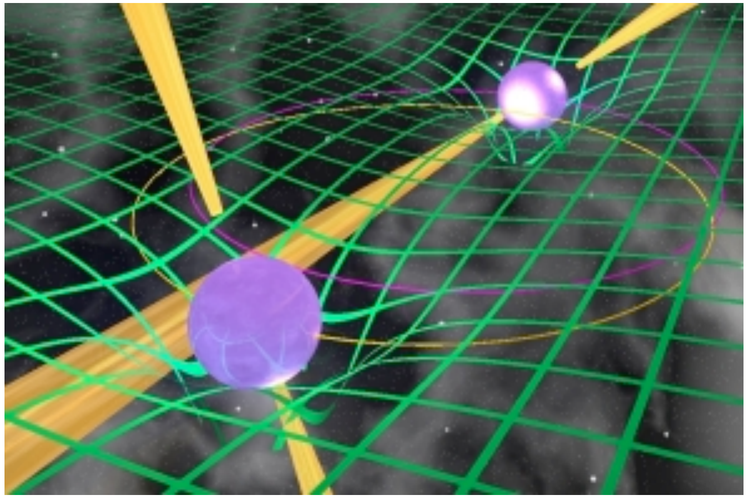
2) failure of the laws of gravity on cosmic scales

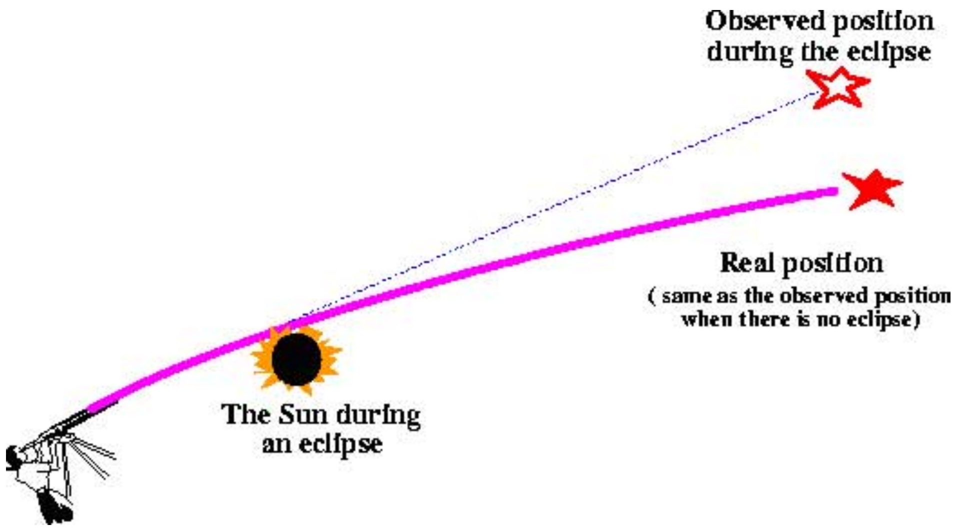
3) failure to correctly model inhomogeneity

Tests of large-scale gravity

- Can tests of G.R. be extended to cosmic scales?
  And can that yield insight into dark energy?





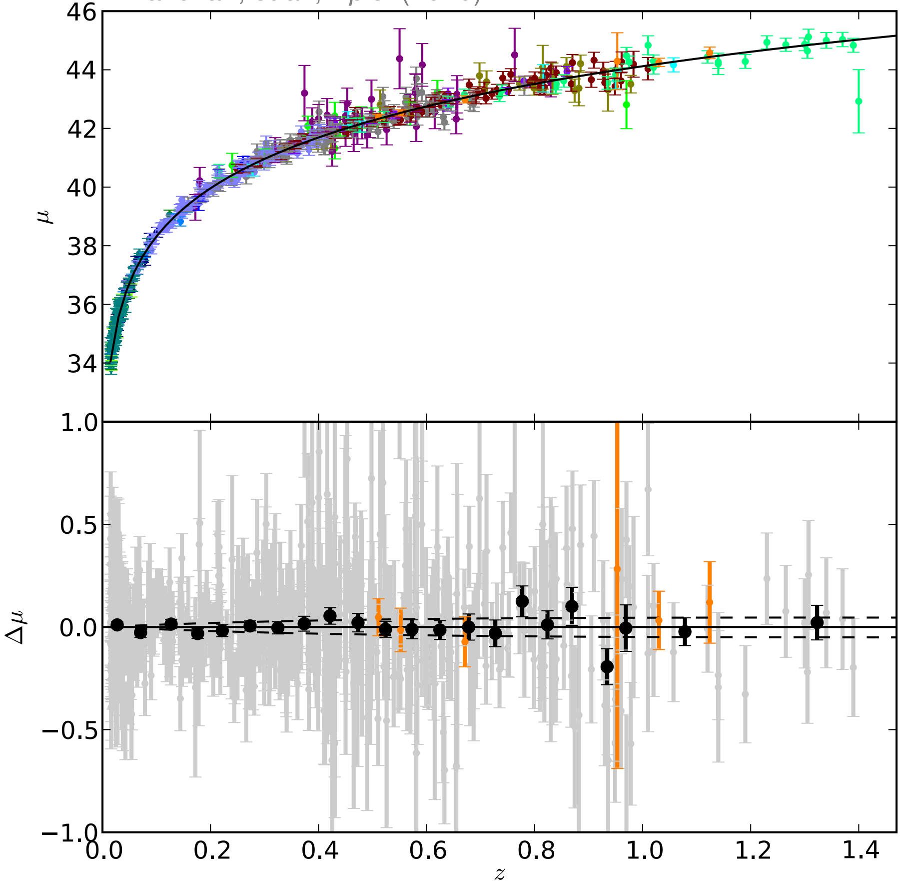


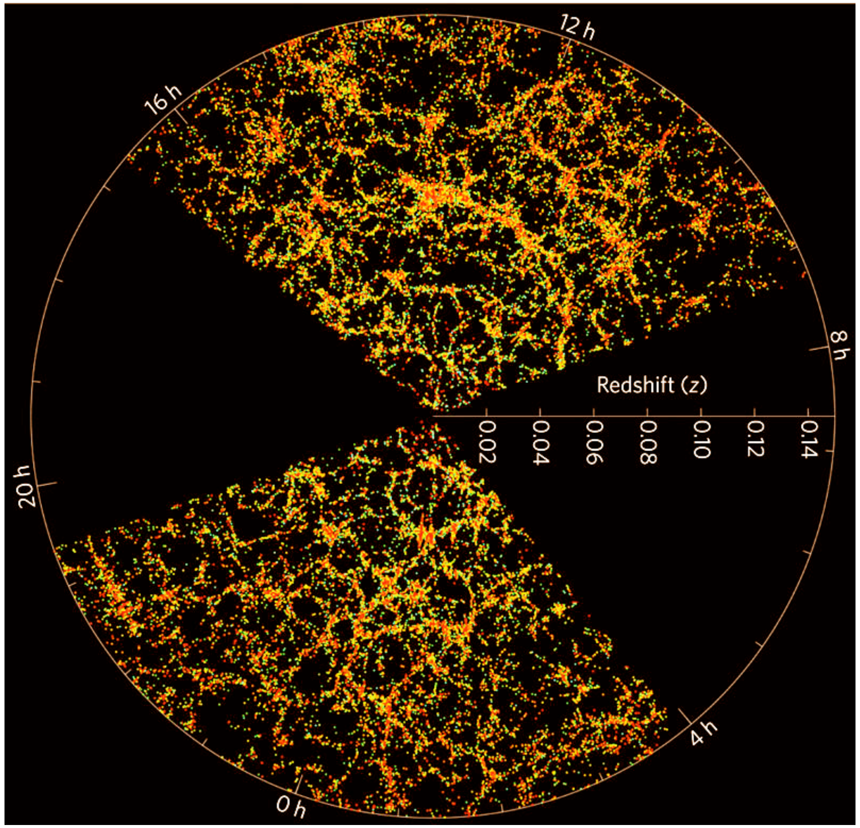
Probes of the cosmological model

How fast is the Universe expanding with time?

How fast are structures growing within it?

Supernova Cosmology Project
Amanullah, et al., *Ap.J.* (2010)





Full Taipan survey cosmology case

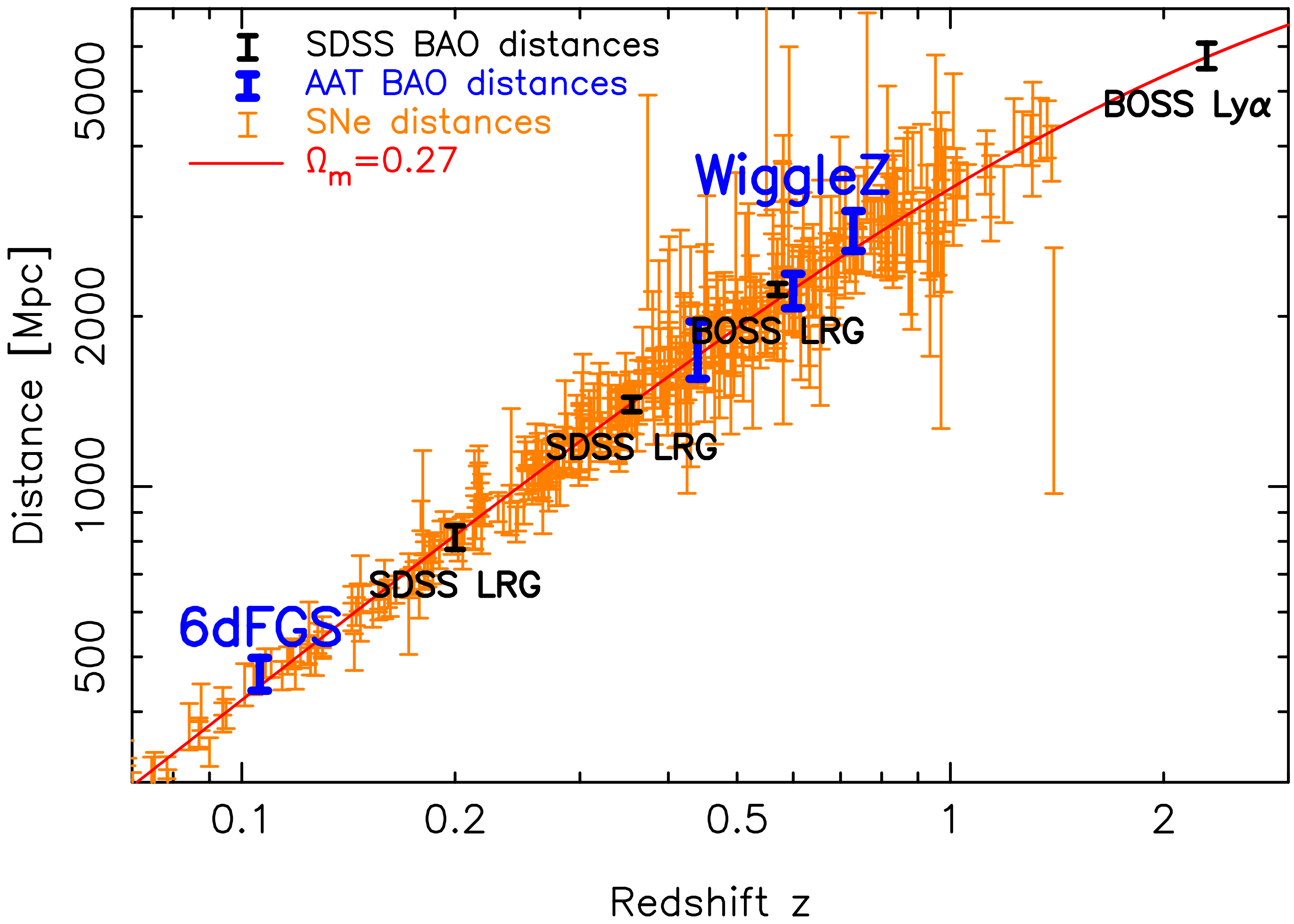
- Obtain complete cosmological information in the low-z Universe, where dark energy dominates, to complement current and future high-z galaxy surveys

- Make a 1% measurement of the expansion parameter H_0 using the baryon acoustic peak, enabling fundamental tests of the cosmological model

- Perform new tests of General Relativity across a range of scales using two complementary methods, galaxy peculiar velocities and redshift-space distortions

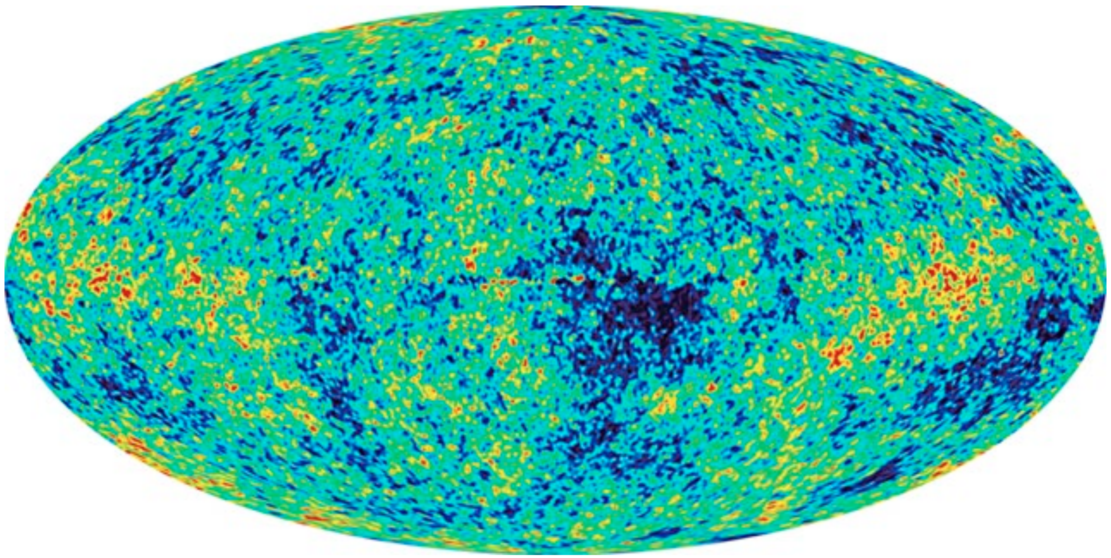
Baryon acoustic peak

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



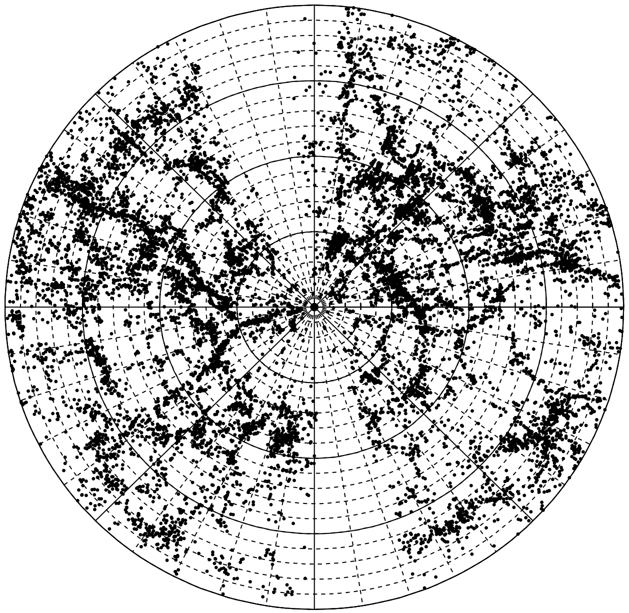
Baryon acoustic peak

- 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!

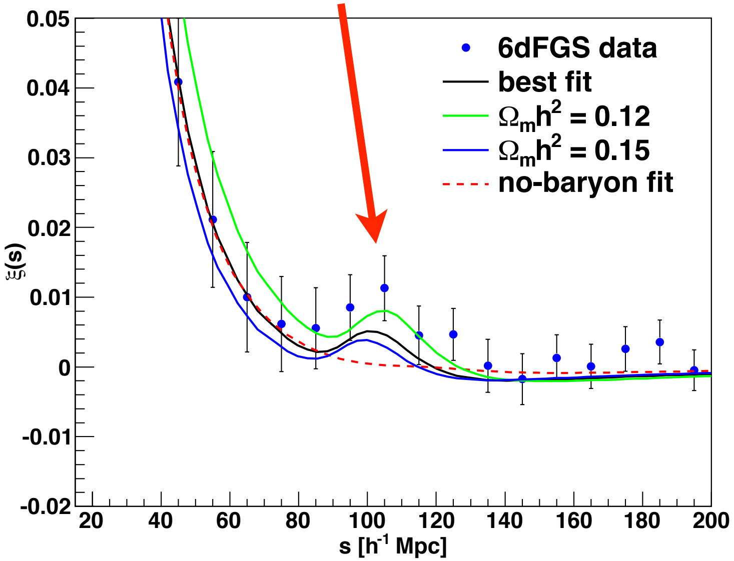


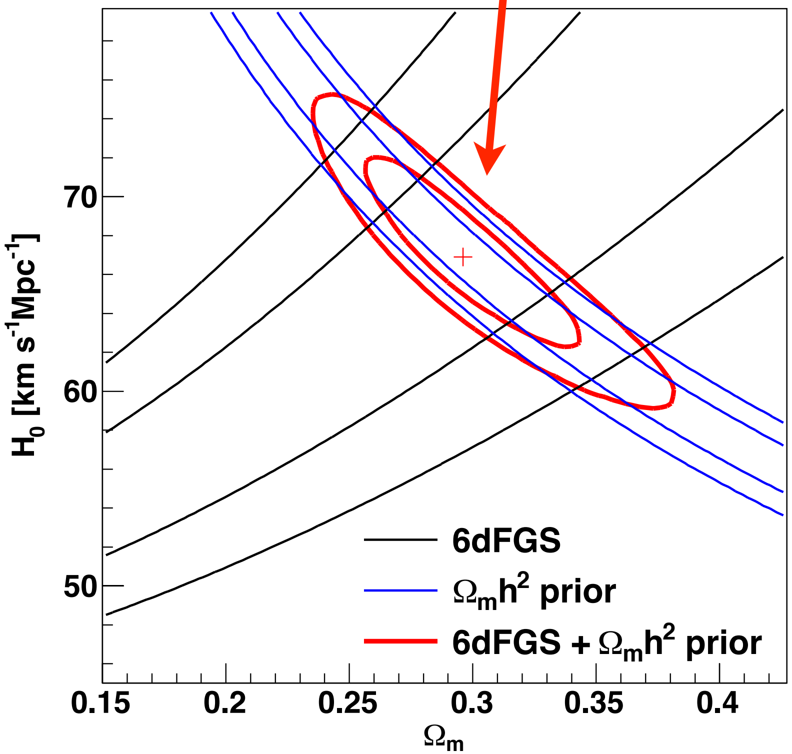
6dF Galaxy Survey

Beutler et al. (2011)

H$_0$ = 67.0 +/- 3.2 km s^{-1} Mpc^{-1}

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



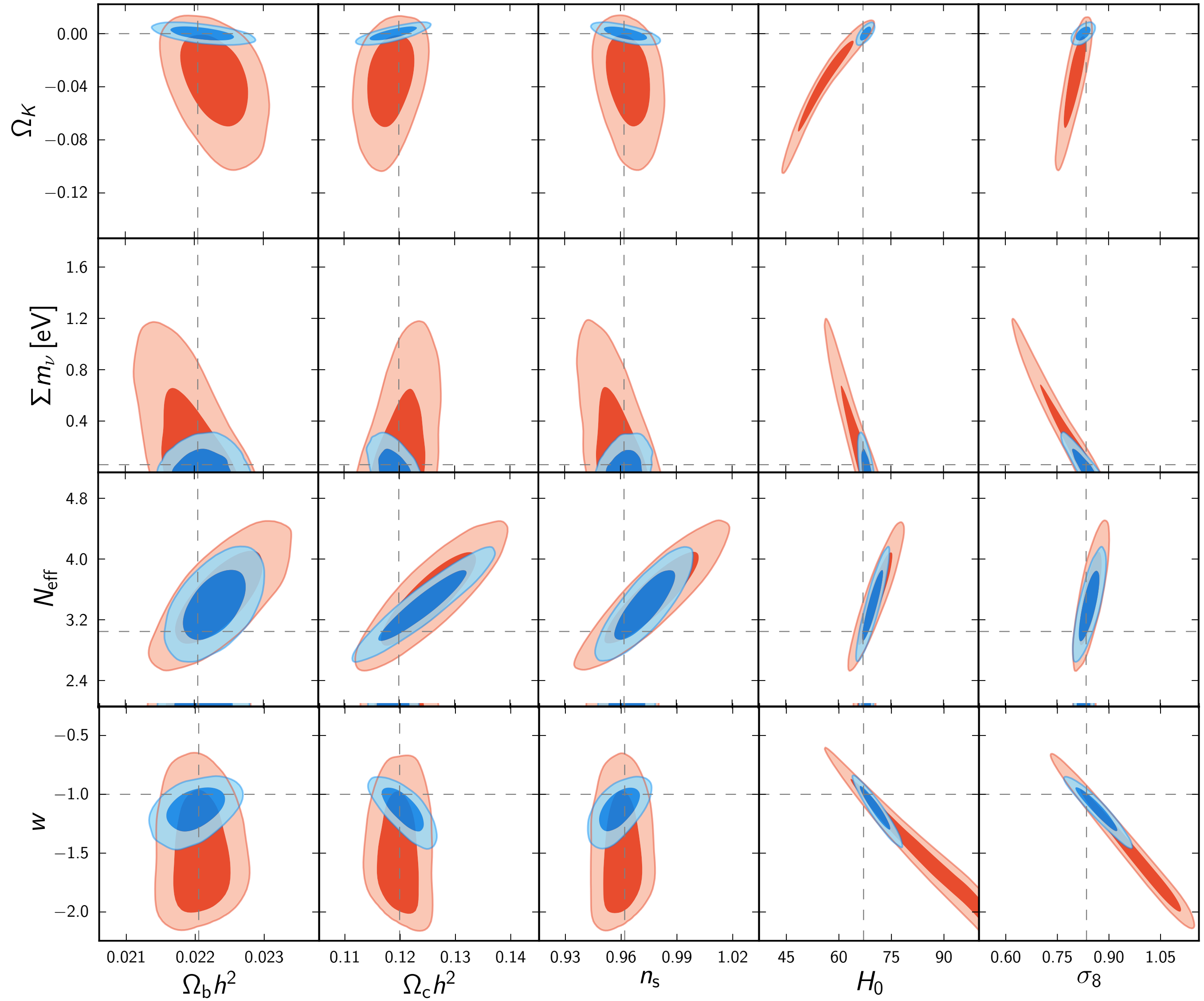


Why measure H_0?

- Full Taipan survey 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 ~1.5%, 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

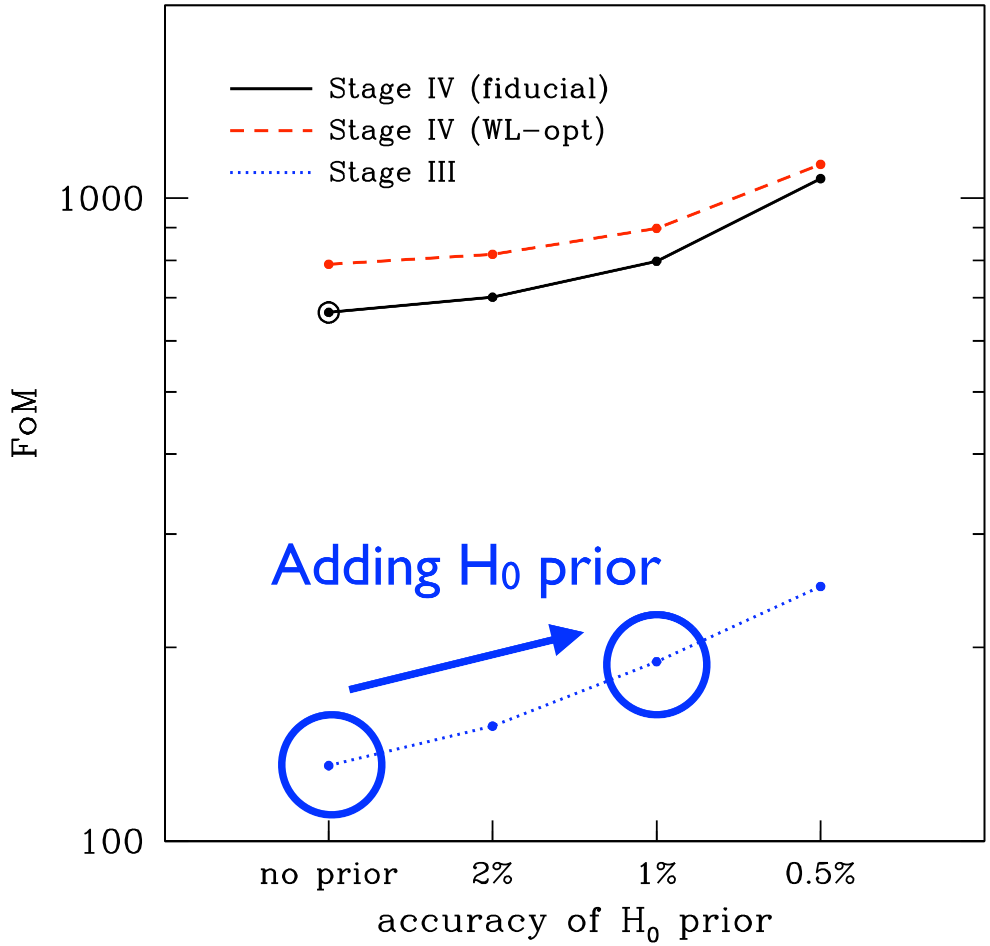
Red : CMB only

Blue : CMB+BAO

Why measure H_0?

- H_0 prior helps with measurements of dark energy

Weinberg et al. (2012)

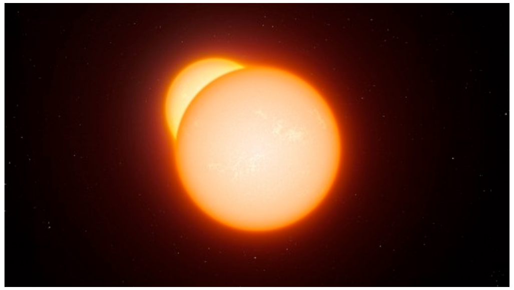


- Assuming (w_0, w_a) model, 1% H_0 measurement adds about 40% to Stage III dark energy experiments [e.g. BOSS, DES, etc.]
- Adds very little to Stage IV experiments [e.g. LSST, SKA, etc.]

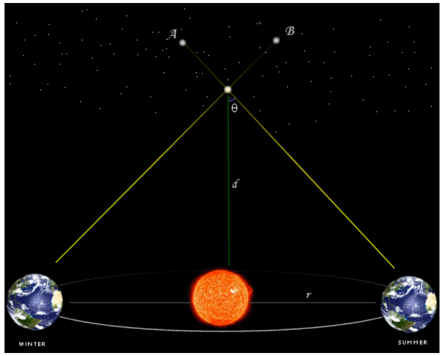
Why measure H_0?

- Local determinations of H_0

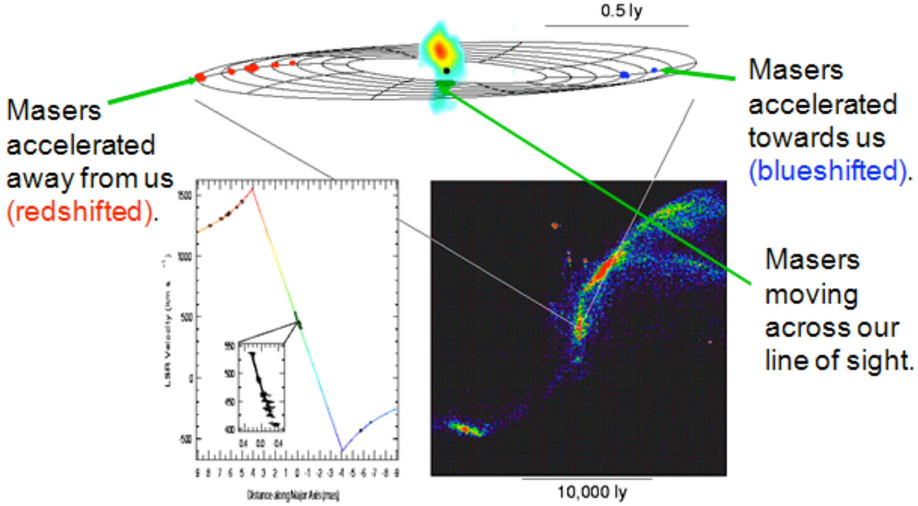
Eclipsing binaries (in LMC, 50 kpc)



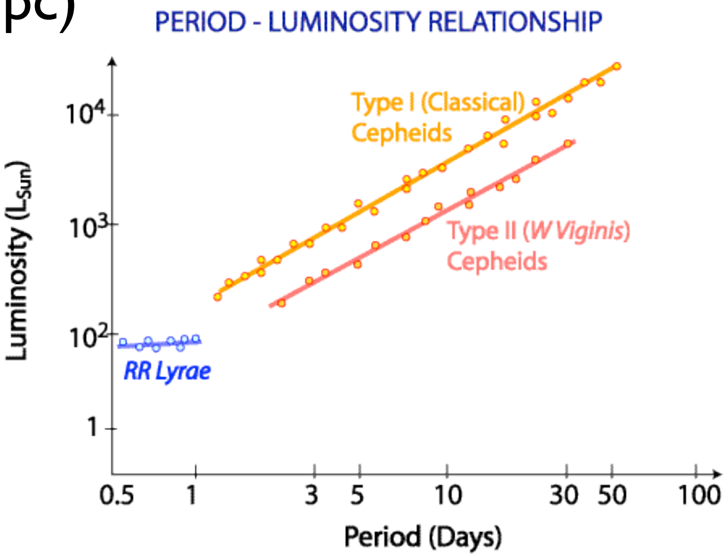
Parallax (< 1 kpc)



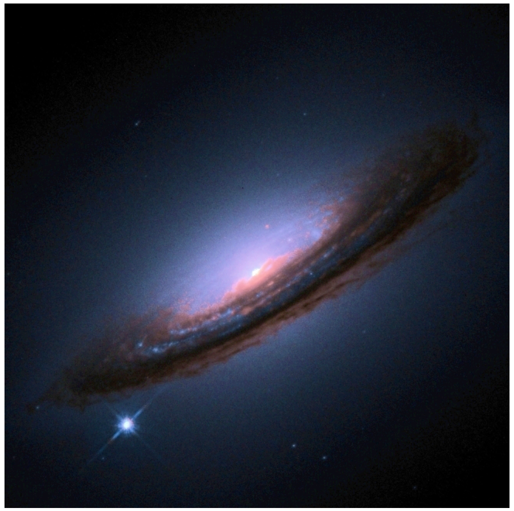
Masers (NGC4258 at 7.6 Mpc)



Cepheids (< 30 Mpc)

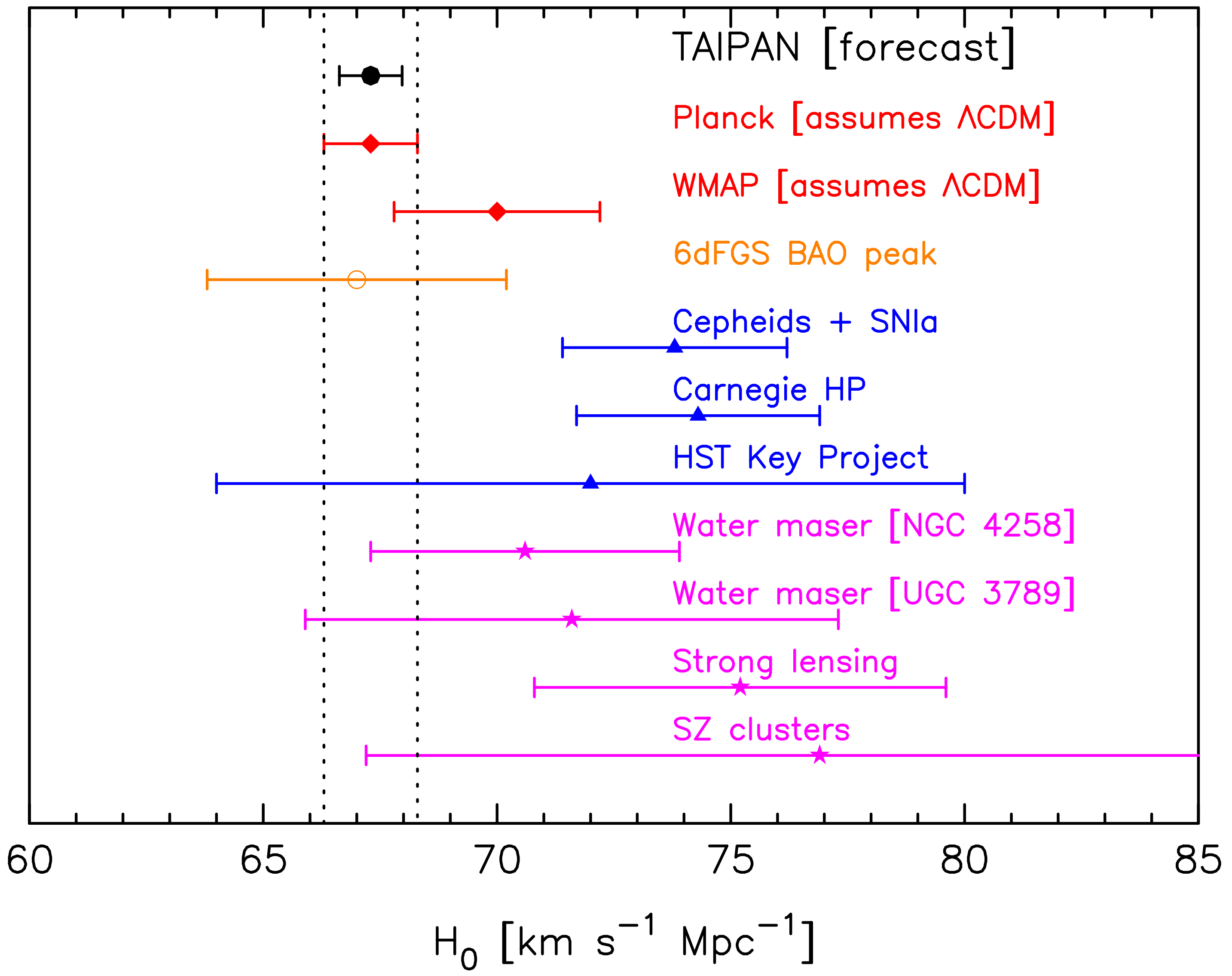


Supernovae (z < 0.1)



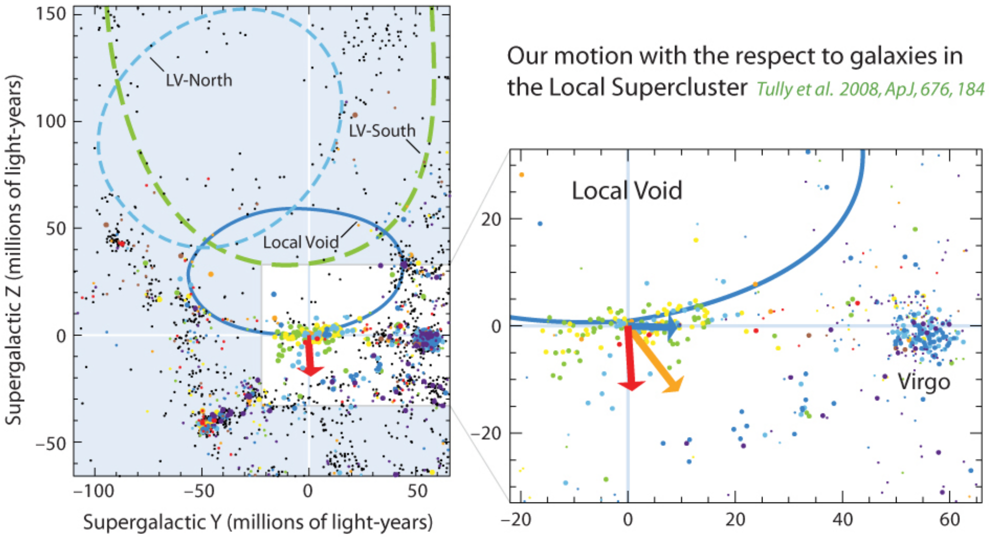
Why measure H_0?

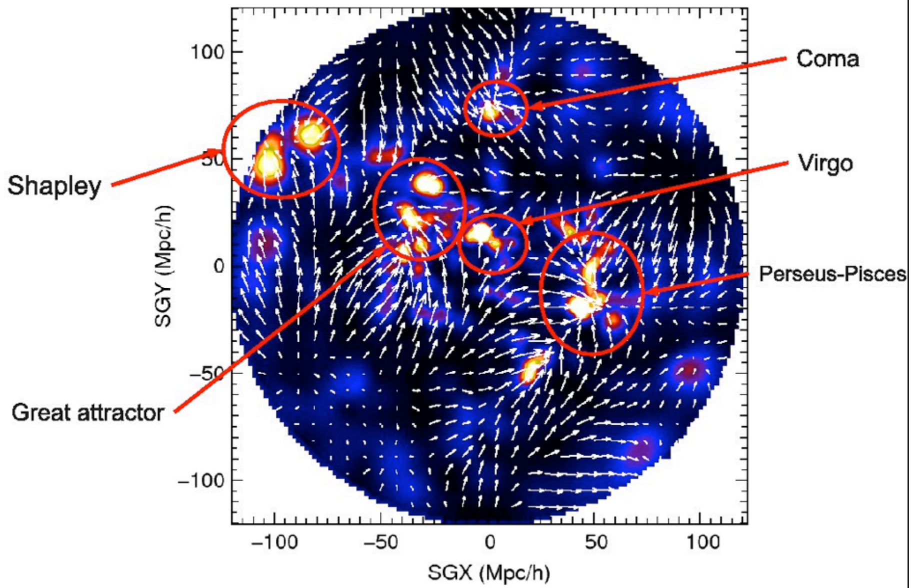
- Discrepancies between Planck and local measurements



Why measure H_0?

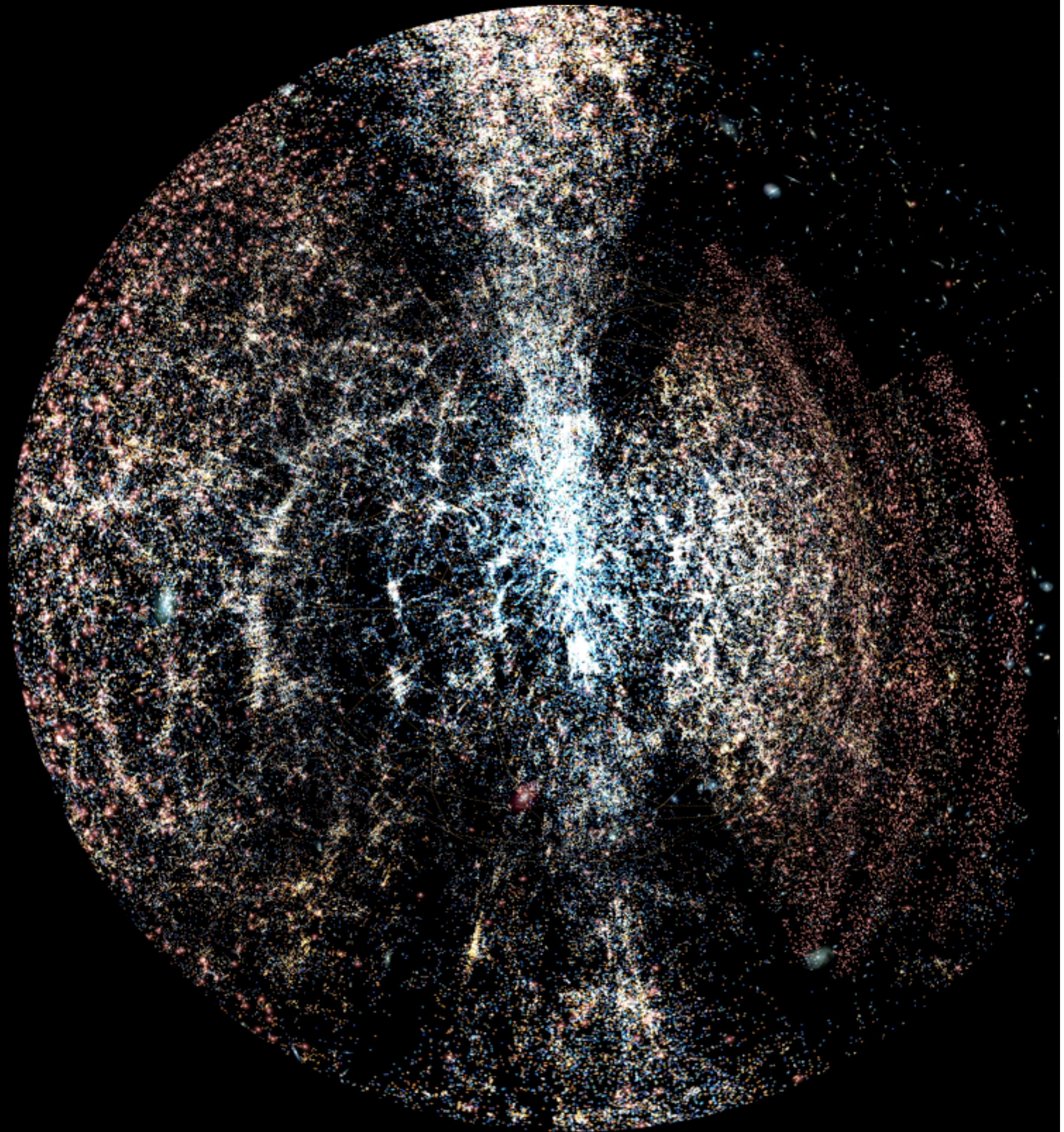
- Discrepancies could be systematic errors ...?
- ... or signatures of non-LCDM physics?
- ... or signature of gravitational physics driven by inhomogeneity / backreaction ?





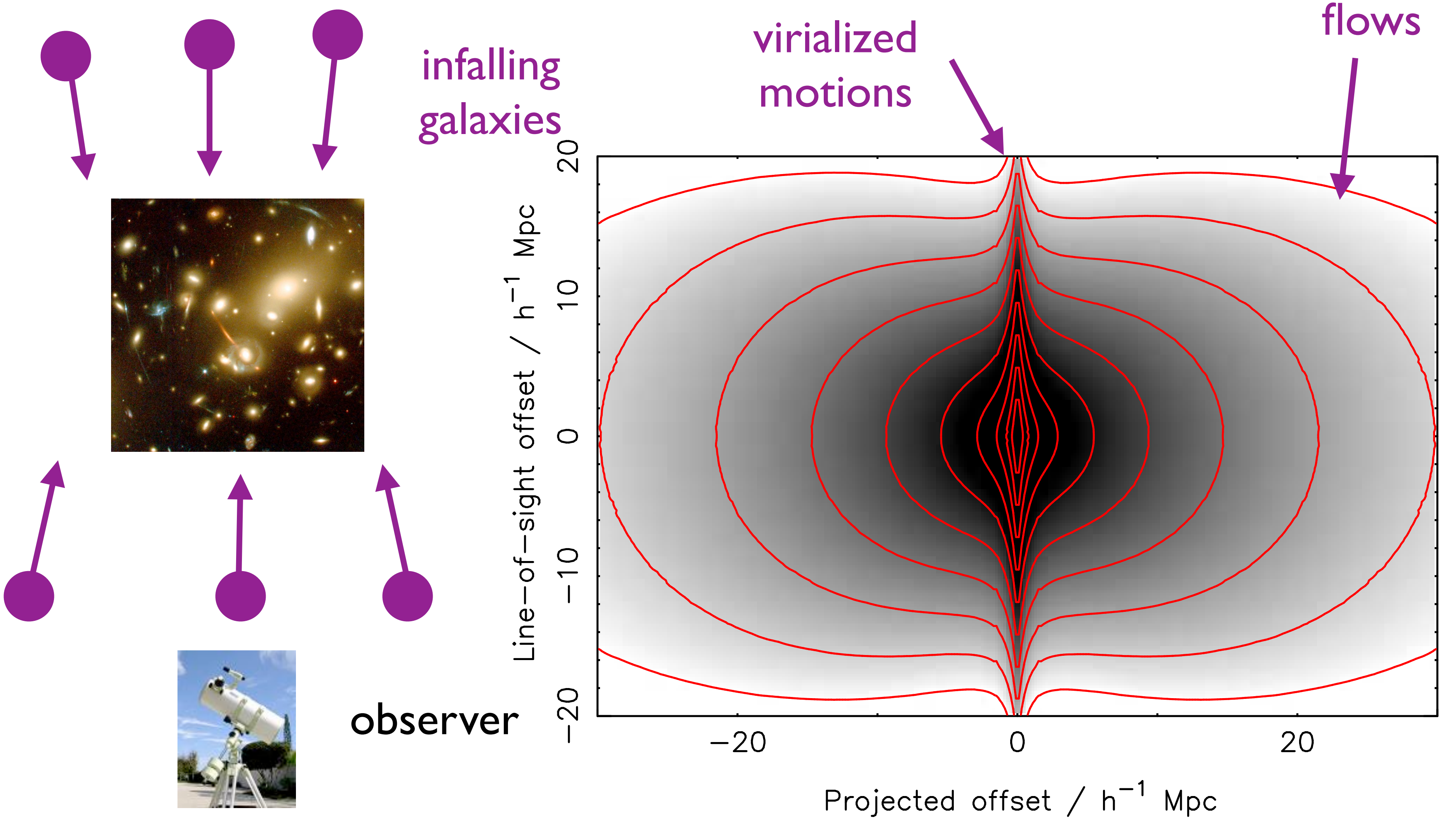
Tests of large-scale gravity

- Is the growth rate of structure consistent with the cosmic expansion history?
- Is the gravitational physics of the homogeneous and inhomogeneous Universe consistent?
- Need to measure galaxy velocities ...



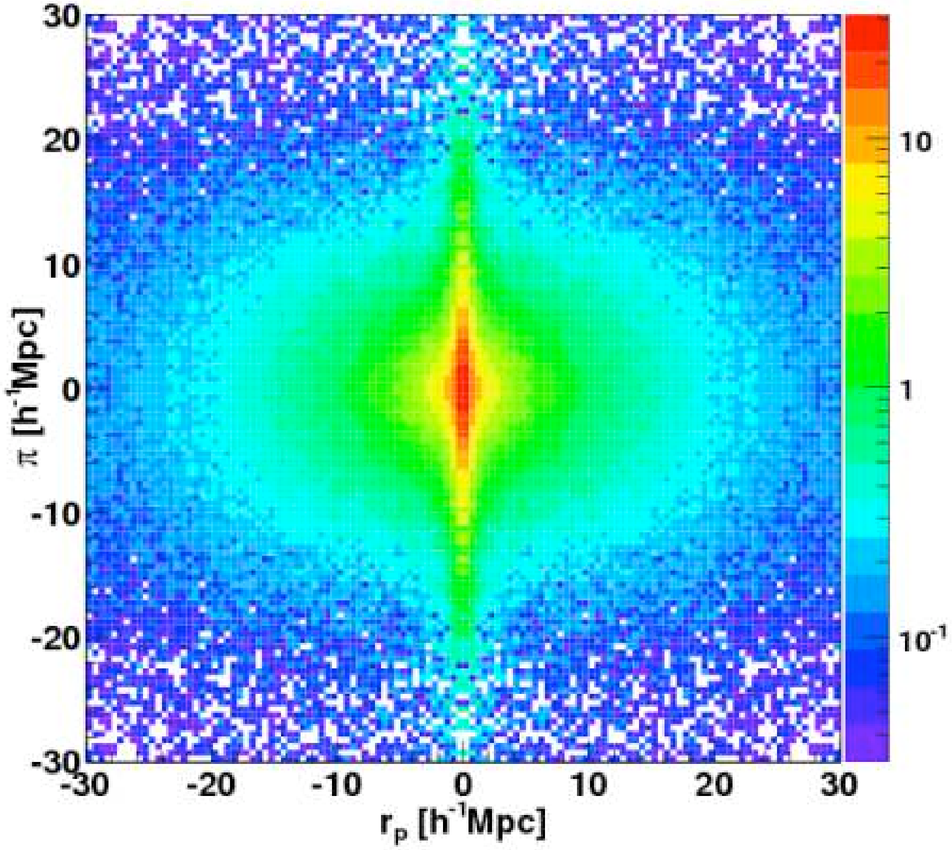
Measuring correlated galaxy velocities

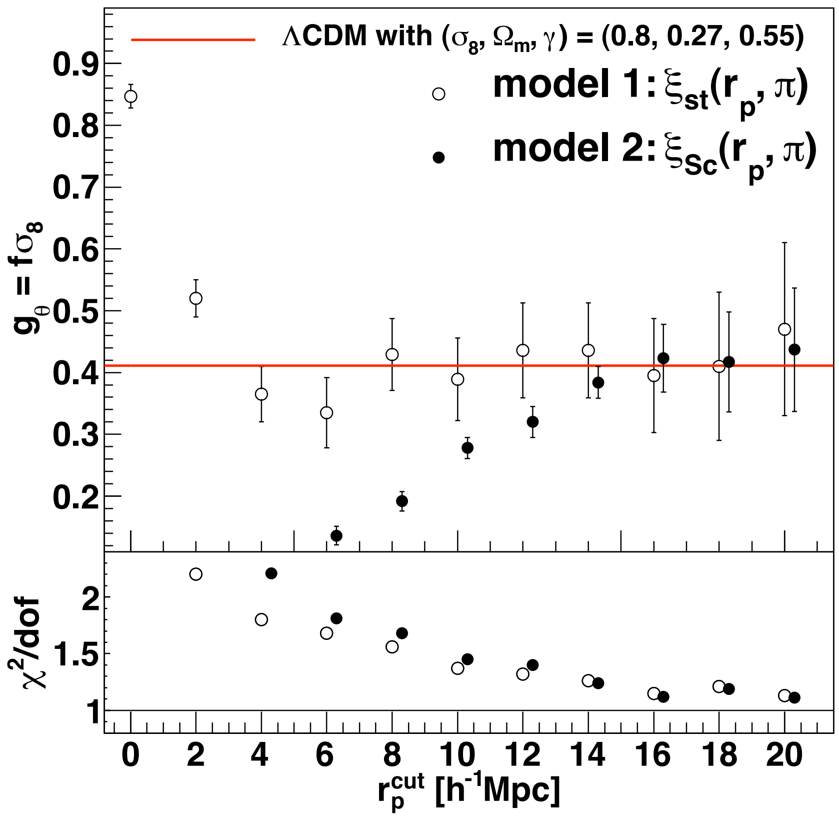
- Can detect galaxy velocities statistically via redshift-space distortion in galaxy redshift surveys



Existing low redshift measurement!

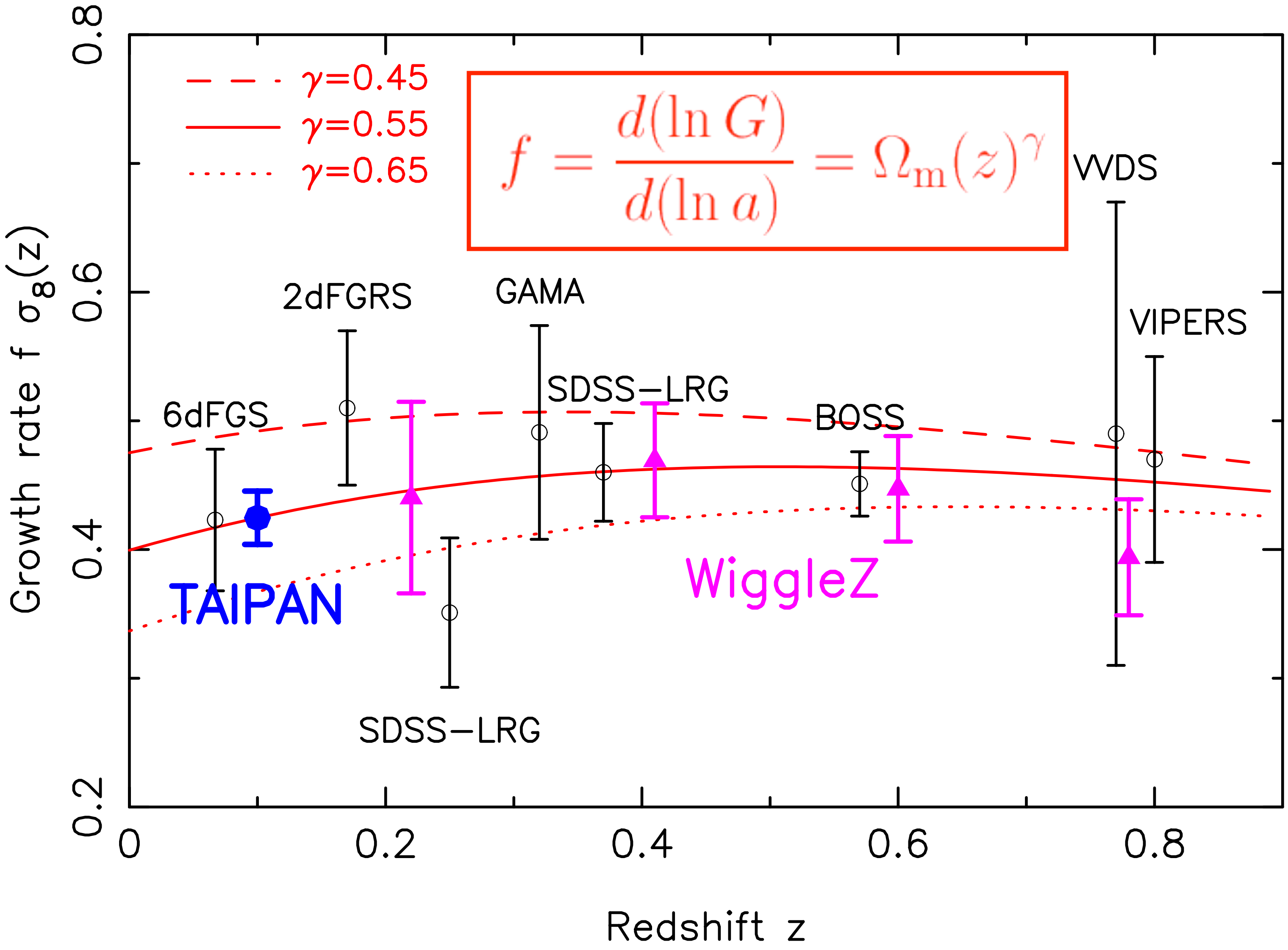
- 6dFGS measurement from Beutler et al. (2012)
- (13% growth rate accuracy)





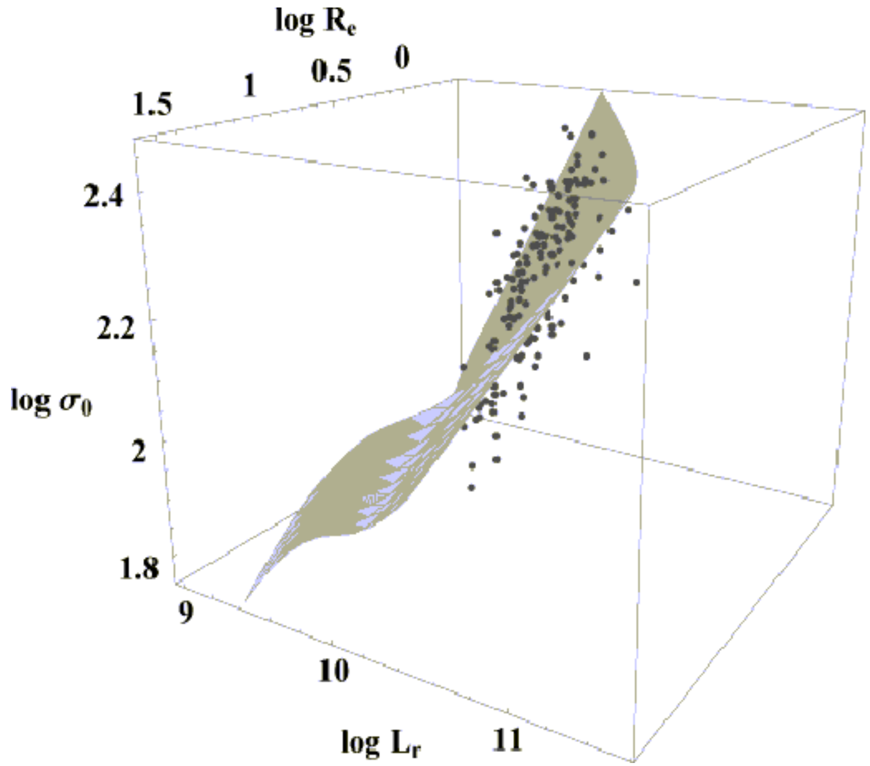
Measuring correlated galaxy velocities

- Full Taipan survey will make 5% growth measurement



Measuring velocities of individual galaxies

- Simultaneous measurements of distance D and redshift z
- Use standard candle (supernovae, fundamental plane, ...)

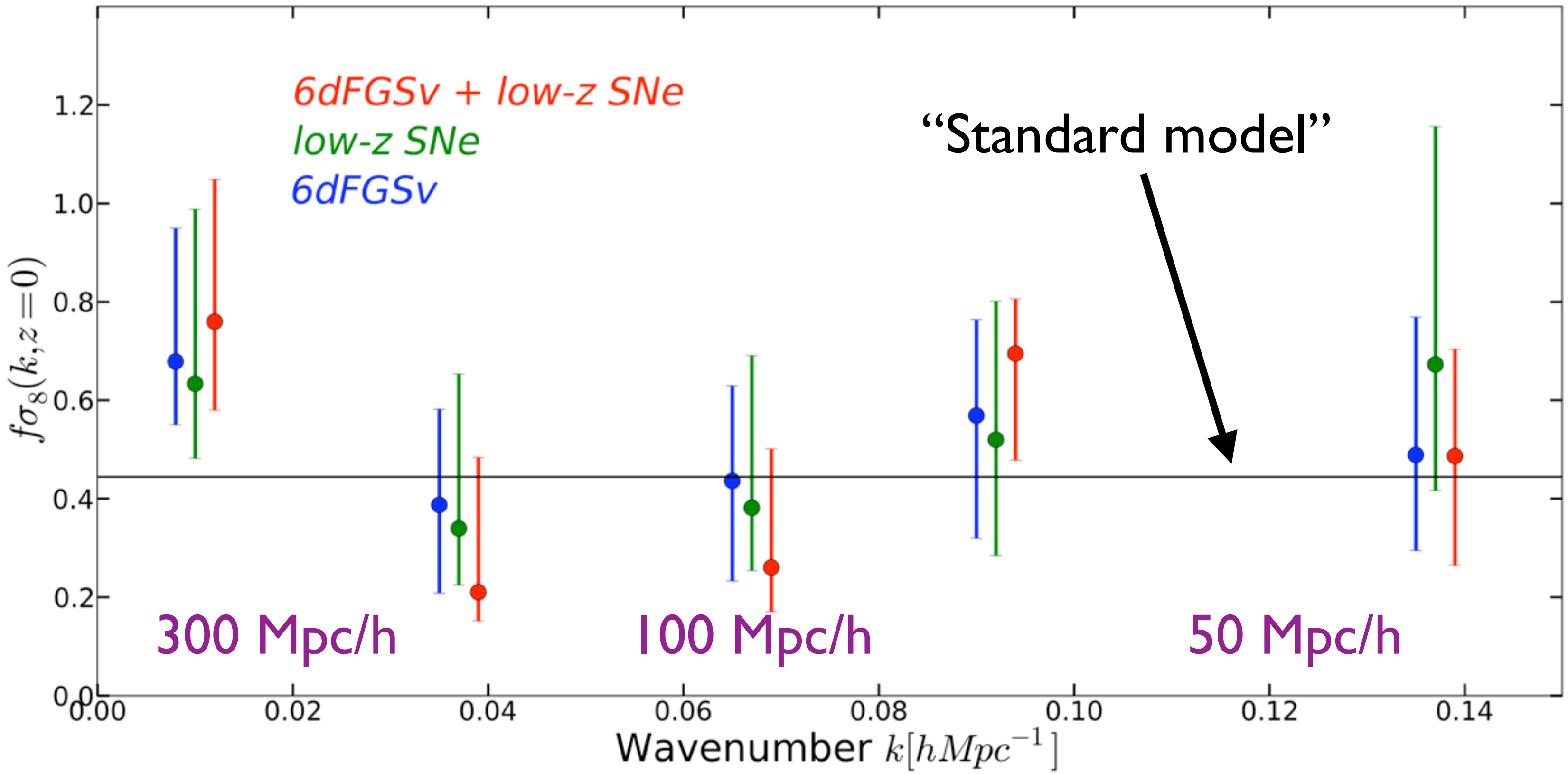


$$v_{\rm peculiar} = c\,z - H_0\,D$$

[Small print :
this equation is not exact!]

Existing low redshift measurement!

- Measurement of Johnson et al. (2014) : consistency with standard model with particular sensitivity to large scales



- Taipan survey velocity sample will be 10 times larger !!

Joint fits to the density and velocity fields

- The density fluctuations source the large-scale velocity field, so sample variance cancels
- We obtain greatly improved measurements of beta = f/b
- Scale-dependence of "beta" on large scales would be a "smoking gun" for non-standard cosmological physics such as non-Gaussianity or modified gravity
- See Koda et al. (2014) for full density+velocity Fisher matrix forecasts including the Taipan survey
- PhD student Caitlin Adams currently implementing a joint likelihood analysis for 6dFGS

Year-1 Taipan cosmology survey

- At the last Taipan workshop we decided to focus initially on a self-contained 1-year survey which could target ~400,000 sources
- Taipan Y1 cosmology survey will be selected from 2MASS : what is the optimal selection?
- If the full 4-year Taipan survey will produce a 1% H_0 measurement, can we produce a 2% measurement Y1?

Optimization of Y1 cosmology survey

- Need to maximize the survey volume spanned by ~400,000 targets, given observational limits
- Do not re-observe 6dFGS redshifts in Y1
- Reach higher redshifts by: (1) including 2MASS point sources, (2) using a minimum J-K cut
- We do not know optical magnitudes, but can estimate with Ned's $r_{proxy} = J + 1.1 + 0.8(J-K)$
- SDSS-matched "sandbox" catalogue provides us with redshift distributions, fibre magnitudes

Optimization of Y1 cosmology survey

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

IMPROVED FORECASTS FOR THE BARYON ACOUSTIC OSCILLATIONS AND COSMOLOGICAL DISTANCE SCALE

Hee-Jong Seo & Daniel J. Eisenstein

Steward Observatory, University of Arizona, 933 North Cherry Avenue, Tucson, AZ 85721

hseo@as.arizona.edu,deisenstein@as.arizona.edu

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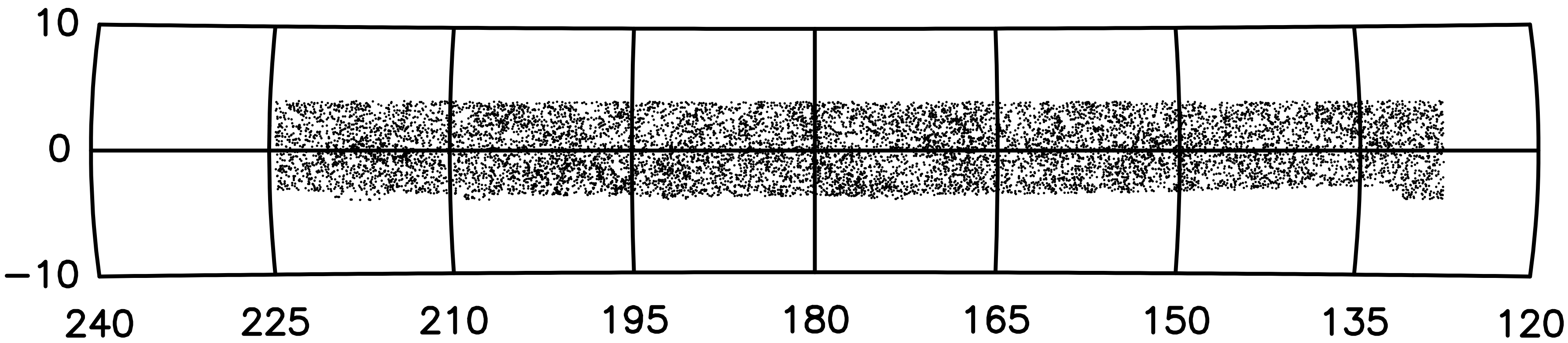
ABSTRACT

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

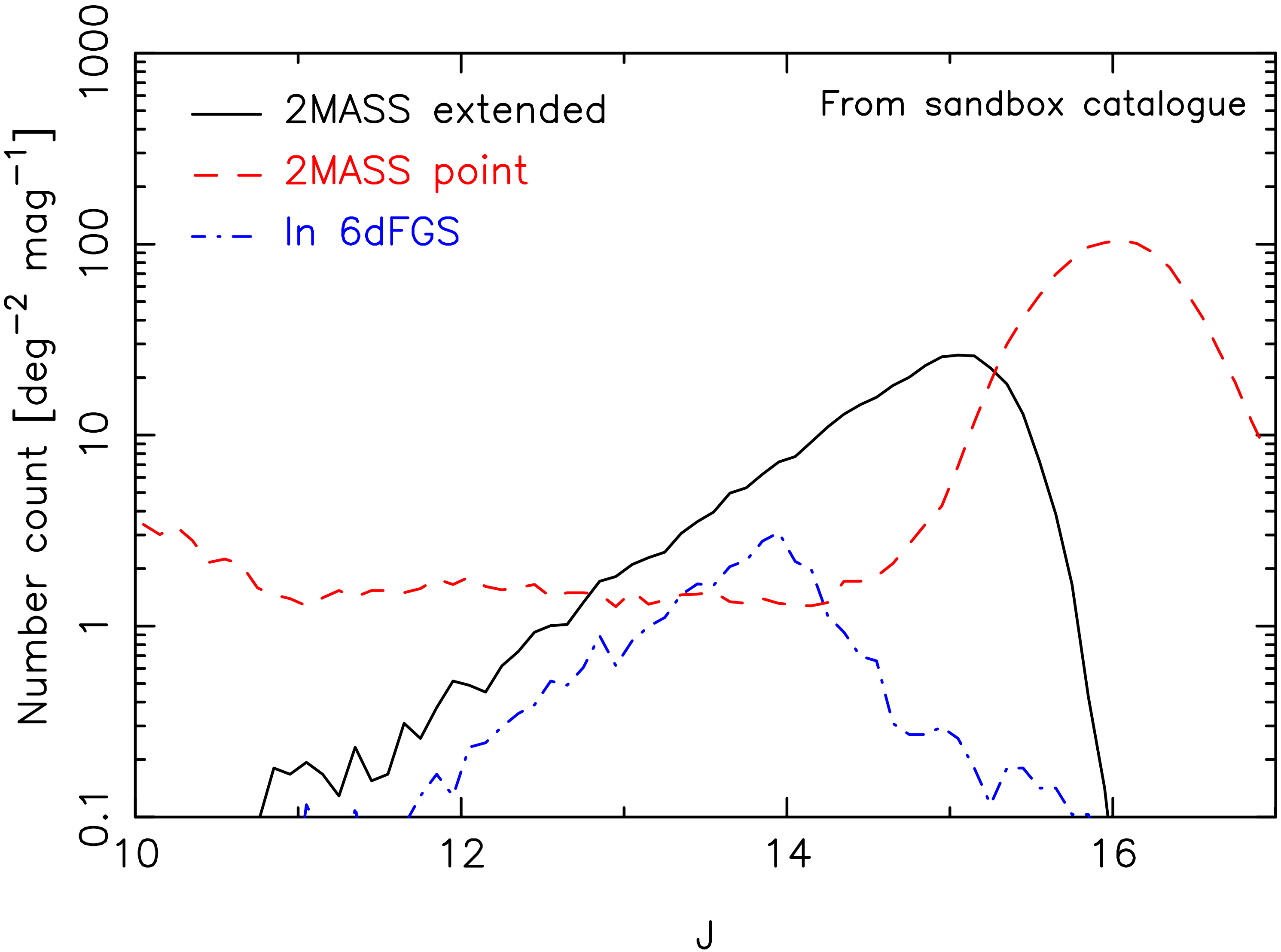
Analysis of sandbox catalogue

- Analysis based on Ned's SDSS-matched "sandbox" catalogue Taipan_equatorial_sandbox_151021.fits



Analysis of sandbox catalogue

- Inclusion of 2MASS point sources



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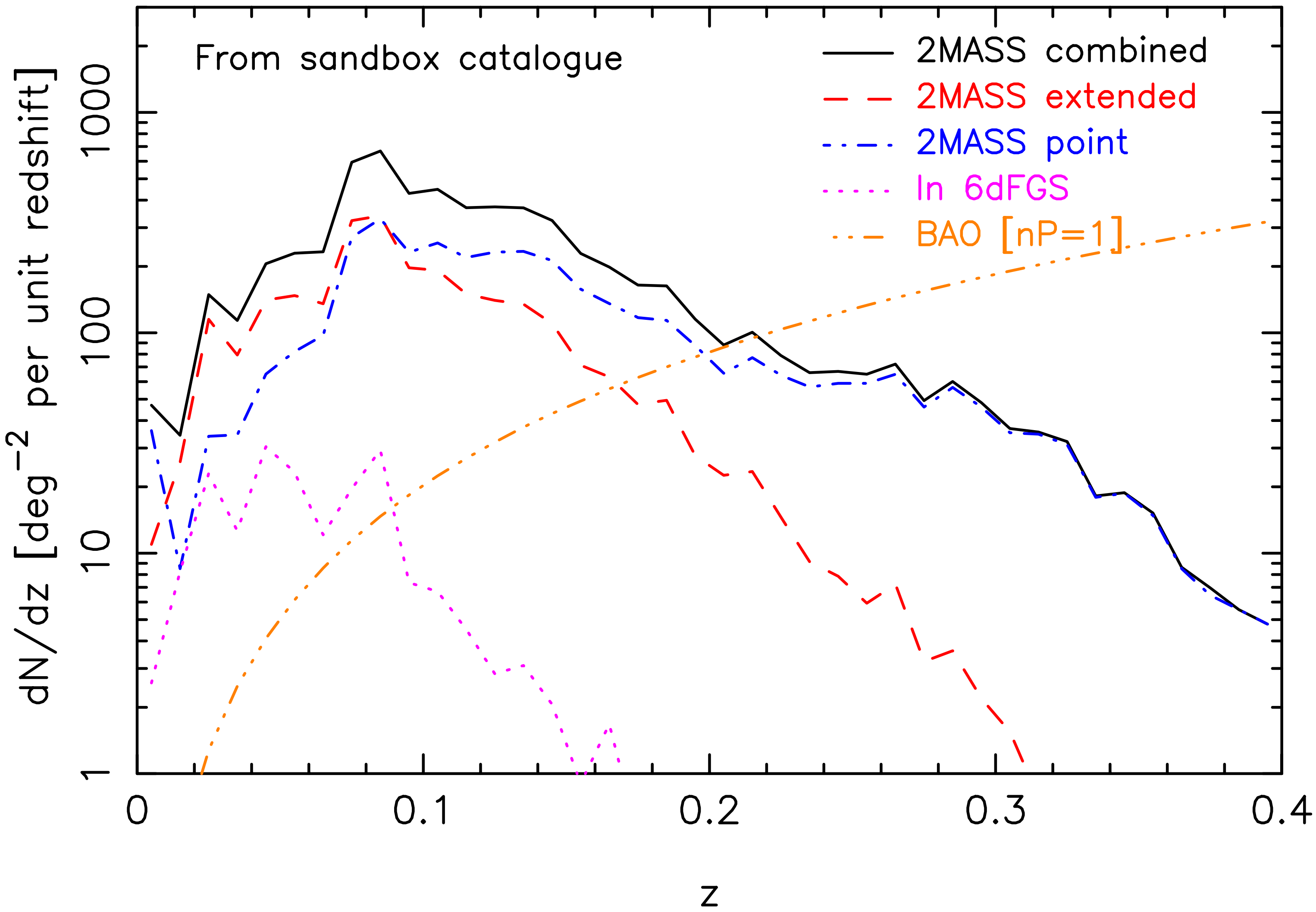
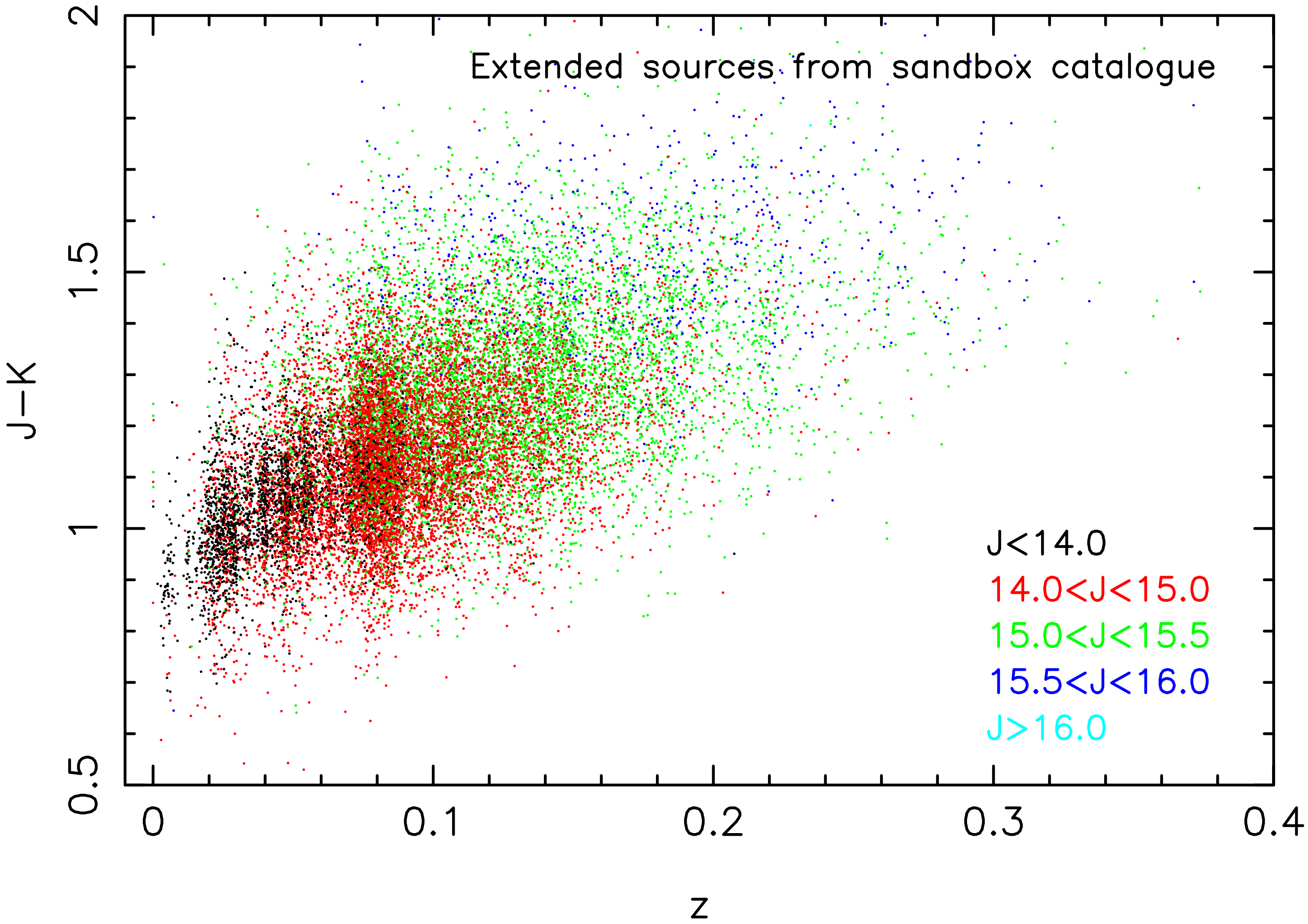


Analysis of sandbox catalogue

- Correlation between J-K and redshift



Analysis of sandbox catalogue

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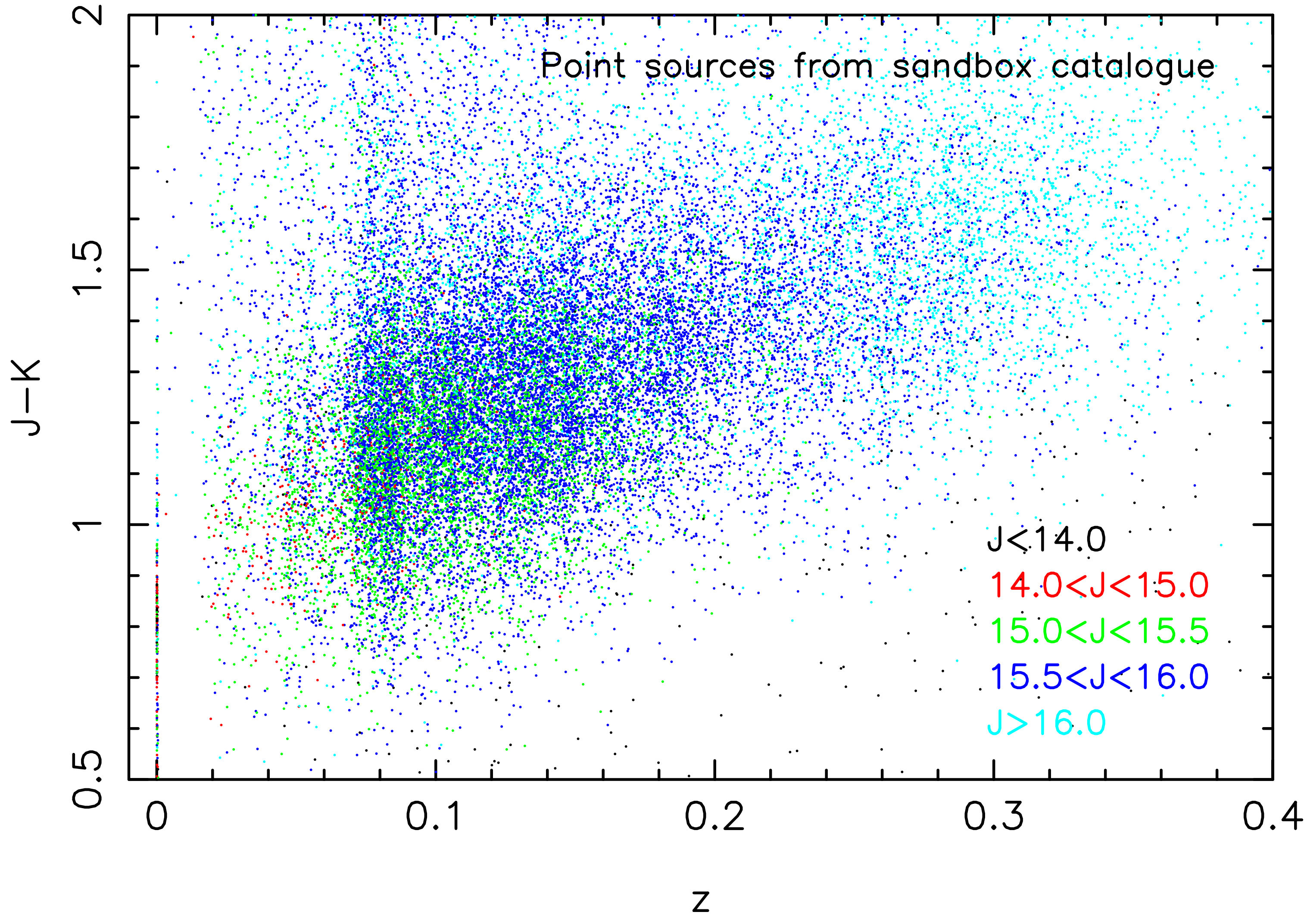

Analysis of sandbox catalogue

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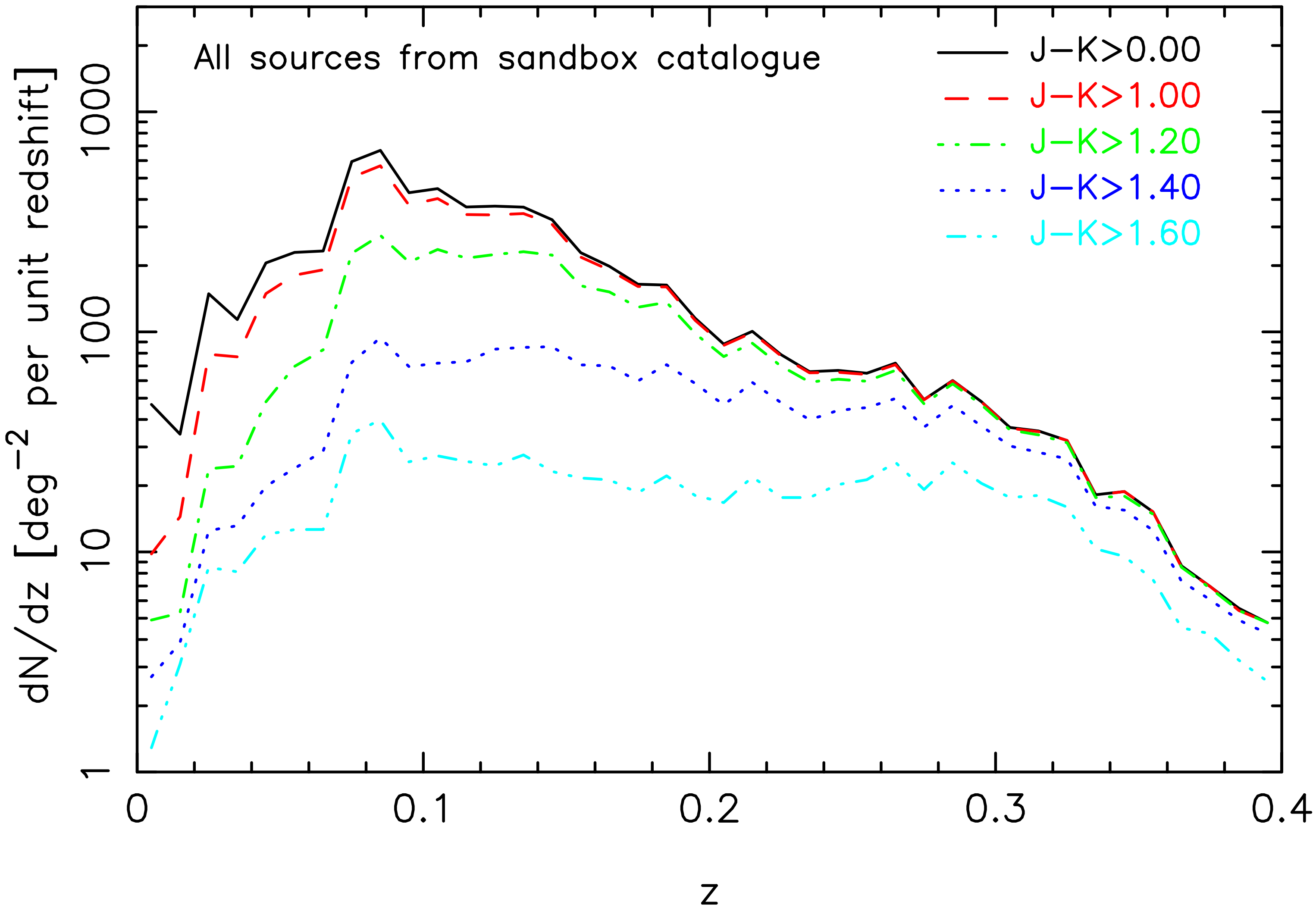
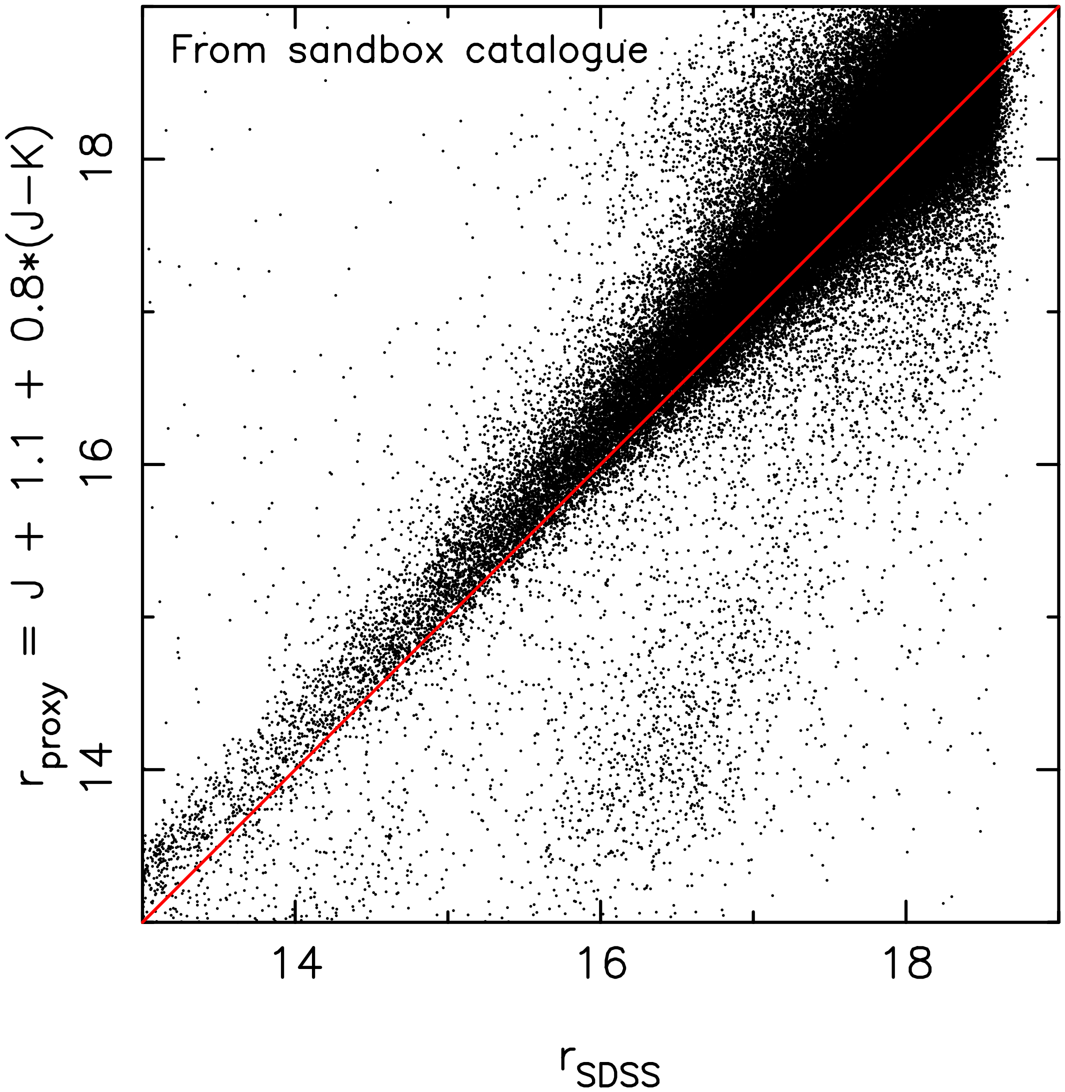


Analysis of sandbox catalogue

- How faint in optical magnitude can we go?



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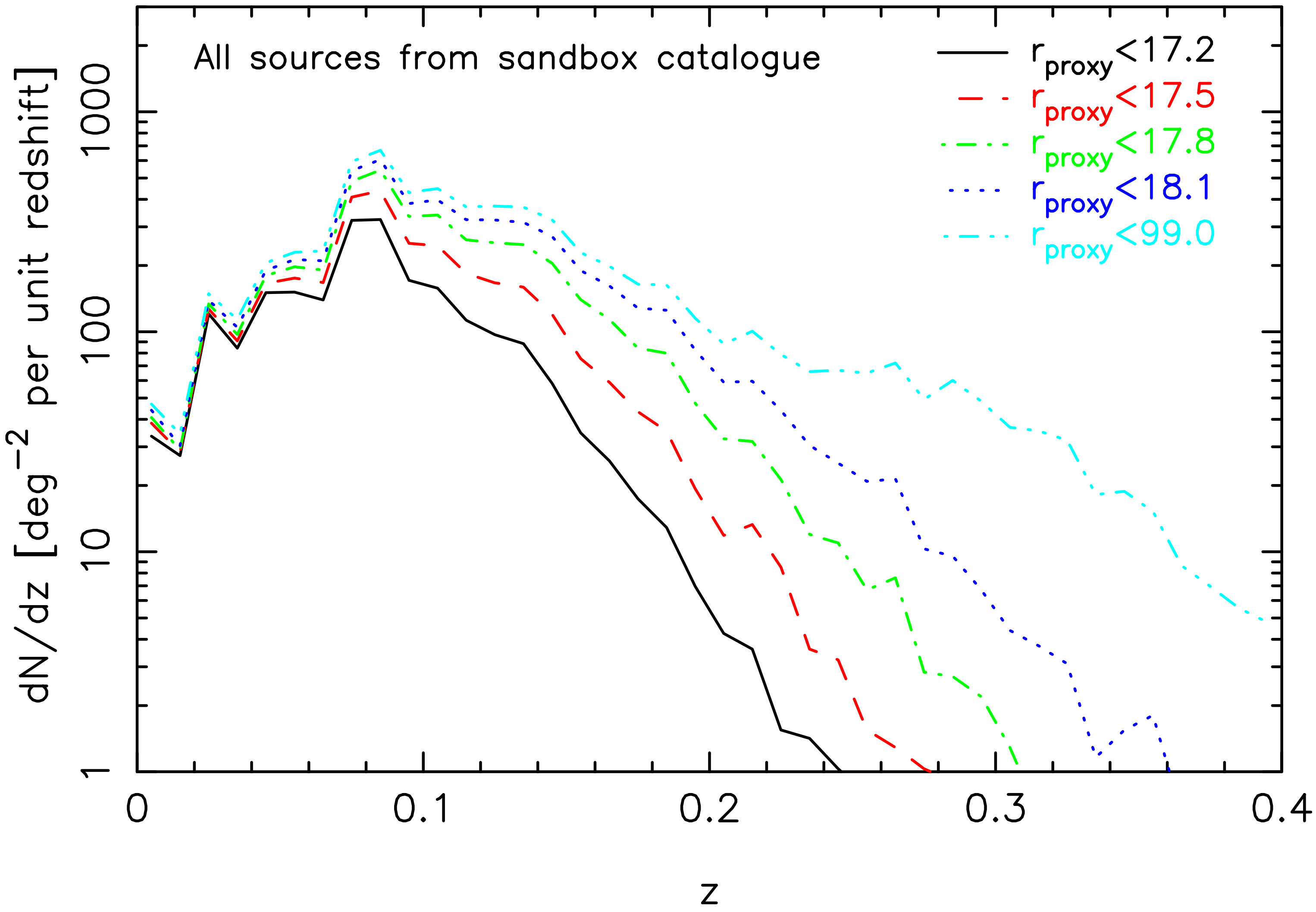
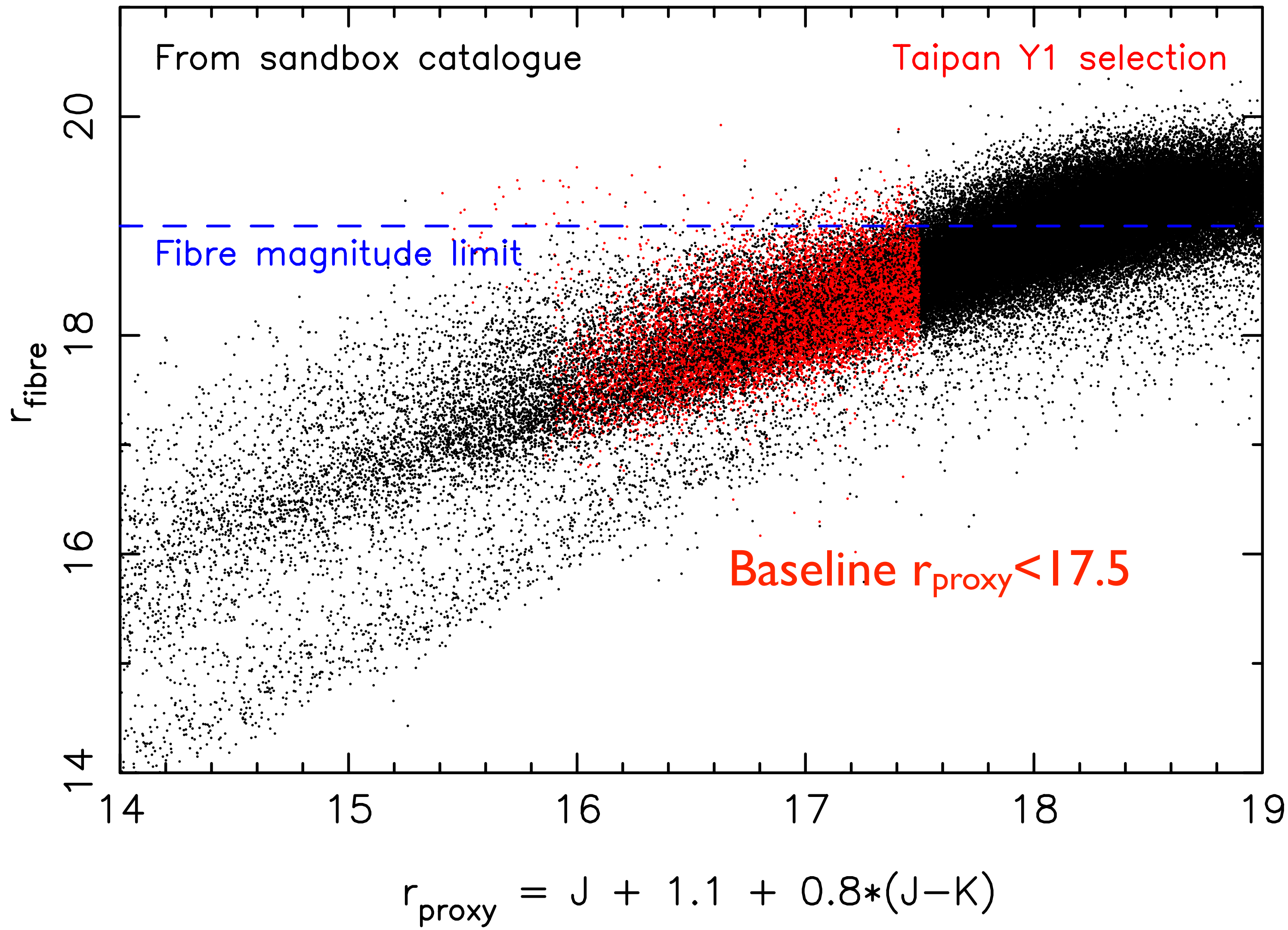


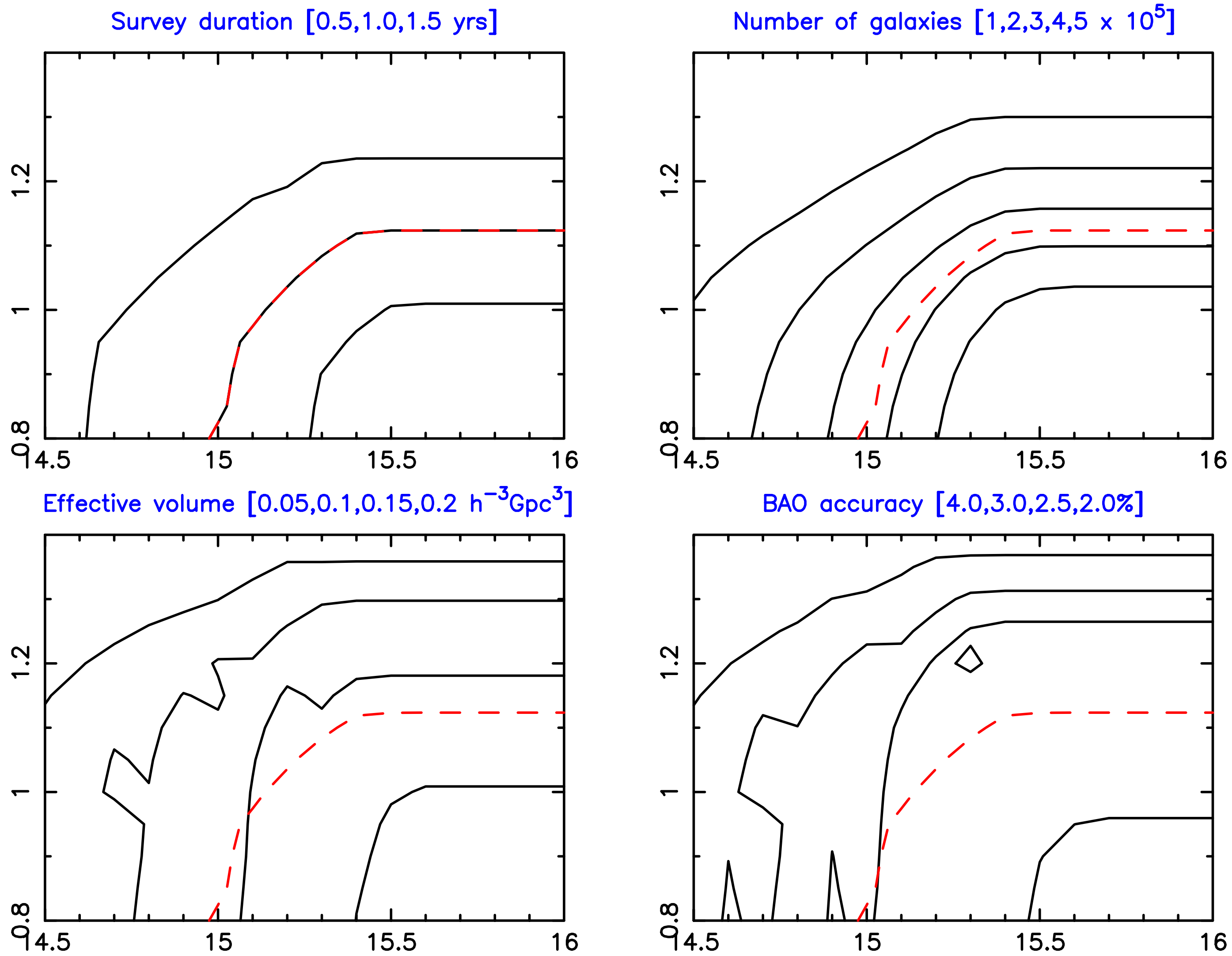
Analysis of sandbox catalogue

- How faint in optical magnitude can we go?



Optimization of Y1 cosmology survey

- BAO optimization for r_{proxy}<17.5 : J<15.5, J-K>1.1

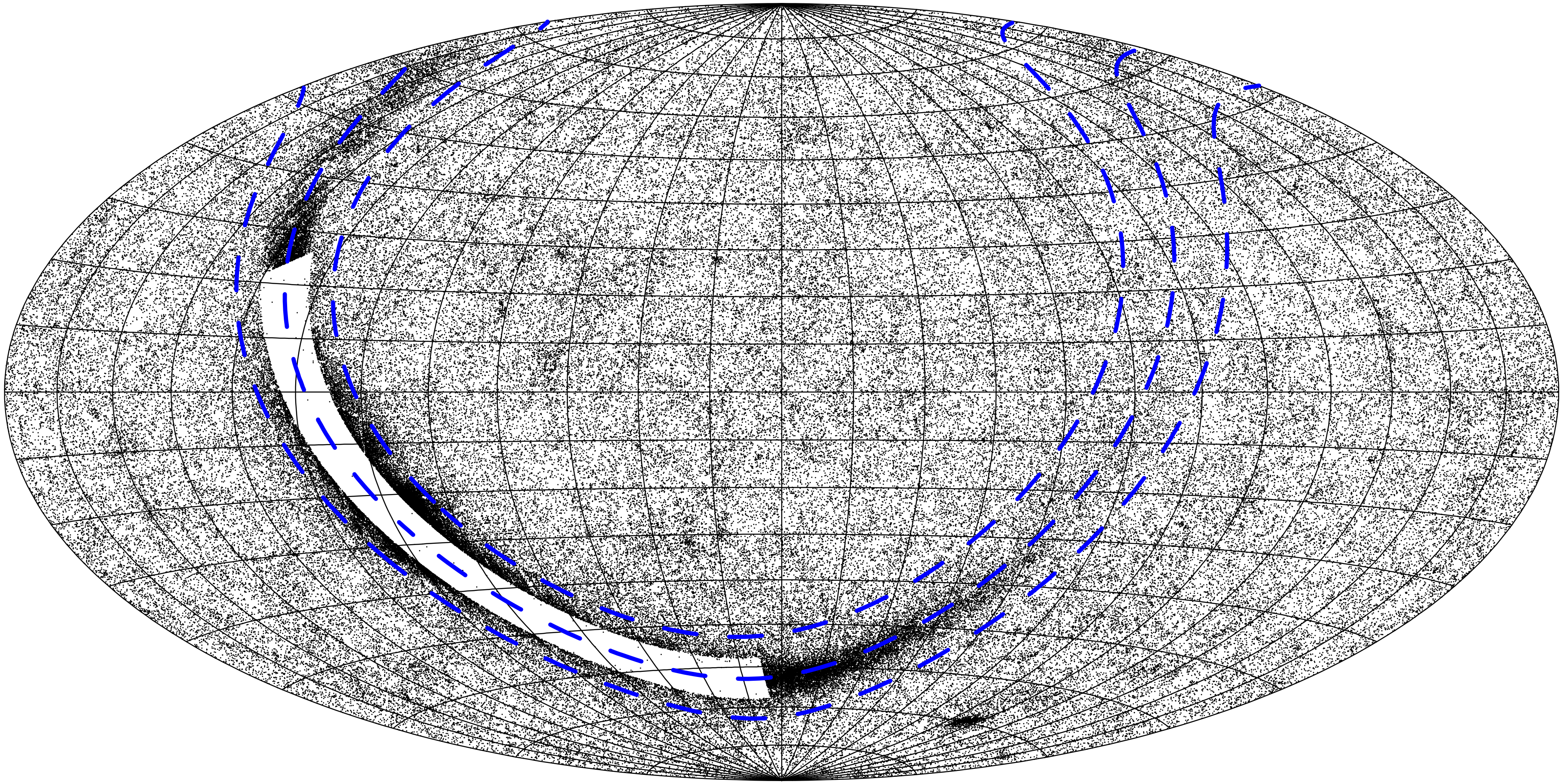


Optimization of Y1 cosmology survey

J	J-K	r_{proxy}	V_{eff} $(Gpc/h)^3$	BAO (%)	growth (%)	Notes
<15.5	>1.1	<17.5	0.183	2.1	7.8	Taipan Y1 baseline
<15.0	none	<17.5	0.161	2.3	8.7	no J-K cut
<15.5	>1.0	<17.2	0.146	2.4	8.9	brighter r_{proxy}
<15.7	>1.2	<17.8	0.213	1.9	7.1	fainter r_{proxy}
<15.5	>1.05	<17.5	0.169	2.2	8.1	just extended
<15.5	>1.1	<17.5	0.238	1.9	7.1	adding in 6dFGS

Baseline Taipan Y1 cosmology catalogue

- Start from Ned's combined 2MASS all-sky catalogue "Taipan_InputCat_v0.101_20151125.fits"



Baseline Taipan Y1 cosmology catalogue

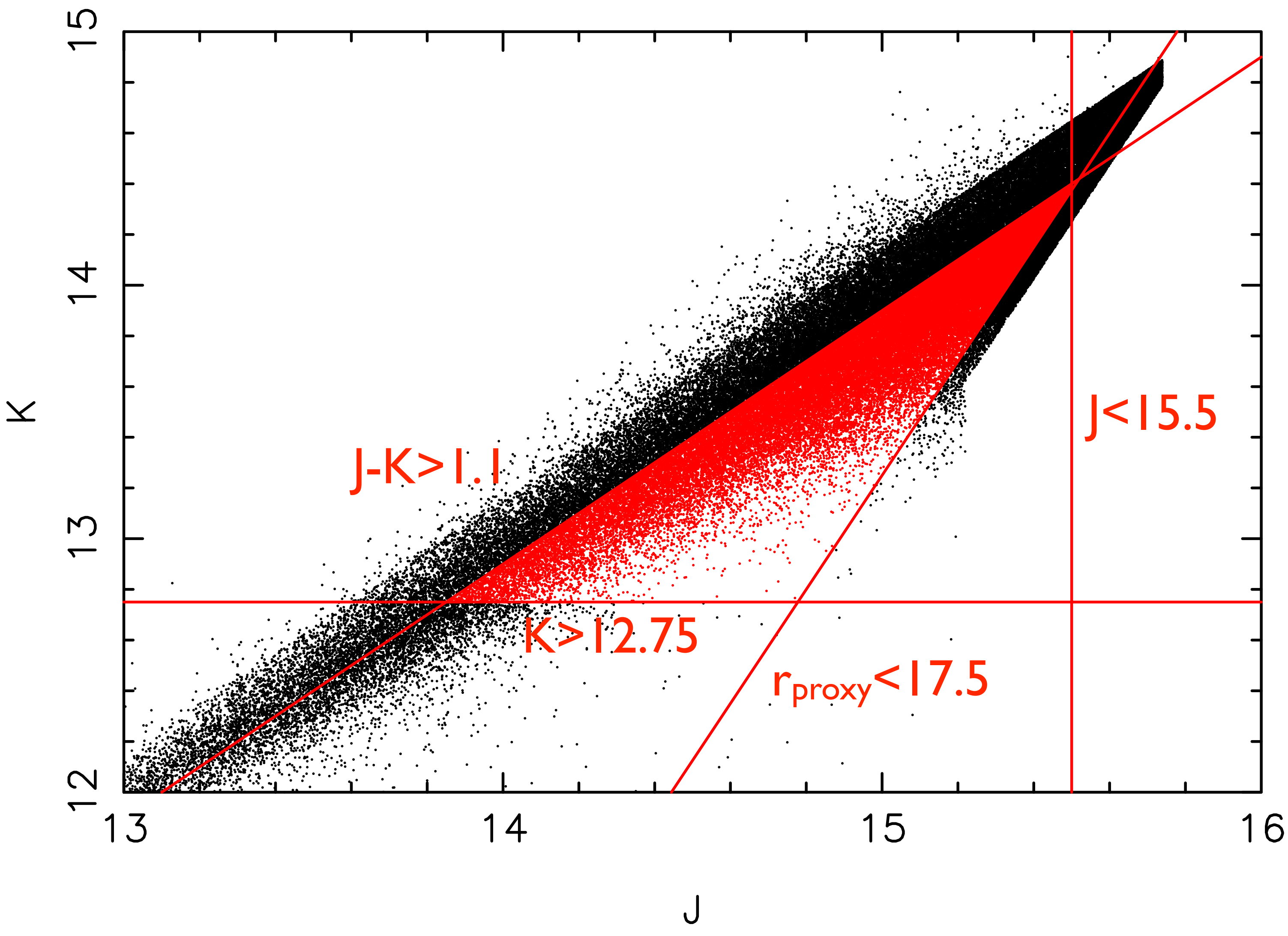
- Baseline selection cuts

Cut	Explanation	Number
none	Taipan_InputCat_v0.101_20151125	2,413,252
dec<10, |b|<10	Visibility, avoid Galactic plane	1,020,721
$r_{proxy}<17.5$	Approximate observational Taipan limit	902,073
J<15.5	NIR limit [not much effect given r_{proxy}]	860,880
K>12.75	Do not re-observe 6dFGS sources	747,376
J-K>1.1	Preferentially restrict to high-z	408,590

[Note : 15% point sources, 3% fainter than fibre limit, ??% stars]

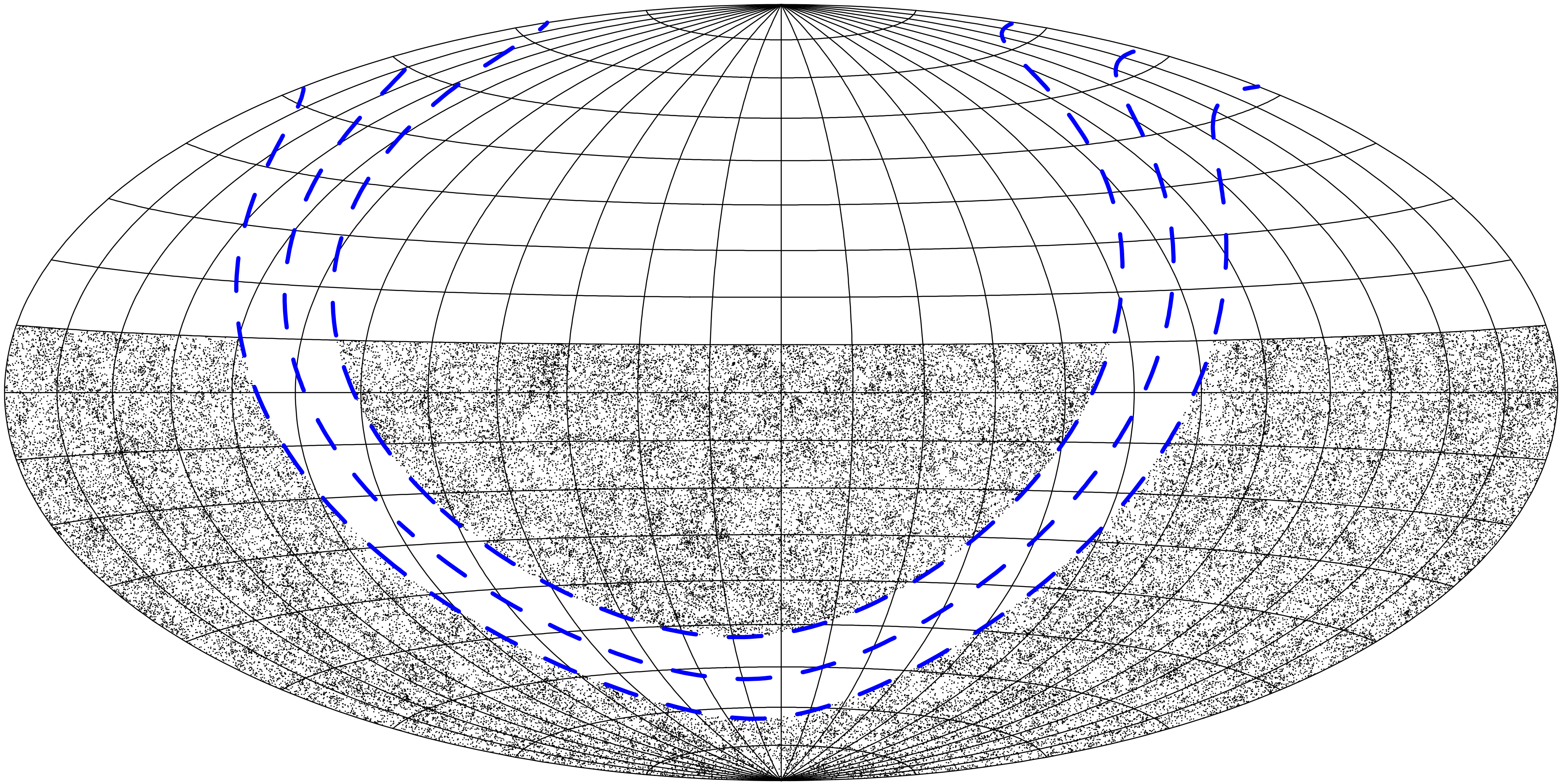
Baseline Taipan Y1 cosmology catalogue

- Selection box in (J, K) magnitudes



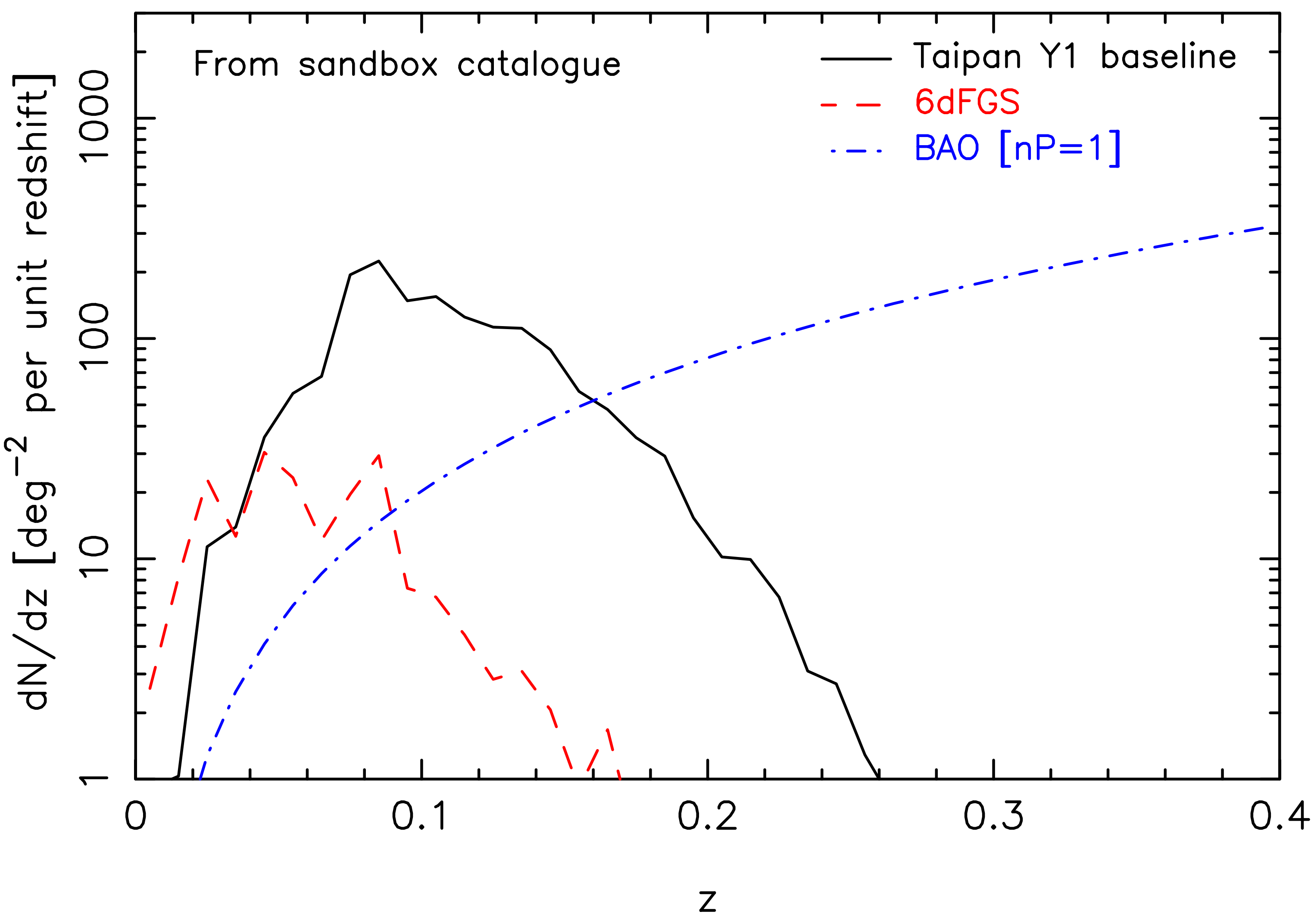
Baseline Taipan Y1 cosmology catalogue

- Sky distribution of baseline selection



Baseline Taipan Y1 cosmology catalogue

- Redshift distribution of baseline selection



Next steps

- Apply tiling code to baseline Taipan Y1 cosmology catalogue, what is the efficiency of target allocation?
- To what extent does the Y1 cosmology catalogue allow the Taipan peculiar velocity science to be completed?
- Generate first version of mock catalogues
- Apply tiling code to mocks, investigate clustering systematics due to correlation of allocation with density
- Develop curved-sky BAO reconstruction code
- Continue cosmological science with 6dFGS

Conclusions

- Taipan survey will allow the ultimate low-redshift tests of cosmic expansion and gravity
- Baryon acoustic peak will measure H_0 to 1%, cross-checking CMB vs. local standard candles
- Redshift-space distortions in the galaxy sample will produce the best measurement of the z=0 growth rate, testing G.R. on intermediate scales
- Peculiar velocity sample will allow new tests of G.R. on the largest scales of 100s Mpc/h
- Year 1 survey will make major progress in these goals