Forecasting Constraints from Peculiar Velocity Power Spectrum

— Fisher Matrix Analysis

Jun Koda
Swinburne University of Technology
with Chris Blake

Cosmic Flow: In The Rain Forest, 21 Feb 2012

CAASTRO
ARC CENTRE OF EXCELLENCE FOR ALL-SKY ASTROPHYSICS

SWINBURNE UNIVERSITY OF TECHNOLOGY

Peculiar Velocity

from Tully-Fisher/fundamental plane/supernovae

$$z_{pec} = z_{meas} - z_{Hubble}$$

$$\mathcal{F} = \frac{L_{abs}}{4\pi d_L(z_{Hubble})}$$

Uncertainty in absolute luminosity

→ 20% uncertainty in Hubble velocity

$$\begin{aligned} \Delta v_{pec} &\approx 0.2 H_0 d \\ &\approx 6000 \left(\frac{z}{0.1}\right) \text{km/s} \end{aligned}$$ per galaxy

This increasing uncertainty is the main disadvantage

Peculiar Velocity

in Fourier Space

$$u \equiv v \cdot \hat{r} \approx v_3 \quad \text{(plane parallel)}$$

In linear theory,

$$u_k = \frac{iH_0 f \mu}{k} \delta_k$$

where,

$$\mu \equiv \cos\theta \equiv k \cdot \hat{r}/k$$

$$f \equiv d\ln D/d\ln a \approx \Omega_m^\gamma \quad (\gamma = 0.55)$$

f is an interesting quantity to constrain

Constraints from
Velocity Power Spectrum (alone)

$$P_{uu}(k) = \frac{1}{V}\langle u_k^* u_k \rangle$$

Fisher Matrix $\theta = (f, \sigma_8, h, \Omega_m, \Omega_b, \dots)$

$$F_{ij} = \frac{1}{2}\int \frac{d^3r d^3k}{(2\pi)^3}\frac{\partial P}{\partial \theta_i}\frac{\partial P}{\partial \theta_j}\frac{1}{(\Delta P)^2}$$

$\langle \Delta\theta_i \Delta\theta_j \rangle = (F^{-1})_{ij}$

$\Delta P = P$ cosmic variance

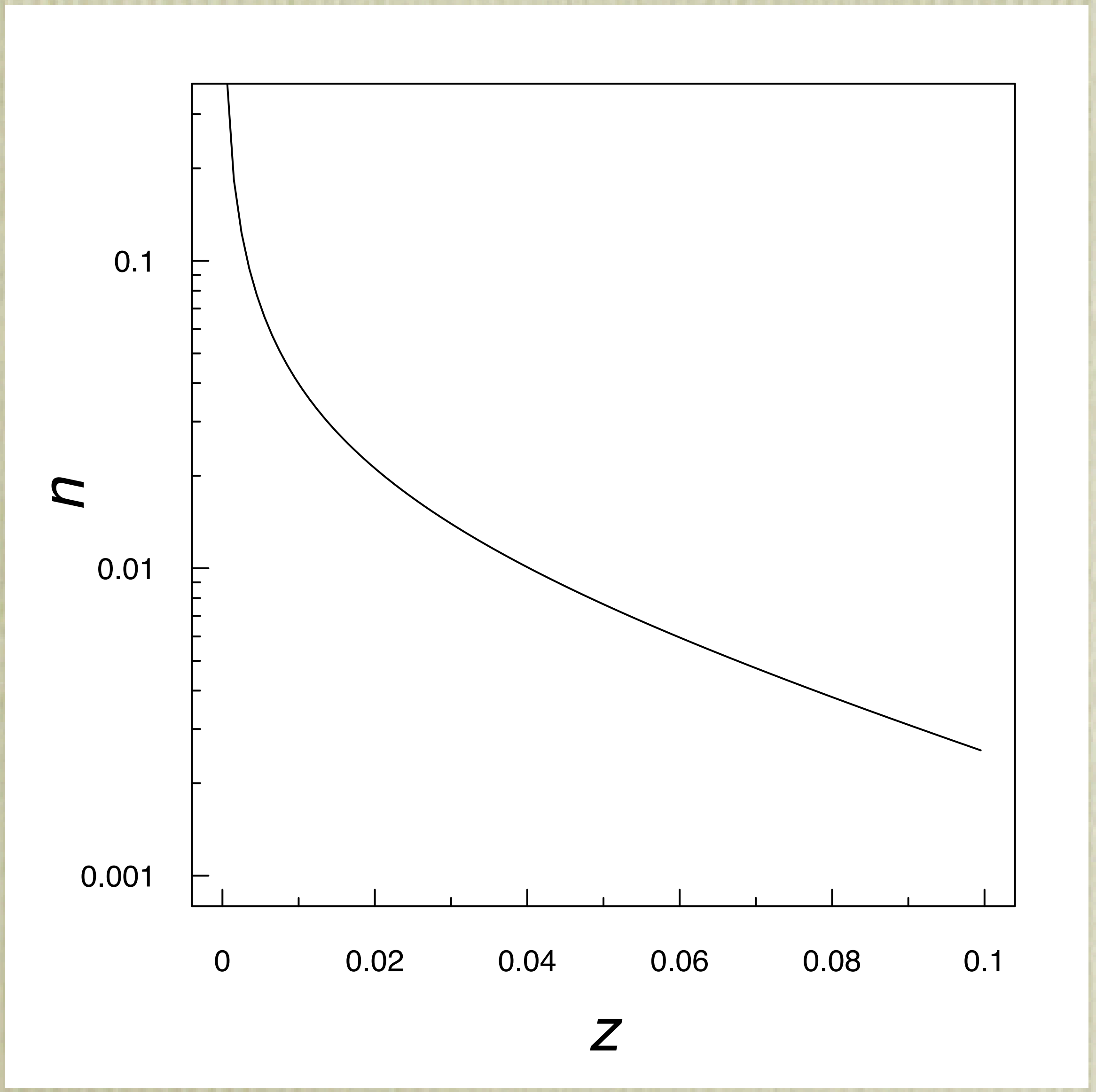
$\Delta P_{gg} = P_{gg} + n^{-1}$ galaxy shot noise

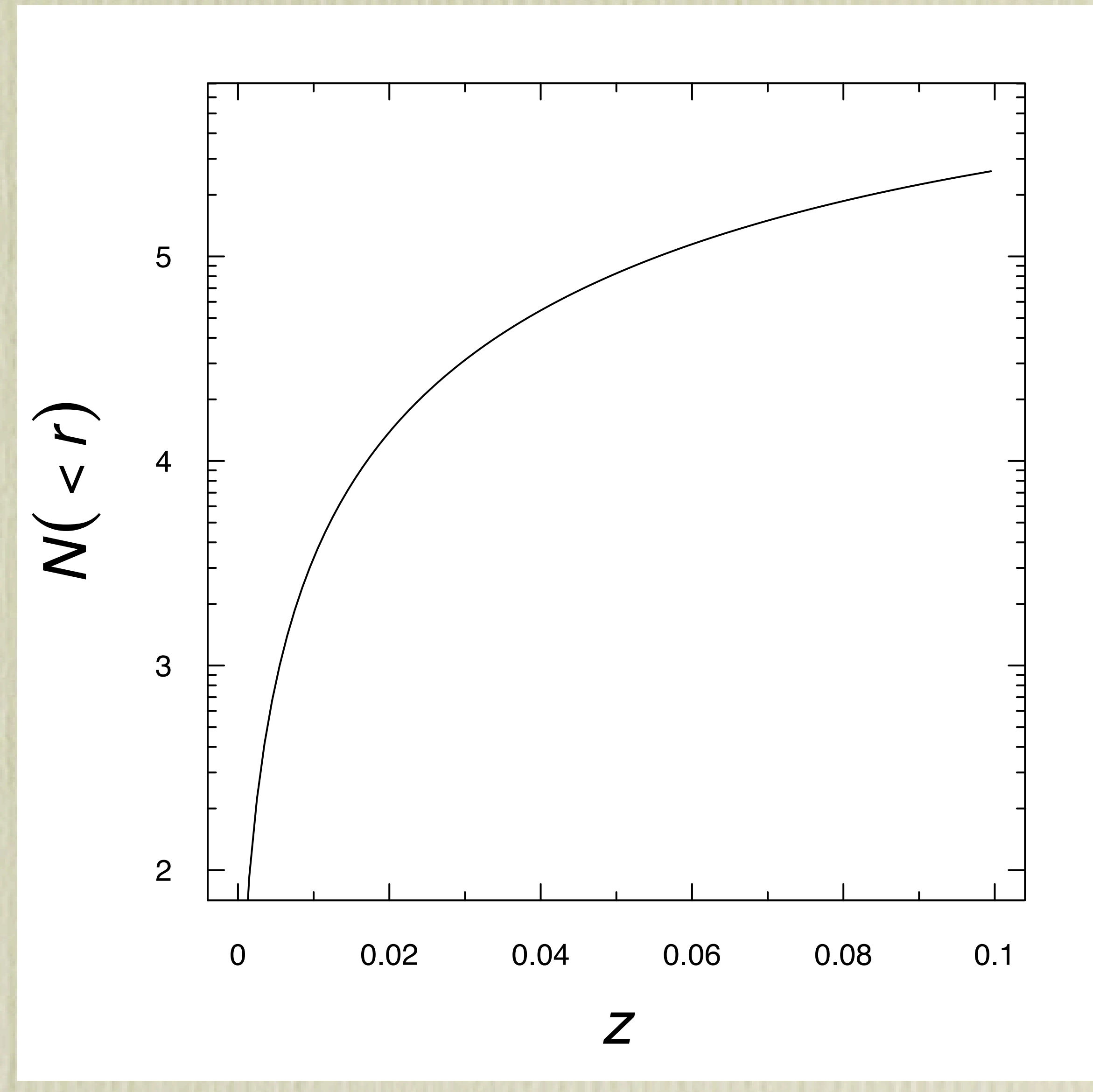
$\Delta P_{uu} = P_{uu} + \frac{\sigma_v^2}{n}$ pec. vel. measurement error

Burkey & Taylor 2004 MNRAS **347**, 255 (for 6dF survey)

Number density in WALLABY Survey

- HI Mass Function
- Spectral flux density $\mathcal{J}$ > 5 mJy
- V_c width w > 100 km/s

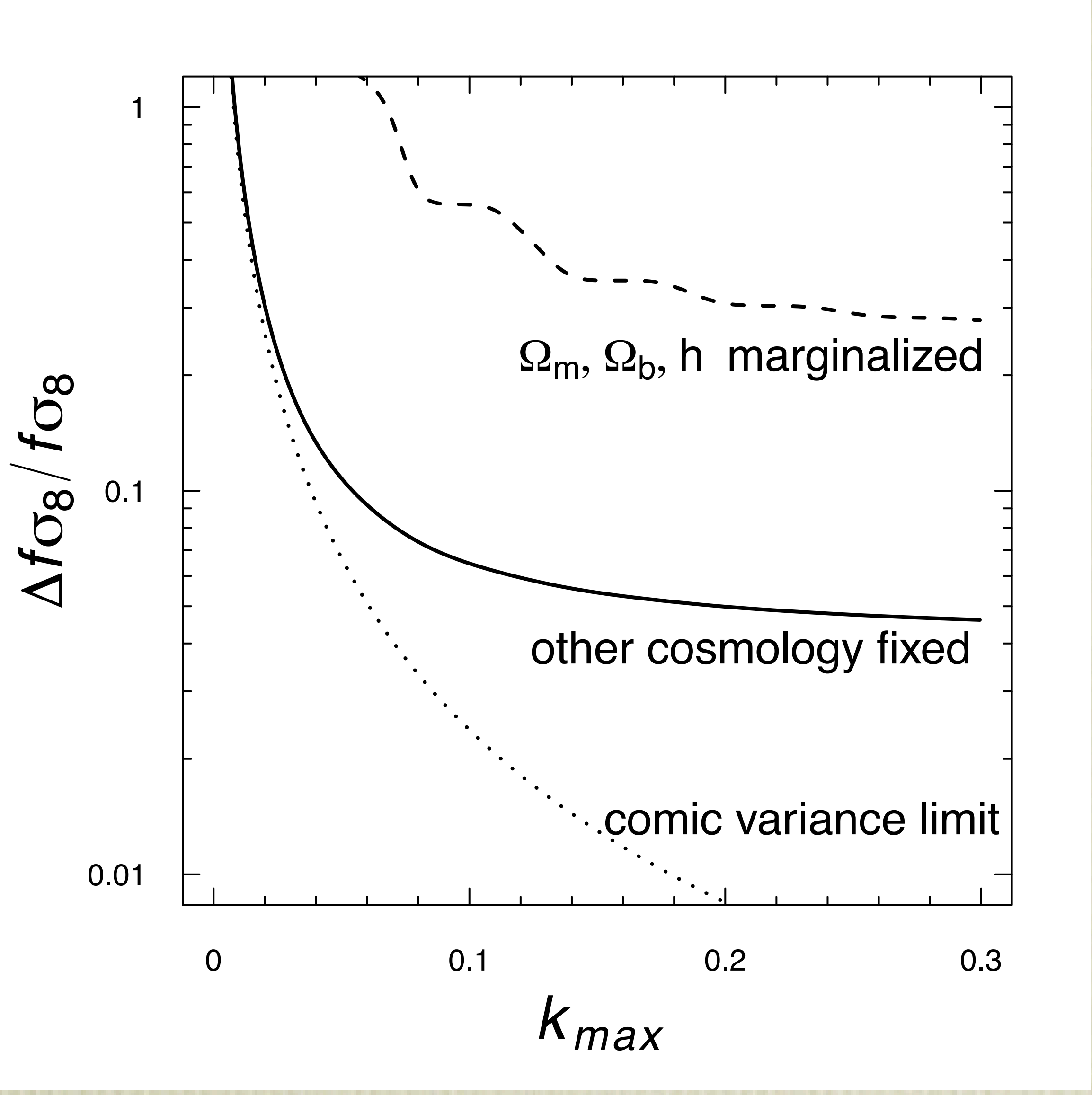




Constraints from
Velocity Power Spectrum (alone)

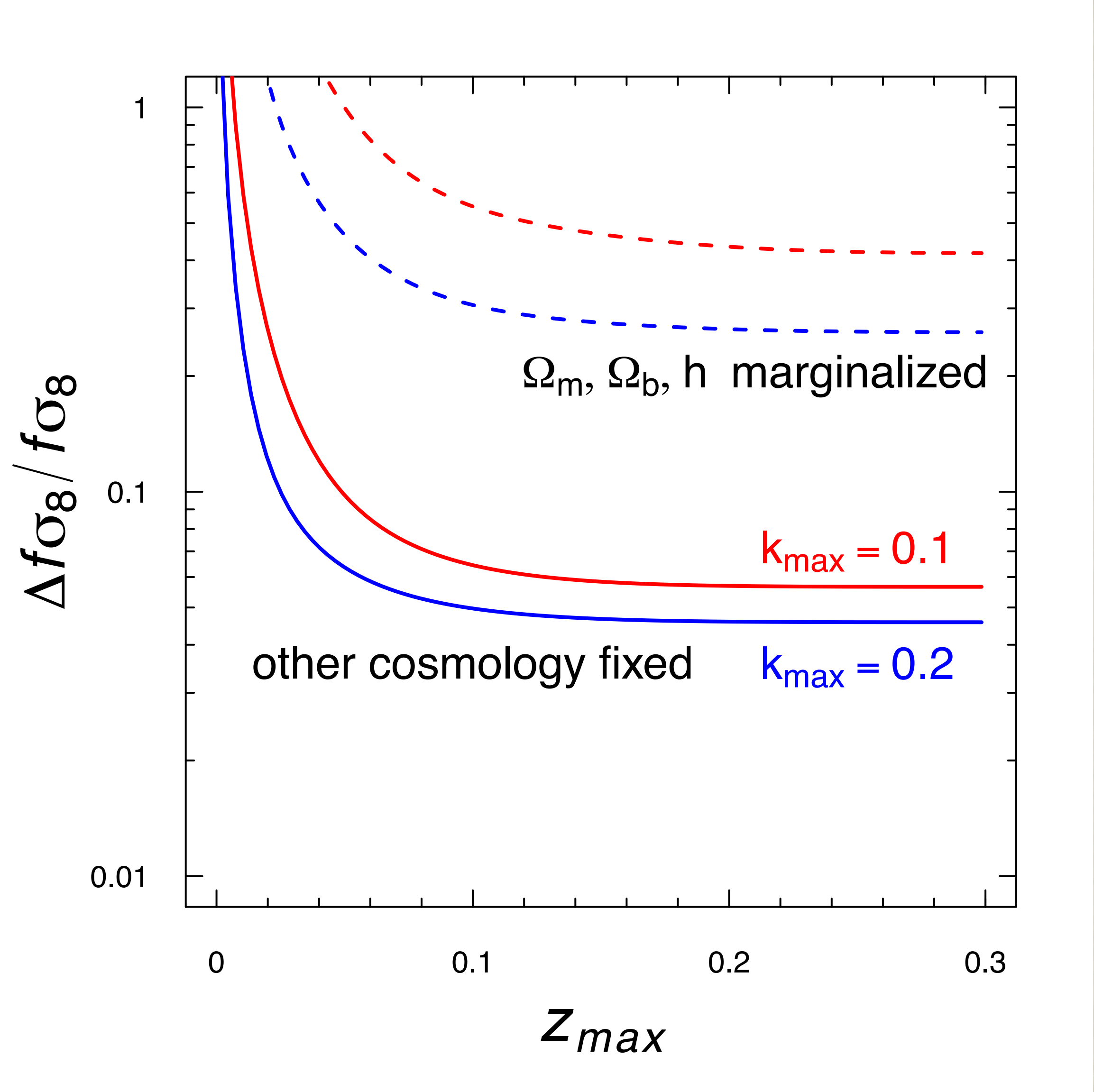
- 20,000 deg²
- WALLABY *n(z)*
- $\sigma_v \sim 0.20 \times H_0\, d$

	$\Delta f\sigma_8$	
k_{max}	fixed	mar.
0.1	6.4%	56%
0.2	5.0%	31%



Constraints from
Velocity Power Spectrum (alone)

- 20,000 deg^2
- WALLABY $n(z)$
- $\sigma_v \sim 0.20 \times H_0\, d$



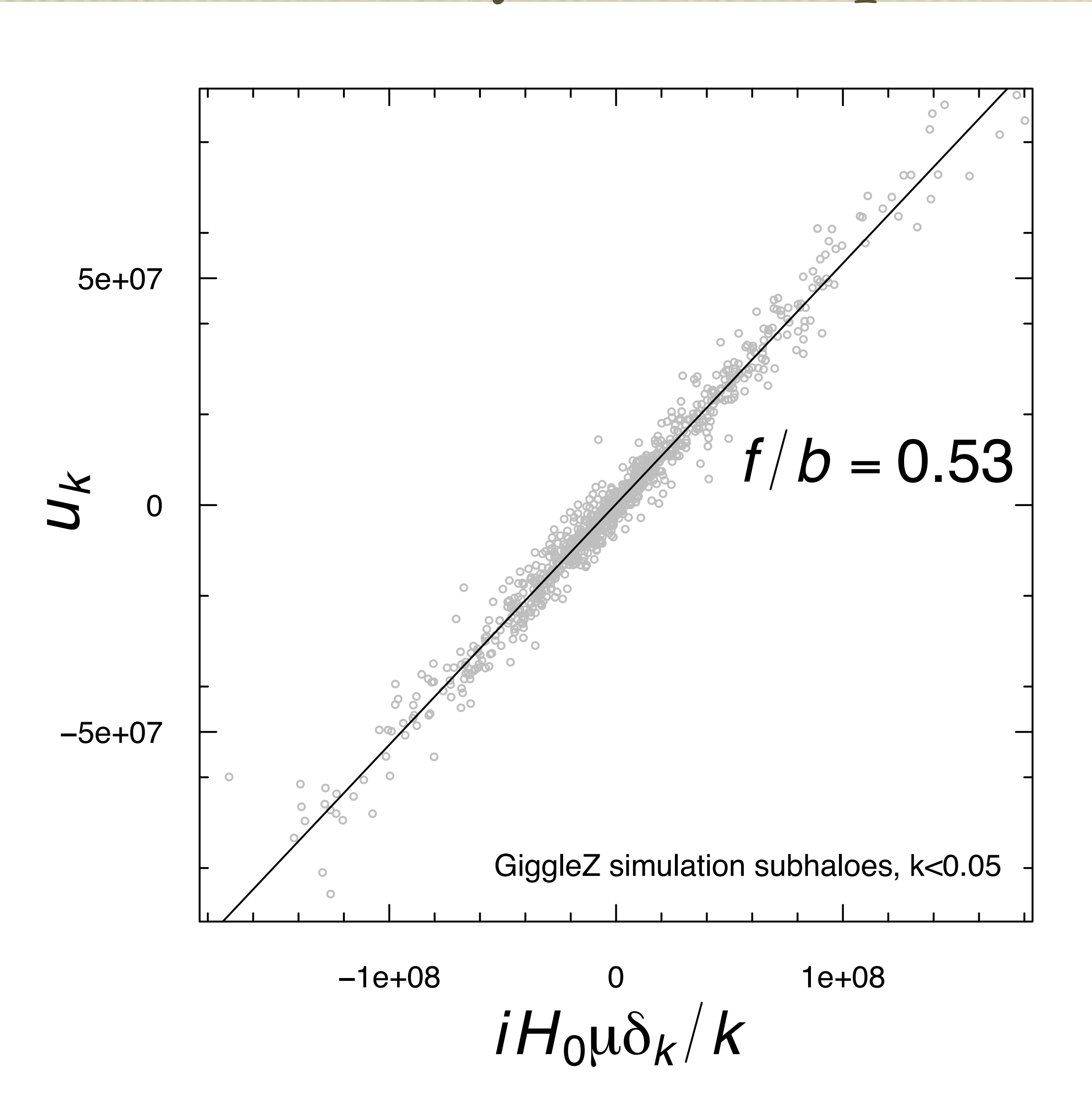
Constrains from δ & u combined

Toy Model (linear theory in real space)

$$\begin{cases} \delta_g &= b\delta_m \\ u &= \frac{iH_0 f\mu}{k}\delta_m \end{cases}$$

or

$$u = (f/b)\frac{iH_0\mu}{k}\delta_g$$



δ_m(k) are random Gaussian variables with variance *P(k)*, but that randomness and cosmological parameter dependence cancels out for $\beta \equiv f/b$.

Constrains from δ & u combined

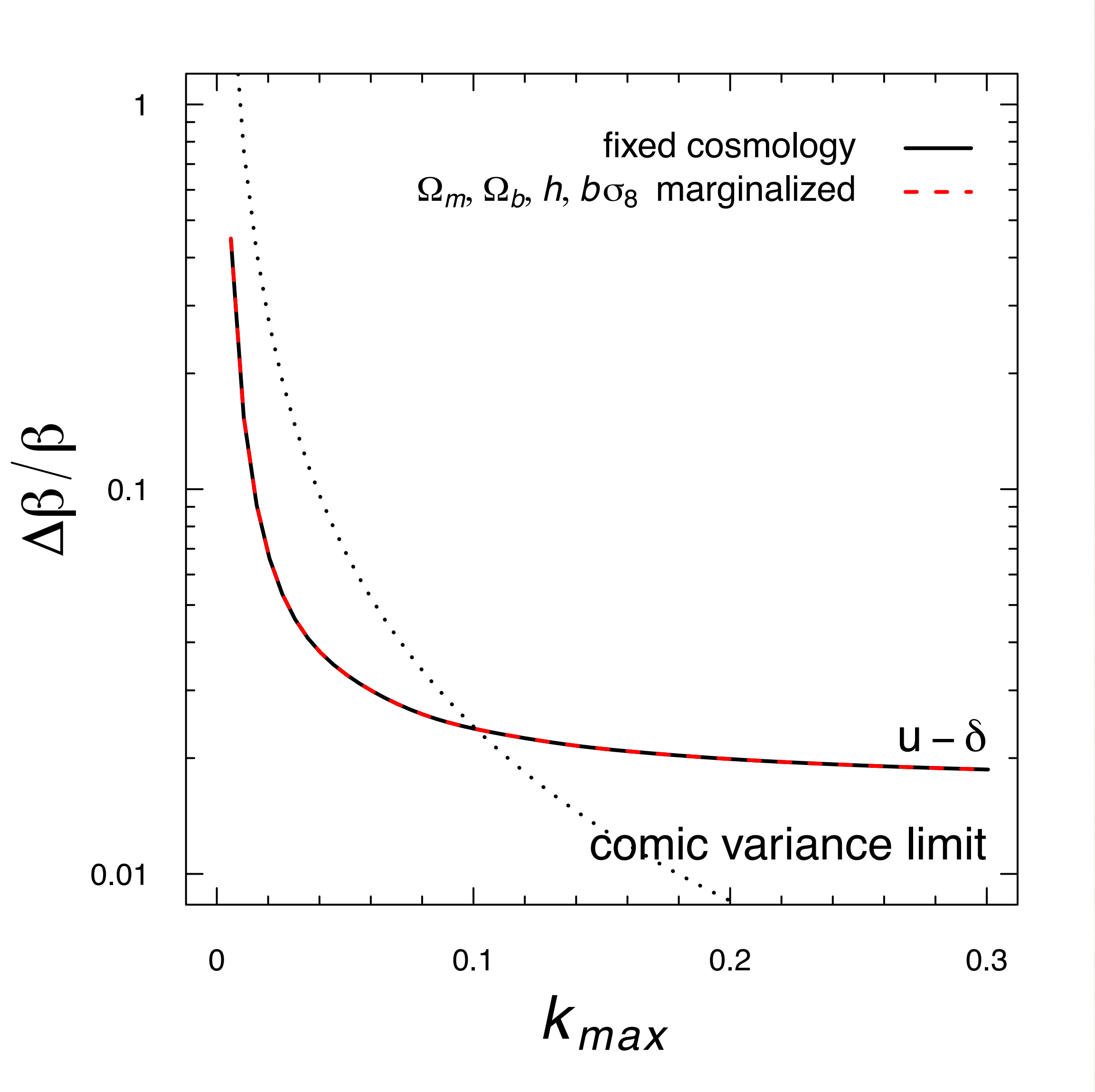
Toy Model (linear theory in real space)

$$\begin{cases} \delta_g &= b\delta_m \\ u &= \frac{iH_0 f\mu}{k}\delta_m \end{cases}$$

$$(\beta \equiv f/b)$$

	$\Delta\beta$	
k_{max}	fixed	mar.
0.1	2.4%	2.4%
0.2	2.0%	2.0%

Good constraint on β, but good b needed for f



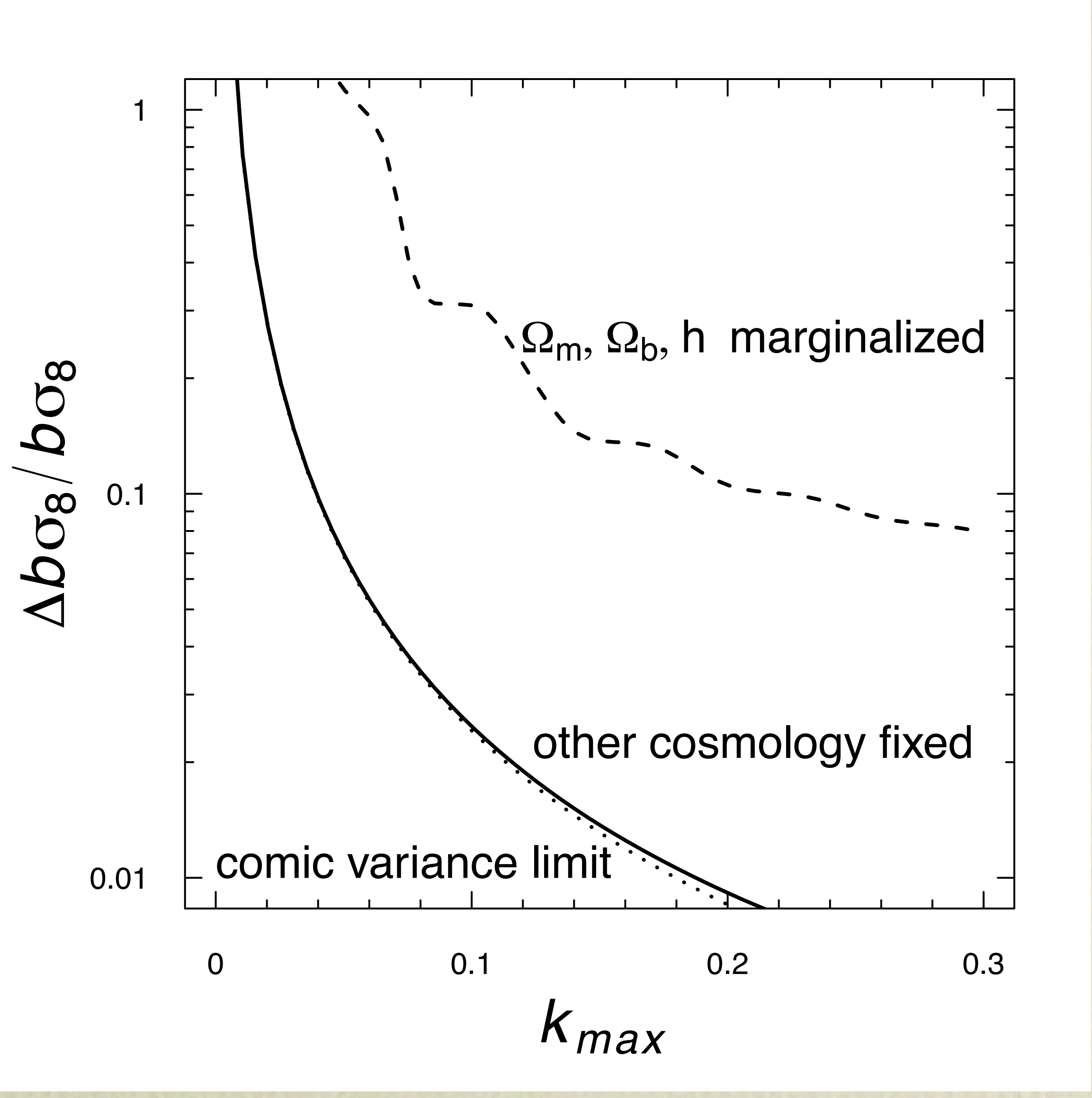
... and this is at z=0, when Ω_m<1

(Fihser matrix of correlated δ & u)

Constrains from δ & u combined

Toy Model (linear theory in real space)

- $b\sigma_8$ is (probably) easy to measure with some prior on cosmological parameters



few % constraint on $b\sigma_8$

×

2% constraint on f/b

↓

few % constraint on $f\sigma_8$ (?)

Constrains from δ & u combined

Toy Model (linear theory in real space)

- $b\sigma_8$ is (probably) easy to measure with some prior on cosmological parameters

around here →

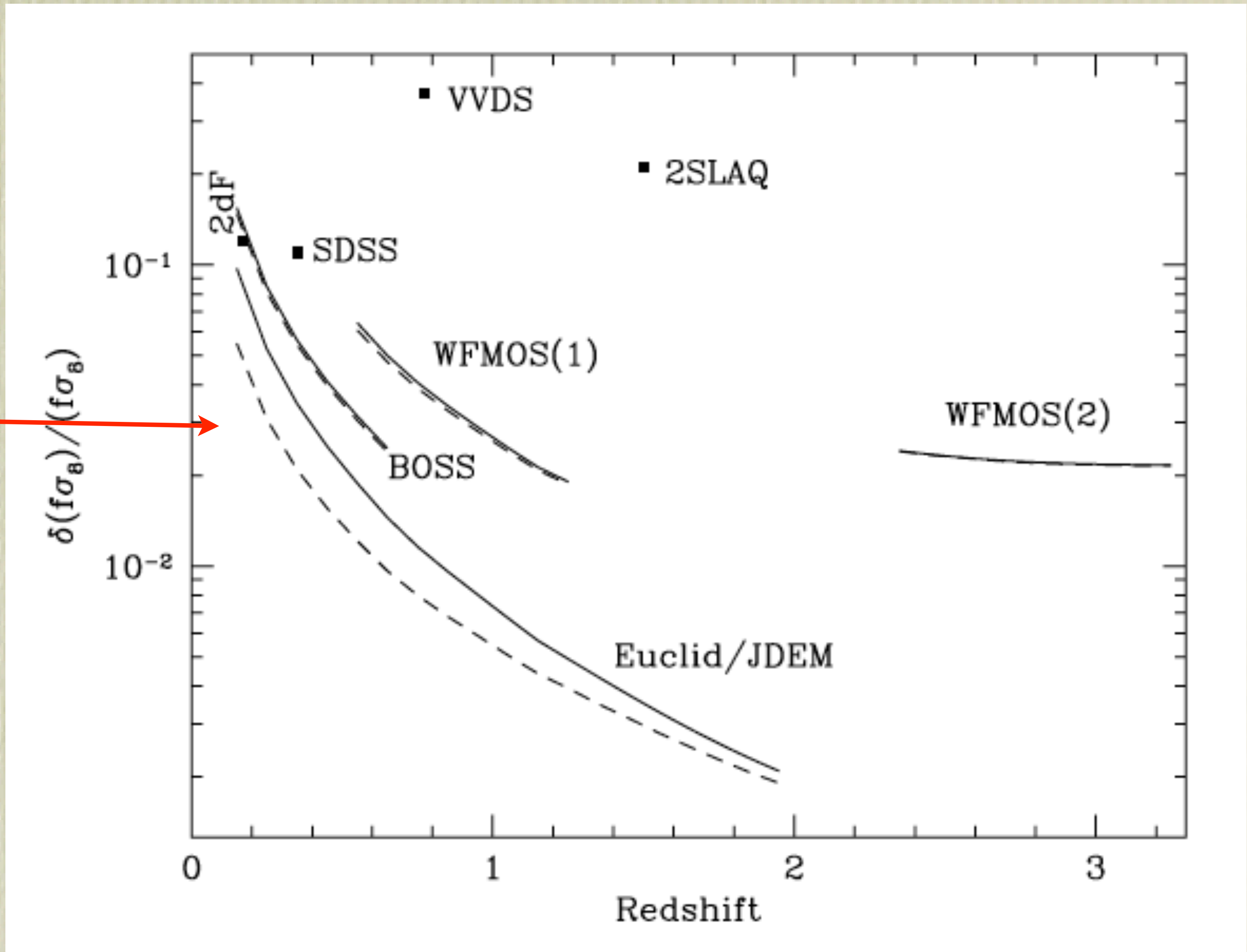
few % constraint on $b\sigma_8$

×

2% constraint on f/b

↓

few % constraint on $f\sigma_8$ (?)



White 2009 MNRAS **397**, 1348 (Fisher matrix analysis for RSD)

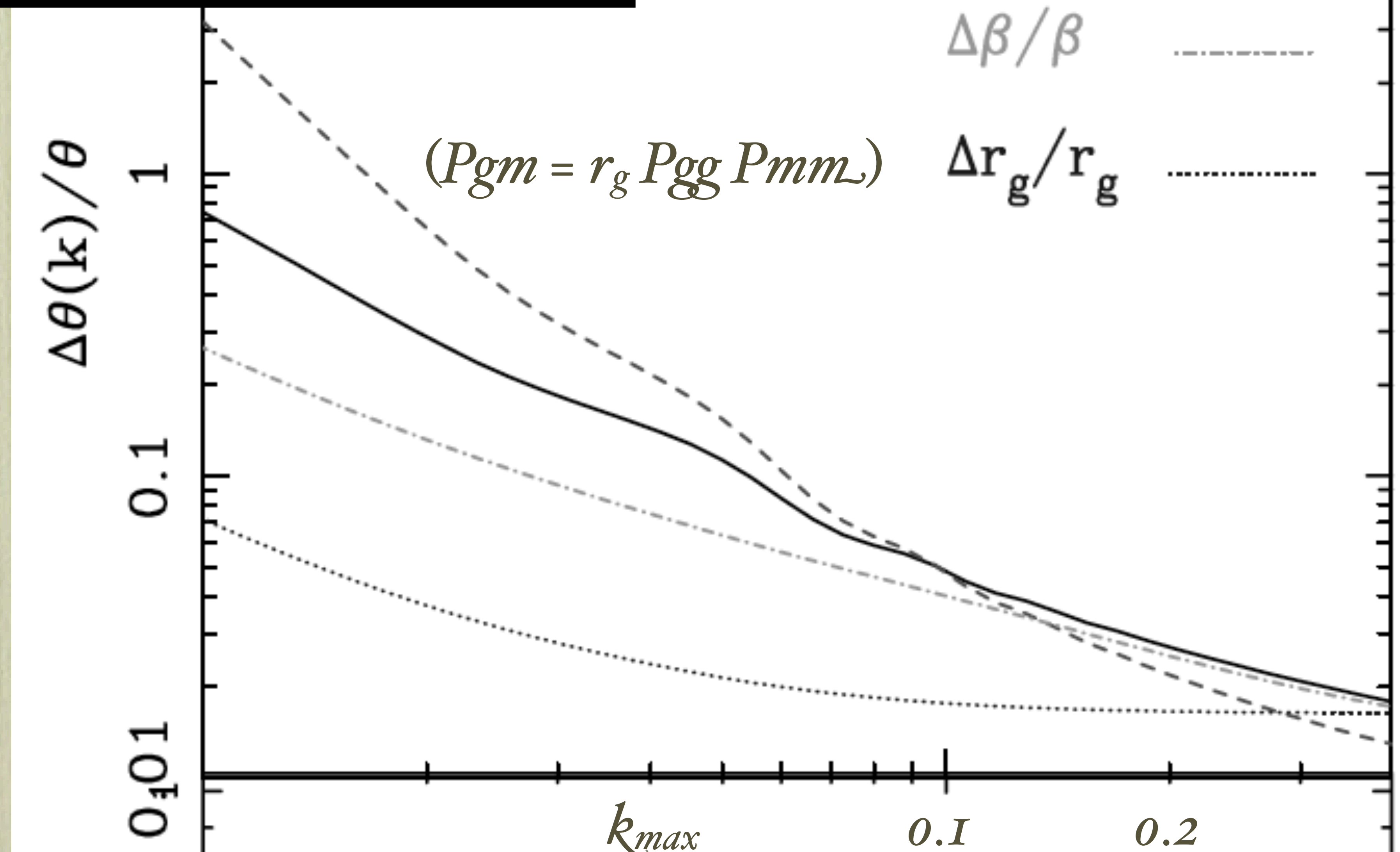
Constrains from δ & u combined

linear theory + some redshift-space distortion

$$P^s_{\rm gg}(\boldsymbol{k}) = D^2(k\sigma_{\rm v}\mu)\left(1 + 2\mu^2 r_{\rm g}\beta + \mu^4\beta^2\right) b^2 P_{\rm mm}(k),$$

$$P_{u'u'}(\boldsymbol{k}) = \mu^4 H^2 \beta^2 b^2 P_{\rm mm}(k),$$

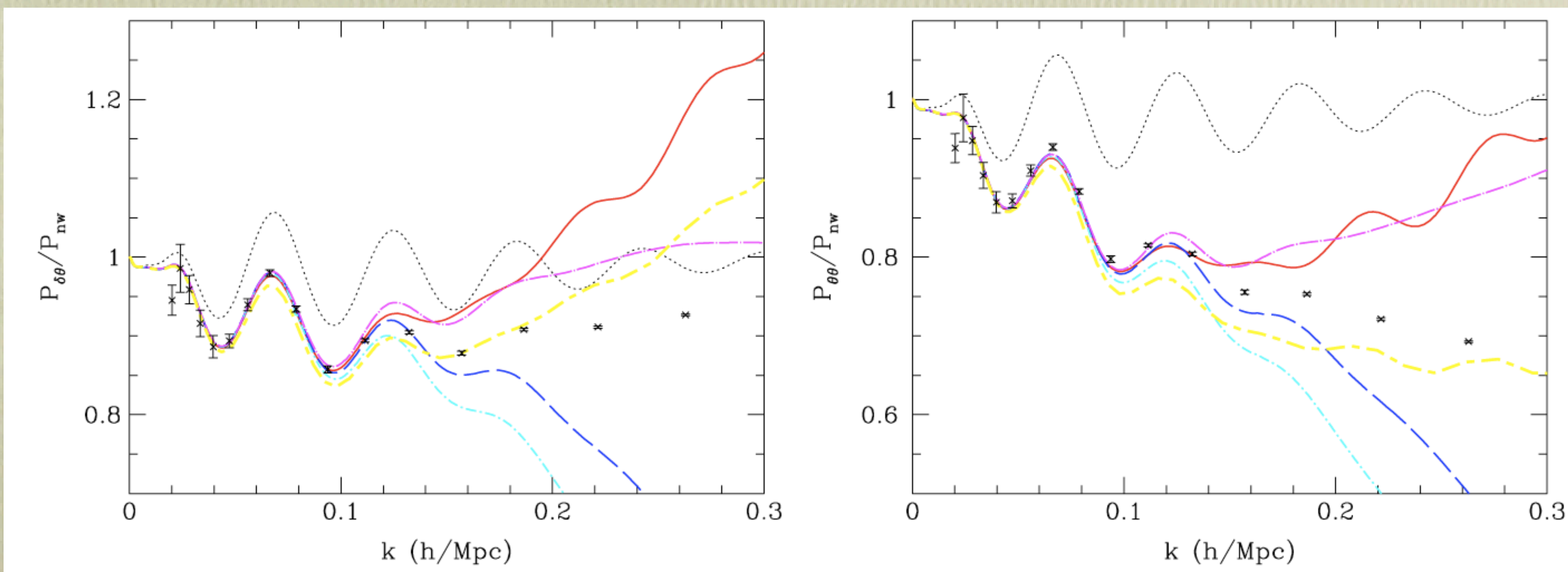
$$P^s_{{\rm g}u'}(\boldsymbol{k}) = -\mu^2 H \beta D(k\sigma_{\rm v}\mu)\left(r_{\rm g} + \mu^2\beta\right) b^2 P_{\rm mm}(k),$$



Burkey & Taylor 2004 MNRAS **347**, 255 (for 6dF survey)

Theoretical Work needed to be done (a lot!)

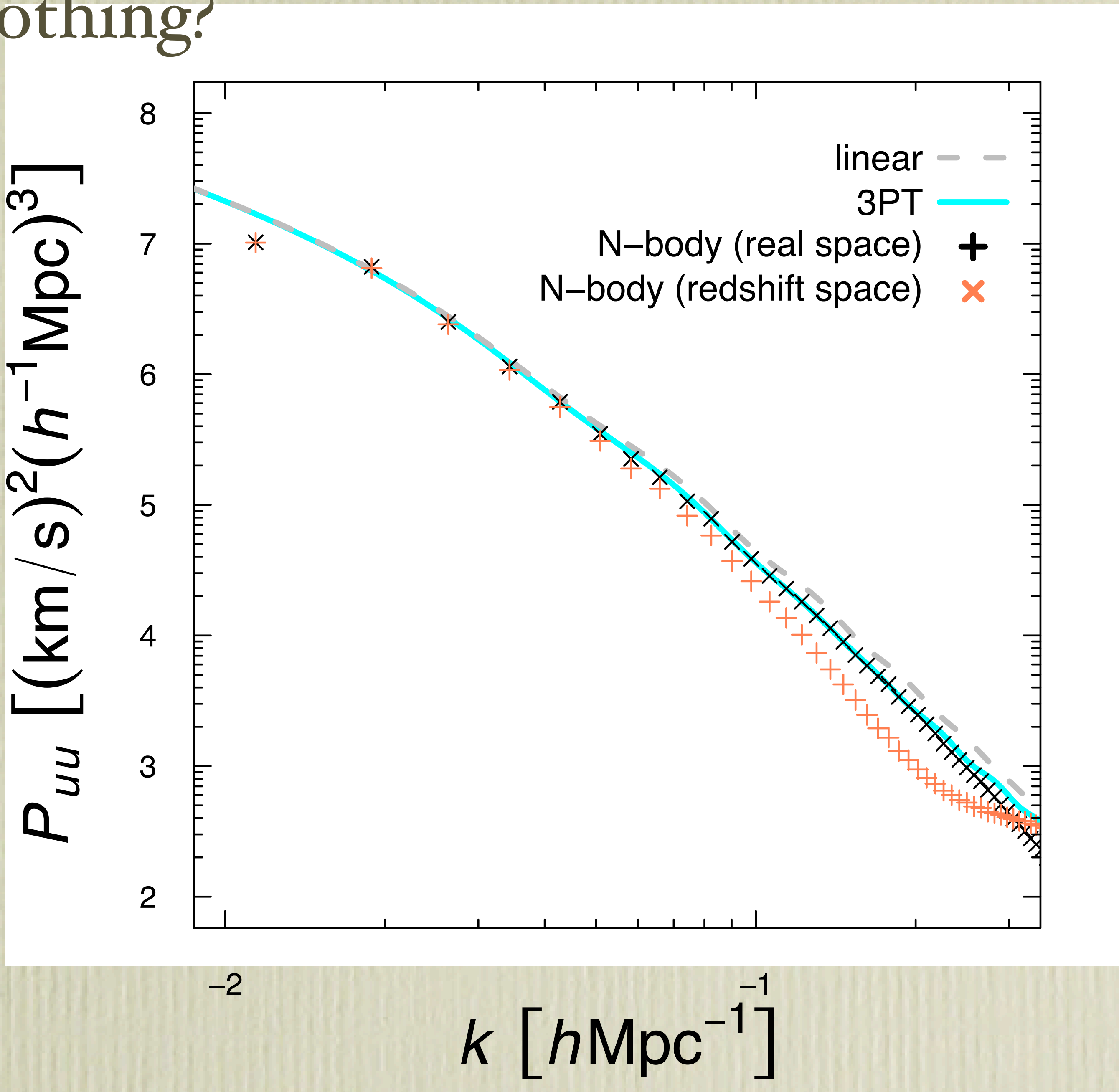
- Nonlinear velocity power spectrum
  - ➡ systematic effect on β estimation
  - ➡ HaloFit for velocity power spectrum?
  - ➡ cosmological dependence may affect β precision



Calson, White & Padmanabhan 2009 Phys. Rev. D MNRAS 80, 043531

Theoretical Work needed to be done (a lot!)

- Redshift-space distortion of velocity power
  - ➡ Linear effect?
  - ➡ Nonlinear damping/smoothing?
  - ➡ Any new information?



Theoretical Work needed to be done
(a lot!)

- Bias *b*; bottle neck of measuring *f*
  - ➡ bispectrum/HOD?
  - ➡ how precise can we determine?

Summary

- $f\sigma_8$ can be measured ~5% from P_{uu}
- $\beta=f/b$ 2% No cosmic variance/cosmological parameter dependence (on leading order)

  ➡ for GR f, good measurement of b or $b(k)$

  ➡ b is the limiting factor for f

- $f\sigma_8$ ~3% with δ_g, u and accurate cosmological parameters (I guess...)
- Is this worth doing? Any other way of analysis?