Growth Rate Forecasts for Combined and Future Peculiar Velocity Surveys

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Contents

- Theory
  - Fisher Matrices
    - Multi-tracer and multi-survey
    - Model power spectra
- Forecasts for current surveys
- Forecasts for future surveys
- Systematic Effects

Fisher Matrix Forecasts

Can forecast the precision on parameters using:

$$F_{ij} = \frac{1}{2}\int \frac{d^3x d^3k}{(2\pi)^3} \mathrm{Tr}\left[\mathbf{C}^{-1}\frac{\partial \mathbf{C}}{\partial \theta_i}\mathbf{C}^{-1}\frac{\partial \mathbf{C}}{\partial \theta_j}\right]$$

C is a matrix of power spectra. For PV surveys we can use density, velocity and cross

$$\mathbf{C}(r,k,\mu) = \begin{bmatrix} P_{gg}^{AA}(k,\mu) + \frac{1}{\bar{n}_g^A(r)} & P_{ug}^{AA}(k,\mu) \\ P_{gu}^{AA}(k,\mu) & P_{uu}^{AA}(k,\mu) + \frac{(\sigma_u^A(r))^2}{\bar{n}_u^A(r)} \end{bmatrix}$$

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We solve the combined case by treating the overlapping and non-overlapping parts separately:

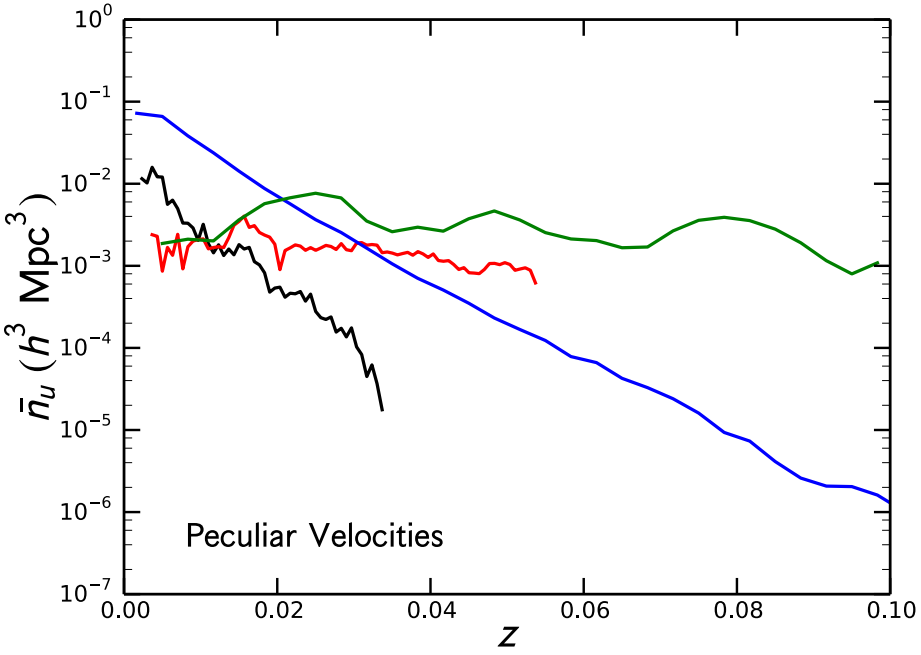
$$F_{ij} = F_{ij}(\Omega_{sky,A}) + F_{ij}(\Omega_{sky,B}) + F_{ij}(\Omega_{sky,AB})$$

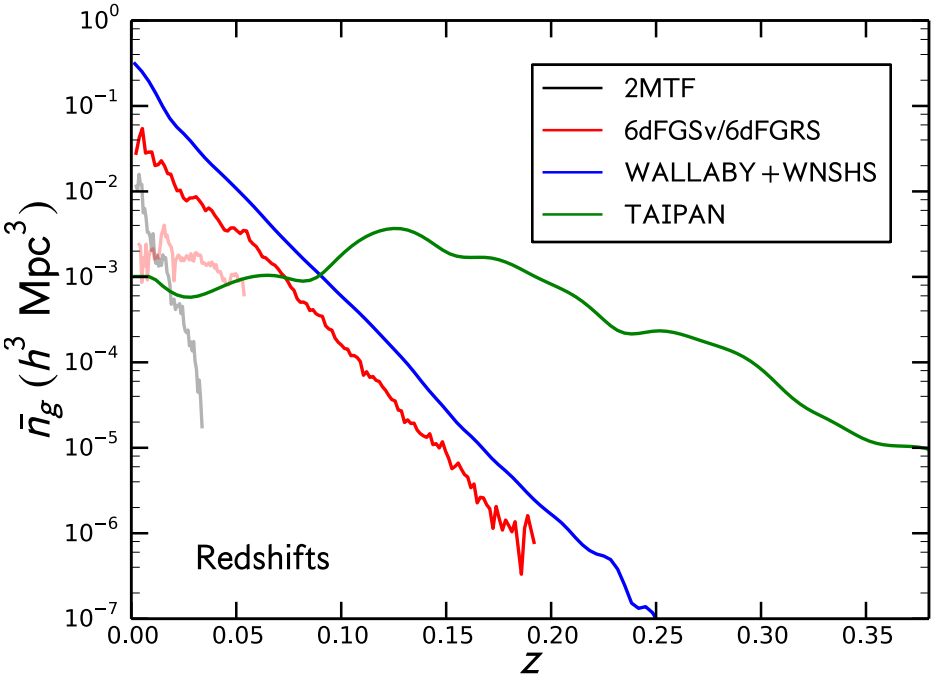
We also need some model power spectra. Based on Koda et. al., 2014.

$$P_{gg}^{AA}(k,\mu) = (\beta_A^{-2} + 2r_g\beta_A^{-1}\mu^2 + \mu^4) f^2 D_g^2 P_{mm}(k),$$
$$P_{ug}^{AA}(k,\mu) = aH\mu k^{-1}(r_g\beta_A^{-1} + \mu^2) f^2 D_g D_u P_{m\theta}(k),$$
$$P_{uu}^{AA}(k,\mu) = (aH\mu)^2 k^{-2} f^2 D_u^2 P_{\theta\theta}(k).$$

+ second survey and cross spectra between surveys!

We then extend these to incorporate primordial non-Gaussianity, velocity bias, scale dependent bias and zero-point offsets. More on velocity bias later on (others not in this talk, but please talk to me later!)


$\bar{n}_u\,(h^3\,\mathrm{Mpc}^3)$
z
Peculiar Velocities


$\bar{n}_g\,(h^3\,\mathrm{Mpc}^3)$
z
Redshifts
2MTF
6dFGSv/6dFGRS
WALLABY+WNSHS
TAIPAN

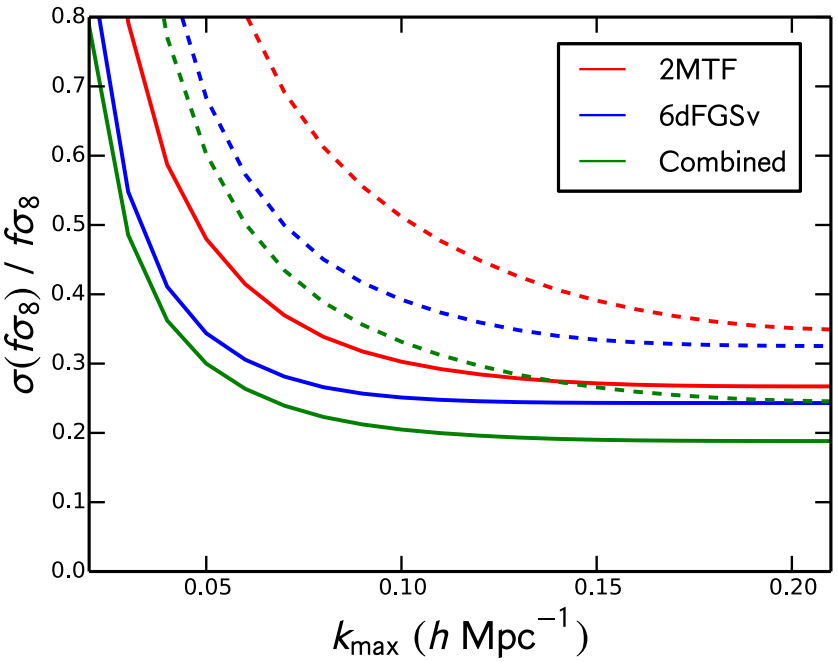
Current Surveys

2MTF

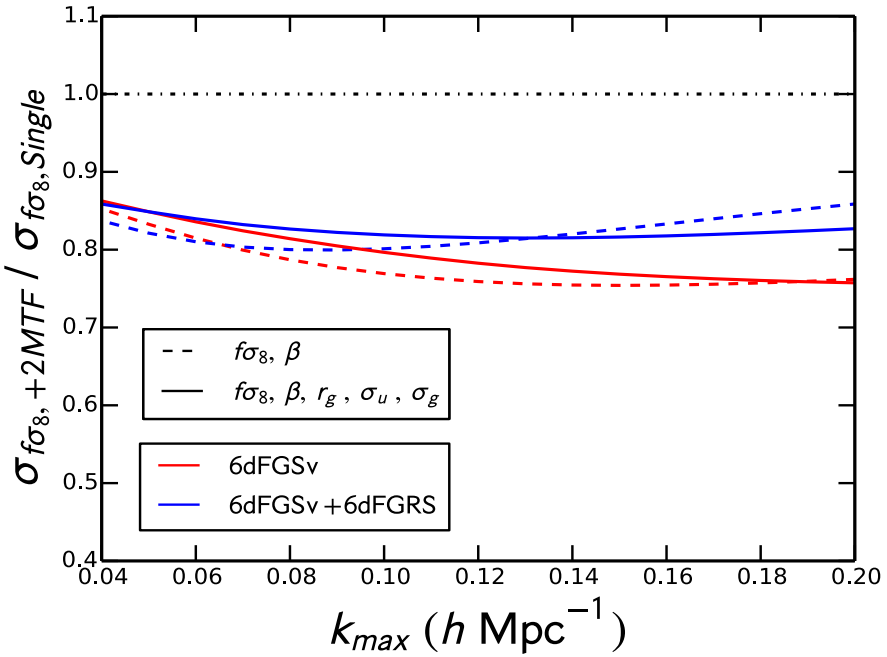
- ~2000 T-F spiral galaxies with redshifts
- Full-sky (except b < |5°|)
- cz < 17,000 km/s. Low redshift
- b = 1.0
- 22% distance error
- Talks by Lister Staveley-Smith and Tao Hong.

6dFGRS/6dFGSv

- ~110,000 redshifts with 8,000 FP PV's
- Southern sky (except b < |10°|)
- Z < 0.2 (0.06)
- b = 1.4
- 26% distance error
- Talks by Jeremy Mould, Christina Magoulas, Caitlin Adams



Forecasts for 2MTF velocities similar to 6dFGSv despite far fewer galaxies. These forecasts compare well to actual measurements for 6dFGSv (Johnson et al., 2014)



We can gain 20% improvement in the growth rate measurements by adding just 2MTF to 6dFGSv AND 6dFGRS.

- A few PV's have great constraining power!

Future Surveys

WALLABY+WNSHS

- H1 survey using ASKAP complemented by Westerbork.
- ASKAP to cover southern ¾ of sky. WNSHS covers remainder.
- b = 0.7
- 20% distance error
- Z < 0.25
- Total ~500,000 expected redshift and 45,000 T-F measurements.

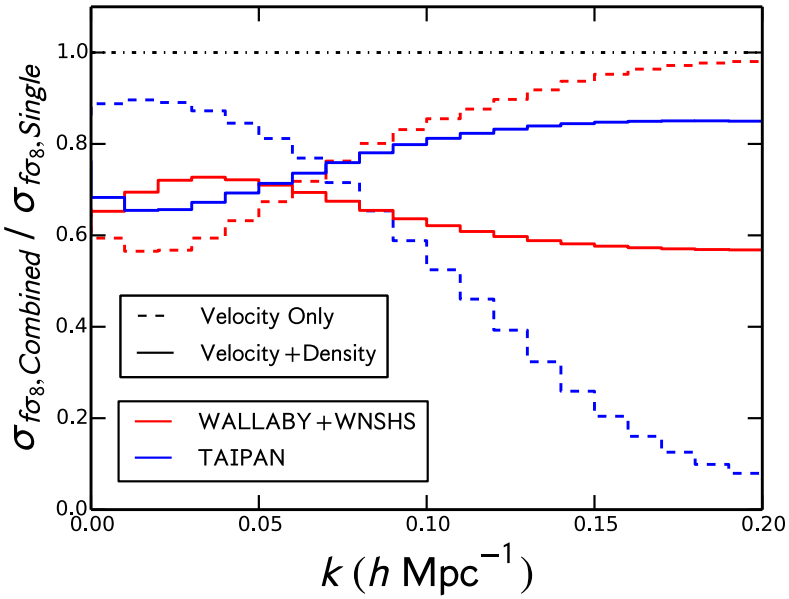
TAIPAN

- ~1,000,000 redshifts with 100,000 FP distances.
- Southern sky (except b < |10°|)
- b = 1.2
- 20% distance error
- Z < 0.4 (0.1)
- Talks by Matthew Colless, Jeremy Mould

TAIPAN	$f\sigma_8$, β	2.3	2.6	-	-	-
	$f\sigma_8$, β, r_g, σ_u, σ_g	4.1	4.2	2.3	12.1	6.8
WALLABY + WNSHS	$f\sigma_8$, β	2.7	3.3	-	-	-
	$f\sigma_8$, β, r_g, σ_u, σ_g	4.2	4.4	0.3	6.8	12.9
TAIPAN + WALLABY + WNSHS	$f\sigma_8$, β	1.8	2.2, 2.0	-	-	-
	$f\sigma_8$, β, r_g, σ_u, σ_g	2.8	3.0, 3.1	1.1, 0.3	10.9, 6.4	5.7, 9.7

Amazing constraints on the growth rate from TAIPAN, WALLABY+WNSHS and their combination!

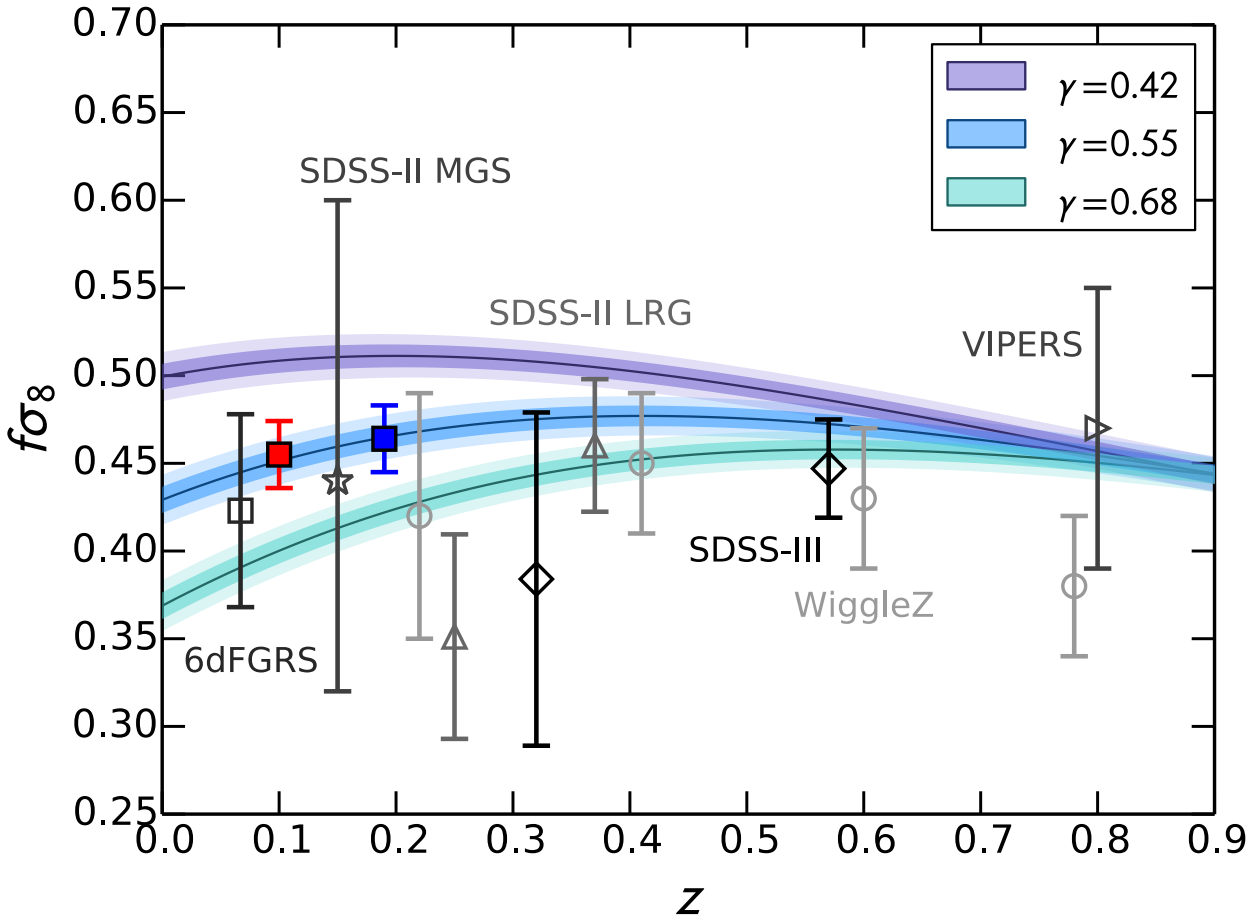
3% Measurement from the combo, including all nuisance parameters.



Same plot as Matthew Colless. Just to drive this point home!

WALLABY+WNSHS

TAIPAN



Systematic Effects

Can compute bias from ignoring physical effects (scale-dependent bias, velocity bias, zero-point offsets) within the Fisher Matrix formalism.

$$B_i = \frac{1}{2}\int \frac{d^3x d^3k}{(2\pi)^3}\,\mathrm{Tr}\left[\mathbf{C}^{-1}\frac{\partial \mathbf{C}}{\partial \theta_i}\mathbf{C}^{-1}(\tilde{\mathbf{C}}-\mathbf{C})\right]$$

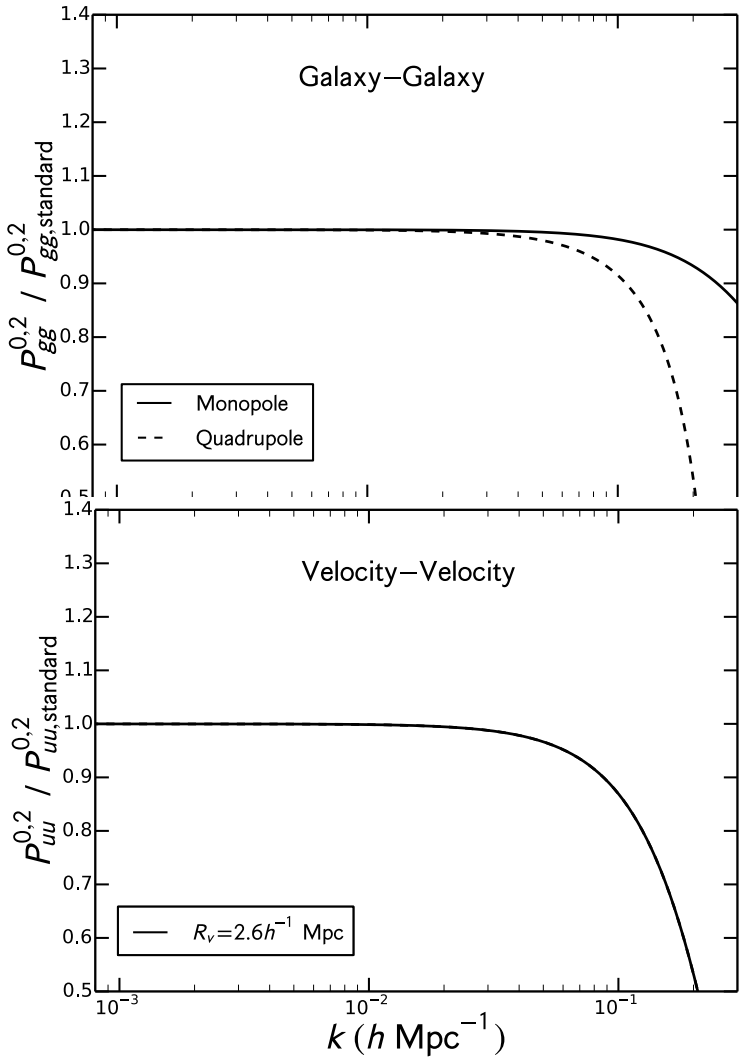
Use peaks approach of Desjacques and Sheth, 2010 to model scale-dependent and velocity bias. In particular:

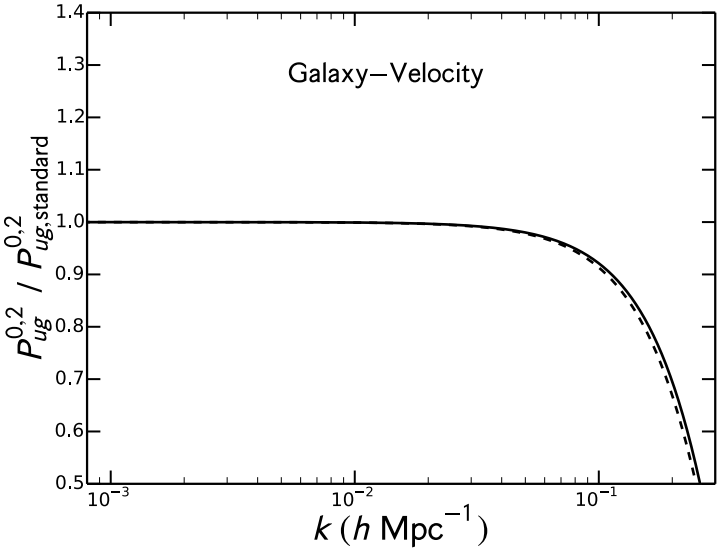
$$b_v = 1 - R_v^2 k^2.$$

$$P_{gg}^{AA}(k,\mu) = (\beta_A^{-2} + 2b_{v,A}r_g\beta_A^{-1}\mu^2 + b_{v,A}^2\mu^4)f^2D_g^2P_{mm}(k), \quad (22)$$

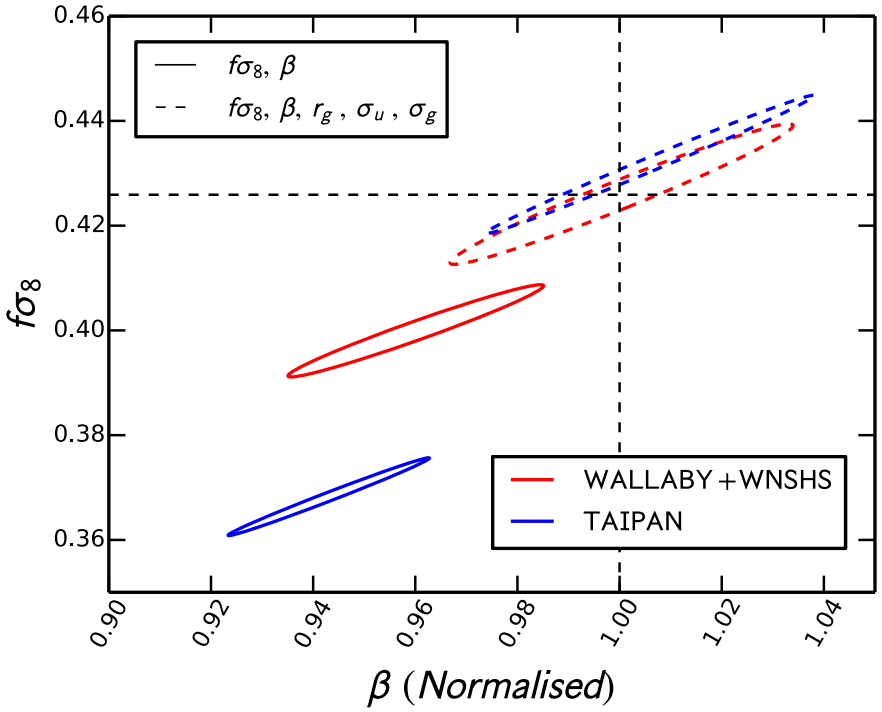
$$P_{ug}^{AA}(k,\mu) = aH\mu k^{-1}(r_g\beta_A^{-1} + b_{v,A}\mu^2)b_{v,A}f^2D_gD_uP_{m\theta}(k), \quad (23)$$

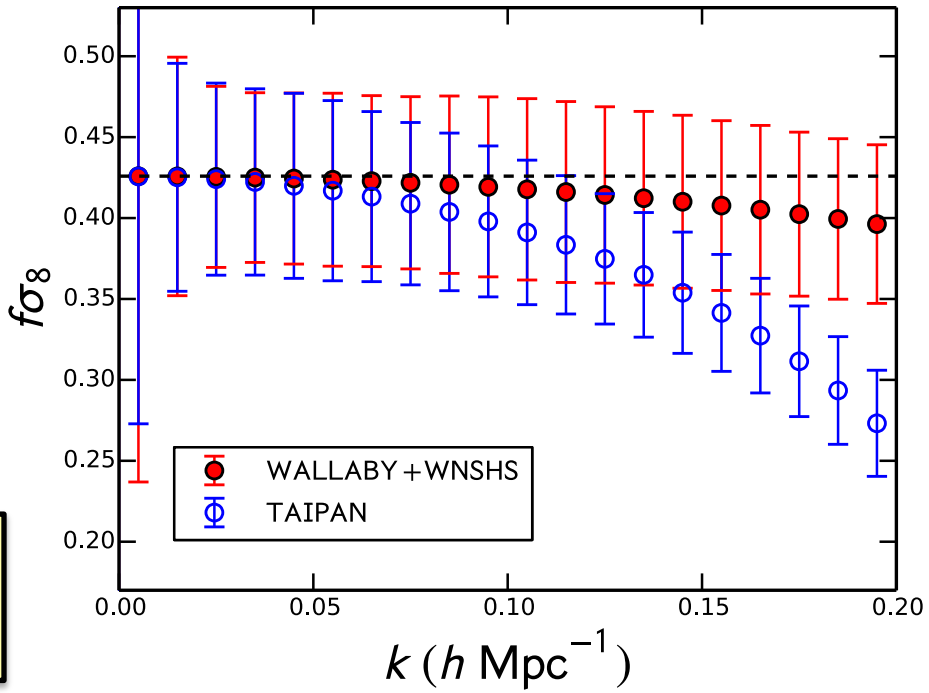
$$P_{uu}^{AA}(k,\mu) = (aH\mu)^2k^{-2}b_{v,A}^2f^2D_u^2P_{\theta\theta}(k) \quad (24)$$


Galaxy–Galaxy
$P^{0,2}_{gg}$ / $P^{0,2}_{gg,\mathrm{standard}}$
Monopole
Quadrupole
Velocity–Velocity
$P^{0,2}_{uu}$ / $P^{0,2}_{uu,\mathrm{standard}}$
R_v=2.6h^{-1} Mpc
k (h Mpc^{-1})


Galaxy–Velocity
$P^{0,2}_{ug}$ / $P^{0,2}_{ug,\mathrm{standard}}$
k (h Mpc^{-1})

Velocity Bias… biases results





Could bias TAIPAN measurements by 5σ… if it exists.

Conclusions

- We present an extended Fisher matrix method for forecasting peculiar velocity and redshift surveys in combination
- Significant improvement can be gained from combining multiple PV surveys, such as 2MTF + 6dF (improves growth rate by 20%)
- TAIPAN and WALLABY+WNSHS will be AMAZING for growth rate measurements. Combining these can give 3% measurement!
- We may have to start considering scale-dependent effects in more detail for future surveys as they are so constraining.

Paper submitted to MNRAS, so keep and eye out on ArXiV for Howlett, Staveley-Smith and Blake 2016. Could extend this to look at modified gravity?