Stochastic, non-linear biasing and Redshift Space Distortions

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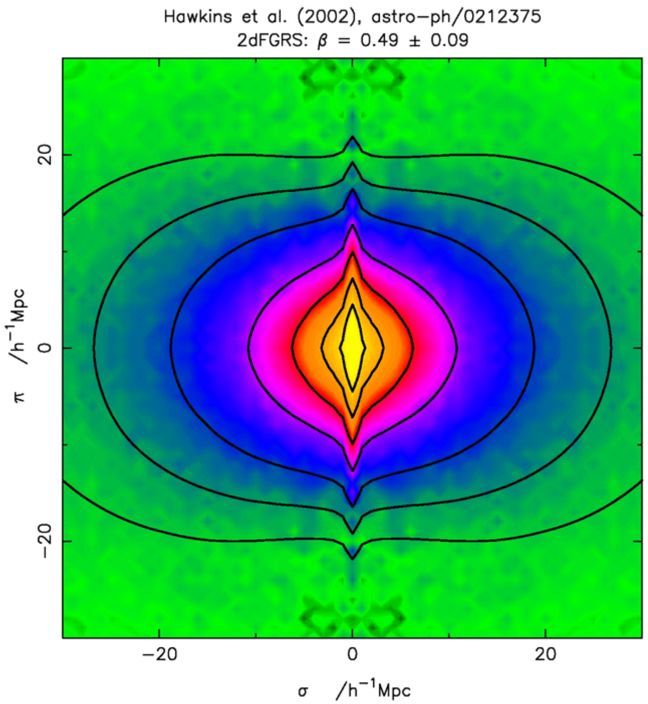
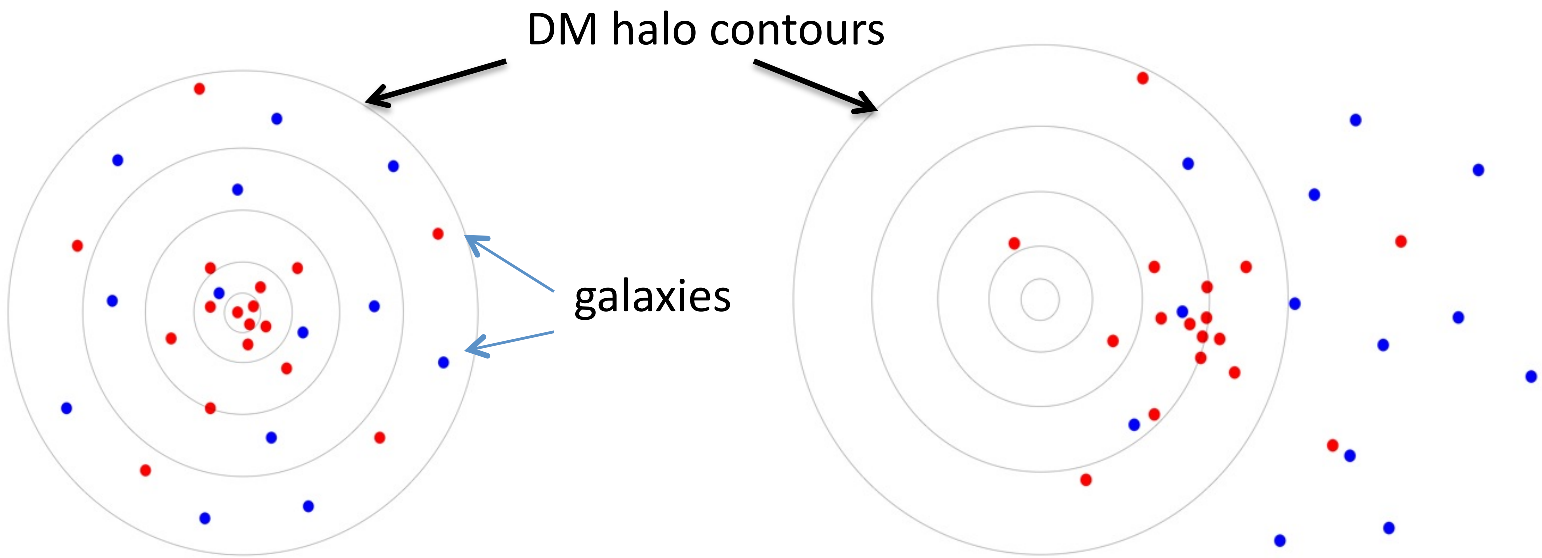
Lensing and RSD

- Redshift Space Distortions probe $\nabla\delta$
- Lensing probes δ
- The combination is a powerful probe of gravity



How do galaxies trace the Dark Matter?

- Galaxy bias
- Cross correlation coefficient

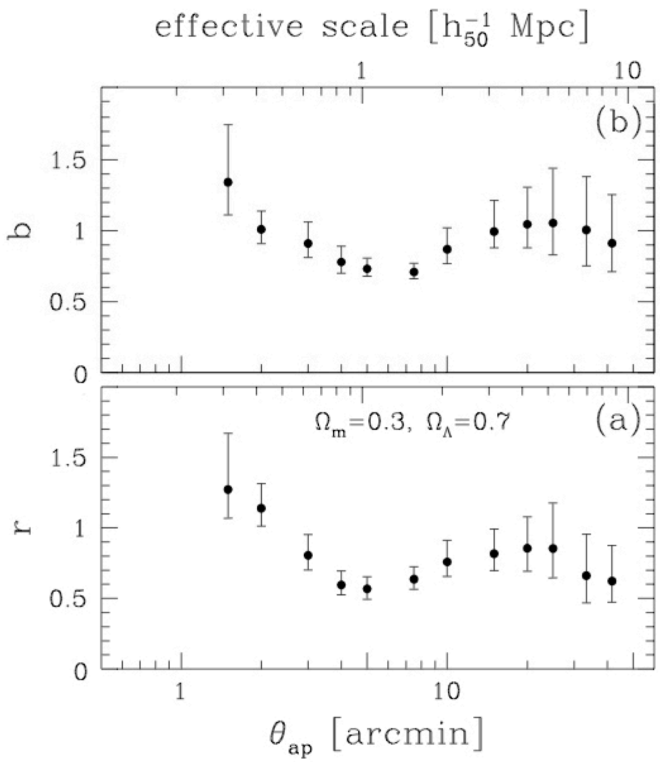


Galaxy bias
(Bias red>bias blue)

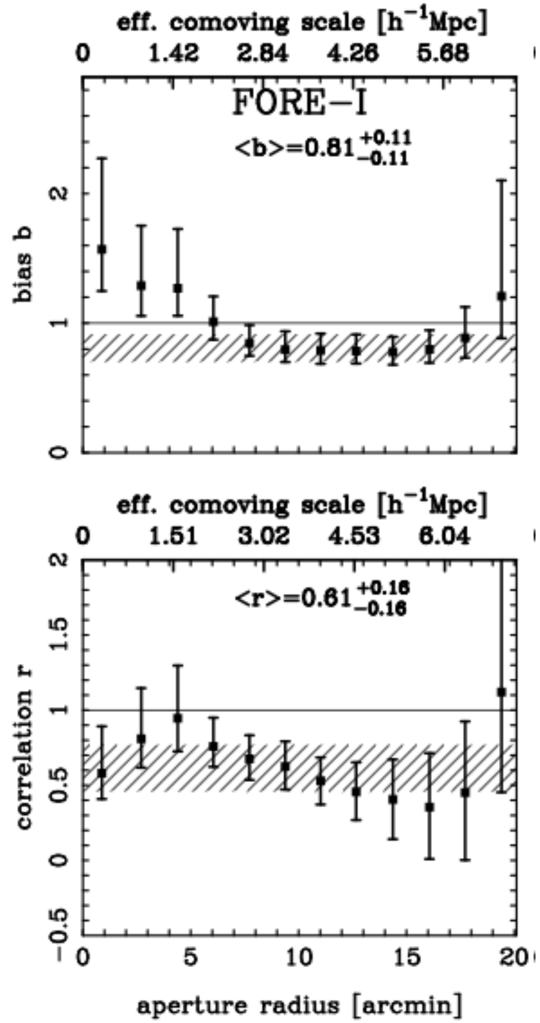
Cross correlation coefficient
(r red > r blue)

Weak Lensing bias results

Hoekstra et al 2002

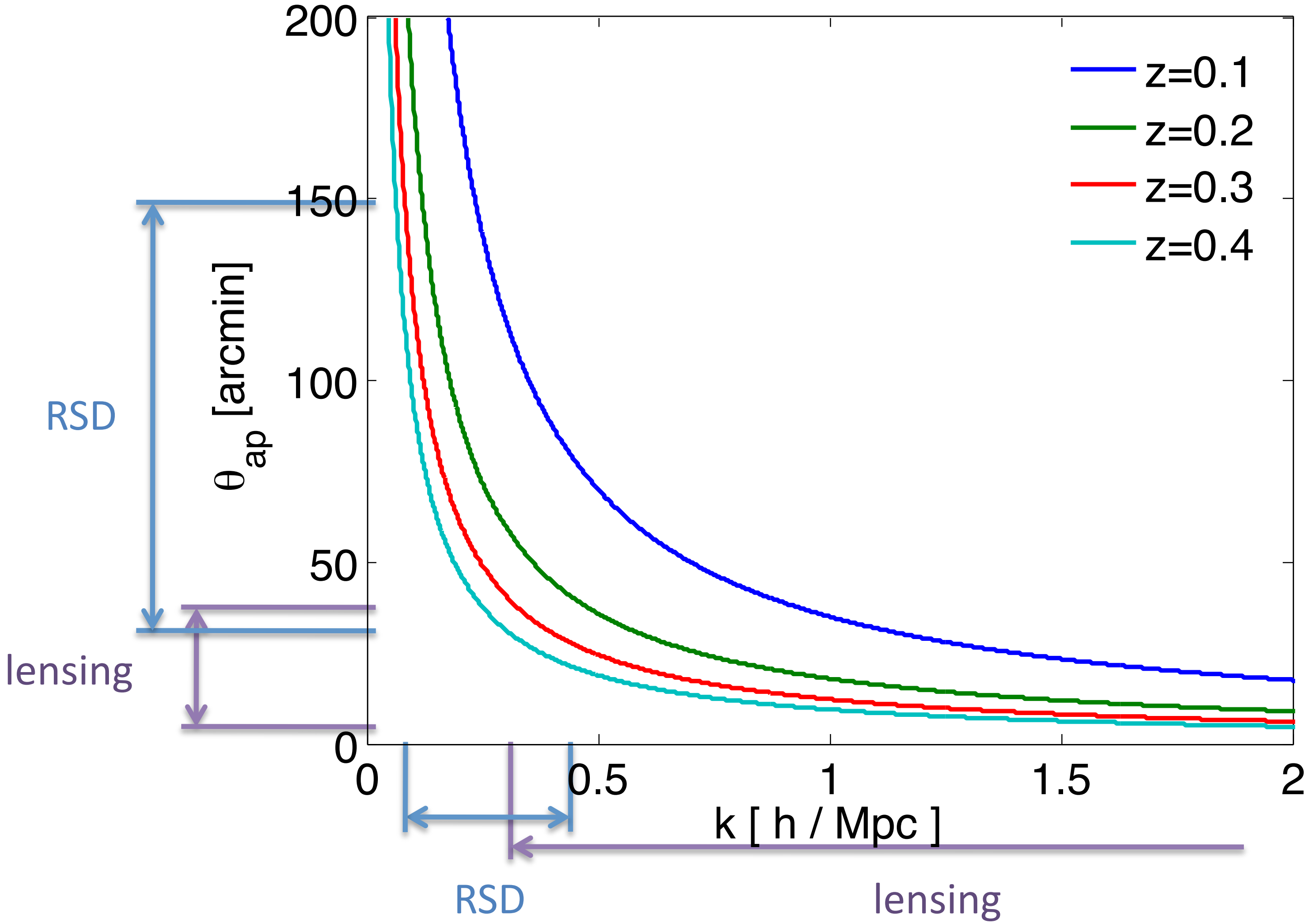


Simon et al 2007



Scale issue

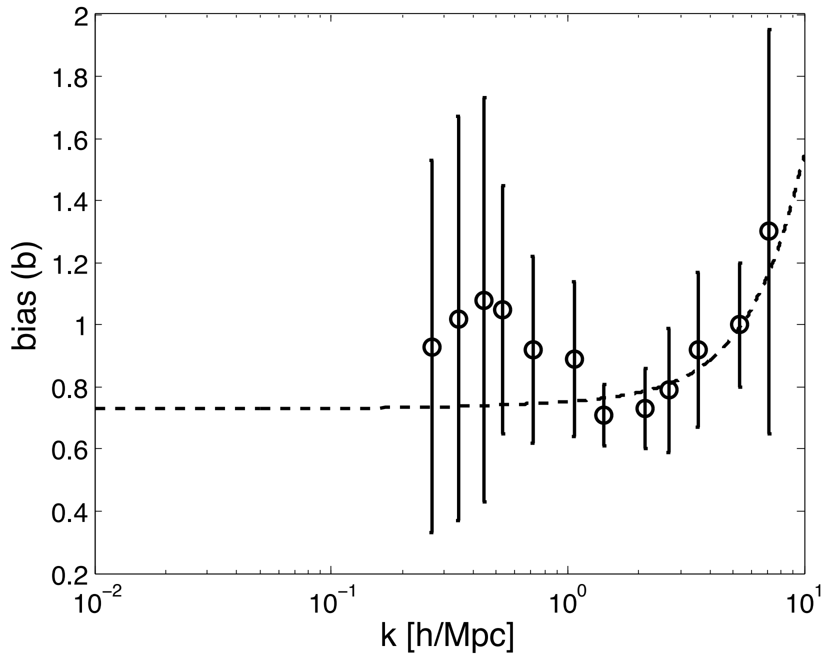
Lensing measurements need to go out to much larger angular scales!

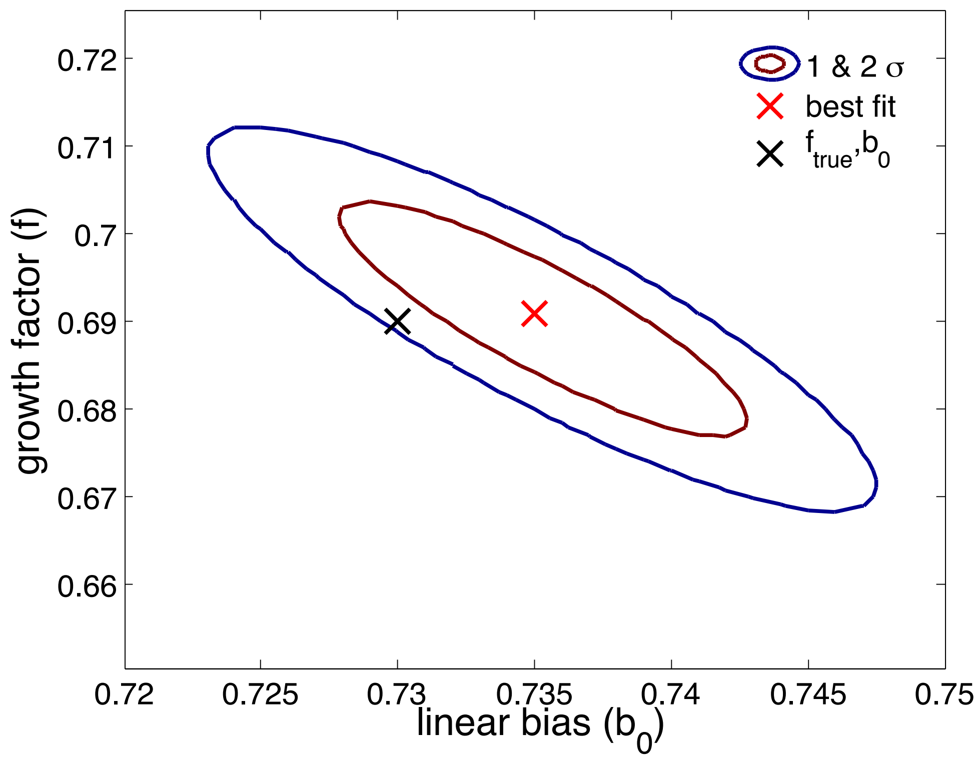


Scale dependent bias

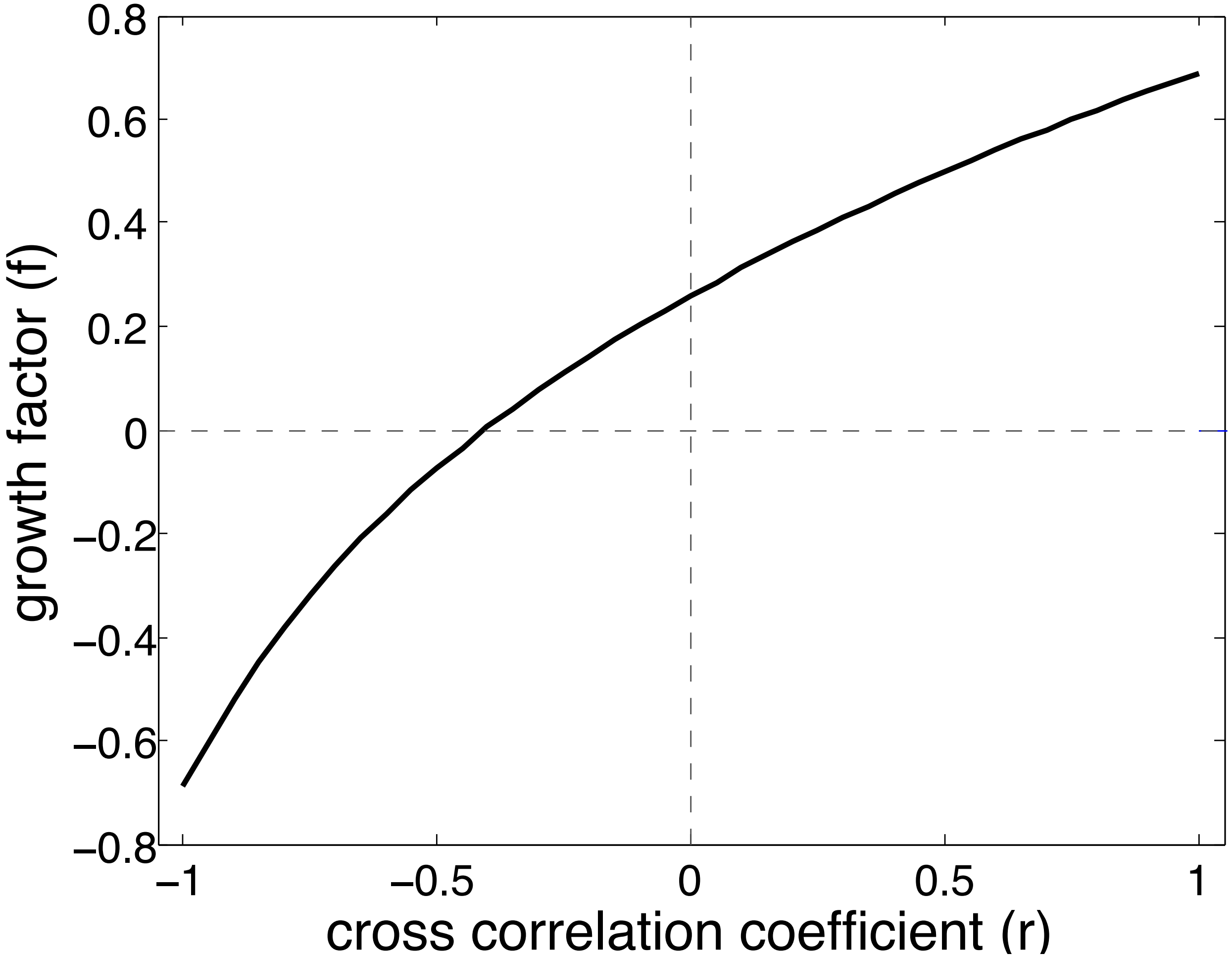
- Schulz & White (2005): $$\Delta_g^2 = b^2 \Delta_{\rm lin}^2(k) + \left(\frac{k}{k_1}\right)^3$$
  - Only two free parameters
  - Automatically includes z-dependence

Schulz White fit to Hoekstra data:





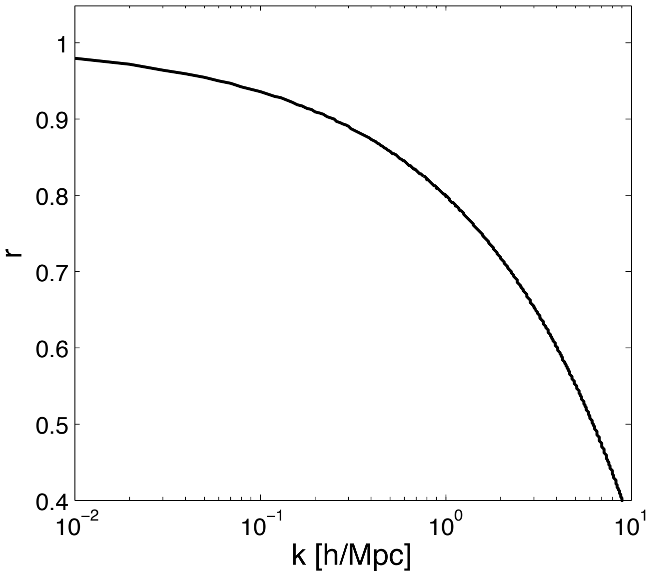
Stochastic bias

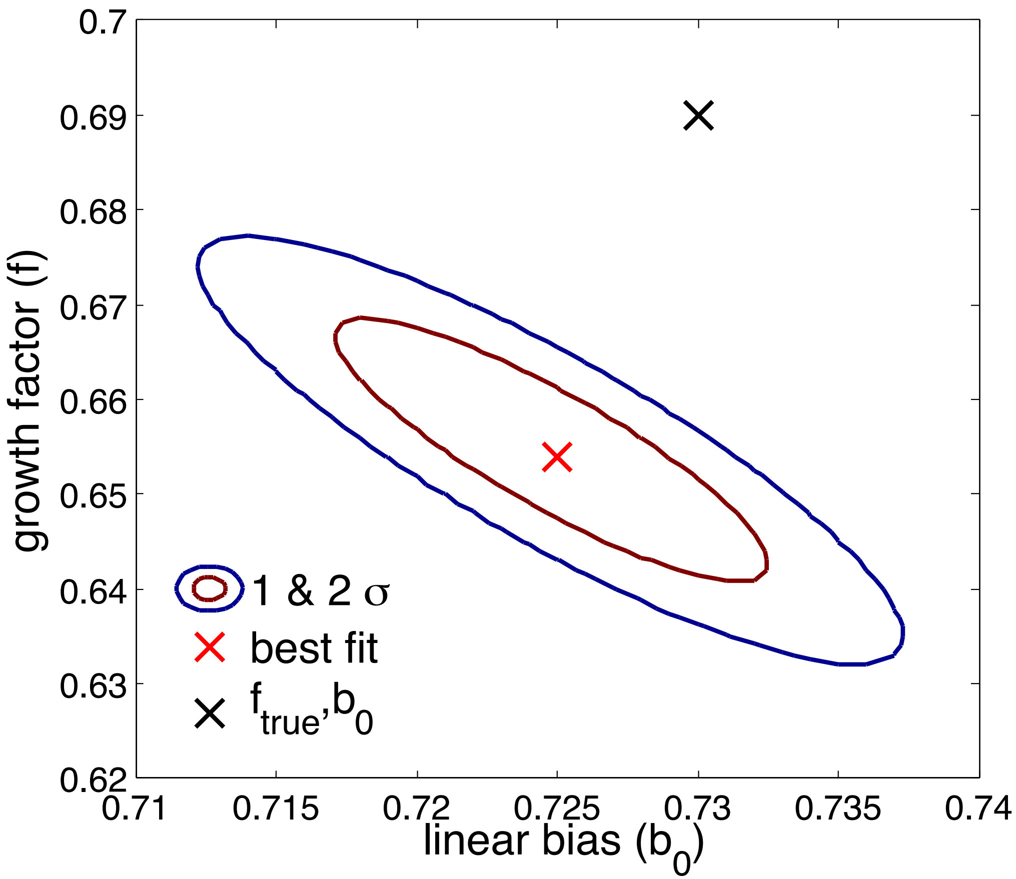


Stochastic bias

- Kaiser Formula (Kaiser 1987) with r not necessarily 1

toy model for r(k):





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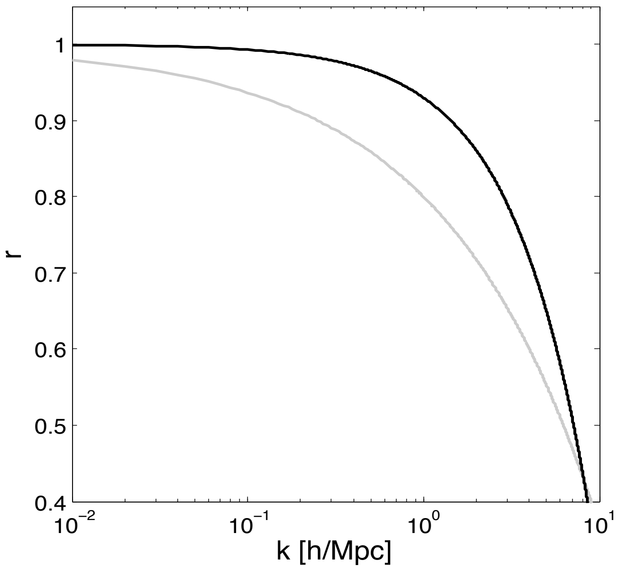

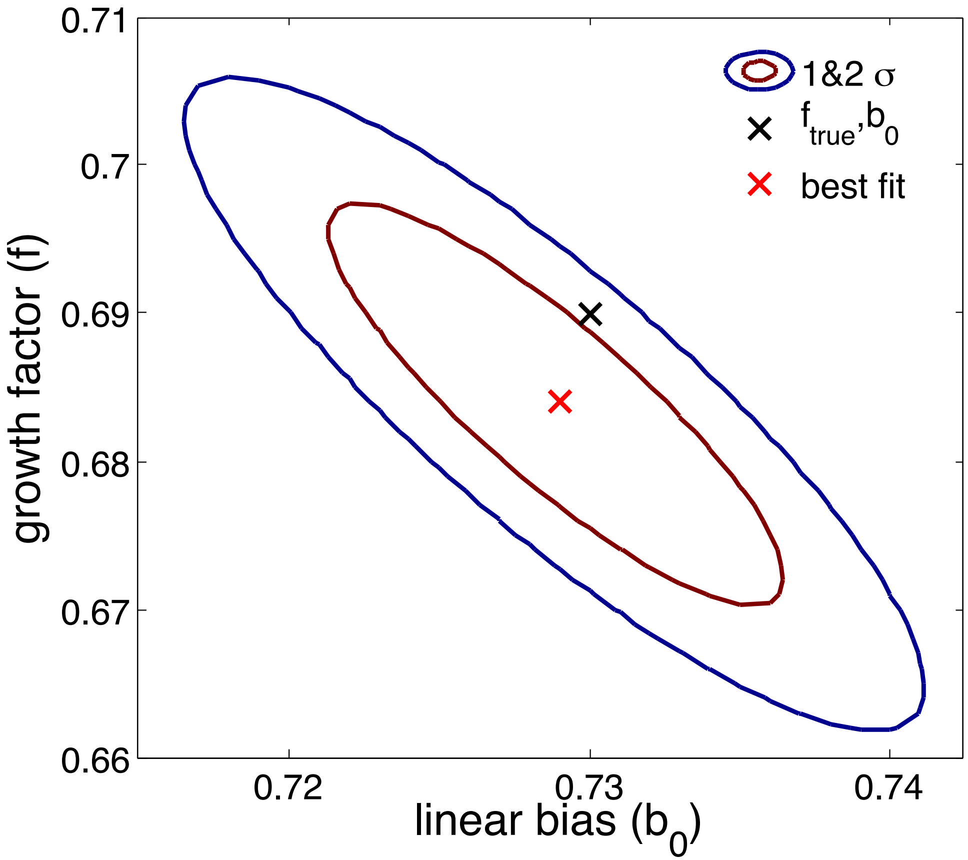

Summary:

- lensing measurements show $b=b(k)$ and $r\neq1$
- b and r model
- Systematic error in RSD when assuming $r=1$ and $b=b_0$

Future:

- Find more accurate b(k) and r(k) model
- Investigate why lensing measurements infer such a low r with simulations.
- Long term goal: use a combination of probes

Lensing measurement of galaxy biasing

Aperture statistics:

$$M_{\mathrm{ap}}(\theta) = \int \mathrm{d}^2\phi U(\phi)\kappa(\phi) \qquad \mathcal{N}(\theta_{\mathrm{ap}}) = \int \mathrm{d}^2\phi U(\phi)\Delta n_g(\phi)$$

angle on the sky | filter function | convergence | galaxy number over density

$$b^2 \equiv \frac{P_{\mathrm{gg}}}{P_{\delta\delta}} \propto \frac{\langle \mathcal{N}^2(\theta_{\mathrm{ap}}) \rangle}{\langle M_{\mathrm{ap}}^2(\theta_{\mathrm{ap}}) \rangle}$$

$$r^2 \equiv \frac{P_{\mathrm{g}\delta}}{P_{\mathrm{gg}}P_{\delta\delta}} \propto \frac{\langle M_{\mathrm{ap}}\mathcal{N}(\theta_{\mathrm{ap}}) \rangle^2}{\langle M_{\mathrm{ap}}^2(\theta_{\mathrm{ap}}) \rangle \langle \mathcal{N}^2(\theta_{\mathrm{ap}} \rangle}$$

Simulations

Shot noise correction || No shot noise correction

Guzik & Seljak 2001

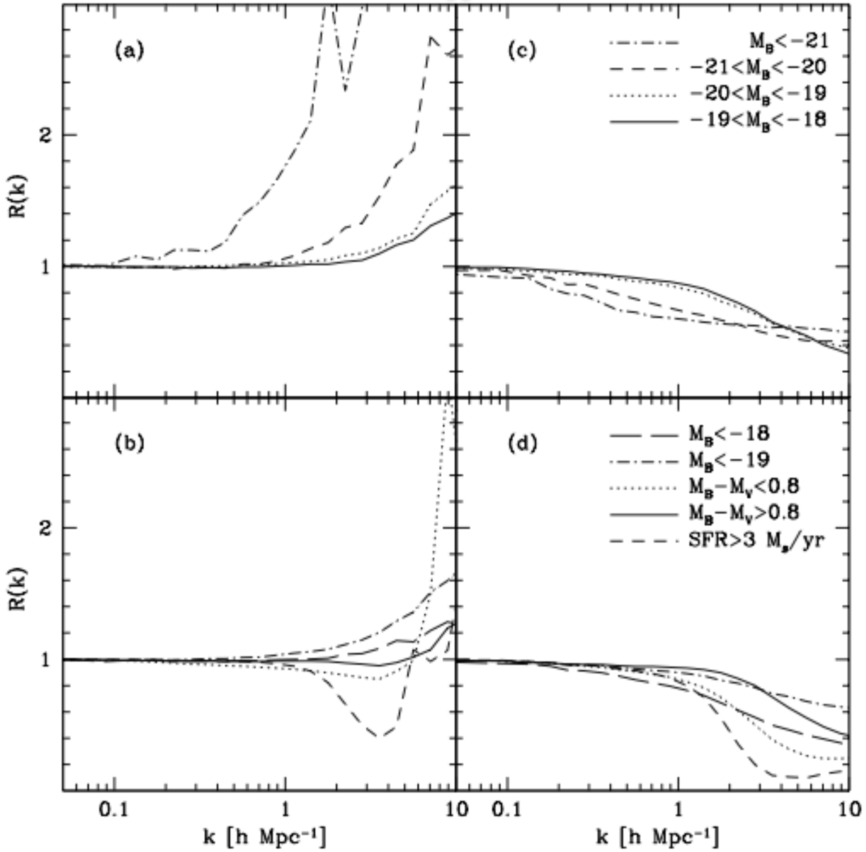

Figure 6. Correlation coefficient $R(k)$ as a function of wavevector k and galaxy sample. In panels (a) and (b) $R(k)$ is derived from the shot noise corrected spectra, while in panels (c) and (d) it is derived without the shot noise correction. Galaxy samples are the same as in Fig. 2.

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In deriving Kaiser formula:

$$
\begin{aligned}
\delta_s^l &= \delta_r^m(1+f\mu^2)+(b-1)\delta_r^m && (62)\\
&= \delta_r^m+\delta_r^m f\mu^2+b\delta_r^m-\delta_r^m && (63)\\
&= \delta_r^m f\mu^2+b\delta_r^m && (64)\\
&= \delta_r^m(b+f\mu^2) && (65)\\
&= \frac{\delta_r^m}{b}(1+f/b\mu^2) && (66)\\
&= \delta_r^l(1+\beta\mu^2) && (67)
\end{aligned}
$$

7 stochasticity

We know from (65) that

$$\delta_s^l = \delta_r^l + \delta_r^m f\mu^2 \tag{97}$$

So we can write

$$
\begin{aligned}
\langle \delta_s^l \delta_s^l \rangle &= \langle (\delta_r^l + \delta_r^m f\mu^2)(\delta_r^l + \delta_r^m f\mu^2) \rangle && (98)\\
&= \langle \delta_r^l \delta_r^l + 2\delta_r^l \delta_r^m f\mu^2 + \delta_r^m \delta_r^m f^2\mu^4 \rangle && (99)\\
&= \langle \delta_r^l \delta_r^l \rangle + 2\langle \delta_r^l \delta_r^m \rangle f\mu^2 + \langle \delta_r^m \delta_r^m \rangle f^2\mu^4. && (100)
\end{aligned}
$$

Using the definition for stochasticity, bias, and the growth parameter β

$$
\begin{aligned}
r &\equiv \frac{\langle \delta^l \delta^m \rangle}{\sqrt{\langle \delta^l \delta^l \rangle \langle \delta^m \delta^m \rangle}} && (101)\\
b &\equiv \sqrt{\frac{\langle \delta^l \delta^l \rangle}{\langle \delta^m \delta^m \rangle}} && (102)\\
\beta &\equiv f/b && (103)
\end{aligned}
$$

we have

$$
\begin{aligned}
\langle \delta_s^l \delta_s^l \rangle &= \langle \delta_r^l \delta_r^l \rangle \left(1 + 2\beta\mu^2 r + \beta^2\mu^4\right) && (104)\\
&= b^2 \langle \delta_r^m \delta_r^m \rangle \left(1 + 2r\beta\mu^2 + \beta^2\mu^4\right) && (105)
\end{aligned}
$$

So we obtain for the Kaiser formula with stochasticity

$$P_{gg}^s(k,\mu) = b^2 P_{\delta\delta}^r(k)\left(1 + 2r\beta\mu^2 + \beta^2\mu^4\right) \tag{106}$$

We know that in case $r = 1$ the above should satisfy the Kaiser formula. This is easily seen when rewriting (106)

$$P_{gg}^s(k,\mu) = b^2 P_{\delta\delta}^r(k)\left(1 + \beta\mu^2\right)^2 + b^2 P_{\delta\delta}^r(k) 2\beta\mu^2 (r-1). \tag{107}$$

Kaiser formula   Extra term due to r