The Extinction Distortion of the Galaxy Correlation Function

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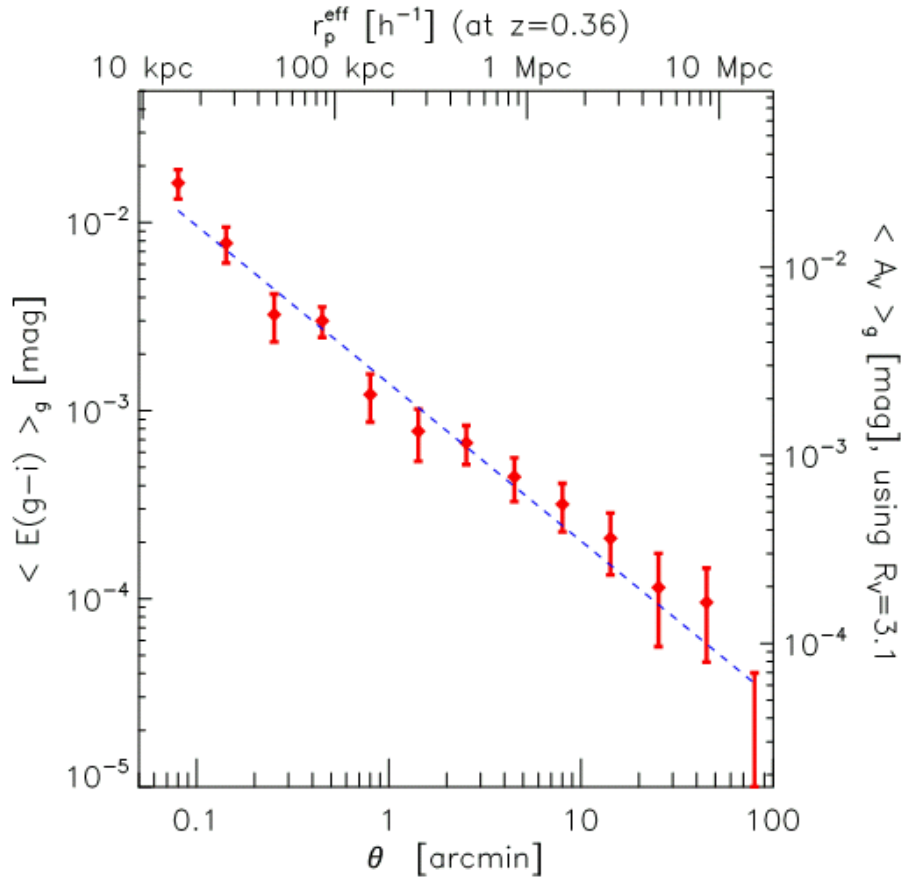
Correlation between Dust Extinction and Galaxy Distribution

- Evidence from SDSS
  - Quasars (1 < z < 2.2) are redder when there are more galaxies ($\bar{z} = 0.36$) in the foreground
  - Detection is made up to a physical transverse separation of ~20 Mpc/h
  - Converted to extinction

$$< A_V(\boldsymbol{\theta_1})\delta_g^{2D}(\boldsymbol{\theta_2}) >$$
$$= 2.4 \times 10^{-3} \left(\frac{|\boldsymbol{\theta_1} - \boldsymbol{\theta_2}|}{1'} \right)^{-0.84}$$



B. Menard et al (2009)

Galaxy Distribution in Redshift Space

- δ_g is subject to modifications by
  - Peculiar velocity: $\delta_v = -\frac{1}{aH}\frac{\partial v_{//}}{\partial \chi}$
  - Gravitational lensing: $\delta_\mu = (5s-2)\kappa$

    s: slope of the cumulative galaxy number counts at the limiting magnitude
  - Dust extinction: $\delta_e = -2.5 s \delta\tau$

    Note the negative sign in front of s, and the wavelength dependence of τ.
- In summary $\delta_{obs} = \delta_g + \delta_v + \delta_\mu + \delta_e$

Galaxy Correlation in Redshift Space

- 15 correction terms in total

$$\xi_{obs} = \sum \begin{pmatrix} \xi_{gg} & \xi_{gv} & \xi_{g\mu} & \xi_{ge} \\ \xi_{vg} & \xi_{vv} & \xi_{v\mu} & \xi_{ve} \\ \xi_{\mu g} & \xi_{\mu v} & \xi_{\mu\mu} & \xi_{\mu e} \\ \xi_{eg} & \xi_{ev} & \xi_{e\mu} & \xi_{ee} \end{pmatrix} \Rightarrow \begin{aligned} \xi_{obs} = \xi_{gg} & \\ & + \xi_{gv} + \xi_{vg} + \xi_{vv} \\ & + \xi_{g\mu} + \xi_{\mu g} + \xi_{\mu\mu} \\ & + \underline{\xi_{ge} + \xi_{eg}} \end{aligned}$$

new

Reduce to 8 with the following approximations

1). Limber → cross terms between v and (e, μ) vanish

2). $\tau << 1$ → $\xi_{e\mu}/(\xi_{g\mu} + \xi_{\mu g}) \sim o(\tau) << 1$

$\xi_{ee}/(\xi_{ge} + \xi_{eg}) \sim o(\tau) << 1$

The Extinction Correction

- Depends only on the separation transverse to LOS

$$\xi_{ge} + \xi_{eg} = -2.5s(1+z)^{-1}\rho_{\mathrm{d}}(z)\, f(z,\lambda_{\mathrm{obs}}) \int \frac{d^2k_\perp}{(2\pi)^2} e^{i\boldsymbol{k}_\perp \cdot \chi(\boldsymbol{\theta}_1 - \boldsymbol{\theta}_2)} P_{\mathrm{gd}}(k_\perp, z)$$

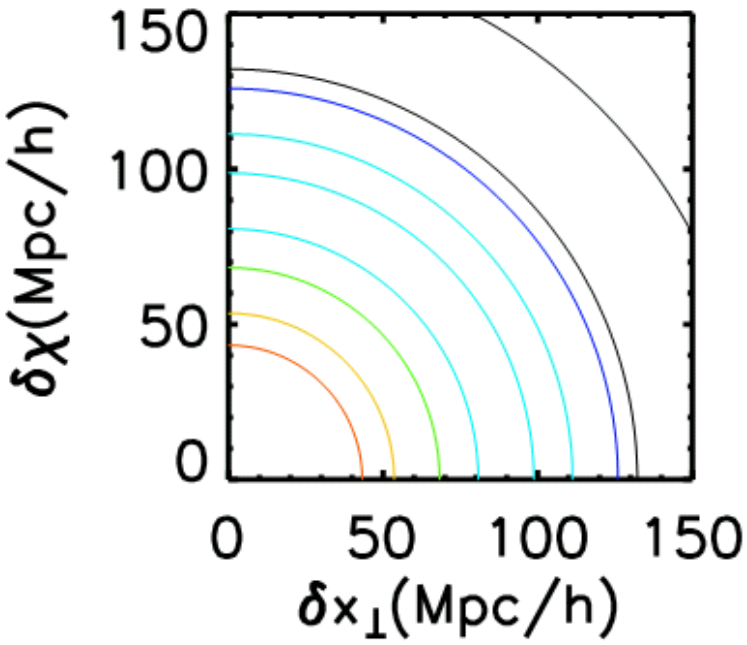
- Use observational results for $\delta x_\perp < \sim 30\ h^{-1}$ Mpc, z=0.36

$$\xi_{ge} + \xi_{eg} = -\ln 10 sb < \mathrm{A_V}(\boldsymbol{\theta}_1)\delta_{\mathrm{g}}^{2\mathrm{D}}(\boldsymbol{\theta}_2) >$$

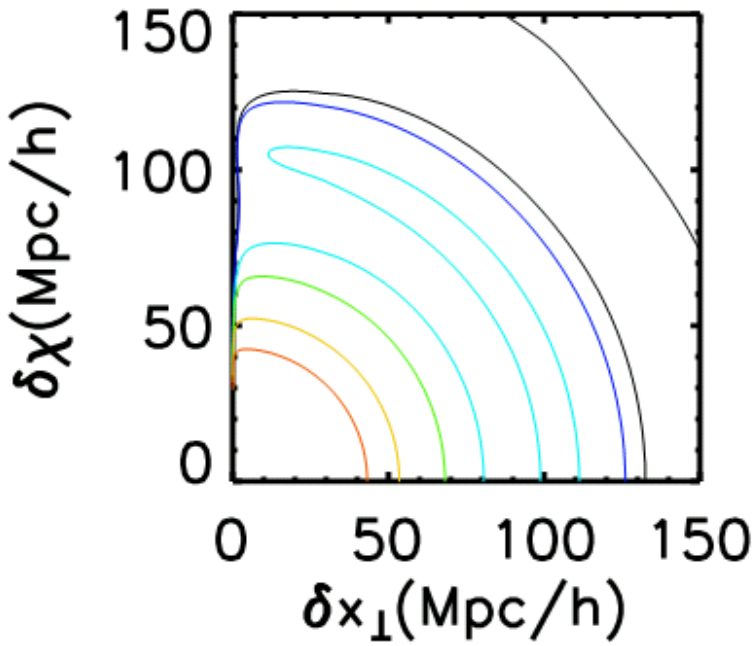
- Extended to larger $\delta x_\perp$ by assuming dust distribution traces that of galaxies.
- Extended to other redshift by assuming dust formation follows the cosmic star formation rate.

Anisotropic Extinction Distortion

- z=0.36, V-band, s=1.5, b=2, similar to LRG.



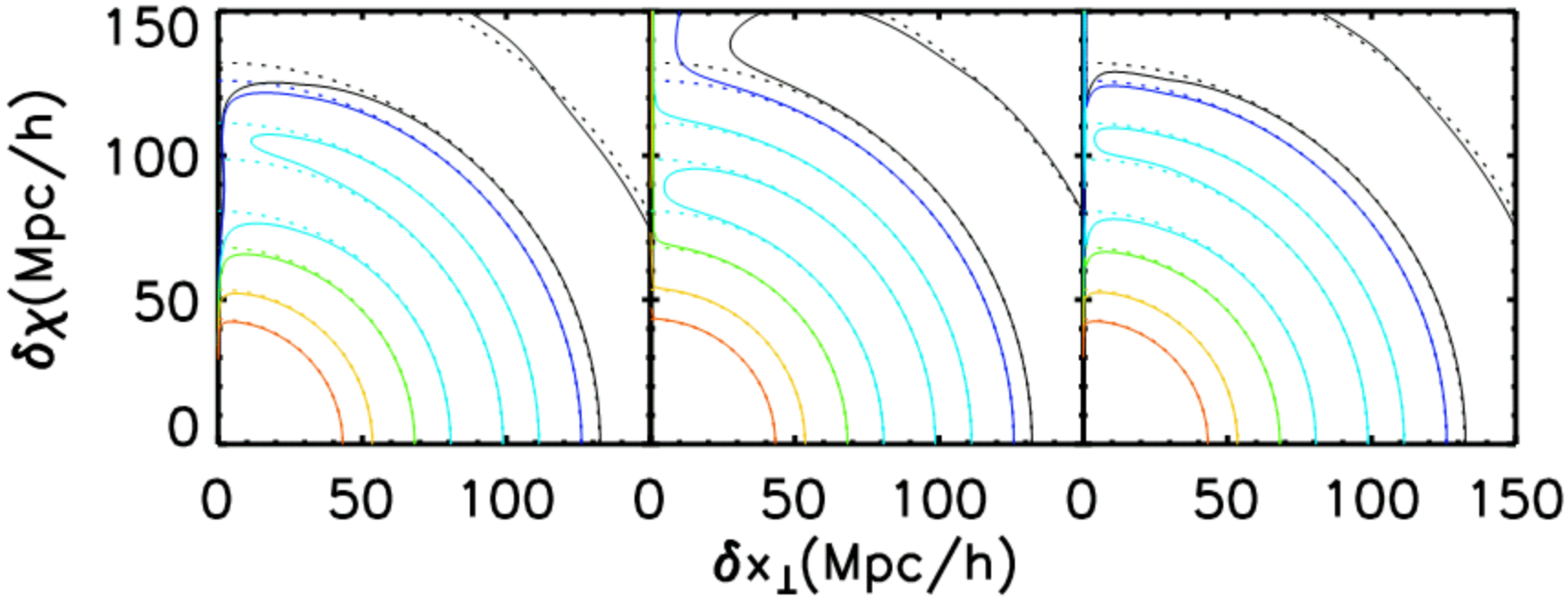
isotropic for the intrinsic



Anisotropic with extinction correction

Comparison with Magnification Bias

- Distortions strongest along the LOS and at large separations
- Opposite anisotropic features

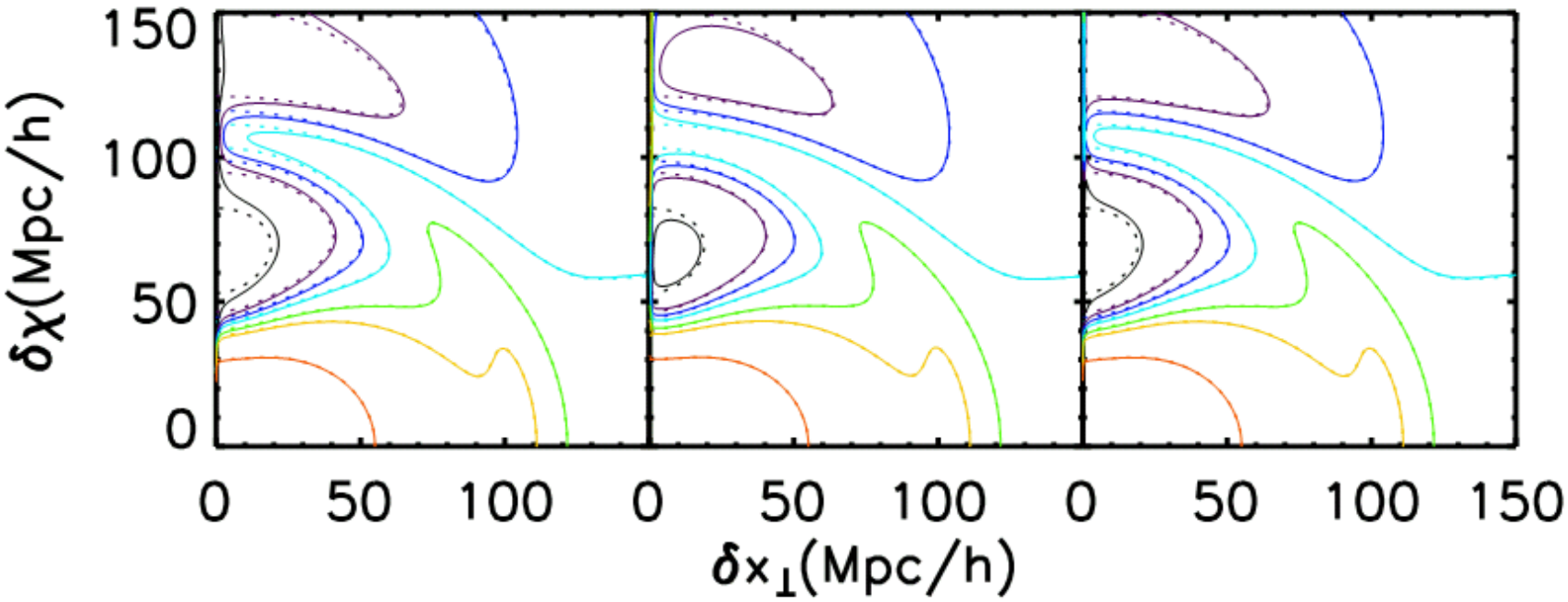


Extinction anisotropy

Magnification anisotropy (5*s*-2)=5.5>0

Combination of the two

Including Redshift Distortion



Extinction anisotropy

Magnification anisotropy

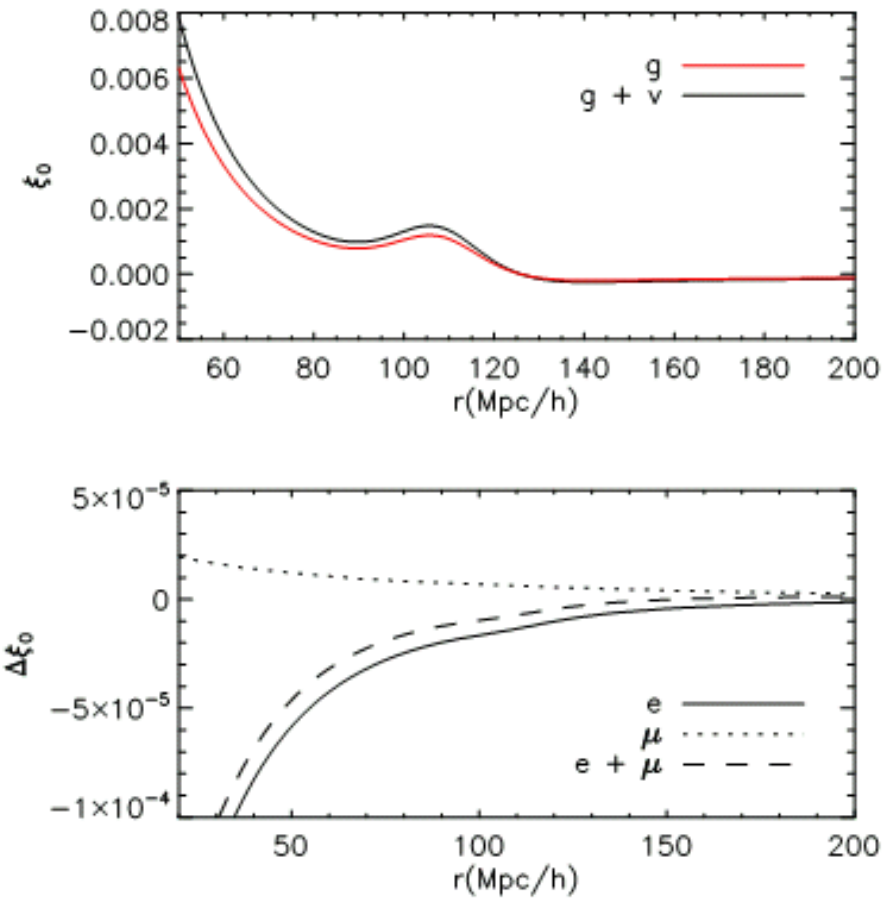
Combination of the two

Changes to the Monopole

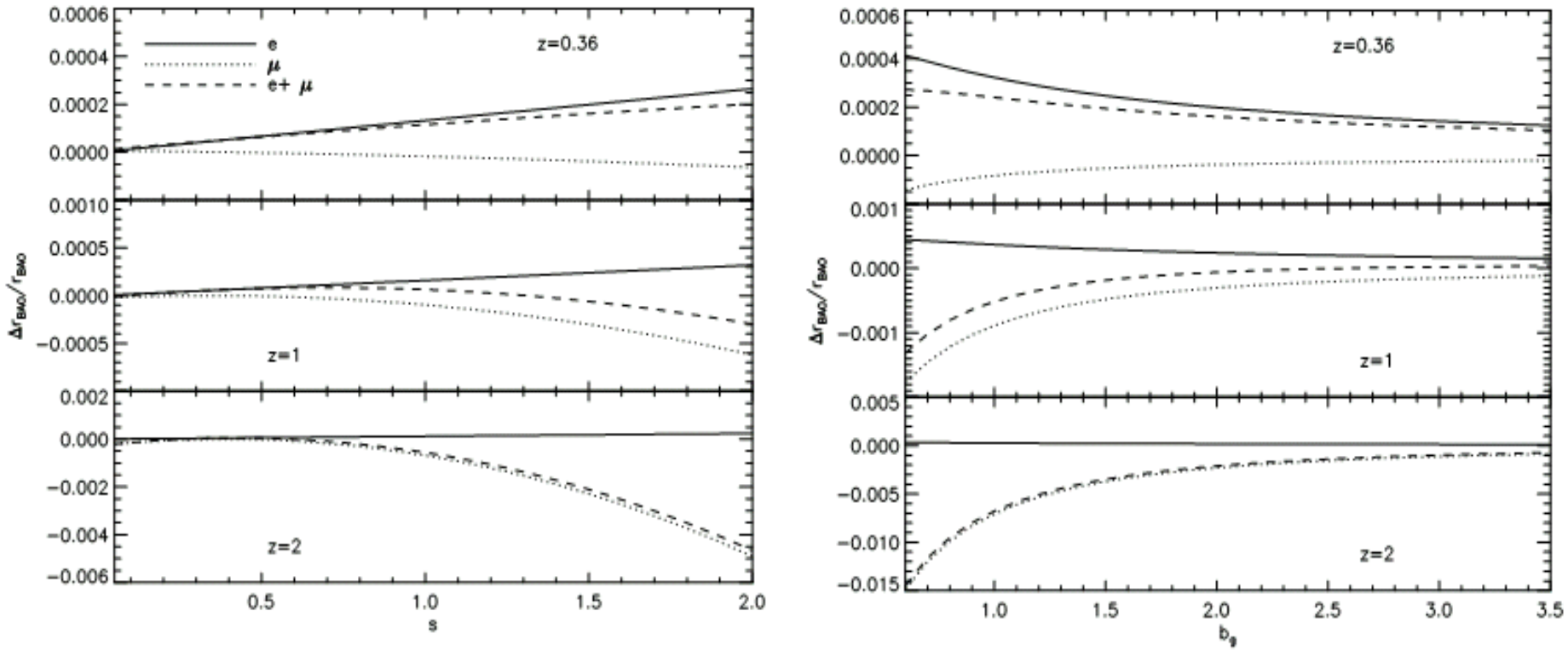
- Redshift distortion increases the monopole by a constant factor of $(1+2\beta/3+\beta^2/5)$, does not shift BAO.

- Dust extinction gives a negative increasing correction, shifts the BAO peak to larger scales.

- Opposite results from magnification bias, for $(5s-2)>0$.



Changes to the BAO from the Monopole

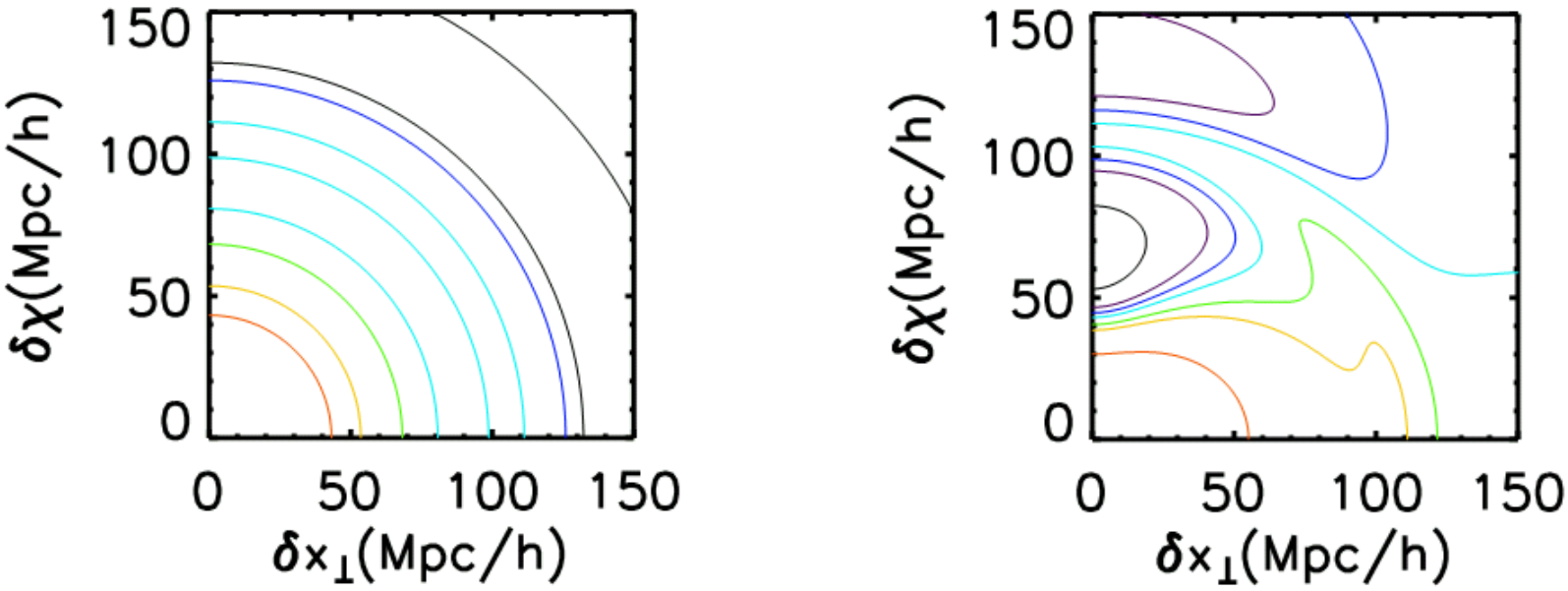


- Dust extinction shifts the location of the monopole BAO peak by order of 0.01%, irrespective of the values of *s*, *b* and *z*, hence negligible.
- Effects on LOS BAO depends on how it is measured.

The Linear Redshift Distortion Parameter

- With linear redshift distortion, $\beta(= f / b)$ can be inferred from the anisotropy of the galaxy correlation function by

$$Q(r) \equiv \frac{\xi_2(r)}{\xi_0(r) - \overline{\xi_0}(r)} = \frac{4\beta/3 + 4\beta^2/7}{1 + 2\beta/3 + \beta^2/5}$$

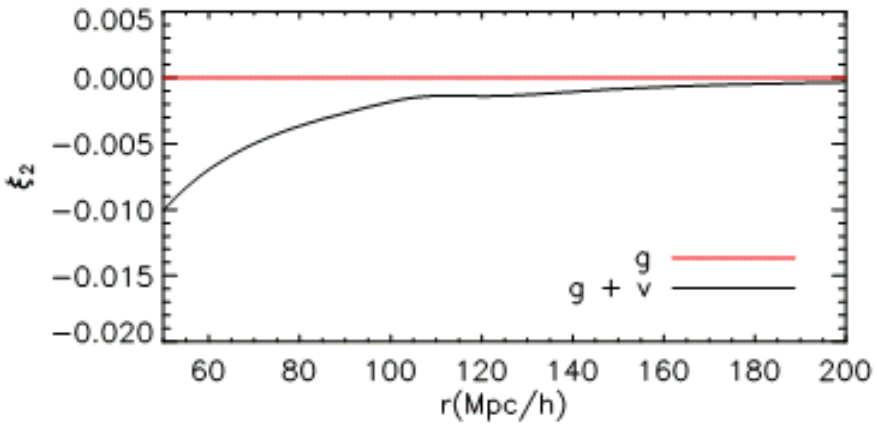


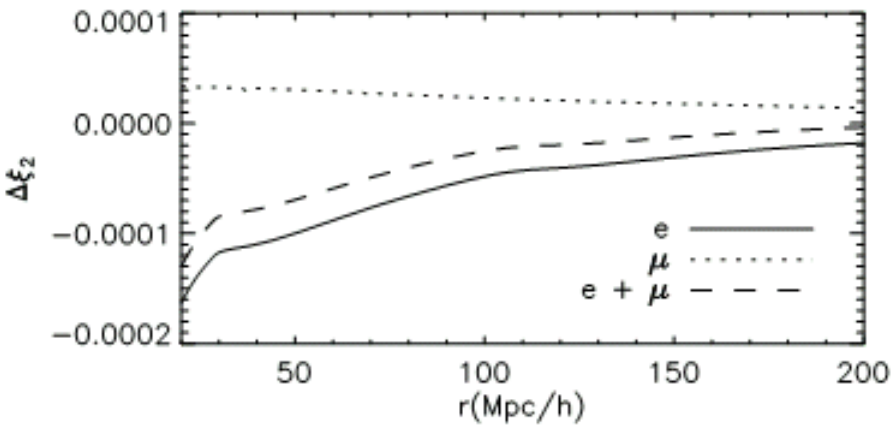
Changes to the Quadrupole

- Redshift distortion gives a negative quadrupole, both Q and β are scale-independent.

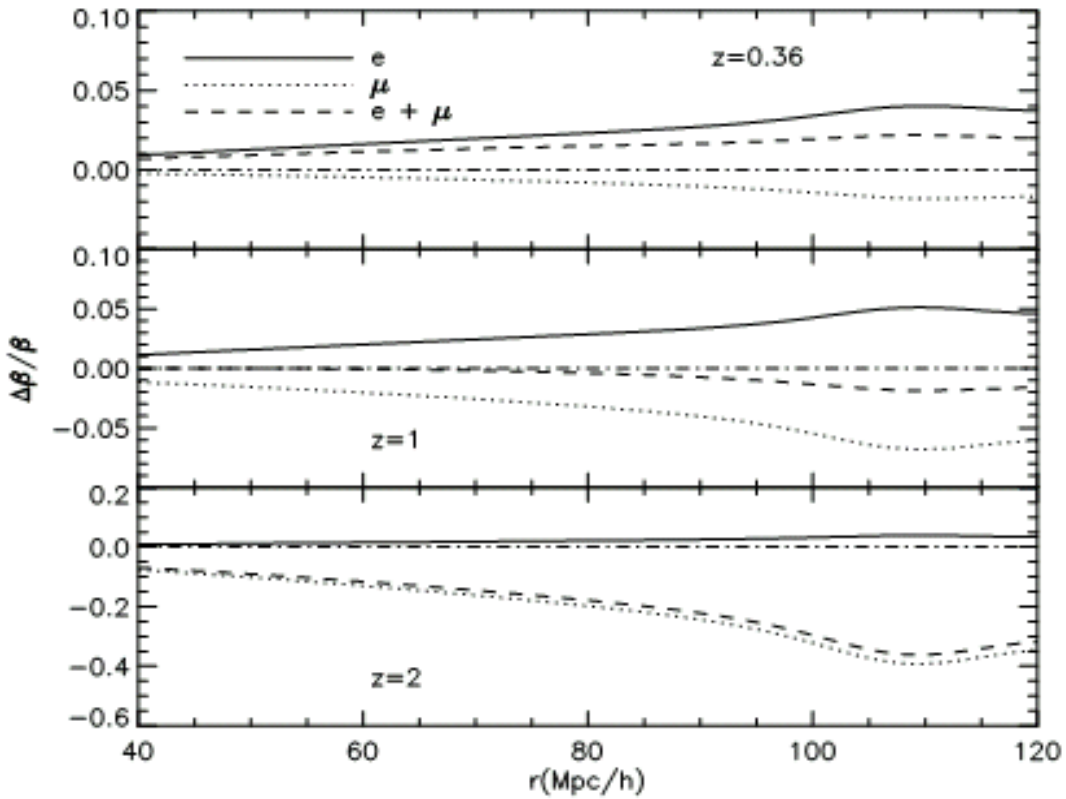
- Dust extinction gives a negative correction to the quadrupole, and causes β to be larger and scale-dependent.

- Opposite results from magnification bias, for (5*s*-2)>0.





Changes to the Inferred β



- Dust extinction causes β to be larger by a few percentage.
- Magnification bias causes β to be smaller by 1% at low z but ~40% at high z.

Non-negligible!

Conclusions

- Dust extinction distorts the galaxy correlation function to be anisotropic in ($\delta\chi$, $\delta x_{\perp}$).
- The distortions are most significant along the LOS and at large separations; with $5s$-2>0, the distortions are in opposite directions to those by magnification bias, hence sum of the two tends to reduce the distortions.
- Effects on measuring the location of the BAO peak from the monopole is $\sim o(10^{-4})$, hence negligible.
- Effects on measuring the linear redshift distortion parameter is a few percentage, with (s, b)=(1.5, 2), hence non-negligible, the effects of magnification bias can be even larger.

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