Systematics: Experience from BOSS

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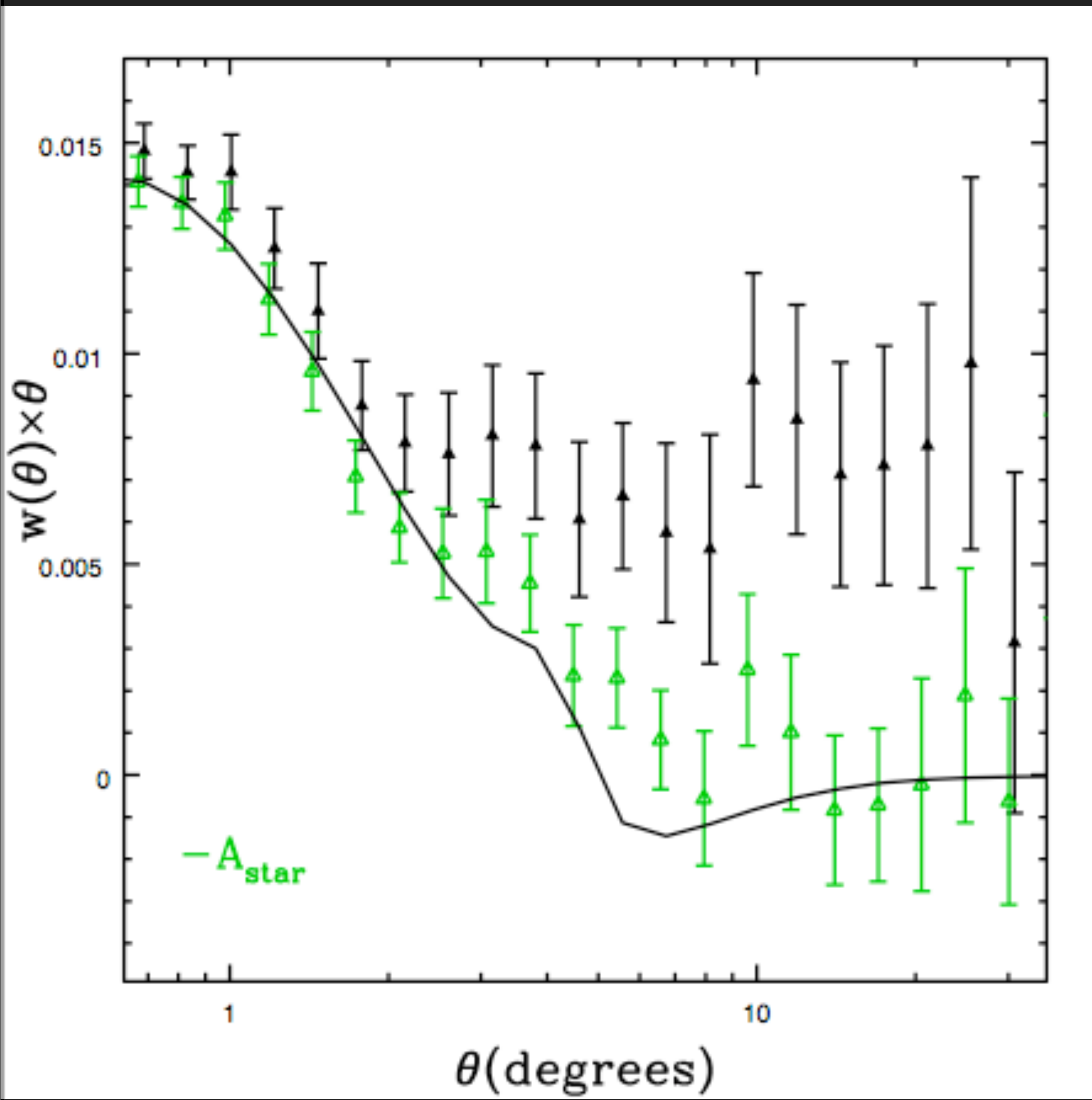
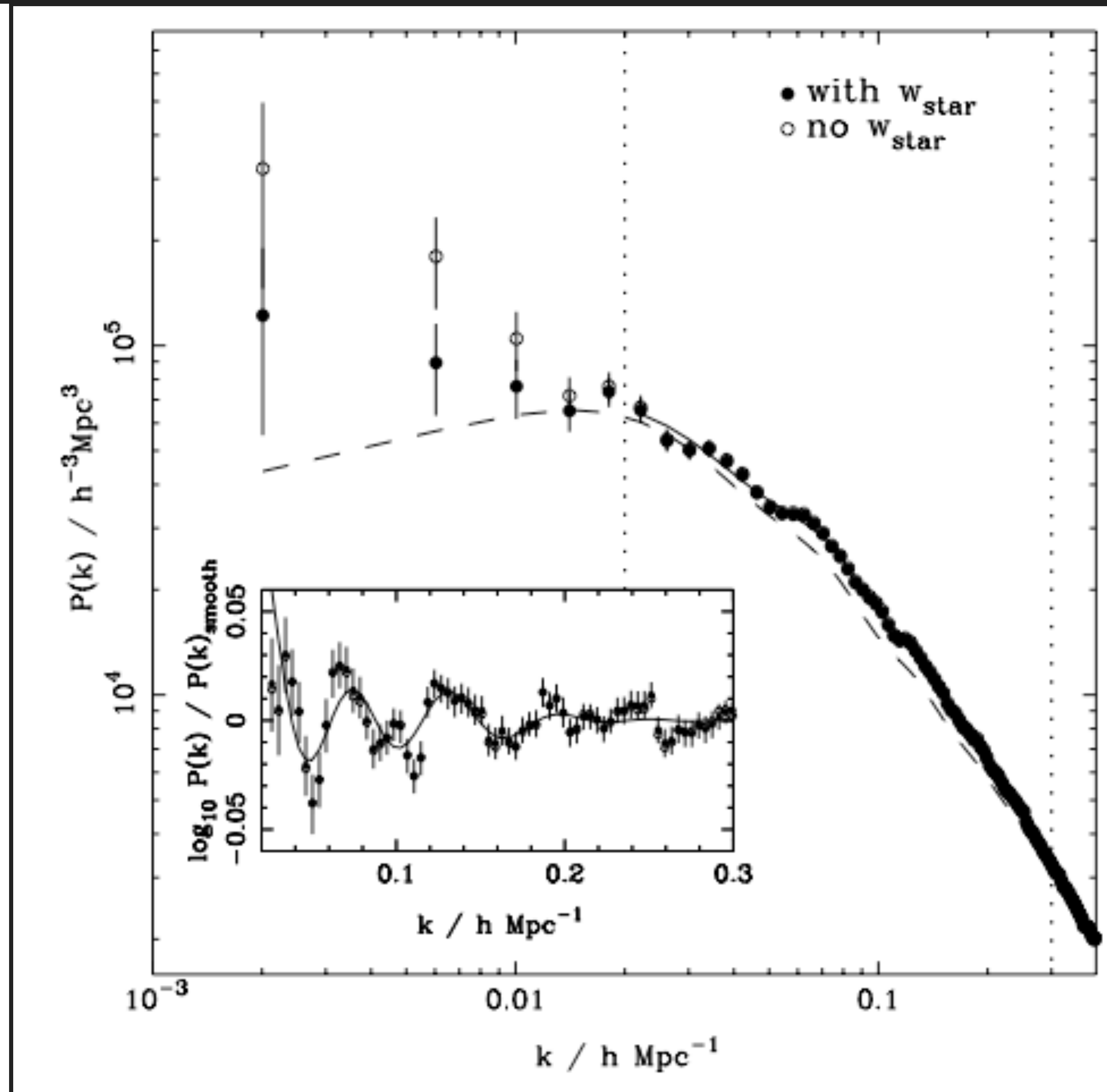
Anderson et al. arXiv:1203.6904

Lauren Anderson[1], Eric Aubourg[2], Stephen Bailey[3], Dmitry Bizyaev[4], Michael Blanton[5], Adam S. Bolton[6], J. Brinkmann[4], Joel R. Brownstein[6], Angela Burden[7], Antonio J. Cuesta[8], Luiz N. A. da Costa[9,10], Kyle S. Dawson[6], Roland de Putter[11,12], Daniel J. Eisenstein[13], James E. Gunn[14], Hong Guo[15], Jean-Christophe Hamilton[2], Paul Harding[15], Shirley Ho[3,14], Klaus Honscheid[16], Eyal Kazin[17], D. Kirkby[18], Jean-Paul Kneib[19], Antione Labatie[20], Craig Loomis[21], Robert H. Lupton[14], Elena Malanushenko[4], Viktor Malanushenko[4], Rachel Mandelbaum[14,21], Marc Manera[7], Claudia Maraston[7], Cameron K. McBride[13], Kushal T. Mehta[22], Olga Mena[11], Francesco Montesano[23], Demetri Muna[5], Robert C. Nichol[7], Sebastián E. Nuza[24], Matthew D. Olmstead[6], Daniel Oravetz[4], Nikhil Padmanabhan[8], Nathalie Palanque-Delabrouille[25], Kaike Pan[4], John Parejko[8], Isabelle Pâris[26], Will J. Percival[7], Patrick Petitjean[26], Francisco Prada[27,28,29], Beth Reid[3,30], Natalie A. Roe[3], Ashley J. Ross[7], Nicholas P. Ross[3], Lado Samushia[7,31], Ariel G. Sánchez[23], David J. Schlegel[*3], Donald P. Schneider[32,33], Claudia G. Scóccola[34,35], Hee-Jong Seo[36], Erin S. Sheldon[37], Audrey Simmons[4], Ramin A. Skibba[22], Michael A. Strauss[21], Molly E. C. Swanson[13], Daniel Thomas[7], Jeremy L. Tinker[5], Rita Tojeiro[7], Mariana Vargas Magaña[2], Licia Verde[38], Christian Wagner[12], David A. Wake[39], Benjamin A. Weaver[5], David H. Weinberg[40], Martin White[3,41,42], Xiaoying Xu[22], Christopher Yeche[25], Idit Zehavi[15], Gong-Bo Zhao[7,43]

Manera et al. arXiv:1203.6609
Reid et al. arXiv:1203:6641
Ross et al. arXiv:1203.6499
Sanchez et al. arXiv:1203.6616
Tojeiro et al. arXiv:1203.6565

The Matter at Hand



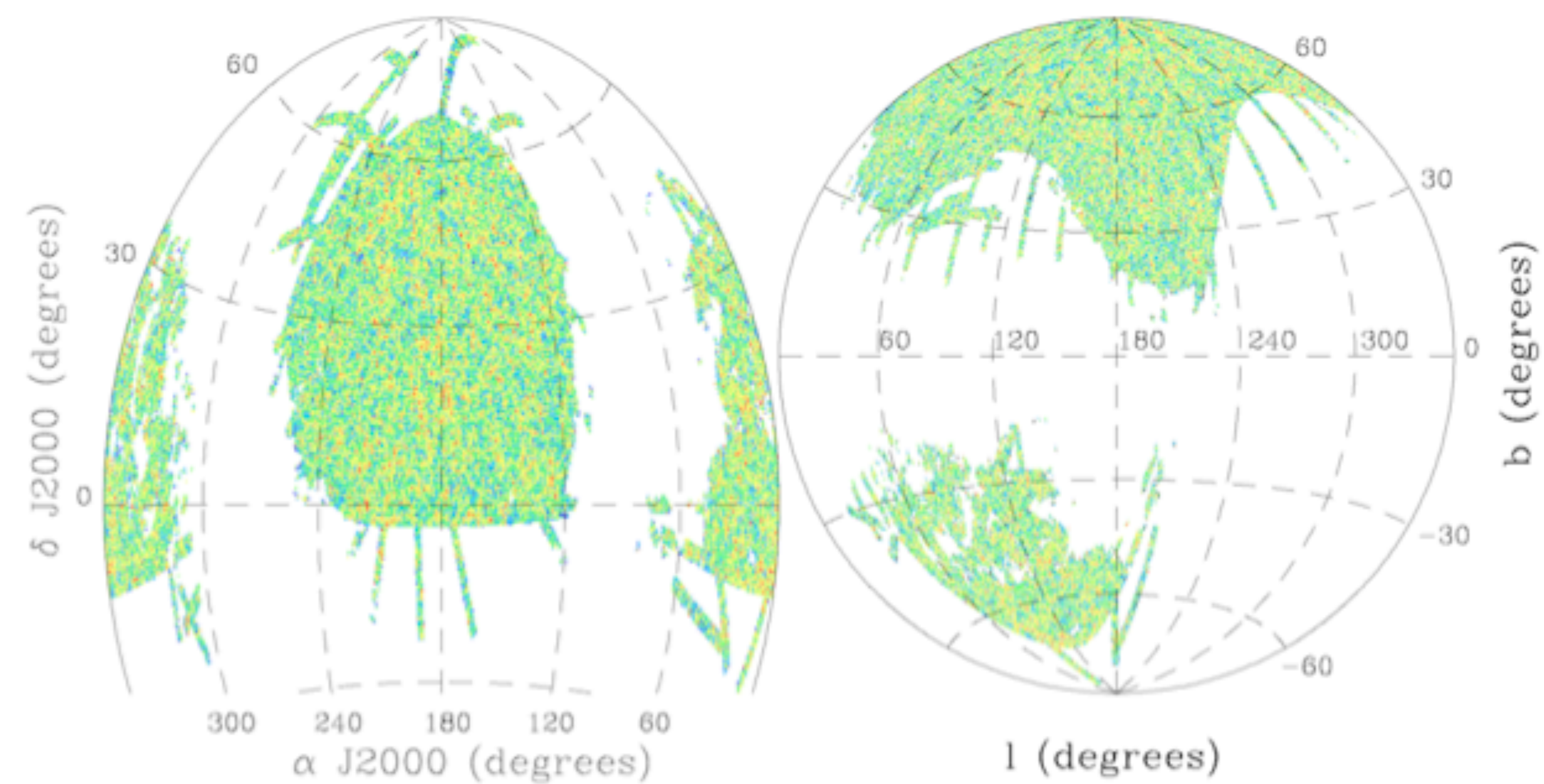


Outline

- BOSS data samples
  - photoz and specz
- Observational systematics
  - Corrections
- f_{NL} measurements

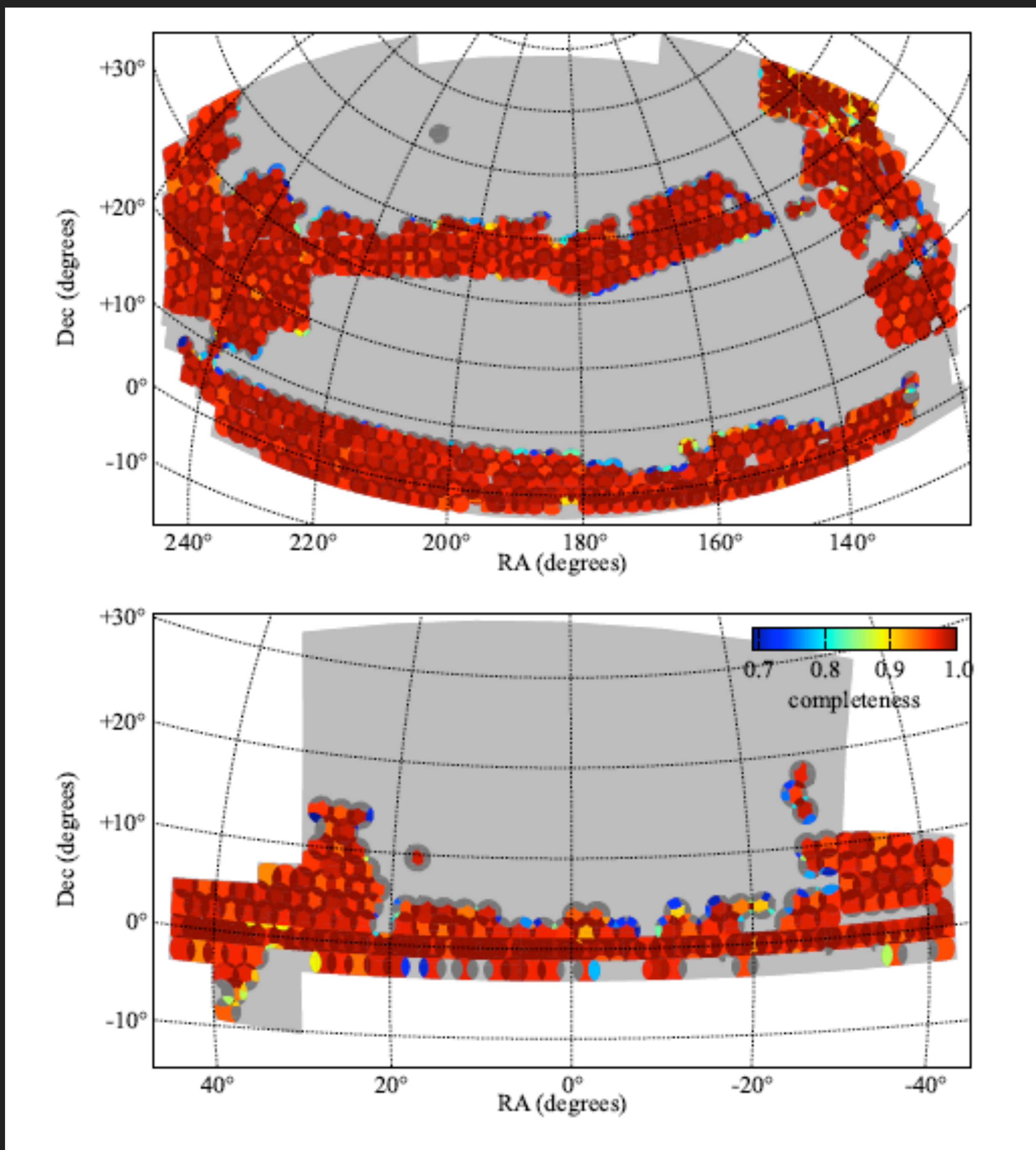
BOSS-trained SDSS DR8 Photozs

- Used over 100,000 BOSS spectra
- Over 1,000,000 photozs over 10,000 sq degrees



Ross, A. J. et al. 2011 (ArXiv:1105:2320)
Ho, S. et al. 2012 (ArXiv:1201:2137)
Seo, H. et al. 2012 (ArXiv: 1201:2172)
de Putter, R. et al. 2012 (ArXiv: 1201:1909)

SDSS DR9 BOSS Specz 'CMASS' Sample



- Targeted 1 million galaxies
  8600 sq degrees of NGC
  3100 sq degrees of SGC
- DR9 footprint 3345 sq. deg
  21% in Southern galactic cap
- 270,000+ redshifts 0.43<z< 0.7
- Redshift completeness >98%
- Public July 2012

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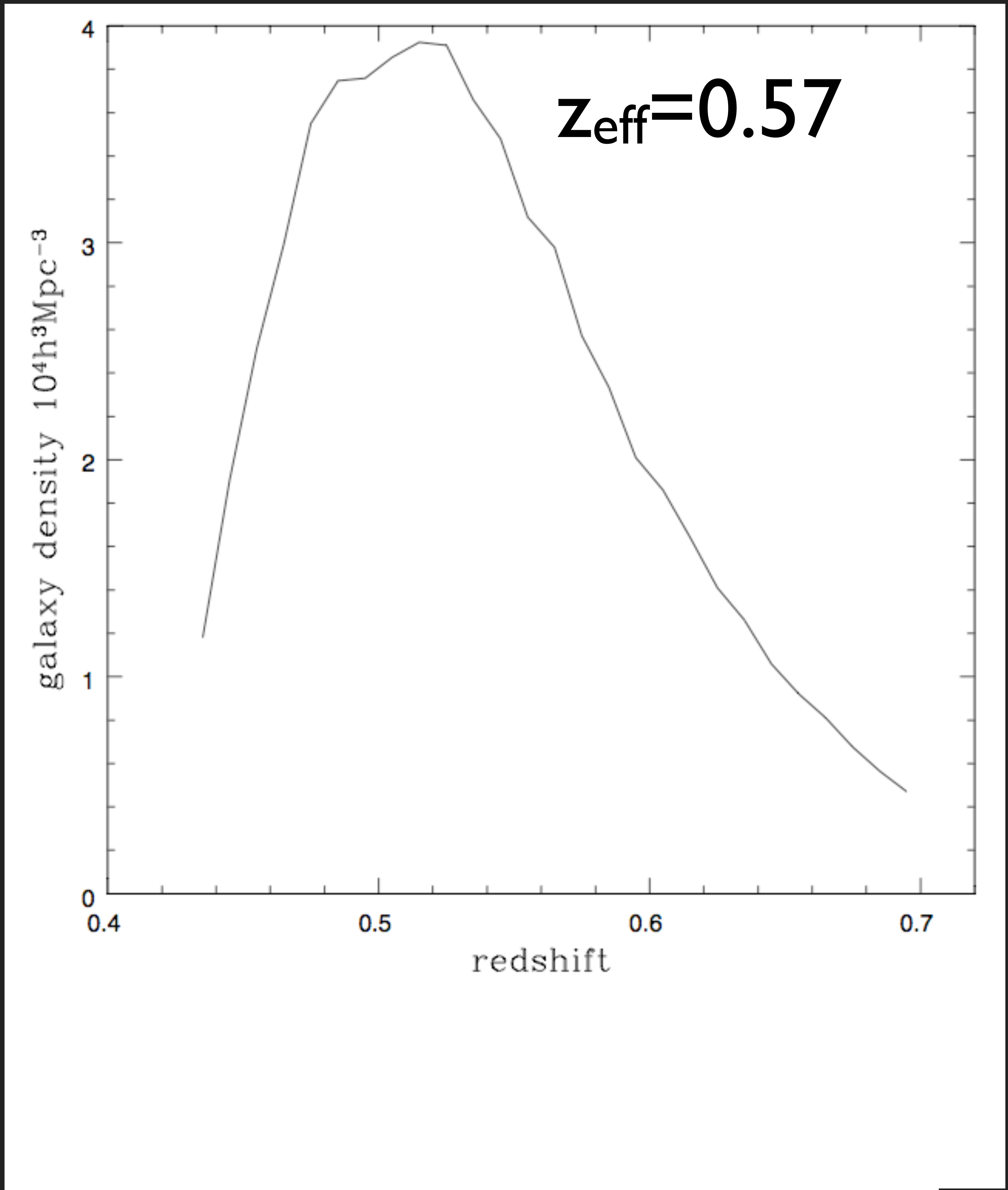

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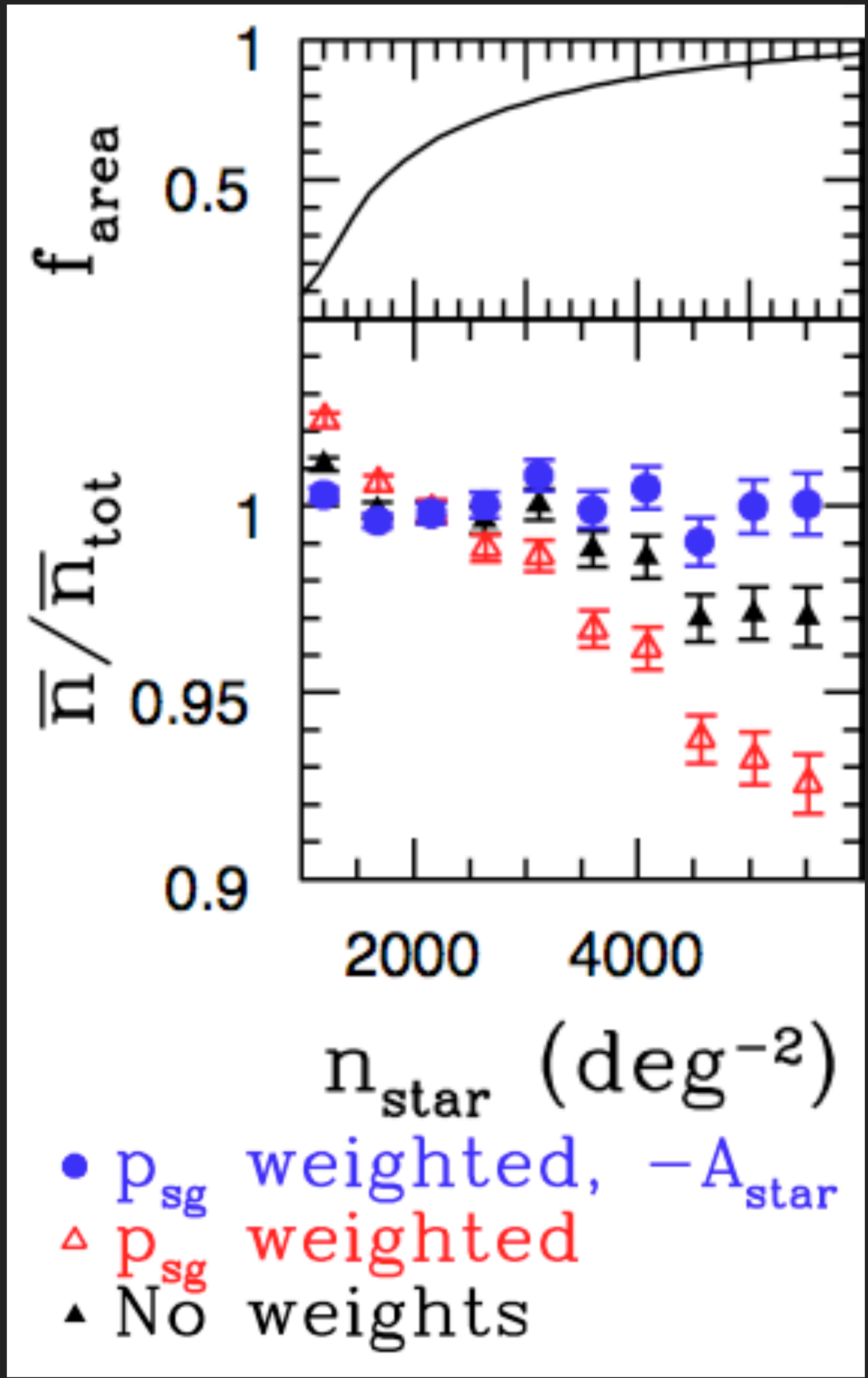
SDSS III SLOAN DIGITAL SKY SURVEY III

Observational Systematics

- Object classification
  - Star/galaxy/quasar
  - Use probabilities
- Galactic foregrounds
  - Stars, Galactic Extinction
- Observing conditions
  - Seeing, Sky Background, Airmass
- Photometric offsets, varying dust law?
  - See Schlafly et al. (2011a,b)
- Obtaining redshifts

Stars

- ~3% stellar contamination → n_{CMG} should increase with n_{star}
- Opposite is observed
- "removing" stellar contamination → huge anti-correlation
- NOT observed in previous SDSS data releases



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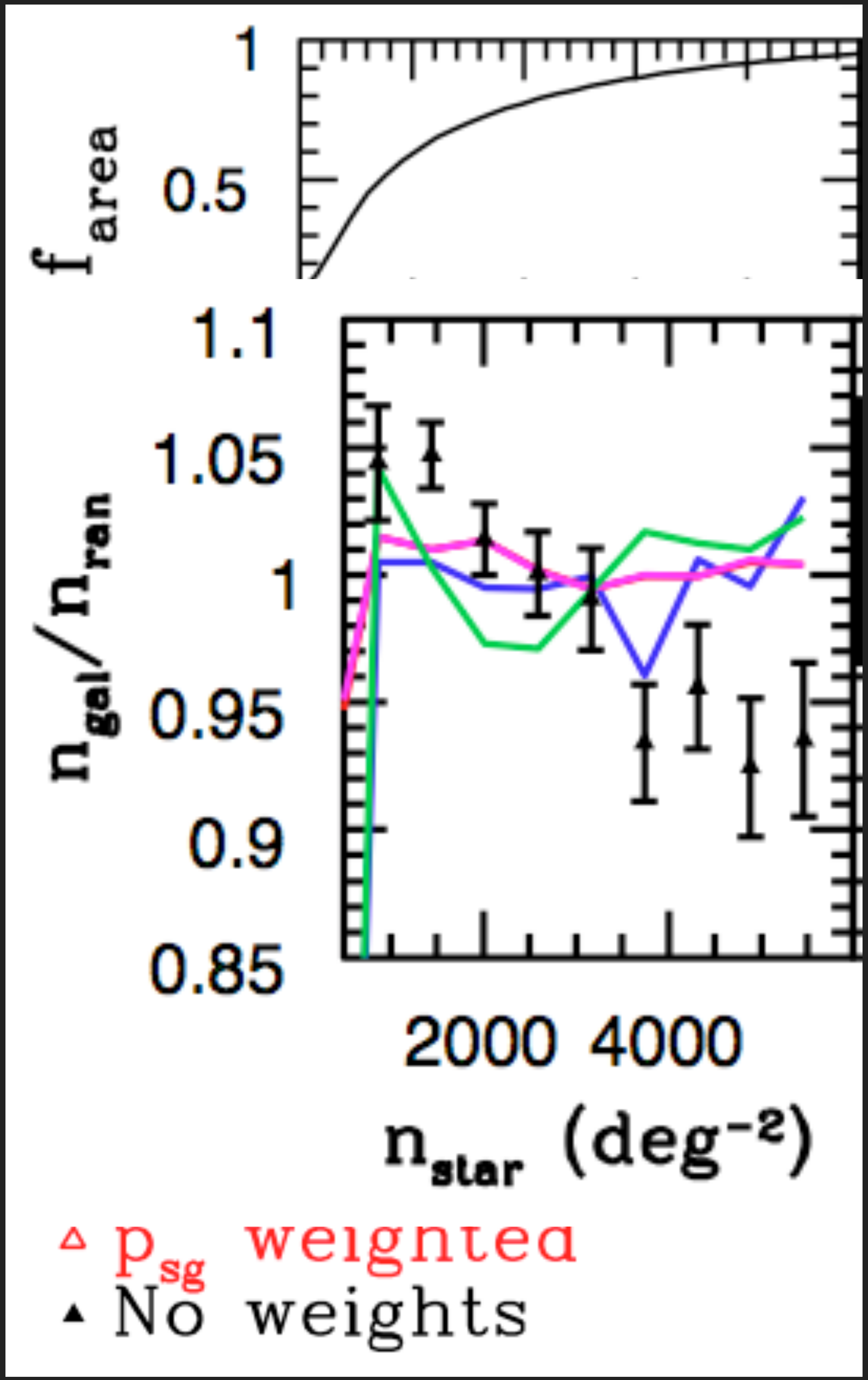
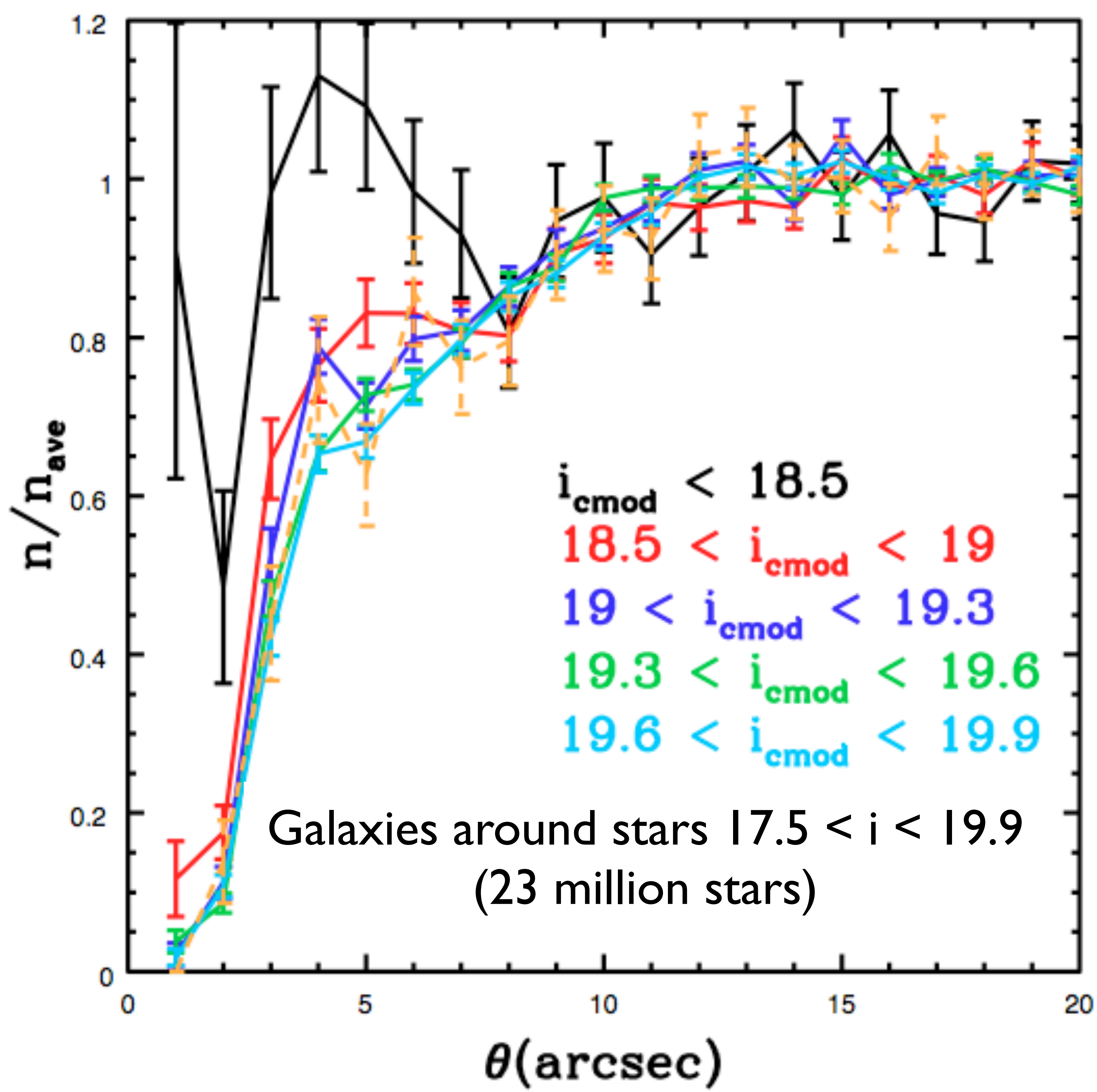
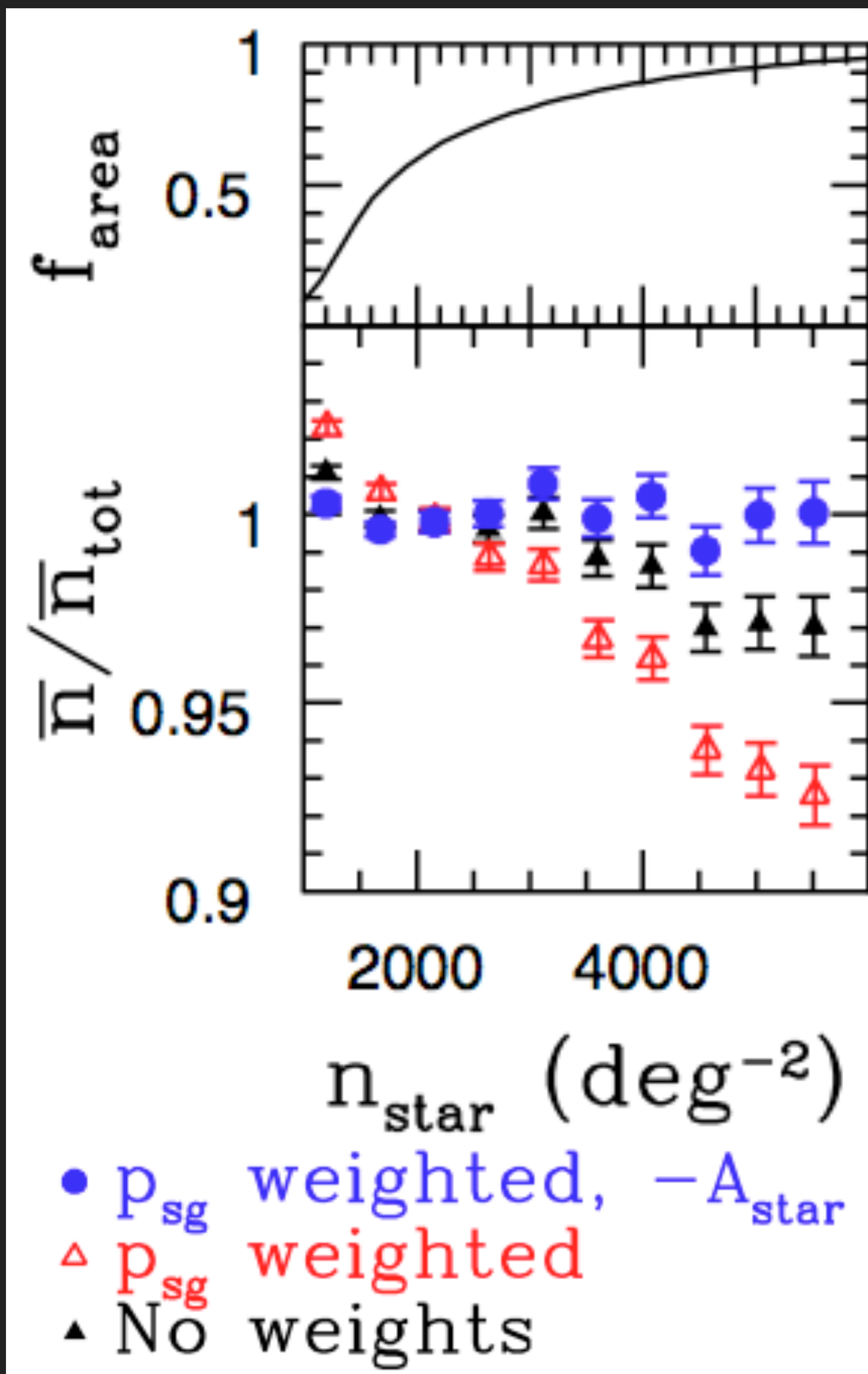
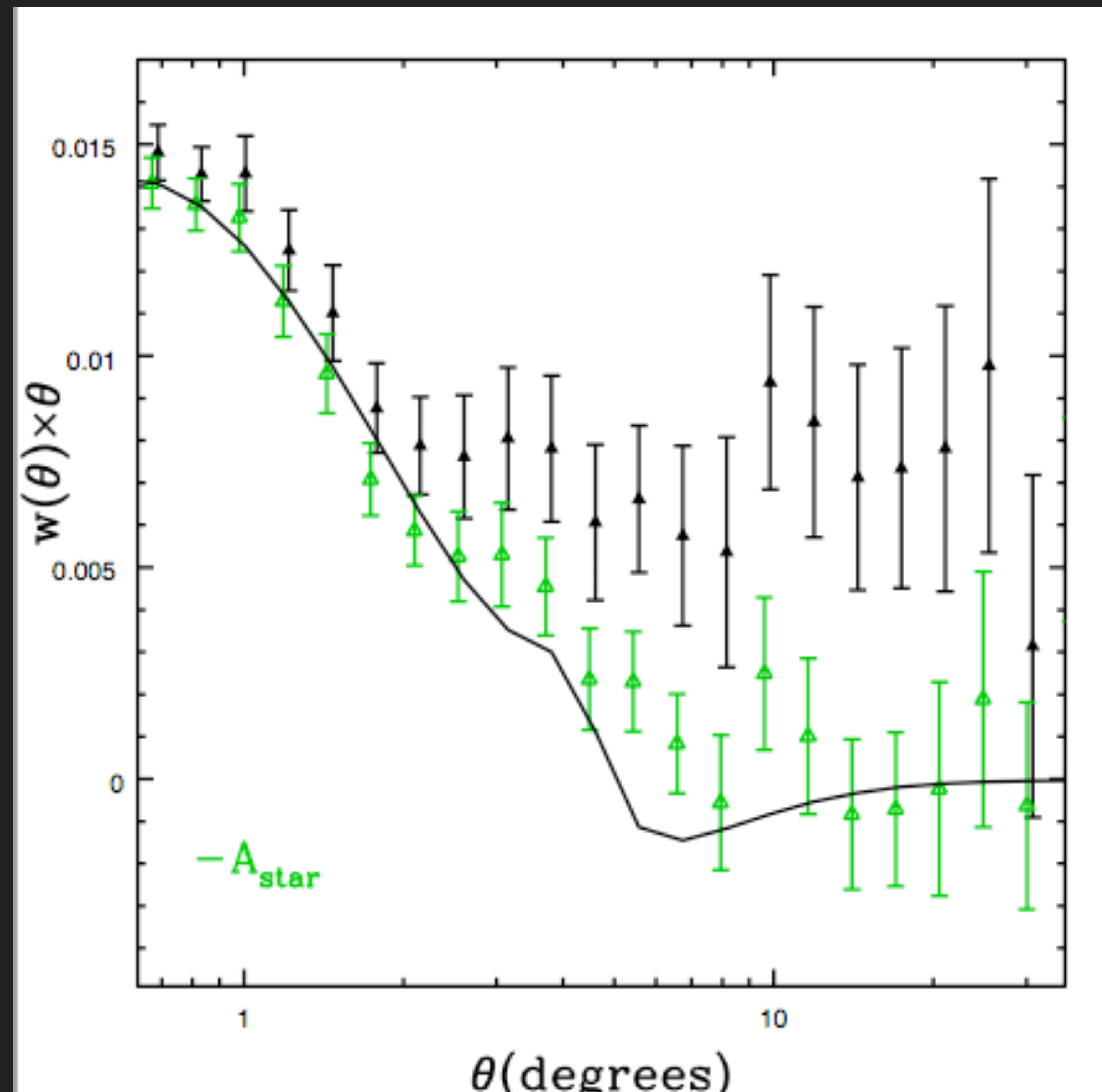


Stars Occult Area



Correcting for Stars





General Solution

- If you can make a map
- 1) Assume intrinsic cross-correlations are 0, subtract measured contribution
- 2) Assume intrinsic no local relationship, weight appropriately

Corrections with Cross-correlations

$$\delta_g^o = \delta_g^t + \sum_i \epsilon_i \delta_i .$$

$$w(\theta) = \langle \delta_i \delta_j \Theta_{i,j}(\theta) \rangle$$

Assume true cross-correlation = 0

$$w_g^t(\theta) = w_g^o(\theta) - \sum_i \epsilon_i^2 w_i(\theta) - \sum_{i,j>i} 2\epsilon_i \epsilon_j w_{i,j}(\theta)$$

$$w_{g,i}^o = \sum_j \epsilon_j w_{i,j}(\theta)$$

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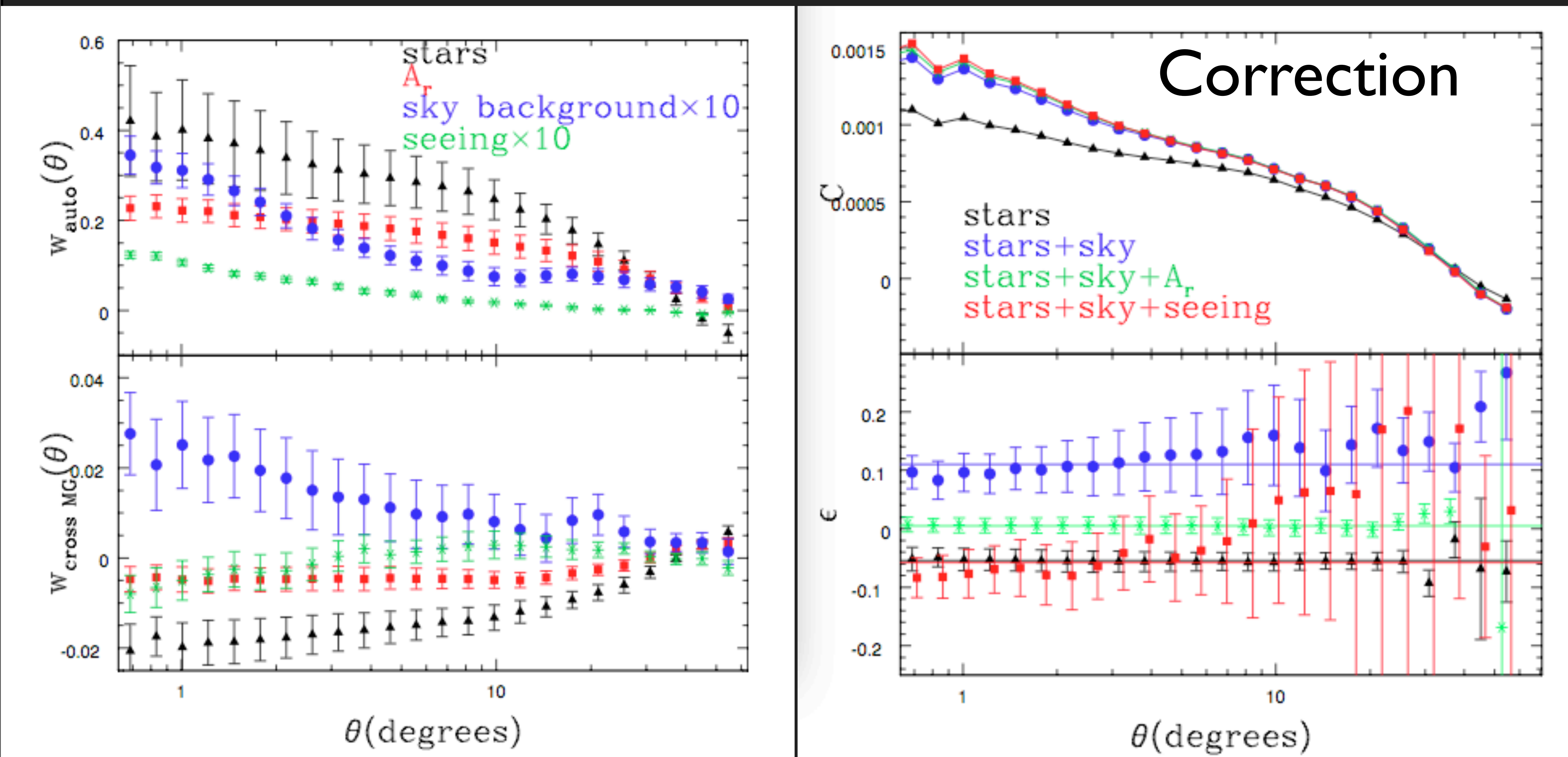
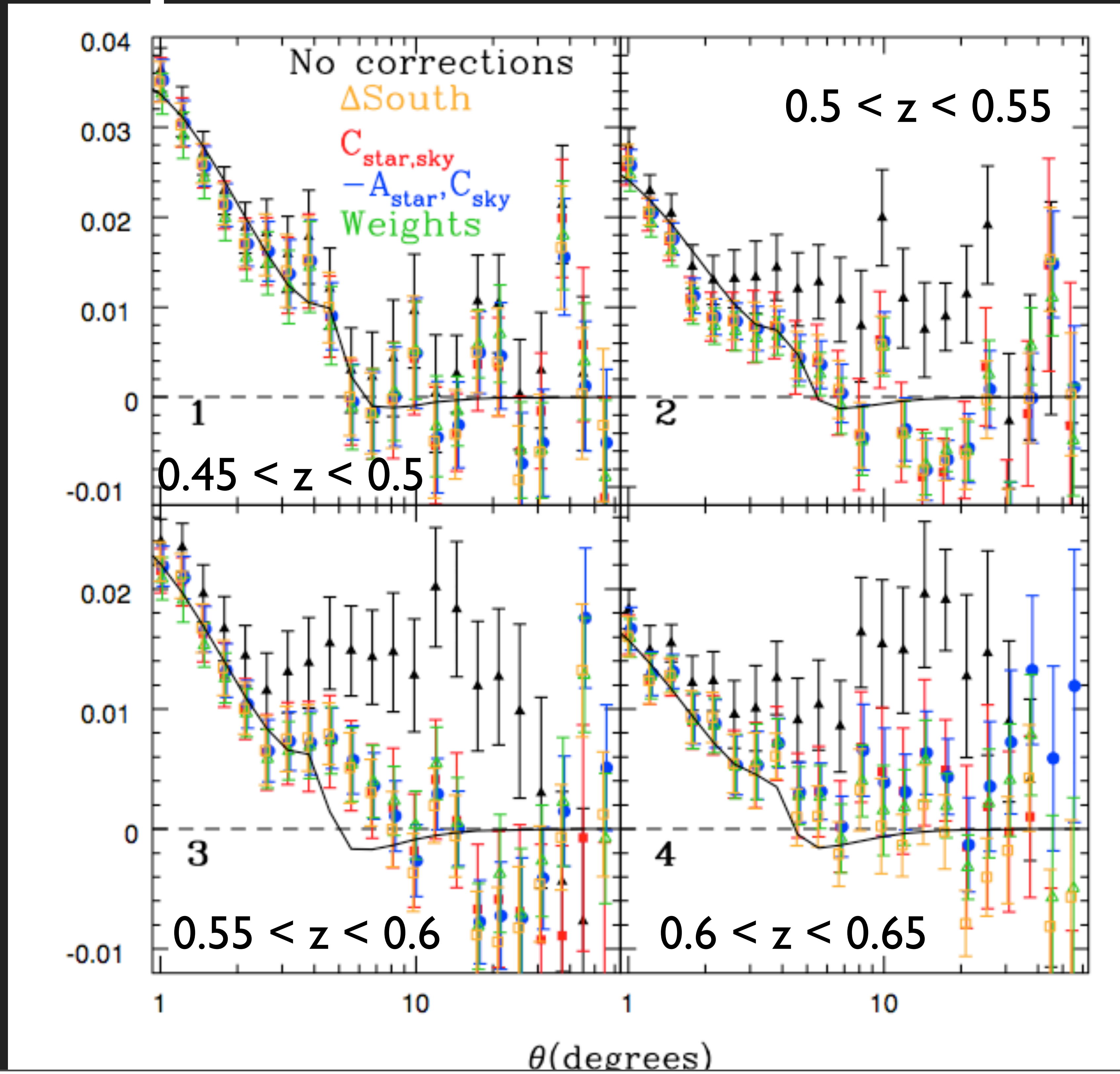
$$A = w_{g,sys}/w_{sys}$$
$$C = A^2 w_{sys} \sim (w_{g,sys}^2/w_{sys})$$

Auto-/cross-correlations

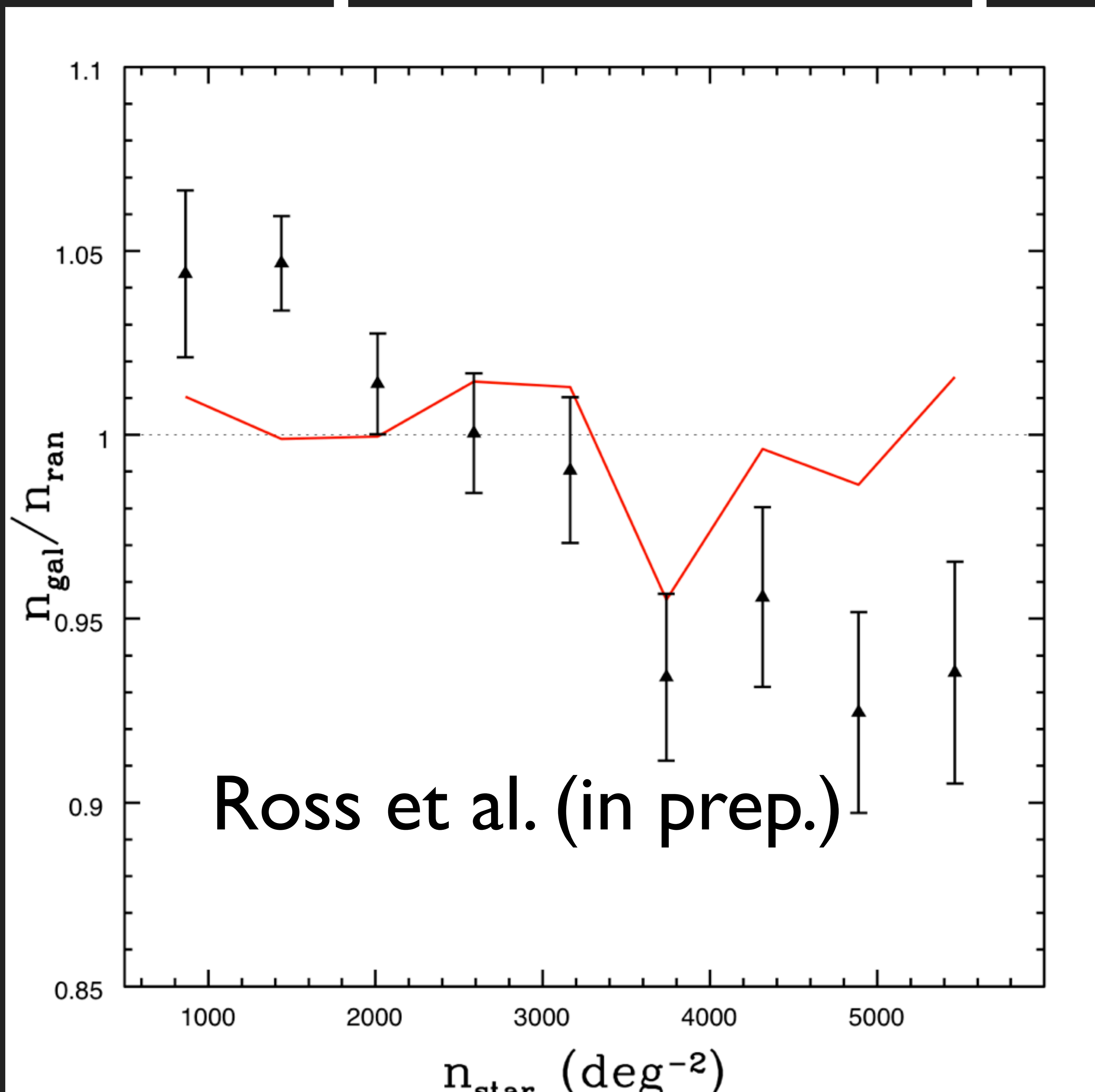


w(θ) for photoz shells

- fit for bias with basic ΛCDM model
- with corrections: χ^2/d.o.f = 0.79, 1.8, 0.99, 1.0
- without corrections: χ^2/d.o.f = 0.99, 3.9, 7.0, 6.4

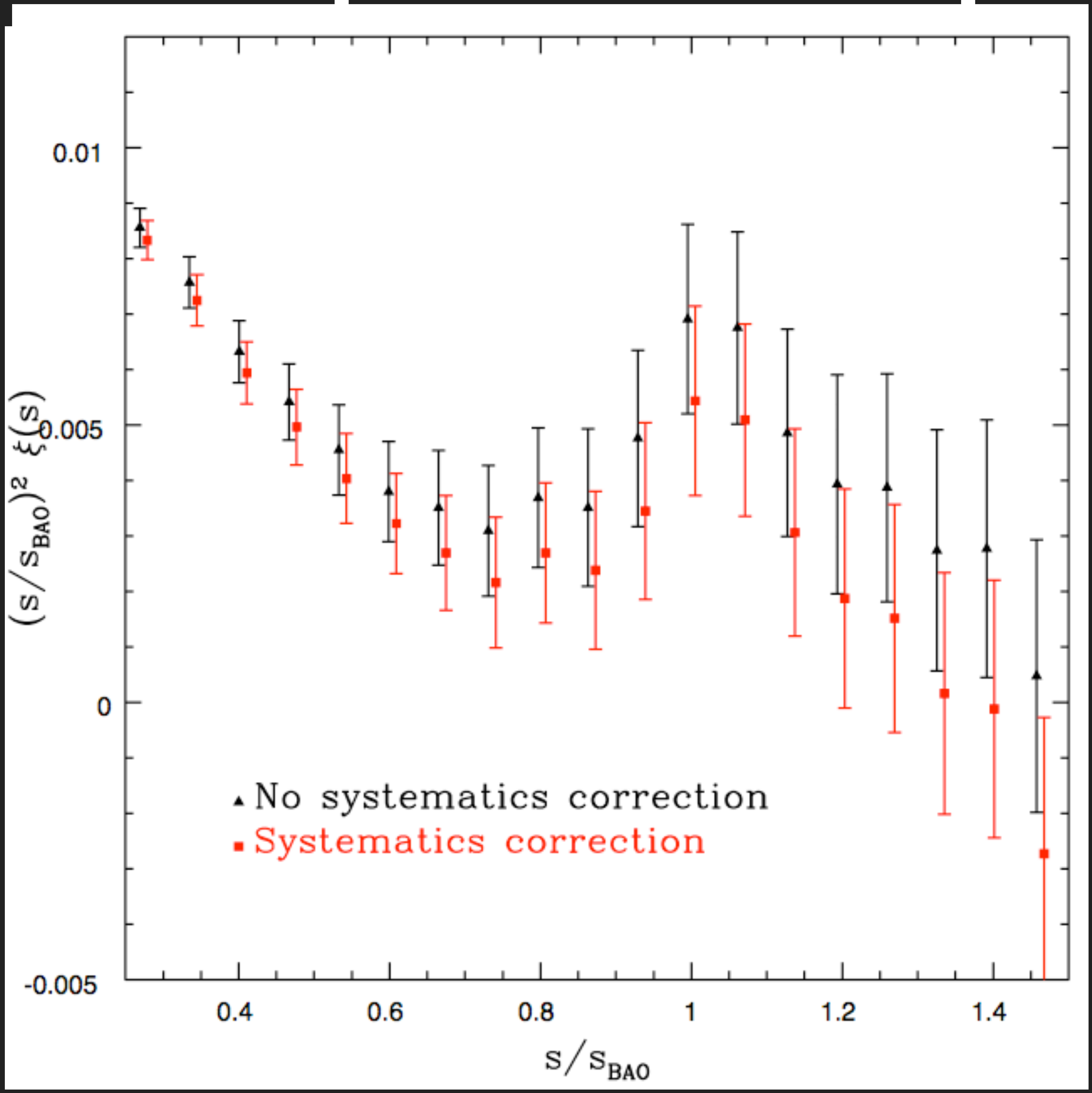


Spectroscopic Sample



- Again went through all potential systematics
- Most important: Correct for presence of stars via weights linear fit to $n_g(n_{star})$ relationship
- Extensive test on mocks: indicate unbiased and ~10% uncertainty on size of correction

Spectroscopic Sample



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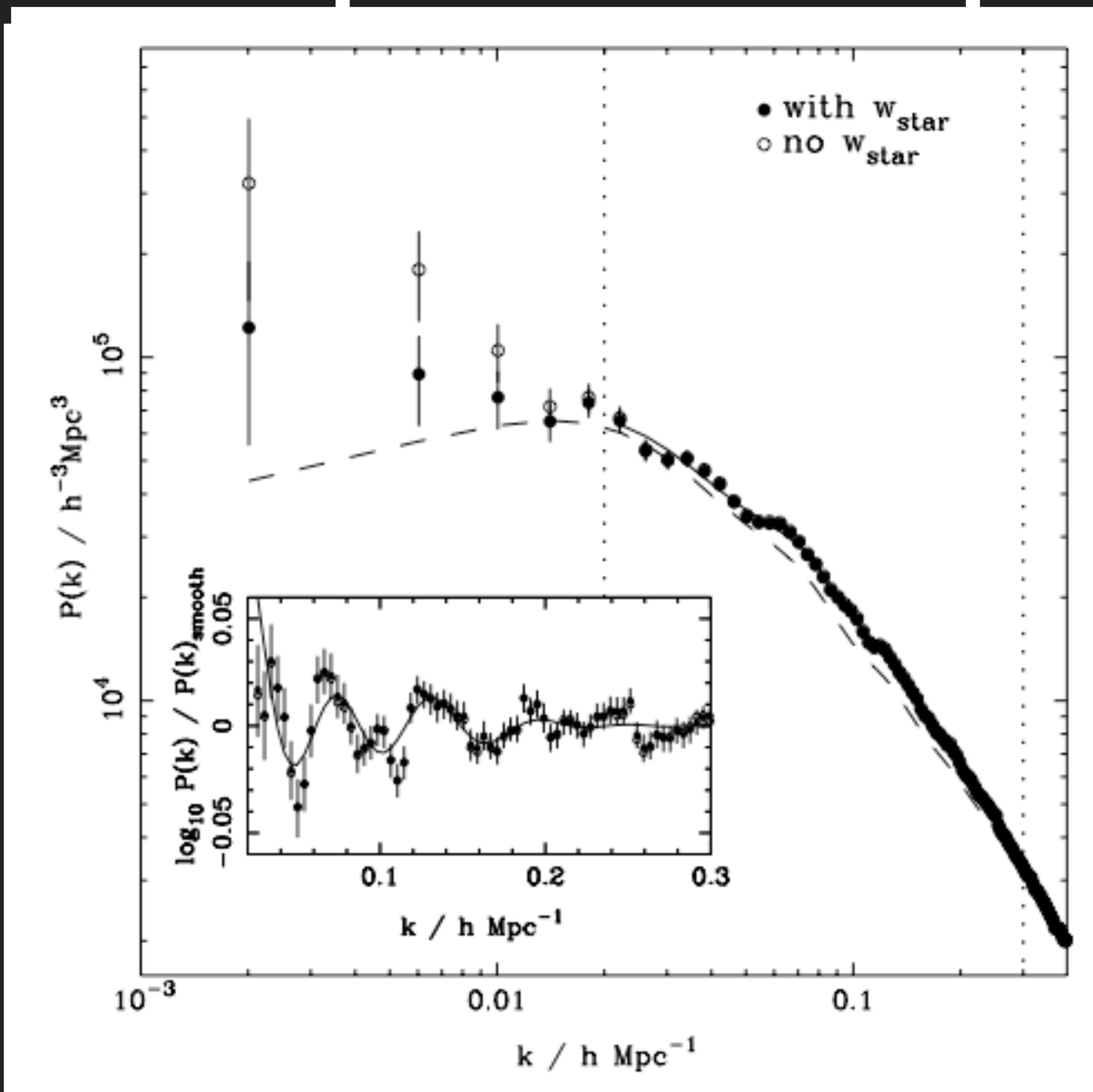

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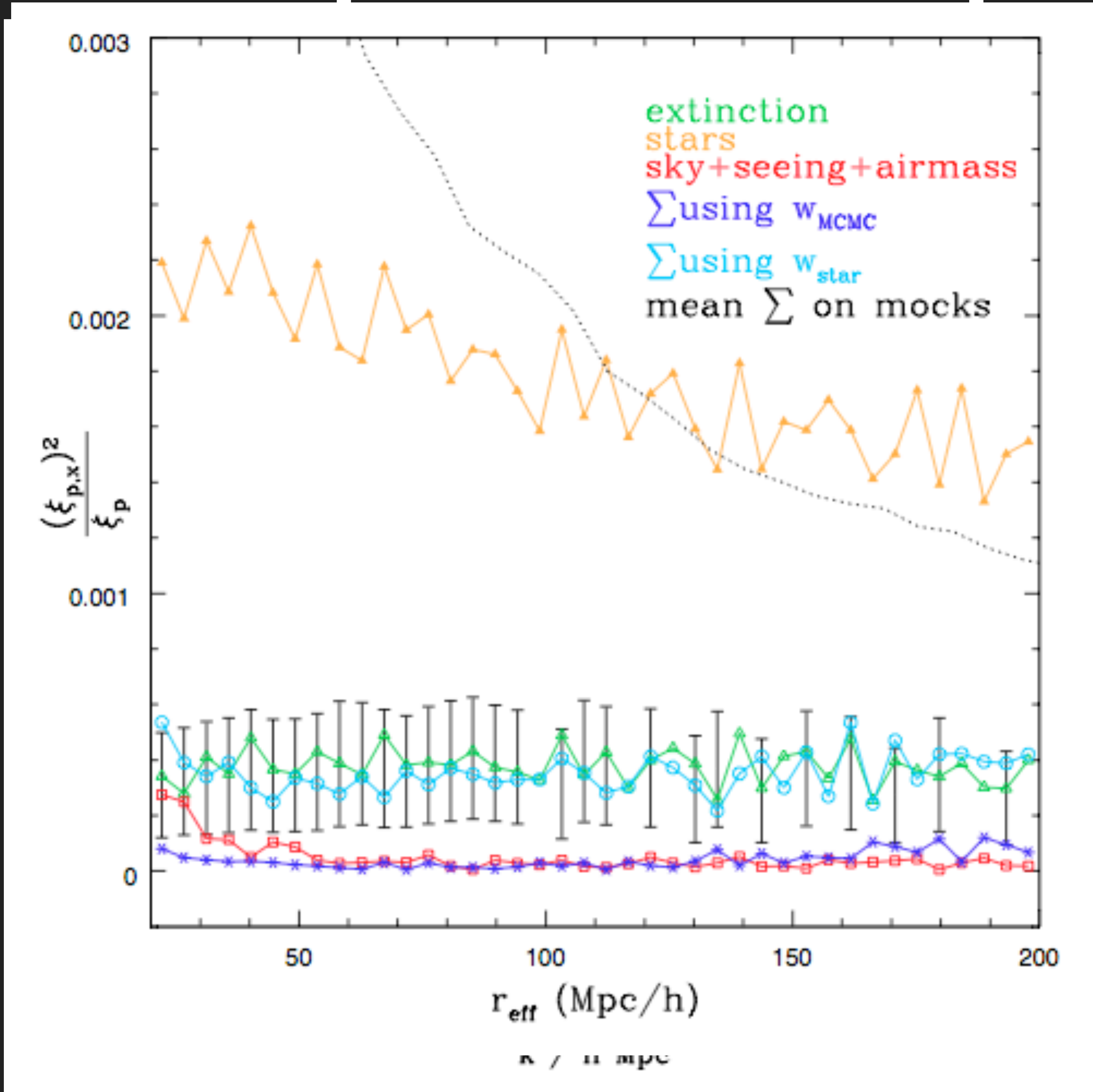

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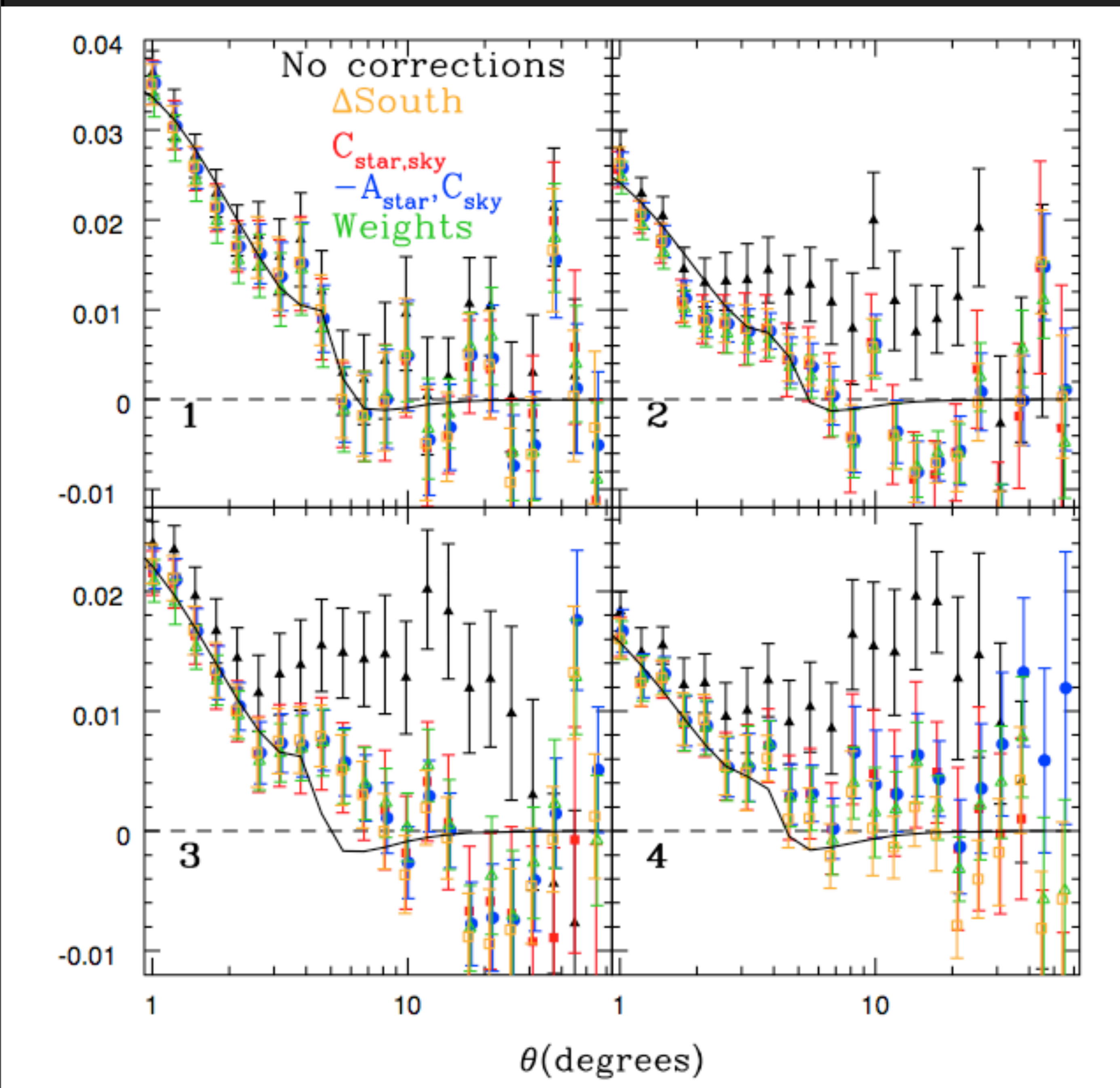
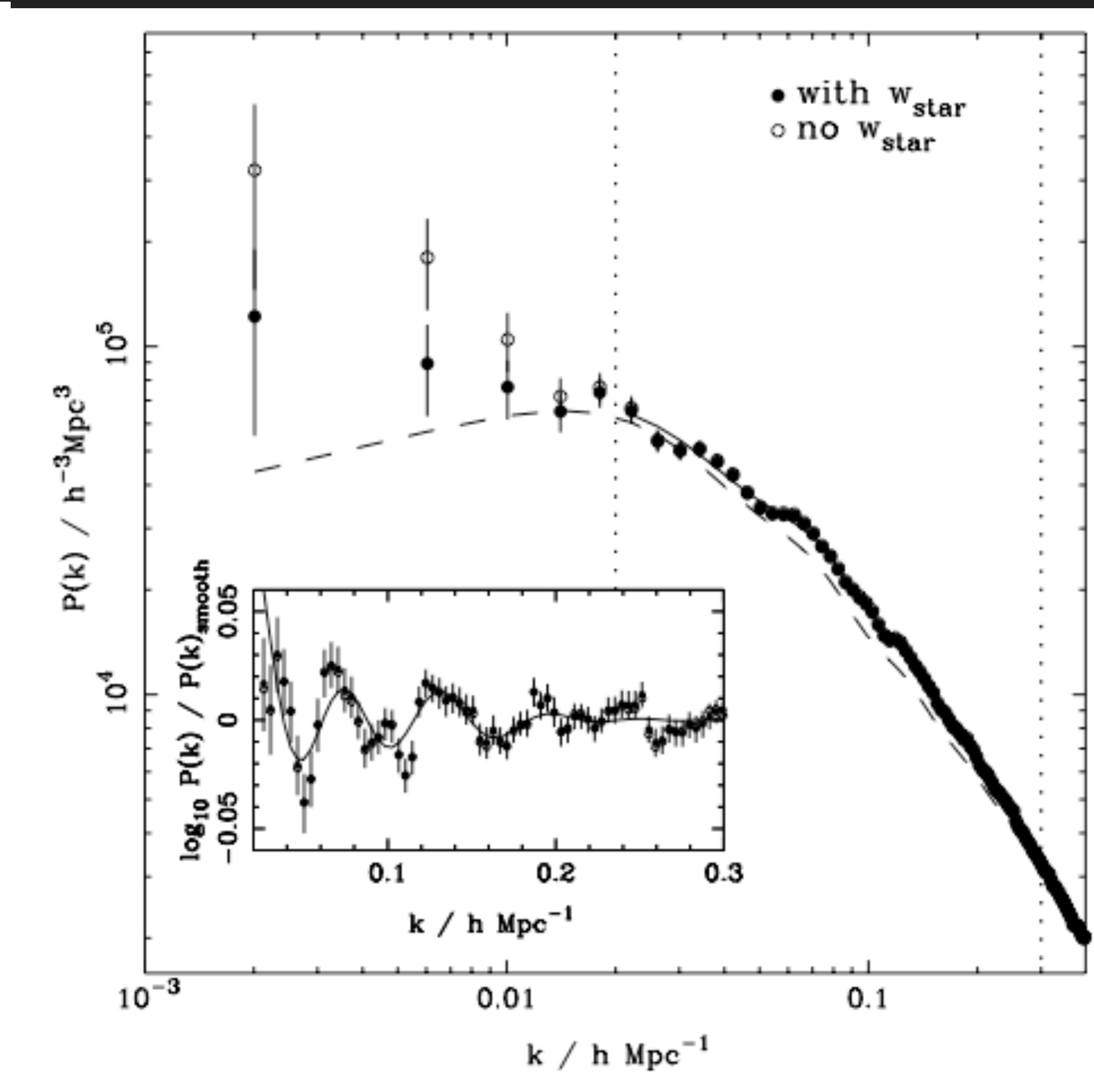
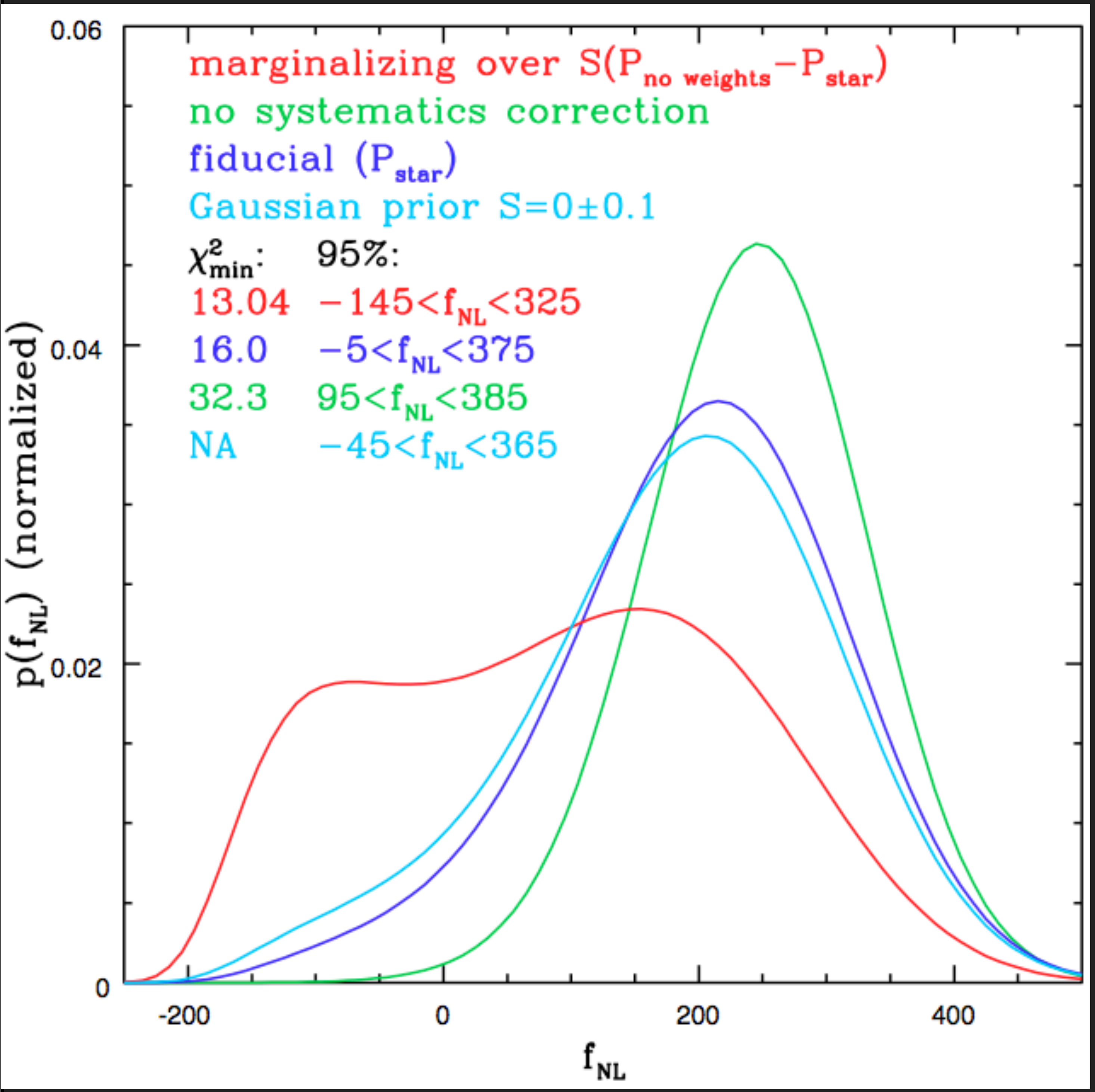
Clustering Estimators





f_{NL} from P(k)

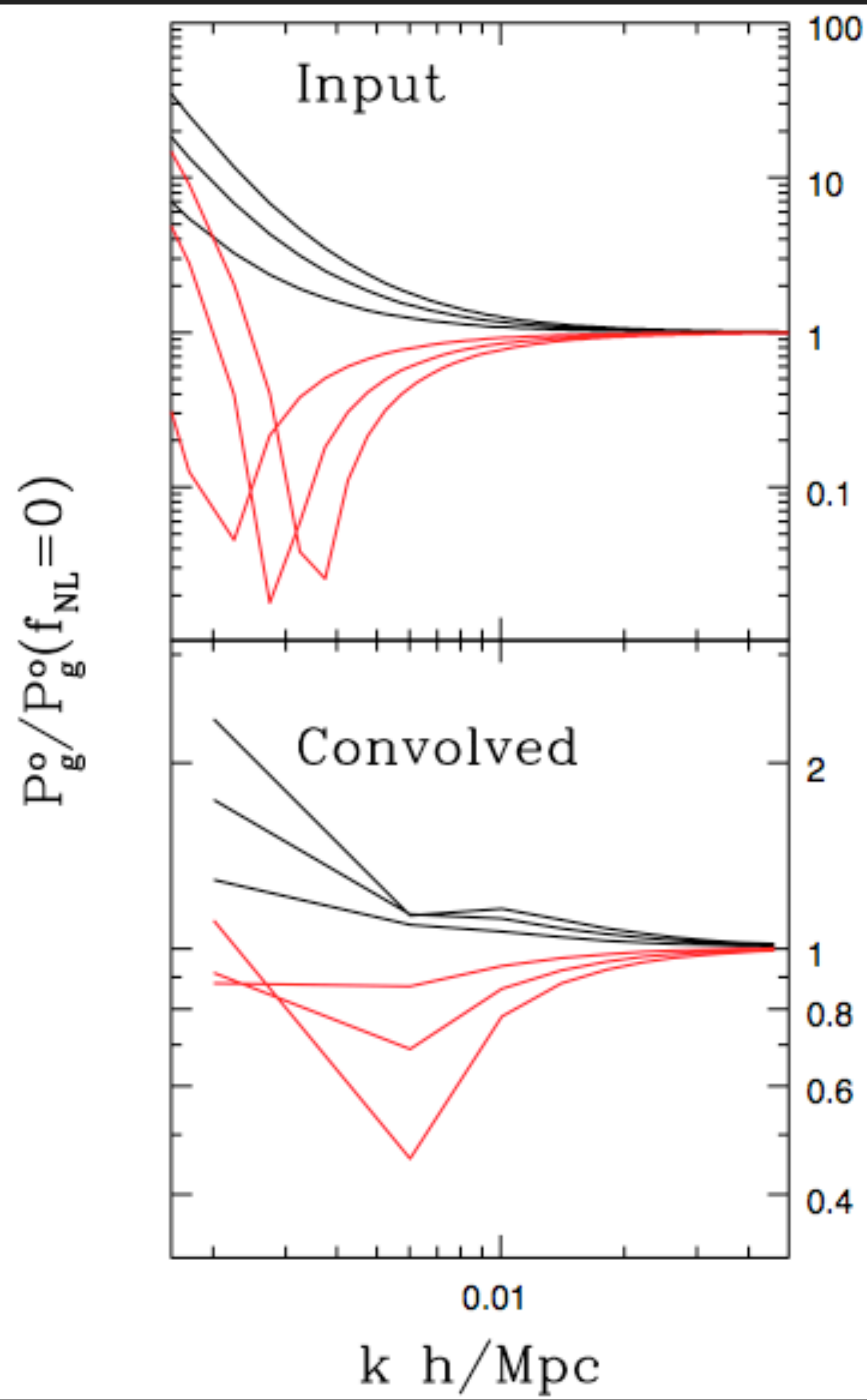


- Using P(k)

$$\Delta b_{NG}(k) \propto f_{NL} \frac{3(b_{halo}-1)\Omega_m \delta_c}{k^2 T(k) D(z)} \left(\frac{H_o}{c}\right)^2$$

- (11 deg of freedom)
- window quite important

f_{NL} from P(k)



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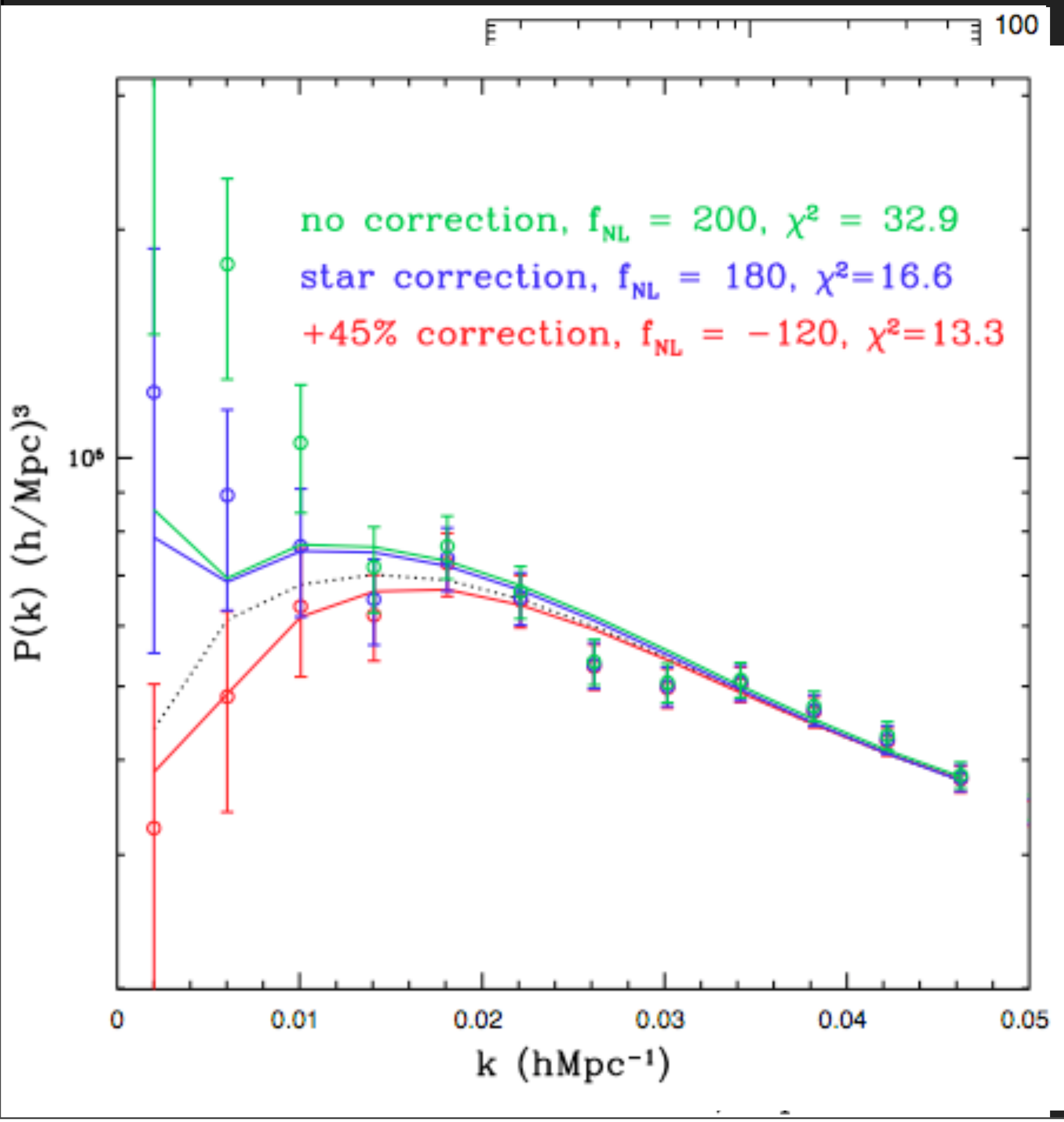

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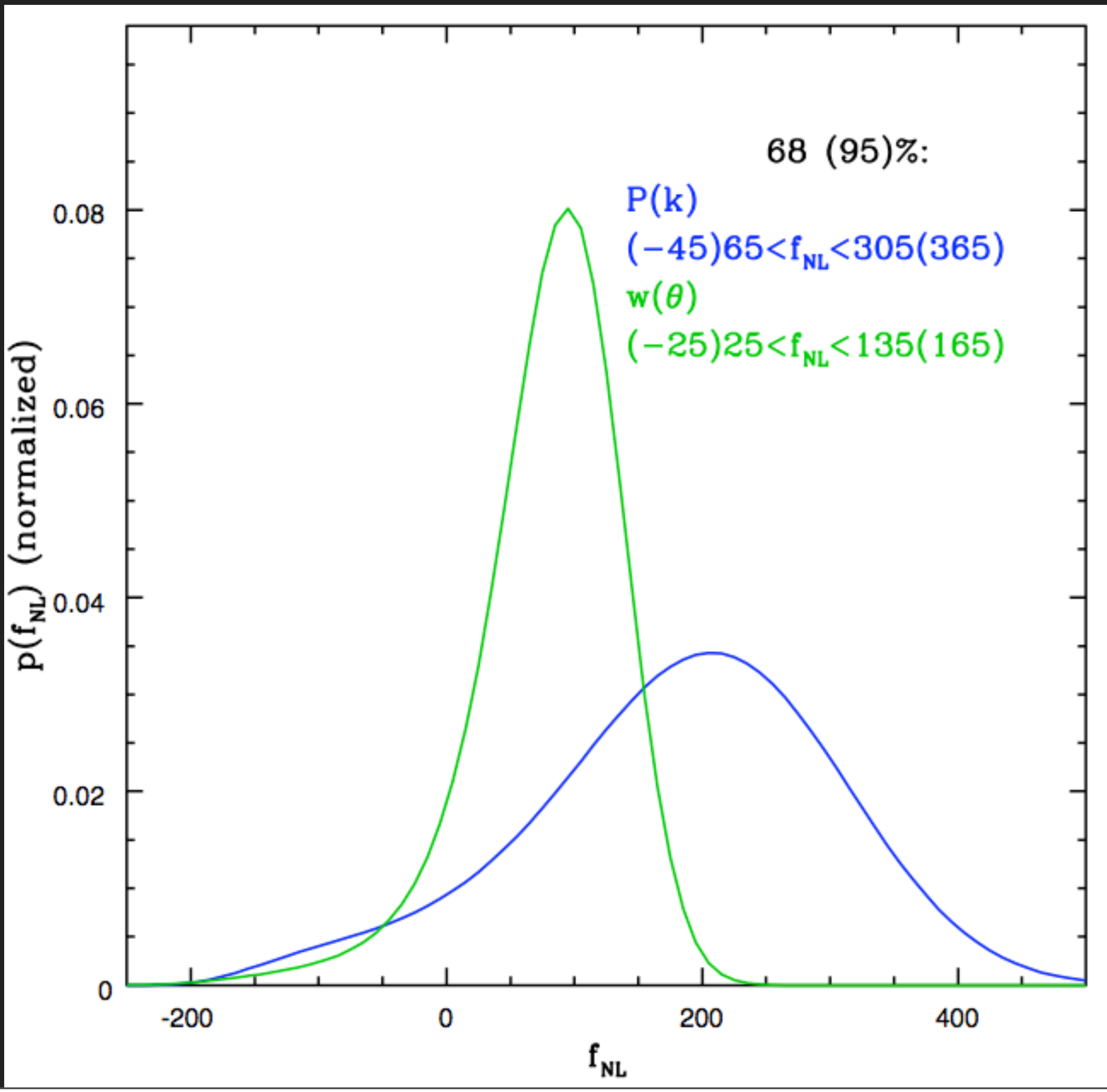
Comparison of Estimators



- photoz doing significantly better than spec
- (spec has 1/3 angular footprint)

Conclusions

- (faint) foreground stars present challenge for all forthcoming surveys
- Systematic effect pretty degenerate with fNL
  - ...but utilizing all of the information, robust constraints can be obtained
  - (BAO position appear robust to observational systematics)

Model Correlation Functions

- redshift space correlation function (Halofit w/ linear RSD)
- *w*(θ), project over n(z)

$$w(\theta) = \int dz_1 \int dz_2 n(z_1) n(z_2) \xi^s(\mu, r_{ev}(\theta, z_1, z_2))$$

$$r_{ev}(\theta, z_1, z_2) = \sqrt{\chi^2(z_1) + \chi^2(z_2) - 2\chi(z_1)\chi(z_2)\mathrm{cos}\theta}$$

$$\mu = (\chi(z_1) - \chi(z_2))/r_{ev}$$

Redshift Space Distortions (RSD)

- Intrinsic velocities of galaxies imply redshift space is distorted from real-space
- Small scales - finger of God effect
- Large scales - infall onto clusters

Redshift Space

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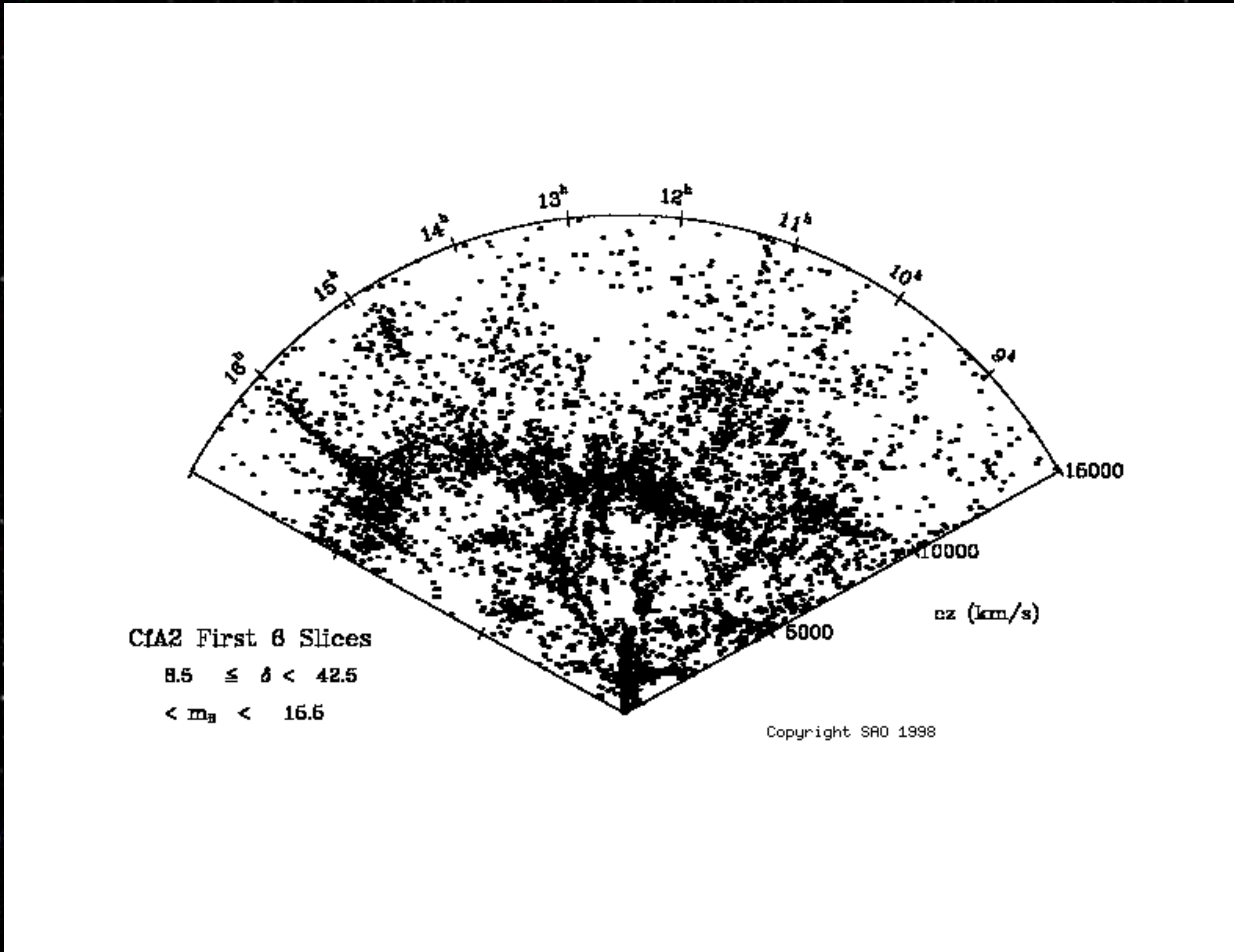

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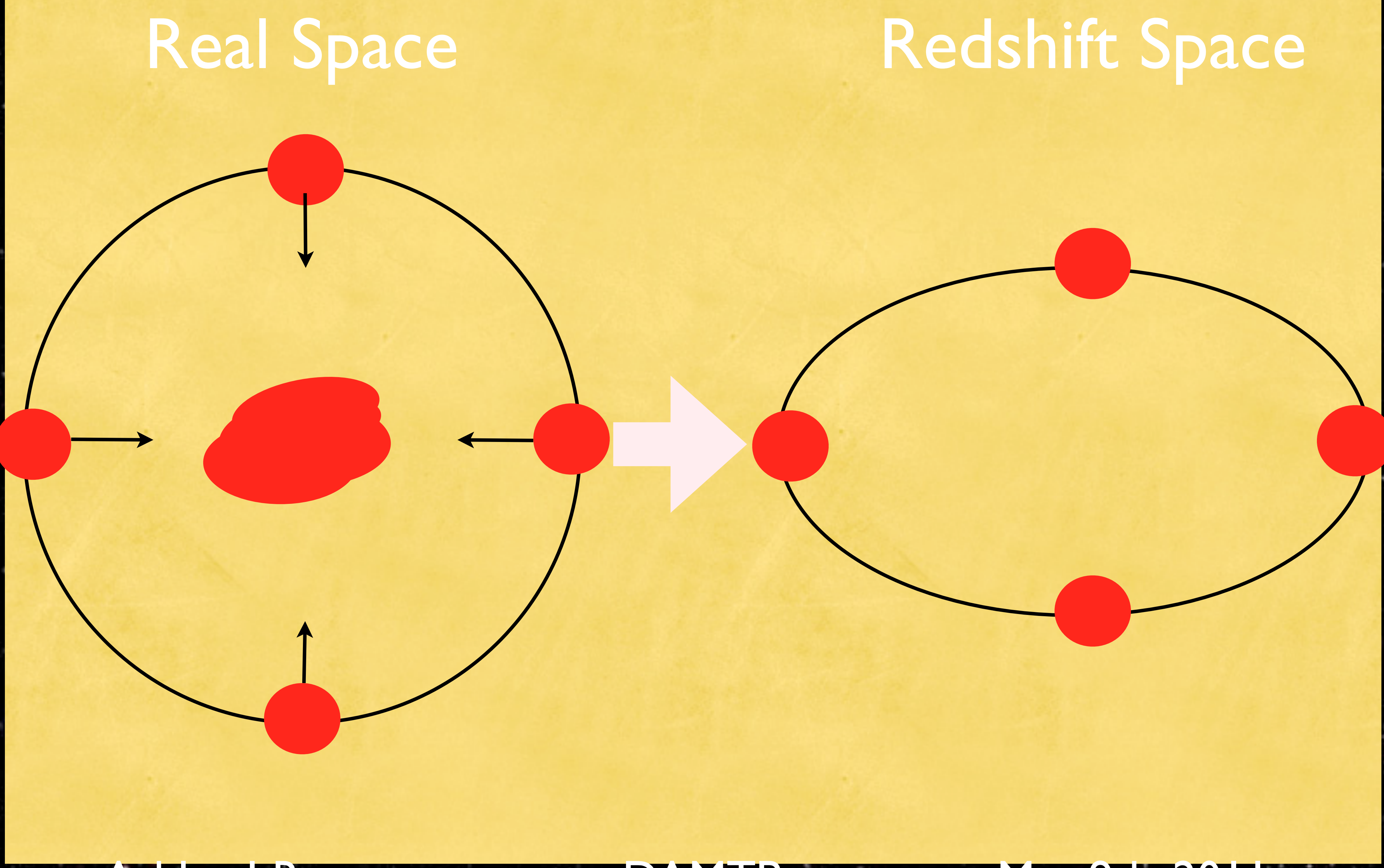
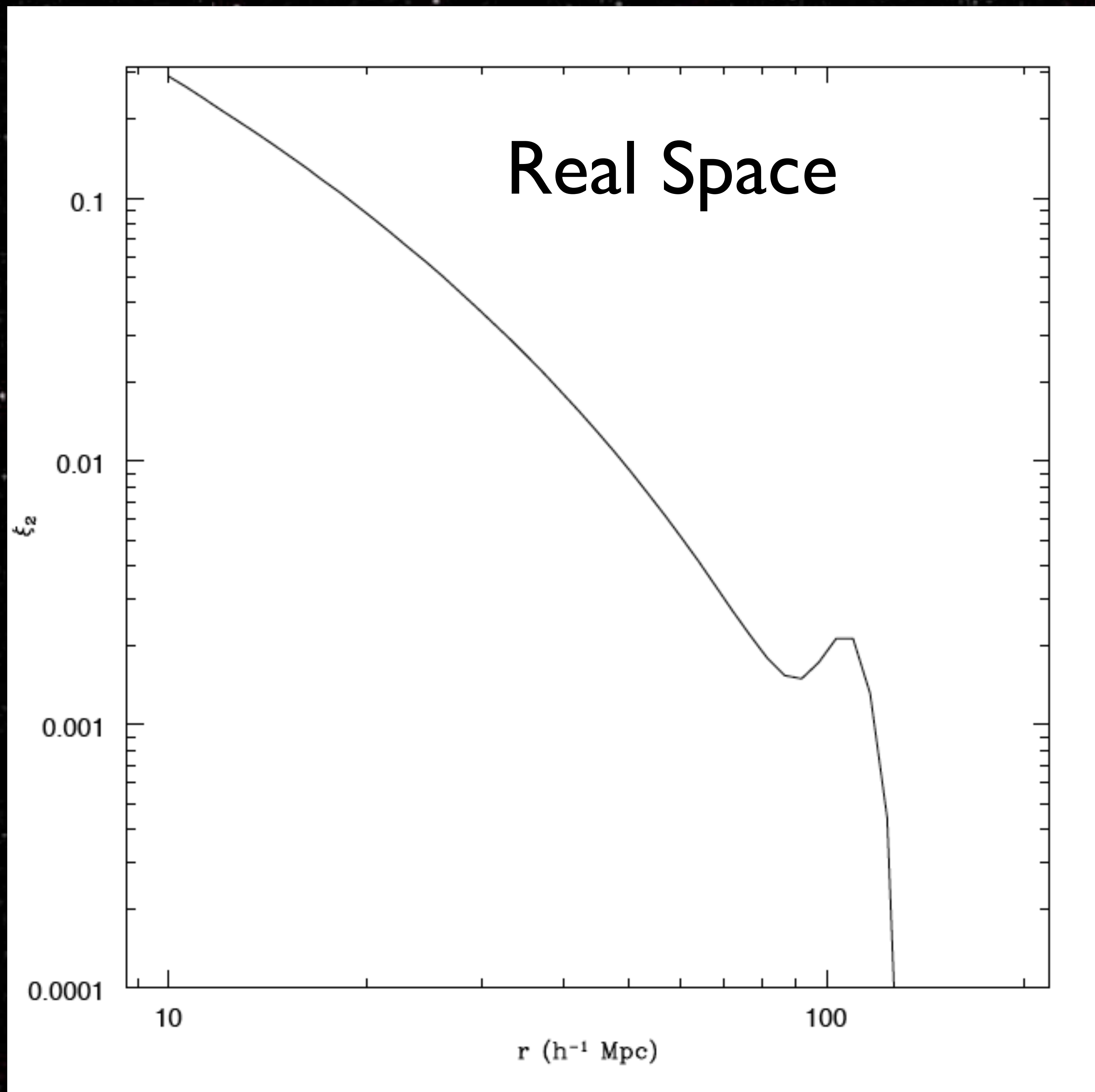


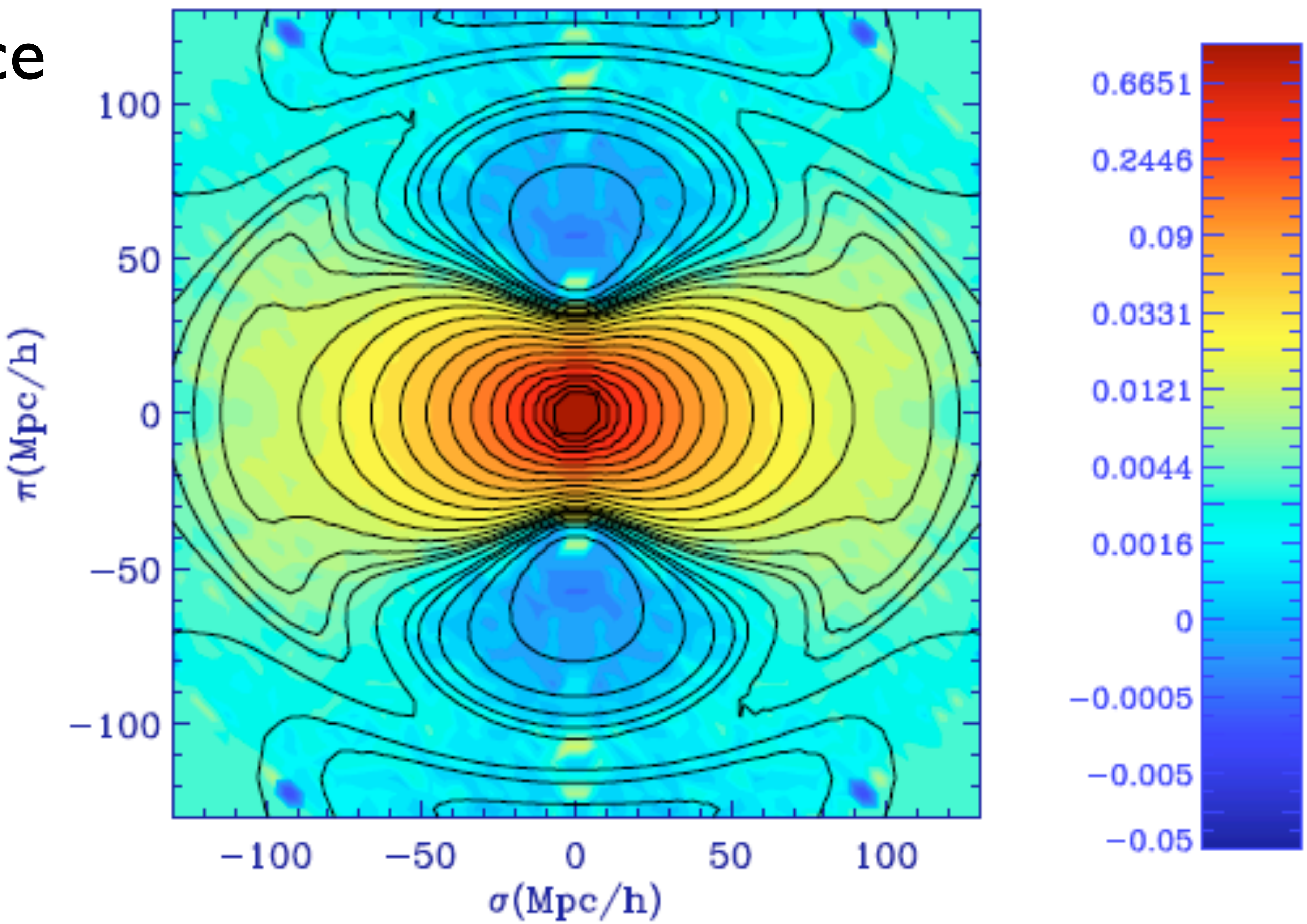
Real/Redshift Space Clustering



Real/Redshift Space Clustering

Redshift Space

Cabré & Gaztañaga (2008)



Redshift Space Clustering

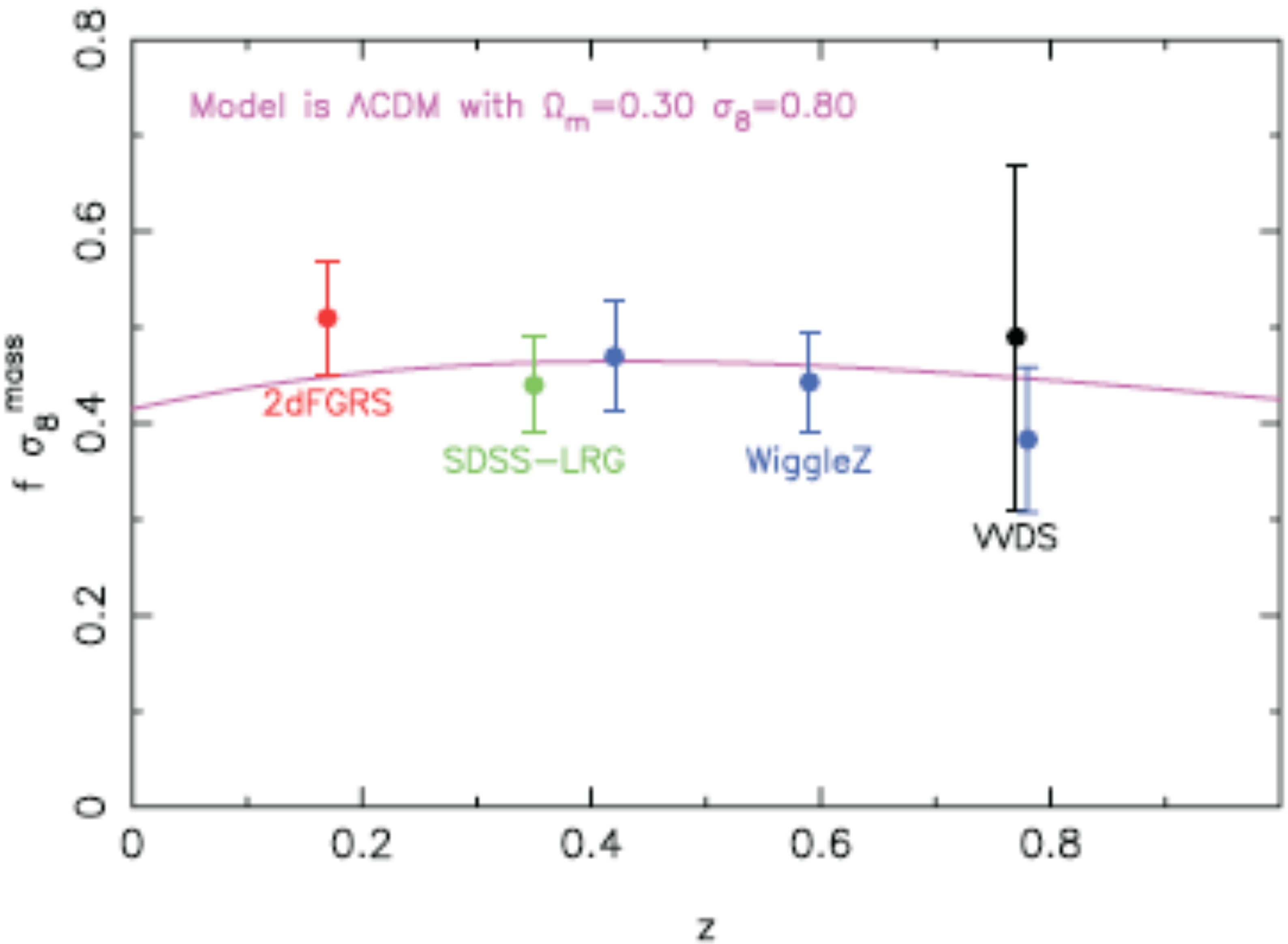
- Large scale distortions can be modeled with linear theory:

$$P(k,\mu) = (1 + f\mu^2)^2 P(k)$$

$$\mu = \cos(\theta); f = \mathrm{dln}(D)/\mathrm{dln}(a) \sim \Omega^{\gamma}_{matter}$$

- GR predicts γ = 0.557

Redshift Space Clustering

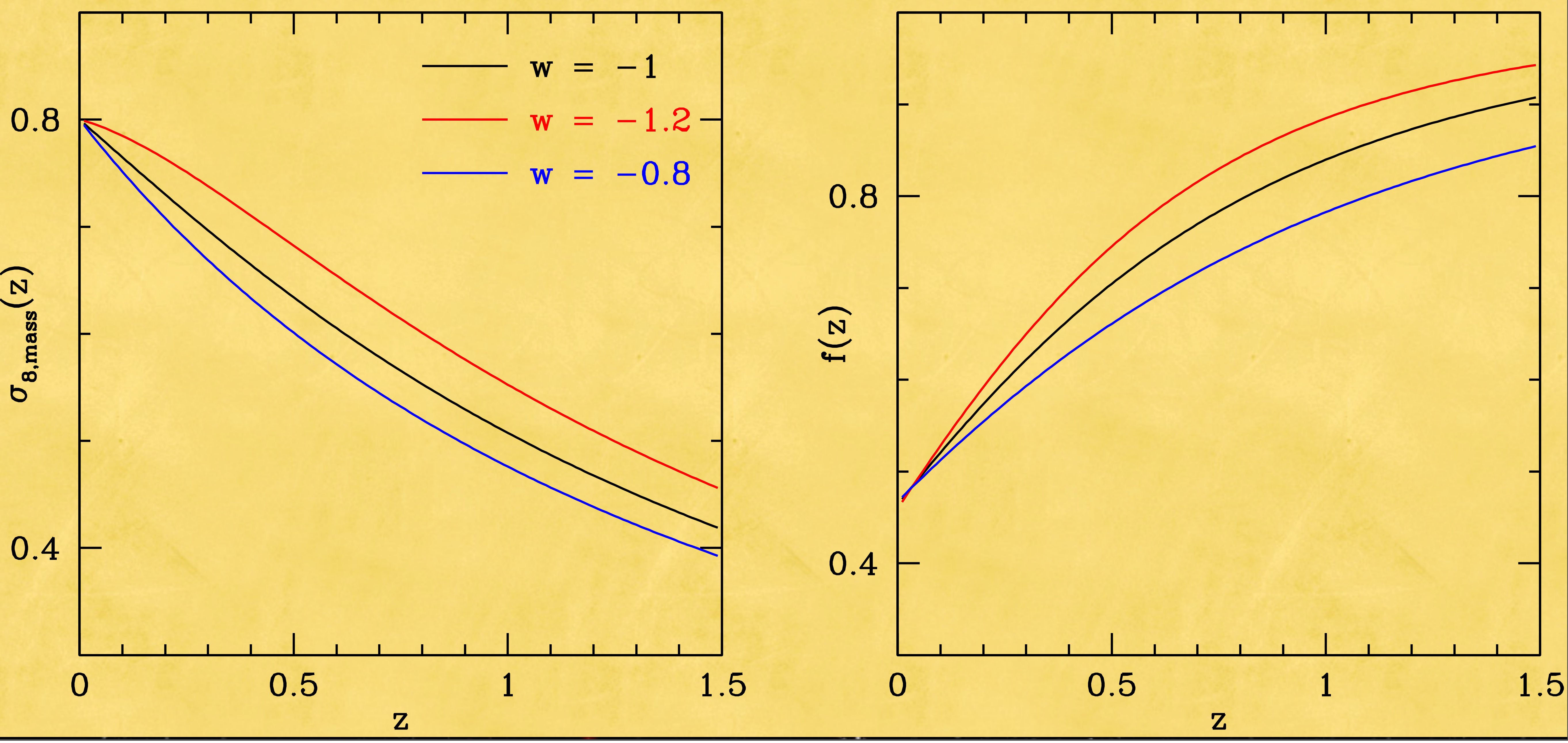


Blake et al. (2010)

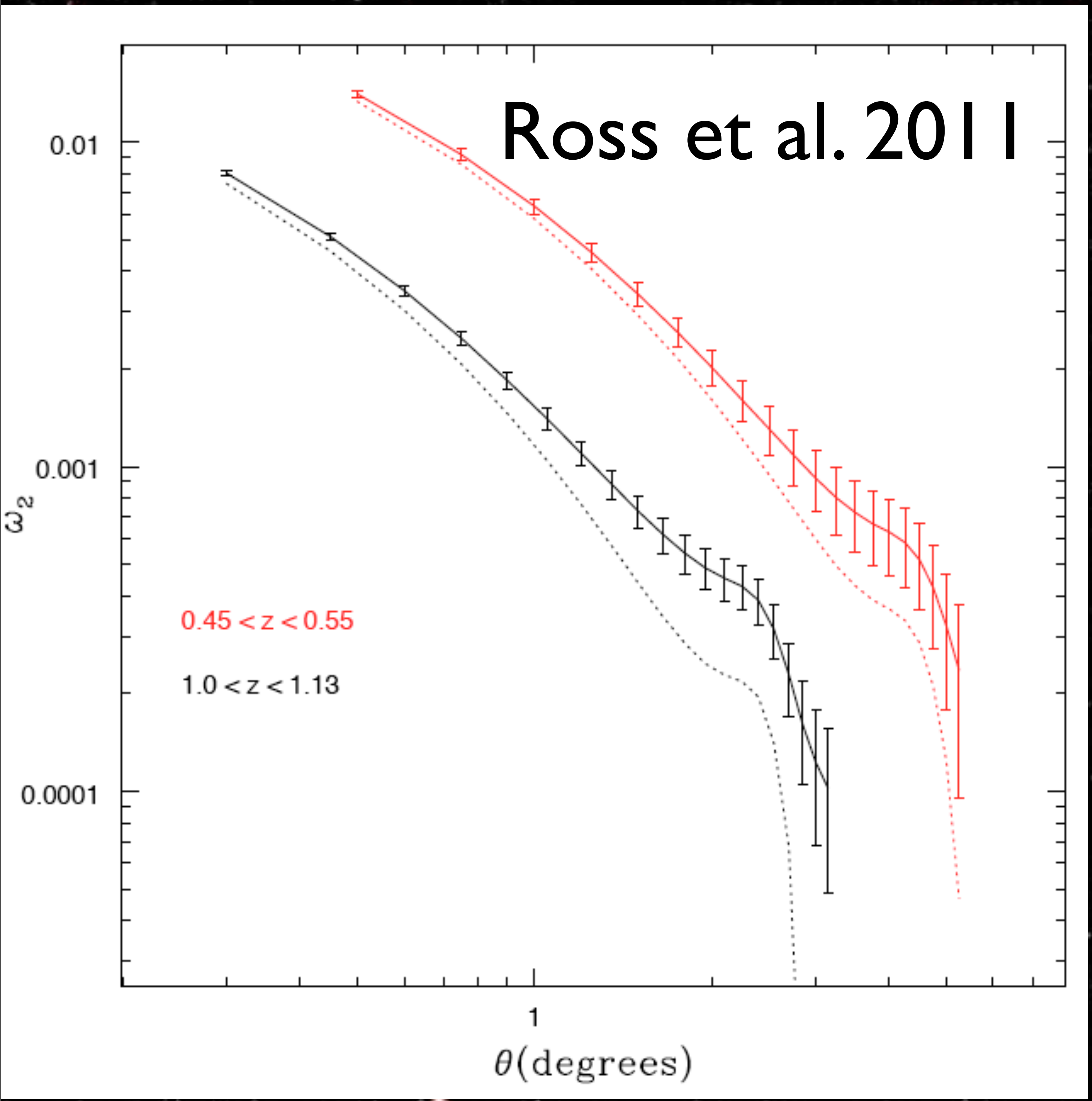
RSD/ Dark Energy

$$\sigma_{8,mass}(z) = \sigma_{8,mass}(0)D(z)$$

$$f(z) = d\ln(D)/d\ln(a)$$

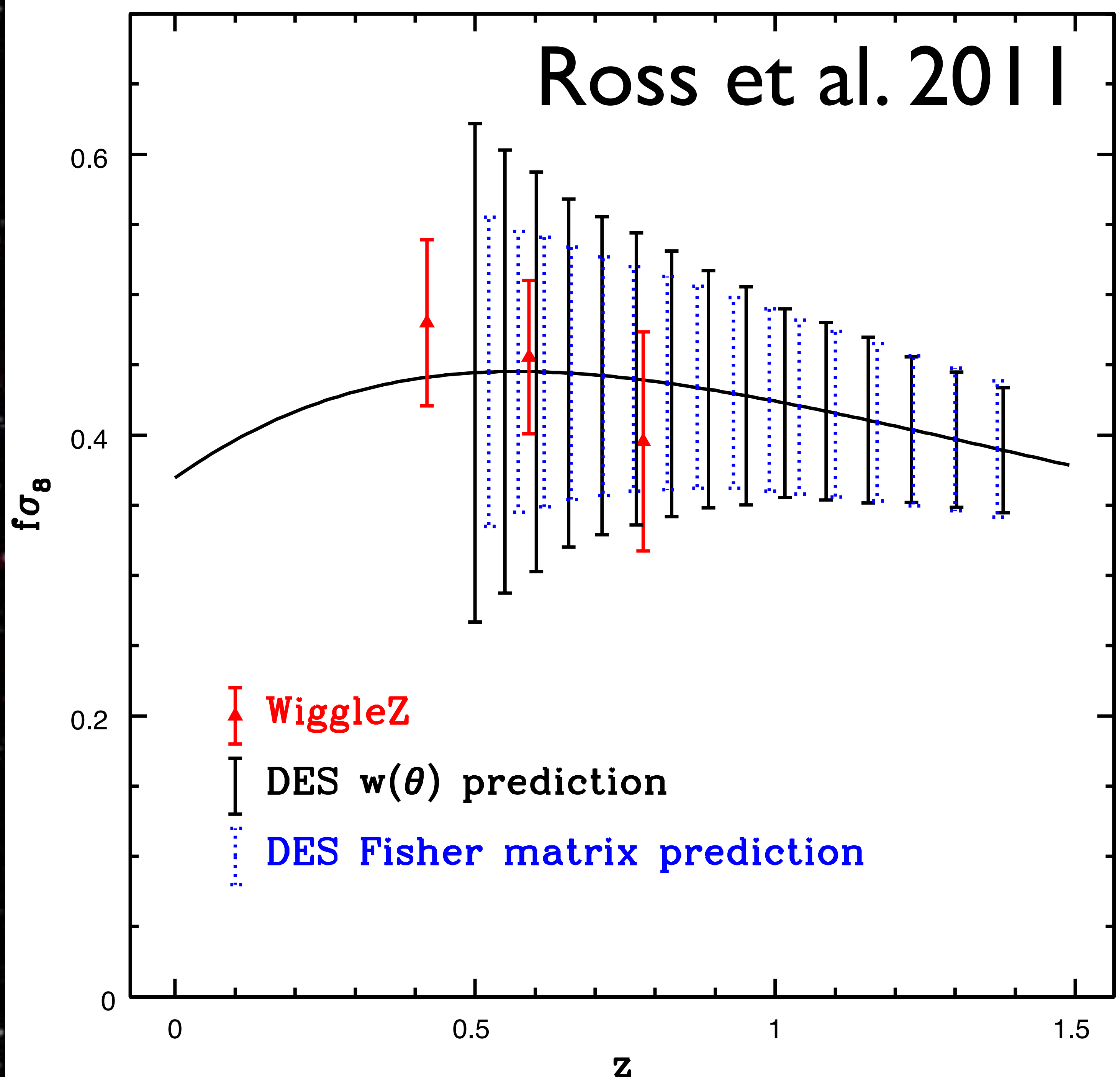


RSD with Photozs?



- Projections for Dark Energy Survey

Measure $f\sigma_8$ with DES?



assuming
$\Delta z = \sigma_z = 0.03(1+z)$

Redshift Space Distortions (RSD)

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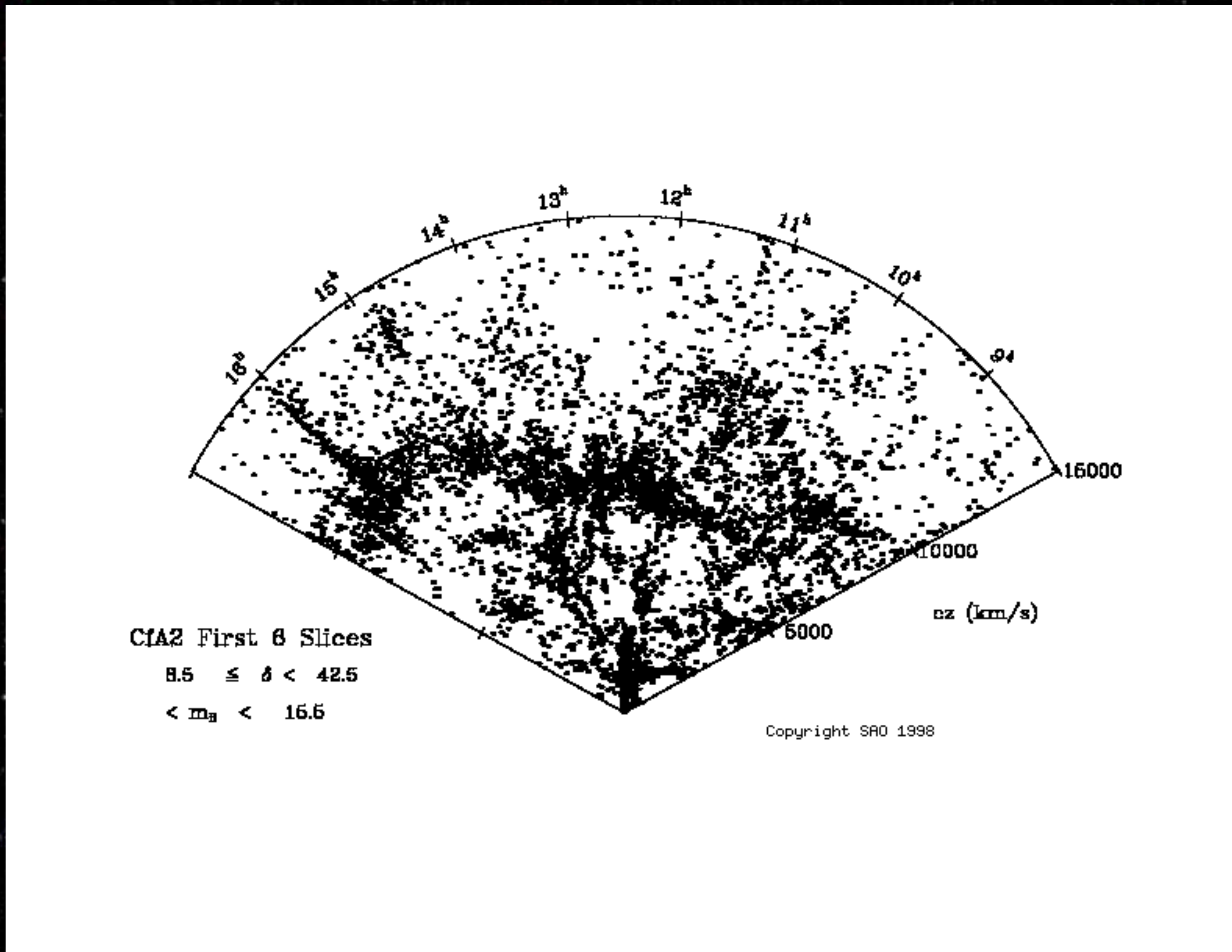
Redshift Space



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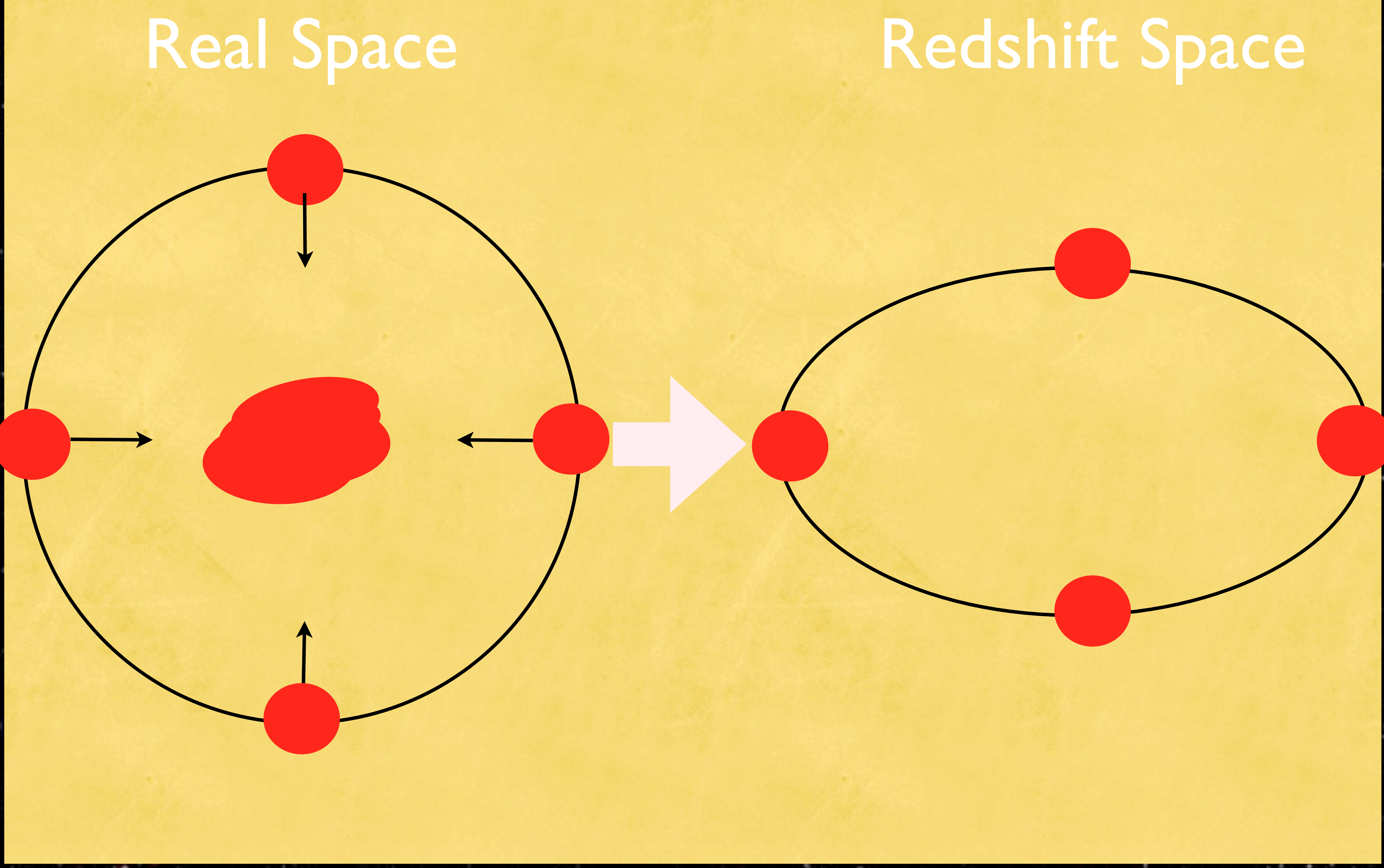


Friday, 20 April 2012

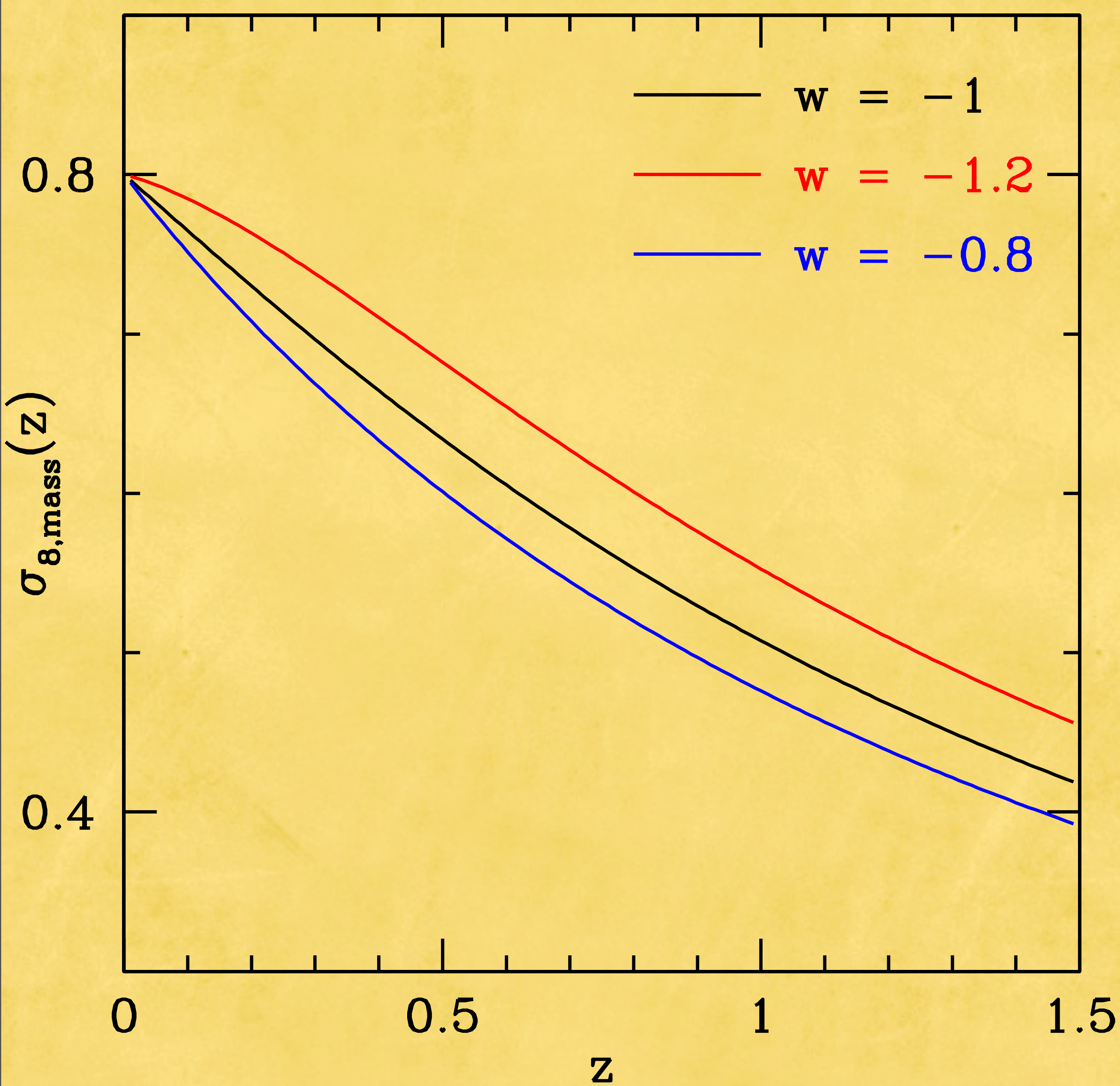
Redshift Space Clustering

$$P(k,\mu) = (1+\beta\mu^2)^2 P(k)$$

$$\mu = \cos\theta;\ \beta = f/b;\ f = \mathrm{dln}(D)/\mathrm{dln}(a) \sim \Omega_m(z)^{0.557}$$

RSD/ Dark Energy

$$\sigma_{8,mass}(z) = \sigma_{8,mass}(0)D(z)$$



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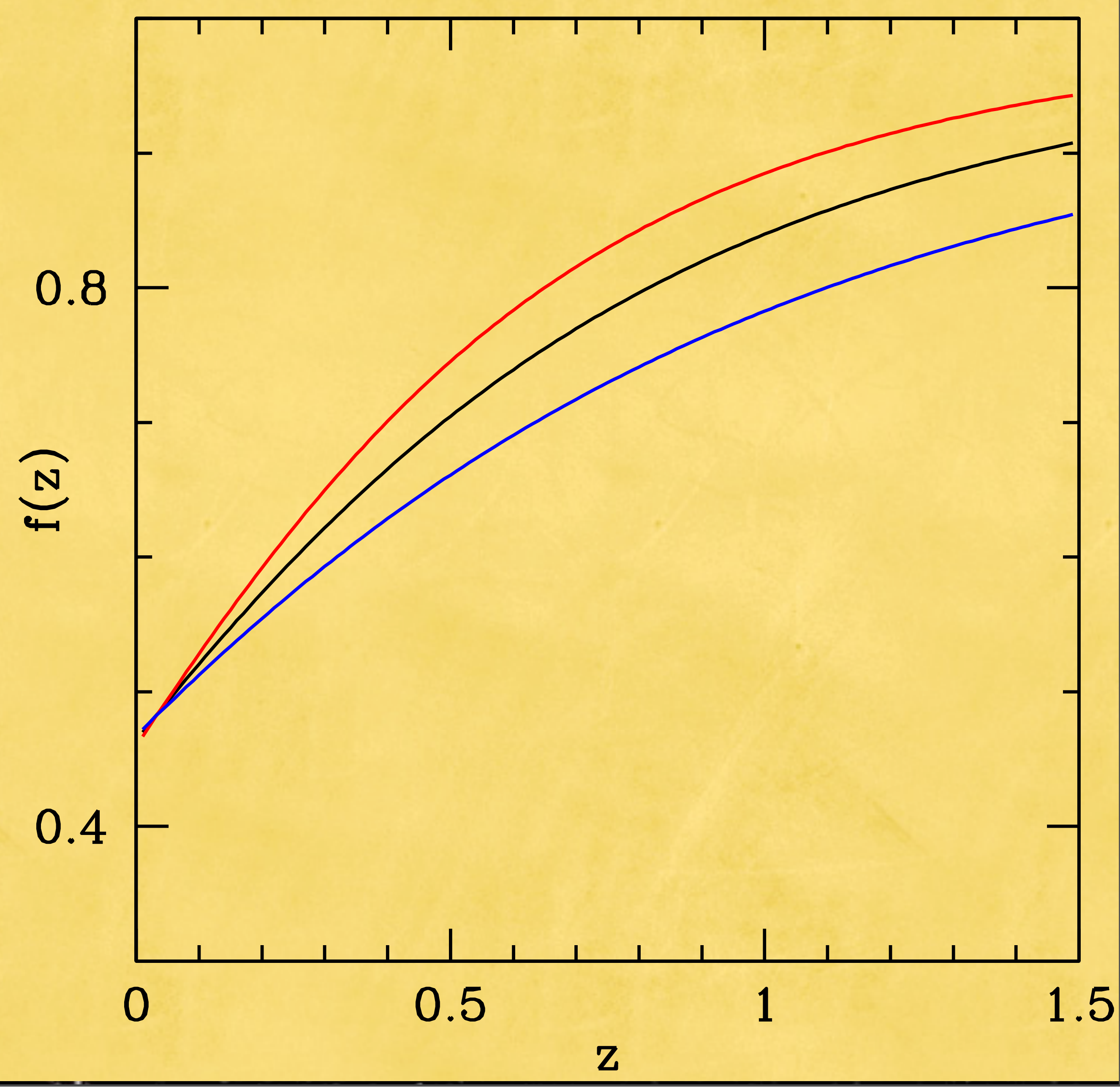
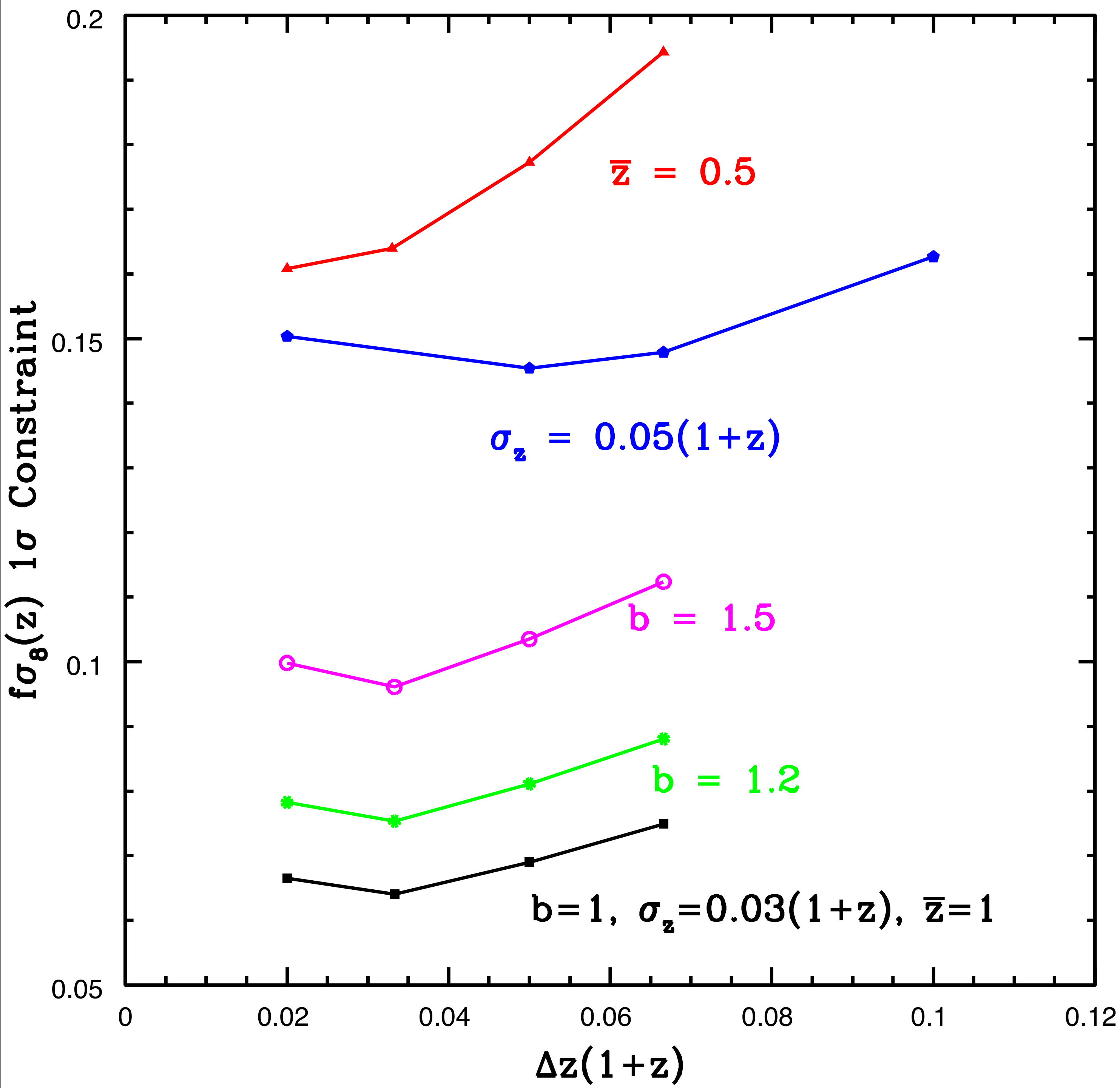


Optimal Galaxy Sample?



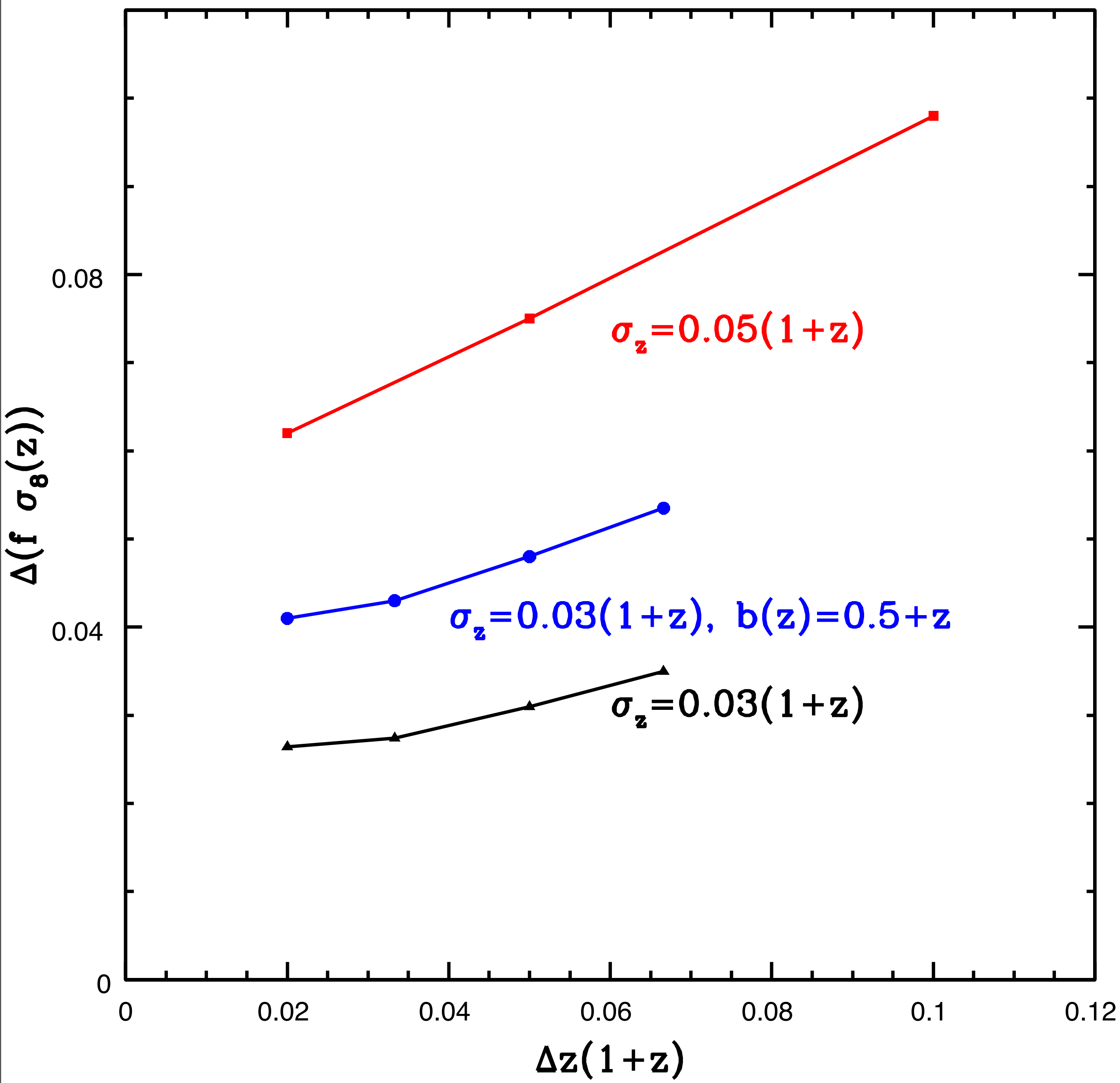
Bias, redshift error, and median redshift are important factors

- Assumes 10 million galaxies per Δz = 0.066 (1+z)
- 1/8th sky cover

Combined Constraints

Constant offset from ΛCDM

$$\Delta\left(f(z)\sigma_8(z)\right) = 1/\sqrt{\sum_{i,j} C_{i,j}^{-1}},$$



DES should be able to detect 10% deviation in f(z) from ΛCDM

Combining 2nd and 3rd-order clustering

- Produces tighter cosmological constraints
- $\bar{\omega}_N$ easy to calculate with photometric data
- Reminder:
- $\bar{\omega}_N(\theta) = \langle \delta^N \rangle_c \;\; s_N(\theta) = \frac{\bar{\omega}_N}{\bar{\omega}_2^{N-1}}$

Measuring σ8

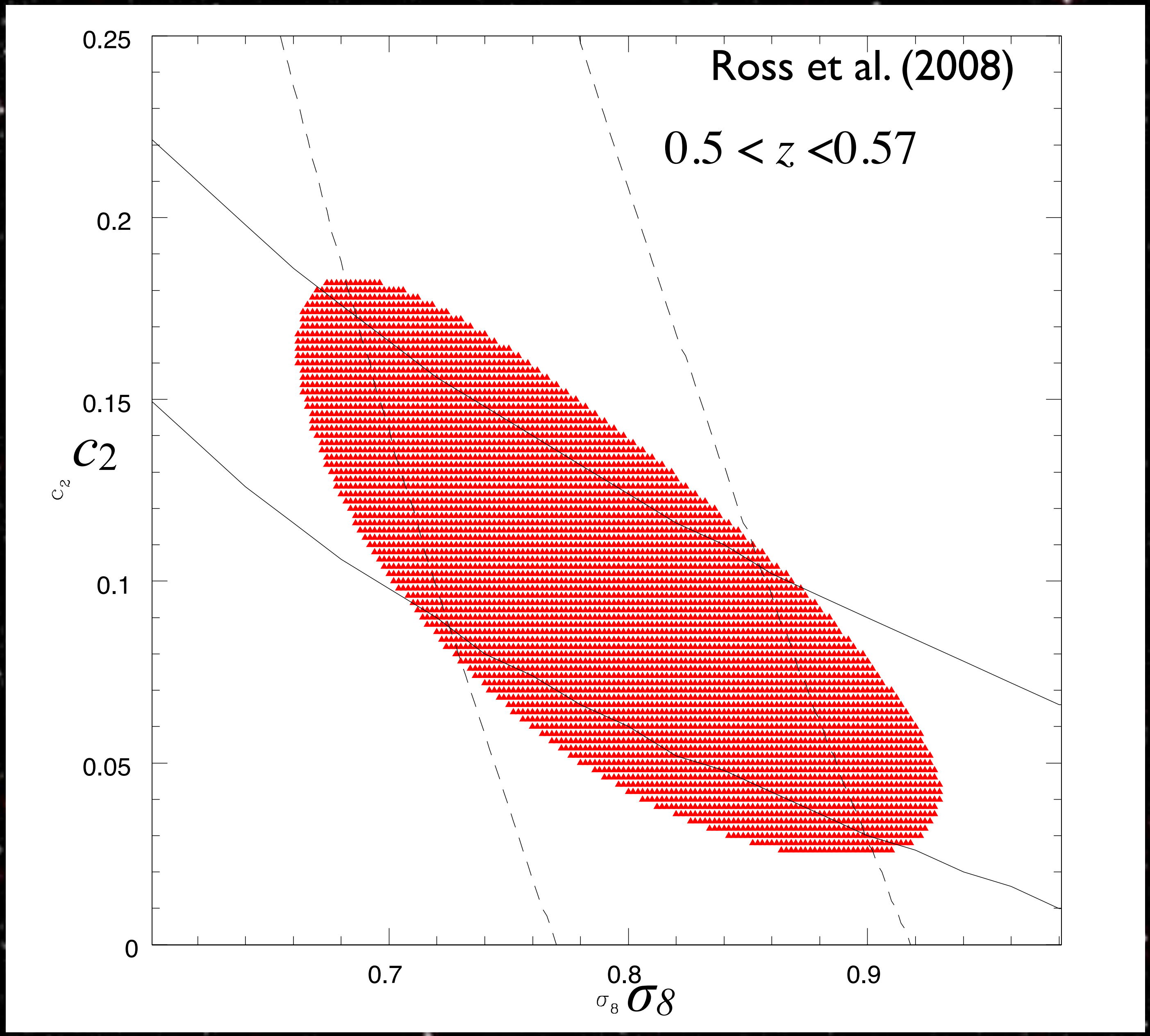
- σ_8 : rms mass fluctuation at $8\ h^{-1}$ Mpc
- $\langle \delta_{DM}^2 \rangle \propto \sigma_8^2$ so $b_1 \propto 1/\sigma_8$
- This makes it nuisance parameter for 2-point measurements
- Adding s_3:
  - Measure s_3 for galaxies, determine $c_2(\sigma_8)$
  - Turn δ_{g} to δ_{DM} with assumed b_1 and b_2, measure *corrected* ϖ_2, match to model $\varpi_{2,\mathrm{DM}}$, yields separate $c_2(\sigma_8)$

SDSS LRG Catalog

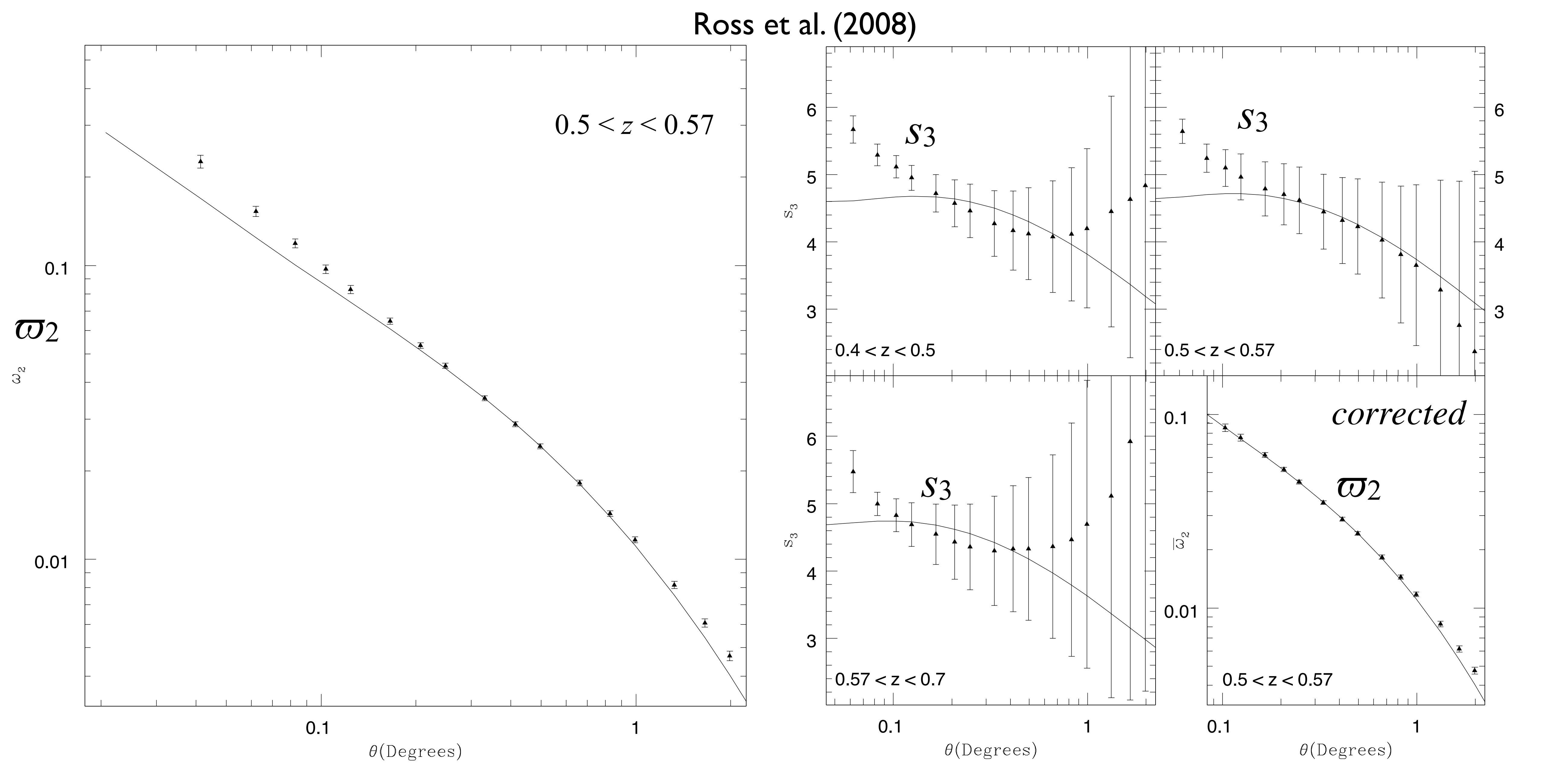
- SDSS DR5 LRGs with MegaZ-LRG color cuts (Collister et al. 2007) and ANNz for photozs and star/galaxy separation
- Over 1.6 million LRGs with $0.4 < z < 0.7$ and median redshift of 0.52
- Split into three distinct redshift ranges with median redshifts of 0.47, 0.53, and 0.61

LRG Results

- Measured $\sigma_8 = 0.78 \pm 0.08$, 0.80 ± 0.09, and 0.80 ± 0.09
- Combine for $\sigma_8 = 0.79 \pm 0.05$
- Find $b_1 = 1.47 \pm 0.09$, 1.65 ± 0.09, 1.80 ± 0.10
- $c_2 = 0.09 \pm 0.04$, 0.09 ± 0.05, 0.09 ± 0.03



LRG Results



Ross et al. (2008)
0.5 < z < 0.57
ϖ2
ω2
0.1
0.01
0.1
1
θ(Degrees)
s3
0.4 < z < 0.5
0.5 < z < 0.57
0.57 < z < 0.7
6
5
4
3
corrected
0.5 < z < 0.57

Testing on Millennium Simulation

- $M_r < -23$ and $B - R > 1.4$ from Blaizot et al. (2005)
- Found $\sigma_8 = 0.898 \pm 0.062$
- (Input is $\sigma_8 = 0.9$)