Large Scale Clustering, Systematics and Non-gaussianities

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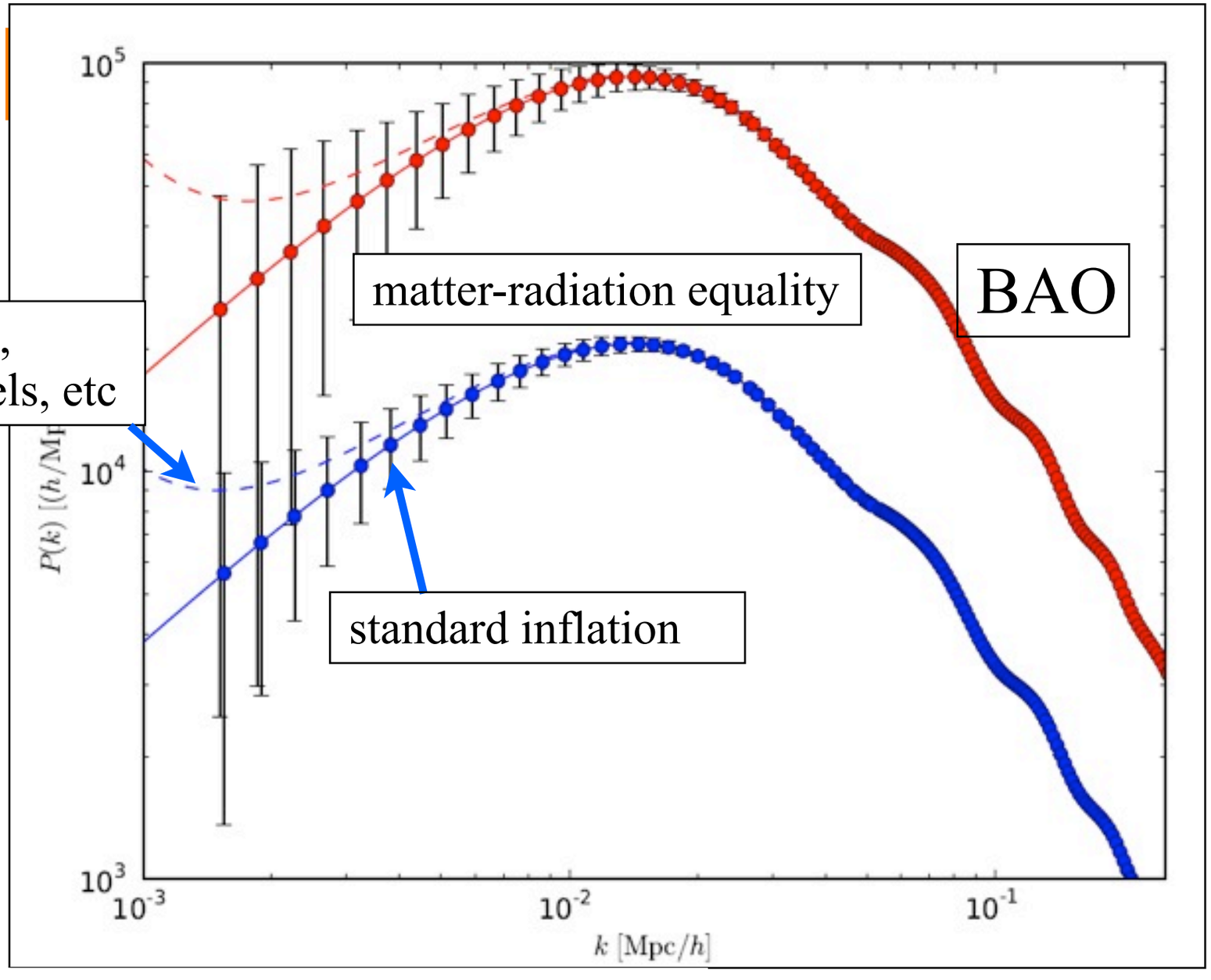
and

Sloan Digital Sky Survey III Collaboration

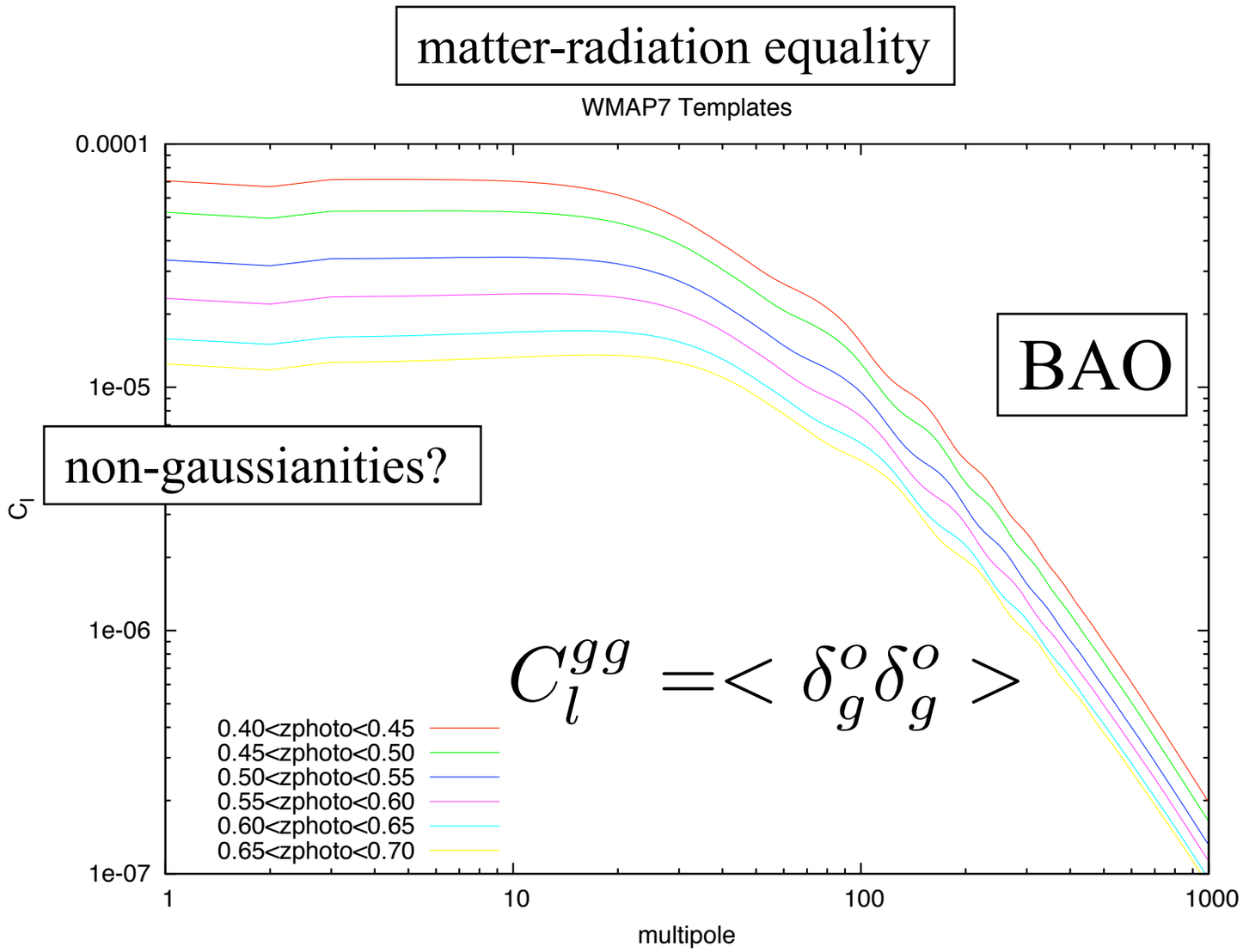
The 3D power-spectrum



ghost inflation,
curvaton models, etc

Dalal, Dore, Huterer, Shirokov 2008

Angular Power-spectrum



Slosar, Hirata, Seljak, SH, Padmanabhan 2008

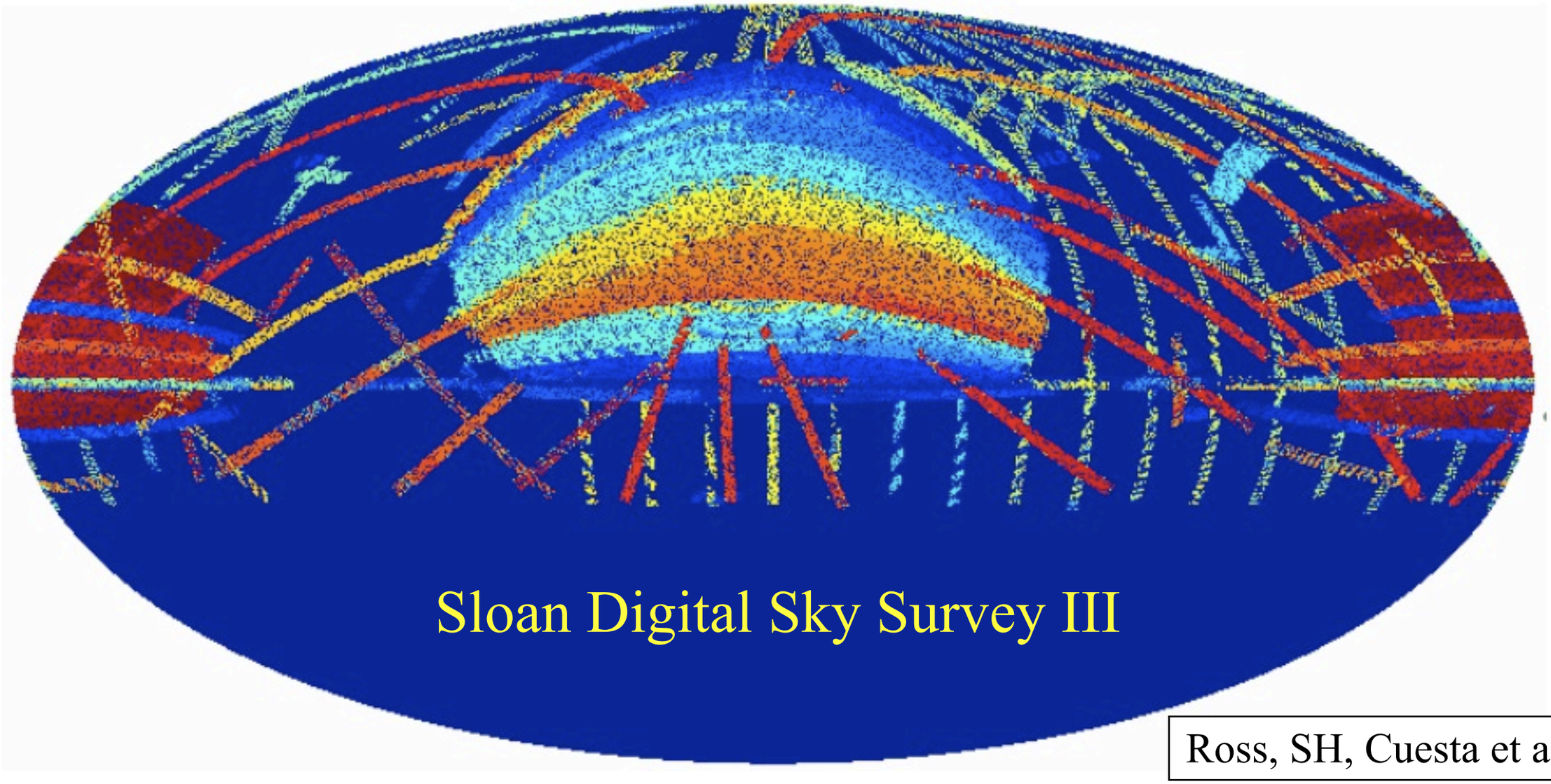
Xia, Baccigalupi, Mattarese, Verde, Viel 2011

Xia et al. 2010

The Data

Total Area: 14,555 sq deg

1.5 million LRGs: 0.4<z<0.7



Ross, SH, Cuesta et al. (2011)

SH, Ross, Cuesta, Seo, White, Schlegel et al. (in prep)

note: Colors only indicates the when a certain area of the sky is surveyed.

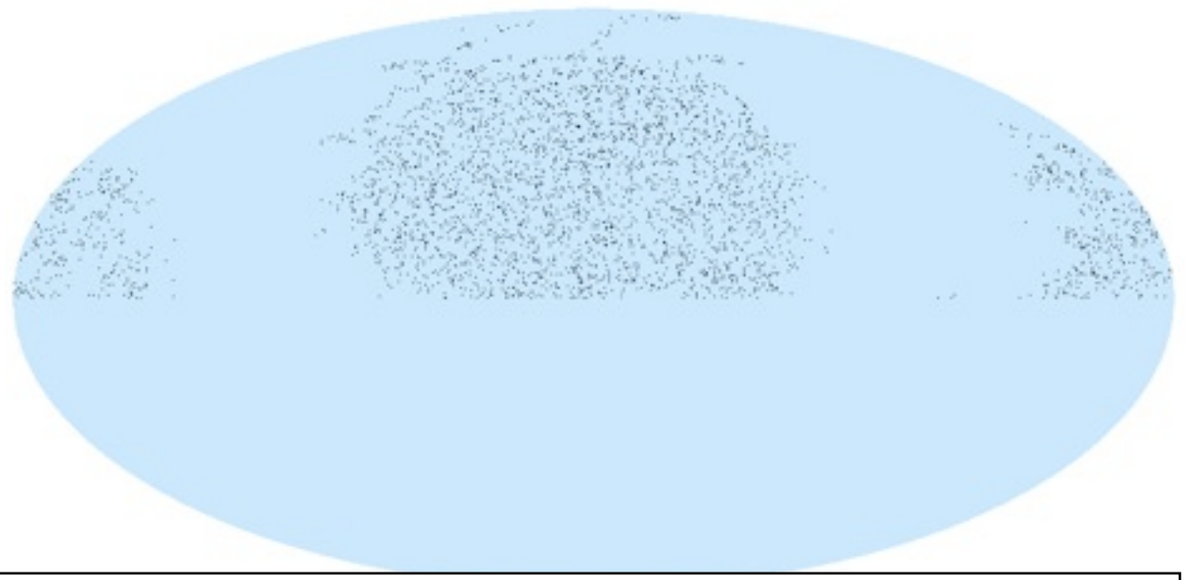
The Data: Splitting them into redshift bins

z=0.45-0.5

z=0.5-0.55

z=0.55-0.6

z=0.6-0.65



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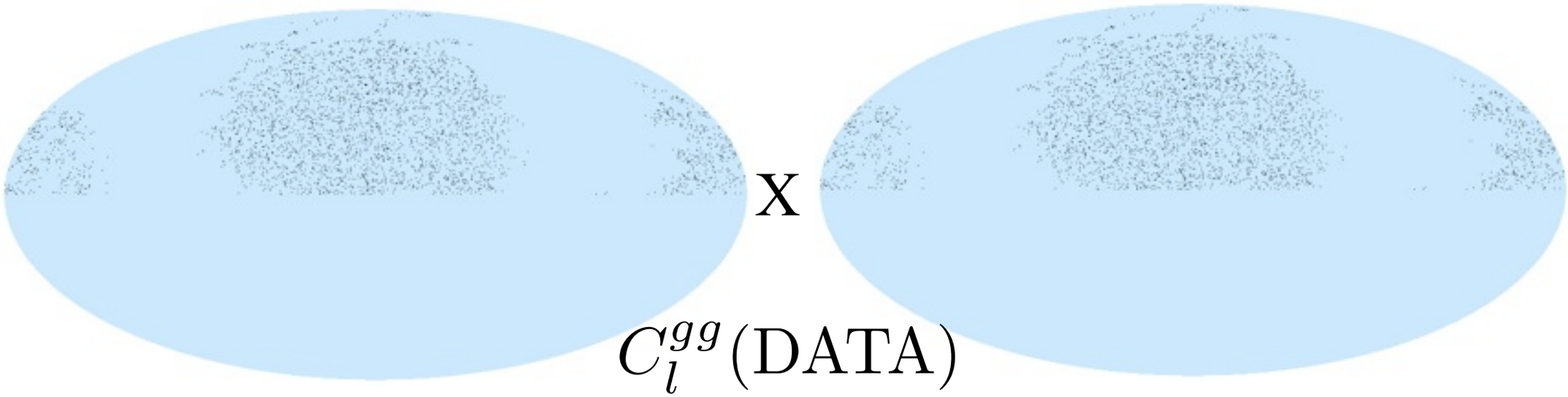
How to do this?

- For each of the redshift bin, we cross-correlates the Luminous Red Galaxies with themselves, and we get the angular power-spectra of the galaxies.



$$C_l^{gg}(\mathrm{DATA})$$

- We want the best measurement of the angular power-spectra possible, from the stand point of not only statistical error, but also systematic errors.
- To get the best statistical errorbar, we apply “Quadratic Estimator”, which are proven to provide:
  - Unbiased Minimum variance measurement of the parameters that are being estimated if the field is gaussian.
  - Many people have worked on this Quadratic Estimators: Hamilton, Tegmark, Bond, Jaffe and Knox, White, Padmanabhan, Hirata, Blake, et al.

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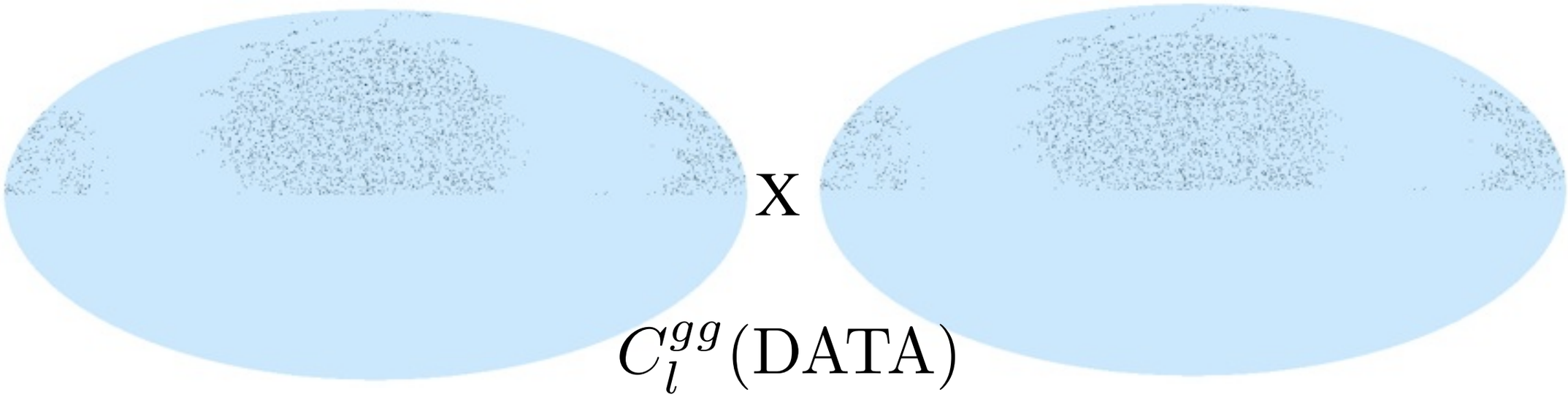

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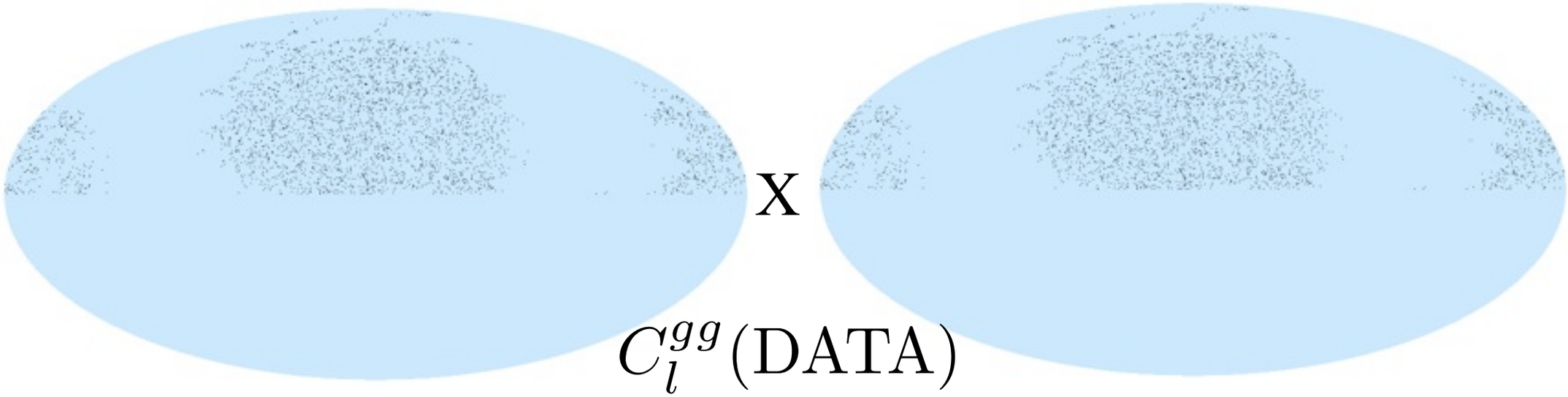

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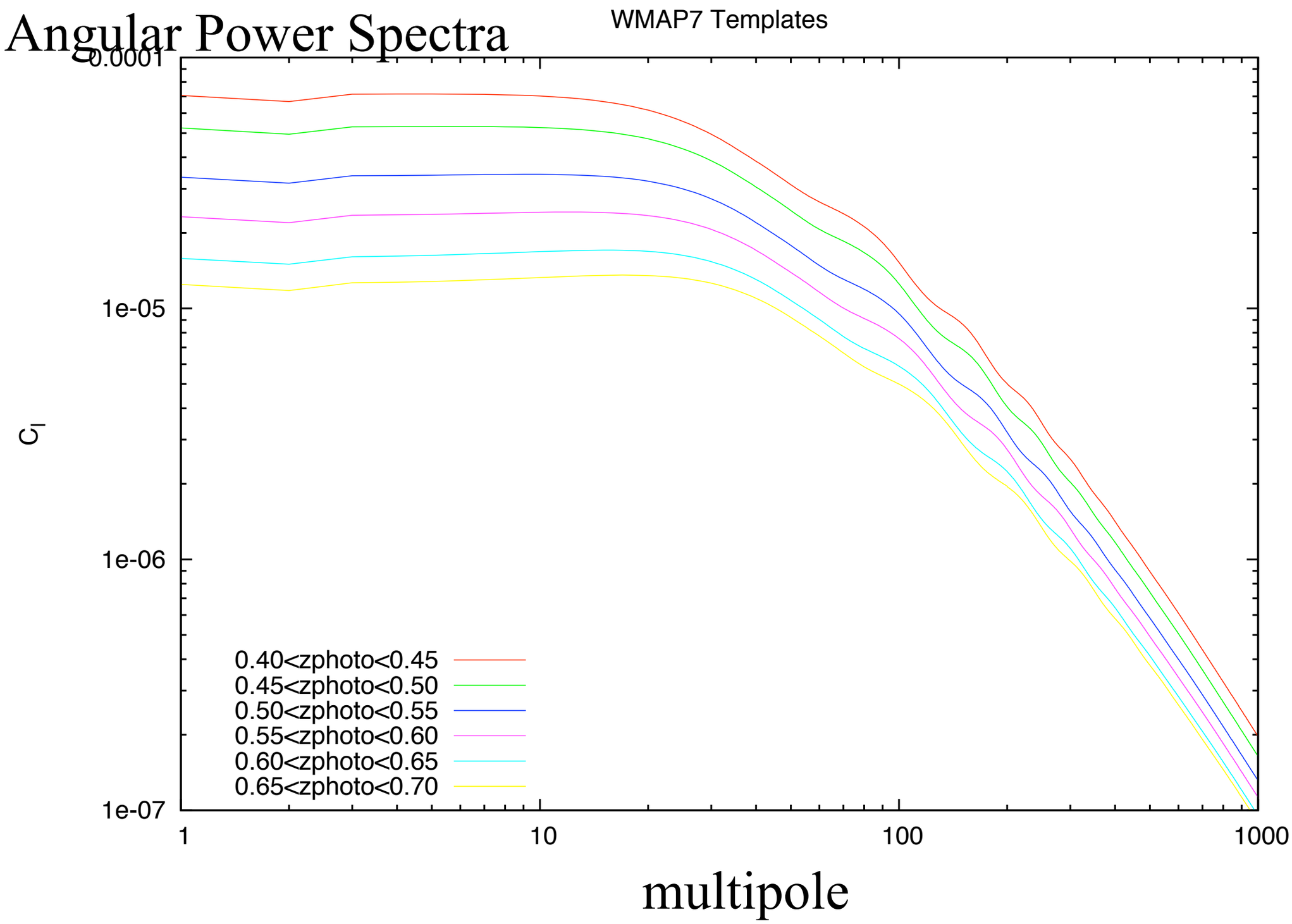
What we expect to see

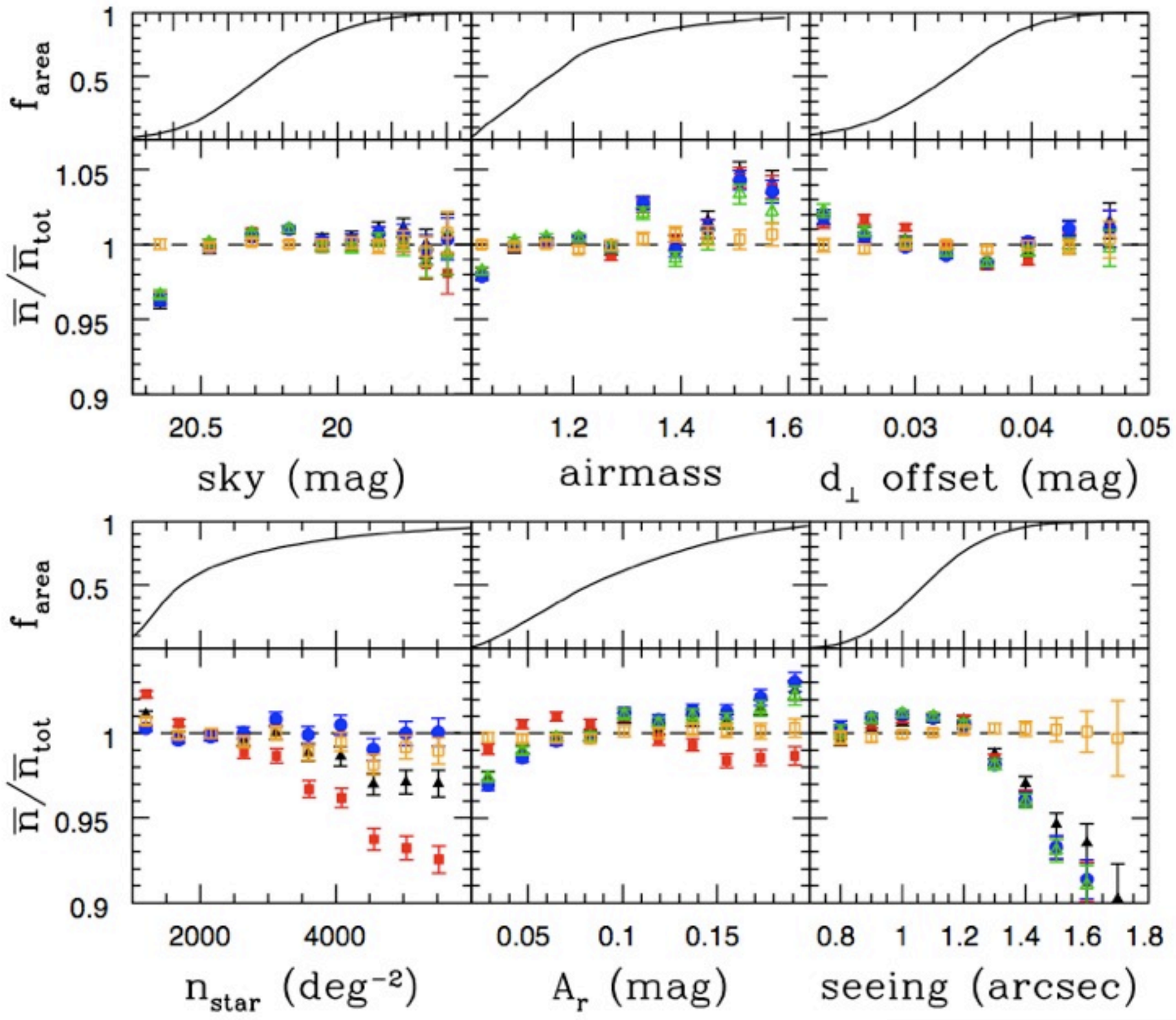


Systematics

- Therefore, the systematics I am going through here are mostly for getting a clean angular power-spectrum which contains information such as the shape of matter power-spectrum, scale dependent bias that can be caused by non-gaussianities at the early Universe.

$$C_l^{gg}(Data) = C_l^{g_{real}g_{real}} + \epsilon_1 C_l^{stars,stars} + \epsilon_2 C_l^{sky,sky} + \epsilon_3 C_l^{c,c} + ...$$

Short summary:



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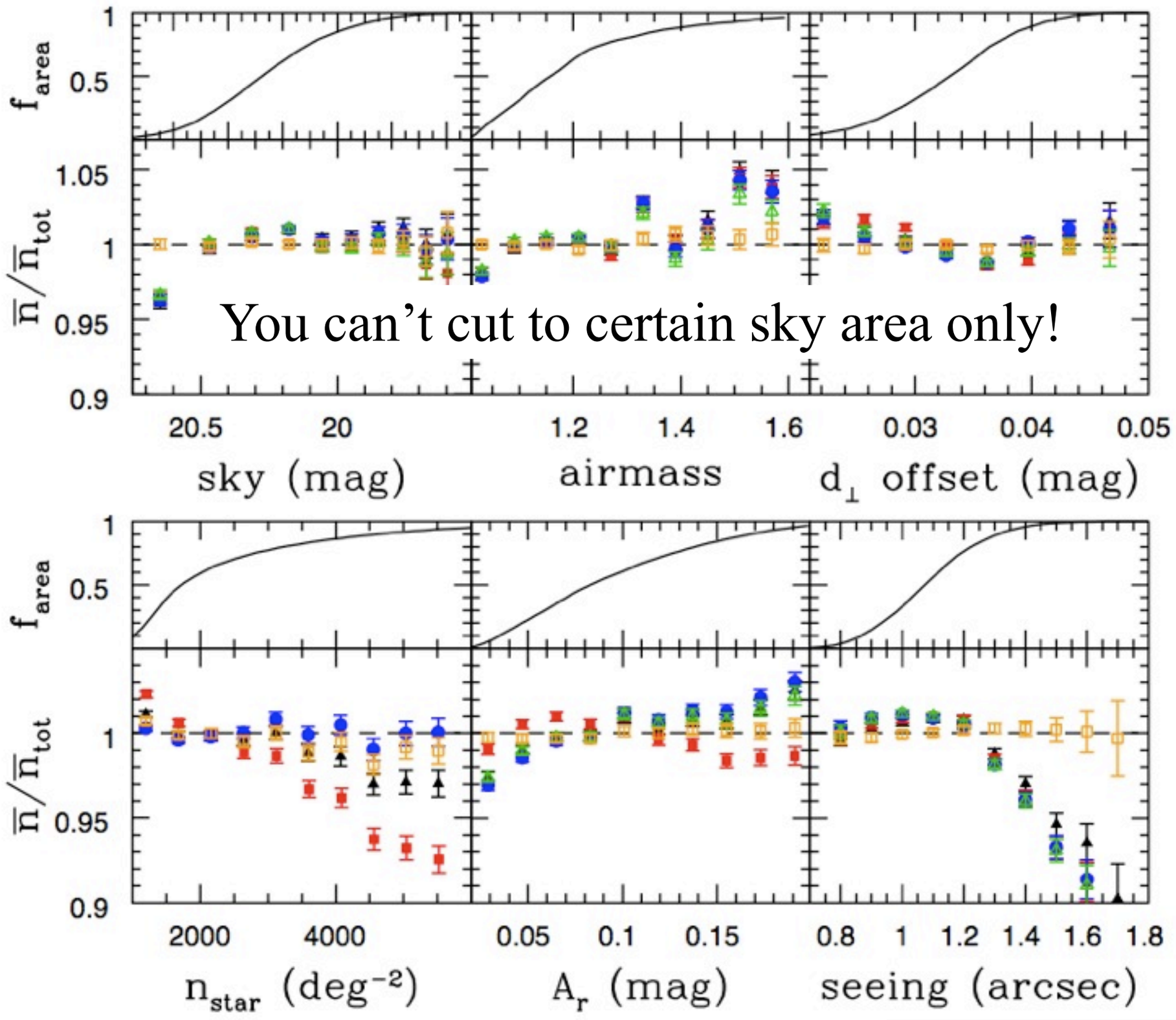

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Real Galaxy Power Stars Sky Brightness Color Offset

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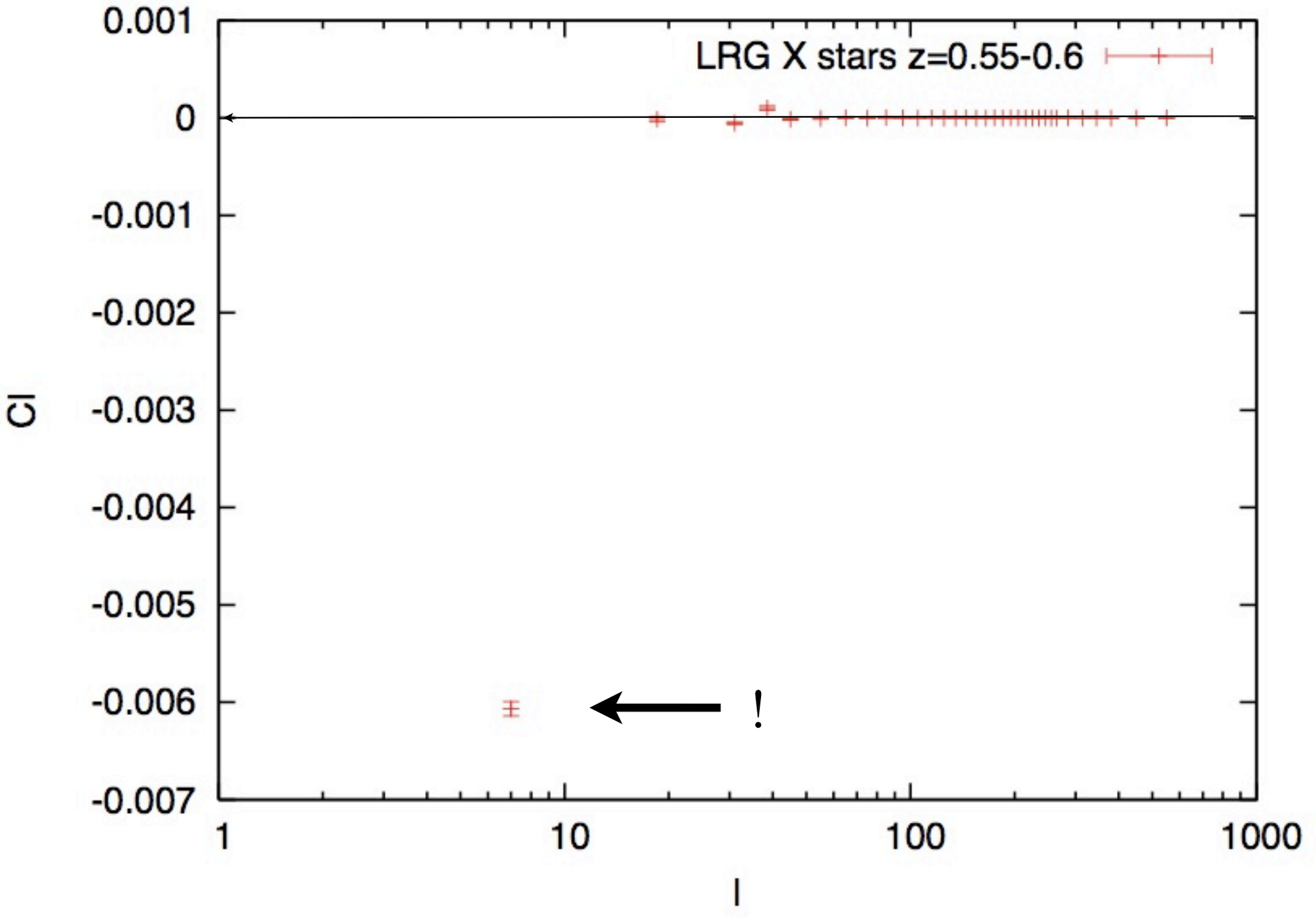
Effect of stars



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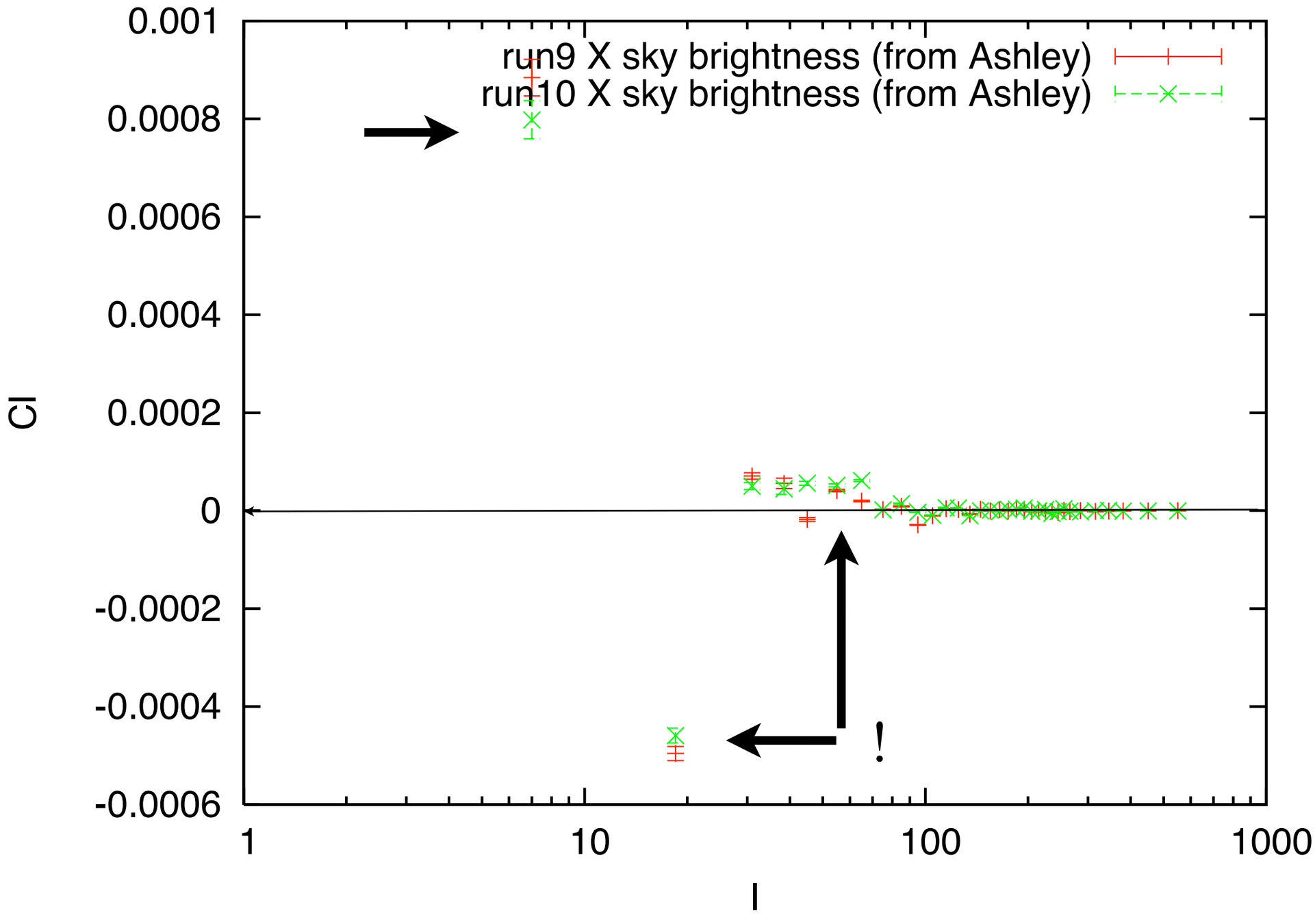
The effect of sky brightness



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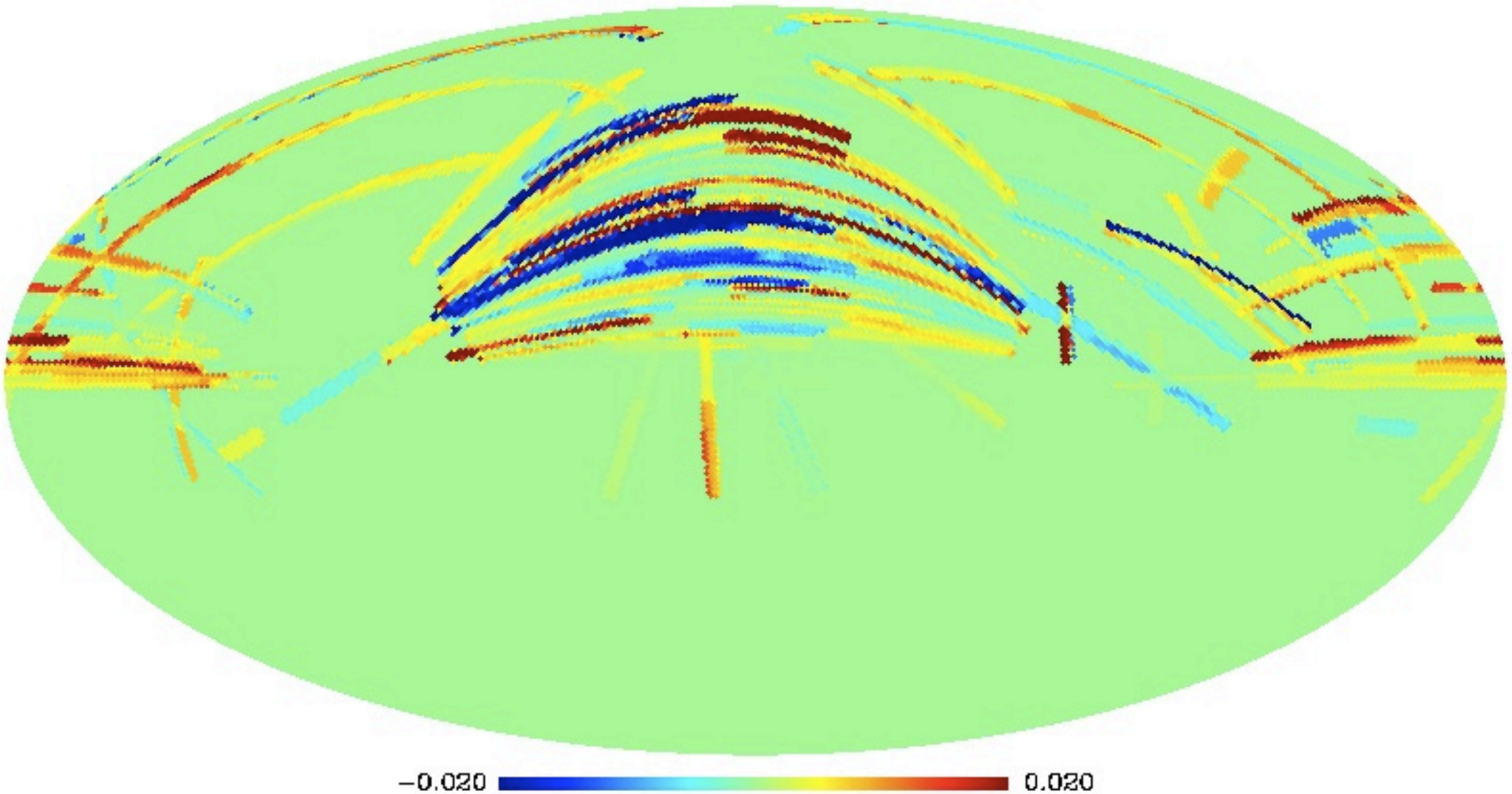
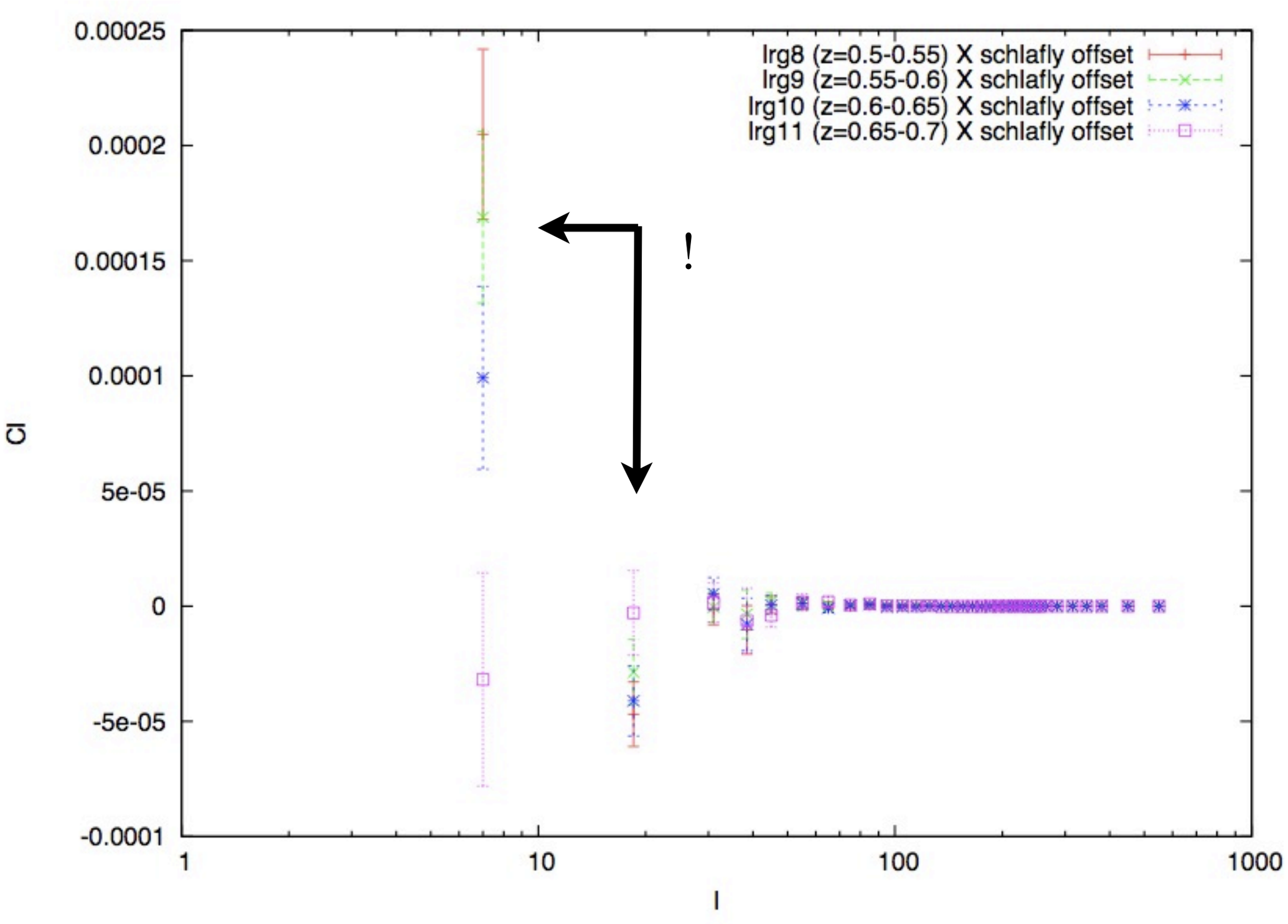
Color offsets

DR8 Color offsets in g-r



Color offsets as discussed in Schlafly et al. 2010

The effect of the color offsets



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Systematics

What can we do when we can’t/ don’t want to cut to a certain l-range?

Systematics: Taking them out of the equation

True galaxy overdensity

Observed galaxy overdensity $\delta_g^o = \delta_g^t + \sum_{i=0}^{N} \epsilon_i \delta_{s_i}$ Various systematics

For example, if i=2 only:

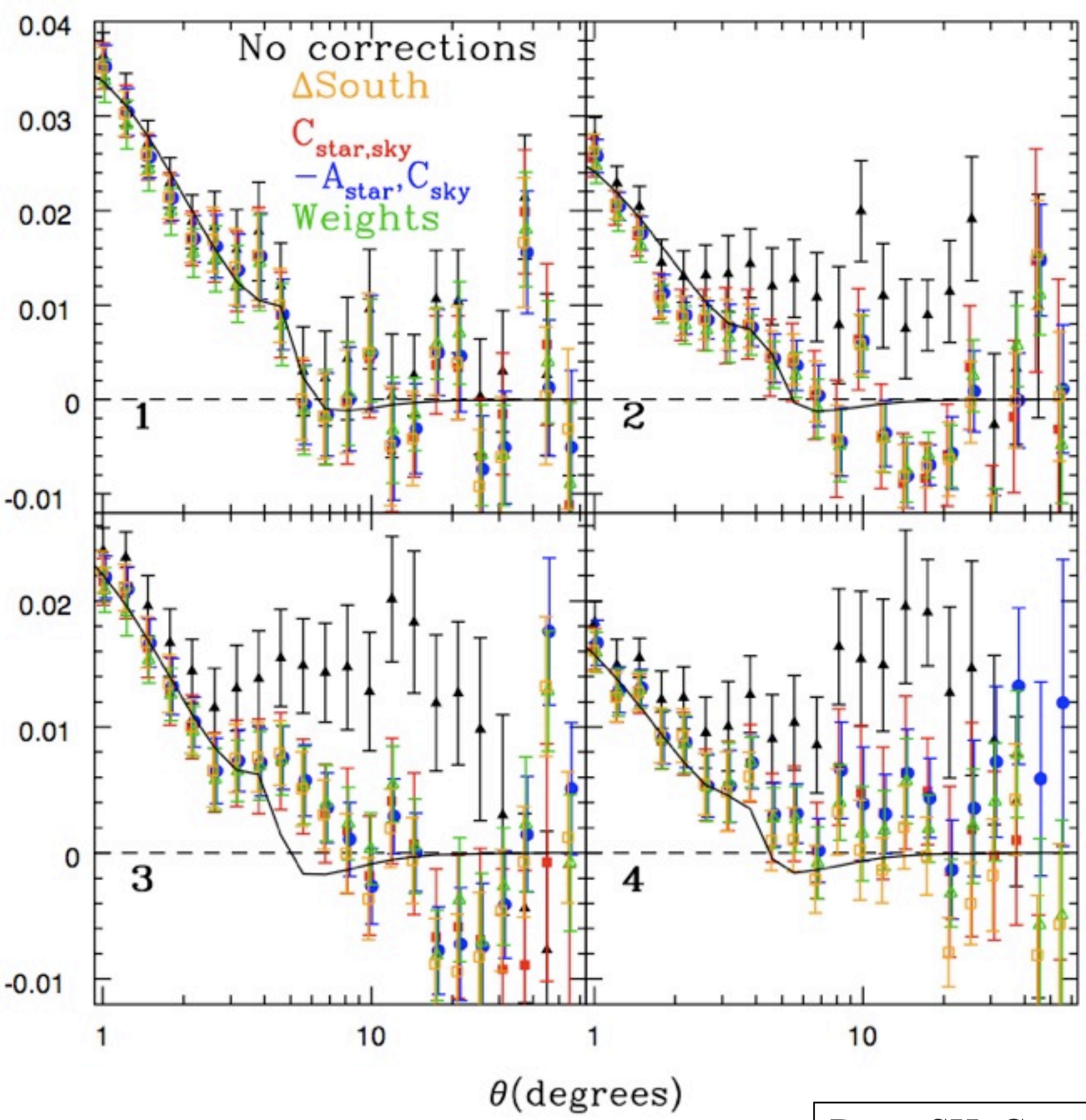
$$< \delta_g^o \delta_{s_1} >=< \delta_g^t \delta_g^t > +\epsilon_1 < \delta_{s_1} \delta_{s_1} > +\epsilon_2 < \delta_{s_2} \delta_{s_1} >$$

$$< \delta_g^o \delta_{s_2} >=< \delta_g^t \delta_g^t > +\epsilon_1 < \delta_{s_1} \delta_{s_2} > +\epsilon_2 < \delta_{s_2} \delta_{s_2} >$$

$$< \delta_g^o \delta_g^o >=< \delta_g^t \delta_g^t > +\epsilon_1^2 < \delta_{s_1} \delta_{s_1} > +2\epsilon_1 \epsilon_2 < \delta_{s_2} \delta_{s_1} > +\epsilon_2^2 < \delta_{s_2} \delta_{s_2} >$$

We also need to take into account of all the covariances between systematics and across different band power

SH, Ross, Cuesta, Seo, White, Schlegel et al. (in prep)



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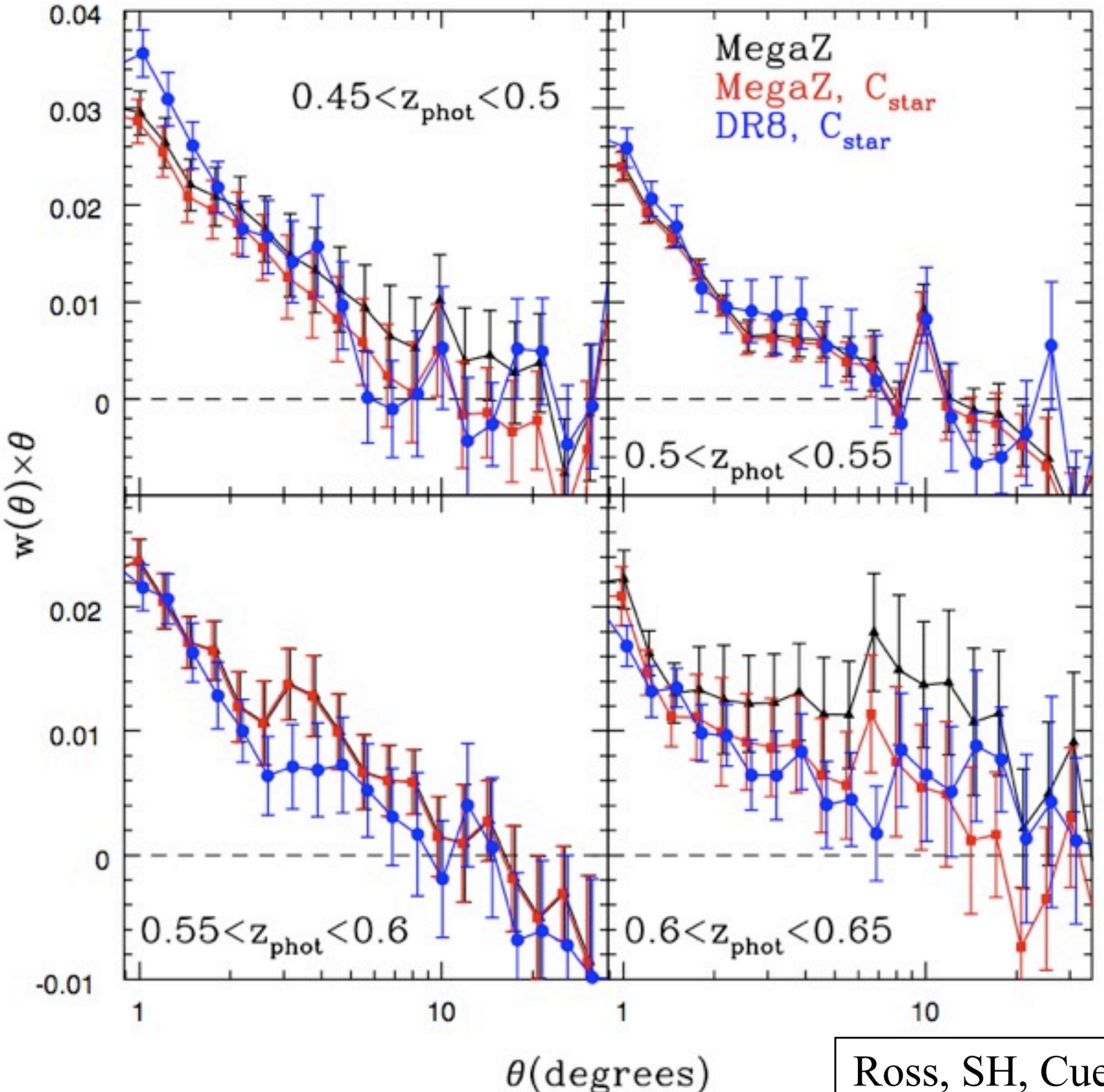

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Conclusions

- **Systematics, systematics...**
- **Cross-correlations with systematics can be very useful in not only detecting them, but also removing the systematics.**
- **Systematics can easily give spurious signals that mimick large scale power.**
- **The analysis shown earlier are mostly concentrated on the LRGs, but the systematics with quasars are fairly similar.**

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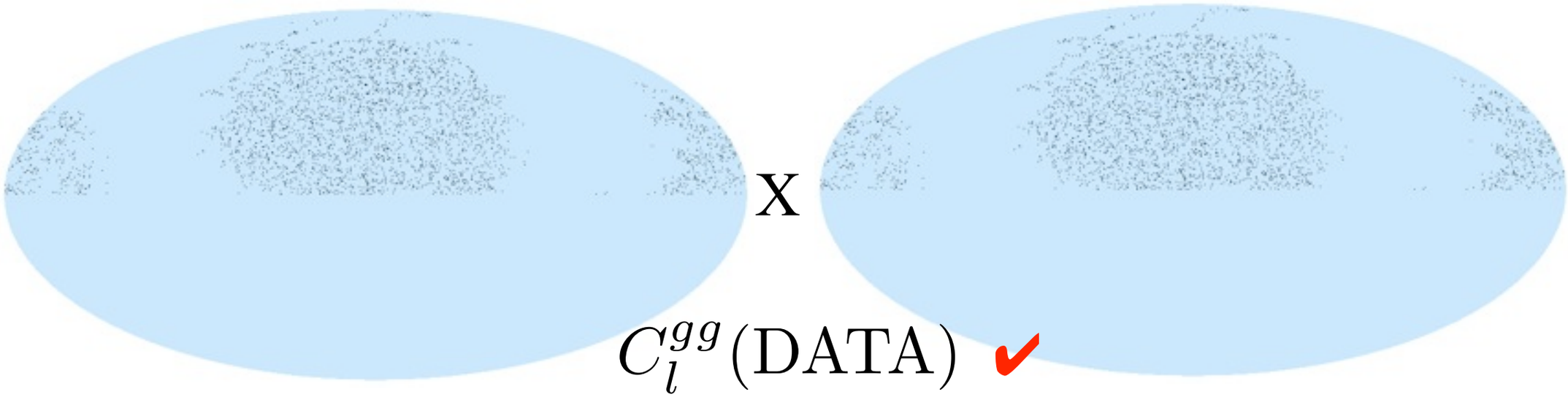

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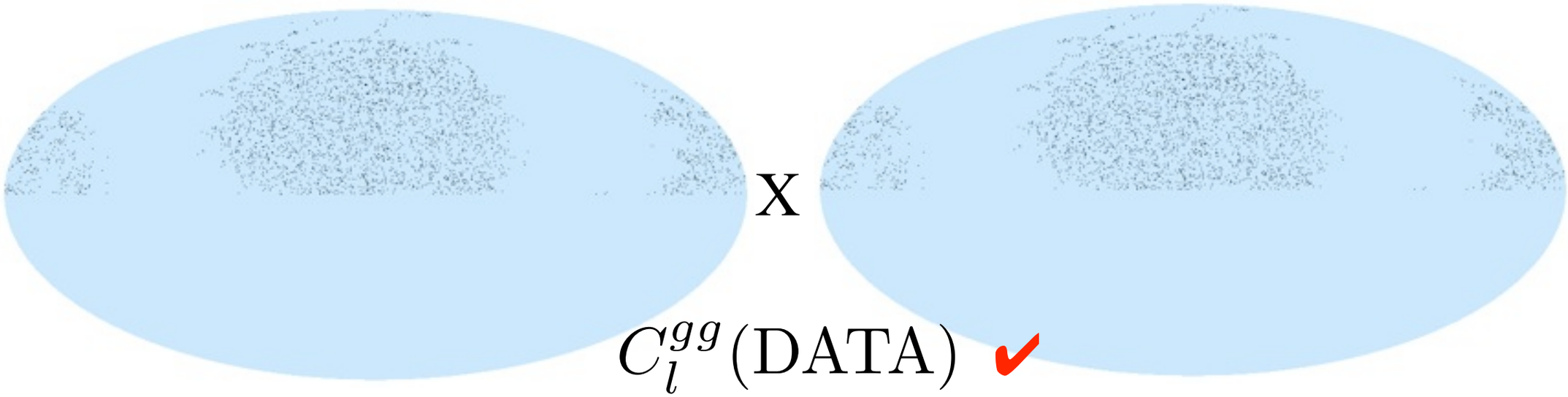

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- But in order to derive cosmological constraints, we need to be able to predict the angular power-spectra given any cosmological models.
- That's why: we need the **theory**:

$$C_l^{gg} = \int dz \frac{H_0}{c} b^2(z)(dN/dz)^2 D^2(z) P(\frac{l+\frac{1}{2}}{\chi})$$

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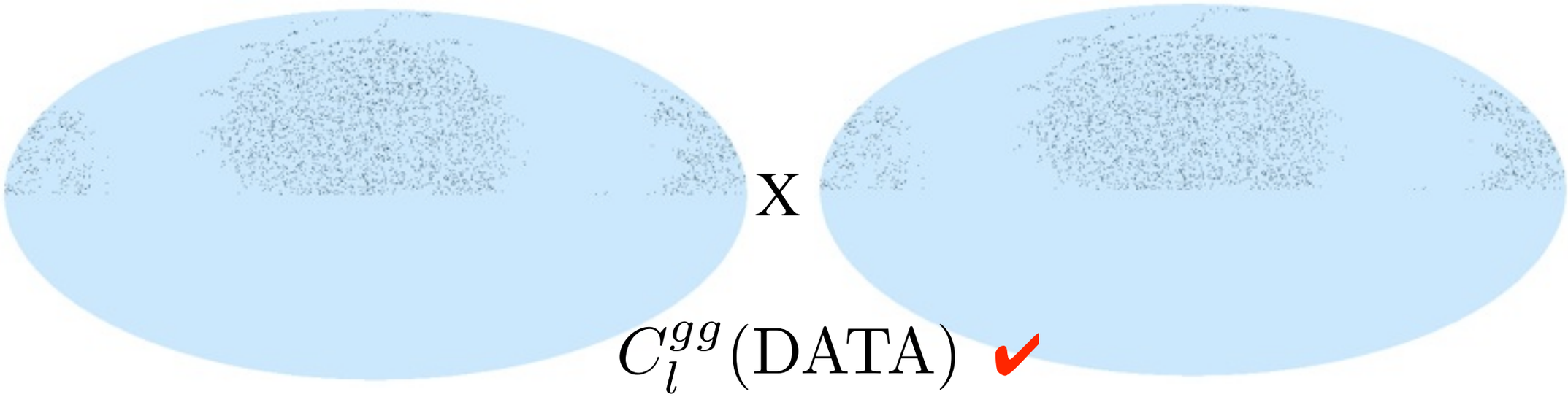

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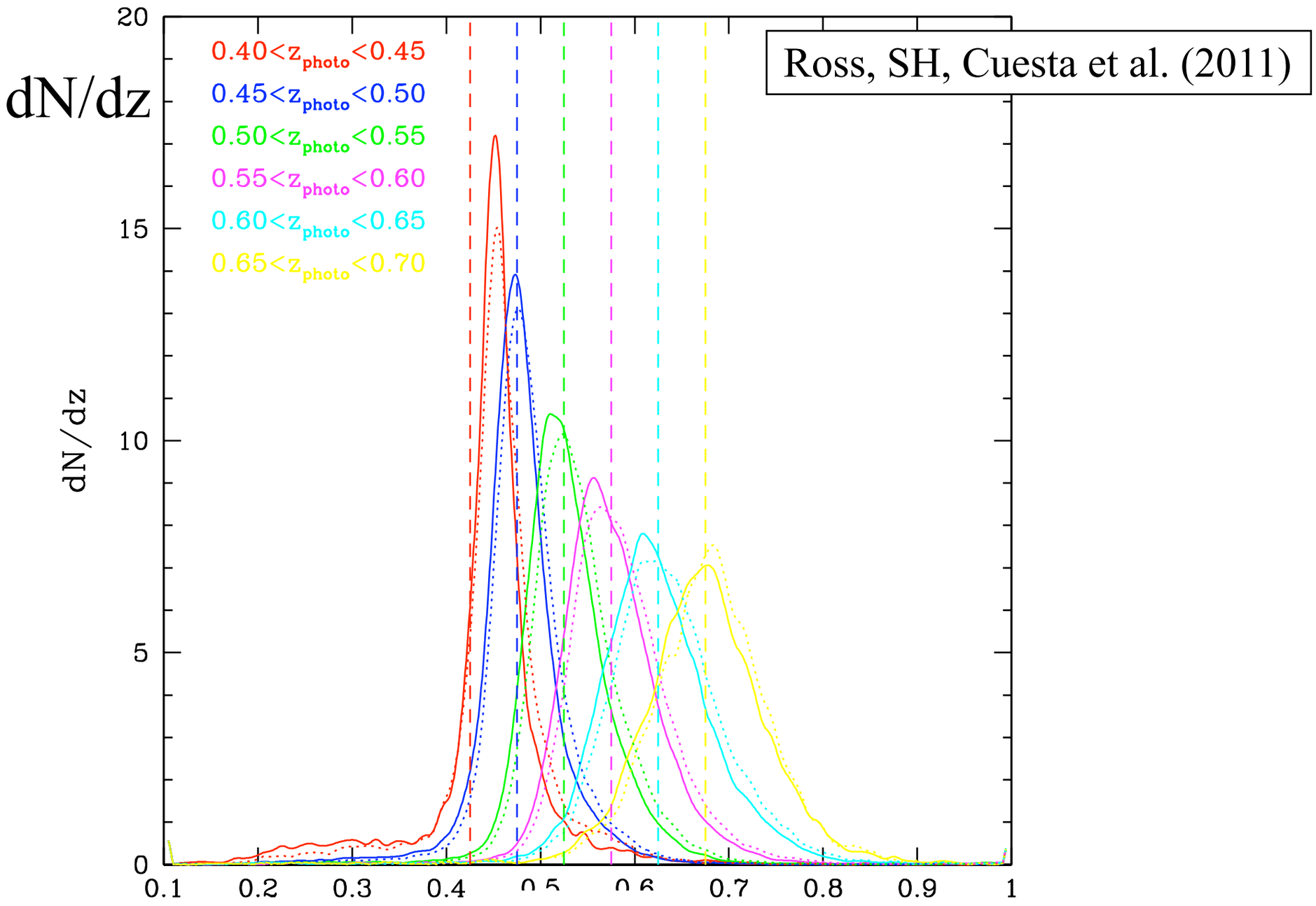
- Given a cosmological model, we can predict the theory, except we need two inputs: bias b(z) and redshift distribution dN/dz.

BAO: with Luminous Red Galaxies
The Data: Redshift distribution

SDSS III has been taking spectra of all of these photometric LRGs, therefore, we have an unbiased spectroscopic confirmation of the photometric redshifts for ~10% of the sample, therefore, we have very good understanding of the redshift distribution of the sample.



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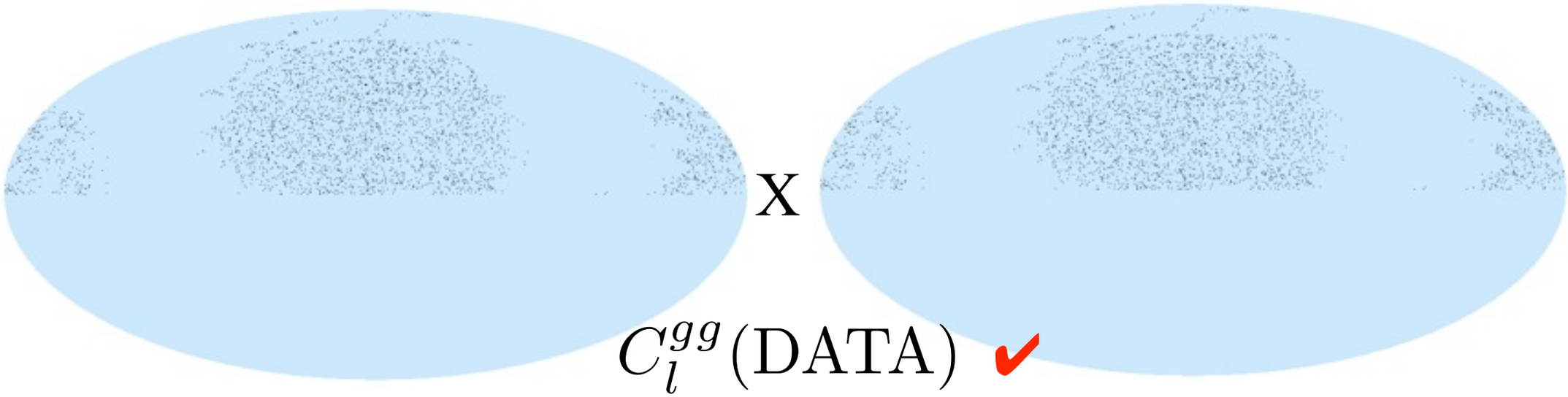

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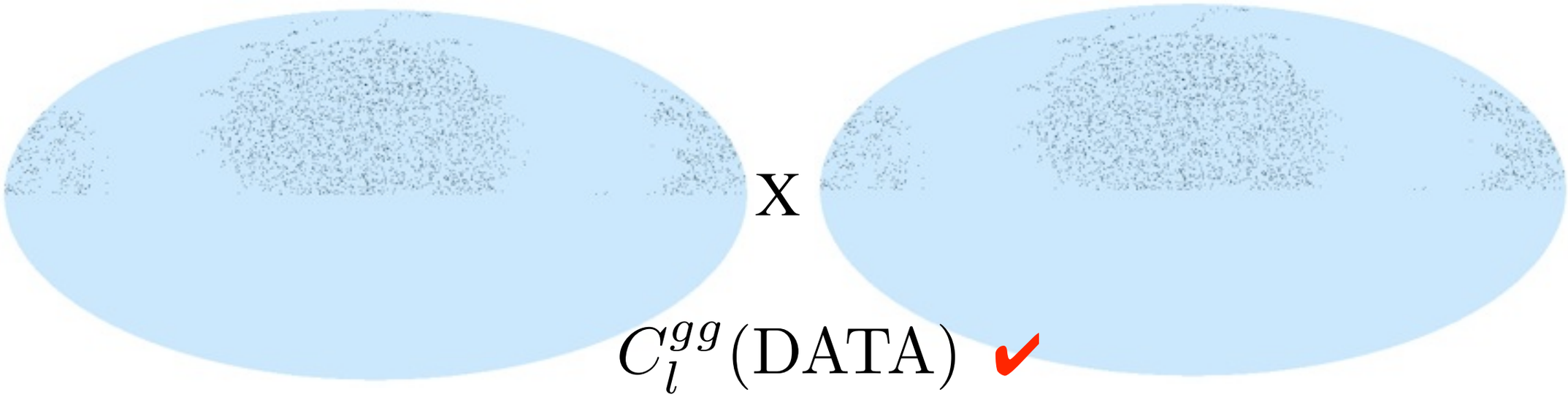

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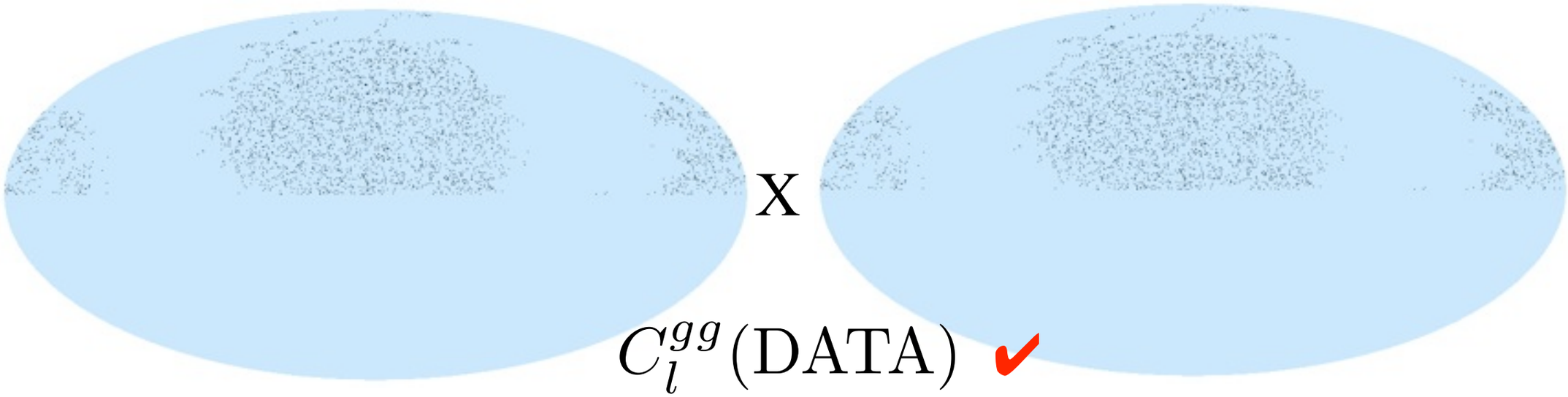

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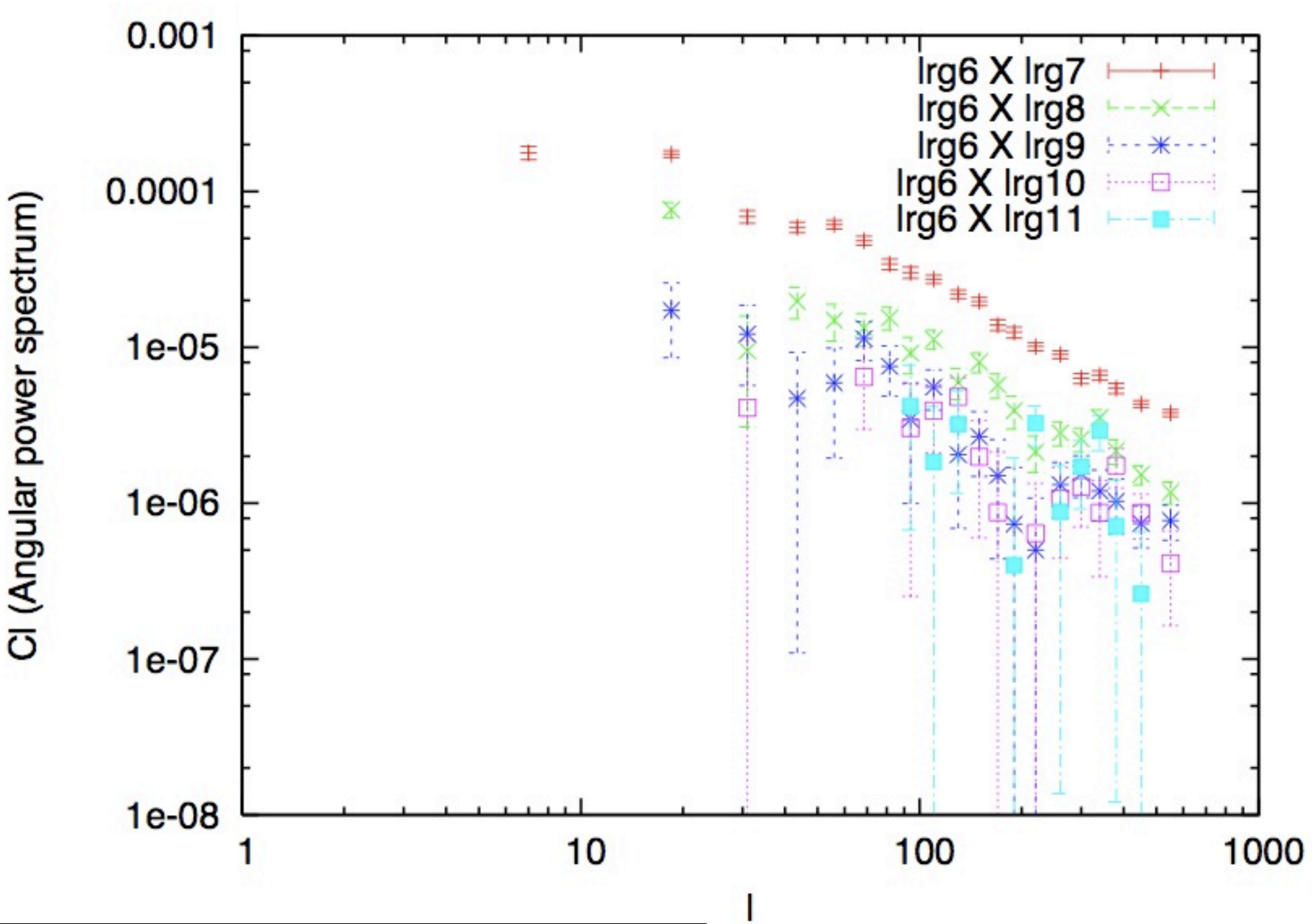
Overlap of the redshift bins



Ho, Ross, Seo, White, Schlegel et al. (in prep)

BAO: with Luminous Red Galaxies
Systematics

- The Reason why BAO become so popular is that it is one of the cleanest probe of cosmology, since there are not that many systematics that can cause a shift in BAO scale (~100 Mpc)
- Therefore, the systematics I am going through here are mostly for getting a clean angular power-spectrum which contains other information such as the shape of matter power-spectrum, scale dependent bias that can be caused by non-gaussianities at the early Universe.

Color offsets: We compute cross-correlations between all of the photometric offsets (from Schlafly et al. 2010)

$$C_l^{gg}(\mathrm{DATA}) = \mathrm{b}^2 \mathrm{C}_\mathrm{l}^{\delta_\mathrm{m}\delta_\mathrm{m}} + \mathrm{C}_\mathrm{l}^{\mathrm{d,d}} + \mathrm{C}_\mathrm{l}^{\mathrm{s,s}} + \mathrm{C}_\mathrm{l}^{\mathrm{g(z),g(z')}} + \ldots$$

Dust Extinction:
We cross-correlate the extinction map (SFD) with the galaxies to see if there is any correlations.

Stellar Contamination:
We cross-correlate the stellar density maps (generated from SDSS) with the galaxies.

Galaxies from next photometric slice:
We compute all the correlations between different redshift slices, and take into account of the covariances and correlations between different slices.

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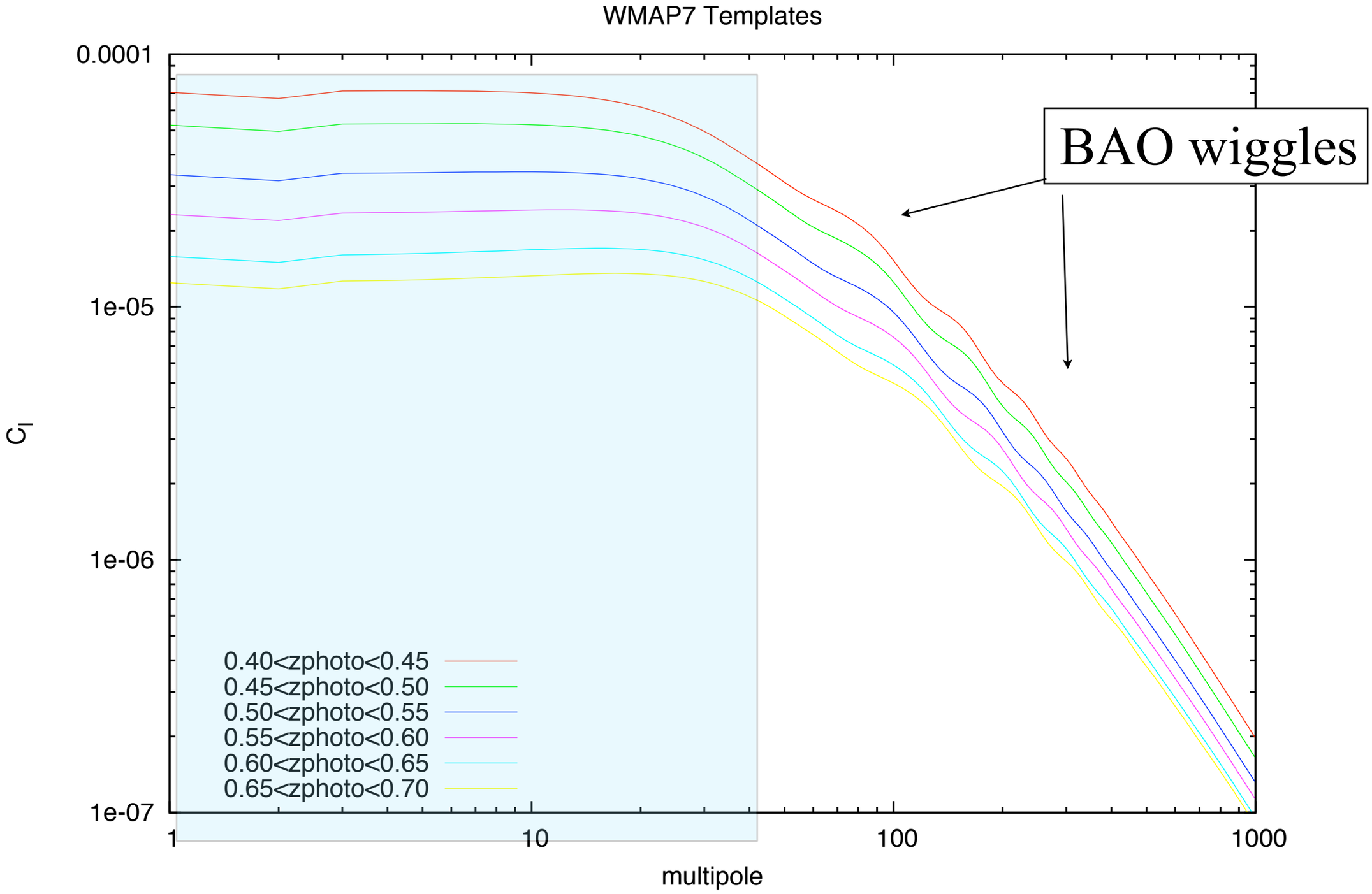
Dust Extinction

Stellar Contamination

Galaxies from next photometric slice

If we don't take out the systematics, we won't be able to trust the power-spectra until at least **l> 40**

Remember? What we expect to see



Physics of Angular Clustering

$b = \frac{\delta g}{\delta \rho}$ describe how galaxies are related to cold dark matter

$\frac{dN}{dz}$ describe how many galaxies are there at each dz bin

$D(z)$ describe how matter grows

$P(\frac{l+\frac{1}{2}}{\chi})$ describe how matter cluster (matter powerspectrum, describes the rms fluctuations)

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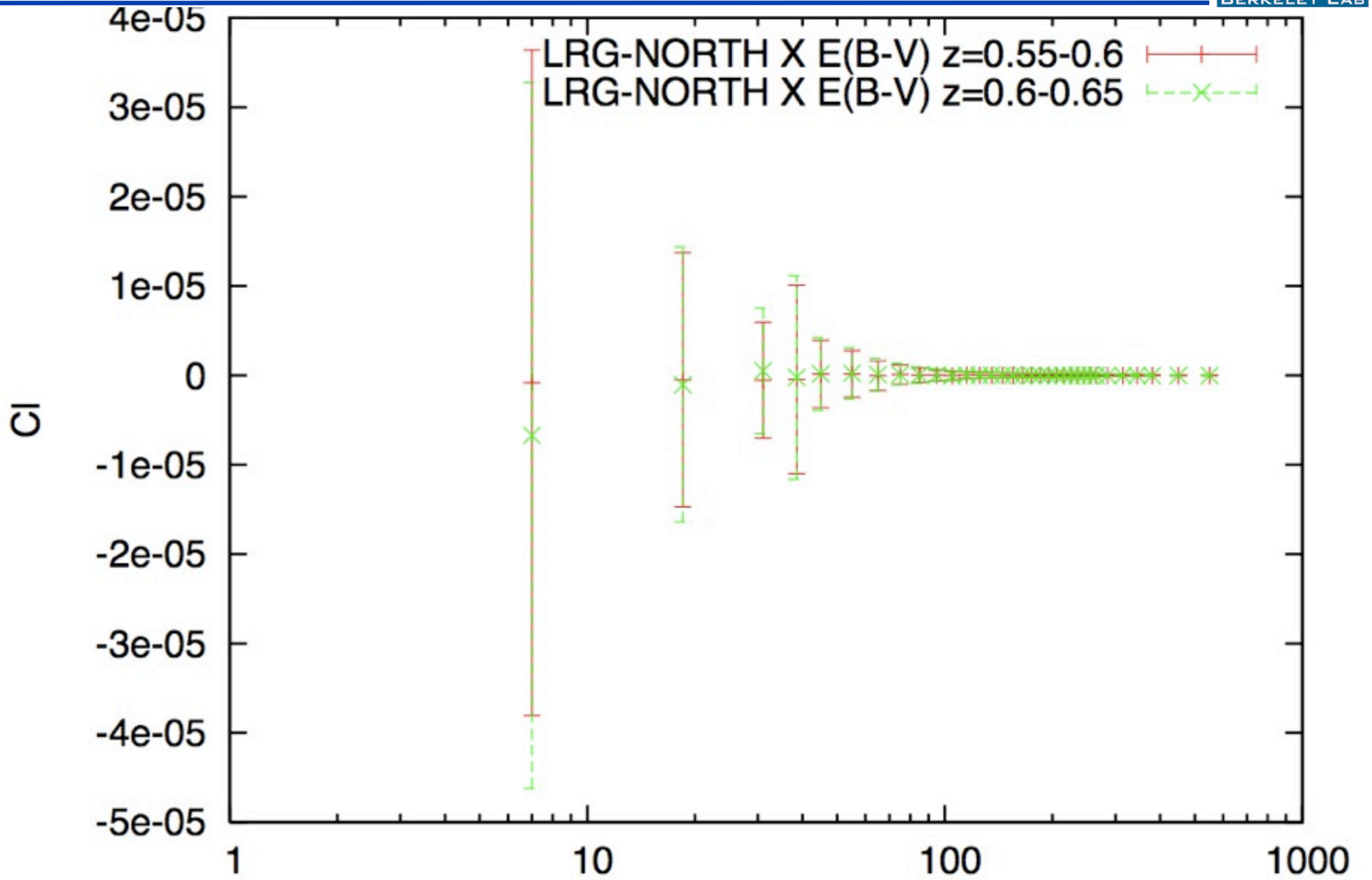
Galaxy Angular power-spectrum contains a wealth of cosmological information ranging from

a) What is **dark energy**? to

b) What happened at the very early Universe? Inflation? What kind?

The effect of dust extinction



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