A closer look at dust decorrelation in Planck data

Chris Sheehy
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Simplest foreground models

- The simplest phenomenological sky model is that, at any frequency, the observed sky is the linear combination of fixed component templates:

  $$\mathbf{map(f,\Omega) = a_1(f)*comp_1(\Omega) + a_2(f)*comp_2(\Omega) + \ldots}$$

- One form of foreground complexity is strangeness in a(f), e.g. deviation of dust from a modified blackbody, synchrotron curvature, etc.

- Another form is if a is a function of both frequency and line of sight, so that **a = a(f,Ω)**

- If so, the foreground component at f_1 is not simply a scaled version of the foreground component at f_2

Decorrelation

- If a = a(f,Ω), then the correlation coefficient R between a foreground component at different frequencies is <1.
- If this is not accounted for, the result is an **upward bias on r.** Even if accounted, for produces an increase in σ_r.

Dust decorrelation

- 353 and 217 GHz BB are dominated by dust at both 353 and 217, with a small lensing contribution at sub-degree scales. A recent Planck paper (Planck Intermediate Paper L, “PIP L”) uses these two maps to test the no decorrelation hypothesis R=1.

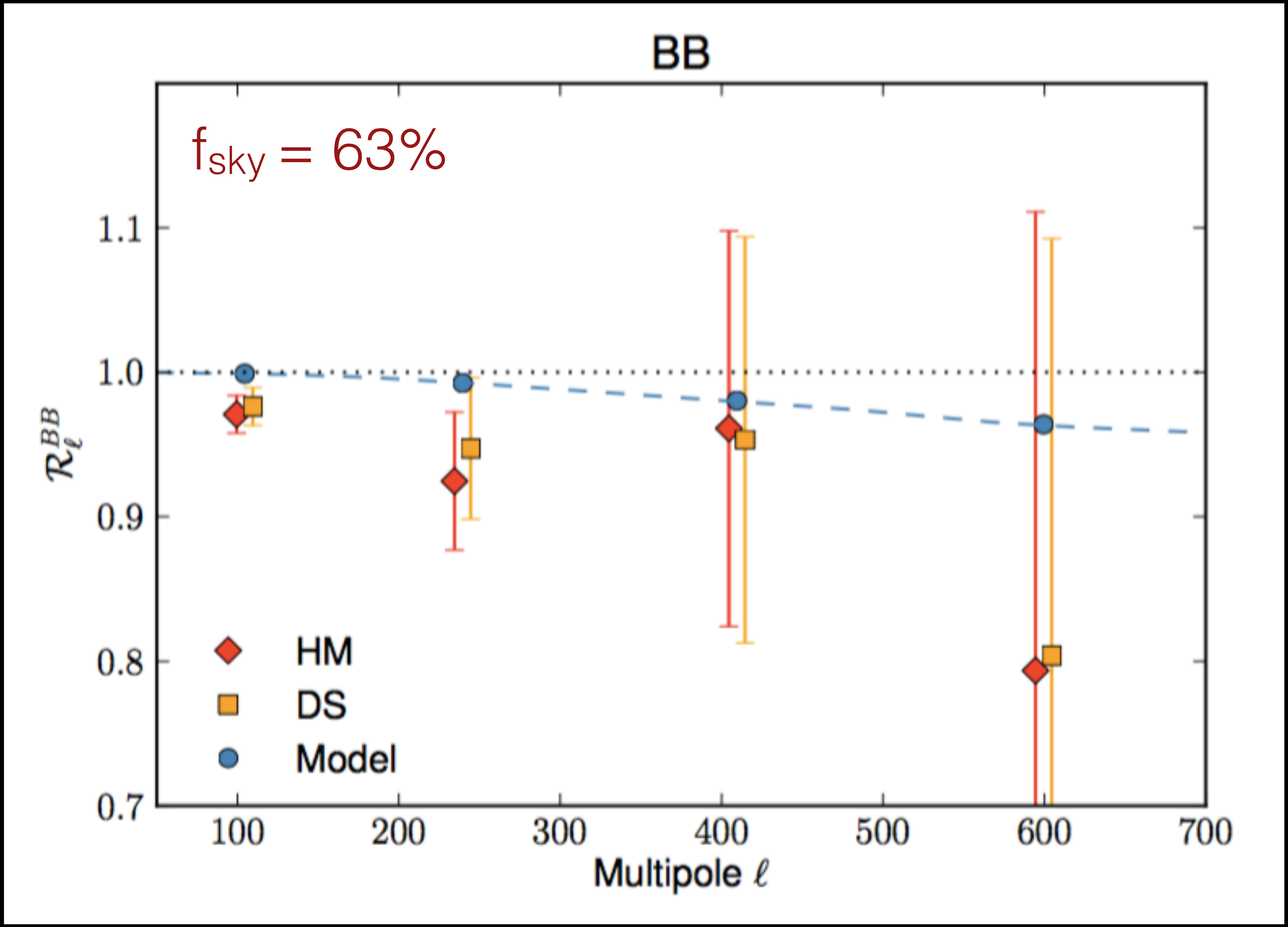
- Computes correlation coefficient as function of multipole:

$$R_l^{BB} = \frac{C_l^{217x353}}{[C_l^{217x217}\, C_l^{353x353}]^{1/2}}$$

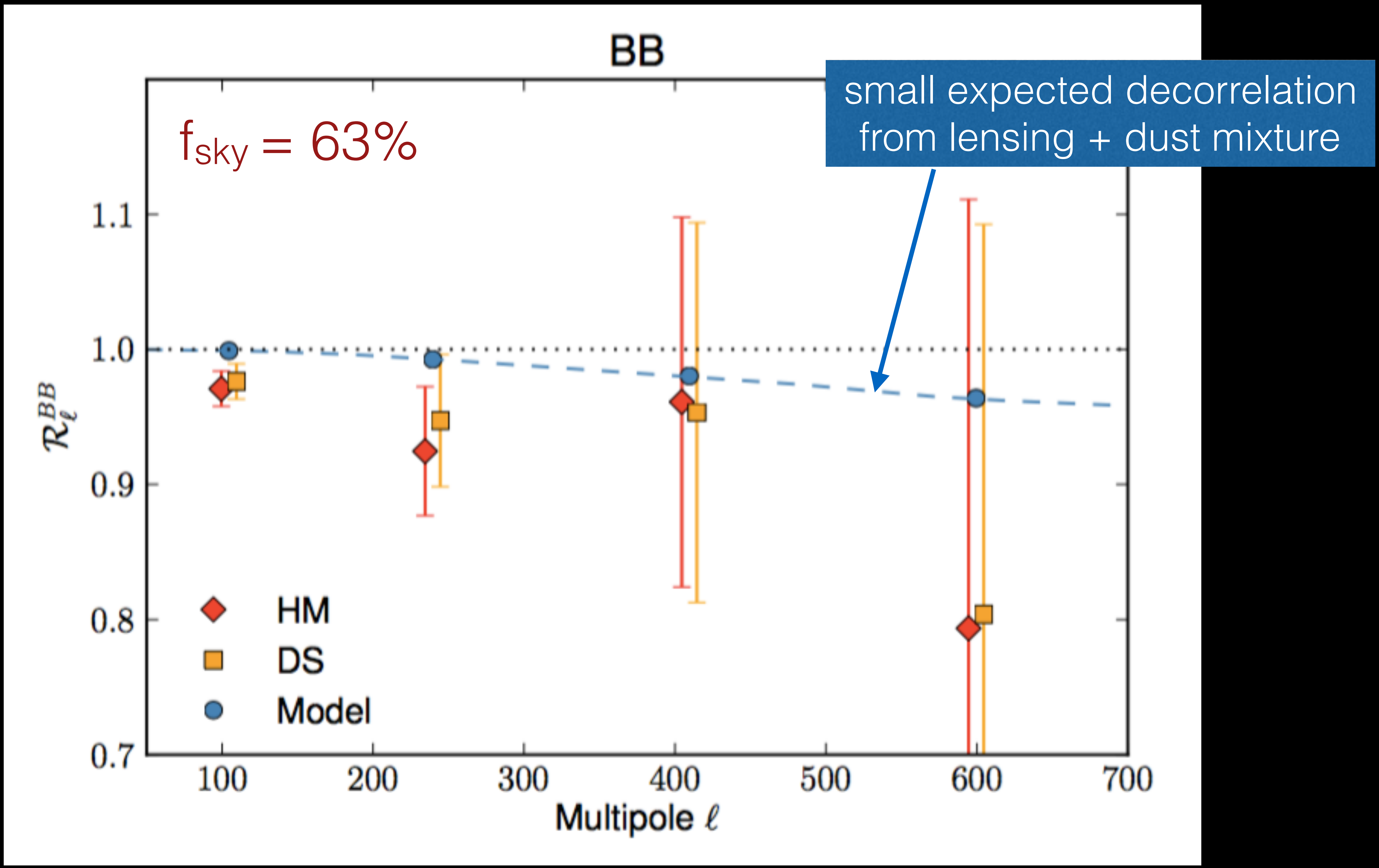
- To avoid noise bias in the auto spectrum terms in denominator, uses cross spectra between data splits (e.g. half mission or detector set).

- Unbiased by anything that multiplies C_l, like beam window function.

PIP L


BB
f_{sky} = 63%
1.1
1.0
0.9
0.8
0.7
$\mathcal{R}_\ell^{BB}$
HM
DS
Model
100
200
300
400
500
600
700
Multipole ℓ

PIP L



BB
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small expected decorrelation from lensing + dust mixture
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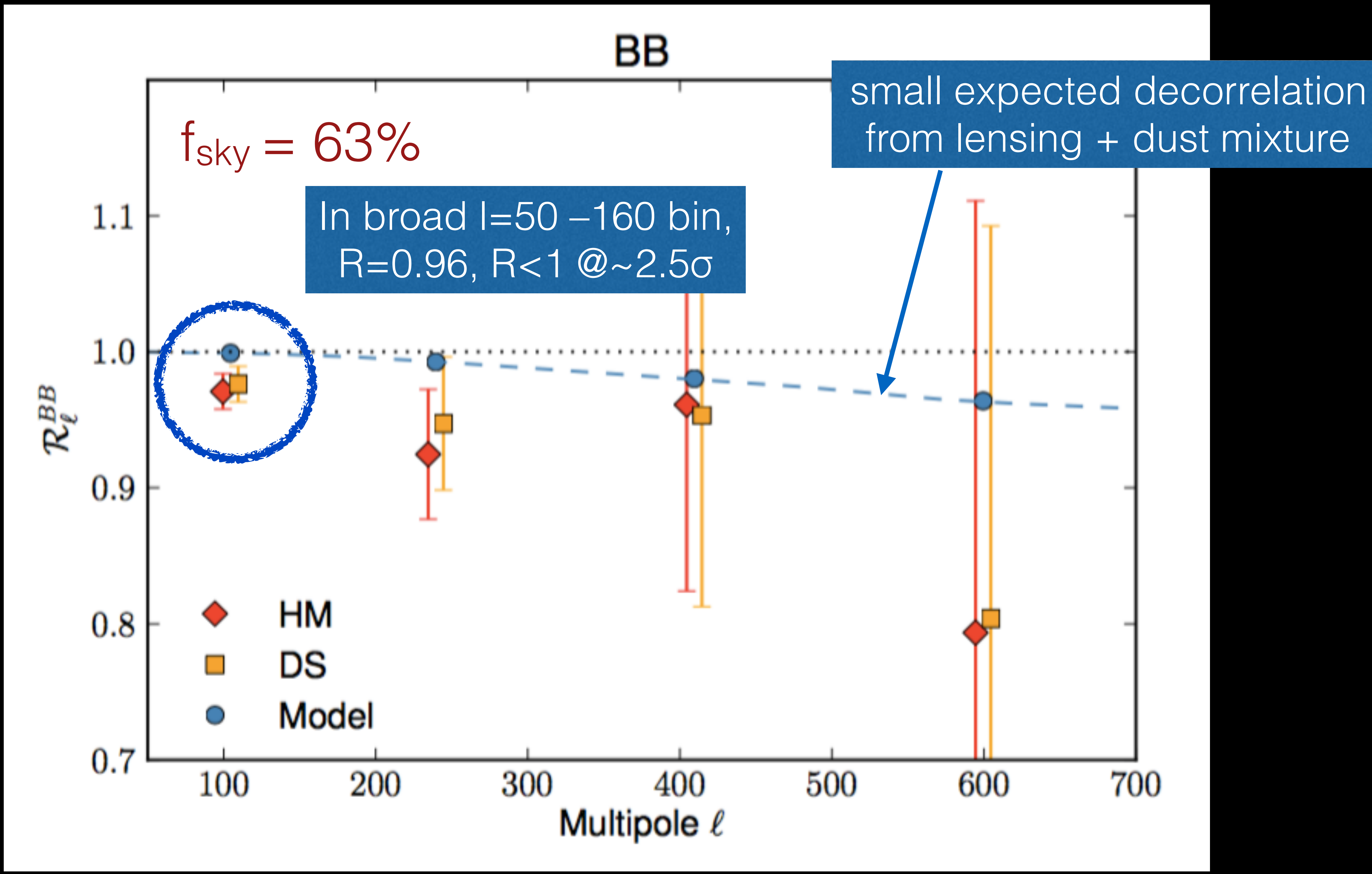
BB
f_{sky} = 63%
In broad l=50 –160 bin,
R=0.96, R<1 @~2.5σ
small expected decorrelation
from lensing + dust mixture
HM
DS
Model
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1.0
0.9
0.8
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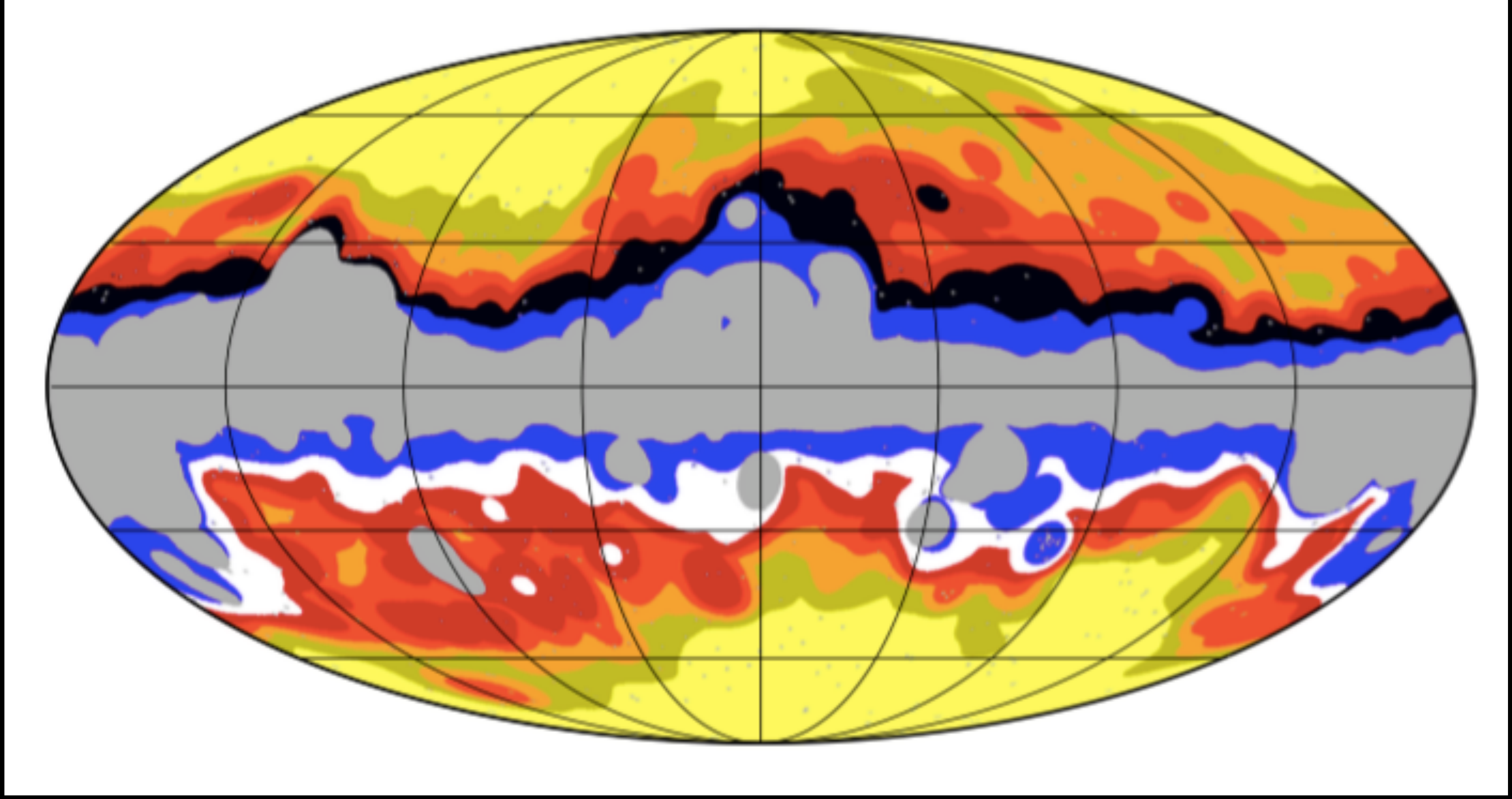
Multipole ℓ
$\mathcal{R}_\ell^{BB}$

PIP L

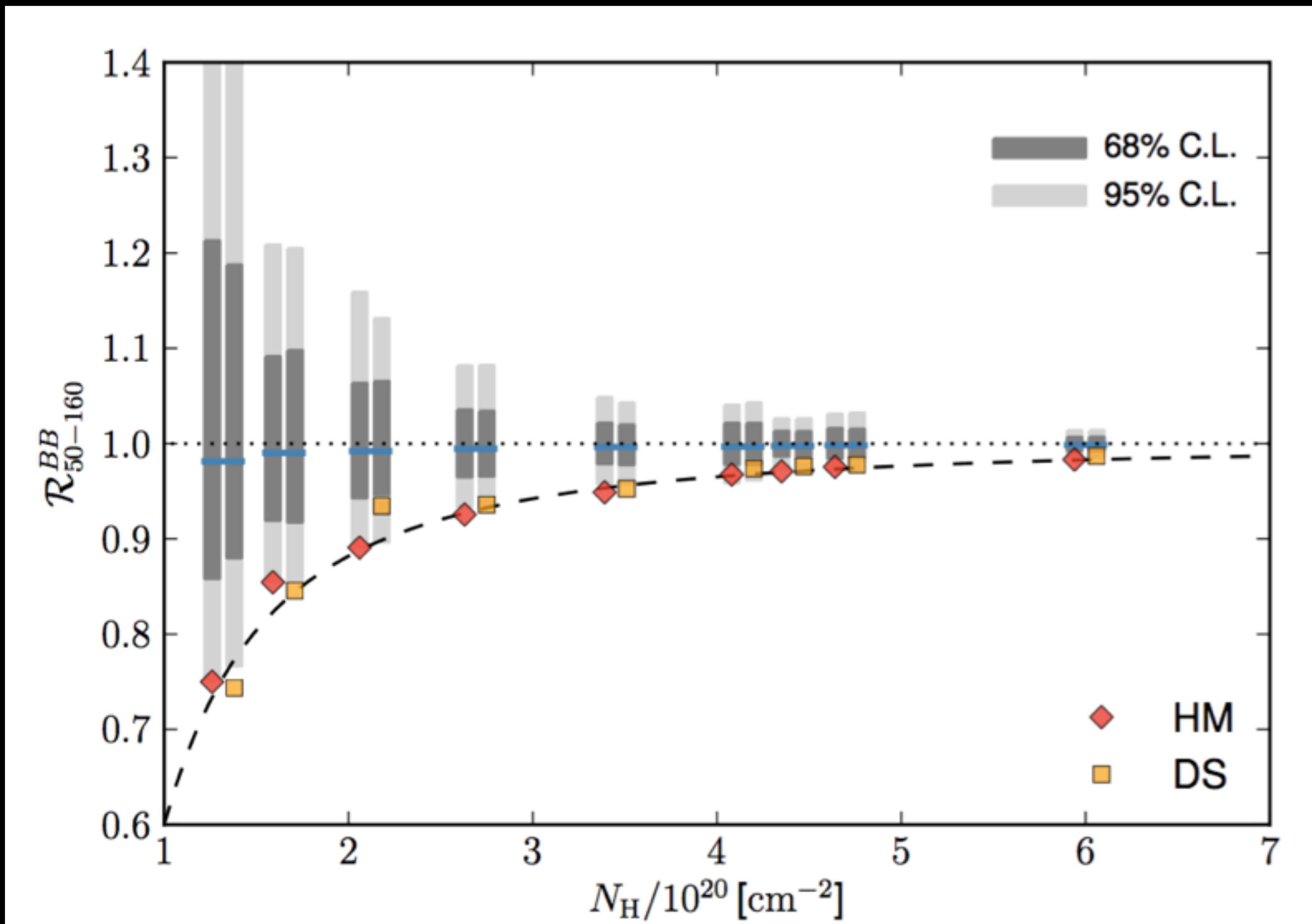
Repeat analysis of $R_{l=50—160}$ in different nested sky regions.



PIPL

PIP L

Plotted as function of mean HI column density



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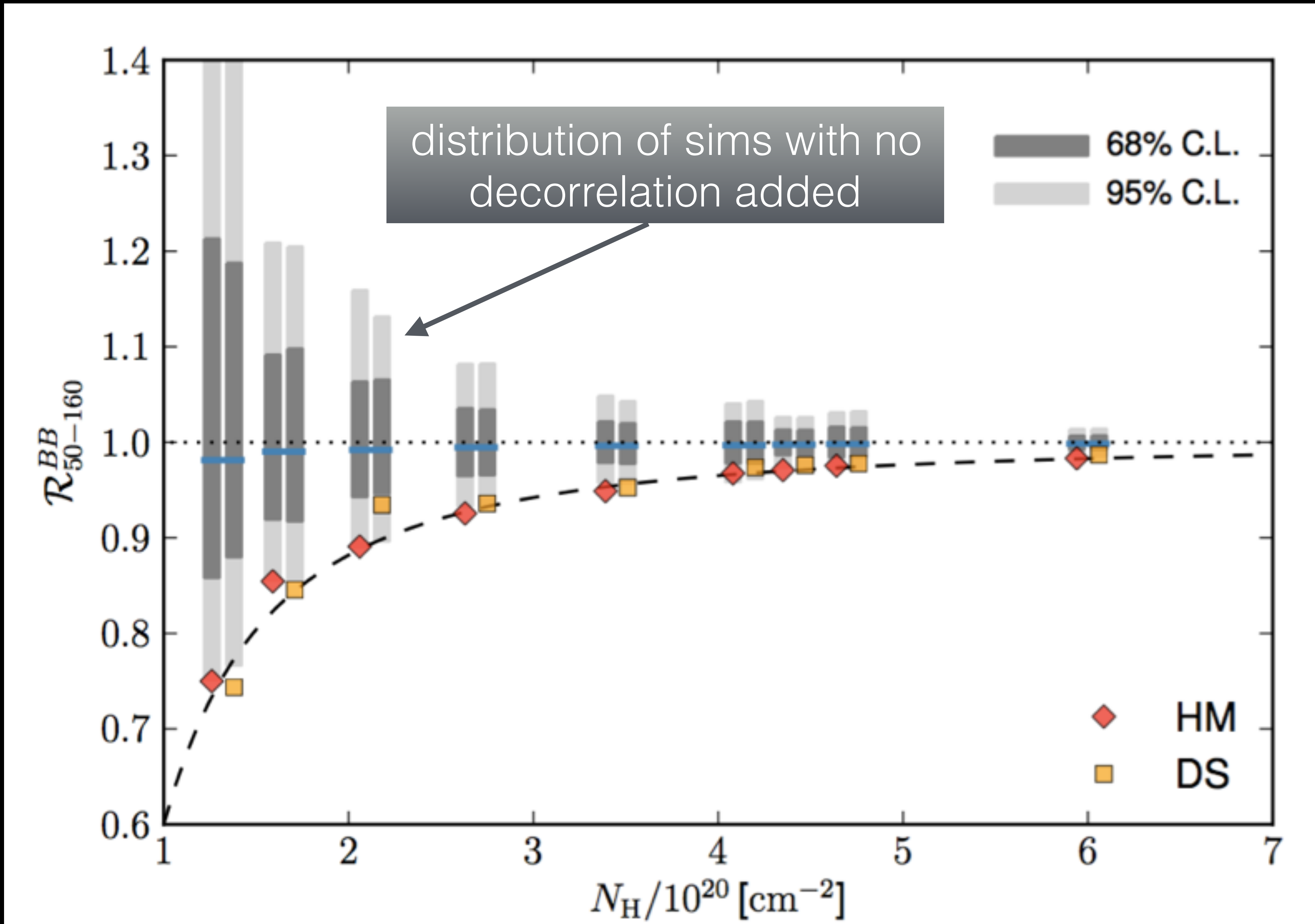

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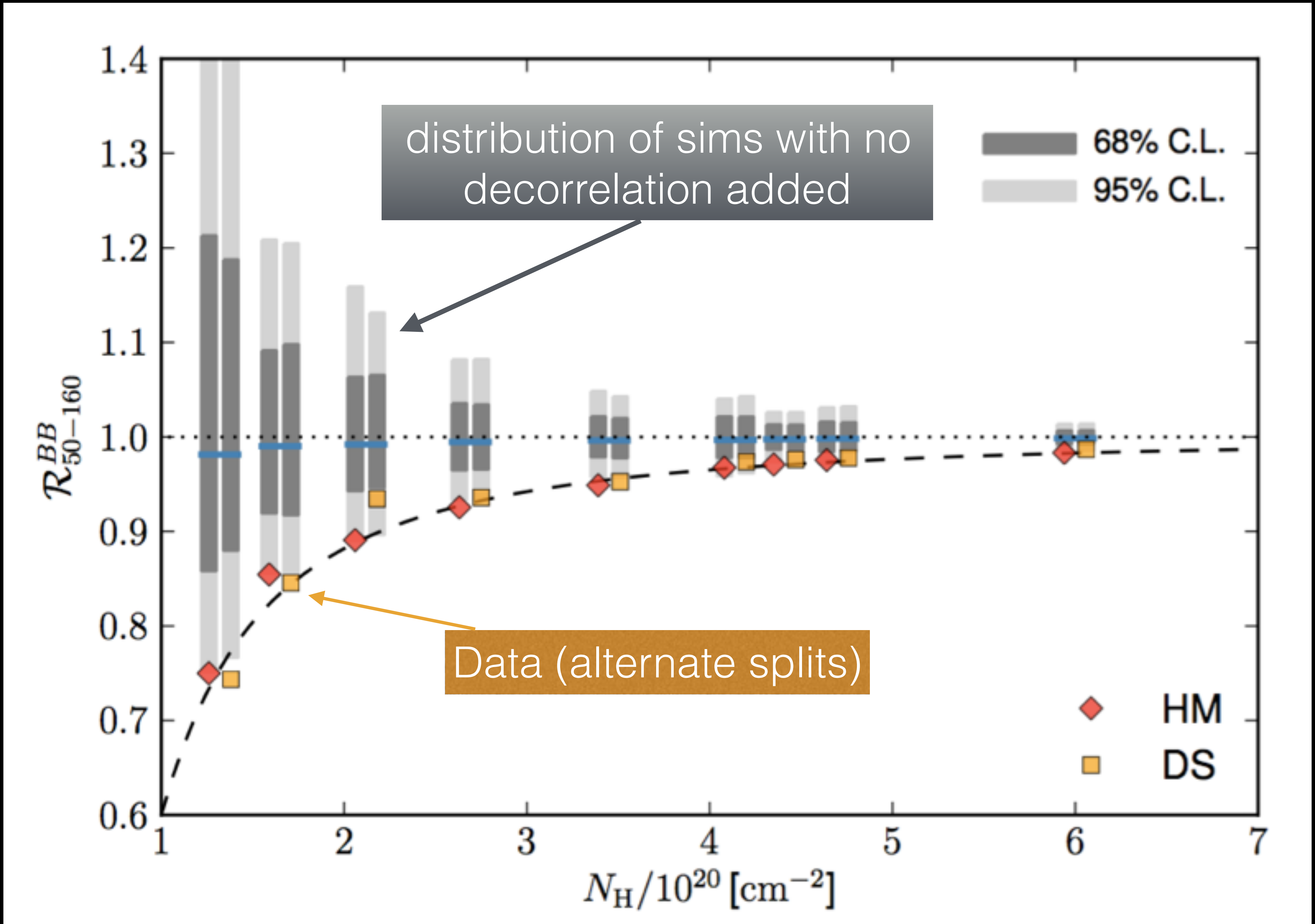

PIPL

PIP L

- From PIPL: "*Measurements of the correlation ratio obtained in different regions can be considered as statistically independent to a good approximation…*"
- If this is true and there are no systematic biases, there is a significant measurement of dust decorrelation and a strong trend to more decorrelation in the cleanest regions of sky.

Impact on r

From CMB Stage IV CDT report

		ILC		Parametric	
r value	Sky model	$\sigma(r) \times 10^4$	r bias $\times 10^4$	$\sigma(r) \times 10^4$	r bias $\times 10^4$
0	0	5.7	0.0	6.7	0.2
	1	7.0	0.3	7.8	5.8
	2	7.7	0.8	7.1	3.1
	3	5.6	0.8	8.1	1.8
	4	7.5	5.0	9.3	−3.4
	5[a]	16	18	14	−2.5
	6	5.8	−1.1	7.3	1.1
0.003	0	7.2	−4.0	10	0.3
	1	9.1	0.0	9.0	6.2
	2	9.6	−1.9	9.4	3.5
	3	7.2	−0.3	10	1.6
	4	10	5.8	11	−1.8
	5[a]	20	20	15	3.0
	6	8.3	−1.1	9.9	1.1

[a] An extreme decorrelation model—see § A.1.2. The parametric analysis includes a decorrelation parameter. No attempt is made in the ILC analysis to model decorrelation.

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Possible bias on r, definite ~2x increase in σ_r above baseline models

Closer look at Planck data

Work referenced is Sheehy & Slosar (2017)
arXiv: 1709.09729

Closer look at Planck data

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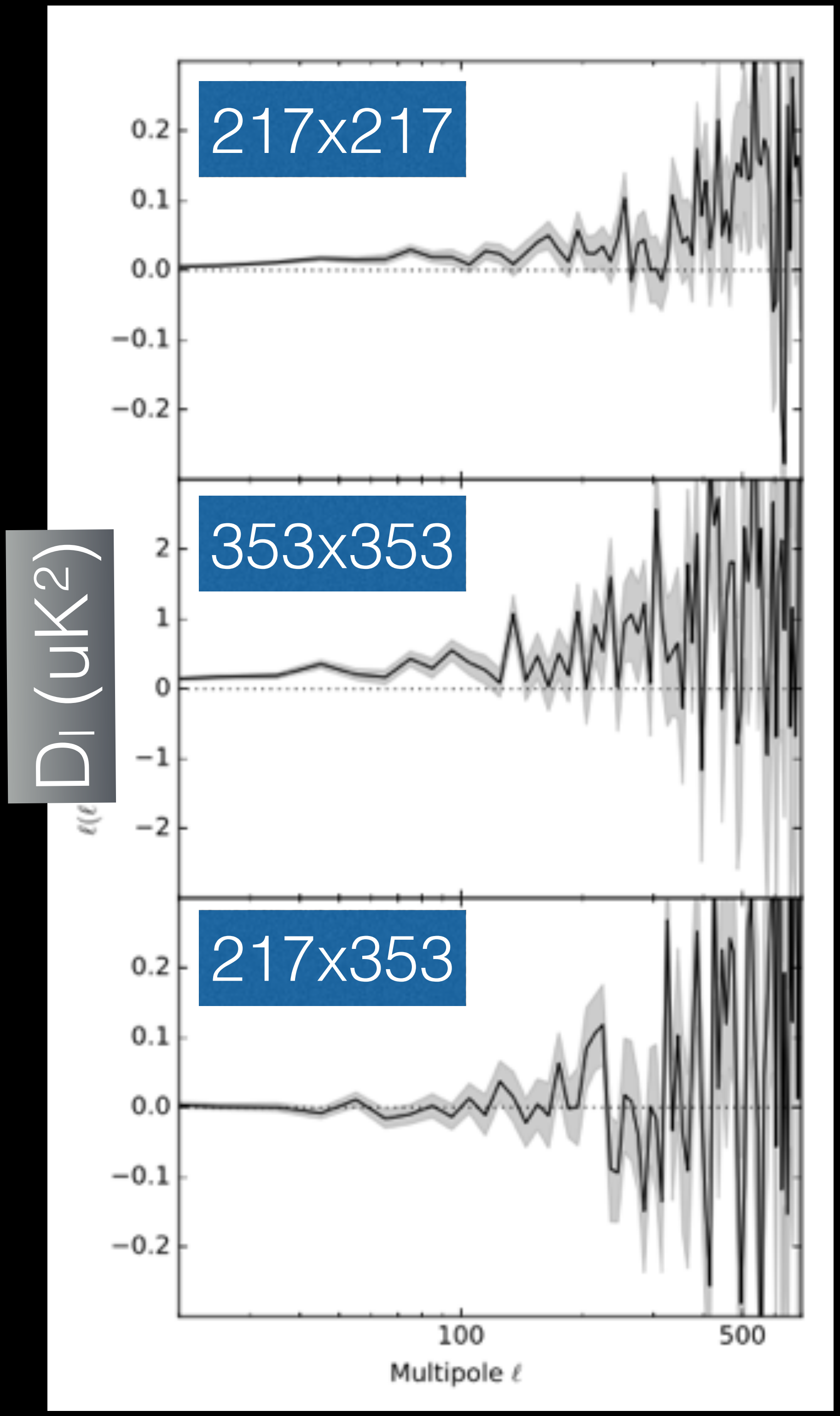
- PIP L uses random Gaussian noise simulations that are by definition uncorrelated. Look at the FFP8 noise simulations, which include noise correlations between splits produced by destriping (see Planck 2015 VIII).

Closer look at Planck data

1) Noise correlations?

- Mean and error on mean of 500 Planck FFP8 noise simulations, auto and cross spectra.
- Positive bias ranges from ~1% of the dust signal at l=50 to ~15% at l=700 in 217×217.
- No observed bias in 217x353.



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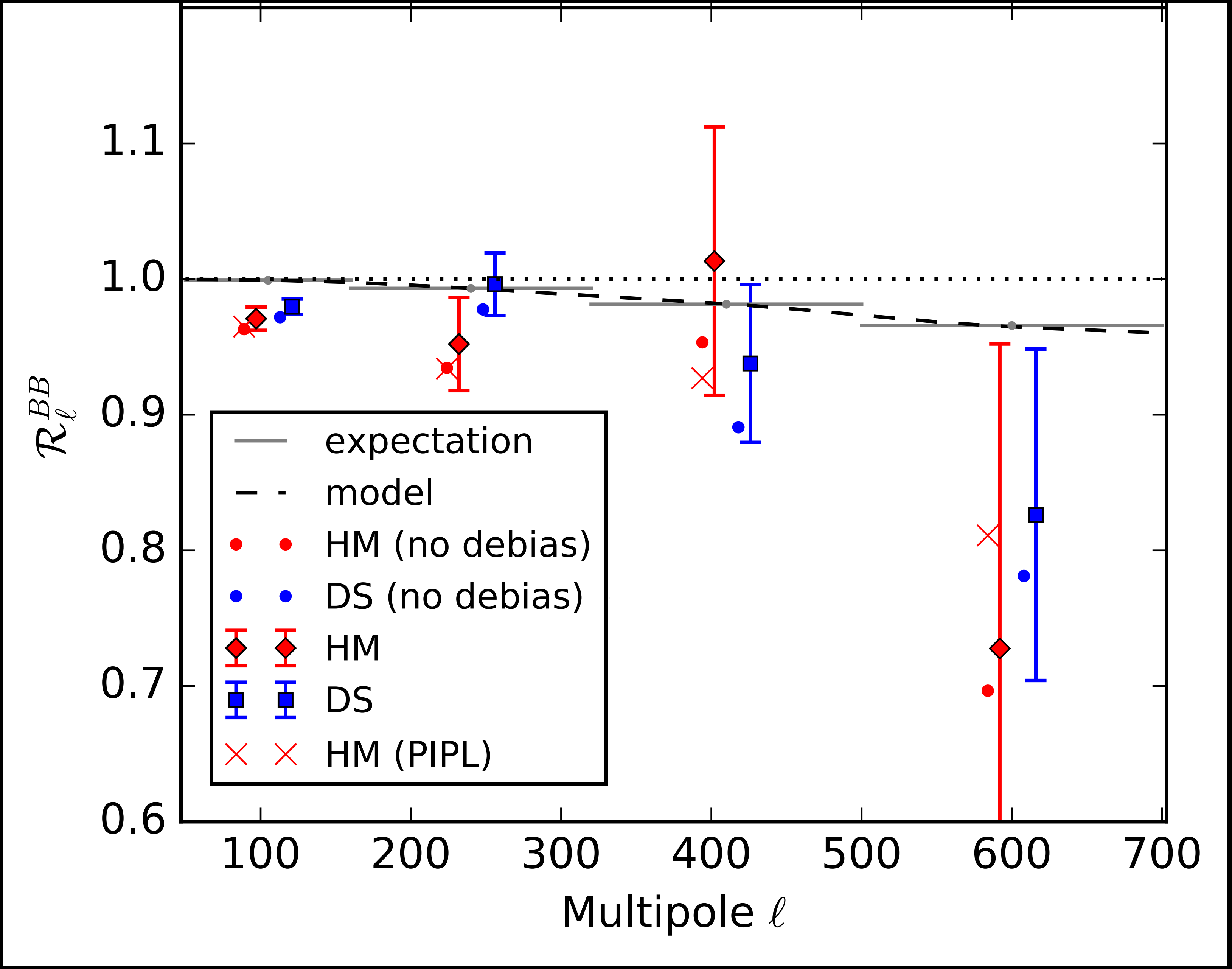

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- From PIPL: "*For each of the regions described in Sect. 2.2, we built 1000 independent dust, CMB and noise realizations with these properties.*"
- By construction, such simulations have no correlation between R measured on different sky regions. More accurate would be to hold the signal and noise realizations fixed when analyzing different sky regions.
- We find that while holding the dust realization makes negligible difference in the results, holding the noise realization fixed produces large correlations between sky regions.

Closer look at Planck data

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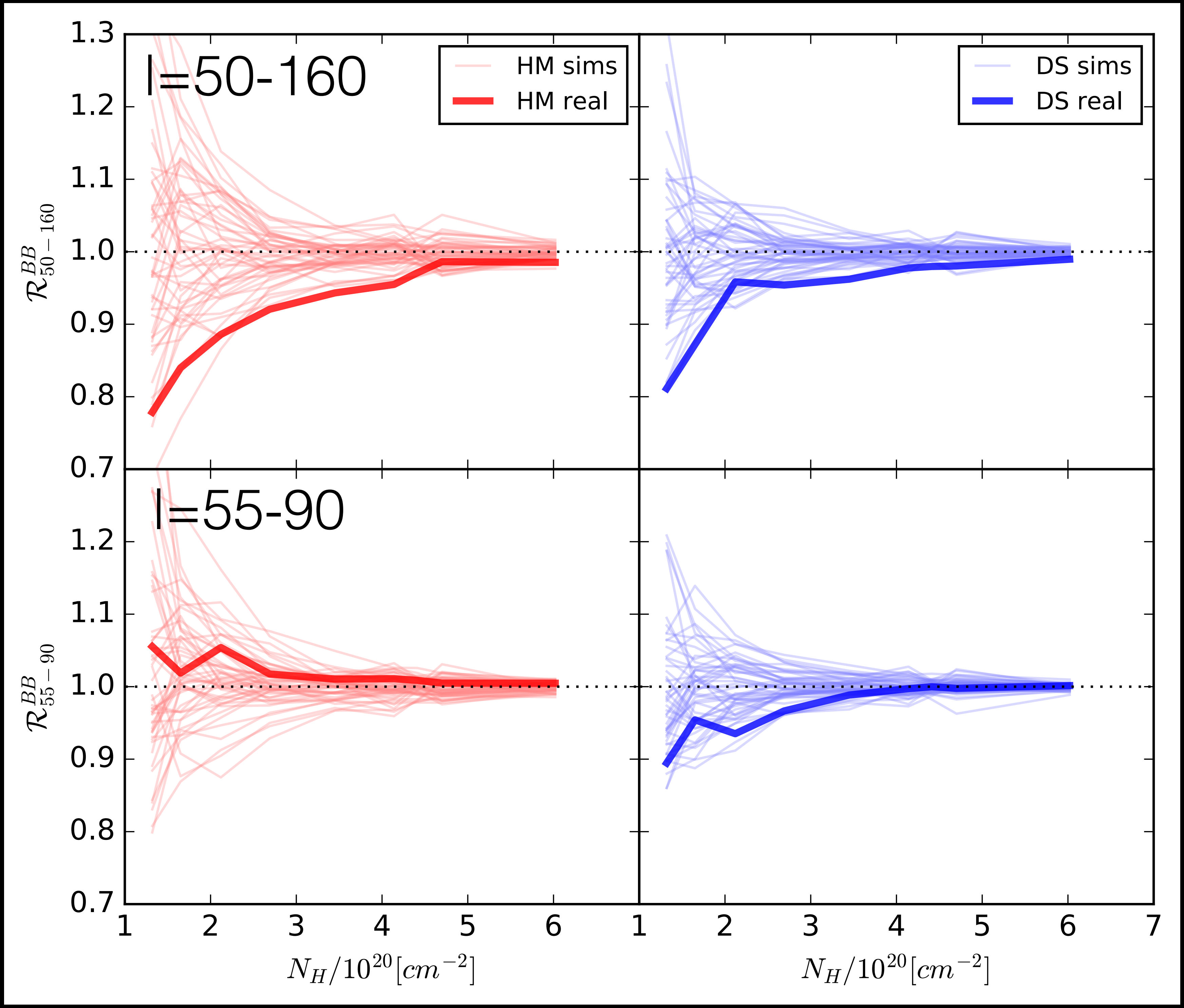

Closer look at Planck data

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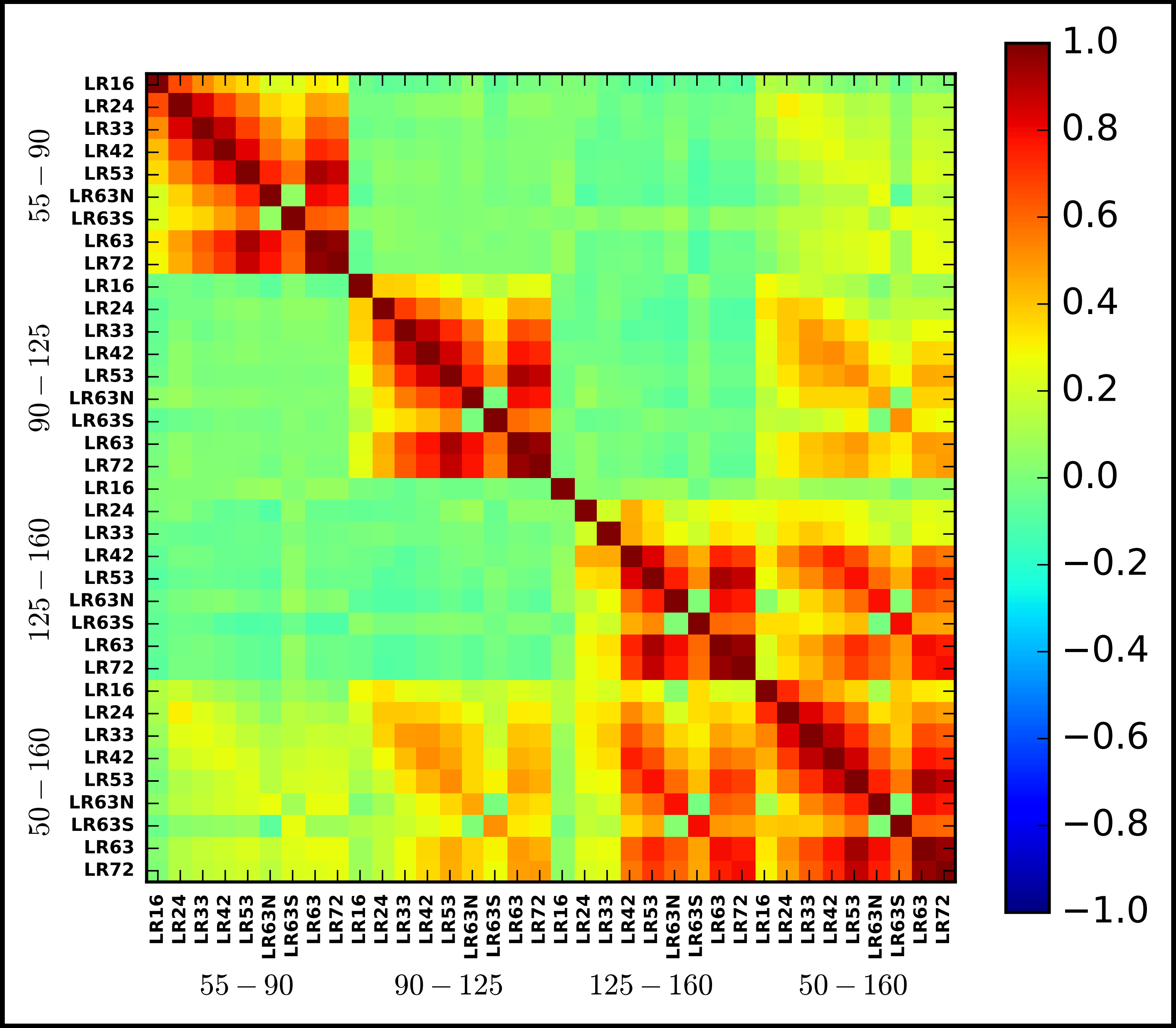
Correlation matrix between multipole bins and sky regions ("LR")



Closer look at Planck data

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- Perform a null test in narrower ell bins by computing R using two "quarter data" splits containing no overlapping data:

  (half mission 1, detector set 1) x (half mission 2, detector set 2)

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Closer look at Planck data

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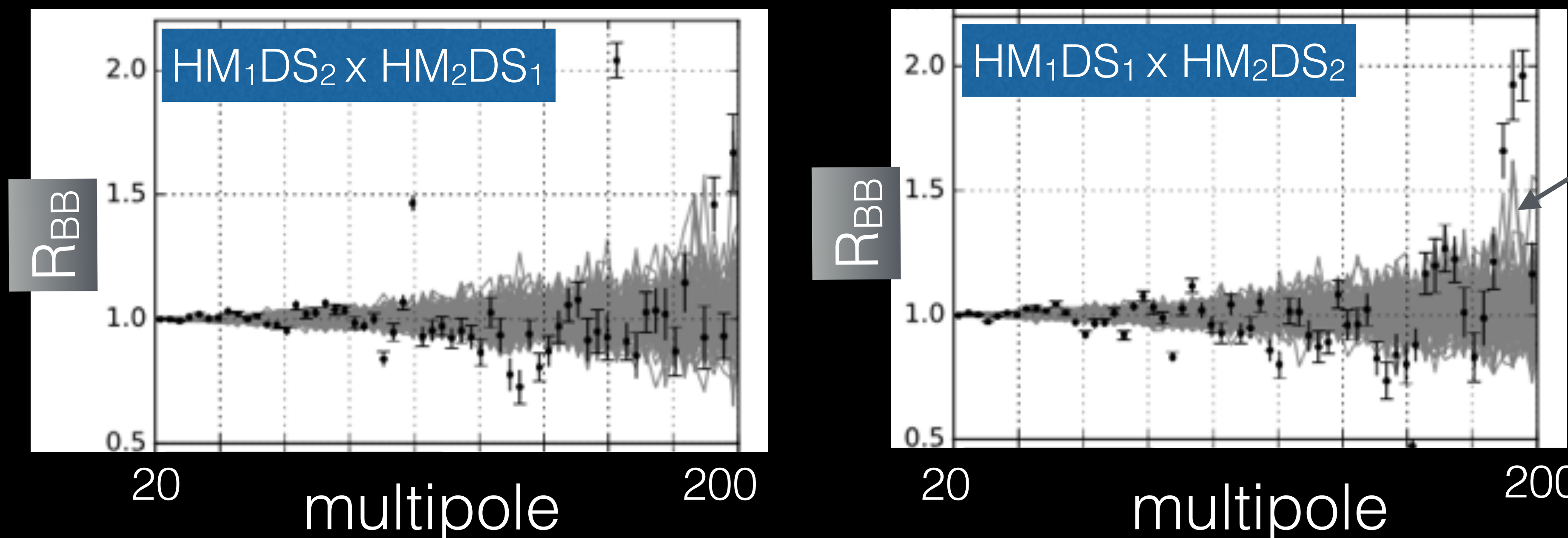

error bars are rms of100 signal +noise sims, plotted here for reference

Closer look at Planck data

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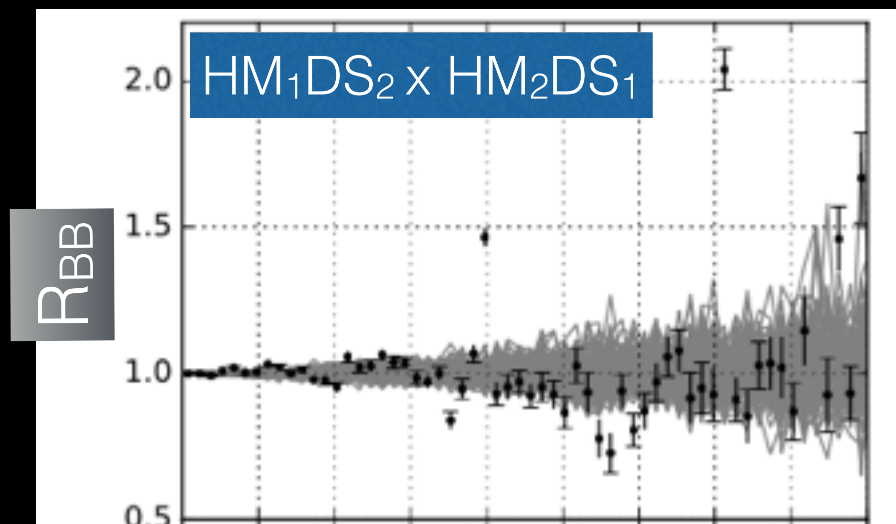

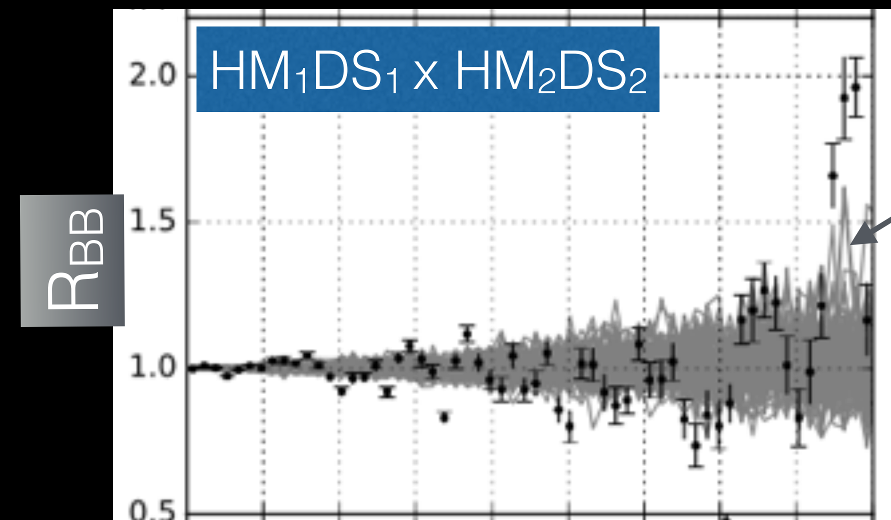

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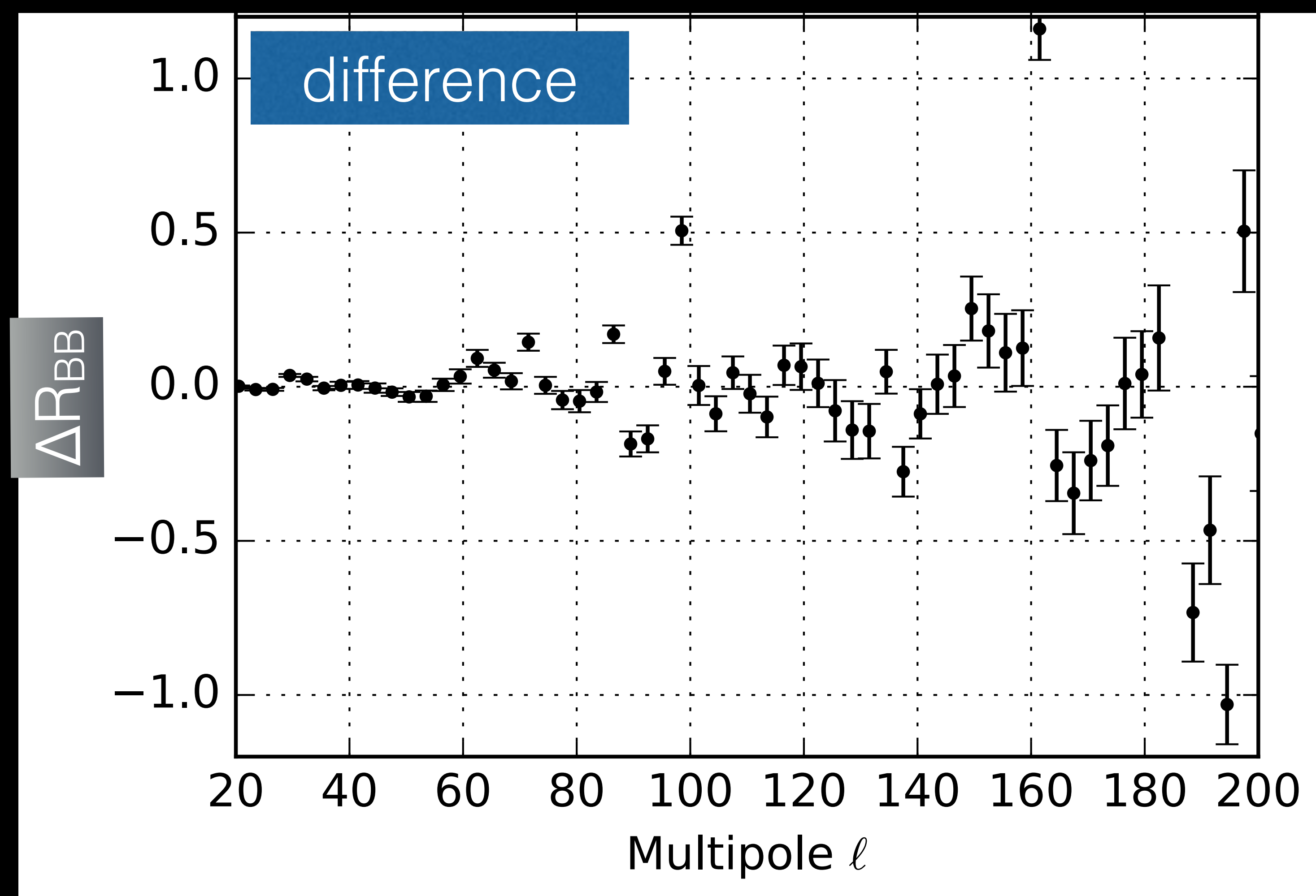

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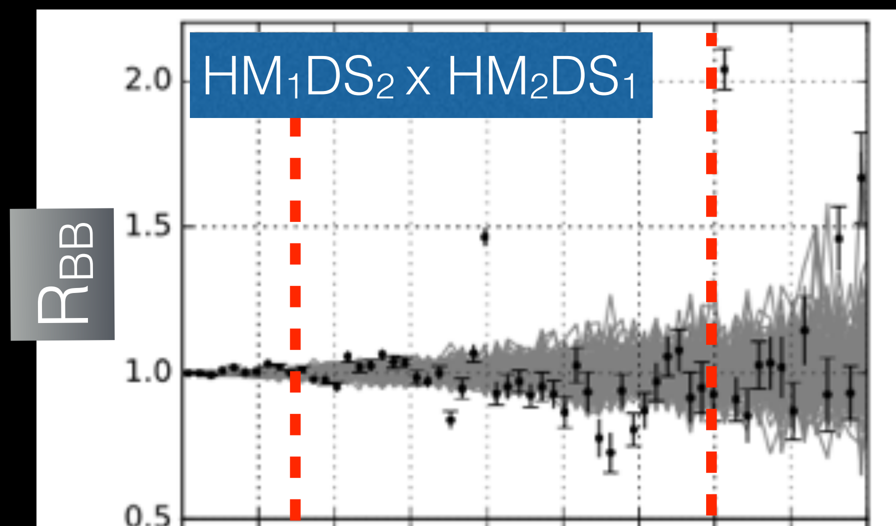

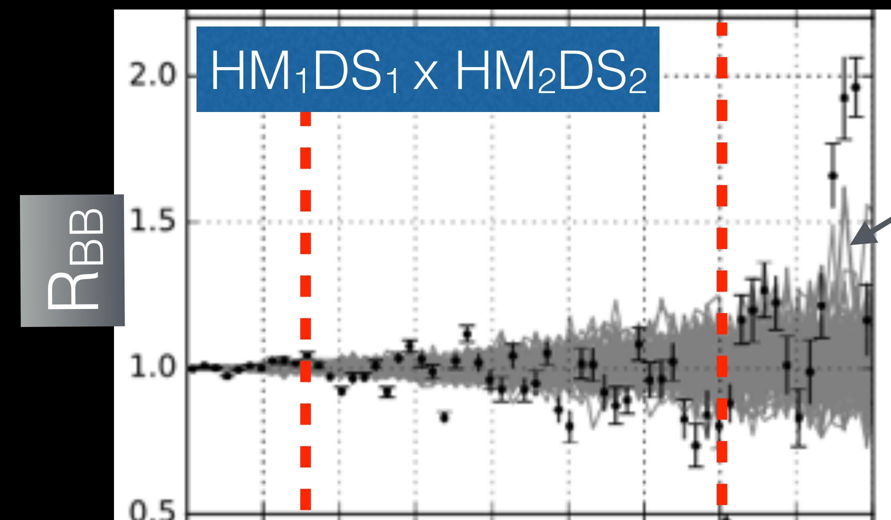

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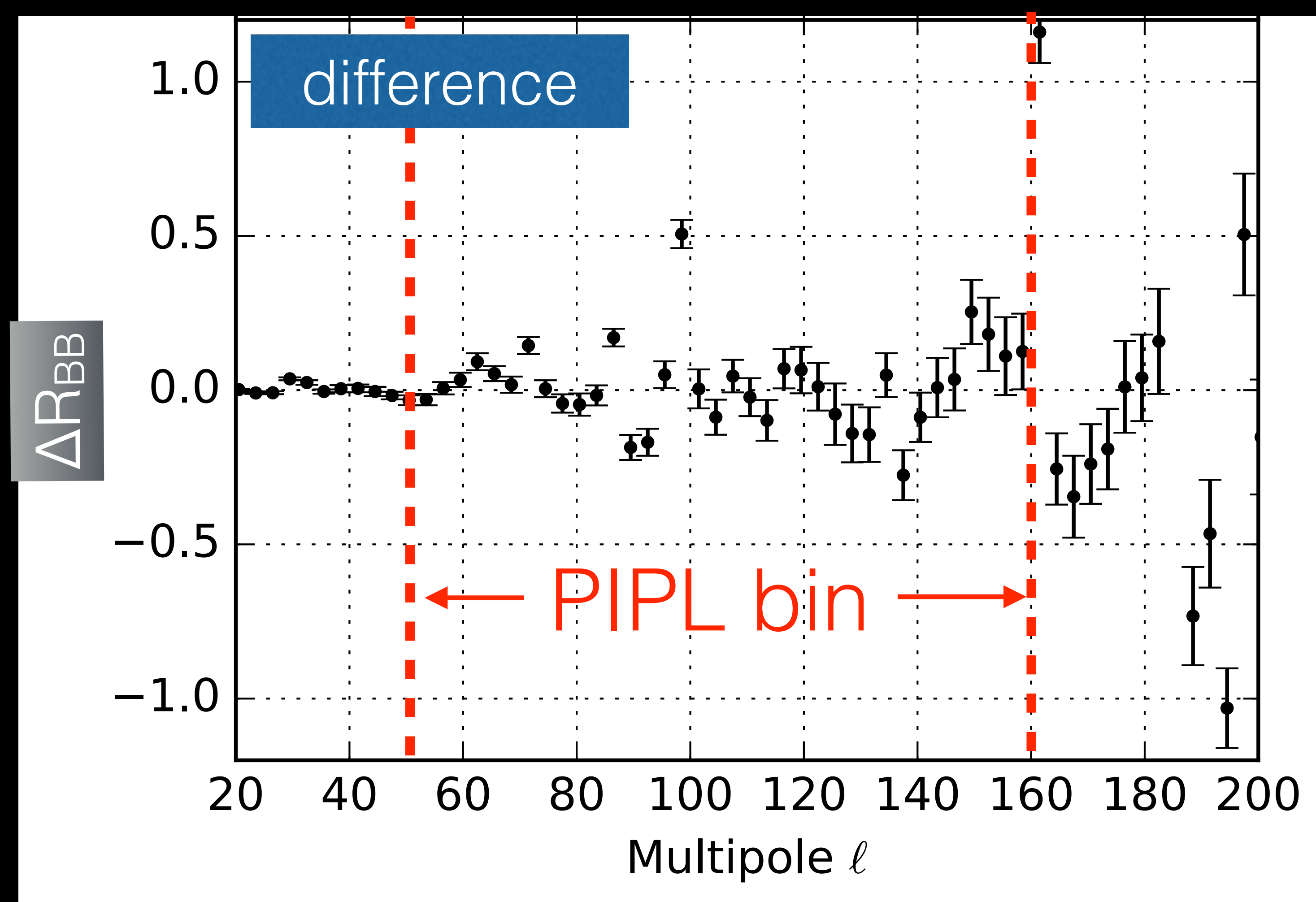
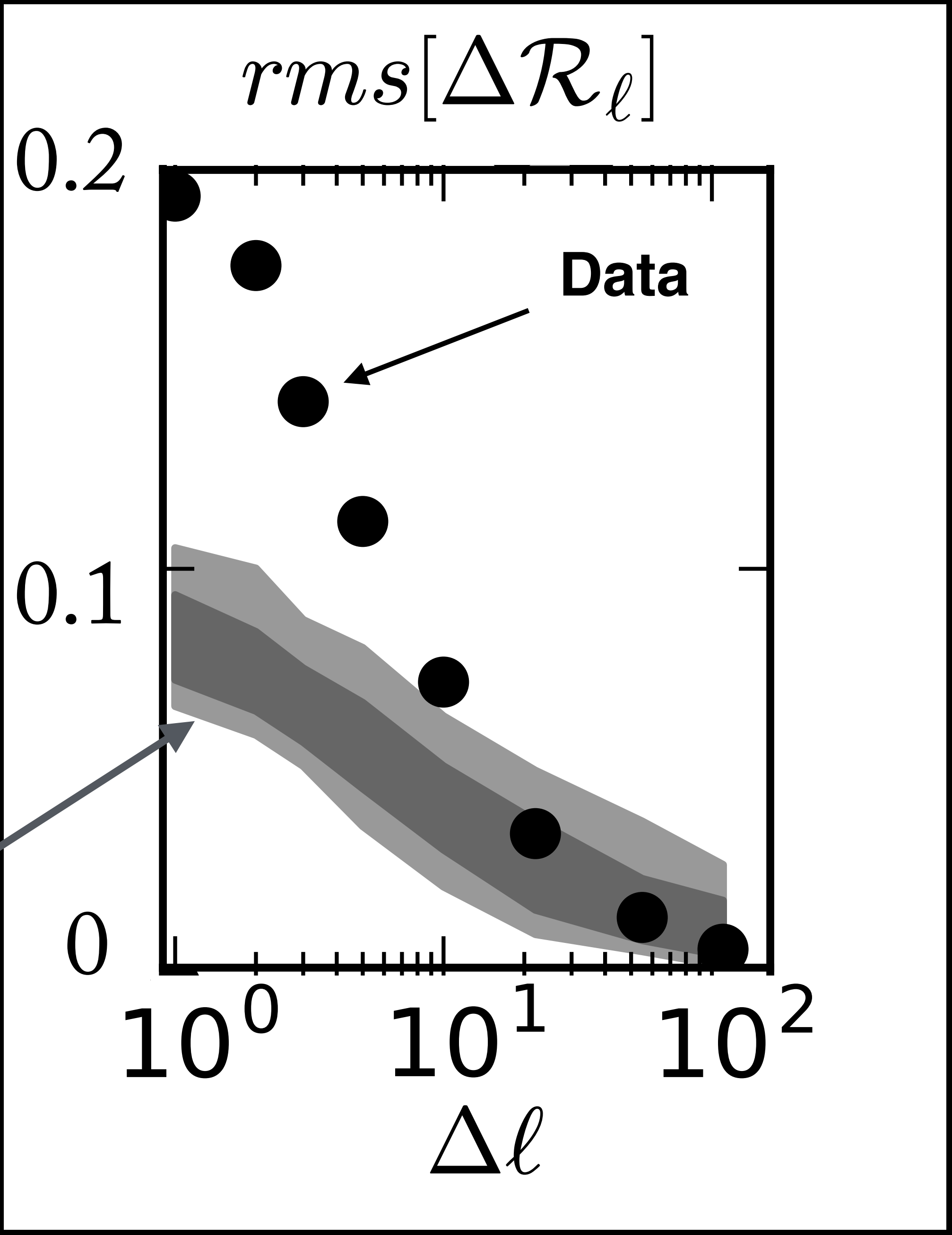


Closer look at Planck data

3) Possible instrumental systematics?

l = 50-160 bin null test r.m.s.
as function of bin width



Regions enclosing 68 and 95% of sims.

Closer look at Planck data

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Adopt Δl = 3 and Δl = 55 bins as pessimistic and optimistic estimate of magnitude of systematics

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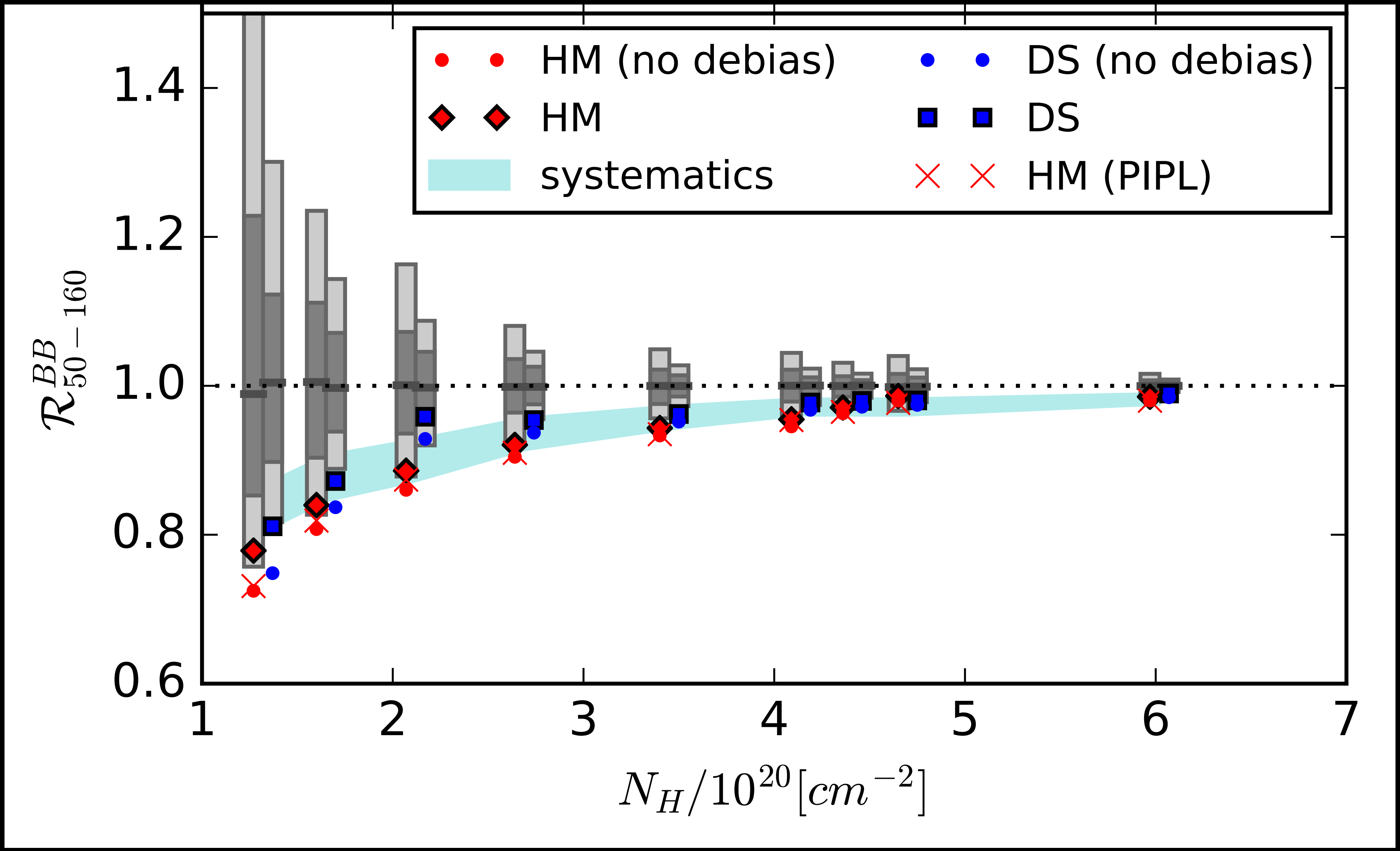

Closer look at Planck data

4) Use finer bins with no loss of constraining power

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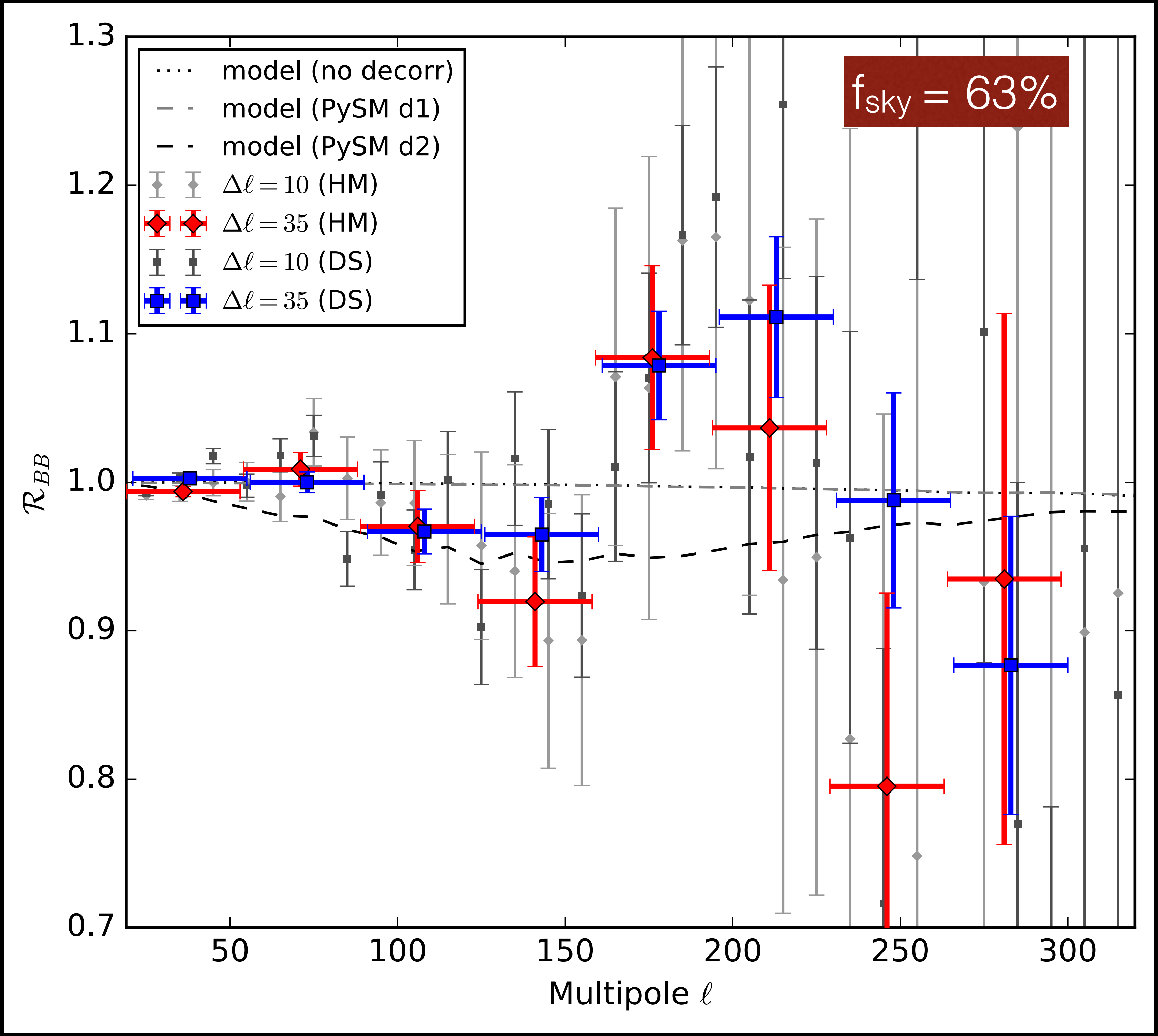

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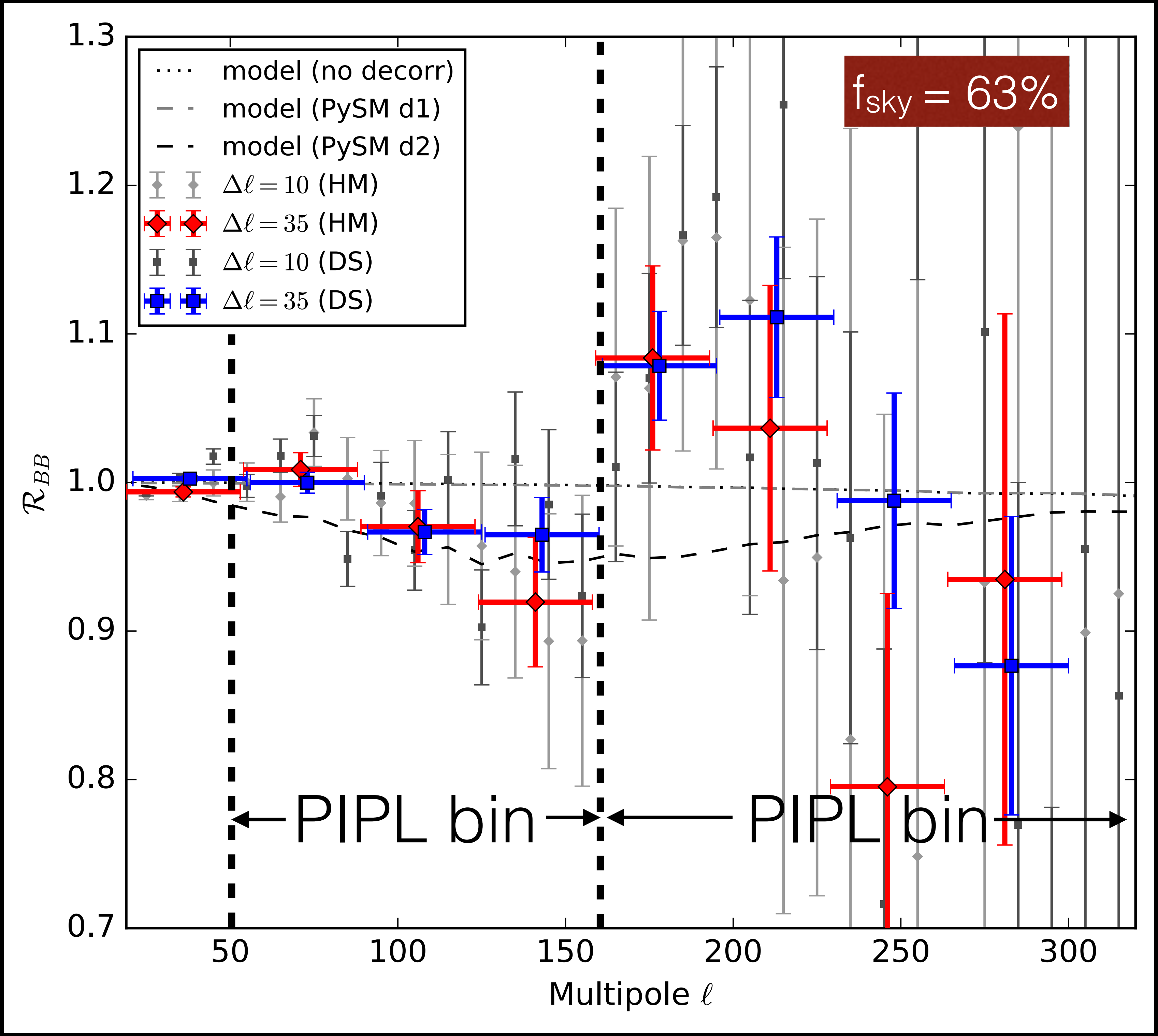

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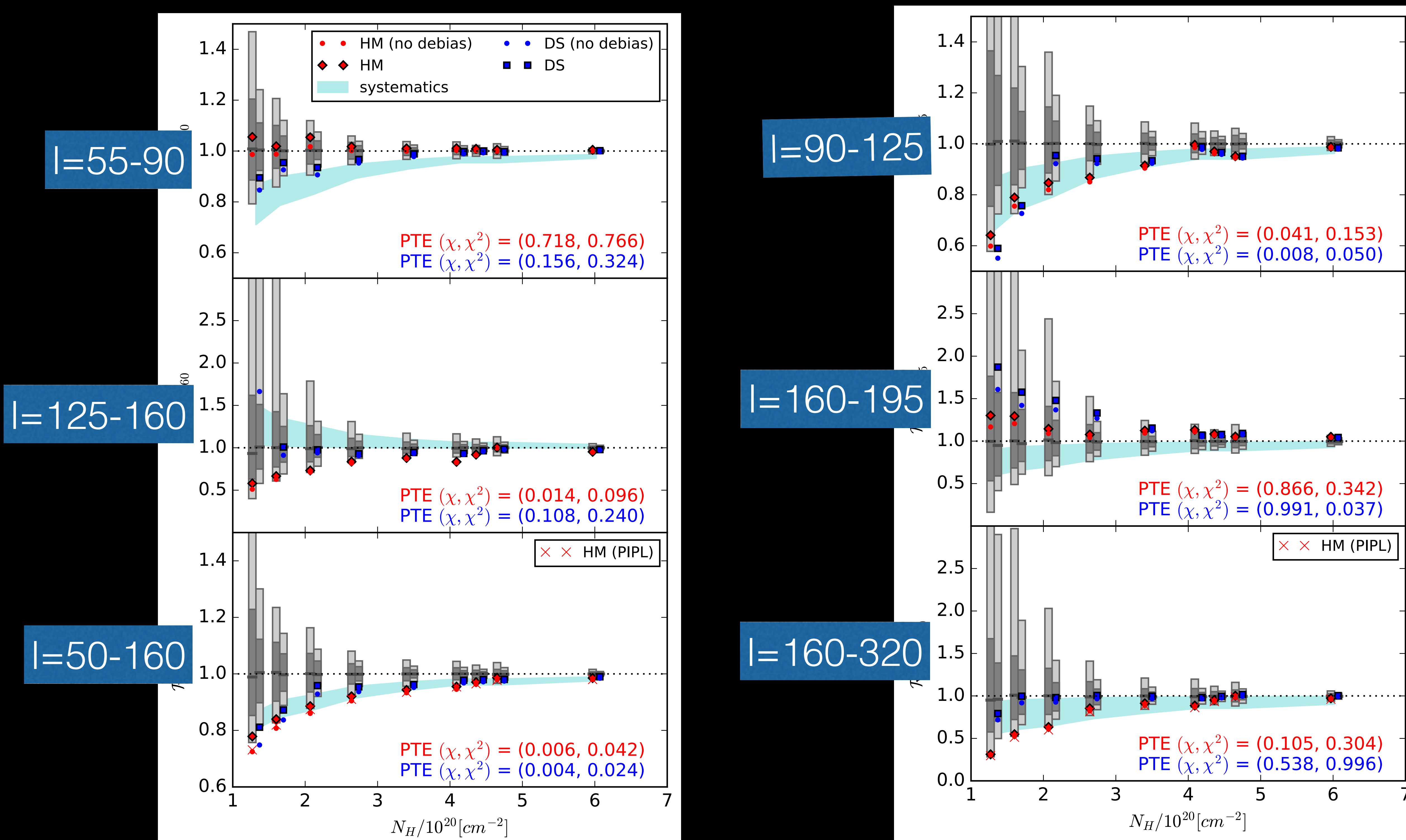

Summary

Accounting for:

1) a small but significant downward bias on R from noise correlations between data splits,
2) strong correlations between R measured in nested sky regions
3) the estimated magnitude of possible systematic contamination in the data

…we conservatively conclude that there is no evidence for decorrelation of galactic dust in the Planck data.

Thanks.