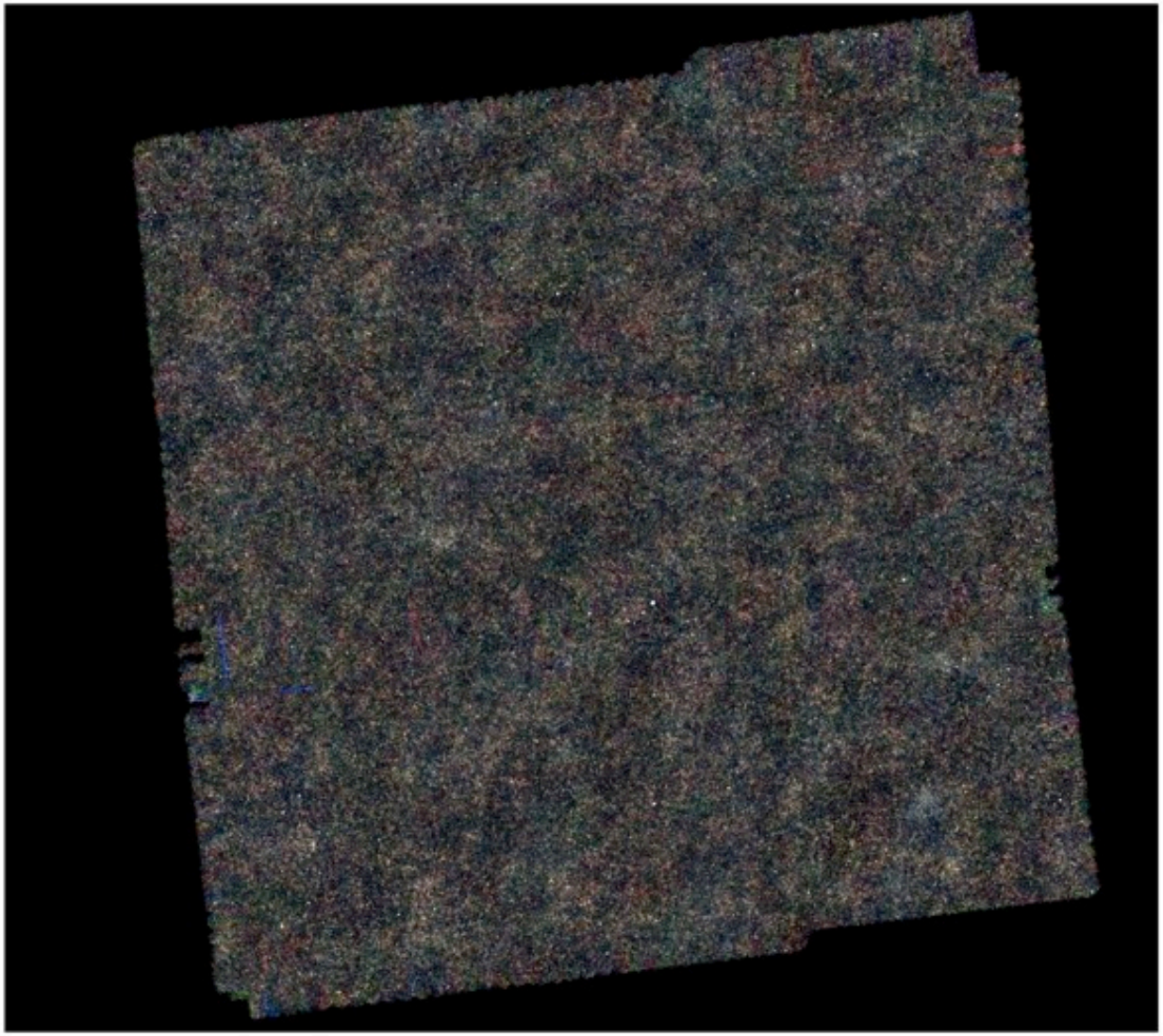
Too perfect?
Where are the fluctuations?

Gil Holder

Herschel (Spire)

- 100 sq deg with full overlap with SPT deep field (23h30,-55d)
- 250,350,500 um



Clustering of Galaxies:

Projected sky maps of large scale structure have ~1-10% fluctuations

- Radio and IR/submm sources presumably trace the large scale matter fluctuations
- Back of the envelope:
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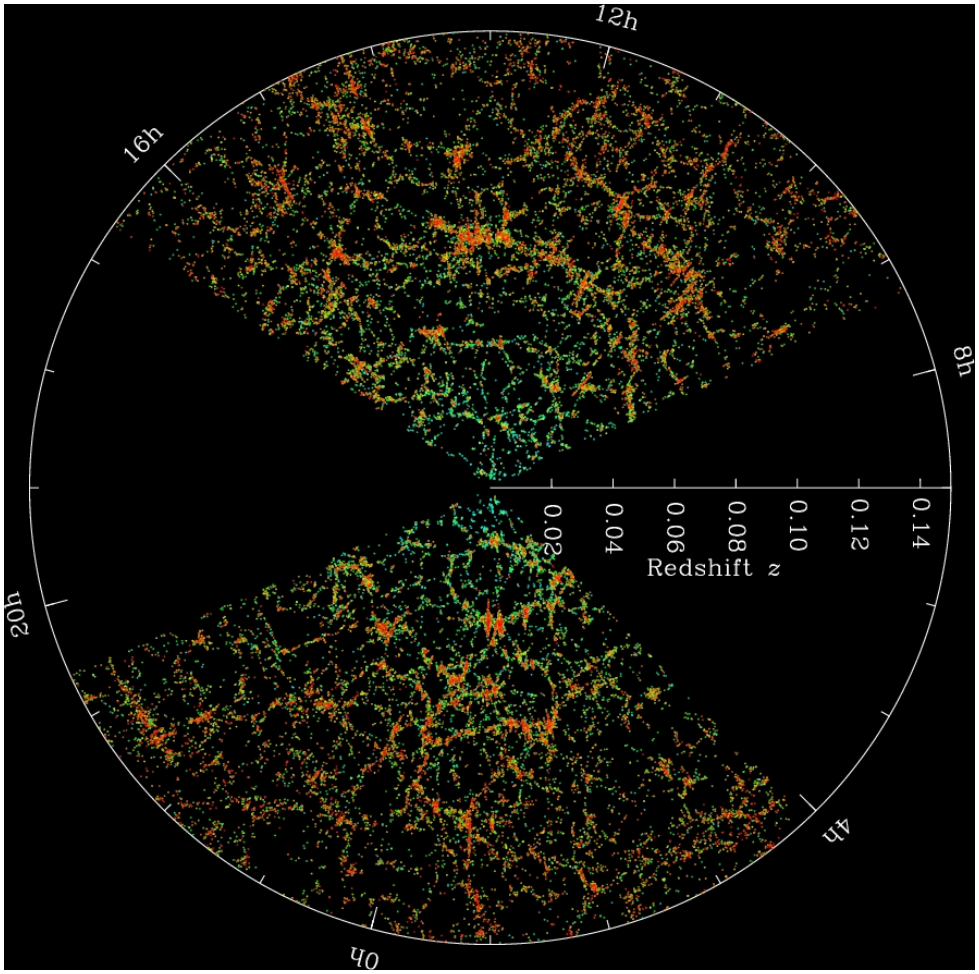
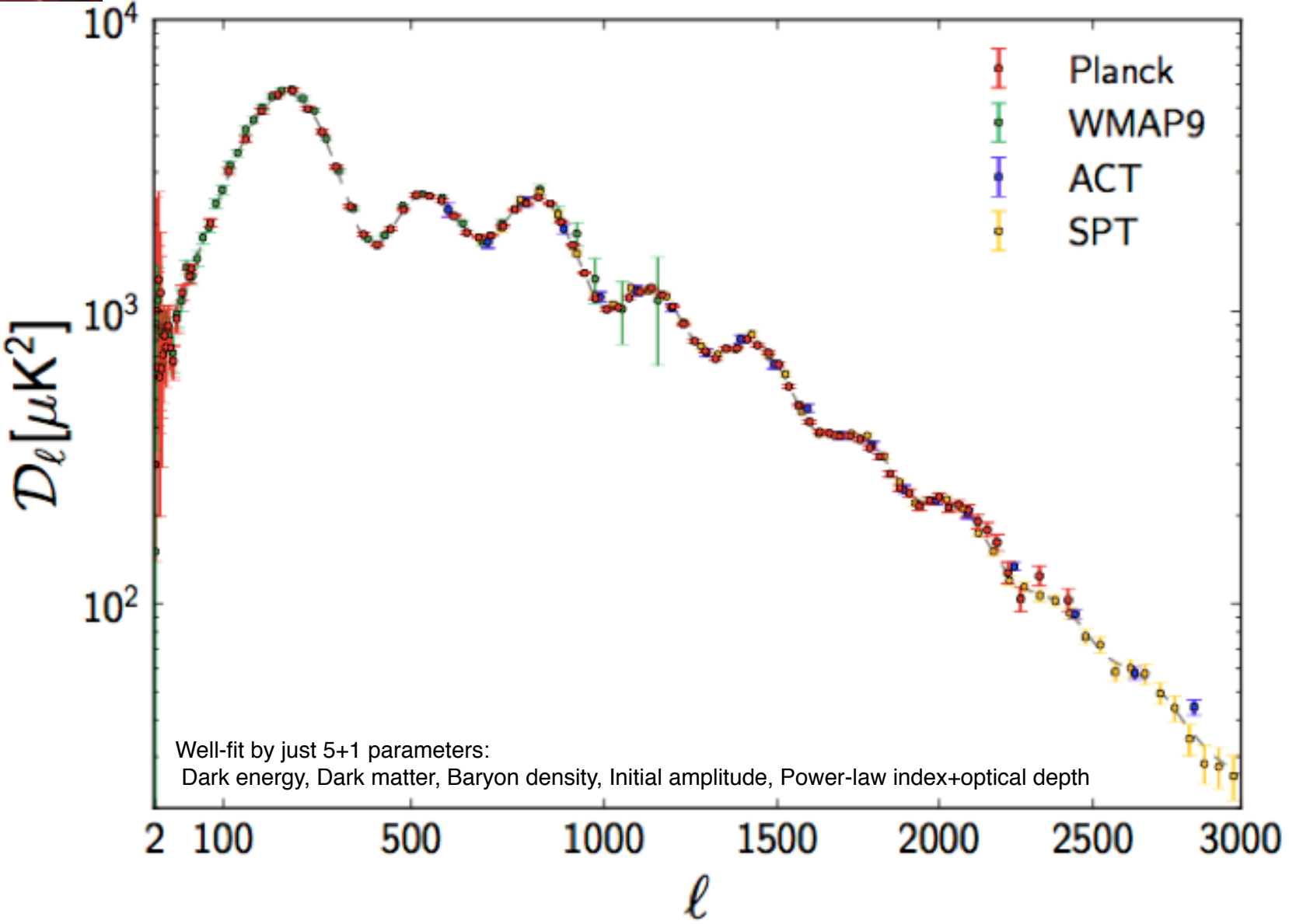


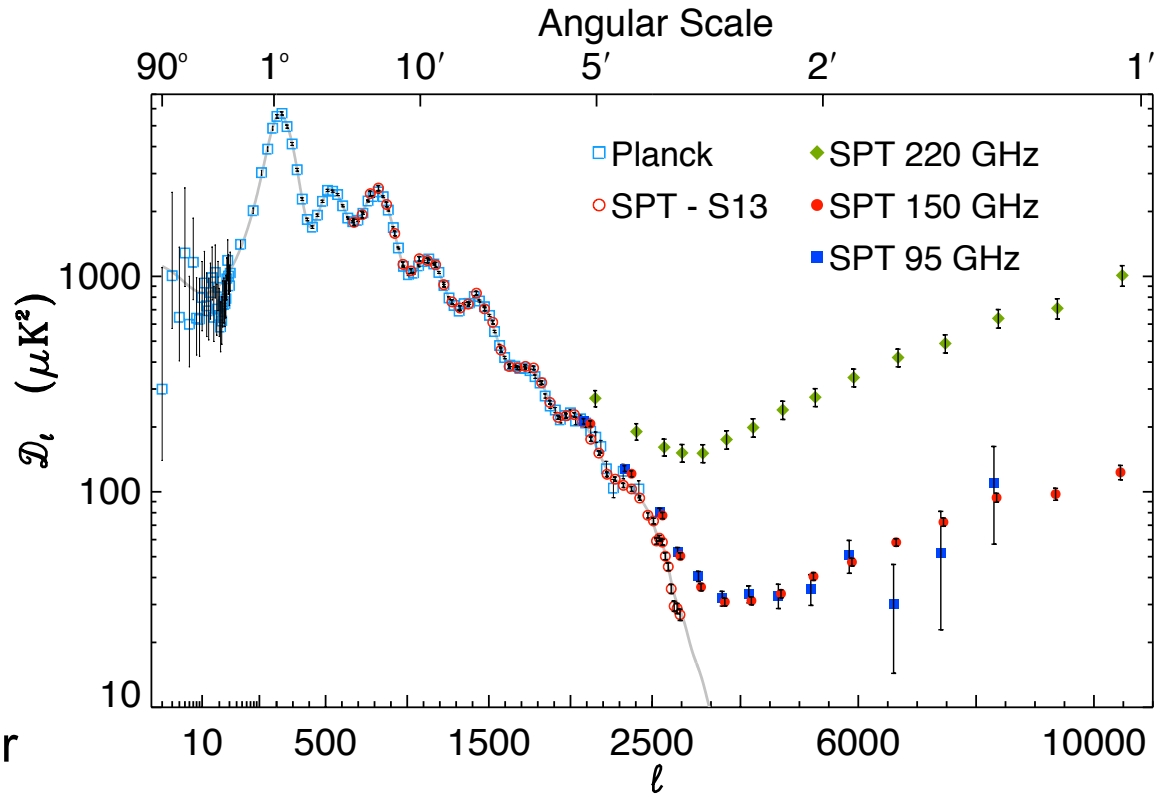
CMB Angular Power Spectrum



Well-fit by just 5+1 parameters:
Dark energy, Dark matter, Baryon density, Initial amplitude, Power-law index+optical depth

Angular Power Spectra at mm-wavelengths

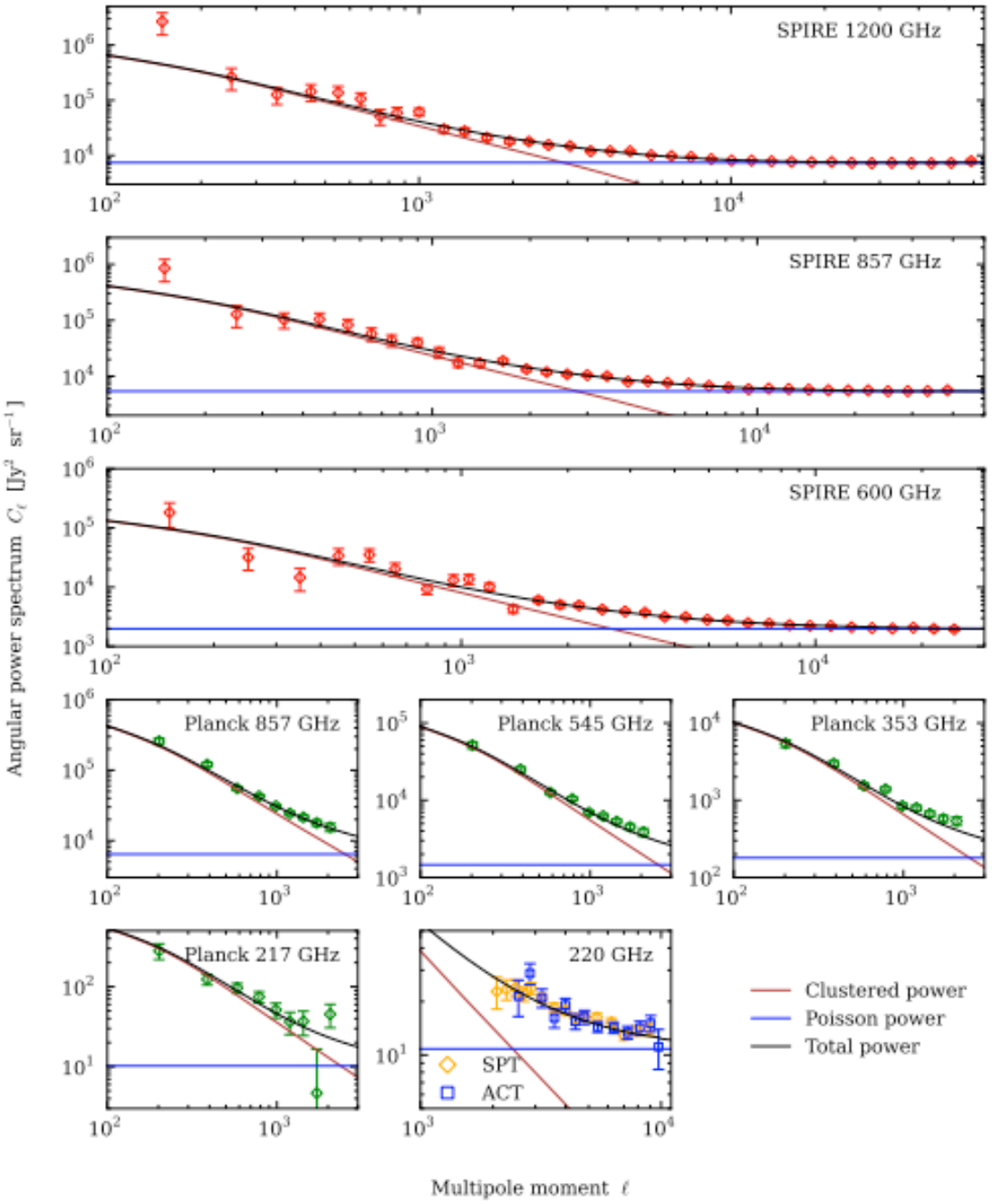
- large angles dominated by CMB
- small scales dominated by emission from galaxies
  - combination of shot noise in galaxy number & intrinsic clustering from large scale structure



George et al 2015

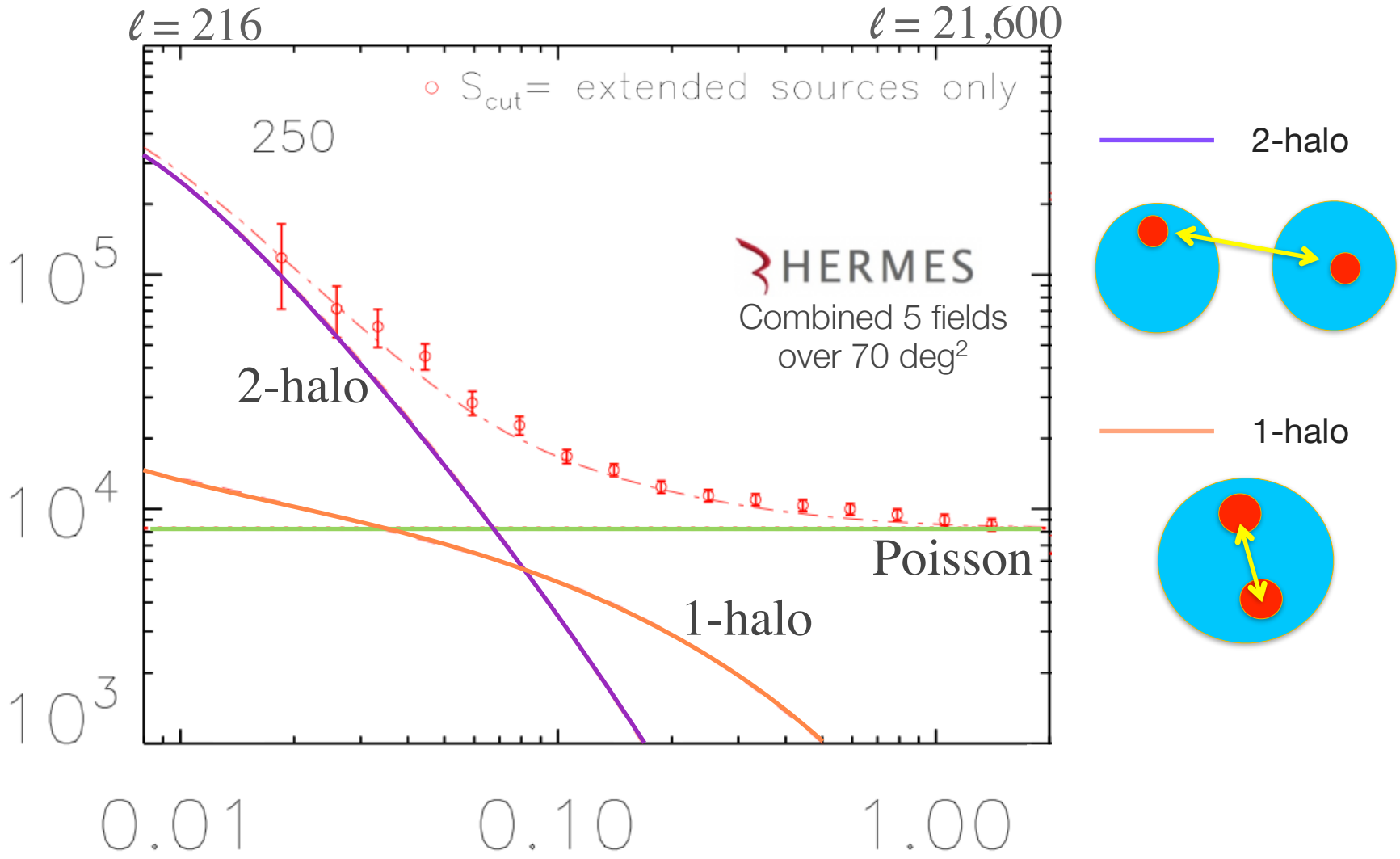
Galaxy clustering at mm/submm wavelengths

- cleanly measured at many frequencies
- consistent with ~10% rms fluctuations on scales of a few arcminutes



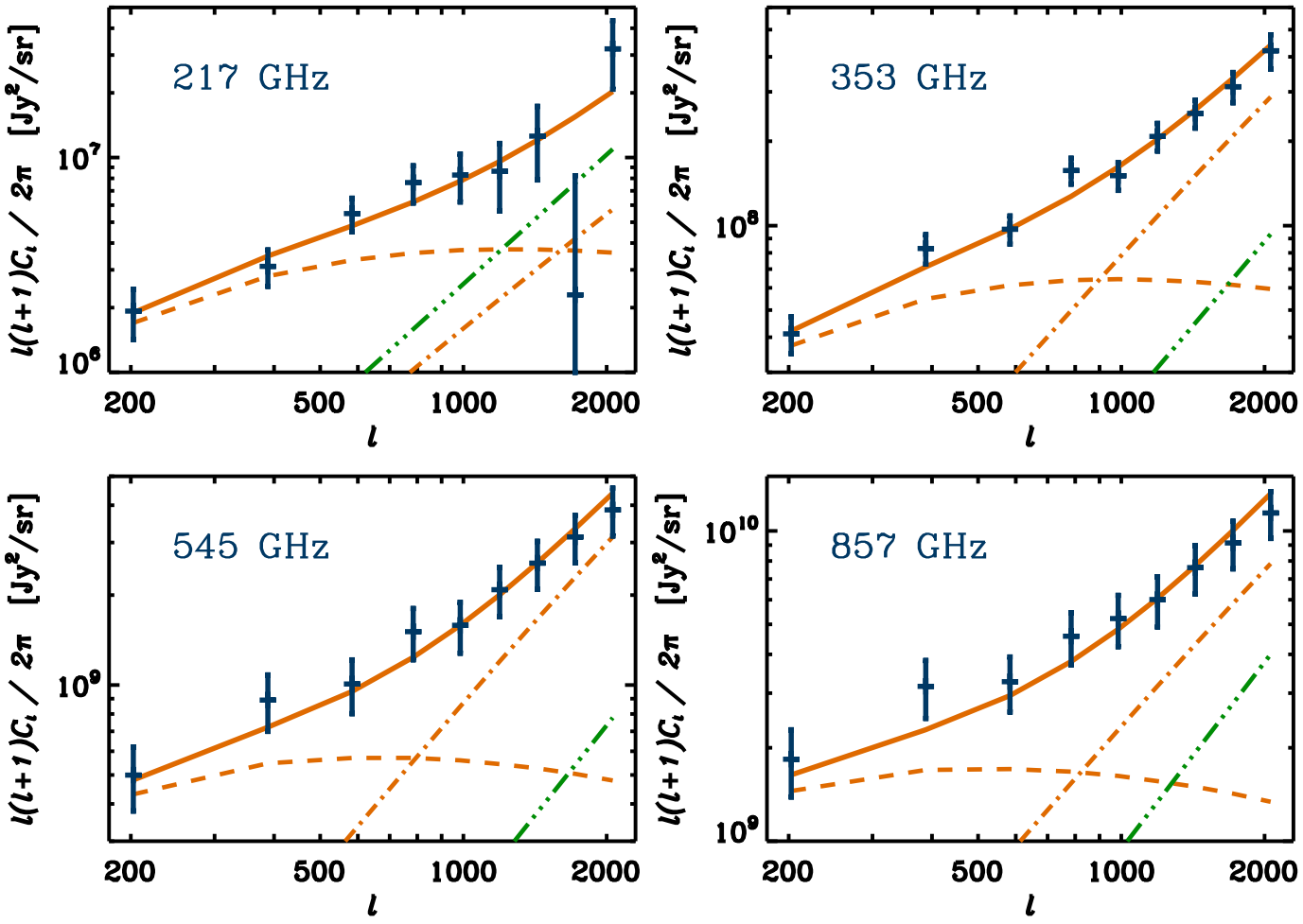
Addison, Dunkley & Bond 2013

HerMES power spectra

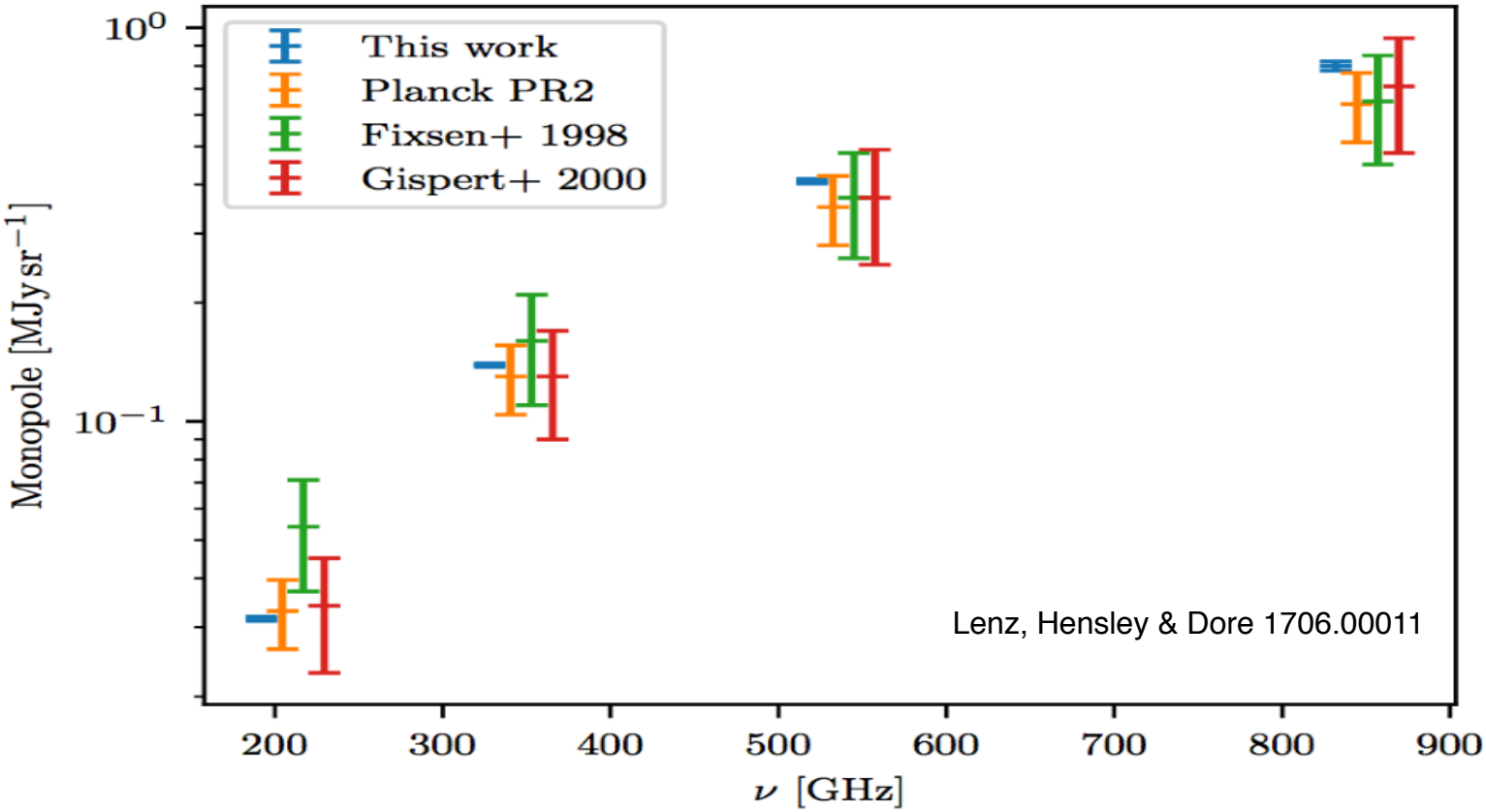


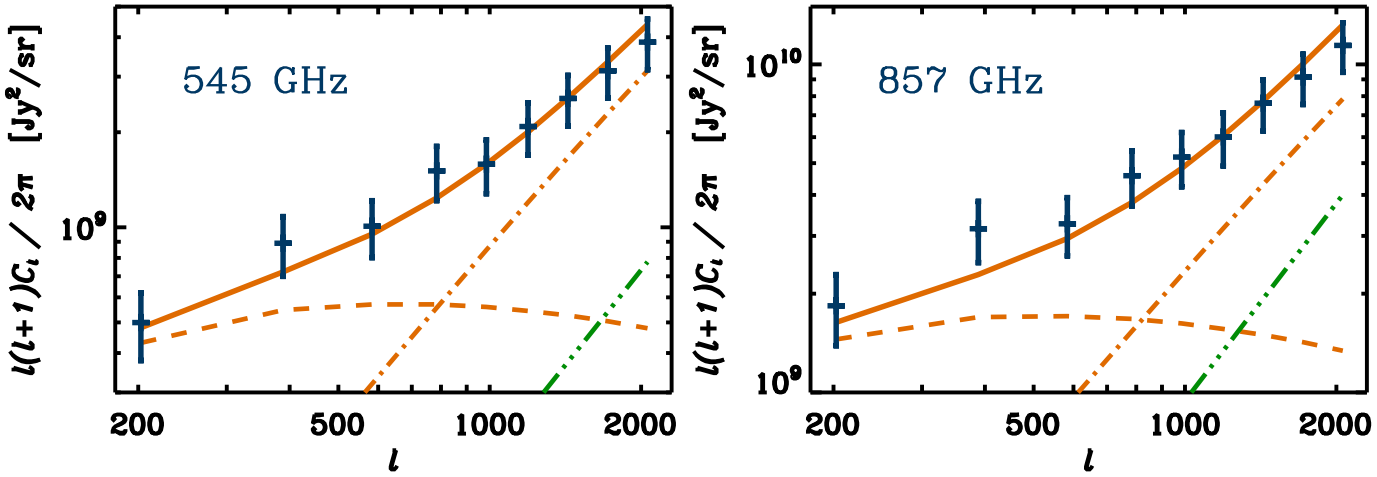
Viero & Wang et al. (2012b)
arXiv: 1208.5049

Planck CIB Measurements



Planck collaboration 2012





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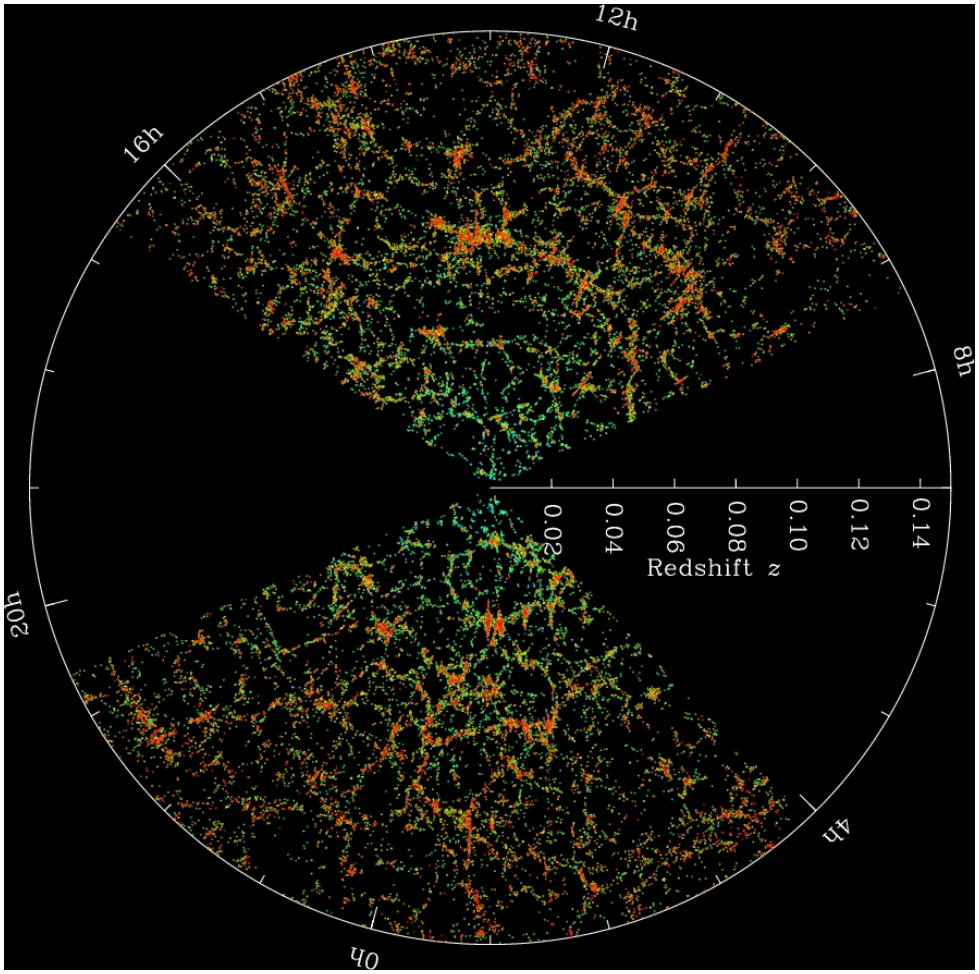

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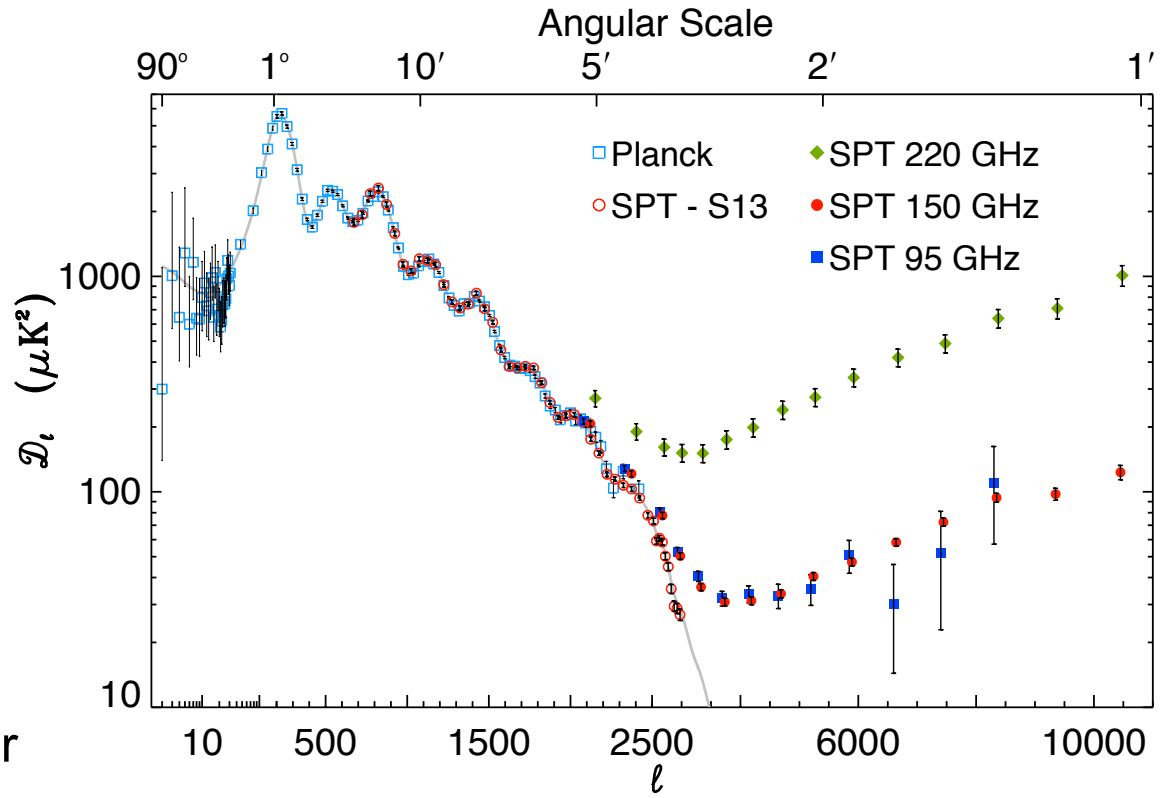
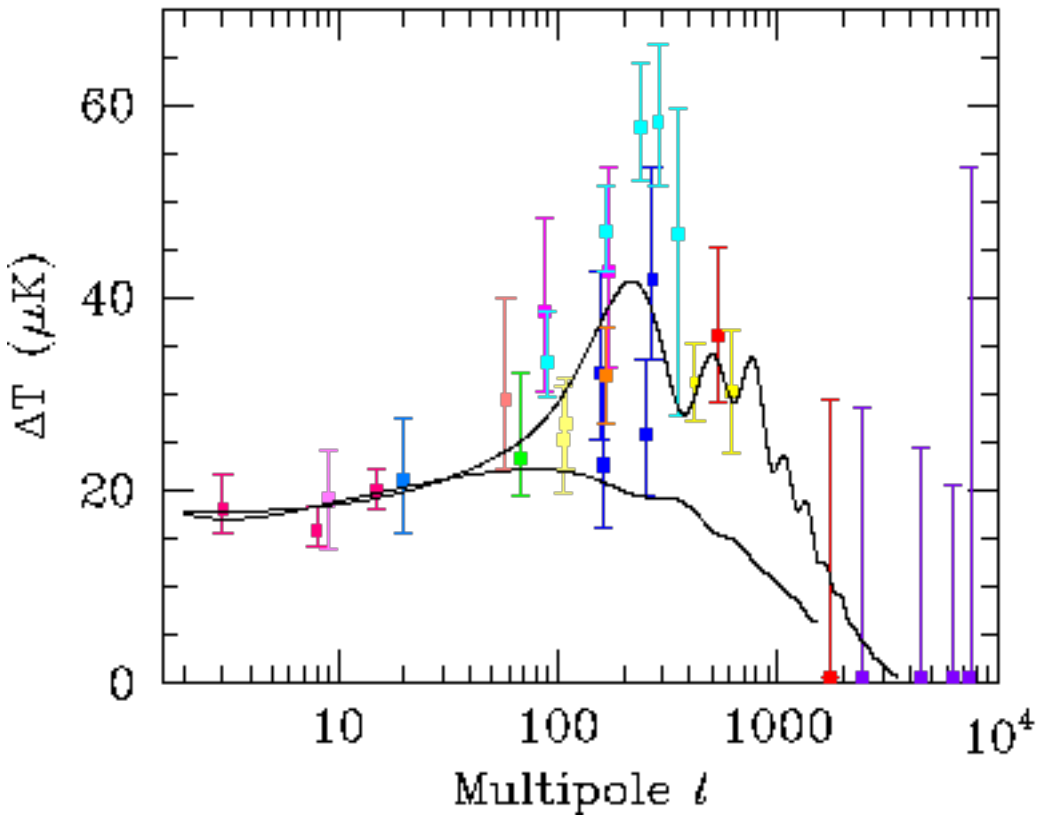


George et al 2015

CMB 20 years ago….

- possibly a peak, upper limits on small scales
- typical upper limits measured in 10s of uK



Bennett, Turner & White 1997

Upper limits ~2000

TABLE 8

COMPARISON WITH PREVIOUS WORK

$Q_{flat}^2 = 5/12\, l(l+1) C_l/2\pi$

EXPERIMENT	ν (GHz)	Ω_{sky} (arcmin^2)	θ_c (arcmin)	95% Confidence Limits $C_0^{1/2}/T_{CMB}$	95% Confidence Limits Q_{flat} μK²
SuZIE	142	213	1.1	2.1×10^{-5}	...
OVRO 40 m	20	~60	2.6	1.7×10^{-5}	...
VLA	8.4	20	~1.0	...	35.2
ATCA	8.4	28	1.0	1.6×10^{-5}	23.6
BIMA	28.5	240	0.9	9.6×10^{-6}	14.1

NOTE.—Frequency, sky coverage, coherence angle, and 95% confidence limits on the variance and flat-band power from previous work and the BIMA results.

Holzapfel et al 2000

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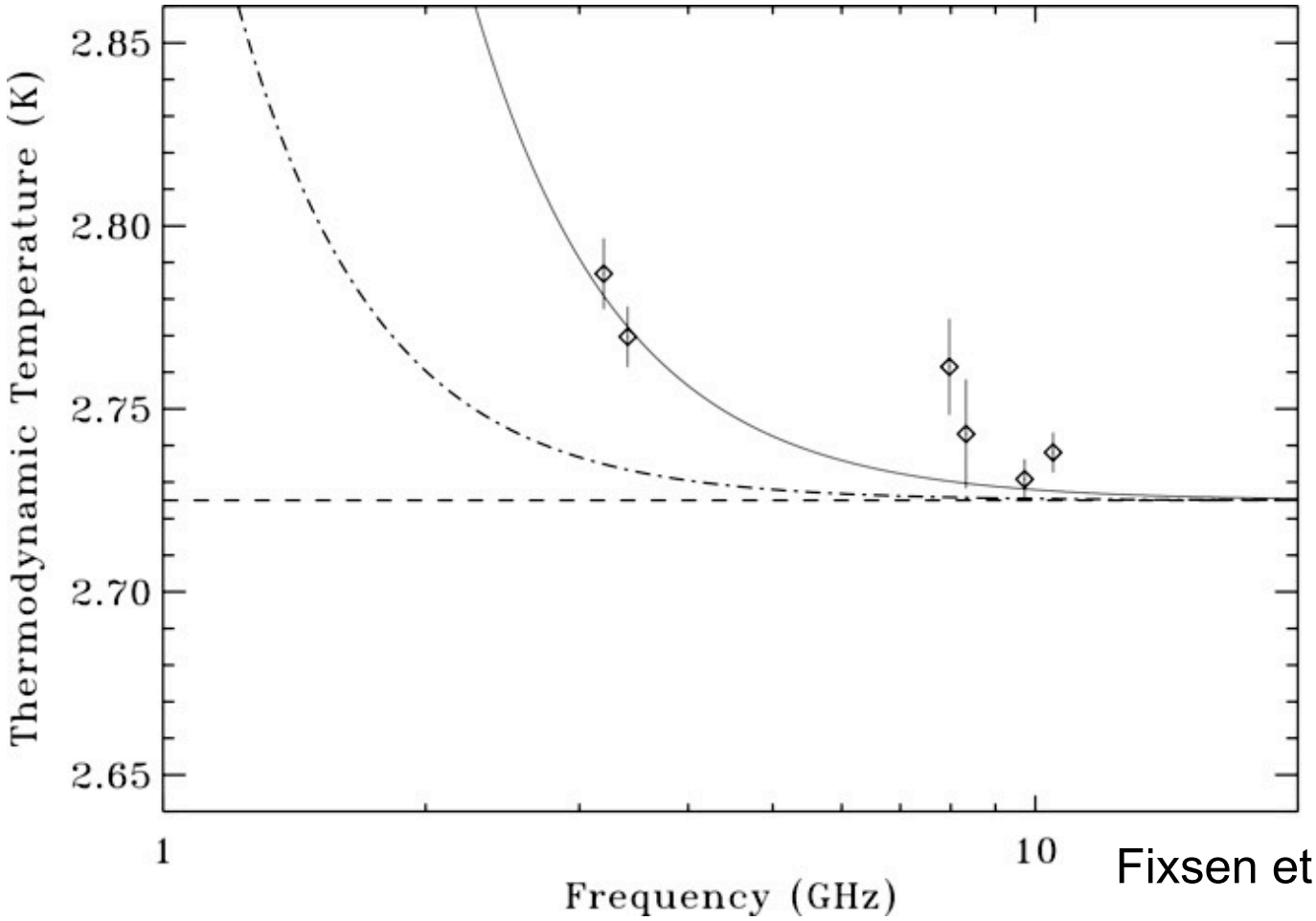
Excess radio emission at low frequencies?



Fixsen et al 2011

Low-frequency CMB/Radio Background Upper Limits

Frequency	$\theta('')$	95% confidence upper limits dT/T_{cmb}	dT/T_{arcade}	dT/T_{excess}
4.86 GHz Fomalont et al (1988)	12	8.5×10^{-4}	0.11	0.13
	18	1.2×10^{-4}	0.016	0.019
	30	8×10^{-5}	0.011	0.013
	60	6×10^{-5}	0.008	0.009
8.4 GHz Partridge et al (1997)	6	1.3×10^{-4}	0.070	0.082
	10	7.9×10^{-5}	0.043	0.051
	18	4.8×10^{-5}	0.026	0.031
	30	3.5×10^{-5}	0.019	0.023
	60	2.0×10^{-5}	0.011	0.013
	80	2.1×10^{-5}	0.011	0.014
8.7 GHz Subrahmanyan et al (2000)	120	1.4×10^{-5}	0.0084	0.0099

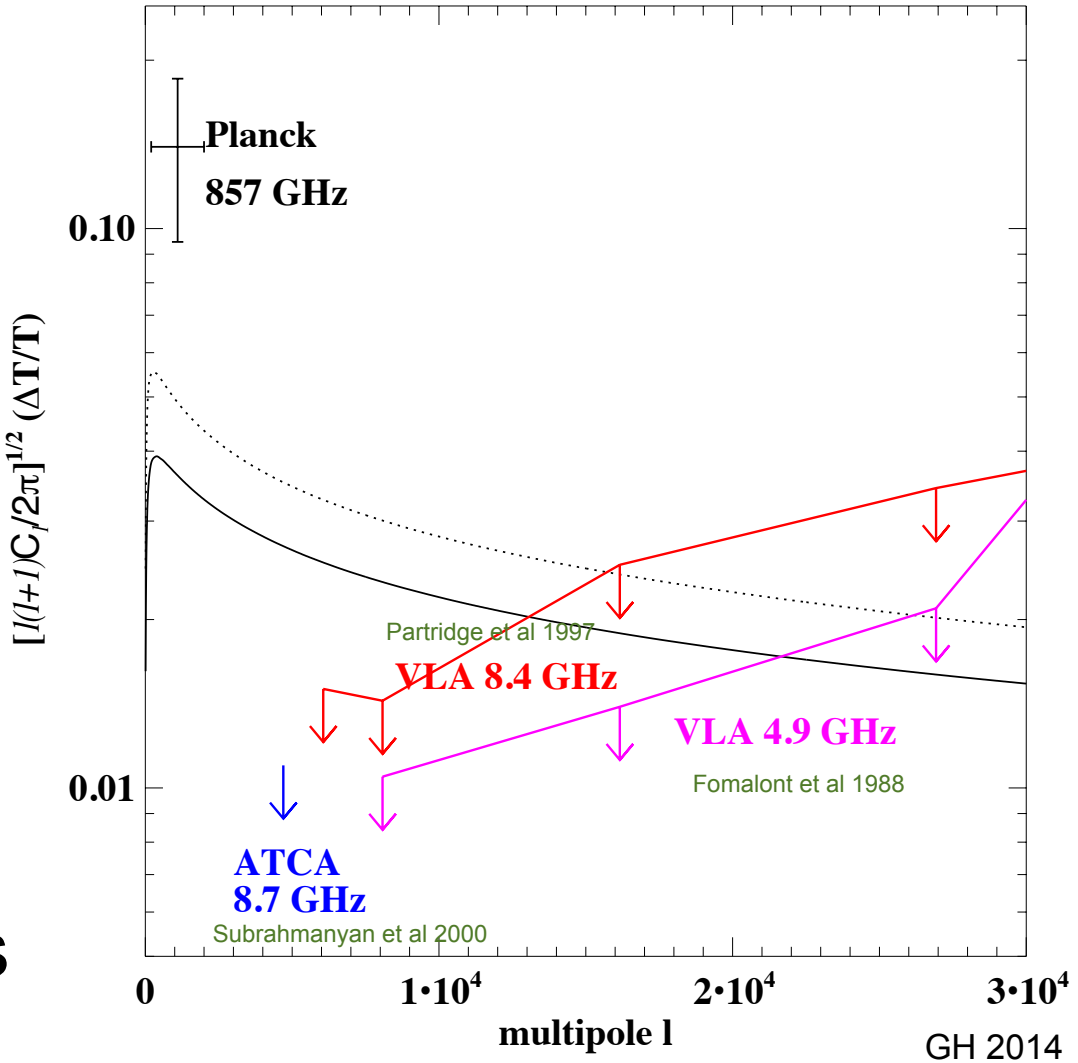
$T-T_{cmb}$ $T-T_{cmb}-T_{counts}$

If there is an excess, it is remarkably unclustered

- minimal assumption: unbiased tracer of <u>linear</u> (2-halo) fluctuations

$$C_\ell(\ell) = \int d\chi \frac{1}{\chi^2} \left(\frac{df}{d\chi}\right)^2 P\left(\frac{\ell}{\chi}, \chi\right)$$

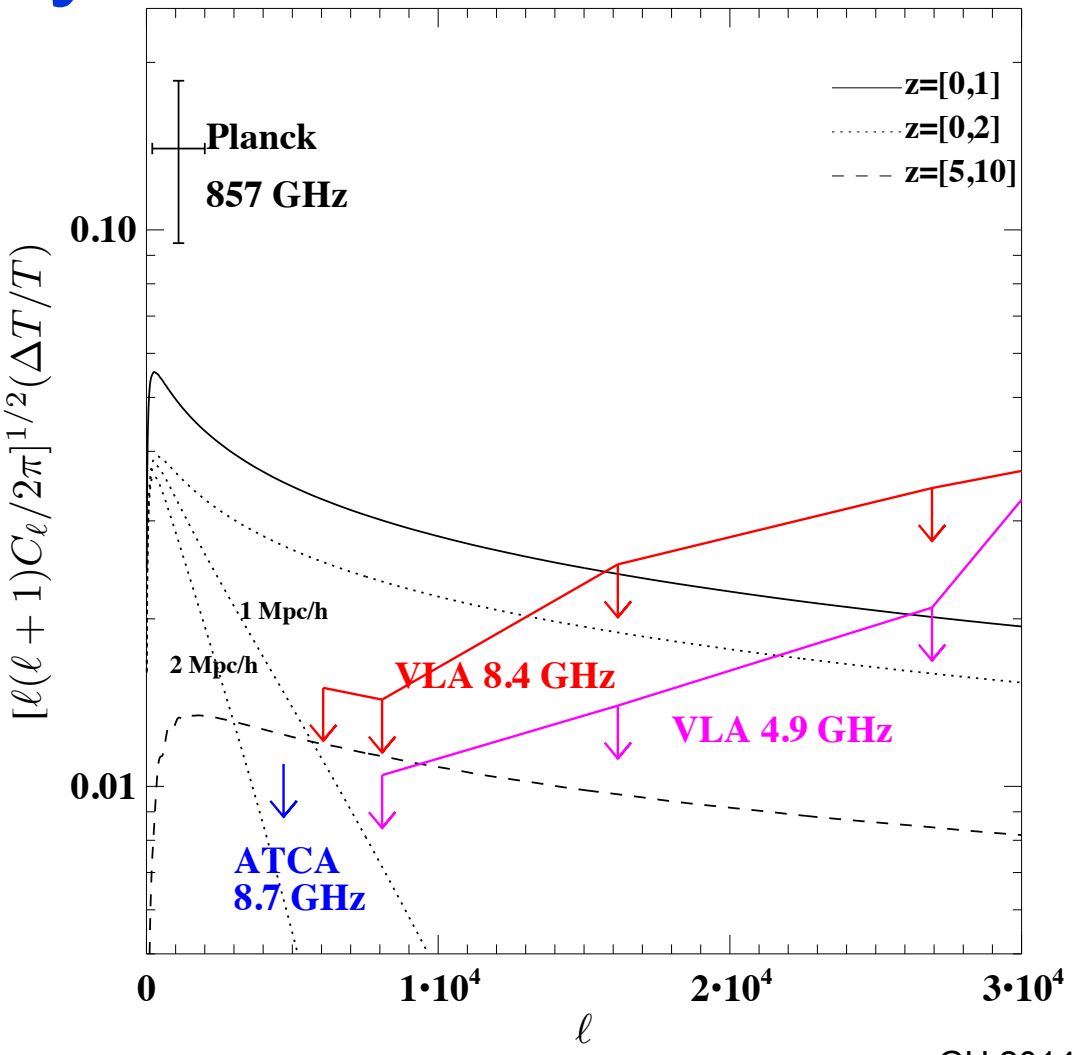
- old searches for CMB anisotropy found no evidence for any fluctuations at radio wavelengths



GH 2014

If there is an excess, it is remarkably unclustered

- if not foreground contamination, must be either
  - extremely diffuse (no small scale structure on scales probed by VLA or ATCA)
  - at very high redshift (where intrinsic clustering amplitudes are lower)



GH 2014

Conclusions

- galaxies are clustered
  - presumably because they are tracing dark matter, which is clustered
- a background that is a superposition of a bunch of galaxies will show clustering
  - e.g., the cosmic infrared background shows clustering at the level of ~10% on scales of a few arcminutes
- the radio background on arc minute scales is smooth at the percent level
  - it probably isn't made up of a simple superposition of galaxies
    - unless: small-scale features are smoothed out or at high redshift so that the dark matter is relatively unclustered or coming from rare enough sources that the (small-area) radio CMB limits don't apply