Cluster Science

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with inputs from Z.-Y. Cai, G. De Zotti, M. Remazeilles, J. Delabrouille

PICO workshop, Minneapolis, May 1st 2018

Outline

- Sky simulations, predicted PICO cluster counts
- Impact of intra cluster dust on PICO cluster counts
- Comparison to CMB-S4

Simulations

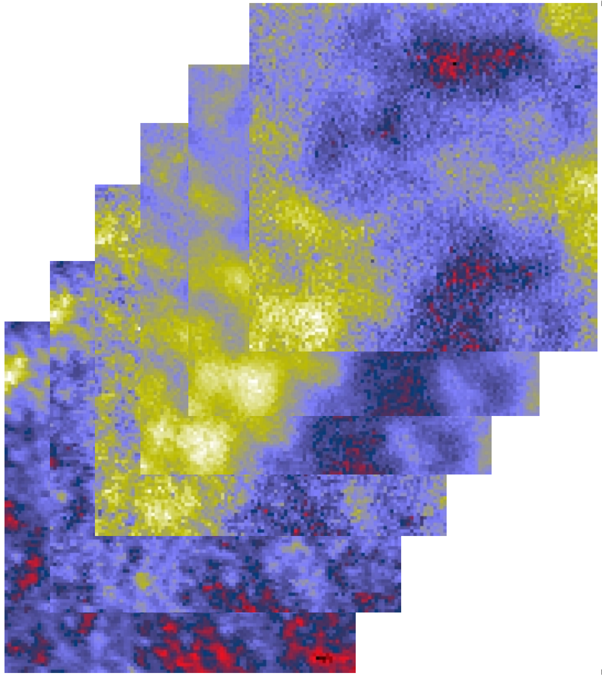
- Maps simulated by M. Remazeilles using the Planck Sky Model (Delabrouille et al. 2013) and based on **banddefinitionsv2-1.4.xls**
- 21 bands: 21, 25, 30, 36, 43, 52, 62, 75, 90, 110, 130, 155, 185, 225, 270, 320, 385, 460, 555, 665, 800 GHz
- Beam FWHM: 40.9, 34.1, 28.4, 23.7, 19.7, 16.4, 13.7, 11.4, 9.5, 7.9, 6.6, 5.5, 4.6, 3.8, 3.2, 2.7, 2.2, 1.8, 1.5, 1.3, 1.1 arcmin
- Instrumental noise (pol): 50, 33, 22.4, 15, 9.1, 7, 5, 4, 3.2, 2.9, 2.7, 2.6, 3.6, 5.3, 9, 16, 32, 75, 220, 1100, 10000 μKarcmin

➔Note that the latest configuration for PICO (v3.0) has a better sensitivity (factor of >~SQRT(2) improvement in CMB channels)

The SZ Multifrequency Matched Filter

adopted by the Planck, SPT & ACT collaborations

PICO maps

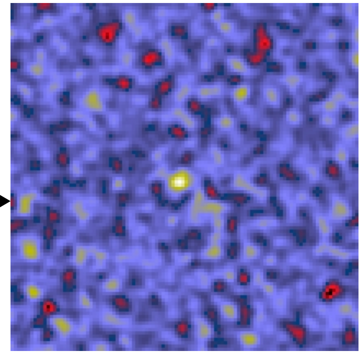


MMF

assumes
- SZ frequency spectrum
- cluster profile
- noise cross-power spectra

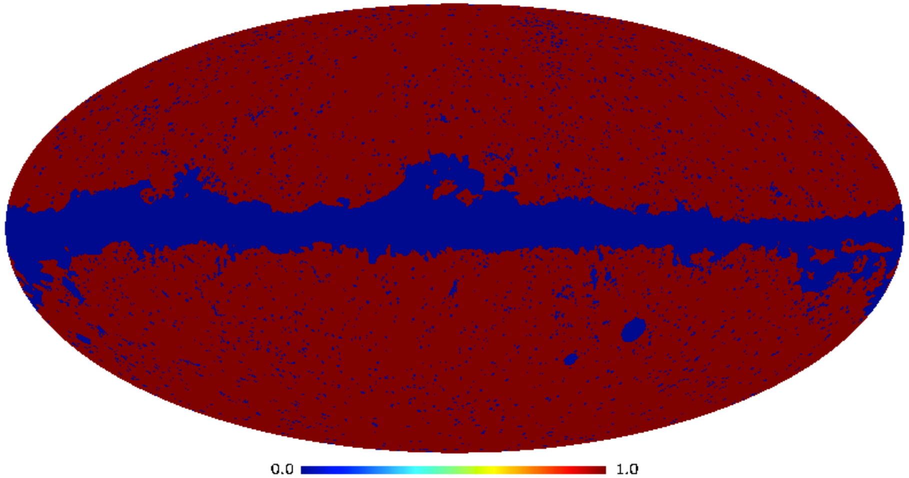
Herranz et al. 2002
Melin, Bartlett, Delabrouille 2006

Filtered map



✧ Linear estimator
✧ Minimizes the variance of the noise
✧ Unbiased

Method



➔Work on the **cleanest 85%** of the sky (Planck mask)

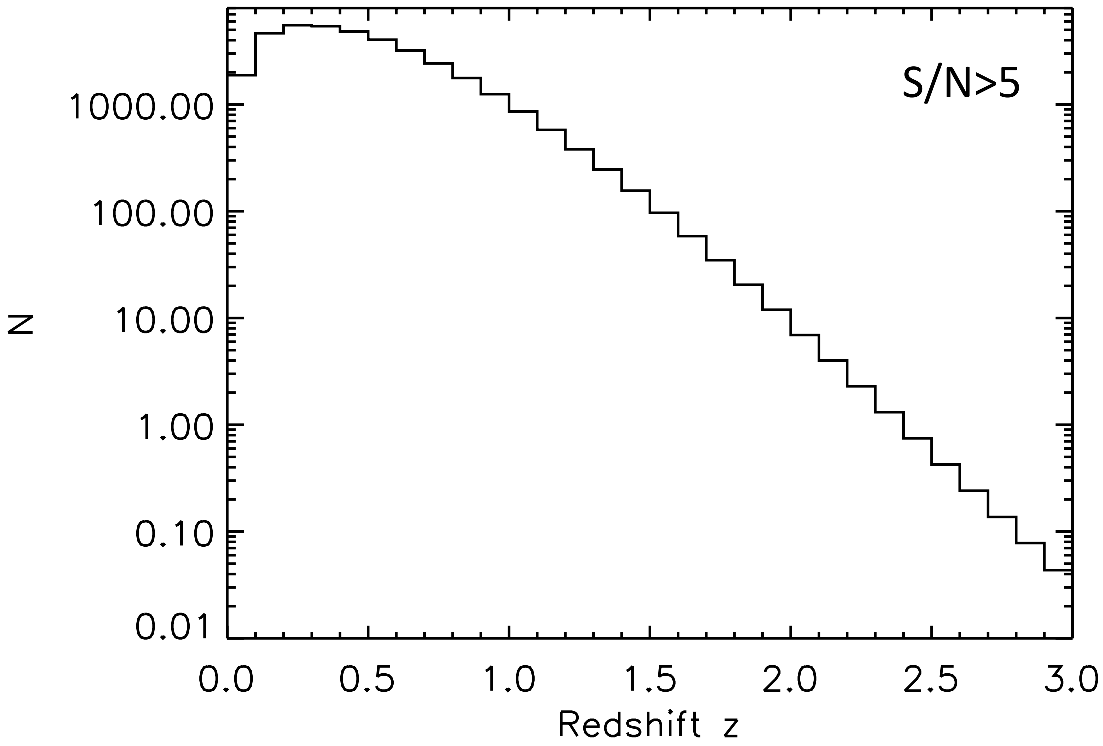
➔Cluster counts based on **multifrequency matched filters** (MMF)

➔We do not extract clusters directly from M. Remazeilles' maps. This would require significant improvements from the existing Planck tools. Instead, we apply the MMF to the maps and simply estimate the **SZ noise level**.

➔Using the **SZ noise level,** we build the **survey completeness**, and predict the **expected cluster counts** from the Tinker et al. mass function

Expected counts

Frequencies [GHz]
21, 25, 30, 36, 43, 52, 62, 75, 90, 110, 130, 155, 185, 225, 270, 320, 385, 460, 555, 665, 800

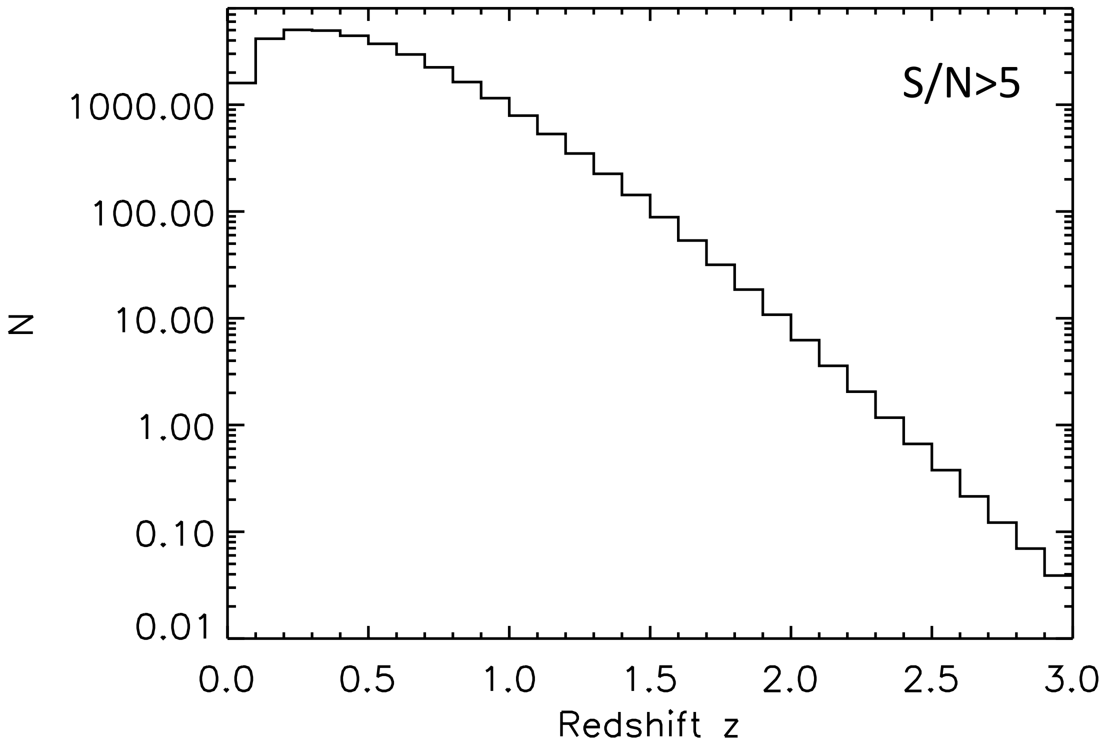


37,400 clusters (all z)
230 clusters (z>1.5)

(close to CORE M5 for v2-1.4)

Expected counts

Frequencies [GHz]
110, 130, 155, 185, 225, 270, 320, 385, 460, 555, 665, 800

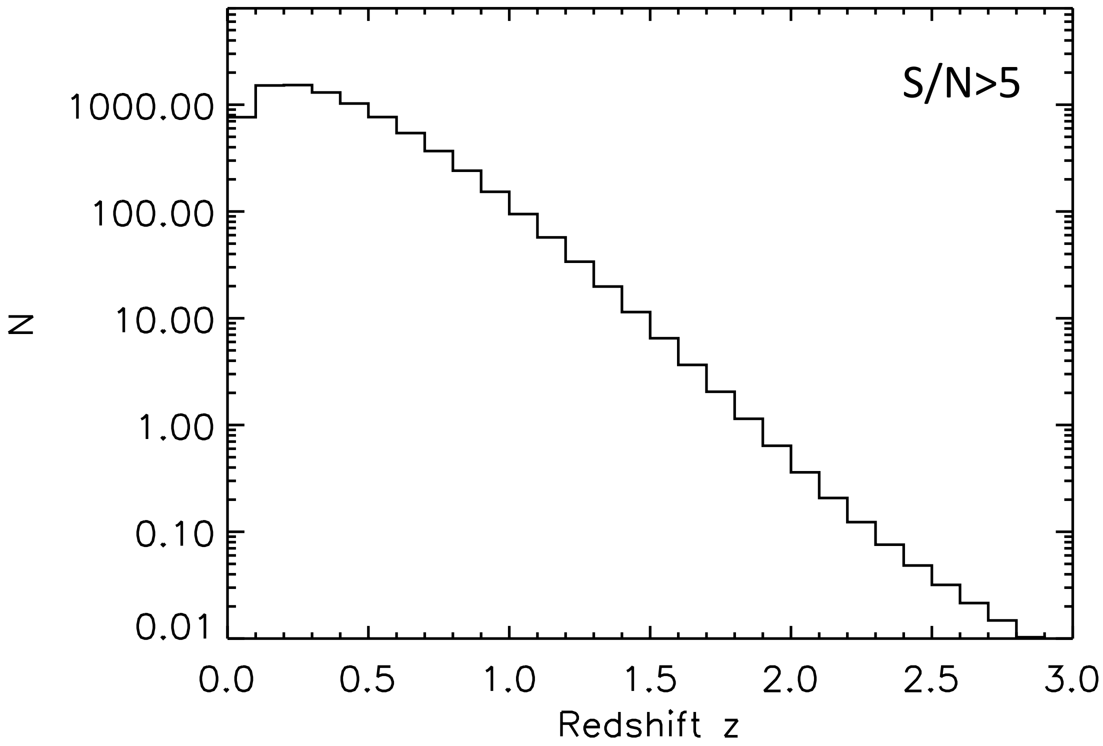


34,100 clusters (all z)
210 clusters (z>1.5)

➔Low frequencies (<100 GHz) participate only weakly to SZ detection

Expected counts

Frequencies [GHz]
110, 130, 155, 185, 225, 270



8,400 clusters (all z)
10 clusters (z>1.5)

➔High frequencies (>300 GHz) participate strongly to SZ detection

Outline

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Dust model

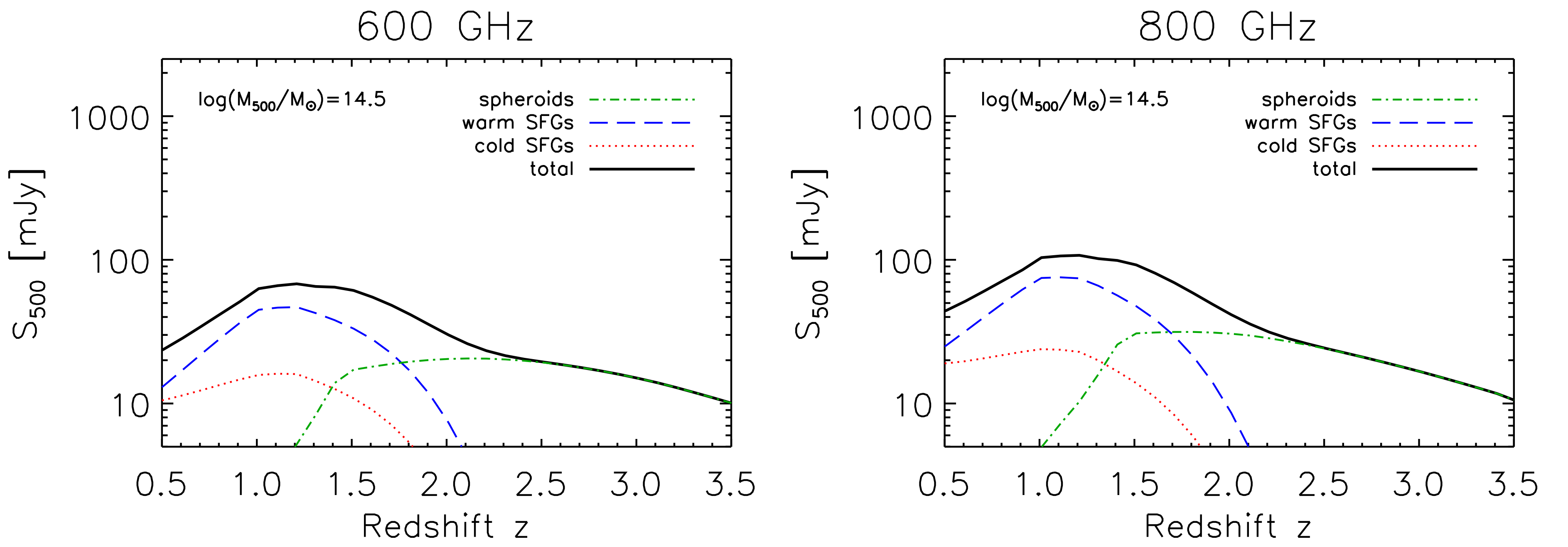
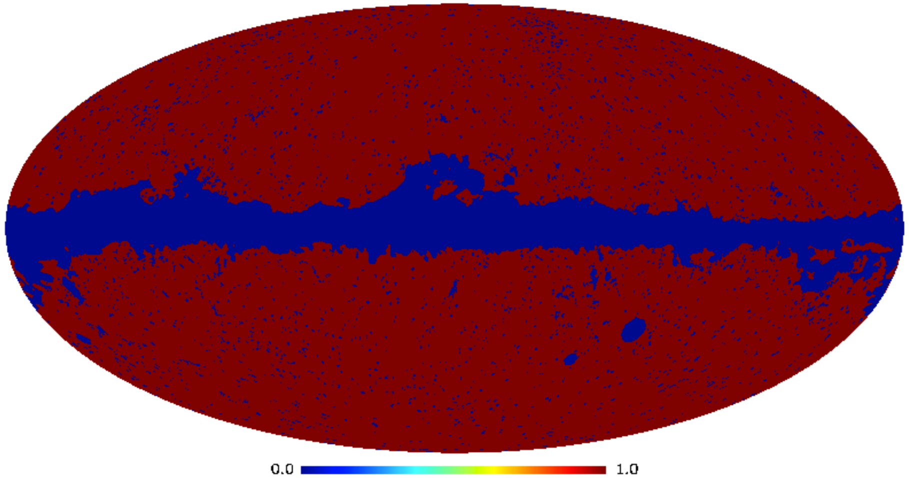


Figure adapted from De Zotti et al. 2016

De Zotti et al. 2016, Melin et al. (submitted to A&A)

➔based on *Herschel* observations (Alberts et al. 2014, 2016) and on the model from Cai et al. 2013 for the luminosity functions and spectral energy distributions

Method



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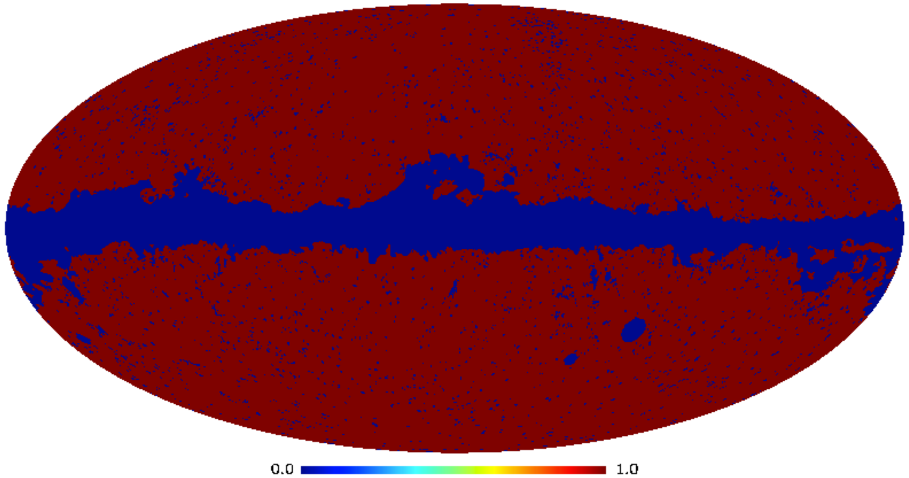
➔Using the **SZ noise level,** we build the **survey completeness**, and predict the **expected cluster counts** from the Tinker et al. mass function

Method



➔Work on the **cleanest 85%** of the sky (Planck mask)

➔Cluster counts based on **multifrequency matched filters** (MMF)

➔We do not extract clusters directly from M. Remazeilles' maps. This would require significant improvements from the existing Planck tools. Instead, we apply the MMF to the maps and simply estimate the **SZ noise level**.

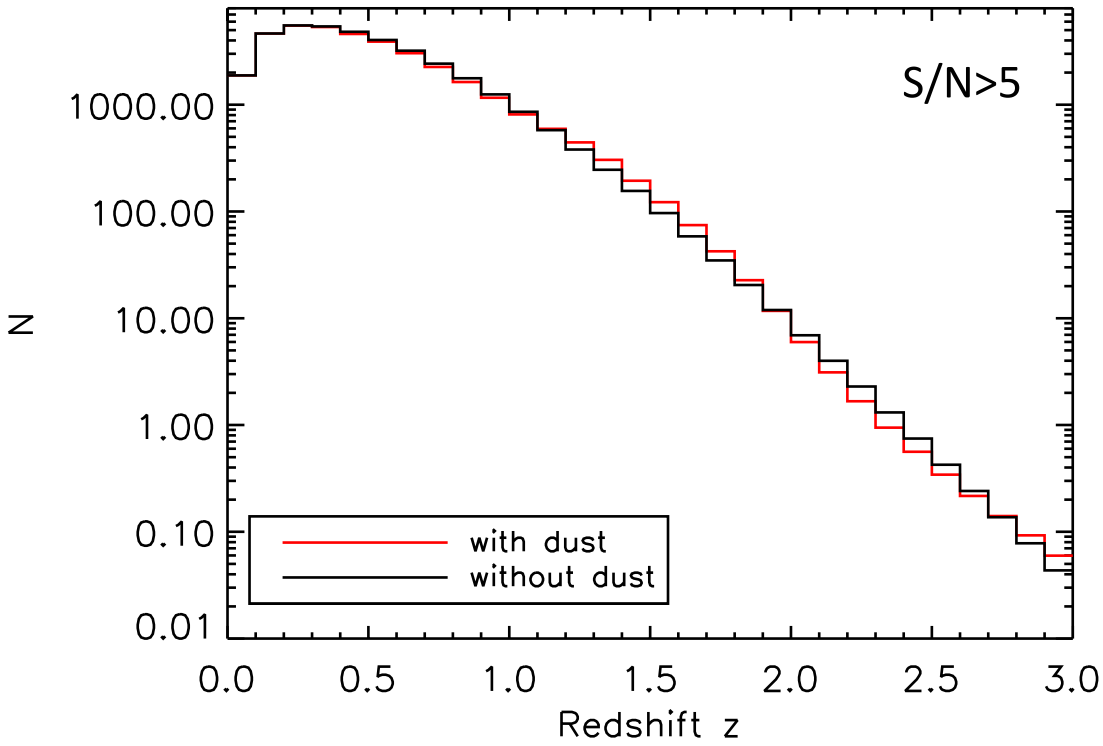
➔The **bias on the recovered SZ flux due to the dust component** is computed from the MMF weights and the assumed dust model.

➔Using the **SZ noise level,** we build the **survey completeness**, and predict the **expected cluster counts** from the Tinker et al. mass function

➔We modify **the survey completeness** according to the bias on the recovered SZ flux and compute the expected cluster counts with dust.

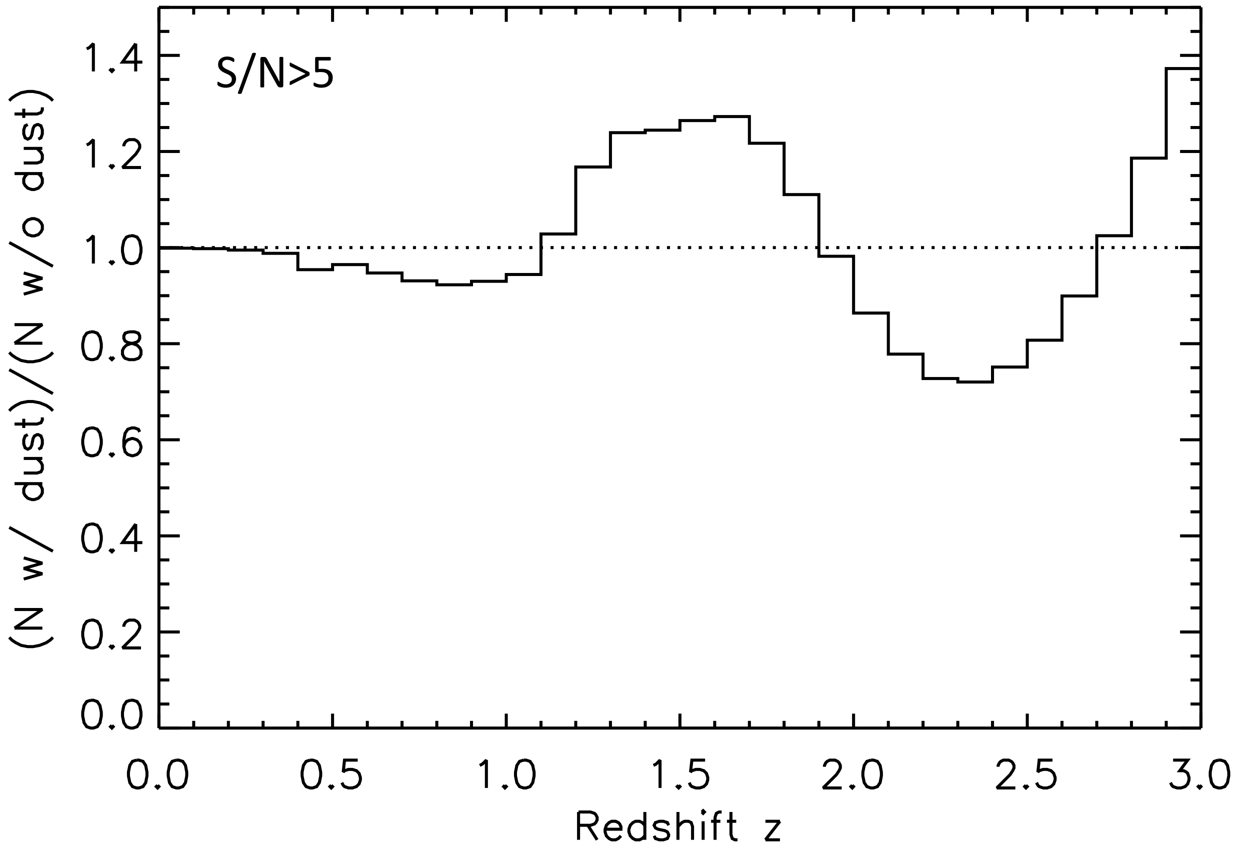
Expected counts

Frequencies [GHz]
21, 25, 30, 36, 43, 52, 62, 75, 90, 110, 130, 155, 185, 225, 270, 320, 385, 460, 555, 665, 800



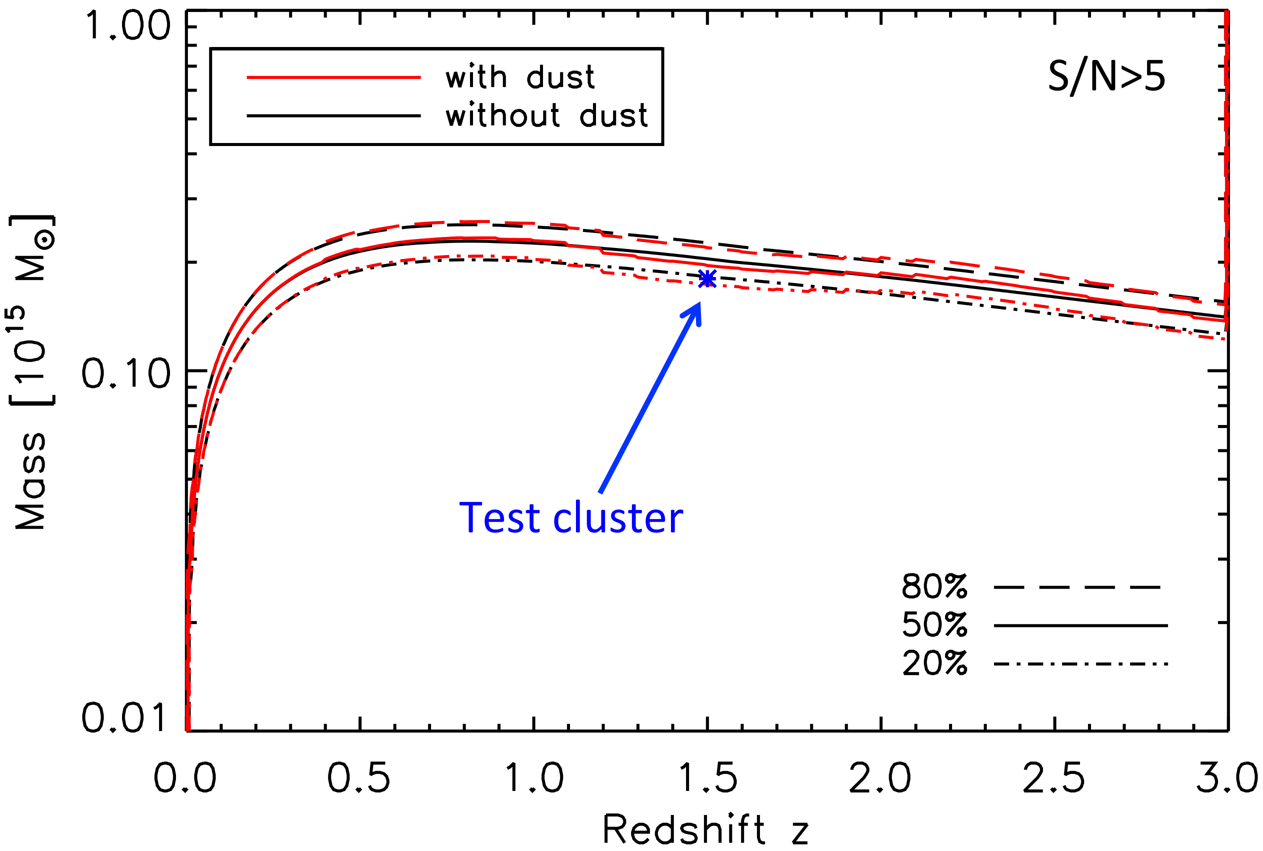
37,400 clusters (without dust)
36,500 clusters (with dust)

Expected counts (ratio)



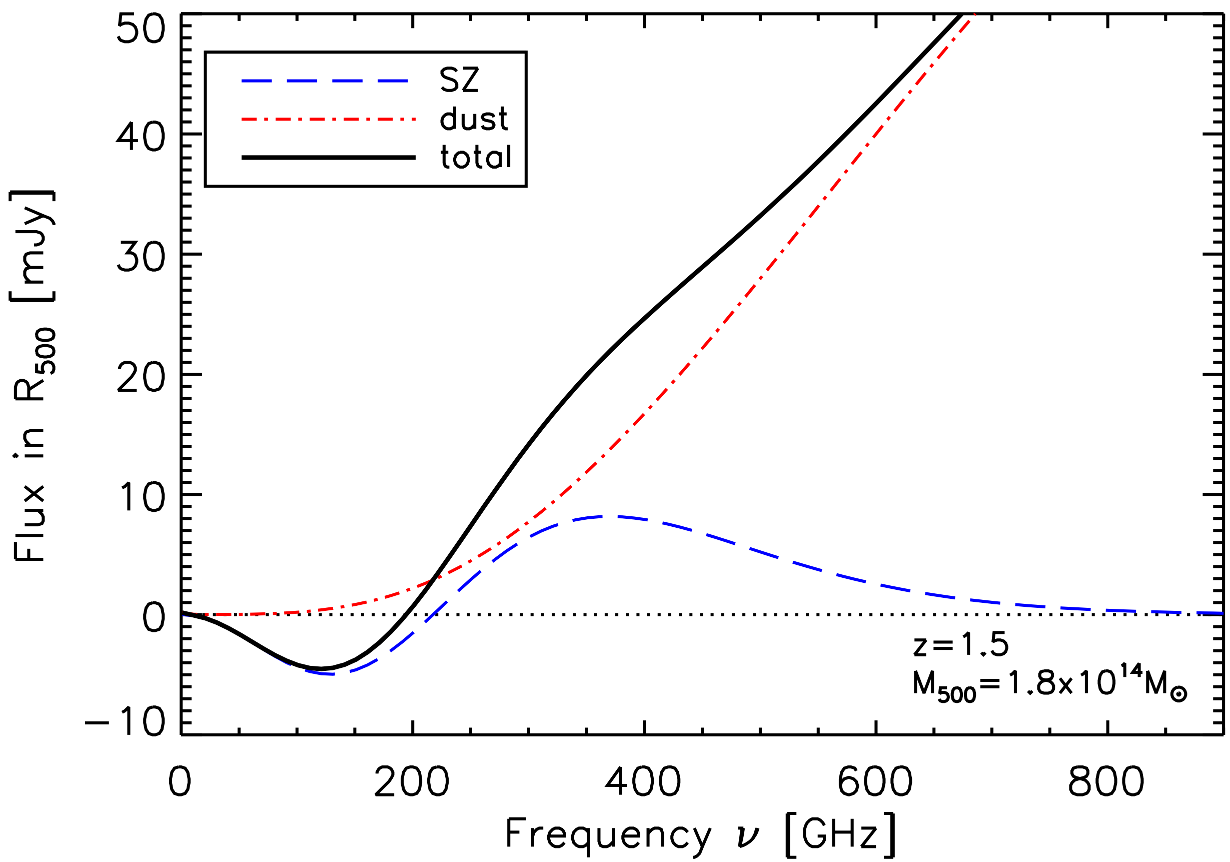
➔Up to 40% difference at a given redshift between observation (“N w/ dust”) and expectation if dust cannot be or is not modelled (“N w/o dust”)

Completeness



➔"With dust" oscillates around "without dust" as can also be seen in the counts

A test cluster (blue star)



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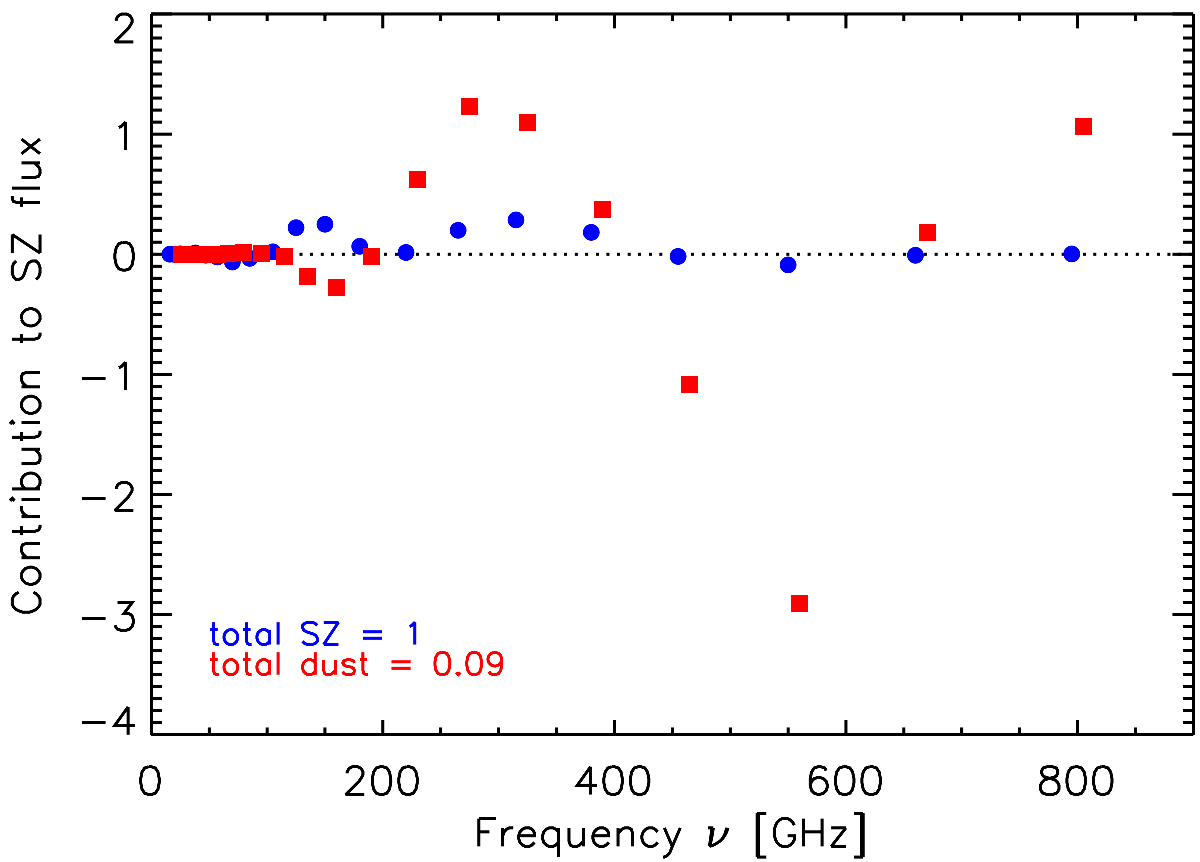
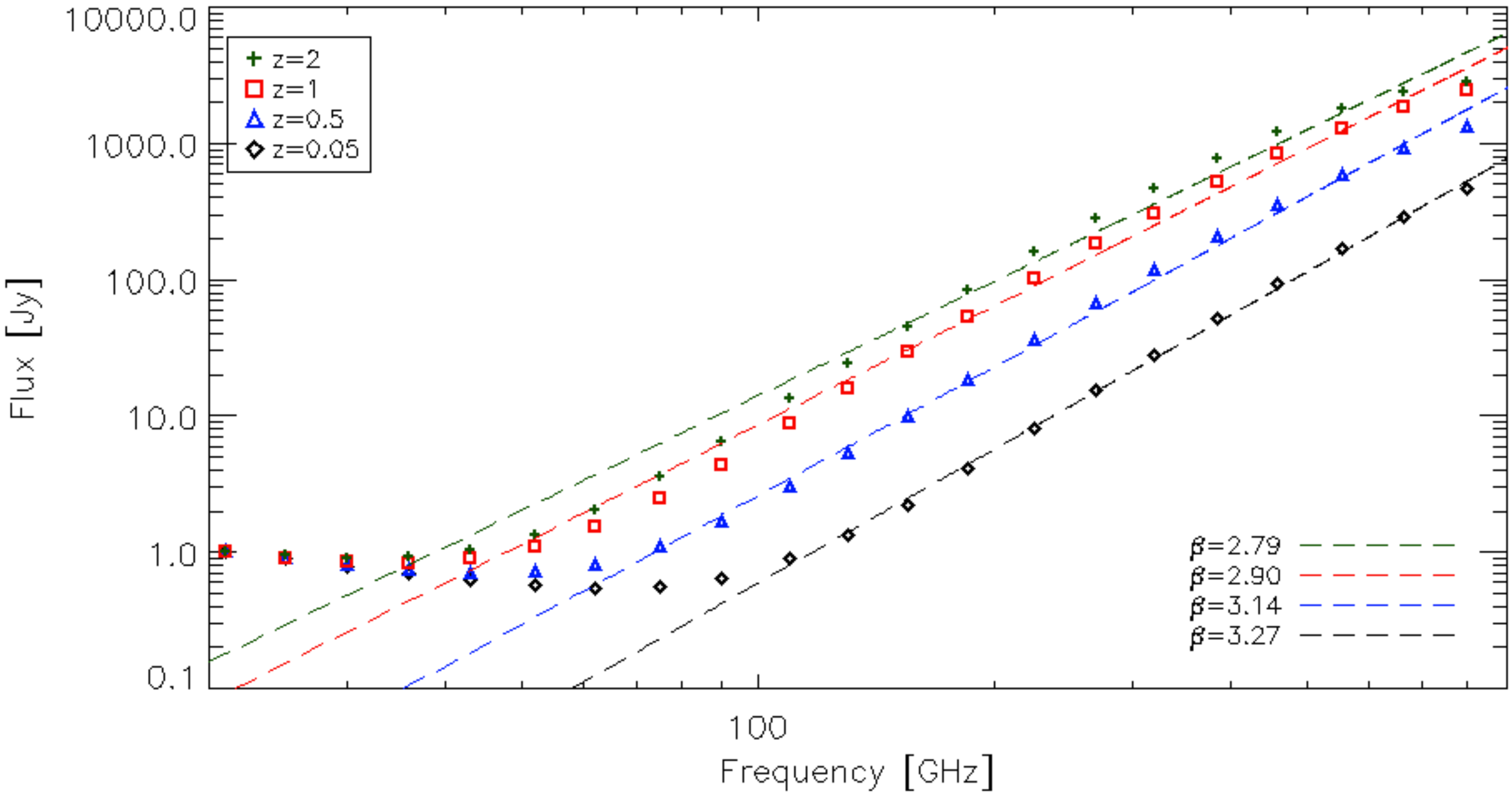


➔Total emission through the SZ MMF = SZ emission + 9% due to dust (see increase of completeness in the redshift range [1.1,1.9])

A SZ+dust MMF ?

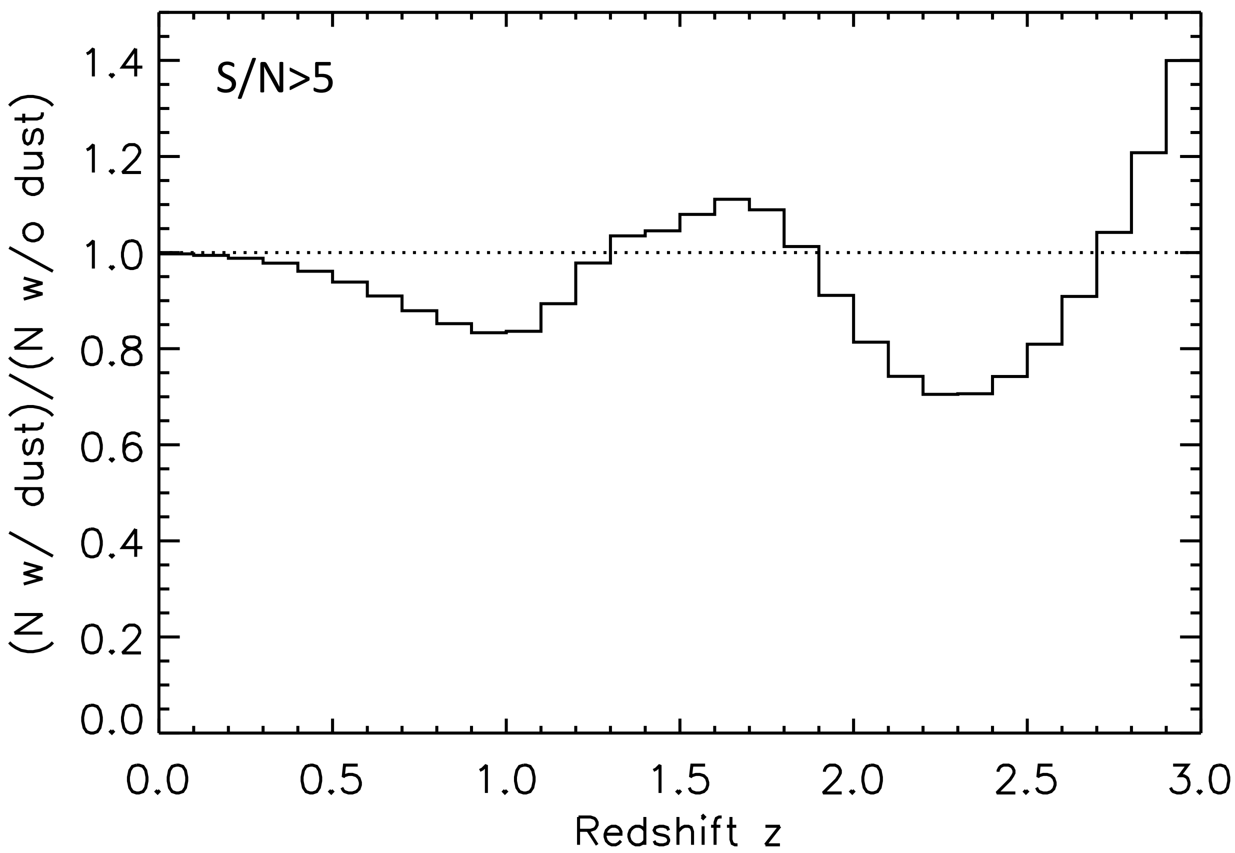
Dust SED



➔Actual dust SED complex. Make a first approximation: adopt ν^{β} with β=2.9 at all z

Expected counts (ratio)

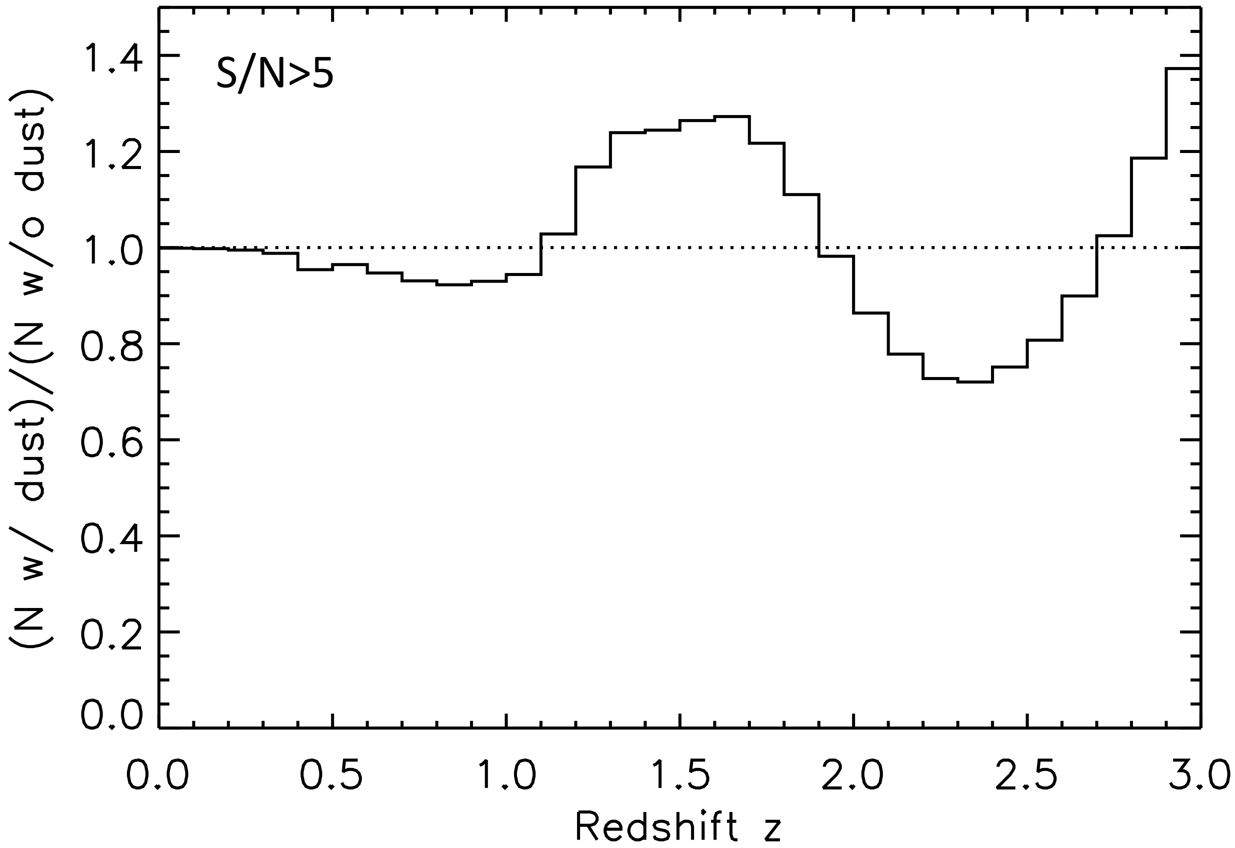
SZ+dust MMF
dust SED $\nu^{2.9}$



➔Only a small improvement with respect to the standard SZ MMF

Expected counts (ratio)

Standard
SZ MMF



➔Only a small improvement with respect to the standard SZ MMF

Outline

- Sky simulations, predicted PICO cluster counts
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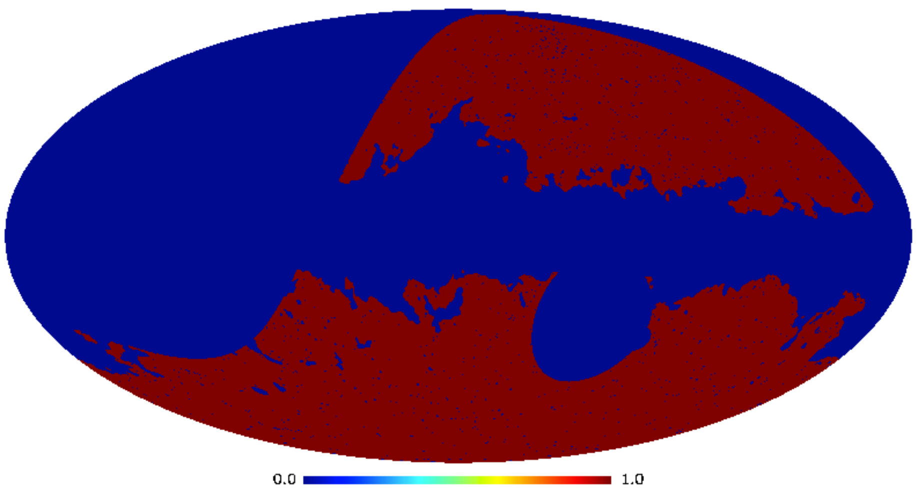
CMB-S4 configuration

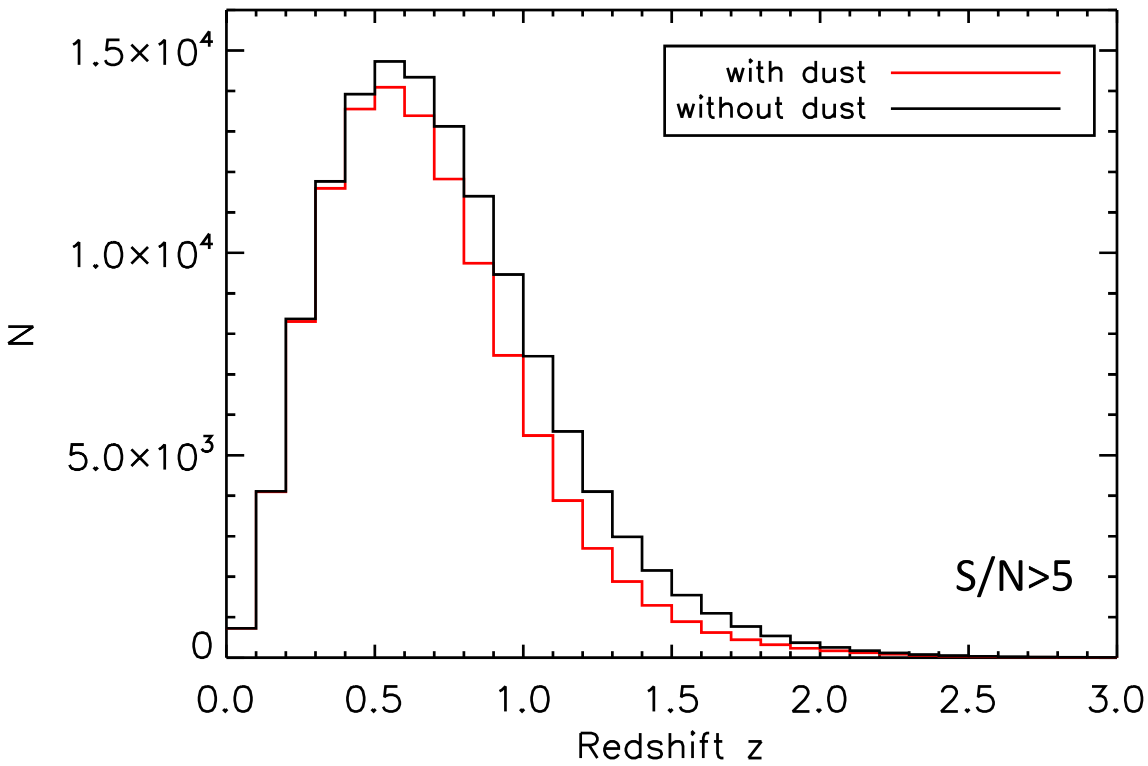
- Maps simulated by M. Remazeilles using the Planck Sky Model (Delabrouille et al. 2013)
- 5 bands: 40, 95, 145, 220, 270 GHz
- Beam FWHM: 5.2, 2.2, 1.4, 1.0, 0.8 arcmin
- Instrumental noise: 5.6, 1.3, 1.8, 9.1, 17.1 μKarcmin



➔40% of the sky (cleanest part visible from Atacama)

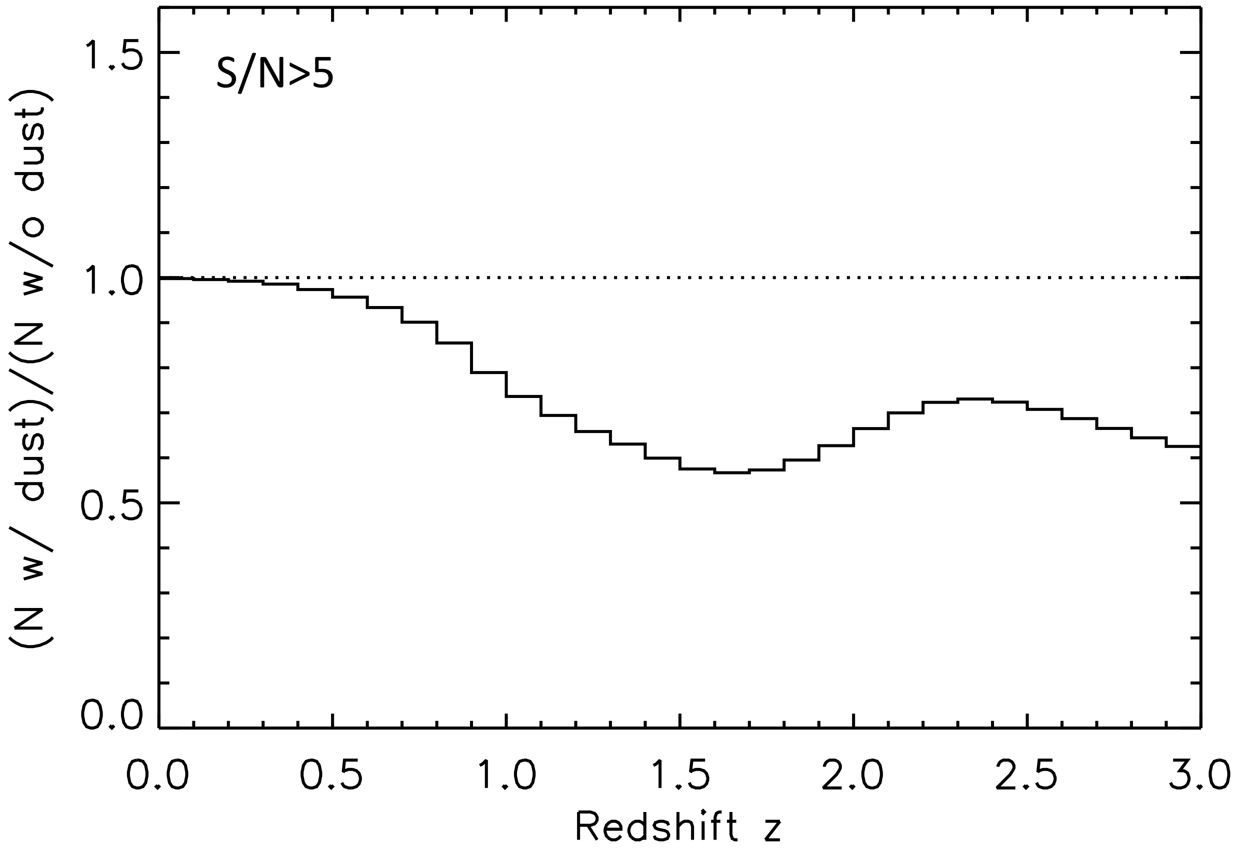
Expected counts CMB-S4

Frequencies [GHz]
40, 95, 145, 220, 270



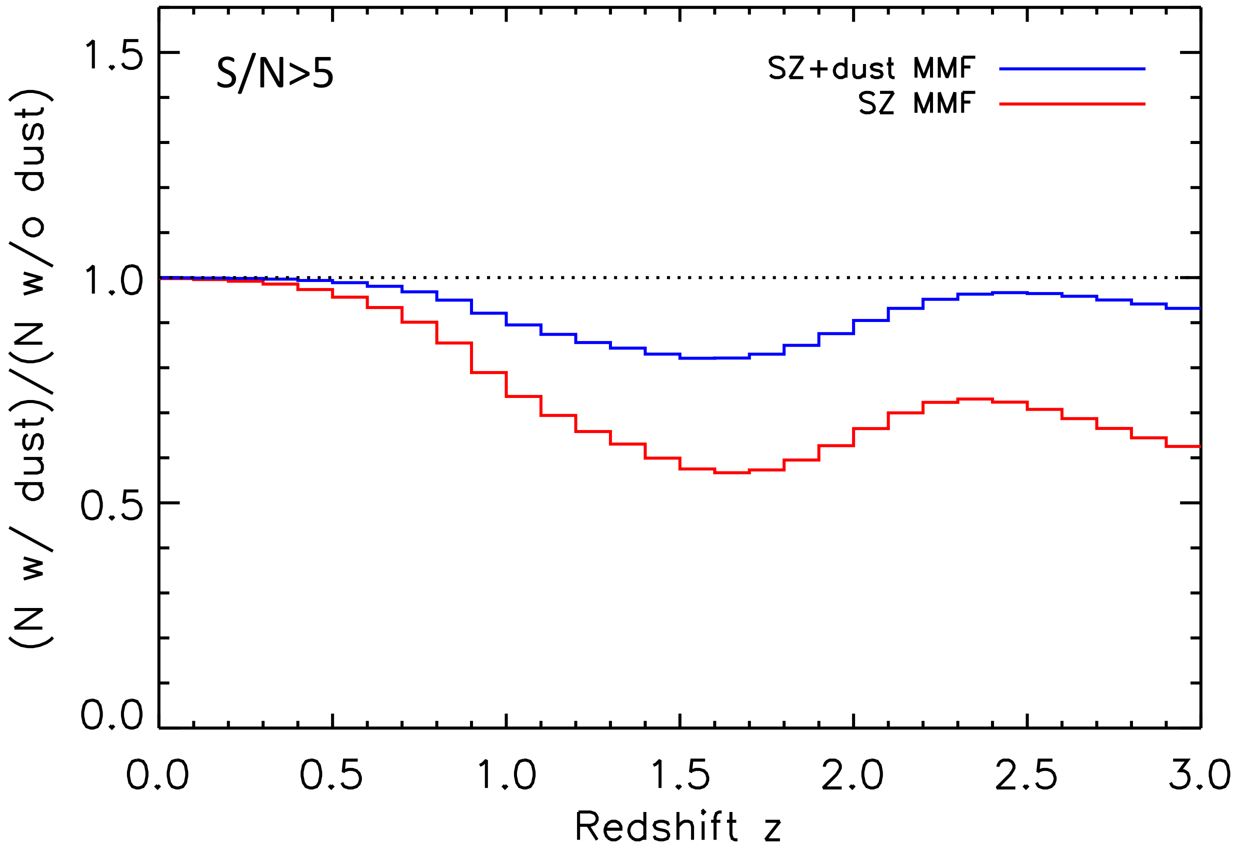
129,000 clusters (without dust)
113,000 clusters (with dust)

Expected counts CMB-S4 (ratio)



➔Effect larger than PICO and shape differs (sensitive to instrumental characteristics)

Expected counts CMB-S4 (ratio)



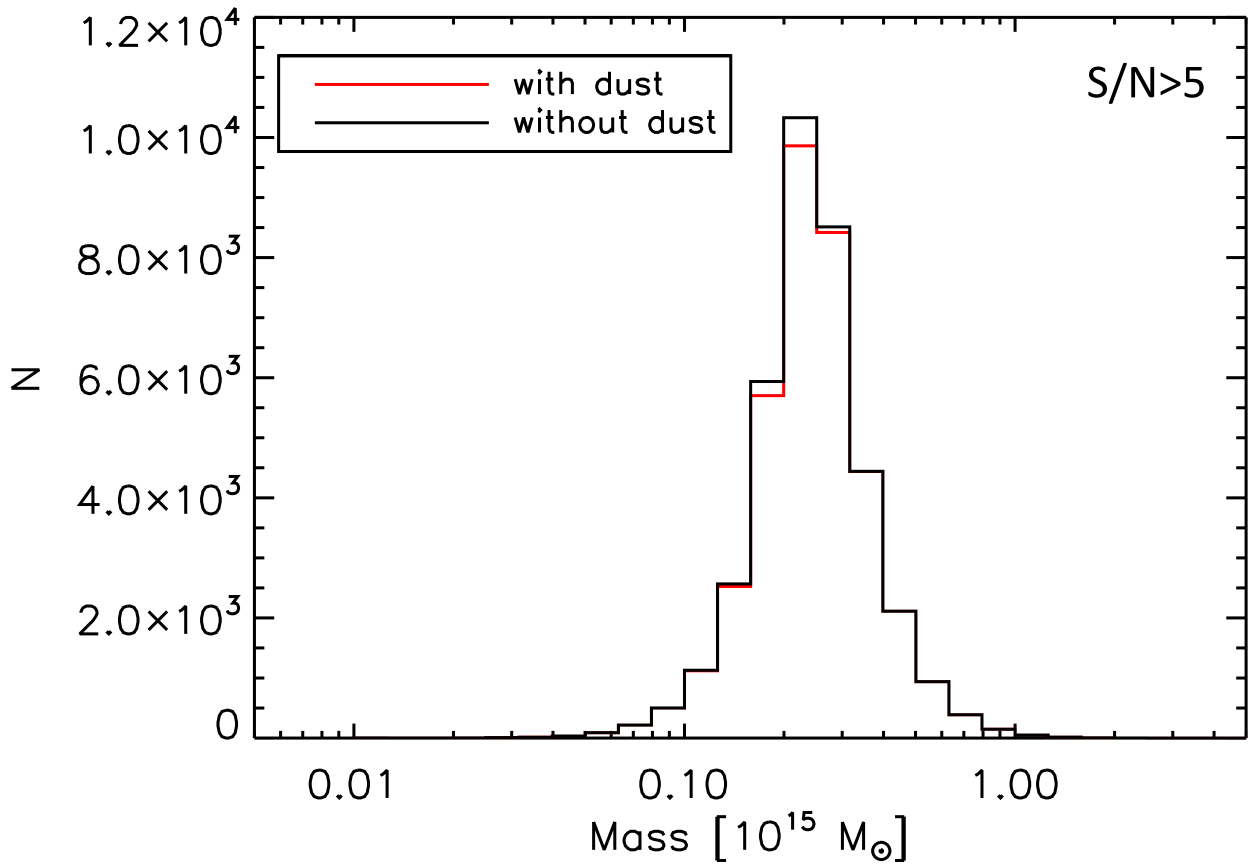
➔SZ+dust MMF (assuming dust SED is a power law at all z)

Conclusions

- Low frequencies (<100GHz) only participate weakly to SZ sensitivity. High frequencies (>300GHz) participate significantly to SZ detection.
- Dust SED in clusters expected to be complex. High frequency coverage (>300 GHz) crucial to characterize it.
- Dust characterization important both for cosmology (handling of the cluster catalogue selection function) and for cluster astrophysics (contamination of the SZ flux by dust, see also J. Bartlett's talk)
- CMB-S4 cluster counts also sensitive to dust contamination which we will have to be characterized
- Impact of other cluster emissions (e.g. radio sources)?

Back-up slide

Expected PICO counts (mass)



➔Differences in counts mostly at low cluster mass