

# Joint cluster detection in X-ray/SZ and ground-SZ/space-SZ surveys



## Perspective for cluster studies with future millimeter datasets

Jean-Baptiste Melin (CEA Saclay)

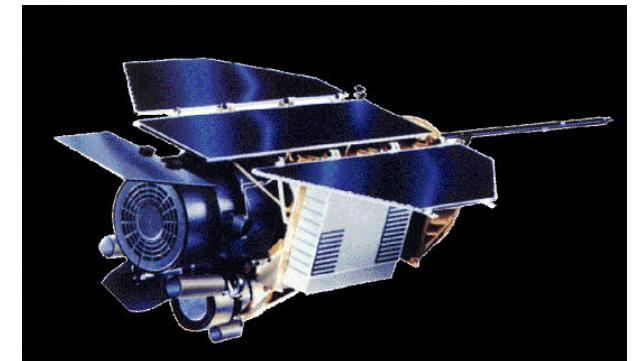
Collaborators: J. G. Bartlett (APC-U. of Paris, JPL), P. Tarrío (OAN Madrid),  
M. Arnaud (CEA Saclay), G. W. Pratt (CEA Saclay)

# Content

- Joint cluster detection in X-ray/SZ surveys:  
ROSAT(RASS) and Planck
- Joint cluster detection in ground-SZ/space-SZ surveys:  
SPT-SZ and Planck
- Perspective for cluster studies with future millimeter datasets:  
cluster catalogues, cluster mass estimation via CMB halo lensing

# Motivations – data public!

- **ROSAT(RASS)** data public (since 2000) – all-sky  $42,000 \text{ deg}^2$
- **Planck** data public (since 2013) – all-sky  $42,000 \text{ deg}^2$
- Ground based **SPT** data –  $2,500 \text{ deg}^2$  *Chown et al. 2018*  
ACT data –  $18,000 \text{ deg}^2$  *Naess et al. 2020*  
also public (only recently)



ROSAT satellite



Planck satellite



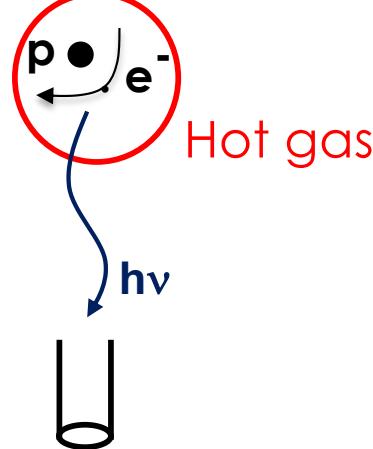
South Pole Telescope  
(SPT)



Atacama Cosmology Telescope  
(ACT)

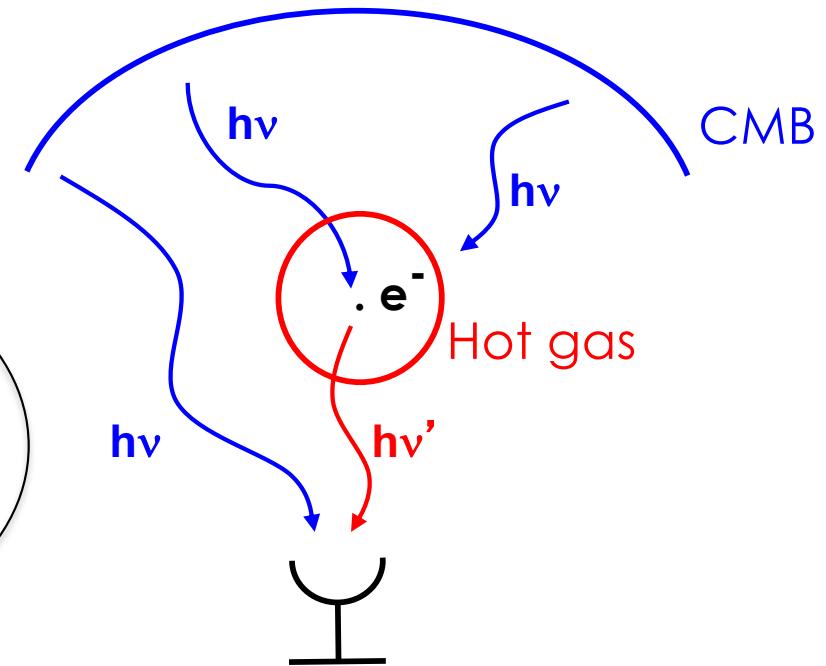
# Motivations – complementarity!

Bremsstrahlung



ROSAT

Sunyaev-Zeldovich effect



Planck, SPT, ACT

Different physical processes

Different resolutions, different sensitivities, different astrophysical noises

# Motivations – combination!

- **Comparing** the datasets allows better understanding of the characteristics/systematics of the experiments and cluster physics
- **Combining** the datasets allows the detection of fainter clusters



- First catalogue ROSAT+Planck (*Tarrio et al. 2019*)
- First combination ACT+Planck by *Aghanim et al. 2019*
- First catalogue SPT+Planck (*Melin et al. 2020*)

# **ROSAT(RASS) and Planck datasets Combination!**

**ComPRASS**

*Tarrío P., Melin J.-B., Arnaud M., 2019, A&A, 626, A7*

*Tarrío P., Melin J.-B., Arnaud M., 2018, A&A, 614, A82*

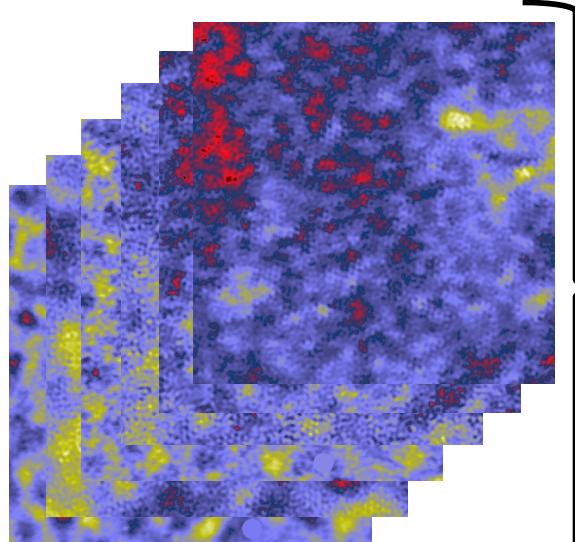
*Tarrío P., Melin J.-B., Arnaud M., Pratt G. W., 2016, A&A, 591, A39*

**M2C ERC project (PI: M. Arnaud)**

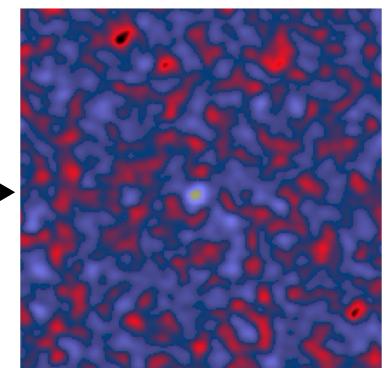
# The thermal SZ Matched Multi-Filter (MMF)

→ Sunyaev-Zeldovich

Planck maps



Filtered map



## MMF

assumes

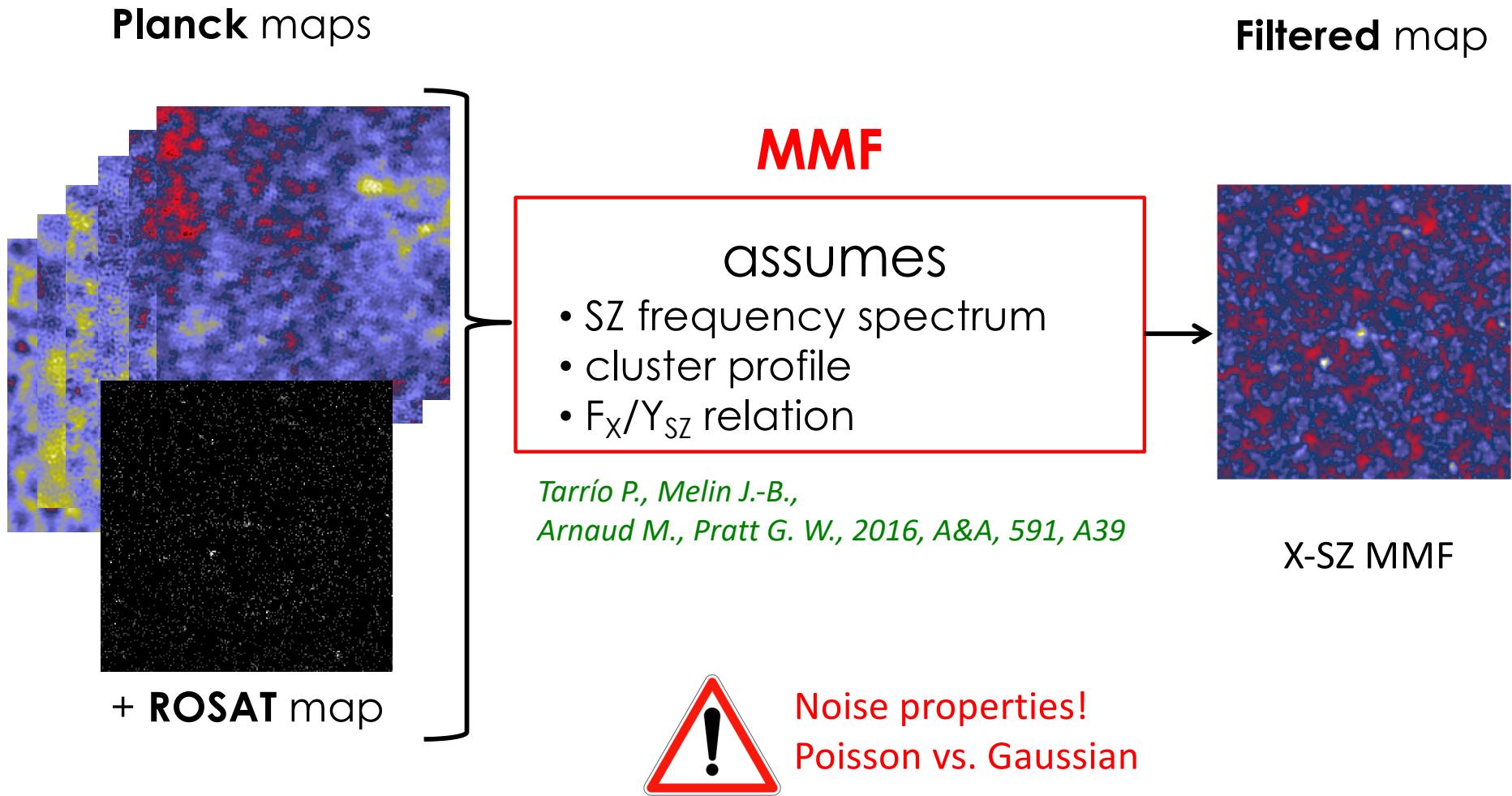
- SZ frequency spectrum
- cluster profile

*Herranz et al. 2002  
Melin, Bartlett, Delabrouille 2006*

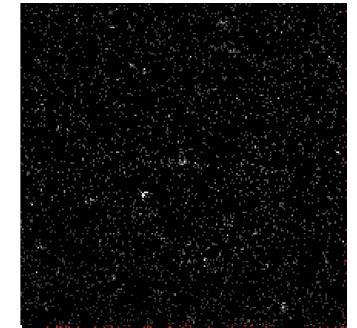
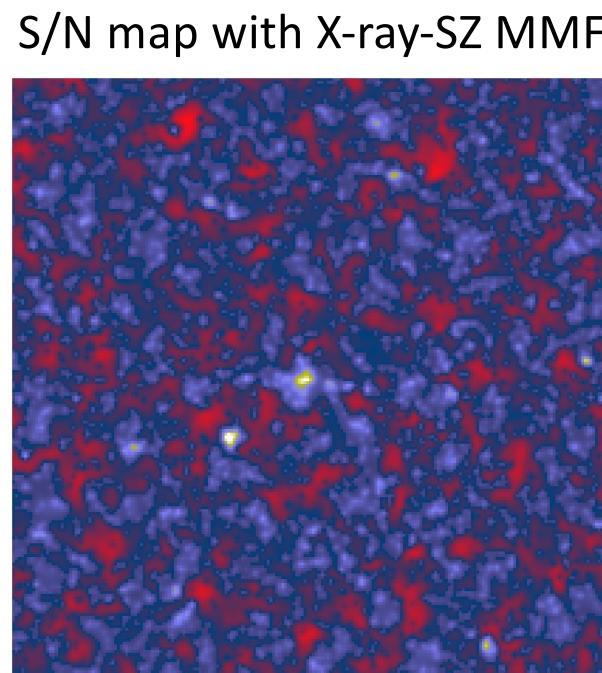
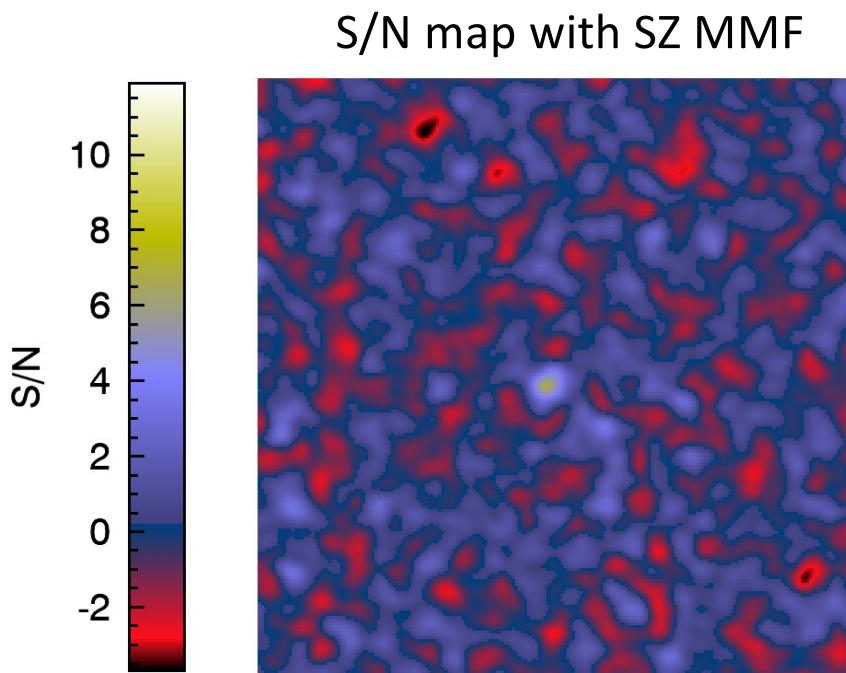
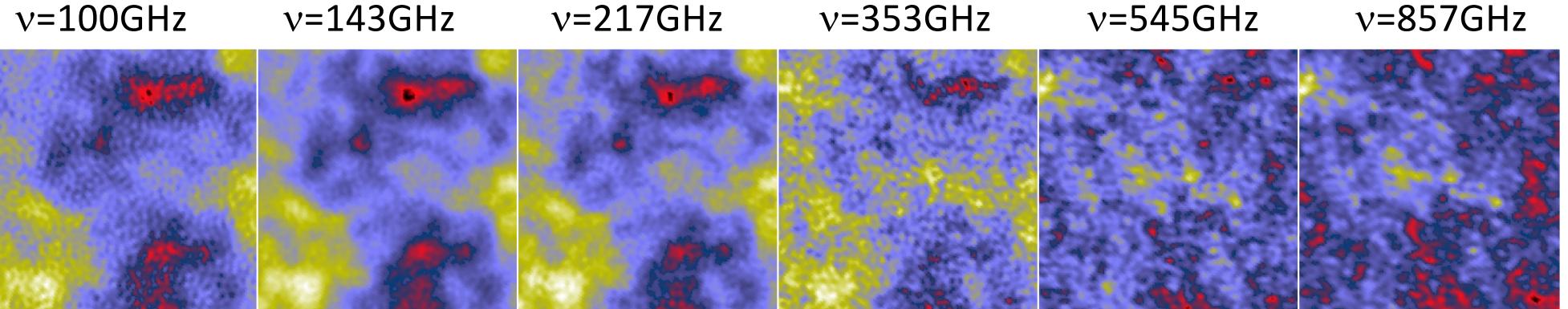
Planck MMF3

- ❖ Linear estimator
- ❖ Minimizes the variance of the noise
- ❖ Unbiased

# The X-SZ Matched Multi-Filter



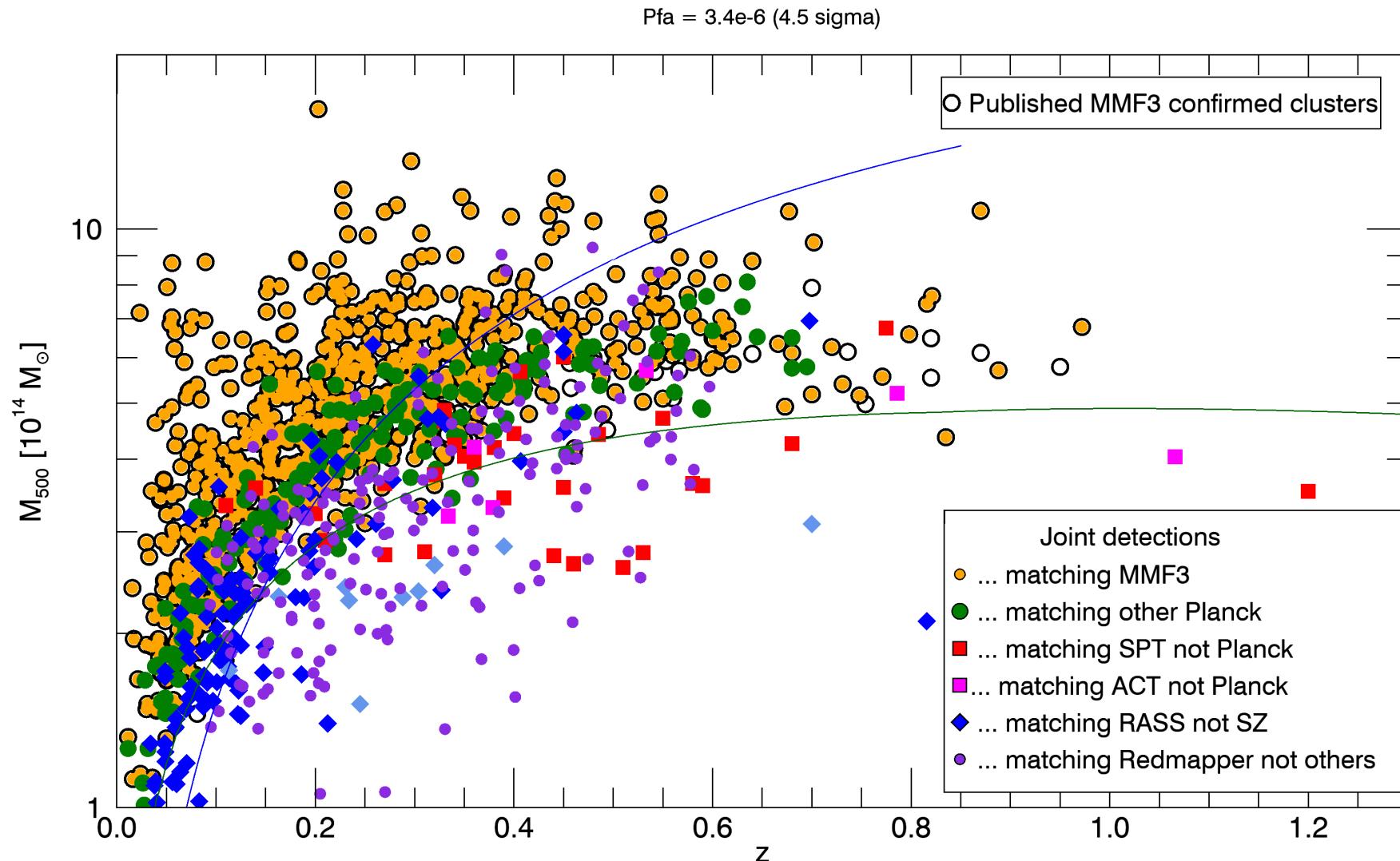
# Example PSZ2 G156.26+59.64 (z=0.59)



X-ray (RASS)  
(converted into  
equivalent SZ map  
through  $F_x/Y_{500}$ )

# ComPRASS: comparison w.r.t. PSZ2-MMF3

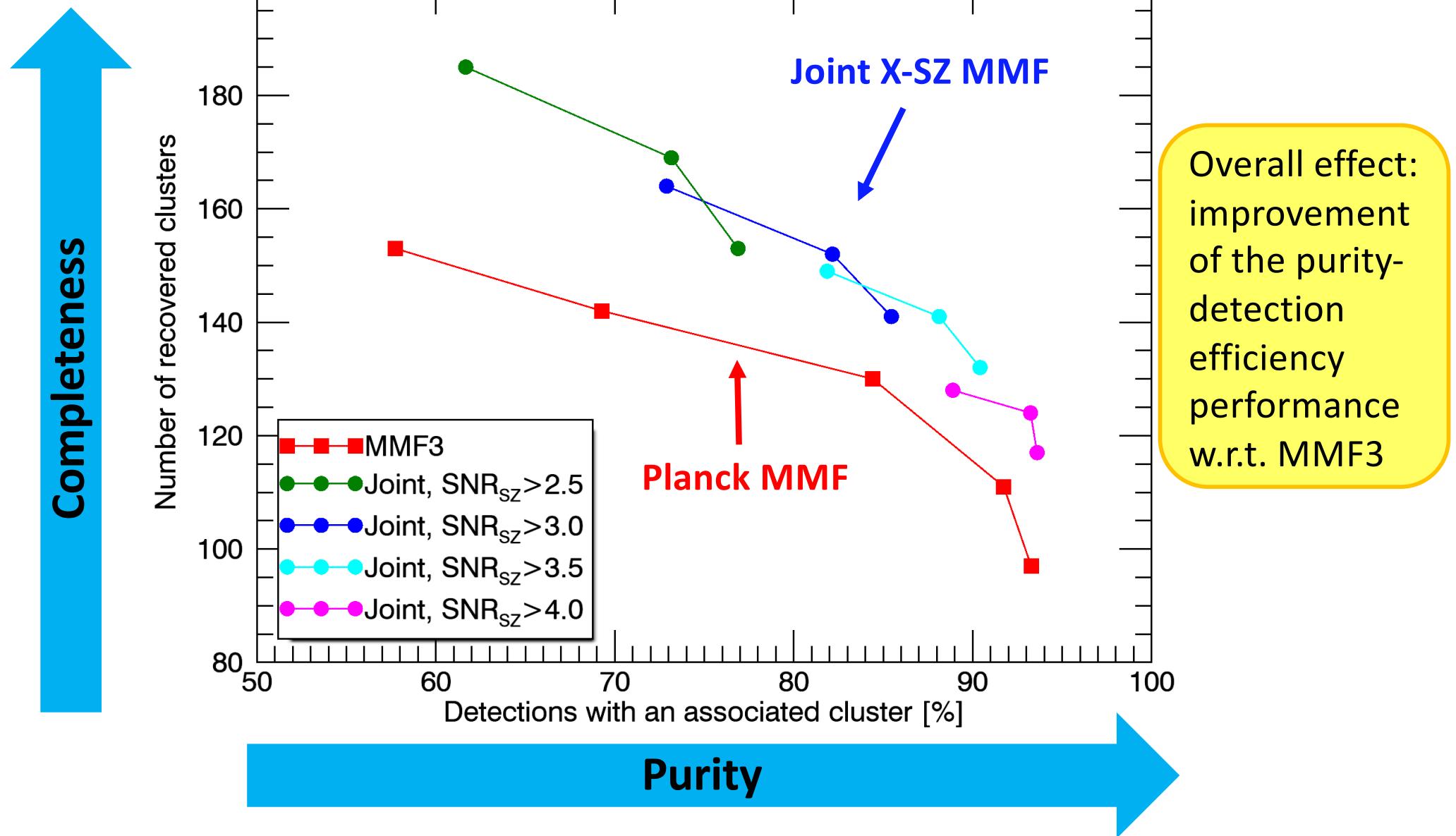
Tarrio P. et al. 2019



- Small fraction of MMF3 clusters missed (<15%)
- Other known clusters (missed by MMF3) detected ([168](#)+[43](#)+[143](#)+[311](#))

# Comparison w.r.t. PSZ2-MMF3 (in SPT footprint)

Tarrio P. et al. 2019



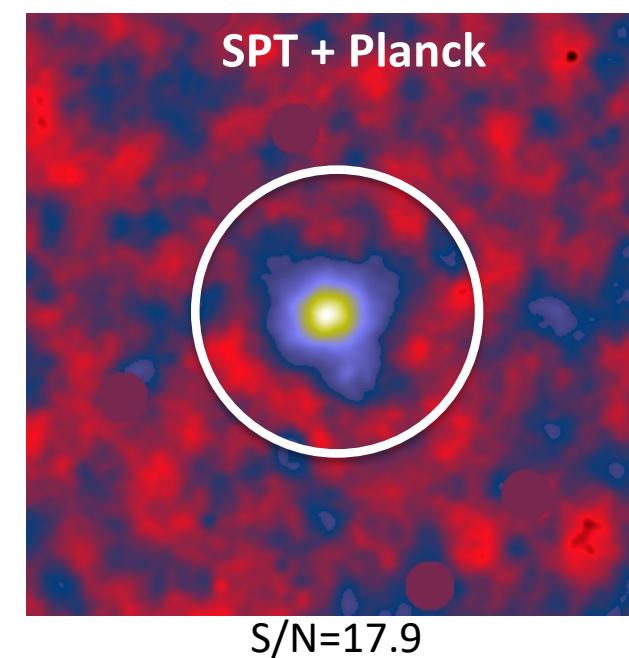
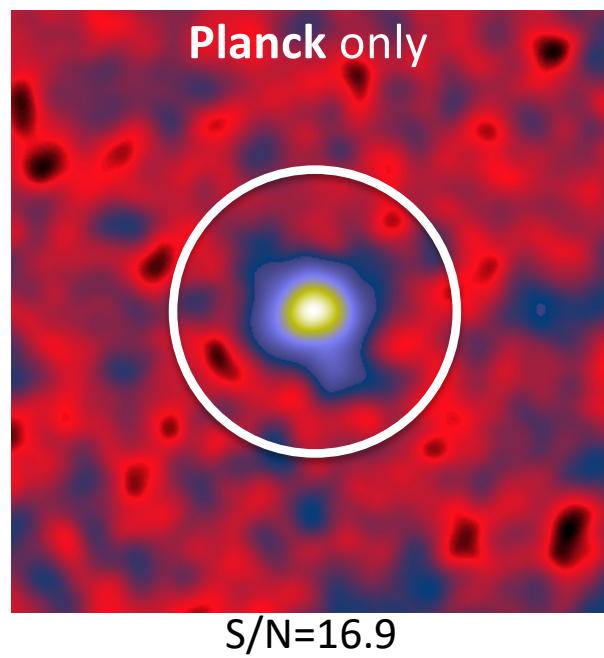
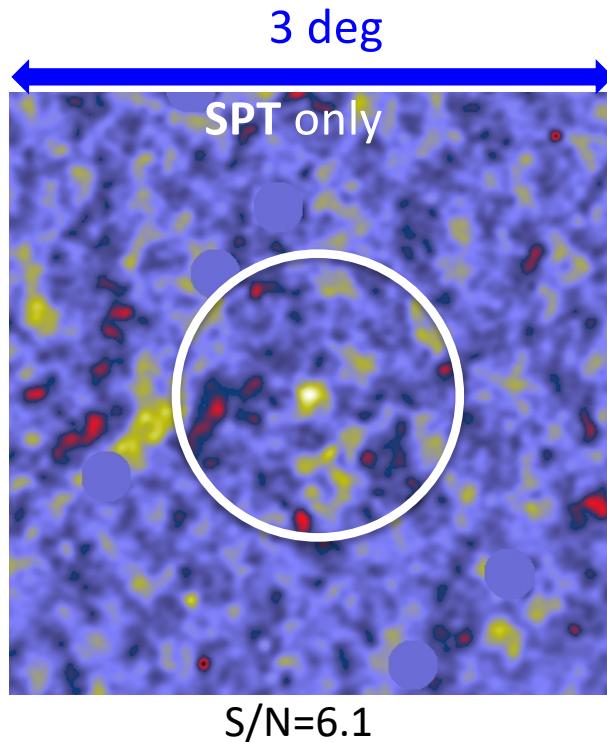
# **SPT-SZ and Planck datasets Combination!**

**PSZSPT**

*Melin J.-B., Bartlett J. G., Tarrío P., Pratt G. W. , submitted to A&A , arXiv:2009.08822*

# Filtered maps

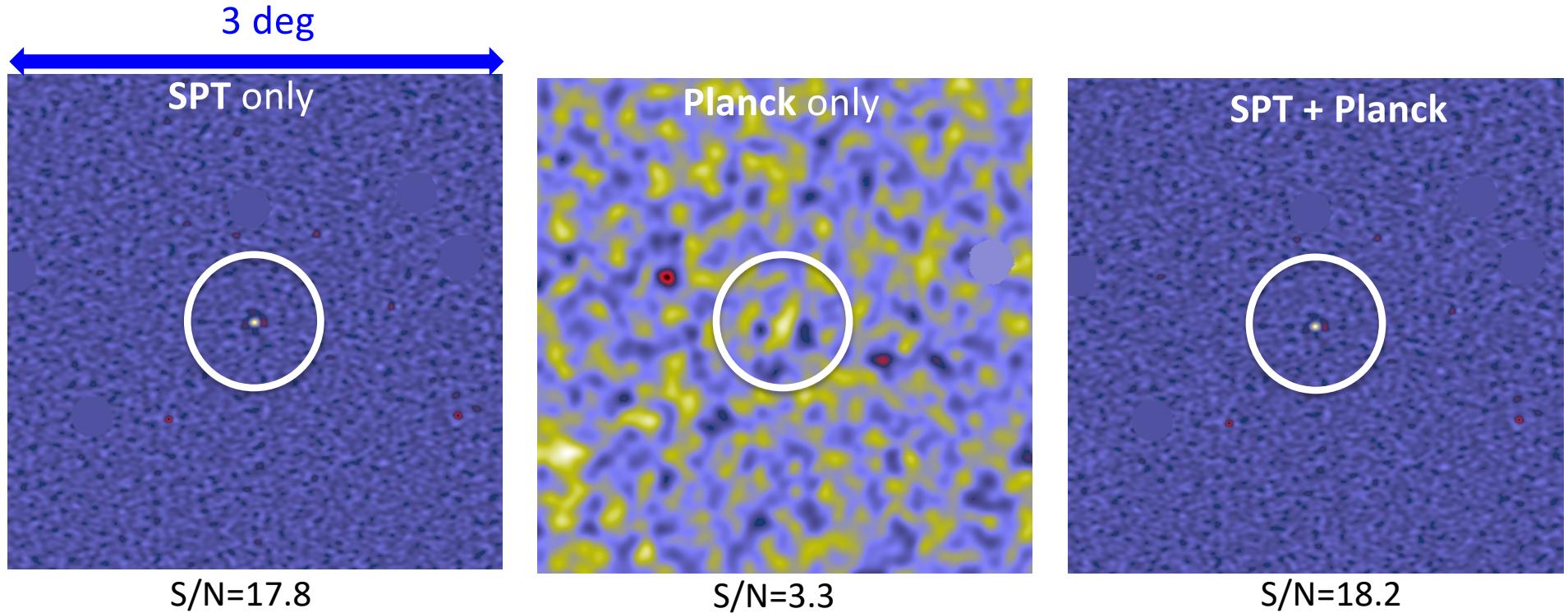
PSZ2 G265.02-48.96 (not in the SPT cluster catalogue)



Extended, low- $z$  ( $z=0.06$ ) cluster

# Filtered maps

SPT-CL J2106-5844 (not in the Planck cluster catalogue)

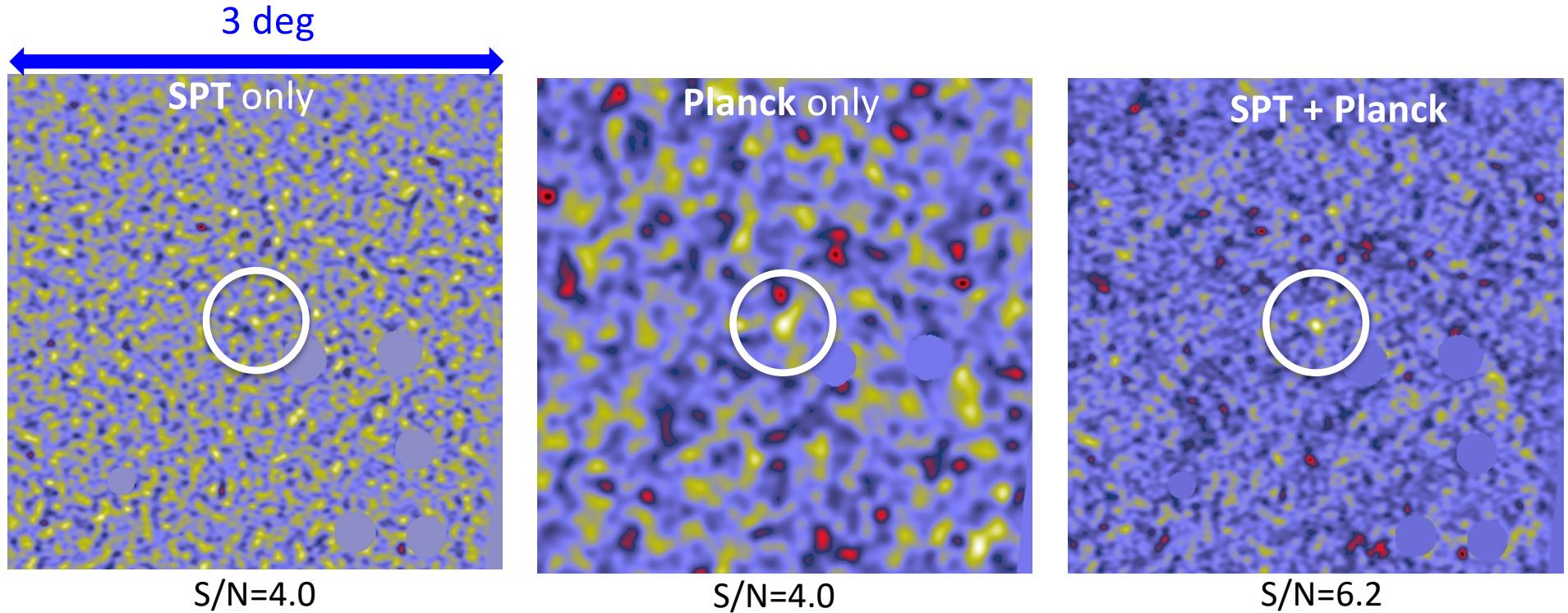


Compact, high- $z$  ( $z=1.13$ ) cluster

Joint SPT+Planck extraction provides the best of the two data sets

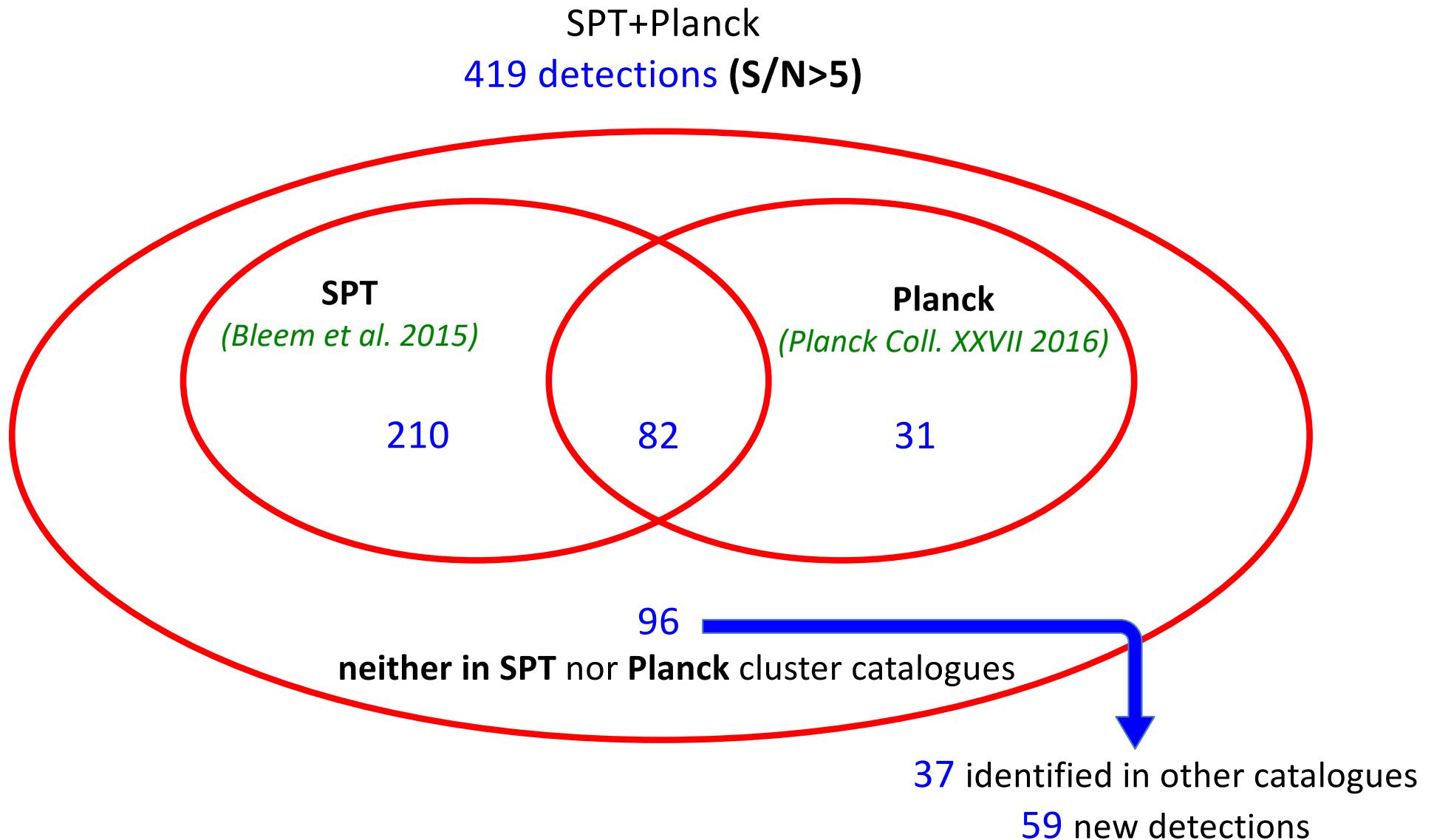
# Filtered maps

New SPT + Planck detection (neither in SPT nor Planck cluster catalogues)

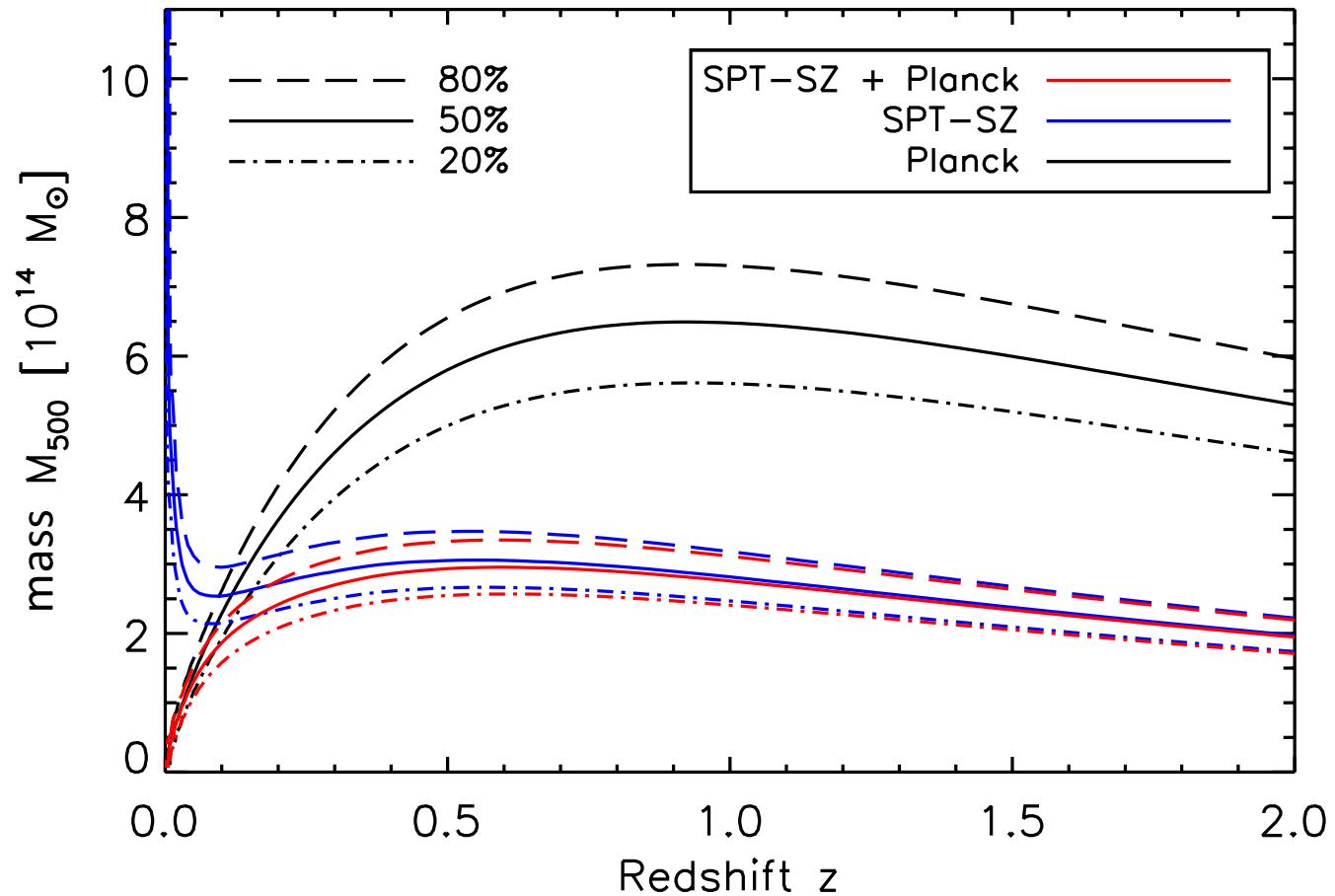


Joint SPT+Planck extraction goes deeper into the two data sets

# Joint SPT+Planck blind SZ catalogue



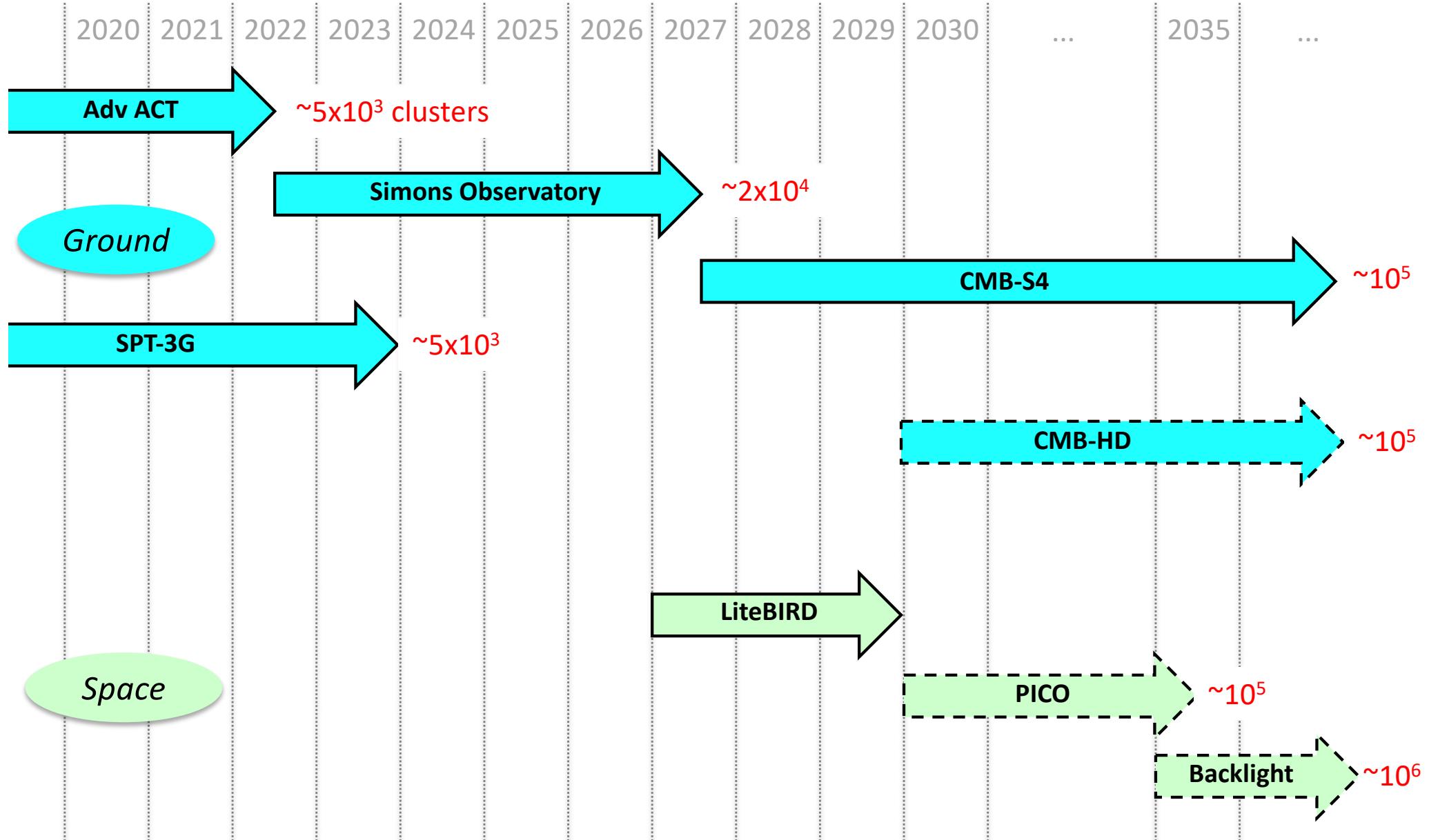
# Joint SPT+Planck blind SZ catalogue



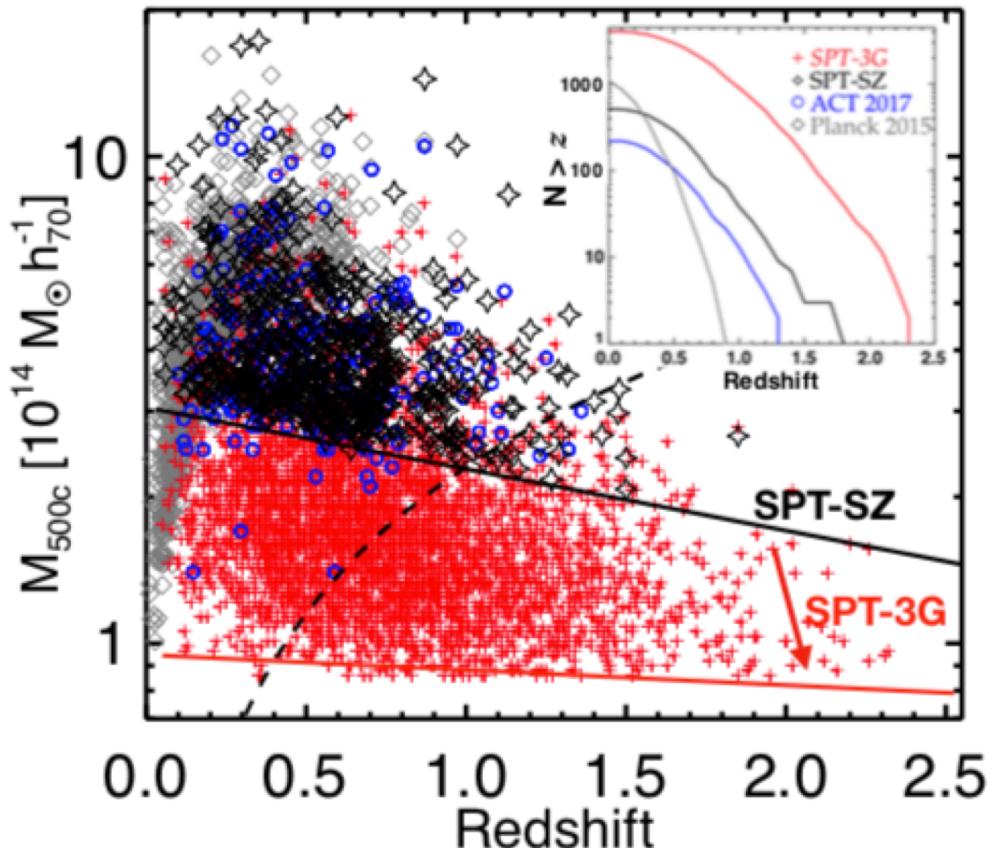
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# Current and future SZ surveys

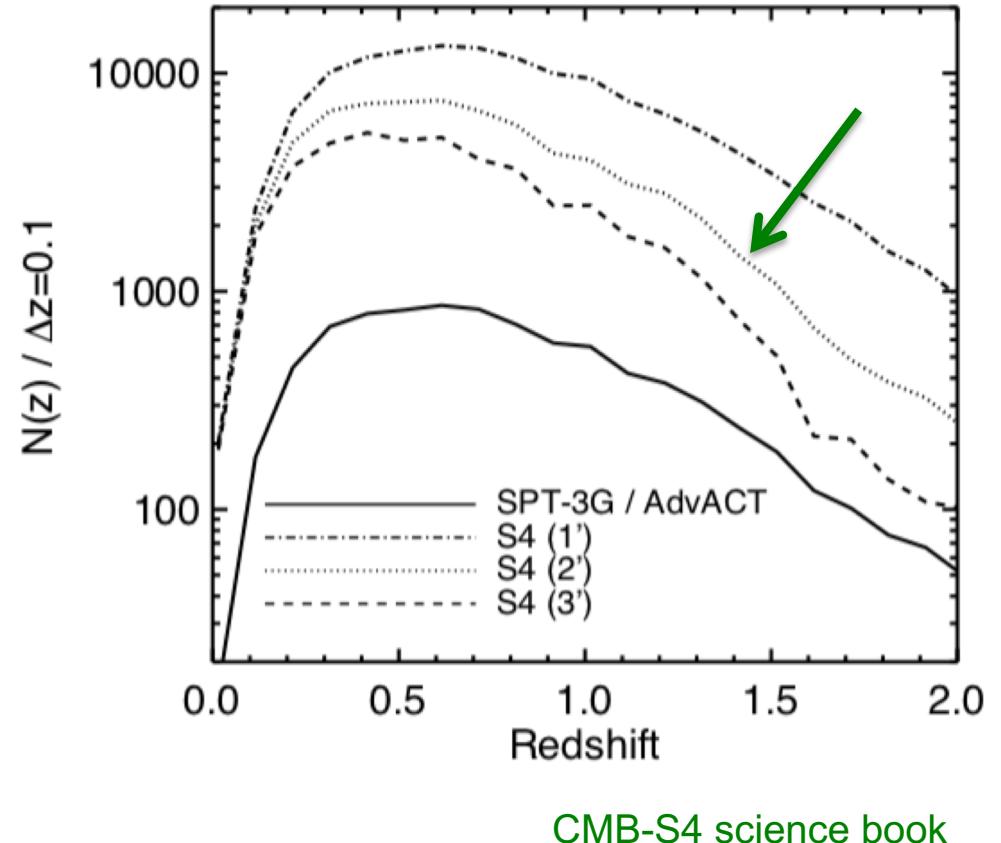


# Future SZ cluster catalogues



Benson @ Sesto2019

- ~1000 clusters at  $z > 1$  with SPT-3G
- hundreds of clusters at  $z > 2$  with CMB-S4

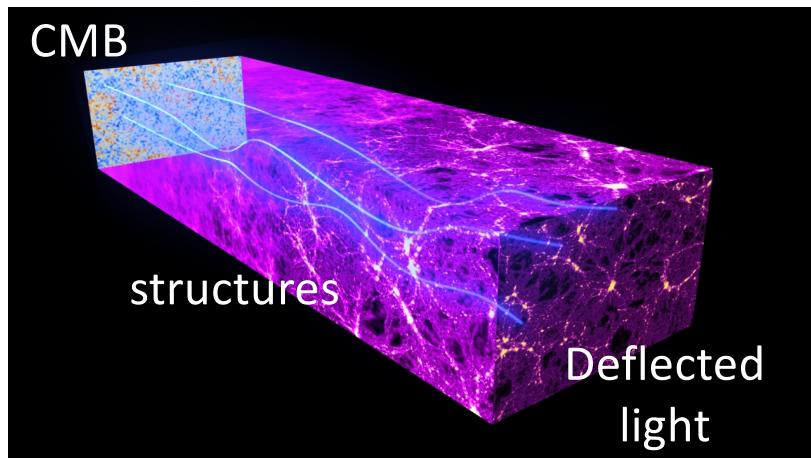


CMB-S4 science book

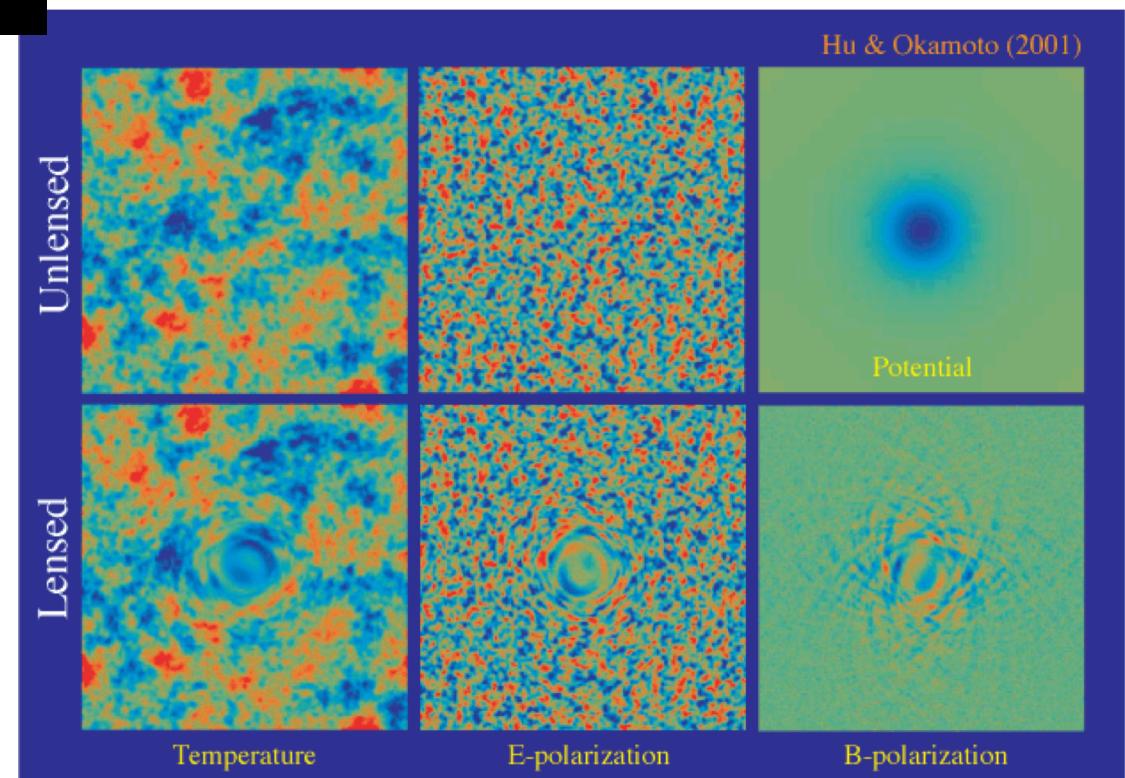
In the coming years, SZ surveys will:

- detect the first clusters
- increase redshift leverage  
(important for cosmology !)

# Cosmic Microwave Background halo lensing

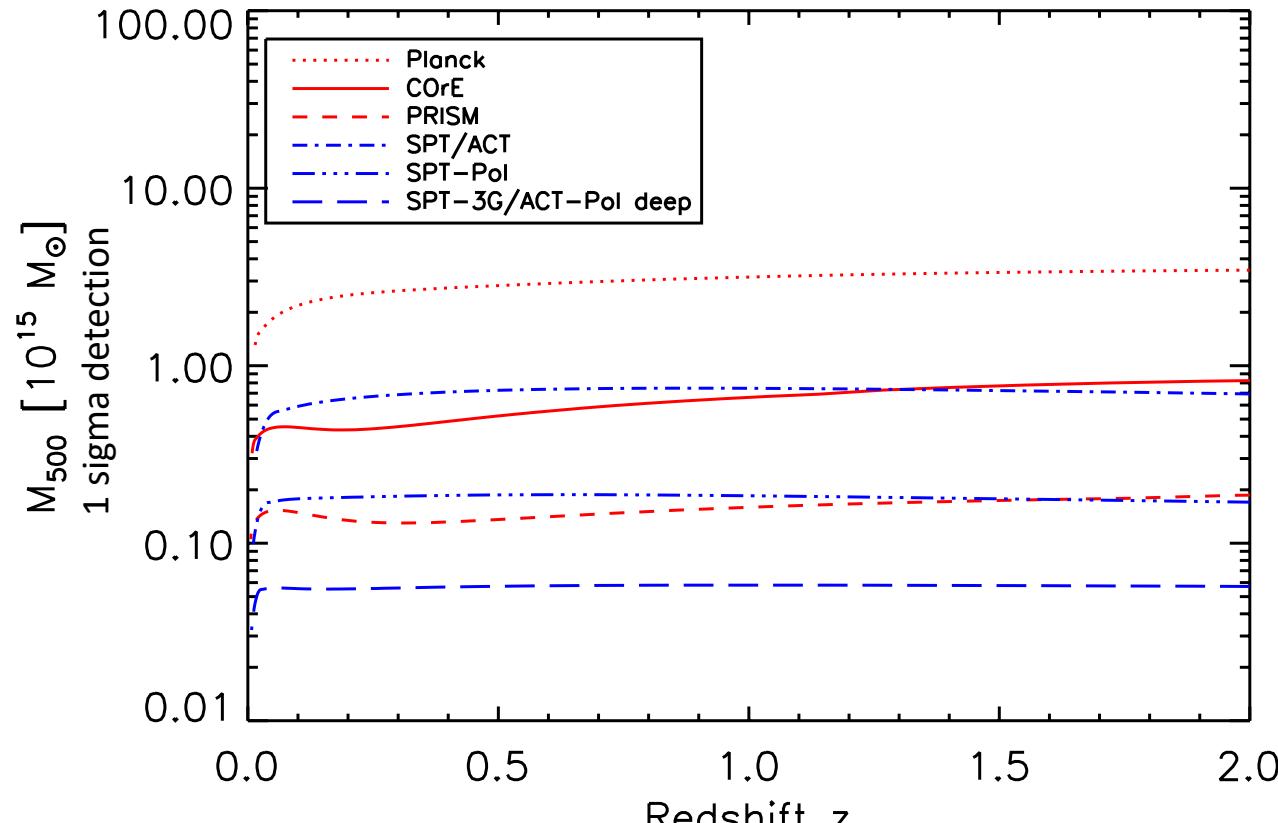


Credit: ESA



Hu & Okamoto 2001

# High redshift cluster mass from millimeter data



Melin & Bartlett 2015

→ Lensing mass detected at  $S/N \sim 1$  in future  
millimeter datasets for clusters with  
 $M_{500} \sim 10^{14} M_\odot$

# Conclusions

- ROSAT+Planck extraction (*Tarrio et al. 2016, Tarrio et al. 2018, Tarrio et al. 2019*) provides a catalogue deeper and purer than Planck only
  - Main difficulty: dealing with different noise properties between ROSAT and Planck
- Joint SPT+Planck extraction provides the best of the two datasets, and allows for detection of new objects (*Melin et al. submitted to A&A arXiv:2009.08822*)
  - Main difficulty: matching high resolution (from SPT) and large scales (from Planck) at the same time, SPT transfer function
- Future blind SZ surveys will detect  $\sim 10^4$  clusters (Simons Observatory, <2030) and  $\sim 10^5$  clusters (CMB-S4, <2040)
- Future millimeter datasets are ideal to measure cluster masses at all redshifts using CMB halo lensing