Science with clusters

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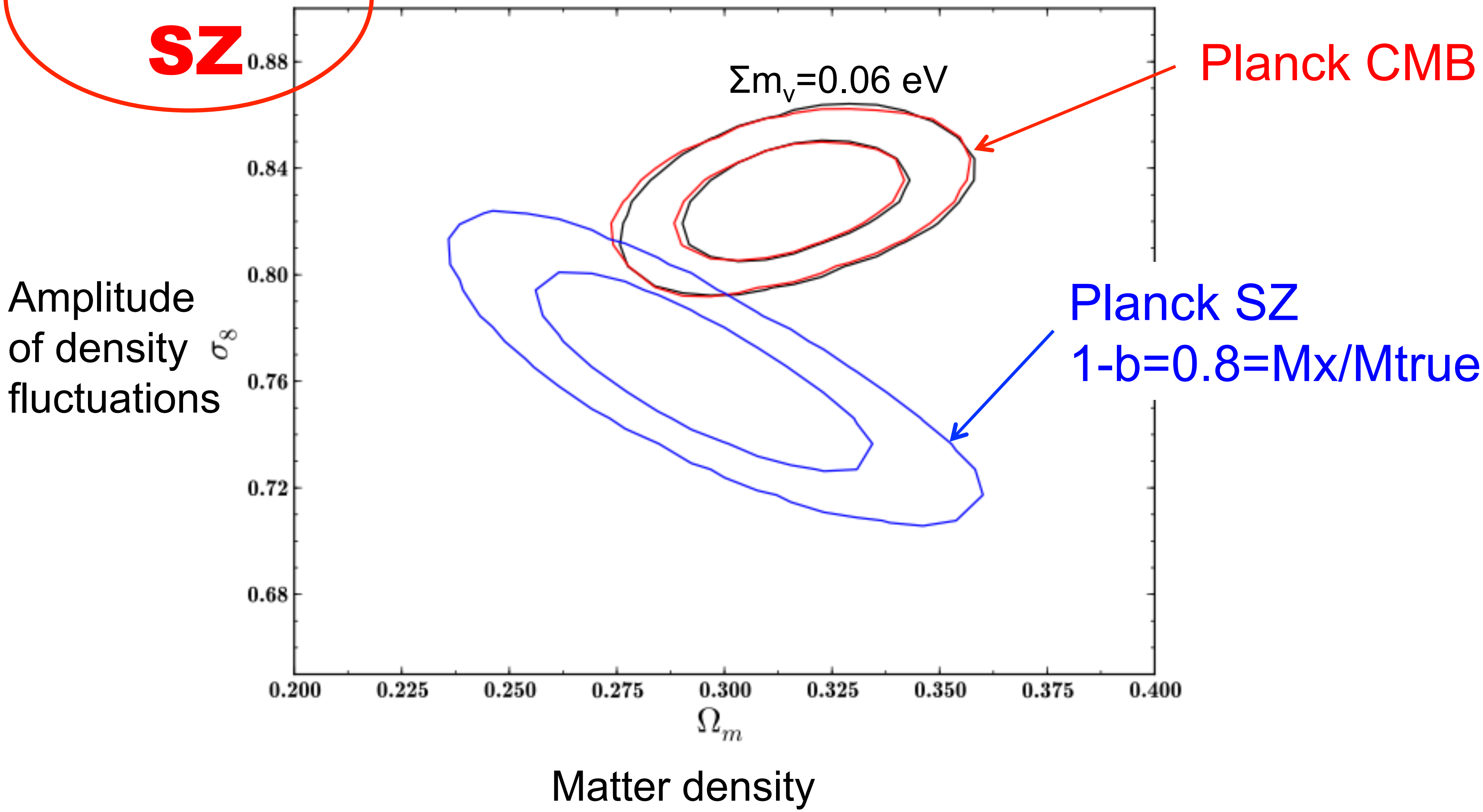
Clusters as cosmological probes

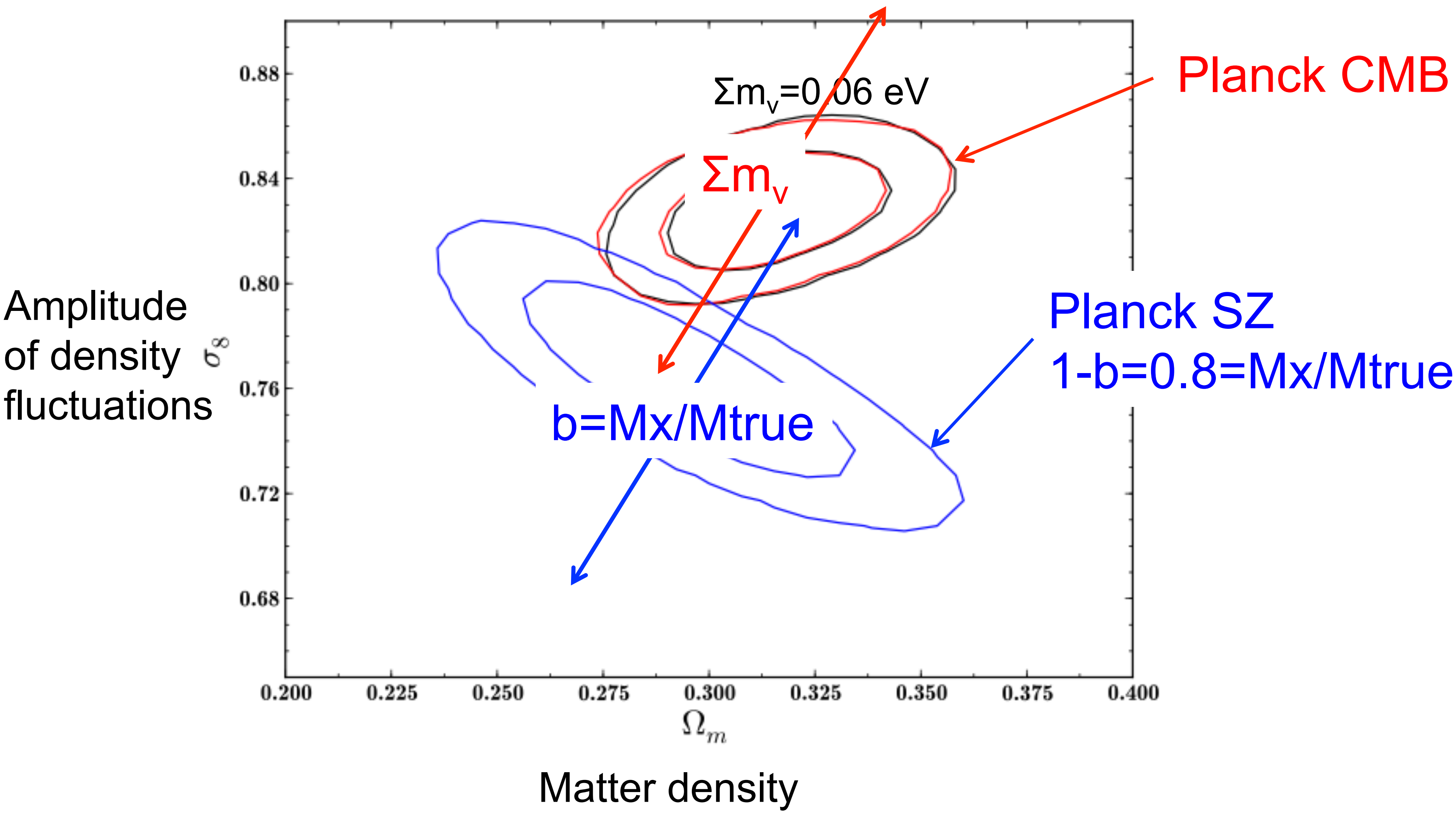
Planck 2013 results XX

Thermal SZ



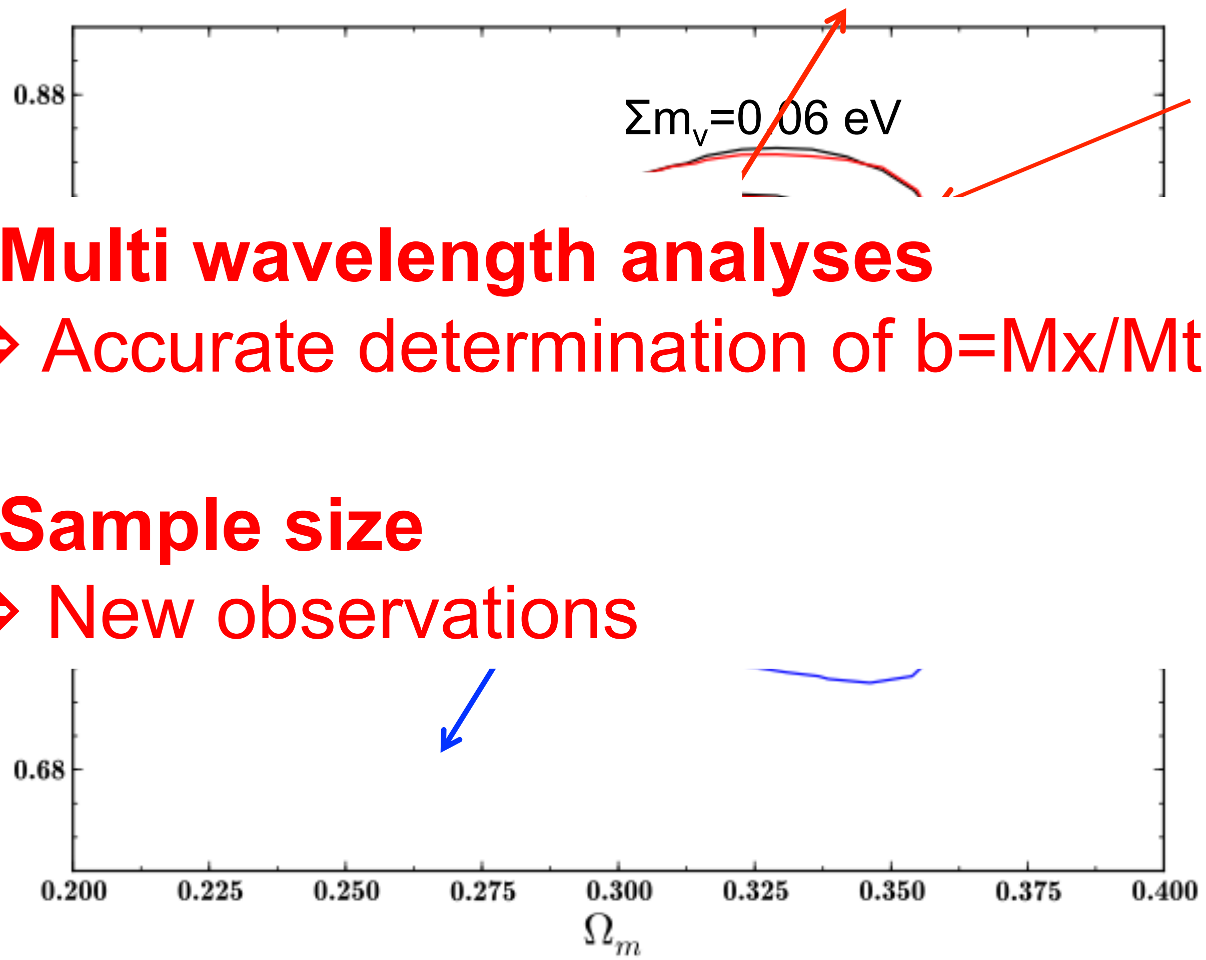
Clusters as cosmological probes

Planck 2013 results XX



Clusters as cosmological probes

Planck 2013 results XX



Planck CMB

Amplitud
of densit
fluctuatic

- **Multi wavelength analyses**

⇒ Accurate determination of b=Mx/Mtrue

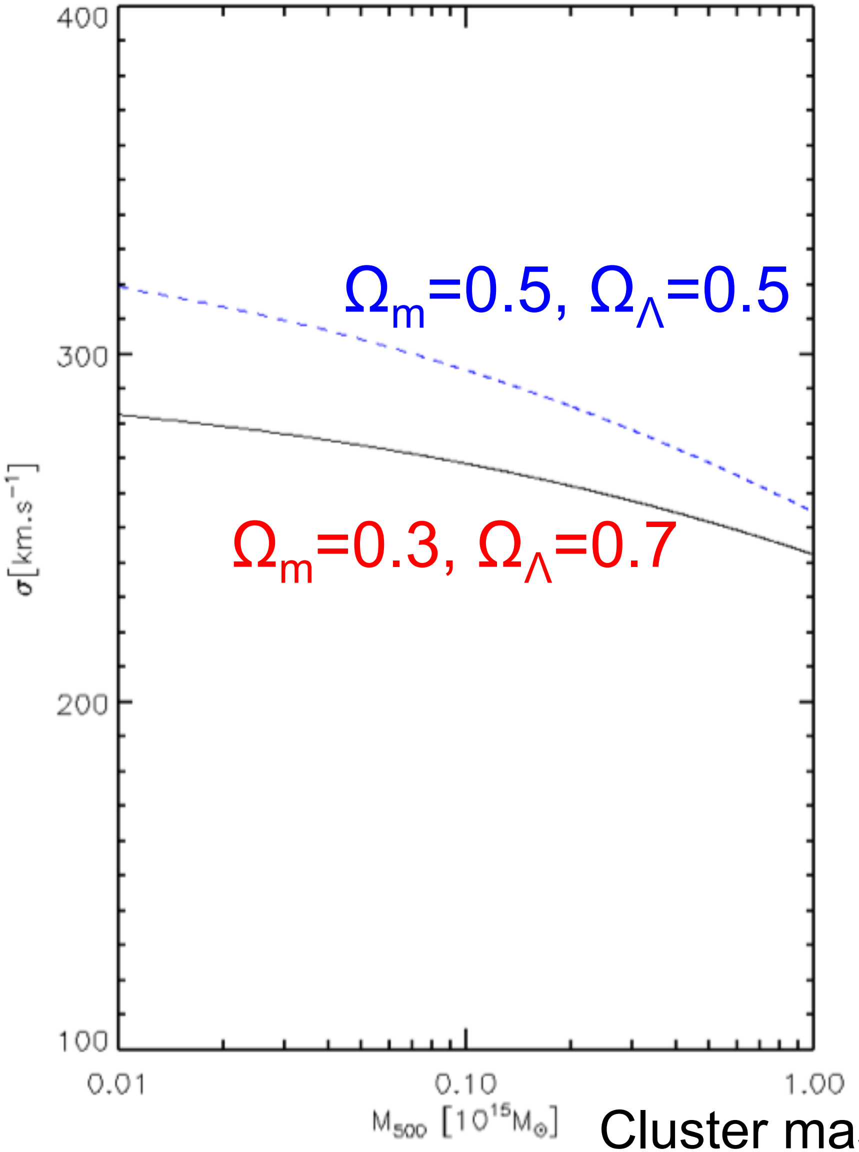
- **Sample size**

⇒ New observations

Mx/Mtrue

Matter density

Clusters as cosmological probes



Cluster velocity dispersion

Cluster mass

Kinetic SZ

Simulations

- sky coverage: 75%
- Planck 2013 primary CMB cosmology (except sig8=0.75)
- Tinker mass function

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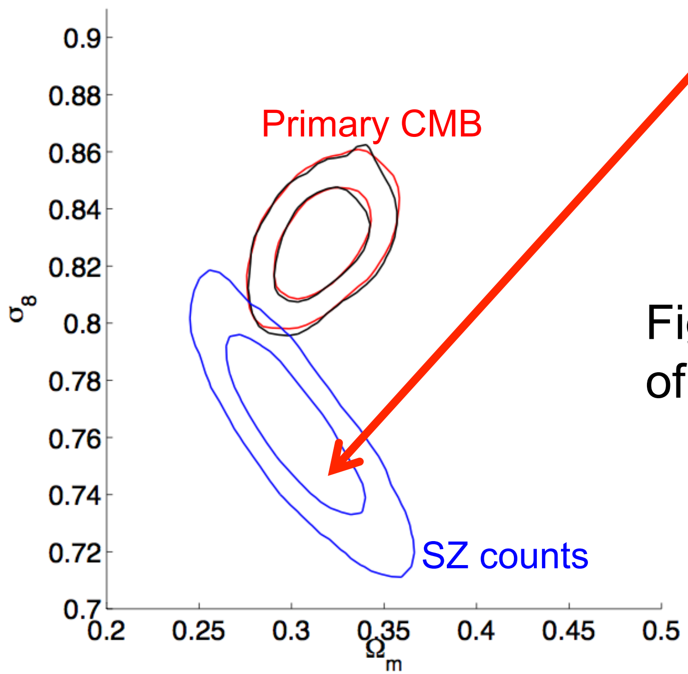

Fig. 11
of Planck results 2013 XX

Simulations

- sky coverage: 75%
- Planck 2013 primary CMB cosmology (except sig8=0.75)
- Tinker mass function

- Tangential 10*10deg maps
- CMB, Galaxy (dust from Planck 857GHz map, lat=30°, grey body spectrum),
- Gaussian beams, homogeneous white noise
- Matched Multi Filter for noise estimation as a function of (flux,size)

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- Y-M from Planck 2013 results XX

  self-similar evolution (in redshift)

  hydro bias on the mass (20%)

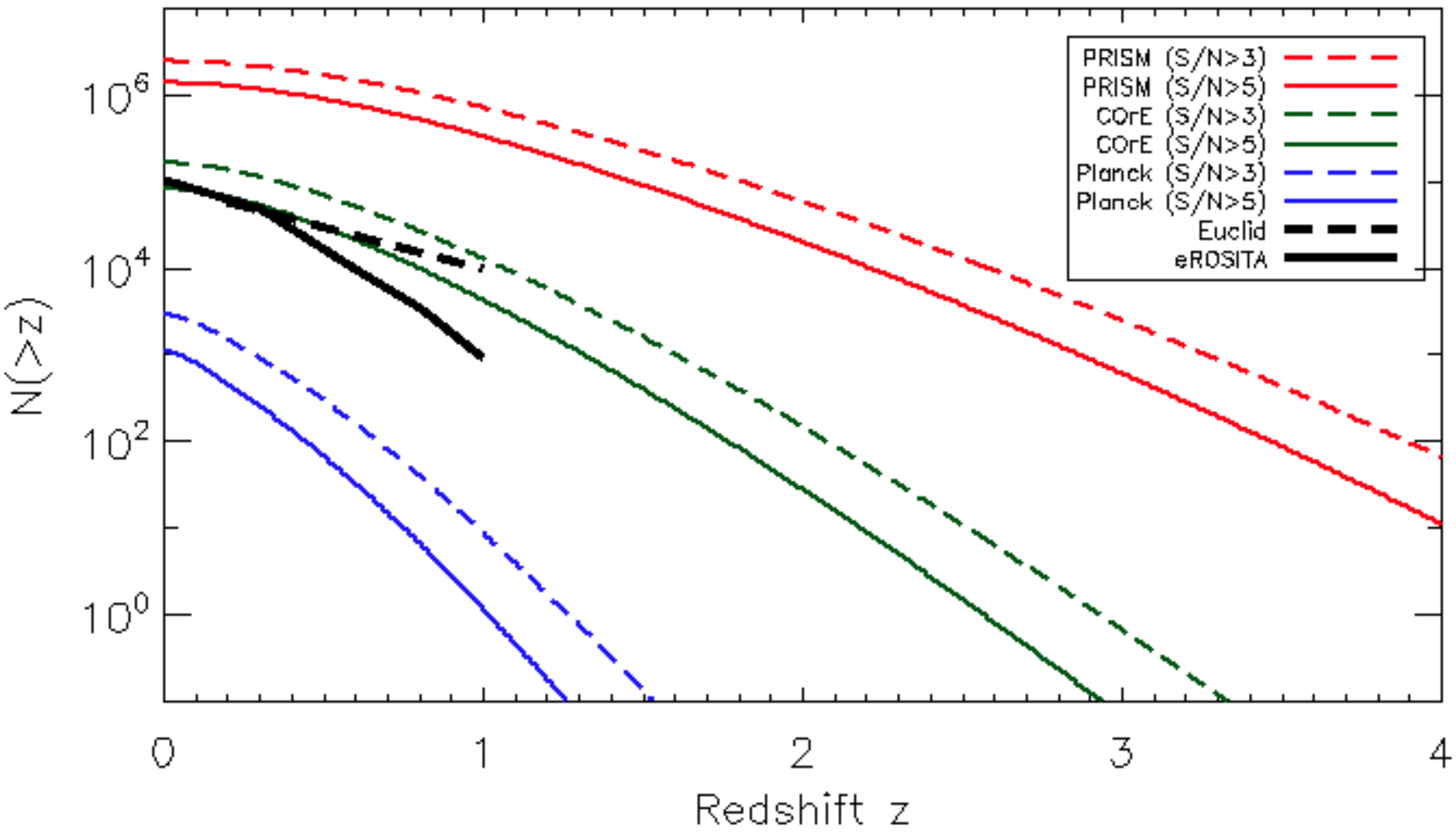
Simulations

Planck $\Rightarrow$ nominal mission
blue book sensitivity

COrE $\Rightarrow$ M3 proposal

PRISM $\Rightarrow$ L2-L3 proposal

Expected cluster counts from COrE and PRISM



Simulations

Planck ⇒ nominal mission
blue book sensitivity

COrE ⇒ M3 proposal

PRISM ⇒ L2-L3 proposal

M4 ⇒3 types **“M4-COrE”**

“M4-PRISM req.”

“M4-PRISM goal”

Simulations

from J. Delabrouille

ν (GHz)	$d\nu/\nu$	resol. arcmin.	phot. noise (μK.s$^{1/2}$)	ΔI_{det} (μK.arcmin)	Δy_{SZ} / det. ($10^{-6}\, y_{SZ}$.arcmin)	N_{det} (req.)	comment	main CO lines
45	0.33	23.3'	30.47	61	11.8	2	radio-source monitor	none
75	0.20	14.0'	34.27	69	14.6	18	radio-source monitor	none
105	0.14	10.0'	38.74	77	19.5	106	radio-source monitor	^{13}CO
135	0.11	7.8'	44.60	89	28.8	504	SZ channel	none
165	0.091	6.4'	52.64	103	51	1066	SZ channel	none
315	0.048	3.3'	195.0	390	90	882	SZ channel	none
375	0.040	2.8'	403.2	806	113	1002	SZ channel	none
555	0.35	1.9'	1371	2743	174	62	dust / CIB /CO monitor	^{12}CO and ^{13}CO
675	0.29	1.6'	8242	16484	767	66	dust / CIB /CO monitor	^{12}CO and ^{13}CO
795	0.25	1.3'	51952	103900	3812	100	dust / CIB /CO monitor	^{12}CO and ^{13}CO

Table 4: Proposed channels for SZ effect observation with a COrE-type instrument. Requirements can be met with 3808 detectors. The goal of detecting nearly all clusters in the Hubble volume cannot be reached with this configuration.

"M4-COrE" ⇒ ~as many clusters as eROSITA and Euclid

Simulations

from J. Delabrouille

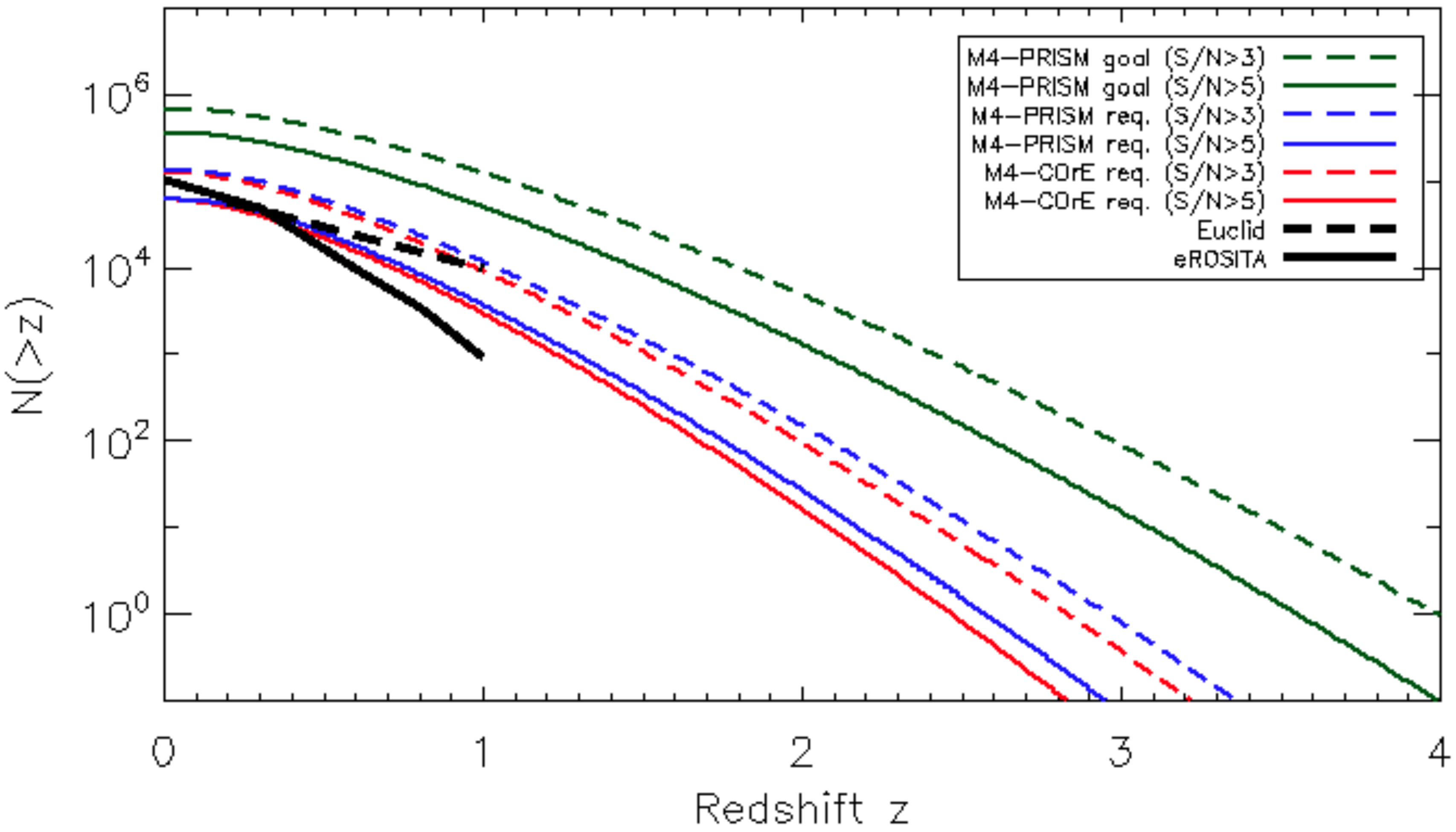
ν (GHz)	$d\nu/\nu$	resol. arcmin.	phot. noise (μK.s$^{1/2}$)	ΔI_{det} (μK.arcmin)	Δy_{SZ} / det. ($10^{-6}\, y_{SZ}$.arcmin)	N_{det} (req.)	N_{det} (goal)	comment	main CO lines
78	0.25	6.5'	30.6	61	13.2	6	86	radio-source monitor	none
90	0.35	5.6'	25.2	50	11.6	8	104	radio-source monitor	none
100	0.2	5.0'	33.0	66	16.0	16	274	radio-source monitor	none
135	0.28	3.7'	28.2	56	18.2	46	788	SZ channel	none
143	0.33	3.5'	26.30	52	18.6	42	736	SZ channel	none
340	0.35	1.5'	92.58	185	33.7	26	444	SZ channel	^{12}CO and ^{13}CO
395	0.20	1.3'	226.7	453	56.0	54	920	SZ channel	none
445	0.35	1.1'	316.4	633	60	26	422	dust / CIB / CO monitor	^{12}CO and ^{13}CO
520	0.20	0.97'	1117	2235	158	36	590	dust / CIB monitor	none
600	0.35	0.84'	2541	5083	284	18	292	dust / CIB / CO monitor	^{13}CO

Table 5: Proposed channels for SZ effect observation with a PRISM-type instrument. Requirements can be met with only 278 detectors in 10 frequency channels. Reaching the goal of detecting nearly all galaxy clusters in the Hubble volume requires 4656 detectors.

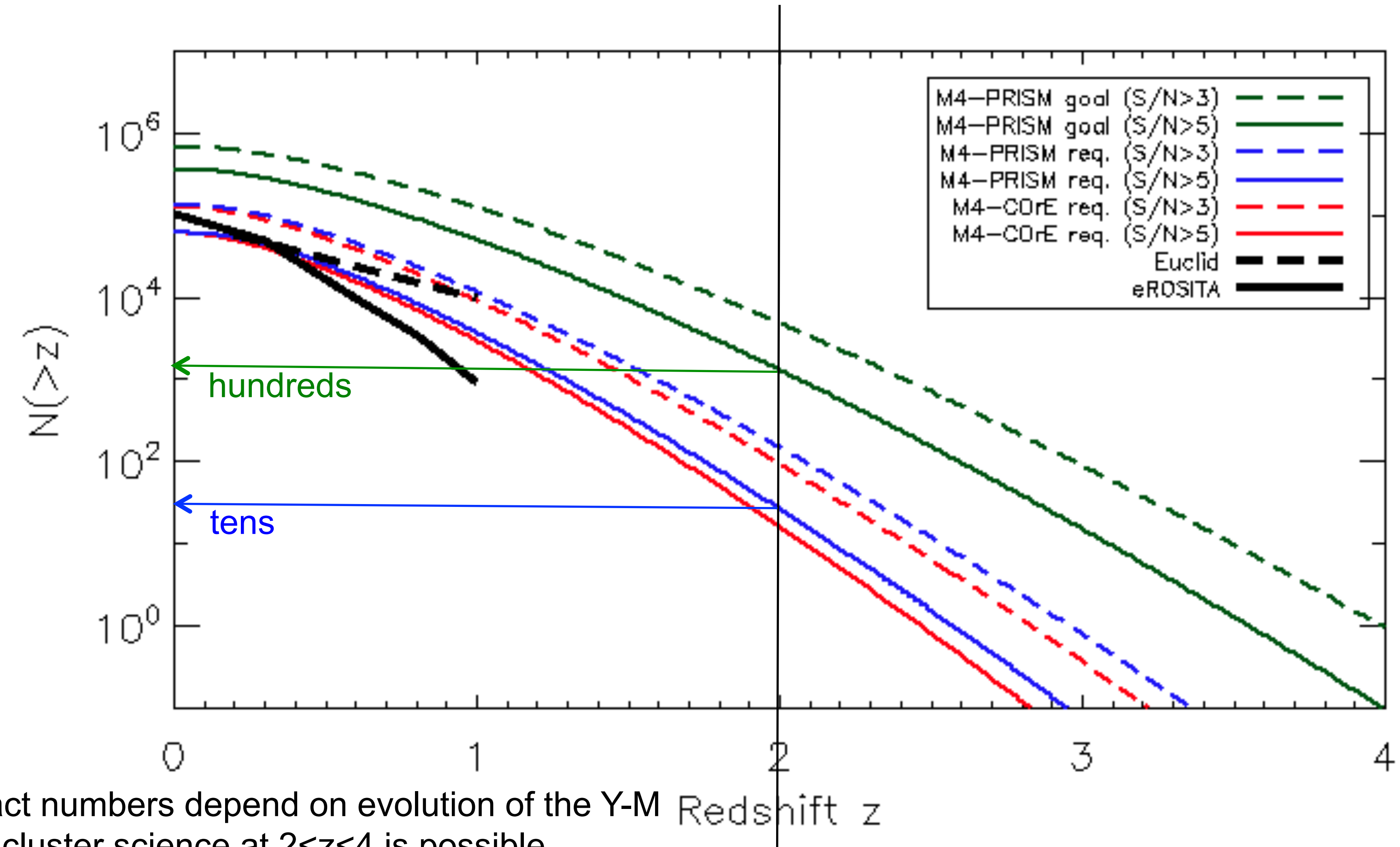
"M4-PRISM req." ⇒ requirement
(~as many clusters as eROSITA and Euclid)

"M4-PRISM goal" ⇒more clusters (>500,000)

Expected cluster counts for a M4 mission



Expected cluster counts for a M4 mission



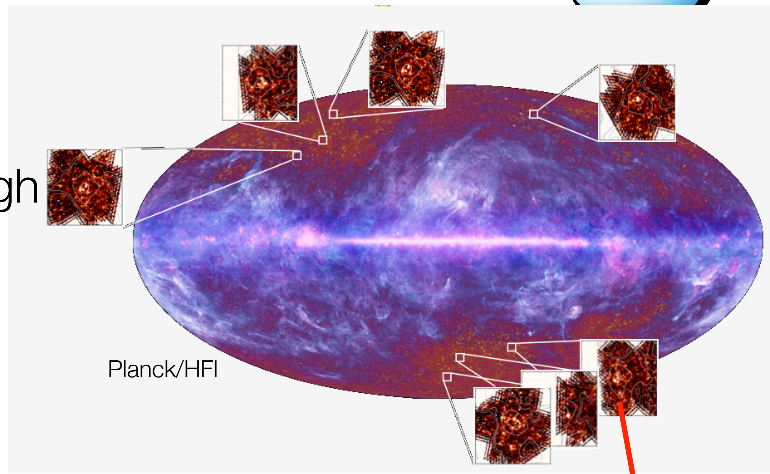
Exact numbers depend on evolution of the Y-M but cluster science at 2<z<4 is possible

From Hervé Dole

Planck z>2 structures

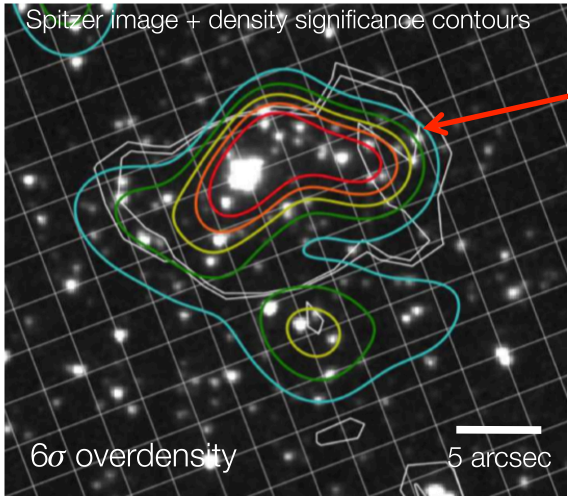
- how clusters form ? search for z>1 clusters
- what are ISM properties at z>2 ?

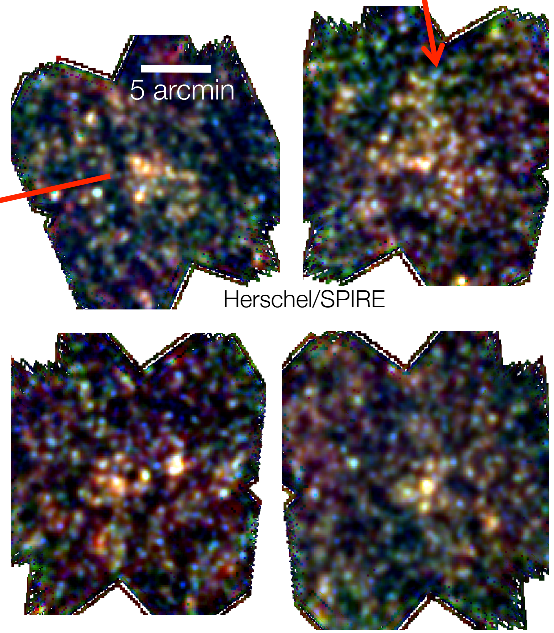
- hundreds of Planck high-z candidates at high Galactic latitude
- 220+ Planck sources were followed-up by Herschel/SPIRE at higher angular resolution, and Spitzer



- all show photo-z z > 1.5
- are either z>2.2 strongly gravitationally lensed galaxies
- or could be z> 1.5 galaxy clusters in their burst phase, containing IR galaxies

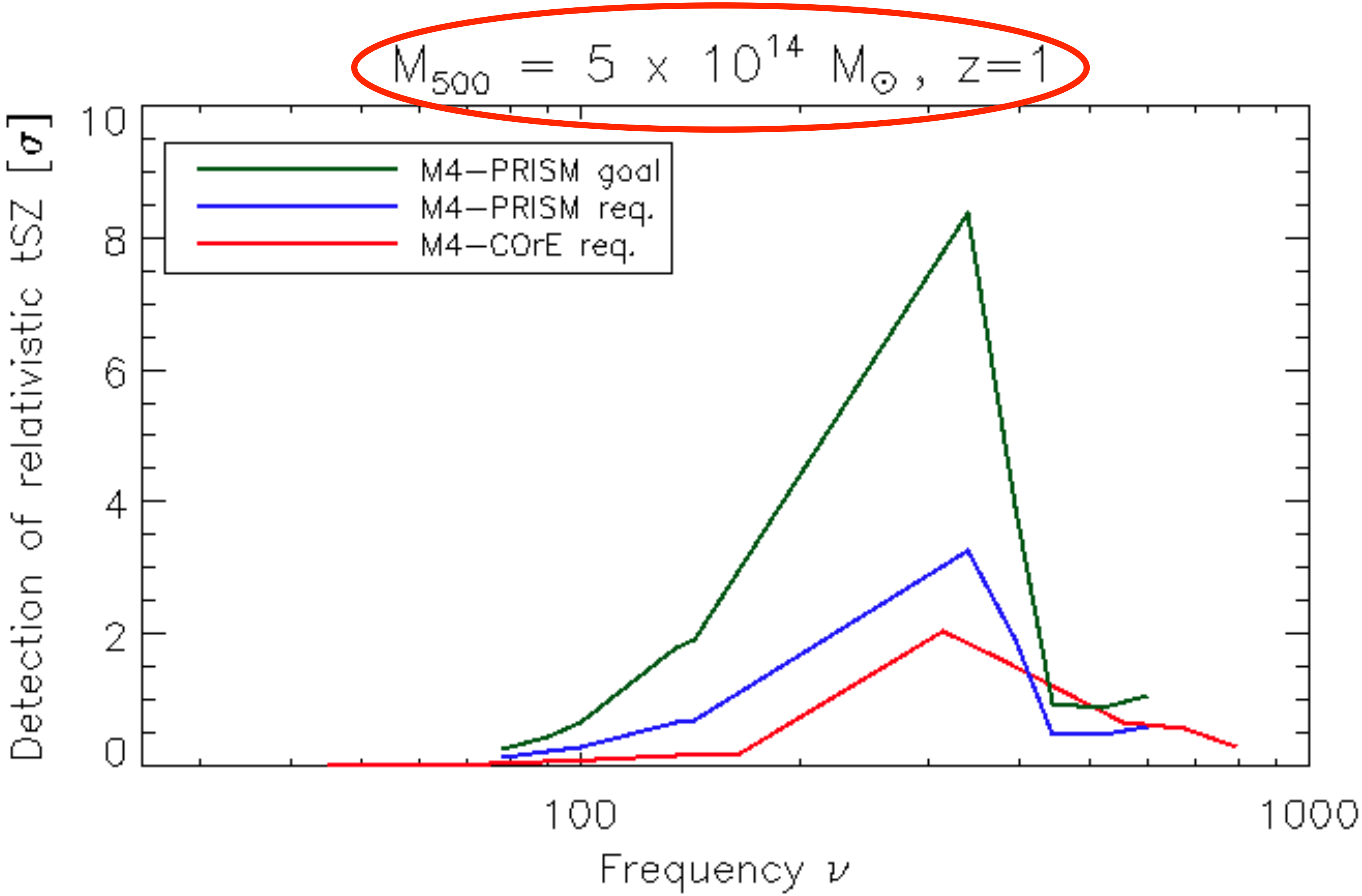
Spitzer/IRAC





Dole et al., in prep
Nesvadba et al., in prep

Individual temperature measurement (relativistic tSZ effect)



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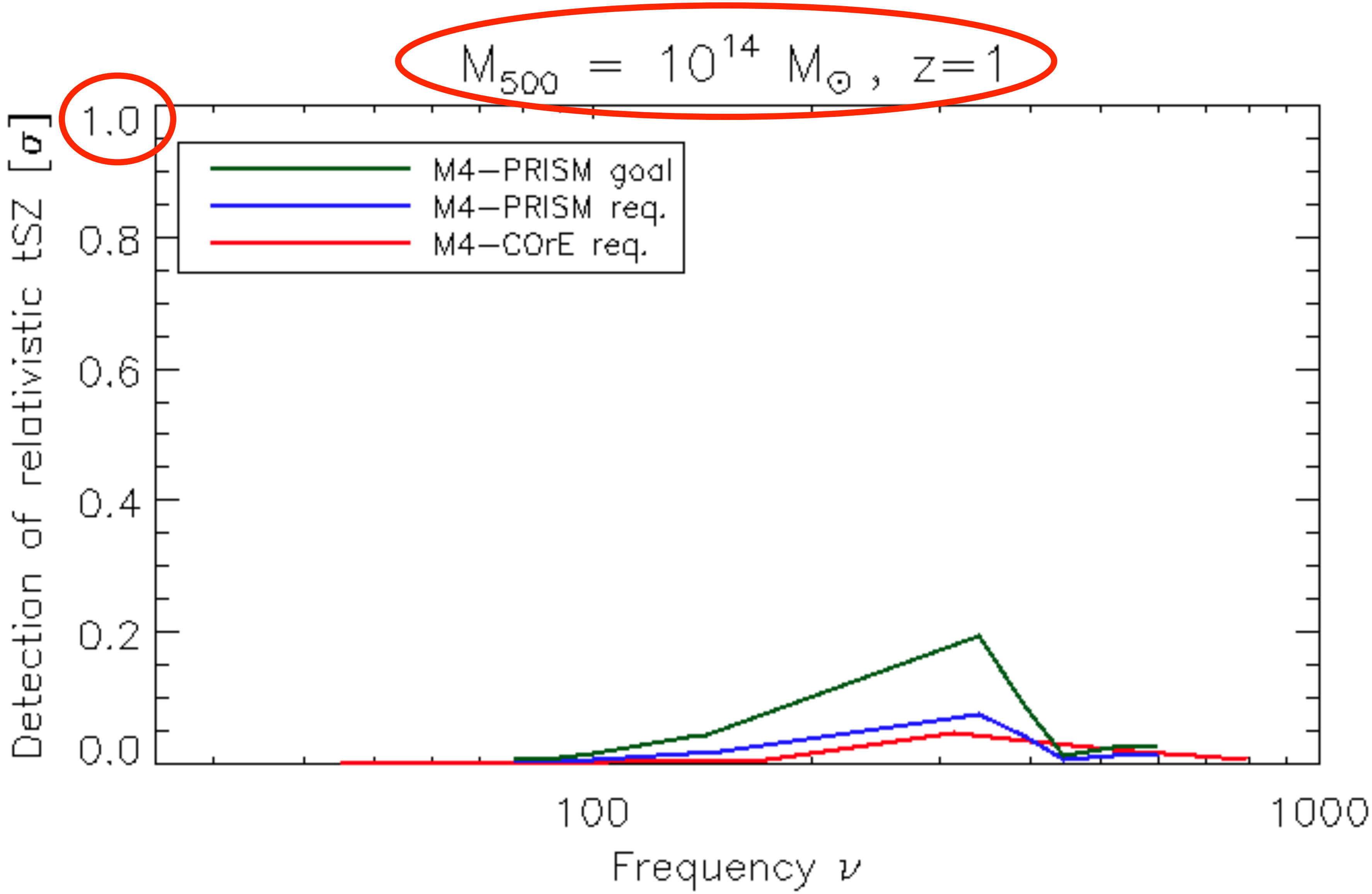
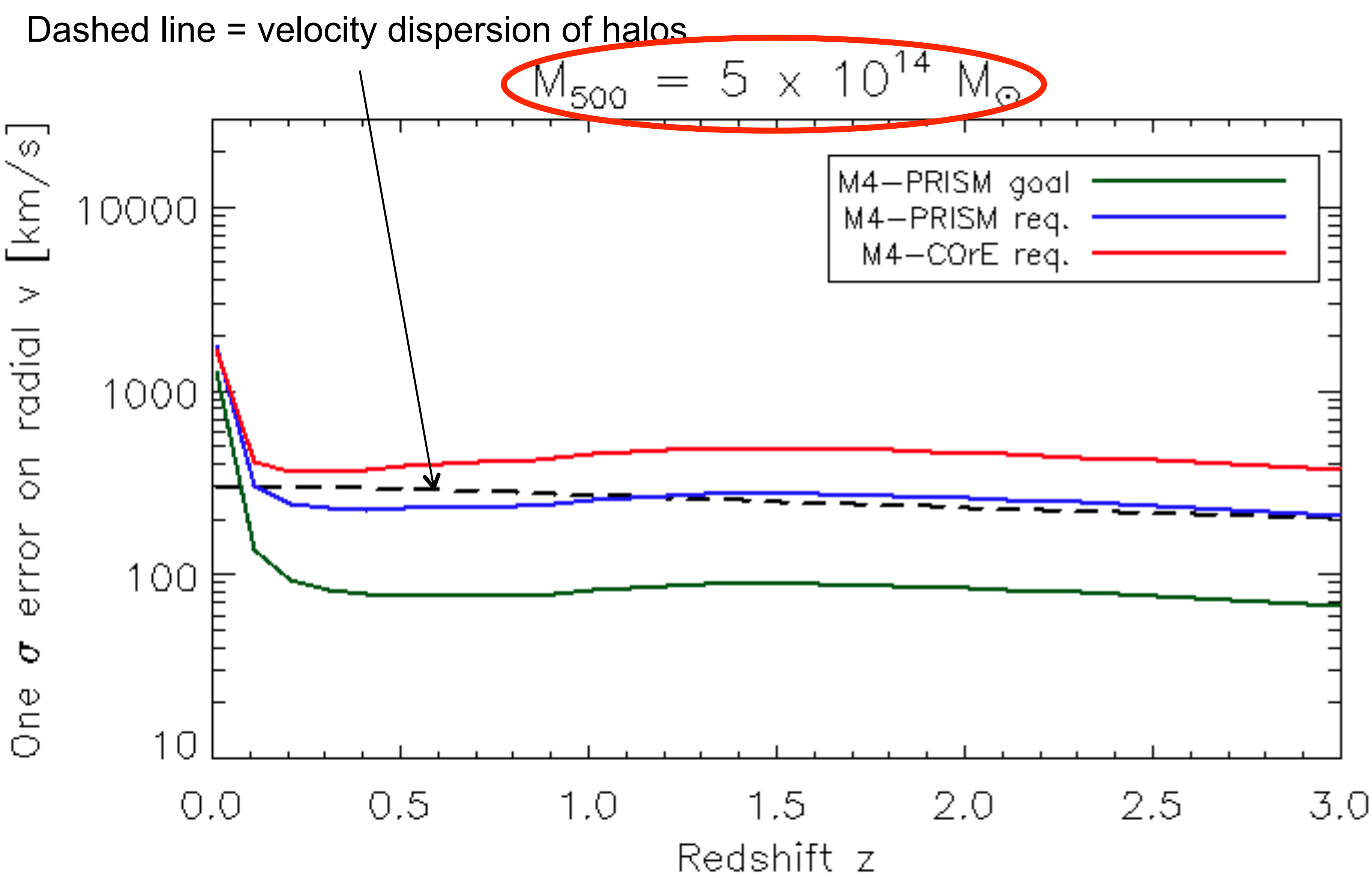
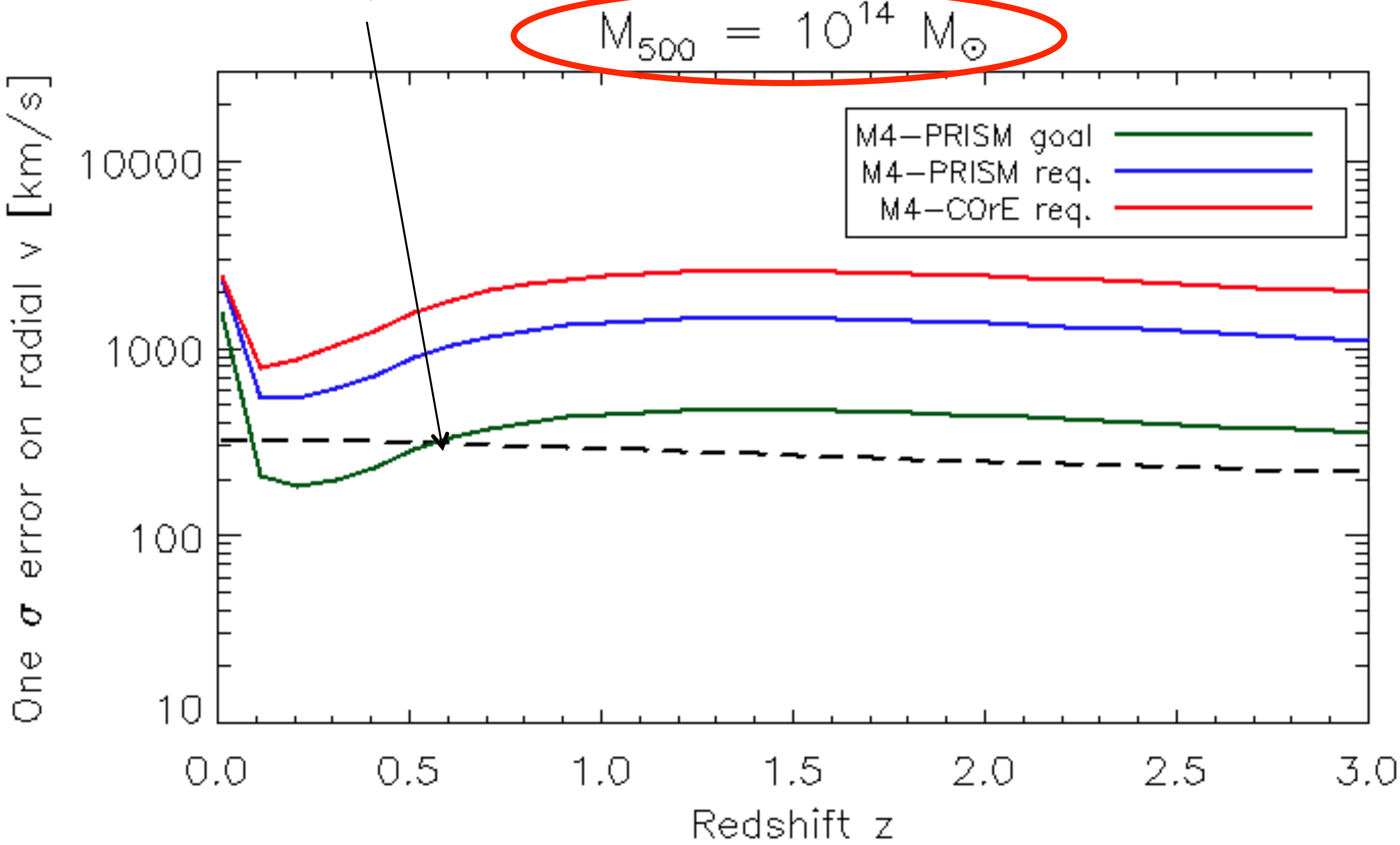


Individual velocity measurement (kSZ effect)

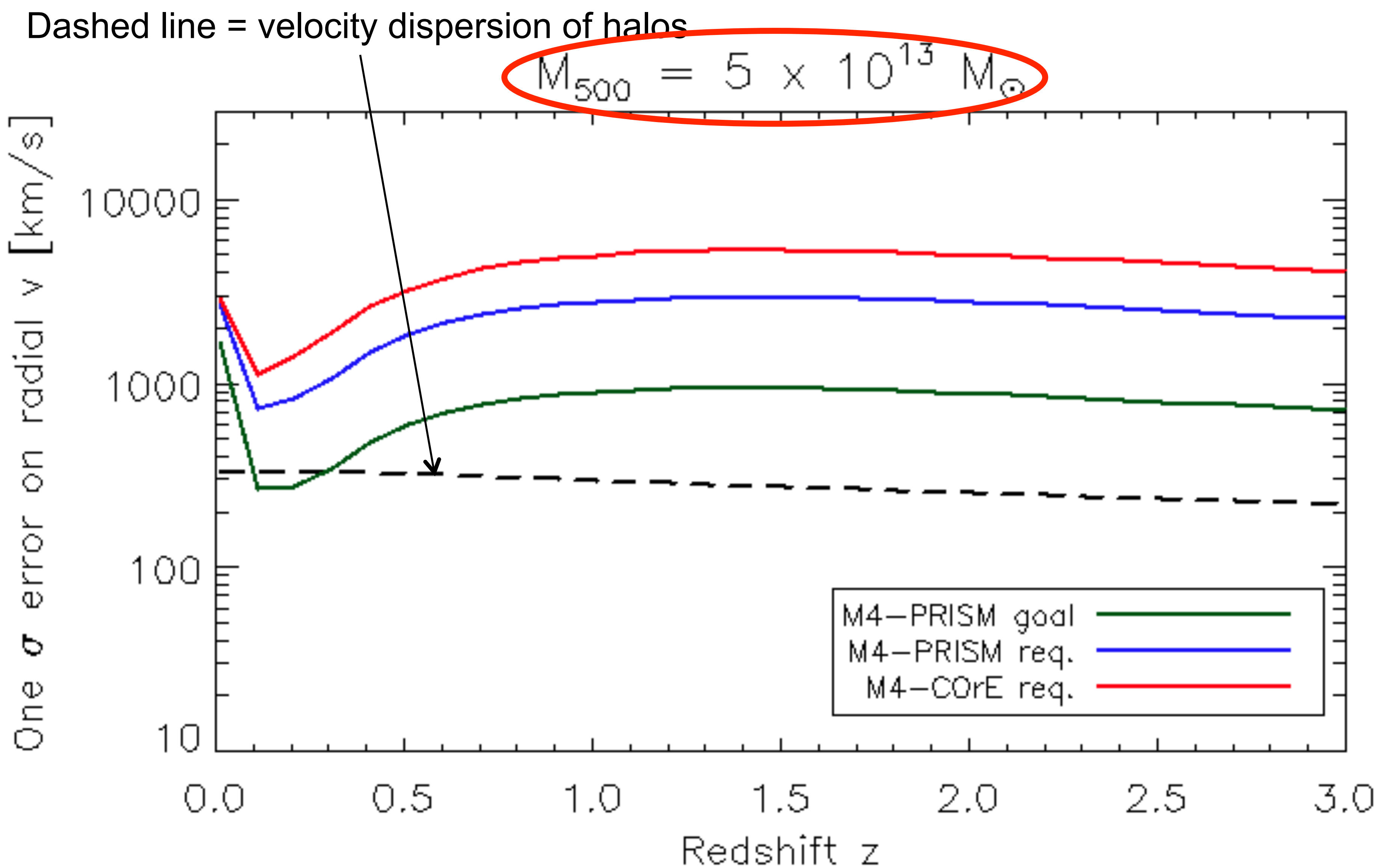


Individual velocity measurement (kSZ effect)

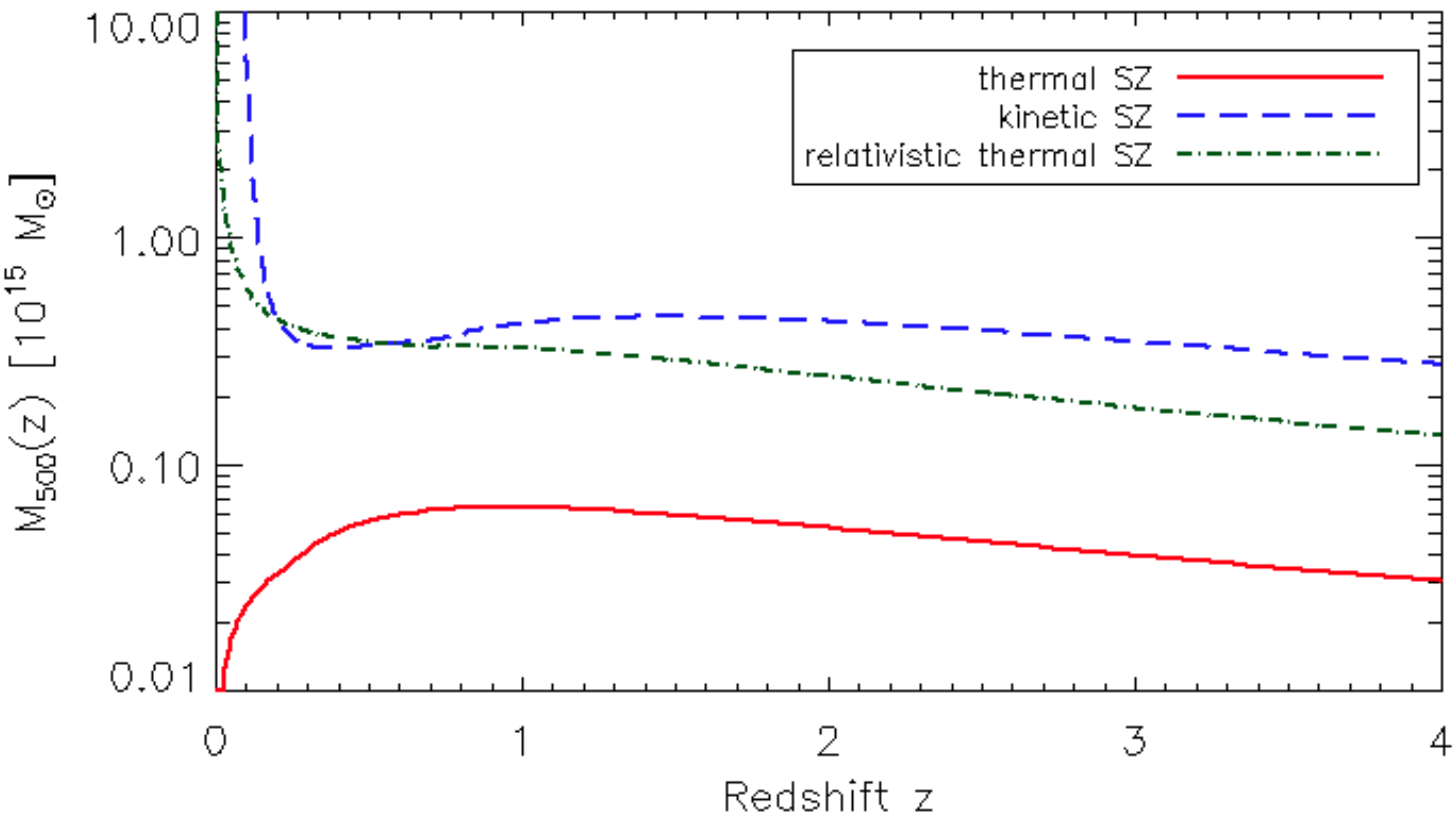
Dashed line = velocity dispersion of halos



Individual velocity measurement (kSZ effect)



Mlim(z) (S/N>3)



thermal SZ
kinetic SZ
relativistic thermal SZ
10.00
1.00
0.10
0.01
0
1
2
3
4
Redshift z
$M_{500}(z)$ [10^{15} $M_\odot$]

Accessing cluster key properties without any follow-up ?

- Temperature ⇒ should be possible for the hottest clusters
  using the relativistic SZ effect
  HIGH SENSITIVITY NEEDED

- Mass ⇒ CMB lensing reconstruction at the position of the clusters
  possible
  HIGH RESOLUTION NEEDED

- Redshift ⇒ dust in clusters (see Planck Intermediate Paper XI)
  could be used to get the redshift
  or GROUND BASED FOLLOW-UPS…

Space vs. ground
A Planck vs. SPT/ACT like case ?

- **M4 (2026):** a few μK arcmin @ [100,150]GHz, all-sky
- **CMB - S4 (>2021):** 1 μK arcmin @ 150GHz, ~½ sky

- Space: frequency & sky coverage
- Ground: resolution & sensitivity

⇒ Complementary sciences

Possible space synergies

- Euclid (optical) 2020, eROSITA (X-ray) 2015
- M4 (submillimetrer) 2026

  ⇒3 all-sky experiments (multi-wavelength analyses)

- Athena (X-ray) 2028

  ⇒ Follow-ups of high z (z>2) detections

Conclusions

- "M4-COrE" or "M4-PRISM req." can detect ~10^5 clusters (~Euclid or eROSITA counts), "M4-PRISM goal" can detect >5 times more.
- tens or hundreds between 2<z<4 depending on Y-M evolution
- M_{500}lim(z) below 10^{14} M_{sun}

- SZ spectrum measurement
- Temperature measurement for massive clusters (M_{500}>5 10^{14} M_{sun})
- Cluster mass from CMB lensing (high sens./res. required)

⇒ Study of the 2<z<4 cluster population (high sens./res. required)
⇒ Study of cluster peculiar velocities with kSZ (high sens./res. required)

- **SZ** science return scales with **resolution** and **sensitivity** ("M4 PRISM goal")