RedMaPPEr selected clusters from DES science verification data and their SPT-SZE signature

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+SPT coll.
+DES coll.

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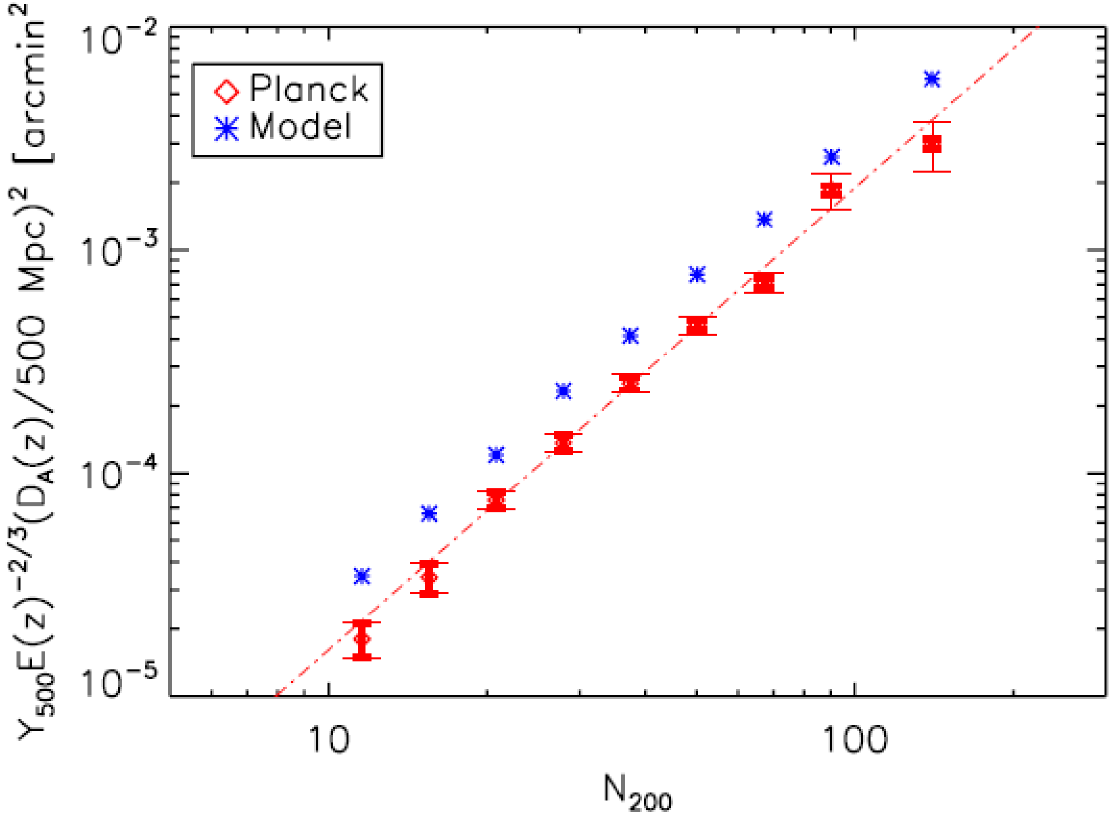
Outline

- Motivation
- Data set
- Temperature evolution of the CMB
- RedMaPPer properties of SPT-SZE selected clusters
- SPT-SZE properties of RedMaPPer selected clusters
- Conclusions

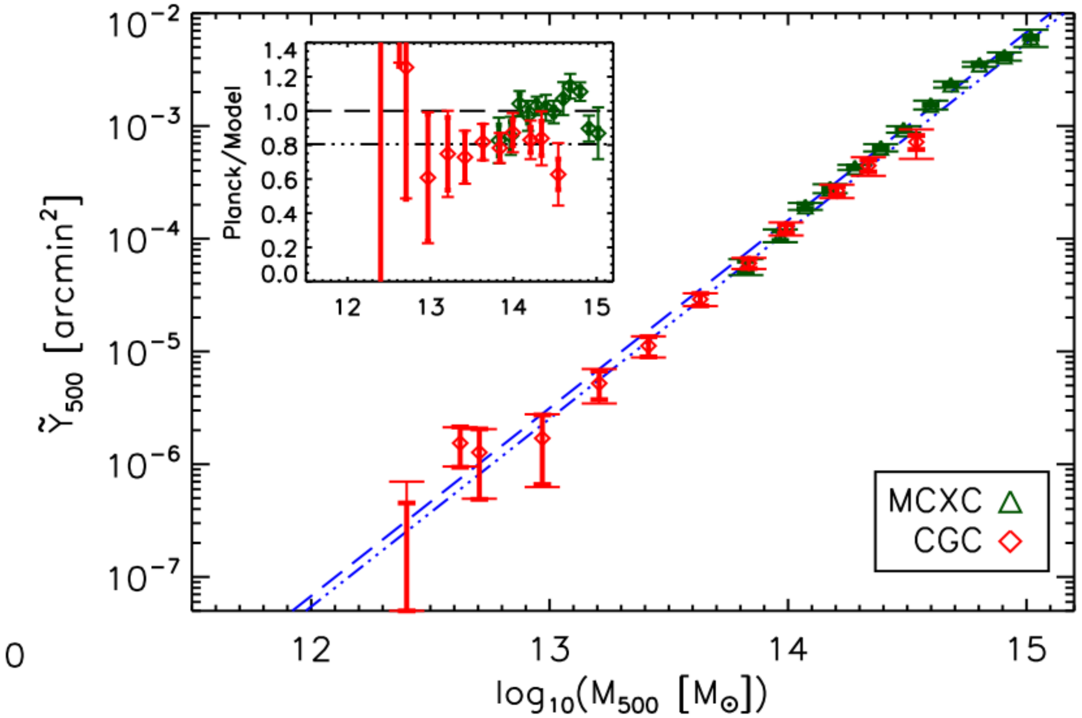
Motivation

Planck

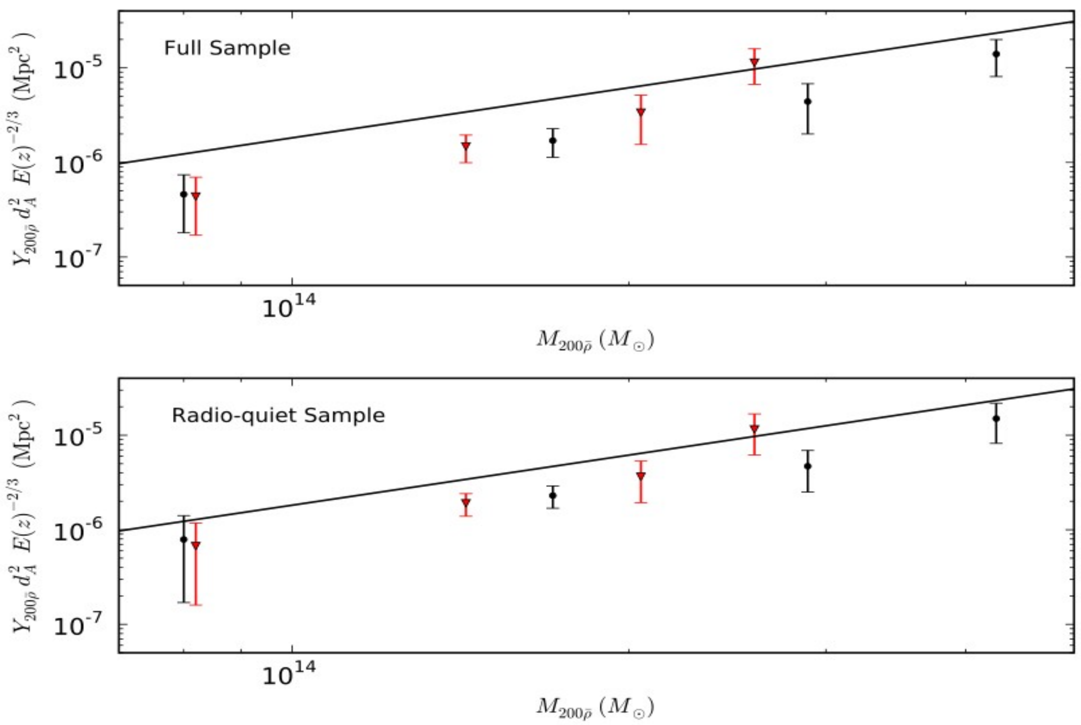
Planck col. 2011



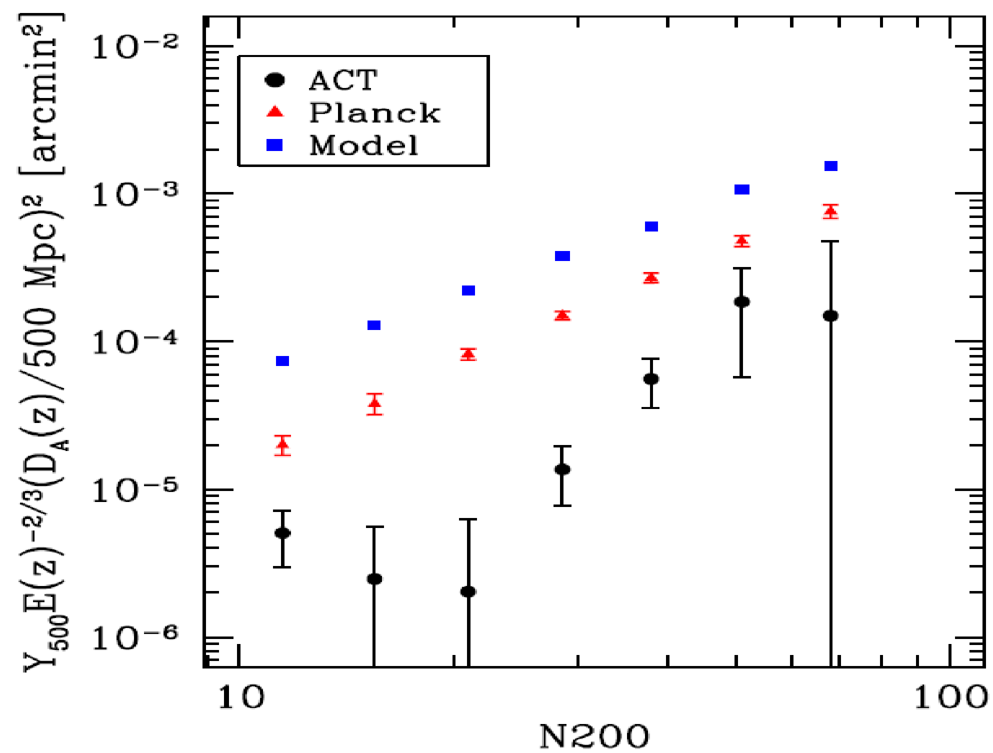
Planck col. 2012



ACT



Hand et al. 2011



Sehgal et al. 2013

Our dataset

DES-SV

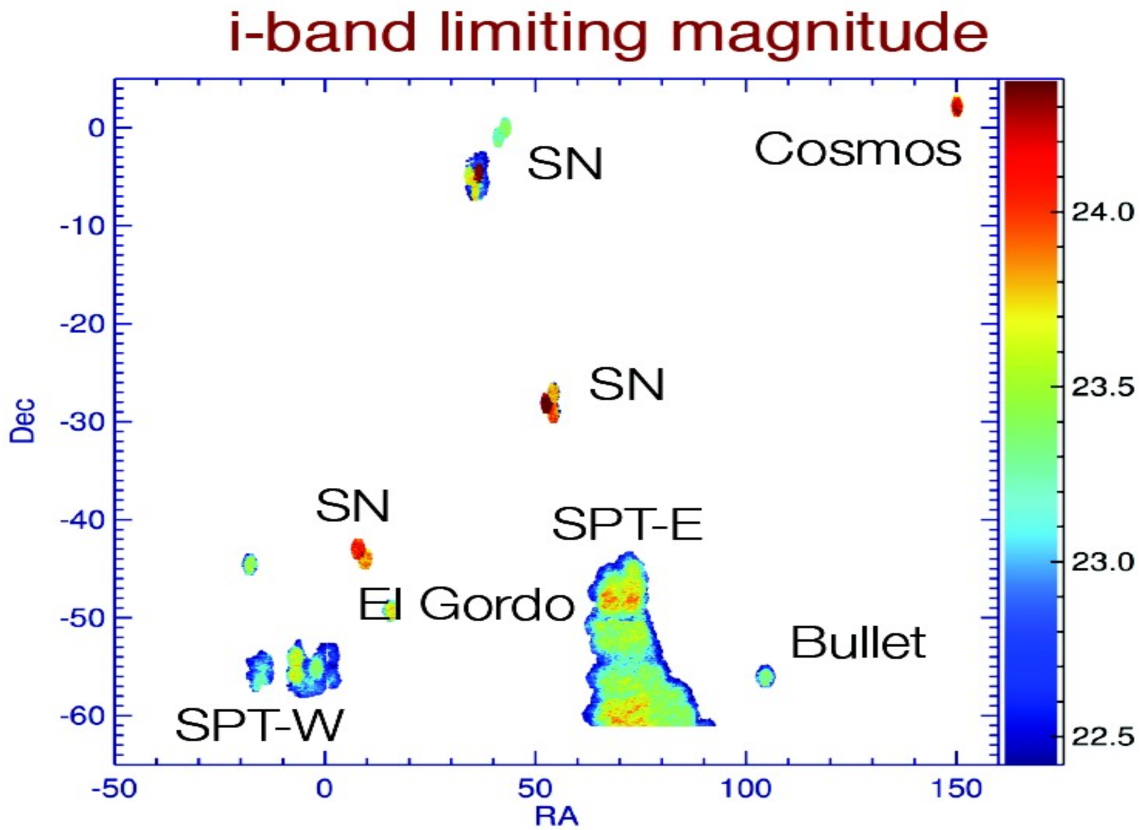
- ~250 sq. deg^2 of good imaging (griz)
- Overlap with SPT and other fields
- Preliminary analysis underway in all the main science areas: Clusters, Weak Lensing, Supernovae, Large-Scale Structure

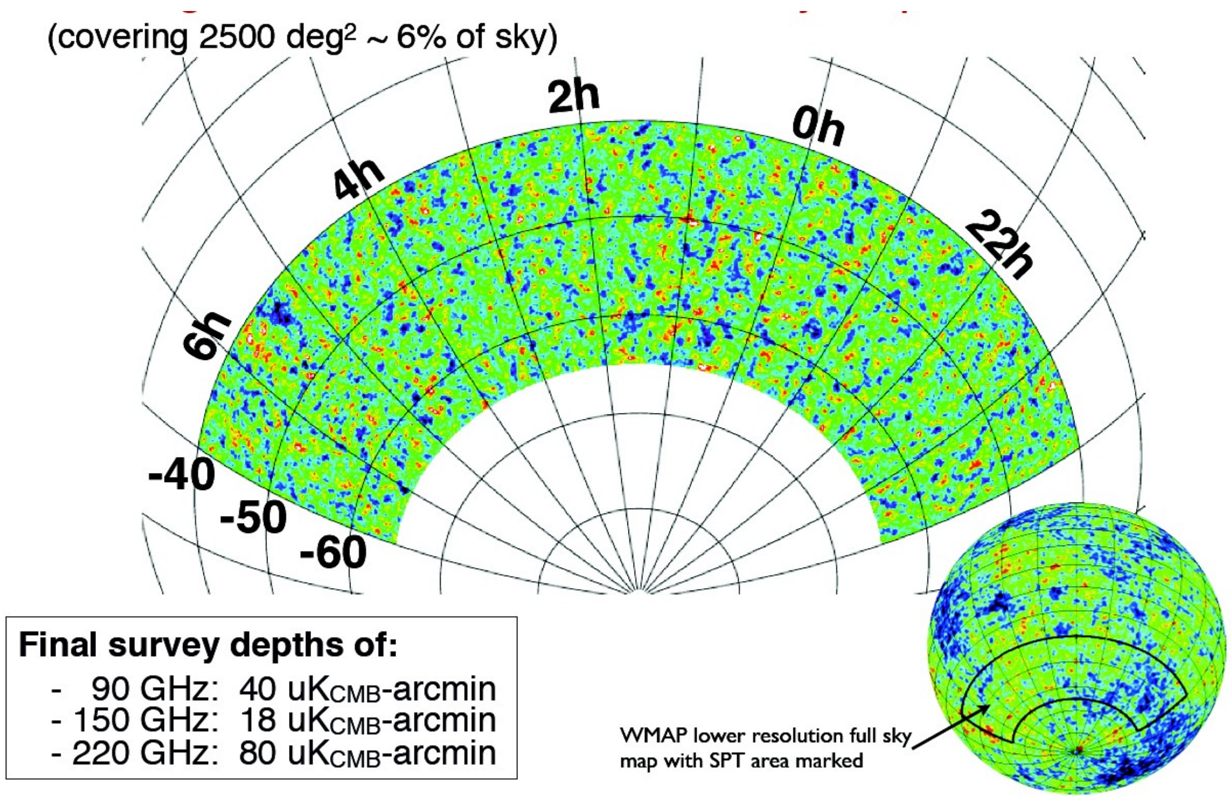
SPT-SZE

- 10 meter aperture
- 1' FWHM beam at 150 GHz
- 2500 deg^2

Bleem et al. 2014

Bocquet et al. 2014





RedMaPPer

- Red sequence Matched-filter Probabilistic Percolation algorithm and catalogs
- Based on the λ richness (Rozo+09; Rykoff+12; Rozo+14)
- Optimized to minimize scatter in L_X-richness
  - Richness λ fully optimized (Rykoff+12). Scatter in mass at fixed richness $\sigma \ln M|\lambda \sim 0.25$
- Go to every galaxy and measure the richness λ, and the associated likelihood $\lambda = \Sigma\, p_i$: p_i = probability that galaxy i belongs to cluster.
  - Probability assigned using a *Matched-Filter*.
- Rank by galaxies likelihood and percolate:
  - Probabilistic Percolation: If a galaxy contributes a probability p to one cluster, the probability that it belongs to another cluster is reduced by (1-p).

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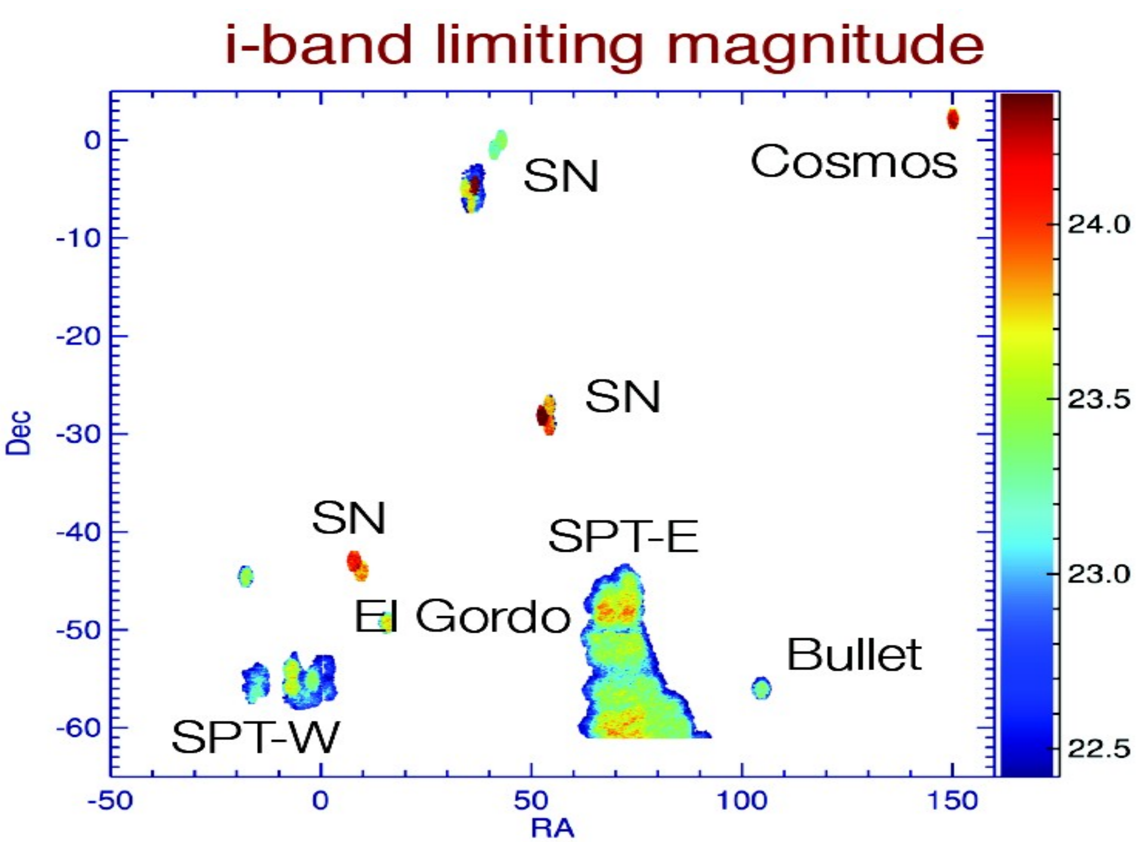
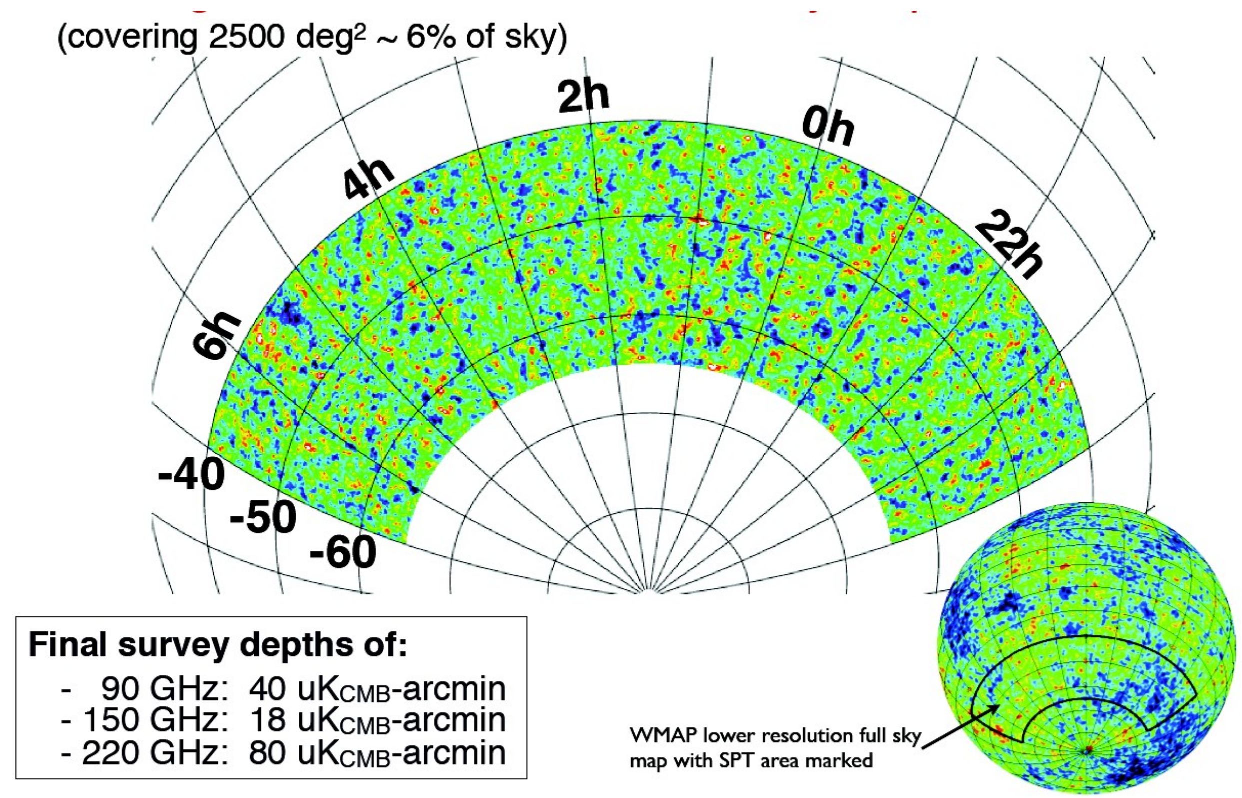
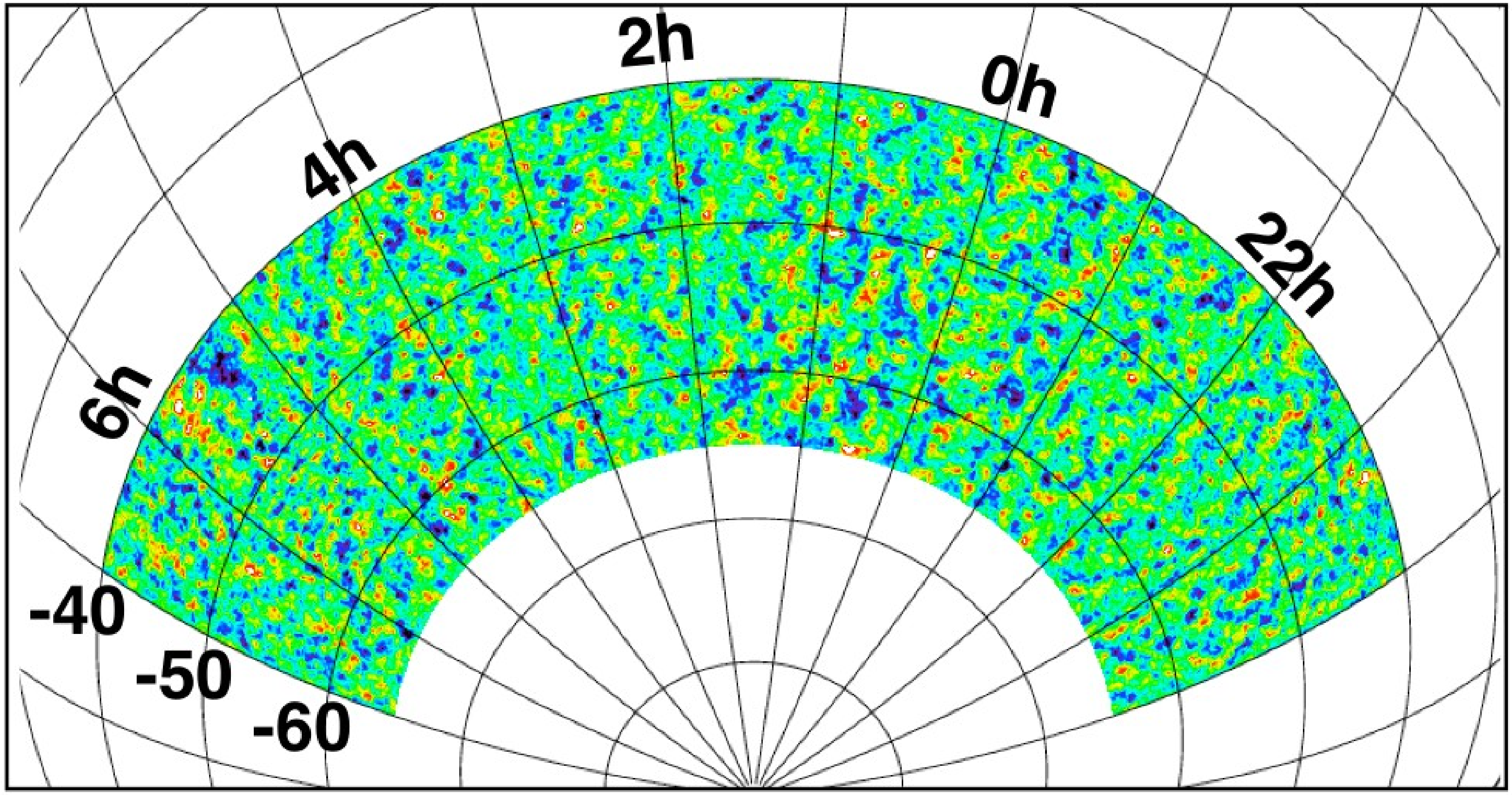




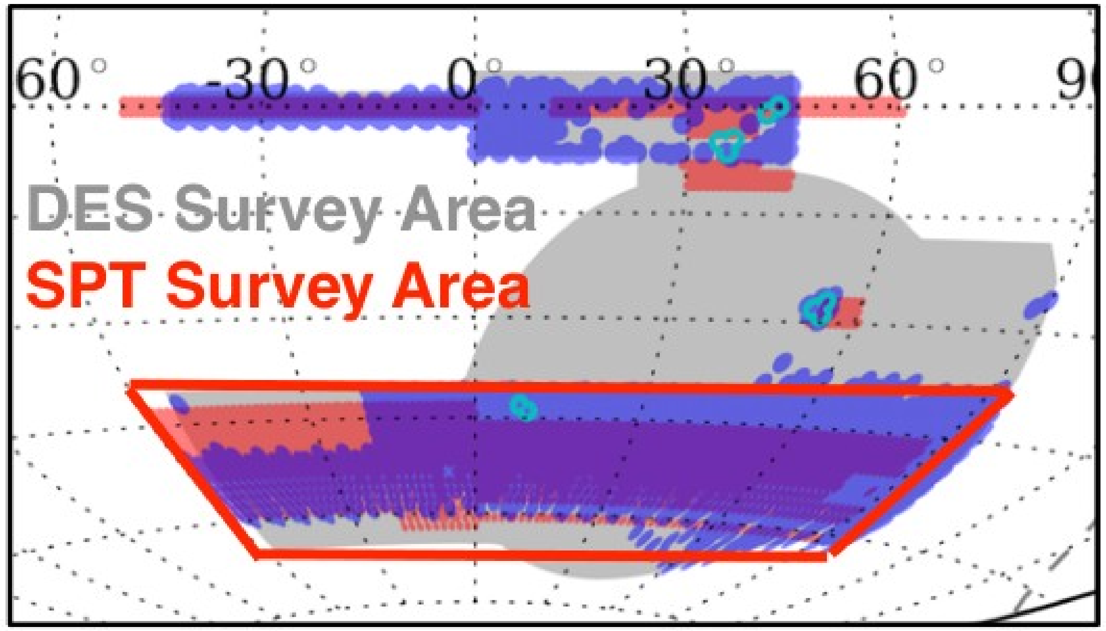
The 2500 deg² SPT-SZ Survey (2007-2011):



Final survey depths of:

- **90 GHz:** 40 uK$_{CMB}$-arcmin
- **150 GHz:** 17 uK$_{CMB}$-arcmin
- **220 GHz:** 80 uK$_{CMB}$-arcmin

Complete overlap with DES survey

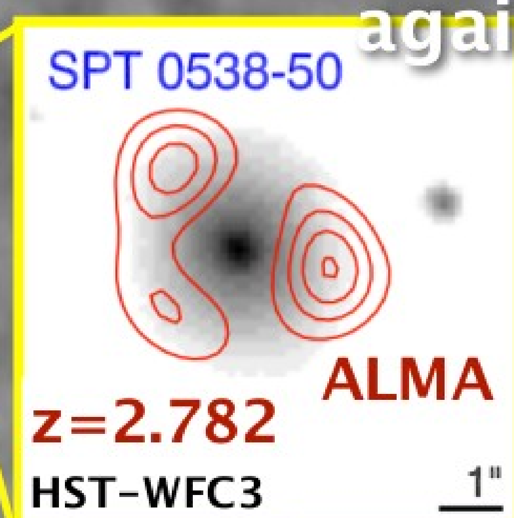


Zoom in on an SPT map

50 deg^2 from 2500 deg^2 survey

CMB Anisotropy
– Primordial and secondary anisotropy in the CMB

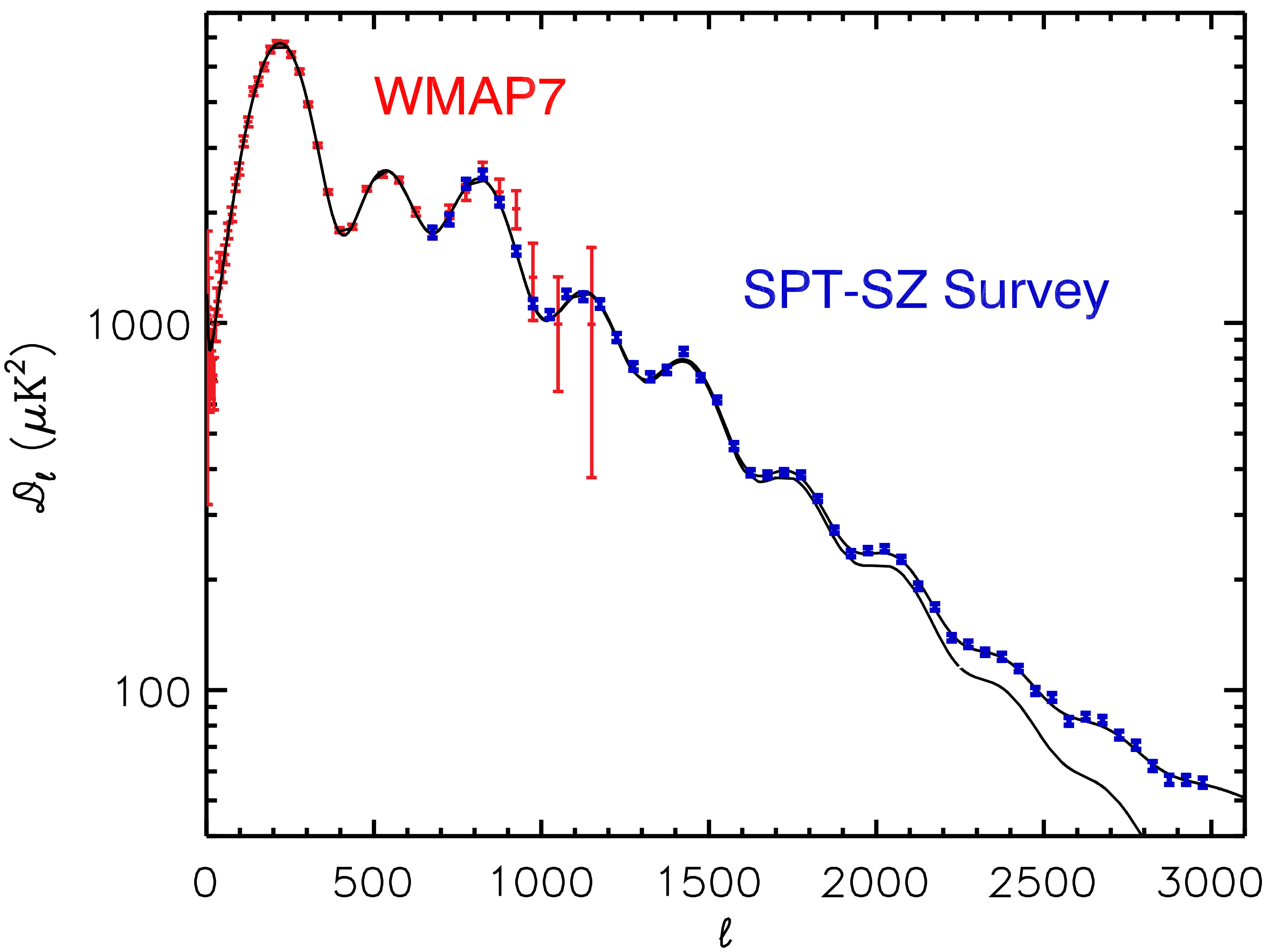
Point Sources – High-redshift dusty star forming galaxies and Active Galactic Nuclei



Clusters – High signal to noise SZ galaxy cluster detections as “shadows” against the CMB!

Sky at mm wavelenght

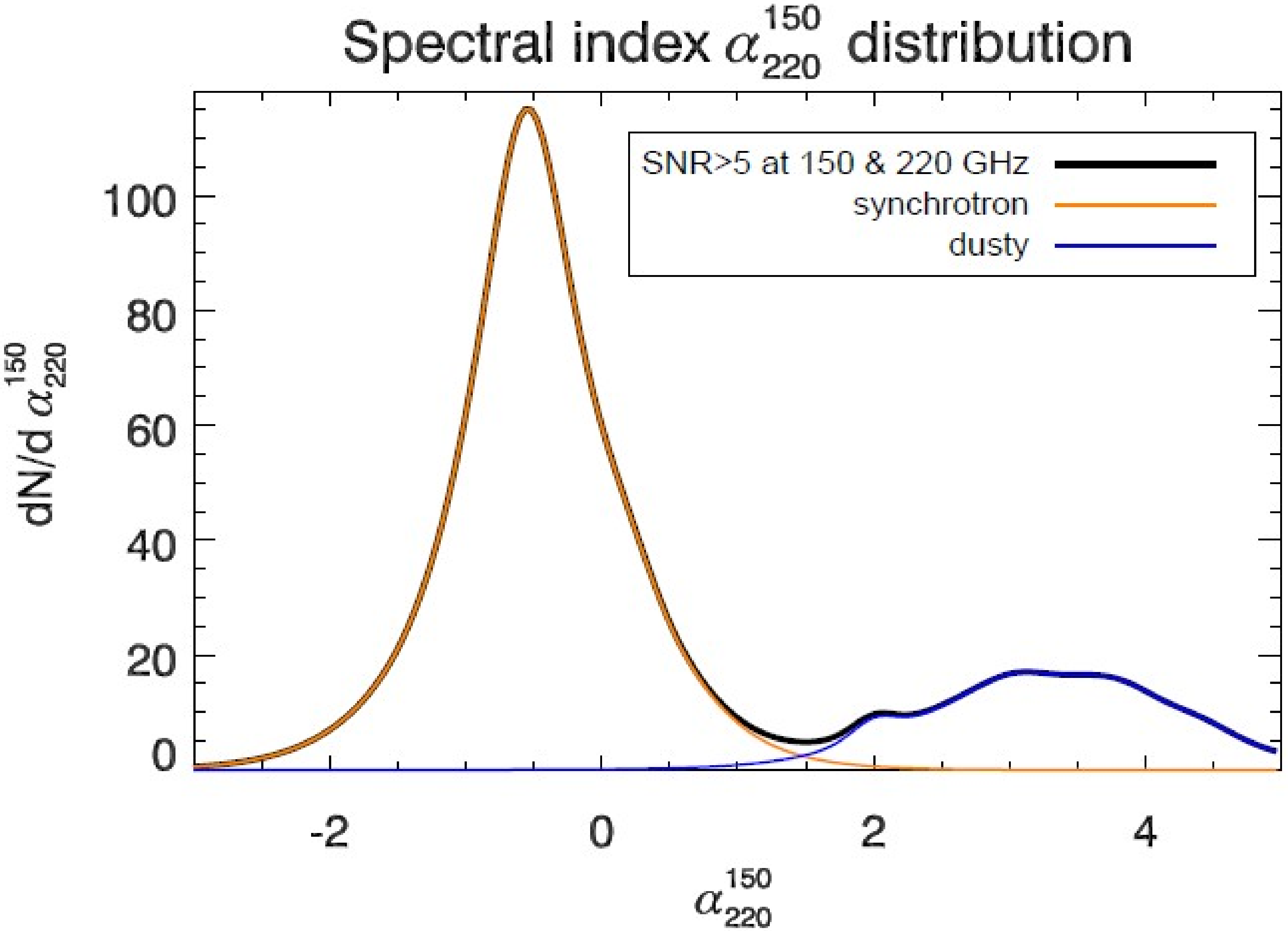
- CMB



e.g. Planck coll. 2013, Story et al. 2012, Das et al. 2011, Fowler et al. 2010, Keisler et al. 2011, etc.

Sky at mm wavelenght

- CMB
- Point sources

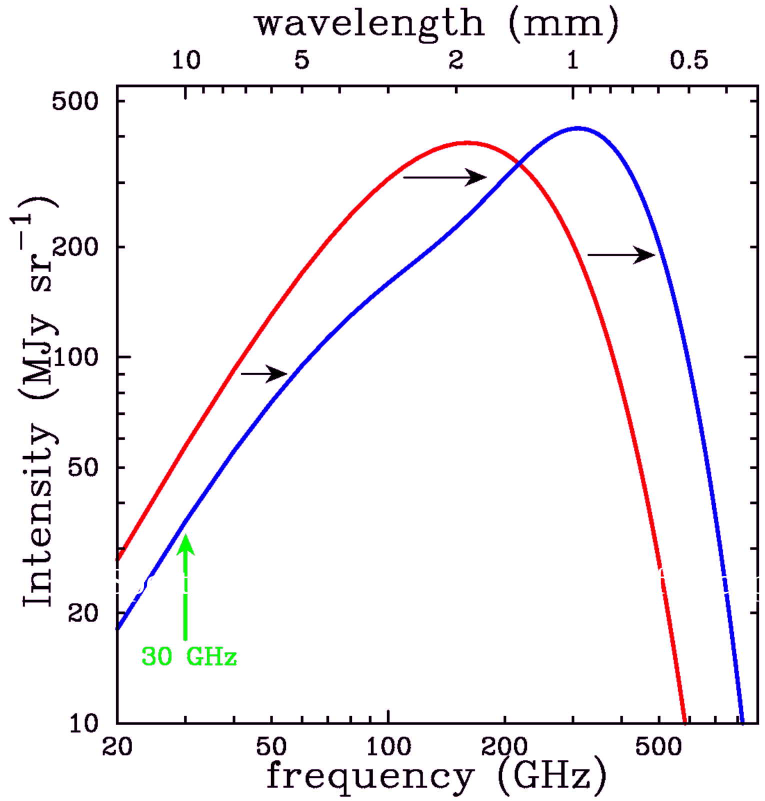


e.g. Mocanu et al. 2013, Greve et al. 2012, Viera et al. 2010, etc.

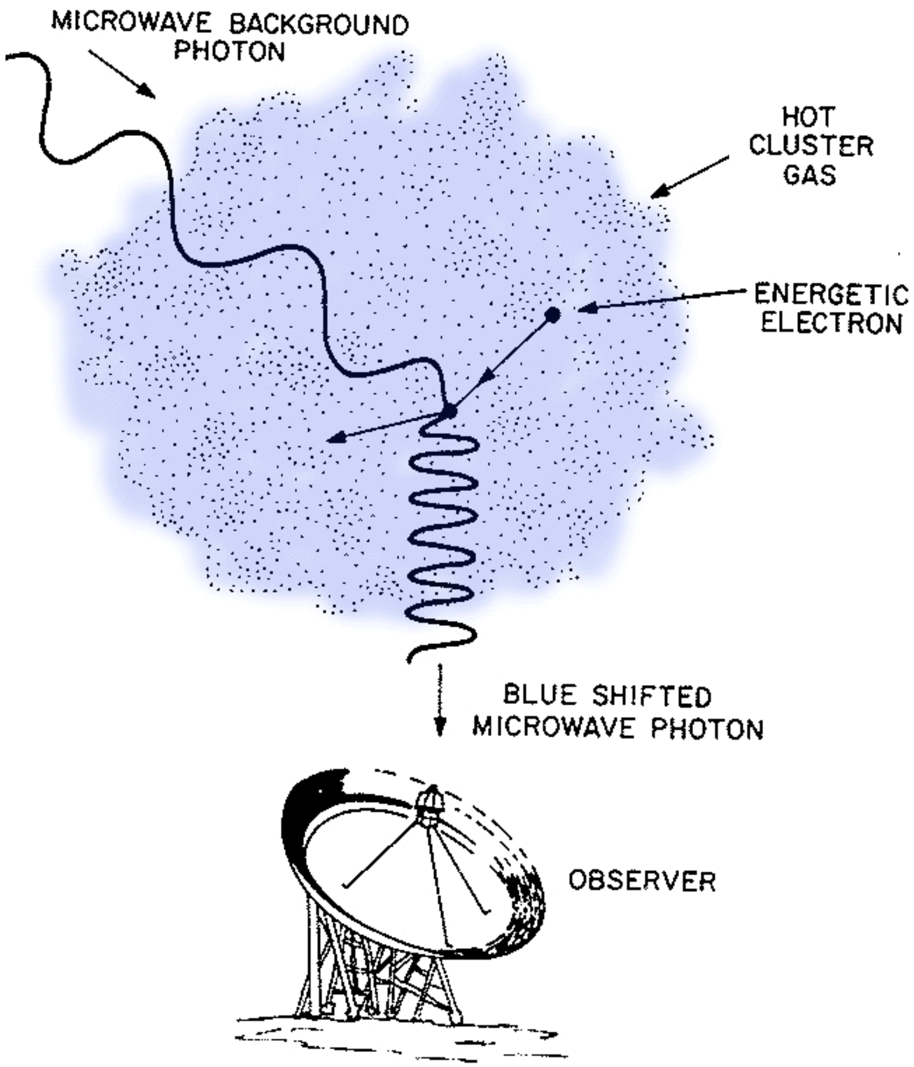
Sky at mm wavelenght

- CMB
- Point sources
- Clusters

Spectral Distortion of CMB



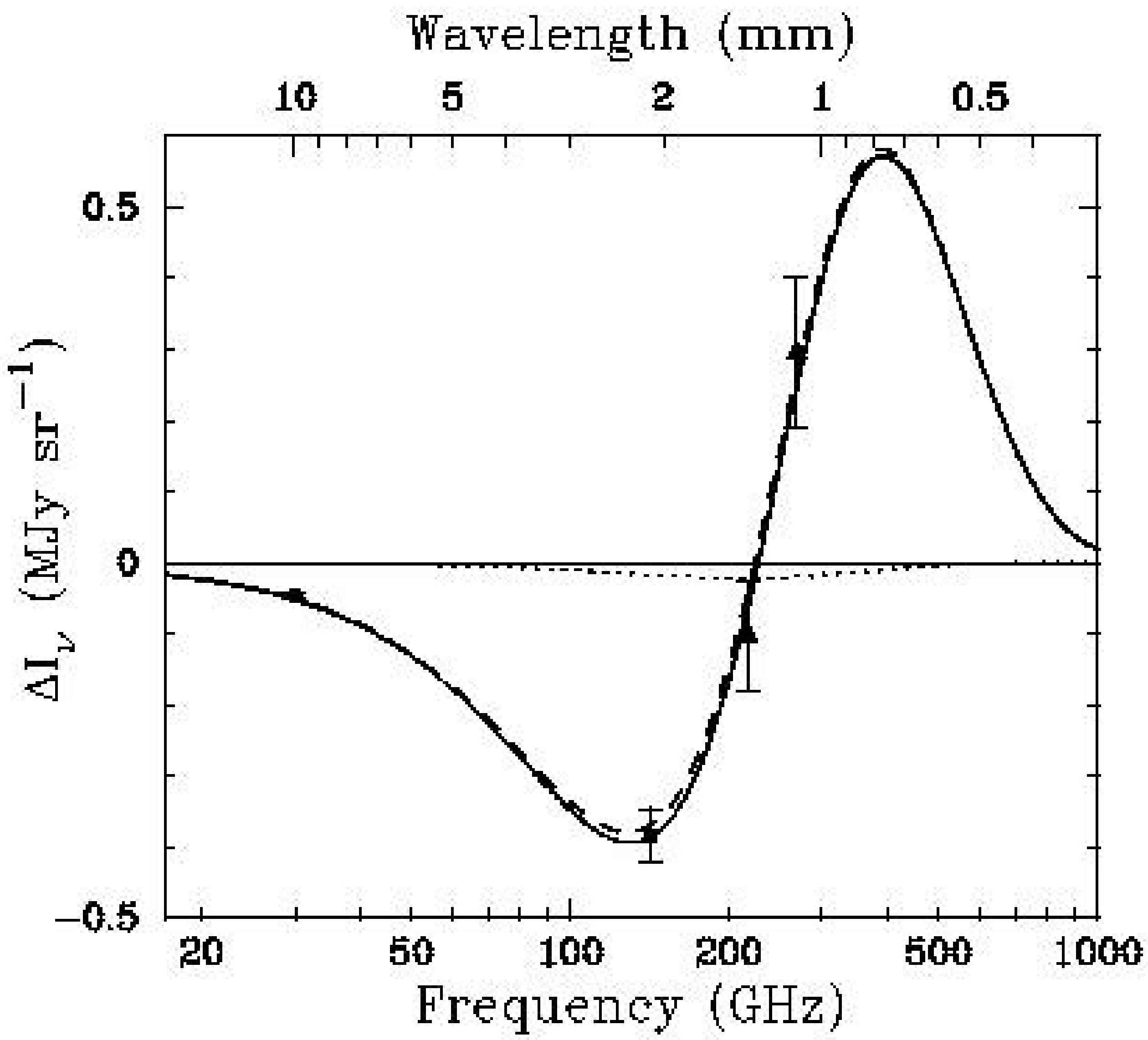
Sunyaev & Zel'dovich 1970, 1972



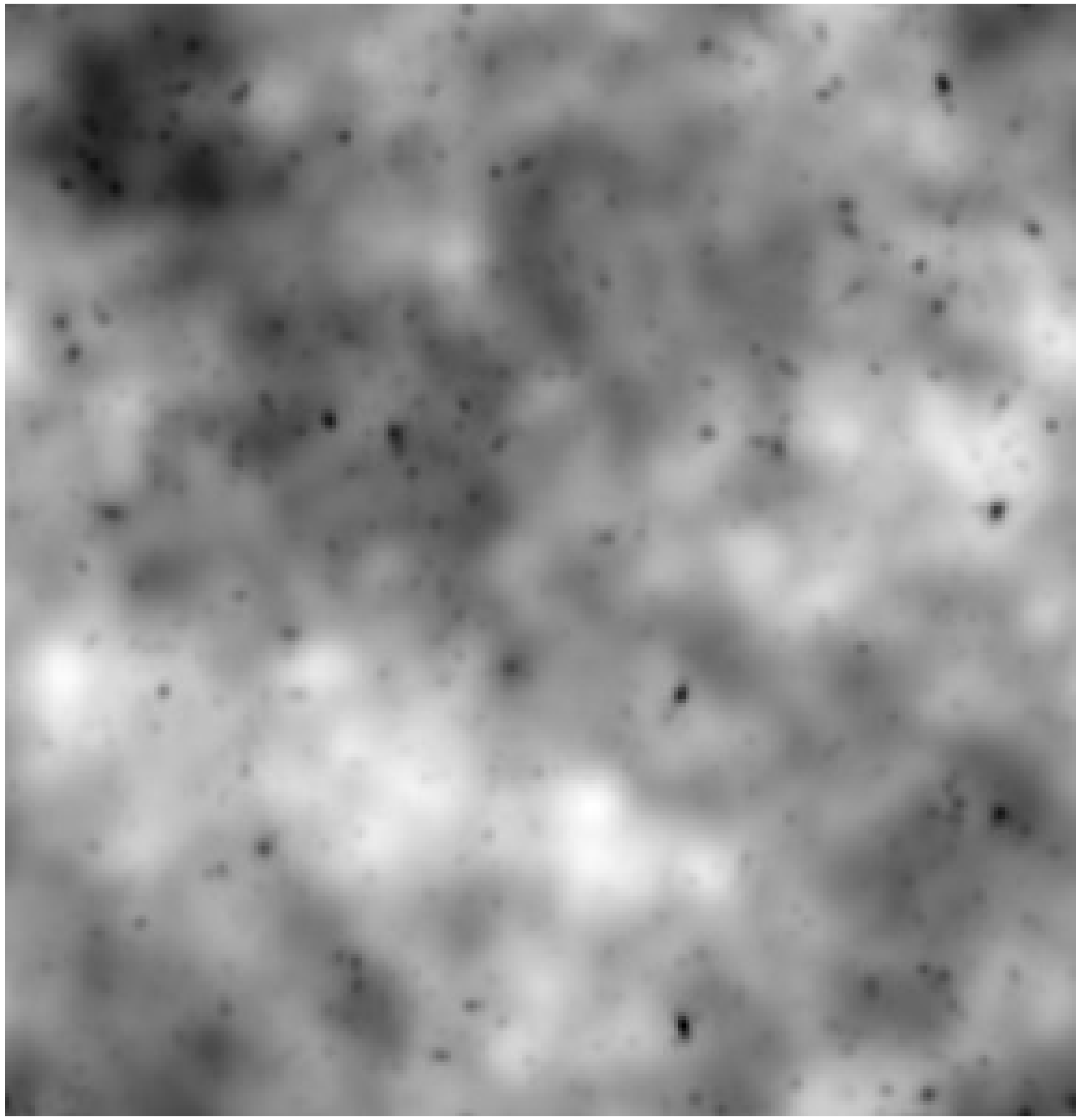
Adapted from L. Van Speybroeck

Clusters and the Sunyaev & Zel'dovich Effect

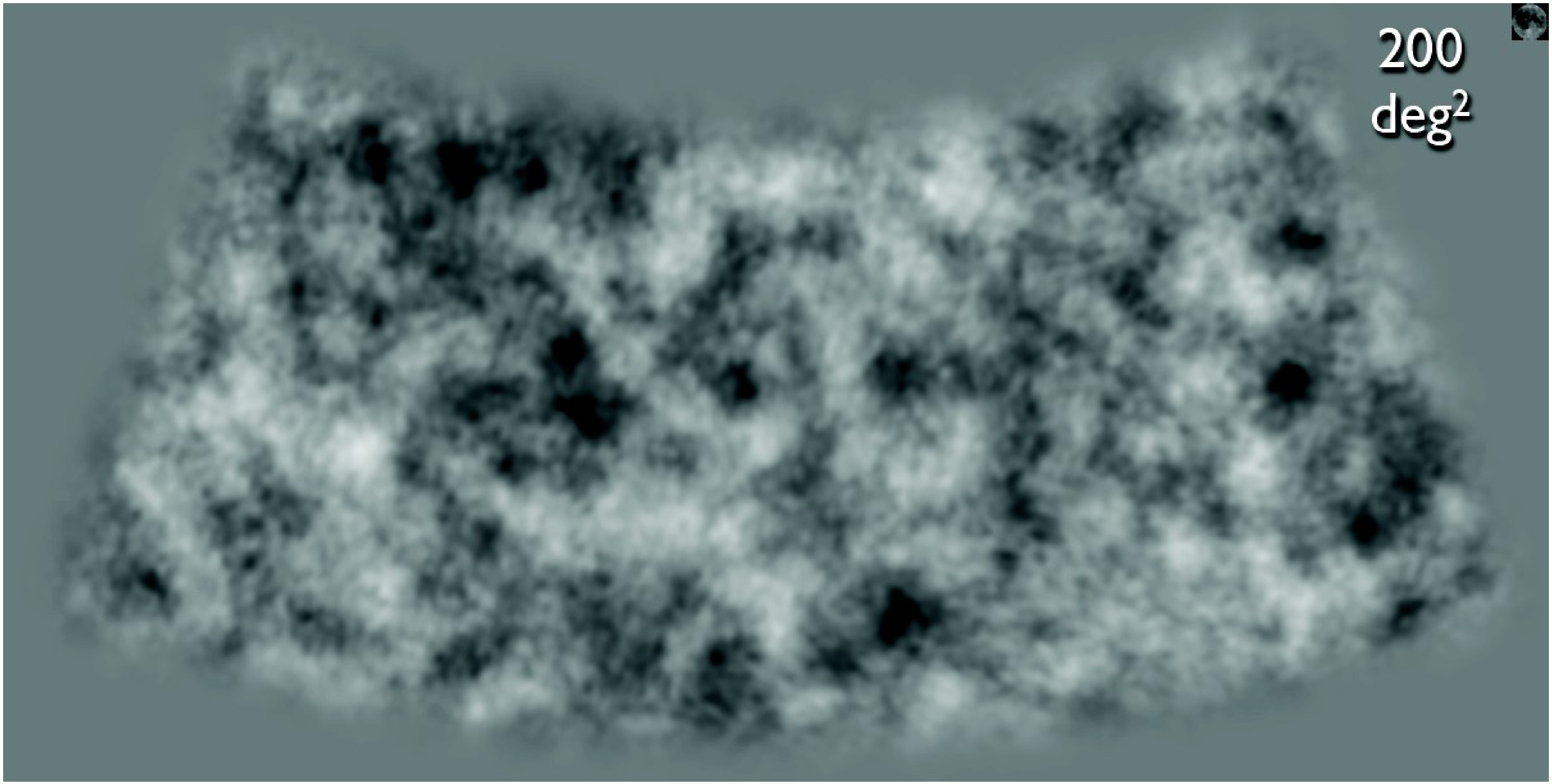
Unique spectrum



Unique angular scale

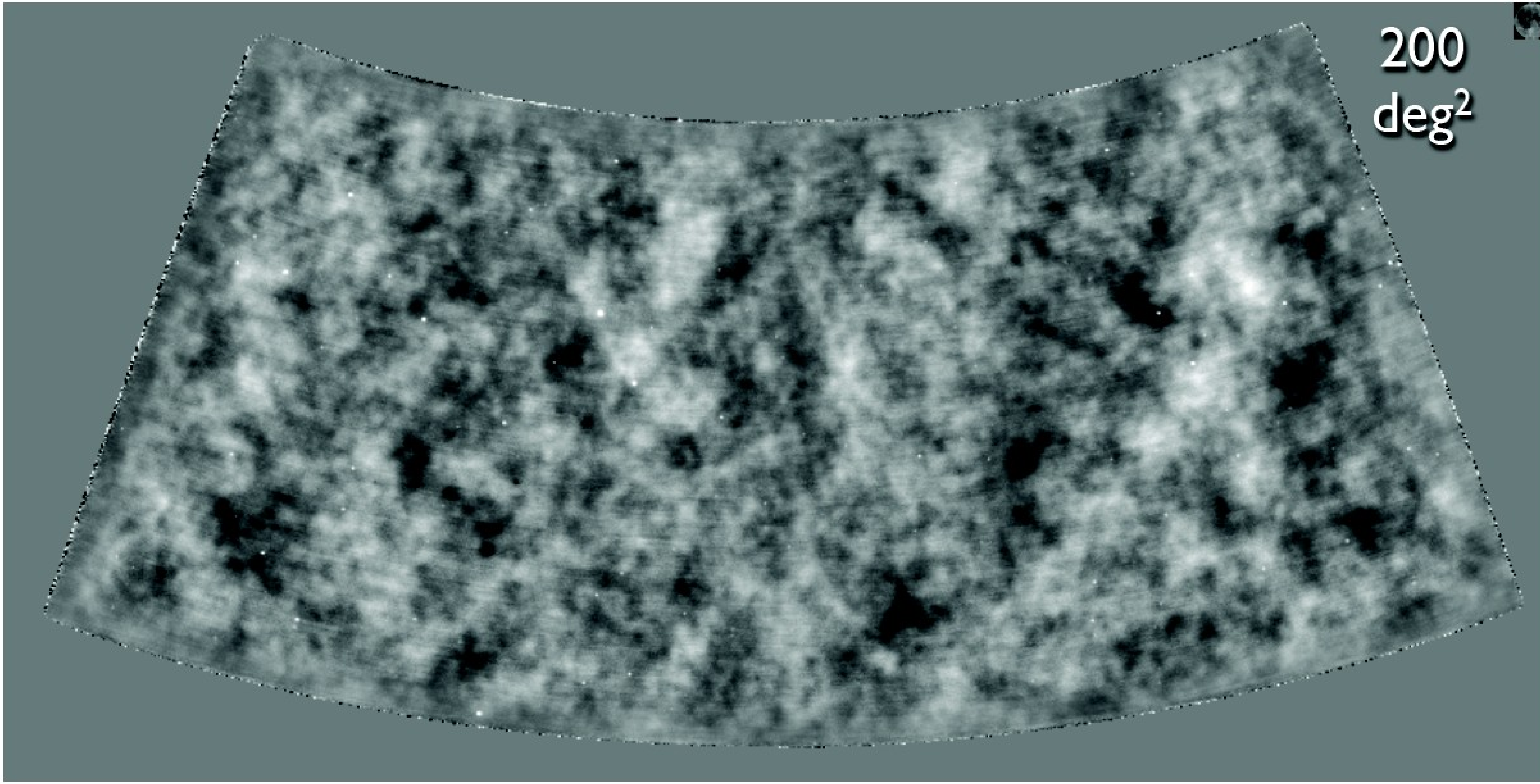


Clusters and the Sunyaev & Zel'dovich Effect



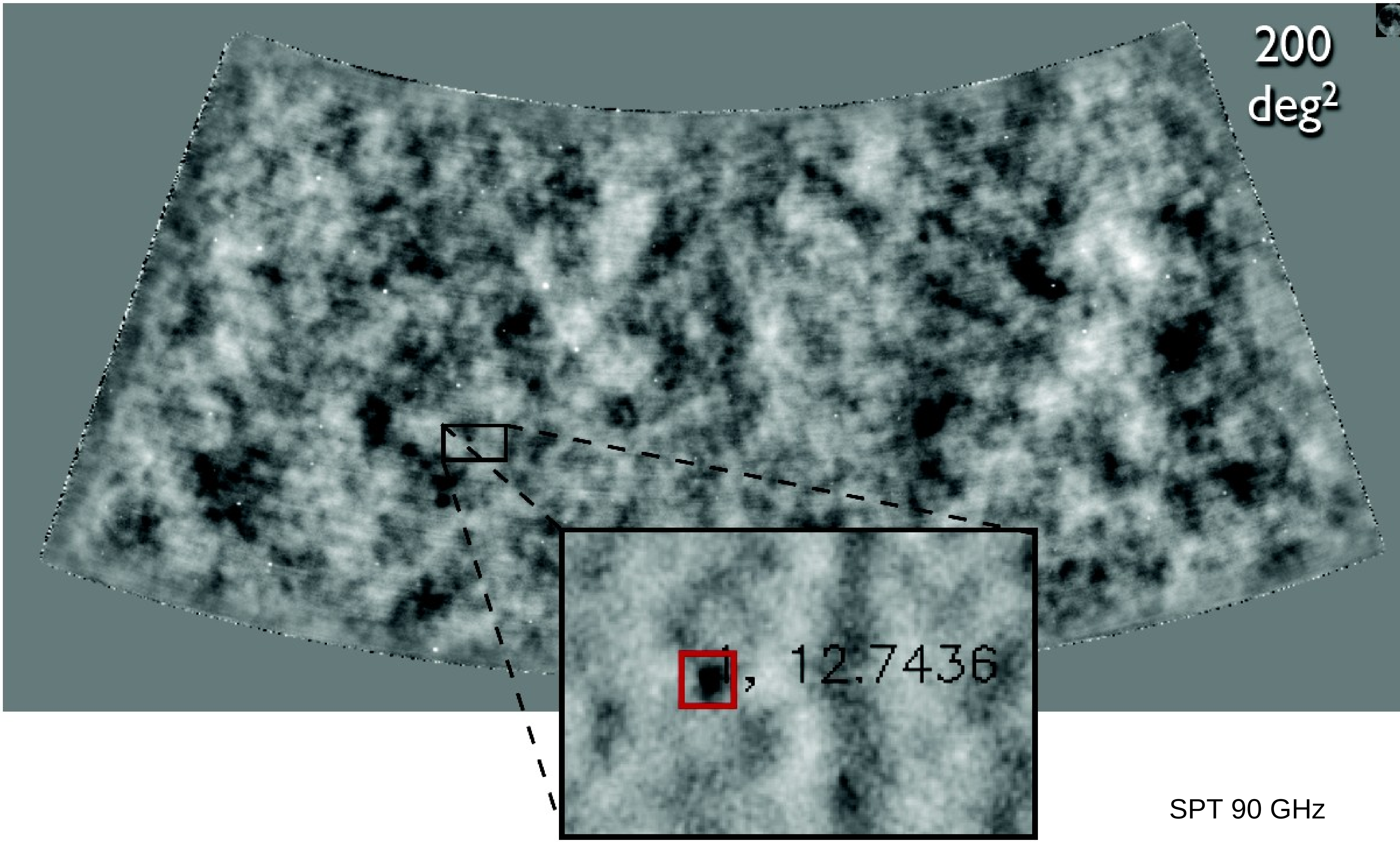
WMAP 90 GHz

Clusters and the Sunyaev & Zel'dovich Effect



SPT 90 GHz

Clusters and the Sunyaev & Zel'dovich Effect



SPT 90 GHz

Clusters and the Sunyaev & Zel'dovich Effect

Neglecting relativistic corrections we can express the SZE as:

$$\frac{T(\hat{n}) - T_0}{T_0} = \int \left[G(\nu) \frac{k_B T_e}{m_e c^2} - \frac{\vec{v}_{cl} \hat{n}}{c} \right] d\tau = G(\nu) y_c - \tau \frac{\vec{v}_{cl} \hat{n}}{c}$$

Where:

$y_c = (k_B \sigma_T / m_e c^2) \int n_e T_e dl$ and $G(x) = x \coth(x/2) - 4$

$$Y = \int y_c \, d\Omega \qquad x \equiv h\nu / kT$$

If the Universe expands adiabatically we have:

$$T(z) = T_0(1+z) \qquad \nu(z) = \nu_0(1+z)$$

$$x = h\nu(z)/kT(z) = h\nu_0/kT_0 = x_0$$

Neglecting KSZ follows:

$$\Delta T(\hat{n}) \simeq T_0 y_c(\hat{n}) G(\nu).$$

Evolution of $T_{CMB}(z)$

➔Adiabatic evolution of $T_{CMB}(z) = T_0(1+z)$ is a fundamental prediction of the "Standard Cosmological Model"

- ➔Violation of the local position invariance and equivalence principle (e.g. variation of dimensionless coupling constants) Martins+ 02; Murphy+ 03; Srianand+ 04; etc..
- ➔Non conservation of the number of photons (e.g. decaying vacuum energy density model, coupling between axion-like particles and photons, modified gravity scenarios..) Matjasek+ 95; Lima+ 00; Puy 04; Jetzer+ 11; etc..

➔Low z ($z \leq 1$):

Through SZE in galaxy clusters. (e.g. Battistelli+ 02; Luzzi+ 09; Avgoustidis+ 12; De Martino+ 12, Hurier+14)

➔High z ($z \geq 1$)

Atomic and molecular fine structure levels excited by the photon-absorption of CMB radiation in QSO absorption lines spectra. (e.g. Srianand+00; Molaro+02; Srianand+08; Notaerdame+11, Müller+13)

Evolution of $T_{CMB}(z)$

We study the Lima et al. (2002) model $T(z) = T_0(1+z)^{1-\alpha}$

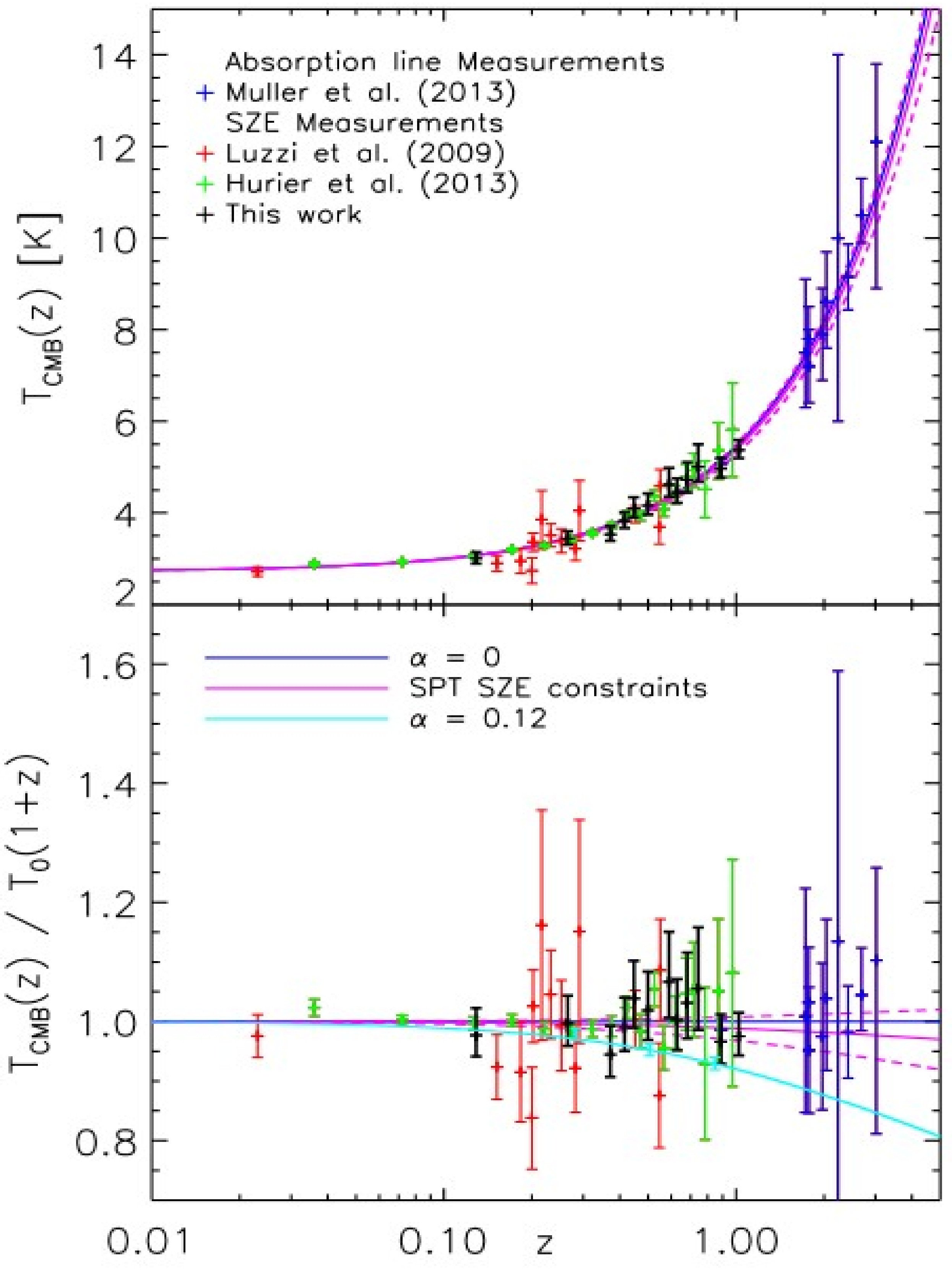
Therefore

$$\Delta T(\hat{n}) \simeq T_0 y_c(\hat{n}) G(\nu, \alpha)$$

Which implies

$$\frac{\Delta T(\hat{n},\nu_1)}{\Delta T(\hat{n},\nu_2)} = \frac{G(\nu_1,\alpha)}{G(\nu_2,\alpha)} \simeq \frac{x_{1,\alpha}\coth(x_{1,\alpha}/2) - 4}{x_{2,\alpha}\coth(x_{2,\alpha}/2) - 4}$$

Constrain α by studying the ratio of the measured SZ-Temperature decrements at 150 and 95 GHz as a function of z



Saro et al. 2014

Evolution of $T_{CMB}(z)$

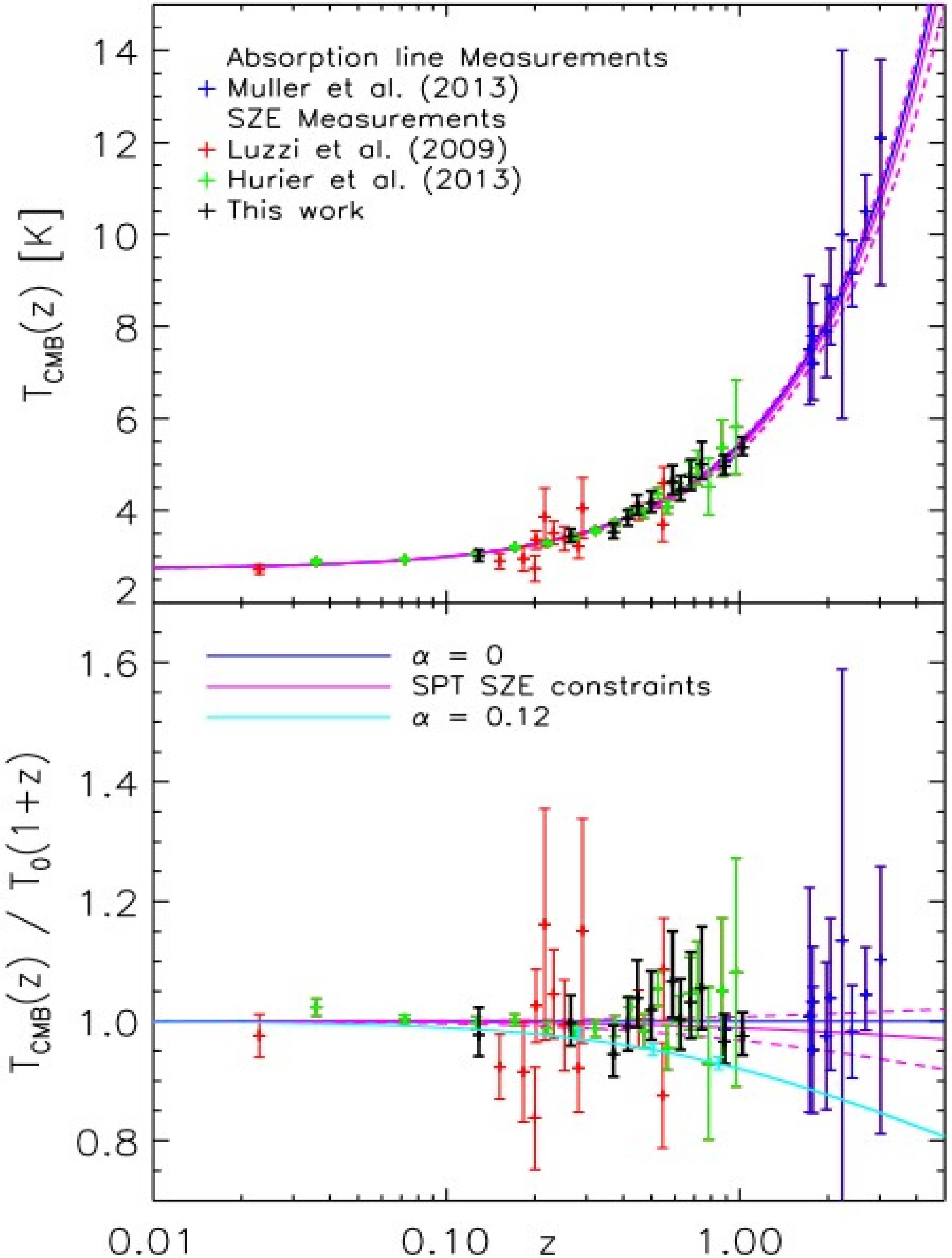
Tight combined constraints

on $T(z) = T_0(1+z)^{1-\alpha}$

$$\alpha = 0.005 \pm 0.012$$

Constrained equation of state for decaying DE models

$$w_{\rm eff} = -0.994 \pm 0.010$$

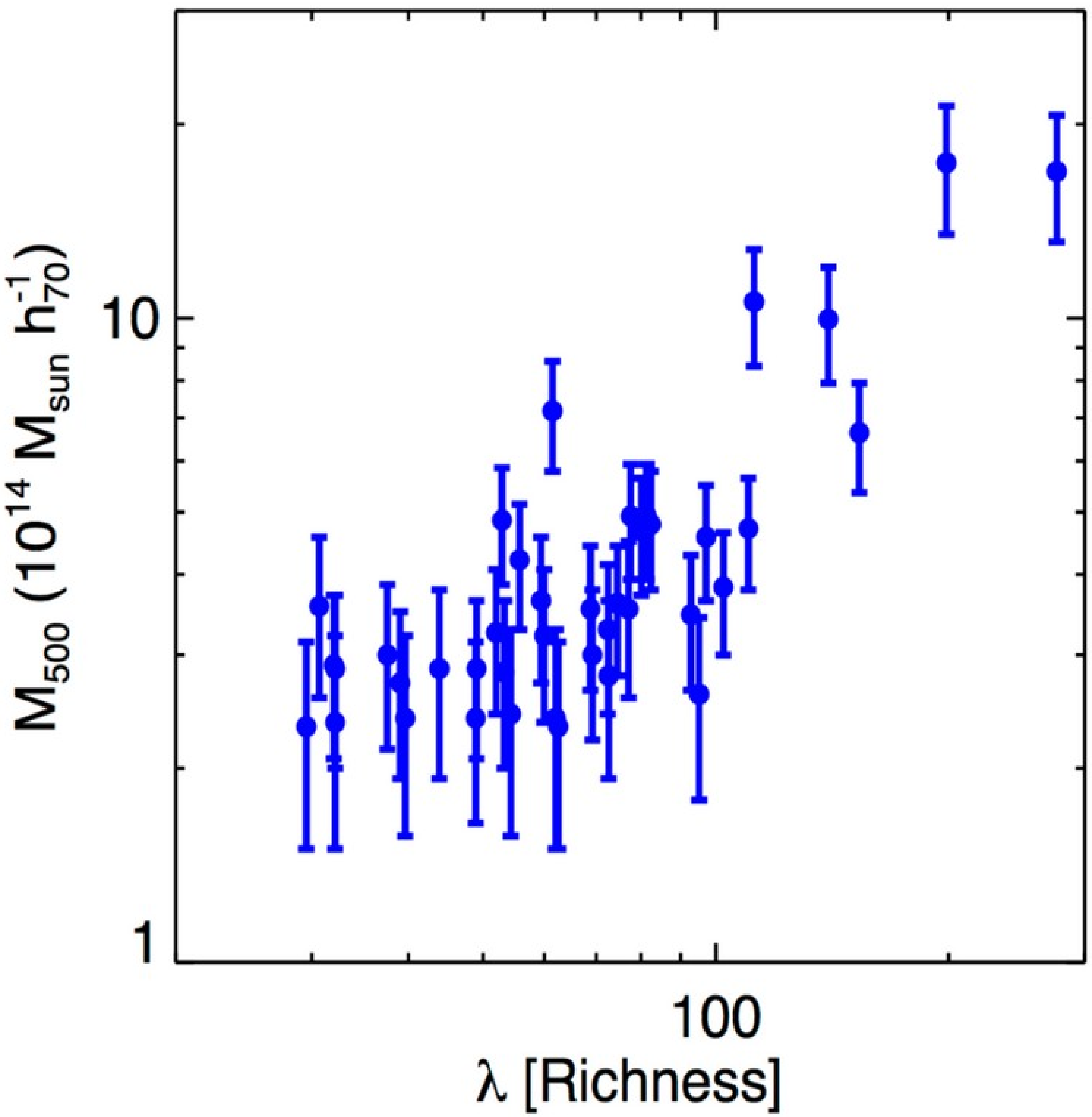


Saro et al. 2014

RedMaPPer properties of SPT-SZE selected clusters

- ➔ Calibrate λ-Mass scaling relation
- ➔ SPT-SZE - RedMaPPer central offset distribution

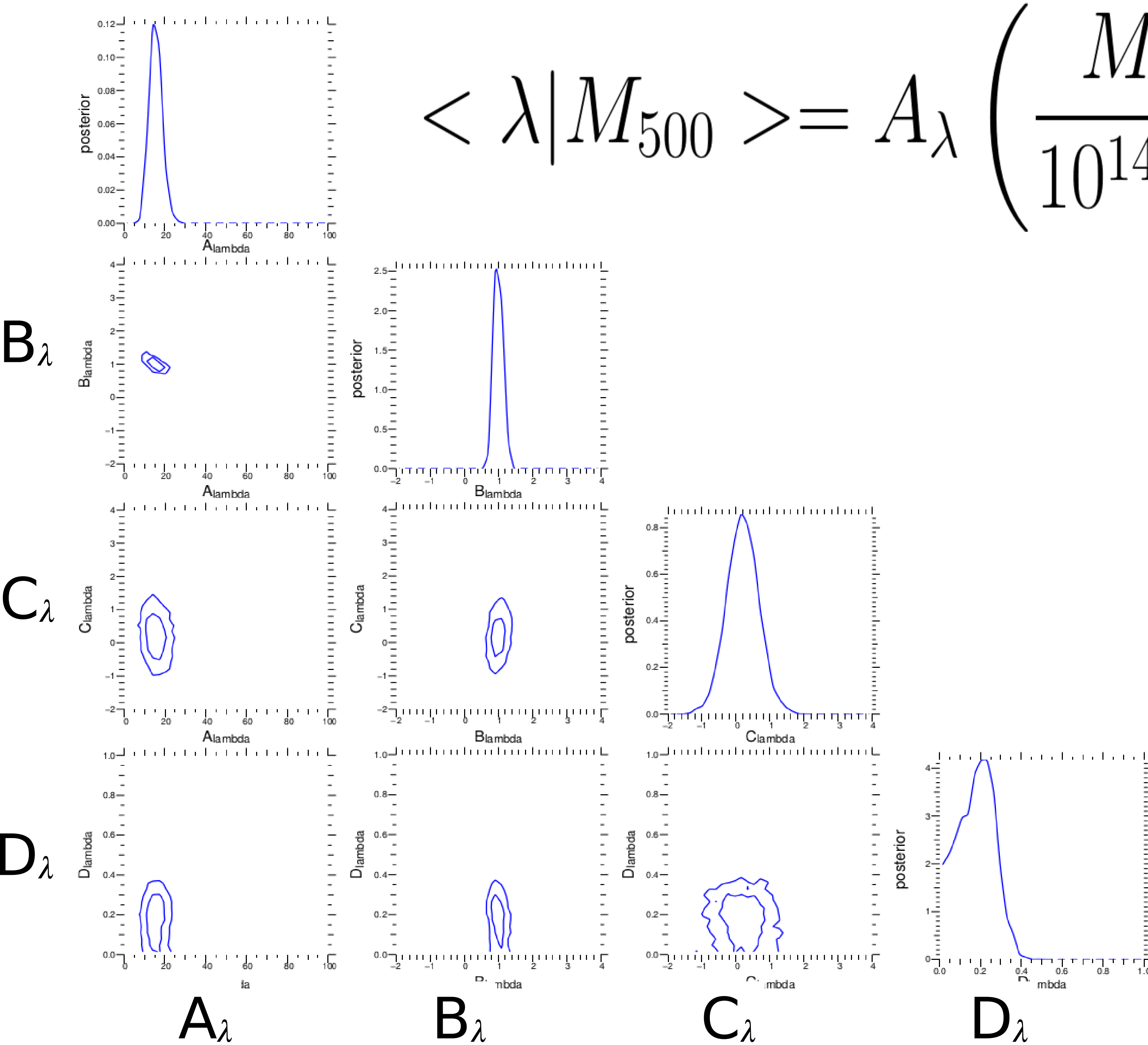
λ-Mass Relation for SPT-selected Clusters



- Use our knowledge of SPT-SZE clusters to infer RedMaPPer properties
- Use the SPT-SZ 2500 deg^2 cluster catalog from Bleem et al. (2014), de Haan et al (2014, in prep)
- 39 DES-SV RedMaPPer clusters cross-match with the SPT-SZ cluster catalog (Rozo et al. 2014), Hennig et al. (2014, in prep)

λ-Mass Relation for SPT-selected Clusters

$$\langle \lambda | M_{500} \rangle = A_\lambda \left(\frac{M_{500}}{10^{14} M_\odot} \right)^{B_\lambda} \left(\frac{E(z)}{E(z=0.5)} \right)^{C_\lambda}$$

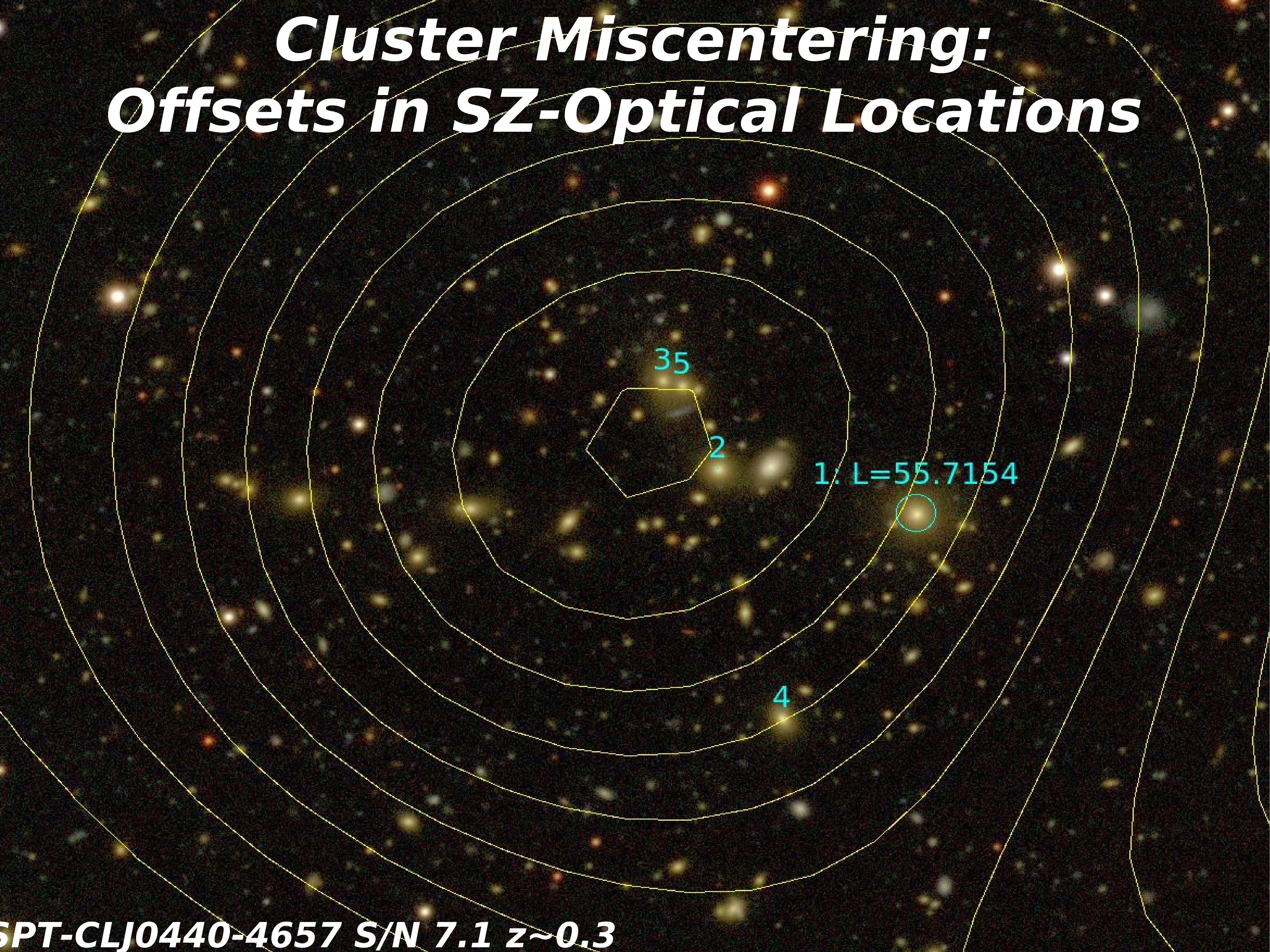


Fit λ-Mass relation, using masses from Bocquet et al. (2014)

(16 Yx + 63 velocity dispersions + self-calibration from 720 deg² + fixed cosmology)

+ CAVEAT No correlated scatter included

Cluster Miscentering: Offsets in SZ-Optical Locations

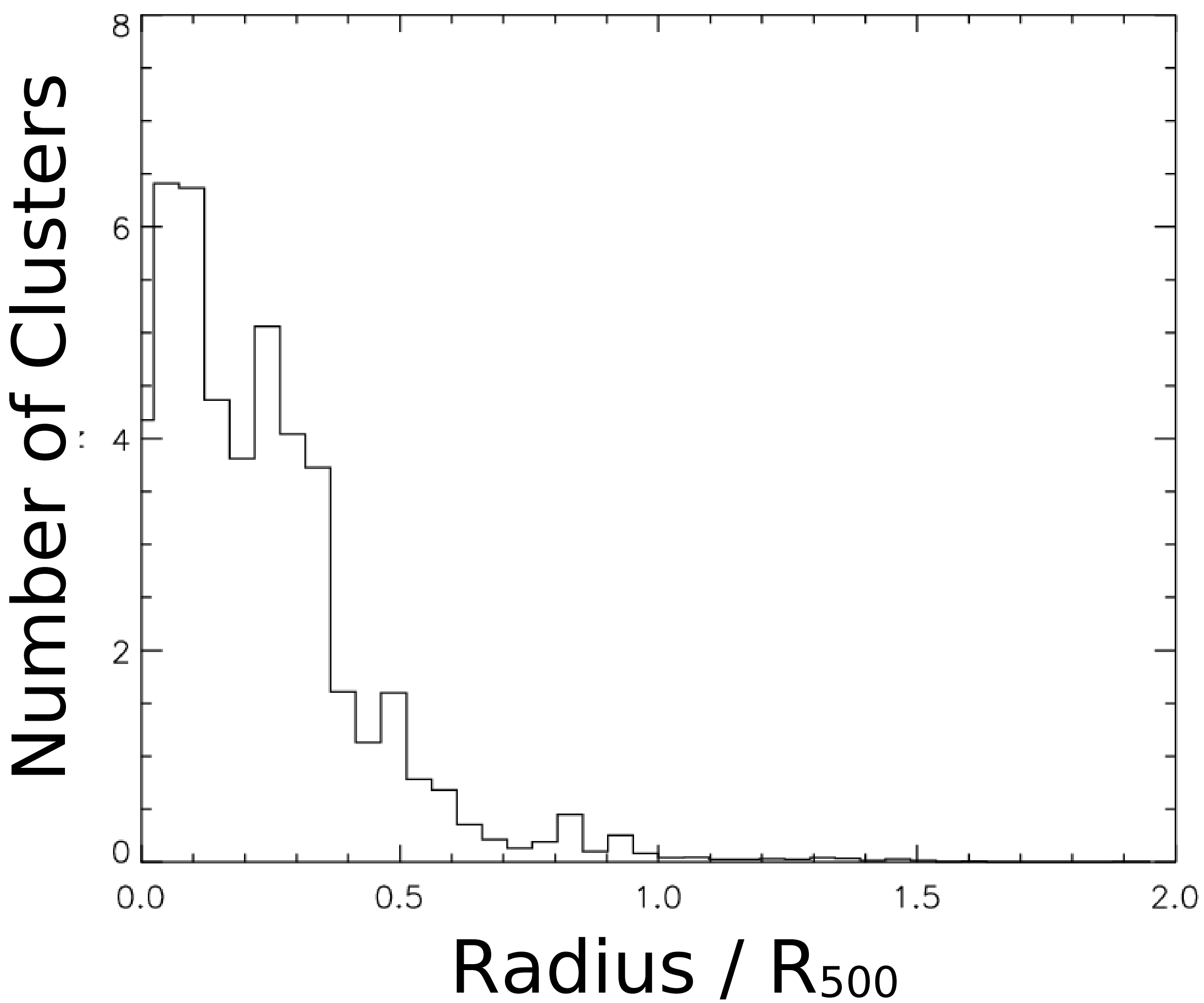


SPT-CLJ0440-4657 S/N 7.1 z~0.3

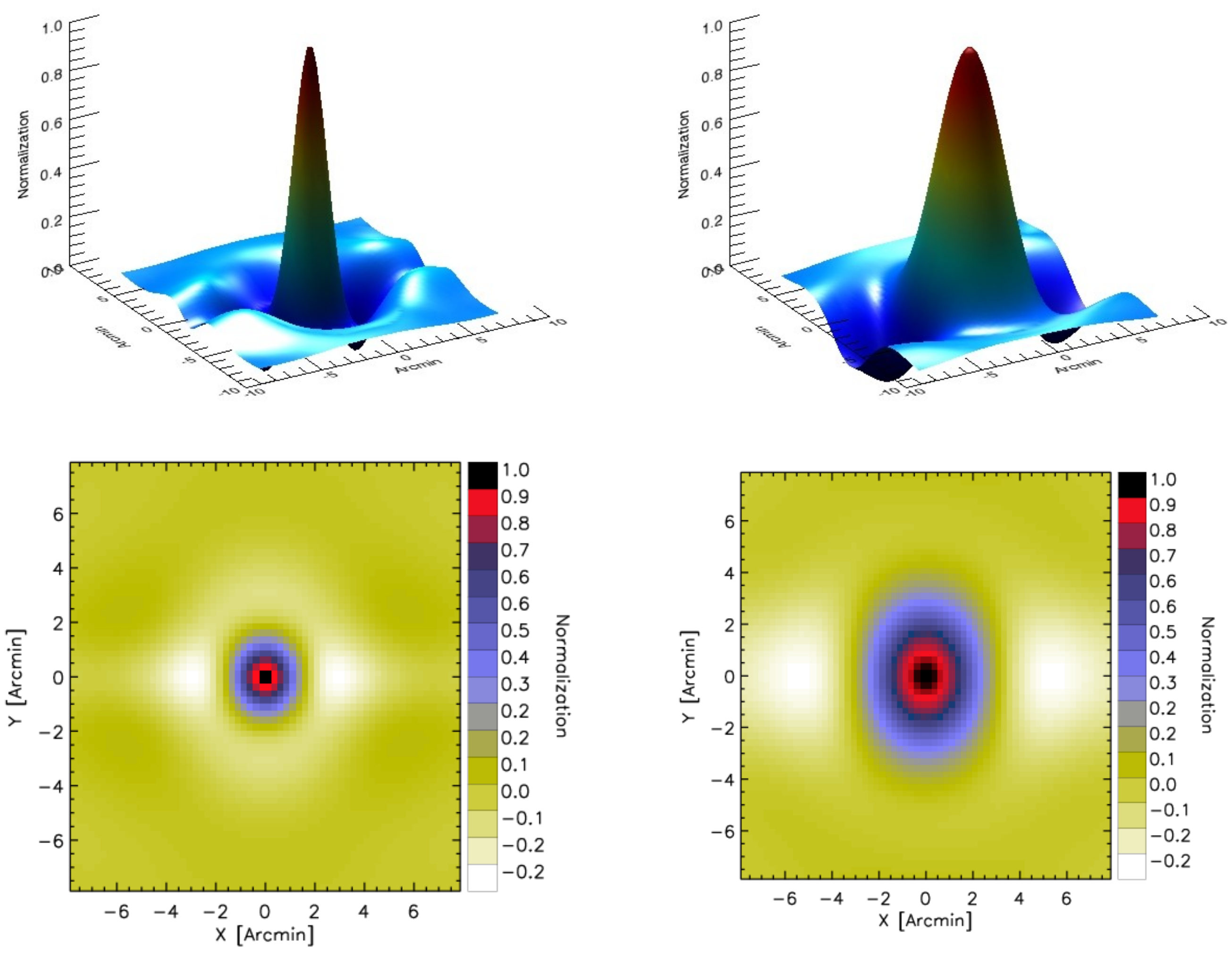
Cluster Miscentering: Offsets in SZ-Optical Locations

Distribution of the SZ-RedMaPPer center offsets:

- Correct for miscentering effect on measured Y_{500} for RedMaPPer selected clusters (Biesiadzinski+12,Sehgal+13,Rozo+14+,...)

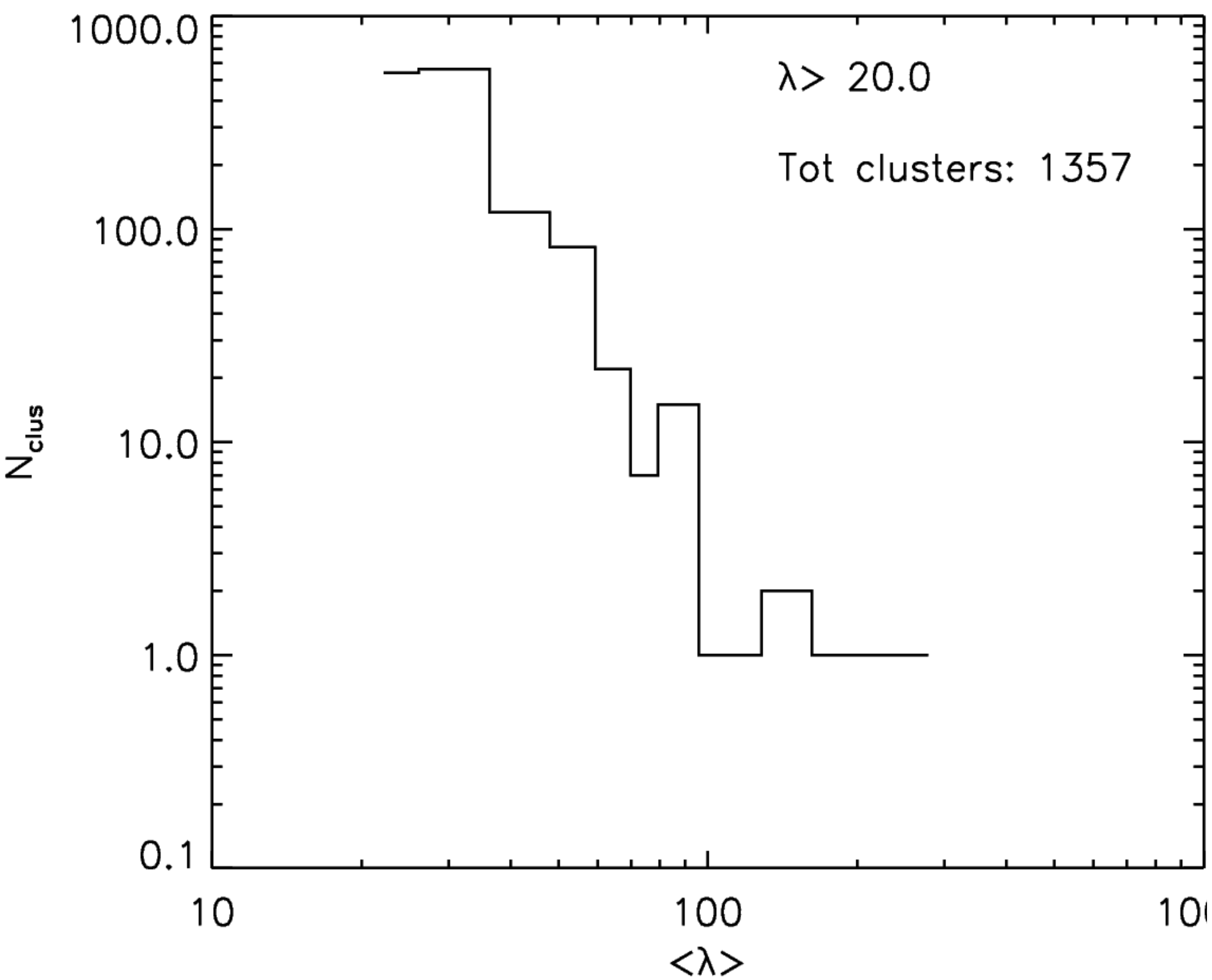


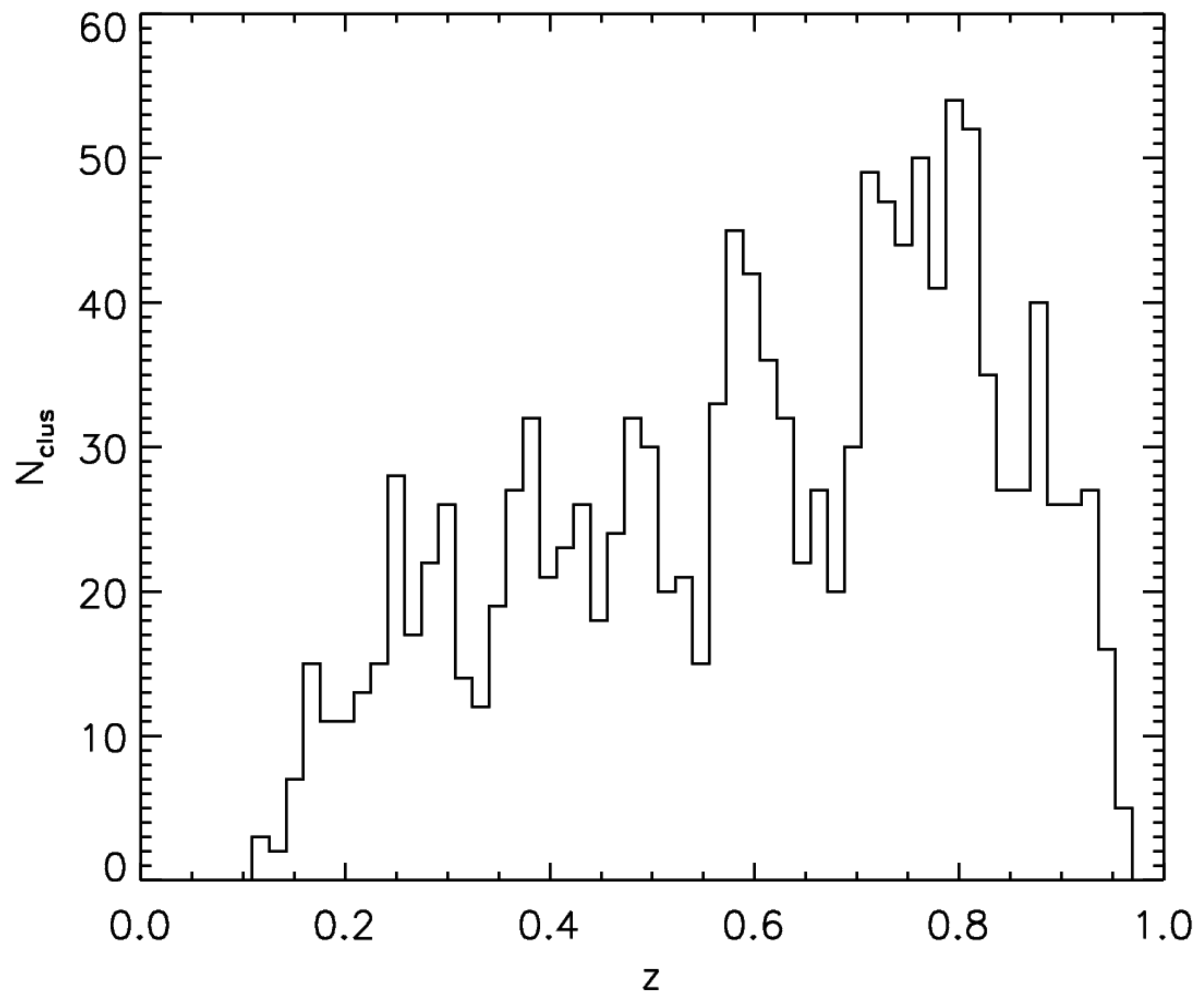
Optimal matched filters



SZE-properties of RedMaPPer selected clusters

1357 RedMaPPer selected clusters from SVA1 Gold 1.0.2 RedMaPPEr 6.2.7 match-filtered according to Rykoff+12 λ-M_{500} rel.





SZE-properties of RedMaPPer selected clusters

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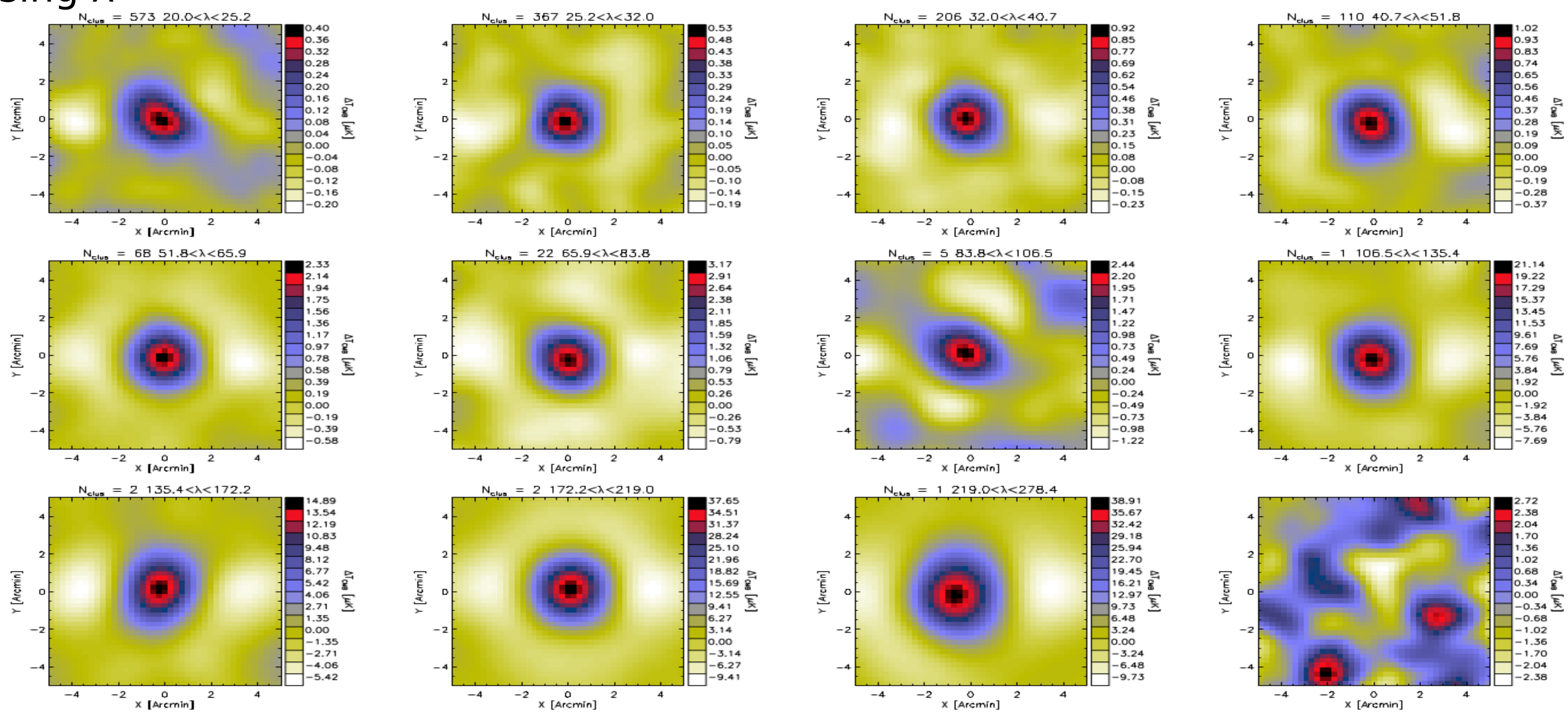
Increasing λ



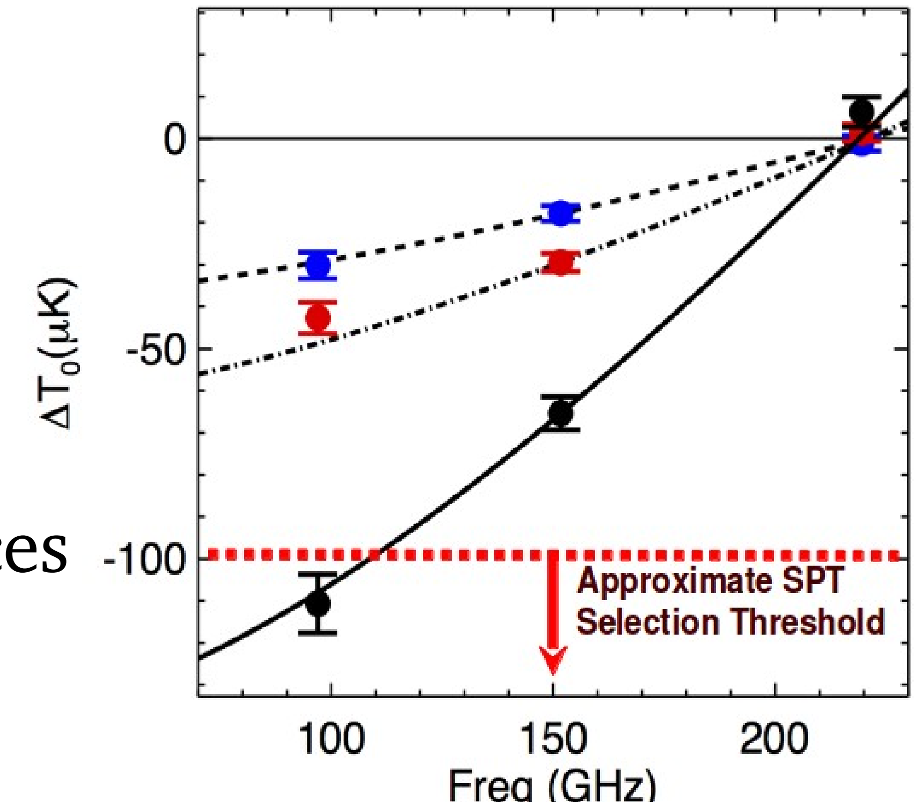
Stacked SPT maps for 11 log-equispaced λ-bins

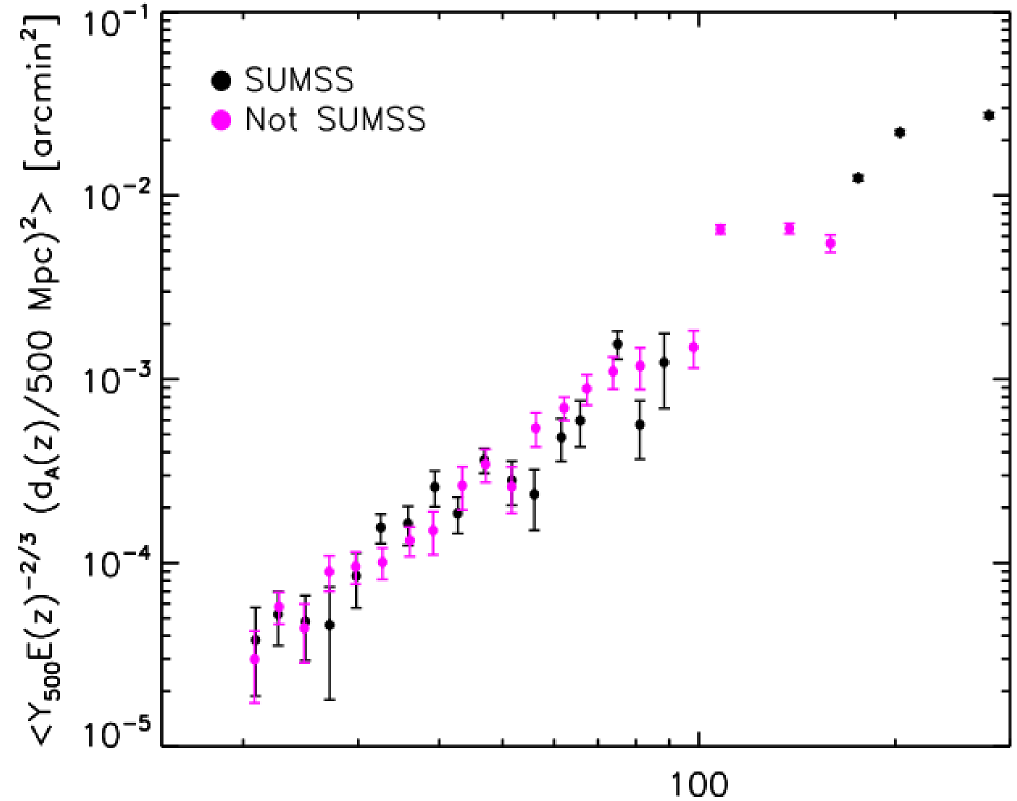
Random

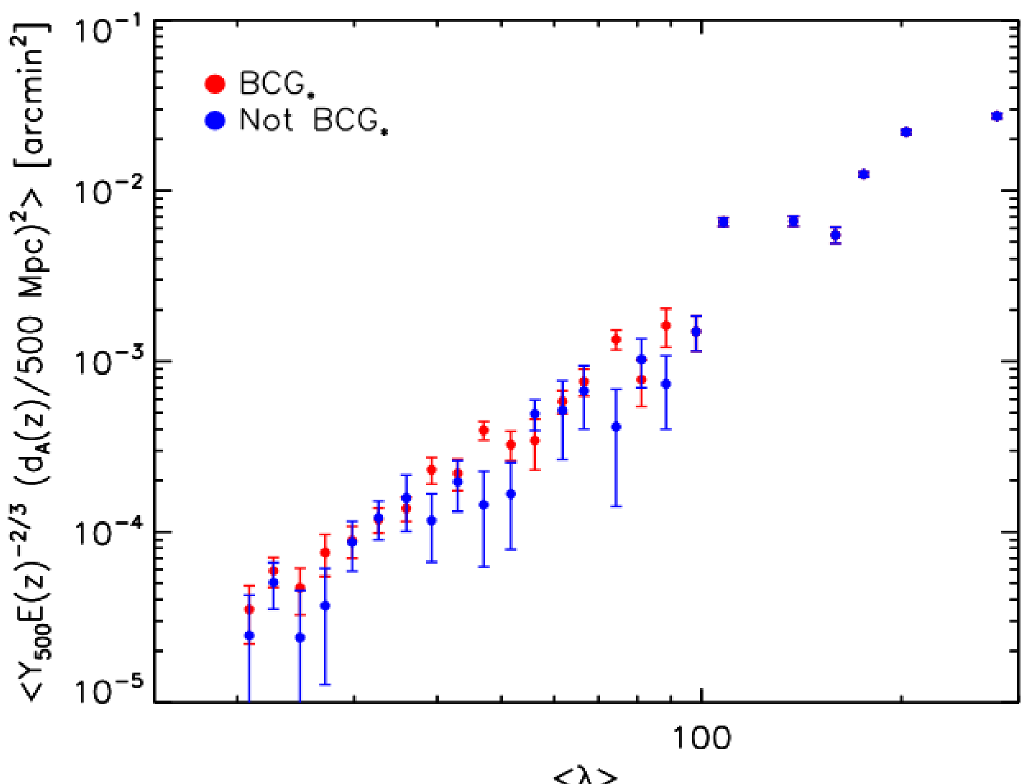
SZE-properties of RedMaPPer selected clusters

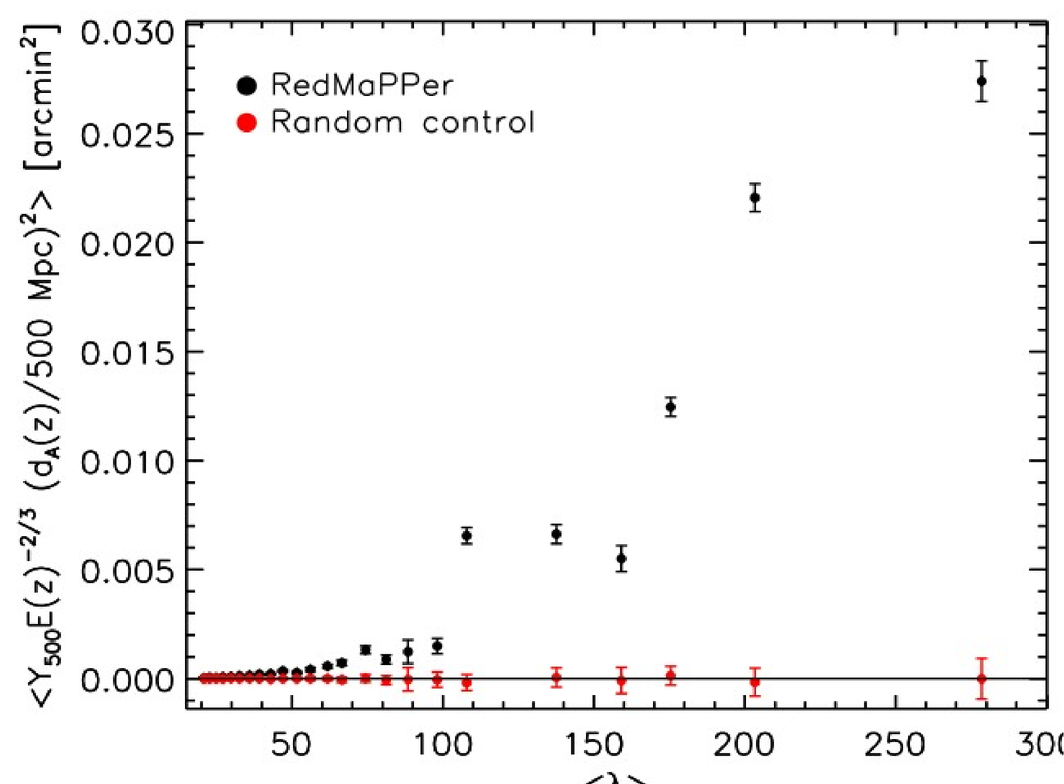
Systematics checks:

- Random positions
- SUMSS radio sources
- Well defined BCGs
- SZE spectrum

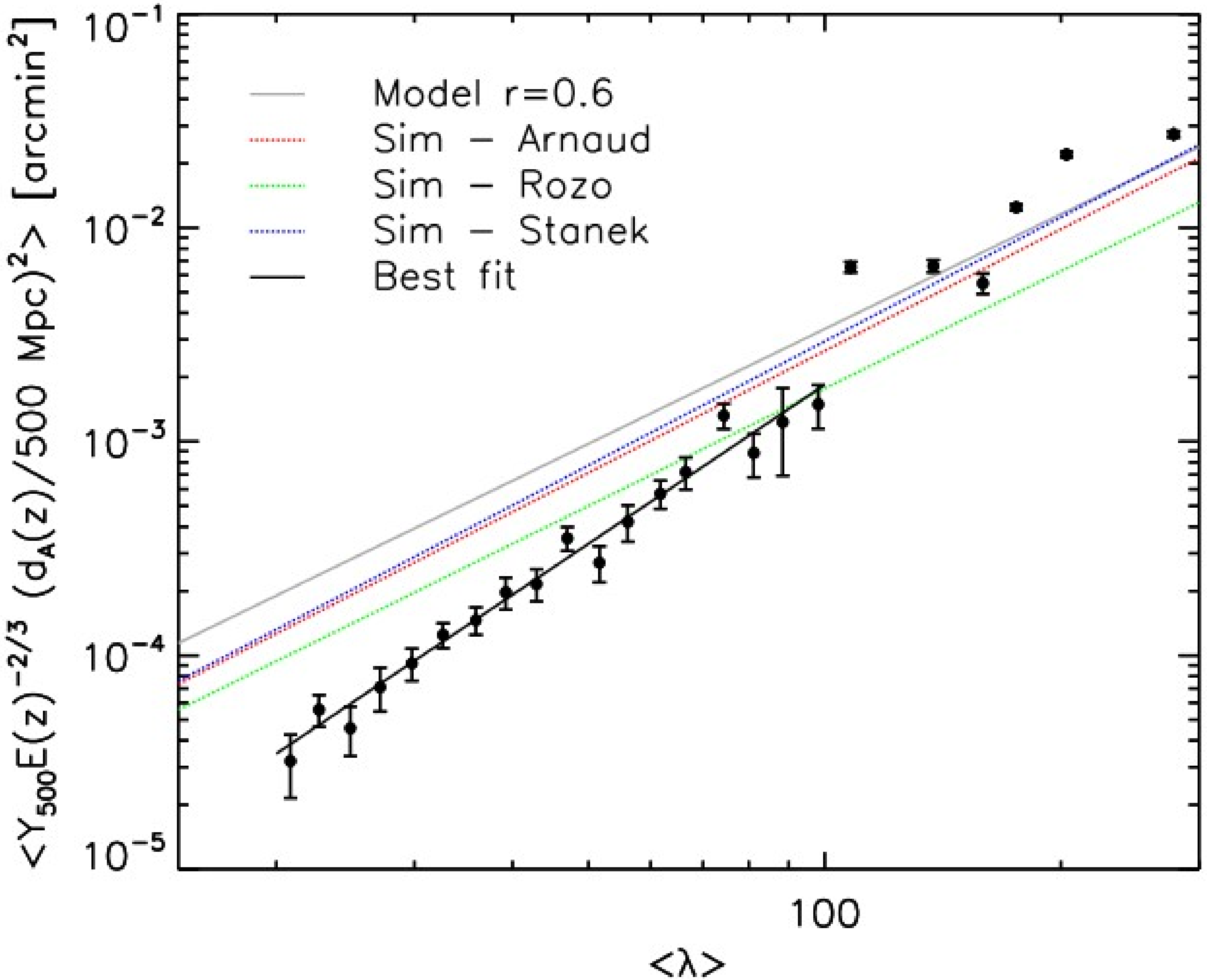




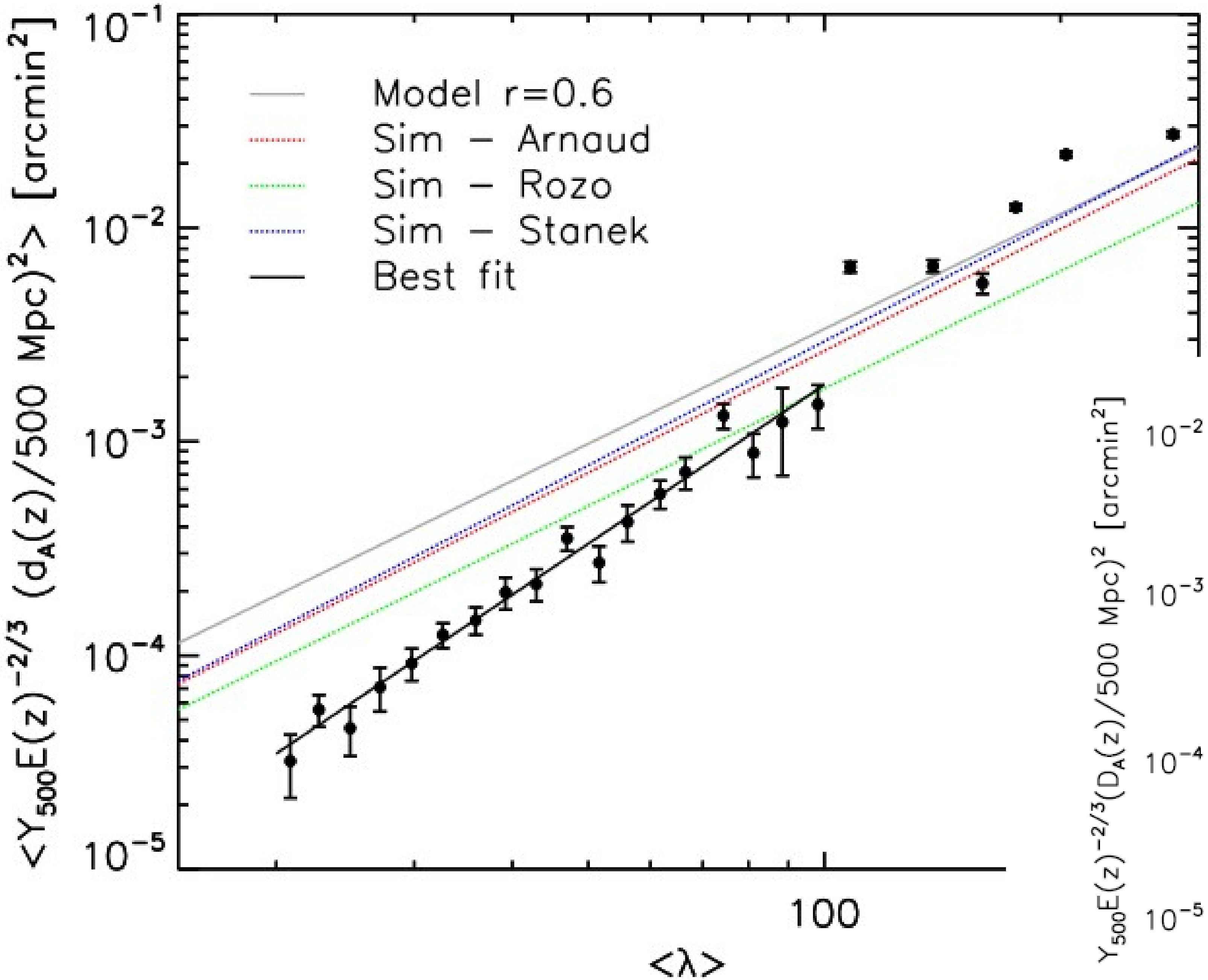




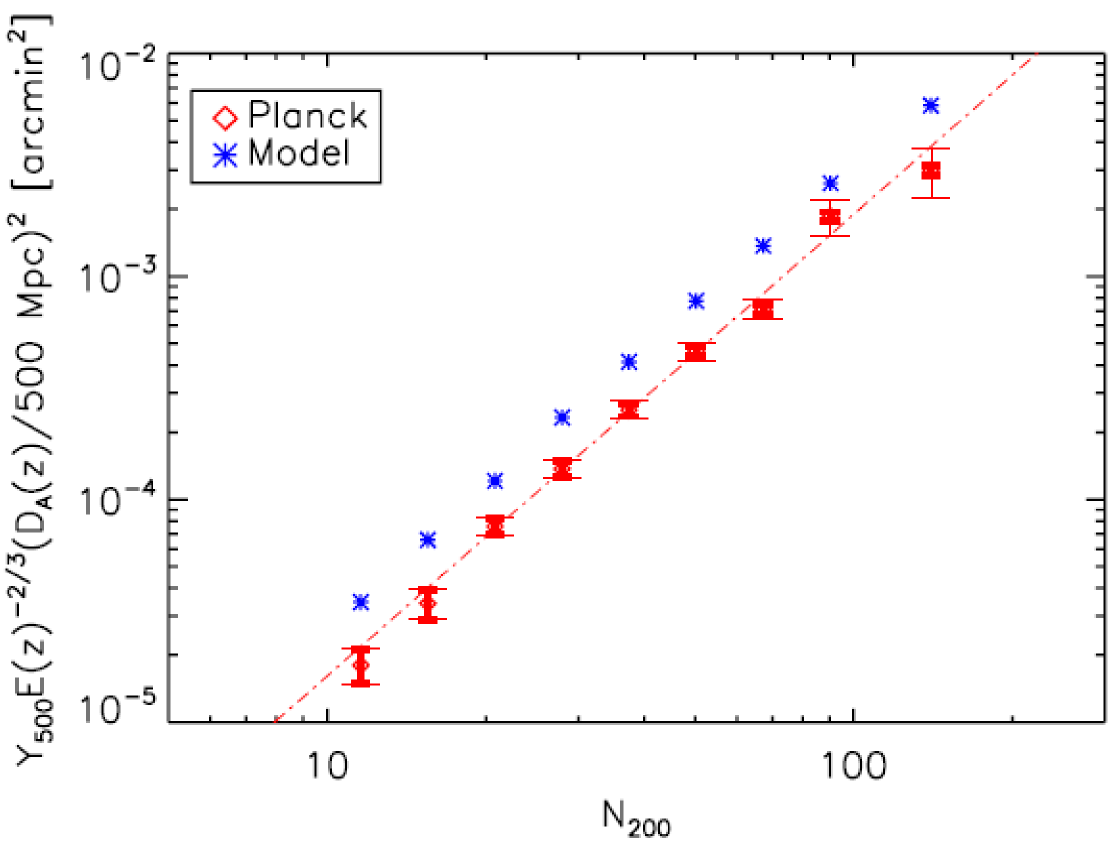
Y_{500}-λ relation



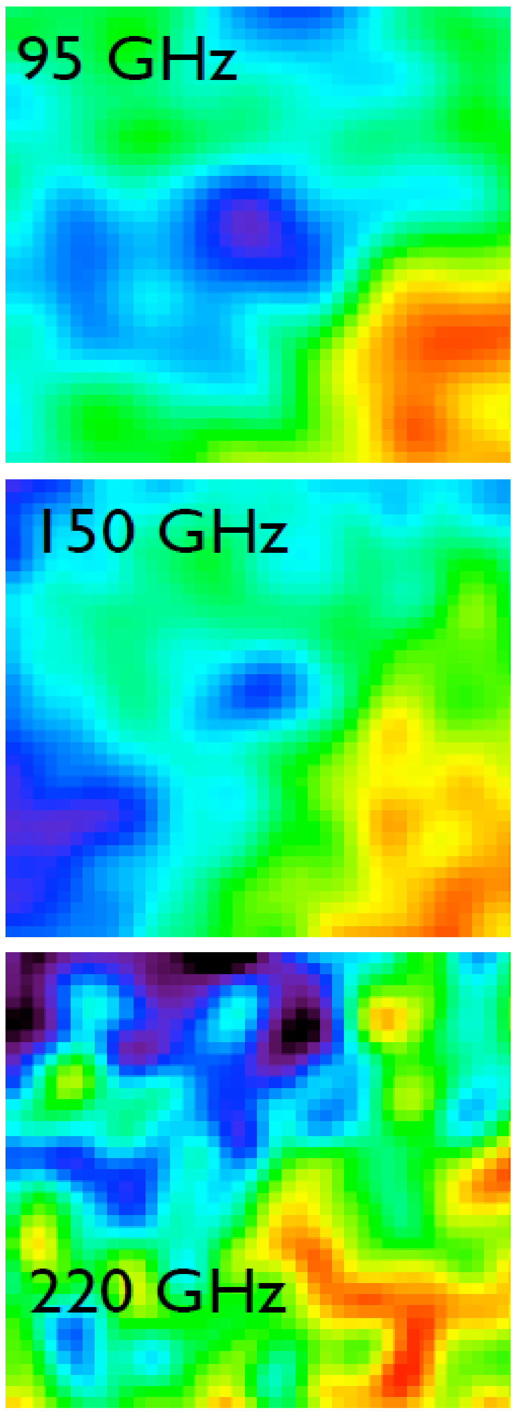
Are we observing the same Planck-MaxBCG tension?



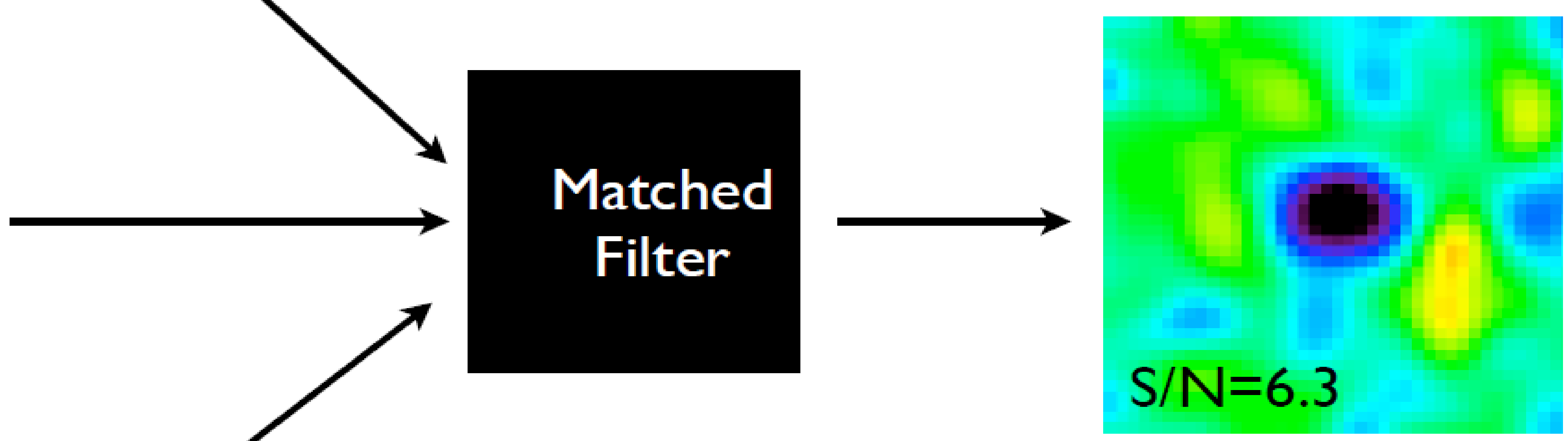
Not sure if it is a well defined question..



One step back
What is the SPT observable?



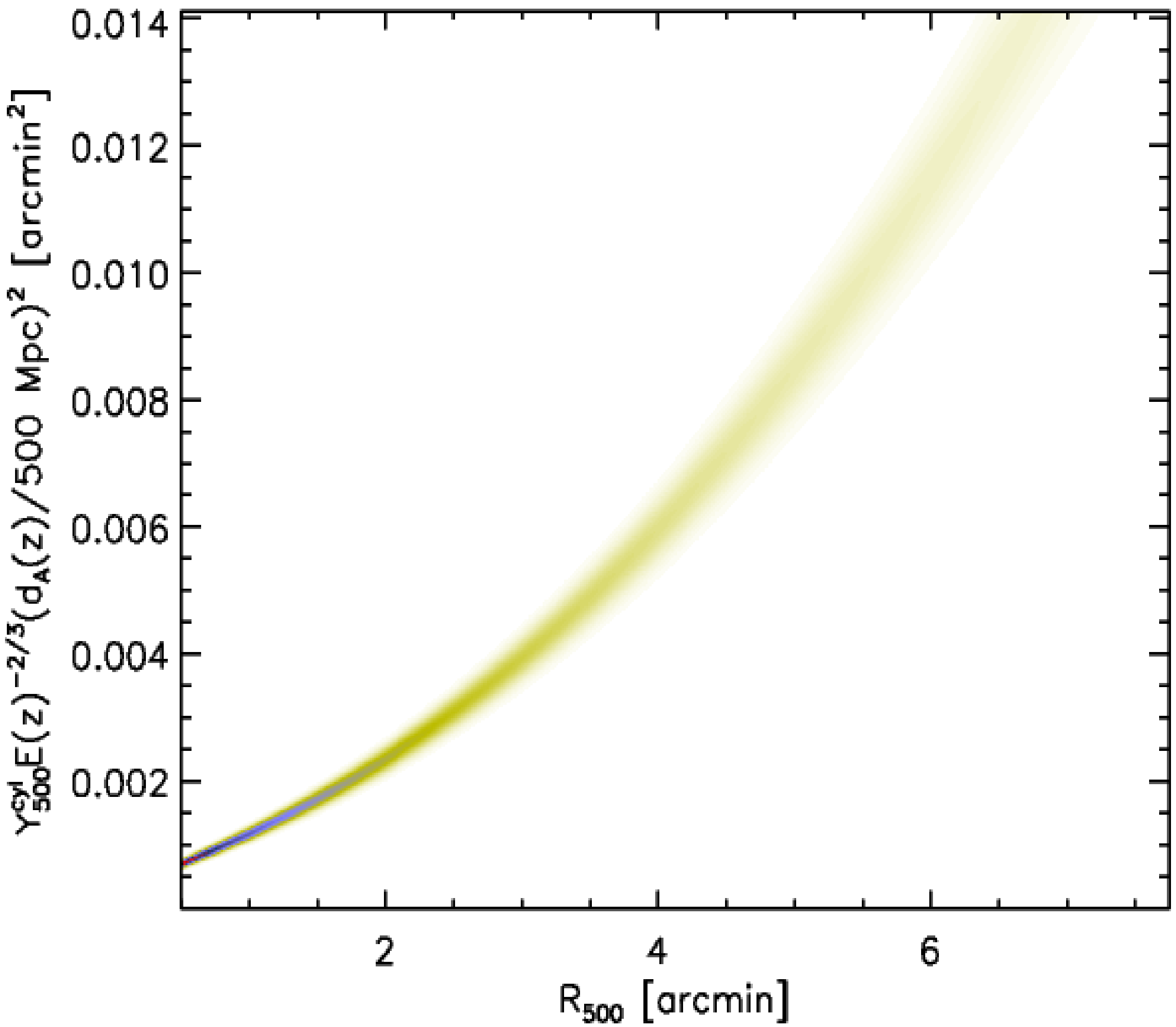
- Combine maps at different frequencies into a synthesized thermal SZ map, and find significant objects in that map
- [OR: these steps can be combined into a single spatial-spectral filter (e.g. Tegmark 2000, Herranz et al 2002, Melin et al. 2006).]

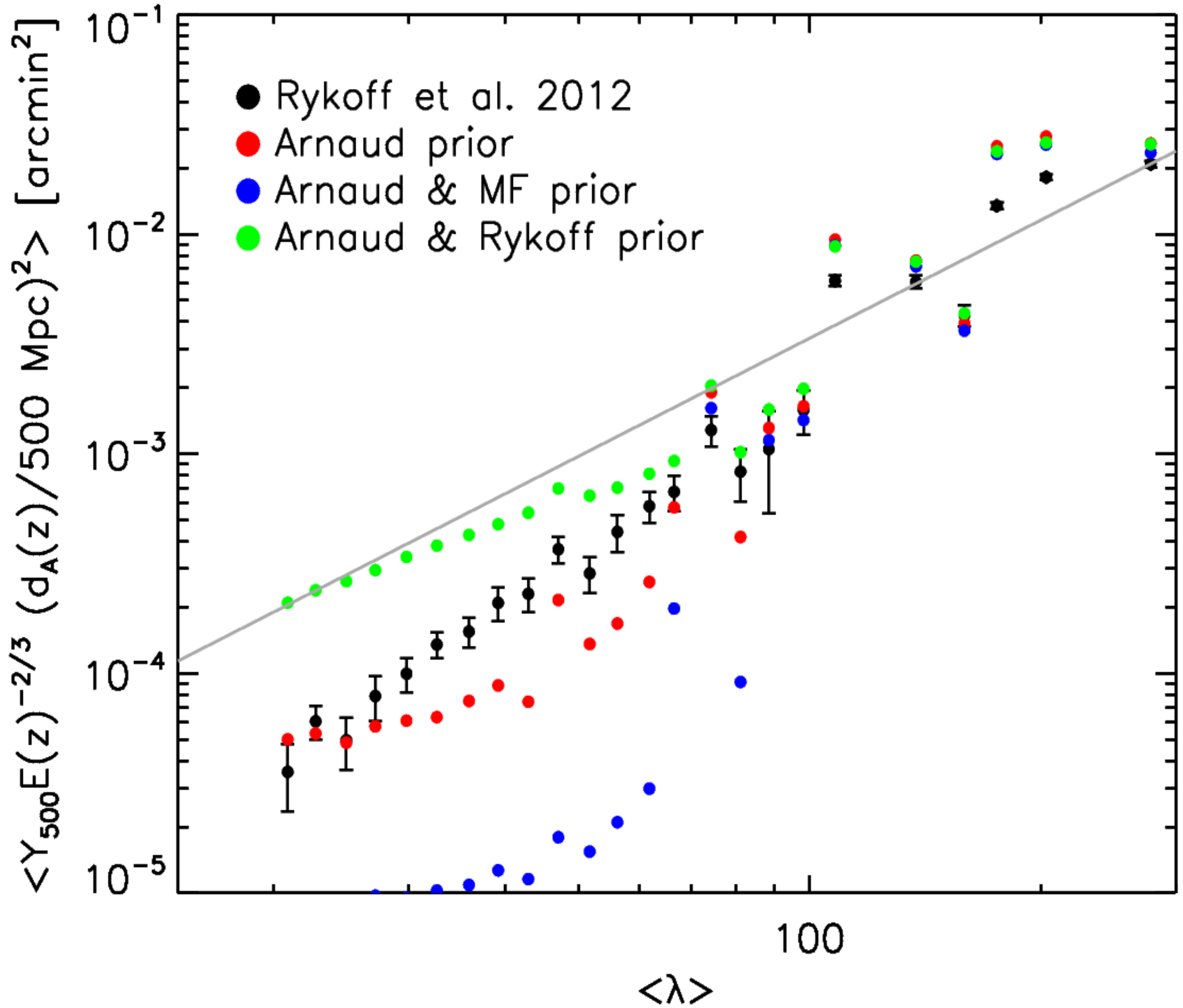


$$\psi(\vec{k}) = \frac{B(\vec{k})S(|\vec{k}|)}{B(\vec{k})^2 N_{\rm astro}(|\vec{k}|) + N_{\rm noise}(\vec{k})}$$

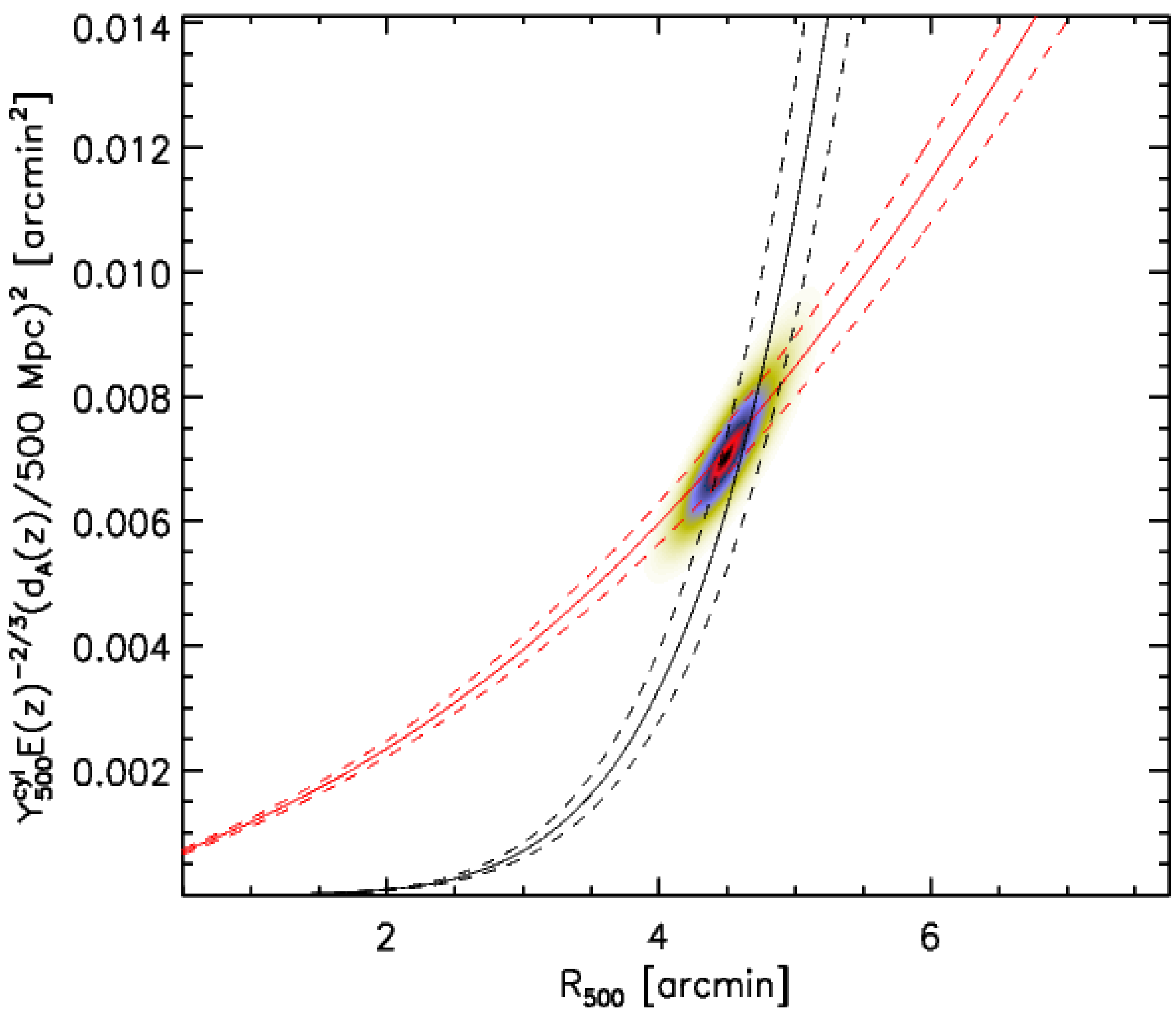
$$S(\vec{\theta}) = \Delta T_0 (1 + |\vec{\theta}|^2/\theta_c^2)^{-1}$$

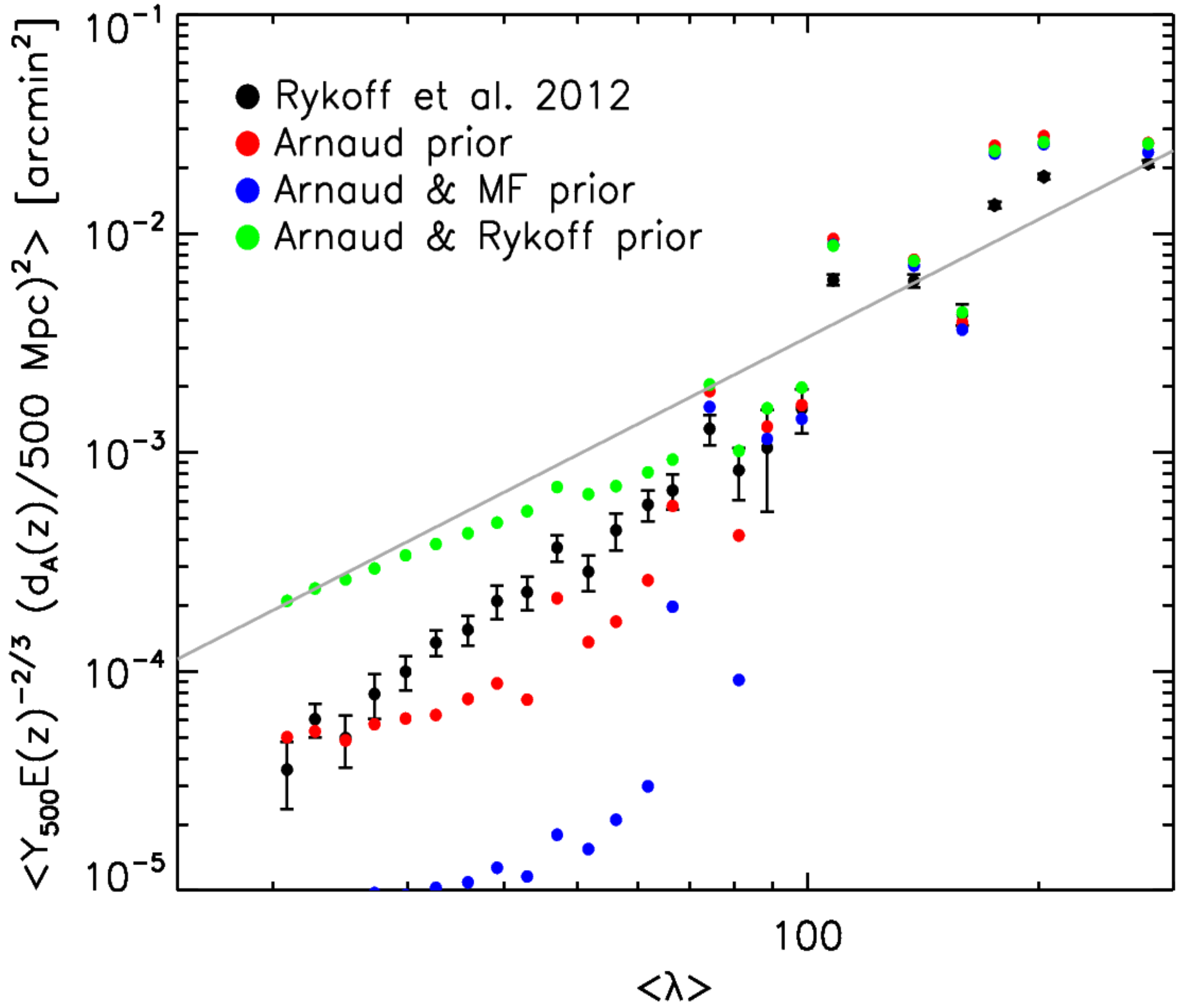
One step back
What is the SPT observable?





One step back
What is the SPT observable?





Conclusions

- Tight constraints on deviation from adiabacity and decaying DE EOS
- Calibration of λ-Mass scaling relation from SPT-SZE selected clusters
- λ-SZ offset distribution (miscentering corrections)
- Strong correlation between richness and SPT-SZE signature detected for RM selected clusters
- Consistency checks show relatively low contamination levels from point-sources
- Model of optical-SZE central offset included (consinstent with previous works)
- Qualitatively agreement with previous literature works (but large impact of priors!)