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

Collaborators:
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+SPT coll.
+DES coll.

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Outline

- SPT-SZE and DES-SV
- 1) Optical properties of SPT-SZE selected clusters
- 2) SPT-SZE properties of optically selected clusters
- Conclusions

Our dataset

DES-SV

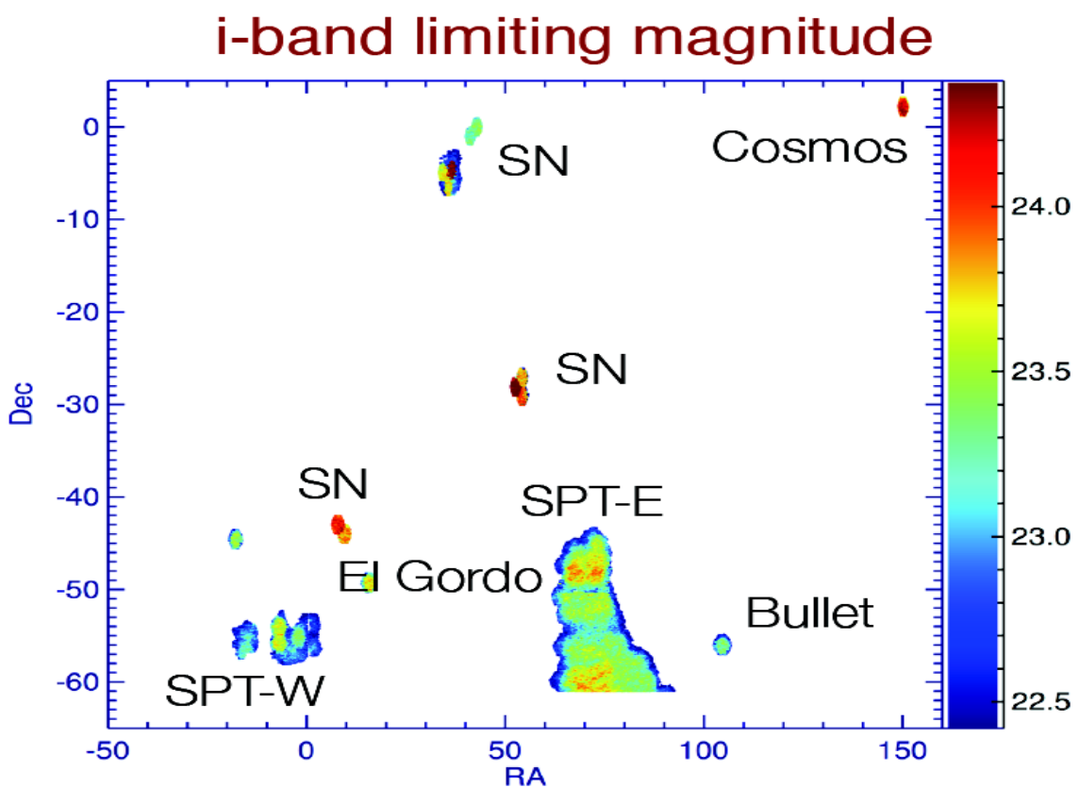
- ~250 sq. deg^2 of good imaging (griz)
- Overlap with SPT and other fields
- Preliminary analysis underway in all the main science areas: Clusters, Weak Lensing, Supernovae, Large-Scale Structure

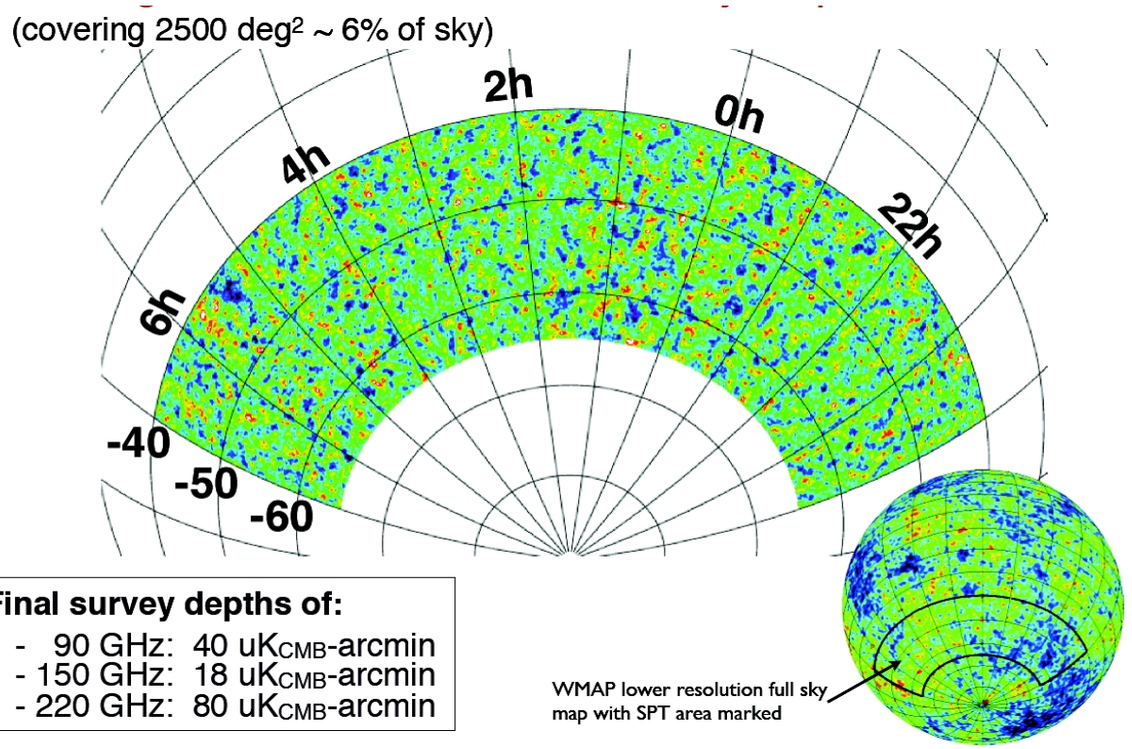
SPT-SZE

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

Bleem et al. 2015

Bocquet et al. 2014

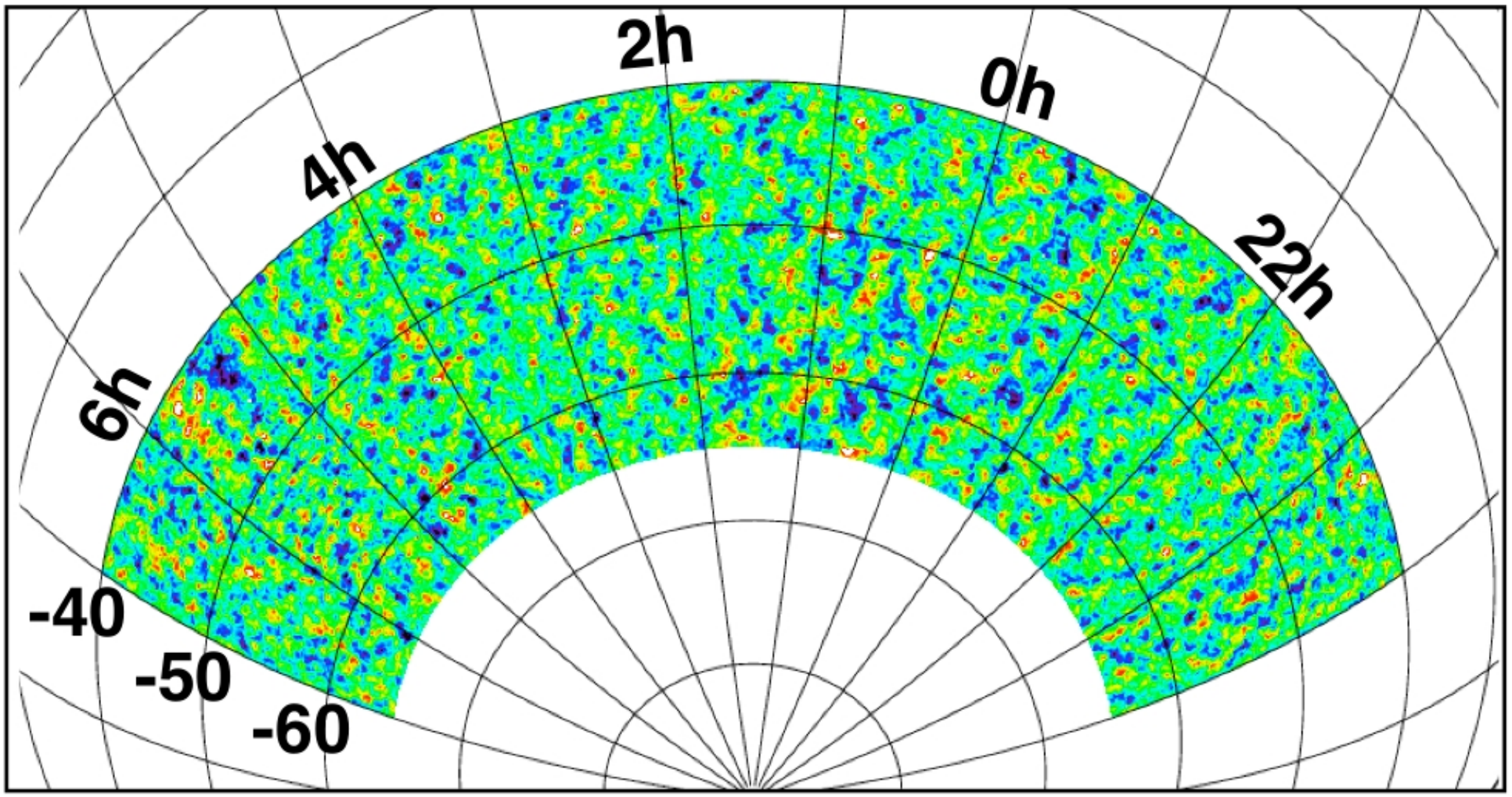




Final survey depths of:

- 90 GHz: 40 uK$_{CMB}$-arcmin
- 150 GHz: 18 uK$_{CMB}$-arcmin
- 220 GHz: 80 uK$_{CMB}$-arcmin

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



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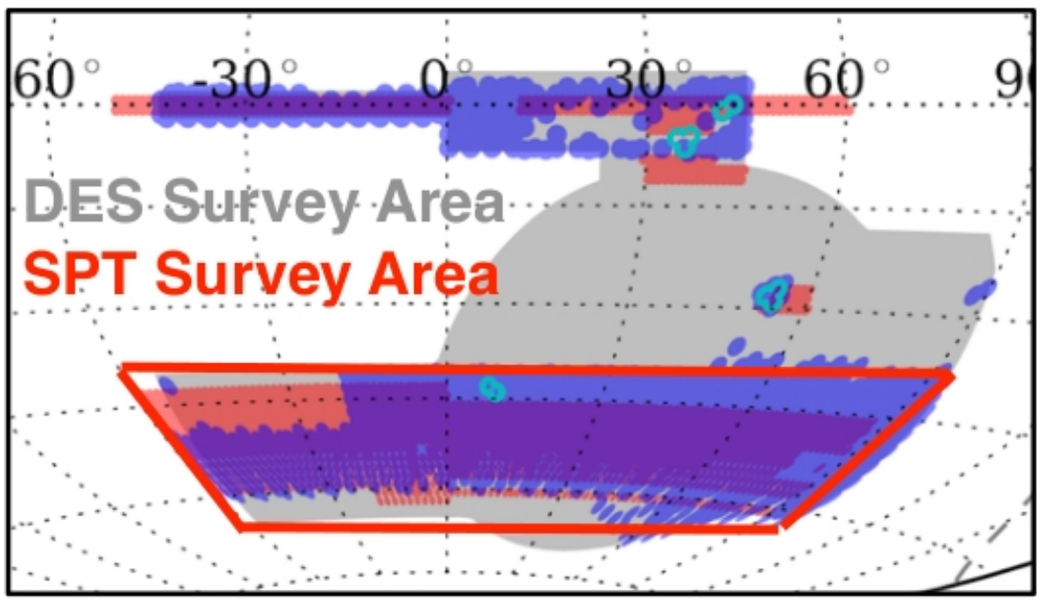
Complete overlap with DES survey



Zoom in on an SPT map

50 deg² from
2500 deg² survey

CMB Anisotropy

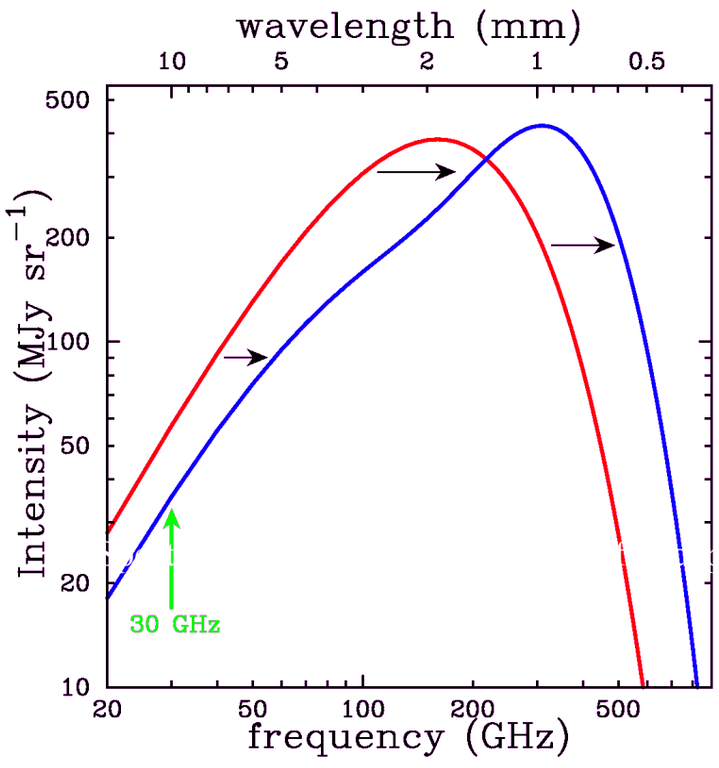
– Primordial and secondary anisotropy in the CMB

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

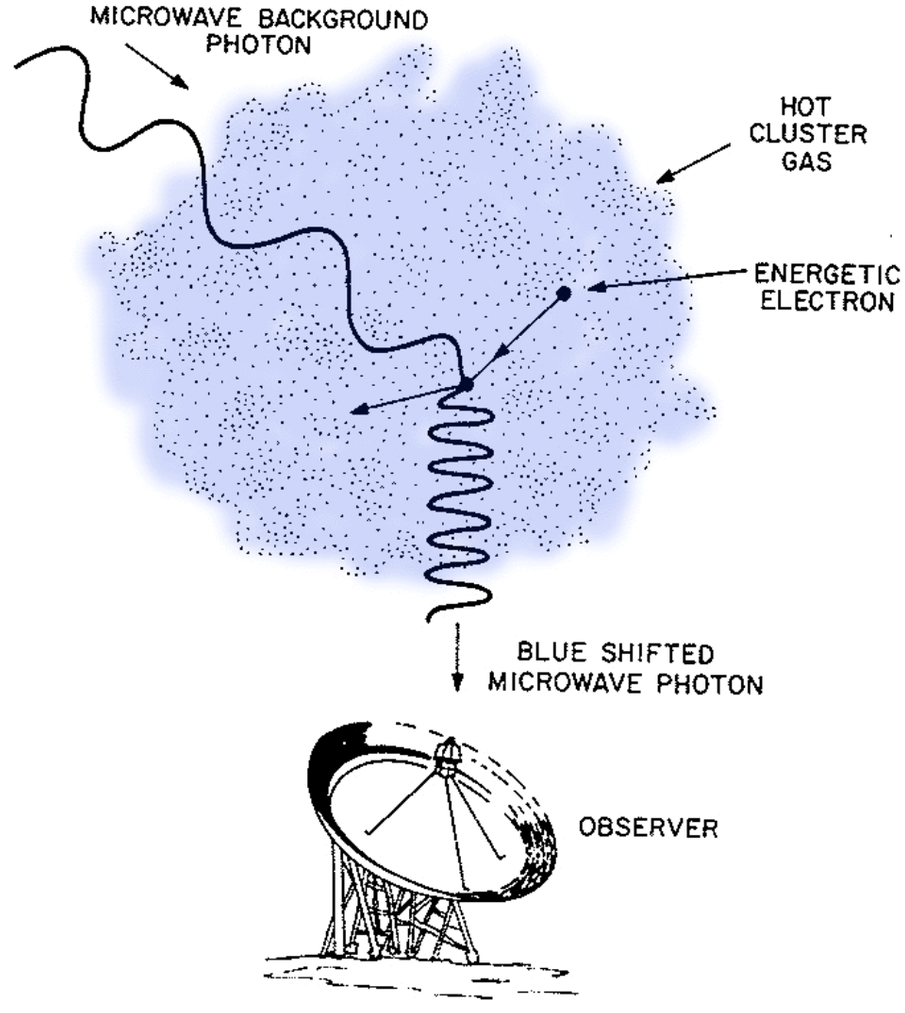
Clusters – High signal to noise SZ galaxy cluster detections as “shadows” against the CMB!

Sky at mm wavelenght

Spectral Distortion of CMB



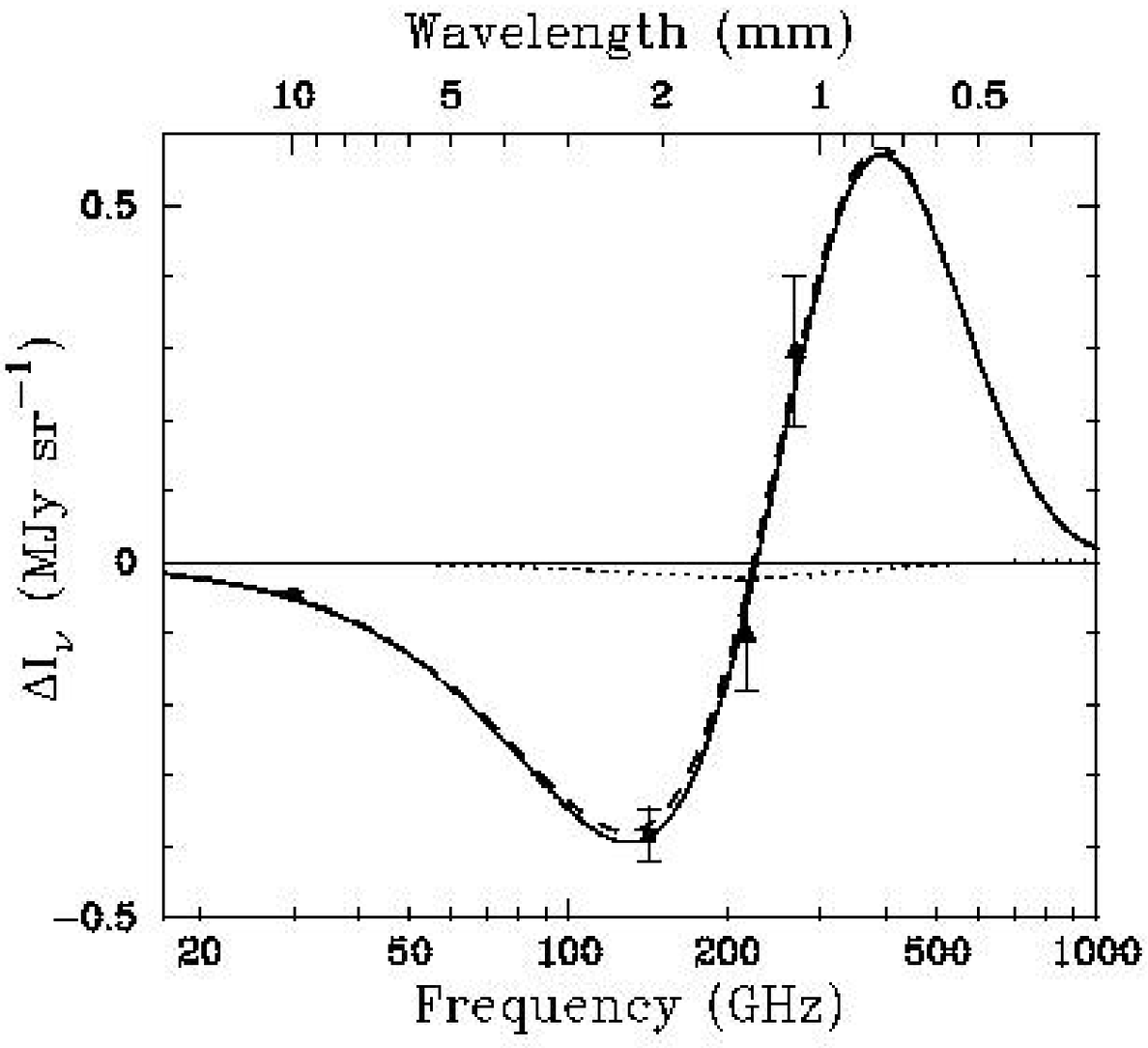
Sunyaev & Zel'dovich 1970, 1972



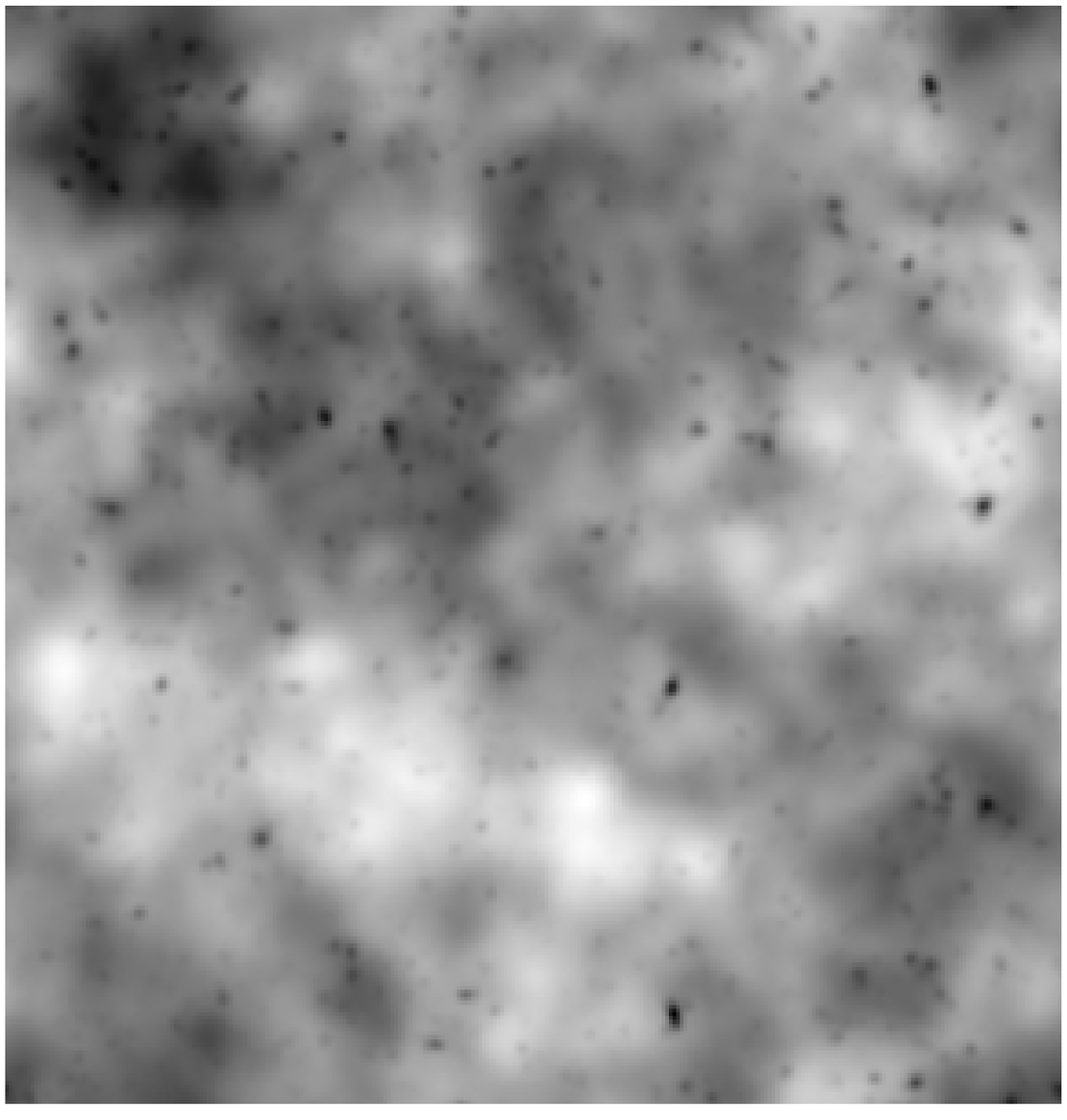
Adapted from L. Van Speybroeck

Clusters and the Sunyaev & Zel'dovich Effect

Unique spectrum

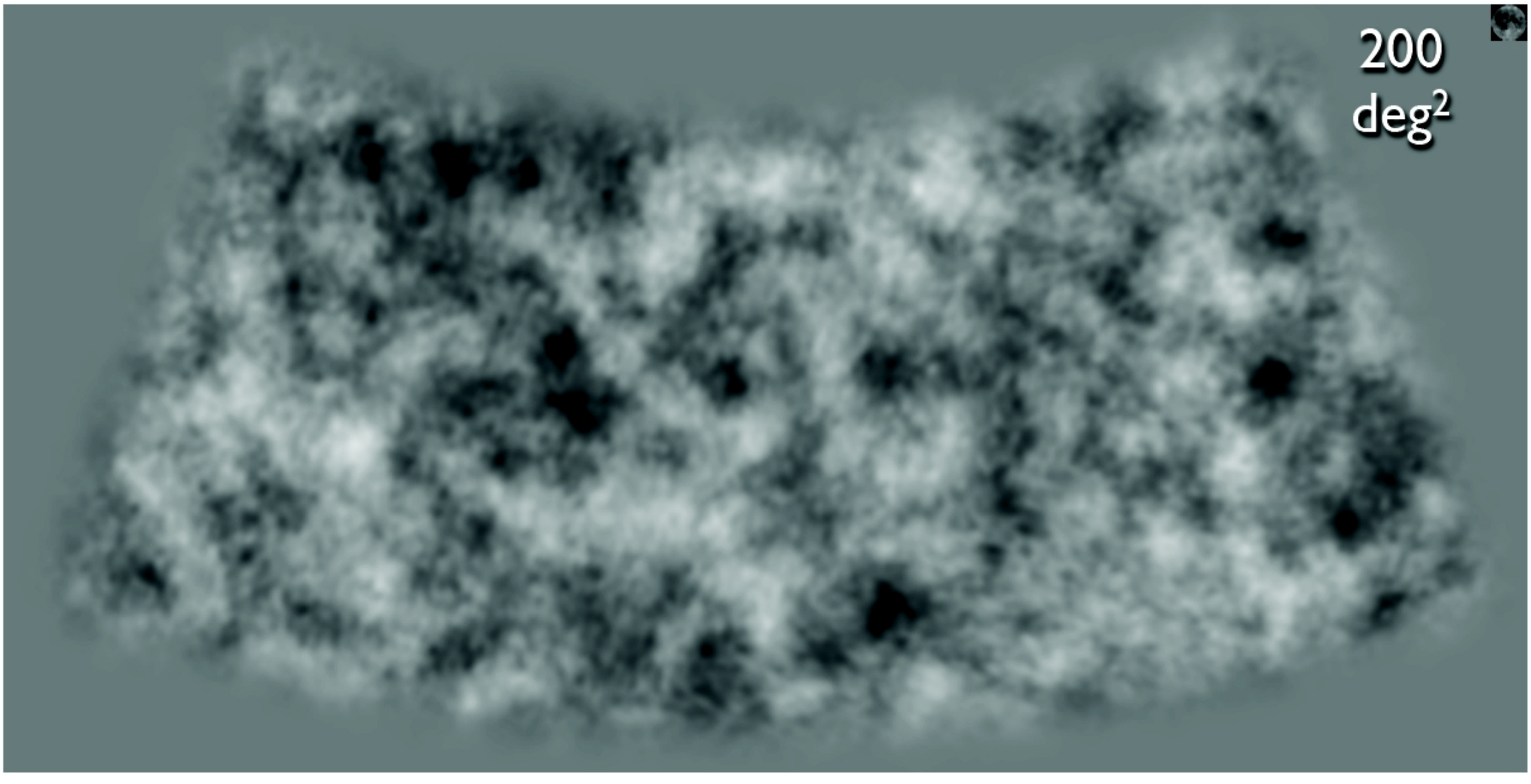


Unique angular scale



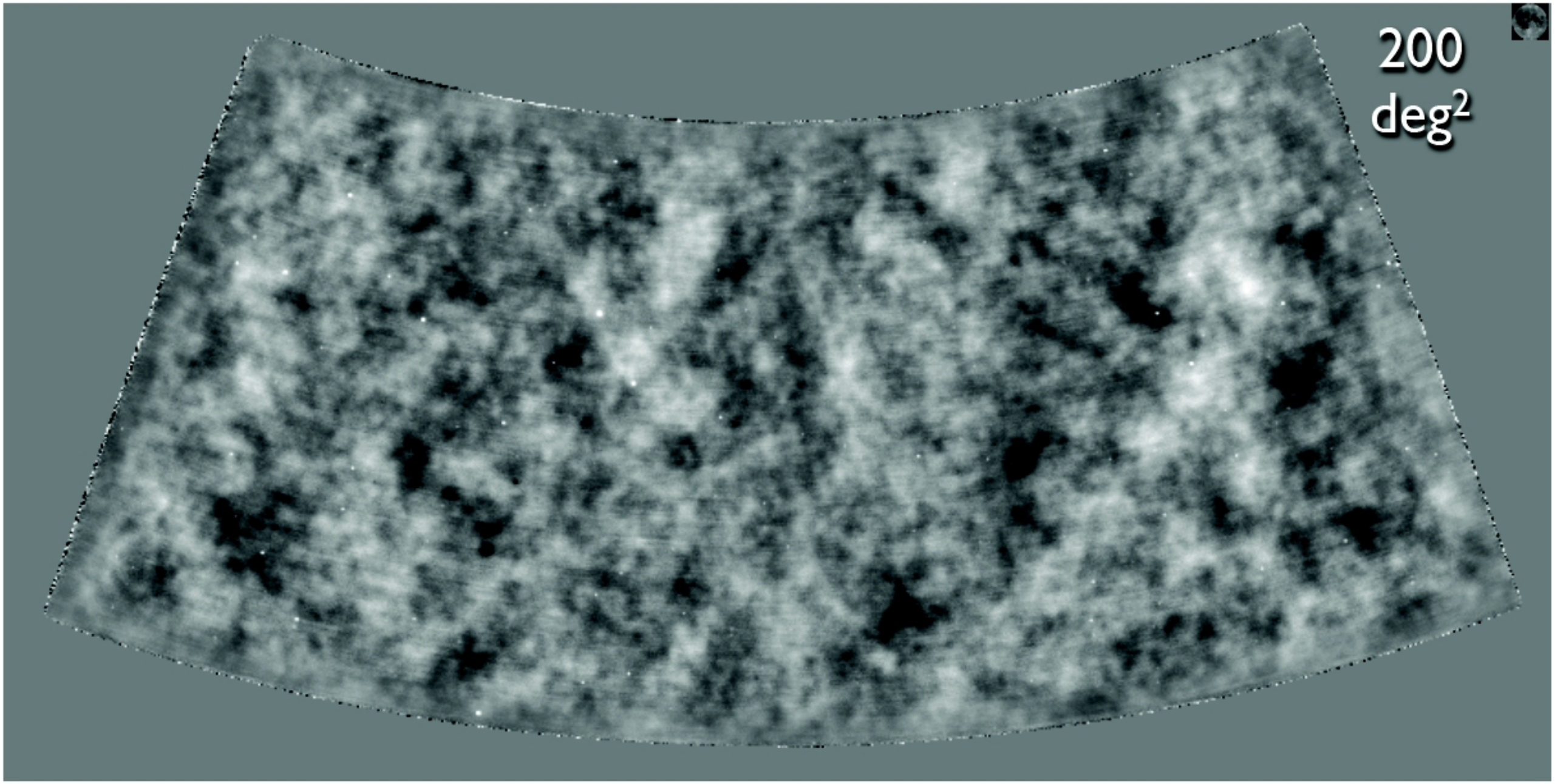
Clusters and the Sunyaev & Zel'dovich Effect

DARK ENERGY SURVEY



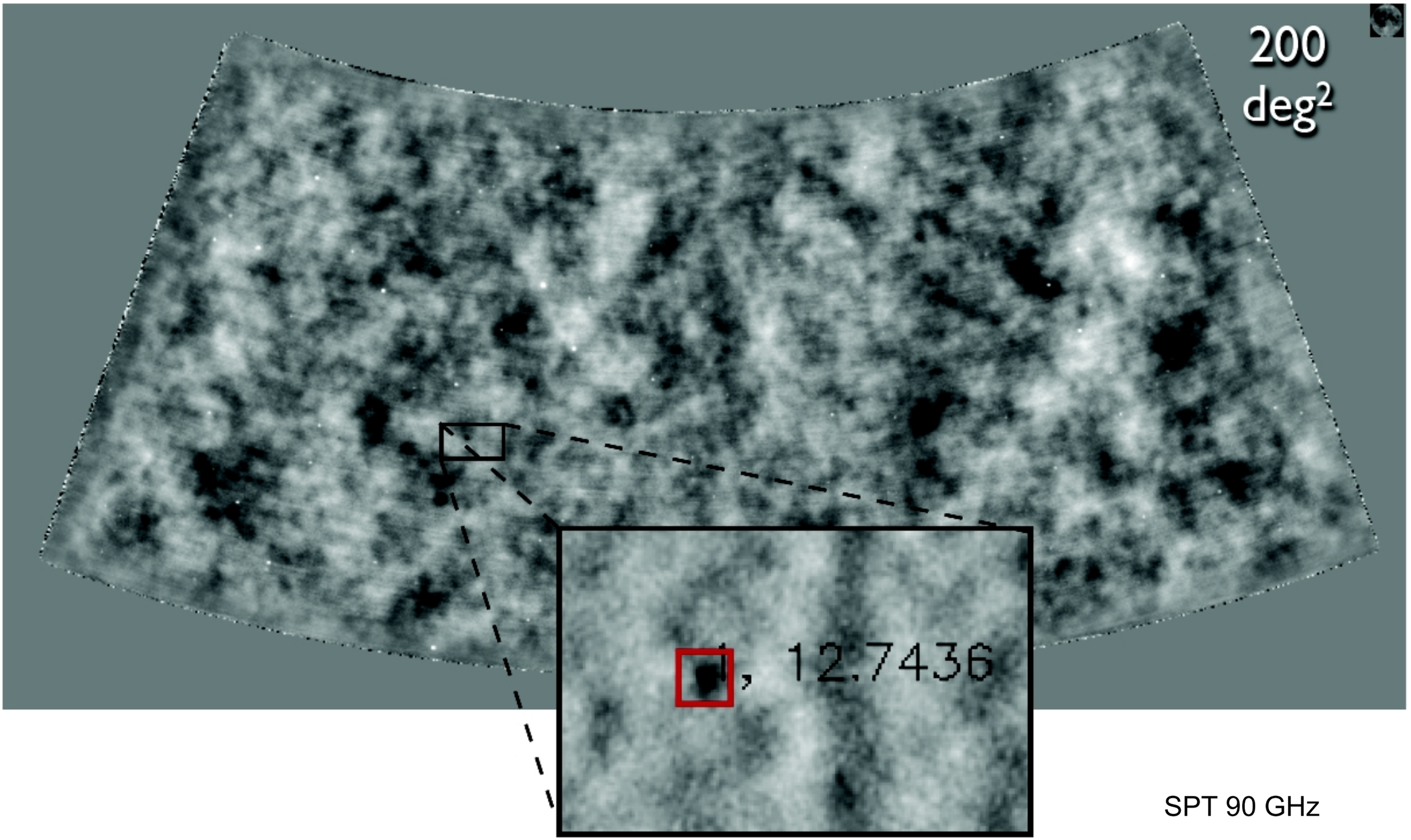
WMAP 90 GHz

Clusters and the Sunyaev & Zel'dovich Effect



SPT 90 GHz

Clusters and the Sunyaev & Zel'dovich Effect

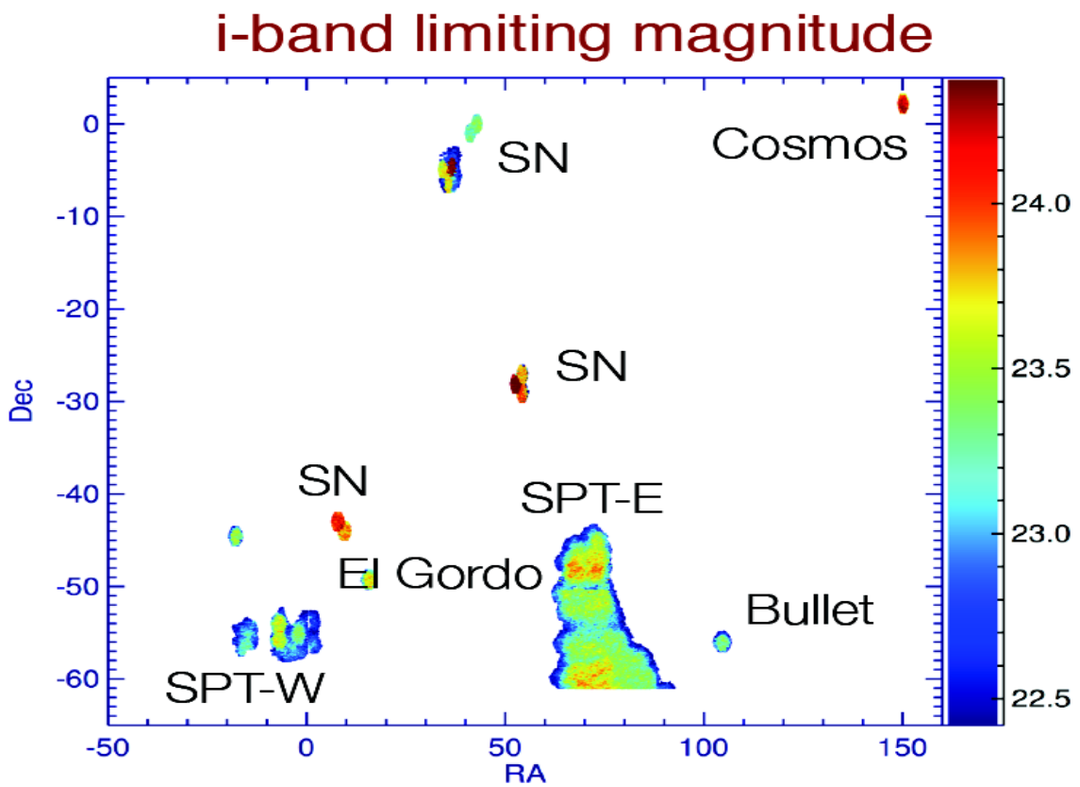


Our dataset

DES-SV

redMaPPer

- Based on the λ richness (Rozo+09; Rykoff+12,14; Rozo+14)
- ~10^4 clusters with richness λ>5 with 0.1<z<0.95

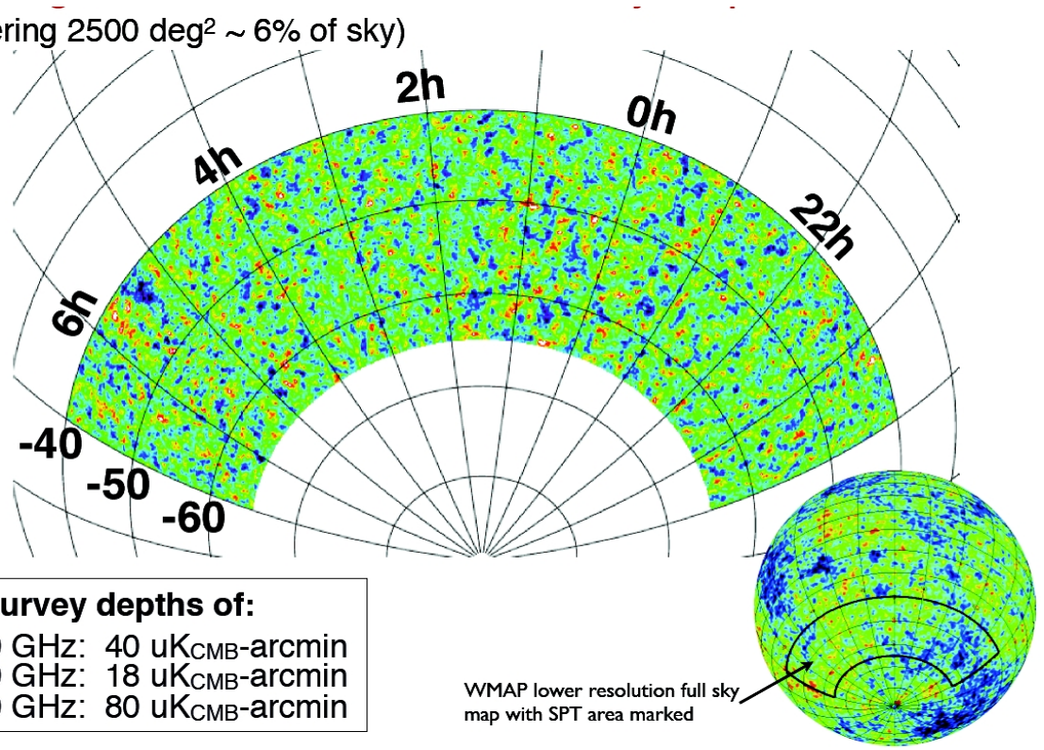


SPT-SZE

Bleem et al. (2015)

- 677 SPT cluster candidates above a signal-to-noise threshold of ξ = 4.5
- 516 confirmed SPT clusters up to z>1.5

(covering 2500 deg² ~ 6% of sky)



Final survey depths of:

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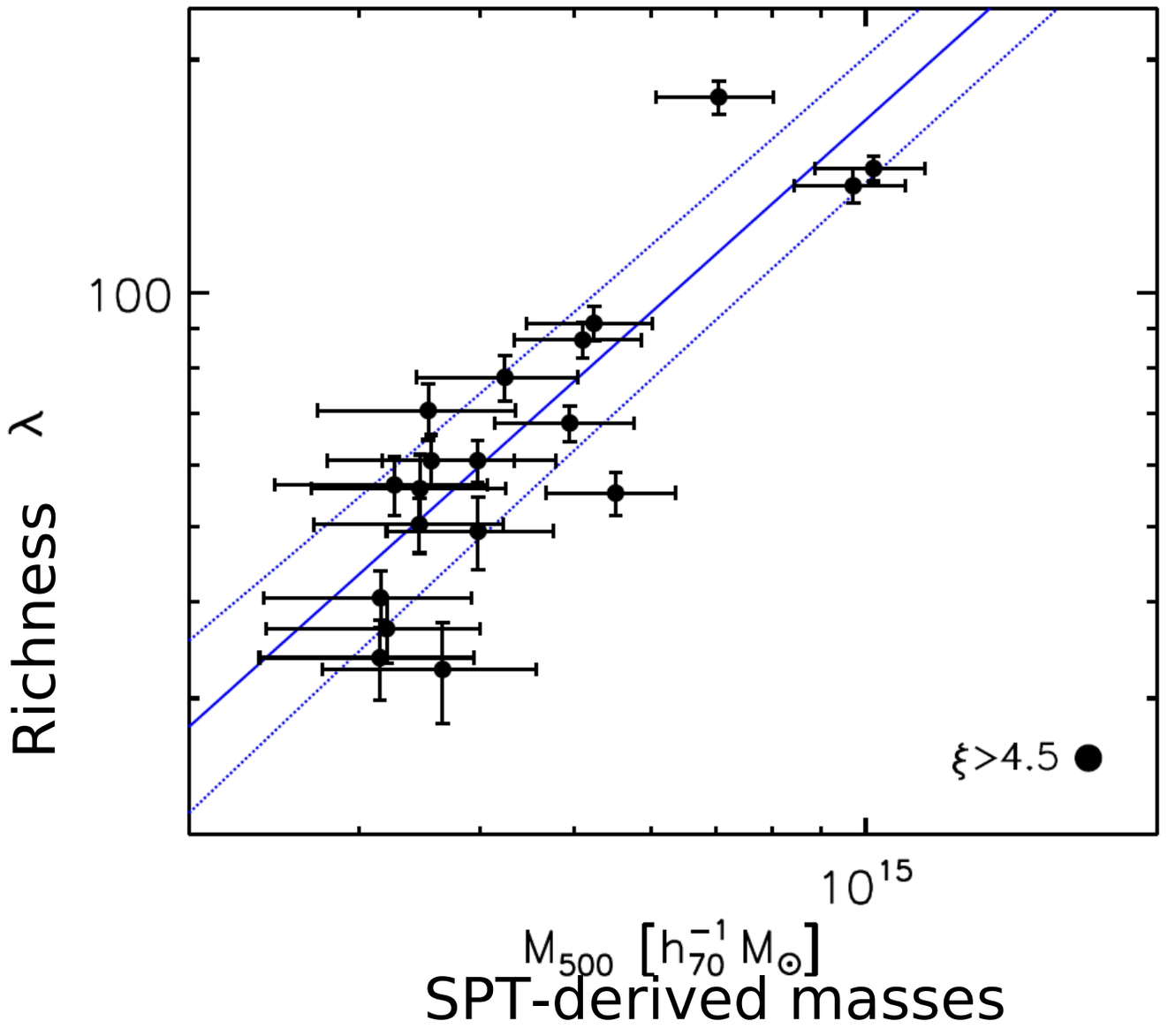
1)Richness-Mass Relation for SPT-selected Clusters

- Use our knowledge of SPT-SZE clusters to infer redMaPPer properties
- Use the SPT-SZ 2500 deg^2 cluster catalog from Bleem et al. (2015), de Haan et al (2015, in prep)
- 19 DES-SV redMaPPer clusters cross-match with the SPT-SZ cluster catalog (Rozo et al. 2014)
- Use cosmology to constrain the Richness-Mass relation



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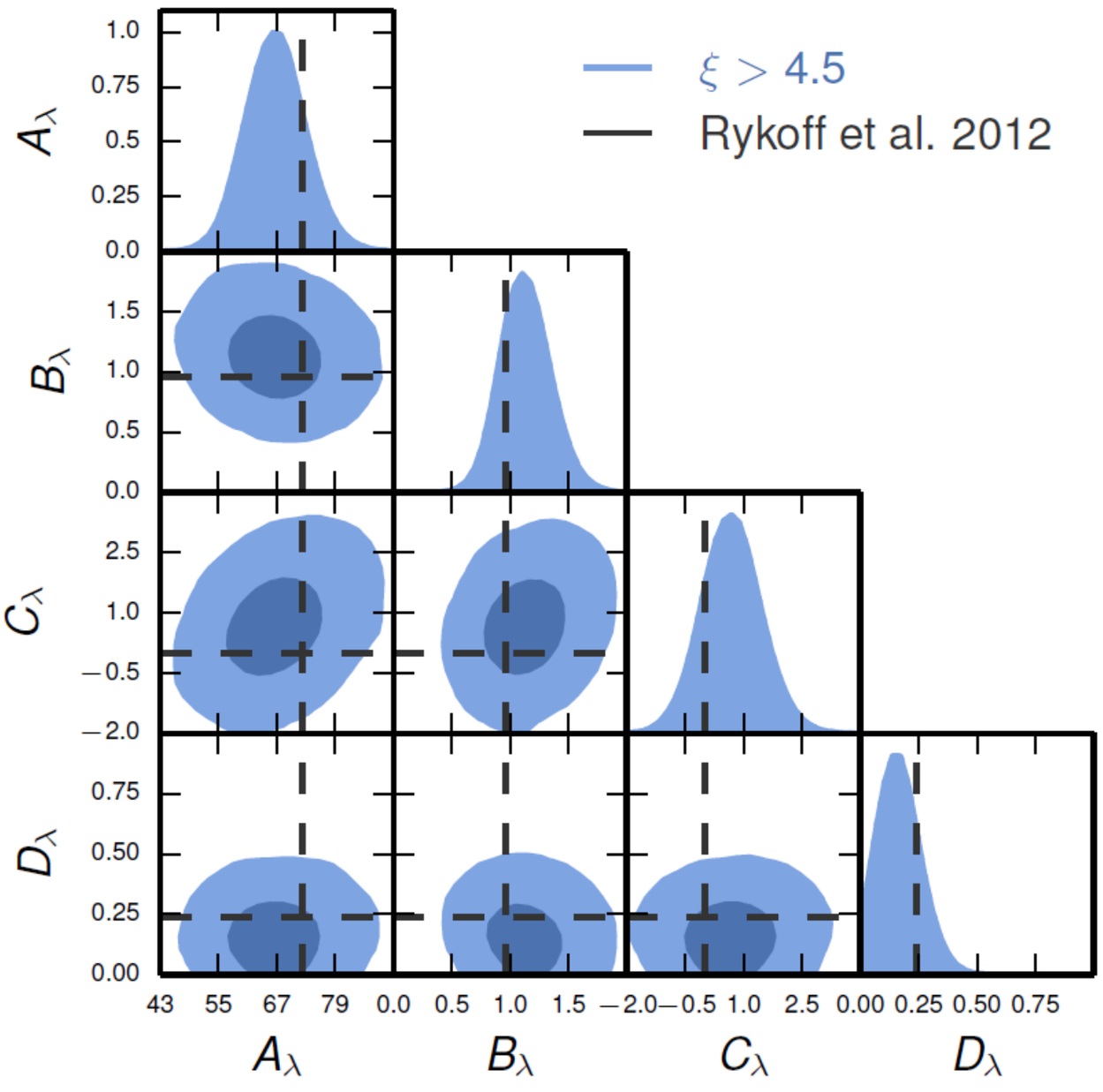


- Fit a 4 parameters model

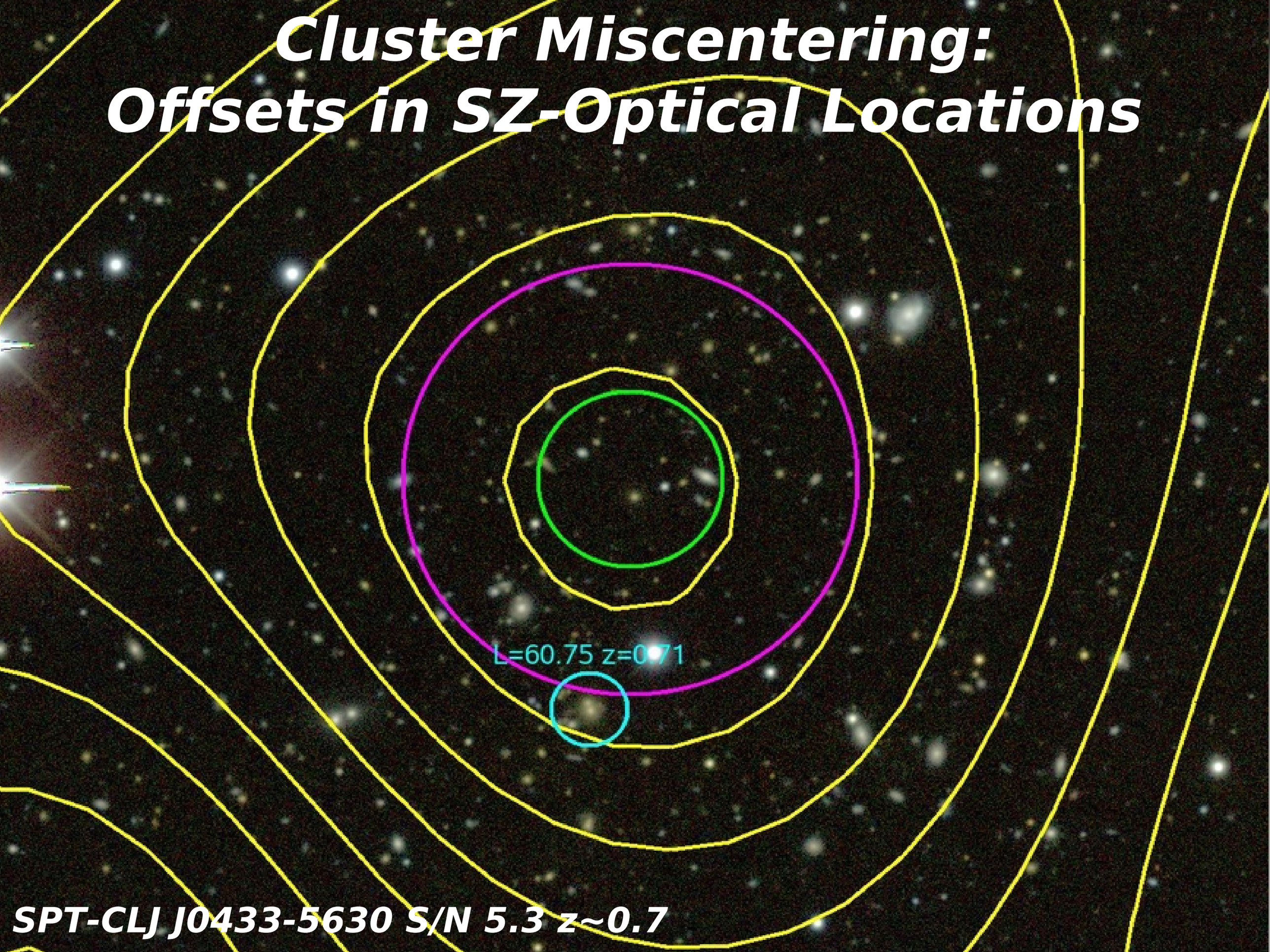
$$\langle \ln\lambda | M_{500}, z\rangle = \ln A + B\ln\left(\frac{M_{500}}{3\times 10^{14}\,\mathrm{M}_\odot}\right) + C\ln\left(\frac{E(z)}{E(z=0.6)}\right)$$

$$\mathrm{Var}(\ln\lambda|M_{500}) = \exp(-\langle \ln\lambda|M_{500}\rangle) + D^2$$

Catalog	A	B	C	D
SPT-RM $\xi > 4.5$	$66.1^{+6.3}_{-5.9}$	$1.14^{+0.21}_{-0.18}$	$0.73^{+0.77}_{-0.75}$	$0.15^{+0.10}_{-0.07}$
SPT-RM $\xi > 4$	$69.8^{+6.0}_{-4.9}$	$1.17^{+0.19}_{-0.17}$	$1.71^{+0.63}_{-0.57}$	$0.20^{+0.09}_{-0.08}$

- Parameters in agreement with low-z SDSS estimates by Rykoff et al. (2012)

Cluster Miscentering: Offsets in SZ-Optical Locations

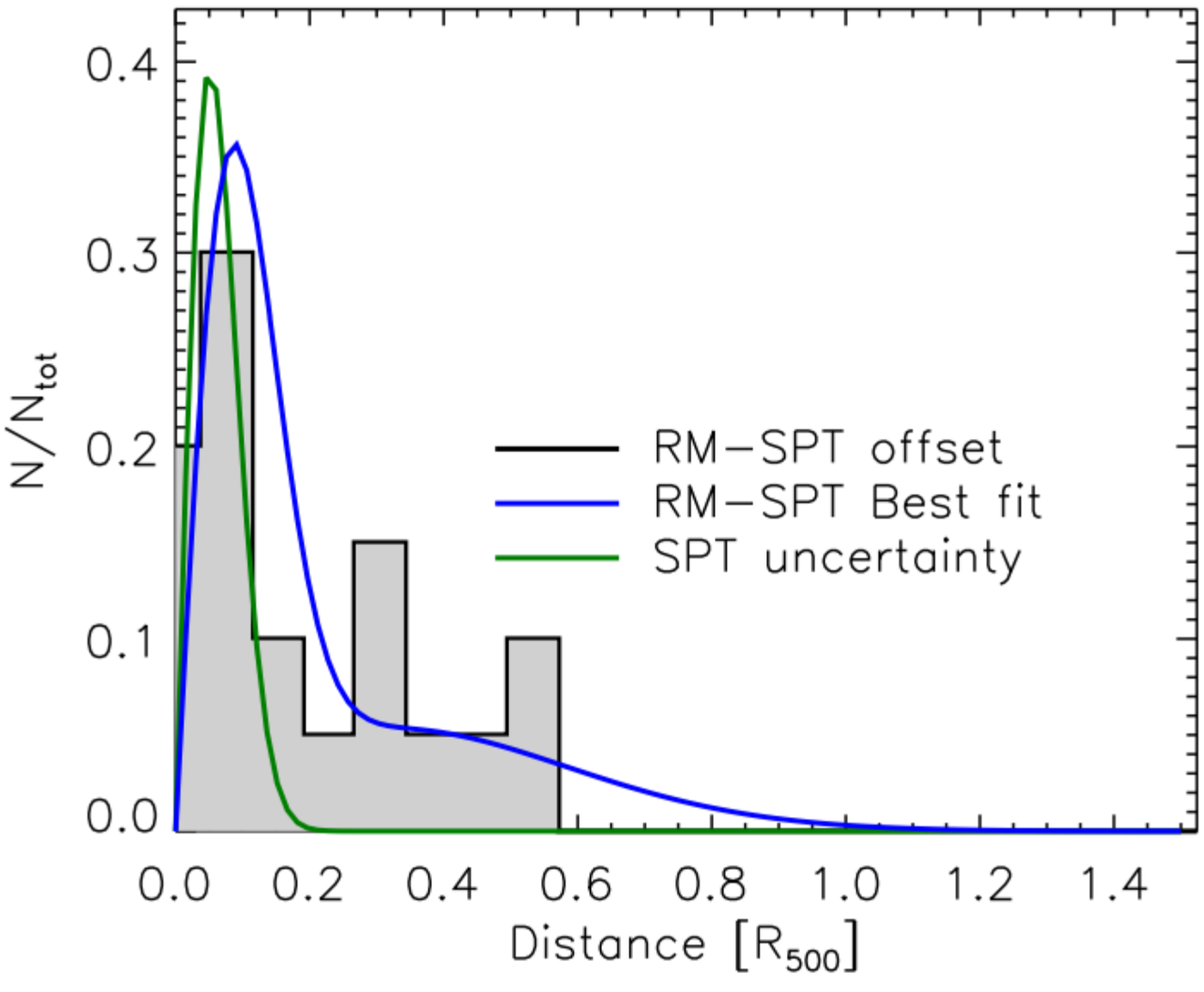


SPT-CLJ J0433-5630 S/N 5.3 z~0.7

1)SZ-Optical Central Offsets

Distribution of the SZ-redMaPPer center offsets:

- Important for future works (SZ properties of optically selected clusters, e.g., Biesiadzinski+12,Sehgal+13,Rozo+14)



- Propagate the SPT positional uncertainty

$$\Delta\theta = \xi^{-1}\sqrt{\theta^2_{\rm beam} + \theta^2_c},$$

- Fit a 3 parameters model

$$P(x) = 2\pi x\left(\frac{\rho_0}{2\pi\sigma_0^2}e^{-\frac{x^2}{2\sigma_0^2}} + \frac{1-\rho_0}{2\pi\sigma_1^2}e^{-\frac{x^2}{2\sigma_1^2}}\right)$$

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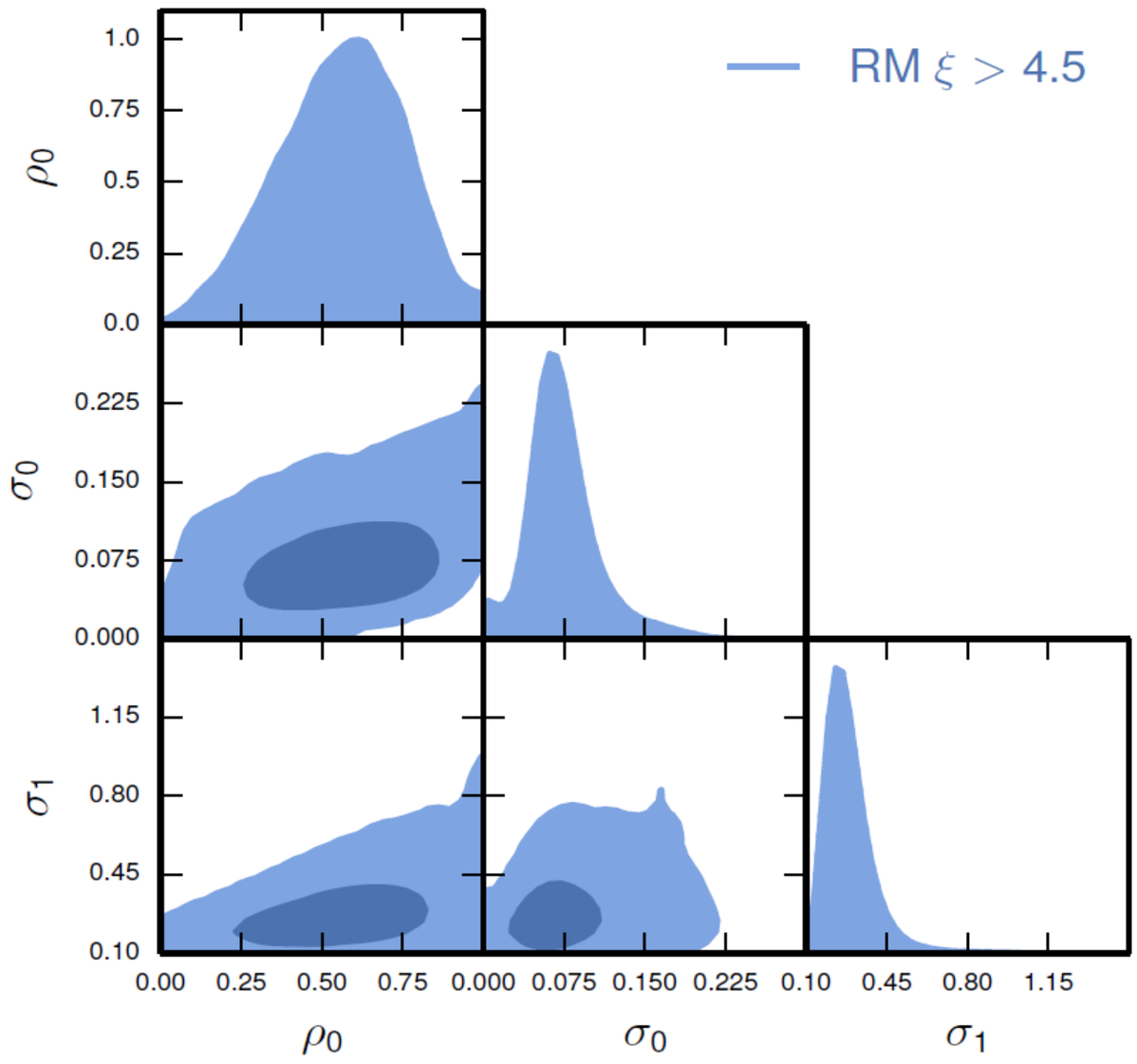

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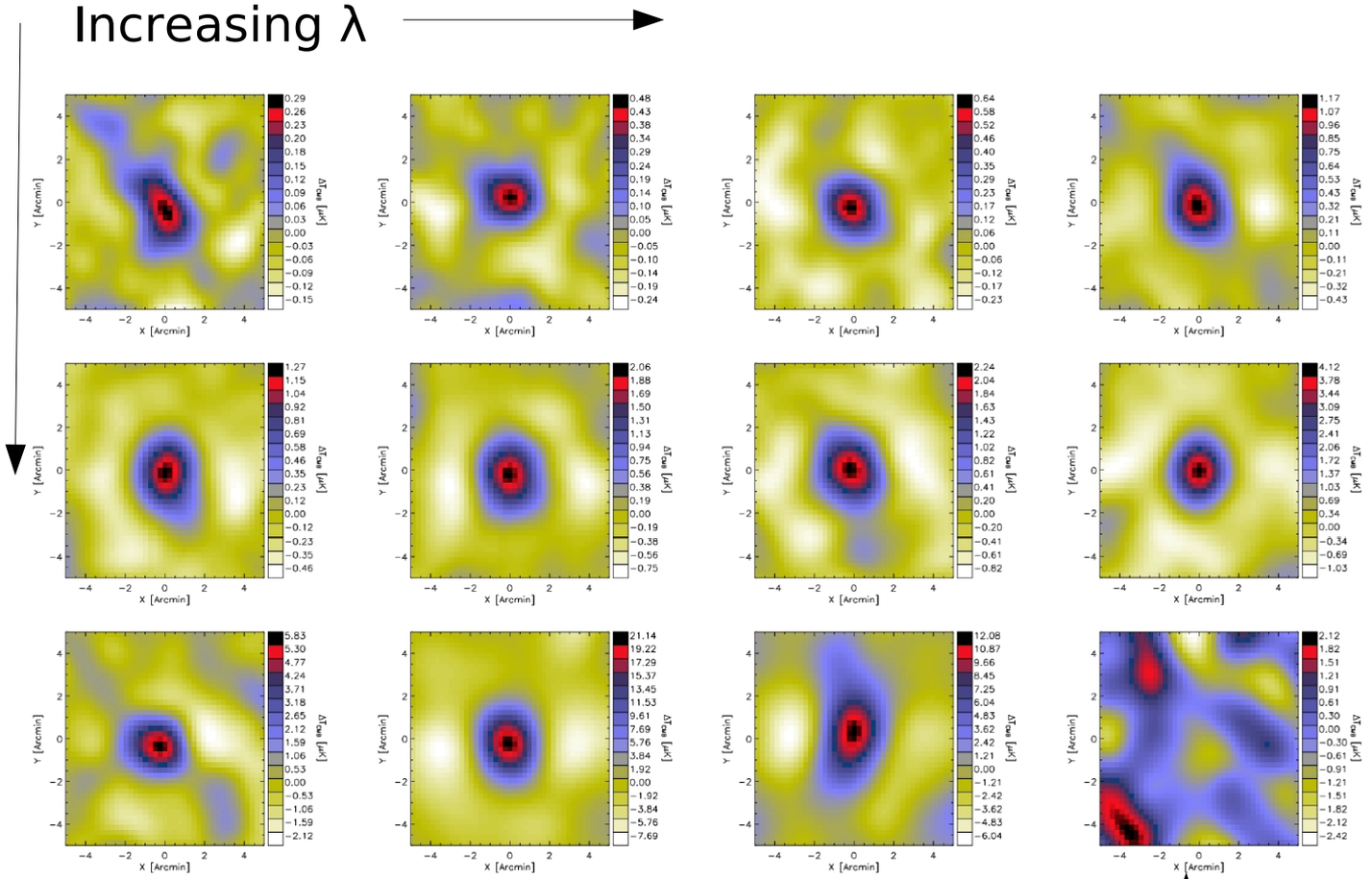
Catalog	ρ_0	$\sigma_0[R_{500}]$	$\sigma_1[R_{500}]$
RM-$\xi > 4.5$	$0.63^{+0.15}_{-0.25}$	$0.07^{+0.03}_{-0.02}$	$0.25^{+0.07}_{-0.06}$

2)SZE-properties of Optically Selected Clusters

Stacked 719 RedMaPPer selected clusters from the largest contiguous region in DES-SV (SPT-E) match-filtered according to S15 λ-M_{500} rel.

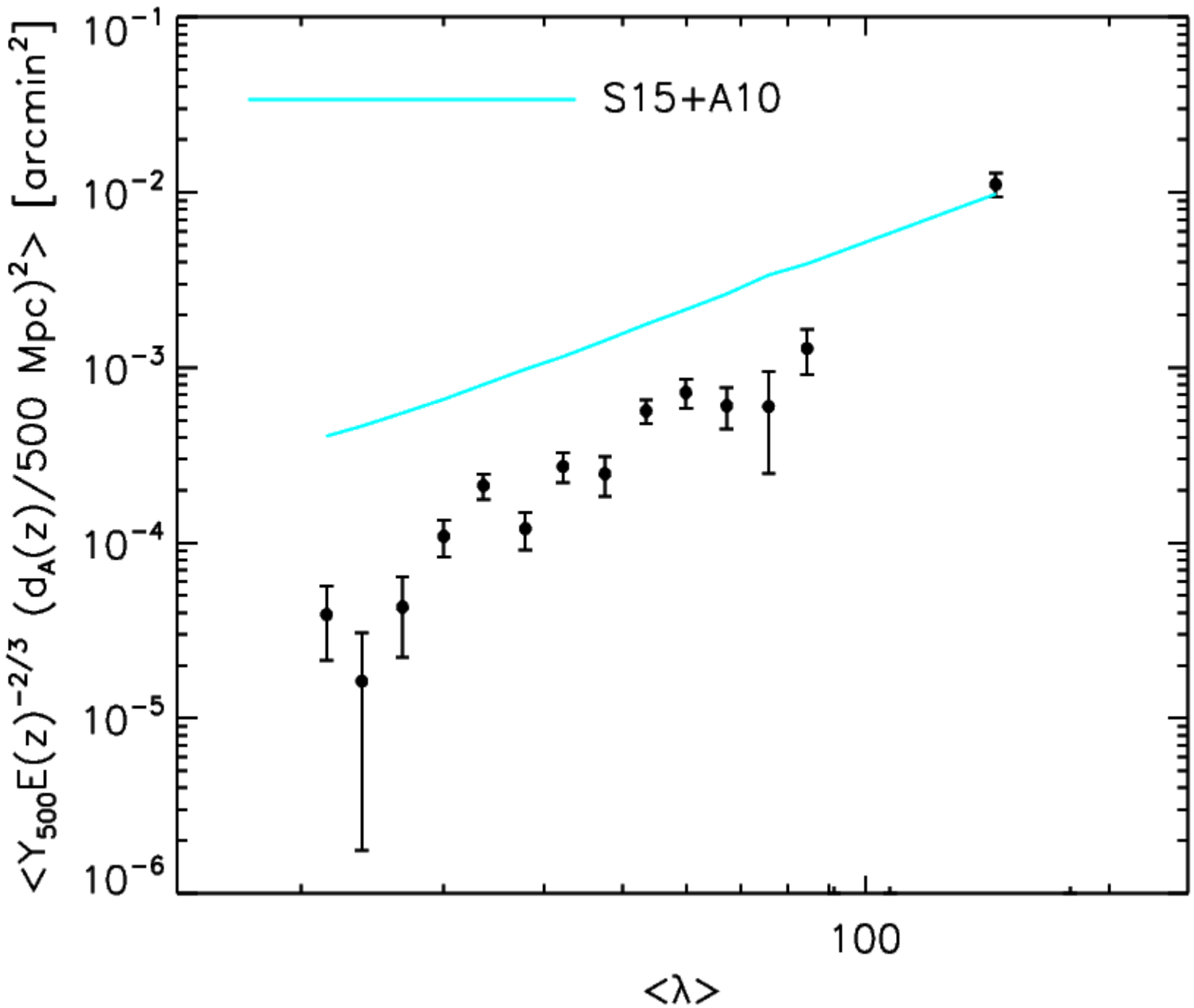


Y_{500}-λ relation

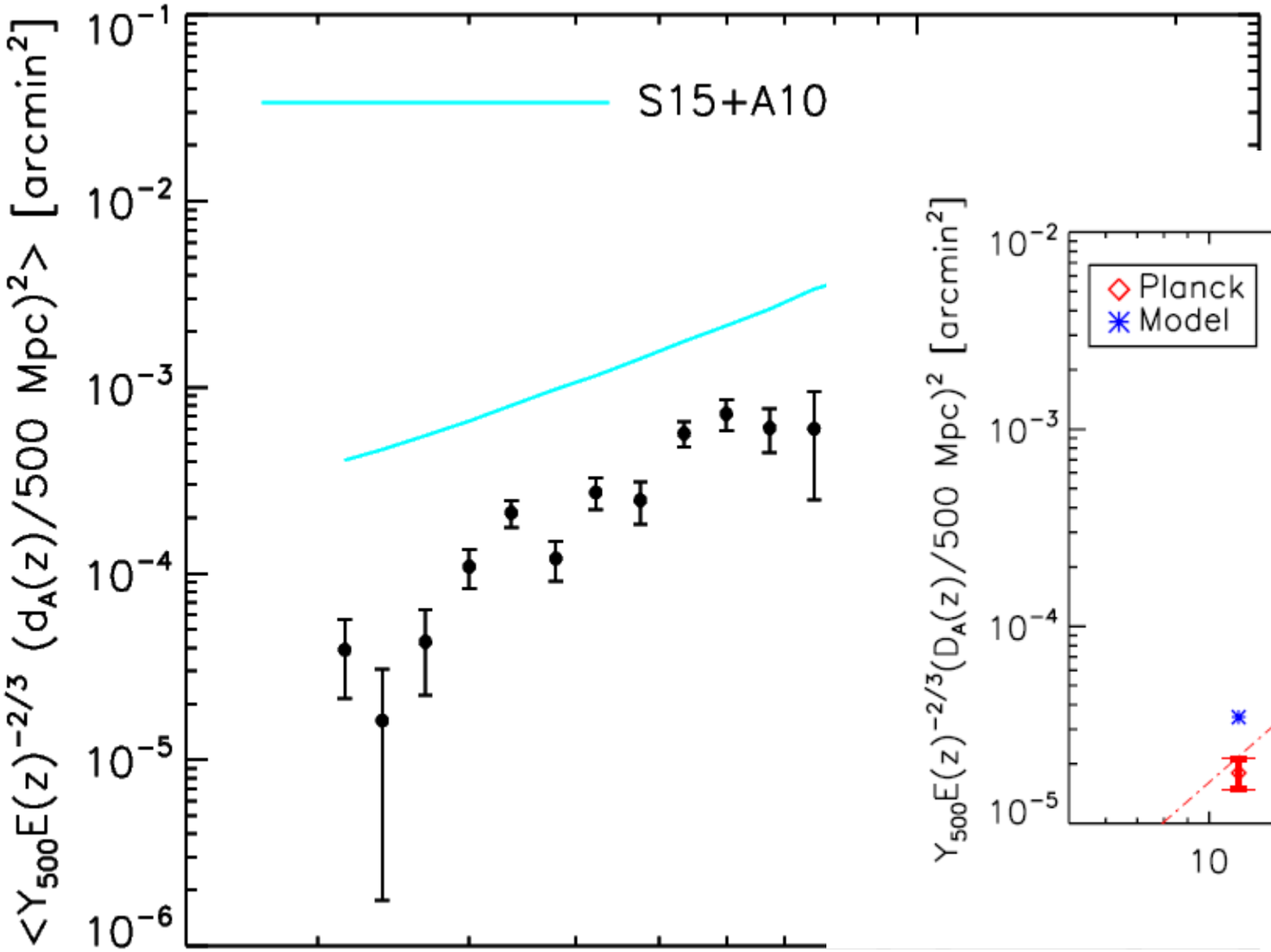
Including Arnaud+10, S15 λ-mass calibration and bias due to SZ-optical miscentering priors

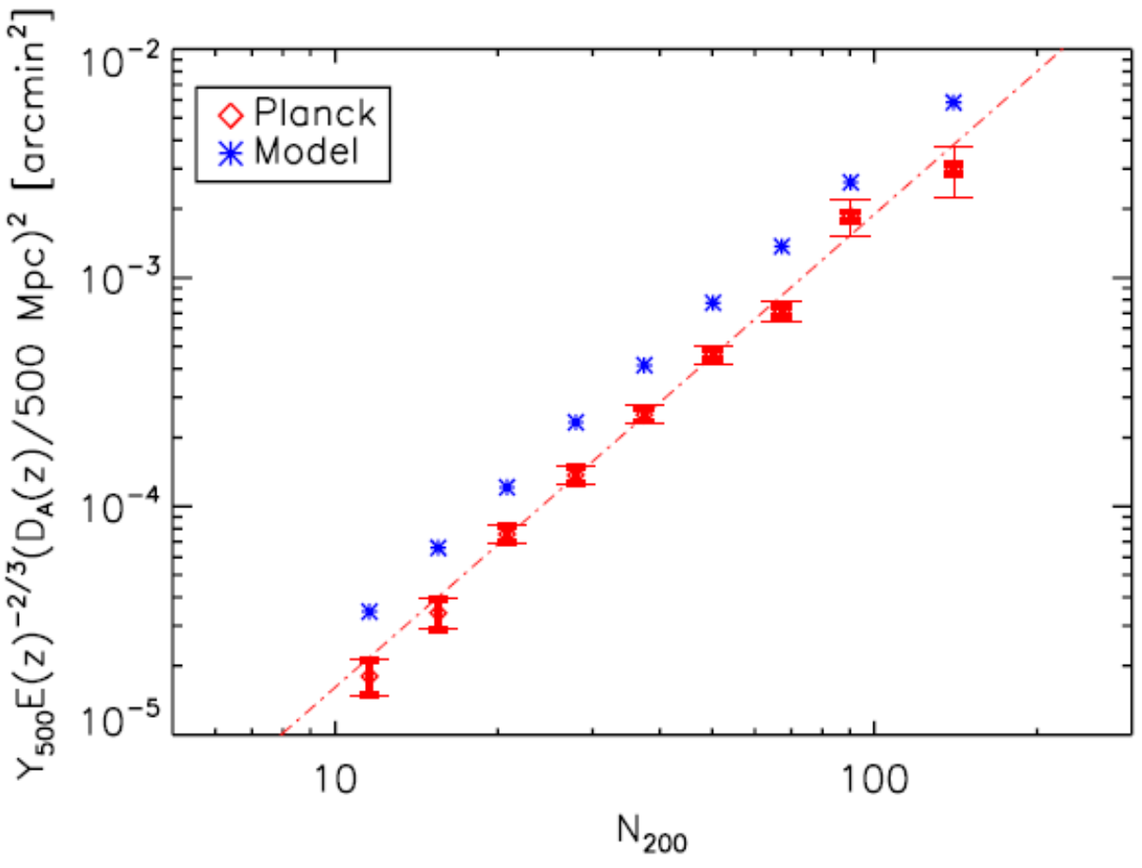
For every RM selected cluster:

- Predict for a given point in $\boldsymbol{p}$(scaling relations): $P(M_{500}|\lambda,z,\boldsymbol{p})$ and $P(Y_{500\text{-expected}}|\lambda,z,\boldsymbol{p})$.
- Correct for bias due to miscentering
- Marginalize over scaling relations and miscentering distributions



Are we observing the same Planck-MaxBCG tension?

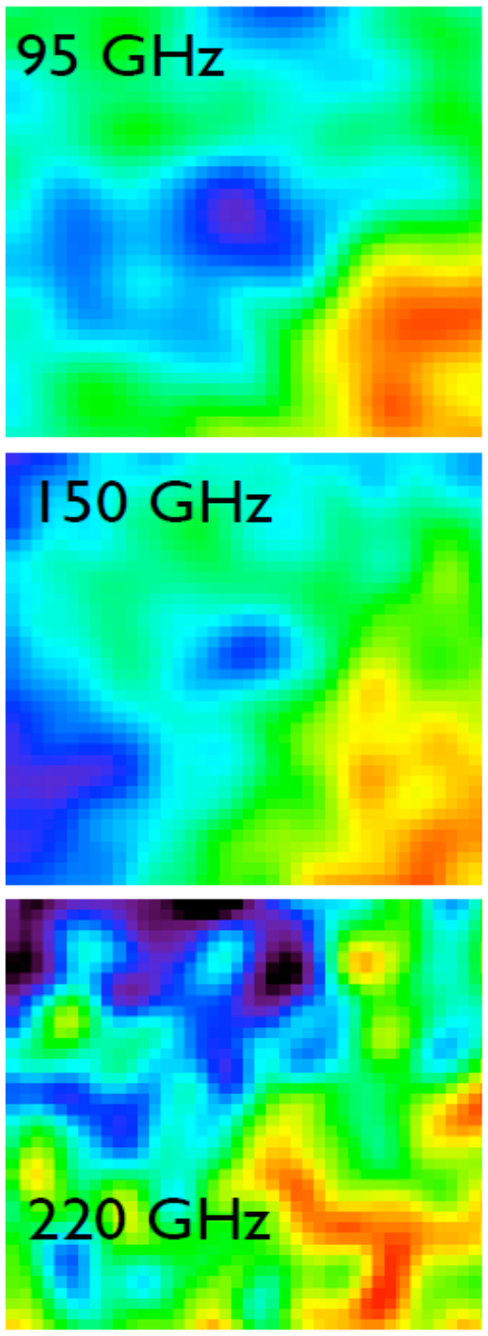




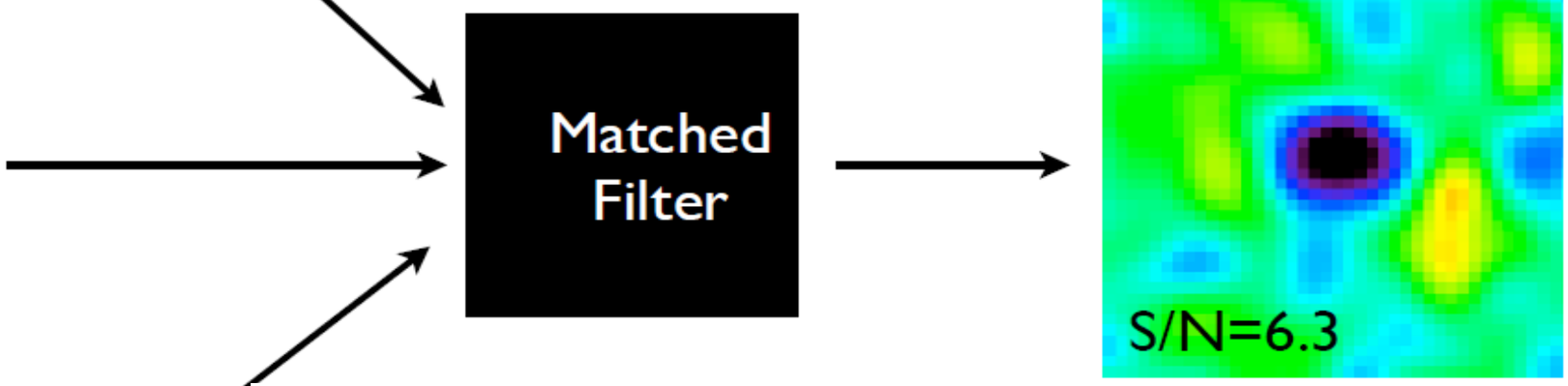
Not sure if it is a well defined question..

And similar results obtained by the ACT team

One step back
What is the SPT observable?

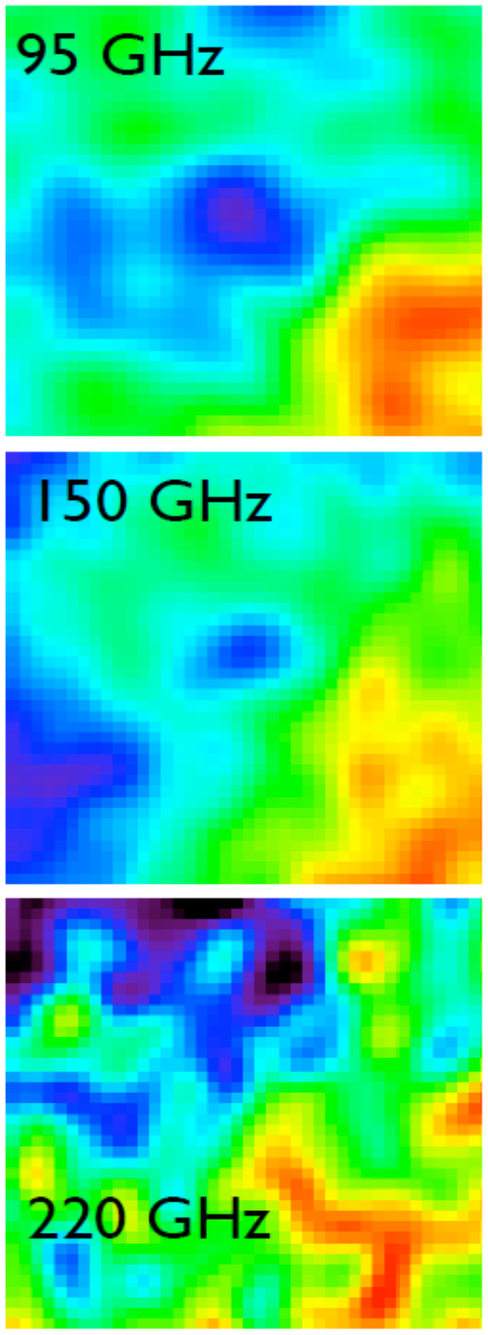


- Combine maps at different frequencies into a synthesized thermal SZ map, and find significant objects in that map
- [OR: these steps can be combined into a single spatial-spectral filter (e.g. Tegmark 2000, Herranz et al 2002, Melin et al. 2006).]



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

One step back
What is the SPT observable?



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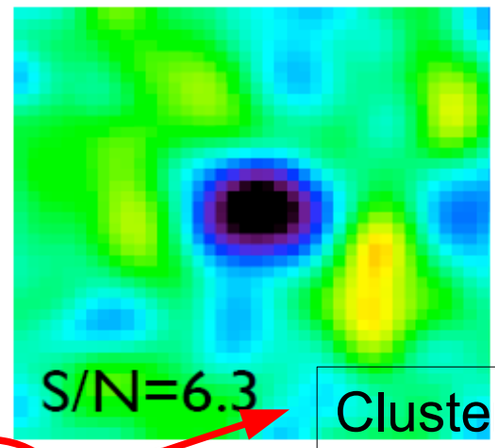
Matched Filter



Cluster profile

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

Beam

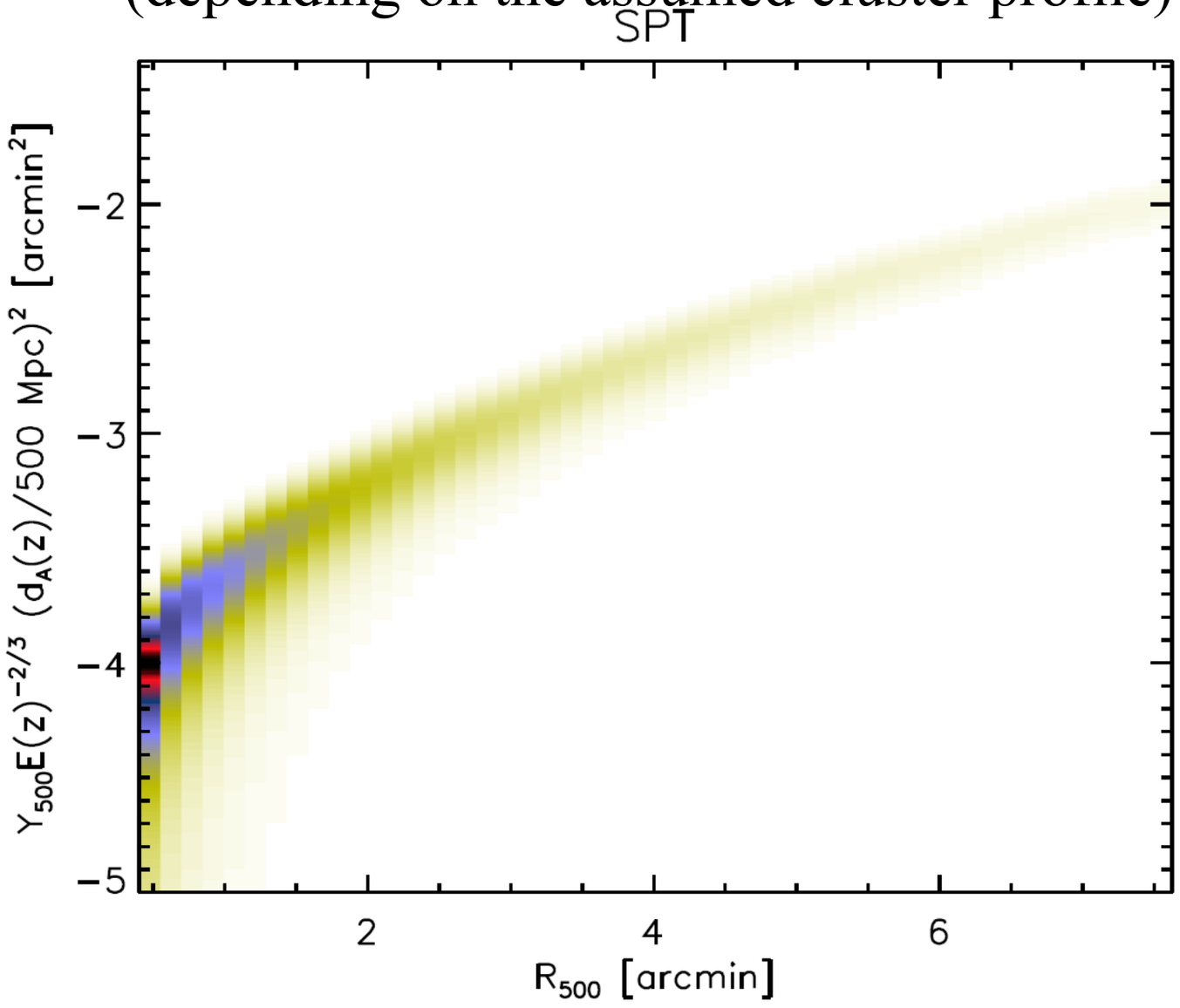
Filter in Fourier space

CMB+ other astro terms

Instrumental Noise

SZ - Estimator

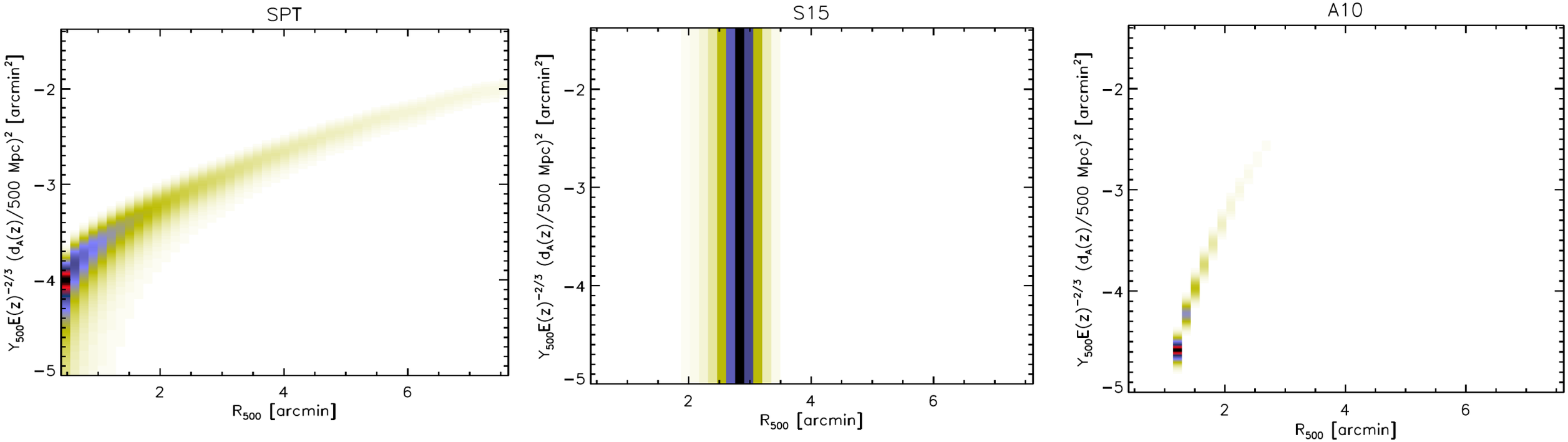
SPT observable is a very degenerate Y-M plane
(depending on the assumed cluster profile)



X-axis can be read as mass for given redshift and cosmology

SZ - Estimator

For every cluster selected with richness λ at redshift z can compute:



SPT-Data $P(M_{500}|\lambda,z,\boldsymbol{p})$ $P(Y_{500}|M_{500},z,\boldsymbol{p})$

X-axis can be read as mass for given redshift and cosmology

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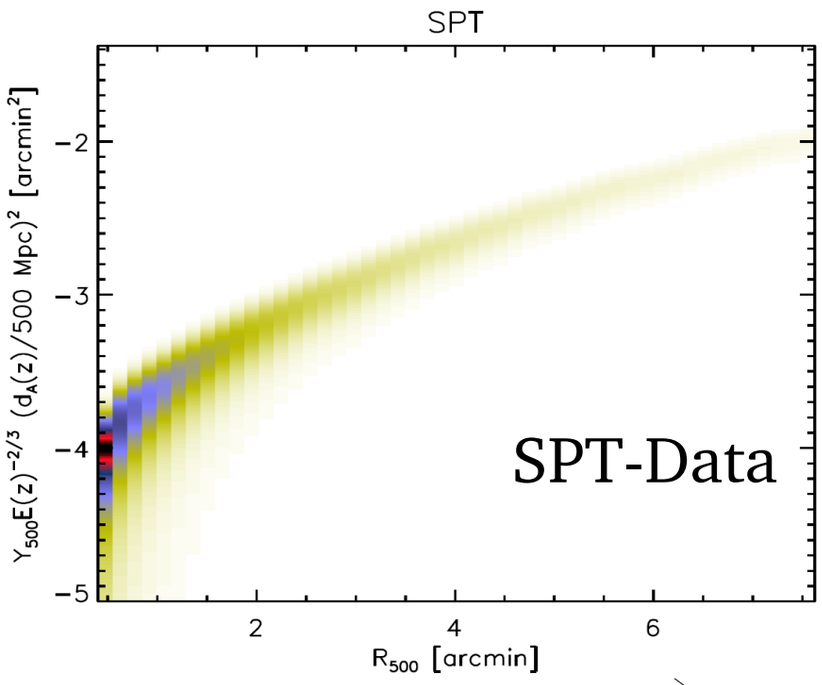
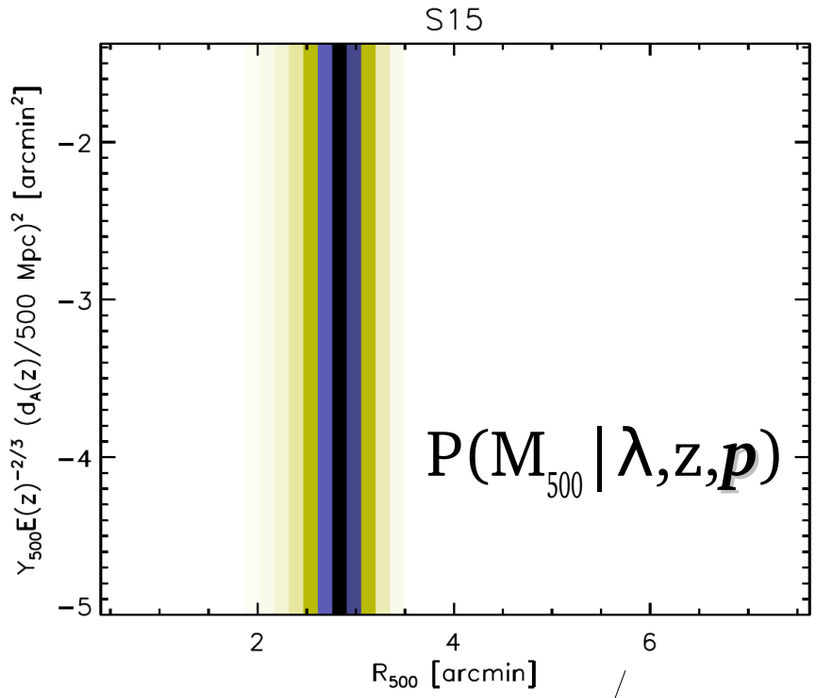
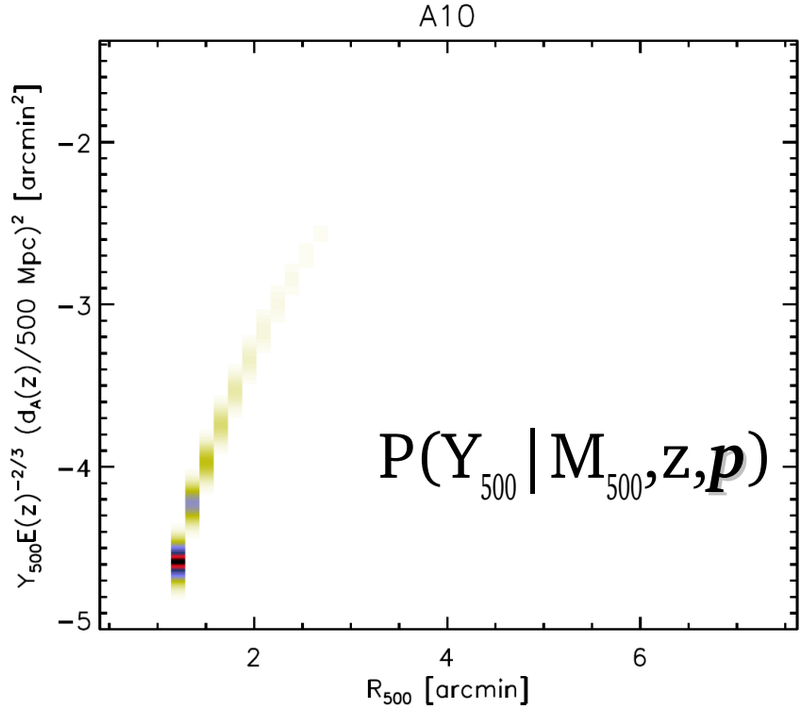
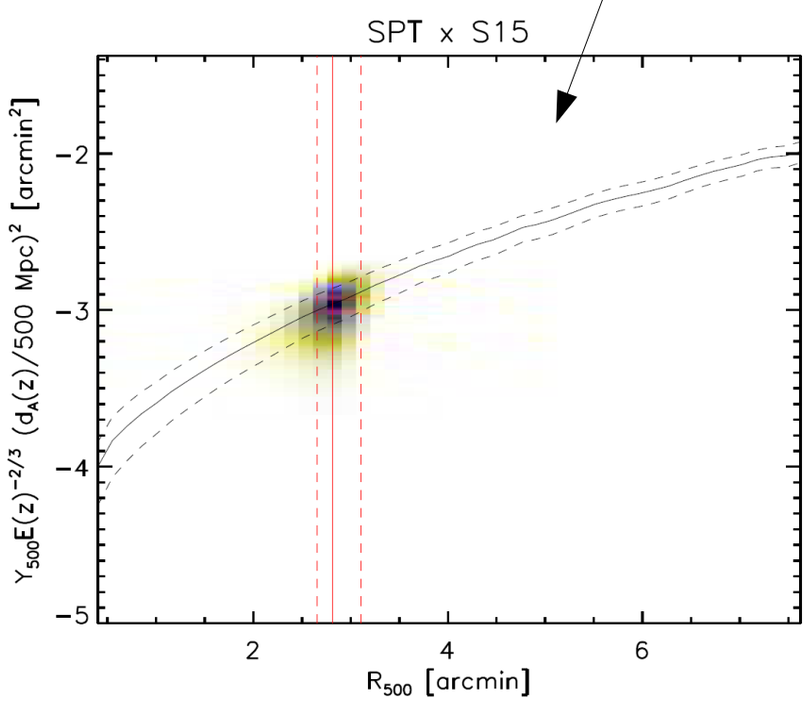






DataxP(M|λ)



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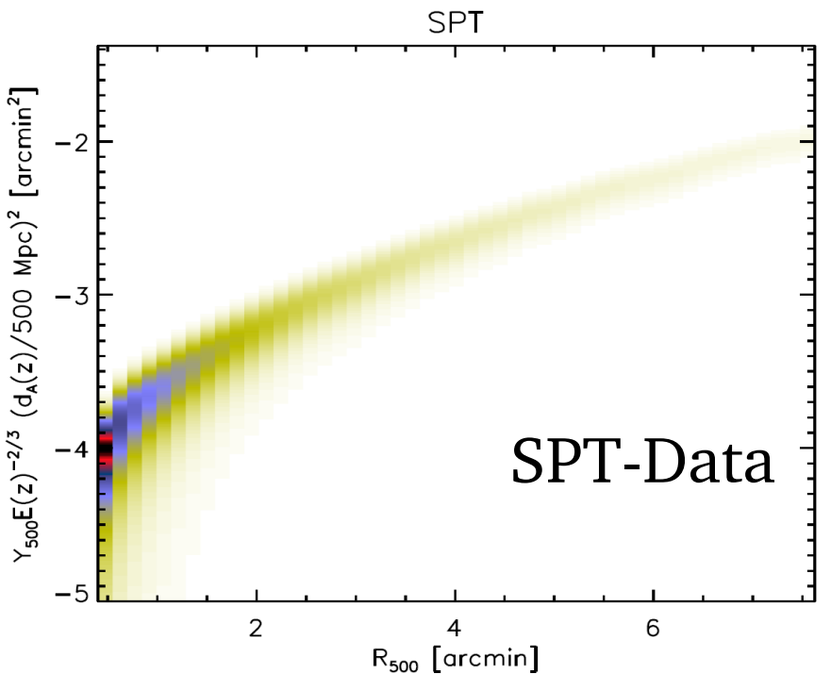
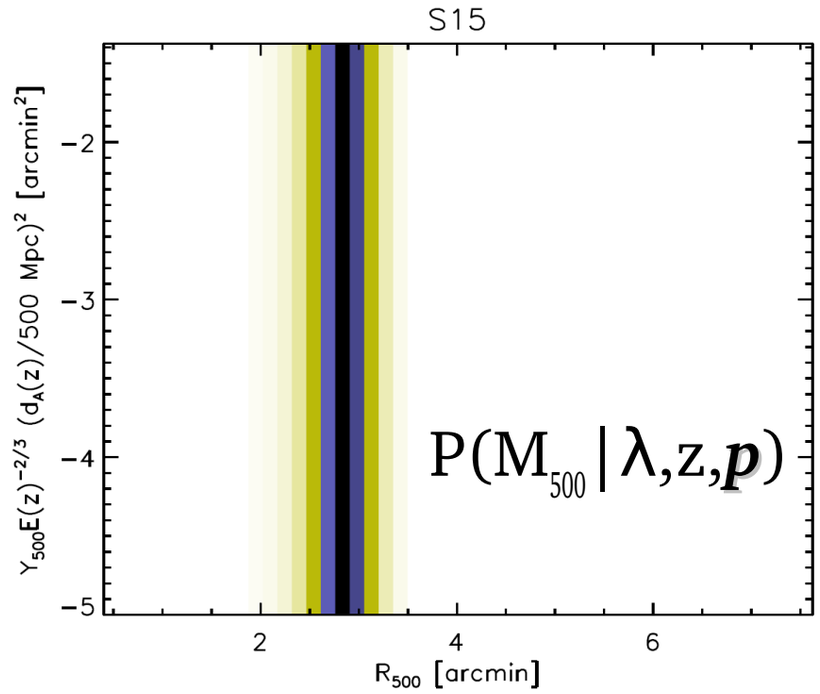
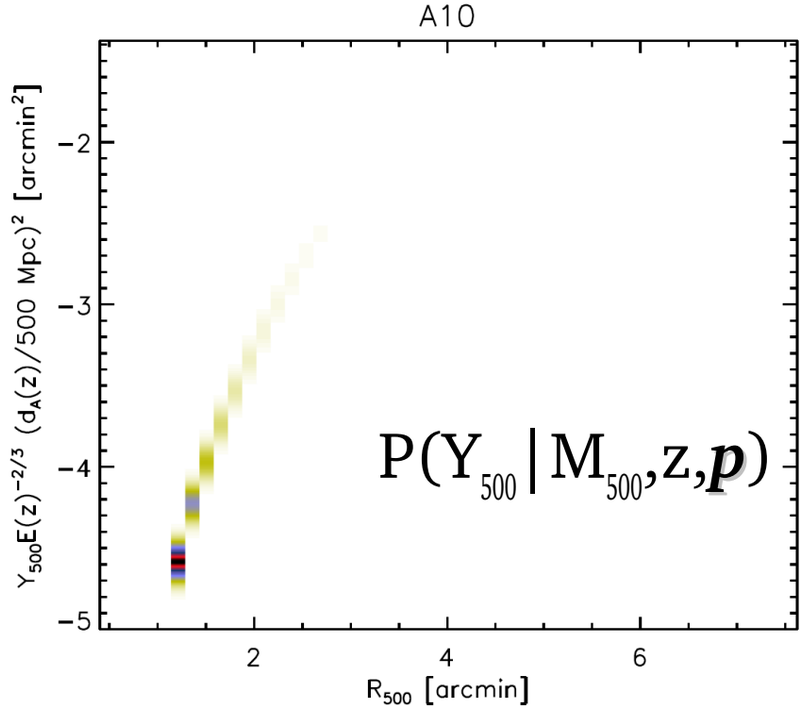
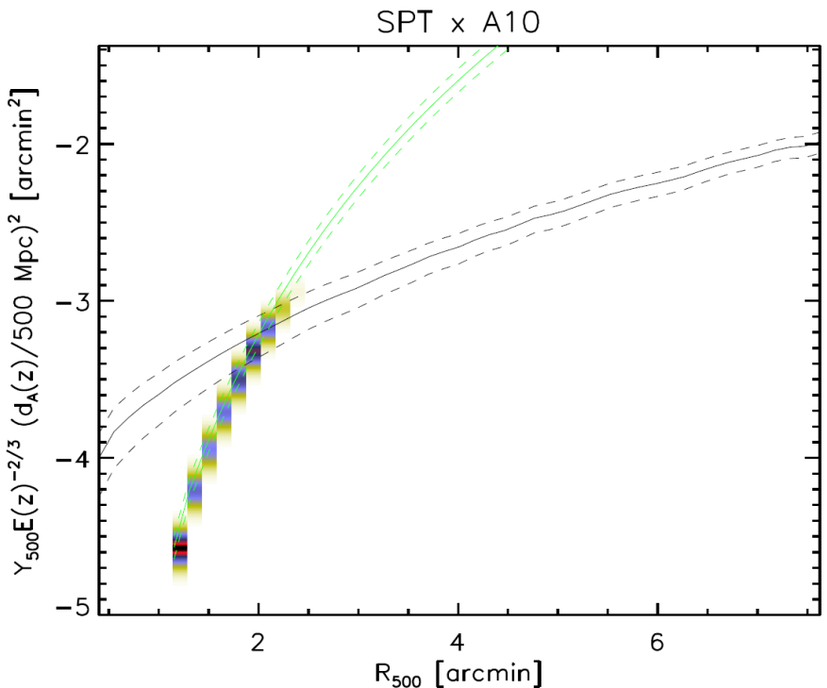






DataxP(Y|M)



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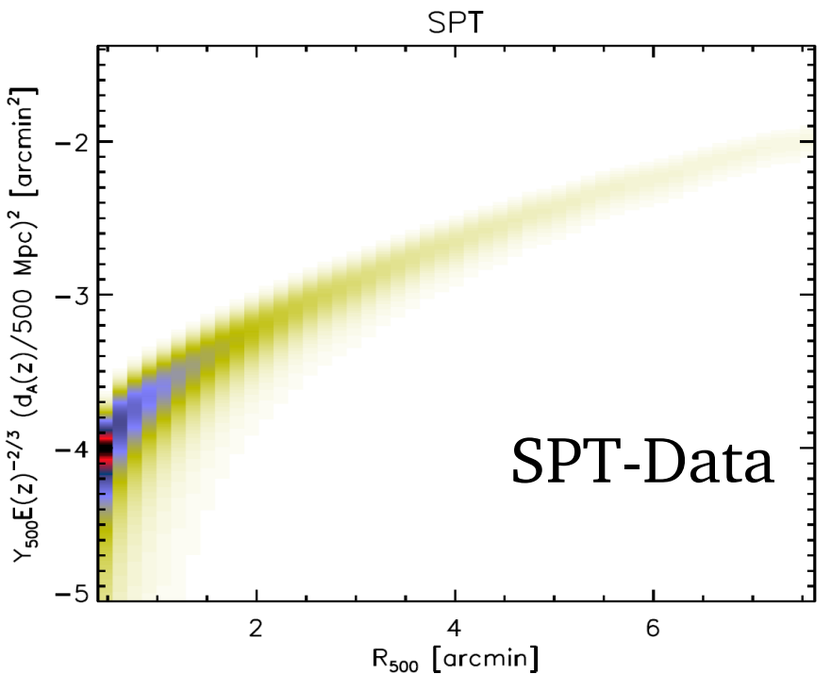
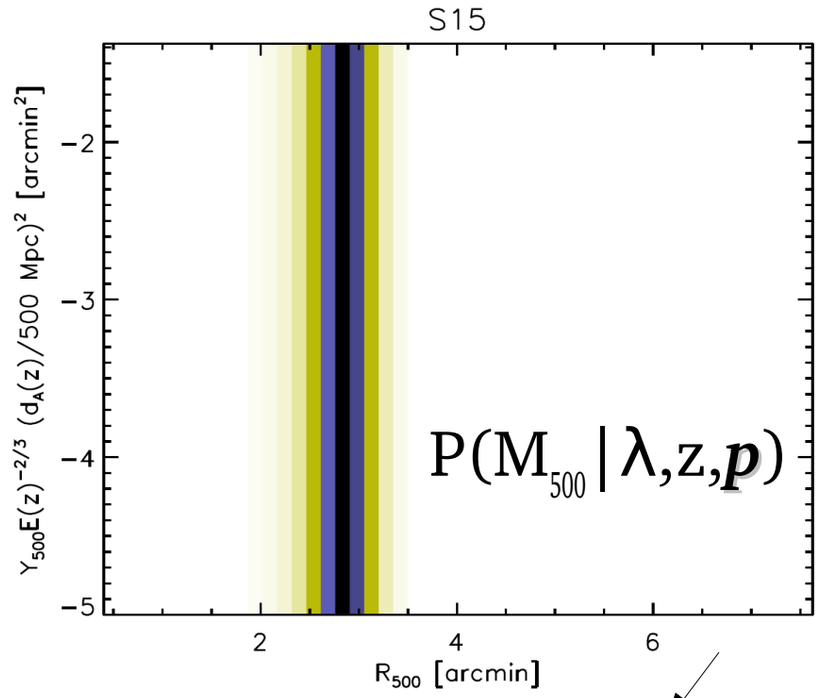
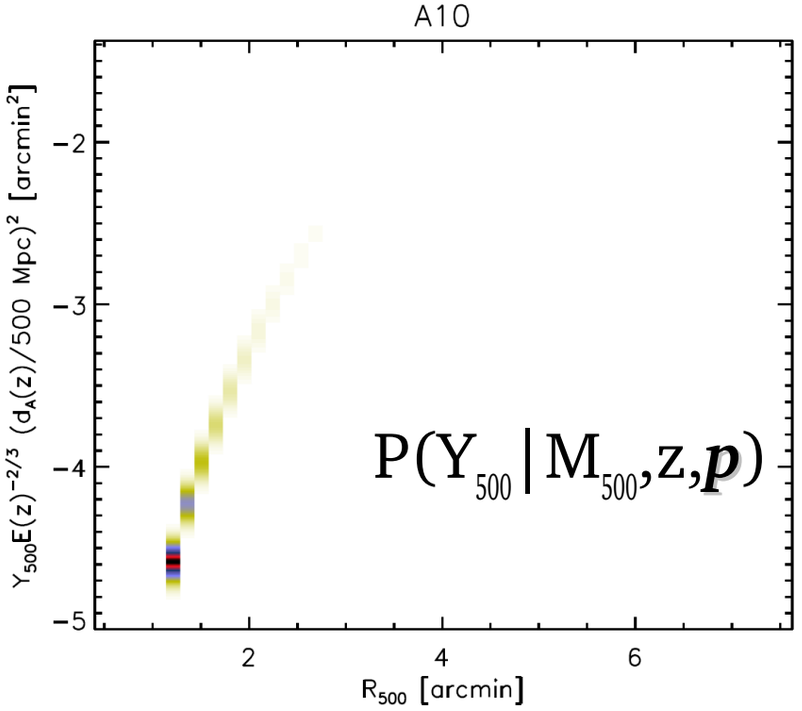
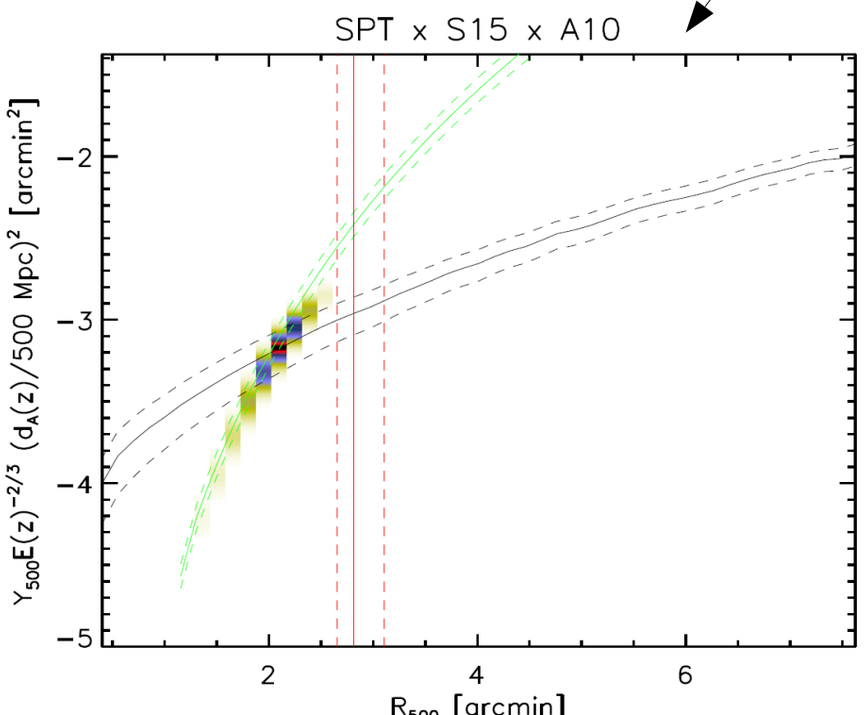






DataxP(Y|M)xP(M|λ)



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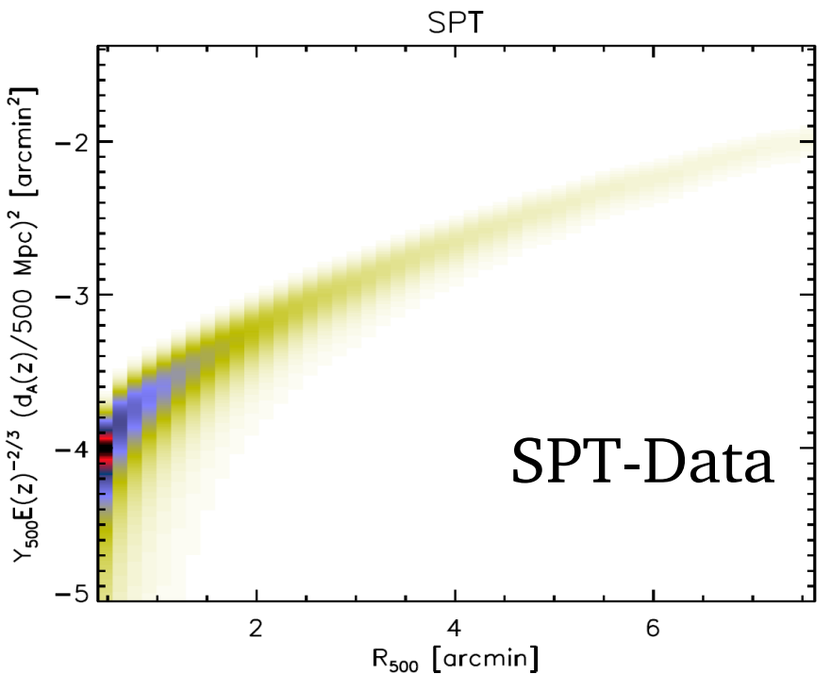
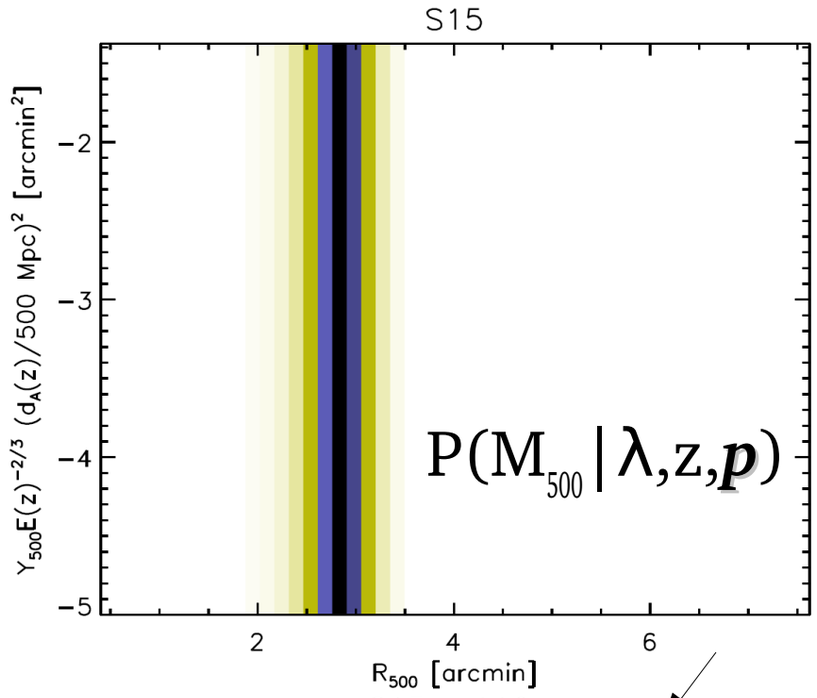
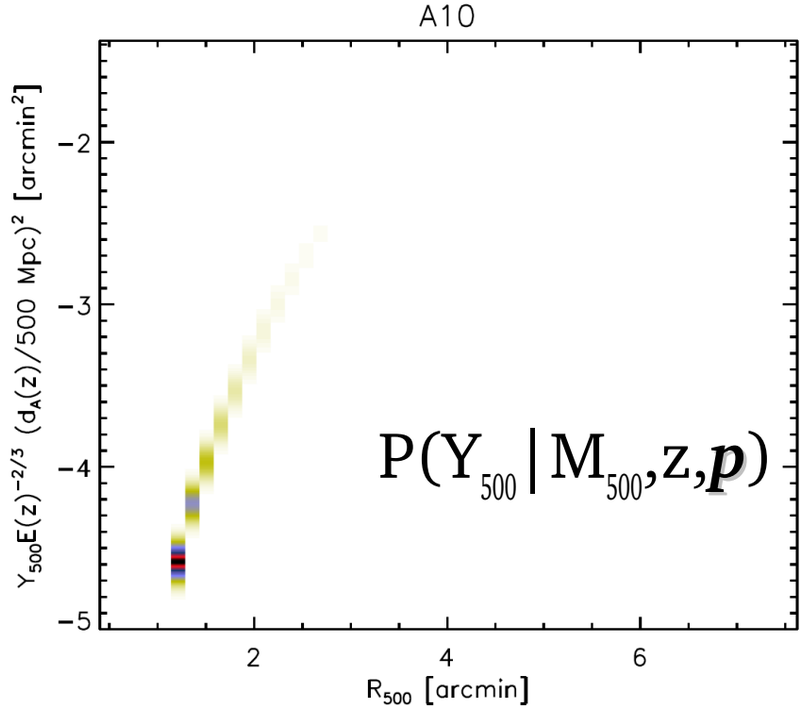
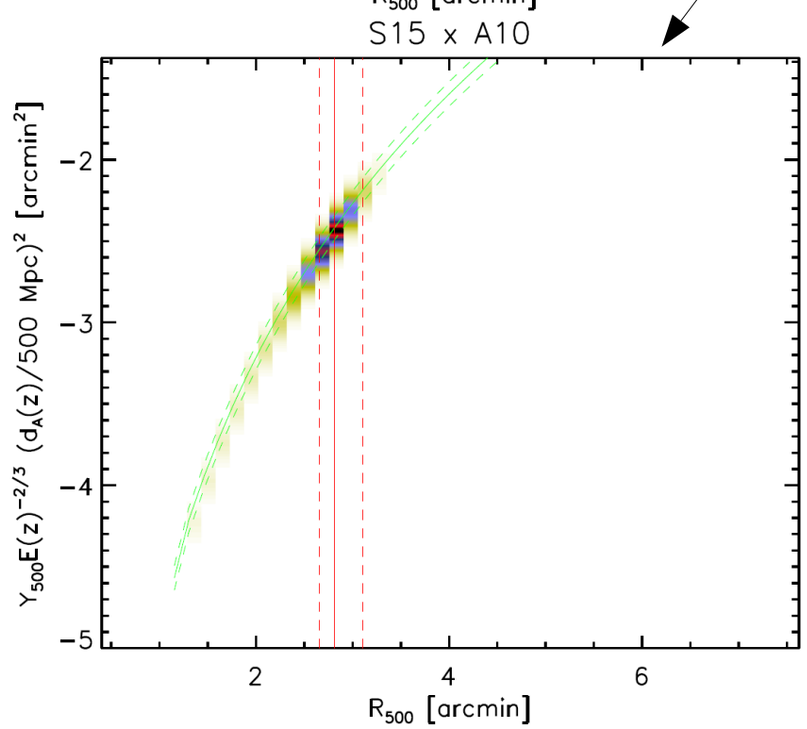






Prediction:
P(Y|M)xP(M|λ)

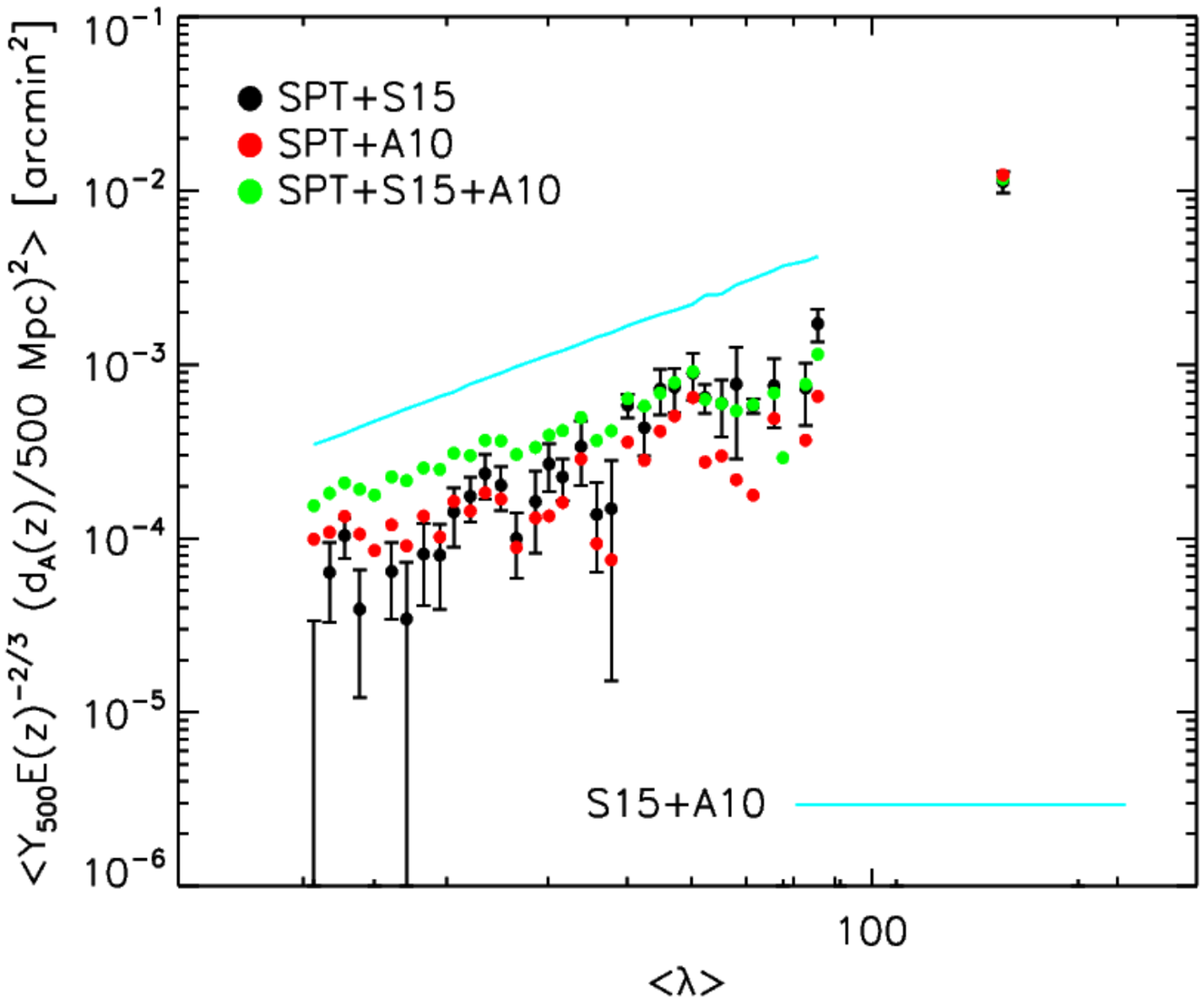


SZE-properties of redMaPPer selected clusters

Including Arnaud+10, S15 λ-mass calibration and bias due to SZ-optical miscentering priors.

For every RM selected cluster:

- Predict for a given point in ***p***(scaling relations): $P(M_{500}|\lambda,z,\boldsymbol{p})$ and $P(Y_{500\text{-expected}}|\lambda,z,\boldsymbol{p})$.
- Correct for bias due to miscentering
- Marginalize over scaling relations and miscentering distributions



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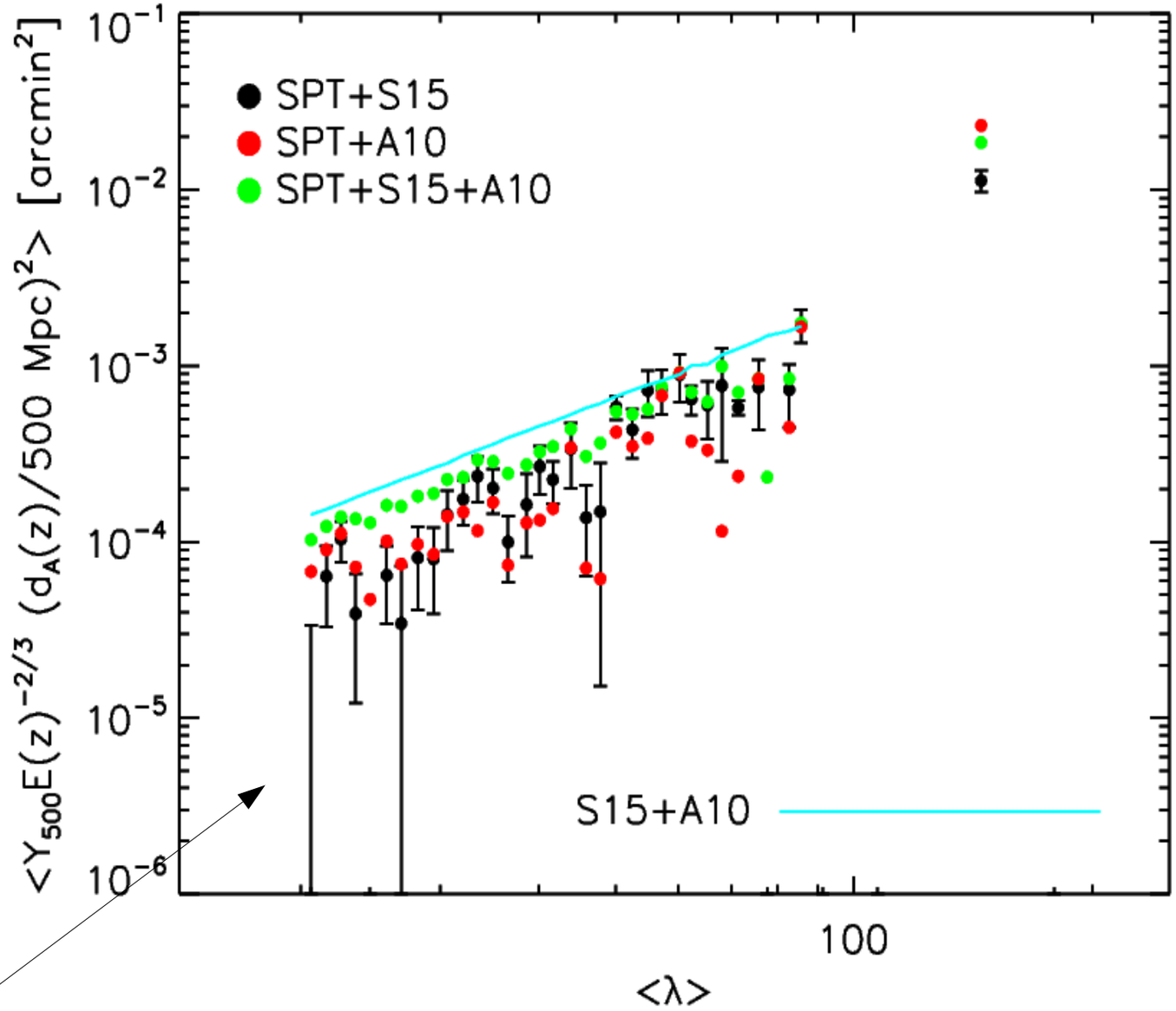

Including preferred Planck bias 0.58

Conclusions

- Two cluster surveys: SPT-SZE at mm and redMaPPer from DES at optical.
- Robust and reliably cross-match of SPT-SZE selected clusters with optically selected clusters from the Science Verification data of the Dark Energy Survey.
- Calibrate Richness-Mass scaling relation from SPT-SZE selected clusters and test the adopted model.
- Calibrate the Optical-SZ central offset distribution
- 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
- Qualitatively agreement with previous literature works (but large impact of priors) and hint for a large bias (consistent with Planck results)