Astrophysics with the SZ effects (Chapter 6)

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CMB-S4

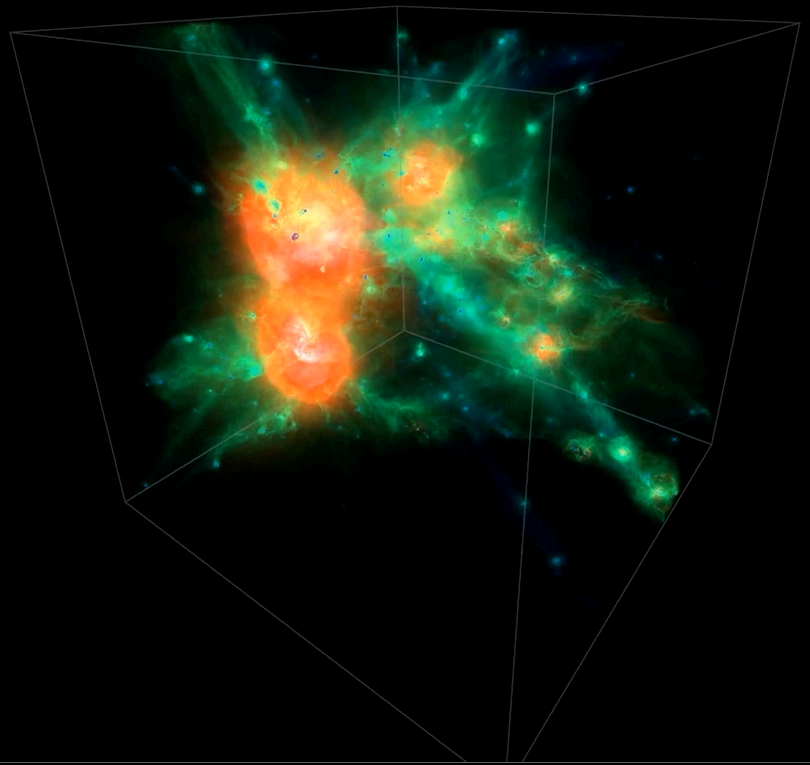
Argonne NATIONAL LABORATORY

Overview

- Overview of Scientific Opportunity
- Outline of Science Chapter
- Plans for Completion

The CMB-S4 deep and wide field surveys will provide a powerful census of the total matter in the Universe (*CMB lensing*) as well as the spatial distribution (*kSZ*) and thermal energy (*tSZ*) of its ionized gas.

Additional measurements of *dusty* and *synchrotron* sources (see Mel Archipley's talk tomorrow) will further elucidate the formation and evolution of structures in the Universe.



visualization Mark Vogelsberger

The IllustrisTNG Team

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https://www.tng-project.org/media/

Fundamental Data Products

- tSZ cluster catalogs
- Lensing Maps
- tSZ/kSZ component separated maps
- Emissive source catalogs

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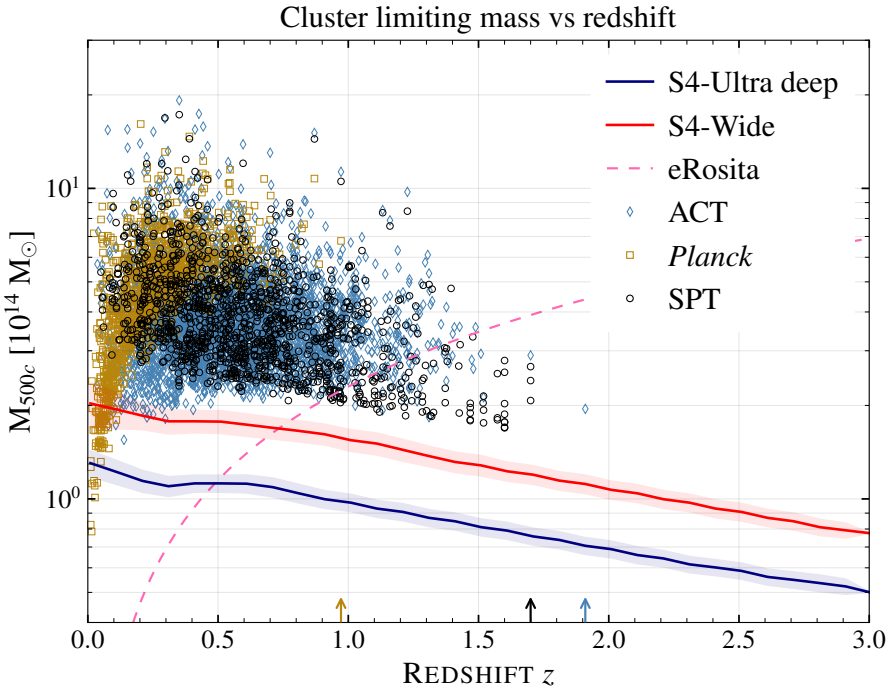
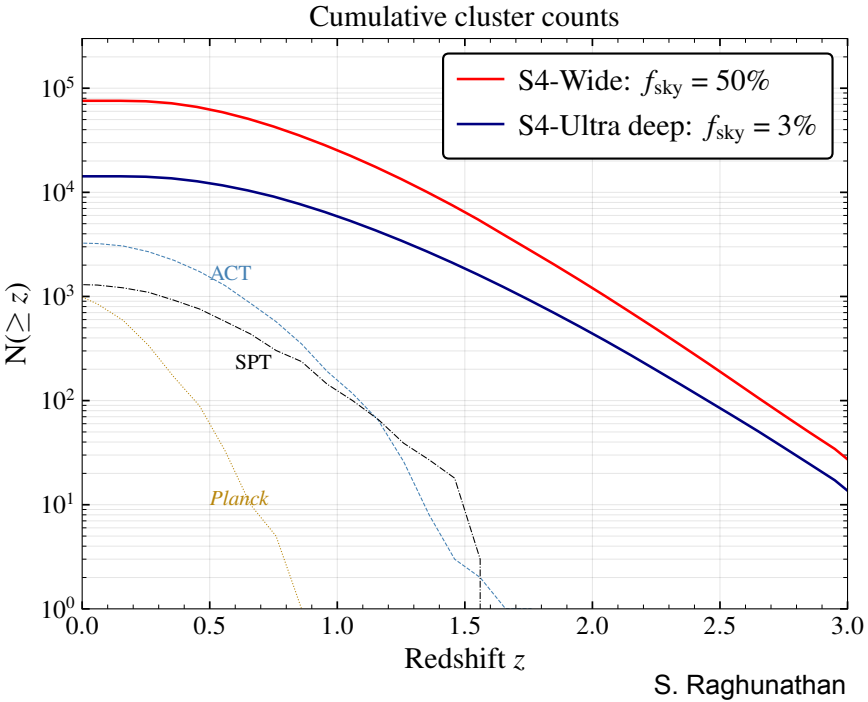
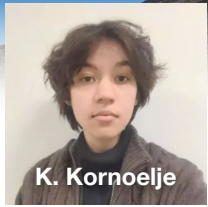




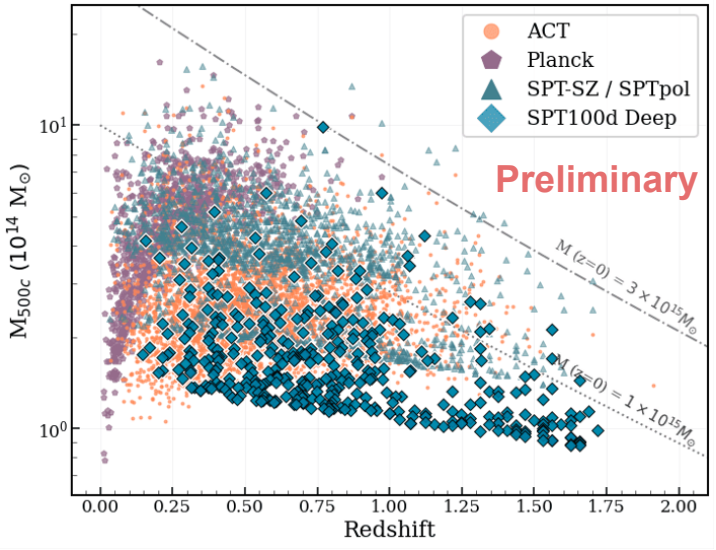
S. Raghunathan

CMB-S4 will discover an order of magnitude more of the highest-redshift (z > 1.5) clusters than previous surveys.

The First SPT-3G Cluster Catalog: 100d Deep Field



- The 100d SPT deep field combines data from 5 years of SPT-3G with the SPTpol 100d+ 500d surveys (10 years of CMB observations in total!)
- First cluster catalog to be constructed from data at CMB-S4 noise levels.



	Median Redshift (z)	Median Mass ($M_{500c} \times 10^{14}$)	Cluster Density (deg^{-2})
Planck	0.22	4.74	0.02
ACT	0.52	2.38	0.32
SPT-SZ/SPTpol	0.58	3.72	0.49
SPT100d Deep	0.75	1.48	3.92

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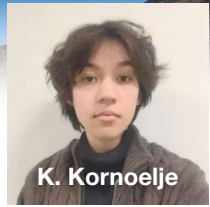

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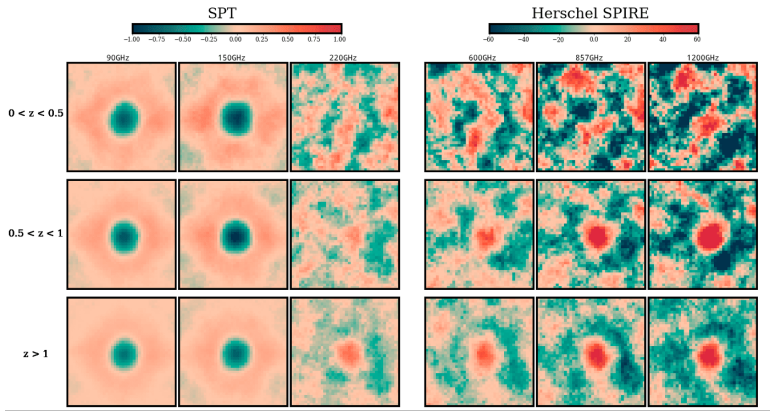
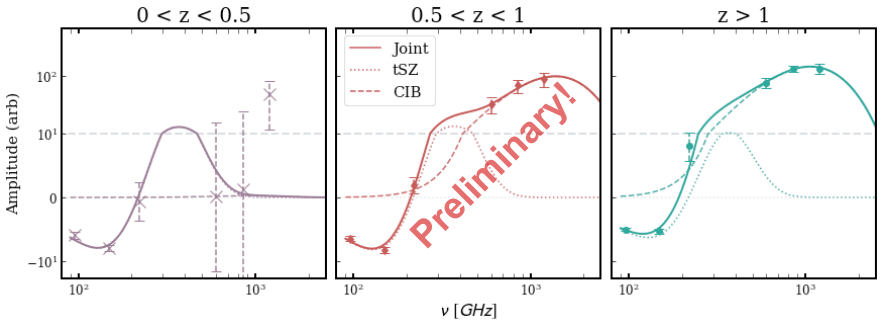
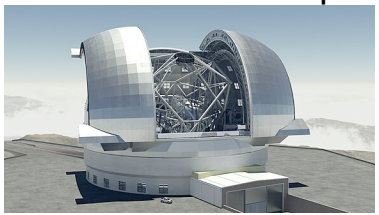




A (very incomplete) view of the astronomical landscape

Targeted Follow-up Facilities

30 m Class Telescopes



Now | 2025 | 2026 | 2027 | 2028 | 2029

Survey Facilities

Updated slide
originally by A Gonzalez

A rich and diverse science case

6.1 Cluster Astrophysics
- 6.1.1 Proto-clusters to clusters
  - Comparison of tSZ and lensing to infer degree of virialization
- 6.1.2 High-z cluster sample
  - Feedback / ICM enrichment / star formation
  - Systematic biases: radio/dust contamination of the SZ signal
- 6.1.3 Measurements of ICM pressure profiles
  - Detailed studies of low-z systems
  - Resolving shocks / cold fronts resolved in nearby systems
  - Measurements of Splash back / outer accretion shock
  - Non-thermal pressure profiles
  - SZ fluctuations
  - Probe of mass accretion rate/history
- 6.1.4 Cluster Scaling relations
- 6.1.5 Relativistic SZ distortions
- 6.1.6 Rotational kSZ

6.2 Galaxy/Field astrophysics
- 6.2.1 CGM studies for massive galaxies
- 6.2.2 Stacking studies for underdense regions and filaments
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6.3 Tracing the mass-gas connections
- 6.3.1 y-map x lensing/galaxies for gas studies
- 6.3.2 Impact of baryons on lensing

6.4 Connections to High-resolution SZ follow-up experiments

6.5 Synergies with other wavelengths (X-ray, optical, radio)

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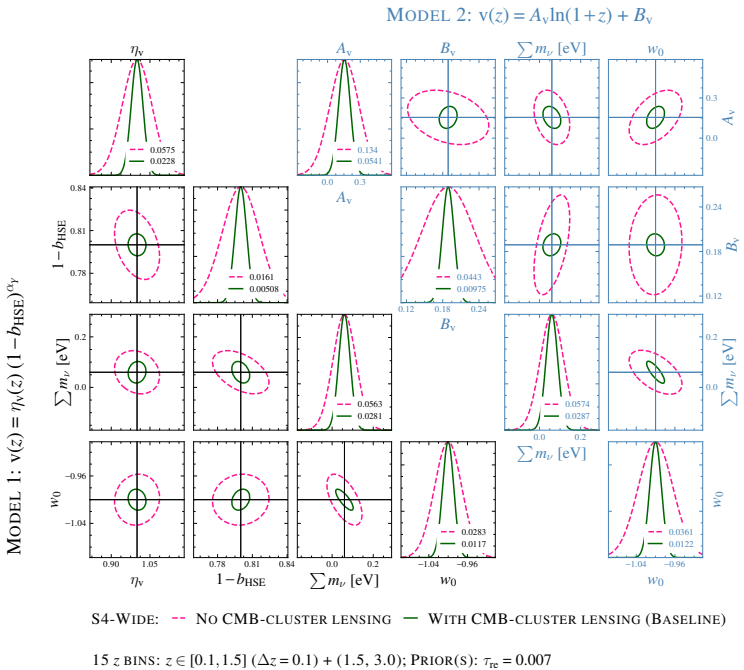

Raghunathan et al.
Astrophysical Journal, Volume 926, Issue 2, id.172

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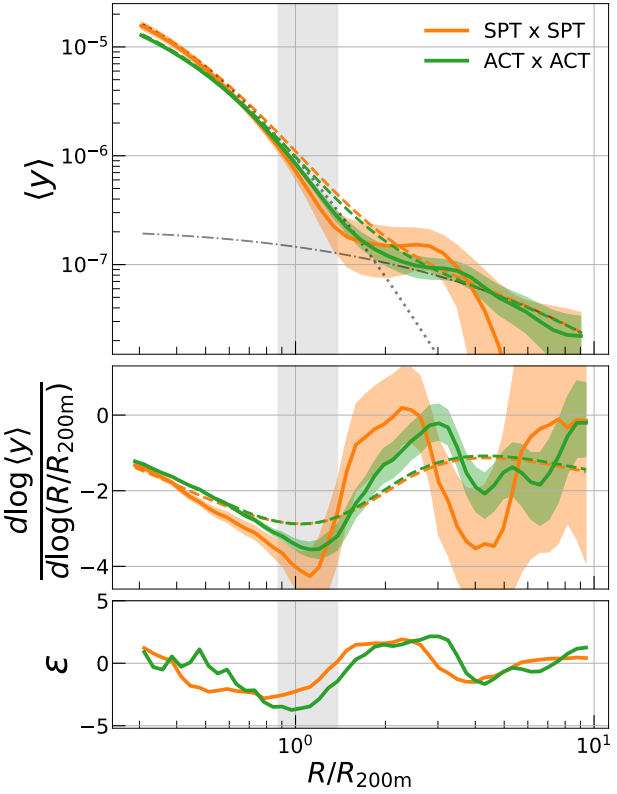

D. Anbajagane et al.
MNRAS, Volume 527, Issue 3

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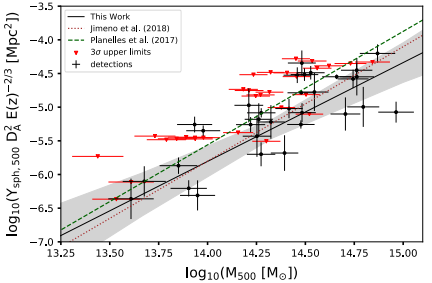

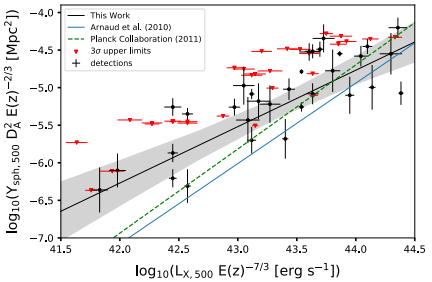

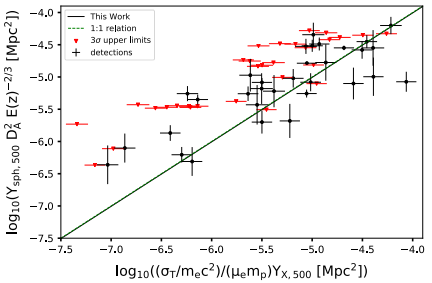

Pratt et al. ApJ 890, 2 id 186

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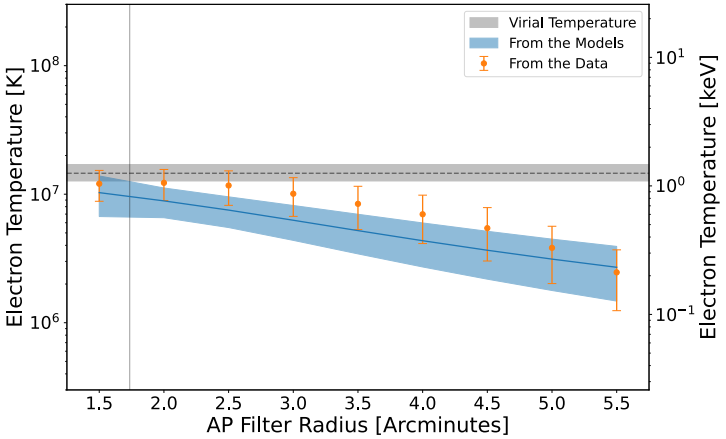

The electron temperature profile given by the ratio of the kSZ and tSZ measurements of DES redMaGiC galaxies.

M. Mallaby-Kay et al.
Physical Review D, Volume 108, Issue 2, article id.023516

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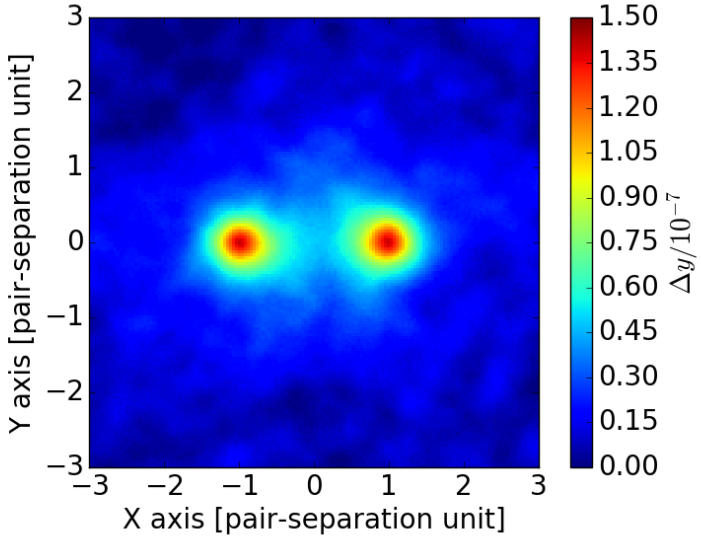

Tanimura et al.
MNRAS, Volume 483 Issue 1

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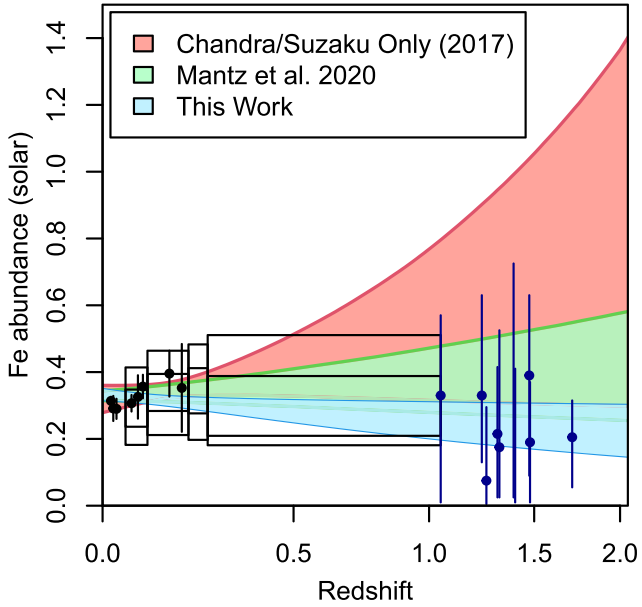

Flores et al.
MNRAS, Volume 507 Issue 4

Path to completion

- Further coordination with LSS and emissive sources to define boundaries in chapters
  - (e.g., protoclusters, cross-correlation of Compton-*y* map with other tracers, kSZ)
- Updating forecasts for CMB-S4 and highlighting science cases with largest gains from Stage 3 → Stage 4 CMB data
  - Check the impact of using end-to-end simulations (like DC)
  - Variations amongst current/upcoming hydrodynamic simulations (CRK-HACC, EAGLE, FIRE, Flamingo, Illustris, Magneticum, SIMBA, ..) as well as “baryonification” of N-body sims (Agora, Baryon-pasters, PICASSO, Websky, …)
- Identifying missed synergies between CMB-S4 and multi-wavelength surveys for cluster/galaxy astrophysics
- Assign writing assignments to members of the group to finish chapter 6.
  - Volunteers at the moment: Jim Bartlett, Lindsey Bleem, Sebastian Bocquet, Jean-Baptiste Melin, Elena Pierpaoli, Srinivasan Raghunathan (+ you!)