Multi-Wavelength Observations of Galaxy Clusters

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CMB-S4 Collaboration Meeting
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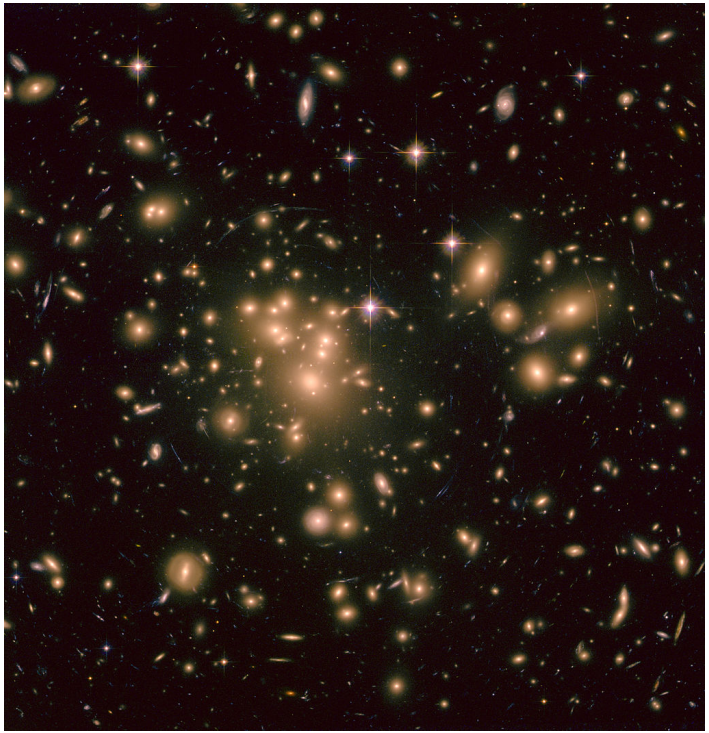
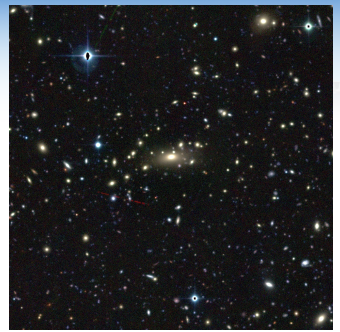
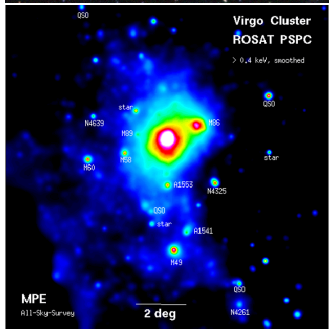
Galaxy Clusters are the largest collapsed objects in the Universe and have Masses $\gtrsim 1 \times 10^{14}\ M_\odot$

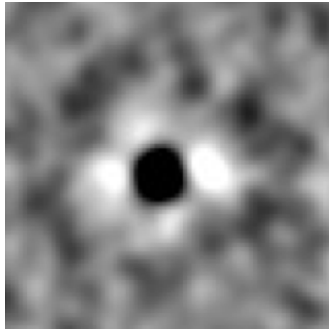
Matter Component	% total mass
Dark Matter	85-90%
Normal Matter	10-15%
Hot Gas	*7-14%*
Galaxies	*0.5-4%*

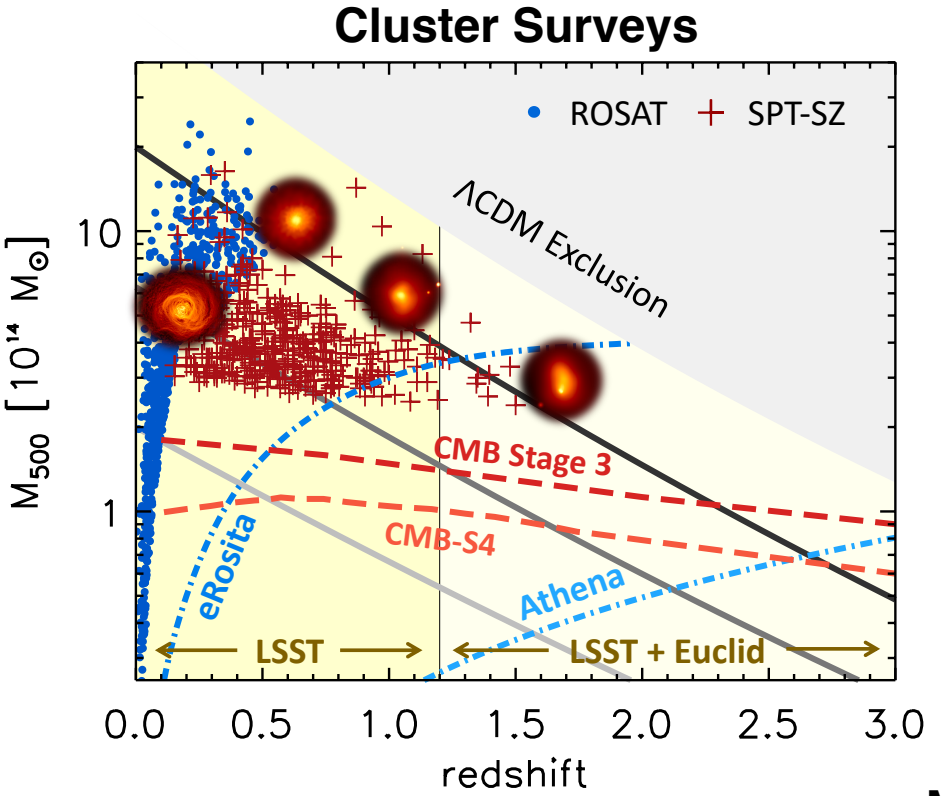


3 Approaches: Optical, X-ray, SZ





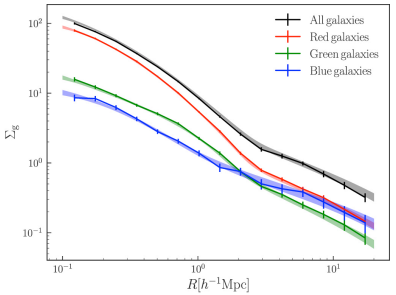




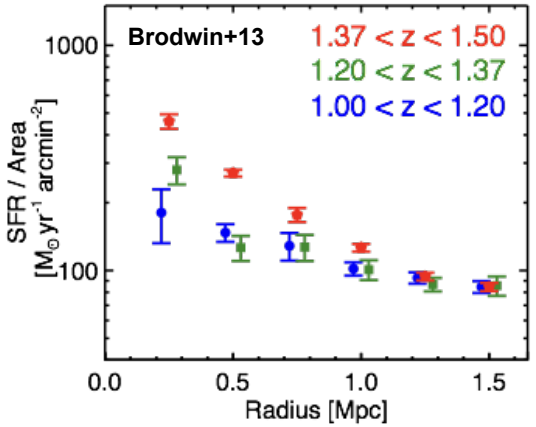
Mantz+ 1903.05606

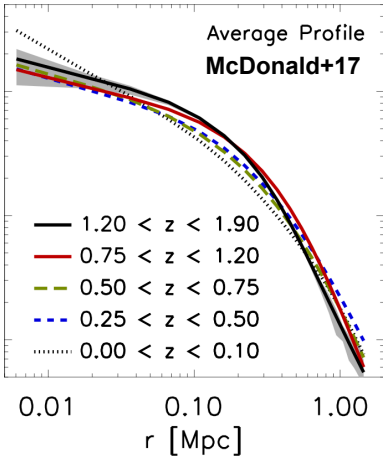
Galaxy Clusters are powerful probes of both cosmology and astrophysical processes.

Combined with other next generation multi-wavelength surveys, the combined CMB-S4 cluster and protocluster sample will offer an unprecedented opportunity to explore the evolution of both the intracluster medium and the most massive galaxies across the entire epoch of cluster formation.

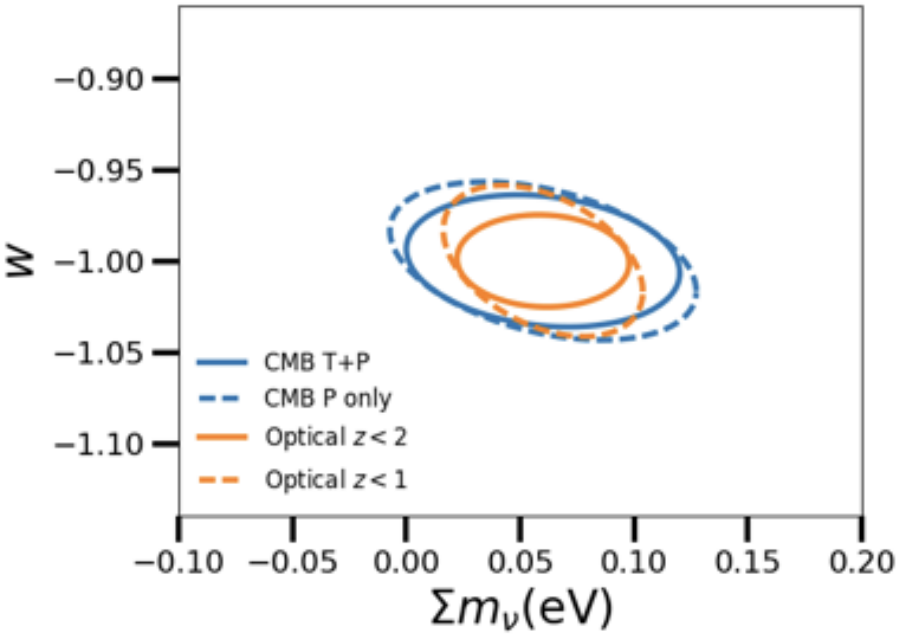


Adhikari+21

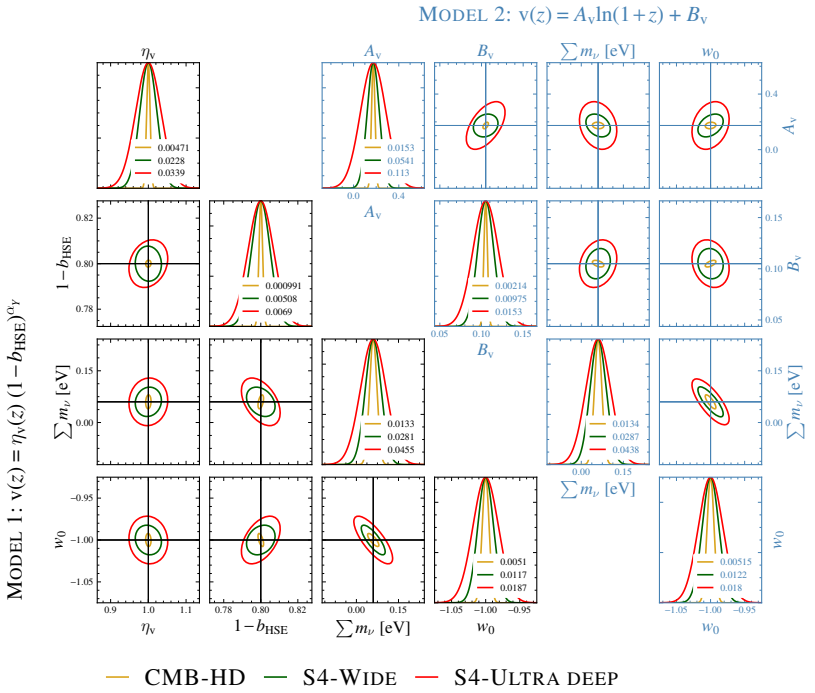




“The number of massive galaxy clusters could emerge as the most powerful cosmological probe…

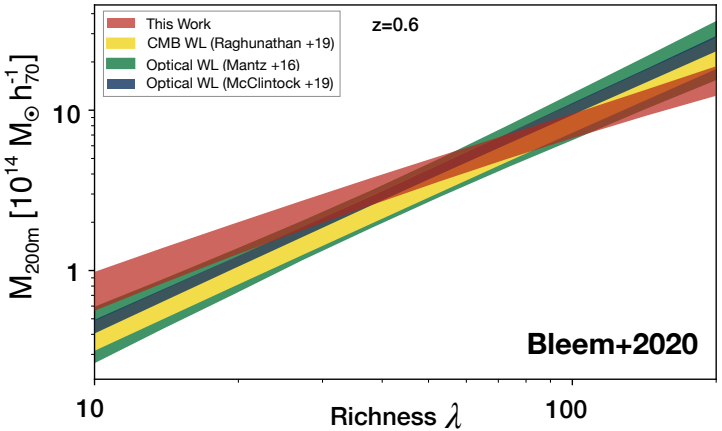


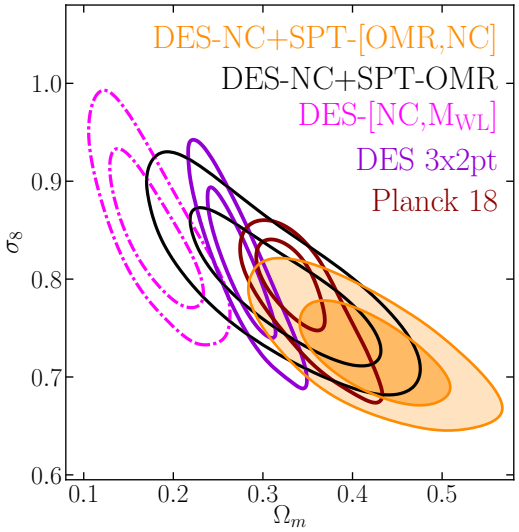
Madhavacheril, Battaglia, Miyatake 2017



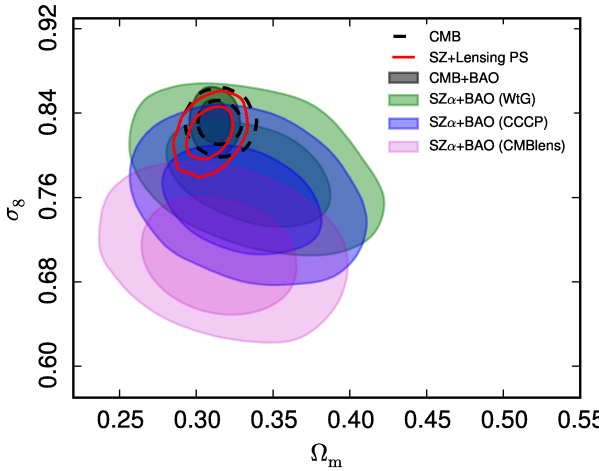
Raghunathan+21

… [if systematics can be controlled]”
- DOE Cosmic Visions Dodelson+1604.07626



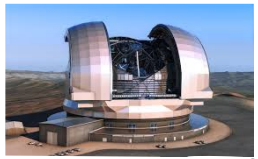


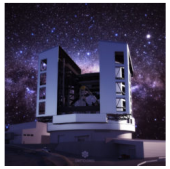
Costanzi+2021
DES Collaboration 2020



Planck Collaboration 2016

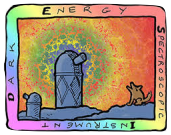
Targeted Observation facilities



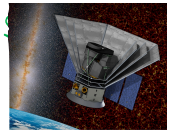


30-m class telescopes

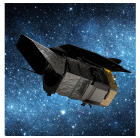
Now	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029



euclid

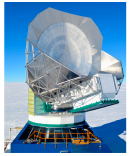


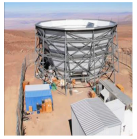
SPHEREx



Roman

SKA
SQUARE KILOMETRE ARRAY





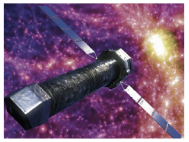
SIMONS OBSERVATORY

Rubin Observatory

SuMIRe Prime Focus Spectrograph

Survey class facilities

Targeted Observation facilities



Athena

ngvla

X-RAY OBSERVATORY LYNX

LUVOIR

2030-2035

ORIGINS Space Telescope

2035-2040?

lisa

Survey class facilities

Conclusion

- SZ cluster selection will lead to fantastic samples for cosmological and astrophysical studies. CMB-S4 will detect >70,000 SZ clusters.
- Multi-wavelength survey data will be crucial in identifying and mitigating potential systematic baises.
- The future is bright! Wide variety of cutting-edge targeted and survey facilities coming online over the next decade+ that will enable us to achieve the full potential of the CMB-S4 cluster sample to constrain cosmological and astrophysical models.