Mass Estimation of Galaxy Clusters with Deep Learning

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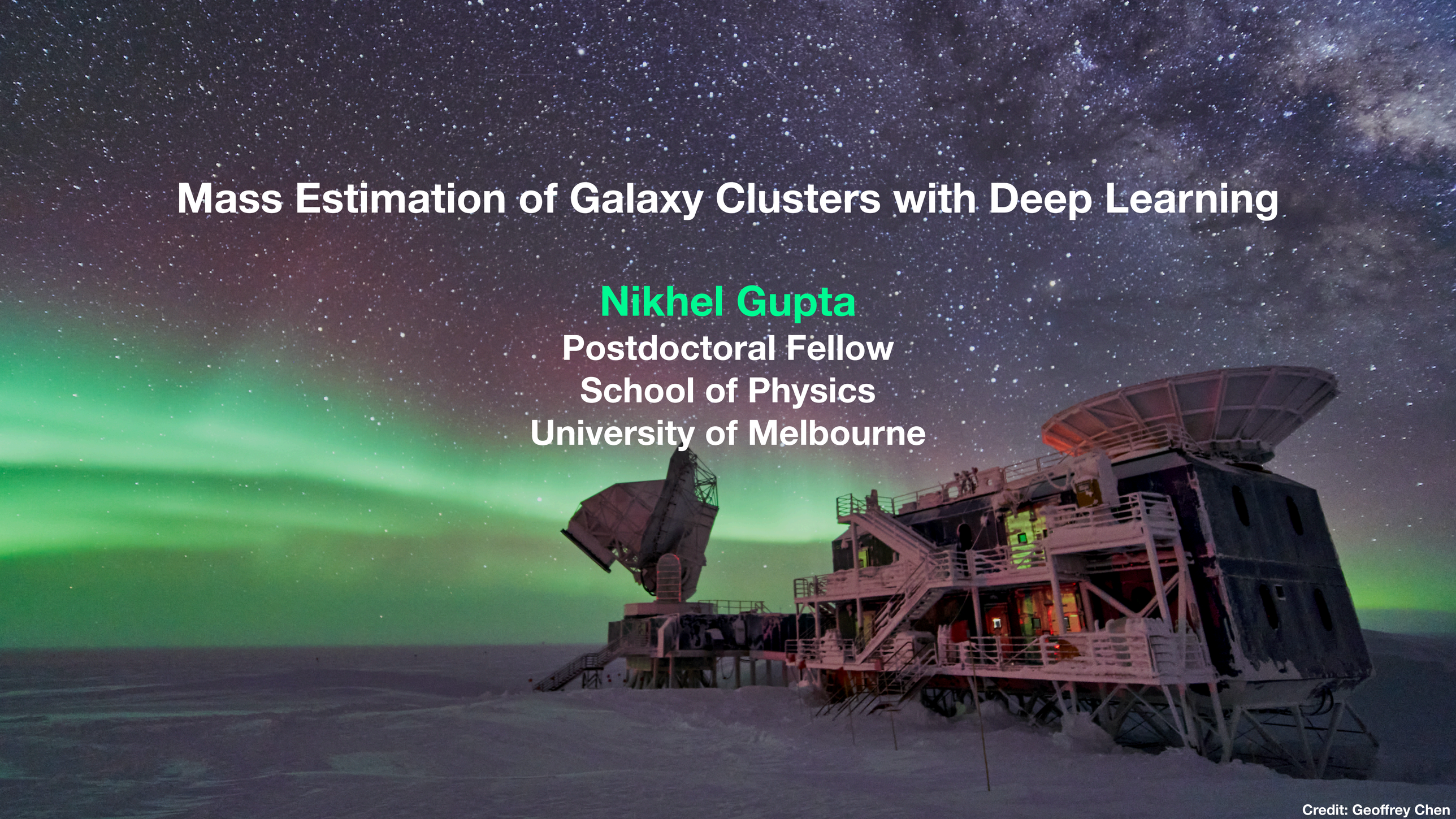
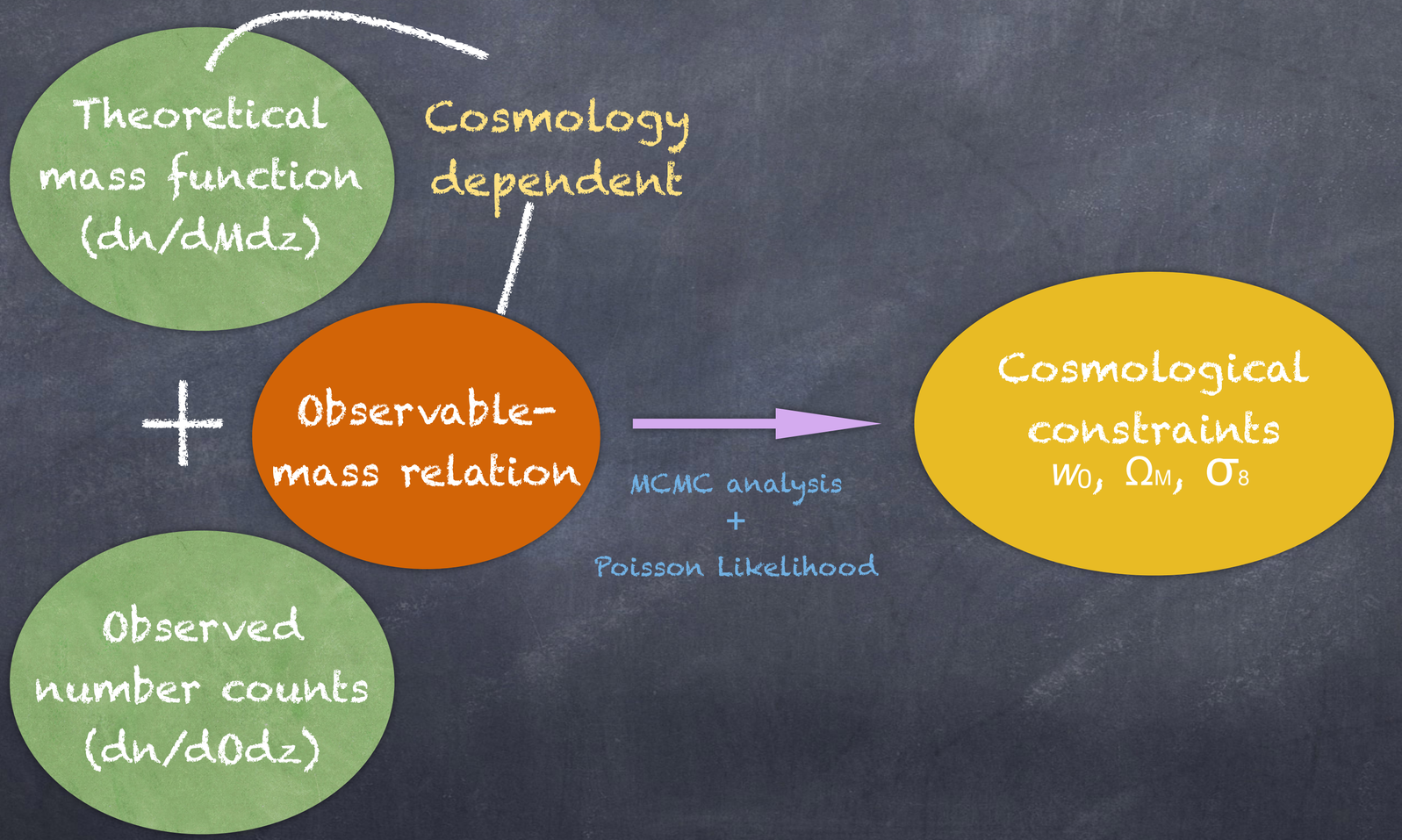


Credit: Geoffrey Chen

Outline

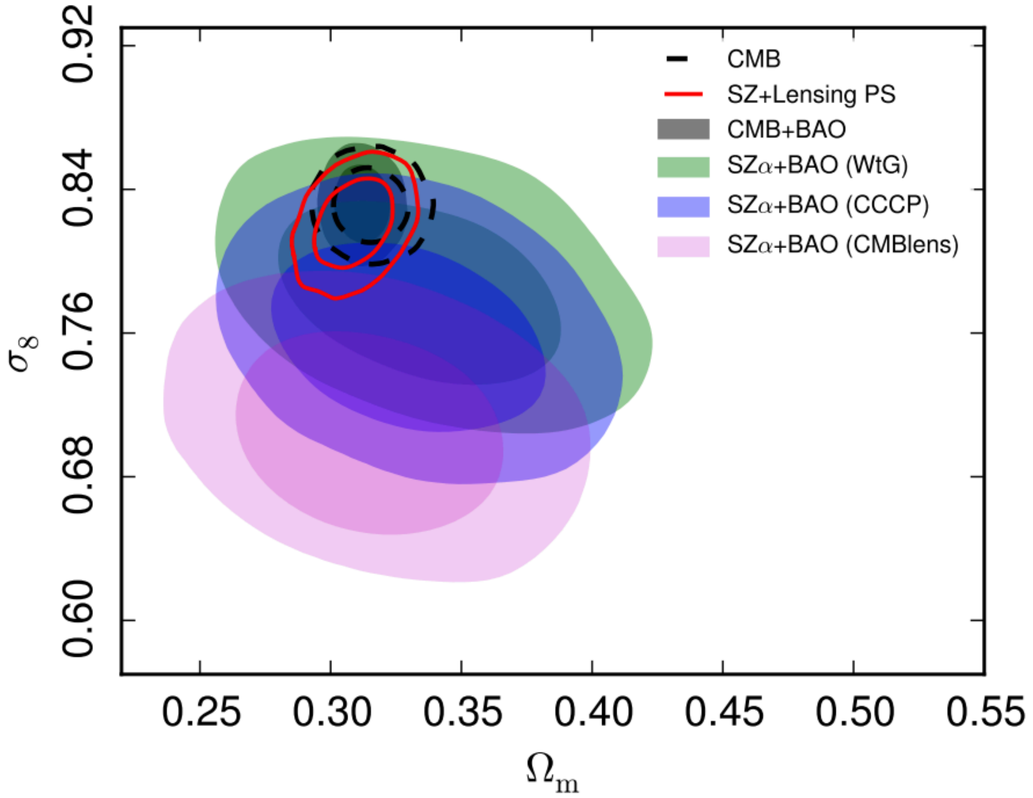
- Why are we interested in mass of galaxy clusters?
- Overview of Sunyaev Zel'dovich (SZ) Effect.
- The deep learning model.
- Estimating SZ mass directly from the images of the microwave sky.

Galaxy Clusters for Cosmology

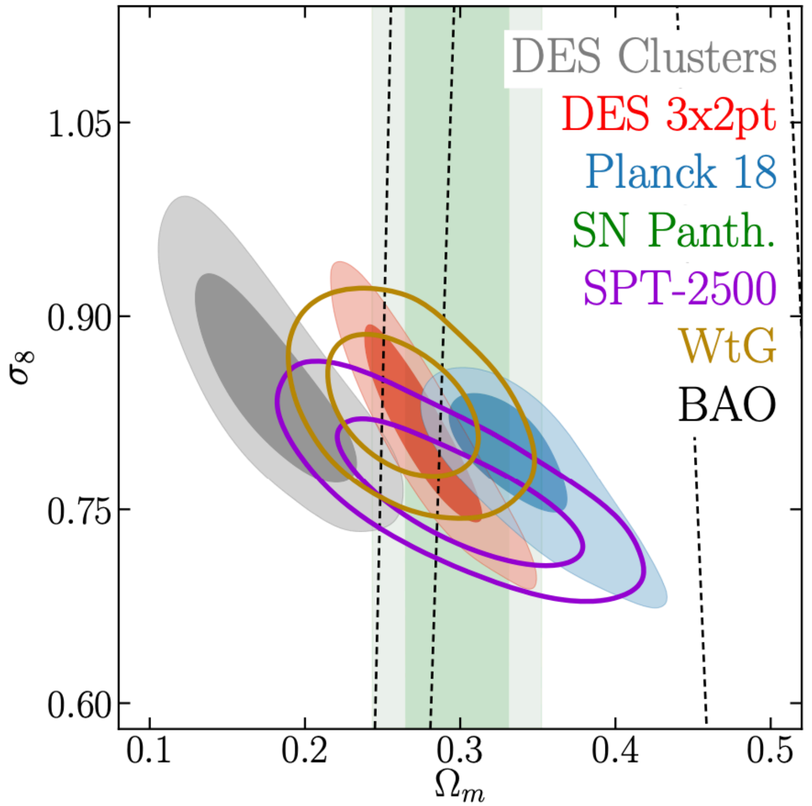


Why galaxy cluster masses are crucial?

- At present, cluster abundance studies are limited by the ability to calibrate the relation between halo mass and the observable.

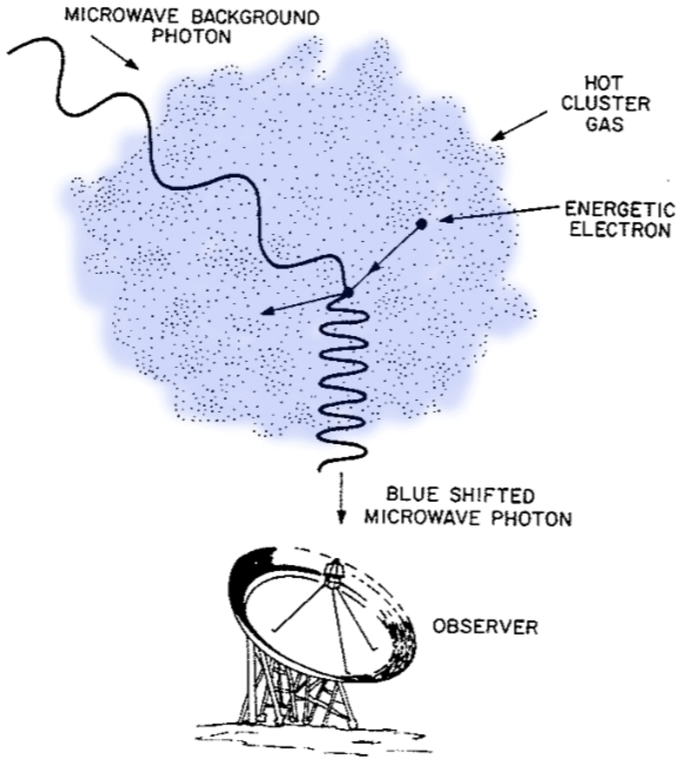


Planck Collaboration (2015)

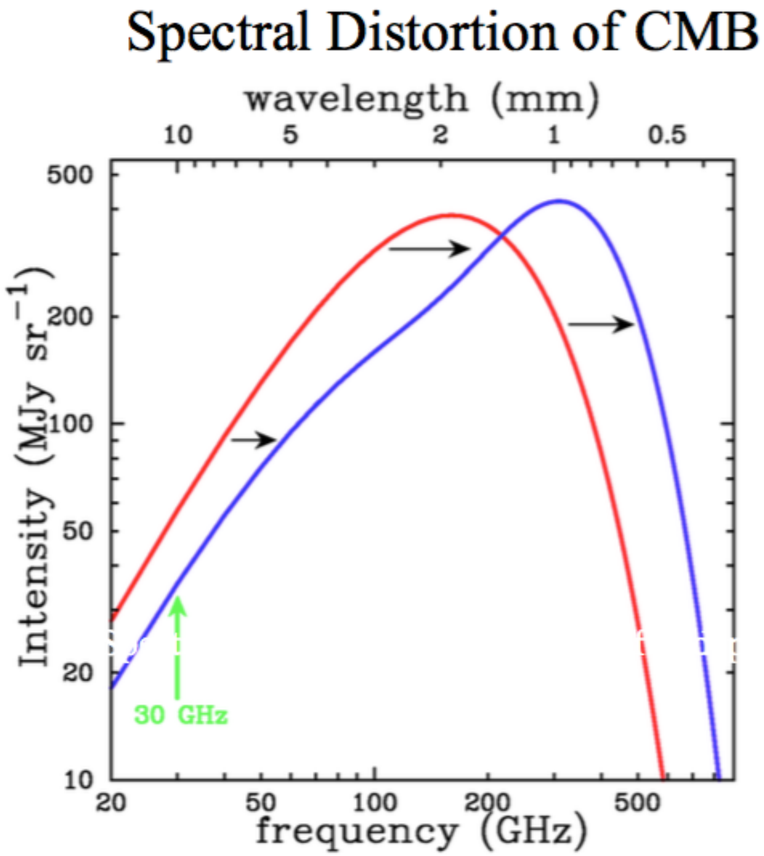


DES collaboration (2020)

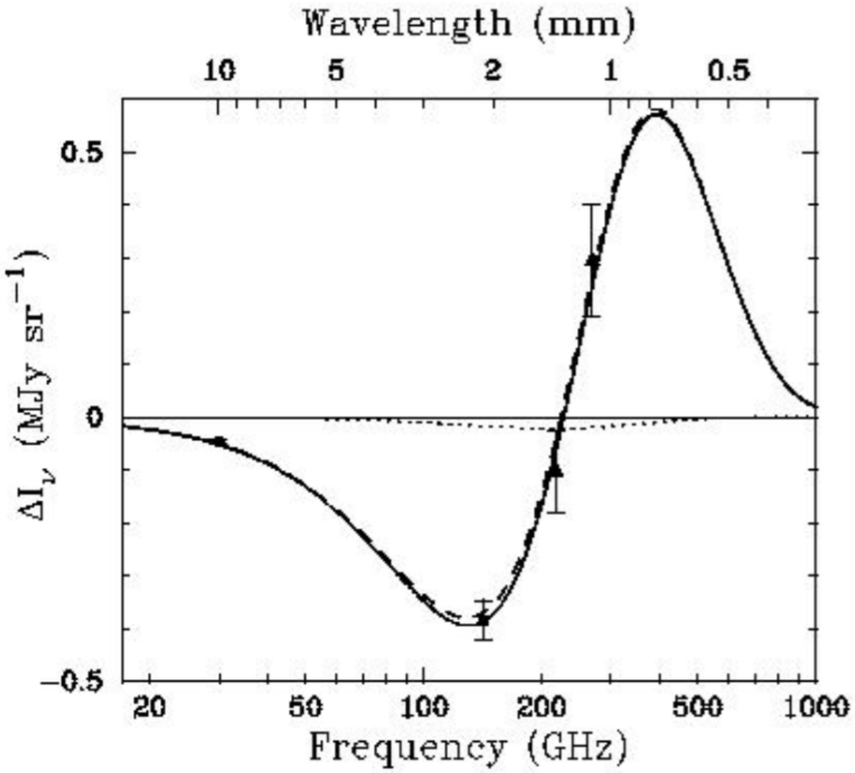
Sunyaev Zel'dovich (SZ) Effect



Adapted from L. Van Speybroeck

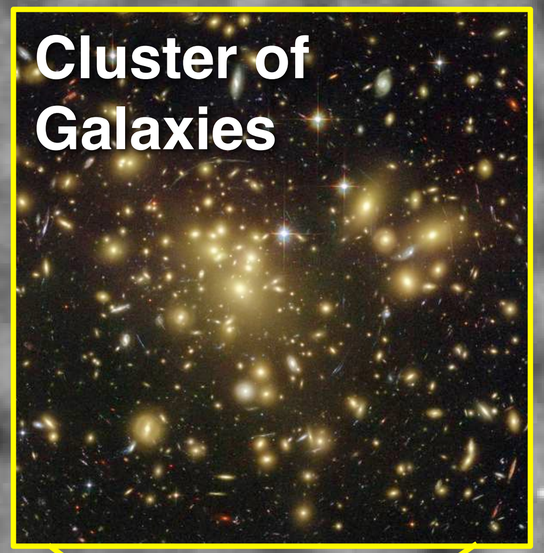


Sunyaev & Zel'dovich 1970, 1972

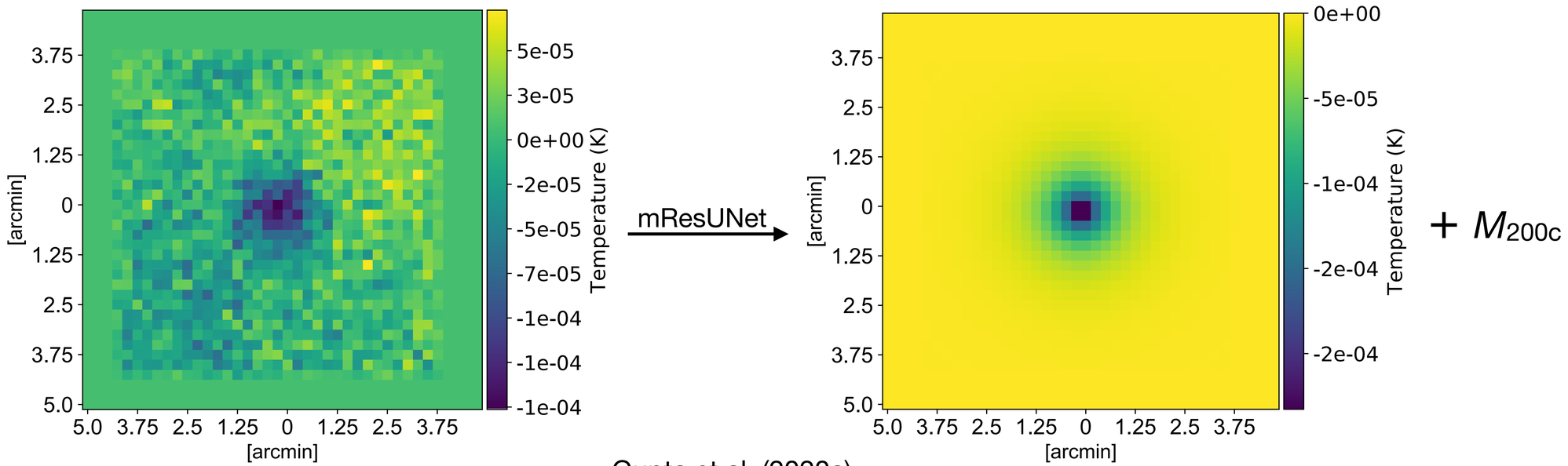


SPTpol
150 GHz
50 deg^2

Clusters of Galaxies
"Shadows" in the microwave background from clusters of galaxies. The **Sunyaev-Zel'dovich (SZ)** effect



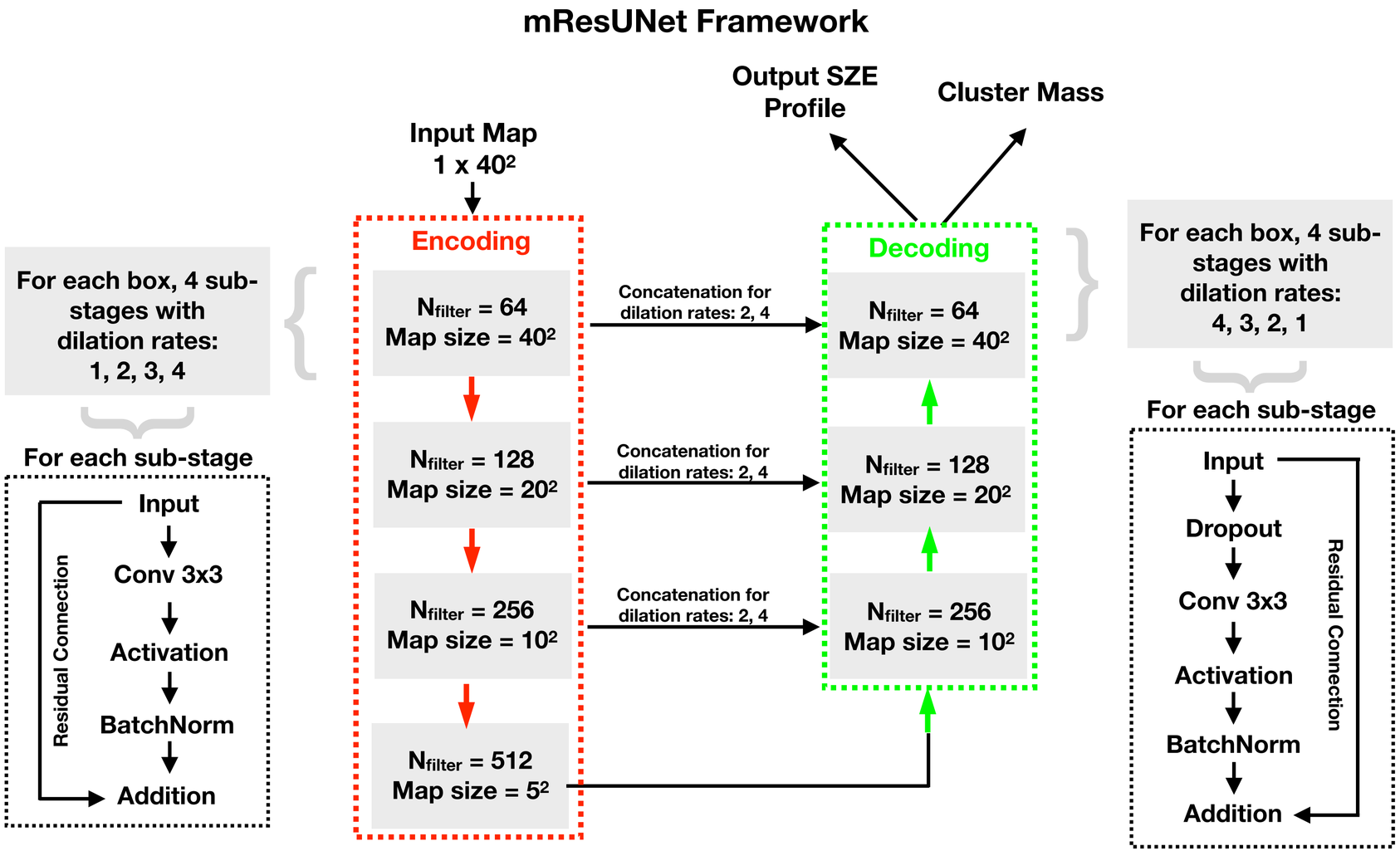
Simulations



Gupta et al. (2020a)

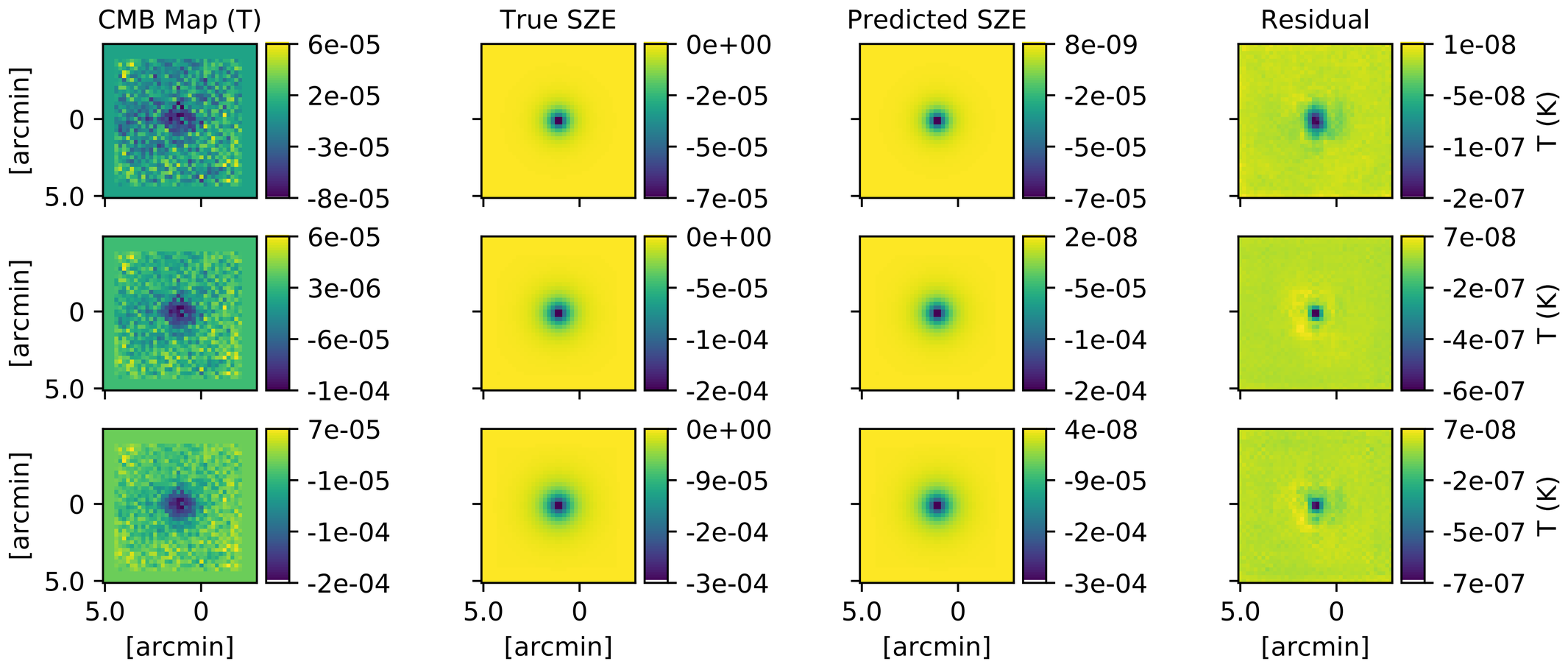
- 19 distinct set of simulations for galaxy clusters with M_{200c} = (0.5, 0.75, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8, 9, 10)×10^{14} M_{sol} at z = 0.7
- Microwave sky: Gaussian realisations of CMB + Astrophysical foregrounds (George+ 2015) + 5 uK-arcmin noise + 1 arcmin beam smoothing + SZ signal (Arnaud+ 2010) + 20% log-normal scatter on SZ.
- Training + Validation sample —> 400 + 200 maps for each cluster mass.
- Testing the trained model —> 200 maps for each cluster mass.

Deep learning model



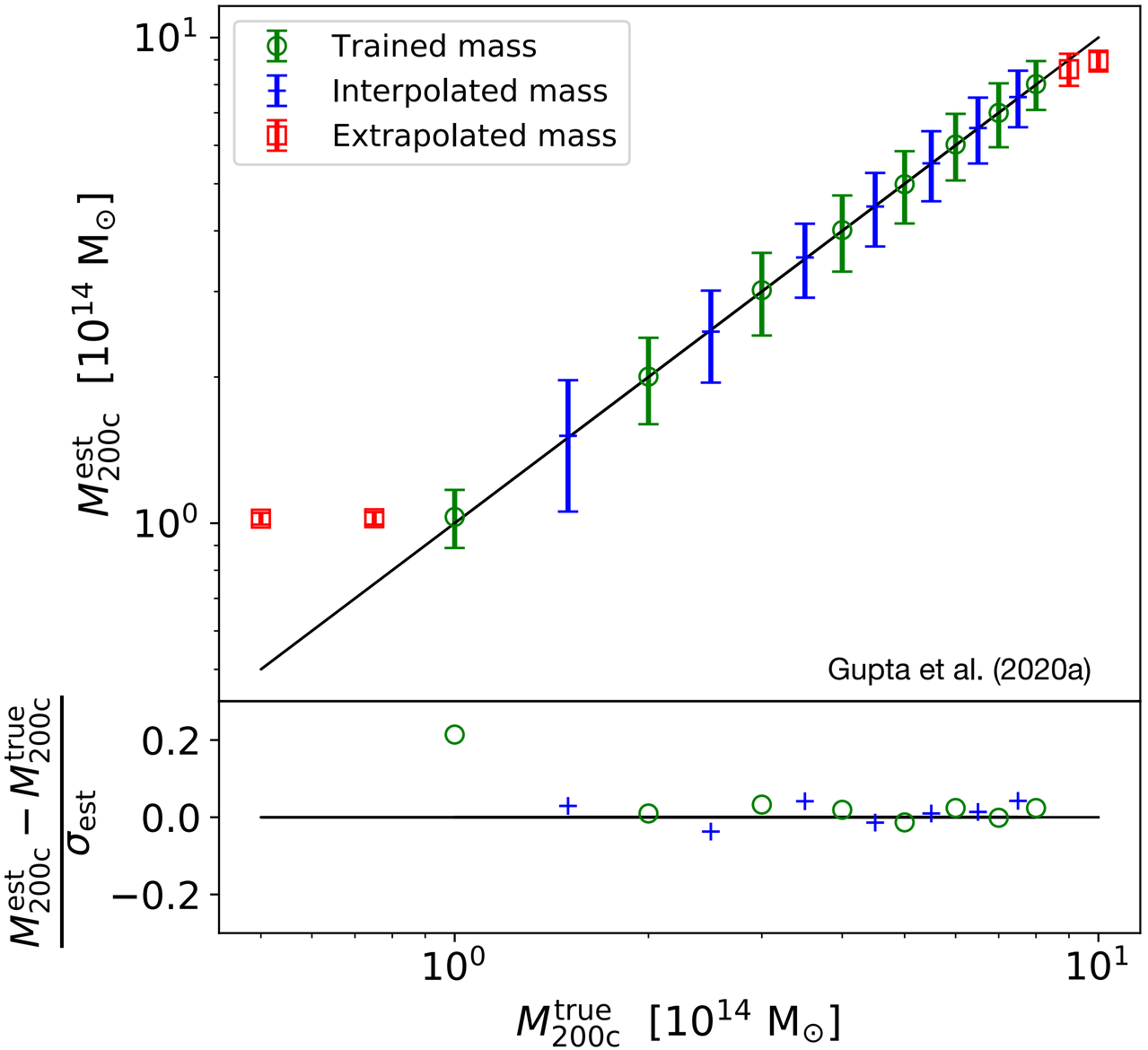
Gupta et al. (2020a)

Results: SZE profiles

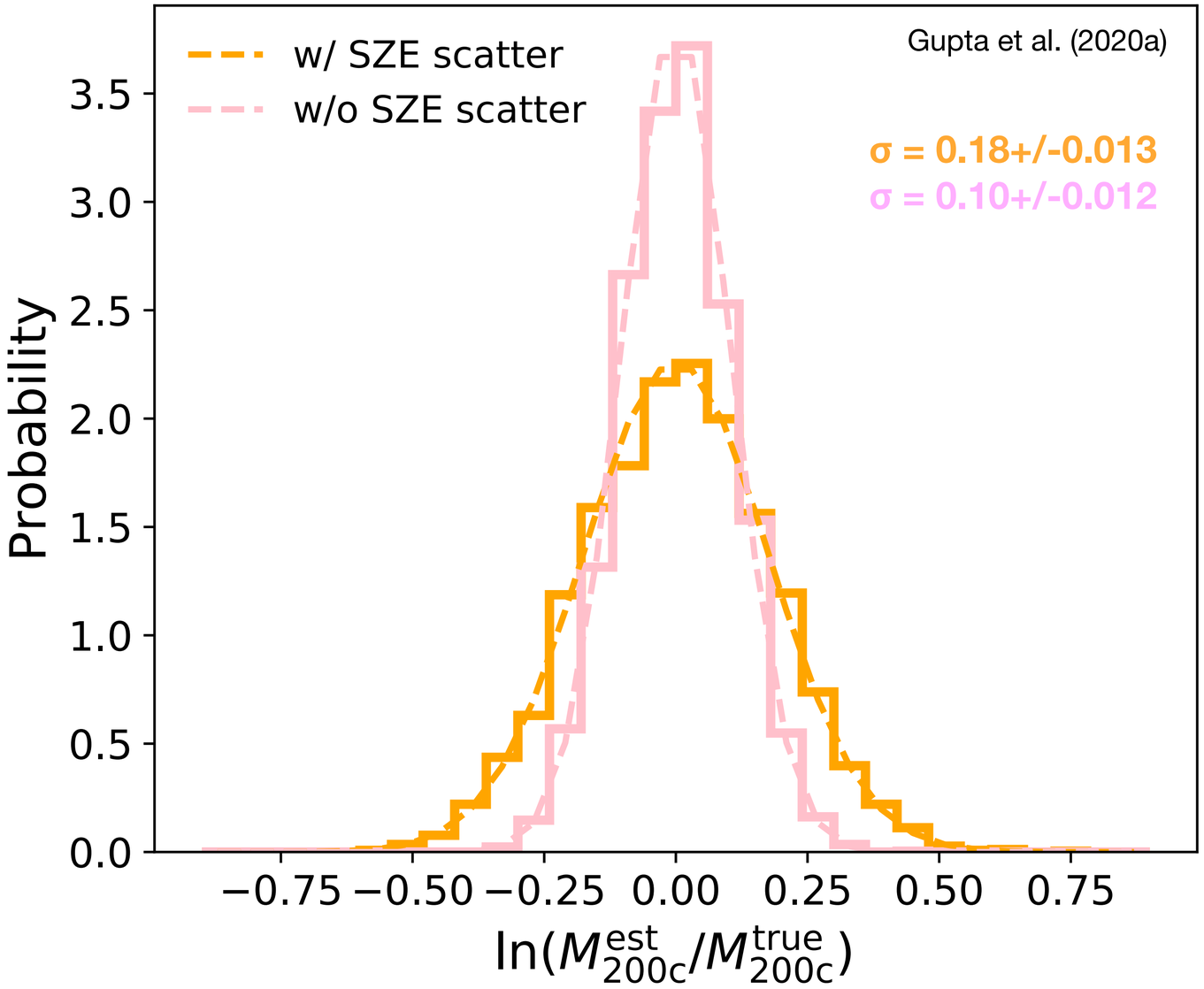


Gupta et al. (2020a)

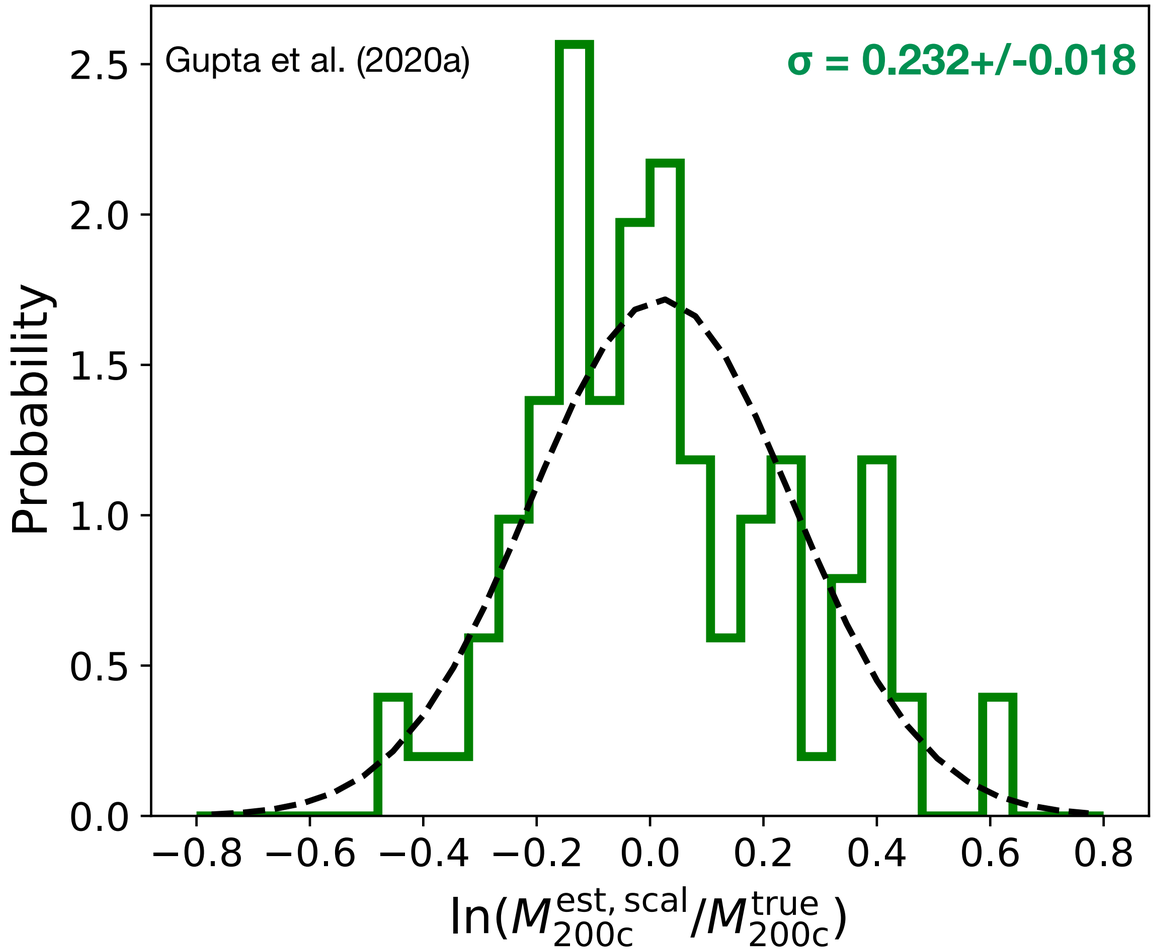
Results: Mass Estimations



Results: Scatter



Results: Testing with External Hydrodynamical Simulations (Magneticum)



In the same light cone, the log-normal scatter in Y-mass relation = 0.194 (Gupta et al. 2017)

Conclusions

(see Gupta et al. 2020a, arXiv:2003.06135, accepted in APJ)

- We can now estimate the mass of galaxy clusters just by looking at them in the microwave sky using deep learning/ computer vision models.
- The log-normal scatter (observational + intrinsic) for M_{est} as a mass proxy is consistent with intrinsic scatter for SZ *Y* signal.

Not discussed today!

(CMB cluster lensing with deep learning; see Gupta et al. 2020c, arXiv:2005.13985, accepted in APJ)