Exploring the Dark Universe with the Simons Observatory

Steve Choi (Cornell)
for the Simons Observatory Collaboration

Rencontres de Blois
May 25, 2022

Photo: Debra Kellner

Simons Observatory (SO)

SIMONS FOUNDATION
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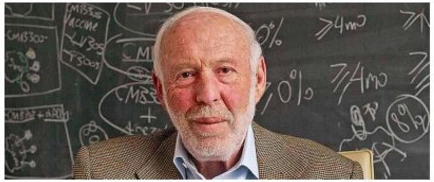


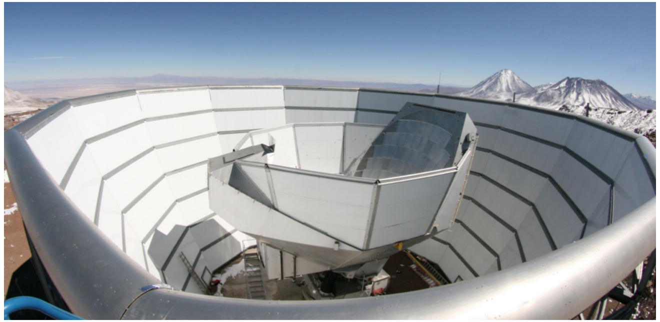
>10 countries, >300 people

Planck

2009 – 2013
Full sky

0.35 – 10 mm (9 bands)
5 – 33’ resolution

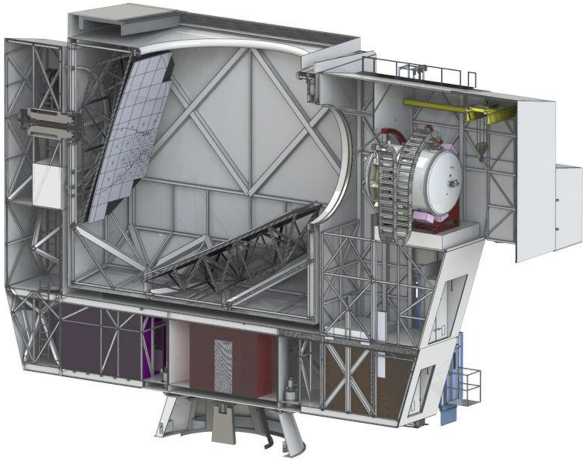
Atacama Cosmology Telescope



2008 – 2022+
~40% sky fraction
Noise ~1.5–3 times better than Planck

1.4 – 10 mm (5 bands)
1 – 7’ resolution

Simons Observatory



2023 – 2030+
~40% sky fraction
Noise ~3 times better than ACT

1 – 10 mm (6 bands)
1 – 7’ resolution

Summary of SO key science goals

SO science overview
(arXiv:1808.07445)

	Parameter	SO-Baseline[b] (no syst)	**SO-Baseline**[c]	SO-Goal[d]	Current[e]	Method	Sec.
Primordial perturbations	r	0.0024	**0.003**	0.002	0.03	BB + ext delens	3.4
	$e^{-2\tau}\mathcal{P}(k=0.2/\mathrm{Mpc})$	0.4%	**0.5%**	0.4%	3%	$TT/TE/EE$	4.2
	$f_{\mathrm{NL}}^{\mathrm{local}}$	1.8	**3**	1	5	$\kappa\kappa \times$ LSST-LSS + 3-pt	5.3
		1	**2**	1		kSZ + LSST-LSS	7.5
Relativistic species	N_{eff}	0.055	**0.07**	0.05	0.2	$TT/TE/EE + \kappa\kappa$	4.1
Neutrino mass	Σm_ν	0.033	**0.04**	0.03	0.1	$\kappa\kappa$ + DESI-BAO	5.2
		0.035	**0.04**	0.03		tSZ-N $\times$ LSST-WL	7.1
		0.036	**0.05**	0.04		tSZ-Y + DESI-BAO	7.2
Deviations from Λ	$\sigma_8(z=1-2)$	1.2%	**2%**	1%	7%	$\kappa\kappa$ + LSST-LSS	5.3
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How many relativistic species are there?

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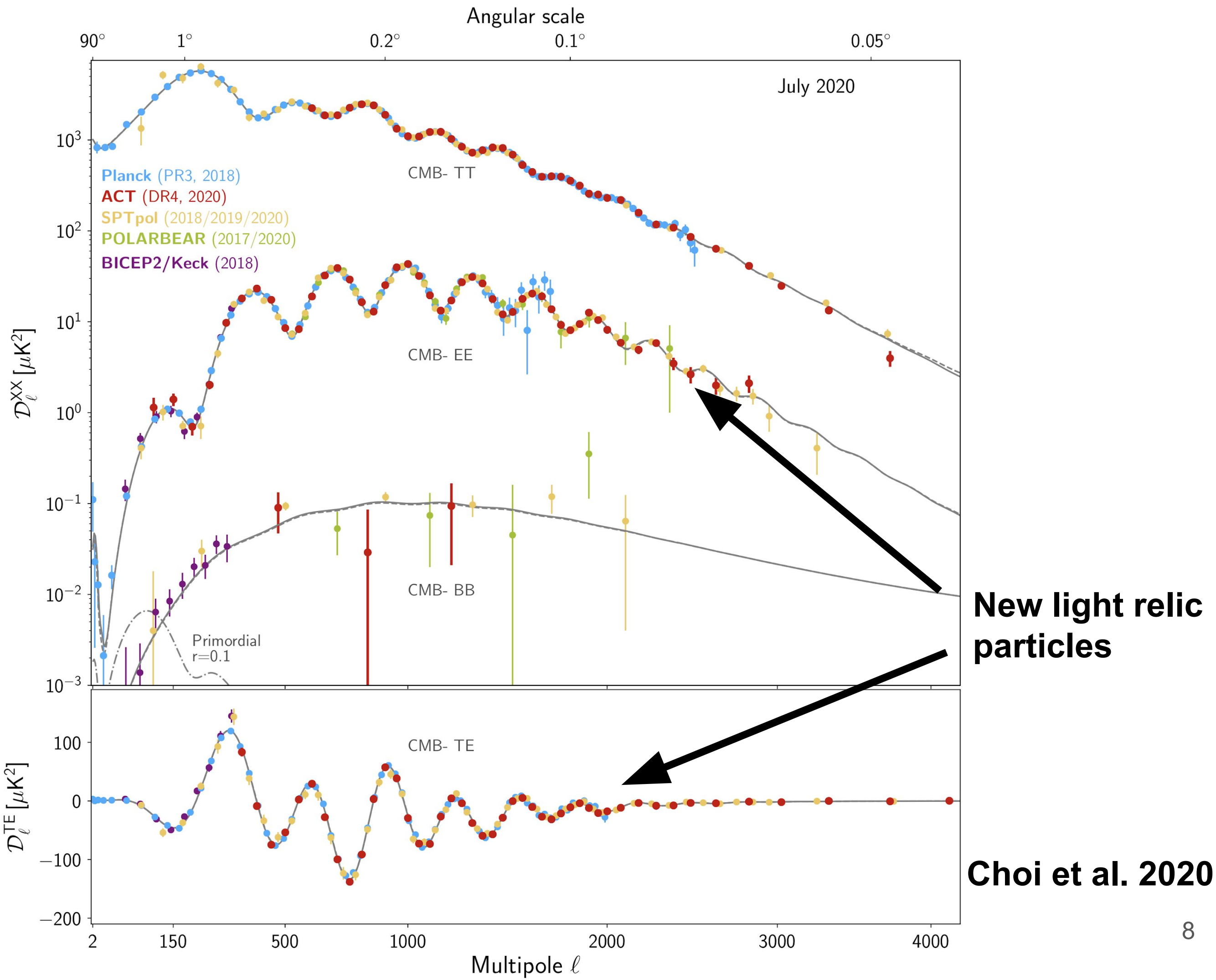
Fundamental physics from the CMB with SO



Choi et al. 2020

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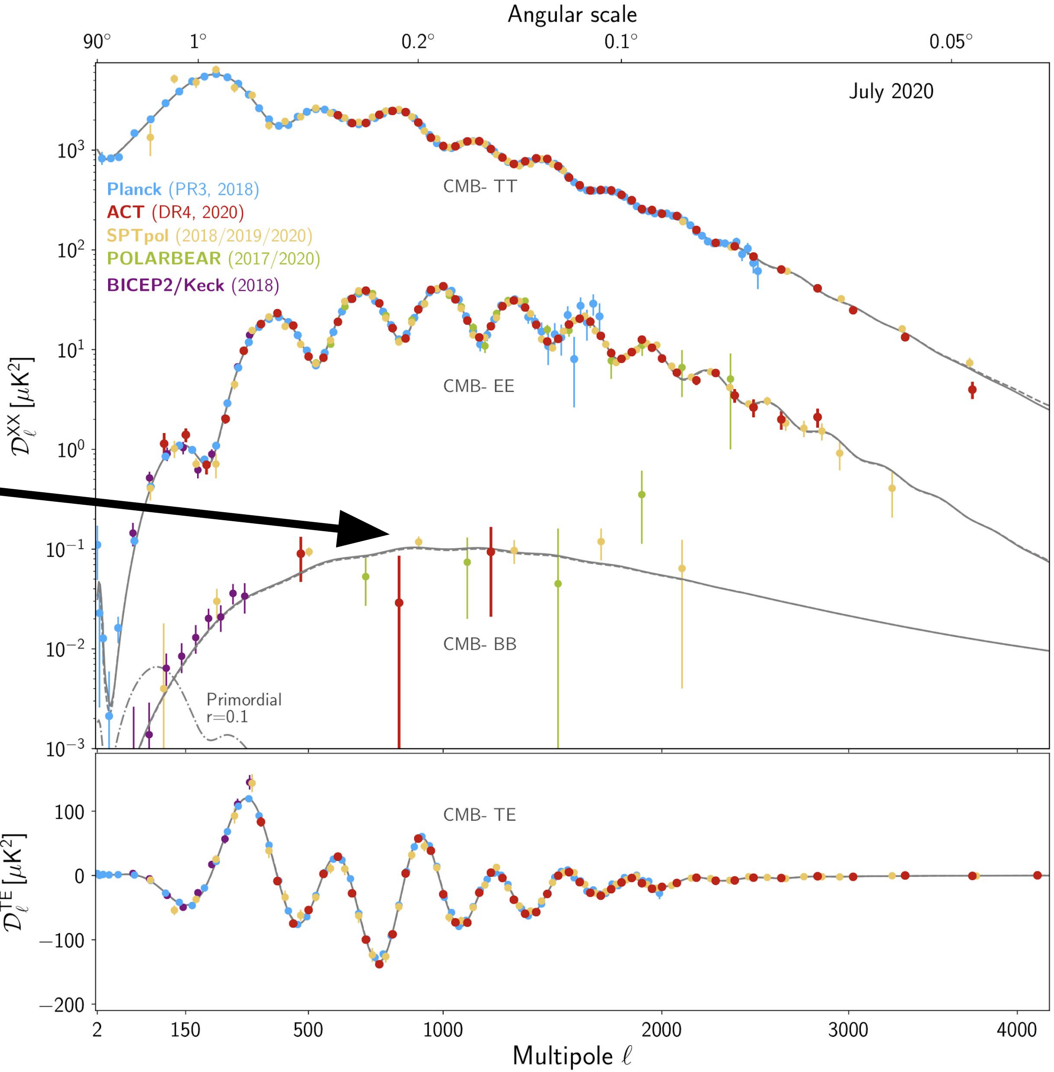
What is the mass sum of the neutrinos?

Fundamental physics from the CMB with SO

Neutrino mass sum from CMB lensing due to large scale structure



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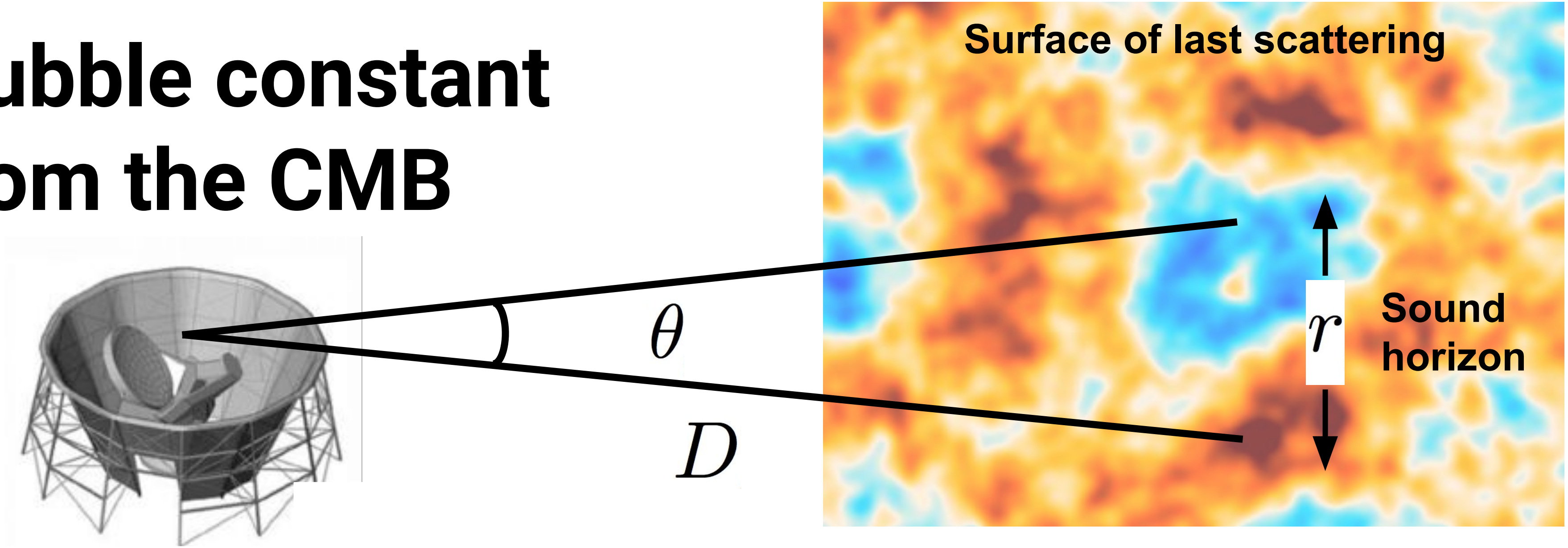
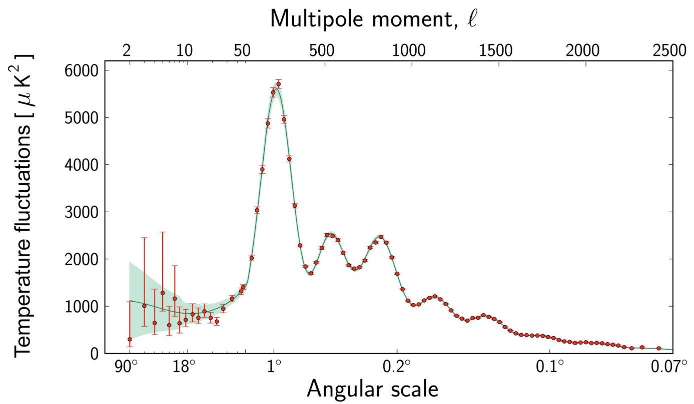
Is the accelerated expansion just Λ?

Hubble constant from the CMB





$$D_A^* = r_s^* / \theta^*$$

bigger distance = older universe
older universe = smaller expansion rate

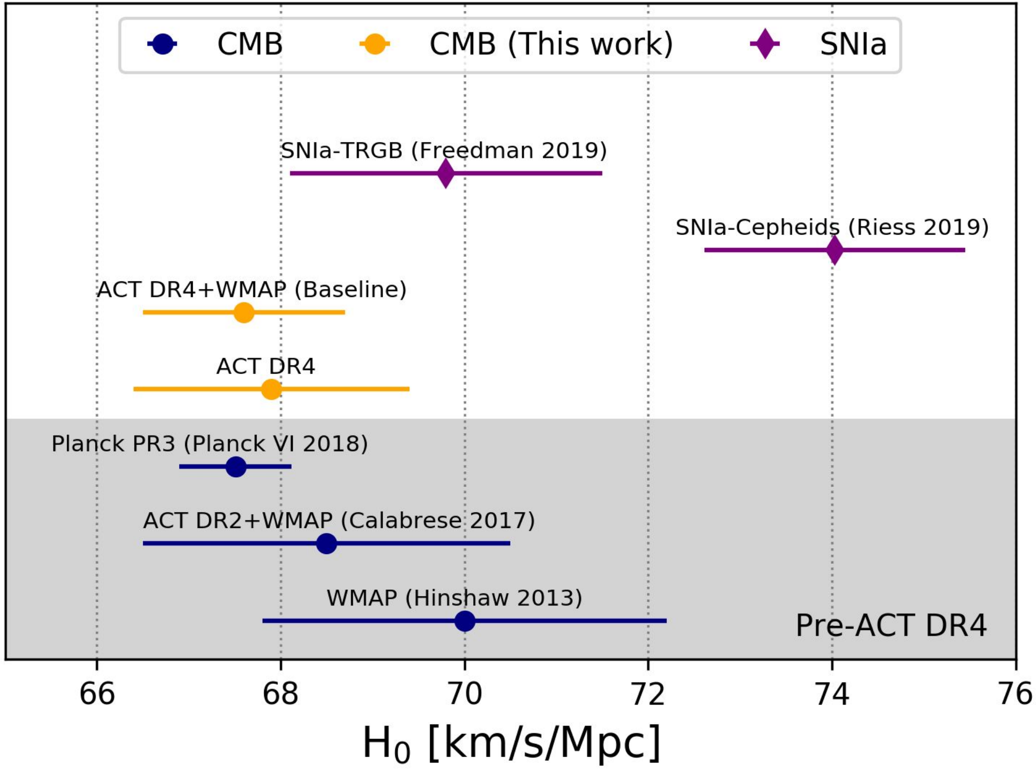
ACT DR4 H_0 Estimate (blind analysis)

ACT DR4 + WMAP: H_0= 67.6 ± 1.1 km/s/Mpc

- agrees with Planck within 1σ
- agrees with SNIa-TRGB within 1σ
- ~4σ tension with SNIa-Cepheids

Since then, SPT also measured

H_0= 68.8 ± 1.5 km/s/Mpc (Dutcher et al. 2021)



Aiola et al. 2020 **Choi et al. 2020**

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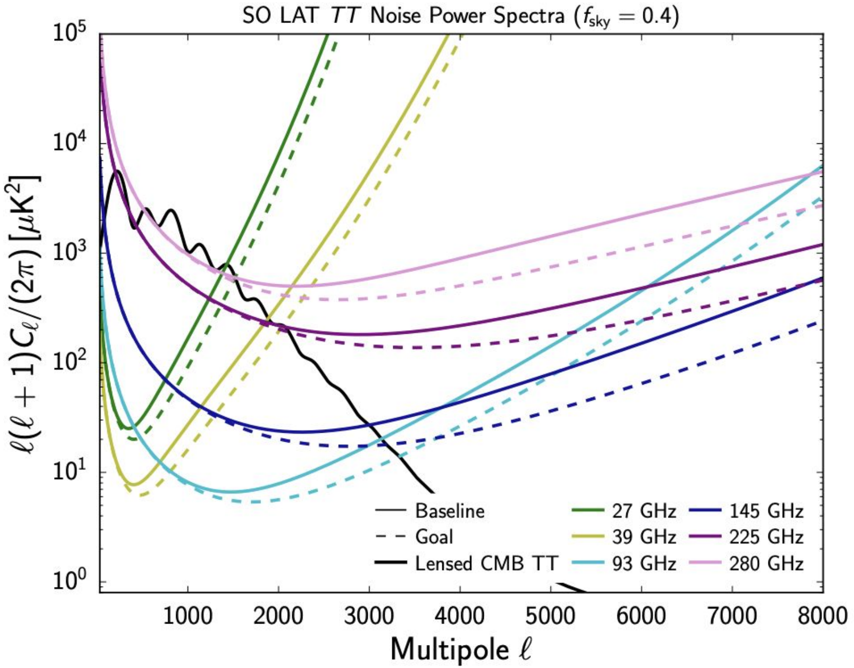
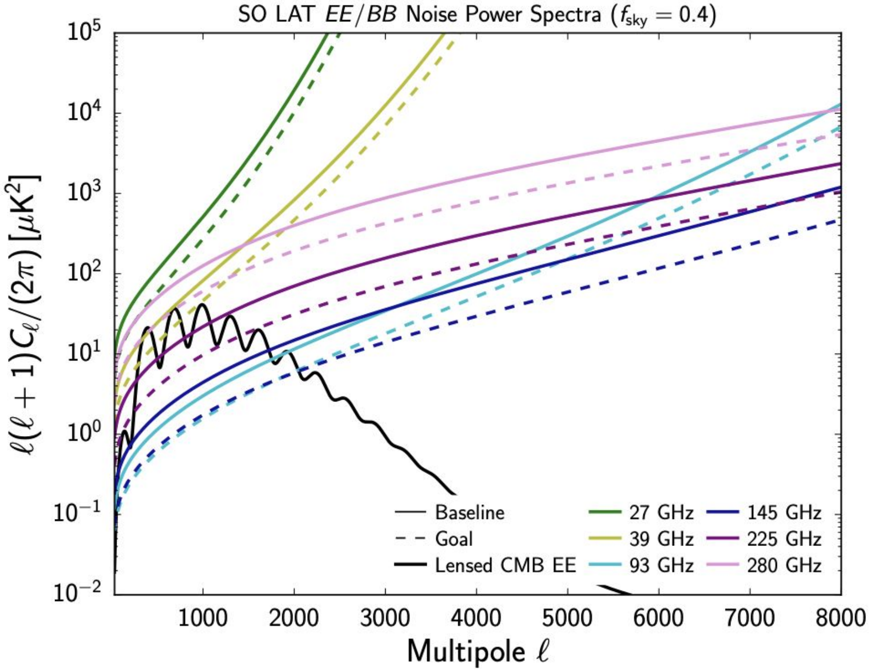
SO noise curves

SO science overview
(arXiv:1808.07445)

With realistic calculations/assumptions on instrument sensitivities and atmospheric noise.



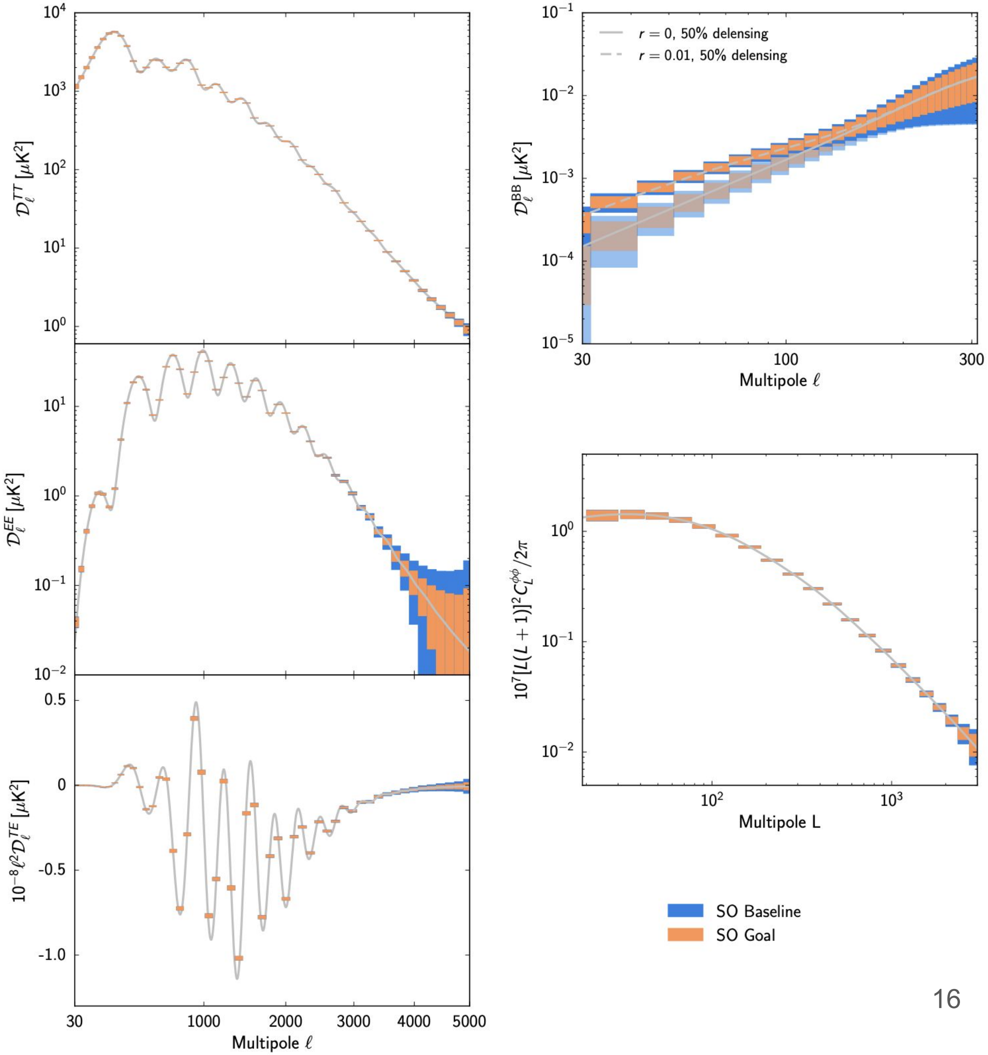


SO simulated power spectra

Need to measure many modes to high precision to study the dark universe with SO.

→ Need a large sky area survey with a large telescope.

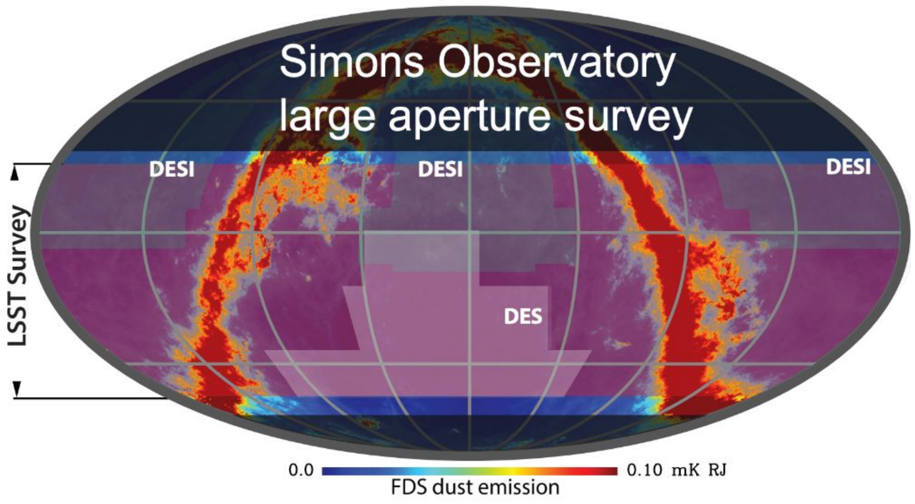
SO science overview (arXiv:1808.07445)



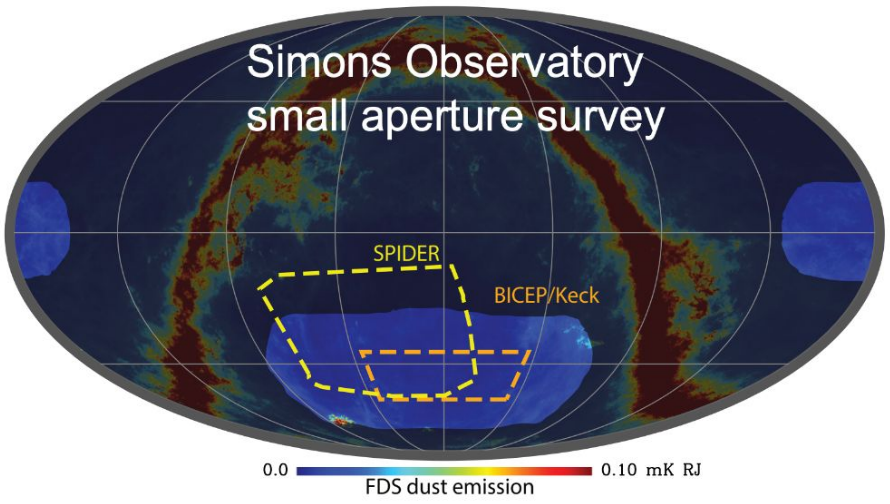
Simons Observatory Survey

SO science overview (arXiv:1808.07445)

Large Aperture Telescope (LAT)

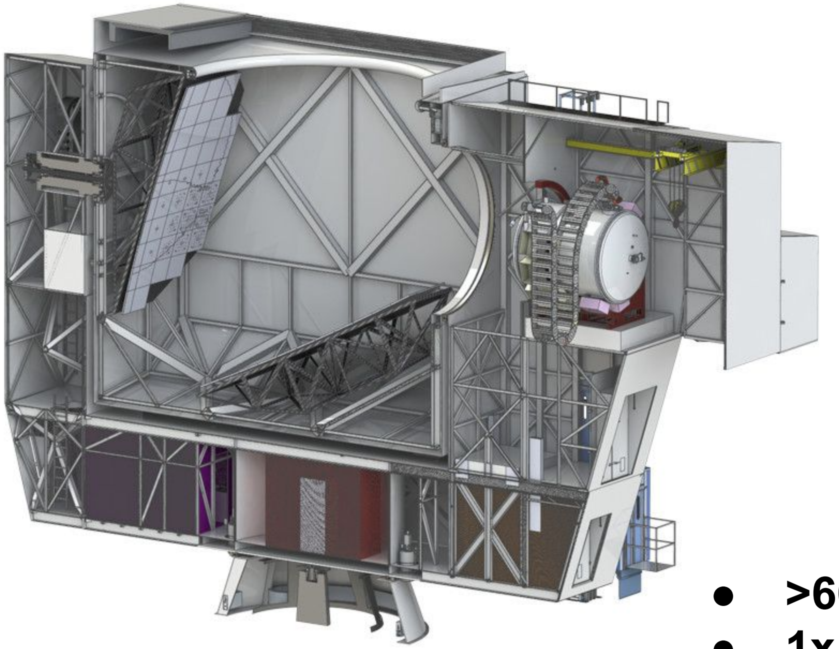


Small Aperture Telescope (SAT)

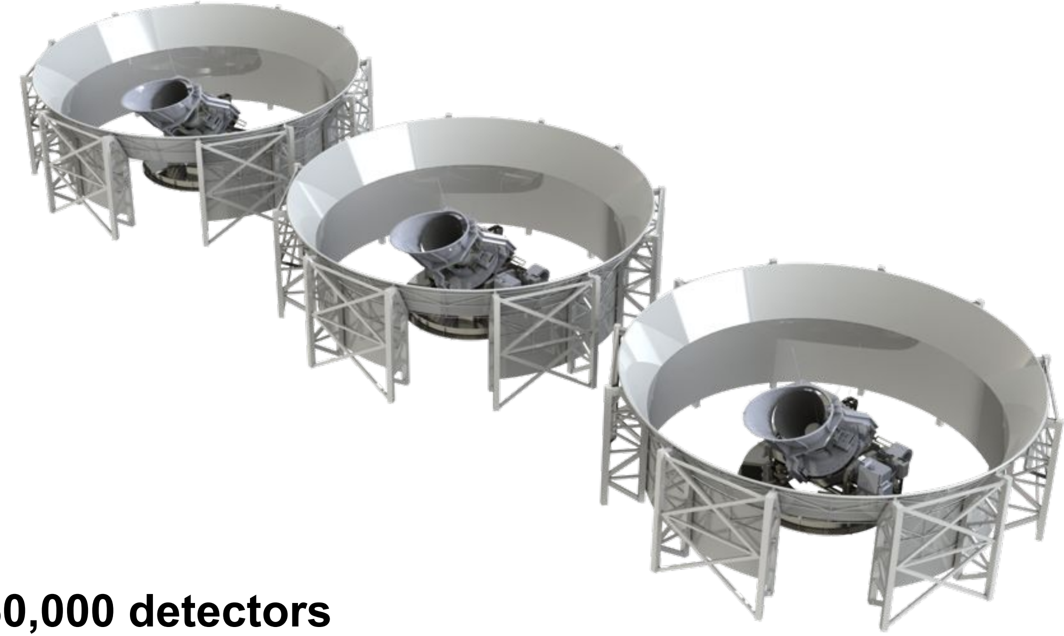


SO telescopes

Large Aperture Telescope



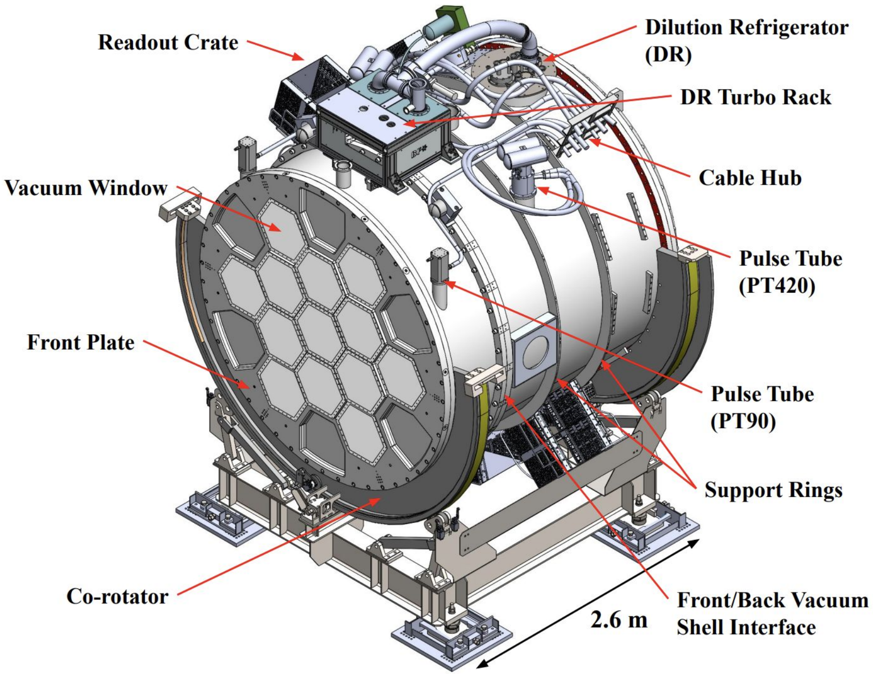
Small Aperture Telescopes



- **>60,000 detectors**
- **1x 6-m large aperture telescope**
- **3x 42-cm small aperture telescopes**

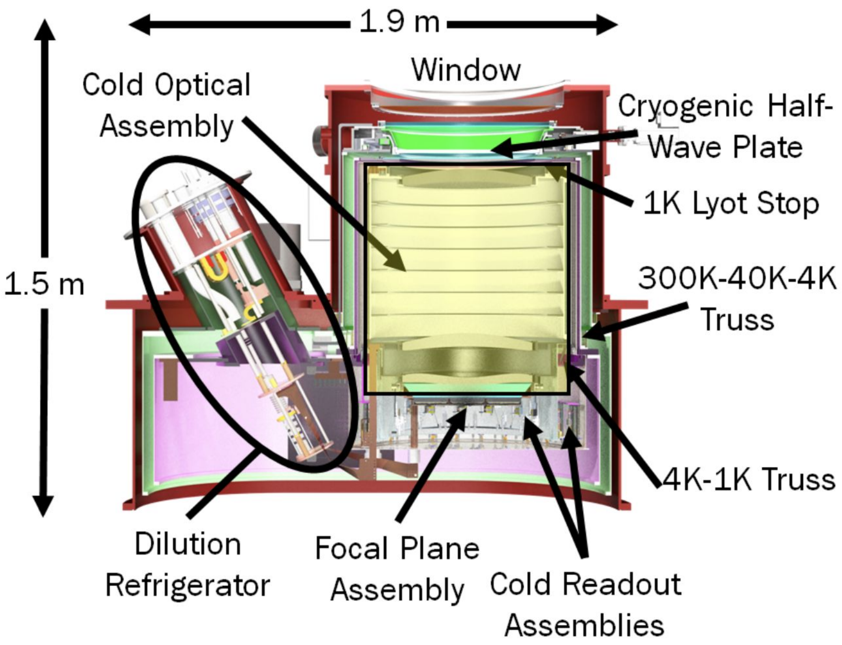
SO telescope receivers

Large Aperture Telescope Receiver



Zhu et al. 2020

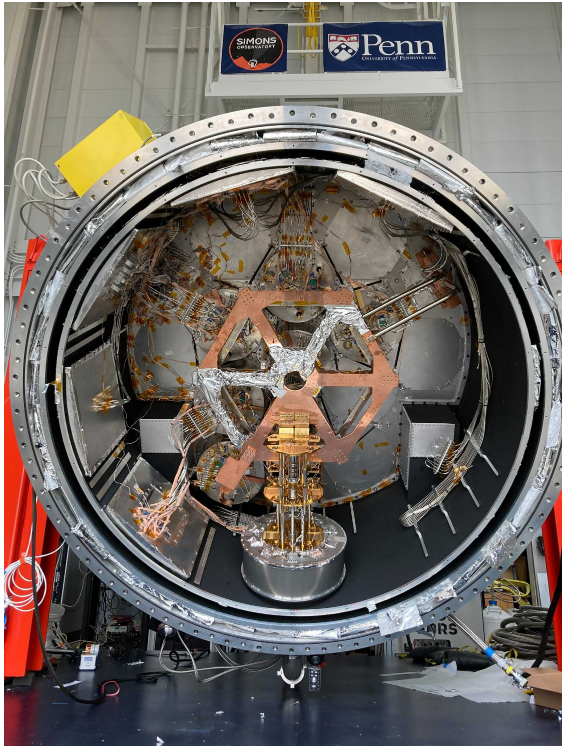
Small Aperture Telescope



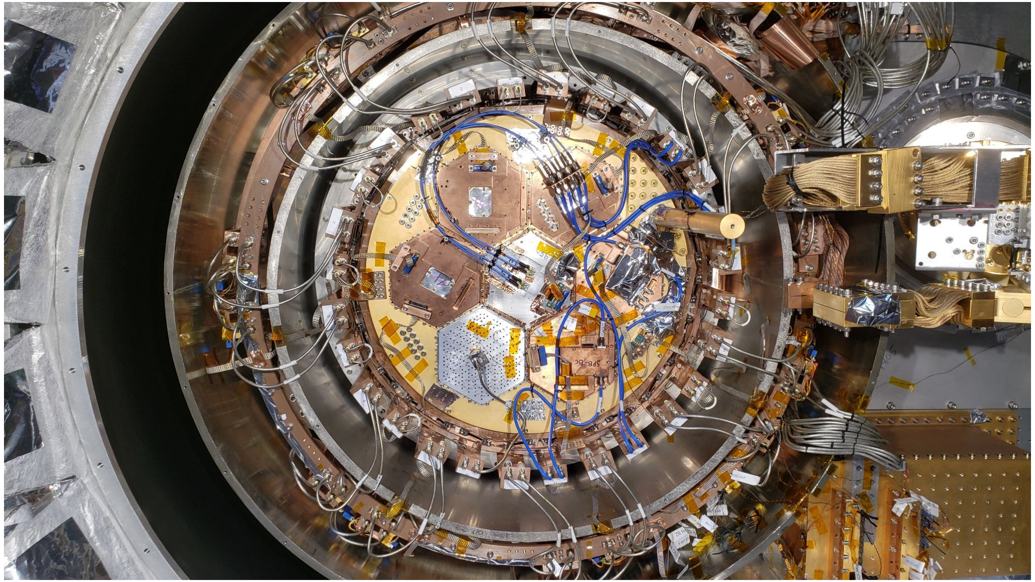
Ali et al. 2020

SO integration and testing

LATR at UPenn

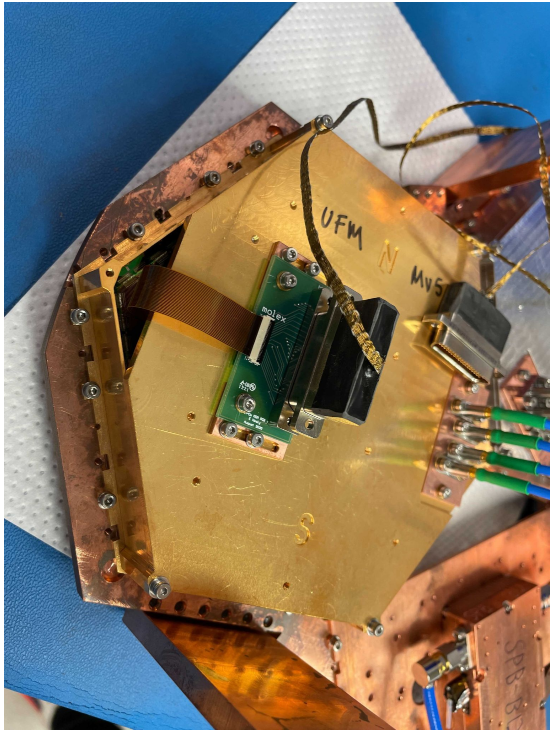


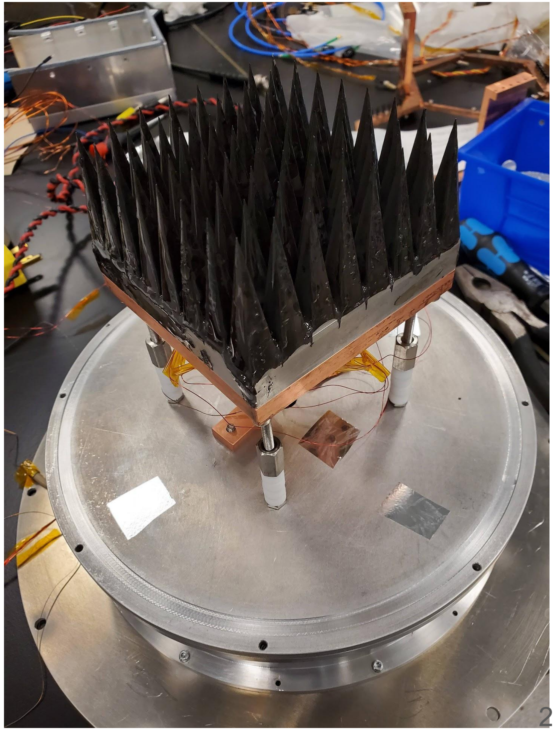
SAT-MF1 at UCSD



SO integration and testing

Detector testing at Princeton and Cornell





SO site and telescope/platform status

SO site and telescope/platform status

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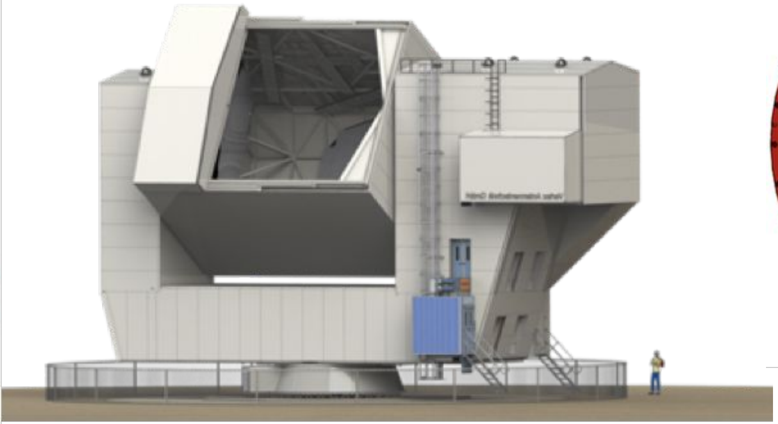
Photo: Debra Kellner

CCAT-prime

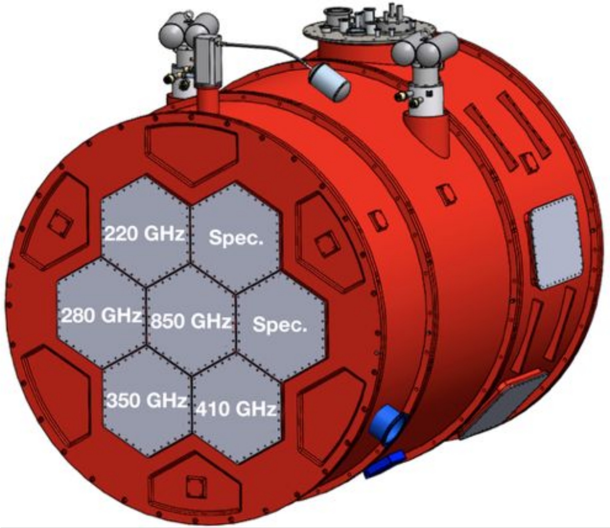
Fred Young Sub-mm Telescope



Better telescope: same as SO LAT but **better mirror surface accuracy** for high frequency observations. Observing at a superior 5,600-m site.

Parshley et al. 2018
Stacey et al. 2018

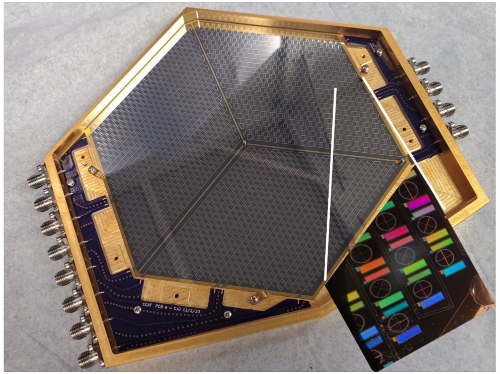
Prime-Cam receiver



Unique instrument: 1.8-m diameter, 7-module receiver under construction. **High frequency** broadband channels & **spectrometers**.

Vavagiakis et al. 2018
Choi et al. 2020

280 GHz MKID array



New detectors: Microwave kinetic inductance detectors (MKIDs)
→ **Allows for >100,000 detectors** in the Prime-Cam receiver.

Duell et al. 2020
Choi et al. 2021

Conclusion

- State-of-the-art cosmology from Planck.
- Existing data in hand (e.g., ACT) will soon improve on constraining cosmological parameters beyond Planck.
- With rapid progress in mm and sub-mm instrumentation, Simons Observatory (and CCAT-prime) will soon enable next generation cosmological studies of the dark universe.