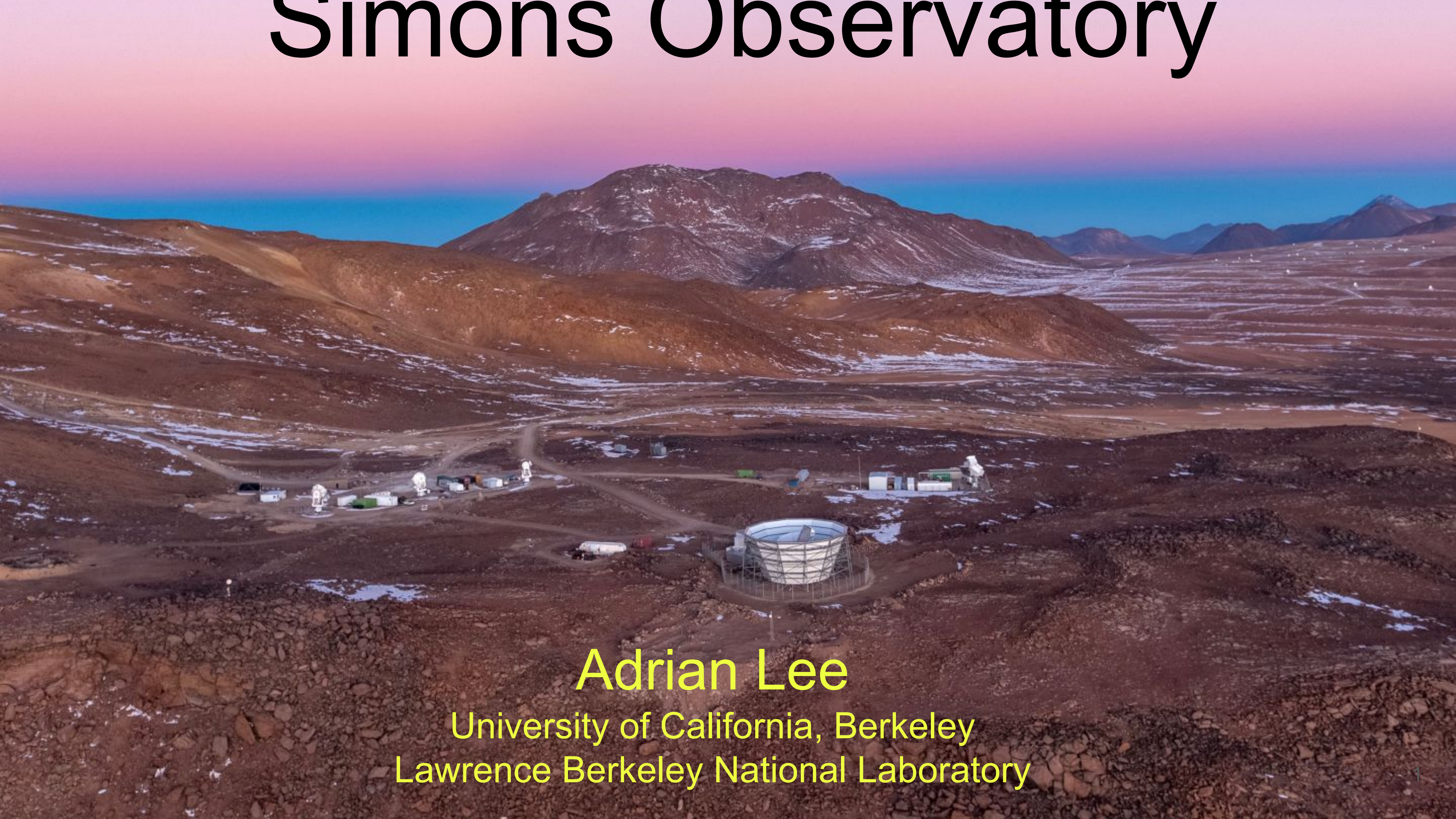
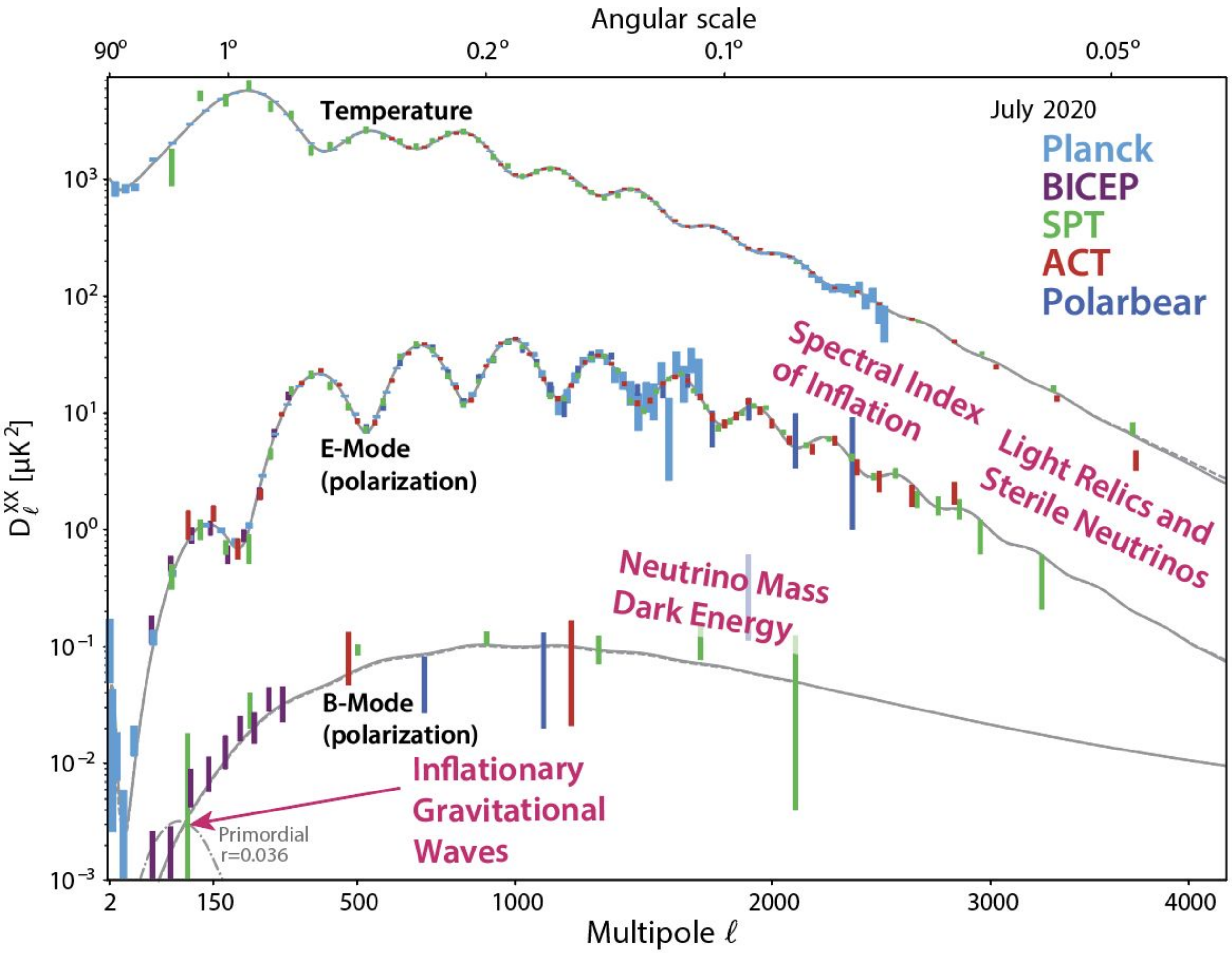
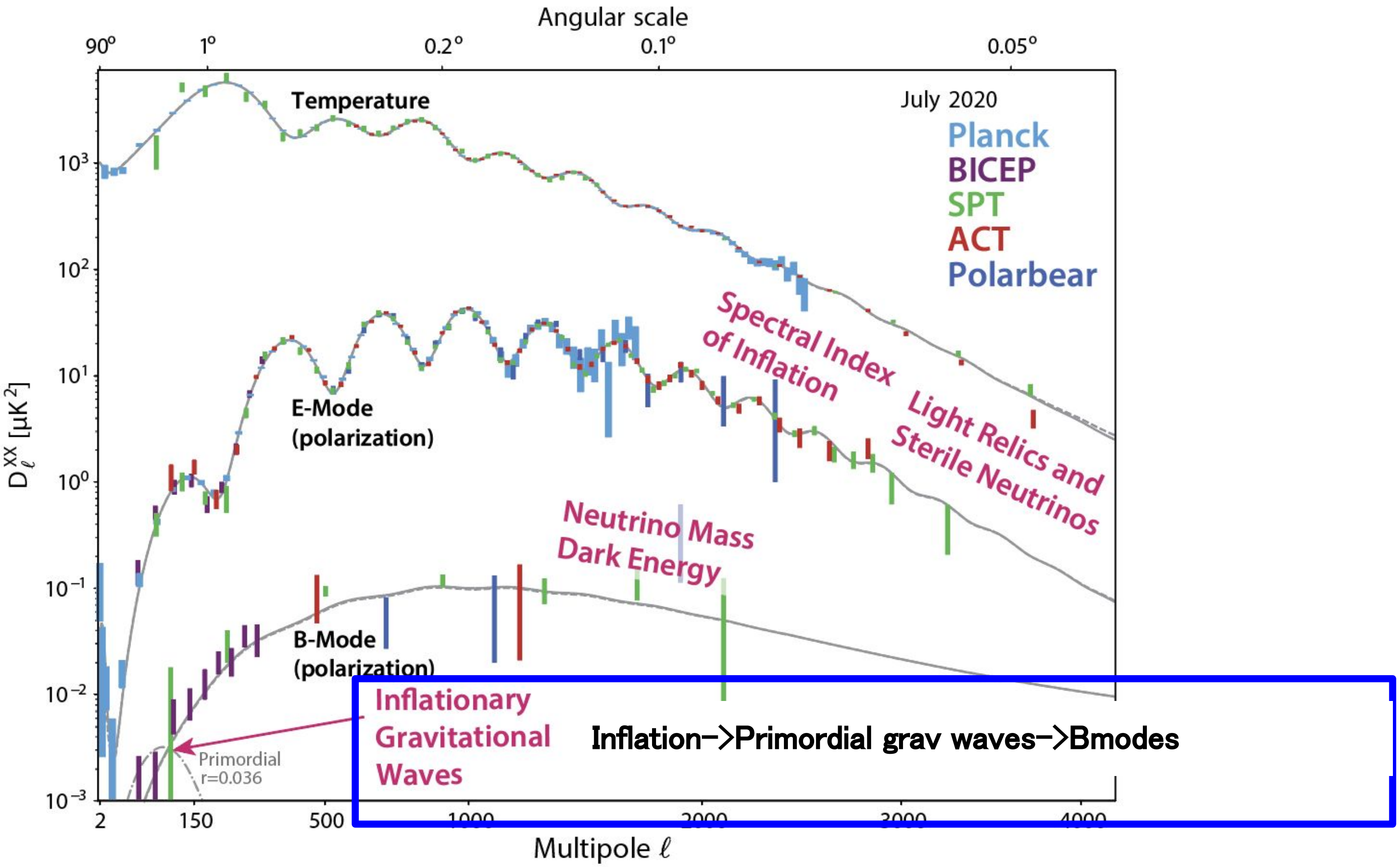
Simons Observatory



Adrian Lee
University of California, Berkeley
Lawrence Berkeley National Laboratory


Angular scale
90°
1°
0.2°
0.1°
0.05°
July 2020
Planck
BICEP
SPT
ACT
Polarbear
Temperature
E-Mode
(polarization)
B-Mode
(polarization)
Spectral Index
of Inflation
Light Relics and
Sterile Neutrinos
Neutrino Mass
Dark Energy
Inflationary
Gravitational
Waves
Primordial
r=0.036
D_ℓ^{XX} [μK^2]
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
2
150
500
1000
2000
3000
4000
Multipole ℓ



Angular scale
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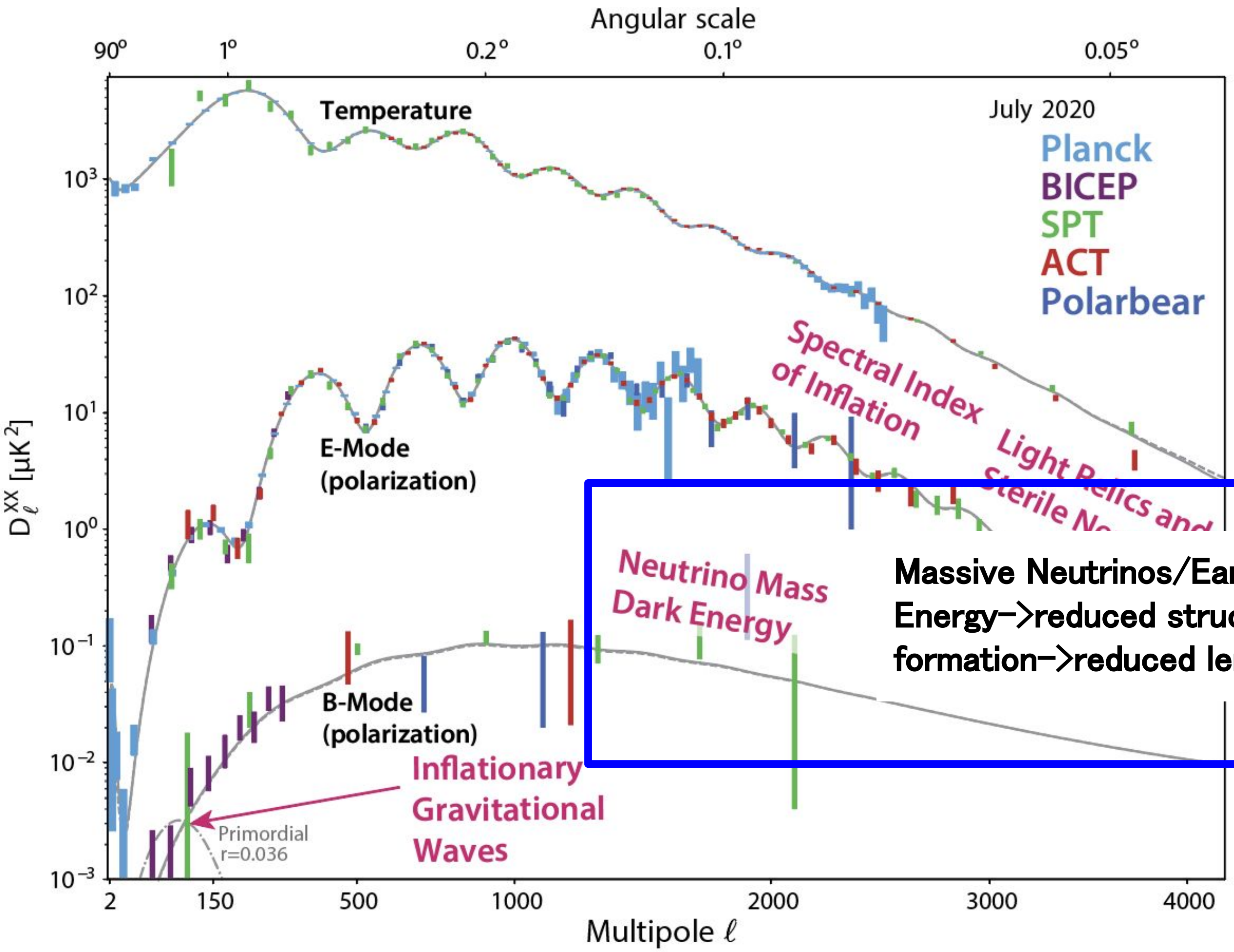
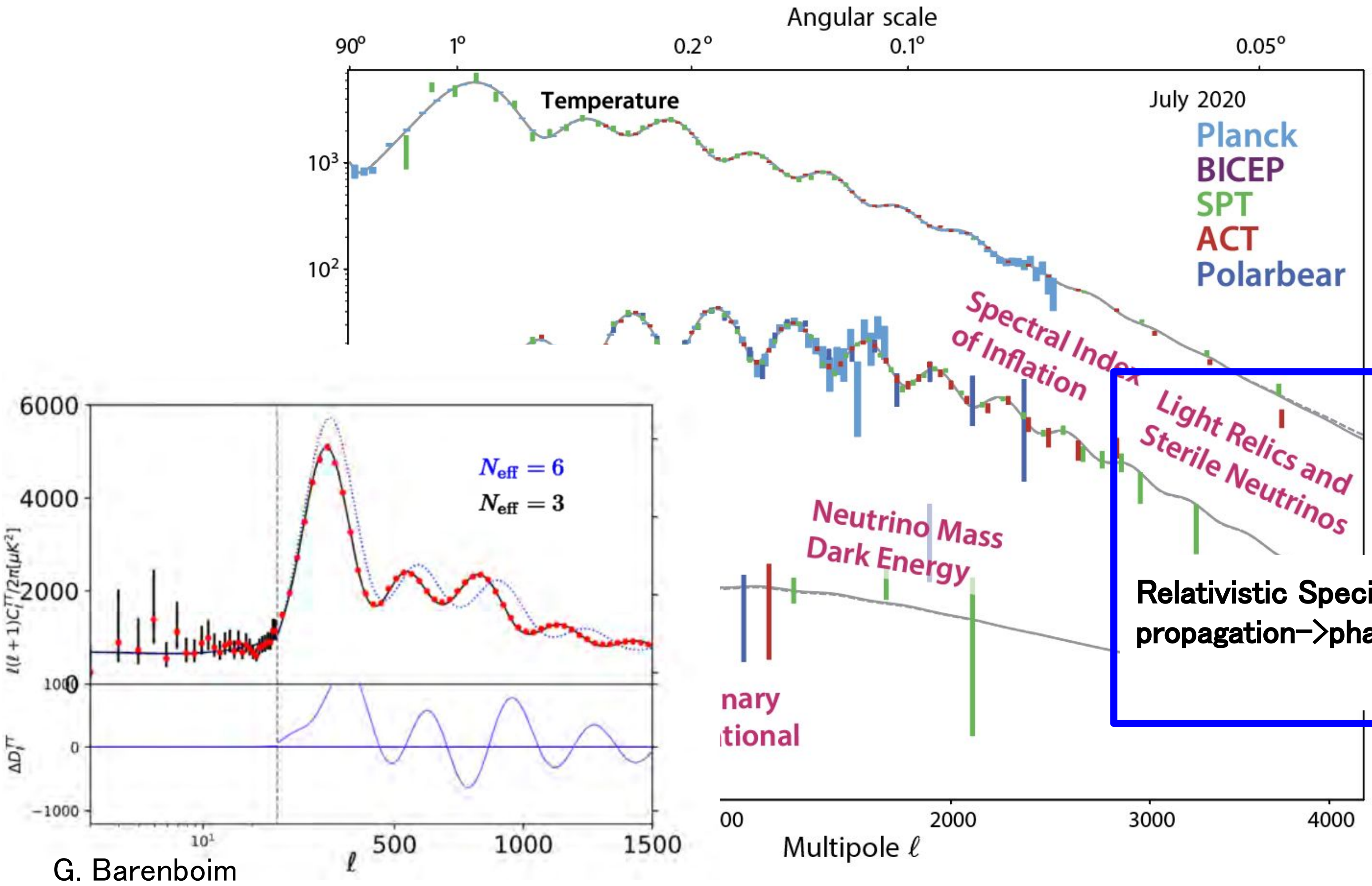
10^{-2}
10^{-3}
2
150
500
1000
2000
3000
4000
Multipole ℓ
Inflation->Primordial grav waves->Bmodes



Massive Neutrinos/Early Dark Energy->reduced structure formation->reduced lensing



Relativistic Species->faster propagation->phase shift of peaks

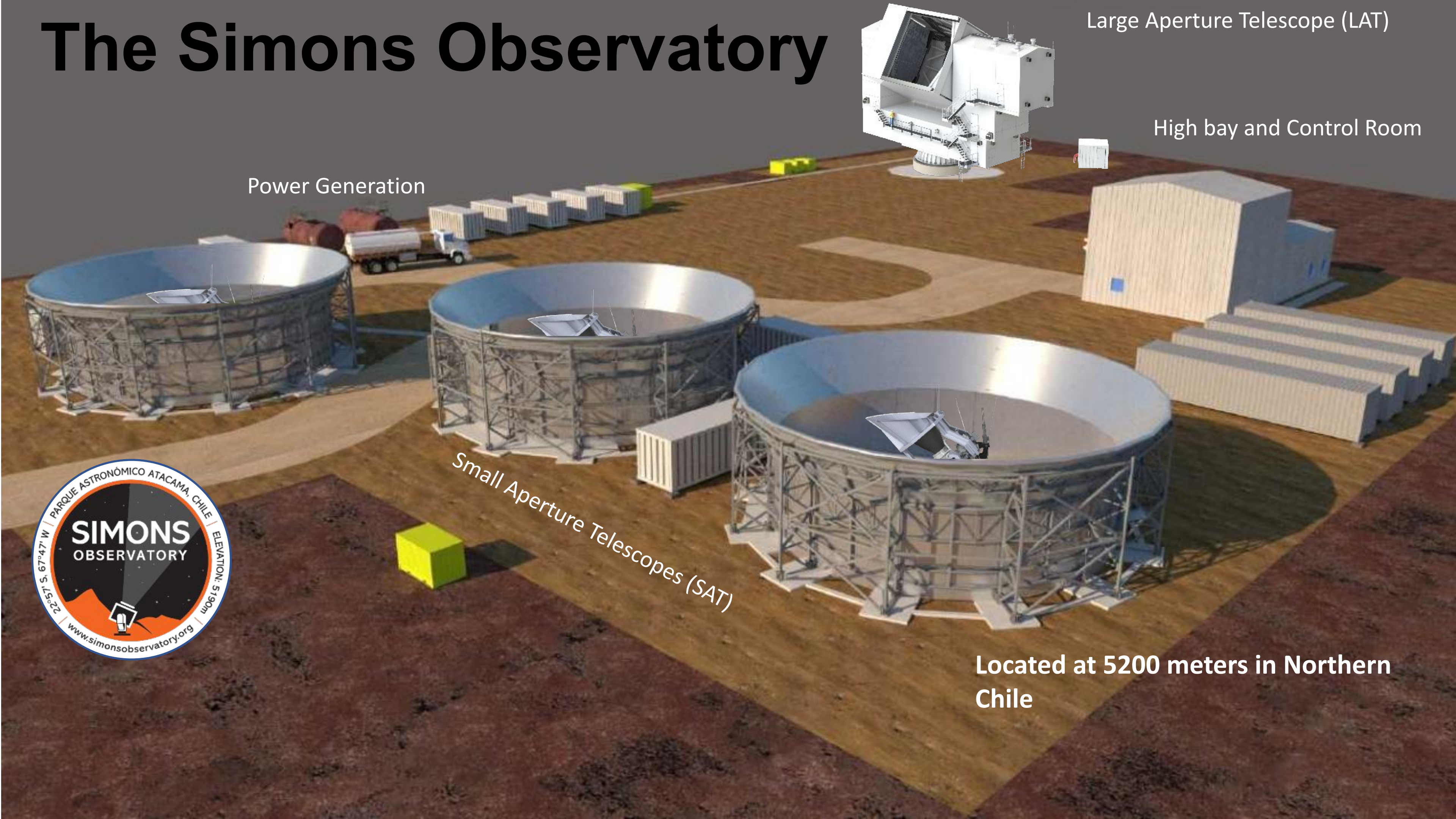
G. Barenboim

SIMONS OBSERVATORY

SIMONS FOUNDATION

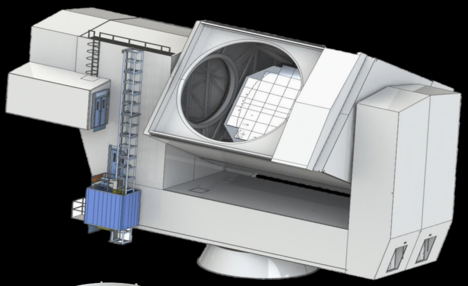
HEISING-SIMONS FOUNDATION

The Simons Observatory

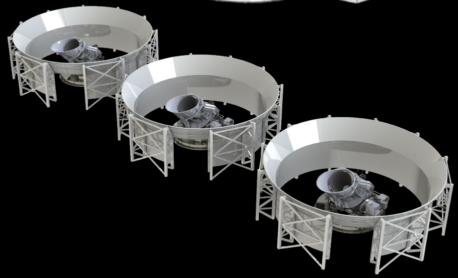


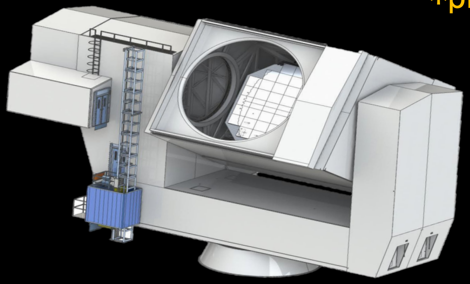
Expansion: UK, Japan, and NSF funds*

*proposed



#optics tube
7/13





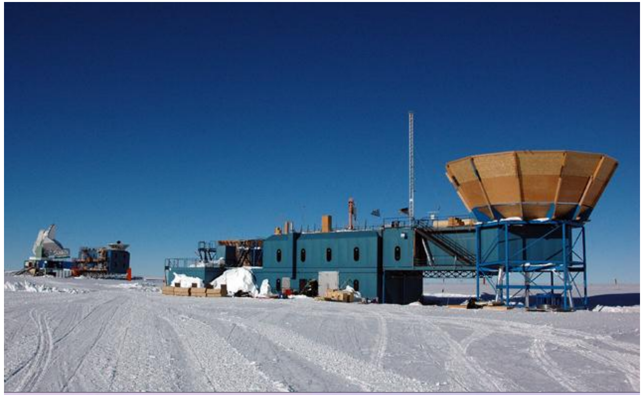
#optics tube
13/13

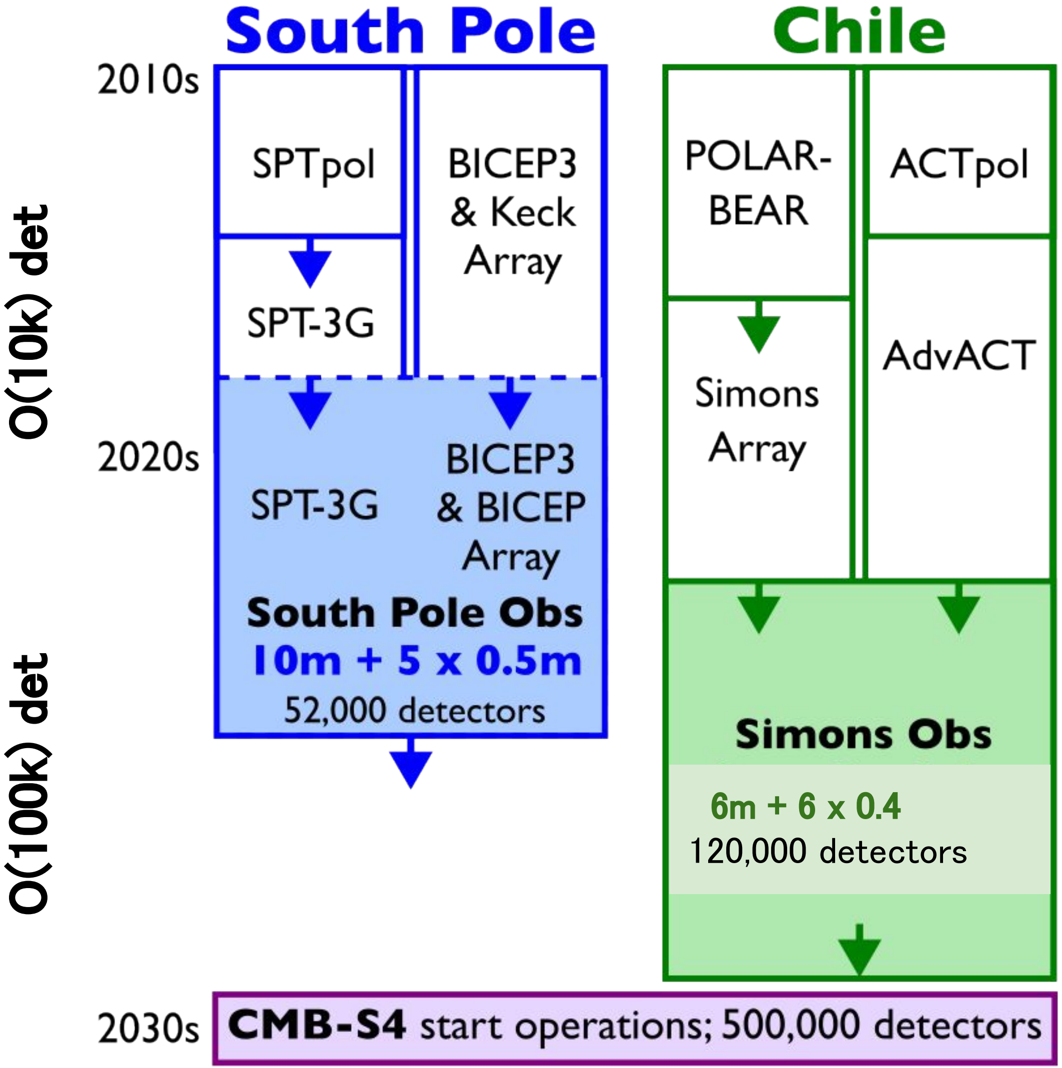
Doubling of SAT and LAT mapping speeds

~60,000 -> ~120,000 detectors

2023～

2026～



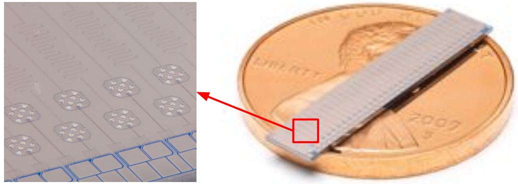

South Pole
Chile
O(10k) det
O(100k) det
2010s
2020s
2030s
SPTpol
SPT-3G
BICEP3
& Keck
Array
SPT-3G
BICEP3
& BICEP
Array
South Pole Obs
10m + 5 x 0.5m
52,000 detectors
POLAR-
BEAR
Simons
Array
ACTpol
AdvACT
Simons Obs
6m + 6 x 0.4
120,000 detectors
CMB-S4 start operations; 500,000 detectors

Simons Observatory Readout and Detectors (Simons Foundation scope alone)

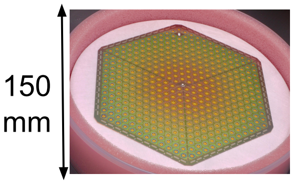
Readout: SO is using microwave SQUID multiplexing (umux) readout with a 1000x multiplexing factor in collaboration with SLAC (warm electronics) and NIST (cold).

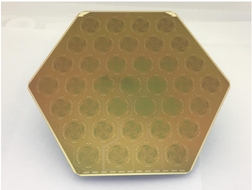
Detectors: SO will use dual-polarization, dichroic TES bolometer detectors spanning 27 - 270 GHz. Each mid-frequency (MF) and high-frequency (HF) array contains ~1700 detectors, with >60,000 detectors total.

Focal plane design: the universal focal-plane modules, common to both the SATs and LATR, contain the cold readout, detectors, and optical coupling (MF/UHF: horns, LF: lenslets).

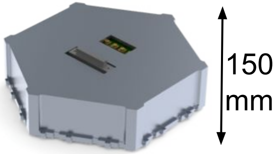


uMux readout channels (left) and NIST uMUX chip with 66 channels (right)

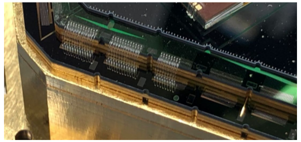




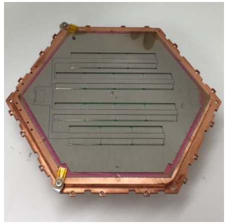
SO MF detector array (left) and LF array (right)



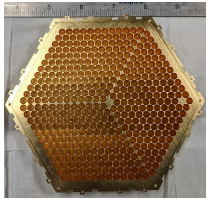
universal focal plane (UFM) module

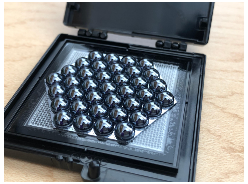


focal plane module detail showing side of horn array, detector stack, and readout.

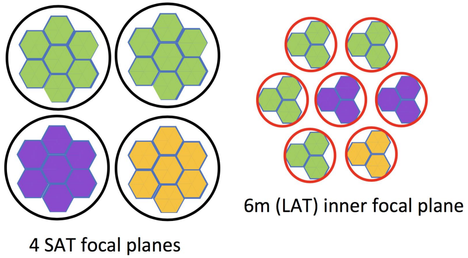


Prototype SO cold readout module with 1848 readout channels (left). SMuRF warm electronics with 12,000 tones (right).





Horn array (left) and lenslet (right) optical coupling for the MF and UFM detector arrays and LF detector array, respectively.



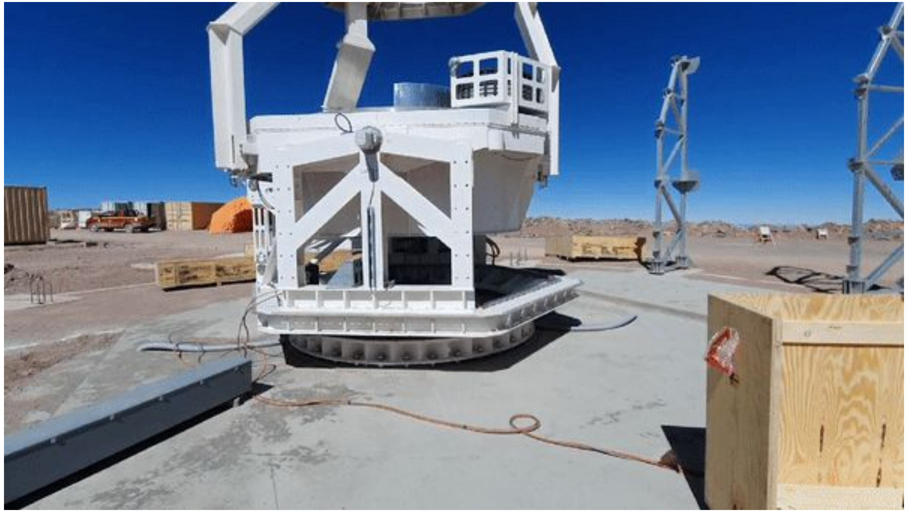
UFM distribution in the four SATs and LATR.

SOLAT and LATR

LAT in Germany – now, arriving in Chile

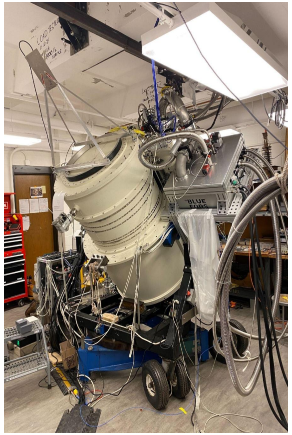
LATR being assembled in Chile

Small Aperture Telescopes (SATs)



SAT MF-1 @ UCSD

SAT UHF @ LBNL



SAT MF-2 (TSAT) @ Princeton

Deployment of SATs in 2023

SO Science Goals

From: The Simons Observatory: science goals and forecasts

SO Collaboration, JCAP02 (2019) 056

https://ui.adsabs.harvard.edu/abs/2019JCAP...02..056A/abstract

	Parameter	SO-Baseline[a] (no syst)	**SO-Baseline[b]**	SO-Goal[c]	Current[d] (2018-19)	Method	Sec.
Primordial	r	0.0024	**0.003**	0.002	0.03	BB + ext delens	3.4
perturbations	$e^{-2\tau}\mathcal{P}(k=0.2/\mathrm{Mpc})$	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
		1.2%	**2%**	1%		tSZ-N $\times$ LSST-WL	7.1
	H_0 (ΛCDM)	0.3	**0.4**	0.3	0.5	$TT/TE/EE + \kappa\kappa$	4.3
Galaxy evolution	η_{feedback}	2%	**3%**	2%	50-100%	kSZ + tSZ + DESI	7.3
	p_{nt}	6%	**8%**	5%	50-100%	kSZ + tSZ + DESI	7.3
Reionization	Δz	0.4	**0.6**	0.3	1.4	TT (kSZ)	7.6

[a] This column reports forecasts from earlier sections (in some cases using 2 s.f.) and applies no additional systematic error.

[b] This is the nominal forecast, increases the column (a) uncertainties by 25% as a proxy for instrument systematics, and rounds up to 1 s.f.

[c] This is the goal forecast, has negligible additional systematic uncertainties, and rounds to 1 s.f.

[d] Primarily from [44] and [287].

[44] BICEP2 and Planck collaborations, Joint Analysis of BICEP2/Keck Array and Planck Data, Phys. Rev. Lett. 114 (2015) 101301
[287] Planck collaboration, Planck 2018 results. VI. Cosmological parameters

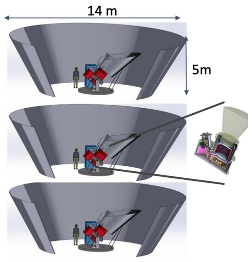
Forecasts including SO:UK, SO:JP, and ASO additions forthcoming: 2x mapping speed and longer observation period

SO and CMB-S4

- A first MOU between SO and CMB-S4 (Nov 2021) described collaboration on:
  - Chile site infrastructure
  - Instrumentation
  - Algorithms and pipeline tools
  - Techniques for large high-sensitivity CMB surveys
- Since the MOU was established, there has been an ongoing discussion of using the SO Large-Aperture Telescope in CMB-S4.
- SO and CMB-S4 teams have large overlap
- Technology flow between SO and S4: A significant contribution to CMB-S4
  - Chile LAT design/verification
  - Chile LAT receiver: Verification of design foundations
  - Manufacturing/Verification of horn-coupled detector arrays
  - Dilution refrigerator: Test of concept

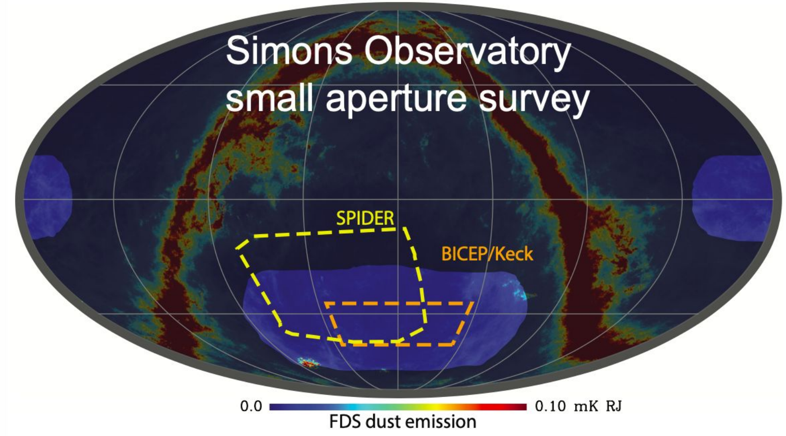
Backup

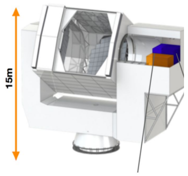
SO Surveys



	SATs ($f_{\rm sky} = 0.1$)		
Freq. [GHz]	FWHM (′)	Noise (baseline) [μK-arcmin]	Noise (goal) [μK-arcmin]
27	91	35	25
39	63	21	17
93	30	2.6	1.9
145	17	3.3	2.1
225	11	6.3	4.2
280	9	16	10

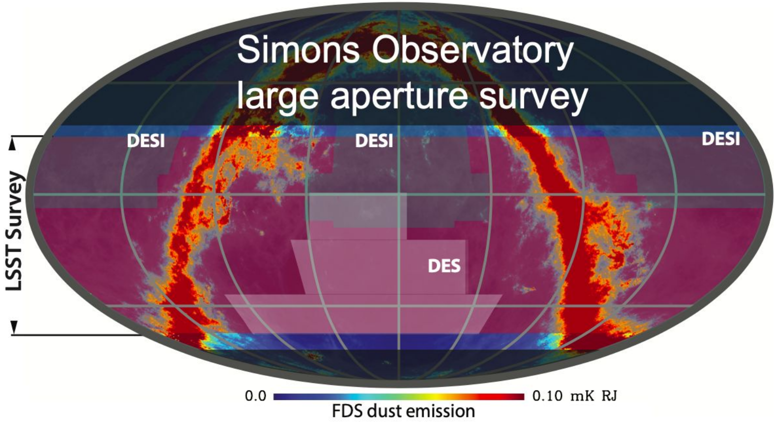
} 2 μK-arcmin (93 and 145 GHz, baseline)





	LAT ($f_{\rm sky} = 0.4$)		
Freq. [GHz]	FWHM (′)	Noise (baseline) [μK-arcmin]	Noise (goal) [μK-arcmin]
27	7.4	71	52
39	5.1	36	27
93	2.2	8.0	5.8
145	1.4	10	6.3
225	1.0	22	15
280	0.9	54	37

} 6 μK-arcmin (93 and 145 GHz, baseline)



From June, 2020 SO+LSS Zoomference

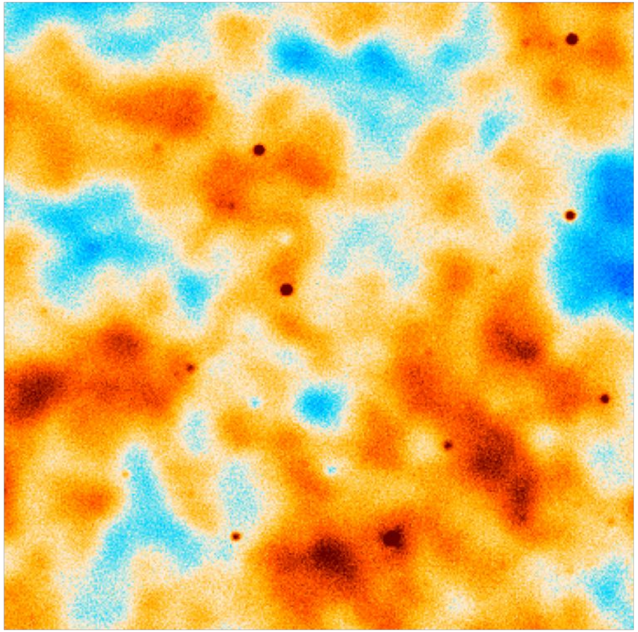
SO: New Opportunities in mm-Transient Science

Variable Active Galactic Nuclei:
track thousands daily/weekly/monthly at 1-10 mm.

Potential of mm transients:
e.g. orphan afterglows of Gamma Ray Bursts

Potential follow-up of Rubin Observatory optical transients

In addition to wealth of CMB science (early and late-time signals), 30k high-z dusty galaxies, 20k clusters and Galactic science



[Previous | Next | ADS]

ACT-T J061647-402140: a Strongly Variable, Flaring Source at 90, 150 and 220 GHz Positionally Coincident with the Transient Gamma-Ray Blazar, Fermi 0617-4026

ATel #12738; *Sigurd Naess (Center for Computational Astrophysics, Flatiron Institute) on behalf of the ACT Collaboration*
on 8 May 2019; 23:32 UT
Credential Certification: John P. Hughes (jph@physics.rutgers.edu)

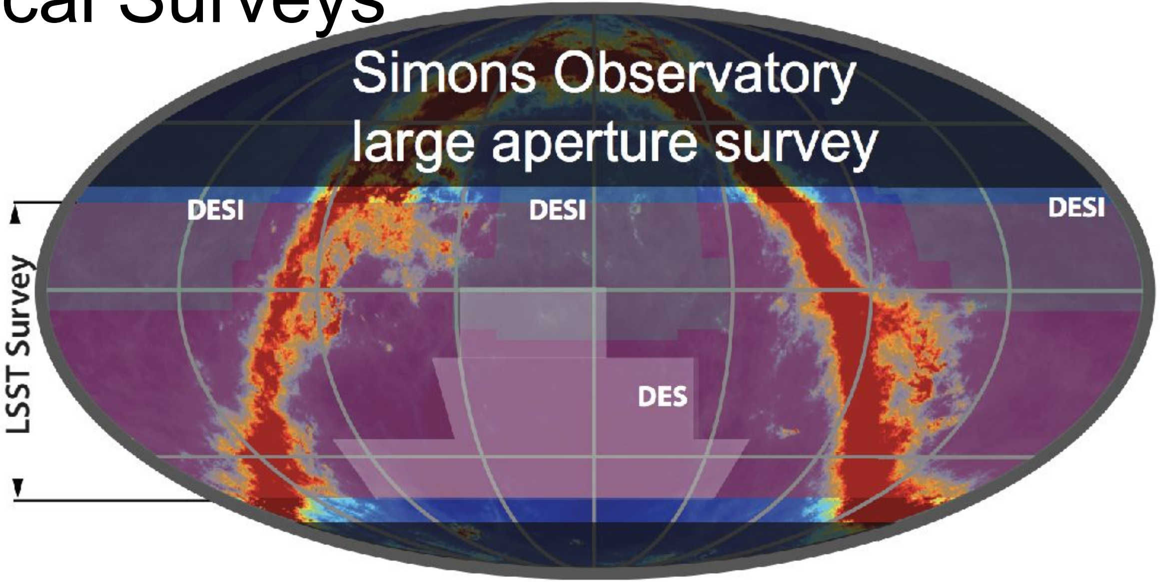
Subjects: Millimeter, Gamma Ray, AGN, Blazar, Transient, Variables

SO Synergy with Optical Surveys

SO's 2023-28 observing timeline overlaps with Rubin Observatory, DESI, Euclid

CMB and optical surveys both measure large-scale matter and baryon distribution.

Better together!
Growth of cosmic structure, constraints on baryonic feedback, calibrating systematic effects…



ACT and SO are community oriented.
Regular planned releases of maps, catalogs, likelihoods on NASA LAMBDA and/or other platforms
Code, notebooks and tutorials: to read and manipulate maps, and to train students

Additional Goals and Data Combinations

SO Collaboration (2019)

Table 11
Catalogs and additional science from SO

	Parameter	**SO-Baseline**	Method
Legacy catalogs	SZ clusters	20,000	tSZ
	AGN	10,000	Sources
	Polarized AGN	300	Sources
	Dusty star-forming galaxies	10,000	Sources
Primordial perturbations	$f_{\rm NL}$ (equilateral)	30	T/E
	$f_{\rm NL}$ (orthogonal)	10	
	n_s	0.002	$TT/TE/EE + \kappa\kappa$
Big bang nucleosynthesis	Y_P (varying $N_{\rm eff}$)	0.007	$TT/TE/EE + \kappa\kappa$
	$\Omega_b h^2$ (ΛCDM)	0.00005	$TT/TE/EE + \kappa\kappa$
Dark matter	DM–baryon interaction (σ_p, MeV)	5×10^{-27}	$TT/TE/EE$+$\kappa\kappa$
	UL axion fraction (Ω_a/Ω_d, $m_a = 10^{-26}$ eV)	0.005	$TT/TE/EE$+$\kappa\kappa$
Dark energy or modified gravity	w_0	0.06	tSZ +LSST
	w_a	0.2	tSZ + LSST
	Growth rate ($\Delta(\sigma_8 f_g)/\sigma_8 f_g$)	0.1	kSZ + DESI
Shear bias calibration	$m_{\rm z=1}$	0.007	$\kappa\kappa$+LSST
Reionization	$\log_{10}(\lambda_{\rm mfp})$	0.3	$TT/TE/EE$ (kSZ)
	Ionization efficiency (ζ)	40	$TT/TE/EE$ (kSZ)