Road to first light

An overview of Simons Observatory in 2024

Benjamin Beringue - APC

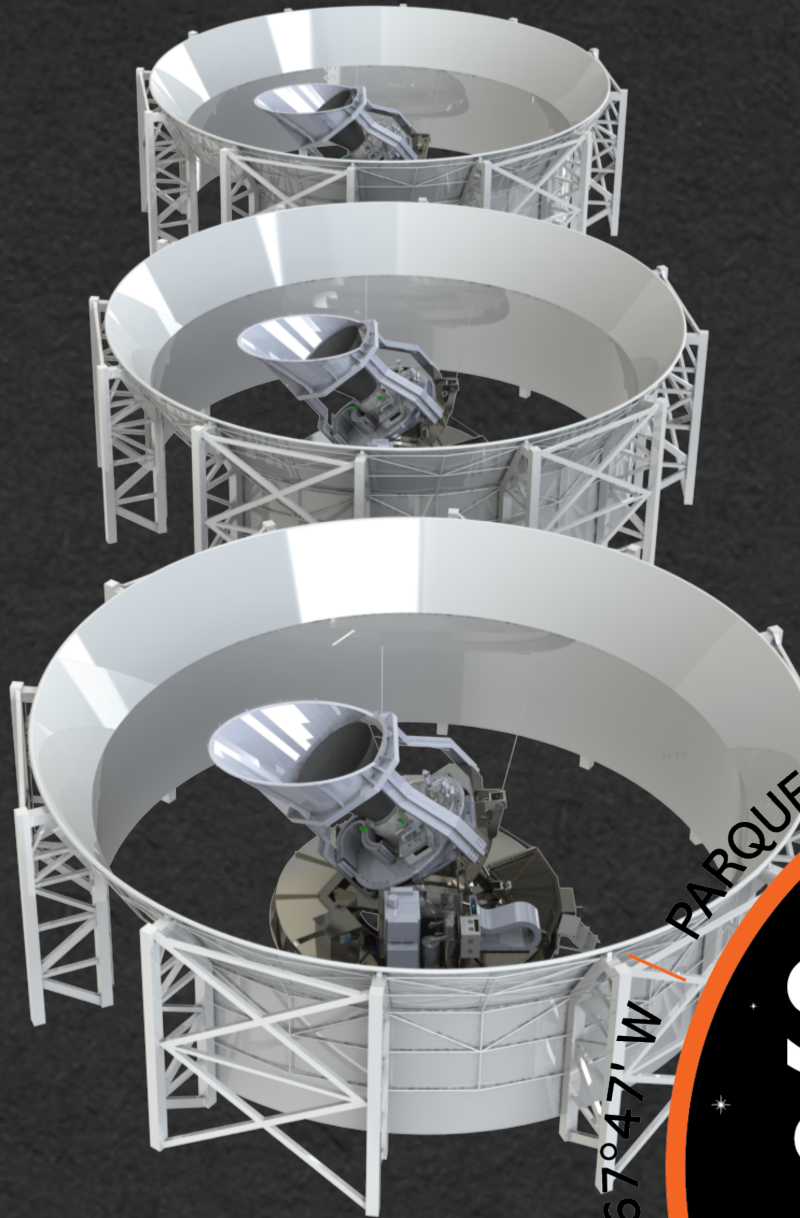
Colloque national CMB-France#5 : Dec 4/5 2023

Simons Observatory collaboration

- Nominal project privately funded by Simons Foundation and Heising-Simons Foundation

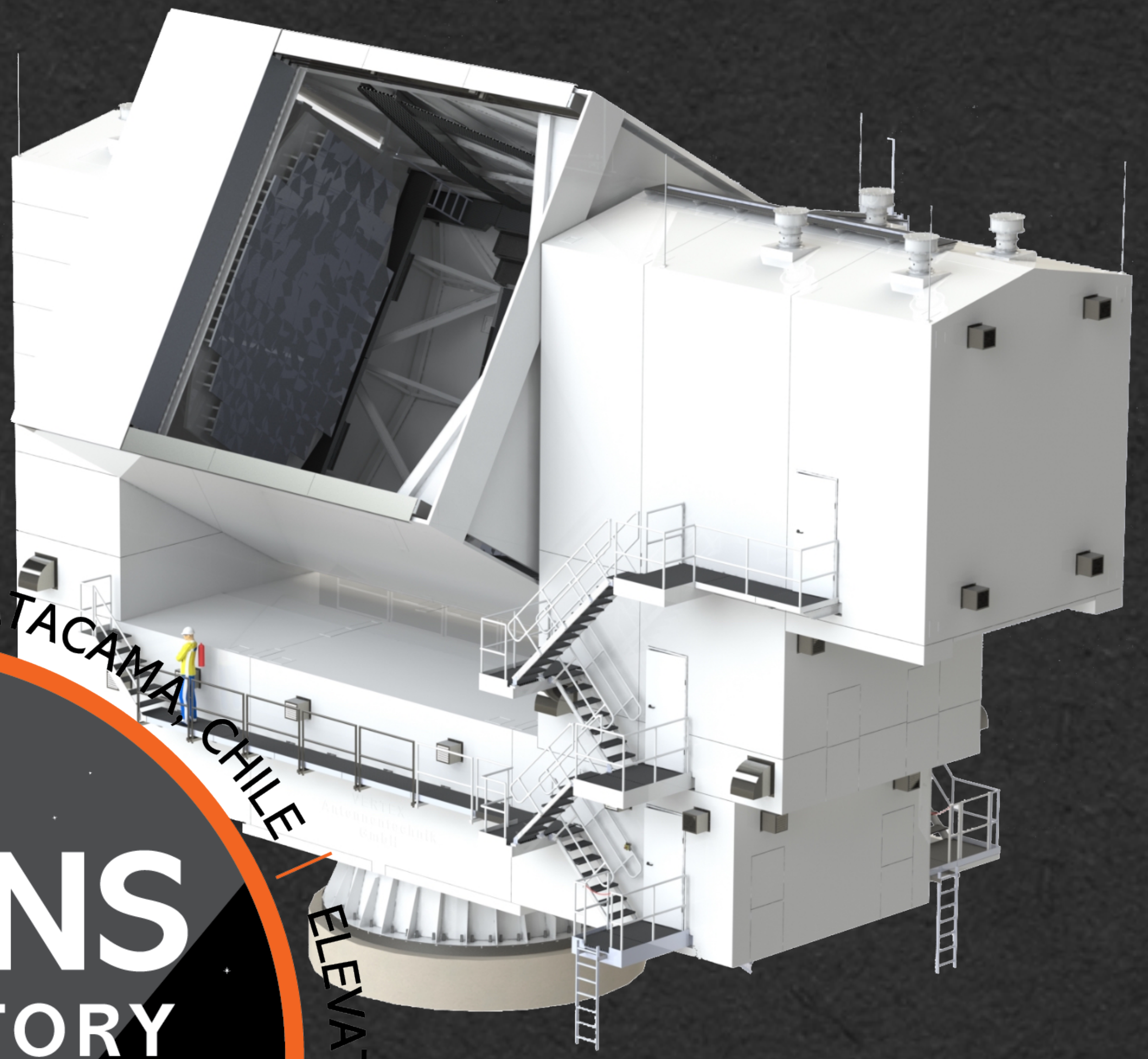
- > 300 collaborators across the globe

Simons Observatory telescopes



SO Small Aperture Telescopes (SATs)

- Nominally 3 telescopes
- 30.000 TES detectors
- 6 frequency bands [27, 39, 93, 145, 225, 280] GHz
- Focusing on large scale polarisation modes (B-modes)



SO Large Aperture Telescope (LAT)

- 6m cross-Dragone telescope
- 30.000 TES detectors
- 6 frequency bands [27, 39, 93, 145, 225, 280] GHz
- Observing small scale anisotropies over a large fraction of the sky

Simons Observatory site

Chajnantor plateau (~5200m above sea level)

Done shot by Deborah Kellner


CCAT
ALMA
CLASS
PolarBear / Simons Array
ACT
Done shot by Deborah Kellner


CCAT
ALMA
CLASS
PolarBear / Simons Array
ACT
SIMONS
OBSERVATORY
PARQUE ASTRONÓMICO ATACAMA, CHILE
ELEVATION: 5190m
22°57' S, 67°47' W
www.simonsobservatory.org
Done shot by Deborah Kellner

Simons Observatory science

Credit: ESA

Inflation

Radiation dominated expansion

CMB photons decoupling

Dark Ages

Structure formation and galaxy evolution

Simons Observatory science

Credit: ESA

Inflation

- Large scale B-modes
- Primordial power spectrum (via TT,TE,EE)
- Primordial bispectrum

Radiation dominated expansion

- Y_p and $N_{\rm eff}$ (via damping tail)

CMB photons decoupling

- Imprints of ΛCDM

Dark Ages

Properties of reionisation:
- Duration (via kSZ)
- Mean free path of photons (via kSZ)

Structure formation and galaxy evolution

- Σm_ν (via lensing potential)
- Galaxy evolution
  - cluster properties (via tSZ)
  - feedback efficiency (via tSZ)
- Properties of Dark energy:
  - σ_8 (via lensing and tSZ)

Simons Observatory science

Credit: ESA

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- Primordial power spectrum (via TT,TE,EE)
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Radiation dominated expansion

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CMB photons de…

…Ages

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SIMONS OBSERVATORY
PARQUE ASTRONÓMICO ATACAMA, CHILE
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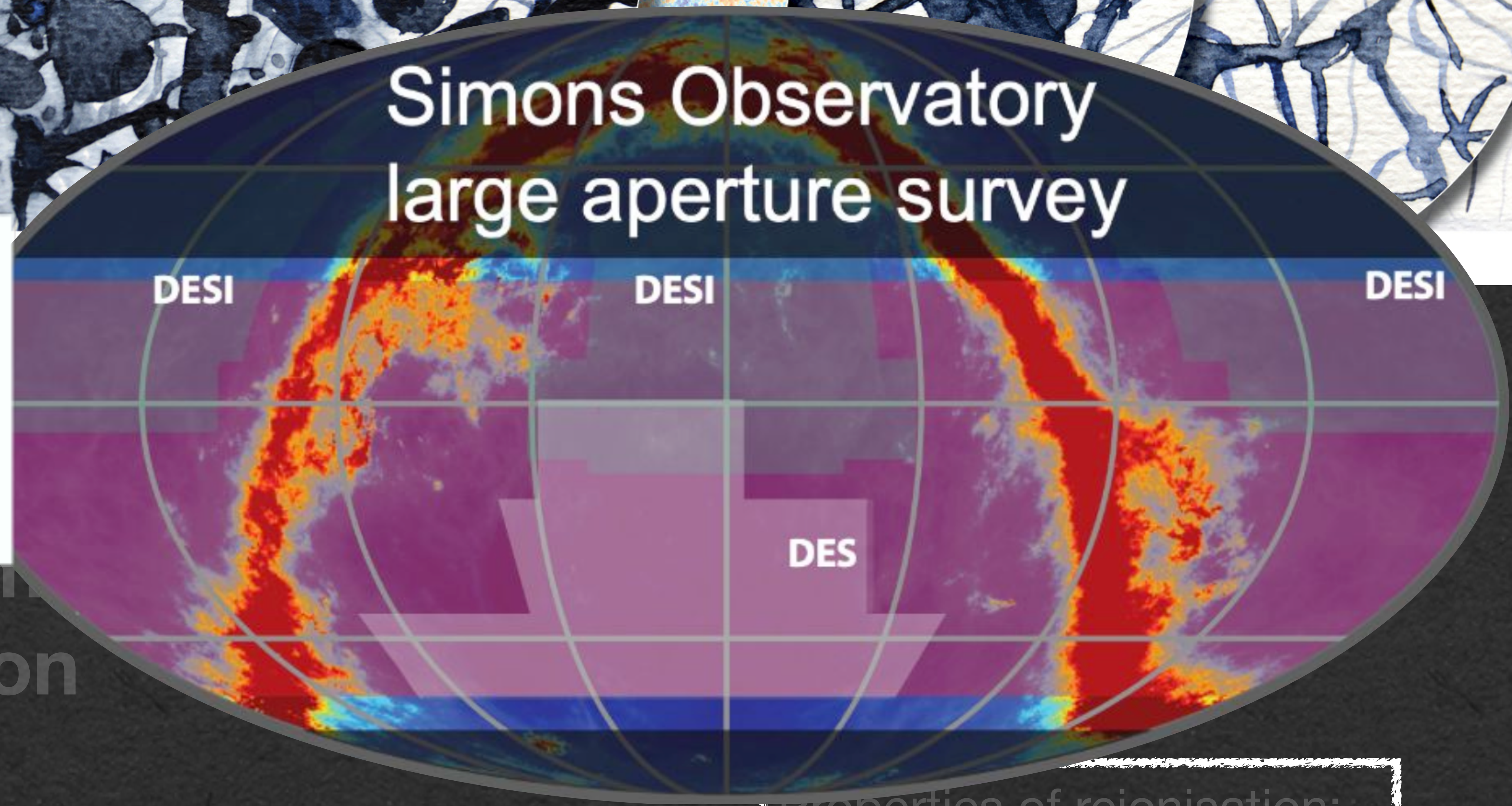
Simons Observatory science



Radiation dom…

expansion

Structure formation

Properties of reionisation:
- Duration (via kSZ)
- Mean free path of photons (via kSZ)

- σ_8 (via lensing and tSZ)

Simons Observatory science

Journal of Cosmology and Astroparticle Physics
An IOP and SISSA journal

The Simons Observatory: science goals and forecasts

SO forecast paper (link)

- Forecasts of the constraints brought by SO under different scenarios (Pessimistic, Baseline, Goal)
- Highlight improvements over current (2019) constraints

	Parameter	SO-Baseline[a] (no syst)	**SO-Baseline[b]**	SO-Goal[c]	Current[d]	Method
Primordial	r	0.0024	**0.003**	0.002	0.03	BB + ext delens
perturbations	$e^{-2\tau}\mathcal{P}(k=0.2/\mathrm{Mpc})$	0.4%	**0.5%**	0.4%	3%	$TT/TE/EE$
	$f_{\mathrm{NL}}^{\mathrm{local}}$	1.8	**3**	1	5	$\kappa\kappa \times$ LSST-LSS + 3-pt
		1	**2**	1		kSZ + LSST-LSS
Relativistic species	N_{eff}	0.055	**0.07**	0.05	0.2	$TT/TE/EE + \kappa\kappa$
Neutrino mass	Σm_ν	0.033	**0.04**	0.03	0.1	$\kappa\kappa$ + DESI-BAO
		0.035	**0.04**	0.03		tSZ-N $\times$ LSST-WL
		0.036	**0.05**	0.04		tSZ-Y + DESI-BAO
Deviations from Λ	$\sigma_8(z=1-2)$	1.2%	**2%**	1%	7%	$\kappa\kappa$ + LSST-LSS
		1.2%	**2%**	1%		tSZ-N $\times$ LSST-WL
	H_0 (ΛCDM)	0.3	**0.4**	0.3	0.5	$TT/TE/EE + \kappa\kappa$
Galaxy evolution	η_{feedback}	2%	**3%**	2%	50-100%	kSZ + tSZ + DESI
	p_{nt}	6%	**8%**	5%	50-100%	kSZ + tSZ + DESI
Reionization	Δz	0.4	**0.6**	0.3	1.4	TT (kSZ)

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

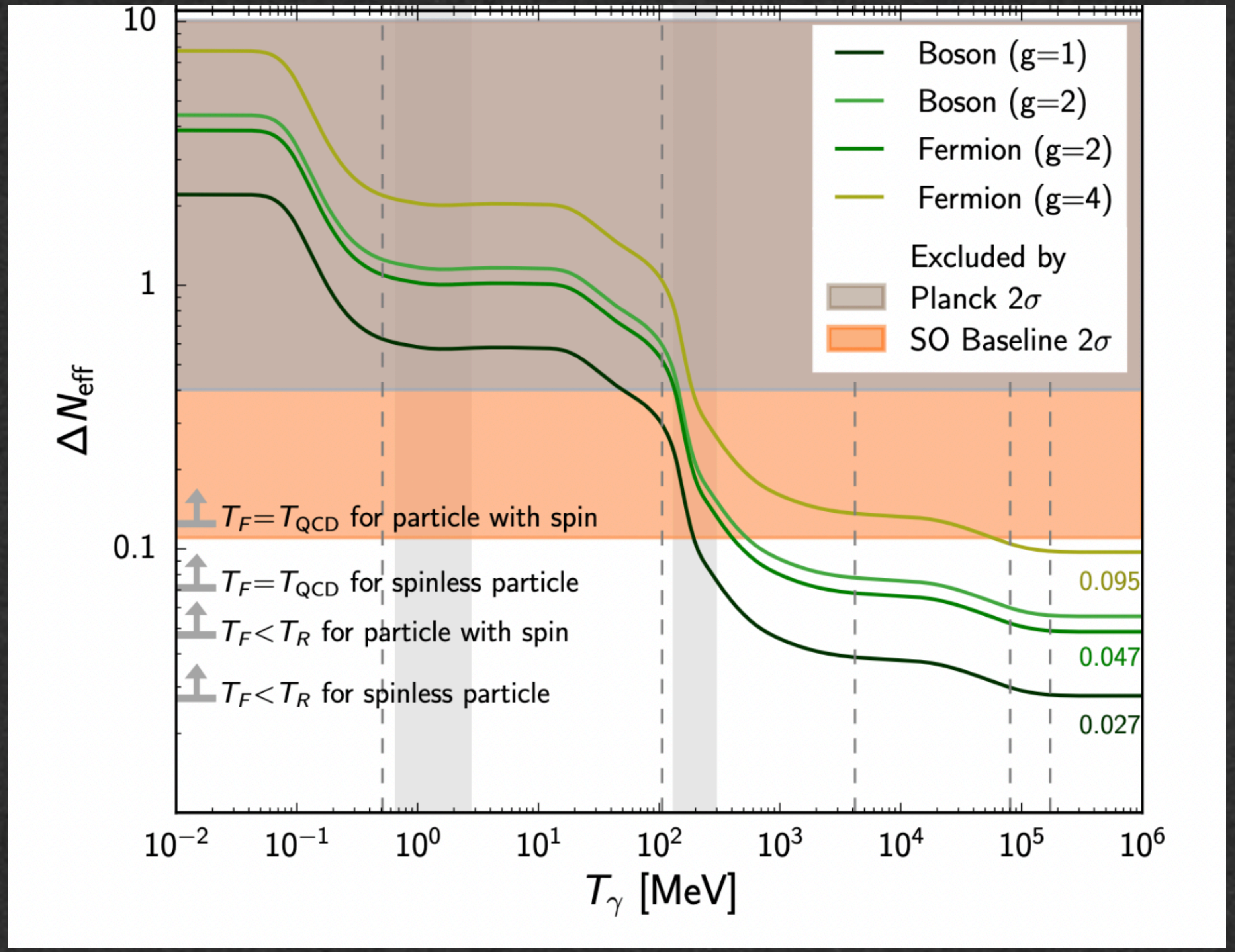
[b] This is the nominal forecast, increases the column (a) uncertainties by 25% as a proxy for instrument systematics, and rounds up to 1 s.f.

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

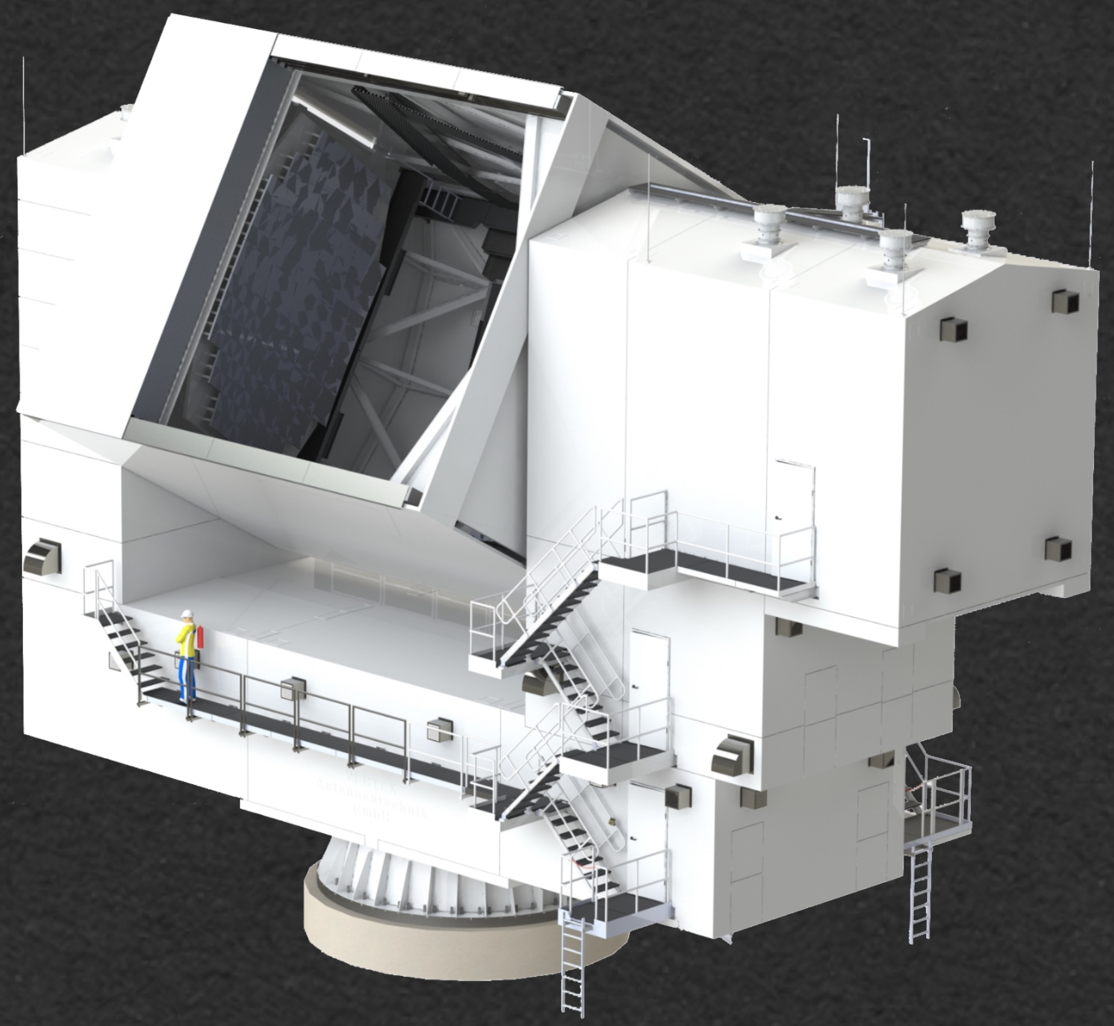
[d] Primarily from [44] and [287].

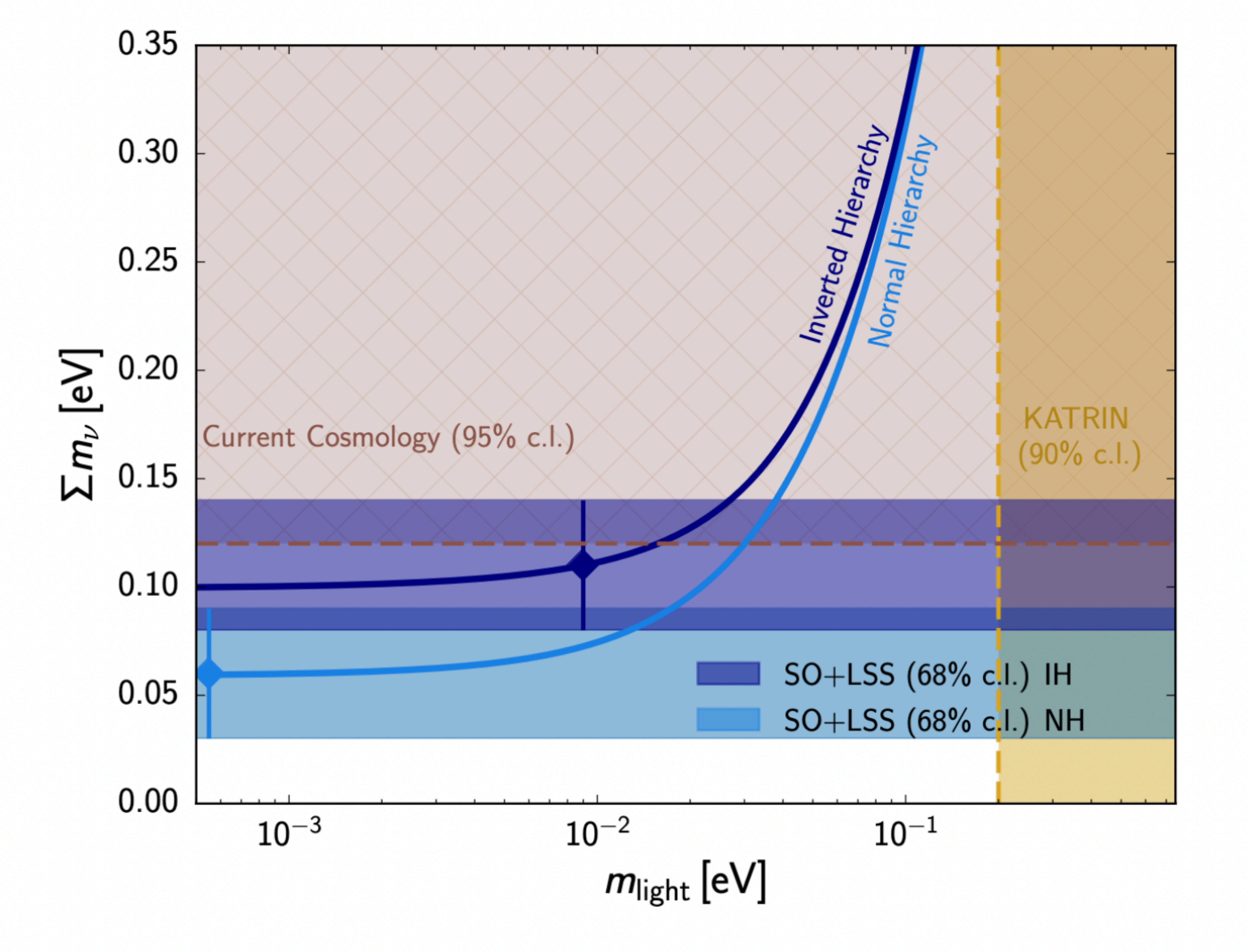
Simons Observatory science

Science from the LAT

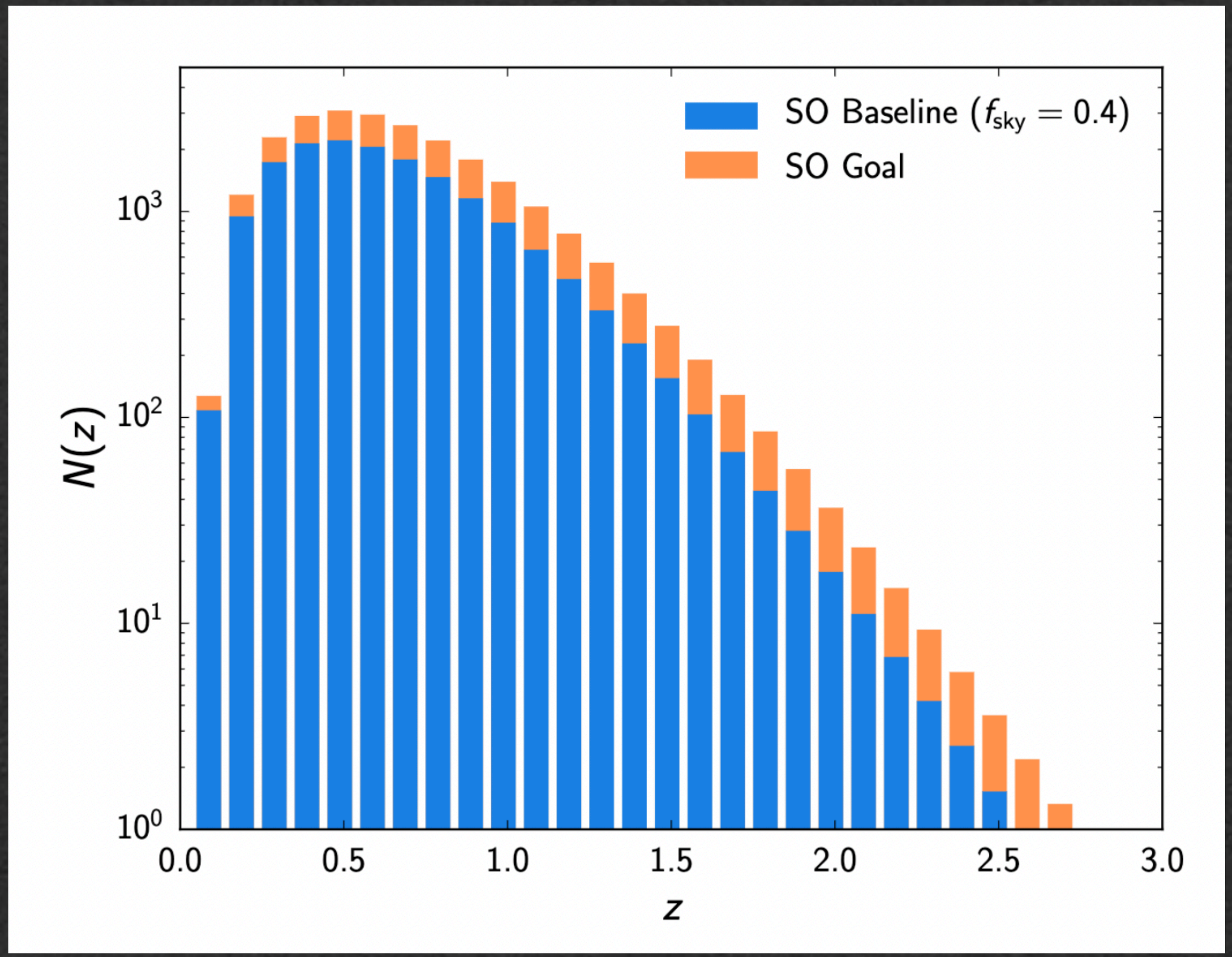


Constraints on the number of relativistic species





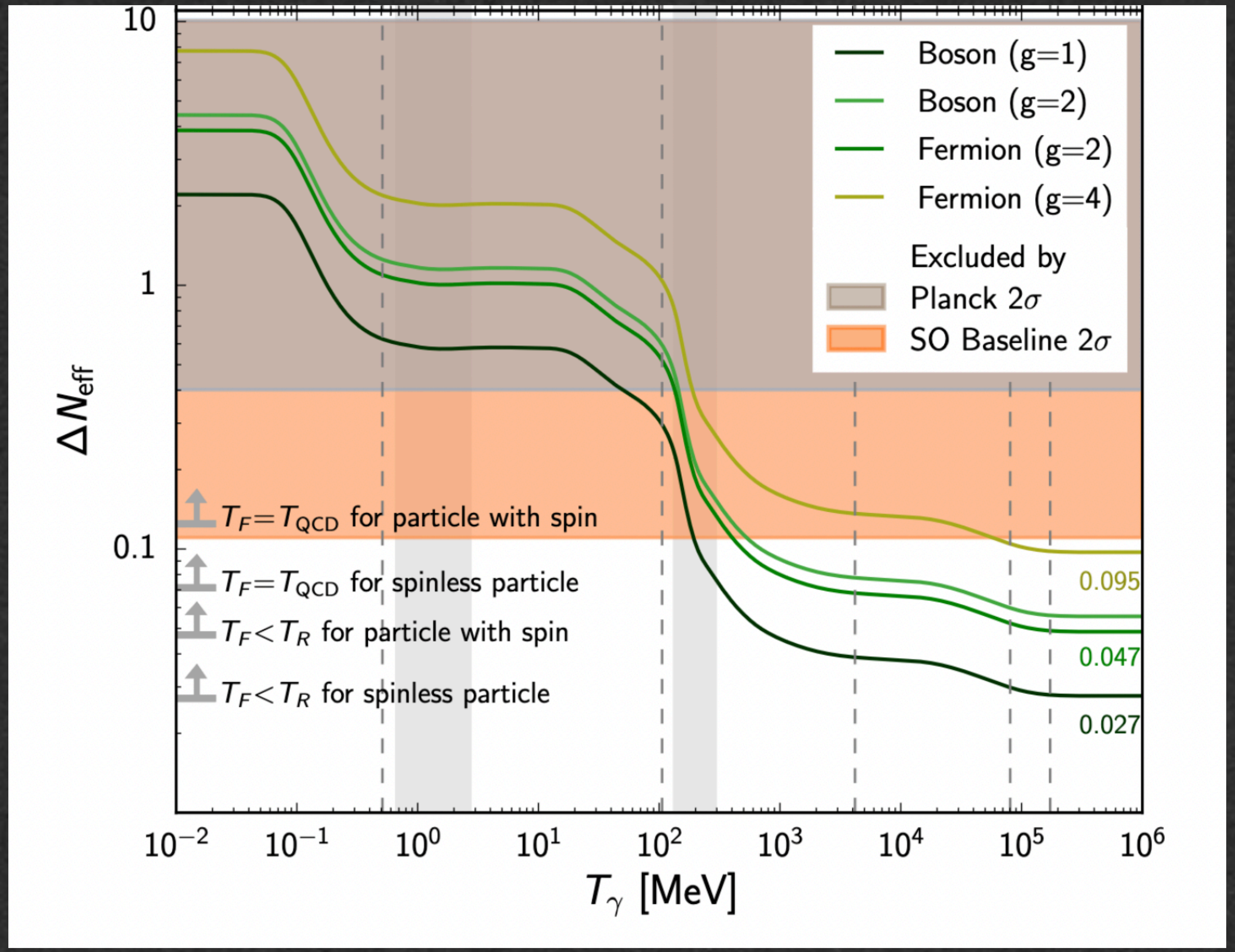
Constraints on the neutrino masses



Constraints on cluster abundances

Simons Observatory science

Science from the LAT



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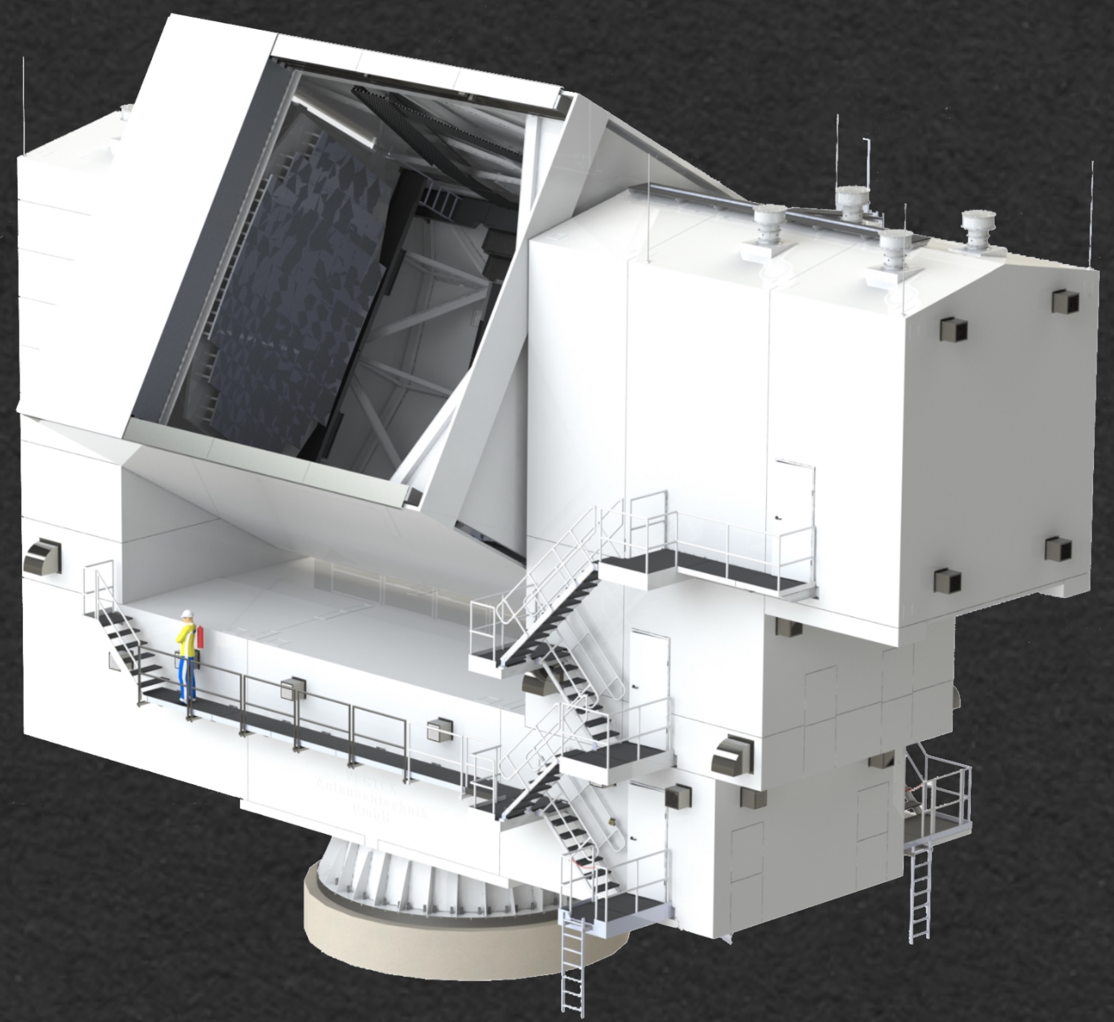
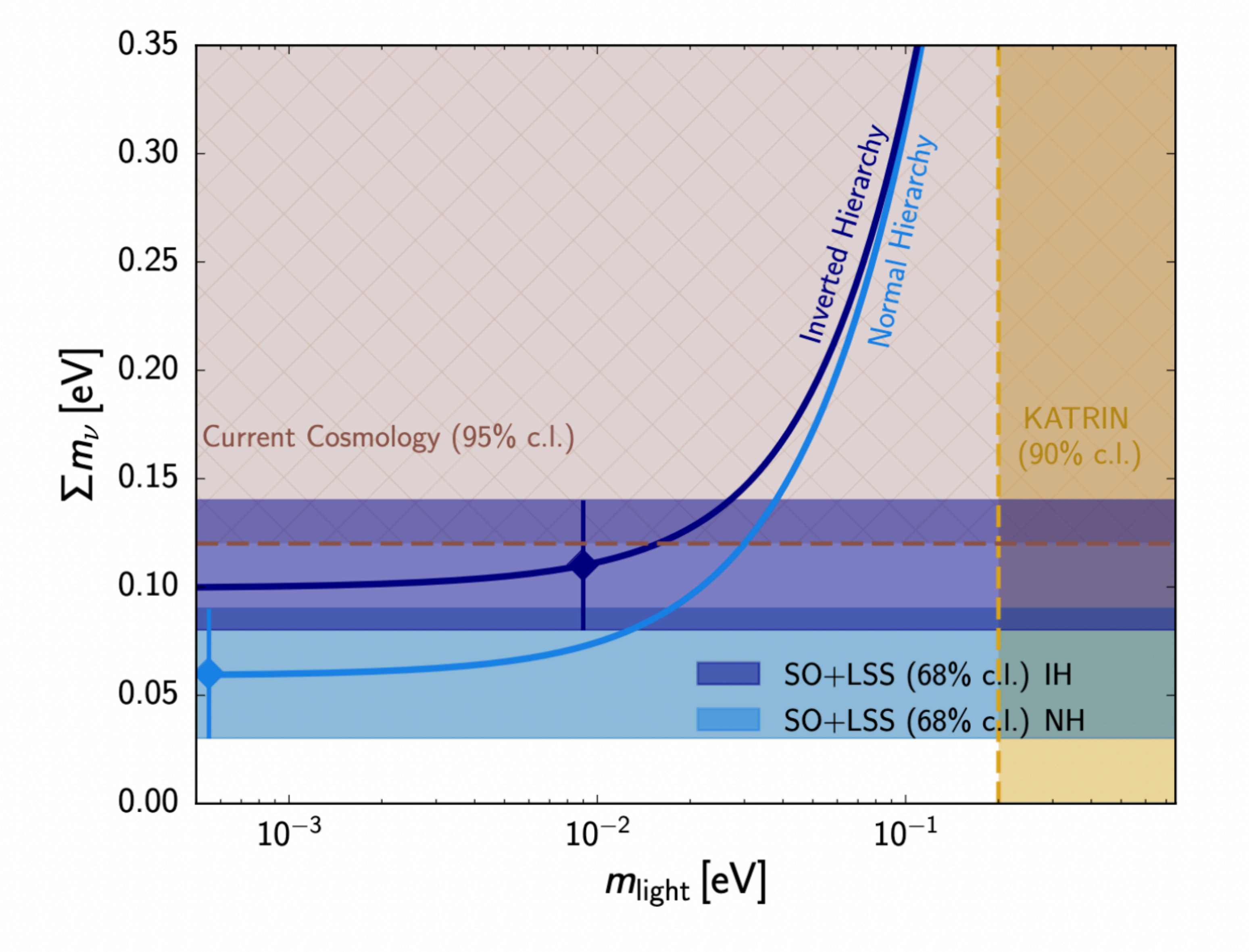
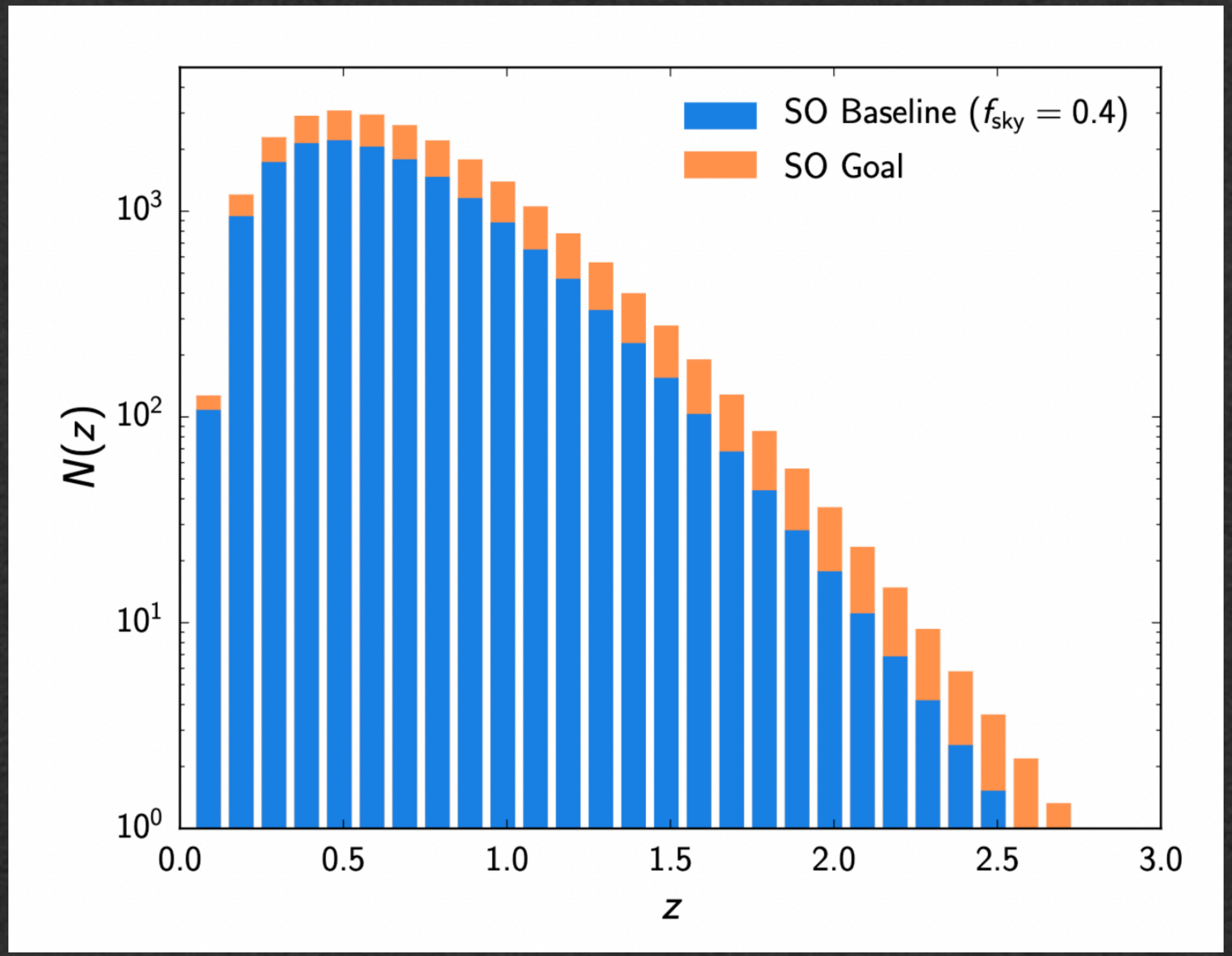




Constraints on the neutrino masses



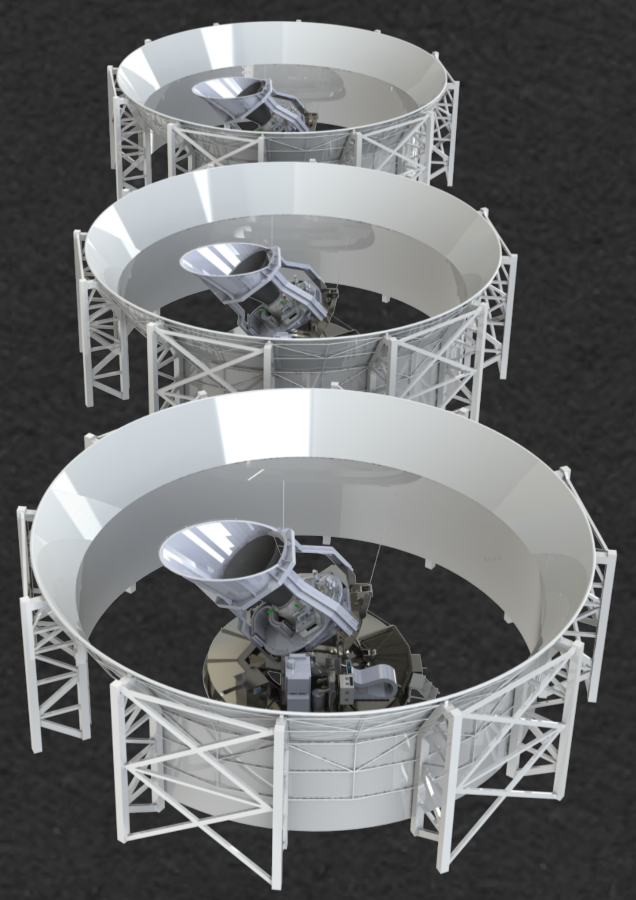
Constraints on cluster abundances

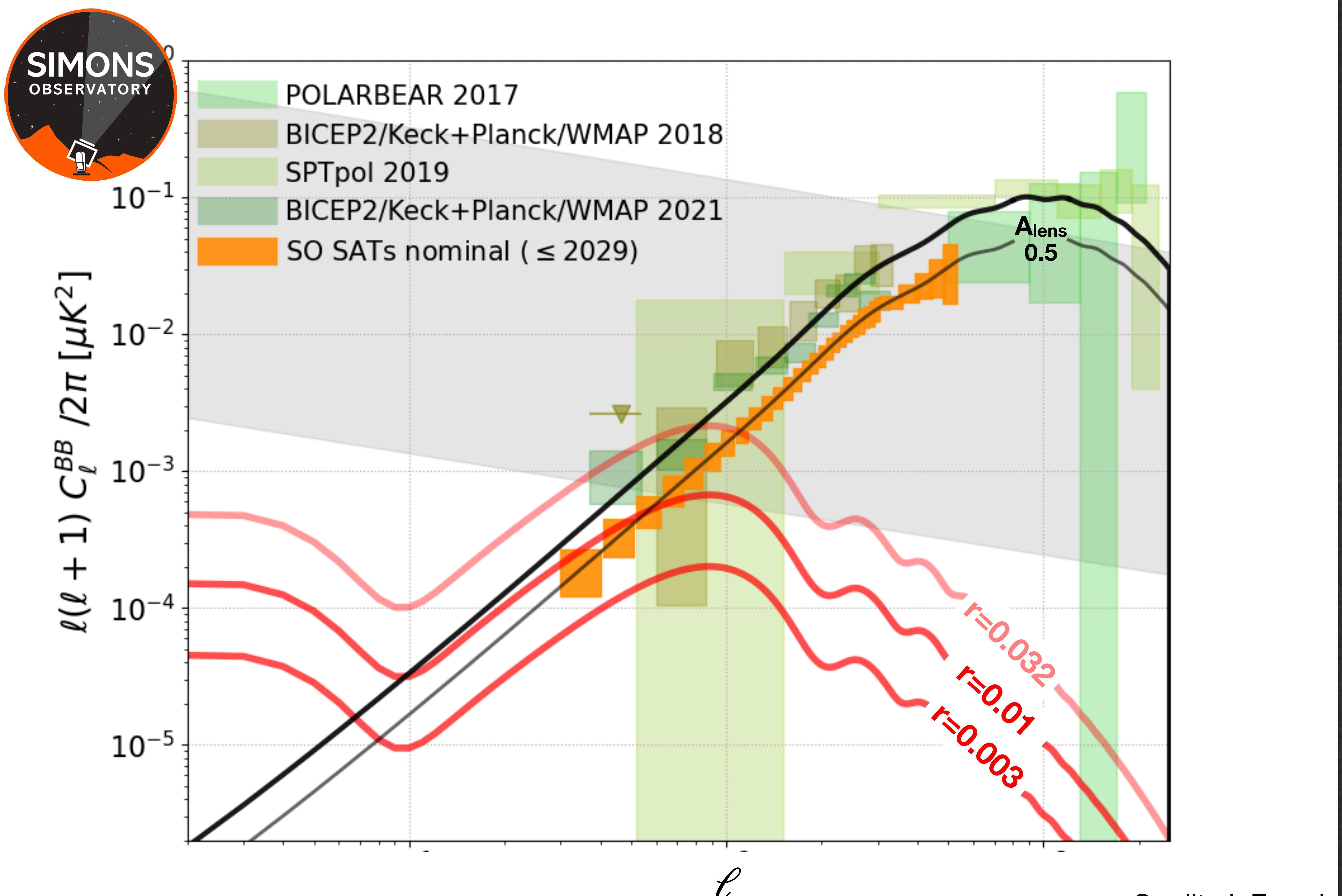
Much more in SO forecast paper !!

Simons Observatory science

Science from the SATs

- $\sigma(r) = 0.003$
- Constraints on cosmic birefringence





Credit: J. Errard

Where are we now ?

Deployment in Chile

Done shot by Deborah Kellner

Where are we now ?

Deployment in Chile

Credit: Mark Devlin

Where are we now ?

Deployment in Chile

Where are we now ?

Deployment in Chile

LAT (Assembled and tested)

Oct 2023

Credit: Mark Devlin

LAT (Assembled and tested)

Oct 2023

Mirrors delivered next year (built in Germany by Vertex GmBH)

First light in 2024

Credit: Mark Devlin

LATr (Cooled down and dark tests)

Aug 2023

Credit: Mark Devlin

SAT MF1 (undergoing commissioning)

Oct 2023

SAT MF1 (undergoing commissioning)

Oct 2023

SAT MF2 (currently being assembled on site)

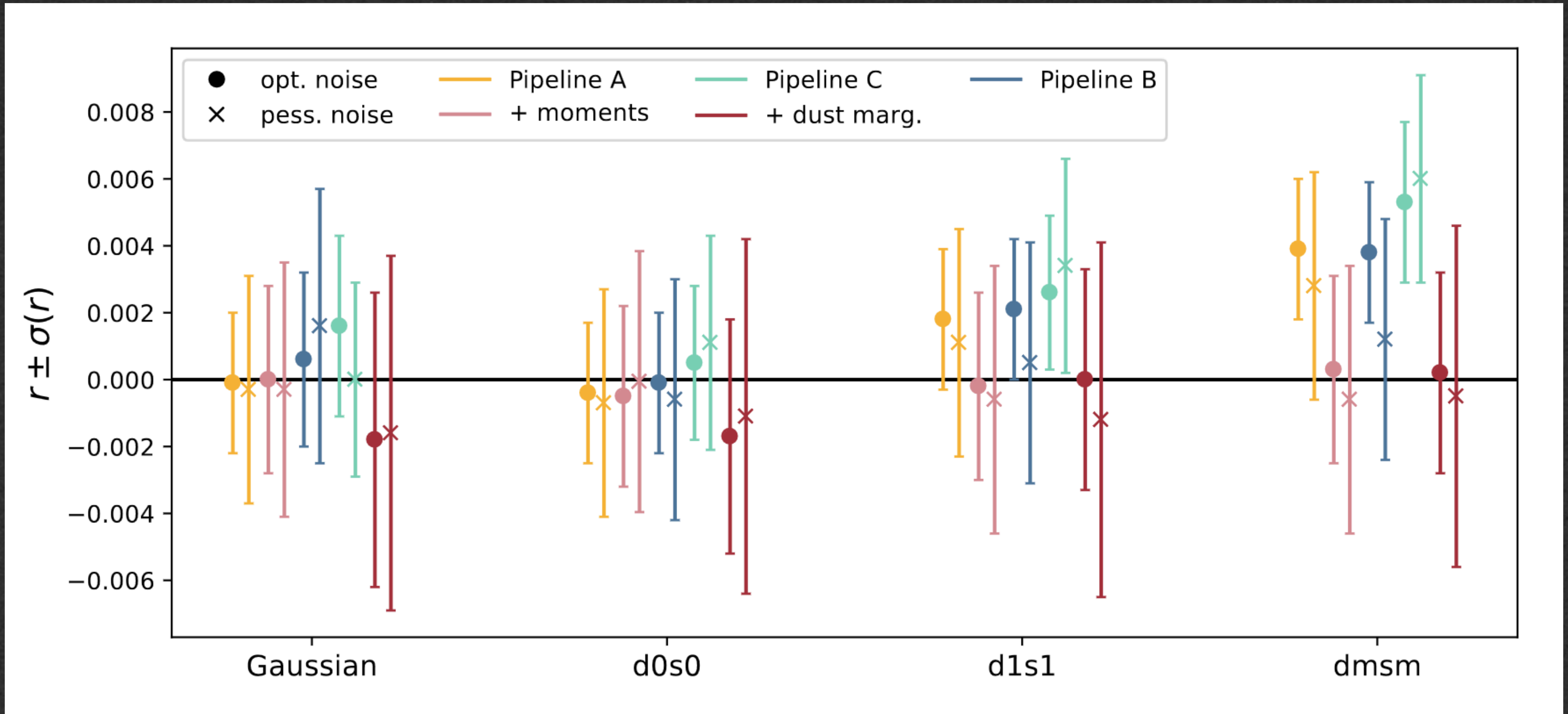
SAT UHF (Due to be shipped to Chile soon)

Pipeline development and testing

B-mode pipeline validation on simulations:

The Simons Observatory: pipeline comparison and validation for large-scale B-modes

Kevin Wolz[1,2,*], Susanna Azzoni[3,4], Carlos Hervías-Caimapo[5,6], Josquin Errard[7], Nicoletta Krachmalnicoff[1,2,8], David Alonso[3], Carlo Baccigalupi[1,2,8], Antón Baleato Lizancos[9,10], Michael L. Brown[11], Erminia Calabrese[12], Jens Chluba[11], Jo Dunkley[17,18], Giulio Fabbian[12,13], Nicholas Galitzki[14], Baptiste Jost[7,15], Magdy Morshed[7], and Federico Nati[16]

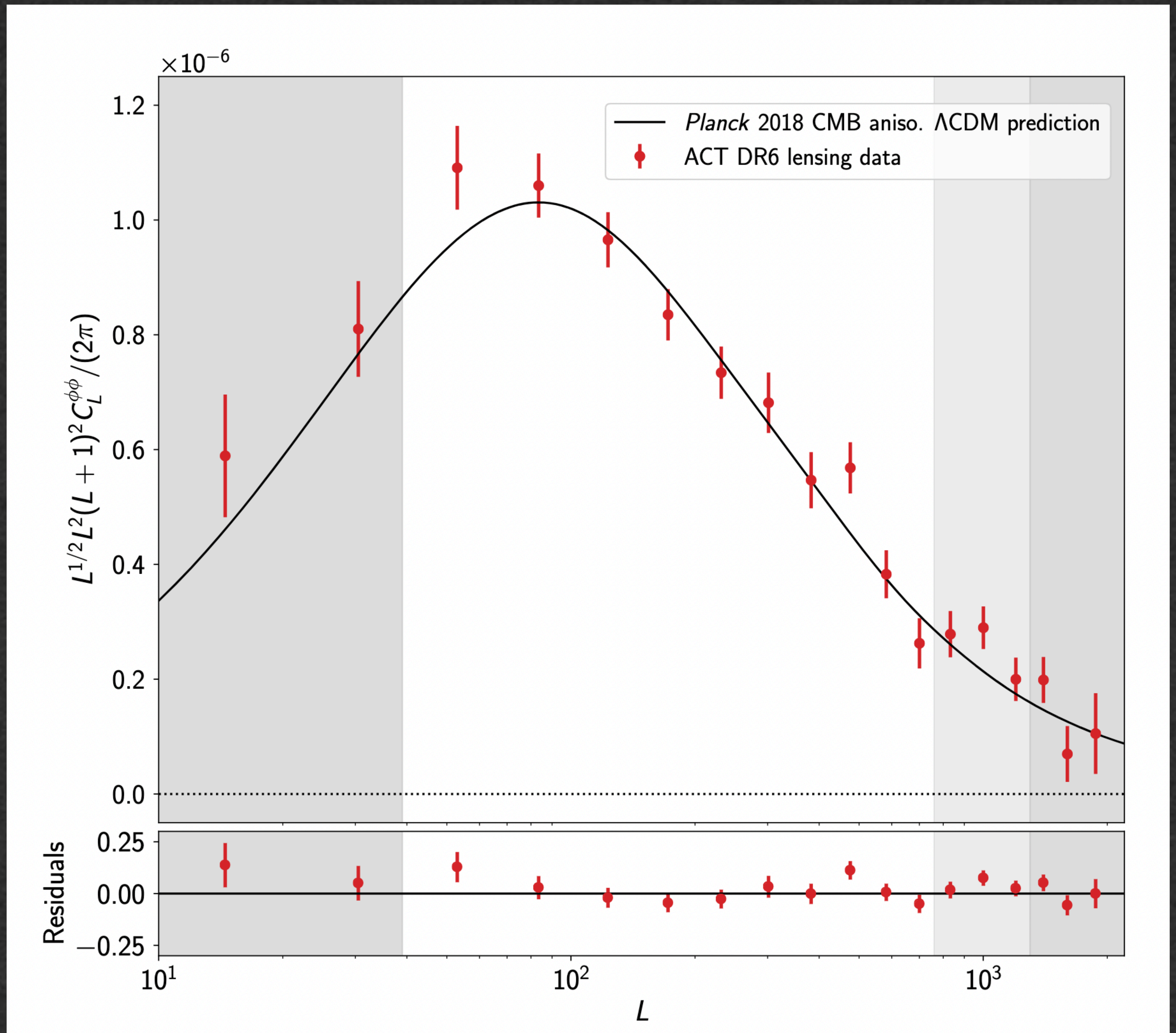


SO BB pipeline paper (link)

- Tested three different pipelines using different sky models
- $\sigma(r=0) = 0.003$ (SO nominal)

Pipeline development and testing

LAT pipelines extensively tested on ACT DR6



The Atacama Cosmology Telescope: A Measurement of the DR6 CMB Lensing Power Spectrum and its Implications for Structure Growth

Frank J. Qu,[1] Blake D. Sherwin,[1,2] Mathew S. Madhavacheril,[3,4] Dongwon Han,[1] Kevin T. Crowley,[5]
Irene Abril-Cabezas,[1] Peter A. R. Ade,[6] Simone Aiola,[7,8] Tommy Alford,[9] Mandana Amiri,[10]
Stefania Amodeo,[11] Rui An,[12] Zachary Atkins,[8] Jason E. Austermann,[13] Nicholas Battaglia,[14]
Elia Stefano Battistelli,[15] James A. Beall,[13] Rachel Bean,[14] Benjamin Beringue,[6] Tanay Bhandarkar,[3]
Emily Biermann,[16] Boris Bolliet,[1] J. Richard Bond,[17] Hongbo Cai,[16] Erminia Calabrese,[6] Victoria Calafut,[17]

arxiv:2304.05202

arxiv:2307.01258

The Atacama Cosmology Telescope: High-resolution component-separated maps across one-third of the sky

William Coulton,[1] Mathew S. Madhavacheril,[2,3] Adriaan J. Duivenvoorden,[1,4] J. Colin Hill,[5,1]
Irene Abril-Cabezas,[6,7] Peter A. R. Ade,[8] Simone Aiola,[1,4] Tommy Alford,[9] Mandana Amiri,[10] Stefania Amodeo,[11]
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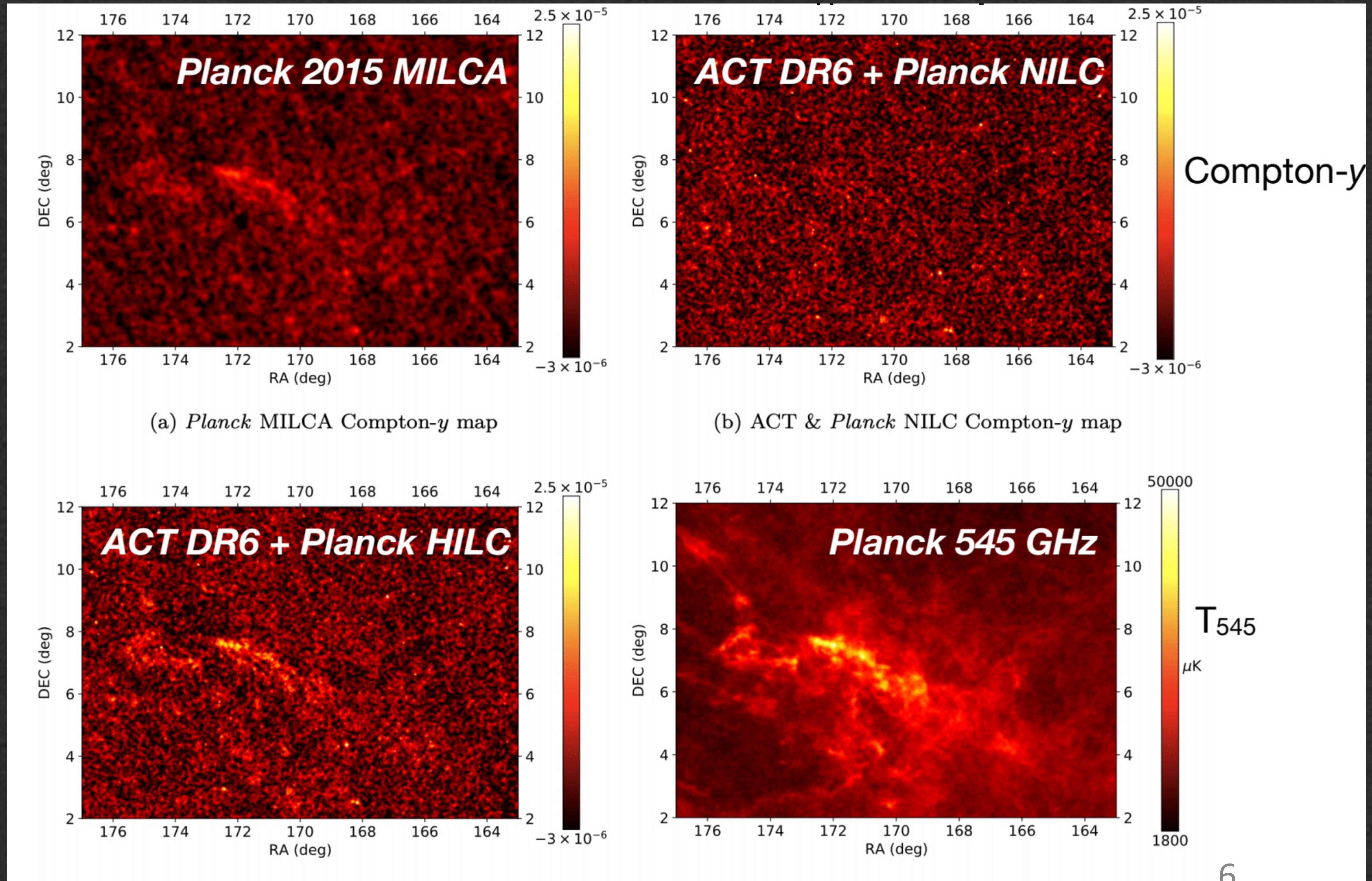


(a) *Planck* MILCA Compton-y map

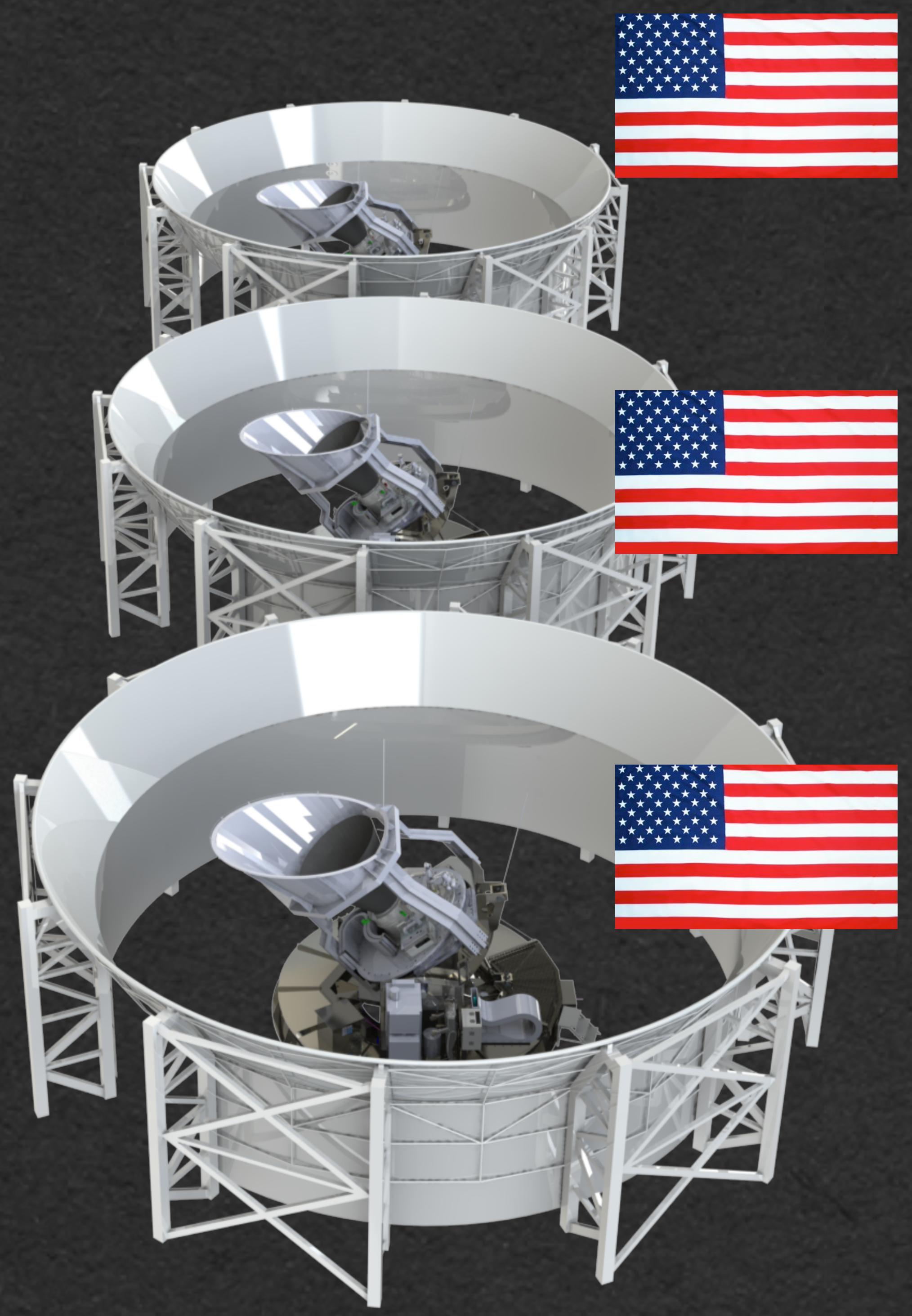
(b) ACT & *Planck* NILC Compton-y map

(c) ACT & *Planck* Harmonic ILC Compton-y map

(d) *Planck* 545 GHz map

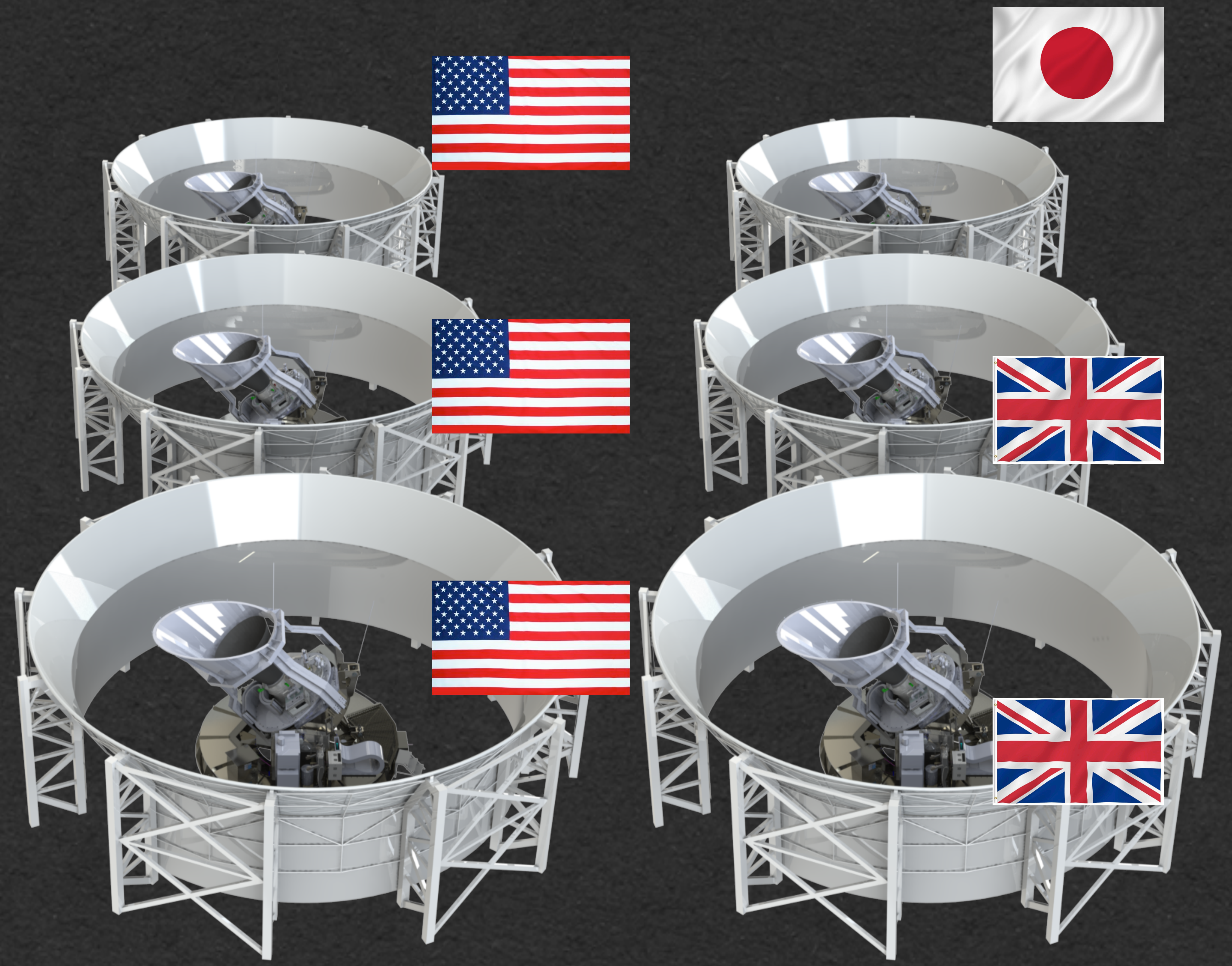
What’s next ?

SO family’s is getting bigger !



SO nominal (~2024)

- 3 telescopes
- 30.000 TES detectors
- 6 frequency bands



SO nominal + SO:UK + SO:JP (~2028)

- **6 telescopes**
- **60.000 TES detectors**
- 6 frequency bands

What's next ?

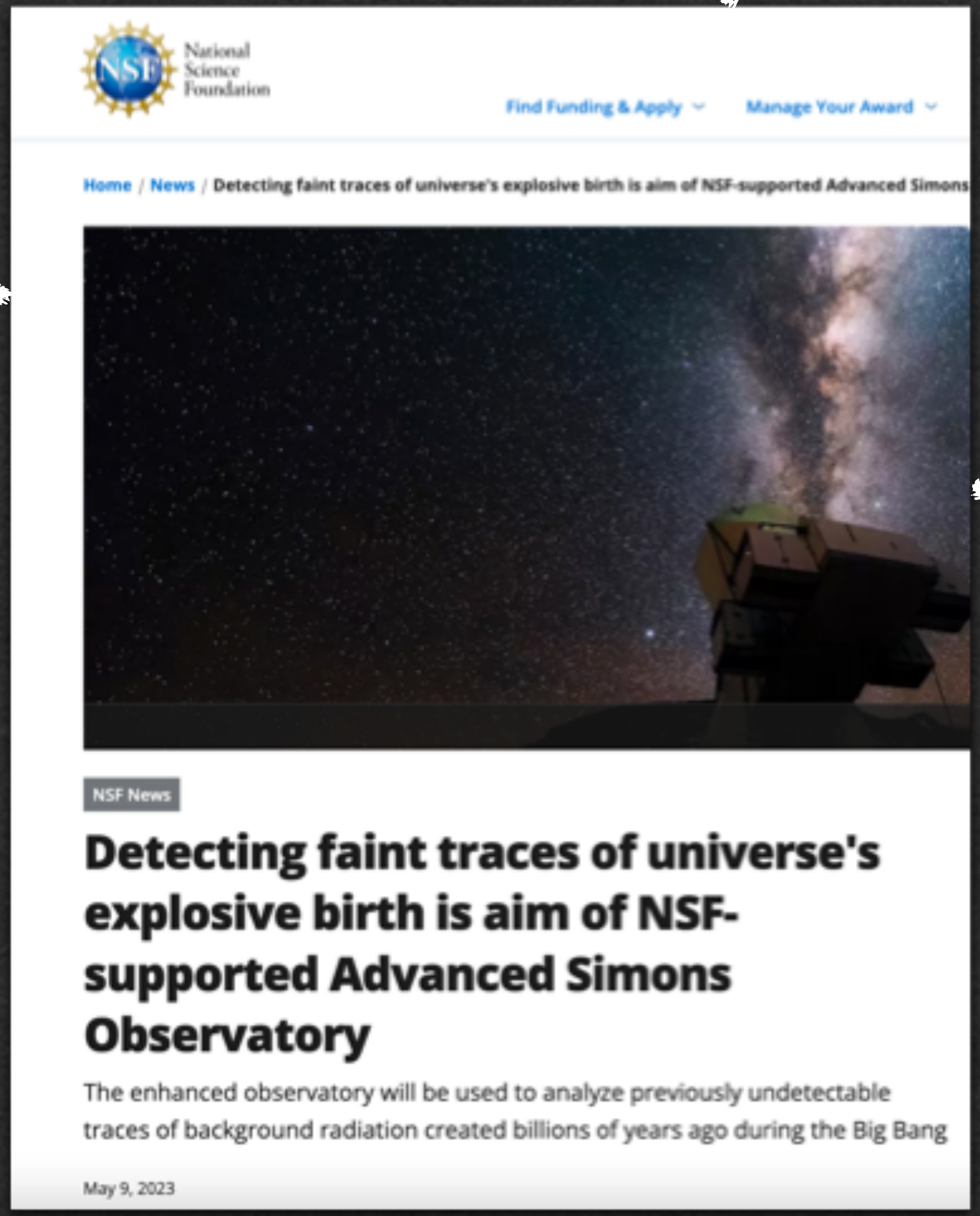
SO family's is getting bigger !

LAT Tubes

- 6 additional optics tubes for the LAT
- Doubling of the mapping speed
- More efficient transient detection
- Using same technology (no tech. development required)

Photovoltaic Array

- Reduced carbon footprint (reduce diesel consumption by 70%)
- Increase efficiency by 9%
- Reduced maintenance costs



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NSF News

Detecting faint traces of universe's explosive birth is aim of NSF-supported Advanced Simons Observatory

The enhanced observatory will be used to analyze previously undetectable traces of background radiation created billions of years ago during the Big Bang

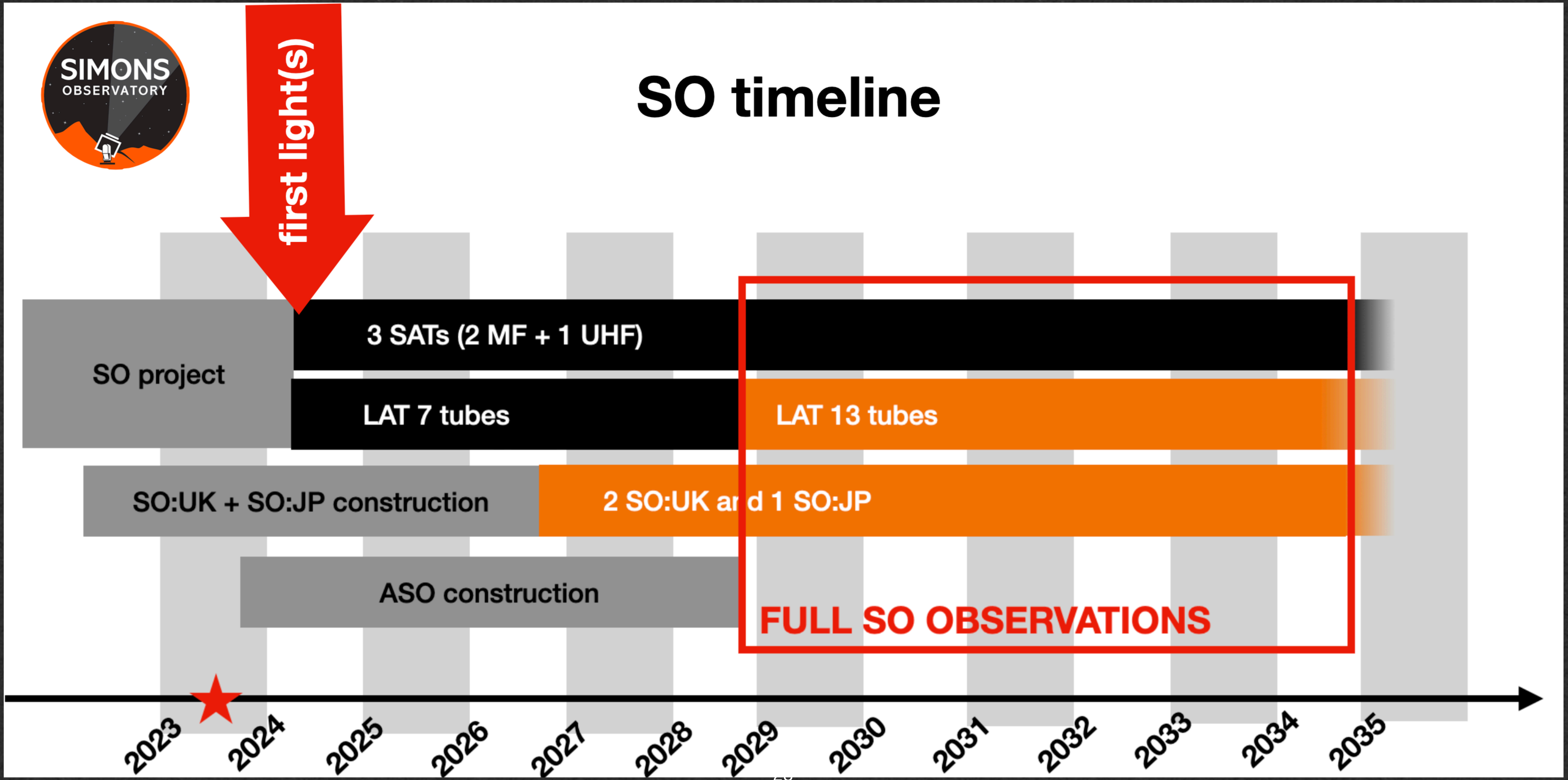
May 9, 2023

Data Management

- Full maps processed in 6 months
- Daily transients alerts
- Tools and maps delivered to the community
- Systematics mitigation across detector arrays

What's next ?

SO first science observation in 2024



Any questions ?

Credit: Mark Devlin