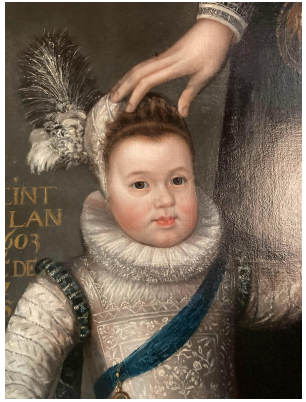
The Simons Observatory: Science Goals, Sensitivity Forecasting, and Instrumentation

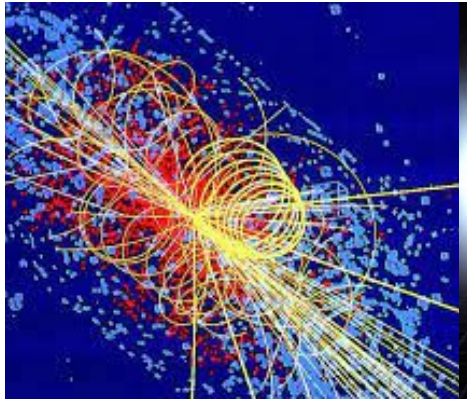
Benjamin Westbrook for the Simons Observatory

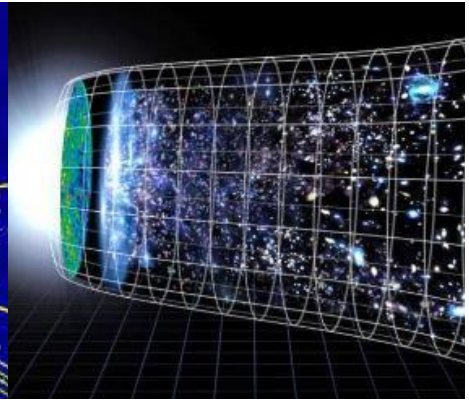
Rencontres de Blois: Particle Physics and Cosmology

Blois, Loire Valley, France

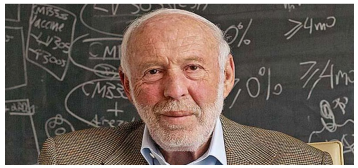
May 18, 2023







The Simons Observatory Collaboration

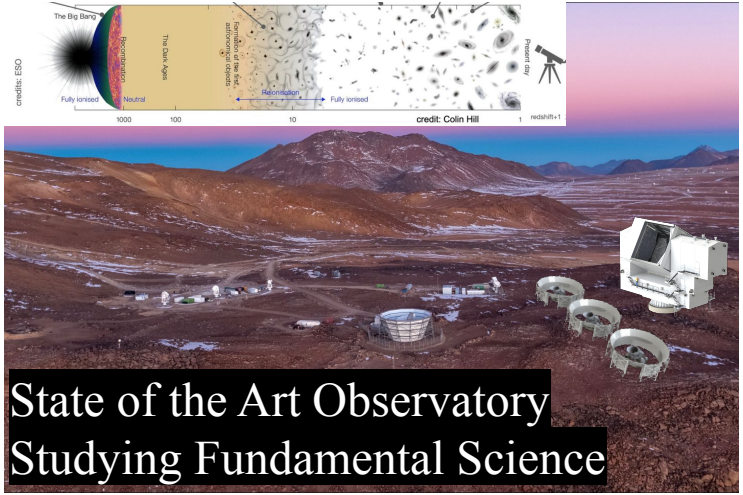


SIMONS FOUNDATION

HEISING-SIMONS FOUNDATION

Construction of nominal project is funded privately and is fully under way. >300 collaborators

The Ethos of Simons Observatory



State of the Art Observatory
Studying Fundamental Science

Training the Next Generation of Scientists

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SIMONS FOUNDATION

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ATACAMA ASTRONOMICAL PARK

10 Countries | 40+ Institutions | 300+ Researchers

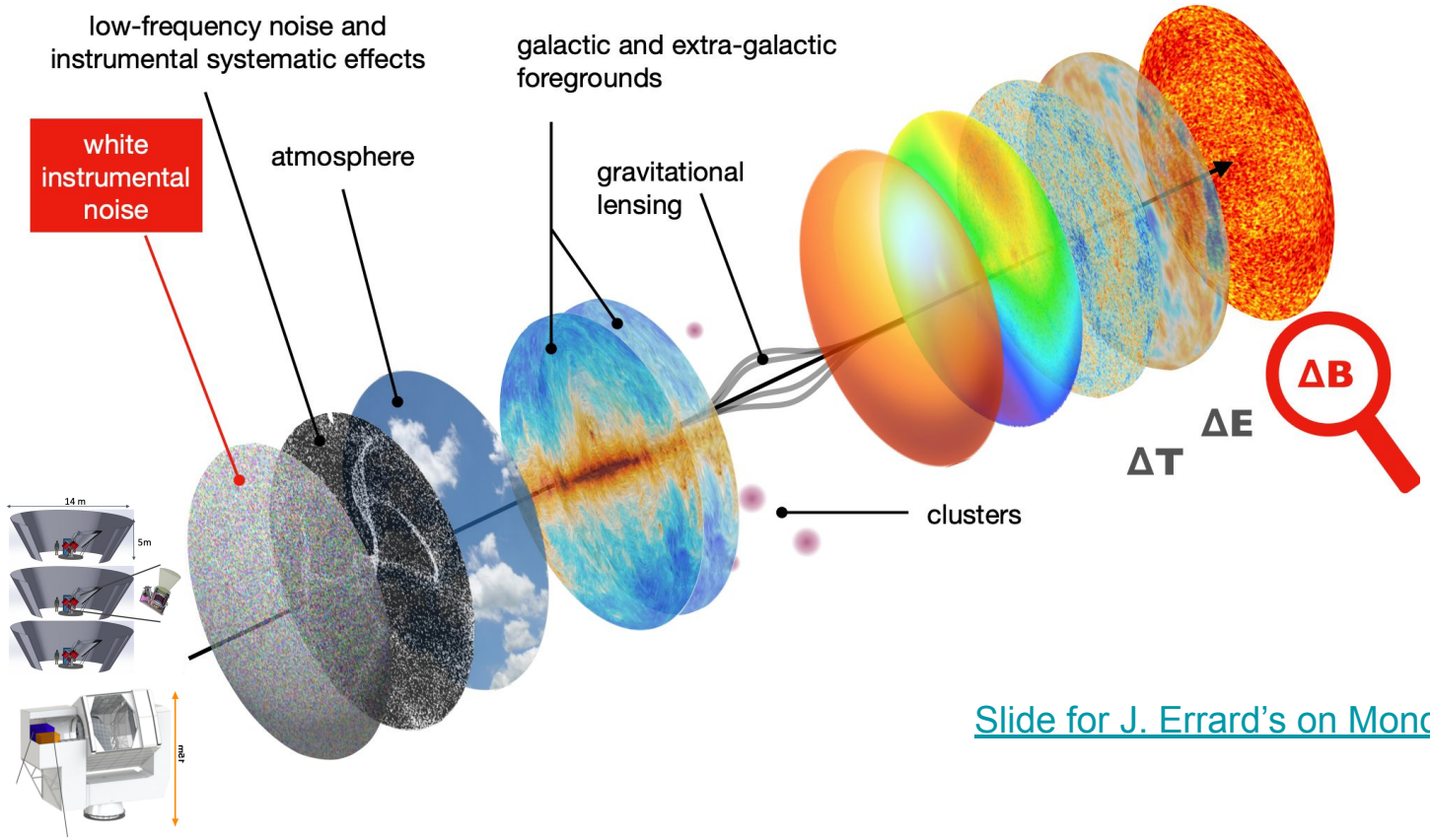
Talk Outline

1. Science Goals of the Simons Observatory
2. Sensitivity Forecasting
3. Instrument Overview
4. Plans for the future

Science Goals of SO

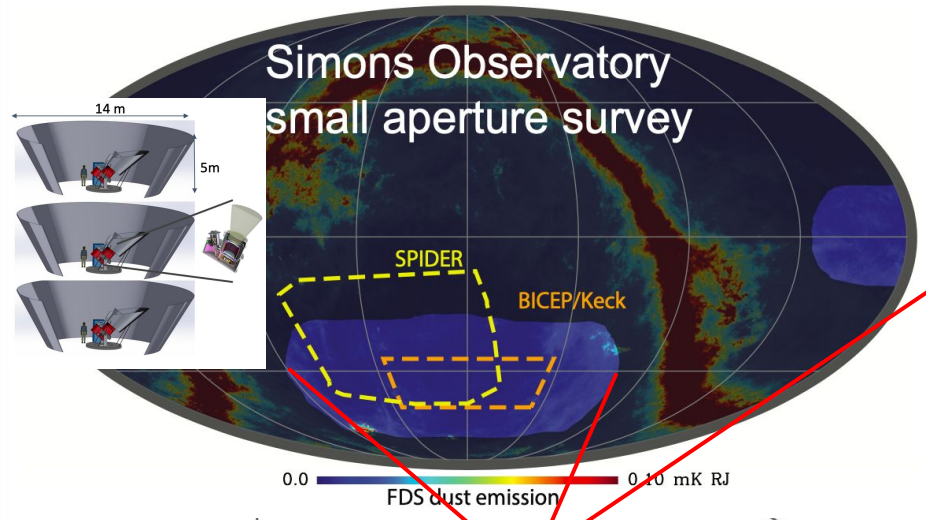
1. **Science Goals of the Simons Observatory**
2. Sensitivity Forecasting
3. Instrument Overview
4. Plans for the future

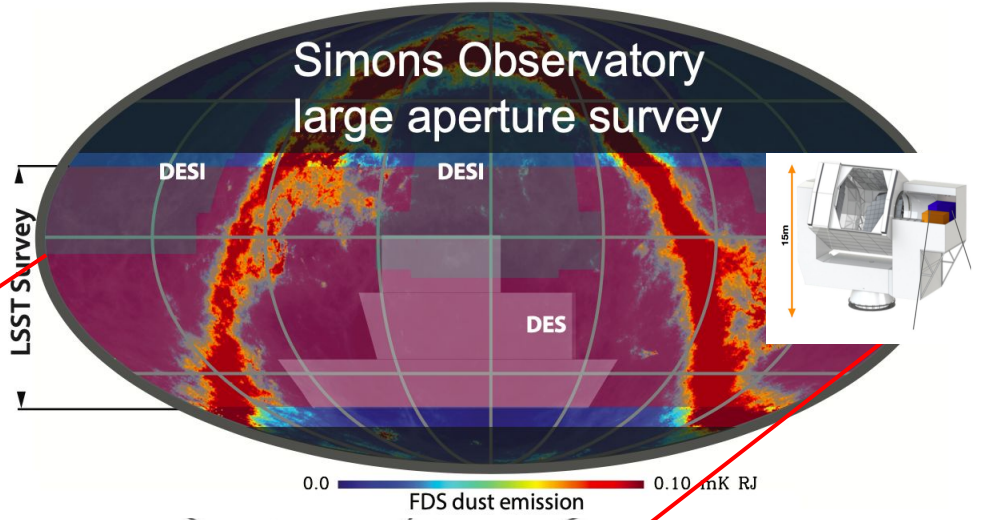
Science Goals of SO

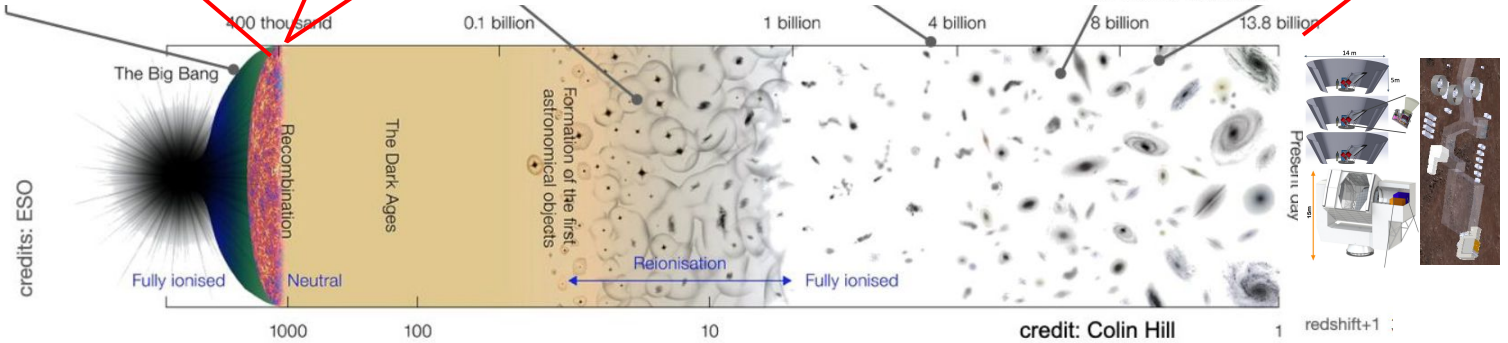


Slide for J. Errard's on Monday

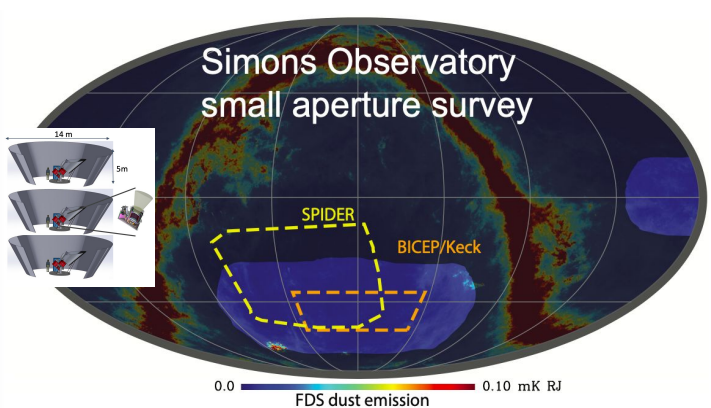
Science Goals of SO

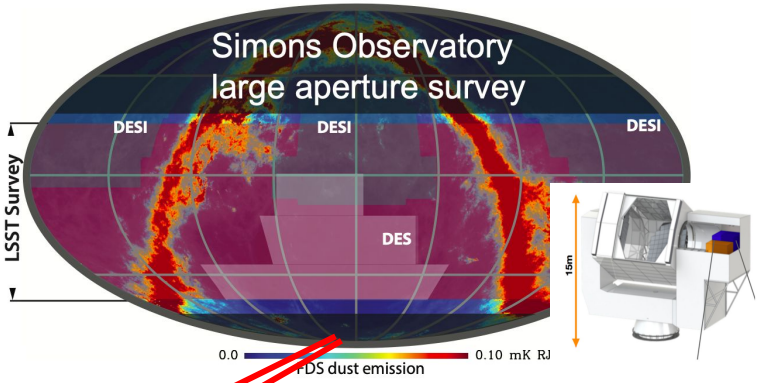


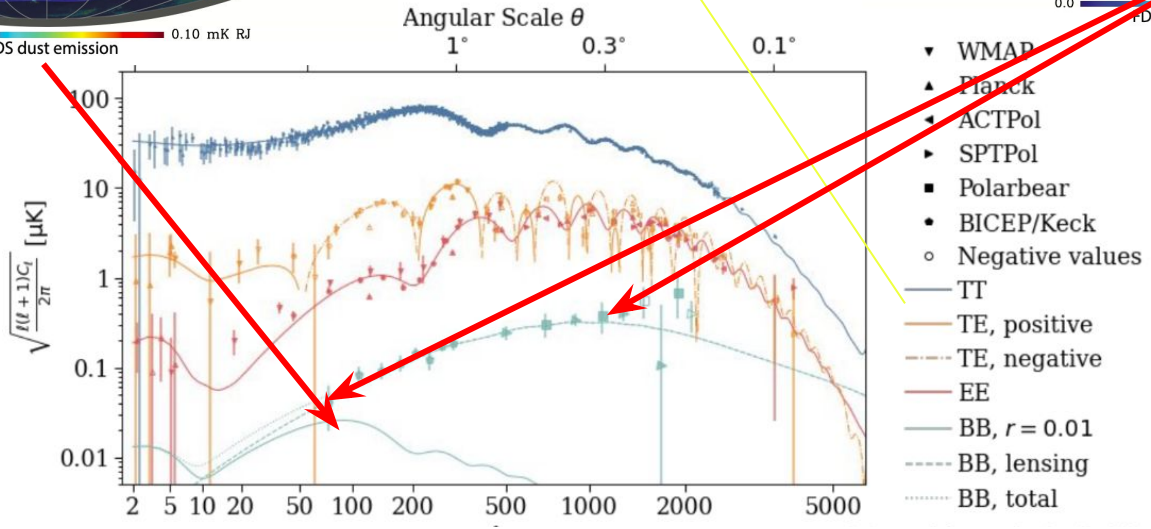




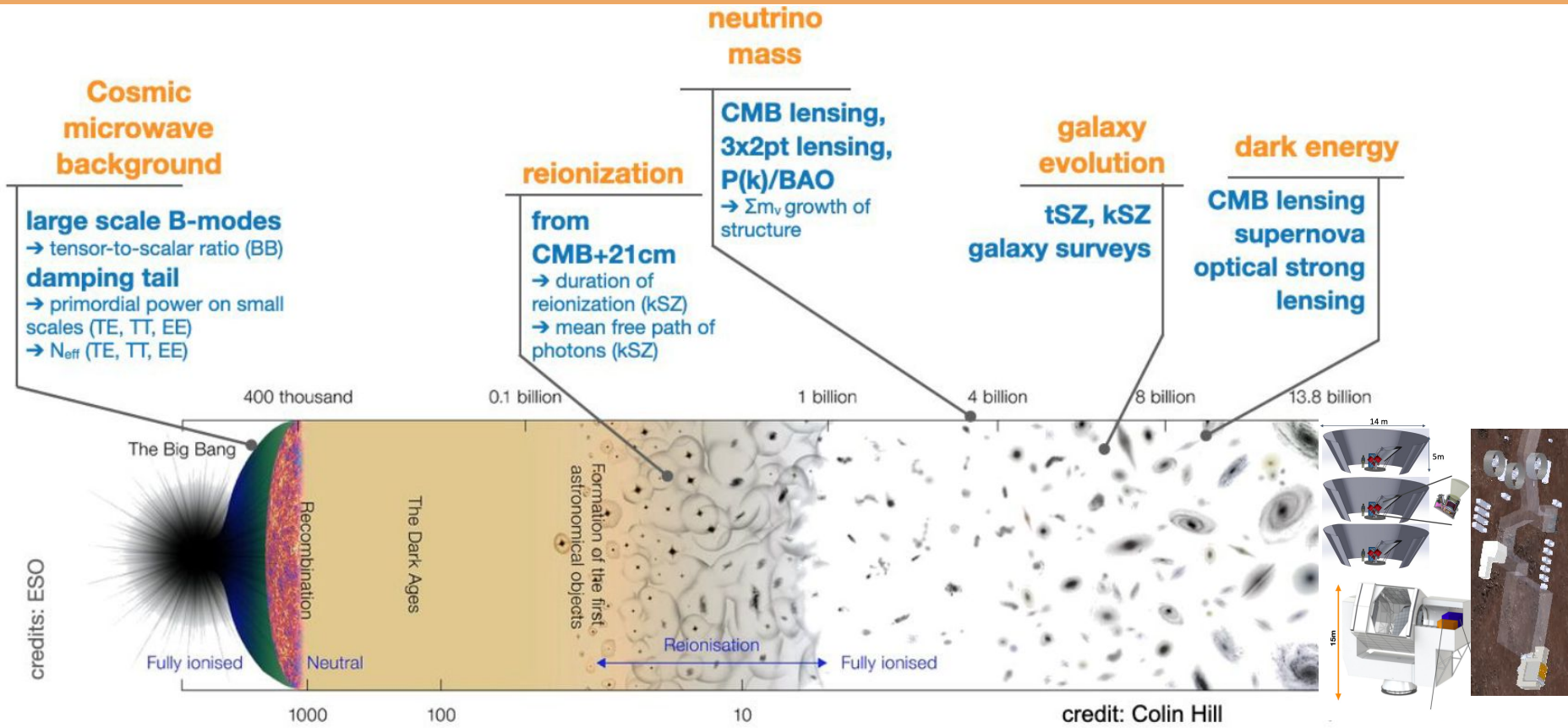
Science Goals of SO: CMB







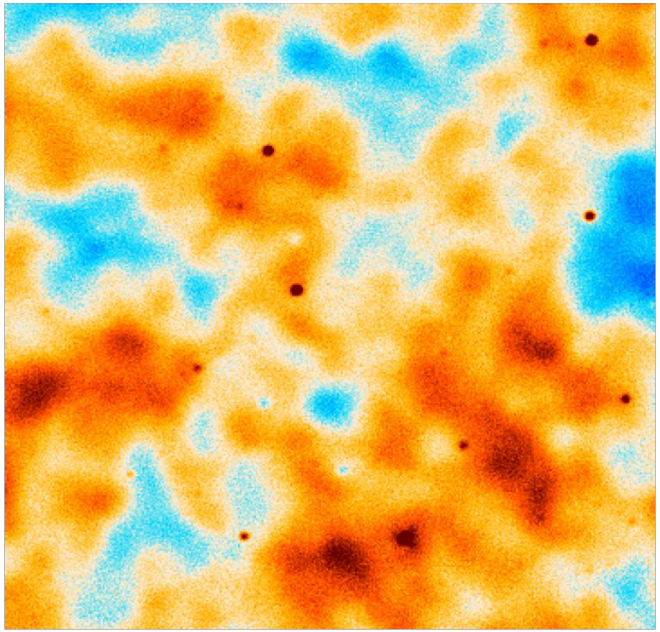
Science Goals of SO



See: The Simons Observatory: science goals and forecasts

Science Goals of SO: Astonomical Objects

- Variable Active Galactic Nuclei: O(100-1000s) / monthly at 1-10 mm.
- Potential of mm transients:
  - Orphan afterglows of Gamma Ray Bursts
  - Potential follow-up of Rubin Observatory optical transients
- 30k high-z dusty galaxies
- 20k galaxy clusters (Agnes Ferte's talk)
- Oort clouds, planet 9, tidal disruption
- Galactic star formation, magnetic fields



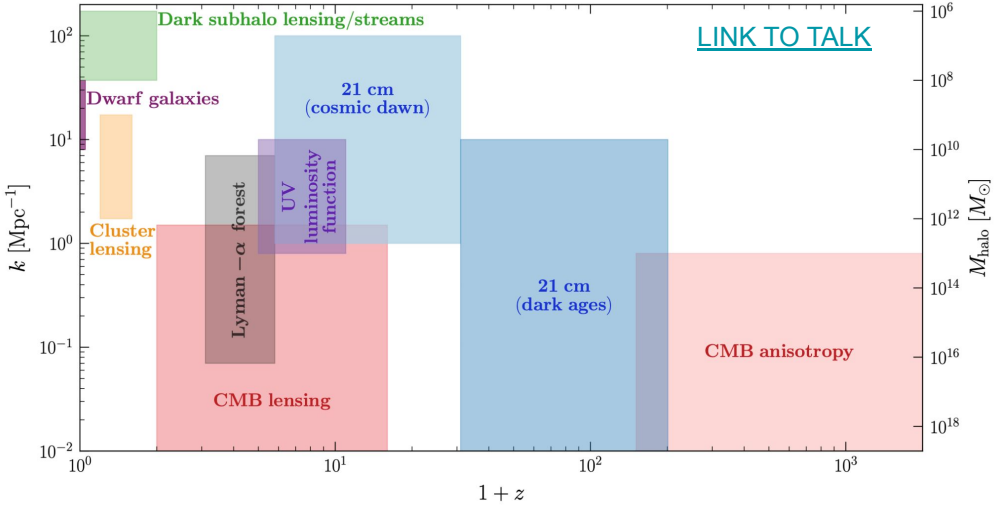
[Previous | Next | ADS]

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)

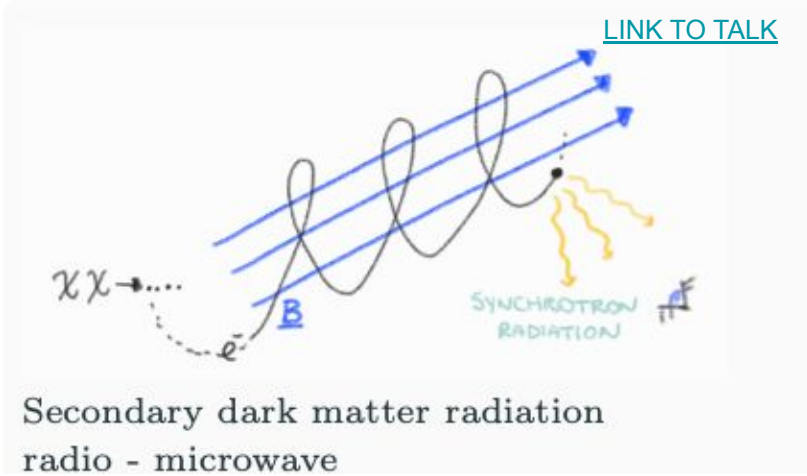
Subjects: Millimeter, Gamma Ray, AGN, Blazar, Transient, Variables

Science Goals of SO: Dark Matter



LINK TO TALK

- CMB is already a prime motivator of DM
- Mapping Large Scale Structure = locating Dark Matter
- Delensing magnitude = growth of structure history
- Cluster Lensing: optical + SZ surveys
- K. Boddy et. al. 2022



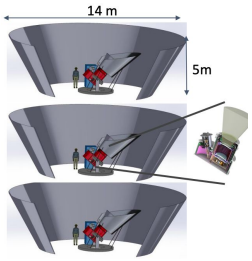
LINK TO TALK

- CR e+- produced by DM decay/annihilation in the galactic plane
- Once ‘captured’ by a magnetic field line they will emit synchrotron radiation
- CMB optimized telescopes (e.g. Planck, SO) will be sensitive to this radiation
- S. Maconi et. al. 2022

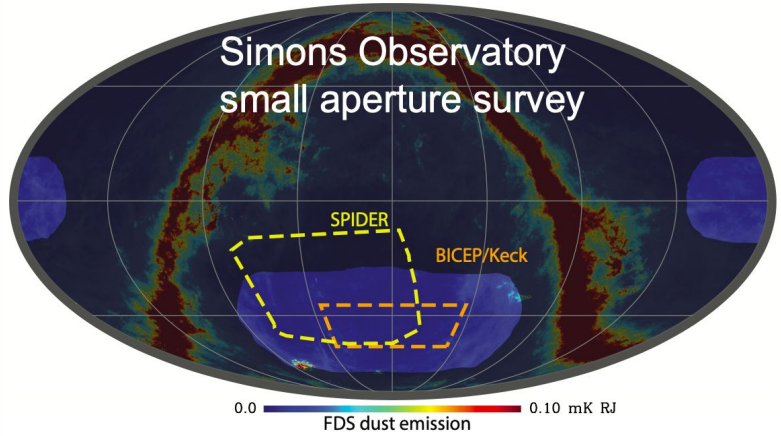
Sensitivity Forecasting

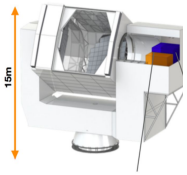
1. Science Goals of the Simons Observatory
2. **Sensitivity Forecasting**
3. Instrument Overview
4. Plans for the future

Sensitivity Forecasting by Band

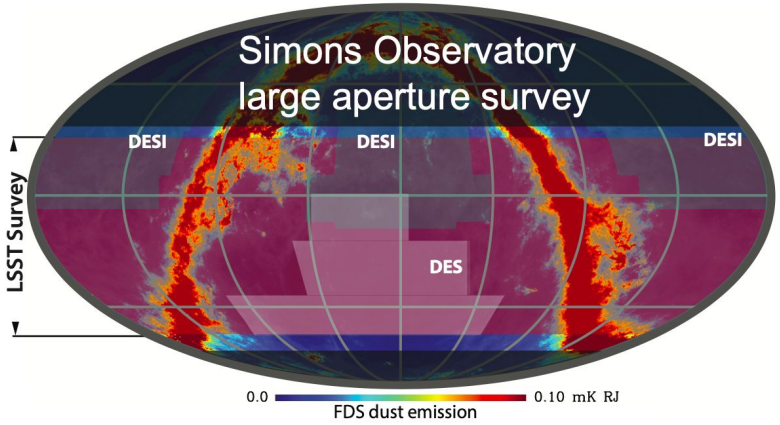


	SATs ($f_{\rm sky} = 0.1$)		
Freq. [GHz]	FWHM ($'$)	Noise (baseline) [μK-arcmin]	Noise (goal) [μK-arcmin]
27	91	35	25
39	63	21	17
93	30	2.6 } 2 μk-arcmin	1.9
145	17	3.3 } 2 μk-arcmin	2.1
225	11	6.3	4.2
280	9	16	10





	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 } 6 μk-arcmin	5.8
145	1.4	10 } 6 μk-arcmin	6.3
225	1.0	22	15
280	0.9	54	37



Sensitivity Forecasting and Science Goals

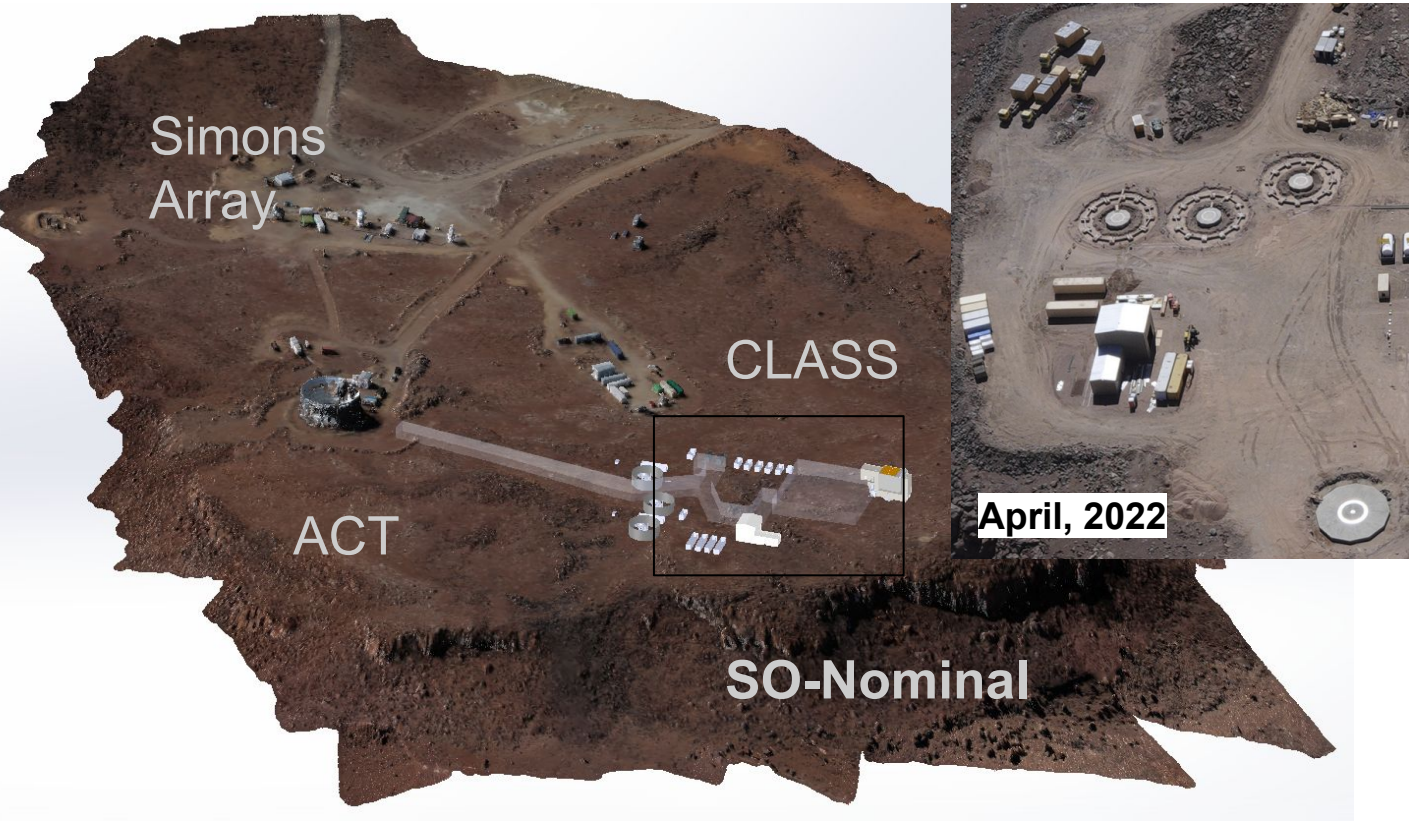
	Parameter	SO-Baseline[a] (no syst)	**SO-Baseline**[b]	SO-Goal[c]	Current[d]	Method	Sec.
Primordial perturbations	r	0.0024	**0.003**	0.002	0.03	BB + ext delens	3.4
	$e^{-2\tau}\mathcal{P}(k=0.2/\mathrm{Mpc})$	0.4%	**0.5%**	0.4%	3%	$TT/TE/EE$	4.2
	$f_{\mathrm{NL}}^{\mathrm{local}}$	1.8	**3**	1	5	$\kappa\kappa \times$ 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 × 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 × 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

SO Forecasting JCAP 02 (2019) 056 (1808.07445)

Instrument Overview

1. Science Goals of the Simons Observatory
2. Sensitivity Forecasting
3. **Instrument Overview**
4. Plans for the future

Simons Observatory: Site



5,200 meters

High and dry

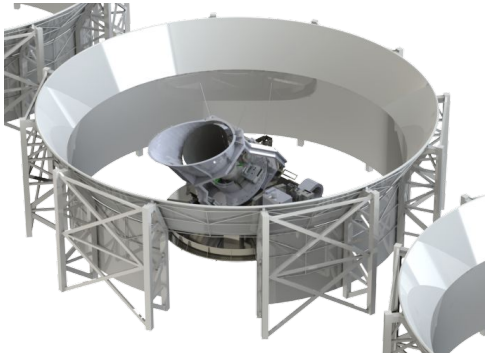
23 degree South Latitude

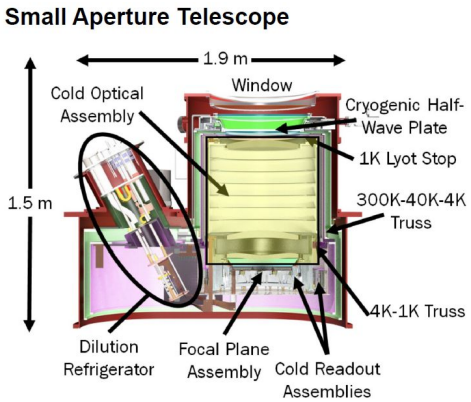
Established site

Room for expansion

Upgrade to PVA

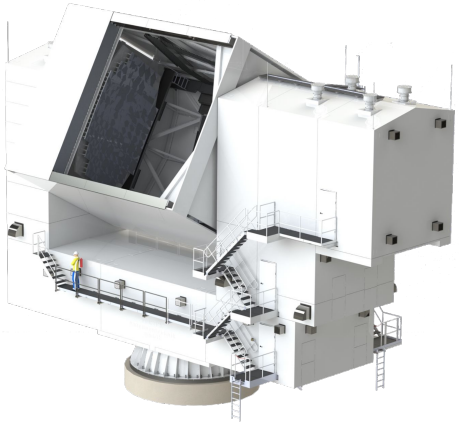
Simons Observatory (Nominal): SATs





- SO will initially deploy three small aperture telescopes (SATs)
- Refractive telescopes
- 42 cm apertures
- 10,000 detectors per telescope
- Observations from 1 to 10 mm
- See end of talk for planned expansion of SO

Simons Observatory: LAT



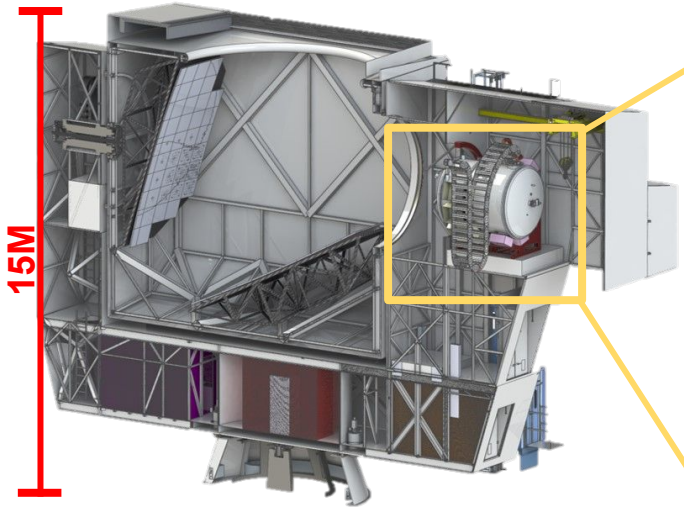
Large Aperture Telescope Receiver Enclosure

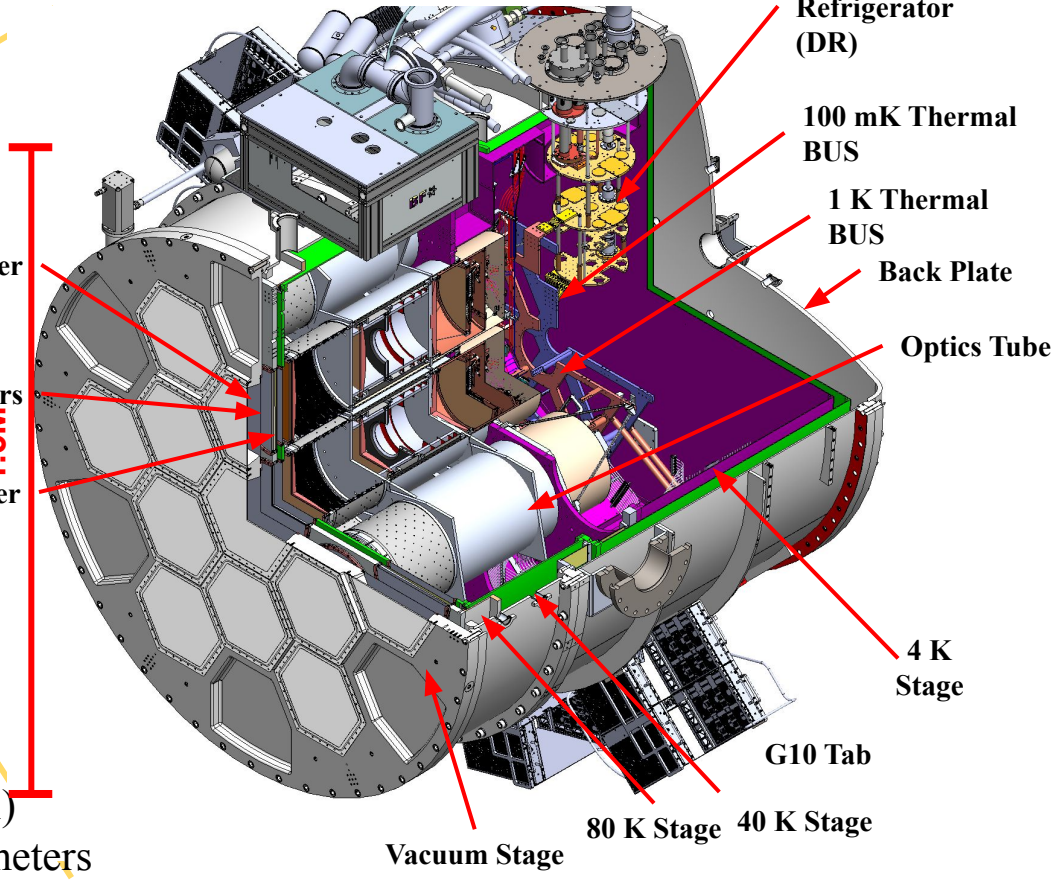
Construction of the LAT at Vertex in Germany

Pouring of the foundation of the LAT platform at the site

Integration of LAT at UPenn

Simons Observatory: LAT + Receiver

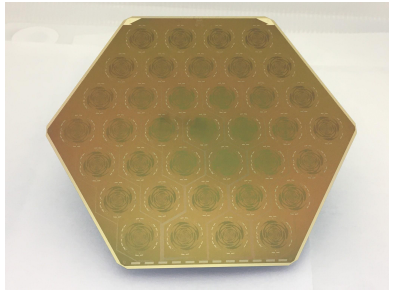


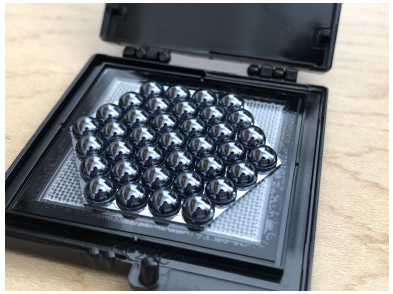


- 6 m primary mirror
  - Small angular resolution
  - Large focal plane
- Observations from 1 to 10 mm
- 13 Optics tubes slot (7 filled in SO-nominal)
- ~30,000 transition edge sensor (TES) bolometers

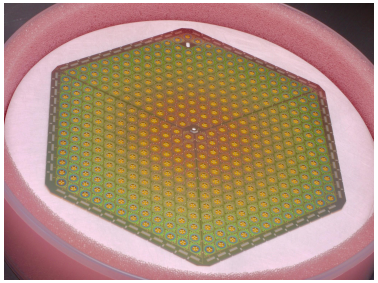
Simons Observatory: Detector & Modules

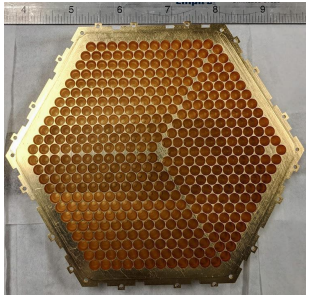
Low frequency (LF) detector arrays & lenslets





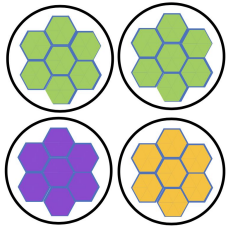
Mid frequency (MF) and ultra-high frequency (UHF) detector & horn arrays



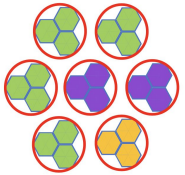


SO will use **dual-polarization, dichroic TES bolometer detectors**, cooled to 100 mK**.** The LF detector arrays build on the proven performance of POLARBEAR and the MF and UHF on ACT.

Detector modules



4 SAT focal planes



6m (LAT) inner focal plane

Top: The **universal focal-plane modules** (UFMs) contain the cold readout, detectors, and optical coupling. Bottom:UFM frequency distribution *(green:MF, purple:UHF, yellow:LF)*.

SO detectors

- >60,000 TES bolometer detectors across the LATR and four SATs
- Spanning six spectral bands centered between 27-270 GHz.
- Focal planes are populated with close-packed UFMs.
- The UFMs are common to the SATs and LATR and maintain a common footprint across frequency bands.

Plans for the Future

1. Science Goals of the Simons Observatory
2. Sensitivity Forecasting
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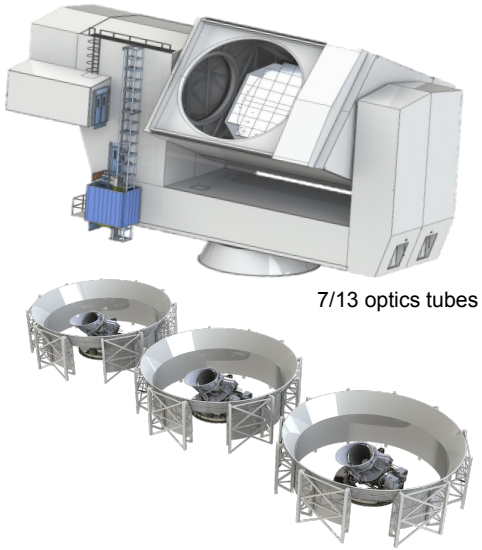
4. **Plans for the future**

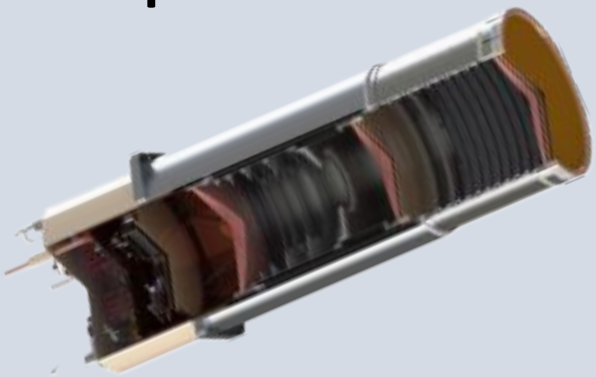
Simons Observatory: SO-JAPAN + SO-UK



- Double number of SATs
- Build an optics tube for the LAT
- Funded in Japan and UK
- Motivation: Doubles the sensitivity to primordial gravitational waves!

Simons Observatory: Advanced-SO

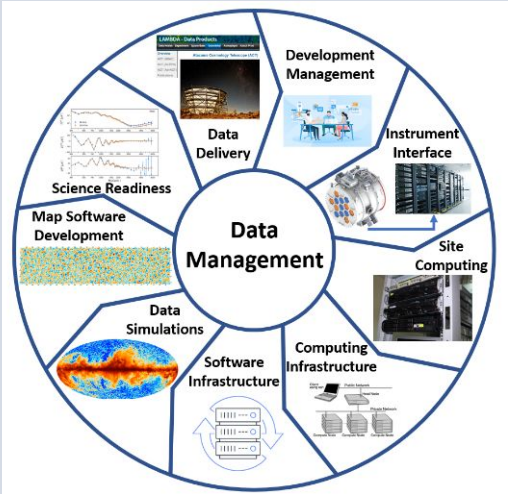
Optics Tubes



- Six New Optics Tubes
- Double Mapping Speed for Delesning and other science
- Enable Transient Detection
- No Development Required

[NSF ANNOUNCEMENT](): May 9, 2023

Data Management



- Full Maps Processed in 6 Months
- Daily Transient Alerts
- Verification and Systematics Mitigation
- Community Maps and Tools

Photovoltaic Array

- 9% increase in Observing Efficiency
- Reduced Carbon Footprint
- Reduced Maintenance Costs

Simons Observatory: Advanced-SO

Optics Tubes

- Six New
- Double
- Enable
- No Dev

Data Management

- Community Maps and Tools

Photovoltaic Array

n Observing

- Reduced Carbon Footprint
- Reduced Maintenance Costs

[NSF ARTICLE May 9, 2023](new.nsf.gov/news/detecting-faint-traces-universes-explosive-birth)

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

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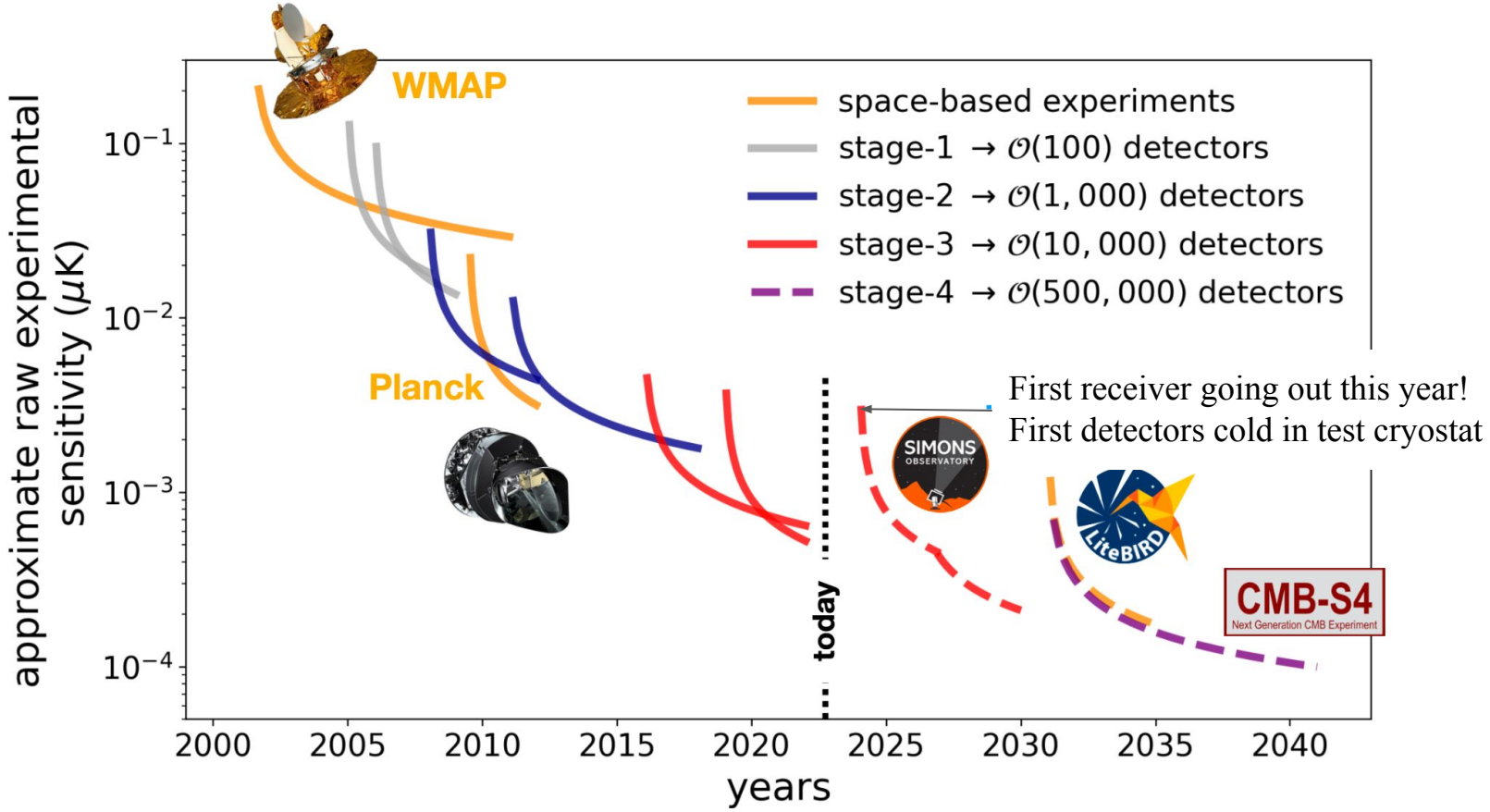
Related stories

Timeline for SO



First receiver going out this year!
First detectors cold in test cryostat

Summary

Time Domain Astrophysics

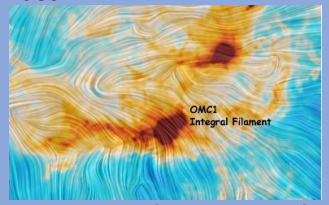

Tidal Disruption


Stellar Flares


Variable AGN

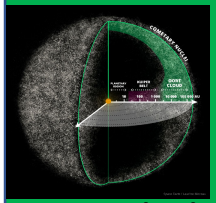
Galactic Astrophysics


Interstellar Dust



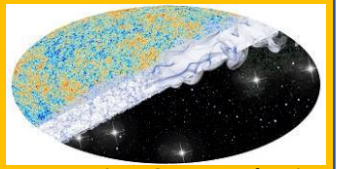
Star Formation, Magnetic Fields and Turbulence

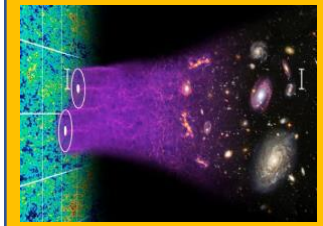
Planetary Science

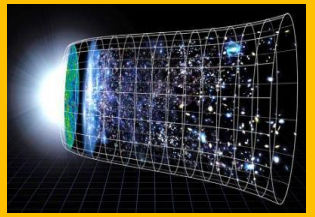

Exo-Oort Clouds


Planet 9

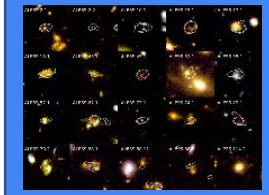
Cosmology and Particle Physics


H_0 Tension & New Physics

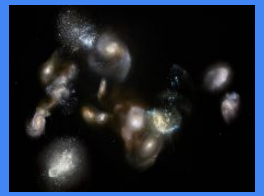

Light Relics and Neutrinos


Evolution of the Universe Over Cosmic Time

Extragalactic Astronomy


Sources


Missing Baryons


Galaxy Clusters

Thank you! Any Questions?

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arxiv.org/abs/1808.07445

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