

Erminia Calabrese



School of
Physics and
Astronomy

ASTRONOMY INSTRUMENTATION



OFFERYNIAETH SERYYDDIAETH

ASTRONOMY



SERYDDIAETH

Site via drone from Deborah Kellner

The Simons Observatory

CMB@60, Torino, May 2025



European
Research
Council



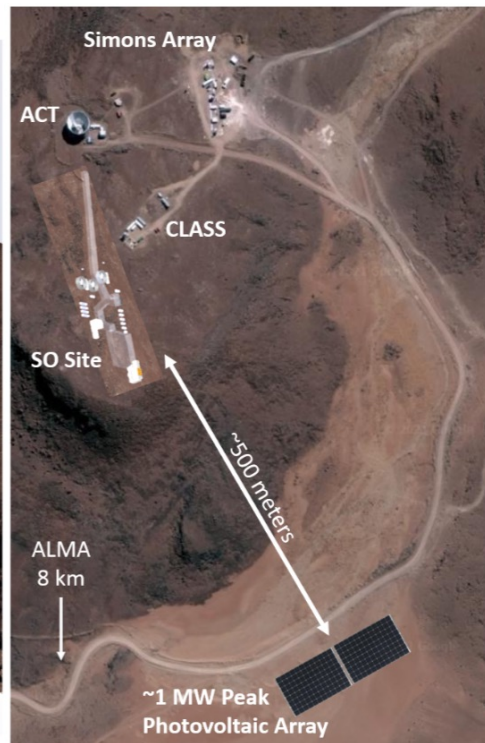
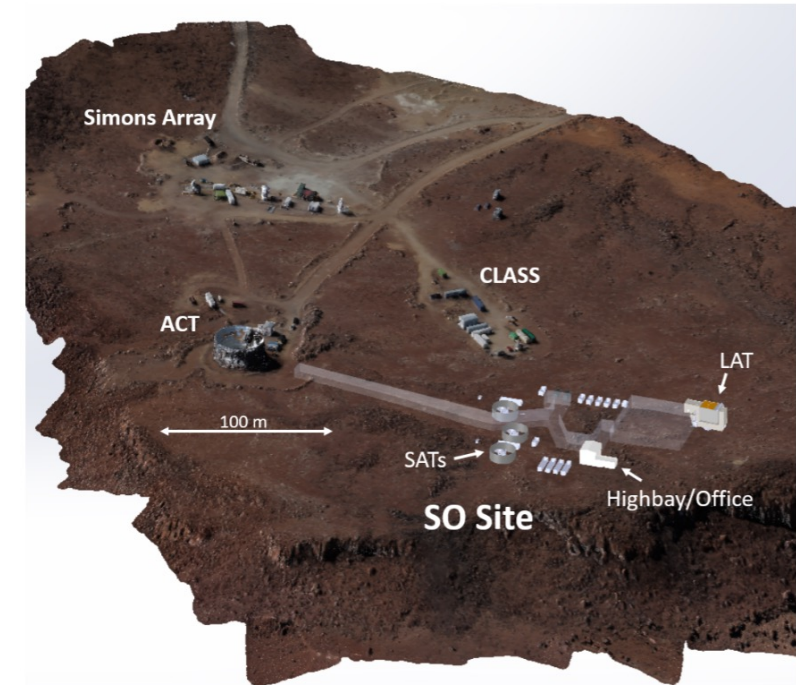
Science & Technology
Facilities Council



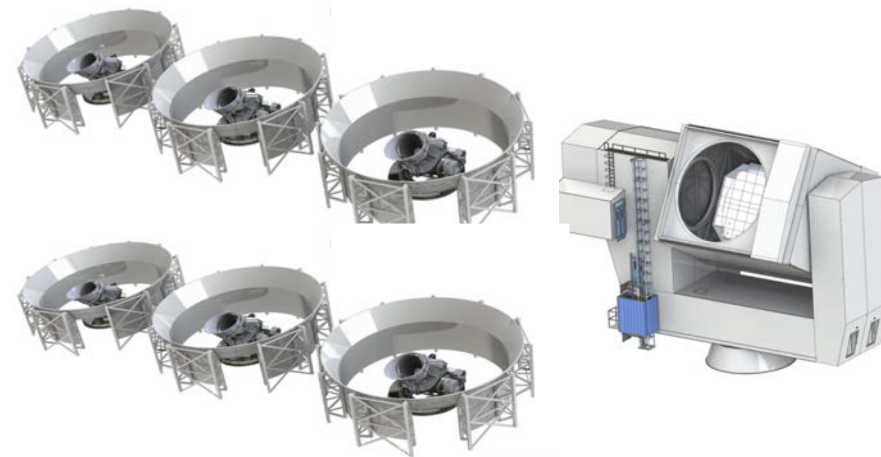
UK Research
and Innovation



The Simons Observatory



Six 0.5-m Small Aperture Telescopes
One 6-m Large Aperture Telescope fully populated with 13 tubes



a little over 123,000 detectors
6 frequency bands in the mm

Operations started!

Green Observatory, replacing 70% of the power at the site with Solar Energy

Large international collaboration
15+ countries, 60+ institutions
~375 collaborators





<https://simonsobservatory.org/>



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SO Nominal



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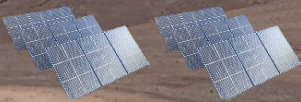
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<https://simonsobservatory.org/>

Solar Power (2025)
(courtesy of NSF and UKRI)



SO Nominal

ASO (2028)
(fully populating
the LAT)

SO:JP – One SAT (2026)

SO:UK – Two SATs (2026)

Permissions request underway



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Time Domain Astrophysics

Tidal Disruption Events



Stellar Flares



Variable AGN



Training the Next Generation



Extragalactic Astronomy



Missing Baryons



Sources



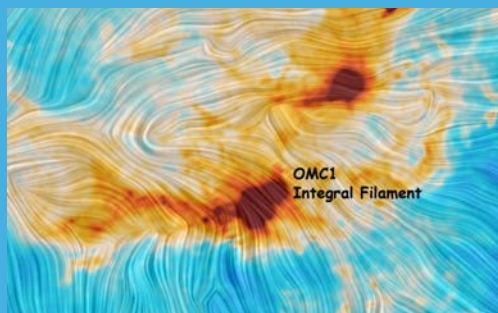
Galaxy Clusters



Galactic Astronomy

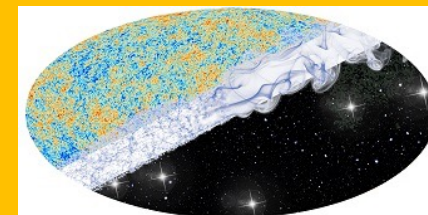


Interstellar Dust

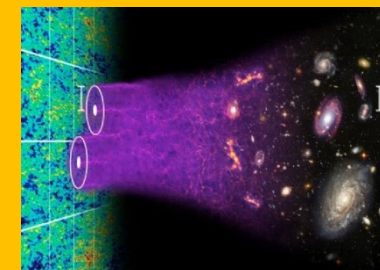


Star Formation, Magnetic Fields and Dust Turbulence

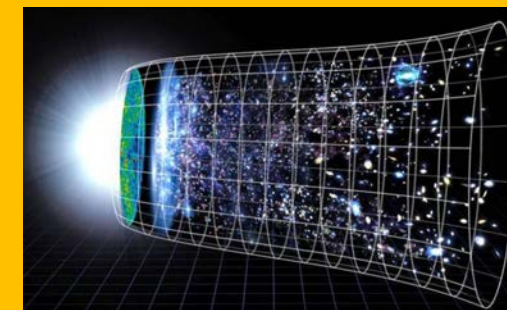
Cosmology and Particle Physics



H_0 Tension and New Physics

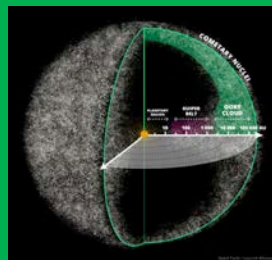


Light Relics and Neutrinos



The Evolution of the Universe Over Cosmic Time

Planetary Science



Exo-Oort Clouds



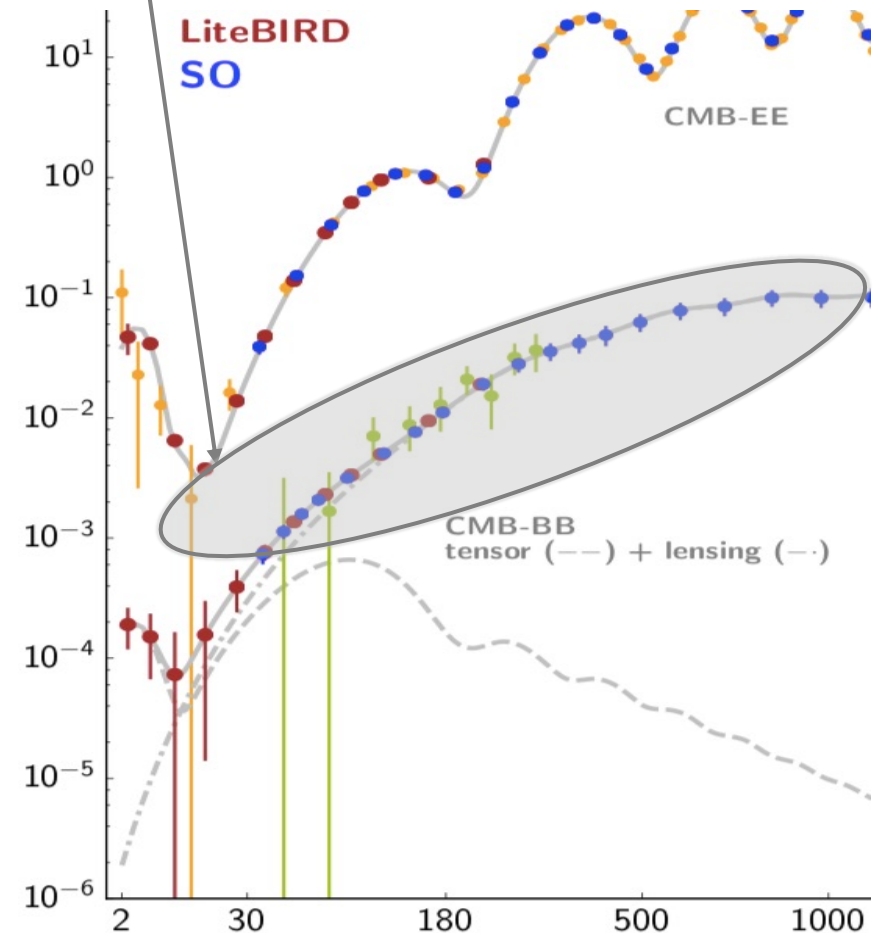
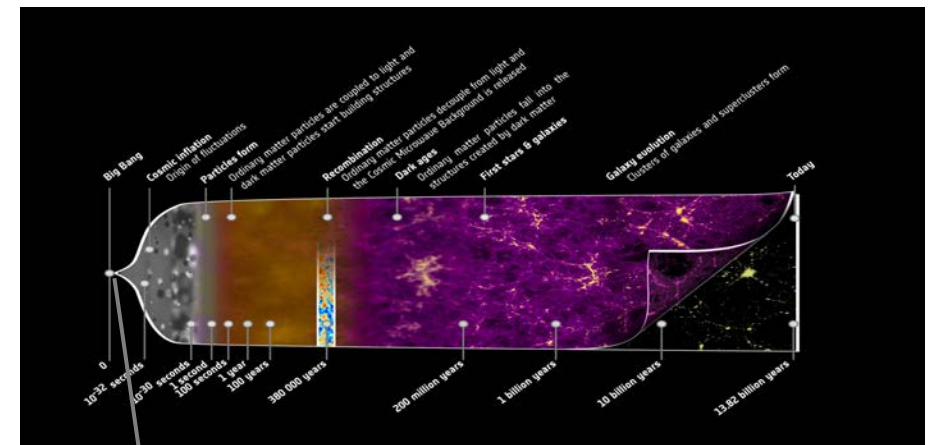
Planet 9



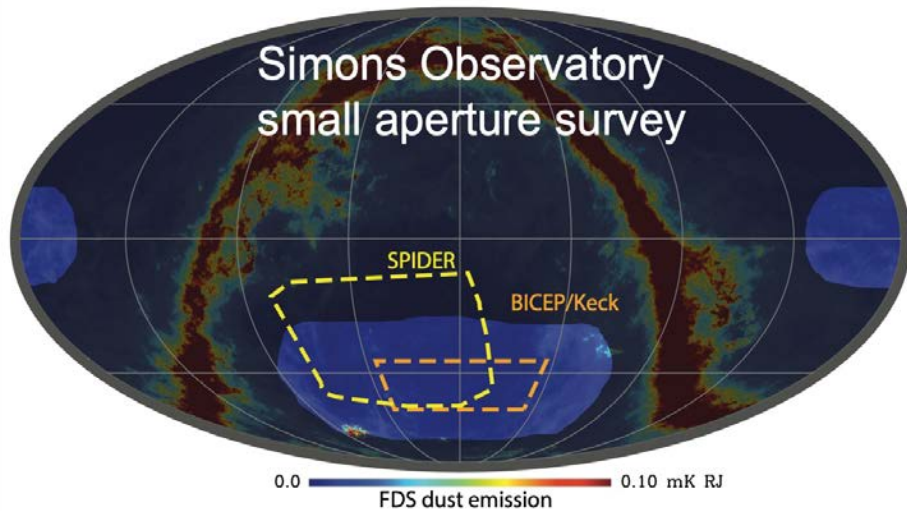
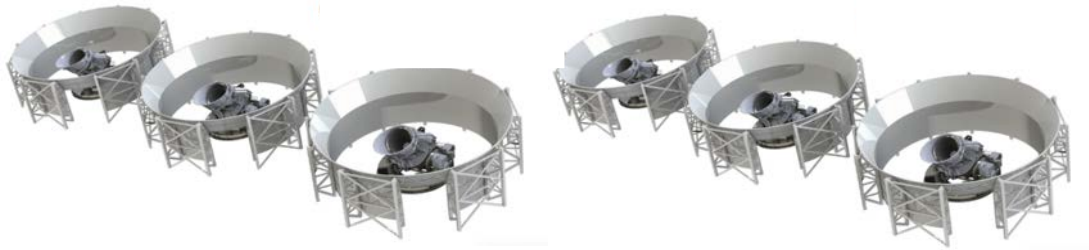
1 μ K arcmin (@90/150GHz) over 5000°² after 6-SAT 9-year survey
covering 6 frequencies (30-280 GHz)

The Simons Observatory Collaboration 2019

**On sky
since 2023!**



Primordial Perturbations



Small Aperture Survey

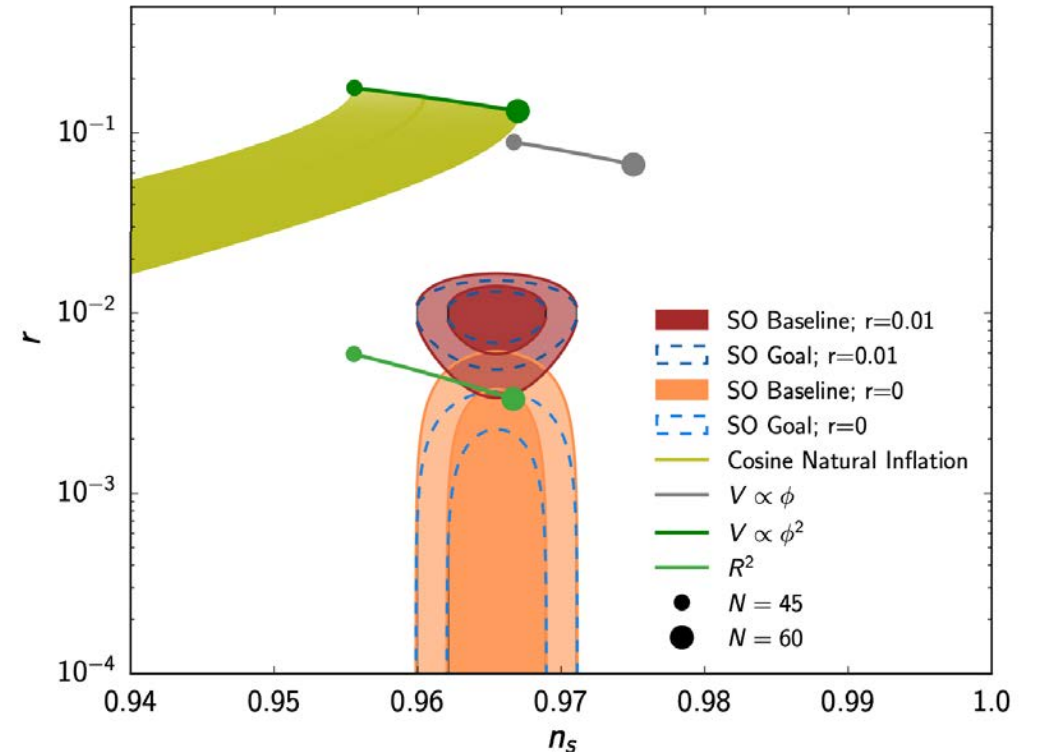
Deep, high sensitivity

1 μK arcmin (@90/150GHz) over 5000°² after 6-SAT 9-year survey covering 6 frequencies (30-280 GHz)

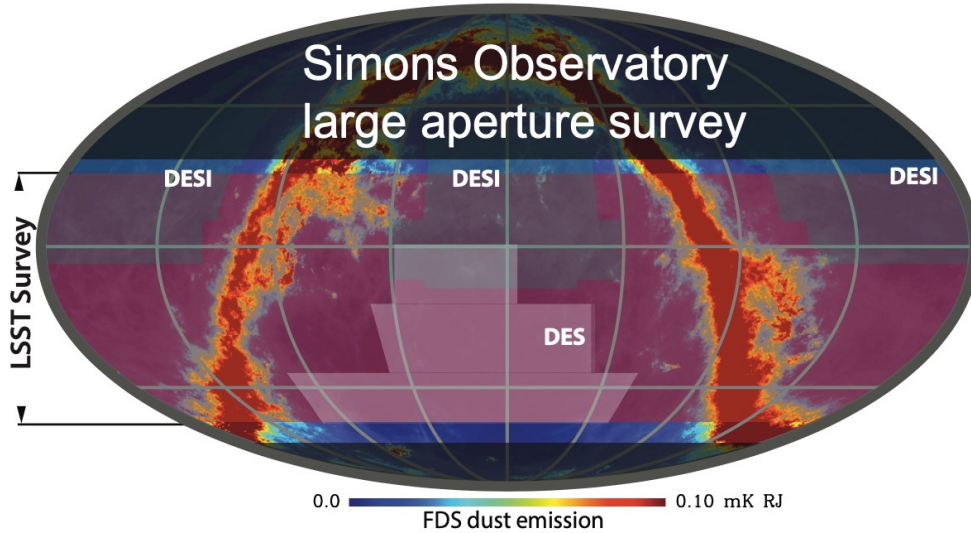
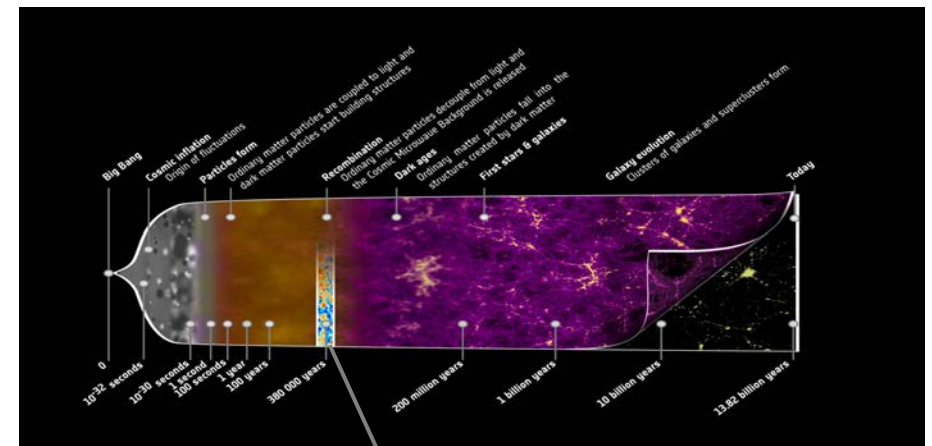
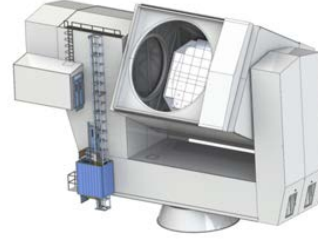
Dedicated to B-mode searches → primordial gravitational waves/primordial perturbations

SO will detect or rule out models with $r \geq 0.01$ at 3σ or greater

Goal is $\sigma(r) = 0.002-0.003$ with first 3 SATs



High precision tests of the cosmological model

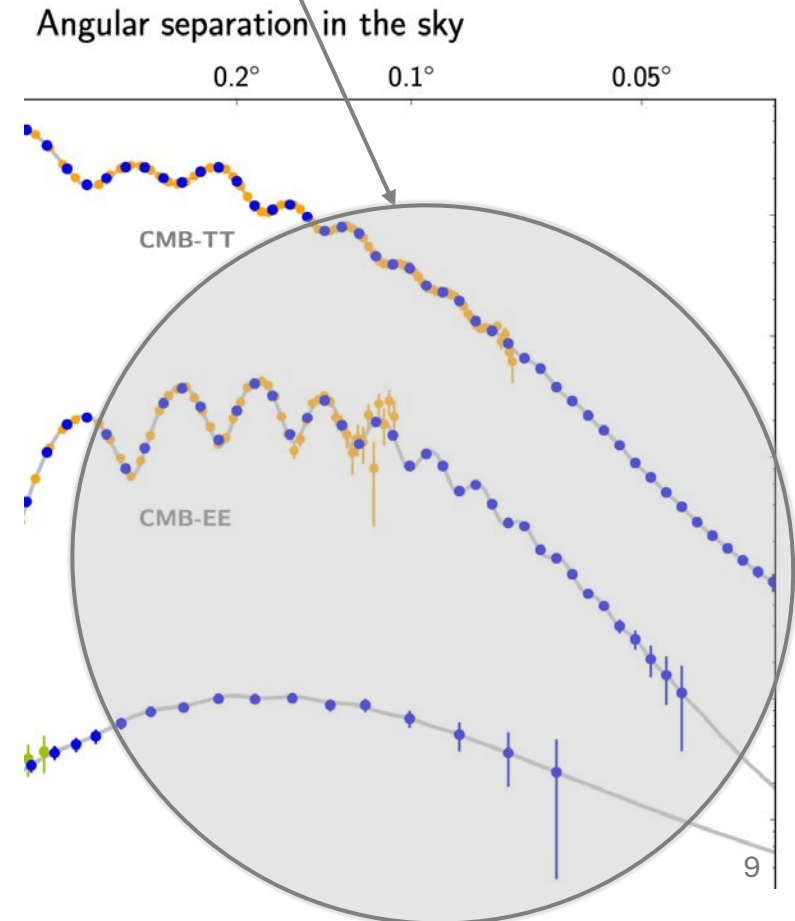


**First light
Feb 2025!**

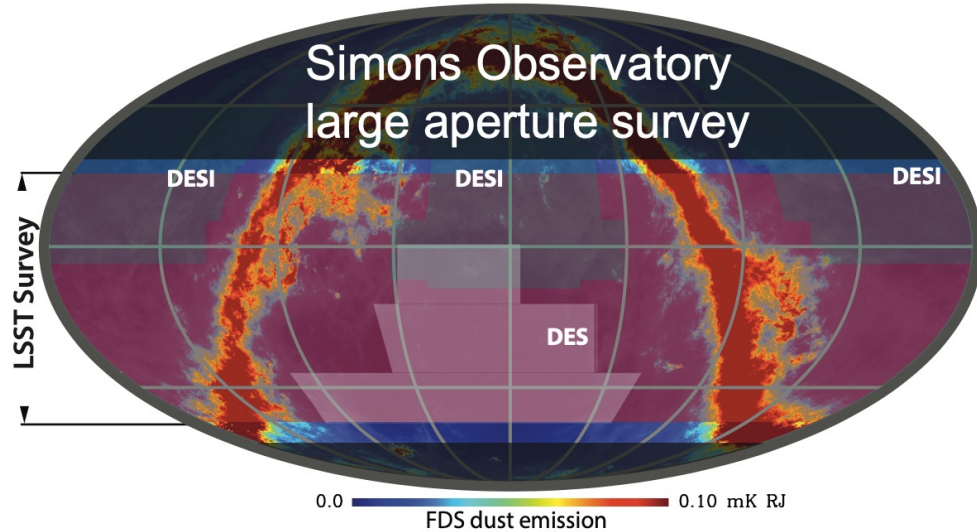
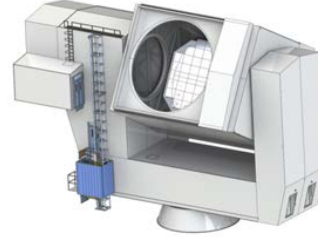
Large Aperture Survey

Wide (40-70% of sky), at high resolution (1.4' at 150 GHz) and high sensitivity (6 μ K-arcmin in combined 90/150), over 6 frequencies (30-280 GHz)

New results on dark matter and matter distribution, neutrinos, expansion/age of the Universe and much more



High precision tests of the cosmological model

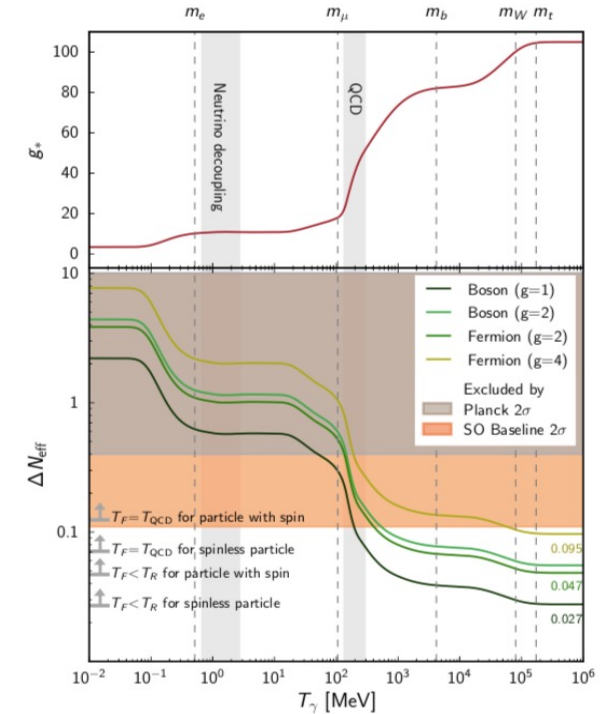


Large Aperture Survey

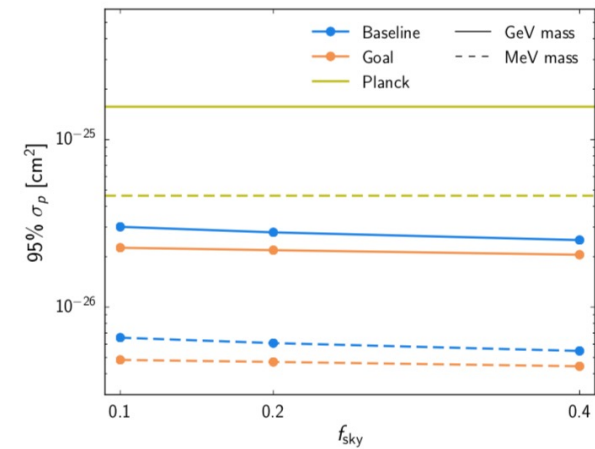
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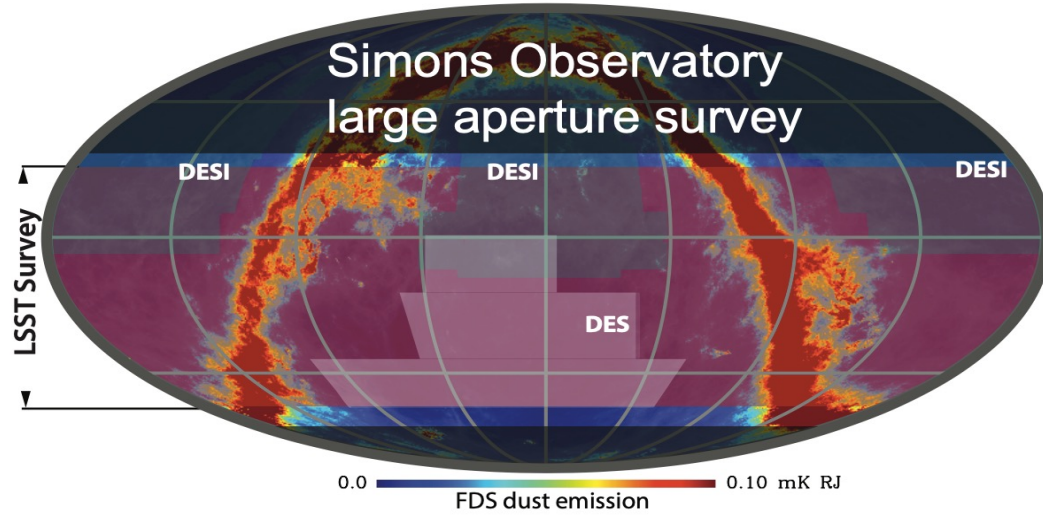
SO can detect any particle with spin that decoupled after the start of the QCD phase transition (at 2σ)



Strong limits on DM-proton elastic scattering;
Better limits and detection at intermediate mass scales of a DM axion fraction of 2%



Multi-survey science

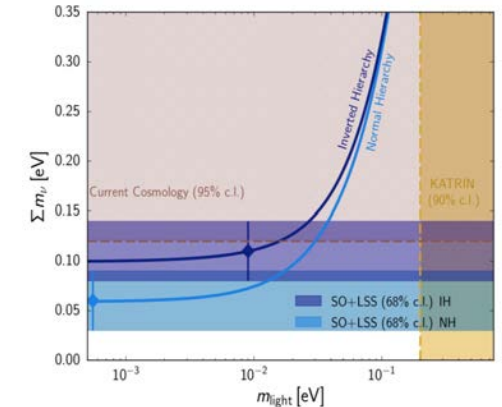
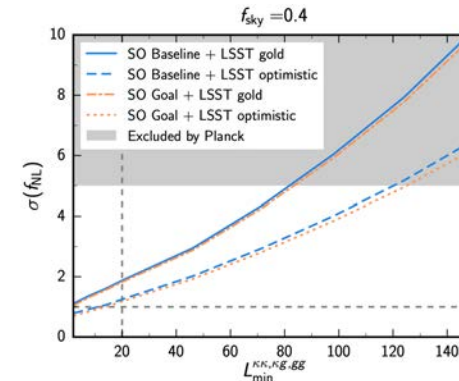
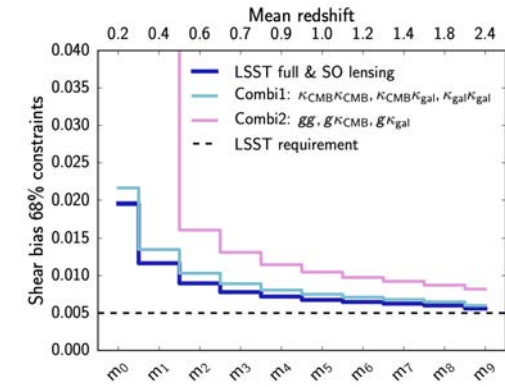
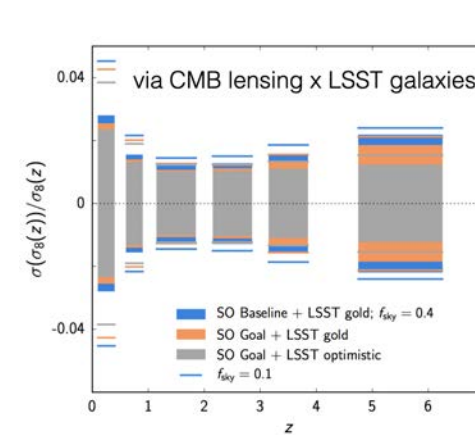


- *Enabling joint science from CMB lensing, tSZ, kSZ x Optical galaxy shear, clustering and clusters*
 - Neutrino mass
 - Structure growth: σ_8 at $z > 1$
 - Non-Gaussianity: fnl
 - Cluster mass calibration
 - Shear bias calibration
 - Constraints on baryonic feedback

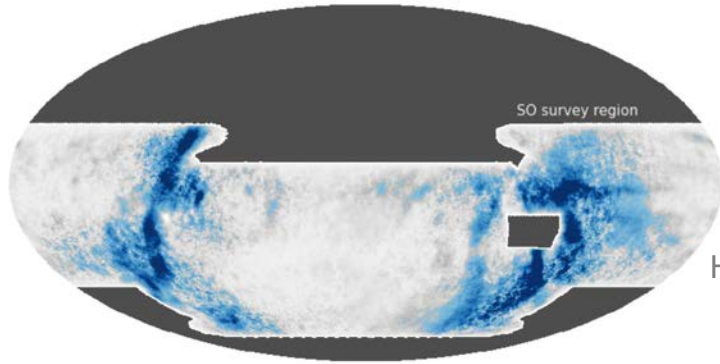
The Simons Observatory Collaboration 2019, 2025



* with some post-pandemic and war updates

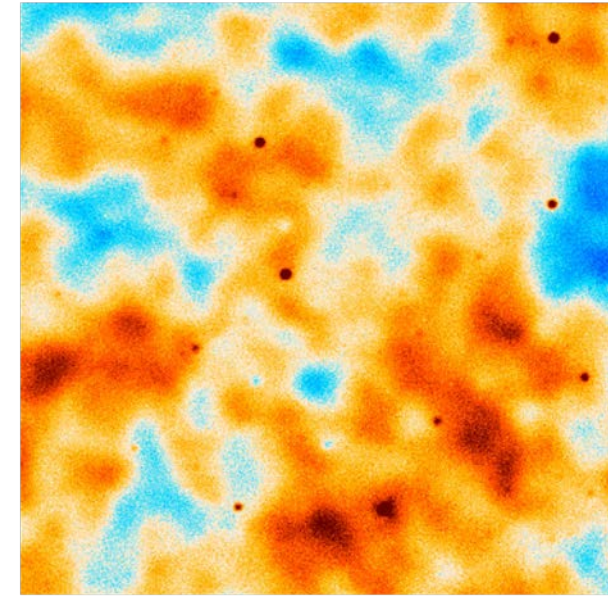
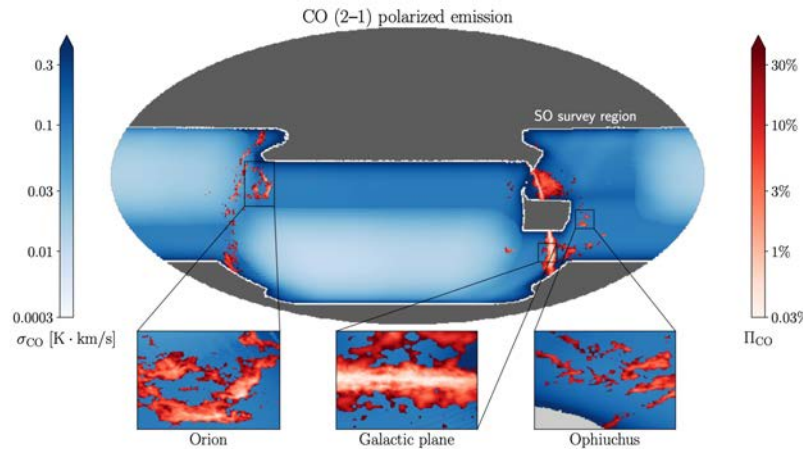


New Opportunities in mm-Transient Science and Galactic Science



Hensley, Clark + 2021

Polarized Dust SNR (P/σ_P)



[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

Track thousands of Variable Active Galactic Nuclei 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

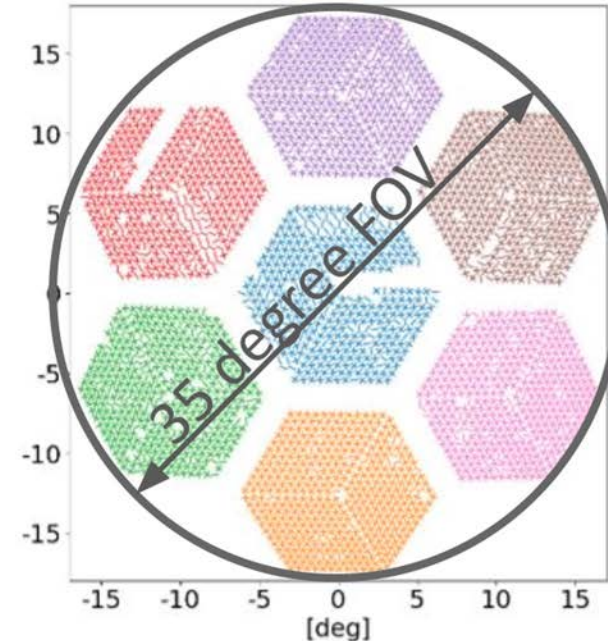
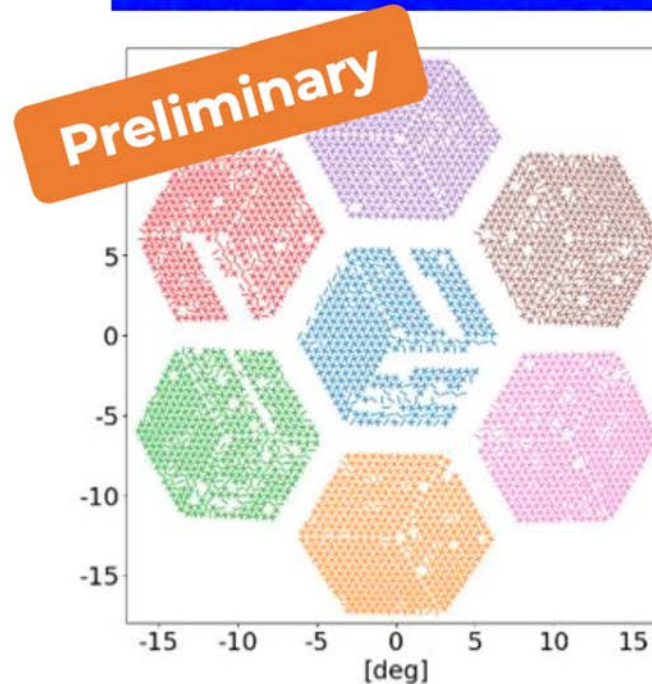
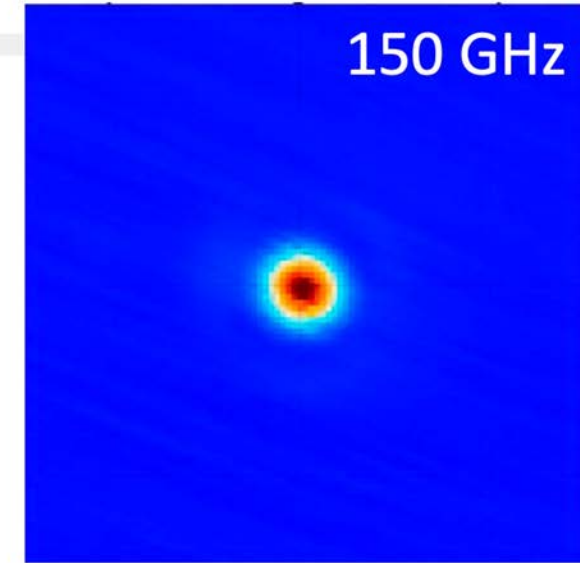
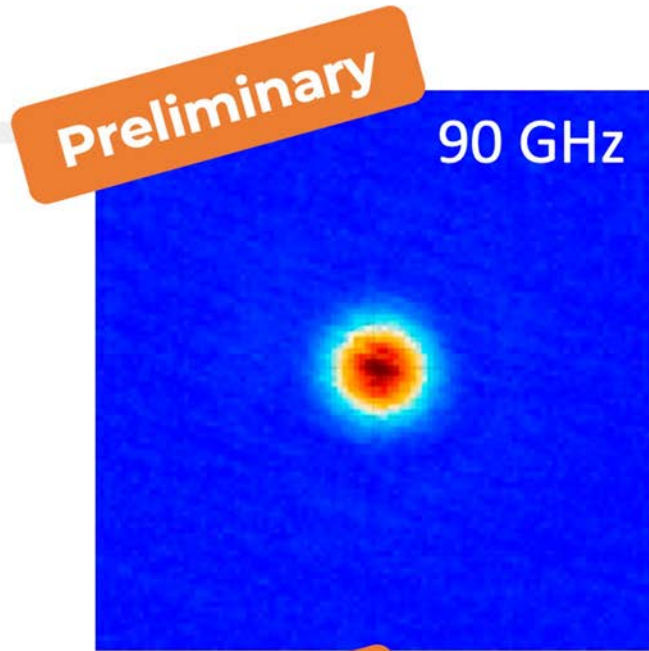
Deep, high-resolution observations of the Galaxy

SAT First Light

October 2023

First light of Jupiter
Observations show
expected beam shapes

Per-detector pointing
developed from Moon and
Jupiter observations



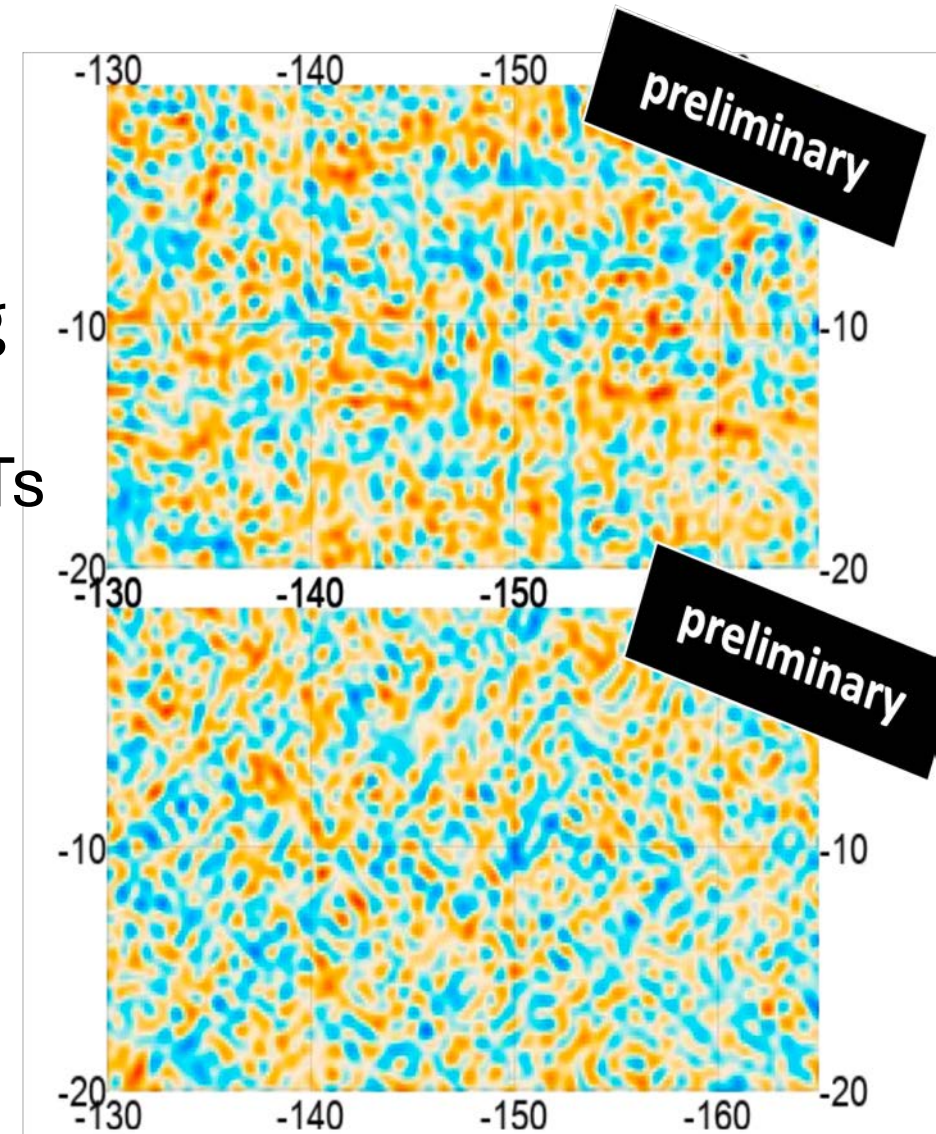


Preliminary SAT Maps

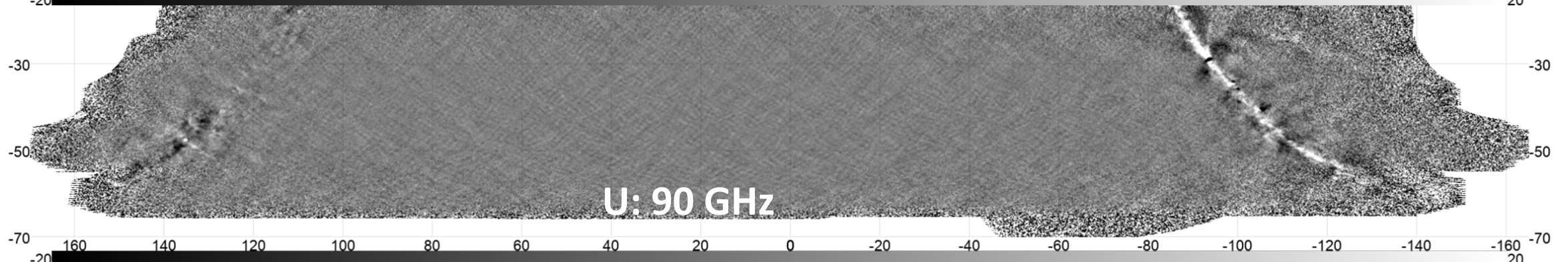
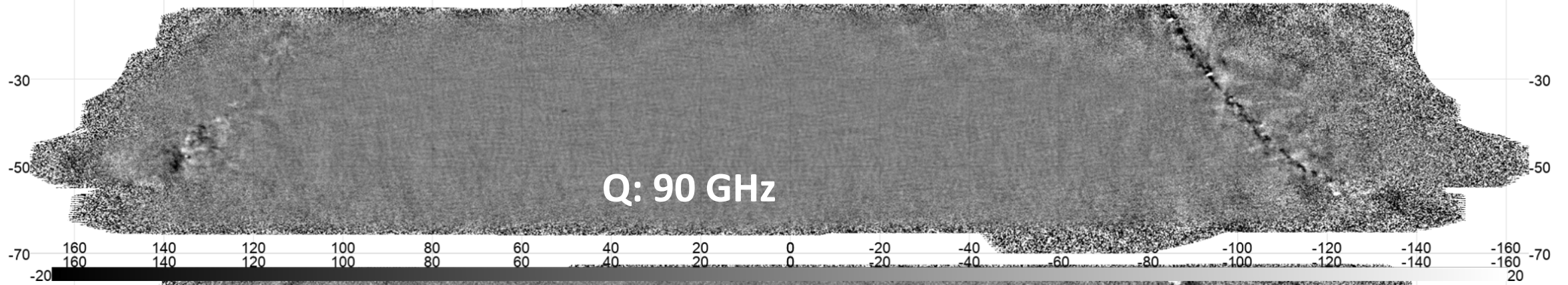
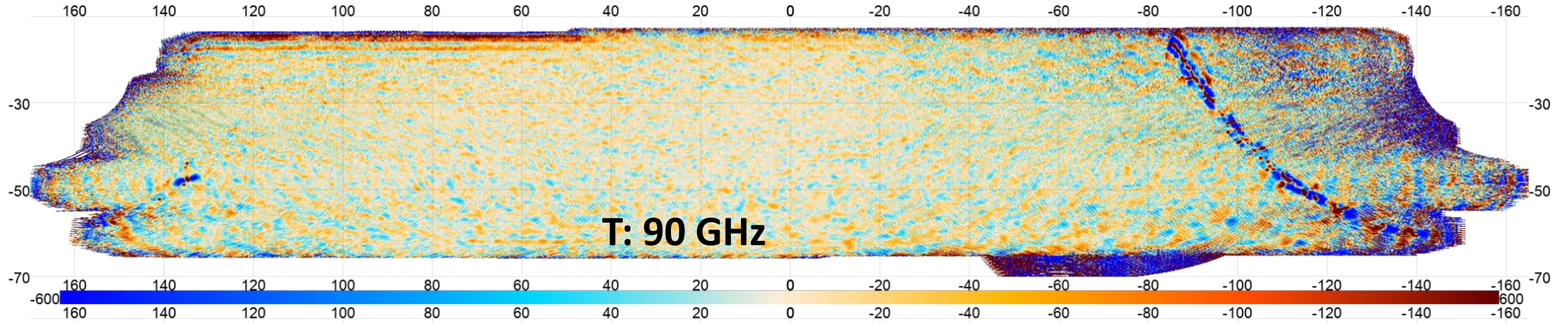
Q/U maps

Started mapping the sky with two MF (90/150) SATs

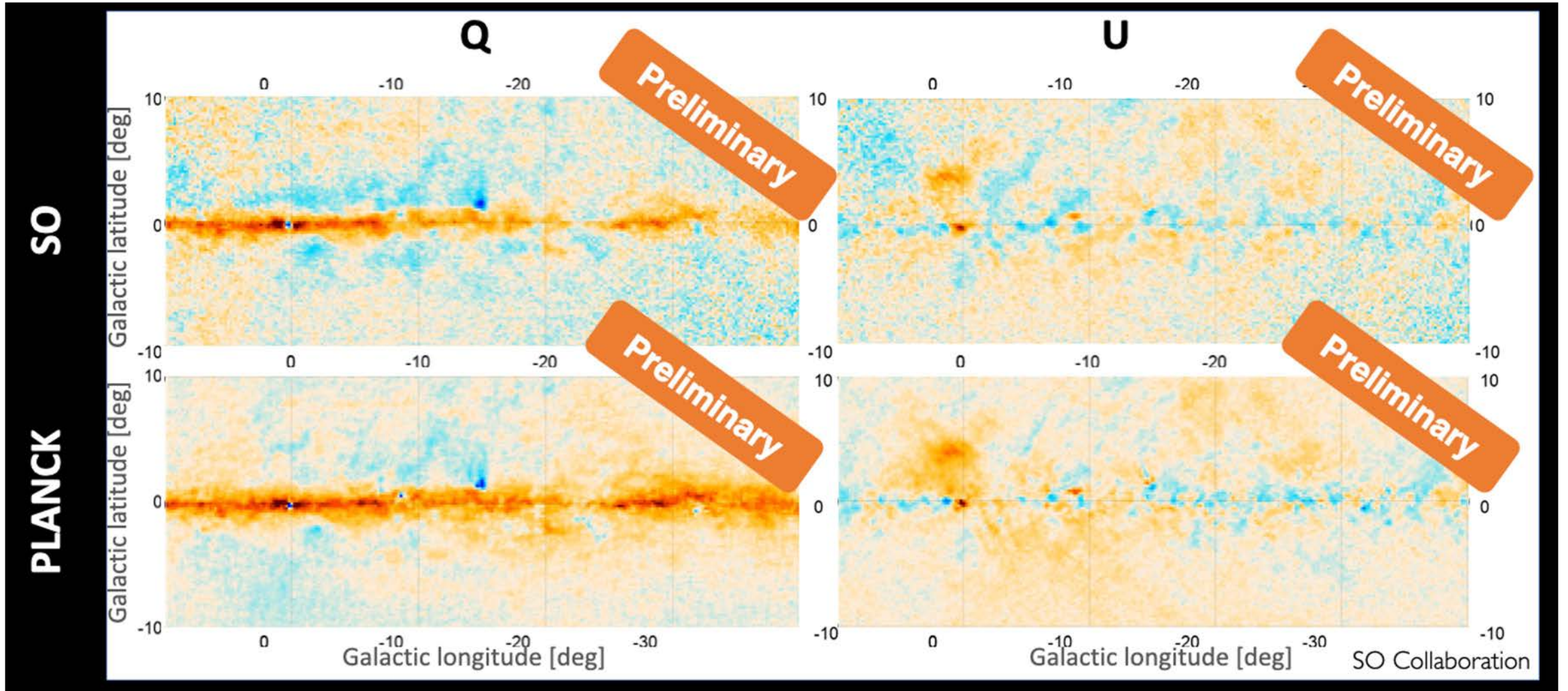
Polarization patterns start being visible in the targeted SAT region



Preliminary SAT Maps: 90 GHz from one telescope



Preliminary SAT Maps



Polarized galaxy center maps in comparison with Planck demonstrate instrument performance and larger scale recovery.



Large Aperture Telescope First Light February 2025!

24,000 + Detectors
on the Sky.

Preliminary map of
Mars

Mirrors not yet fully
aligned/focused.

Signal to Noise of
4000+ per detector.
743 detectors used
for this map.

SO Collaboration

