BICEP updates and Plans

The South Pole Observatory: Inflationary Science

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NAS, Committee on Astronomy and Astrophysics

Science of Inflationary B-modes

- A unique key test of inflation and the cosmic origin
- Probing physics at the scale of unification, a trillion times beyond the reach of particle colliders.

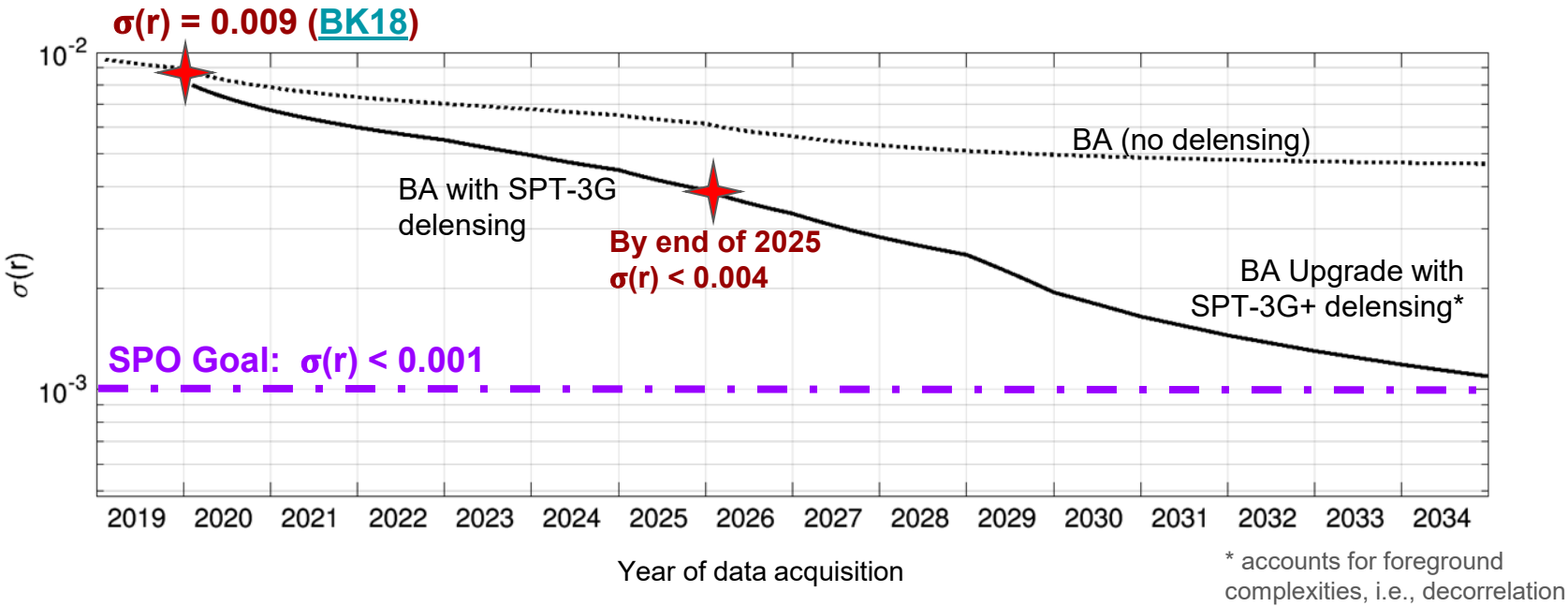
$$\text{energy} = 10^{16} \left(\frac{r}{0.01}\right)^{\frac{1}{4}} \text{GeV}$$

- Insights into quantum gravity (*a la* Lyth bound)
- A relic from 10^{-35} seconds, much earlier than the light elements created at t = 1 second.

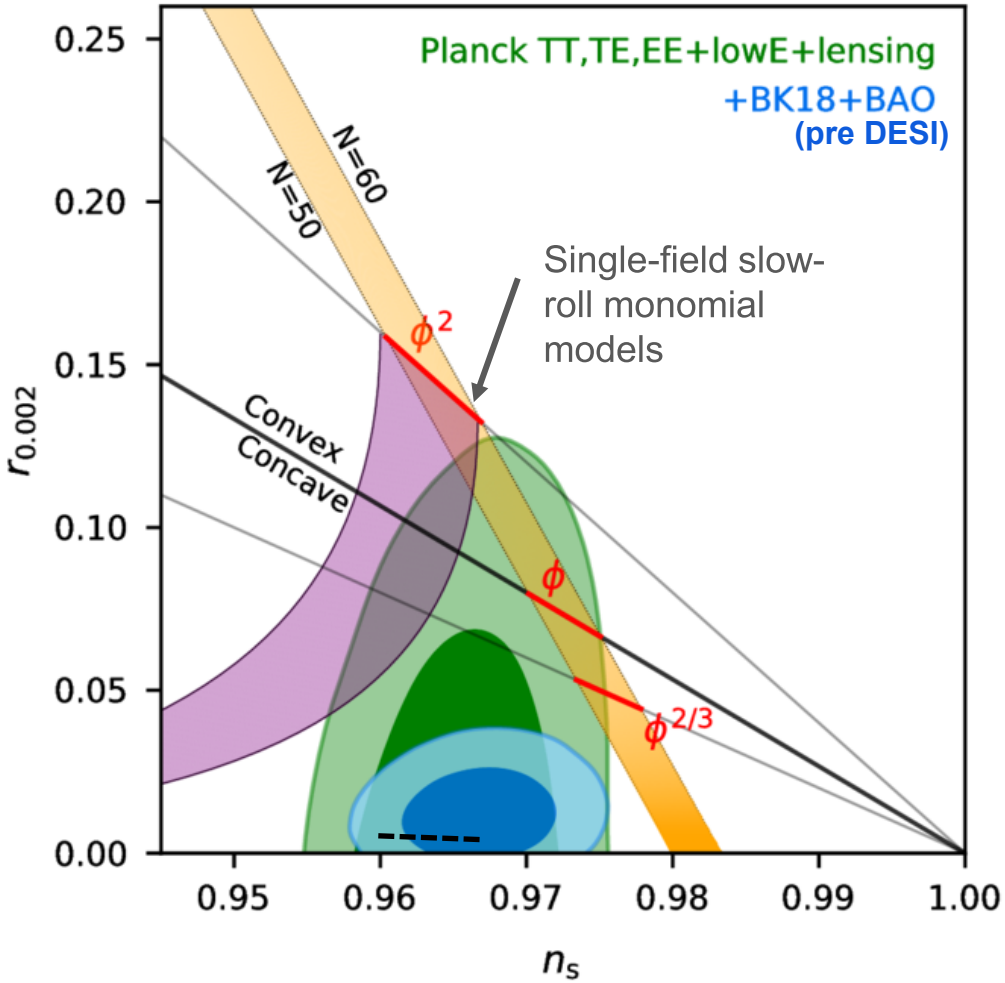
Inflation caused by a single-field, slow-roll inflaton predicts a small negative departure from scale invariance (which has already been confirmed*) and $r > 0.001$.

The ***SPO goal is to achieve σ(r) = 0.001 by 2034.*** This will either lead to a detection, a strong hint of *r*, or rule out these leading inflationary models and motivate alternate models for the origin of the universe.

SPO: Future Inflationary Constraints on Tensor-to-Scalar ratio, r



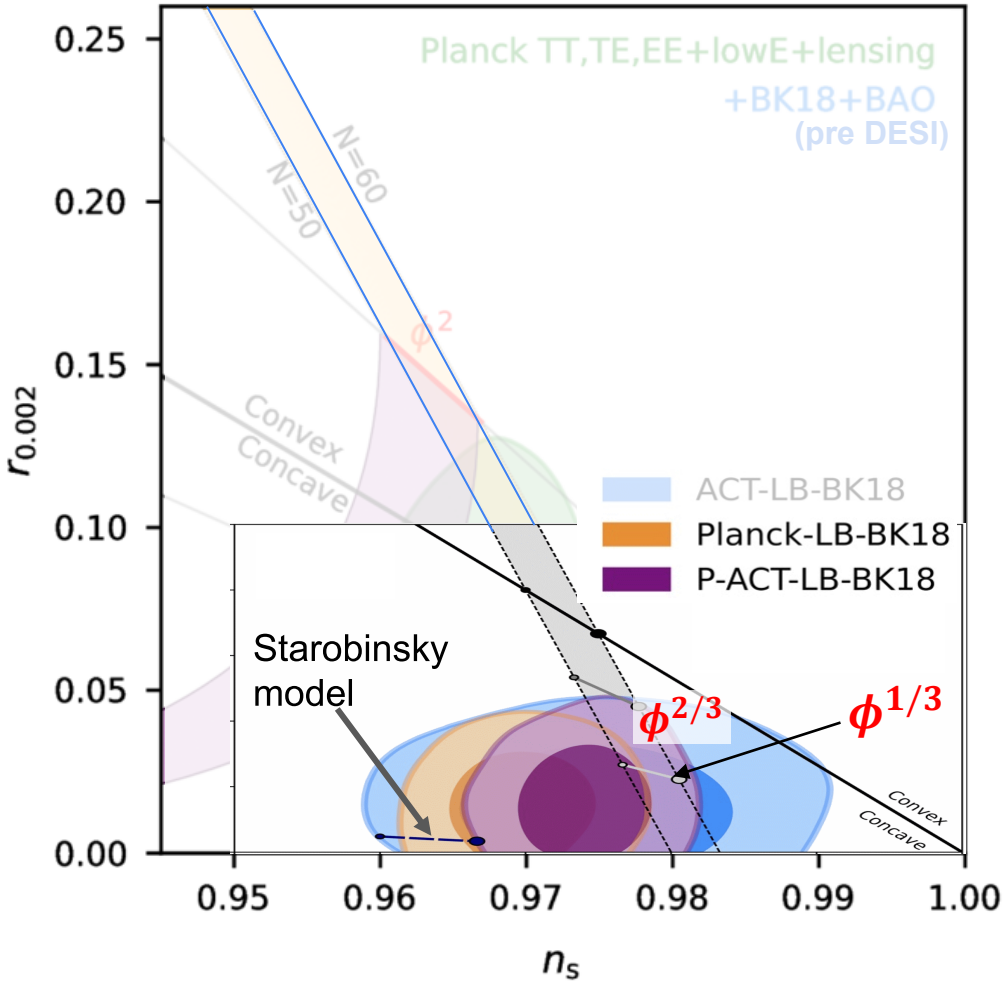
These σ(r) forecasts are anchored in the demonstrated performance of BICEP and SPT measurements over the last decade



How inflation model space gets constrained by B-mode measurements

BK18

Phys. Rev. Lett. **127**, 151301 – **October, 2021**



How inflation model space gets constrained by B-mode measurements & n_s

BK18

Phys. Rev. Lett. **127**, 151301 – **October, 2021**

"LB": CMB lensing & DESI
P-ACT: arXiv 2503.14454

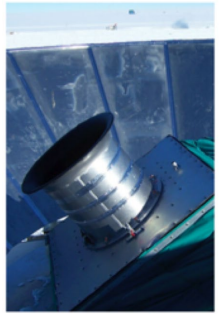
See also arXiv 2506.20707 (SPT-3G)

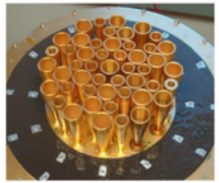
BICEP program 2006-present

Compact CMB cameras with sensitivity to inflation

Generation 1

BICEP1
(2006-2008)
100, 150 GHz

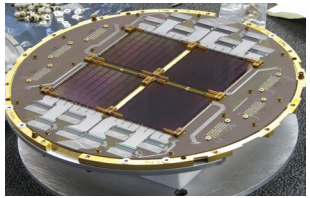




~100 sensors

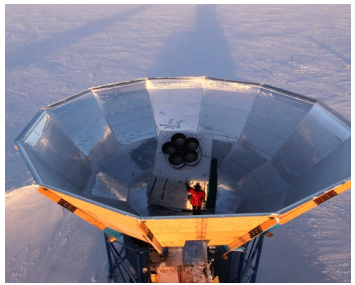
Generation 2 →

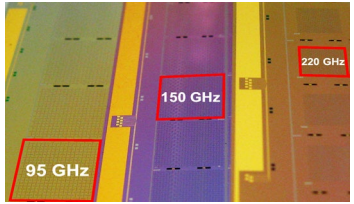
BICEP2
(2010-2012)
150 GHz



~500 sensors

Keck Array
(2012-2019)
95, 150, 220, 270 GHz

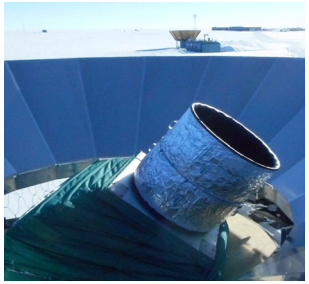


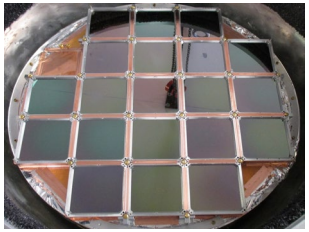


~2500 sensors in five BICEP2-like cameras

Generation 3 →

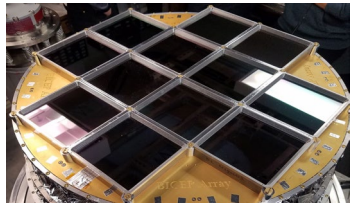
BICEP3
(2015+)
95 GHz





~2500 sensors

BICEP Array
(2020+)
30, 40, 95, 150, 220, 270 GHz



~30k sensors in four BICEP3-like cameras

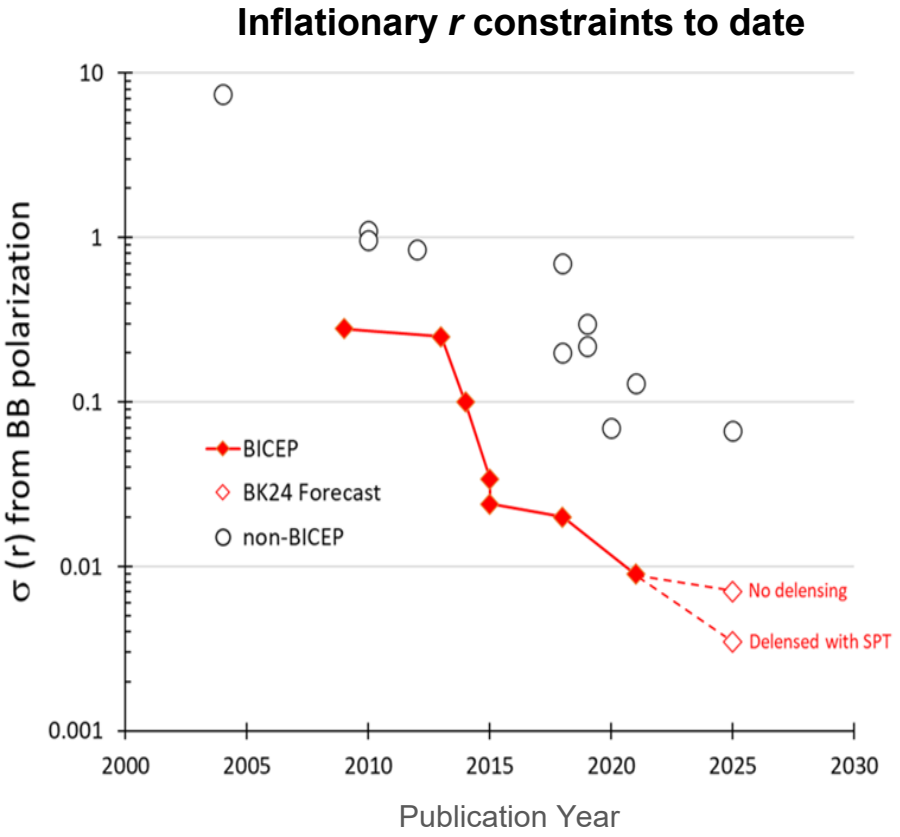
BICEP and the Search for Inflation

The South Pole offers the best ground-based site for conducting *r* measurements, due to 24/7 access to ultra-low foreground sky and exceptionally stable atmosphere.

BICEP constraints on inflation have led the field for over 15 years.

The BA *r* constraints have now reached the regime where (as expected) they are limited by the lensed CMB B-mode foreground.

The next phase of SPO, by design, is optimized to continue the search for *r* in this lensing dominated regime, and prepare for an anticipated increase in foreground complexity.



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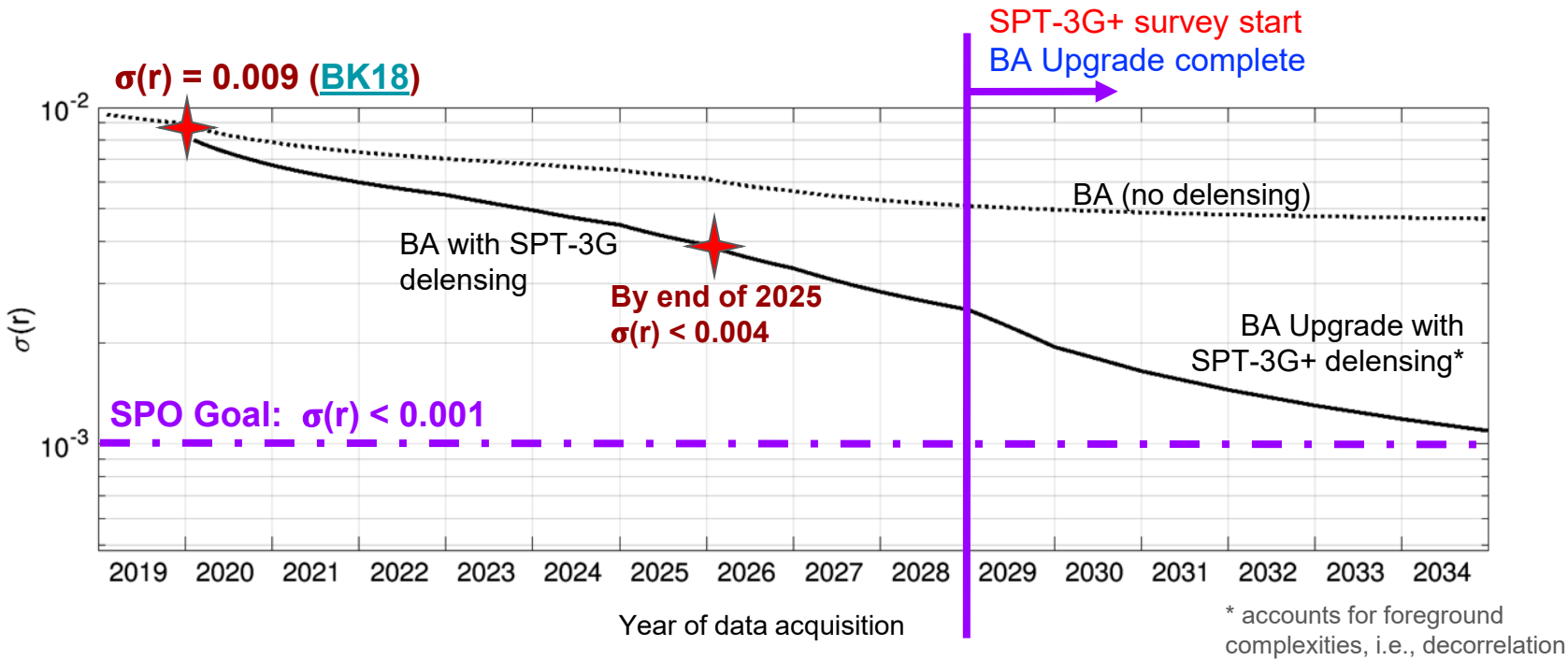

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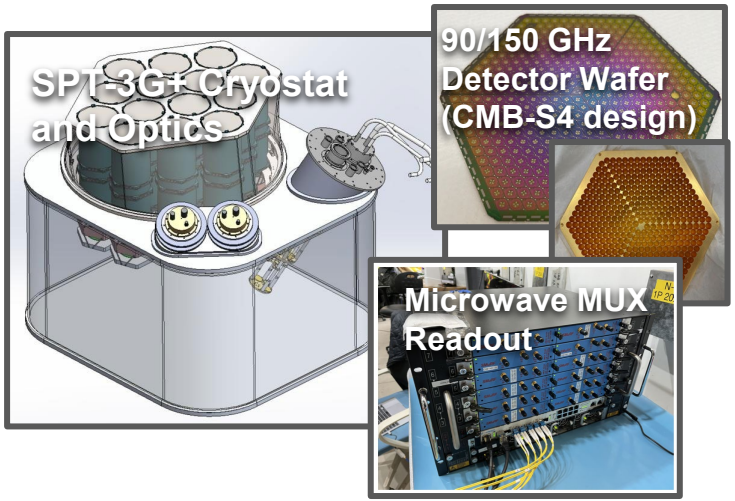
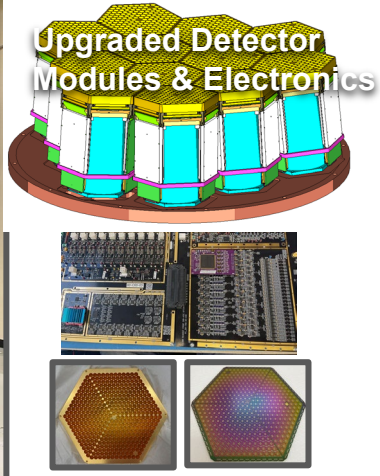
SPO: Future Inflationary Constraints on Tensor-to-Scalar ratio, r

SPT-3G+ Camera



BICEP-Array+ Upgrade



- SPT and BICEP upgrades have begun design and prototyping work, aiming to deploy new systems to the South Pole by 2029
- Already partially funded through NSF and private support. SPO is in discussion about DOE involvement, in particular leveraging previous technical development for CMB -S4.

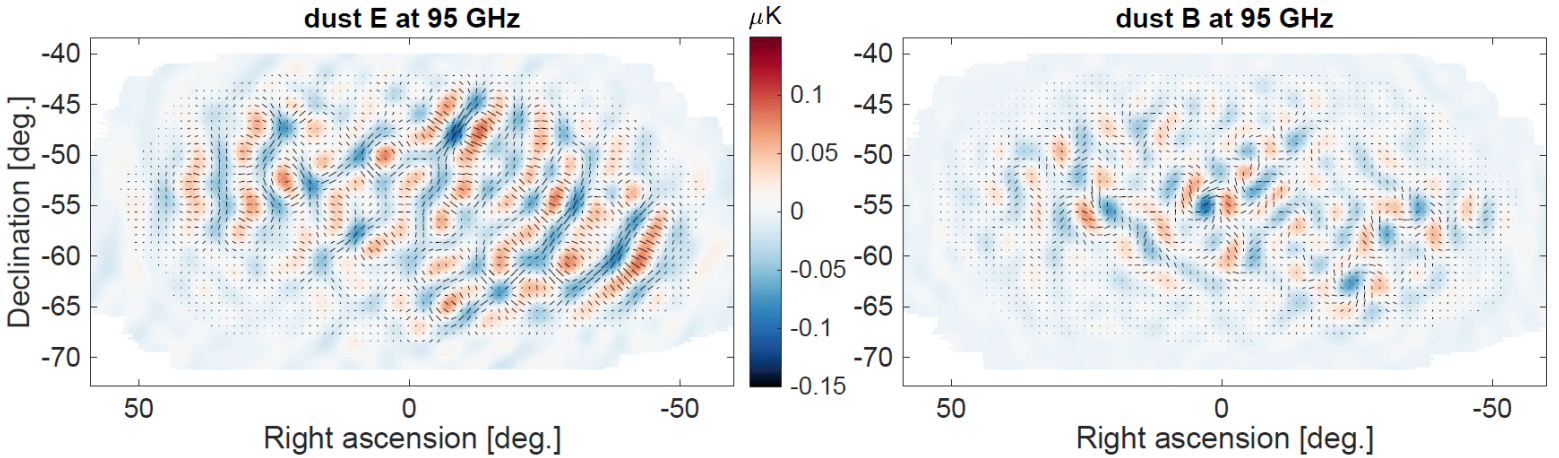
SPO Collaboration Members

SPO collaboration consists of over 150 members across 25 institutions.

Harvard
Stanford
California Institute of Technology
Minnesota
cea
JPL
UBC
SLAC
NATIONAL ACCELERATOR LABORATORY
NIST
Cardiff University
Boston University
Cincinnati
The University of Chicago
Berkeley
University of California
Argonne
NATIONAL LABORATORY
Fermilab
IAP
University of Illinois
KICP
McGill
Case Western Reserve University
The University of Melbourne
Michigan State University
Colorado
University of Colorado at Boulder
Center for Astrophysics
Harvard & Smithsonian

Decadal Challenges: Foregrounds, Atmosphere, Systematics, Delensing

- **Foregrounds**: possible variations in parameters such as spectral index, non-uniformity, non-Gaussian or other complicated behaviors , …
- **Atmospheric fluctuations**: observed polarized atmospheric fluctuations impacting sensitivities at high freq., starting ~150 GHz (arXiv 2407.20579)
- **Systematics**: under-characterized, uncorrected/irreducible beam/band variations
- A practical **delensing** pipeline that is robust (“hardened”) against all these effects



Component-separated **dust** map observed by BICEP:

* E modes are *brighter* & *filamentary*

arXiv 2509.21648

Backup slide

SPO Future: SPT-3G+ and BA Upgrade to Achieve σ(r) = 0.001 in 2034

To achieve σ(r) = 0.001 we need to build, install, and operate *both* SPT-3G+ and the BA Upgrade, and work together to analyze the data.

Combining the datasets mitigates against contamination from both dominant foregrounds: the CMB lensing signal, and Galactic foregrounds.

SPO r-forecasts for analysis of combined SPT and BA observations through 2034

σ(r) forecasts for 2034	SPT-3G (Current sensitivity)	SPT-3G+ (2029 start)
BA (Current sensitivity)	0.0022	0.0015
BA Upgrade (2027 start)	0.0019	0.0011

Current published σ(r) = 0.009