Future challenges and new approaches in astrophysics at mm-wavelengths

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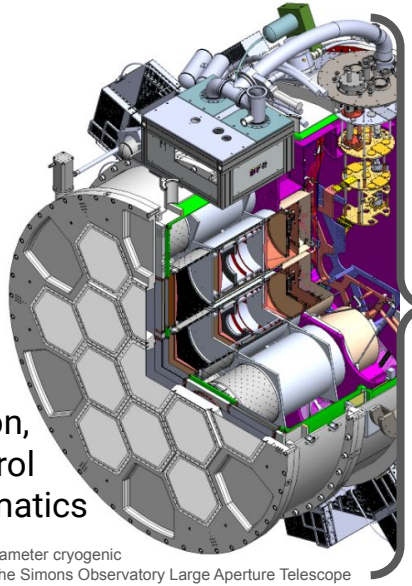
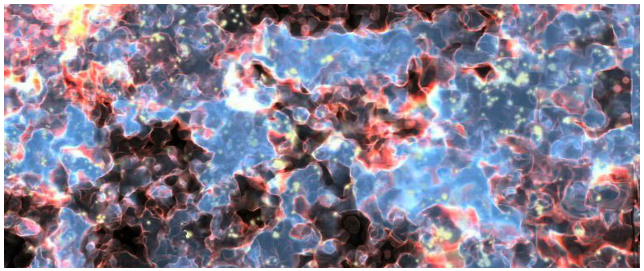


The 2.5-m diameter cryogenic receiver for the Simons Observatory Large Aperture Telescope

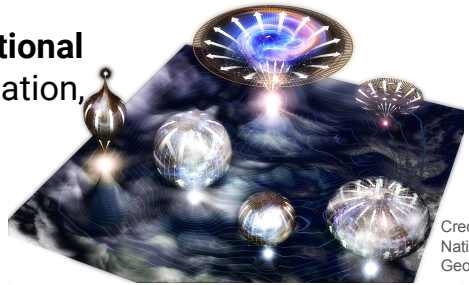
Optical design, critical calibration, and control of systematics



Credit: SKA

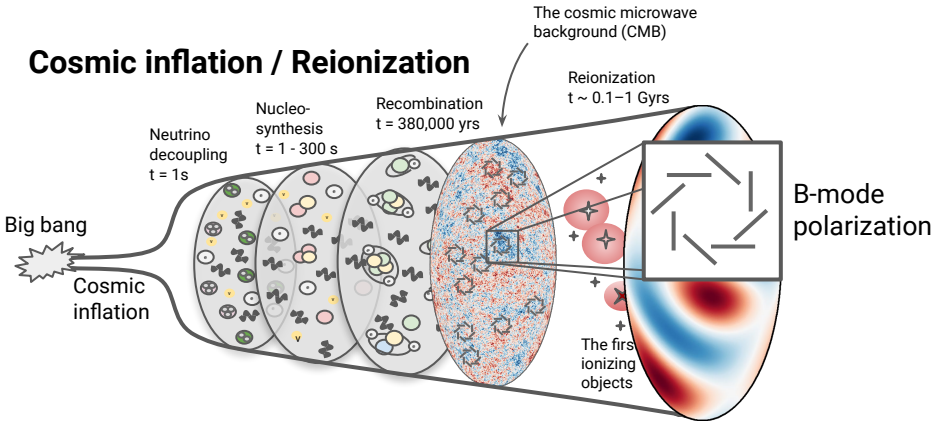
Reionization, early star formation, and cosmological parameters

Primordial gravitational waves, cosmic inflation, and fundamental physics



Credit: National Geographic

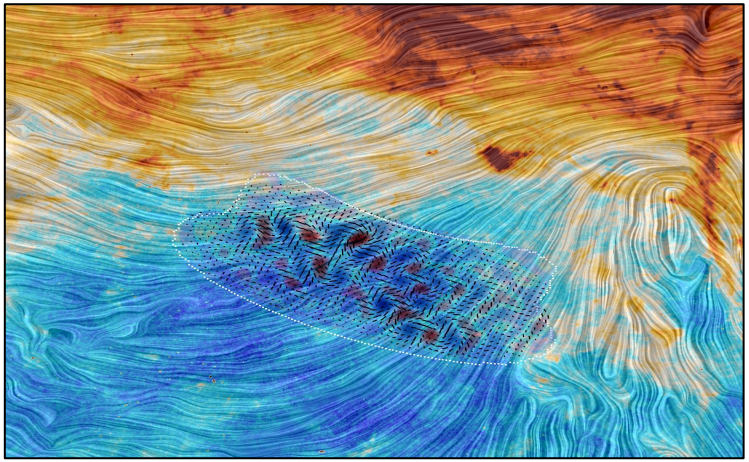
Scientific motivation



When did reionization occur? –> optical depth (τau)
What were the main ionizing sources?

Reionization leaves an imprint in CMB polarization on very large angular scales

We have the technology to make a definitive search for a signal from reionization and cosmic inflation in CMB polarization maps



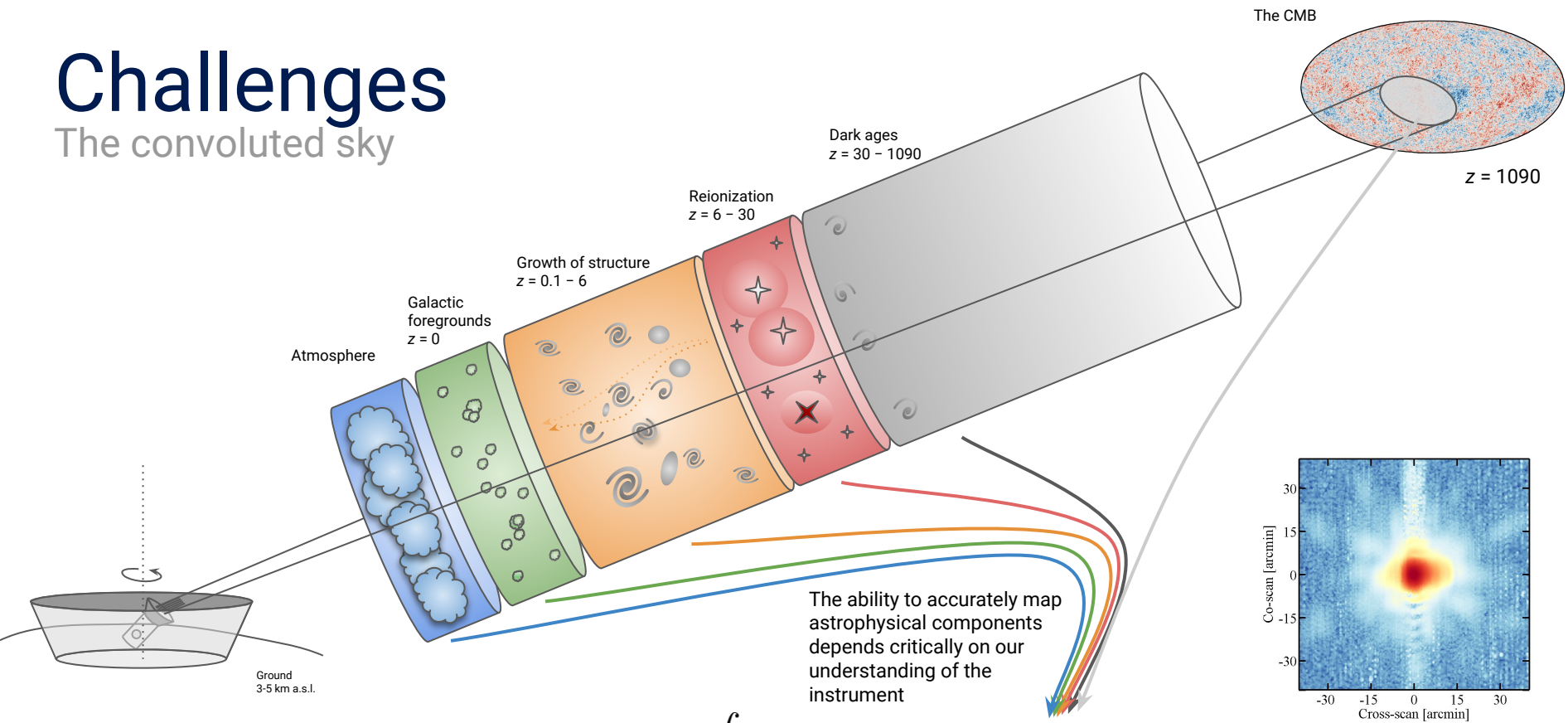
Composite Planck and BICEP2/Keck map

Two key challenges:

- Galactic foregrounds (above)
- Instrument systematics

Challenges

The convoluted sky



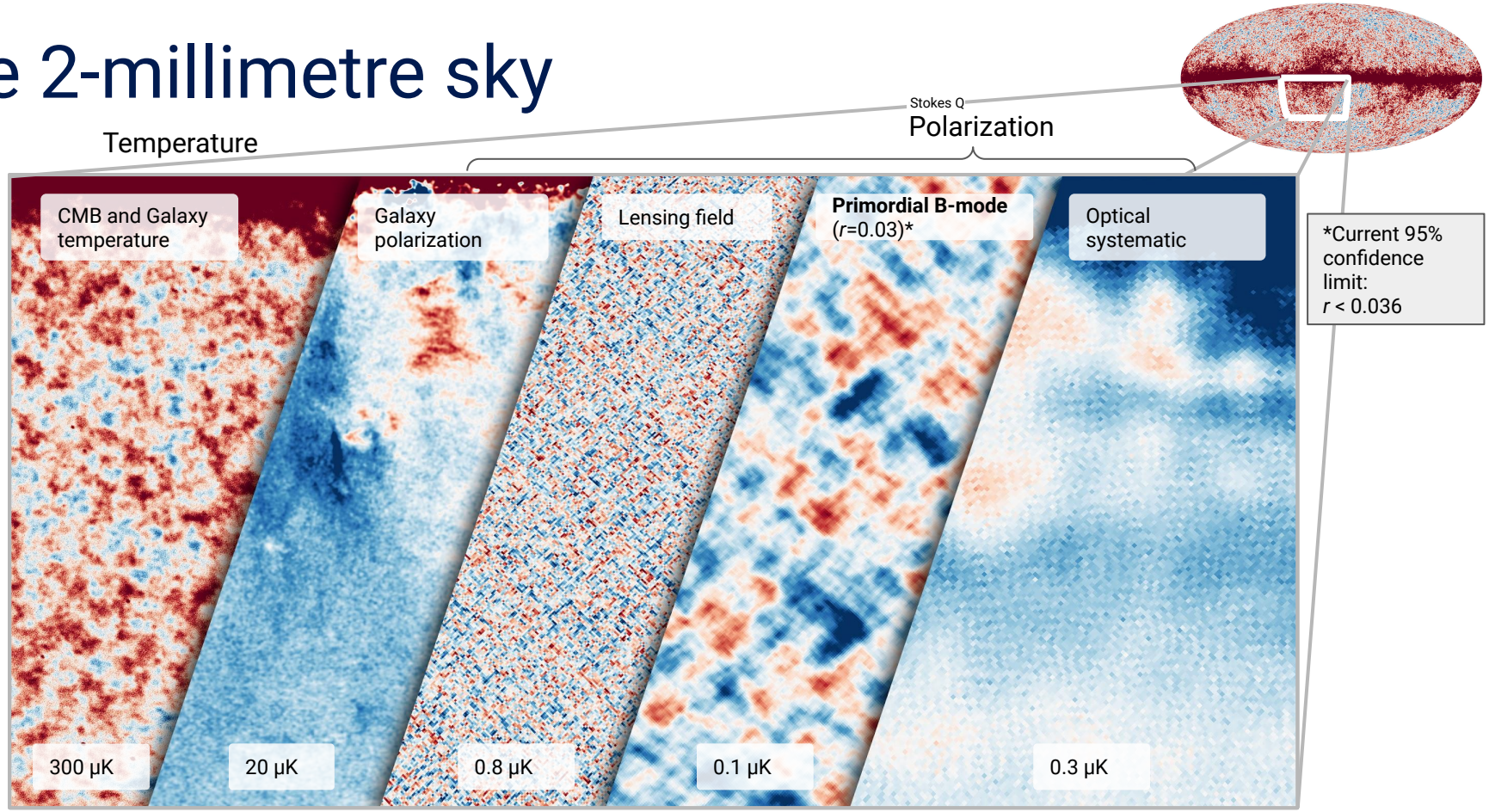
The ability to accurately map astrophysical components depends critically on our understanding of the instrument

$$\text{signal} \propto \int \underbrace{B(\theta-\theta_0,\phi-\phi_0)}_{\textit{Beam}} \underbrace{P(\theta,\phi)}_{\textit{Power}} d\Omega$$

Example beam, $B(\theta,\phi)$, for a Planck detector at 545 GHz

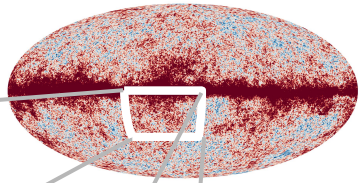
Planck 2015 results. VII. A&A (2016)

The 2-millimetre sky



Full panel covers a roughly 80 × 35° region on the sky with the Galactic plane near the top
Simulations generated with beamconv, see **Duivenvoorden et al., MNRAS** (2018 and 2021)

Polarization systematics



Stokes Q
Polarization

Remember:
r = 0.03 roughly corresponds to 0.100 μK at the map-level

Beam ellipticity

HWP non-ideality

Random pol. angle error

Systematic pol. angle error

Extended sidelobe

0.015 μK

0.050 μK

0.020 μK

0.150 μK

0.300 μK

Full panel covers a roughly 80 × 35° region on the sky with the Galactic plane near the top
Simulations generated with beamconv, see **Duivenvoorden et al., MNRAS** (2018 and 2021)

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Vetenskapsrådet

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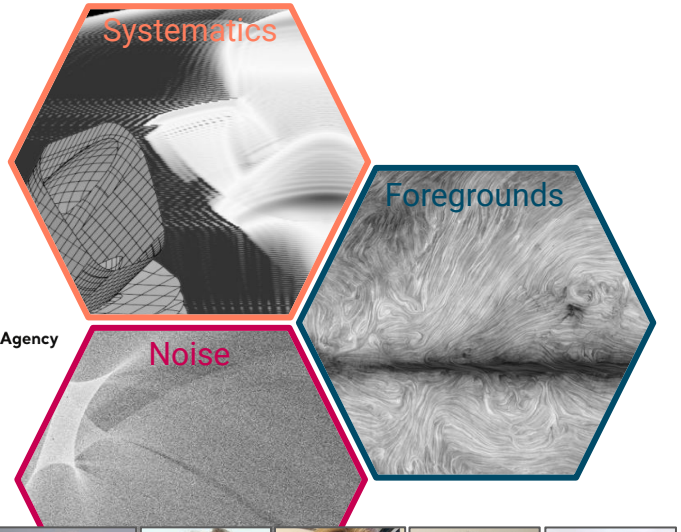
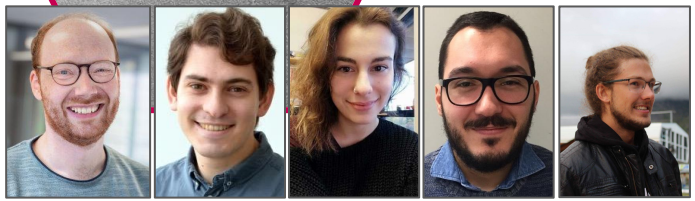
HORIZON 2020





Duivenvoorden
SU '19

A. Adler
SU '23

N. Dachlythra
SU '23

M. Billi
U. Bologna '21

Alexeï Molin
Université Paris-Saclay

Instrument calibration

- Pointing control (Planck 2013 results. VII.)
- Beam response (Planck 2015 results. VII.)
- Cross calibration and planet flux density, JEG et al, (Planck intermediate results. LII., 2017)
- Beam, pointing, absolute gain (SPIDER, 2021)
- SO beam reconstruction (Dachlythra, in progress)

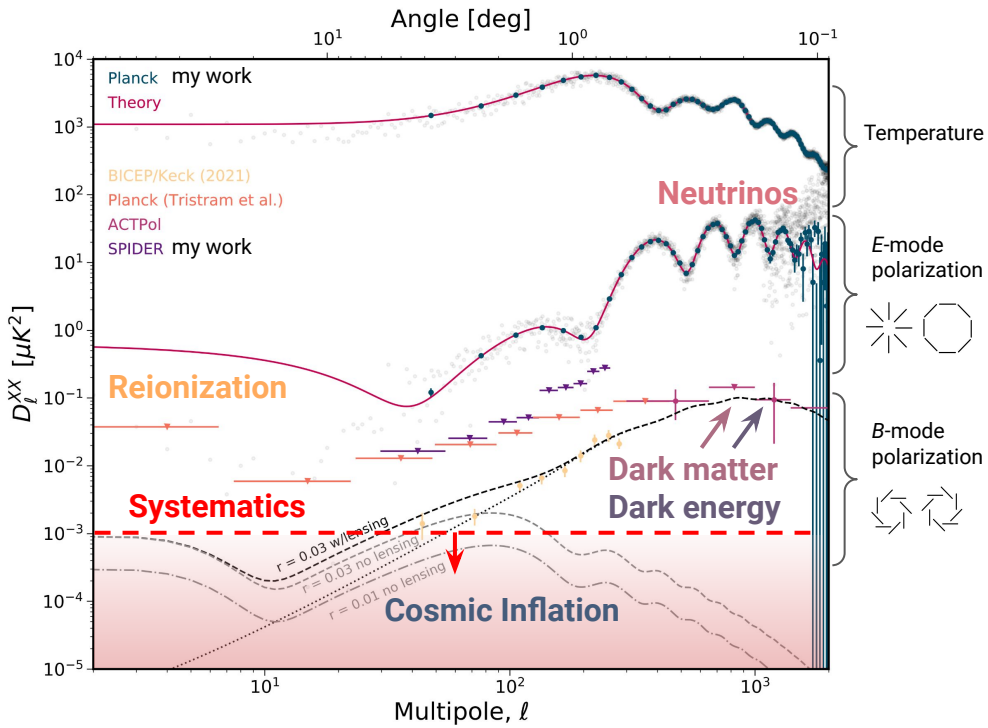
Cryogenic optics

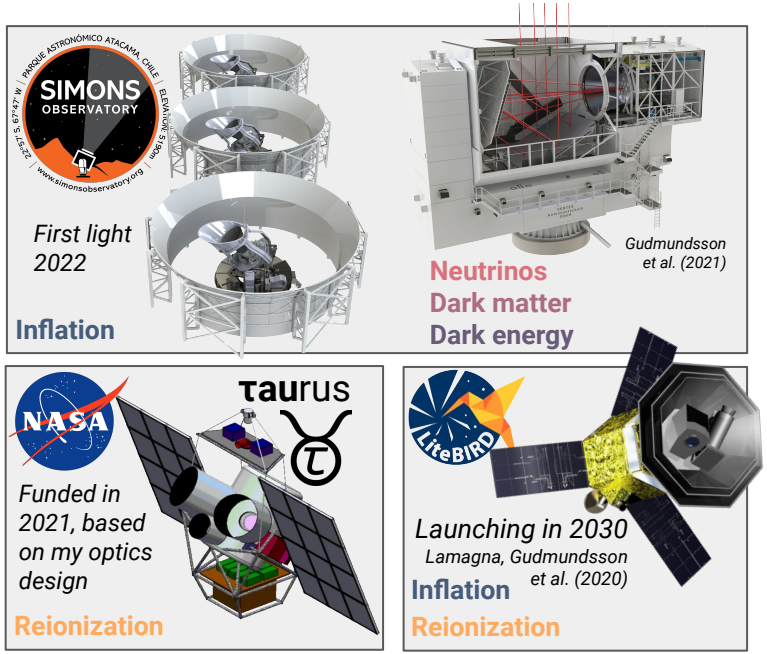
- Lightweight metamaterial absorber tech for LiteBIRD (Swedish Space Agency) [PI]
- Large-diameter lens anti-reflection coating technologies (ESA) [co-I]

Optical modeling and design

- The SO LAT optical systematics (JEG et al. for SO, Applied Optics, 2021)
- Beamconv (MNRAS 2019 and MNRAS 2021)
- Sidelobe response with geometrical theory of diffraction (A.E. Adler and JEG, SPIE, 2020)
- LiteBIRD MHFT Optics design (Lamagna, JEG, et al., SPIE, 2020)

The experimental challenge





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