Instrumental systematic effects for the new generation of CMB polarisation experiments

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AstroParticles and Cosmology (APC)

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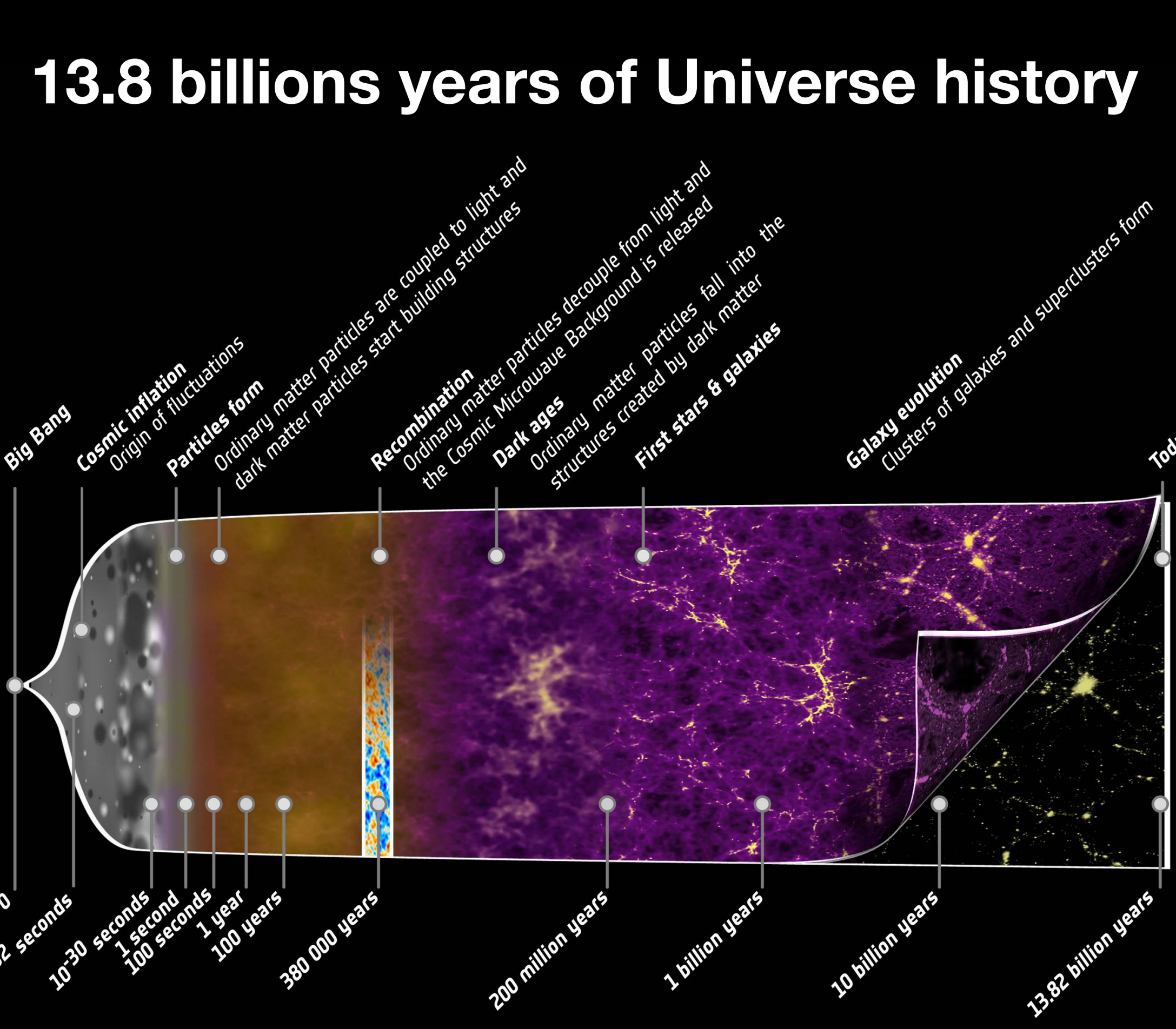
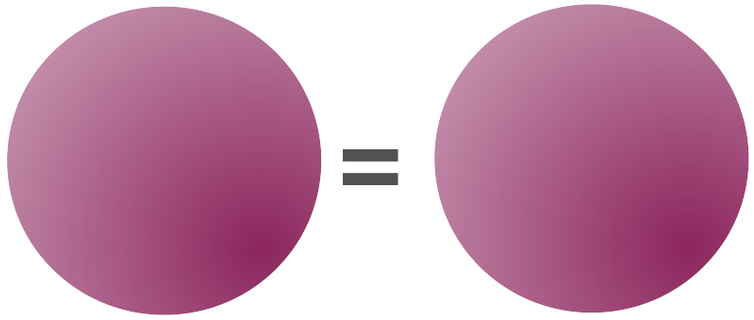
Instrumental systematic effects for the new generation of **CMB polarisation** experiments

13.8 billions years of Universe history



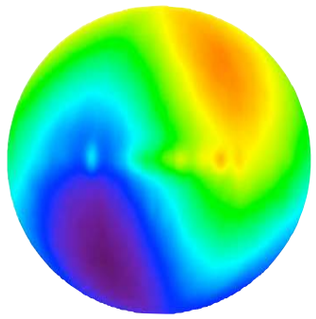
CMB anisotropies



=

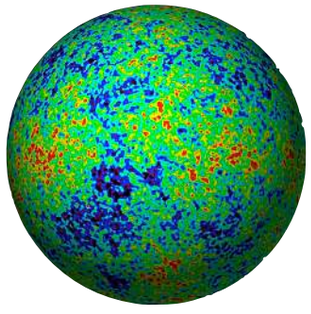
T = 2.7 K

+



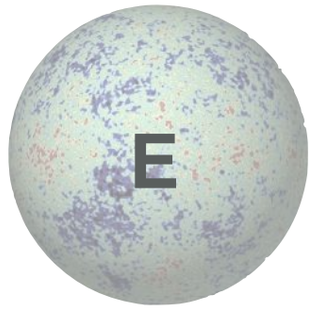
ΔT/T ~ 10^{-3}

+



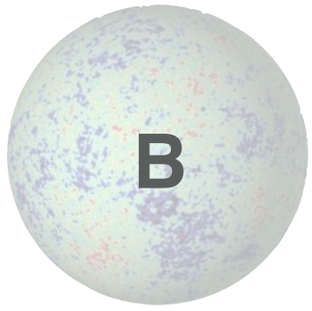
ΔT/T ~ 10^{-5}

+



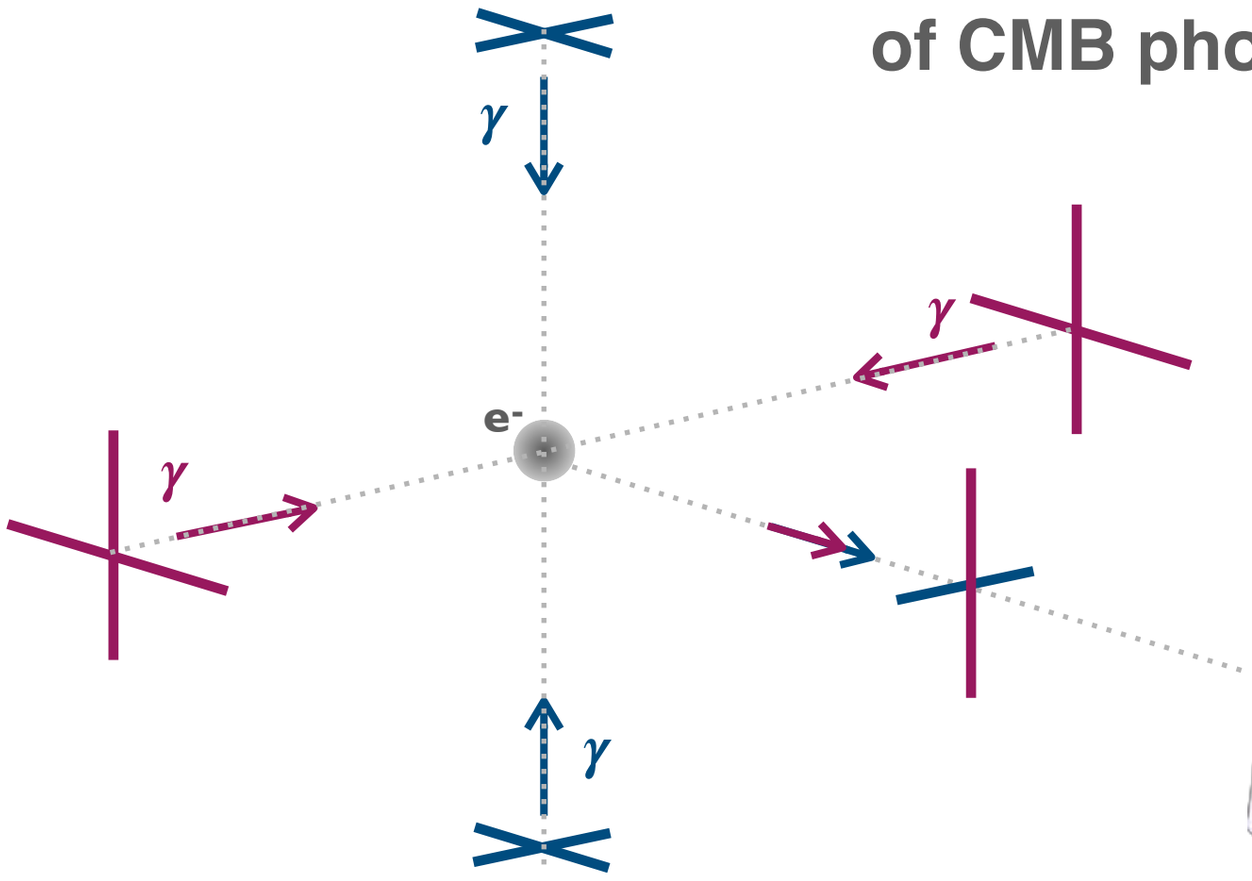
ΔE/T ~ 10^{-6}

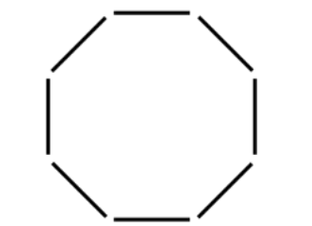
+



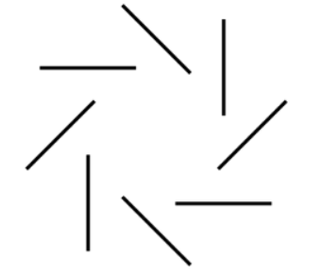
ΔB/T ~ 10$^{-7\text{-}8}$

Thomson scattering of CMB photons

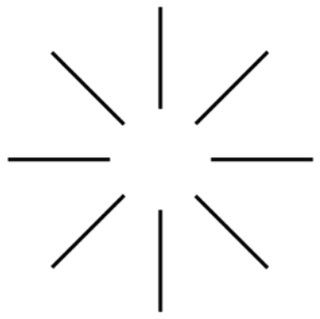


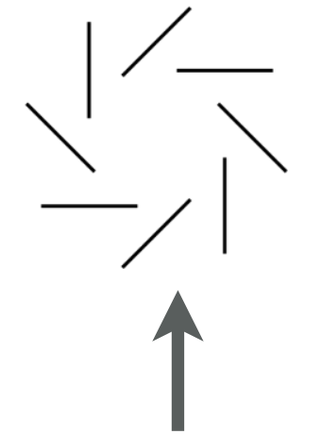


pure E patterns



pure B patterns





Scalar perturbations

Primordial gravitational waves

Why B-modes?

Because inflation!

- **period of extremely rapid expansion of the Universe, shortly after the Big-Bang**
- **explains flat and isotropic universe**
- **generates primordial gravitational waves ⟶ B modes**

Have we found it ? Not yet because…

- **Low signal compared to temperature or E-modes ⟶ sensitivity is the biggest challenge**
- **Large scale**
- **Astrophysical contamination: foregrounds (synchrotron and dust) and lensing (turns E-modes into B-modes)**

+ atmosphere for ground experiments

Instrumental systematic effects for the **new generation** of CMB polarisation **experiments**

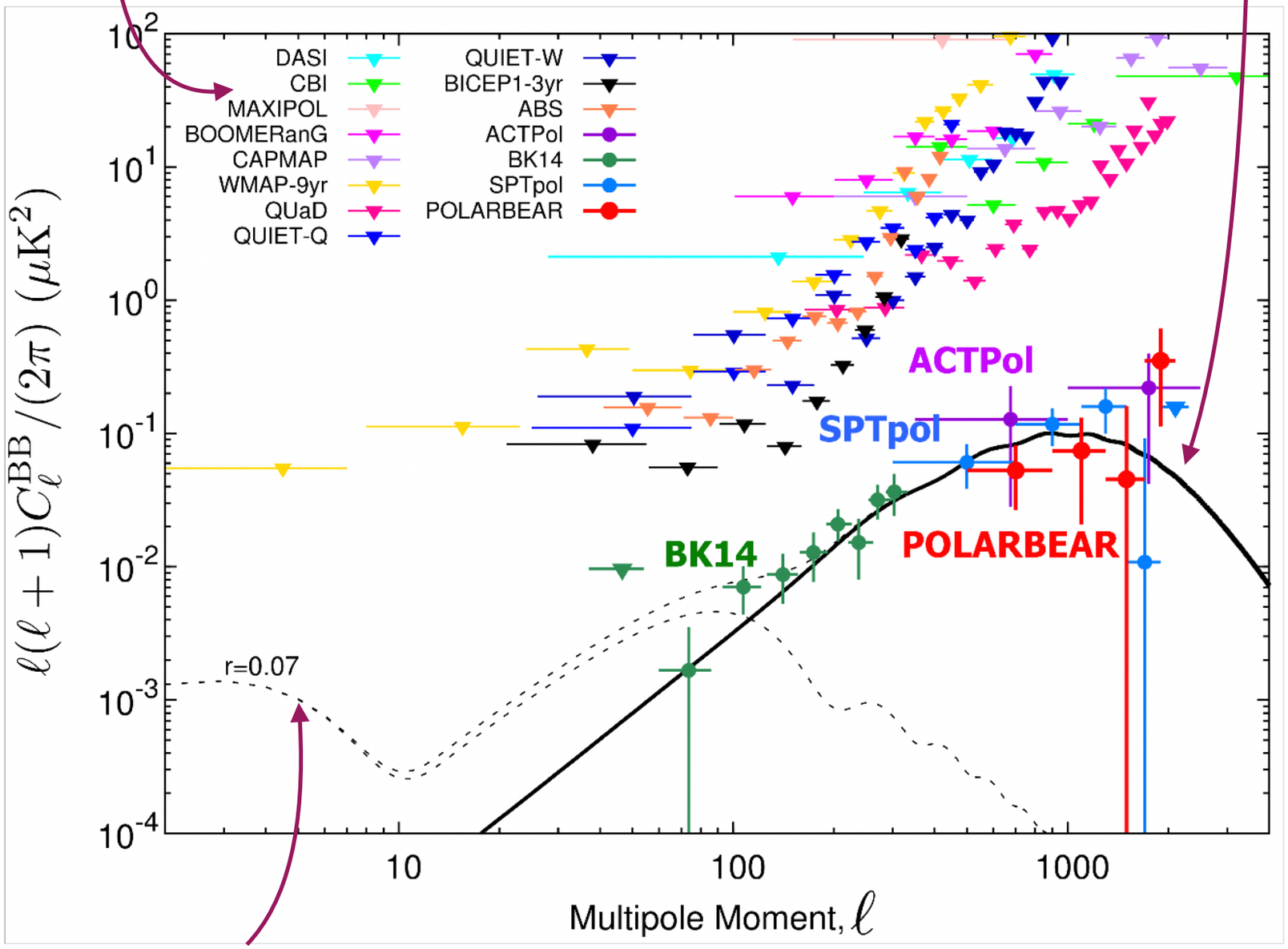
Current status of observations

Many past and present experiments

And more to come!

Small scale B-modes from lensing

Probes large scale structure formation



Large scale B-modes from inflation

Experiments

Basic rule: the bigger the better

POLARBEAR-1

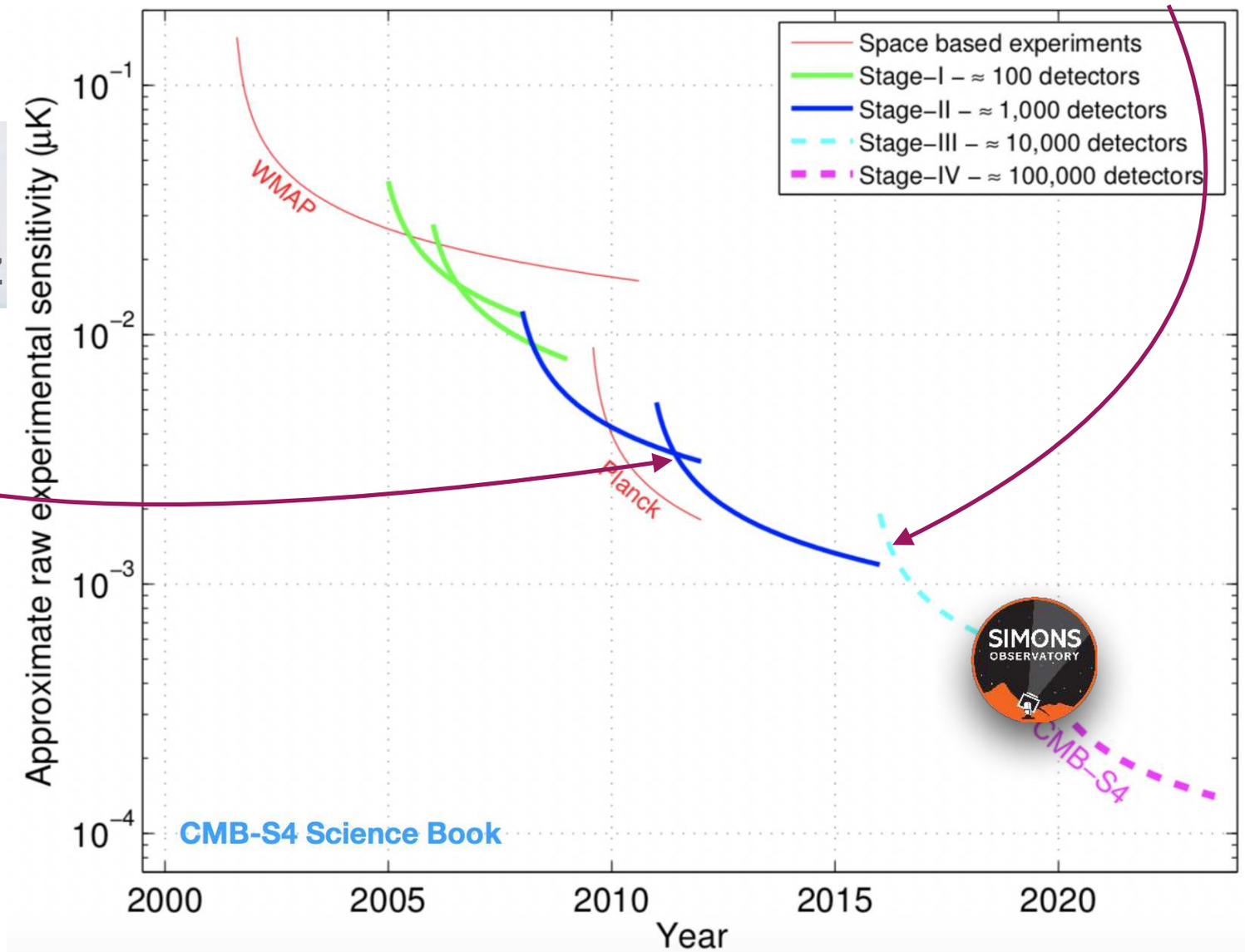
Operating since 2012

1,274 detectors at 150 GHZ

POLARBEAR-2a and Simons Array

Deployment in 2018-2019

22,764 detectors at 95/150/220/270 GHz in 3 receivers



Simons Observatory

Expected in 2021

Large aperture (1) and small aperture (3) telescopes

Up to ~70,000 detectors at 30/40/95/150/220/270 GHz

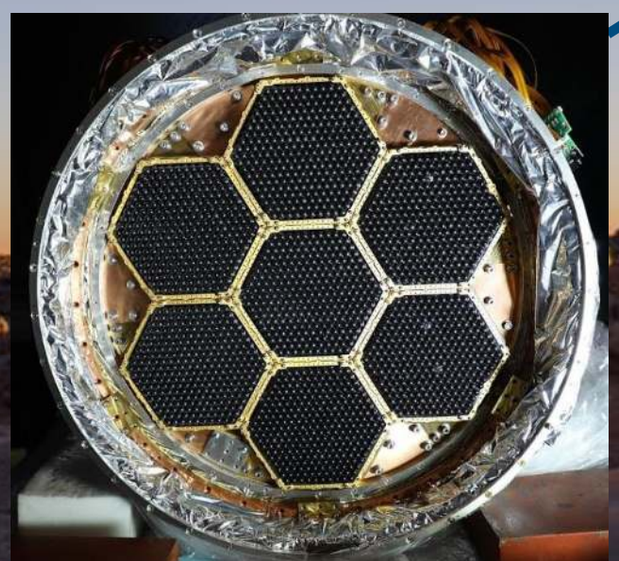
CMB photons

Primary mirror

Optics

Readout electronic

Focal plane
~1 000 to 10 000 detectors

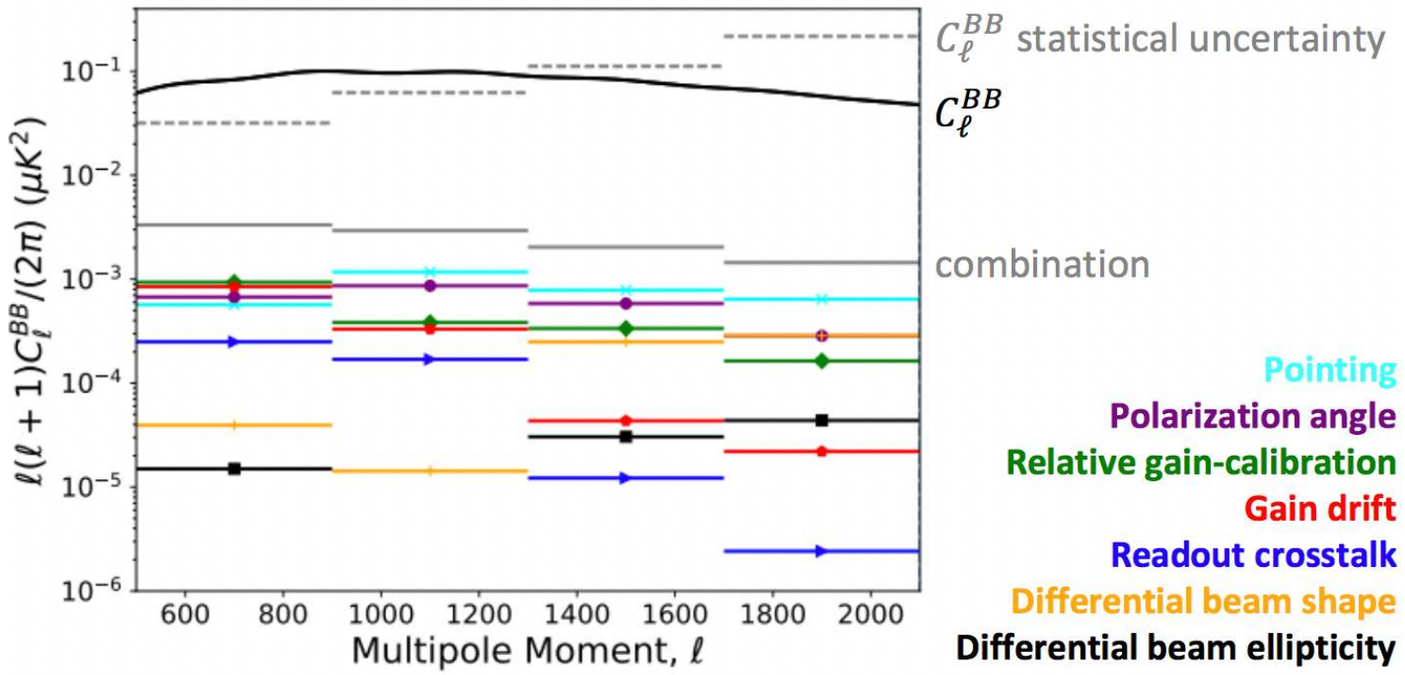


Instrumental systematic effects for the new generation of CMB polarisation experiments

Can we achieve raw instrumental sensitivity ?

No, because… (list is of course non exhaustive!)

- **Detector gain (drifts, non linearity)**
- **Readout system**
- **Bandpass mismatch**
- **Optical leakage**
- **Beam (shape, non uniformity)**
- **<anything else that could happen**



Impact of systematics on power spectrum
*(*A measurement of CMB B-modes polarization power-spectrum at sub-degree scales from 2 years of POLARBEAR data
The POLARBEAR Collaboration, 2017)

Can we mitigate these instrumental effects?

This is exactly what I try to do in my PhD ;)

Improve simulation model

- **Implement more realistic instrument model (hardware architecture)**
- **Use physical model for systematic effects instead of statistical estimation**

Data analysis and calibration

- **Use parameter estimation methods to reconstruct instrument model from observation data**
- **Correct and/or account for systematic effects in science analysis**

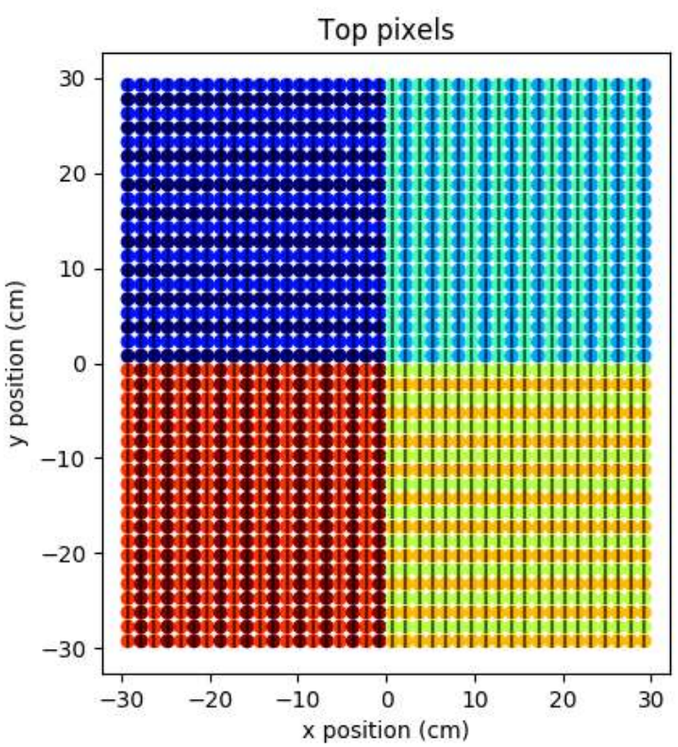
Future experiments

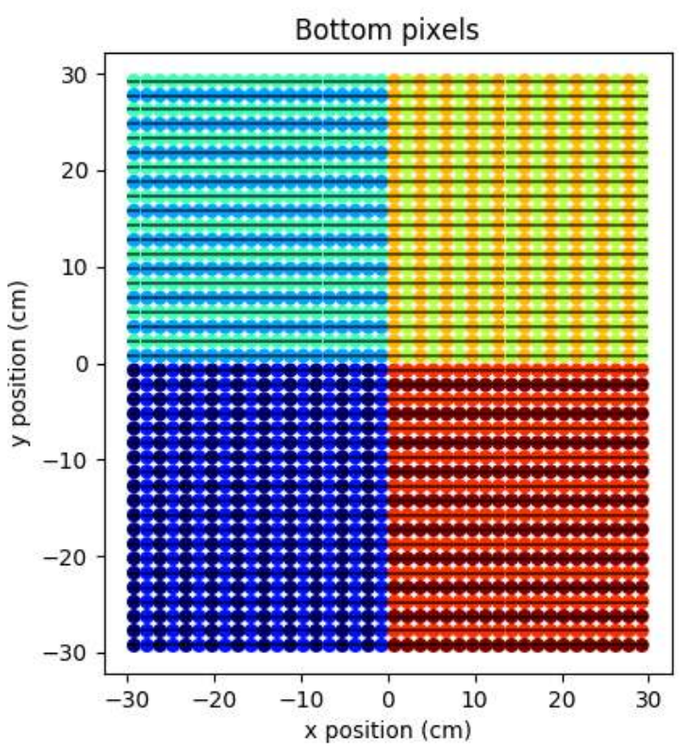
- **Optimise experiment design to minimise instrumental effects**
- **Prepare calibration**

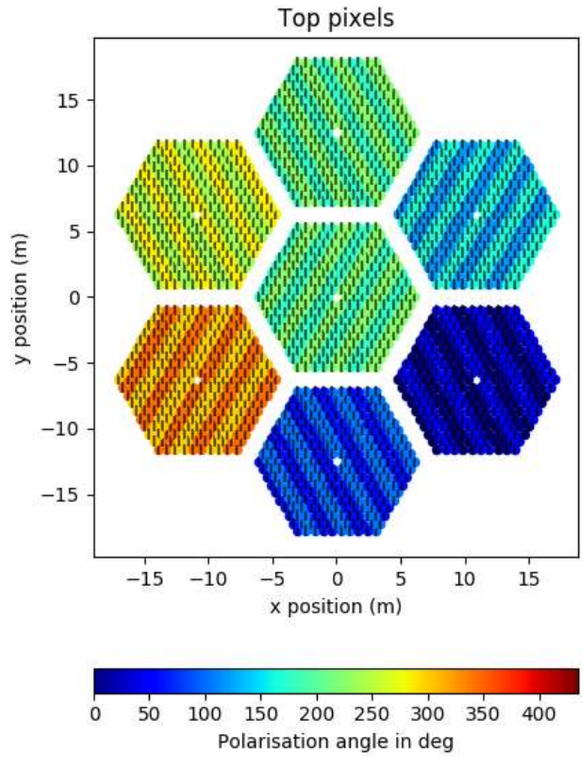
Focal plane architecture

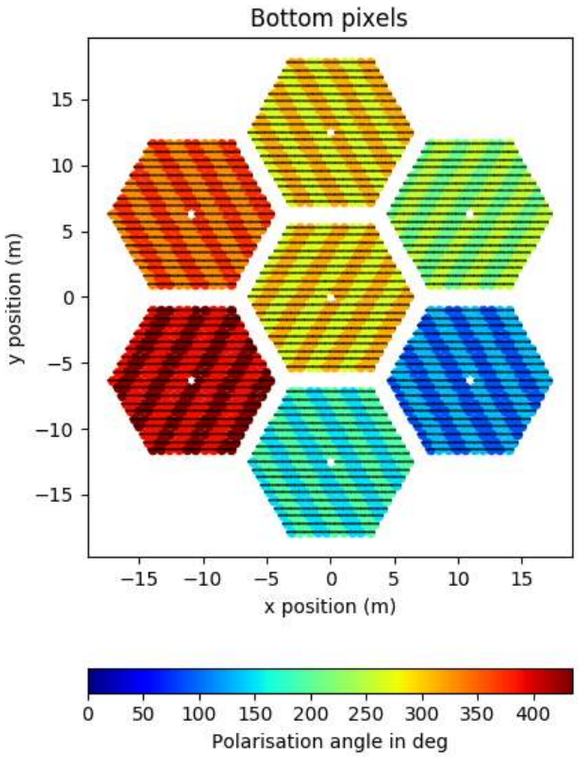
From simplified model to realistic instrumental model

- **Shape**
- **Wafers position and rotation**
- **Pixel type (polarisation)**
- **Readout frequency scheduling**
- **Polarisation angles**









Typical focal plane used for simulation: a year ago and now ;)

Thank you!