BeyondPlanck and LiteBIRD

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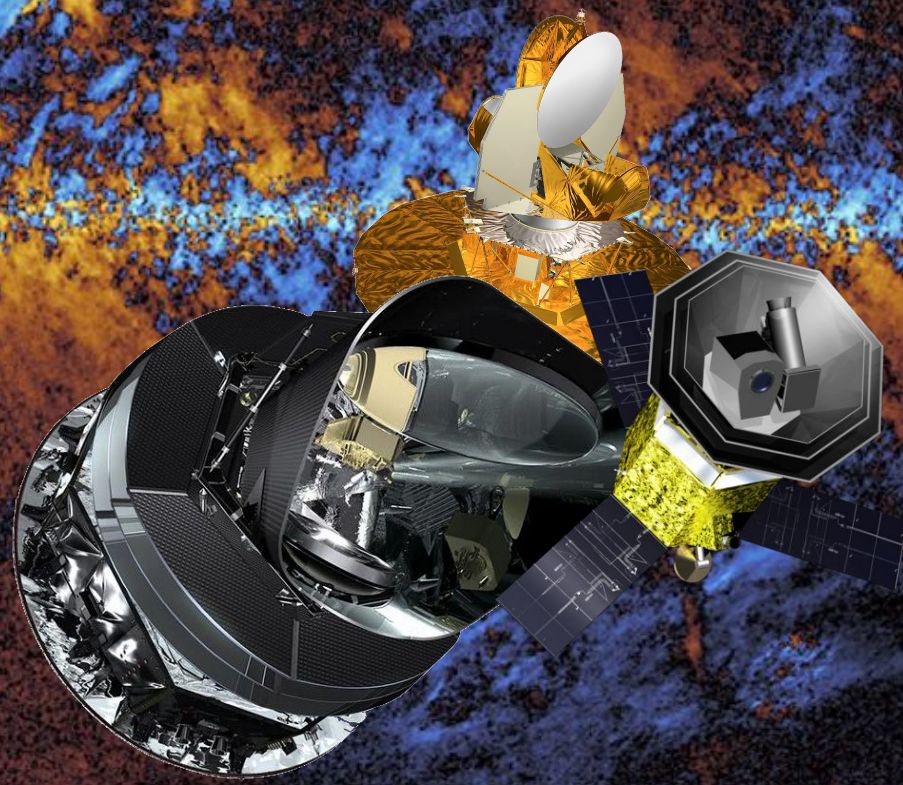


BeyondPlanck online release conference, November 18-20, 2020

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776282

Future mission: LiteBIRD

Next big goal in cosmology:
measure primordial B-mode from Big Bang

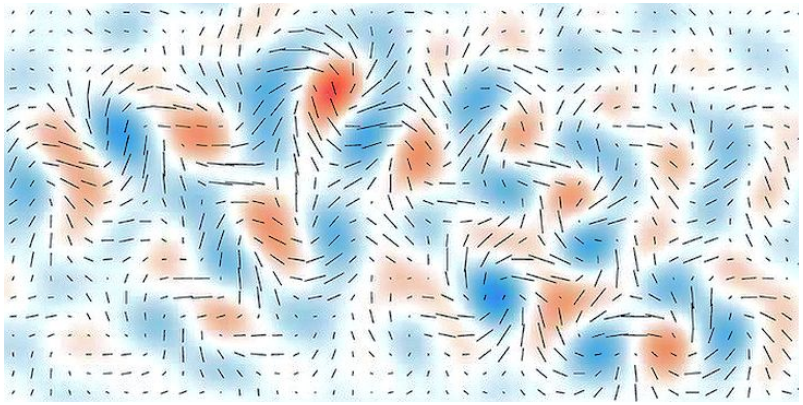
- Extremely weak signal
  - Tensor-to scalar ratio $r < 0.044$ (Tristram et.al., 2020)
- Detection dependent on control of
  - Instrumental systematics
  - Foreground contamination
  - Interplay between these

BeyondPlanck addresses these challenges through end-to-end analysis

LiteBIRD
LiteBIRD is a JAXA fullsky mission to observe the CMB sky in polarization

LiteBIRD goal:

- Detect tensor fluctuations in CMB polarisation at sensitivity of $\delta r \sim 0.001$

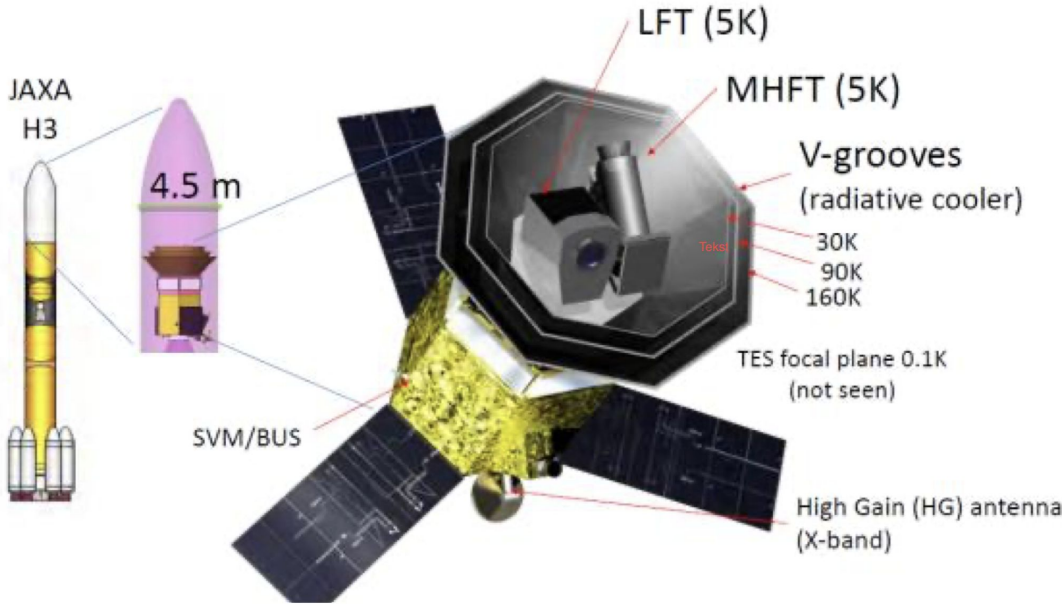


B-mode signal
Source: Nature special (March 17, 2014)

European Commission

- 15 frequencies between 40-400 GHz
- 4508 polarization sensitive detectors
- 3 rotating Half-wave-plates (HWP) to control noise and systematics
- 0.5º at 100 GHz
- 19 Hz sampling rate

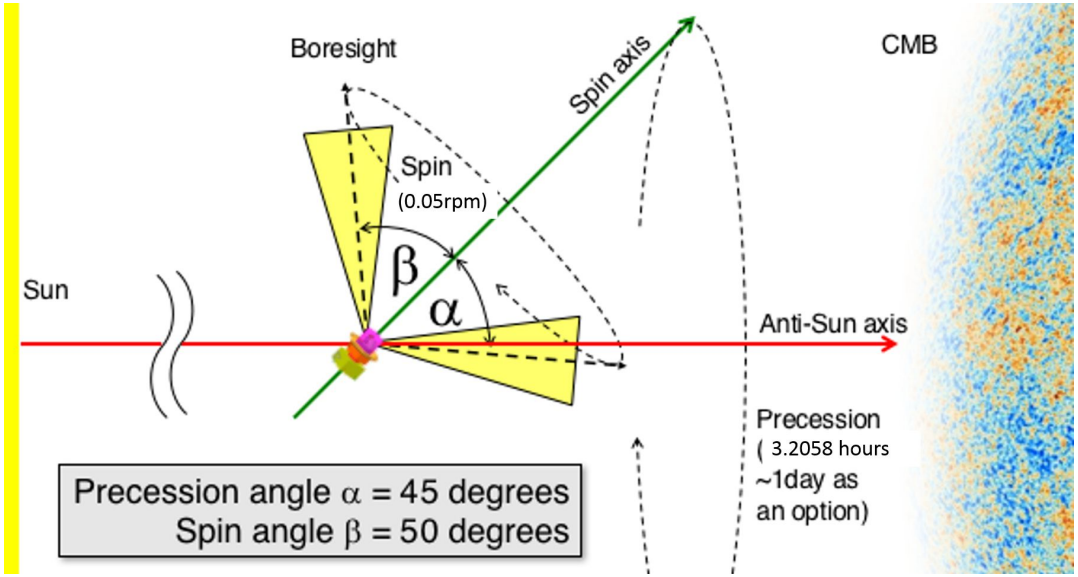
- 3 years observations from late 2020's



LiteBIRD satellite
(*Source: Hugai et.al, 2020*)

Time ordered simulations with *Genesys*

Code called "*Genesys*" written by Ranajoy Banerji
https://github.com/ranajoy-cosmo/genesys.git

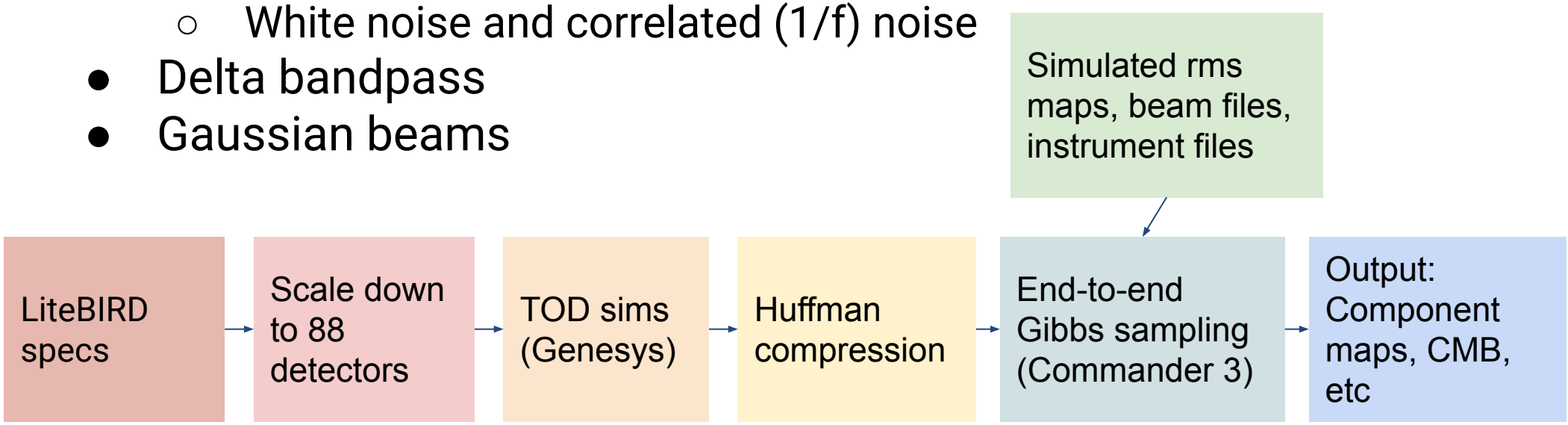


LiteBIRD scanning strategy

- Python based code
- Simulate timestreams for CMB space satellites
- Scans input sky maps pr frequency band
- Fast pointing generation using quaternion algebra
- Ideal half wave plate (HWP): pointing angle includes both pointing of telescope and rotation of HWP
- Inject systematics:
  - Bandpass mismatch, pointing offset, 1/f noise…
- Destriper mapmaker for systematics corrections

Pipeline and sky models

- 1 year of data
- 4 detectors pr frequency band - total of 88 detectors
  - White noise level scaled down to maintain full mission sensitivity
- LiteBIRD official simulated sky maps from PySM
  - CMB realization with r = 0
  - Foregrounds: thermal dust (d1) and synchrotron (s1)
  - White noise and correlated (1/f) noise
- Delta bandpass
- Gaussian beams

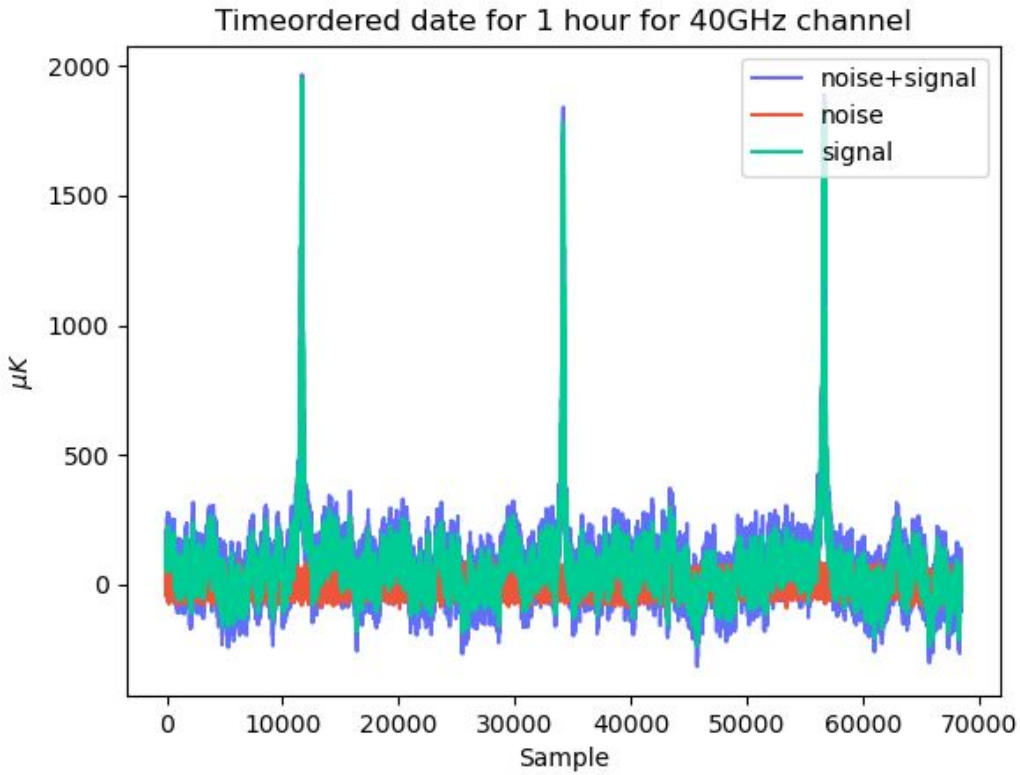


Time ordered simulations with Genesys

Data volume current simulations

88 detectors, 1 year:

- Data volume 200 GB
- 60 GB after Huffman compression
- ~50 min simulation time on 24 cores



Estimated full mission data volume

4508 detectors, 3 years:

- Data volume 30 TB
- 10 TB after Huffman compression
- ~1,5 day simulation time on 24 cores

Computational costs on 36 cores

88 detectors, 1 year of data

- **Memory usage:** ~500 GB
- **Time usage:**
  - One TOD band: 80 s
  - All 22 bands: 29 minutes
  - One sample: 3 hours (with component separation)
    ~240 samples in month

4508 detectors, 3 years of data

- **Memory usage:** Estimate ~11 TB
- **Time usage:**
  - TOD processing, all data: 3 days
    ~8 samples in a month

Groups best computer node today: 1.5 TB and 72 cores

Computational costs on 36 cores

88 detectors, 1 year of data

- **Memory**
- **Time**
  - On
  - All
  - On

4508 det

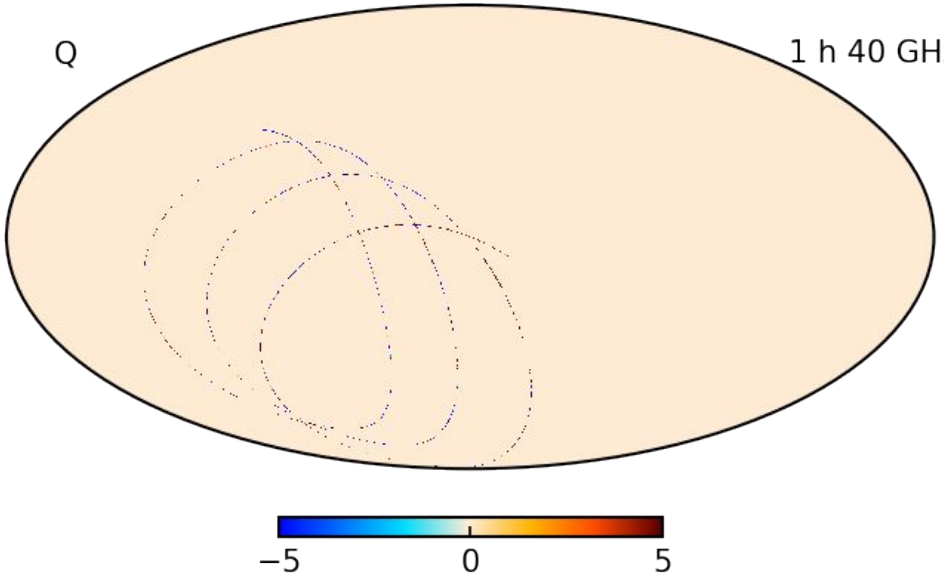
- **Memo**
- **Time**
  - TOD processing, all data ~8 samples in a month

It is safe to assume that the memory and computational power available in the 2030's will make end-to-end analysis of the full LiteBIRD data set possible

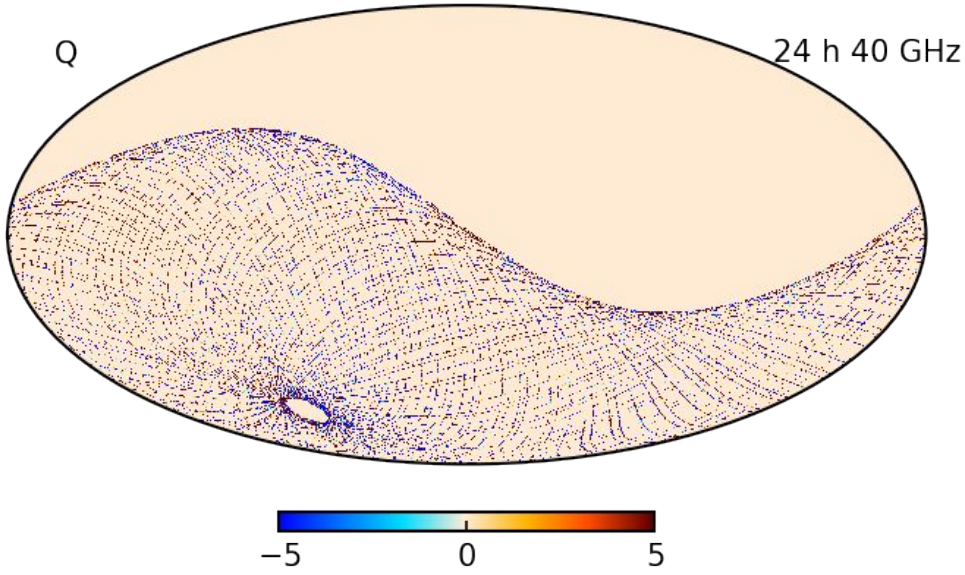
Groups best computer node today: 1.5 TB and 72 cores

LiteBIRD scanning strategy

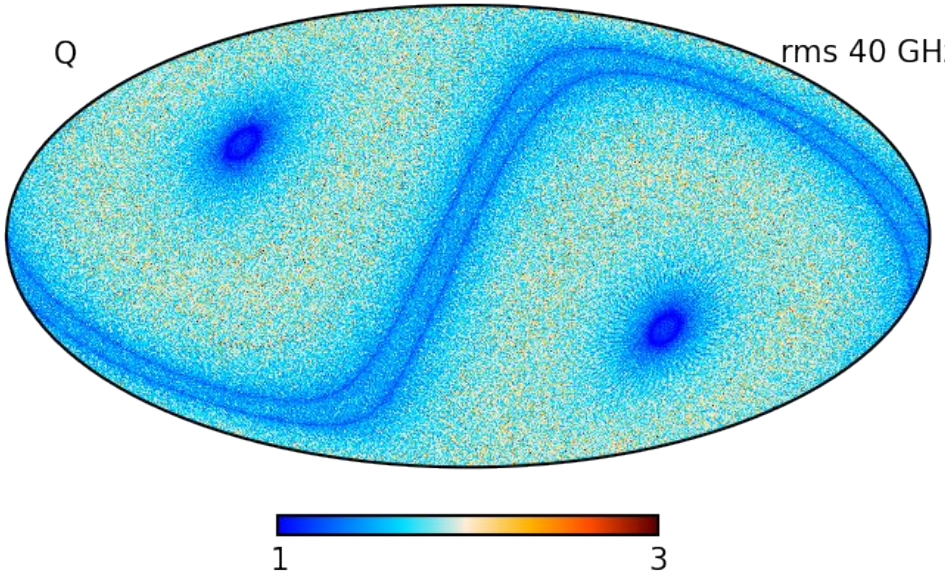
1 hour of data, 1 frequency



24 hours of data, 1 frequency

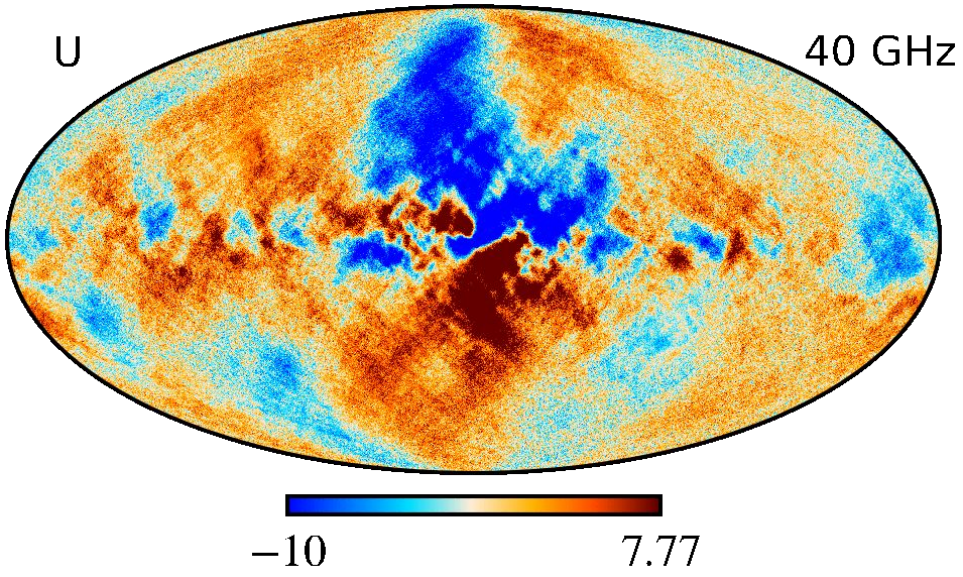


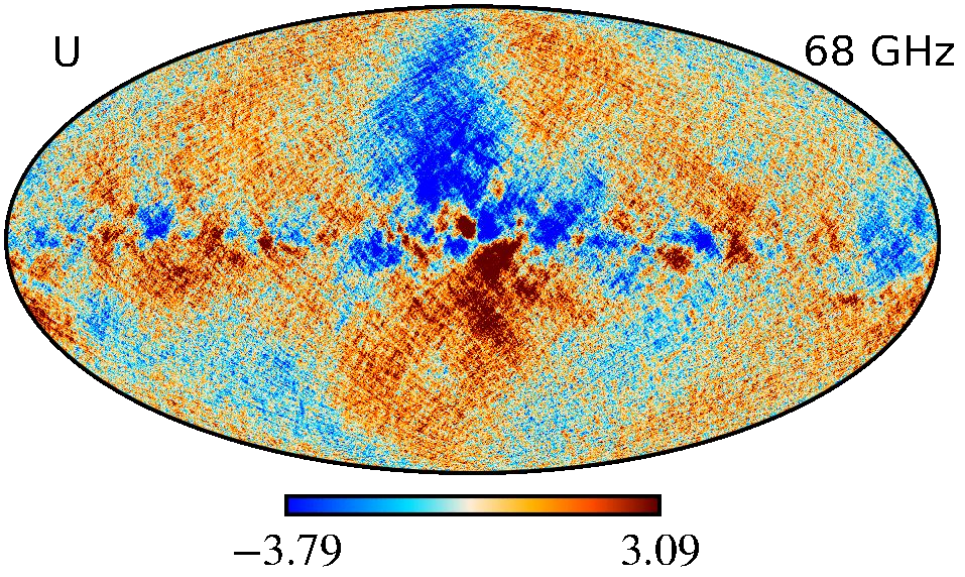
RMS map showing scanning strategy

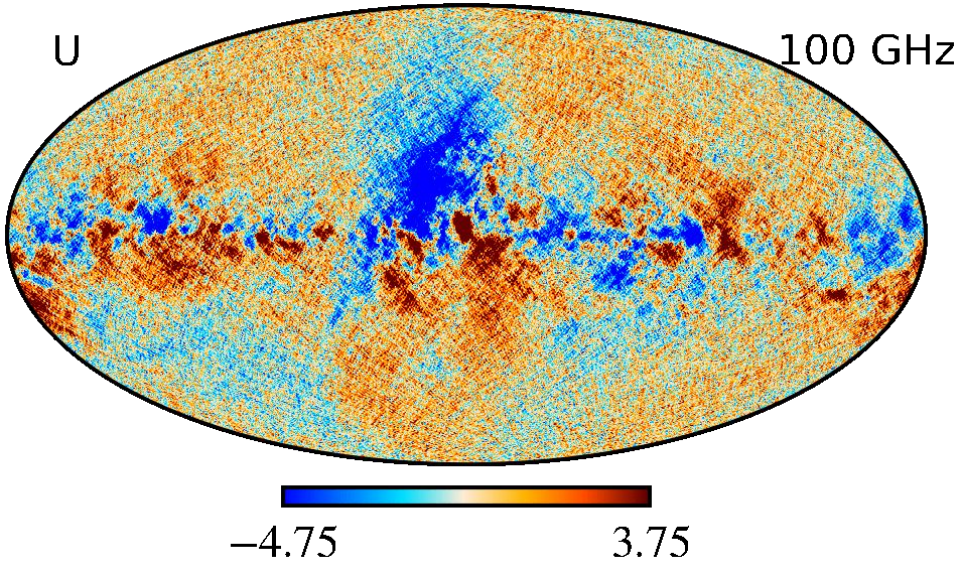


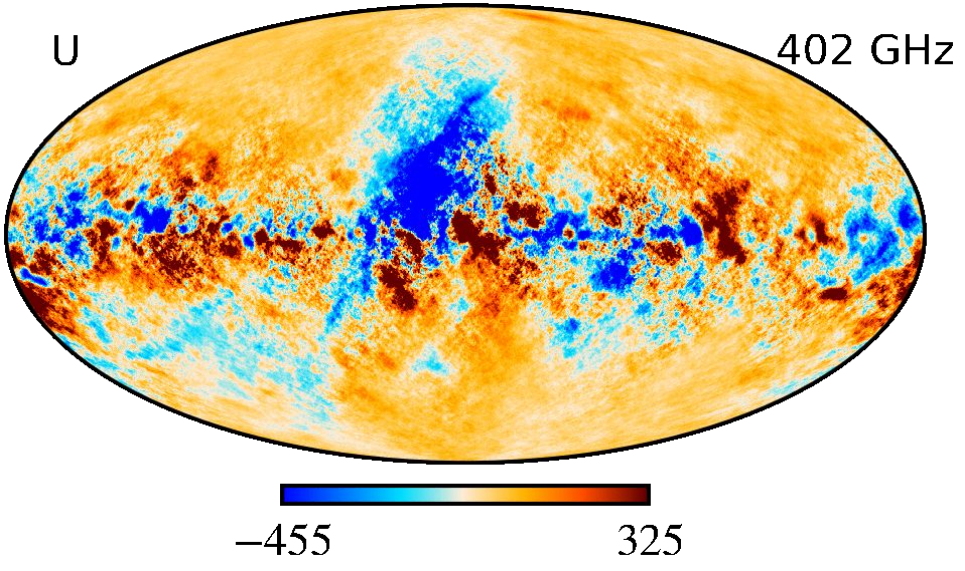
Difference in maps due to correlated noise

Frequency maps containing cmb, thermal dust, synchrotron, and noise, with 1/f noise removed



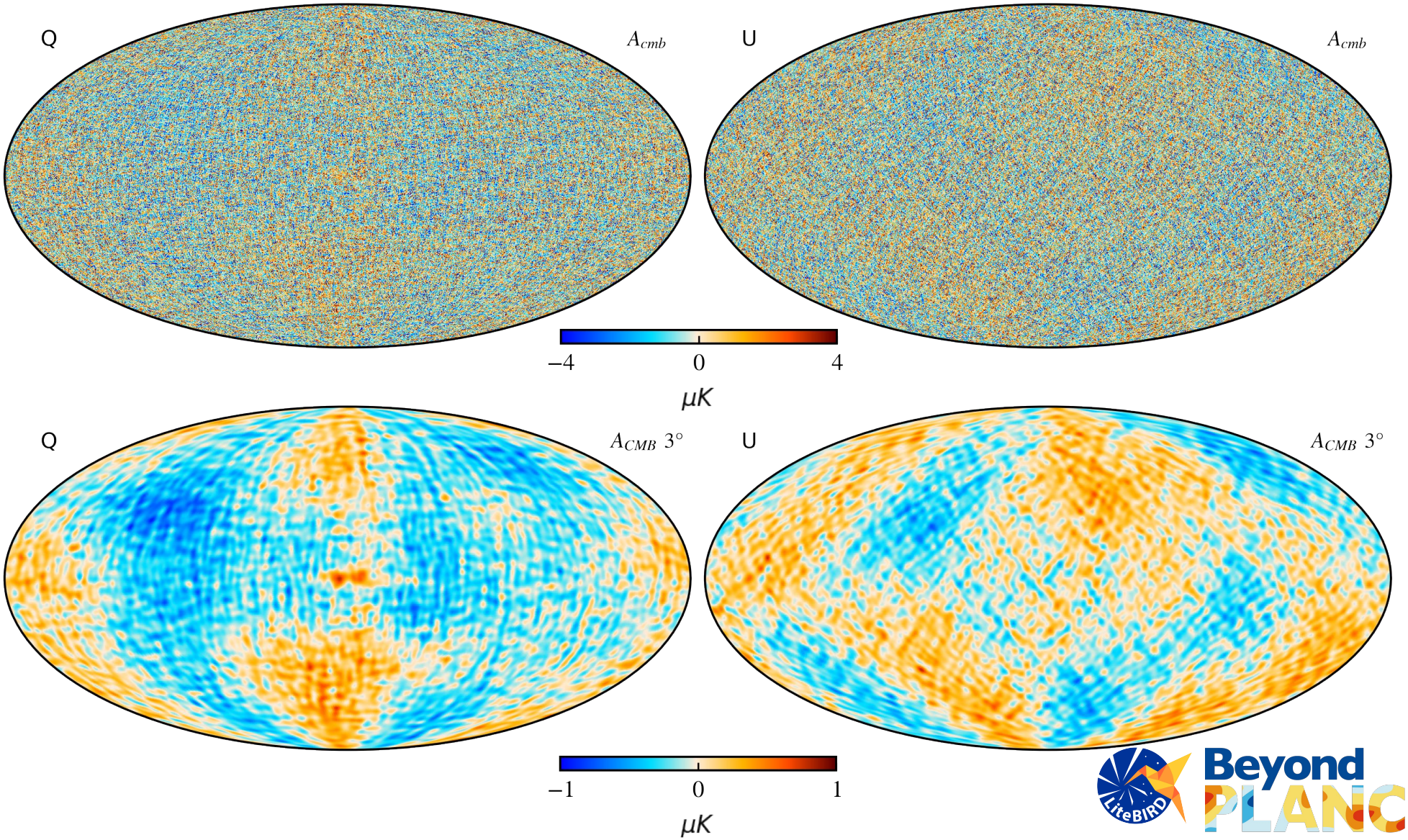






Component separation: synchrotron + cmb + white noise

CMB map from Commander3 with nside 256



Conclusions and further work

- We have shown that Commander3 is suitable for analysis of simulated time ordered LiteBIRD data
- We estimate the data volume needed to store and analyze the full LiteBIRD data and assume that we have the computational power needed to do end-to-end analysis in 10-13 years

Further work

- Use more realistic sky models
- Use more realistic bandpasses and beams
- Add systematic effects into the TOD simulations to see how these propagate to the cosmological parameters

Funding

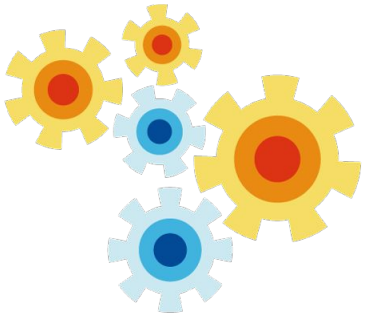
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776282

- "*BeyondPlanck*"
  - COMPET-4 program
  - PI: Hans Kristian Eriksen
  - Grant no.: 776282
  - Period: Mar 2018 to Nov 2020

Collaborating projects:

- "*bits2cosmology*"
  - ERC Consolidator Grant
  - PI: Hans Kristian Eriksen
  - Grant no: 772 253
  - Period: April 2018 to March 2023
- "*Cosmoglobe*"
  - ERC Consolidator Grant
  - PI: Ingunn Wehus
  - Grant no: 819 478
  - Period: June 2019 to May 2024

Questions?

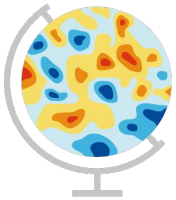


Commander

HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI

planetek
hellas

HAVERFORD
COLLEGE



Cosmoglobe

Beyond
PLANCK