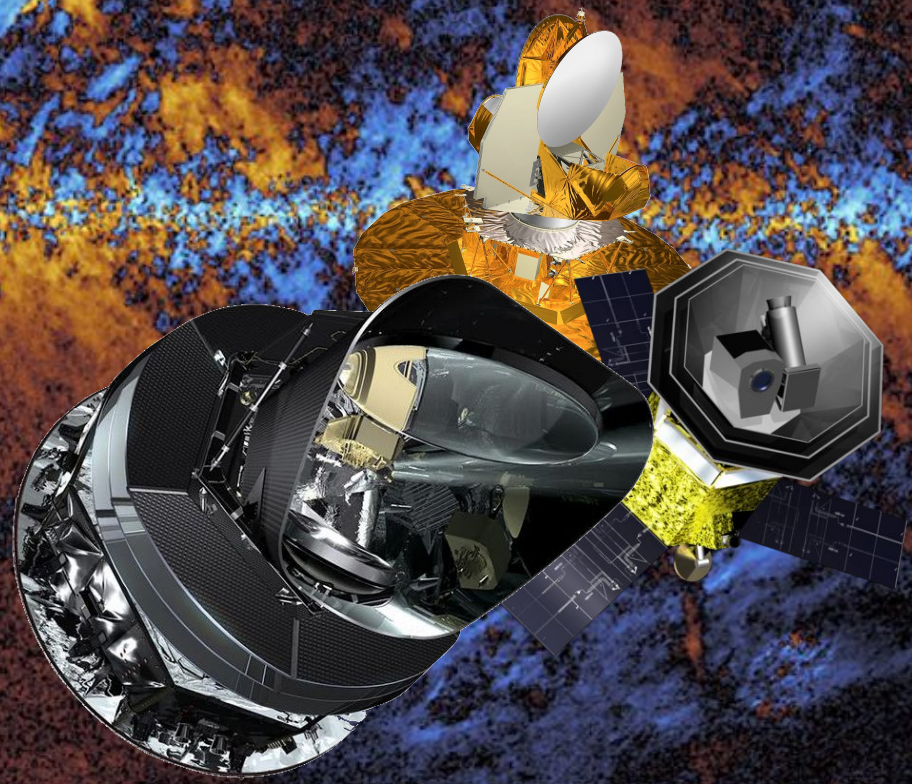
Leakage corrections

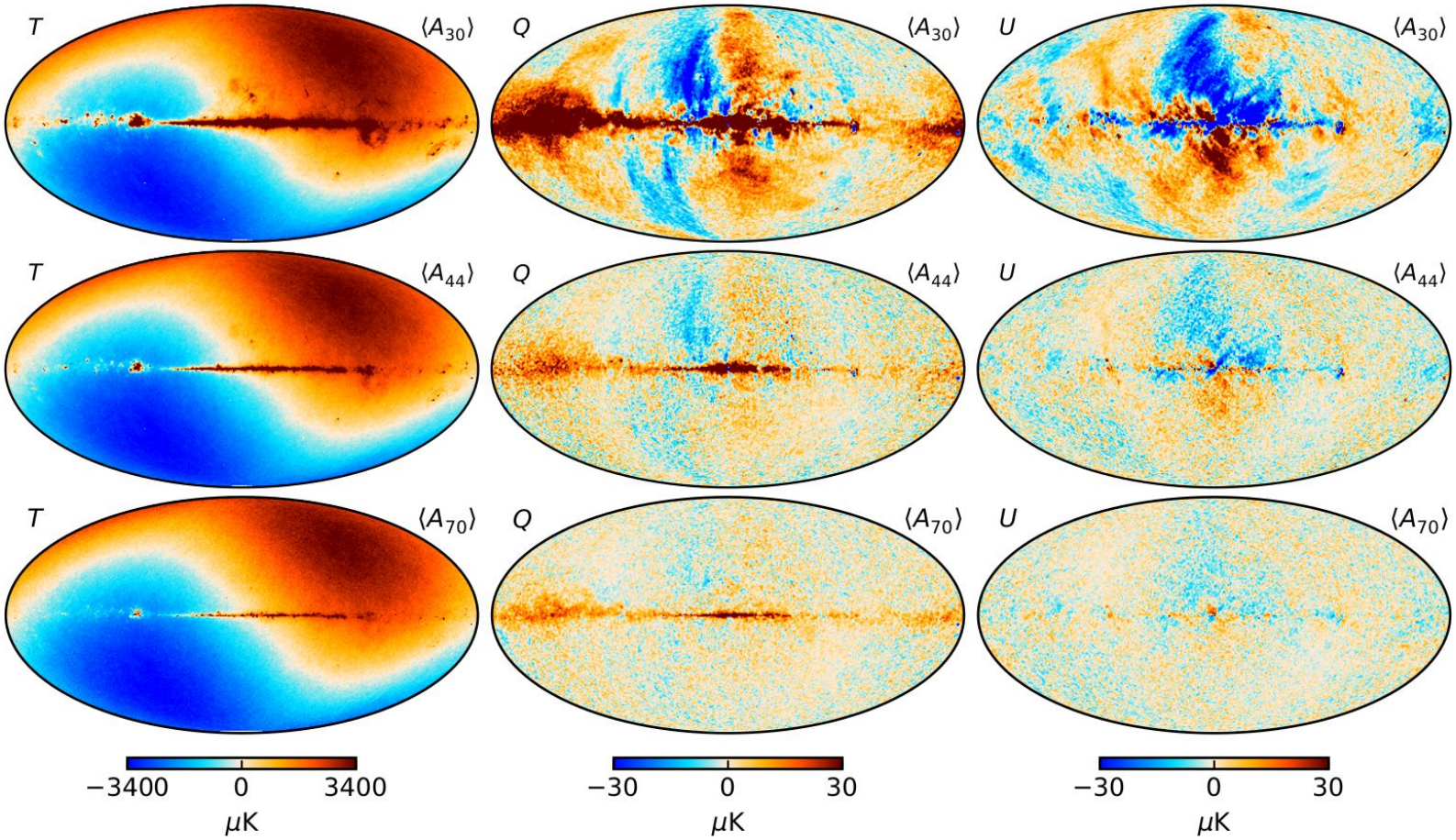
Trygve Leithe Svalheim



BeyondPlanck online release conference, November 18-20, 2020

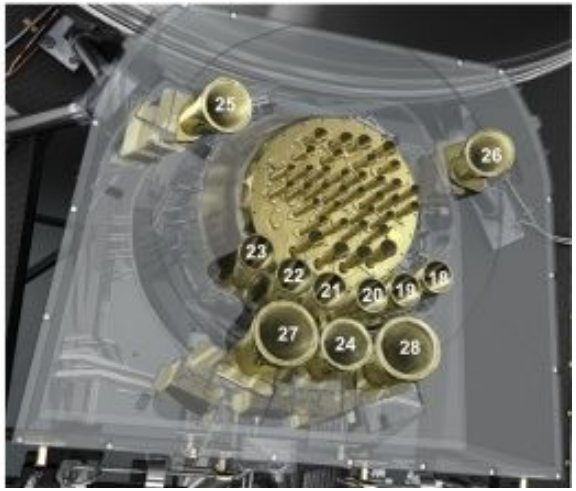
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776282

The sky as seen by Planck LFI



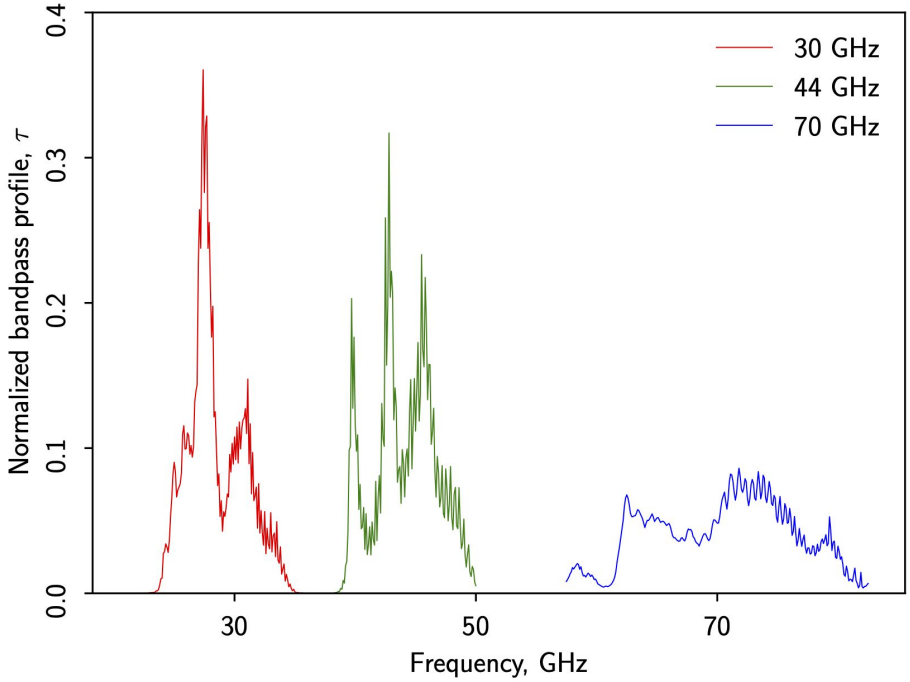
- **Bandpass:** The sky is not observed at a single sharp frequency
- **Beam:** Spatial shape of instrument sensitivity
- Estimated before commission - Uncertainties!
- **If not properly controlled:** Leakage

The Planck instrument

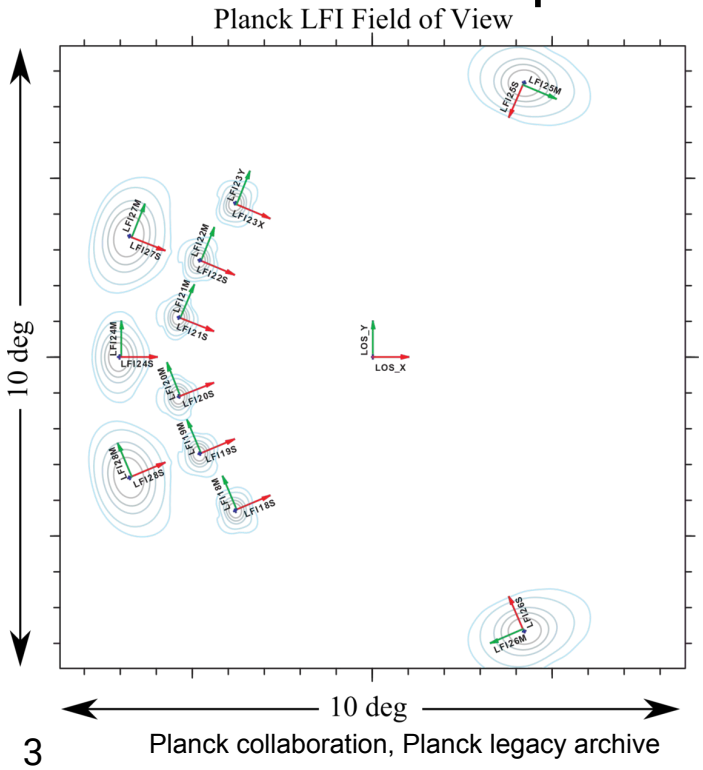


Planck collaboration, explanatory supplement
https://wiki.cosmos.esa.int/planckpla2015/index.php/File:Lfi_instrument.jpg

Planck LFI **bandpass** averaged over all radiometers



Planck LFI **beam** profiles



Planck collaboration, Planck legacy archive

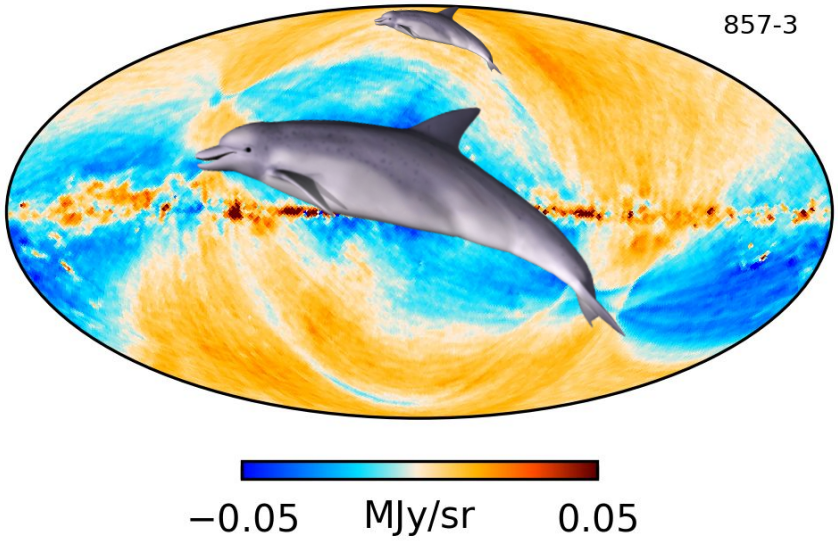
Leakage

- Combine multiple radiometers
- Sky looks different to every radiometer
  - Bandpass and beams differ
- Mapmaking algorithms interpret differences between detector maps as noise.
  - Solving for correlated noise; this is down-weighted according to scanning strategy
  - “dolphins”

Mapmaking:

$$\left(\sum_{j\in\nu} P'_j (N_j^w)^{-1} P_j\right) m_\nu = \sum_j P'_j (N_j^w)^{-1} d_j.$$

All radiometers assumed to see the same sky!



Parameterizing the leakage

- New parameter for quantifying leakage in BeyondPlanck
- $\delta s^{\mathrm{leak}}_{j,t}$ is then a measure of the leakage per detector.
  - Difference relative to the mean of the sky per radiometer
  - Subtract from data for each radiometer before combining!

$$\delta s^{\mathrm{leak}}_{j,t} = \mathsf{P}^{j}_{tp}\mathsf{B}^{j}_{pp'}\left(s^{\mathrm{sky}}_{jp'} - \left\langle s^{\mathrm{sky}}_{jp'}\right\rangle\right),$$

One of several corrections

$$r_{j,t} = \frac{d_{j,t} - n^{\mathrm{corr}}_{j,t}}{g_{t,j}} - \left(s^{\mathrm{orb}}_{j,t} + s^{\mathrm{fsl}}_{j,t} + s^{\mathrm{mono}}_{j} + \delta s^{\mathrm{leak}}_{j,t}\right).$$

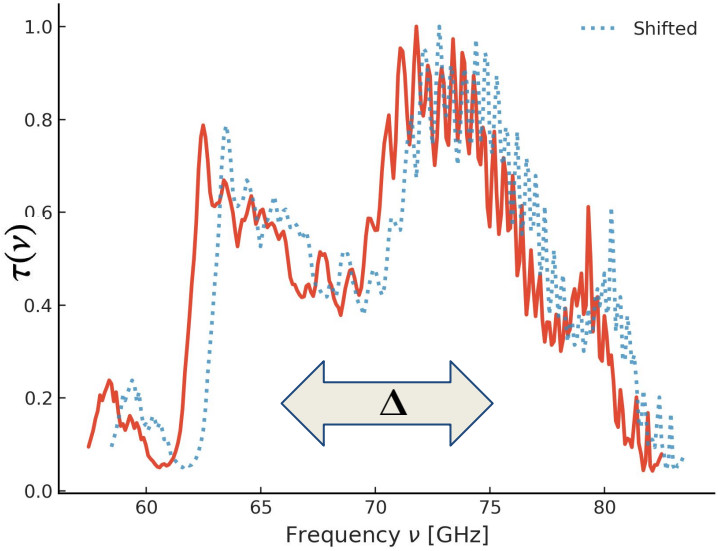
Parameterizing the correction

- How do we correct the leakage?
  - A linear shift in frequency

$$\tau(\nu) = \tau_0(\nu + \Delta_{bp})$$

$$\Delta^j_{\rm bp} = \bar{\Delta}_{\rm bp} + \delta^j_{\rm bp}$$

Total = Band average + relative



- Not necessarily ideal or physical
  - Uncertainties to tails of the profiles

Estimating the leakage corrections

- Sample using a Metropolis Hastings sampler
  - Requires an error statistic

- **Spurious maps**: A measure of how different a detector is from the mean

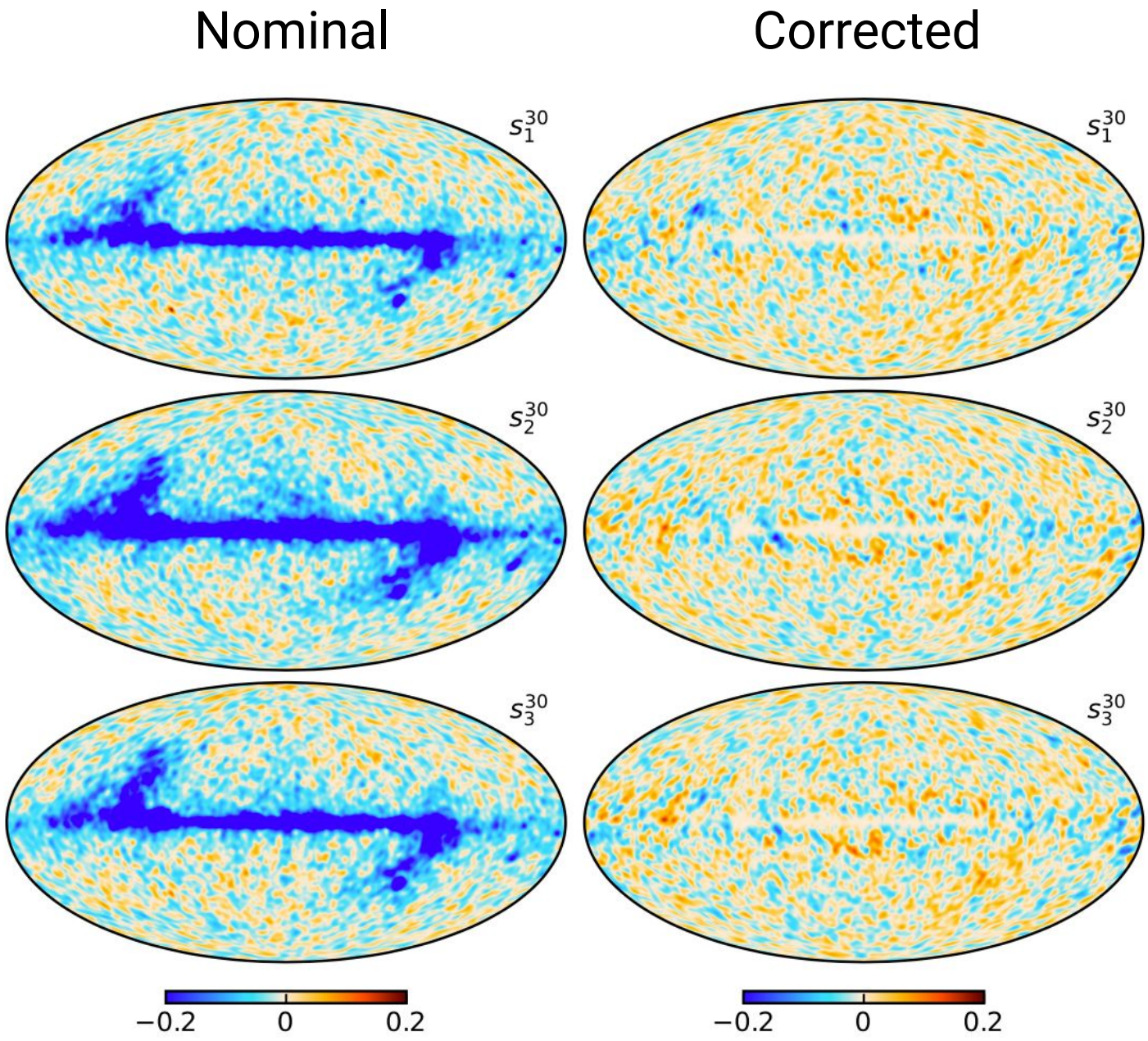
$$s_j = T + Q\cos 2\psi_j + U\sin 2\psi_j + \sum_{i=1}^{N_{\rm det}} S_i \delta_{ij}.$$

- Map-making equation for 3 detector case:

$$\begin{bmatrix} 1 & \cos 2\psi & \sin 2\psi & \delta_{1j} & \delta_{2,j} \\ \cos 2\psi & \cos^2 2\psi & \cos 2\psi \sin 2\psi & \cos 2\psi\ \delta_{1j} & \cos 2\psi\, \delta_{2,j} \\ \sin 2\psi & \sin 2\psi \cos 2\psi & \sin^2 2\psi & \sin 2\psi\ \delta_{1j} & \cos 2\psi \sin 2\psi\, \delta_{2,j} \\ \delta_{1j} & \cos 2\psi\, \delta_{1i} & \sin 2\psi\, \delta_{1j} & \delta_{1j} & 0 \\ \delta_{2j} & \cos 2\psi\, \delta_{2i} & \sin 2\psi\, \delta_{2j} & 0 & \delta_{2j} \end{bmatrix} \begin{bmatrix} T \\ Q \\ U \\ S_1 \\ S_2 \end{bmatrix} = \begin{bmatrix} d \\ d\cos 2\psi \\ d\sin 2\psi \\ d\,\delta_{1j} \\ d\,\delta_{2j} \end{bmatrix}$$

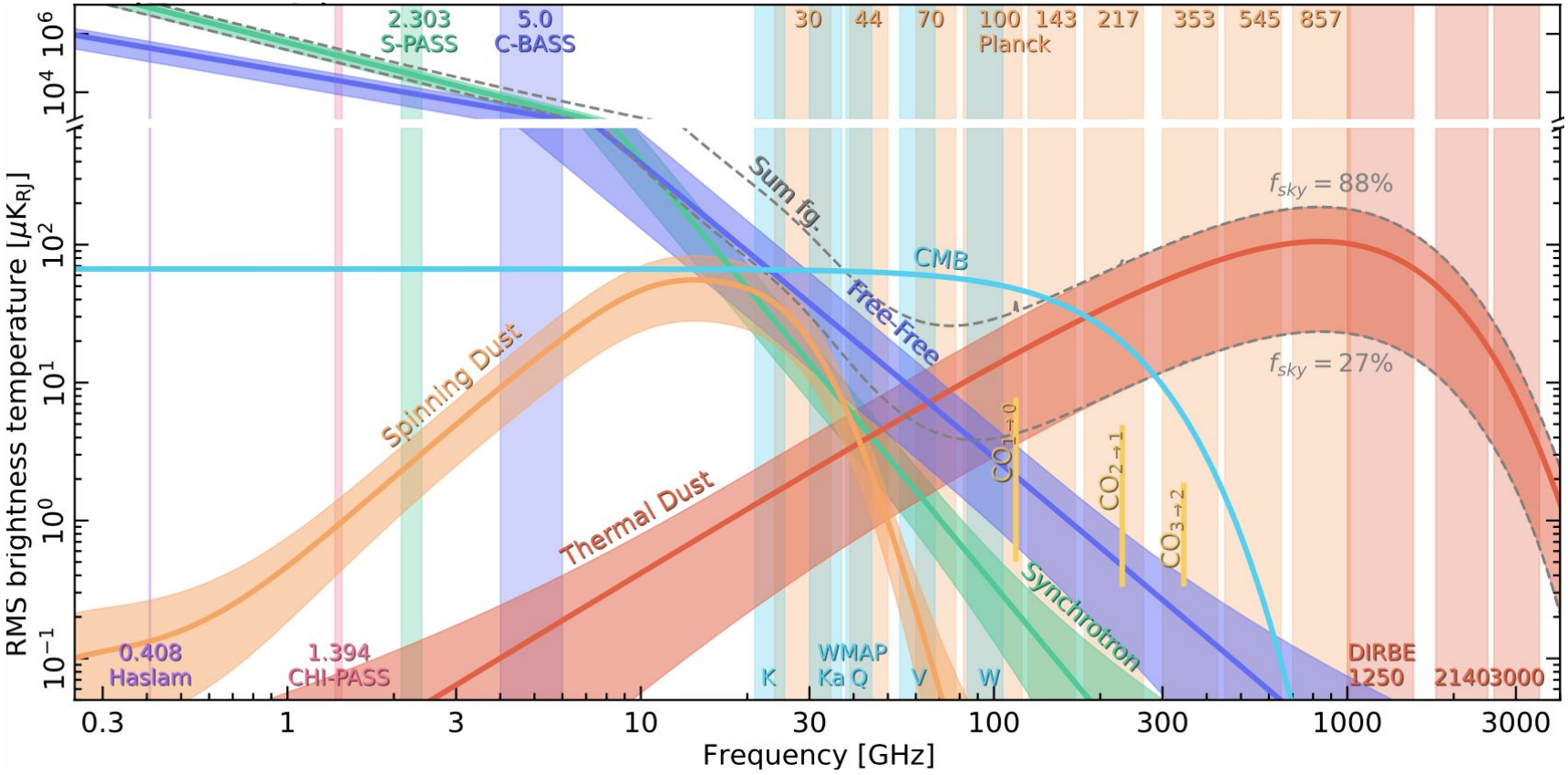
- **Only** used as an error statistic, TQU calculated again later

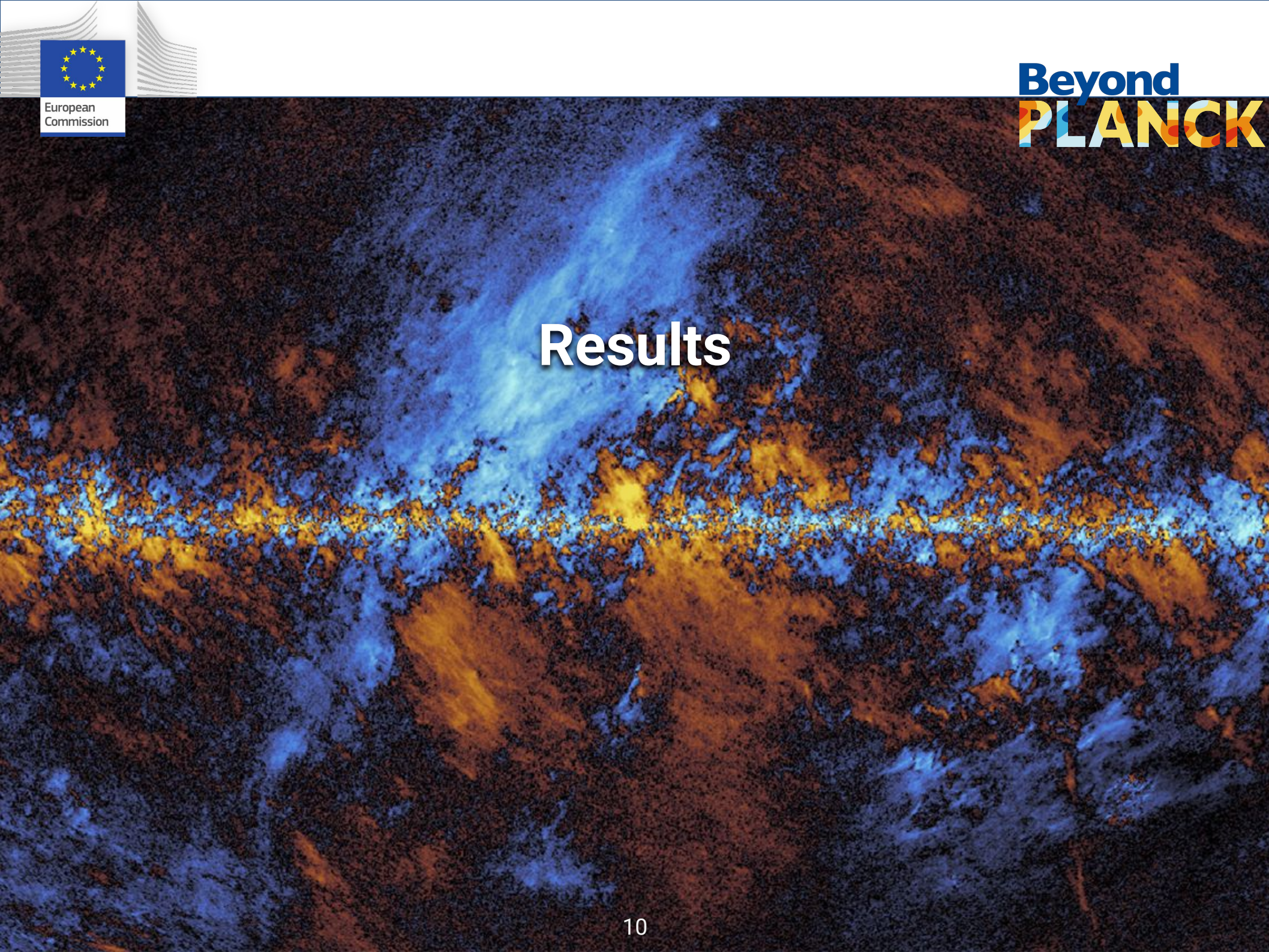
Spurious maps



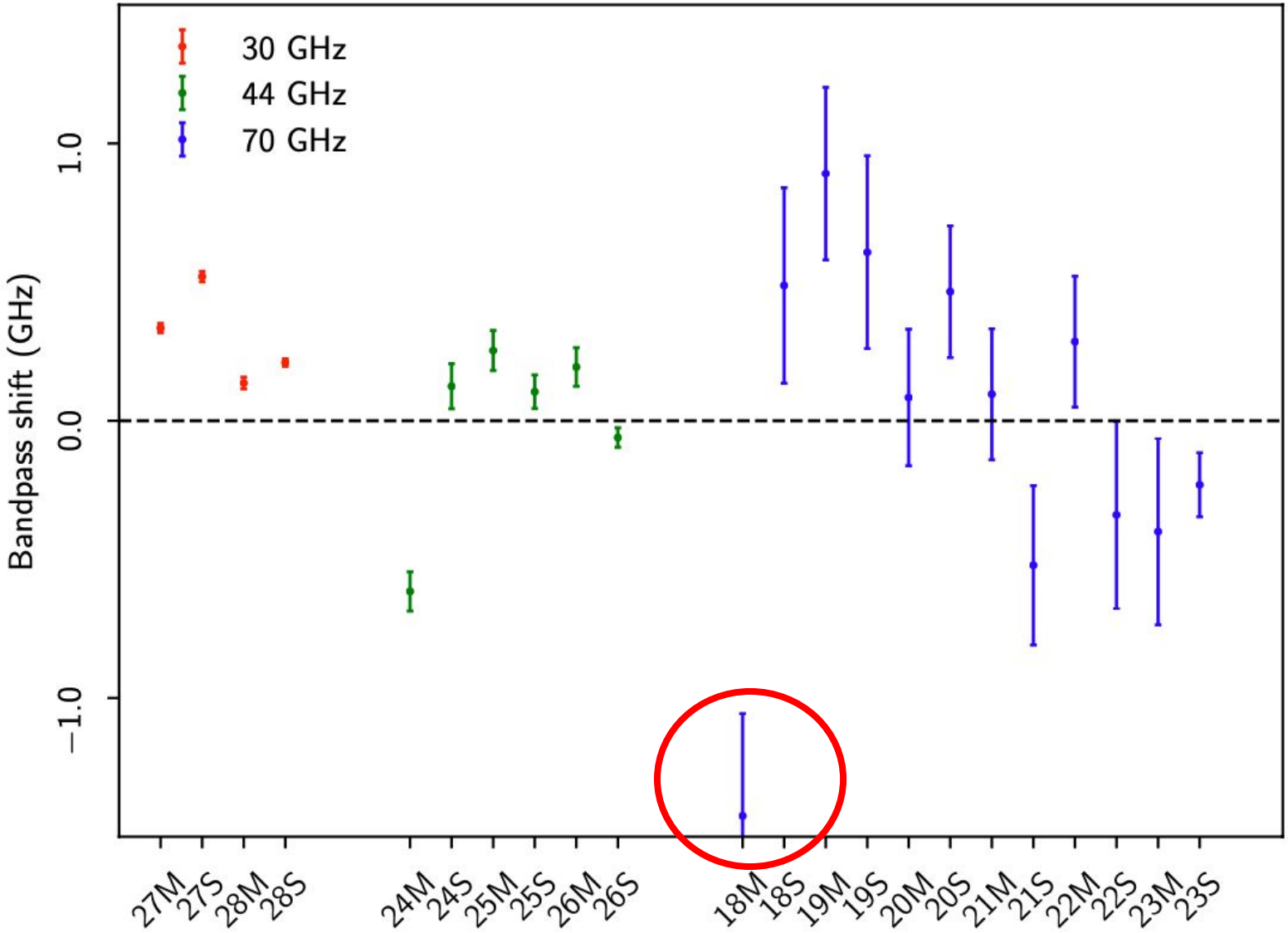
Challenges

- Bandpass leakage influences to many analysis steps
- Absolute corrections degenerate with foregrounds
  - Shift to 70 GHz may induce bias to Thermal dust Beta
- Only apply absolute shift to of 0.3 GHz to 30 GHz band

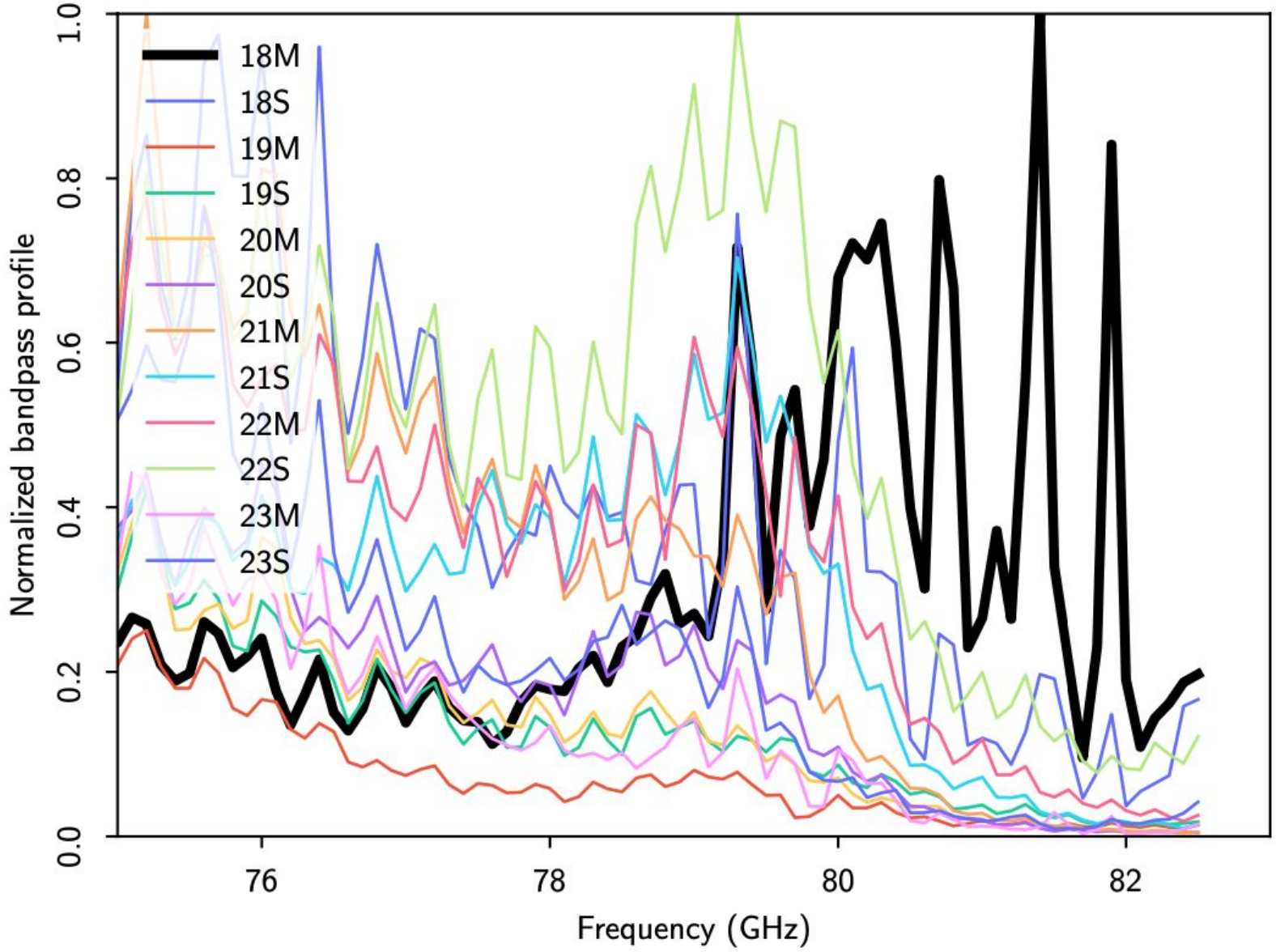



European Commission
Beyond PLANCK
Results

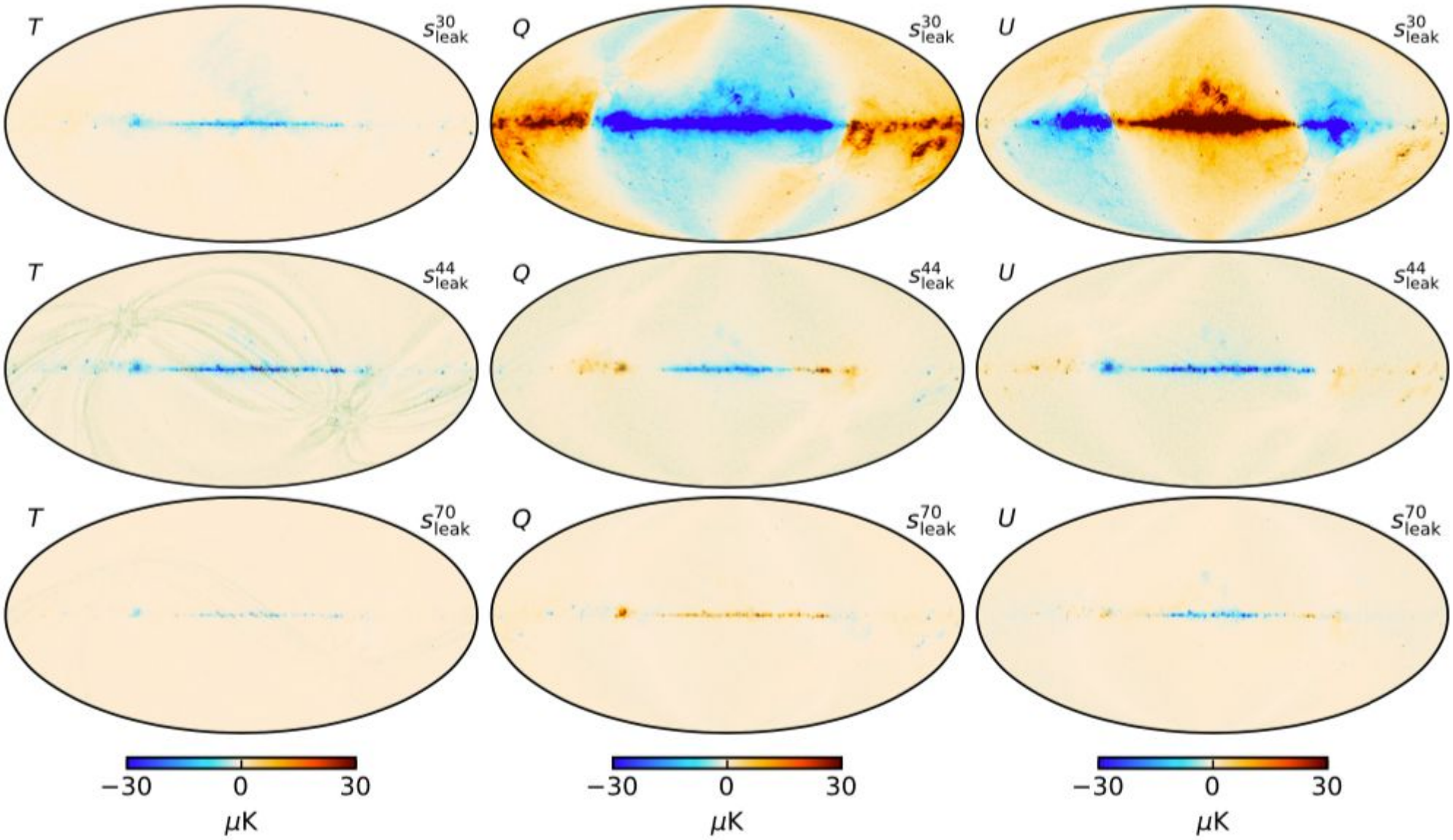
Posterior bandpass corrections



18M discrepancy

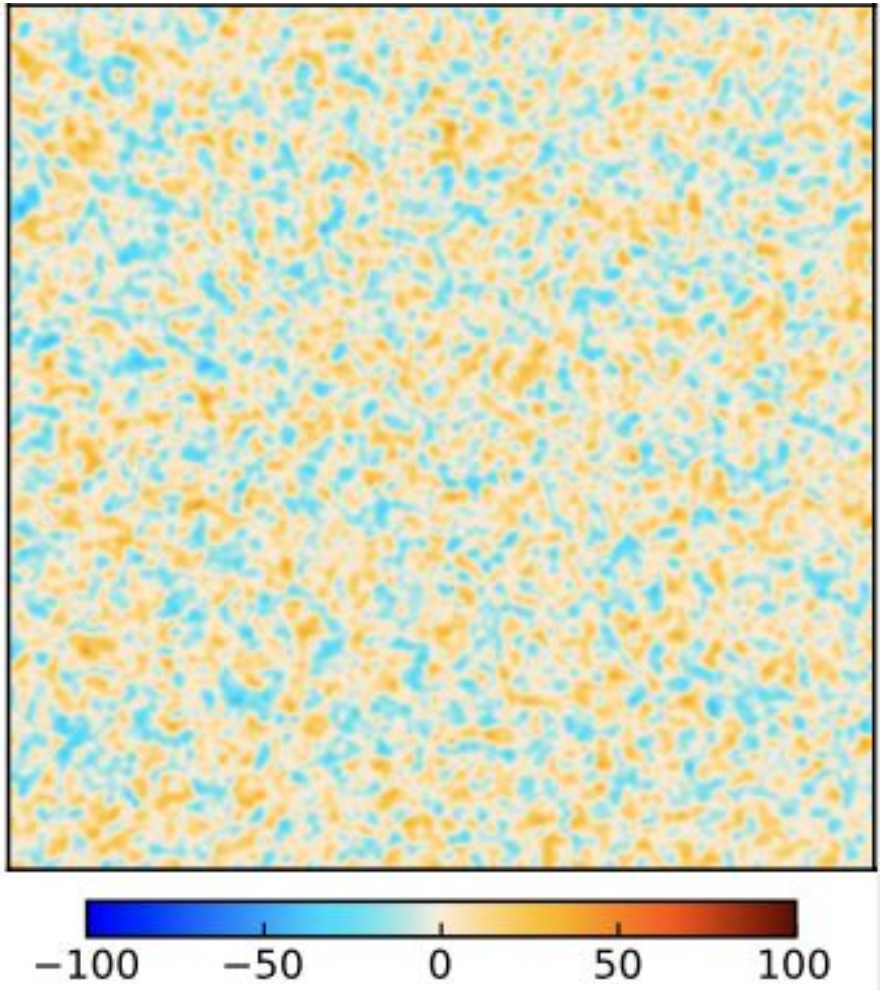


Leakage correction templates per band

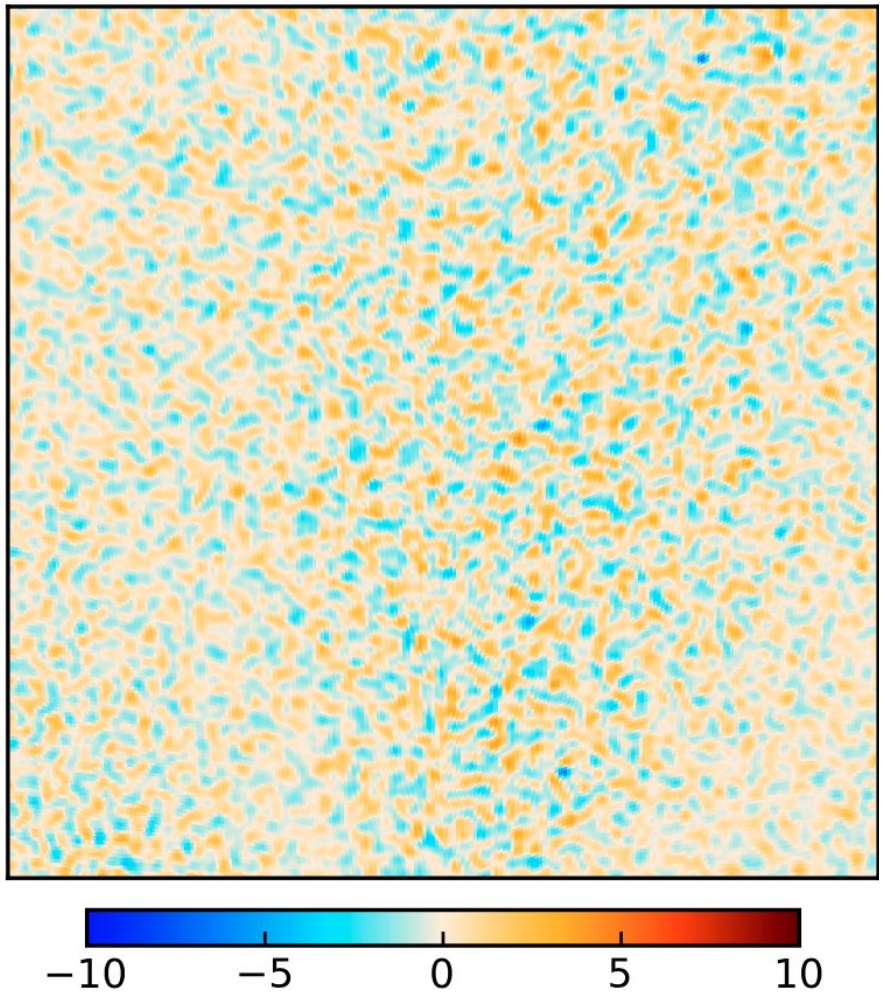


Beam leakage

CMB



LEAKAGE



Summary

- Corrections show significant improvement
- More sophisticated approaches could improve the results in the future

Funding

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- "*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?

Beyond PLANCK

Commander

Cosmoglobe