Cosmoglobe

Cosmoglobe

connecting the near and far universe through global analysis

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Nicolaus Copernicus World Congress, 19-21 February 2023

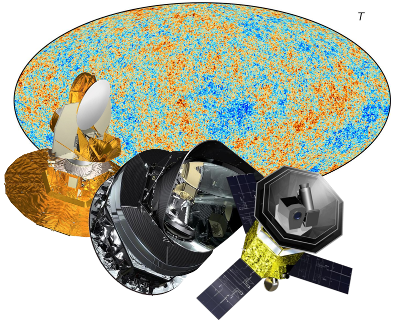
UNIVERSITAS OSLOENSIS MDCCCXI

European Commission

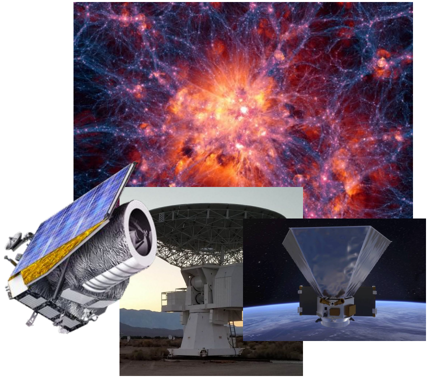
Cosmoglobe

-mapping the universe from the Solar system to the Big Bang

Early universe

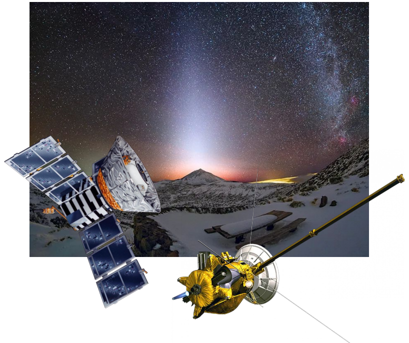


Large-scale structure

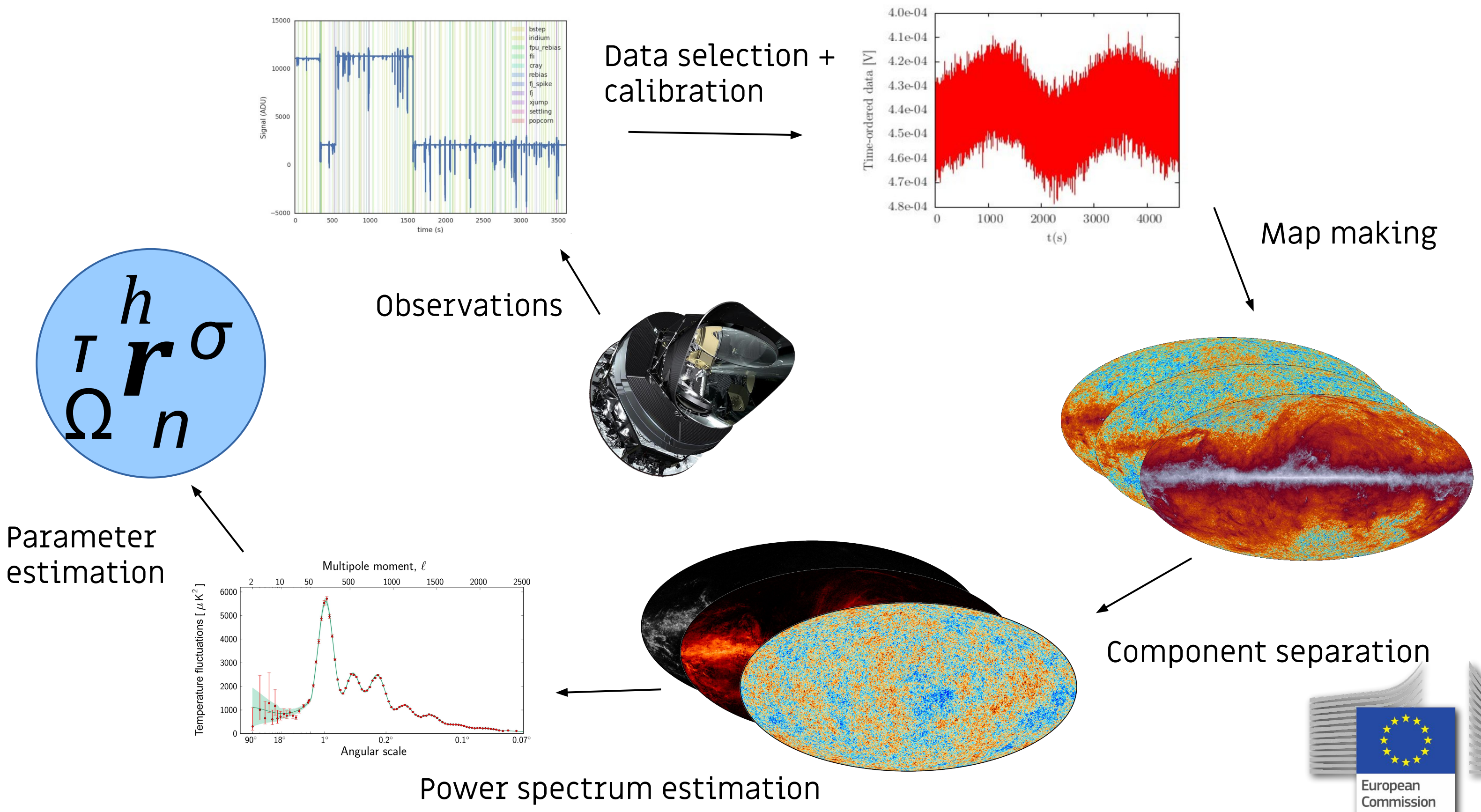


Milky Way

Solar system



Classic linear CMB analysis pipeline



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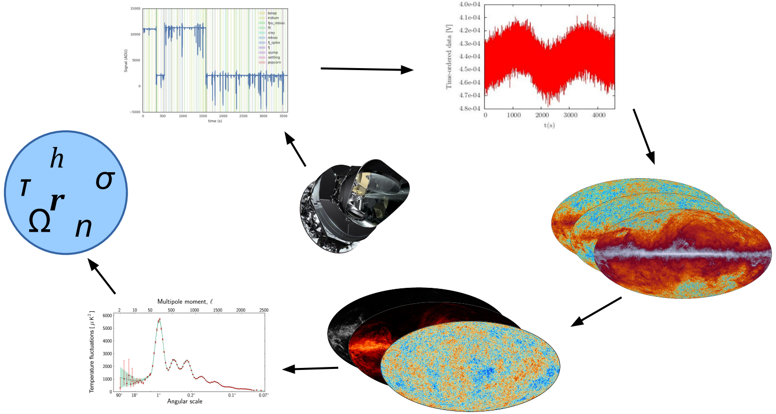
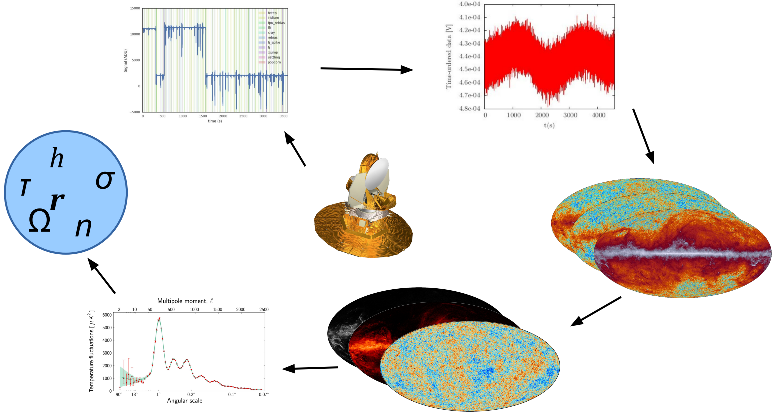
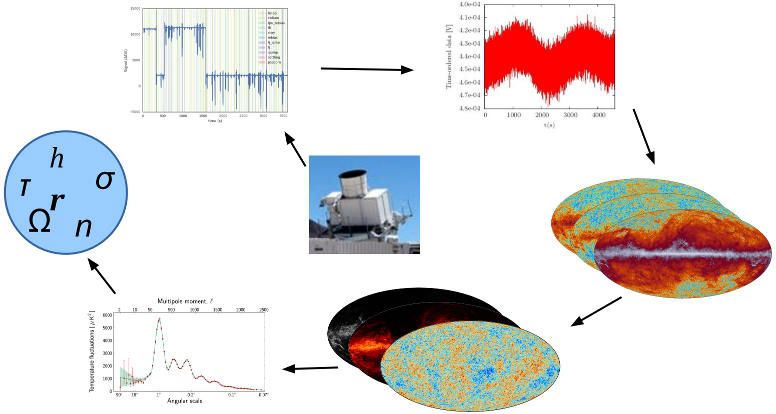
Classic linear CMB analysis pipelines







Challenges

- parameter degeneracies
- single-experiment blind spots
- information loss
- resource demanding

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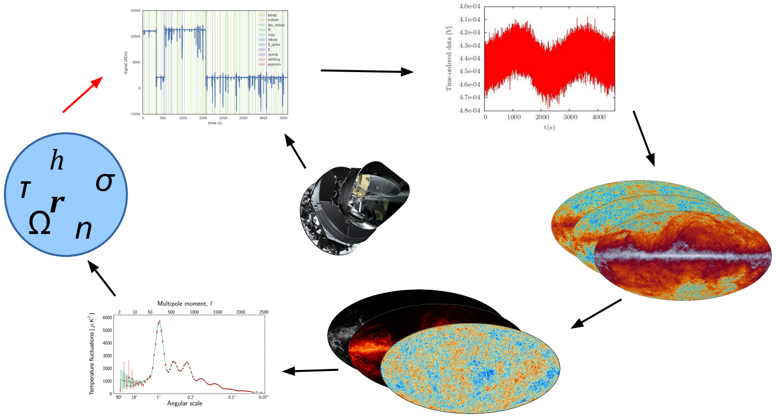
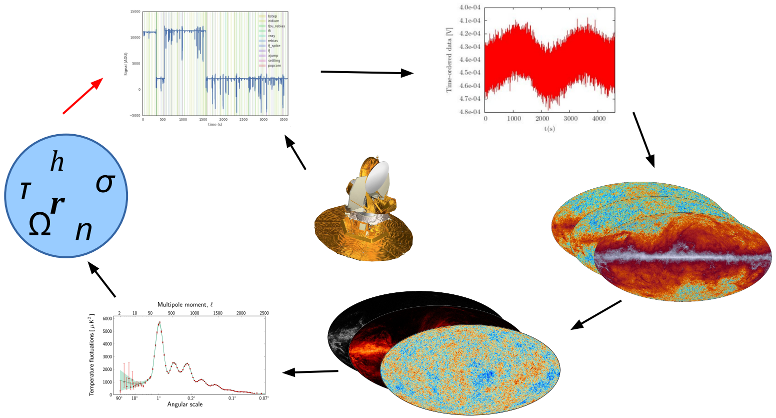
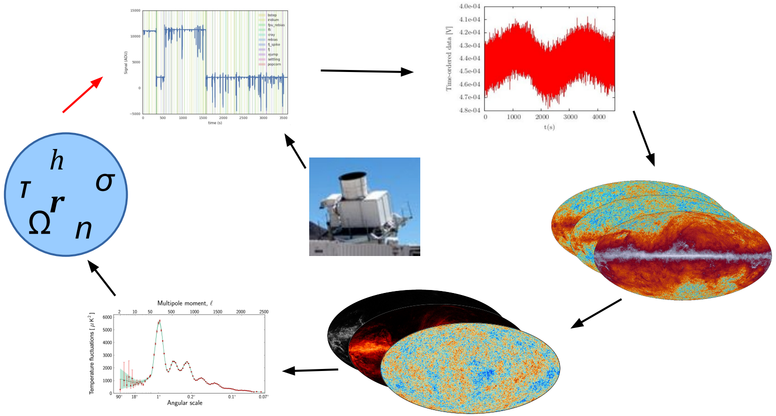
Classic linear CMB analysis pipelines







Challenges

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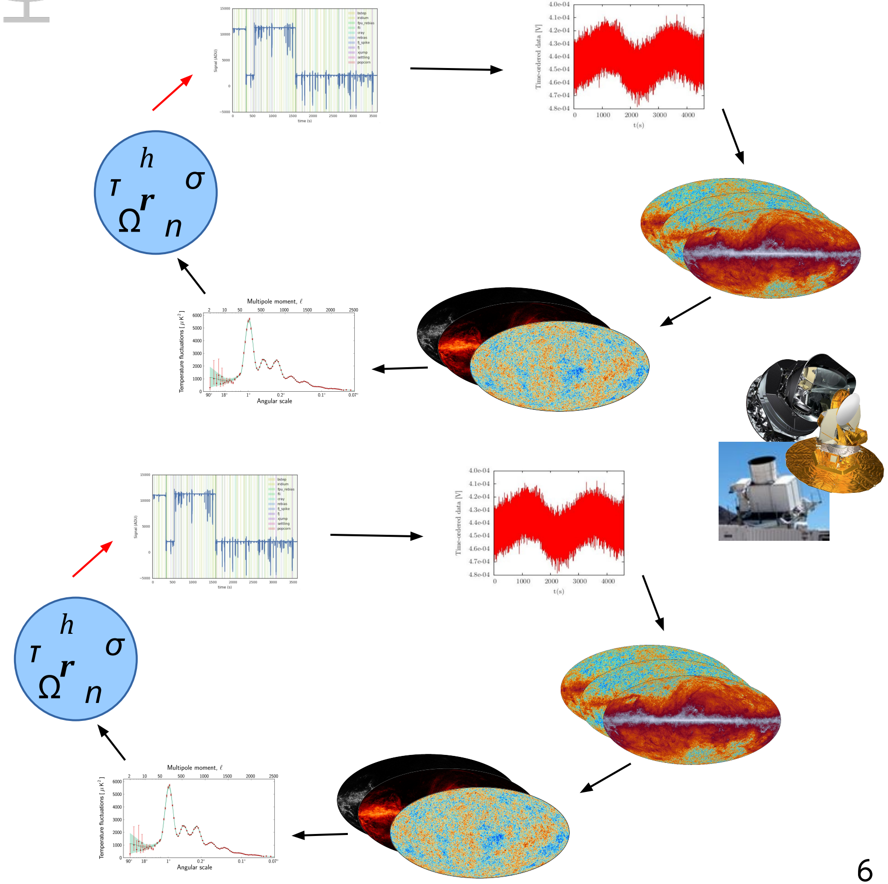
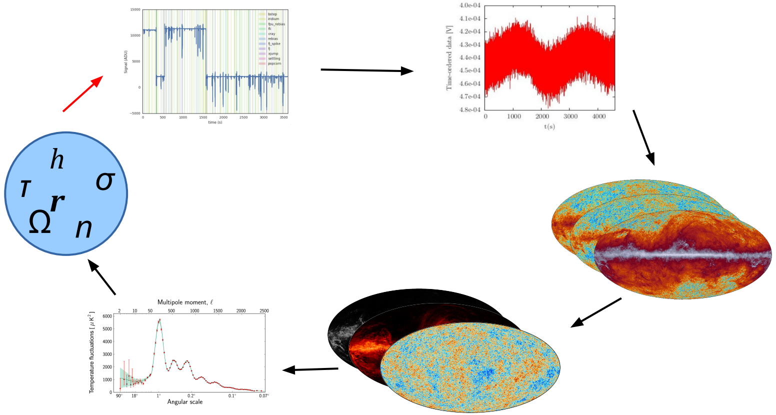
Classic linear CMB analysis pipelines

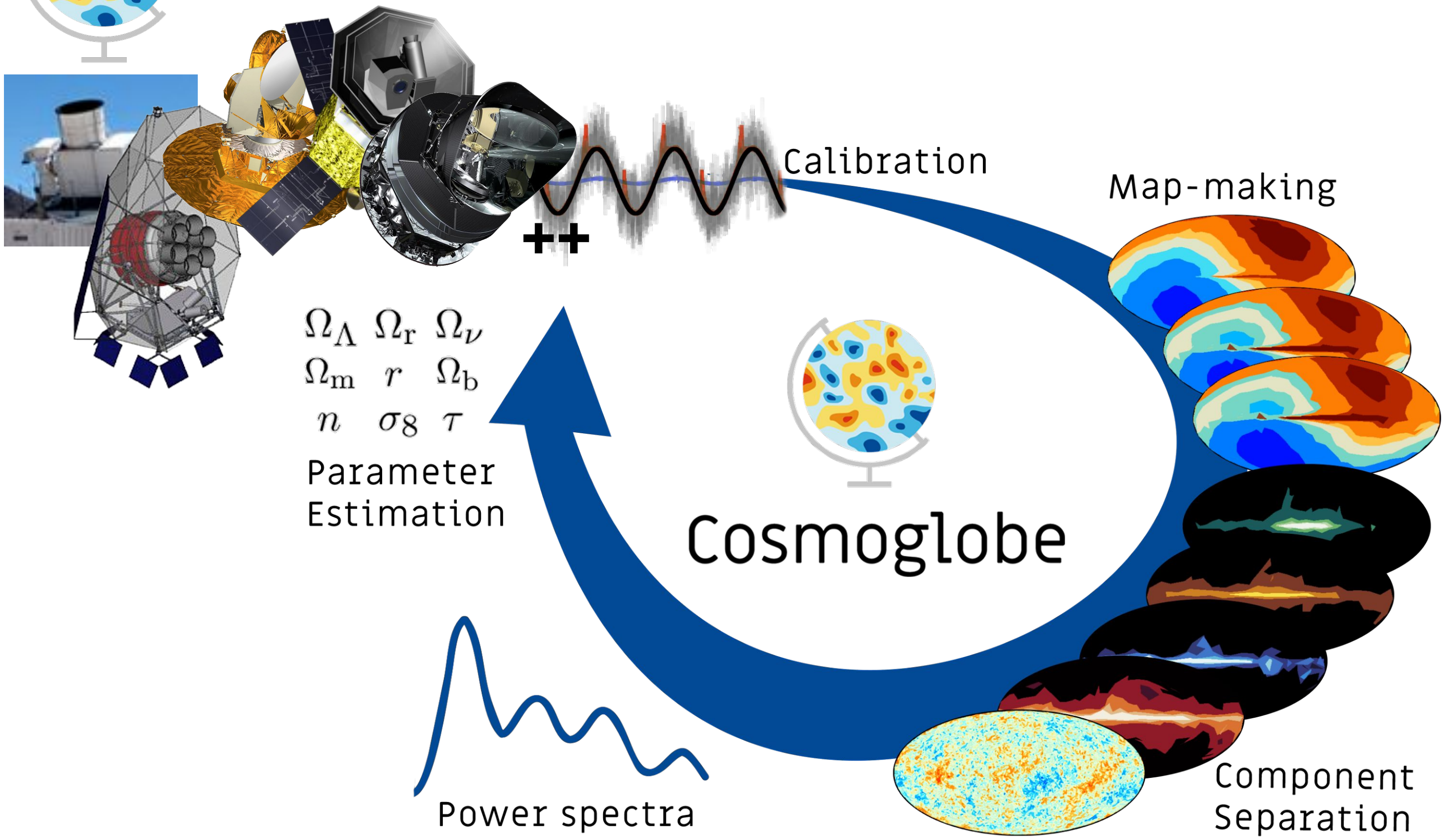




Challenges

- parameter degeneracies
- single-experiment blind spots
- information loss
- resource demanding

Global end-to-end analysis pipeline



Cosmoglobe

-mapping the universe from the Solar system to the Big Bang

- Main idea: **To integrate the world's best data from radio to sub-mm wavelengths into a single model** through **global analysis**

- Global analysis: Joint end-to-end pipeline
  - joint estimation of instrumental, astrophysical and cosmological parameters
  - implemented in the Commander code, developed by Planck and BeyondPlanck

- Global analysis: Joint multi-experiment analysis
  - complementary experiments break each other's degeneracies
  - data can be integrated both in the form of (preferably) time-ordered data and (secondarily) sky maps

- Global analysis: Joint effort from global community
  - open Science philosophy with strong focus on collaboration
  - the Cosmoglobe idea/project/community is input driven and evolving
  - driven by young scientists

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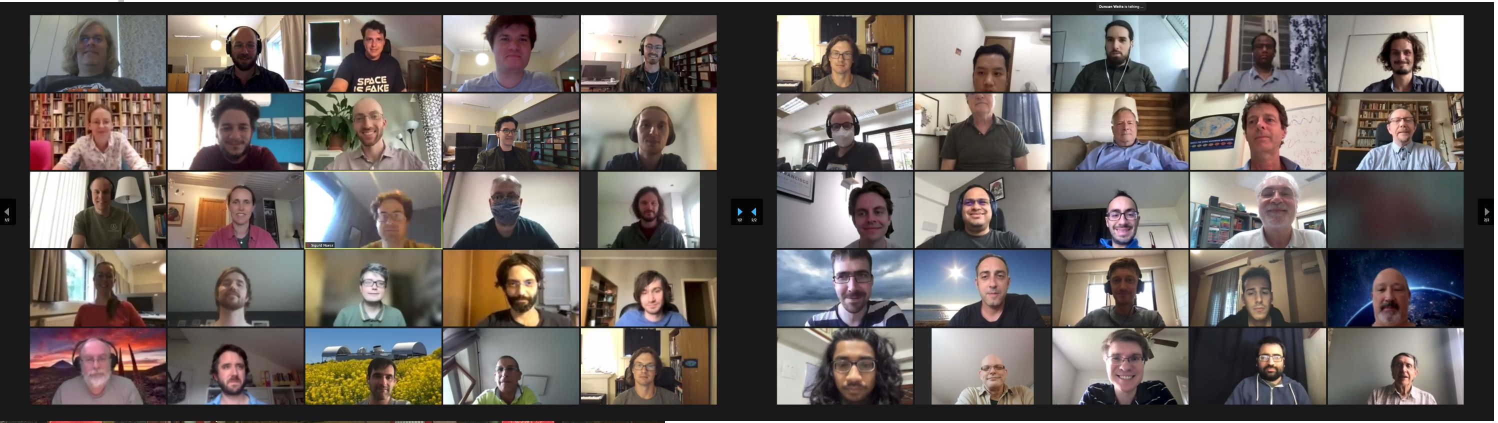
Cosmoglobe global community

cosmoglobe.uio.no



Yearly intensive course and workshops

Please join us :-)

Cosmoglobe algorithm in one slide

1. Write down an explicit parametric model for the observed data:

$$d_{j,t} = g_{j,t}\mathsf{P}_{tp,j}\left[\mathsf{B}^{\mathrm{symm}}_{pp',j}\sum_{c}\mathsf{M}_{cj}(\beta_{p'},\Delta^{j}_{\mathrm{bp}})a^{c}_{p'} + \mathsf{B}^{\mathrm{asymm}}_{j,t}\left(\boldsymbol{s}^{\mathrm{orb}}_{j} + \boldsymbol{s}^{\mathrm{fsl}}_{t}\right)\right] + n^{\mathrm{corr}}_{j,t} + n^{\mathrm{w}}_{j,t}.$$

Let ω = {all free parameters}

2. Derive the joint posterior distribution with Bayes' theorem:

$$P(\omega \mid \boldsymbol{d}) = \frac{P(\boldsymbol{d} \mid \omega)P(\omega)}{P(\boldsymbol{d})} \propto \mathcal{L}(\omega)P(\omega),$$

3. Map out $P(\omega \mid \boldsymbol{d})$ with standard Markov Chain Monte Carlo (MCMC) methods, in particular Gibbs sampling

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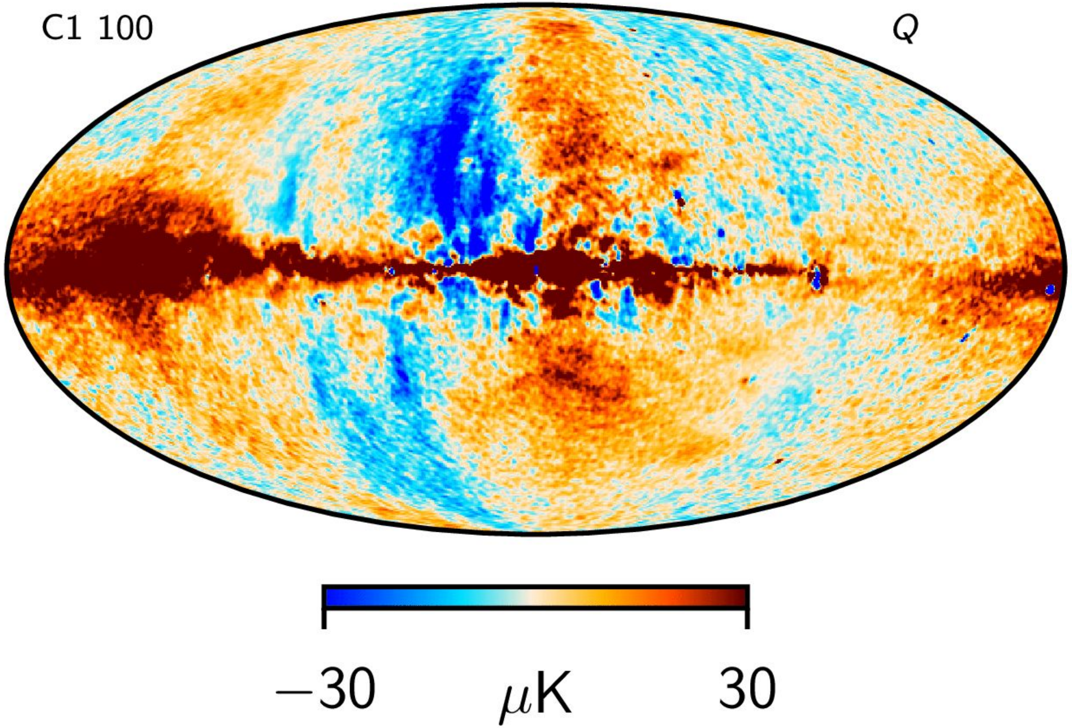
Global analysis proof of concept:

BeyondPlanck - reanalysis of Planck LFI data

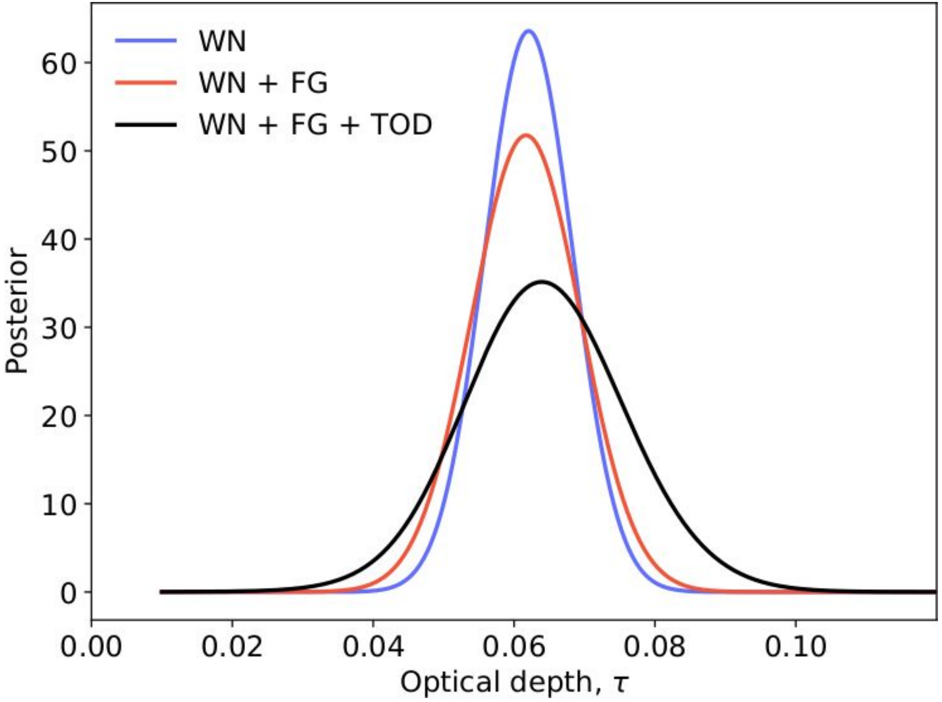
Joint analysis of Planck LFI (tod) + 353/857 + WMAP Ka-V + Haslam (maps)



BeyondPlanck (2023)

Global analysis impact on cosmological parameters

BeyondPlanck

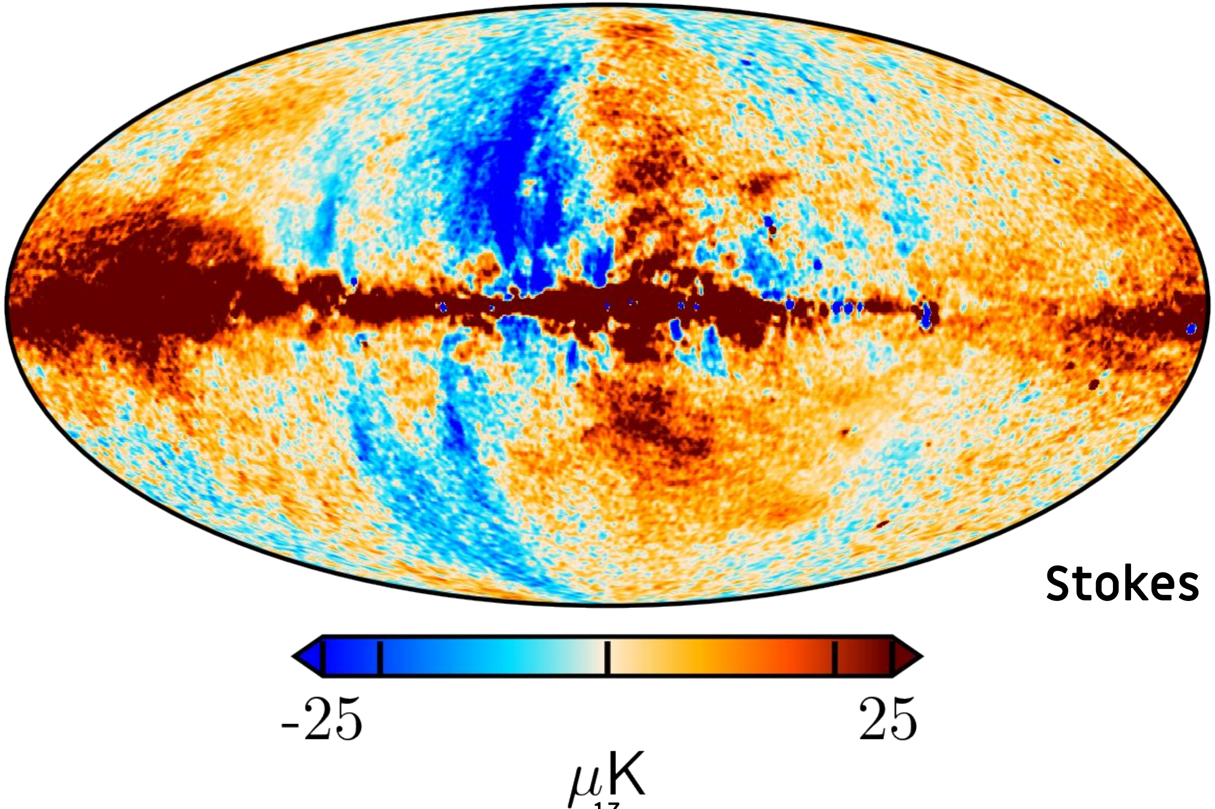


End-to-end global analysis generally yields:

- larger *and more accurate* uncertainties
- lower systematic uncertainties

BeyondPlanck - map results

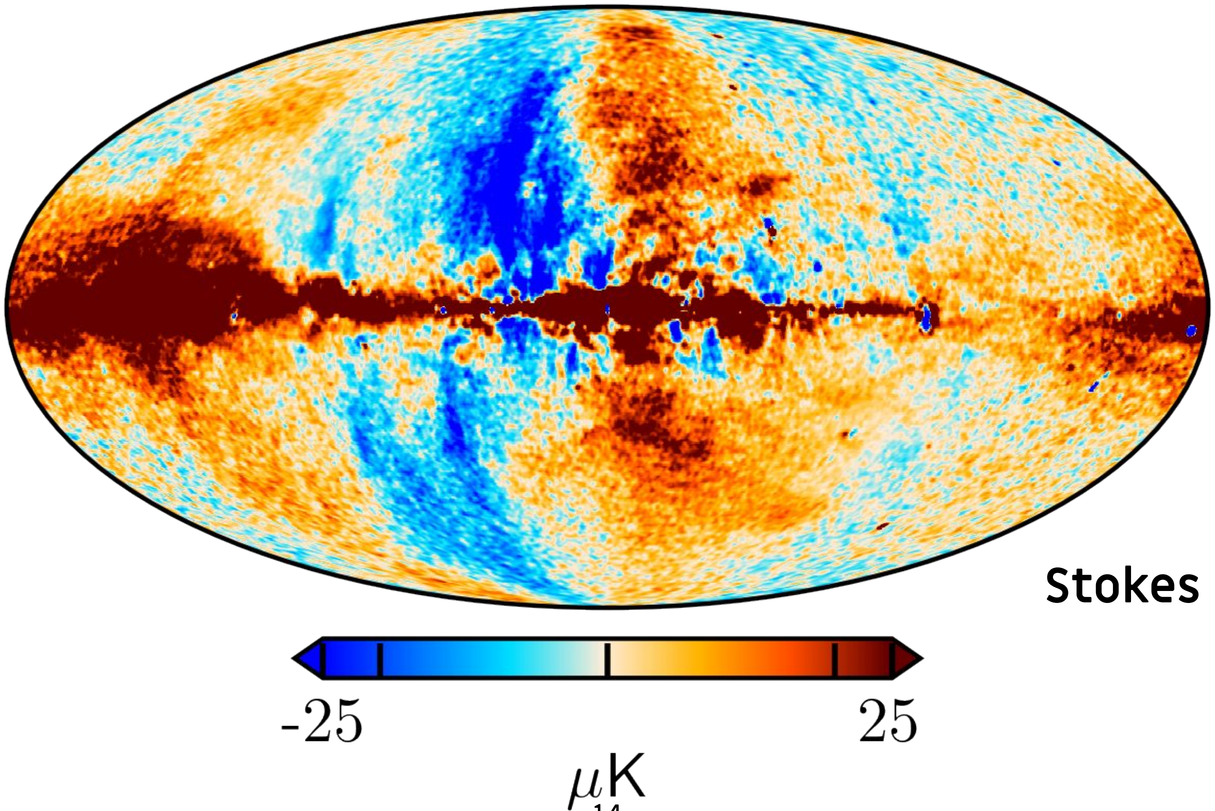
30 GHz Planck legacy map



Stokes Q

BeyondPlanck - map results

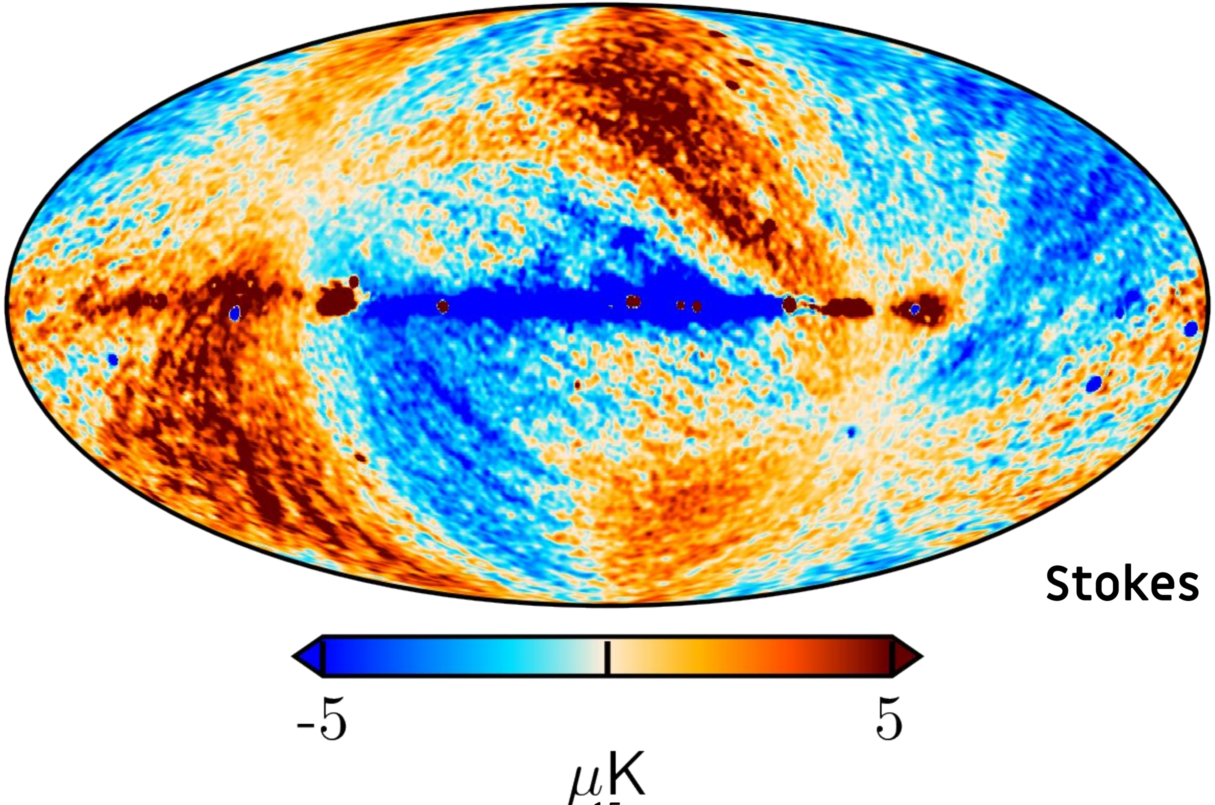
30 GHz BeyondPlanck map



Stokes Q

BeyondPlanck - map results

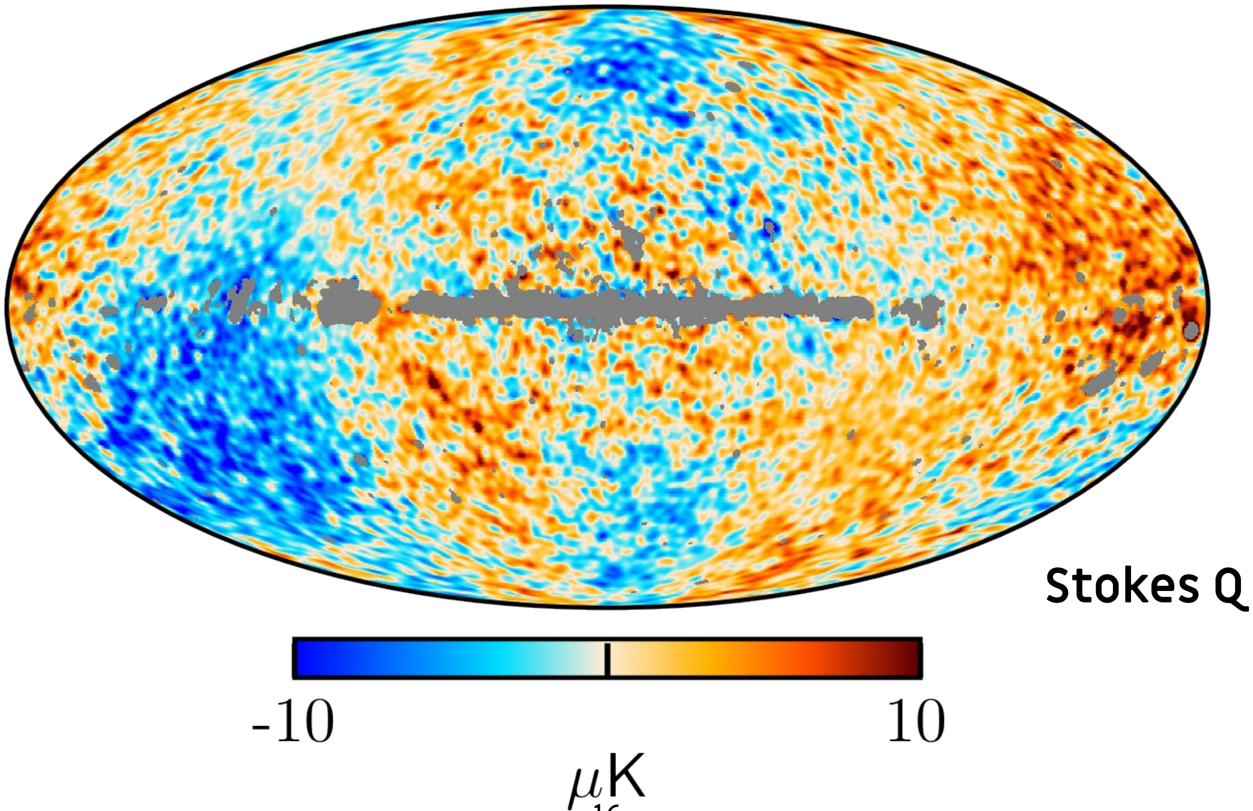
Planck 30 GHz difference map (BeyondPlanck - Planck legacy)



Stokes Q

0.495 * WMAP 23 GHz - 30 GHz Planck consistency

WMAP 9-year - Planck legacy



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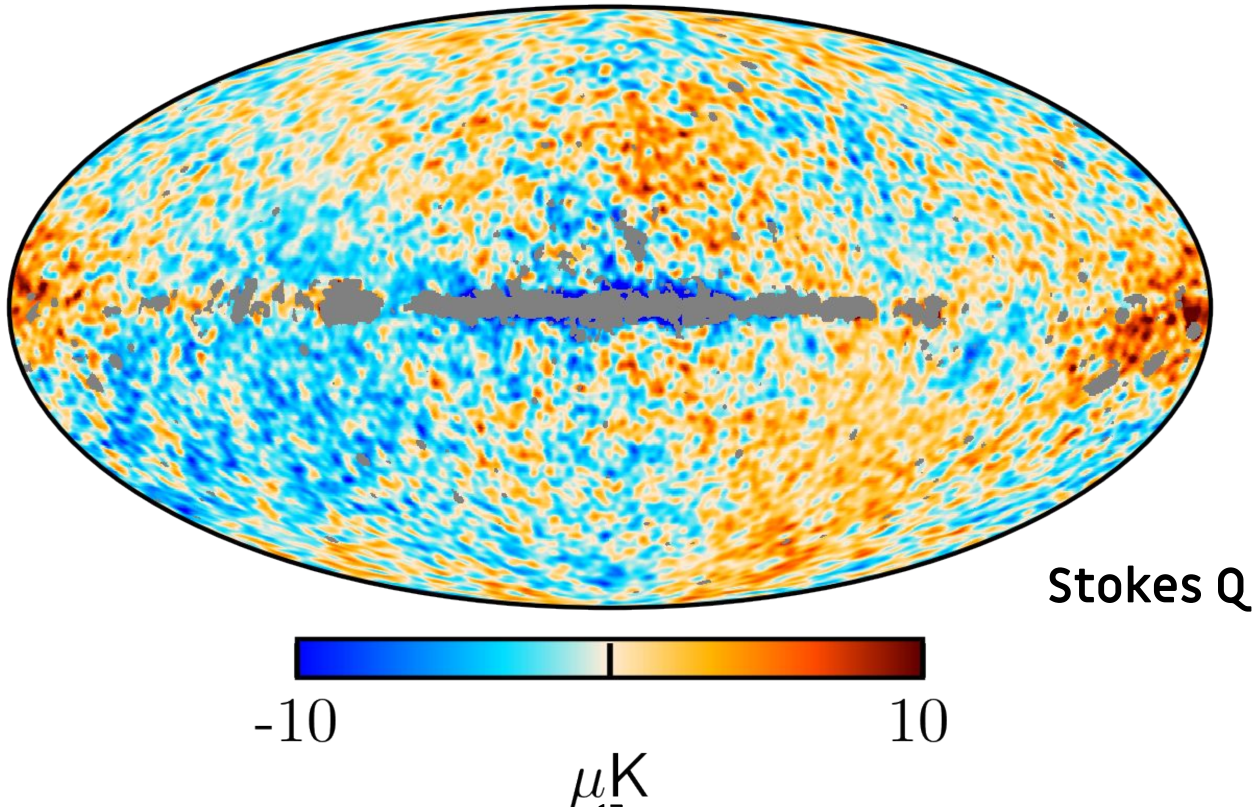
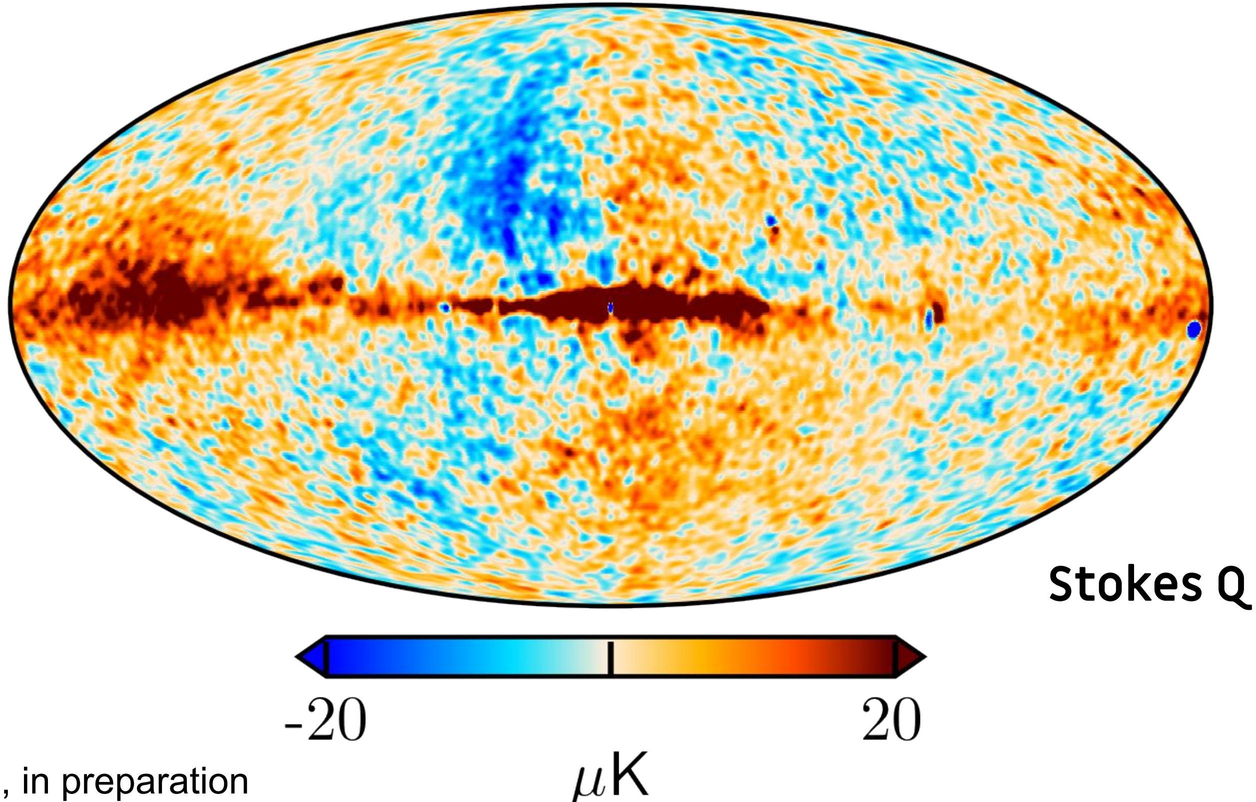
WMAP 9-year - BeyondPlanck



Cosmoglobe - WMAP reanalysis

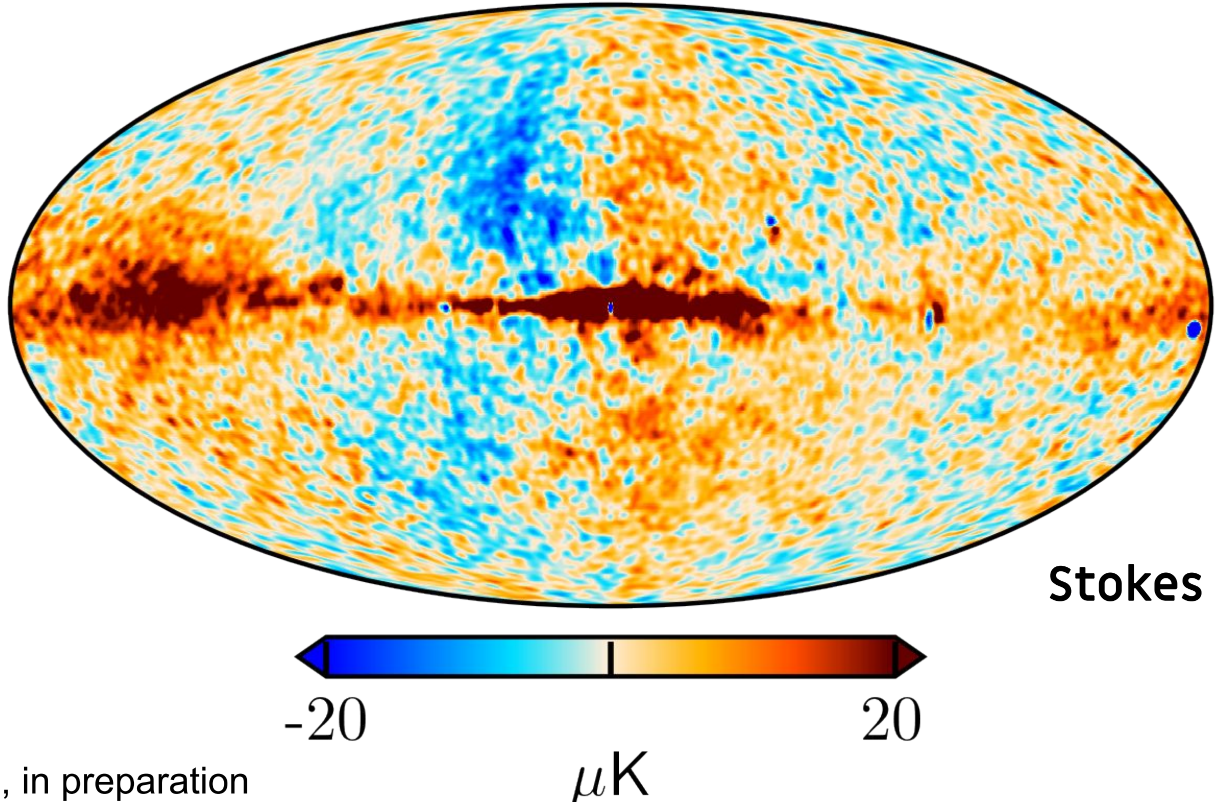
Q-band (41 GHz) 9-year WMAP



Watts et al. (2023), in preparation

Cosmoglobe - WMAP reanalysis

Q-band (41 GHz) Cosmoglobe WMAP

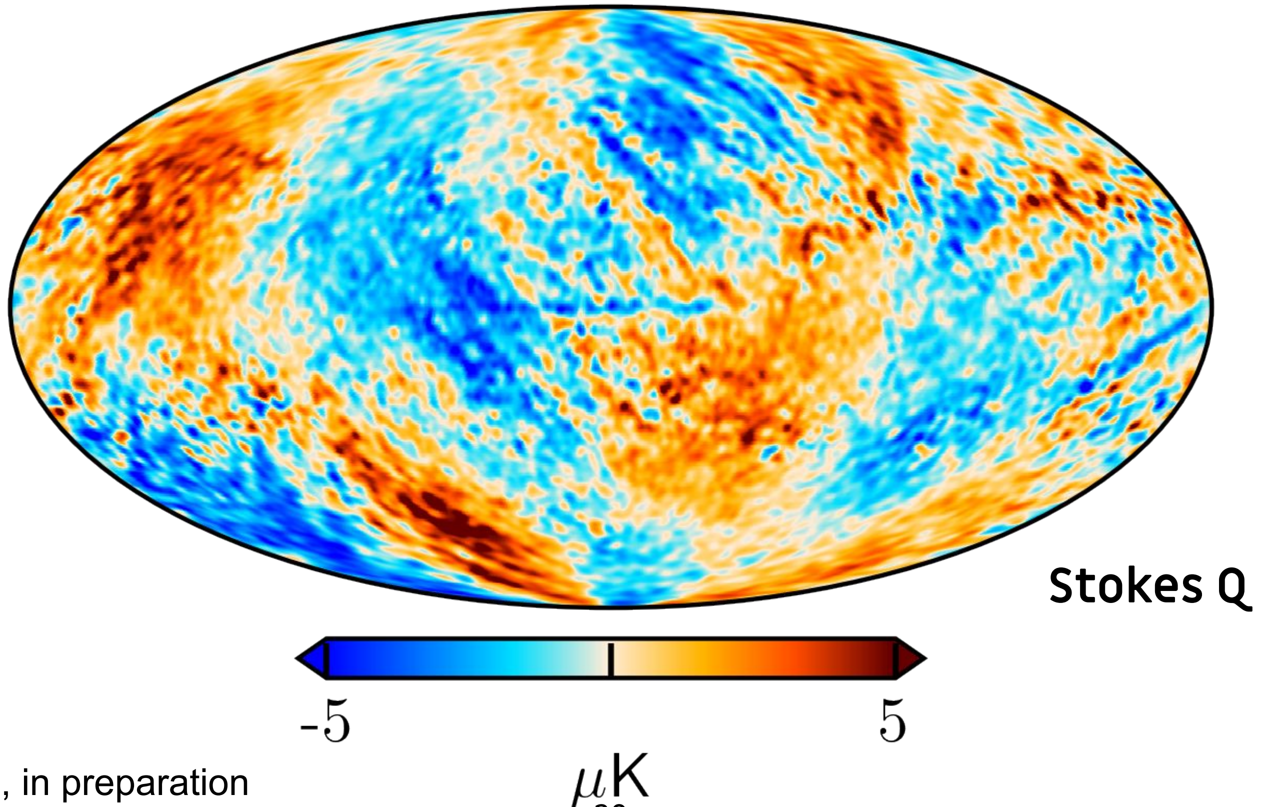


Stokes Q

Watts et al. (2023), in preparation

Cosmoglobe - WMAP reanalysis

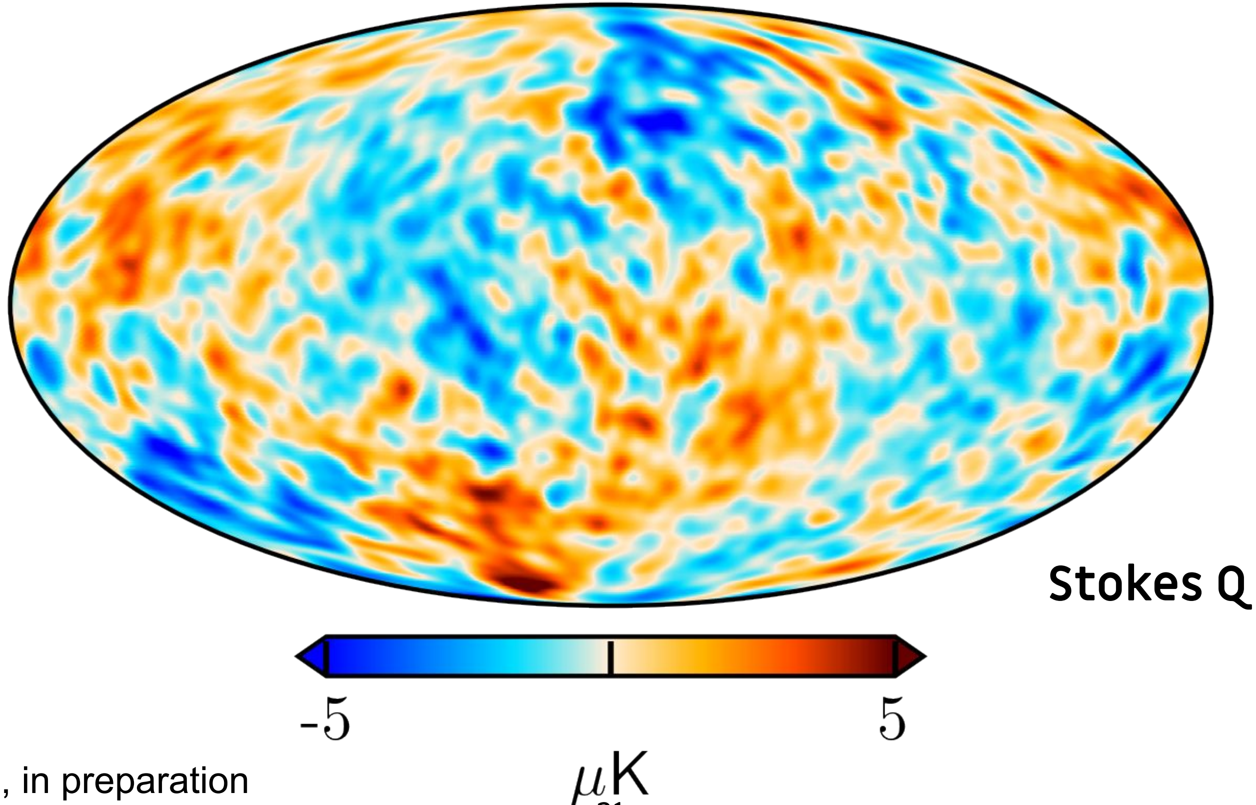
WMAP Q-band difference map (Cosmoglobe - 9-year)



Watts et al. (2023), in preparation

Cosmoglobe - WMAP reanalysis

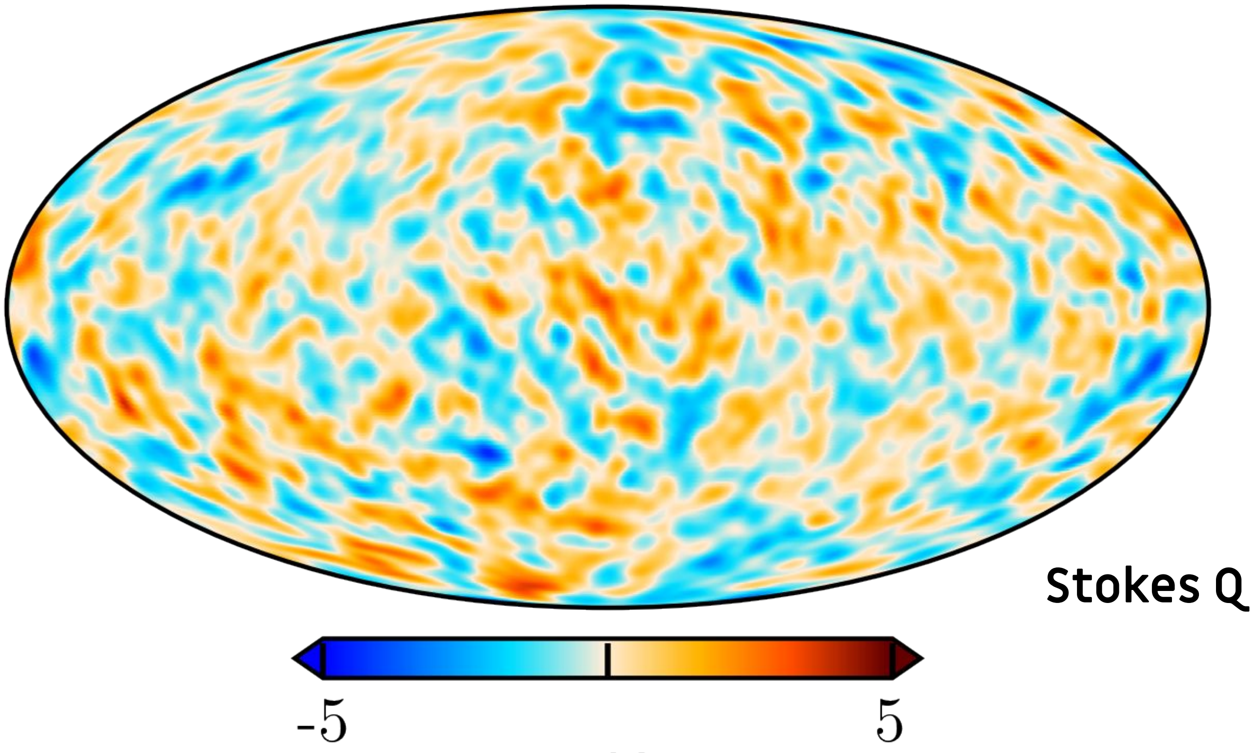
WMAP Q-band internal detector (Q1-Q2)/2 difference map: 9-year



Watts et al. (2023), in preparation

Cosmoglobe - WMAP reanalysis

WMAP Q-band internal detector (Q1-Q2)/2 difference map: Cosmoglobe



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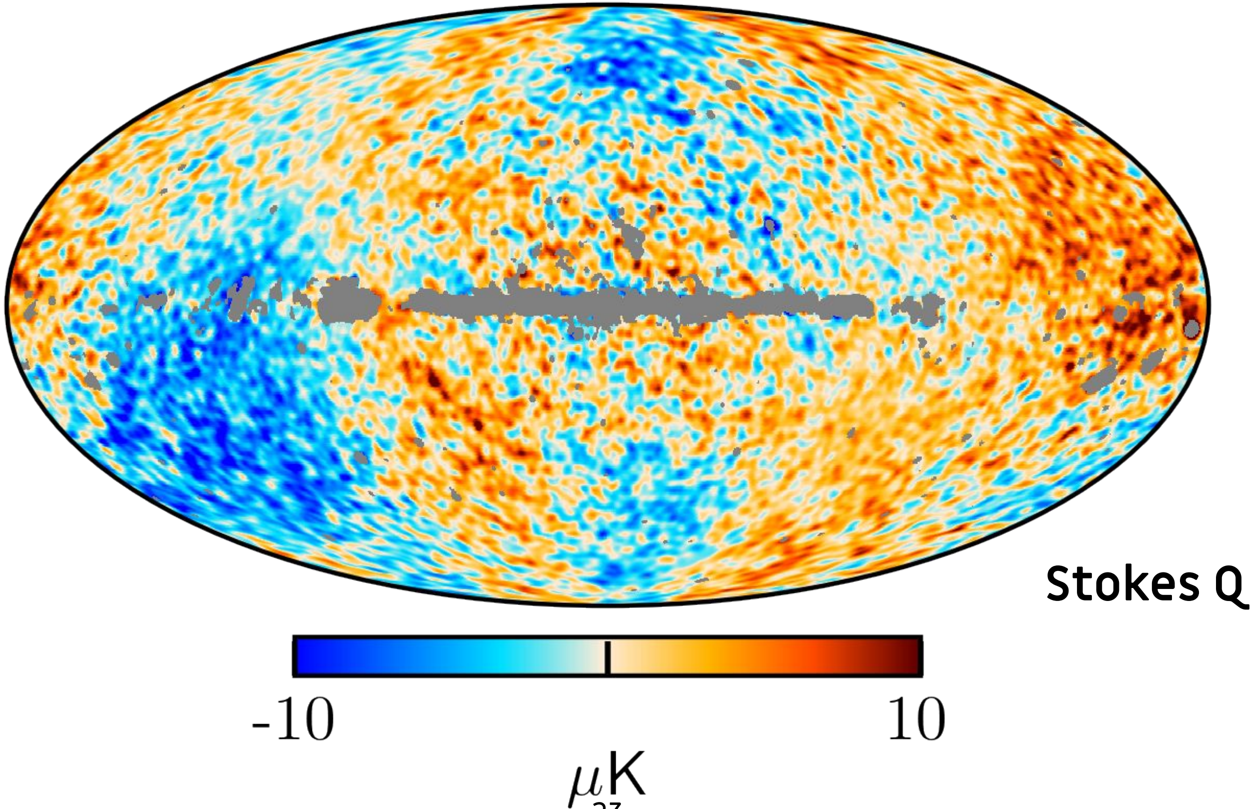
WMAP 9-year - Planck legacy



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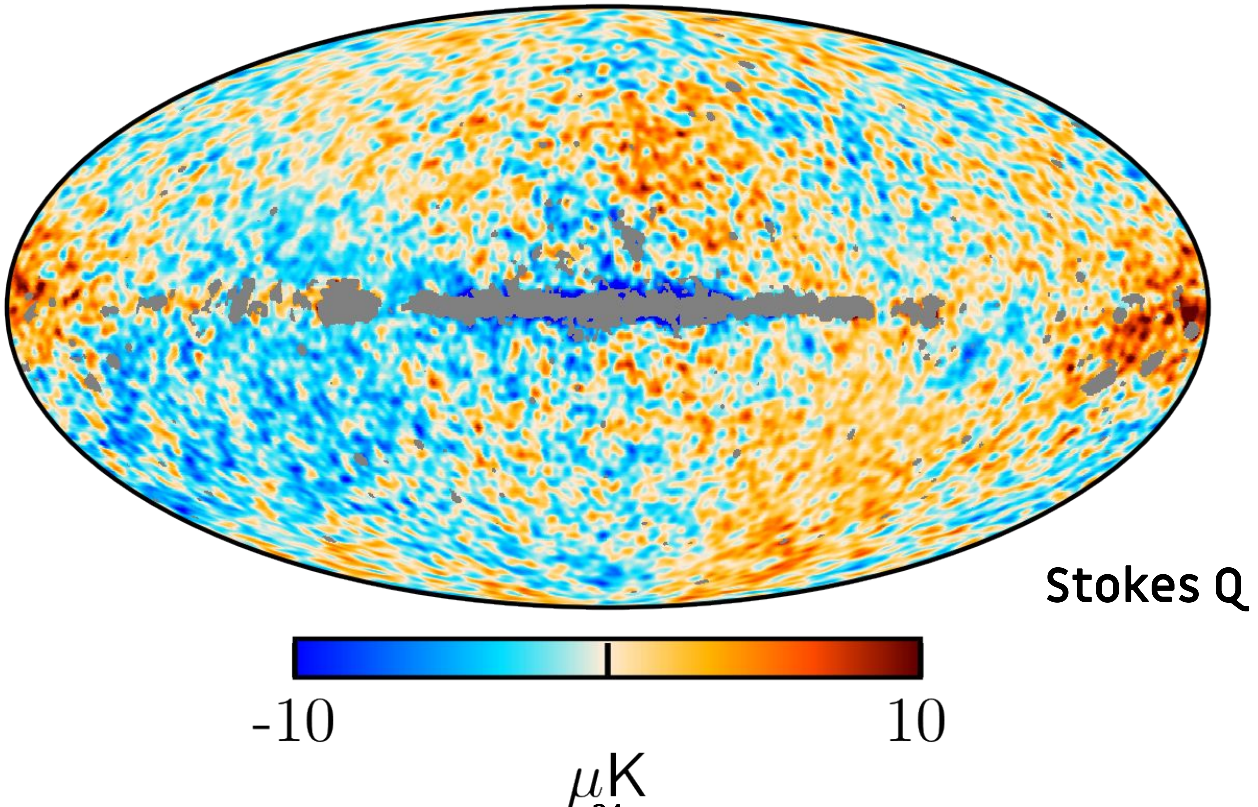
WMAP 9-year - BeyondPlanck



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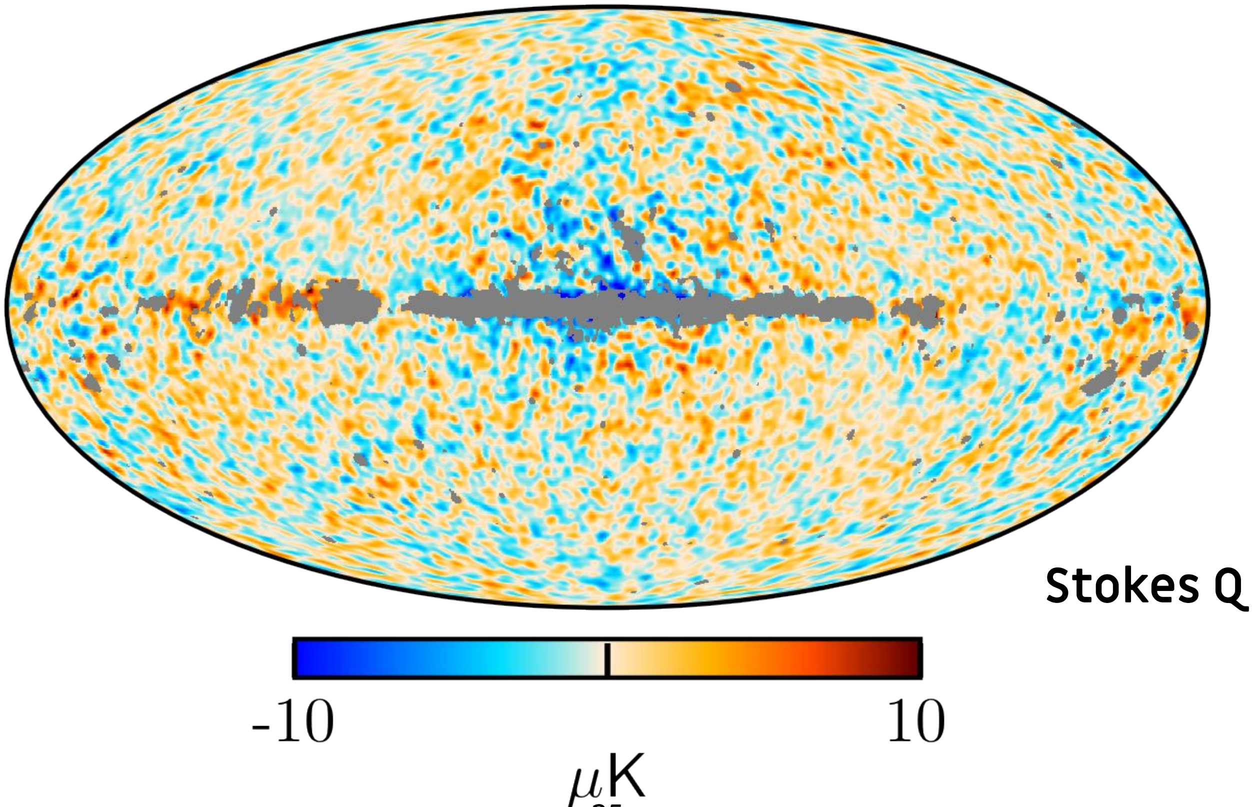
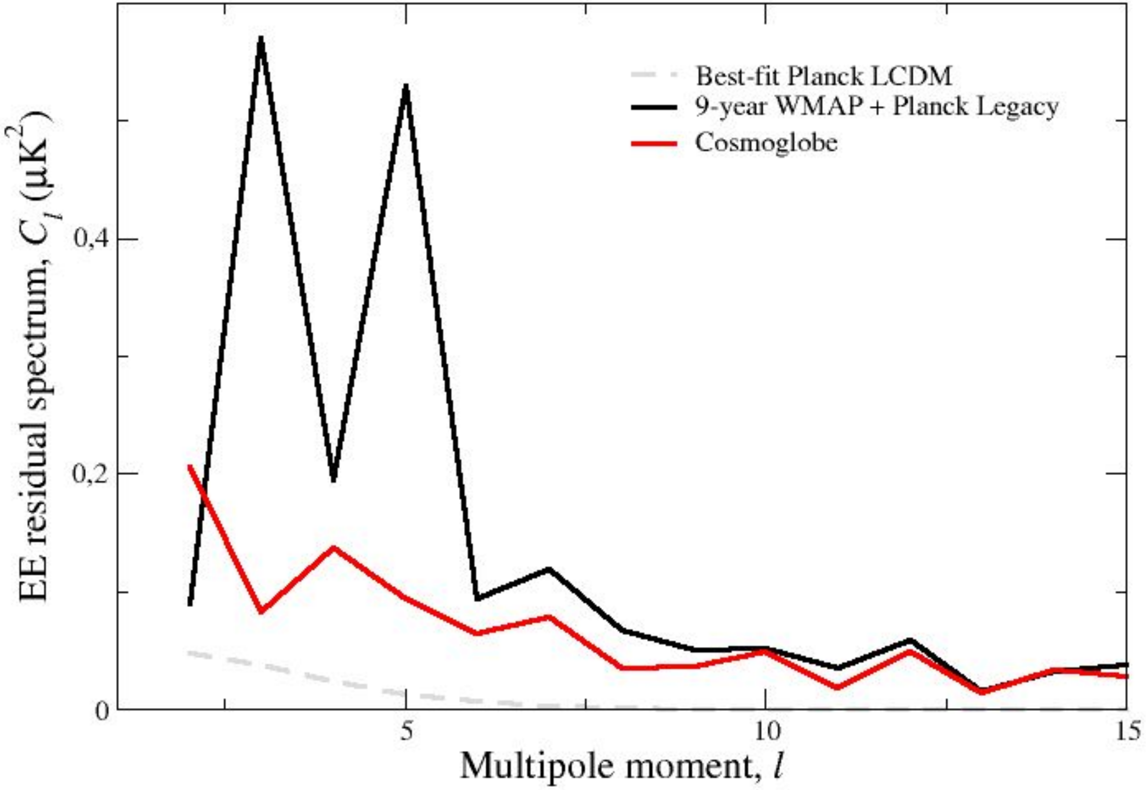
Cosmoglobe WMAP - Cosmoglobe LFI



WMAP 23 GHz - Planck 30 GHz: Difference map spectra



Watts et al. (2023), in preparation

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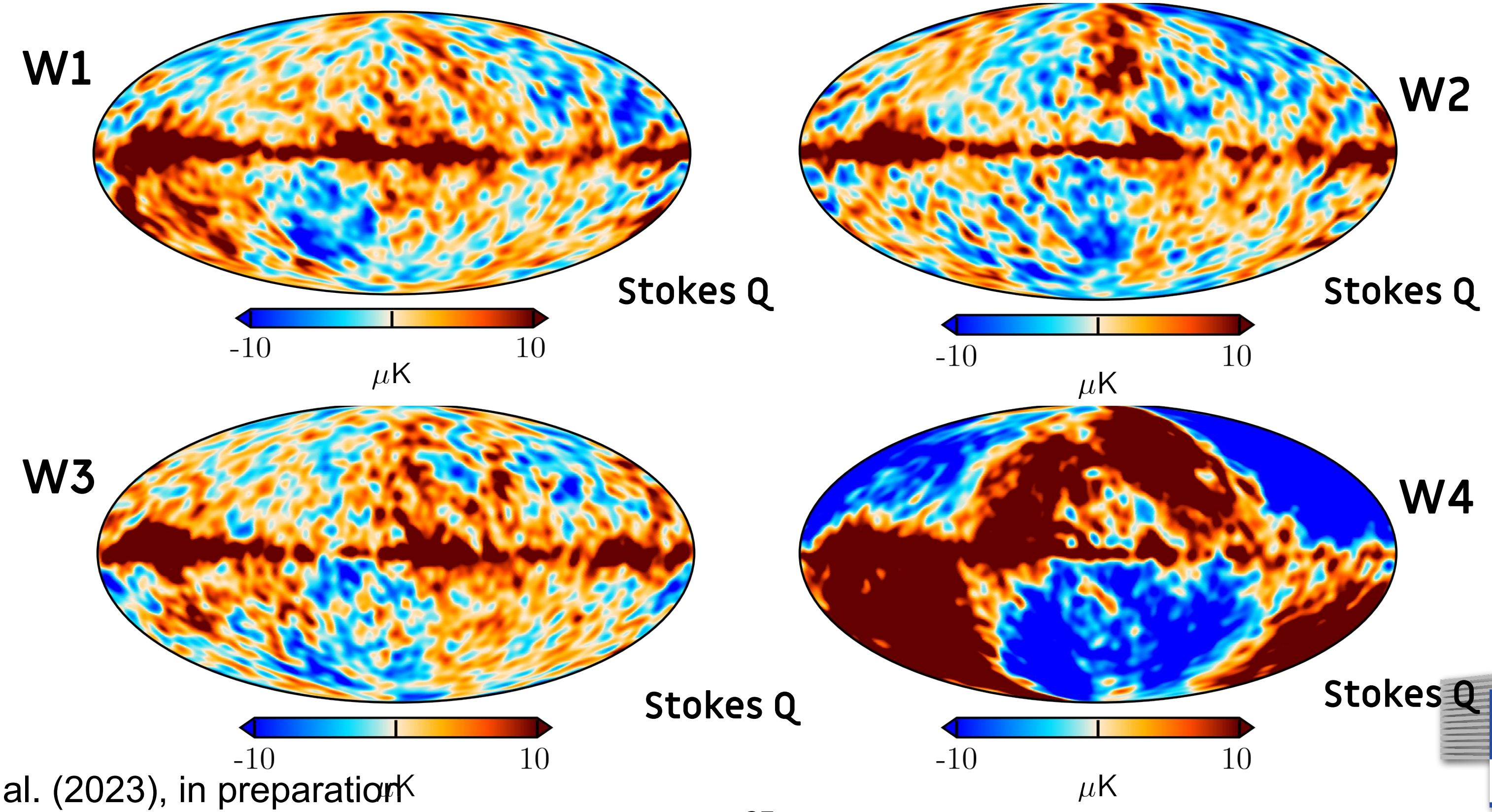
Cosmoglobe - WMAP reanalysis

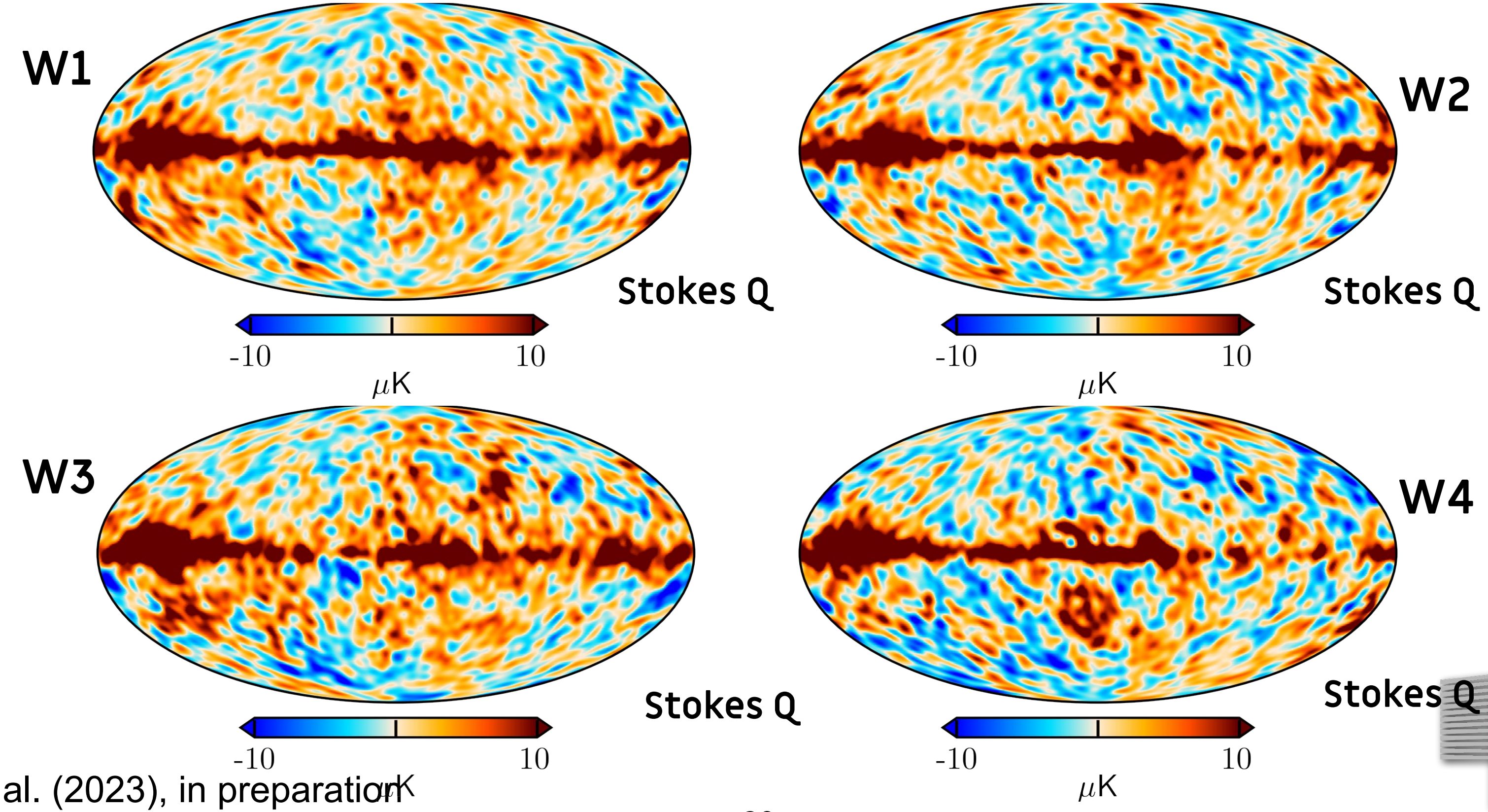
W-band (94 GHz) 9-year WMAP detector maps



Watts et al. (2023), in preparation

Cosmoglobe - WMAP reanalysis

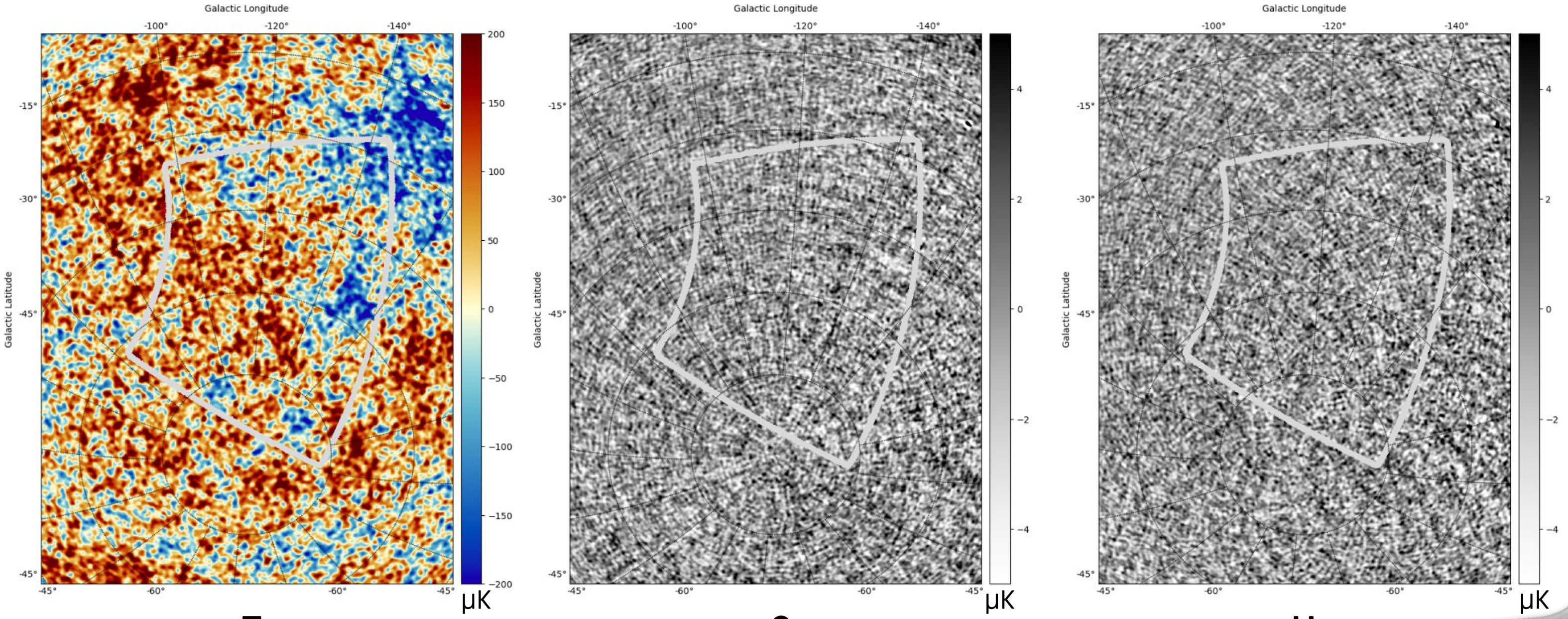
W-band (94 GHz) Cosmoglobe WMAP detector maps



Watts et al. (2023), in preparation

SPIDER – first demonstration of partial sky analysis

Joint Planck + WMAP + Haslam analysis (without SPIDER)

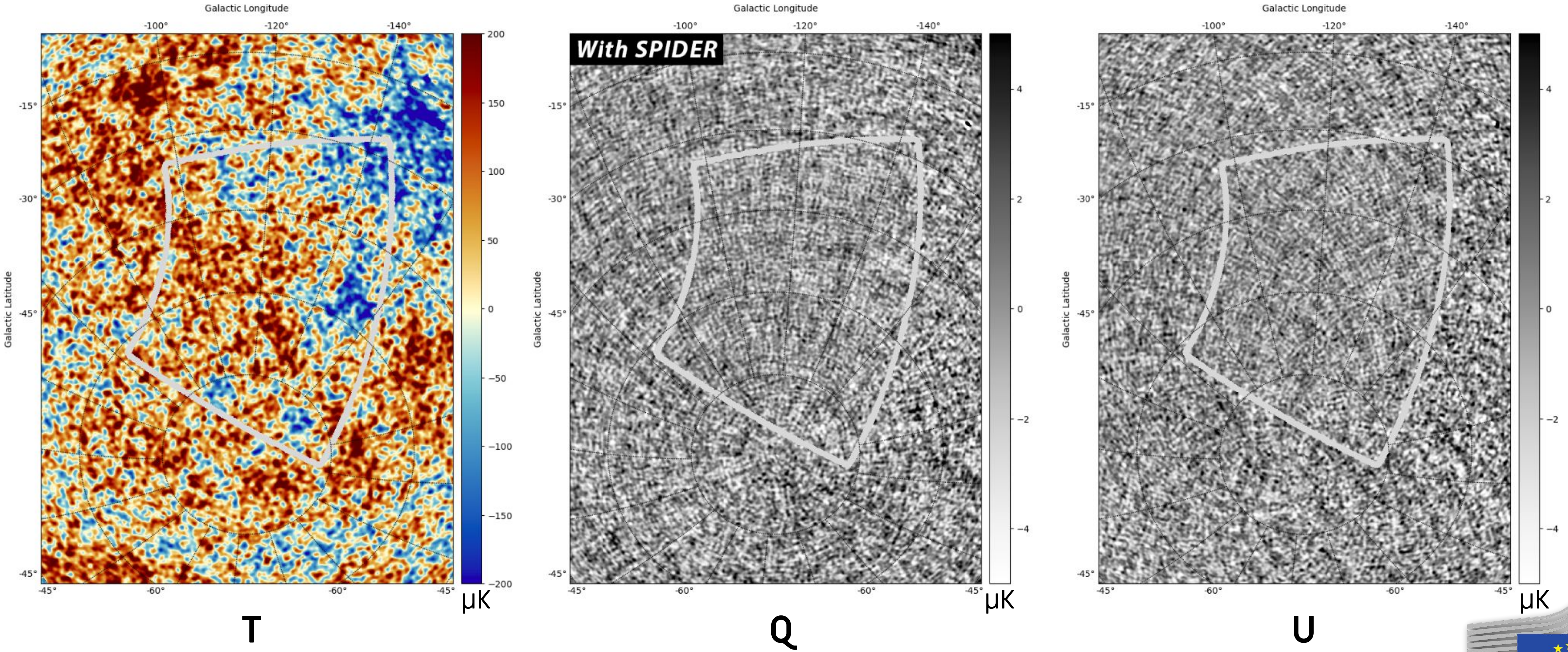


T **Q** **U**

Thommesen et al. (2023), in preparation

SPIDER – first demonstration of partial sky analysis

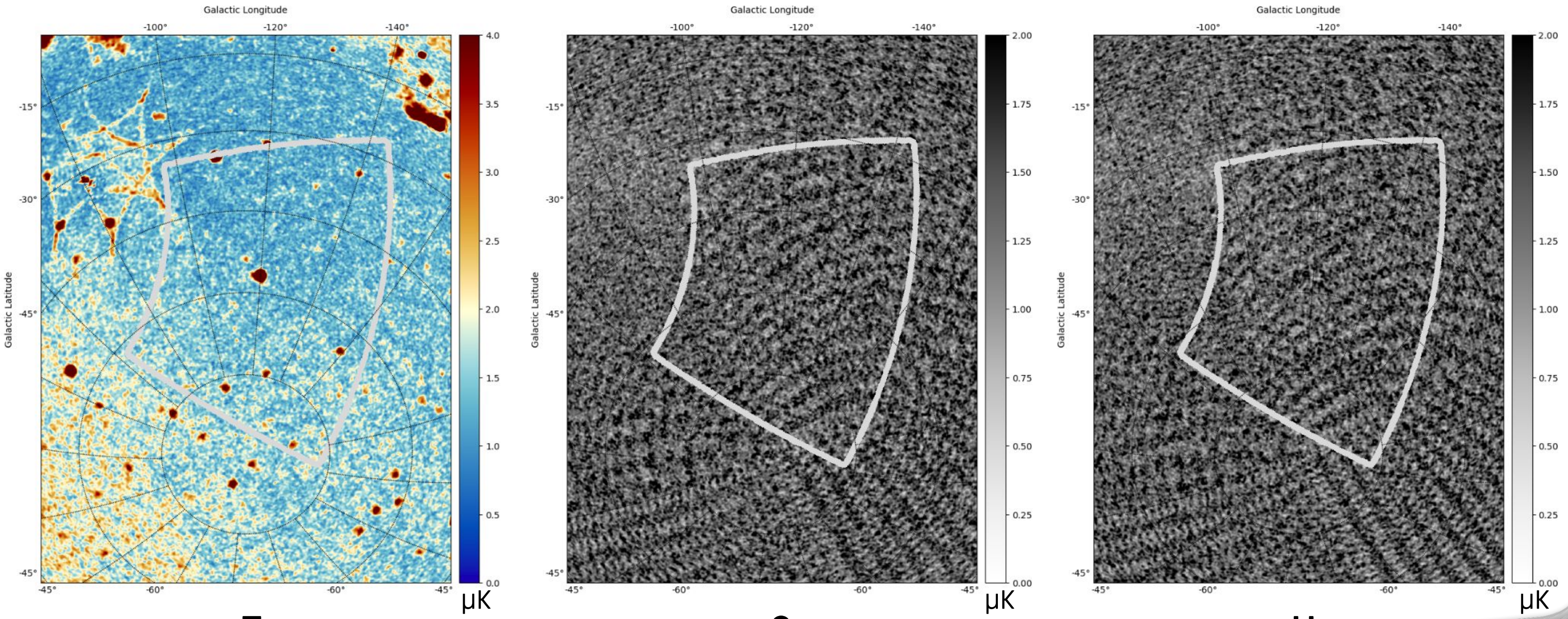
Joint Planck + WMAP + Haslam + SPIDER analysis



Thommesen et al. (2023), in preparation

SPIDER – noise uncertainty per pixel

Joint Planck + WMAP + Haslam analysis (without SPIDER)



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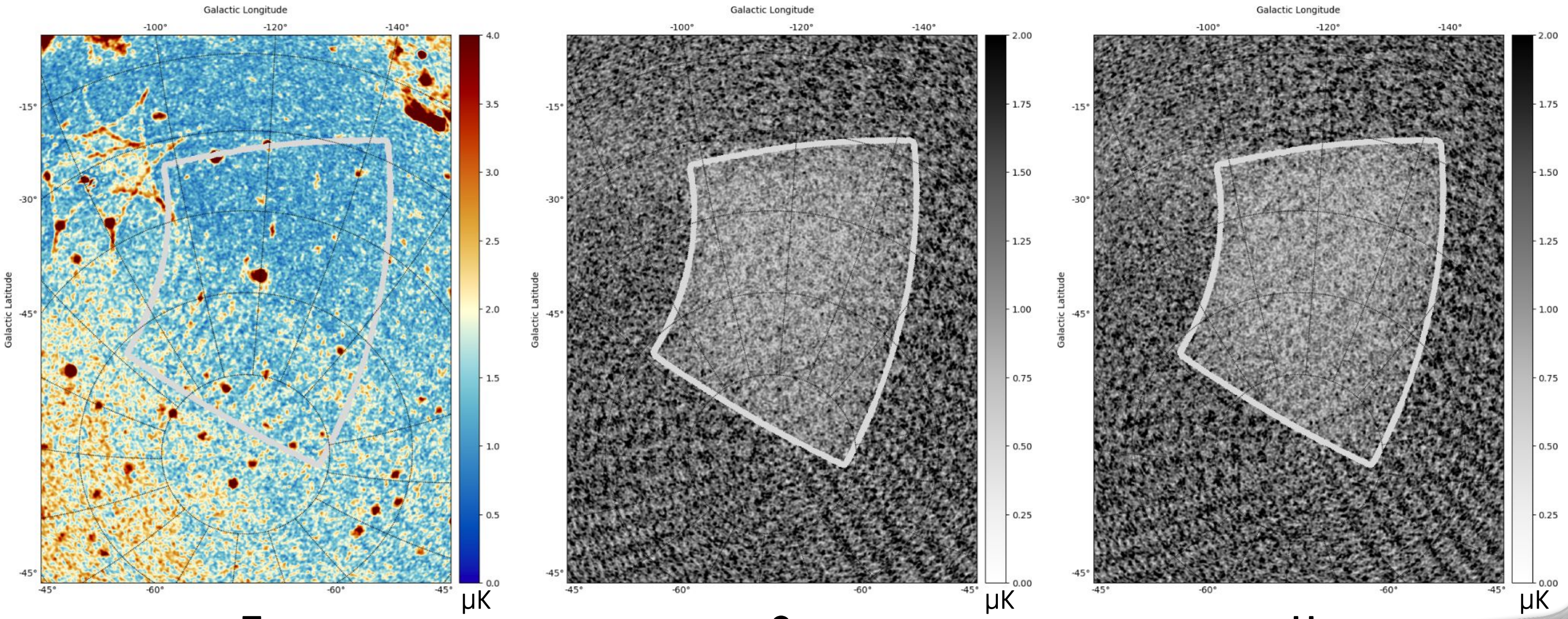
Thommesen et al. (2023), in preparation

SPIDER – noise uncertainty per pixel

Joint Planck + WMAP + Haslam + SPIDER analysis

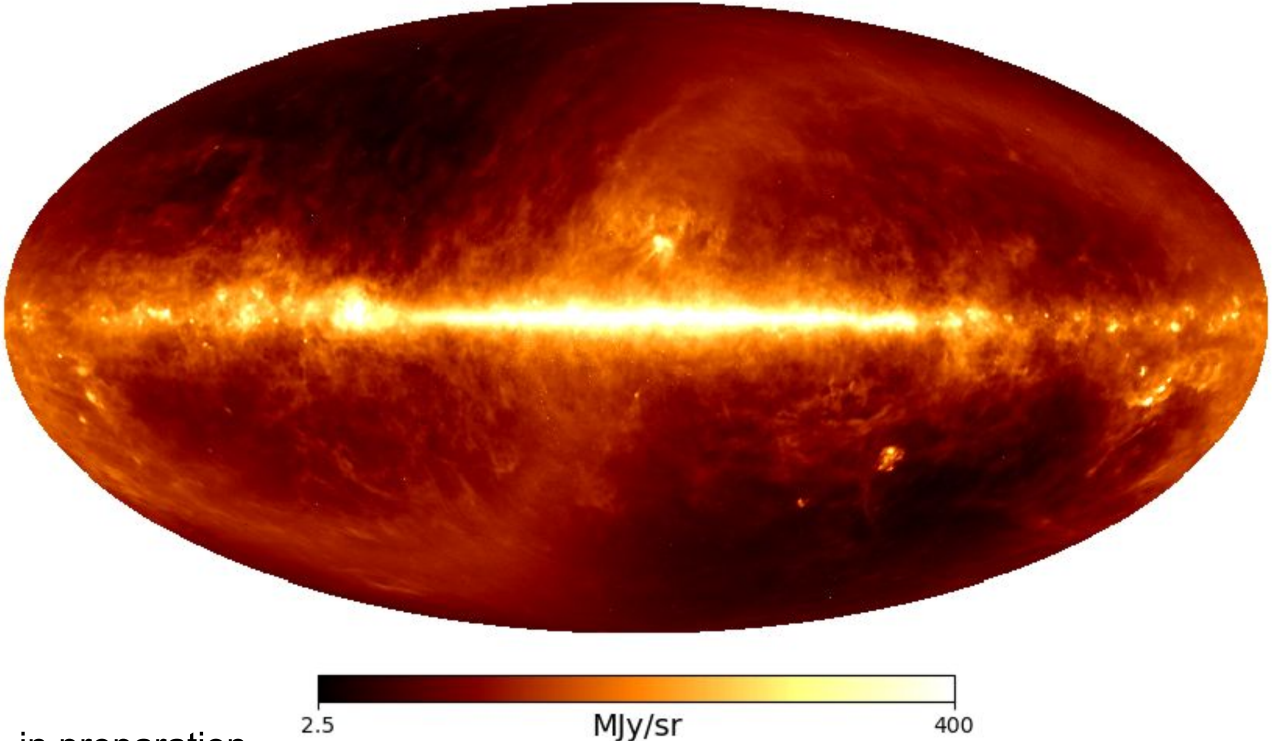


T **Q** **U**

Thommesen et al. (2023), in preparation

DIRBE reanalysis and Zodiacal light modeling

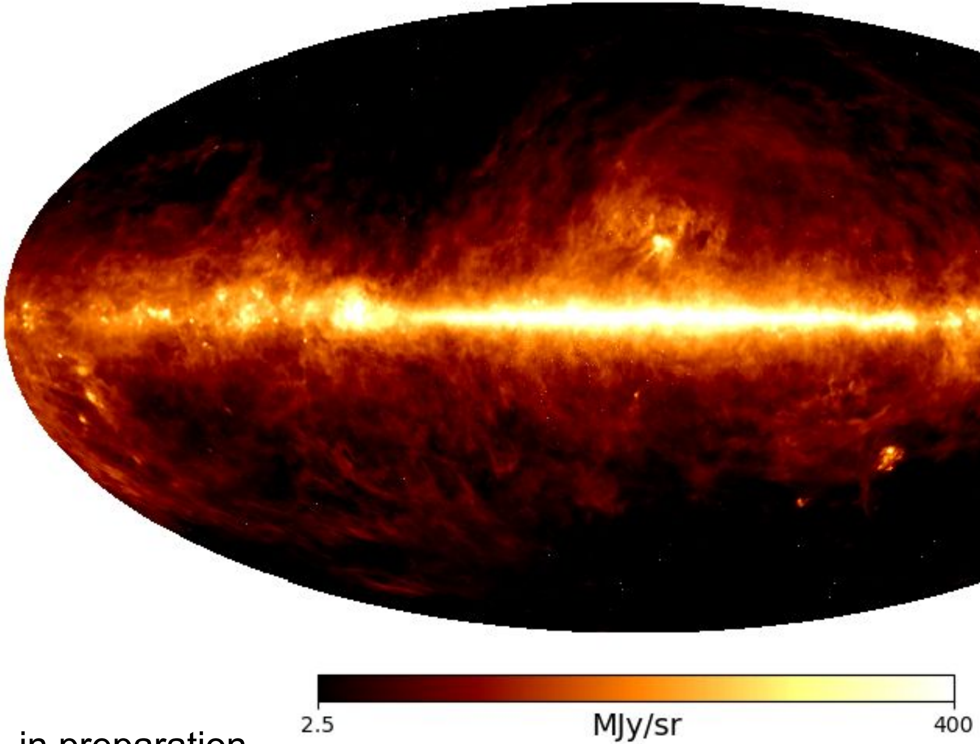
DIRBE 100μm map



San et al. (2023), in preparation

DIRBE reanalysis and Zodiacal light modeling

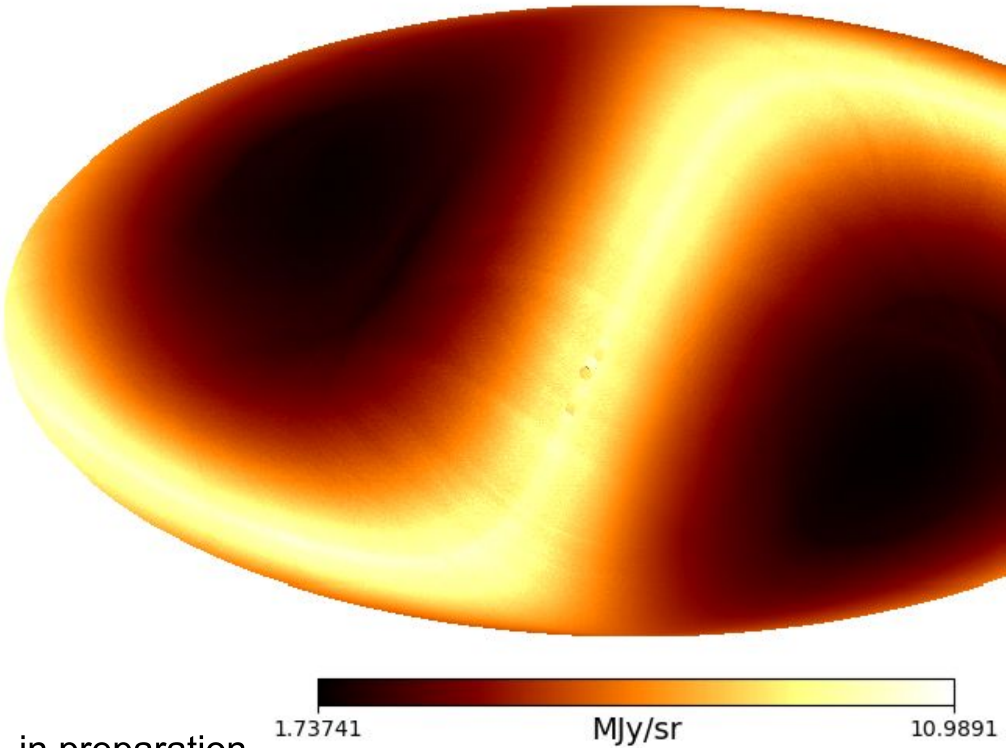
DIRBE 100μm map zodicorrected



San et al. (2023), in preparation

DIRBE reanalysis and Zodiacal light modeling

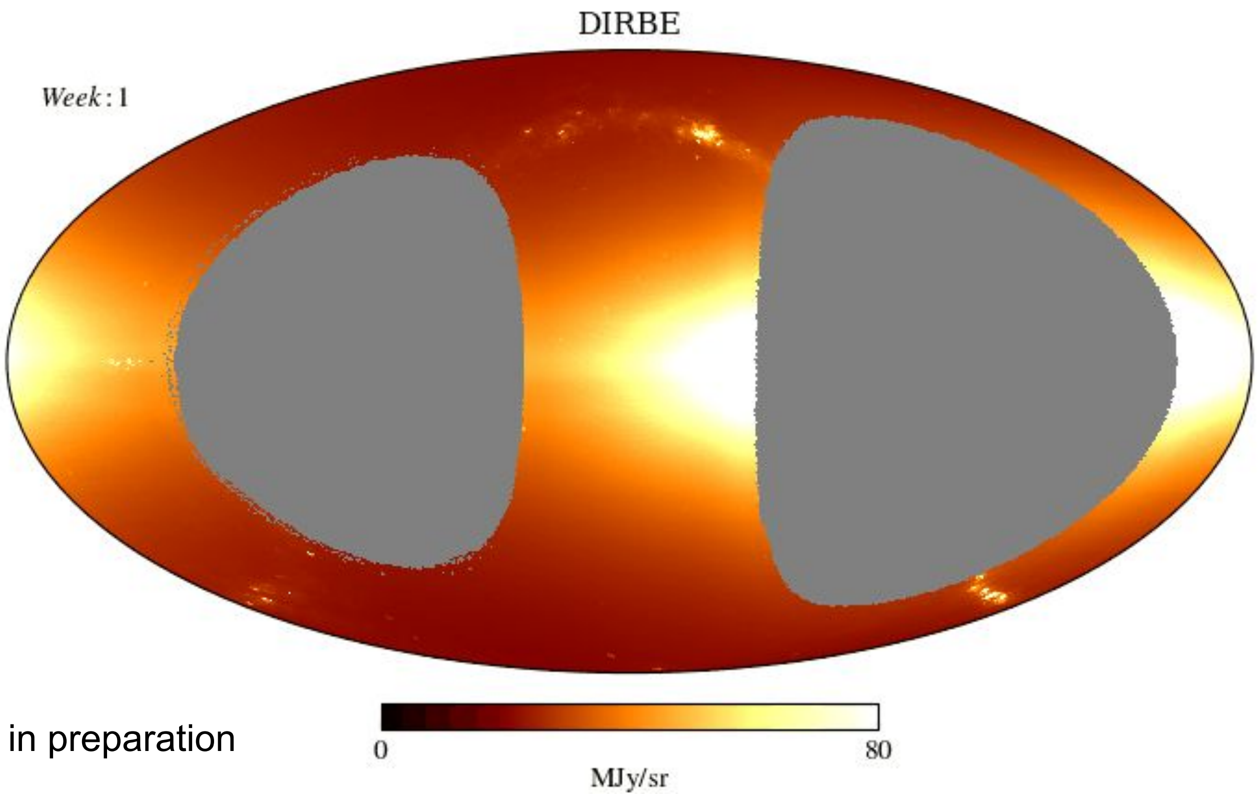
DIRBE 100μm map zodiacal light correction



San et al. (2023), in preparation

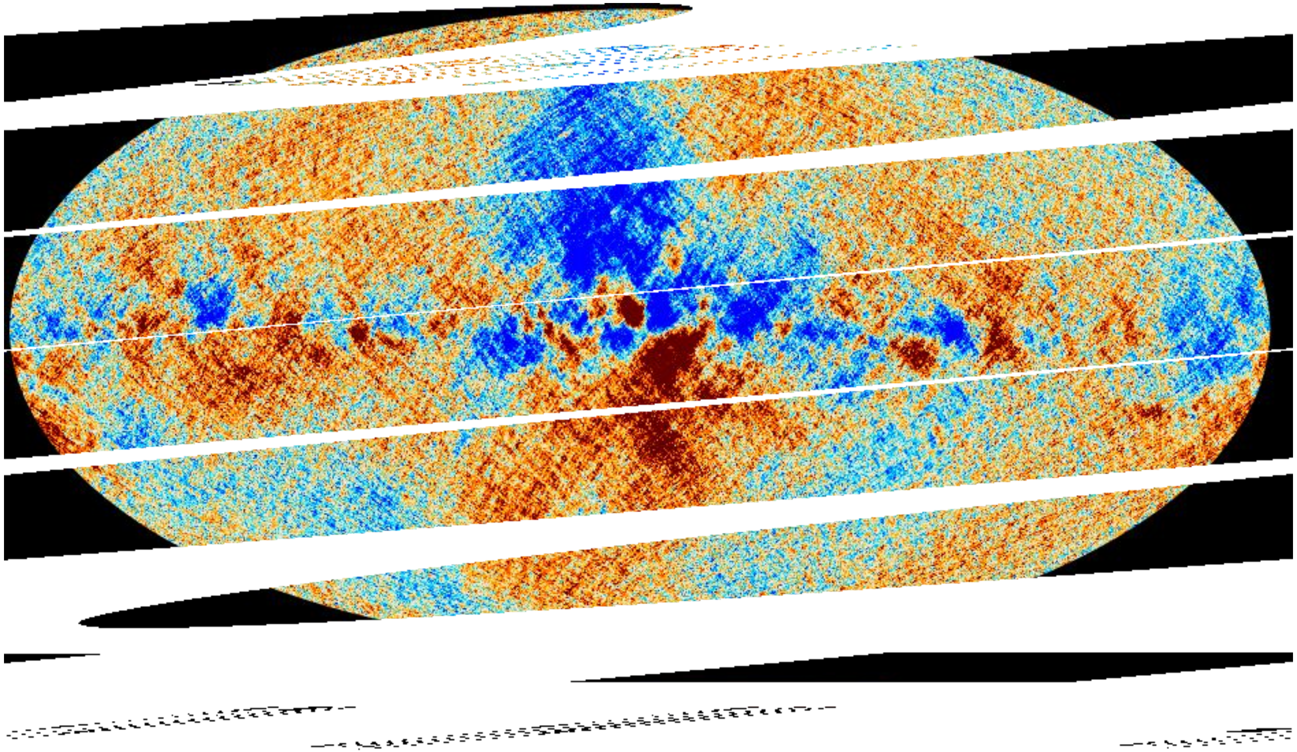
DIRBE reanalysis and Zodiacal light modeling

Dynamical zodiacal light modeling based on weekly DIRBE maps



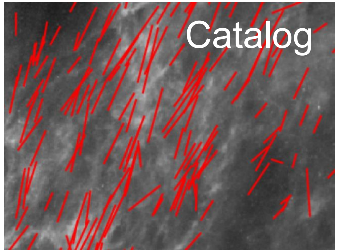
San et al. (2023), in preparation

LiteBIRD simulated TOD analysis

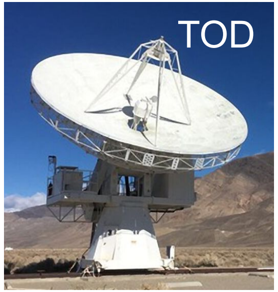


Aurlien et al. (2023), in preparation

On-going (but early days) efforts



PASIPHAE
Optical 3D starlight polarization



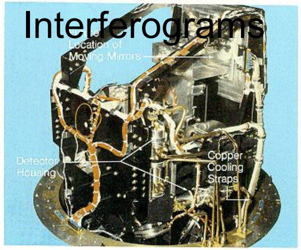
COMAP
High-res 26-34 GHz spectrometer

CHIPASS
1.4 GHz survey

QUIJOTE
11-19 GHz polarization

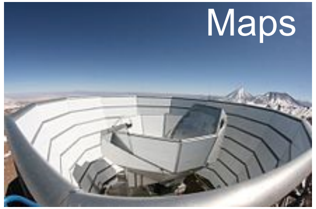
C-BASS
5 GHz all-sky T+P

Planck HFI
100 - 857 GHz



Test unit being prepared for vibration test. Horn, calibrator, and mirror mechanism are not shown.

COBE-FIRAS
Absolute calibration

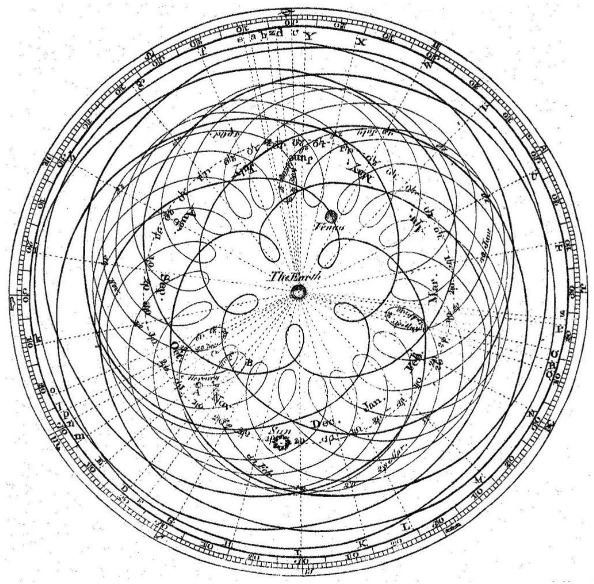


ACT
High-res T+P

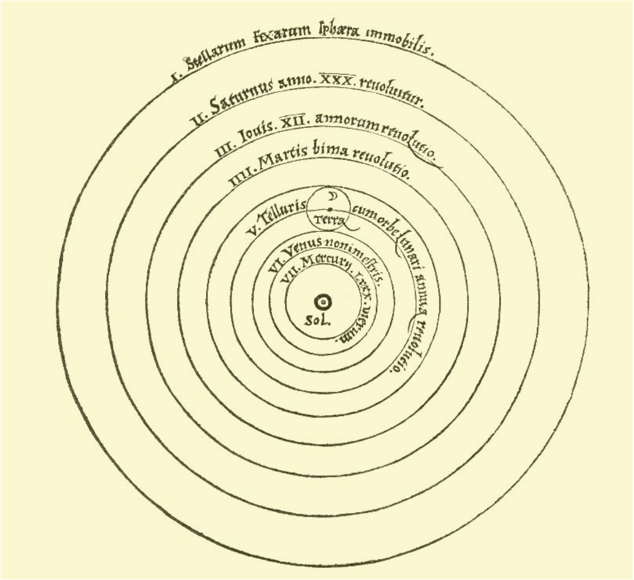
Global analysis summary

- Joint end-to-end analysis needed to constrain correlated parameters
- Joint analysis of independent experiments break each other degeneracies
- Joint analysis give more complete noise characterization
- Single pipeline is fast and effective and require less human interaction

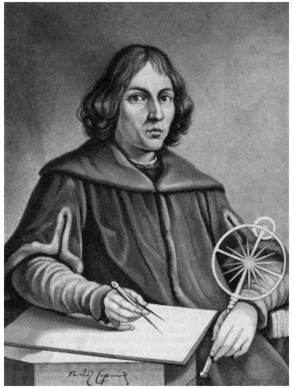
Global modeling makes life simpler



Geocentric universe



Heliocentric universe



Mikołaj
Kopernik

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- Cosmoglobe
  - EU ERC-CoG Grant agreement No. 819478 - PI I. K. Wehus - 2019-2024
- bits2cosmology
  - EU ERC-CoG Grant agreement No. 772253 - PI H. K. Eriksen - 2018-2023
- BeyondPlanck
  - EU COMPET-4 Grant agreement No. 776282 - PI H. K. Eriksen - 2018-2020
- Global Component Separation Network
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