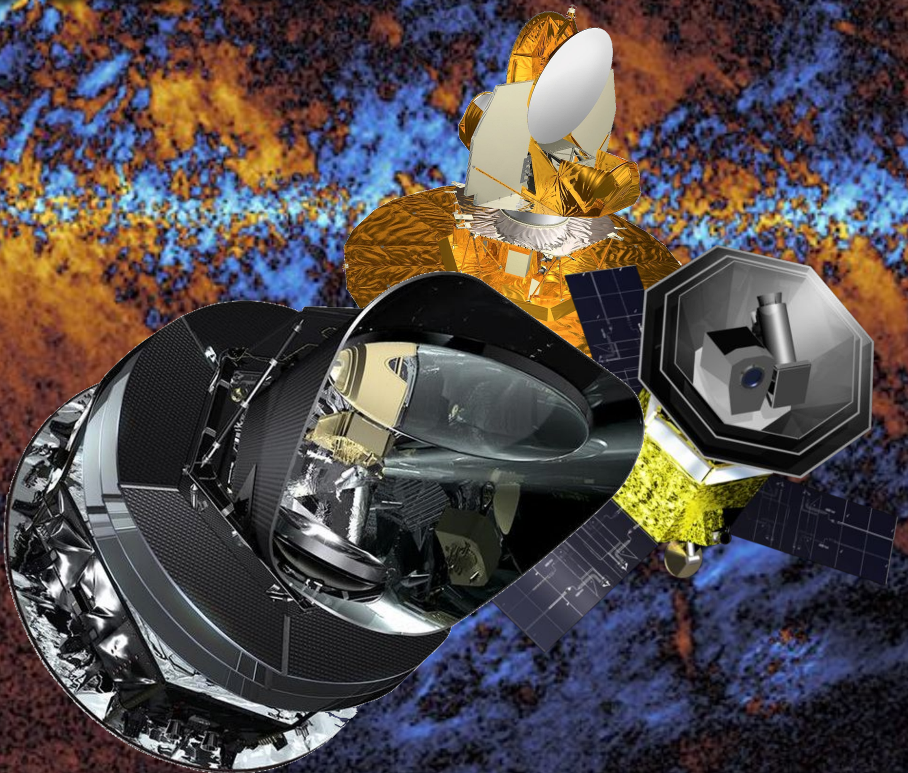
European Commission

Beyond PLANCK

Final review
WP6: Component Separation

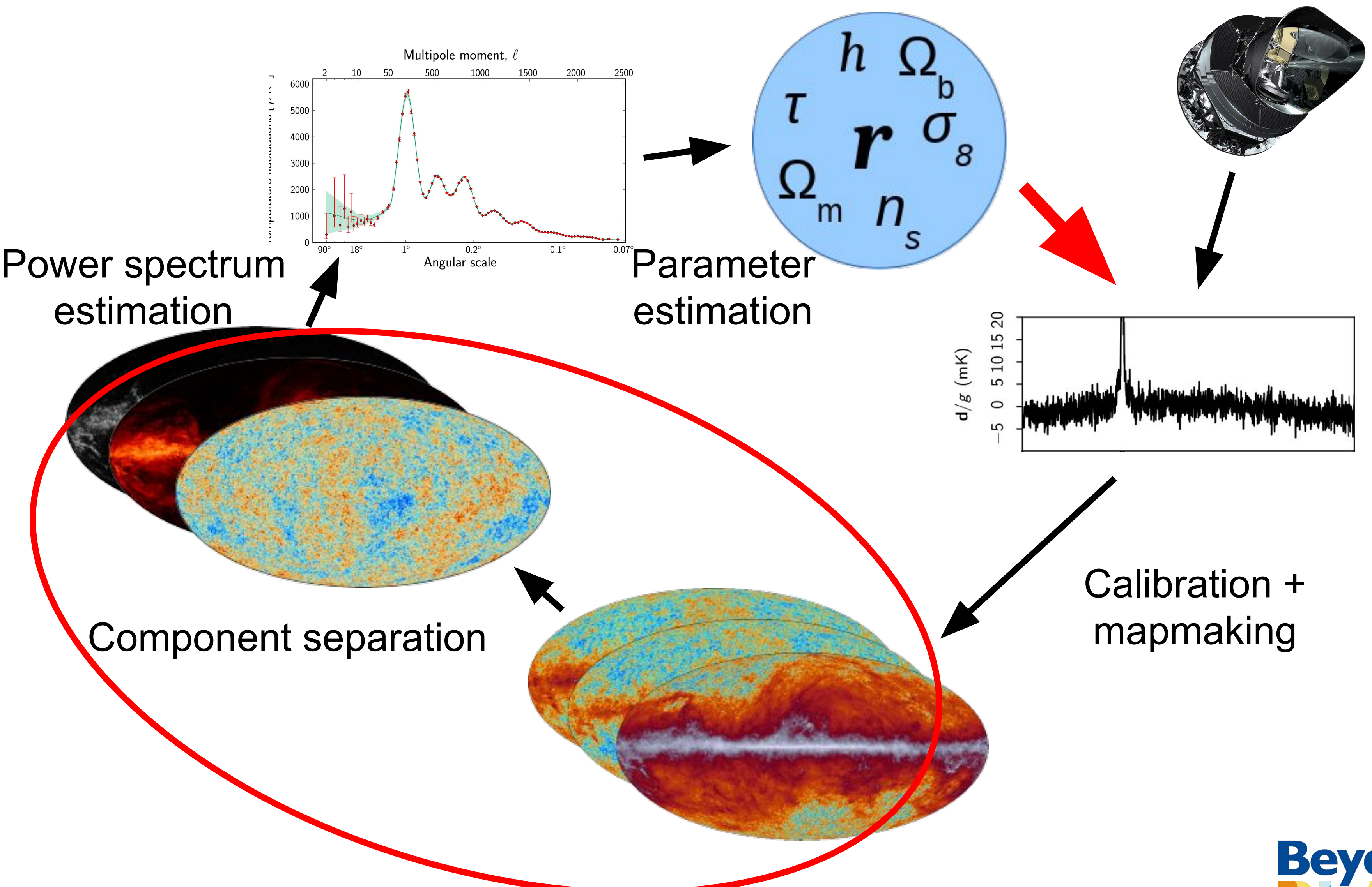
Trygve Leithe Svalheim



BeyondPlanck online release conference, November 18-20, 2020

WP6 Objective

Objectives Produce astrophysical component maps from frequency maps



New with BeyondPlanck

- Accounting for the interplay between foregrounds and systematics by sampling jointly

$$
\begin{aligned}
\boldsymbol{g} &\leftarrow P(\boldsymbol{g} \mid \boldsymbol{d}, \xi_n, \Delta_{\mathrm{bp}}, \boldsymbol{a}, \beta, C_\ell) \\
\boldsymbol{n}_{\mathrm{corr}} &\leftarrow P(\boldsymbol{n}_{\mathrm{corr}} \mid \boldsymbol{d}, \boldsymbol{g}, \xi_n, \Delta_{\mathrm{bp}}, \boldsymbol{a}, \beta, C_\ell) \\
\xi_n &\leftarrow P(\xi_n \mid \boldsymbol{d}, \boldsymbol{g}, \boldsymbol{n}_{\mathrm{corr}}, \Delta_{\mathrm{bp}}, \boldsymbol{a}, \beta, C_\ell) \\
\Delta_{\mathrm{bp}} &\leftarrow P(\Delta_{\mathrm{bp}} \mid \boldsymbol{d}, \boldsymbol{g}, \boldsymbol{n}_{\mathrm{corr}}, \xi_n, \boldsymbol{a}, \beta, C_\ell) \\
\boldsymbol{a} &\leftarrow P(\boldsymbol{a} \mid \boldsymbol{d}, \boldsymbol{g}, \boldsymbol{n}_{\mathrm{corr}}, \xi_n, \Delta_{\mathrm{bp}}, \beta, C_\ell) \\
\beta &\leftarrow P(\beta \mid \boldsymbol{d}, \boldsymbol{g}, \boldsymbol{n}_{\mathrm{corr}}, \xi_n, \Delta_{\mathrm{bp}}, \boldsymbol{a}, C_\ell) \\
C_\ell &\leftarrow P(C_\ell \mid \boldsymbol{d}, \boldsymbol{g}, \boldsymbol{n}_{\mathrm{corr}}, \xi_n, \Delta_{\mathrm{bp}}, \boldsymbol{a}, \beta)
\end{aligned}
$$

This WP { ($\boldsymbol{a}$ and β steps)

Data model and external data

Free parameters

$$s_{\mathrm{RJ}} = \left(a_{\mathrm{CMB}} + a_{\mathrm{quad}}(\nu)\right)\frac{x^2 e^x}{(e^x - 1)^2} +$$

$$+ a_{\mathrm{s}}\left(\frac{\nu}{\nu_{0,\mathrm{s}}}\right)^{\beta_{\mathrm{s}}} +$$

$$+ a_{\mathrm{ff}}\left(\frac{\nu_{0,\mathrm{ff}}}{\nu}\right)^2 \frac{g_{\mathrm{ff}}(\nu; T_{\mathrm{e}})}{g_{\mathrm{ff}}(\nu_{0,\mathrm{ff}}; T_{\mathrm{e}})} +$$

$$+ a_{\mathrm{sd}}\left(\frac{\nu_{0,\mathrm{sd}}}{\nu}\right)^2 \frac{f_{\mathrm{sd}}\left(\nu \cdot \frac{\nu_{\mathrm{p}}}{30.0\,\mathrm{GHz}}\right)}{f_{\mathrm{sd}}\left(\nu_{0,\mathrm{sd}} \cdot \frac{\nu_{\mathrm{p}}}{30.0\,\mathrm{GHz}}\right)} +$$

$$+ a_{\mathrm{d}}\left(\frac{\nu}{\nu_{0,\mathrm{d}}}\right)^{\beta_{\mathrm{d}}+1} \frac{e^{h\nu_{0,\mathrm{d}}/k_{\mathrm{B}}T_{\mathrm{d}}} - 1}{e^{h\nu/k_{\mathrm{B}}T_{\mathrm{d}}} - 1} +$$

$$+ \sum_{j=1}^{N_{\mathrm{src}}} a_{j,\mathrm{src}}\left(\frac{\nu}{\nu_{0,\mathrm{src}}}\right)^{\alpha_{j,\mathrm{src}}-2},$$

CMB

Synchrotron

Free-free

AME / Spinning dust

Thermal dust

Point sources

Not: Sunyaev-Zeldovich effect, zodiacal light, cosmic infrared background

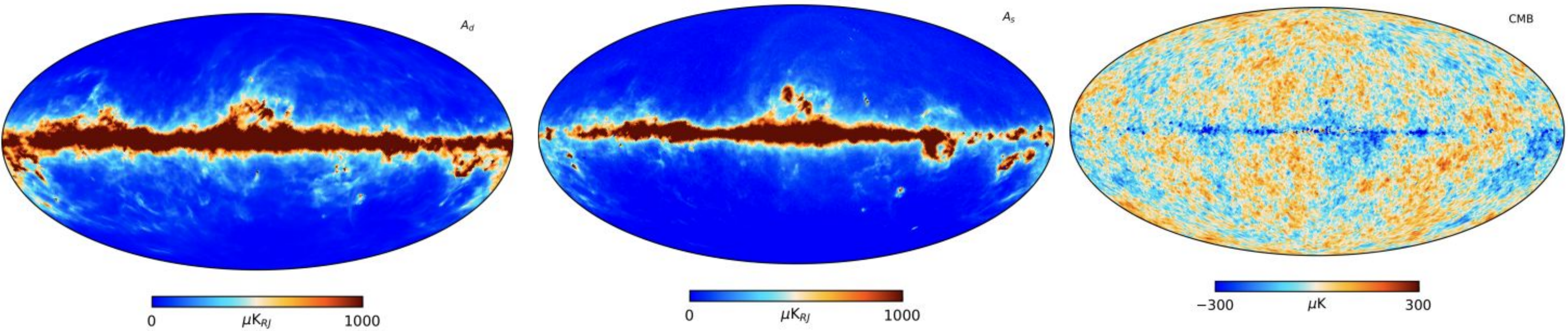
List of deliverables

1. First iteration of astrophysical sky maps, needed for initialization. Based on existing Commander sky model.
   a. Approved 22 January, 2020
2. Modularized Commander code, suitable for insertion into main Gibbs sampler
   a. Approved 22 January, 2020
3. First end-to-end astrophysical sky maps (CMB, synchrotron, free-free and spinning dust in temperature, and CMB and synchrotron in polarization) from new Gibbs sampler
   a. Approved 22 January, 2020
4. Final release candidate maps
   a. Submitted 30 Nov 2020

Deliverable 1

First iteration of astrophysical sky maps, needed for initialization. Based on existing Commander sky model.

Used NPIPE to create a sky model to initialize on.

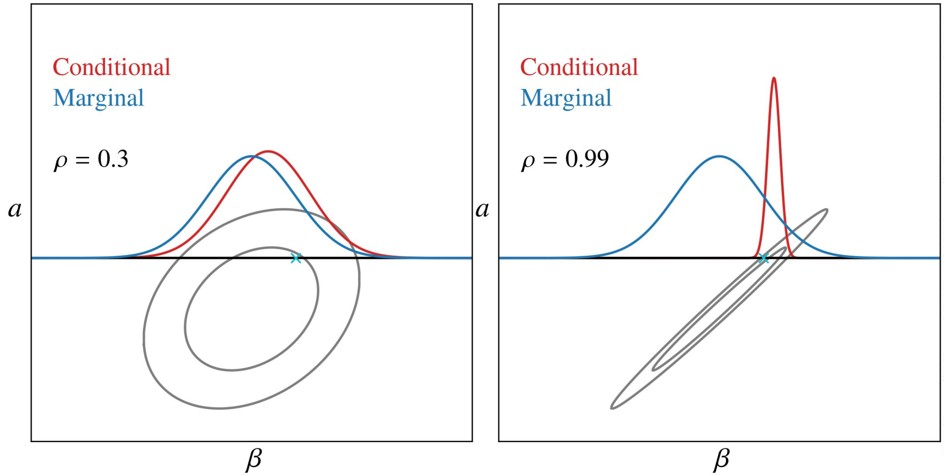


Deliverable 2

Modularized Commander code, suitable for insertion into main Gibbs sampler

Code is missing spectral index sampling procedures

- Temperature
  - Marginal sampler for efficient sampling over narrow spectral index distributions implemented in “comm_nonlin_mod.f90”
- Polarization
  - Metropolis hastings sampler for non-linear spectral index sampling in “comm_nonlin_mod.f90”.



Deliverable 3

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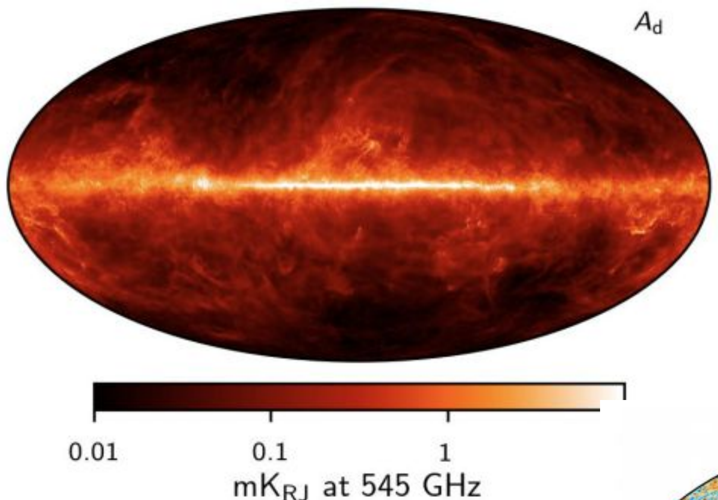
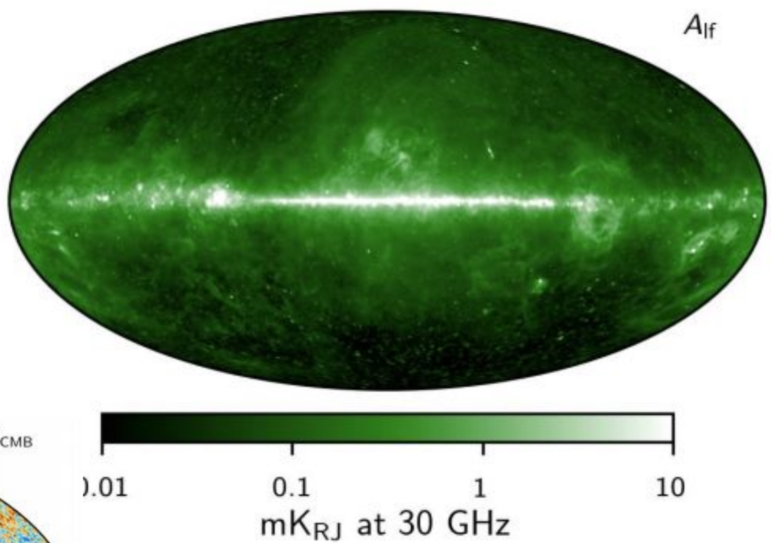
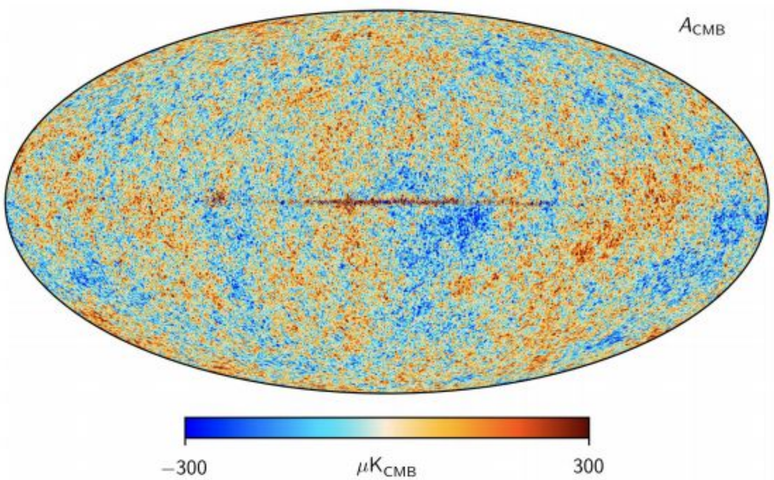
First end-to-end astrophysical sky maps (CMB, synchrotron, free-free and spinning dust in temperature, and CMB and synchrotron in polarization) from new Gibbs sampler

First high resolution component maps with new NPIPE data.
Constructing the sky model with state of the art observations







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Final release candidate maps
Temperature analysis

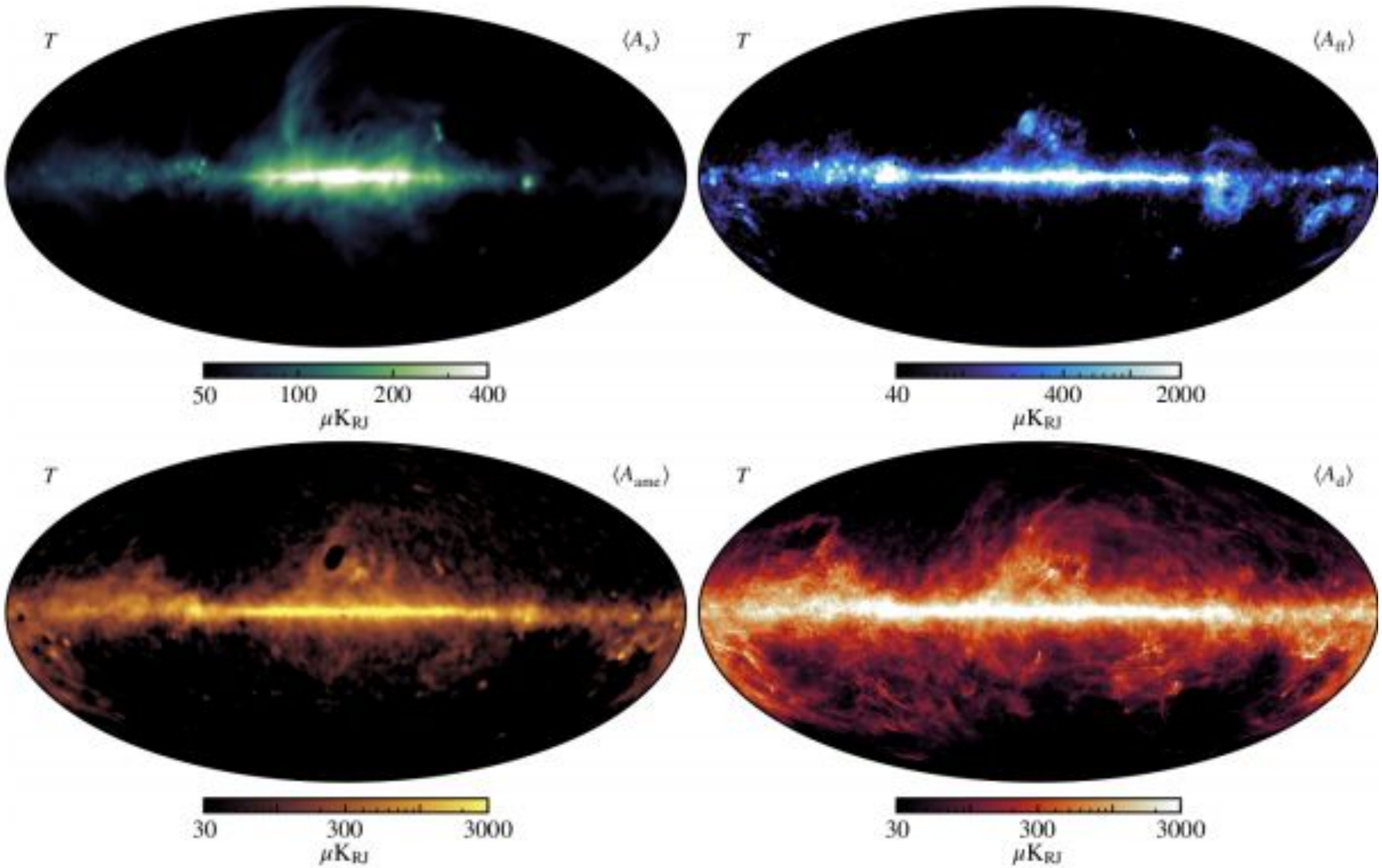

Figure 1: Foreground amplitude intensity maps as estimated with the BeyondPlanck pipeline. From top to bottom and left to right, the four panels show 1) synchrotron, 2) free-free, 3) AME, and 4) thermal dust emission.

Final release candidate maps

Polarization analysis

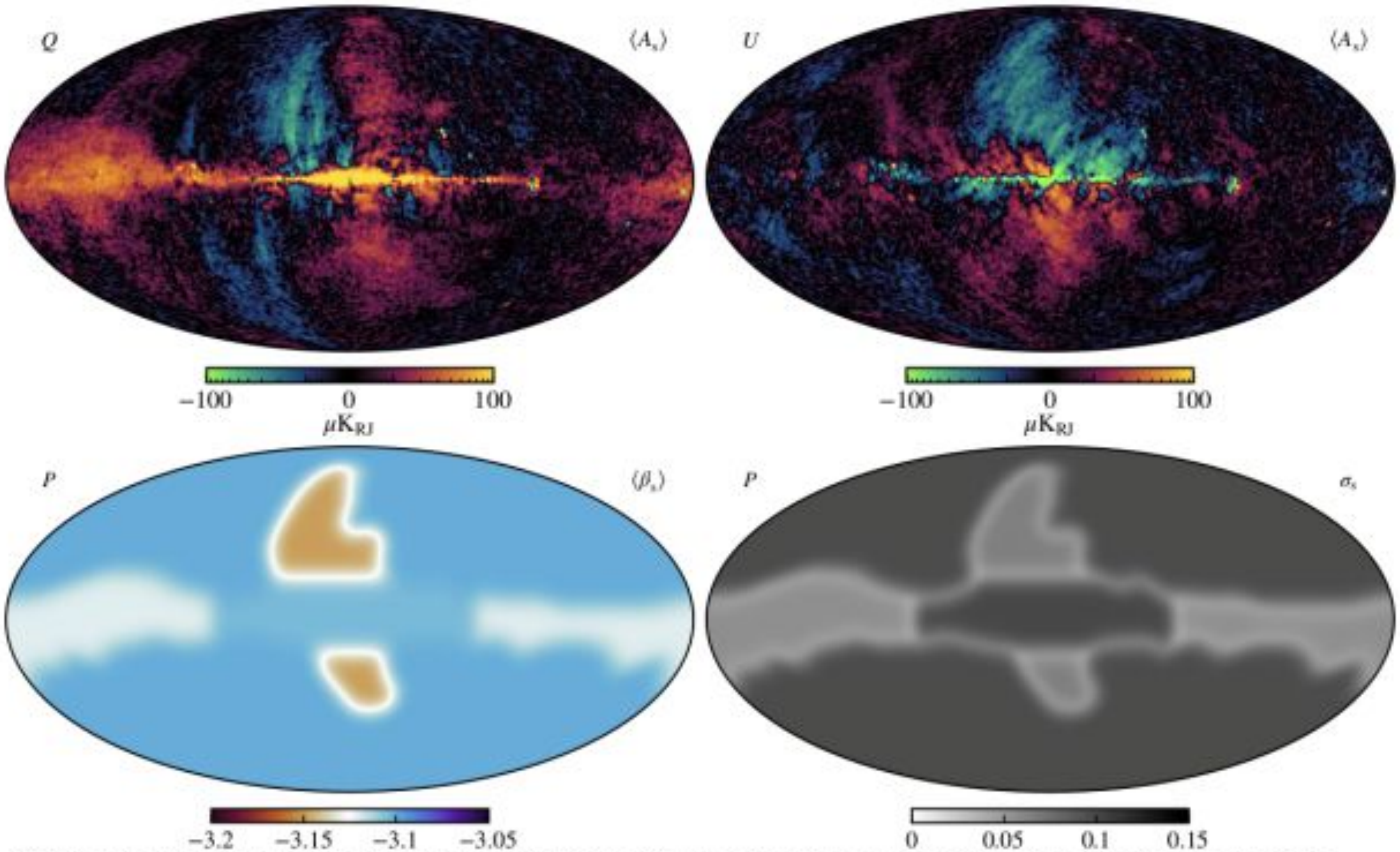

Figure 2: Polarized synchrotron amplitude Stokes Q and U (top left and right) parameters, and spectral index and its uncertainty (bottom left and right), as estimated with the BeyondPlanck pipeline.

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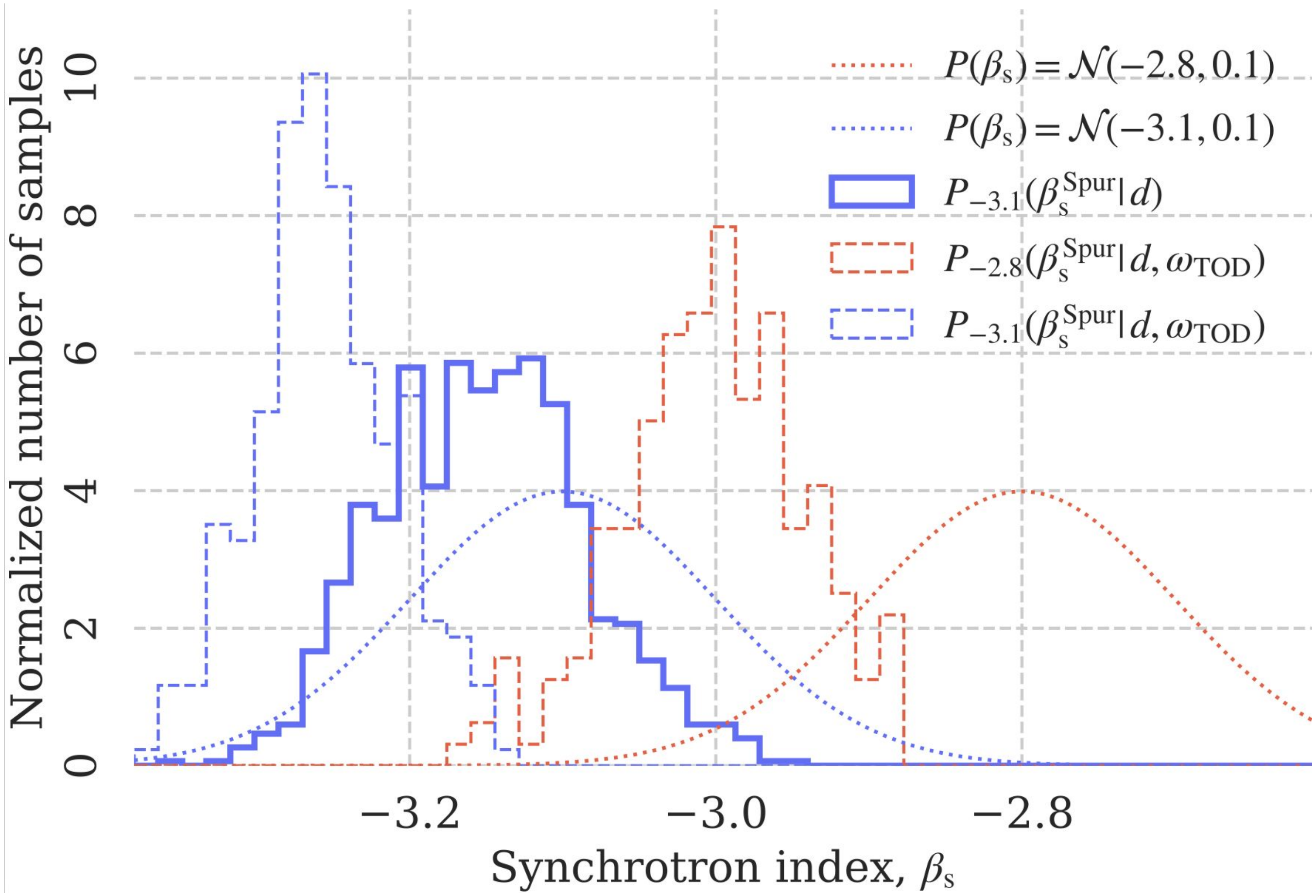
Demonstrated benefits of joint analysis by robust error propagation in component separation



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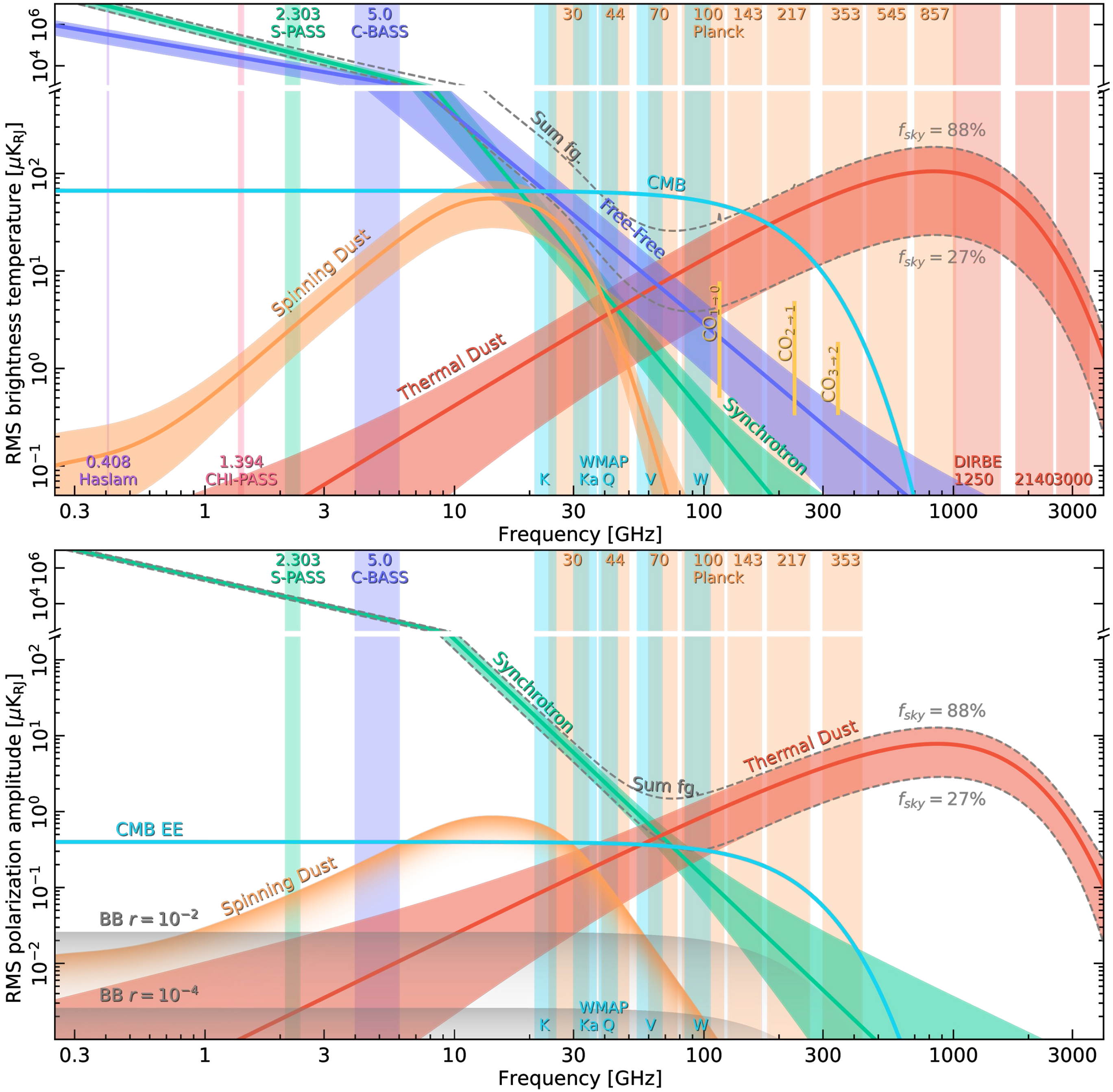
Foreground results



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All data available online

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BP_c000x_Tresamp_v1.h5 (1, 2, 3, 4, 5, 6)	High-res CMB T resamp chain files	(2.3, 1.5, 1.7, 1.6, 1.5, 1.7) GB	File Formats
BP_c000x_Presamp_v1.h5 (1, 2, 3, 4, 5, 6)	Low-res CMB P resamp chain files	(437, 437, 437, 376, 397, 392) MB	File Formats

Frequency Maps

Filename	Content	Filesize	Format specification
BP_030_IQU_n0512_v1.fits	LFI 30 GHz frequency map	108 MB	
BP_044_IQU_n0512_v1.fits	LFI 44 GHz frequency map	108 MB	
BP_070_IQU_n1024_v1.fits	LFI 70 GHz frequency map	432 MB	

Astrophysical Component Maps

Filename	Content	Filesize	Format specification
BP_ame_I_n1024_v1.fits	AME (spinning dust) map	193 MB	
BP_dust_IQU_n1024_v1.fits	Thermal dust emission map	769 MB	
BP_freefree_I_n1024_v1.fits	Free-free emission map	193 MB	
BP_synch_IQU_n1024_v1.fits	Synchrotron map	577 MB	

CMB Maps

Filename	Content	Filesize	Format specification
BP_cmb_resamp_I_n1024_v1.fits	CMB posterior mean temperature map	96 MB	
BP_CMB_I_map_n1024_v1.fits	A single constrained CMB realisation	96 MB	
BP_CMB_QU_map_n8_v1.fits	CMB posterior mean polarization map	28 KB	

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Time reporting

	EU funded	**In Kind**
Oslo	32.5	4.5
Sum	32.5	4.5
Budgeted	**36**	**0**
Deviation total	-3.5	4.5

The BeyondPlanck collaboration

European Commission

EU-funded institutions

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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

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Questions?

Beyond PLANCK

Commander

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THE FRAMEWORK PROGRAMME FOR RESEARCH AND INNOVATION
HORIZON 2020

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