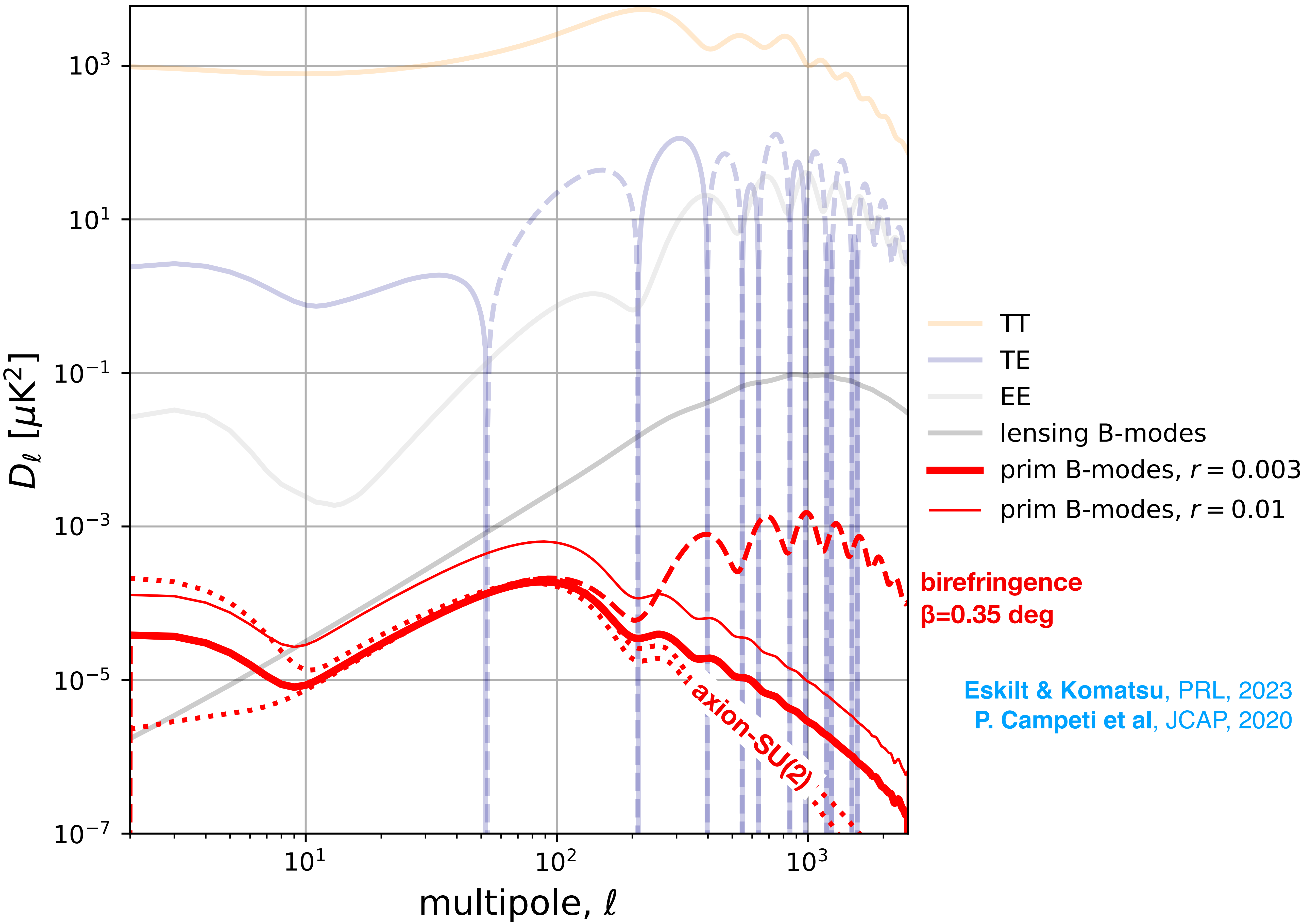
The SciPol project

characterizing and mitigating the instrumental, astrophysical and environmental systematics effects

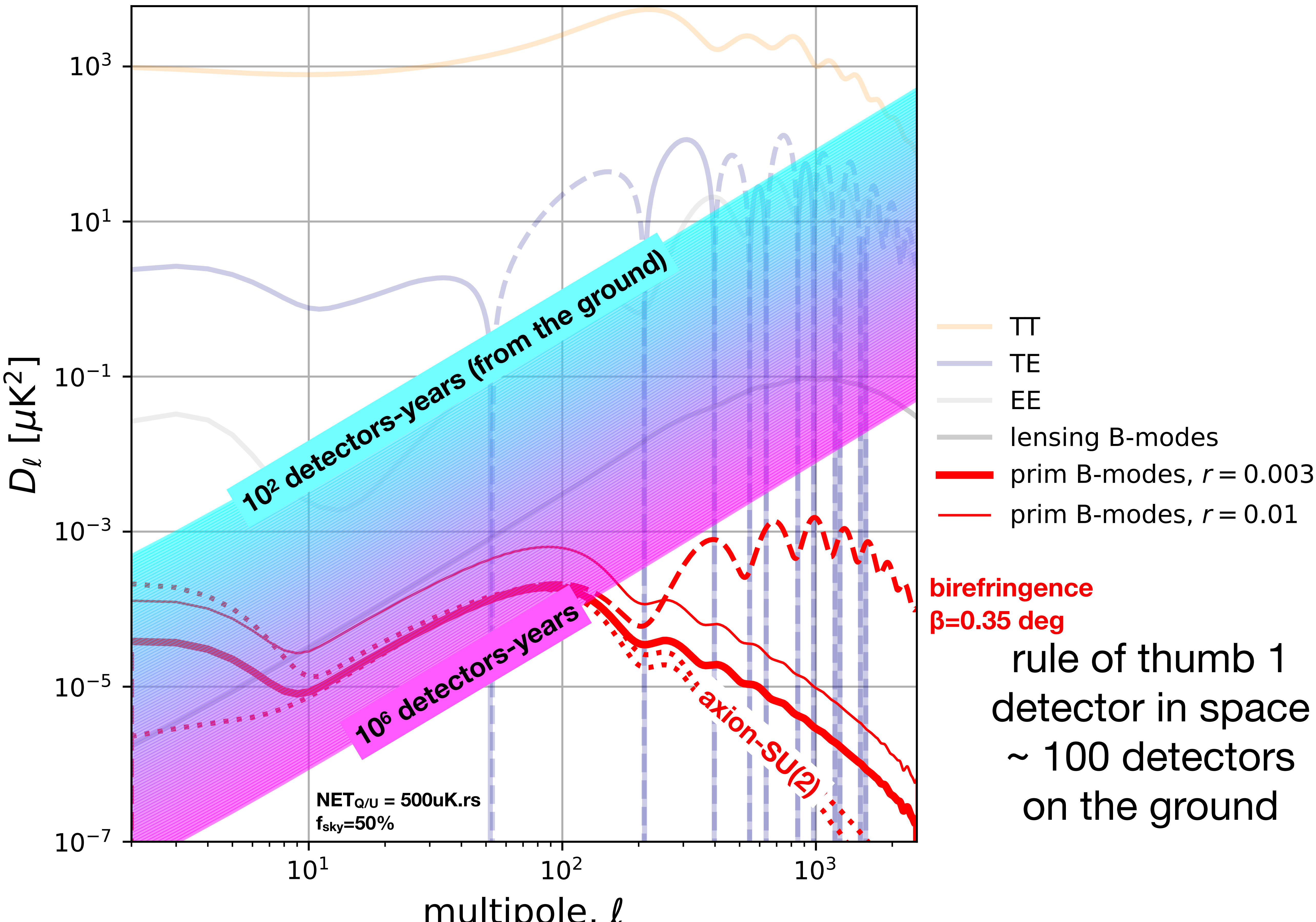
SciPol

Science from the large scale cosmic microwave background polarization structure

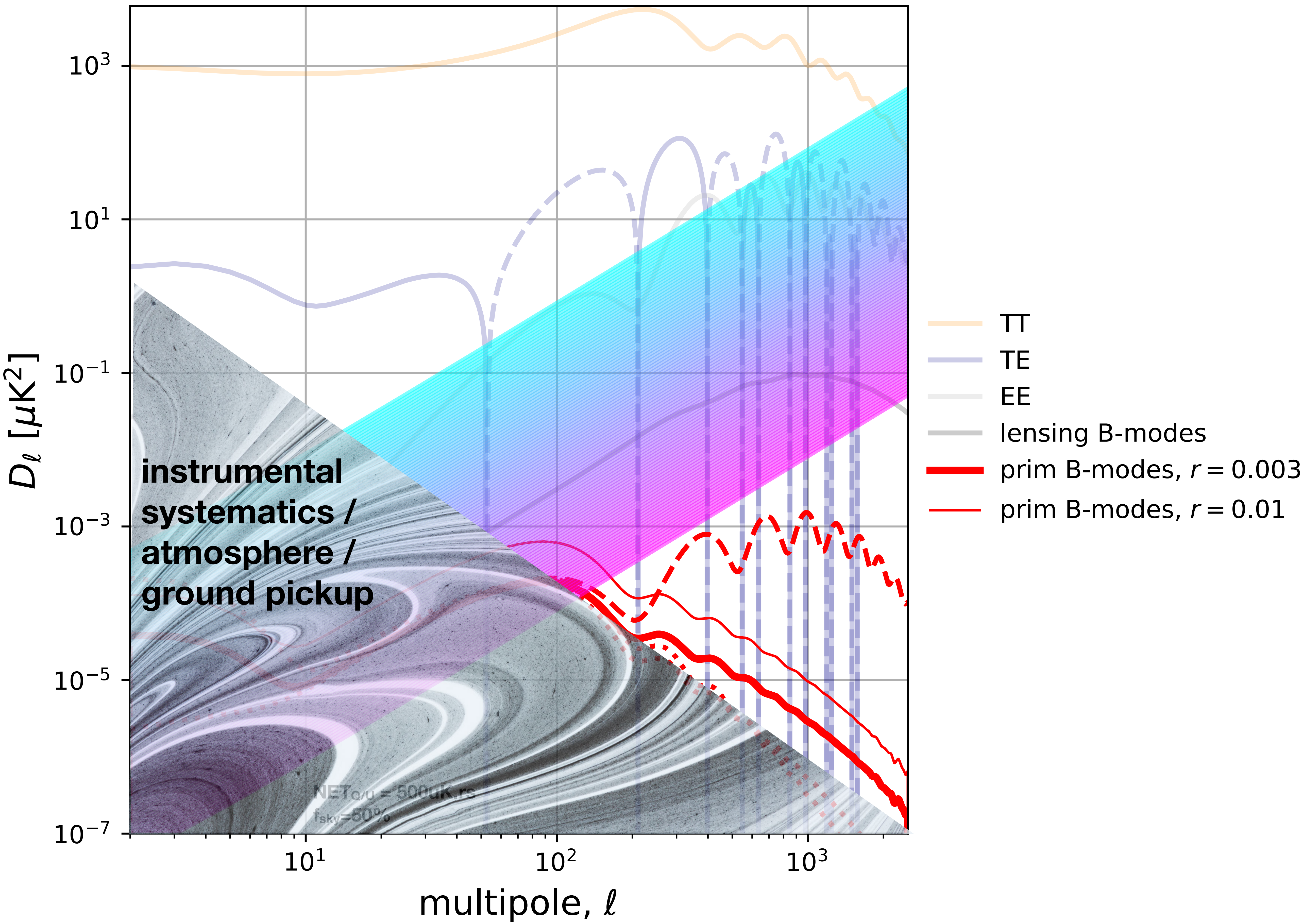
Josquin Errard, APC / CNRS, Friday Nov 8, 2024 — Milan Bicocca



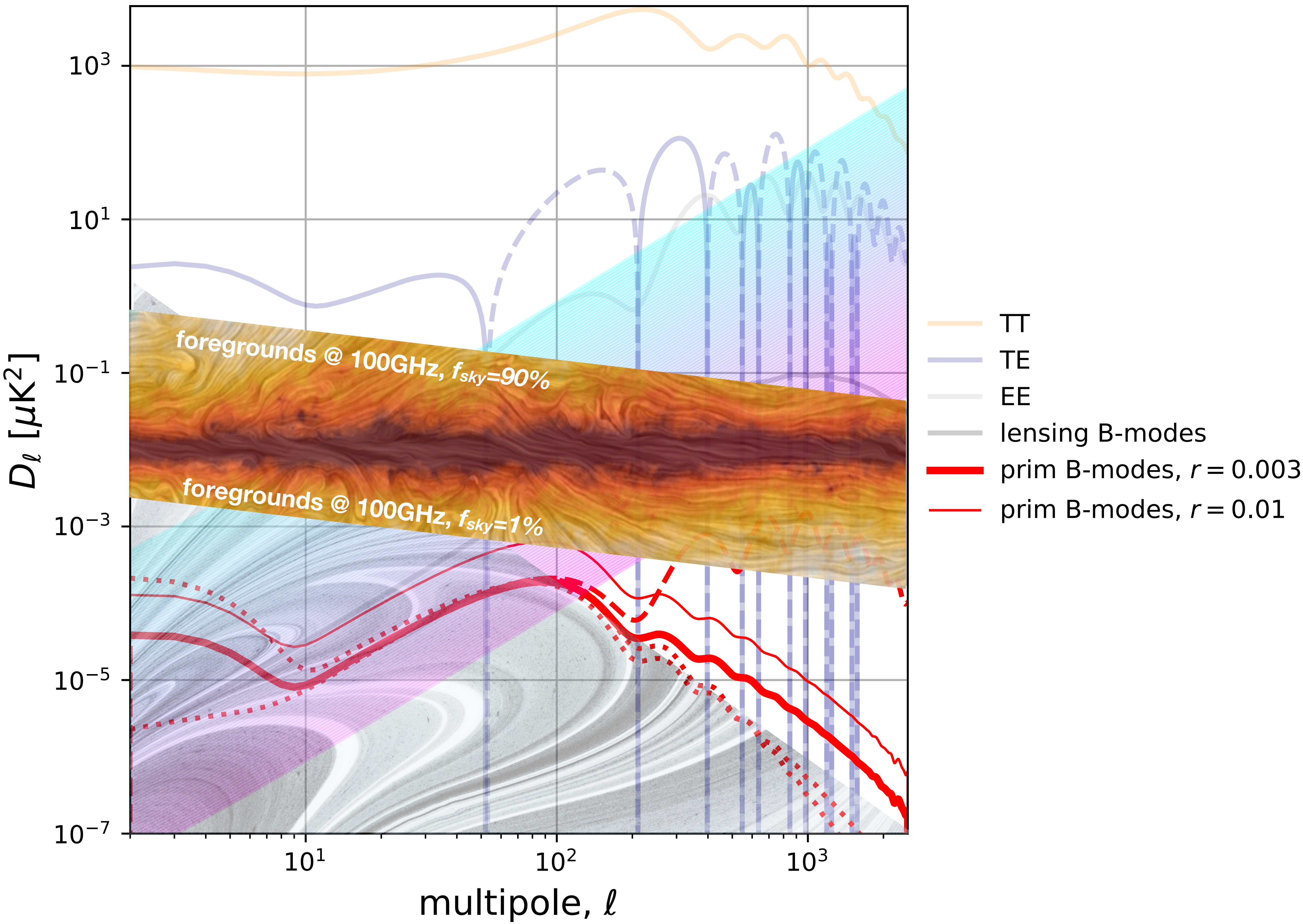
10^3
10^1
10^{-1}
10^{-3}
10^{-5}
10^{-7}
D_ℓ [μK^2]
10^1
10^2
10^3
multipole, ℓ
TT
TE
EE
lensing B-modes
prim B-modes, $r = 0.003$
prim B-modes, $r = 0.01$
birefringence
β=0.35 deg
axion-SU(2)
Eskilt & Komatsu, PRL, 2023
P. Campeti et al, JCAP, 2020



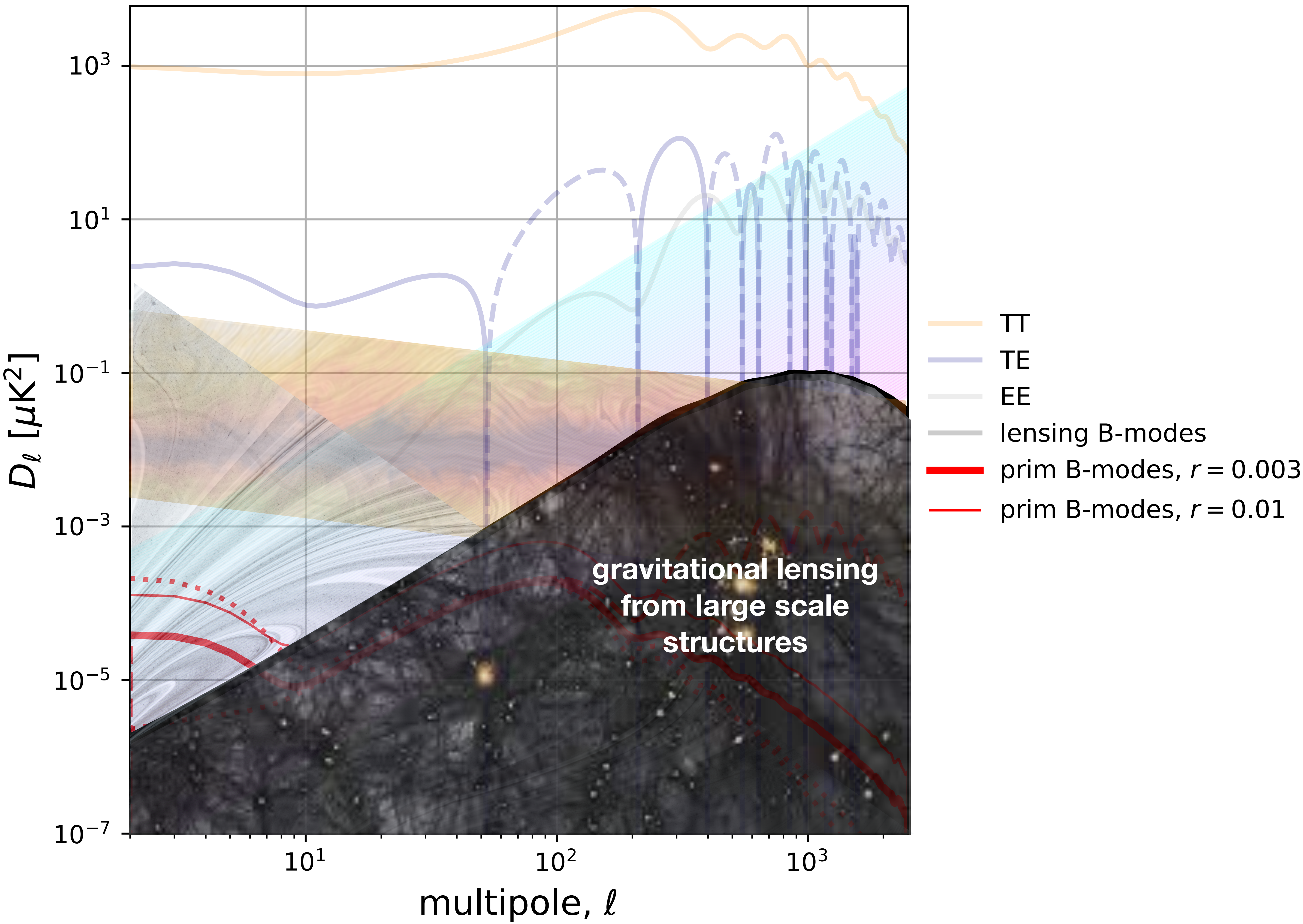
rule of thumb 1 detector in space ~ 100 detectors on the ground



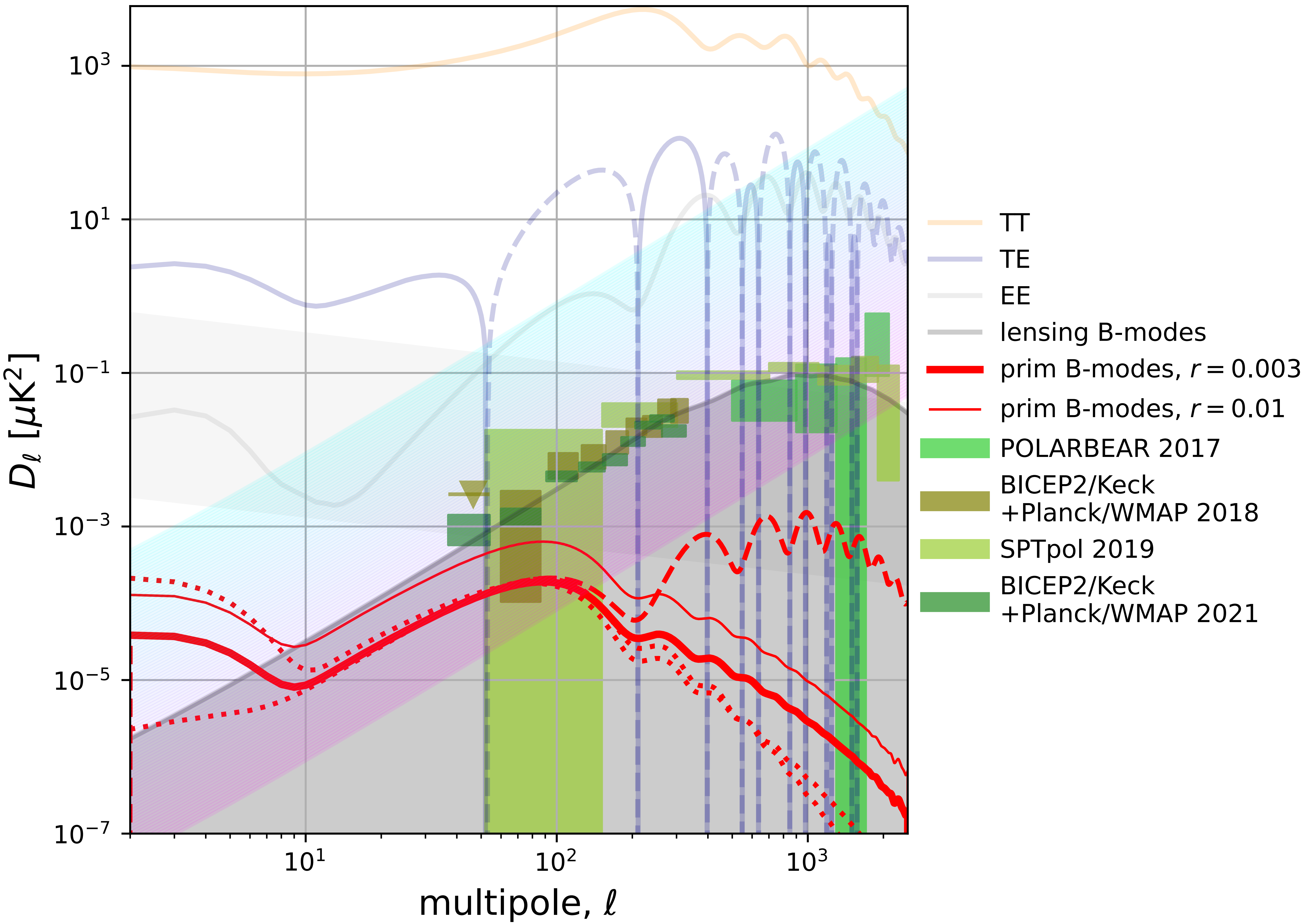
10^{3}
10^{1}
10^{-1}
10^{-3}
10^{-5}
10^{-7}
$D_\ell\ [\mu K^2]$
10^{1}
10^{2}
10^{3}
multipole, ℓ
instrumental systematics / atmosphere / ground pickup
TT
TE
EE
lensing B-modes
prim B-modes, $r = 0.003$
prim B-modes, $r = 0.01$



10^3
10^1
10^{-1}
10^{-3}
10^{-5}
10^{-7}
10^1
10^2
10^3
D_ℓ [μK^2]
multipole, ℓ
foregrounds @ 100GHz, f_{sky}=90%
foregrounds @ 100GHz, f_{sky}=1%
TT
TE
EE
lensing B-modes
prim B-modes, $r = 0.003$
prim B-modes, $r = 0.01$



10^3
10^1
10^{-1}
10^{-3}
10^{-5}
10^{-7}
$D_\ell\ [\mu K^2]$
10^1
10^2
10^3
multipole, ℓ
TT
TE
EE
lensing B-modes
prim B-modes, $r = 0.003$
prim B-modes, $r = 0.01$
gravitational lensing
from large scale
structures



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10^1
10^{-1}
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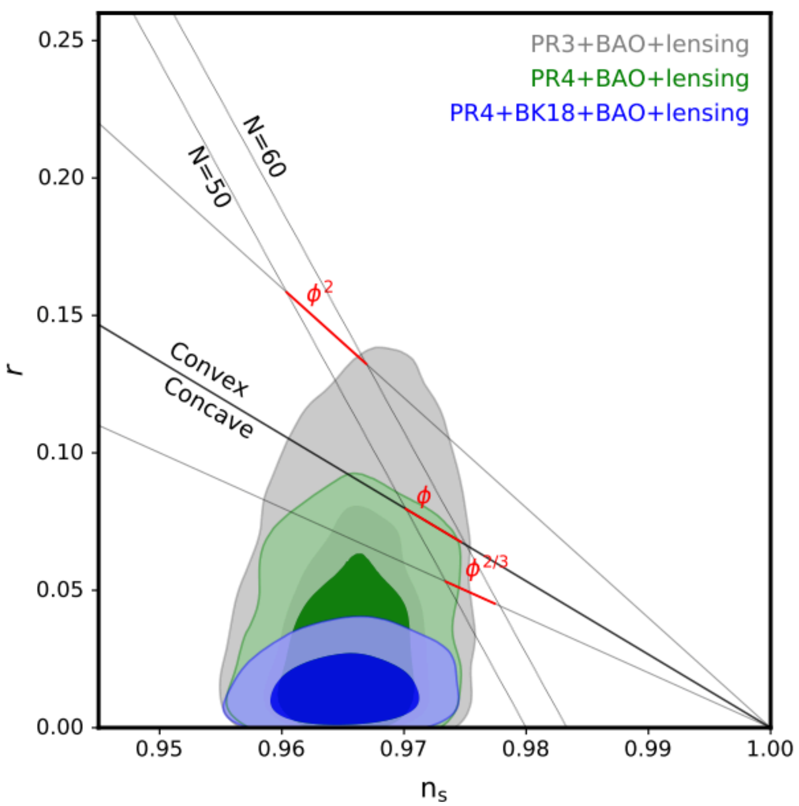
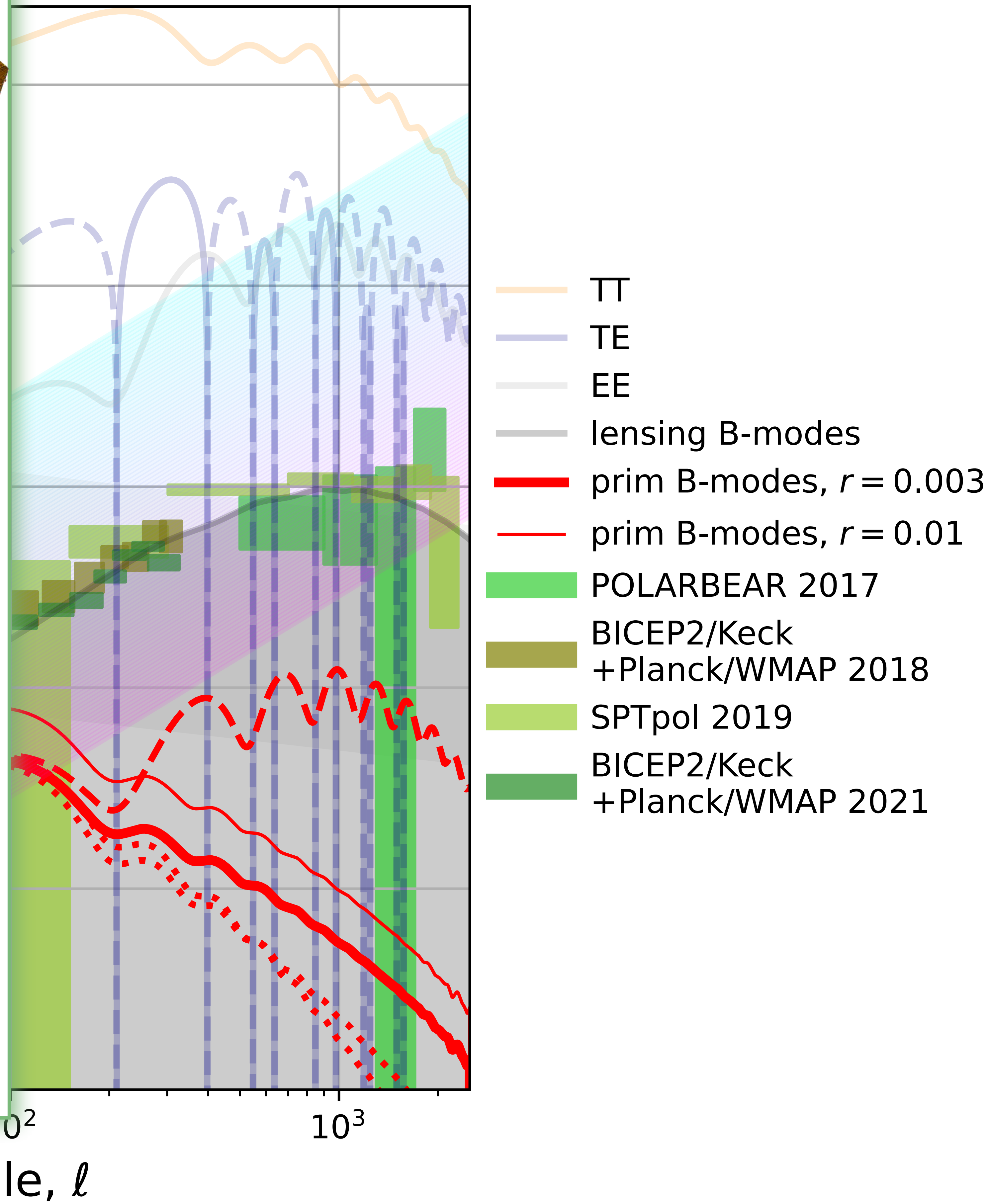
10^{-7}
10^1
10^2
10^3
D_ℓ [μK^2]
multipole, ℓ
TT
TE
EE
lensing B-modes
prim B-modes, $r = 0.003$
prim B-modes, $r = 0.01$
POLARBEAR 2017
BICEP2/Keck +Planck/WMAP 2018
SPTpol 2019
BICEP2/Keck +Planck/WMAP 2021

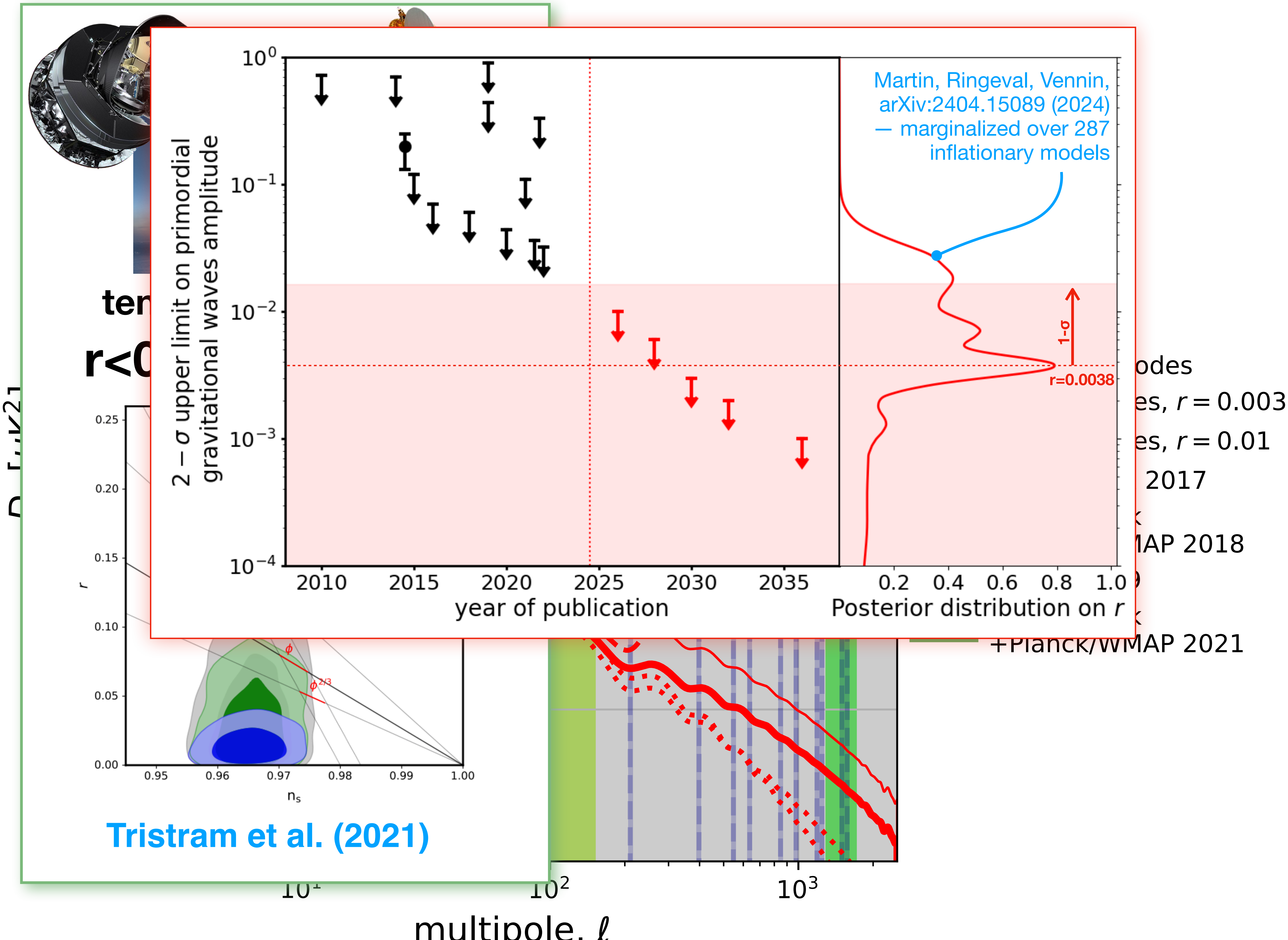
tensor-to-scalar ratio

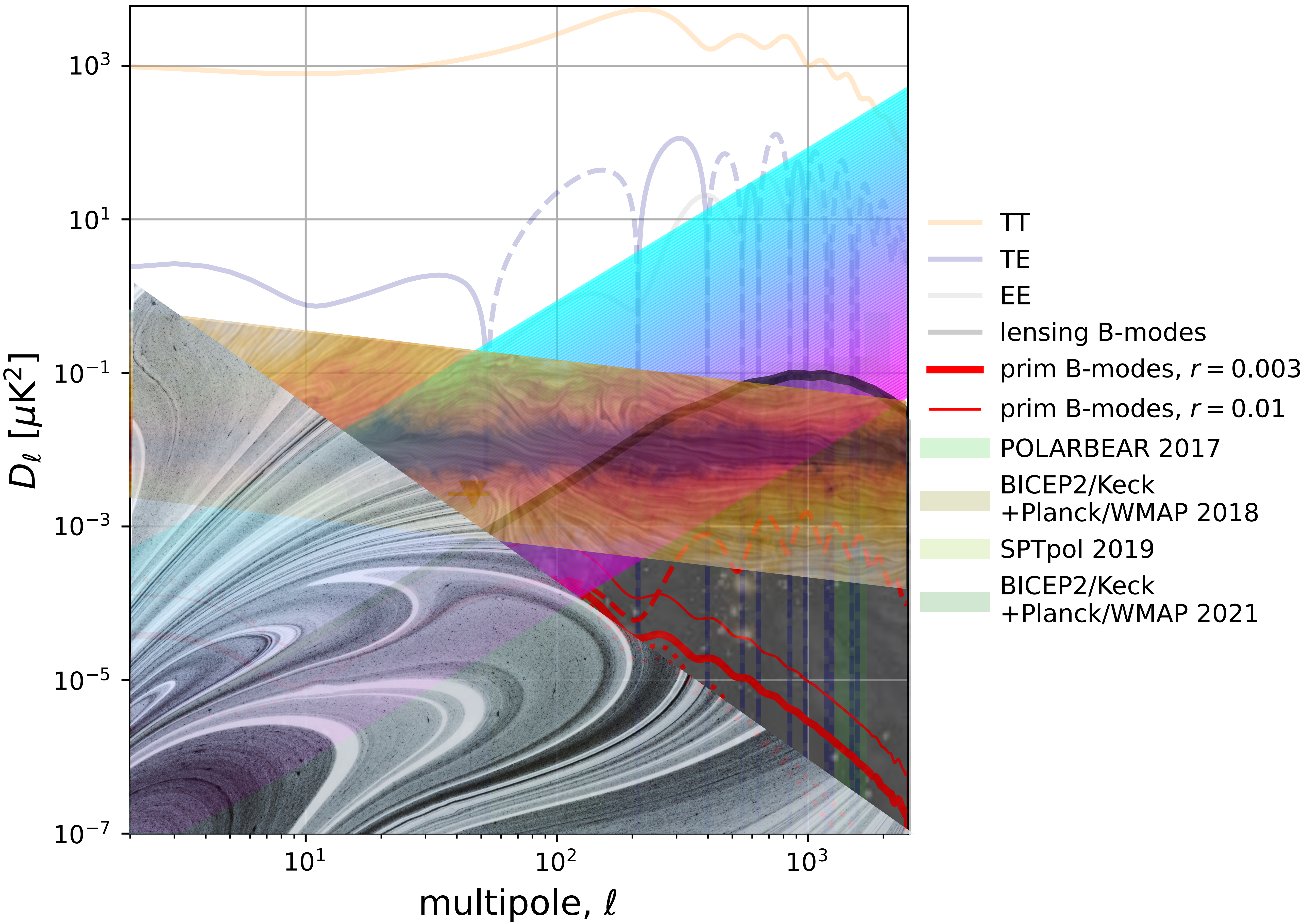
r<0.032 (95% c.l.)



Tristram et al. (2021)




Martin, Ringeval, Vennin, arXiv:2404.15089 (2024) — marginalized over 287 inflationary models
2 − σ upper limit on primordial gravitational waves amplitude
year of publication
Posterior distribution on r
r=0.0038
1-σ
Tristram et al. (2021)
multipole, ℓ
+Planck/WMAP 2021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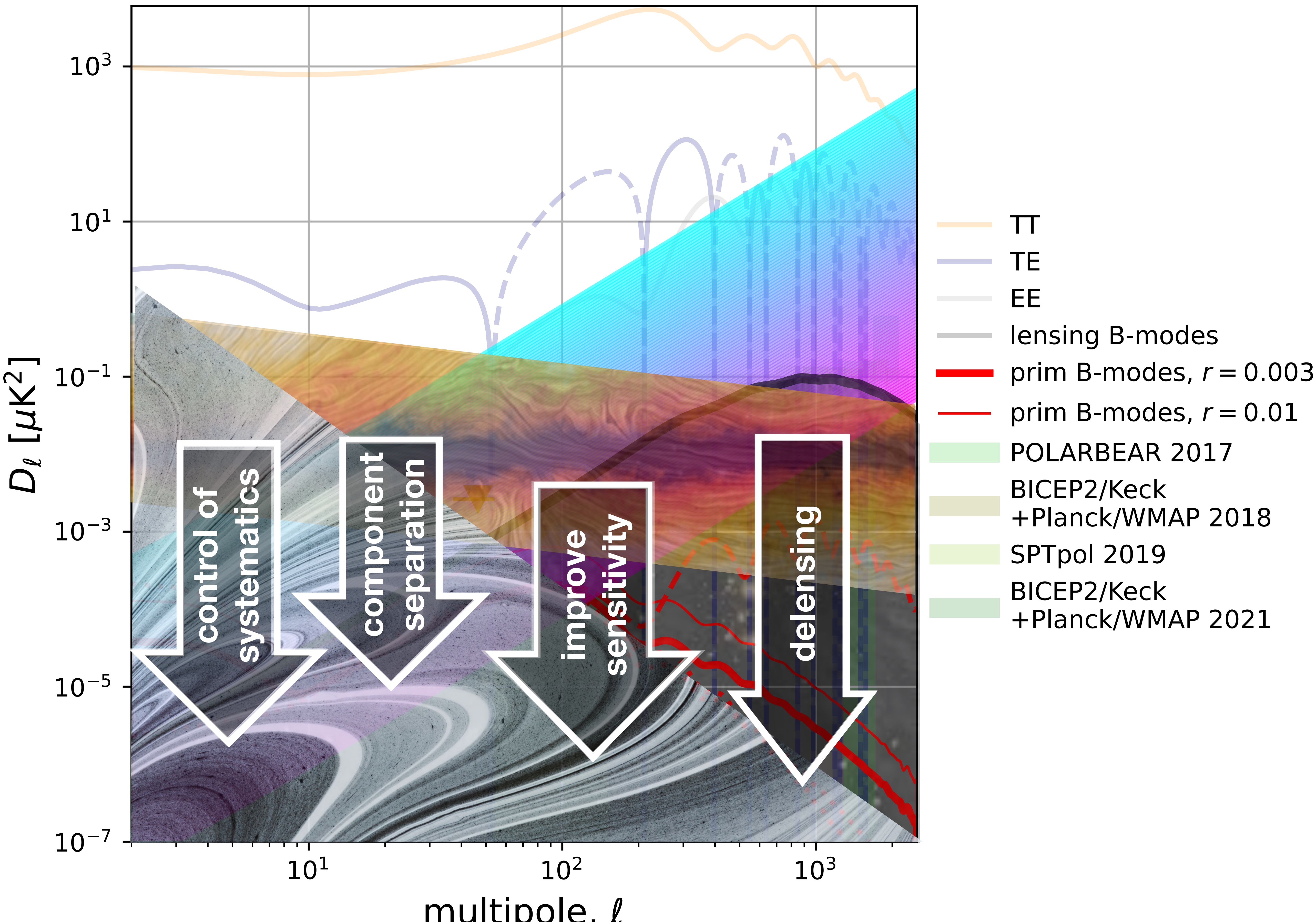
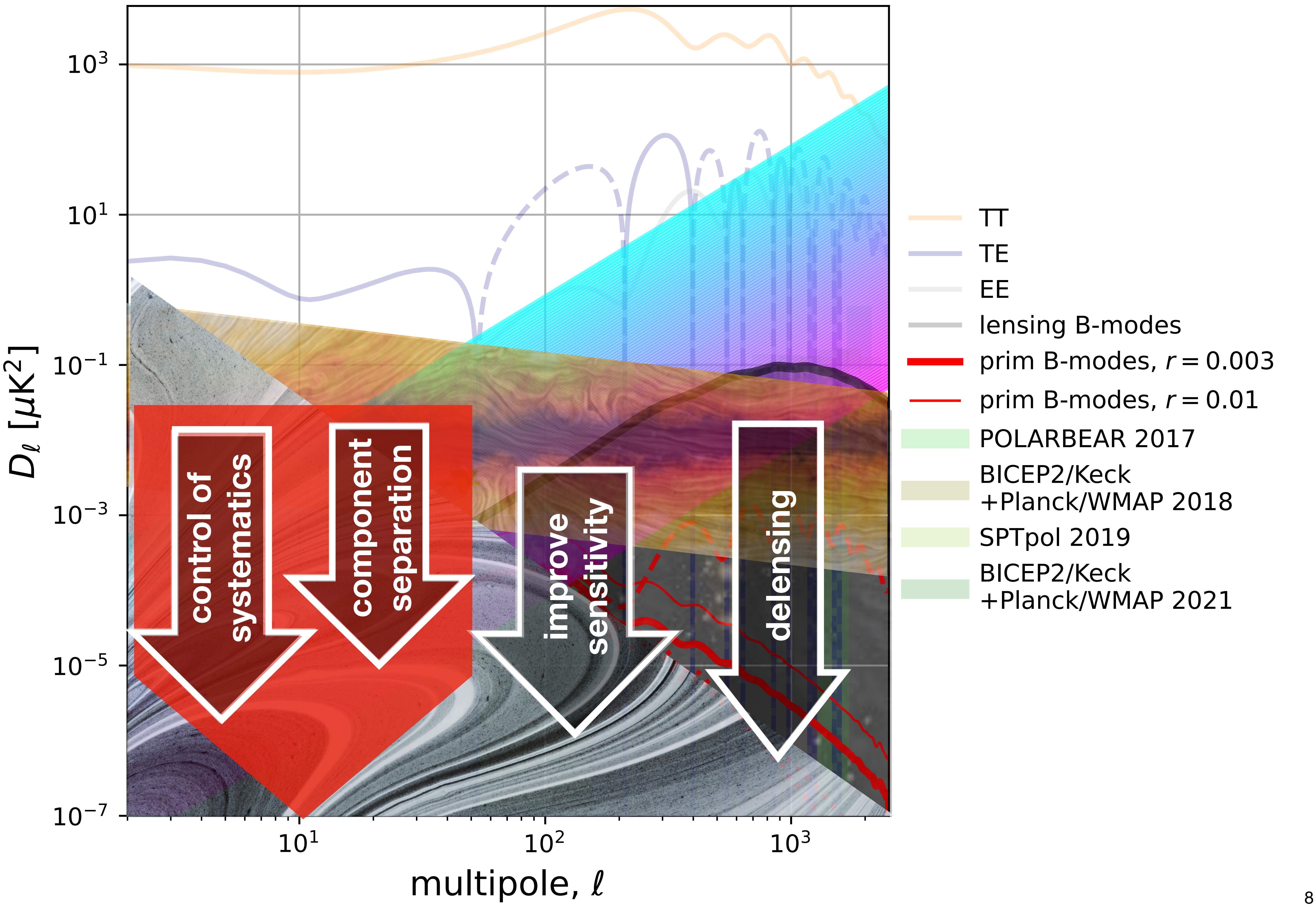


10^3
10^1
10^{-1}
10^{-3}
10^{-5}
10^{-7}
D_ℓ [μK^2]
10^1
10^2
10^3
multipole, ℓ
control of systematics
component separation
improve sensitivity
delensing
TT
TE
EE
lensing B-modes
prim B-modes, $r = 0.003$
prim B-modes, $r = 0.01$
POLARBEAR 2017
BICEP2/Keck +Planck/WMAP 2018
SPTpol 2019
BICEP2/Keck +Planck/WMAP 2021



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BICEP2/Keck +Planck/WMAP 2018
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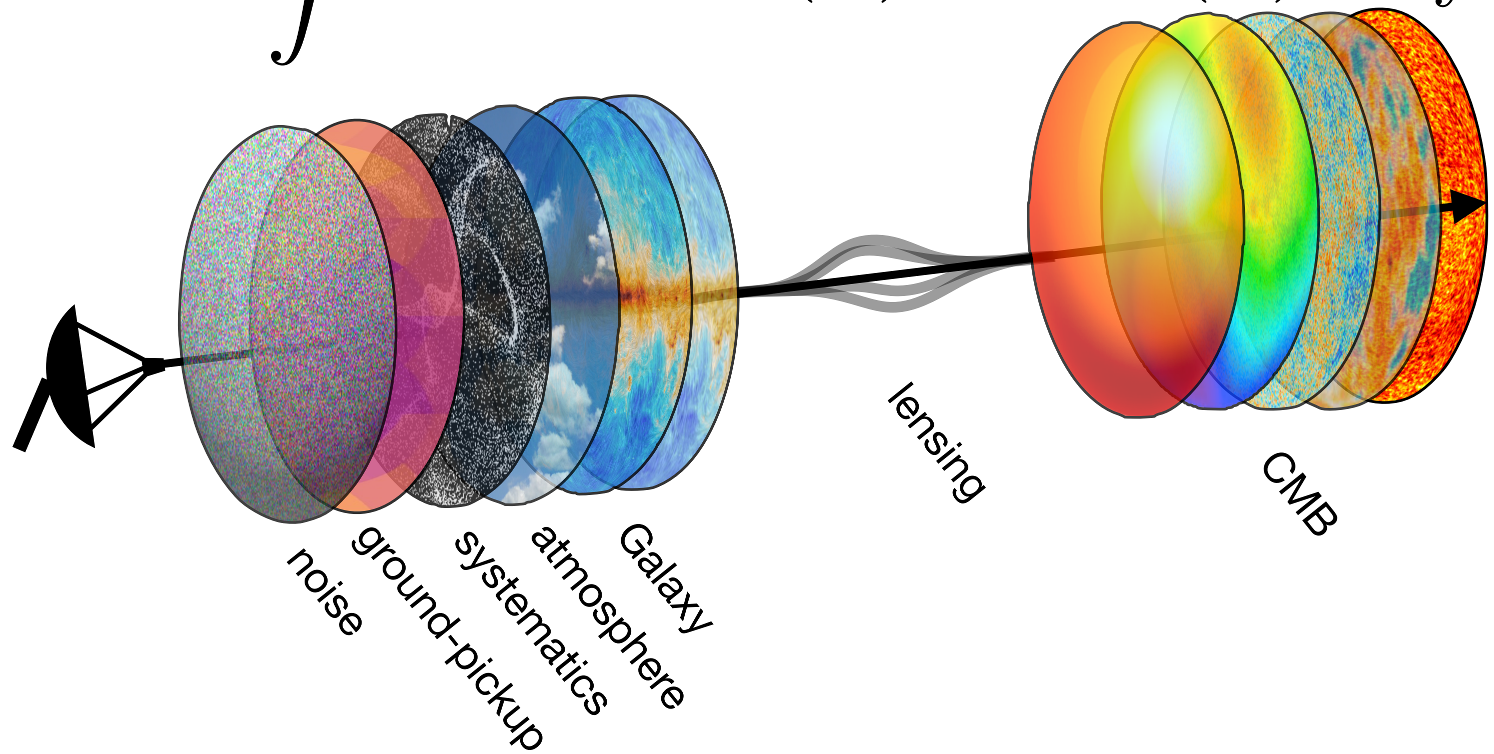
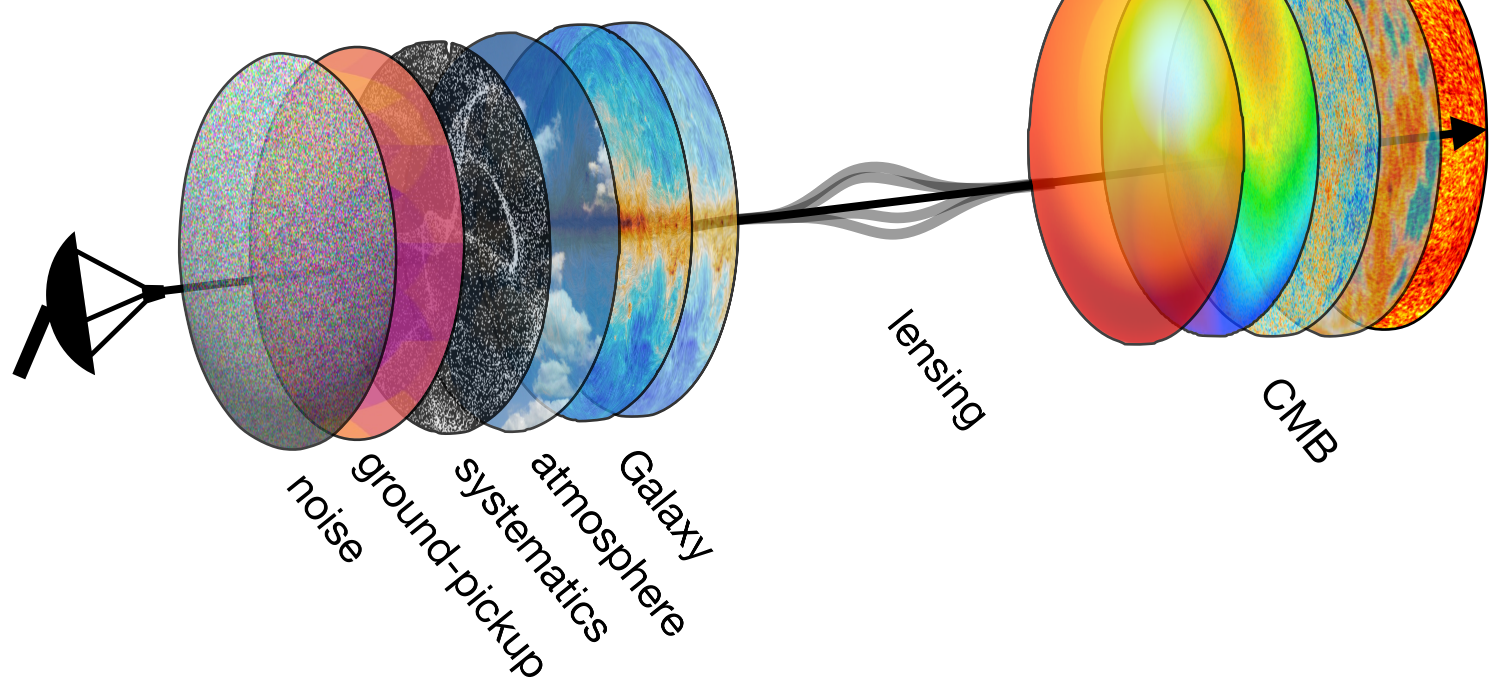
BICEP2/Keck +Planck/WMAP 2021

$$\bar{d} = \int d\nu \mathbf{M}_{\mathrm{instr}}(\nu)\mathbf{A}_{\mathrm{SED}}(\nu)s_{\mathrm{sky}} + n$$

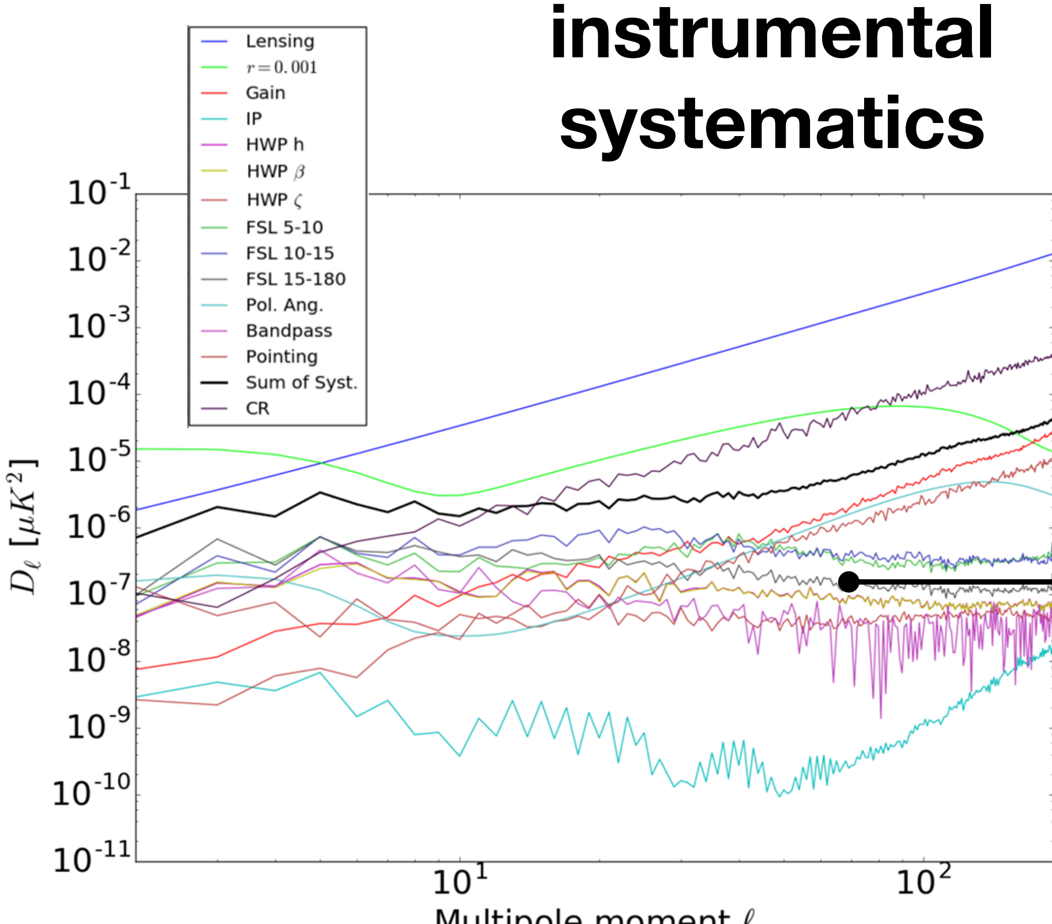


instrumental systematics $\otimes$ **environmental + Galactic foregrounds**

$$\bar{d} = \int d\nu \mathbf{M}_{\rm instr}(\nu) \mathbf{A}_{\rm SED}(\nu) s_{\rm sky} + n$$

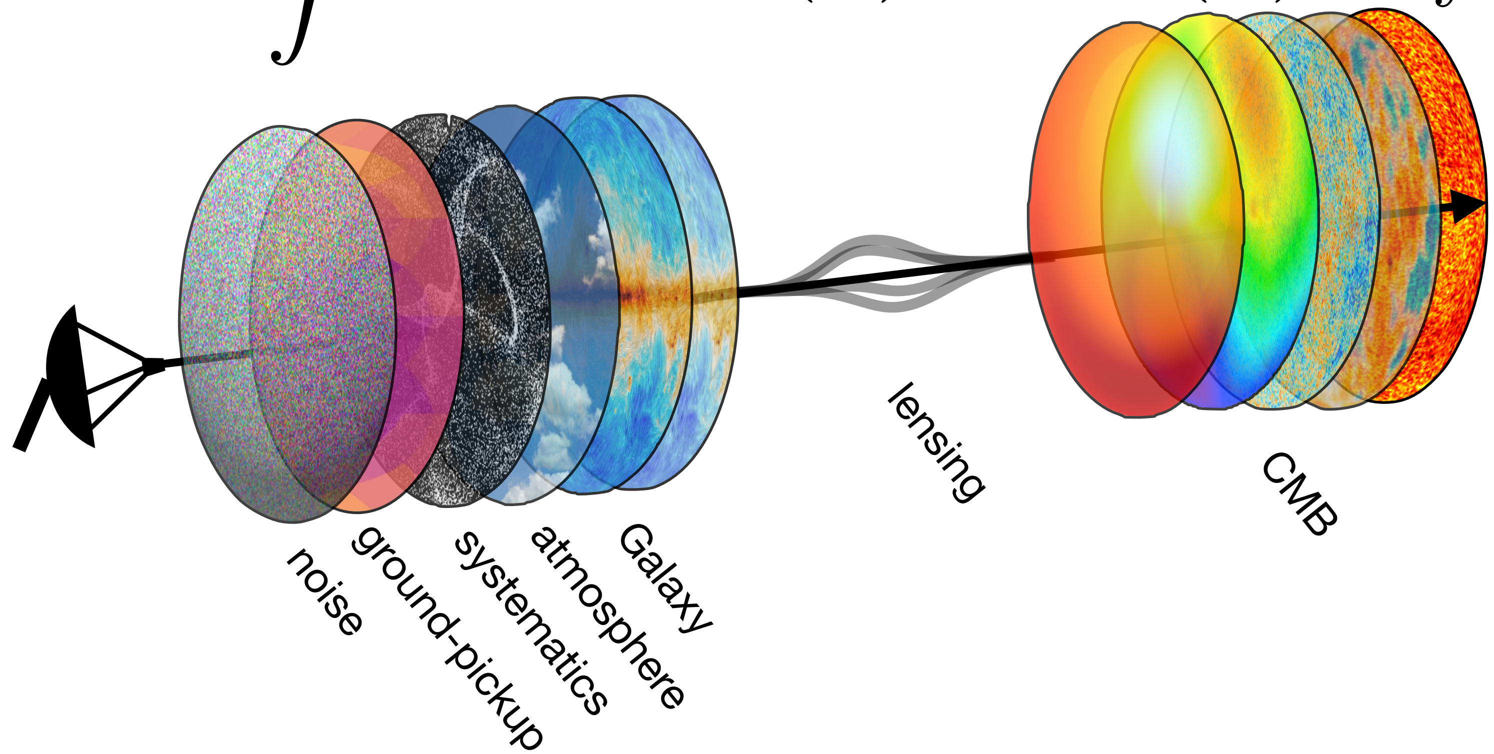


instrumental systematics $\otimes$ **environmental + Galactic foregrounds**



- instrumental requirements are usually derived from component separation (instr. syst. biases for LiteBIRD look like dust e.g. **2202.02773** — see also **talks by Marco, Davide, Nadia, …**)
- **Ward et al. 2018 (1803.07630)** in the context of SO

$$\bar{d} = \int d\nu \mathbf{M}_{\mathrm{instr}}(\nu) \mathbf{A}_{\mathrm{SED}}(\nu) s_{\mathrm{sky}} + n$$

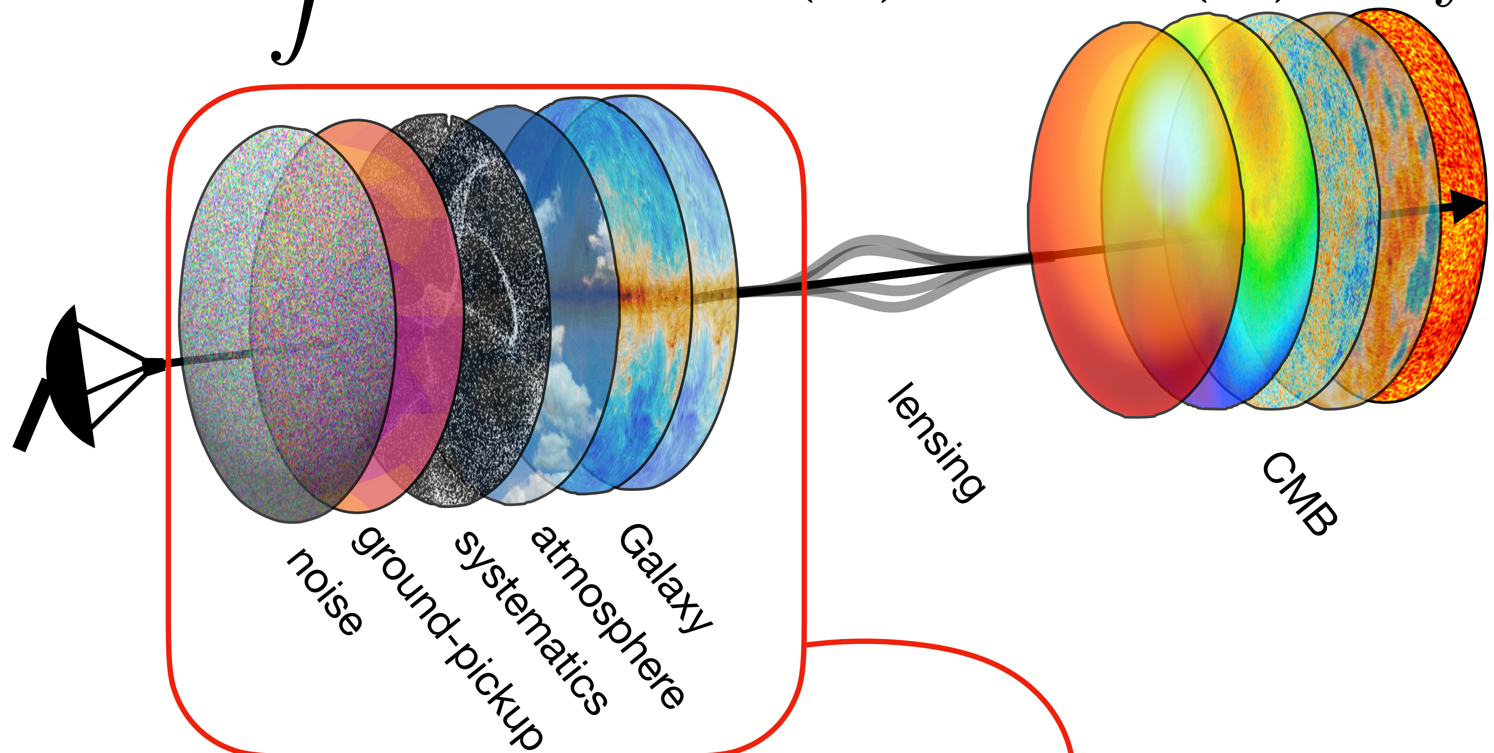


instrumental systematics $\otimes$ **environmental + Galactic foregrounds**

we cannot treat these separately. Effective systematic residuals are complex :(

we can/have to consider the two effects together and calibrate out our instruments + foregrounds SEDs :)

$$\bar{d} = \int d\nu \mathbf{M}_{\mathrm{instr}}(\nu)\mathbf{A}_{\mathrm{SED}}(\nu)s_{\mathrm{sky}} + n$$



instrumental systematics $\otimes$ **environmental + Galactic foregrounds**

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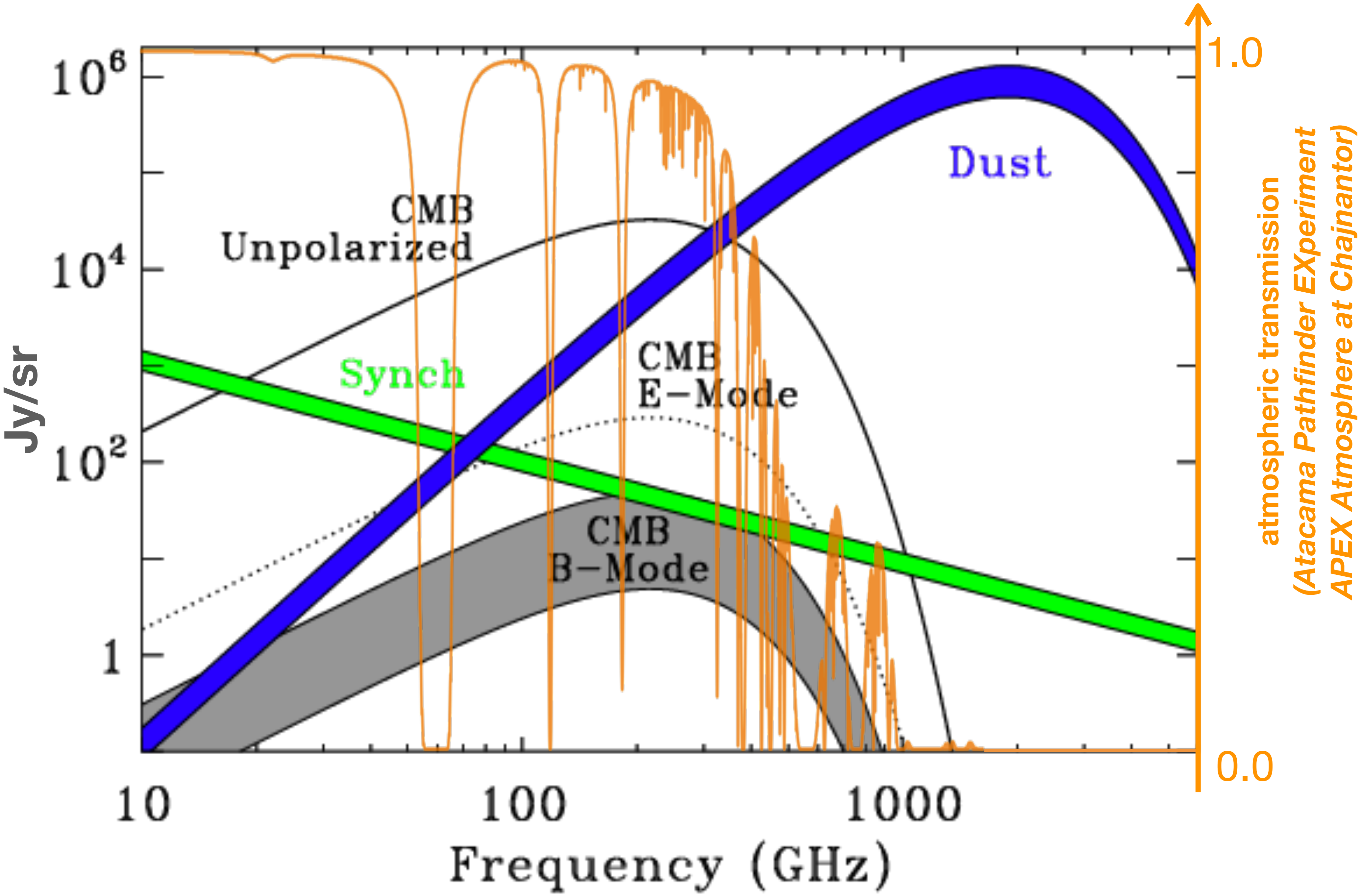
we can/have to consider the two effects together and calibrate out our instruments + foregrounds SEDs :)

Component separation

adapted from
Kogut et al. 2016



Component separation

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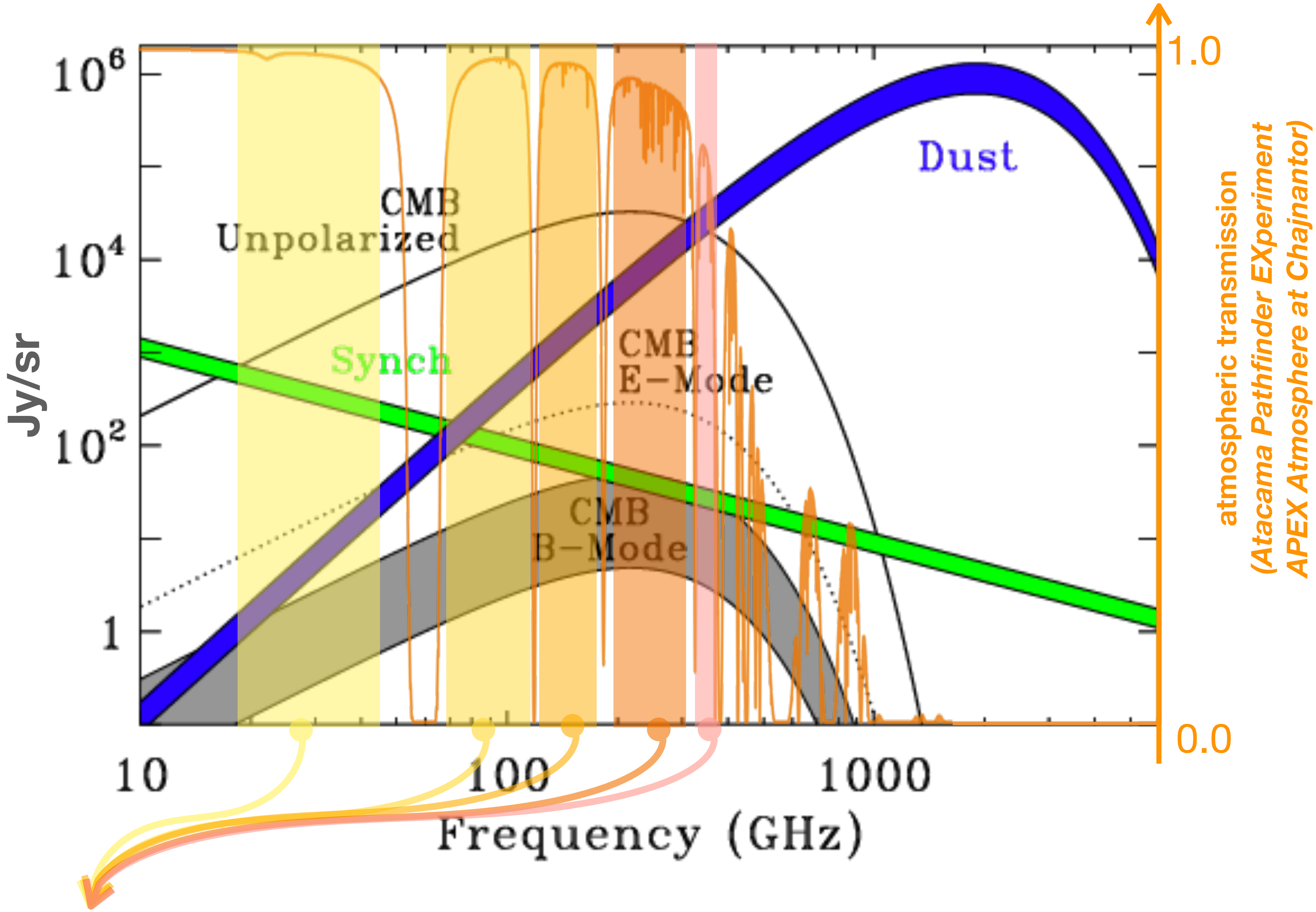
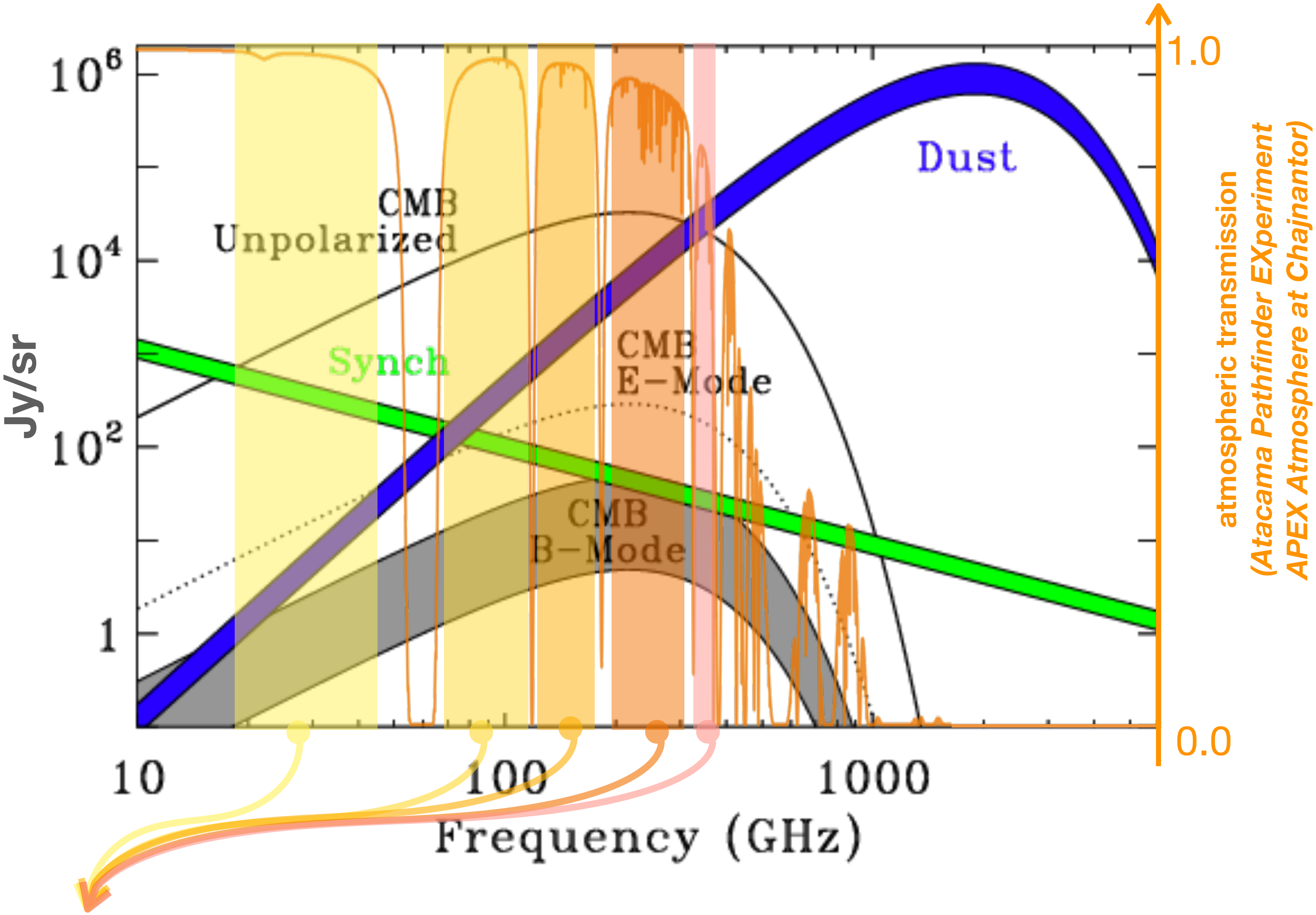


$$d(\nu_i) = \mathbf{A}^{\nu_i}_{\mathrm{dust}} s_{\mathrm{dust}} + \mathbf{A}^{\nu_i}_{\mathrm{synch}} s_{\mathrm{synch}} + \mathbf{A}^{\nu_i}_{\mathrm{CMB}} s_{\mathrm{CMB}} + n(\nu_i)$$

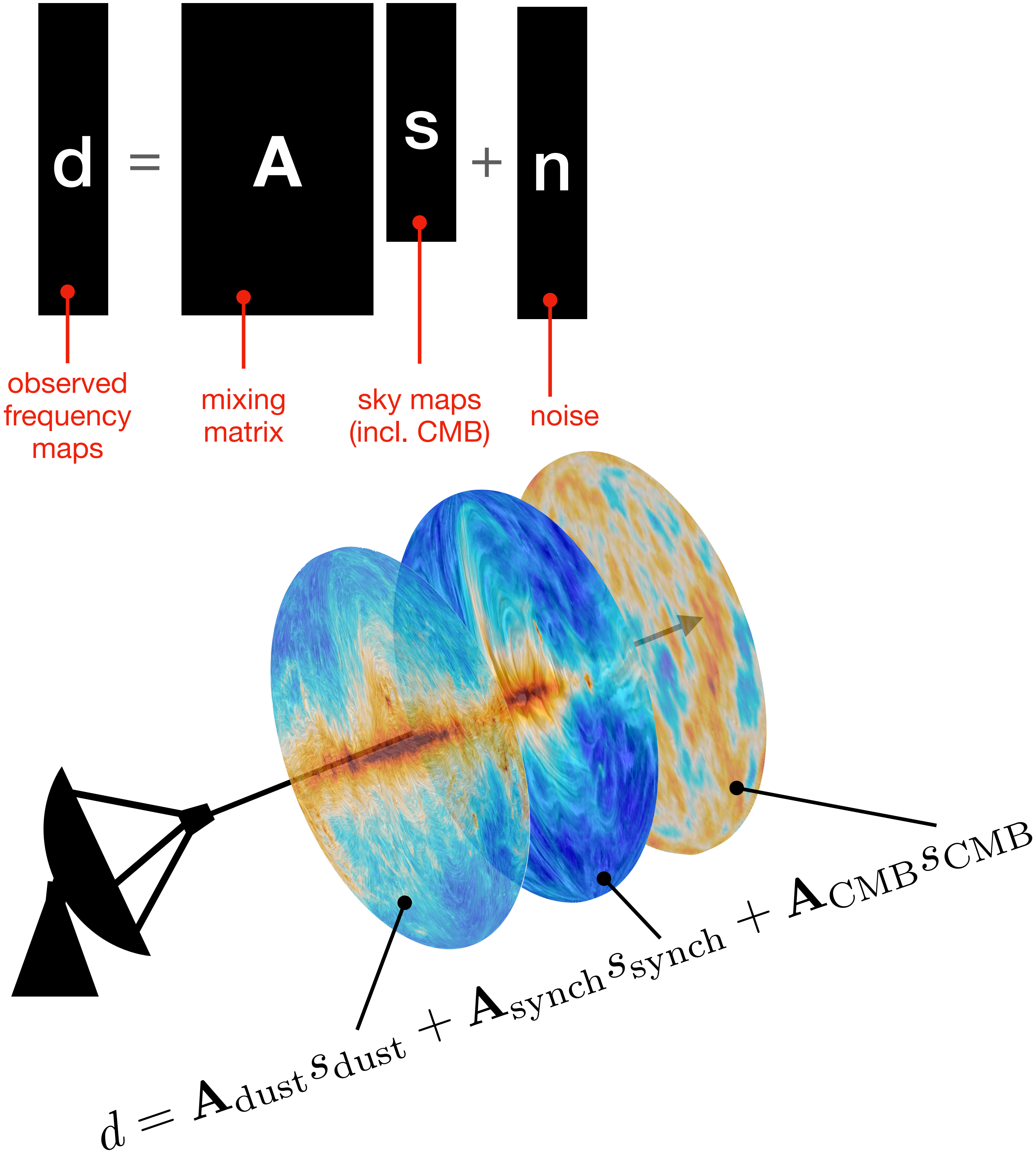
Component separation

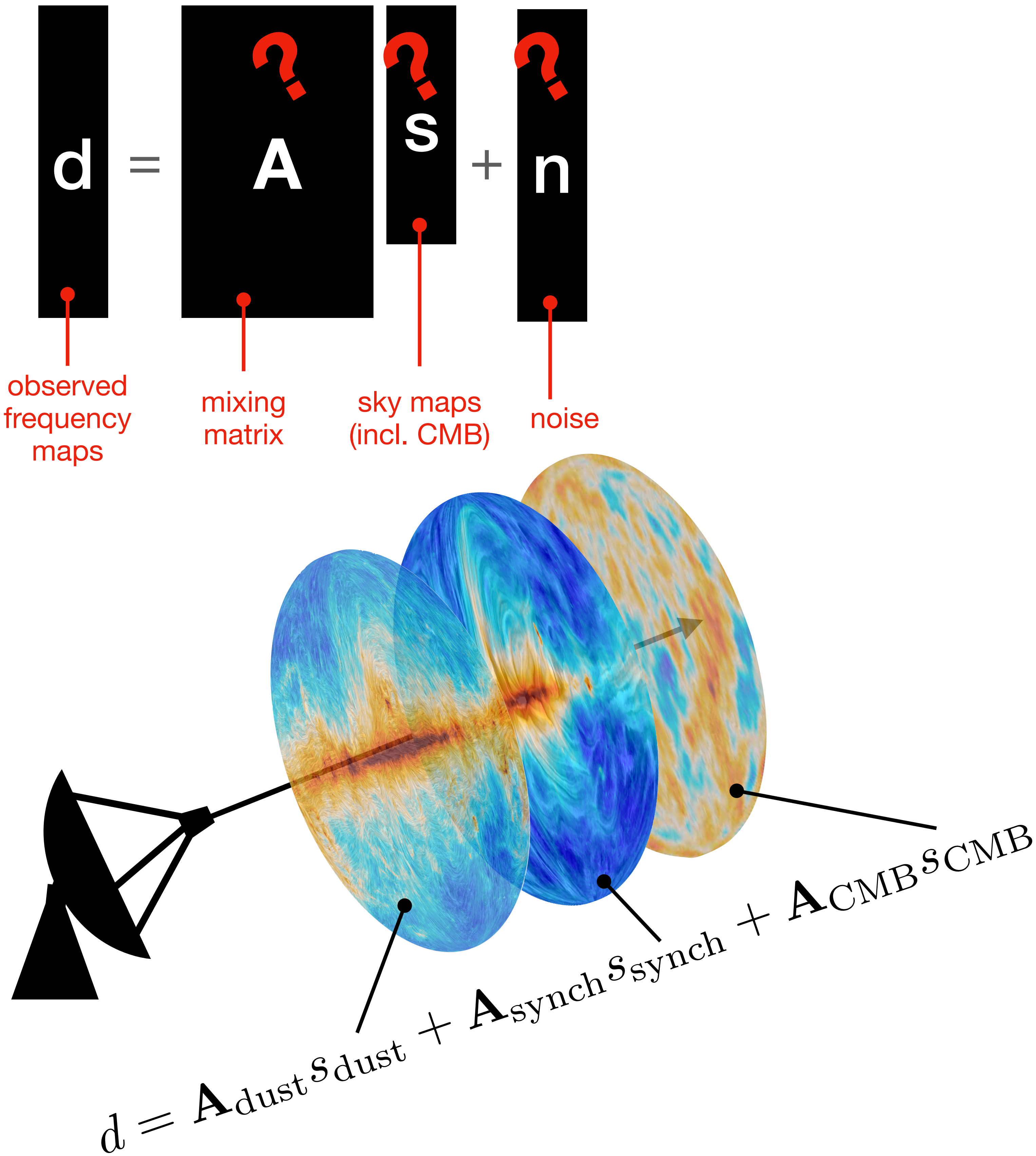
adapted from Kogut et al. 2016



$$d(\nu_i) = \mathbf{A}^{\nu_i}_{\mathrm{dust}} s_{\mathrm{dust}} + \mathbf{A}^{\nu_i}_{\mathrm{synch}} s_{\mathrm{synch}} + \mathbf{A}^{\nu_i}_{\mathrm{CMB}} s_{\mathrm{CMB}} + n(\nu_i)$$

$$\Rightarrow \quad \tilde{s}_{\mathrm{CMB}} + \tilde{n}_{\mathrm{CMB}} = \sum_i \mathbf{W}_i d(\nu_i)$$


d = A s + n
observed frequency maps
mixing matrix
sky maps (incl. CMB)
noise
$d = \mathbf{A}_{\rm dust} s_{\rm dust} + \mathbf{A}_{\rm synch} s_{\rm synch} + \mathbf{A}_{\rm CMB} s_{\rm CMB}$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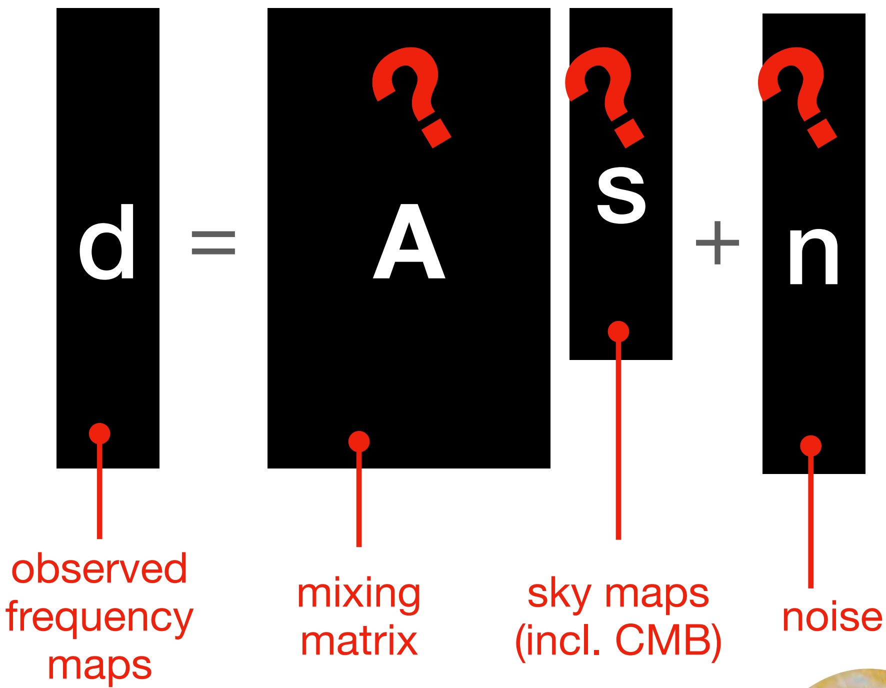
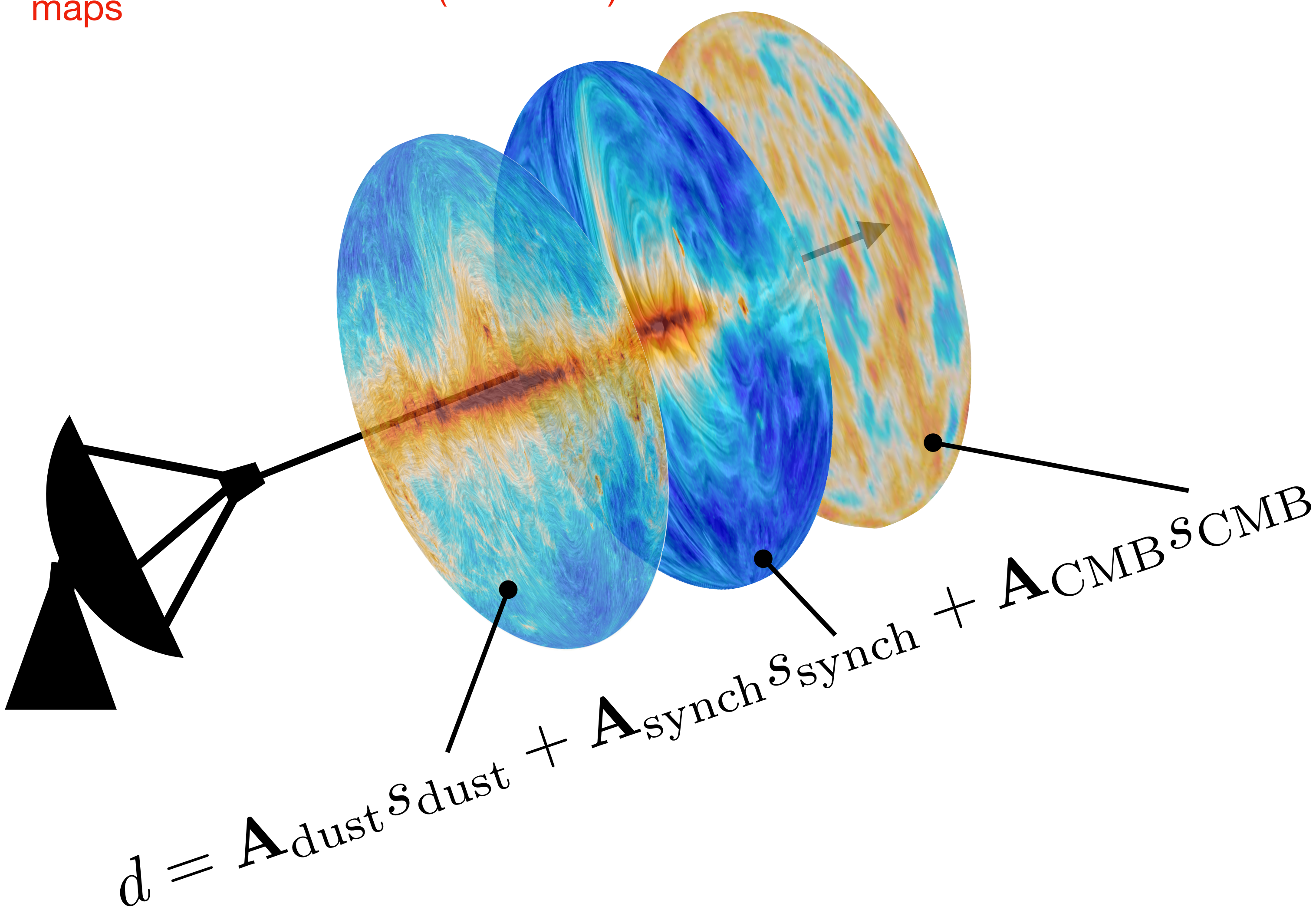
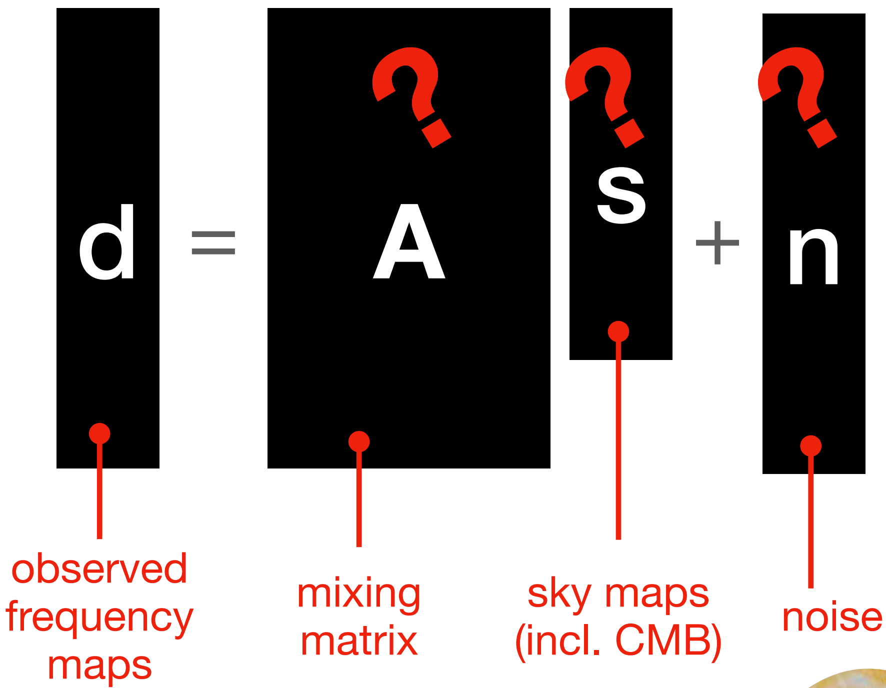


$$-2\log(\mathcal{L})\left(\mathbf{A}, s\right) = \left(d - \mathbf{A}s\right)^T \mathbf{N}^{-1}\left(d - \mathbf{A}s\right)$$

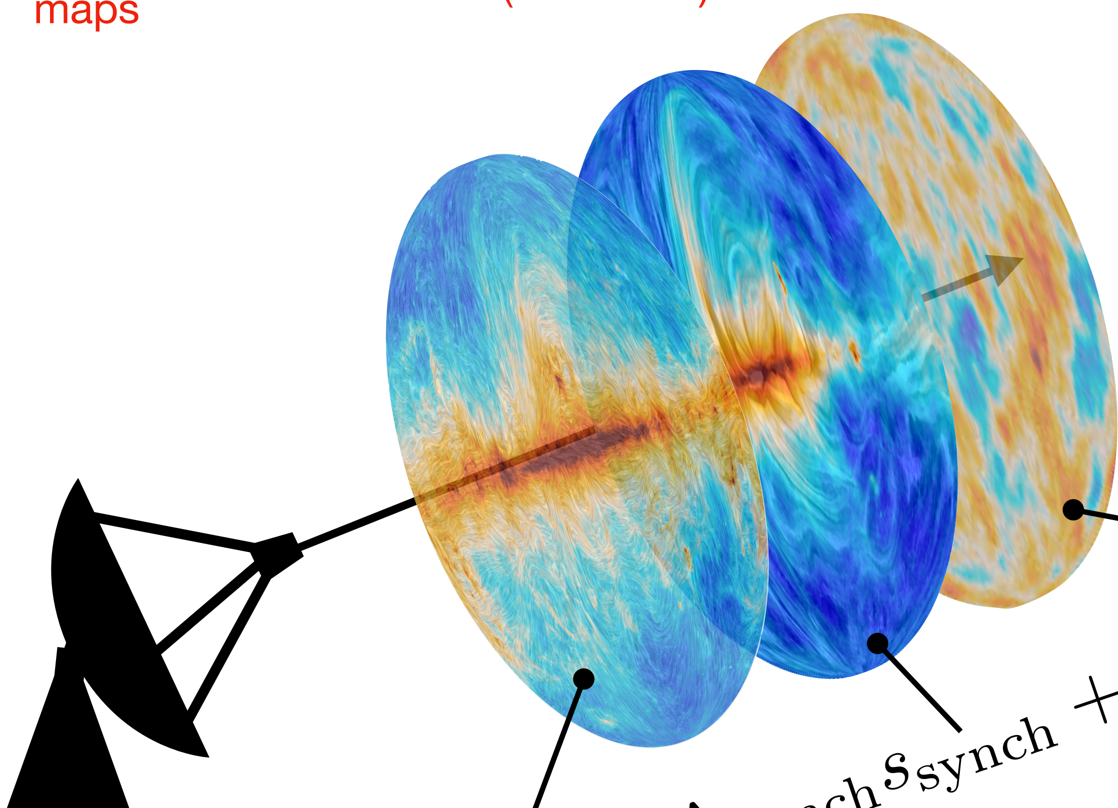




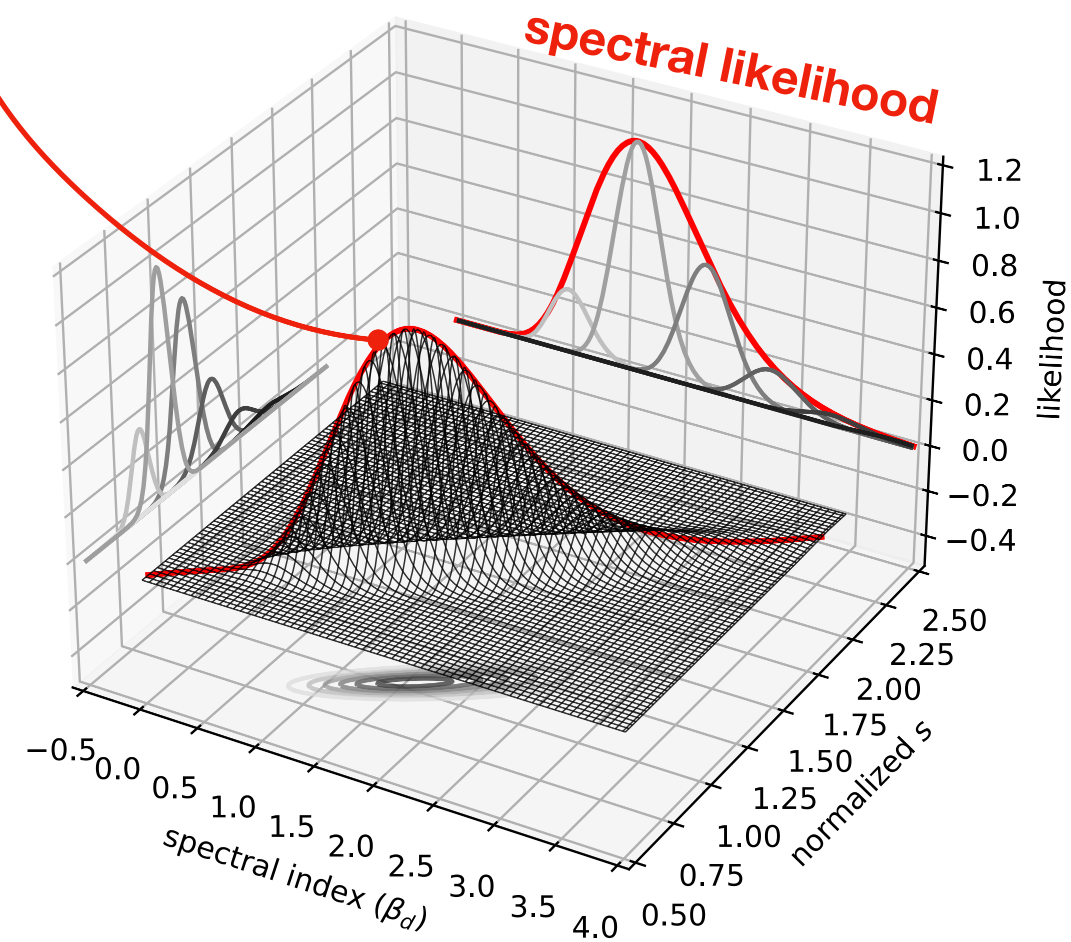
$$-2\log(\mathcal{L})\,(\mathbf{A},s) = (d-\mathbf{A}s)^T\,\mathbf{N}^{-1}\,(d-\mathbf{A}s)$$

$$\begin{aligned}\tilde{s} &= \left(\mathbf{A}^T\mathbf{N}^{-1}\mathbf{A}\right)^{-1}\mathbf{A}^T\mathbf{N}^{-1}d\\ &\equiv \mathbf{W}d\end{aligned}$$

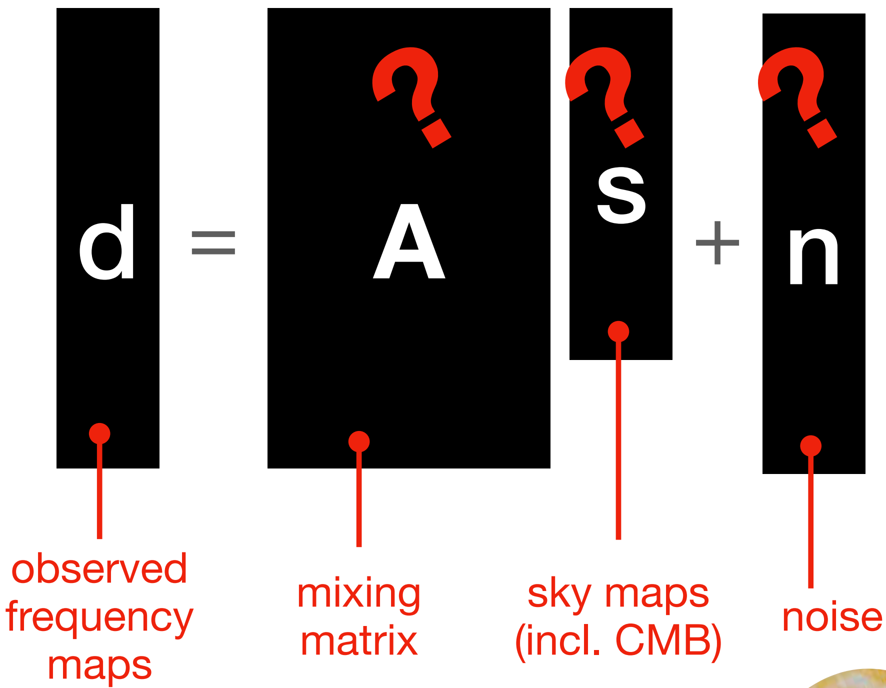
$$\begin{aligned}-2\log(\mathcal{L}_{\rm spec})\,(\mathbf{A}) &\equiv -2\log(\mathcal{L}_{\rm spec})\,(\mathbf{A},\tilde{s})\\ &= -d^T\mathbf{N}^{-1}\mathbf{A}\left(\mathbf{A}^T\mathbf{N}^{-1}\mathbf{A}\right)^{-1}\mathbf{A}^T\mathbf{N}^{-1}d.\end{aligned}$$



$$d = \mathbf{A}_{\rm dust}s_{\rm dust} + \mathbf{A}_{\rm synch}s_{\rm synch} + \mathbf{A}_{\rm CMB}s_{\rm CMB}$$



Stivoli et al. (MNRAS, 2010)
JE, Stivoli and Stompor (PRD, 2011)
JE and Stompor (PRD, 2012)
JE, Feeney, Peiris, Jaffe (JCAP, 2016)
Stompor, JE and Poletti (PRD, 2016)
JE and Stompor (PRD, 2019)



$$-2\log(\mathcal{L})\,(\mathbf{A}, s) = (d - \mathbf{A}s)^T\,\mathbf{N}^{-1}\,(d - \mathbf{A}s)$$

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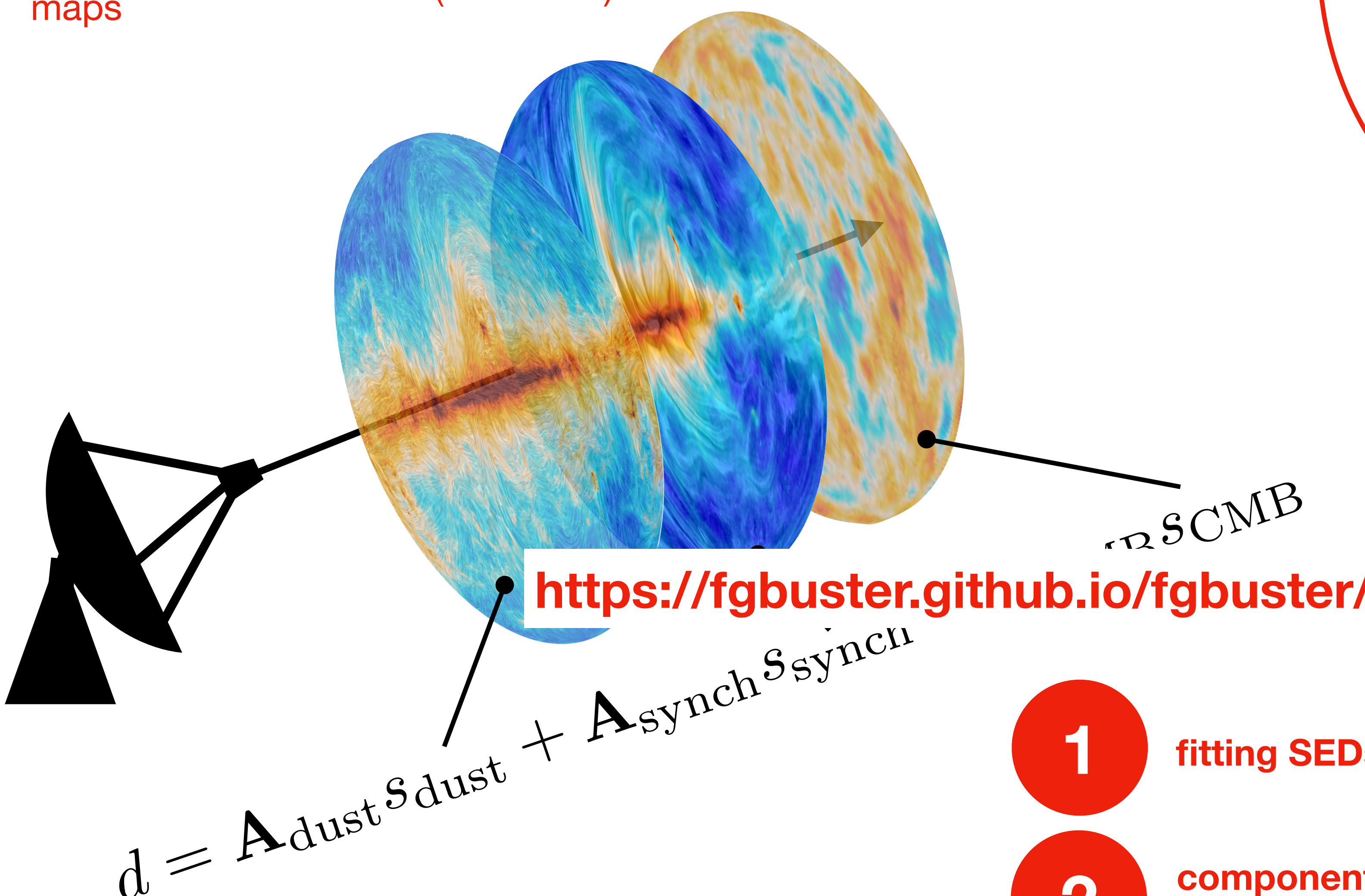
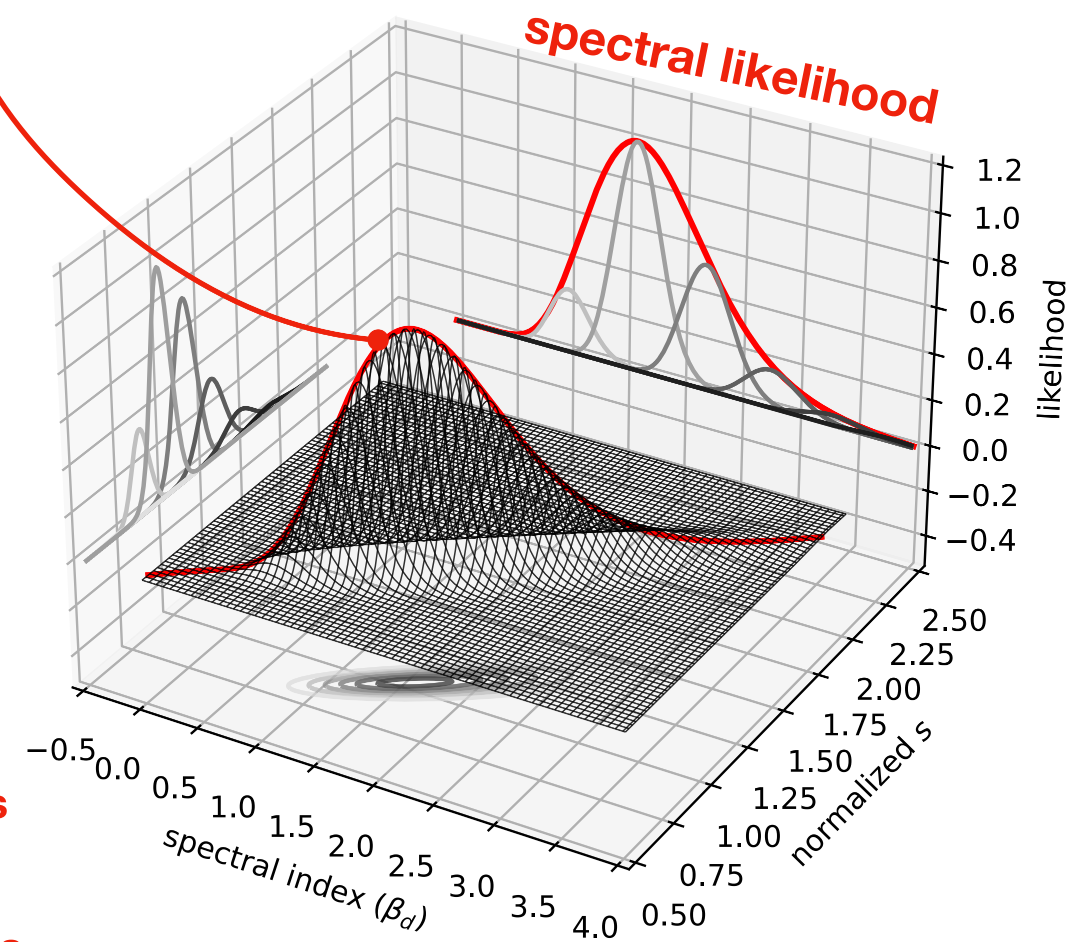
$$\begin{aligned}-2\log(\mathcal{L}_{\rm spec})\,(\mathbf{A}) &\equiv -2\log(\mathcal{L}_{\rm spec})\,(\mathbf{A}, \tilde{s})\\ &= -d^T\mathbf{N}^{-1}\mathbf{A}\left(\mathbf{A}^T\mathbf{N}^{-1}\mathbf{A}\right)^{-1}\mathbf{A}^T\mathbf{N}^{-1}d.\end{aligned}$$





1. **fitting SEDs**
2. **components maps (CMB)**
3. **cosmology**

Stivoli et al. (MNRAS, 2010)
JE, Stivoli and Stompor (PRD, 2011)
JE and Stompor (PRD, 2012)
JE, Feeney, Peiris, Jaffe (JCAP, 2016)
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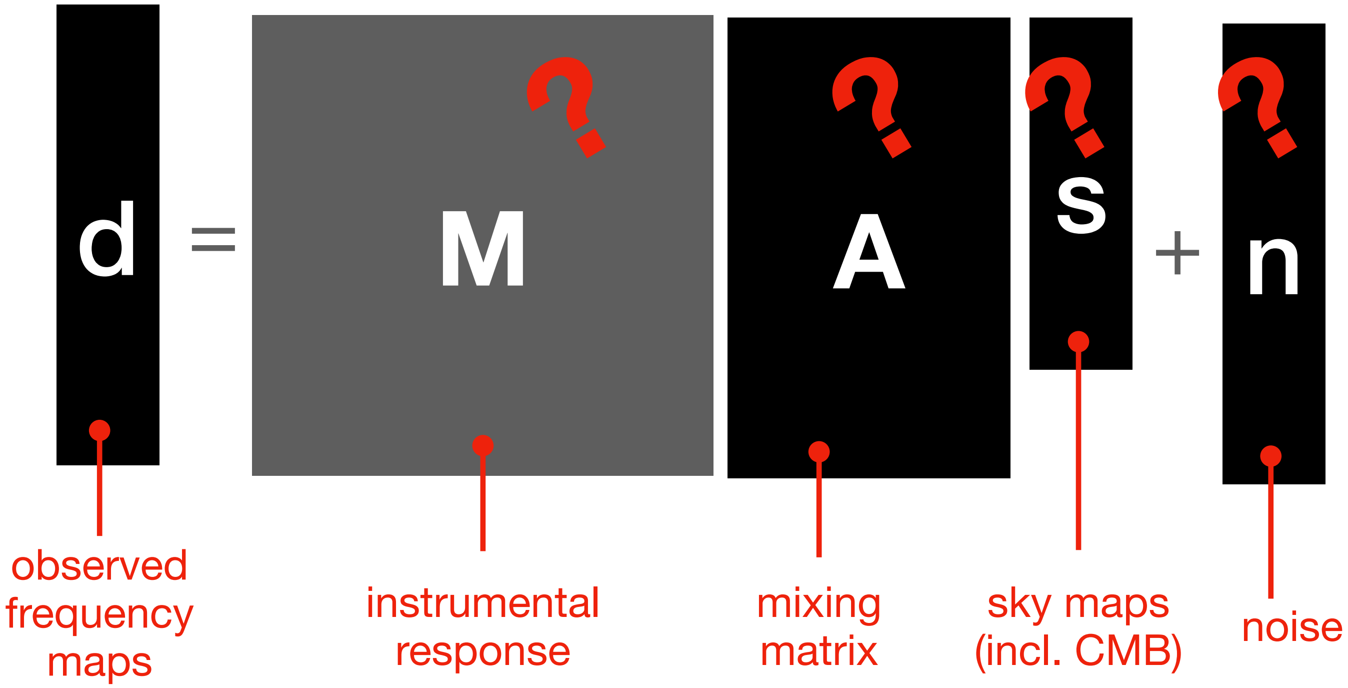
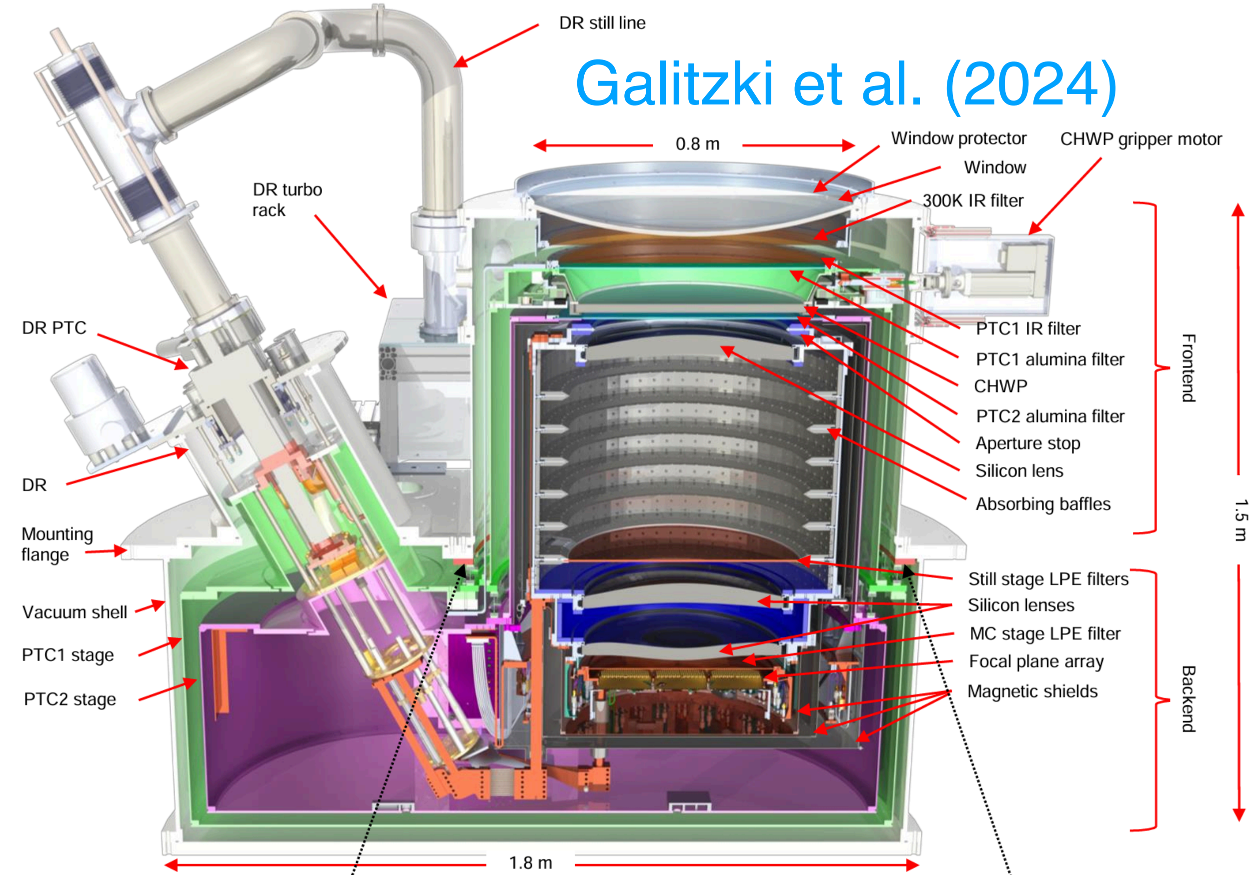


Vergès, JE, Stompor (2020)



Galitzki et al. (2024)

$$d = M\,A\,s + n$$

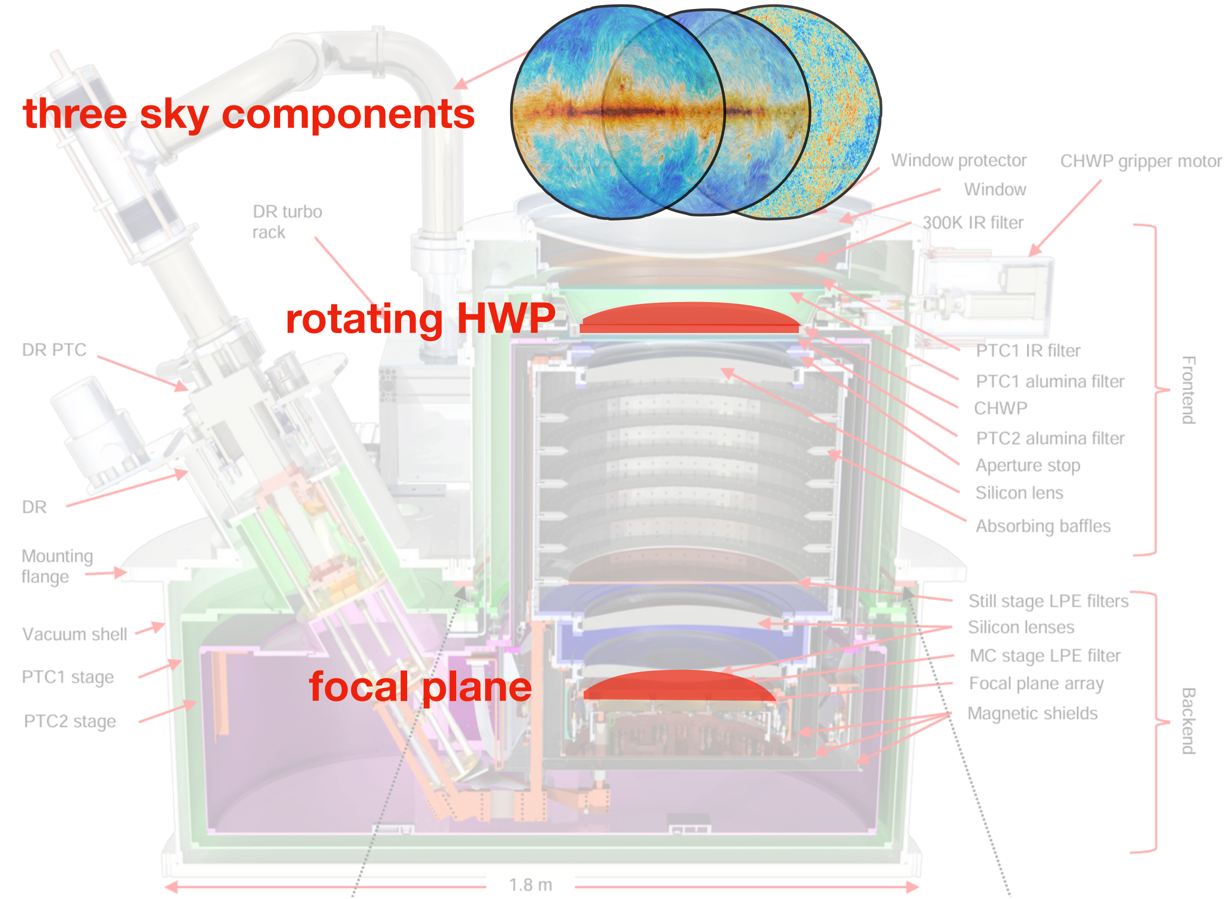
observed frequency maps

instrumental response

mixing matrix

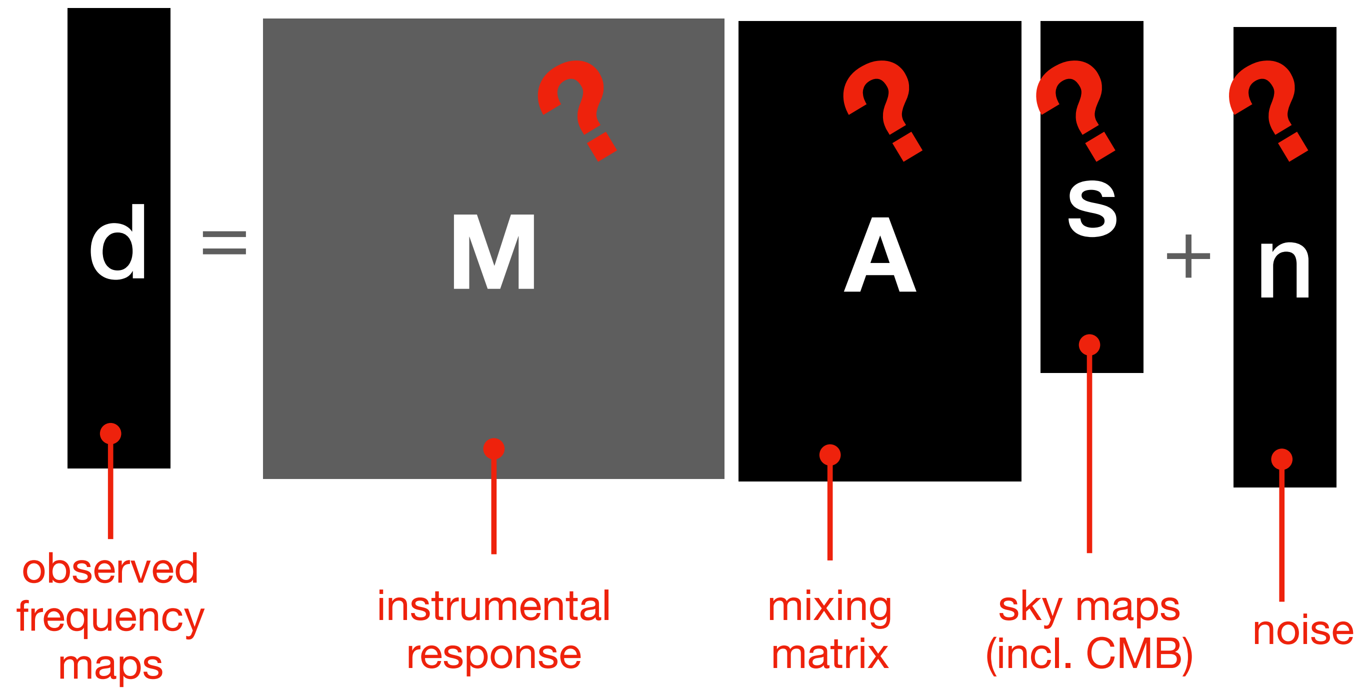
sky maps (incl. CMB)

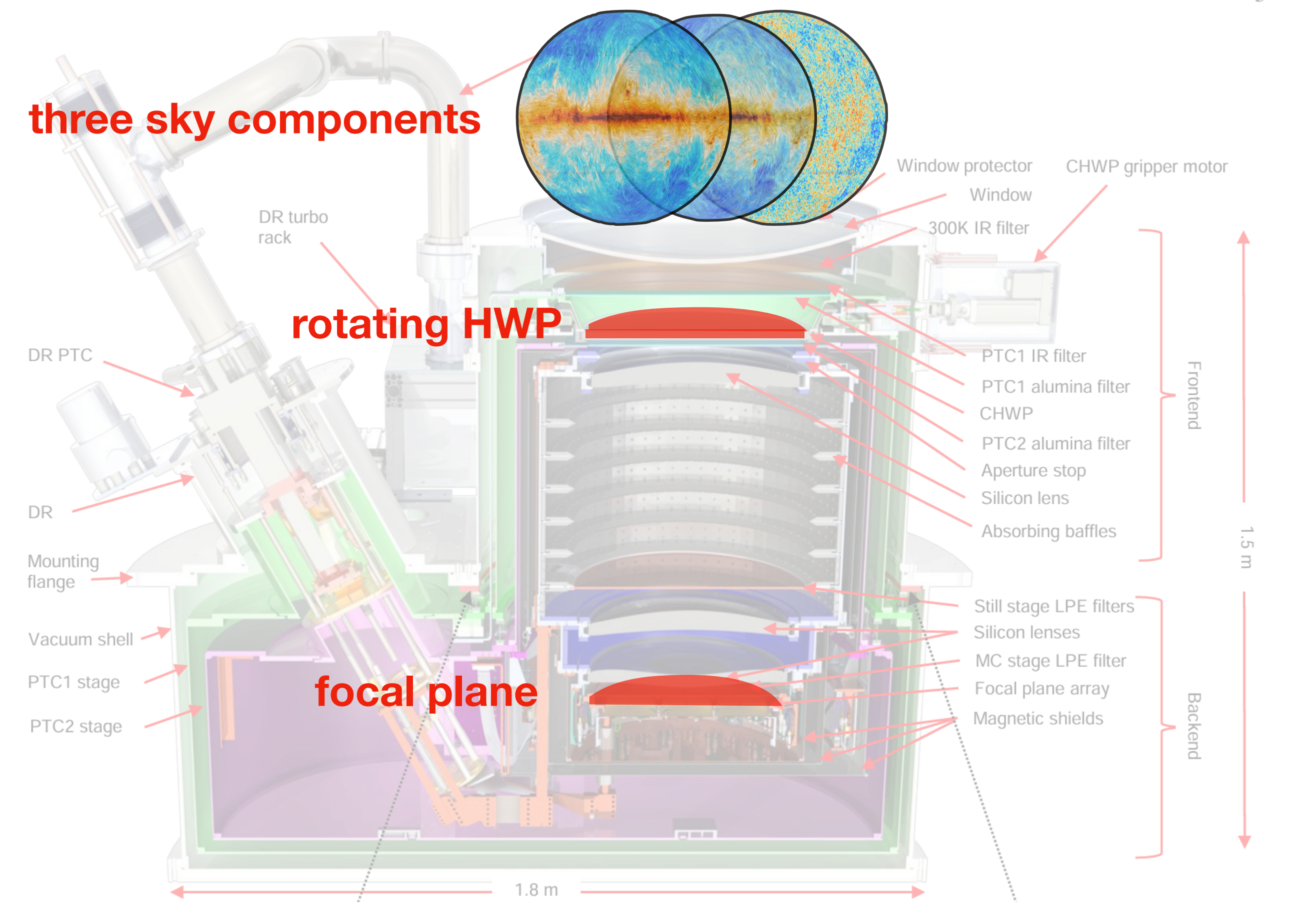
noise



Vergès, JE, Stompor (2020)

+ see talk by Ema yesterday

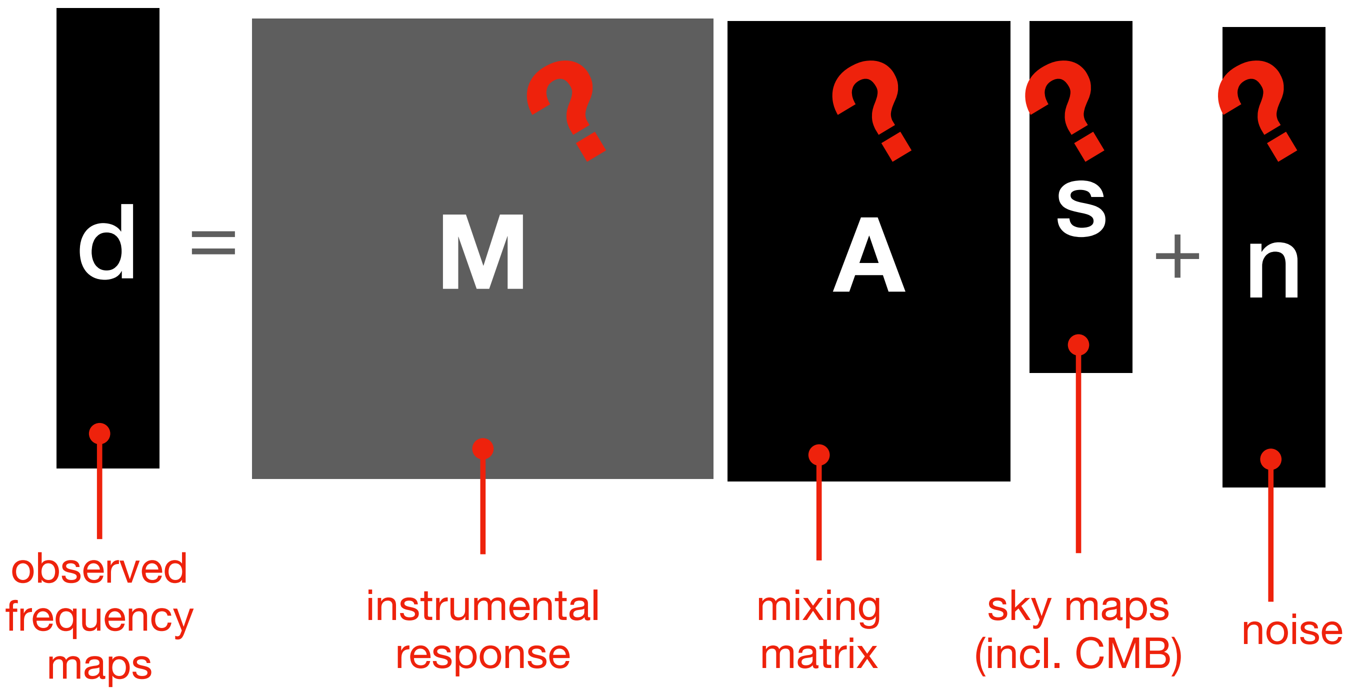


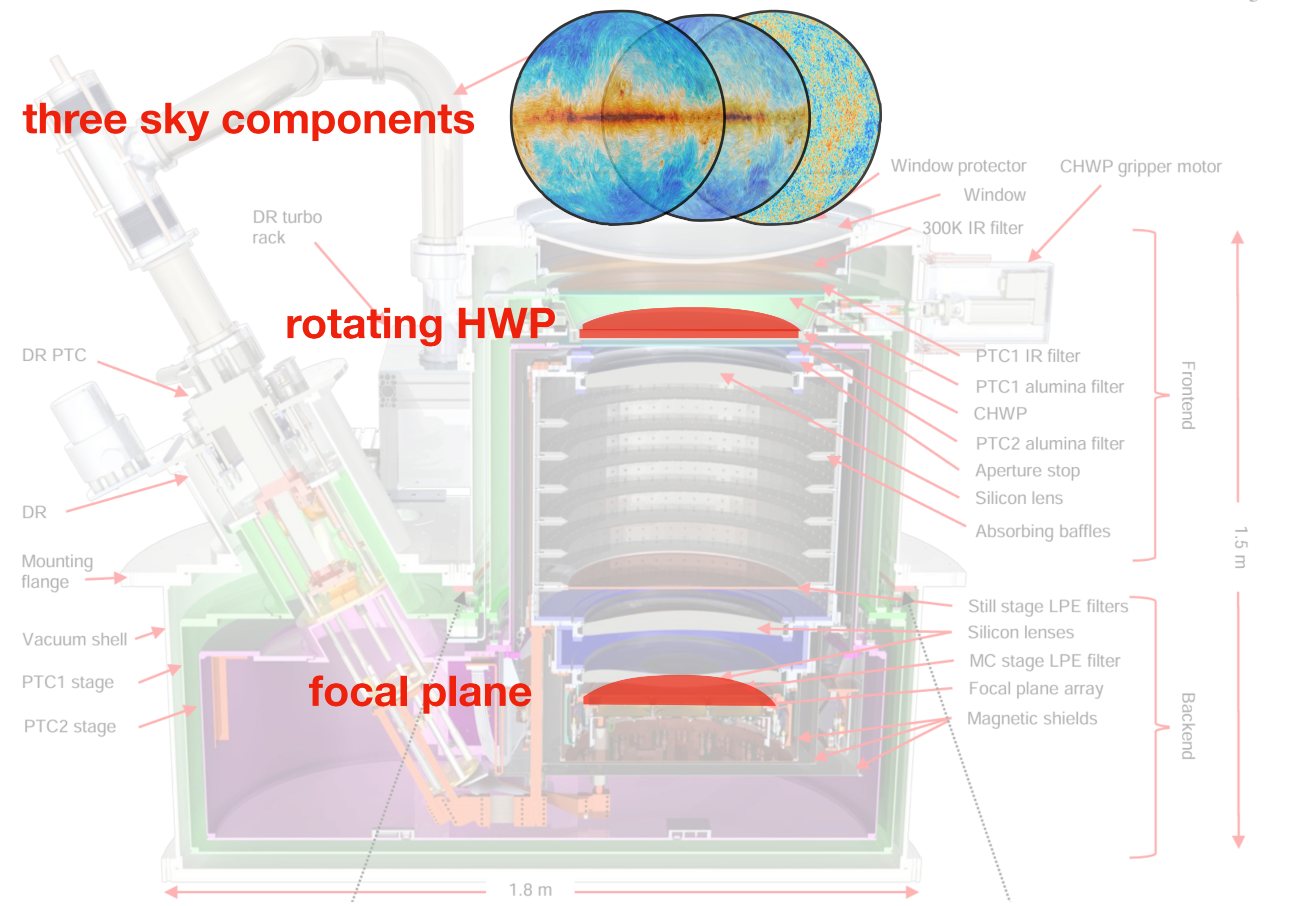


Vergès, JE, Stompor (2020)

+ see talk by Ema yesterday

$$\underbrace{\begin{pmatrix} \mathcal{I}(\gamma_t,\nu) \\ \mathcal{C}_0(\gamma_t,\nu) \\ \mathcal{S}_0(\gamma_t,\nu) \\ \mathcal{C}_4(\gamma_t,\nu) \\ \mathcal{S}_4(\gamma_t,\nu) \end{pmatrix}}_{\equiv\ d(\gamma_t,\nu)} \equiv \sum_{\substack{\text{comp=cmb}\\ \text{dust,sync}}} \underbrace{\mathbf{M}(\nu)\,\mathbf{A}^{\text{comp}}(\nu,\nu_0)}_{\equiv\ \mathbf{\Lambda}^{\text{comp}}(\nu,\nu_0)} \underbrace{\begin{pmatrix} \mathrm{I}_{\text{comp}}(\gamma_t,\nu_0) \\ \mathrm{Q}_{\text{comp}}(\gamma_t,\nu_0) \\ \mathrm{U}_{\text{comp}}(\gamma_t,\nu_0) \end{pmatrix}}_{\equiv\ s_{\text{comp}}(\gamma_t,\nu_0)}$$



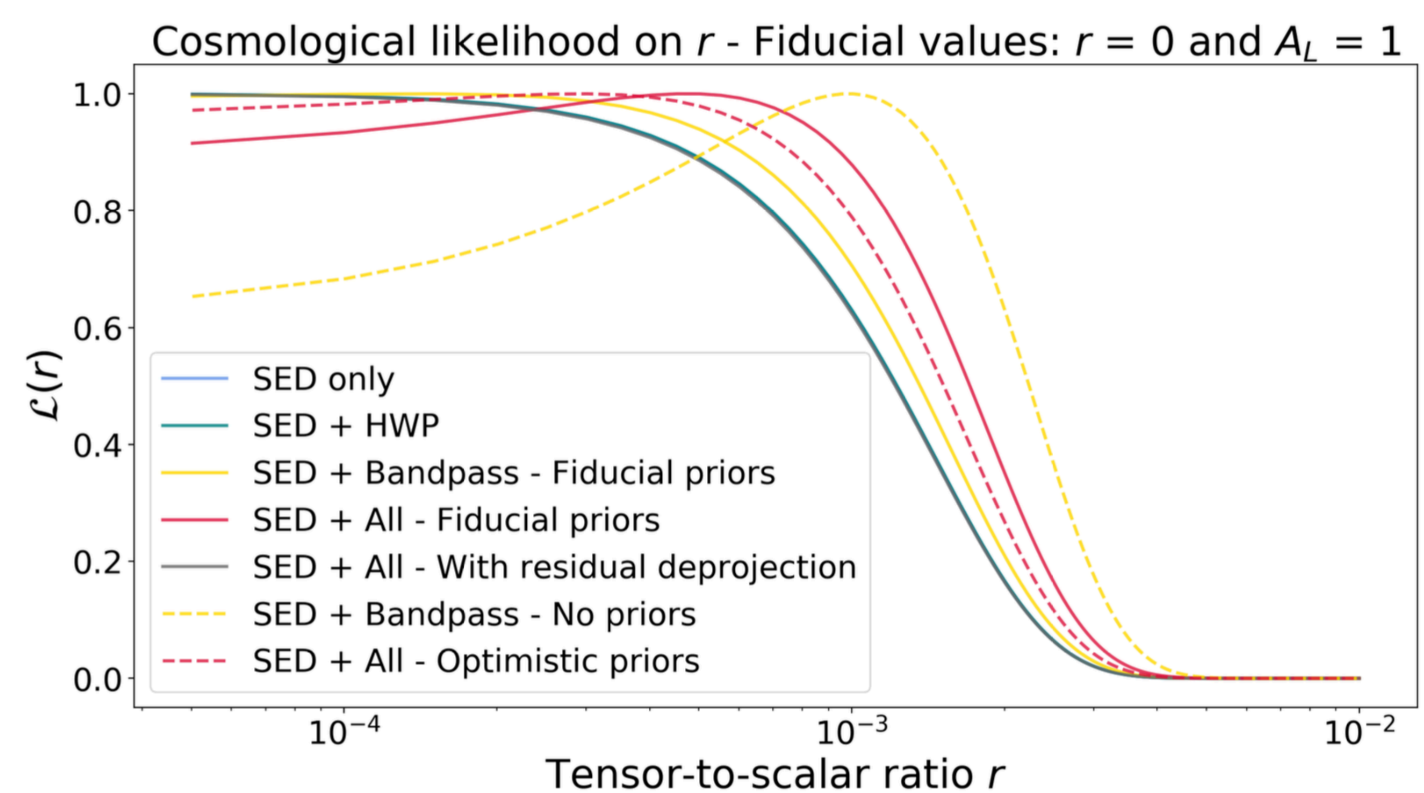


Vergès, JE, Stompor (2020)

+ see talk by Ema yesterday

$$\underbrace{\begin{pmatrix}\mathcal{I}(\gamma_t,\nu)\\ \mathcal{C}_0(\gamma_t,\nu)\\ \mathcal{S}_0(\gamma_t,\nu)\\ \mathcal{C}_4(\gamma_t,\nu)\\ \mathcal{S}_4(\gamma_t,\nu)\end{pmatrix}}_{\equiv\, d(\gamma_t,\nu)} \equiv \sum_{\substack{\mathrm{comp=cmb}\\ \mathrm{dust,sync}}} \underbrace{\mathbf{M}(\nu)\,\mathbf{A}^{\mathrm{comp}}(\nu,\nu_0)}_{\equiv\, \mathbf{\Lambda}^{\mathrm{comp}}(\nu,\nu_0)} \underbrace{\begin{pmatrix}\mathrm{I}_{\mathrm{comp}}(\gamma_t,\nu_0)\\ \mathrm{Q}_{\mathrm{comp}}(\gamma_t,\nu_0)\\ \mathrm{U}_{\mathrm{comp}}(\gamma_t,\nu_0)\end{pmatrix}}_{\equiv\, s_{\mathrm{comp}}(\gamma_t,\nu_0)}$$

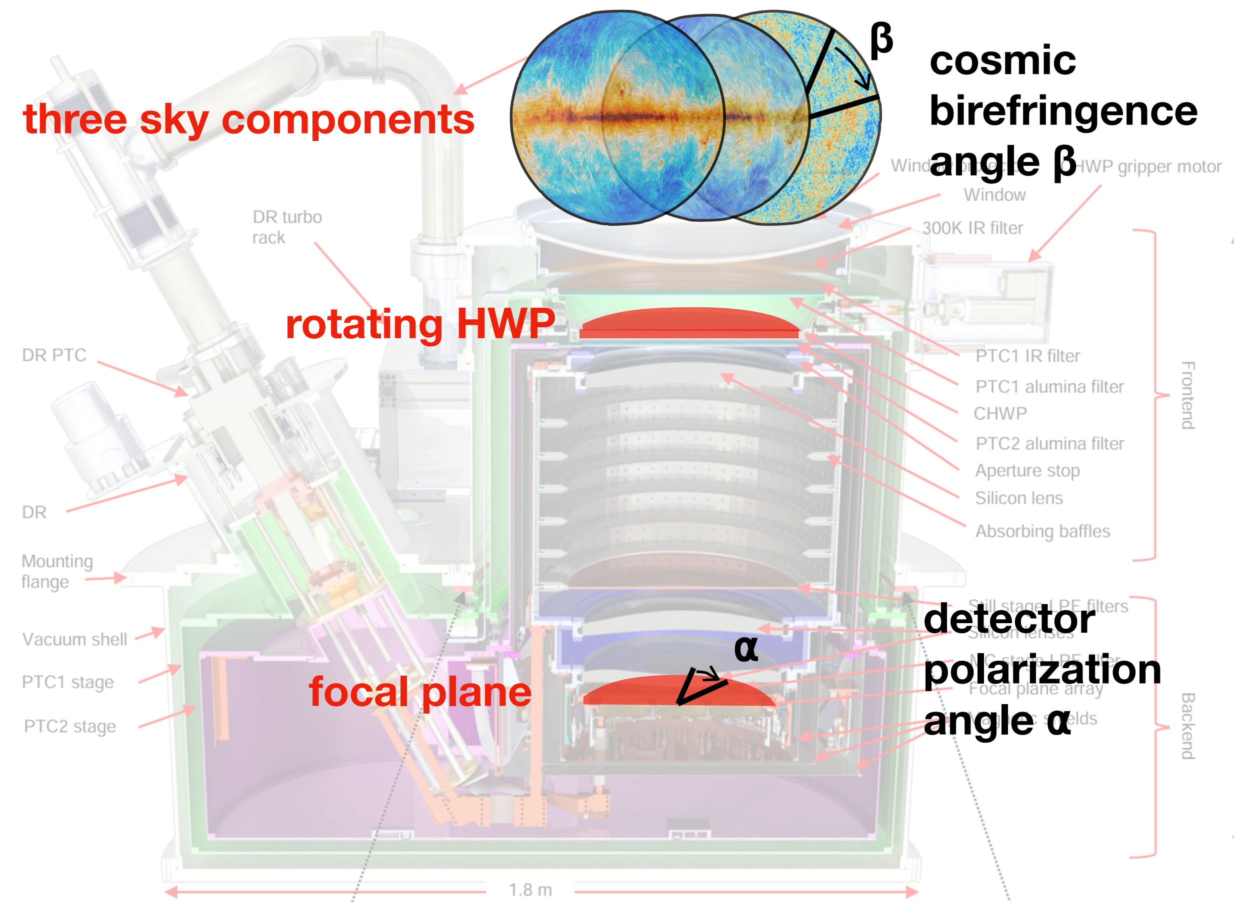
"[…] We find that some of the instrumental parameters, in particularly those describing the HWP can be successfully constrained by the data themselves without need for external information, while others, like bandpasses, need to be known with good precision in advance."

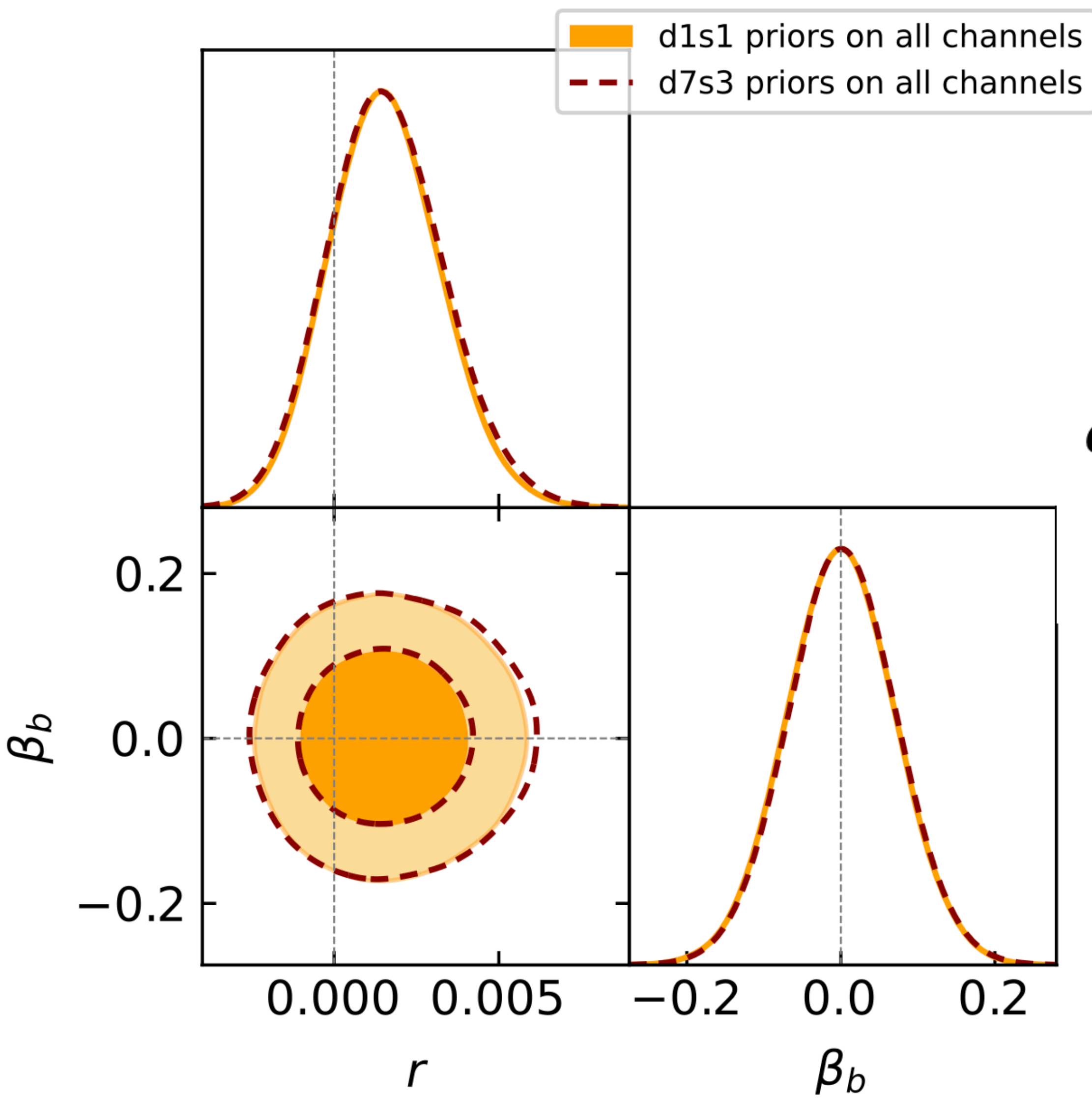


Jost, JE, Stompor (2023)

➔ **see talk by Baptiste this morning**

+ LiteBIRD article on cosmic birefringence (in prep, 2024)





$$\boldsymbol{d}_p = \underbrace{\boldsymbol{M}_p(\{\alpha_1, \dots, \alpha_{n_f}\})\, \boldsymbol{A}_p(\{\beta_{fg}\})}_{\boldsymbol{\Lambda}_p(\{\Gamma\})}\, \underbrace{\boldsymbol{\mathcal{B}}(\beta_b)\, \boldsymbol{c}_p}_{s_p} + \boldsymbol{n}_p$$

spectral likelihood

$$\langle S \rangle = \overbrace{-2 \sum_p \mathrm{tr}\left(\boldsymbol{N}_p^{-1} \boldsymbol{\Lambda}_p (\boldsymbol{\Lambda}_p^t \boldsymbol{N}_p^{-1} \boldsymbol{\Lambda}_p)^{-1} \boldsymbol{\Lambda}_p^t \boldsymbol{N}_p^{-1} \langle \boldsymbol{d}_p \boldsymbol{d}_p^t \rangle \right)}^{\text{spectral likelihood}}$$

$$\underbrace{+ \sum_{\alpha_i} \frac{(\alpha_i - \hat{\alpha}_i)^2}{2\sigma_{\alpha_i}^2}}_{\text{prior}}$$

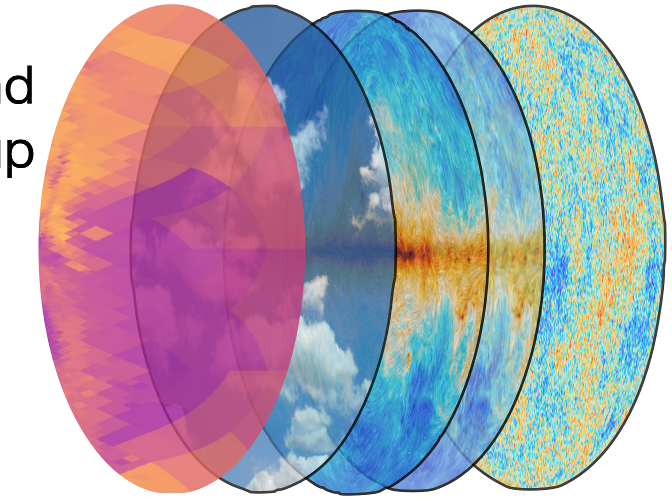
prior

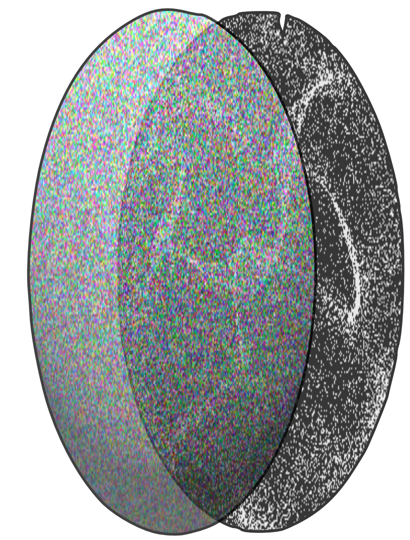
$$\begin{pmatrix} I \\ Q \\ U \end{pmatrix} = d = \mathbf{M}_{\mathrm{inst}}(\gamma)\mathbf{A}(\beta)s + n(\sigma)$$

global operator depending on time, frequency, non-linear parameters

$$\begin{pmatrix} I \\ Q \\ U \end{pmatrix} = d = \boxed{\mathbf{M}_{\mathrm{inst}}(\gamma)\mathbf{A}(\beta)} s + n(\sigma)$$

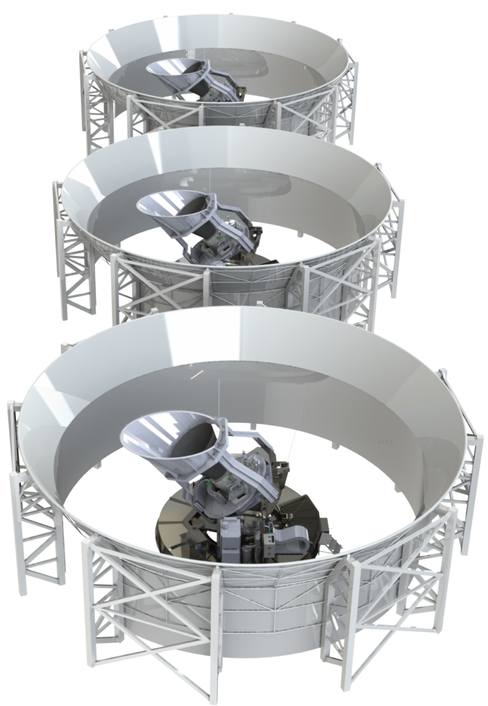
global operator depending on time, frequency, non-linear parameters





$$\begin{pmatrix} I \\ Q \\ U \end{pmatrix} = d = \mathbf{M}_{\rm inst}(\gamma)\mathbf{A}(\beta)s + n(\sigma)$$

- Pointing, beams
- HWP modulation
  see talk by Ema
- bandpasses
- polarization angles
- gains
- …

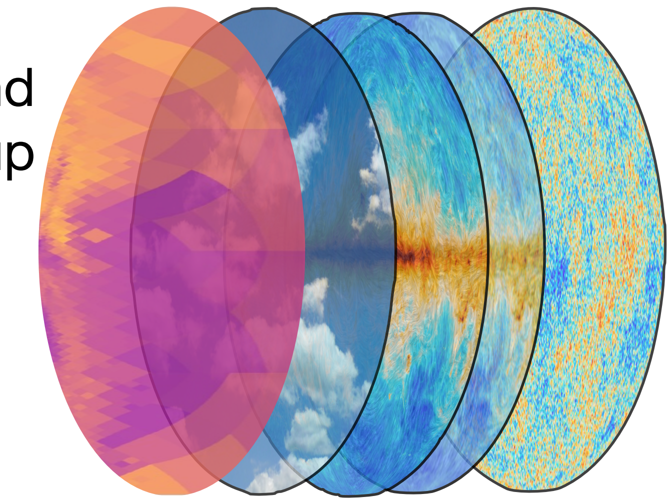


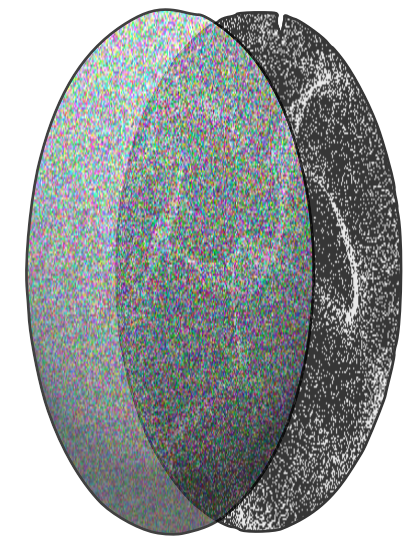
atmosphere contamination

Galactic foregrounds

CMB

Ground pickup





instrumental noise

1/f noise

global operator depending on time, frequency, non-linear parameters

$$\begin{pmatrix} I \\ Q \\ U \end{pmatrix} = d = \boxed{\mathbf{M}_{\mathrm{inst}}(\gamma)\mathbf{A}(\beta)} s + n(\sigma)$$

- Pointing, beams
- HWP modulation
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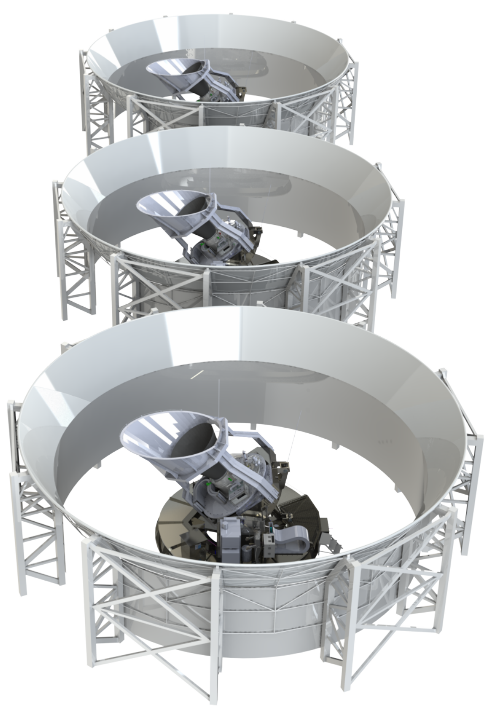

external information is required to solve the global problem!

SO drone / CosmoCal / wiregrid projects

see talks by Rolando, Alessia, Hironobu

SciPol

Science from the large scale cosmic microwave background polarization structure

➔ CMB data analysis toolbox for a generalized (time-domain) component separation

$$d = \mathbf{M}_{\rm inst}(\gamma)\mathbf{A}(\beta)s + n(\sigma)$$

WP1-1 hardware model

$\mathbf{M}(\gamma)$

$\mathbf{\Lambda} \equiv \mathbf{MA}$

WP1-2 foregrounds model

$\mathbf{A}(\beta)$

WP1-3 noise model

$\mathbf{W}, \mathbf{W}^{-1}$

Simons Array

SIMONS OBSERVATORY

CMB-S4 Next Generation CMB Experiment

LiteBIRD

real and simulated data

Planck / WMAP / SPASS / C-BASS

WP2-1generalized spectral likelihood

$$2\log\mathcal{L}(\beta,\gamma) = -\left(\mathbf{\Lambda}^T\mathbf{W}d\right)^T\left(\mathbf{\Lambda}^T\mathbf{W}\mathbf{\Lambda}\right)^{-1}\left(\mathbf{\Lambda}^T\mathbf{W}d\right) + d^T\mathbf{W}d + \log\left(2\pi|\mathbf{W}^{-1}|\right) + \text{priors}$$

$\tilde{\mathbf{\Lambda}} \equiv \mathbf{\Lambda}(\tilde{\gamma}, \tilde{\beta}),\ \tilde{\mathbf{W}} \equiv \mathbf{W}(\tilde{\sigma}, \tilde{\sigma}')$

WP2-2 generalized map-making

$$\tilde{s} = \left(\tilde{\mathbf{\Lambda}}^T\tilde{\mathbf{W}}\tilde{\mathbf{\Lambda}}\right)^{-1}\tilde{\mathbf{\Lambda}}^T\tilde{\mathbf{W}}d$$

$\tilde{s},\ \sigma(\tilde{s})$

WP3 cosmological analysis

SciPol

Science from the large scale cosmic microwave background polarization structure

➔ CMB data analysis toolbox for a generalized (time-domain) component separation

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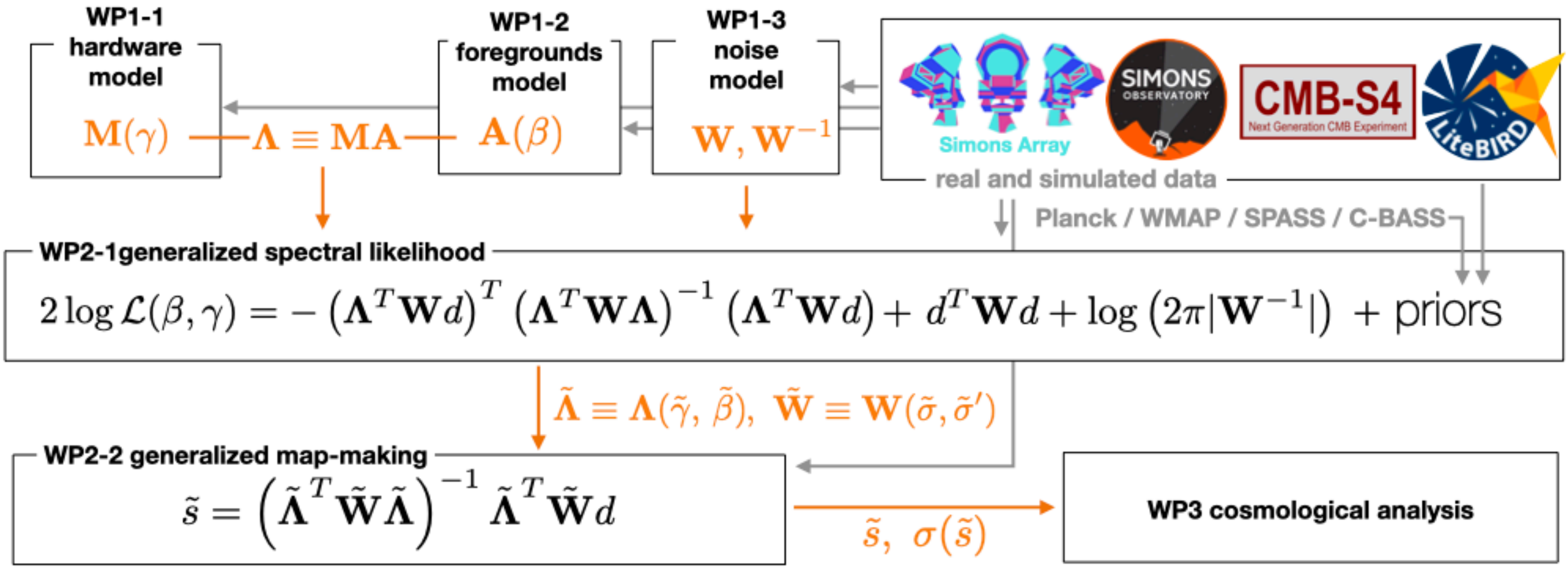


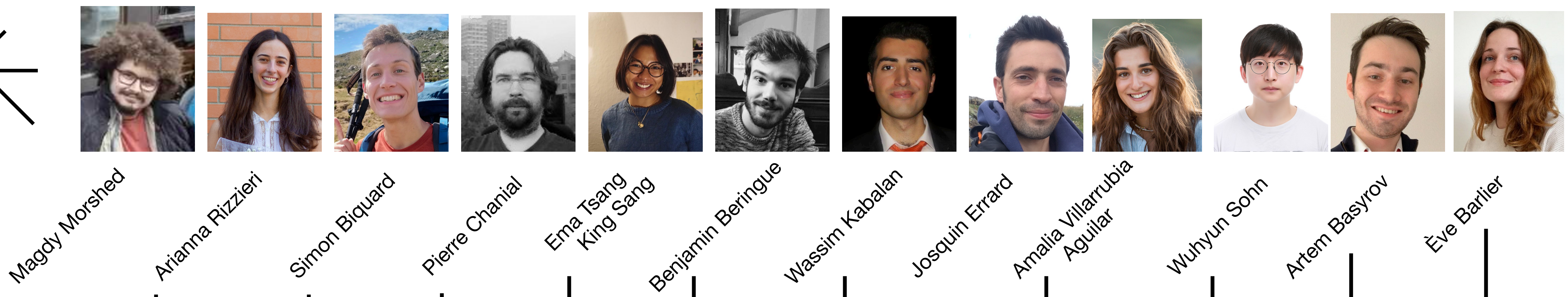
➔ huge numerical challenge!

Global scientific goal: derive robust estimates of the CMB maps and their cosmological inference

This involves

- modeling of the instrumental response (WP1-1), foregrounds (WP1-2), noise properties (WP1-3)
- generalization of the map-making and component separation operations (WP2-1 and WP2-2), their optimisation and exploitation (WP2-3)
- perform cosmological inference (WP3-1), delensing (WP3-2), and the creation and application of robustness tests (WP3-3)

SciPol



MICMAC non-parametric pixel-based max-likelihood component separation

Morshed et al. (2024) arXiv:2405.18365

inclusion of beam operator in the component separation

Rizzieri et al. (2409.12944)

- adaptive multiresolution parametric component separation for E and B-modes
- inclusion of selected instrumental systematics in the process

map-making (MAPPRAISER, jax-mapmaker)

astrosim — JAX framework for SciPol

HWP and SO optical chain modeling

MegaTop python-version of SMICA

- JAX-powered version of SMICA (in development)

astrosim
S2FFT
JAX optimization
fgbuster

time-domain comp sep (atmosphere and noise covariance estimation) + MegaTop

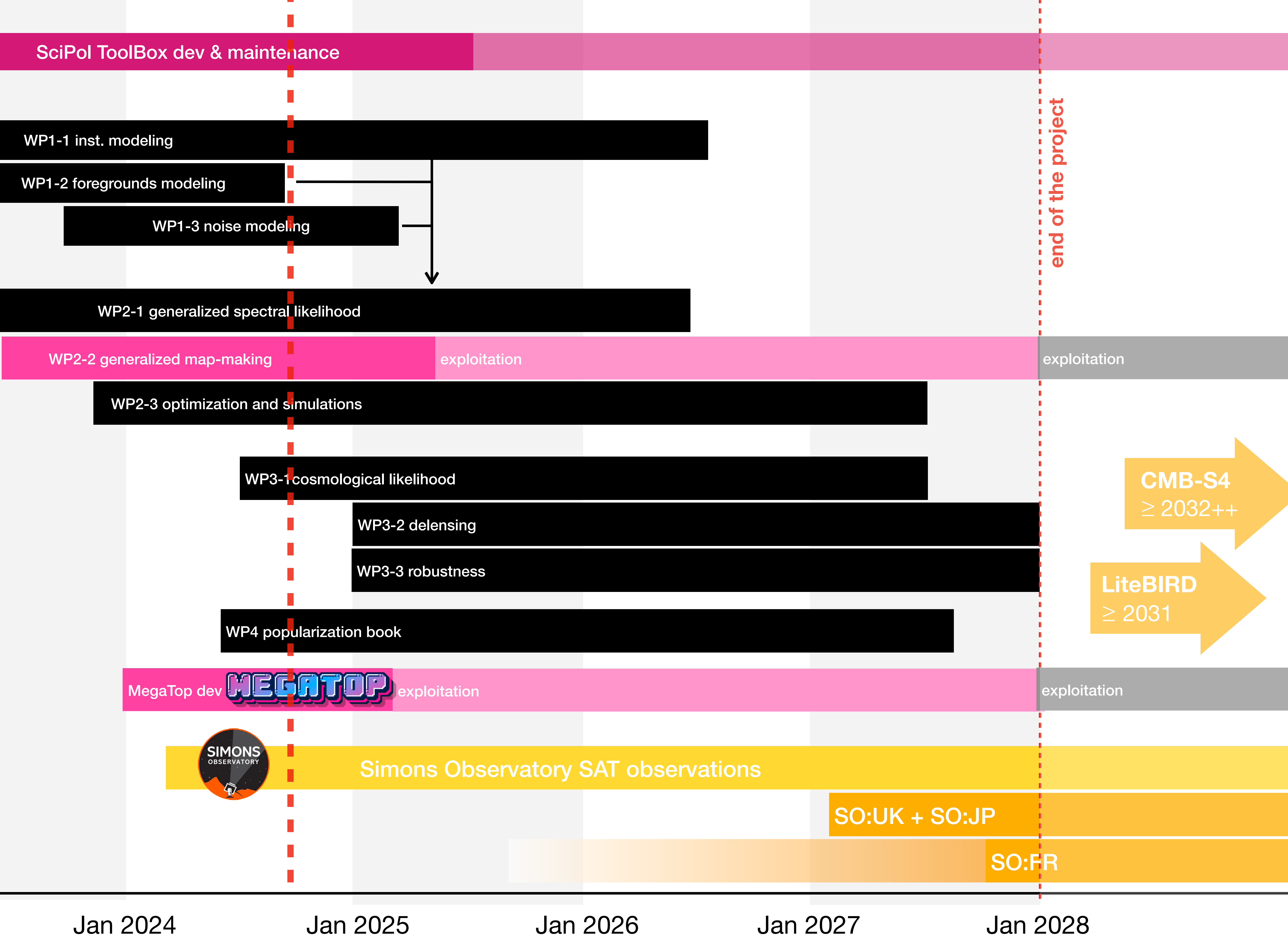
MegaTop, cosmology inference

systematics modeling and TOD pre-processing

popularization activities (books+school programs)

+ regulars

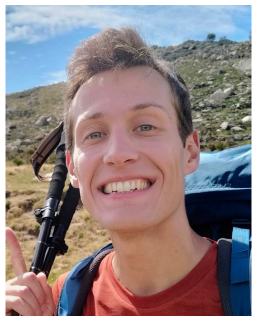
- L3/M1/M2 **interns**
- **collaborators** (Radek Stompor, Alexandre Boucaud) local and international (Clément Leloup, Baptiste Jost)
- **visitors**



SciPol ToolBox dev & maintenance
WP1-1 inst. modeling
WP1-2 foregrounds modeling
WP1-3 noise modeling
end of the project
WP2-1 generalized spectral likelihood
WP2-2 generalized map-making
exploitation
exploitation
WP2-3 optimization and simulations
WP3-1 cosmological likelihood
CMB-S4
≥ 2032++
WP3-2 delensing
WP3-3 robustness
LiteBIRD
≥ 2031
WP4 popularization book
MegaTop dev
MEGATOP
exploitation
exploitation
SIMONS
OBSERVATORY
Simons Observatory SAT observations
SO:UK + SO:JP
SO:FR
Jan 2024
Jan 2025
Jan 2026
Jan 2027
Jan 2028


Pierre Chanial


Wuhyun Sohn


Simon Biquard


Wassim Kabalan

Framework for Unified and Robust data Analysis with JAX

Beginners tutorial available here: https://scipol.in2p3.fr/scipol-science-from-the-large-scale-cosmic-microwave-background-polarization-structure/workshops-and-events/

automatic differentiation (autodiff)

Just-In-Time (JIT) compilation

GPU-accelerated computing

support for vectorized computation

functional programing paradigm

SciPol Toolbox

- Modularity, extensibility, simplicity
- Able to handle SO- and S4-like data sets volumes
- Compatibility with TOAST
- **Non-ideal optical components (talks by Ema and Matteo yesterday)**
- **JAX**: Just In Time (JIT) compilation, run the same code anywhere — on CPUs and GPUs, laptops and super-computers (e.g., NERSC, national infrastructures)
- 1st steps: “max-L” and “template” map-making (following **MAPPRAISER**’s formalism)
- Multi-GPU parallelization (soon)
- Framework for robust B-mode analysis

data collection for detector *i*, time sample *t* and for frequency band ν

operator modeling the instrument response (pointing, beam, band passes, imperfections, etc.)

maps of the amplitudes of the sky components (pixel *p*, component *c*) normalized at a reference frequency that is shared with the mixing matrix.

$$d_{(i,t,\nu)} = \int_{BP(\nu')} d\nu' \mathbf{M}^{(\gamma)}_{(i,t,\nu',p)} \mathbf{A}^{(\beta)}_{(t,\nu',c,p)} s_{(p,c)} + n_{(i,t,\nu)}$$

boundaries of the band pass centered on frequency ν.

operator modeling the frequency scaling of the sky components *c* (CMB, astrophysical foregrounds, atmosphere, ground, etc.)

noise term, likely Gaussian with a covariance **N**

data collection for detector i, time sample t and for frequency band ν

operator modeling the instrument response (pointing, beam, band passes, imperfections, etc.)

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boundaries of the band pass centered on frequency ν.

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noise term, likely Gaussian with a covariance **N**

example in FURAX

```
h = bandpass @ pol @ rot @ hwp @ sampling @ mixing matrix

tod = h(sky signal)

solution = ((h.T @ invN @ h).I @ h.T @ invN)(tod)
```

data collection for detector i, time sample t and for frequency band ν

operator modeling the instrument response (pointing, beam, band passes, imperfections, etc.)

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example in FURAX

h = bandpass @ pol @ rot @ hwp @ sampling @ mixing matrix

tod = **h**(sky signal)

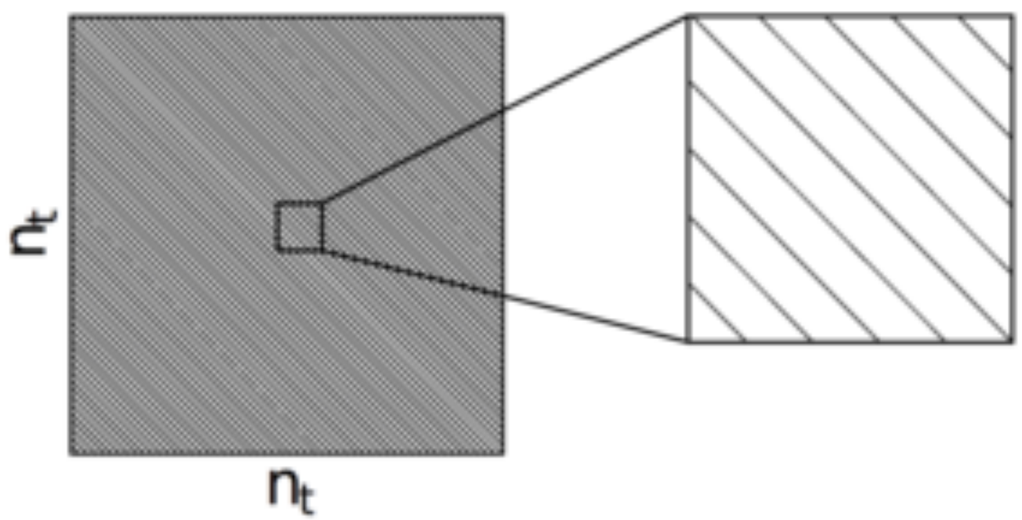
solution = ((**h**.T @ invN @ **h**).I @ **h**.T @ invN)(tod)

if **h** contains unknown (non-linear) parameters

spectral likelihood optimization for non-linear parameter estimation

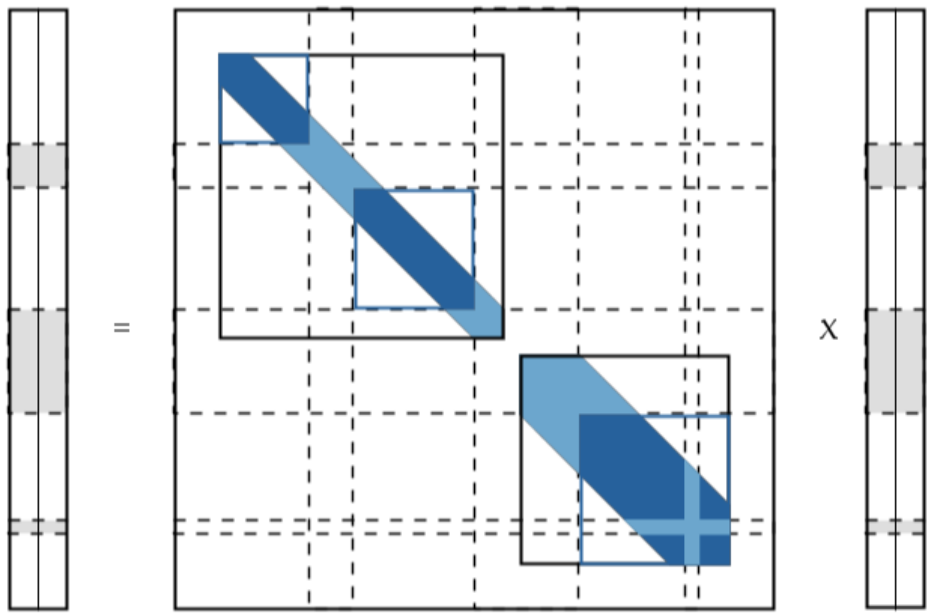
logL = (tod @ invN @ **h**)(solution)

credits: BICEP2



Toeplitz noise covariance

credits: B3DCMB



gaps treatment

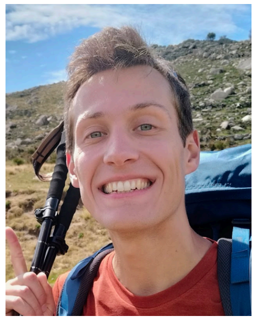
max-likelihood map-making

example in FURAX

h = bandpass @ pol @ rot @ hwp @ sampling @ mixing matrix

tod = **h**(sky signal)

solution = ((**h**.T @ **invN** @ **h**).I @ **h**.T @ **invN**)(**gap_fill**(tod))



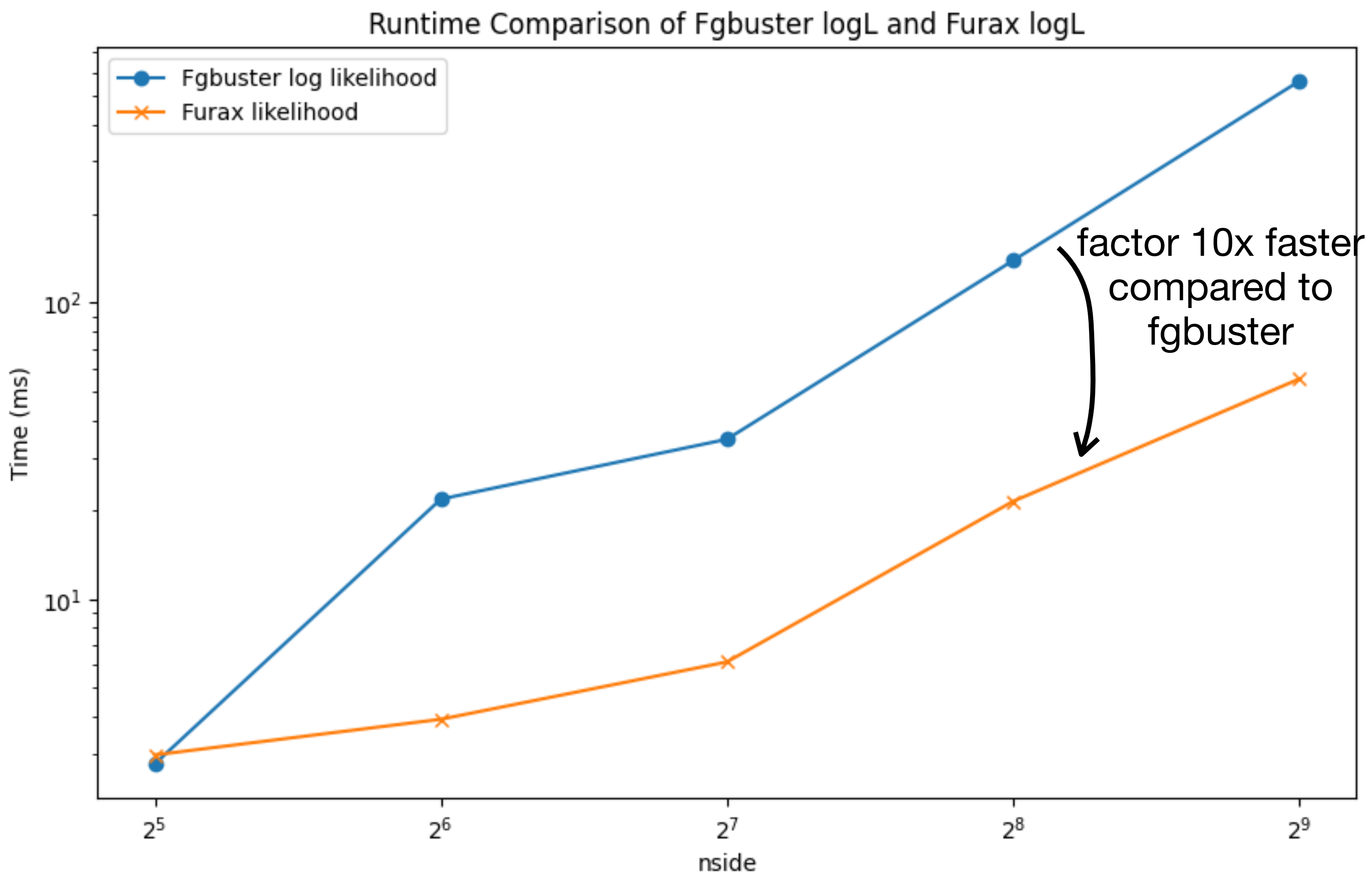
Simon Biquard

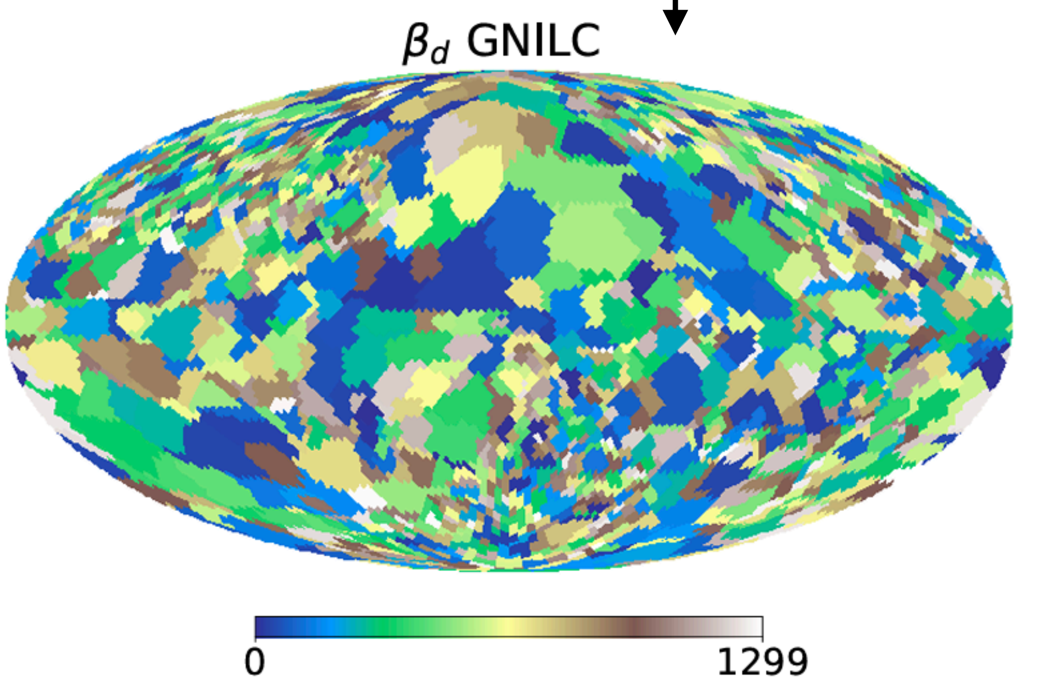
Wassim Kabalan

On-going development of parametric component separation within the FURAX framework

- Does everything **fgbuster** does but “better"
  - Uses the FURAX operators to represent linear algebra to efficient computing
  - Is written in JAX, hardware accelerated and have easy access to gradients

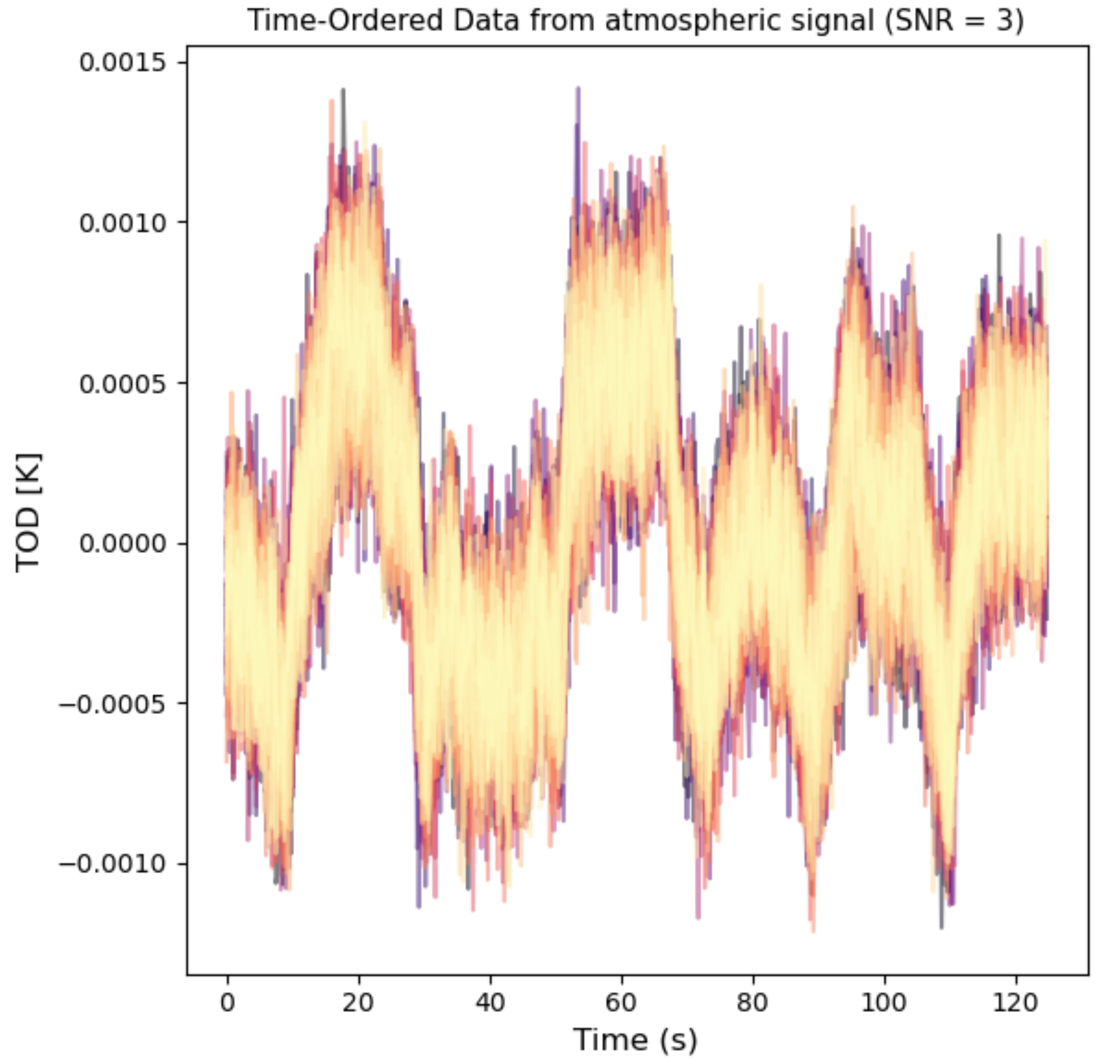
- Beyond **fgbuster**
  - Uses a full bayesian approach to find **optimal patches for component separation**
  - Gives access to true model incertitude for each parameter

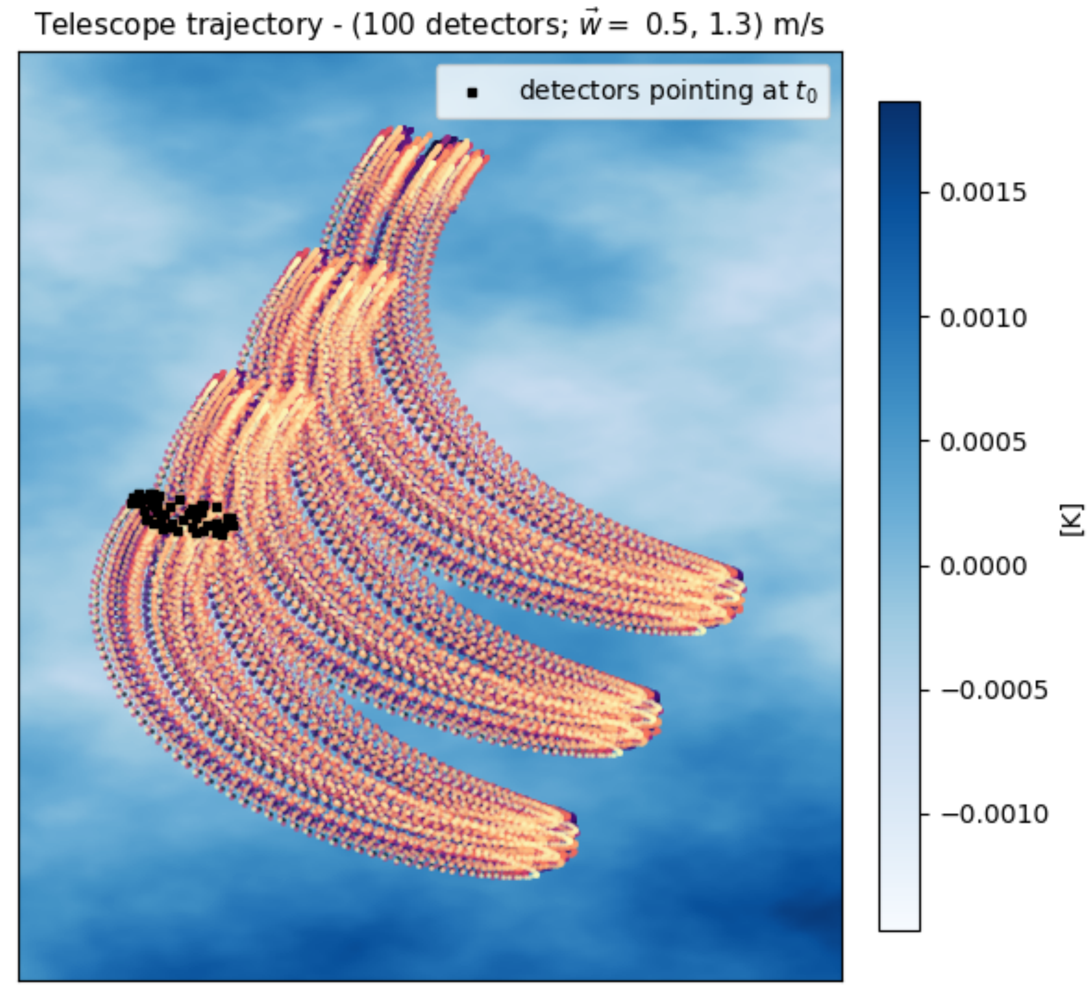




from Puglisi et al., 2021

Amalia Villarrubia Aguilar





- preliminary tests for an atmospheric time-domain component separation are promising (non-linear parameters are the **wind** and the **PWV**)
- by combining this component separation with instrumental modeling, our target is to use atmosphere to characterize the instrumental response (I-to-P leakage for instance)

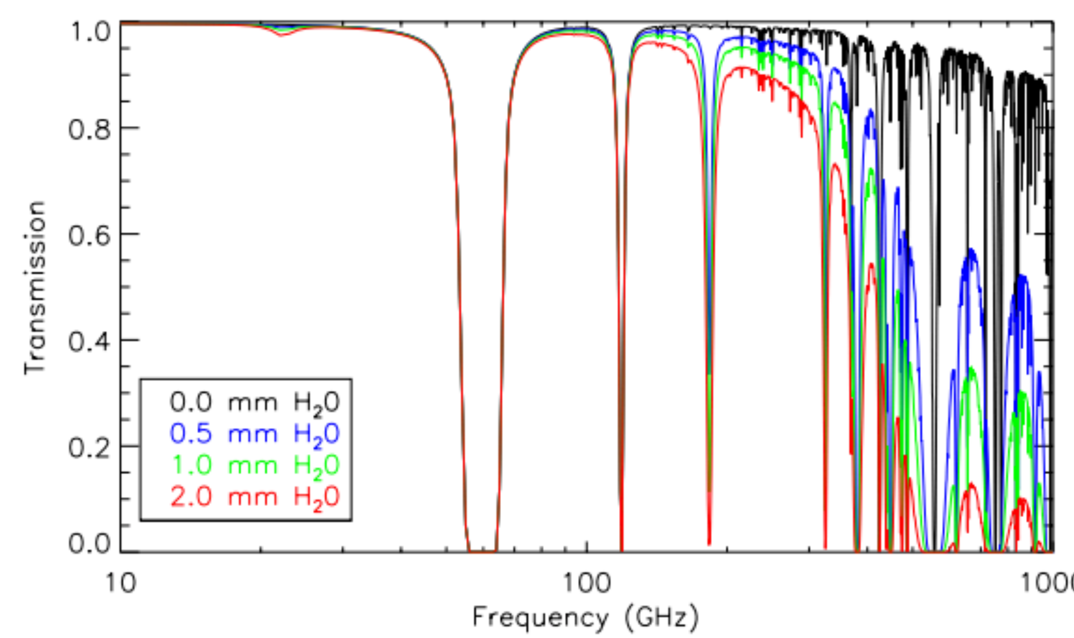


FIG. 1.— Atmospheric transmission from the Atacama plateau at the zenith for different amounts of precipitable water vapor. This is obtained using the ATM code, Pardo et al. (2001).

Benjamin Beringue

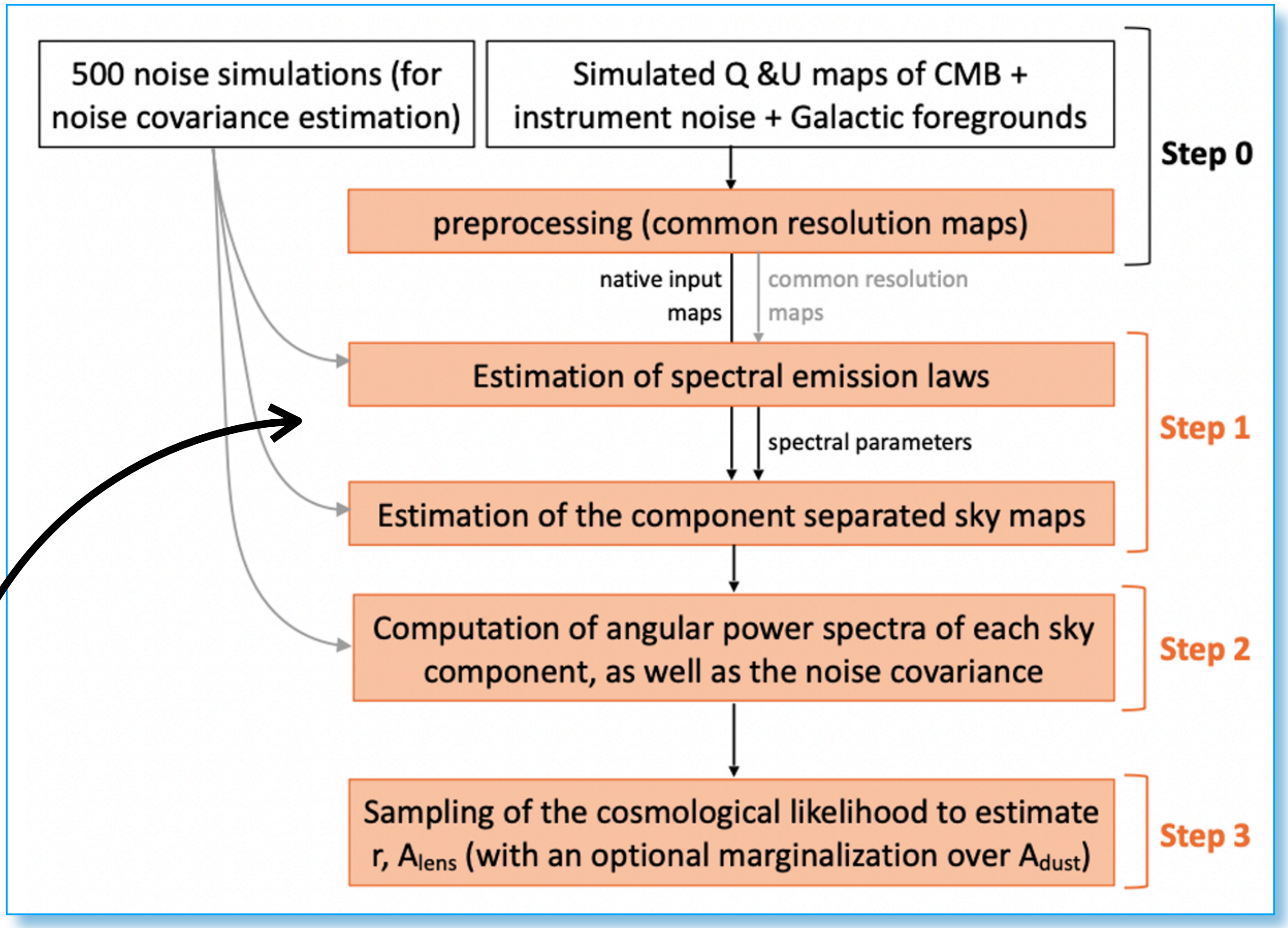
Baptiste Jost

Magdy Morshed

MEGATOP

Map-basEd Generalized Analysis for Testing cOsmological Physic
(test-bed for SciPol time-domain analysis)

from Wolz et al. “pipeline comparison and validation for large-scale B-modes”, 2302.04276



+ Observation matrix
+ Beam correction (Rizzieri, JE, Stompor 2024)
+ Multiresolution
+ Instrumental Modeling

Science from the large scale cosmic microwave background polarization structure

Morshed et al. (2024)

scipol.in2p3.fr

github.com/CMBSciPol

under intense development
stay tune & visit us in Paris!

MICMAC Public
Pixel implementation for the non-parametric component separation
data-analysis · component-separation · cmb · gibbs-sampling · jax
Jupyter Notebook · GNU General Public License v3.0 · 2 · 2 · 1 · 0 · Updated 2 days ago

Megatop Private
A map-based CMB polarization experiment data analysis pipeline from component separation to r estimation
Jupyter Notebook · 0 · 2 · 0 · 0 · Updated 4 days ago

MICMAC_playground Private
Jupyter Notebook · 0 · 0 · 0 · 0 · Updated last week

cmb_map_visualisation Private
Visualisation of 3D CMB maps using blender
Jupyter Notebook · 0 · 0 · 0 · 0 · Updated on Jun 13

jax-healpy Public
Healpy with JAX
Python · 3 · 2 · 0 · 0 · Updated on Jun 12

SMICAX Private
SMICA, accelerated with JAX
Jupyter Notebook · 0 · 0 · 0 · 0 · Updated on Jun 3

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C++ · 0 · 0 · 0 · 0 · Updated on Feb 28

astrosim Private
JAX building blocks for astrophysical reconstructions
Python · 0 · 2 · 0 · 0 · Updated on Feb 14