

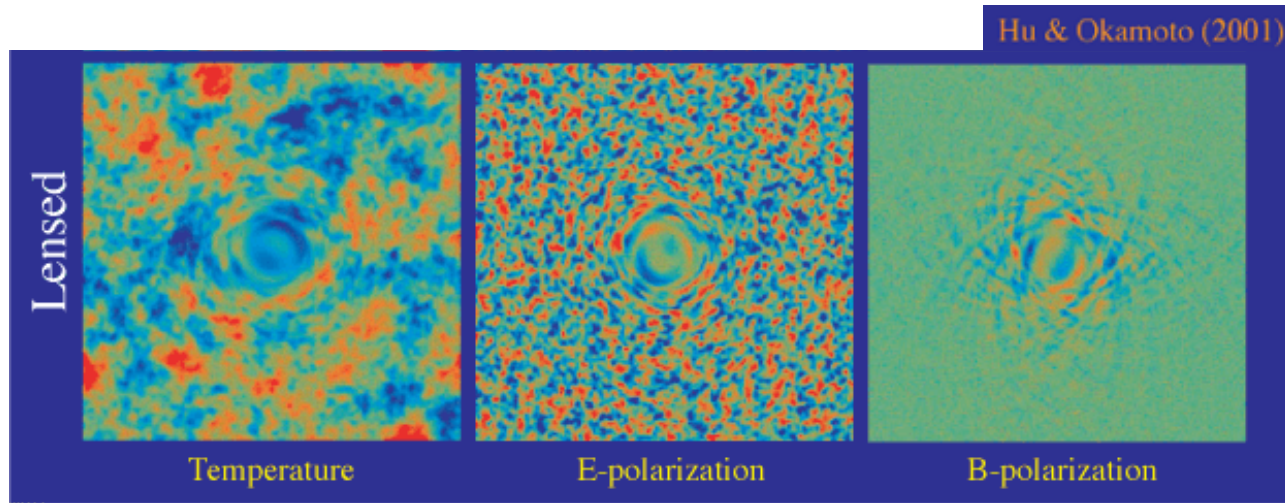
Galactic foregrounds for lensing: κκ autospectrum & delensing

Alex van Engelen (CITA)

with

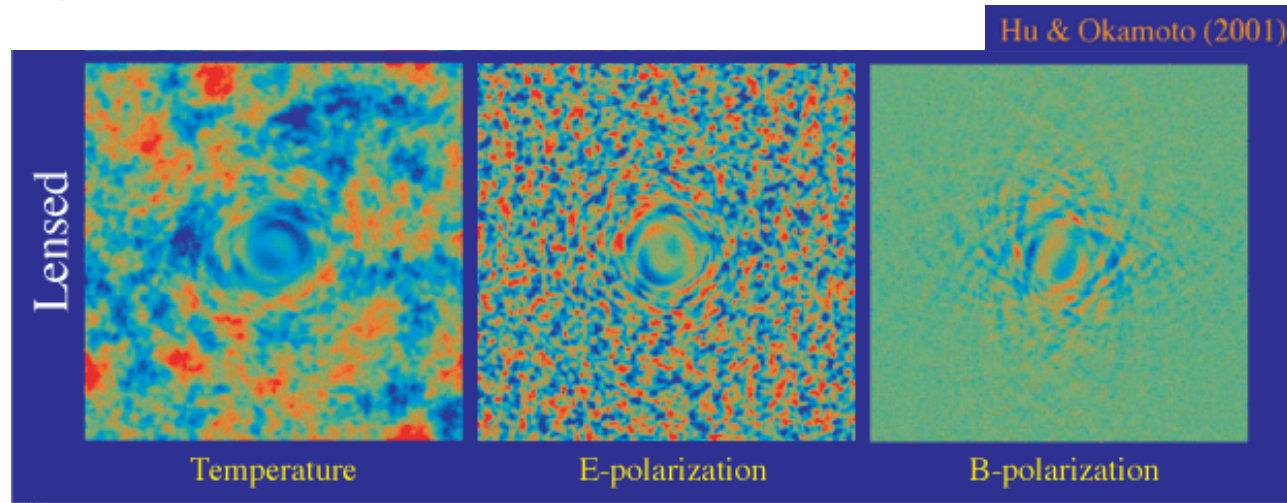
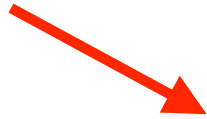
- DW Han (Stony Brook), Neelima Sehgal,
Blake Sherwin, Colin Hill, Susan Clark

Lensing/Delensing



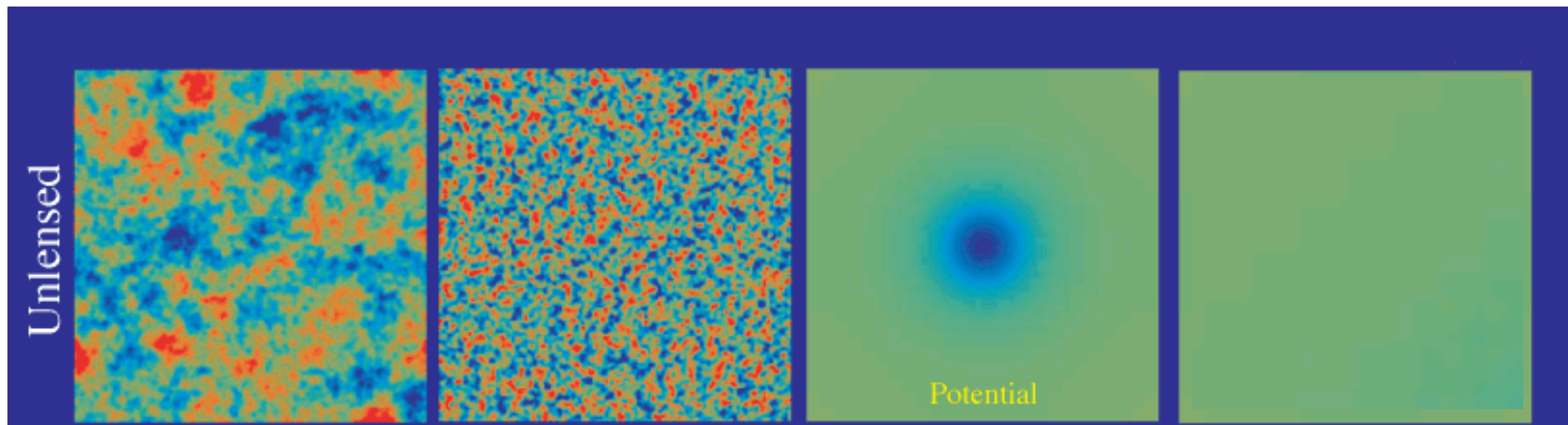
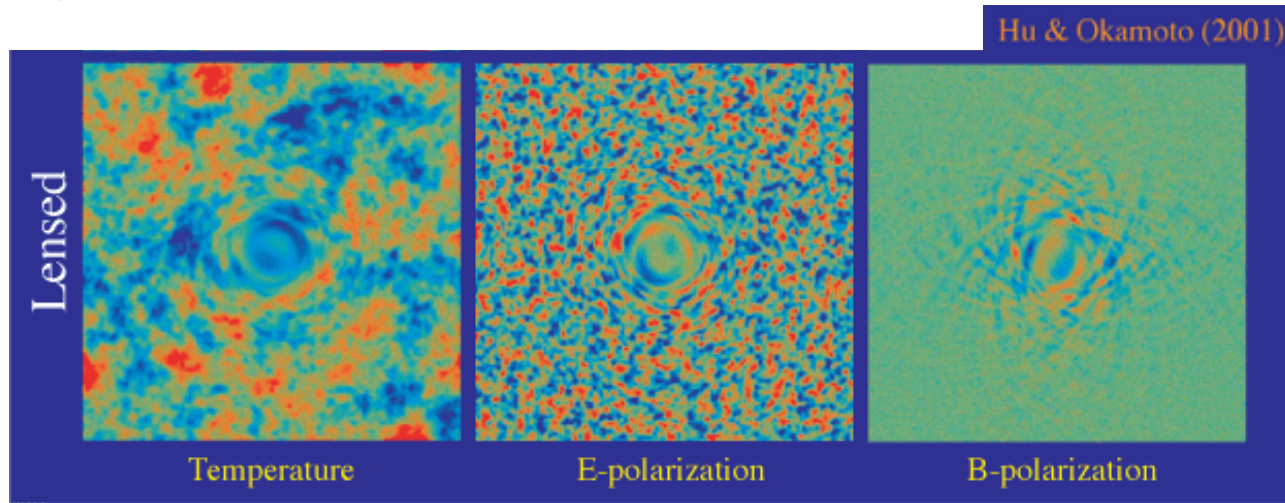
Lensing/Delensing

We measure this



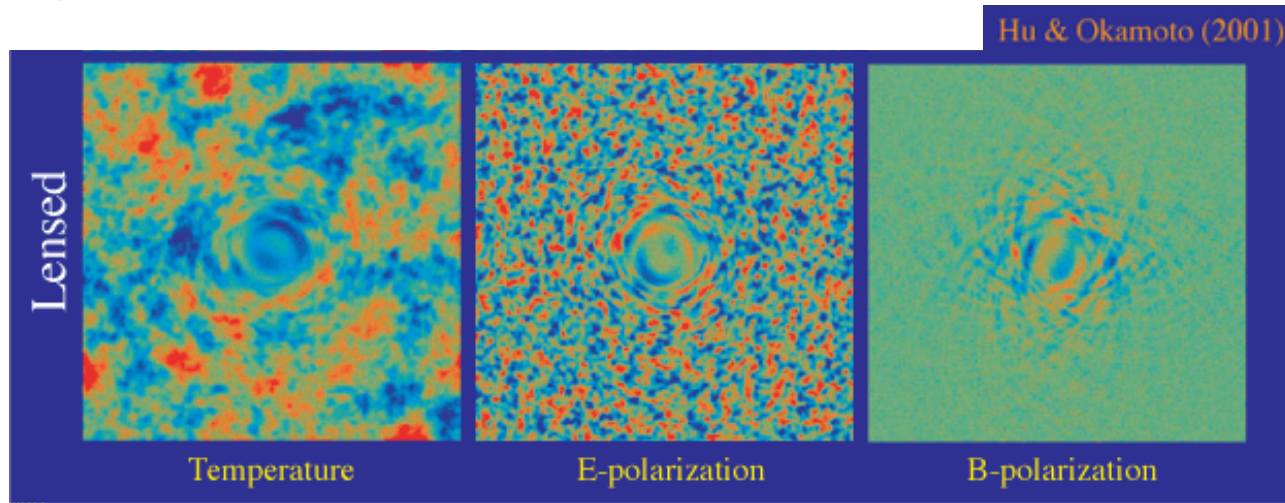
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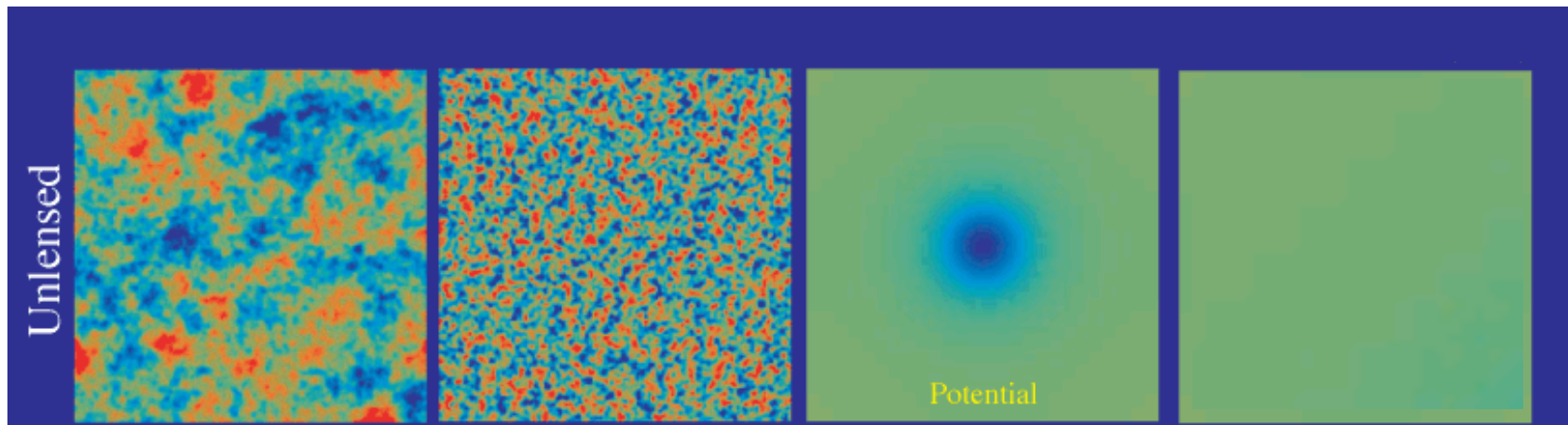


Lensing/Delensing

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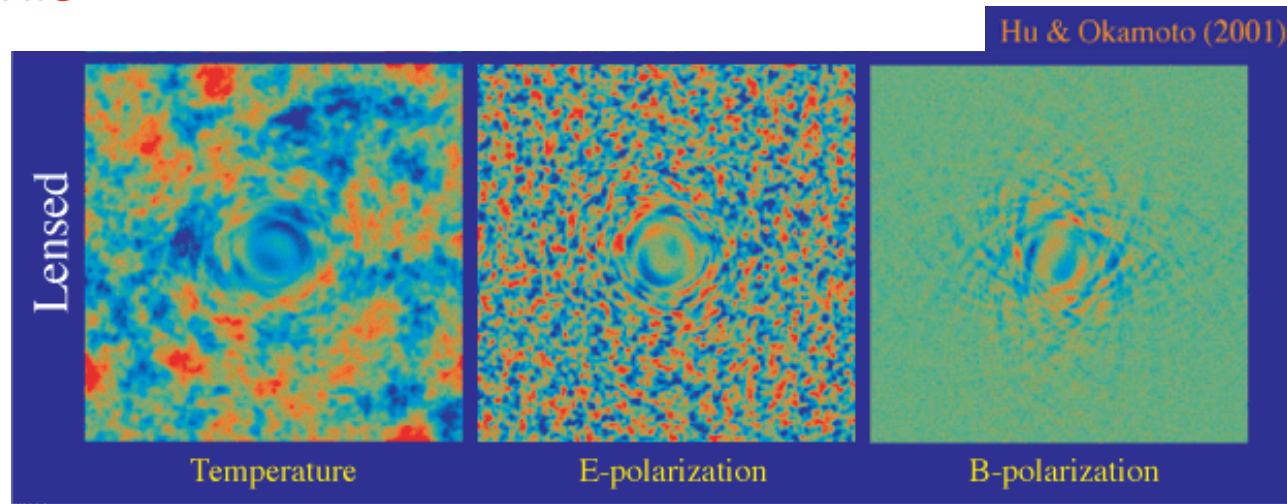


We want this

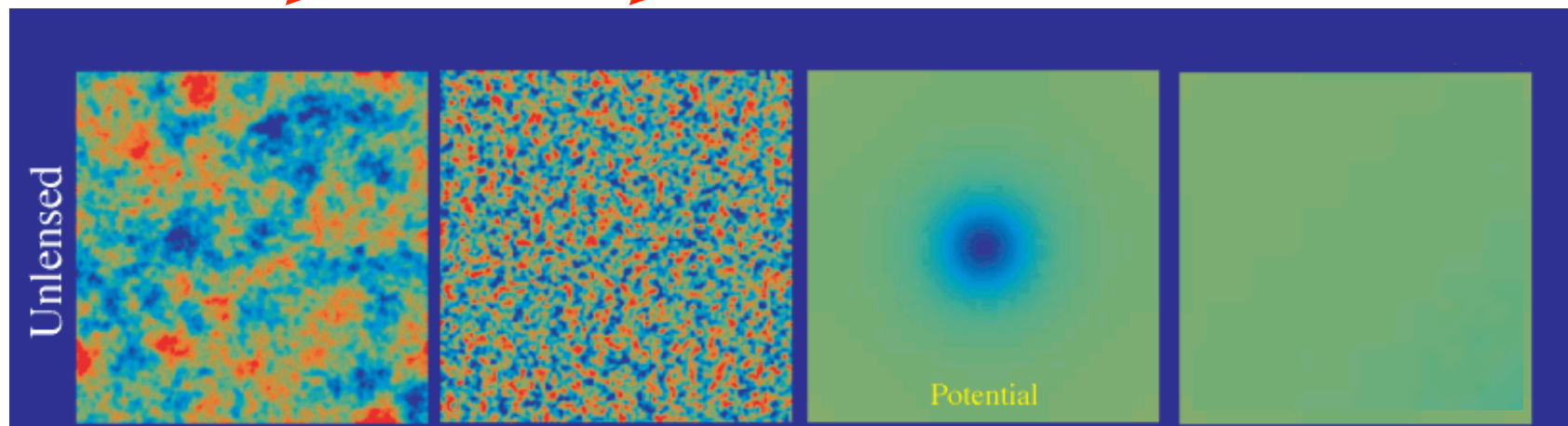


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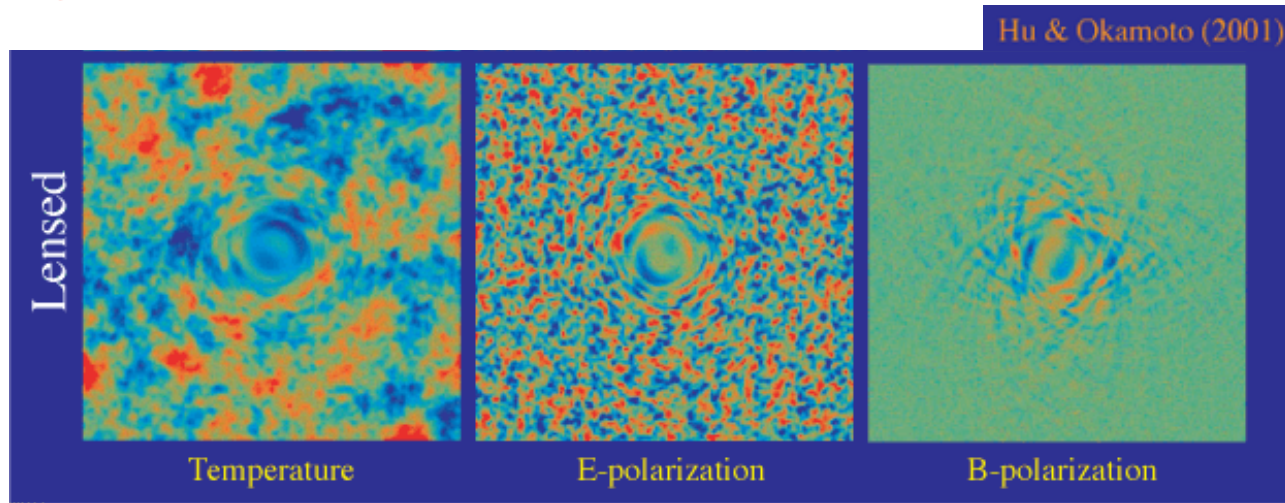
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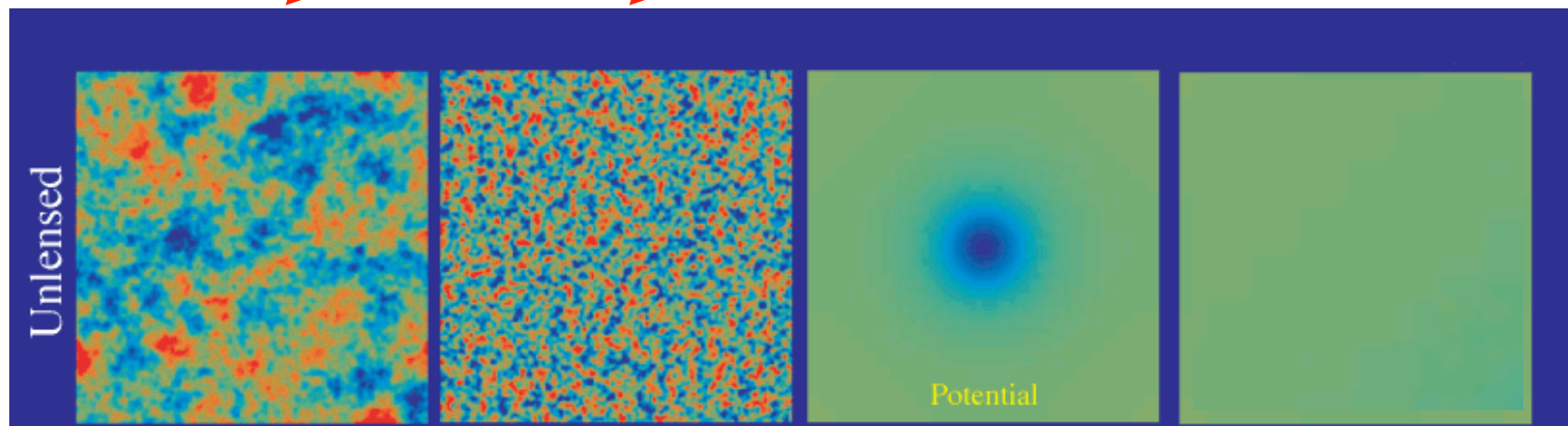
Separation of primordial CMB and mass map
from Lensing analysis

Lensing/Delensing

We measure this



We want this



N_{eff} constraints

$\sum m_\nu$ w constraints

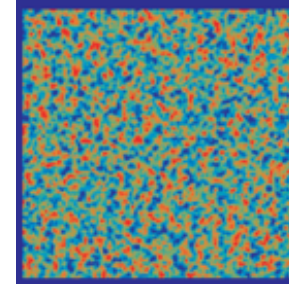
Areas of Lensing

Areas of Lensing

- Delensing $\rightarrow r, N_{\text{eff}}$

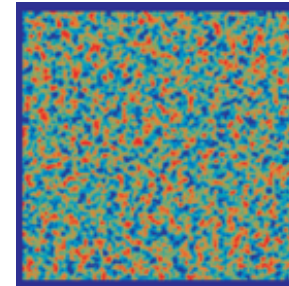
Areas of Lensing

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Areas of Lensing

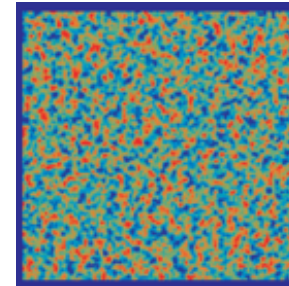
- Delensing $\longrightarrow r, N_{\text{eff}}$



- Large-scale lensing $\longrightarrow \sum m_\nu, w, dm$

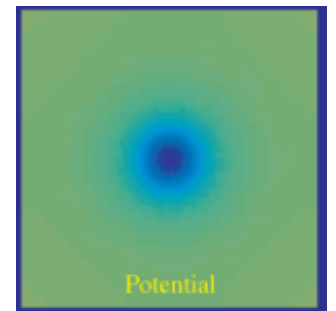
Areas of Lensing

- Delensing $\rightarrow r, N_{\text{eff}}$



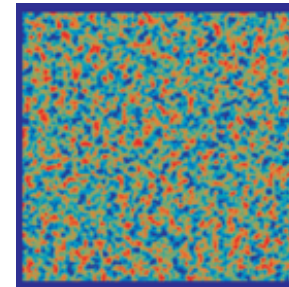
- Large-scale lensing $\rightarrow \sum m_\nu, w, dm$

- Small-scale lensing $\rightarrow w, \sum m_\nu$



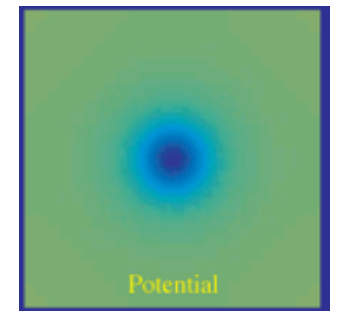
Areas of Lensing

- Delensing $\rightarrow r, N_{\text{eff}}$



- Large-scale lensing $\rightarrow \sum m_\nu, w, \text{dm}$

- Small-scale lensing $\rightarrow w, \sum m_\nu$

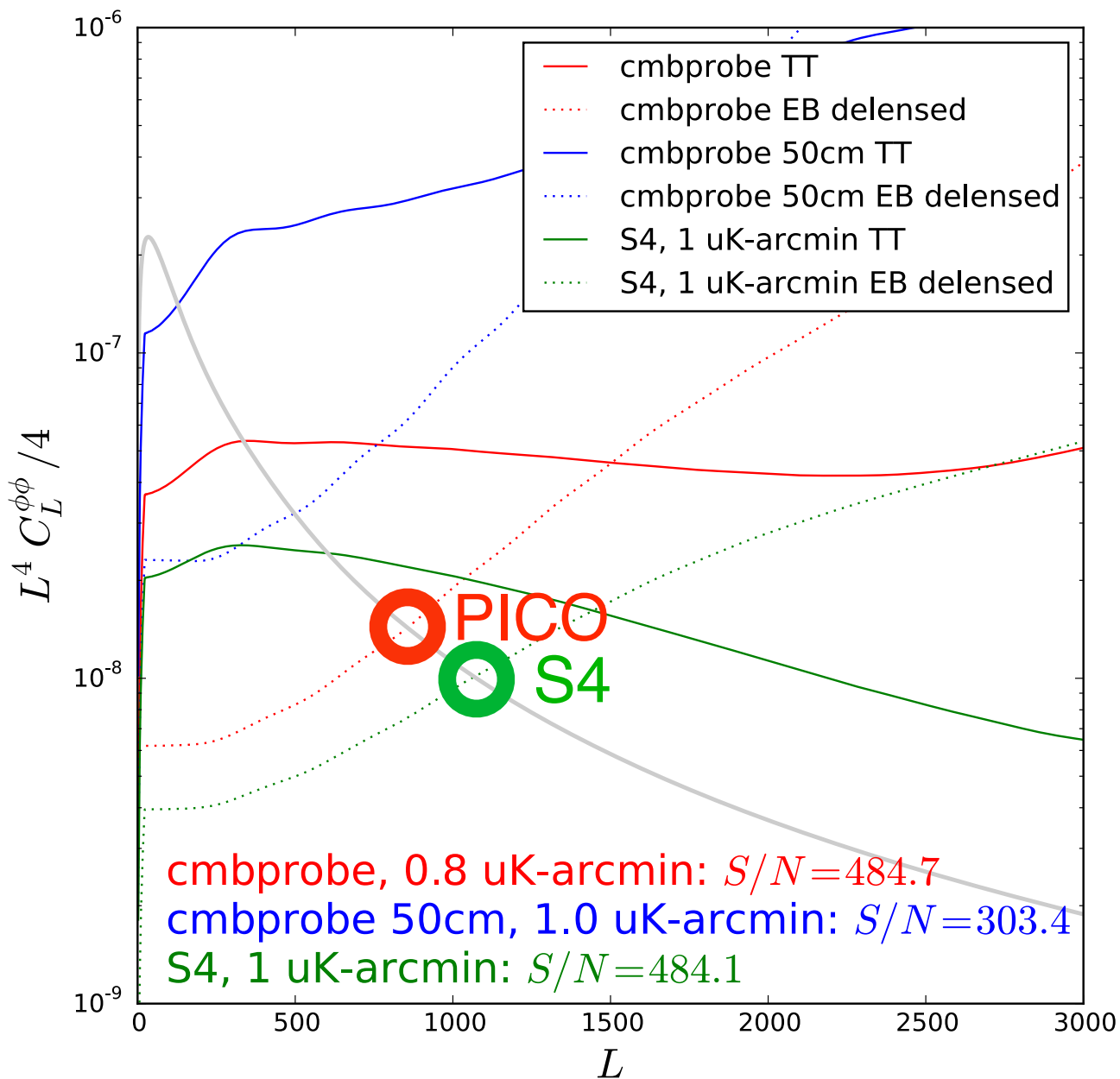


- Cross-correlation between CMB lens and other data sets $\rightarrow w, \sum m_\nu$

- Lensing maps can come from:
 - CMB temperature - $\kappa(TT)$
 - Polarization - $\kappa(EB)$
 - External tracers
 -

- Lensing maps can come from:
 - CMB temperature - $\kappa(TT)$
 - Polarization - $\kappa(EB)$
 - External tracers
 -
- Today (Planck)
- Future (S4 / PICO)
- Today (Planck CIB / Herschel CIB)

Lensing map noise



- Polarization lensing will dominate for PICO
- Temperature: extragalactic foregrounds
- Polarization: galactic foregrounds

Targets

- $\kappa\kappa$ autospectrum
- Delensing

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$$\langle \kappa\kappa \rangle \sim \langle EBEB \rangle \text{ or } \langle TTTT \rangle$$

$$B_{\text{templ}} \sim E \star \kappa(EB)$$

$$\text{Bias if } \langle B_{\text{low}} B_{\text{templ}} \rangle \sim \langle EBEB \rangle \neq 0$$

Targets

- $\kappa\kappa$ autospectrum
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$$\langle \kappa\kappa \rangle \sim \langle \text{EBEB} \rangle \text{ or } \langle \text{TTTT} \rangle$$

Non-Gaussianity of
dust polarization
on small scales?

$$B_{\text{templ}} \sim E \star \kappa(\text{EB})$$

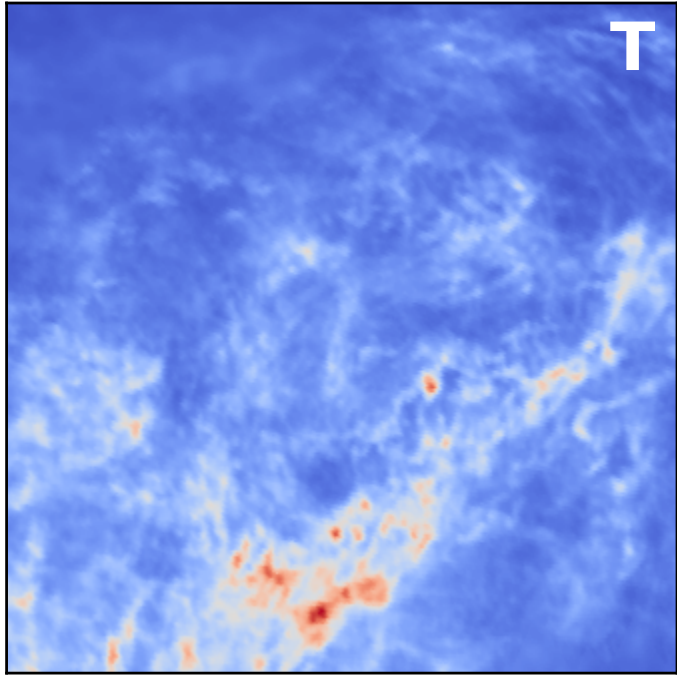
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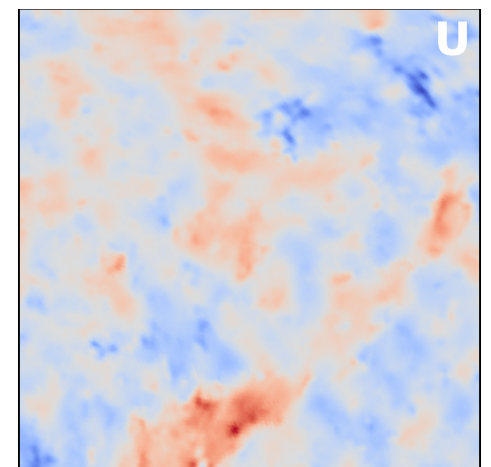
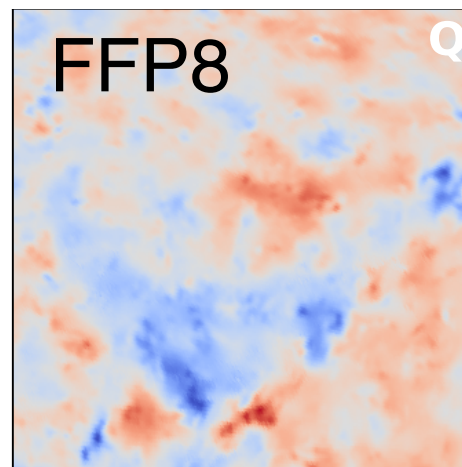
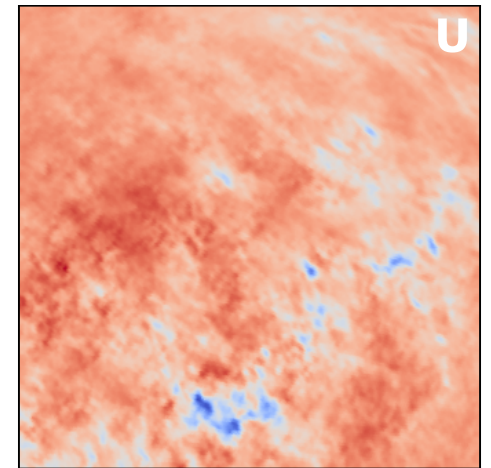
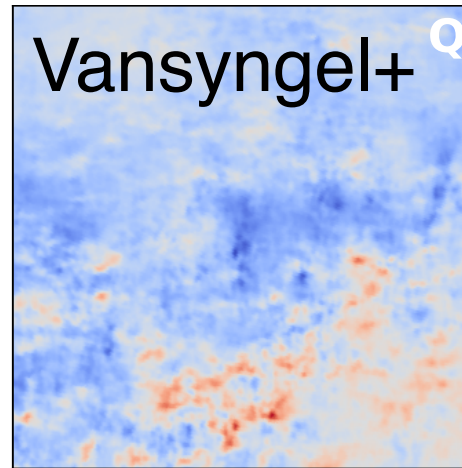
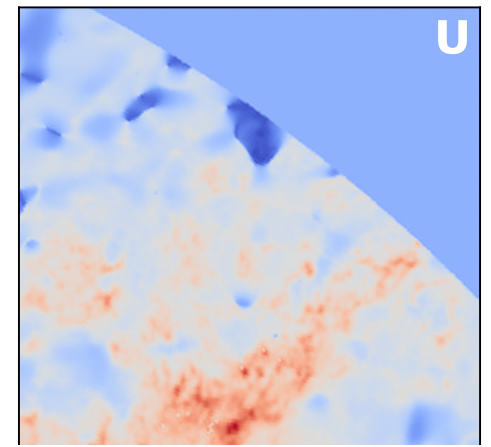
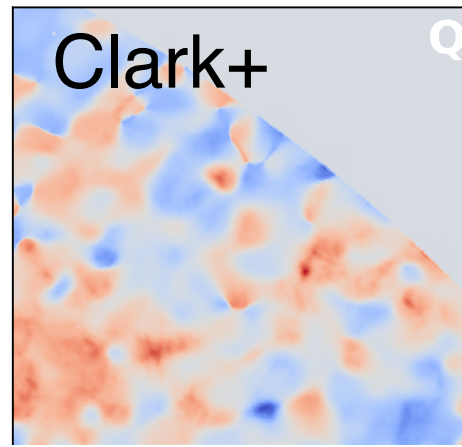
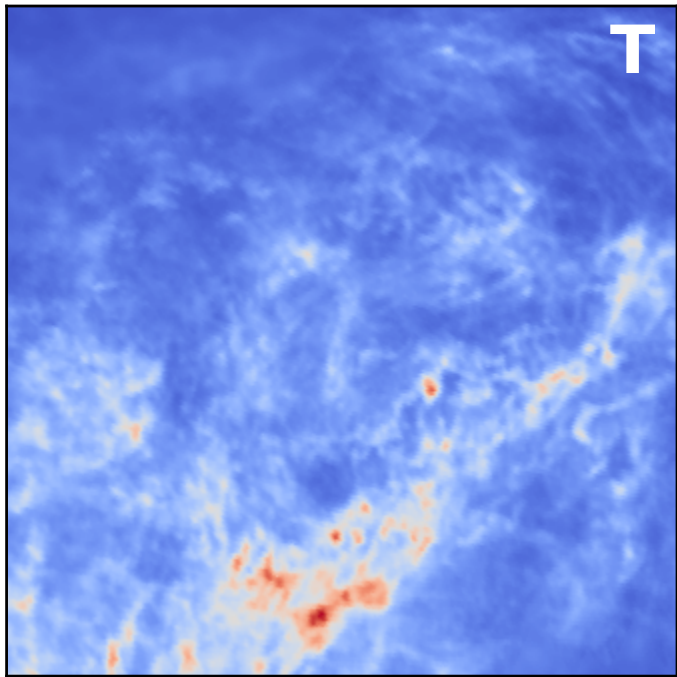
Targets

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Models for small-scale pol dust

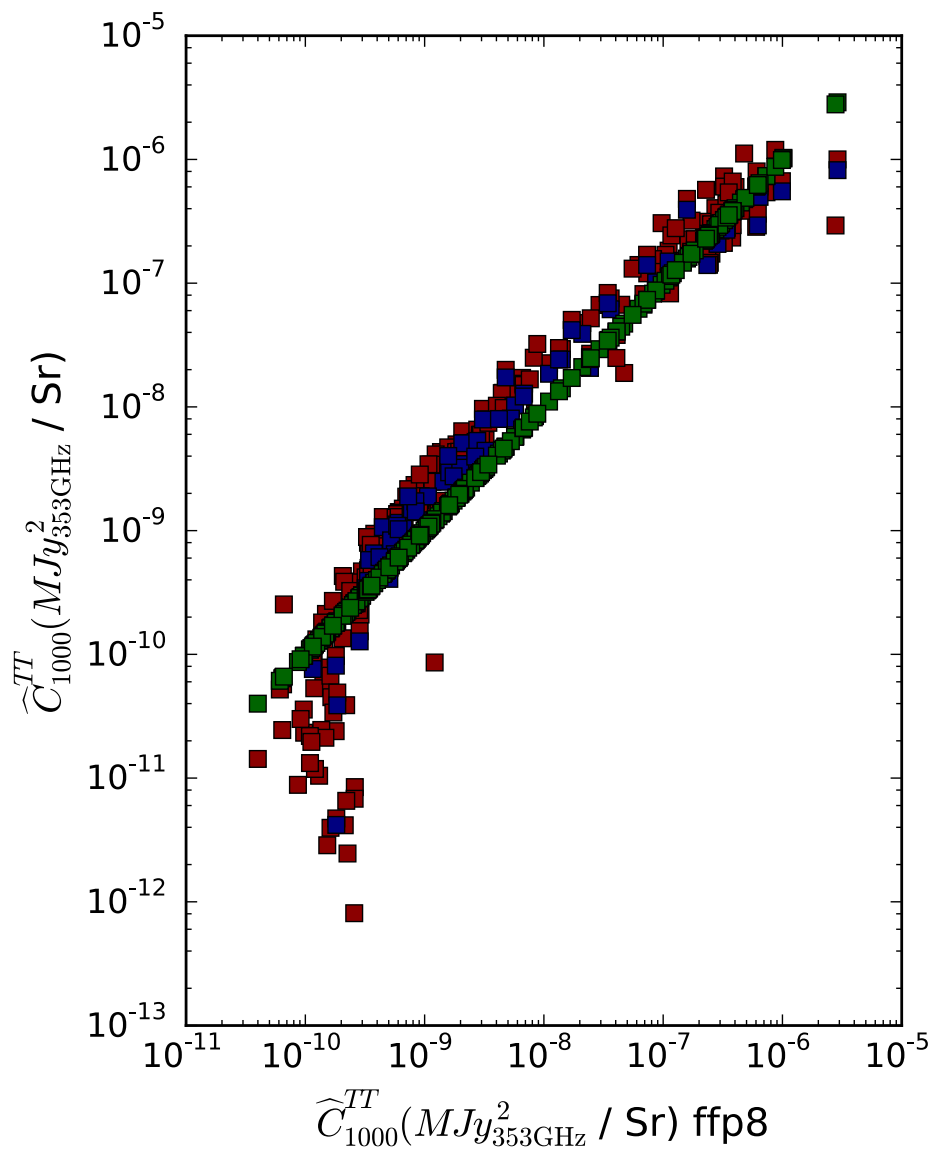
- Extending large-scale pol directions to small scales
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- Correlation between pol direction and filaments (HI maps)
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 - *Vansyngel+ sims*



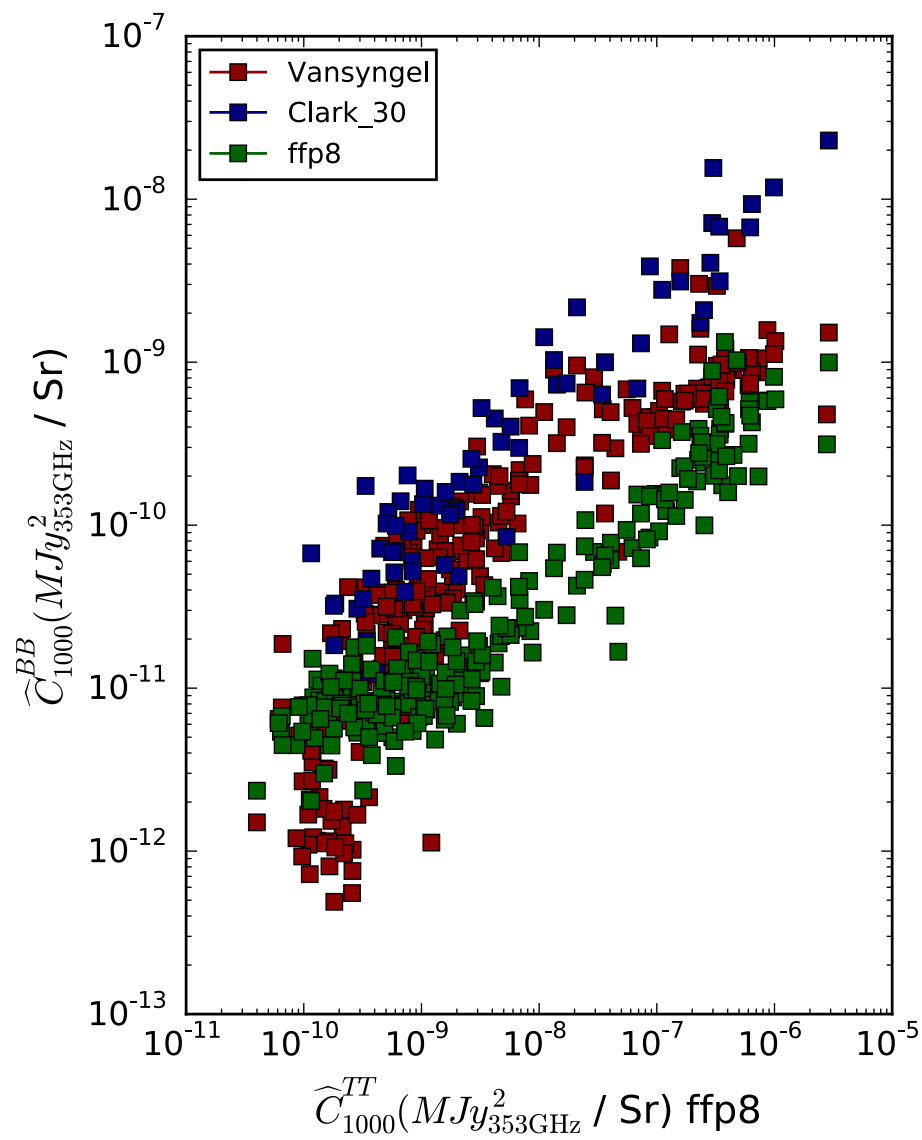


Dust models

TT power



BB power



Targets

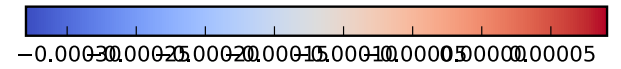
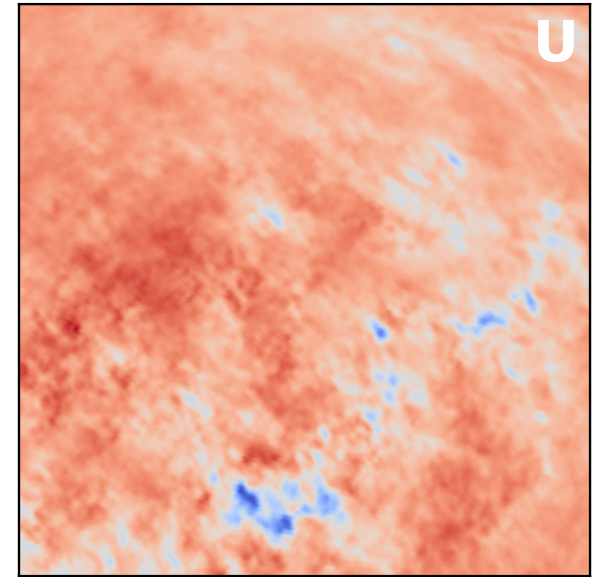
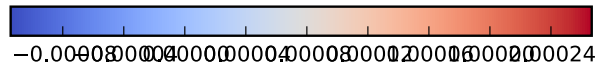
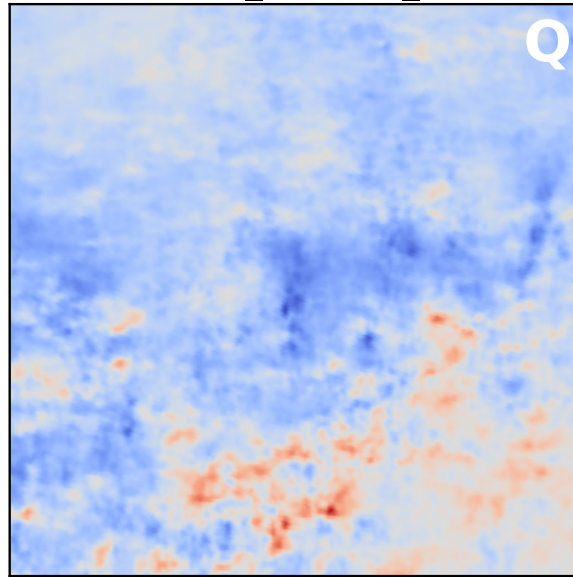
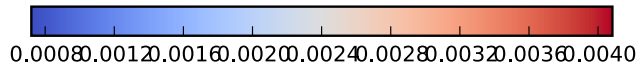
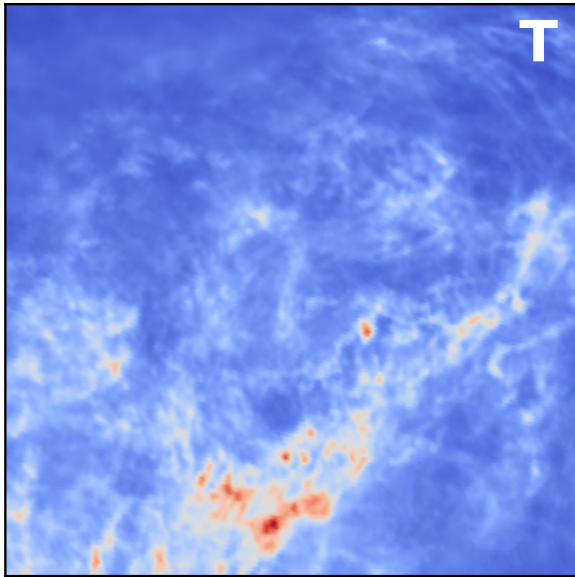
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Models for small-scale pol dust

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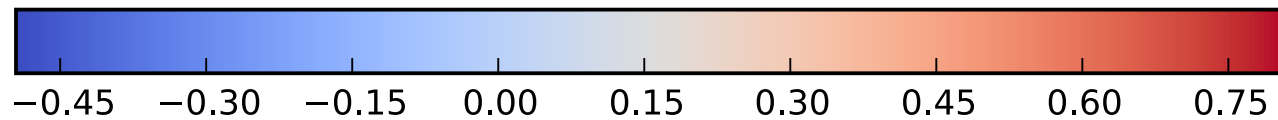
$$[T_{\text{dust}}, Q_{\text{dust}}, U_{\text{dust}}]$$

Vansyngel_mapTqu_00036



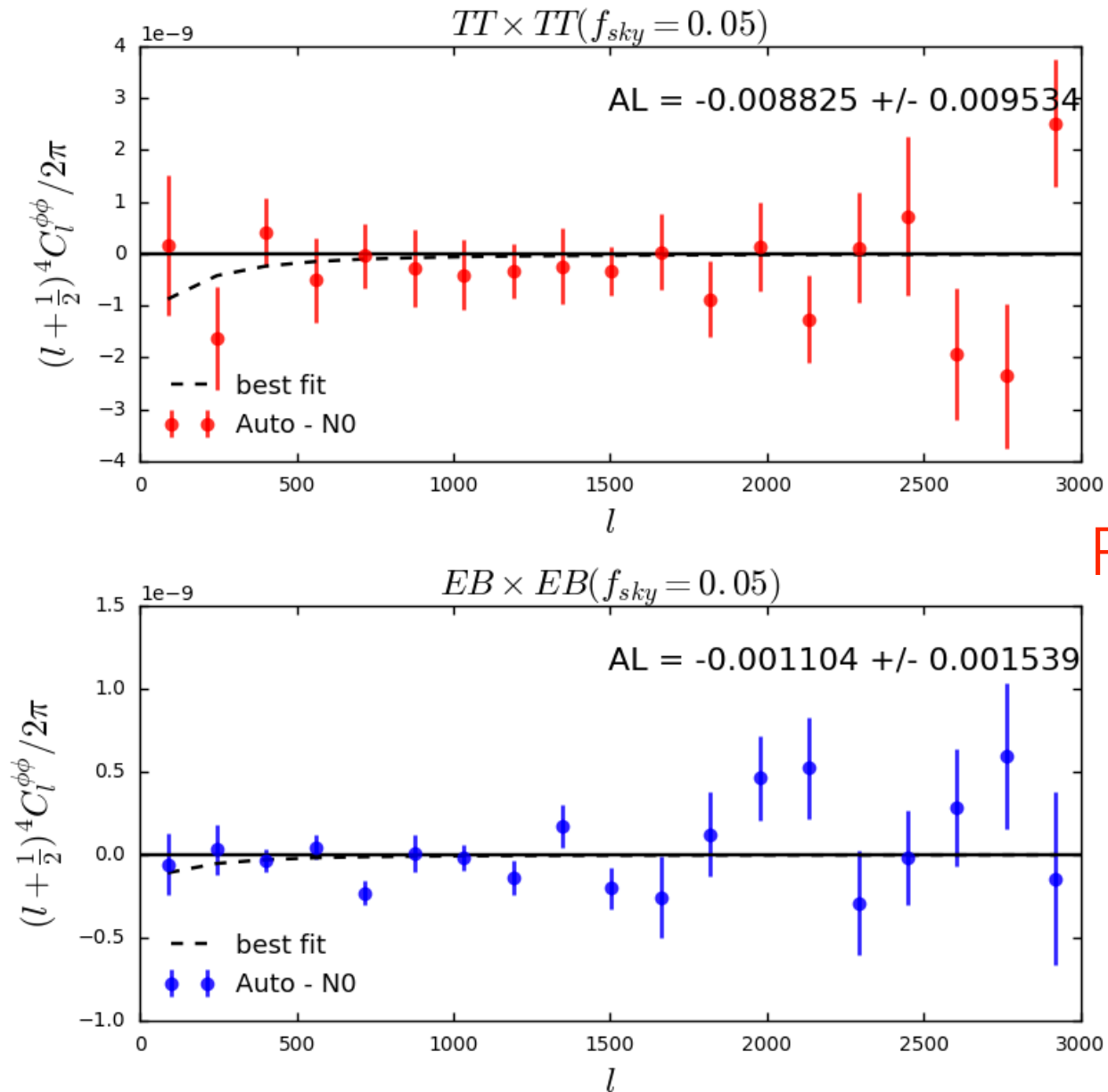
$$\kappa(E_{\text{dust}}, B_{\text{dust}})$$

Vansyngel_kappaMap_00036



Bias to lensing autospectra

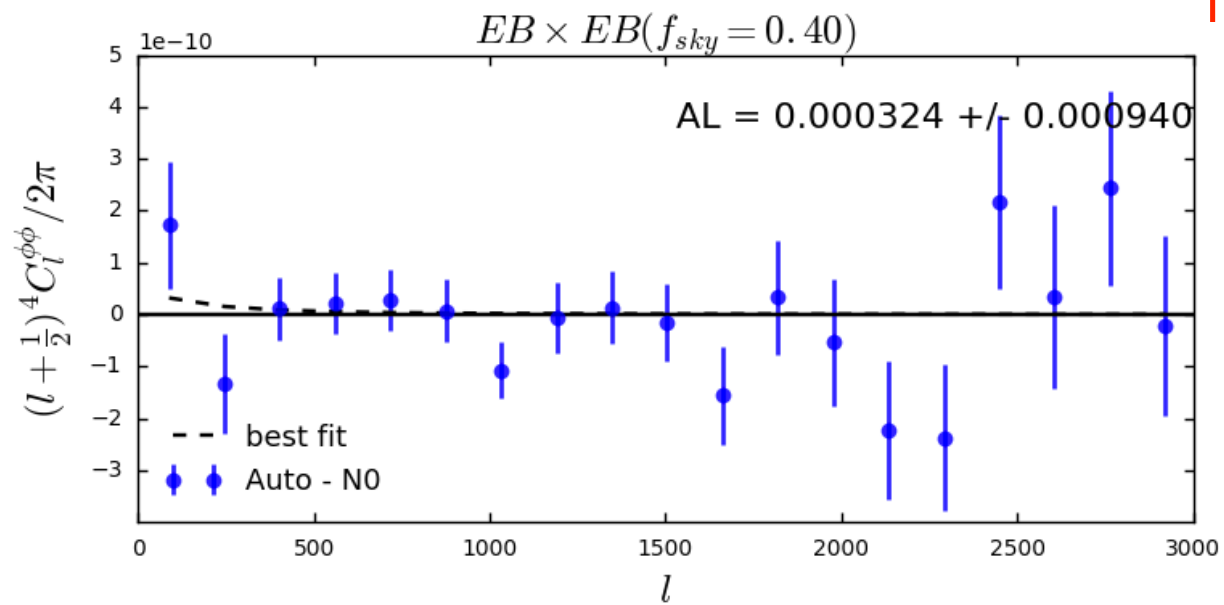
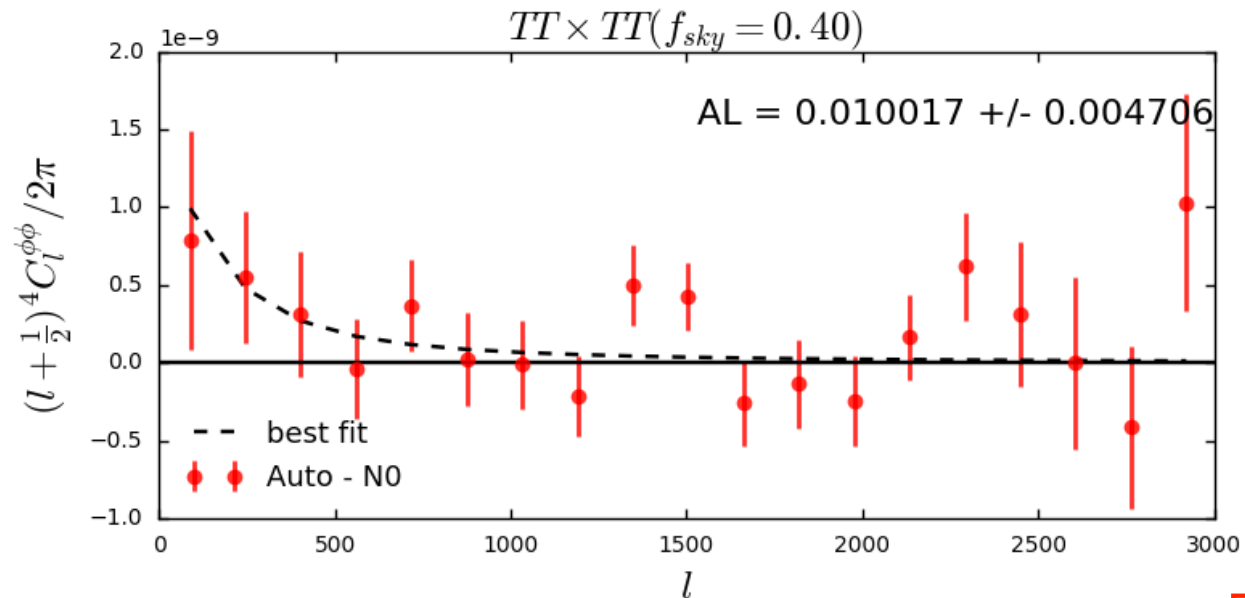
from Vansyngel+ sims
courtesy DW Han (Stony Brook)



Preliminary

Bias to lensing autospectra from Vansyngel+ sims

courtesy DW Han (Stony Brook)



Preliminary

Targets

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Models for small-scale pol dust

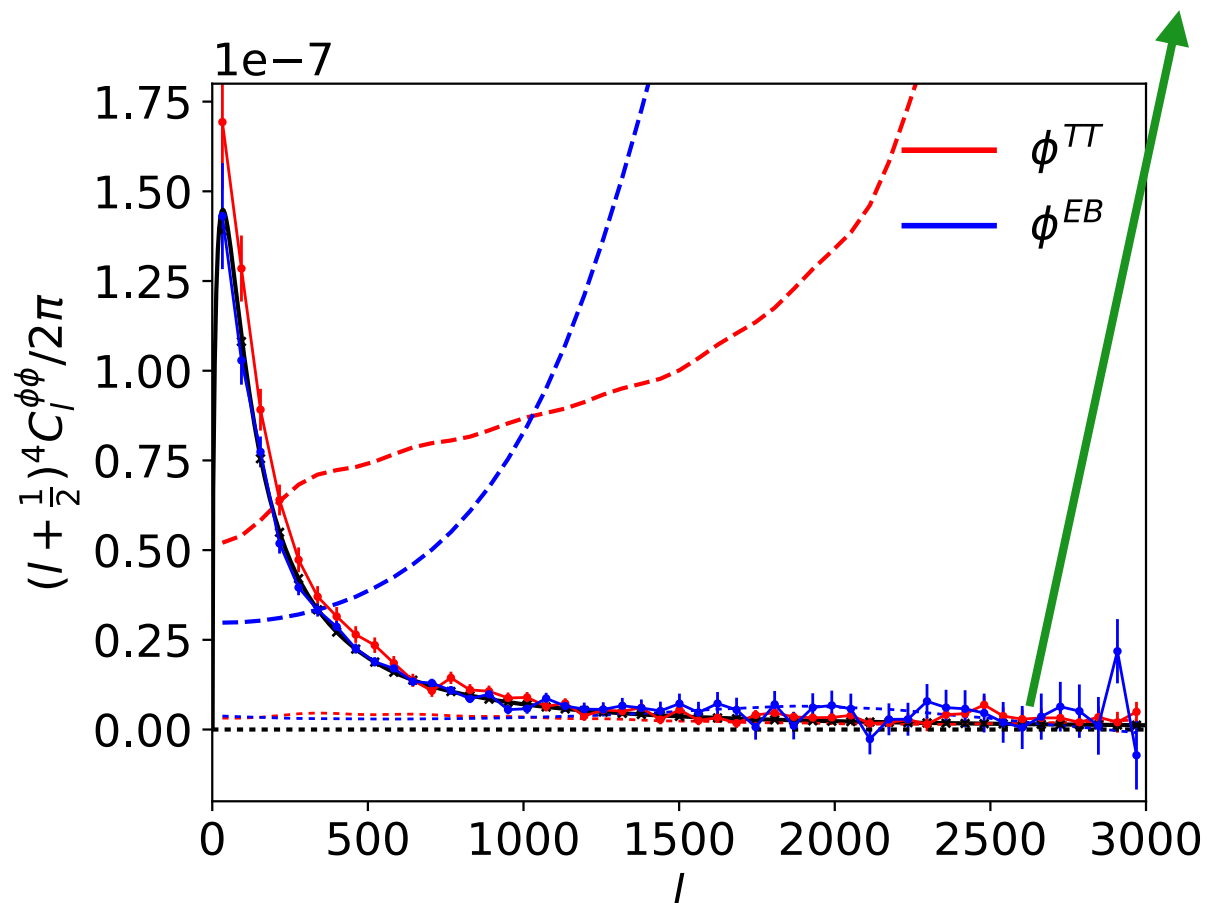
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Bias to lensing autospectra

from Planck FFP8 sims

CORE lensing paper (Challinor, Allison++2017) arXiv:1707.02259

	No dust	Bright dust field	Bright dust field (inc. dust power in filters)
$TT \times TT$	$A = 1.002 \pm 0.008$	$A = 1.169 \pm 0.008$	$A = 1.158 \pm 0.008$
$EB \times EB$	$A = 0.997 \pm 0.004$	$A = 1.615 \pm 0.030$	$A = 0.999 \pm 0.006$



Models for small-scale pol dust

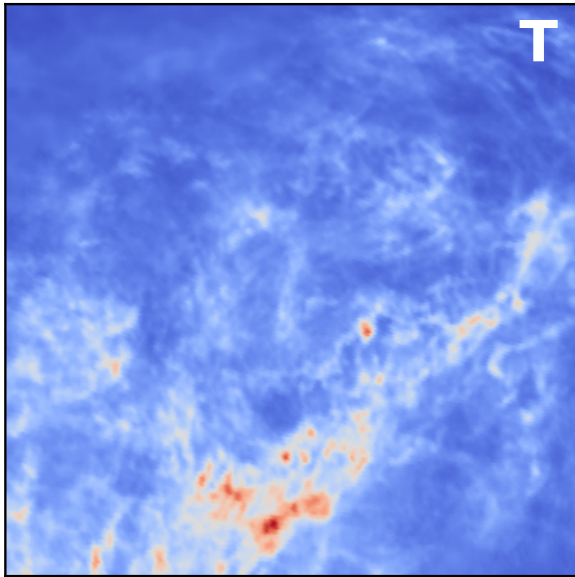
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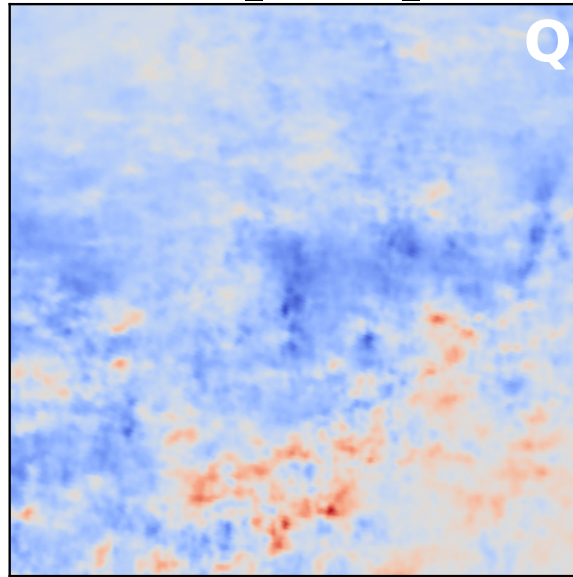
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$$[T_{\text{dust}}, Q_{\text{dust}}, U_{\text{dust}}]$$

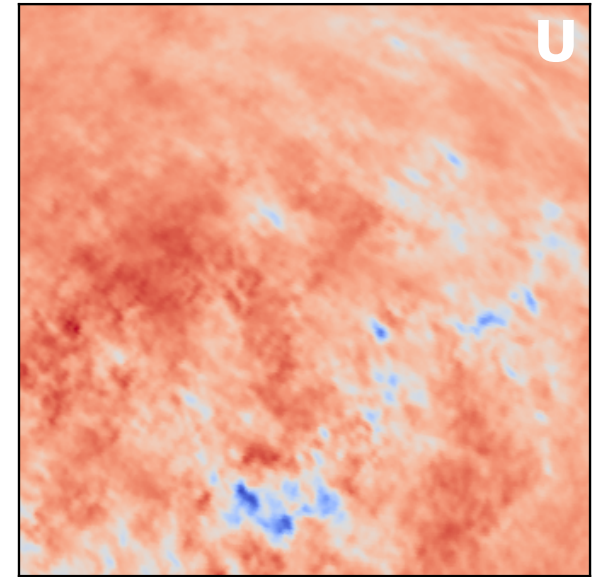
Vansyngel_mapTqu_00036



0.0008 0.0012 0.0016 0.0020 0.0024 0.0028 0.0032 0.0036 0.0040



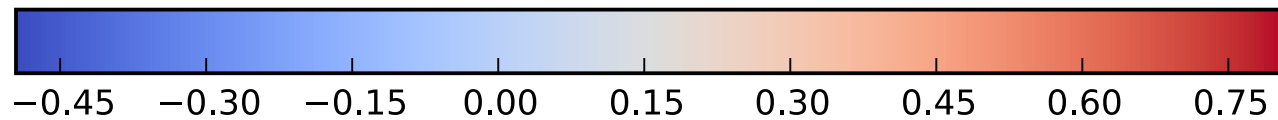
-0.0008 0.0000 0.0008 0.0016 0.0024



-0.0003 0.0000 0.0003 0.0005

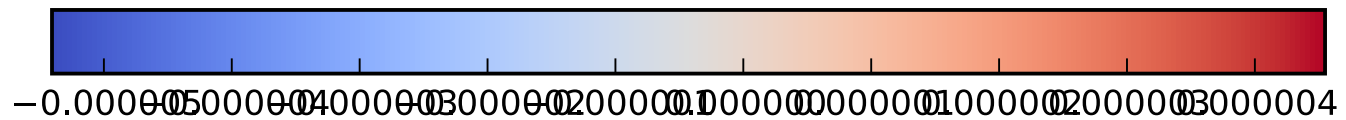
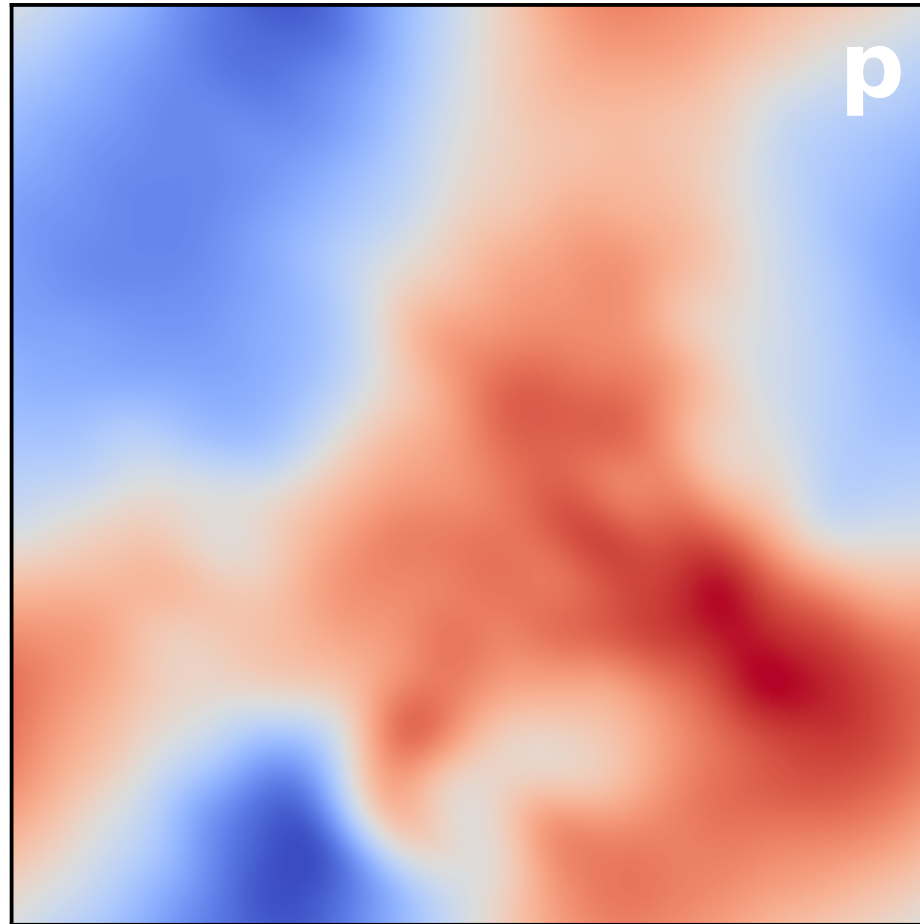
$$\kappa(E_{\text{dust}}, B_{\text{dust}})$$

Vansyngel_kappaMap_00036

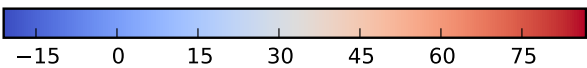
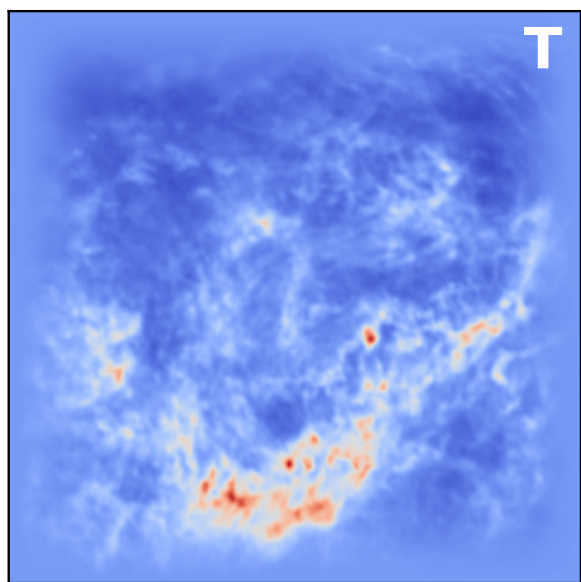


$$\phi(E_{\text{dust}}, B_{\text{dust}})$$

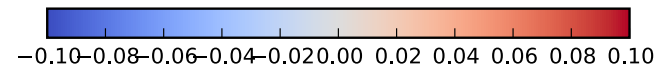
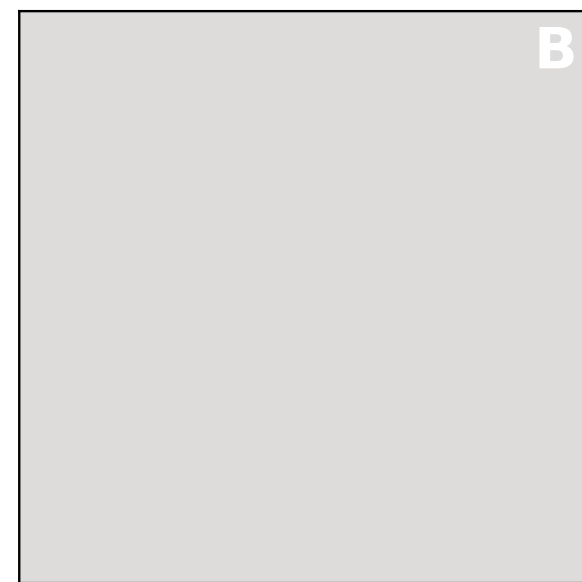
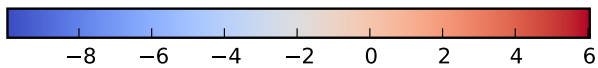
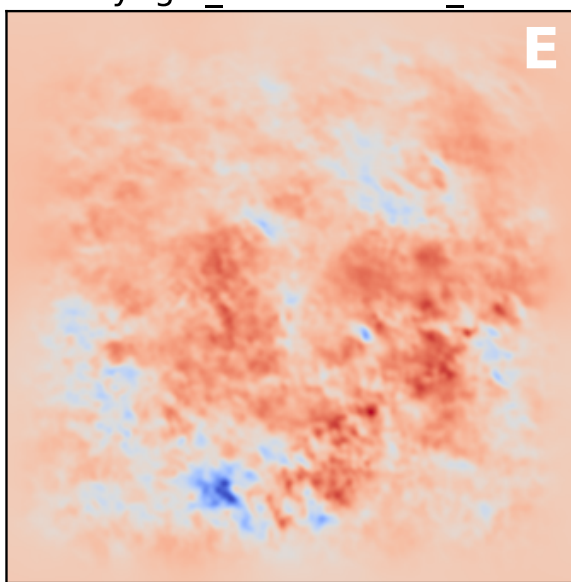
Vansyngel_phiMapFiltered_00036



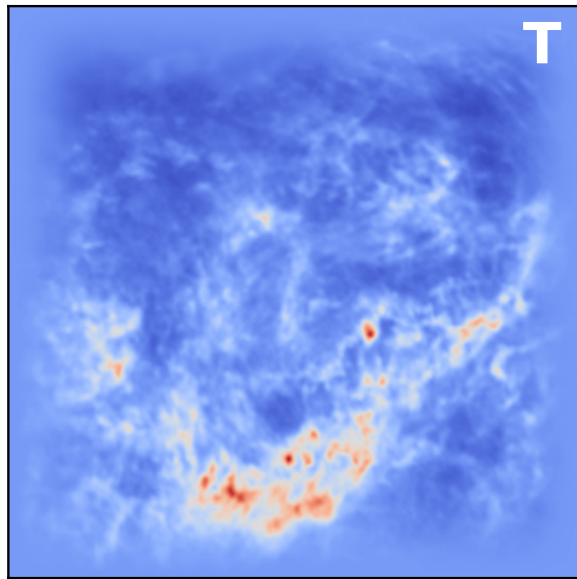
$[T_{\text{dust}}, E_{\text{dust}}, B_{\text{dust}}]$ filtered



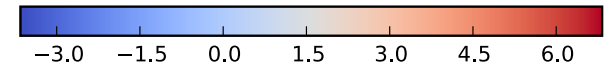
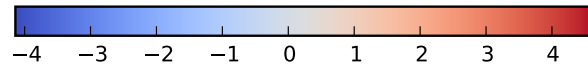
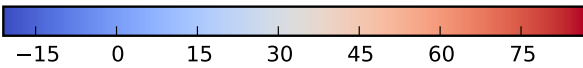
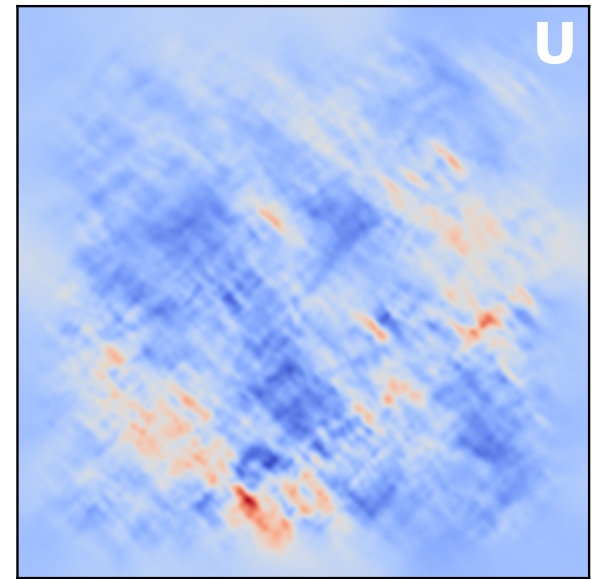
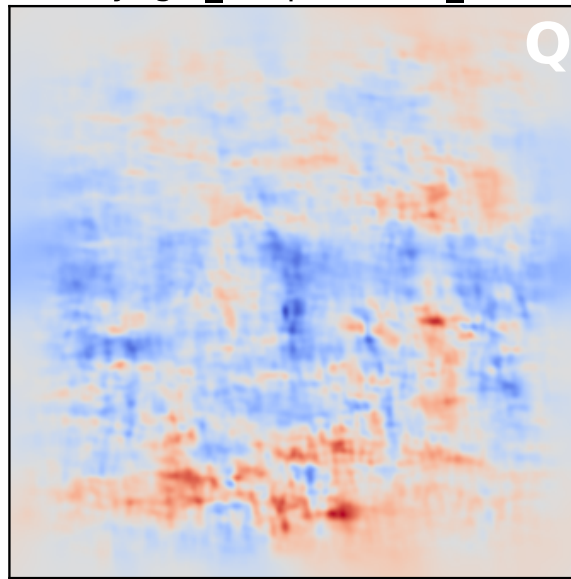
Vansyngel_inTebFiltered_00036



$[T_{\text{dust}}, Q_{\text{dust}}, U_{\text{dust}}]$ filtered

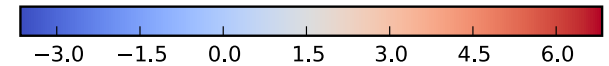
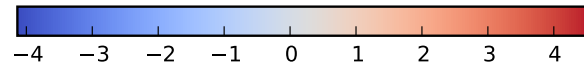
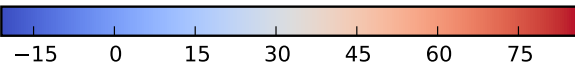
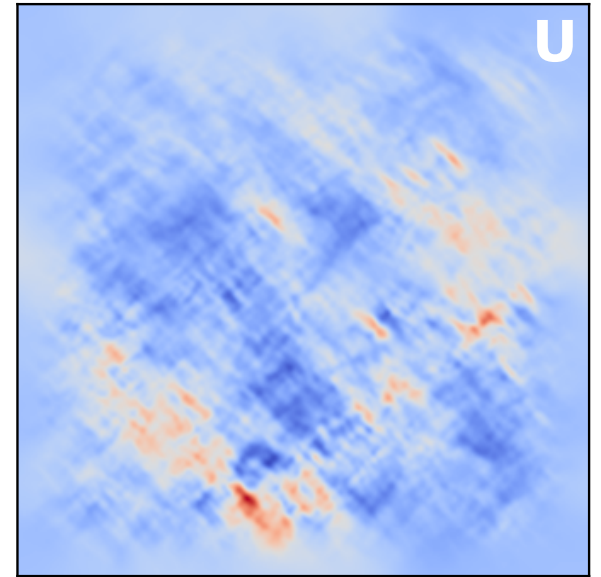
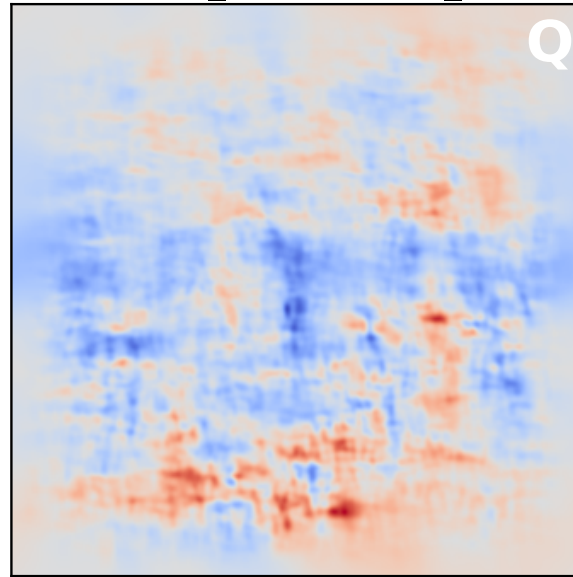
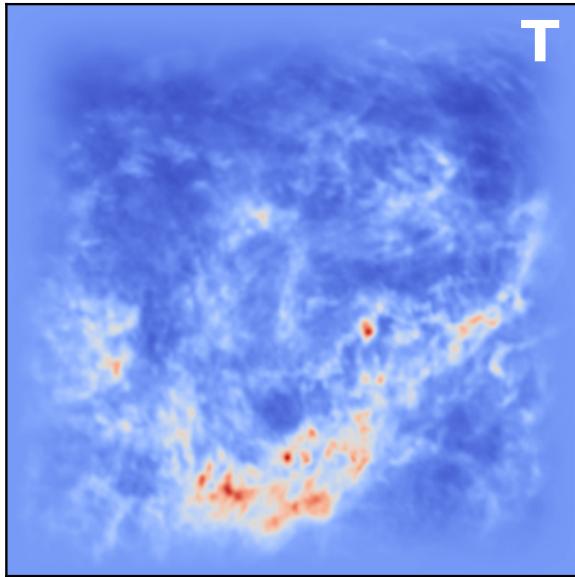


Vansyngel_inTquFiltered_00036



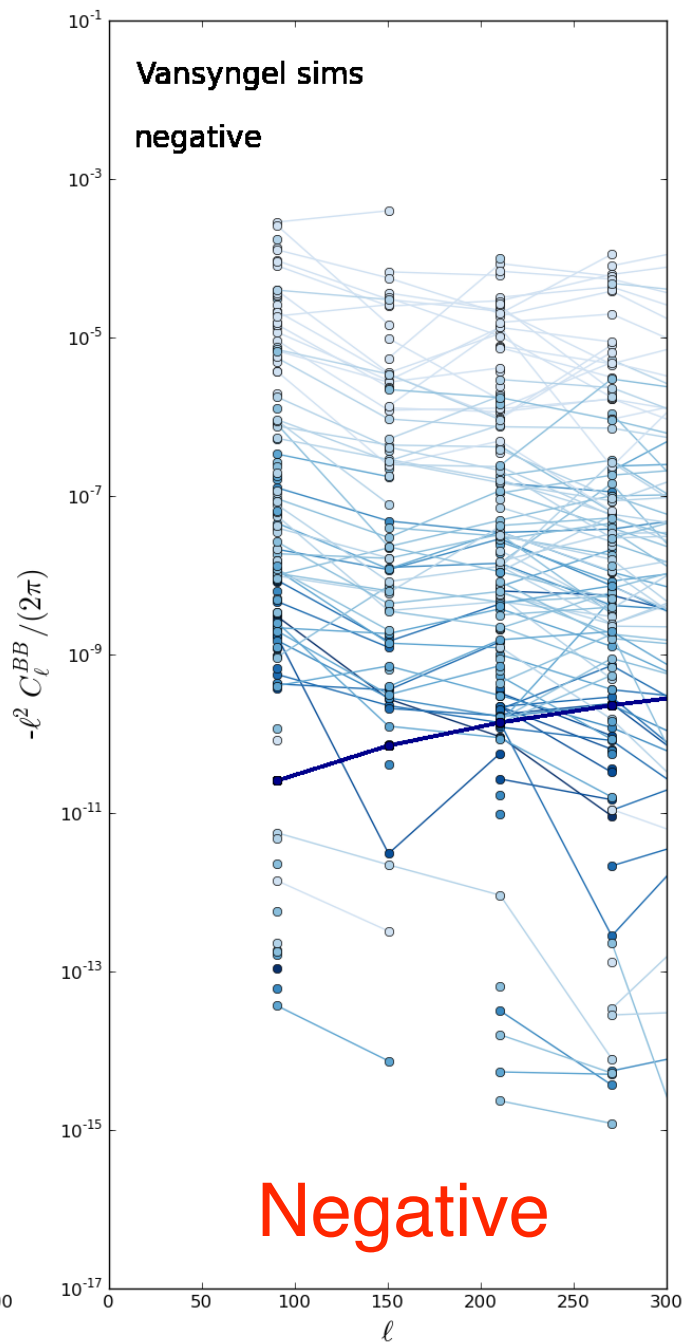
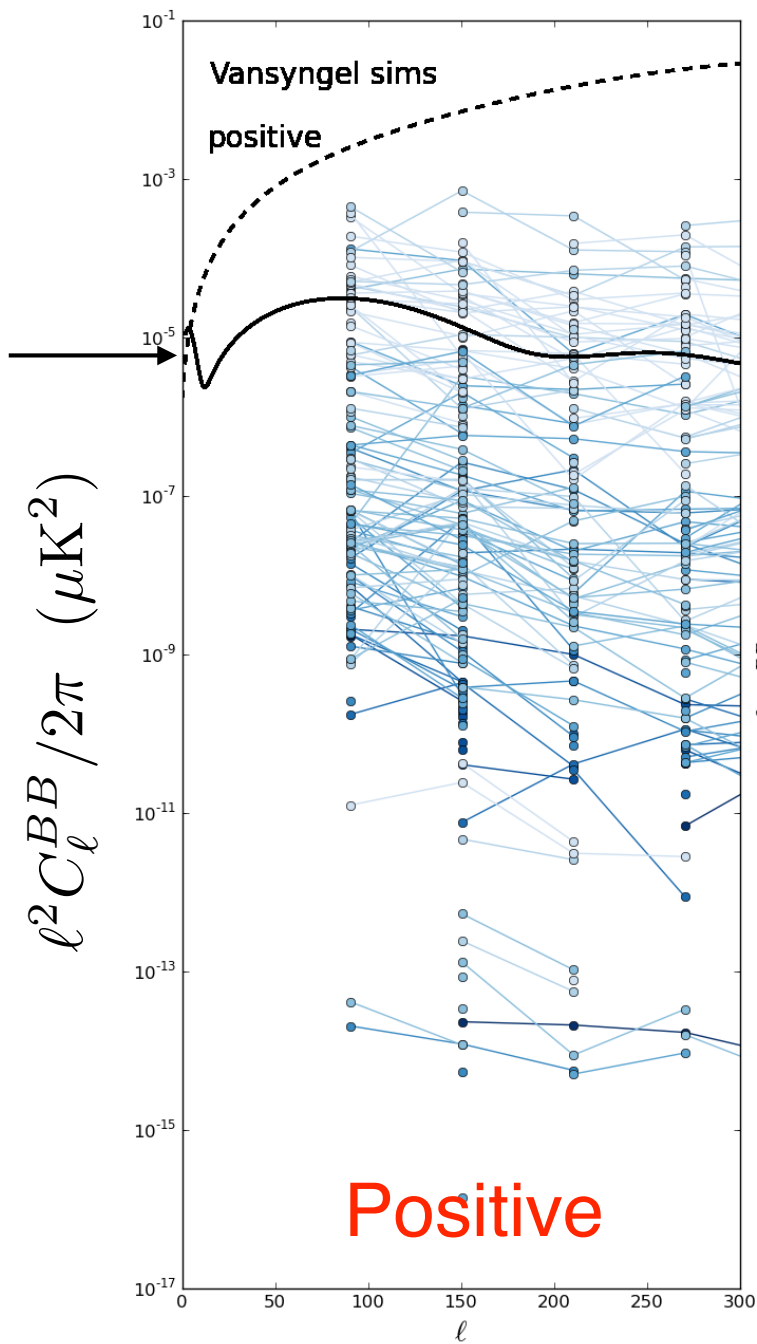
$[T_{\text{dust}}, Q_{\text{dust}}, U_{\text{dust}}]$ filtered
lensed with $\phi(E_{\text{dust}} B_{\text{dust}})$

Vansyngel_delensedTqu_00036



$\langle B_{\text{dust}} B_{\text{template}} \rangle$

$r=5e-4$



Clark sims: no bias seen
(preliminary)

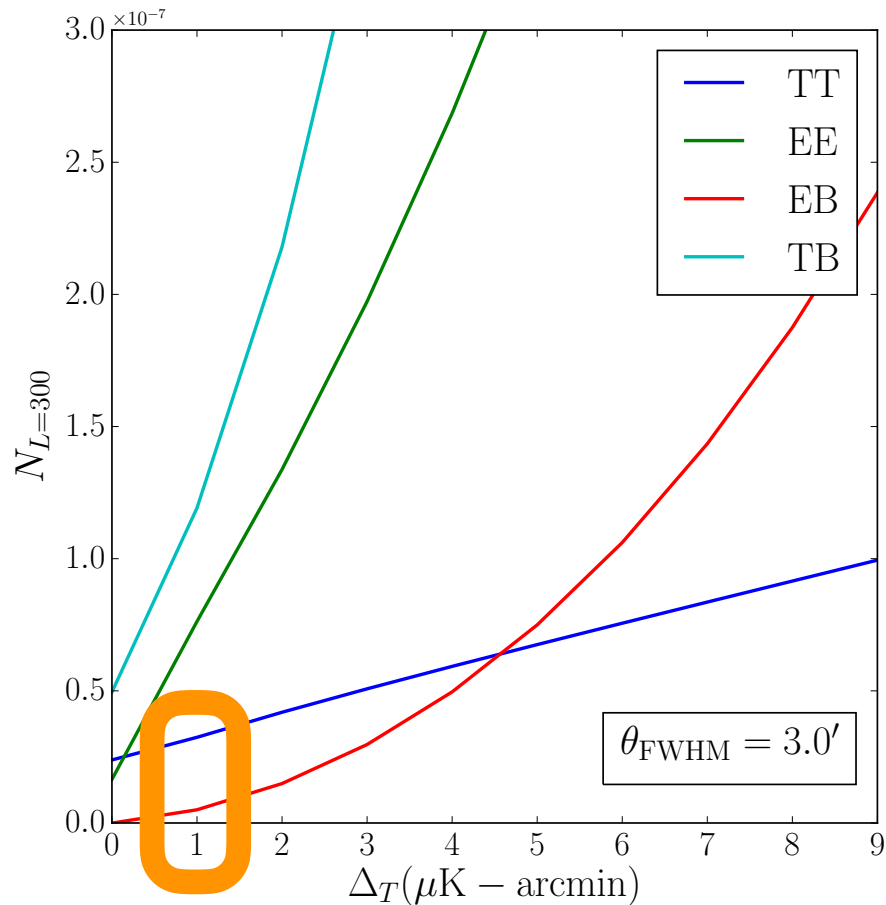
Takeaways

- Dust 4-point function is uncertain and might be important!
- For models analyzed so far (all at one frequency, scaled to 150 GHz):
 - $\langle \kappa(TT)\kappa(TT) \rangle$ is biased from dust.
 - Polarization: CORE+ on PlanckFFP8 found bias that can be removed by down weighting (assumes uniform power over patches!)

Extra slides.....

Outline

Lensing noise vs. instrumental noise

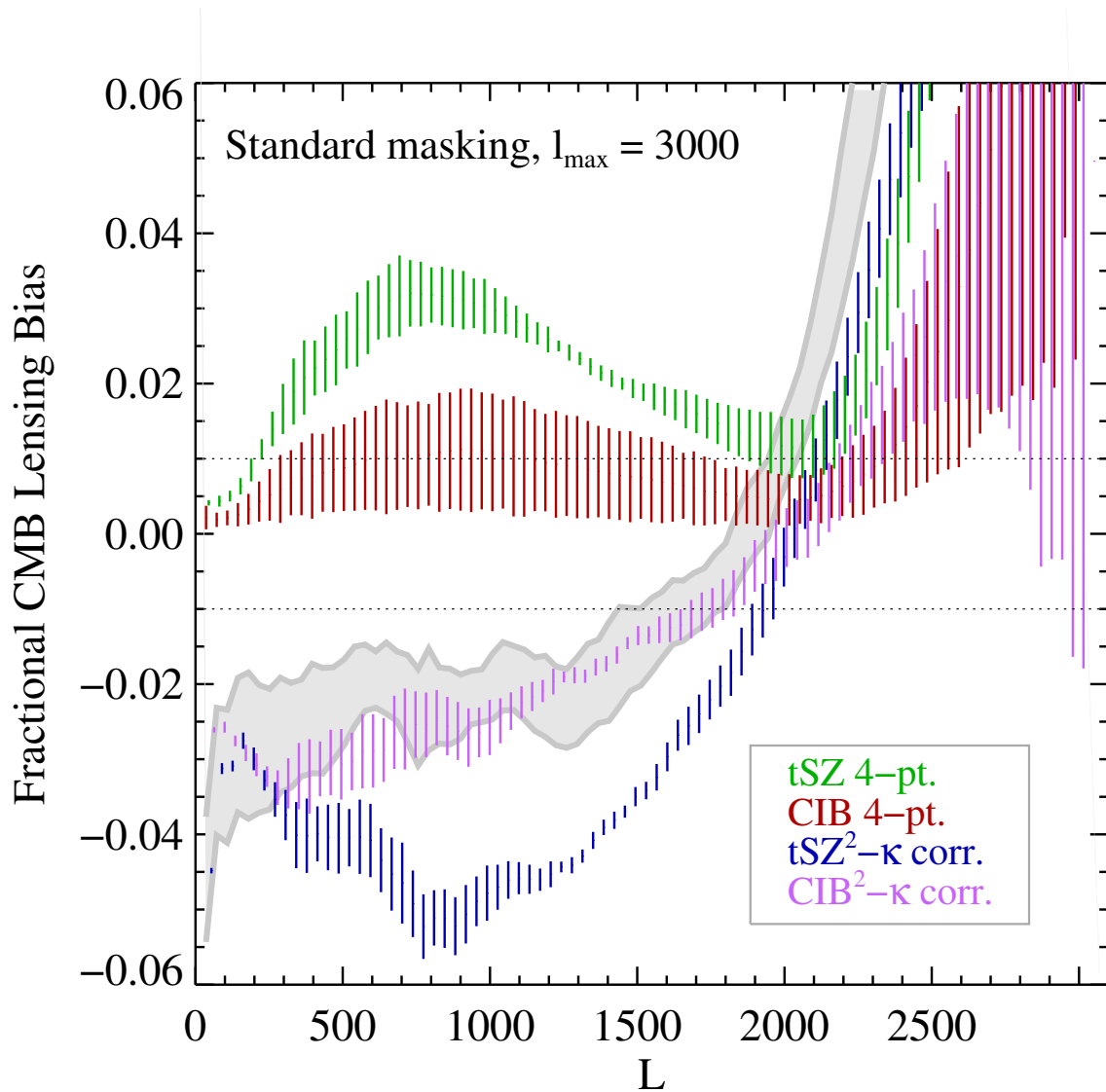


- P lensing will dominate for S4

- T: extragalactic foregrounds

- P: galactic foregrounds

Foregrounds in CMB temperature-based lensing



tSZ-tSZ-tSZ-tSZ

CIB-CIB-CIB-CIB

tSZ-tSZ-κ

CIB-CIB-κ

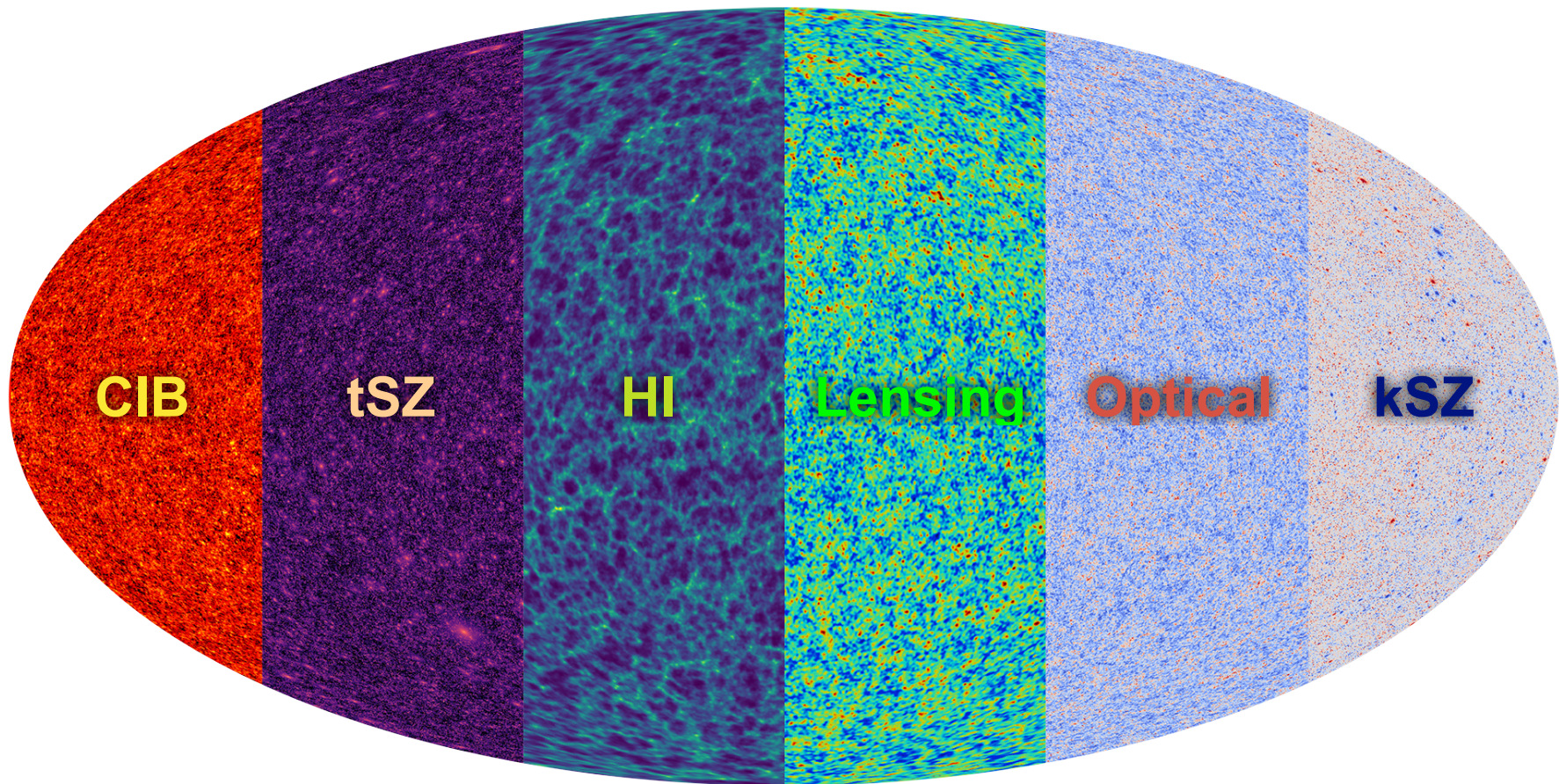
- Biases of several percent at one frequency
 - Here 20 uK-amin noise(!)
- Spectral cleaning (not kSZ - Hill&Ferraro 17)
- Spatial cleaning
- Also, impact of κ non-Gaussianity (Boehm +16)

- CIB/tSZ/kSZ/ κ bi/trispectra are measurable and interesting
- Is bias-hardening feasible?
- Is spectral cleaning feasible? tSZ/CIB bispectrum/trispectrum residuals — comparable to kSZ?

To-do for TT lensing — test both spectral and spatial cleaning with full end-to-end simulation analysis

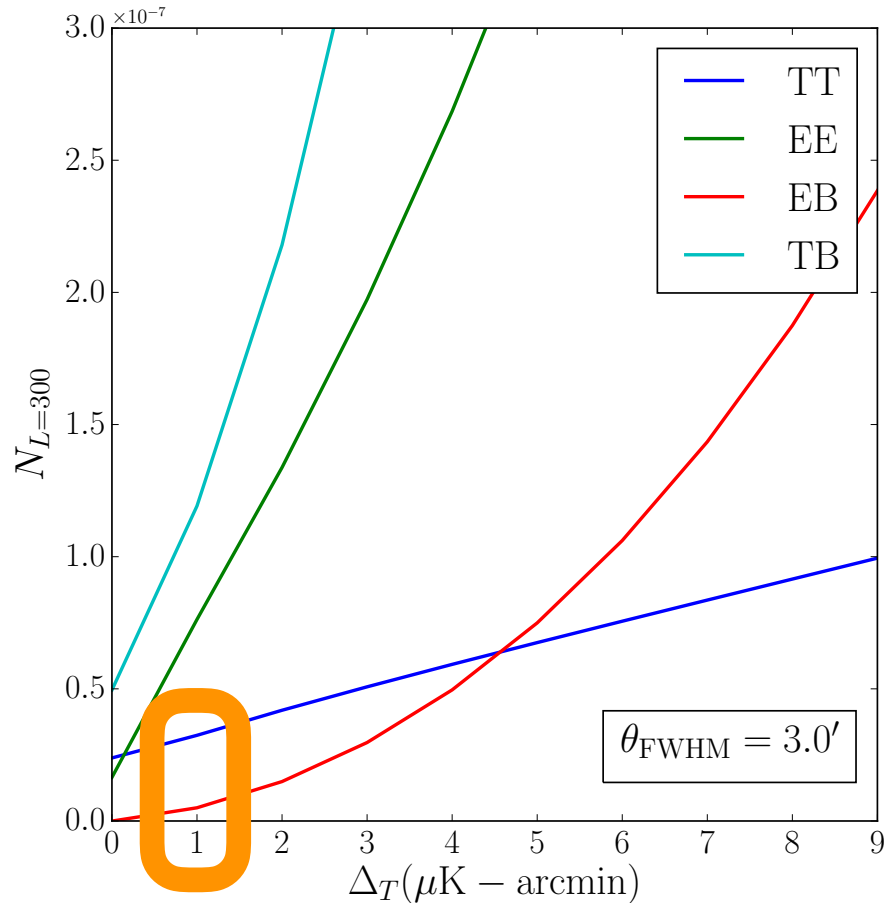
CITA peak-patch simulation

Alvarez, Stein, Bond, Battaglia, van Engelen, Pham, +++



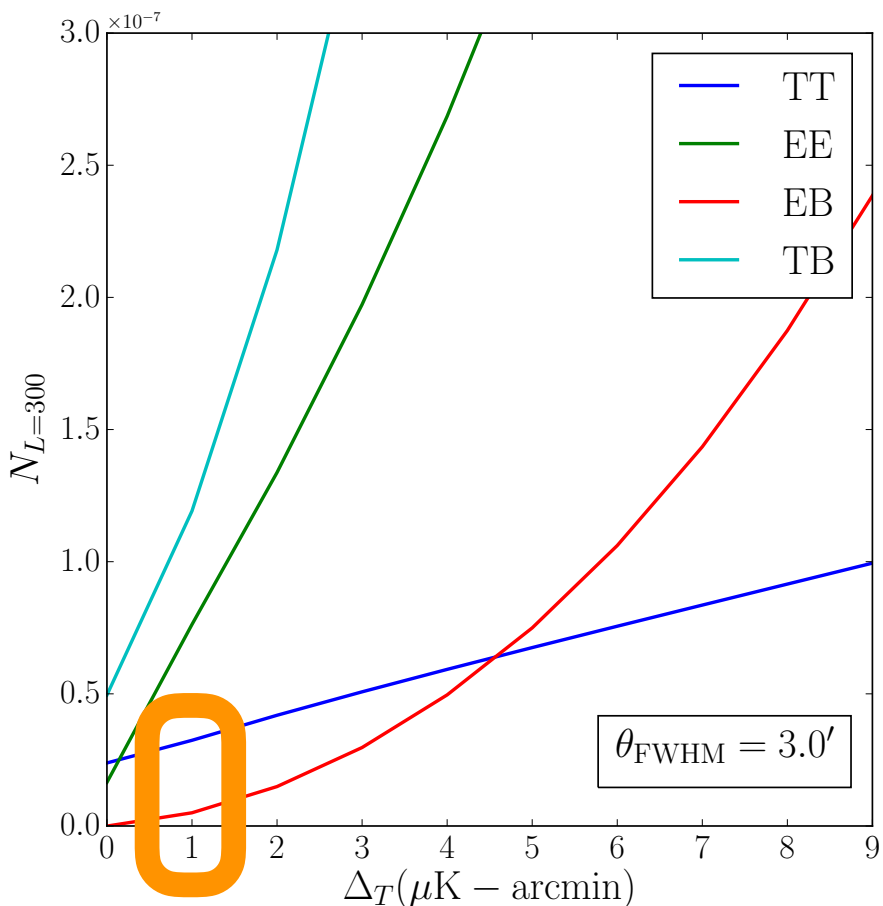
Outline

Lensing noise vs. instrumental noise



- P lensing will dominate for S4
- T: extragalactic foregrounds
- P: galactic foregrounds

Lensing noise vs. instrumental noise



- Polarization lensing will dominate for PICO
- Temperature: extragalactic foregrounds
- Polarization: galactic foregrounds