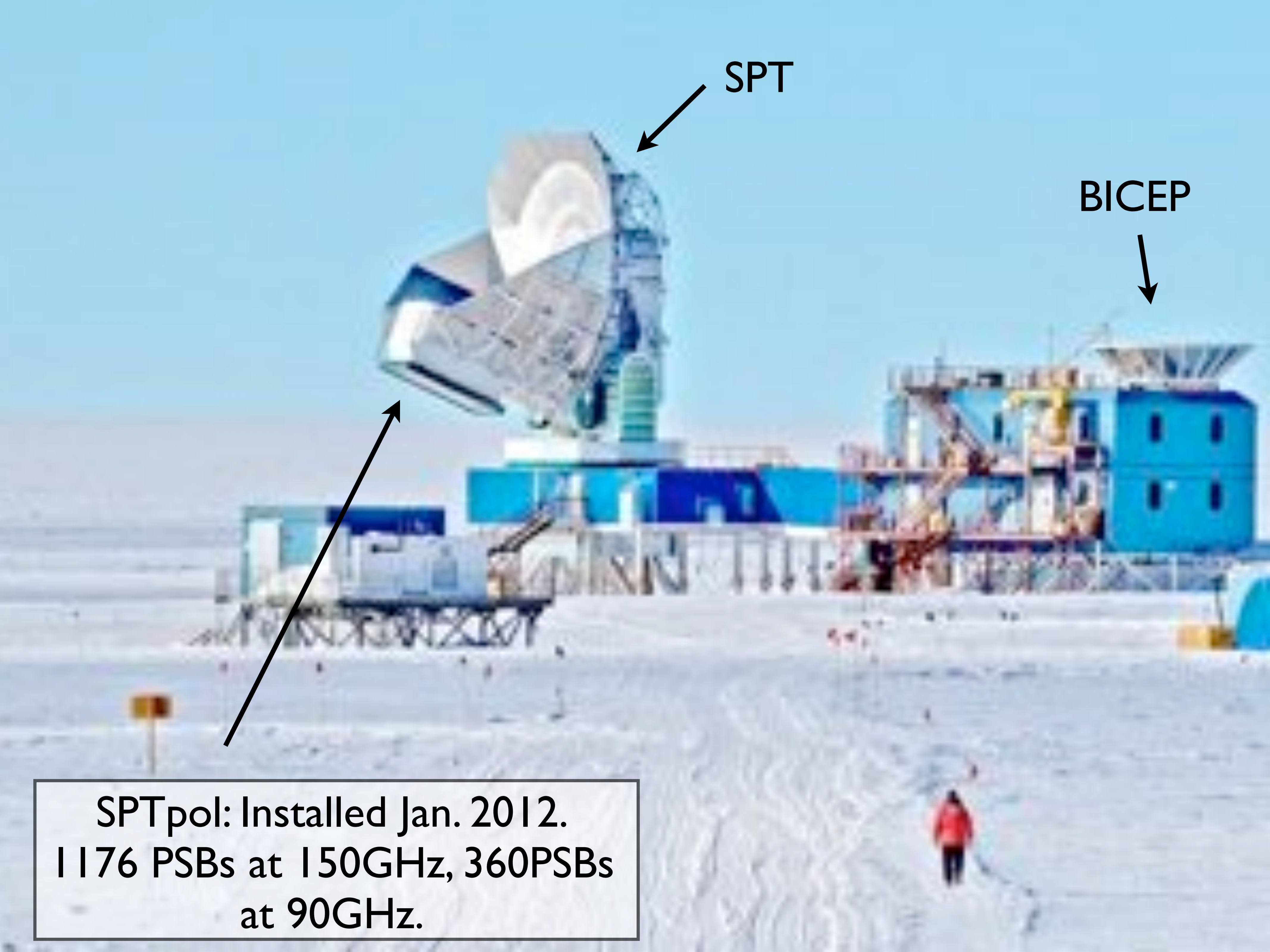
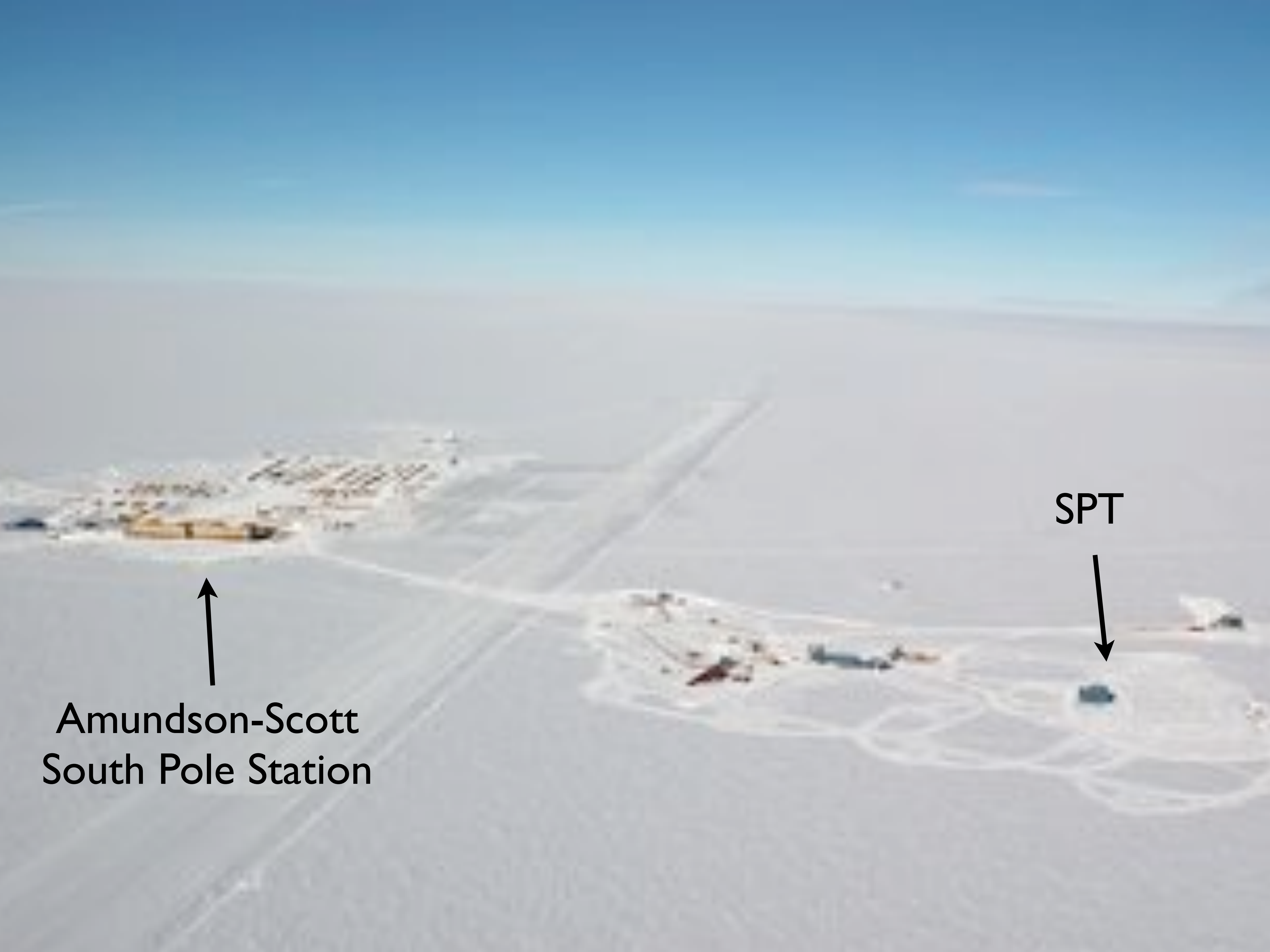
Measurements of B-mode polarization with SPTpol

Duncan Hanson
McGill,
Sept 23rd 2013


SPT
BICEP
SPTpol: Installed Jan. 2012.
1176 PSBs at 150GHz, 360PSBs
at 90GHz.


SPT
Amundson-Scott
South Pole Station


de Haan
George
Chang
Benson
Henning
Holzapfel
Natoli
Crites
Li
Keisler
Hoover
Halverson
Story
Harrington
Austermann

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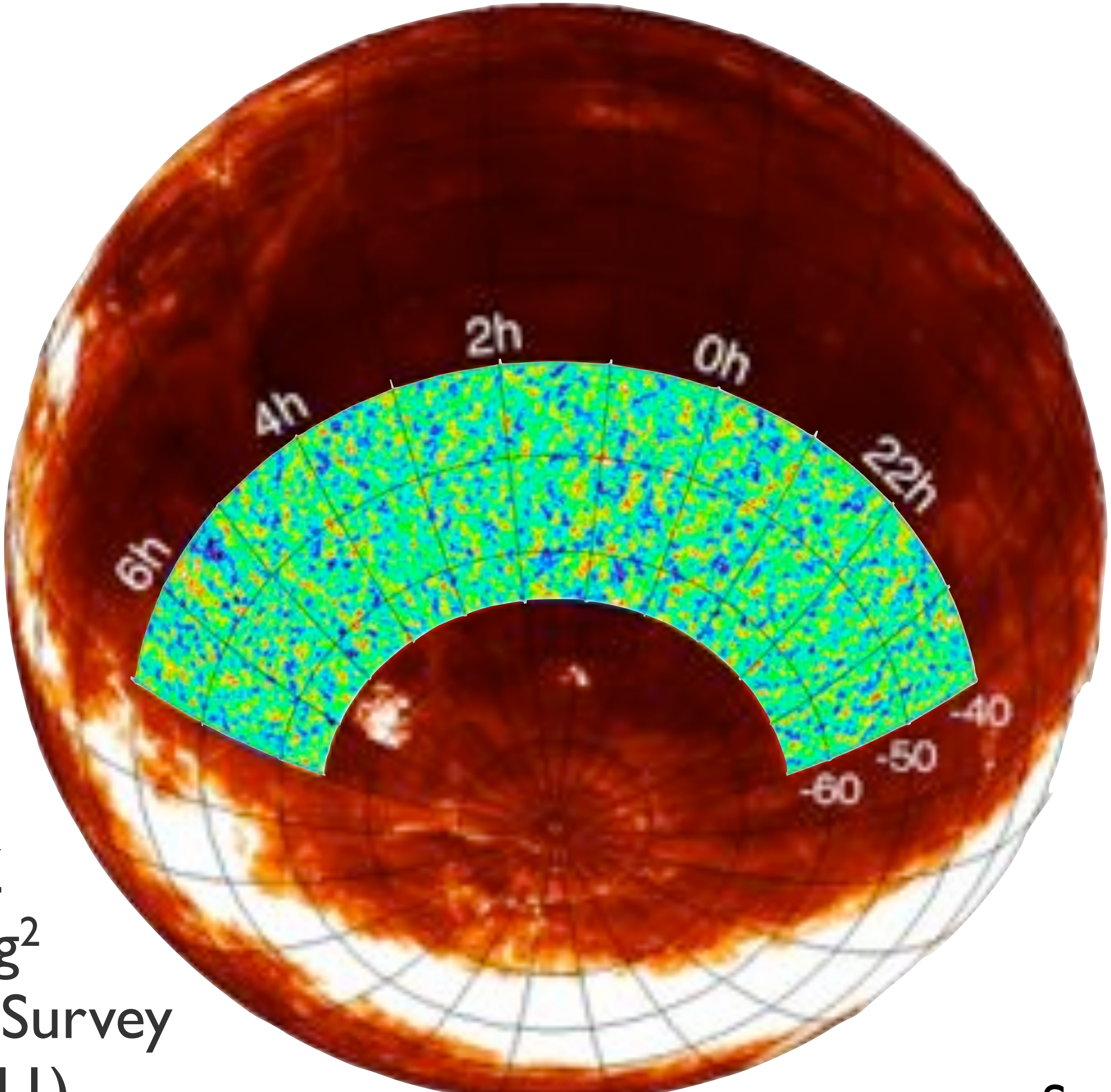
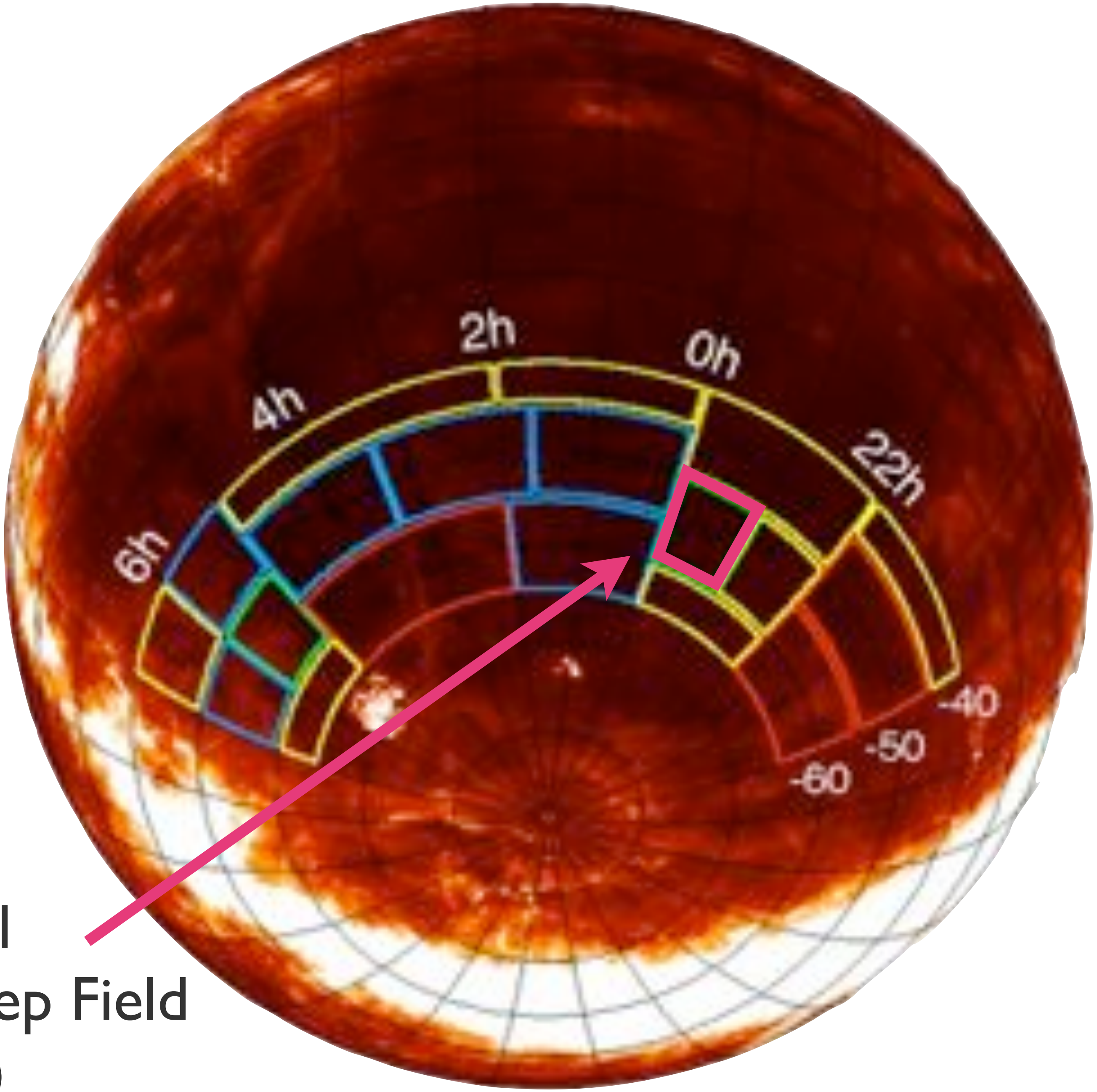
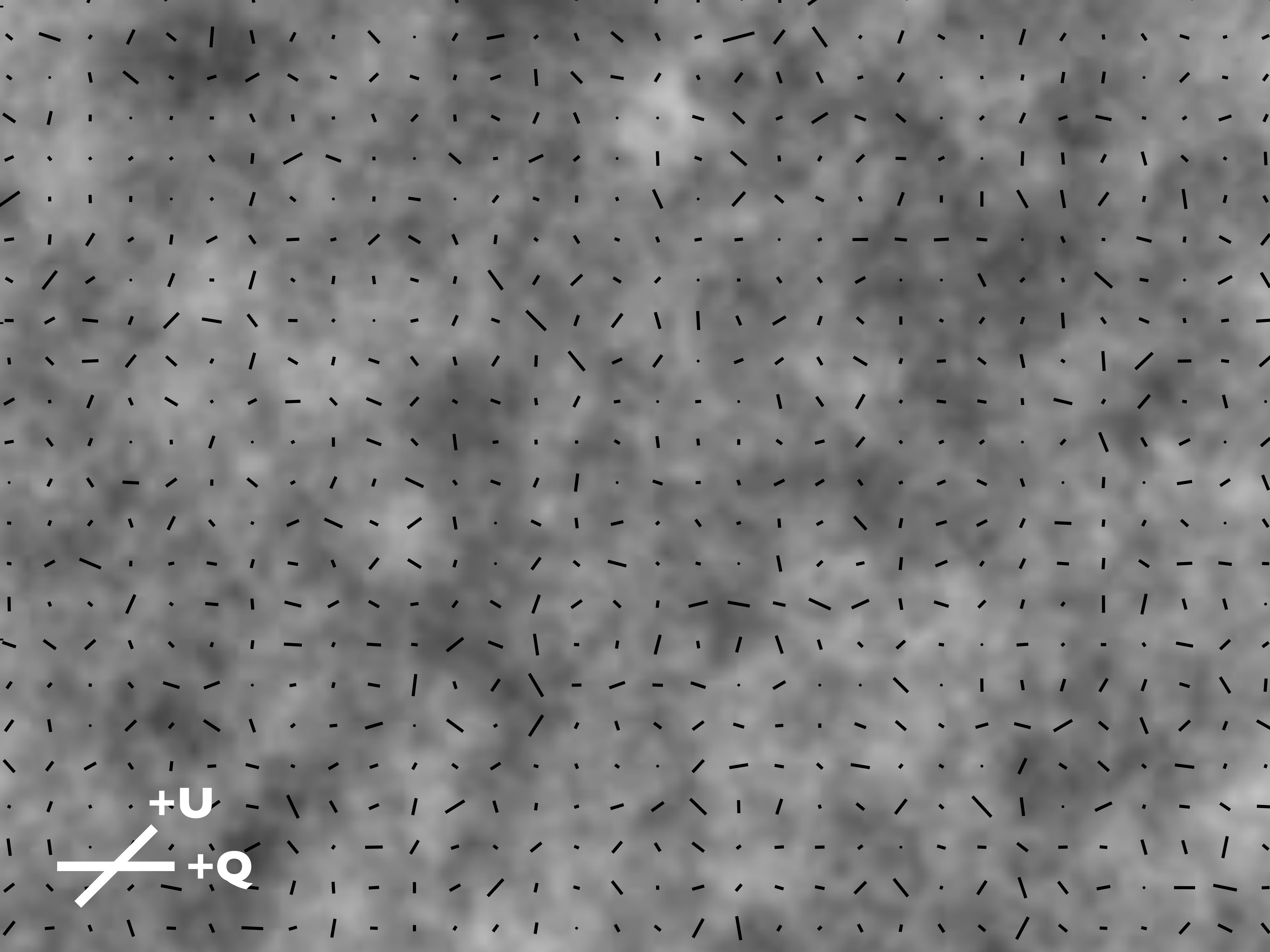


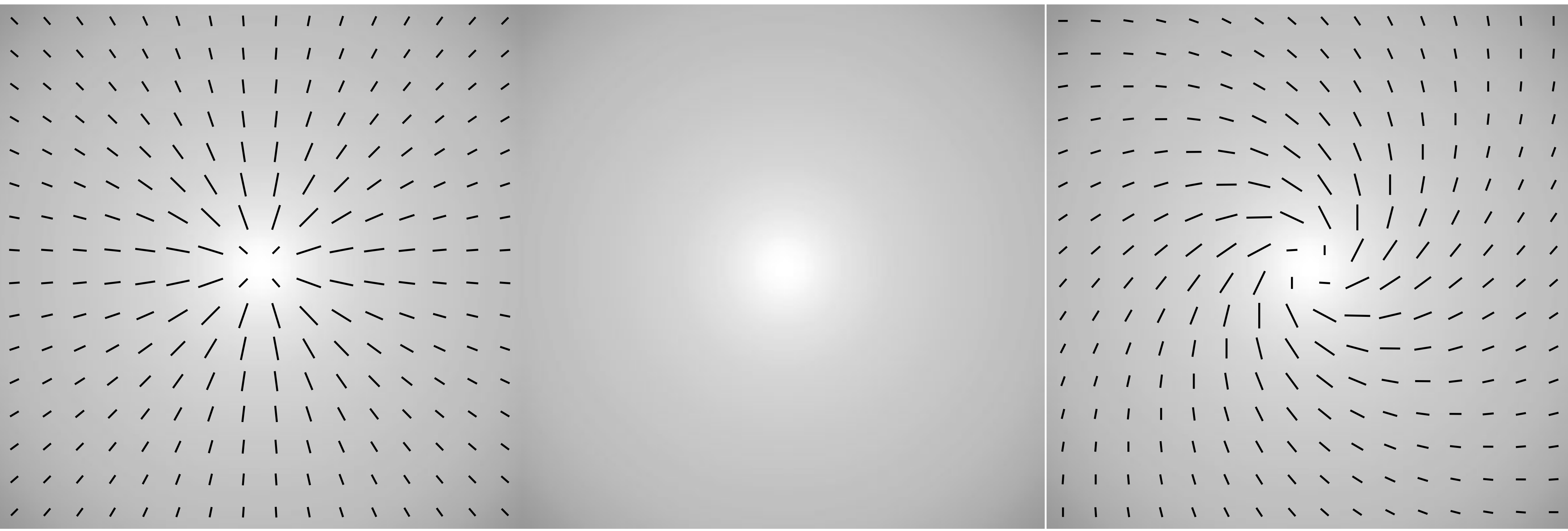
SPT-SZ
2500 deg^2
Temperature Survey
(2008-2011)

Story et. al. 2012

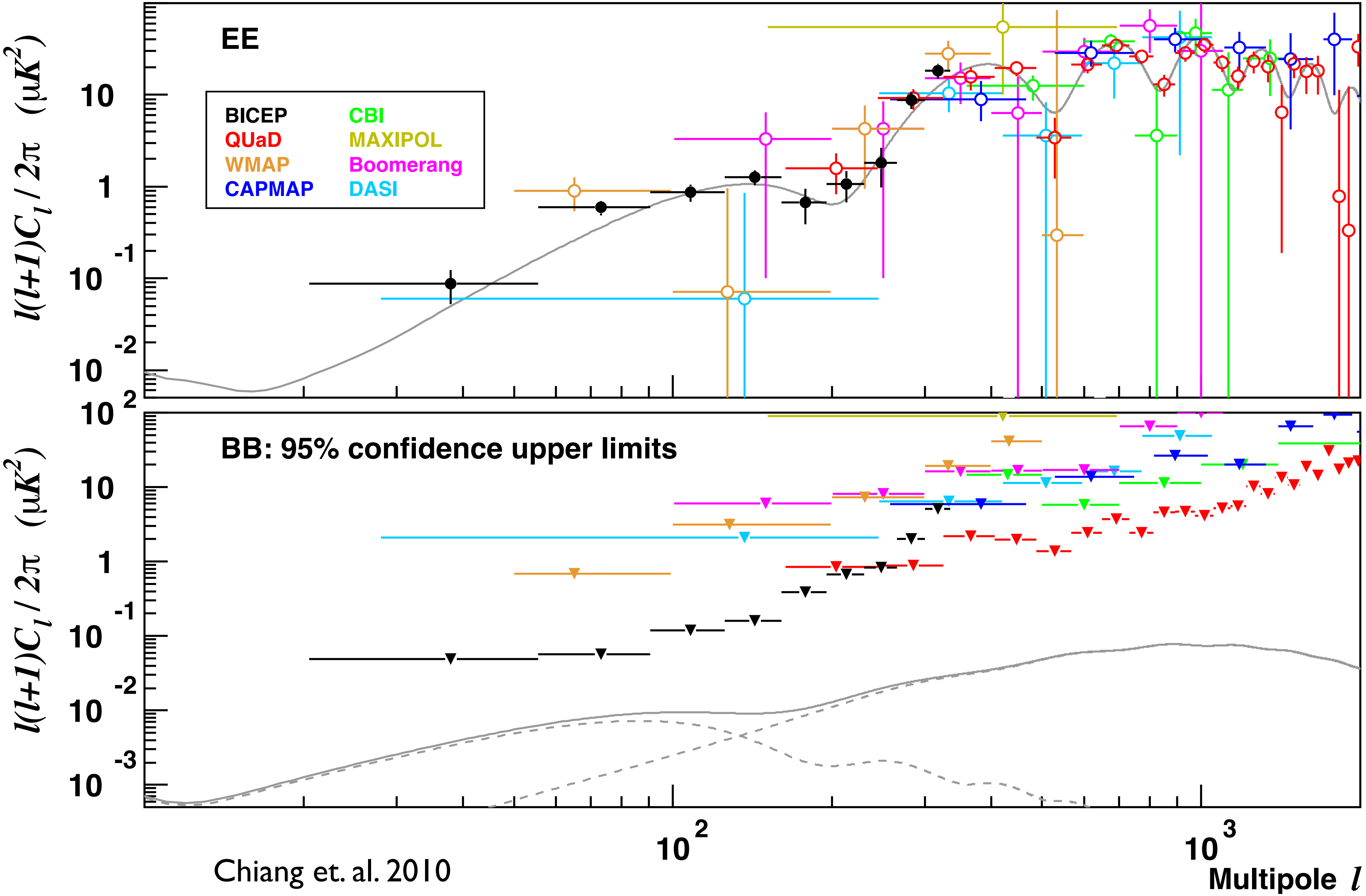


SPTpol
~100deg^2 Deep Field
(2012)

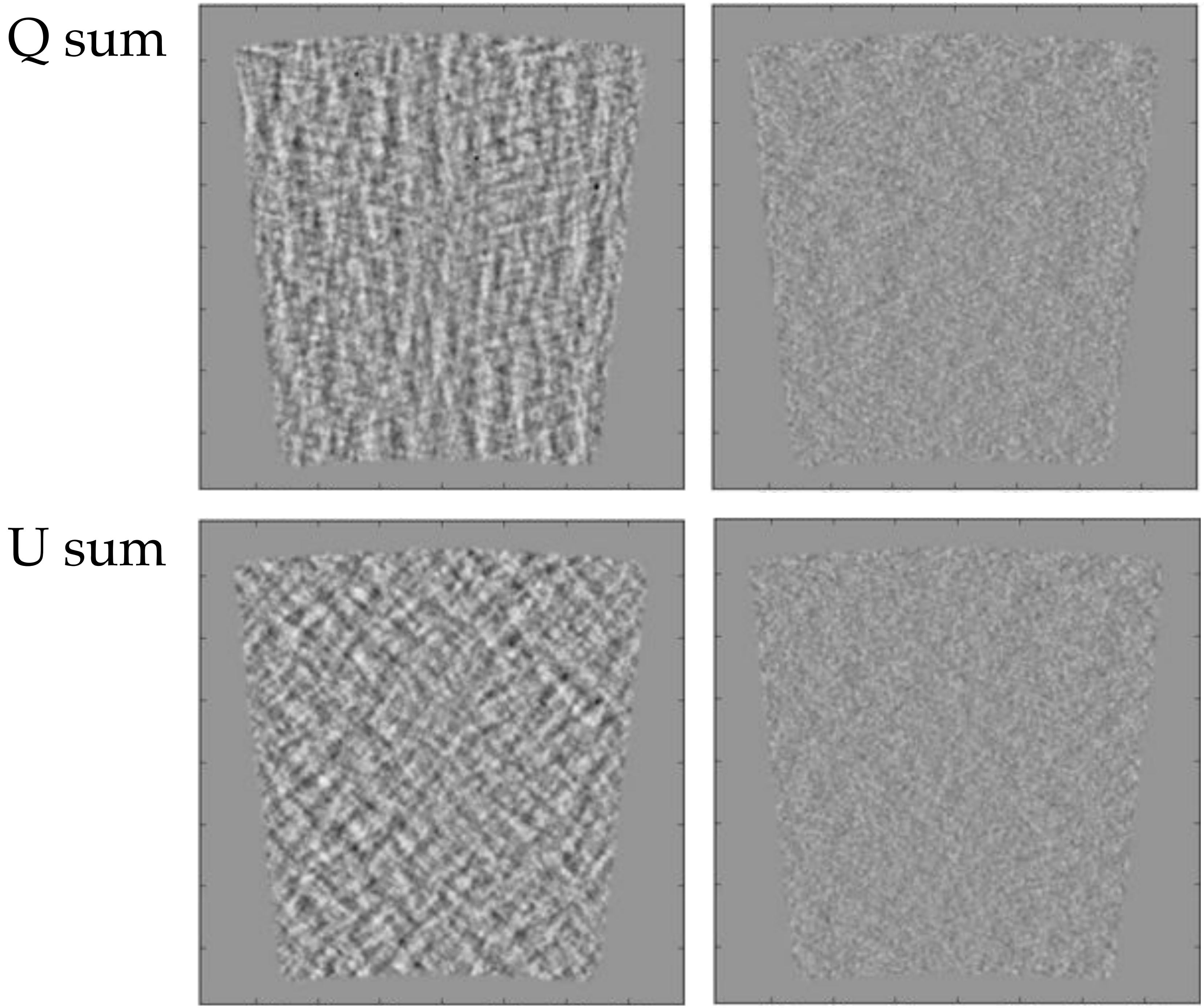

+U
+Q



E-mode Intensity B-mode

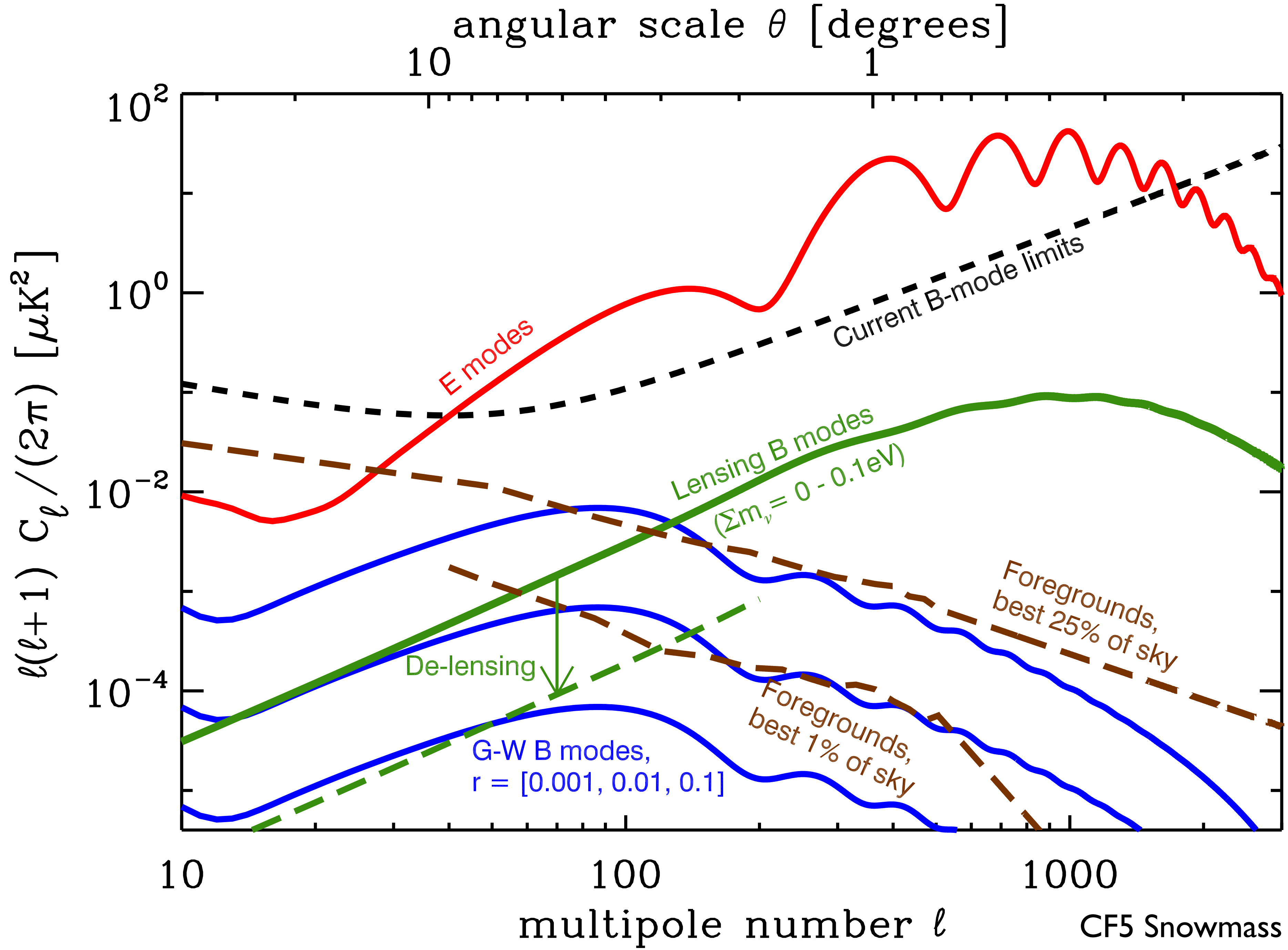


Chiang et. al. 2010

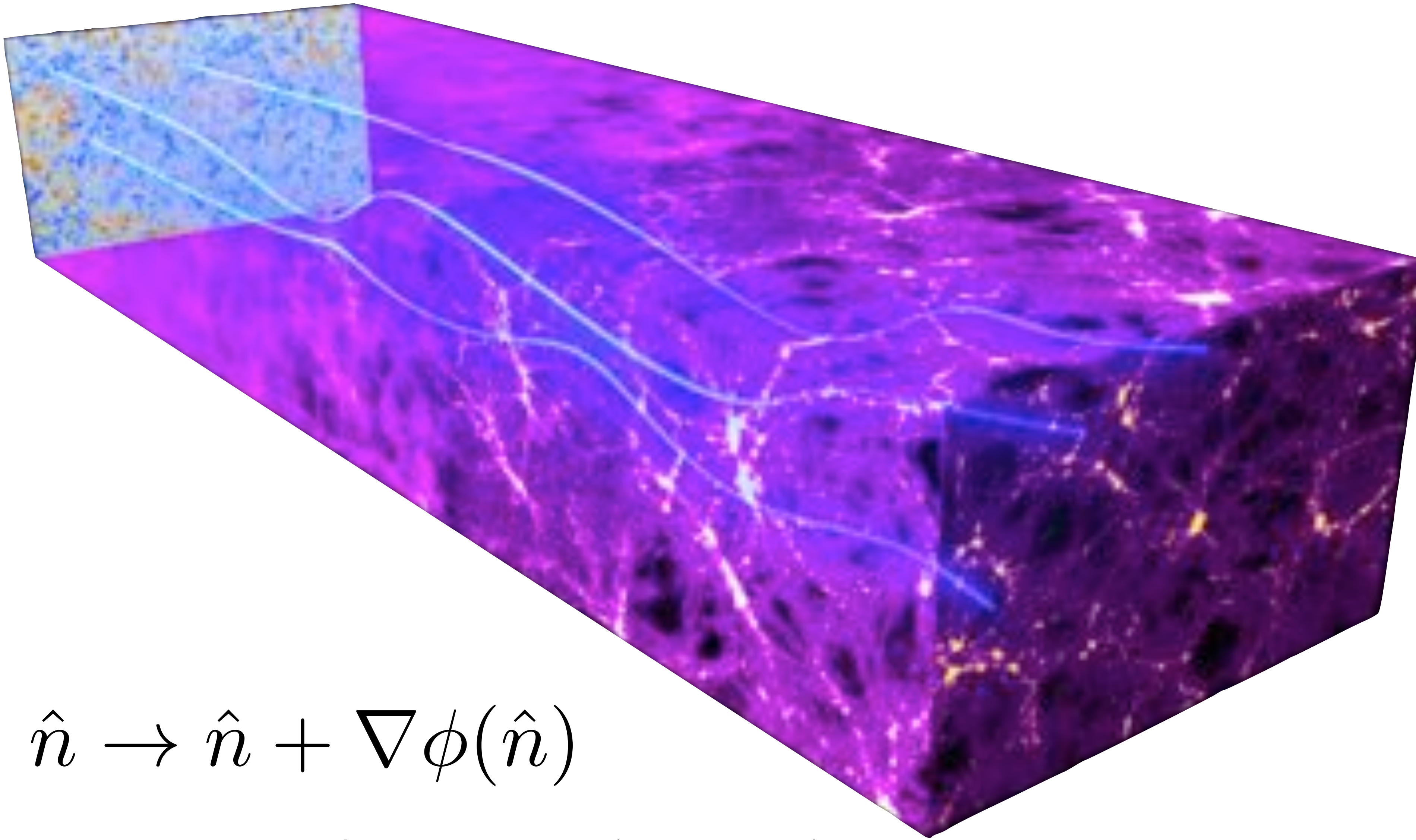


Map noise ~10μK′.

SPTpol Deep Field Q/U maps

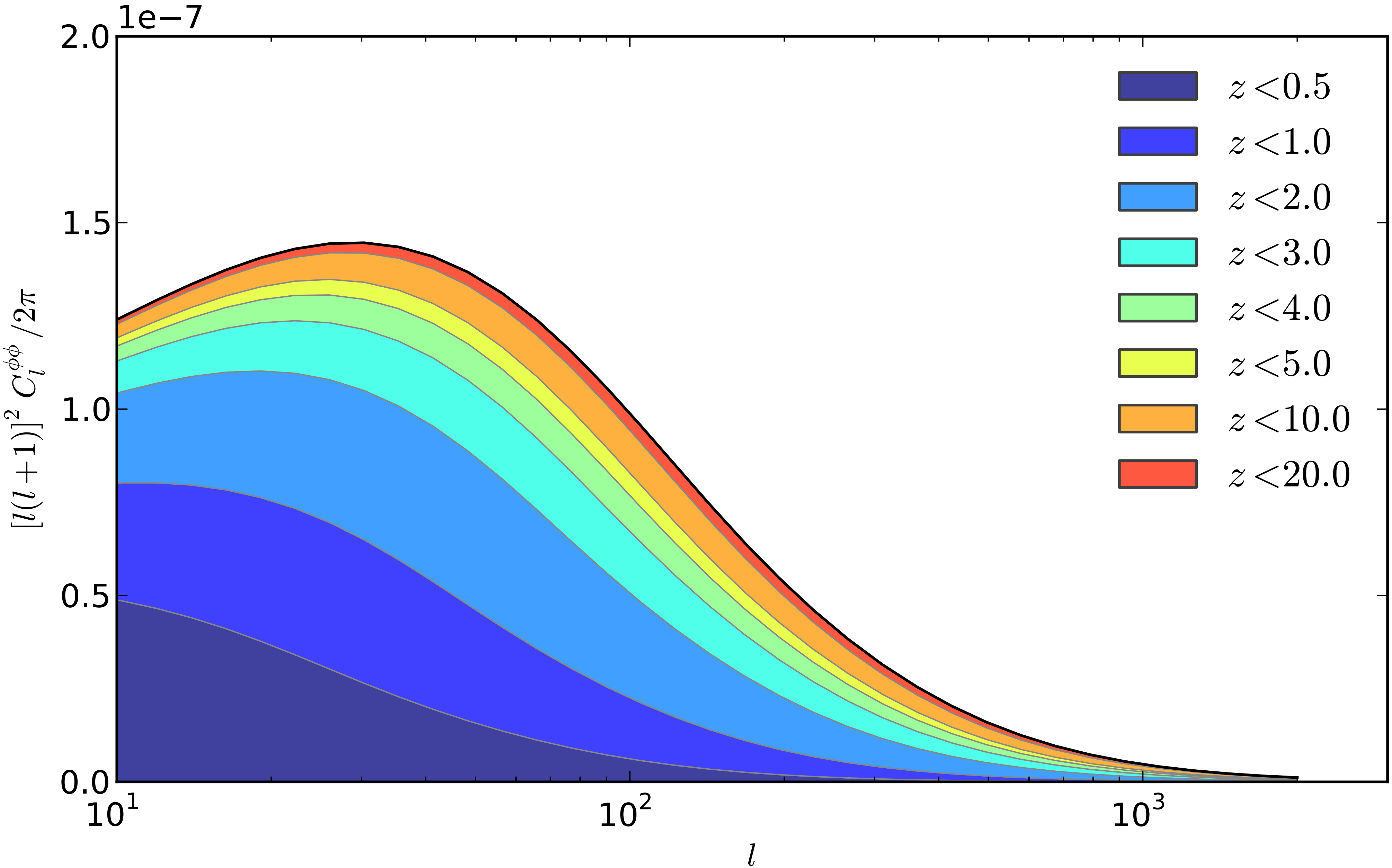


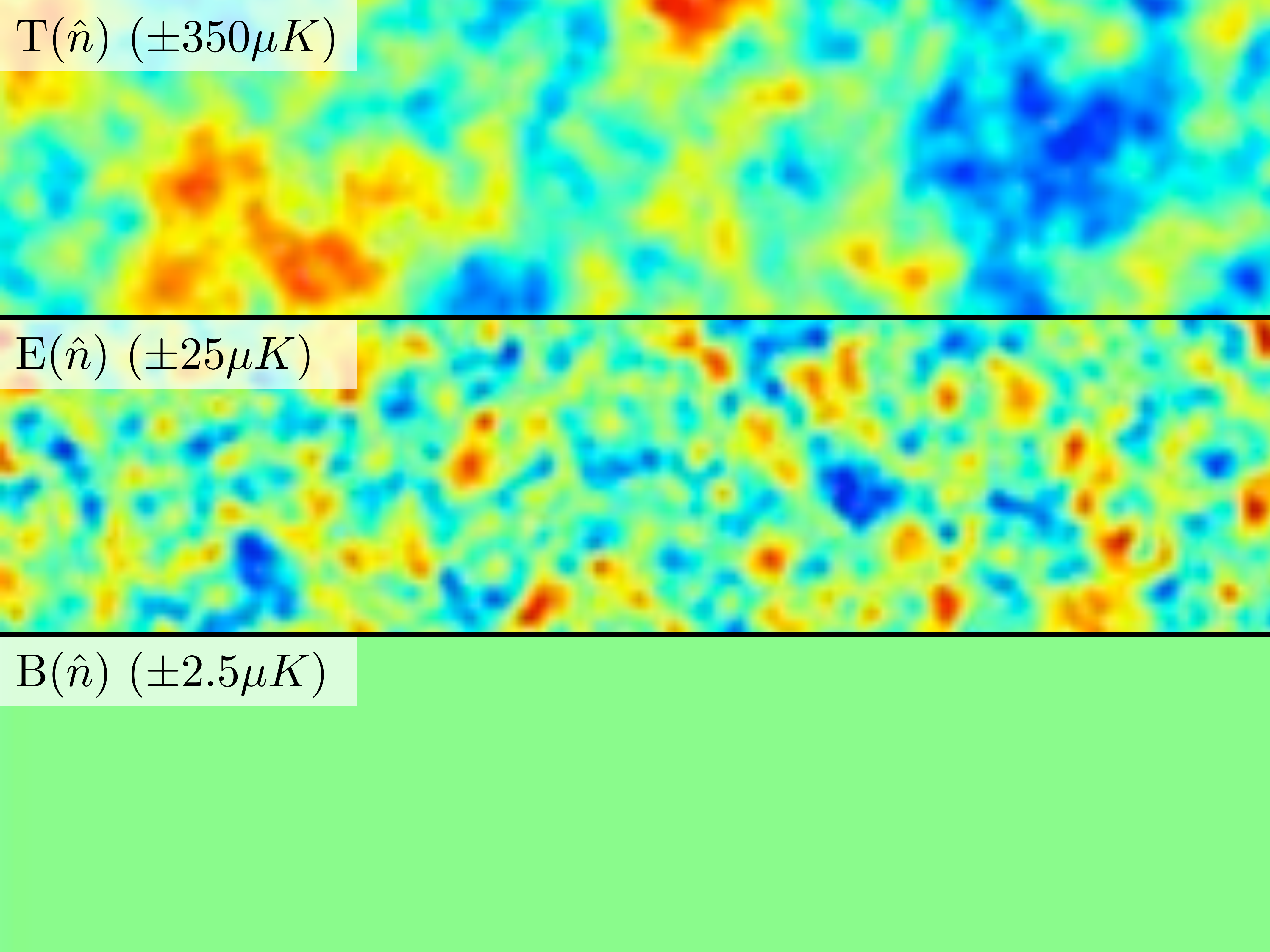
CF5 Snowmass 2013

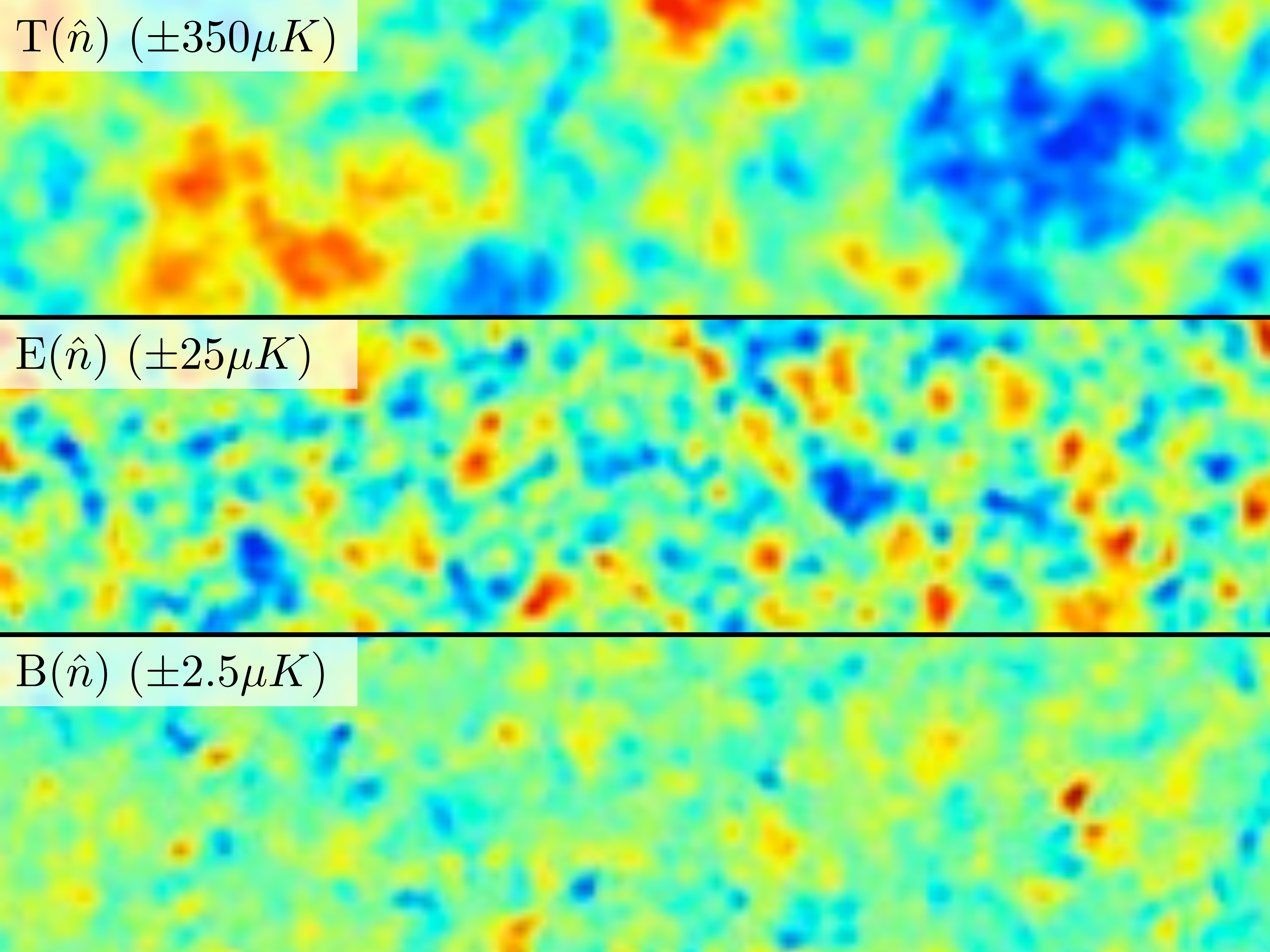


$$\hat{n} \to \hat{n} + \nabla\phi(\hat{n})$$

$$\phi(\hat{n}) = -2\int_0^{\chi_*} d\chi \frac{f_K(\chi_* - \chi)}{f_K(\chi_*) f_K(\chi)} \Psi(\chi\hat{n}; \eta_0 - \chi)$$


1e−7
2.0
1.5
1.0
0.5
0.0
$[l(l+1)]^2\, C_l^{\phi\phi}\,/2\pi$
10^1
10^2
10^3
l
$z<0.5$
$z<1.0$
$z<2.0$
$z<3.0$
$z<4.0$
$z<5.0$
$z<10.0$
$z<20.0$

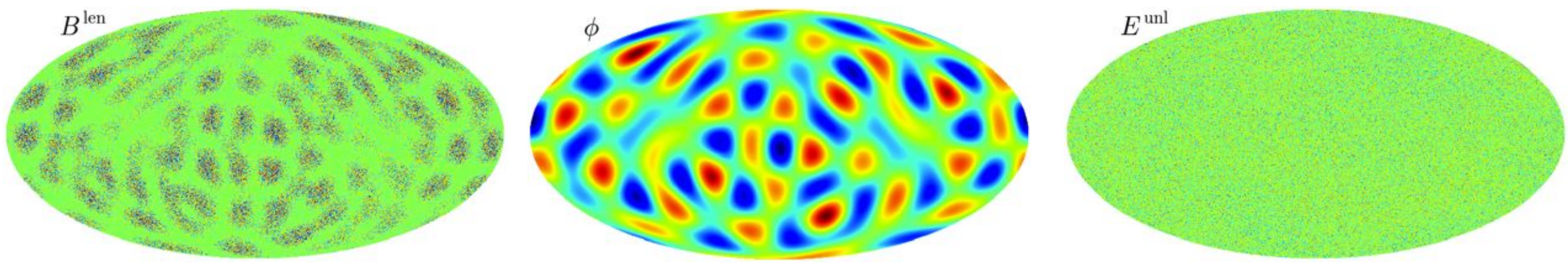

$\mathrm{T}(\hat{n})$ $(\pm 350\mu K)$
$\mathrm{E}(\hat{n})$ $(\pm 25\mu K)$
$\mathrm{B}(\hat{n})$ $(\pm 2.5\mu K)$



$T(\hat{n})$ $(\pm 350\mu K)$
$E(\hat{n})$ $(\pm 25\mu K)$
$B(\hat{n})$ $(\pm 2.5\mu K)$

Lensing B-modes are pretty much linear in E and Phi:

$$B^{\text{lens}}(\vec{l_B}) \approx \int d^2\vec{l_E} \int d^2\vec{l_\phi} W^\phi(\vec{l_E}, \vec{l_B}, \vec{l_\phi}) E(\vec{l_E}) \phi(\vec{l_\phi})$$



Two ideas:

- Given E and Φ, can estimate B^{lens} for delensing.
- Given E and B, can estimate Φ.

Template EB Lens Reconstruction:

Template-fit for the ϕ coefficients by minimizing the χ^2:

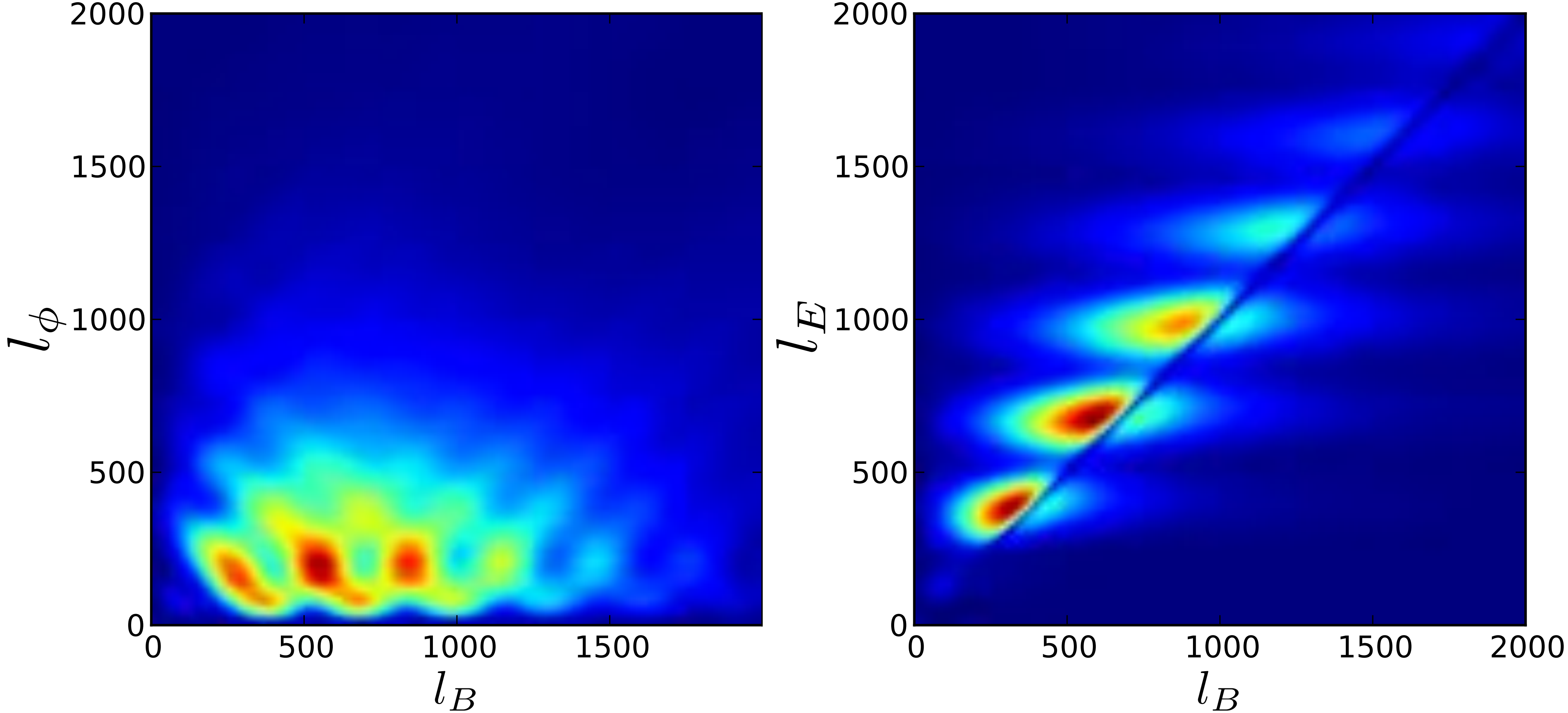
$$\vec{B}^{\rm len} \approx \vec{B}^{\rm unl} + \mathbf{M}\vec{\phi} \qquad\qquad \vec{B}^{\rm del} = \vec{B}^{\rm obs} - \hat{\mathbf{M}}\hat{\vec{\phi}}$$

$$\chi^2 = \vec{B}^{\rm del\dagger}(\mathbf{N}^{B_{\rm del}})^{-1}\vec{B}^{\rm del} + \hat{\vec{\phi}}^{\dagger}(\mathbf{C}^{\phi\phi})^{-1}\hat{\vec{\phi}},$$

$$\hat{\vec{\phi}} = \left[\hat{\mathbf{M}}^{\dagger}(\mathbf{N}^{B_{\rm del}})^{-1}\hat{\mathbf{M}} + (\mathbf{C}^{\phi\phi})^{-1}\right]^{-1}\hat{\mathbf{M}}^{\dagger}(\mathbf{N}^{B_{\rm del}})^{-1}\vec{B}^{\rm obs}.$$

The matrix inversion for $\hat{\vec{\phi}}$ is “expensive”. Accuracy of inversion determines quality of reconstruction–

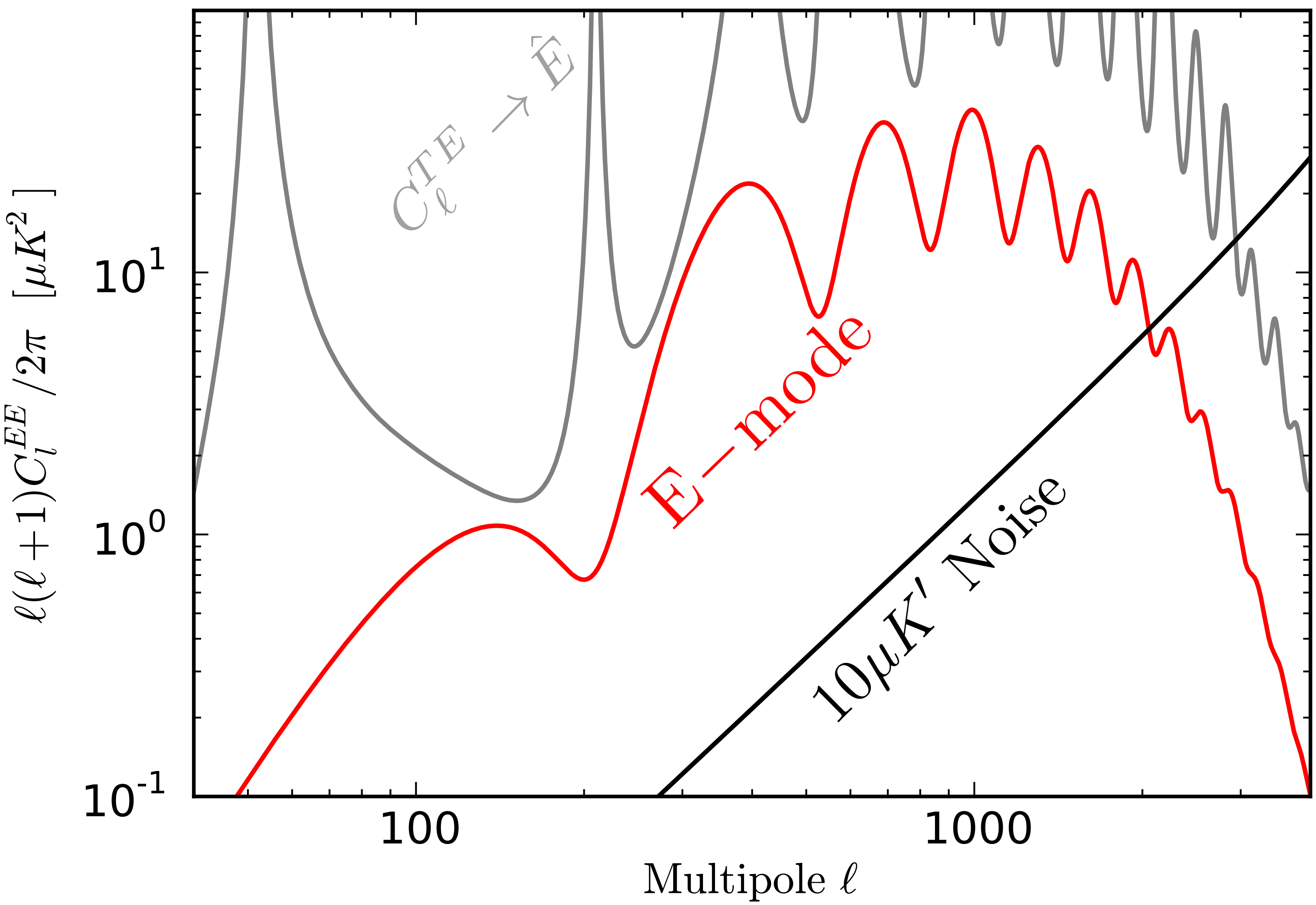
- Diagonal approximation $\rightarrow$ Okamoto and Hu (Quadratic)
- Proper inversion $\rightarrow$ Hirata and Seljak (Iterative Max. Like.)



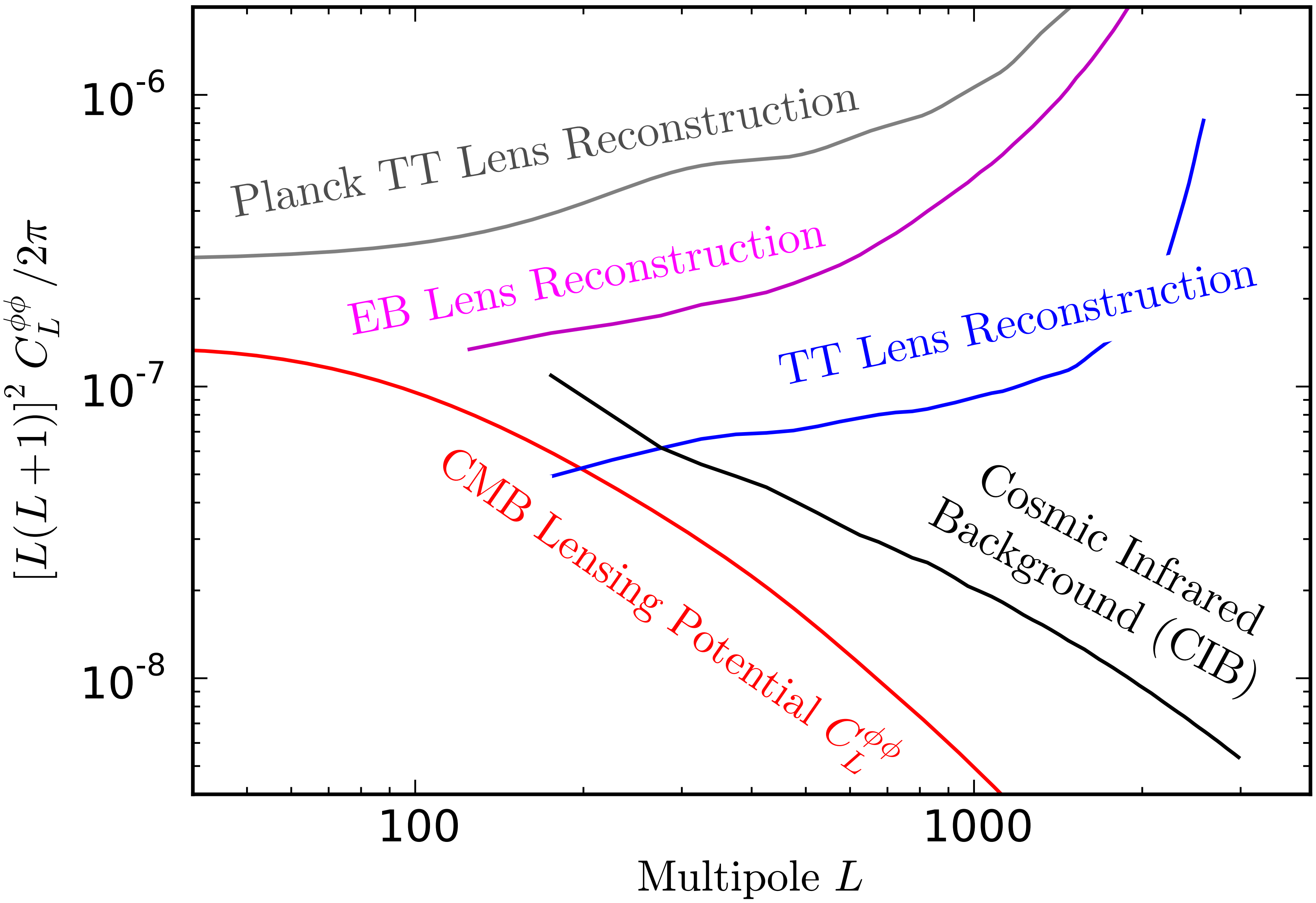
$$l_B \partial C_{l_B}^{BB,\mathrm{lens}} / \partial C_{l_X}^{XX}$$

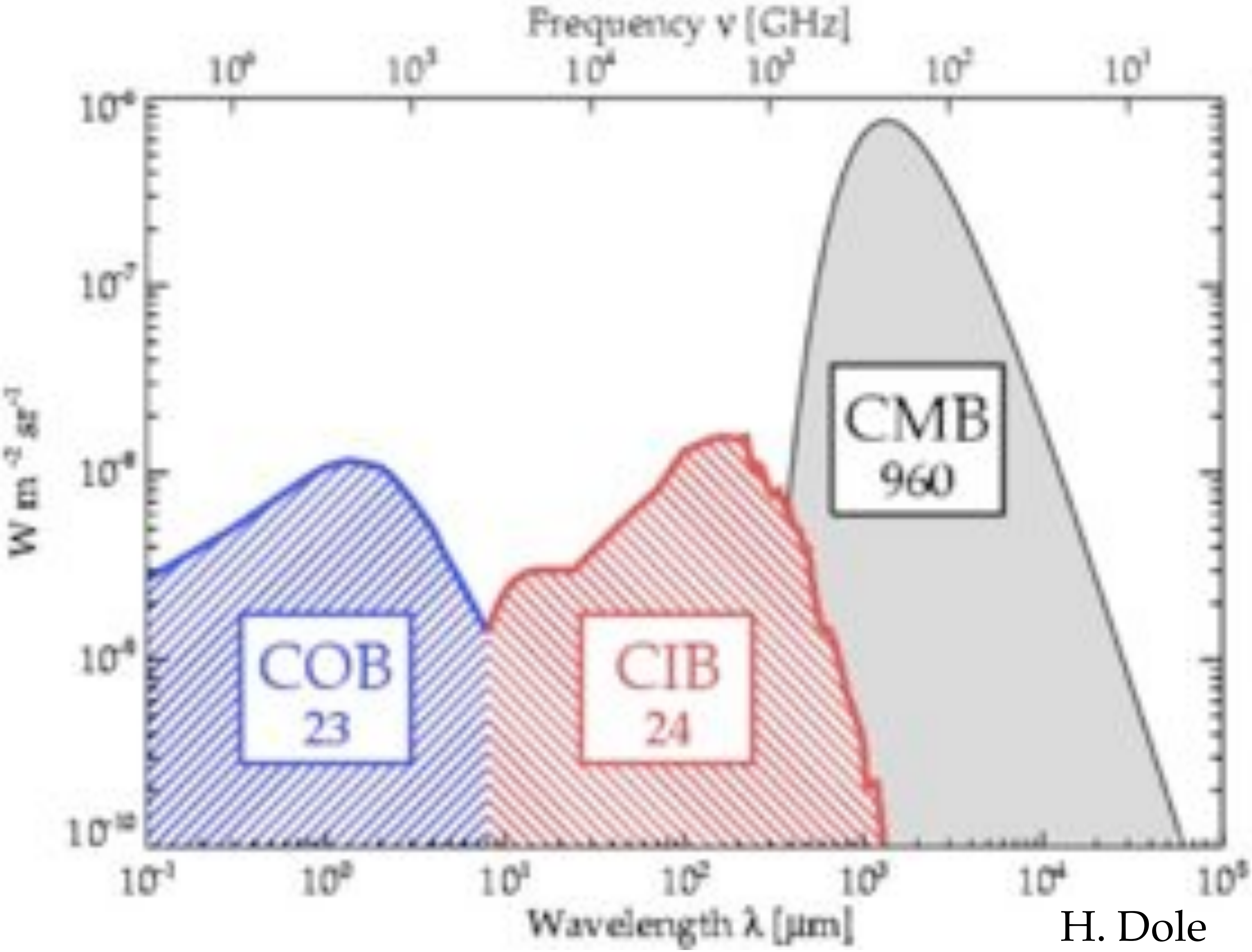
Lensing B modes are sourced by E and ϕ over a range of scales.

E-mode Noise Spectra:

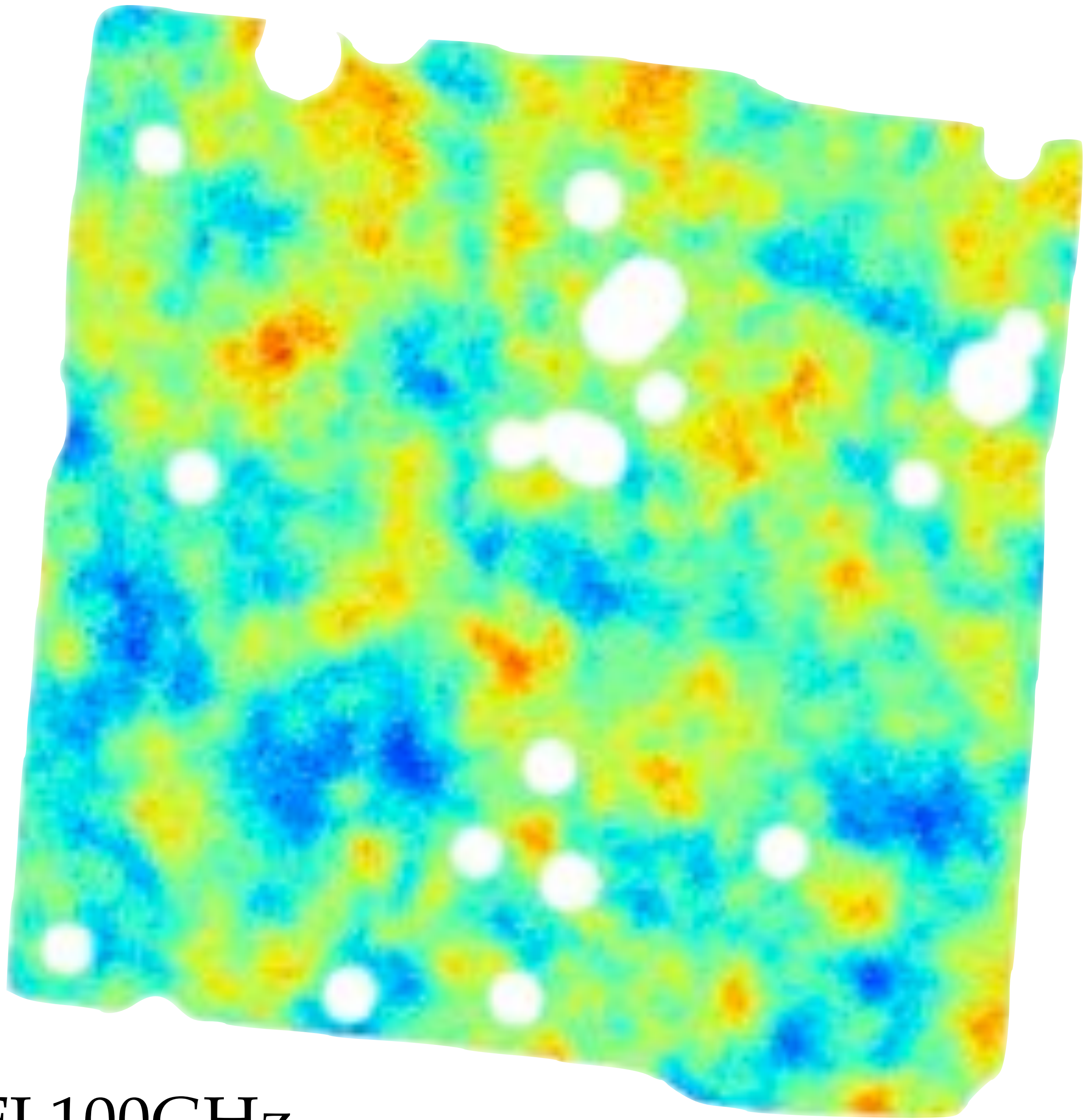


Φ-mode Noise Spectra:

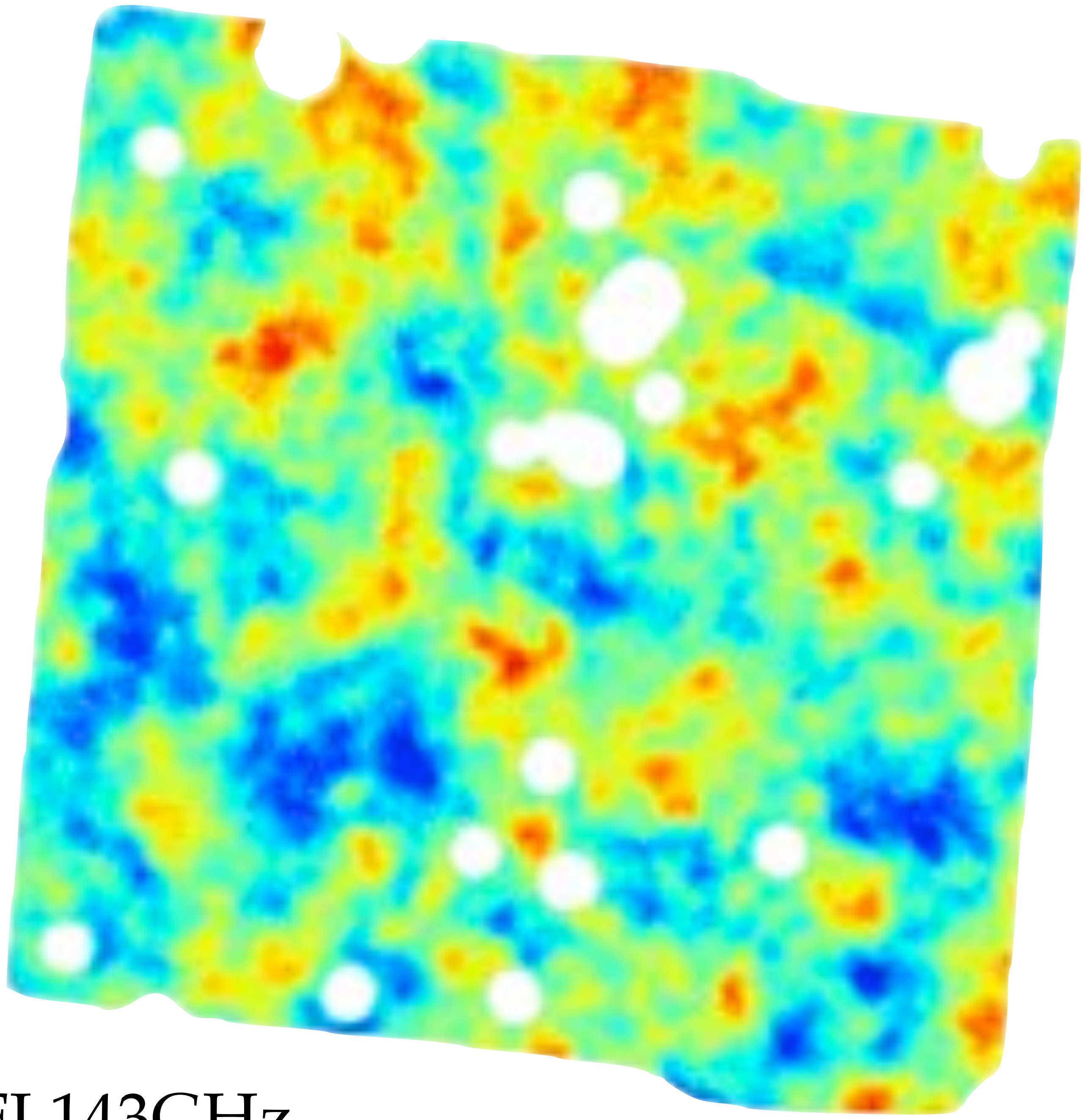




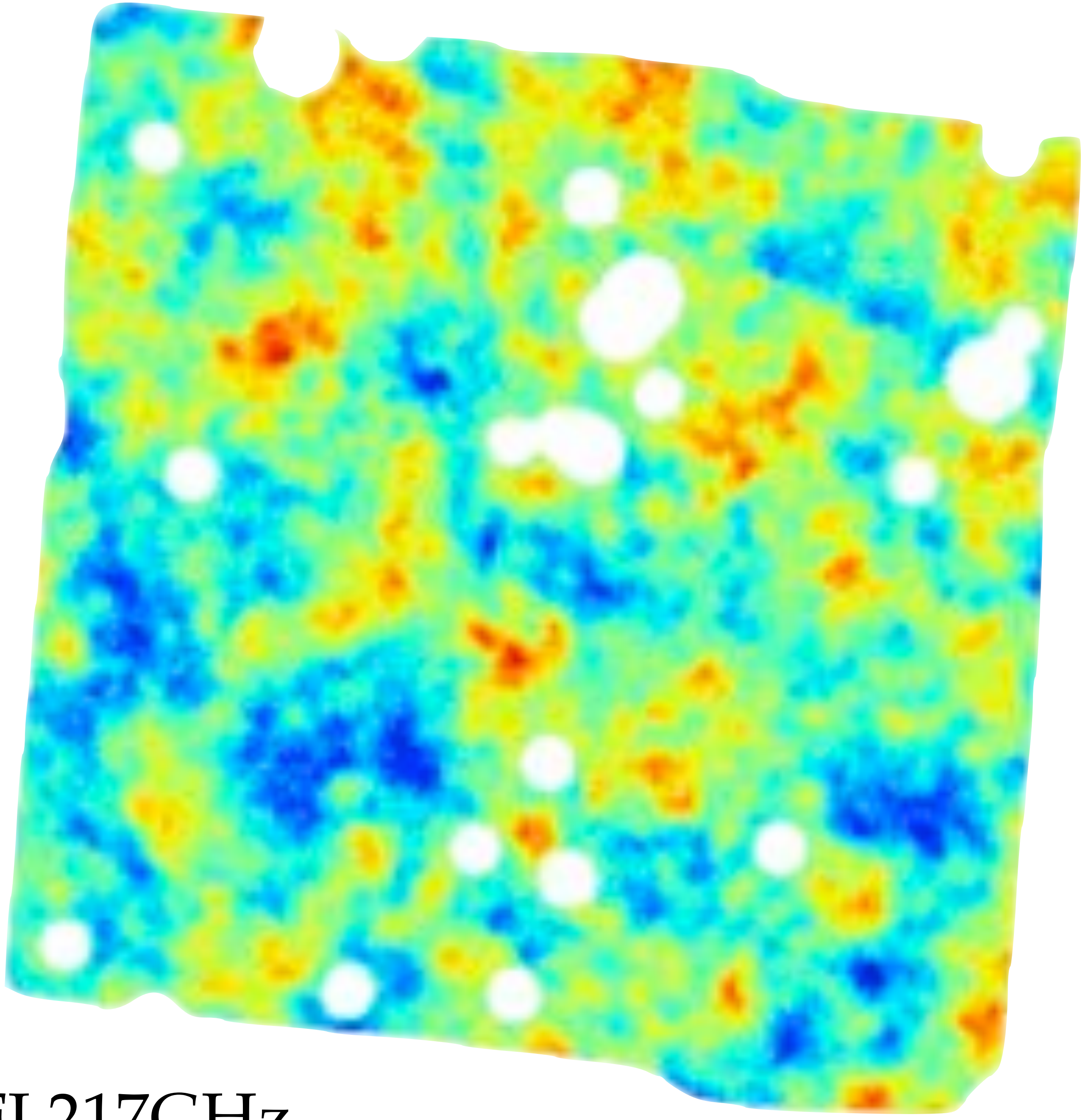
H. Dole



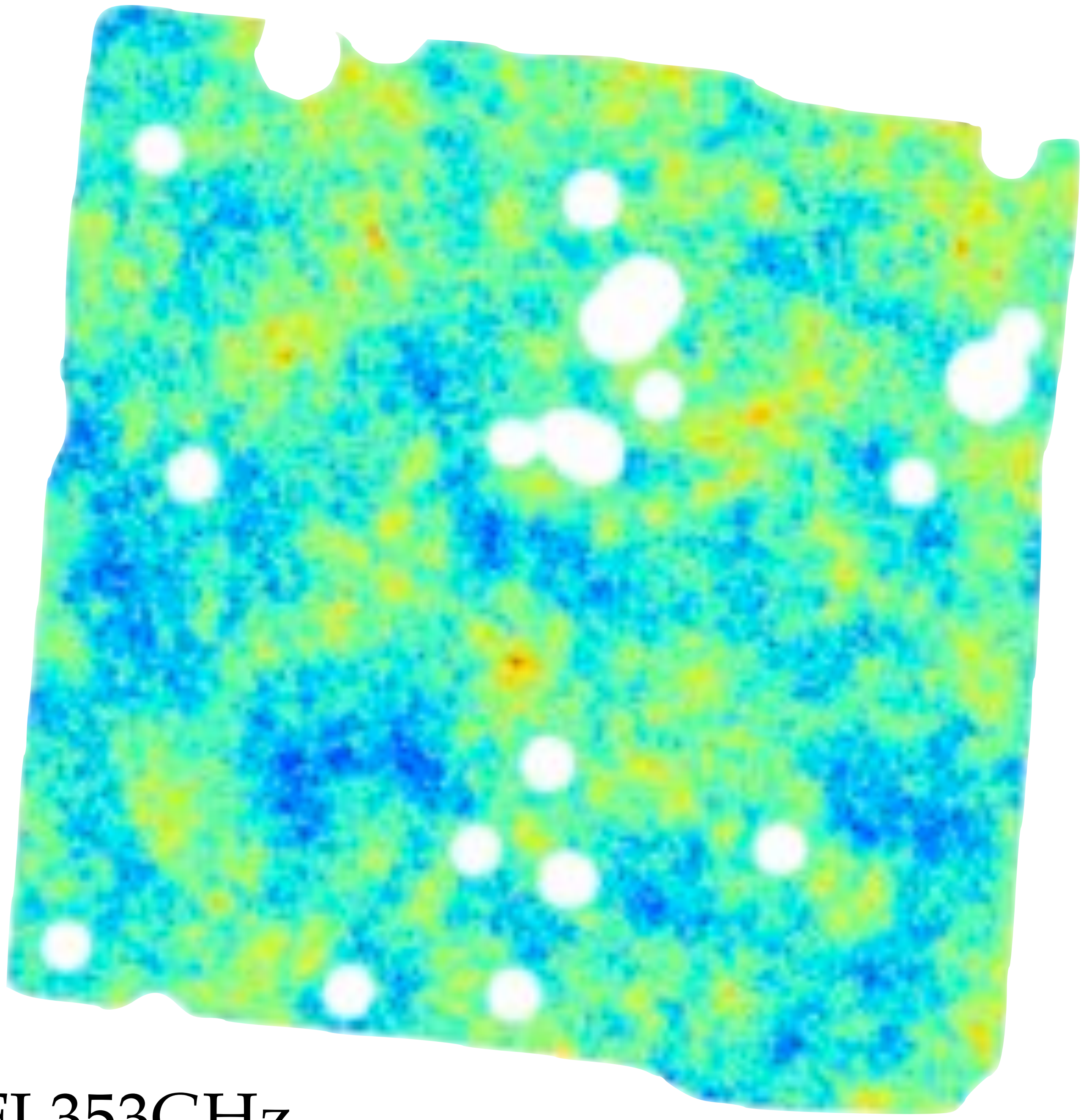
Planck / HFI 100GHz



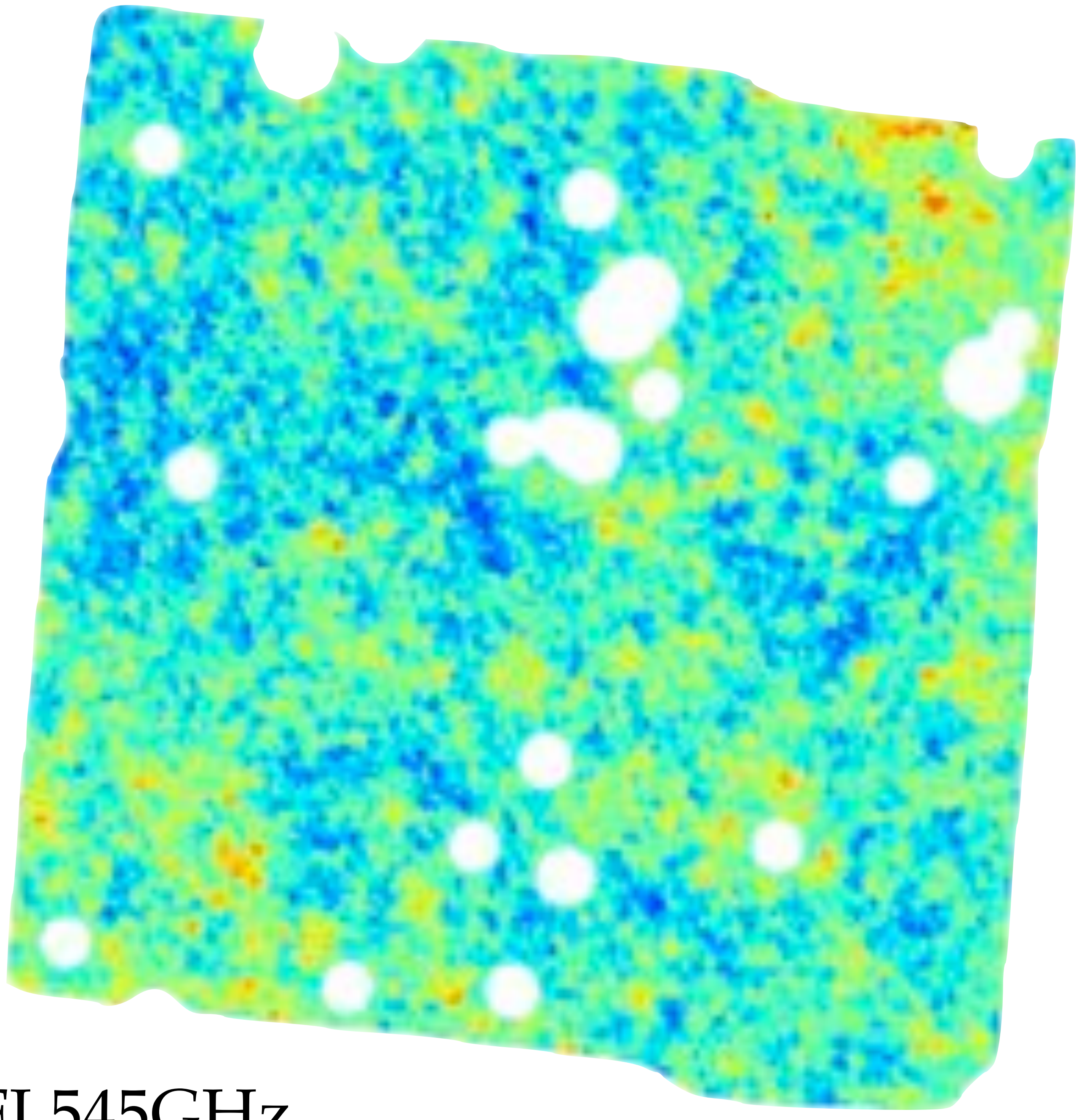
Planck/HFI 143GHz



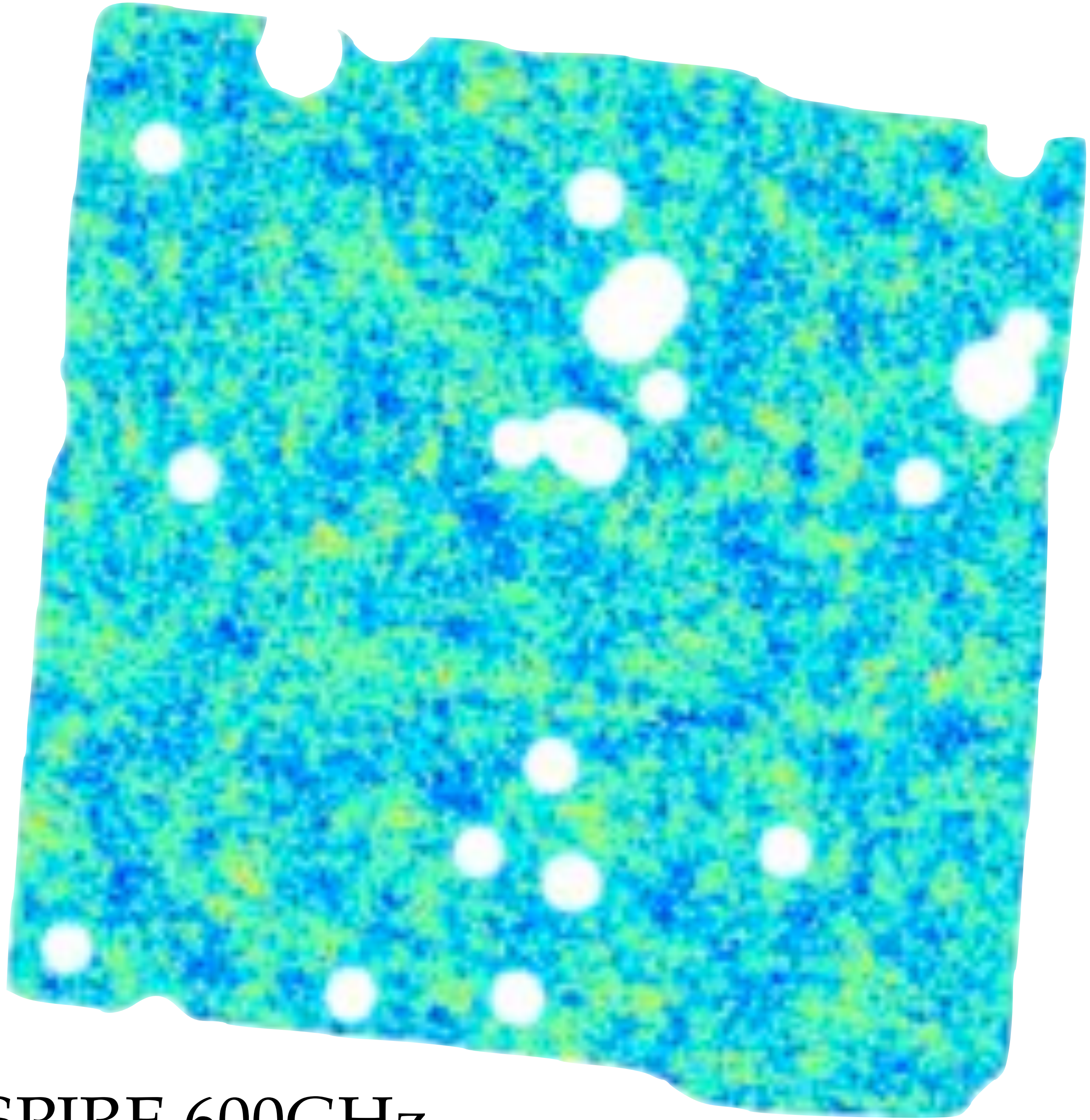
Planck / HFI 217GHz



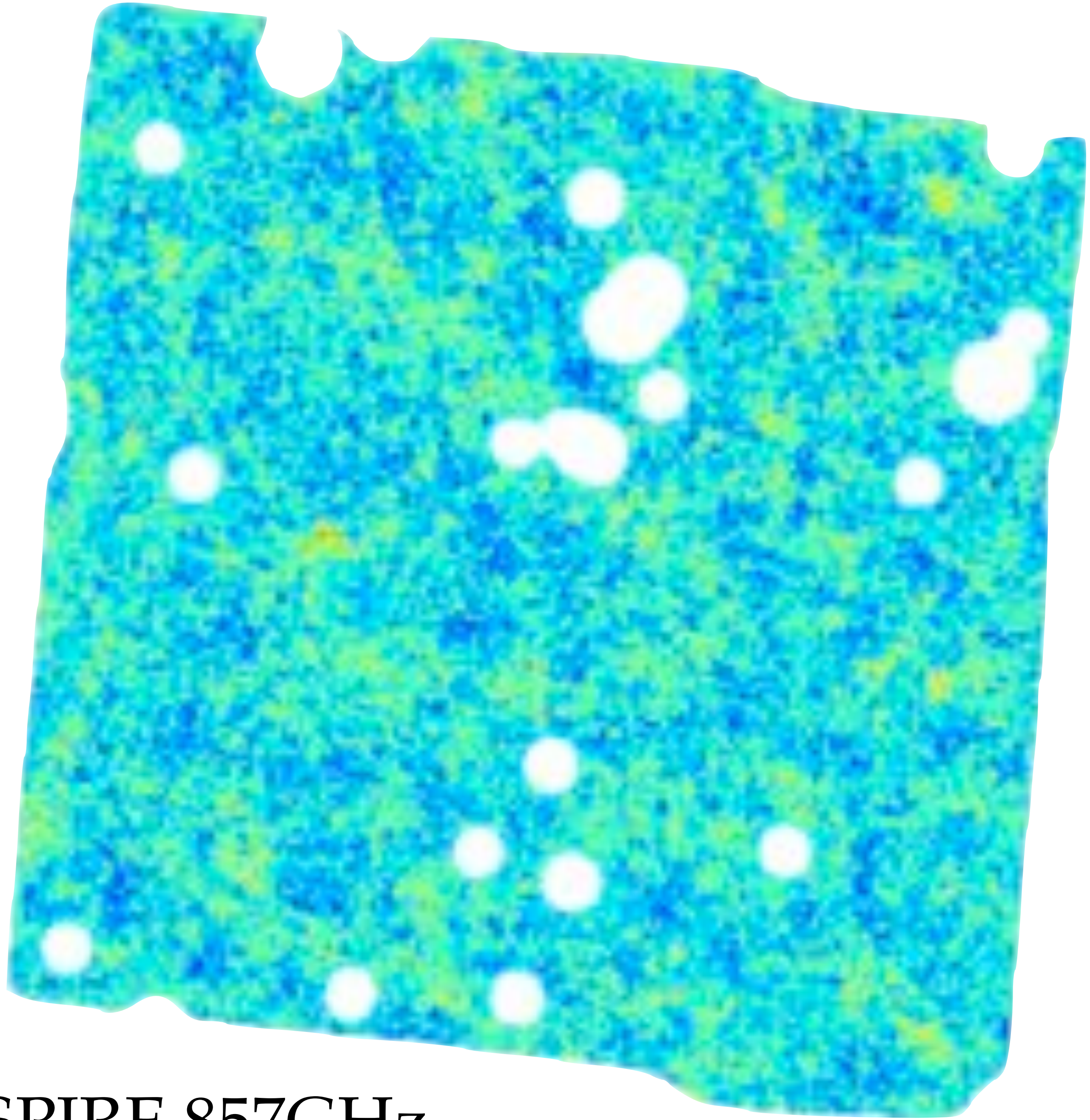
Planck / HFI 353GHz



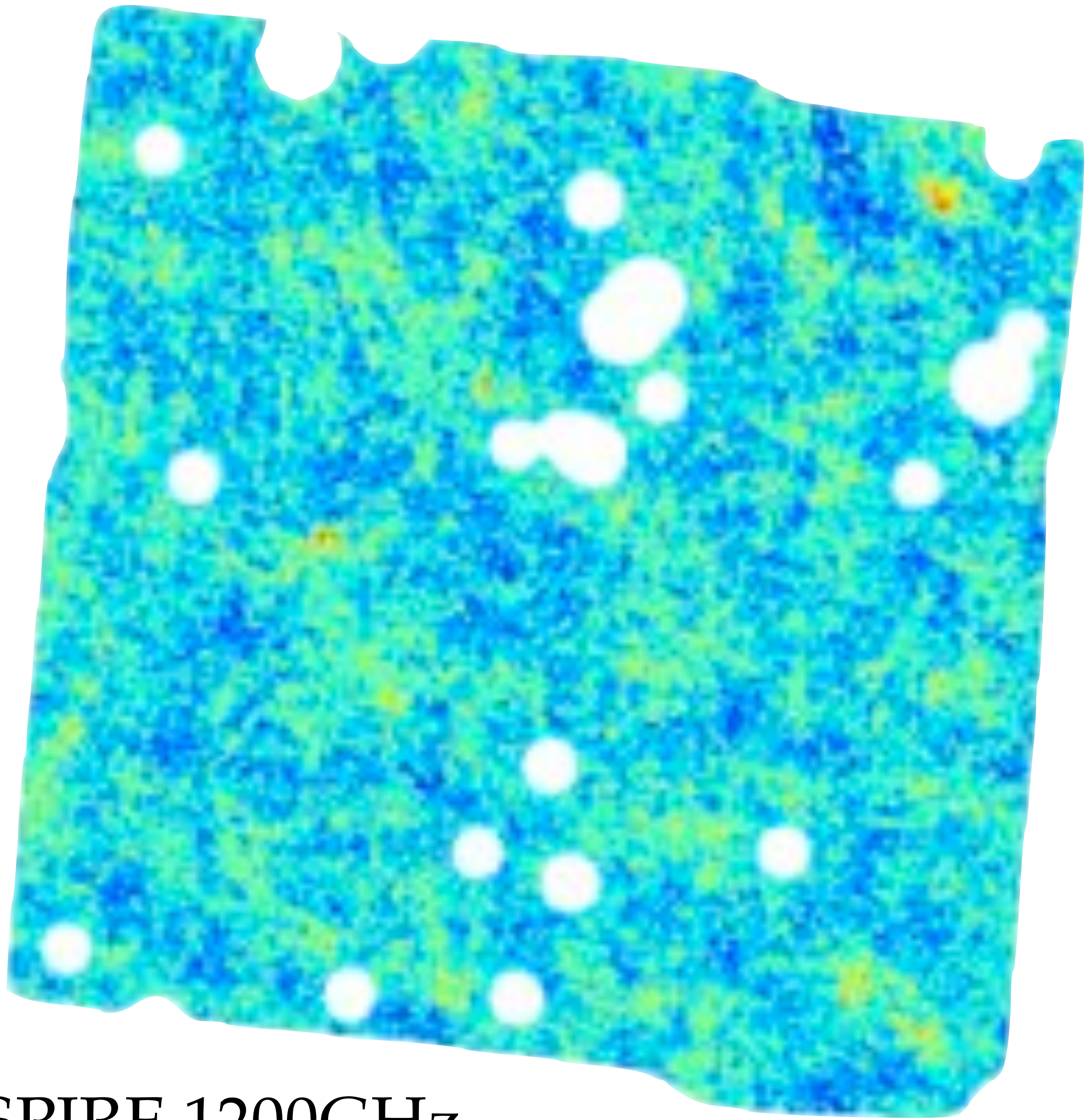
Planck / HFI 545GHz



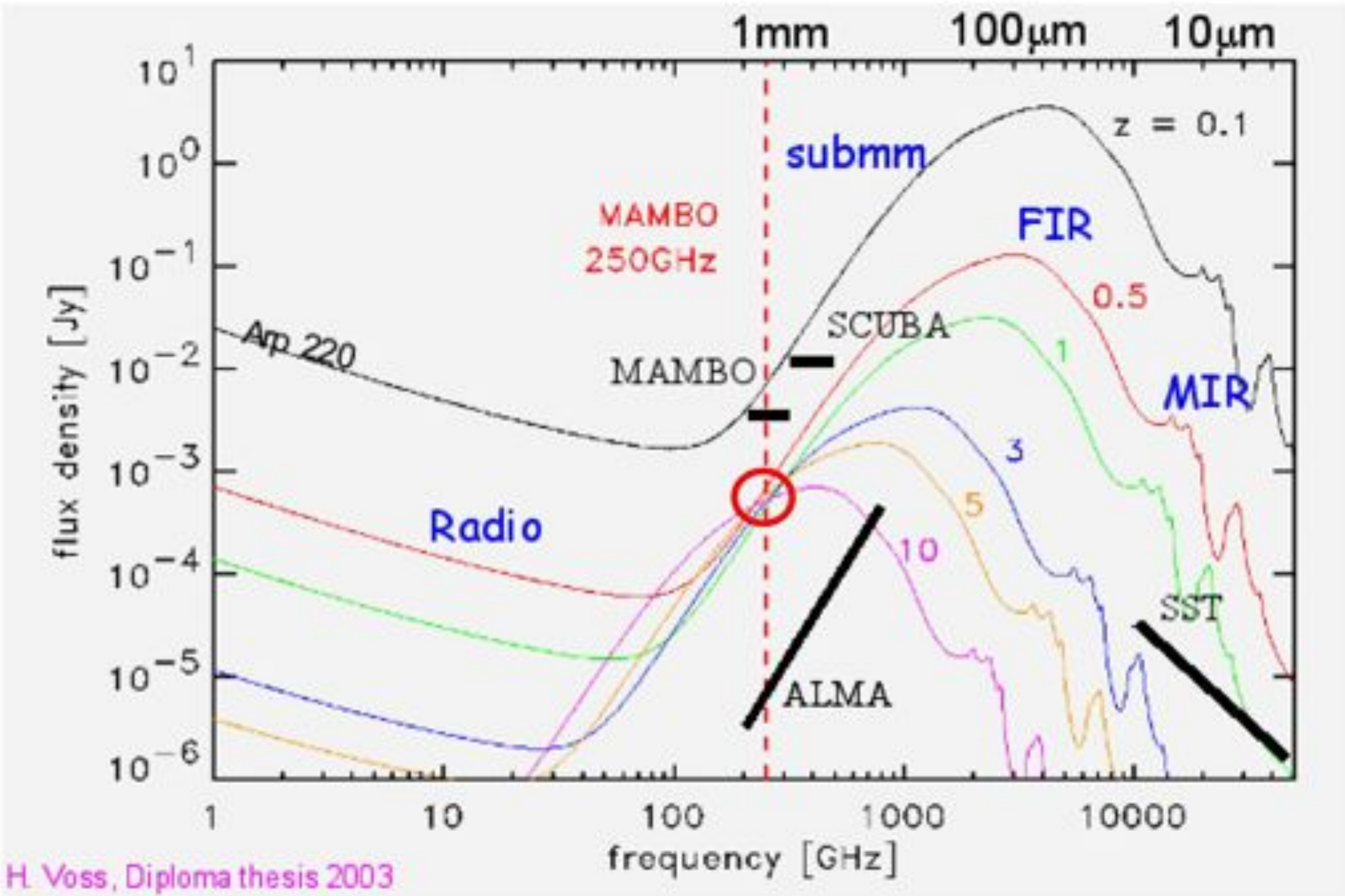
Herschel/SPIRE 600GHz



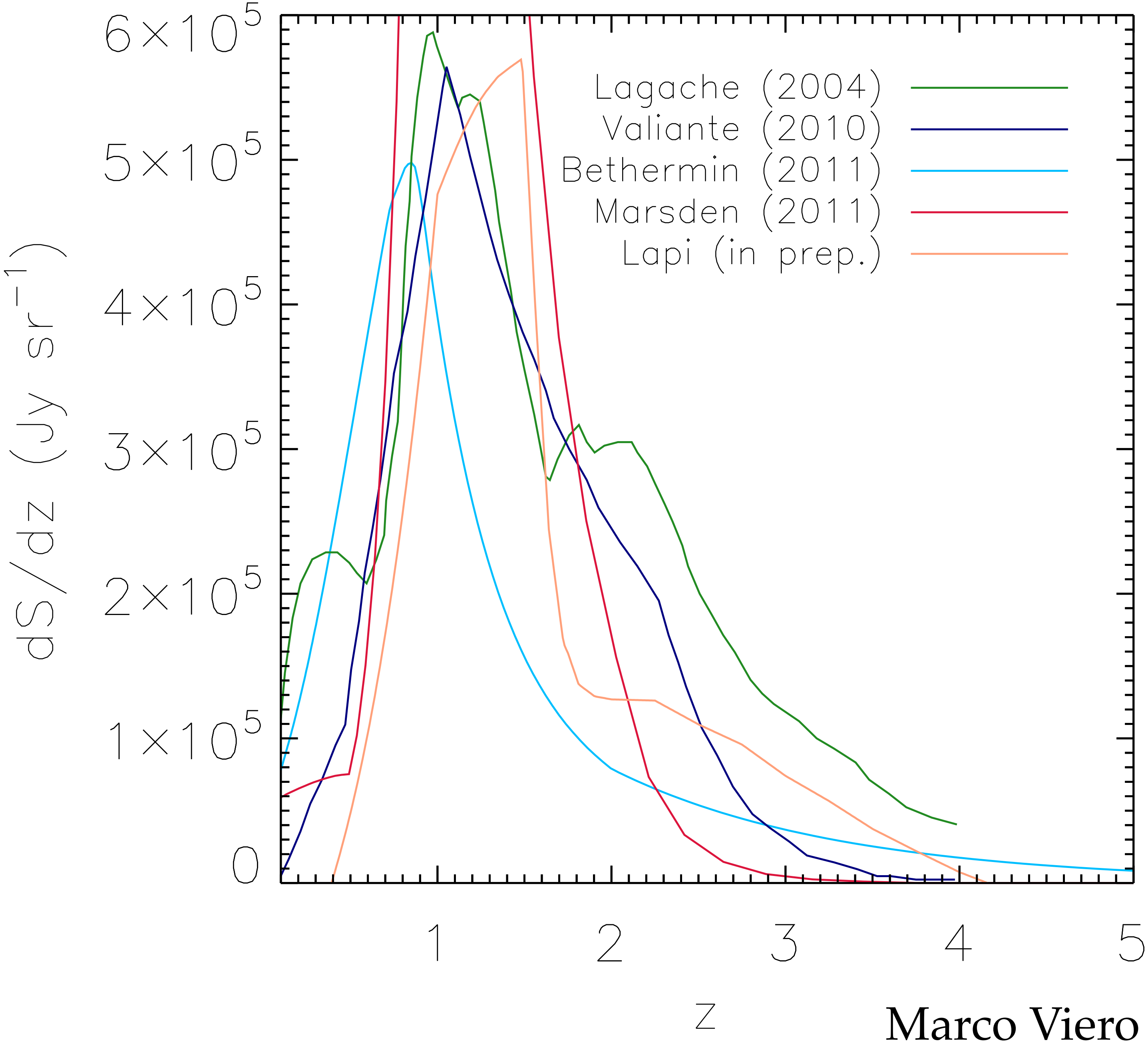
Herschel/SPIRE 857GHz



Herschel/SPIRE 1200GHz

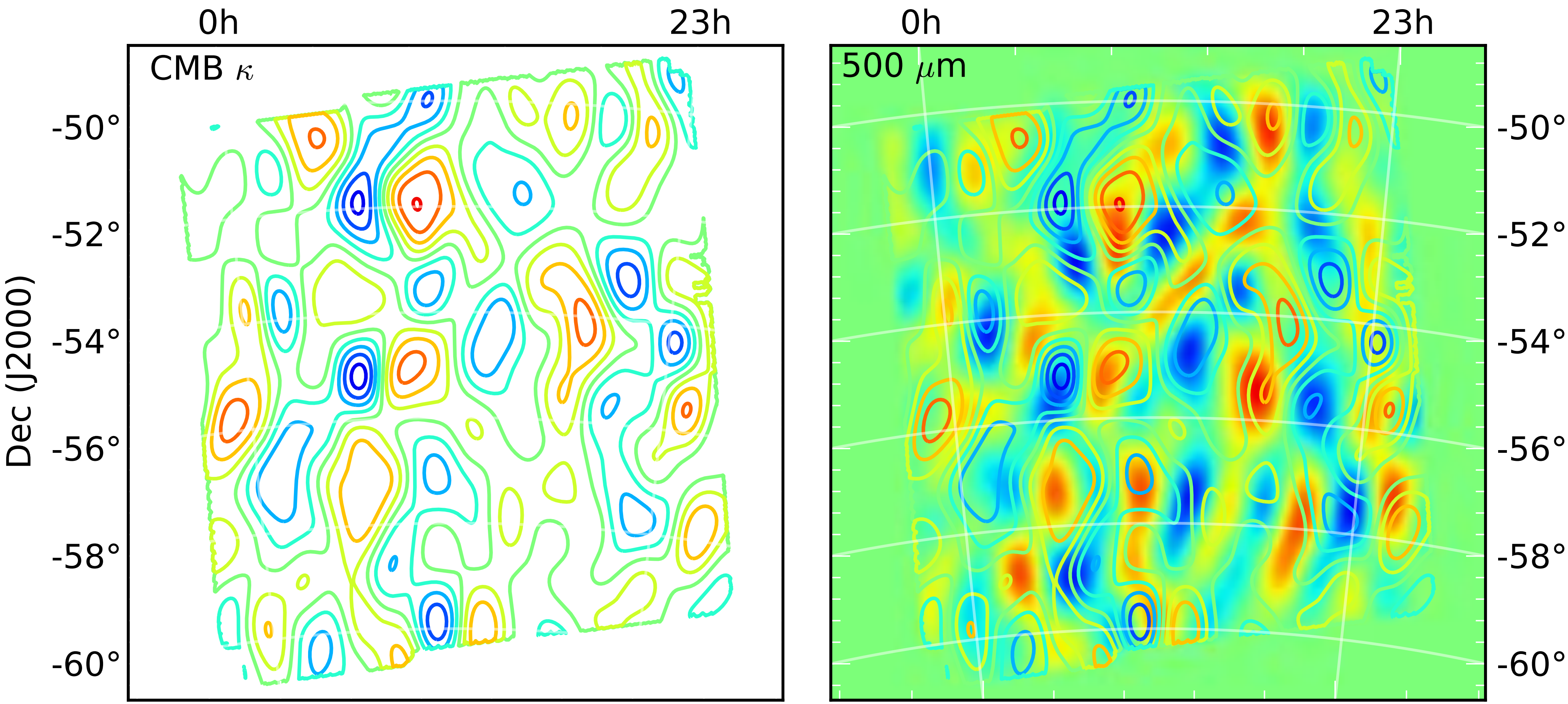


1mm
100μm
10μm
z = 0.1
submm
MAMBO
250GHz
FIR
0.5
SCUBA
1
Arp 220
MAMBO
MIR
3
5
Radio
10
SST
ALMA
flux density [Jy]
frequency [GHz]
H. Voss, Diploma thesis 2003

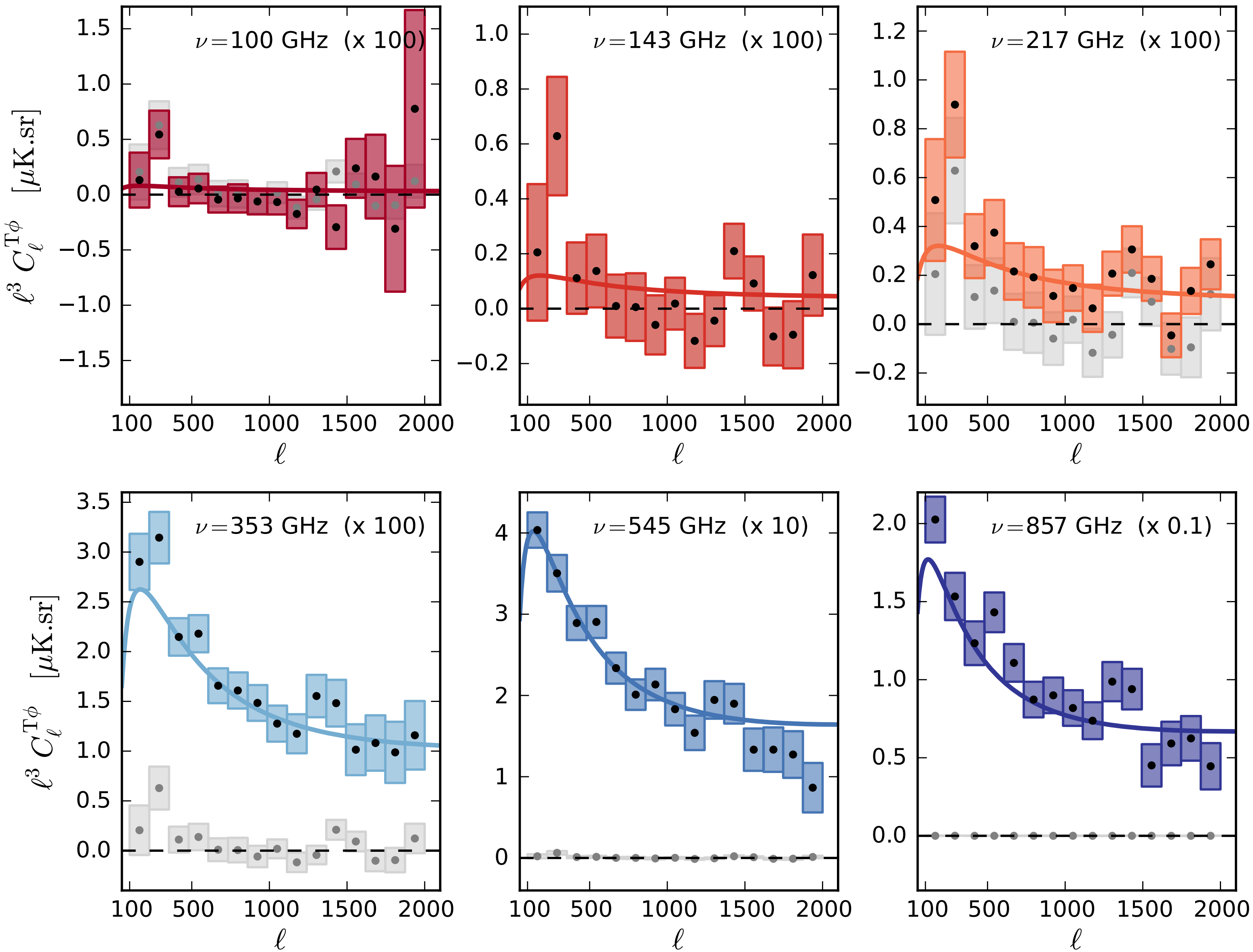


Marco Viero

There is considerable uncertainty in the redshift distribution of the CIB-- but fortunately none of this matters if we just measure the lensing-CIB correlation.

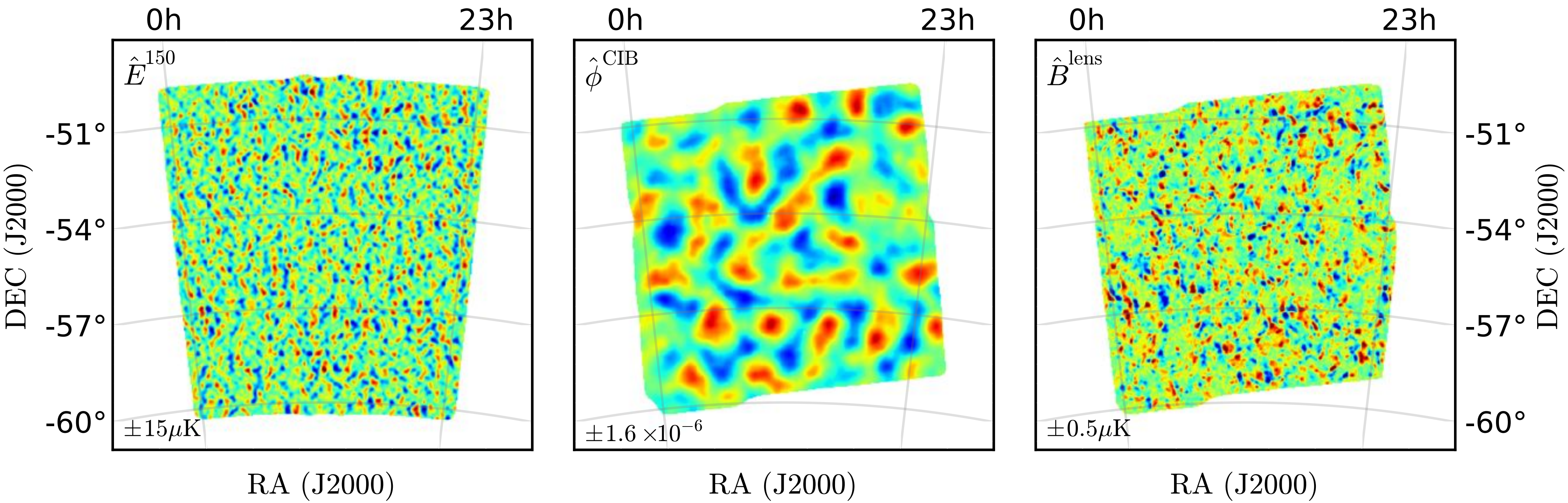


SPT-SZ Mass Map / CIB Overlay
(Holder et. al. 2013)

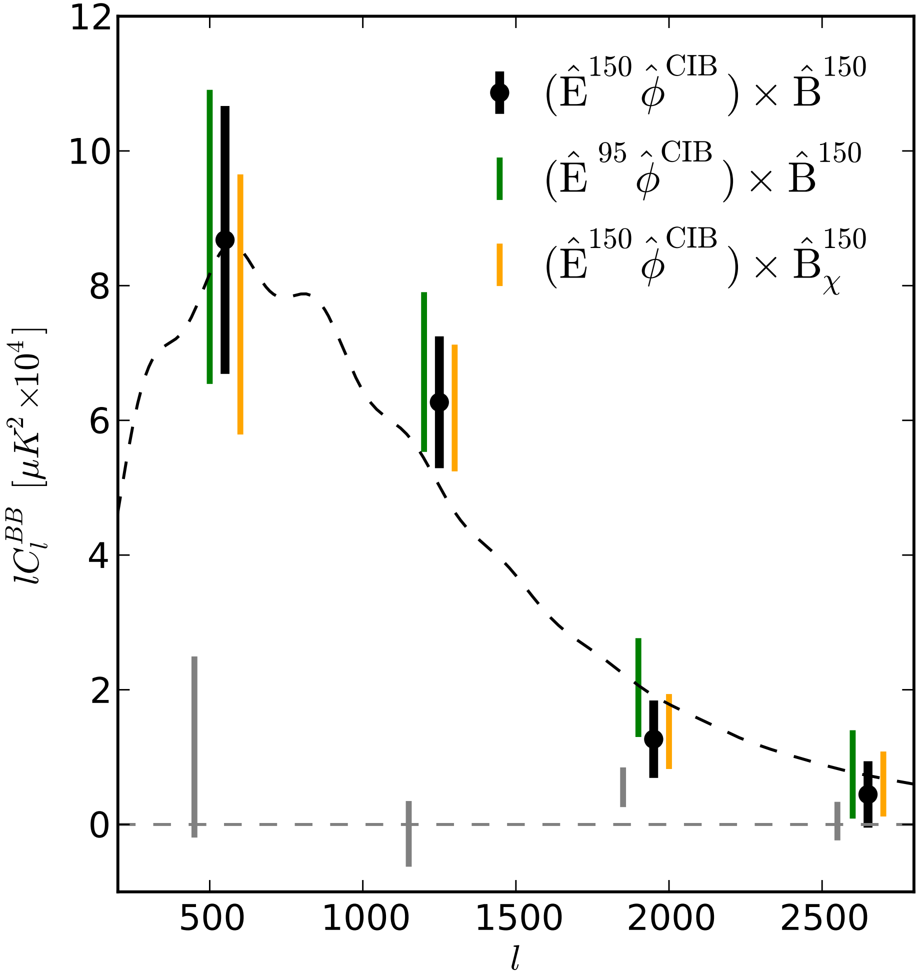


40σ+ CIB-Lensing Cross-correlation
(Planck Collaboration 2013 - Doré and Osborne)

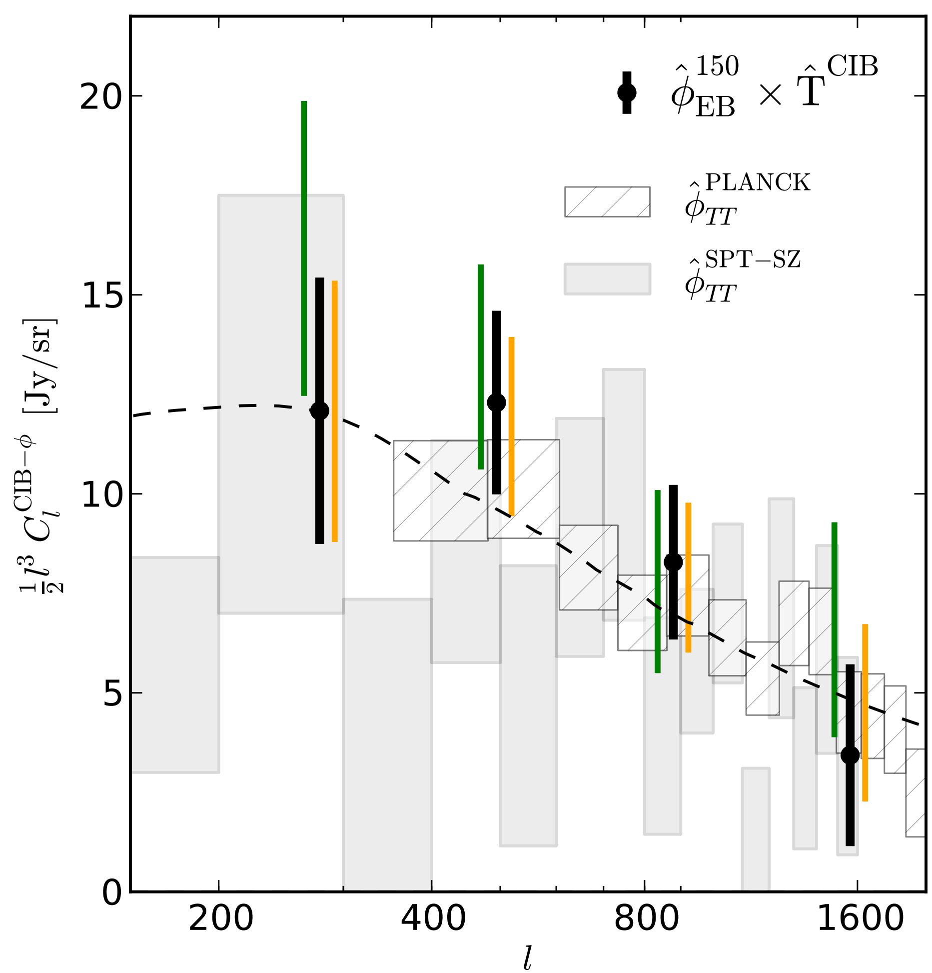
Detection of B-mode Polarization in the Cosmic Microwave Background with Data from the South Pole Telescope



Gravitational lensing of the cosmic microwave background generates a curl pattern in the observed polarization. This "B-mode" signal provides a measure of the projected mass distribution over the entire observable Universe and also acts as a contaminant for the measurement of primordial gravity-wave signals. In this letter we present the first detection of gravitational lensing B modes, using first-season data from the polarization-sensitive receiver on the South Pole Telescope (SPTpol). We construct a template for the lensing B-mode signal by combining E-mode polarization measured by SPTpol with estimates of the lensing potential from a *Herschel*-SPIRE map of the cosmic infrared background. We compare this template to the B modes measured directly by SPTpol, finding a non-zero correlation at 7.7σ significance. The correlation has an amplitude and scale-dependence consistent with theoretical expectations, is robust with respect to analysis choices, and constitutes the first measurement of a powerful cosmological observable.

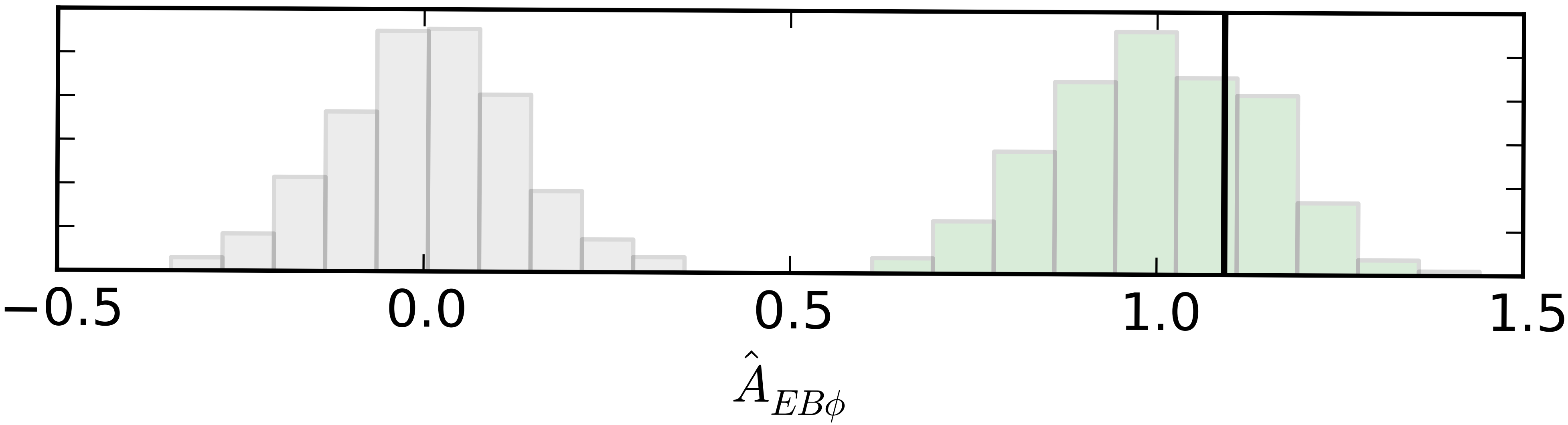


«B mode view»



«Lensing view»

Estimate overall significance from amplitude of EBΦ bispectrum, which is non-zero at 7.7σ significance.

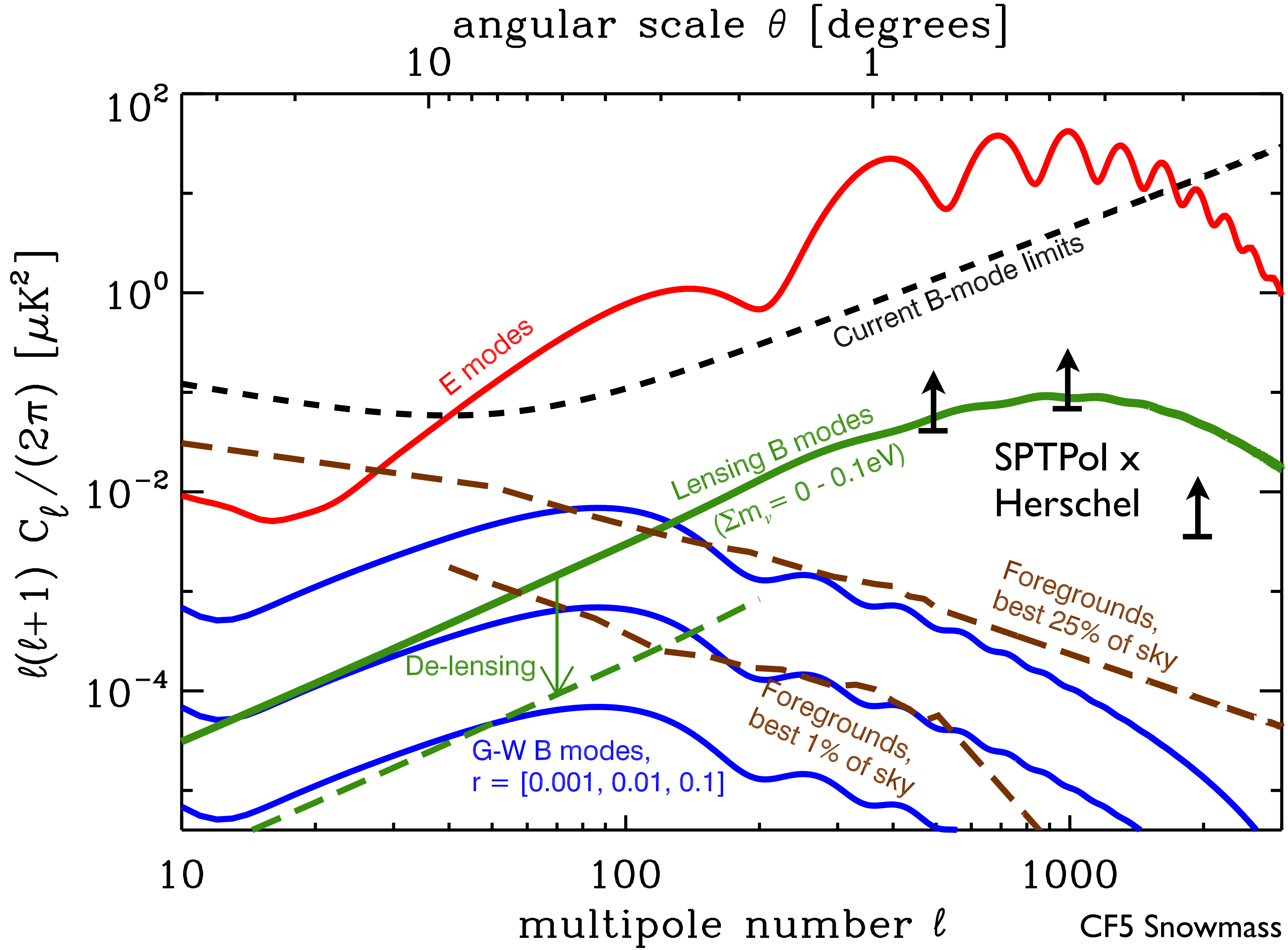


<u>Consistent results using:</u>

- 90GHz E-modes.
- Temperature-derived E-modes.
- TT, TE, EE, EB lensing estimators.

<u>No signal seen using:</u>

- Curl-mode null test.
- E-modes from diff. map.
- B-modes from diff. map.



CF5 Snowmass 2013