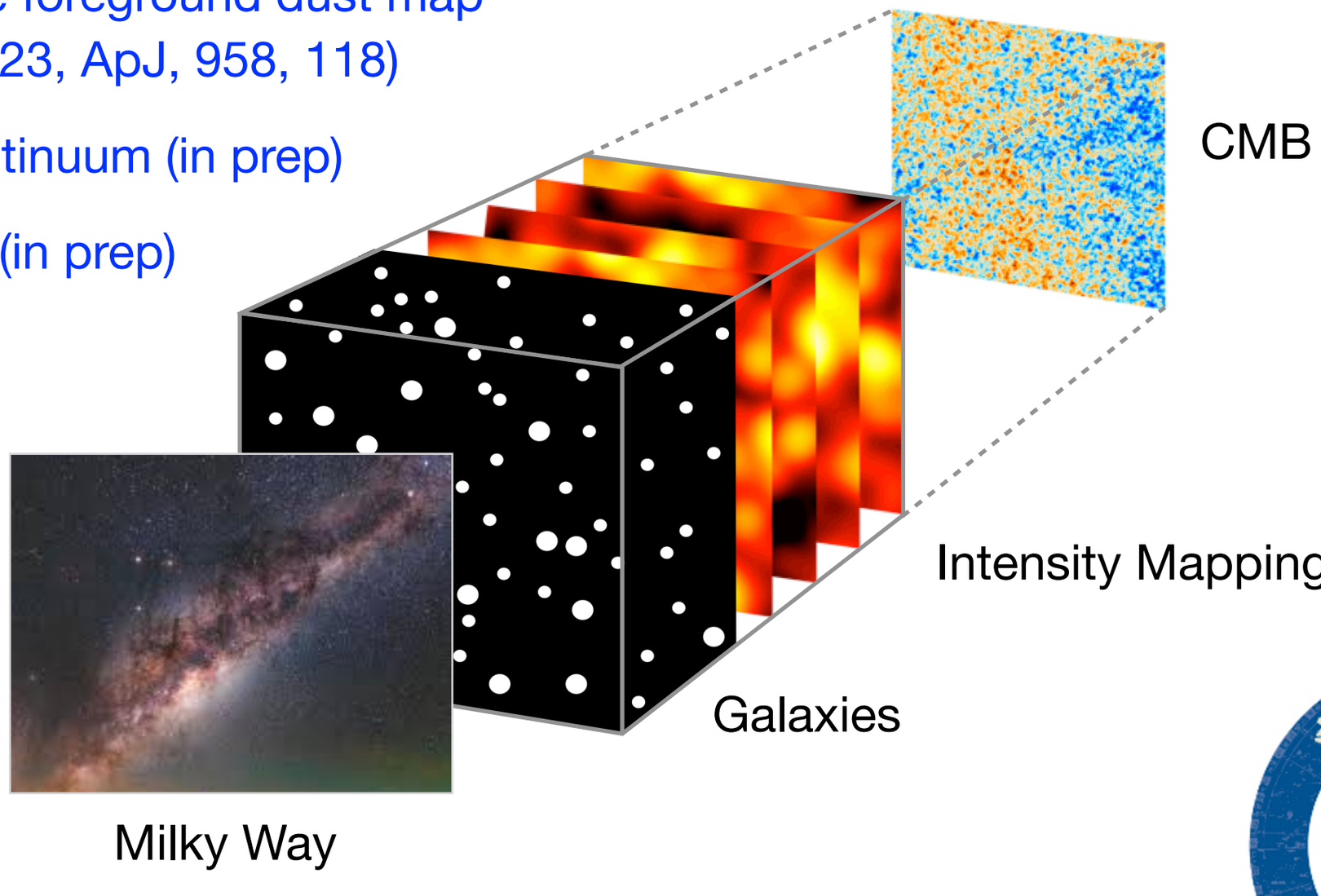
Cosmic Infrared Background Tomography

Revealing the Full Spectrum with Thermal Dust, CO, and CII at 0 < z < 4

Paper 0: CIB-free foreground dust map
(Chiang 23, ApJ, 958, 118)

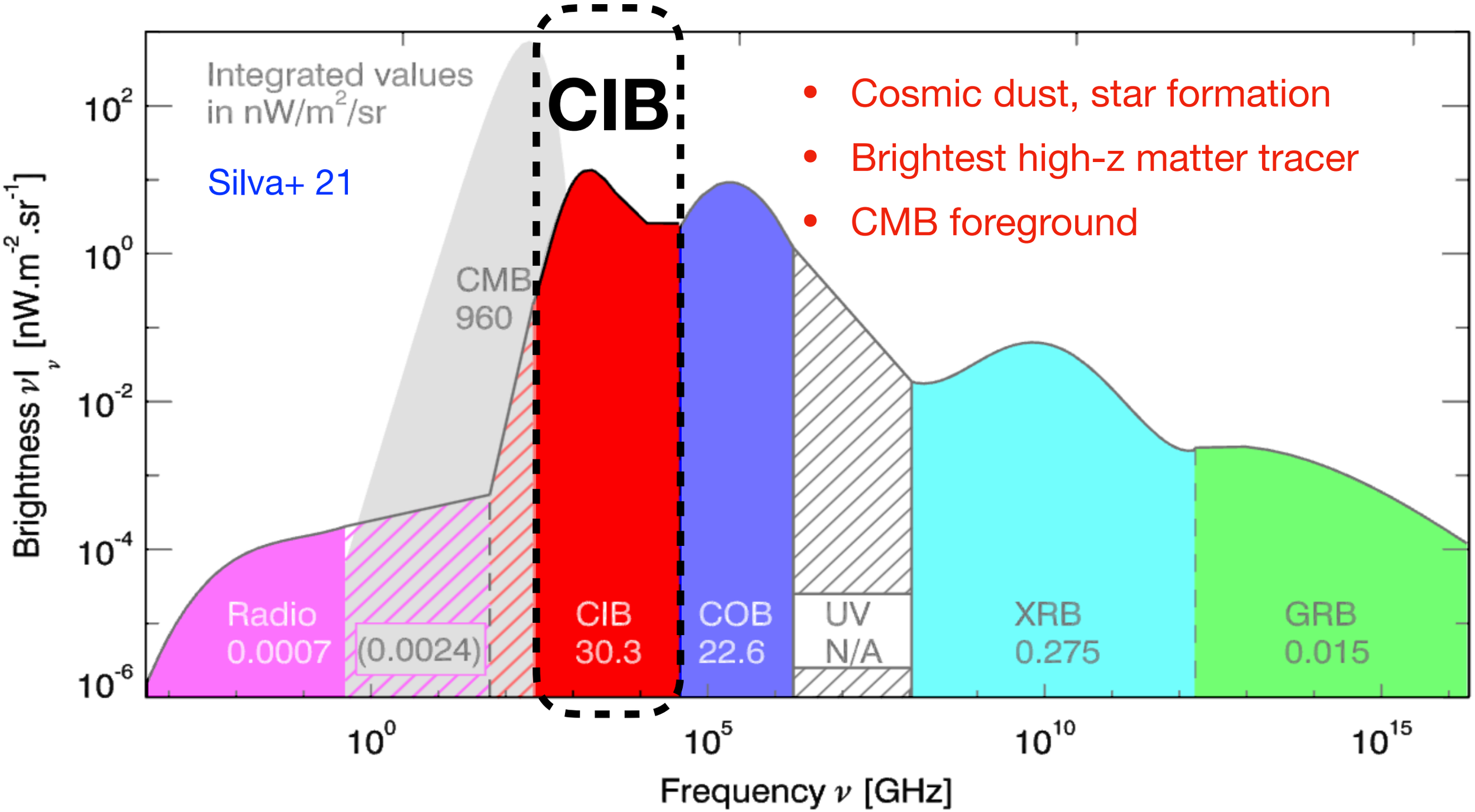
Paper 1: CIB continuum (in prep)

Paper 2: CO, CII (in prep)



Yi-Kuan Chiang — ASIAA

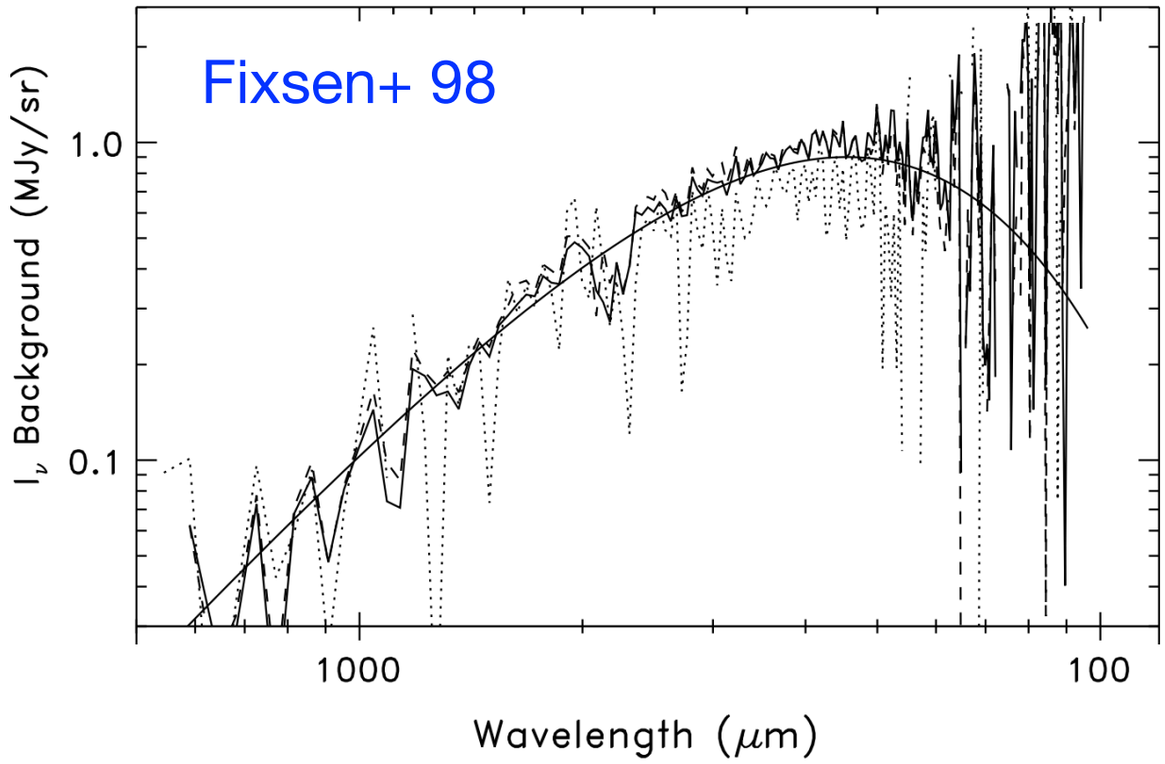
The Cosmic Infrared Background (CIB)



What do we know about the CIB?

- Sky maps (with foreground)
- Power spectrum (Planck)
- Monopole spectrum (FIRAS)

All redshift integrated



What's missing?

- Redshift distributions (frequency dependent)
- Spectrum (evolving and more complex than single galaxies)

Single Tempeature Gray Body (T, β) is Not Enough

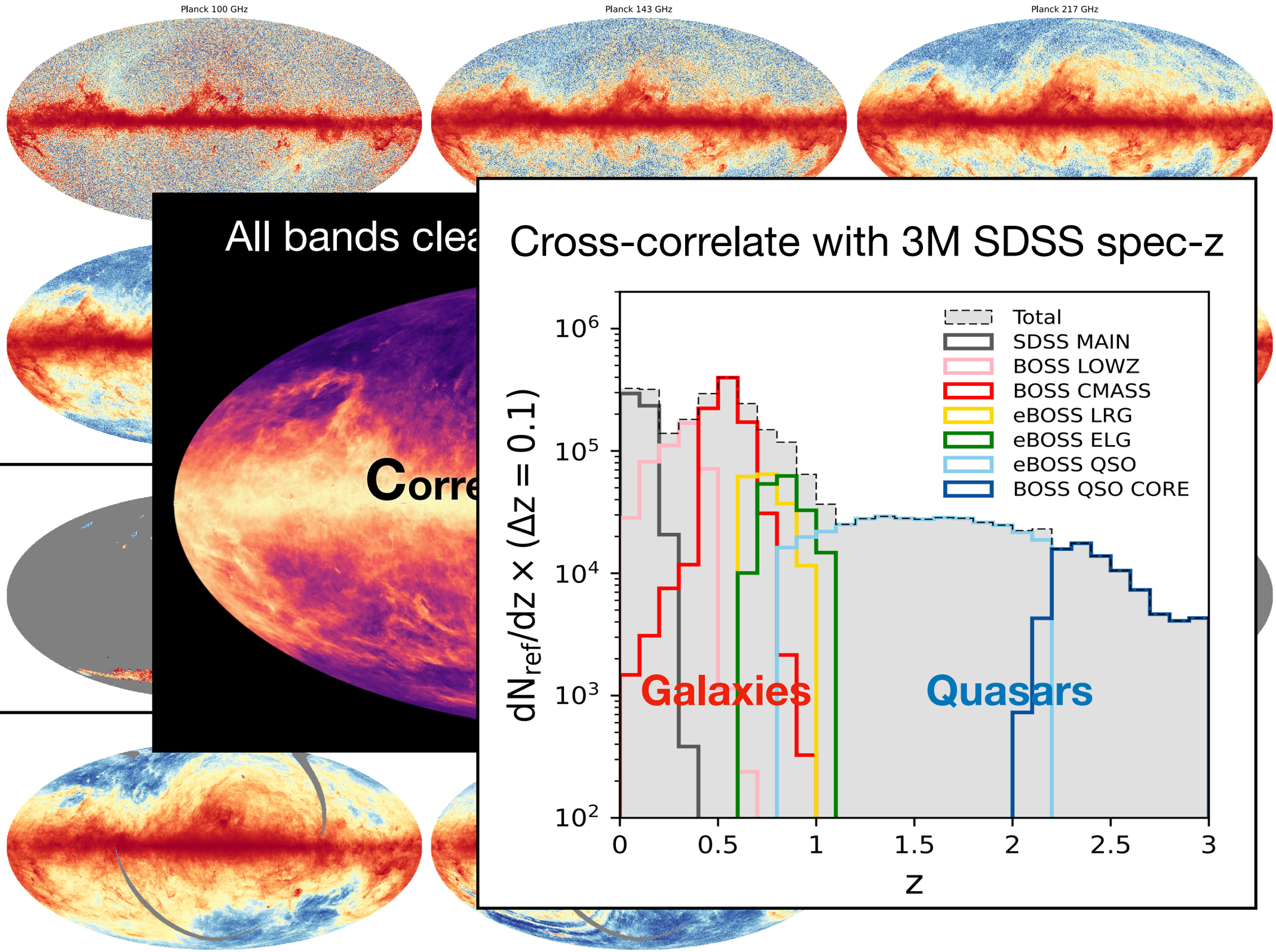
Need redshift tomography

This work — 11 band CIB tomography

Planck

Herschel

IRAS

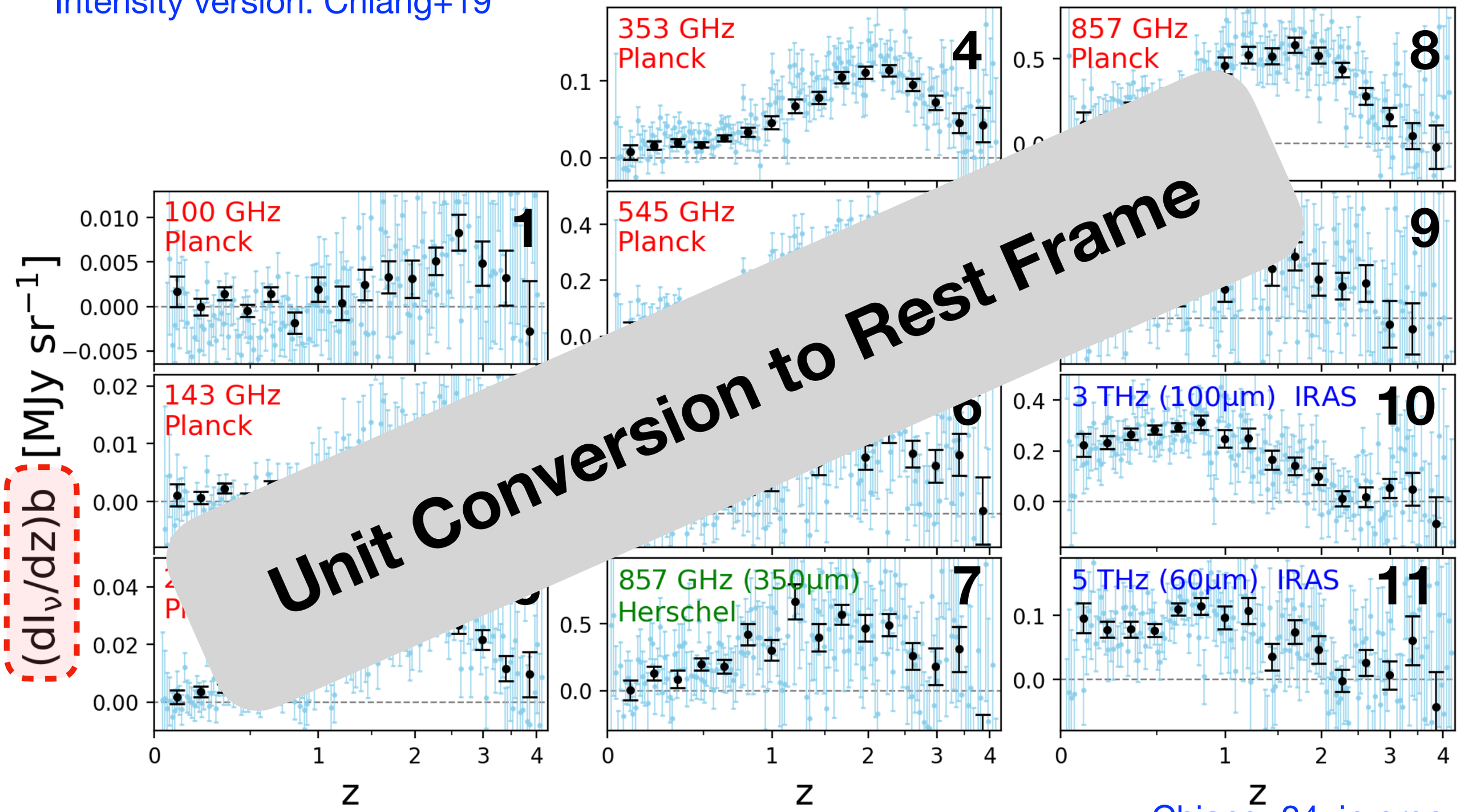


Clustering redshift

$$w_{Ig}(z_i) \propto \frac{dI}{dz} b_I b_g w_m(z_i)$$

Formalism: Ménard+13, Newman+08

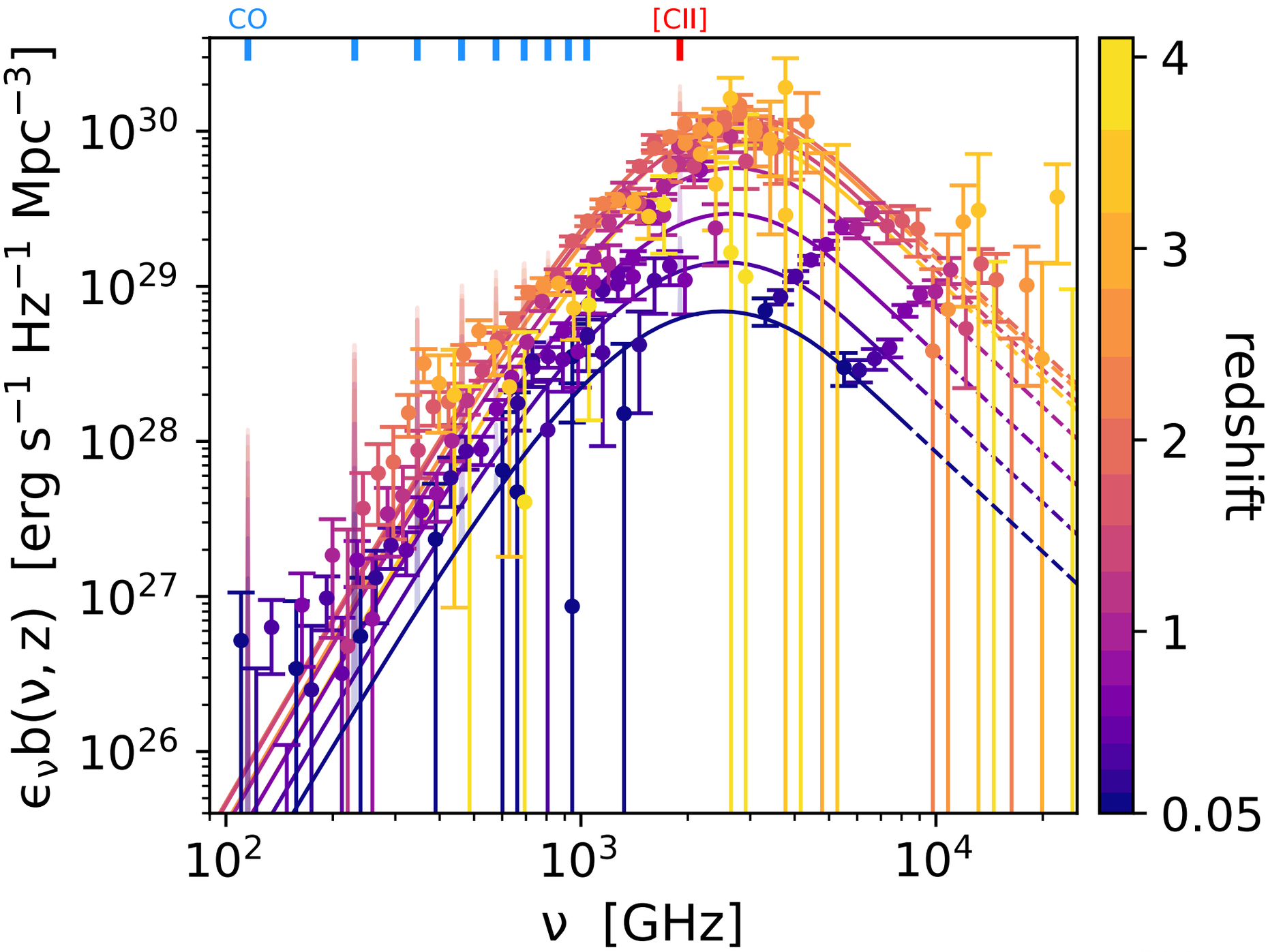
Intensity version: Chiang+19



Chiang+24, in prep

Tomographic CIB spectrum

To be the best sampled Far-IR SED in literature



Chiang+24, in prep

Ensumble cosmic dust SED

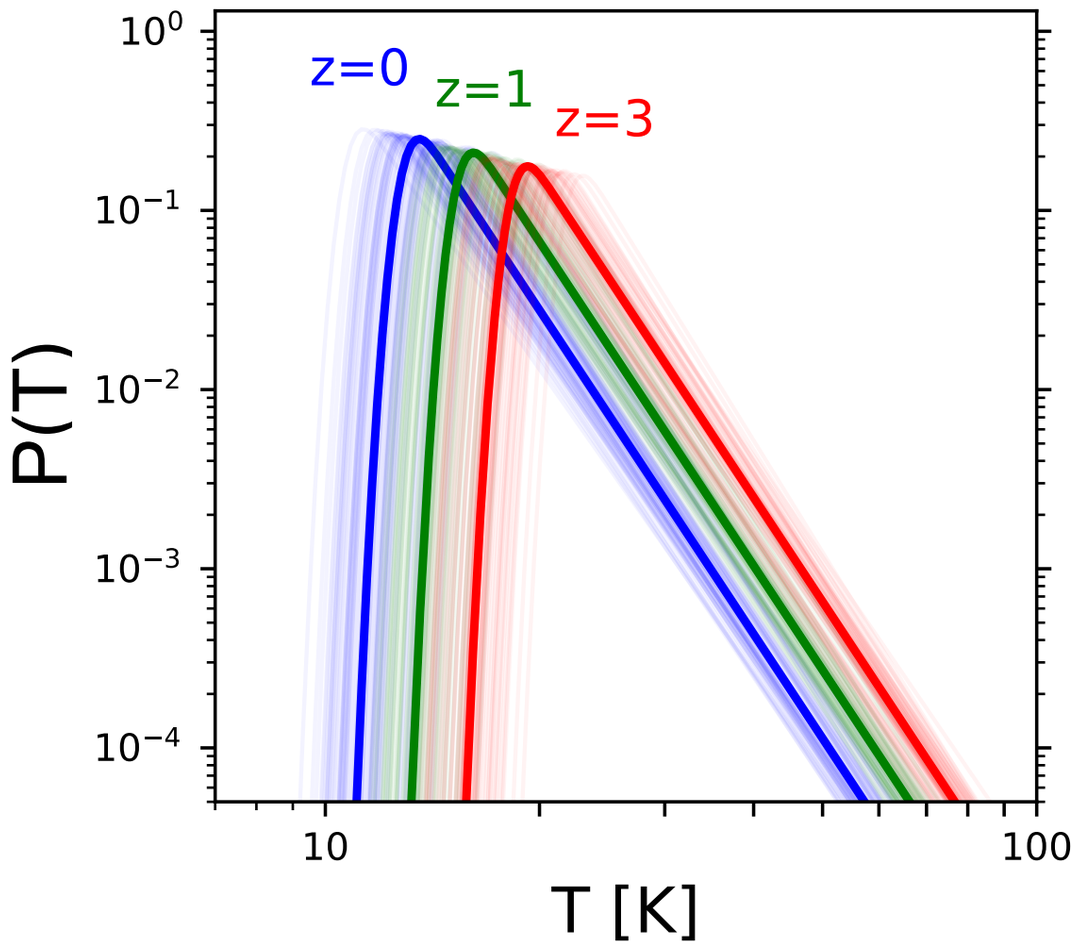
$$\epsilon_\nu b = \frac{4\pi \rho_{\rm d}}{\Sigma_{\rm d}} (1 - e^{-\langle \tau(\nu) \rangle}) \langle B_\nu(\nu) \rangle b(z)$$

Dust mass ρ_d

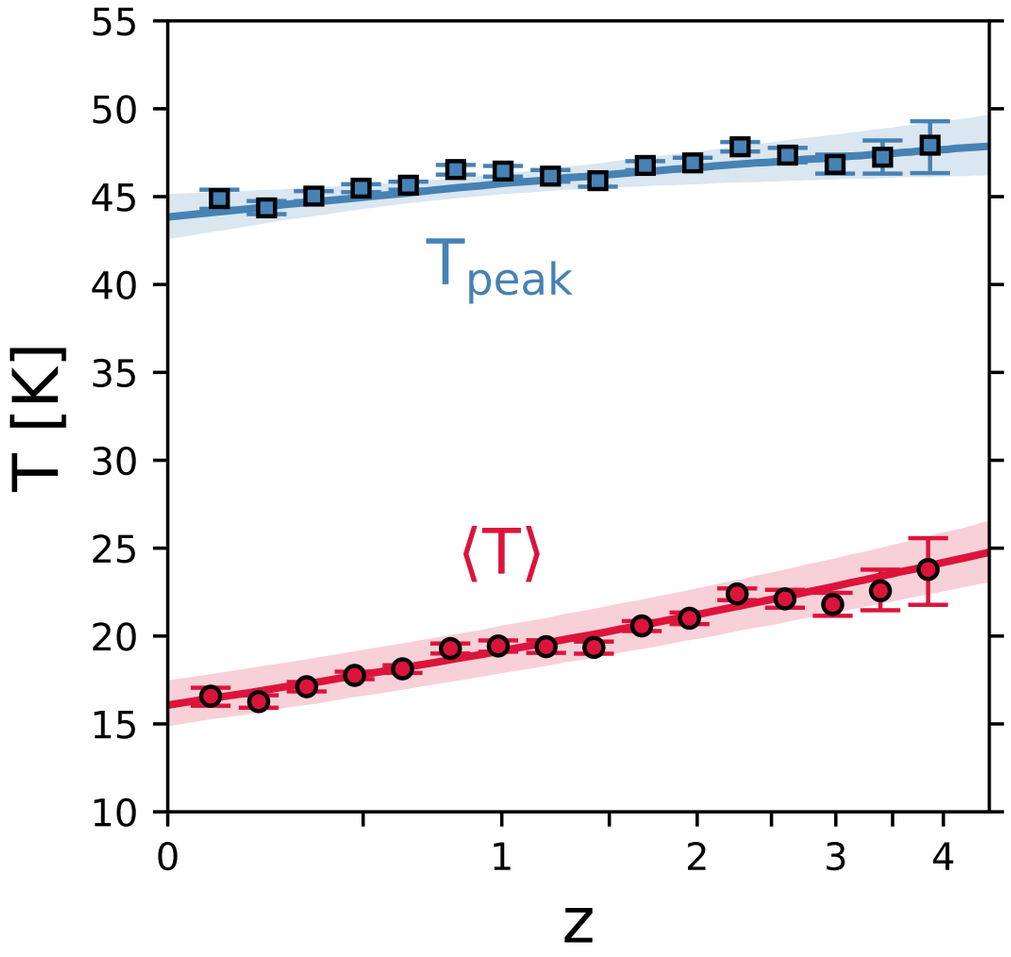
$$\rho_{\rm d}(z) = a \frac{(1+z)^b}{1+[(1+z)/c]^d}$$

Temperature T

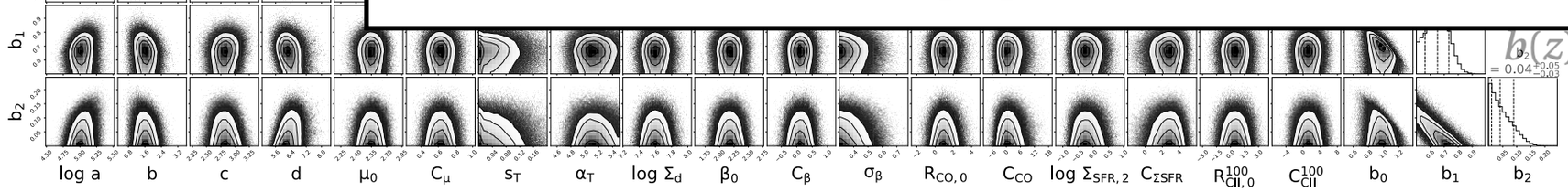
Full T distribution posterior



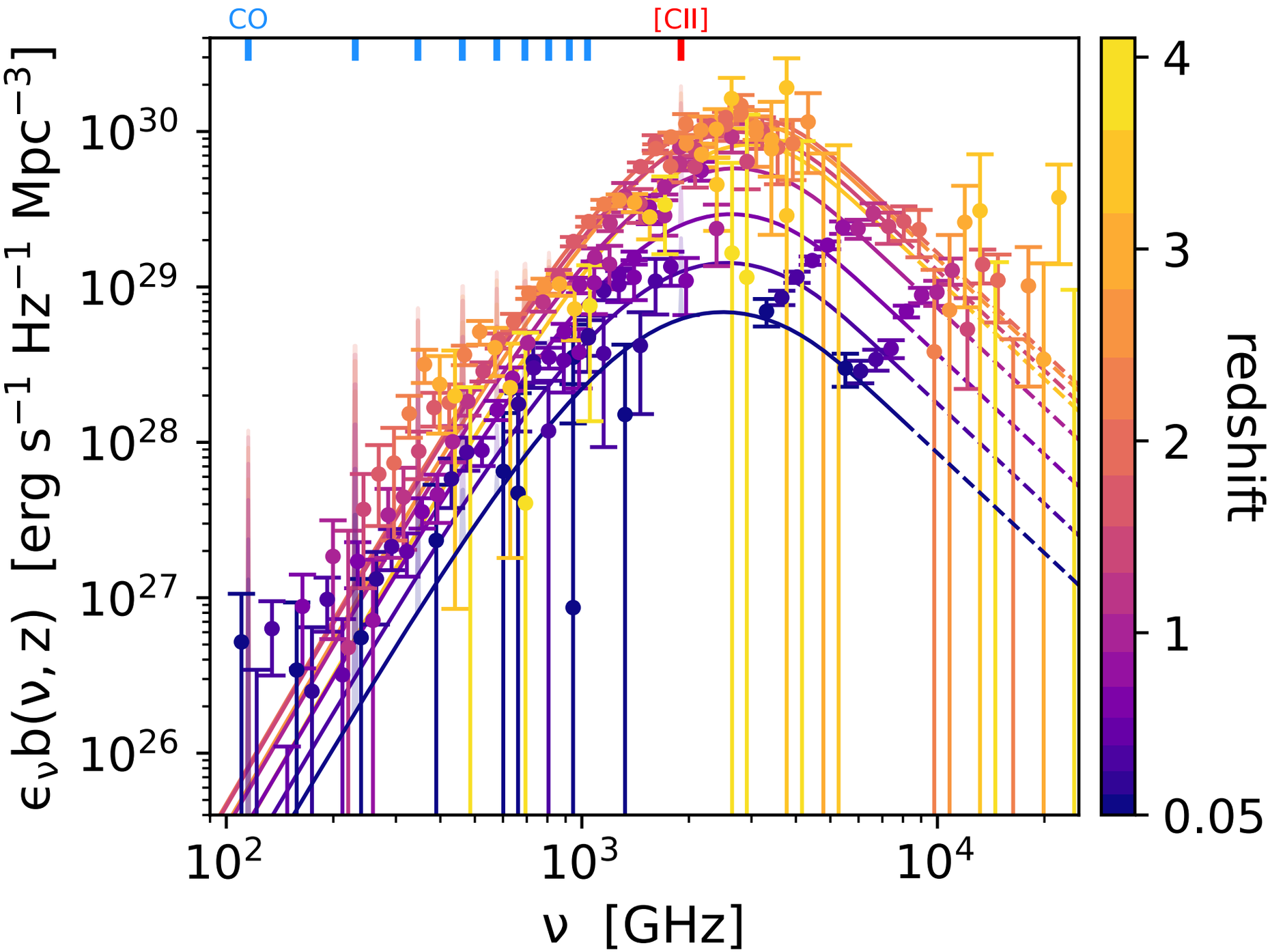
Dust more heated at high z



$$b(z) = b_0 + b_1 z + b_2 z^2$$



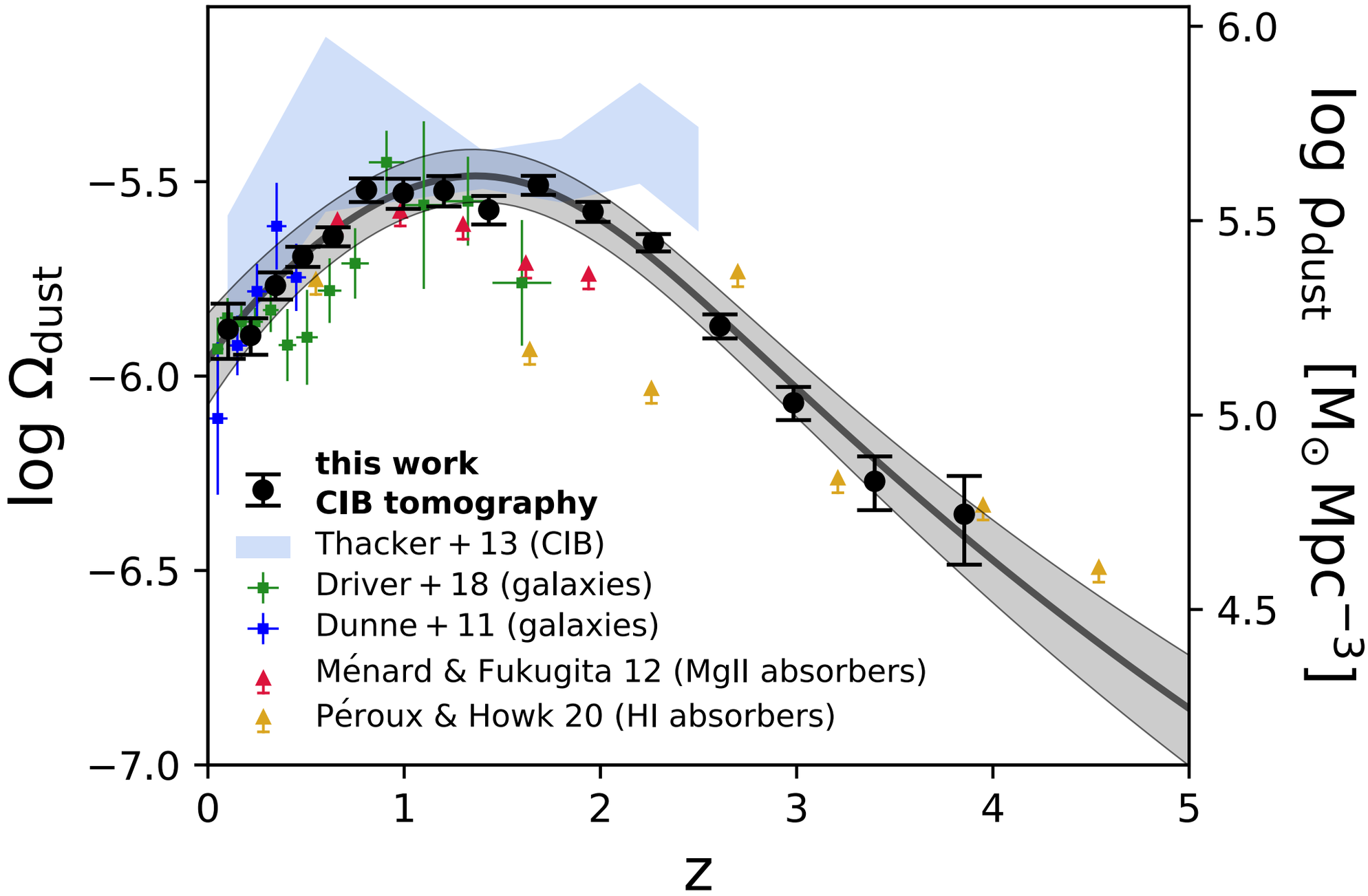
Physical model, but also just a smooth interpolation for already well-sampled data



Chiang+24, in prep

Mass budget of cosmic dust

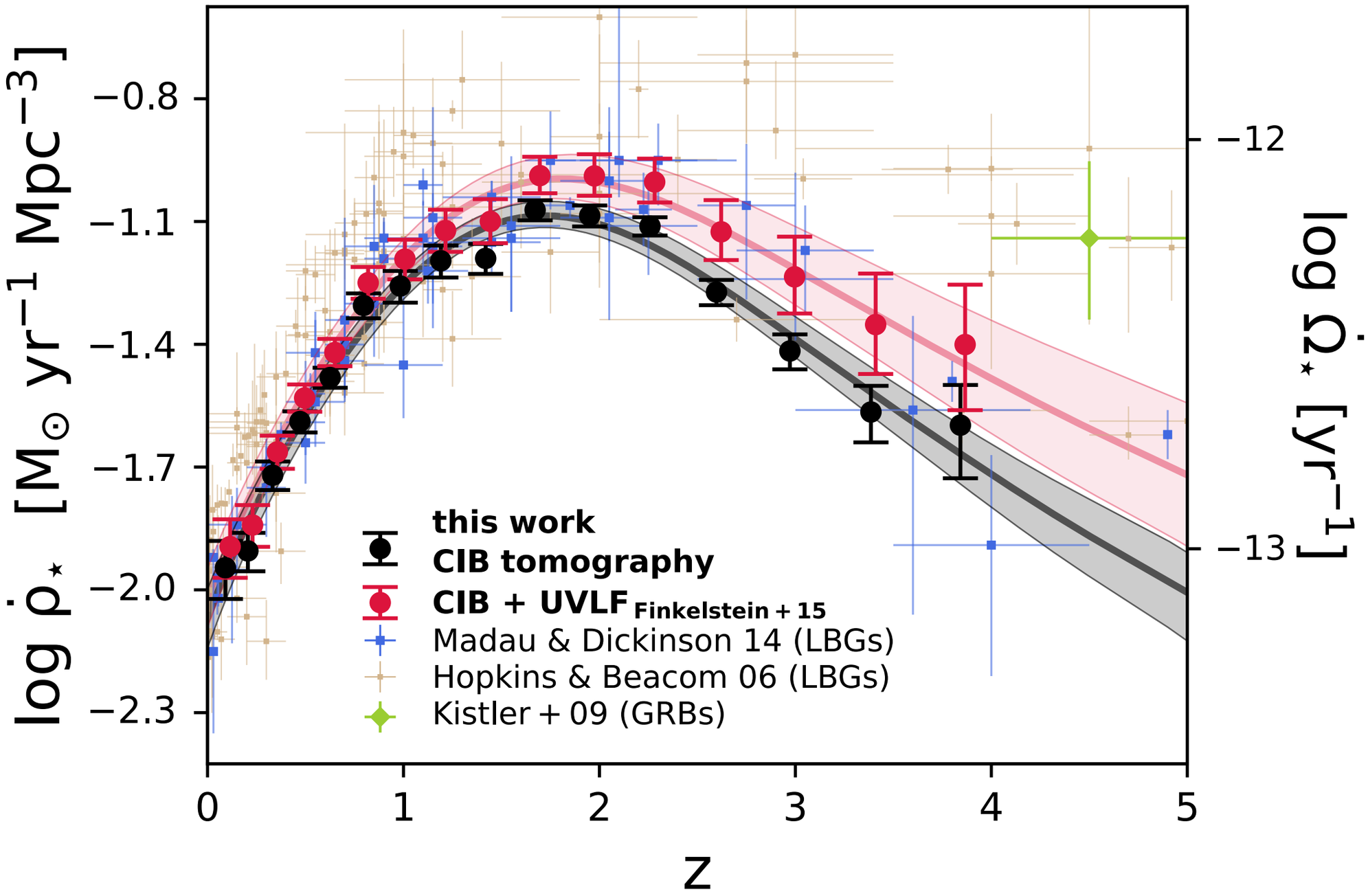
Low-z decline: dust destruction or expelled into the CGM?



Chiang+24, in prep

Cosmic star formation history

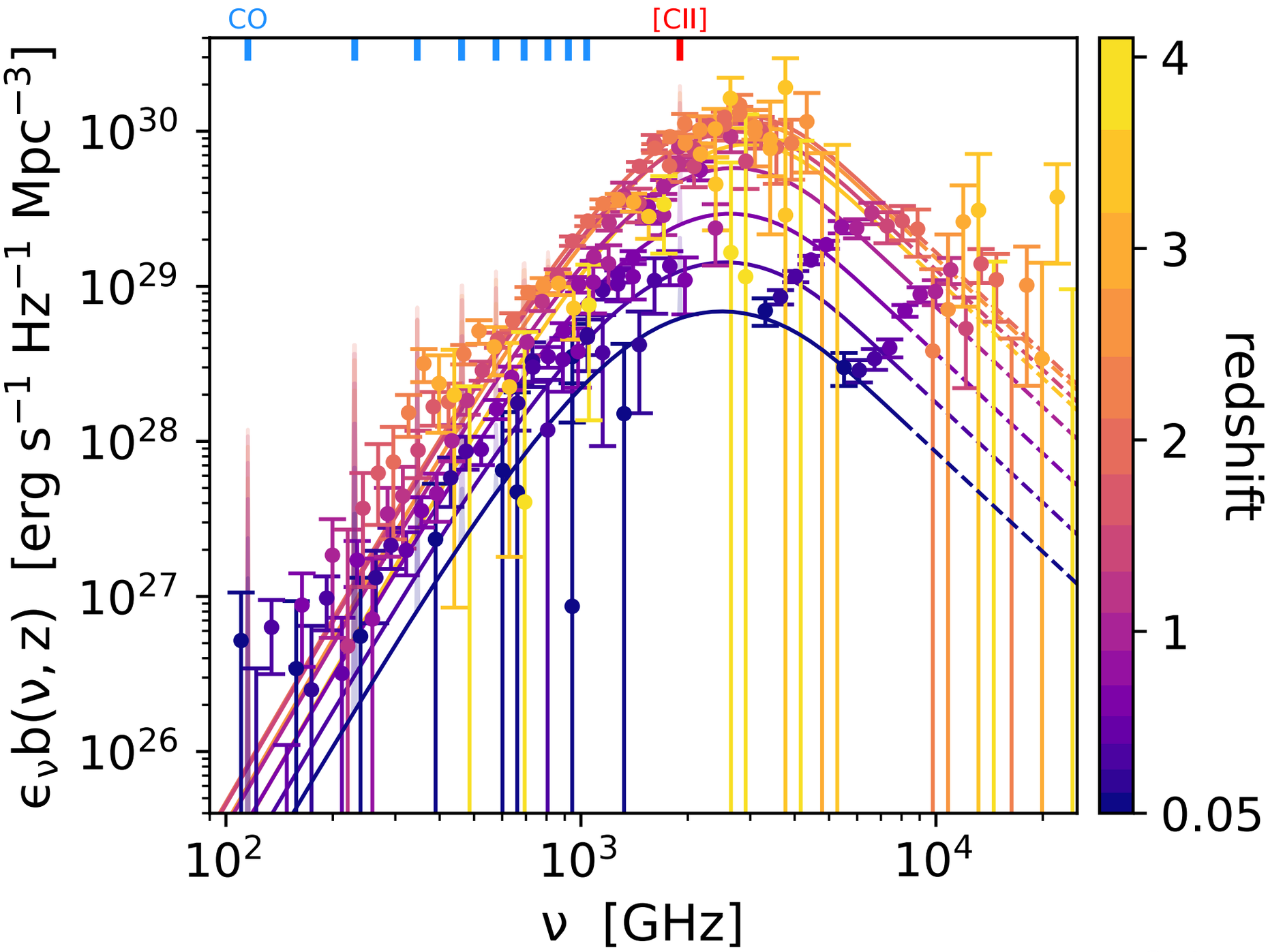
90% dust-obscured at z=0, 65% at z=4



CIB slightly higher than integrated DSFG at z = 3-4 (Zavala+21)

Lines! Only after continuum measured to % level

Generalized form of line intensity mapping, no “line confusion” having z info

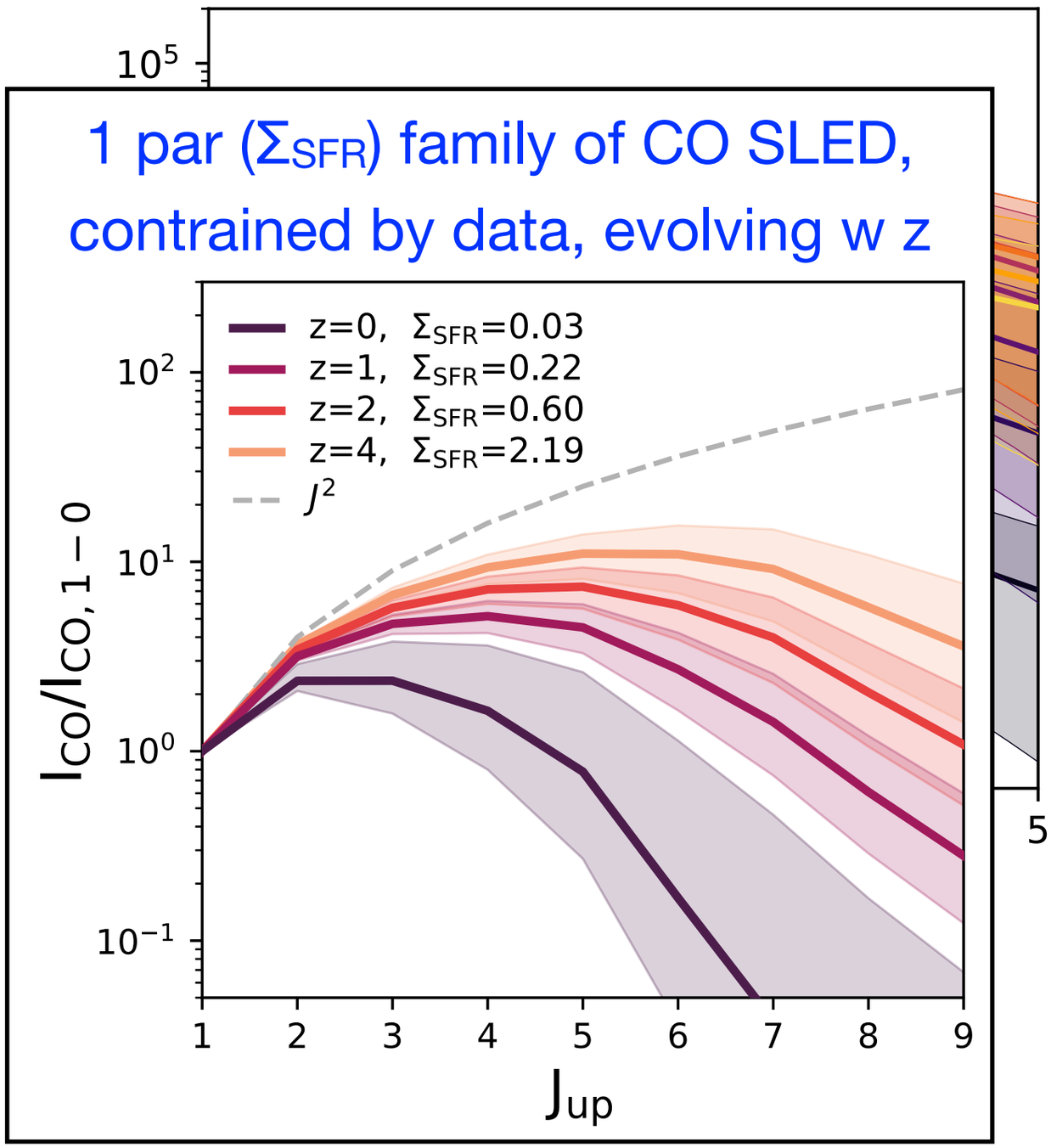


Chiang 25, in prep

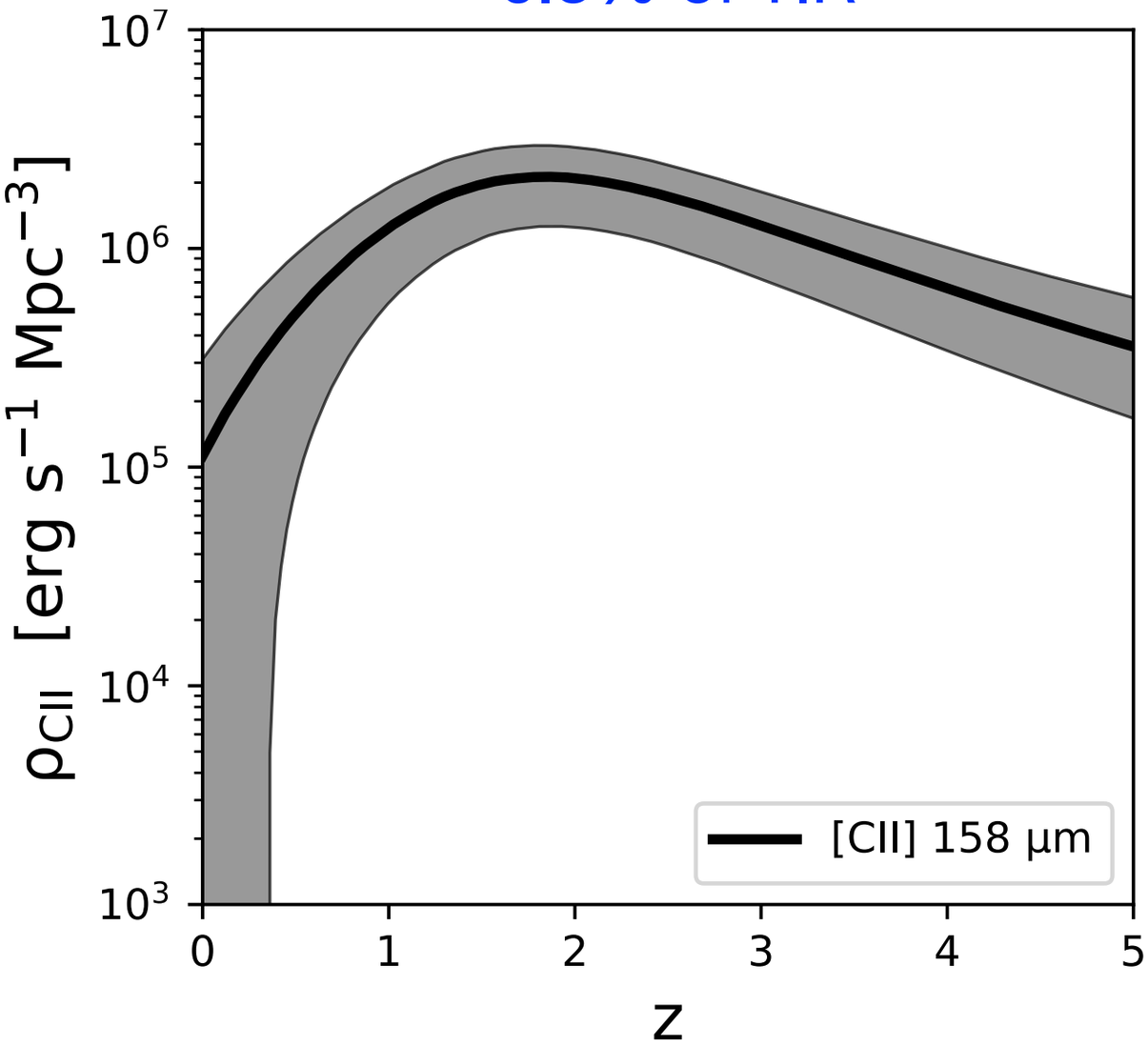
CO, [CII], first “direct” detections w/o line confusion

9 lines combined ~0.03% TIR

1 par (Σ_{SFR}) family of CO SLED, contrained by data, evolving w z



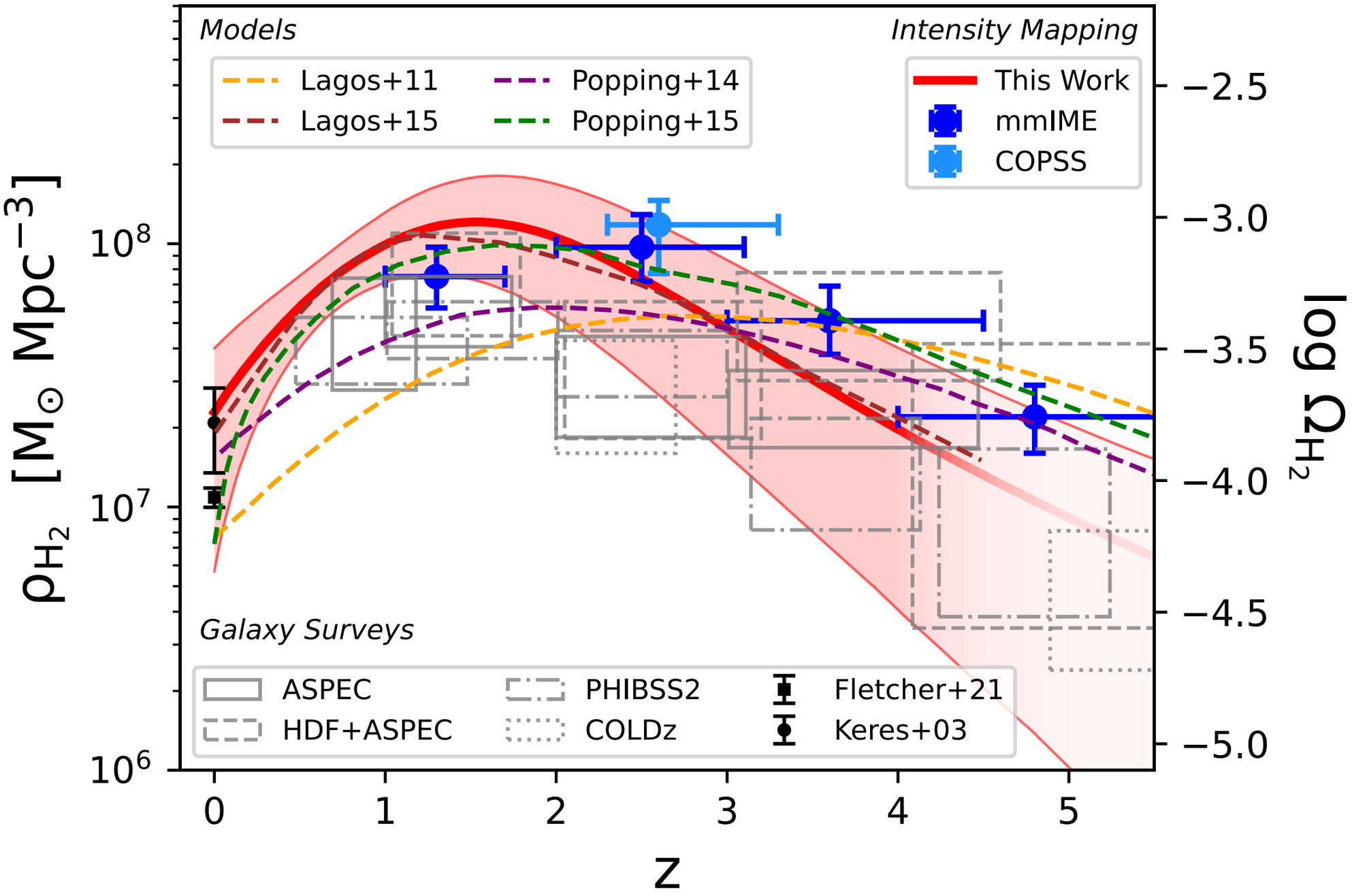
~0.3% of TIR



Chiang 25, in prep

Cosmic H_2 molecular gas resivour from CO

Completing a key sub-branch in baryon cycle: Dust / HI —> H_2 —> SFR



Chiang 25, in prep

Beyond CIB statistics

⬇

Map-level reconstruction?

For diffuse maps in any wavelengths, need component separation:

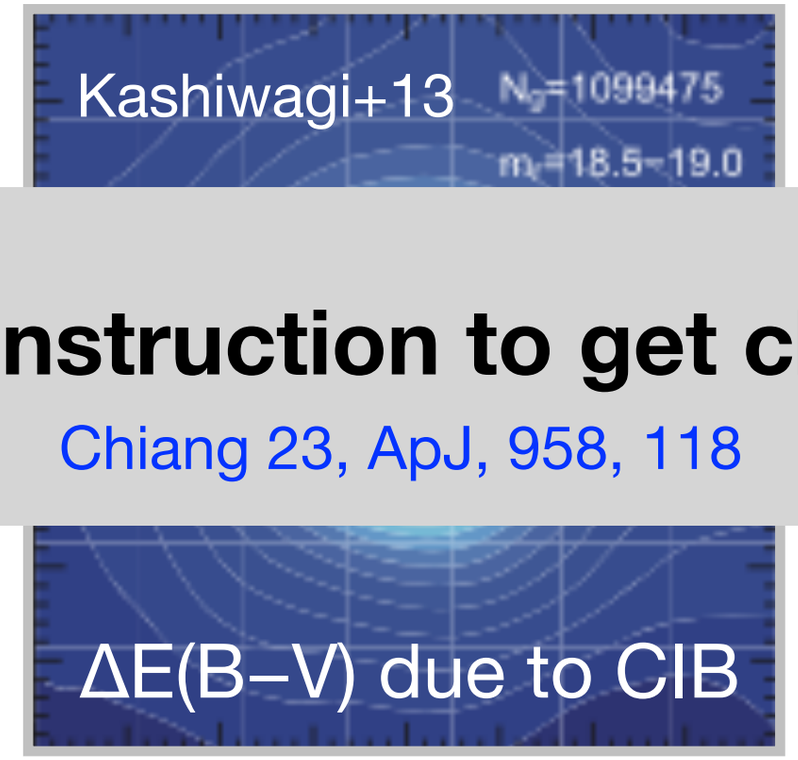
$$I(\phi) \quad = \quad I_{\rm G}(\phi) \; + \boxed{I_{\rm LSS}(\phi)}$$

Possible in the two-halo regime with a data-intensive approach

Example: SFD dust map (100μm) = Milky Way + CIB

Schlegel, Finkbeiner, Davis 1998

Stacking galaxies reveals the CIB



Full-sky CIB reconstruction to get cleaned Milky Way

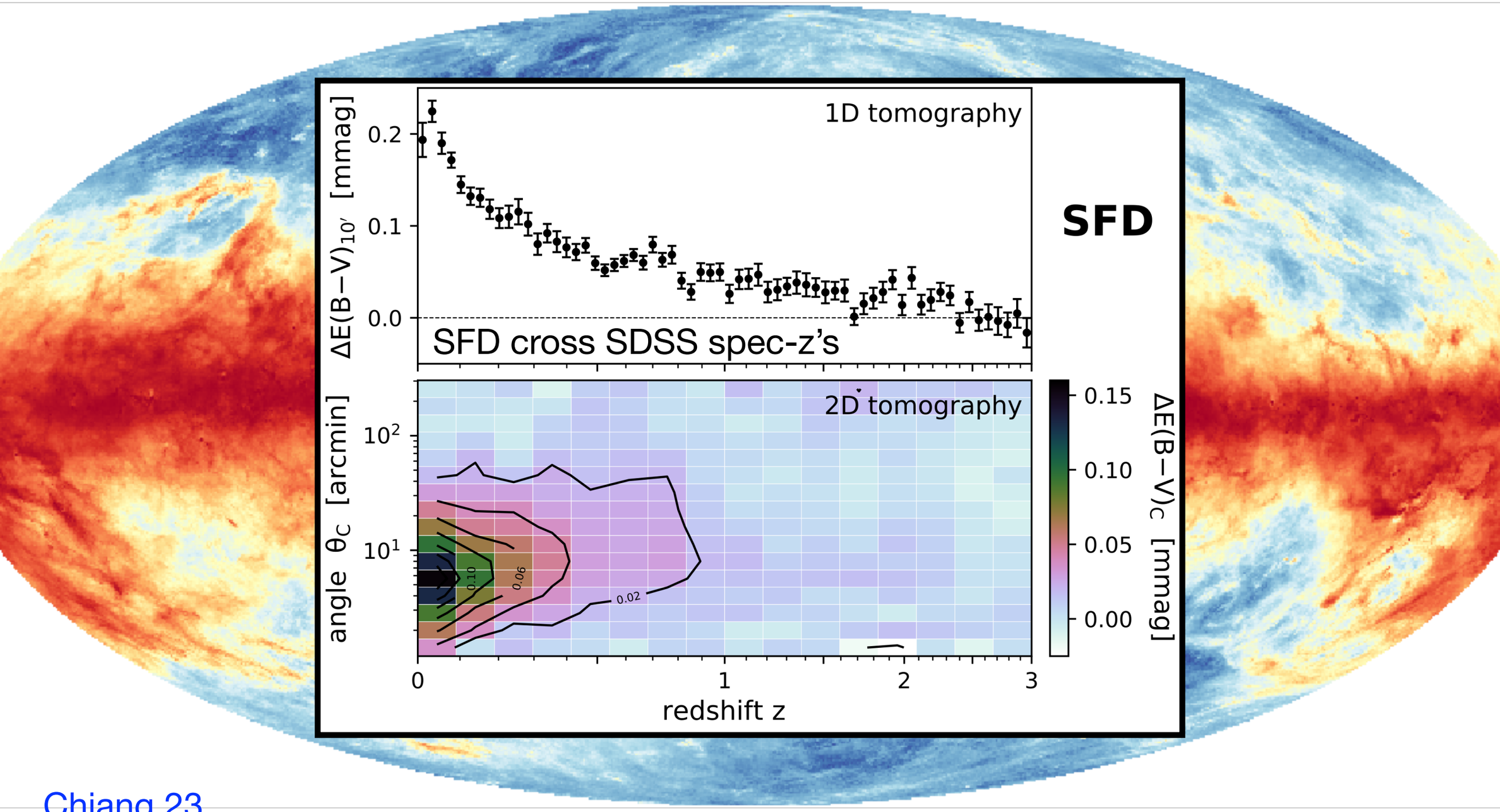
Chiang 23, ApJ, 958, 118

See also, e.g., Yahata+07; Chiang & Menard 19

$E(B-V)$

Step 1: exhaust 2-pt statistics

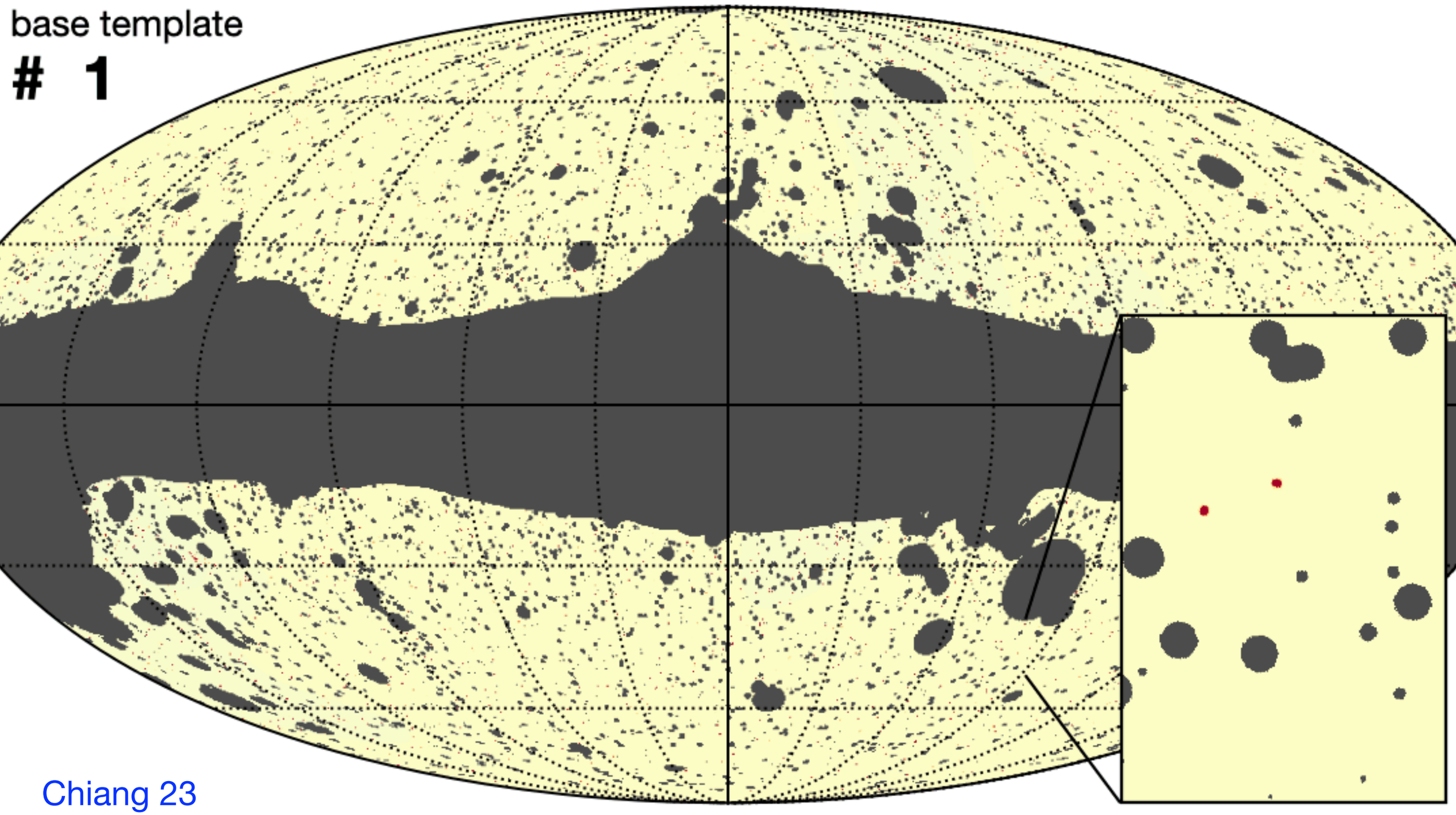
Simlar to the 11-band CIB tomography but now keep full angular



Chiang 23

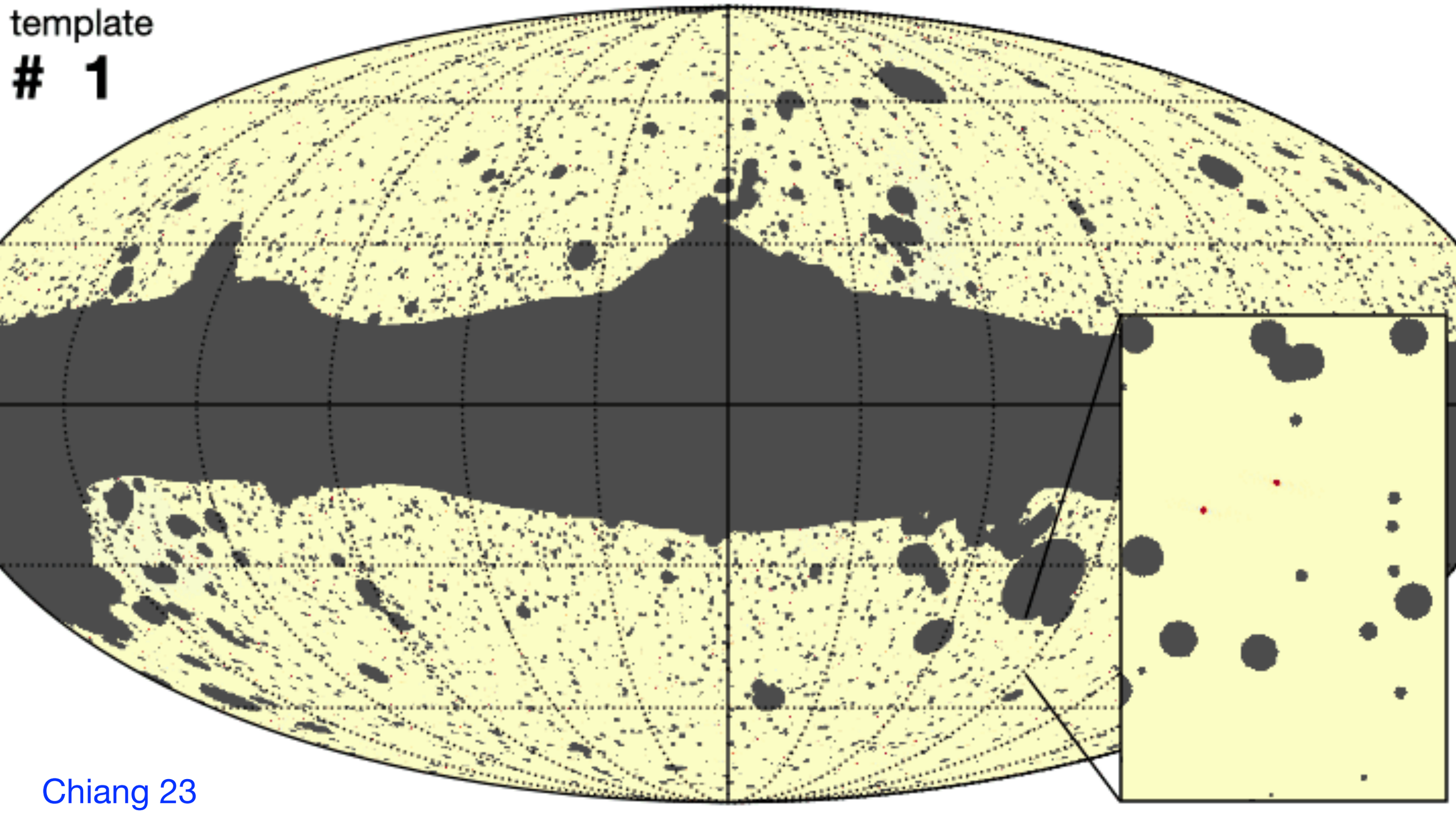
Step 2-a: build a large set of LSS basis

600 million WISE galaxies in 30 color-magnitude cells



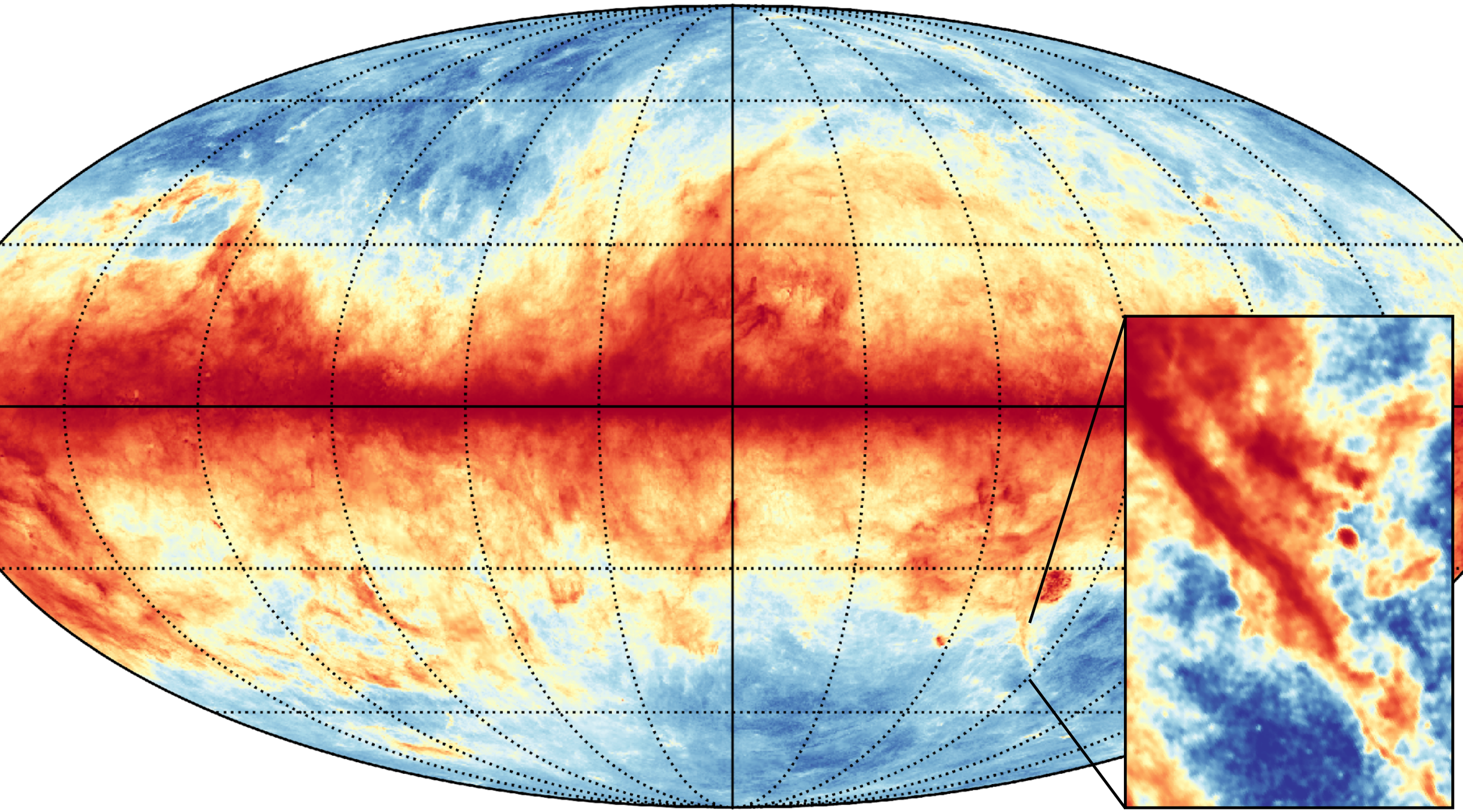
Step 2-b: angular augmentation, 30 × 6 = 180

To form a diverse enough basis set for arbitrary 2-pt stats



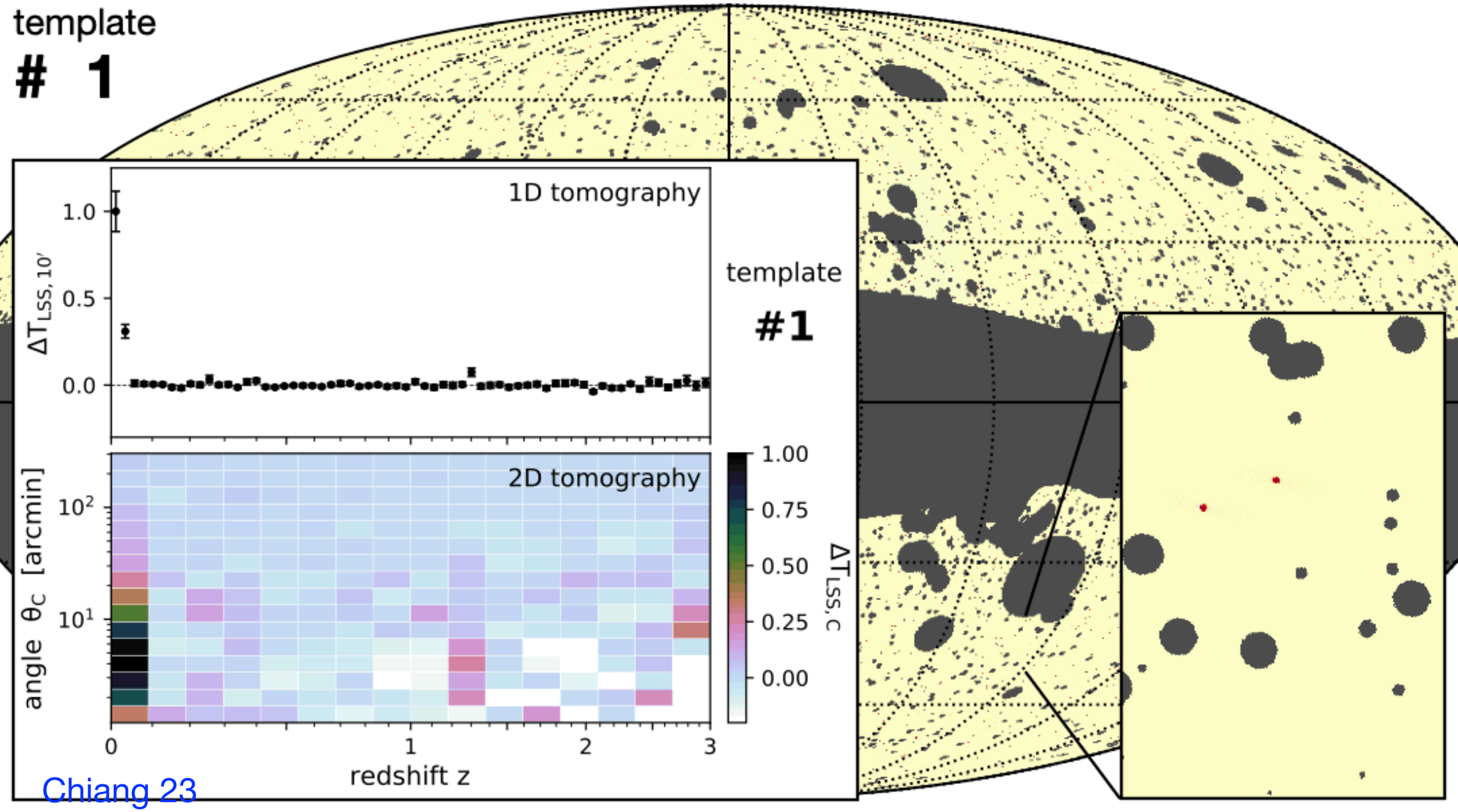
Chiang 23

Unlike SFD, LSS templates are foreground-free



Step 2-c: Cross SDSS to get LSS statistics

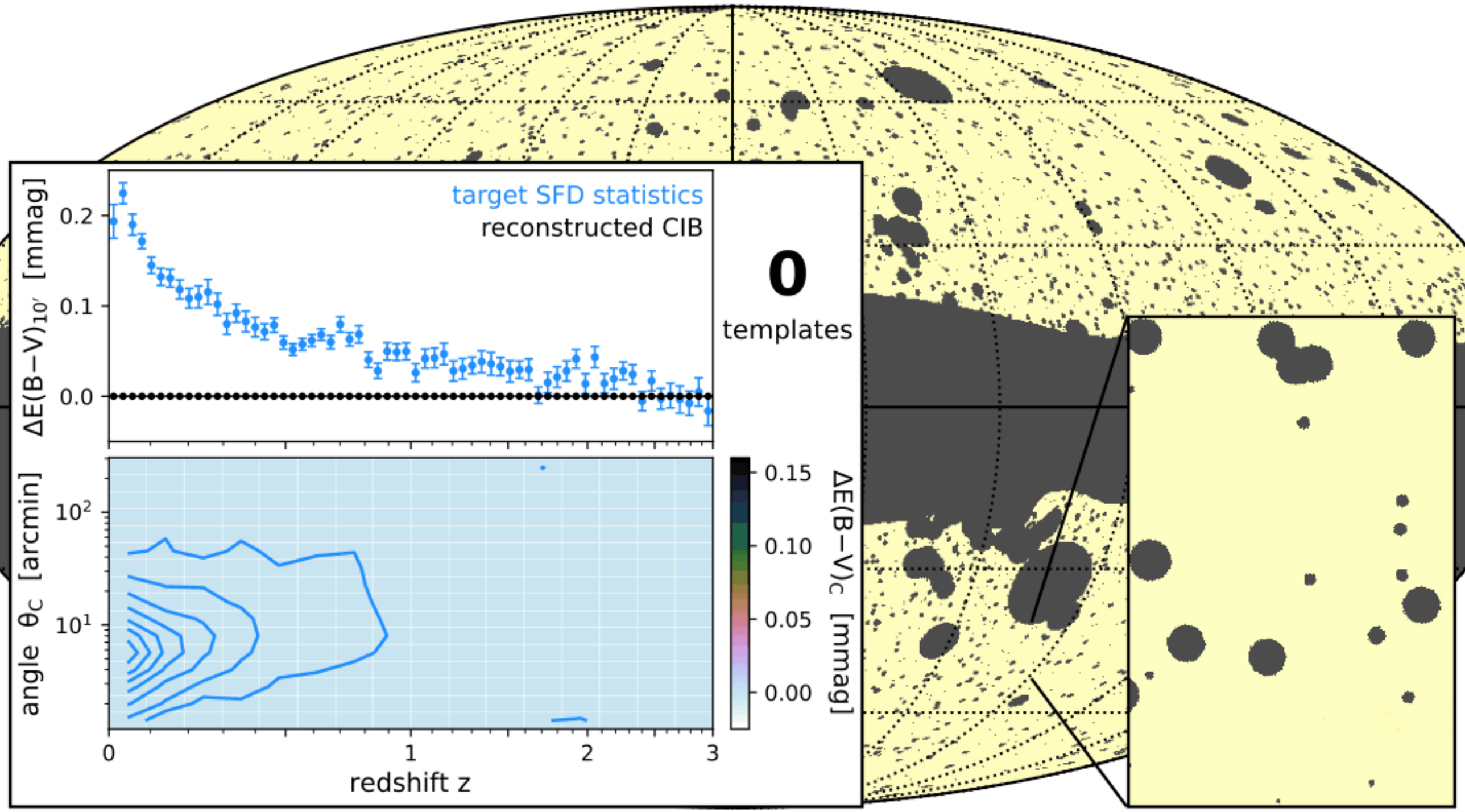
computing intensive: 10^7 2-pt function amplitudes



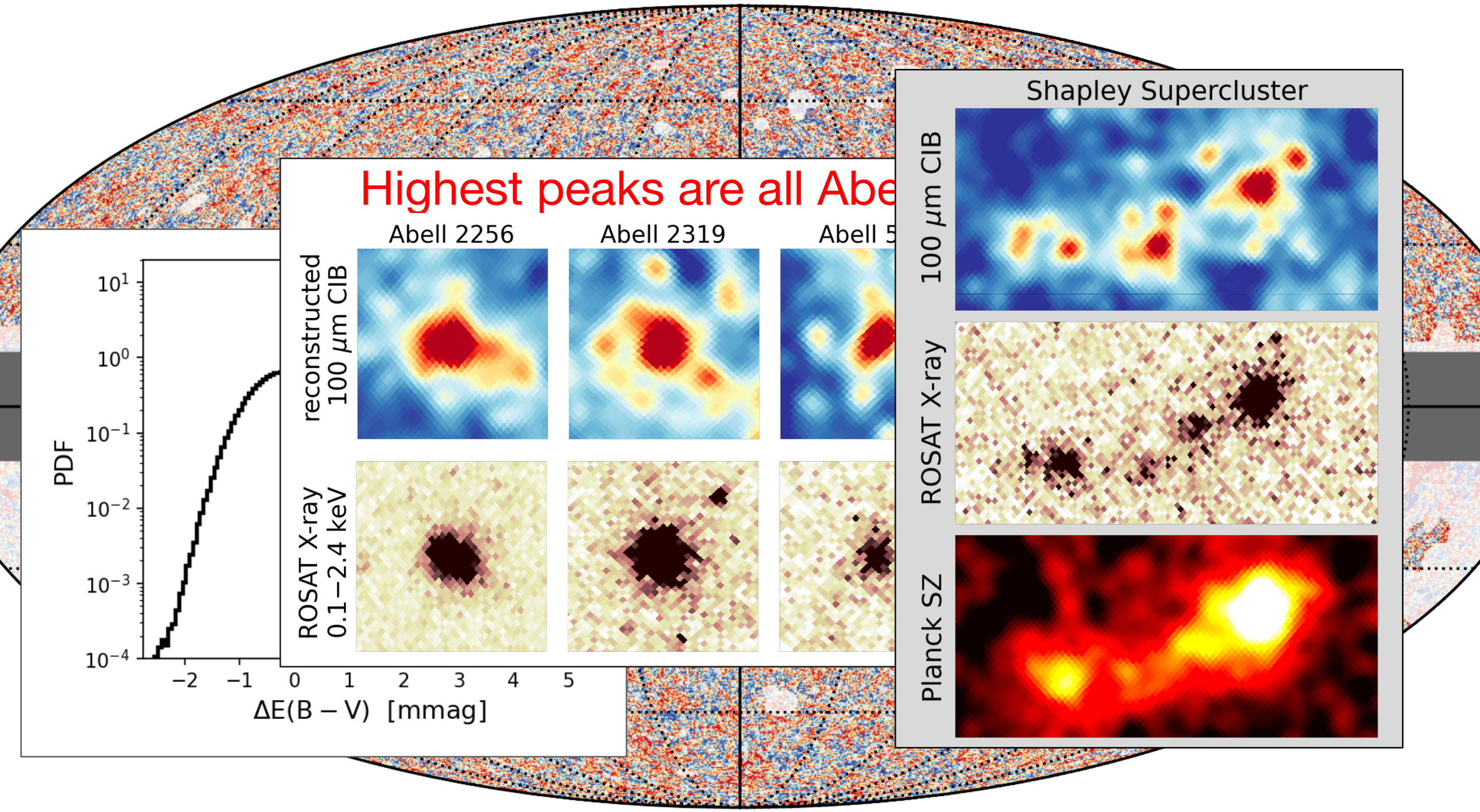
Chiang 23

Step 3: CIB reconstrution w linear combination of basis

$$I_{\mathrm{CIB}}(\phi) \;=\; \sum C_i \times T_{LSS,i}(\phi)$$



Reconstructed CIB map (100 micron)



Chiang 23

Corrected SFD (CSFD) = SFD – CIB

all-purpose dust map for extinction correction and forground cleaning

zenodo 1K VIEWS 1K DOWNLOADS

Or

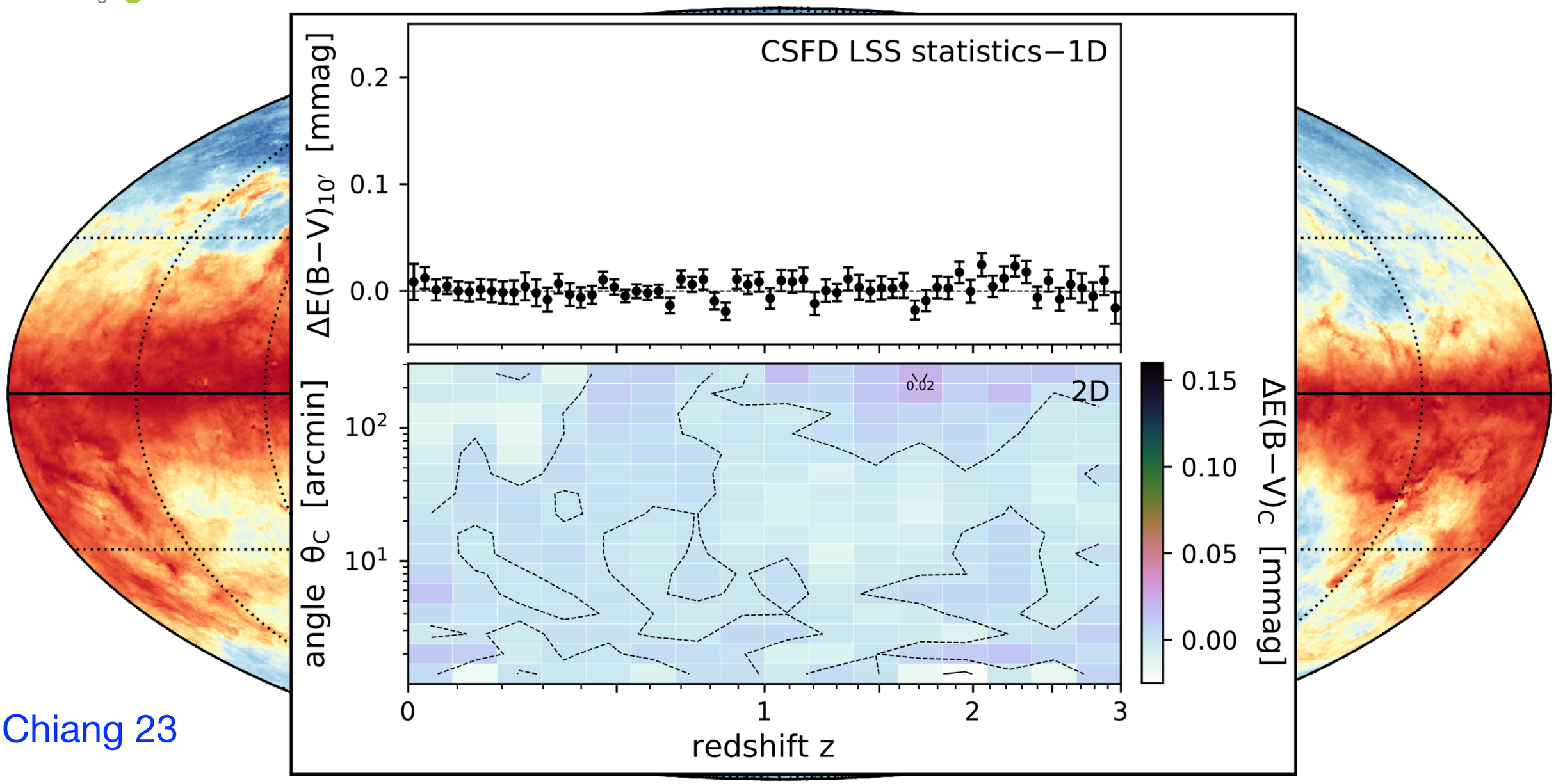
NASA LAMBDA

Or

One line Python query with dustmaps (Green 18) package

CSFD: The Corrected SFD Milky Way Dust Map

Yi-Kuan Chiang[1]



Chiang 23

Take-Aways

Tomographic CIB statistics

- 11 band tomgraphy probes thermal continuum, CO, CII over 0 < z< 4
- Info on baryon cycle: T_dust, dust mass, star-formation, molecular gas

Map-level CIB reconstruction

- SFD dust map separated into pure Milky Way (CSFD) + 100 μm CIB
- Same for all Planck HFI bands comming

Both methods can be applied in any wavelength, e.g.,
UV background (Chiang+19)
tSZ background (Chiang+20)
SPHEREx (launch Feb 25)

Postdoc position(s) with me available at ASIAA