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Funded by the European Union NextGenerationEU

Inferring star-formation history via cross-correlations of Euclid's photometric clustering and shear and the cosmic infrared background

Euclid consortium

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Cosmic Infrared Background Radiationc

Cosmic Infrared Background Radiation(CIB) mainly comes from the heated dust within the galaxies.

CIB carries the integrated history of star formation between the redshift $1 \leq z \leq 3$, which highly overlaps with the galaxy clustering signals.

Without additional information it is not possible to disentangle the contribution to the CIB from sources at different redshifts.

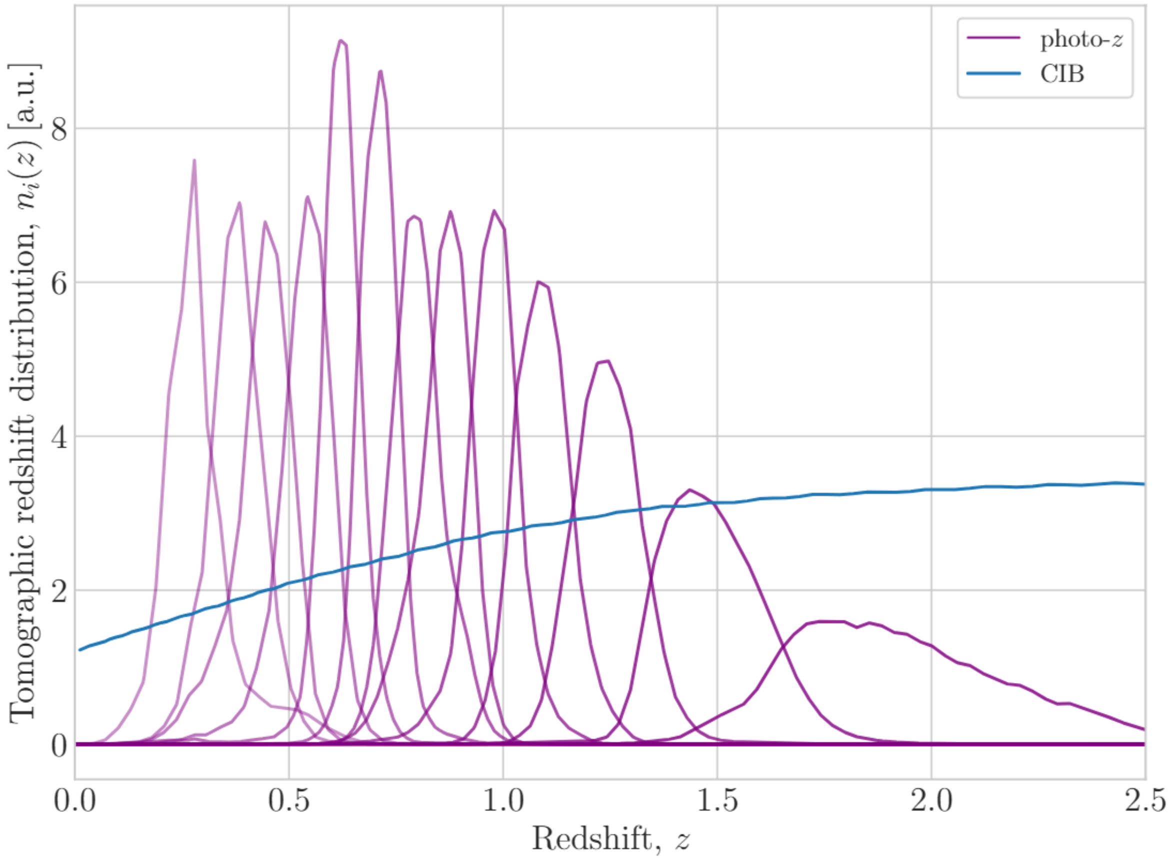
Through the use of galaxy clustering tomography, the CIB contribution from different redshift bins can be constrained.

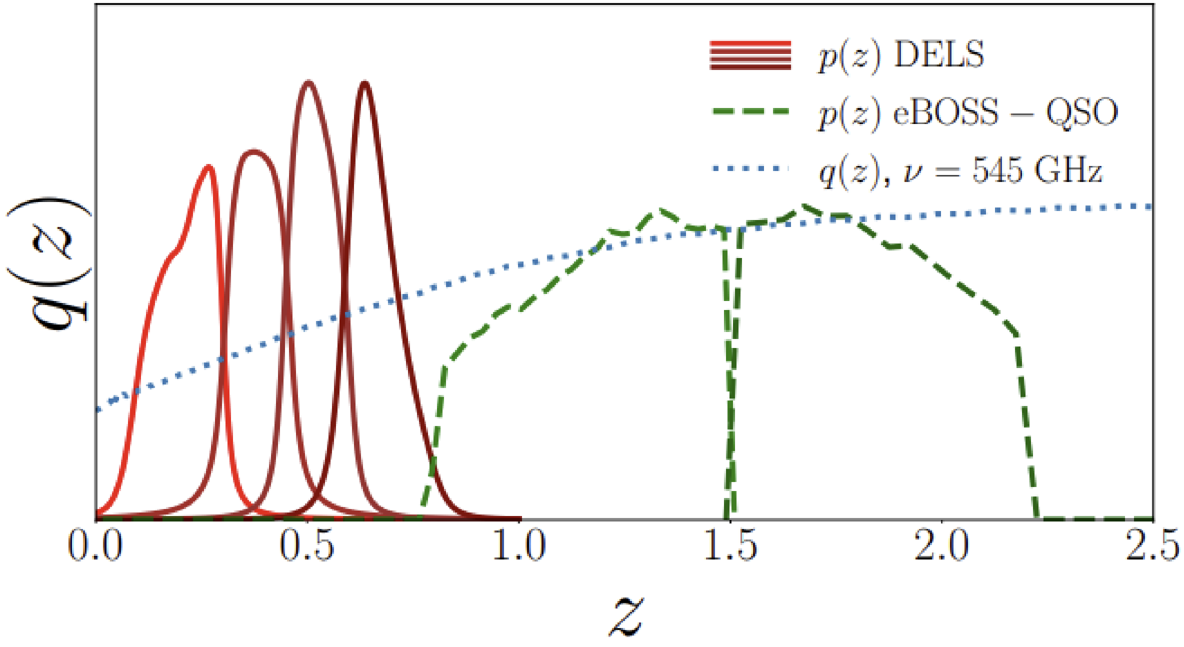
Measure the bias-weighted SFR density

[Jego et. al 2022] report their method of measuring the bias weighted SFR density $<b\rho_{\mathrm{SFR}}>$ base on the Planck CIB data and a galaxy data sets combining DELS and eBoss

Bin	Redshift range	Mean redshift	Density (deg^{-2})
		DELS	
1	[0.10, 0.30)	0.21	808
2	[0.30, 0.15)	0.37	651
3	[0.45, 0.60)	0.50	760
4	[0.60, 0.80]	0.63	409
		eBOSS	
5	[0.80, 1.50)	1.12	34
6	[1.50, 2.20]	1.87	35

Equi-populated Euclid Photometric Bins





Halo Model of CIB

$$C_{\ell,\nu\nu'} = \int \frac{dz}{\chi^2} \frac{d\chi}{dz} a^2 \bar{j}(\nu, z) \bar{j}(\nu', z) P_{j,\nu\nu'}(k = l/\chi, z)$$

Assuming CIB is sourced by galaxies

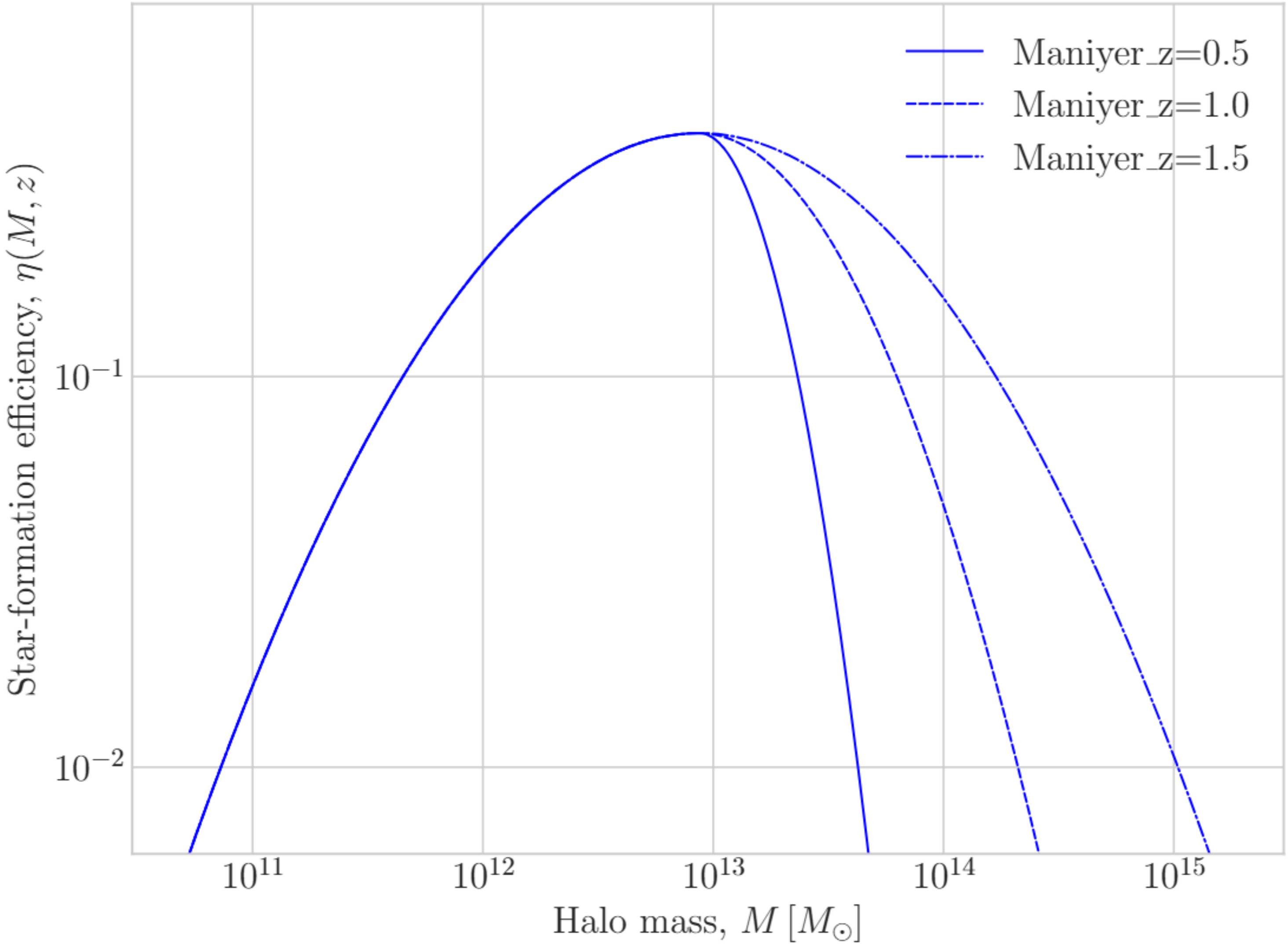
$$P_{gal}(k, z) = P_{1h}(k, z) + P_{2h}(k, z)$$

How should we model $j_\nu(z)$?

Halo Model of CIB

	Maniyer, et al. 2021	Shang, et al. 2012
Model	$\frac{\mathrm{d}j_{v,\mathrm{sub}}}{\mathrm{d}\log M_\mathrm{h}}(M_\mathrm{h},z) = \frac{\mathrm{d}^2 N}{\mathrm{d}\log M_\mathrm{h}\mathrm{d}V} \times \chi^2(1+z)$ $\frac{\mathrm{d}j_{v,\mathrm{c}}}{\mathrm{d}\log M_\mathrm{h}}(M_\mathrm{h},z) = \frac{\mathrm{d}^2 N}{\mathrm{d}\log M_\mathrm{h}\mathrm{d}V} \times \chi^2(1+z) \times \frac{\mathrm{SFR_{dc}}}{K} \times S_v^{\mathrm{eff}}(z)$ $\frac{\mathrm{SFR}}{\mathrm{BAR}}(M_\mathrm{h},z) = \eta = \eta_{\max} e^{-\frac{(\log M_\mathrm{h} - \log M_{\max})^2}{2\sigma^2_{M_\mathrm{h}}(z)}},$	$j_\nu(z) = \int dM \frac{dN}{dM}(z) \frac{1}{4\pi} \left[N_{cen} L_{cen,(1+z)\nu}(M,z) + \int dm \frac{dn}{dm}(M,z) L_{sat,(1+z)\nu}(m) \right],$
Source of emission	**central halo contribution & sub-halo contribution**	**central galaxies contribution& satellite galaxies contribution**
Parameter	**minimal, physically motivated parameter set with weak degeneracy(4-6 free parameter)**	**flexible parameterization of the luminosity–mass relation(more than 10 free parameter)**
Main goal	**Fitting with large scale tracers cross-correlation with Planck and Herschel data**	**Fitting with multi-frequency fine-tuning as well as optimization of SED prior**

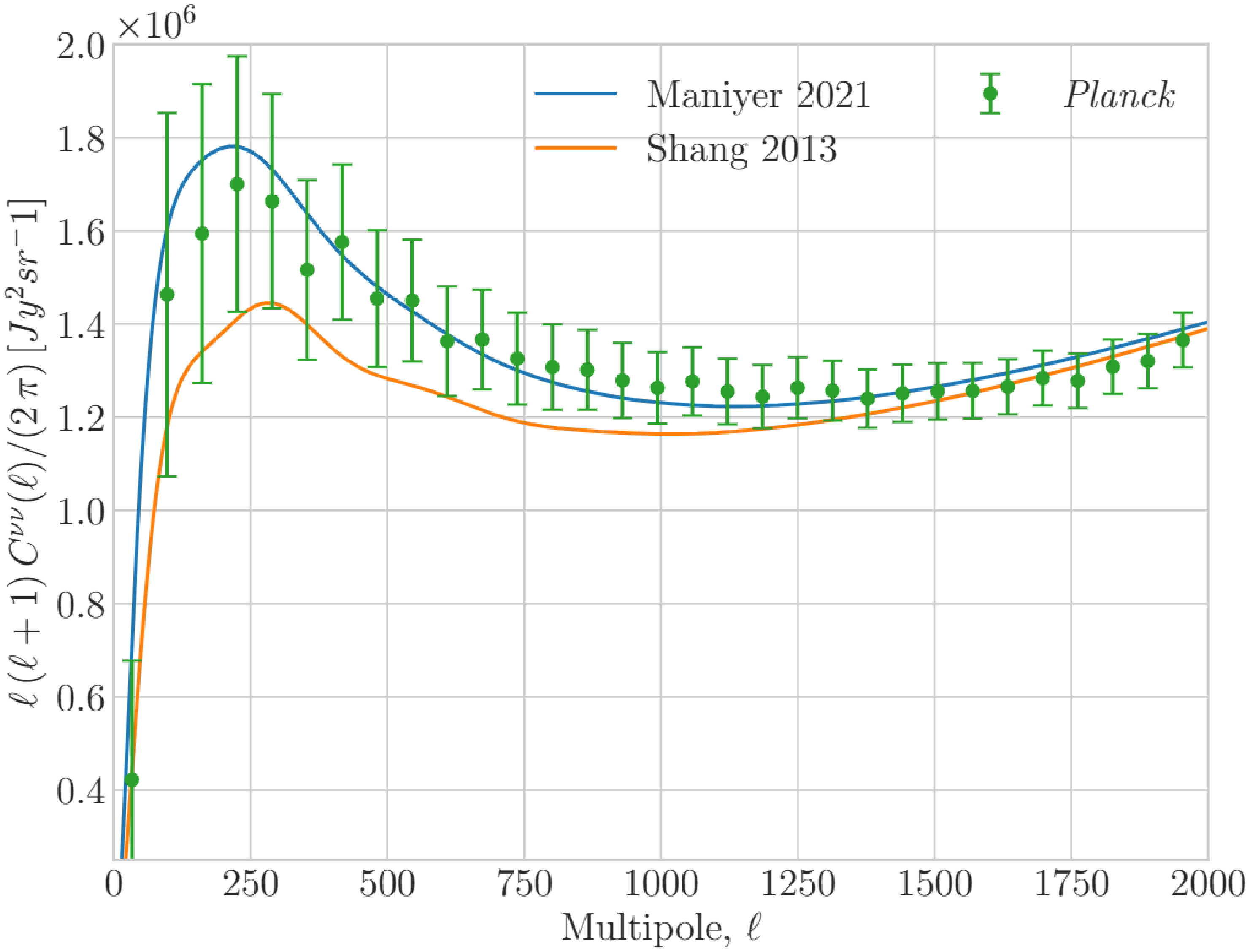
Star Forming Rate Model of CIB



$$\frac{\mathrm{SFR}}{\mathrm{BAR}}(M_\mathrm{h}, z) = \eta = \eta_\mathrm{max} e^{-\frac{(\log M_\mathrm{h} - \log M_\mathrm{max})^2}{2\sigma^2_{M_\mathrm{h}}(z)}},$$

[Jiakang Han, S. Camera, G. Fabbian, M. Migliaccio — in preparation.]

Auto-Power Spectrum from Halo Model of CIB



Cross-power spectrum(CIB-LSS tracers)

$$C^{uv}(\ell) = \int \frac{\mathrm{d}z}{H(z)} \frac{q_u(z)\, q_v(z)}{r^2(z)} P_{UV}\left[\frac{\ell + 1/2}{r(z)}, z\right]$$

Galaxy number density transfer function: $q_{\mathrm{g}}(z) = H(z)\, p(z)$

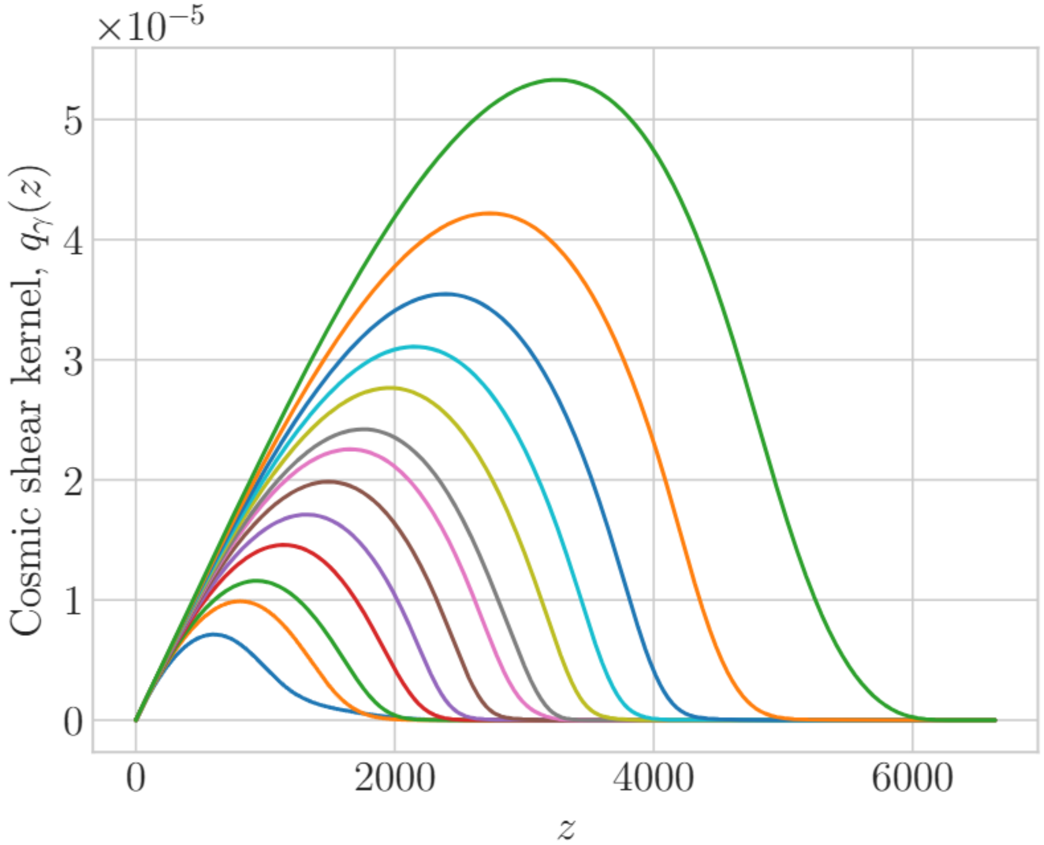
Shear transfer function: $q_\gamma(z) = \frac{3}{2} \frac{H_0^2}{c^2} \Omega_{\mathrm{m}} (1+z)\, r(z) \int_z^\infty \mathrm{d}z'\, p(z') \frac{r(z') - r}{r(z')}$

CIB transfer function: $q_\nu(z) = \frac{r^2(z)}{K} S_\nu^{\mathrm{eff}}(z)$

[PyCCl. 2019]

Cosmic Shear Kernel

$$q_\gamma(\chi) = \frac{3}{2} H_0^2 \Omega_m (1+z) \chi \int_z^\infty dz' \, p(z') \, \frac{\chi(z') - \chi}{\chi(z')},$$

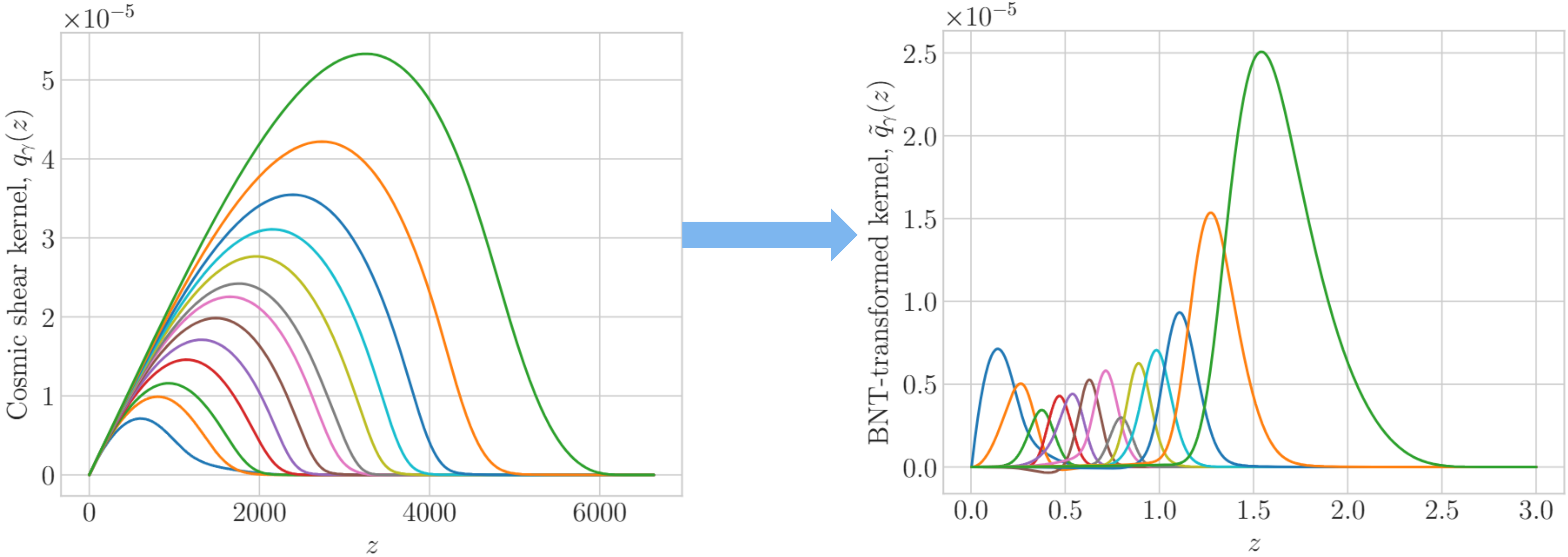


Cosmic Shear Kernel

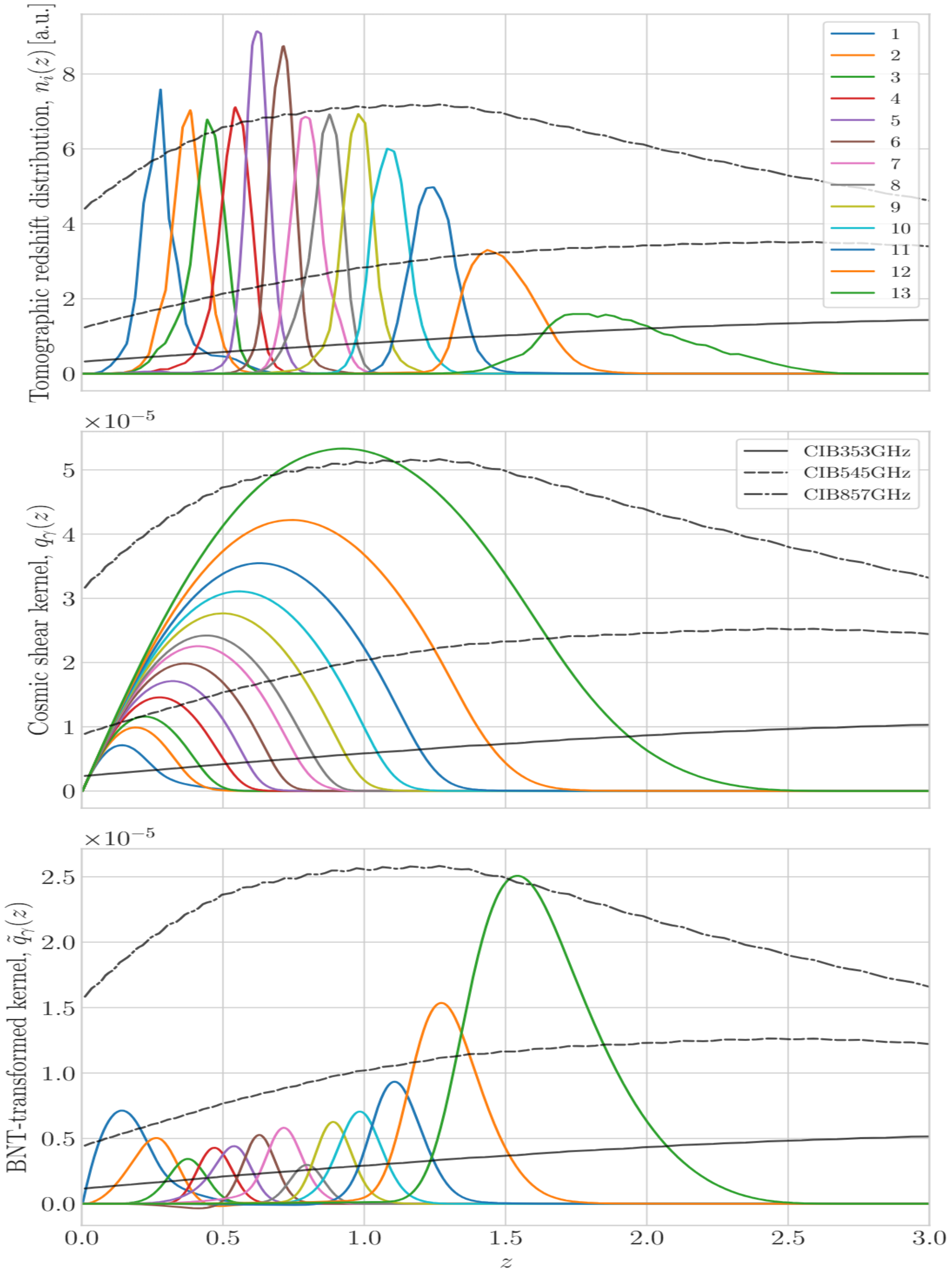
$\mathsf{M}\,\mathsf{S}_\ell^{\epsilon\epsilon}\,\mathsf{M}^\mathsf{T}$

BNT Transform

$$q_\gamma(\chi) = \frac{3}{2}H_0^2\Omega_m(1+z)\chi\int_z^\infty dz'\,p(z')\,\frac{\chi(z')-\chi}{\chi(z')},$$



Joint analysis



Cross-power spectrum(CIB-LSS tracers)

$$P_{UV}(k) = P_{UV}^{1\mathrm{h}}(k) + P_{UV}^{2\mathrm{h}}(k)$$

sufficient large scale

$$P_{UV}(k) \simeq \langle bU \rangle \langle bV \rangle P_{\mathrm{lin}}(k) + N_{UV}$$

[PyCCl. 2019]

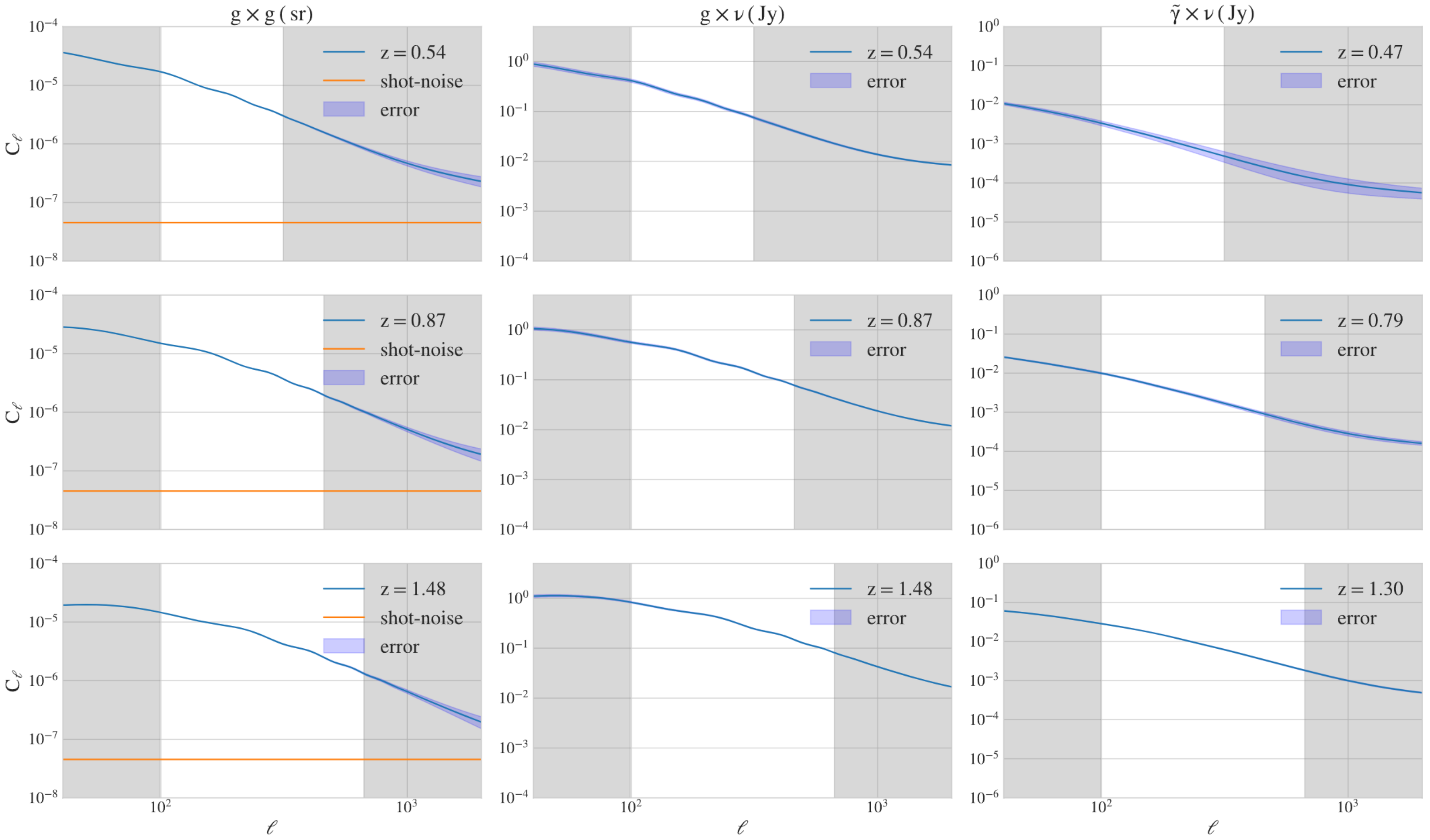
Power Spectrum Templates

$$C_\ell^{gg} \simeq b_g^2 M_\ell^{gg} + n_{gg}$$

$$C_\rho^{gv} \simeq b_g \langle b\rho_{\rm SFR} \rangle M_\rho^{gv} + n_{gv},$$

$$M_\ell^{uv} \equiv \int \frac{d\chi}{\chi^2} q_u(\chi) q_v(\chi) P_M\left(\frac{\ell + 1/2}{\chi}, z\right)$$

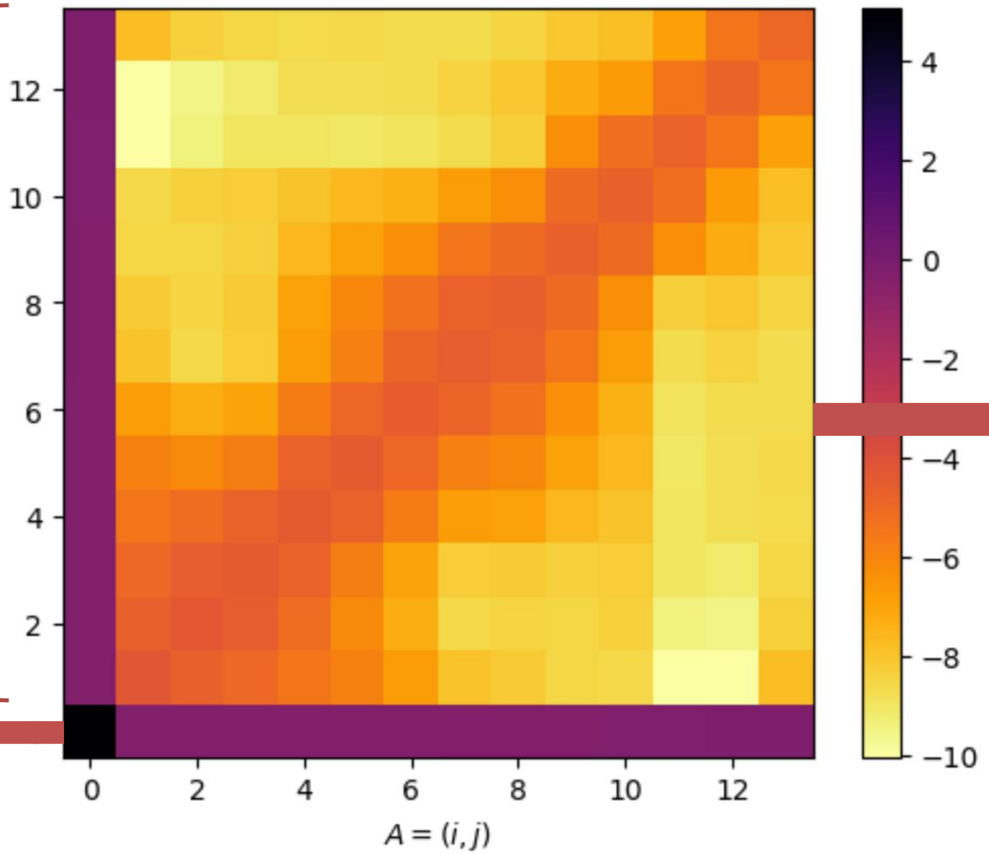
Cross-power spectrum(CIB-Galaxy clustering)



Fisher Matrix Method

Power Spectrum Variance Matrix

13 Euclid Galaxy Bins
X
CIB 545Hz power spectrum variance



13 Euclid galaxy bins auto-&cross-power spectrum variance

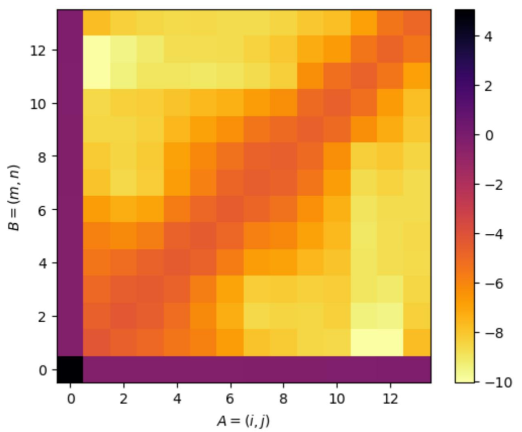
CIB 545Hz auto-power spectrum variance

[Jiakang Han, S. Camera, G. Fabbian, M. Migliaccio — in preparation.]

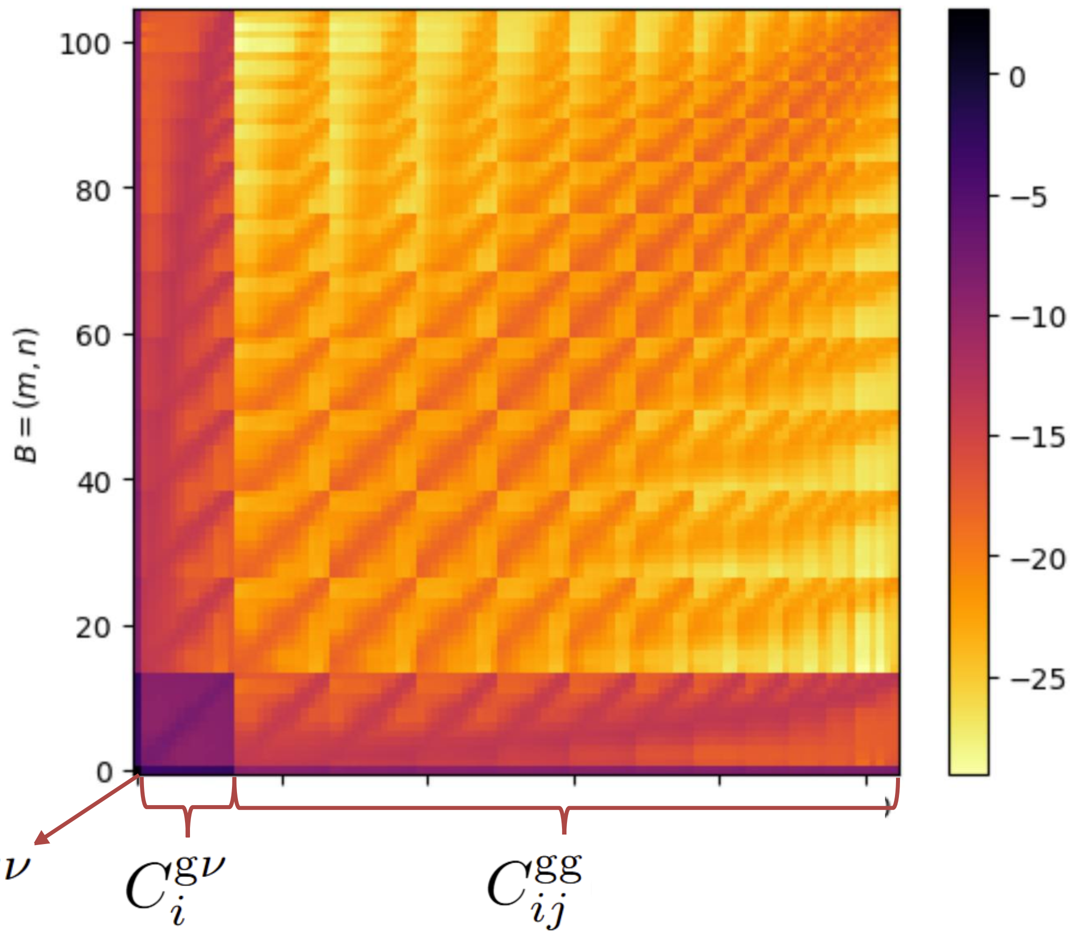
Fisher Matrix Method

$$\mathrm{SNR} = \sqrt{\sum_{\ell,\ell'} C_\ell \mathbb{C}^{-1}_{\ell\ell'} C_{\ell'}}$$

Variance Matrix



Covariance Matrix



$C^{\nu\nu}$ $C^{g\nu}_i$ C^{gg}_{ij}

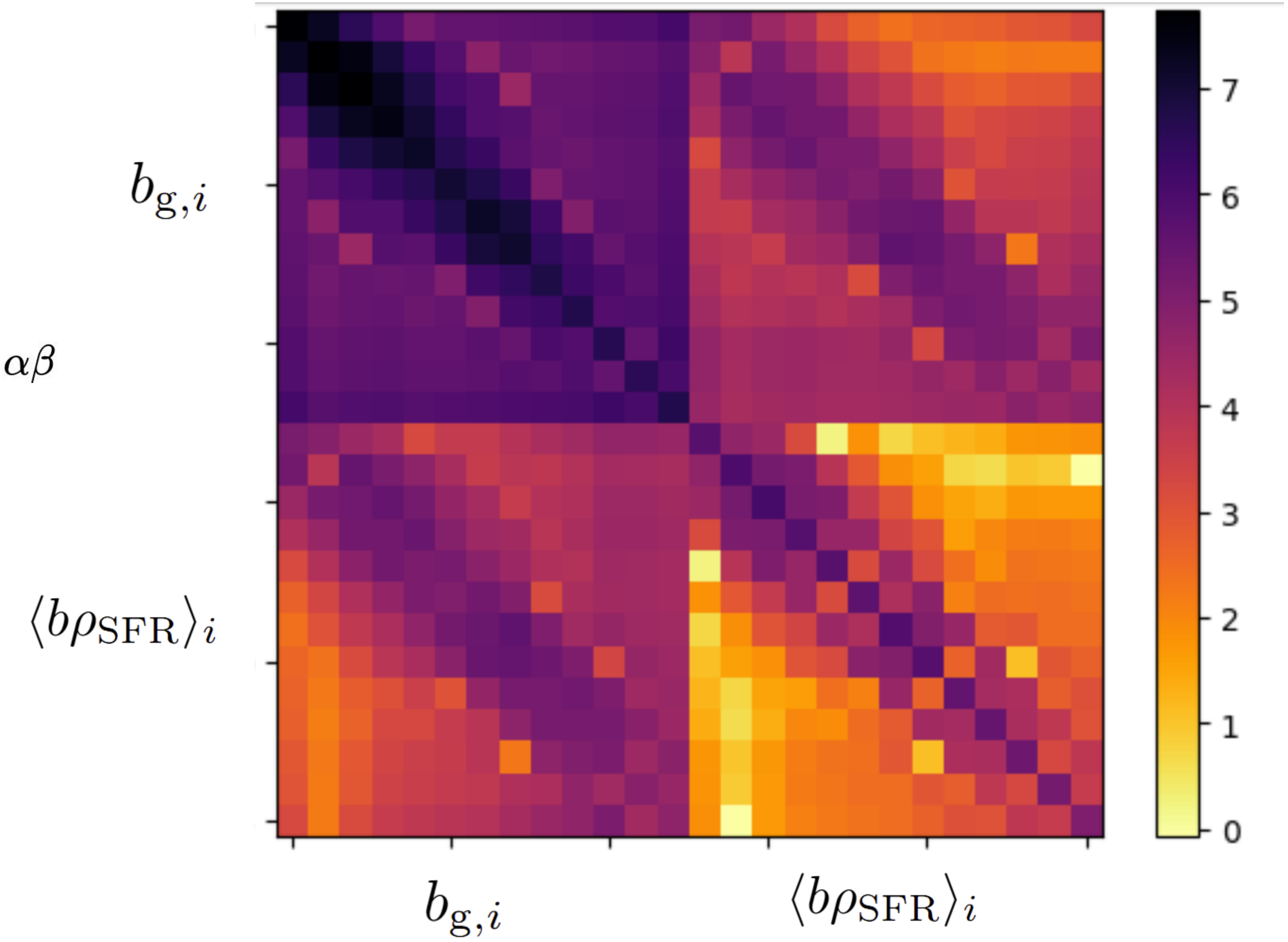
[Jiakang Han, S. Camera, G. Fabbian, M. Migliaccio — in preparation.]

Fisher Matrix Method

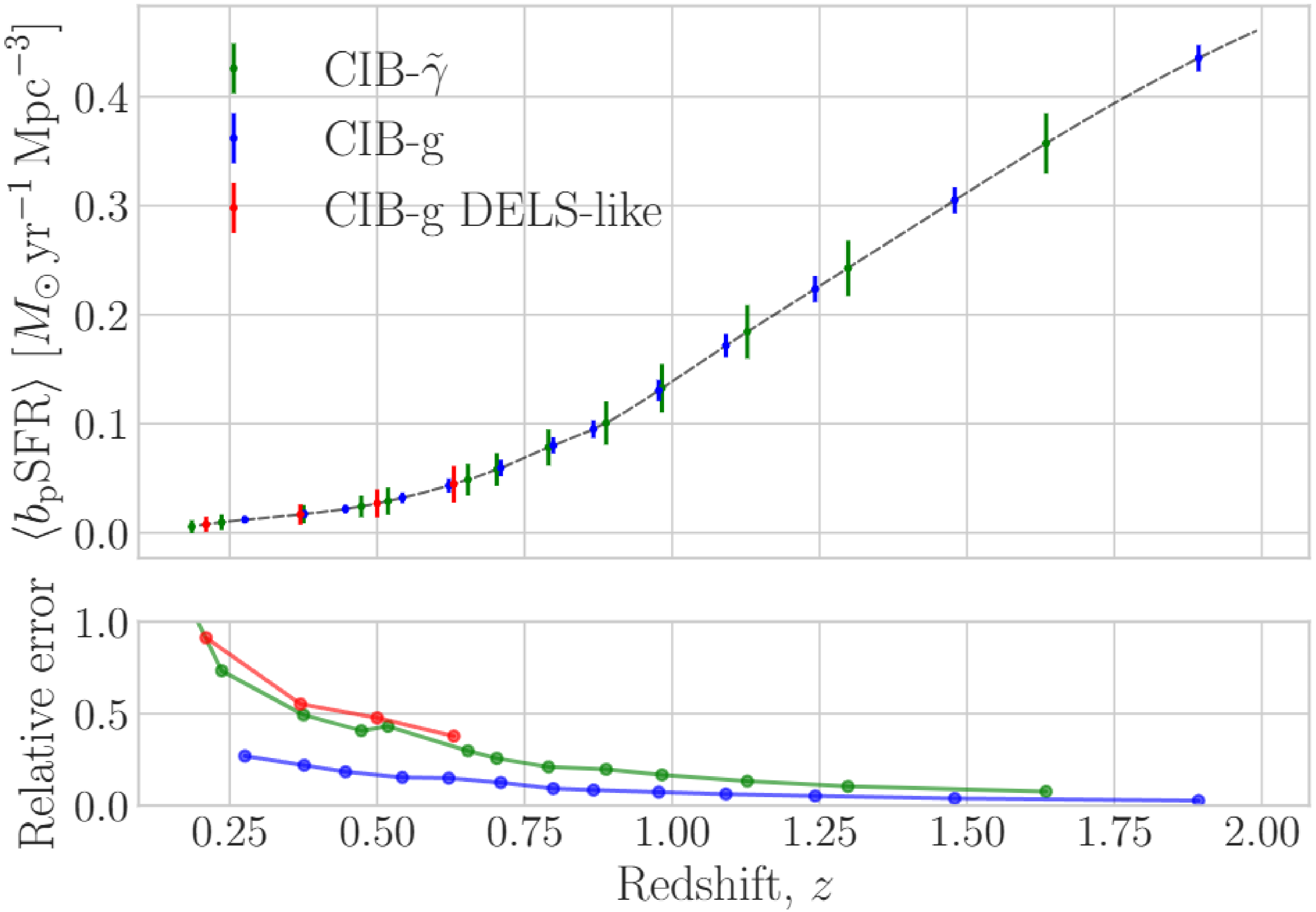
$$\widetilde{F}_{\kappa\lambda} = \sum_{\alpha,\beta} J_{\alpha\kappa} F_{\alpha\beta} J_{\beta\lambda},$$

$$J_{\alpha\kappa} = \frac{\partial \alpha}{\partial \kappa} \qquad C_{\alpha\beta} = \left(\mathrm{F}^{-1}\right)_{\alpha\beta}$$

$$\sigma_\alpha = \sqrt{C_{\alpha\alpha}}$$



Fisher Matrix Method

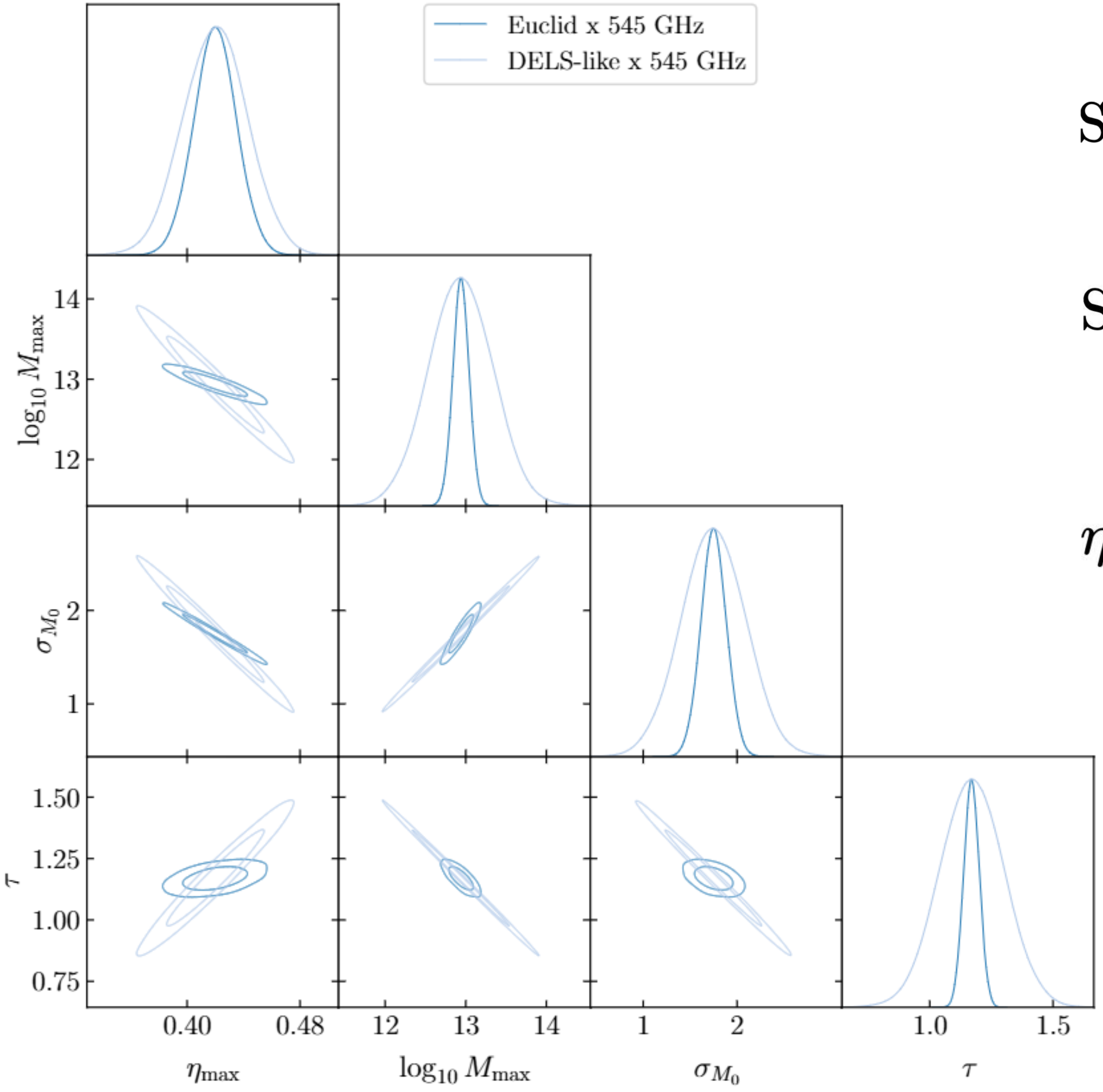


$$C_\ell^{gg} \simeq b_g^2 M_\ell^{gg} + n_{gg}$$

$$C_\rho^{gv} \simeq b_g \langle b\rho_{\mathrm{SFR}} \rangle M_\rho^{gv} + n_{gv},$$

[Jiakang Han, S. Camera, G. Fabbian, M. Migliaccio — in preparation.]

Fisher Matrix Method



$$\mathrm{SFR}(M,z) = \mathrm{SFR}_c(M,z) + \mathrm{SFR}_S(M,z).$$

$$\mathrm{SFR}_c(M,z) = \eta(M,z)\,\mathrm{BAR}(M,z)$$

$$\eta(M,z) = \eta_{\rm max} \exp\left[-\frac{(\log M_{\rm max} - \log M)^2}{2\sigma_M^2(M,z)}\right]$$

Parameter	Fiducial value	$\pm 1\,\sigma$
$\log_{10} M_{\rm max}$	12.94	0.15
$\eta_{\rm max}$	0.420	0.015
σ_{M_0}	1.75	0.10
τ	1.17	0.032

[Jiakang Han, S. Camera, G. Fabbian, M. Migliaccio — in preparation.]

Summary

- Disentangle the CIB contribution from different z bins through correlation between CIB and galaxy clustering.
- Enhance the constraint on the star-formation history with cross-correlation between CIB and cosmic shear

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THANKS FOR YOUR ATTENTION

Halo term from Shang

$$P_{2h}(k,z) = P_M(M,z) \times \left[\int dM \frac{dN}{dM}(M,z) \frac{N_{gal}(M,z) b(M,z) u(k,z|M)}{\bar{n}_{gal}}\right]^2$$

$$P_{1h}(k,z) = \int dM \frac{dN}{dM}(M,z) \times \frac{2N_{\mathrm{cen}}(M) N_{\mathrm{sat}}(M) u(k,z|M) + N_{\mathrm{sat}}^2(M) u^2(k,z|M)}{\bar{n}_{\mathrm{gal}}^2}$$

Halo Model of CIB [Maniyer, et al. 2021]

$$C^{2\,\mathrm{h}}_{\ell,v,v'} = \iiint \frac{\mathrm{d}\chi}{\mathrm{d}z}\left(\frac{a}{\chi}\right)^2 \left[\frac{\mathrm{d}j_{v,c}}{\mathrm{d}\log M_\mathrm{h}} + \frac{\mathrm{d}j_{v,\,\mathrm{sub}}}{\mathrm{d}\log M_\mathrm{h}} u(k, M_\mathrm{h}, z)\right]$$
$$\times \left[\frac{\mathrm{d}j_{v',c}}{\mathrm{d}\log M'_\mathrm{h}} + \frac{\mathrm{d}j_{v',\,\mathrm{sub}}}{\mathrm{d}\log M'_\mathrm{h}} u(k, M_\mathrm{h}, z)\right]$$
$$\times\, b(M_\mathrm{h}, z) b\left(M'_\mathrm{h}, z\right) P_\mathrm{lin}(k, z) \mathrm{d}\log M_\mathrm{h} \mathrm{d}\log M'_\mathrm{h} \mathrm{d}z$$

$$C^{1\,\mathrm{h}}_{\ell,v,v'} = \iint \frac{\mathrm{d}\chi}{\mathrm{d}z}\left(\frac{a}{\chi}\right)^2 \left[\frac{\mathrm{d}j_{v,\mathrm{c}}}{\mathrm{d}\log M_\mathrm{h}} \frac{\mathrm{d}j_{v',\mathrm{sub}}}{\mathrm{d}\log M_\mathrm{h}} u(k, M_\mathrm{h}, z)\right.$$
$$+ \frac{\mathrm{d}j_{v',\mathrm{c}}}{\mathrm{d}\log M_\mathrm{h}} \frac{\mathrm{d}j_{v,\mathrm{sub}}}{\mathrm{d}\log M_\mathrm{h}} u(k, M_\mathrm{h}, z)$$
$$\left.+ \frac{\mathrm{d}j_{v,\mathrm{sub}}}{\mathrm{d}\log M_\mathrm{h}} \frac{\mathrm{d}j_{v',\,\mathrm{sub}}}{\mathrm{d}\log M_\mathrm{h}} u^2(k, M_\mathrm{h}, z)\right]$$
$$\times \left(\frac{\mathrm{d}^2 N}{\mathrm{d}\log M_\mathrm{h} \mathrm{d}V}\right)^{-1} \mathrm{d}z\, \mathrm{d}\log M_\mathrm{h}$$

Halo Model of CIB

$$C_{\ell,\nu\nu'} = \int \frac{dz}{\chi^2}\frac{d\chi}{dz} a^2 \bar{j}(\nu, z)\bar{j}(\nu', z) P_{j,\nu\nu'}(k = l/\chi, z)$$

$$P_{gal}(k, z) = P_{1h}(k, z) + P_{2h}(k, z)$$

$j_\nu(z)$

Halo Model of CIB

Maniyer, et al. 2021

$$\frac{\mathrm{d}j_{v,\,\mathrm{sub}}}{\mathrm{d}\log M_\mathrm{h}}(M_\mathrm{h}, z) = \frac{\mathrm{d}^2 N}{\mathrm{d}\log M_\mathrm{h} \mathrm{d}V} \times \chi^2 (1+z)$$

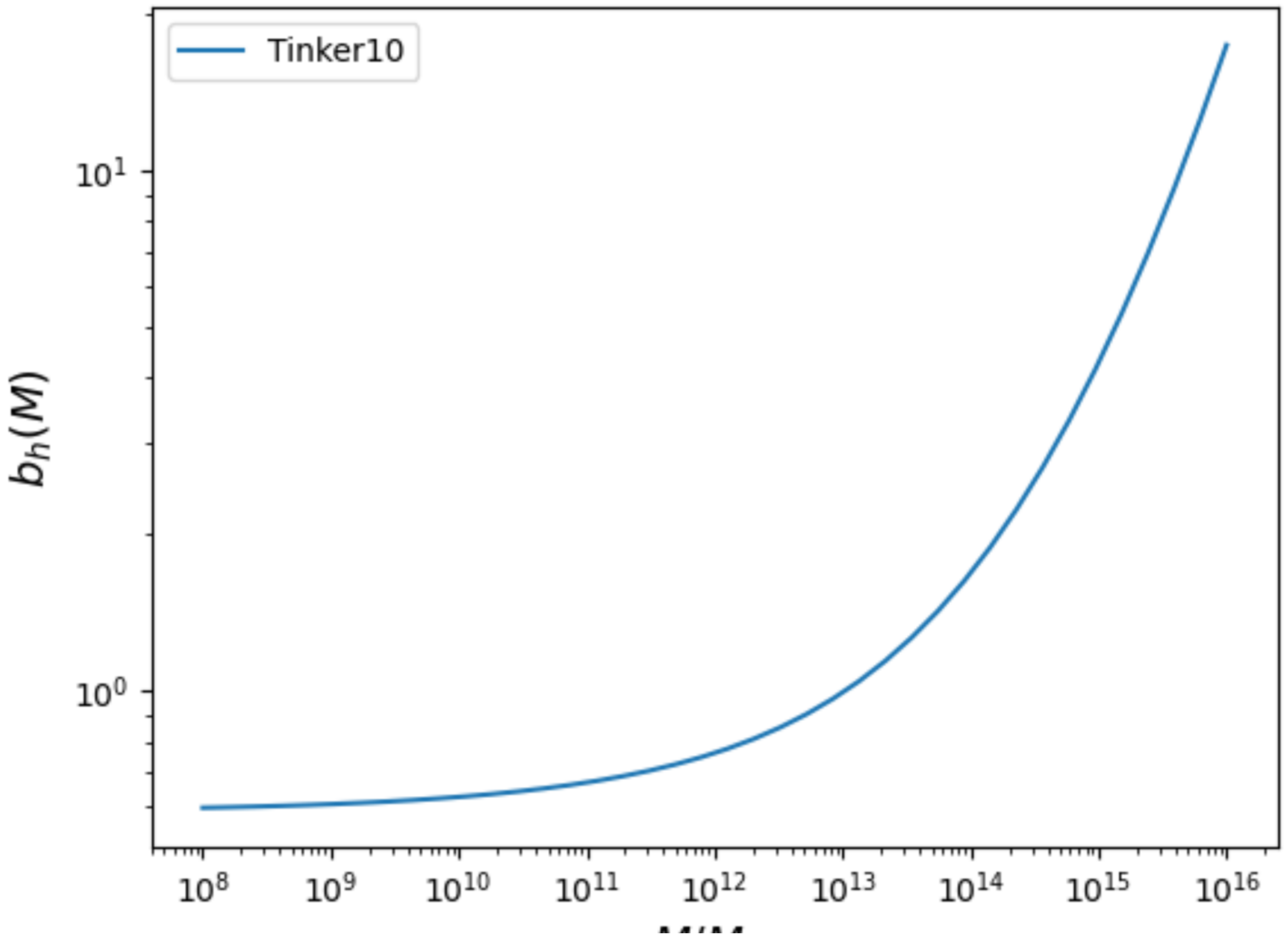
$$\frac{\mathrm{d}j_{v,\mathrm{c}}}{\mathrm{d}\log M_\mathrm{h}}(M_\mathrm{h}, z) = \frac{\mathrm{d}^2 N}{\mathrm{d}\log M_\mathrm{h} \mathrm{d}V} \times \chi^2 (1+z) \times \frac{\mathrm{SFR}_\mathrm{dc}}{K} \times S_v^\mathrm{eff}(z)$$

$$\frac{\mathrm{SFR}}{\mathrm{BAR}}(M_\mathrm{h}, z) = \eta = \eta_\mathrm{max} e^{-\frac{(\log M_\mathrm{h} - \log M_\mathrm{max})^2}{2\sigma^2_{M_\mathrm{h}}(z)}},$$

Shang, et al. 2012

$$j_\nu(z) = \int dM \frac{dN}{dM}(z) \frac{1}{4\pi} \left[N_{cen} L_{cen,(1+z)\nu}(M,z) + \int dm \frac{dn}{dm}(M,z) L_{sat,(1+z)\nu}(m) \right],$$

Fisher Matrix Method [Tinker, et al. 2012]



Star Forming Rate Model of CIB

$$\mathrm{SFR}(M,z) = \mathrm{SFR}_c(M,z) + \mathrm{SFR}_S(M,z).$$

$$\mathrm{SFR}_c(M,z) = \eta(M,z)\,\mathrm{BAR}(M,z)$$

$$\mathrm{BAR}(M,z) = \dot{M}_0 \frac{\Omega_b}{\Omega_M} \left(\frac{M}{10^{12} M_\odot} \right)^{1.1} (1 + 1.11z) \frac{H(z)}{H_0}$$

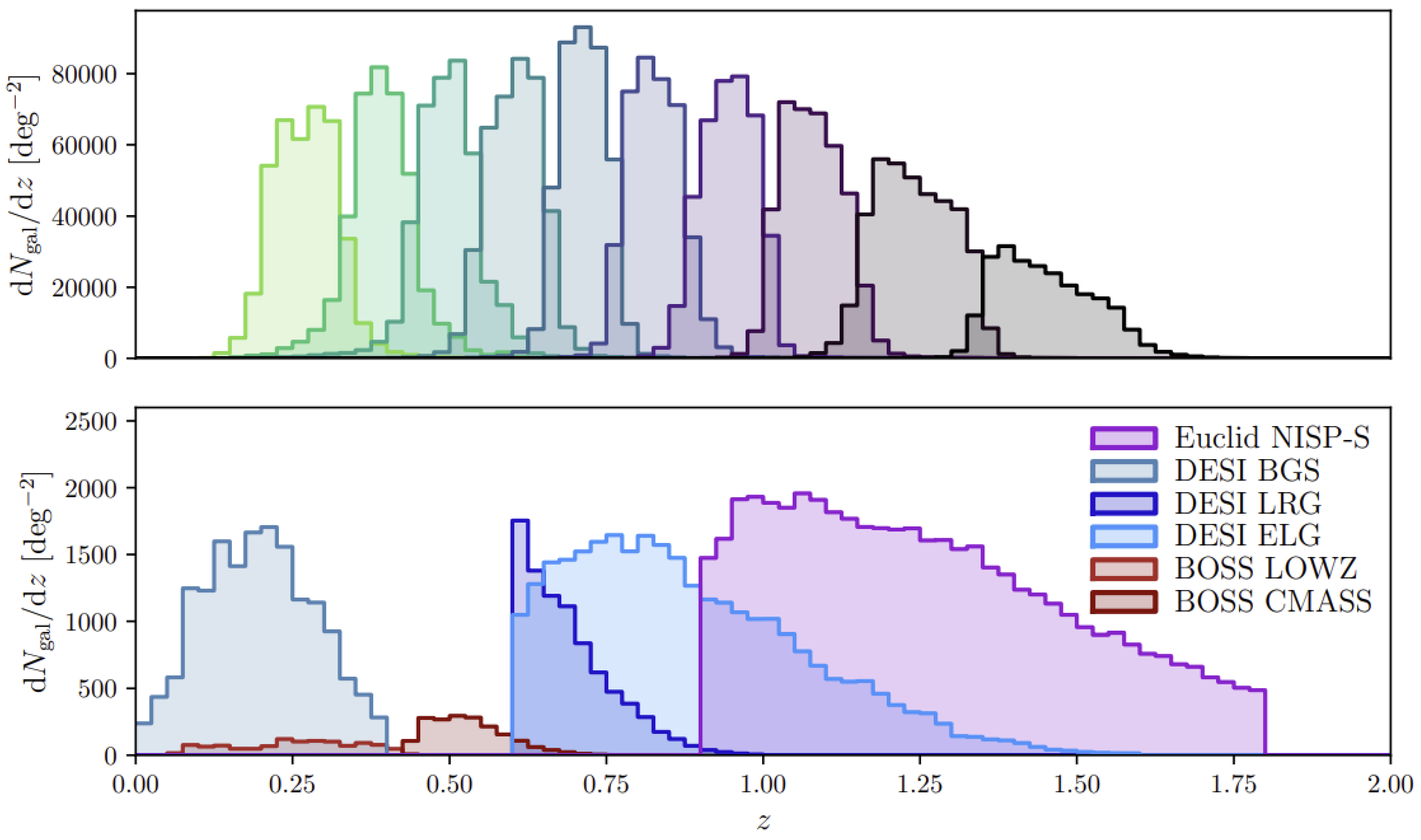
[Jego, et al. 2022

Star Forming Rate Model of CIB

$$\eta(M, z) = \frac{2\eta_*}{(M_1/M)^\beta + (M/M_1)^\gamma}$$

$$\eta(M, z) = \eta_{\max} \exp\left[-\frac{(\log M_{\max} - \log M)^2}{2\sigma_M^2(M, z)}\right]$$

$$\sigma_M(M, z) = \sigma_{M,0} - \tau\Theta(M - M_{\max}) \max(0, z_c - z)$$



80000
60000
40000
20000
0
$\mathrm{d}N_{\mathrm{gal}}/\mathrm{d}z$ [deg^{-2}]
2500
2000
1500
1000
500
0
$\mathrm{d}N_{\mathrm{gal}}/\mathrm{d}z$ [deg^{-2}]
Euclid NISP-S
DESI BGS
DESI LRG
DESI ELG
BOSS LOWZ
BOSS CMASS
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
z