PRIMA: « Cosmology » with diffuse Cosmic IR and line backgrounds

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Dusty off the secrets of the COSMOS with PRIMA
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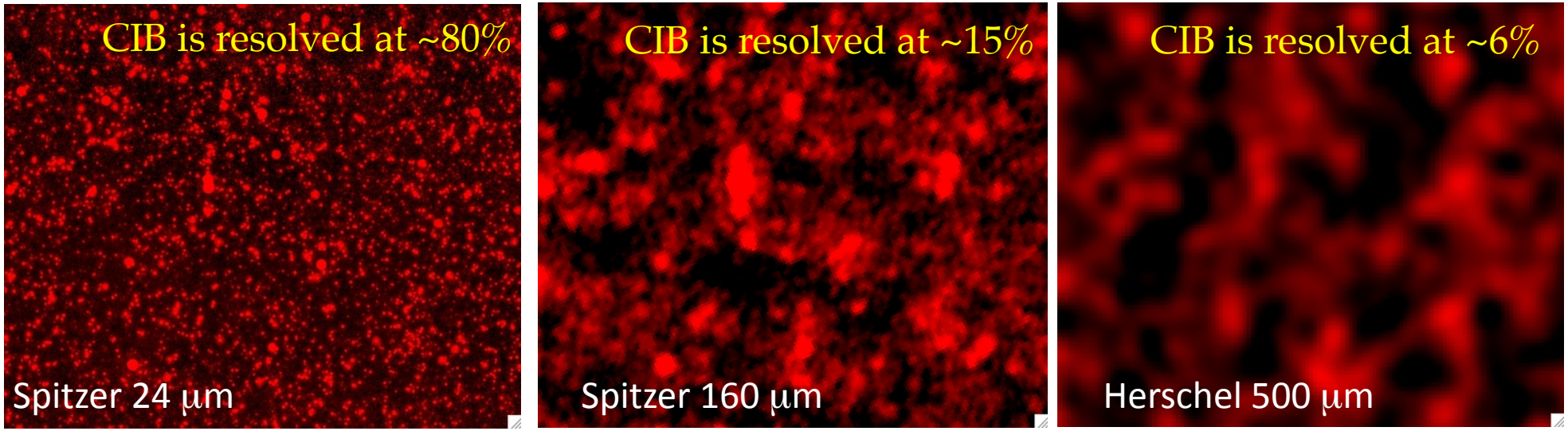
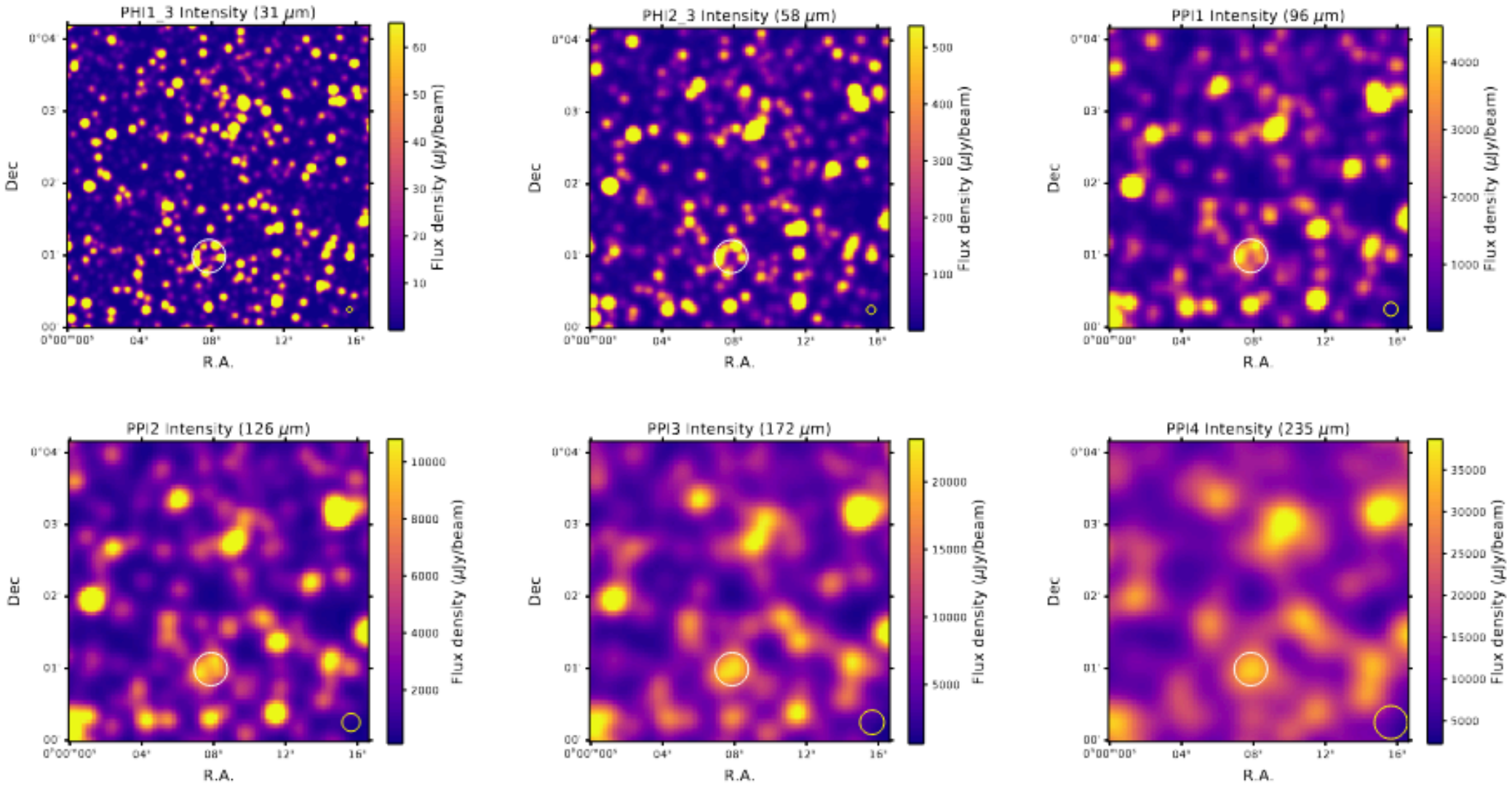
Extragalactic-source confusion: our « business »

In the far-IR and submm, galaxies are so faint and numerous, compared to the angular resolution achievable, that confusion plagues observations substantially.

CIB: Cumulative far-IR emission from all galaxies throughout cosmic history (all z)



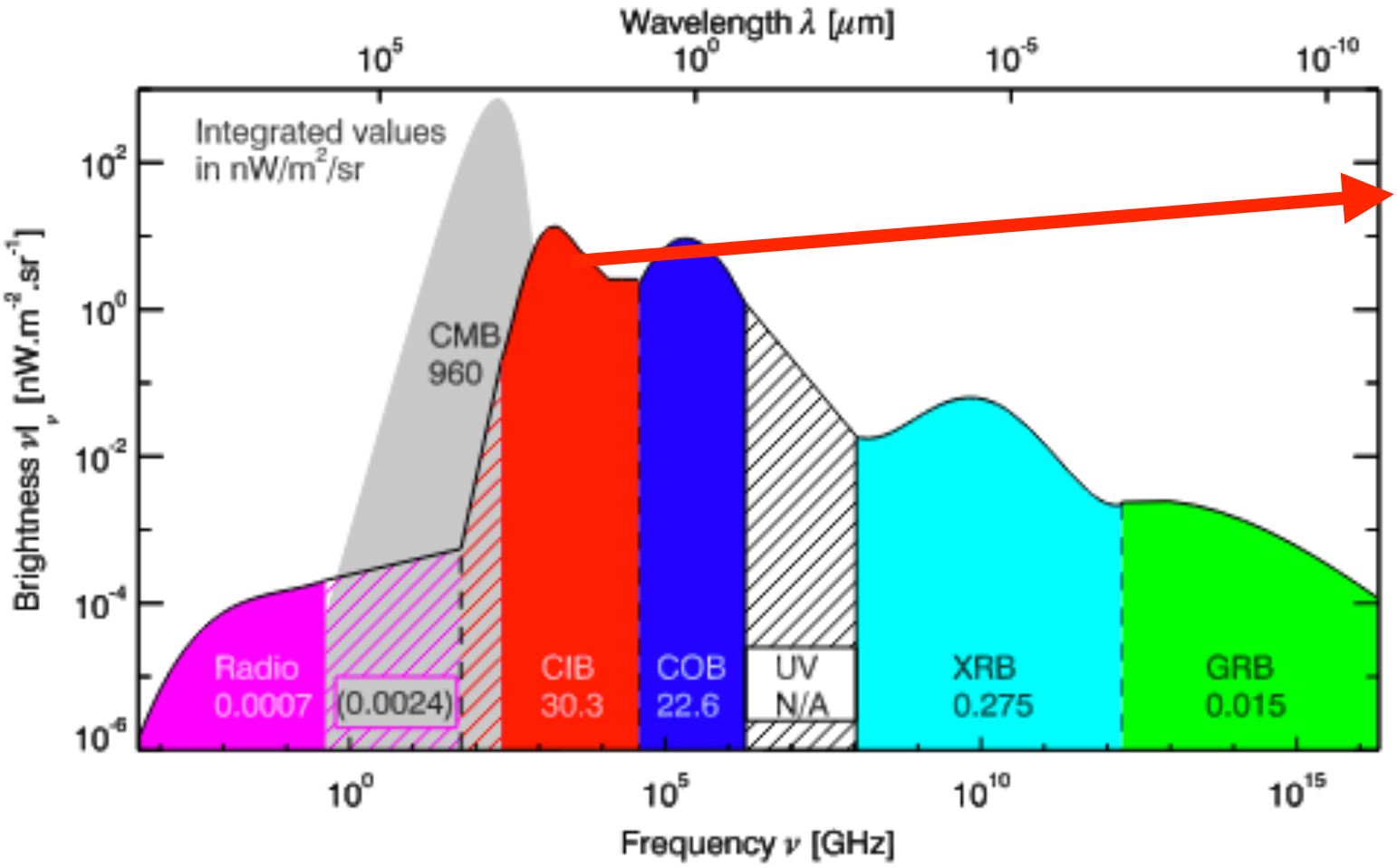
Extragalactic-source confusion: our « business »



Cutouts (18 arcmin^2) of simulated PRIMAger noiseless maps produced by SIDES

Bethermin+24

Extragalactic Background Light: Inventory of light throughout the cosmic history



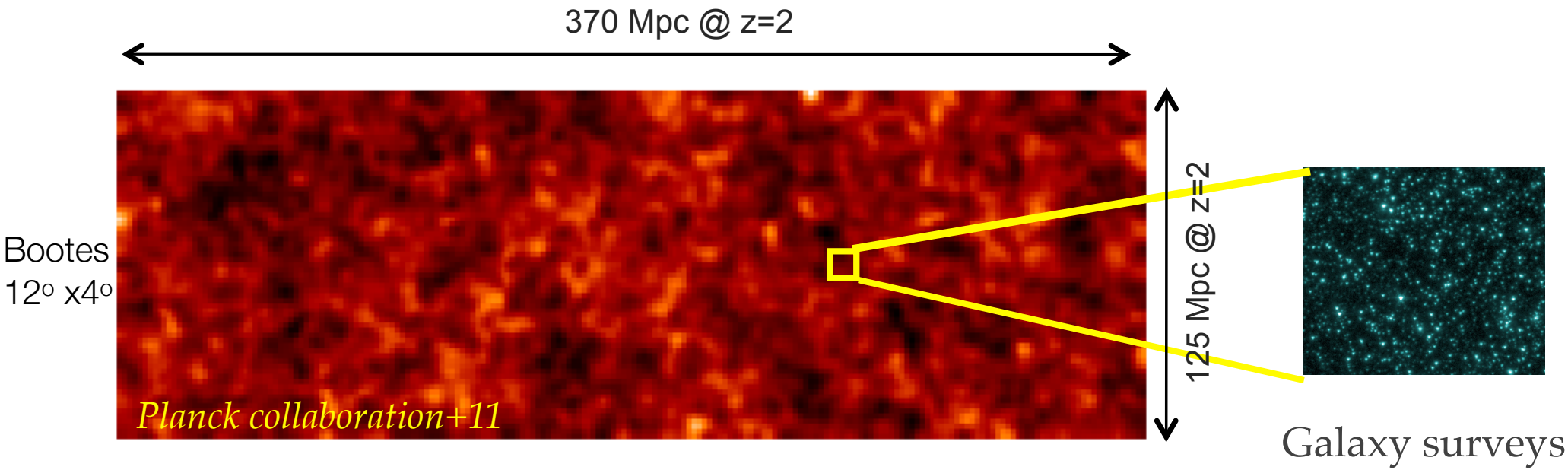
High level of obscured SFR density (Gispert+00 for the first « inversion » of CIB into SFRD)

No zero level => CIB anisotropies

Dole+06, Béthermin+11

CIB anisotropies: 2D intensity mapping

Intensity mapping: basic idea



Intensity mapping
(confusion-limited surveys)

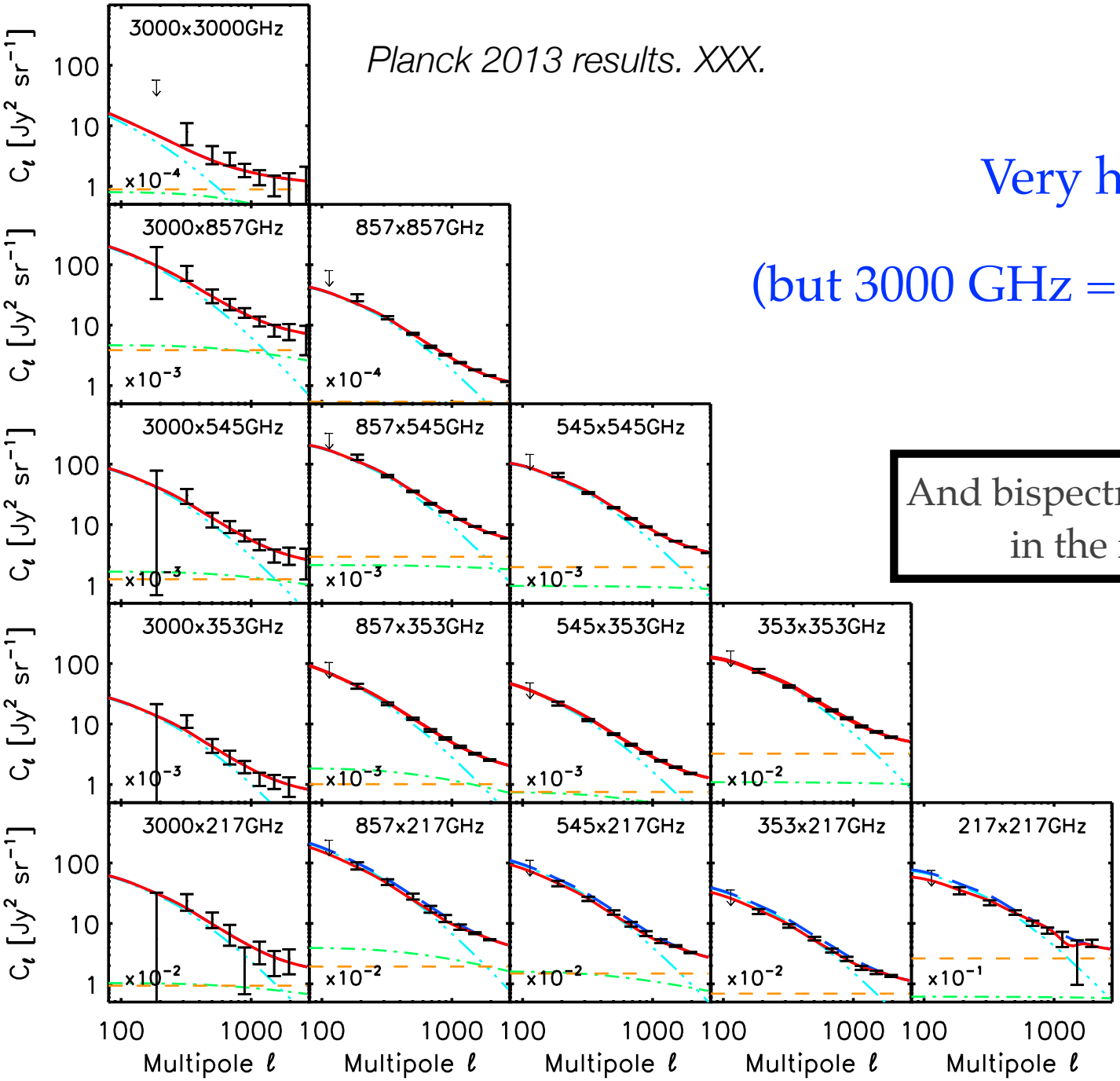
Intensity mapping:

- measure angular fluctuations in the brightness of the sky at a particular frequency

- naturally sensitive to the radiation from faint sources and from the diffuse intergalactic medium

- basic tool : angular power spectrum; intensity fluctuations are used to reconstruct the power spectrum of matter fluctuations

CIB anisotropies: power spectrum



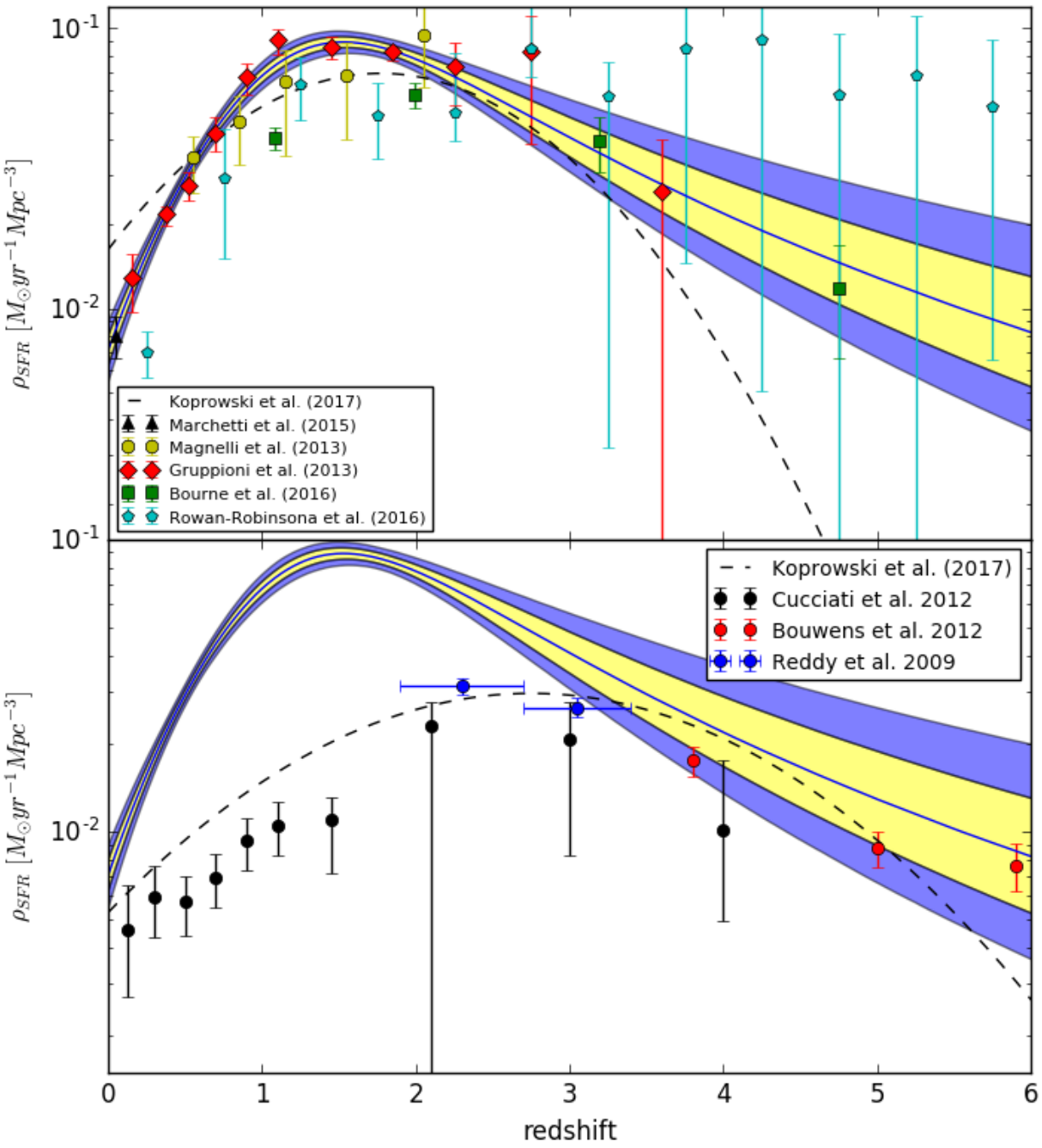
Planck 2013 results. XXX.

Very high SNR

(but 3000 GHz = 100 microns IRAS)

And bispectrum at 217, 353, 545 GHz in the range ell= 200–700

CIB anisotropies: obscured SFRD

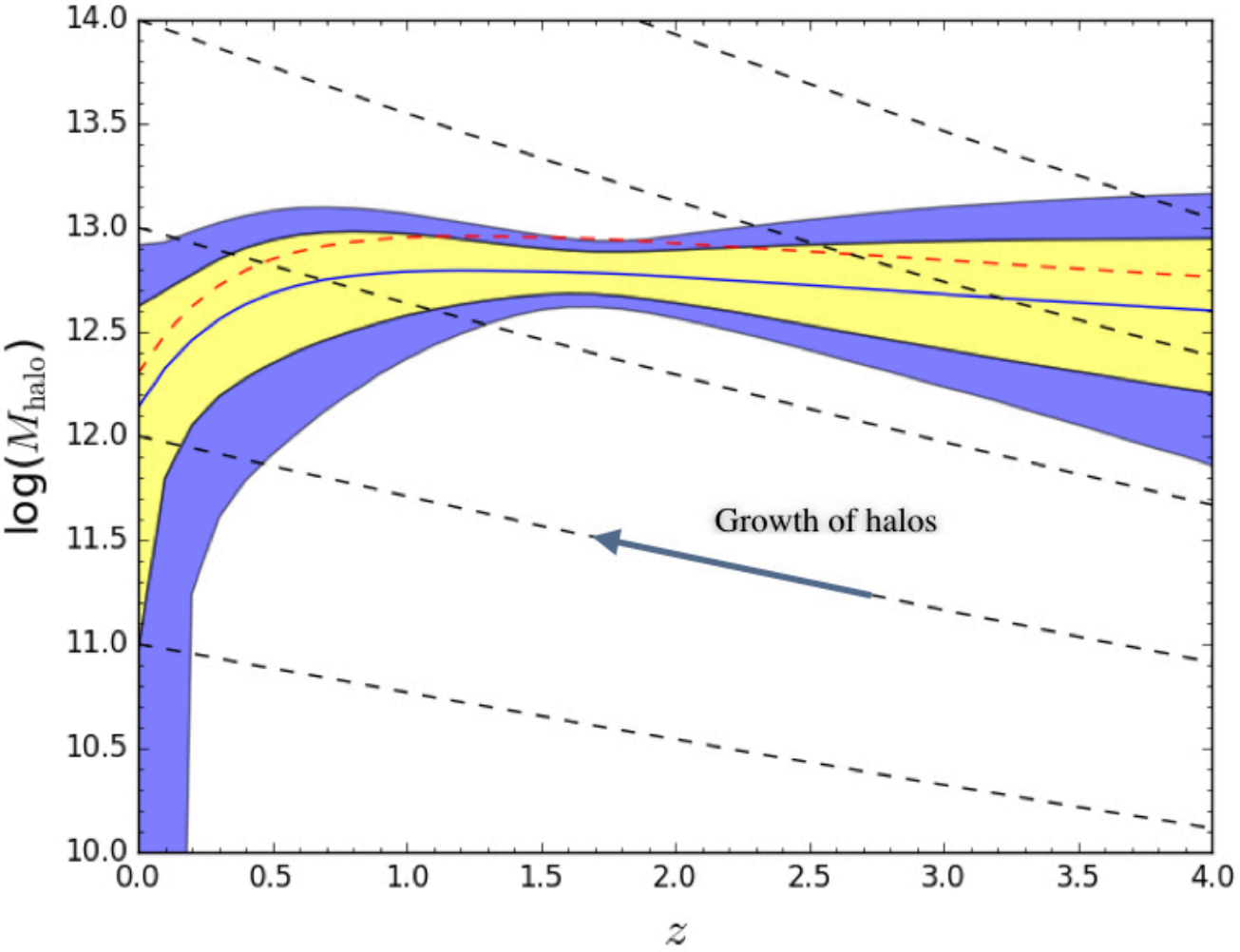


Need a model to link the dark-matter- CIB emissivities (linear clustering at large scale).

The model depends on the cosmology and halo-baryon connexion.

Maniyar+18

CIB from Planck: most efficient mass halo



Mass of the dark matter halos hosting the galaxies contributing to the CIB as a function of redshift

For z > 2.5

$M_h(z=0) > 10^{13.5} M_\odot$

Progenitors of clusters

For 0.3 < z < 2.5

$10^{12.5} < M_h(z=0) < 10^{13.5} M_\odot$

Groups

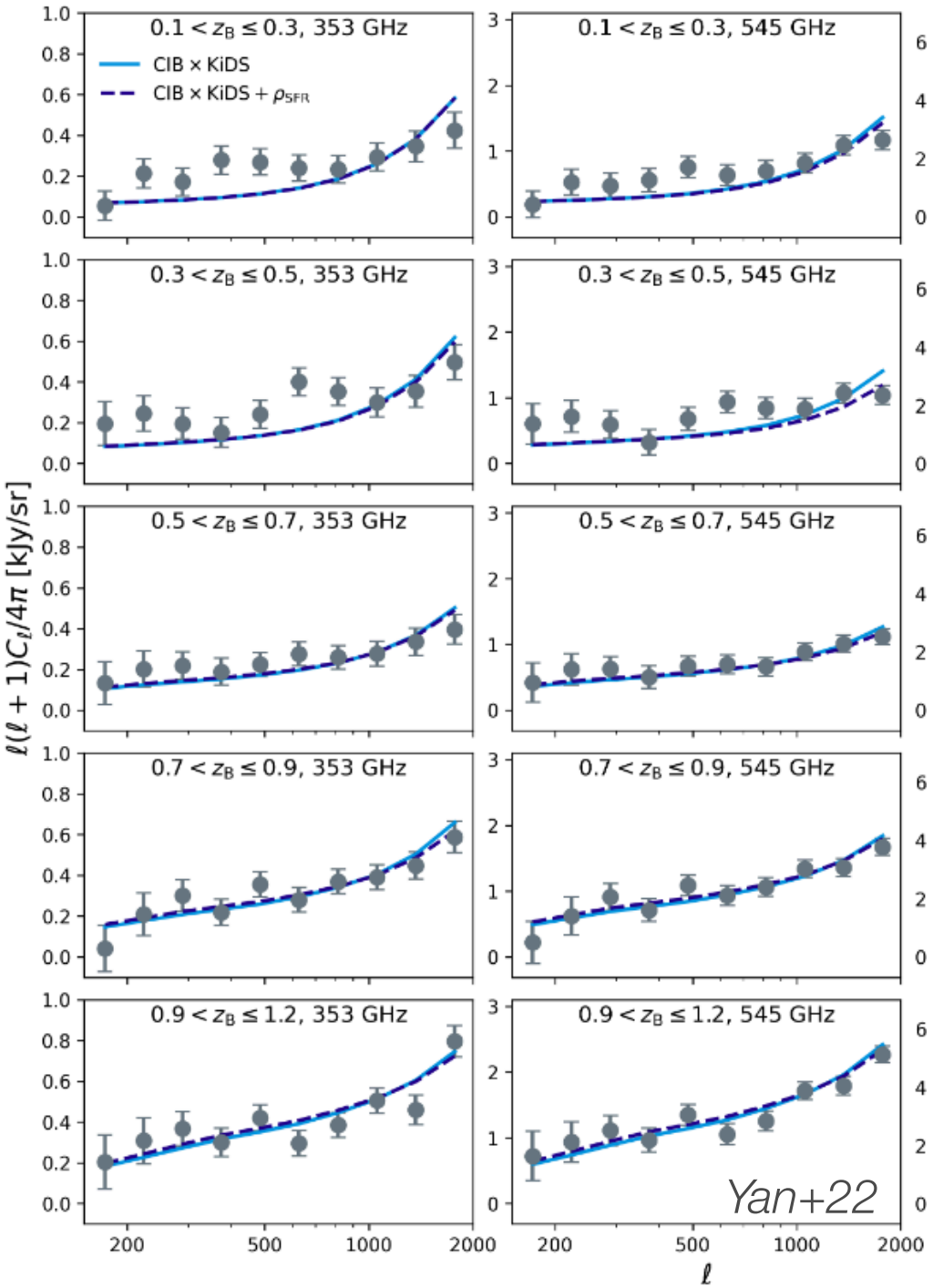
For z < 0.3

$10^{12} < M_h(z=0) < 10^{12.5} M_\odot$

Milky Way like halos

Maniyar+18

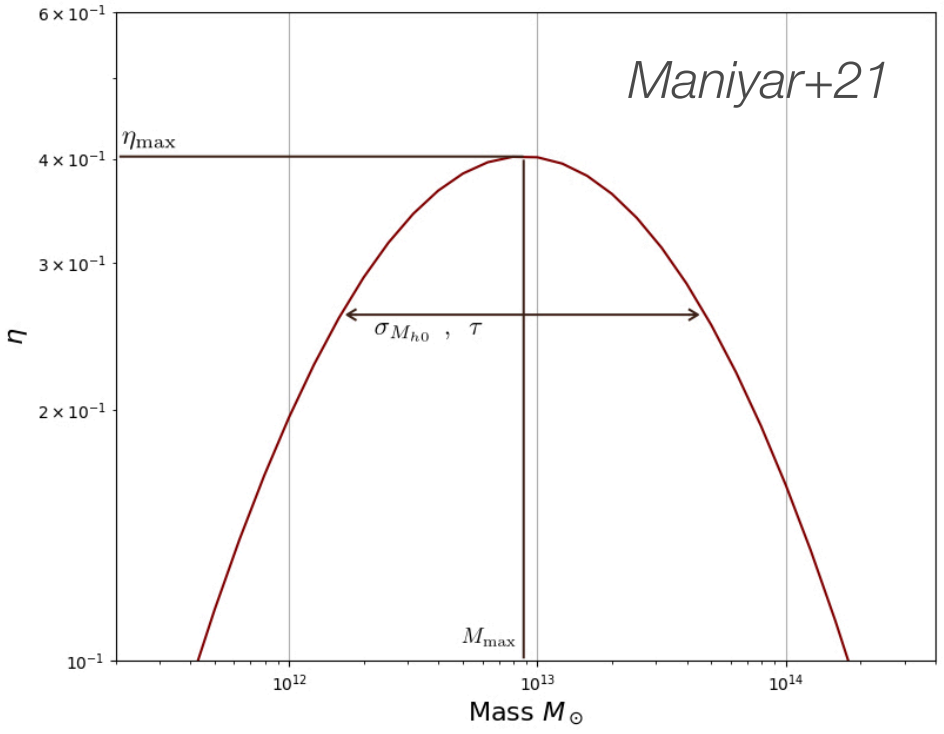
Tomographic cross-correlation between the CIB and galaxy samples



Cross-correlation between KiDS galaxies (30 millions) and CIB.

Significance of 43σ (even if only low redshift)

Maximum star formation efficiency of η_{max} = 0.41 (efficiency of converting the accreted baryons into stars)



CIB background and cross-correlations

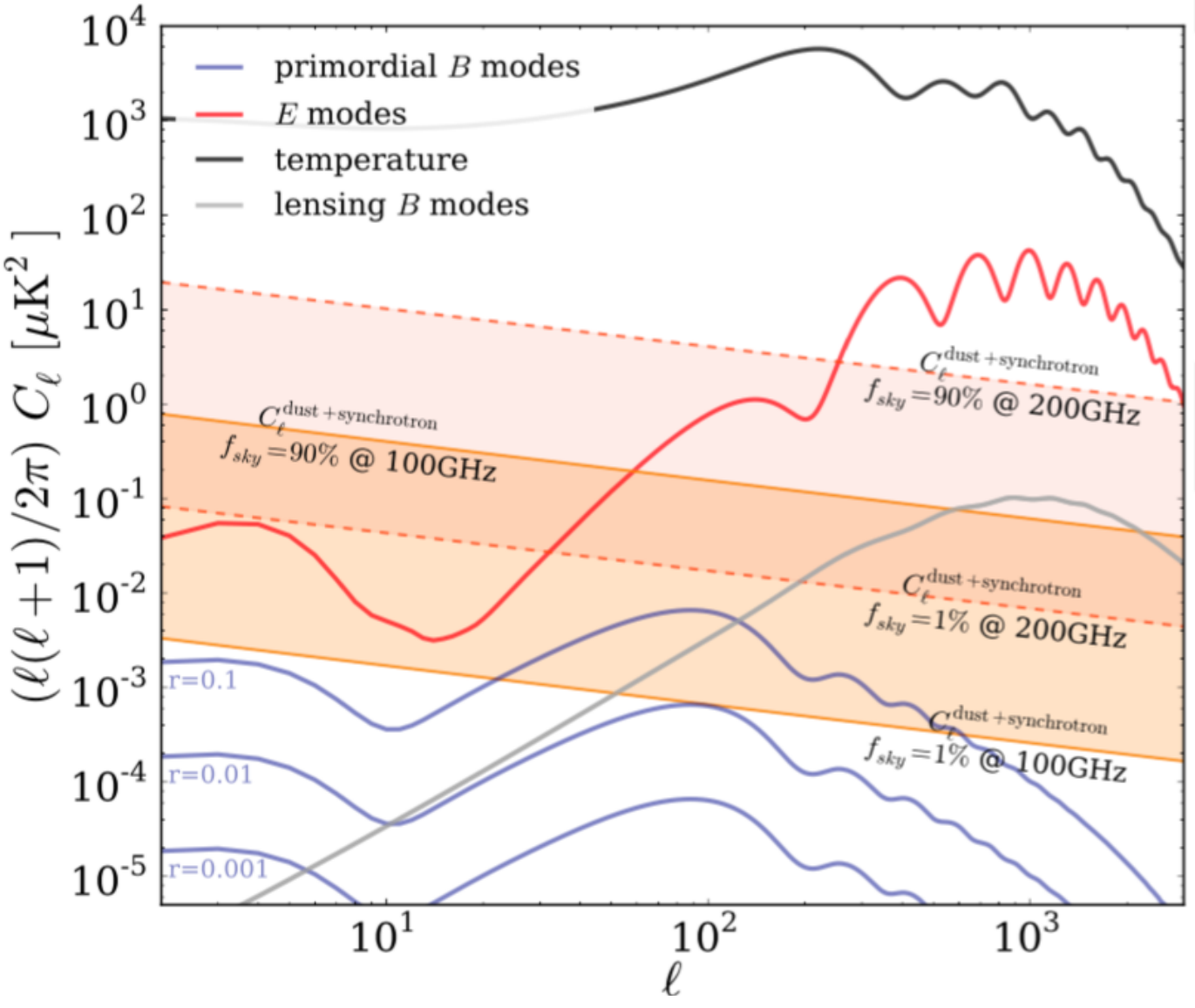
CIB is contaminated (foreground and background) and interpretation is model-dependent
=> cross-correlations

- Learn on the CIB, galaxy formation & evolution
  - CC with LRGs (z<1, Serra+14)
  - CC with SDSS QSOs at 0<z<5 (Schmidt+15)
  - CC with NIR Background (Thacker+14)
  - CC with MaxBCG galaxy clusters at 0.1 < z < 0.3 (Hincks+13)
  - CC with UnWiSE galaxies (Ziang+24)
  - CC with KiDS galaxies (Yan+22)
  - CC with tSZ (predicted Addison+12, measured Planck collaboration 2015 XXIX)
  - CC with cosmic shear (from Dark Energy Survey and Kilo-Degree Survey: Jego+23)

- Learn on Cosmology:
  - CC with CMB for dark energy, through ISW (Ilic+11, Maniyar+18)
  - CC with CMB Lensing for local non-Gaussianities in the initial conditions of the Universe, fNL (McCarthy+23)

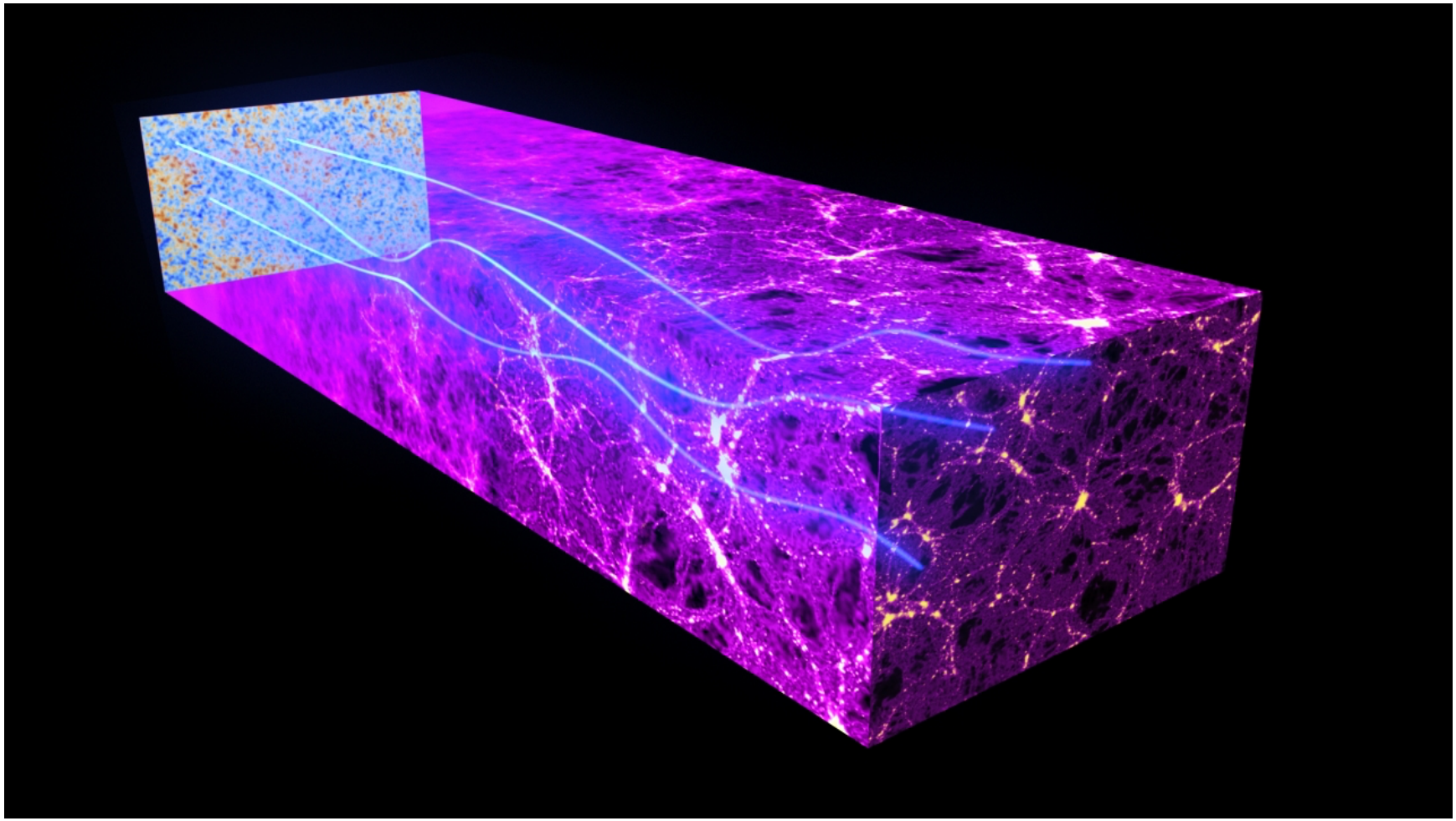
Quest for CMB B-modes

Inflation predicts the existence of a stochastic background of gravitational waves that then induce a specific “B-mode” pattern in the polarization of the CMB



Quest for CMB B-modes

Distribution of dark matter deflects CMB light that passes through!
Gravitational lensing converts E- to B- polarization



CIB in the CMB B-mode quest

- Use CIB Anisotropies as an integrated mass tracer
  - CC with the lensing map (Song+03, Holder+13, Planck collaboration XVIII 2013, Cao+20)
  - Delensing: Sherwin & Schmittfull 15, Simard+15; first detection of lensing B-mode: Hanson+13

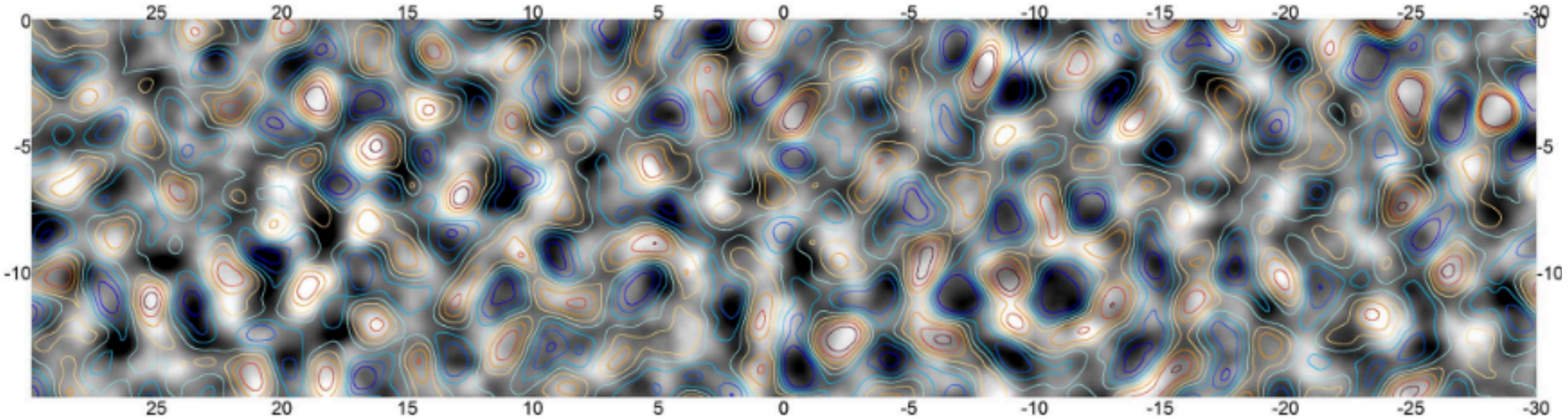
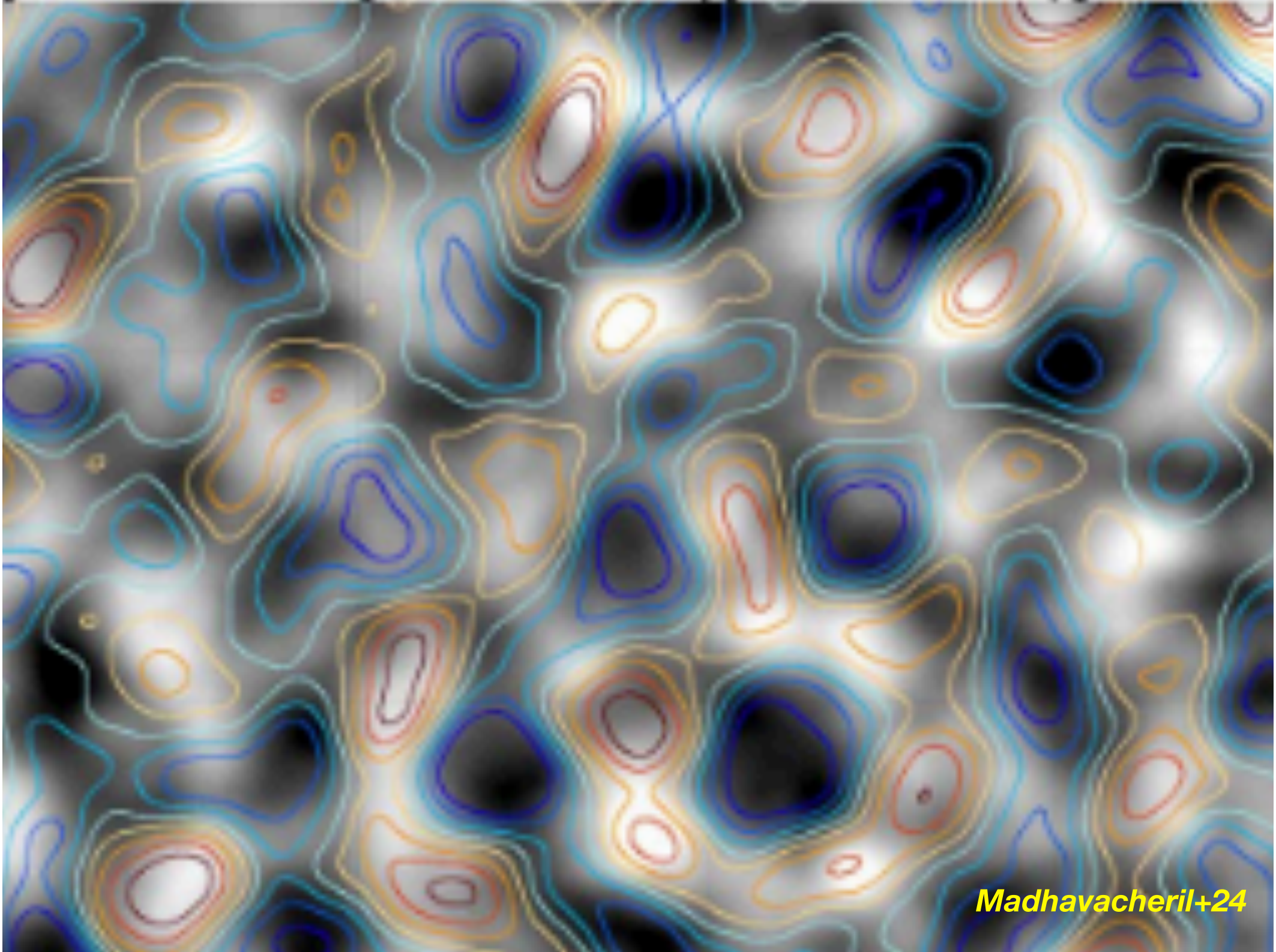


Figure 4. A zoom-in of a 900 deg^2 region of the ACT DR6 mass map shown as the Wiener-filtered gravitational potential (related to the convergence throug $\nabla^2\phi = -2\kappa$). The distribution of dusty galaxies constituting the CIB measured by Planck is overlaid as contours. The overdensities in red correspond well with th bright/white mass-dominated regions of the mass map, and the underdensities in blue correspond well with the darker mass-devoid regions.

Madhavacheril+24


Madhavacheril+24

PRIMA and CIB anisotropies

- PRIMA: short wavelength w.r.t. ground based CMB data experiments, Planck, and Herschel/SPIRE
  - Access to lower redshift ($z \lesssim 1$)
  - Ratio CIB/Galactic dust less favorable than at longer wavelengths
    - Constraining power of such analysis is limited by current Galactic dust cleaning techniques => will be even more critical fro PRIMA

- Compared to Herschel/SPIRE surveys:
  - new and larger area with a high overlap with current very large surveys (DESI/ACT/SPT-3G/SO)

=> An « all-sky » survey at ~confusion with PPI mandatory

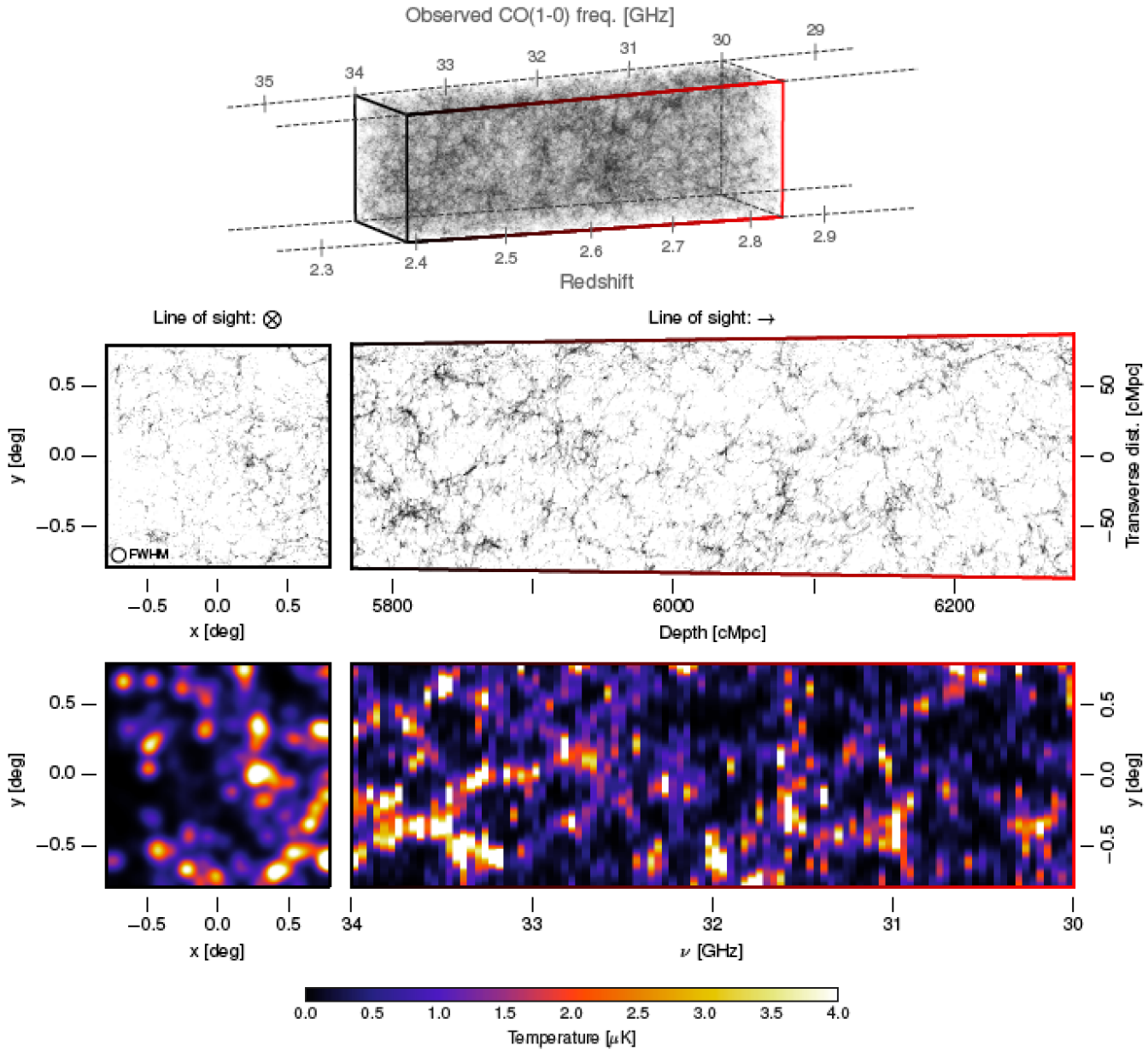
Wright+23, all sky, 5000 hours

Burgarella+25, πIR, 2000 hours

CIB anisotropies are a very good LSS tracer but redshift distribution not so well-known

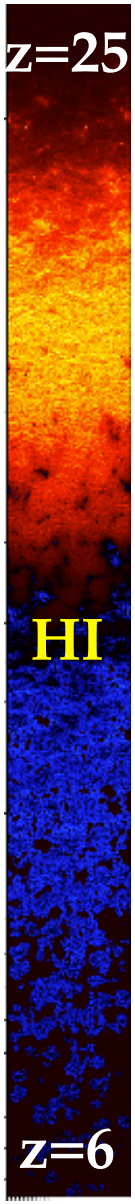
Line (3D) intensity mapping

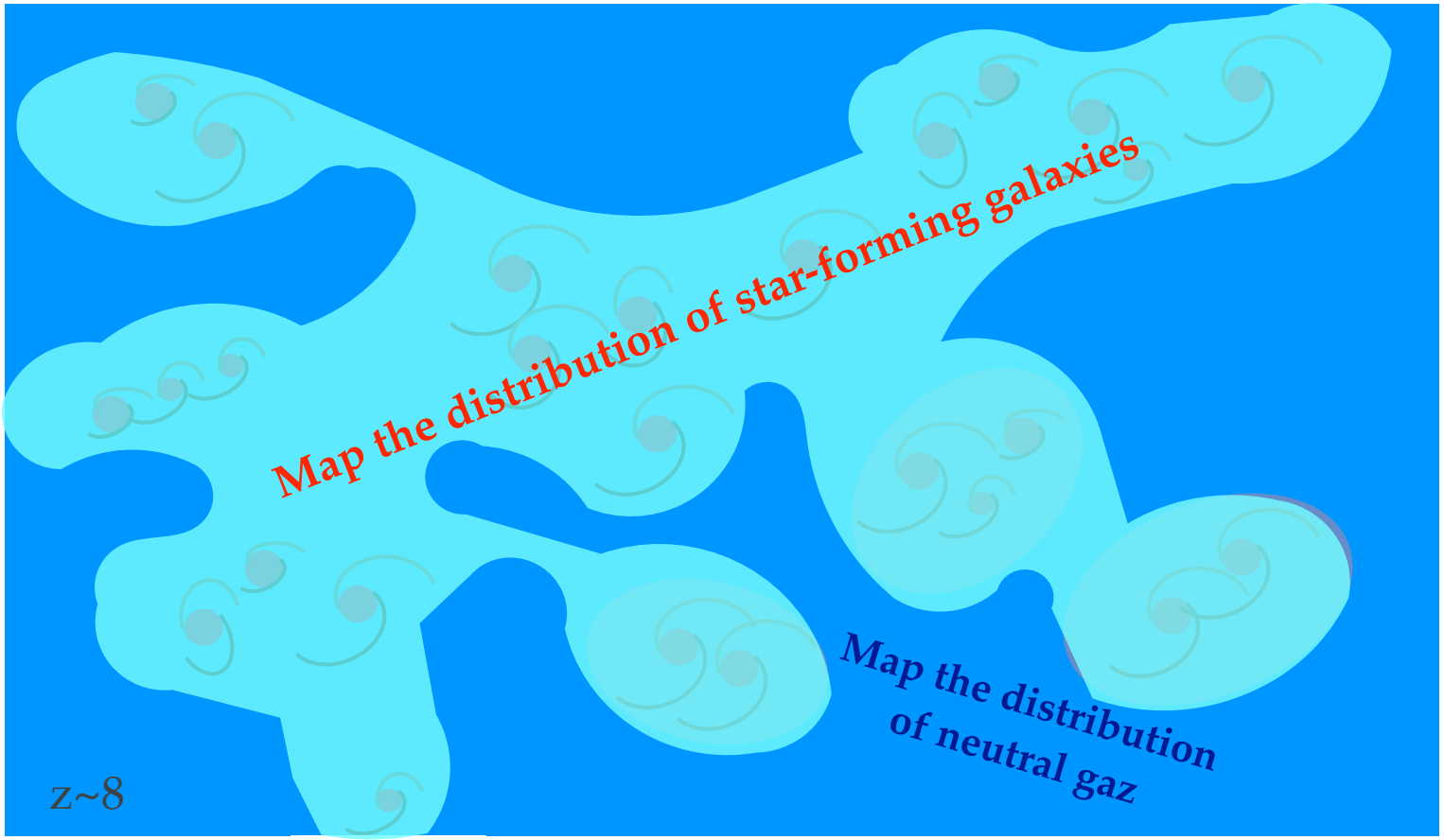
Line intensity mapping

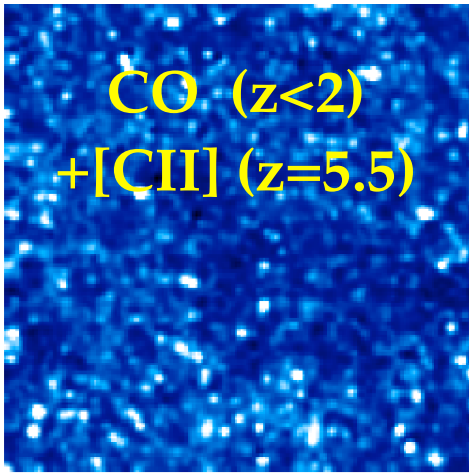


Li+15

Line Intensity mapping







HI: Cosmic Dawn + Reionization + BAOs

CO: Galaxy evolution (z~2-3) + BAOs

[CII]: Reionization + galaxy evolution

Hα : Galaxy evolution + BAOs

Lyα: Reionization + IGM + galaxy evolution

PRIMA and LIM

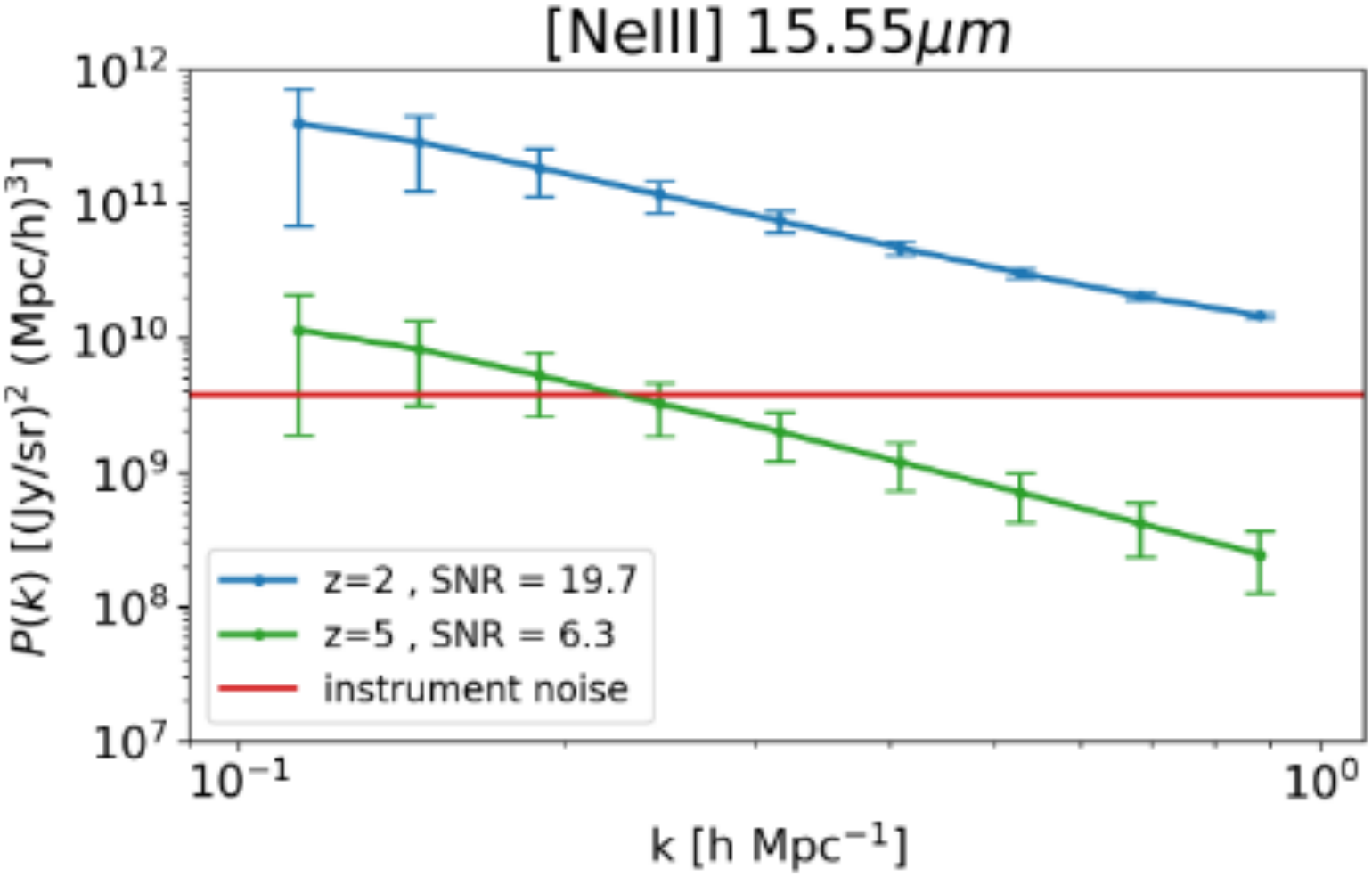
Lines and redshift range (from rest-frame 29-230 microns):

[NeII] 12.81 μm	[NeIII] 15.55 μm	H2 17.03 μm	[SIII] 18.71 μm	[OIV] 25.89 μm	[SIII] 33.48 μm	[SiII] 34.82 μm	[OIII] 51.81 μm	[OI] 63.18 μm	[OIII] 88.36 μm
1.3-17	0.9-14	0.7-13	0.6-11	0.1-8	0-6	0-6	0-3.4	0-2.6	0-1.6

Spectral resolution for LIM: R~100 (at least)

=> FIRESS

PRIMA and LIM



From Yun-Ting Chen (PRIMA GO science Book 2023)
1000 arcmin^2 survey with 1000 hours of total integration time

PRIMA and LIM

Table 1: Power spectrum SNR shown in Fig 2. Cases with SNR > 5 are highlighted in red.

line name/z	z=1	z=2	z=3	z=4	z=5	z=6
[NeII] 12.81 μm	7.9	4.0	1.0	0.3	0.1	0.1
[NeIII] 15.55 μm	10.0	19.7	15.3	6.9	6.4	2.8
H2 17.03 μm	9.8	15.3	7.7	6.4	2.5	1.0
[SIII] 18.71 μm	6.9	2.7	0.6	0.5	0.1	0.1
[OIV] 25.89 μm	6.5	2.3	1.5	0.4	0.3	0.1
[SIII] 33.48 μm	8.9	12.0	4.9	3.6	1.1	0.4
[SiII] 34.82 μm	9.8	19.5	22.9	12.2	5.0	1.9
[OIII] 51.81 μm	5.5	3.5	0.7	—	—	—
[OI] 63.18 μm	19.8	18.1	—	—	—	—
[OIII] 88.36 μm	9.9	—	—	—	—	—

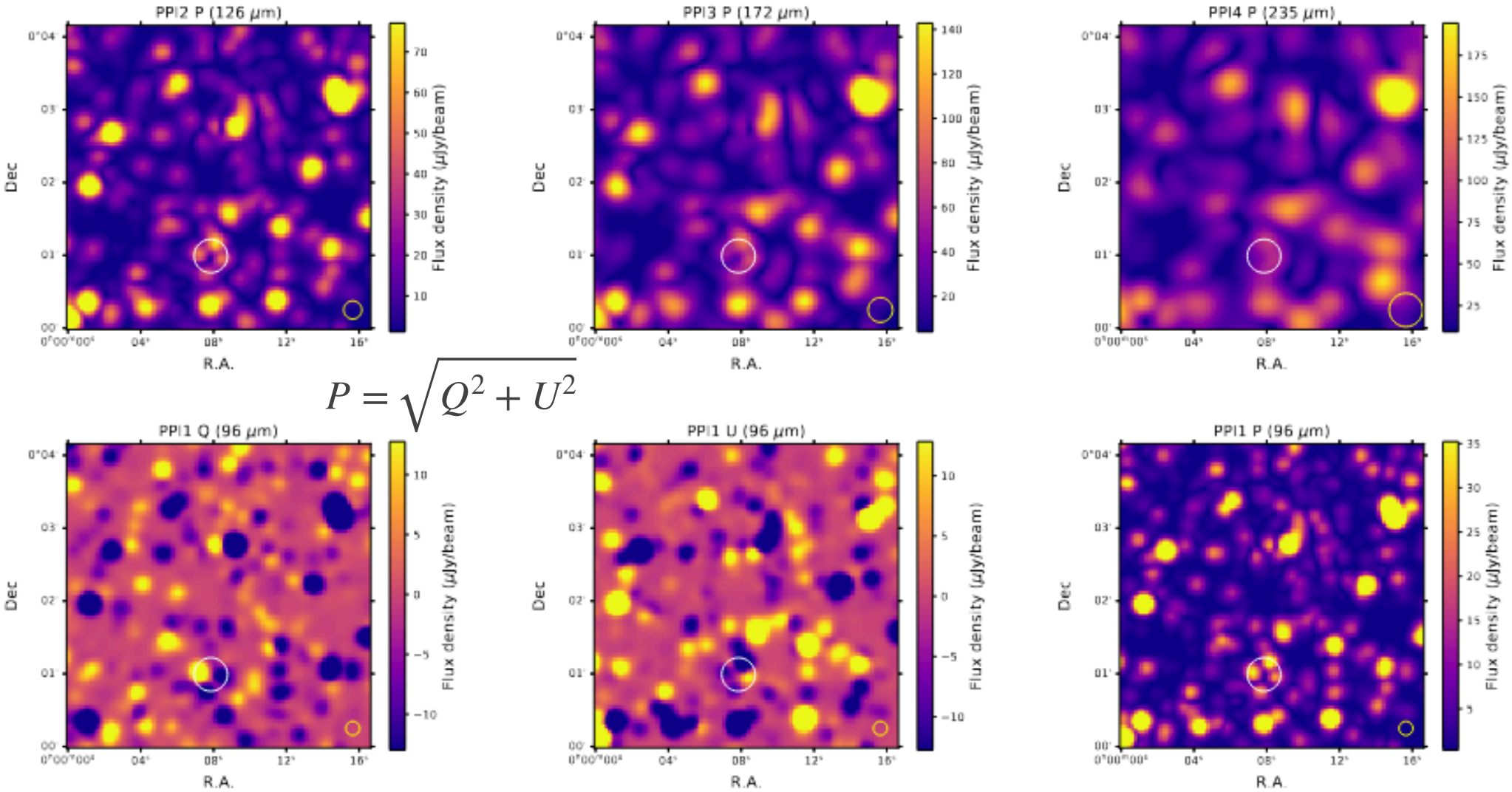
SNR at large scales: 0.1 ~1 h/Mpc

(Not taking into account continuum emission contamination, line confusion)

From Yun-Ting Chen (PRIMA GO science Book 2023)
1000 arcmin^2 survey with 1000 hours of total integration time

Polarised CIB anisotropies

Extragalactic-source confusion: our « business »



$$P = \sqrt{Q^2 + U^2}$$

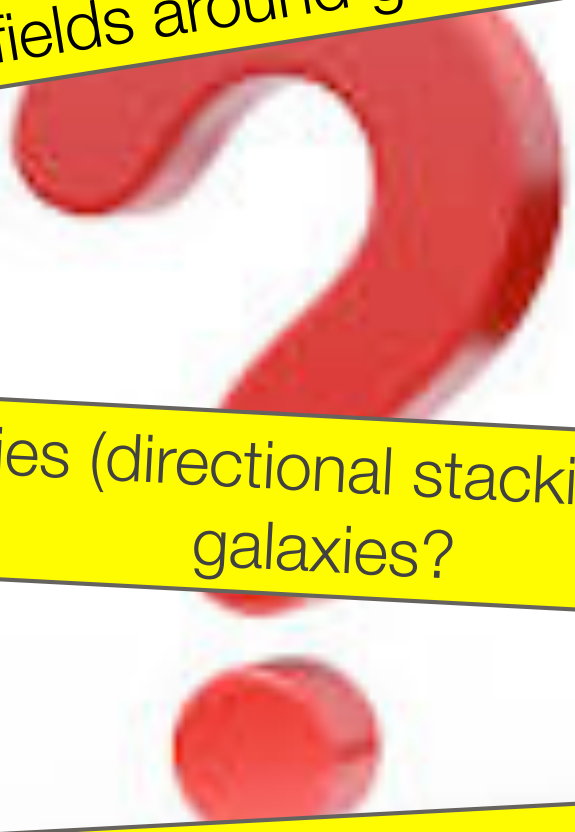
Cutouts (18 arcmin²) of simulated PRIMAger noiseless maps produced by SIDES

Bethermin+24

PRIMA and Polarised CIB anisotropies

PRIMA and Polarised CIB anisotropies

Polarisation directions of individual galaxies could be aligned with tidal fields around galaxies?



Cross-correl with galaxies (directional stacking): polarisation degree of galaxies?

Background for Galactic polarisation and foreground for CMB B-modes

CMB B-mode contamination by polarised Xgalactic sources

- In addition to instrumental challenges, future experiments targeting r ~ 10^{-3} will have to solve the critical problem of component separation.

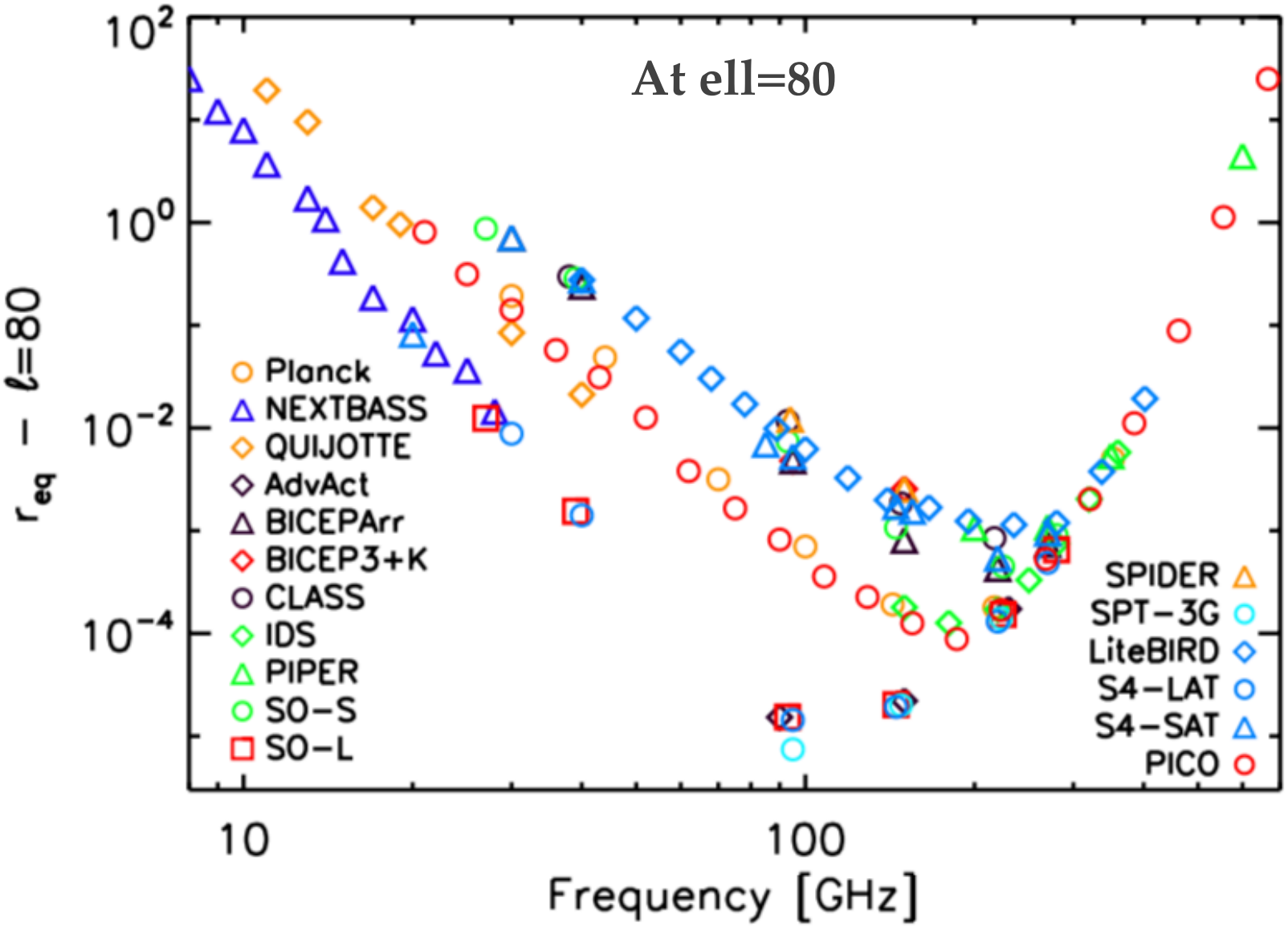
- A lot of effort: lensing + polarised Galactic foregrounds

- Investigate the polarisation fluctuations caused by extragalactic contaminants: radio galaxies and dusty star-forming galaxies
  - $\langle \Pi IR \rangle$ = 1.4% for DSFGs
  - $\langle \Pi rad \rangle$ = 2.8% for radio

- Ignore the intrinsic alignments between the integrated polarization angles of galaxies

=> Polarised extragalactic foregrounds cannot be ignored even at the large scale (ell<150) where the primordial B-modes are the brightest

CMB B-mode contamination by polarised Xgalactic sources



Lagache+20

CONCLUSIONS

- **CIB anisotropies (2D intensity mapping)**
  - Dark-matter halos / baryons connexion
  - Tracer of LSS
  - Foreground/Background
  - *PRIMAGER: An « all-sky » survey (at confusion)*
- **LIM (3D intensity mapping)**
  - Trace star formation activities, black hole growth, the dust and metallicity content (e.g., ionized oxygen and silicon) up to z~3
  - *FIRESS: at least 1000 arcmin^2 survey with 1000 hours*
- **Polarised CIB anisotropies (2D intensity mapping)**
  - Space of discoveries!
  - *PRIMAGER: An « all-sky » survey (inst. noise dominated)*