Cosmic star formation history from galaxy-CIB cross-correlation

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Cosmic star formation history

- Physics:

  - galaxy formation, matter content of the Universe, accretion, feedback,...

- What do we know?

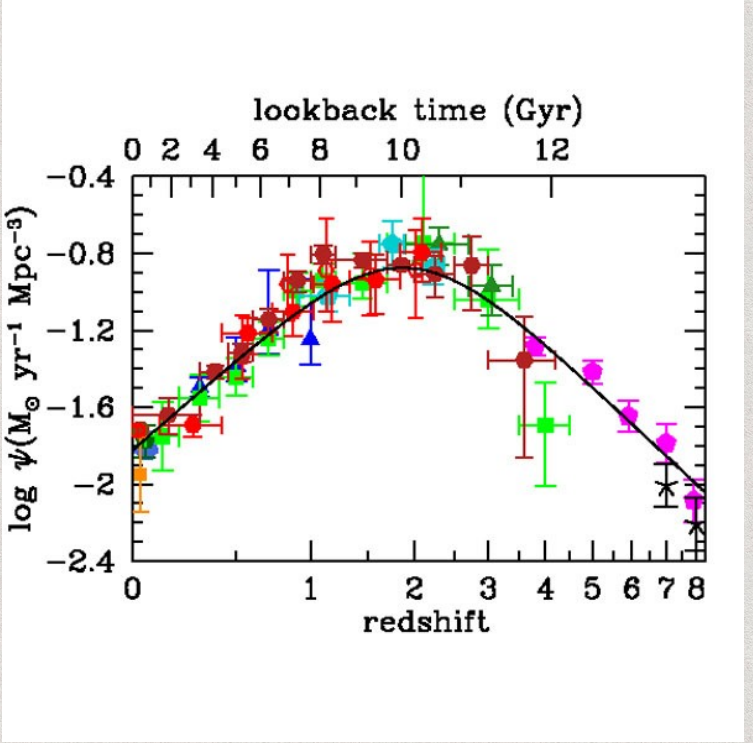
  Started at z~6-20, peaked at z~2 then decreased until now.

- Typical method to study:

  to measure the flux of galaxies, and link their luminosity to stellar population and star formation rate by assuming luminosity function, initial mass function (IMF), accretion model, etc.

- Potential problem:

  selection bias? Incompleteness?



Cosmic star formation history from different probes (Madau & Dickinson 2014)

Cosmic Infrared Background

- What is CIB?

  the cumulative infrared emission from all galaxies throughout cosmic history

- What generates CIB?

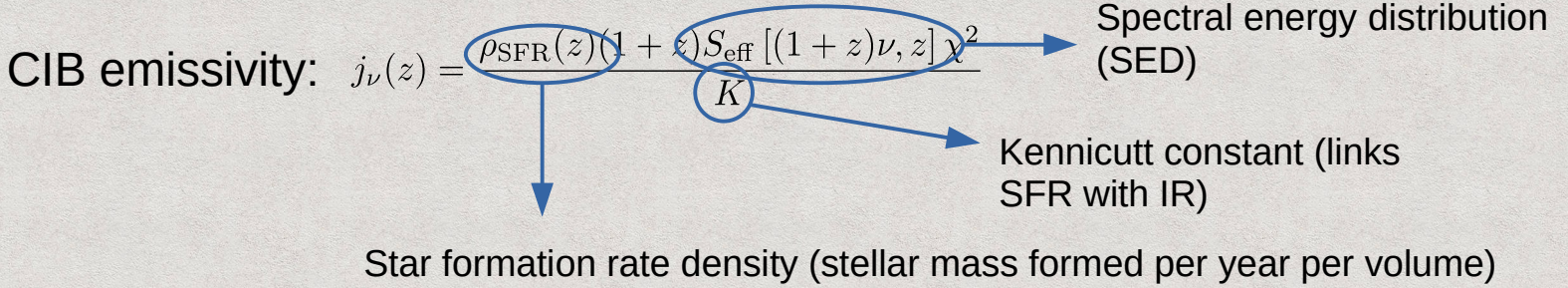
  CIB is mainly generated by thermal dust emission from star-forming galaxy

- What can we learn from CIB?

  Dust properties, star forming history, galaxy distribution...

CIB Model: Maniyar et al. 2020

CIB emissivity: $$j_\nu(z) = \frac{\rho_{\rm SFR}(z)(1+z)S_{\rm eff}\left[(1+z)\nu, z\right]\chi^2}{K}$$

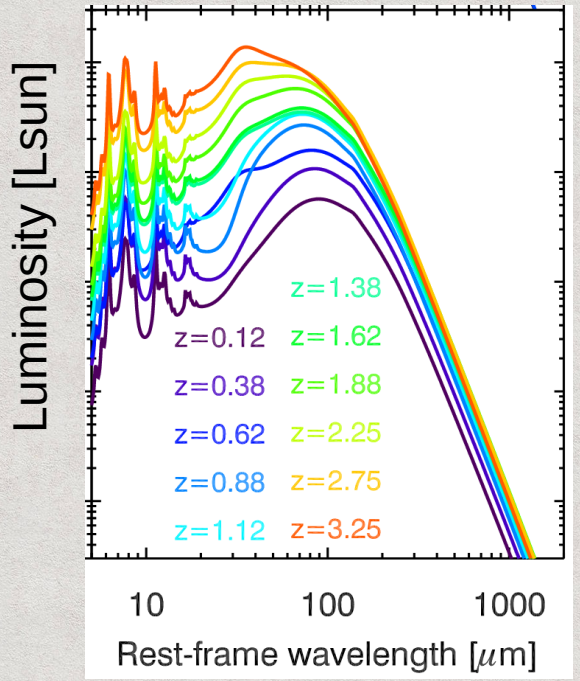


Star formation rate: $$\rho_{\rm SFR}(z) = \int {\rm d}M n(M)\,{\rm SFR}(M,z)$$

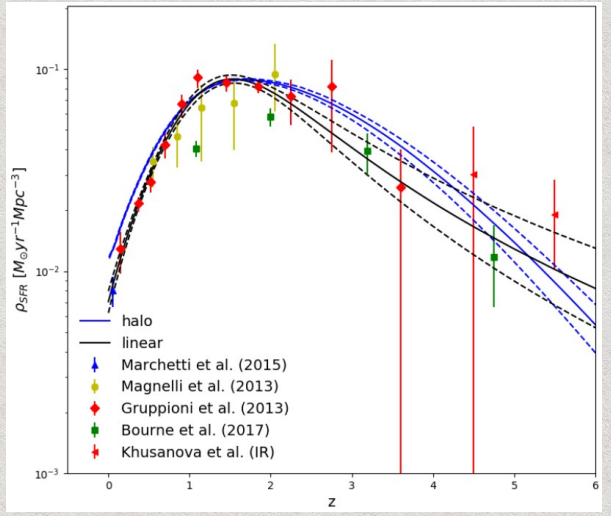
$$\mathrm{SFR} \propto \exp\left[-\frac{(\ln M - \ln M_{\rm peak})^2}{2\sigma_M(z)^2}\right]$$

CIB anisotropies model ingredients

- Spectral energy distribution
- Star formation rate
- Star-forming galaxy abundance



The spectrum of the mean CIB (Bethermin et al. 2015)



Star-forming rate history from CIB power spectra (Planck XXX)

Motivation of CIB-galaxy cross-correlation

- Existing CIB CC works:

  - CIB power spectra (Planck2013 XXX);

  - CIB x CMB lensing (Cao et al. 2020);

  - CIB x tSZ (Planck2015 XXIII)

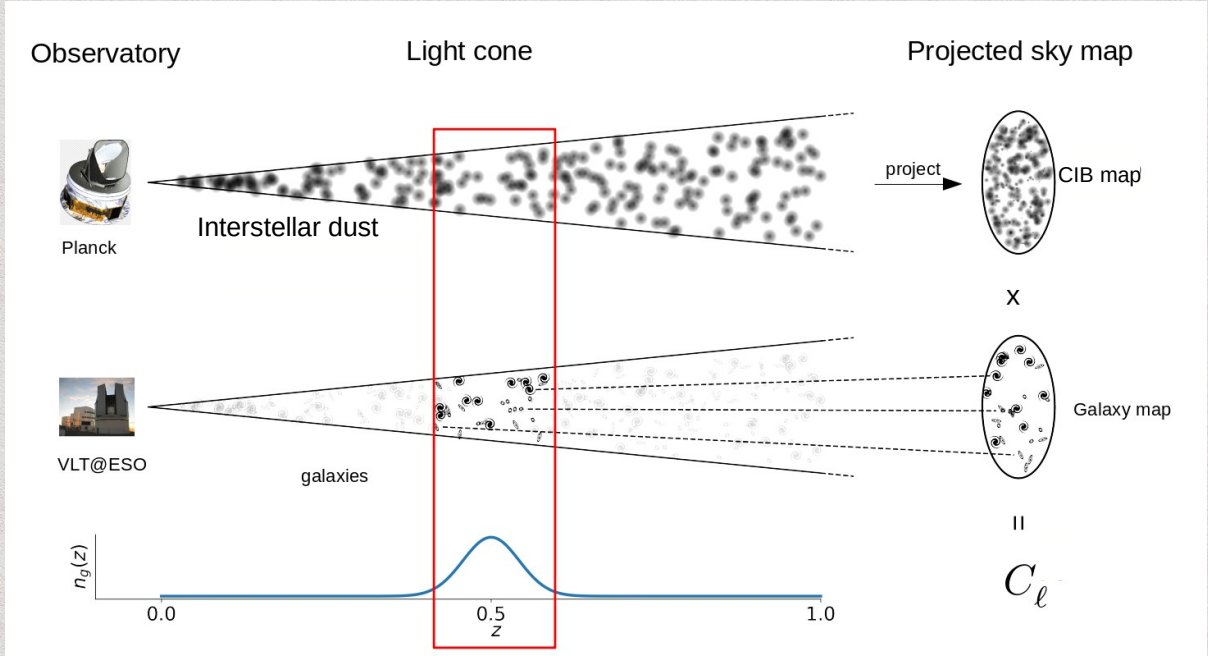
- Advantages of CIB x galaxy:

  - galaxy position is relatively easier to measure

  - higher S/N

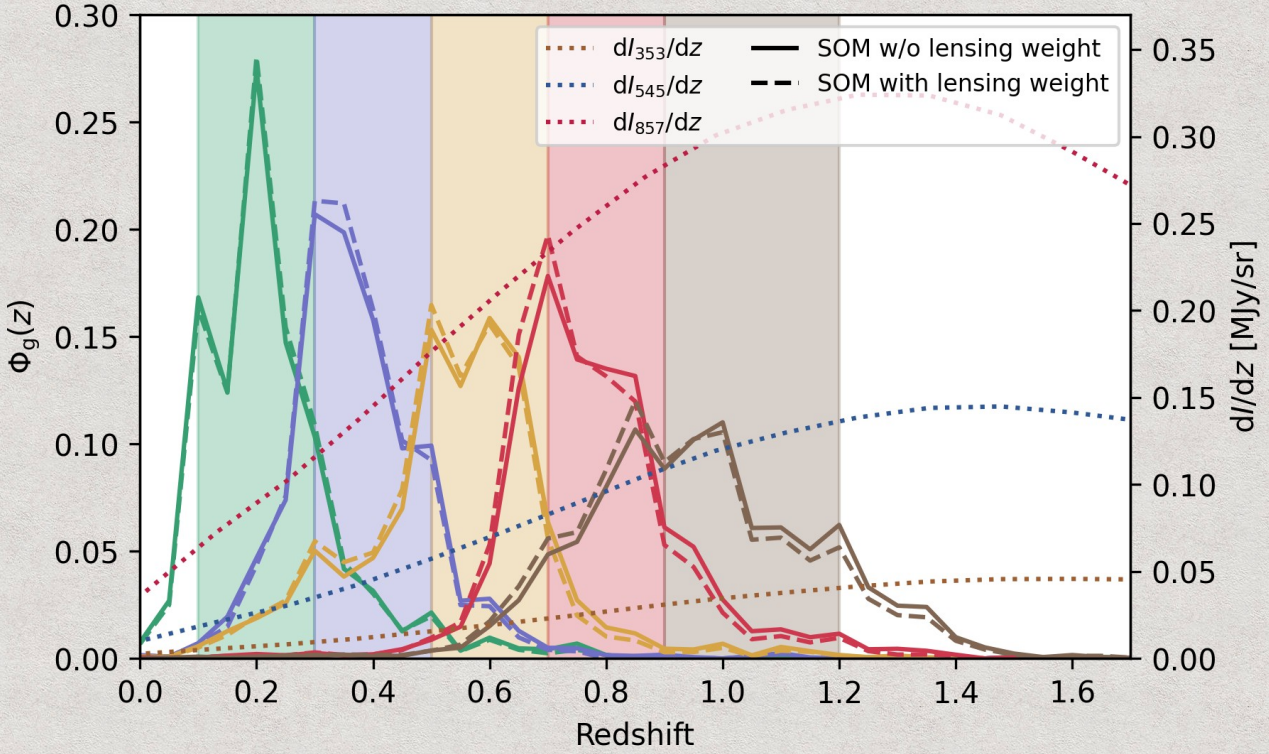
  - tracing SFR history better (through tomographic CC)

  - obtaining CC for different types of galaxies



Galaxy data

- Galaxy sample: KiDS gold sample (positions only)



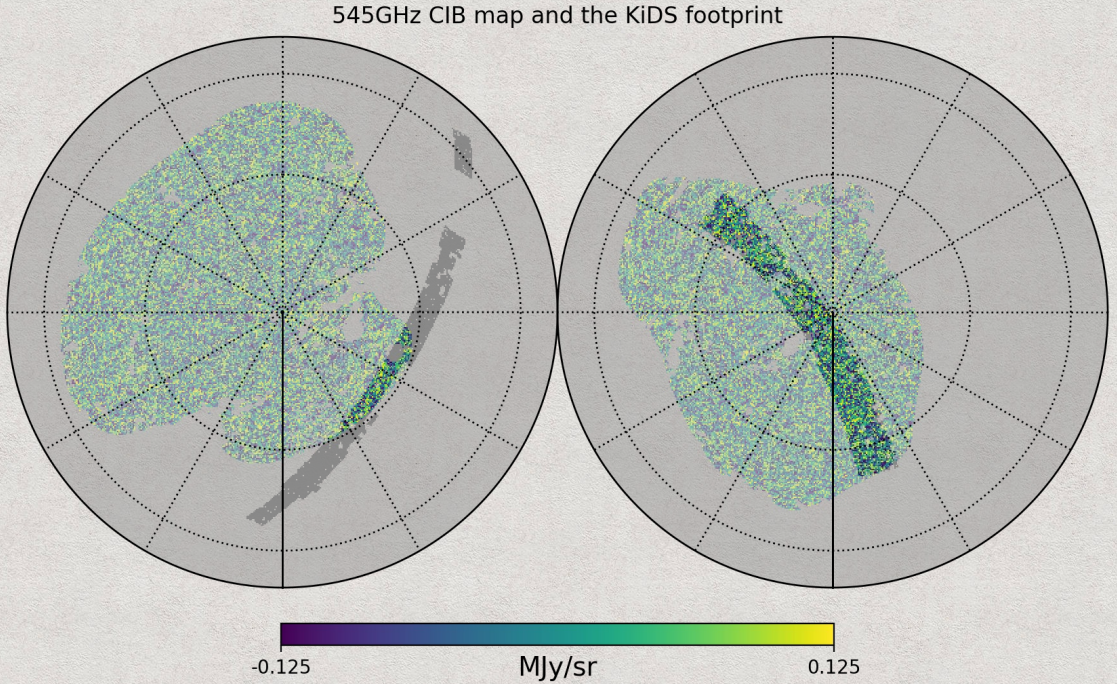
CIB data

- CIB map: from Lenz et al. 2019

  - Galactic signal are removed with an HI template

  - angular resolution: 5 arcmin

  - sky coverage: ~1%



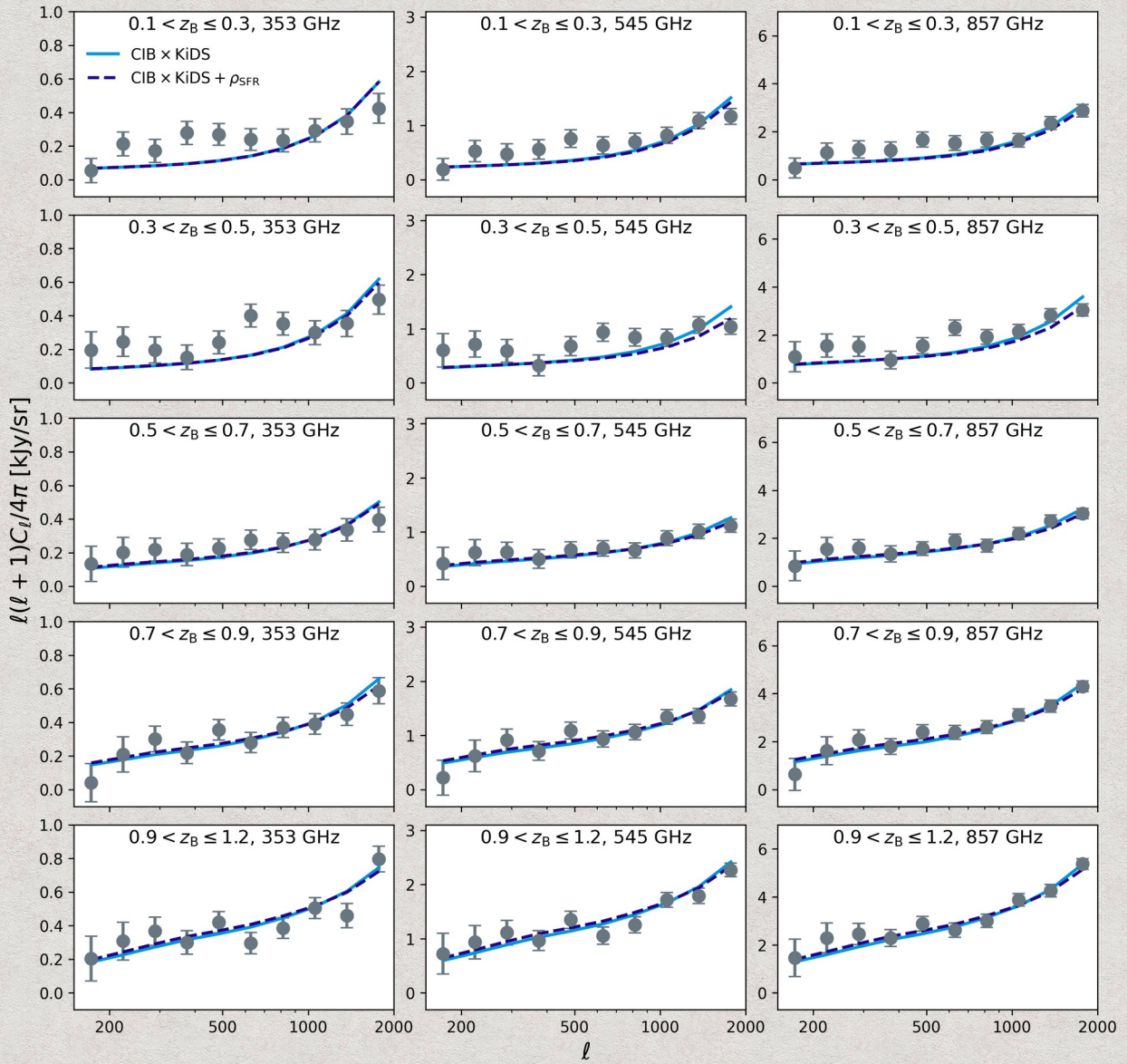
Bandpower measurements

- Tool: NaMaster;

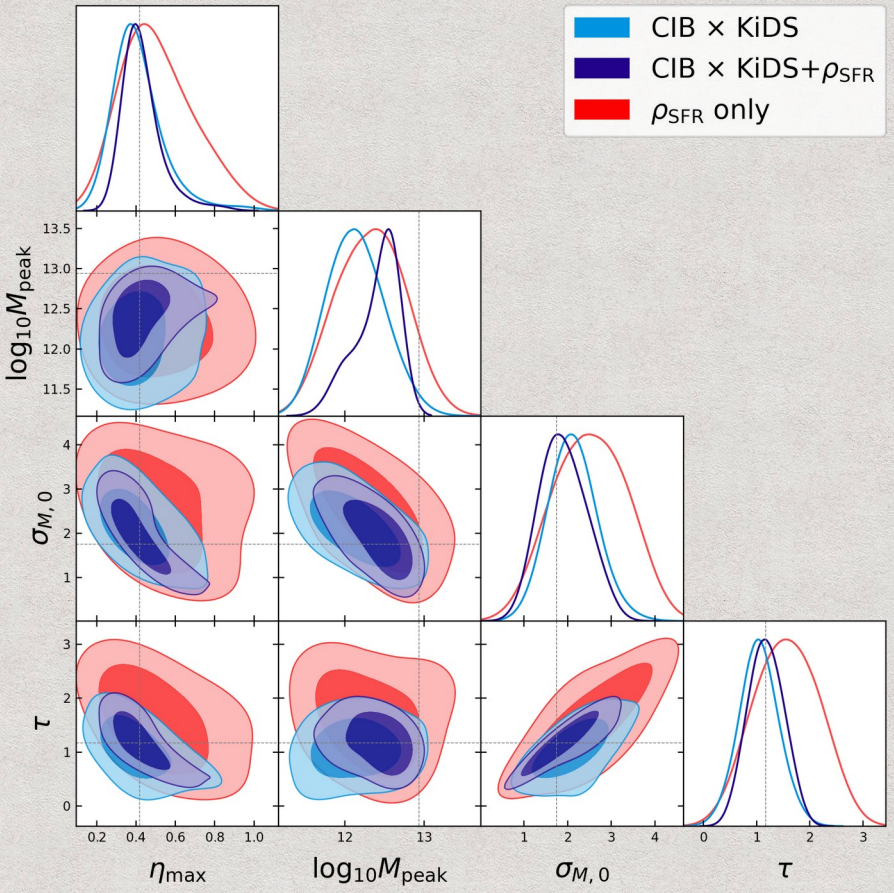
- beam and mode coupling corrected;

- logarithmic ell bin from 100 two 2000

- signal-to-noise: 143



SFR parameters

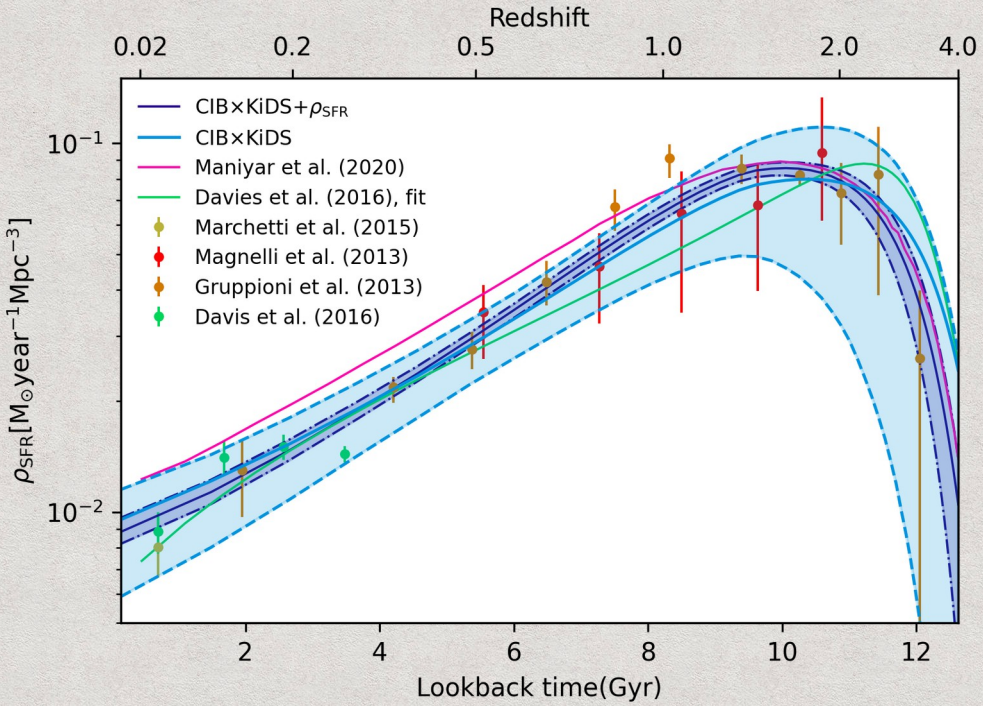


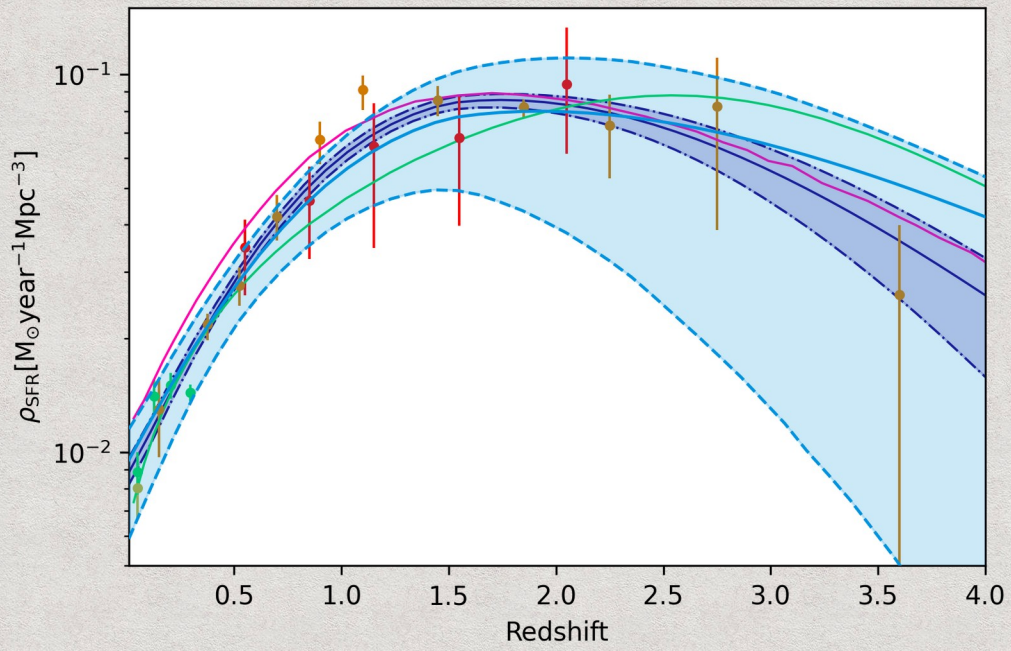
- Most of the parameters are constrained

- Three constraints give consistent constraints

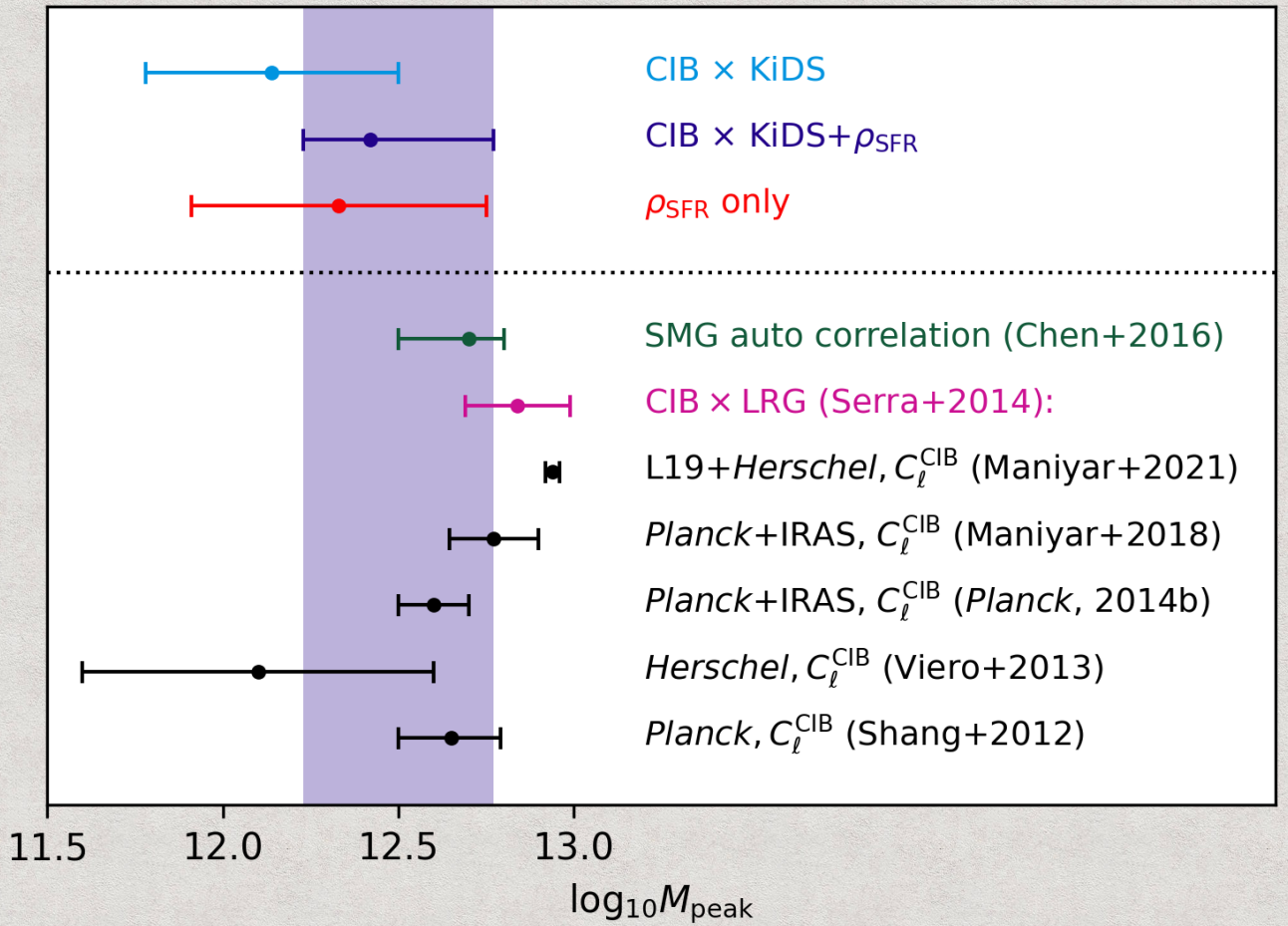
Parameter	Prior	CIB × KiDS	CIB × KiDS + $\rho_{\rm SFR}$	$\rho_{\rm SFR}$ only	M21
$\eta_{\rm max}$	[0, 1]	$0.41^{+0.09}_{-0.14}$	$0.427^{+0.065}_{-0.11}$	$0.51^{+0.16}_{-0.22}$	$0.42^{+0.03}_{-0.02}$
$\log_{10} M_{\rm peak}$	[11.5, 14]	$12.14^{+0.36}_{-0.36}$	$12.42^{+0.35}_{-0.19}$	$12.33^{+0.42}_{-0.42}$	$12.94^{+0.02}_{-0.02}$
$\sigma_{M,0}$	(0, 4]	$2.11^{+0.55}_{-0.55}$	$1.91^{+0.51}_{-0.61}$	$2.52^{+0.82}_{-0.82}$	$1.75^{+0.12}_{-0.13}$
τ	[0, 3]	$1.05^{+0.37}_{-0.37}$	$1.18^{+0.34}_{-0.34}$	$1.57^{+0.61}_{-0.61}$	$1.17^{+0.09}_{-0.09}$
χ^2/d.o.f	-	142.82/125=1.14	155.99/142=1.10	5.76/7=0.82	-
PTE	-	0.13	0.21	0.57	-

SFR history Constraints

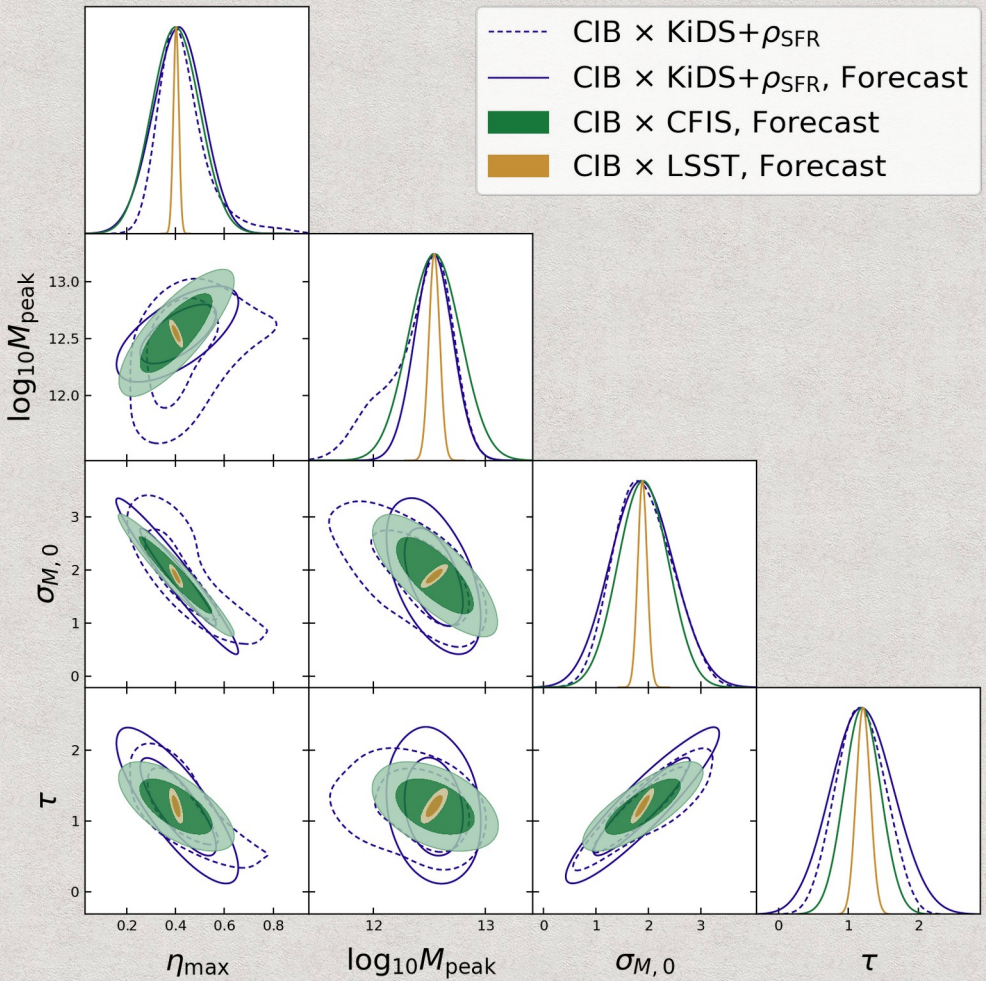




Constraints of most-efficient halo mass



Forecast for future surveys



CFIS: Canada-France Imaging Survey
- sky coverage: 3500 deg^2;
- redshift range: similar as KiDS

LSST:
- sky coverage: 20000 deg^2
- redshift range: ~3

Forecast:
- CFIS can reach similar constaining power as CIBxKiDS+SFRD;
- LSST will improve the constraining a lot!

Conclusions and future prospects

- We make a significant detection of CIB-galaxy cross-correlation;
- The halo model fits well with the cross-correlation;
- The fitting from cross-correlation agrees with that from external SFRD;
- Halo mass with most efficient star formation activity is ~10^12 M_sun;

- Future studies: introducing more sophisticated model (including feedback, quenching, etc); probing SFR for different types of galaxy; try to also constrain dust SED...