The Redshift distribution of the Cosmic Infrared Background from Planck HFI and SDSS quasars

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Exploiting Large Scale Structure

- Galaxies cluster over a very large range of scales (kpc - >Mpc), often measured by 2pt correlation function $w(\theta)$:

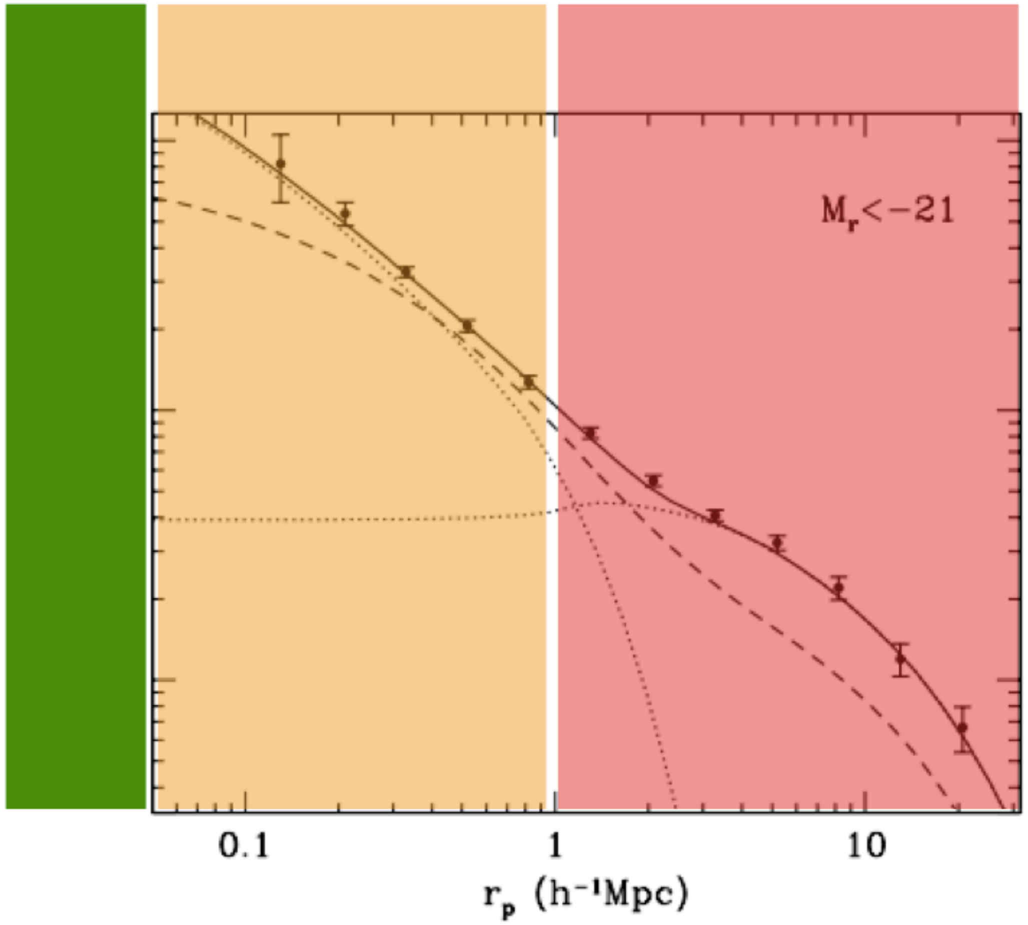
  $dP = n[1+w(\theta)]d\Omega$

- Count pairs and compare to random

  $w(\theta) = 1 - DD/RR$

- Use physical clustering to infer z distn

Zehavi et al (2003)

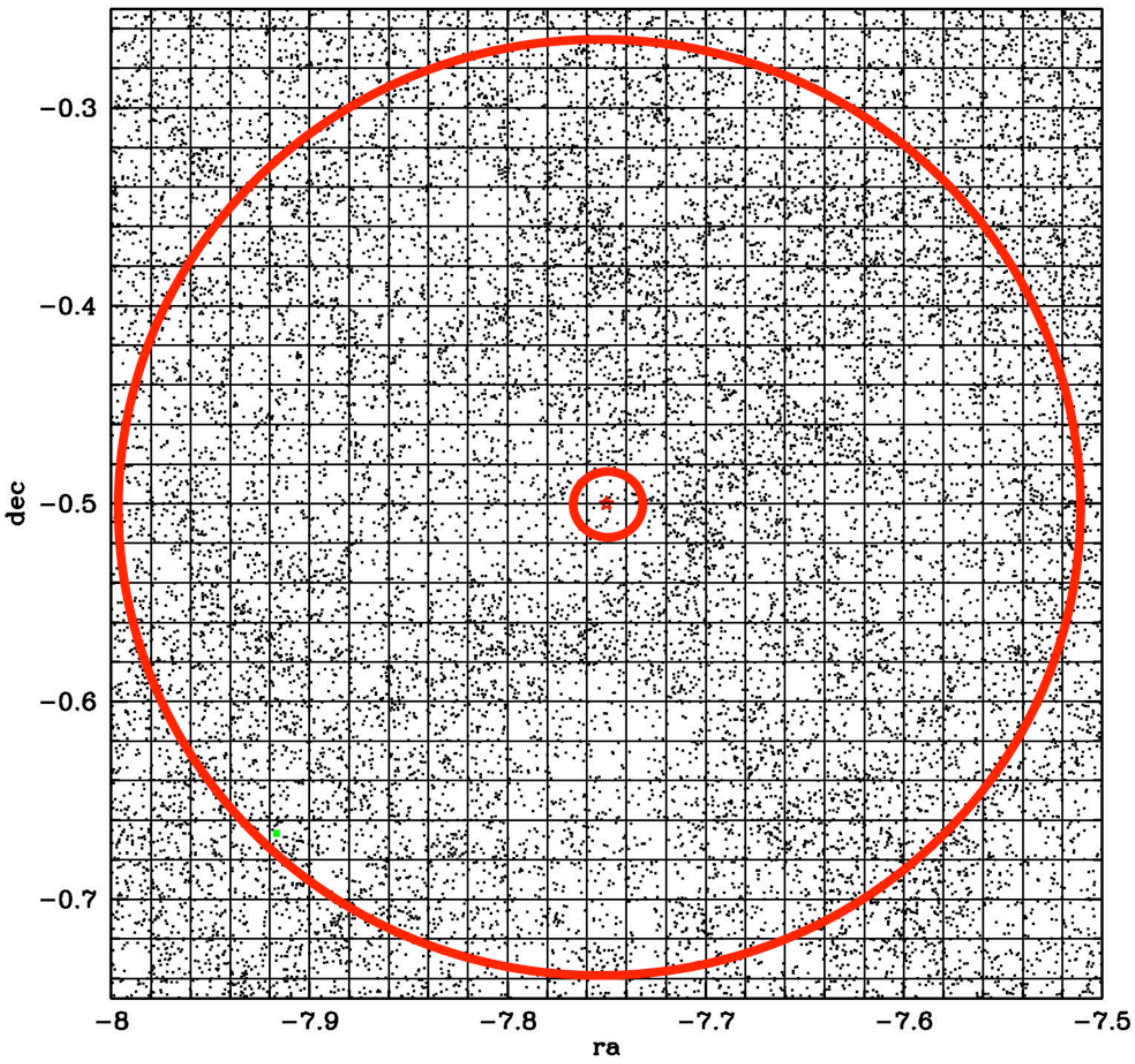


Measure Integral of w(θ)

- Effectively weighted density of objects in aperture (pixelize and weight density per pixel)

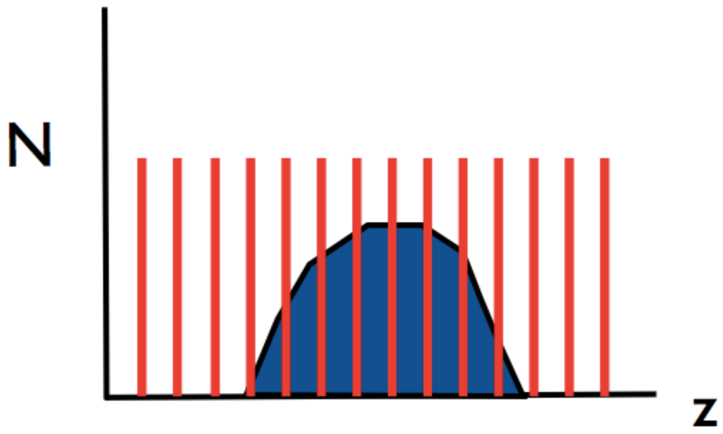
$$\hat{w}_{ur}(z) = \int_{\theta_{min}}^{\theta_{max}} W(\theta') w_{ur}(\theta', z) d\theta'$$

- Example: 300-3000kpc (physical) ~1-10 arcmin



Technique

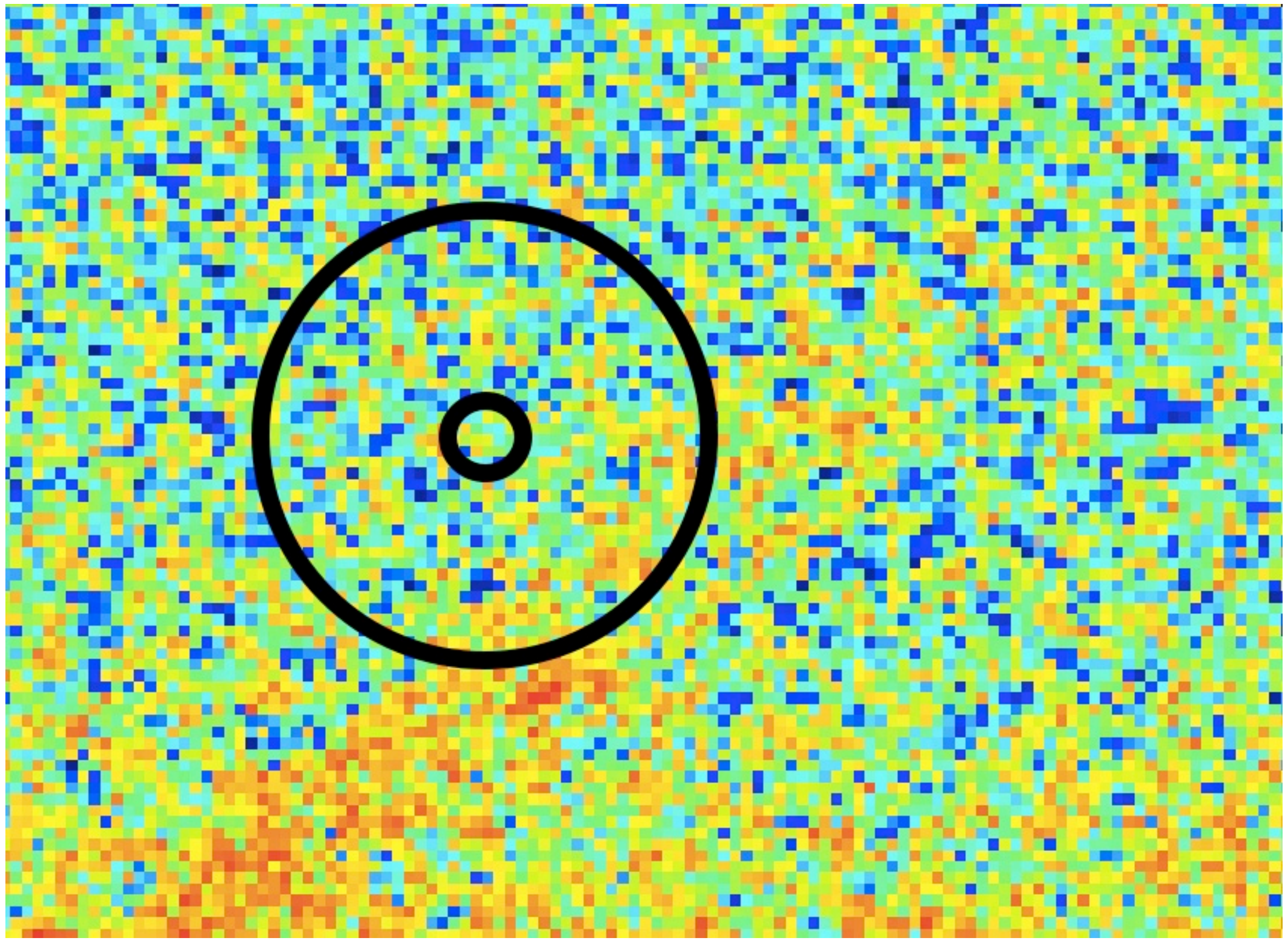
- Divide spectroscopic sample into bins, measure lots of cross-correlation functions to trace out n(z)



- Complication: galaxies are biased tracers, have to remove bias (scale dependent). Linear regime should work best.

Generalize to Unresolved Populations

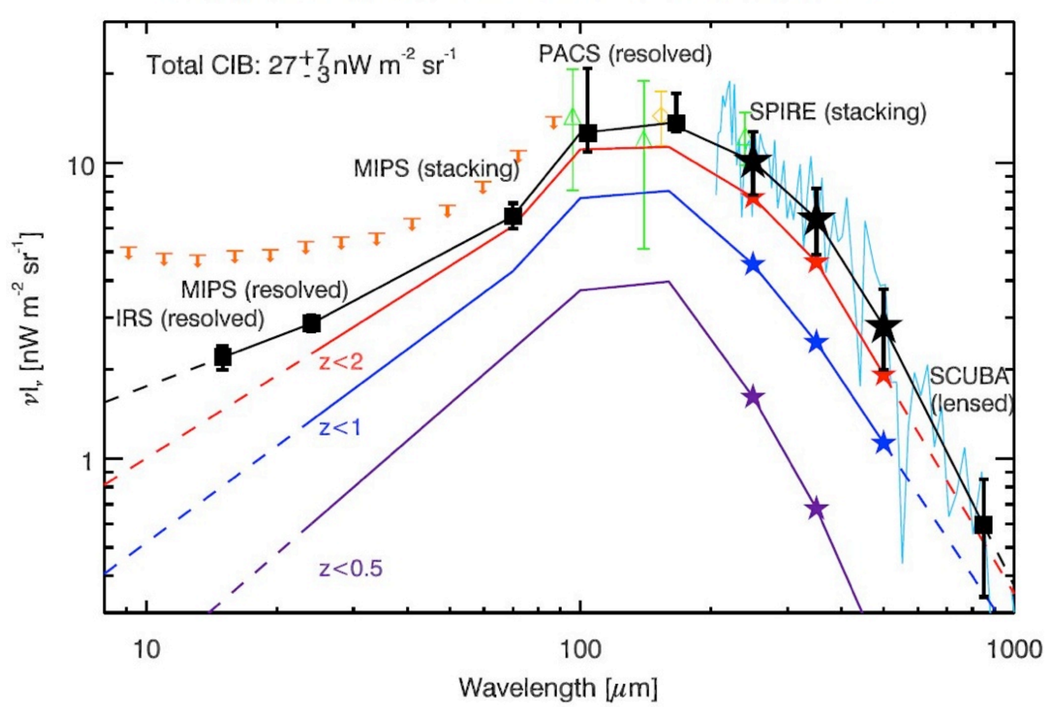
- What if we don't even have individual sources to measure?
- Do pixelized weighted overdensity of flux in aperture
- gives us (normalized) dI_ν/dz, rather than dN/dz (intensity normalized in separate step)

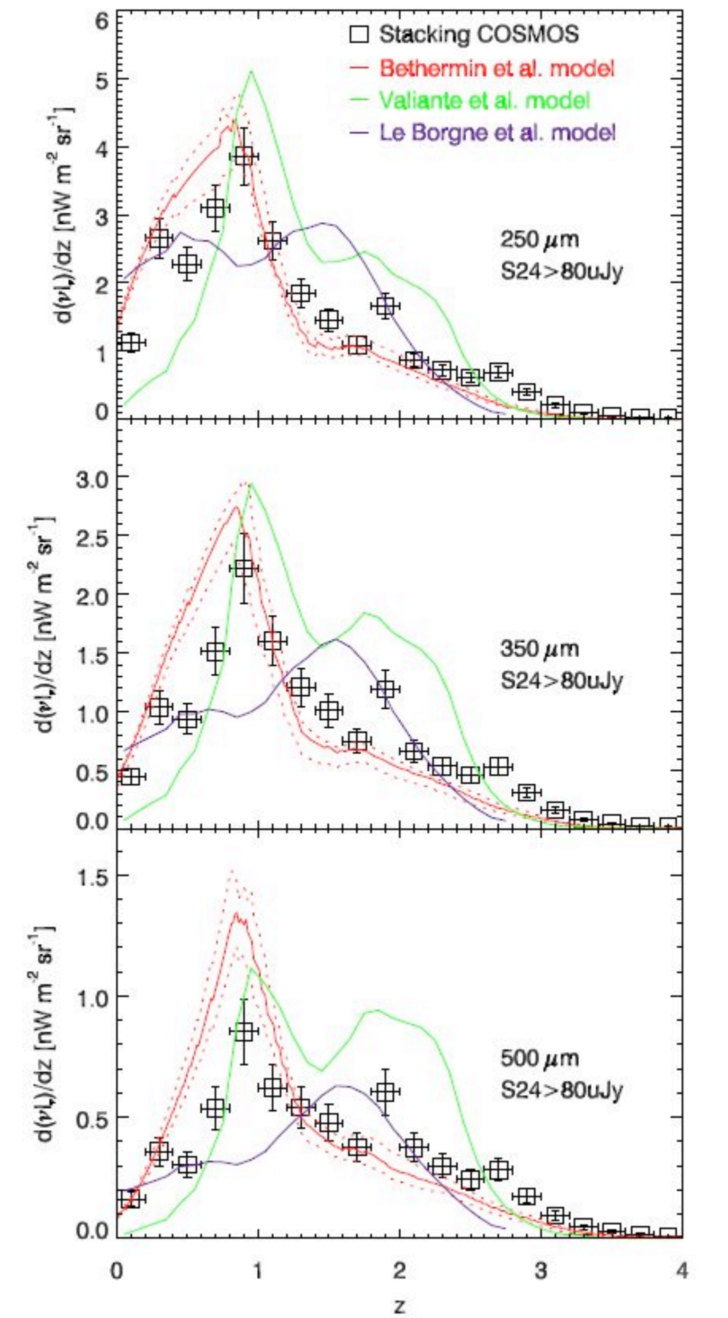


Cosmic Infrared Background

- Mainly due to UV/optical photons absorbed and re-emitted by dust, bulk of which is due to star formation (some AGN, too)
- Very good probe of the integrated star formation history of the Universe (only the reprocessed, no accounting for UV)
- Until recently (via Spitzer in NIR and mid-IR, and Herschel in Far-IR) was largely unresolved, redshift distribution very uncertain
- We can fix that

M. Béthermin et al.: Deep number counts at 250 μm, 350 μm and 500 μm and CIB build-up





Béthermin 2012

Planck

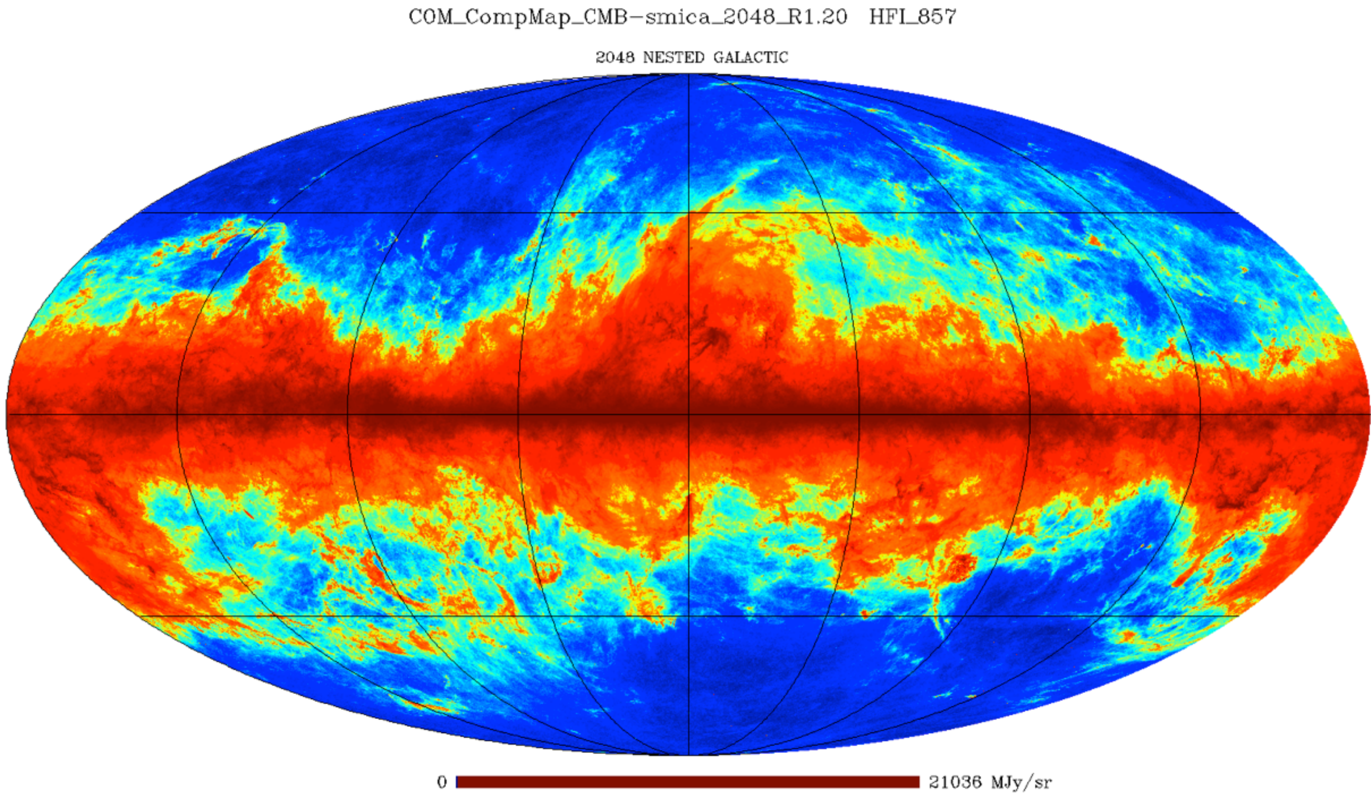
- Planck has the ~arcmin resolution needed to probe interesting physical scales for cross correlations (300-3000 kpc ~1-10 arcmin at z~0-5). Also linear to quasi-linear regime, so bias not a huge problem.

- Very well calibrated dataset covering all sky will give us good statistics and maximize signal

- frequency coverage of HFI covers Far-IR (no mid or near IR, unfortunately), we use 217, 353, 545, 857GHz maps

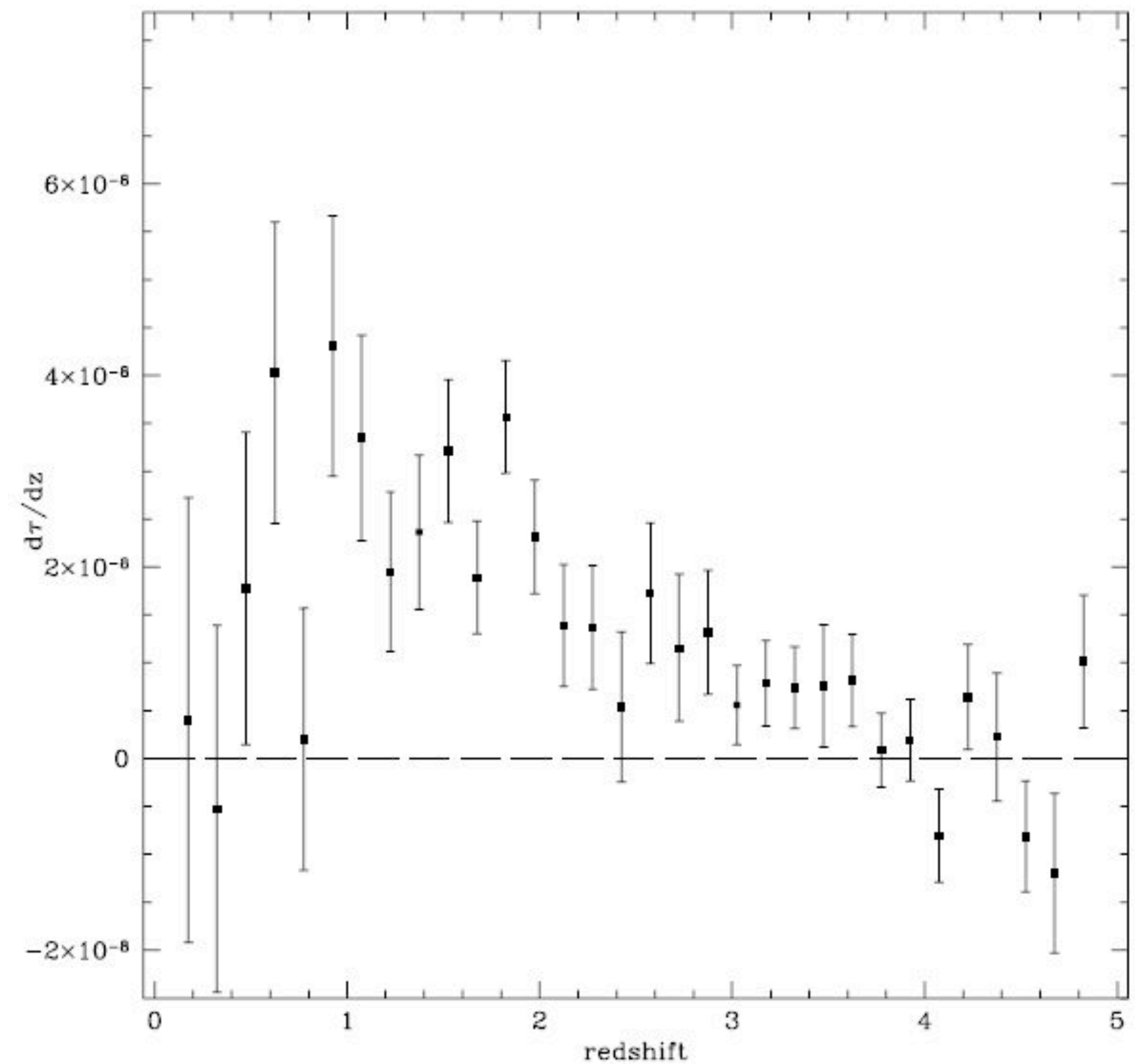
- Big problem: foregrounds!

  - Dust, CO, Zodiacal light, synch, ...



Foregrounds

- Use Zodiacal light subtracted maps (intersect with SDSS DR7, ~5400 deg^2)
- Synchrotron mainly at lower freq, mainly affect 217GHz, where we expect only marginal detection anyway
- Can't use dust map, as it contains systematic bias due to the CIB itself
- dust will not cluster with CIB signal, so removal mainly just reduces jackknife errors
- Simple mean subtraction on ~1 deg scales



Aside: Test for Contaminants

- Method is a good tool for systematics checks, e.g. Planck SMICA CMB map

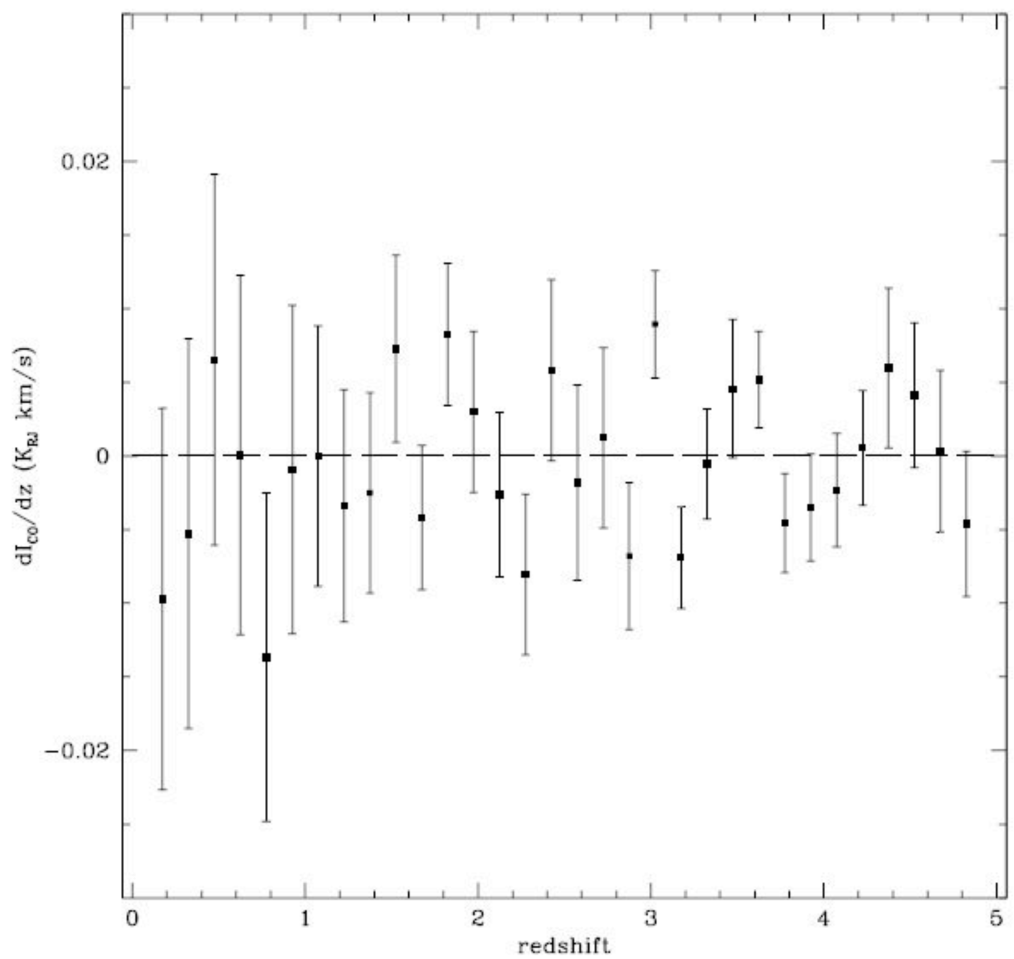


Figure A2. Recovered (type 3) CO intensity distribution as a function of redshift. No coherent signal is observed.

CO recovery

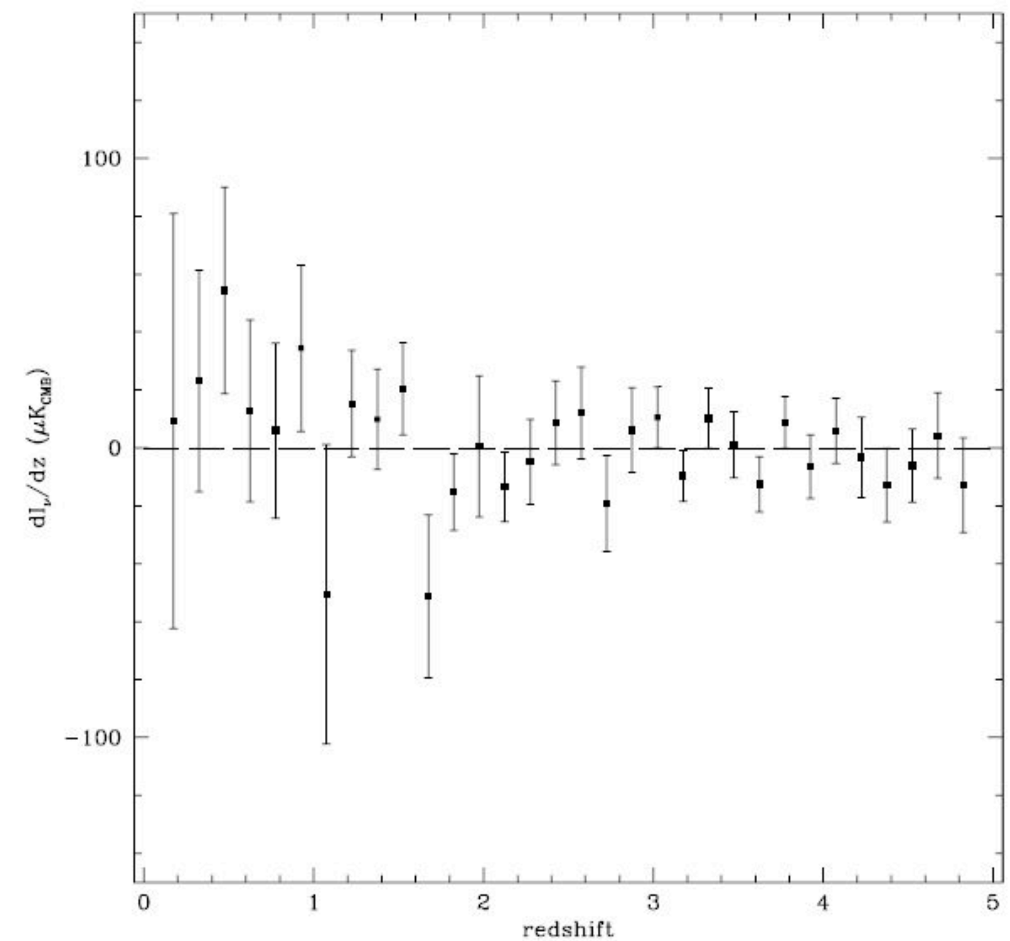
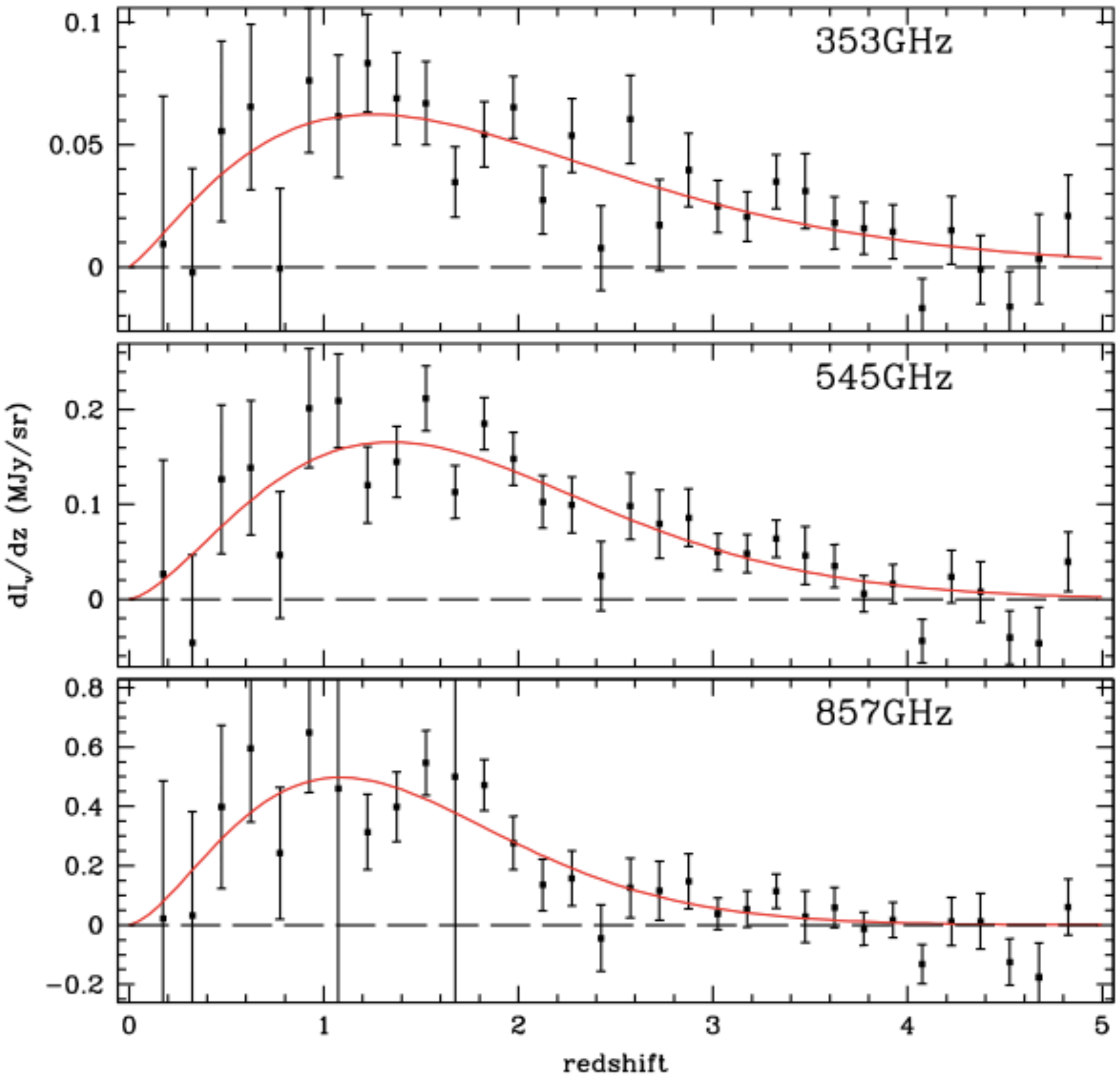


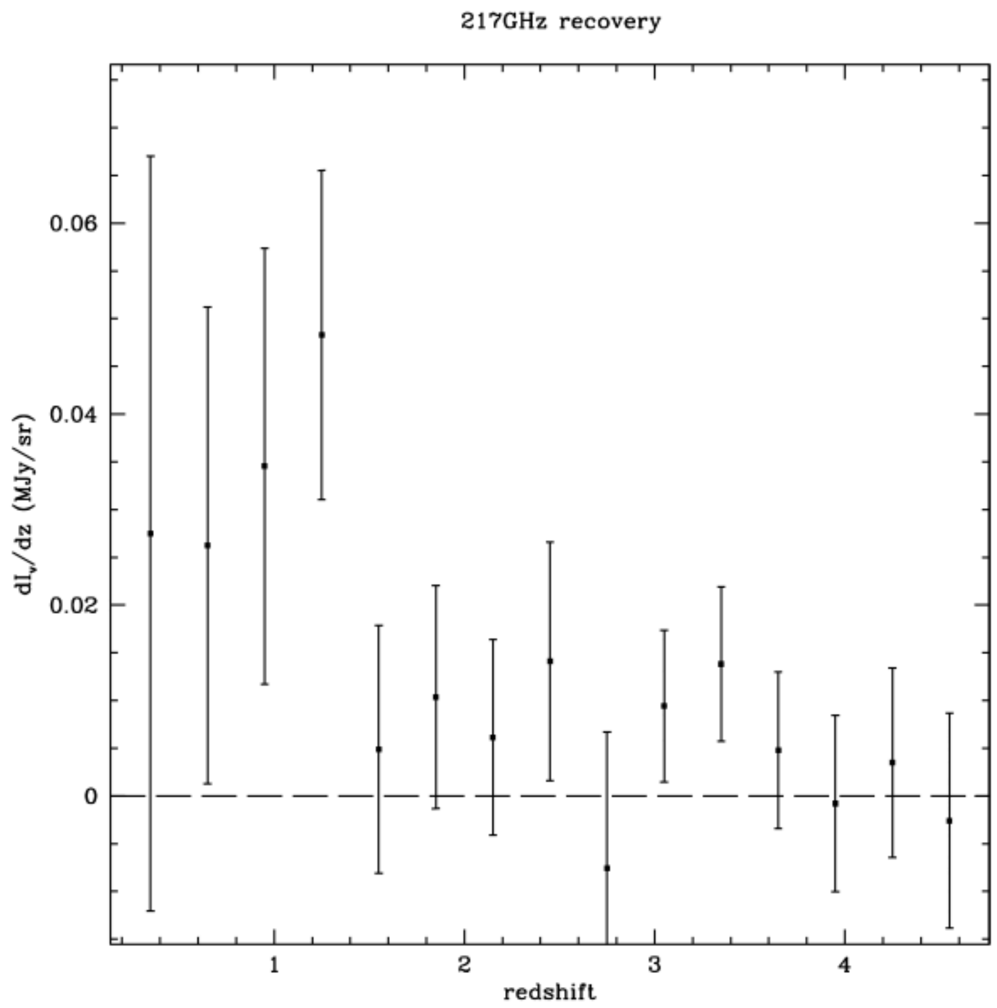
Figure A3. Recovered intensity distribution (in units of μK_{CMB}) for the SMICA map. No coherent signal is detected at low redshifts and no evidence for low redshift contaminants are seen.

SMICA CMB recovery

Results

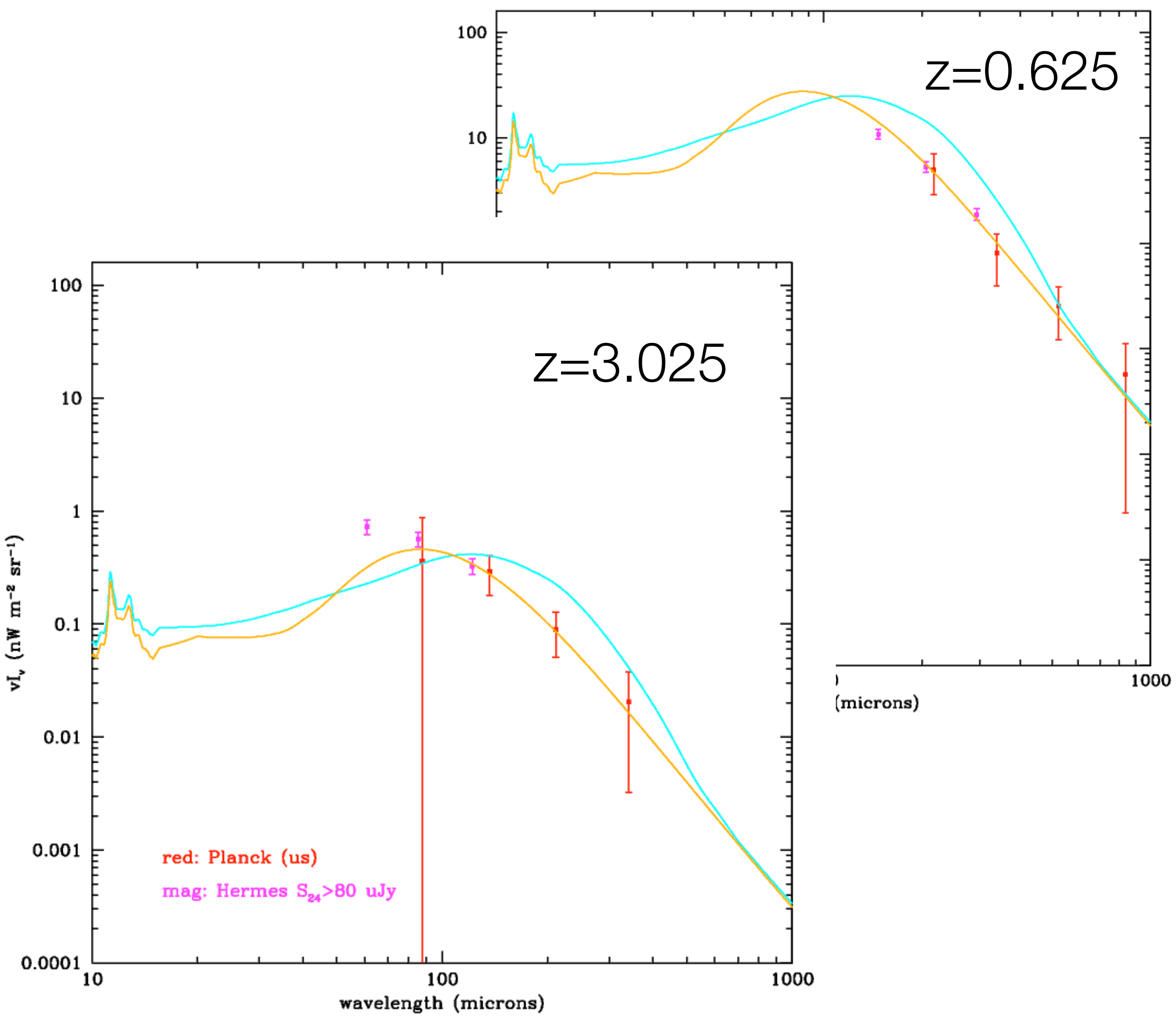
- High S/N detection of CIB in 353, 545, 857GHz bands, lower S/N detection in 217GHz

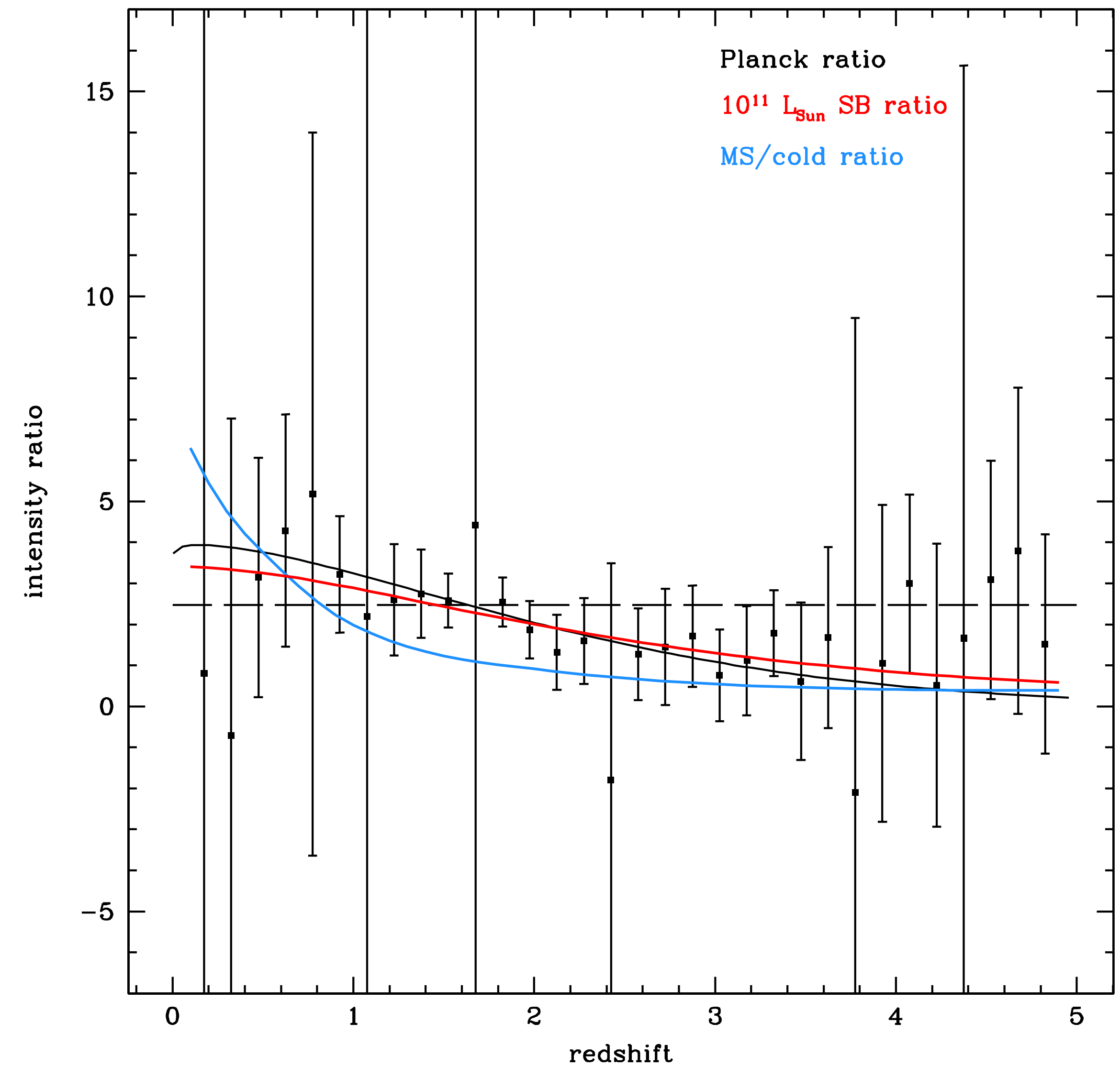




Results

- At most redshifts only probing Rayleigh Jeans tail of CIB dust bump, hard to say much about SED, but “consistent” with starburst templates with T_{eff}~35K and β=1.5 (modified BB)





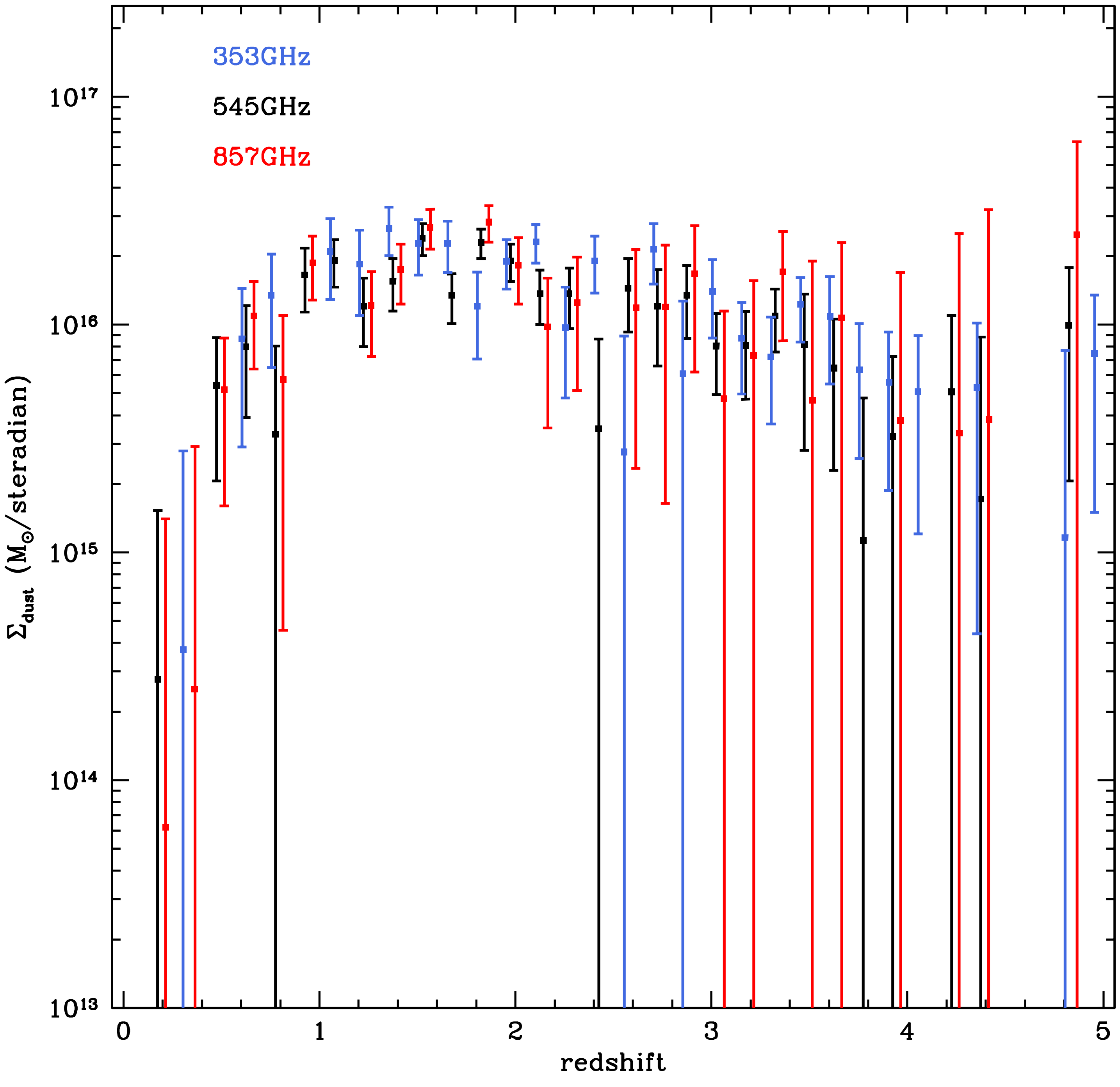
ratio of 857GHz to 545GHz intensity

MBB Dust Mass (zeroth order)

- Assume FIR flux is due to dust emitting as MBB

$$\Sigma_d = \frac{I(\nu_0) D_L^2}{(1+z)\kappa(\nu_0) B(\nu_0, T_d)}$$

$$\kappa = \kappa(\lambda_0)\left(\frac{\lambda_0}{\lambda}\right)^\beta$$



Sensitive to value of T_{eff}, which we do not have a good constraint on!

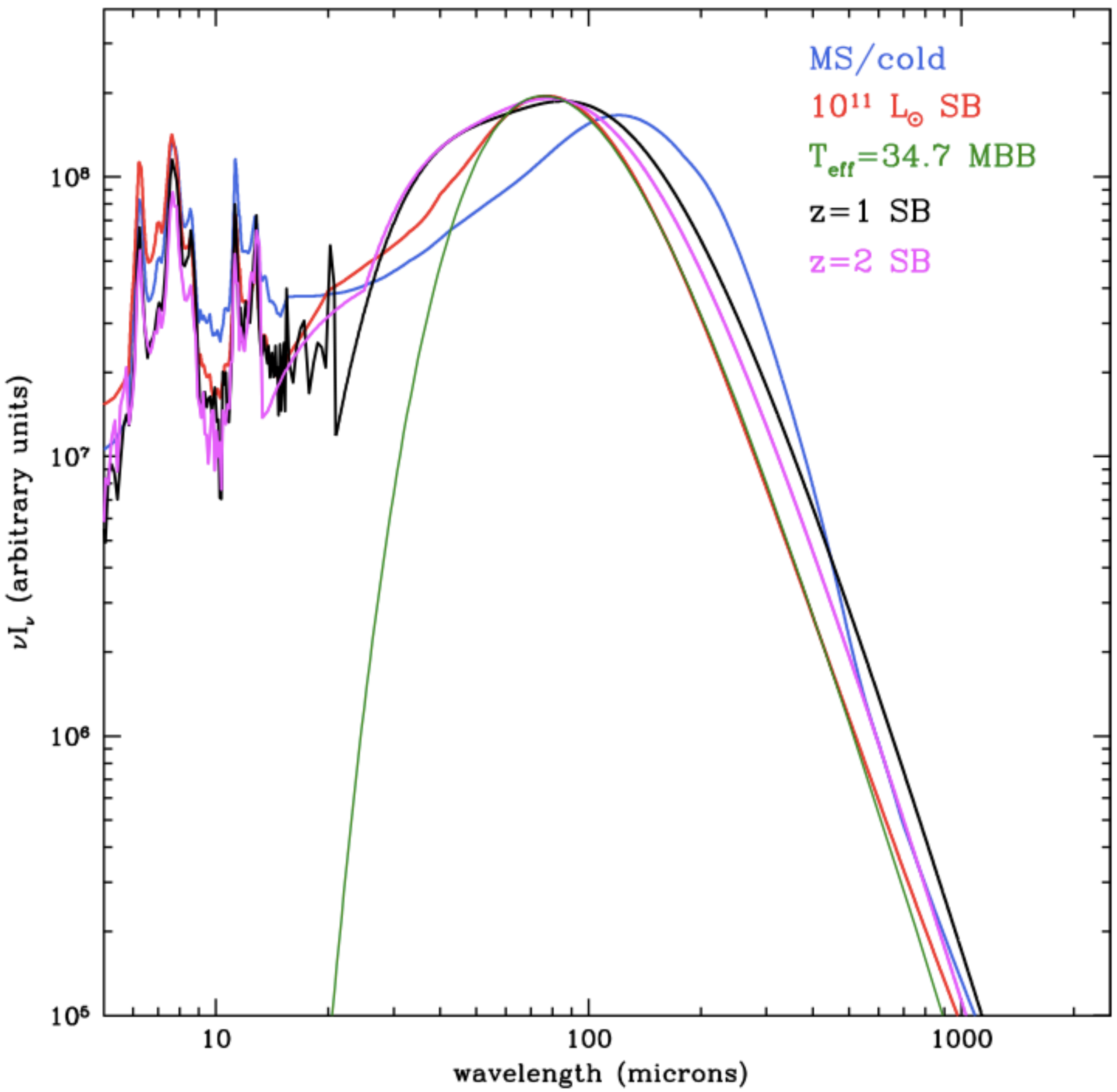
Star Formation Rate

- Use Kennicutt (1998) to translate L_{IR} to SFR, **HIGHLY dependent on bolometric correction**

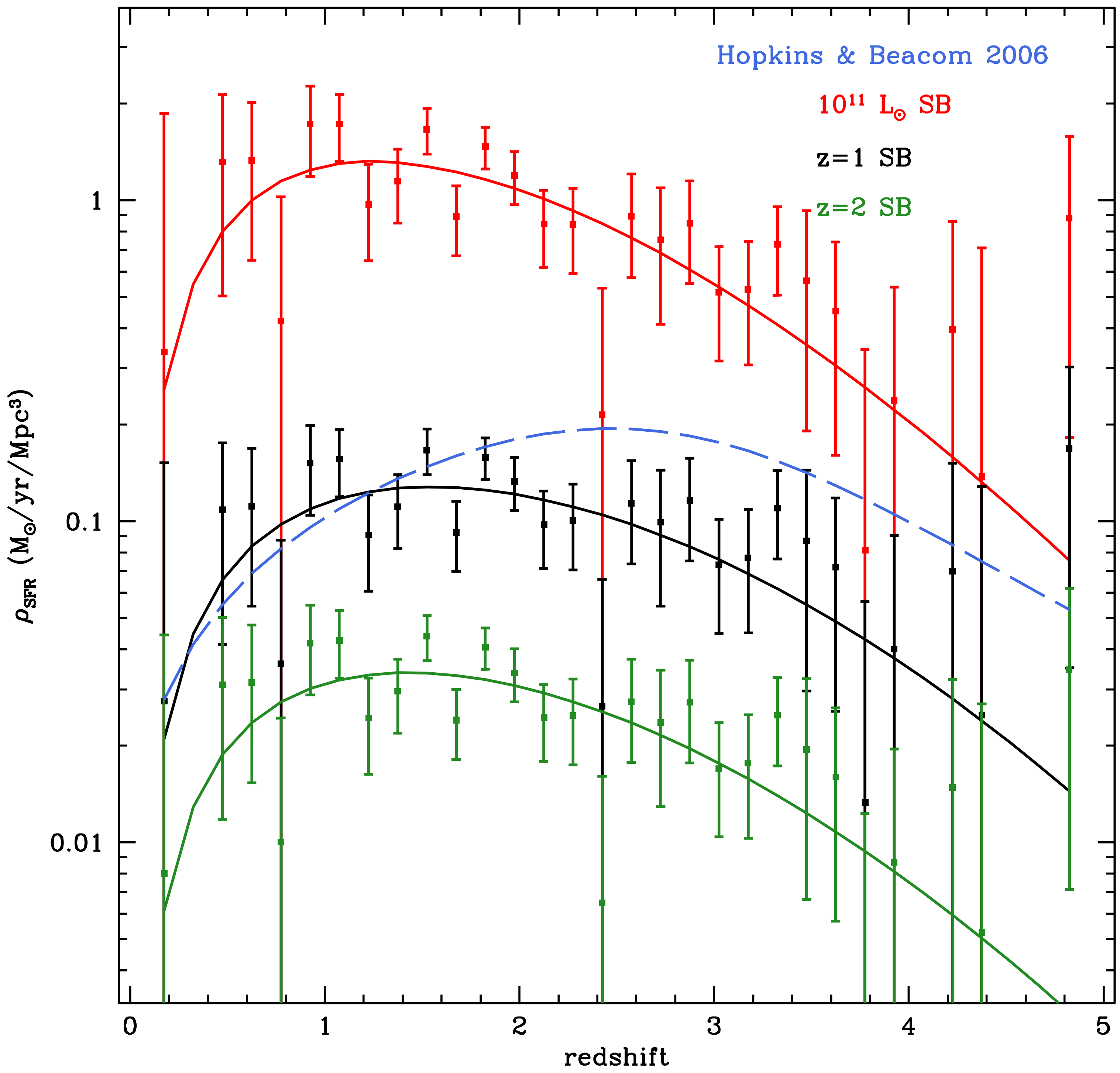
$$L_{\nu(1+z)} = \frac{S_\nu 4\pi D_L^2}{1+z}$$

$$L_{IR} = \int_{8\mu m}^{1000\mu m} L_\nu d\nu$$

$$SFR(M_\odot/yr) = 4.5e^{-44} L_{Bol}(erg/s)$$



Star Formation Rate



Conclusions

- High S/N detection of the unresolved Far-IR CIB as a function of redshift, approximately matches expected spectrum

- Better foreground subtraction would further improve S/N

- Need NIR and mid-IR measurements to properly constrain SFR (which we're looking in to)