A Census of the Cosmic Infrared Background; *or* Combining Measurements Large and Small to Model the Entire Infrared Sky

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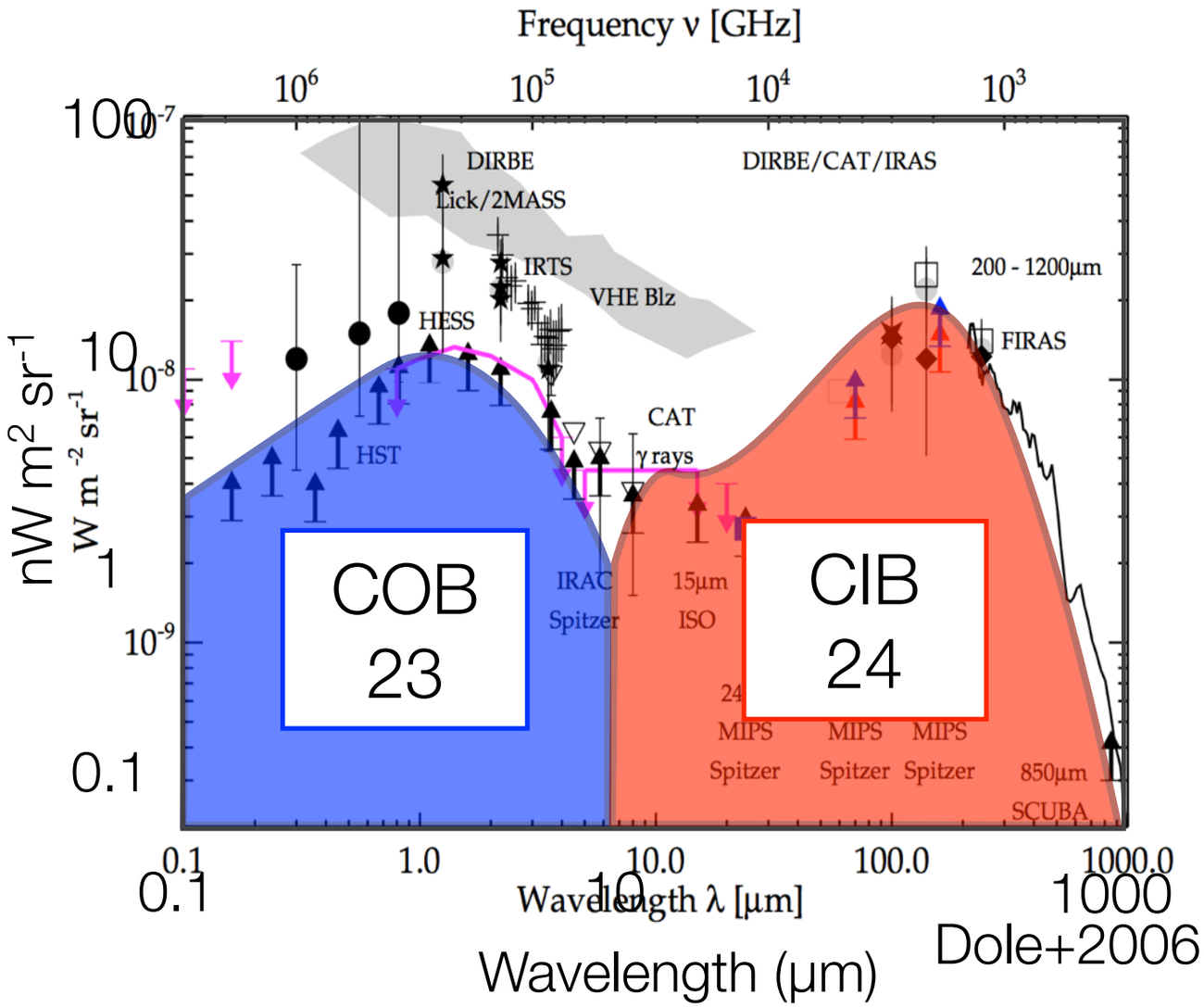
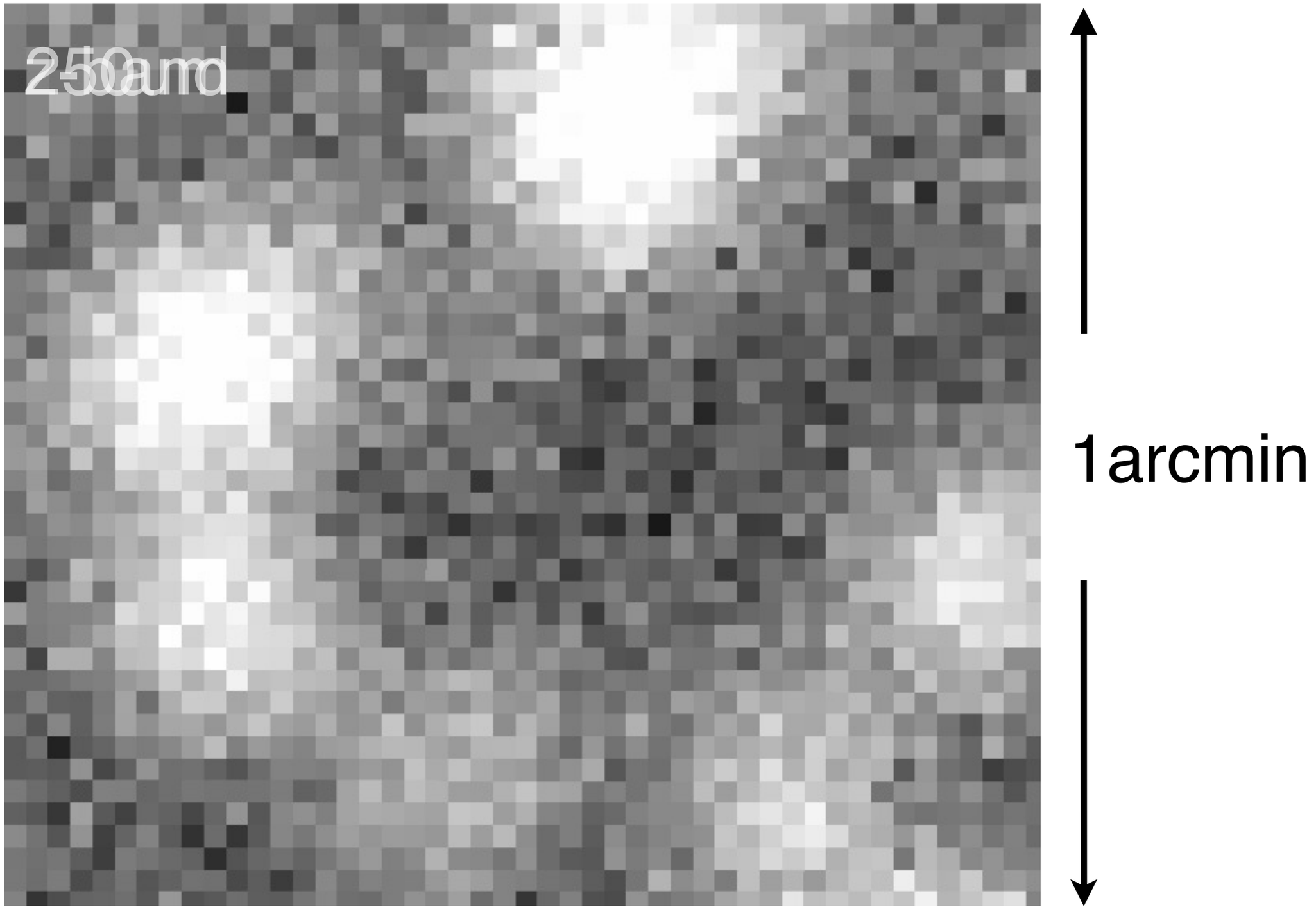
The Cosmic Infrared Background (CIB)

- There is as much intensity in the infrared background as there is in the optical.
- Together these backgrounds contain a fossil record of the star-formation history of the Universe
- What is the relationship of the CIB to the COB, and can it be explained by optical/NIR galaxies?

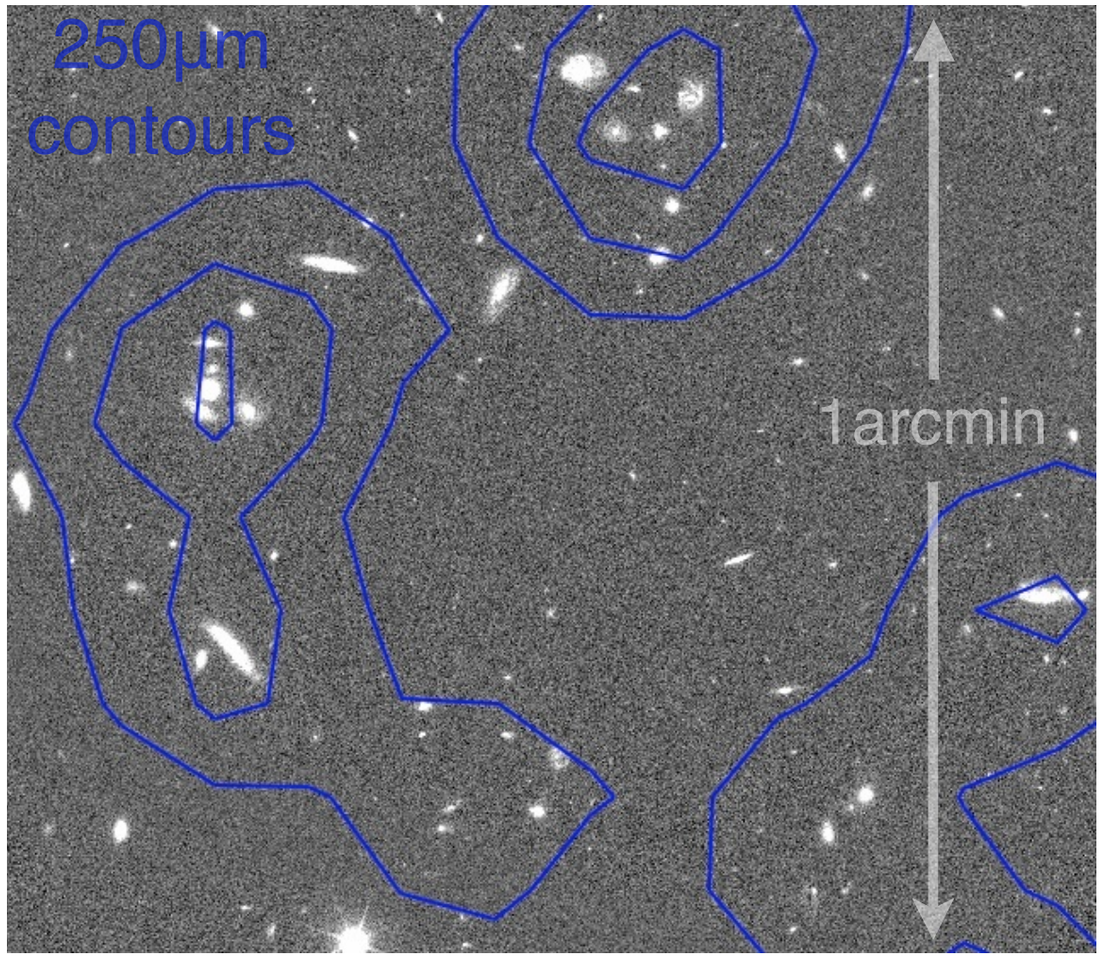


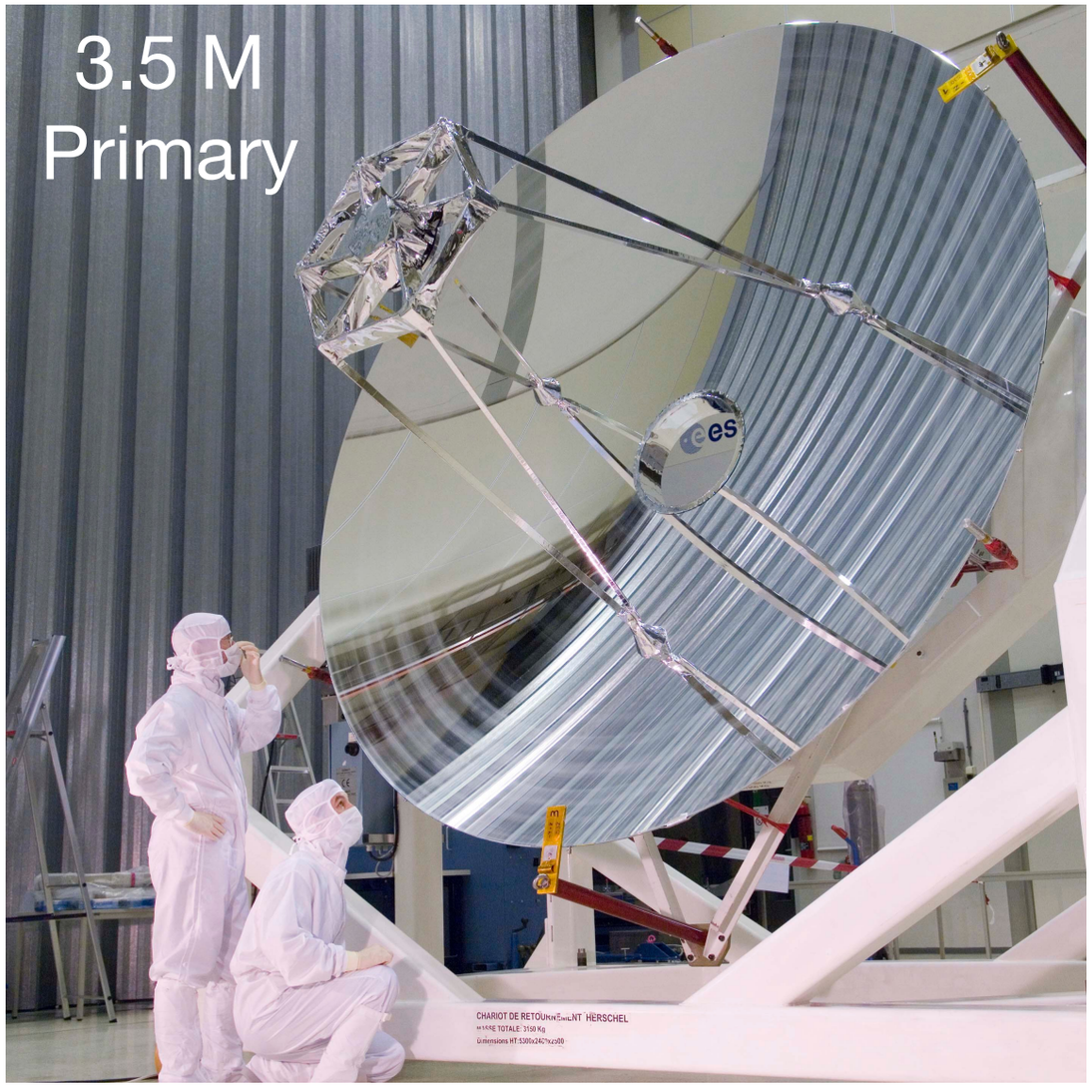
The CIB as seen by SPIRE (1200 to 600 GHz)



Herschel/SPIRE

Band	PSF size (FWHM)	Confusion Limit (5σ)
250 μm:	16”	24.0 mJy
350 μm:	25”	27.5 mJy
500 μm:	36”	30.5 mJy

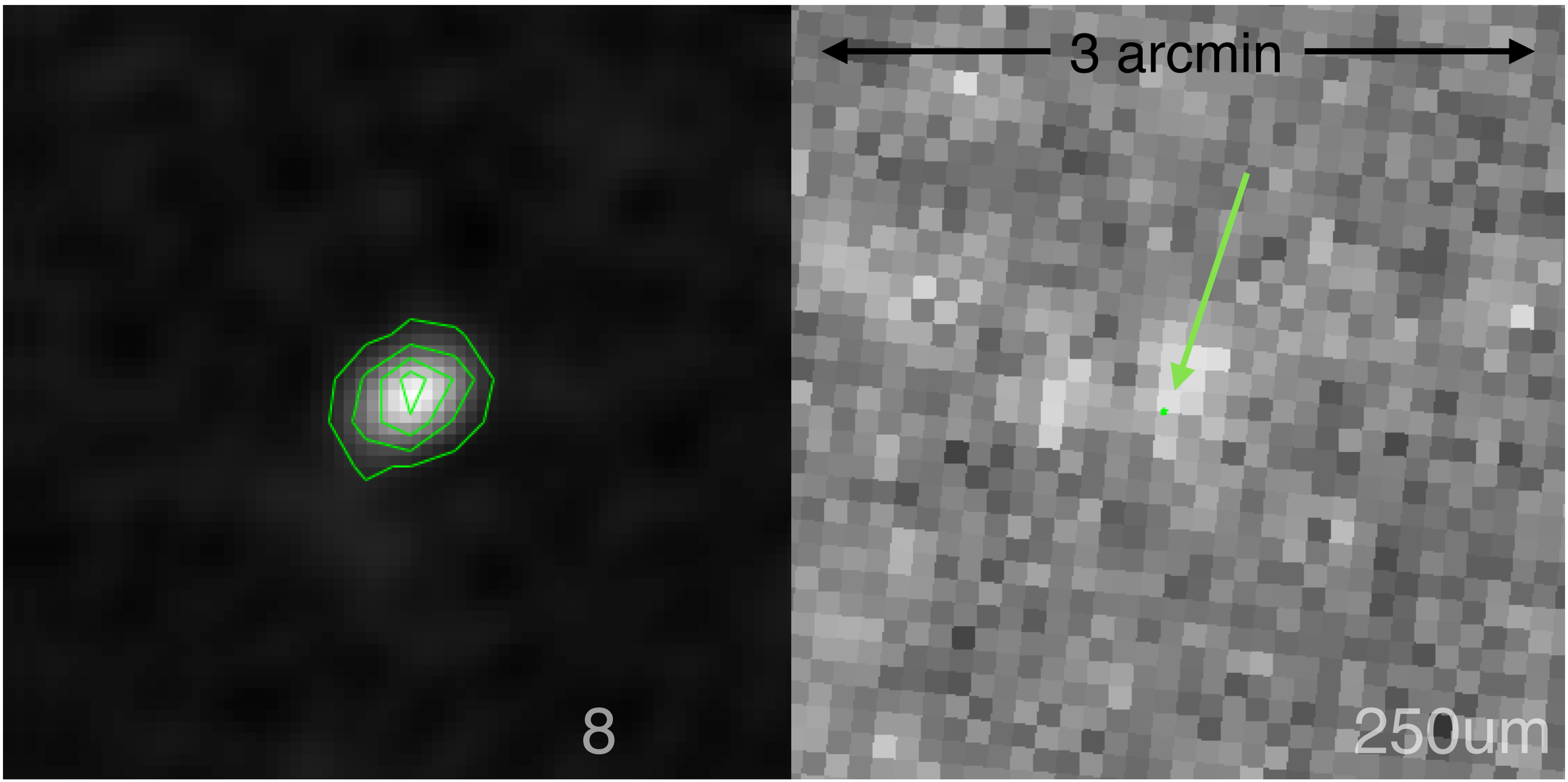




- < 1% of sources resolved at 5σ due to source confusion
- Strength is surveys, with ~1000 deg^2 observed

Near-Infrared
Selected Sources
at z~1.5

The CIB as seen by ALMA

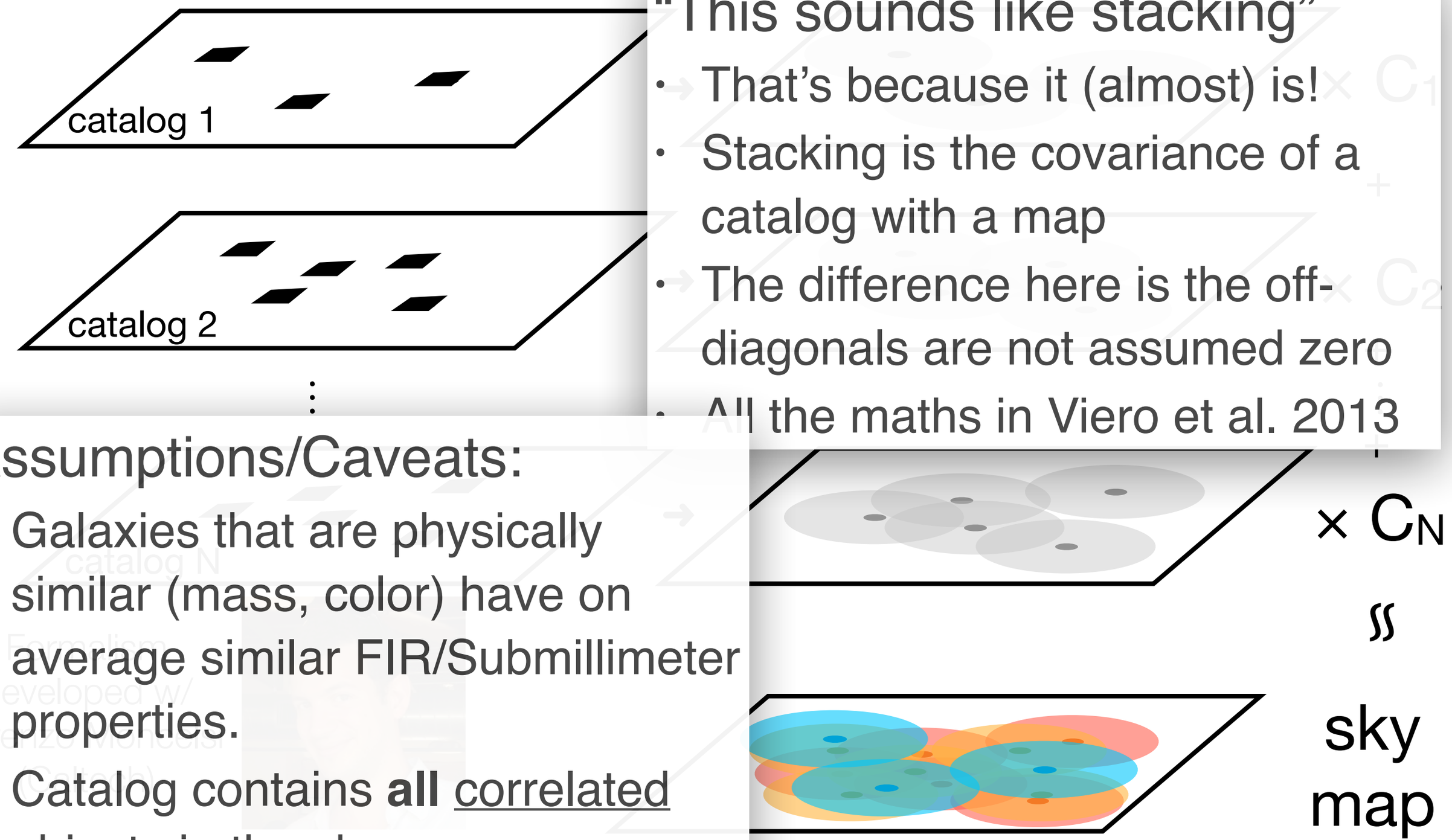


Motivation

- *What is* the Cosmic Infrared Background (CIB)?
  - ➡how much do subsets of galaxies contribute to the CIB?
  - ➡can we know the IR properties of *all* galaxies as well as we know their properties in the UV/optical?
  - ➡Can we develop synergies between
    - large-angular-scale surveys (e.g., Herschel, Planck…);
    - small-angular-scale observations (in particular ALMA); and
    - rich sets of multi-wavelength catalogs (e.g., UDS, UltraVISTA, CANDLES, ZFORGE…)

to model the entire infrared background?

Modeling the Background: SIMSTACK



"This sounds like stacking"

- That's because it (almost) is!
- Stacking is the covariance of a catalog with a map
- The difference here is the off-diagonals are not assumed zero
- All the maths in Viero et al. 2013

Assumptions/Caveats:

- Galaxies that are physically similar (mass, color) have on average similar FIR/Submillimeter properties.
- Catalog contains **all** correlated objects in the sky.

see arXiv:1304.0446

Modeling the Background: SIMSTACK

HERMES

catalog (Williams & Quadri, in prep.)

- UKIDSS/UDS

  uBVRizJHK + IRAC ch1234

  K-band magnitude cut 24 AB

  81,000 sources in ~0.63 deg^2

- redshifts - EAZY (Brammer 2008)
- masses - FAST (Kriek 2009)

maps (HerMES; Oliver et al. 2012)

- *Spitzer*/MIPS

  24, 70um

- *Herschel*/PACS

  100, 160um

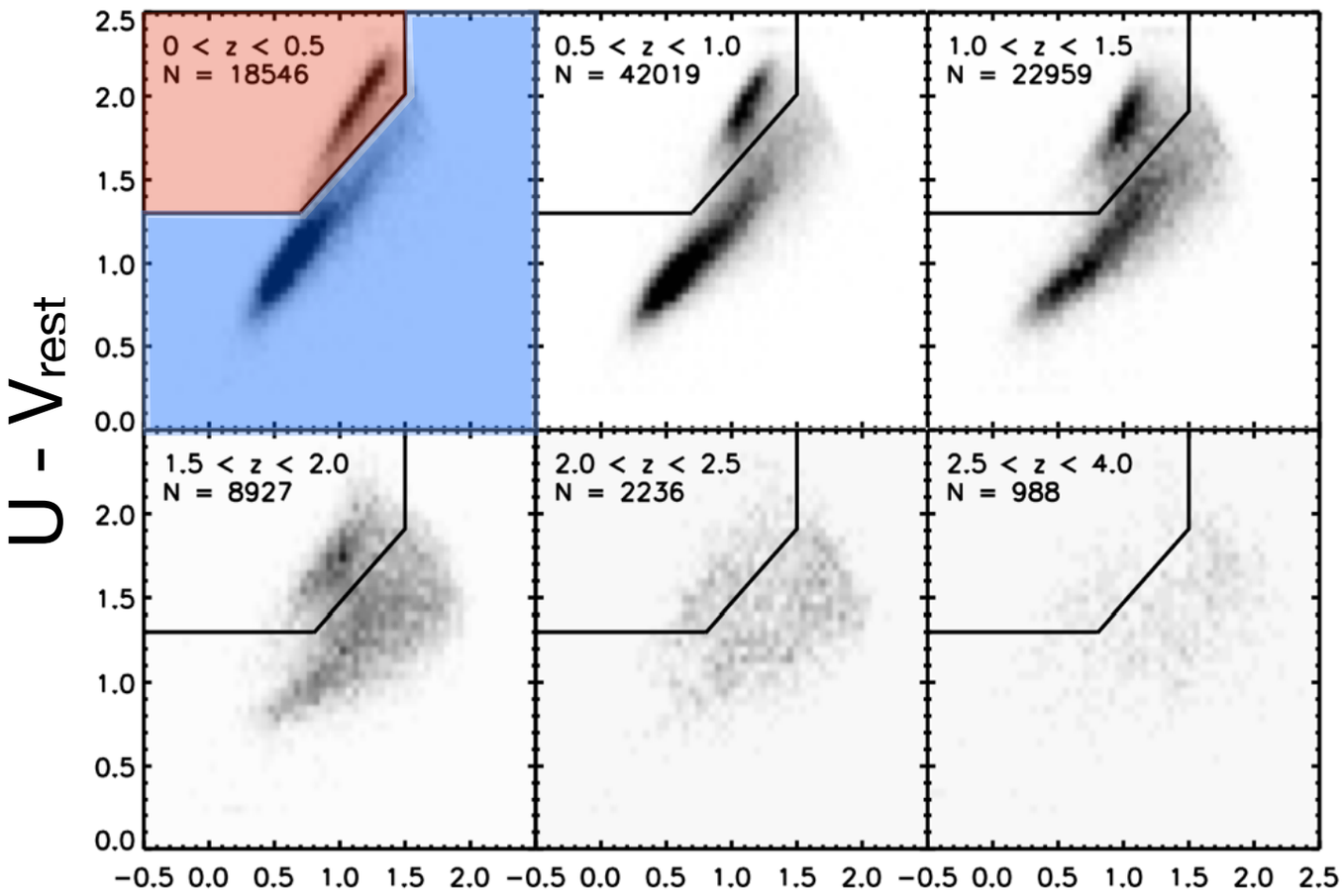
- *Herschel*/SPIRE

  250, 350, 500um

- ASTE/AzTEC

  1100um

Separating Quiescent from Star-forming

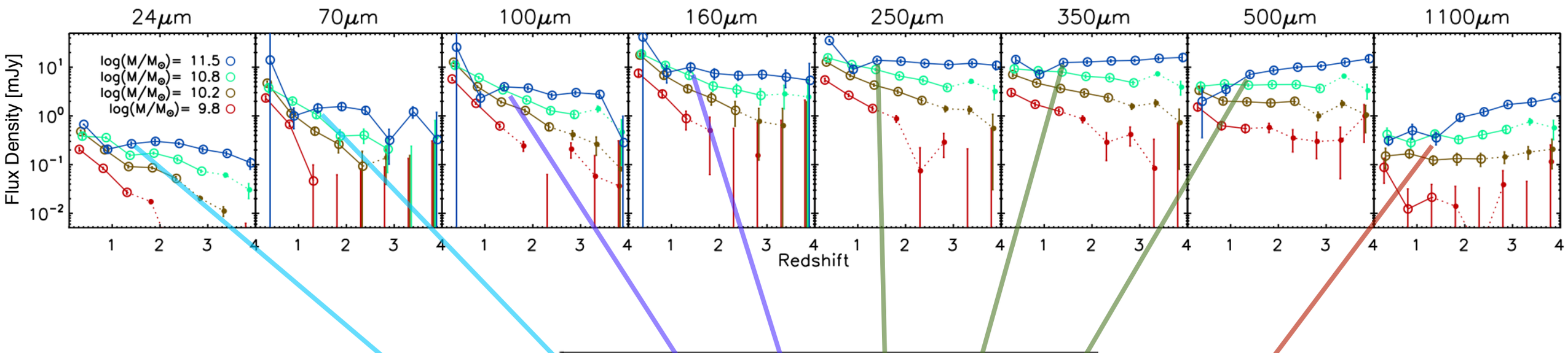


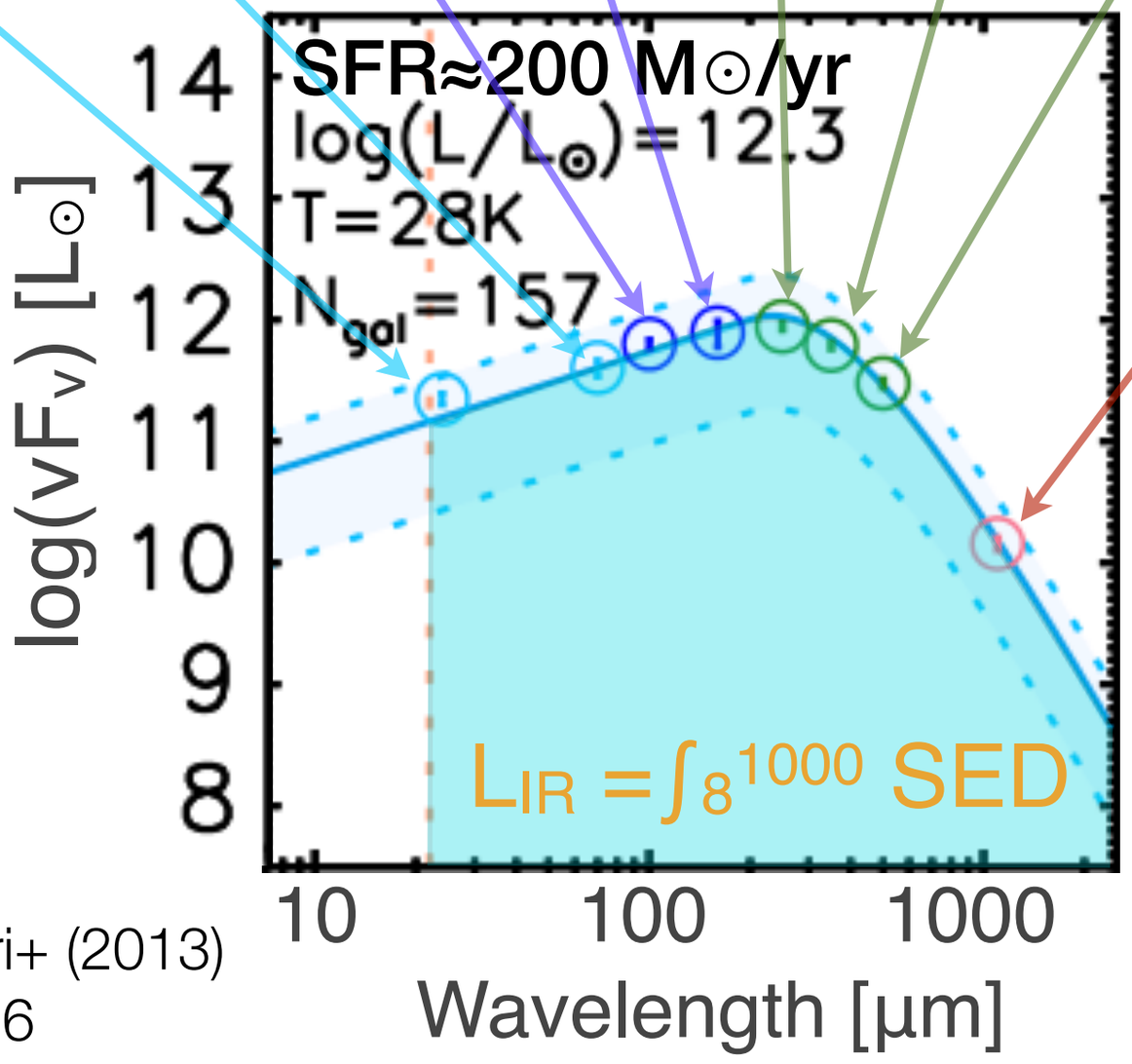
Muzzin et al. (2013)

Viero, Moncelsi, Quadri et al. (2013)
arXiv:1304.0446

Modeling the Background: SIMSTACK

HERMES



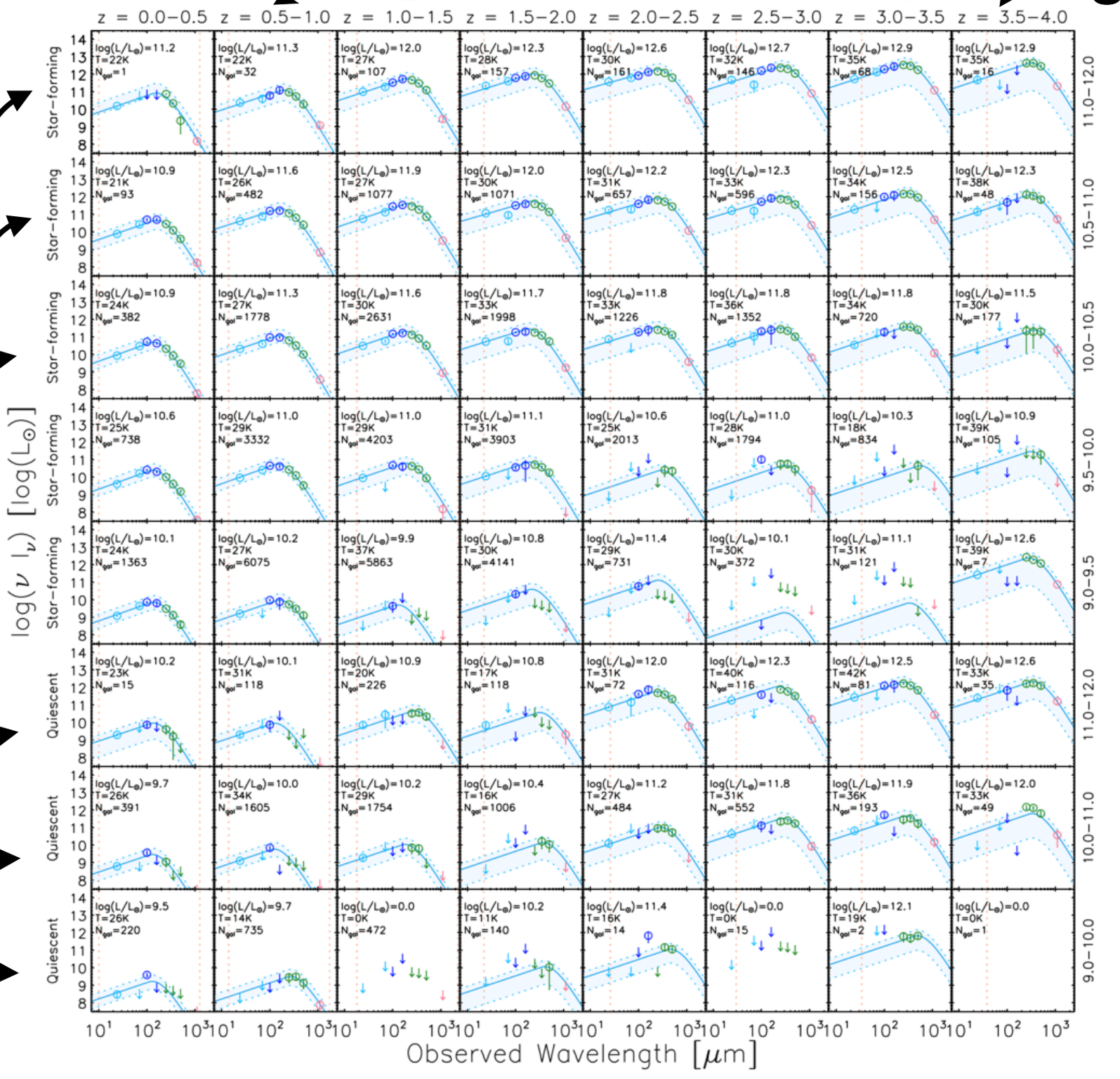


Viero, Moncelsi, Quadri+ (2013)
arXiv:1304.0446

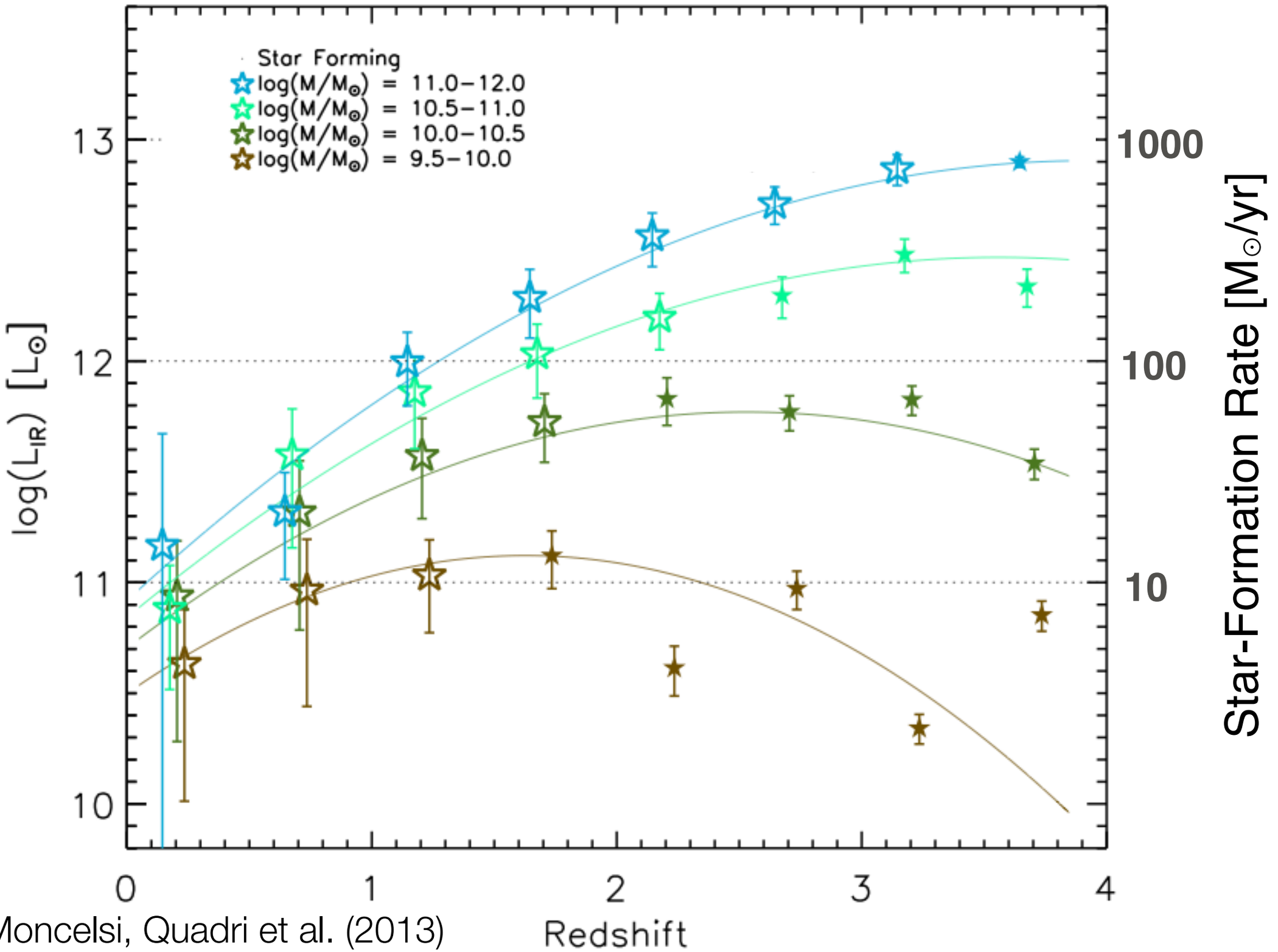
Modeling the Background: SIMSTACK

redshift slices

stellar mass slices



Modeling the Background: SIMSTACK

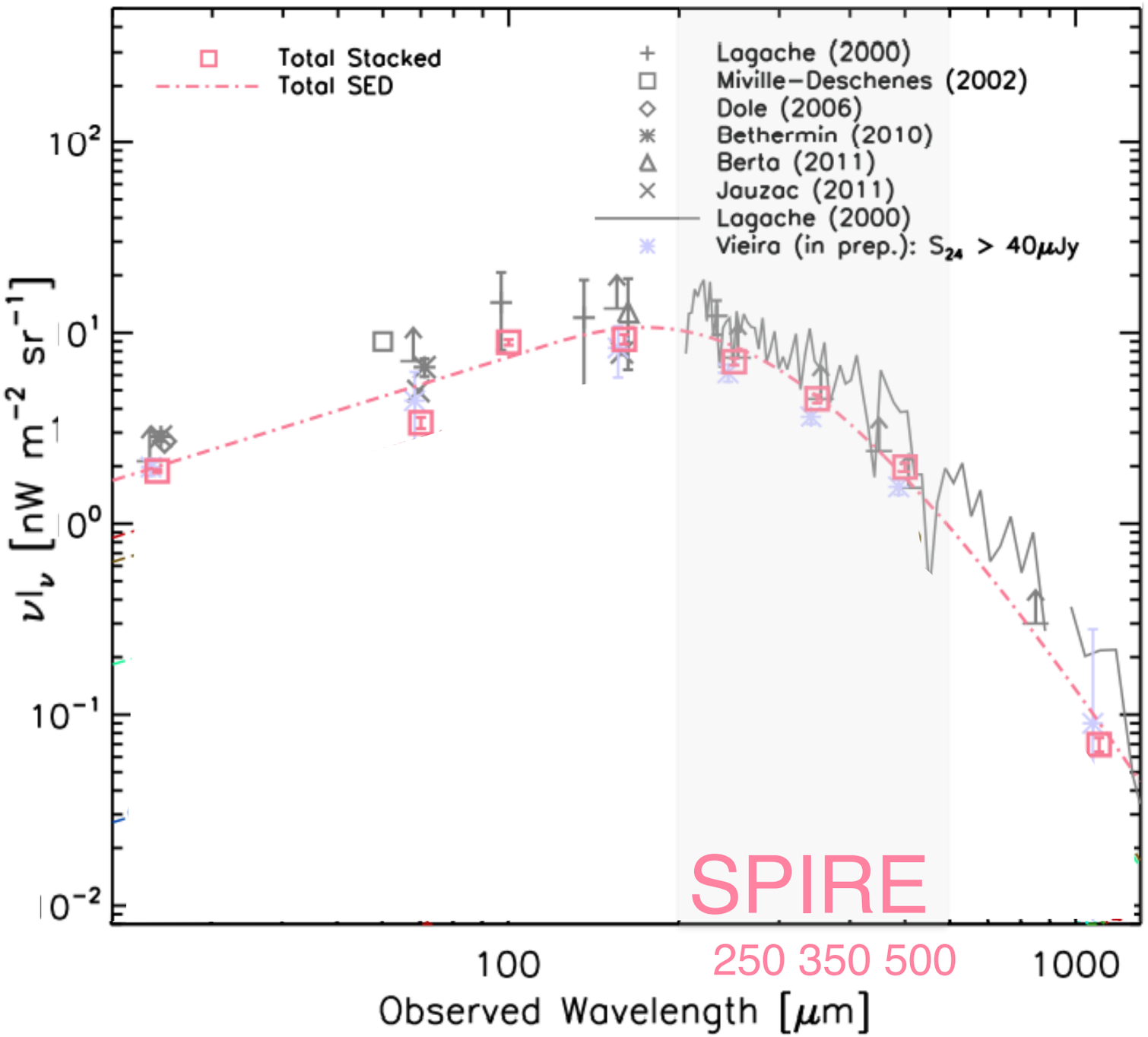


Viero, Moncelsi, Quadri et al. (2013)
arXiv:1304.0446

Origin of the CIB

HERMES

~70% at SPIRE wavelengths



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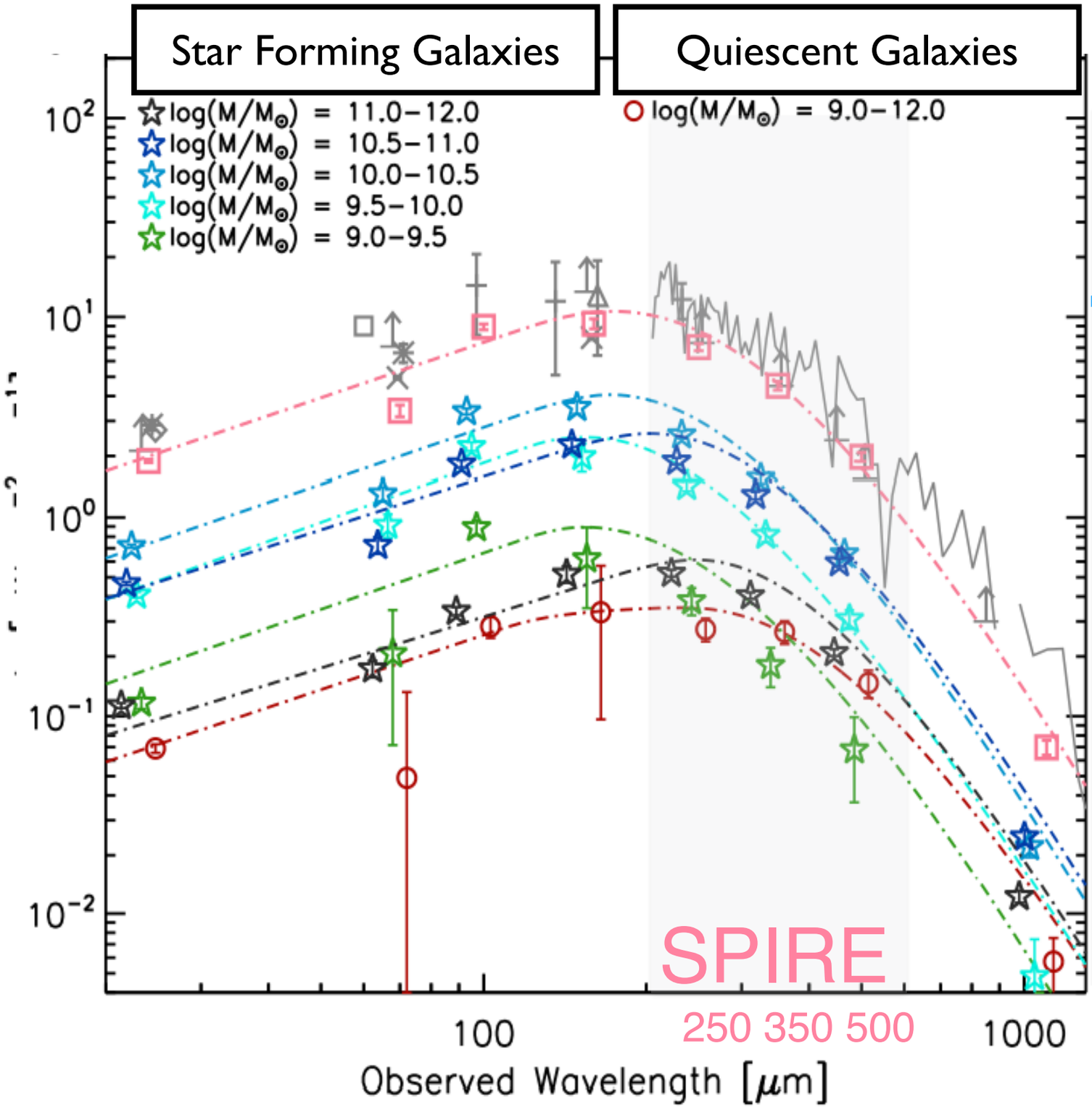


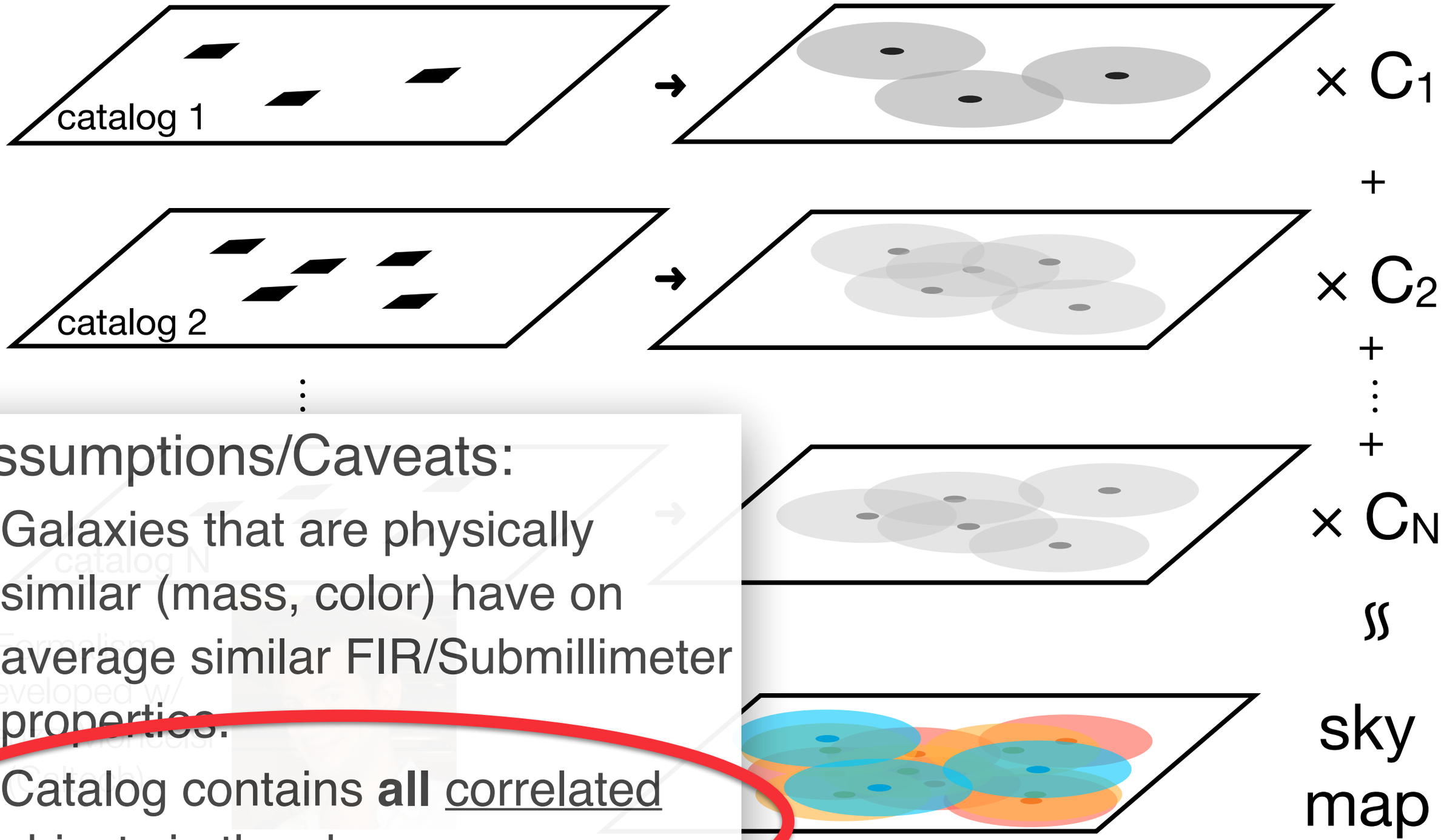
~70% at SPIRE wavelengths

log(M/M⊙~10-11)
i.e., M ≲ M*

What about the rest?

Viero, Moncelsi, Quadri et al. (2013)
arXiv:1304.0446

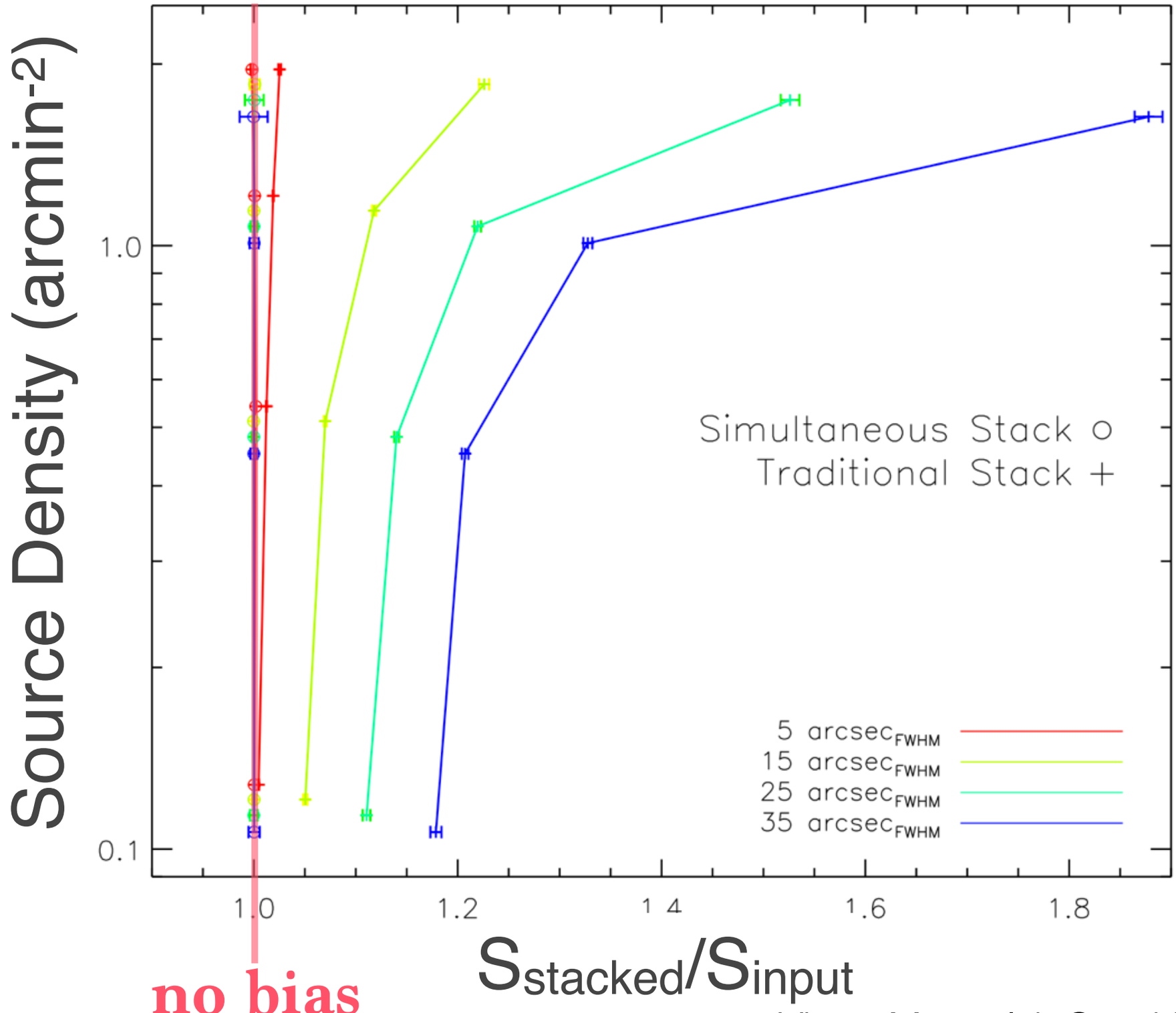
SIMSTACK: Synthetic Image Fitting Algorithm



Assumptions/Caveats:

- Galaxies that are physically similar (mass, color) have on average similar FIR/Submillimeter properties.
- Catalog contains **all** correlated objects in the sky.

Simulation: correlated (i.e., clustered) sources



Viero, Moncelsi, Quadri et al. (2013)
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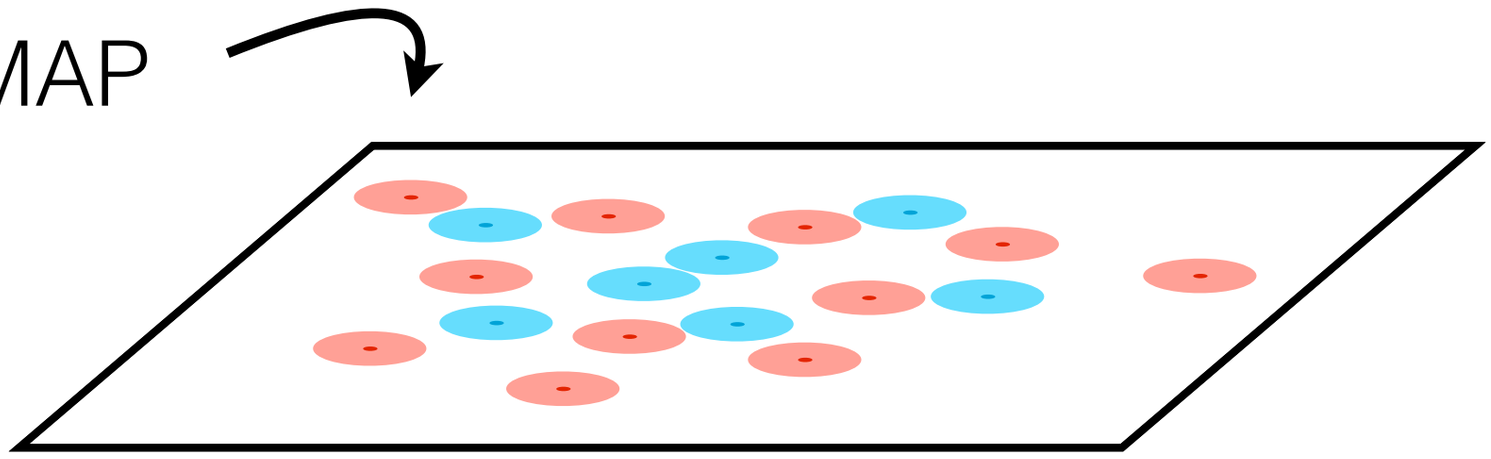
A Census of the Entire CIB

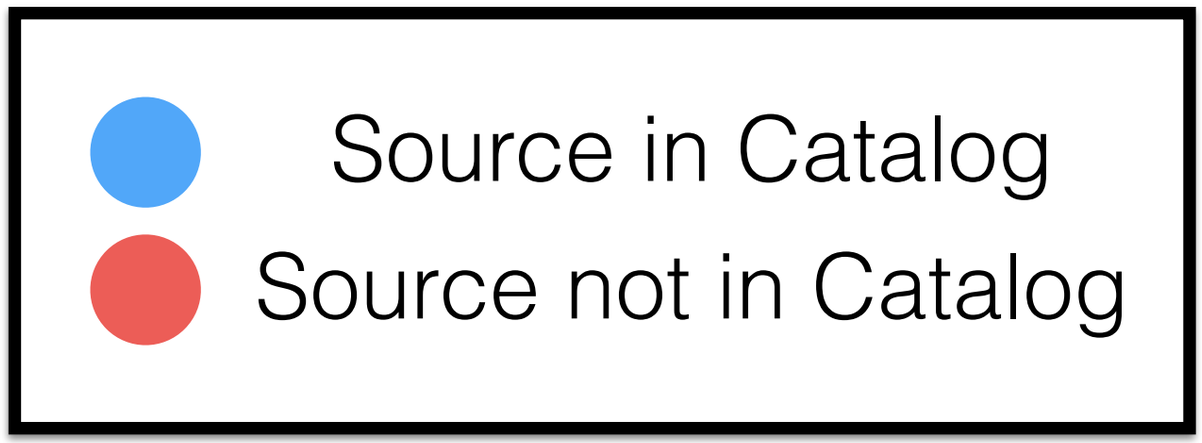
Source in Catalog

Source not in Catalog

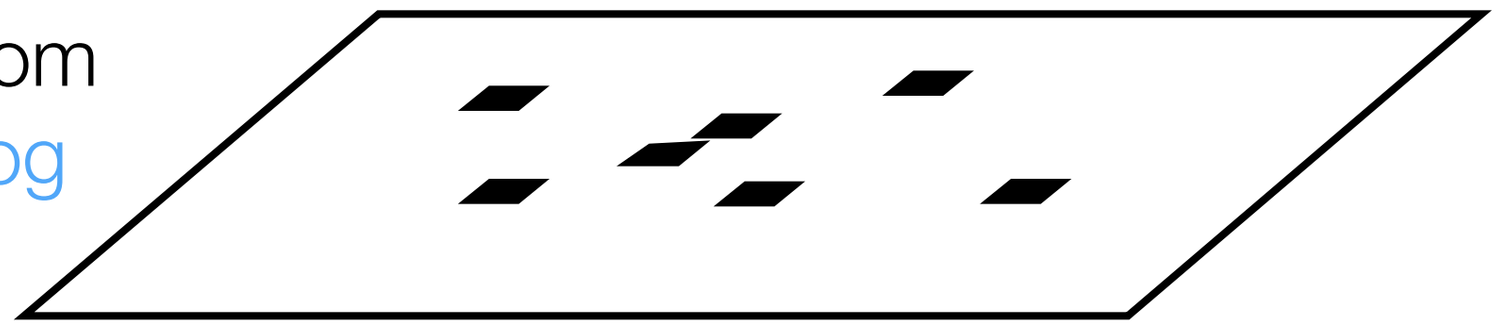
Imagine this is a SKY MAP



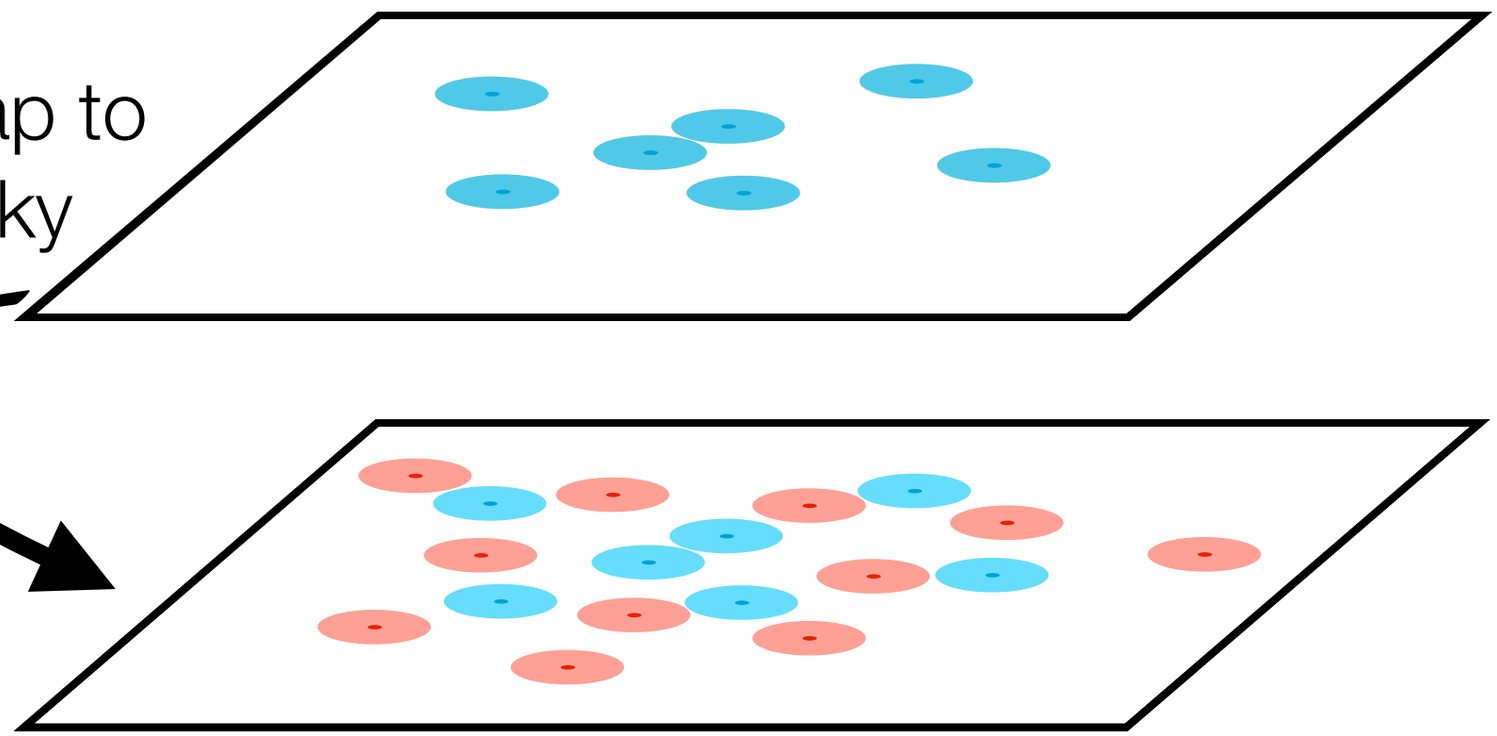
A Census of the Entire CIB



make synthetic “hits” map from positions of sources in catalog



fit “synthetic” map to the map of the sky



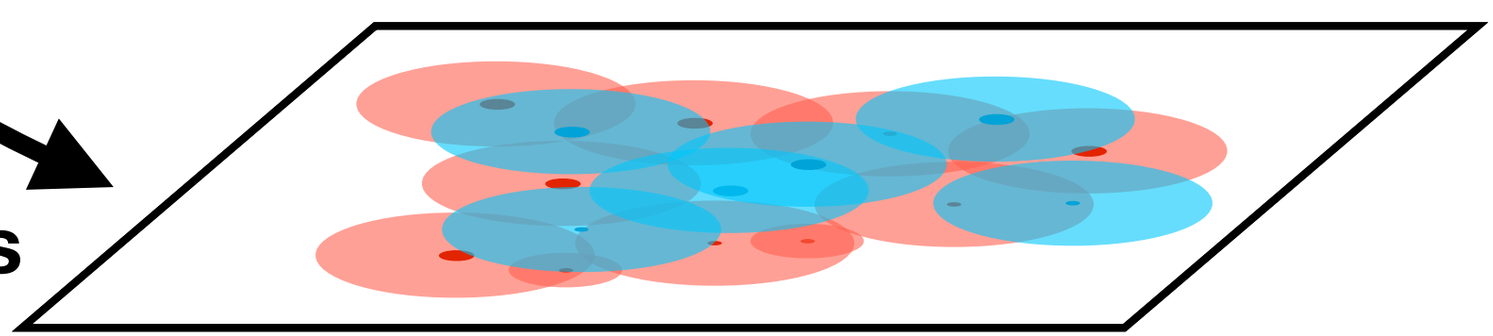
***Un*biased if :**
-beam is small

A Census of the Entire CIB

Review:

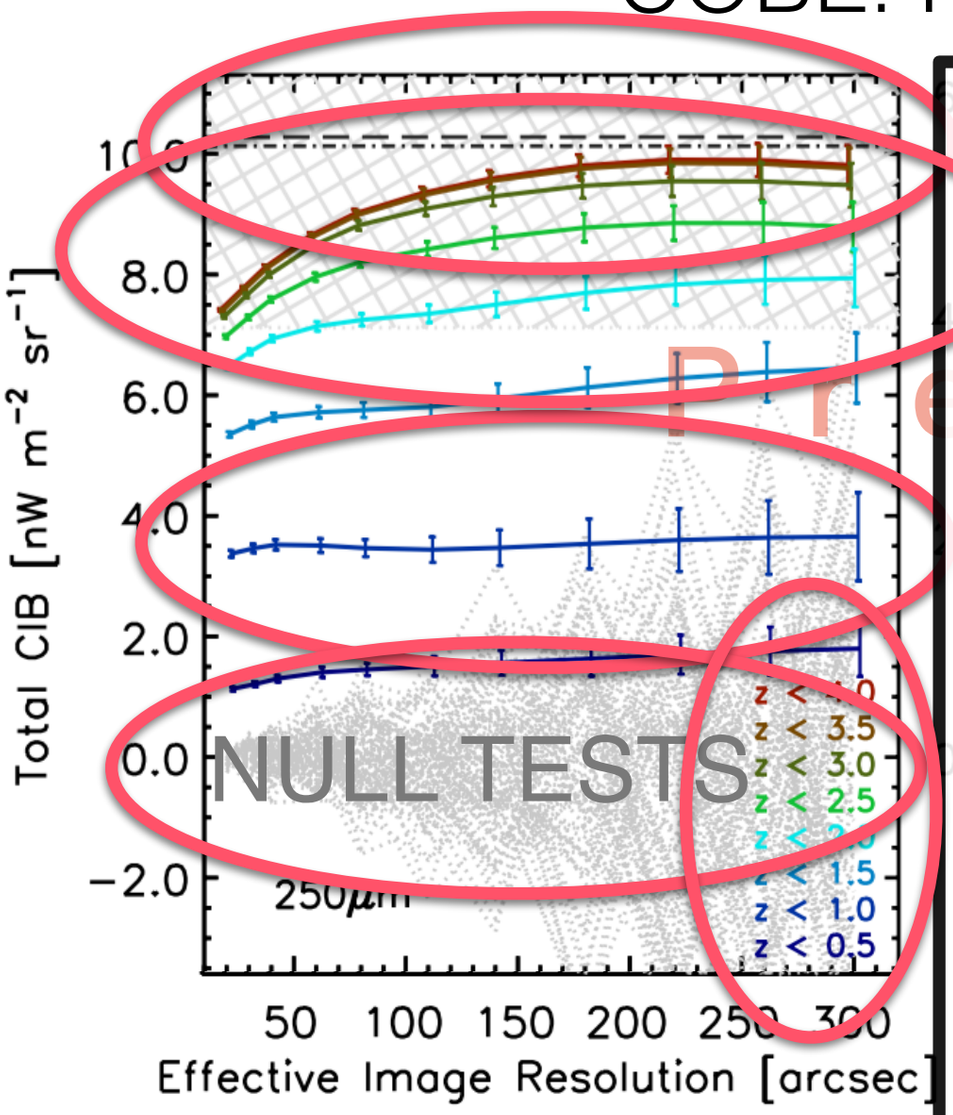
- Bias **only** from correlated sources (e.g., sources at z=1 and at z=3 are not correlated).
- Increase the beam -> increase the bias (and the noise).
- If you recover less that the total CIB, it means missing flux is *uncorrelated*, probably from higher redshift
- Random positions should return Nulls (Synthetic and sky maps are mean-subtracted)

***Biased* if :**
-beam is big
-missing a lot of sources



A Census of the Entire CIB

COBE: Fixsen 1998 ----------



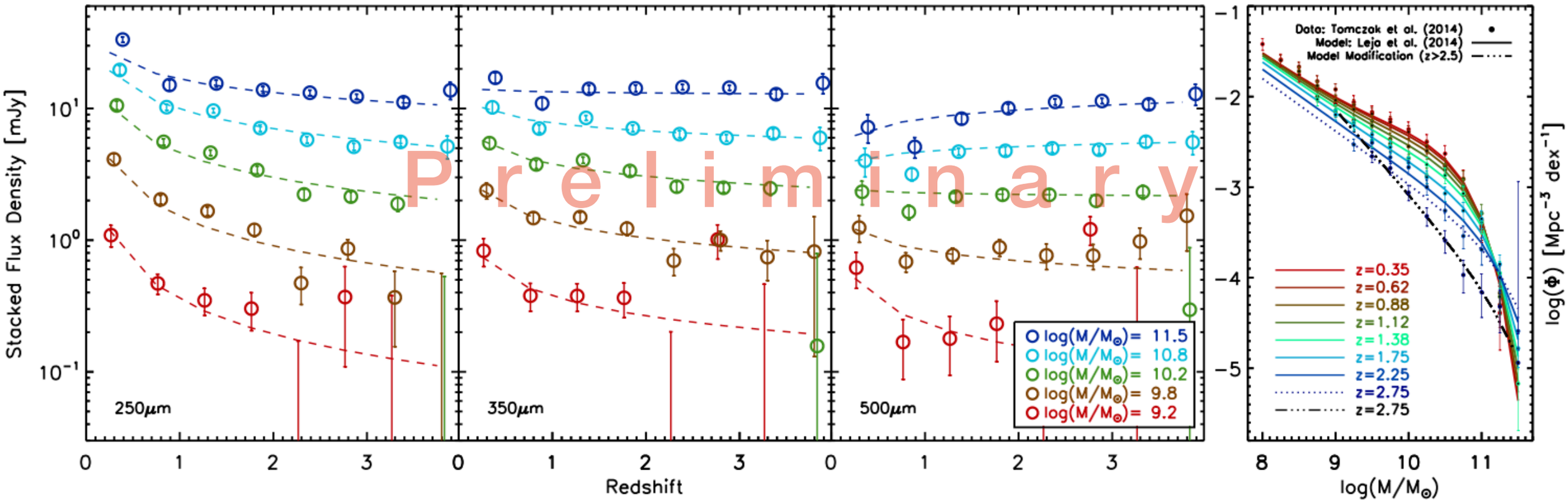
- x-axis increasing beam
- y-axis cumulative Total up to given z
- FIRAS Direct measurement ~30% errors
- Null tests on random positions
- Flat because Catalog is ~100% complete to log(M/Msun) = 9 - 11.5
- Nearly all of the CIB is accounted for by sources correlated with known, cataloged, galaxies. *But is it originating from galaxies, or something else?*

Smooth with bigger beam →

A Census of the Entire CIB

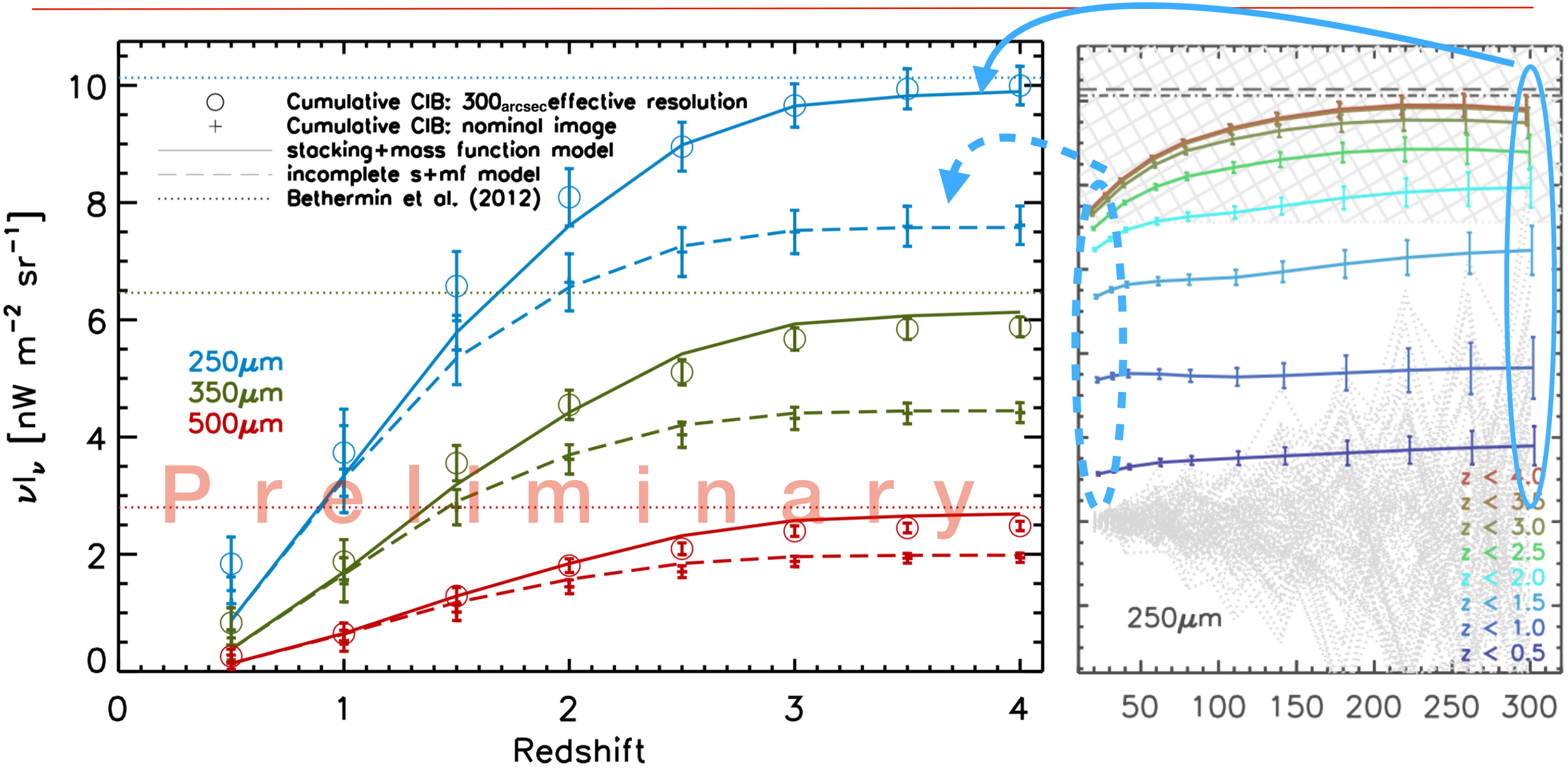
Submillimeter Flux Densities

Stellar Mass Functions



- Parametric fit to the (nominally) stacked flux densities (dotted lines)
- Parametric fit to the stellar mass functions from Leja et al. 2014 (solid lines)

A Census of the Entire CIB



- Circles/Solid lines: Model compared to total CIB after smoothing to 300 arcsec FWHM.

- Crosses/Dashed lines: Model without flux from sources that would be incomplete in catalog, compared to nominal stacking total CIB (WOW!)

Modeling the Background: Synergies with ALMA

- Current State of Model:
  - ➡Discrete Coarse Binning into z, $M_{stellar}$, Star-Forming/Quiescent
  - ➡SF/QT color cut uses (only) rest-frame U, V, J bands
  - ➡Blind fitting with no priors

- How it can be Improved:
  - ➡Further separation (not limited to UVJ) into more sub-classes, e.g.,
    - AGNs, SMGs, Ages/Dustiness
  - ➡Fitting for parameters of continuous functions (including across frequencies)
  - ➡Introduce observational priors in fitting, particularly for intrinsically faint objects

- What's required:
  - ➡Determine adequate number of priors
  - ➡Compile a set of observations:
    - from existing observations (surveys (HUDF!!), targeted, or serendipitous)
    - by proposing for what does not already exist