16/02/2012

Astrophysics from radio to submillimeter

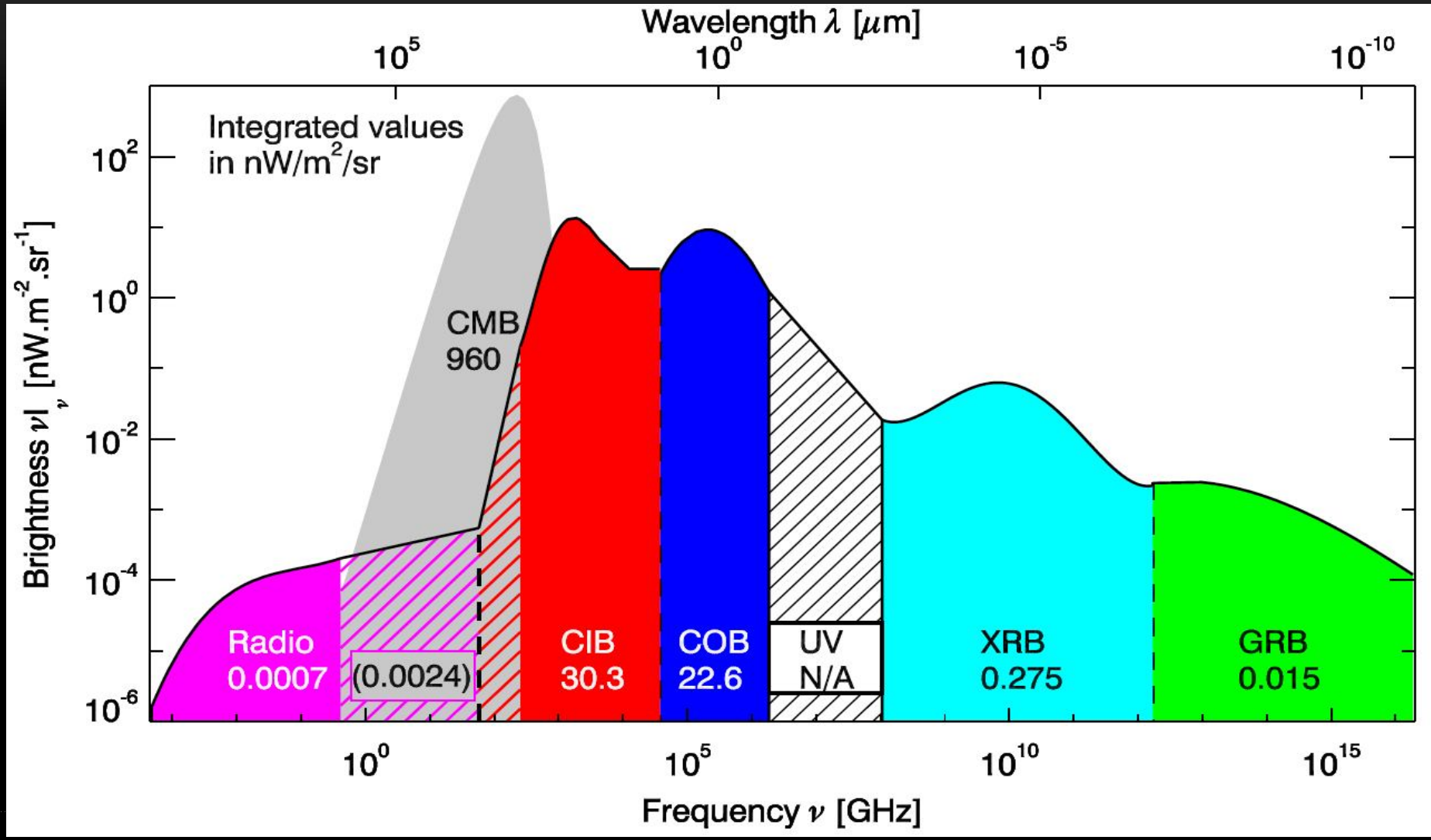
Bologna

WHICH ARE THE SOURCES RESPONSIBLE FOR THE COSMIC INFRARED BACKGROUND AND ITS ANISOTROPIES?

Matthieu Béthermin

CEA Saclay

SED OF THE EXTRAGALACTIC BACKGROUND LIGHT

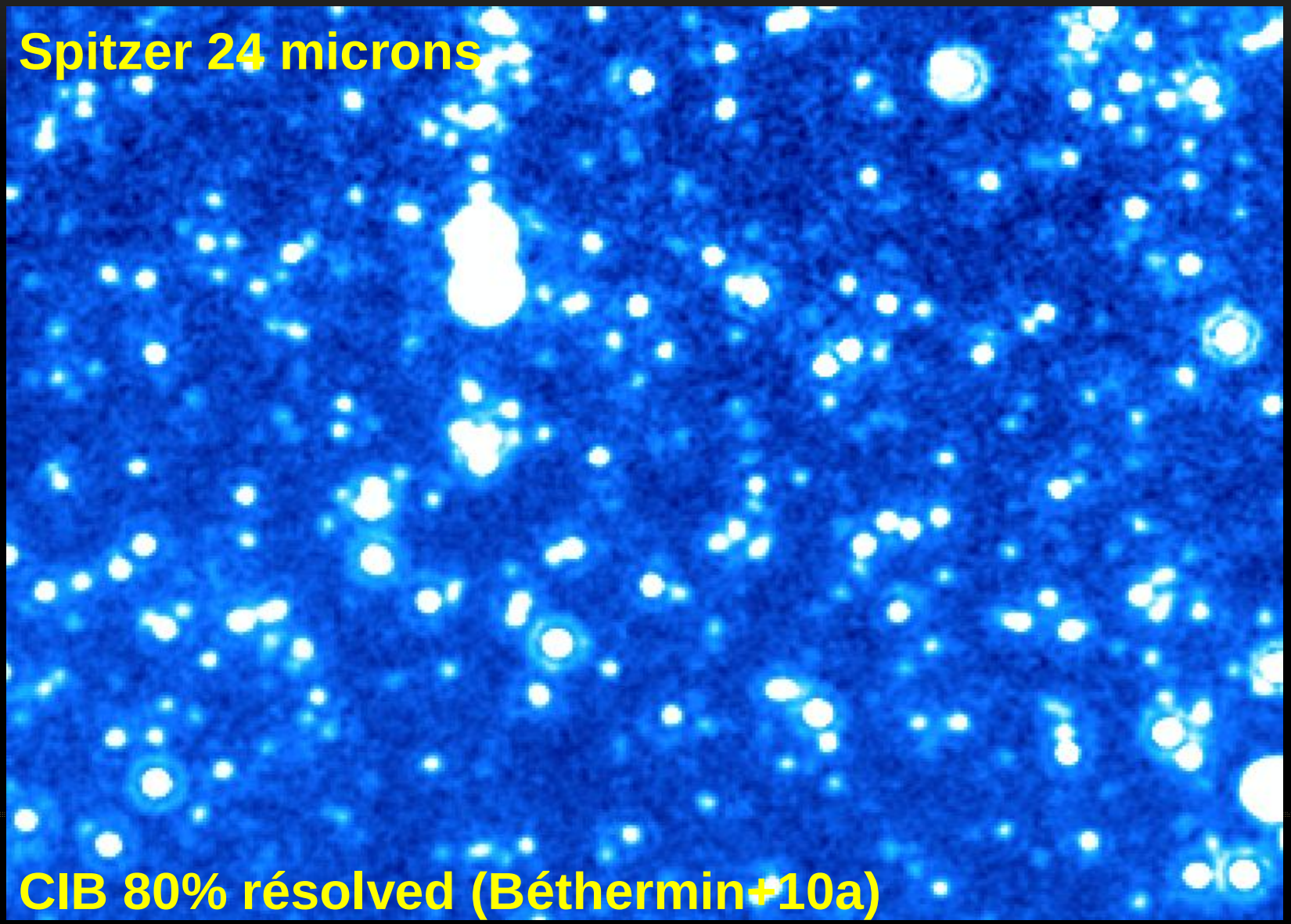


SED of the extragalactic background light (Dole & Béthermin, in prep.)

RESOLVING THE COSMIC INFRARED BACKGROUND

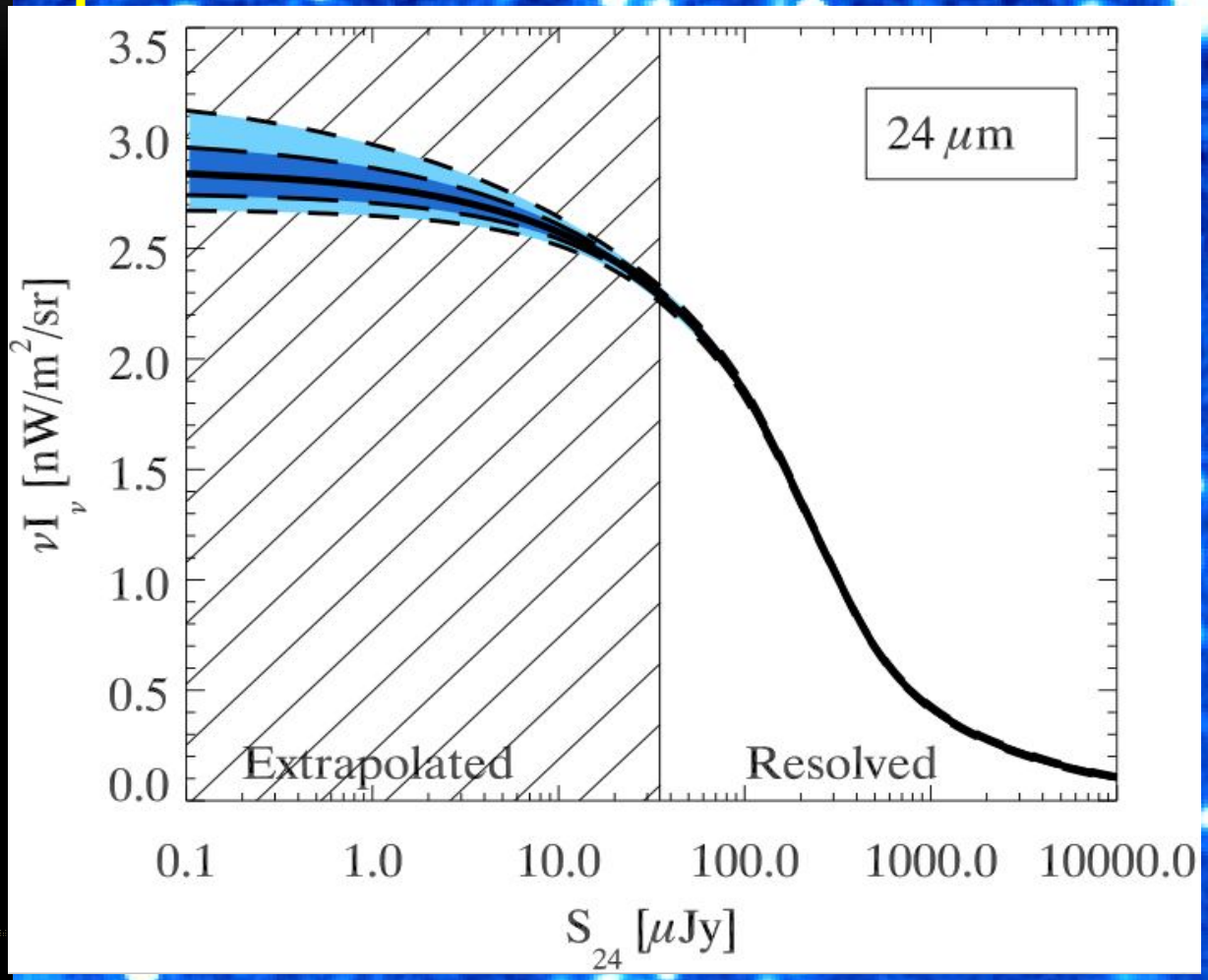
Which are the sources responsible for the cosmic infrared background?

RESOLVING THE CIB



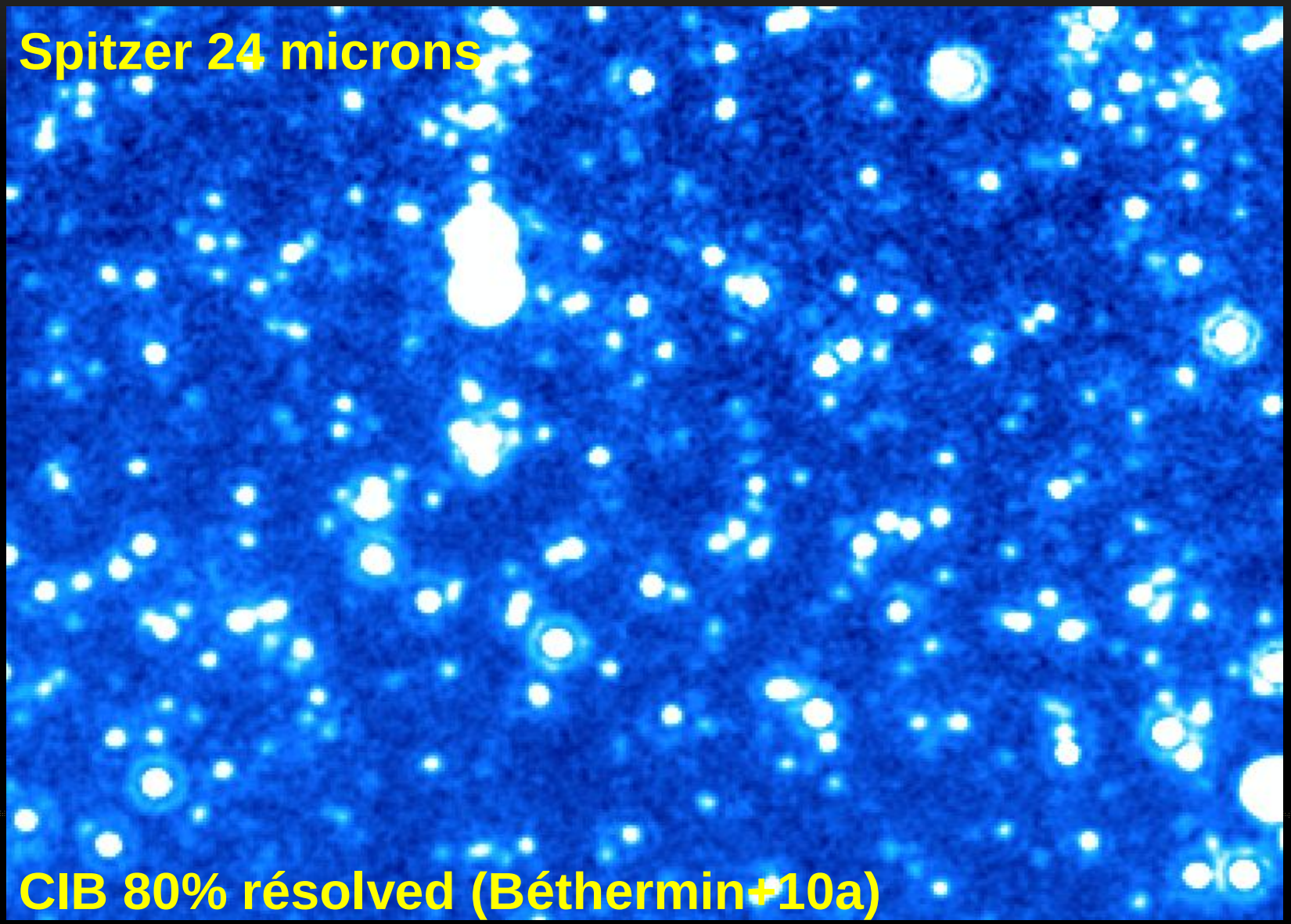
RESOLVING THE CIB

Spitzer 24 microns



CIB 80% résolved (Béthermin+10a)

RESOLVING THE CIB



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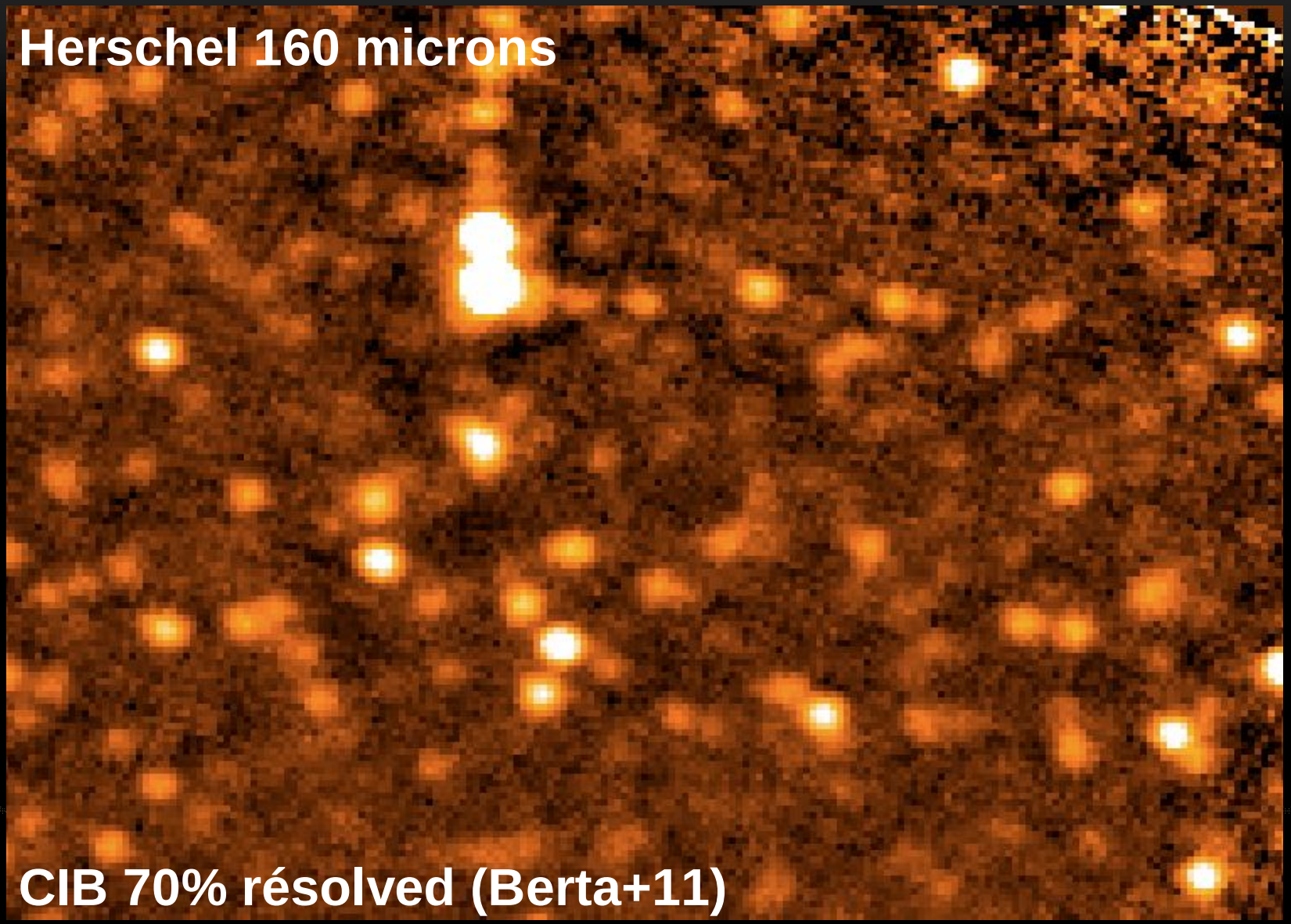
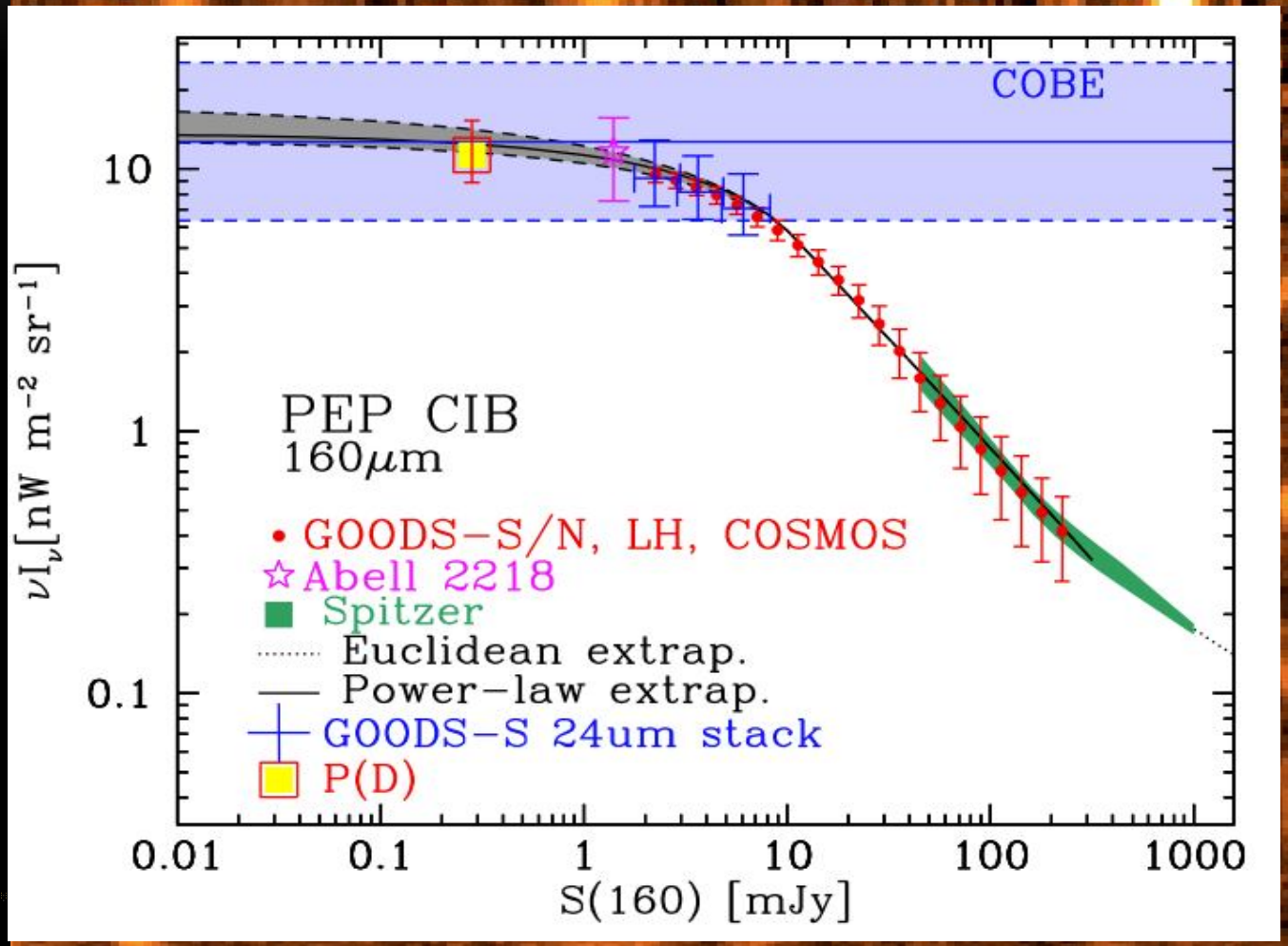


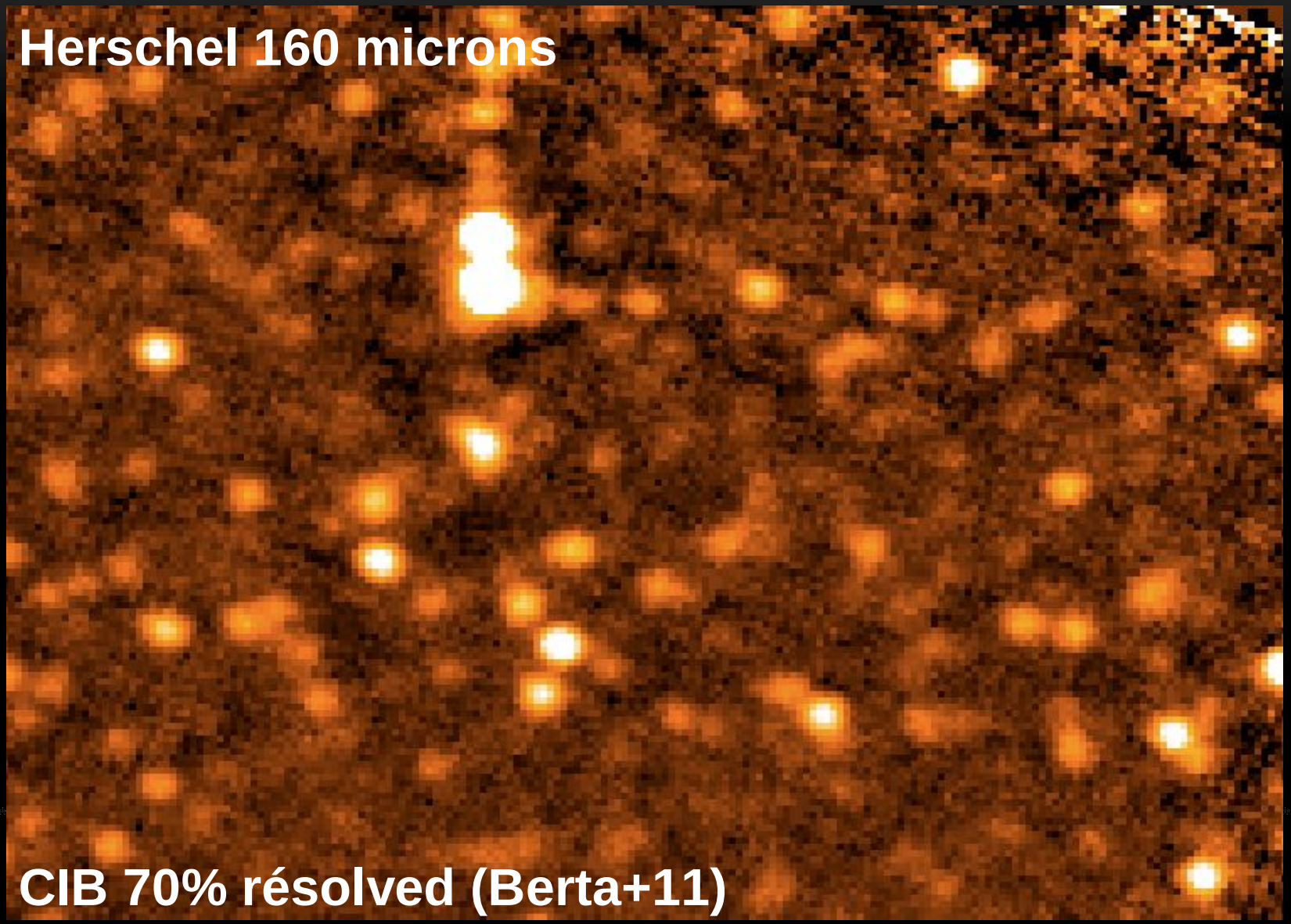
RESOLVING THE CIB

Herschel 160 microns



CIB 70% résolved (Berta+11)

RESOLVING THE CIB



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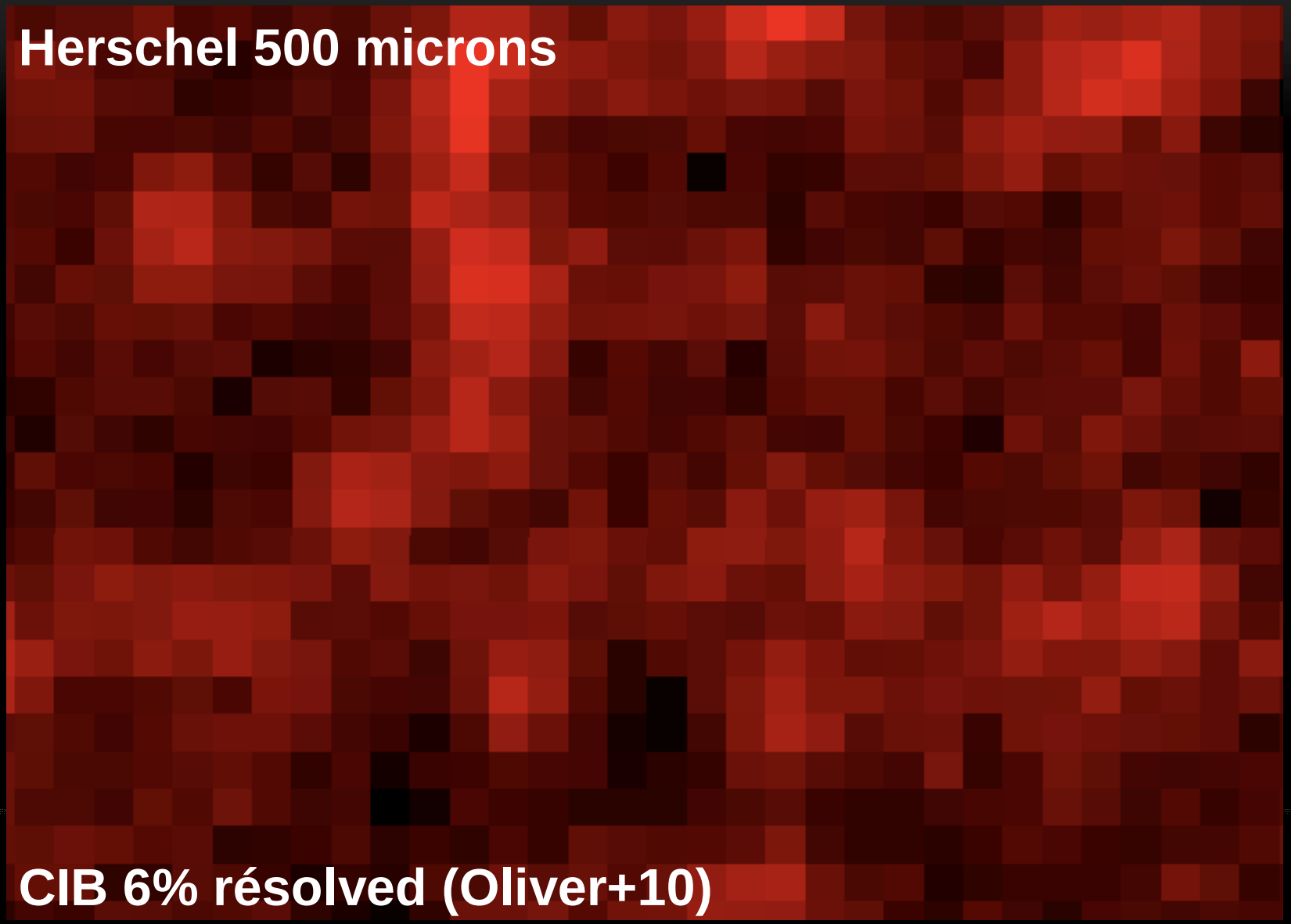
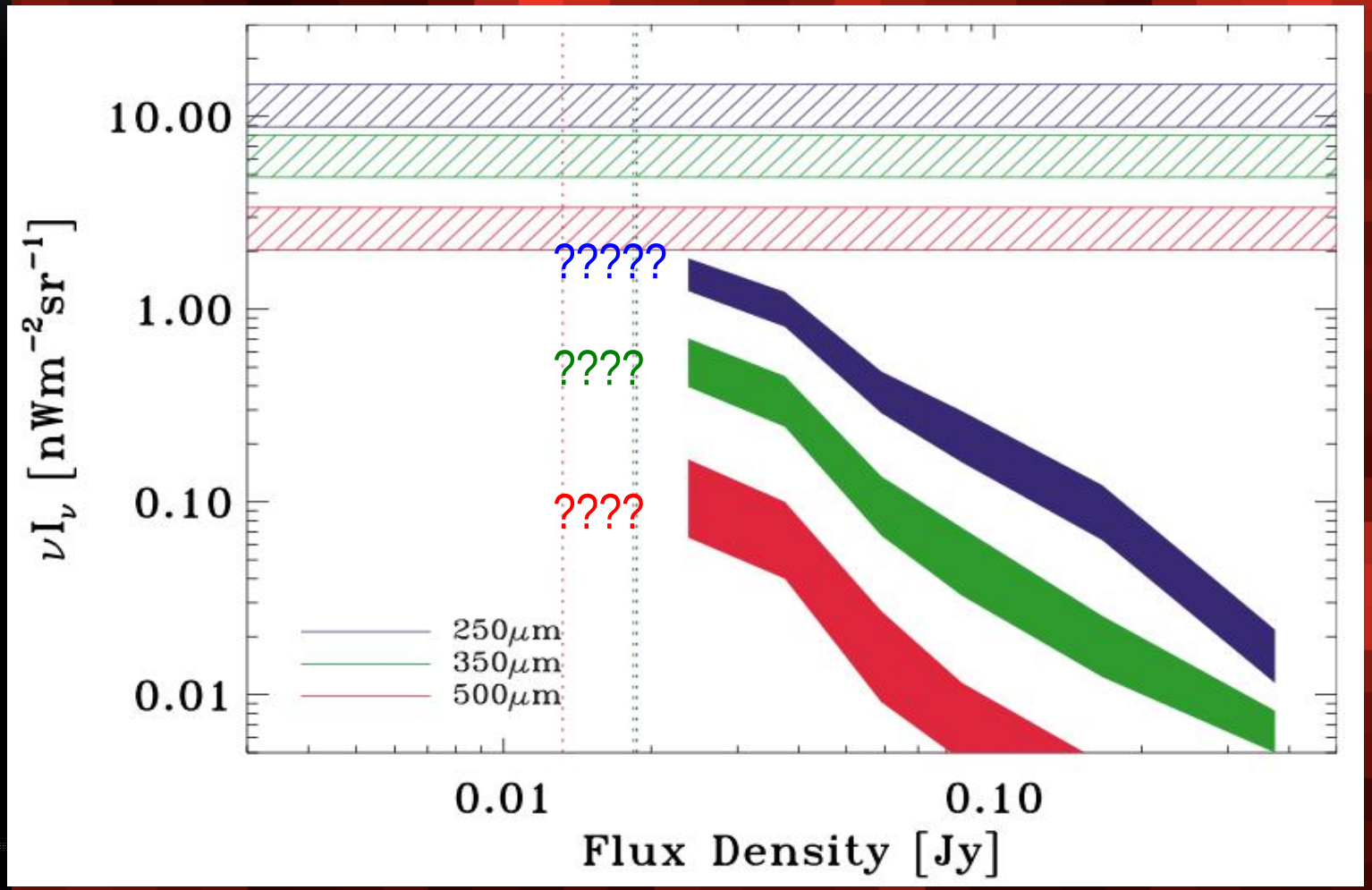


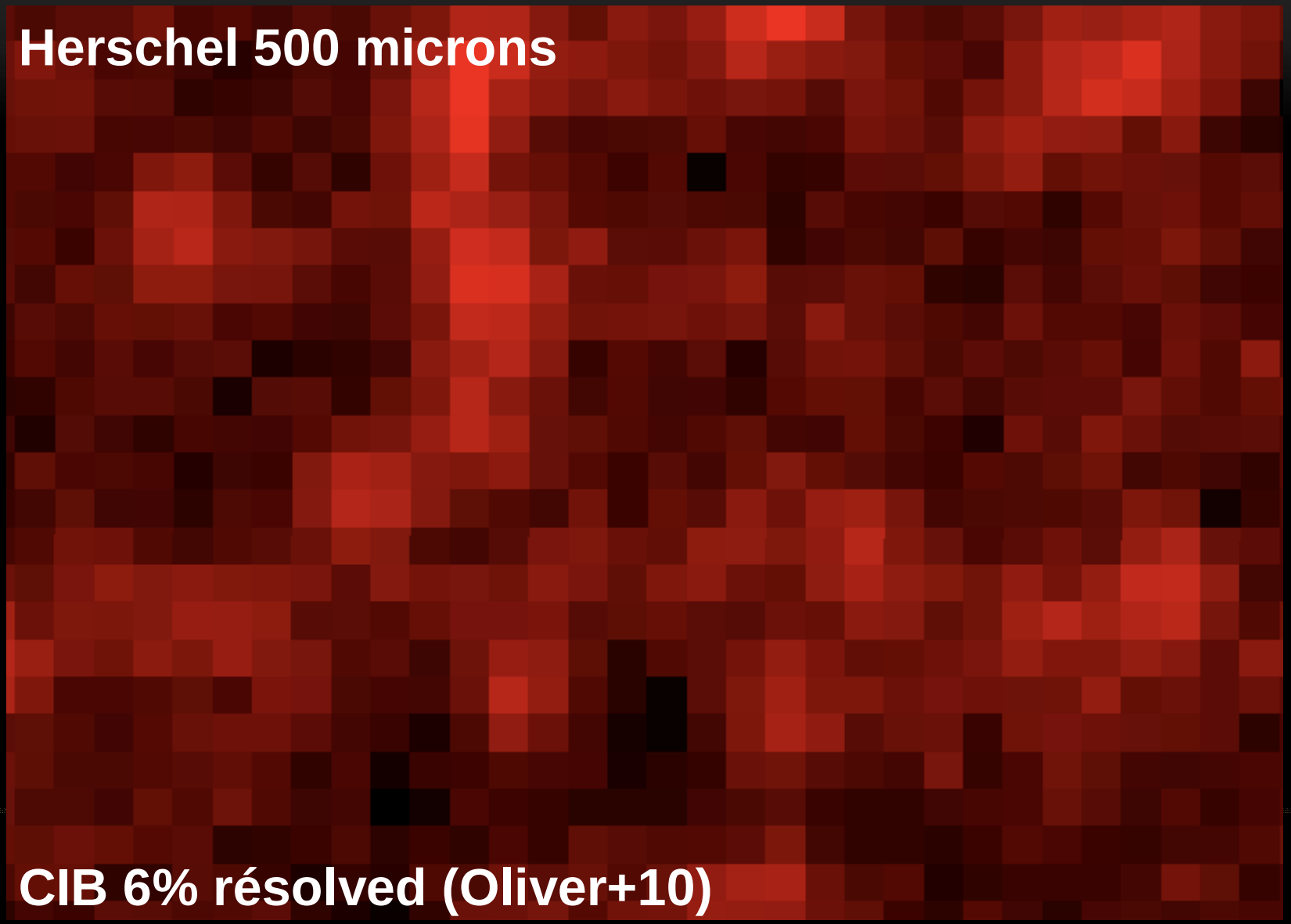
RESOLVING THE CIB

Herschel 500 microns



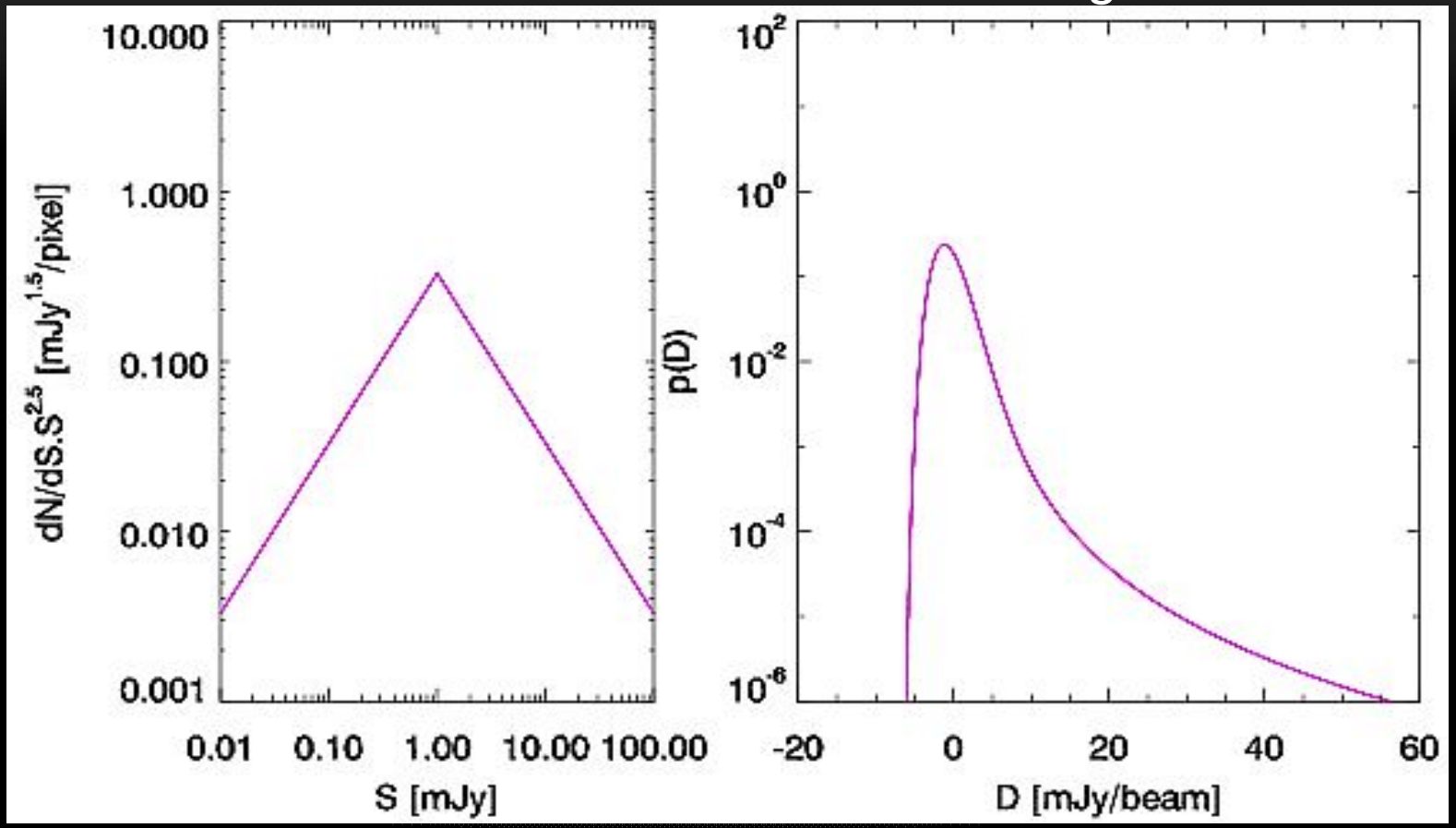
CIB 6% résolved (Oliver+10)

RESOLVING THE CIB



SOURCE COUNTING BY P(D) ANALYSIS

Number counts Histogram



Principle of the P(D) analysis

- HYPOTHESES: - POINT SOURCES
  - POISSON DISTRIBUTION
  - INSTRUMENTAL EFFECTS KNOWN (PSF, NOISE…)

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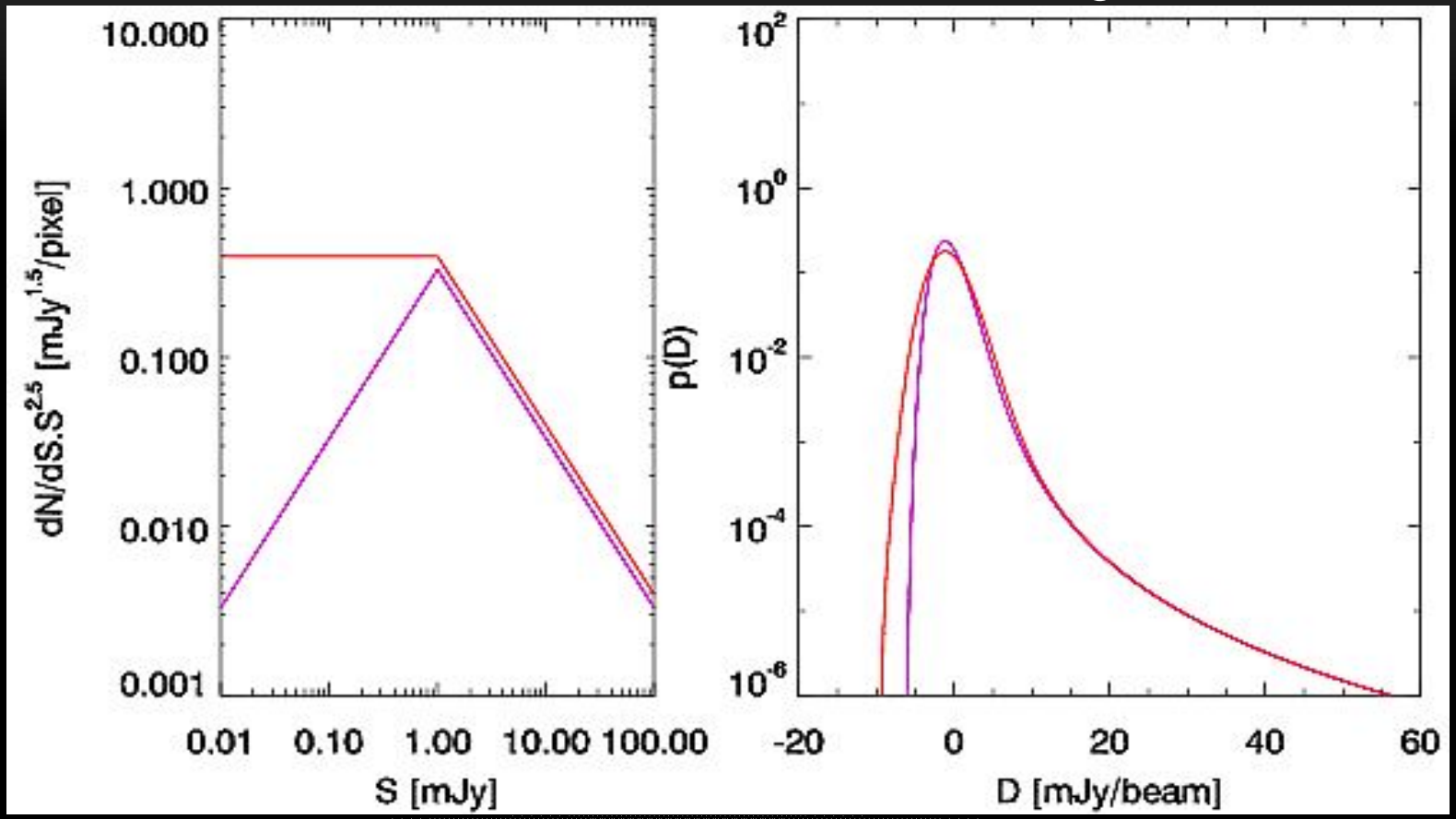

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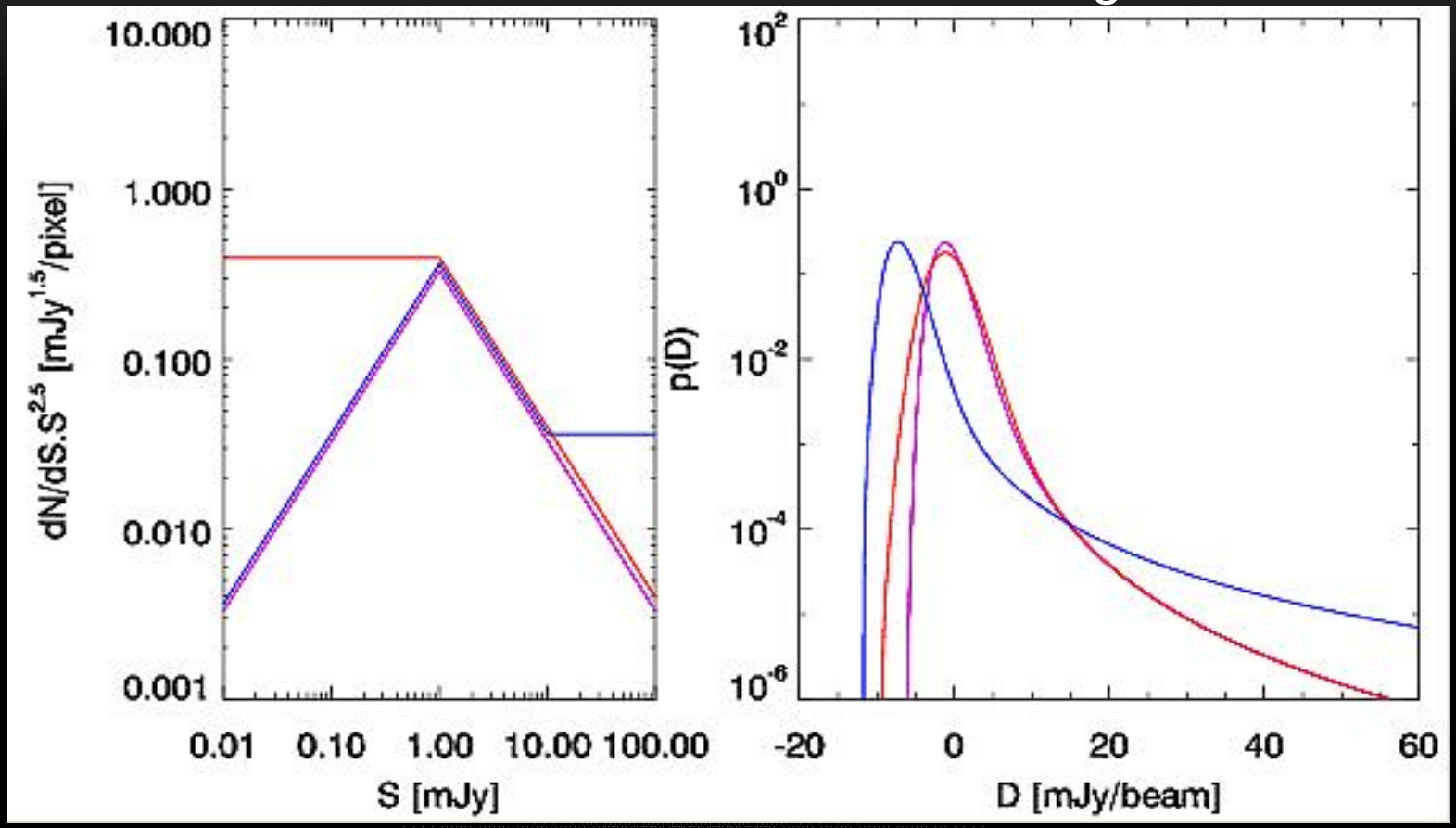

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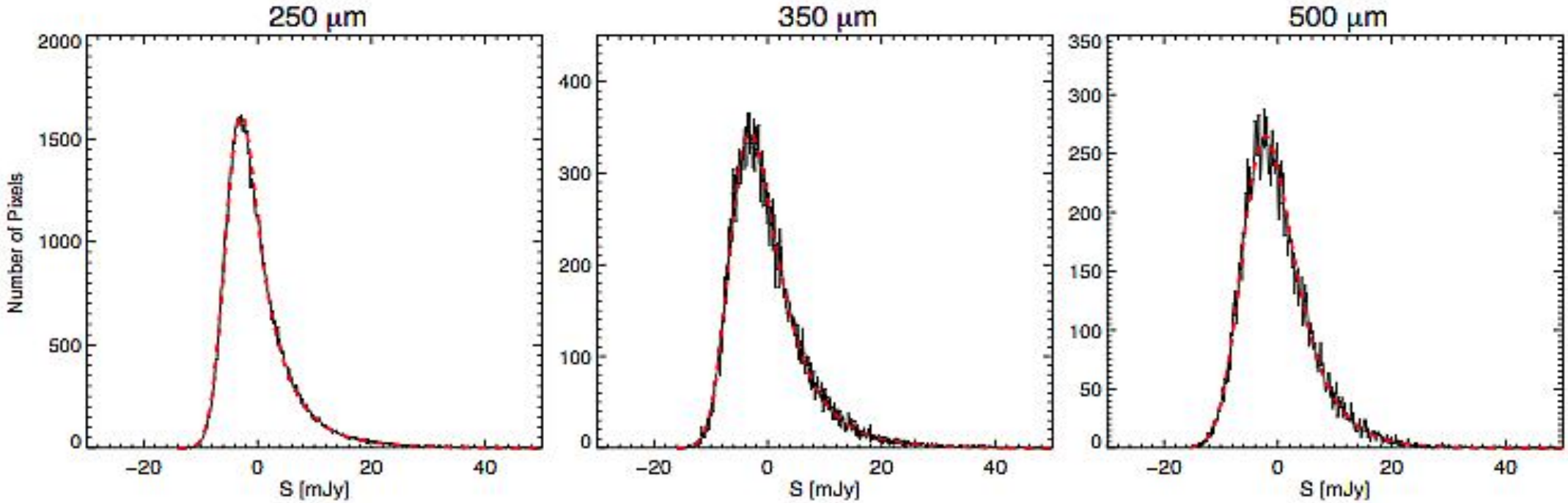
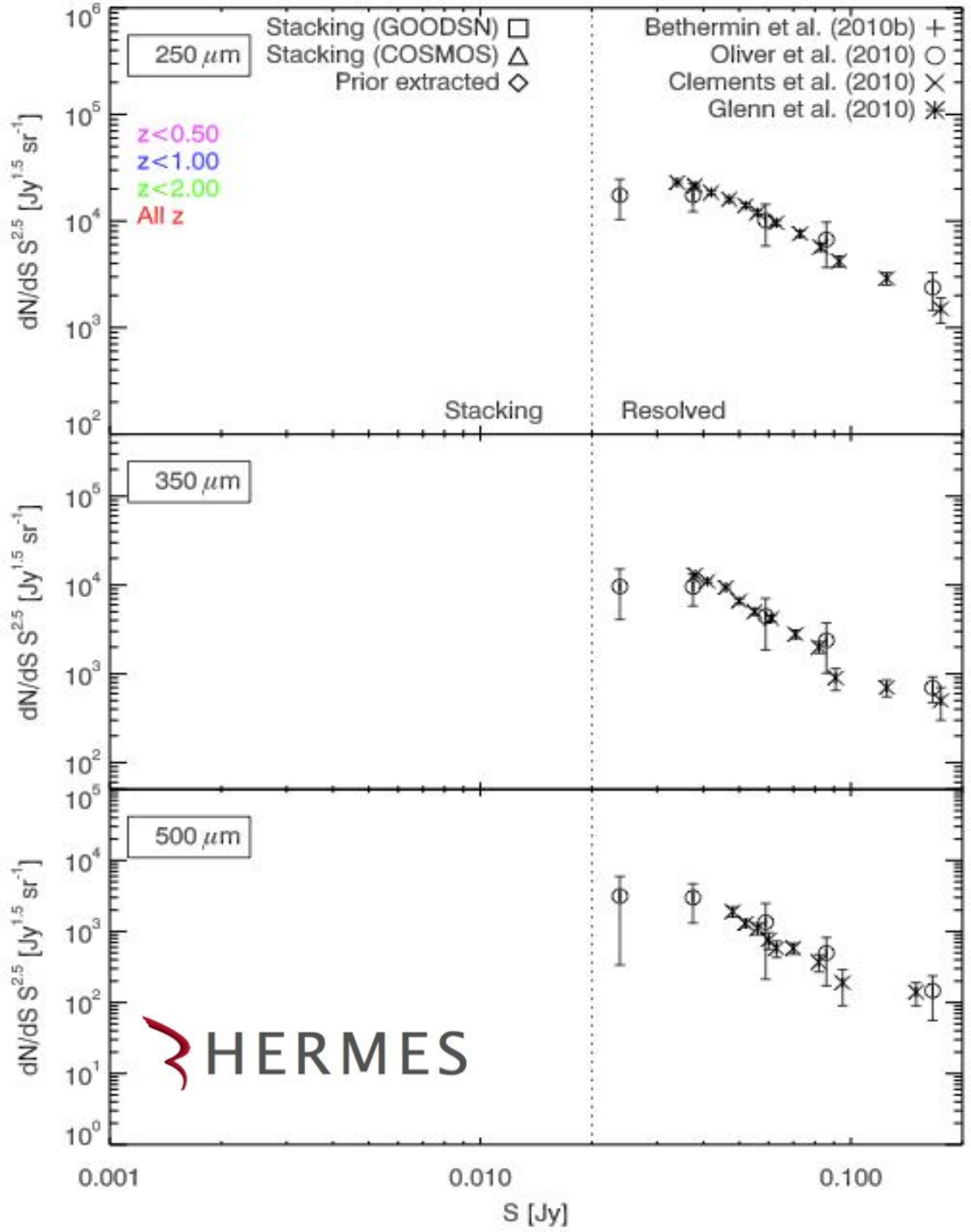


Fit of the histograms of the GOODS-N SPIRE maps (Glenn+10)

SOURCE COUNTS IN THE SUB-MM DOMAIN

- P(D) analysis probes flux densities about 10 times lower than classical methods.
- Clues of a turnover in the counts around 10 mJy.



Number counts at 250, 350 and 500 microns (Béthermin+12b,sub)

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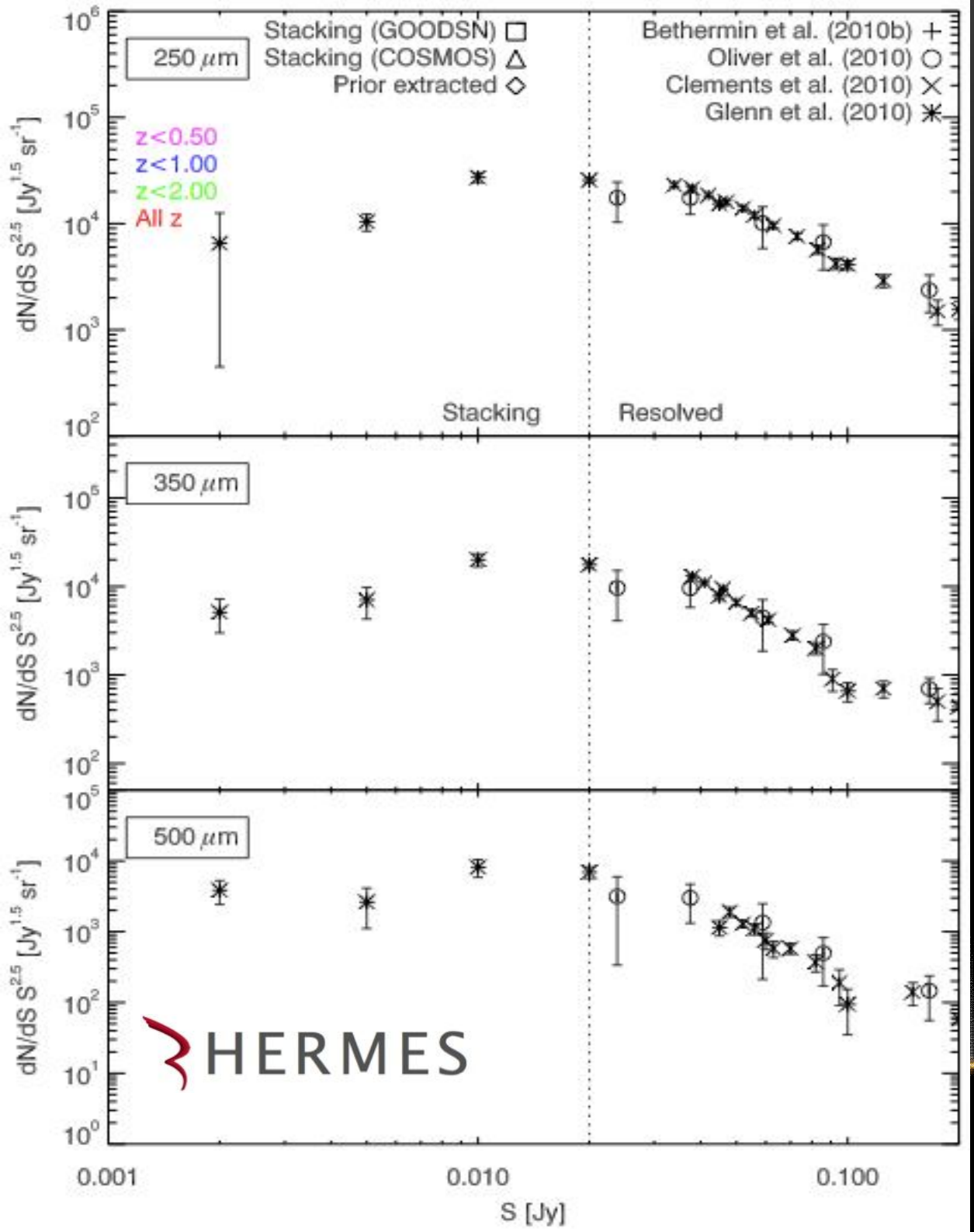

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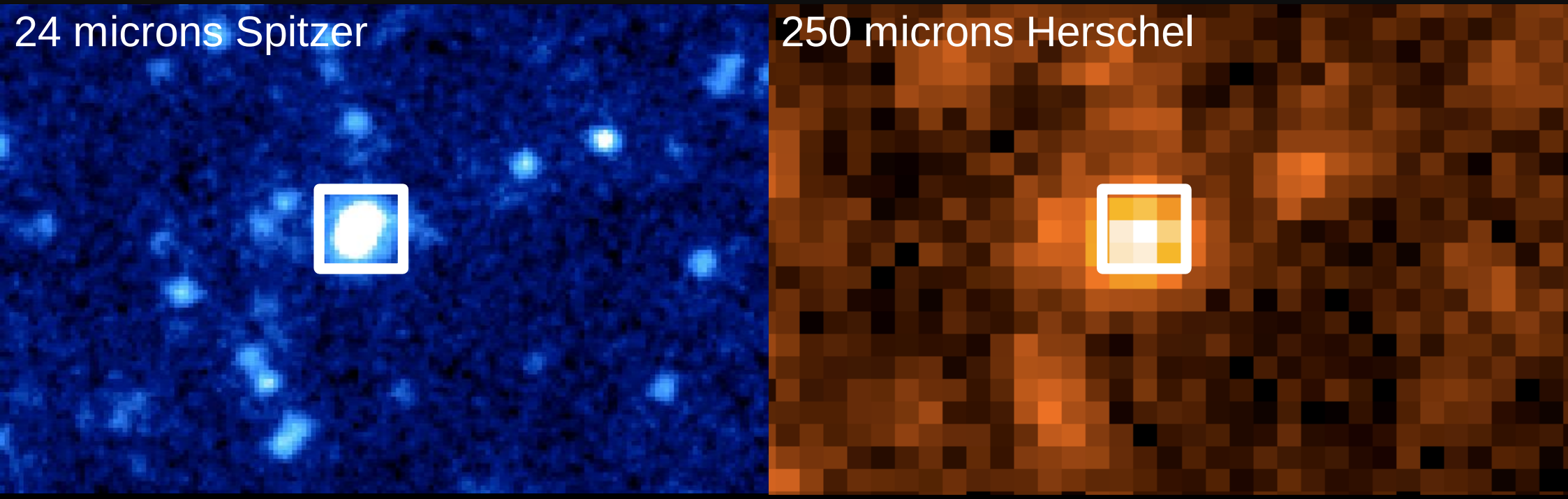
USING THE 24 MICRON OBSERVATIONS AS A PRIOR



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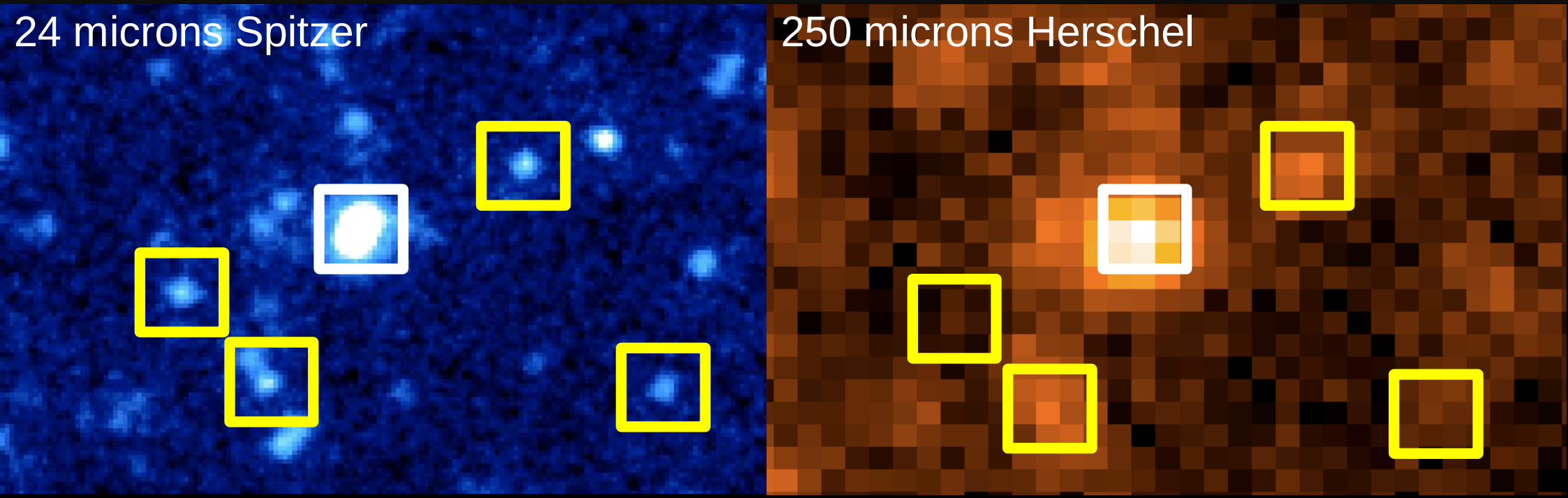
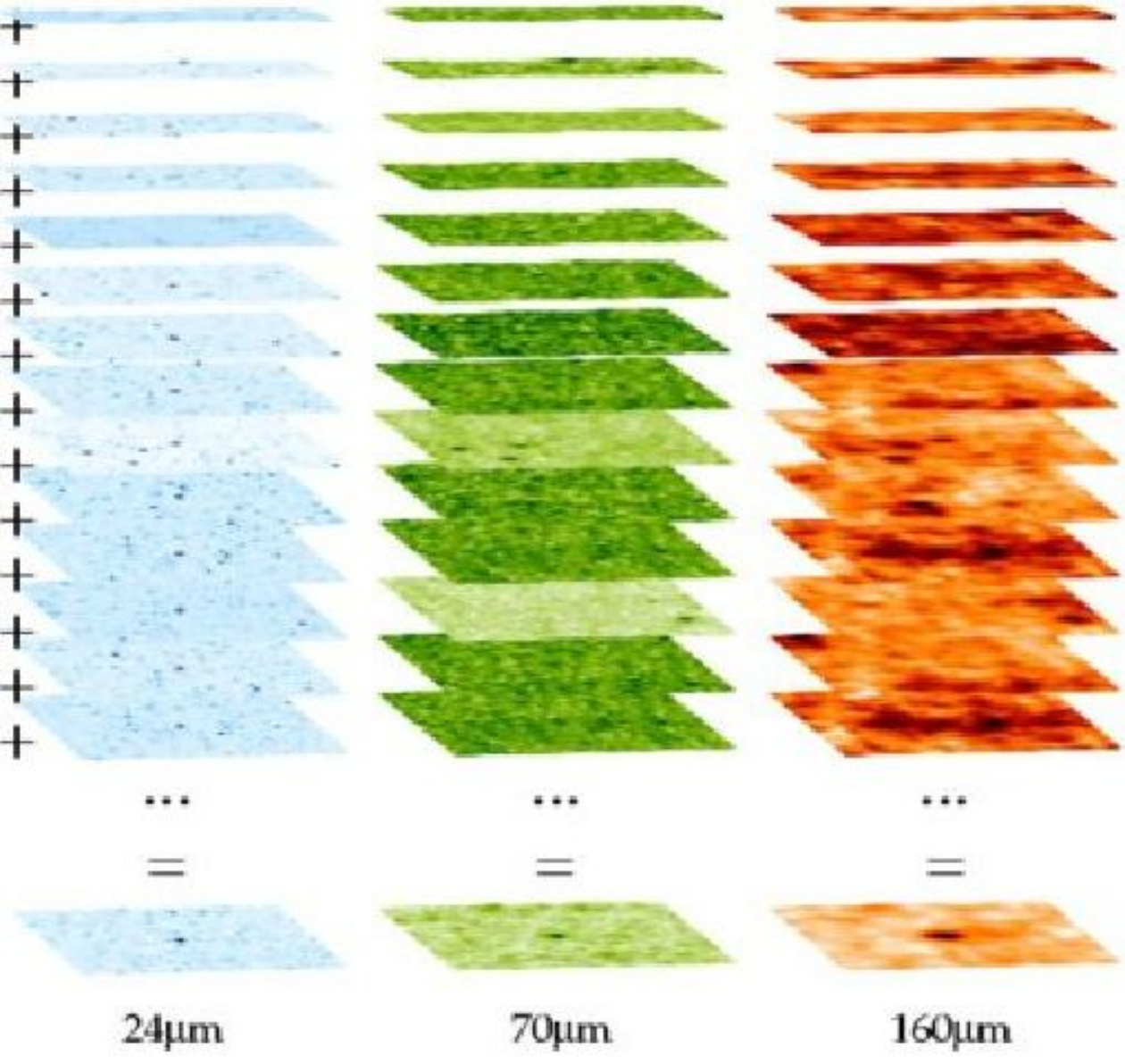


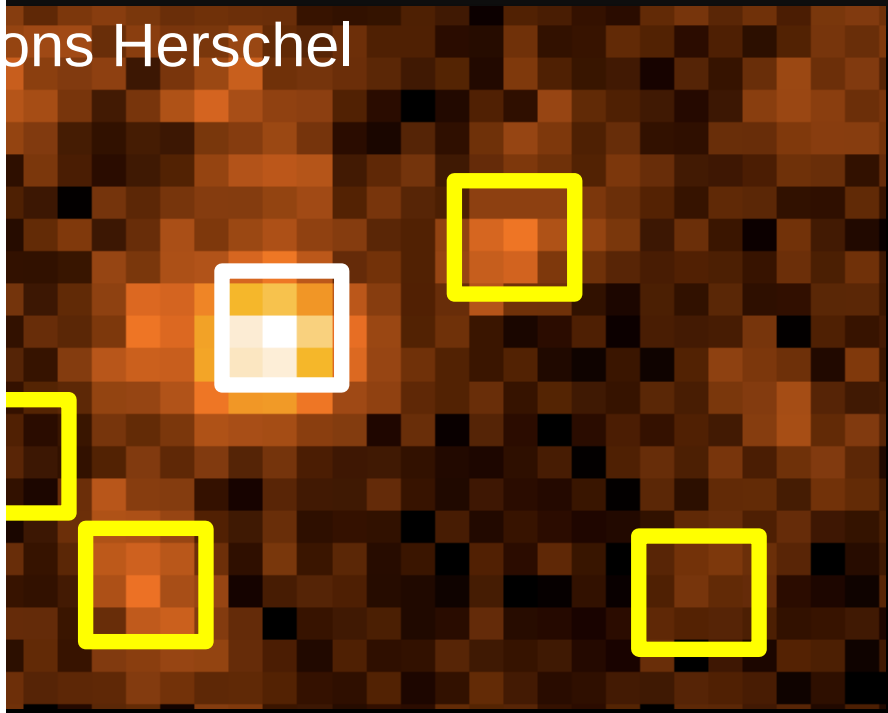
MIPS Stacking Analysis

Dole et al., 2006



TIONS AS A PRIOR

ons Herschel

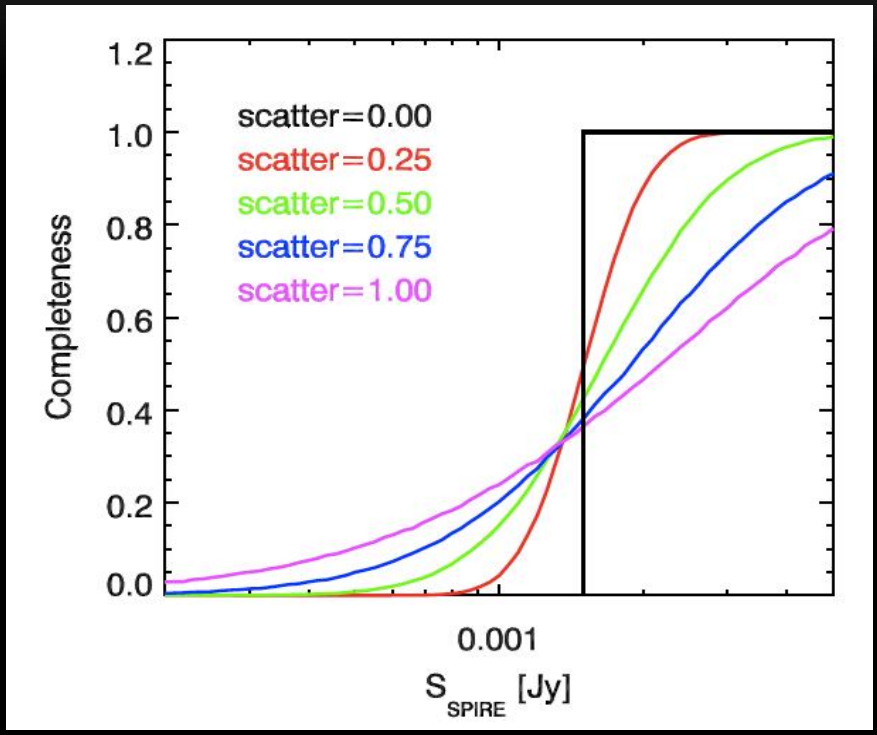


COUNTING SOURCES BELOW THE CONFUSION LIMIT BY STACKING ANALYSIS

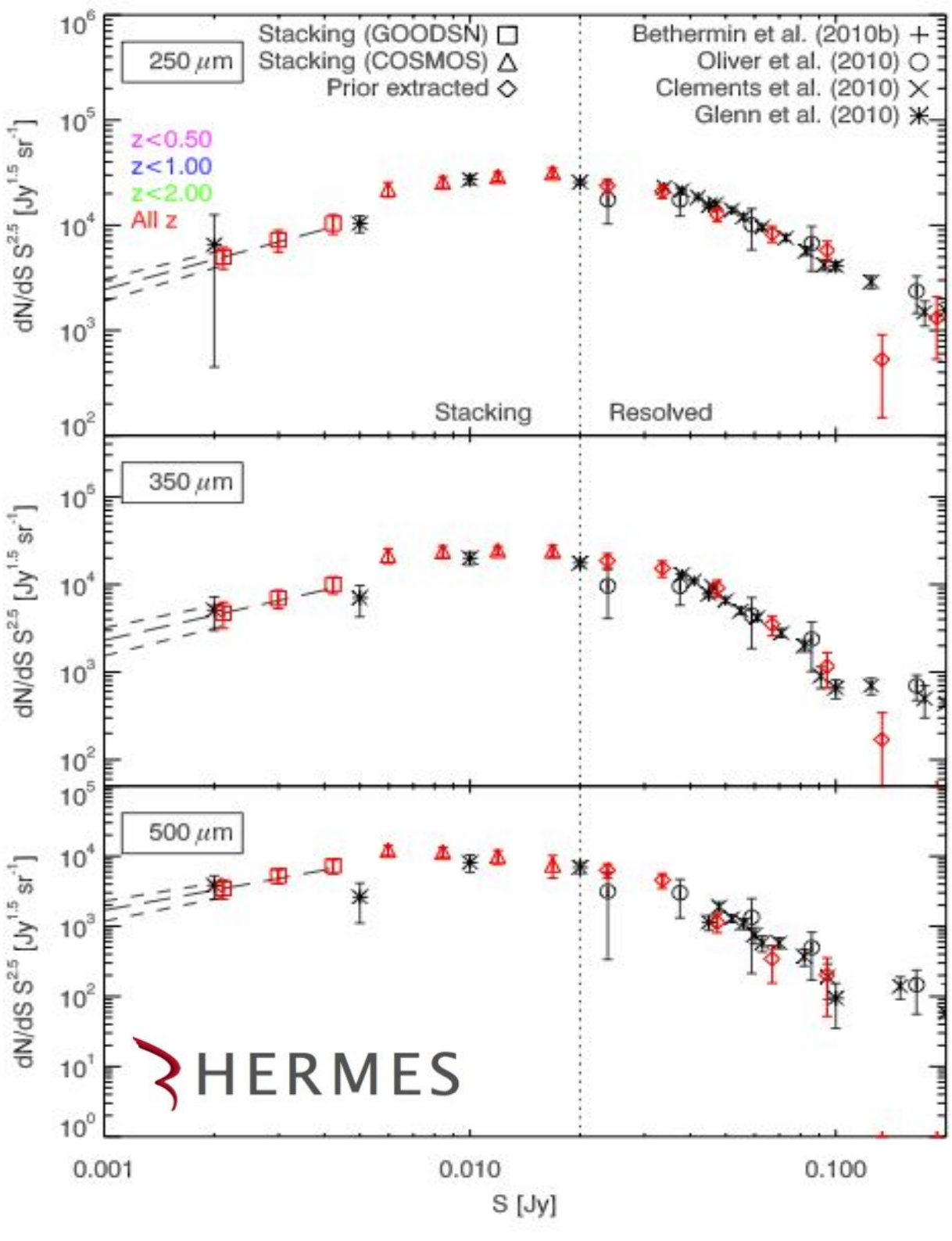
- Measured color per S24 and z slices.
- The scatter is estimated with a bootstrap method:

$$\sigma_{boot} = \frac{\sqrt{\sigma^2_{instr} + \sigma^2_{conf} + \sigma^2_{pop}}}{\sqrt{N_{stack}}}$$

- From the mean color and scatter (assumed to be log-normal), we convert the 24 microns flux into SPIRE flux. Several realizations are used to estimate the uncertainties.
- Correction of completeness taking into account the flux cut at 24 microns.



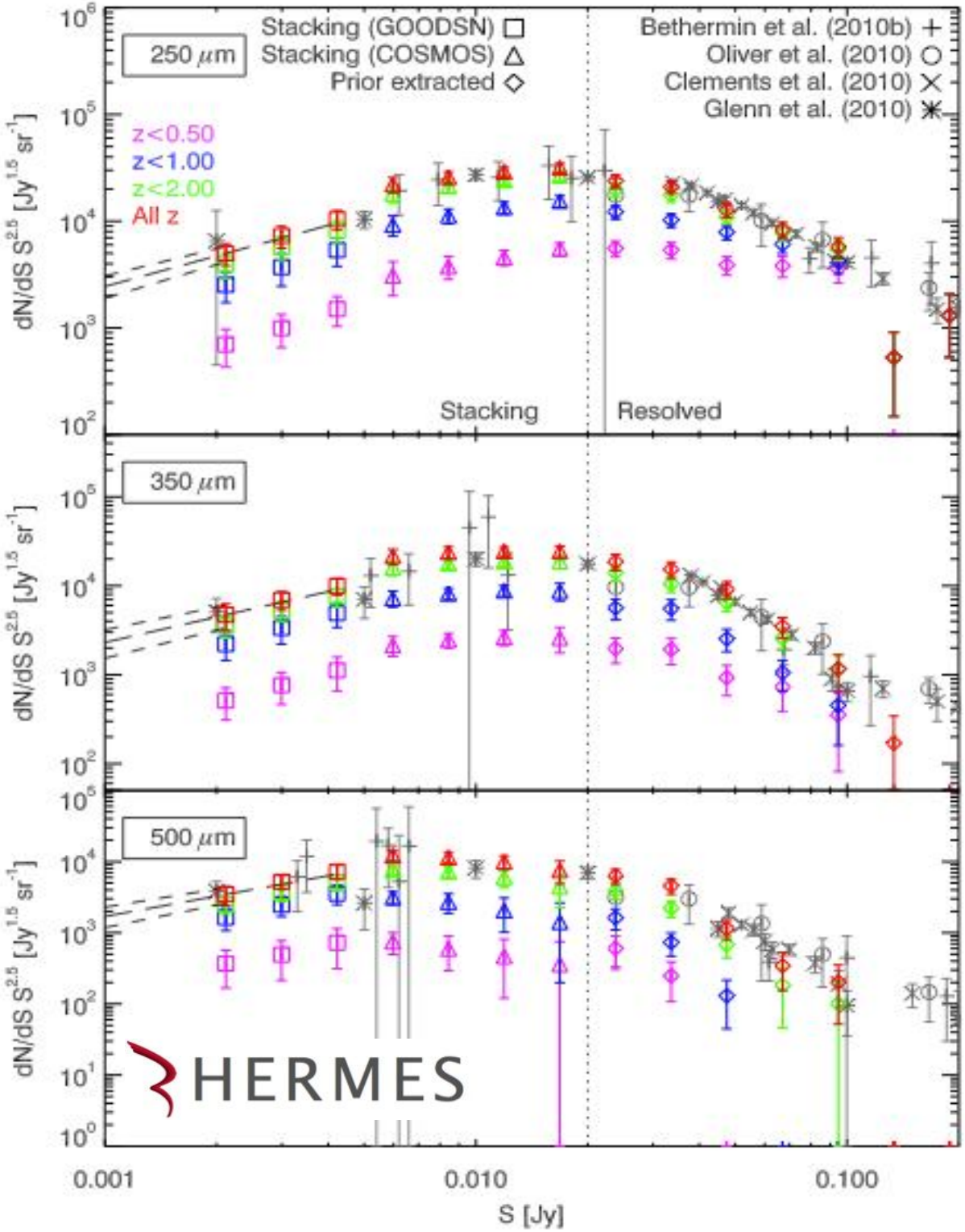
Incompleteness due to the 24 microns flux cut cut for different scatter (Béthermin+12b, sub.).



SOURCE COUNTS IN THE SUB-MM DOMAIN

- Agreement between P(D) analysis and stacking at faint flux.
- Number counts per redshift slices.
- Turnover in the counts now well constrained.
- Provide new strong constraints for models of galaxy evolution.

Number counts at 250, 350 and 500 microns (Béthermin+12b,sub)



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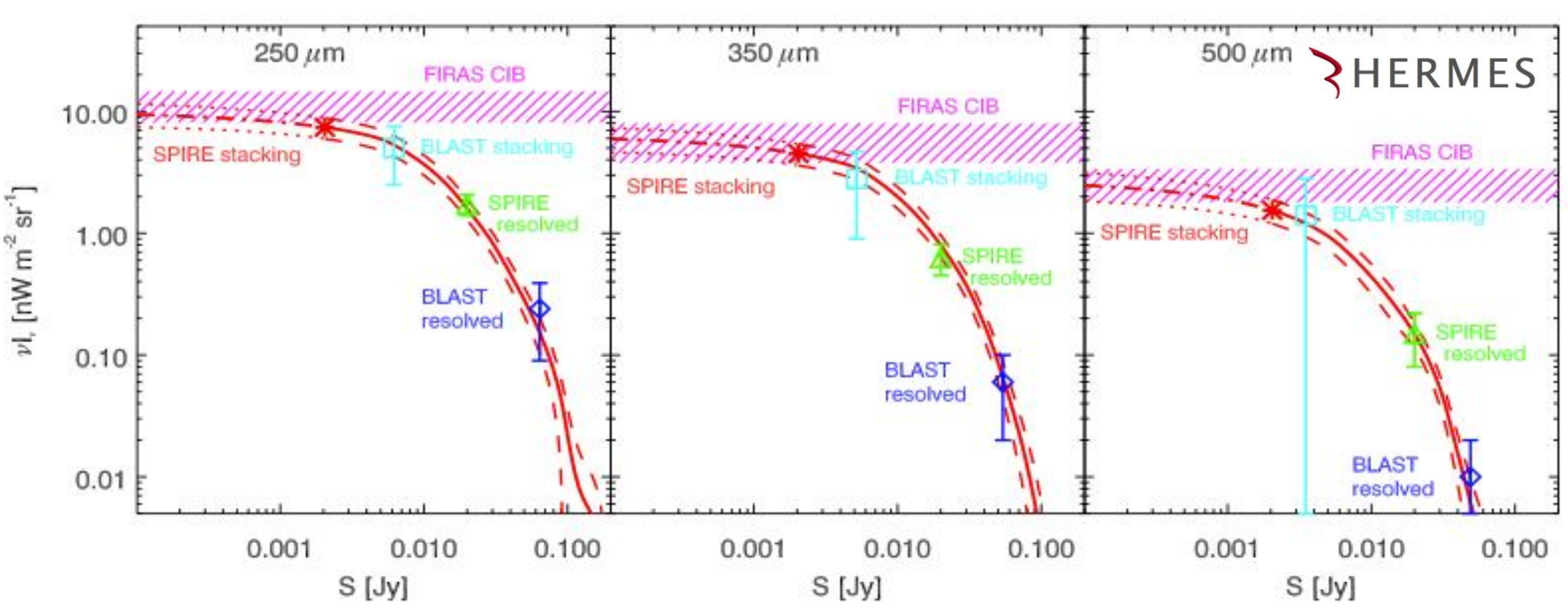
CONTRIBUTION OF THE GALAXIES TO THE CIB



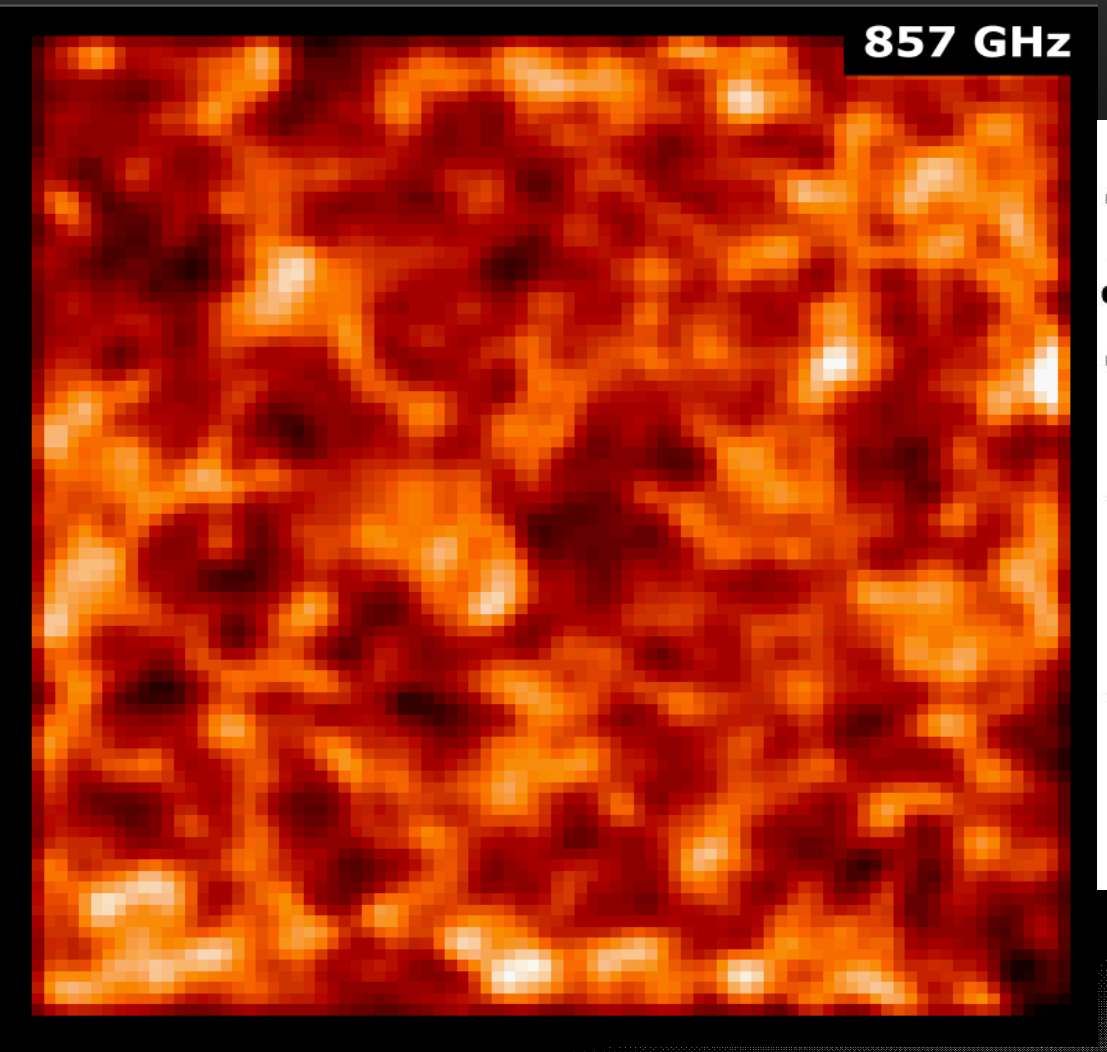
Cumulative contribution of the galaxies to the CIB as a function of the flux cut (Béthermin+12b, sub)

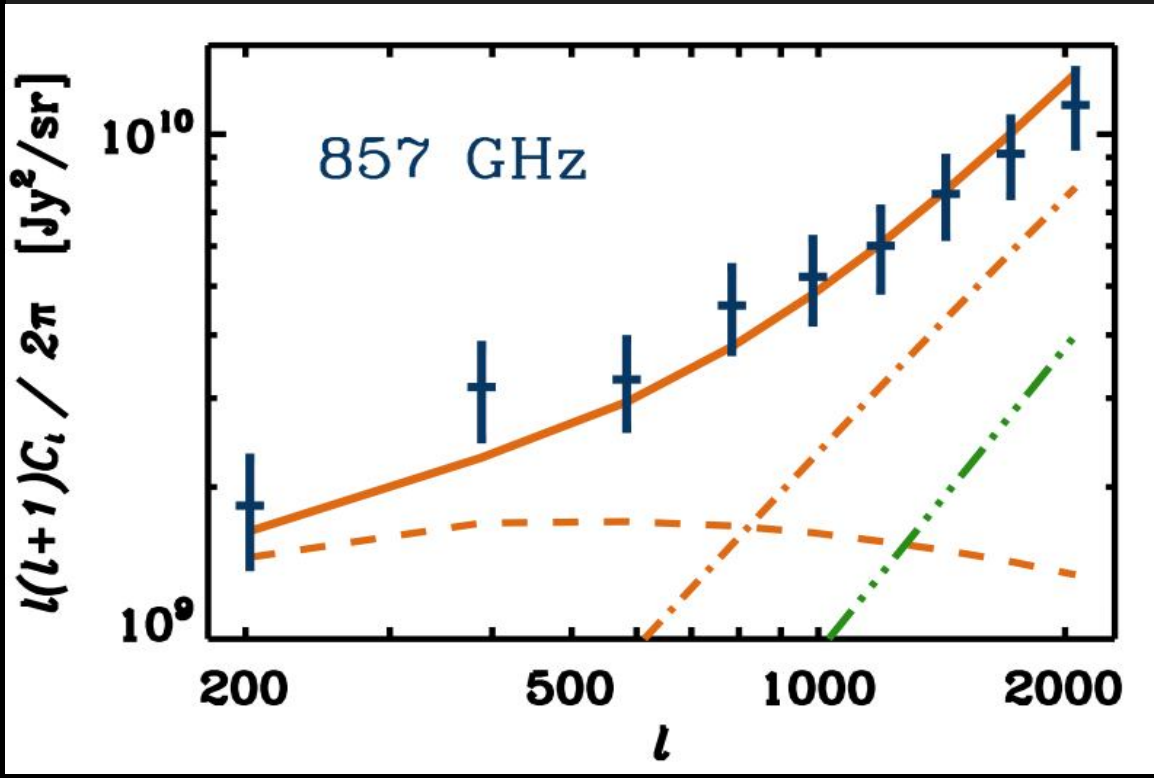
Agreement between absolute measurements of the CIB (FIRAS) and total CIB estimated by extrapolation of the faint–end slope of the counts

ANISOTROPIES OF THE COSMIC INFRARED BACKGROUND

A tool to study the links between the link between dark matter and star formation

CIB FLUCTUATIONS





CIB fluctuations observed by Planck (Planck EP XVIII)

MODELING THE CIB FLUCTUATIONS

- Current CIB fluctuation models (e.g. Pénin+12) interprete the CIB fluctuations using an emissivity model coupled with a halo occupation model:

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

Clustering model

$$\bar{j}_\nu(z) = (1+z)\int_0^{S_{\rm cut}} dS\ S\ \frac{d^2N}{dS\,dz}$$

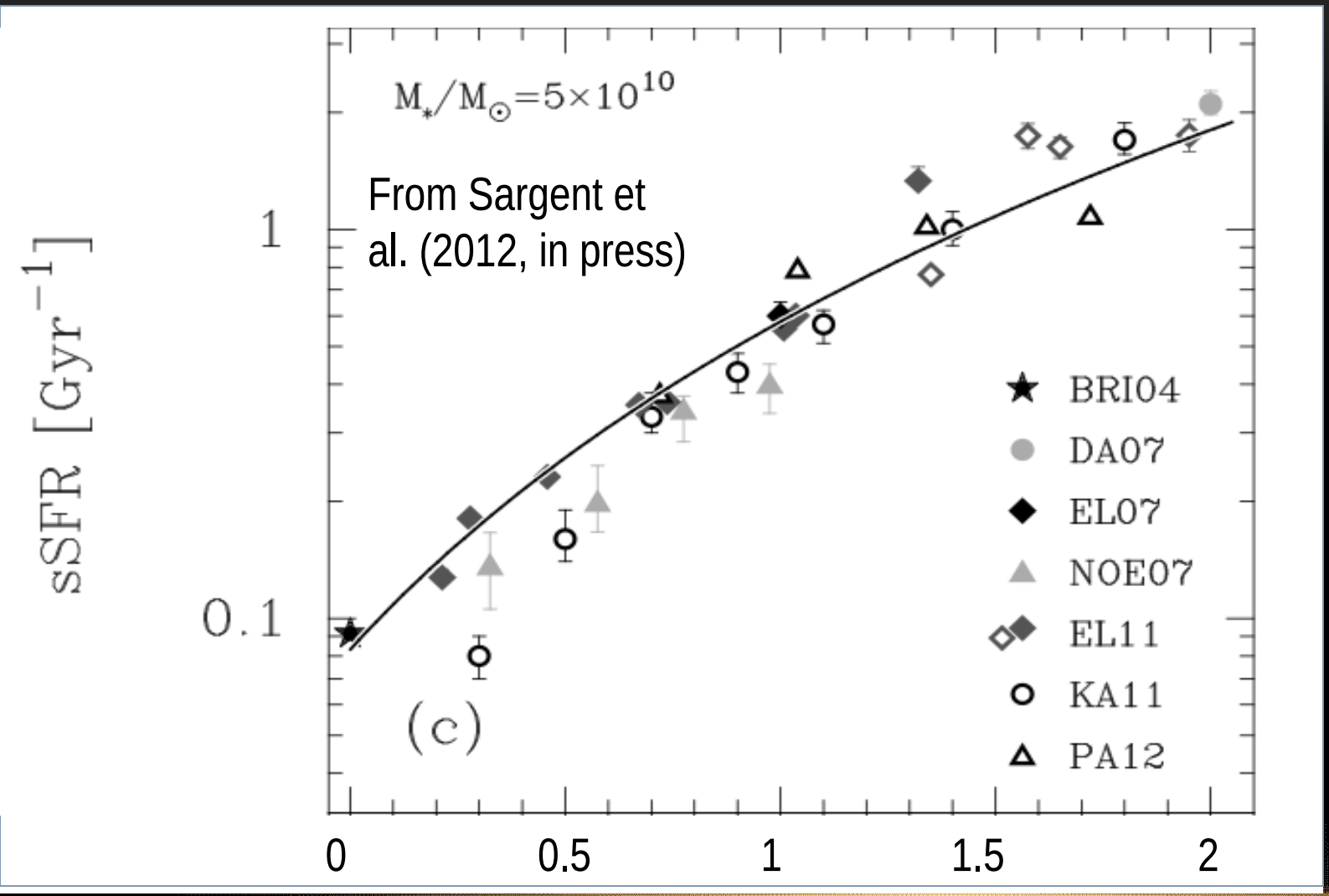
From evolution model or parameteric representation with free parameters

$$P_{gg}(k) = P_{1h}(k) + P_{2h}(k)$$

Halo occupation distribution model, taking into account the clustering between halos (P2h) and in a halo (P1h)

BUT In this simple model, the infrared luminosity of a galaxy does not depend on the mass of the host halo (Shang et al. recently proposed a luminosity dependent model).

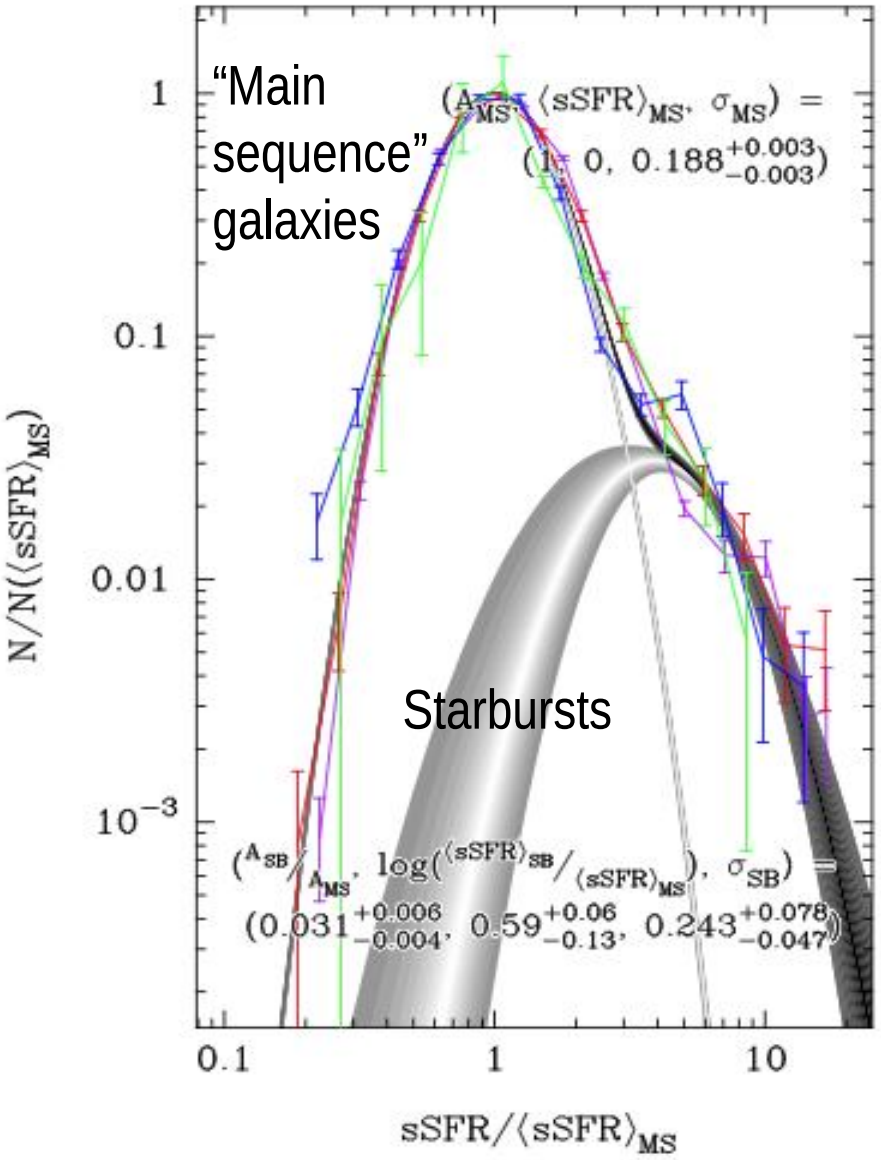
THE “MAIN-SEQUENCE” OF STAR-FORMING GALAXIES

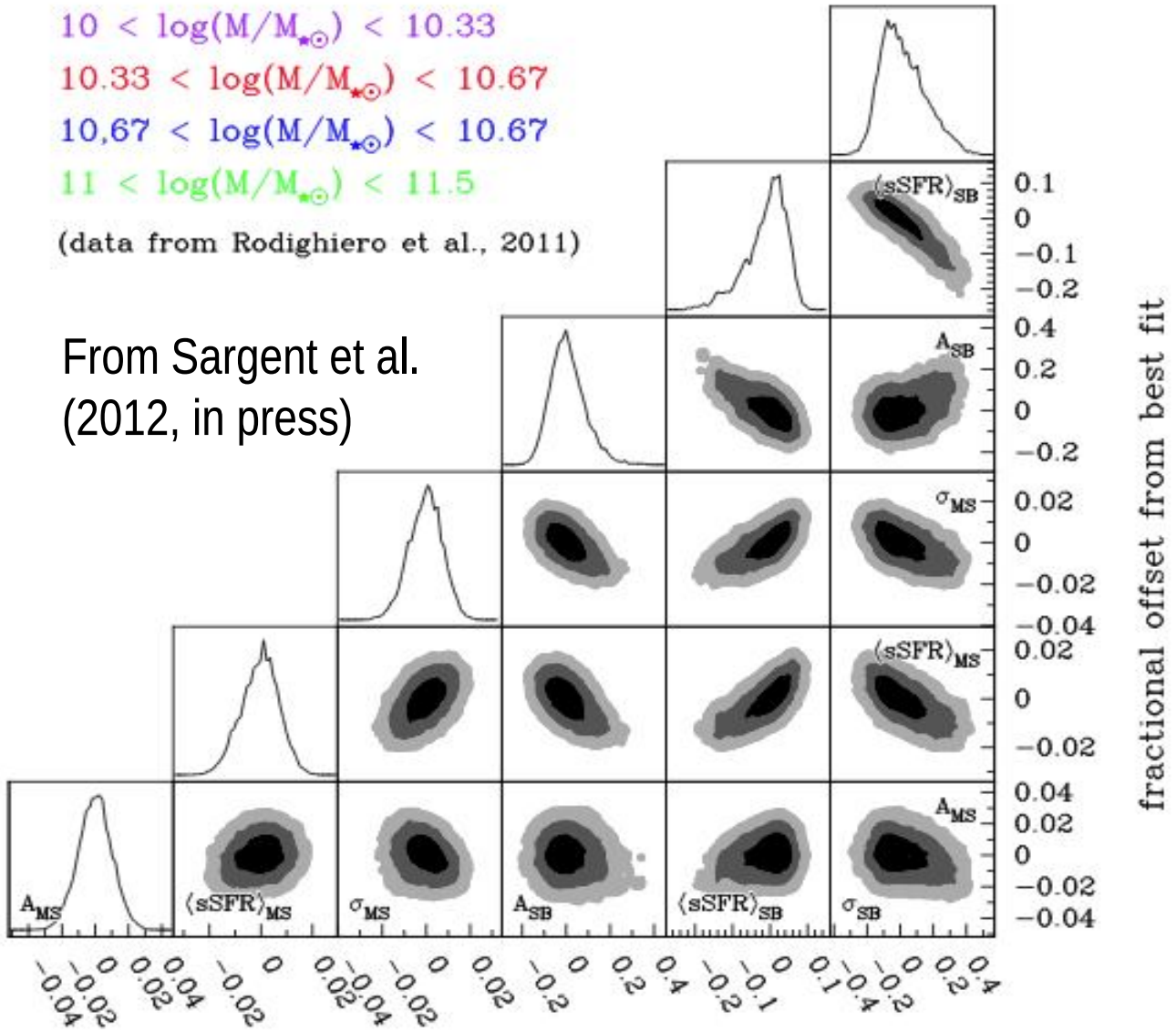


- The mean specific star formation rate (SFR/Mstar) increases quickly with the redshift (e.g. Daddi+07, Elbaz+07,Noeske+07,Elbaz+11,Karim+11).

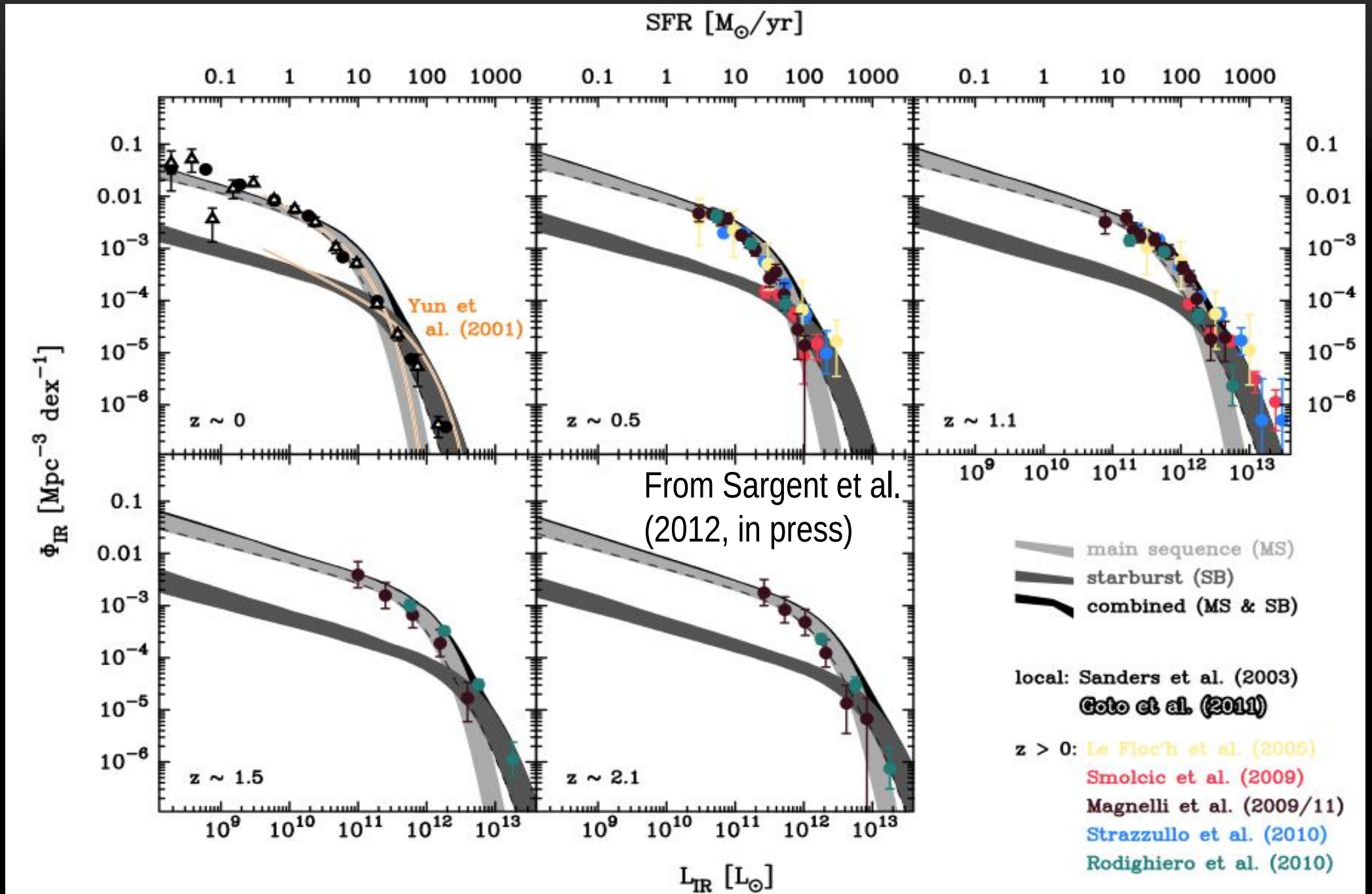
Mean specific star formation rate of star-forming galaxies as a function of redshift

DISTRIBUTION OF THE SPECIFIC STAR FORMATION RATE IN Z~2 STAR-FORMING GALAXIES



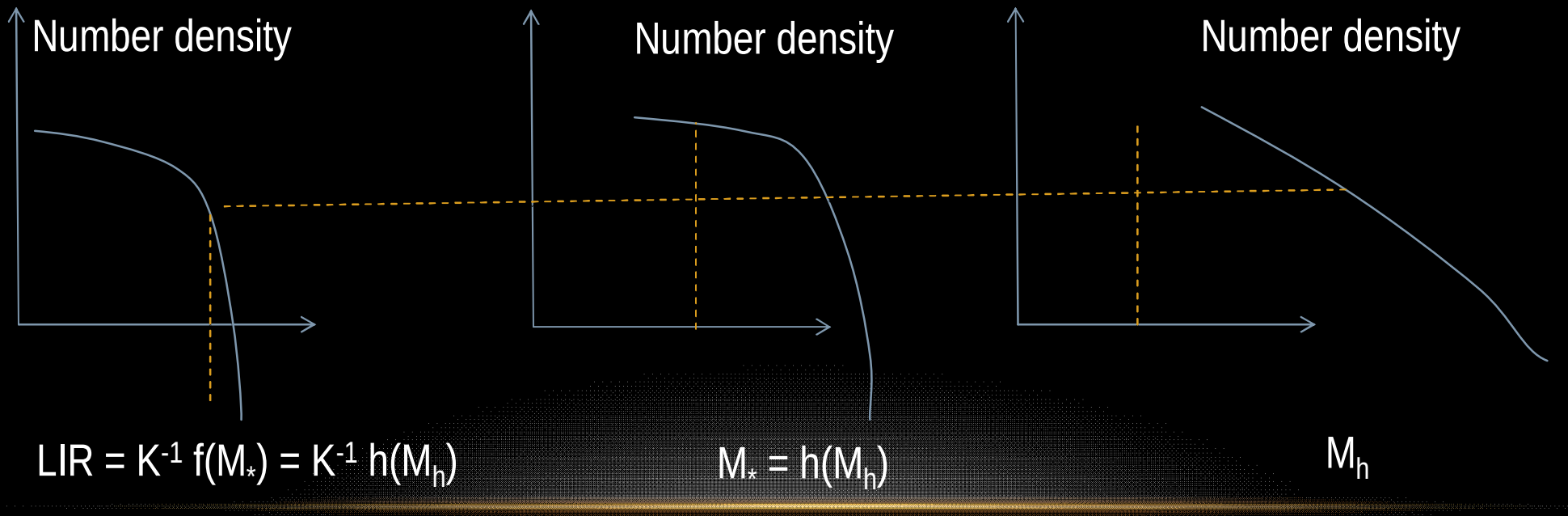


CONTRIBUTION OF MS/SB GALAXIES TO INFRARED LUMINOSITY FUNCTION



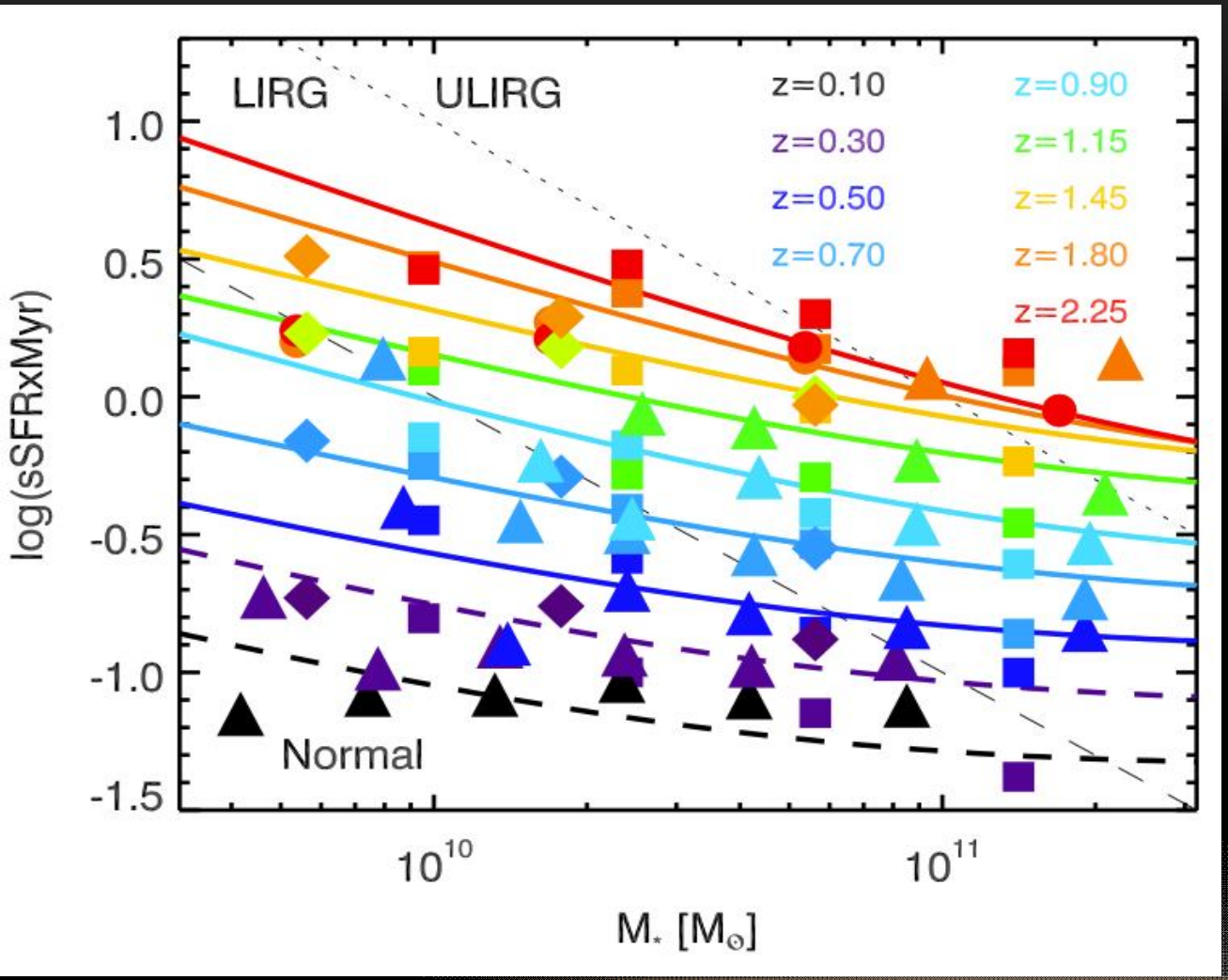
PRINCIPLE OF ABUNDANCE MATCHING TECHNIQUE

$$n_{L_{IR}}\left(> L_{IR} = K^{-1} \times f(M_\star)\right) = n_{M_\star}(> M_\star)$$
$$n_{L_{IR}}\left(> L_{IR} = K^{-1} \times g(M_h)\right) = n_{M_h}(> M_h)$$
$$n_{M_\star}(> M_\star = h(M_h)) = n_{M_h}(> M_h),$$



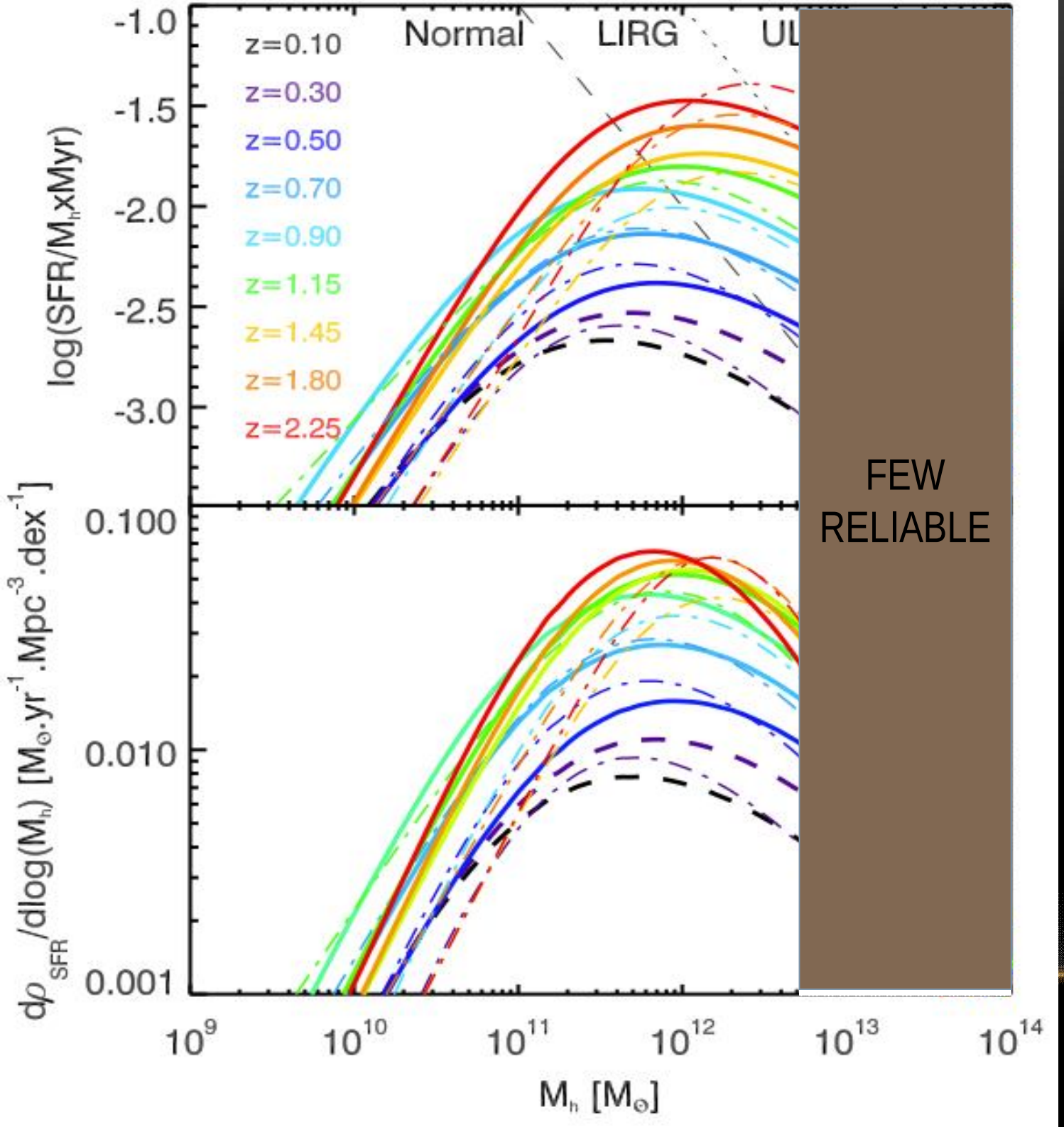
Assume a monotonic relation between infrared luminosity stellar mass and halo mass

MAIN SEQUENCE RECOVERED BY A SIMPLE ABUNDANCE MATCHING



- We recover the evolution of the «main sequence» observed at various wavelengths.

Relation between specific star formation rate and the stellar mass (Béthermin, Doré & Lagache, 2012)



LINK BETWEEN SFR AND HALO MASS

Top: Ratio between SFR and halo mass as a function of halo mass

Bottom: Differential contribution to SFR density as a function of halo mass.

(Béthermin, Doré, Lagache 2012)

- Strong evolution of the SFR-Mhalo relation.
- The mass where SFR/Mhalo is maximal change with the redshift in disagreement with Shang et al. model (could explain why it fails).

CONCLUSION AND PERSPECTIVES

- Thanks to statistical analyses (P(D), stacking…) of the Herschel maps, the sources responsible for the sub-mm part of the CIB are now pretty well identified up to 500 microns (down to 550 GHz).
- Flux density and redshift distributions measured by Herschel and Planck (see Hervé Dole's talk) will constrain the new generation of models of galaxy evolution in preparation.
- The abundance matching technique provides clues about the relationship between halo mass and hosted star formation.
- CIB fluctuations will help to better constrain this link.

THANK YOU FOR YOUR ATTENTION

ADDITIONNAL SLIDES

STACKING AND CLUSTERING

Bias due to clustering estimated using 3 methods:

- Method A: convolving 24 map by SPIRE beam.
- Method B: using 24+z catalog and colors measured by stacking to build a simulation.
- Method C: Fitting the contribution of the clustering on the stacked image.

Right: Stacked image at 250 microns fitted by the following model (Béthermin+12b, sub):

$$M = \alpha \times PSF + \beta \times \left(\frac{PSF * w}{max(PSF * w)} \right)$$

wavelength	Bias due to clustering		
μm	Method A	Method B	Method C
250	5±2%	7.0±0.9%	7.7±0.5%
350	11±2%	10.4± 0.7%	10.3± 0.8%
500	20±5%	20.6±1.2%	19.1±1.8%