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Passadena
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What makes the cosmic infrared background?

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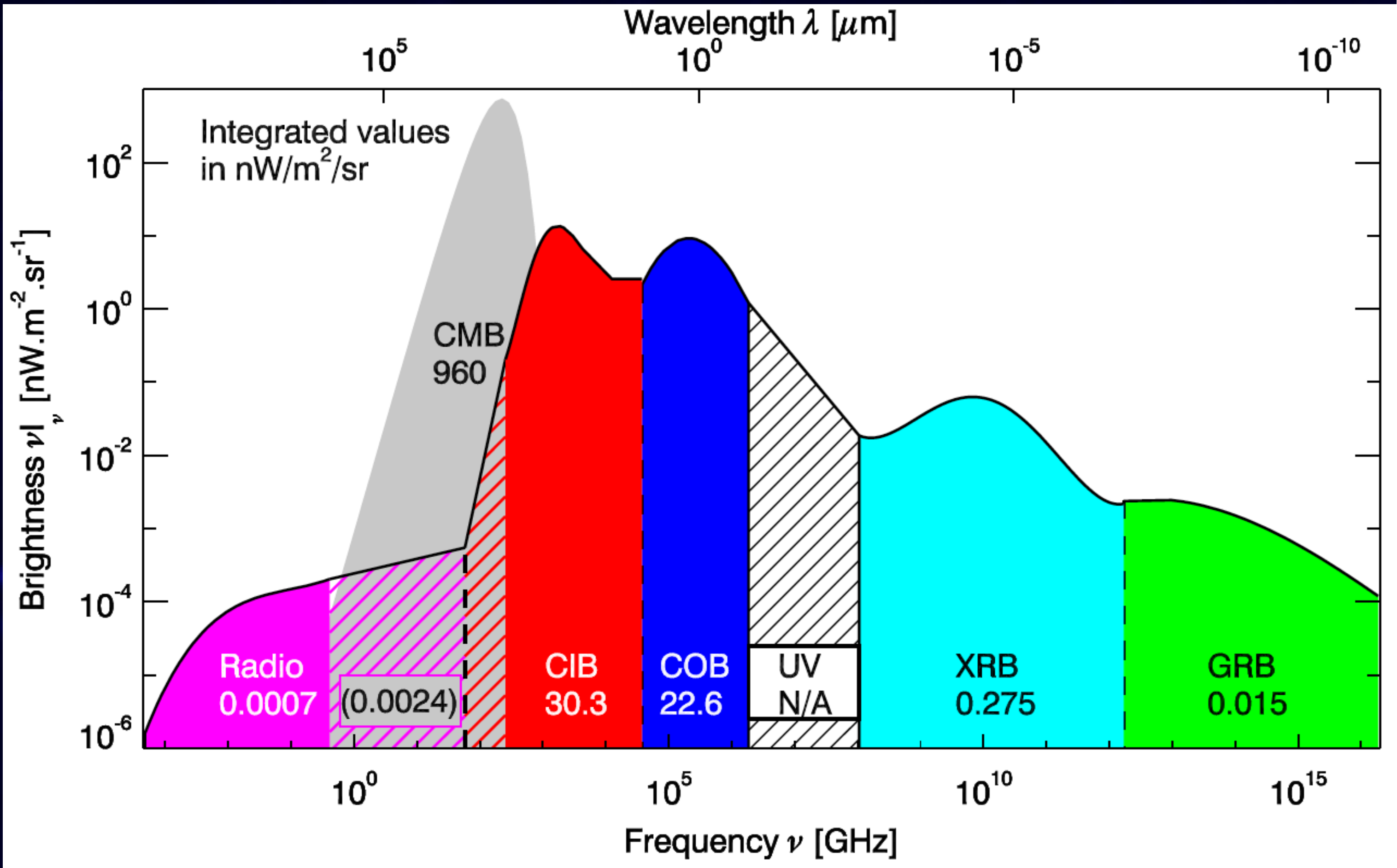
Material at http://www.ias.u-psud.fr/irgalaxies/

The extragalactic background light (EBL)

- Optical/IR ratio ~ 3 in the local Universe (cf Driver+08)
- CIB = COB
- Indicate strong evolution of the IR properties of the galaxies

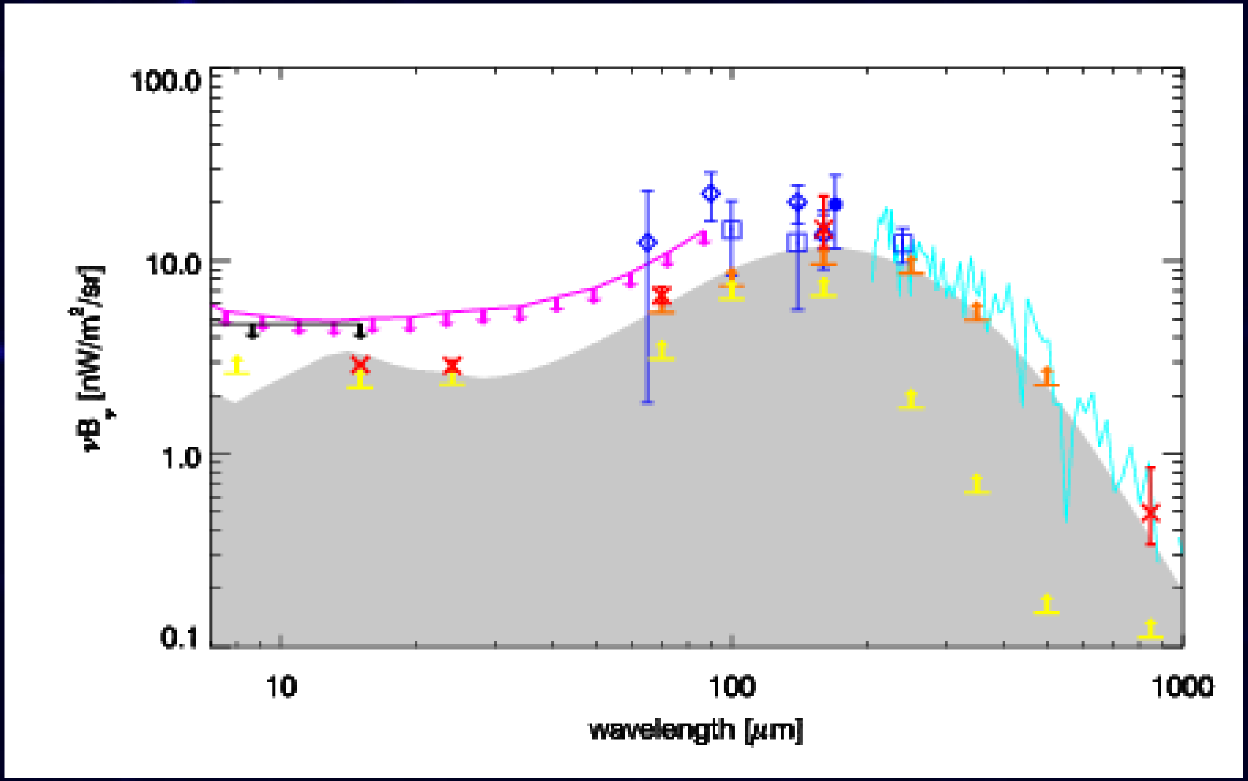


SED of the extragalactic background light (from Dole & Béthermin, in prep.)

Measurements of the cosmic infrared background (CIB) level

- Absolute measurements:
  need an absolute photometry and an accurate removing of the foregrounds.
- Lower limits:
  from the number counts and statistical analyses (stacking, P(D)).
- Upper limits:
  derived from the absorptions of TeV photons from the blazars by the COB/CIB.

Direct counts Stacking Total extrapolated contribution



Measurements of the cosmic infrared background (from Béthermin+11, CRF proceeding)

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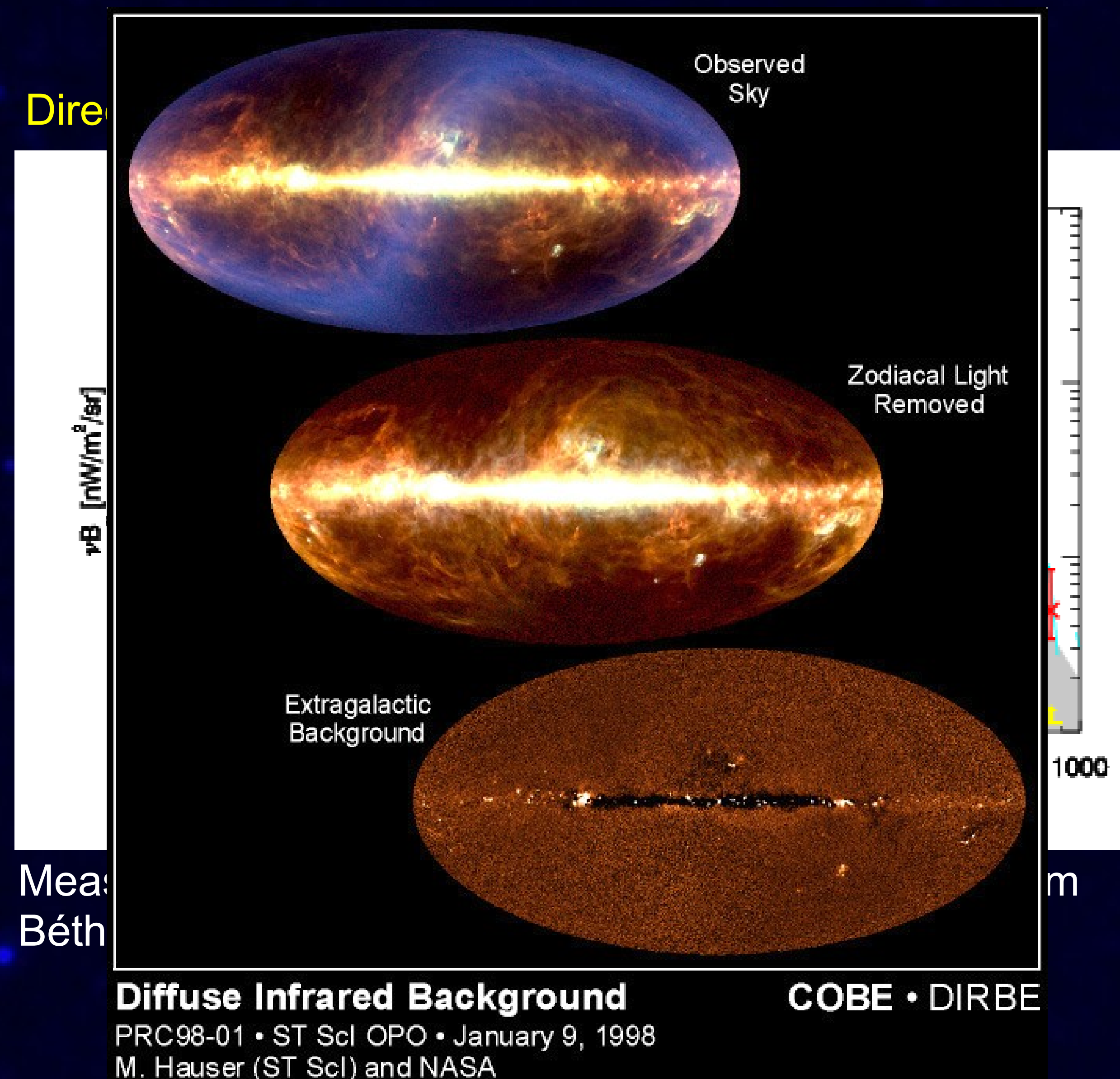

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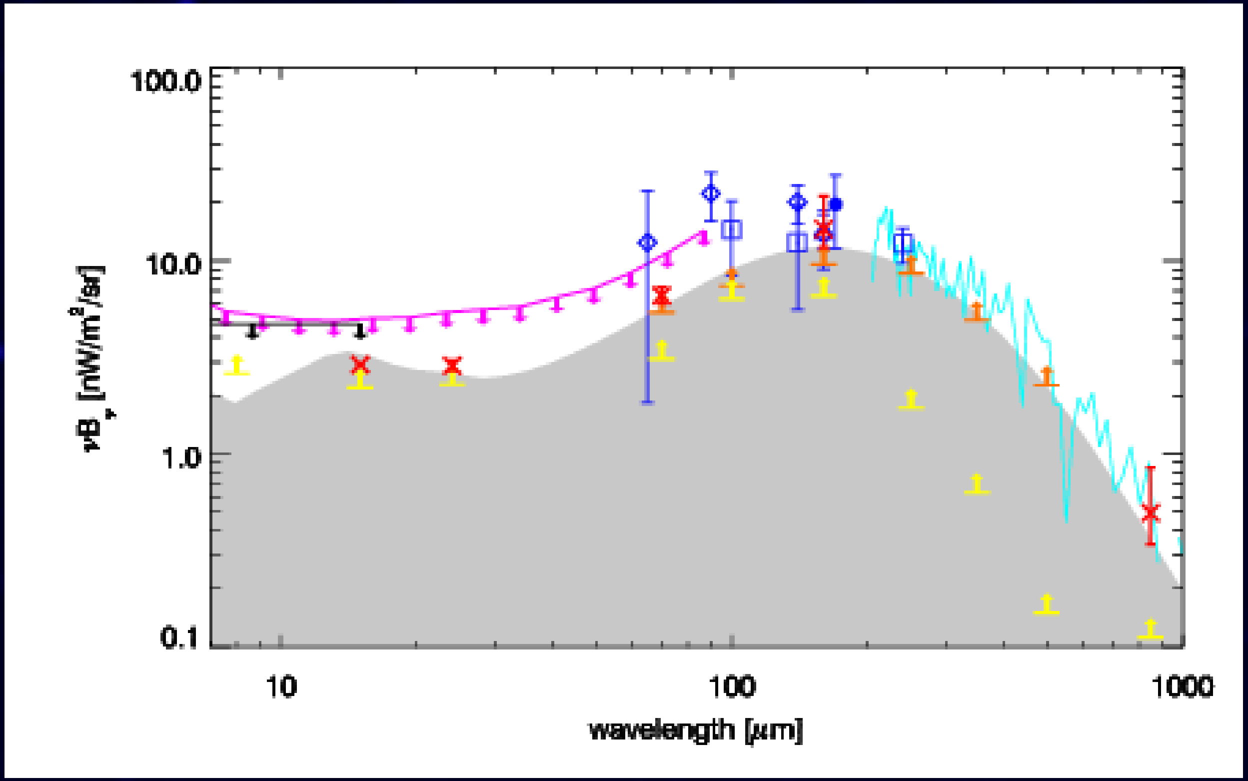


Measurements of the cosmic infrared background (from Béthermin+:astro-ph/1102.1827)

What makes the CIB?

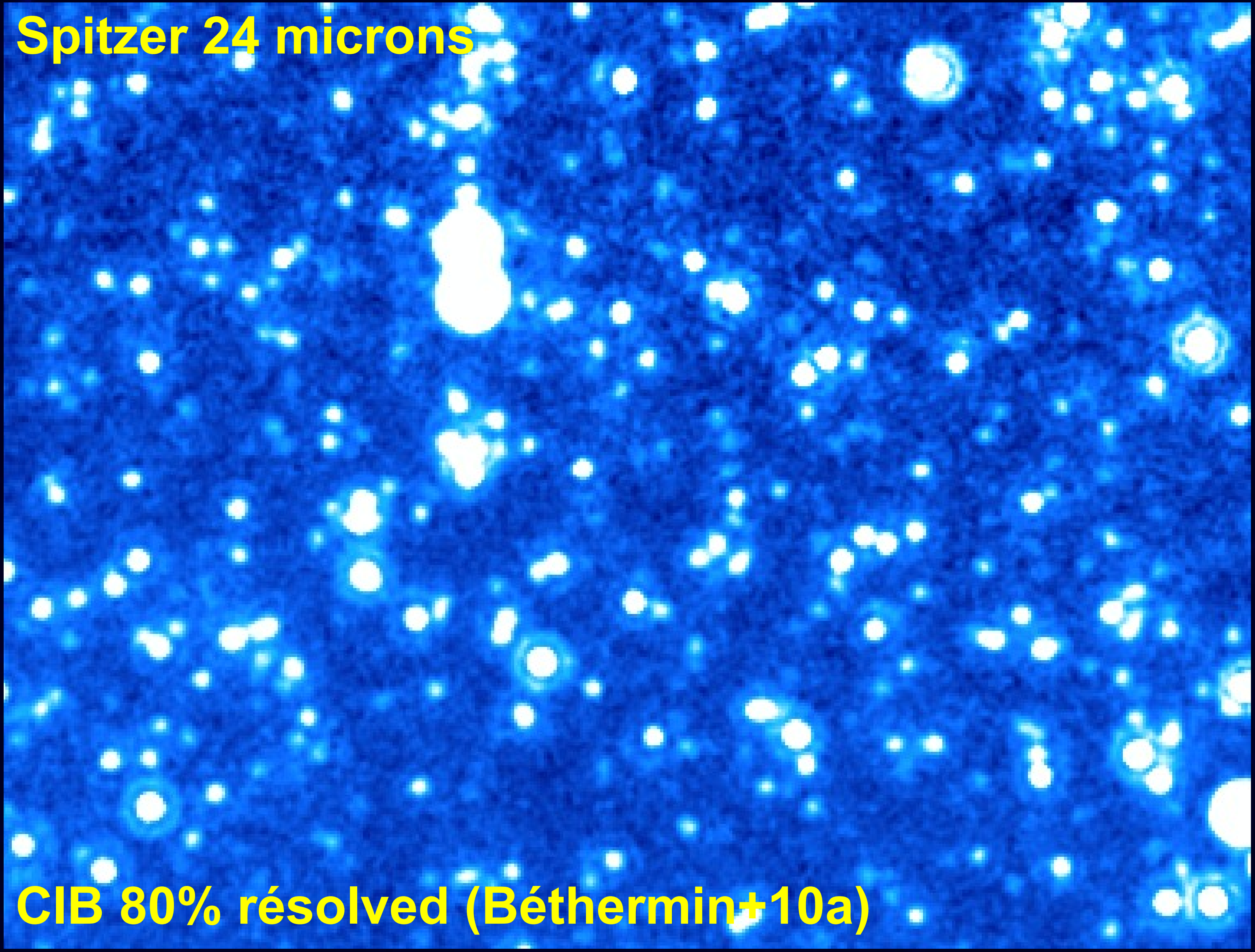
- Origins of the infrared output of the galaxies (e.g. star formation vs accretion)
  ---> physics of galaxies

- Global evolution of the statistical properties of the infrared galaxies
  ---> cosmology

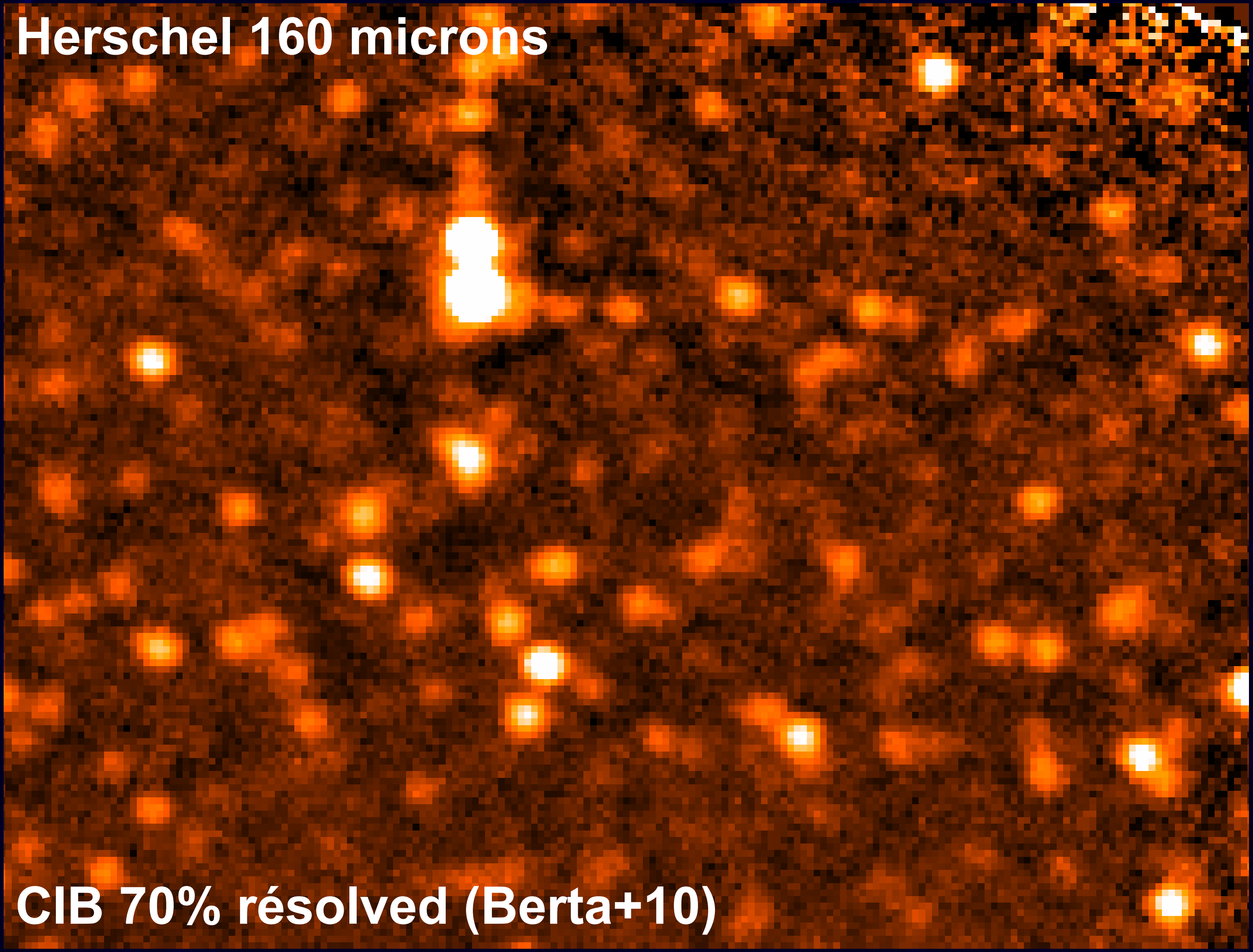
Outline

- Resolving the CIB in the sub-mm domain
- Modeling the evolution of the infrared populations
- Anisotropies of the cosmic infrared background

Resolving the CIB



Resolving the CIB



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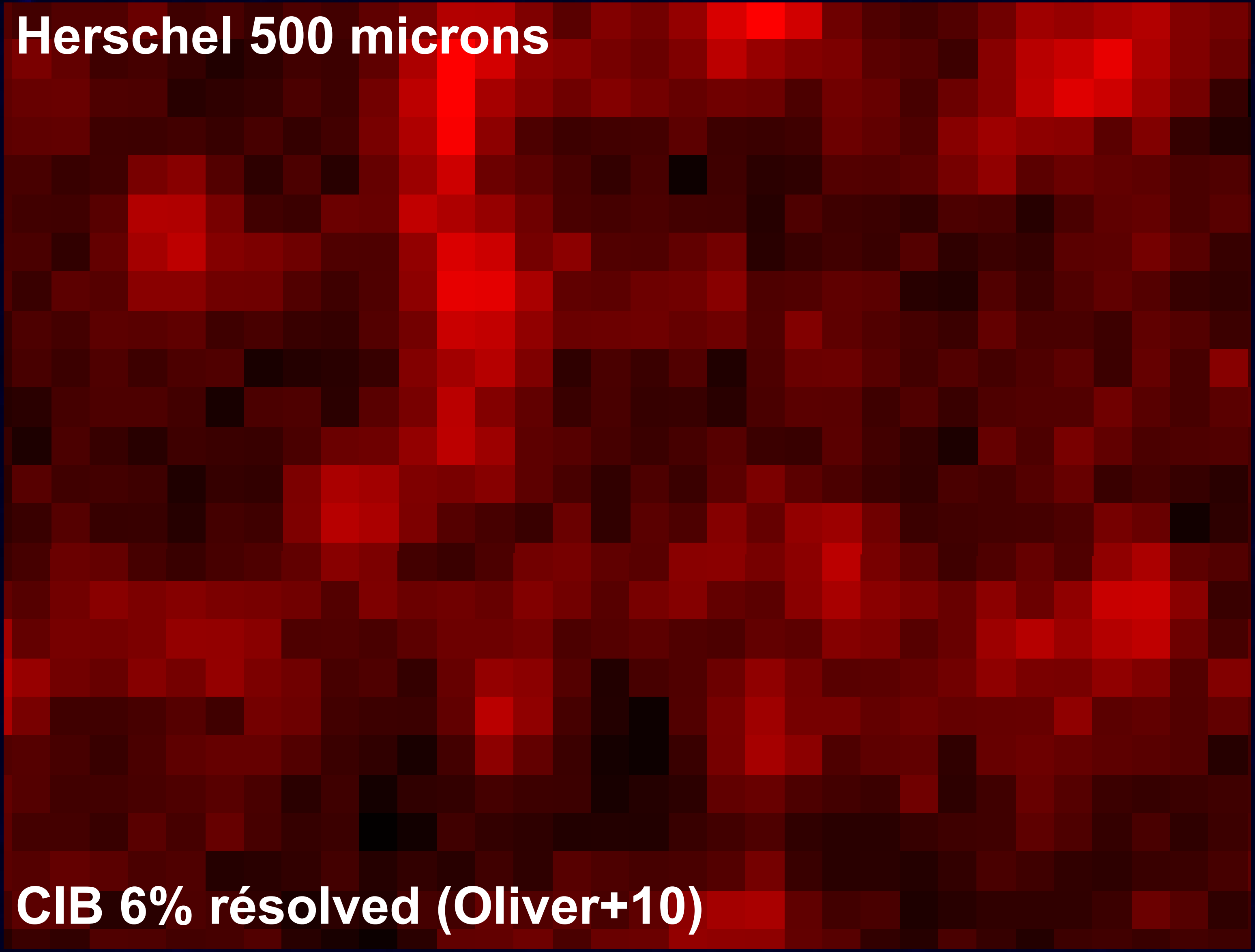
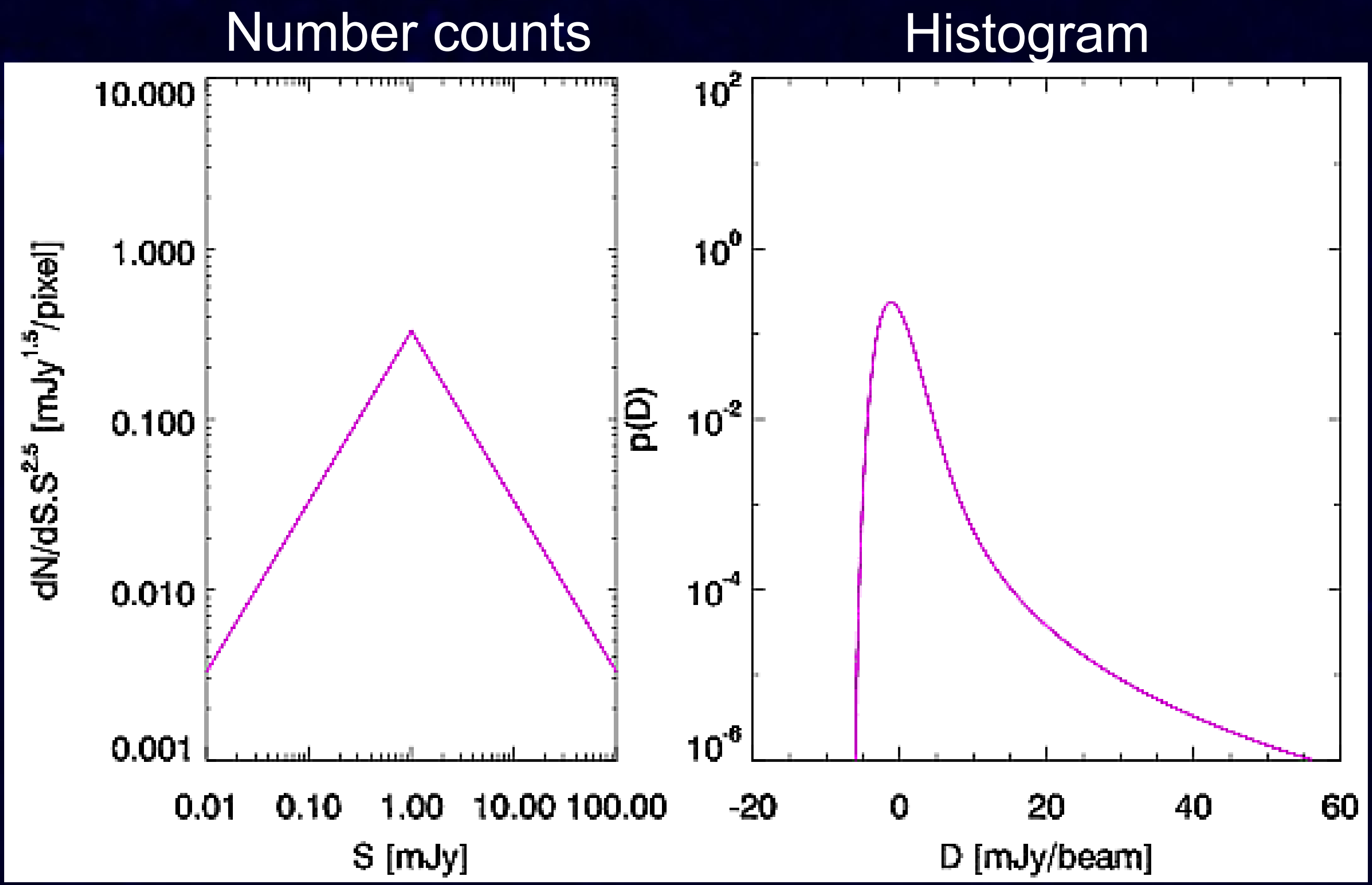


Source counting by P(D) analysis



Principle of the P(D) analysis

- Hypotheses: - point sources
  - Poisson distribution
  - instrumental effects known (PSF, noise, filtering)
- Direct link between the source counts and the pixel histogram.

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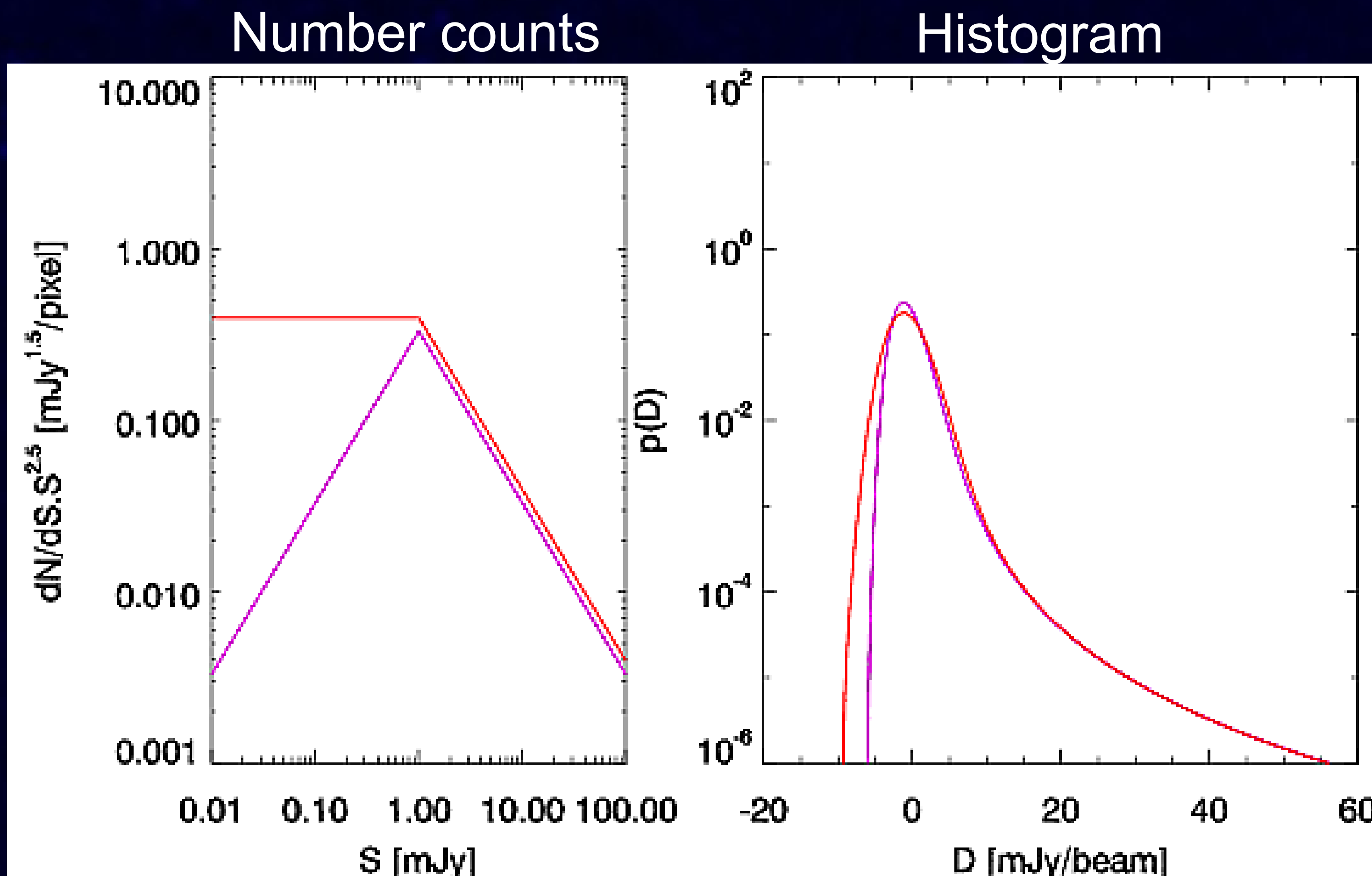

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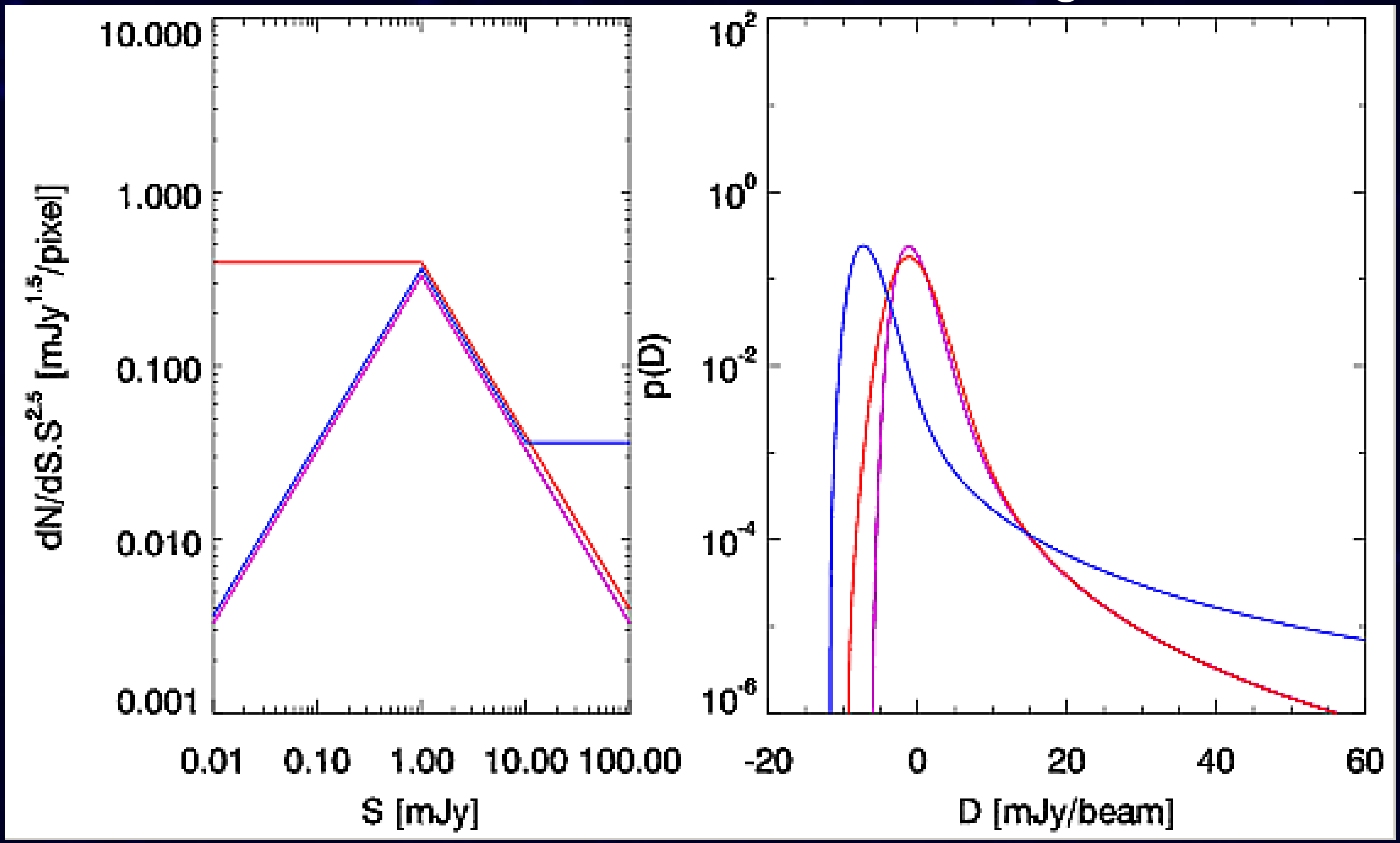
Source counting by P(D) analysis

Number counts Histogram



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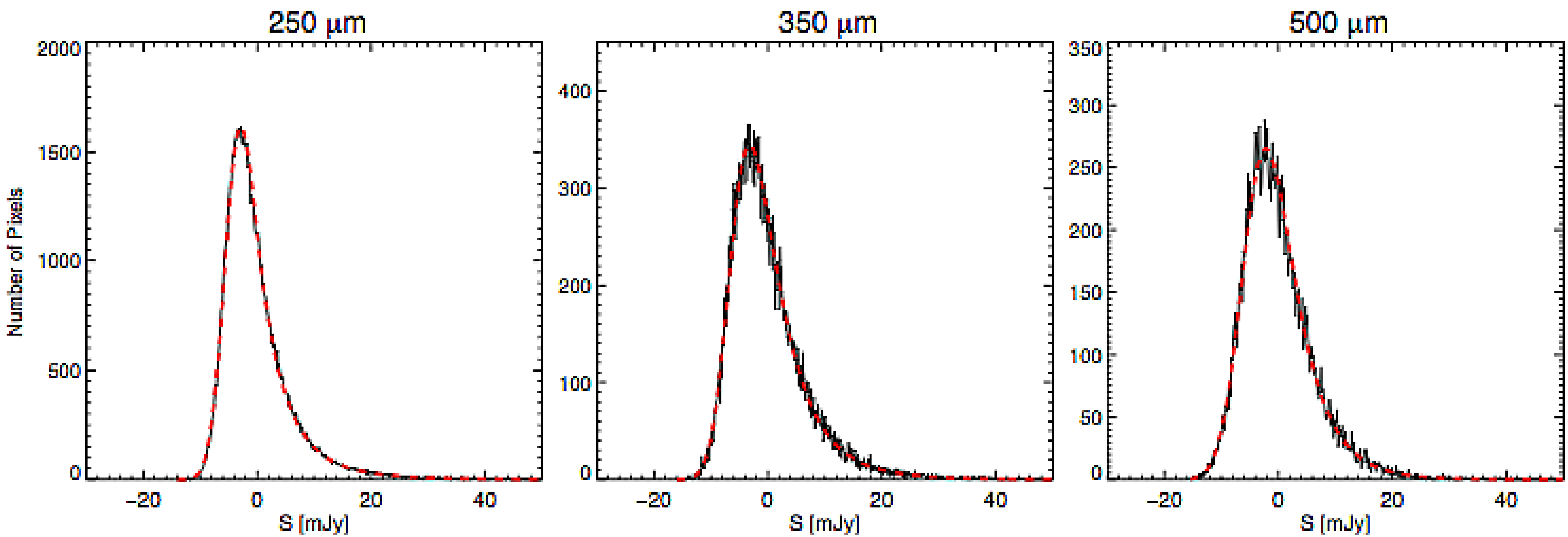
Histograms

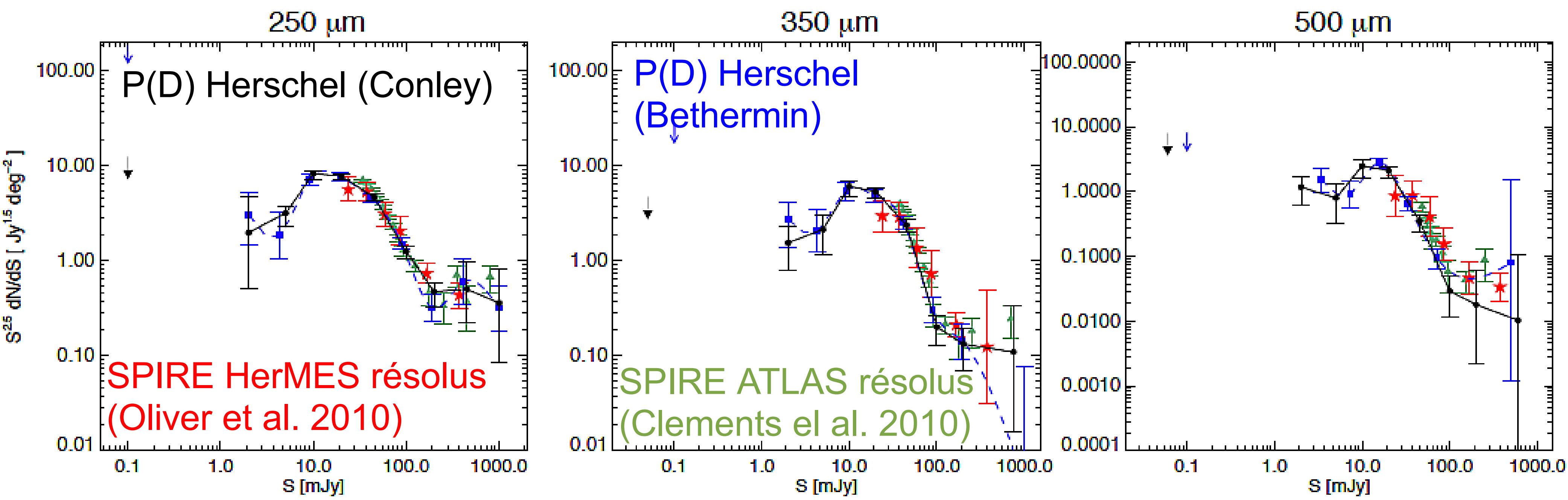


Fit of the histograms of the GOODS-N SPIRE maps (Glenn+10)

- Confusion limited maps obtained by Herschel/SPIRE at 250, 350 and 500 microns.

Source counting by P(D) analysis

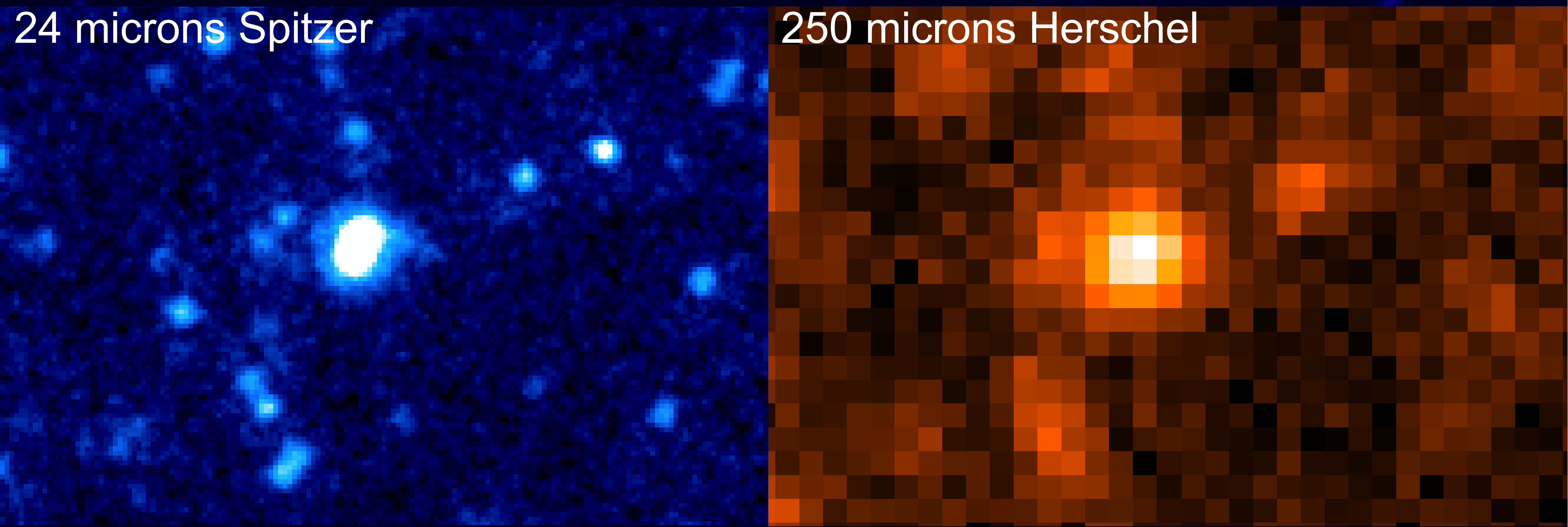
Comptages



Counts measured by P(D) analysis of SPIRE SDP maps (Glenn+10)

- Confusion limited maps obtained by Herschel/SPIRE at 250, 350 and 500 microns.
- Counts obtained by P(D) analysis one order of magnitude deeper.
- Counts explains ~2/3 of the CIB

Using the 24 micron observations as a prior



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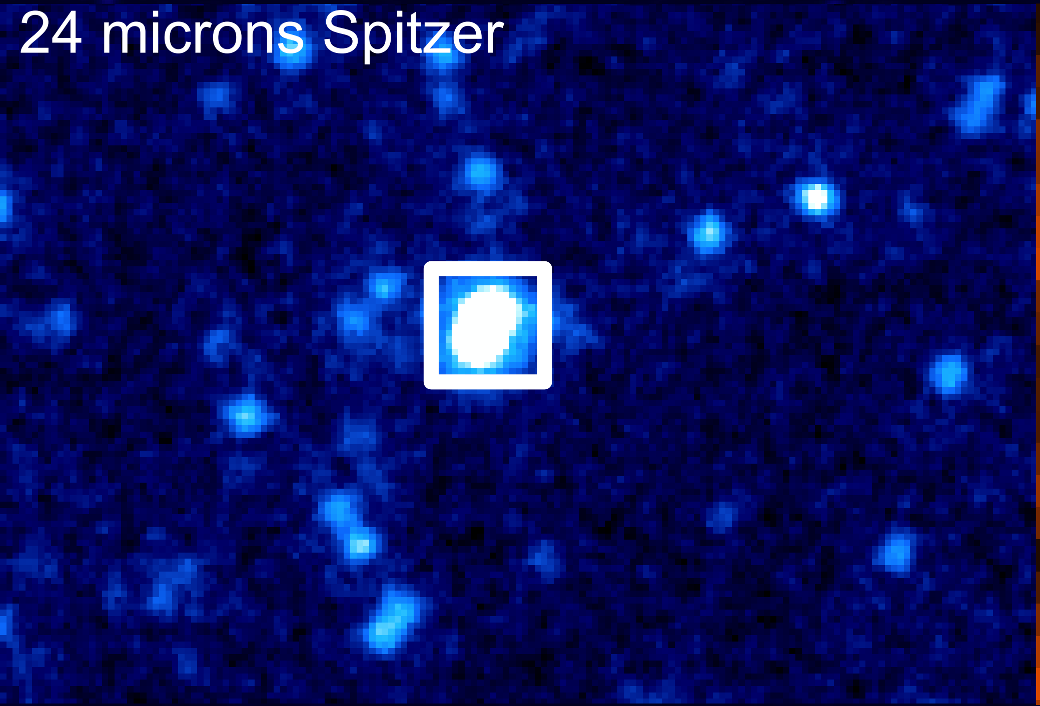

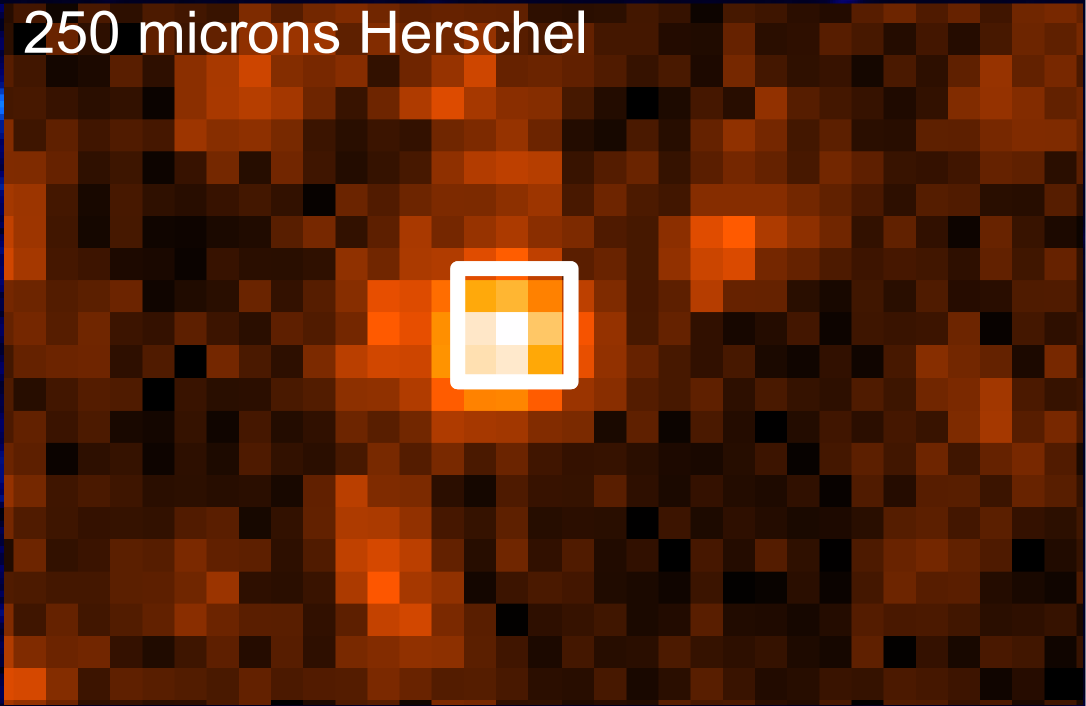

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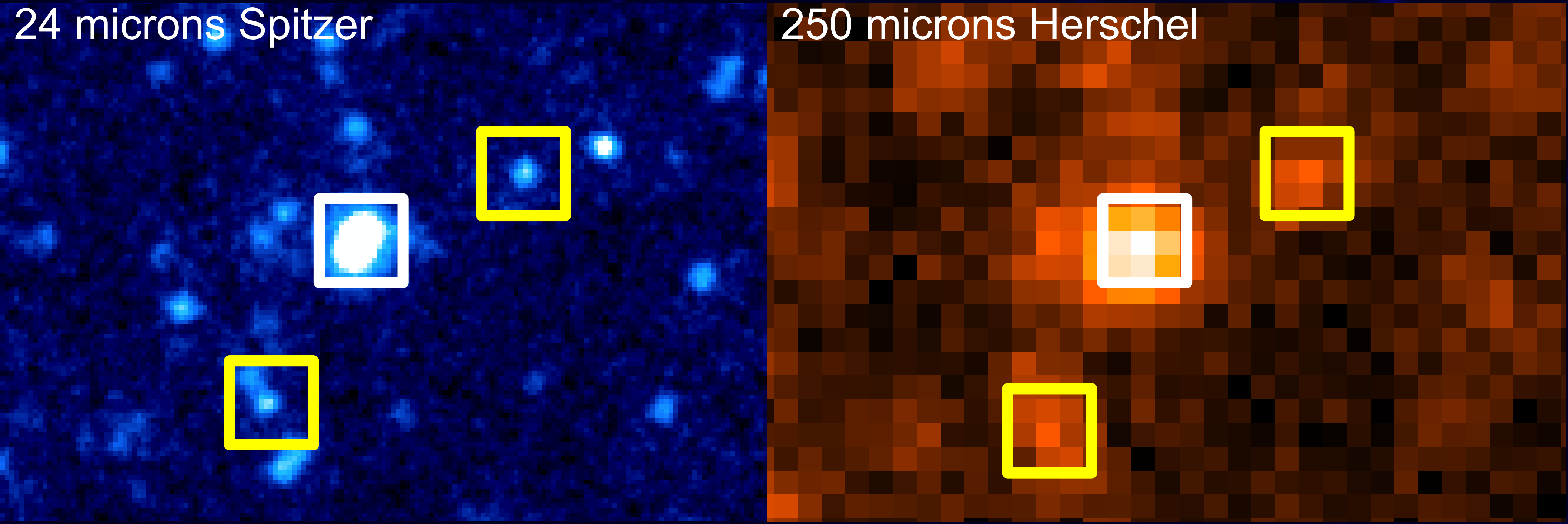
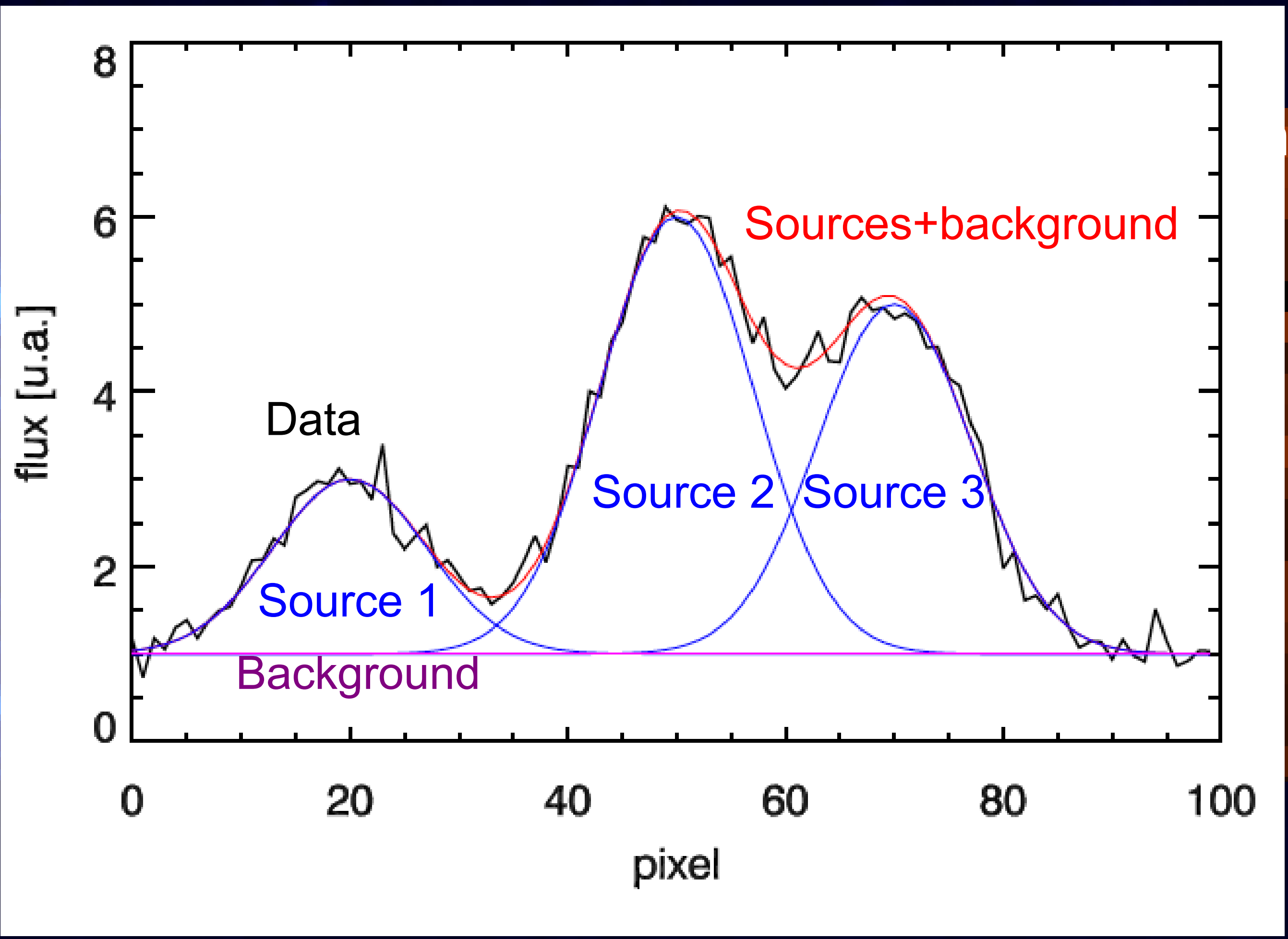
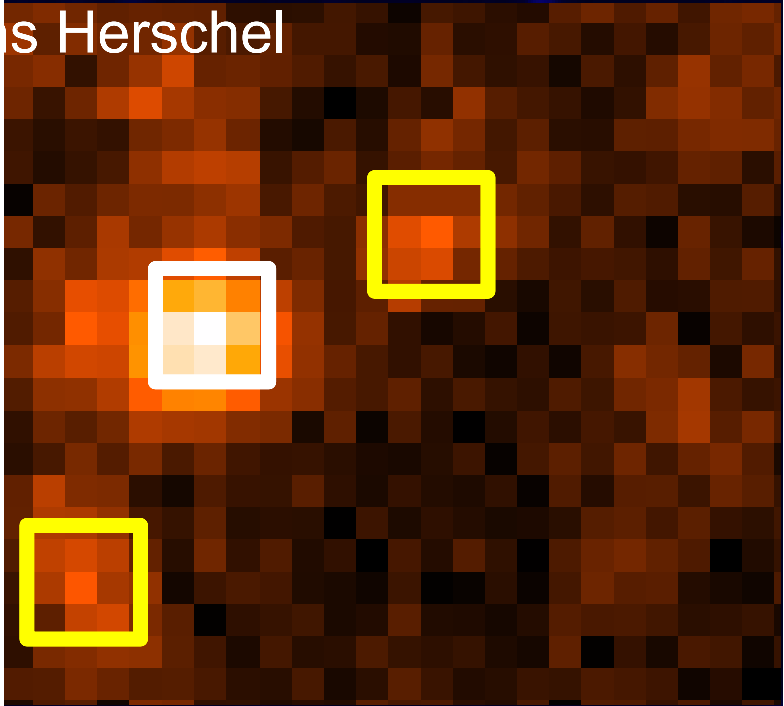


Using the 24 micron observations as a prior



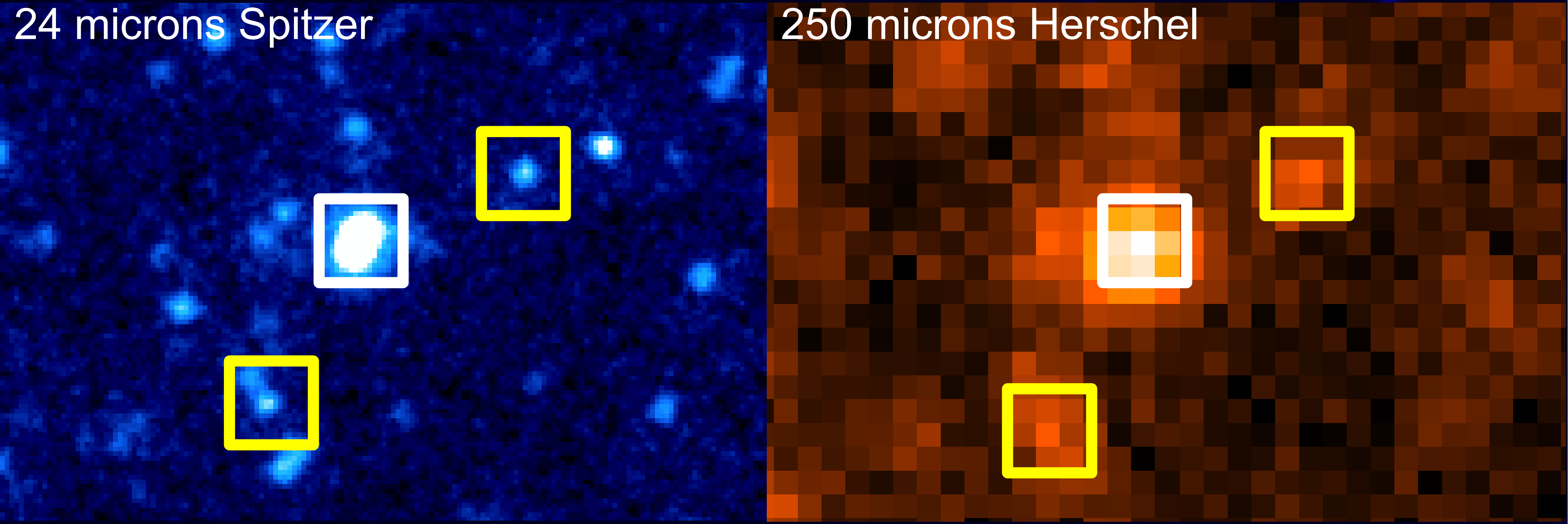
Principle of the PSF-fitting photometry using a prior on positions.



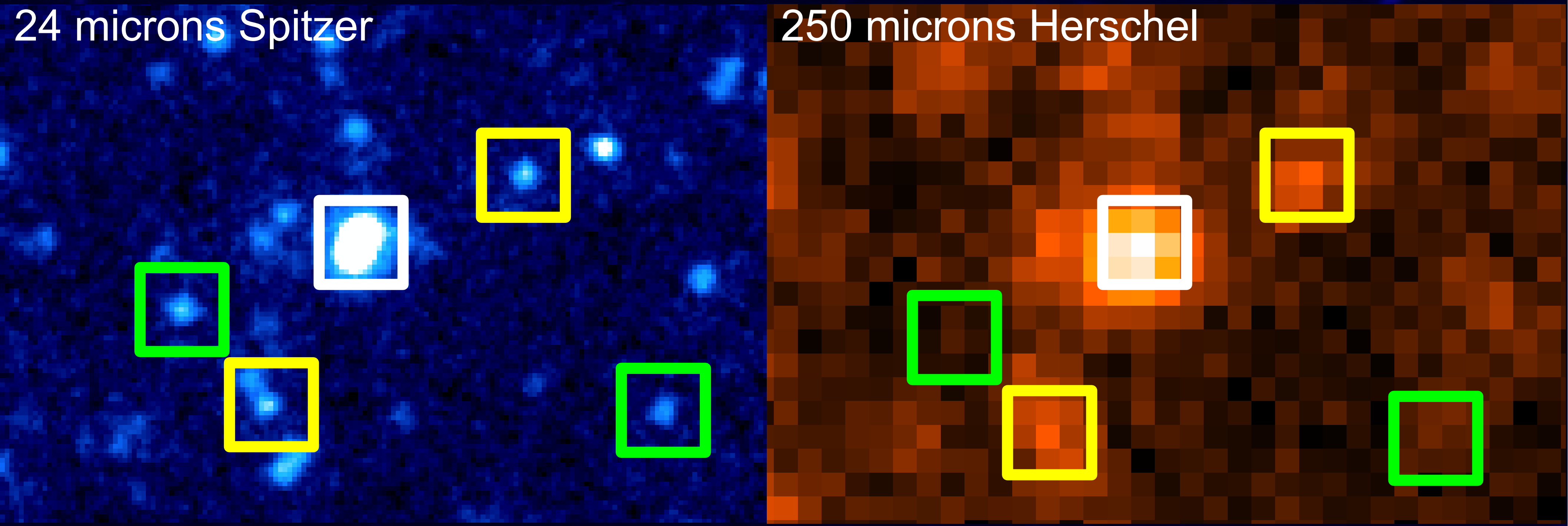
$$m = \sum_{k=1}^{N_s} S_k \times PSF_{x_k,y_k} + \sigma + \mu$$

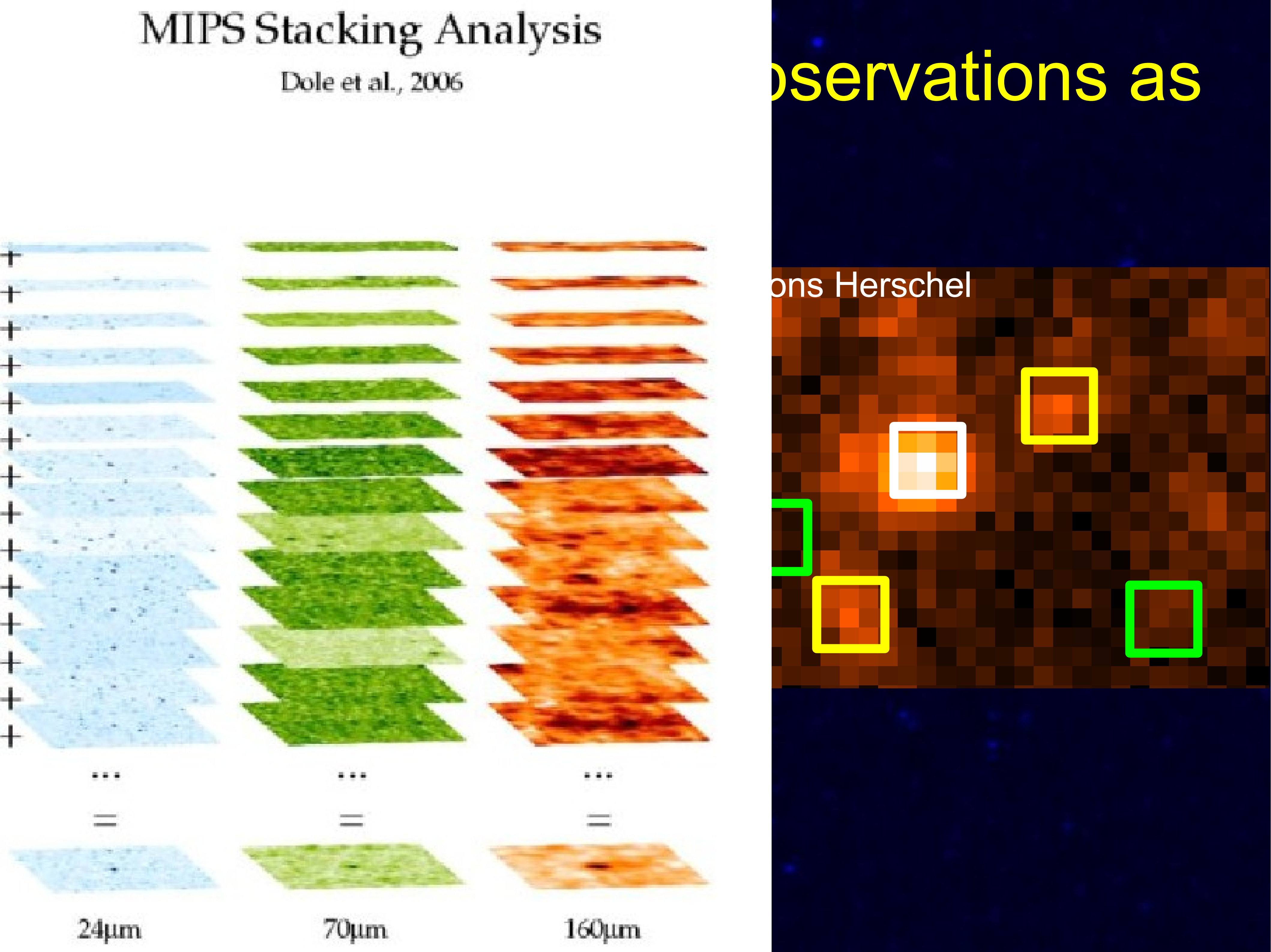
Model fitted to the data

Using the 24 micron observations as a prior



Using the 24 micron observations as a prior





MIPS Stacking Analysis
Dole et al., 2006
24μm
70μm
160μm
servations as
ons Herschel

Stacking and clustering

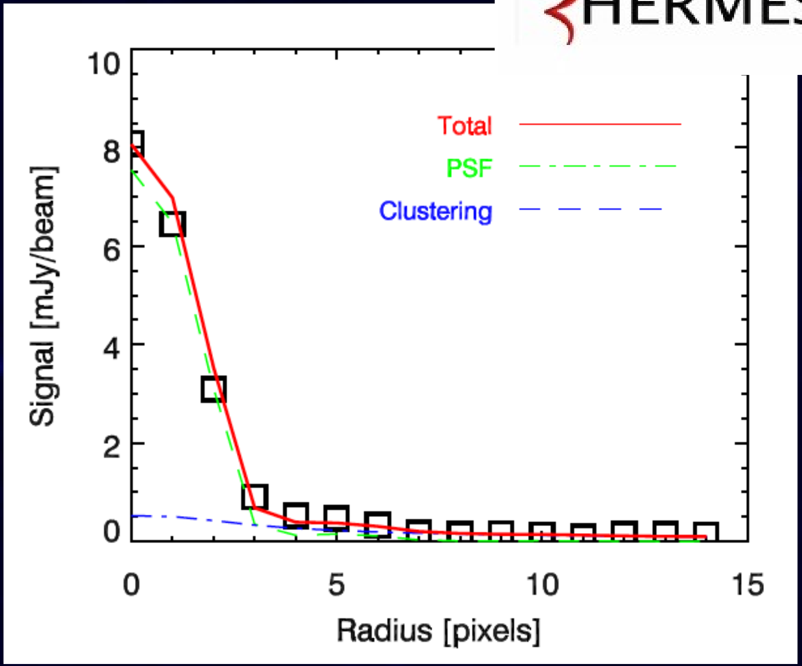
Bias due to clustering estimated using 3 methods:

- 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.

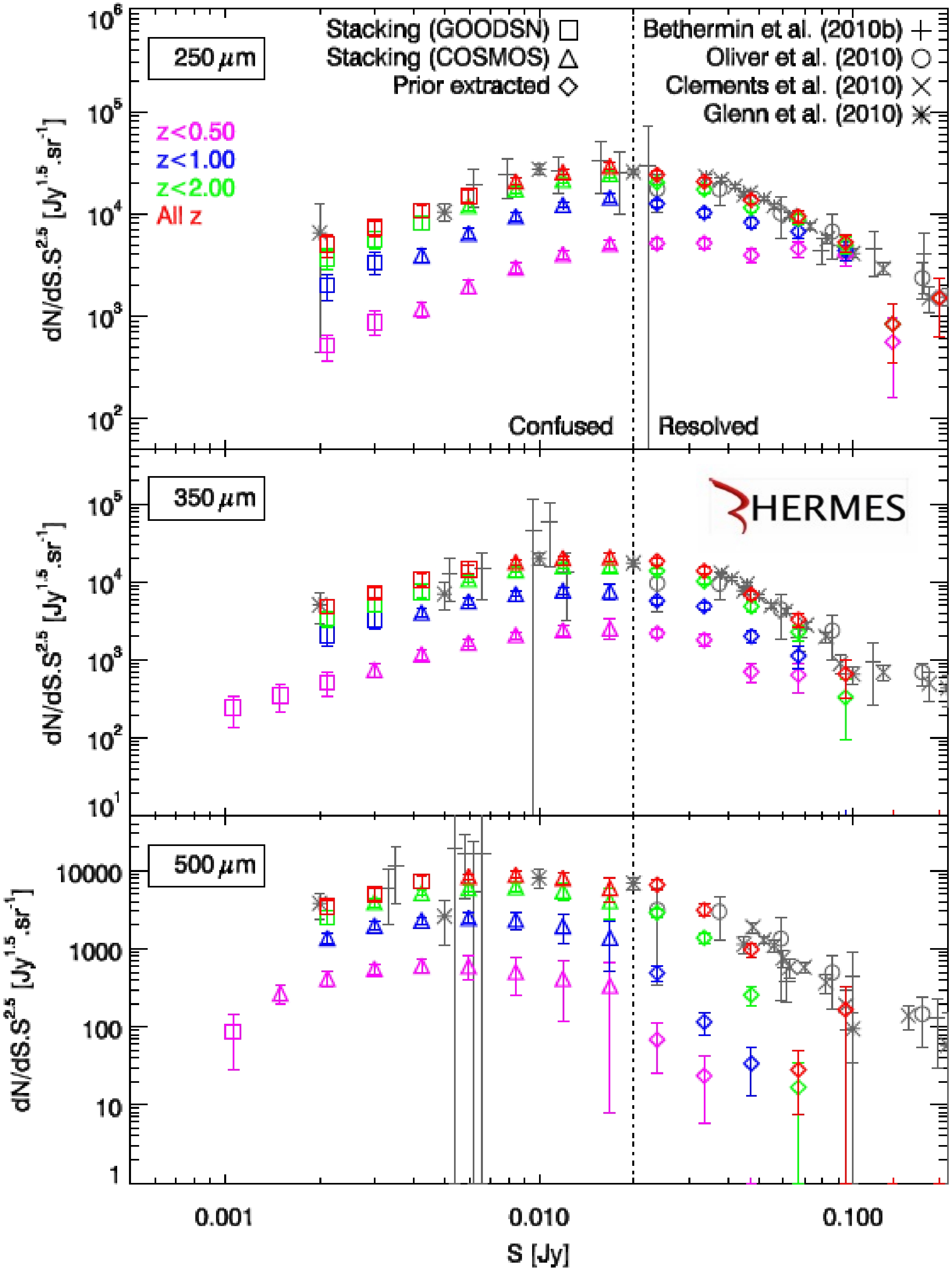
Right: Stacked image at 250 microns fitted by the following model:

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

wavelength	Bias due to clustering		
μm	Method A	Method B	Method C
250	5±2%	6.9±0.8%	7.7±0.5%
350	11±2%	11.7± 0.9%	10.3± 0.8%
500	20±5%	20.9±1.4%	19.1±1.8%



From Béthermin+, in prep

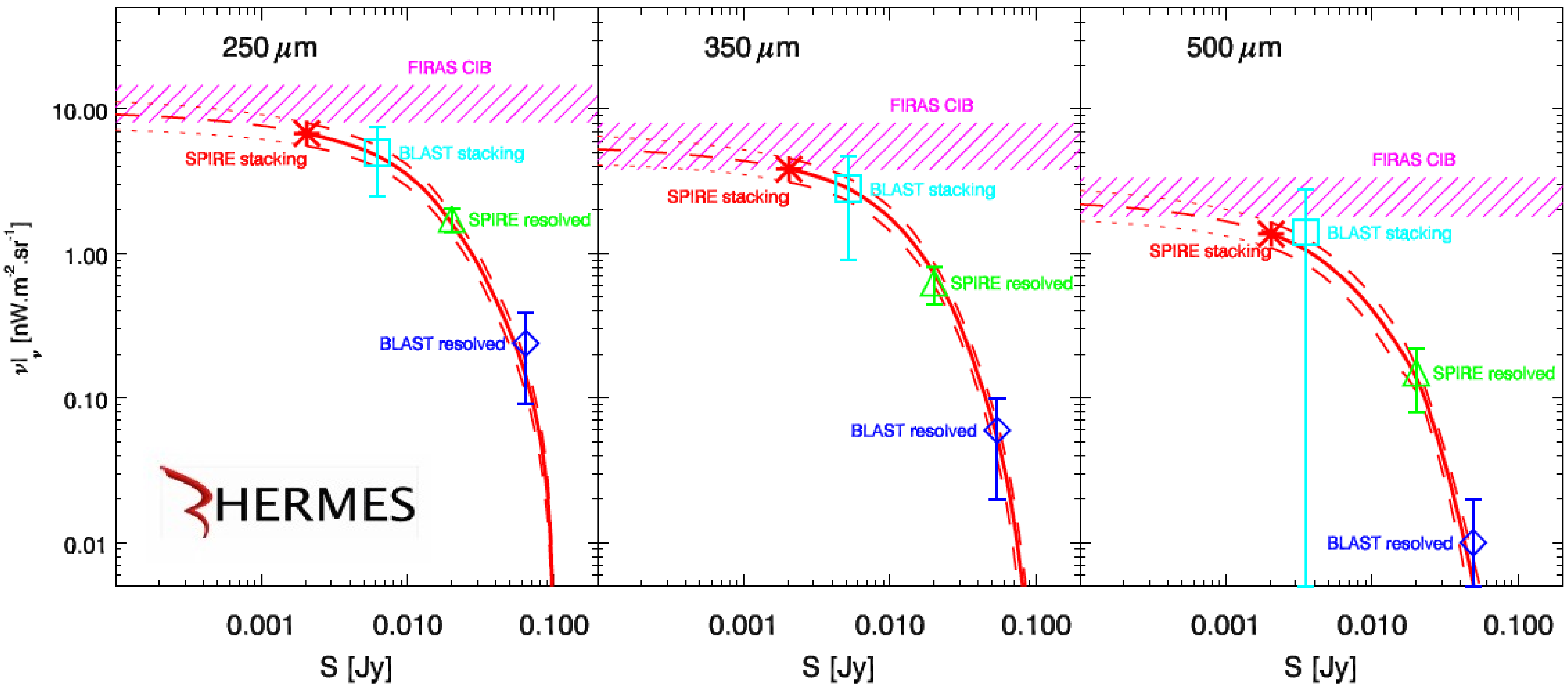


Source counts

- Counts in agreement with previous studies (Bethermin+10b, Oliver+10, Clements+10, Glenn+10)
- Confirmation of Glenn+10 results with improved error bars.
- Redshift slices for the first time.
- Provide strong constraints for future modeling works.

Left: number counts at 250, 350, and 500 microns (Béthermin+, in prep)

Total extrapolated value of the CIB



Cumulative contribution to the CIB as a function of the flux cut (Béthermin+, in prep)

- CIB value computed from the counts and a power-law extrapolation of the faint-end.
- Agreement with the FIRAS measurements.

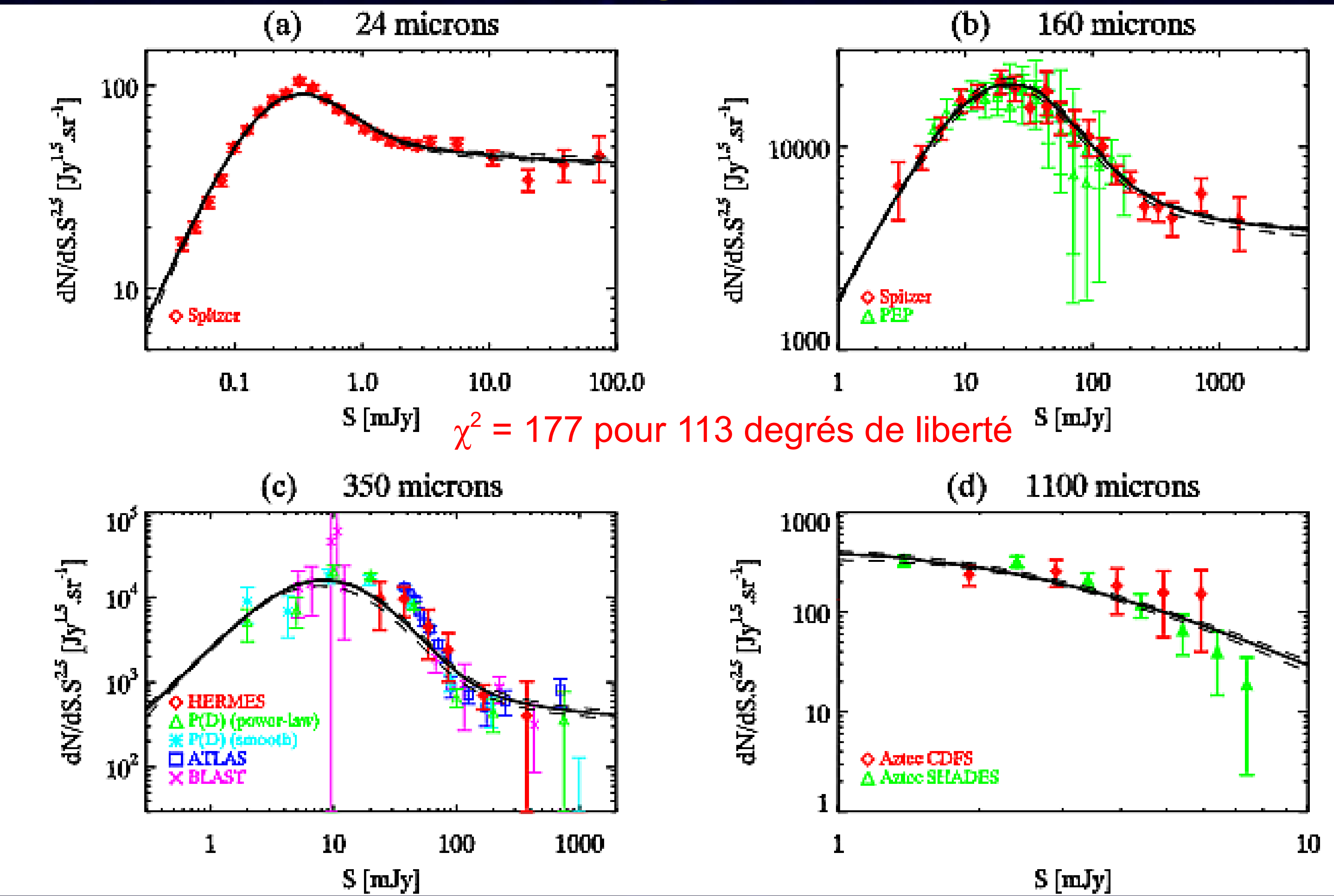
Outline

- Resolving the CIB in the sub-mm domain
- Modeling the evolution of the infrared populations
- Anisotropies of the cosmic infrared background

Backward evolution modelling

- Lots of model of this type published: Lagache+,Franceschini+,Gruppioni+,Le Borgne+, Béthermin+, Marsden+, Yong Shi's poster
- The typical ingredients are:
  - Cosmology
  - SED (Spectral Energy Distribution) library
  - Local luminosity function (LF)
  - Evolution of the LF with the redshift
  - Observables to fit

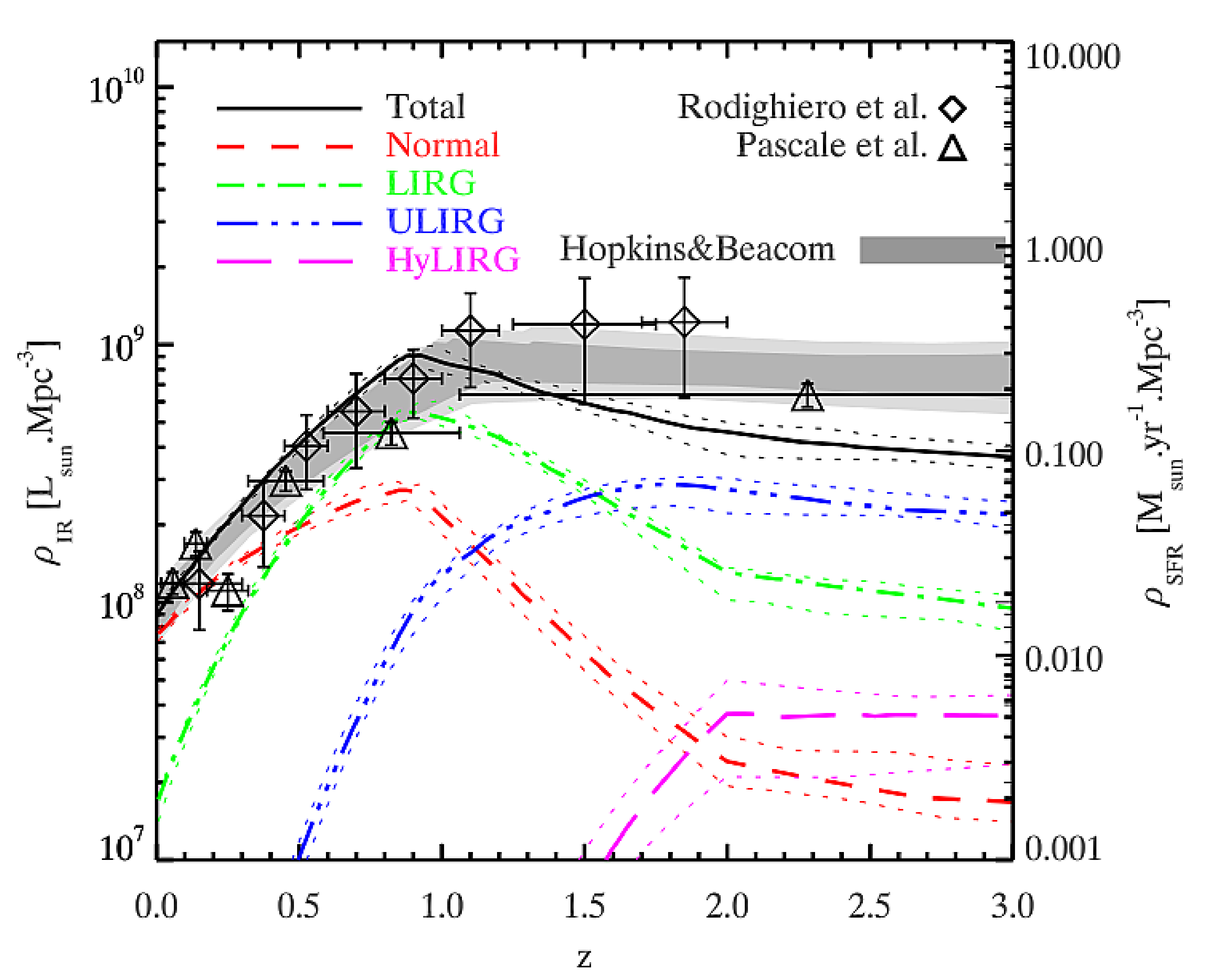
Fitting the counts



- Fit if the counts between 24 microns and 1.1 mm+ monochromatic LFs+CIB FIRAS
- Parameters ajusted with a MCMC.

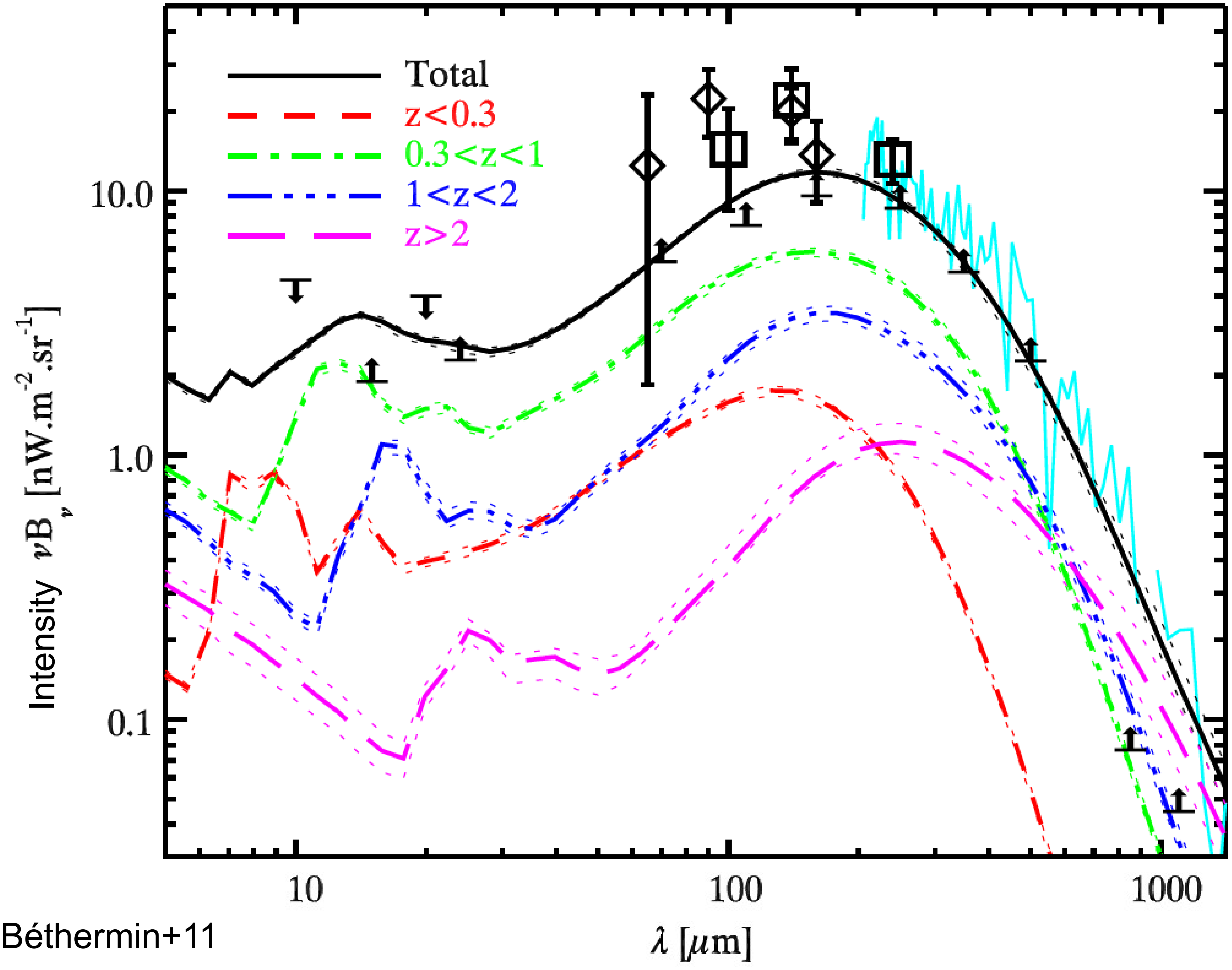
Number counts at 24, 160, 350, and 1100 microns (Béthermin+11)

Obscured star formation history



Evolution of the infrared luminosity and the star formation density (Béthermin+11)

CIB SED



Béthermin+11

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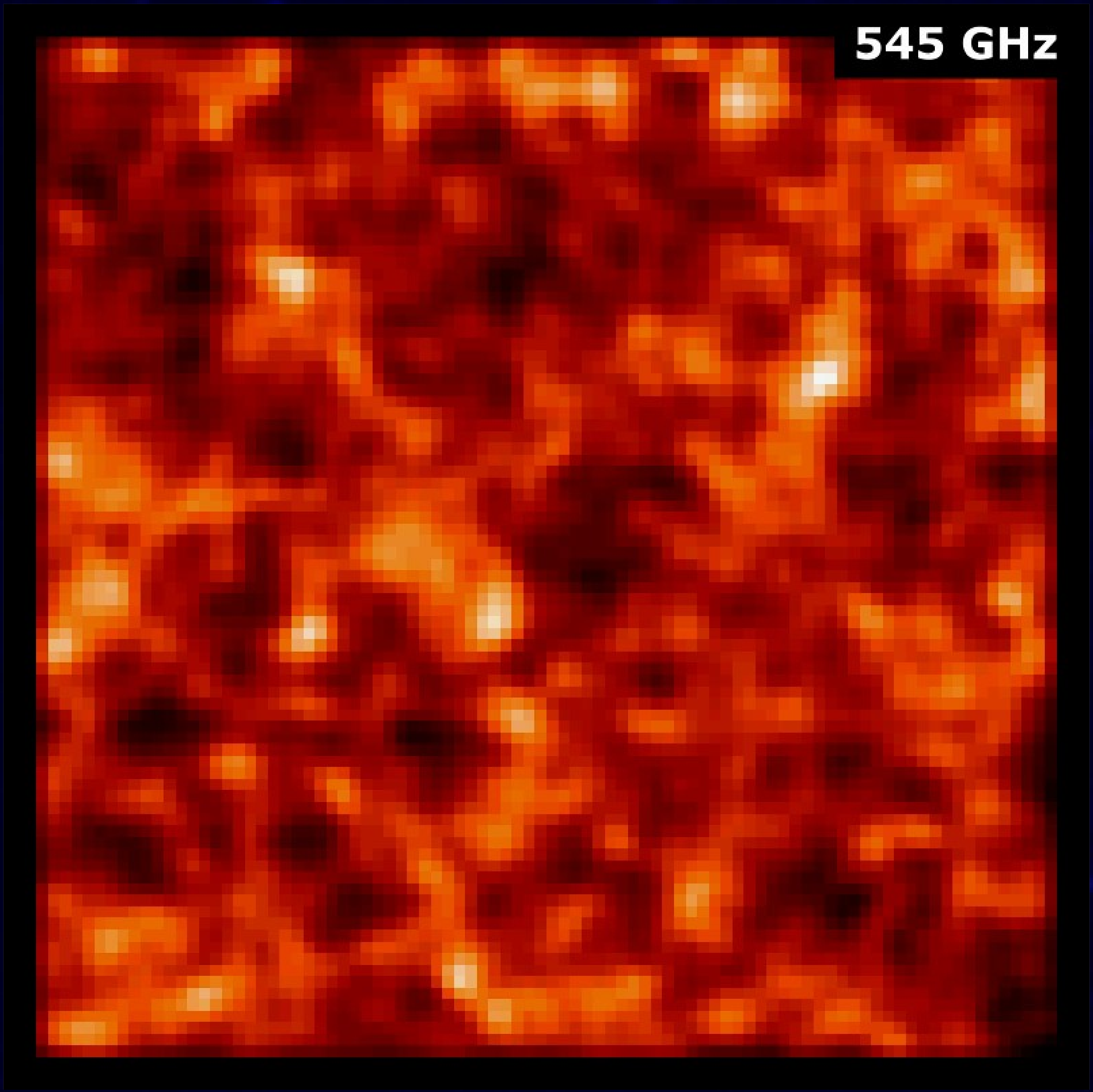
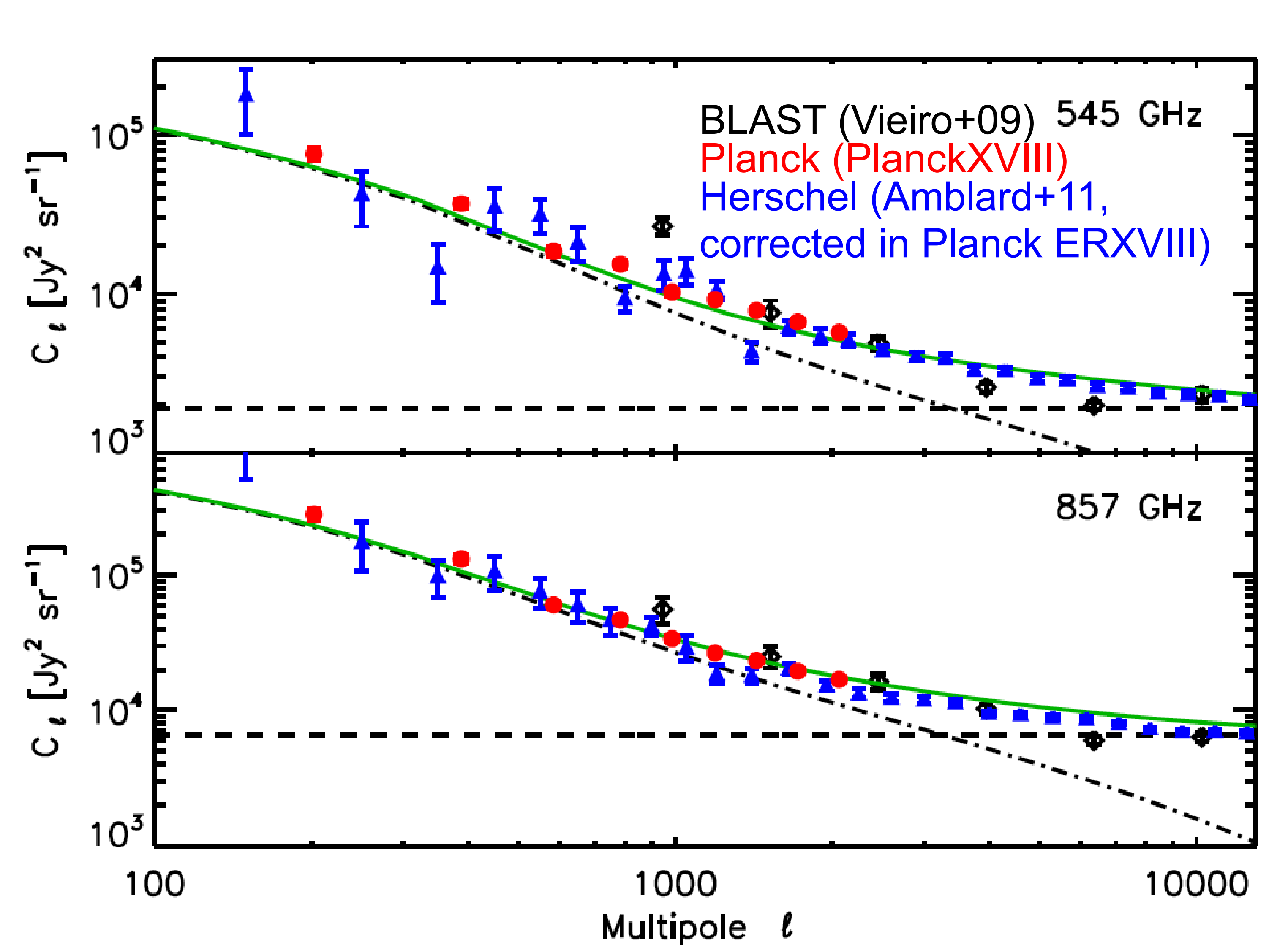
Fluctuations of the CIB



Fluctuations of the CIB observed by Planck (courtesy G. Lagache)

- CIB obtained subtracting the foreground (galactic cirrus) and the background (CMB)
- CMB removed using 143 GHz maps.
- Cirrus removed HI data.
- Information about the clustering of the sources at high-z.

CIB power spectrum



Power spectrum of the cosmic infrared background at 500 microns (545 GHz) and 350 microns (857 GHz) (Planck Early Paper XVIII)

Modeling the CIB fluctuations

- Pénin+11 (on arxiv yesterday): model to intepretе the CIB fluctuations. Based on the Béthermin+11 emissivities, and a HOD model.

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

From evolution model

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

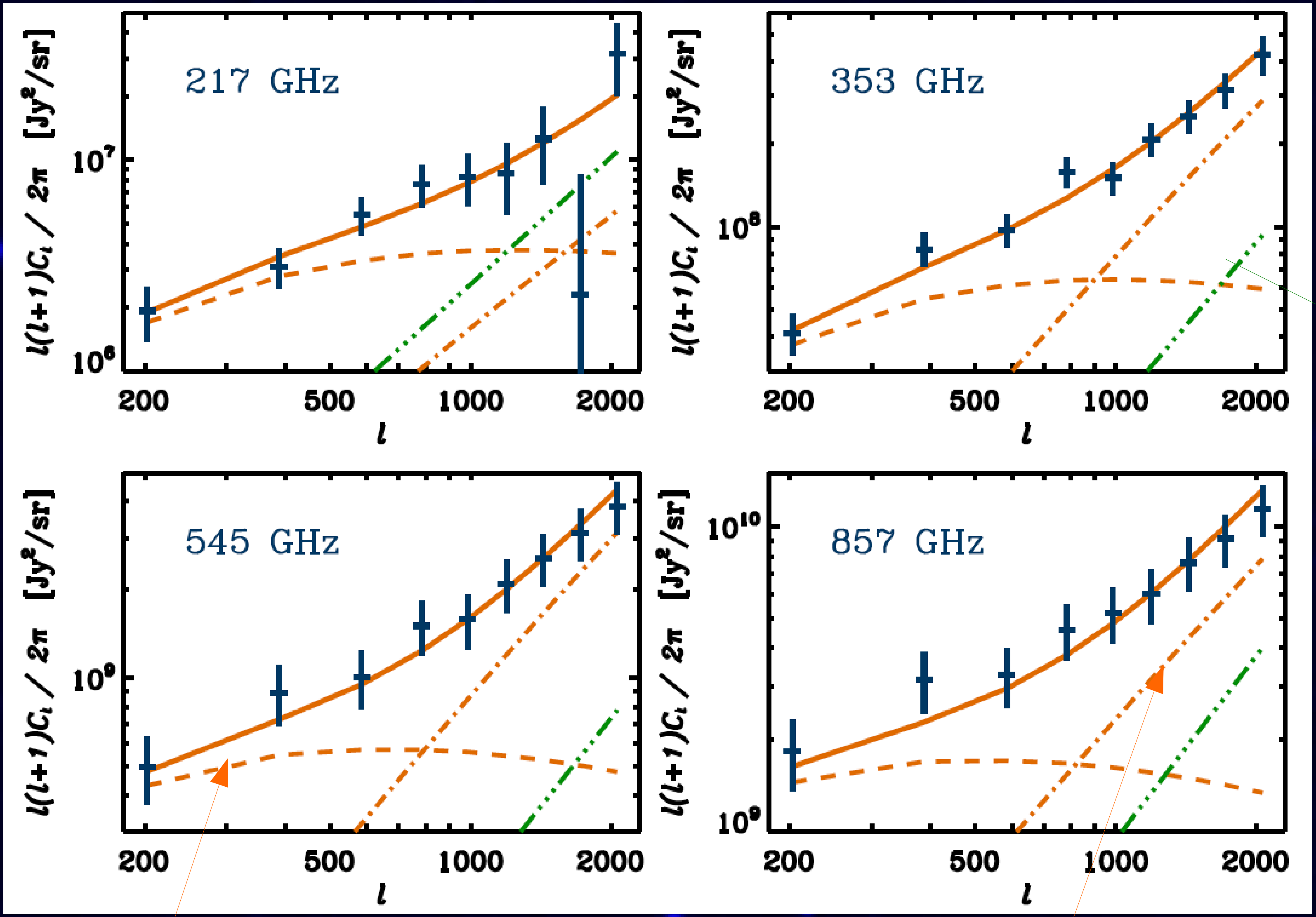
Computed from the Béthermin+11 evolution model

Clustering model

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

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

Fit of the Planck data



Shot noise

$$\sigma_B^2 = \int_0^{S_c} \frac{dN}{dS} S^2 dS$$

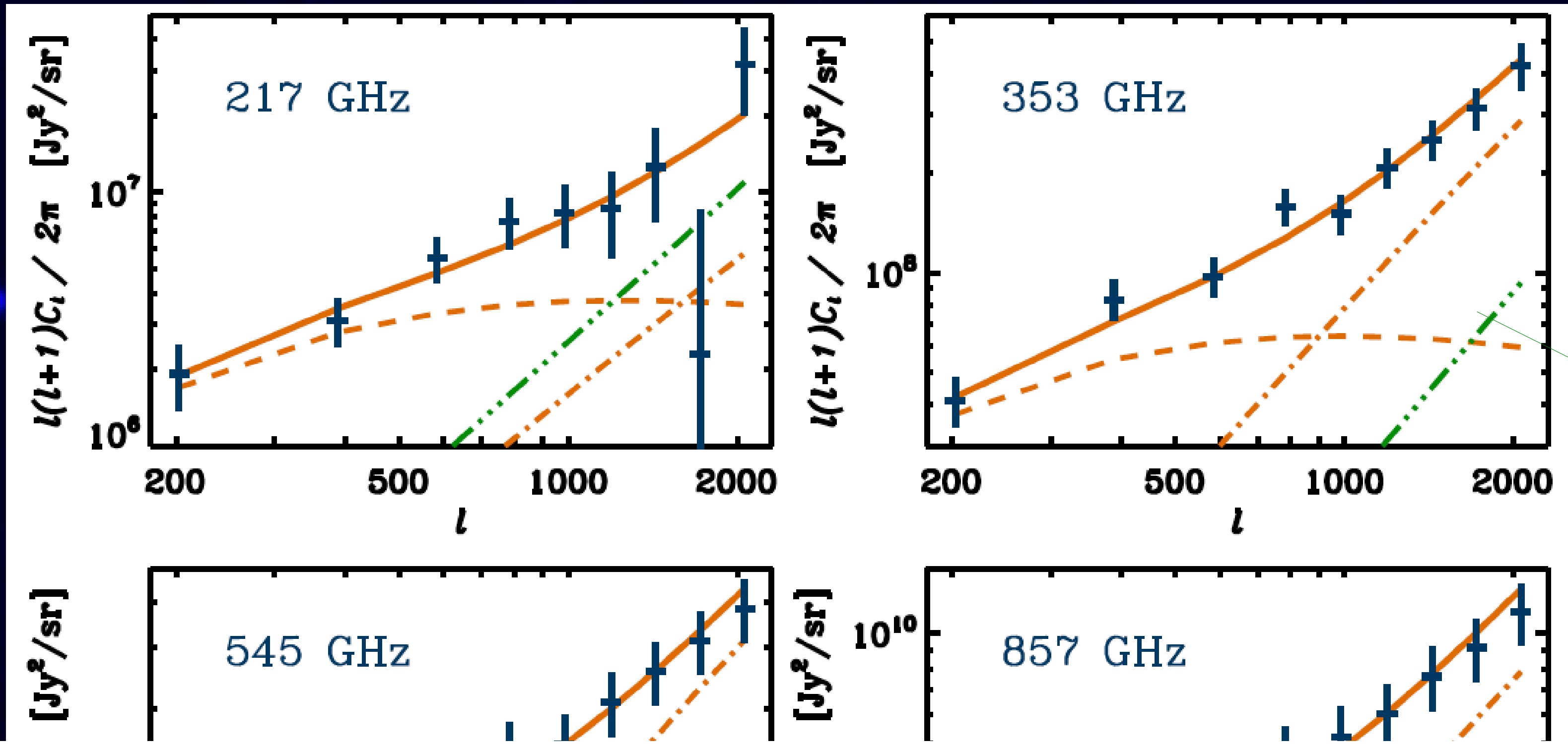
Computed from the counts predicted by the Béthermin+11 model.

2-halos term

1-halo term

Planck Early Paper XVIII

Fit of the Planck data



Shot noise

$$\sigma_B^2 = \int_0^{S_c} \frac{dN}{dS} S^2 dS$$

Frequency (GHz)	$\log_{10} M_{\rm min}$ [$h^{-1}\mathrm{M}_\odot$]	$\alpha_{\rm sat}$	$j_{\rm eff}$ [Jy/Mpc/sr]	Reduced χ^2 (χ^2/dof)
217	11.95 ± 2.10	1.30 ± 1.16	$7.51 \pm 0.75 \times 10^1$	2.68 (16.1/6)
353	12.49 ± 0.42	1.39 ± 0.42	$2.00 \pm 0.29 \times 10^2$	2.42 (14.5/6)
545	12.35 ± 1.01	1.17 ± 0.65	$3.11 \pm 3.85 \times 10^2$	0.50 (3.04/6)
857	12.20 ± 0.51	1.02 ± 0.87	$3.14 \pm 17.0 \times 10^2$	0.73 (4.40/6)
217	11.82 ± 1.92	1.17 ± 2.38	N/A	1.14 (7.96/7)
353	12.50 ± 0.09	1.35 ± 0.20	N/A	0.80 (5.64/7)
545	12.35 ± 0.94	1.17 ± 0.45	N/A	0.35 (2.46/7)
857	12.21 ± 1.23	0.96 ± 0.73	N/A	0.60 (4.22/7)

Conclusion

- CIB resolved in the sub-mm domain with the new statistical methods (stacking, P(D)).

- The recent evolution model well describe the basic infrared statistical observables, and provide a picture of the CIB redshift distribution and obscured star formation history.

- CIB fluctuations provide information on the mass of the halos hosting