Planck-Herschel synergies on extragalactic point sources

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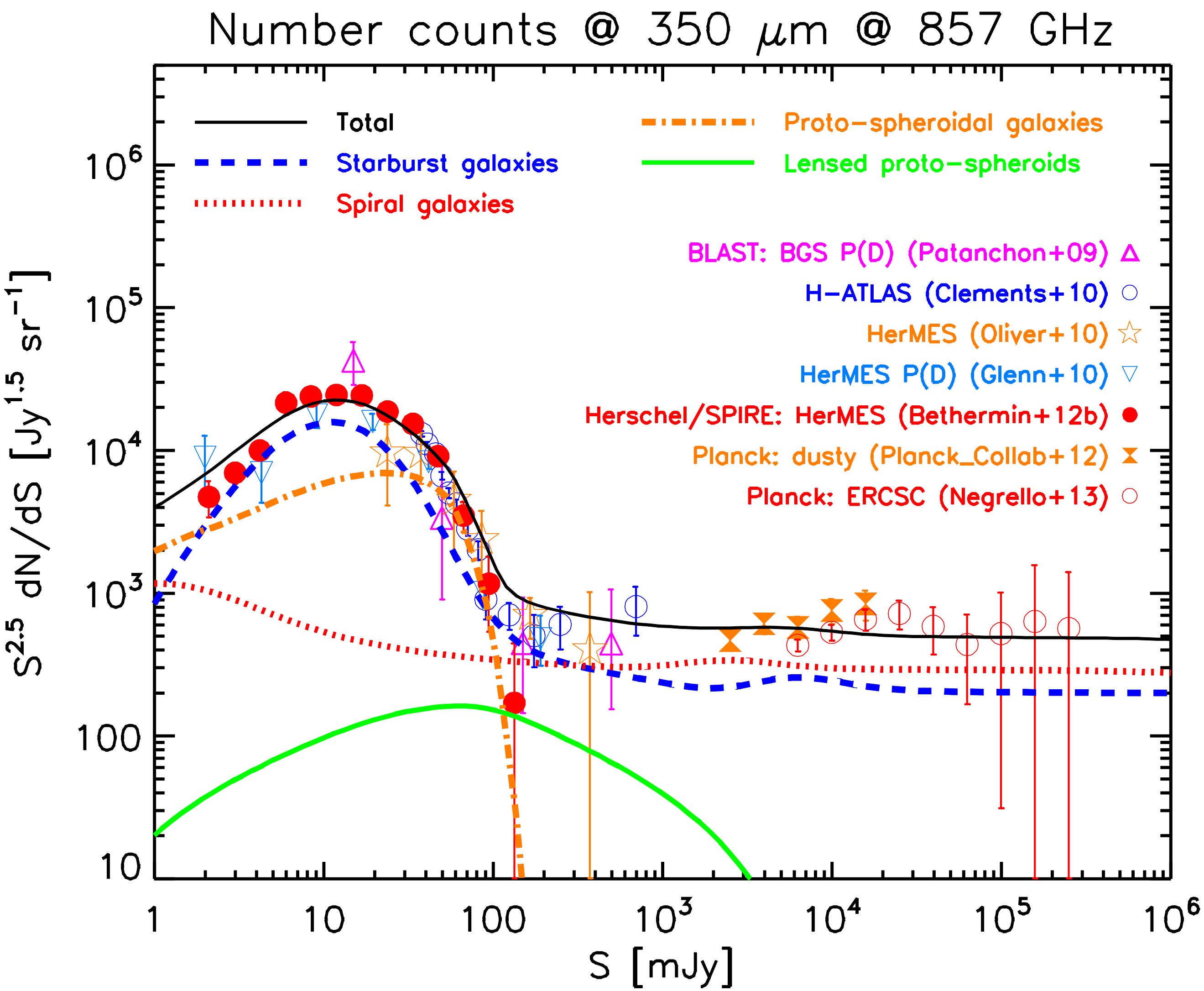
thanks to: Zhen-Yi Cai, Andrea Lapi, Mattia Negrello

The Planck-Herschel complementarity -1

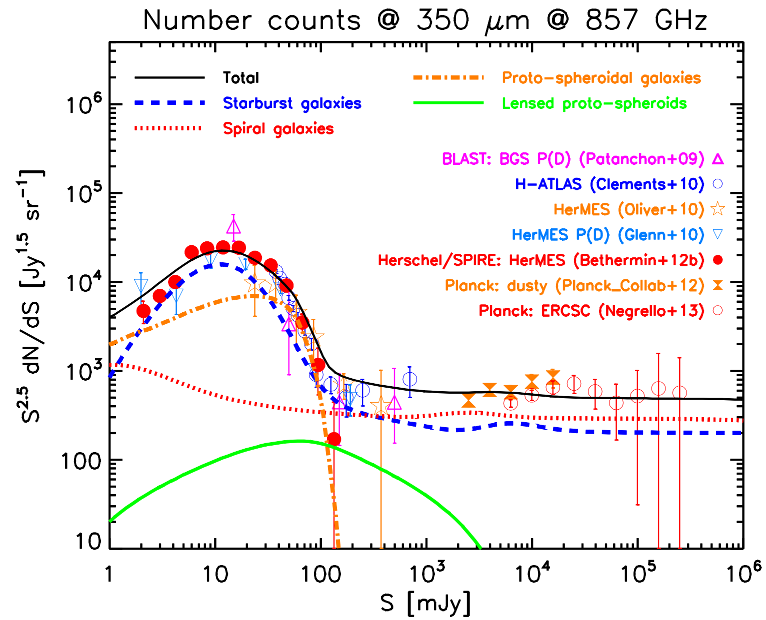


Planck extends by two orders of magnitude in flux density the Herschel counts, provides a rich sample of sub-mm selected galaxies, ideal for determining the local luminosity function (Negrello's talk) and the population properties of local star-forming galaxies (Clemens' talk).

Courtesy of Zhen-Yi Cai

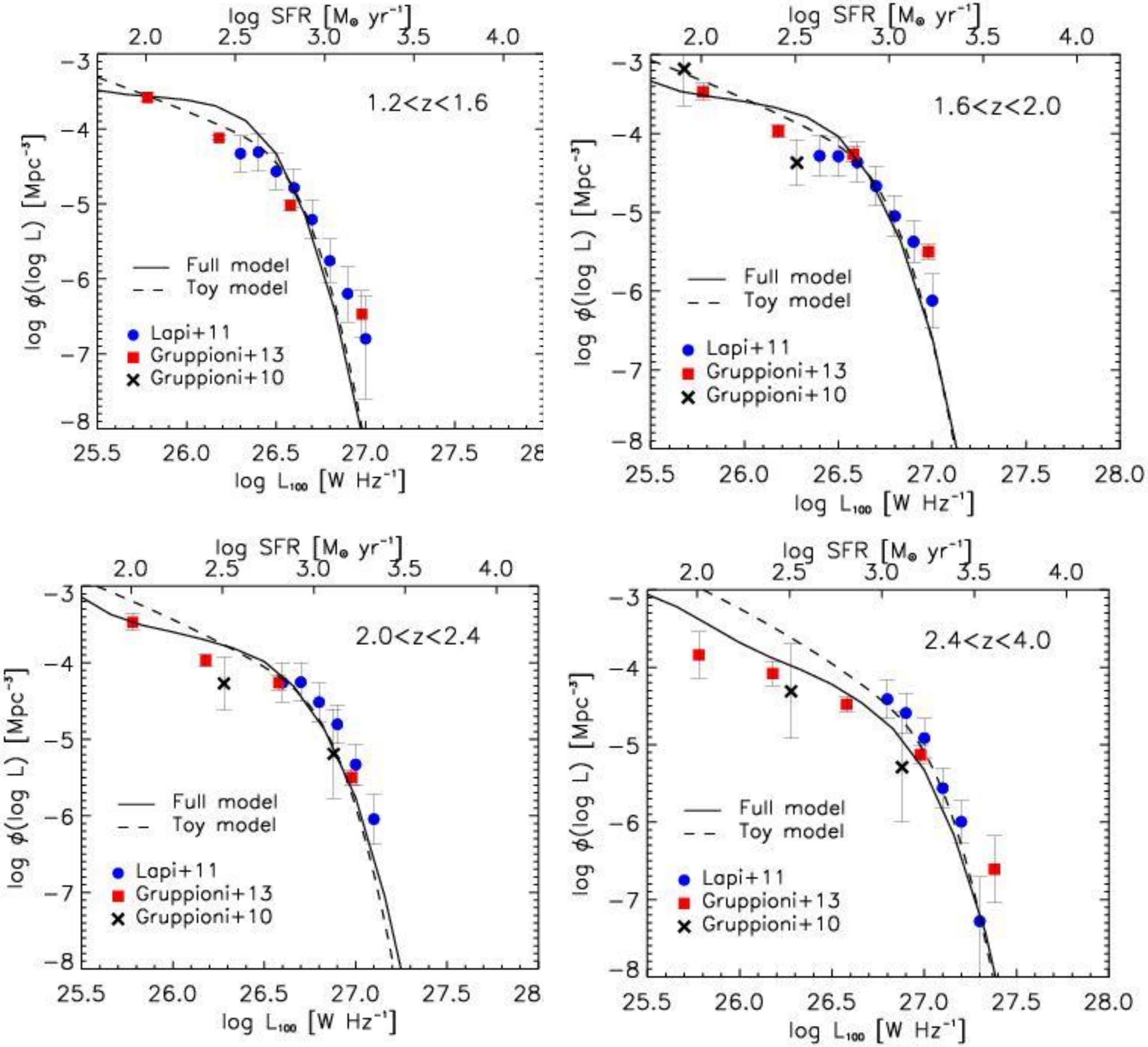
PCCS counts not included yet

The Planck-Herschel complementarity -2



The solid determination of the Euclidean portion of the counts, provided by Planck, constitutes corroborating evidence for the abrupt steepening of the counts at S~100 mJy, indicating the sudden appearance of a different source population, interpreted as proto-spheroidal galaxies at z ≥ 1.5, in the process of forming most of their stars. The lower-z counterparts of these sources are mostly in passive evolution and therefore minor contributors to the sub-mm counts. This abrupt steepening is very hard to account for by models interpreting the counts in terms of evolution of local populations. A sharp discontinuity in the redshift distribution of galaxies above and below ~100 mJy is confirmed by spectroscopy of strongly lensed galaxies (green line) that sample the steep portion of the counts.

From counts to luminosity function



The LFs of high-z galaxies reflect quite well the halo formation rate for a *continuous* duration of the star-formation phase of ~0.7 Gyr (Lapi et al. 2011). This duration is *longer* than that of star-formation bursts triggered by mergers and *shorter* than that of star-formation fuelled by cold flows but consistent with the self-regulated star-formation scenario that also accounts for the observed α-enhancement

Link between IR luminosity and halo mass

The duration of the star-formation episode and the stellar IMF determine the relationship between the SFR and mass of associated dark matter halos. For the Lapi et al. (2011) model and a standard (Chabrier) IMF we have:

$$\mathrm{SFR} \simeq 35 \left(\frac{M_H}{10^{12}\, M_\odot}\right) \left(\frac{1+z}{2.5}\right)^{2.1} M_\odot\, \mathrm{yr}^{-1}$$

implying that the most effective star-formers in the universe at z~2, which have SFR~100–200 $M_\odot$/yr, are associated to M_H~2–4·10^{12} $M_\odot$. "Cold flow" models (Dekel et al. 2009) entail *substantially higher* halo masses (Davé et al. 2010) while the "merger+top-heavy IMF" (Baugh et al. 2005; Lacey et al. 2010) imply *substantially lower* M_H (Almeida et al. 2011; Kim et al. 2011).

Constraints on M_H from clustering power spectrum

$$P(k_\theta) = \int_{z_{\rm min}}^{z_{\rm max}} dz\, P_{\rm gal}\left(k = \frac{2\pi k_\theta + 1/2}{\chi(z)}, z\right) \left(\frac{dS}{dz}(z)\right)^2 \frac{dz}{dV_{\rm c}},$$

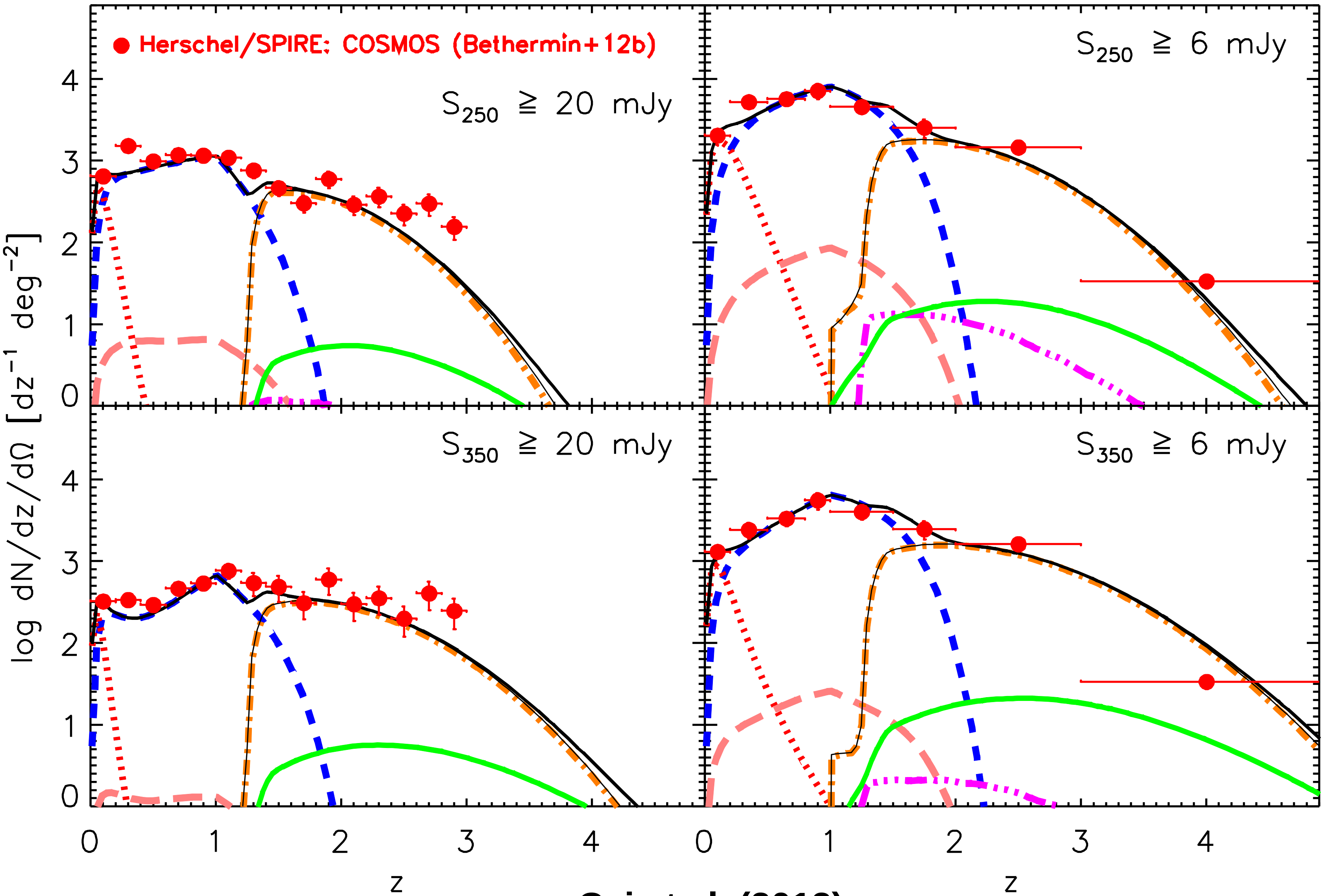
where

$$P_{\rm gal}^{\rm 2h}(k,z) = P_{\rm lin}(k,z) \cdot \left[\int_M dM \frac{dn}{dM} \frac{\langle N_{\rm gal}\rangle}{\bar{n}_{\rm gal}} b(M,z) u_{\rm dm}(k,M)\right]^2$$

and dS/dz is the redshift distribution of the cumulative flux of sources with $S \leq S_{\rm lim}$

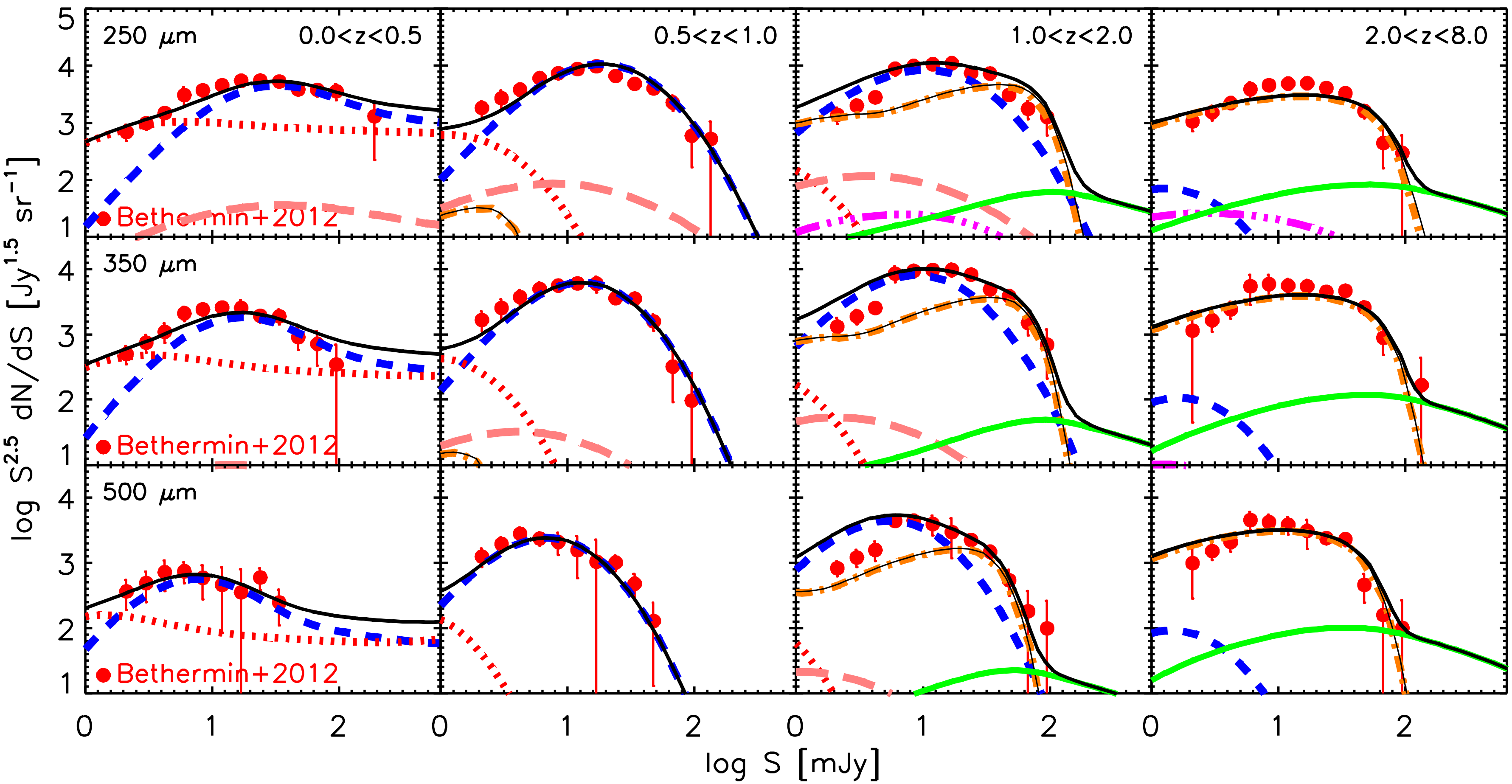
$$\frac{dS}{dz} = \int_0^{S_{\rm lim}} d\log_{10}(S)\, S\, \phi[L(S,z),z]\, \frac{dV_{\rm c}}{dz}.$$

Flux functions tightly constrained by observed redshift distributions …



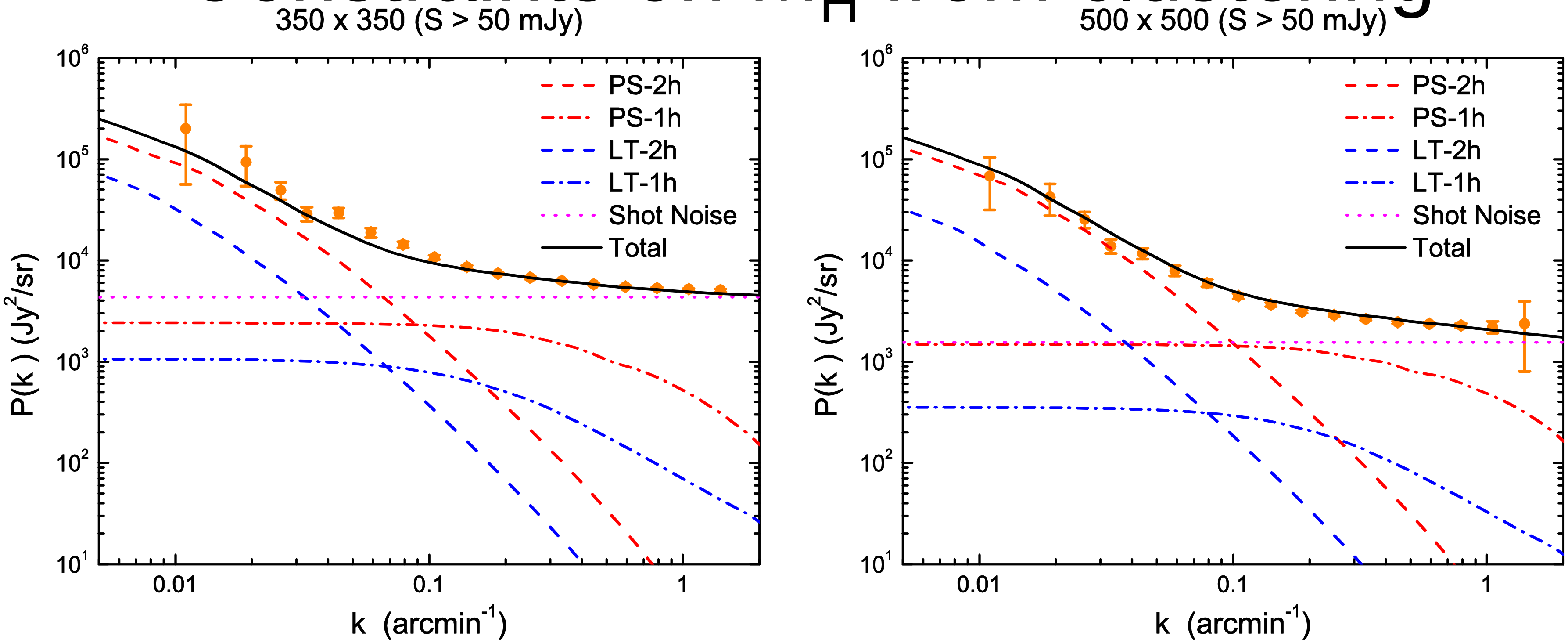
Cai et al. (2013)

… and by counts per redshift bins



Cai et al. (2013)

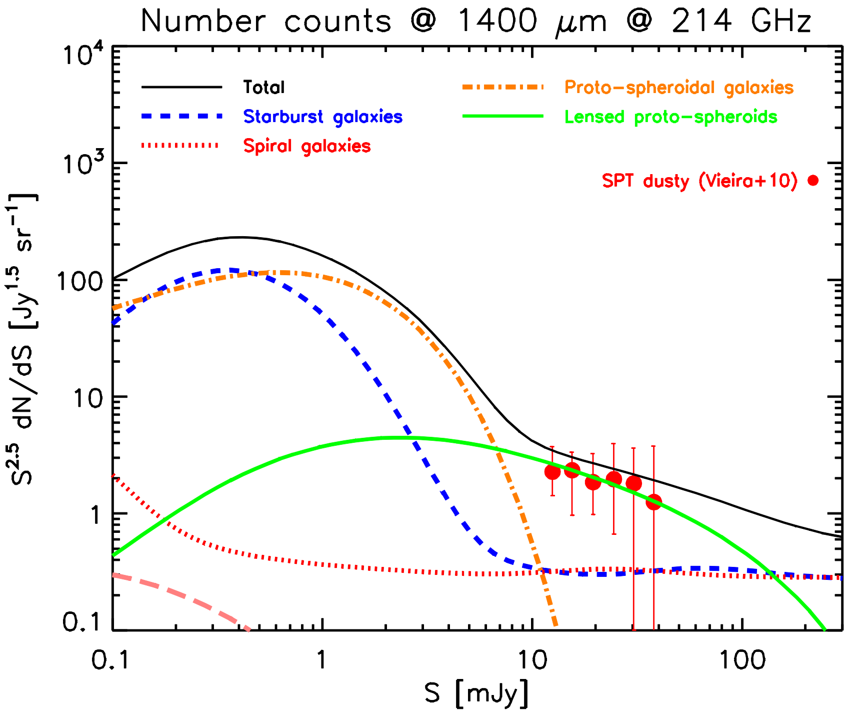
Constraints on M_H from clustering

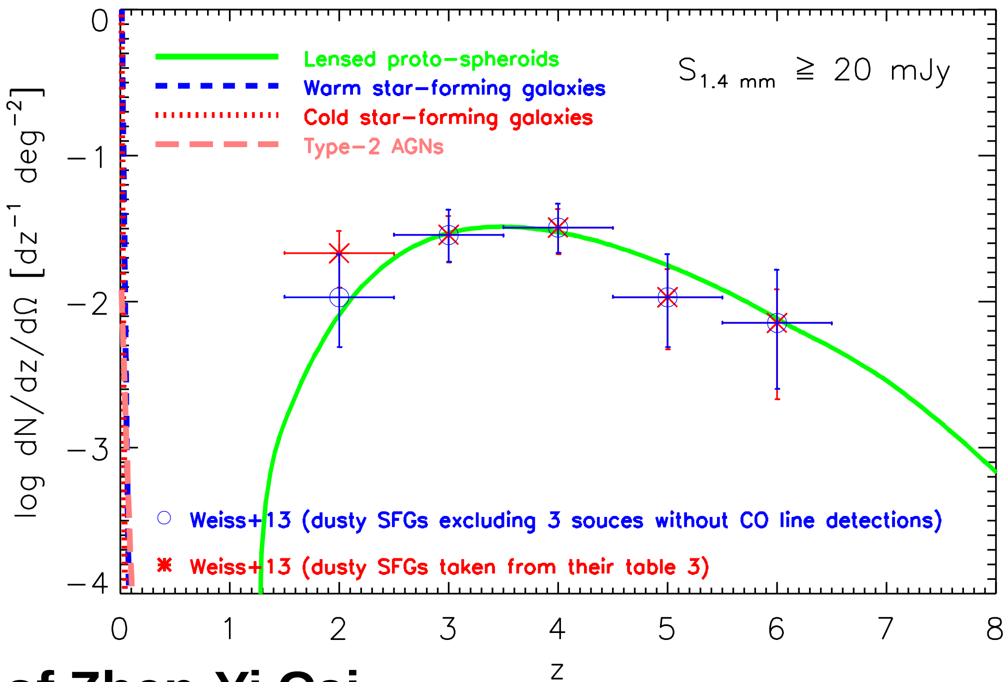


Cai et al. (2013), data from Viero et al. (2012)

Fit only weakly dependent on evolutionary model once the strong constraints from observational determinations of LF(z) are met. Minimum halo mass of protospheroids ~$1.4 \cdot 10^{12}$ $M_{\odot}$, effective halo mass at z=2: $M_{eff} \approx 4.5 \cdot 10^{12}$ $M_{\odot}$, close to the estimated halo masses of the most effective star-forming galaxies ($\approx 3.5 \cdot 10^{12}$ $M_{\odot}$ Tacconi et al. 2008). Similar values of M_{eff} found by Xia et al. (2012), Shang et al. (2012), Thacker et al. (2012).

Gravitational lensing - 1

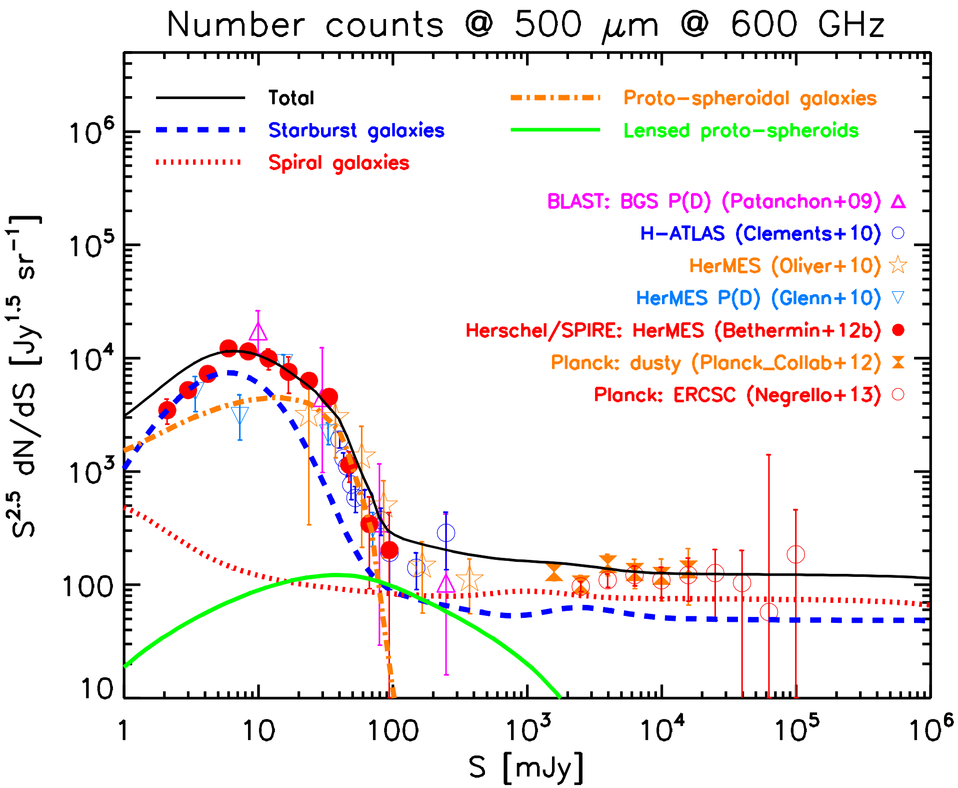




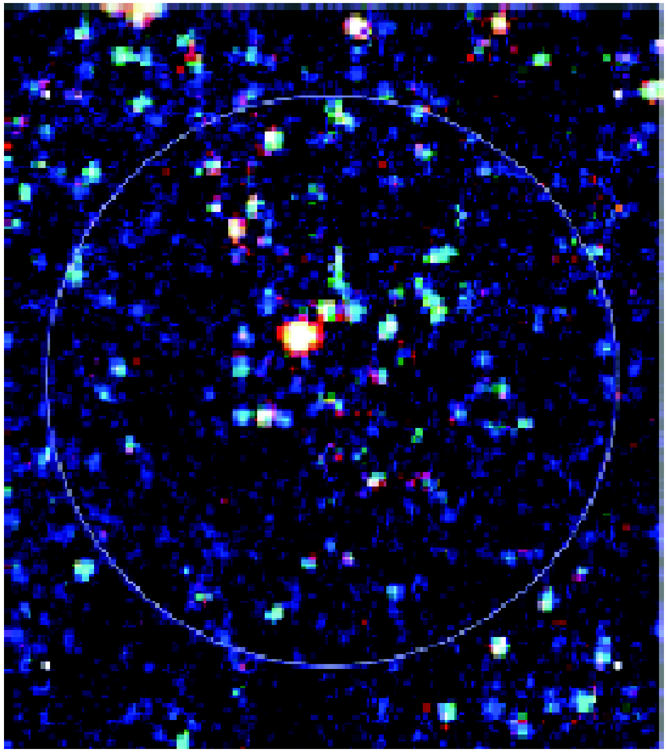
Courtesy of Zhen-Yi Cai

The self-regulated galaxy evolution model (Granato et al. 2004; Negrello et al. 2007; Lapi et al. 2011; Cai et al. 2013) accurately predicted the (sub-)mm counts of strongly lensed galaxies and matches very well the redshift distribution of a sample of 26 galaxies selected to have $S_{1.4mm}$ > 20 mJy, after excluding low-z objects and radio sources (Weiss et al. 2013; Vieira et al. 2013), that are hard to account by alternative semi-analytic and even phenomenological models.

Gravitational lensing - 2



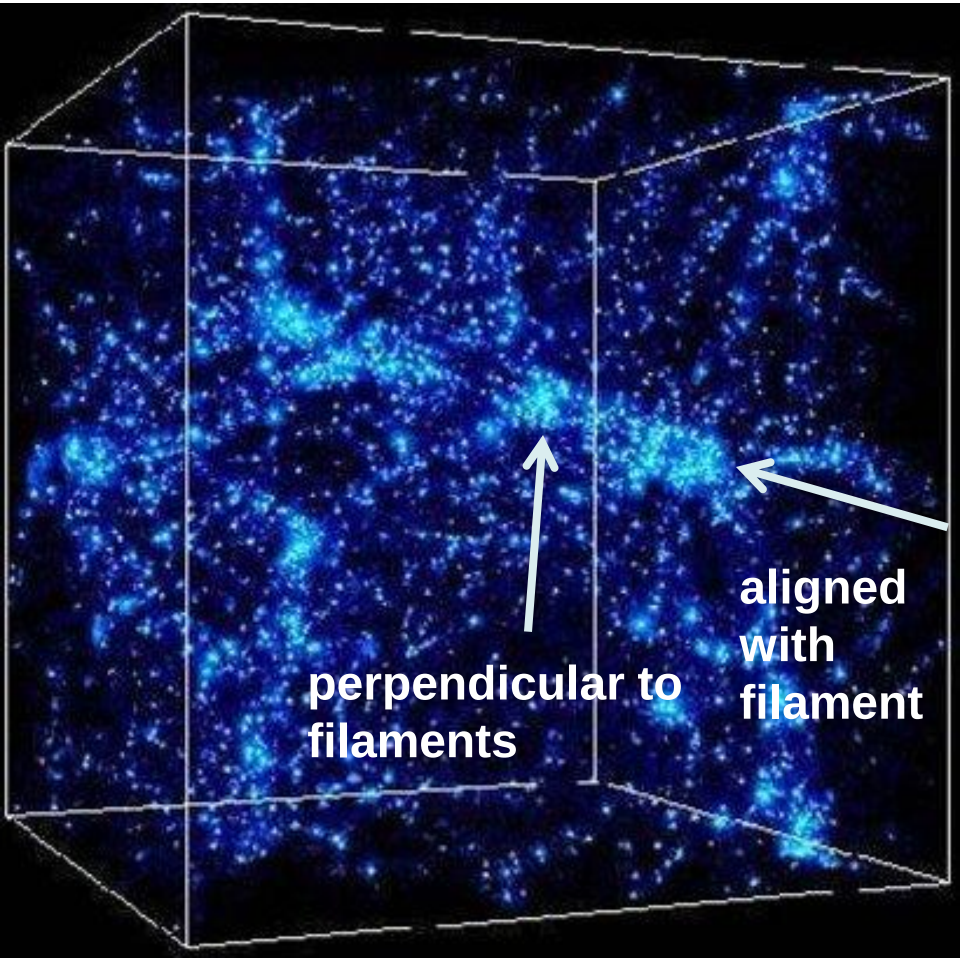
Courtesy of Zhen-Yi Cai



Herranz et al. (2013)

The detection limits of the Planck ERCSC were already not far from the flux density range where strongly lensed galaxies are expected to show up. A boost by an underlying fluctuation peak may however make them visible (Herranz et al. z=3.26 galaxy whose Herschel flux density is ~1/3 of that measured by Planck).

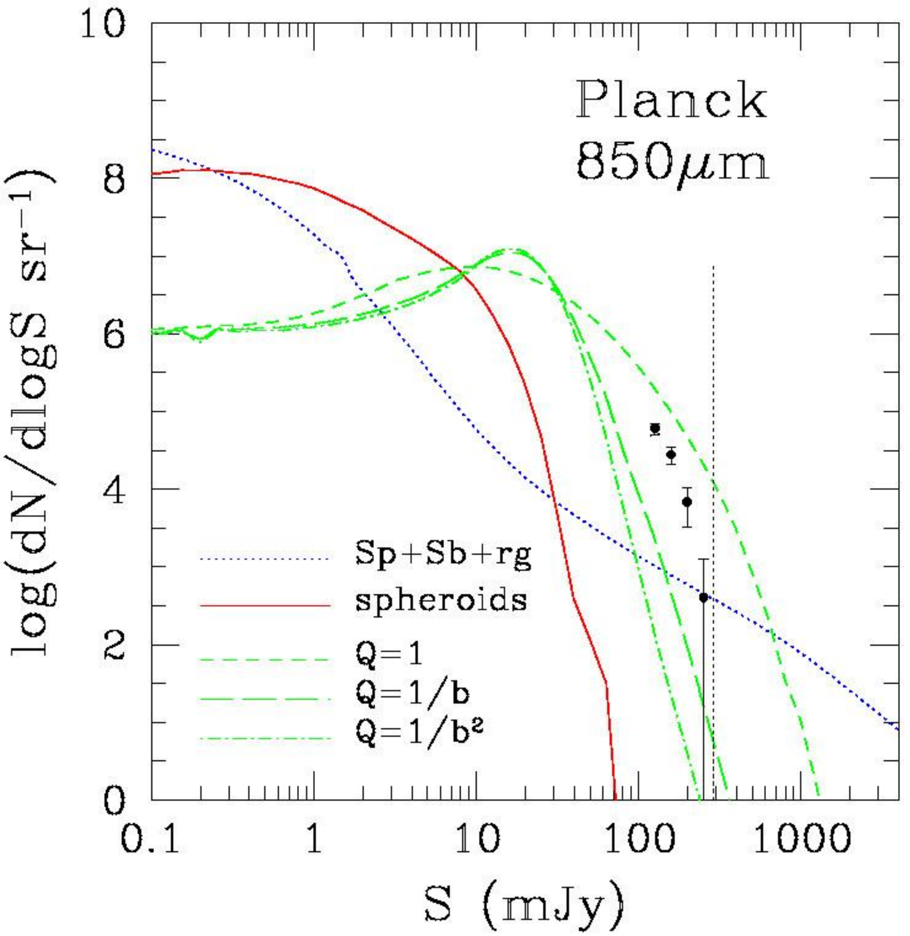
Protoclusters of dusty galaxies - 1

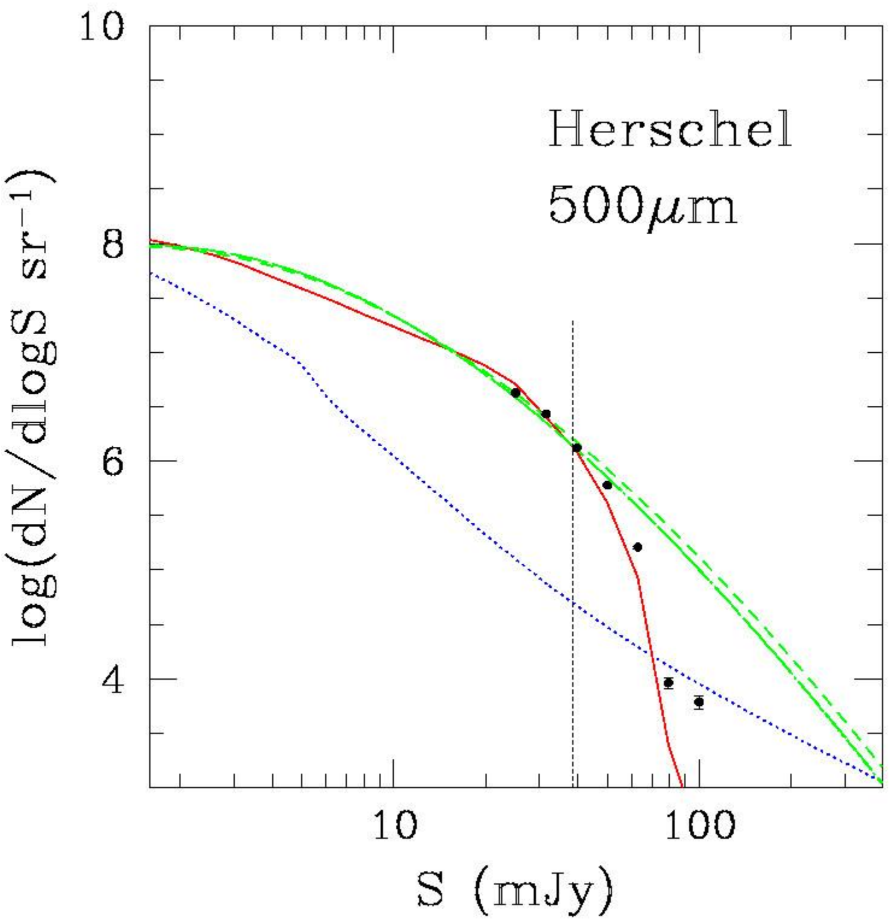


The peak in the CIB pushing up the flux density is not necessarily a random fluctuation. In some cases it must be physically associated to the detected source. E.g. be due to a foreground concentration of dusty galaxies acting as the lens or to a large scale structure (not necessarily a protocluster) associated to the lensed galaxy itself.

That Planck could detect proto-structures of this kind was predicted by Negrello et al. (2005) who pointed out that high-z large scale structures may also cause blending in SPIRE maps.

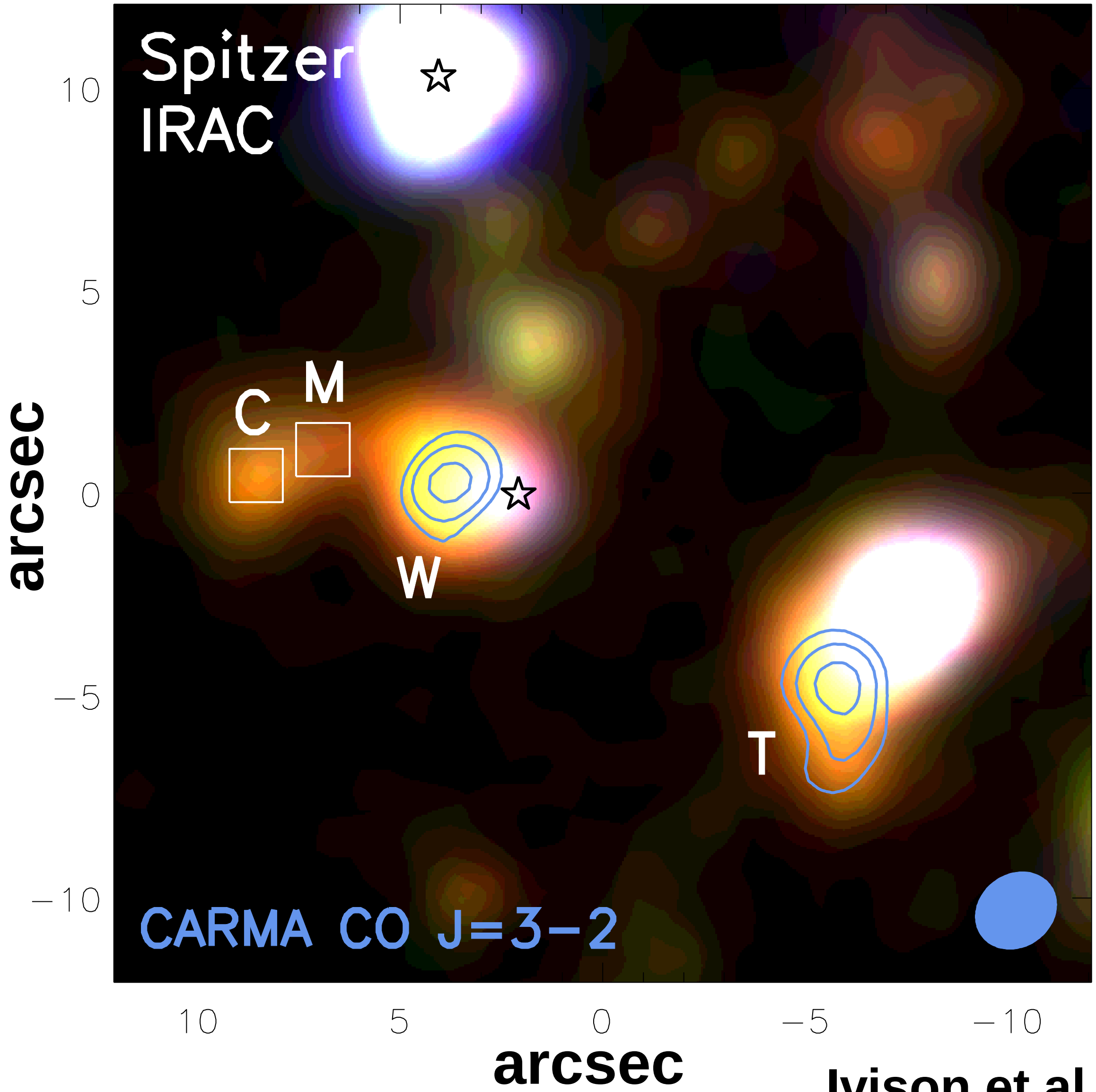
Effect of clustering on source counts





Negrello et al. (2005)

Blend of high-z galaxies within a Herschel/SPIRE beam

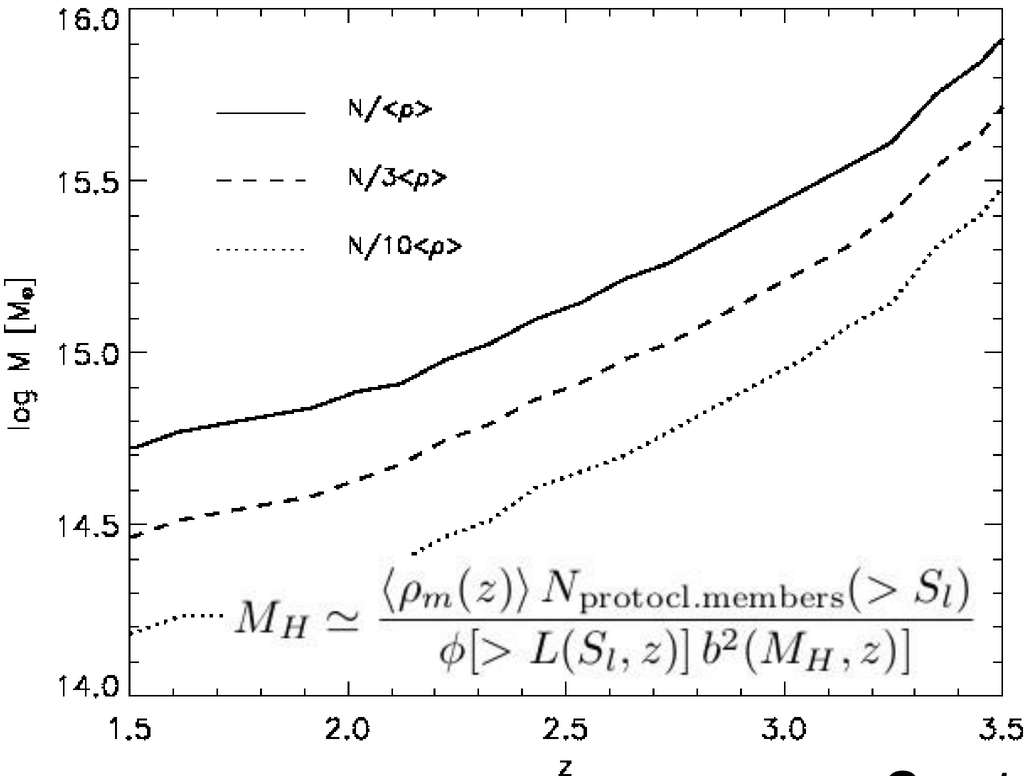


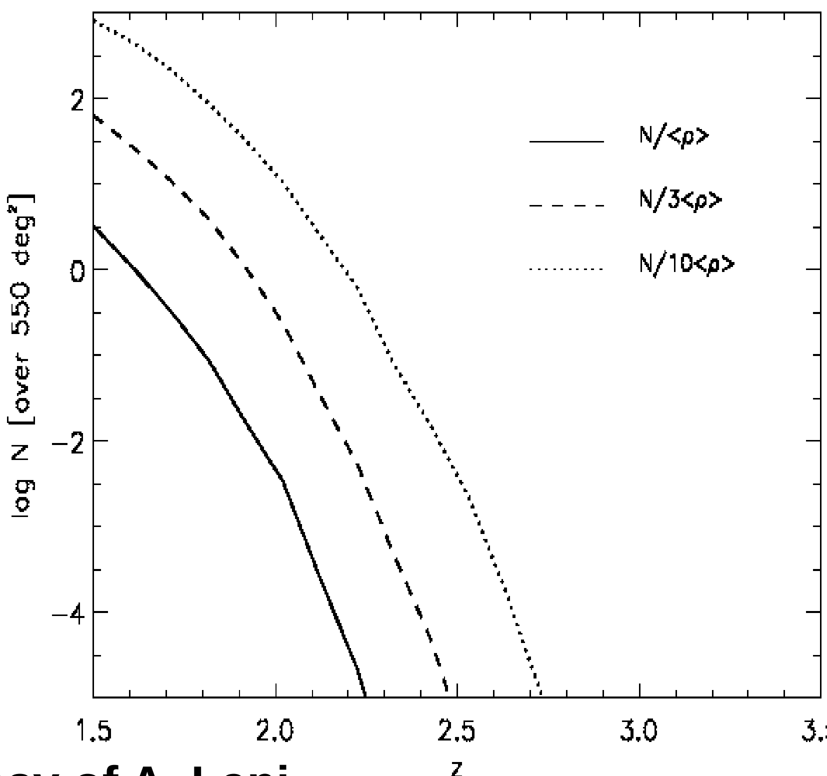
Galaxies W and T at z=2.41, with total $S_{350\mu m}$ = 293 mJy, $S_{500\mu m}$ = 231 mJy, $L_{IR}=4.8\cdot10^{13}\ L_\odot$ are unresolved by Herschel/SPIRE.

Ivison et al. (2013)

Proto-clusters of dusty galaxies - 2

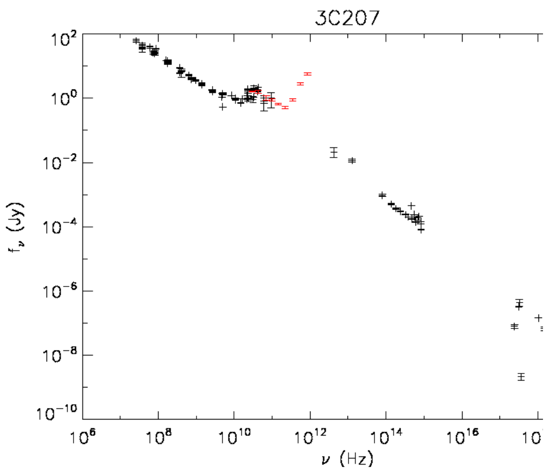
Examples of proto-clusters detected by Planck and confirmed by Herschel were presented by L. Montier (2012). More from D. Clements' and L. Montier's talks. It may be noted that we expect a sharp redshift limit for Planck/Herschel proto-clusters. Strong Planck/Herschel overdensities above z~2.5 are more likely filaments almost aligned with the l.o.s.

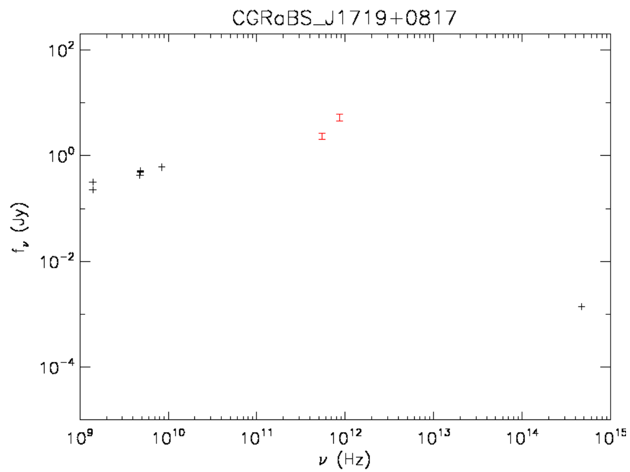


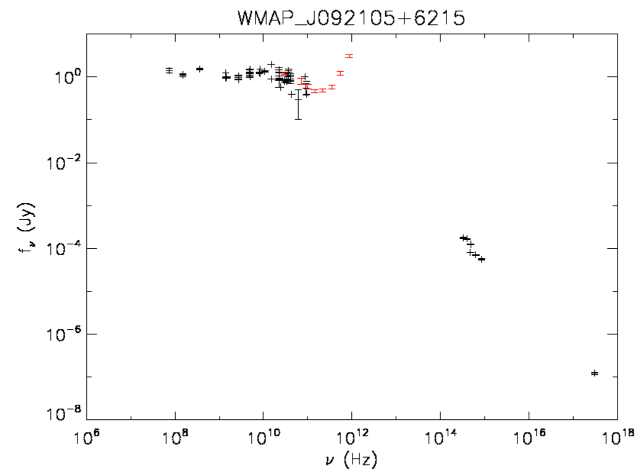


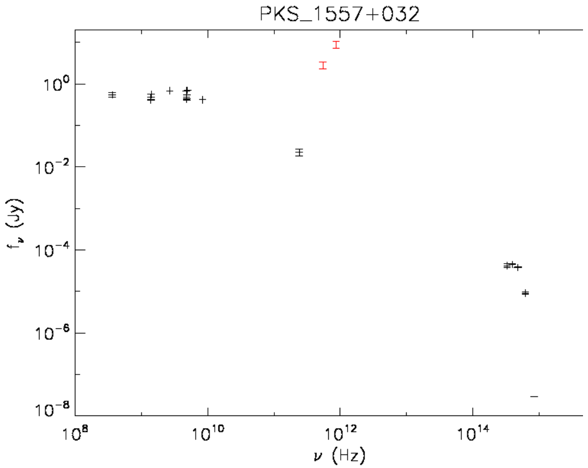
Courtesy of A. Lapi

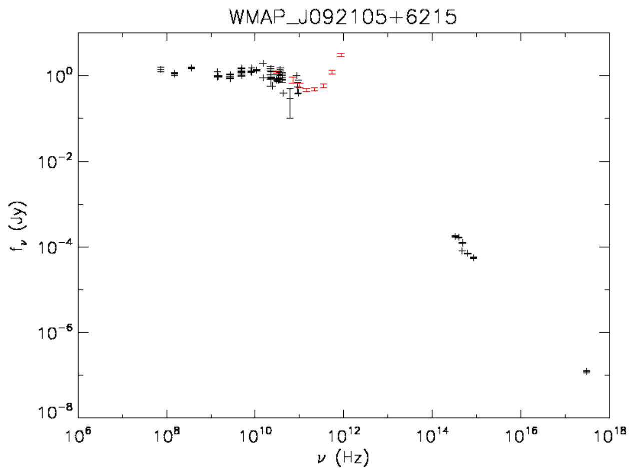
Blazar SEDs







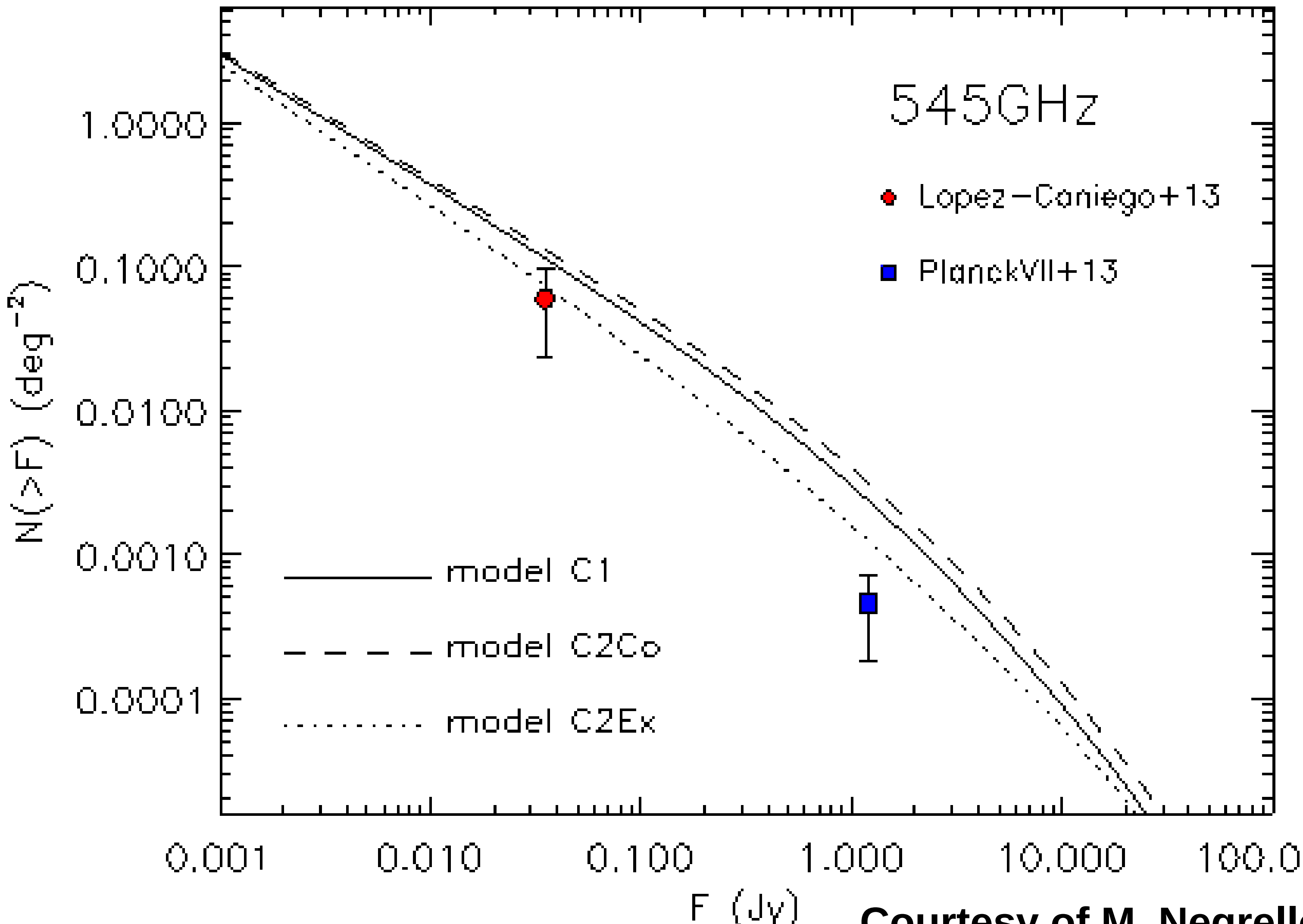




The sub-mm flux density of 5 (+1?) out of 12 (+1?) BZCAT blazars listed in the ERCSC 857 GHz catalog is dominated by thermal dust emission.

May be lost by colour selection; synchrotron/dust emission at transition frequencies may be overestimated. **Courtesy of M. Clemens**

Blazar counts



Courtesy of M. Negrello

First sub-mm counts of blazars compared with models by Tucci et al. (2011).

Conclusions - 1

- Planck data extend by two orders of magnitude the flux density range of Herschel sub-mm counts allowing a detailed characterization of local populations of star-forming galaxies, made of late-type/starbust galaxies.
- This strengthens the case for the dominant population in the steeply rising portion of the counts measured by Herschel being something different, i.e. the progenitors of massive early type galaxies, in passive evolution at $z < 1 – 1.5$.

Conclusions - 2

- The high-z sub-mm luminosity functions match remarkably well the formation rate of massive dark matter halos for a typical *continuous* duration of the star-forming phase of ~0.7 Gyr, consistent with that required to account for the observed α-enhancement of the most massive early-type galaxies.
- This is a strong indication in favour of a *self-regulated galaxy evolution* as opposed e.g. to a *merger-driven* or to a *cold-flow driven* evolution.
- Effective halo masses derived from the analysis of clustering properties support this interpretation.

Conclusions - 3

- The *self-regulated galaxy evolution* model accurately predicted the abundance of strongly lensed galaxies in (sub-)mm surveys and accurately accounts for the redshift distribution of strongly lensed galaxies detected by the SPT survey.
- On the side of radio sources, Planck and Herschel have highlighted the presence of blazars hosted by star-forming galaxies, at variance with the notion that their hosts are passive ellipticals.
- The combination of Planck and Herschel surveys have made possible the first estimate of sub-mm blazar counts.