New extragalactic source science with PICO

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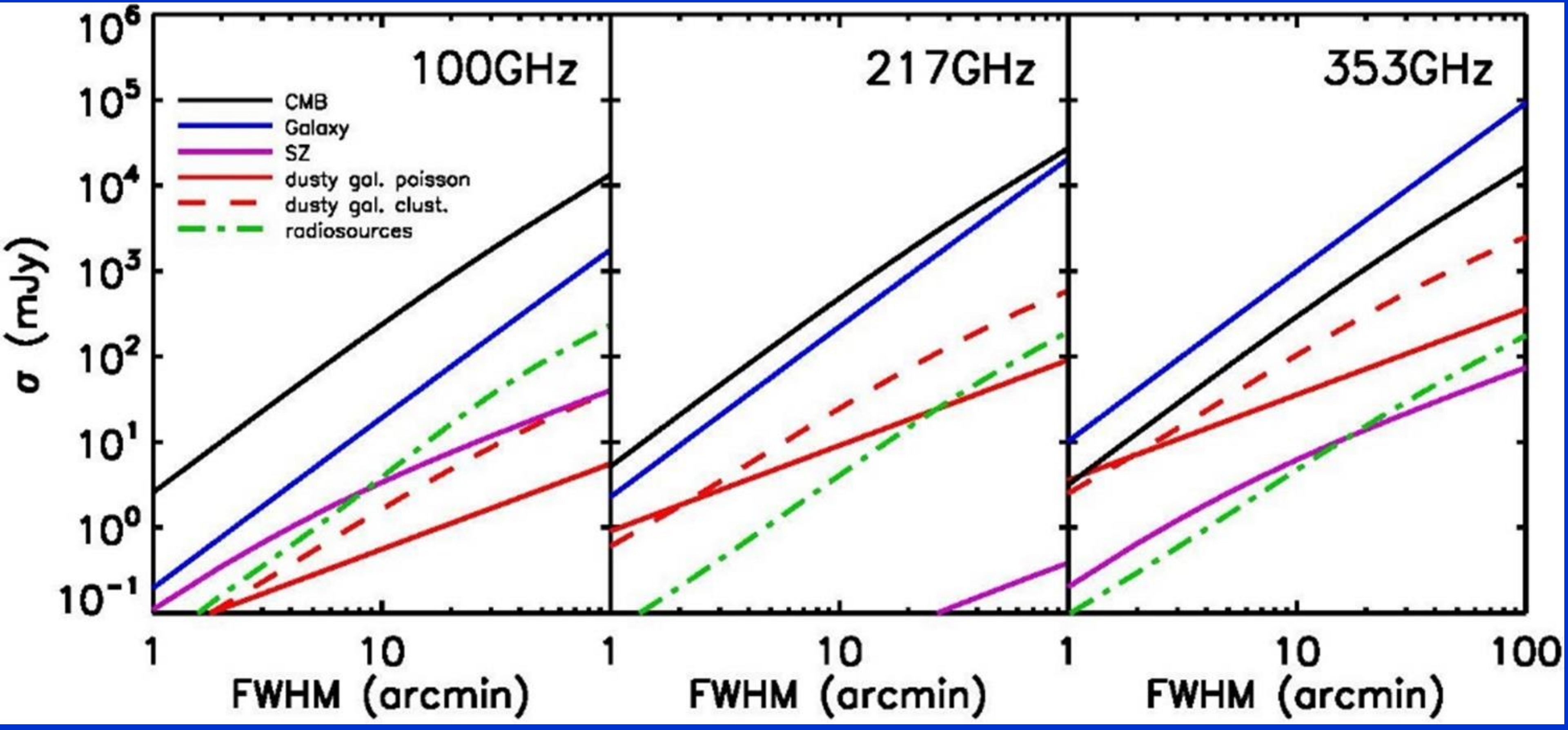
Thanks to Matteo Bonato and Mattia Negrello

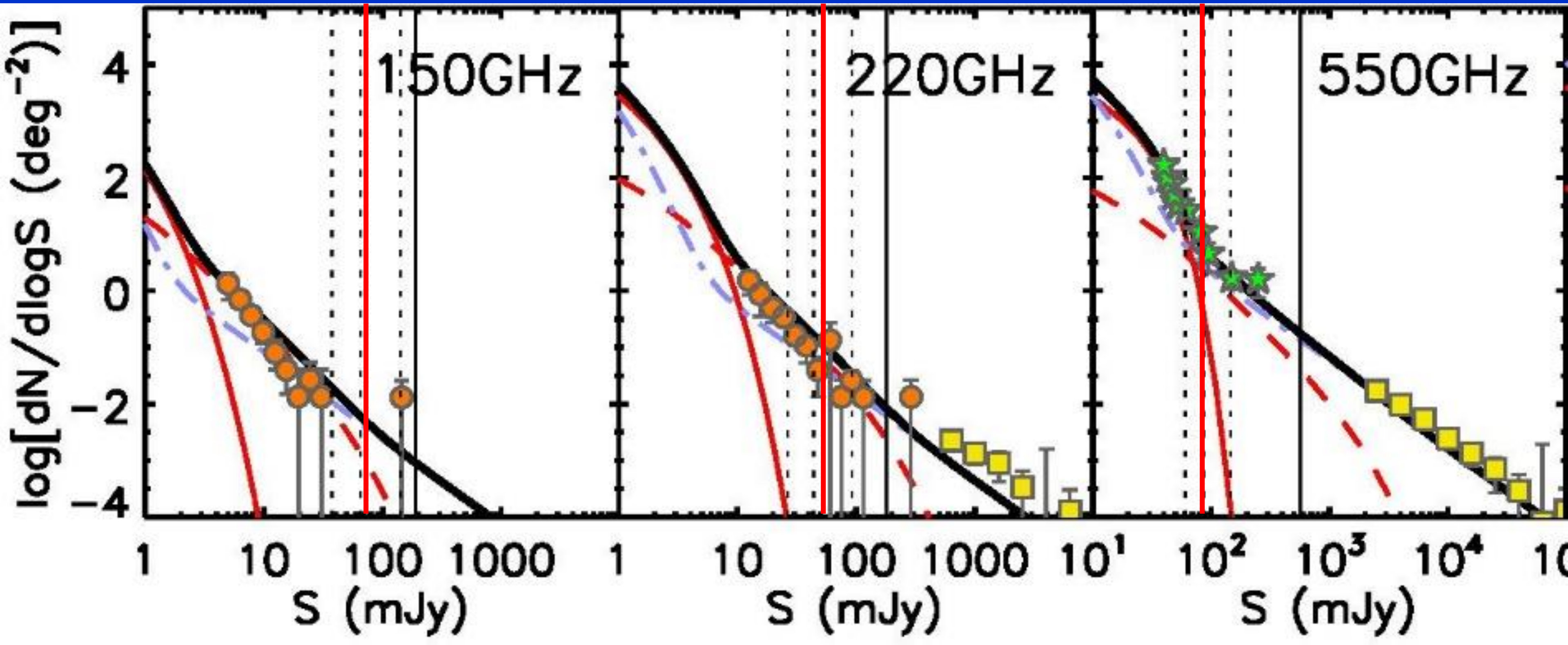
- With current instrumentation sensitivity is not an issue: already for the highest frequency Planck/HFI channels the detection limit was set not by sensitivity but by ″confusion″.
- At frequencies and angular scales of interest the ″confusion″ scales roughly as the $FWHM^2$; so, **angular resolution is the key for extragalactic surveys.**



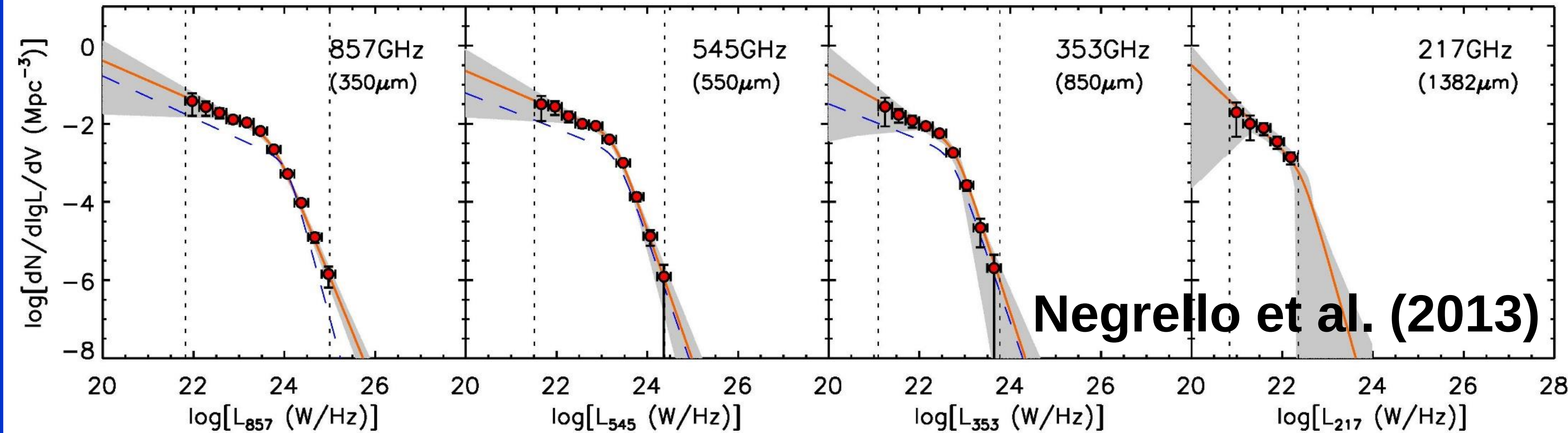
- Planck was diffraction-limited only up to 217 GHz. For example, at 545 and 857 GHz (550 and 350 μm), where dusty galaxies are brightest and easiest to detect, the Planck beam has an effective FWHM of 4.83′ and 4.64′, while the diffraction limits for its 1.5-m telescope are of 1.5′ and 1.0′, respectively.

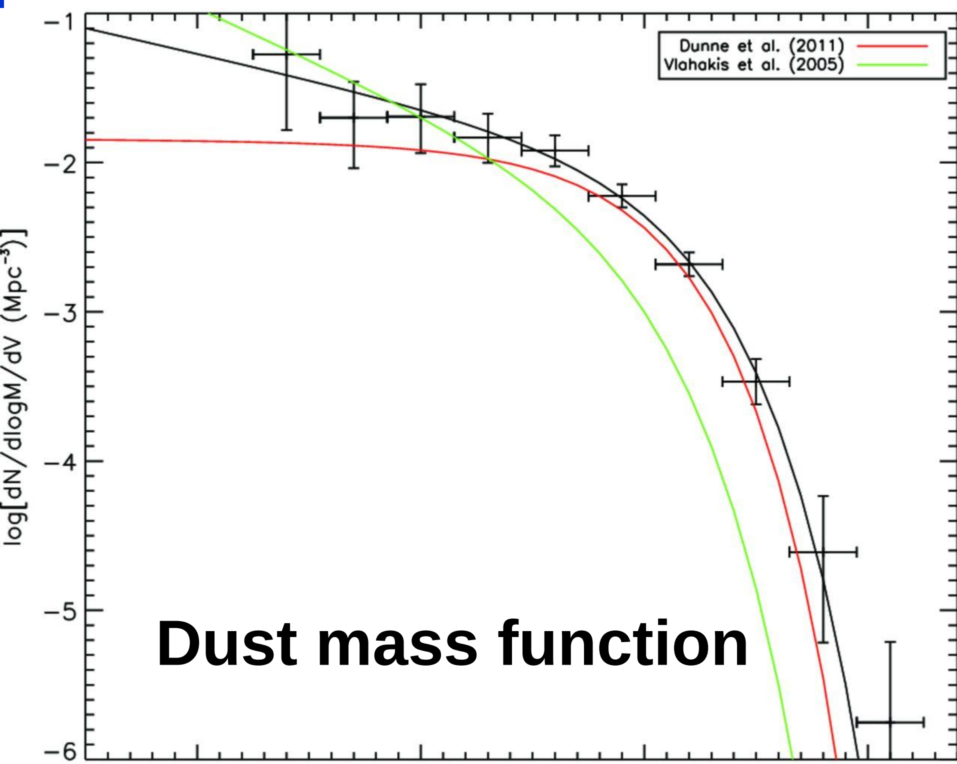
- **A diffraction limited sub-mm survey can substantially improve over Planck even in the case of a somewhat smaller telescope.**

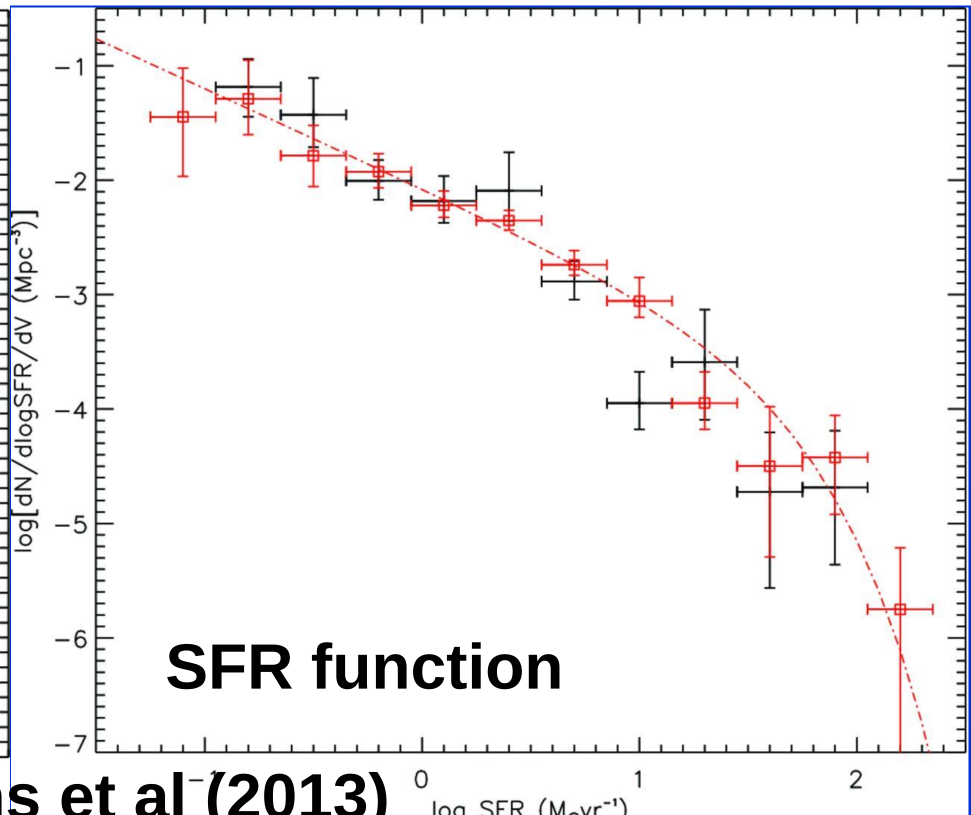
Source counts



The deeper PICO surveys will detect around 30,000 low-z dusty galaxies at 550 GHz. All these will have multi-frequency photometry and spectroscopic, or at least high-quality photometric redshifts. This will make possible to carry out an extensive characterization of the properties of galaxies in the nearby Universe

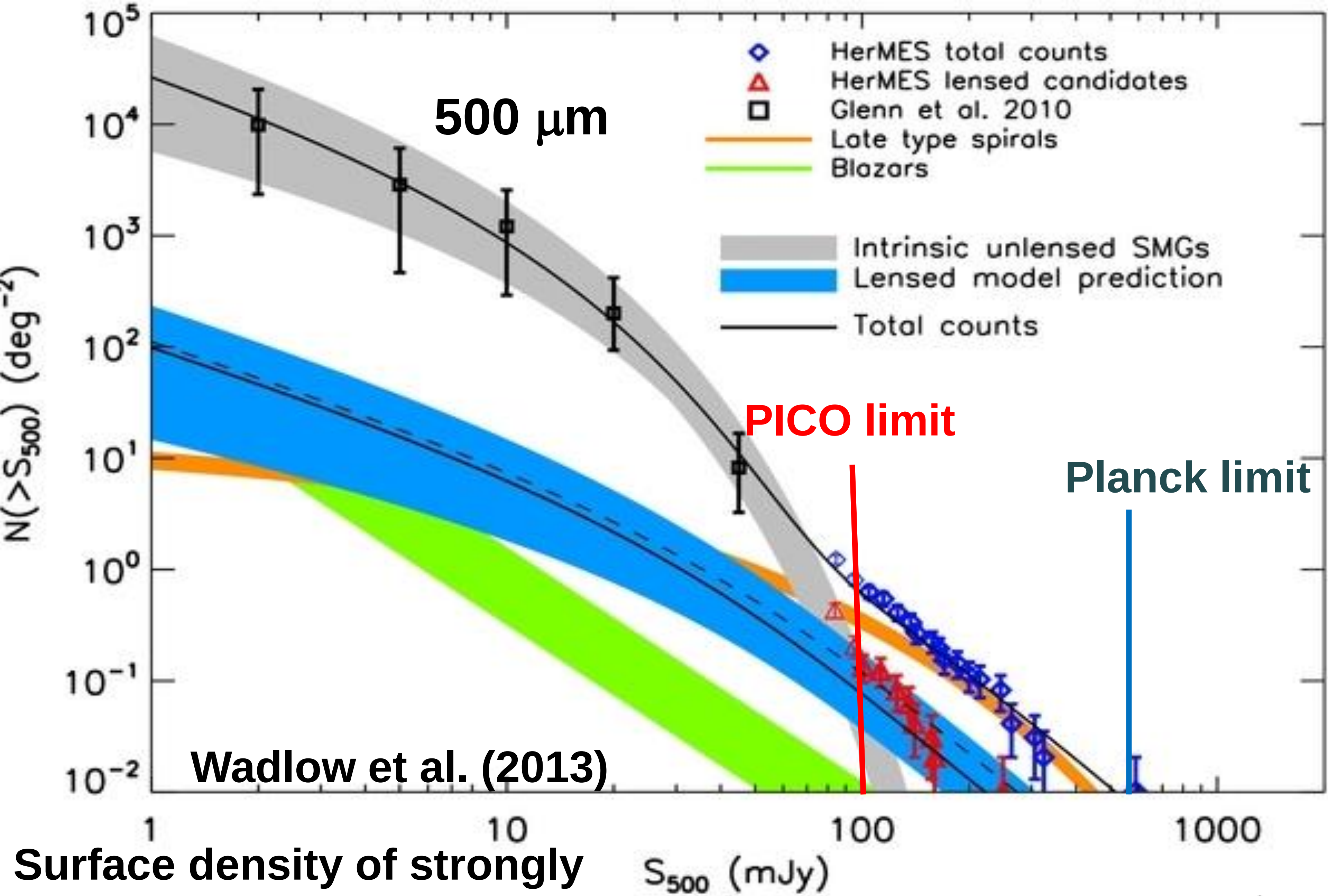




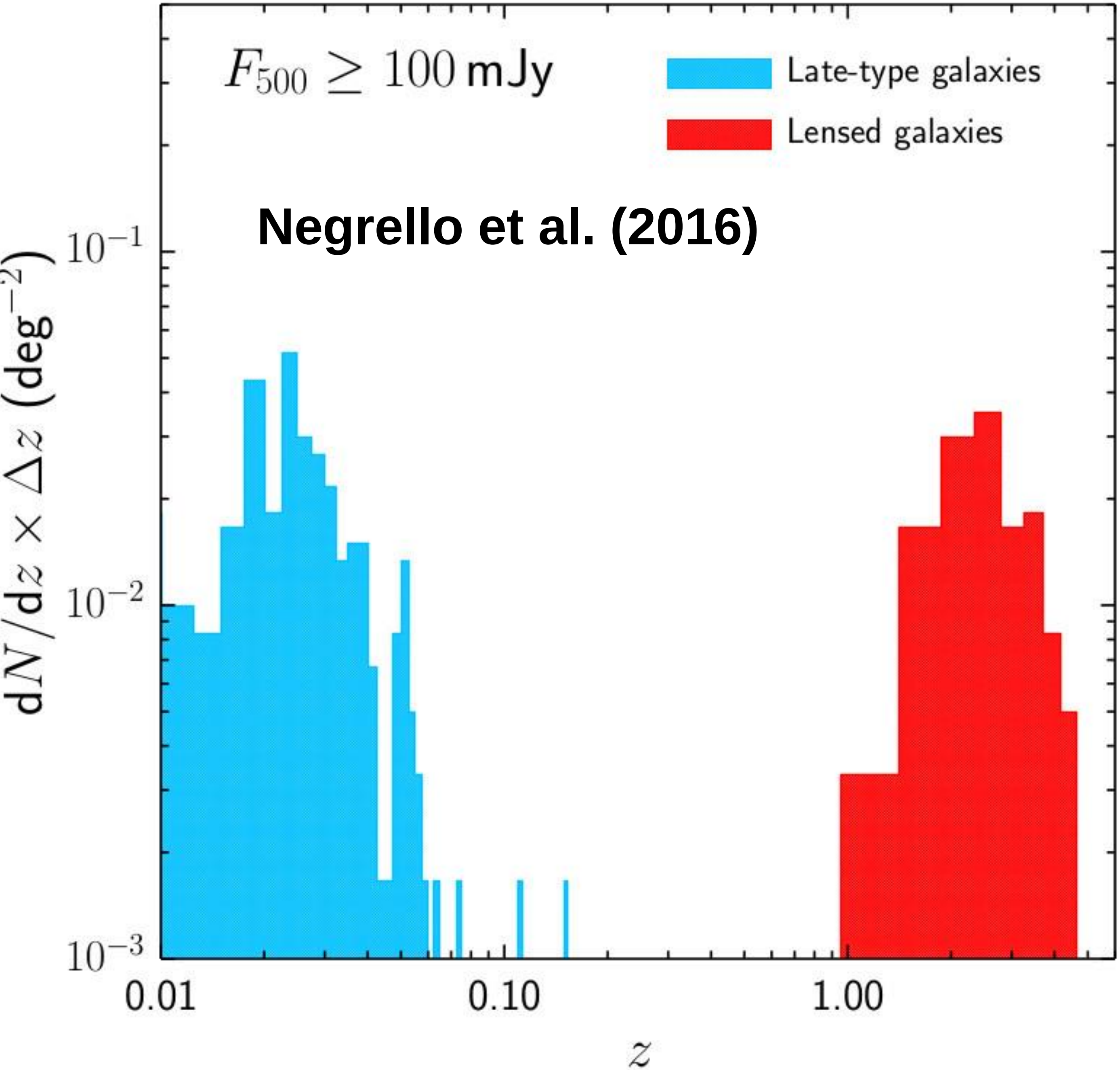


Clemens et al (2013)

Strongly lensed galaxies



Surface density of strongly lensed galaxies brighter than 100 mJy at 500μm ≈0.15 deg^{-2}



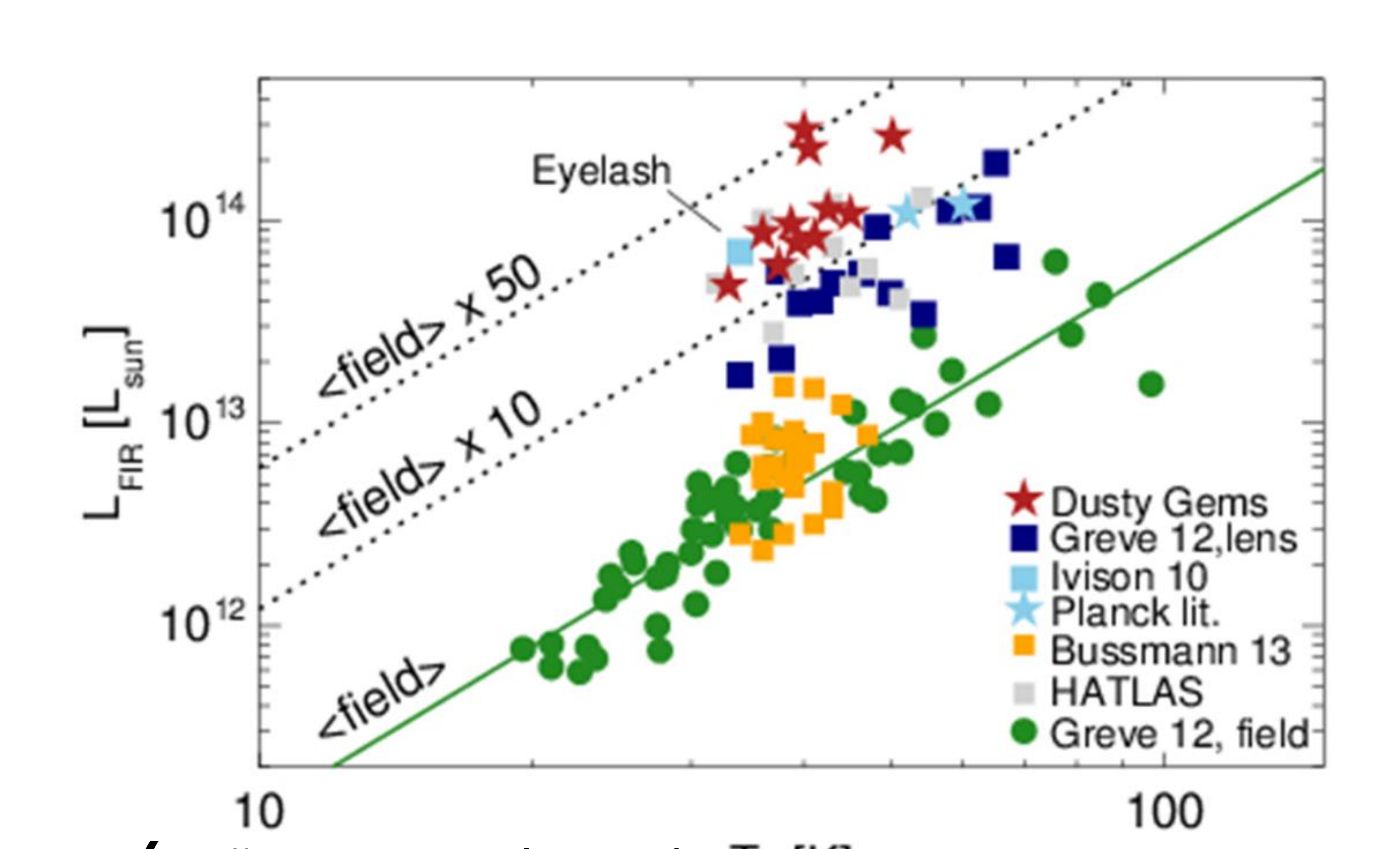
Separation of strongly lensed from local galaxies very easy: local alaxies immediately recognized in shallow optical images.

Why PICO?

All-sky sub-mm surveys have several key advantages over searches for strongly lensed galaxies at other wavelengths:

- They find the **most extreme amplifications**, optimally suited for multi-frequency follow-up.
- They detect, on average, **objects at higher redshifts** (compare, e.g., fig. 7 of Treu et al. 2010 with fig. 5 of Negrello et al. 2017): at early times galaxies were mostly in a dusty star-formation phase) Correspondingly, also lenses typically have higher redshifts (cf. fig. 9 of Gonzalez-Nuevo et al. 2012).
- The background lensed source and the foreground lens are generally visible in different wavebands (far-IR/sub-mm and optical, respectively): little or no mutual contamination of images; possibility of detecting events with very close alignement (maximum amplification).
- Lensed galaxies easily selected with close to 100% efficiency.

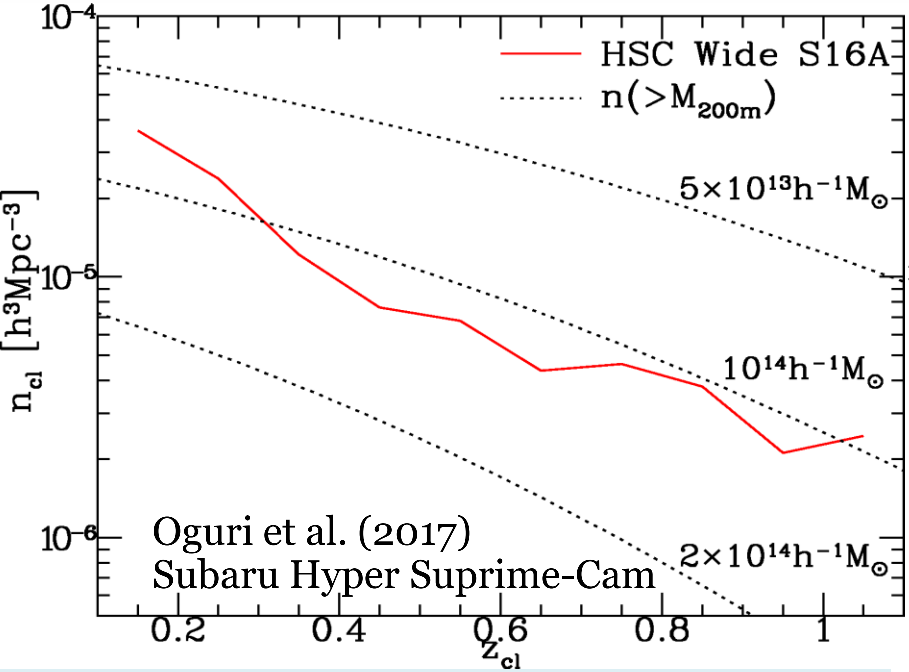
Why strong gravitational lensing is important- 2

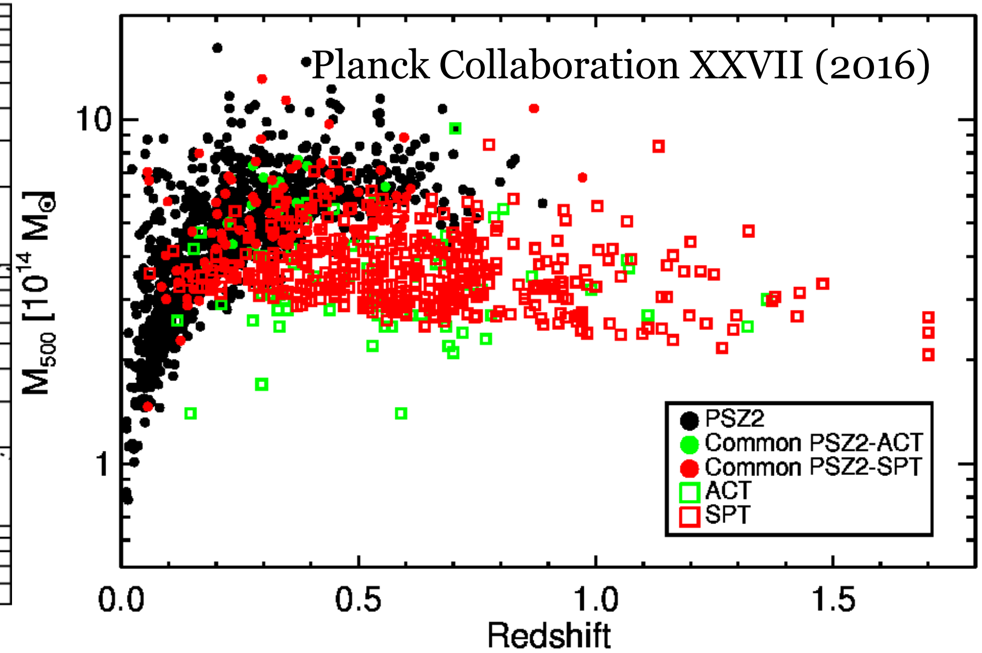


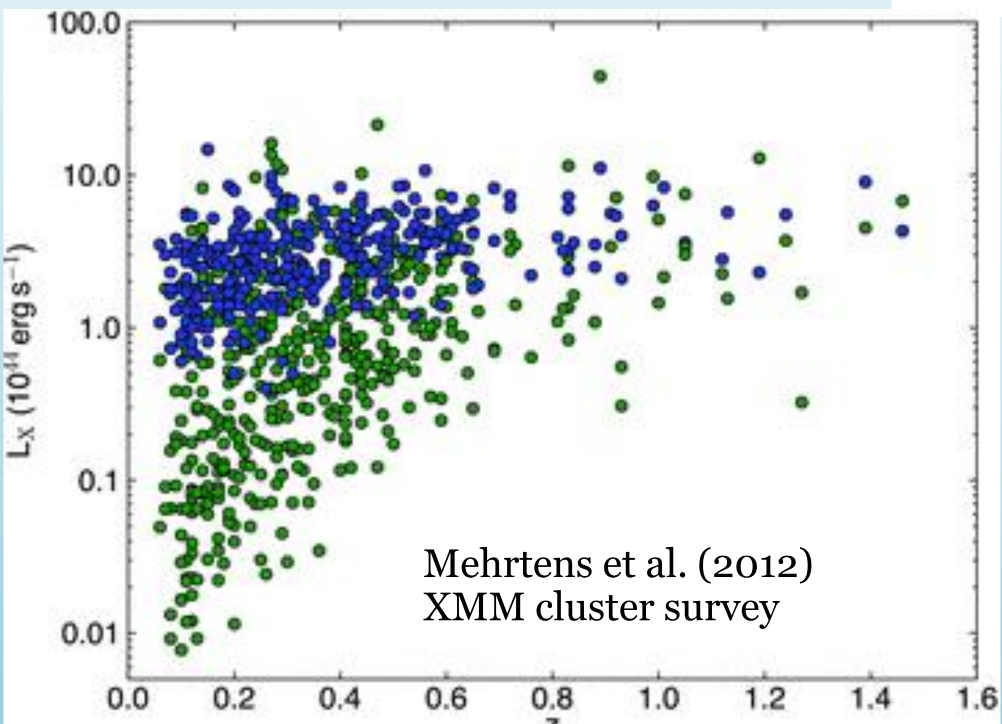
(Cañameras et al. 2015)

Planck has demonstrated the existence of extreme, strongly-lensed, high-z galaxies (Dusty Gems), with estimated gravitational amplifications, μ, of up to 50. Surveys over limited areas miss these very rare objects.

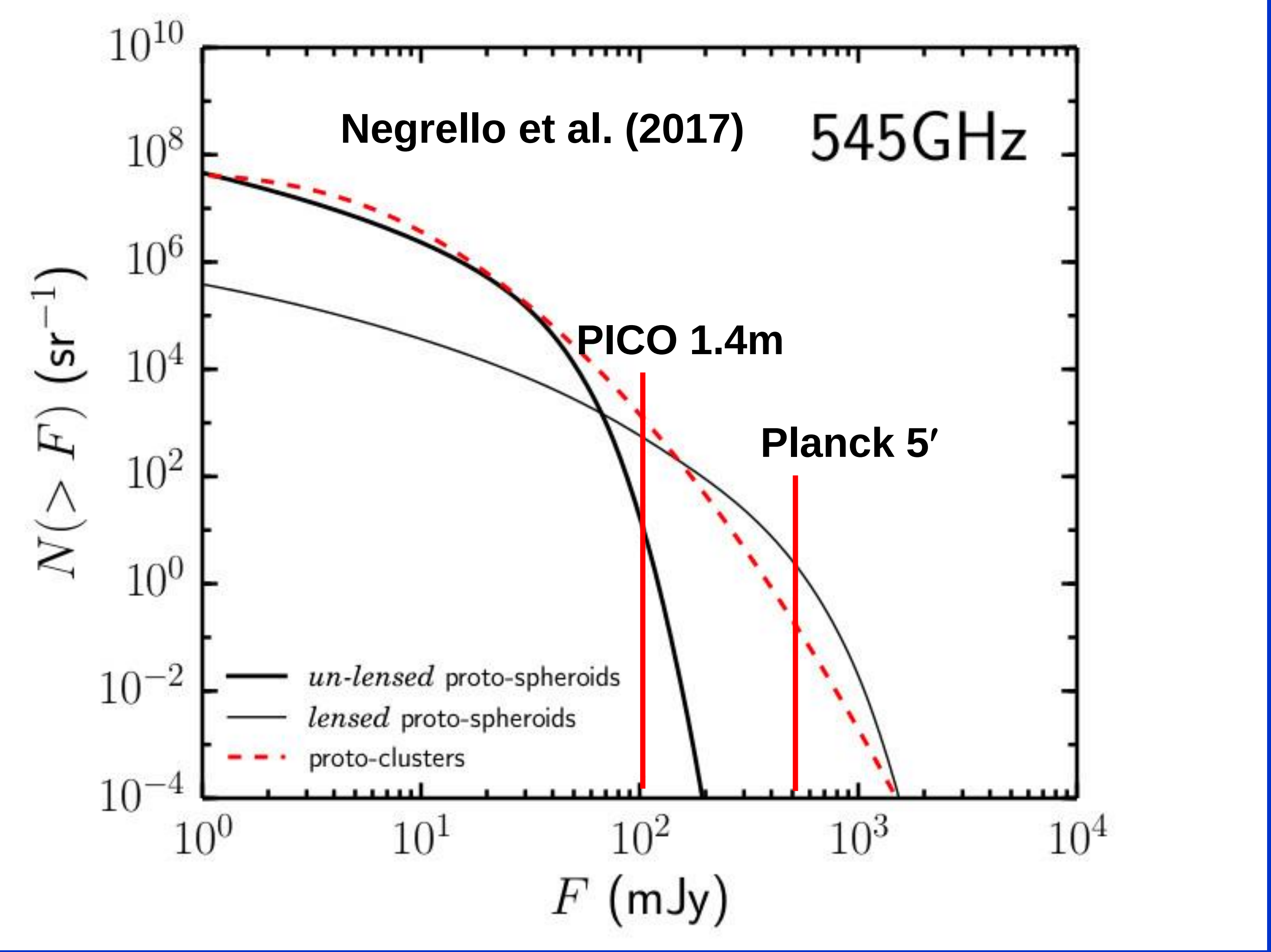
Proto-clusters of galaxies





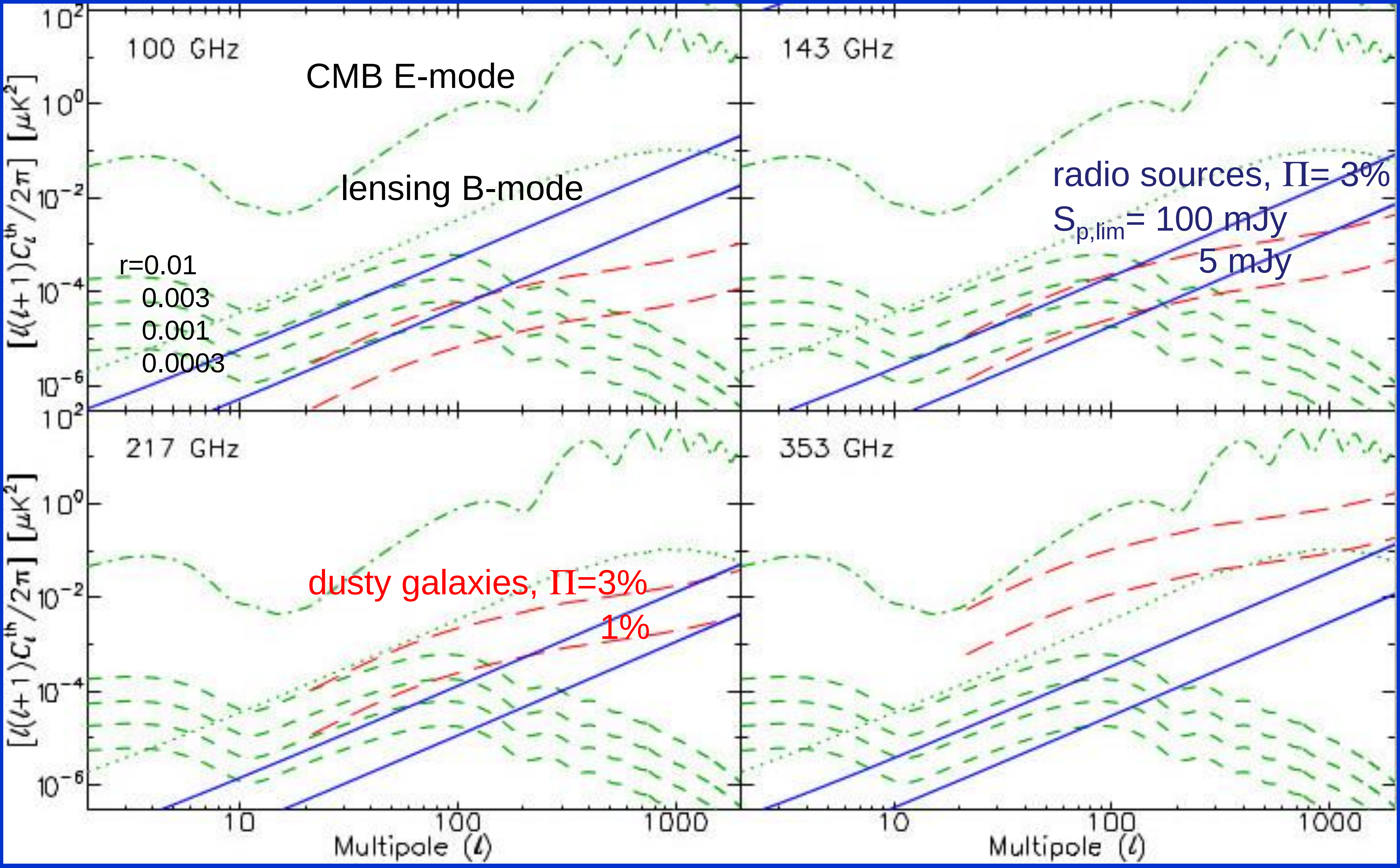


Classical techniques for detecting galaxy clusters (optical/near-IR "red sequence", X-ray emission, SZ effect) preferentially or exclusively select evolved objects, with mature galaxy populations and a hot intra-cluster medium. As a result, most known clusters are at redshifts <1.5, i.e. below that of the peak of global star-formation activity.

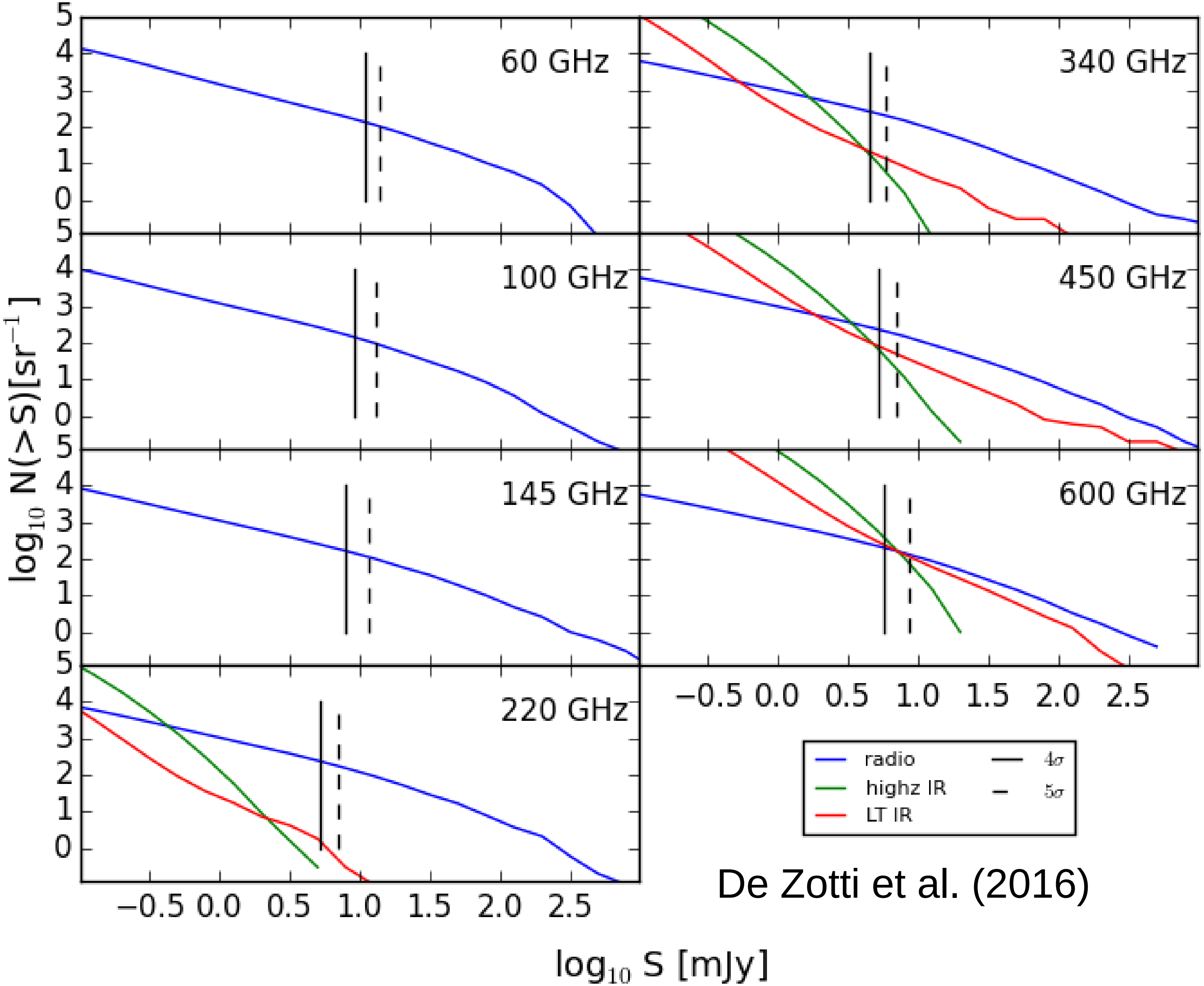


The predicted counts of proto-clusters by Negrello et al. (2017; dashed red line), successfully tested against the (admittedly poor) data currently available, are very steep. Thus the number of detections decreases by orders of magnitude as the resolution worsens.

Polarization



Trombetti et al., in preparation



De Zotti et al. (2016)

Predicted counts in polarization for CORE with 1m (dashed) and 1.5 m telescope (solid).

Conclusions - 1

As amply demonstrated by Planck, space-borne CMB experiments, like PICO, thanks to their all-sky coverage and broad frequency range hardly or not accessible from the ground, provide unique information of great astrophysical interest on extragalactic sources.

Examples are:

- **Population properties and SEDs of blazars and of star-forming galaxies**
- **Discovery of extreme strongly lensed galaxies at high-z**
- **Discovery of candidate proto-clusters of galaxies, caught in the pre-virialization phase, when their member galaxies were forming most of their stars**

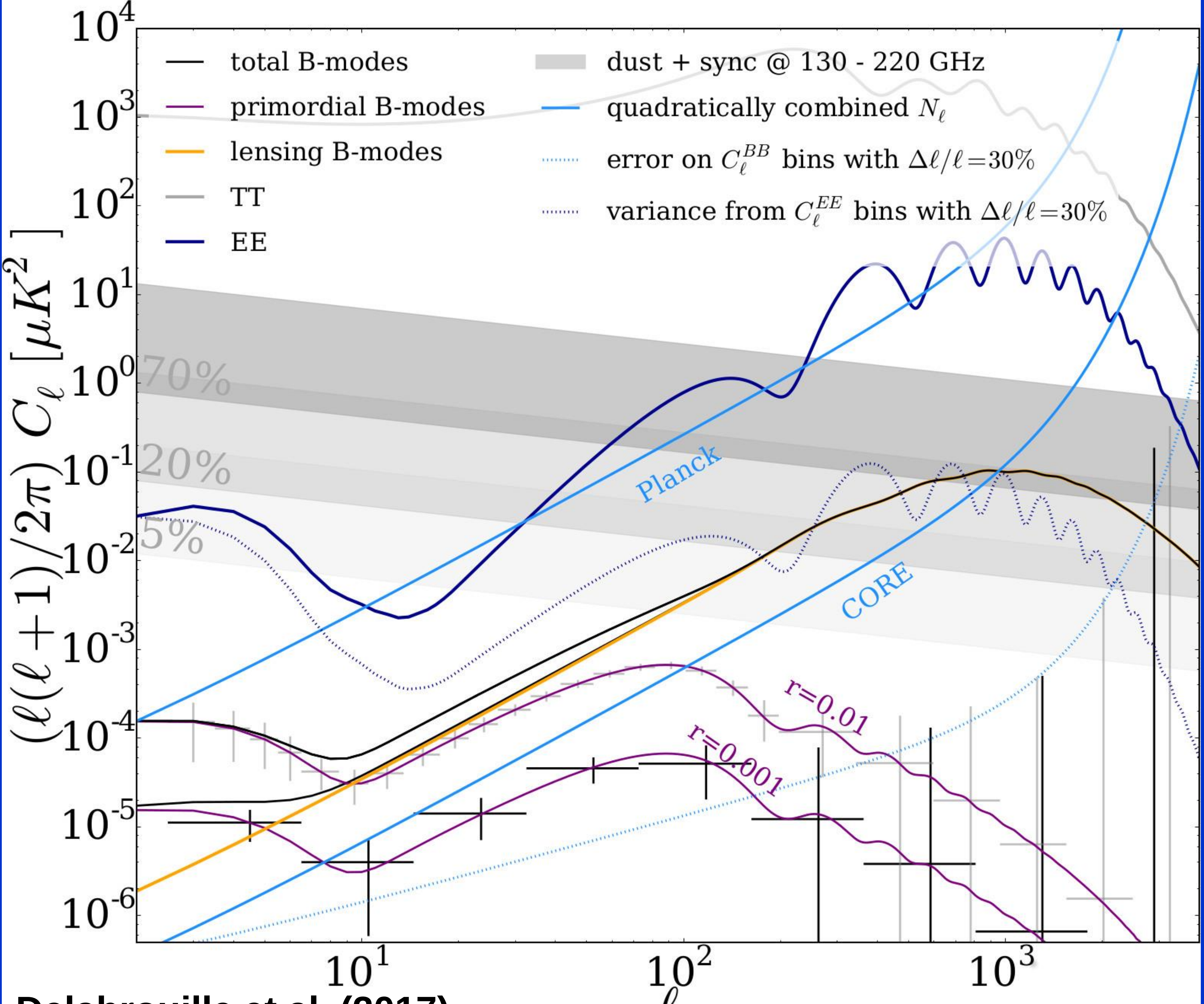
Conclusions - 2

The substantially better angular resolution and sensitivity of planned next generation experiment like CORE and PICO, even with the same telescope size as Planck, will boost by large factors the number of detections. Great progress in the field also expected from the ground-based CMB-S3/S4 project

But next-generation experiments will also make possible entirely new science such as:

- **The direct detection of large proto-cluster samples up to $z \approx 4$**
- **The study of the evolution of the star-formation in virialized groups and cluster of galaxies**
- **The study of the polarization properties of large samples of radio sources and of dusty galaxies at mm and sub-mm wavelengths**

Supplementary slides



Delabrouille et al. (2017)