Extragalactic research paths explored by space-borne CMB experiments

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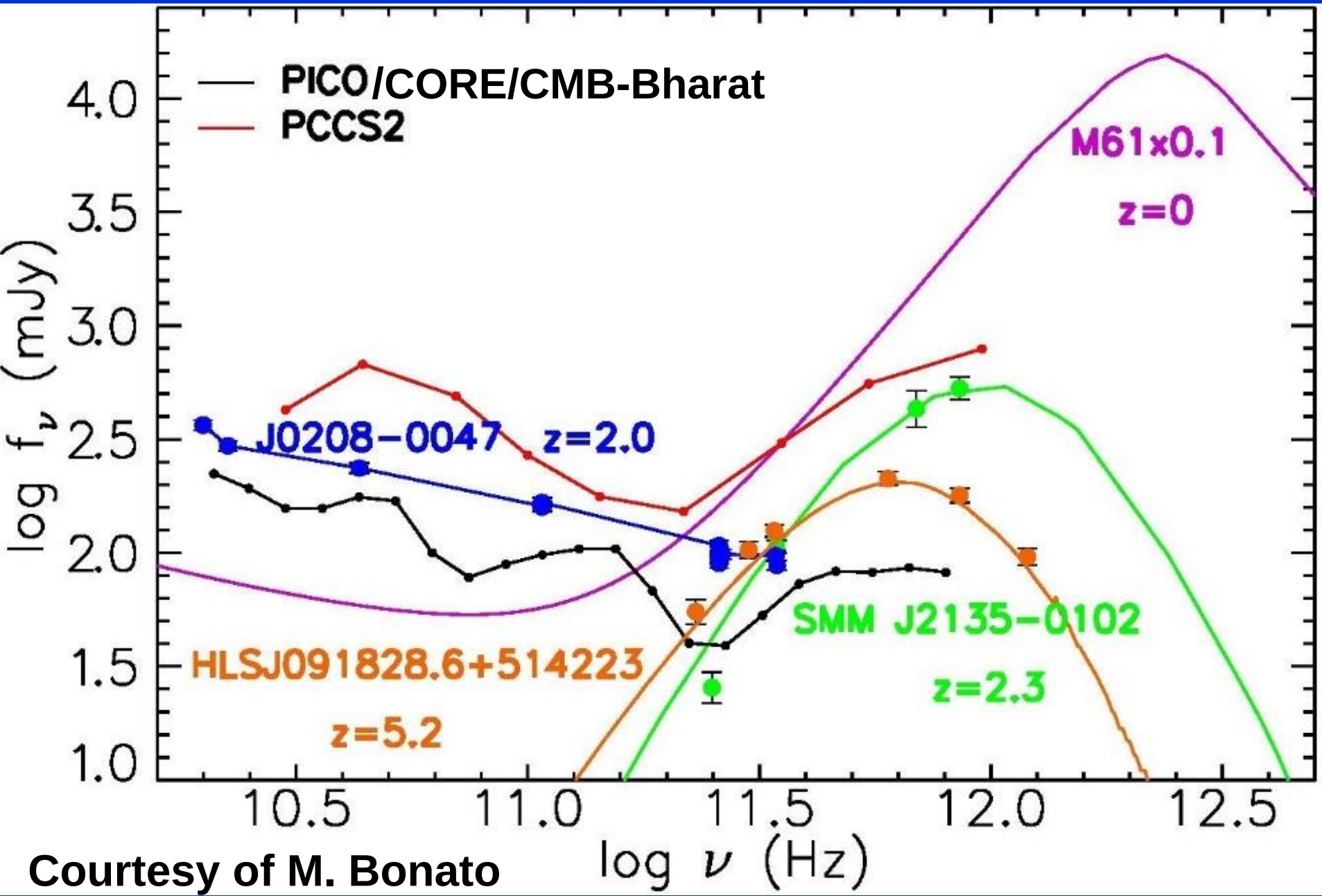
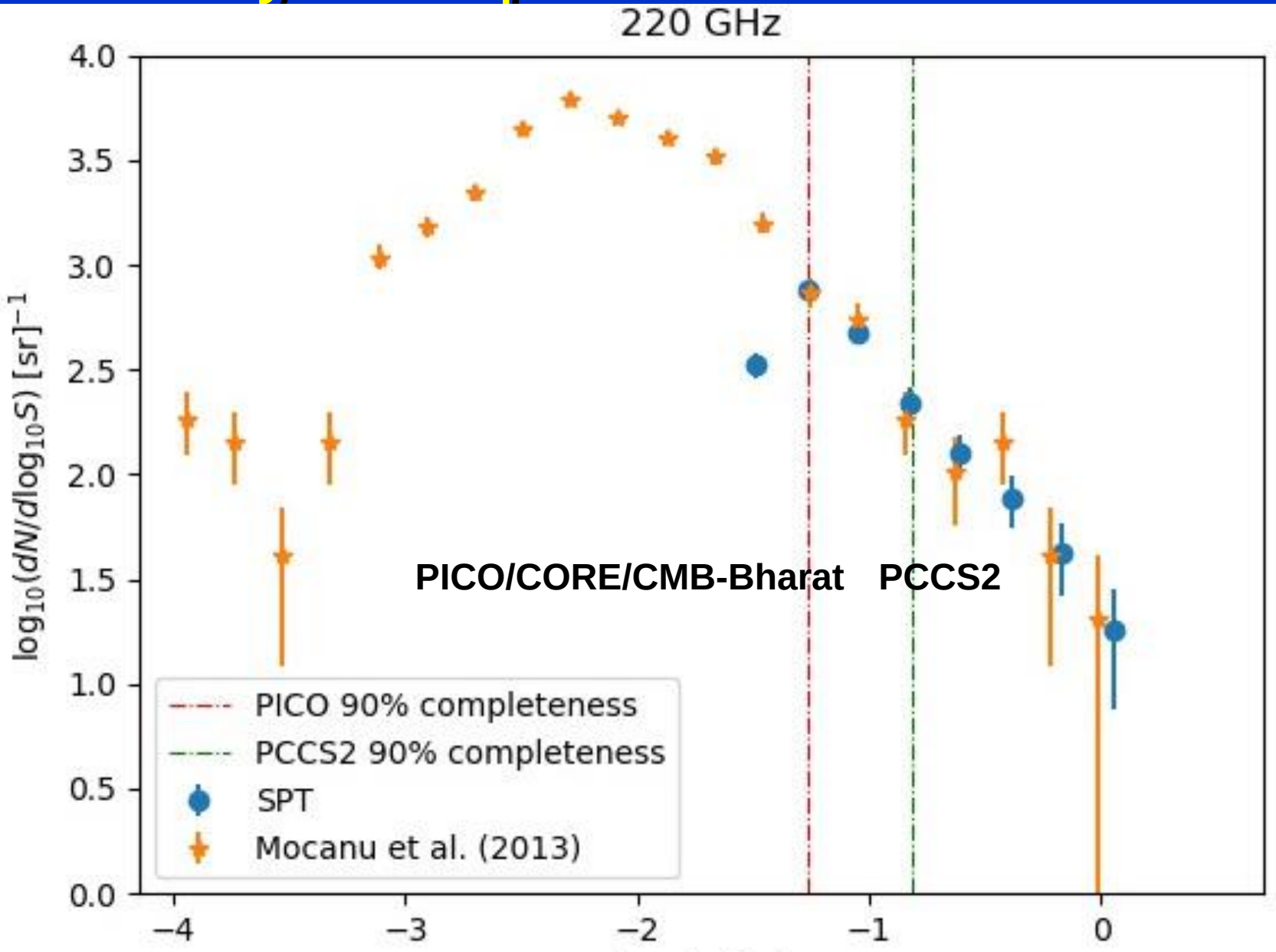
Thanks to: Matteo Bonato, Diego Herranz, Marcos Lopez-Caniego, Mattia Negrello, Tiziana Trombetti

Extragalactic source populations



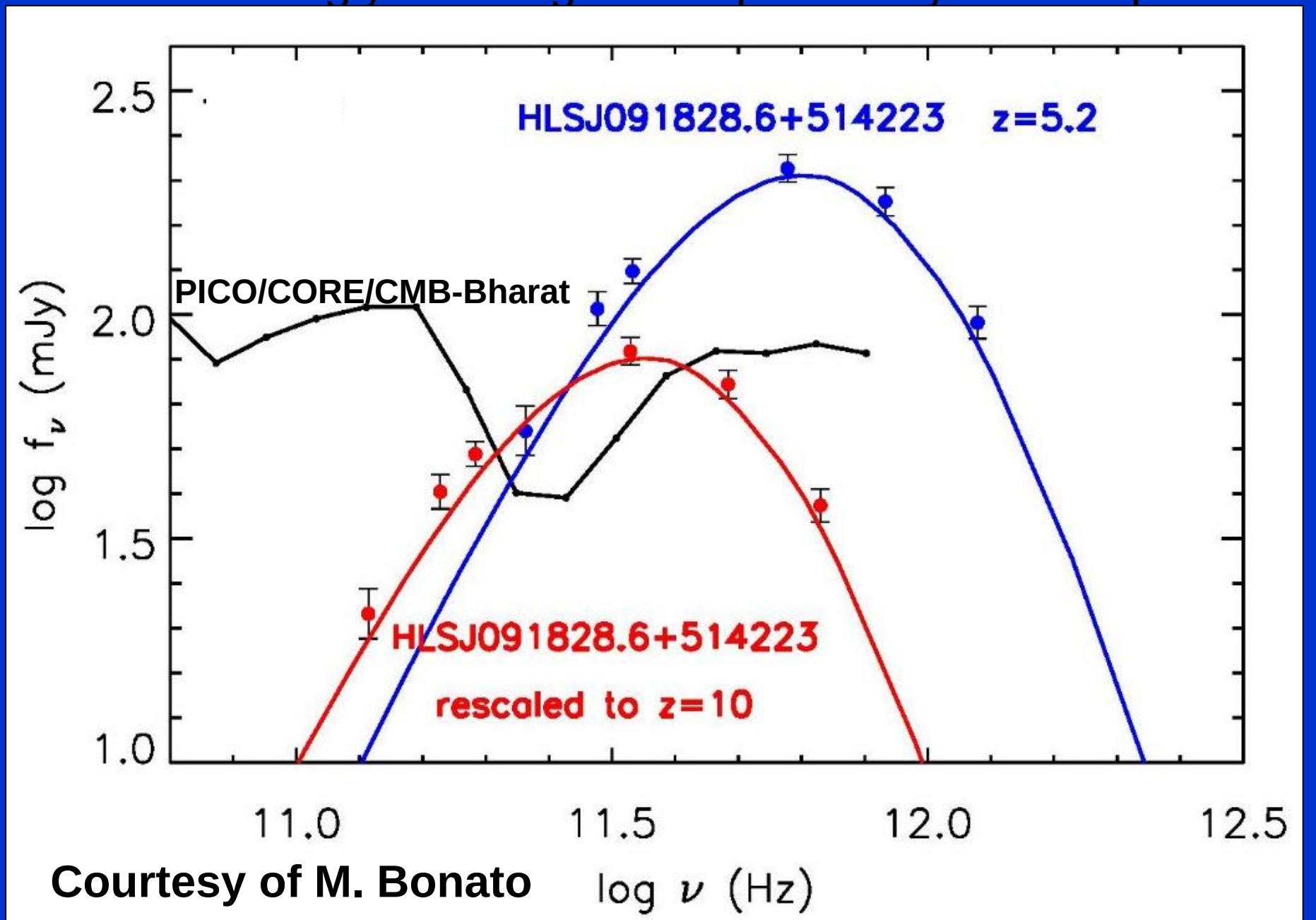
Courtesy of M. Bonato

The key for improvement: resolution

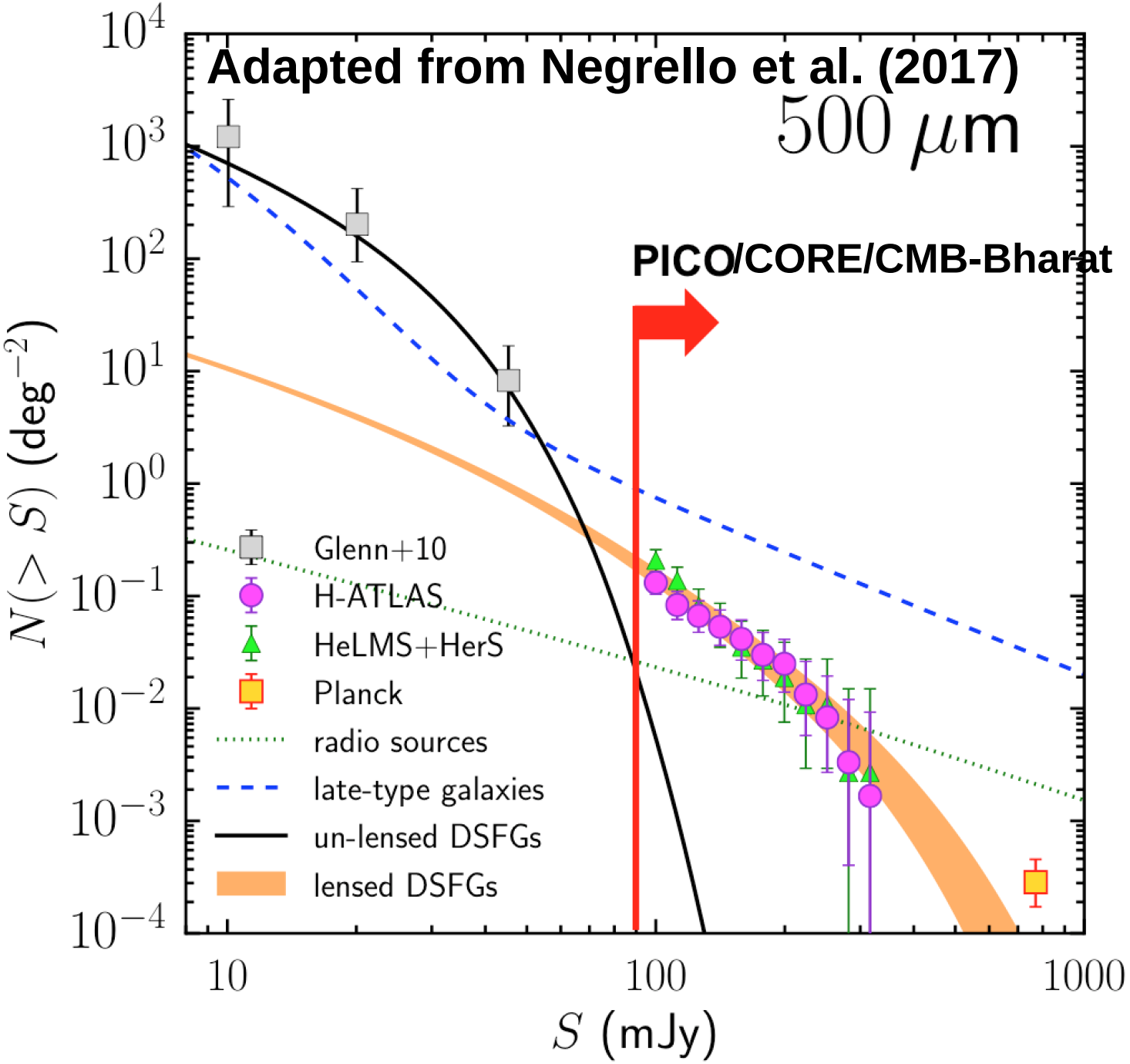


Courtesy of D. Herranz and M. Lopez-Caniego

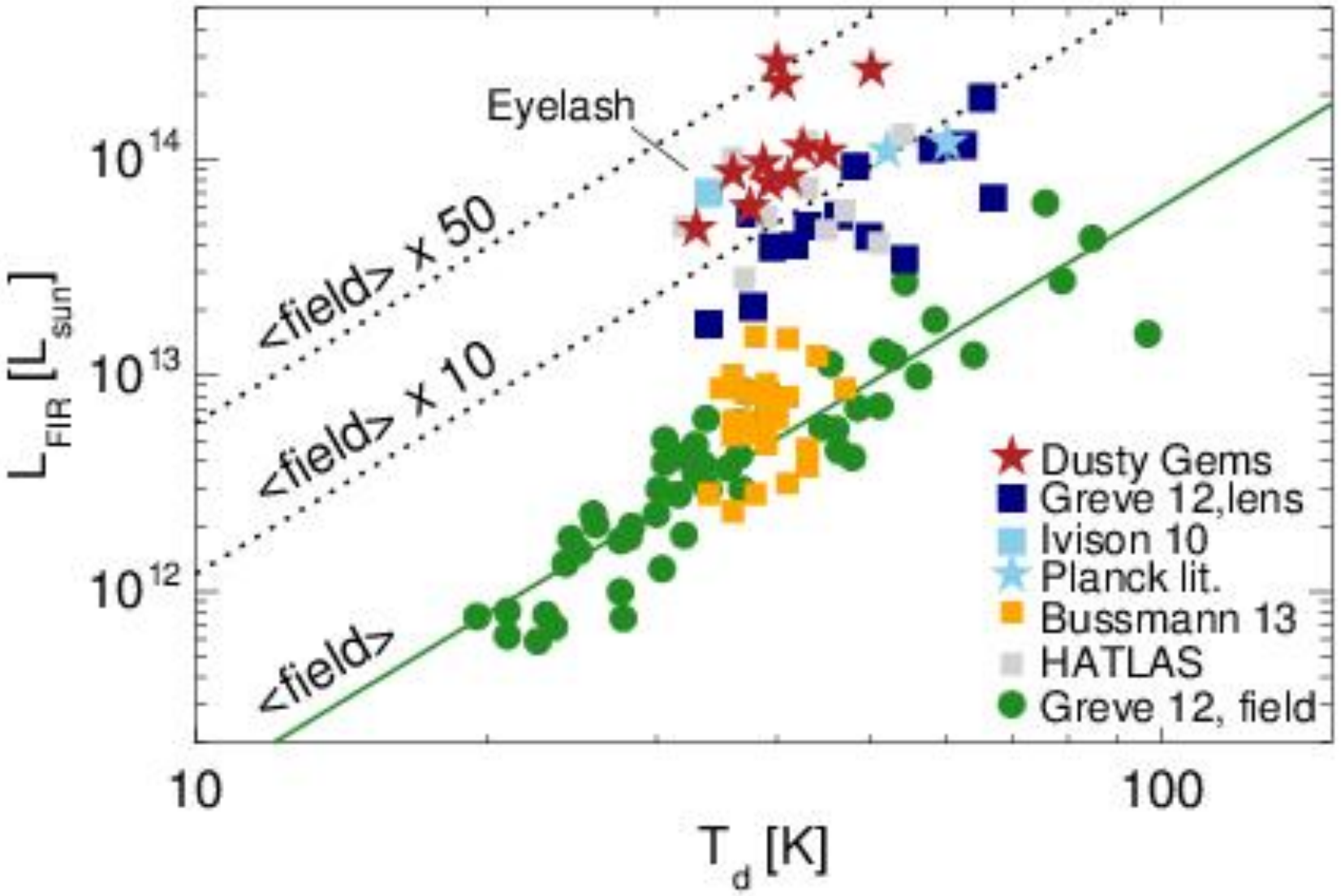
Extreme strongly lensed galaxies potentially visible up to z~10



Courtesy of M. Bonato

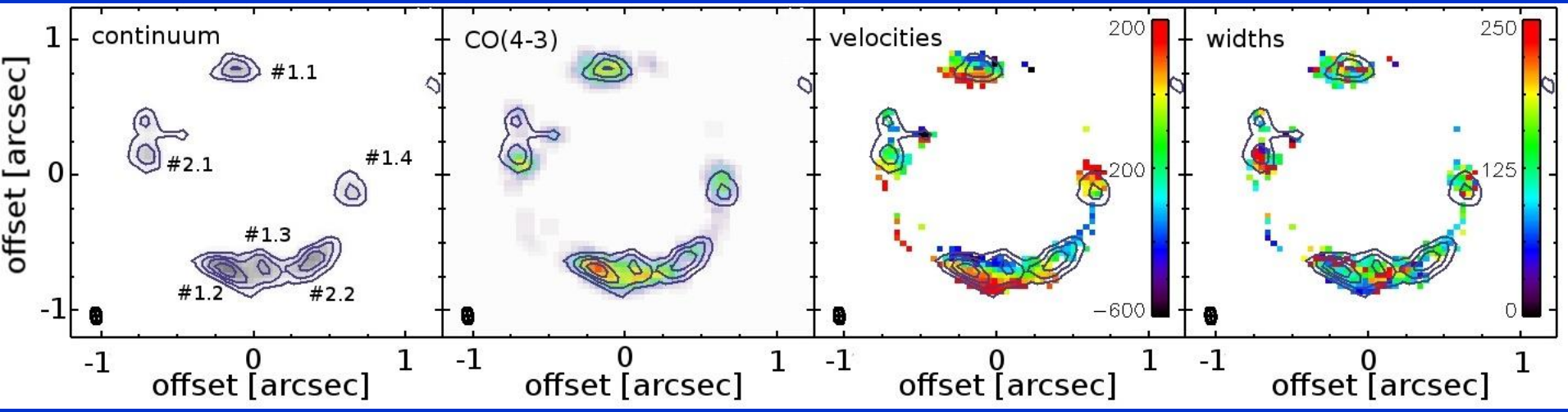


Planned next generation CMB experiments like PICO, CORE, CMB-Bharat will detect several thousands high-z strongly lensed galaxies, reaching approximately the same flux density limit of Herschel searches but over an area more than 30 times larger.



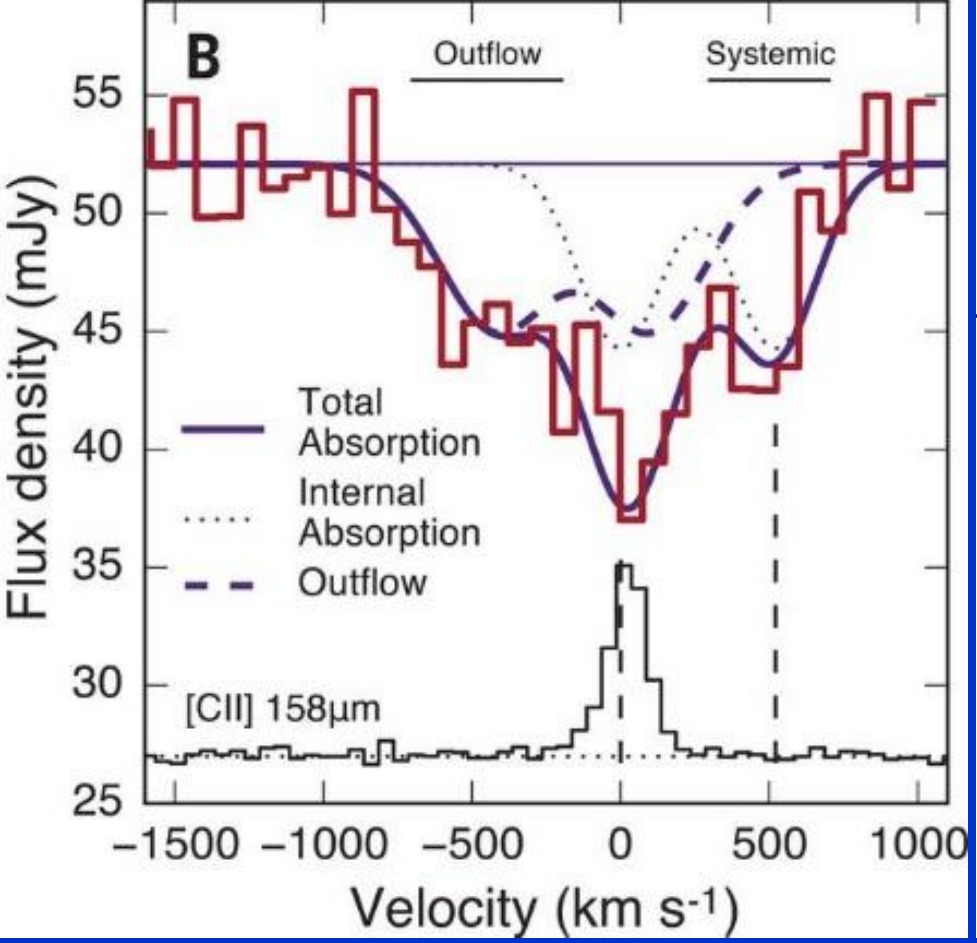
Dusty Gems: 11 strongly gravitationally lensed galaxies at z= 2.2 – 3.6 detected by Planck (Cañameras et al. 2015)

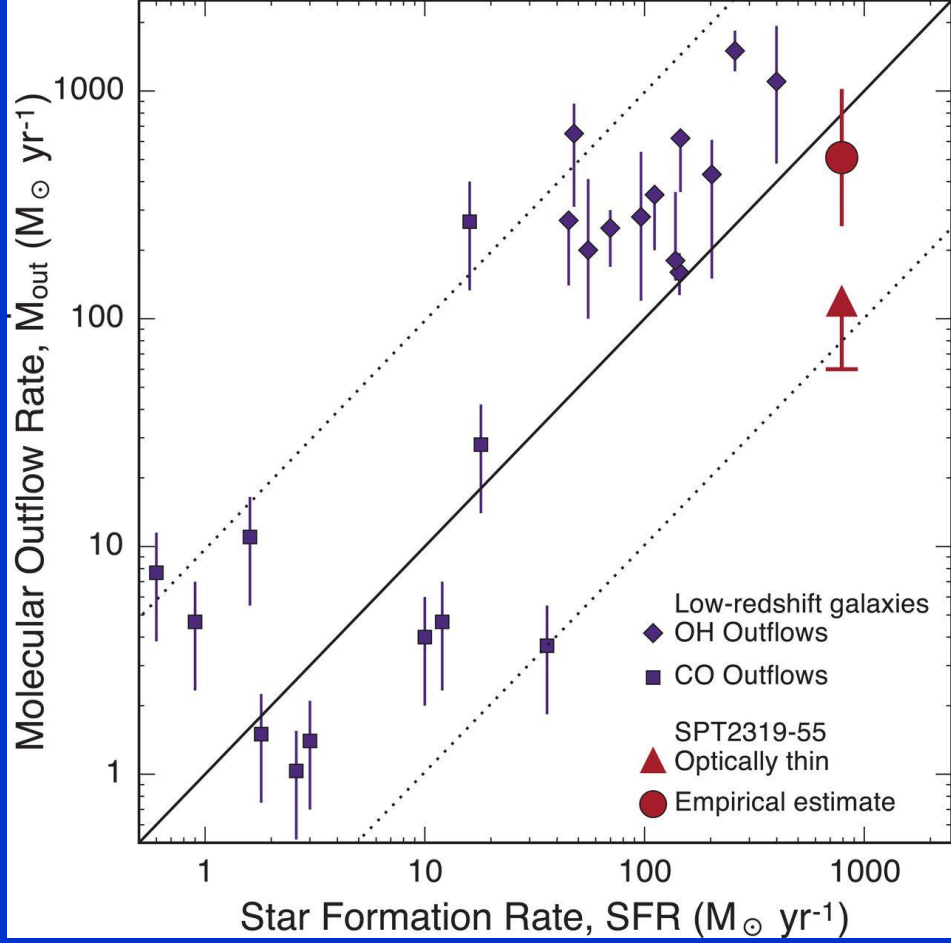
ALMA images



Continuum and CO(4-3) ALMA images of the strongly lensed galaxy PLCK_G244.8+54.9 at z ≈3.0 (Cañameras et al. 2017) with an estimated magnification μ≈30. The combination of extreme brightness, ALMA resolution (0.1″ in this case) and gravitational stretching of the images (by $\mu^{1/2}$, on average) results in a spatial resolution of ≈ 60 pc, substantially smaller than the size of Galactic giant molecular clouds. Unlensed galaxies at this z are hardly resolved even by ALMA or by the HST.

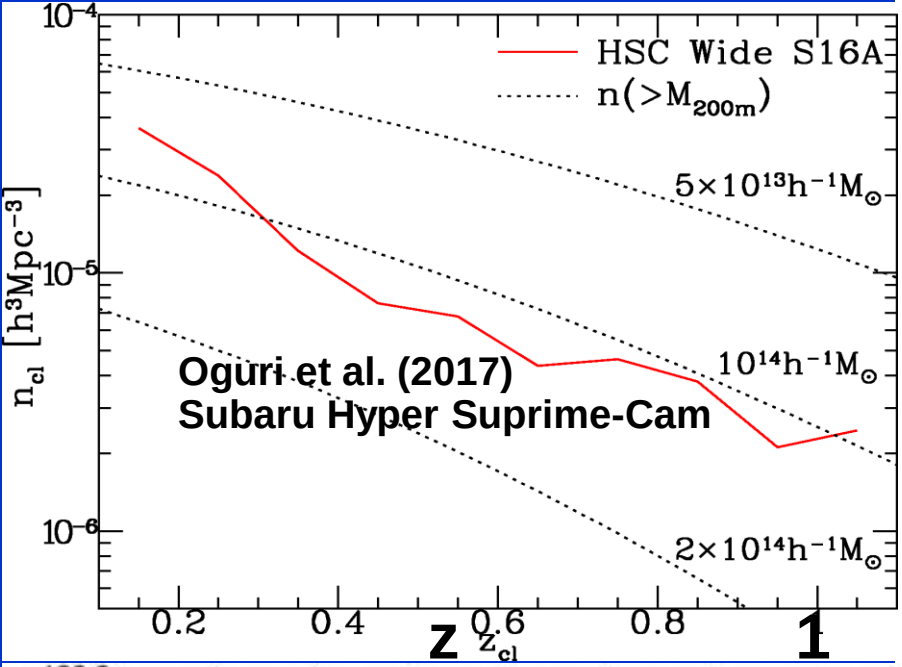
CO spectroscopy has allowed the measurement of the kinematics of the molecular gas with a typical uncertainty of 40-50 km/s.

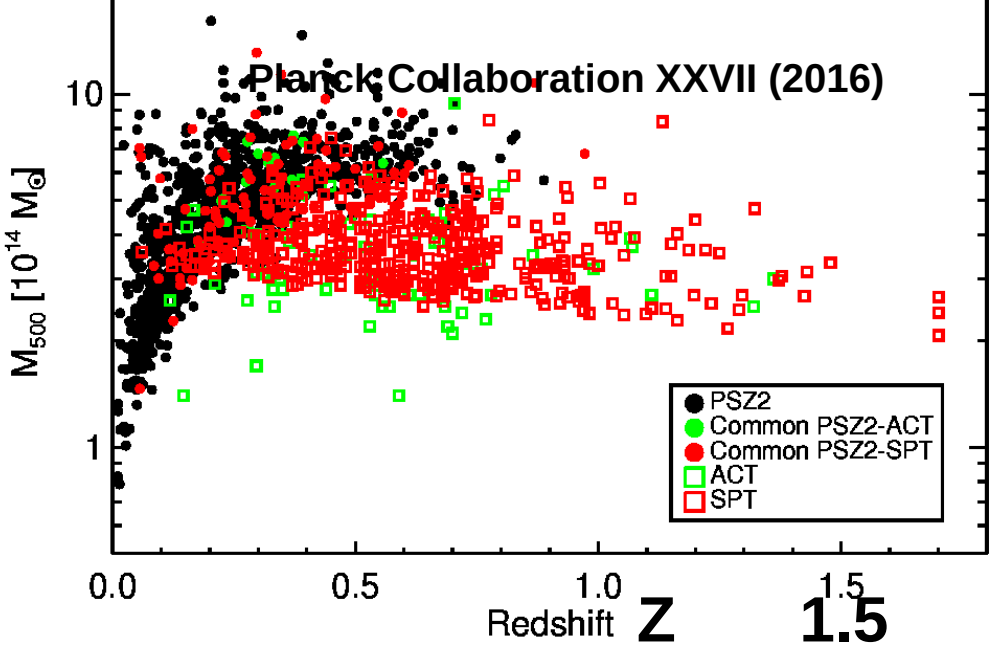


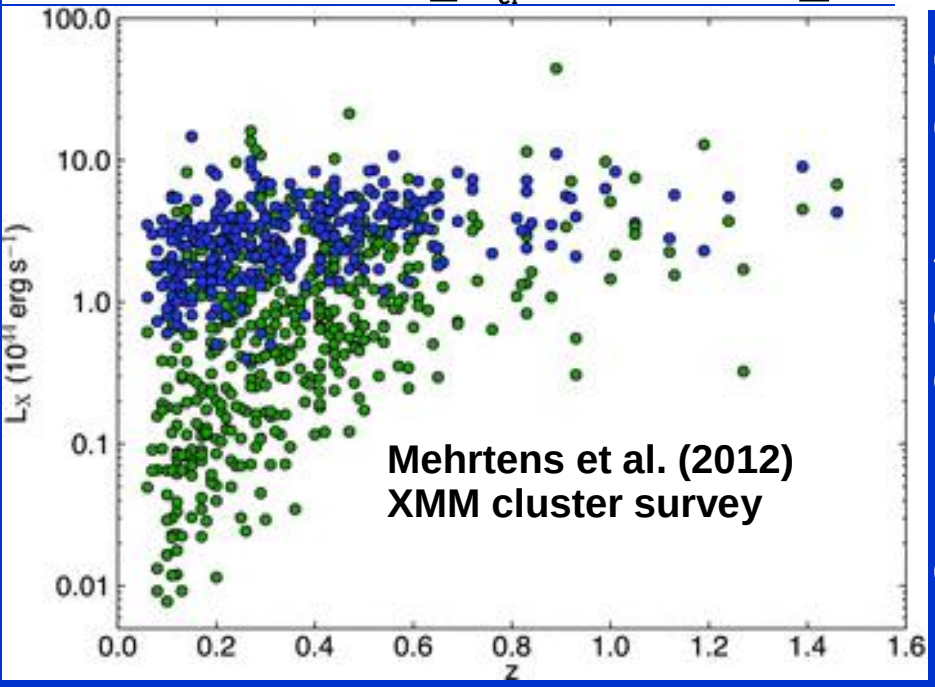


Detection of a massive, fast (800 km/s) molecular outflow due to feedback processes at z=5.3 (Spilker et al. 2018). The outflow carries mass at a rate within a factor of 2 of the SFR and can thus remove a large fraction of the gas from the galaxy. All the other data points on the right-hand panel refer to local ULIRGs.

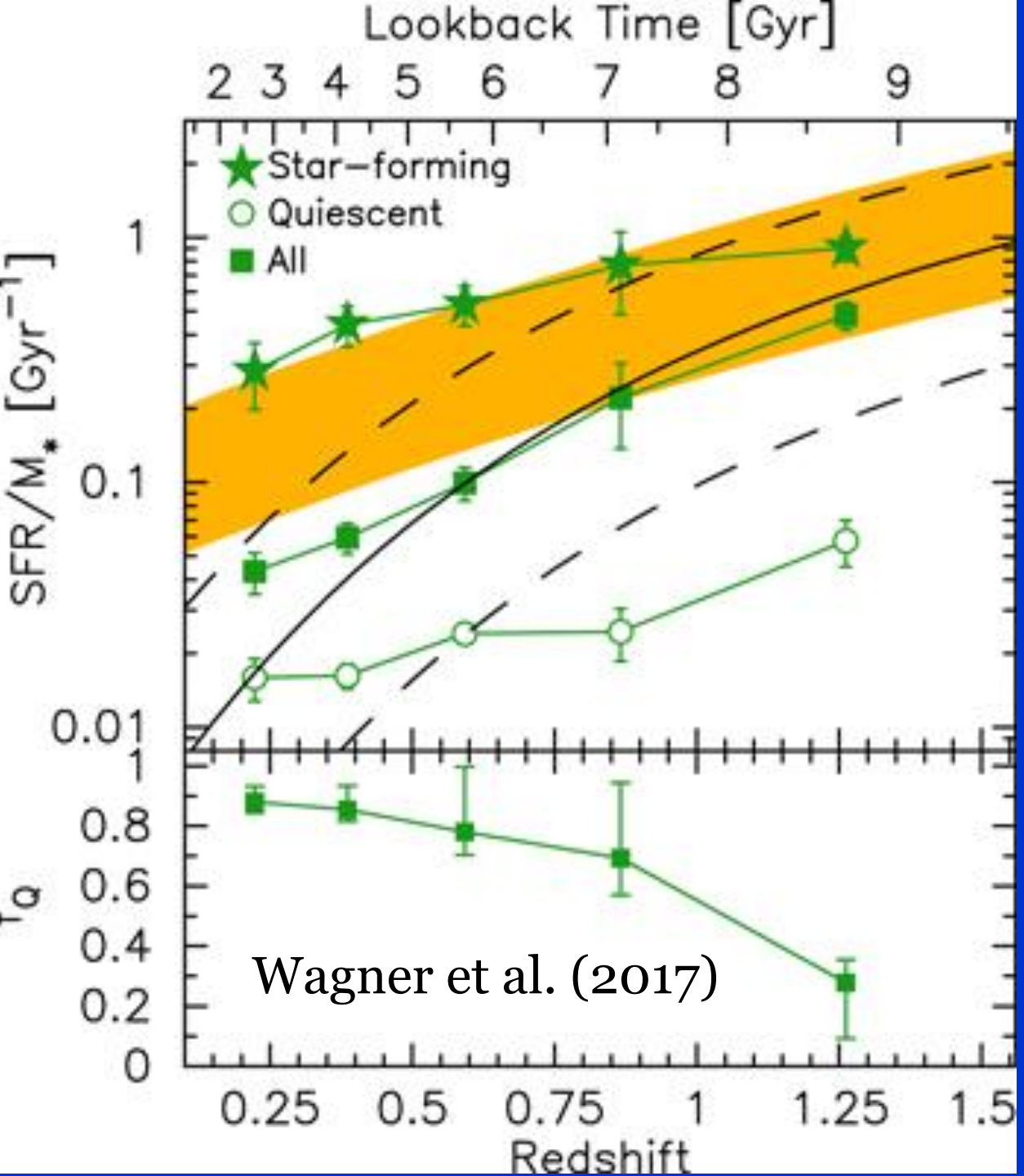
Proto-clusters of galaxies



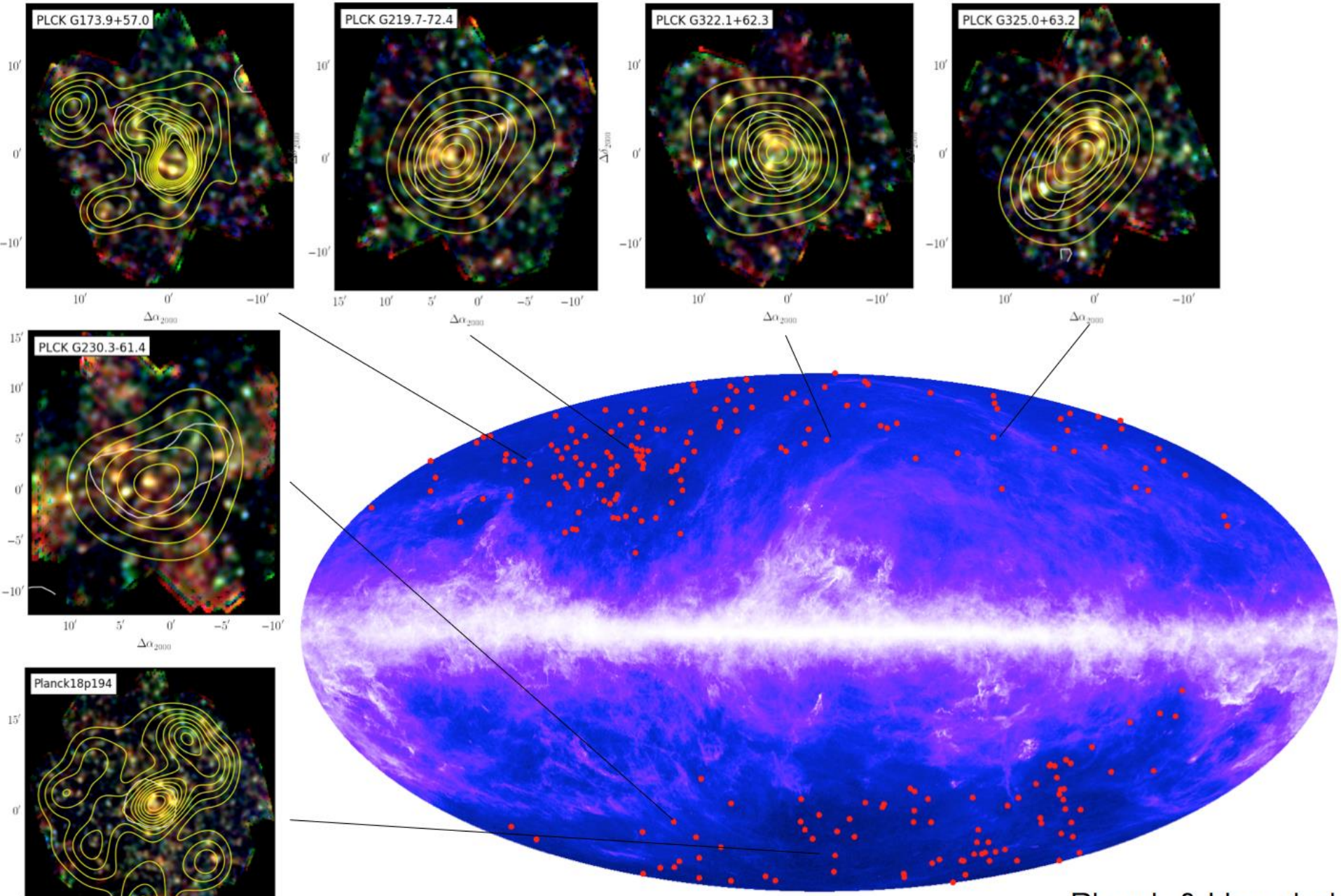




Classical techniques for detecting galaxy clusters (optical/near-IR "red sequence", X-ray emission, SZ effect) preferentially or exclusively select evolved objects, with mature galaxy populations and a hot intra-cluster medium. As a result, most known clusters are at redshifts <1.5, i.e. below that of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



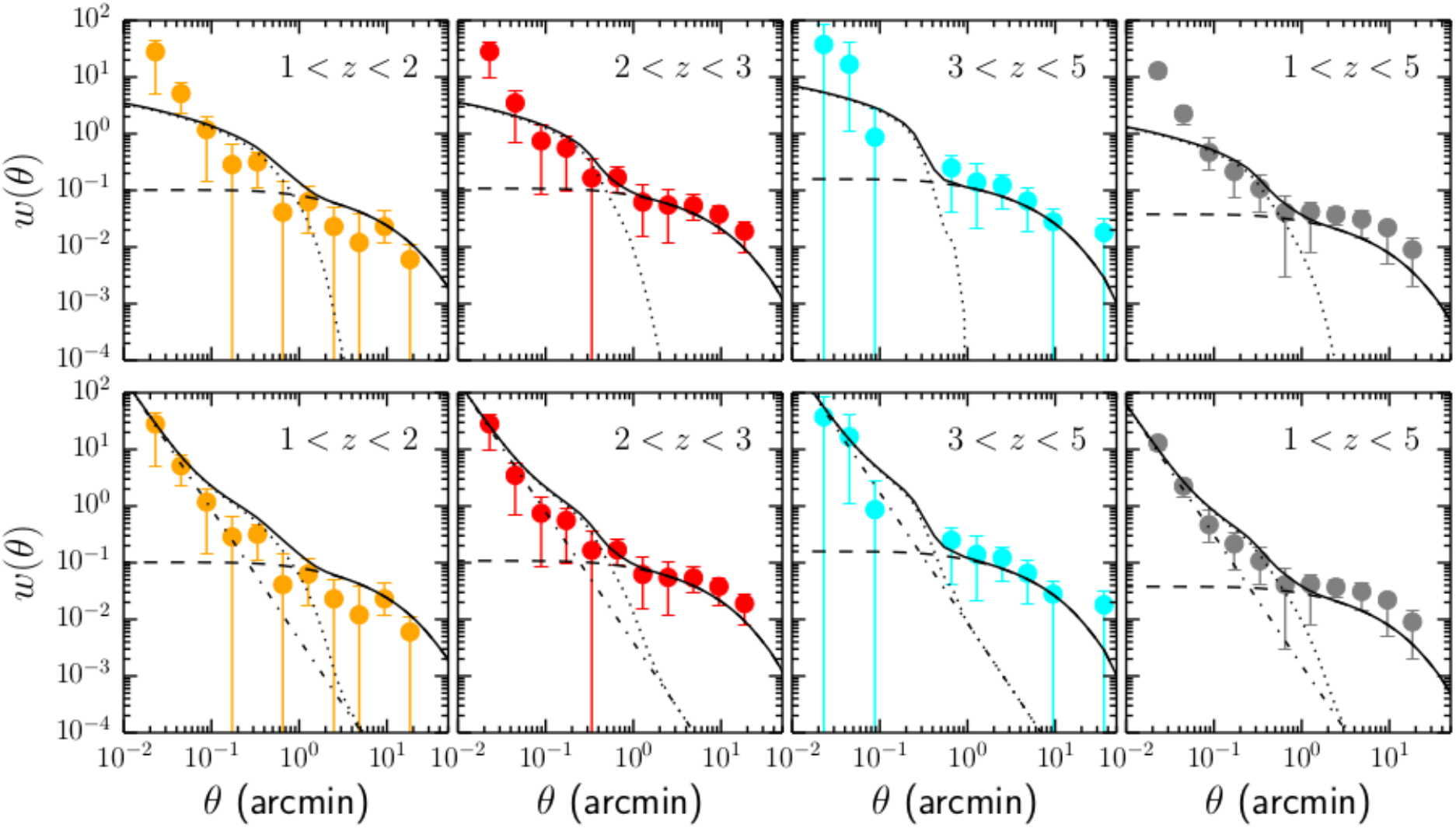
Upper panel: specific SFR vs. redshift for different cluster galaxies and the overall cluster population. The gold shaded region shows the SF main sequence from Elbaz et al. (2011). **Lower panel**: fraction of quiescent cluster galaxies vs. redshift. The quiescent population builds up quickly at earlier times.



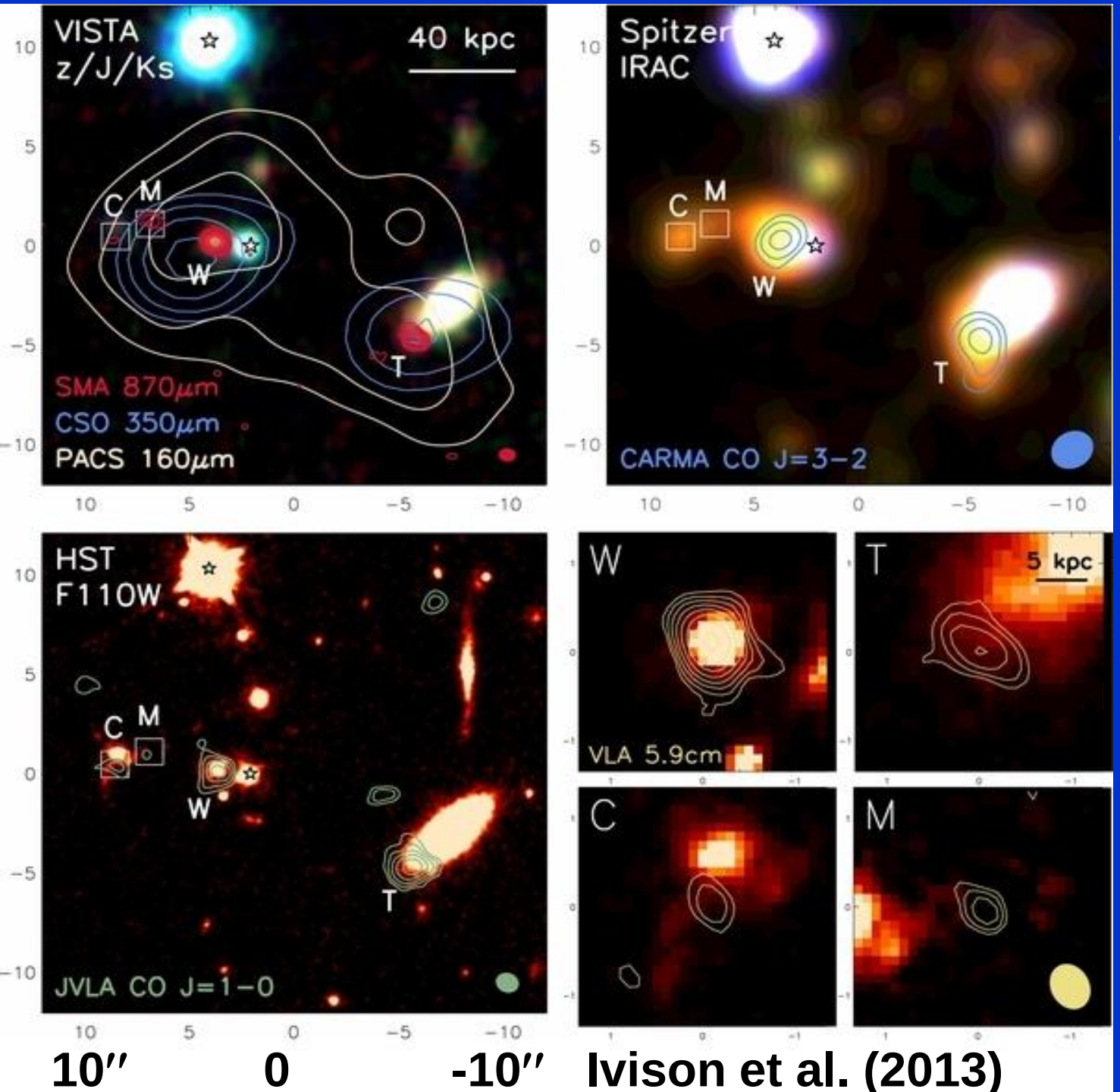
Planck & Herschel

Institut d'Astrophysique Spatiale

Planck intermediate results. XXVII (2015)

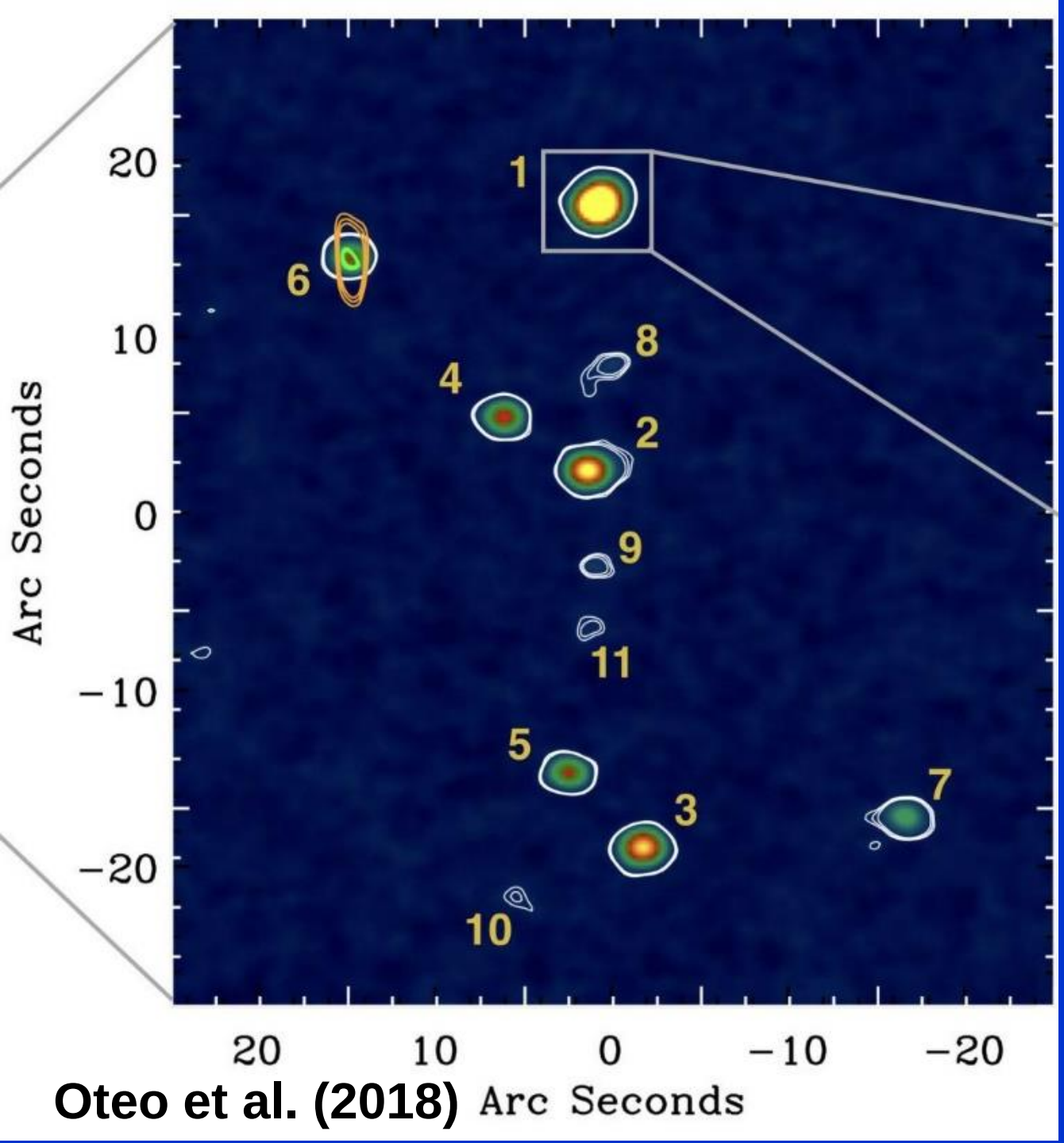


Clustering data of high-z star-forming galaxies show that the typical scale of non-linear overdensities is ~1′, close to the PICO high-frequency resolution (Negrello et al. 2017; data from Chen et al. 2016).



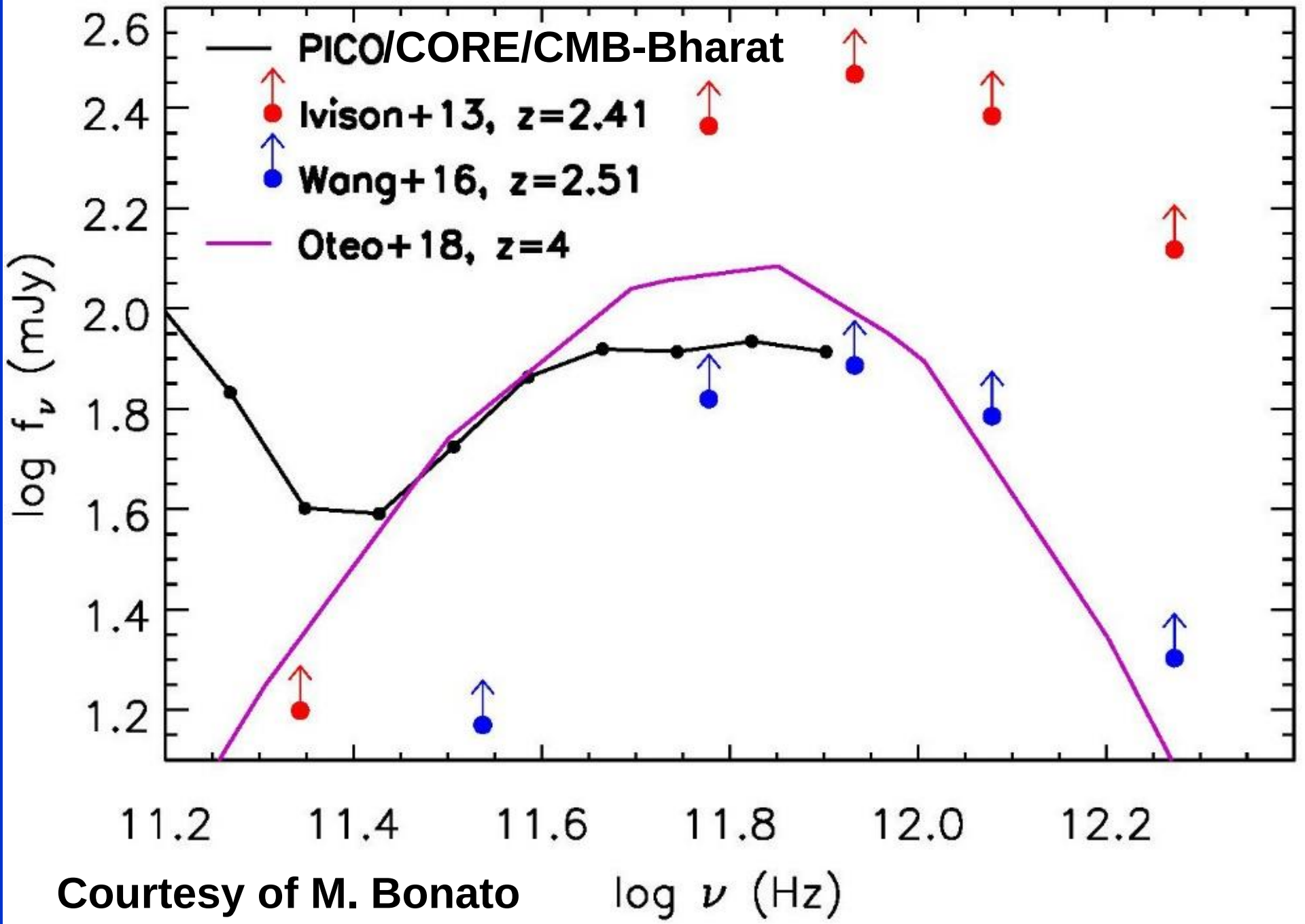
Multi-frequency imaging and CO spectroscopy of a proto-cluster core at z≈2.4 detected by Herschel.

Ivison et al. (2013)



Proto-cluster core at z=4 detected by Herschel.

Oteo et al. (2018)



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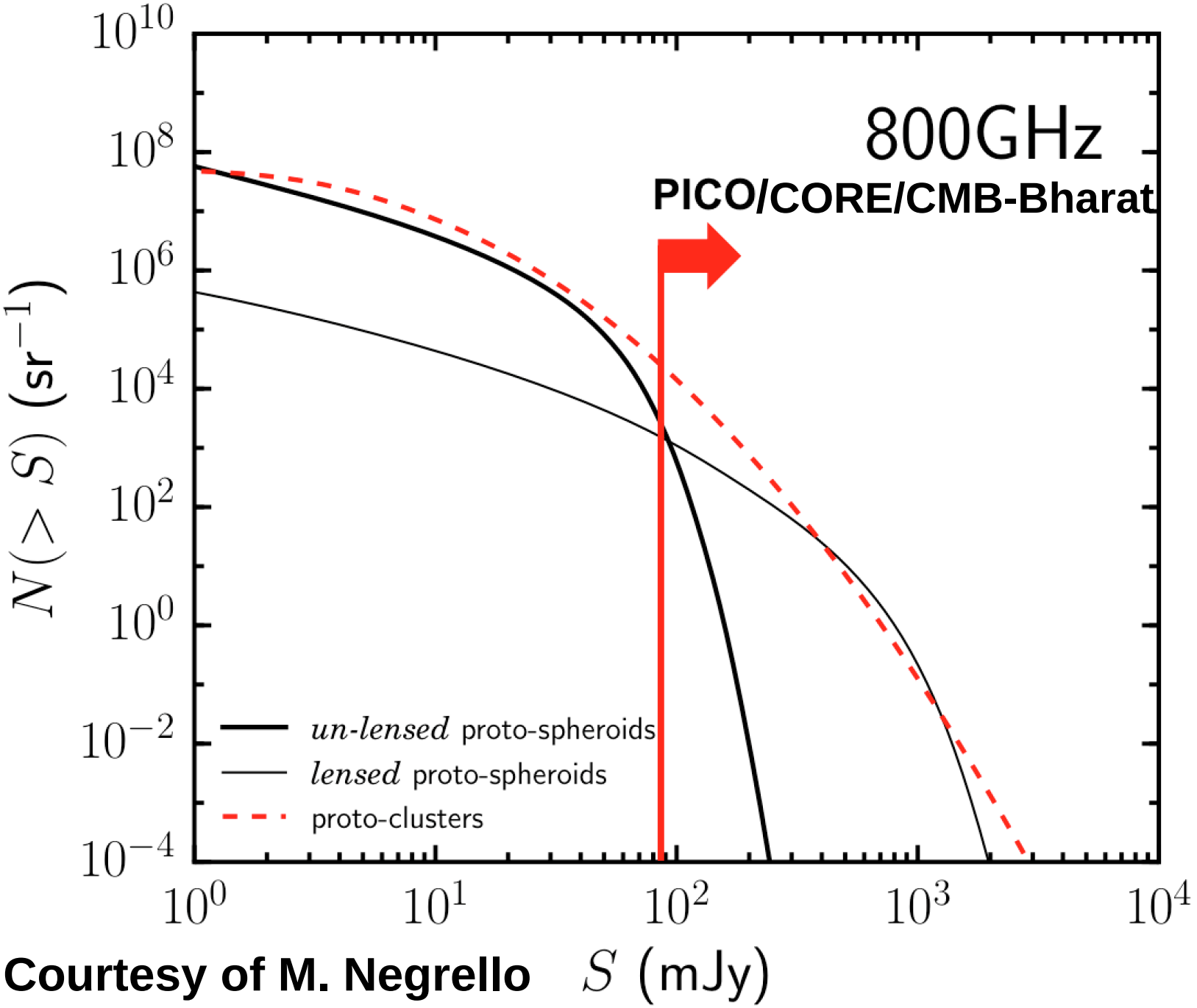

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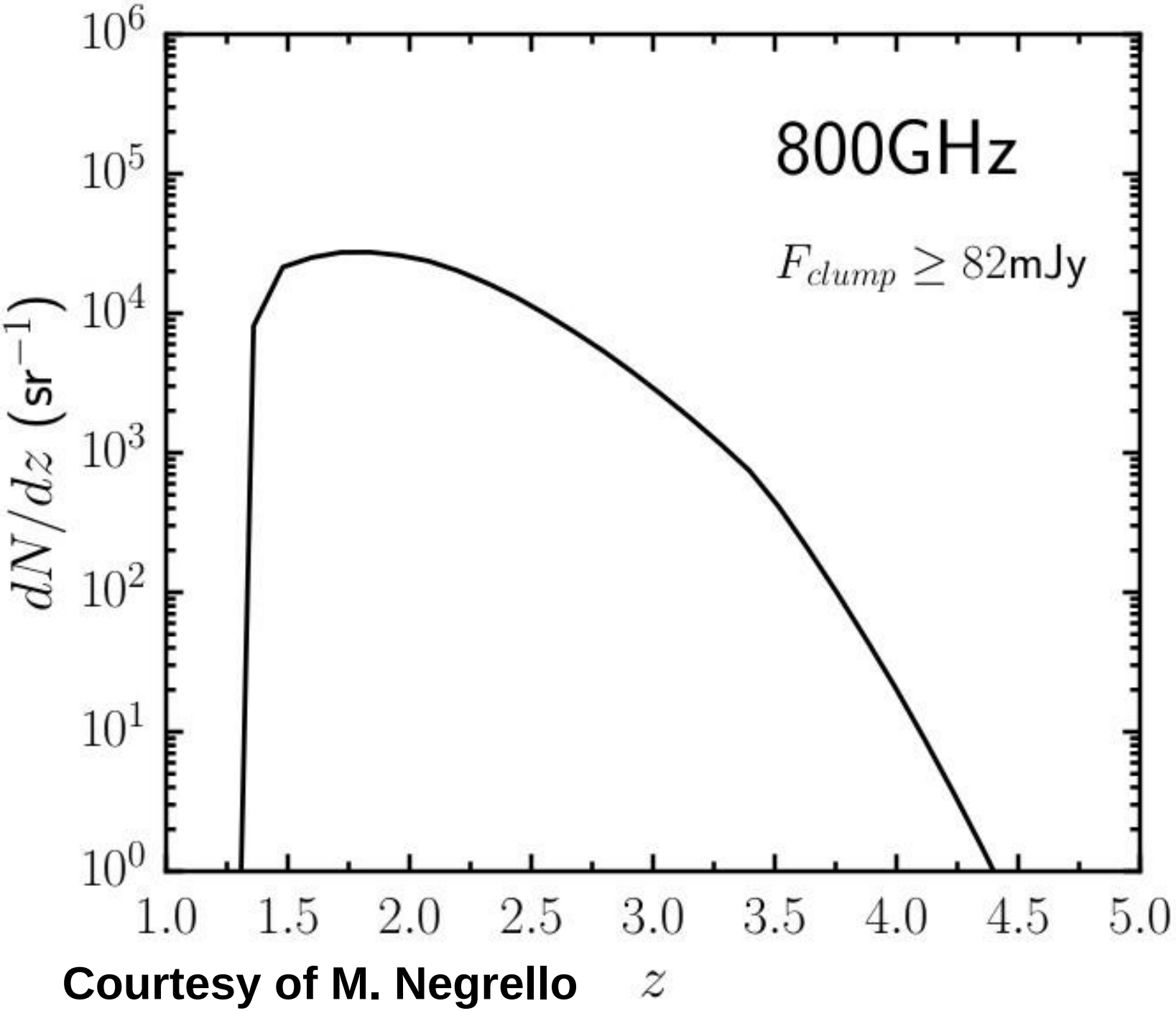

Courtesy of M. Negrello

Conclusions

Planck has demonstrated the unique capability of all-sky CMB experiments to explore astrophysical phenomena otherwise unaccessible to the present day instrumentation.

Those presented are only examples. Other examples are blazar astrophysics and high frequency polarization of extragalactic sources, including dusty galaxies.

Next generation CMB experiments have the capability to make a giant leap forward in these fields.