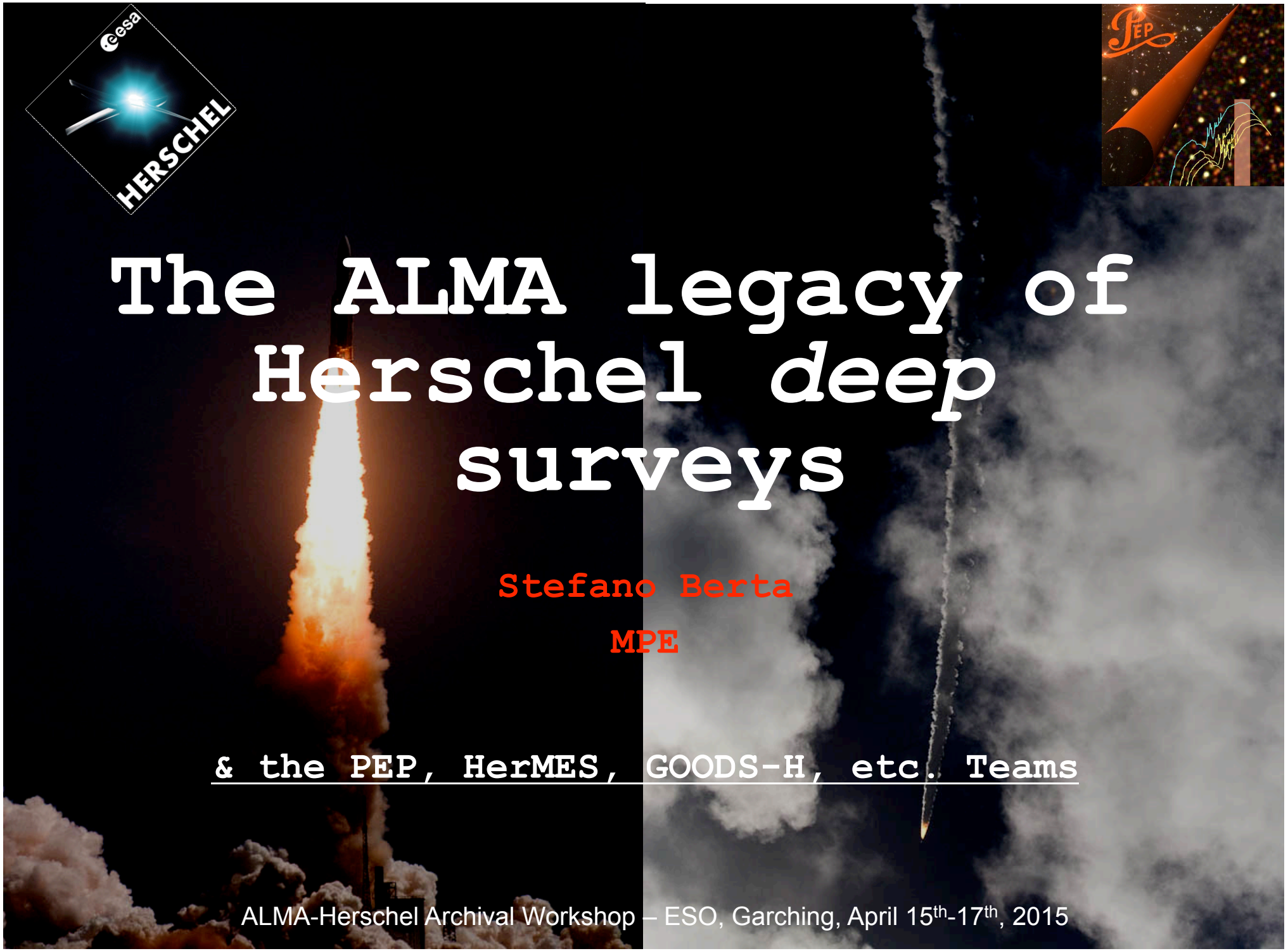


The ALMA legacy of Herschel *deep* surveys

Stefano Berta

MPE

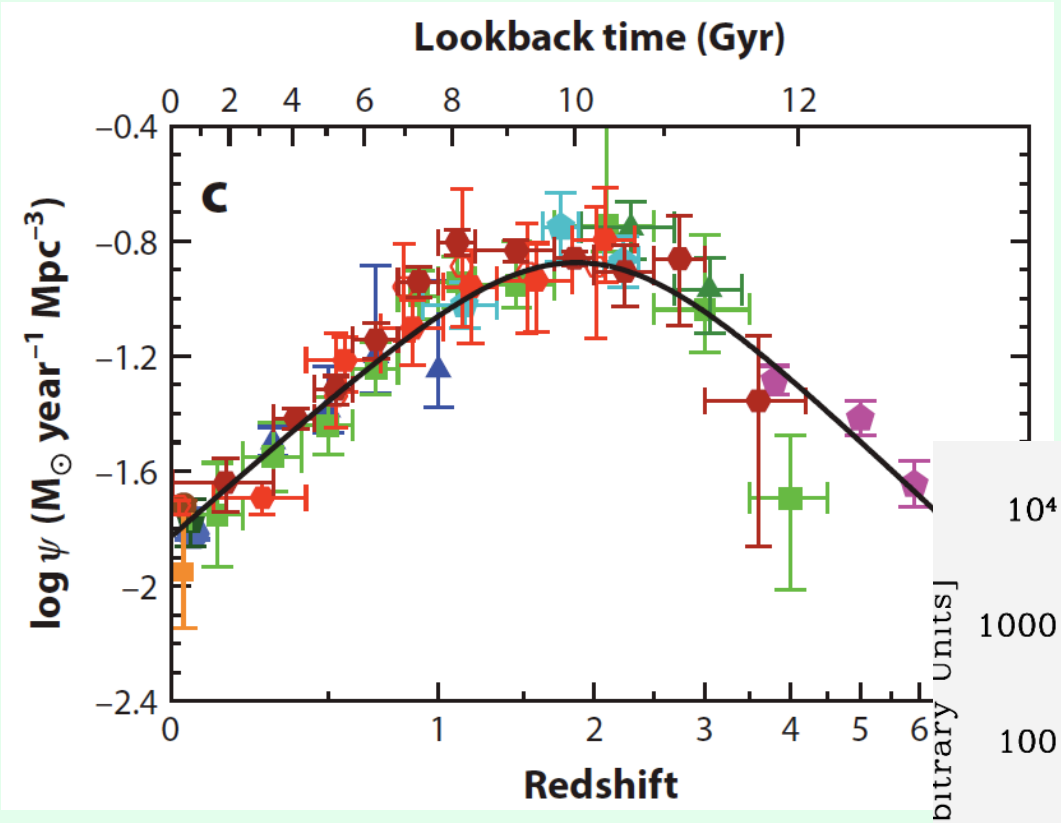
& the PEP, HerMES, GOODS-H, etc. Teams

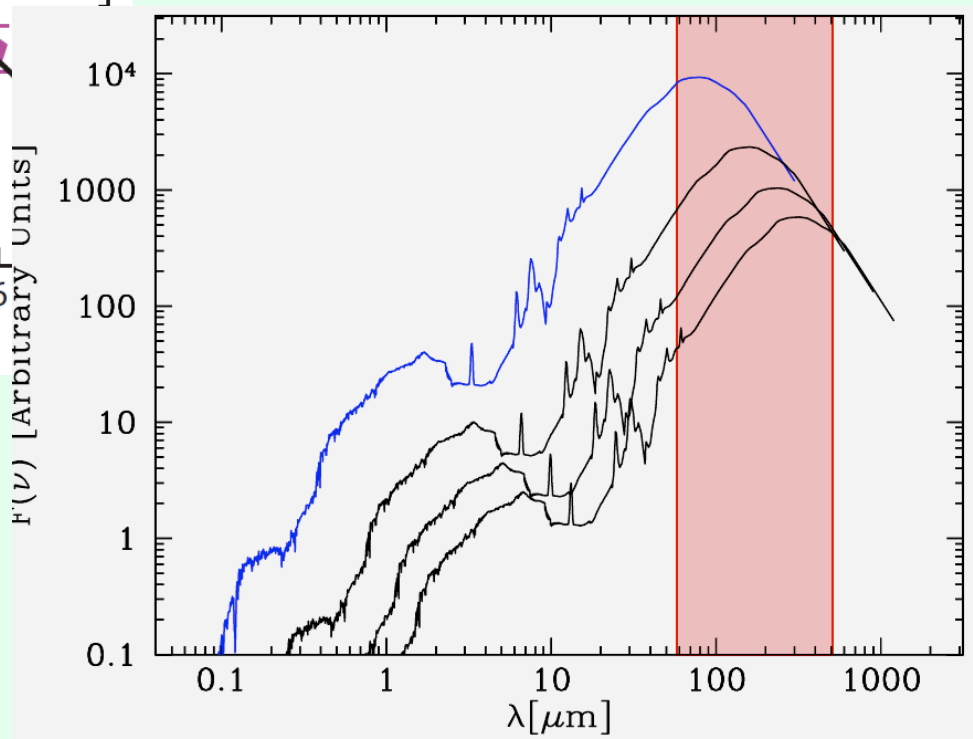
ALMA-Herschel Archival Workshop – ESO, Garching, April 15th-17th, 2015

Overview

- ✓ Far-IR observations and Herschel deep surveys
- ✓ PACS Evolutionary Probe (PEP)
- ✓ PEP and the Gas Mass Function
- ✓ Deriving Gas (dust) masses with ALMA, Herschel or ALMA+Herschel

The FIR and Herschel… because:





Madau & Dickinson (2014), Lutz (2014), Berta et al. (2013a)

The cosmological wedding cake

Depth

Area

Lensing Clusters

Deep H-GOODS (+PEP)

PEP/HerMES GOODS-N/S

PEP/HerMES Lockman, EGS, etc.

PEP/HerMES COSMOS

ATLAS
HerMES wide tiers

…and several other OT surveys

PEP

(70), 100, 160 um

- ✓ 6 main blank fields
- ✓ 9 lensing clusters
- ✓ 2 z~1 clusters

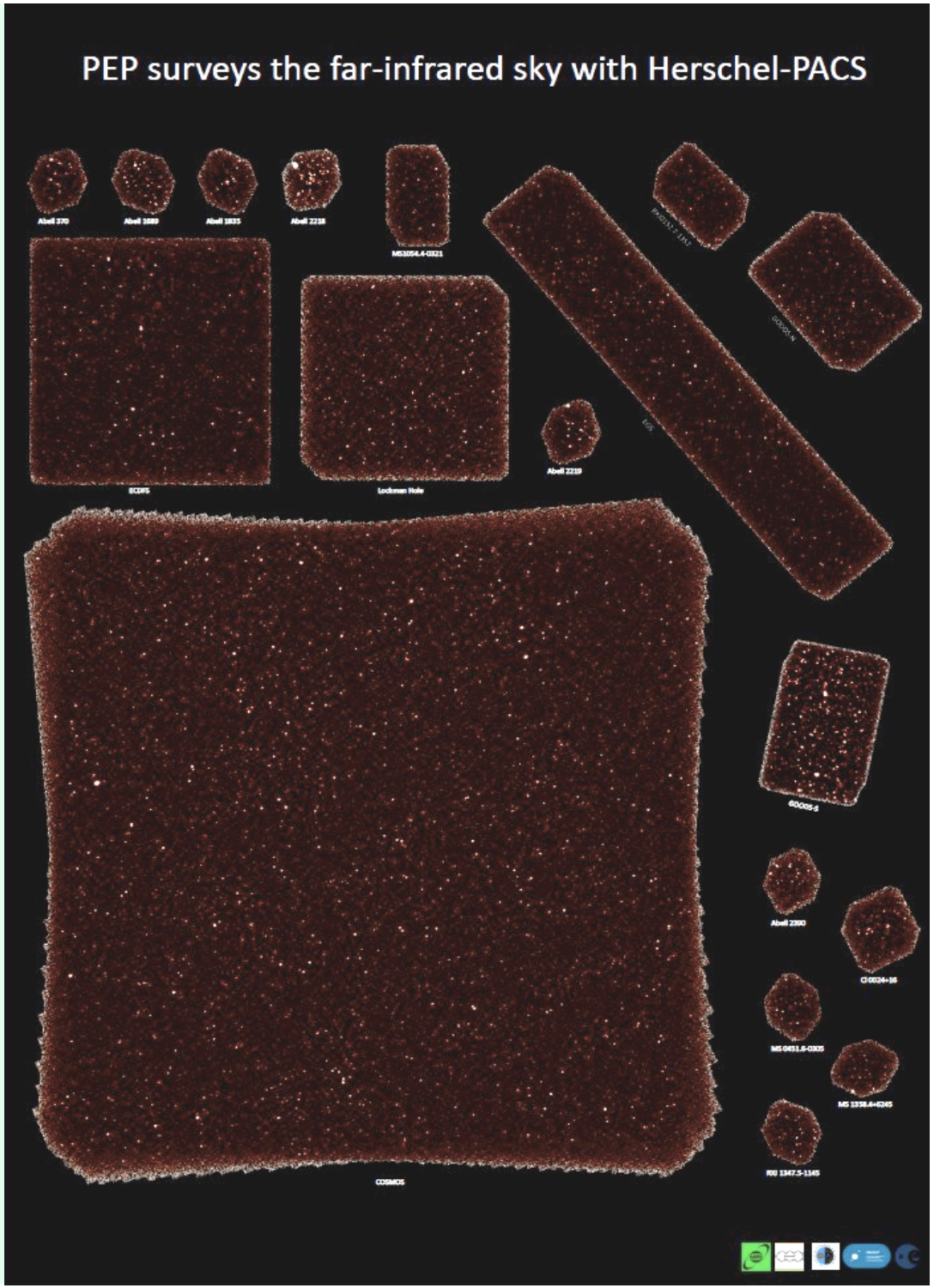
~10000 arcmin^2

~20000 sources

>100 papers

>3000 citations

P.I.: D. Lutz



PEP

(70), 100, 160 um

- ✓ 6 main blank fields
- ✓ 9 lensing clusters
- ✓ 2 z~1 clusters

~10000

~200

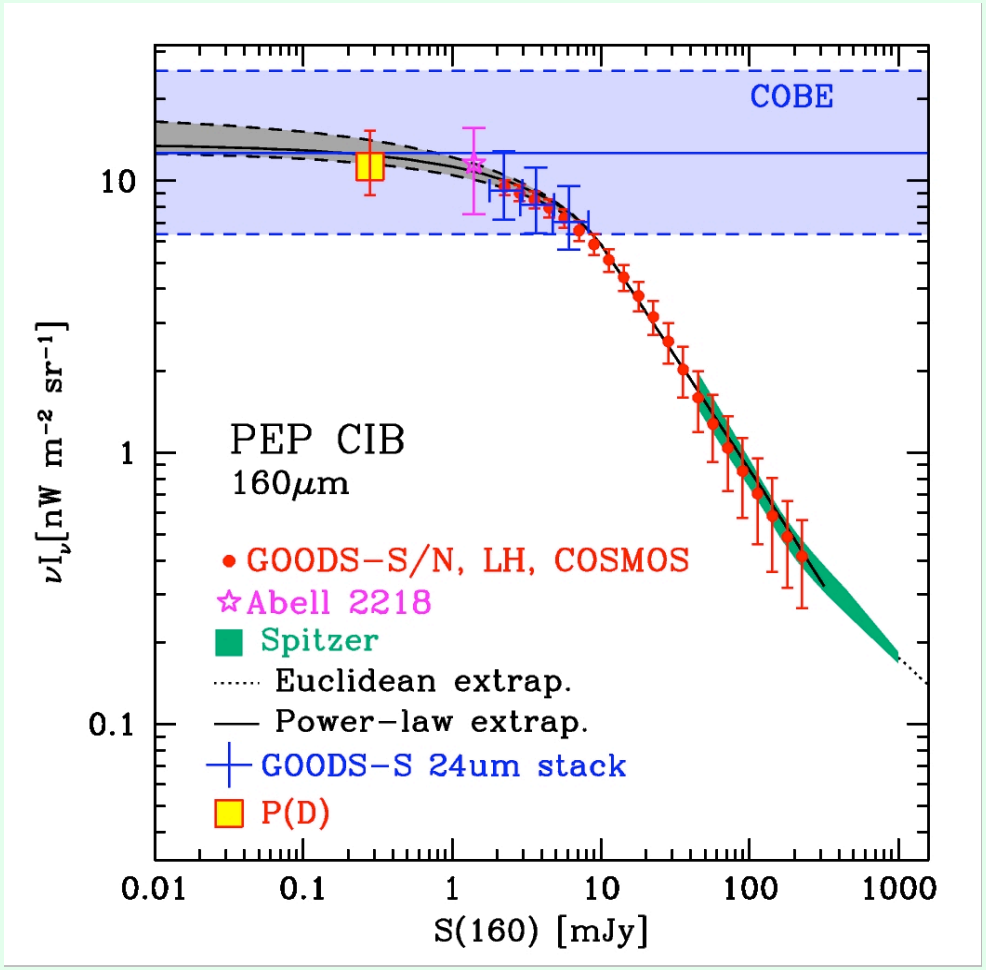
Full data release!

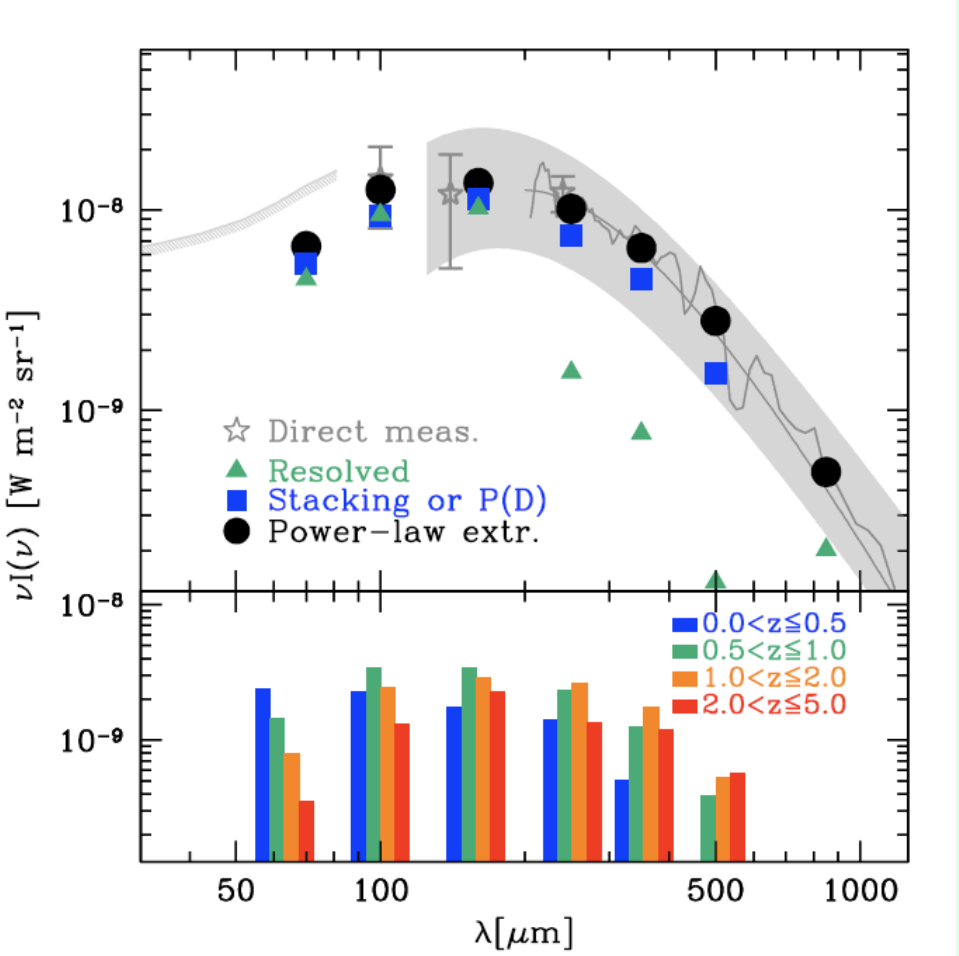
Http://www.mpe.mpg.de/Research/PEP/public_data_releases

Http://www.cosmos.esa.int/web/herschel/user-provided-data-products

D. Lutz

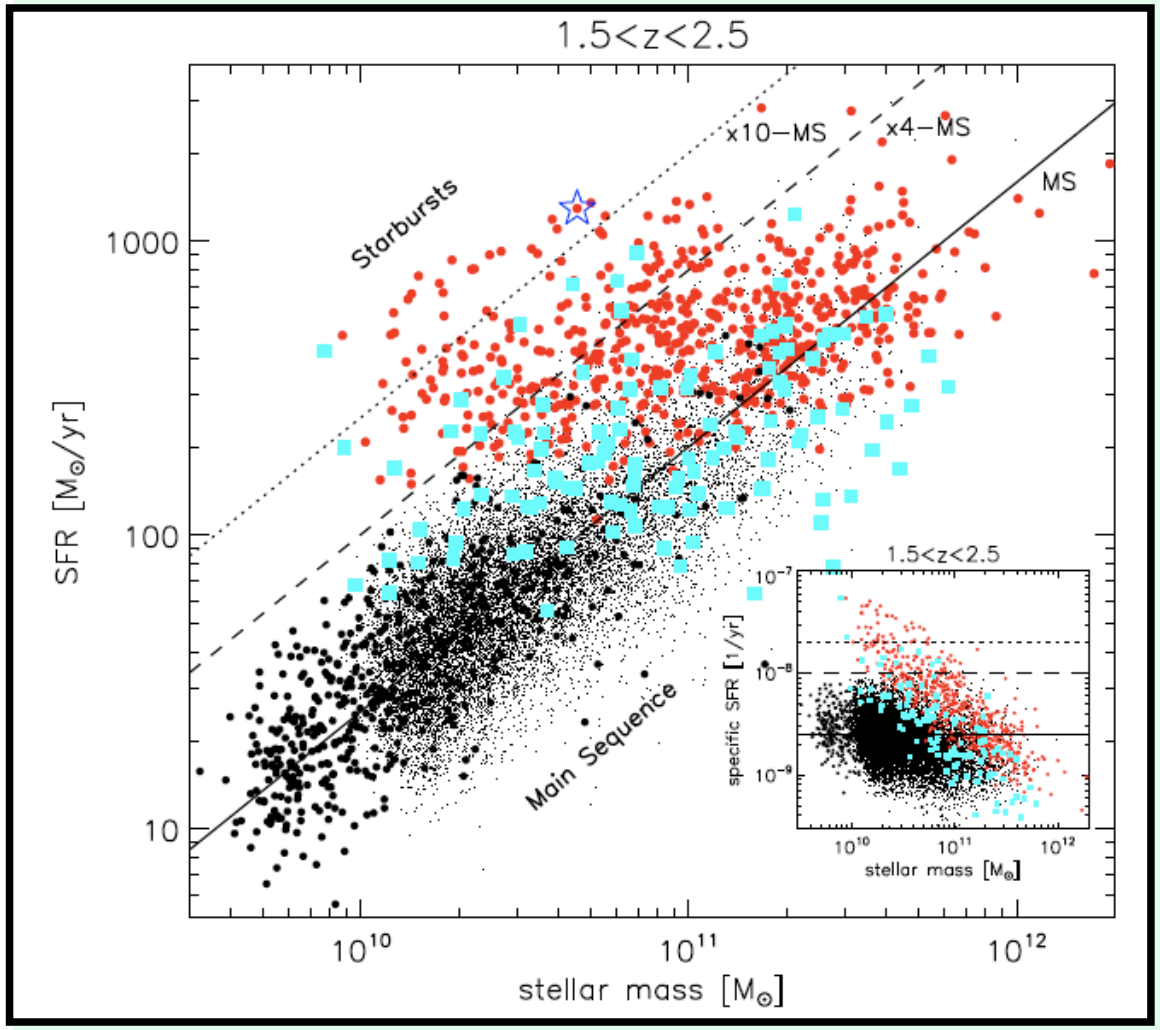
Herschel resolves the CIB





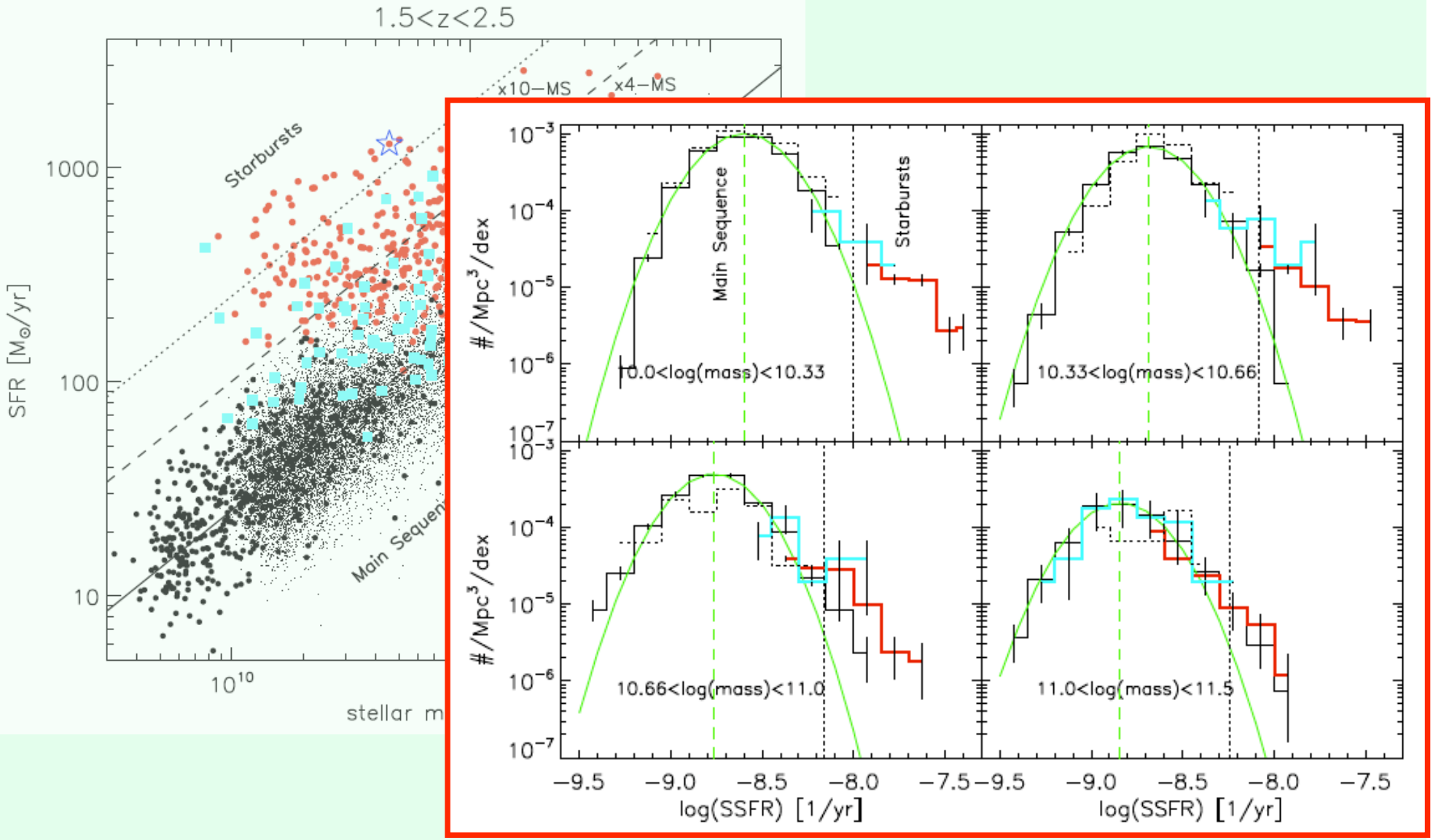
Lutz (2014), Berta et al. (2010,2011), Magnelli et al. (2013), Bethermin et al. (2012), Glenn et al. (2010), see also Leiton et al. (2015), Planck Collab. (2014), Viero et al. (2013), Sibthorpe et al.(2013), Rigby et al. (2011),…

The lesser role of "starbursts"



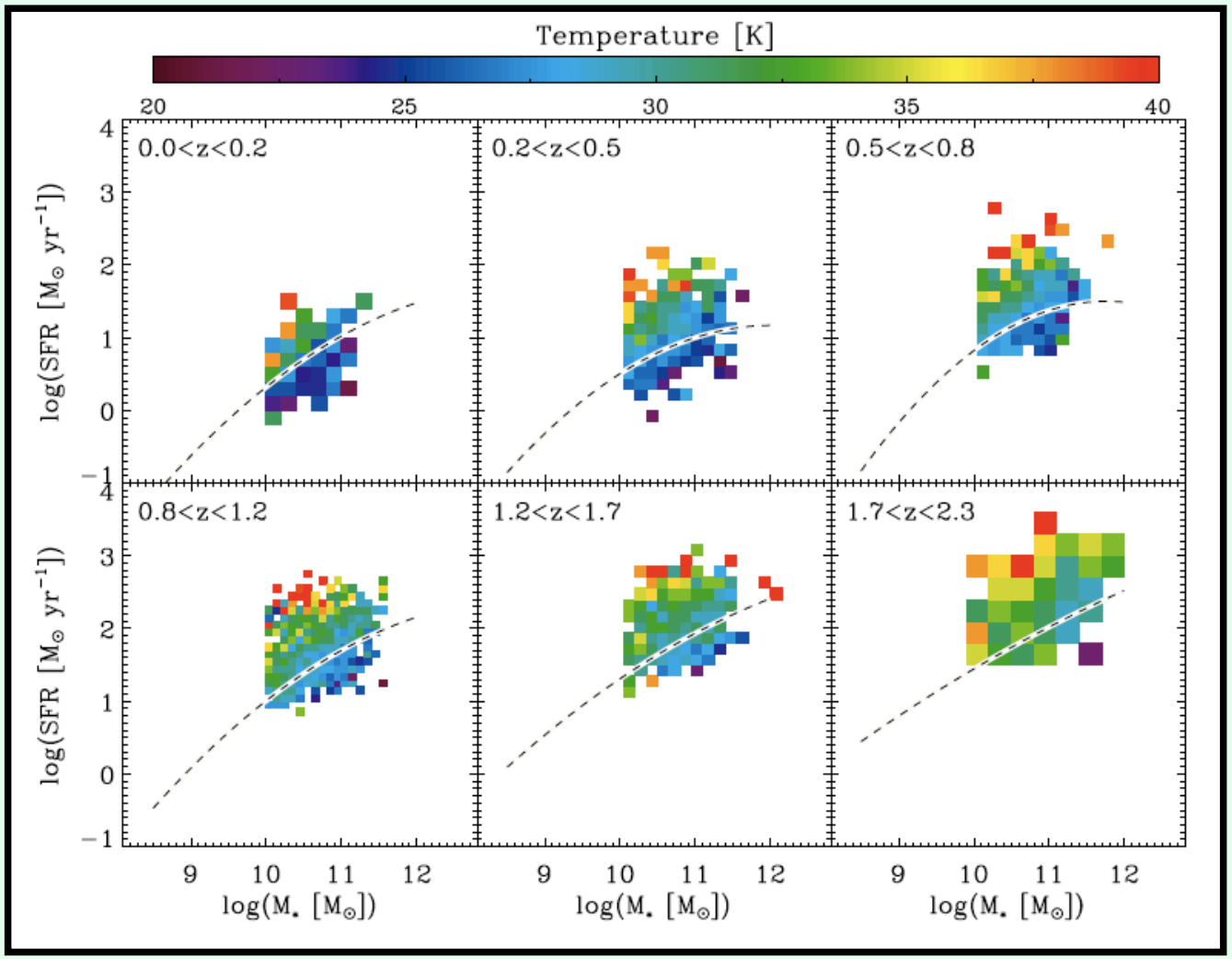
Rodighiero et al. (2011), Sargent et al. (2012, 2013)

The lesser role of "starbursts"



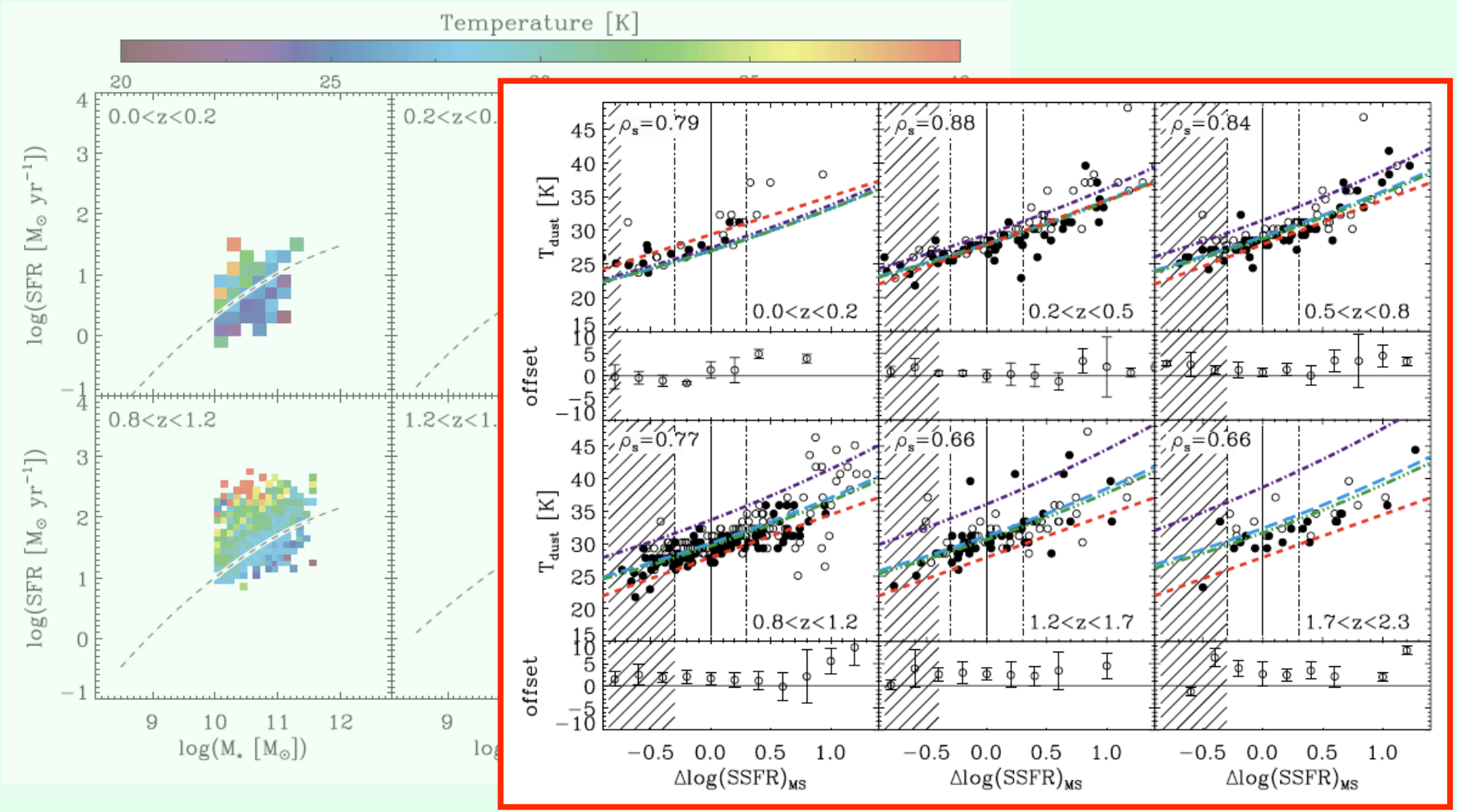
Rodighiero et al. (2011), Sargent et al. (2012, 2013)

Dust Properties along/across the "Main Sequence"



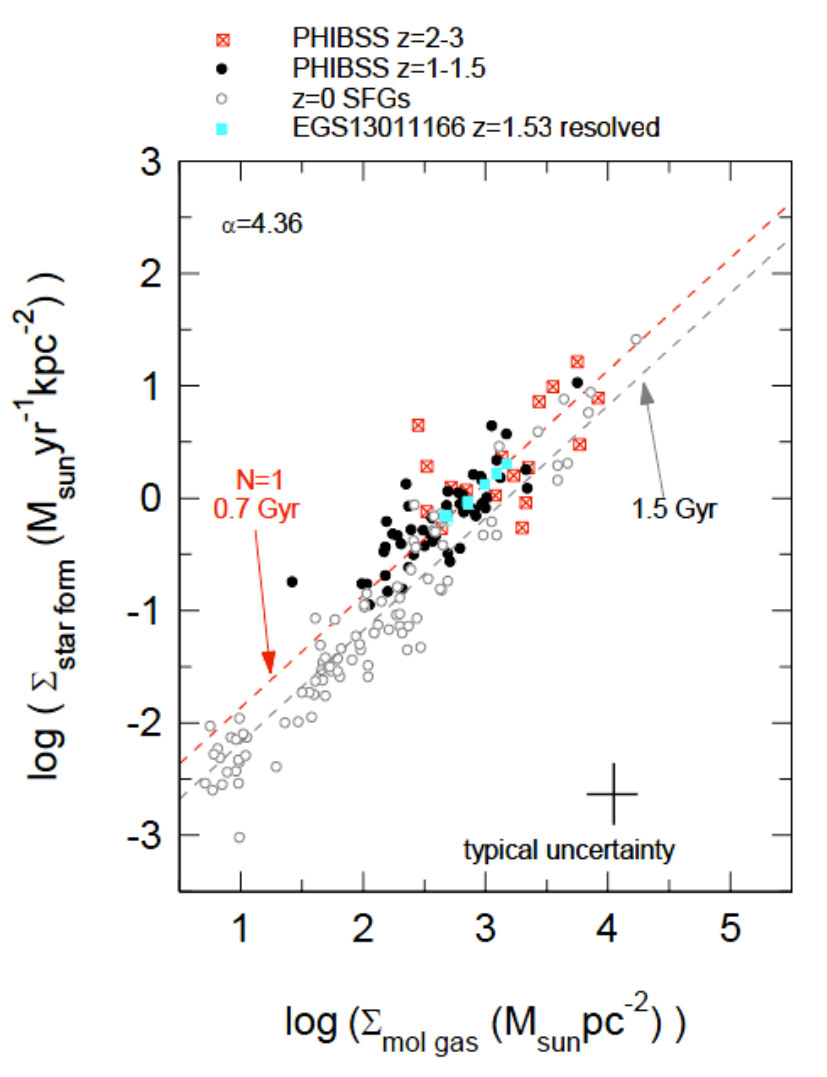
Magnelli et al.(2014)

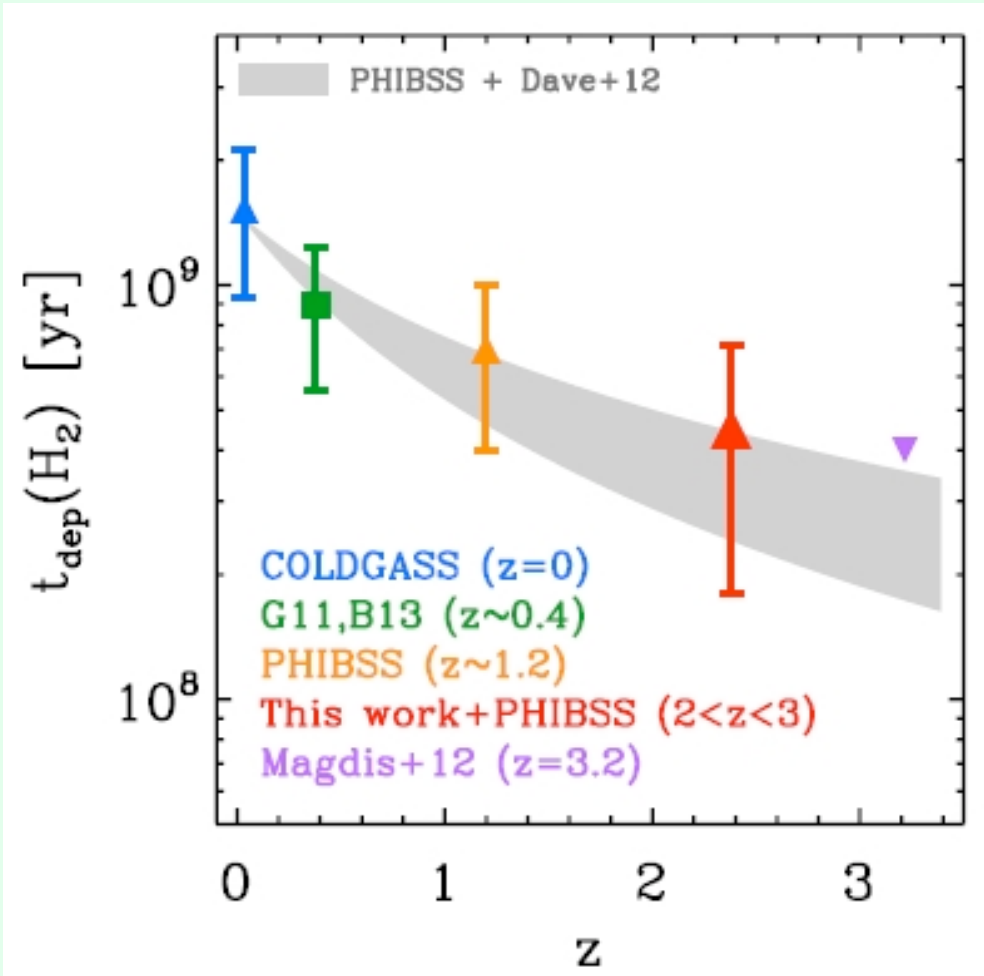
Dust Properties along/across the "Main Sequence"



Magnelli et al.(2014), see also Genzel et al.(2015)

The fuel of star formation



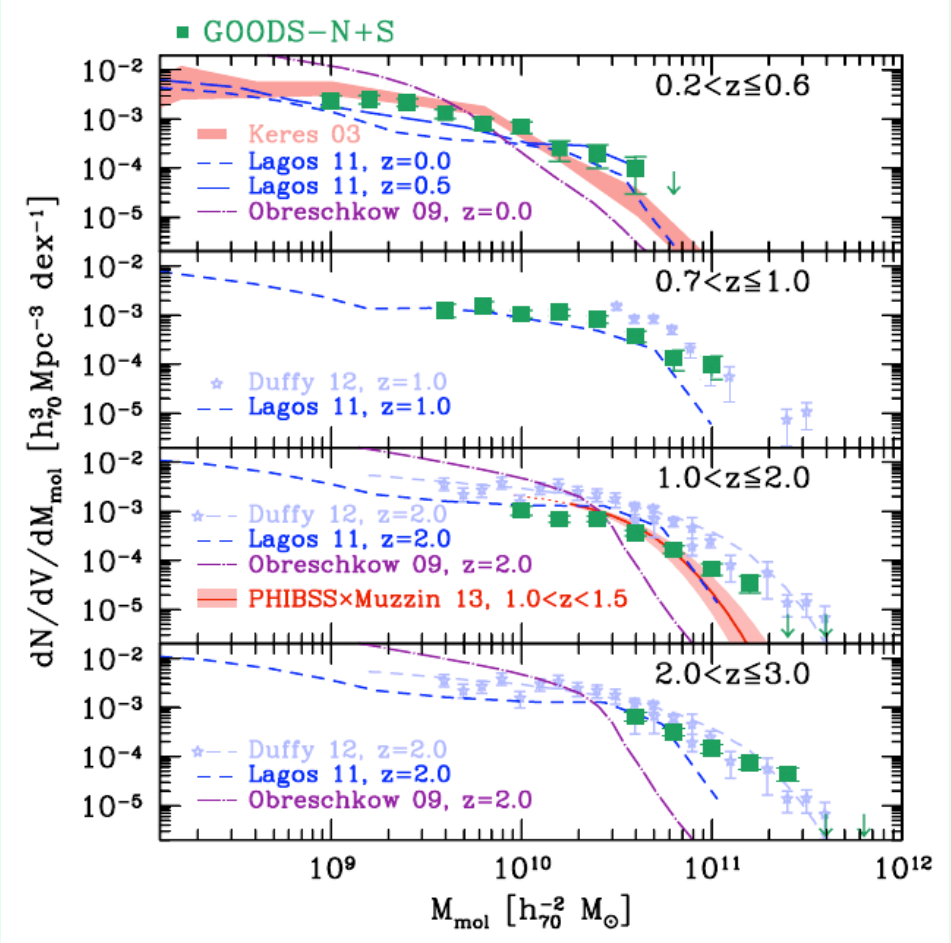


$$t_{depl} = M_{mol\ gas}/SFR = 1.5 \times (1+z)^{-1}\ \mathrm{Gyr}$$

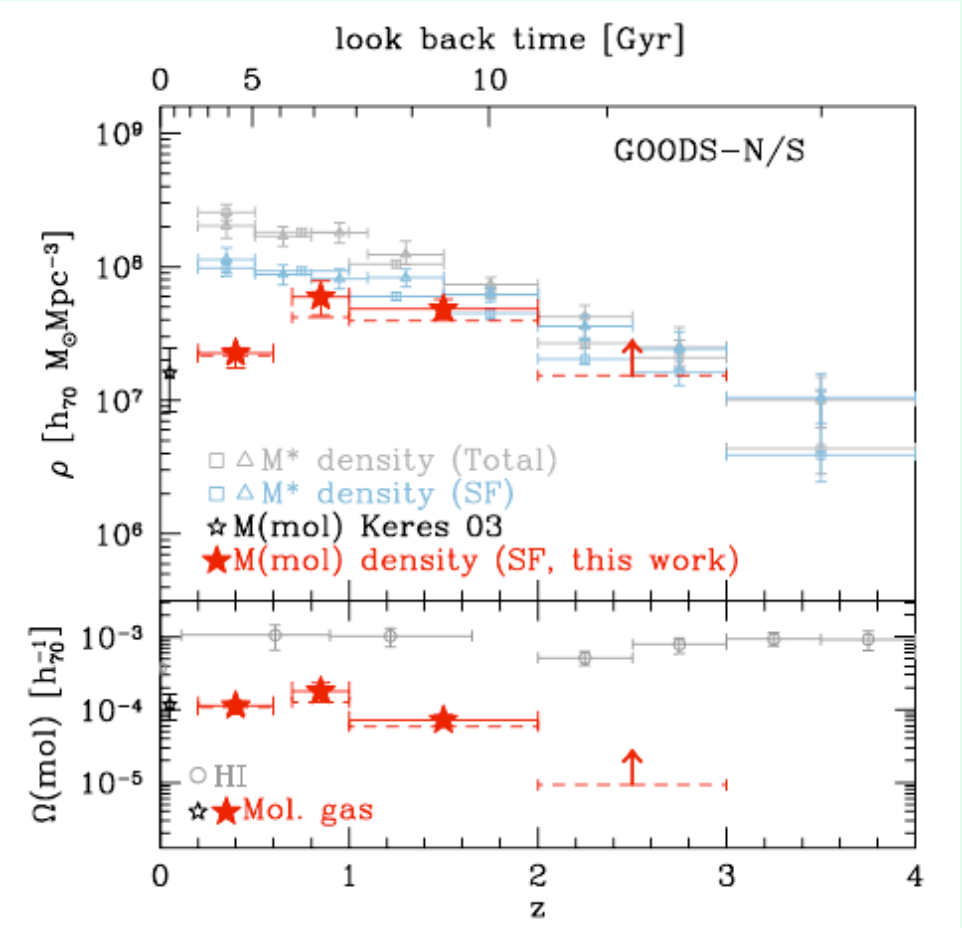
(e.g. Tacconi et al. 2013, Saintonge et al. 2011,2012, Genzel et al. 2015)

The M(mol) Mass Function

1/V(access)



STY



Berta et al. (2013b), see also Sargent et al. (2013)

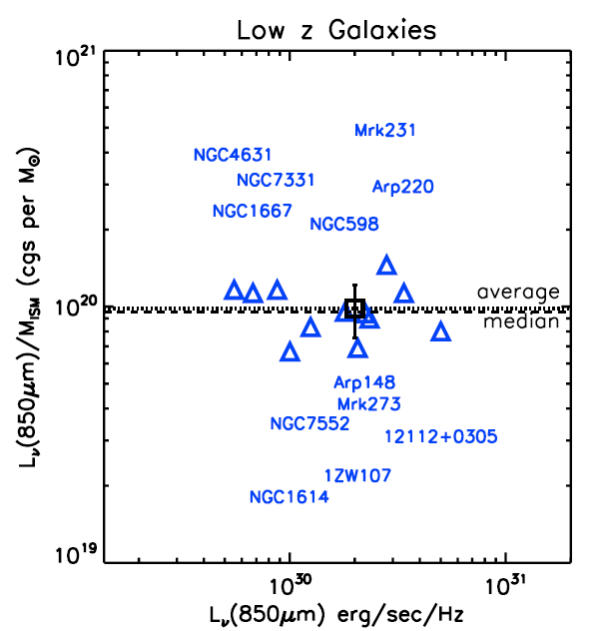
Deriving gas masses

1. CO tracer -> Alpha(CO) ; still limited to small samples at z>0 and still time expensive

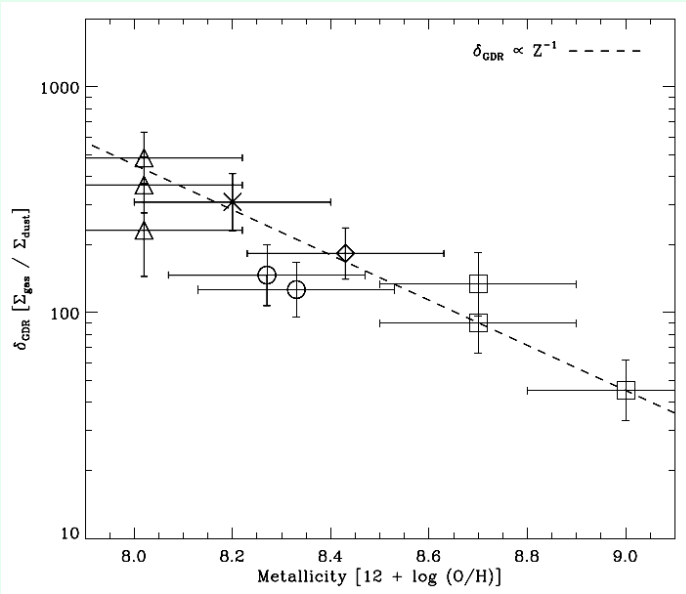
2. Derive M(gas) from t(depl) using KS scaling (seen before)

Deriving gas masses

3. Scaling sub-mm fluxes (e.g. Scoville et al. 2014, Eales et al. 2012)



4. derive M(gas) from M(dust, SED), e.g. via gas/dust scaling with metallicity (e.g. Leroy et al 2011, Magdis et al. 2012, Santini et al. 2014, Remy-Ruyer et al. 2013, Genzel et al. 2015)



Testing ALMA single-band M(gas)

MBB simulation

INPUT:

- Magnelli et al. (2014) T(dust) vs z-M*-sSFR
- Genzel et al. (2015) M(gas) vs z-M*-sSFR
- Modified Black Body

OUTPUT:

- M(gas) based on Scoville et al. (2014) scaling of sub-mm flux

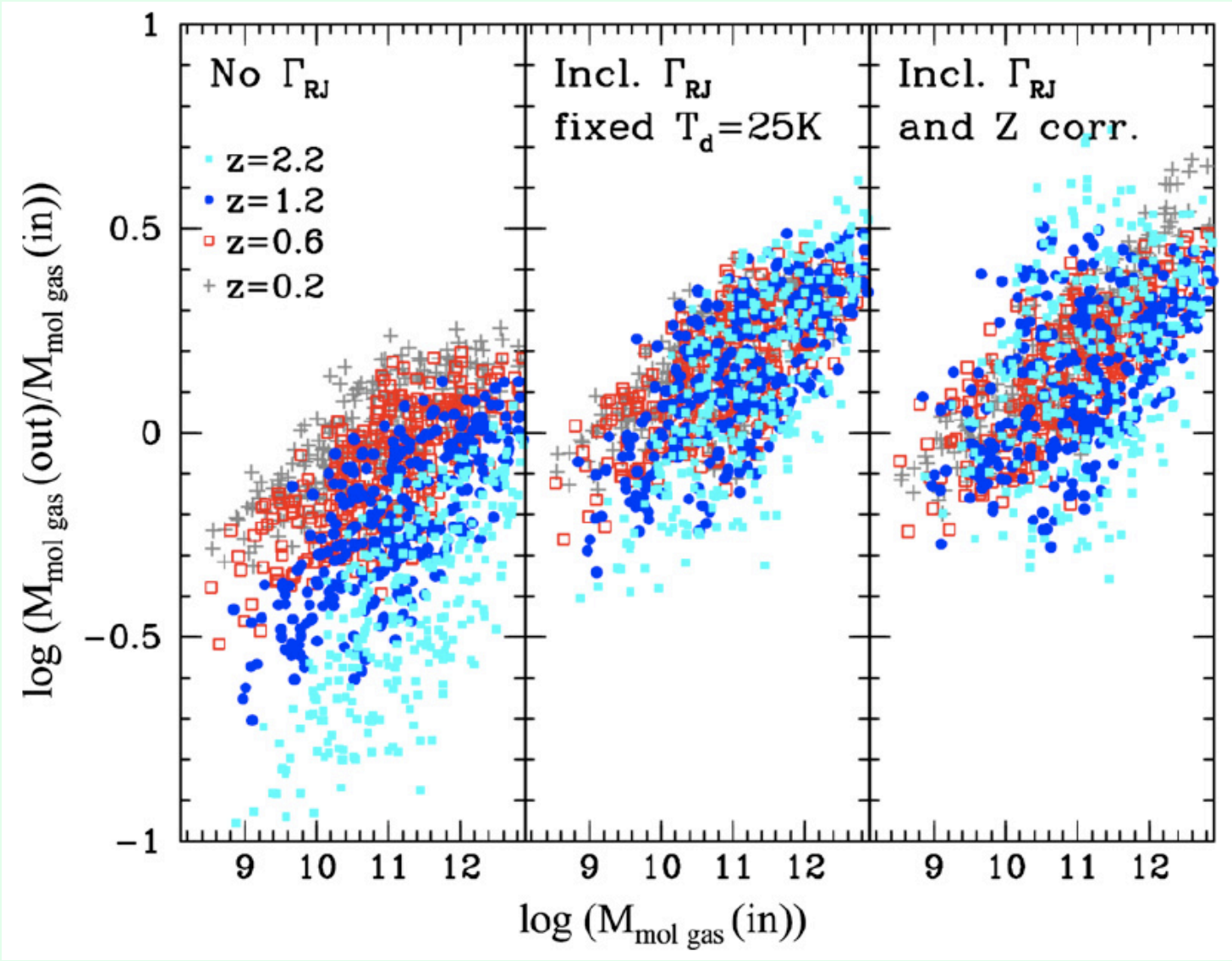
$$\alpha_{850\,\mu\mathrm{m}} = \frac{L_{\nu_{850\,\mu\mathrm{m}}}}{M_{\mathrm{ISM}}} = 4\pi\,\kappa_{\mathrm{ISM}}(\nu_{850\,\mu\mathrm{m}})B_{\nu}(T_d)$$
$$= 0.79 \times 10^{20}\ \mathrm{erg\,s^{-1}\,Hz^{-1}}\ M_{\odot}^{-1}, \qquad (9)$$

(Valid for T(d)=25 K and Planck-based kappa(ISM))

Genzel et al. (2015)

Testing ALMA single-band M(gas)

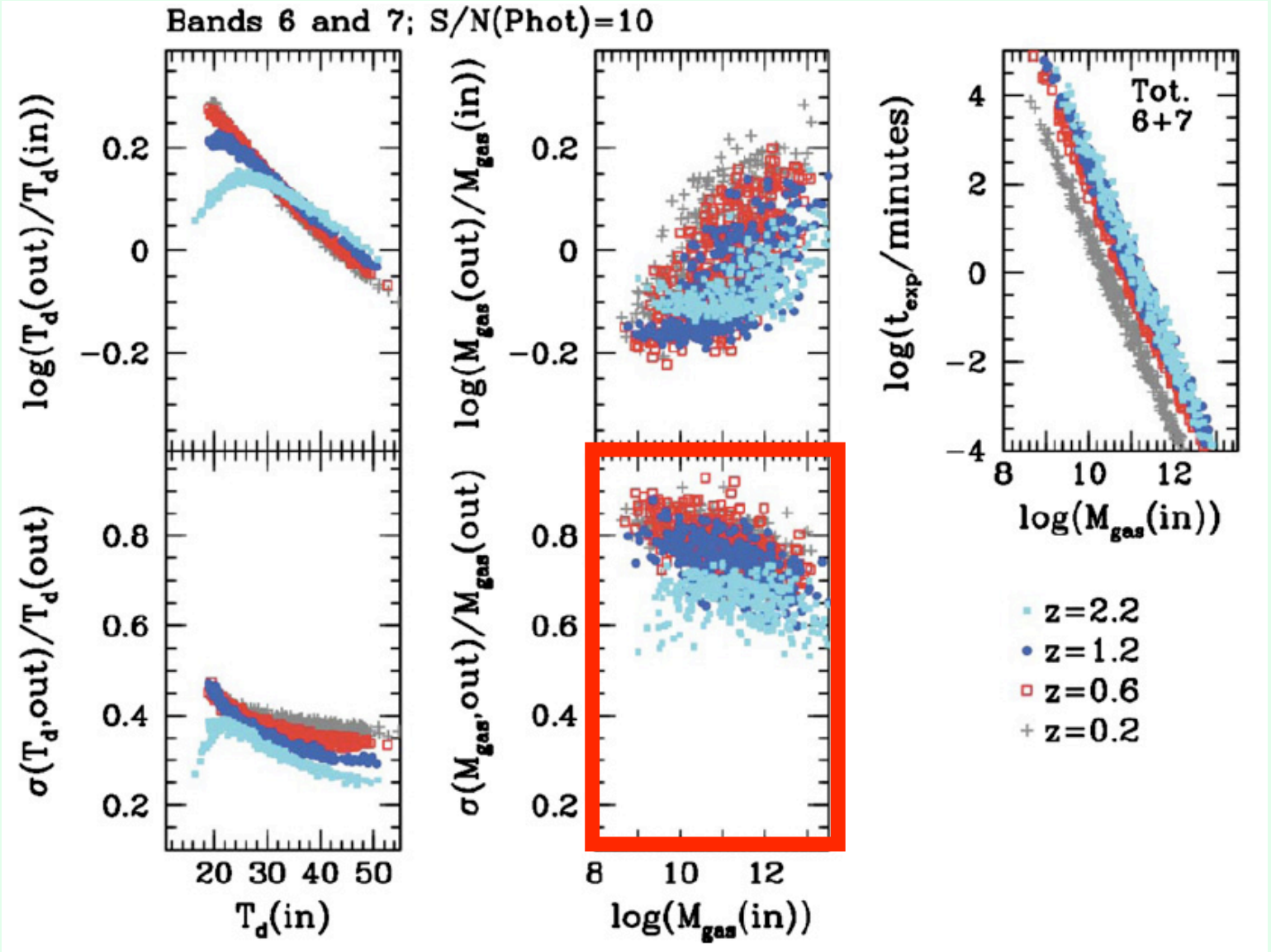
MBB simulation



Genzel et al. (2015)

Switching to two ALMA bands (6+7)

MBB simulation

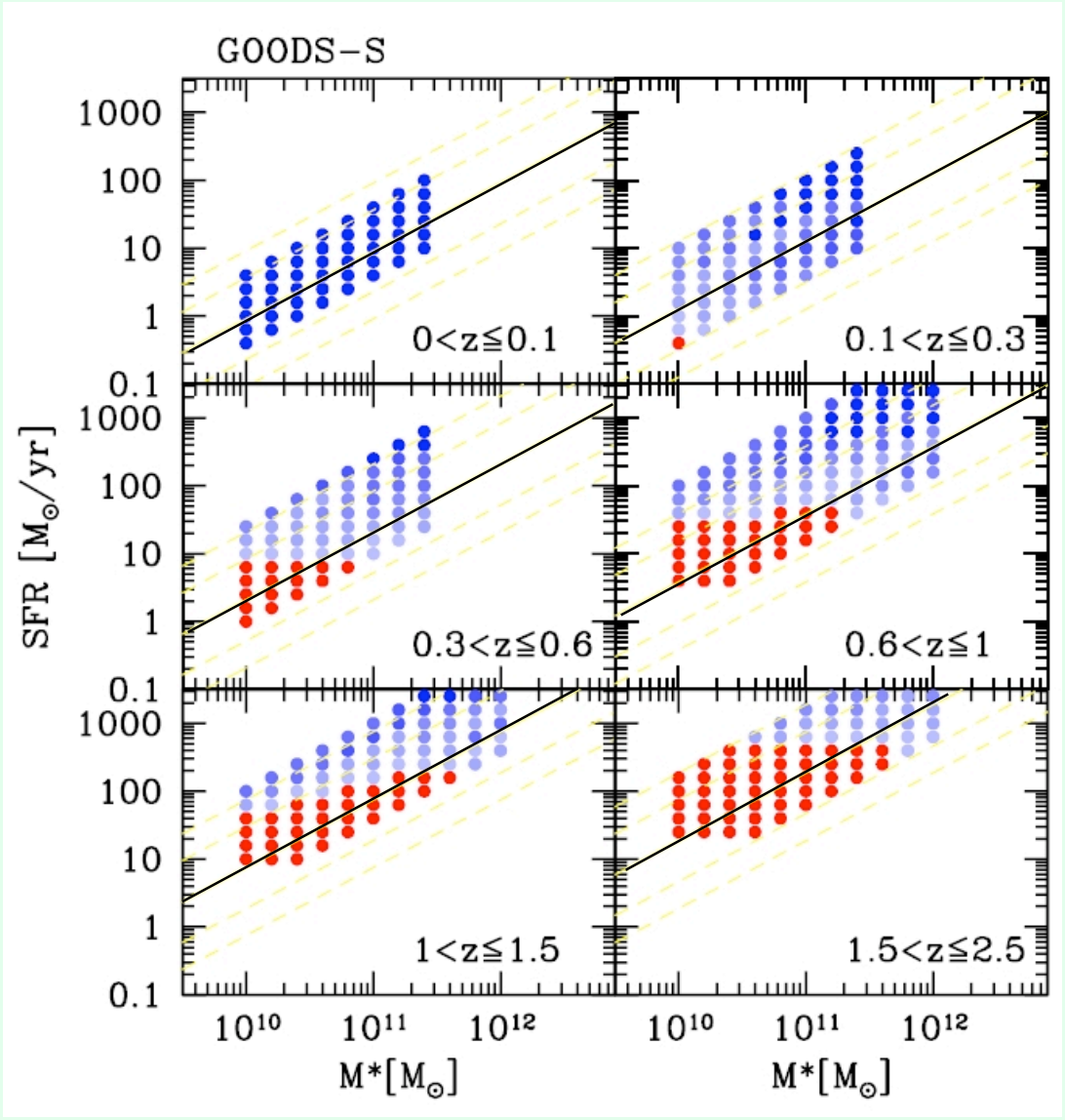


(Time expensive)

Genzel et al. (2015)

Herschel handles dust masses

DL07 Simulation, sampling the M*-SFR space with PEP/HerMES noise

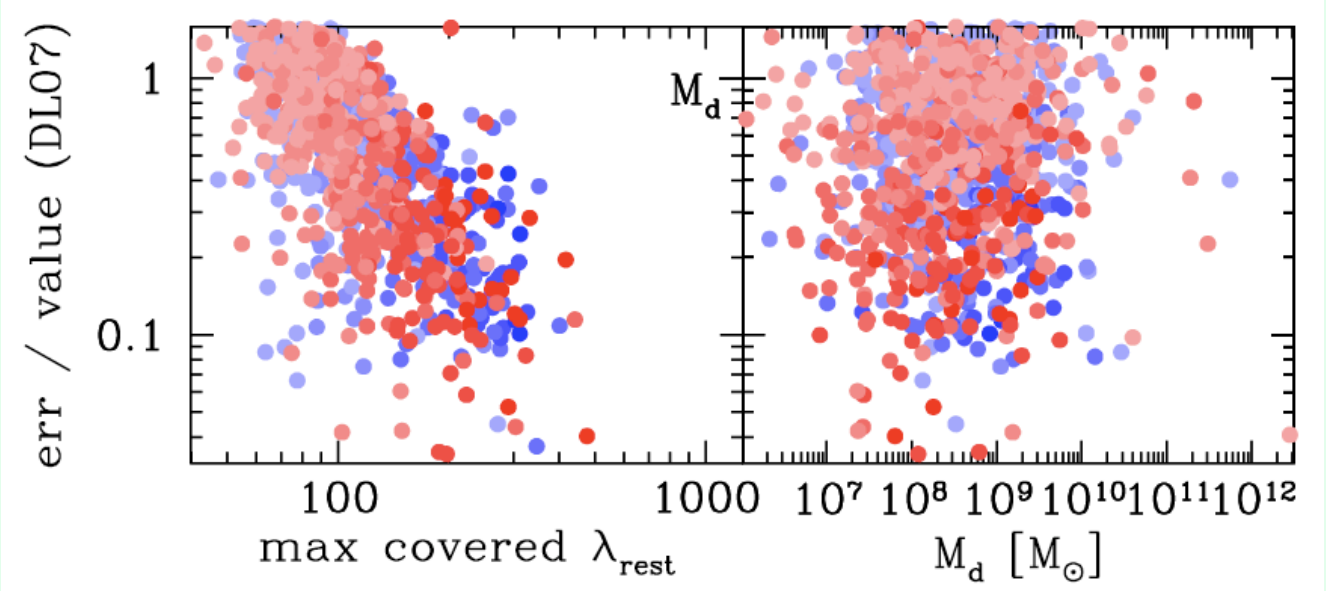


Color coding
x=Δ(M(d))/M(d)

- x≦0.001
- 0.001<x≦0.01
- 0.01<x≦0.05
- 0.05<x≦0.1
- 0.1<x≦0.2
- 0.2<x≦0.33
- x>0.33

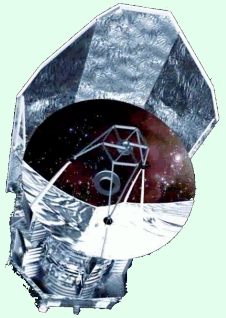
Berta et al. (in prep)

Studying our ignorance in deriving dust masses

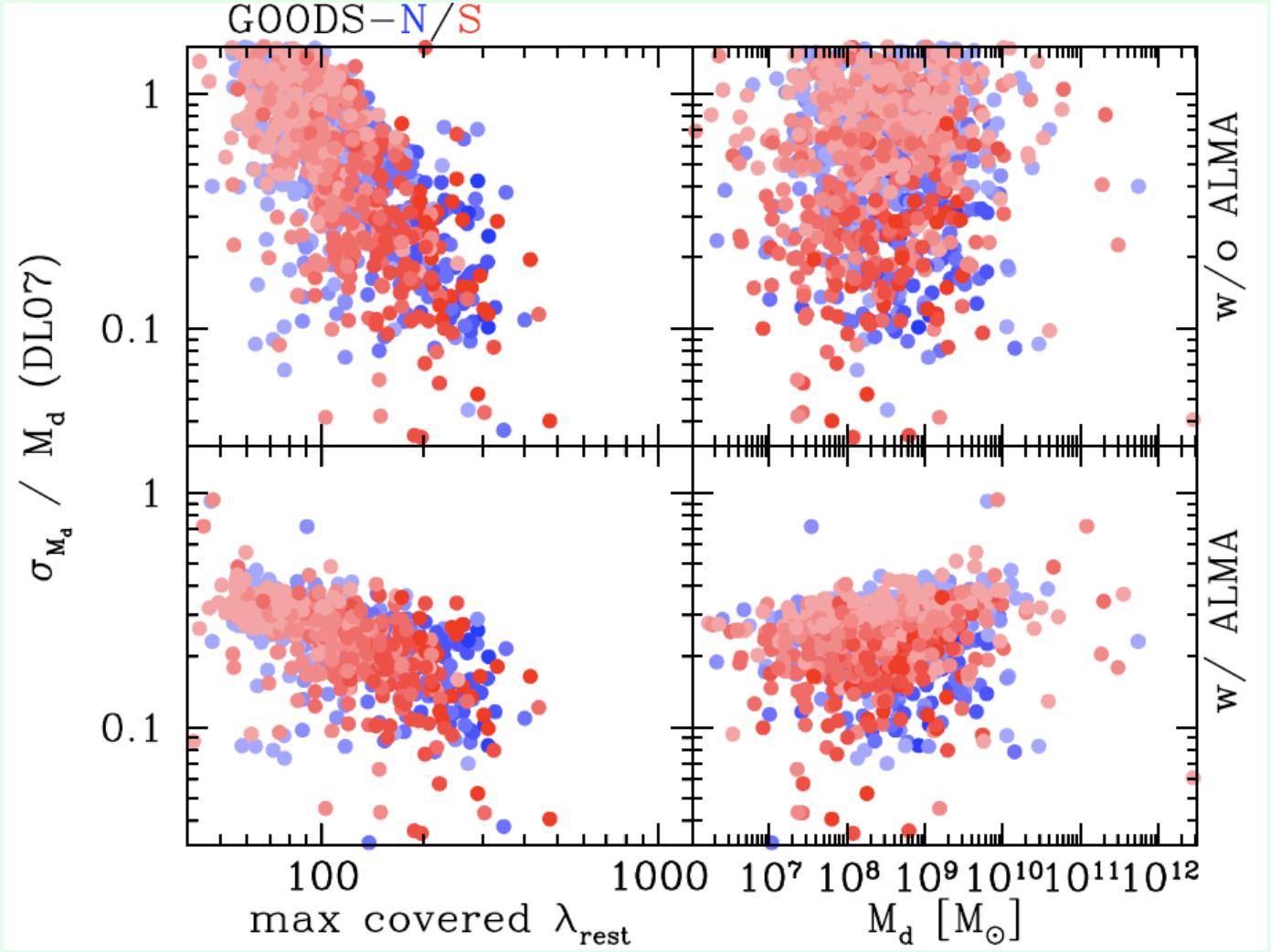


Berta et al. (in prep.)

Based on DL07 fitting



Herschel + ALMA !

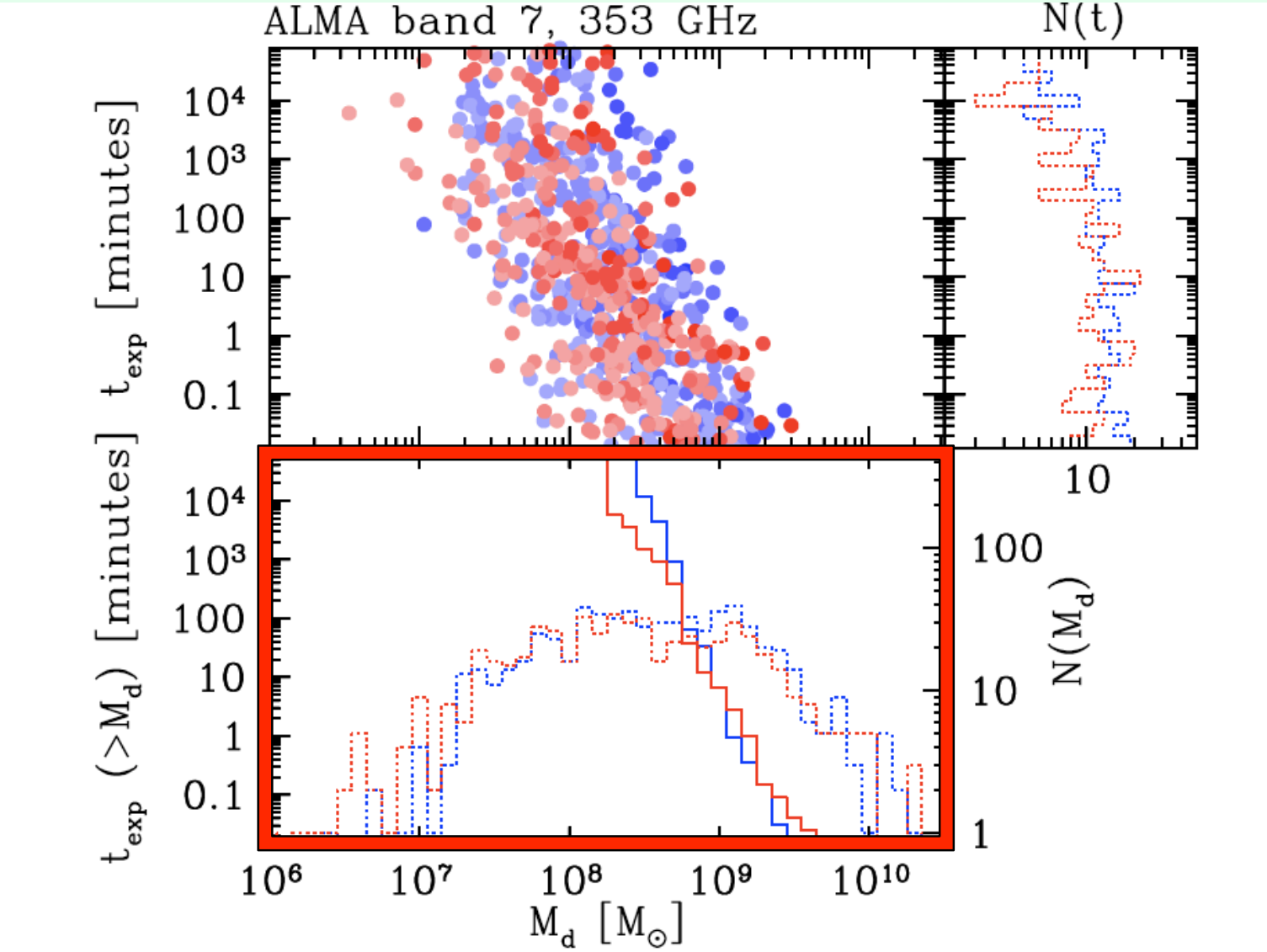


[gives an exposure time for ALMA]

Berta et al. (in prep.)

Based on DL07 fitting

Herschel + ALMA !



34 antennas allow to observe all PACS/Herschel detected sources in GOODS-S down to M(gas)>1e10.5 Msun in few tens of hours (modulo overheads)

Berta et al. (in prep.)

Take home messages

- ✓ The Herschel deep extragalactic surveys have produced advanced data releases. Data are available from the Herschel Archive and dedicated pages.
- ✓ We have derived the first (and only) determination of the gas mass function at z>0 scaling Herschel-based SFR with t(depl).
- ✓ ALMA-only and Herschel-only estimates of gas (dust) masses are affected by large uncertainties and possibly systematics.
- ✓ A combined ALMA+Herschel approach allows to measure dust (gas) masses with SN>3.
- ✓ ALMA requires few tens of hours (on source, e.g. band 7) to target all GOODS-S PACS-detected sources down to M(gas)~1e10.5 up to z~2.

Herschel User-provided data:

Http://www.cosmos.esa.int/web/herschel/user-provided-data-products

PEP full data release:

Http://www.mpe.mpg.de/Research/PEP/public_data_releases

HerMES data release:

Http://hedam.lam.fr/HerMES/

GOODS-H data release:

Http://hedam.lam.fr/GOODS-Herschel/