NÚCLEO DE ASTRONOMÍA udp
FACULTAD DE INGENIERÍA

Filling in scientific missing pieces: showcase of DSFG science

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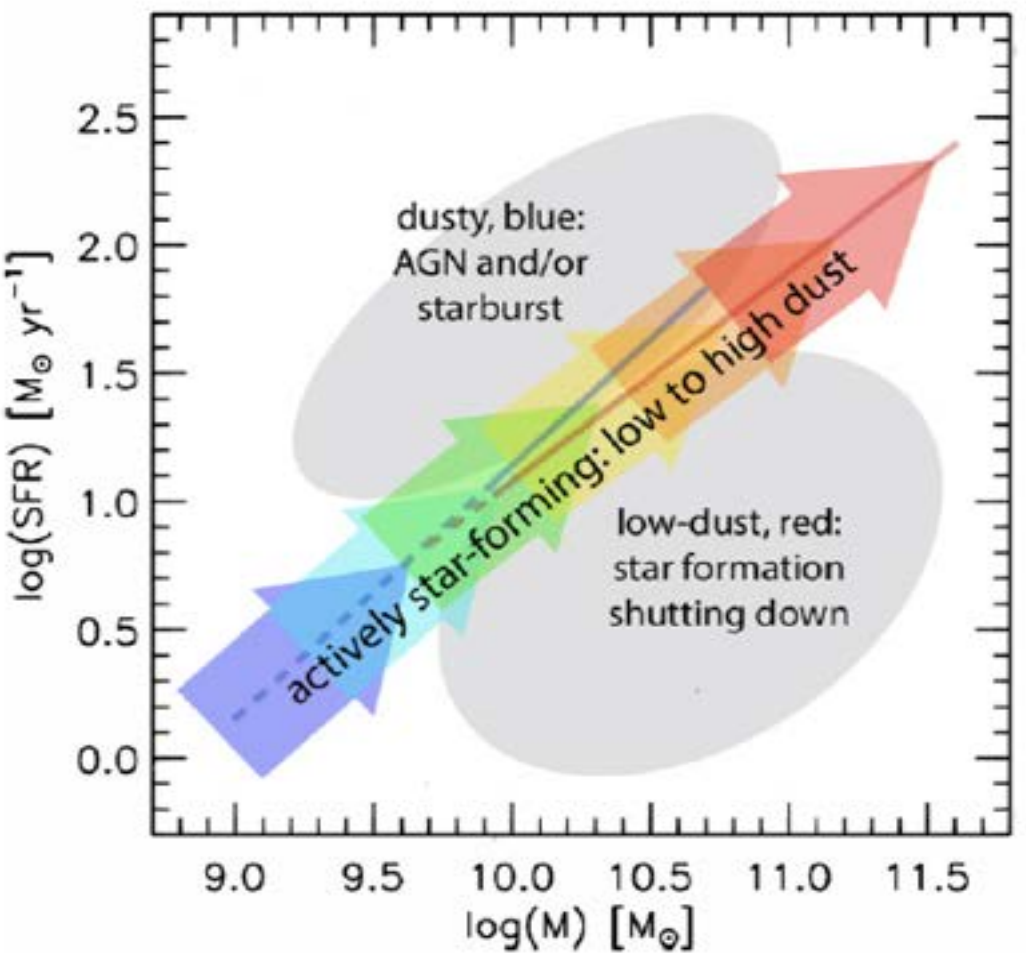
CCAT-p Collaboration

Gas content in high-z galaxies



From Whitaker et al. (2014)

How do galaxies circle around the "MS plot"?

Starburst ignition mechanisms, only mergers?

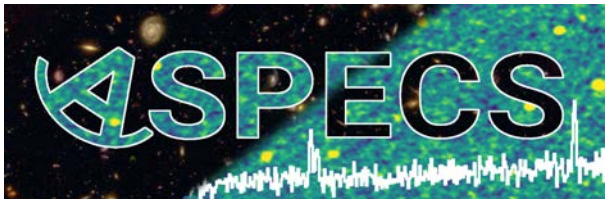
What causes "halt" of star formation (quenching)?

Role of passive galaxies at z>1

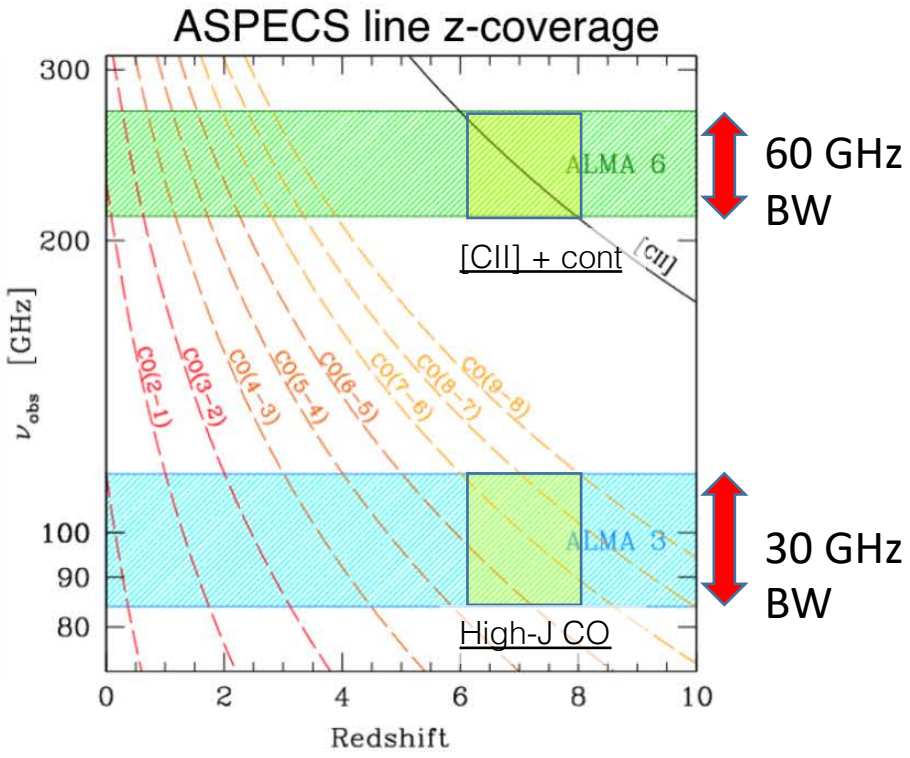
Relation of these processes to large scale structures

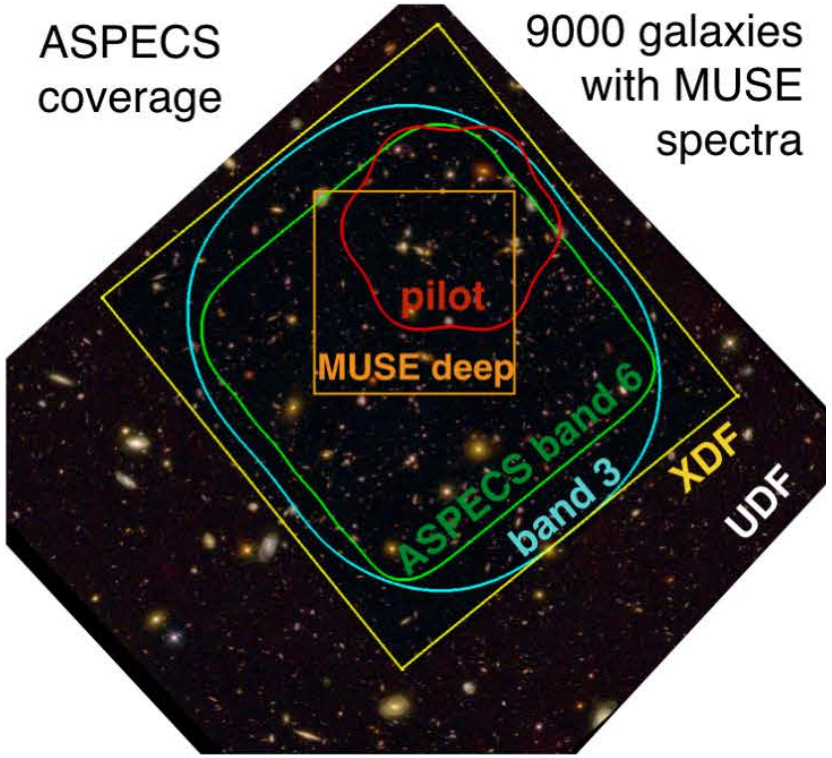
What causes cosmic dawn?
Little known about z>5-8

ALMA Spectroscopic Survey in the *HUDF*

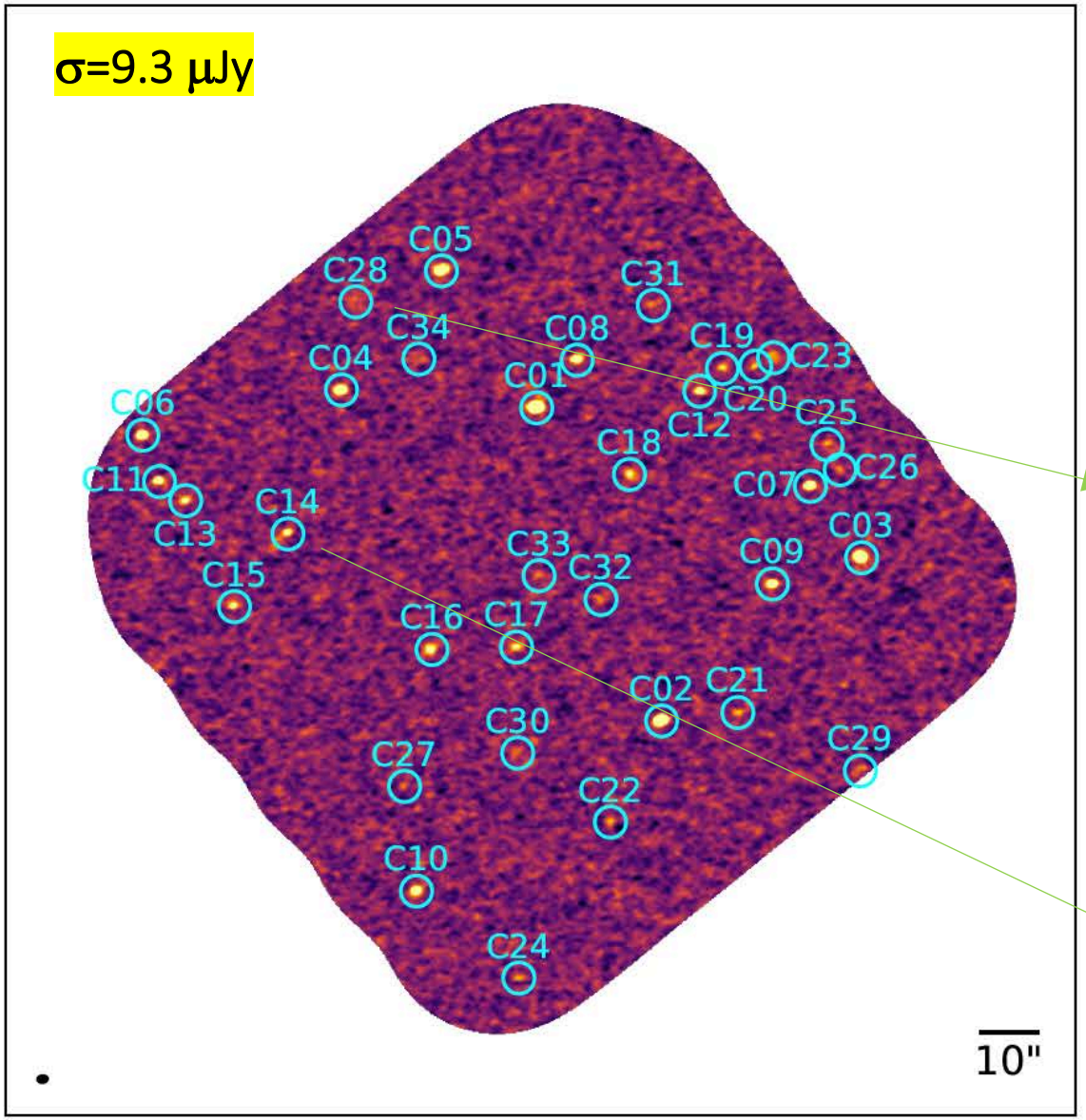


- Spectral scan over the full bands 3 and 6 in a 5 arcmin^2 region in the HUDF/XDF field.
- Frequency coverage covers CO/[CI] at 0<z<6 and and [CII] line at 6<z<8.





ASPECS ultra-deep 1.2-mm continuum map

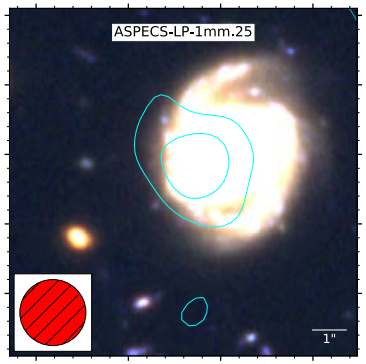


Found 35 sources with Fidelity >50%

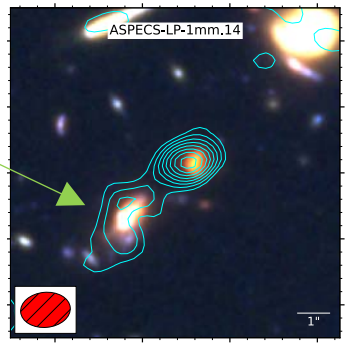
32 of which have HST counterparts

26 additional sources in prior-based sample

ASPECS-LP-1mm.28

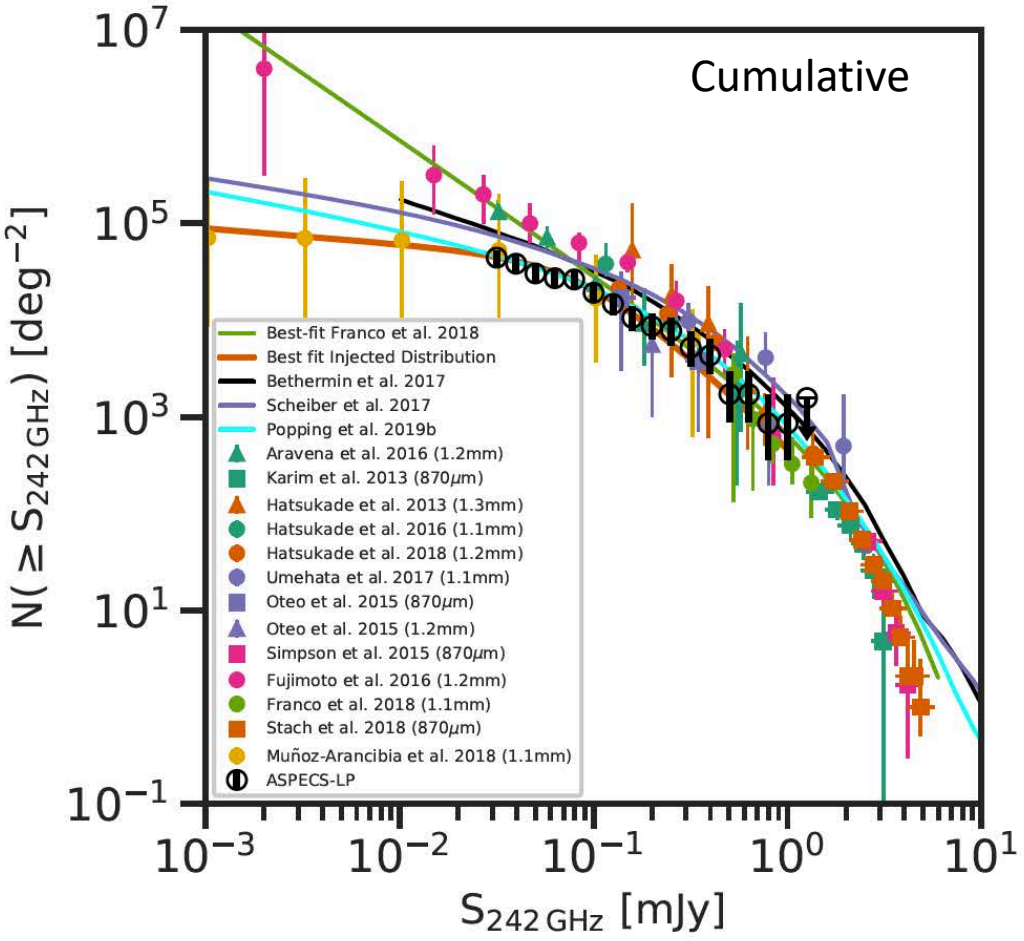


ASPECS-LP-1mm.14



Reassessing the 1.2-mm continuum number counts

- Flattening of the cumulative number counts below ~100 mJy
- Consistent with models
- ~100% of the EBL at 1.2-mm in the HUDF resolved



Gonzalez-López et al. (2020)

Popping et al. (2020)

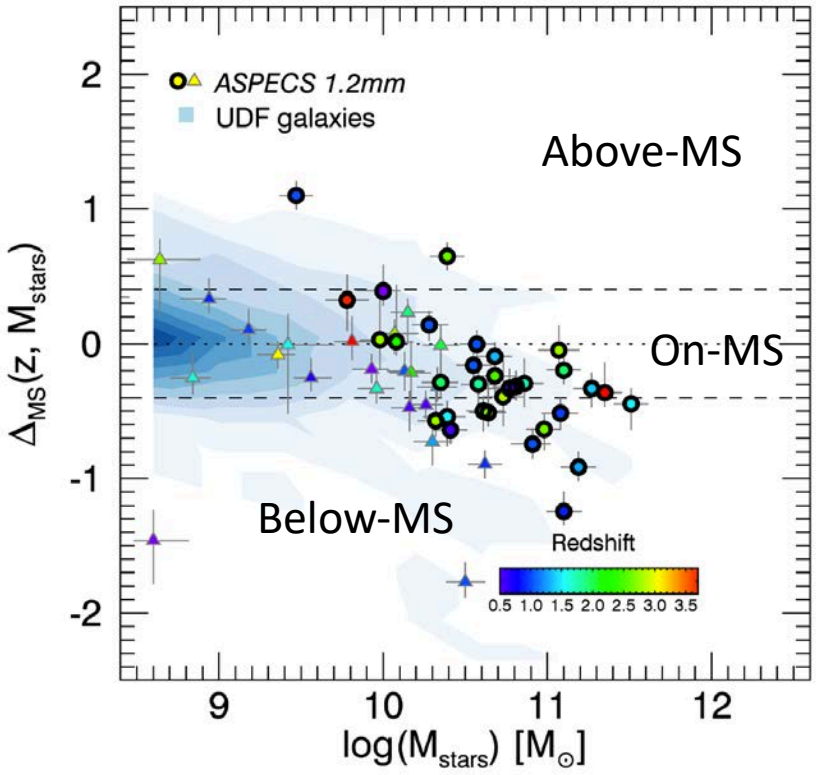
Not worth going deeper with ALMA.

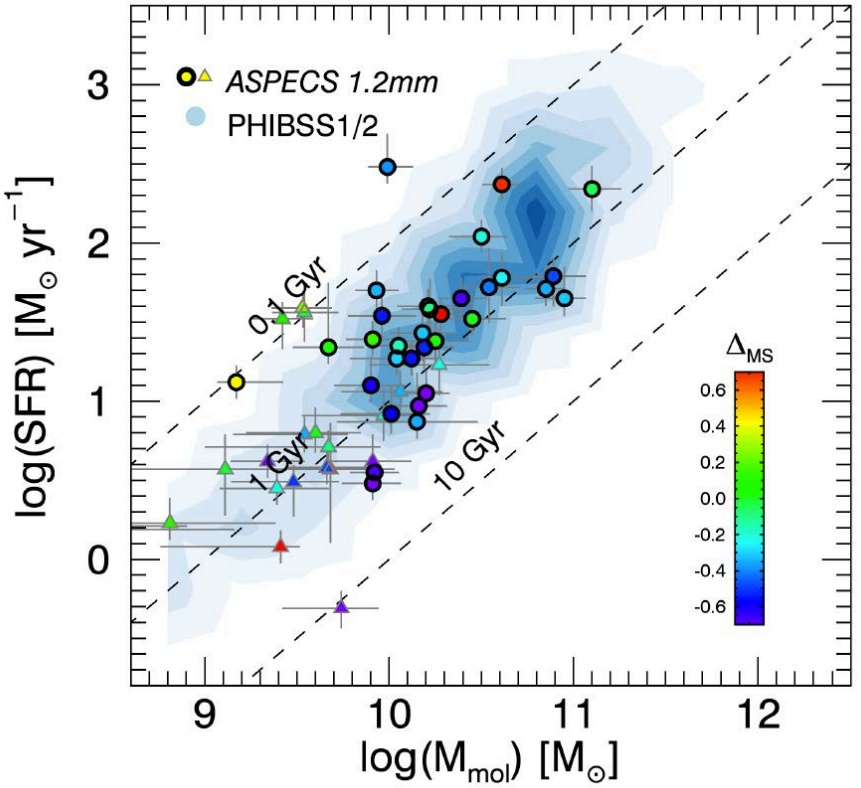
Rather going a bit shallow but wider (at 1.2mm) will yield more detections.

Better to focus on galaxies brighter than the ‘knee’ of number counts

Properties of galaxies that make up most of the EBL/CIB at 1.2-mm

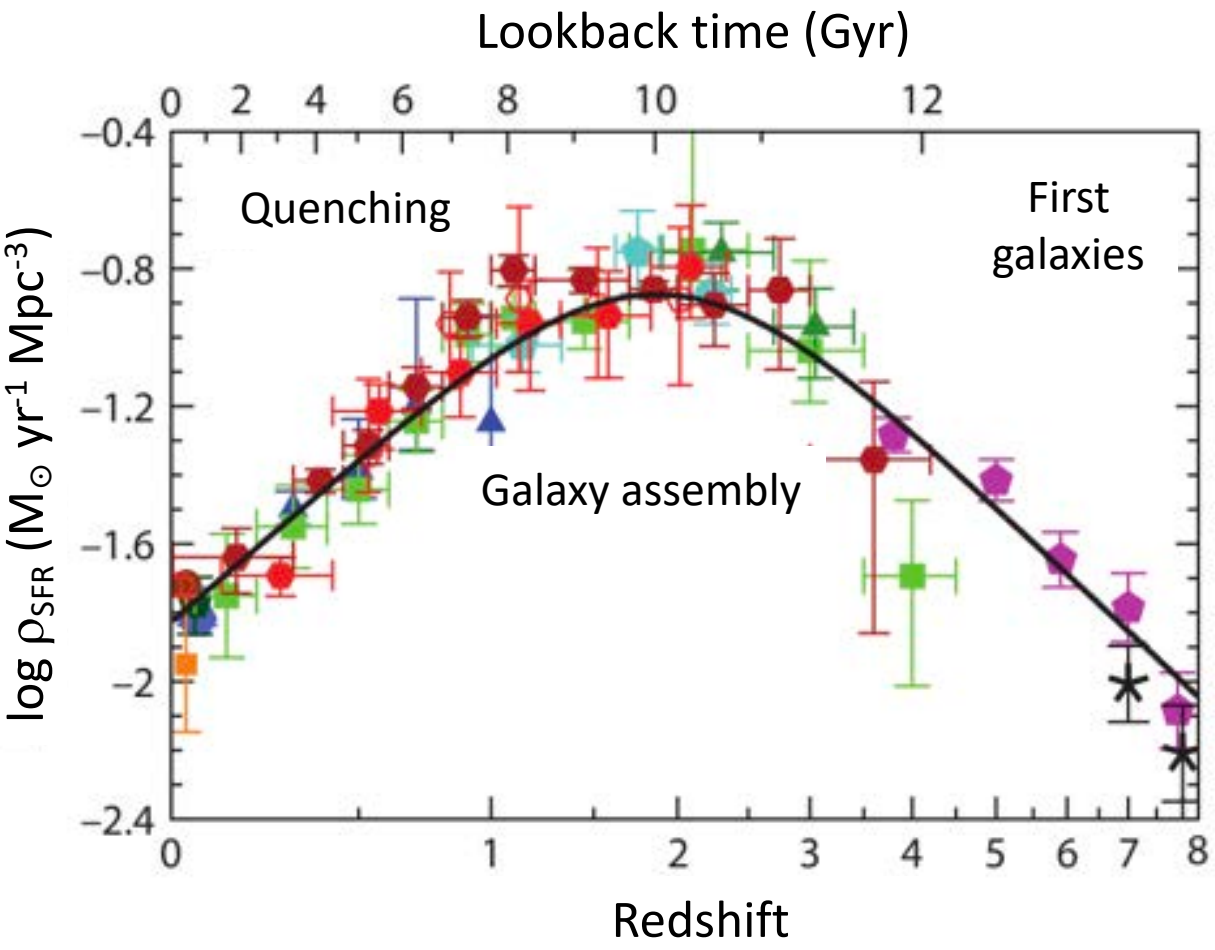
Aravena et al. (2020)





- Faint dusty galaxies follow standard “scaling relations”
- Yet a significant population of galaxies below the MS (quenched?)
- Roughly constant tdep with redshift (~0.7 Gyr), z=0.5-3.5

Measuring the ISM molecular gas content in galaxies



What causes cosmic dawn?

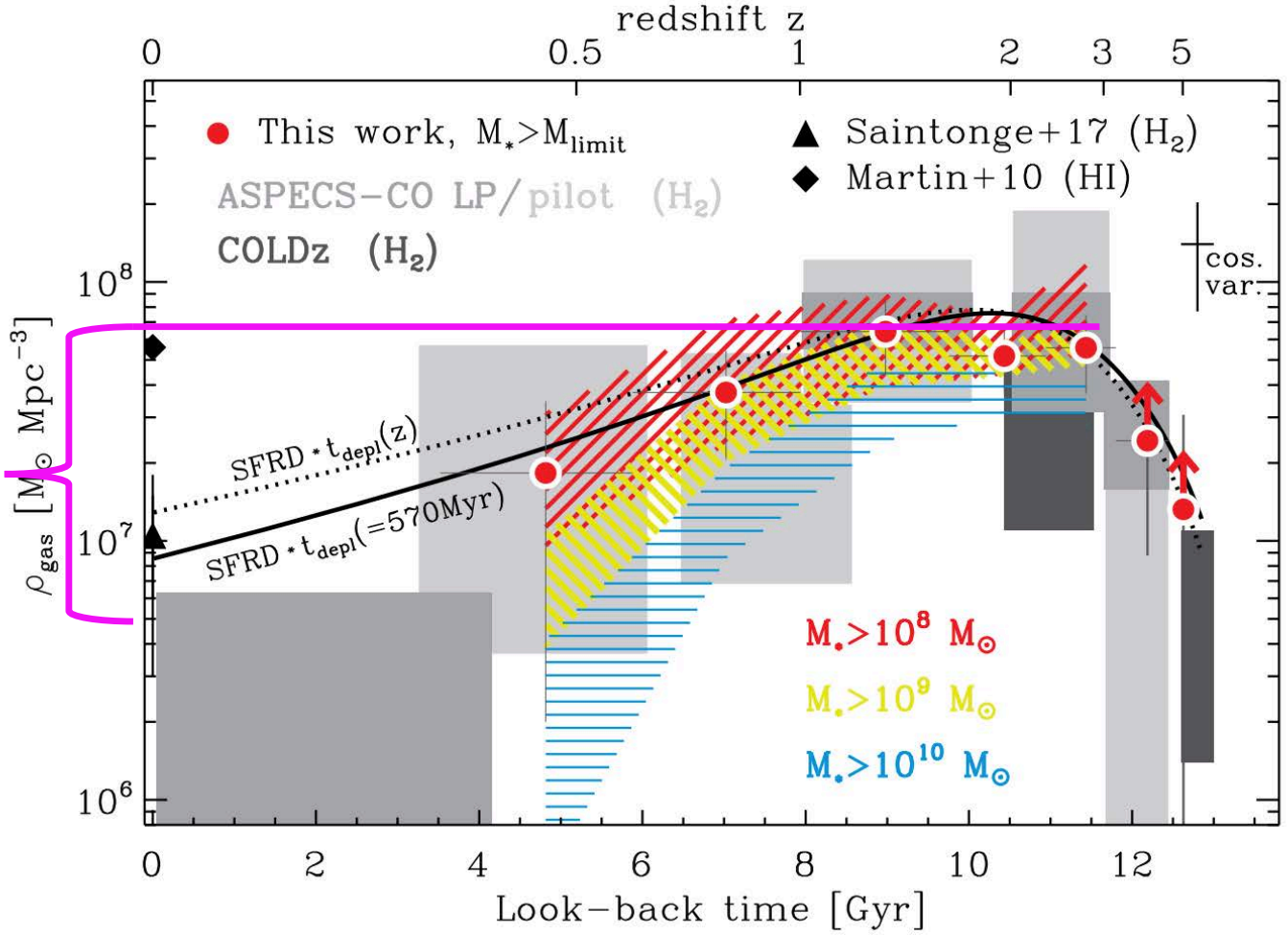
Properties of galaxies that dominate the cosmic SFR density?

Understanding the cosmic evolution of galaxies requires measurements of the ISM content

Ideally, we'd have a census of the ISM content over a blank-field:
cosmic density of molecular gas

Evolution of cosmic density of molecular gas (H_2)

Measurements through dust continuum and blind CO line emission

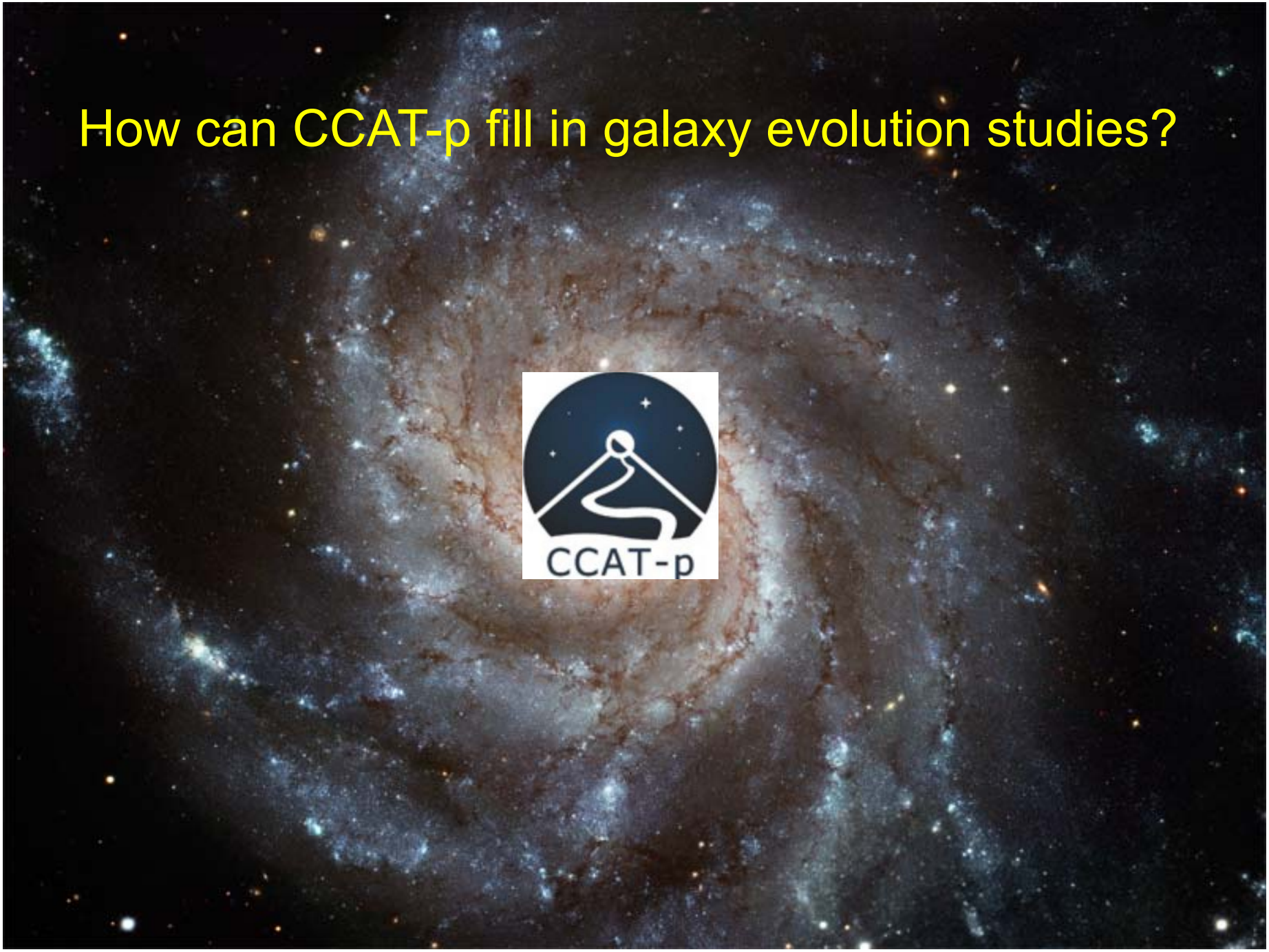


6.5x

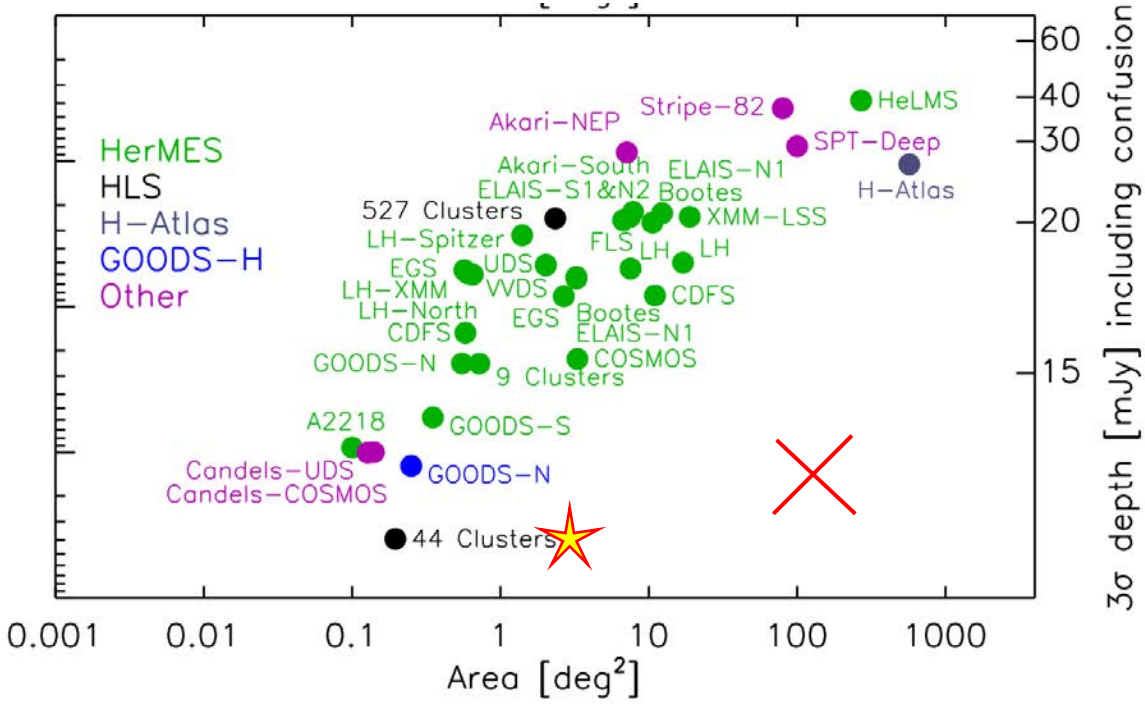
Results pretty uncertain: Need larger areas (beyond UDF) yet with good coverage of dust SED

Plot from Magnelli et al. (2020); see also Riechers et al. (2019); Decarli et al. (2019)

How can CCAT-p fill in galaxy evolution studies?



Area vs Depth for FIR surveys



With a confusion limit of ~2.5 mJy at 350 um, CCAT-p would be able to beat most Herschel surveys in survey area in 1-2 yrs survey but not really in depth.

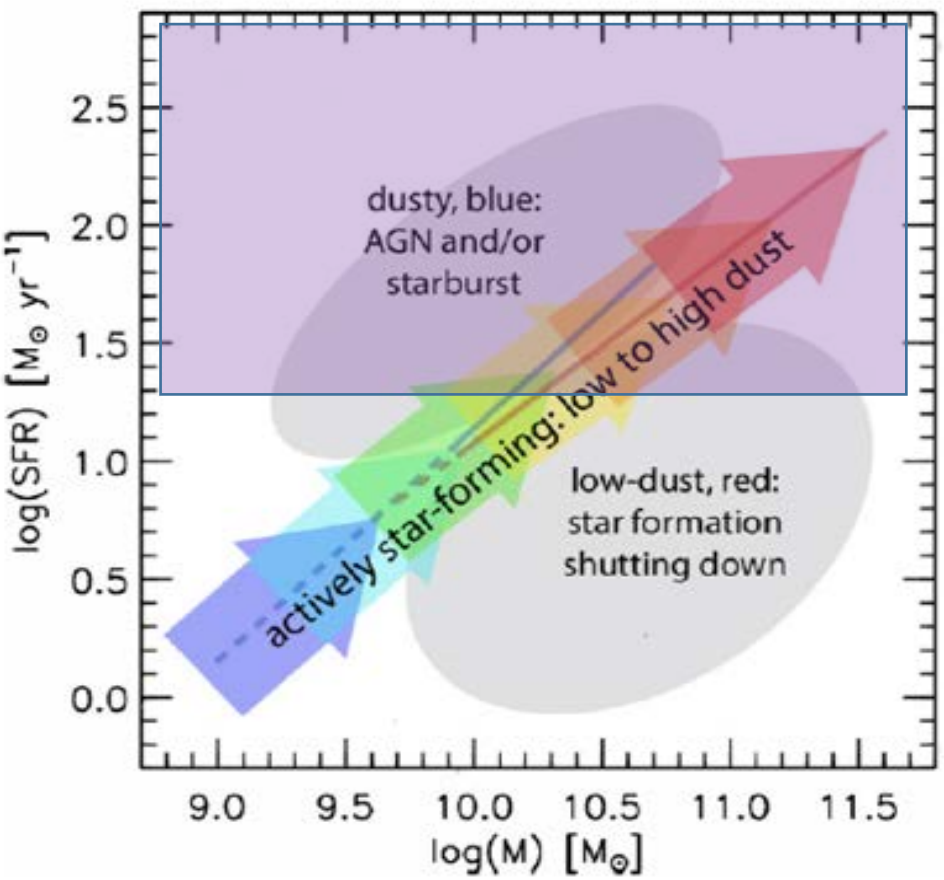
Ref: *Herschel* 350μm conf. limit (3σ) 18 mJy. GOODS-S field depth 9.5mJy (3σ) over 400 arcmin^2.

Confusion limits (1σ) of *CCAT-p* at 350/850um of ~2.5 mJy and ~1.1 mJy, respectively.

Why not going beyond conf limit over smaller area? ~1-2 deg^2

This would enable to access a ”new” population of galaxies and fill the gap with ALMA studies:
- At z=1-3, 2.5 mJy at 350um corresponds roughly to 0.1-0.5 mJy at 850um/1mm (sub-mJy)

Accessing various galaxy populations and their ISM properties



From Whitaker et al. (2014)

Large/deep 350um (SFR) surveys of the sky

Will select most starburst, bulk of MS population down to 10^{10} M_{sol} and massive end of "quiescent" galaxies.

Link to large scale structures by cross-correlations, but also through selection of SFR-driven overdensities (protoclusters)

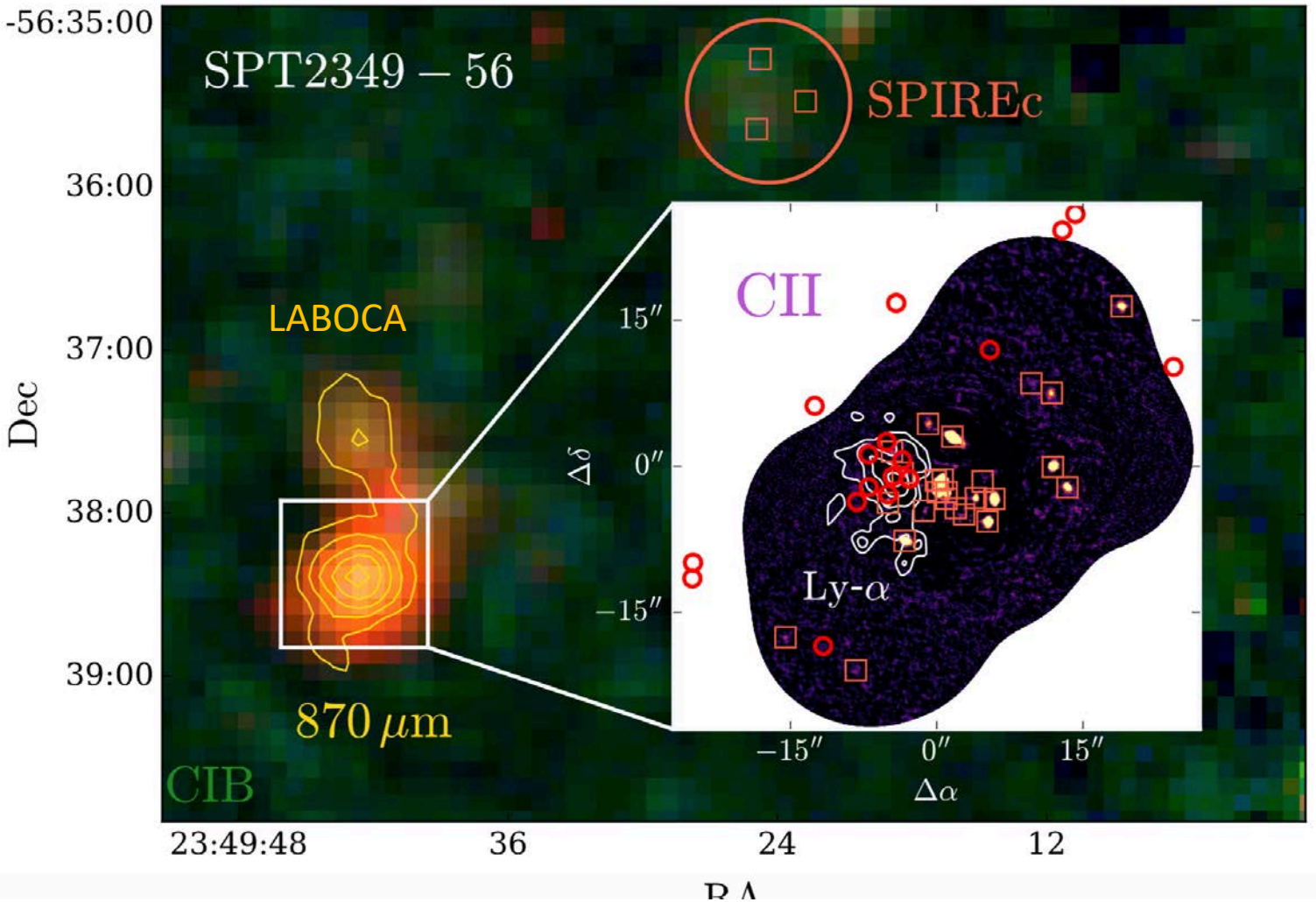
CCAT-p multiple bands (350/850um/1mm) will yield a handle on dust properties.

Dust mass from photometry in the RJ limit

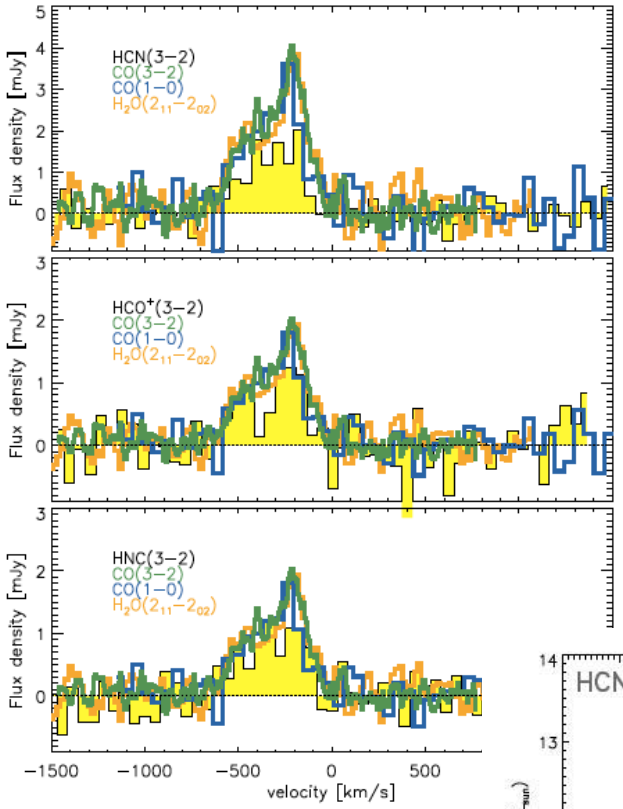
Will we be able to compute the cosmic densities of SFR and M(H2) simultaneously?

Example of massive dense protocluster discovered by SPT

Miller et al. (2018); Hill et al. (2020); Apostolovski et al (in prep)

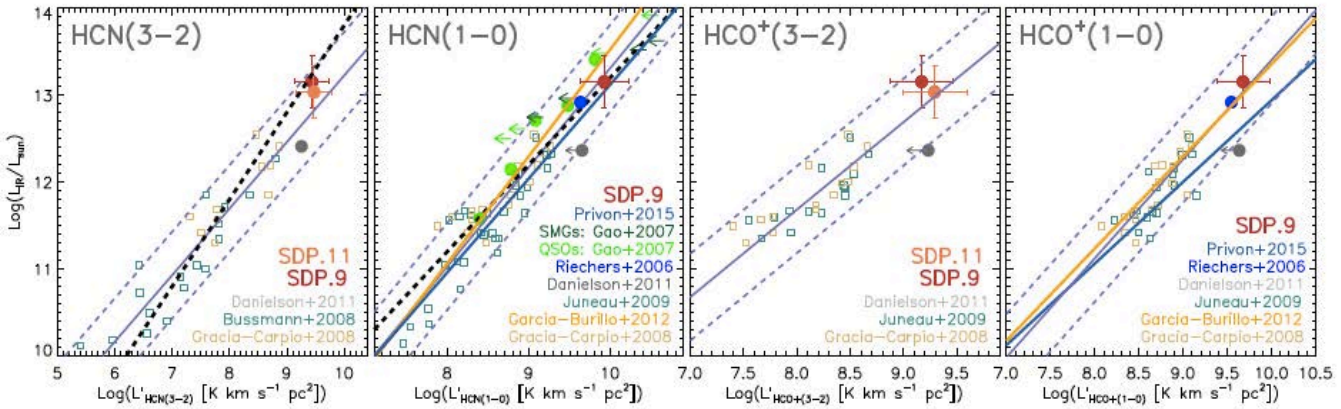


Rare (lensed?) bright objects: detailed studies of the ISM

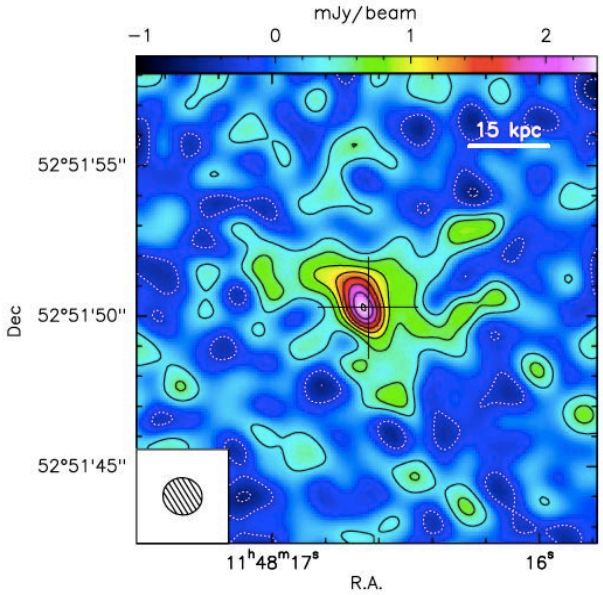


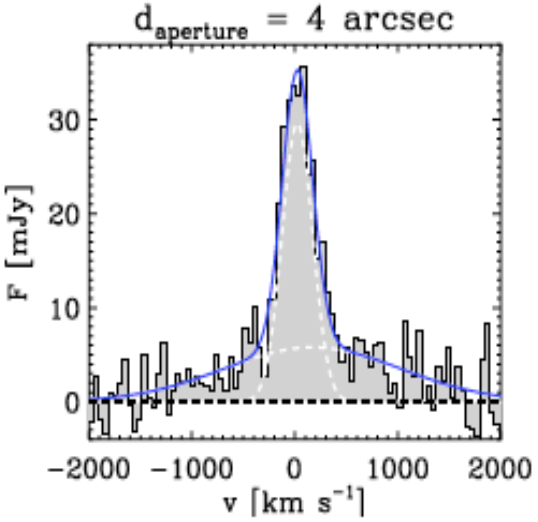
Detection of HCN(3-2), HCO+(3-2) and HNC(3-2) in the lensed SMG SDP.9 at z=1.6 (Oteo et al. 2017).

Comparison of two lensed SMGs, SDP.9 and SDP.11 with other detections in the literature (e.g. Oteo et al. 2017; Riechers et al. 2006: Gao et al. 2007)

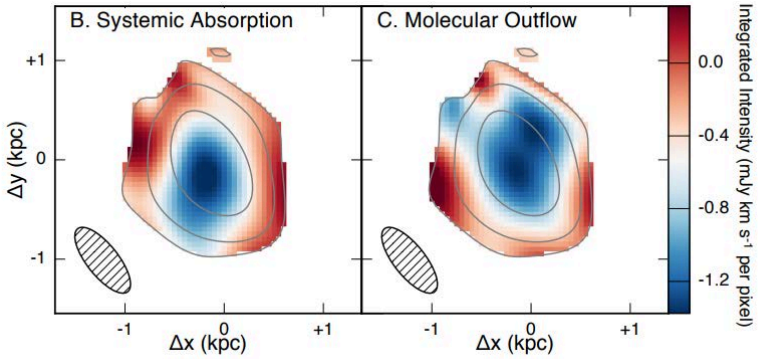


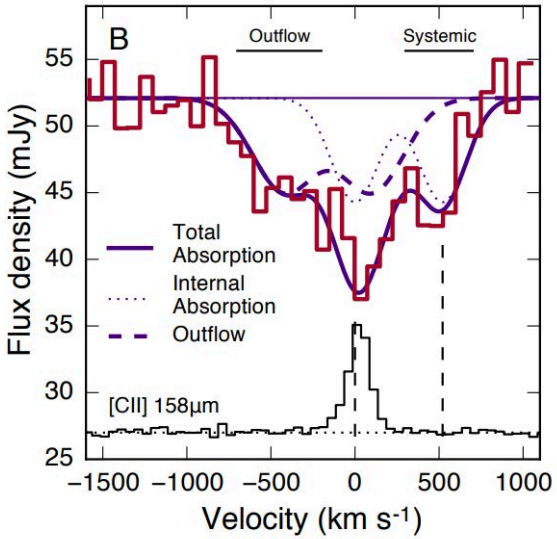
Rare (lensed?) bright objects: Other tests for quenching in starbursts





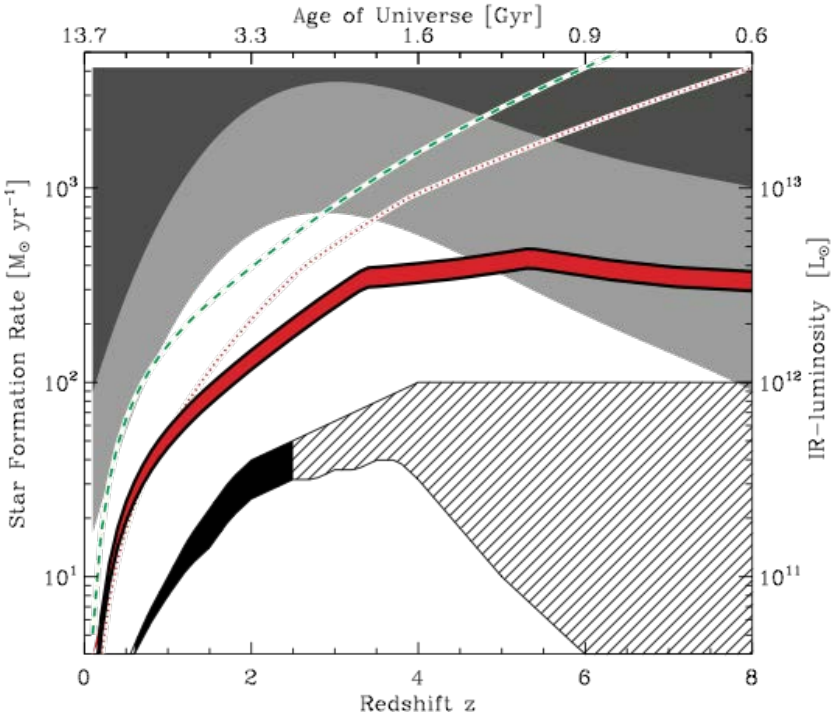
Broad line [CII] wing components have been claimed to be due to large scale outflowing gas from the host galaxy of quasar SDSS1148+64 at z=6.4 (Maiolino et al. 2012; Ciccone et al. 2015)





Blueshifted OH122um absorption consistent with outflows in a lensed SPT DSFG(Spilker et al. 2018, Science)

CCAT-p should access galaxies with SFR>300 M_{sol}/yr at z>4



Courtesy of B. Magnelli

GEvo all bands (350-1100µm; 200deg^2)

SPIRE all bands (250-500µm; ~30deg^2)

Not accessible by < 200 deg^2 surveys

Not accessible by < 2 deg^2 surveys

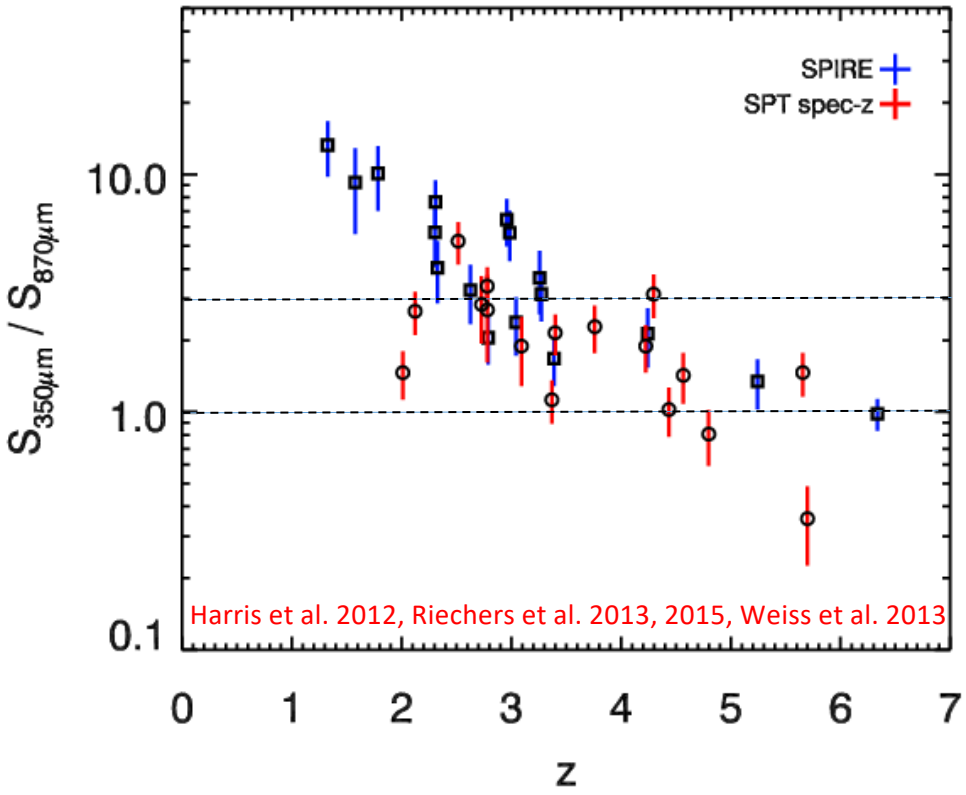
ALMA 350µm — 2 deg^2 — ~2000hrs

Typical SFR of galaxies

Will we be able to break the current record for DSFG of z=6.9? (Strandet et al. 2017; Marrone et al. 2018)

Large scale galaxy surveys: FIR photo-z's for brighter sources

Narrow scatter: method confirmed with spectroscopy
$\Rightarrow$ can independently & efficiently select high-z galaxies



$\Rightarrow$ Confirm redshifts w/ CCAT-p, follow-up imaging w/ ALMA through CO line spectroscopy

Summary

- Deep large surveys with CCAT-p at 350/850um will yield unique coverage for galaxy evolution studies
  - Many lensed (SPT-like) DSFGs: good for detailed studies
  - Environments: star-forming “rich” protoclusters at z>2
  - Early galaxies (z>4): next frontier
- Do we want to go deep in a small area to get to the (sub)mJy regime, comparable to current ALMA studies (at 1mm) ?
- We do need good multi-wavelength coverage to take advantage of the large number of sources. Synergies with LSST/Euclid?