STUDIES

SCUBA-2 Ultra Deep Imaging EAO Survey

Hyunjin Shim
and STUDIES Team

Outline

- Survey description
- Scientific background and goals
- Observation Progress
- Papers published, to be submitted, and in prep.
- Followup proposals
- Summary

STUDIES in a nutshell

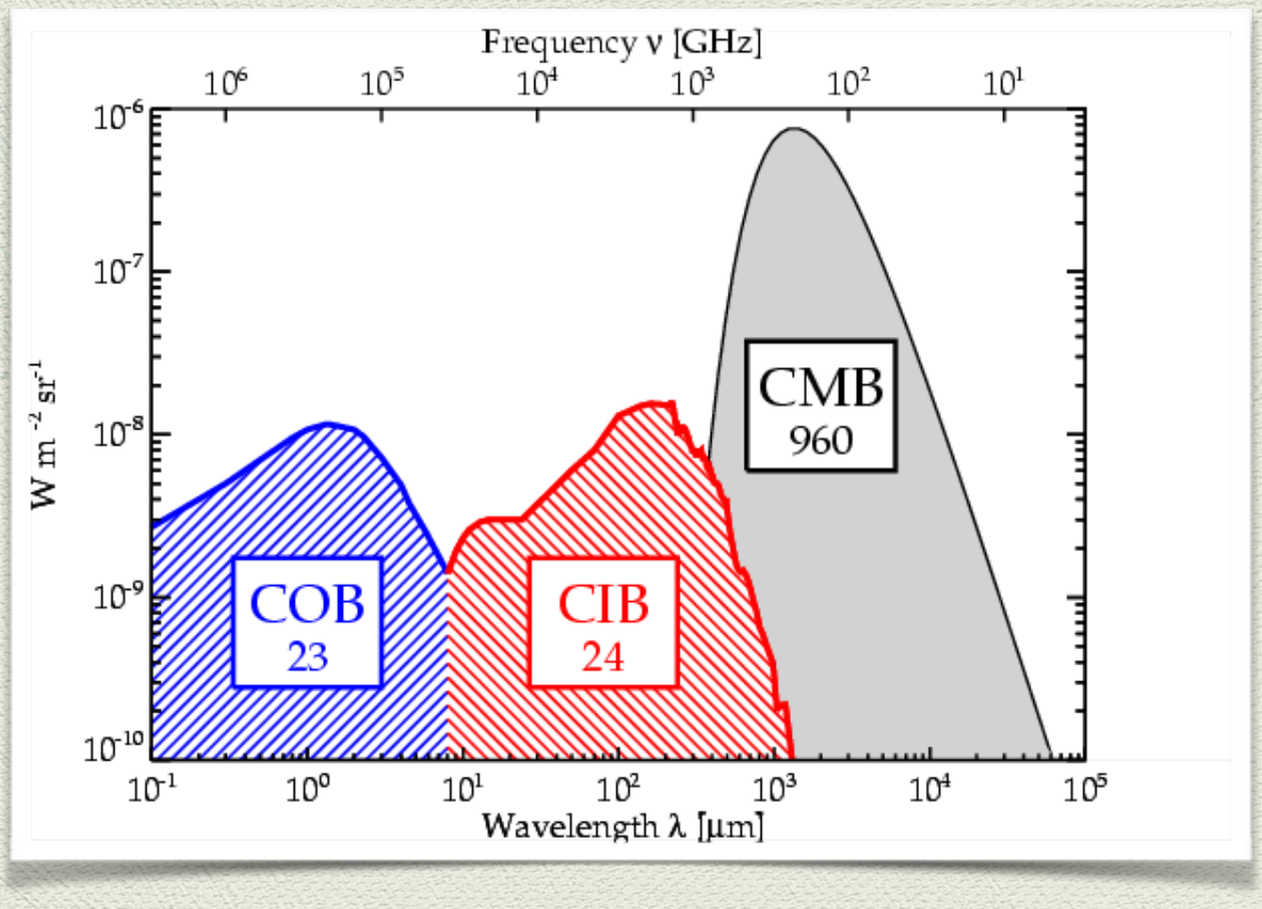
- One of the EAO JCMT Large Programs.
- Taking advantage of SCUBA-2's high resolution at 450 μm.
- To obtain confusion limited SCUBA-2 450 μm maps, deepest ever far-IR sensitivity limit.

Survey Description

- Two ultradeep 450 μm pointings:
  - STUDIES-COSMOS (330 hr, approved in 2015)
  - STUDIES-SXDS (320 hr, approved in 2017)

  both within the CANDELS region.
- carried out under the best submillimeter weather of Maunakea.
- one Daisy pointing in each field.
  ($D = 3'$ ultradeep core, $D = 15'$ deep outer region)
- $\sigma_{450\mu m} < 0.6$ mJy in the ultradeep core, $\lesssim 3$ mJy in entire map.
- Execution period: 2015–2020

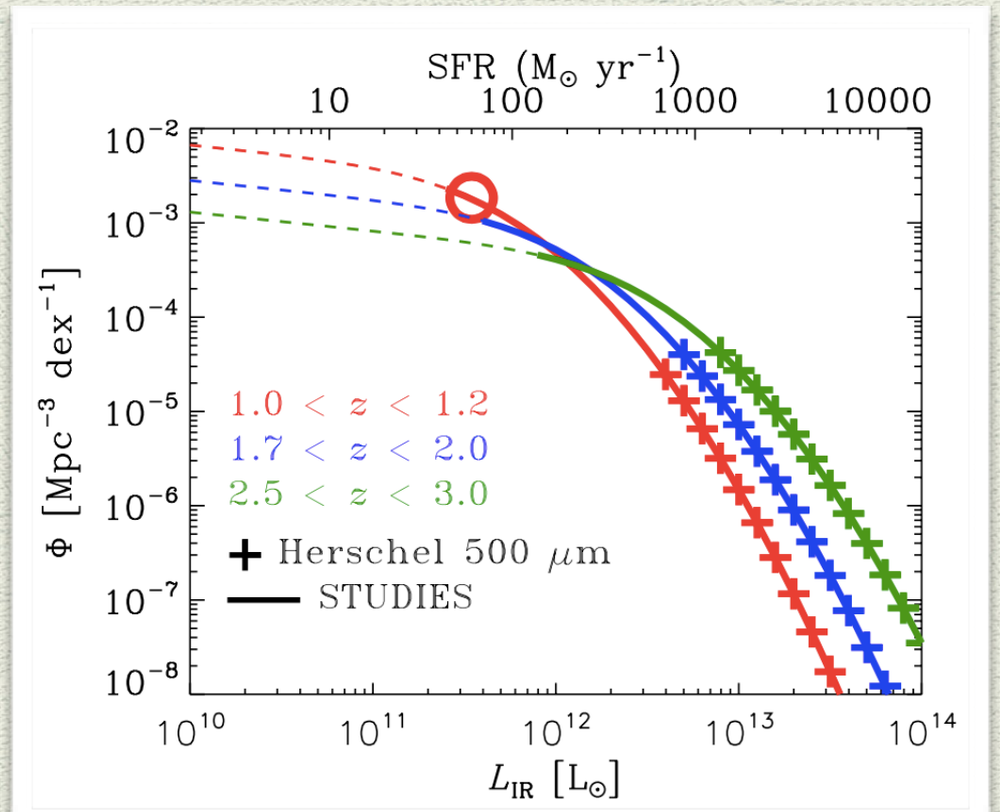
Scientific Background

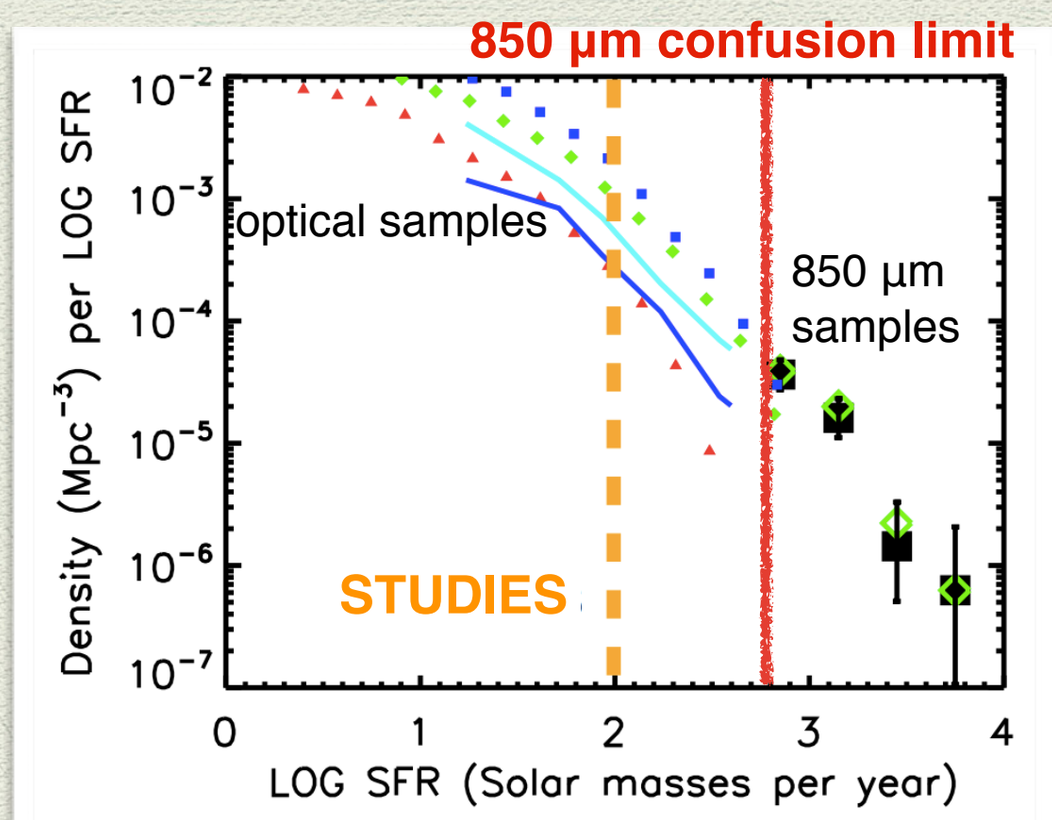


Dole et al. (2006)

- The optical and IR backgrounds have comparable strengths.
- Half of the activities (star formation + black hole accretion) in the universe are hidden in dust.

STUDIES:
The First Confusion Limited 450 μm Survey





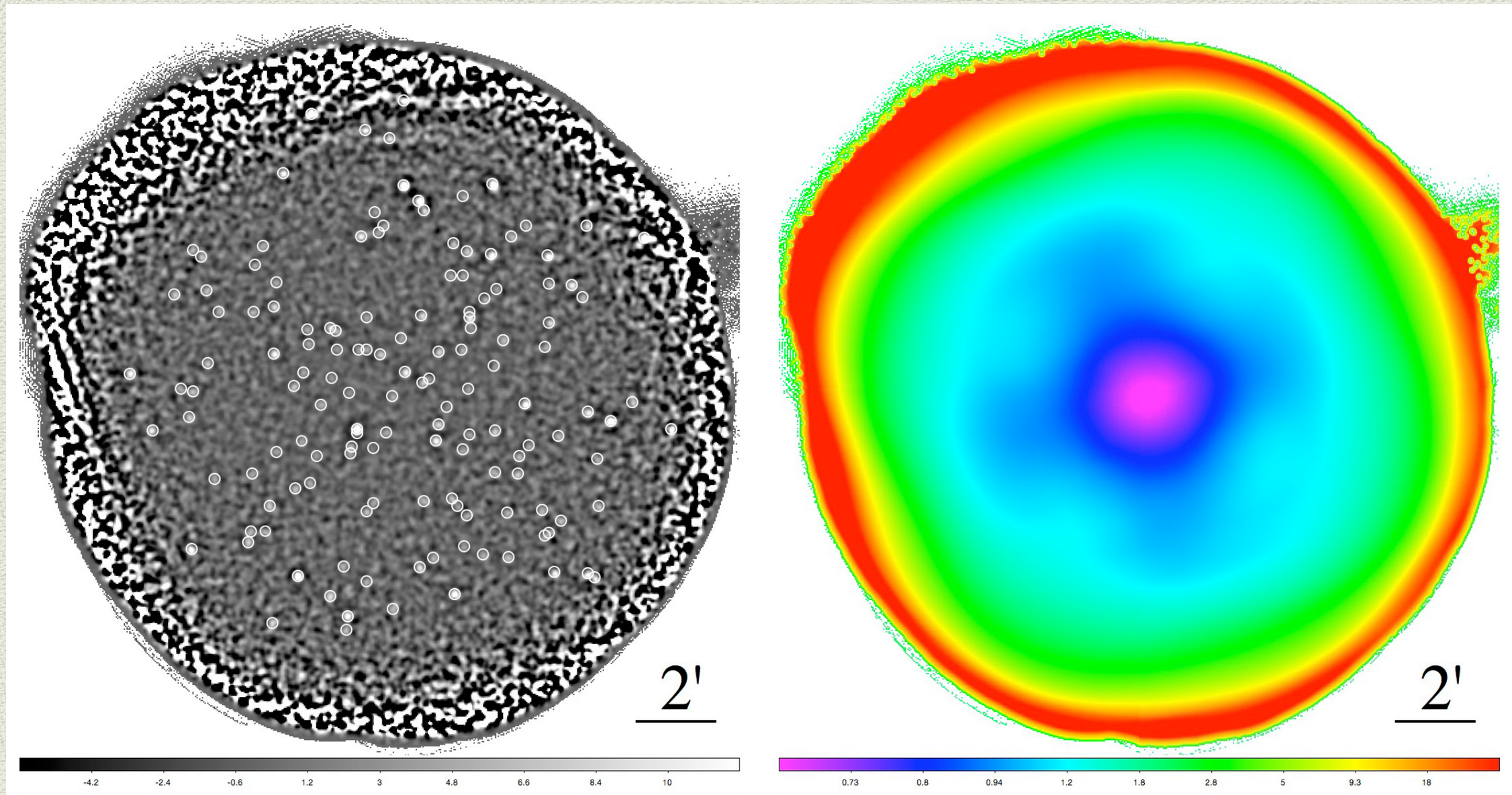
- STUDIES will detect the most typical members in the dusty galaxy population, key star formers in the history of the universe.
- STUDIES will significantly overlap, for the first time, with the SFR range probed by optical surveys.

Current Status

- ~ 140 team members
- A wiki page is used for internal communication, document/data distribution.
- 182 hr of data obtained for COSMOS (55% complete)
  18 hr of data obtained for SXDS (6% complete)
- twos paper published using STUDIES data.
  one more to be submitted soon.
- various ongoing analyses

STUDIES-COSMOS

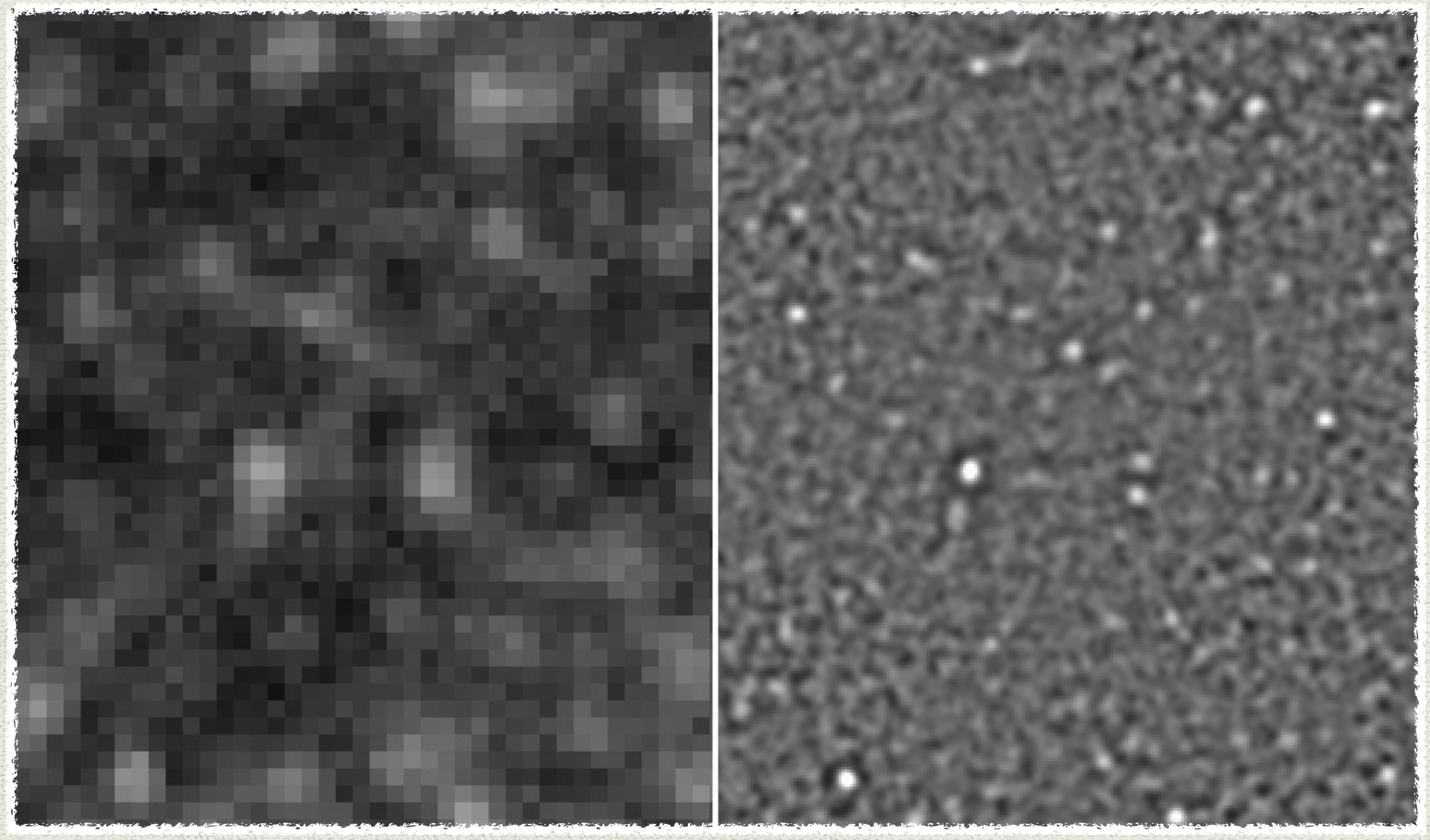
(with data collected until Jan 2018)



140 sources at > 4 σ
~300 expected at full depth

central rms < 7 mJy

Power of SCUBA-2



Herschel 500 μm

STUDIES 450 μm

Two published papers so far

- "An Imperfectly Passive Nature: Bright Submillimeter Emission from Dust-Obscured Star Formation in the z = 3.717 "Passive" System, ZF 20115"
  by J. M. Simpson, et al.
  2017, ApJL, 844, 10

covered in the 2017 users meeting

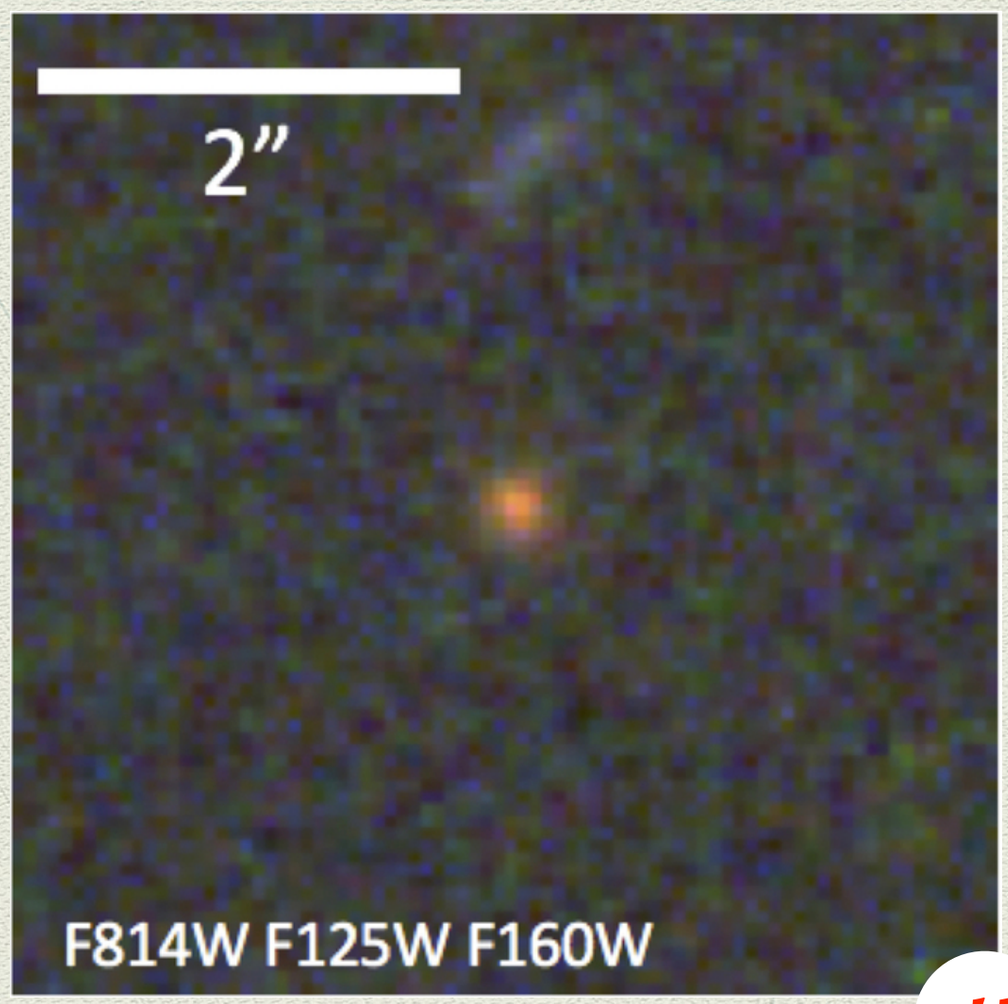
- "SCUBA-2 Ultra Deep Imaging EAO Survey (STUDIES): Faint-End Counts at 450 μm"
  by W.-H. Wang, et al.
  2017, ApJ, 850, 37

A High-z Quiescent Galaxy

- ZF-COSMOS-20115, a old, massive, post-starburst quiescent galaxy at z = 3.717, formed at z ~ 5–8, reported by Glazebrook et al. (2017, Nature).

- Quiescent because:
  1. strong Balmer absorption
  2. no Herschel detection

- Hard to explain the large stellar mass and high formation redshift.



!!

“our picture of early galaxy assembly requires substantial revision”

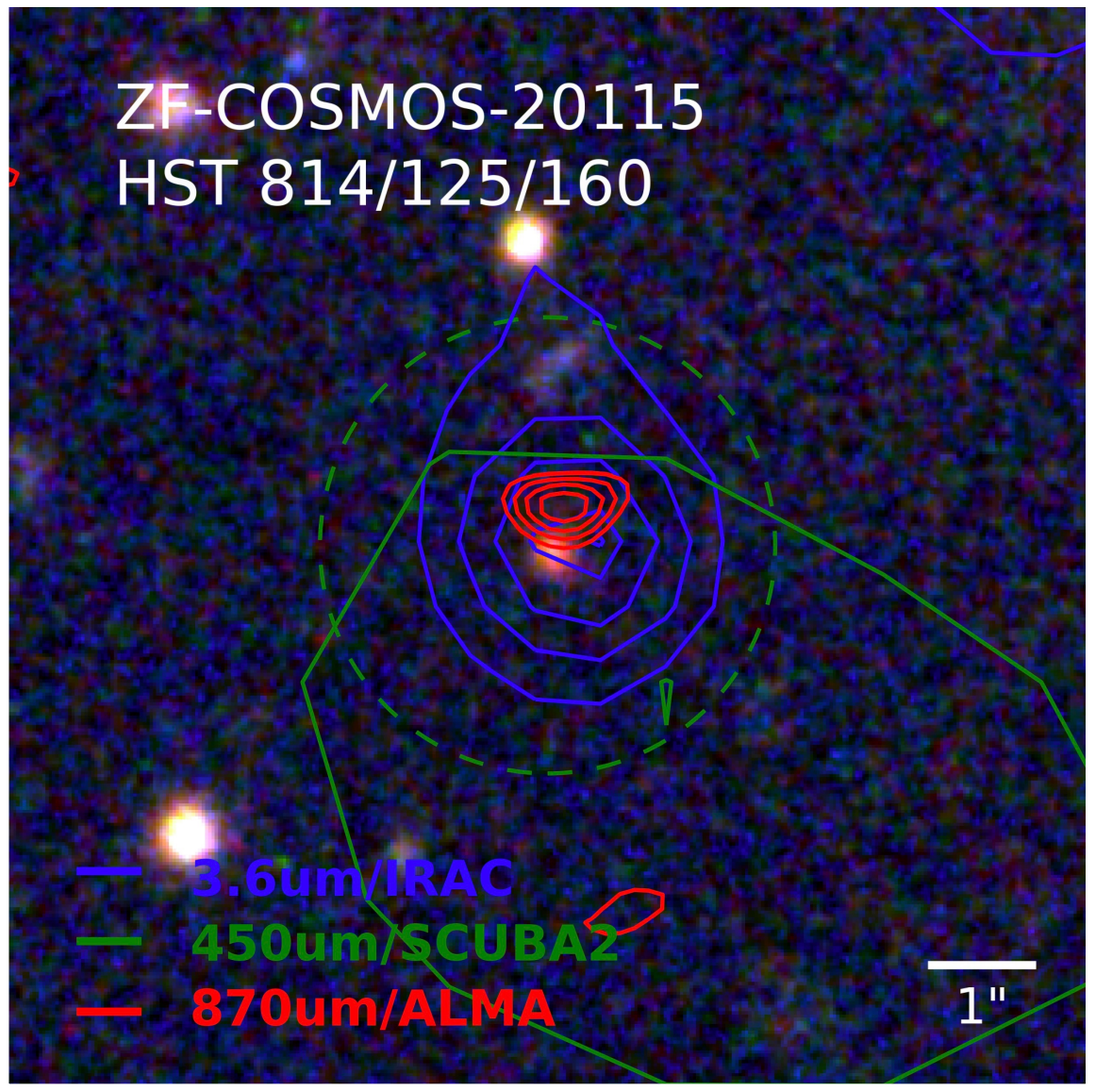
Quiescent or Starburst?

- STUDIES detected it at 450 μm (3 σ) and 850 μm (10 σ).
  ALMA also detected it at 870 μm (7 σ).
  ⇒ SFR ~ 100 $M_\odot$/yr

- Far-IR to optical SED consistent with typical submillimeter galaxies, not a quiescent galaxy.

- Much higher SFR and lower stellar mass.

- No need to revise our view of galaxy formation.

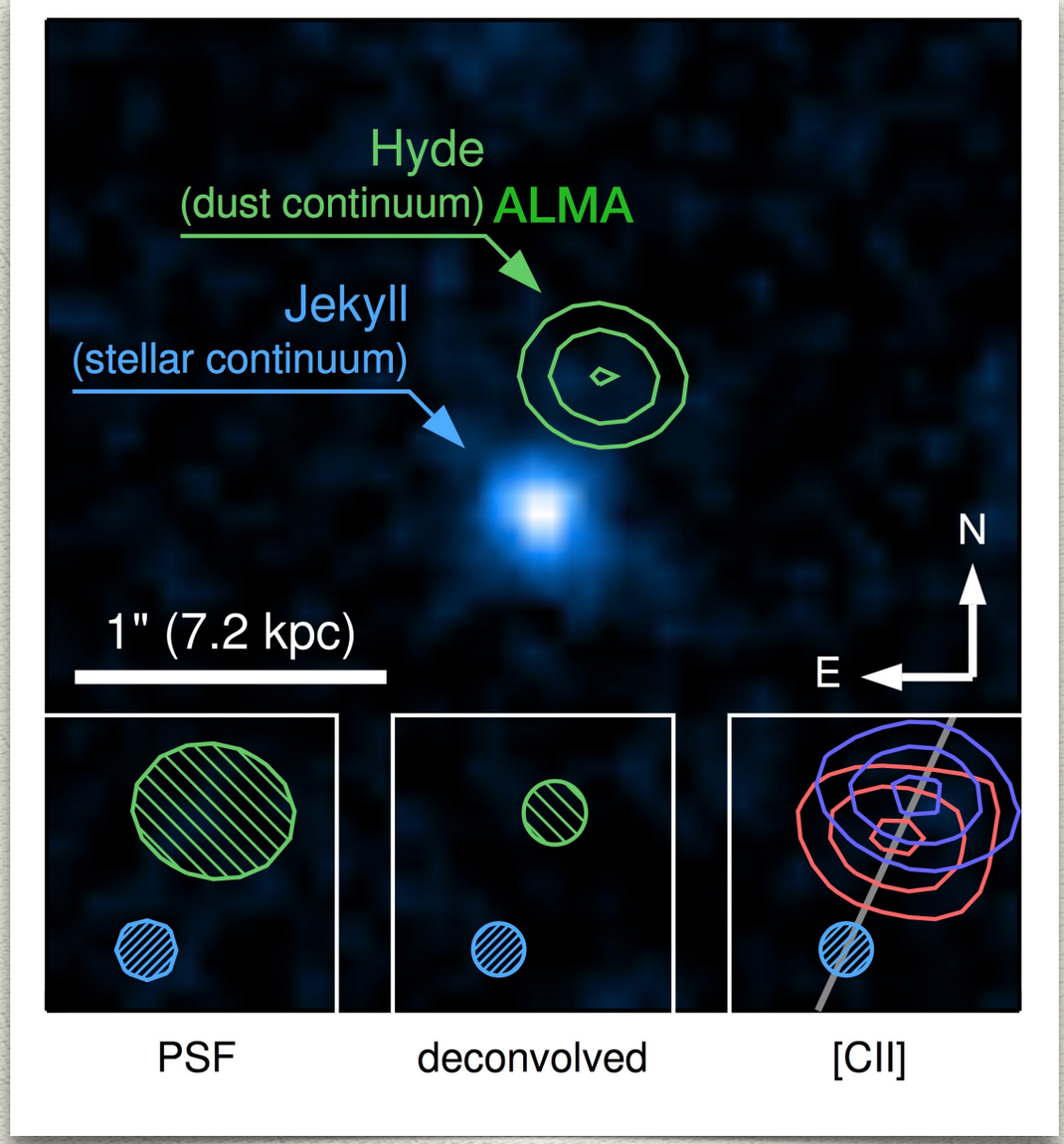


Simpson et al. (2017)

An Interacting System?

- Schreiber et al. (2018, A&A, in press):
  ZF 20115 an interacting system with a dusty starburst (detected by STUDIES +ALMA) and a passive system (originally reported by Glazebrook et al.)

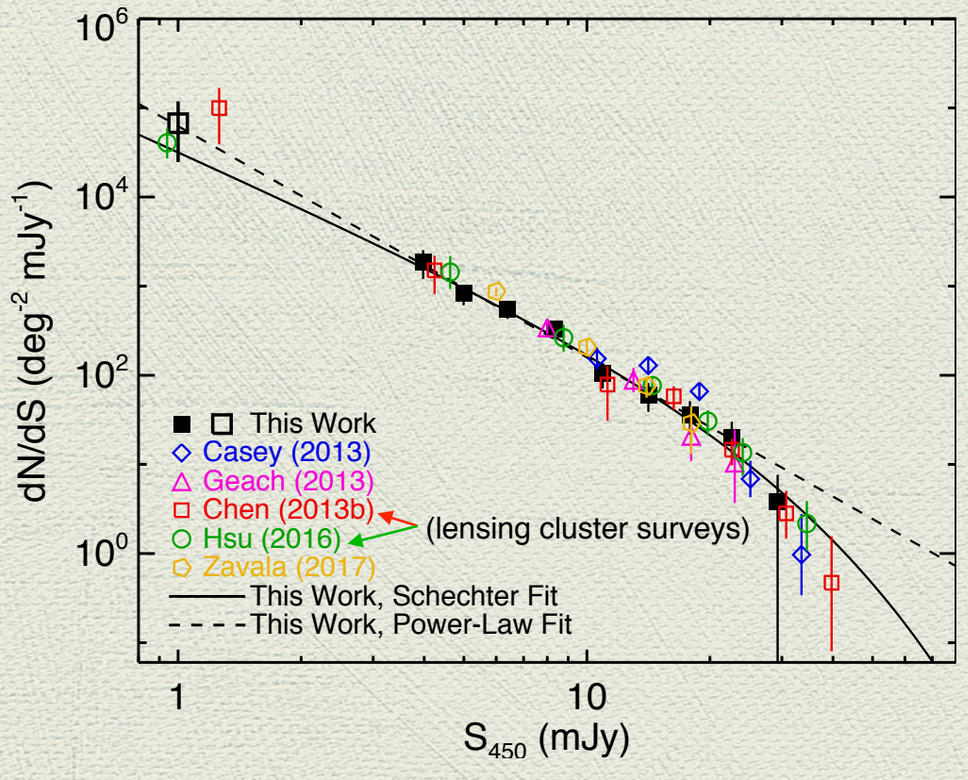
- Bottom line:
  - Herschel (SPIRE) non-detection doesn't imply passiveness. Even a typical dusty starburst can be below Herschel's confusion limit.
  - SCUBA-2 can detect important high-z star-forming systems that are systematically missed by Herschel.



Schreiber et al. (2018)

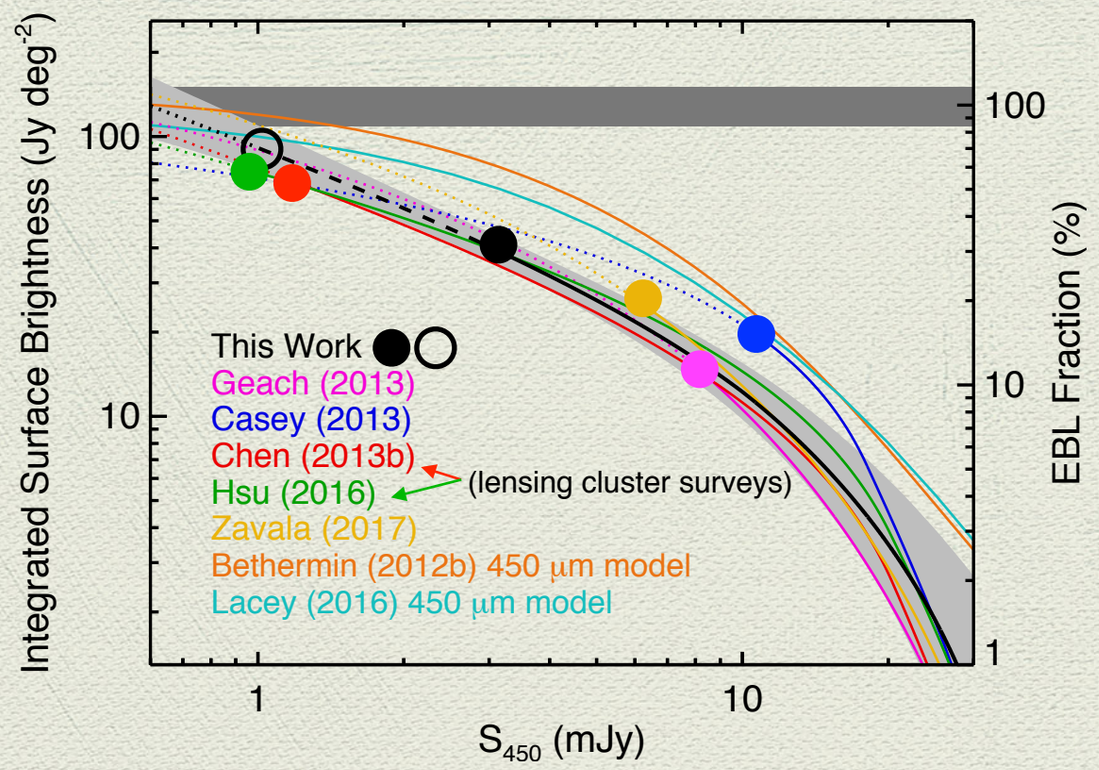
Deep 450 μm Counts

450 μm counts



- ~ 40% deeper than other 450 μm blank-field samples using 1st-yr STUDIES data
- Faint-end analyses based on noise fluctuation pushes the counts to ~1 mJy, comparable to counts derived from lensing cluster surveys.

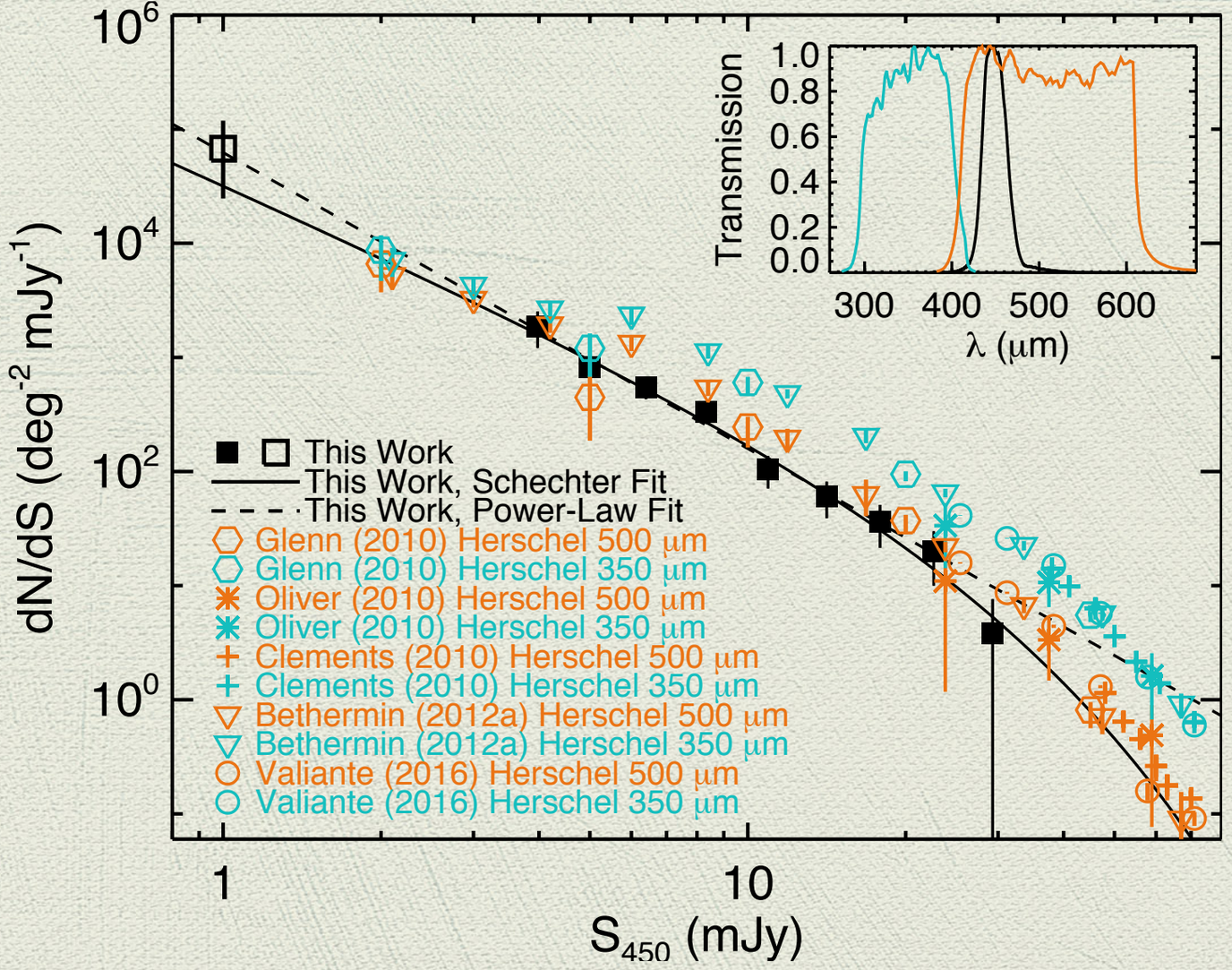
Resolved 450 μm background



- Resolved about 83% of the 450 μm background measured by COBE.
- Full resolution of the background requires detecting sources of 0.5–0.8 mJy, which is below the confusion limit of SCUBA-2 (~2 mJy).

Wang et al. (2017)

Herschel Counts are biased



Herschel 500μm counts:

- 1.4× too high in flux

  or
- 2.5× too high in density

Why?

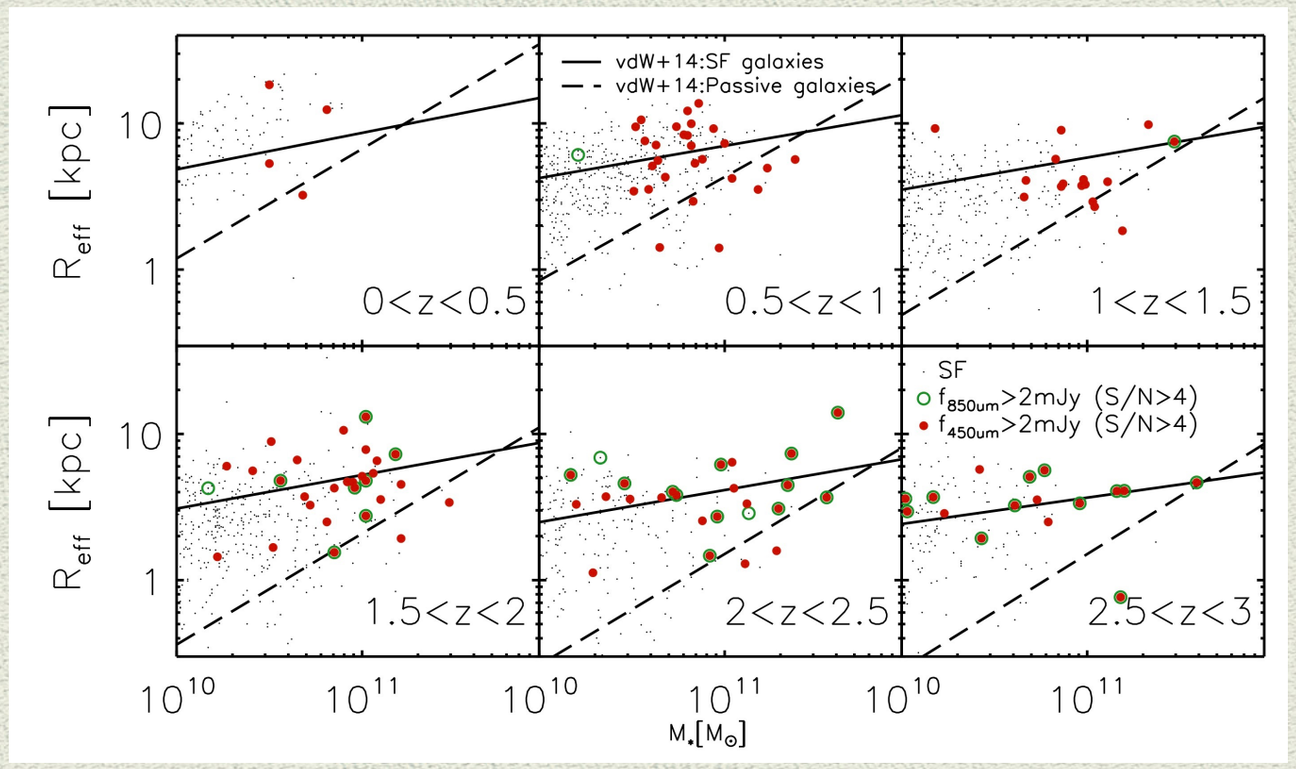
- clustering
- poor resolution (30”)

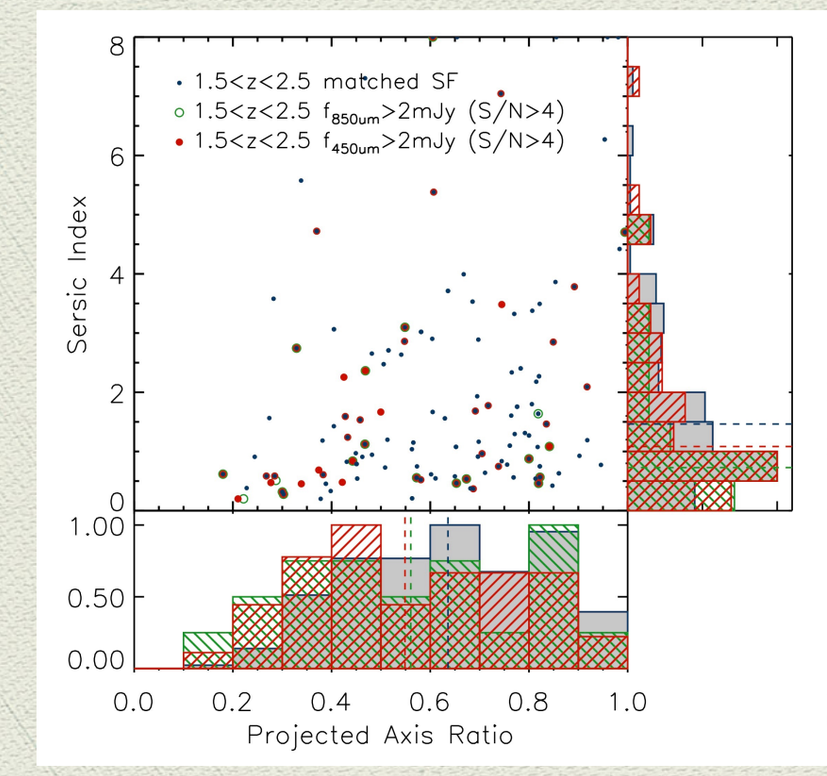
Don’t trust Herschel SPIRE fluxes at faint level.

Wang et al. (2017)

Paper to be submitted soon

- "Structural Properties and Near-Infrared Morphologies of Faint Submillimeter Galaxies"
  by Y.-Y. Chang, et al.

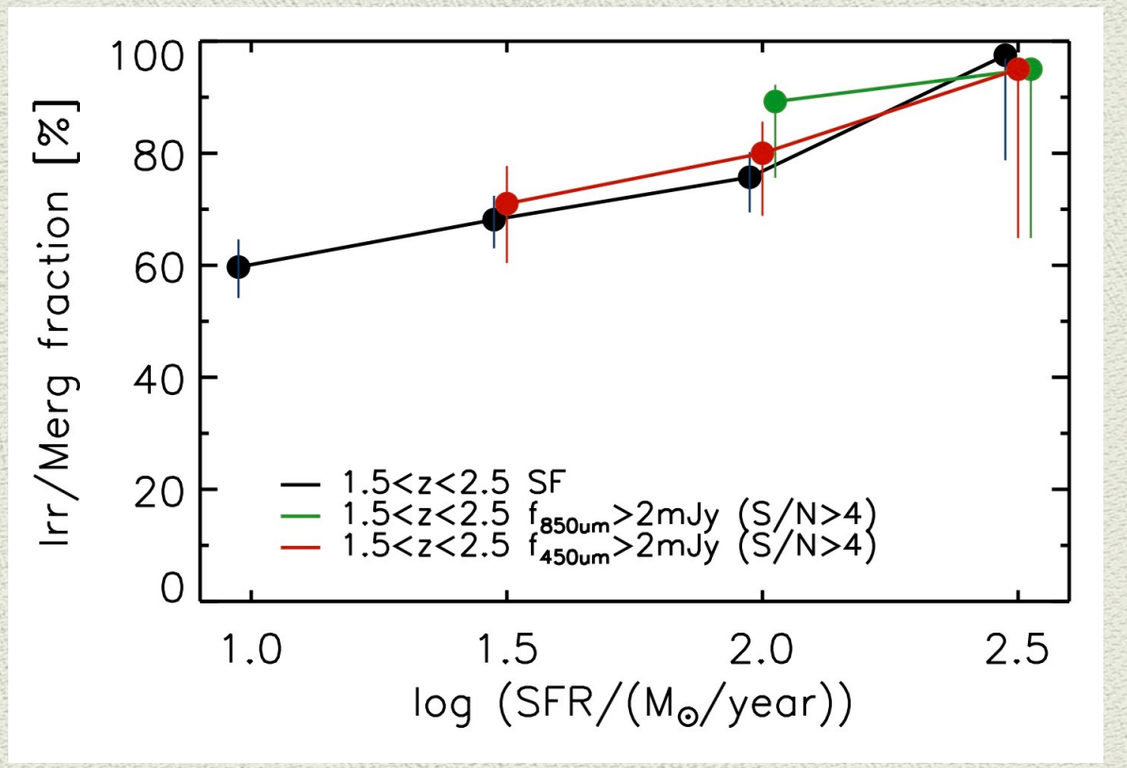


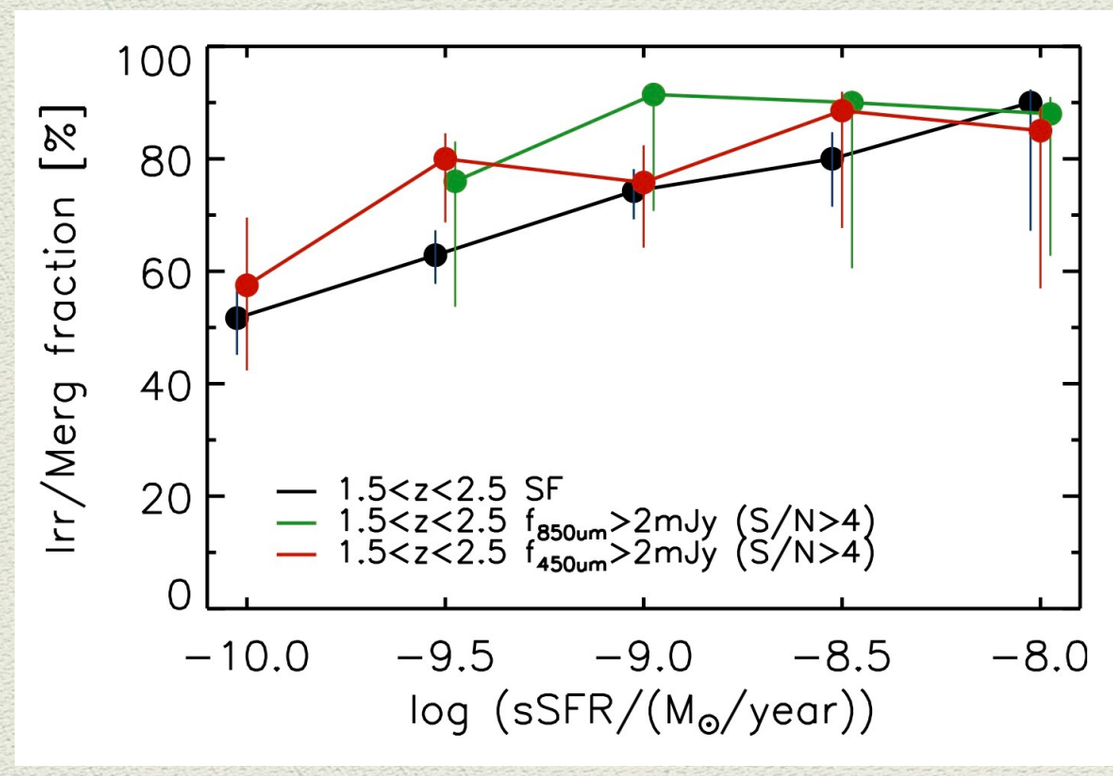


- Size (R_{eff}), Sersic index, and axis ratio of SMGs not different from normal star-forming galaxies selected from the optical.

Paper to be submitted soon

- "Structural Properties and Near-Infrared Morphologies of Faint Submillimeter Galaxies"
  by Y.-Y. Chang, et al.

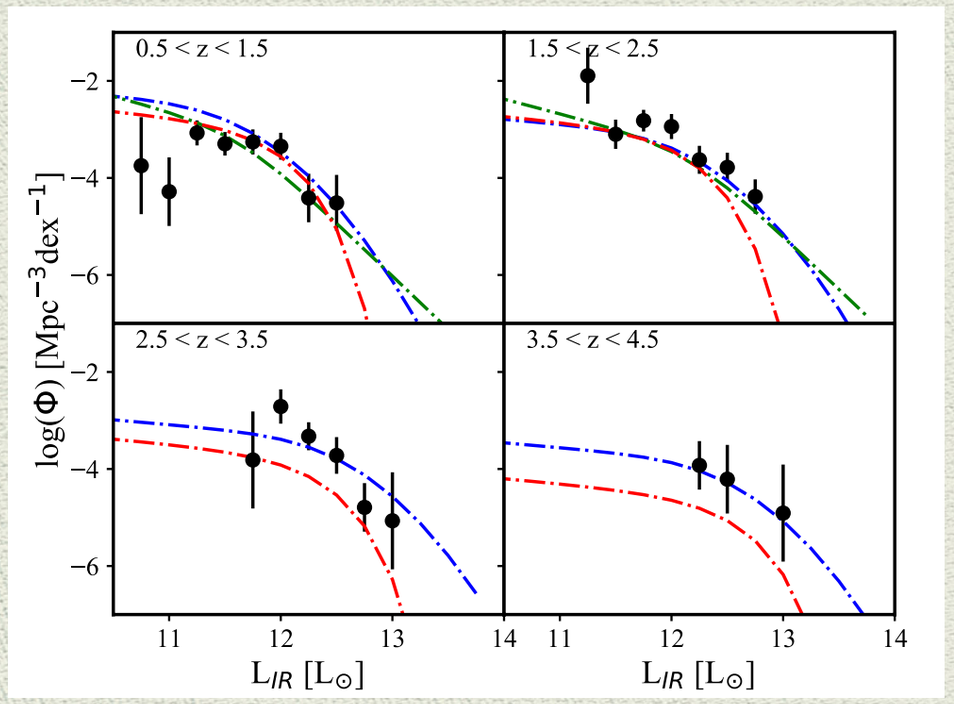




- SMGs follow the same SFR vs. Irr/Merg fraction as normal star-forming galaxies, but have higher Irr/Merg fraction at a given sSFR. Why?

Ongoing Analyses

- Multiwavelength counterpart identification using machine-learning based on S2CLS ALMA sample in the UDS field (F. An, PMO/Durham).
- Evolution of IR luminosity functions of deep 450 μm selected samples (C.-F. Lim, ASIAA).



STUDIES+S2CLS data
(Lin et al., in prep.)

Herschel (Gruppioni et al. 2013)

Herschel (Magnelli et al. 2013)

SCUBA-2 850 μm sample
(Koprowski et al. 2017)

- many other topics signed up by team members in various regions.

Follow-up proposals

- Various SMA, NOEMA, and ALMA proposals had used STUDIES data.

- Two proposals to SMA and NOEMA accepted in late 2016, to identify high-z candidates based on S_{850}/S_{450} ratios. The SMA one eventually got data. Analyses underway.

- ALMA cycle-5 proposal to image a large sample of 450 μm sources was rejected. TAC thinks our JCMT observations are not complete yet, so the samples are not final.

Summary

- STUDIES-COSMOS has good progress in observations and data analyses.
- STUDIES-SXDS started last year, and will eventually double the area that reaches the confusion limit.
- SCUBA-2 can detect important high-z galaxies previously missed by Herschel.
- Morphology of faint SMGs suggest that we start to overlap with the optically selected star-forming galaxies.
- Will soon produce the first IR luminosity functions based on a 450 μm sample.
- Really need to complete STUDIES-COSMOS asap so we can get ALMA time for follow-up.