

# Submillimeter Galaxies (SMGs) with JCMT

Fuyan Bian

Stromlo Fellow

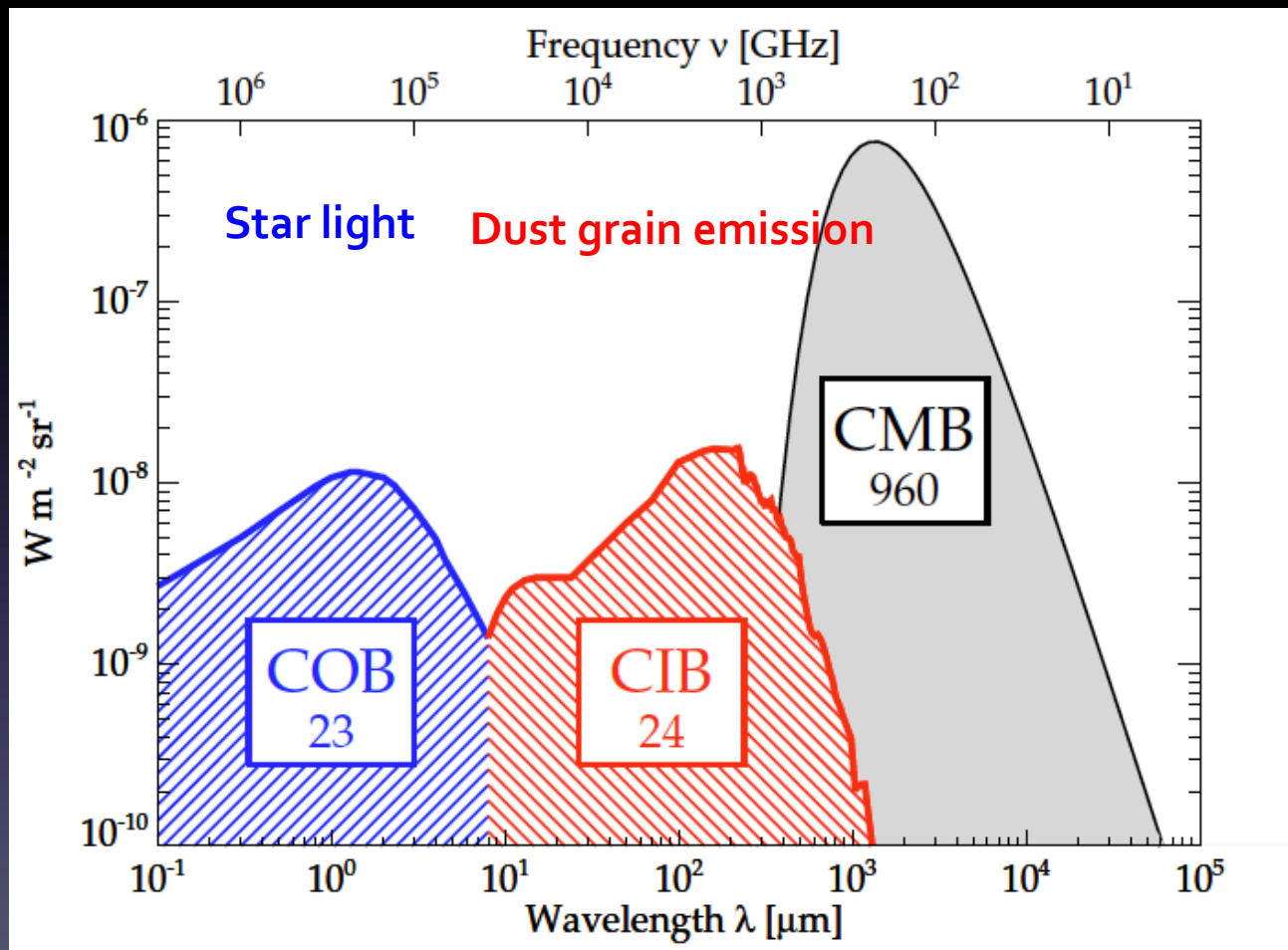
RSAA@ANU

JCMT Workshop UNSW

# Outlines

- Introduction
- Discovery of submm galaxies (SMGs)
- Characterize SMGs
- JCMT legacy survey of SMGs (ongoing)
- JCMT large programs (future)

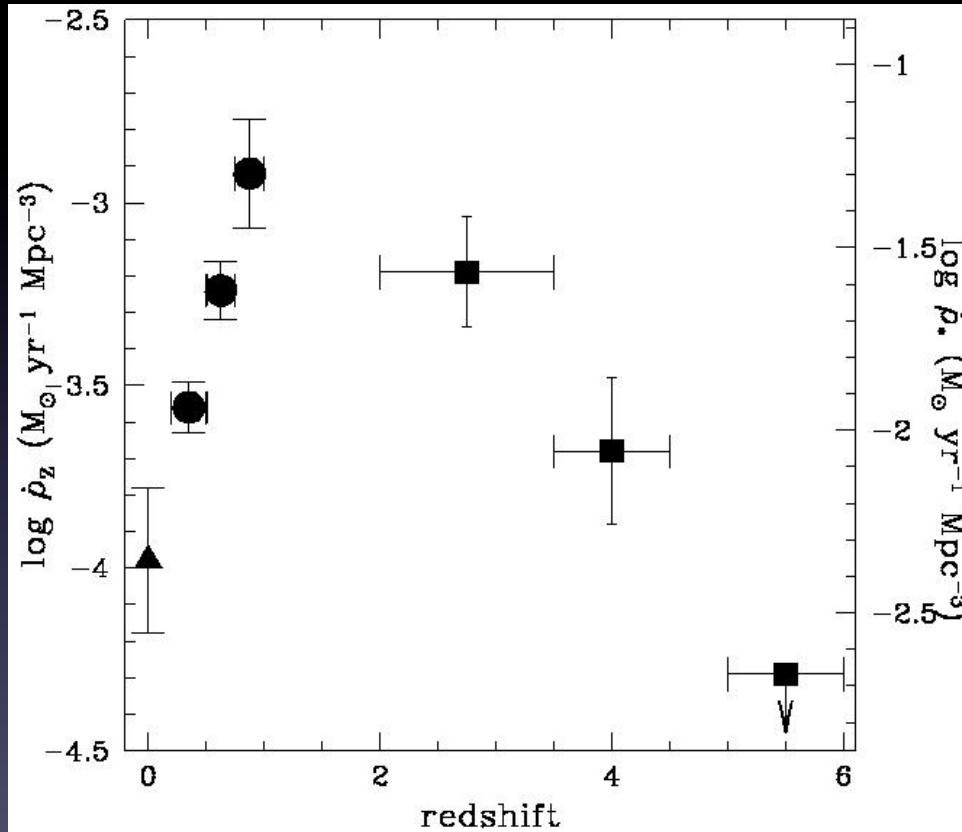
# Cosmic Infrared Background (CIB)



Dole+2006

CIB is comparable to cosmic optical background

# Cosmic Star-formation History

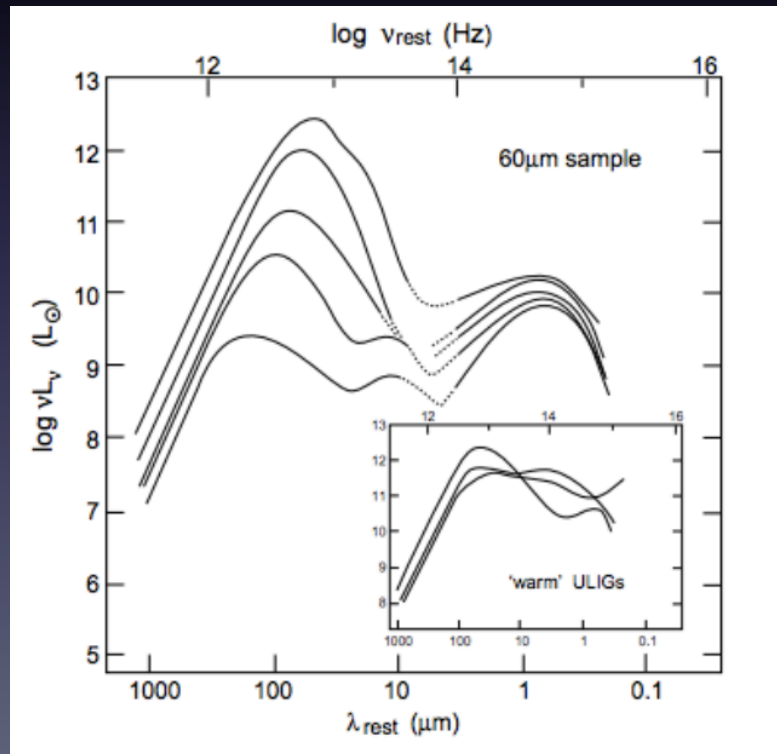


Madau 1998

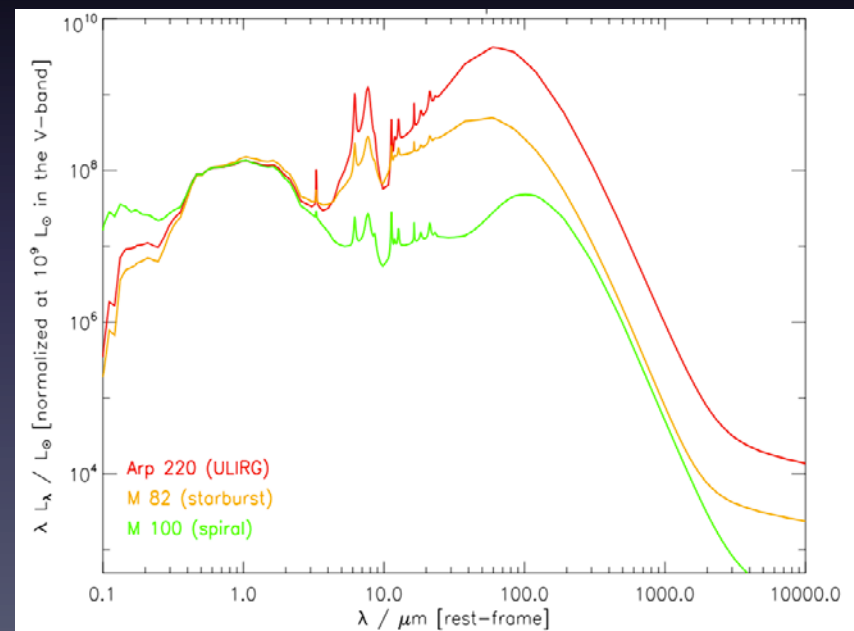
- High-redshift SFR density is based in UV-selected galaxies.
- How to correct dust extinction for SFR measurements?
- Missing optical faint but infrared luminous population.

# Local Dusty Star-forming Galaxies

- Luminous InfraRed Galaxies (LIRGs)  $L_{\text{IR}} > 10^{11} L_{\text{sun}}$
- Ultra-Luminous InfraRed Galaxies (ULIGs)  $L > 10^{12} L_{\text{sun}}$



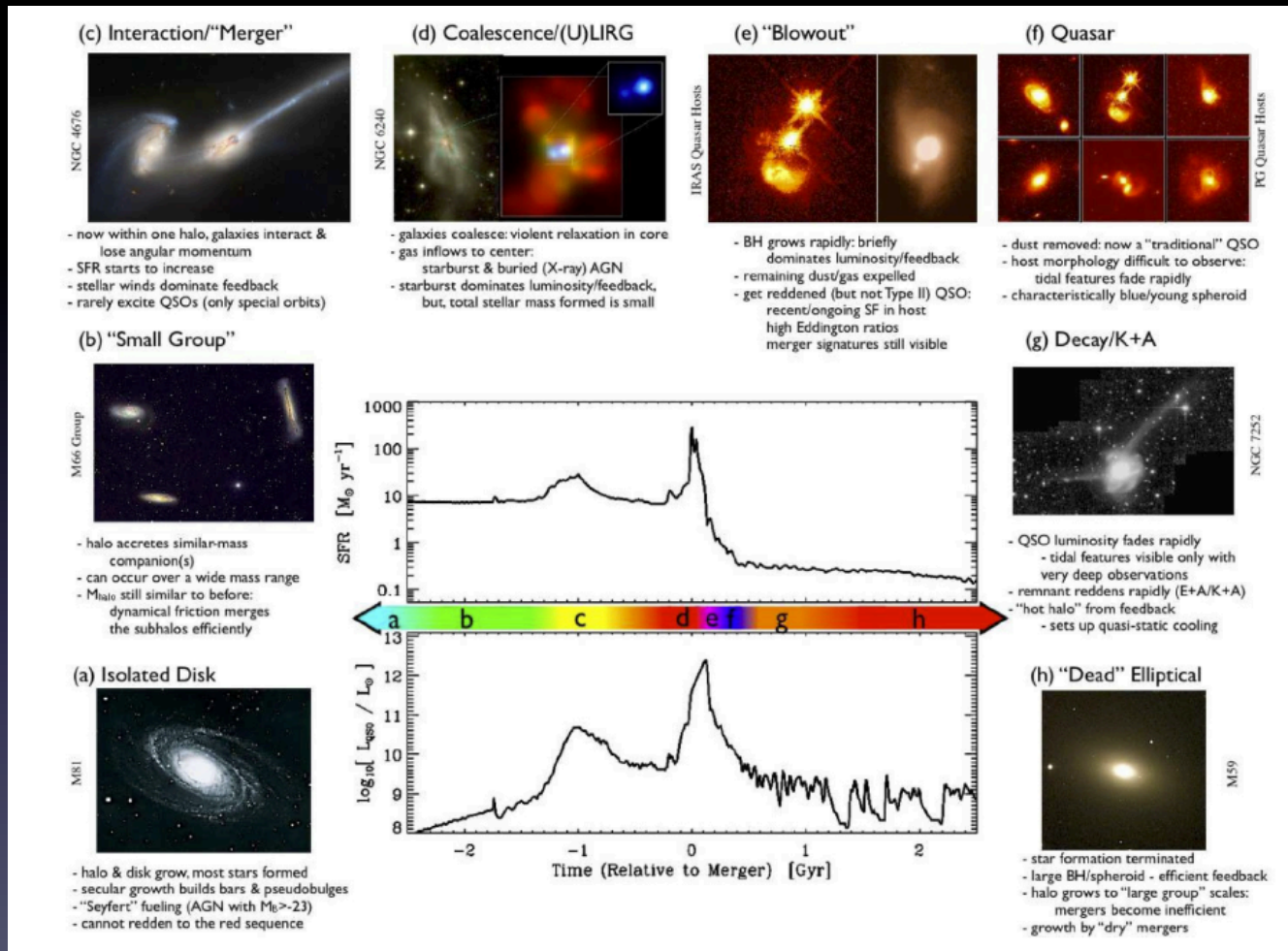
Luminosity



Wavelength

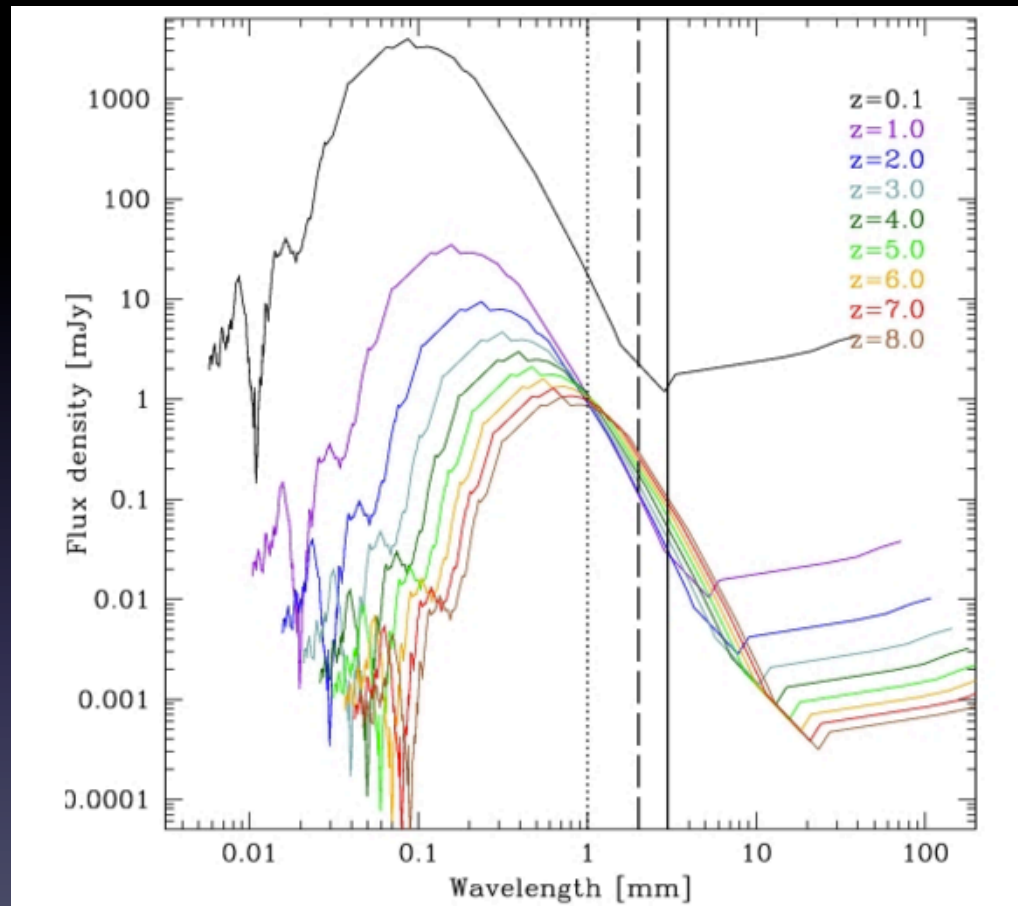
da Cunha+13

# Local Dusty Star-forming Galaxies



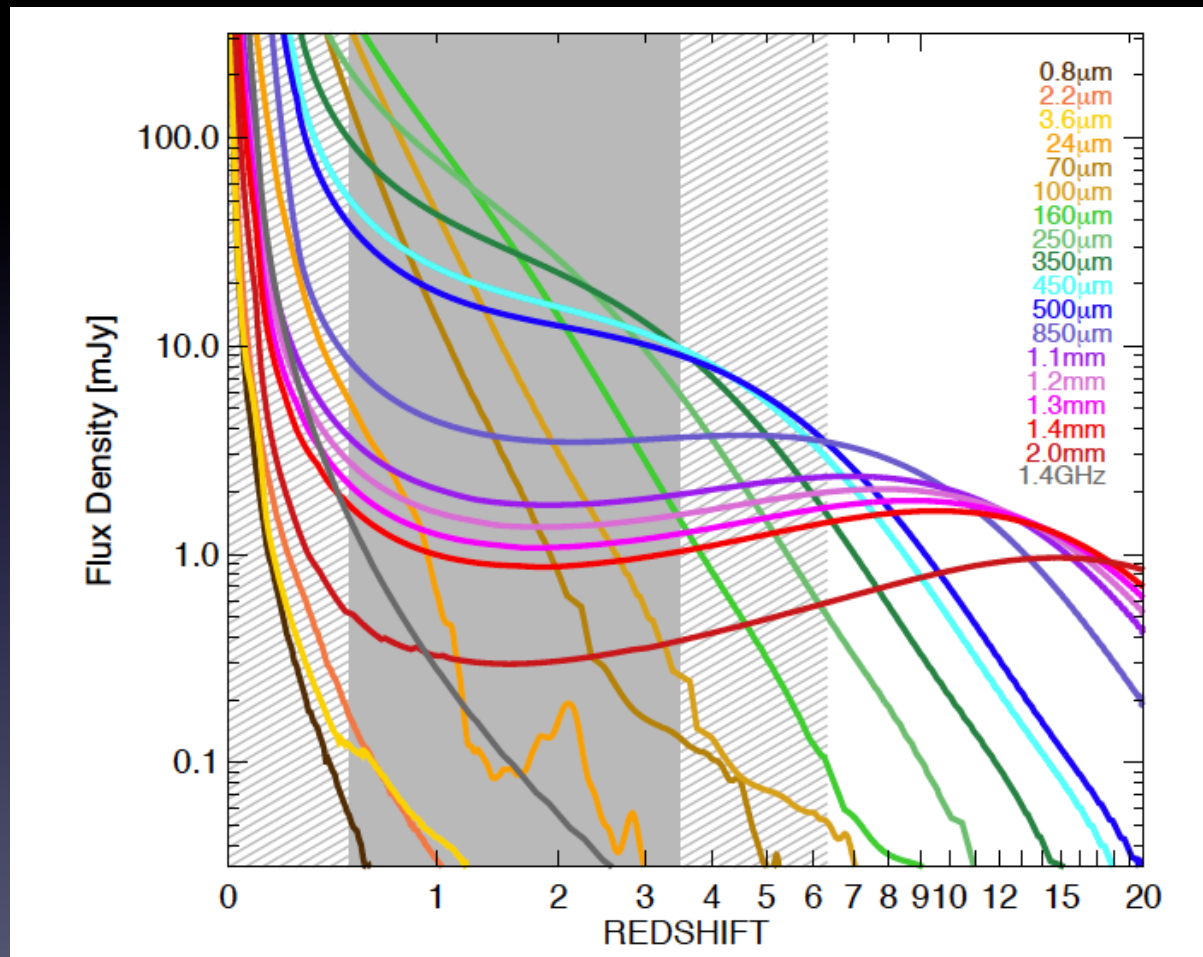
ULIRGs play an important role on massive galaxy formation and supermassive black hole growth

# Negative K-correction



- Modified blackbody peaks at  $100\mu\text{m}$
- Submm wavelength locates in the Rayleigh-Jeans regime.

# Negative K-correction



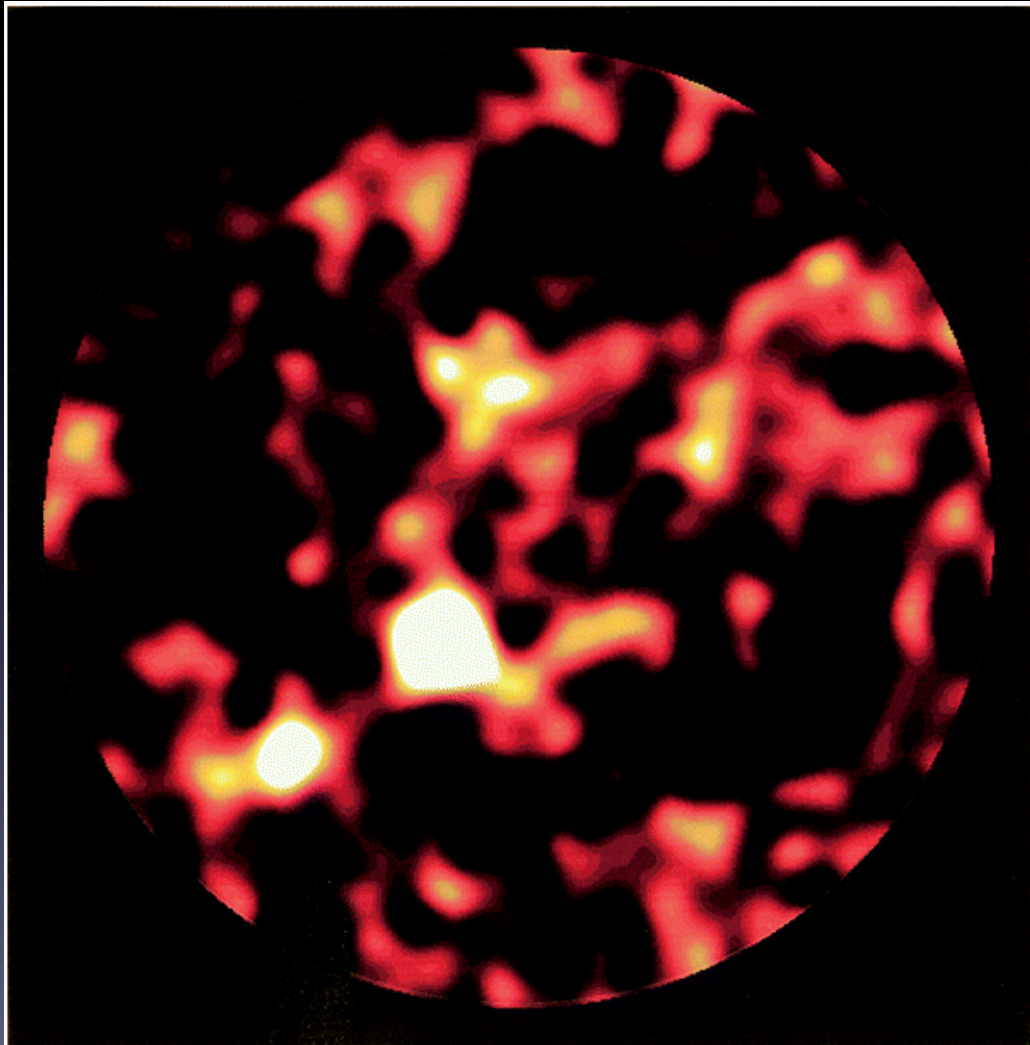


# SCUBA



- SCUBA is the Submillimetre Common-User Bolometer Array
- Operated simultaneously at 450 and 850  $\mu\text{m}$ , with 91 and 37 pixels, respectively.
- When starting operation, it was 20 times more sensitive than its nearest competitor.

# Submm Galaxies with JCMT

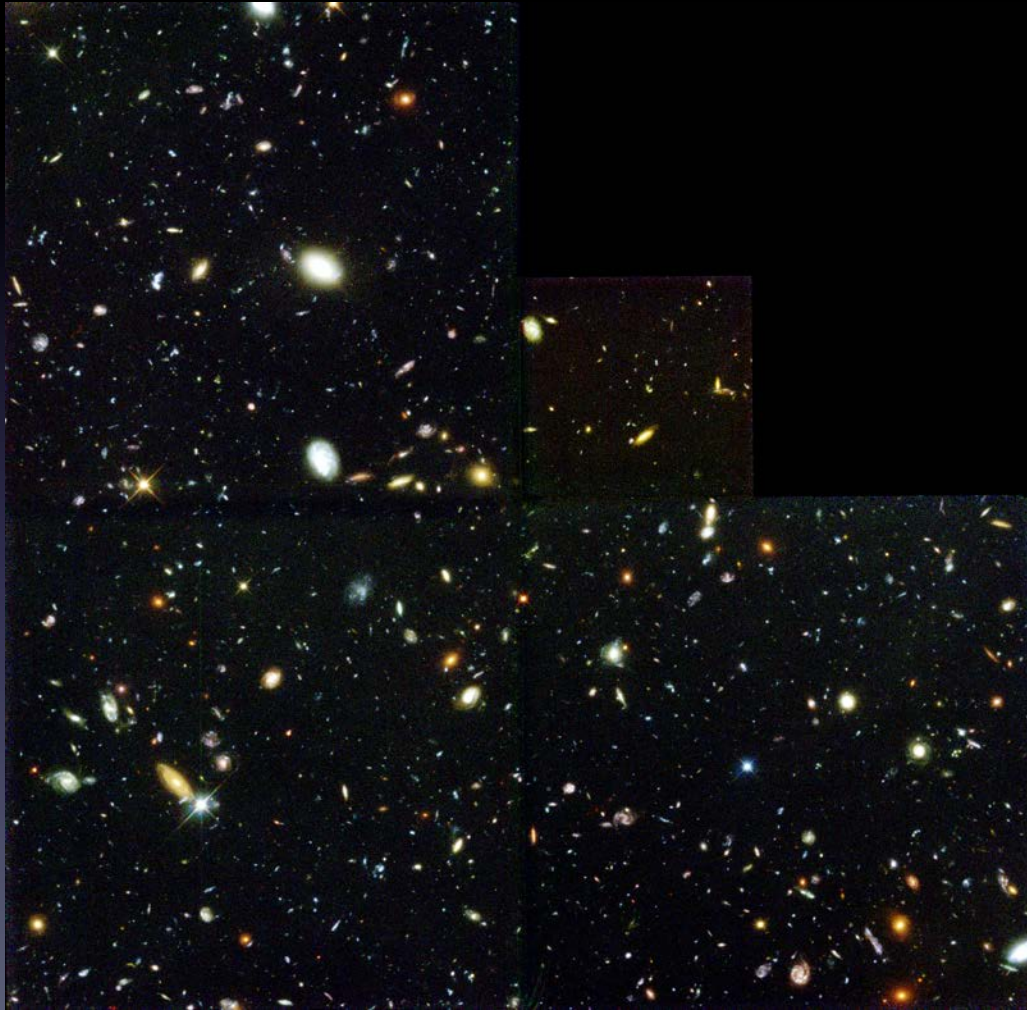


- SCUBA/JCMT 850μm map in the Hubble deep field (HDF).
- HDF850.1 is the brightest submm source in the survey.

Hughes+1998

See also Barger+98, Smail+97

# Submm Galaxies with JCMT

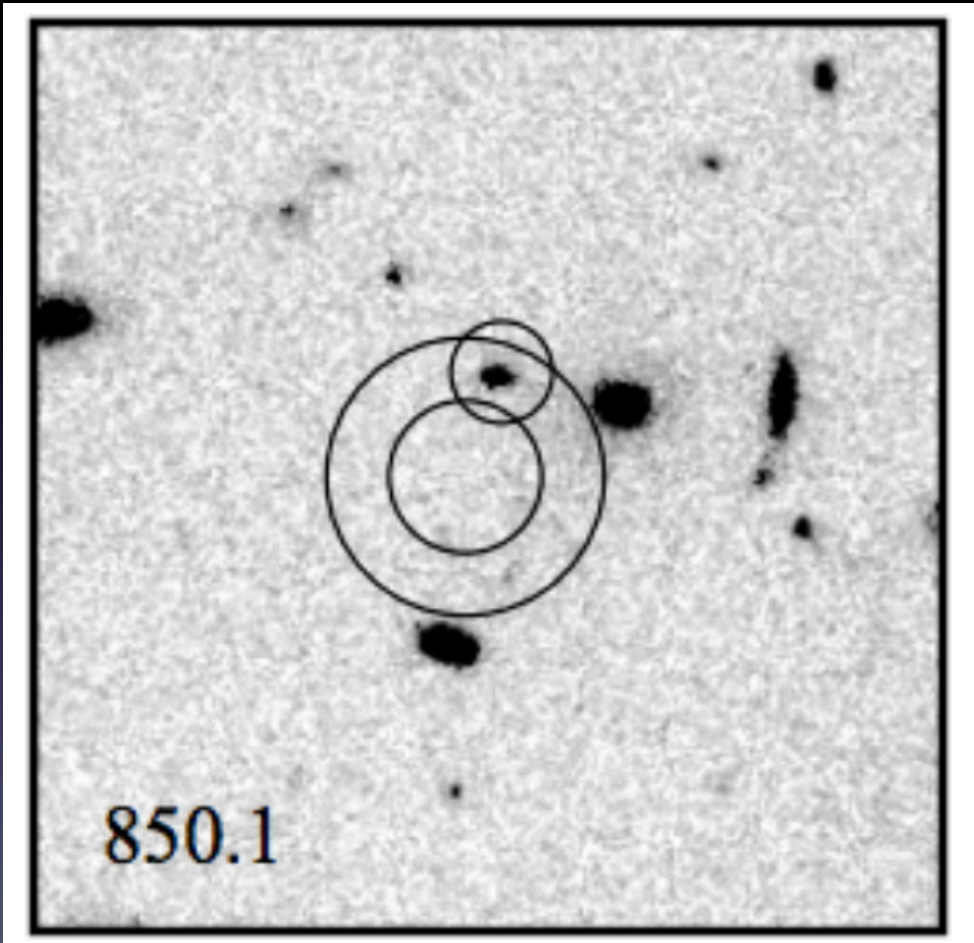


- SCUBA/JCMT 850 $\mu$ m map in the Hubble deep field (HDF).
- HDF850.1 is the brightest submm source in the survey.
- The redshift of HD850.1 is 5.2 and  $SFR=850M_{\text{sun}}/\text{yr}$  (Walter+2012)

Hughes+1998

See also Barger+98, Smail+97

# Submm Galaxies with JCMT

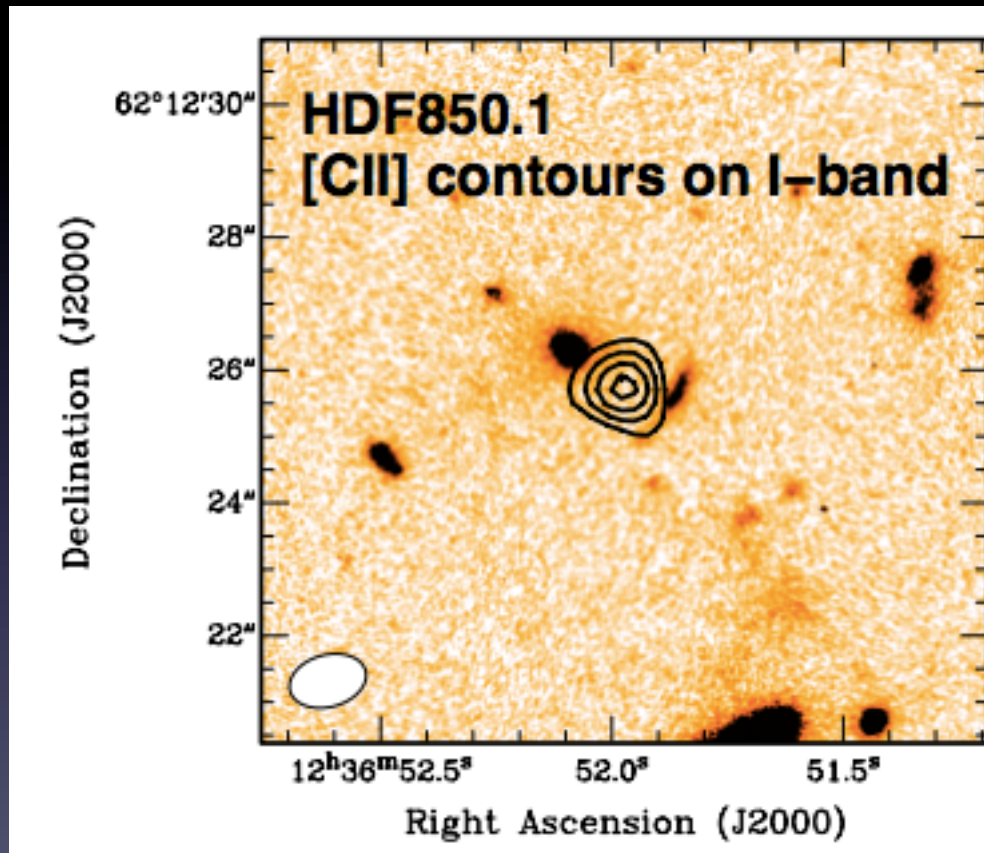


- SCUBA/JCMT 850 $\mu$ m map in the Hubble deep field (HDF).
- HDF850.1 is the brightest submm source in the survey.

Hughes+1998

See also Barger+98, Smail+97

# Submm Galaxies with JCMT



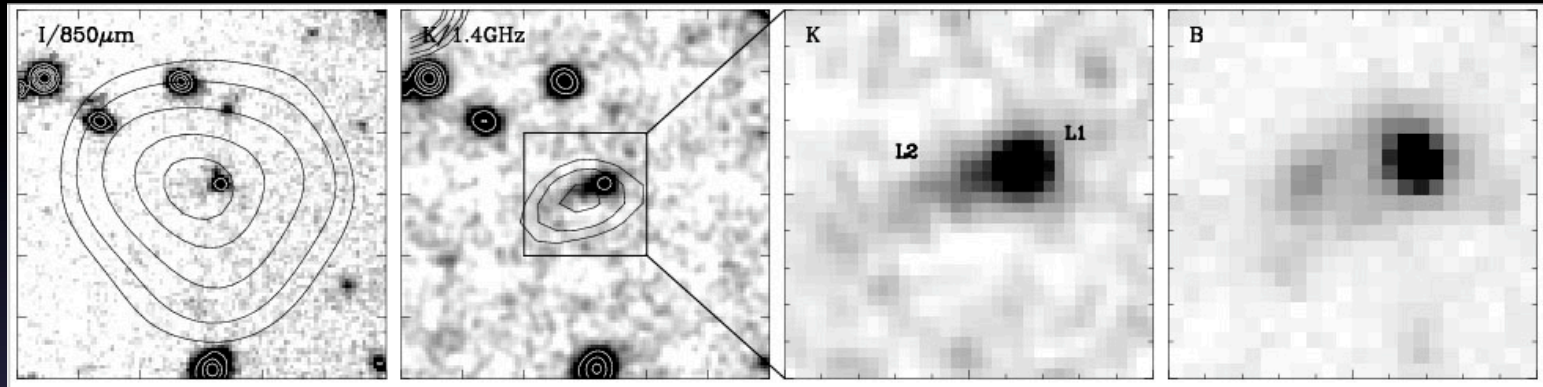
- SCUBA/JCMT 850 $\mu$ m map in the Hubble deep field (HDF).
- HDF850.1 is the brightest submm source in the survey.
- The redshift of HD850.1 is 5.2 and  $SFR=850M_{\text{sun}}/\text{yr}$  (Walter+2012)

Hughes+1998

See also Barger+98, Smail+97

# Redshift Distribution

SMM J02399-0136

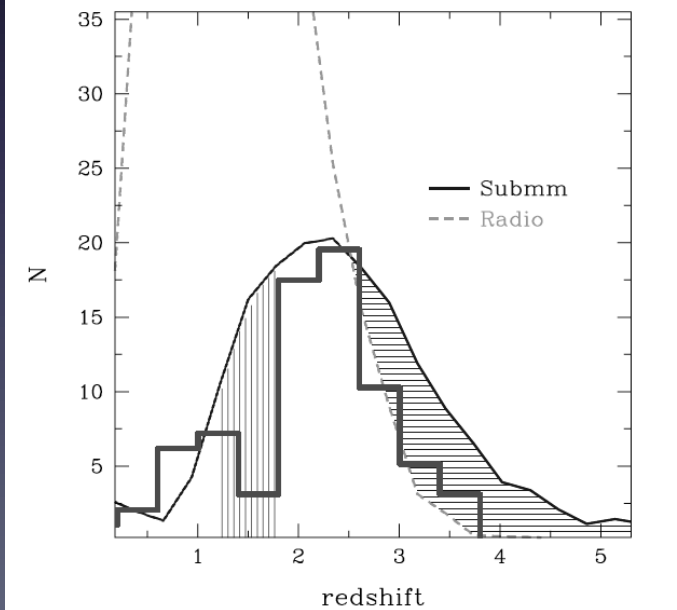
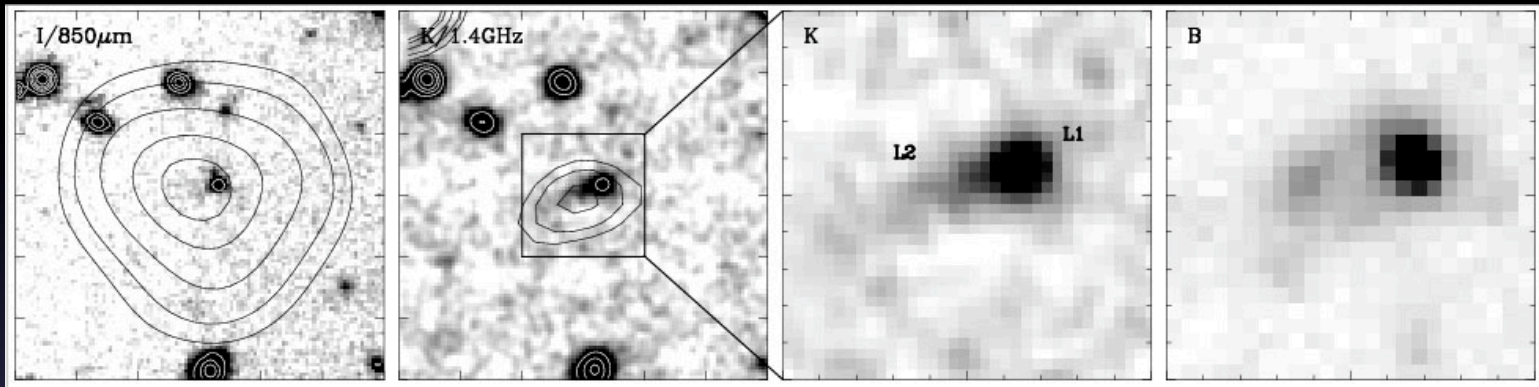


Ivison+98

- High Spatial resolution VLA 1.4GHz continuum image to determine position.
- Optical or radio line follow-up to determine redshift or photometric redshift.

# Redshift Distribution

SMM J02399-0136



Ivison+98

- SMGs are a population of dusty galaxies at high-redshift.
- Median redshift is 2.2

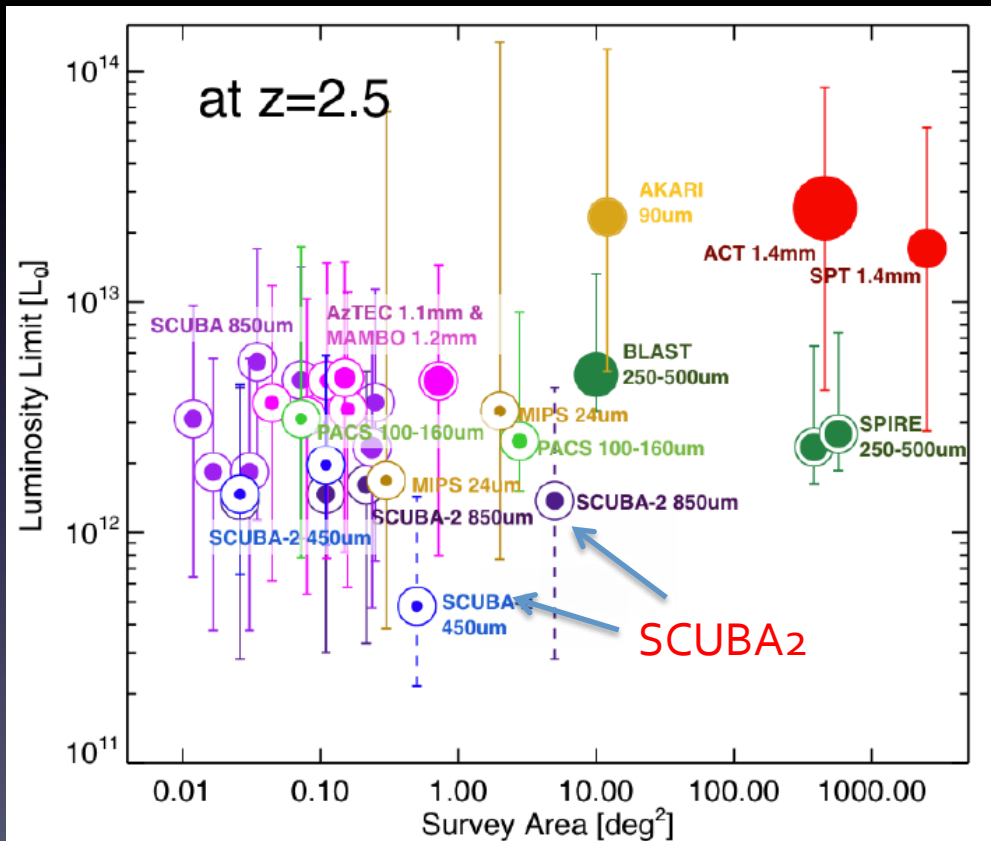
Chapman+05

# Properties of SMGs

- Rare: Volume number density  $\sim 10^{-5} \text{ Mpc}^{-3}$
- Massive: Stellar masses  $\sim 10^{11} M_{\text{sun}}$
- Star-forming: SFR  $> 500 M_{\text{sun}} \text{ yr}^{-1}$
- Dusty: dust mass  $10^8 - 10^9 M_{\text{sun}}$
- Halo mass:  $10^{13} M_{\text{sun}}$

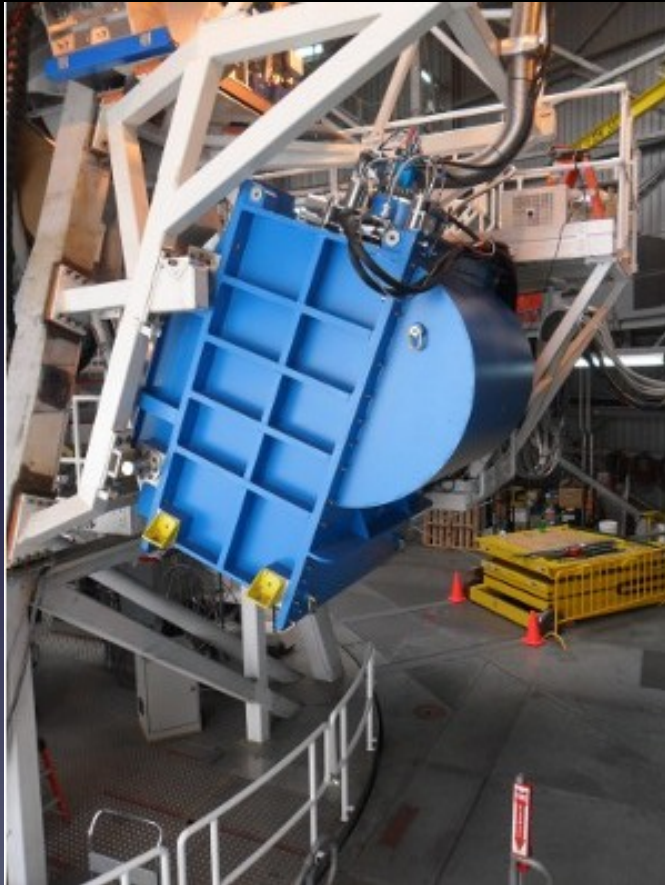


# SMG Surveys



- In the last decade, a large sample of SMGs have been established, using SCUBA, MAMBO, AzTEC, SPT, SPIRE and PACS etc.
- In particular, SCUBA2 allows survey to achieve both deep and wide.

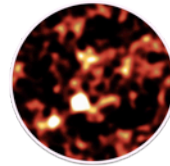
# SCUBA<sub>2</sub>



- Simultaneous imaging at 850  $\mu\text{m}$  and 450  $\mu\text{m}$  with large field of view ( 45 arcmin<sup>2</sup>)
- Mapping the submm sky ~1000 times faster than SCUBA

**15 years ago... our first glimpse, with SCUBA**

**The HDF**

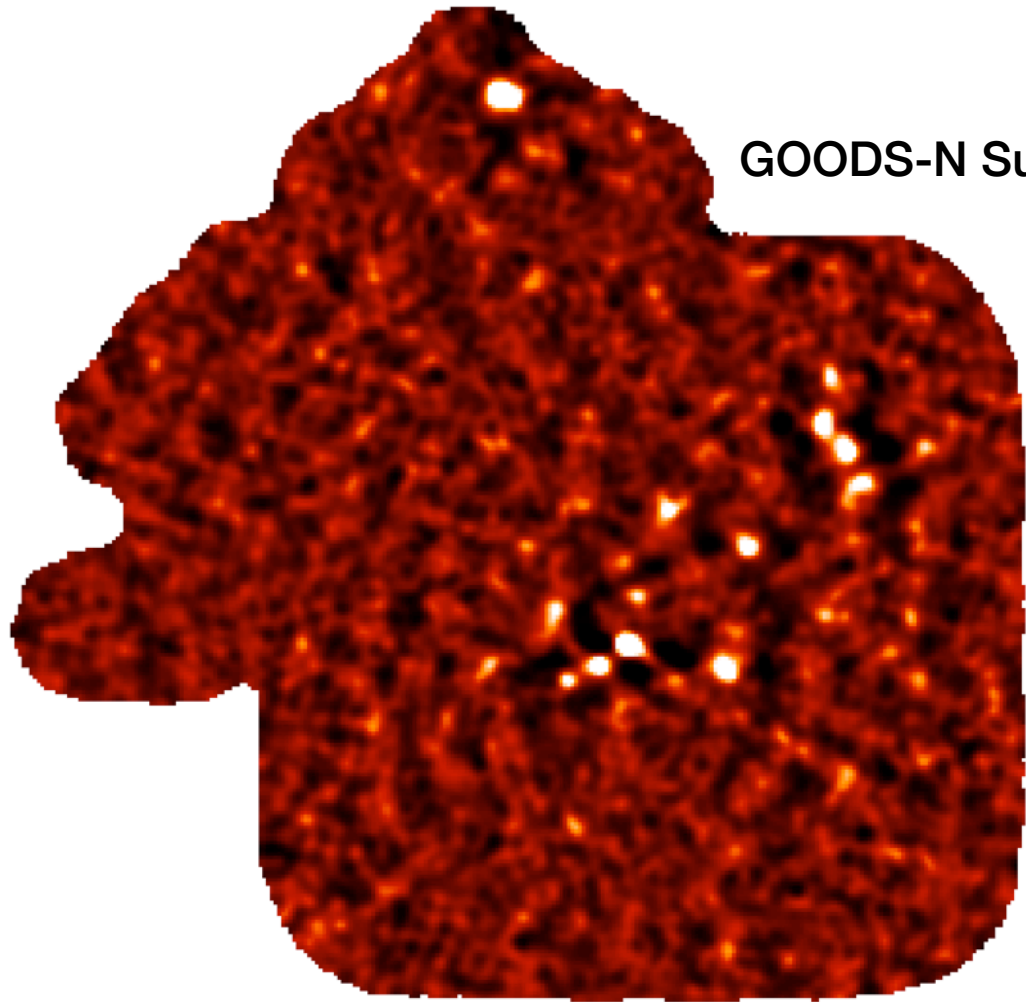


**Hughes et al. (1998)**

courtesy of Jim Geach

**Also: SCUBA surveys of strong lensing clusters, Smail et al. (1997)**

10 years ago... 'proper' surveys



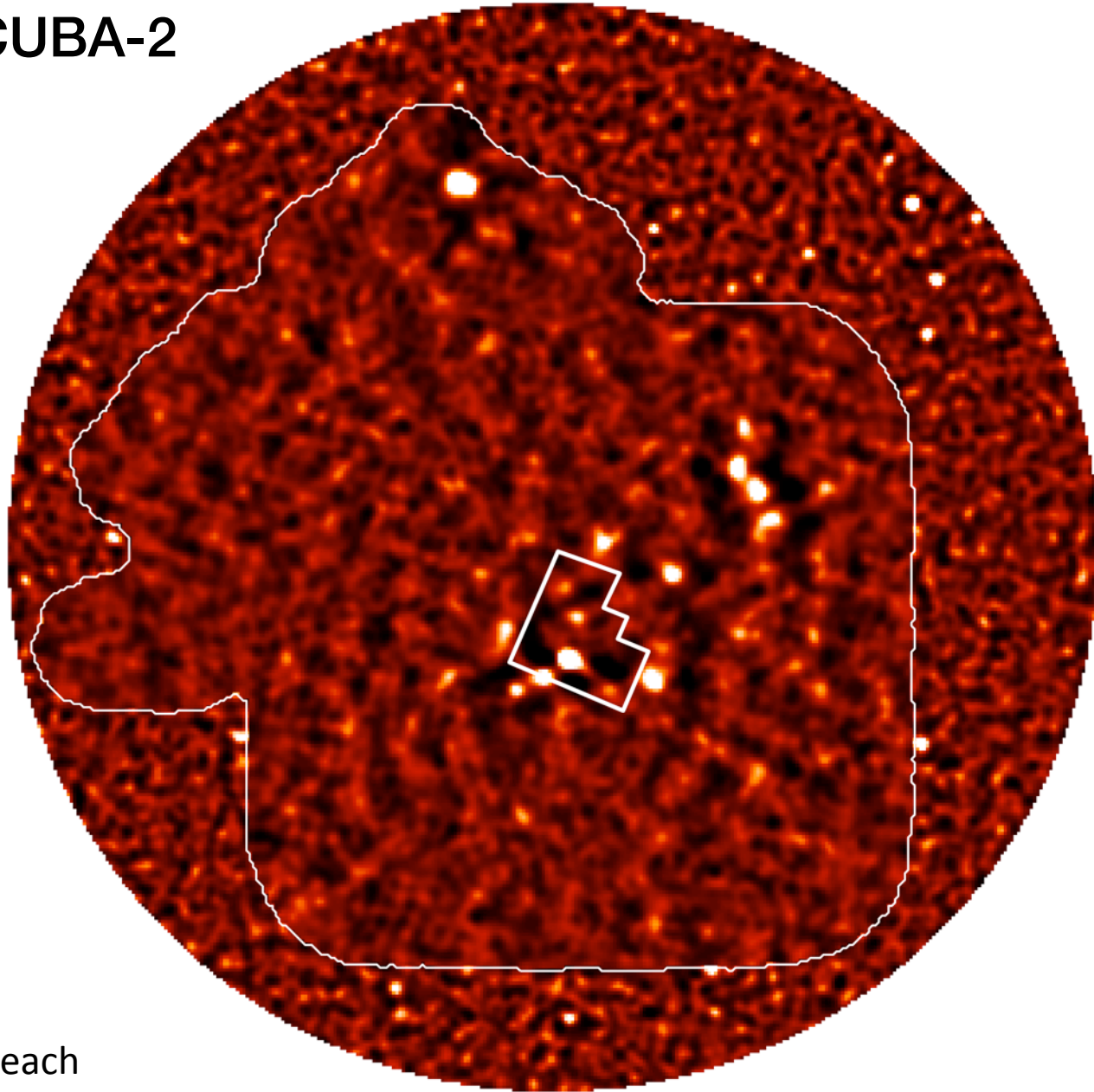
GOODS-N Supermap

Borys et al. (2003)

Pope et al. (2005)

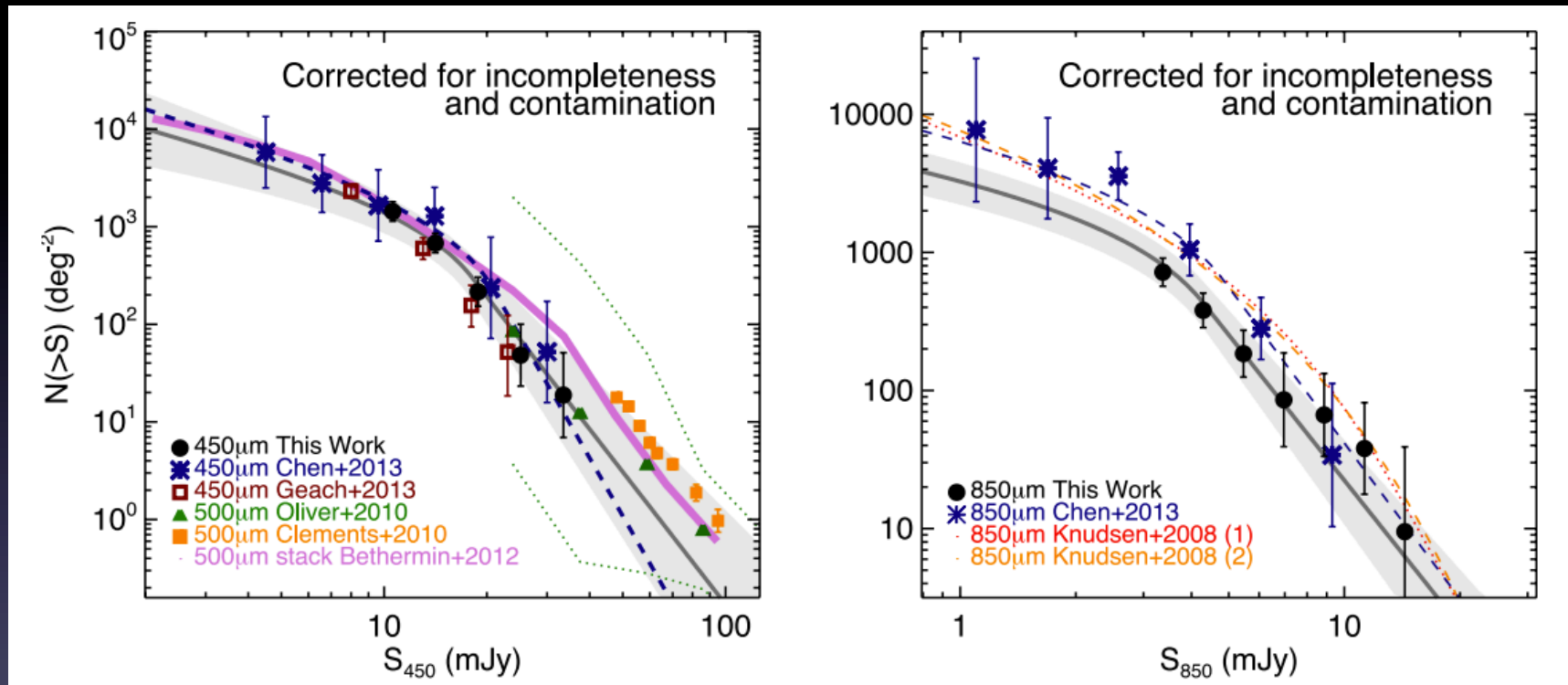
courtesy of Jim Geach

Today... SCUBA-2



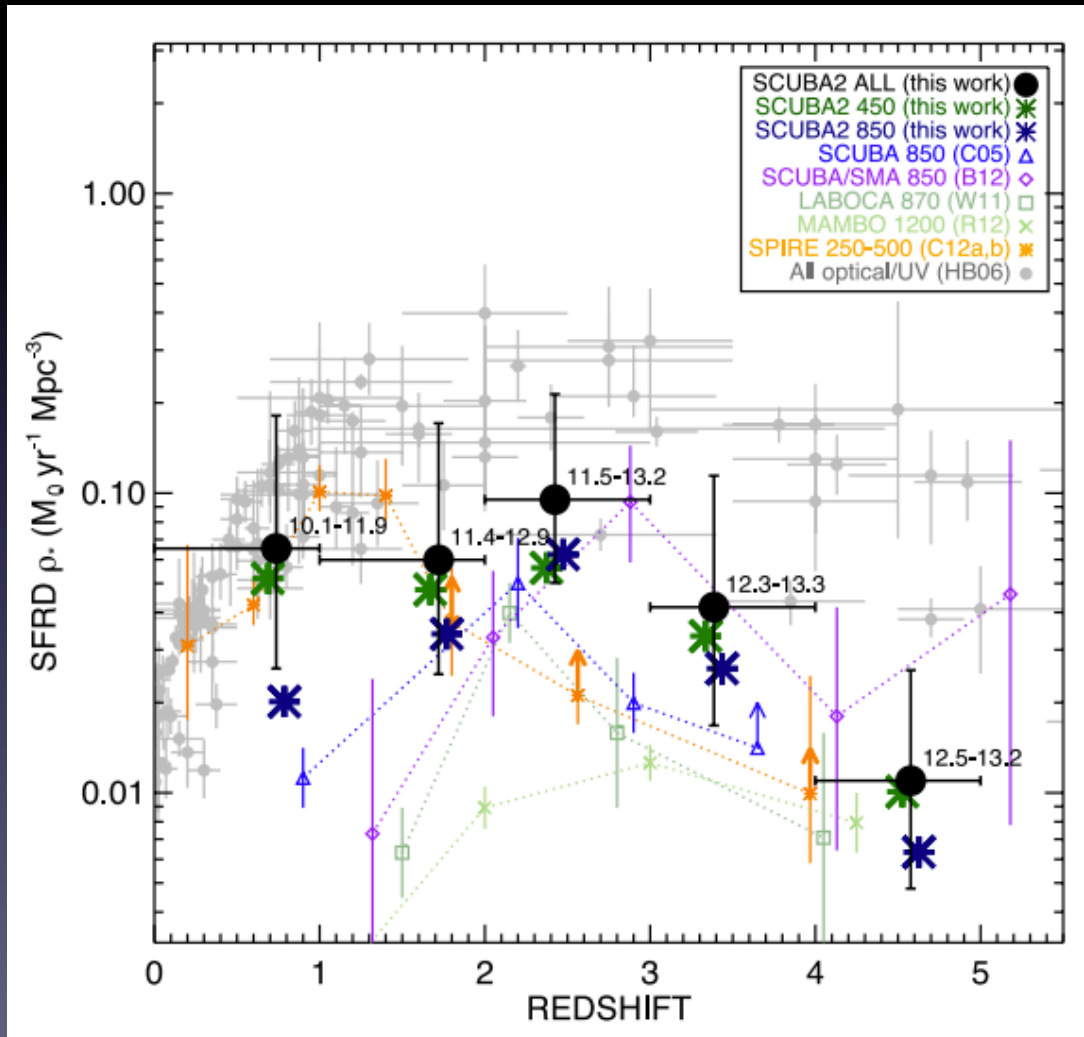
courtesy of Jim Geach

# SMG Number Counts



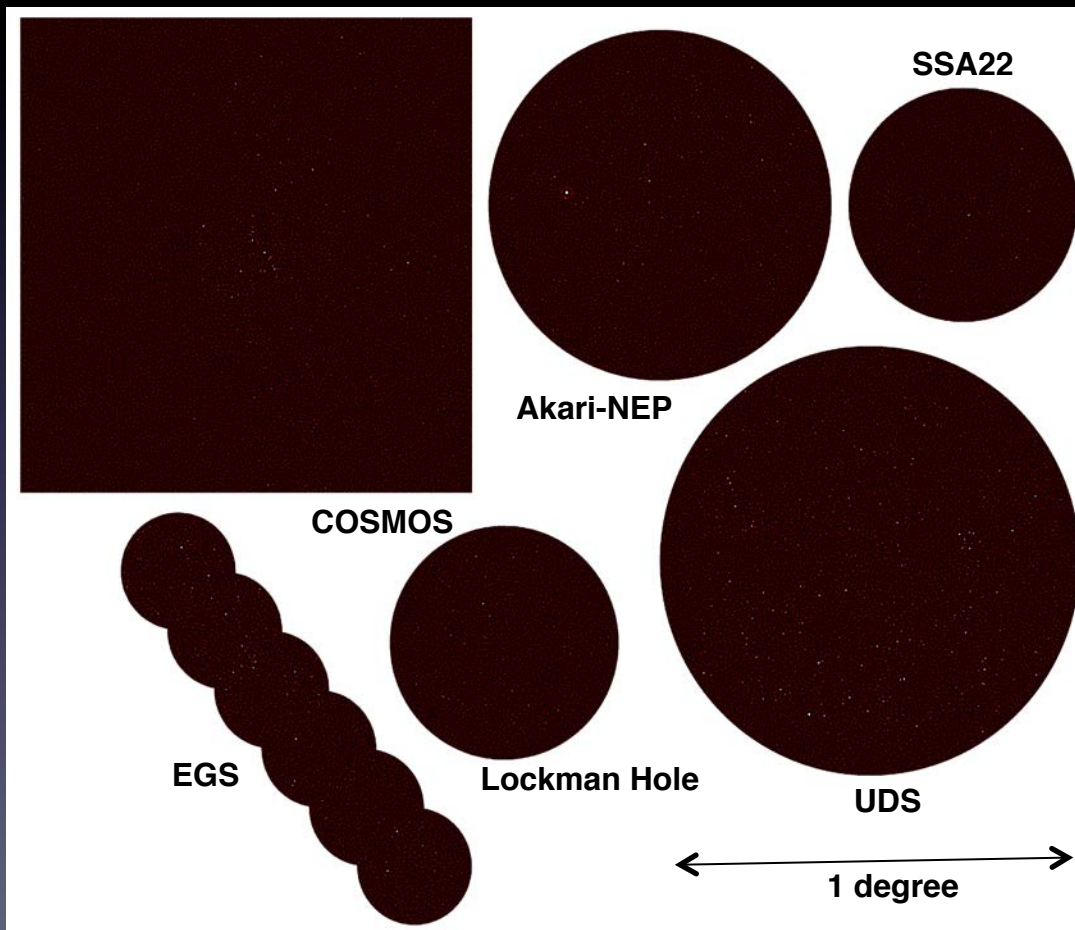
- SMG accumulate number counts in 450 $\mu\text{m}$  and 850 $\mu\text{m}$  in Casey+13 a part of COSMOS field using SCUBA2.
- Multi-wavelength: better constraint on FIR SED reliable photometric redshift

# Cosmic Star-formation History



Casey+13

# SCUBA-2 Cosmology Legacy Survey



- 1778 hours JCMT legacy survey
- Two tier strategy covering well-know field
- Wide survey:  $10 \text{ deg}^2$ ,  $1.2 \text{ mJy}$  at  $850 \mu\text{m}$
- Deep Survey:  $0.25 \text{ deg}^2$ ,  $1.2 \text{ mJy}$  at  $450 \mu\text{m}$

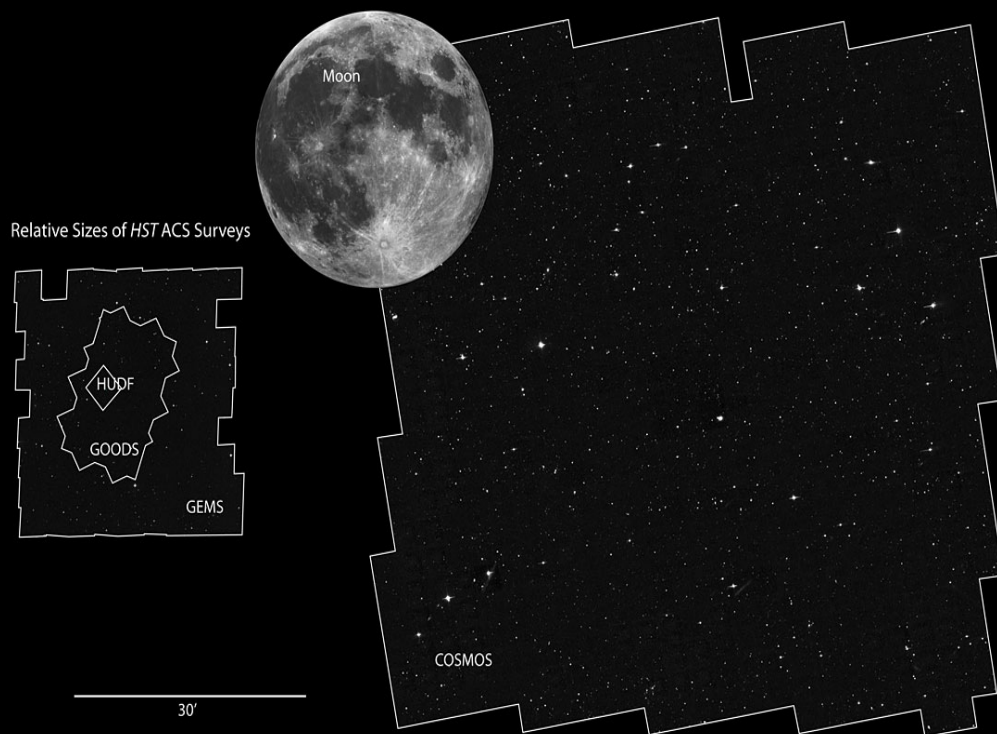


# Science drivers

- Comprehensive survey of SMGs detected at 850 $\mu$ m ( $N \sim 10^4$ ) over several  $\sim$ degree scale fields
  - ▶ measure clustering / halo properties
  - ▶ constrain bright-end counts
  - ▶ reliably probe properties of fainter SMGs (3-5mJy)
  - ▶ AGN/starburst connection, transition objects
  - ▶ ‘very’ high-z science (IR luminosity density at  $z > 5$ , rare objects)
  - ▶ cross-correlation studies
- ‘Keyhole’ confusion limited survey at 450+850 $\mu$ m
  - ▶ properties of 450 $\mu$ m-selected SMGs below HSO confusion limit
  - ▶ resolving CIB at 450 $\mu$ m (closer to peak)
  - ▶ probing very faint end of counts (P(D) analyses)
  - ▶ joint stellar/dust/gas morphologies (CANDELS overlap, ALMA)

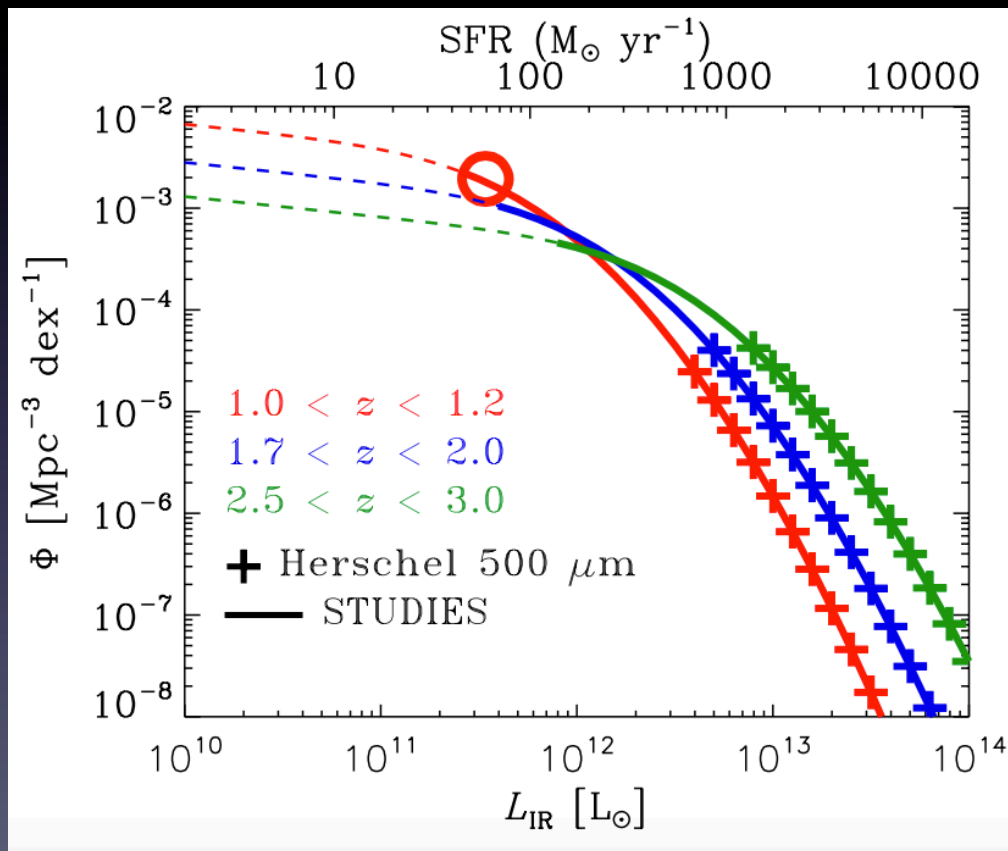
courtesy of Jim Geach

# S<sub>2</sub>-COSMOS



- A SCUBA-2 survey of 1,000 SMGs in the COSMOS field
- Uniform 1.2mJy rms map of the full COSMOS
- Superb supporting multiwavelength data

# STUDIES: SCUBA-2 Ultra Deep Imaging EAO Survey



- Ultra deep, confusion limited 450  $\mu\text{m}$  image in the COSMOS-CANDELS region
- The deepest 450  $\mu\text{m}$  image  $\sim \sqrt{2}$  deeper than the S2CLS
- Triple the area previously achieved by S2CLS in the COSMOS field