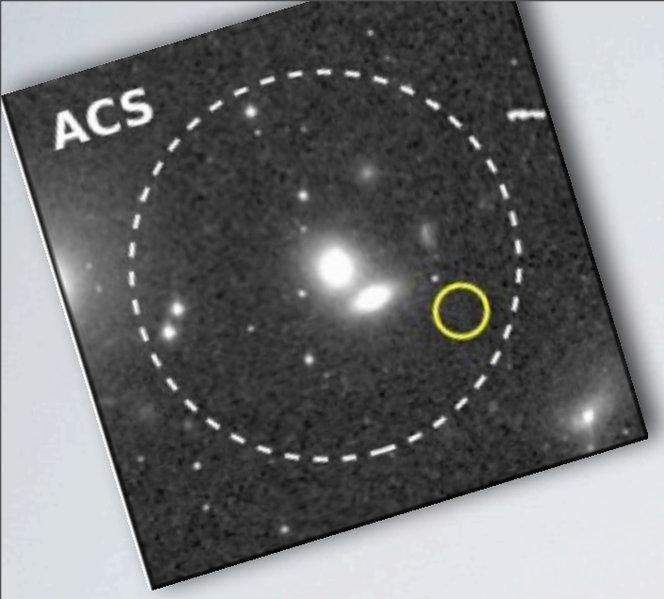
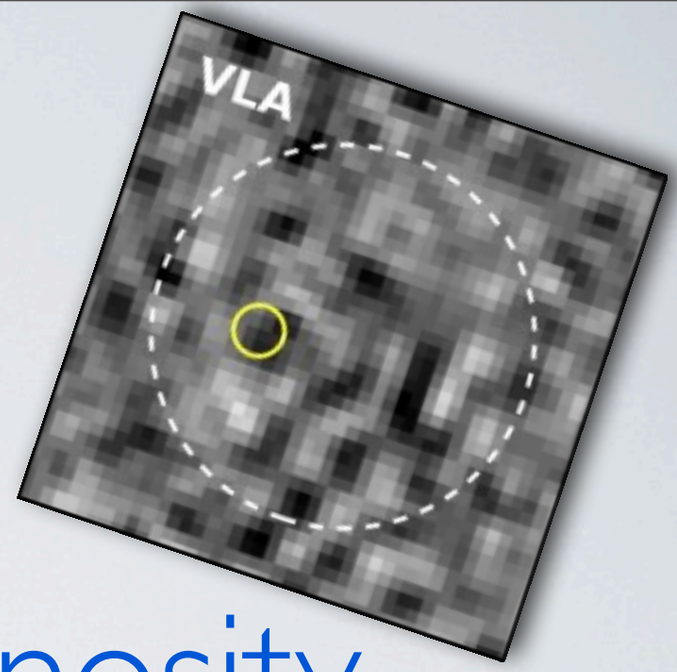


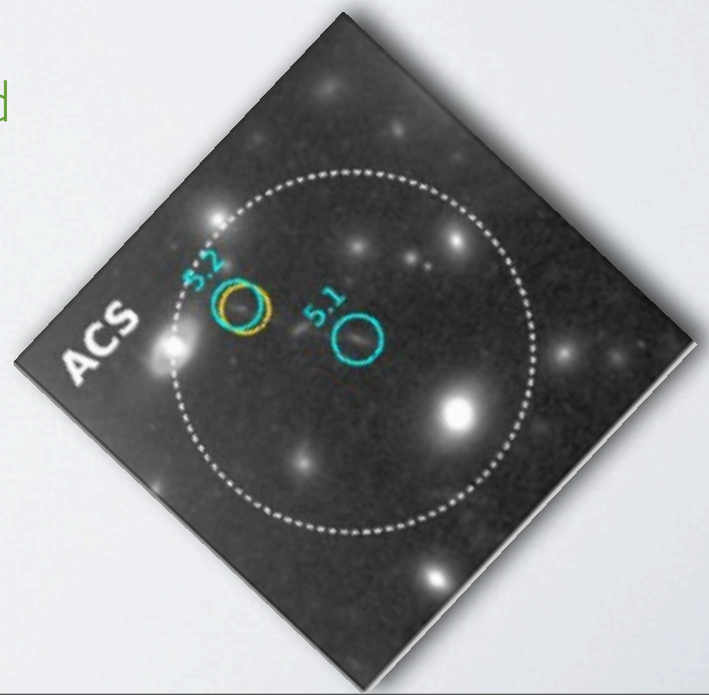


Faint SMGs: Ultra Dusty Low-Luminosity Galaxies at High-Redshift?

Chian-Chou Chen (T.C.)

Len Cowie, Amy Barger, Wei-Hao Wang, Jonathan Williams

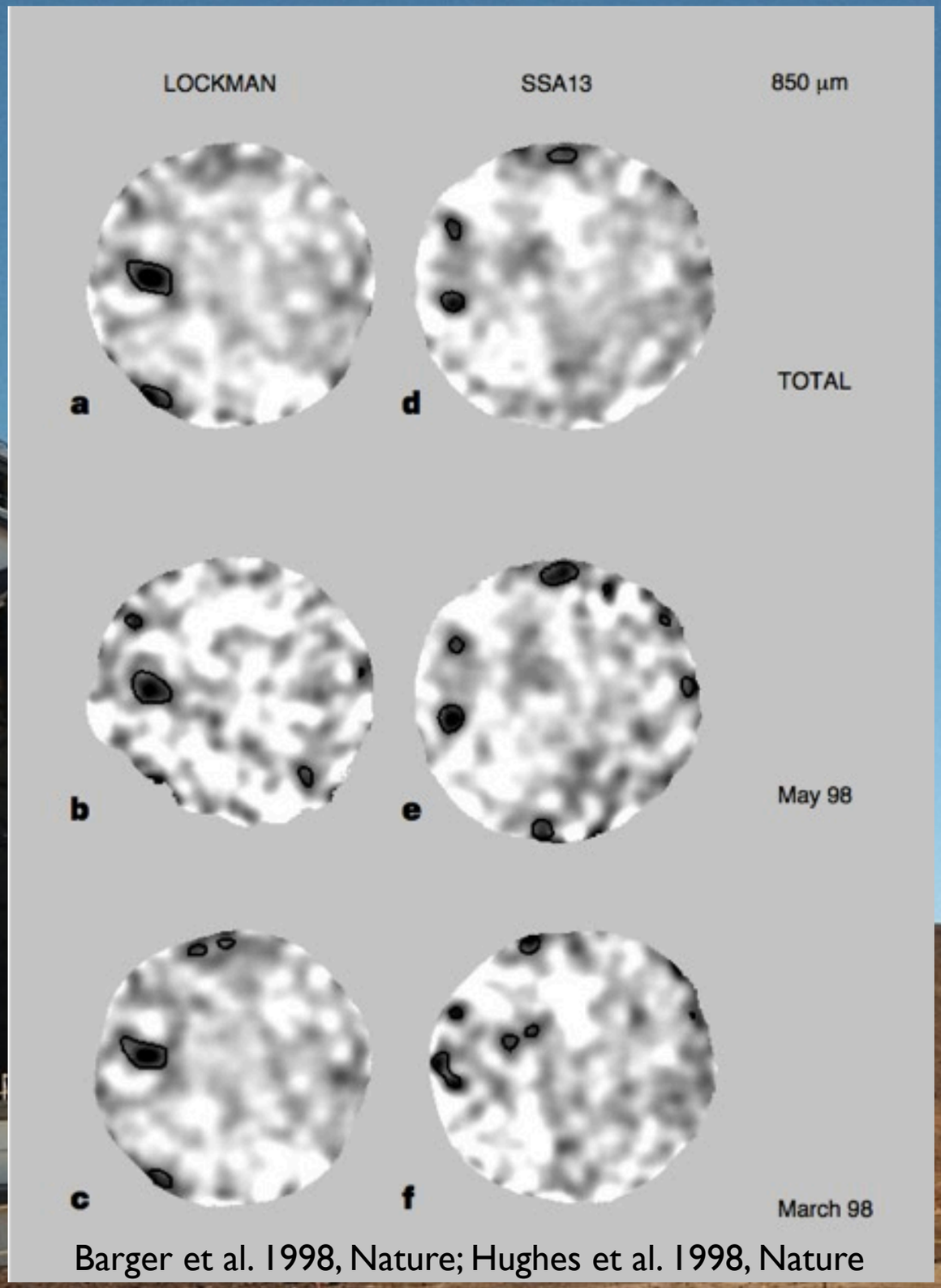
Chen et al. 2014, ApJ, submitted
arXiv: 1311.2943



DEX X Workshop
Jan 9th 2014

What are Sub-Millimeter Galaxies (SMGs)?

SCUBA



Barger et al. 1998, Nature; Hughes et al. 1998, Nature

http://www.jach.hawaii.edu/

Herschel

JCMT

IRAM

BLAST

APEX

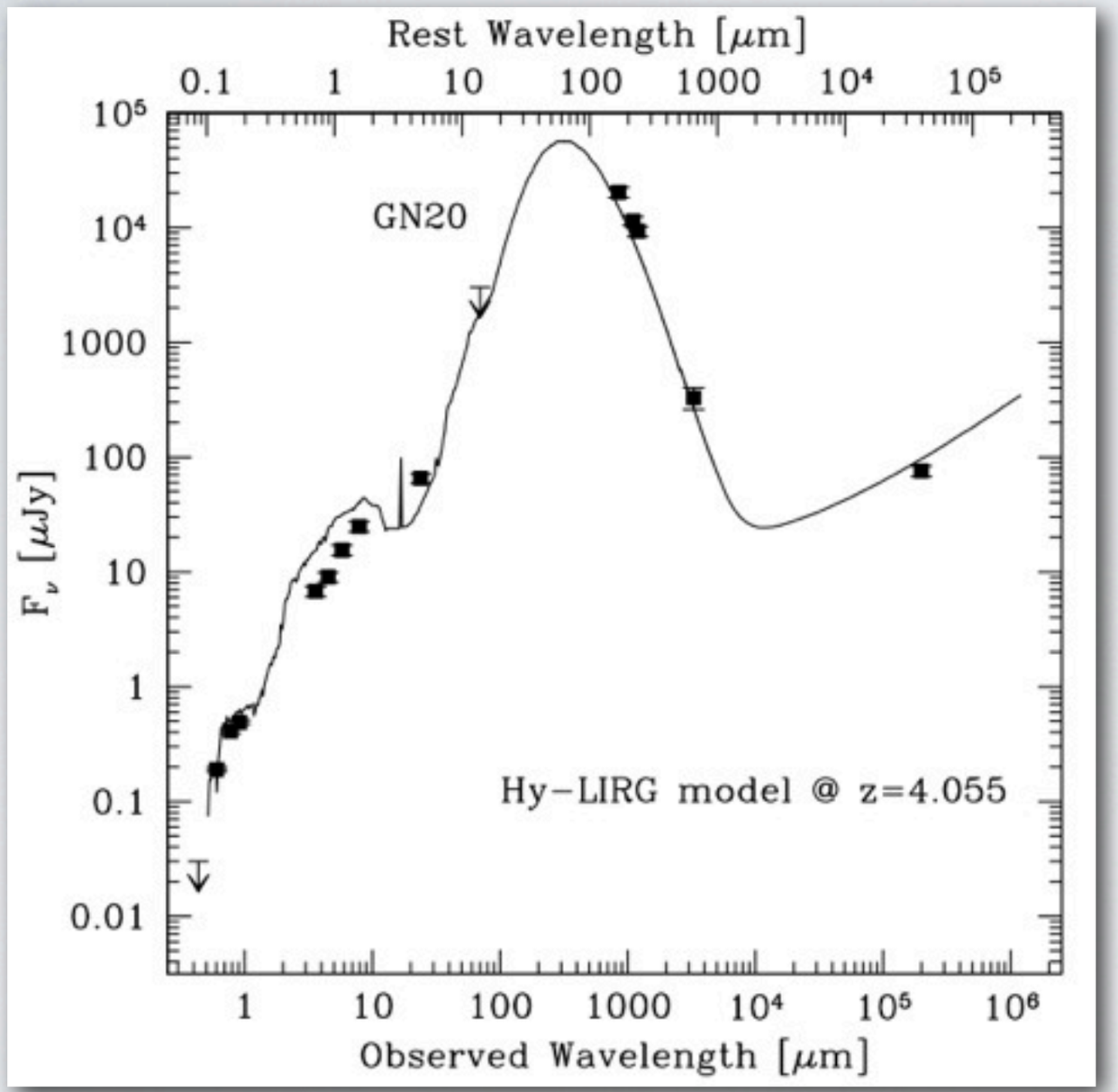
LMT

100 - 500 um

850 um

~1 mm

What are **S**ub-**M**illimeter **G**alaxie**s** (**SMGs**)?



Daddi et al. 2009

Obscured Starburst :

L_{IR} > 3x10^12 $M_\odot$,

SFR > 500 $M_\odot$ / yr

Massive :

M_{star} ~ 10^11 $M_\odot$

M_{gas} ~ 10^10~10^11 $M_\odot$

High redshift :

z ~ 1-5

SMG Jigsaw Puzzle

Theoretical Modeling

William Cowley

Individual SMGs

James Simpson

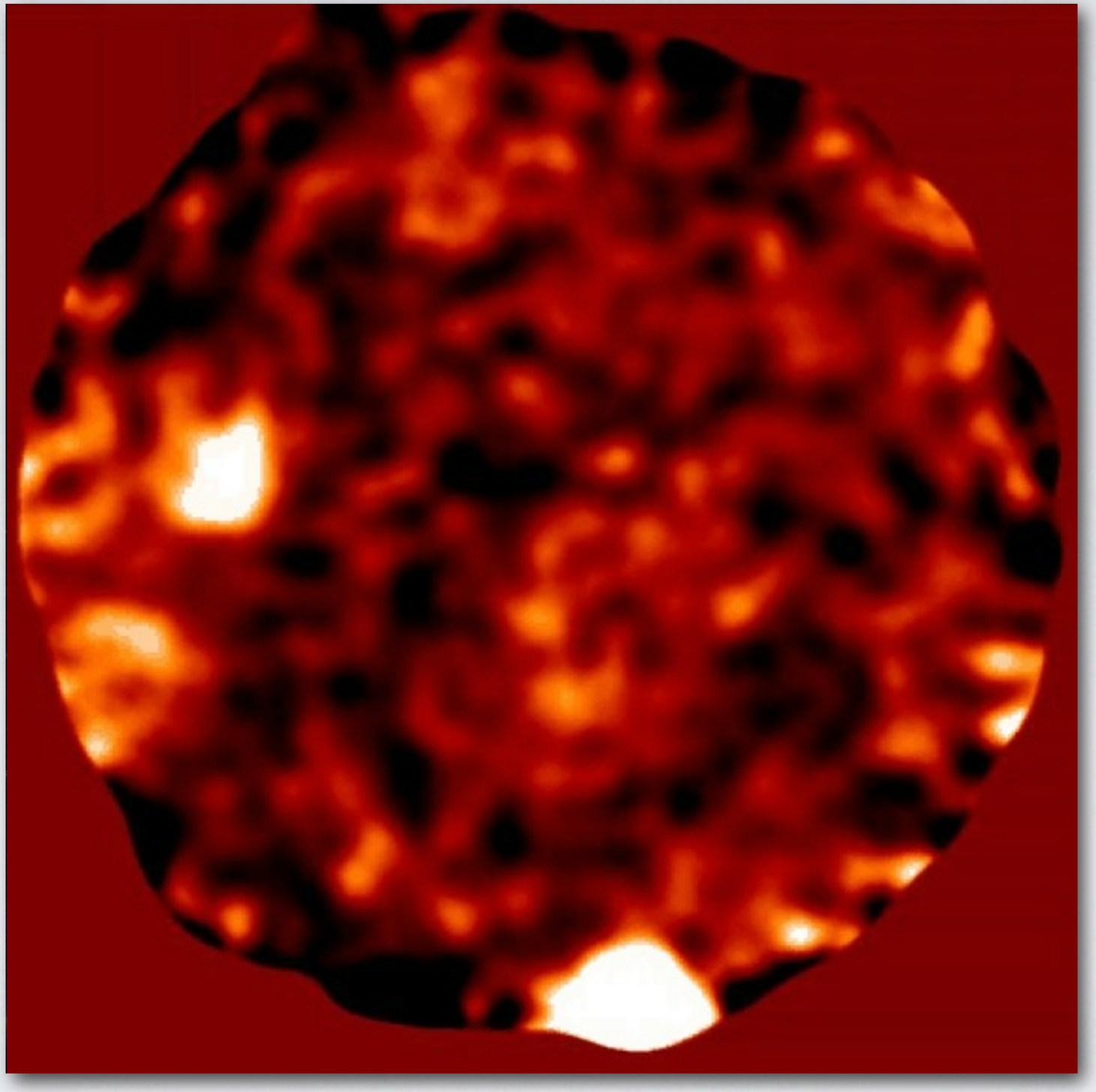
SMG in galaxy clusters

Cheng-Jiun Ma

Bright SMGs? **Faint** SMGs? Why do we care?

Biggest Challenge in FIR/Submm Observations :

Poor Resolution



A370
SCUBA

Cowie, Barger, & Kneib 2002

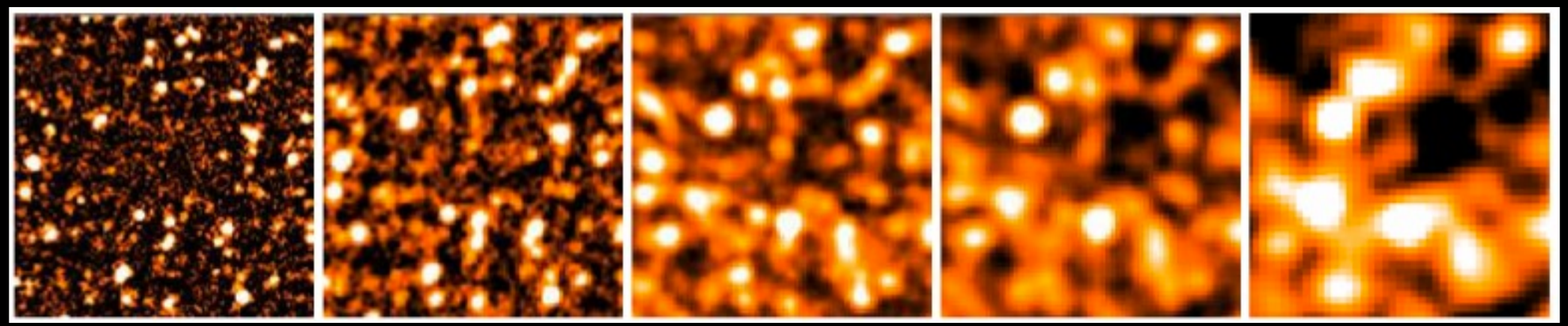
Biggest Challenge in FIR/Submm Observations :

Poor Resolution

A370
SCUBA

Cowie, Barger, & Kneib 2002

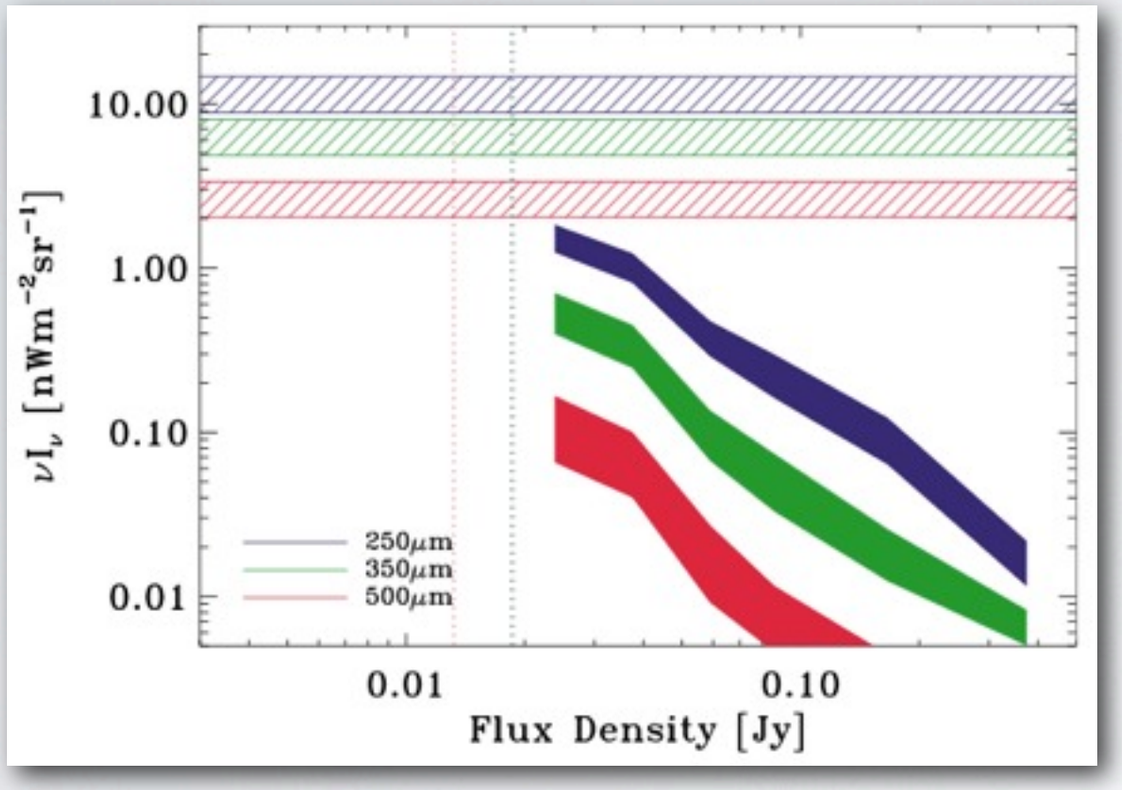
Confusion



Elbaz et al. 2011

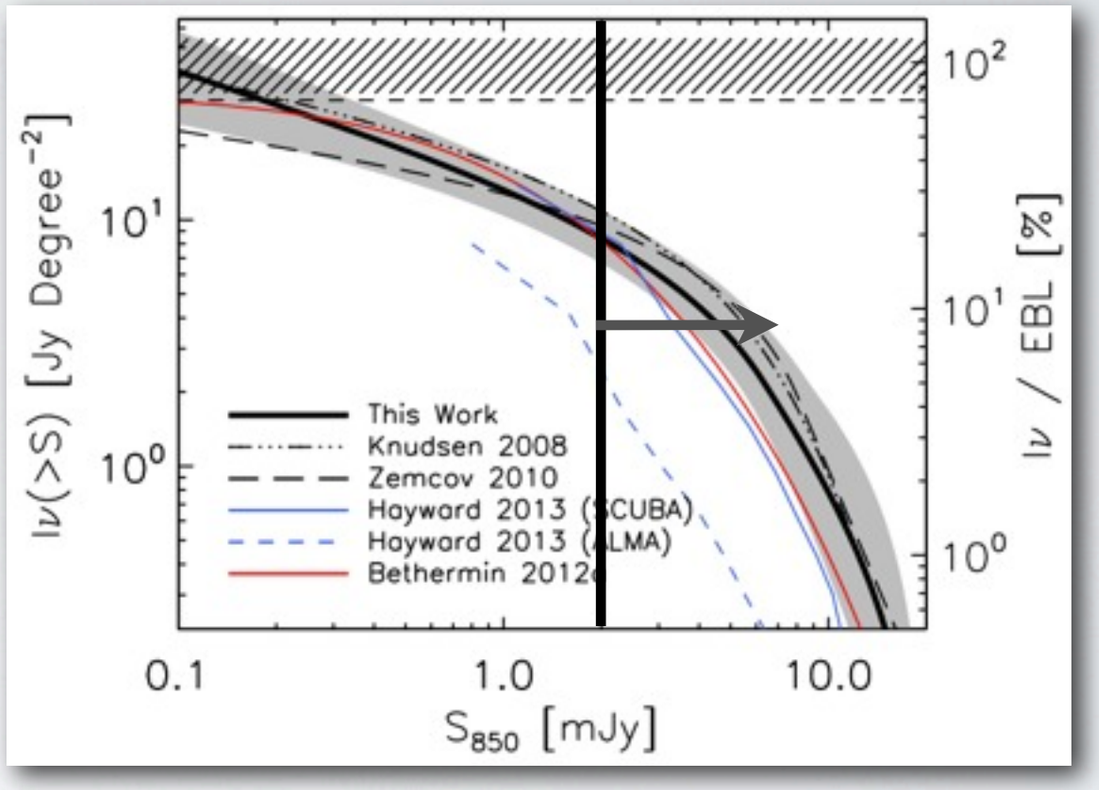
Confusion: Limited Amount of EBL Resolved

Herschel 250, 350, 500 um



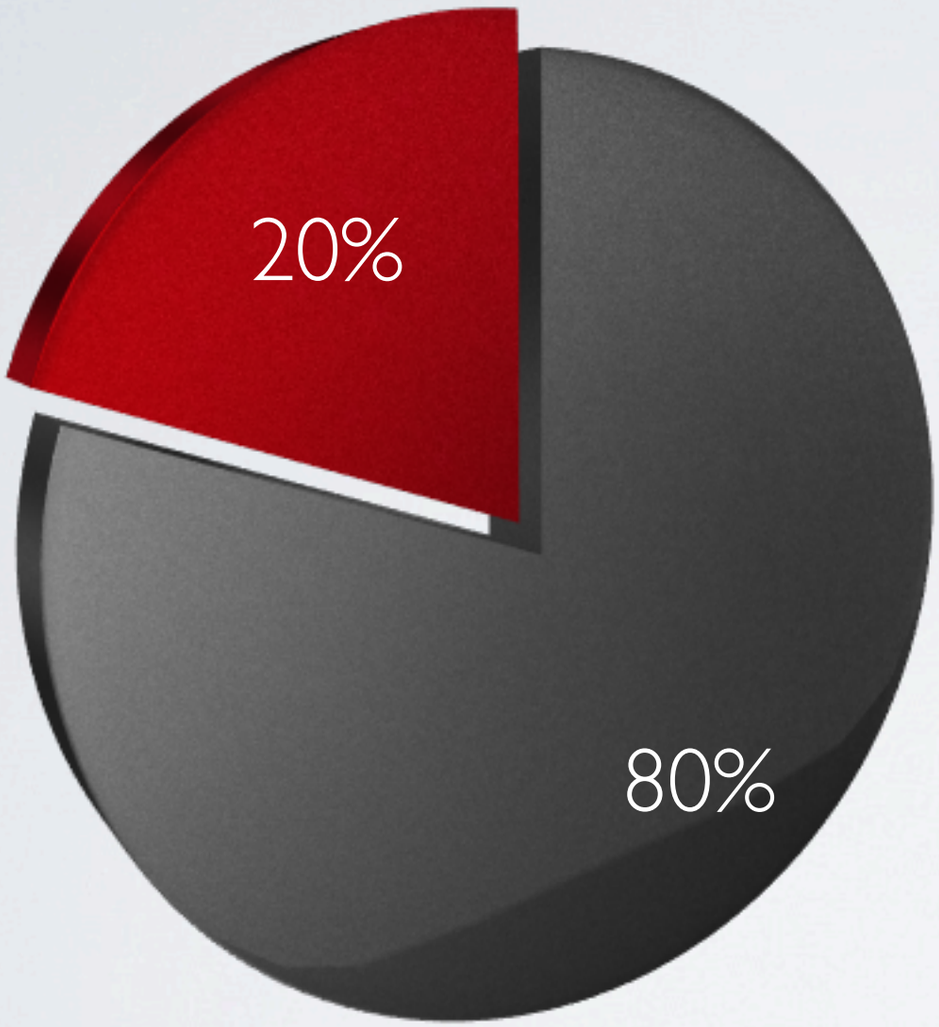
Oliver et al. 2010

SCUBA-2 850 um

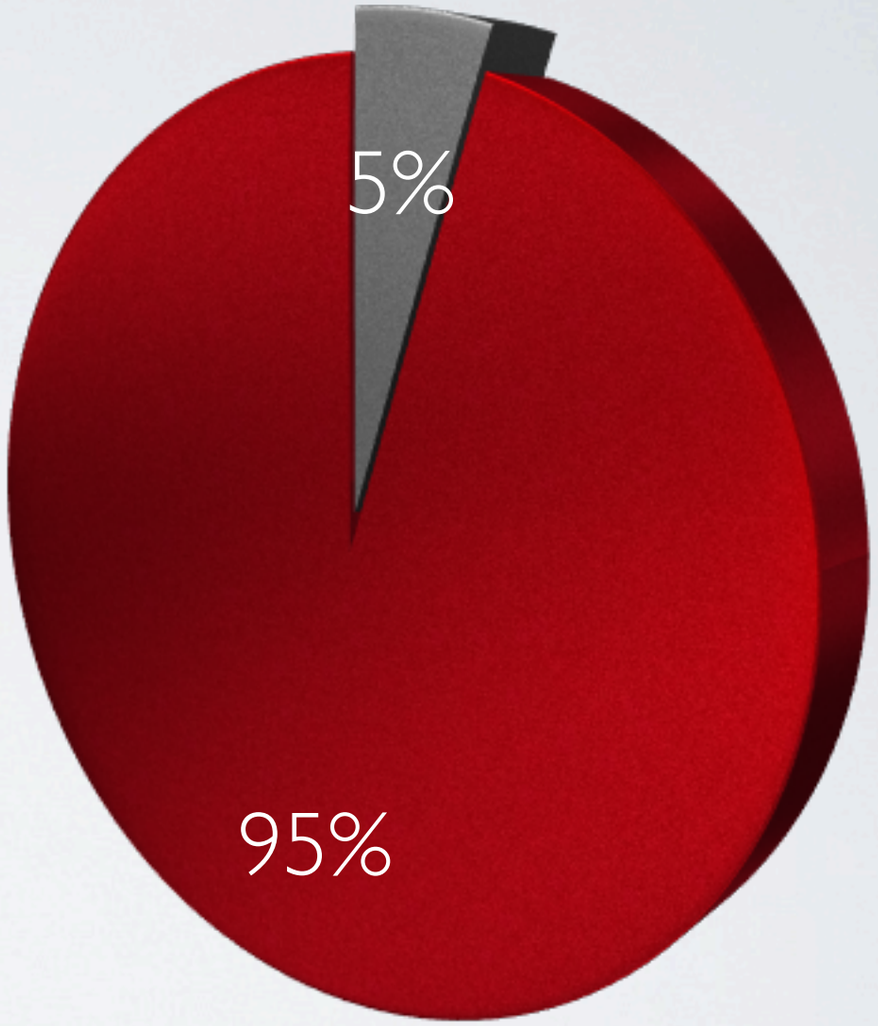


Chen et al. 2013b

850 um EBL



Published SMGs



Faint SMGs
Bright SMGs

Bright SMGs :

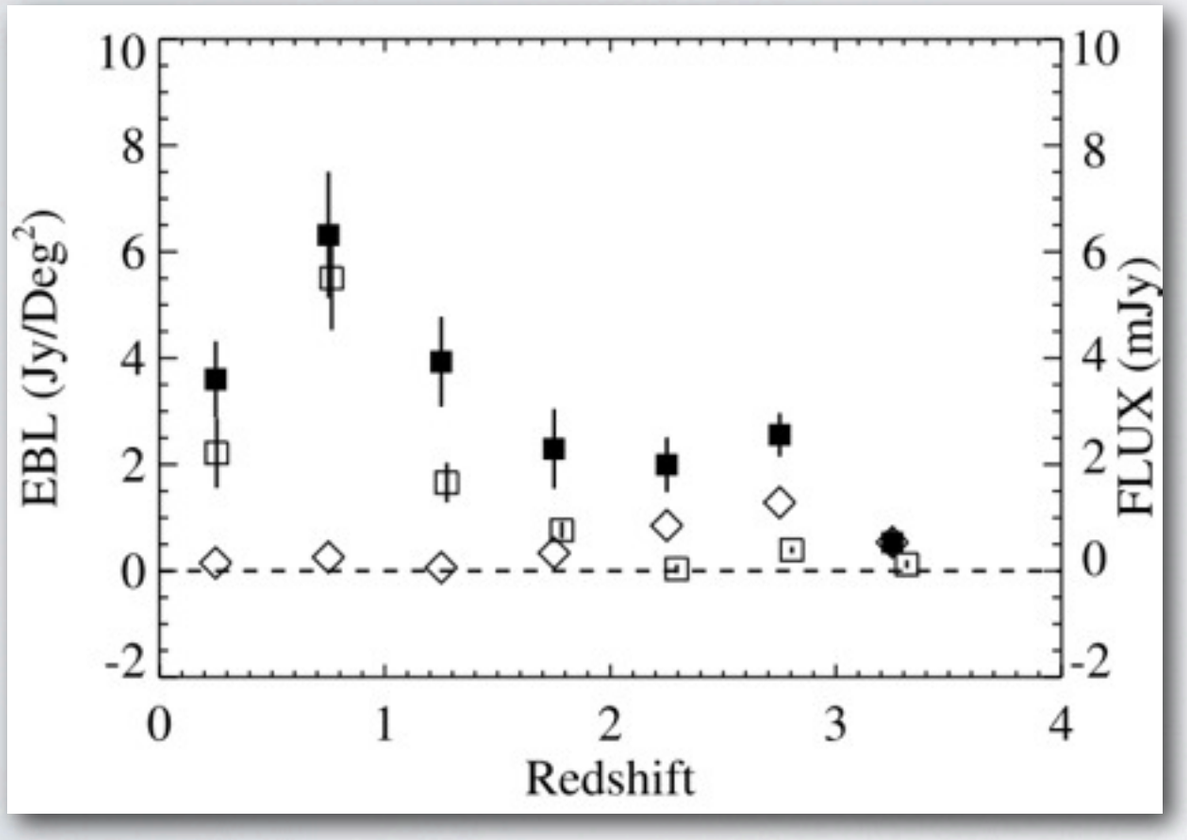
Observed Fluxes above Confusion Limits
Heavily Obscured High-*z* ULIRGs
Progenitors of Local Massive Ellipticals

Faint SMGs :

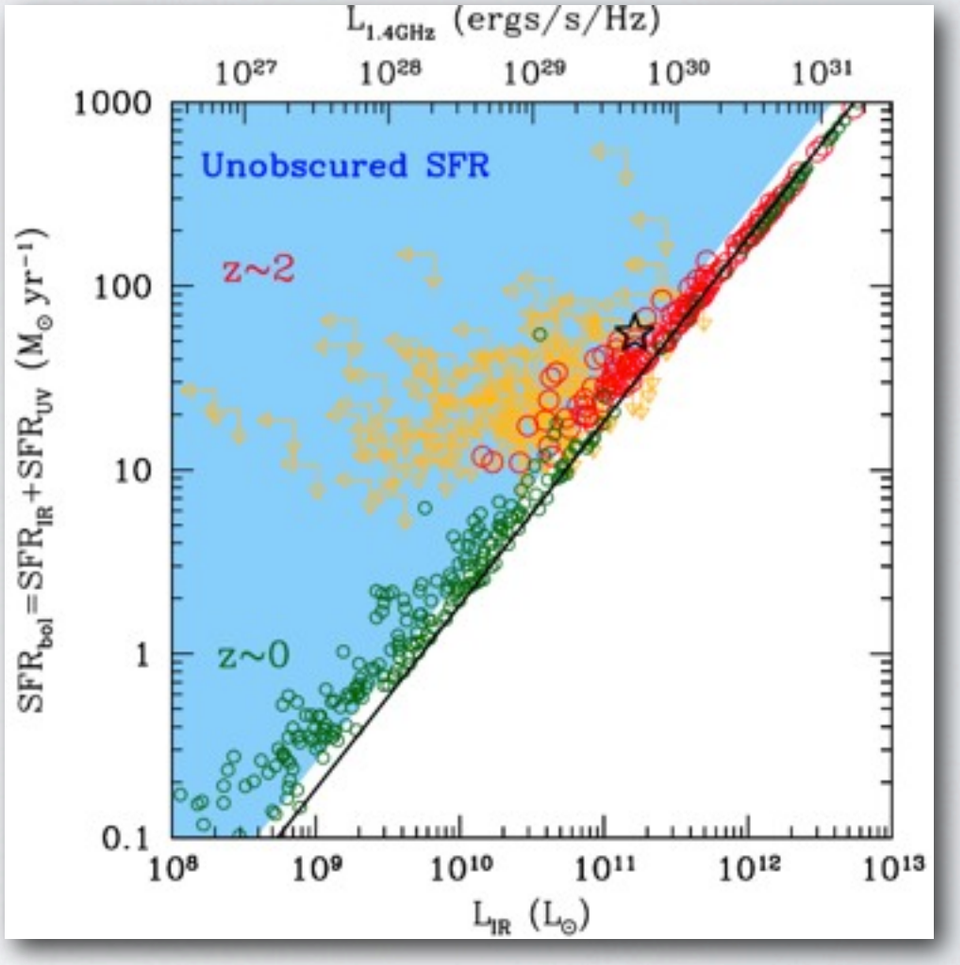
Observed Fluxes below Confusion Limits
Dominant Star-Former in the Dusty Universe
Redshift Distribution?
LIRGs?
Relation to other Star-Formers?

What did we expect from faint SMGs?

- Stacking analysis suggested most of them at z < 2
- LBGs at z~2 shows they are less obscured => UV/Optical bright

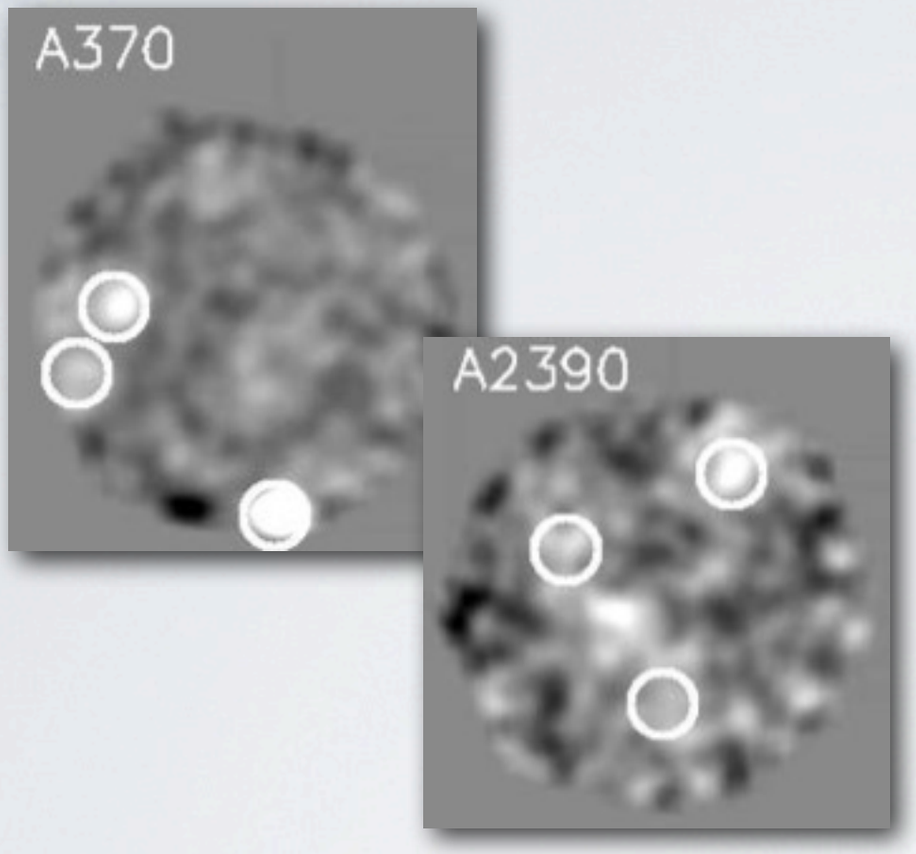


Wang et al. 2006

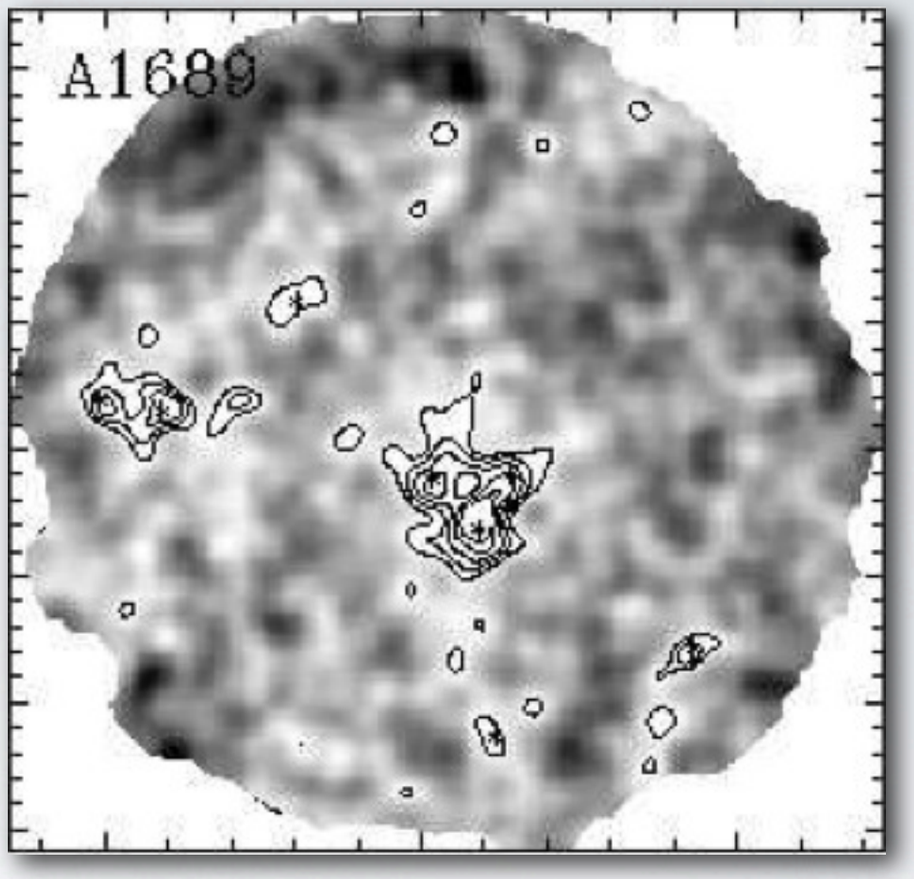


Reddy et al. 2012

Gravitational Lensing : Faint SMG Sample



Cowie, Barger, & Kneib 2002



Knudsen et al. 2008

- Follow-up by the Submillimeter Array (SMA)
- All observed by SCUBA-2 (Chen et al. 2013a,b)
- Well studied clusters - deep multi-wavebands data available

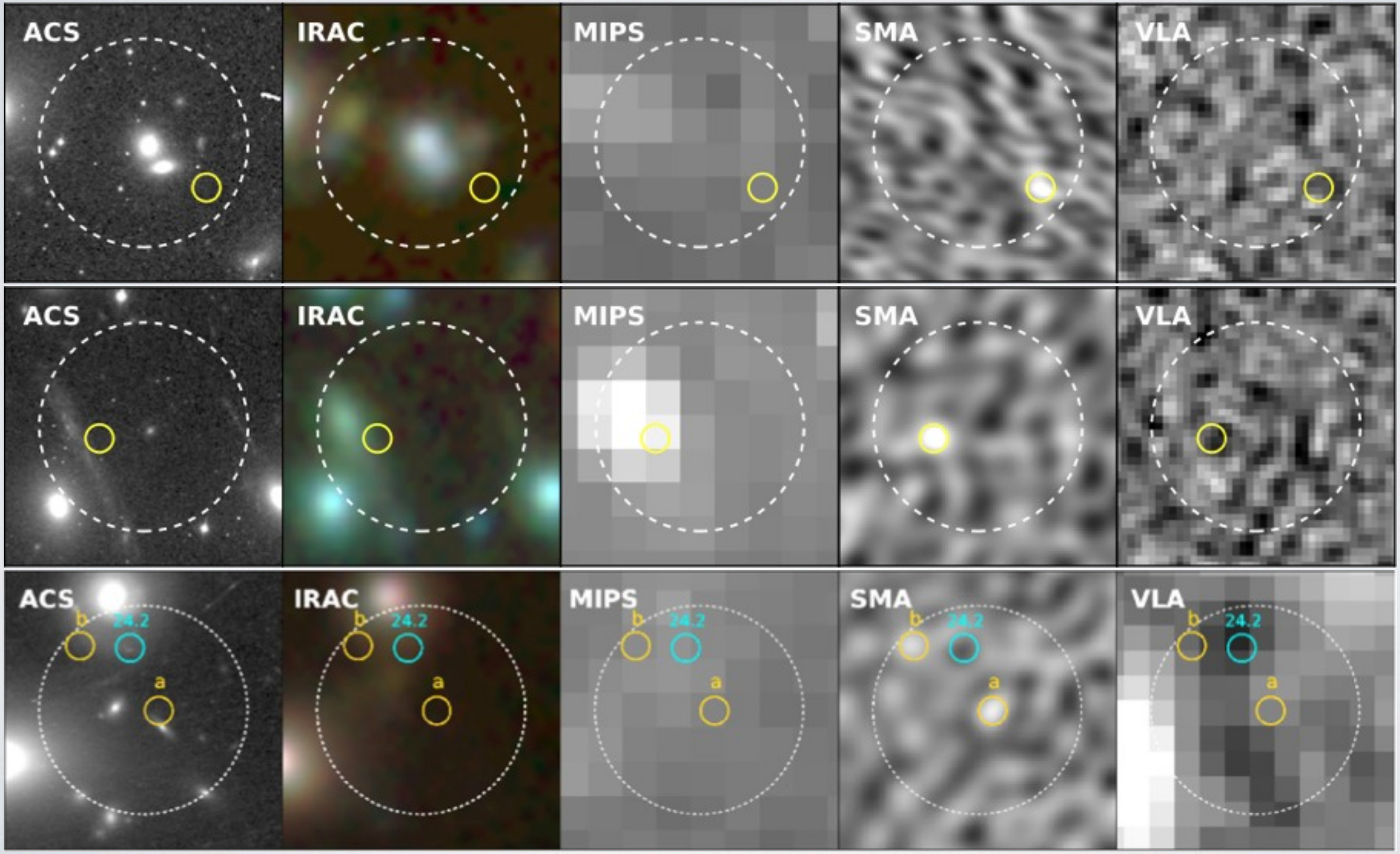
SMA Results: 6 detections

Source Name	SMA R.A. (J2000) (h m s)	SMA Decl. (J2000) (d m s)	SCUBA R.A. (J2000) (h m s)	SCUBA Decl. (J2000) (d m s)	SCUBA 850 μm (mJy)	SCUBA-2 850 μm (mJy)	SMA 870 μm (mJy)
A370-5	...	...	02 39 53.83	-01 33 37.0	2.17±0.57	-0.01±0.51	<1.68(4 σ)
A2390-3	21 53 35.16	17 41 06.1	21 53 35.48	17 41 09.3	3.24±0.78	2.71±0.62	3.96±0.59
A2390-5	21 53 34.37	17 42 01.5	21 53 34.15	17 42 02.3	2.64±0.72	1.19±0.62	4.72±0.76
SMM J131128.6–012036	...	...	13 11 28.6	-01 20 36	2.6±0.8	-0.95±0.48	<2.76(4 σ)
SMM J131129.1–012049	13 11 29.22	–01 20 44.5	13 11 29.1	-01 20 49	4.7±0.8	4.39±0.48	5.25±0.70
SMM J131132.0–011955			13 11 32.0	-01 19 55	3.3±1.0	3.28±0.50	
a	13 11 31.93	–01 19 55.1	...	...	...	...	2.73±0.64
b	13 11 32.30	–01 19 50.4	...	...	...	...	2.41±0.59
SMM J131134.1–012021	...	...	13 11 34.1	-01 20 21	3.2±1.0	4.32±0.52	<1.76(4 σ)
SMM J131135.1–012018	13 11 34.95	–01 20 17.2	13 11 35.1	-01 20 18	4.9±1.6	4.15±0.54	3.92±0.61

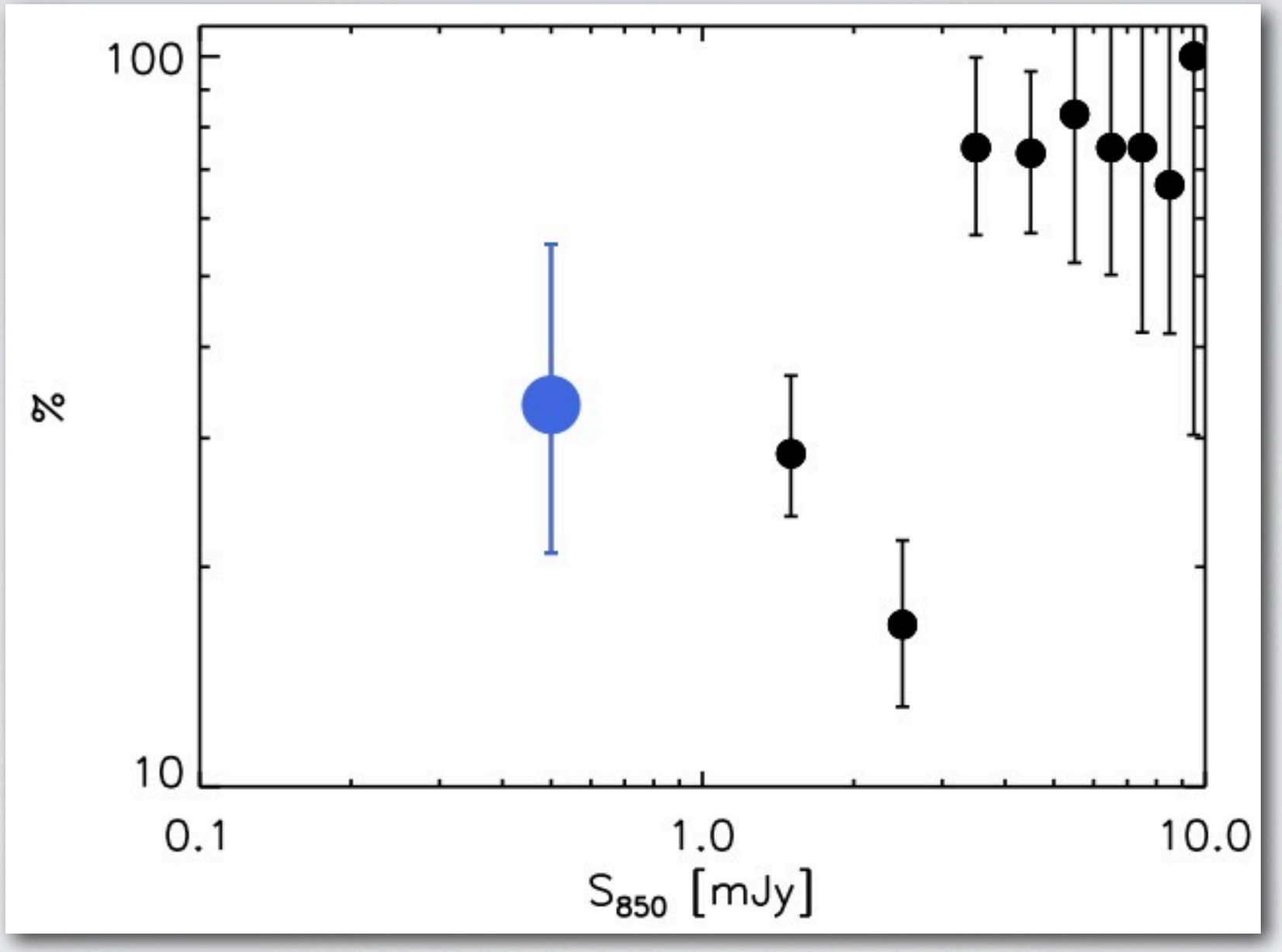
Chen et al. 2014

- First case of single-dish detected faint SMGs broken into multiple sources, ~20% multiple fraction.

SMA Results: Lack of optical/IR/radio counterparts



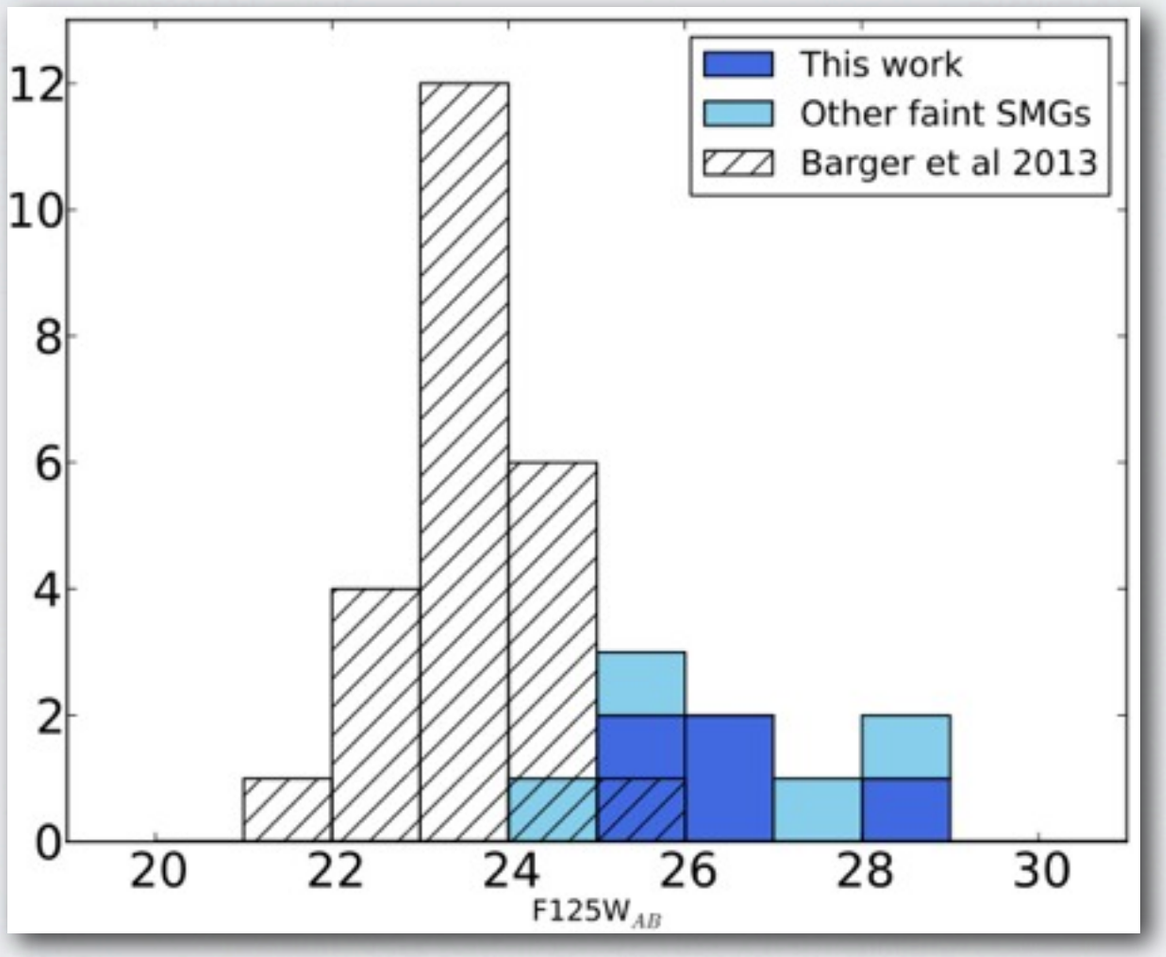
SMA Results: Low Recovery Fraction



Chen et al. 2014

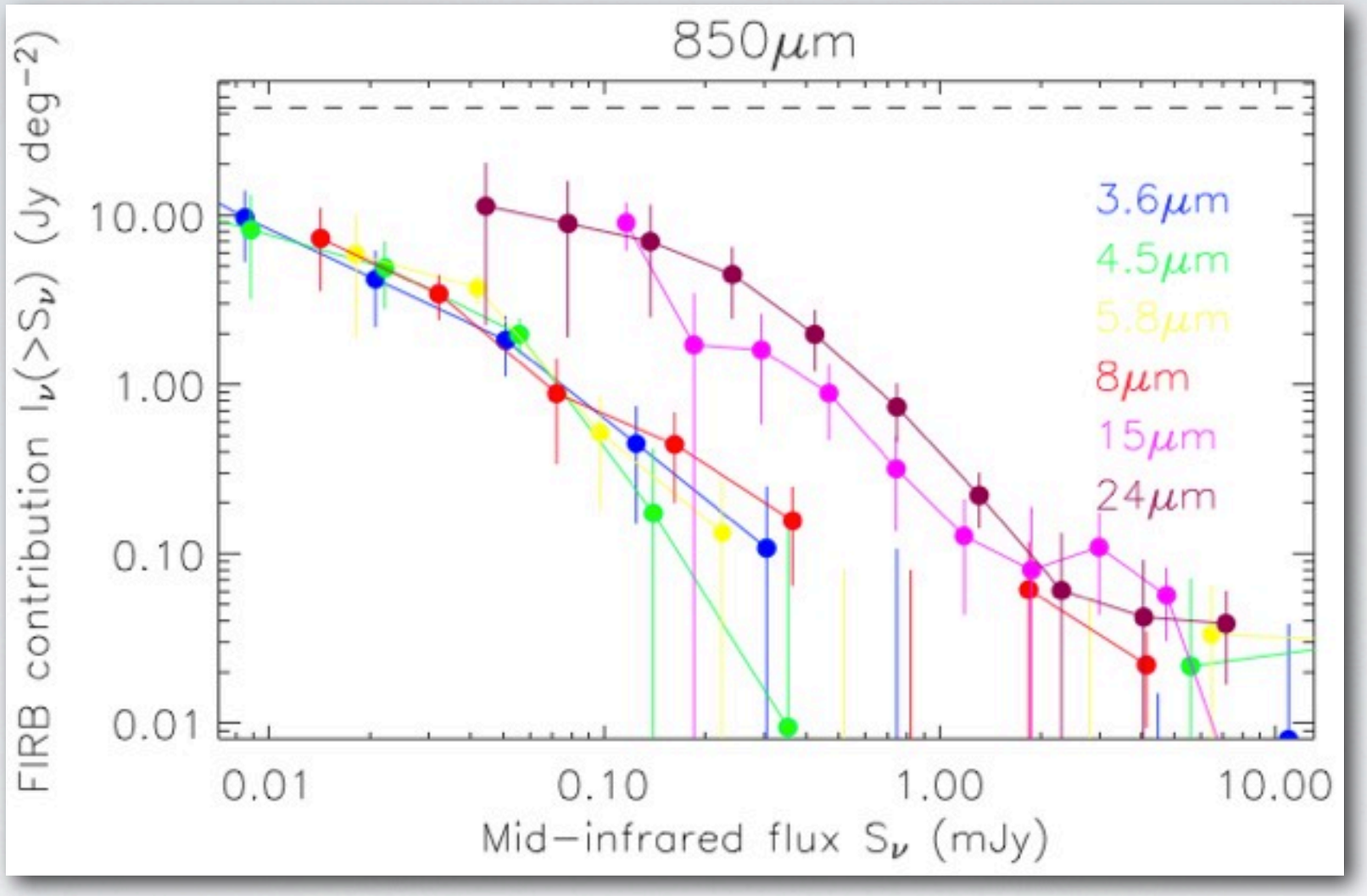
SMA Results: Faint SMGs are Optically Faint

ID	Magnifications	$S_{870,intrinsic}$ (mJy)	$S_{F125W,intrinsic}$ (mag)	z[b]	$\log(L_{8-1000\mu m})$
A2390-3	4.8 (4.7–5.3)	0.83 (0.64–0.97)	>26.8	>3.7	11.8–12.0
A2390-5	45 (>45)	0.12 (<0.12)	>28.2	>4.0	<11.1
SMM J131129.1	19 (16–22)	0.10 (0.08–0.12)[a]	26.6 (26.5–26.8)	2.600	10.9–11.1[a]
SMM J131132.0a	10 (>10)	0.34 (<0.34)	>25.6	>0.5	<11.6
SMM J131132.0b	20 (>20)	0.15 (<0.15)	>25.4	>0.5	<11.8
SMM J131135.1	6 (3–9)	0.65 (0.37–1.51)	···	>0.5	11.6–11.8



Chen et al. 2014

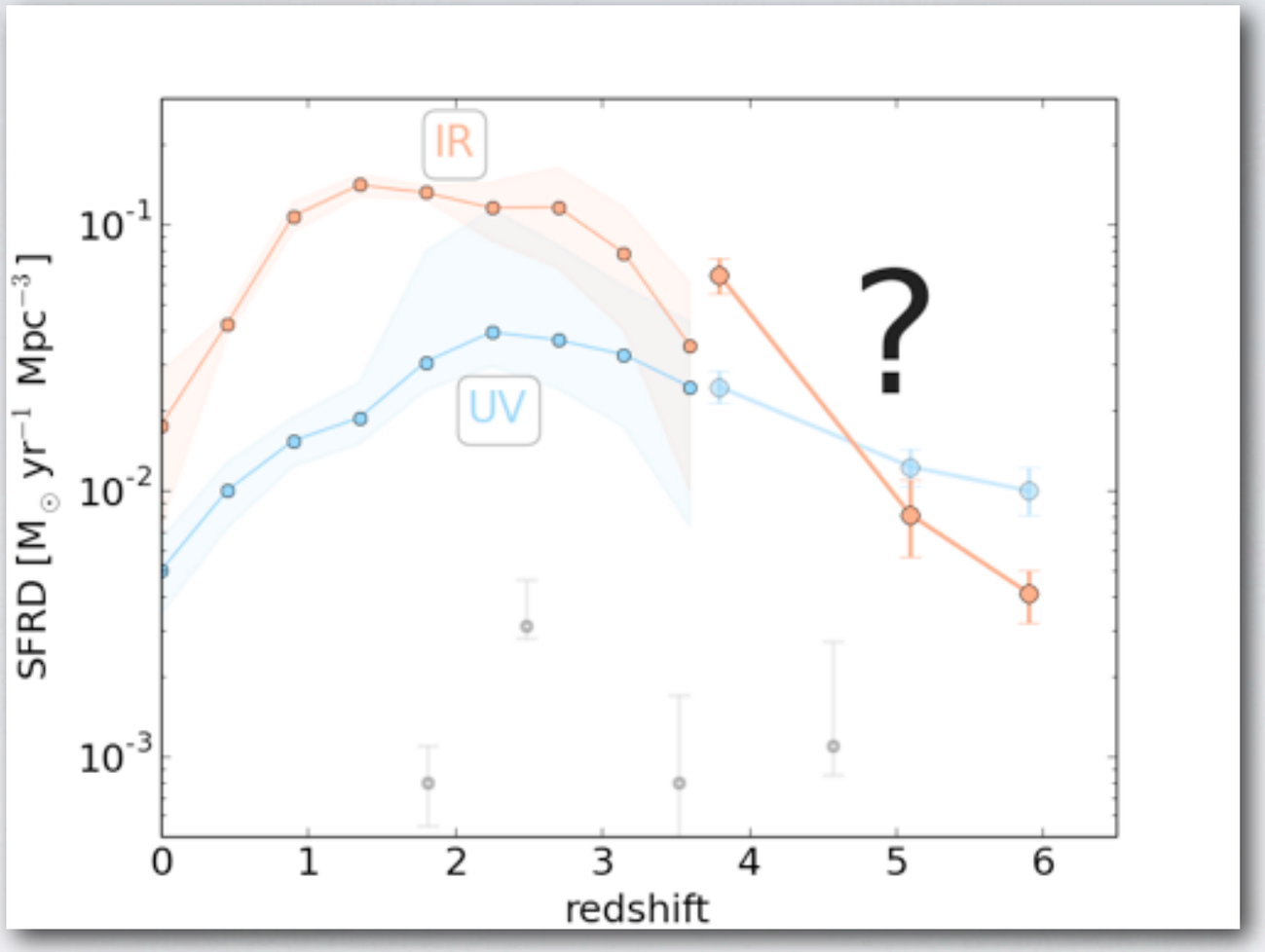
Stacking Analysis Confirm Our Results



Serjeant et al. 2008

- Also in Wang et al. 2006 and Dye et al. 2006
- ~50% of the EBL is still missing in stacking analysis using medium deep NIR/MIR sample.

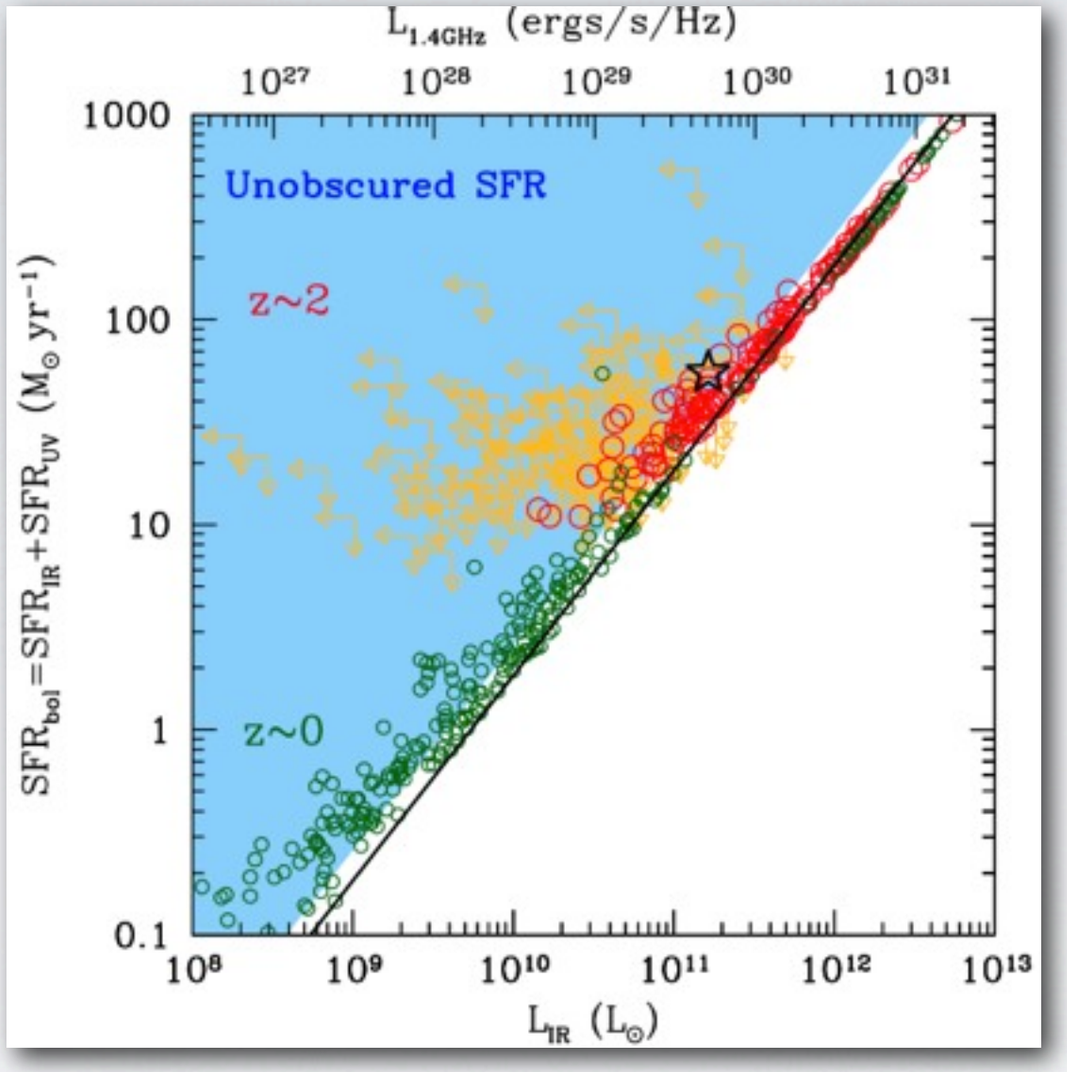
Implications: High-z or Ultra Dusty?



Burgarella et al. 2013 + Bouwens et al. 2009 + Swinbank et al. 2013

- Many high-z obscured star-formation yet to be found ?

Implications: High-z or Ultra Dusty?



Reddy et al. 2012

- Ultra dusty, low luminosity sources?

Summary:

- Using the SMA to pinpoint 6 faint SMGs behind well-studied massive lensing clusters, all confirmed by SCUBA-2.

- Most very faint in optical and IR and some even missed in extremely deep radio maps, suggesting many faint SMGs are high-z and/or very dusty that can only be probed through direct submm observations.

- This pilot study suggests that the properties of the faint SMGs will have fundamental impacts on our understandings of the dusty universe, as well as the connections between obscured and unobscured star formation.