Lensing-corrected galaxy number counts in the ALMA Frontier Fields Survey

Alejandra M. Muñoz Arancibia
Fondecyt Postdoc
Universidad de Valparaíso, Chile

Collaborators:
Jorge González-López, Eduardo Ibar, Franz Bauer,
Nicolas Laporte, Mauricio Carrasco, Rychard Bouwens
and the ALMA Frontier Fields Team

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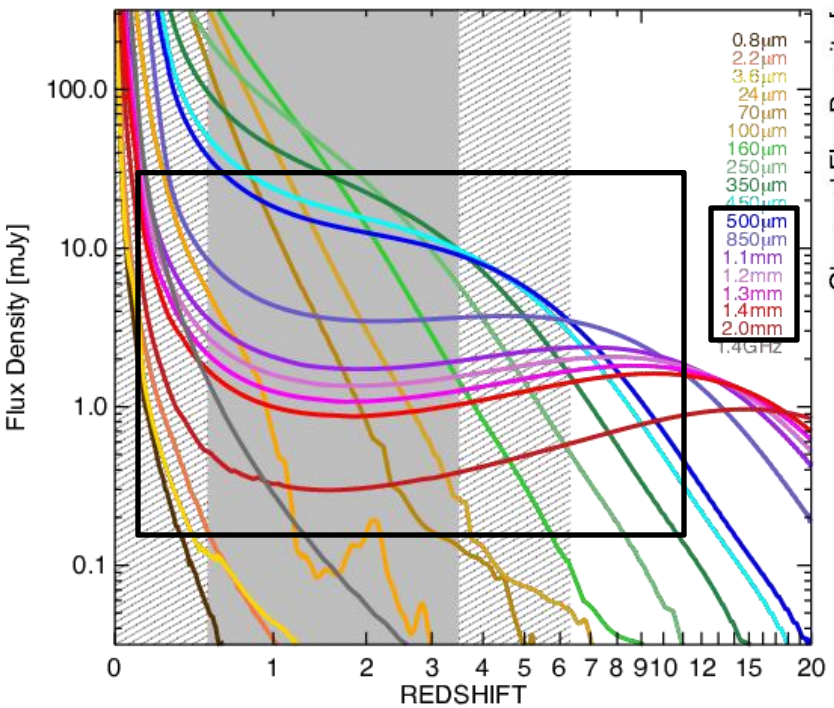
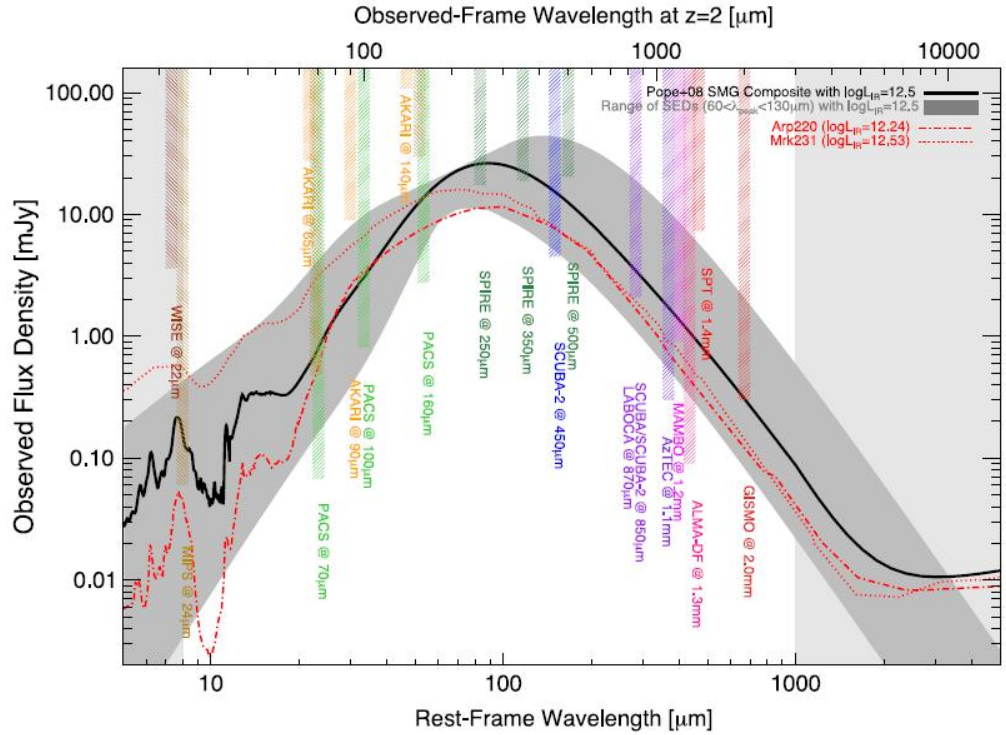
Galaxies in the far infrared to mm

Submillimeter galaxies - dusty star-forming galaxies (DSFGs)





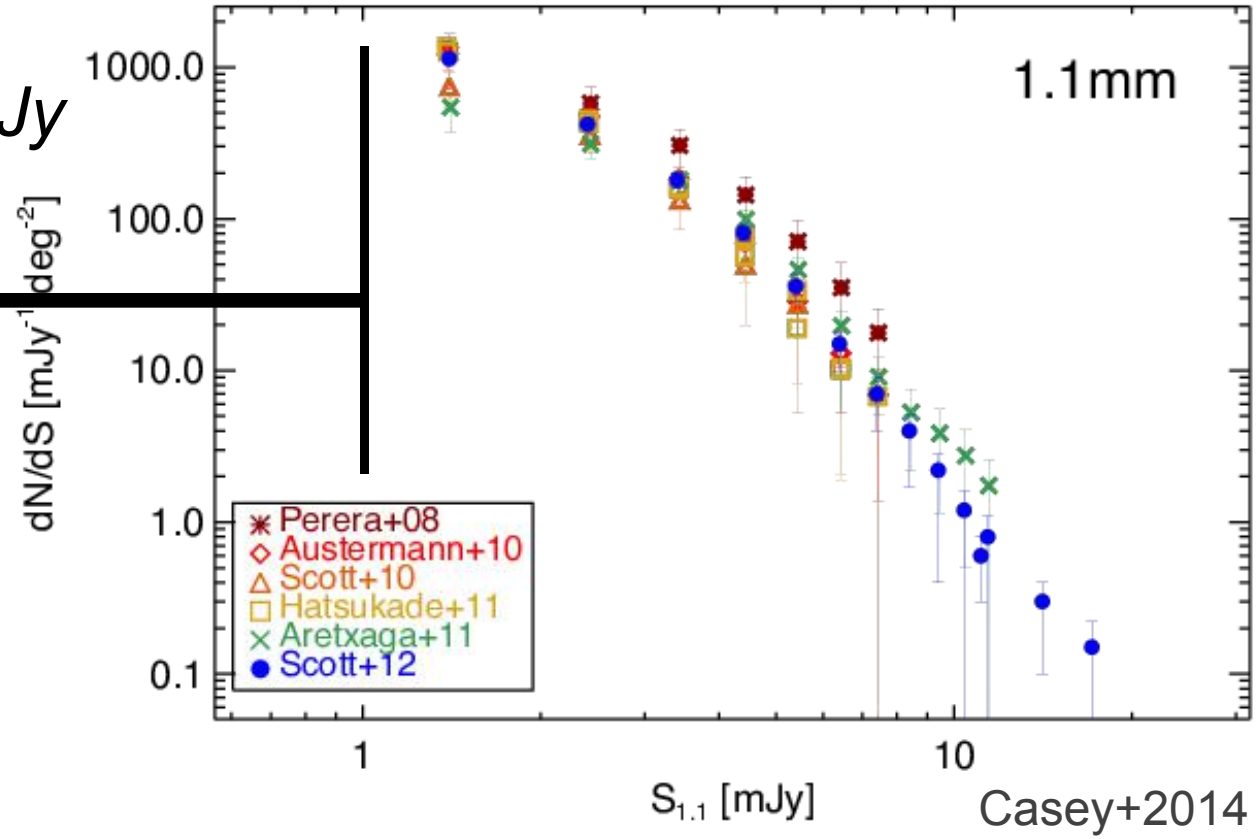
Casey+2014

Galaxies in the far infrared to mm

Submillimeter galaxies - dusty star-forming galaxies (DSFGs)

Number counts

To the submJy population

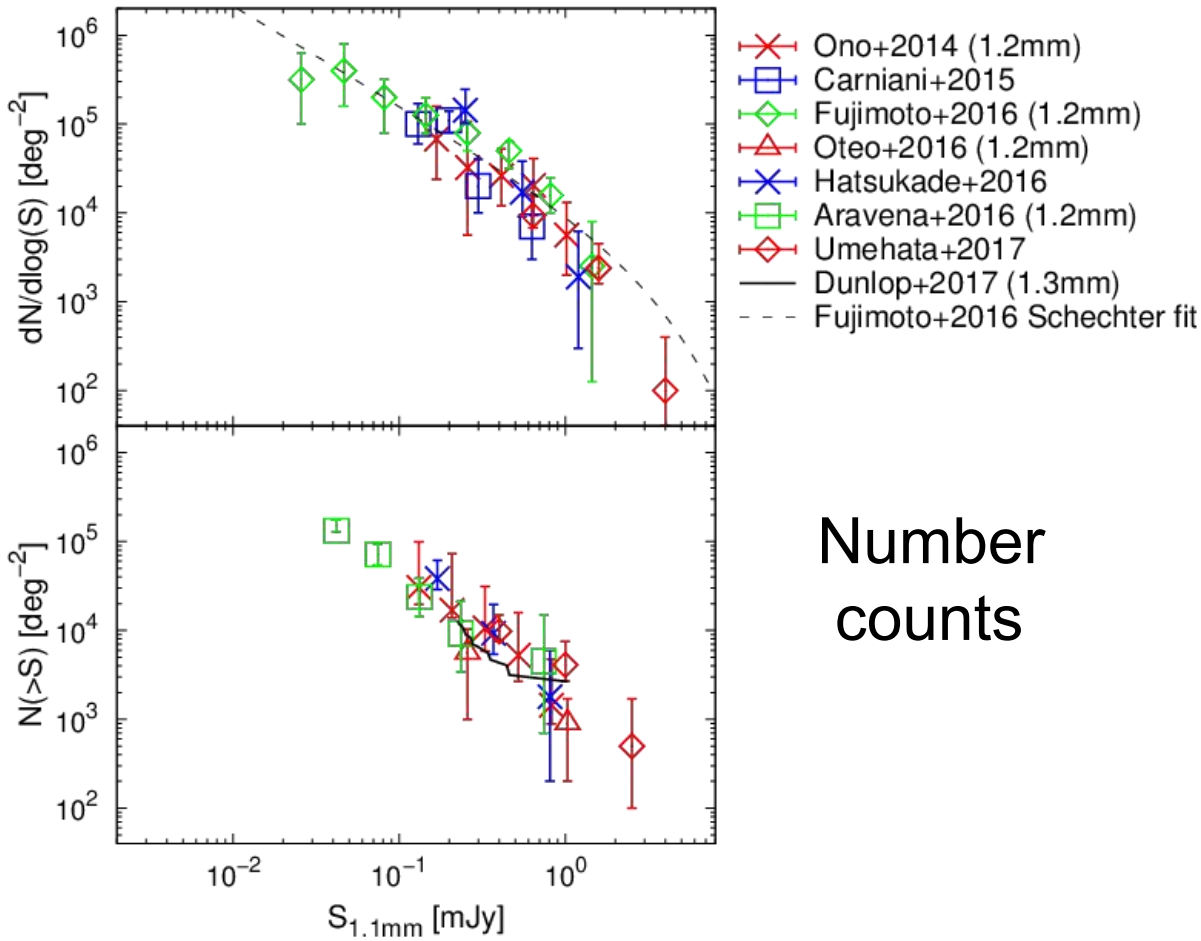


Casey+2014

Galaxies in the far infrared to mm

Submillimeter galaxies - dusty star-forming galaxies (DSFGs)

To the submJy population

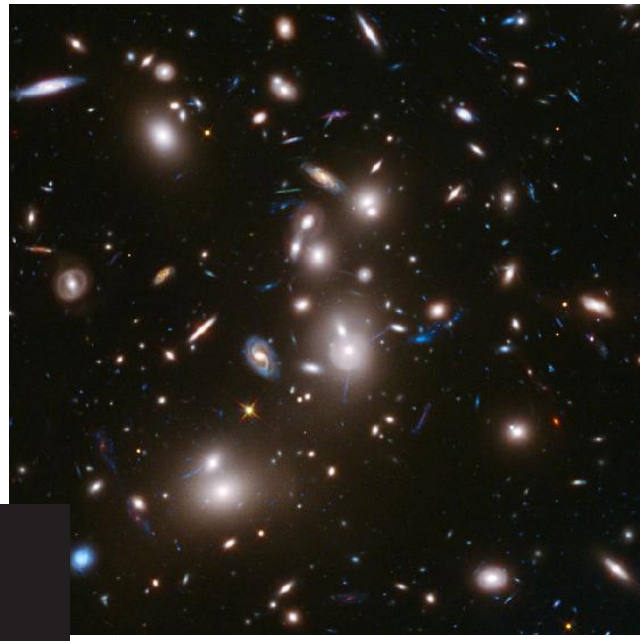


Number counts

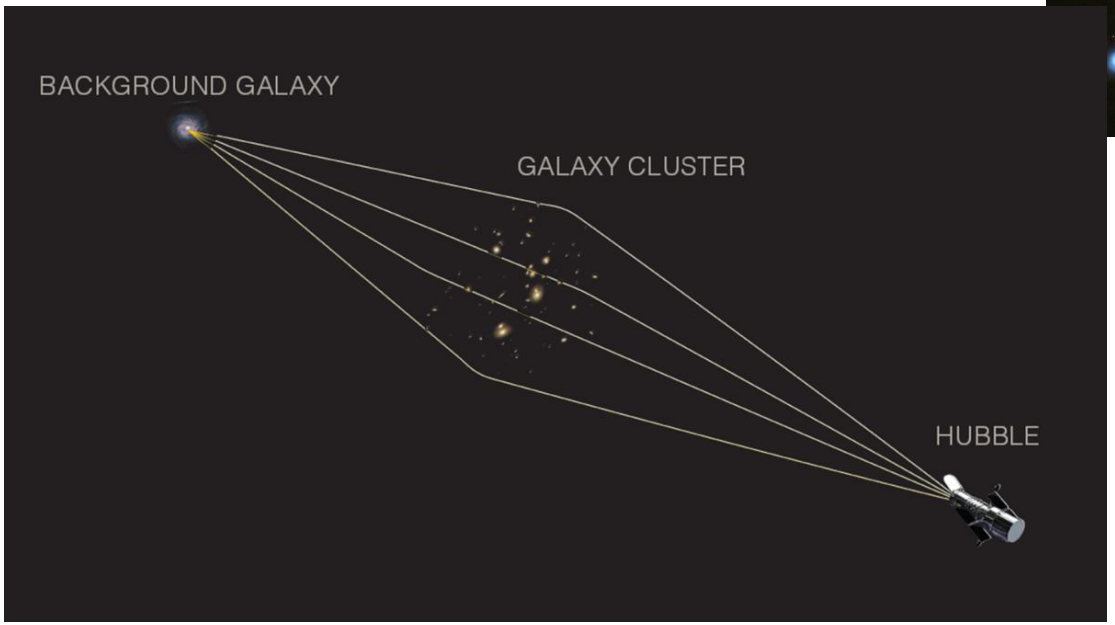
Probing faint DSFGs

Two ways

1) Deeper observations
2) Strong lensing by galaxy clusters



Lotz+2017



frontierfields.org

Probing faint DSFGs

Two ways

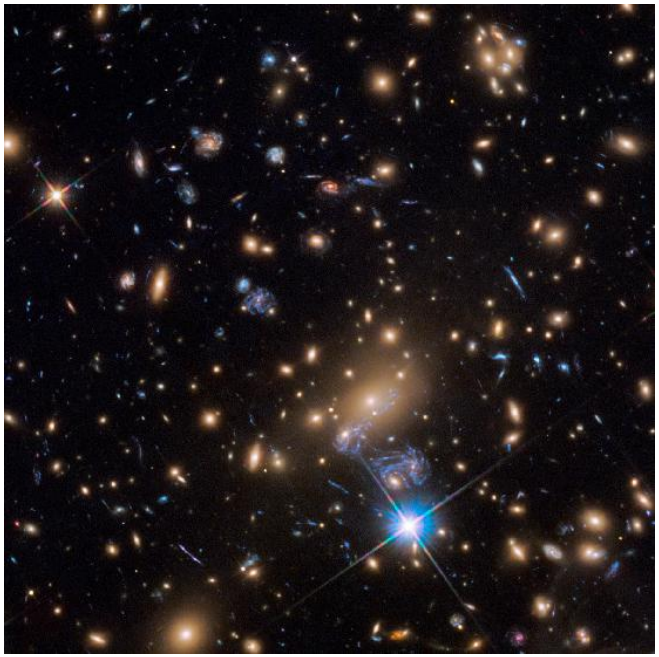
1) Deeper observations
2) Strong lensing by galaxy clusters

We use both!
ALMA observations in the Frontier Fields

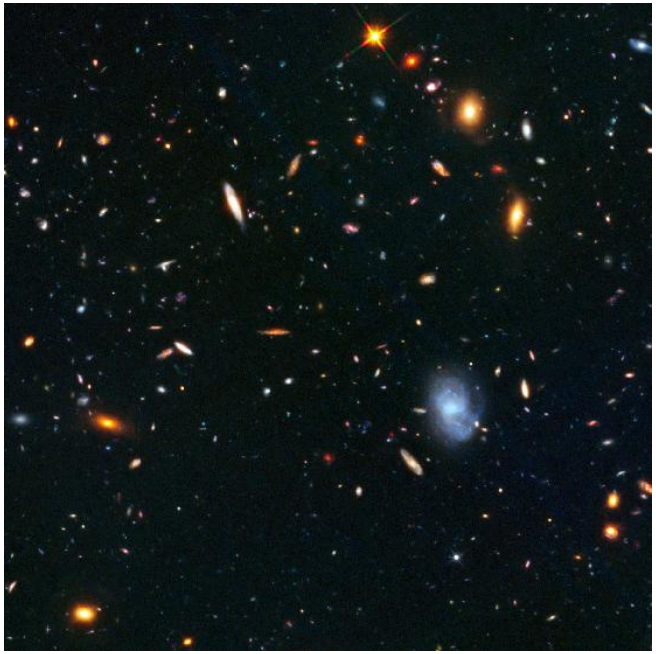
The Frontier Fields (FF)

Legacy program
Deep multi-band HST and Spitzer imaging

Lotz+2017

6 × 

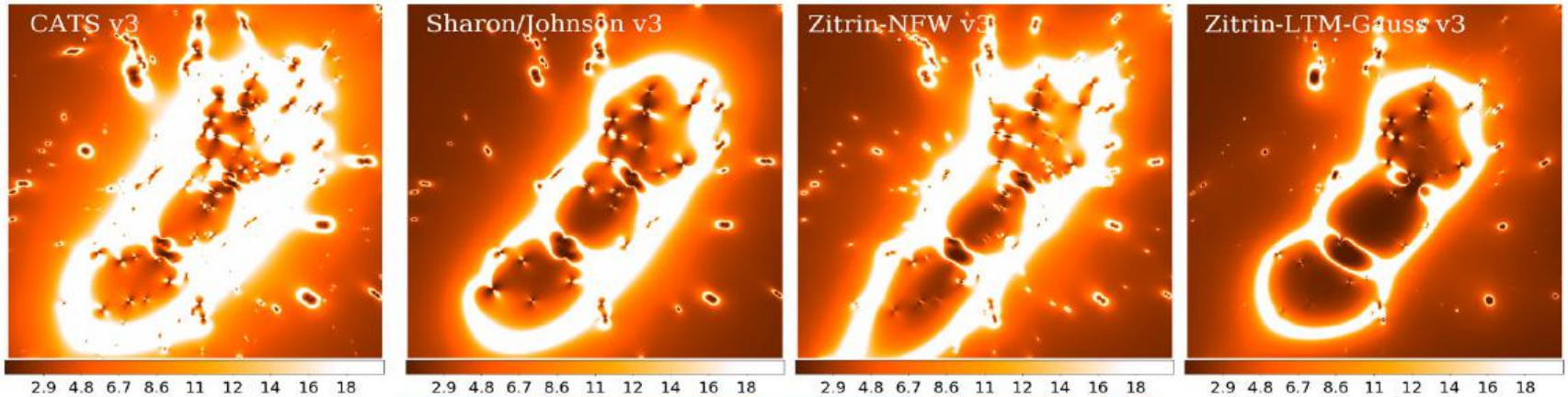
strong lensing
galaxy clusters

+ 6 × 

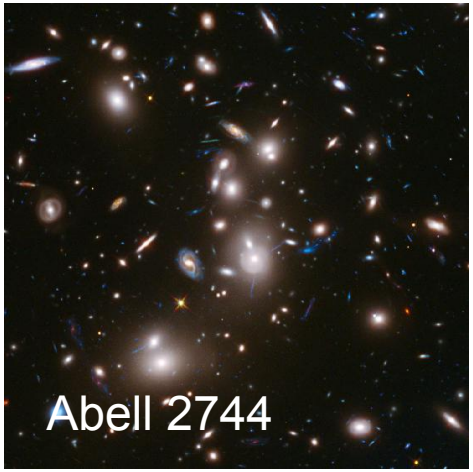
adjacent
parallel fields

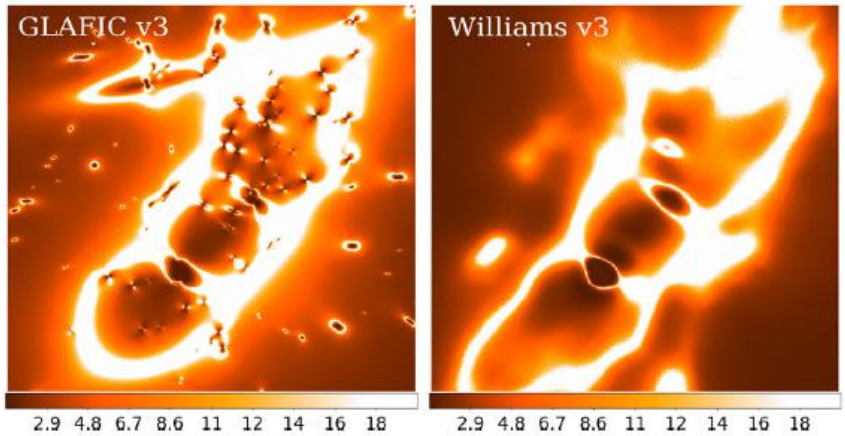
The Frontier Fields (FF)

Gravitational lensing models by several independent teams
Publicly available! archive.stsci.edu/prepds/frontier/lensmodels/



Priewe+2017





Lotz+2017

Magnification maps

This work

Number counts in three FF galaxy clusters

	A2744	**MACSJ0416**	**MACSJ1149**
Full name	Abell 2744	MACSJ0416.1-2403	MACSJ1149.5+2223
Redshift	0.308	0.396	0.543

ALMA observations introduced by González-López+2017
(PI: Bauer)

- 1.1mm continuum maps ~4.6 arcmin^2 each
  (= ~14 arcmin^2 total observed area)
- rms depth ~55-71 μJy/beam
- beam size ~0.5-1.5"

This work

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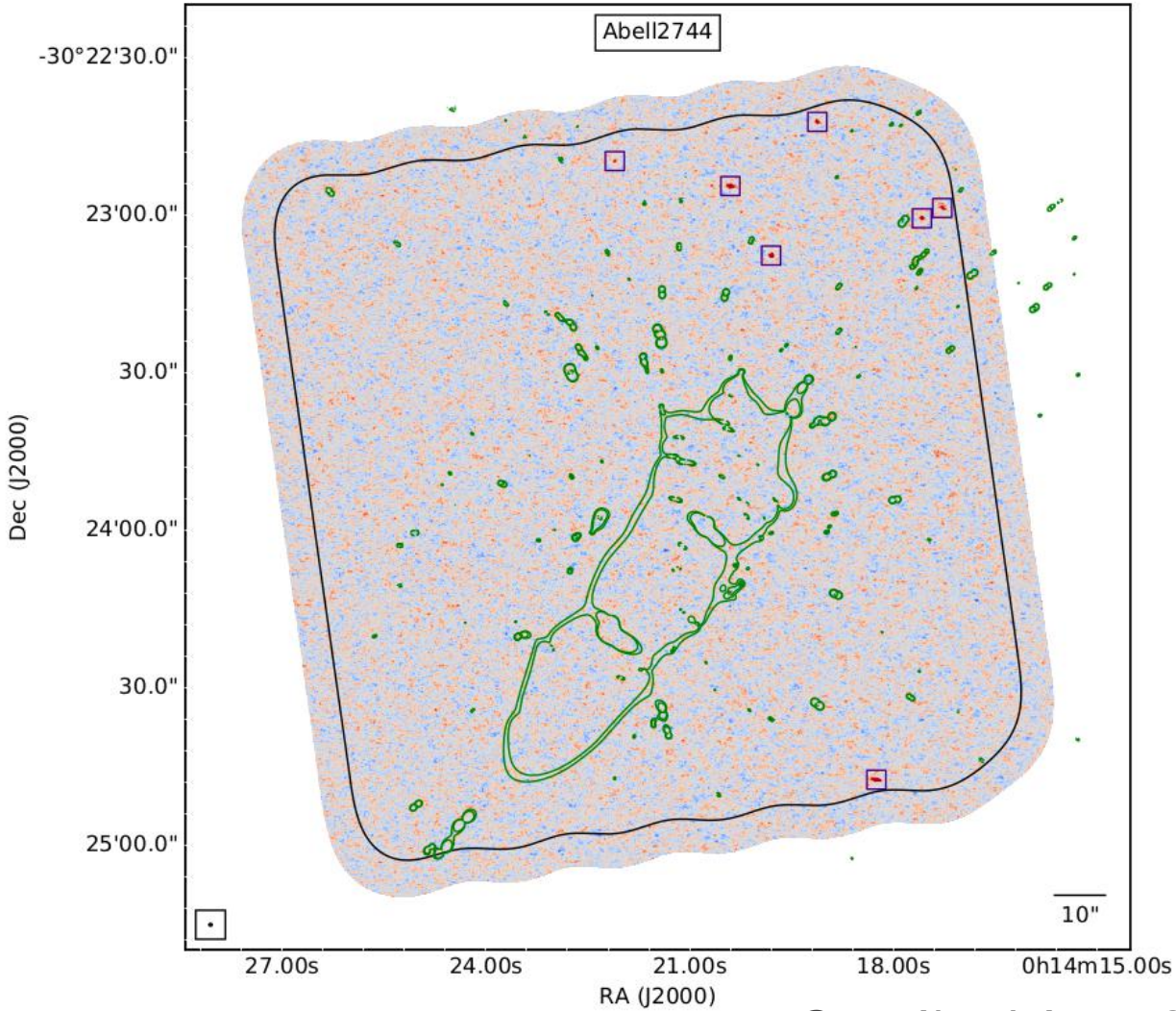
	A2744	**MACSJ0416**	**MACSJ1149**
S/N>=5	7	4	1
4.5<=S/N<5	4	1	2
Total	**11**	**5**	**3**

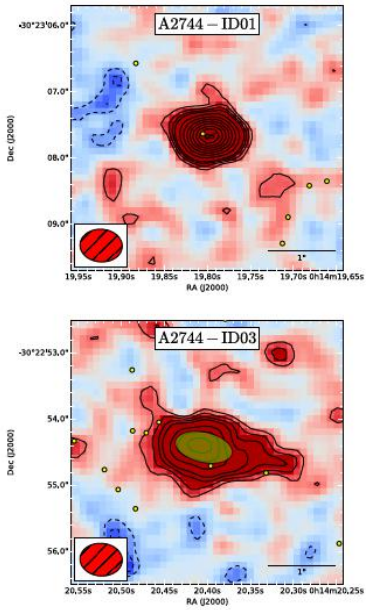
- **19** detections at **S/N>=4.5**
- Observed peak flux densities 0.2-1.5 mJy/beam
- Integrated flux densities 0.2-3 mJy

Example observation+model



A2744,
S/N>=5 detections,
Zitrin-NFW v3
lens model

Some sources
are extended



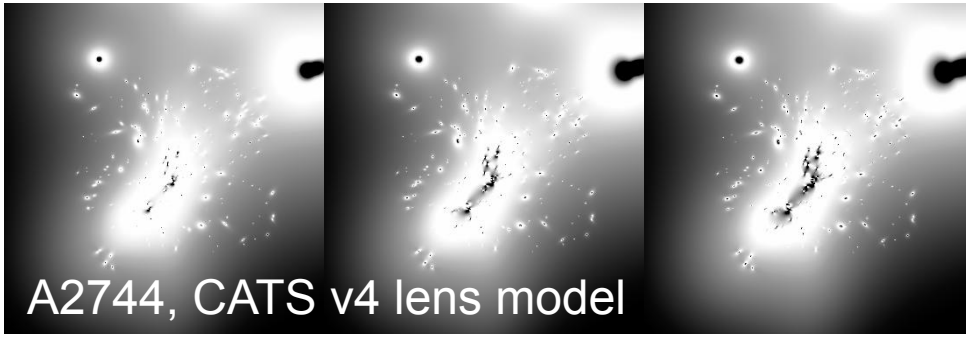
González-López+2017

From lens plane to source plane

Flux density conversion: $S_{demag}=S_{obs}/\mu$

Source magnification μ depends on

- Source redshift z
- Source coordinates
- Lens model



z=1 z=2 z=4

μ maps

From lens plane to source plane

Flux density conversion: $S_{demag}=S_{obs}/\mu$

Source magnification μ depends on

- Source redshift z
- Source coordinates
- Lens model

Adopted redshifts

- When available: spec-z
- S/N>=5: phot-z probability distributions from Laporte+2017 (<z>=1.99±0.27)
- S/N<5: assume N(2,σ=0.5)

From lens plane to source plane

Flux density conversion: $S_{demag}=S_{obs}/\mu$

Source magnification μ depends on

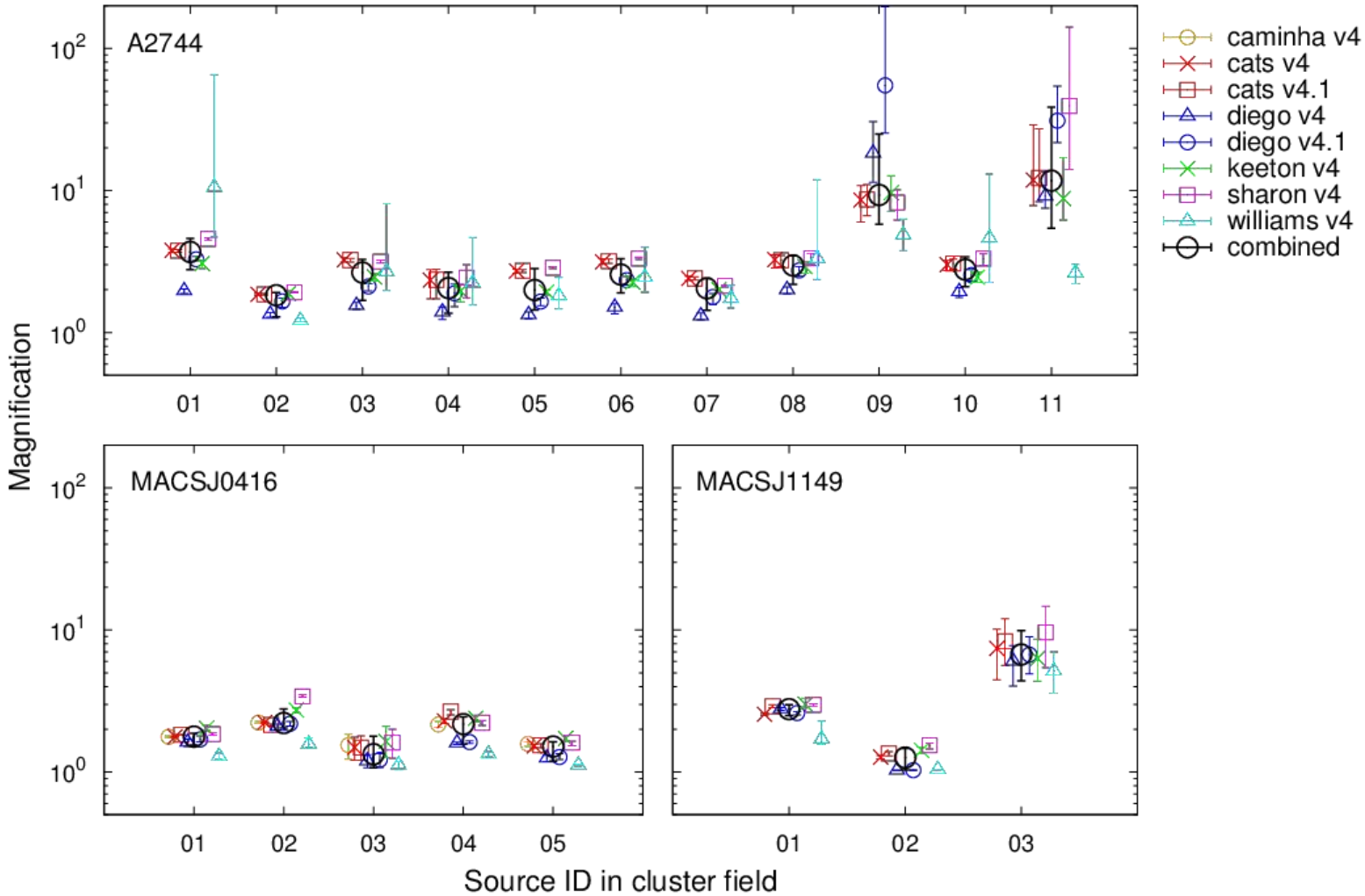
- Source redshift z
- Source coordinates
- Lens model

Use set of μ map realizations for each model and z:
μ uncertainties are not necessarily Gaussian

S_{obs} and μ uncertainties propagated through Monte Carlo simulations

From lens plane to source plane

Median magnification for each model (error bars: 16-84 percentiles)



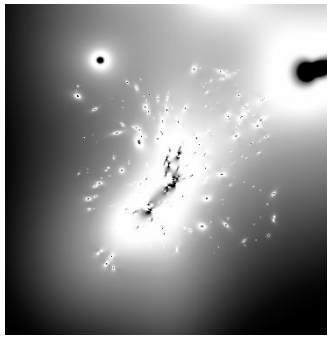
From lens plane to source plane

Differential number counts:

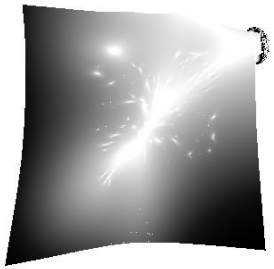
$$\frac{dN}{d\log S} = \frac{1}{\Delta \log(S)} \sum X_i \quad \text{where} \quad X_i = \frac{1 - p_{false,i}}{C_i A_{eff,i}}$$

where

- $p_{false,i}$: false detection rate
- C_i: completeness
- $A_{eff,i}$: effective source-plane area where sources at S/N>=4.5 are detected (recall that $S_{demag}=S_{obs}/\mu$)



Lens plane

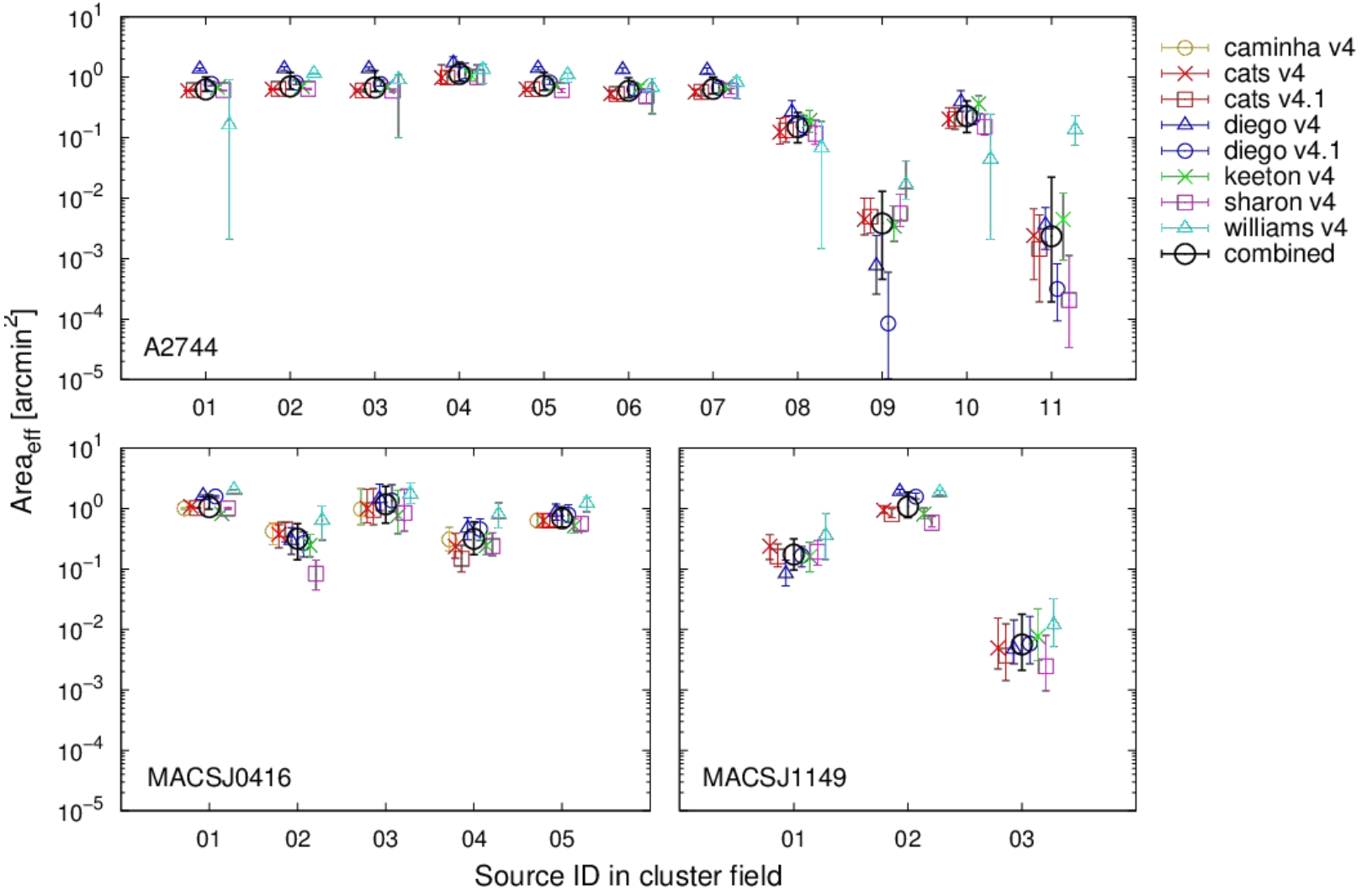


Source plane

A2744
CATS v4

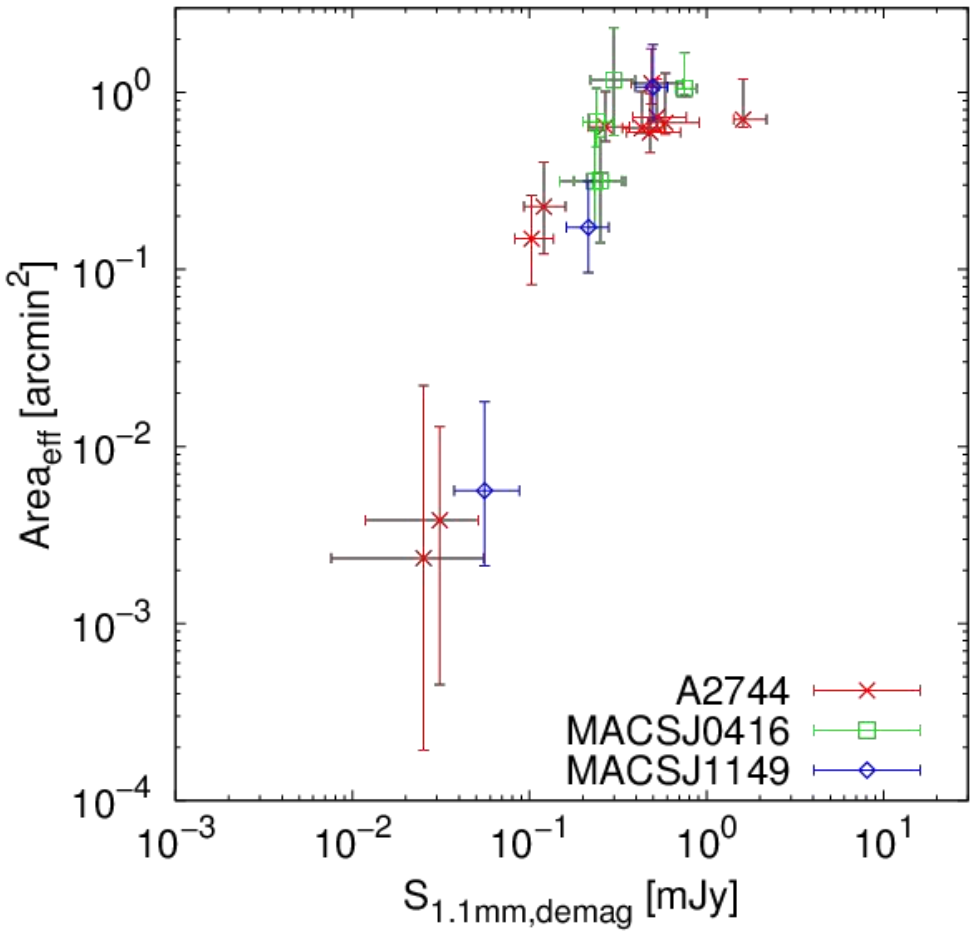
Effective source-plane area

Median A_{eff} for each model (error bars: 16-84 percentiles)

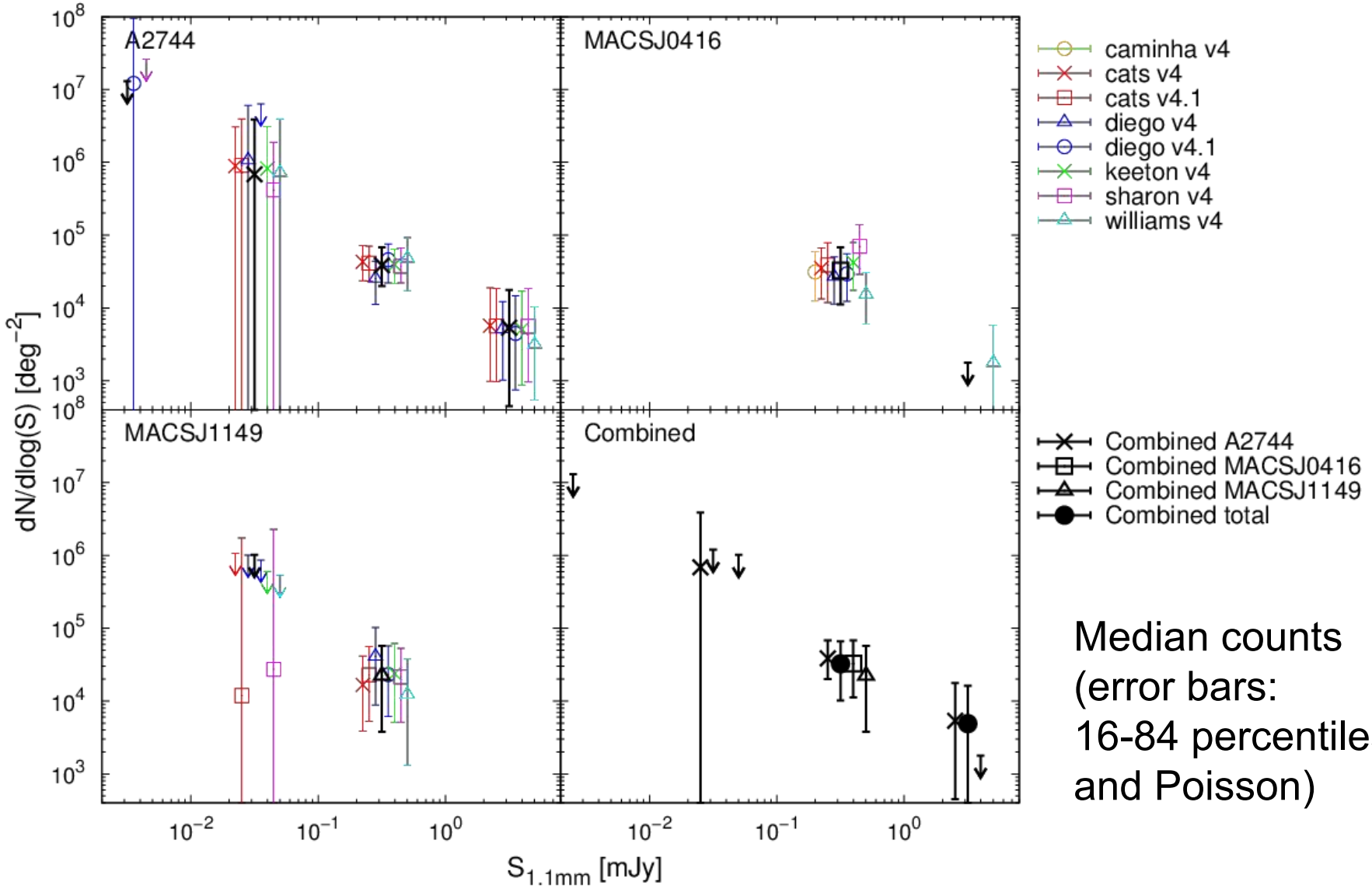


Impact of uncertainties

Median A_{eff} and S_{demag} per source, combining all lens models (error bars: 16-84 percentiles)

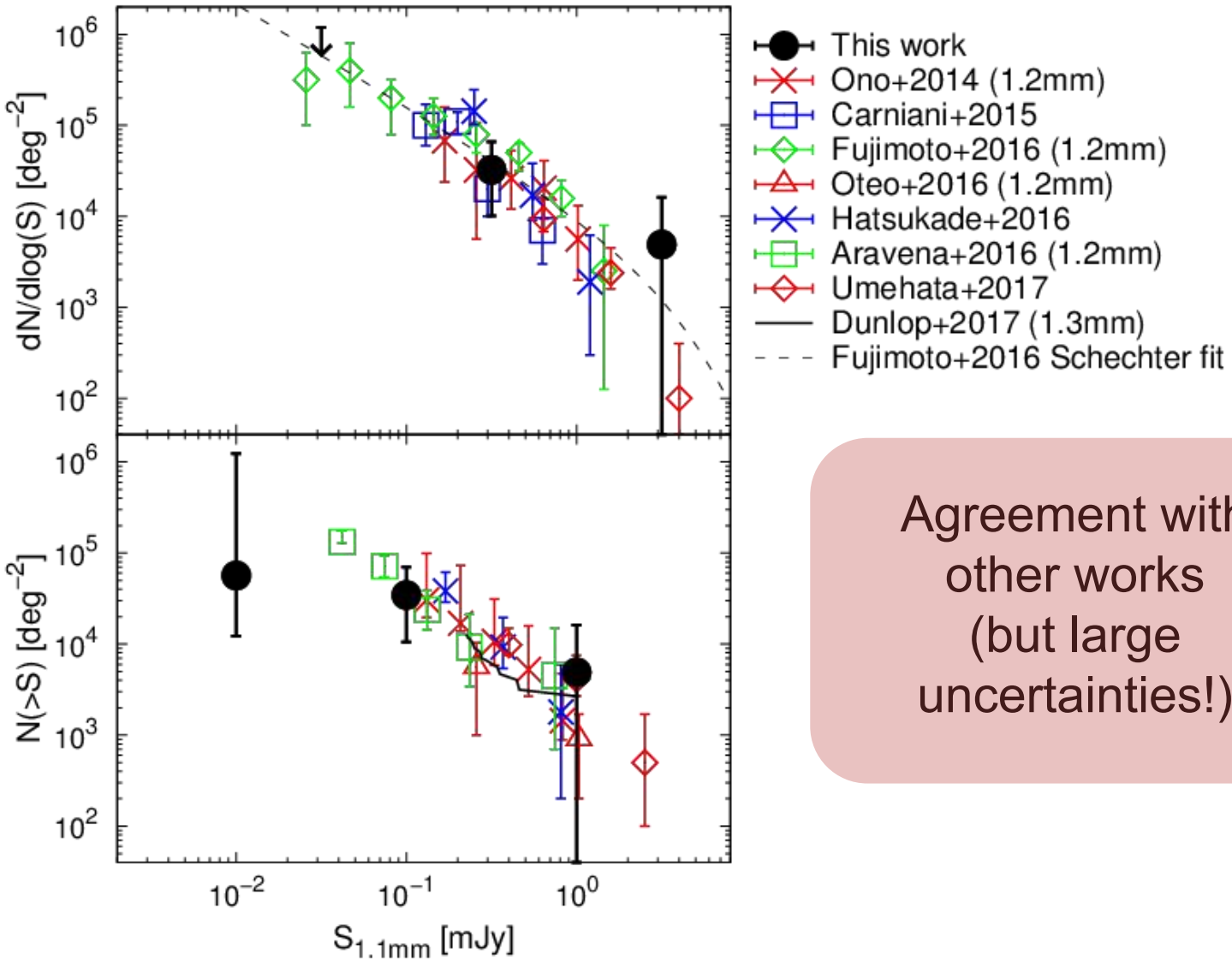


Galaxy number counts



Median counts (error bars: 16-84 percentiles and Poisson)

Galaxy number counts



Agreement with other works (but large uncertainties!)

Concluding remarks

- We derive 1.1mm counts exploiting
  - the high resolution and depth reached in a dedicated ALMA survey of three FF galaxy clusters
  - the public availability of several models for the mass reconstruction of these clusters
- Our survey probes the submJy population at 1.1mm
- Derived counts are ~5 times deeper than ALMA mosaic rms

Could further spec-z determinations for our detections serve as constraints for lensing models?