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

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SMG20
July 31, 2017
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)

To the submJy population
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

6 × strong lensing galaxy clusters + 6 × adjacent parallel fields

Lotz+2017
The Frontier Fields (FF)

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

Abell 2744
Lotz+2017

Magnification maps

Priewe+2017
This work

Number counts in three FF galaxy clusters

<table>
<thead>
<tr>
<th></th>
<th>A2744</th>
<th>MACSJ0416</th>
<th>MACSJ1149</th>
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<tbody>
<tr>
<td>Full name</td>
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<td>Redshift</td>
<td>0.308</td>
<td>0.396</td>
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ALMA observations introduced by González-López+2017 (PI: Bauer)

- 1.1mm continuum maps ~4.6 arcmin² each
  (= ~14 arcmin² total observed area)
- rms depth ~55-71 μJy/beam
- beam size ~0.5-1.5"
**This work**

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<tr>
<td>S/N&gt;=5</td>
<td>7</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>4.5&lt;=S/N&lt;5</td>
<td>4</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td><strong>11</strong></td>
<td><strong>5</strong></td>
<td><strong>3</strong></td>
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- **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: $S_{\text{demag}} = S_{\text{obs}}/\mu$

Source magnification $\mu$ depends on

- Source redshift $z$
- Source coordinates
- Lens model

A2744, CATS v4 lens model

$z=1$  $z=2$  $z=4$

$\mu$ maps
From lens plane to source plane

Flux density conversion: \( S_{\text{demag}} = \frac{S_{\text{obs}}}{\mu} \)

Source magnification \( \mu \) depends on:
- Source redshift \( z \)
- Source coordinates
- Lens model

Adopted redshifts:
- When available: spec-z
- \( S/N \geq 5 \): phot-z probability distributions from Laporte+2017 (\( <z> = 1.99 \pm 0.27 \))
- \( S/N < 5 \): assume \( \mathcal{N}(2, \sigma=0.5) \)
From lens plane to source plane

Flux density conversion: \( S_{\text{demag}} = S_{\text{obs}} / \mu \)

Source magnification \( \mu \) depends on
- Source redshift \( z \)
- Source coordinates
- Lens model

Use set of \( \mu \) map realizations for each model and \( z \):
\( \mu \) uncertainties are not necessarily Gaussian

\( S_{\text{obs}} \) and \( \mu \) 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:

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

where

- $p_{\text{false},i}$: false detection rate
- $C_i$: completeness
- $A_{\text{eff},i}$: effective source-plane area

where sources at $S/N \geq 4.5$ are detected (recall that $S_{\text{demag}} = S_{\text{obs}} / \mu$)
Effective source-plane area

Median $A_{\text{eff}}$ for each model (error bars: 16-84 percentiles)
Impact of uncertainties

Median $A_{\text{eff}}$ and $S_{\text{demag}}$ 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?