The ALMA Frontier Fields Survey

IV. Lensing-corrected 1.1 mm number counts in Abell 2744, MACS J0416.1–2403, and MACS J1149.5+2223 (Corrigendum)

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We noticed an error in the code that conducts the source injection simulations used in our article [Muñoz Arancibia et al. \(2018\)](#). This error led the source scale radii in the image plane to be 1/2.35 times smaller than what it should be. Wrongly computed scale radii primarily affect the calculation of first, completeness as a function of image-plane integrated flux density curves for different image-plane scale radii; and second, image-plane integrated flux densities estimated for low-significance ALMA detections. These in turn affect the calculation of deboosting correction factors, demagnified integrated flux densities (for low-significance ALMA detections), differential and cumulative number counts, and the contribution to the extragalactic background light.

This error has some effect upon the conclusions of the original manuscript. Figures 1, 2, 5, 6, 9, 11–14, and Table 3 are affected in the original manuscript and are corrected in this erratum. Values in the text should be updated accordingly, as shown in the sentences as follows.

In the Abstract. In combining all cluster fields, our number counts span around two orders of magnitude in demagnified flux density, from several mJy down to tens of μ Jy. Both of our differential and cumulative number counts are consistent with

most of the recent estimates from deep ALMA observations at a 1σ level. Below ≈ 0.1 mJy, however, our cumulative counts are lower by ≈ 0.5 dex, suggesting flattening in the number counts.

In Section 2.1.2. From source injection simulations (see Sect. 3.1), we find a typical ratio between the peak and integrated flux density for these size parameters of 0.50, 0.80, and 0.80 in Abell 2744, MACS J0416.1–2403, and MACS J1149.5+2223, respectively (hereafter A2744, MACS J0416, and MACS J1149). By scaling the peak intensities by these ratios, the integrated flux densities of the $4.5 \leq S/N < 5$ detections (with S/N the signal-to-noise ratio) range from ~ 0.38 to ~ 0.65 mJy.

In Section 3.1. However, the completeness drops to 2%, 10%, and 20% at the same flux densities for image-plane source sizes in the range of $0''.20$ – $0''.25$ (i.e., for the image-plane size assumed for our low-significance detections).

At $S/N = 4.5$, we find that the noise boosts the flux densities by 4%, 5%, and 5% for A2744, MACS J0416, and MACS J1149, respectively.

In Section 3.2. We obtain the fraction of spurious sources at a given S/N, p_{false} , defined as the average ratio between the number of sources detected over that peak S/N in the simulated

Fig. 1. Completeness correction C as function of image-plane integrated flux density and separated in bins of image-plane scale radius. Error bars indicate binomial confidence intervals.

noise maps and in the true mosaic. We found this typo in the description after publication of our manuscript.

In Section 3.3. Some sources that have a median of $\mu \gtrsim 10$ reach dispersions $\gtrsim 0.5$ dex, such as source A2744-ID09 in the Diego v4.1 model. After acceptance of our manuscript, Sharon v4 models in the FF website were corrected; in the updated Sharon v4 model, A2744-ID11 has a median $\mu \approx 19$, reaching a dispersion of only ≈ 0.2 dex.

In Section 3.4. Median (combined) lensing-corrected flux densities range from ~ 0.04 to 1.62 mJy; both the faintest and brightest sources in the sample are found around A2744.

Within the uncertainties, combined demagnified flux densities cover around 2.1 orders of magnitude.

At $S_{\text{obs}} \gtrsim 0.5$ mJy, we find a trend of brighter observed sources that are also brighter intrinsically, while sources having lower observed flux densities tend to span ≈ 1.5 dex in demagnified flux.

We also find that sources with the highest magnifications ($\mu \gtrsim 5$) are among the faintest ones both in observed and lensing-corrected flux ($S_{\text{obs}} \lesssim 0.5$ mJy and $S_{\text{demag}} \lesssim 0.1$ mJy, respectively).

In Section 3.5. At ≈ 0.1 – 0.3 mJy, sources with a S_{demag} 1σ interval of 0.3 dex, for example, have an A_{eff} 1σ interval close to 0.5 dex. Below 0.1 mJy, uncertainties in both of those quantities

Fig. 2. Deboosting correction as function of S/N . We display the ratio between the extracted and injected flux densities for our simulated sources as gray dots. Thick red lines correspond to median values while thin red lines indicate the 16th and 84th percentiles.

remain comparable in terms of order of magnitude, which reaches a 1σ interval of $\lesssim 1$ dex.

In Section 4.1. Uncertainties coming from our Monte Carlo simulation (i.e., using the whole probability distributions for observed flux densities, source redshifts, and magnifications together) differ by a factor of ~ 0.03 – 4.62 from what was predicted from Poisson statistics.

We present counts down to the flux density where at least one cluster field has non-zero combined differential counts at the 84th percentile, that is, centered on 0.024 mJy. Combining all cluster fields, our differential counts eventually span ~ 2 orders of magnitude in demagnified flux density, going from the mJy level down to tens of μ Jy. This is ≈ 1.3 times deeper than the observed rms level reached in our deepest ALMA FF mosaic, A2744.

In these three cases, variations in the median counts that combine all cluster fields are only up to ≈ 0.08 dex below 1.3 mJy. Our combined counts are also in agreement within the errors with those obtained centering the Gaussian at $z = 3 \pm 0.5$ for all detections (although it adds a 3σ upper limit of $\sim 10^6 \text{ deg}^{-2}$ at 0.024 mJy due to the larger high-magnification regions for this redshift).

In Section 4.2. At 0.133 – 0.422 mJy, our number counts are consistent within 1σ with all but [Hatsukade et al. \(2016\)](#) data.

Fig. 5. Median demagnified integrated flux density per source for lens models listed in Table 2 (colored symbols), and also combining all models for each cluster field (large black circles). Error bars indicate the 16th and 84th percentiles. Values for each model have been offset around the source ID for clarity.

Fig. 6. Median demagnified integrated flux density as function of observed integrated flux density for A2744 (red crosses), MACSJ0416 (green squares), and MACSJ1149 (blue diamonds). Median values were obtained by combining all models for each cluster field. Error bars in demagnified fluxes correspond to the 16th and 84th percentiles, while for observed fluxes, there are 1σ statistical uncertainties. As a reference, black lines indicate magnification values of one (solid), five (dotted), ten (dashed), and 50 (dot-dashed).

Also below this flux density, our cumulative counts are lower by ≈ 0.5 dex than [Aravena et al. \(2016\)](#) data, but they are consistent with their results at a 1σ level.

In Section 4.3. In this case, we obtain the integrated flux densities of the low-significance detections, scaling the peak intensities by the typical ratios 0.18, 0.46, and 0.47 in A2744, MACSJ0416, and MACSJ1149, respectively.

Fig. 9. Median effective area as function of demagnified integrated flux density for A2744 (red crosses), MACSJ0416 (green squares), and MACSJ1149 (blue diamonds). Median values are obtained combining all models for each cluster field. Error bars correspond to the 16th and 84th percentiles. For comparing uncertainty values, both axes cover the same interval in order of magnitude. Within the errors, both demagnified flux densities and effective areas span around 2.5 orders of magnitude.

We find that assuming $r_{\text{eff,obs}} = 0.5''$ for low-significance sources maintains the agreement with [Aravena et al. \(2016\)](#) at 1σ . Assuming that our low-significance detections are point sources disagrees with their estimates at 1σ , although this remains consistent with [Fujimoto et al. \(2016\)](#) counts assuming our 3σ upper limit.

Below 0.133 mJy, our fiducial number counts are consistent with available data from both serendipitous and blank-field surveys at a 1σ level.

Fig. 11. Demagnified differential counts at 1.1 mm, for each cluster (see legends at top-left) and combining all cluster fields (*bottom-right panel*). Values correspond to median counts for the lens models listed in Table 2 (colored symbols), combining all models for each cluster field (large black crosses, squares, and diamonds) and combining all models for all cluster fields (large black filled circles). Error bars indicate the 16th and 84th percentiles, adding the scaled Poisson confidence levels for 1σ lower and upper limits respectively in quadrature. Arrows indicate 3σ upper limits for flux density bins that have zero median counts and non-zero values at the 84th percentile. In the *first three panels*, counts for each model have been offset in flux around the combined counts for clarity. In the *bottom-right panel*, this is done for each galaxy cluster field around the counts that combine all models for all cluster fields.

Fig. 12. As in Fig. 11, but for demagnified cumulative number counts at 1.1 mm.

Fig. 13. Differential (*top*) and cumulative (*bottom*) counts at 1.1 mm compared to ALMA results and galaxy formation model predictions from literature. Our counts (large black filled circles) correspond to median values combining all models for all cluster fields. Error bars indicate the 16th and 84th percentiles, adding the scaled Poisson confidence levels for 1σ lower and upper limits respectively in quadrature. Arrows indicate 3σ upper limits for flux densities having zero median counts and non-zero values at the 84th percentile. We show previous results reported by Ono et al. (2014) as red crosses, Carniani et al. (2015) as blue squares, Fujimoto et al. (2016) as green diamonds (with their Schechter fit shown as a black dashed line), Oteo et al. (2016) as red triangles, Hatsukade et al. (2016) as blue crosses, Aravena et al. (2016) as green squares, Umehata et al. (2017) as red diamonds, and Dunlop et al. (2017) as a black solid curve. We show number counts predicted by the galaxy formation models from Cowley et al. (2015; orange line), Béthermin et al. (2017; cyan line), and Schreiber et al. (2017; magenta line). We scale the counts derived at other wavelengths as $S_{1.1\text{ mm}} = 1.29 \times S_{1.2\text{ mm}}$ and $S_{1.1\text{ mm}} = 1.48 \times S_{1.3\text{ mm}}$ (following Hatsukade et al. 2016).

Table 3. Demagnified 1.1 mm number counts.

Cluster field	$S_{1.1\text{ mm}}$ [mJy]	$dN/d \log(S)$ [deg $^{-2}$]	# sources	$S_{1.1\text{ mm}}$ [mJy]	$N(> S)$ [deg $^{-2}$]	# sources
A2744	0.024	$<1.869 \times 10^6$	<3.0	0.013	$(1.808^{+2.411}_{-1.474} +0.822_{-0.589}) \times 10^5$	$9.0^{+1.0}_{-1.0} +4.1_{-2.9}$
	0.075	$(1.305^{+2.418}_{-1.305} +2.986_{-1.077}) \times 10^5$	$1.0^{+0.0}_{-1.0} +2.3_{-0.8}$	0.042	$(9.869^{+12.42}_{-7.332} +4.484_{-3.214}) \times 10^4$	$9.0^{+1.0}_{-1.0} +4.1_{-2.9}$
	0.237	$(3.772^{+2.923}_{-2.230} +3.651_{-2.046}) \times 10^4$	$3.0^{+2.0}_{-1.0} +2.9_{-1.6}$	0.133	$(2.998^{+1.481}_{-1.251} +1.471_{-1.033}) \times 10^4$	$8.0^{+1.0}_{-1.0} +3.9_{-2.8}$
	0.750	$(1.710^{+0.460}_{-0.731} +1.346_{-0.815}) \times 10^4$	$4.0^{+1.0}_{-2.0} +3.1_{-1.9}$	0.422	$(1.034^{+0.252}_{-0.352} +0.696_{-0.445}) \times 10^4$	$5.0^{+1.0}_{-2.0} +3.4_{-2.2}$
	2.371	$(4.351^{+0.304}_{-0.824} +9.956_{-3.592}) \times 10^3$	$1.0^{+0.0}_{-0.0} +2.3_{-0.8}$	1.334	$(2.172^{+0.155}_{-0.414} +4.970_{-1.793}) \times 10^3$	$1.0^{+0.0}_{-0.0} +2.3_{-0.8}$
MACS J0416	0.024	$0.000^{+0.000}_{-0.000}$	$0.0^{+0.0}_{-0.0} +1.8_{-0.0}$	0.013	$(3.485^{+8.088}_{-1.672} +2.742_{-1.662}) \times 10^4$	$4.0^{+1.0}_{-1.0} +3.1_{-1.9}$
	0.075	$0.000^{+0.000}_{-0.000}$	$0.0^{+0.0}_{-0.0} +1.8_{-0.0}$	0.042	$(3.485^{+8.079}_{-1.672} +2.742_{-1.662}) \times 10^4$	$4.0^{+1.0}_{-1.0} +3.1_{-1.9}$
	0.237	$(5.263^{+6.983}_{-2.748} +5.094_{-2.854}) \times 10^4$	$3.0^{+1.0}_{-1.0} +2.9_{-1.6}$	0.133	$(3.009^{+3.498}_{-1.415} +2.368_{-1.435}) \times 10^4$	$4.0^{+1.0}_{-1.0} +3.1_{-1.9}$
	0.750	$(3.981^{+0.690}_{-0.601} +9.110_{-3.287}) \times 10^3$	$1.0^{+0.0}_{-0.0} +2.3_{-0.8}$	0.422	$(1.984^{+0.282}_{-0.302} +4.541_{-1.638}) \times 10^3$	$1.0^{+0.0}_{-0.0} +2.3_{-0.8}$
	2.371	$0.000^{+0.000}_{-0.000}$	$0.0^{+0.0}_{-0.0} +1.8_{-0.0}$	1.334	$0.000^{+0.000}_{-0.000}$	$0.0^{+0.0}_{-0.0} +1.8_{-0.0}$
MACS J1149	0.024	$0.000^{+0.000}_{-0.000}$	$0.0^{+0.0}_{-0.0} +1.8_{-0.0}$	0.013	$(6.960^{+16.22}_{-5.715} +9.135_{-4.482}) \times 10^4$	$2.0^{+1.0}_{-1.0} +2.6_{-1.3}$
	0.075	$<1.072 \times 10^6$	<3.0	0.042	$(5.479^{+15.21}_{-4.298} +7.191_{-3.528}) \times 10^4$	$2.0^{+1.0}_{-1.0} +2.6_{-1.3}$
	0.237	$(2.666^{+3.496}_{-1.659} +6.102_{-2.201}) \times 10^4$	$1.0^{+0.0}_{-0.0} +2.3_{-0.8}$	0.133	$(1.535^{+1.765}_{-0.943} +3.512_{-1.267}) \times 10^4$	$1.0^{+1.0}_{-0.0} +2.3_{-0.8}$
	0.750	$(3.231^{+1.769}_{-3.231} +7.394_{-2.668}) \times 10^3$	$1.0^{+0.0}_{-1.0} +2.3_{-0.8}$	0.422	$(1.603^{+0.877}_{-1.603} +3.669_{-1.324}) \times 10^3$	$1.0^{+0.0}_{-1.0} +2.3_{-0.8}$
	2.371	$0.000^{+0.000}_{-0.000}$	$0.0^{+0.0}_{-0.0} +1.8_{-0.0}$	1.334	$0.000^{+0.000}_{-0.000}$	$0.0^{+0.0}_{-0.0} +1.8_{-0.0}$
Combined	0.024	$0.000^{+0.000}_{-0.000}$	$0.0^{+0.0}_{-0.0} +1.8_{-0.0}$	0.013	$(6.132^{+22.30}_{-4.277} +4.824_{-2.924}) \times 10^4$	$4.0^{+5.0}_{-2.0} +3.1_{-1.9}$
	0.075	$<9.396 \times 10^5$	<3.0	0.042	$(4.555^{+15.43}_{-2.824} +3.584_{-2.172}) \times 10^4$	$4.0^{+5.0}_{-2.0} +3.1_{-1.9}$
	0.237	$(3.916^{+4.407}_{-2.284} +5.139_{-2.522}) \times 10^4$	$2.0^{+2.0}_{-1.0} +2.6_{-1.3}$	0.133	$(2.601^{+2.185}_{-1.322} +2.047_{-1.240}) \times 10^4$	$4.0^{+4.0}_{-2.0} +3.1_{-1.9}$
	0.750	$(4.339^{+13.12}_{-1.179} +9.929_{-3.582}) \times 10^3$	$1.0^{+3.0}_{-0.0} +2.3_{-0.8}$	0.422	$(2.111^{+8.353}_{-0.577} +4.831_{-1.743}) \times 10^3$	$1.0^{+4.0}_{-0.0} +2.3_{-0.8}$
	2.371	$<1.312 \times 10^4$	<3.0	1.334	$<6.555 \times 10^3$	<3.0

Notes. Column 1: cluster field where the counts are computed. In the bottom row group, counts combining all cluster fields are listed. Column 2: flux density bin for differential counts. Column 3: median differential counts per flux bin. For non-zero median counts, uncertainties are given separately using the 16th (84th) percentiles and scaled Poisson confidence levels for 1σ lower (upper) limits. For flux density bins having zero median counts and non-zero values at the 84th percentile, only 3σ upper limits are provided. Column 4: median number of sources per flux bin. Uncertainties are given separately using the 16th and 84th percentiles and Poisson confidence levels for 1σ lower (upper) limits. Column 5: flux density limit for cumulative counts. Column 6: median cumulative counts per flux limit. Uncertainties and upper limits are as in Col. 3. Column 7: median number of sources per flux limit. Uncertainties are as in Col. 4.

Fig. 14. Differential (*top*) and cumulative (*bottom*) counts at 1.1 mm for different assumptions regarding image-plane source scale radii for low-significance sources: adopting $r_{\text{eff,obs}} = 0''.23$ (black filled circles, fiducial); assuming they are point sources (red filled diamonds); and adopting $r_{\text{eff,obs}} = 0''.5$ (blue filled squares). Our counts correspond to median values combining all models for all cluster fields. Error bars indicate the 16th and 84th percentiles, adding the scaled Poisson confidence levels for 1σ lower and upper limits respectively in quadrature. Arrows indicate 3σ upper limits for flux densities having zero median counts and non-zero values at the 84th percentile. We show previous results reported by Fujimoto et al. (2016) as green diamonds and Aravena et al. (2016) as green squares. We show number counts predicted by the galaxy formation models from Cowley et al. (2015; orange line), Béthermin et al. (2017; cyan line), and Schreiber et al. (2017; magenta line). We scale the counts derived at other wavelength as $S_{1.1\text{ mm}} = 1.29 \times S_{1.2\text{ mm}}$ (following Hatsukade et al. 2016).

In Section 4.4. We estimate a median contribution of $13.959^{+13.556}_{-8.498}$ ($5.954^{+8.165}_{-3.323}$) Jy deg $^{-2}$ resolved in our demagnified sources at 1.1 mm down to 0.013 (0.133) mJy, with uncertainties computed from the 16th and 84th percentiles.

The contribution provided by our demagnified sources represents $73^{+71}_{-44}\%$ ($31^{+43}_{-17}\%$) of this EBL at 1.1 mm down to 0.013 (0.133) mJy. As expected from Fig. 13, this contribution is lower than the results from Carniani et al. (2015) and Hatsukade et al. (2016), which are both at 1.1 mm. However, this contribution is consistent to $\approx 1\sigma$ with their results.

In Section 5. By combining all cluster fields, our differential number counts span around two orders of magnitude in demagnified flux density, going from the mJy level down to tens of μ Jy.

Within the error bars in our number counts (coming from both Poisson errors and lensing model uncertainties) our results are consistent at 1σ with most of the recent estimates from deep ALMA observations (Ono et al. 2014; Carniani et al. 2015; Fujimoto et al. 2016; Oteo et al. 2016; Hatsukade et al. 2016; Aravena et al. 2016; Umehata et al. 2017; Dunlop et al. 2017). However, below ≈ 0.1 mJy, our cumulative number counts are ≈ 0.5 dex lower than previous estimates.

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