Unveiling High-Z Dusty Galaxies By *Herschel* Selection of 500 μm-risers: Blinded By Colours?

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Motivation

Recent studies of dusty star forming galaxies (DSFGs) have attempted to push the *Herschel* SPIRE surveys beyond the redshift peak of detected sources ($z \sim 2$). To search for $z \geq 4$ galaxies they target the sources with fluxes rising from 250 μm to 500 μm (so-called "500 μm-risers"). It becomes important to use wide *Herschel* surveys to efficiently select larger number of red and massive objects, since they give us insight to prodigious star-forming activity in very distant Universe.

- **This work: We aim to develop a new technique to build the statistical sample of "500 μm-risers". We consider one of the largest and deepest *Herschel* surveys, the Herschel Virgo Cluster Survey(HeViCS). In order to evaluate the selection, we perform end-to-end simulations inspecting different models of galaxy evolution.**

1. Source Extraction Algorithm

- We assign position list at 250 μm using `SUSSEXtractor` [3] as a prior to extract the flux densities at longer wavelengths. We use our novel code (`MBB-fitter`, Boone & Donevski, in prep.) to perform the photometry, simultaneously fitting extracted blends.
- `MBB-fitter` is a code which combines positional priors and spectral information of sources, such that SEDs of fitted galaxies should follow modified blackbody (MBB) shape. We fixed emission slope $\beta = 1.8$. We let dust temperatures T_d to vary from 18.0 K to 65.0 K.

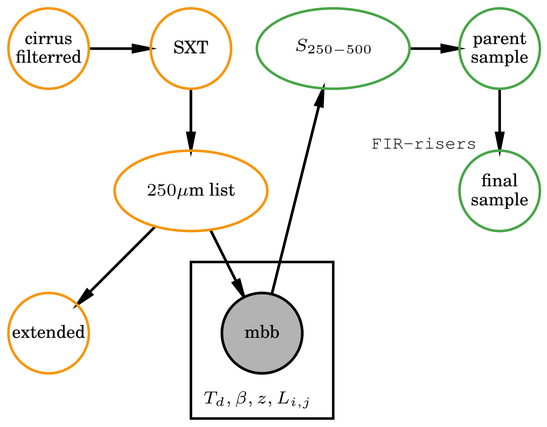


Fig 1. Schematic representation of selection of "500 μm-risers" in the HeViCS field. Coloured in orange and green are segments of source extraction prior and after the use of `MBB-fitter` respectively.

2. Criteria to select "500 μm-risers"

- We select the final list of 133 "500 μm-risers" over the area of 55 deg^2. Selected sources fulfil criteria accepted for the final cut: $S_{500} > S_{350} > S_{250}$, $S_{250} > 13.2$ mJy and $S_{500} > 30$ mJy. The final list of "500 μm-risers" is additionaly cleaned from the flat, radio-bright sources.

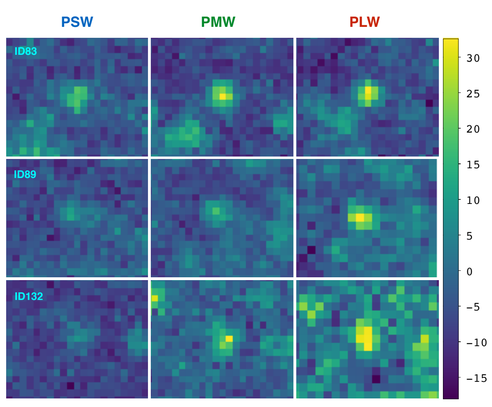


Fig 2. Example 2D cutouts of selected "500 μm-risers" in the HeViCS.

3. Differential counts: Observations and Models

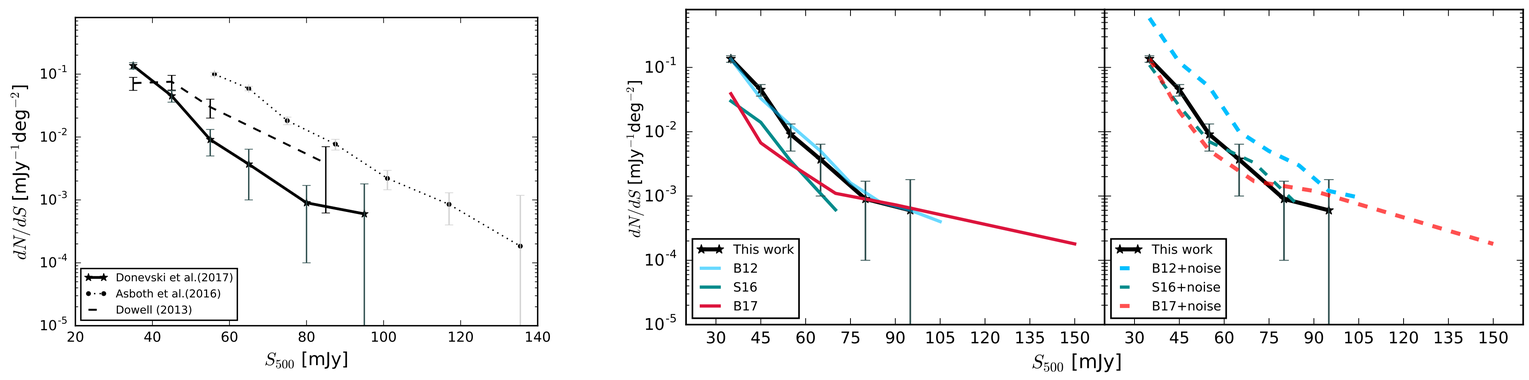
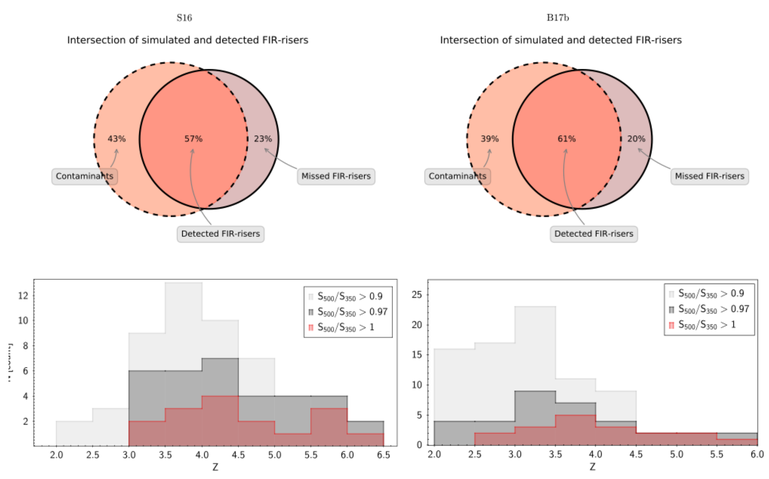


Fig 3. Observed differential number counts of "500 μm-risers" in the HeViCS field (full, black line) confronted to: observations (**left panel**) and models (**right panel**). Number counts of "500 μm-risers" from several empirical models ([5],[6],[7]) are overplotted with coloured lines. To exemplify models, we perform the same flux and colour cuts as we did for our real sources. Dashed coloured lines represent the modelled effect of both confusion and instrumental noise. It is simulated by adding a random Gaussian noise to the modelled fluxes.

4. (a) Simulations



We build simulated maps from mock catalogues based on models (B17 [6] and S16 [7]). Clustering and lensing are simulated in order to fully resolve effects that produce colour uncertainties. **Fig 4.** *Upper panels*: Quantification of galaxies detected in mock maps. Selection criteria are identical as for real HeViCS maps. Dark orange intersected area depicts recovered red sources. Violet area represents missed sources. Contaminants are dominated by red but faint sources. Their redshifts peak at $z > 3.5$. *Lower panels*: Redshift distribution of modelled galaxies.

4. (b) Simulated multiplicity

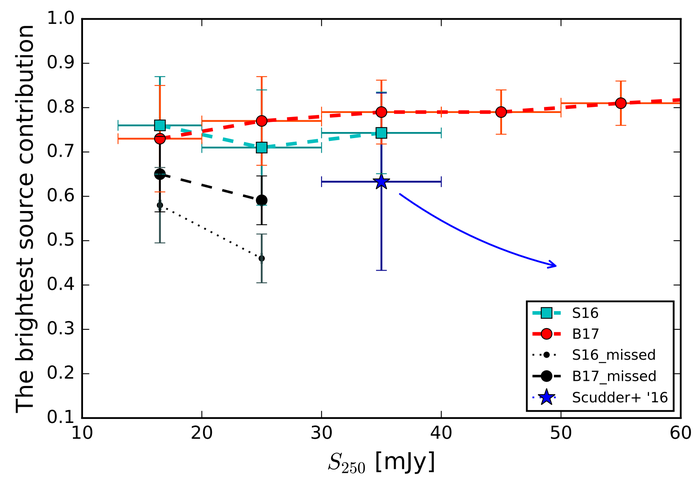
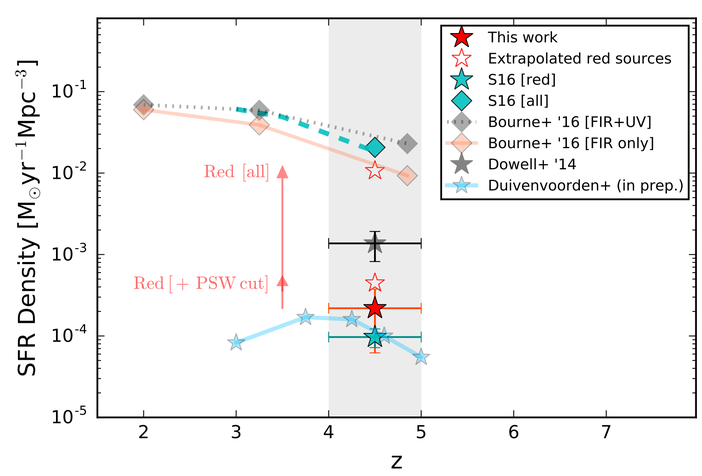


Fig 5. Average fraction of the PSW flux density emitted by the brightest galaxy in the *Herschel* beam versus total 250 μm flux measured in our simulated maps. Blue point represents the trend observed in [8].

5. Star Formation Rate Density



We use statistical properties of our "risers" to determine their role to the SFRD. **Fig 6:** SFRD at $4 < z < 5$: marked with stars are estimations from several "500-riser" selections: this work (filled red), S16 model (cyan), [2] (black) and Duivenvoorden et al, in prep. (blue). Marked with diamonds are results from [9].

References

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Important outcomes

- We show that noise and weak lensing have a significant impact on observed number counts.
- We rely on models to inspect colour uncertainties. Last column in a Table below shows the difference between observed and modelled colours of "500μm-risers" (values in brackets). The reddening (Δ) is shifted redwards in lower flux bins. For the missed intrinsically red sources we found a negative Δ (shifted bluewards by a factor of ~ 0.03).

Flux bin	$S_{500}/S_{350}^{(1)}$ [B17]	$S_{500}/S_{350}^{(2)}$ [HeViCS]	$\Delta^{(3)}$
30-40 mJy	1.03± 0.09	1.07± 0.1	0.04 (0.012)
40-50 mJy	1.10± 0.05	1.12±0.06	0.02 (0.009)
> 50 mJy	1.15±0.11	1.16±0.18	0.01 (0.008)

- **We thus propose a modified colour criterion ($S_{500}/S_{350} > 0.97$) that should be tested in future selections of $z > 4$ sources.** Motivation for the new criterion is twofold: (1) it accounts for colour uncertainties that arise from noise, clustering and weak lensing; (2) to increase the sample of candidate $z > 4$ galaxies. Projected contribution of $2 < z < 3$ contaminants reach the maximum of 15%.
- Weakly lensed and non-lensed "risers" contribute from 49% (B17, modelled values) to 71% (modelled values+Gaussian noise). **It confirms that selecting "500 μm-risers" down to S_{500}=30 mJy is a direct way to detect unlensed, DSFGs at $z > 4$.**
- After correcting for fainter sources, projected contribution of "500 μm-risers" supports the scenario where SFRD is dominated by UV-visible star formation at $z > 4$. **It is in a good match with [9] and [10], and implies that very high values of SFRD reported in [11] are due to noise/blending.**

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