The *Herschel* Dark Field

Probing the deepest FIR field with SCUBA-2 and PRIMA

Ayushi Parmar, Imperial College London

Co-I's: Dave Clements, Chris Pearson, Thomas Varnish, Joana Micó Beltrán, Lucia Barreiro Rius, Borja Pautasso

IMPERIAL

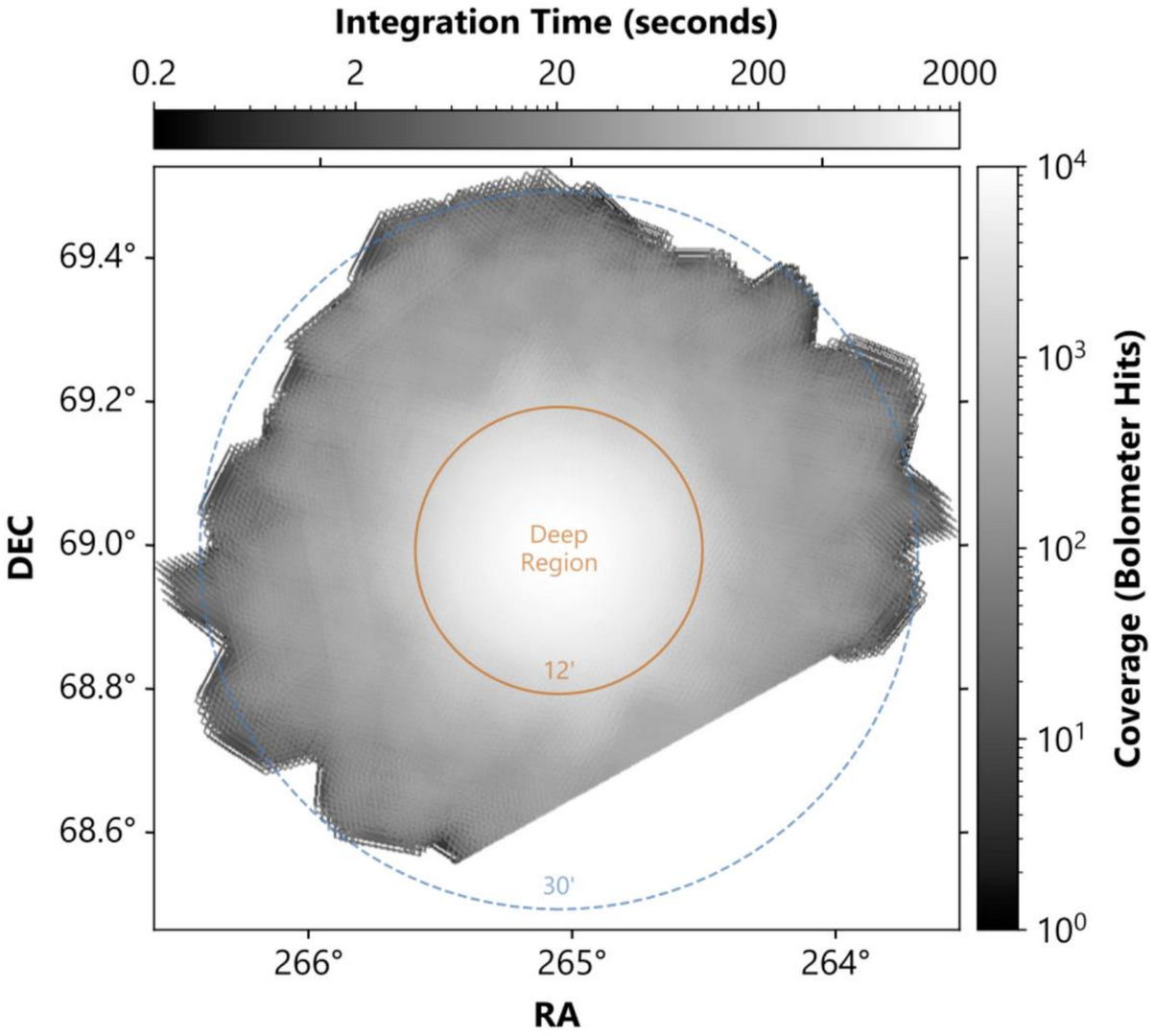
Dusting Off the Secrets of the Cosmos with PRIMA Space IR Telescope

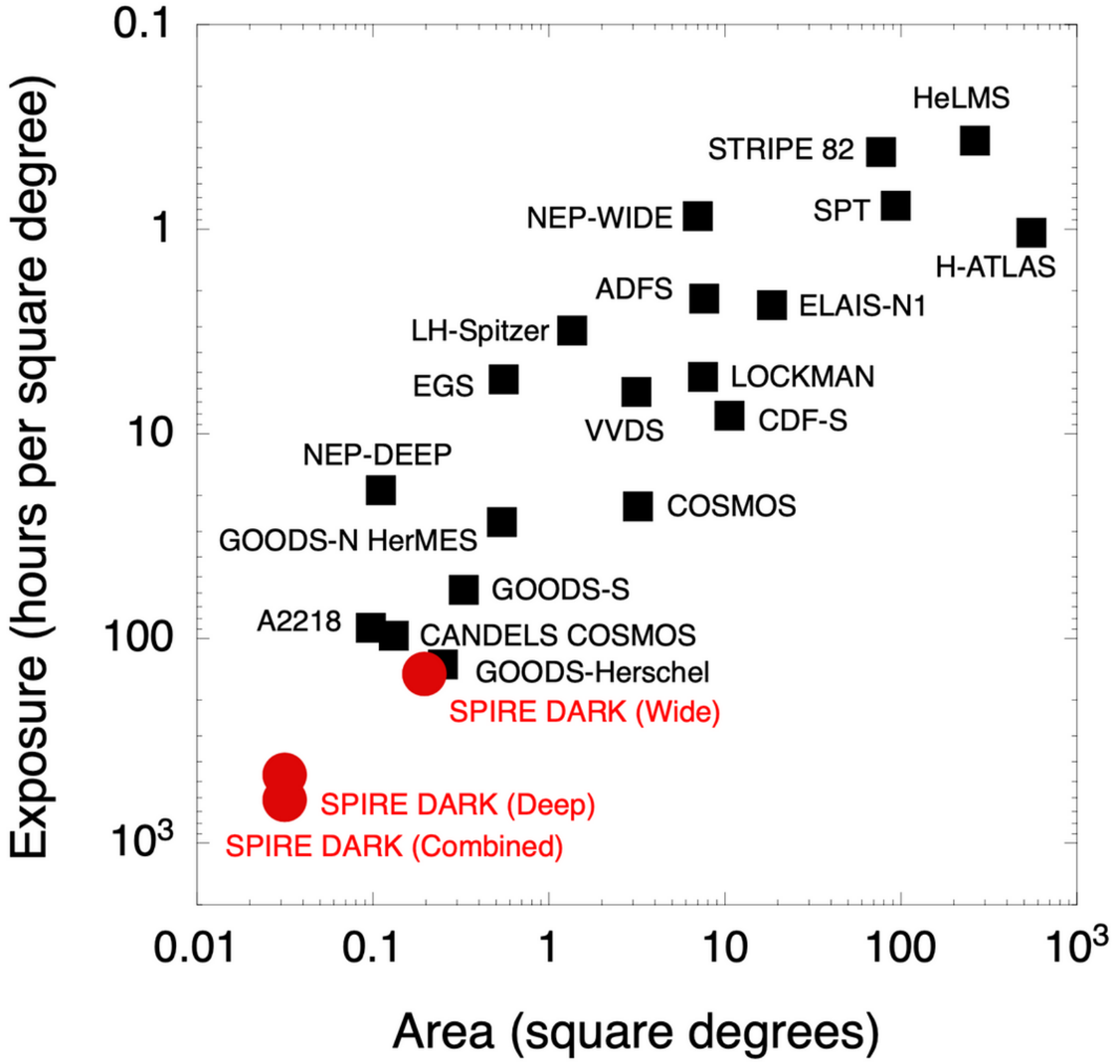
Outline

- The *Herschel* Dark Field
- *Herschel*-SPIRE Number counts, P(D) analysis, implications
- SCUBA-2 Followup, Multi-wavelength cross identifications
- Conclusion - the need for PRIMA

The *Herschel* Dark Field

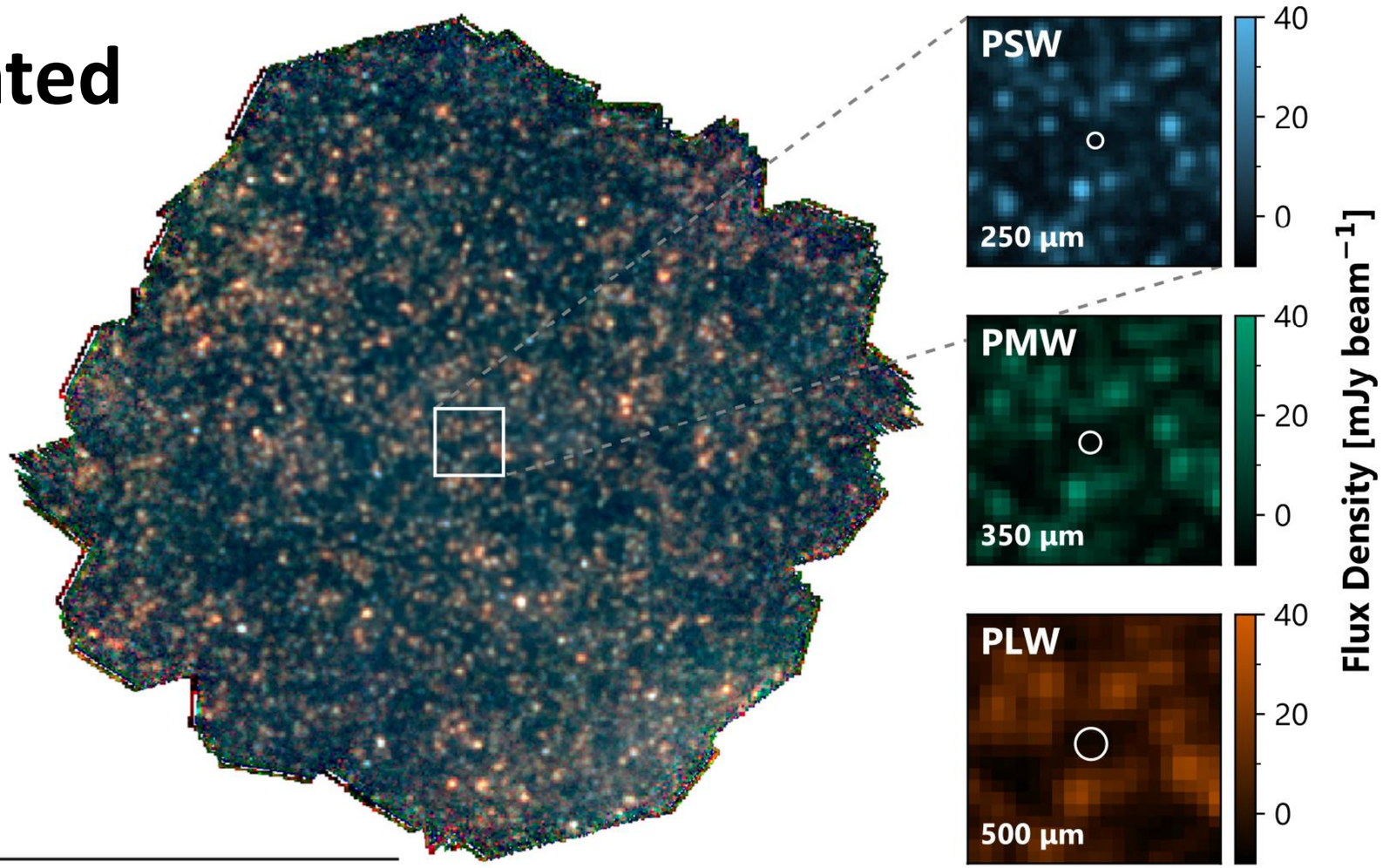
- 3.5 degrees from NEP at R.A. = 17h04m12s, Dec =+69d00m00s (NOT in Euclid Deep Field)
- Used for SPIRE calibration - 141 observations in total
- Observed roughly once a week over the whole Herschel mission to check and validated SPIRE health and calibration
- Coincides with the Spitzer IRAC Dark Field.





Pearson+25, in press.

Confusion noise dominated field



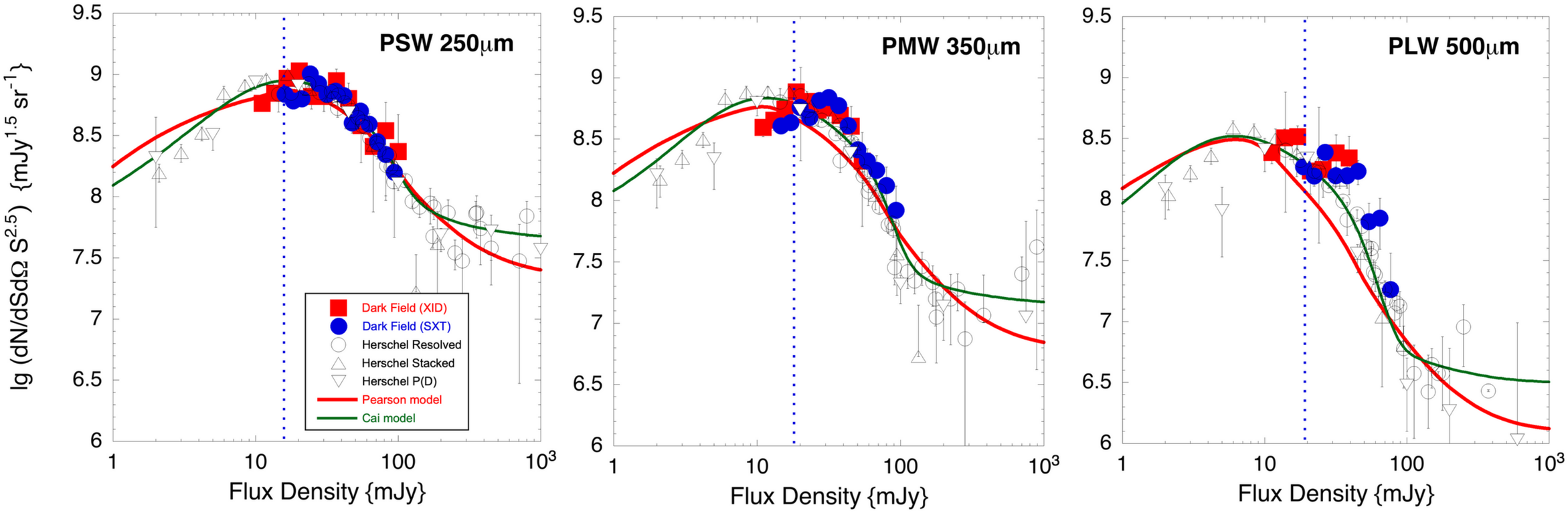
SPIRE Band	Estimated Noise (mJy)		
	Full Map	Deep Region	Confusion
PSW 250 μm	5.87 ± 2.39	5.33 ± 1.75	5.8 ± 0.3
PMW 350 μm	6.05 ± 2.12	5.80 ± 1.62	6.3 ± 0.4
PLW 500 μm	5.82 ± 1.88	5.34 ± 1.60	6.8 ± 0.4

Instrumental sensitivity is sub-mJy in all bands

Pearson+25, in press.

Herschel-SPIRE Number Counts

- Used standard source detection to get counts.
- Used 24 micron guided source extraction using XID algorithm.



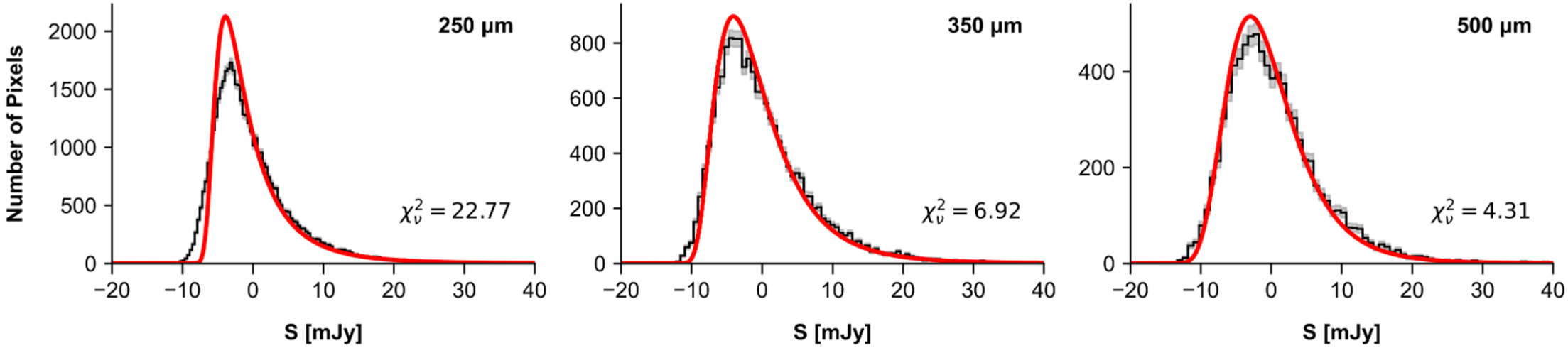
Pearson+25, in press.

P(D) Analysis

- Probability of Deflection Analysis
- Compares distribution of pixel fluxes in observations to those predicted by various counts models
- Uses pofd_affine package as used by Glenn et al. 2010
- Represents the number count model as a spline where each point is a knot
- Move these knots to produce best fit to pixel distribution
- Apply to deepest 12 arcmin diameter region of dark field

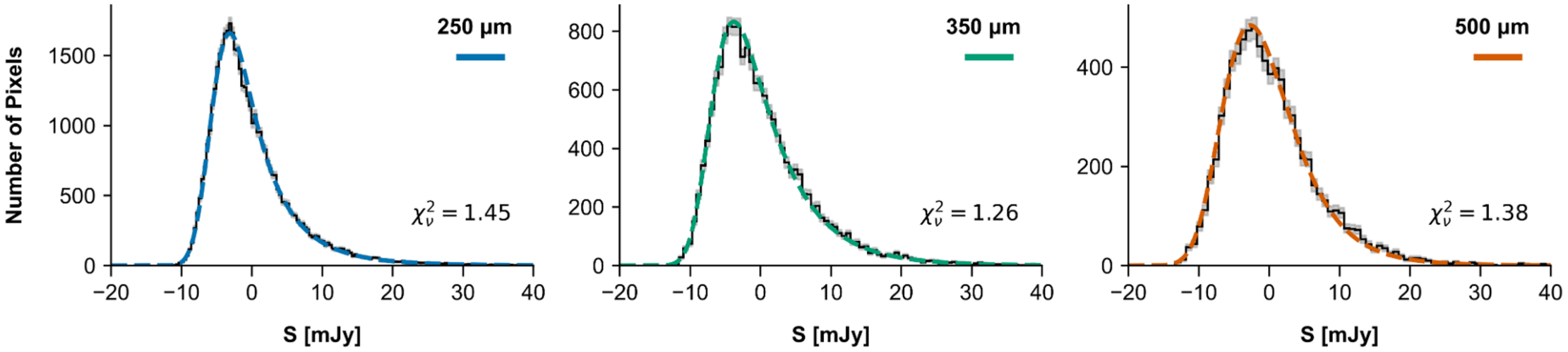
Varnish+25, in press.

Pixel Distributions

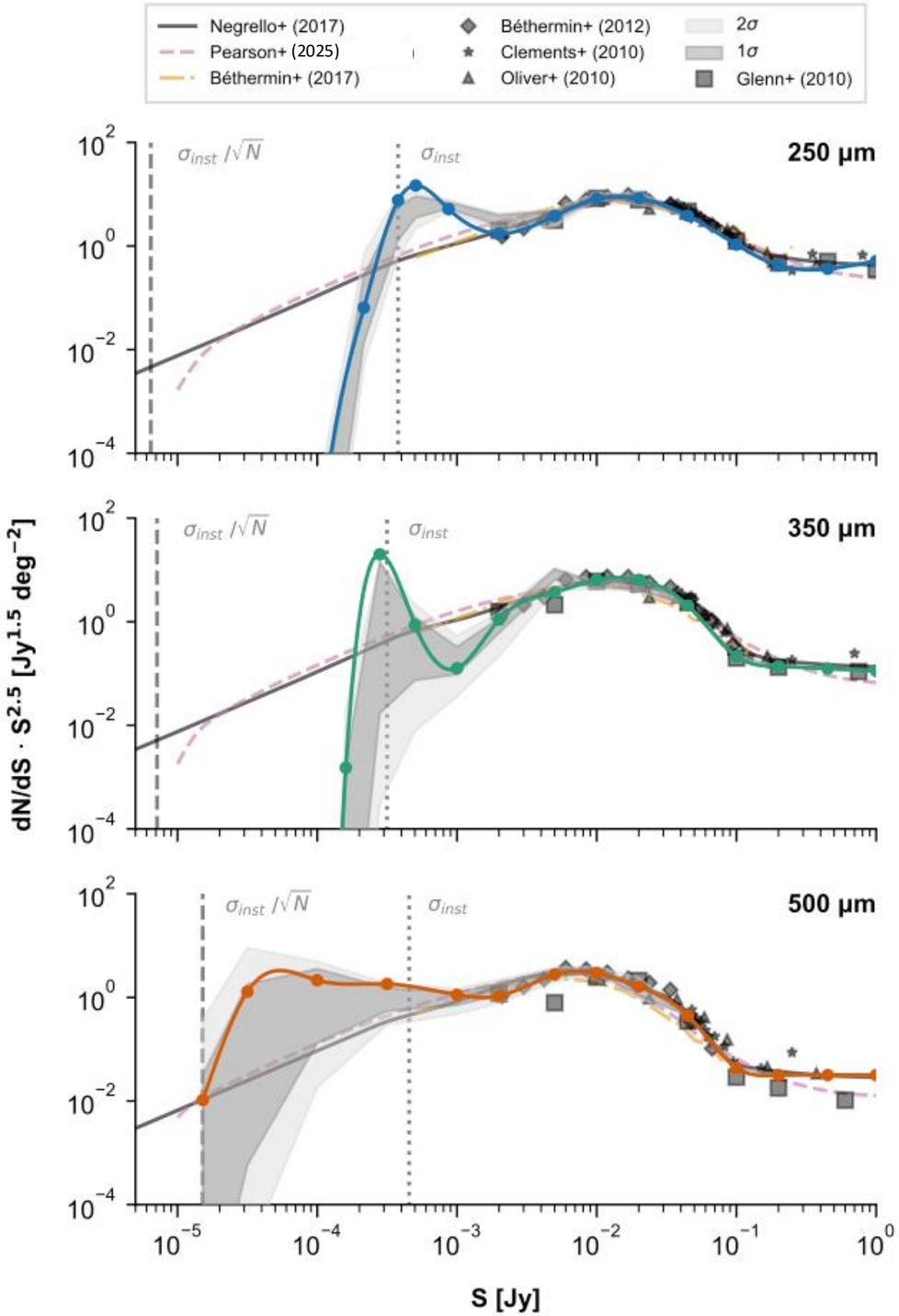


- Dark field pixel distributions compared to predictions of Negrello+2017 counts (other current models have similar disagreements).

Varnish+25, in press.



Model	χ^2_ν 250 μm	350 μm	500 μm	Avg.
Béthermin et al. (2017)	18.44	15.99	16.00	16.81
Negrello et al. (2017)	22.77	6.92	4.31	11.33
Pearson et al. (2024)	16.17	7.11	4.49	9.26
Our P(D) Analysis	1.45	1.26	1.38	1.36



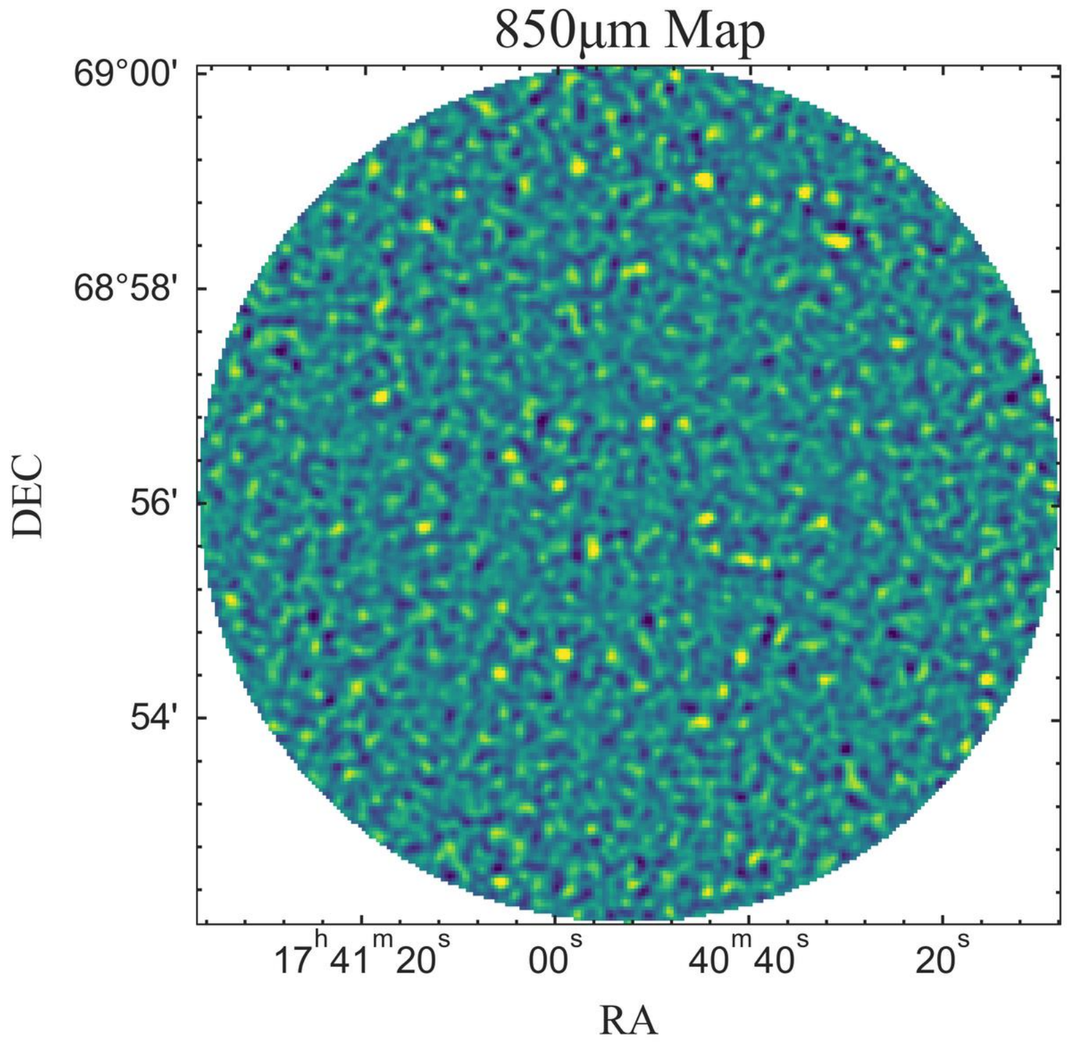
P(D)-derived Counts

- Extra bump in counts at sub-mJy levels indicates that something is missing from current models
- New population? Something known but absent from the models? Is it something special about this field?
- Secondary bump shifts to fainter fluxes with increasing wavelength --> ‘bluer’ population.

Varnish+25, in press.

SCUBA-2 Observations

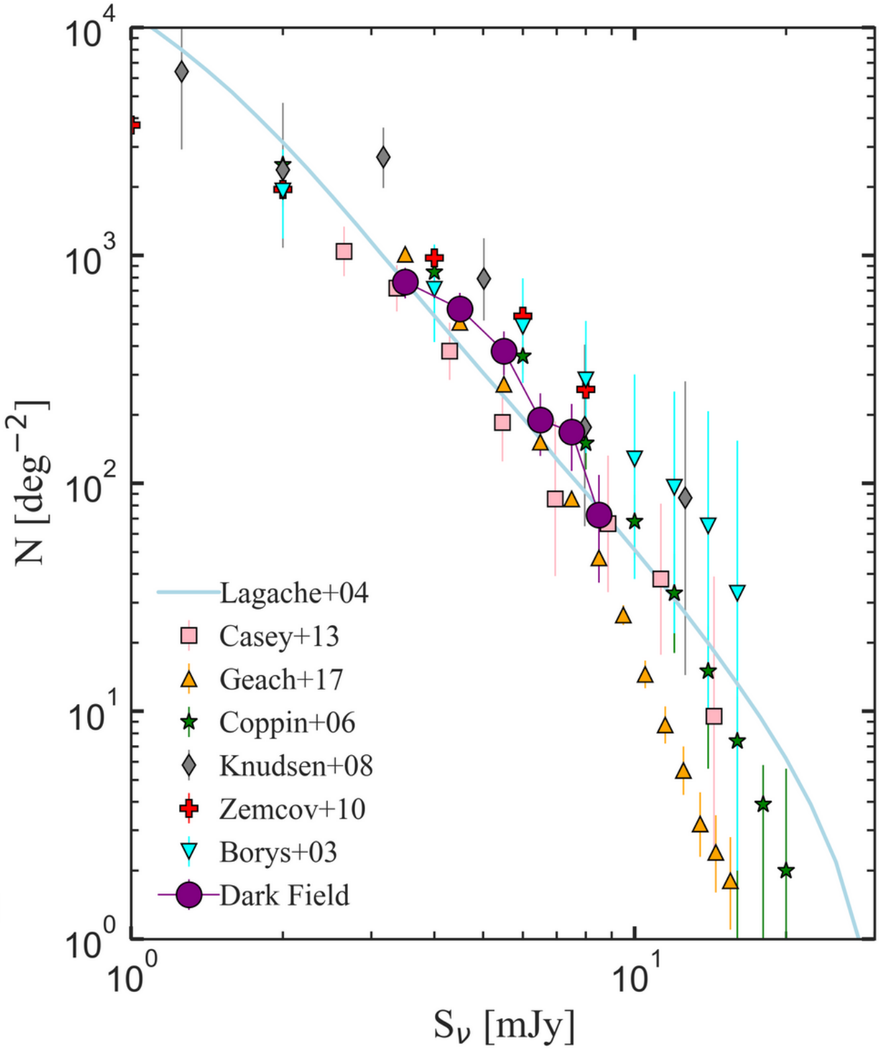
- Archival SCUBA-2 coverage of the central Dark field region
- Reduced and analysed using standard methods.
- Includes deboosting, completeness & reliability corrections.
- 36 sources (> 4σ) detected at 850μm



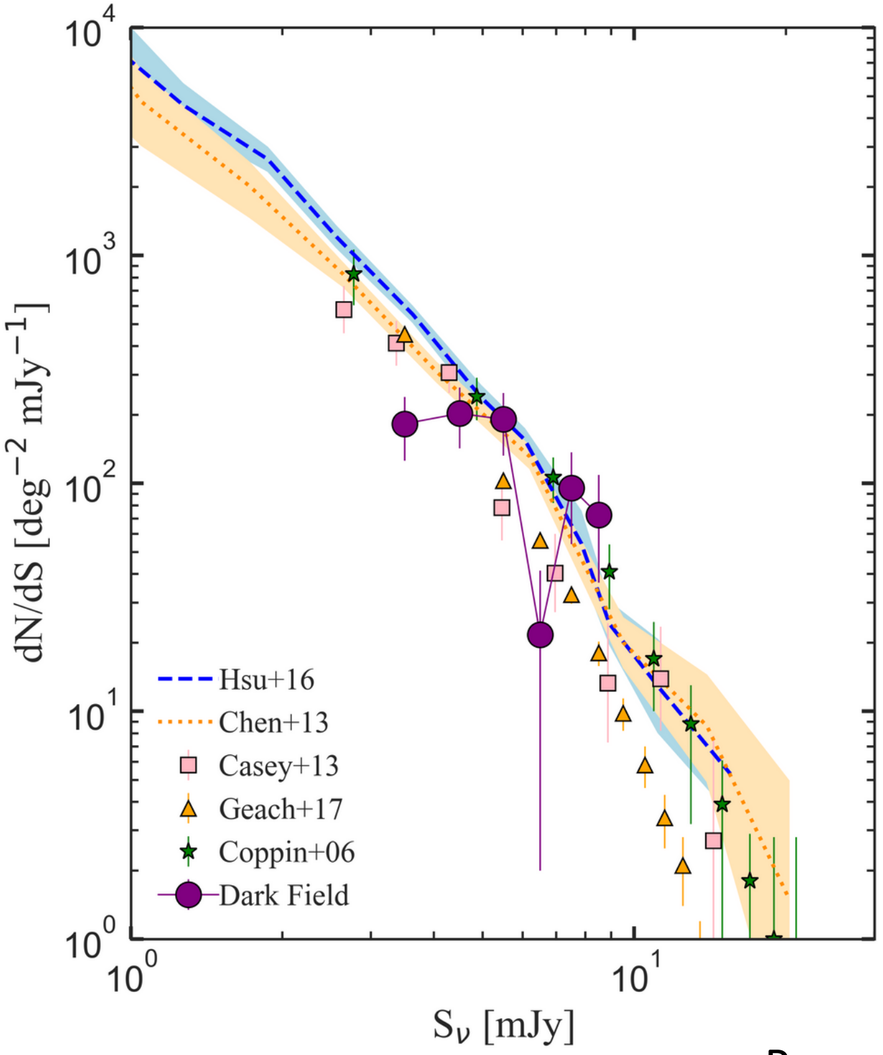
Parmar et al. in prep.

SCUBA-2 Number Counts

Integral



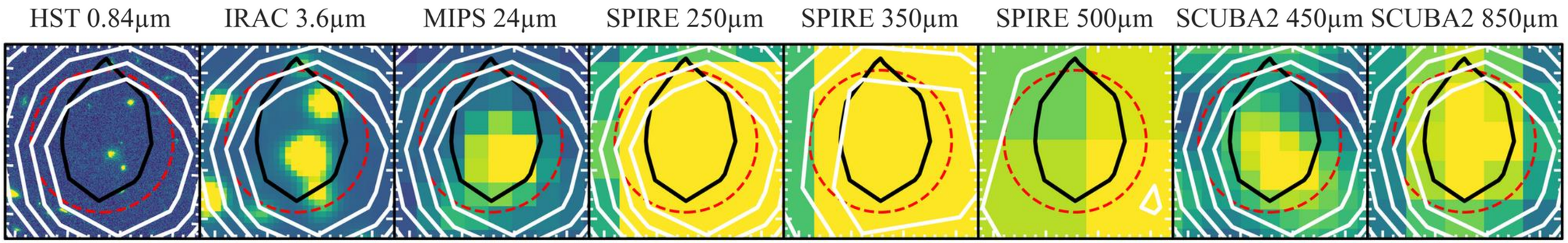
Differential



Corrected for reliability, completeness and flux boosting.

Parmar et al. in prep.

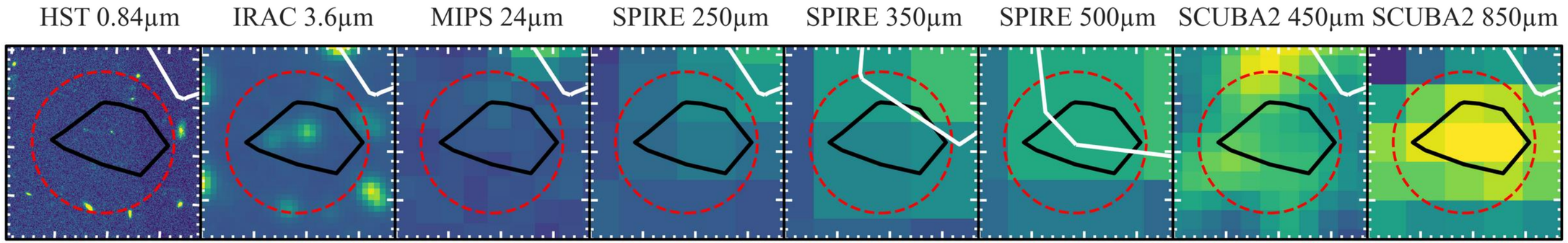
Multiwavelength Cross IDs



- Use SCUBA-2 position to search for cross IDs with the SPIRE sources.
- Then look for other available data from HST, *Spitzer* etc. for multiwavelength photometry.
- We identify cross-IDs for 17/36 sources.

Parmar et al. in prep.

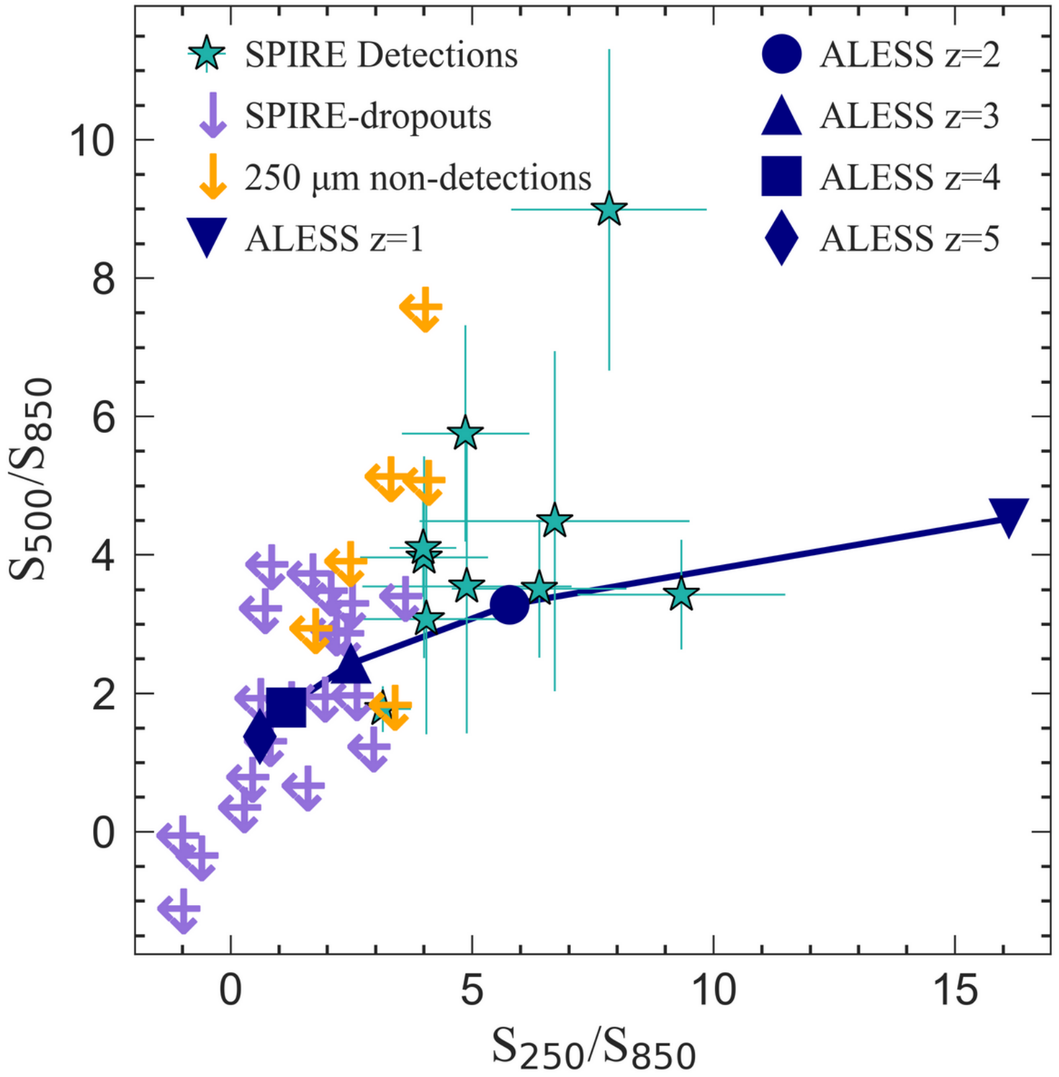
SPIRE dropouts

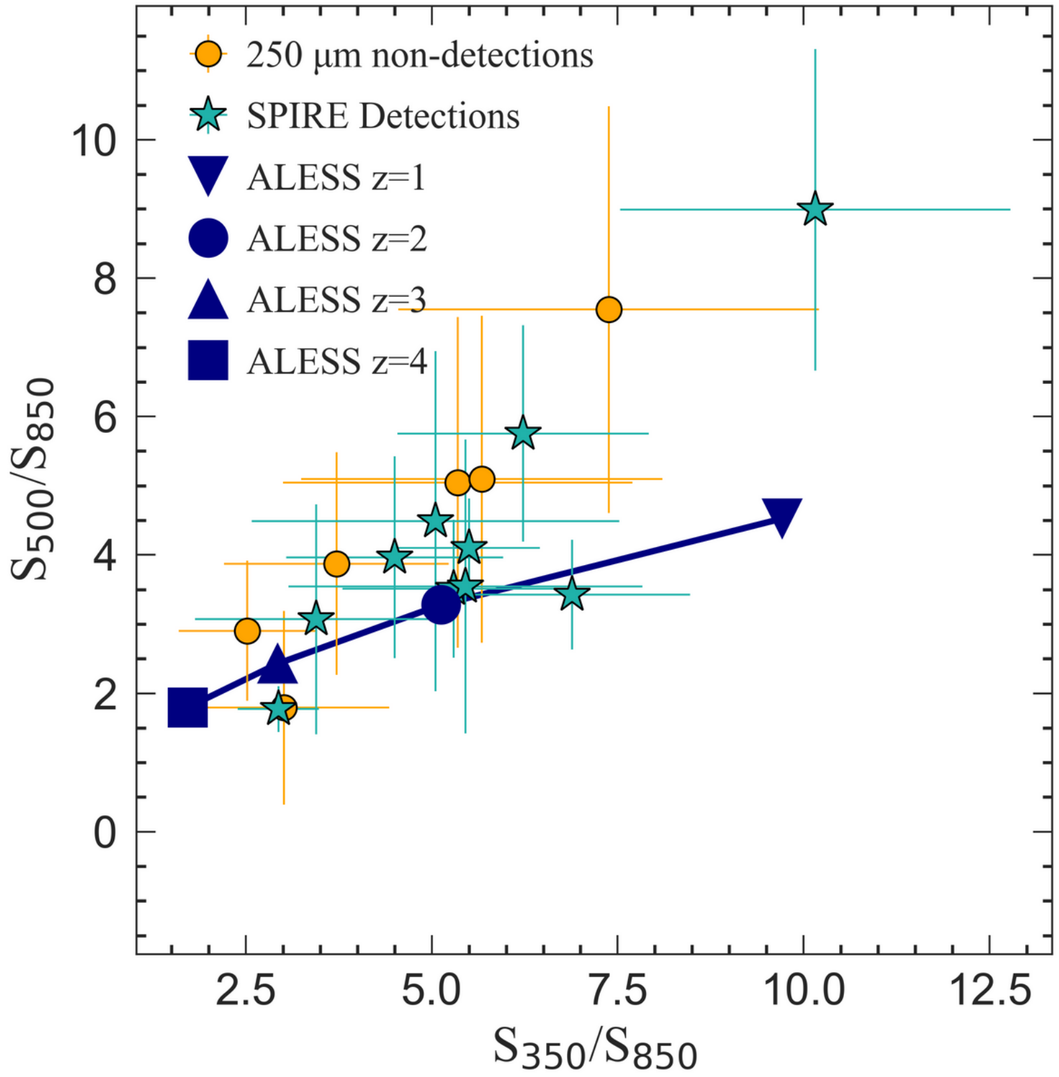


- Out of 36 SCUBA-2 detections, 20 are undetected in all SPIRE bands -> SPIRE dropout.
- Higher fraction of SPIRE dropouts that other SCUBA-2 surveys (estimated fraction ~20%; Greenslade+19)

Parmar et al. in prep.

FIR-submm Colours

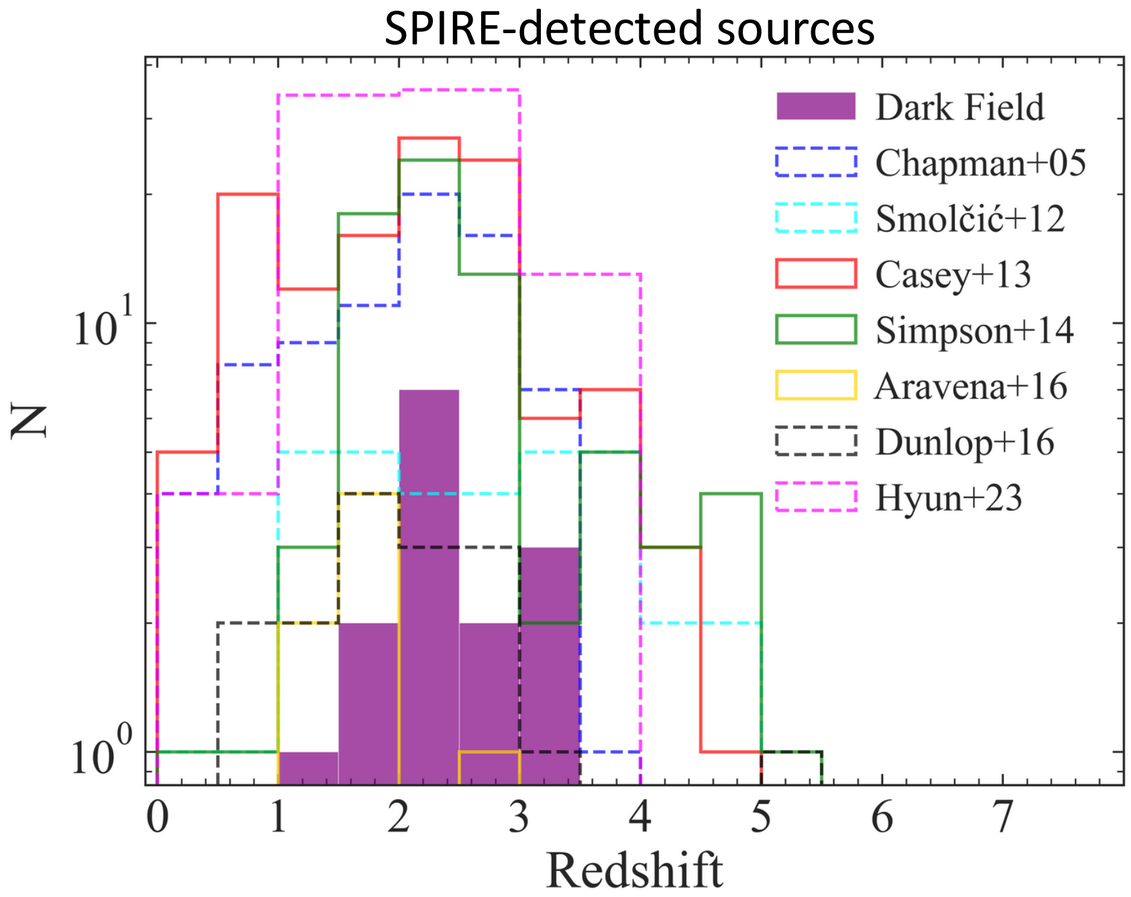




Parmar et al. in prep.

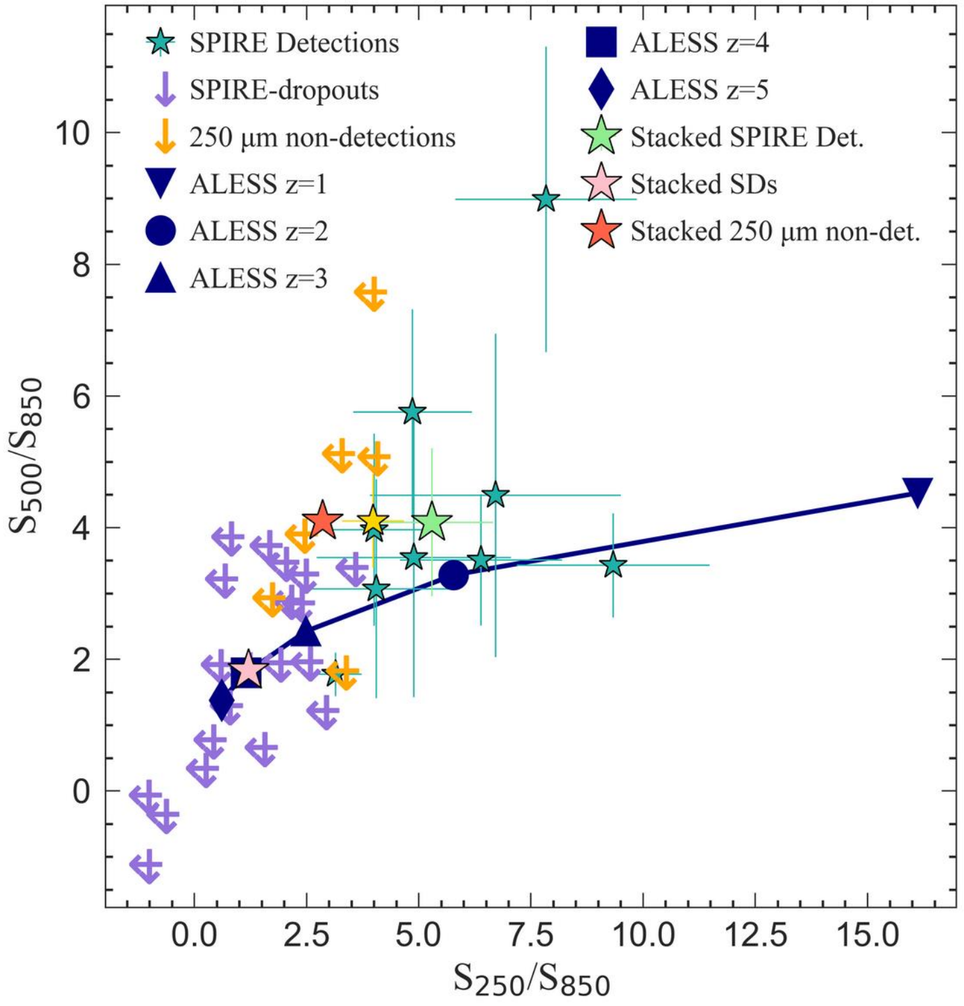
Redshift Estimates

- Photometric redshift estimates using:
  - MMPz (Casey+20) for FIR estimate
  - BAGPIPES (Carnall+18) where optical/NIR data is available.
- SPIRE dropouts consistent with $z > 3$, SPIRE-detected sources consistent with $z \sim 2$ -> in agreement with our colour analysis.

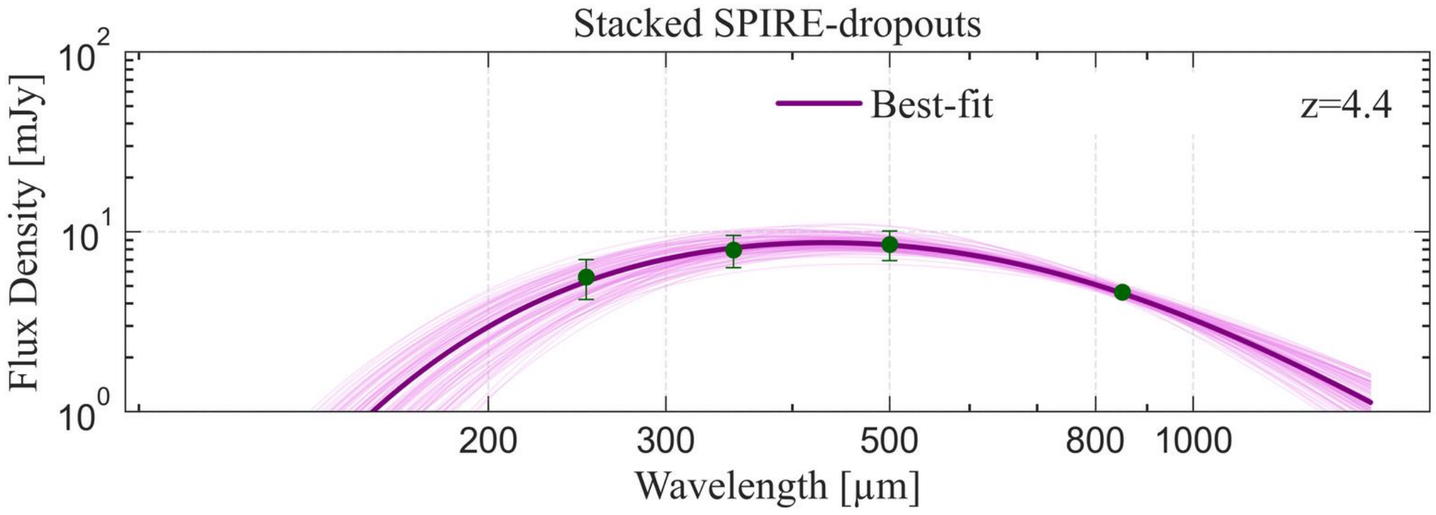


Parmar et al. in prep.

Stacking SPIRE-dropouts



SPIRE Band	Stacked Flux [mJy]
250 μm	5.6 ± 1.4
350 μm	7.9 ± 1.6
500 μm	8.5 ± 1.6
850 μm	4.6 ± 0.2

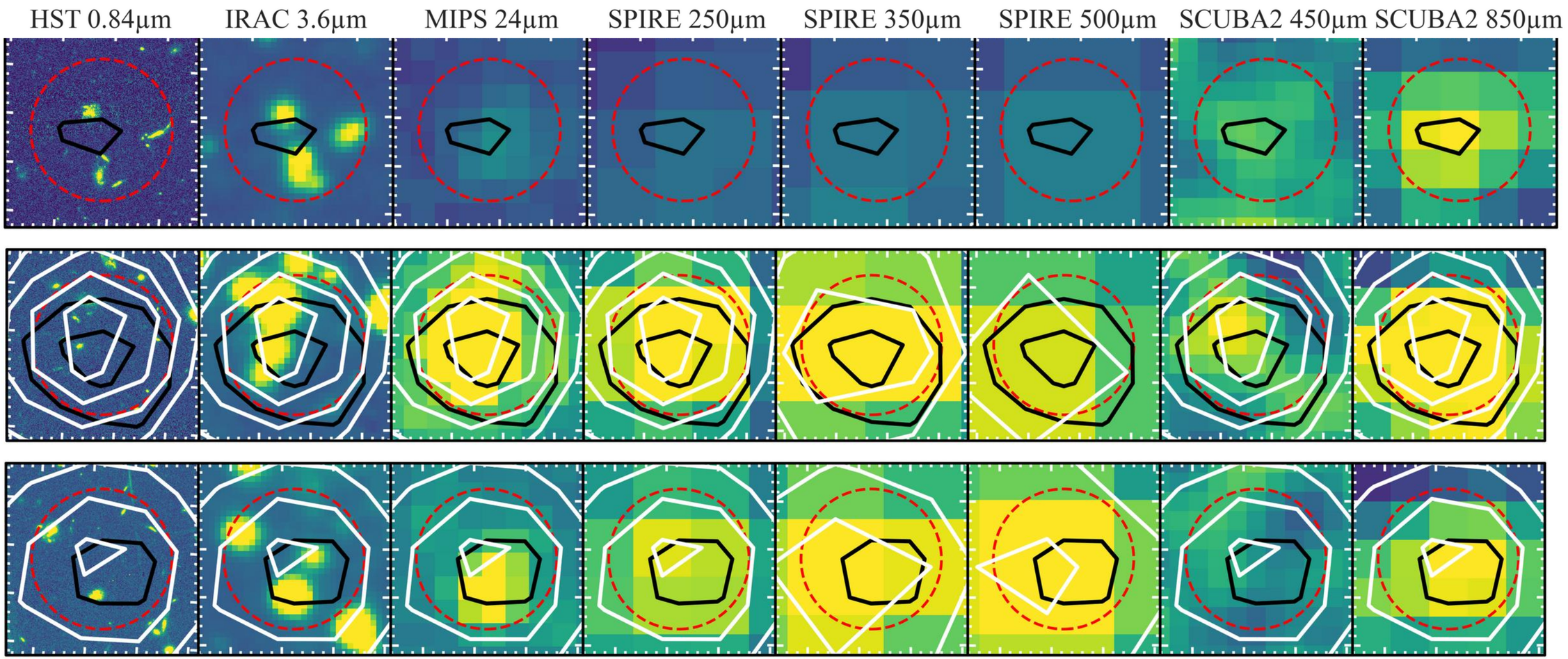


The need for PRIMA

- Small area, deep survey probing below the confusion noise.
- Is the peak a local problem to the dark field or a bigger problem?

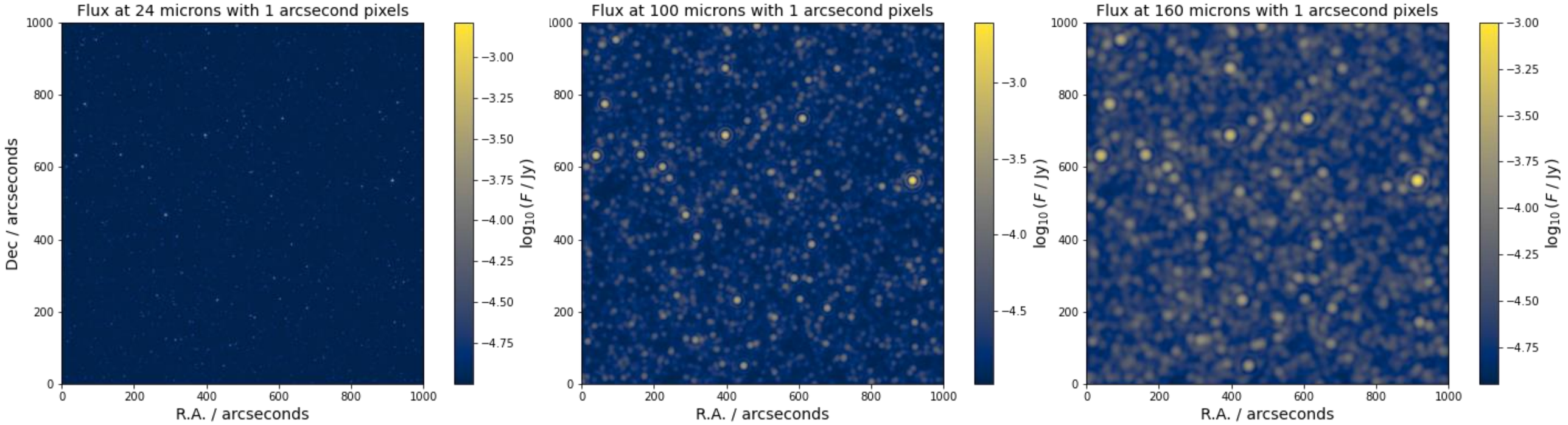
The need for PRIMA

- 19/36 sources don’t have a cross-ID due to a lack of an optical/NIR source or the inability to accurately identify a counterpart from multiple candidate IDs.



The need for PRIMA

- Higher resolution images in the mid-IR with the PRIMA Hyperspectral Imager than *Spitzer* - MIPS.
- Provide accurate positions of MIR counterparts -> overcoming source blending/multiple candidate IDs.



Simulated PRIMA images at 24, 100 and 160µm courtesy of J. Beltrán, L. Rius & B. Pautasso

Conclusions

- **Deepest *Herschel* image ever from *Herschel* Dark Field calibration data.**
- **Discrete SPIRE source counts consistent with other survey data.**
- **P(D) indicates a secondary bump at sub-mJy fluxes not seen in existing models.**
- **SCUBA-2 observations show unusual number of SPIRE dropouts.**
- **Small-area, deep, sub-confusion noise PRIMA fields.**
- **High-res MIR imaging with PRIMA can provide accurate positions for MIR counterparts**

  -> positional priors for e.g. XID+

Coming soon...

Pearson et al. 2025 → The *Herschel*-SPIRE Dark Field: Paper I

Varnish et al. 2025 → The *Herschel*-SPIRE Dark Field: Paper II

Parmar et al. (in prep.) → The *Herschel*-SPIRE Dark Field: Paper III