SPIRE MAPS AND SOURCE CATALOGUES

Chris Pearson [1,2]
Ryan Cheale [1]

October 2013

1. RAL Space
2. The Open University

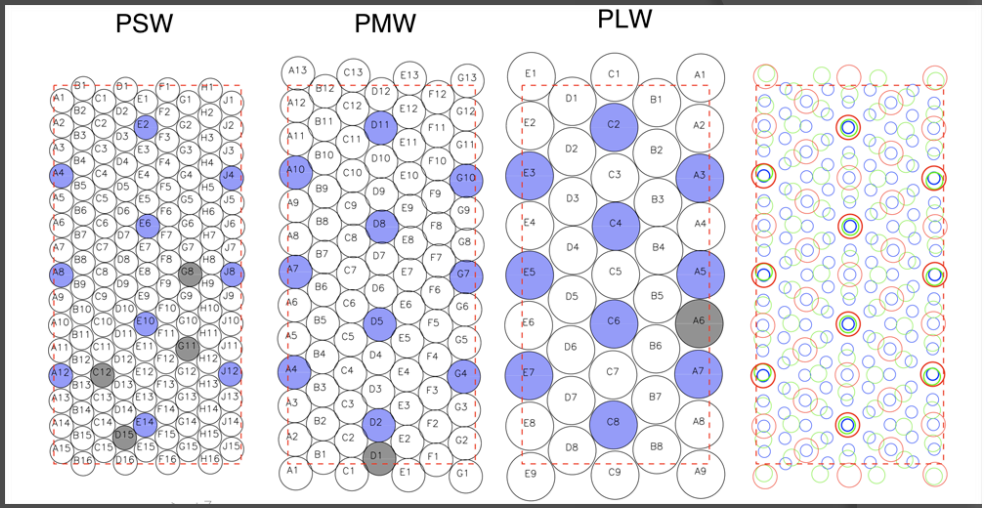
Contents

- SPIRE Overview
- NEP Observations
- Data Reduction and Photometry
- Source Extraction Evaluation
- Iterative Approach to Source Extraction
- Results for OT2 Observations
- OT2 NEP Source Number Histogram and Colours
- NEP All Maps Mosaic
- Source Number Histogram and Colours
- Colour Selection Plots Source Counts
- Completeness and Reliability
- Comparison with other Source Counts
- Future Work

SPIRE Overview

SPIRE Summary: Detector Properties

Sub-instrument	Photometer		
Array	PSW	PMW	PLW
Band (μm)	250	350	500
Resolution ($\lambda/\Delta\lambda$)	3.3	3.4	2.5
Unvignetted field of view	$4' \times 8'$		
Beam FWHM size (arcsec)[b]	18.2	24.9	36.3



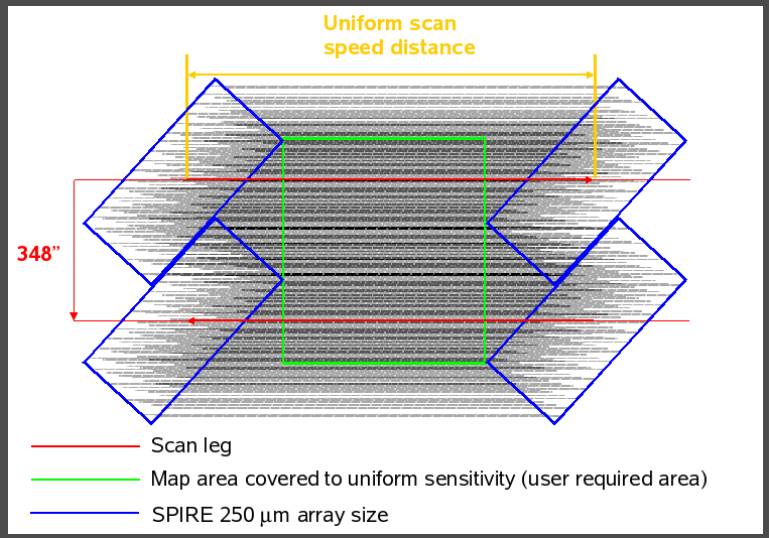
SPIRE photometer bolometer arrays with the bolometer names shown. Detectors centred on same sky positions are shaded in blue, the dead bolometers are shaded in grey. The 4 8 arcmin field of view of each array is shown by a red dashed rectangle.
The figure on the right shows the arrays overlap on the sky where the PLW (500um) array is red, the PMW (350um) array in green and the PSW (250um) array in blue with the circle size corresponding to the FWHM of the beam.

Band	250	350	500
1 σ extragalactic confusion noise (mJy in beam)	5.8	6.3	6.8
SPIRE-only scan map; 30 "/s scan rate			
1 σ instrument noise for one repeat: i.e., two cross-linked scans, A+B (mJy in beam)	9.0	7.5	10.8
1 σ instrument noise for one repeat: i.e., one scan A or B (mJy/beam)	12.8	10.6	15.3

Nguyen et al. (2010), who define confusion noise as the standard deviation of the flux density in the map in the limit of zero instrument noise

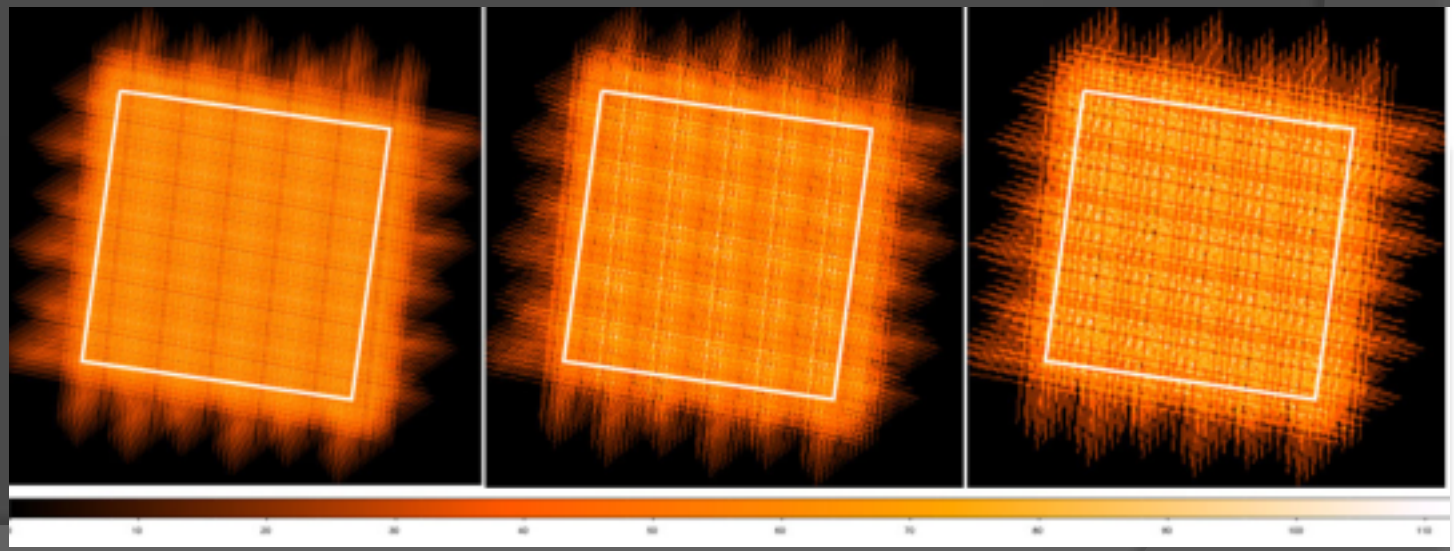
SPIRE Summary: Mapping Strategy

As the SPIRE arrays are not fully filled, the telescope scans are carried out at an angle of 42.4 deg with respect to the Z-axis of the arrays and the scan lines are separated by 348 arcsec to provide overlap and good coverage for fully sampled maps in the three bands



Large Map coverage showing the scan direction with respect to the SPIRE arrays, the scan leg separation step and the uniform sensitivity coverage region. The darker the shading the deeper the coverage.

Orthogonal cross-linked scan of 30x30 arcmin field, the white square is the user requested area.
The pixel size is (6,10,14) arcsec for (PSW, PMW, PLW) and the colour code represents the number of bolometer hits in each sky pixel.

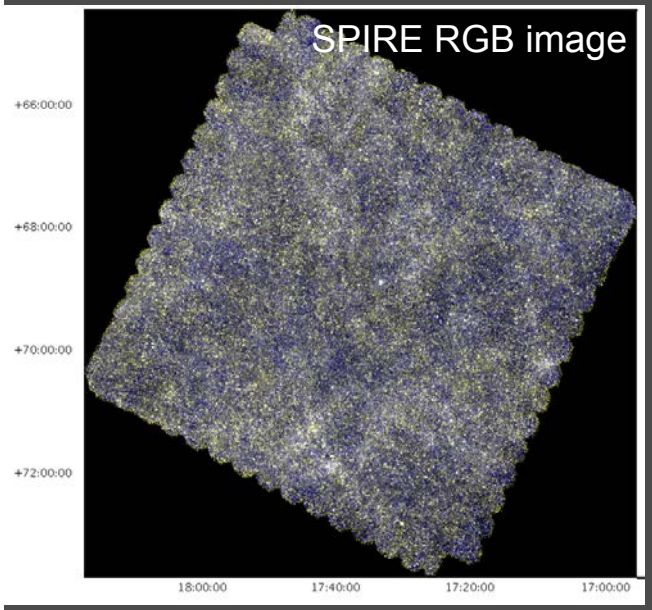


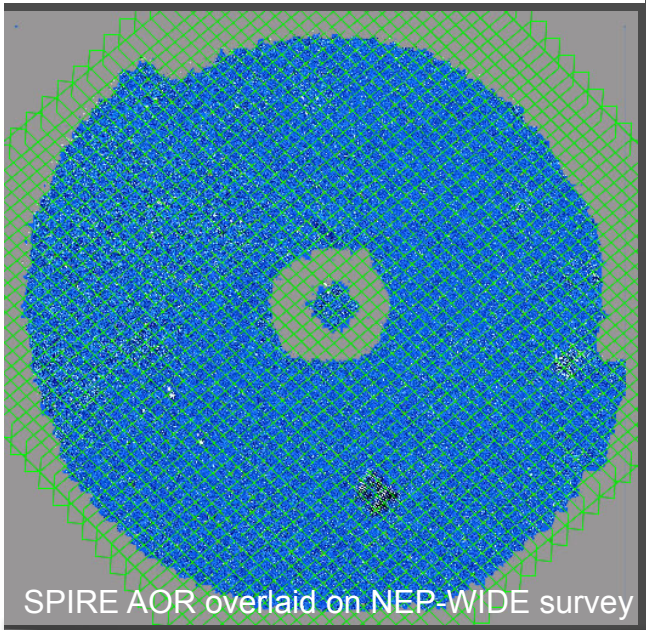
SPIRE Summary: Observations

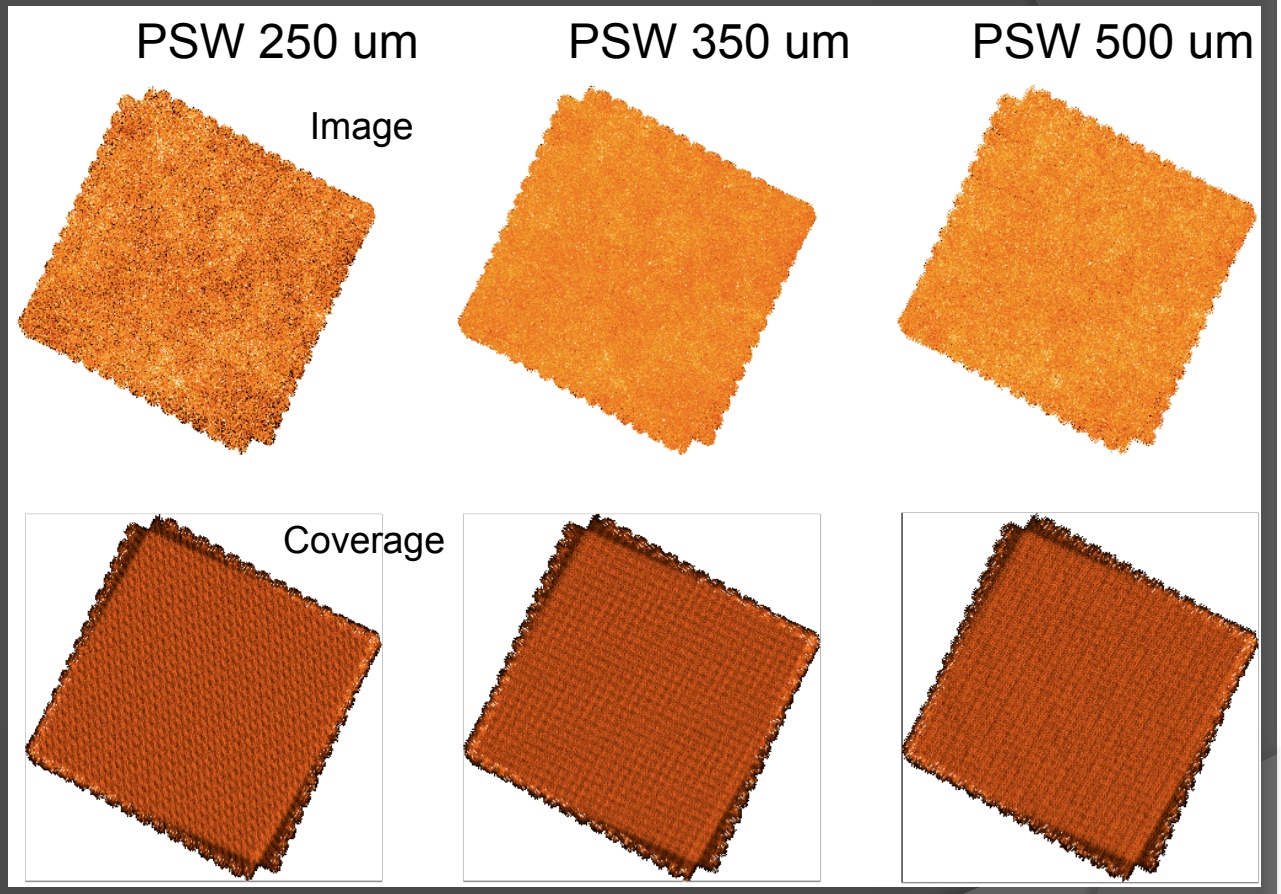
Name	OD	obsid	time	Size	rep	Sensitivity (mJy)		
			(s)	(arcmin)		PSW	PMW	PLW
OT2	1023	1342239959	22178	160x160	1	9.0	7.5	10.8
PV-N	77	1342180954	983	20x20	1	9.0	7.5	10.8
PV-B	77	1342180957	983	20x20	1	32.2	24.0	28.1
GT	226	1342188590	4820	30 x 30	3	5.2	4.3	6.2

NEP Observations

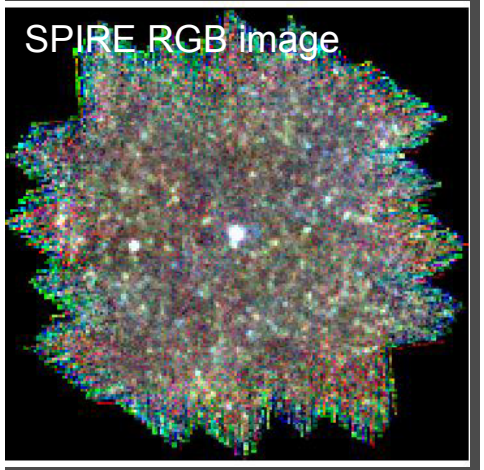
SPIRE Summary: Obs OT2 NEP Wide







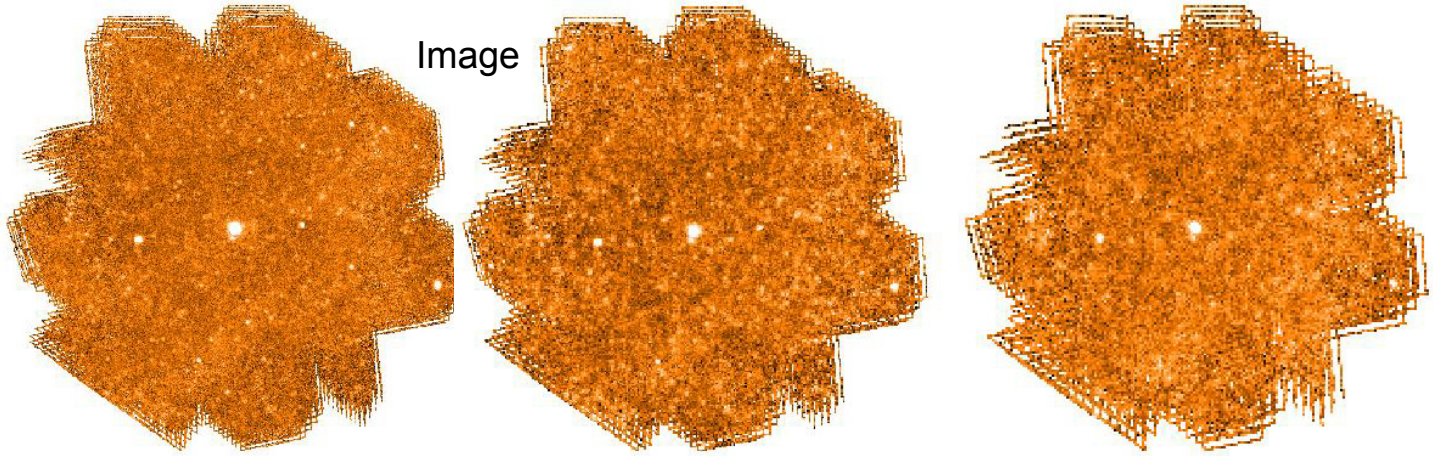
SPIRE Summary: Obs PV Phase OD77 Nominal



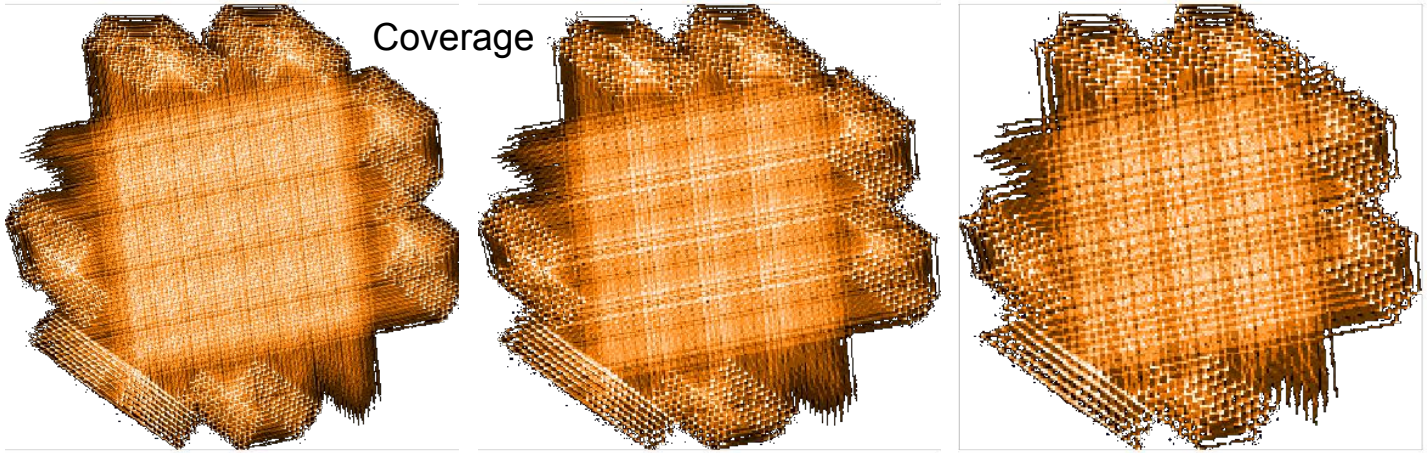
Overlay on AKARI L15 NEP-Deep

PSW 250 um | PSW 350 um | PSW 500 um

Image



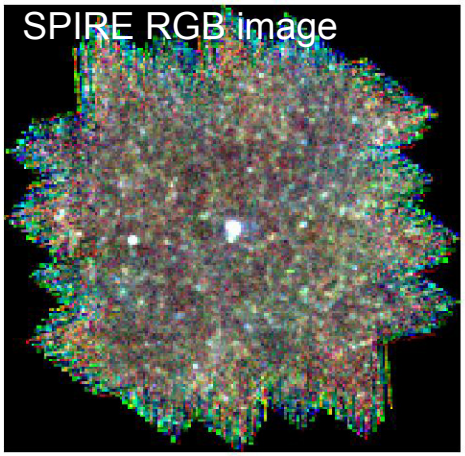
Coverage



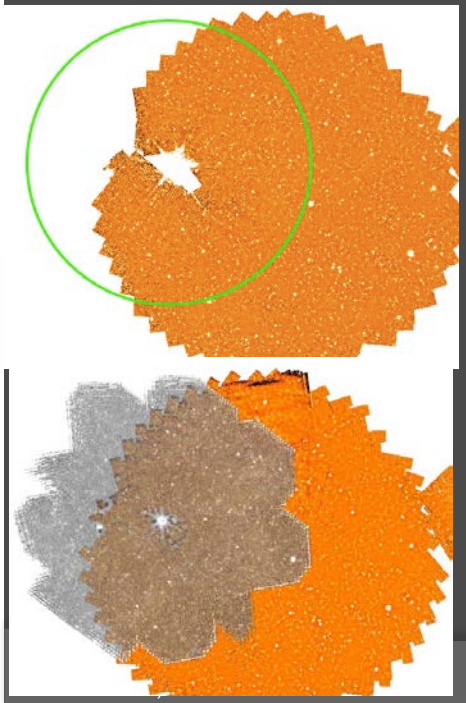
Observations made in Nominal Bias Mode

SPIRE Summary: Obs PV Phase OD77 Bright

SPIRE RGB image

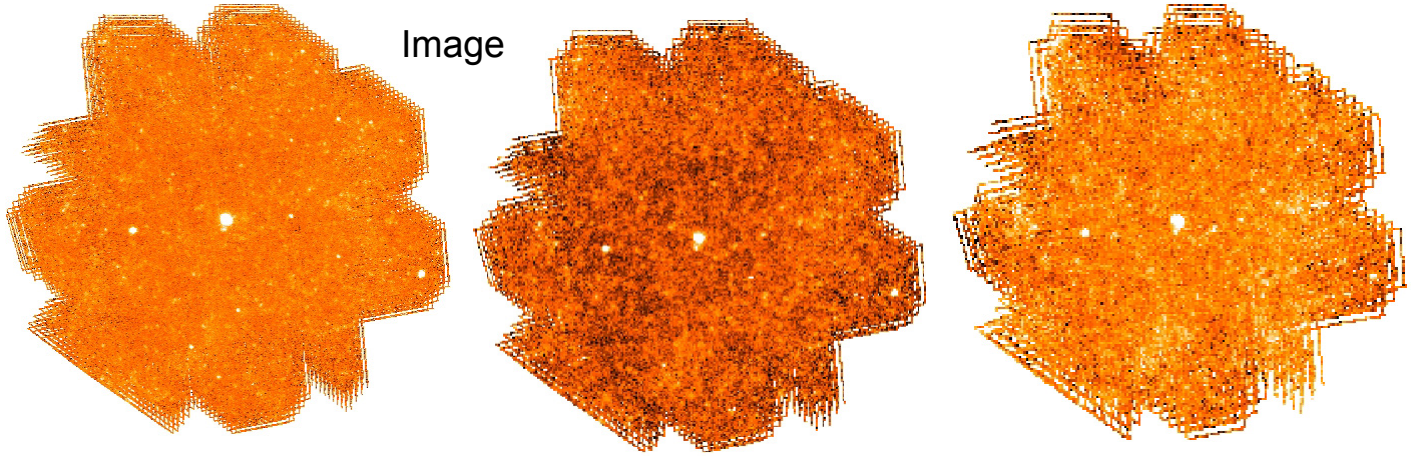


Overlay on AKARI L15 NEP-Deep

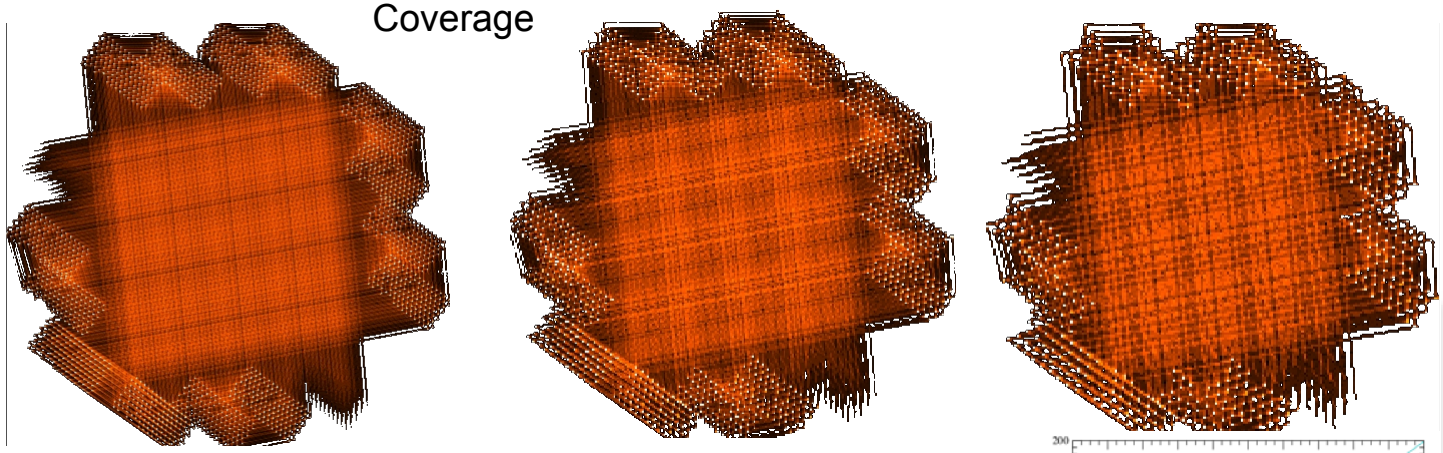


PSW 250 um | PSW 350 um | PSW 500 um

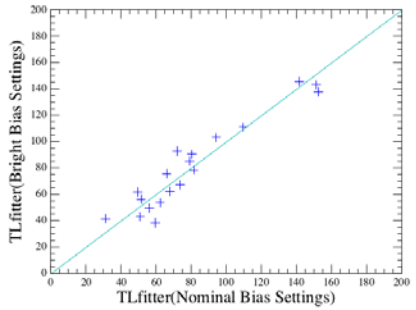
Image



Coverage

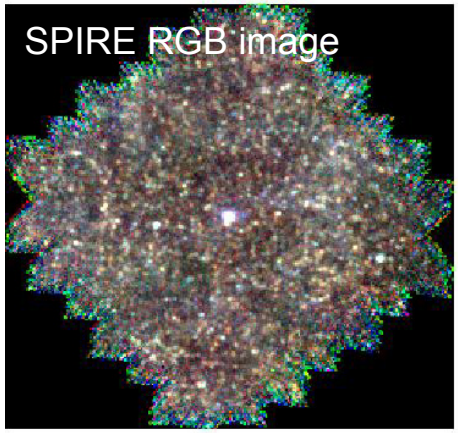


Observations made in Bright Bias Mode
Checked photometry IS consistent between nominal and bright mode

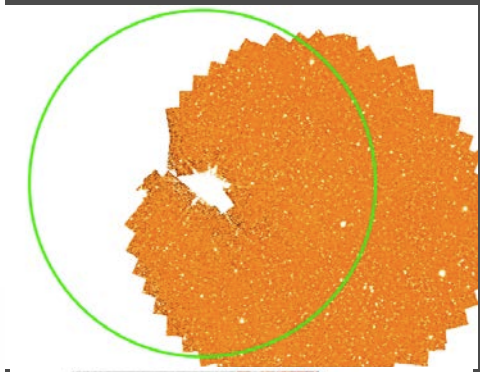


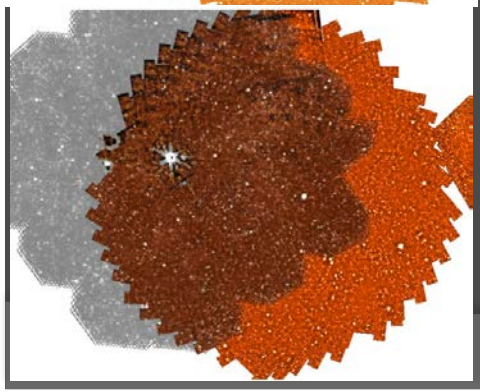
Chris Pearson & Ryan Cheale SPIRE NEP Data Reduction

SPIRE Summary: Obs GT OD226



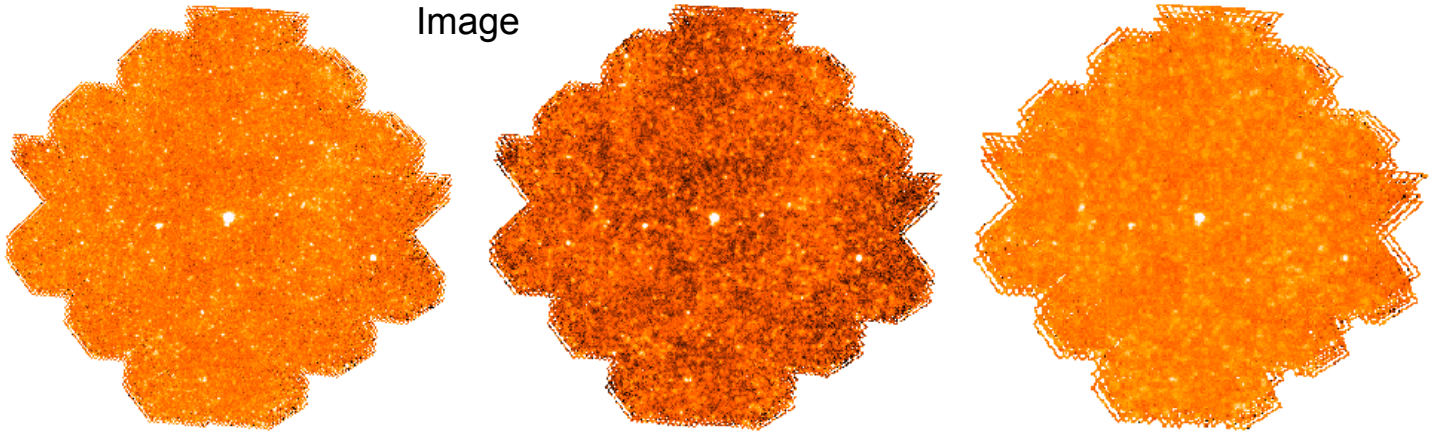
Overlay on AKARI L15 NEP-Deep



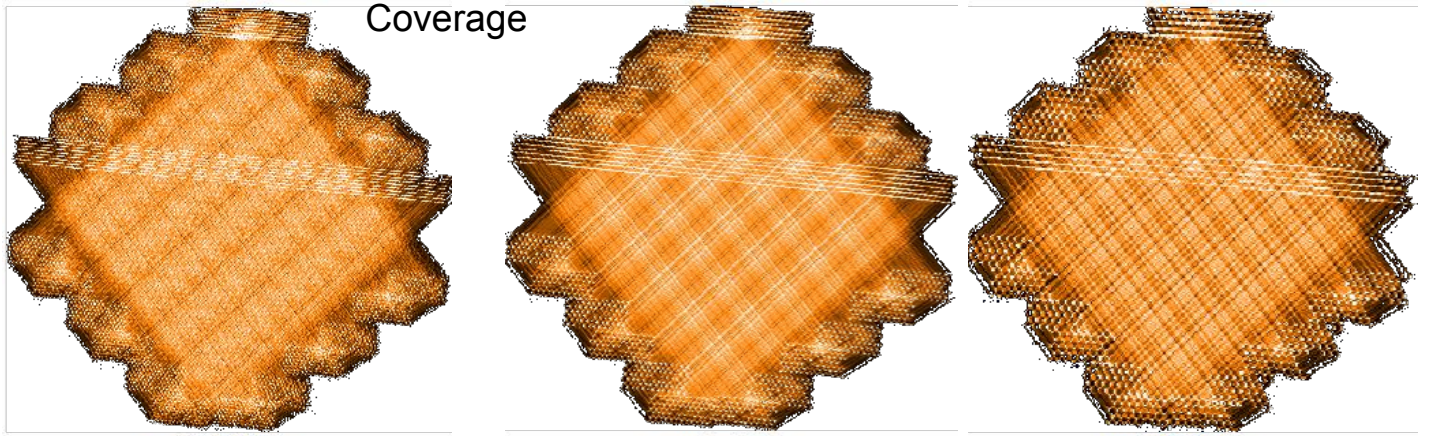


PSW 250 um | PSW 350 um | PSW 500 um

Image



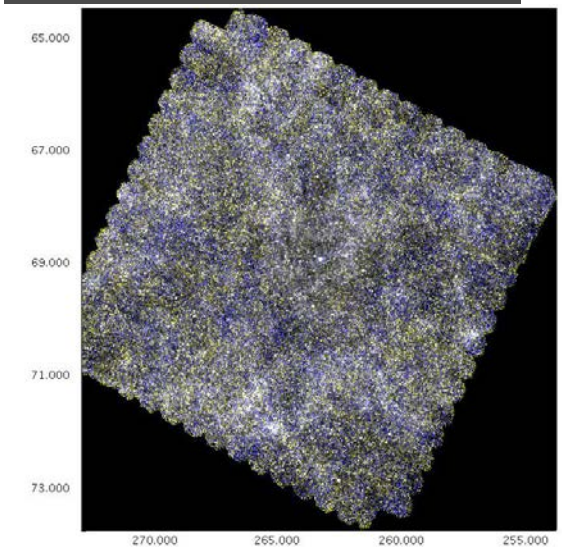
Coverage



Public Data :
The circumstellar environment in post-main-sequence objects"
(PI: Martin Groenewegen)

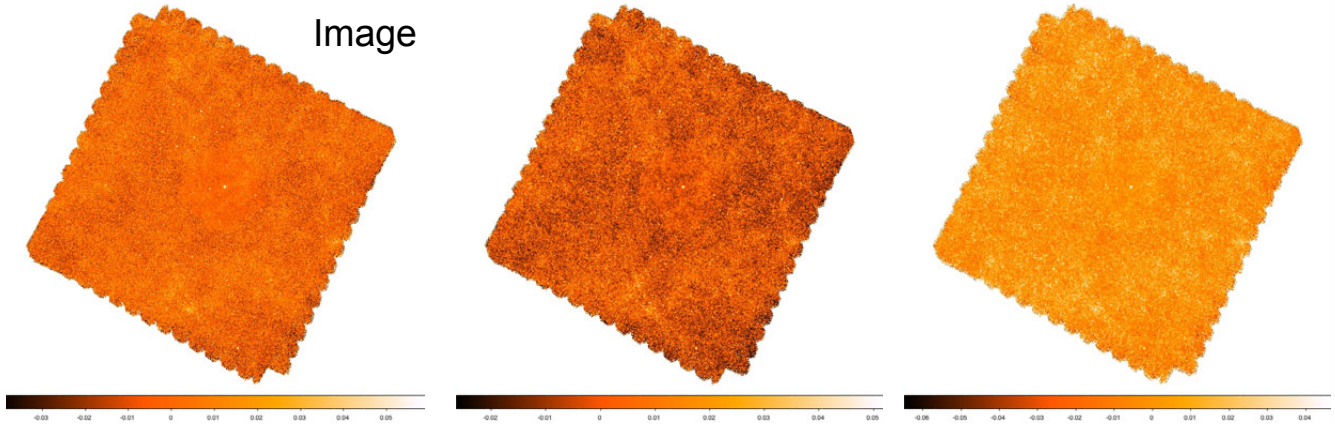
SPIRE Summary: Obs Combined

SPIRE RGB image

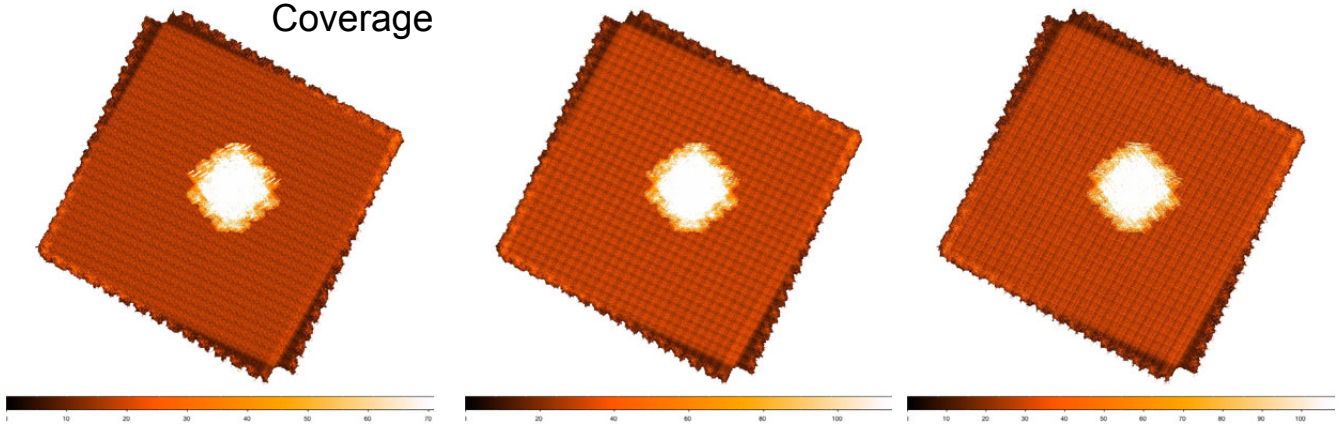


PSW 250 um | PSW 350 um | PSW 500 um

Image



Coverage



A Total of 110 scan lines, between 1 - 6 cross linked scans deep.
Maximum central depth 250 um ~ 4 mJy 350 um ~ 3mJy 500 um ~ 7mJy

Data Reduction and Photometry

Data Reduction Pipeline

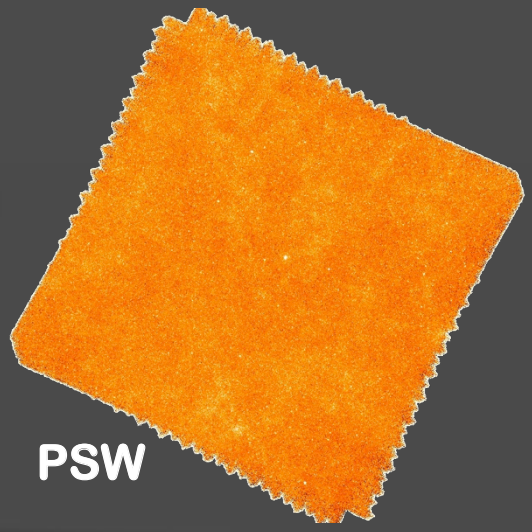
New data reduction of OT2 SPIRE map processed with HIPE 11 build 2813

- **Improved Flux Calibration (Bendo et al. 2013, MNRAS)**
  - The current calibration accuracies are 1.5% for instrumental uncertainties
  - 4% uncertainties in the model flux density of Neptune.
- **Destriped Timelines to remove residual temperature drifts**
- **Maps and Timelines are Point Source Calibrated in Jy/beam**
- **Scan leg turnarounds included to improve map edges**

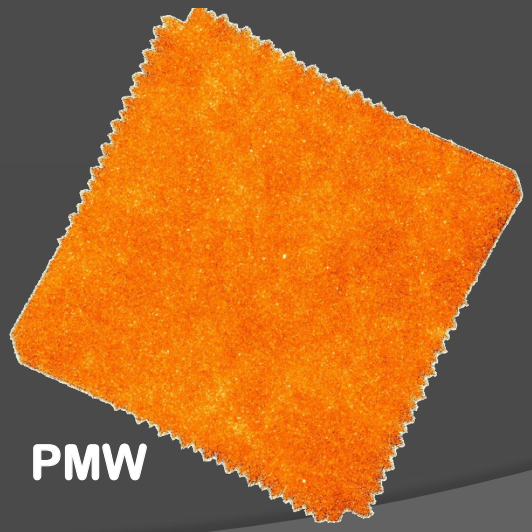
Extended Emission Maps

Absolute Calibrated maps using the Planks Maps are available for the OT2 data for studies of Extended Emission.

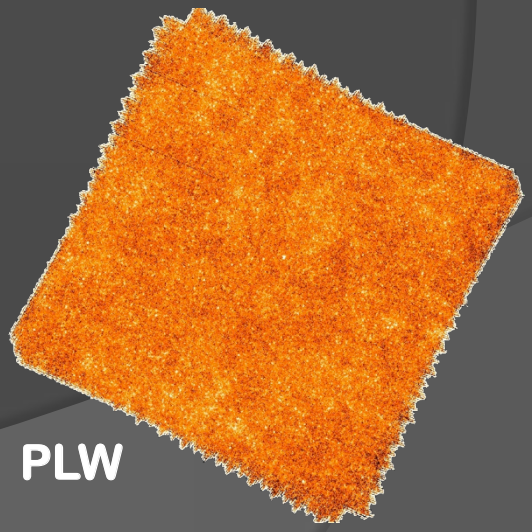
- ❑ Convolve SPIRE map with Planck Beam (HFI Beam Model)
- ❑ Colour correct Planck HFI maps to SPIRE bands
- ❑ Determine absolute zero point offset by comparing with Planck All-Sky maps
- ❑ Apply offset to SPIRE maps
- ❑ Produce SPIRE maps, absolute calibrated for extended emission in MJy/sr



PSW



PMW



PLW

Photometry Methods and Parameters

All photometry methods tested within the HIPE version 11 build 2813
(See Pearson et al, 2013, Experimental Astronomy for details)

- SUSSEXtractor:
  intensity in the smoothed image at the position of a point source is taken as the estimate of the source flux density.

- DAOphot:
  Uses IDL APER for aperture photometry (automatic aperture correction)

- SPIRE Timeline Fitter:
  Fits to timelines projected onto a zero footprint map

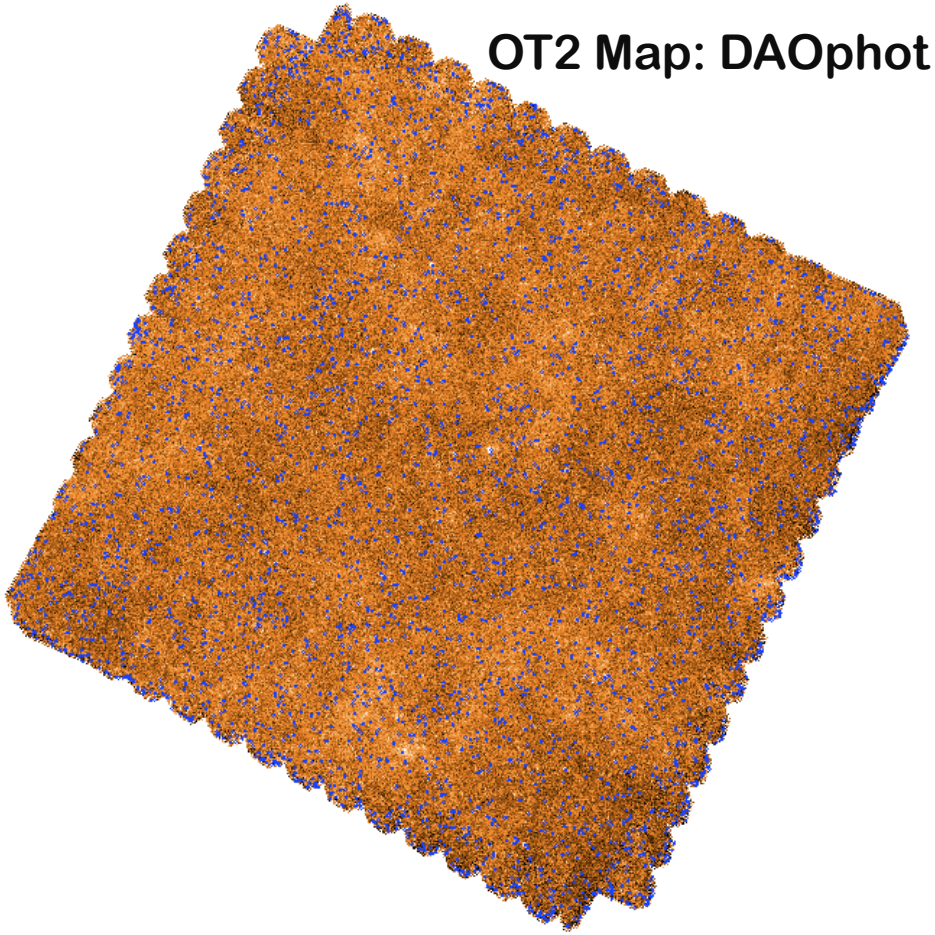
- Aperture Photometry
  Aperture and background annulus

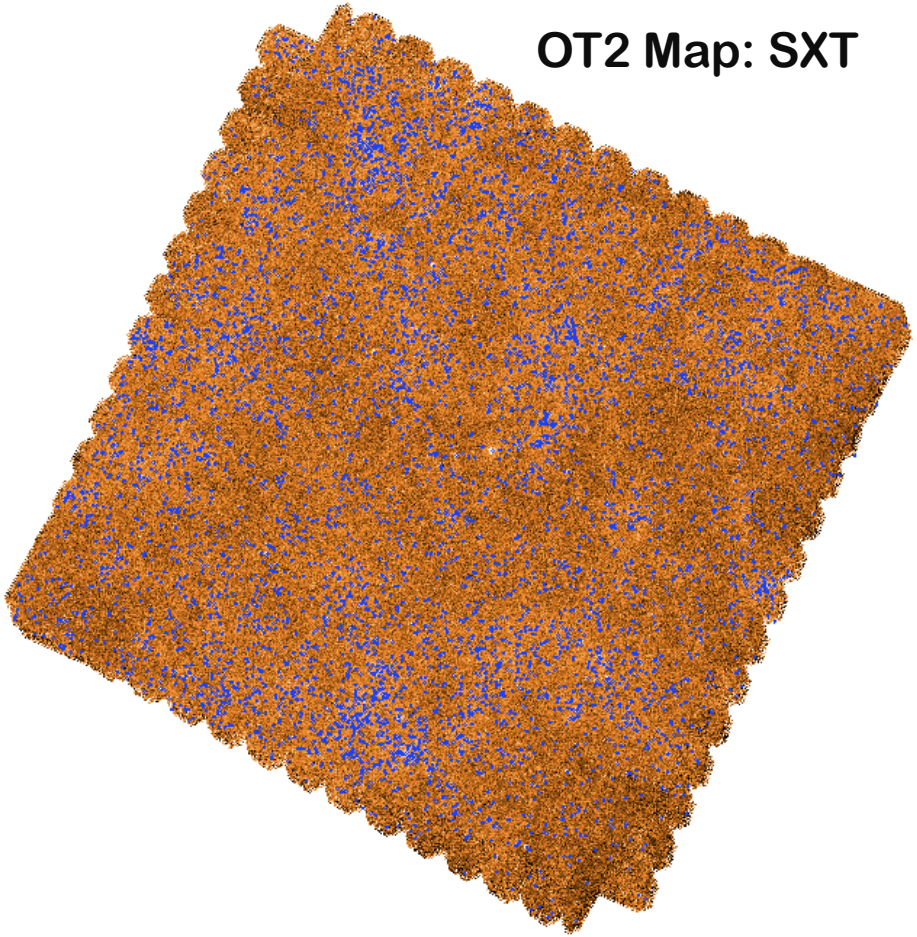
Photometry Methods and Parameters

Parameter	PSW	PMW	PLW
FWHM	17.6	23.9	35.2
Beam (arcsec^2)	465	822	1769
Aperture arcsec	22	30	42
Effective Beam Correction	1.045	1.043	1.075
Aperture Correction	1.295	1.253	1.275
Colour Correction	0.9454	0.9481	0.9432

Source Extraction Evaluation

Source Extraction 1: DAO v SUSSEXtractor





DAOphot

Threshold = 4

DAOphot picks up map edge artefacts as sources

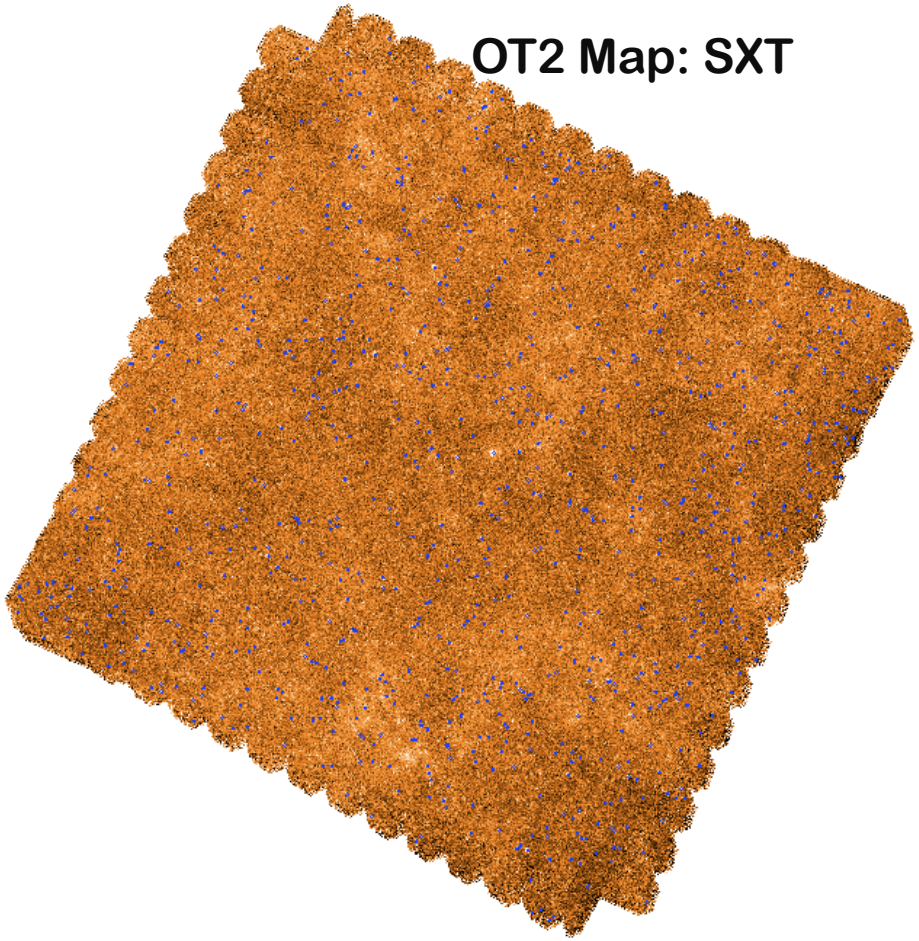
SUSSEXtractor

Threshold=4, no Fit background

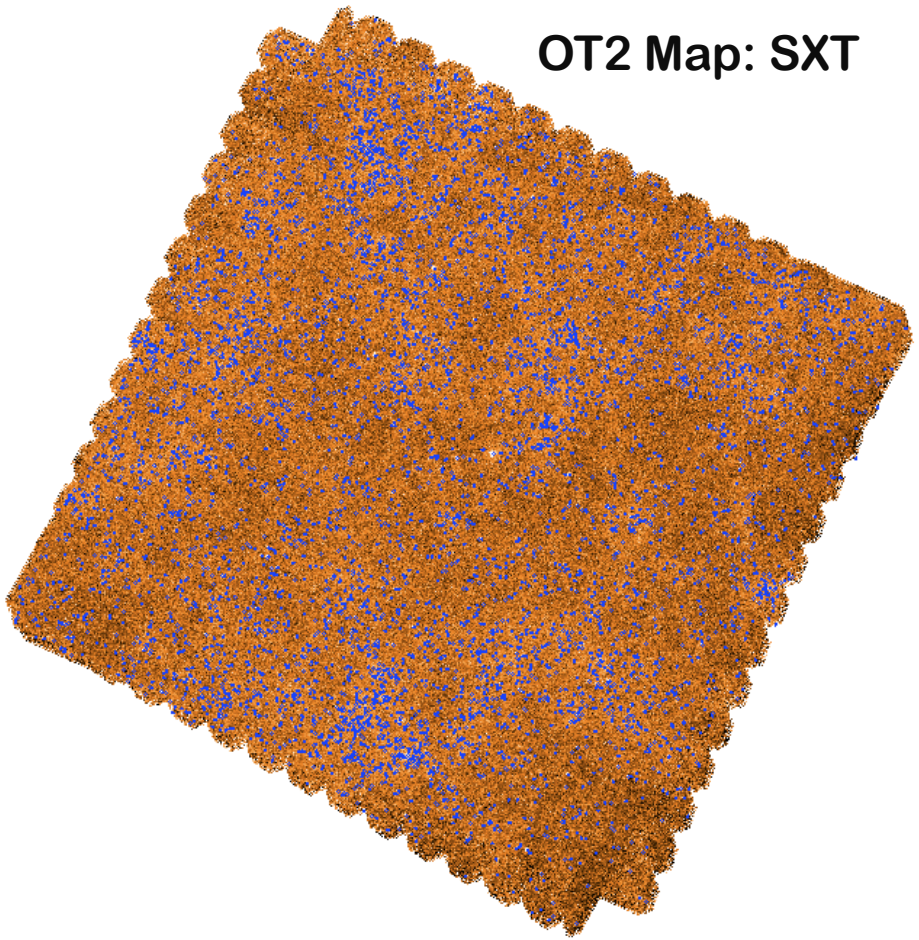
Results show more reliable results than DAOphot

But also seems to pick up background structure

Source Extraction 2: SXT w/o Background Fit

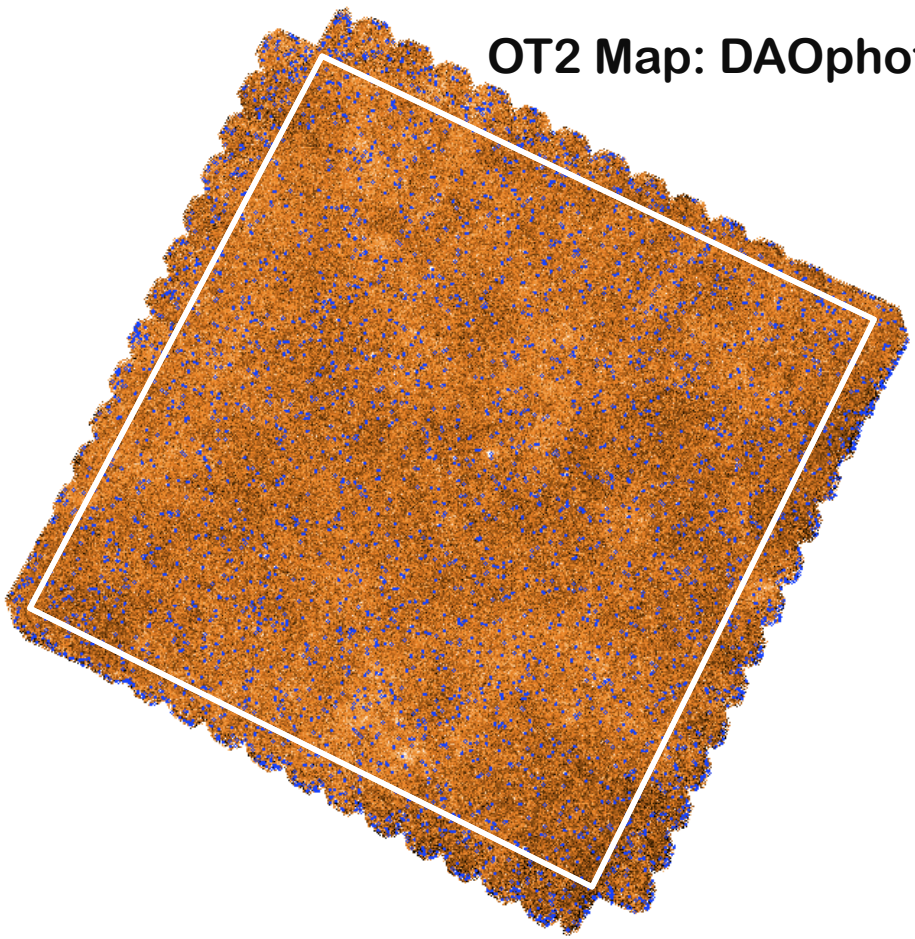


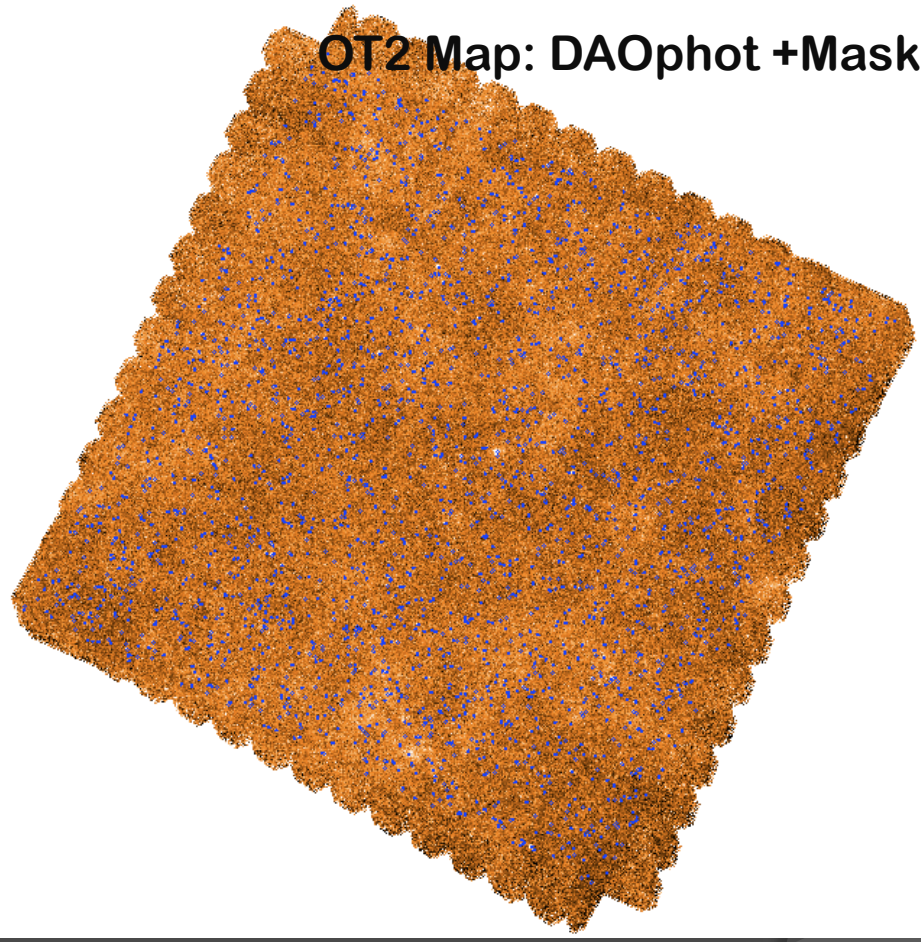
SUSSEXtractor
Threshold = 4, with Background Fit
Relatively few sources detected (since shallow map)



SUSSEXtractor
Threshold=4, no Fit background
Results show more reliable results than DAOphot
But also seems to pick up background structure

Source Extraction 3: DAO v DAO Masked



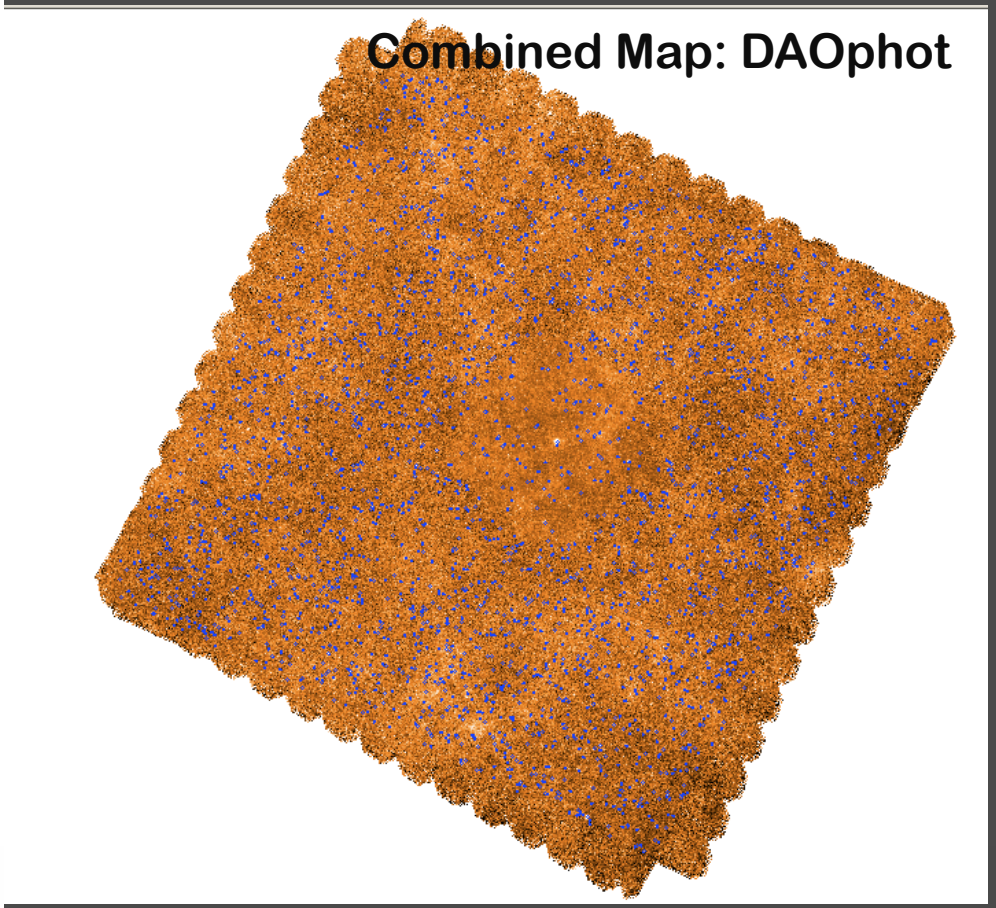


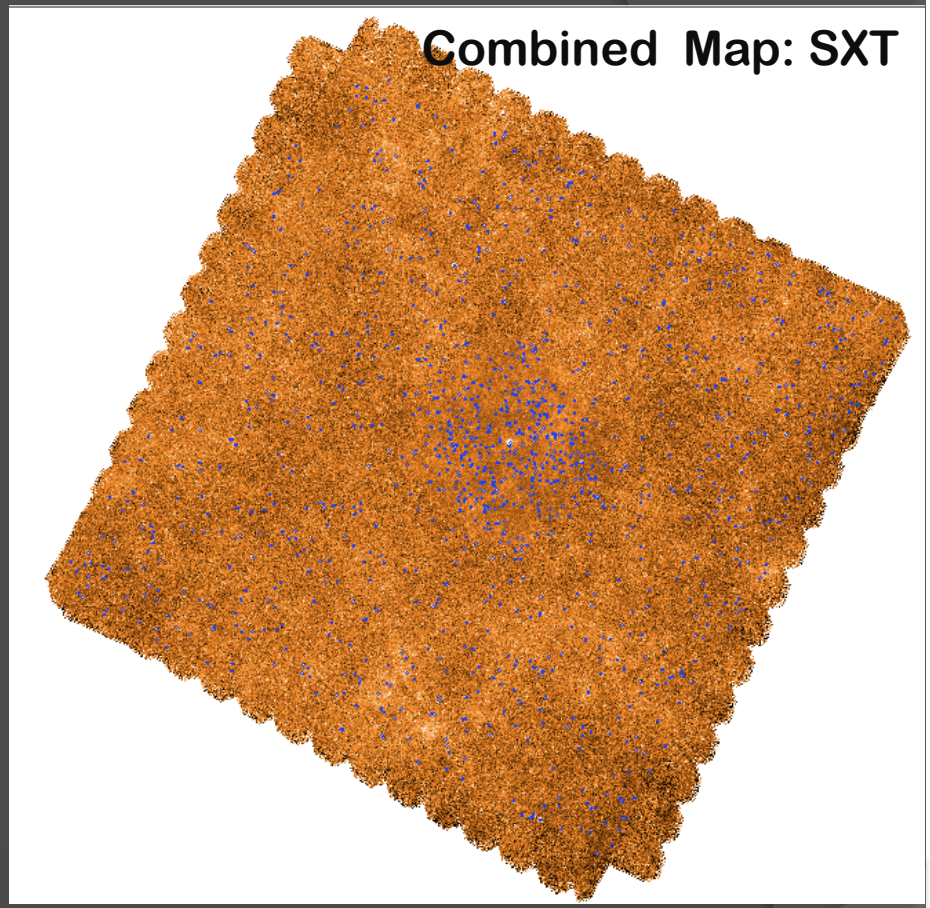
DAOphot
Threshold = 4
DAOphot without mask picks up map edge artefacts as sources

DAOphot Masked
Threshold=4
Result shows that the mask successfully rids of artefact sources along edges

Extract sources using DAOphot from 250um map
Carry out photometry at these positions in all maps

Source Extraction 4: DAO problem with coverage

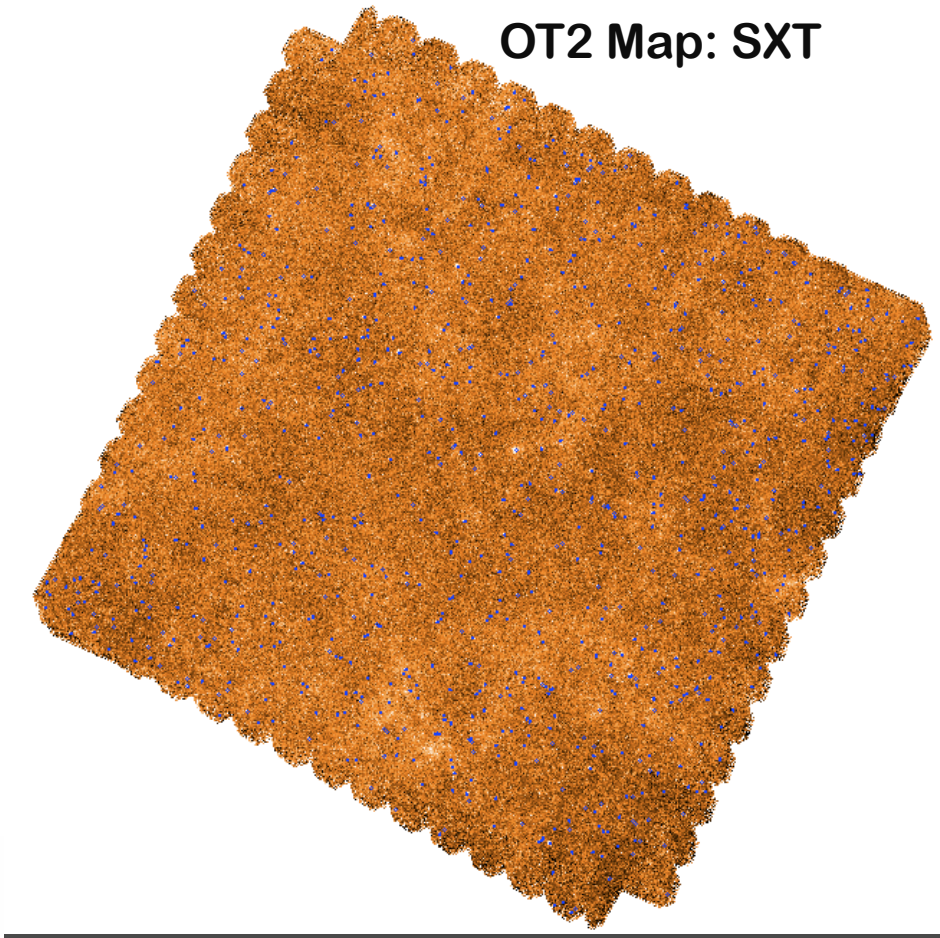




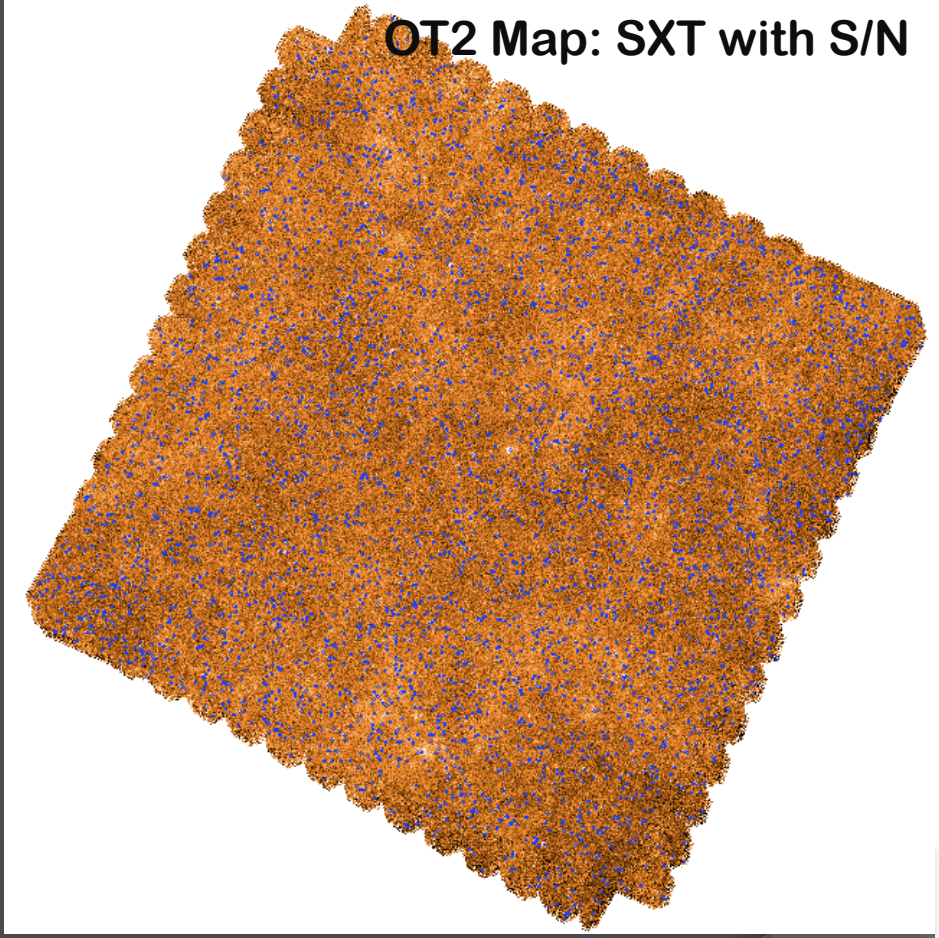
DAOphot
Threshold = 4
DAOphot shows a distinct lack of sources where several maps have been combined

SUSSEXtractor
Threshold=4
SUSSEXtractor shows a larger concentration of sources in the combined area but is sparse elsewhere

Source Extraction 5: SXT using S/N



SUSSEXtractor
Threshold = 4
SXT using Background Fit



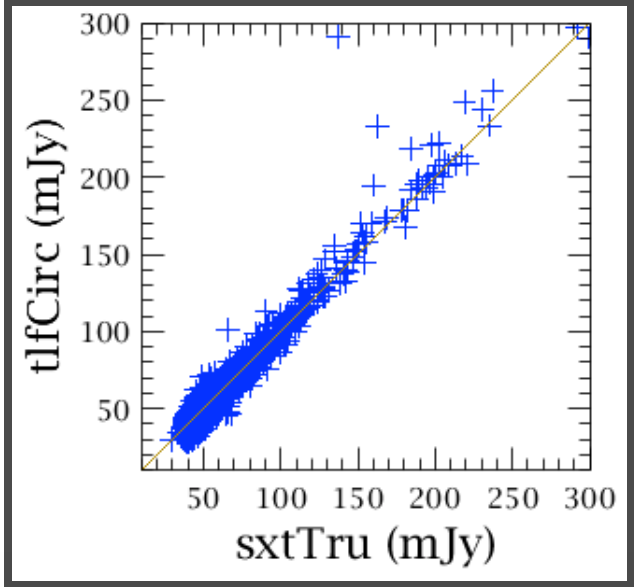
SUSSEXtractor
Threshold=4
SXT with Background Fit but Detection using S/N rather than Bayesian evidence (no mask required)

Extract sources using SUSSEXtractor, with background fit and S/N detection from 250um map and do photometry at these positions

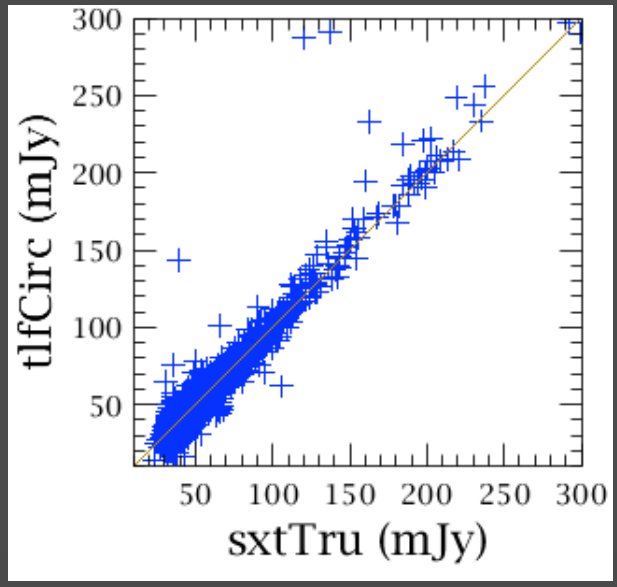
OT2: Photometry Evaluation: Detection Threshold

Select SUSSEXtractor & Timeline Fitter for photometry.
Select Threshold = 4 to detect most sources reliably

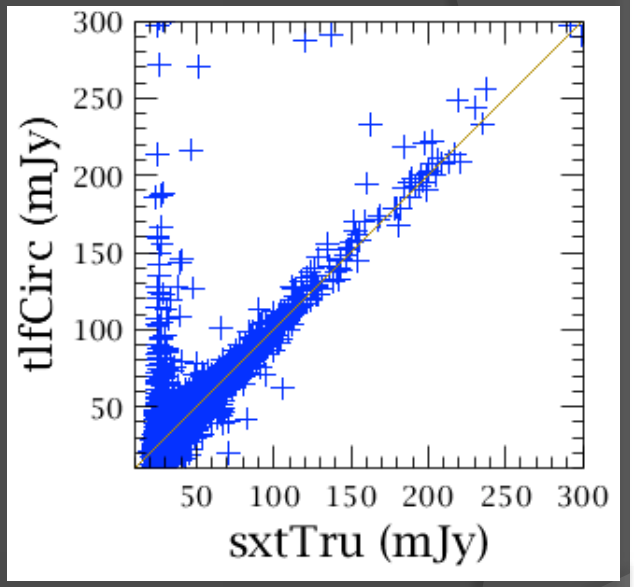
Sigma = 5



Sigma = 4

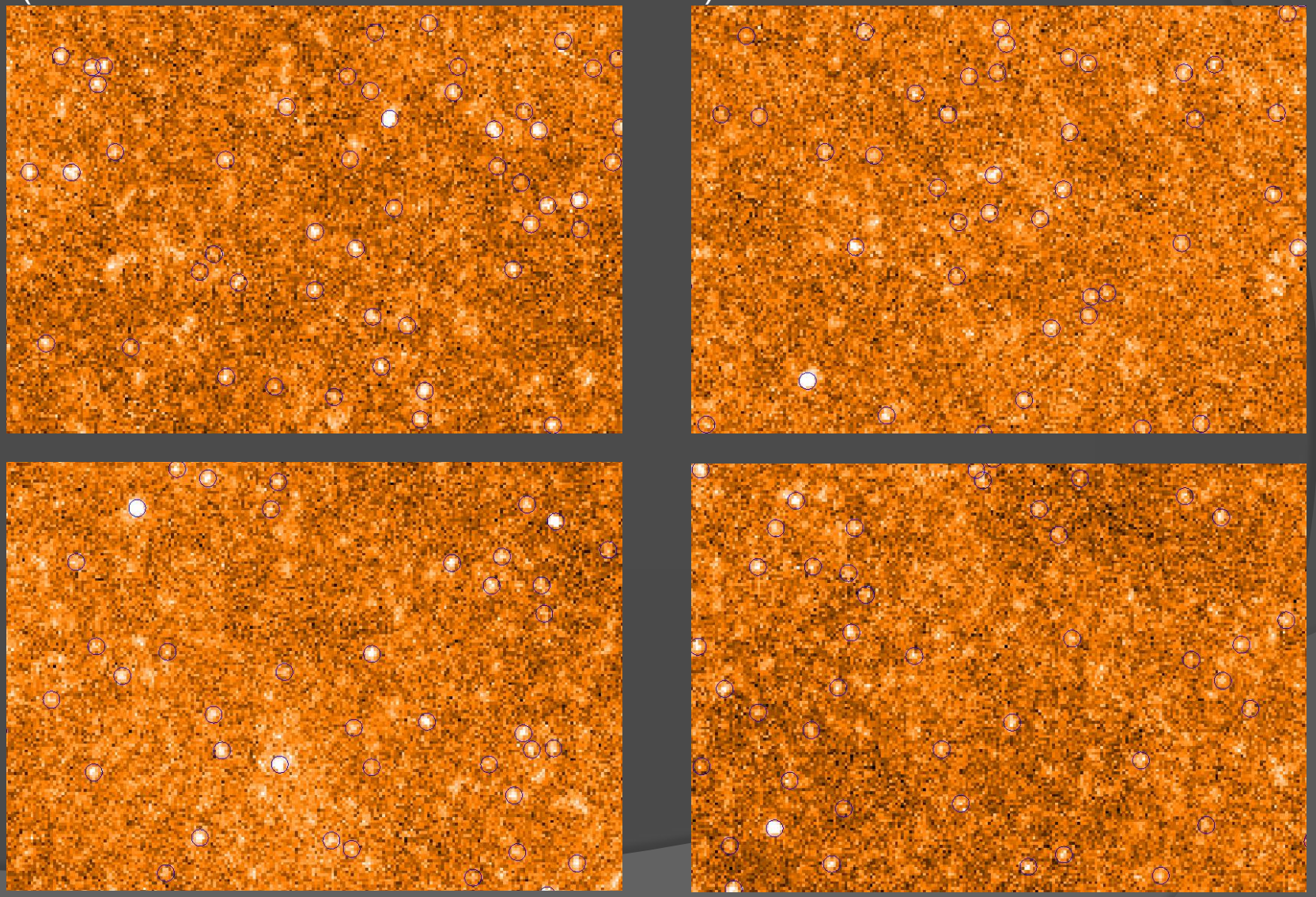


Sigma = 3



Source Extraction Summary

SUSSEXtractor using Background Fit + S/N for detection works best :
e.g. (Threshold 4 believable source detection)



Iterative Approach to Source Extraction

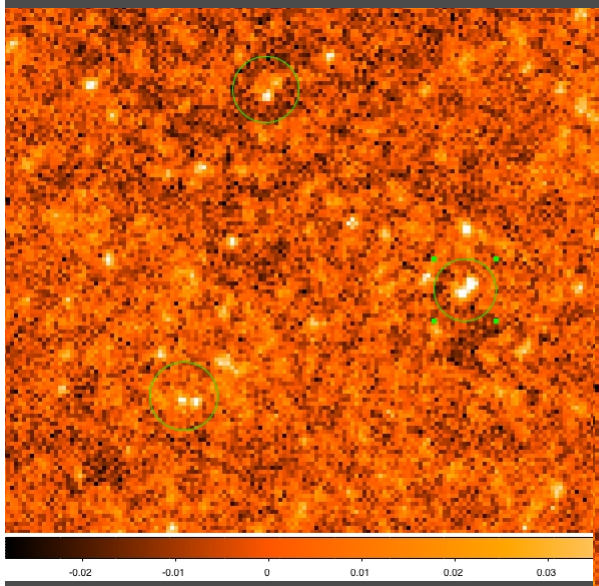
Iterative Approach to Source Extraction

To reduce the effects of blending of sources, follow an iterative approach to source extraction with the following algorithm (similar to what has been done within SAG2)

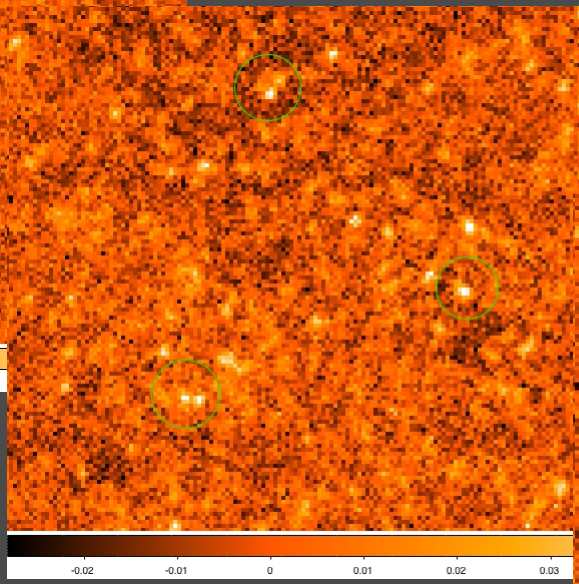
1. Set the threshold for source detection starting at sigma=10
2. Carry out source extraction
3. Subtract detected bright sources from the **timeline** assuming Gaussian with instrument FWHM and peak flux as measured
4. Remake the map from the new timeline data
5. Reduce sigma
6. Repeat steps 2-5

Iterative Approach to Source Extraction

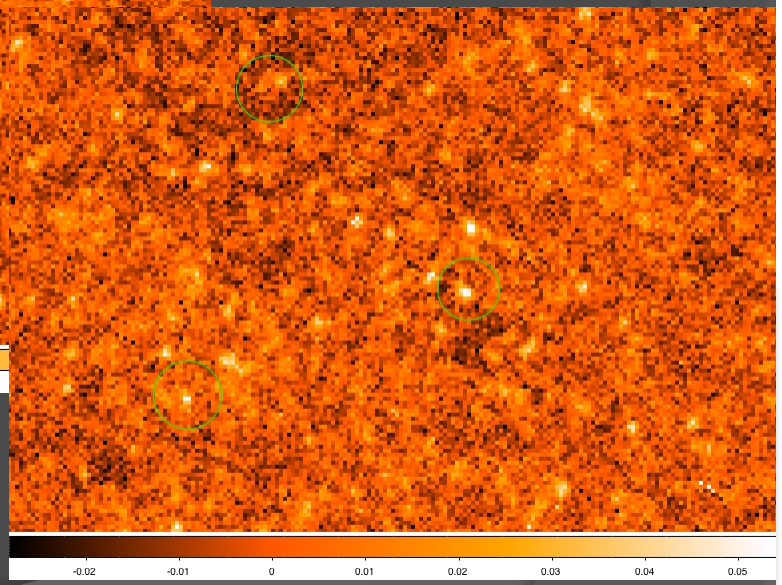
Sigma = 10



Sigma = 8



Sigma = 5



Noise Measurements

Noise in the maps calculated by laying down apertures on maps and blank sky positions and calculating the flux within each.

5 x 100 apertures laid down on PSW, PMW, PLW maps
Median flux calculated:

- PSW: 8.60 mJy
- PMW: 7.08 mJy
- PLW: 8.61 mJy

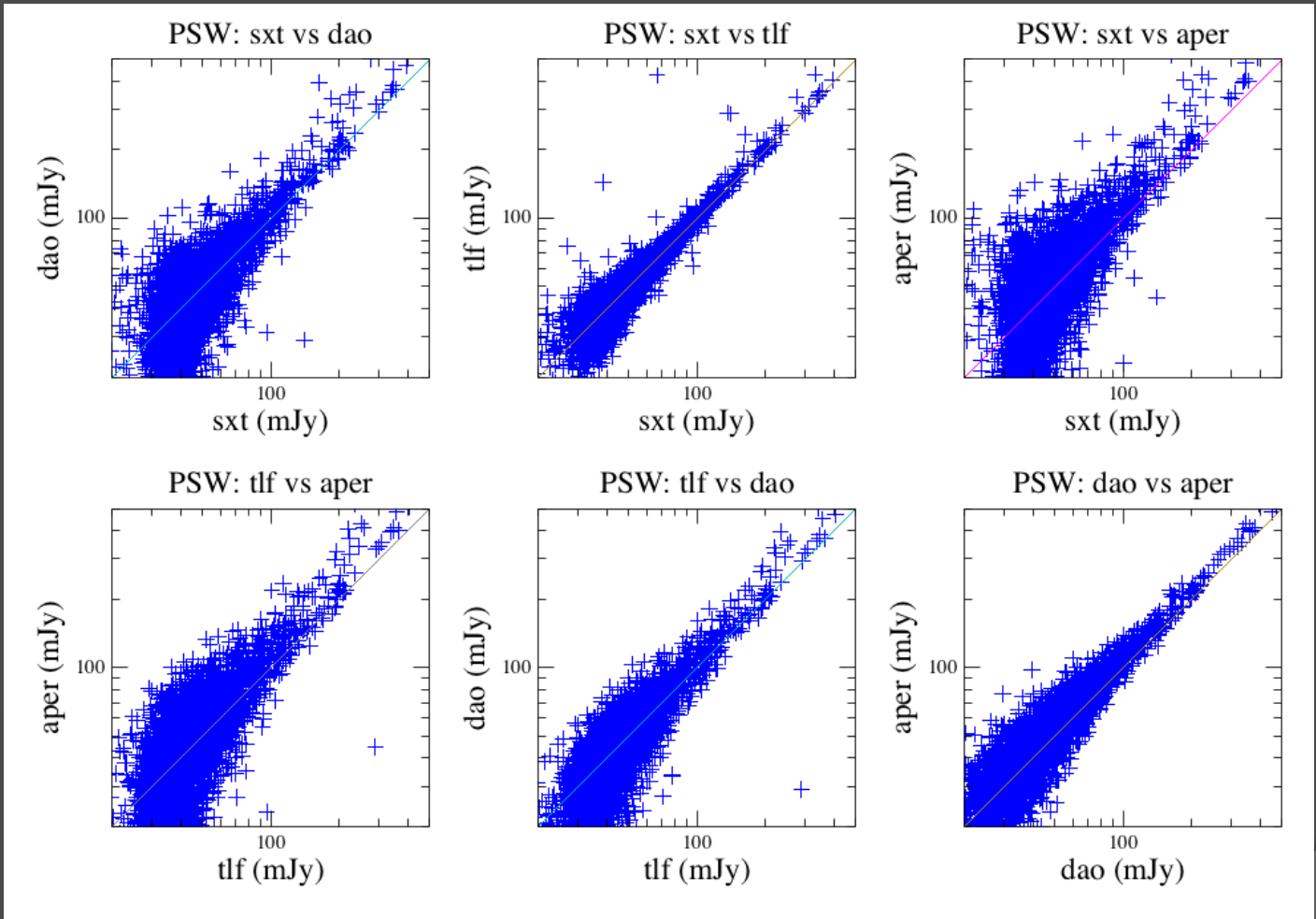
Comparable within ±2mJy with HSPOT estimates

Results for OT2 Observations

obsid 1342239959

OT2: Photometry Evaluation

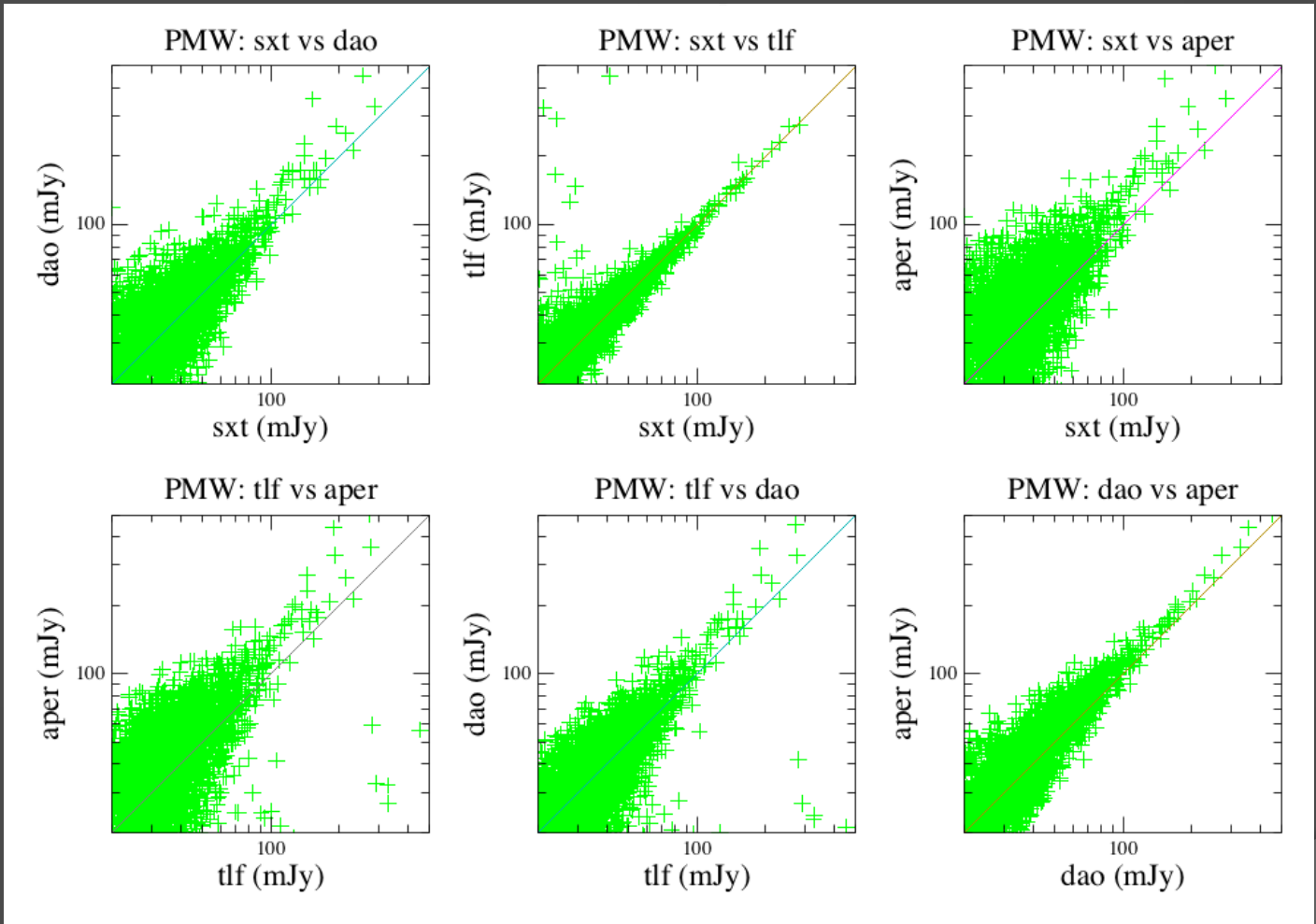
Compare: SUSSEXtractor, Timeline Fitter, DAOphot, Aperture Photometry



SUSSEXtractor and Timeline Fitter consistent.
DAOphot and Aperture Photometry show offsets and larger scatter

OT2: Photometry Evaluation

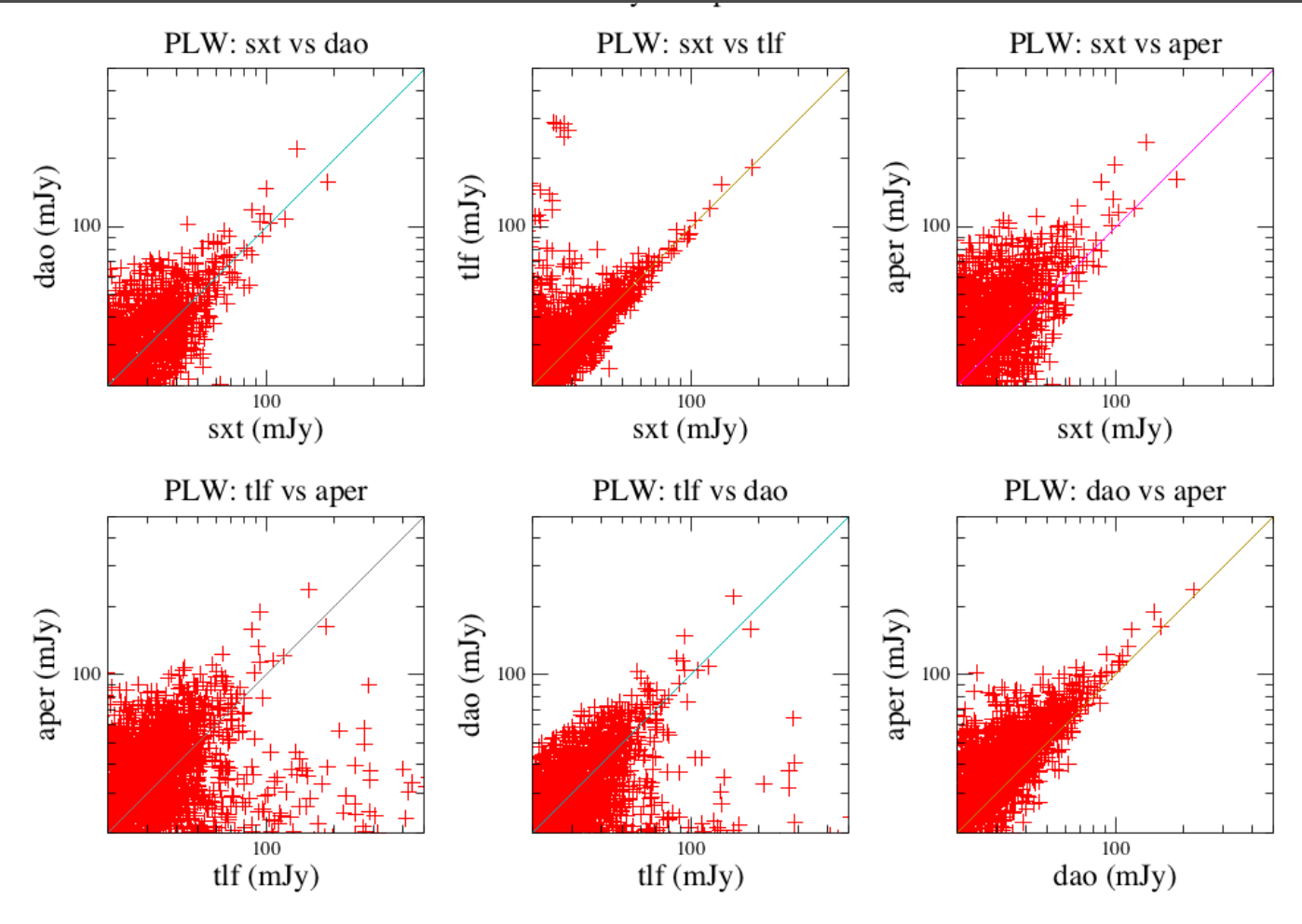
Compare: SUSSEXtractor, Timeline Fitter, DAOphot, Aperture Photometry



SUSSEXtractor &Timeline Fitter consistent except at low fluxes where TLF is scattered up (this is also evident in the sources counts for the TLF).

OT2: Photometry Evaluation

Compare: SUSSEXtractor, Timeline Fitter, DAOphot, Aperture Photometry



SUSSEXtractor &Timeline Fitter consistent except at low fluxes where TLF is scattered up (this is also evident in the sources counts for the TLF).

OT2: Photometry Evaluation

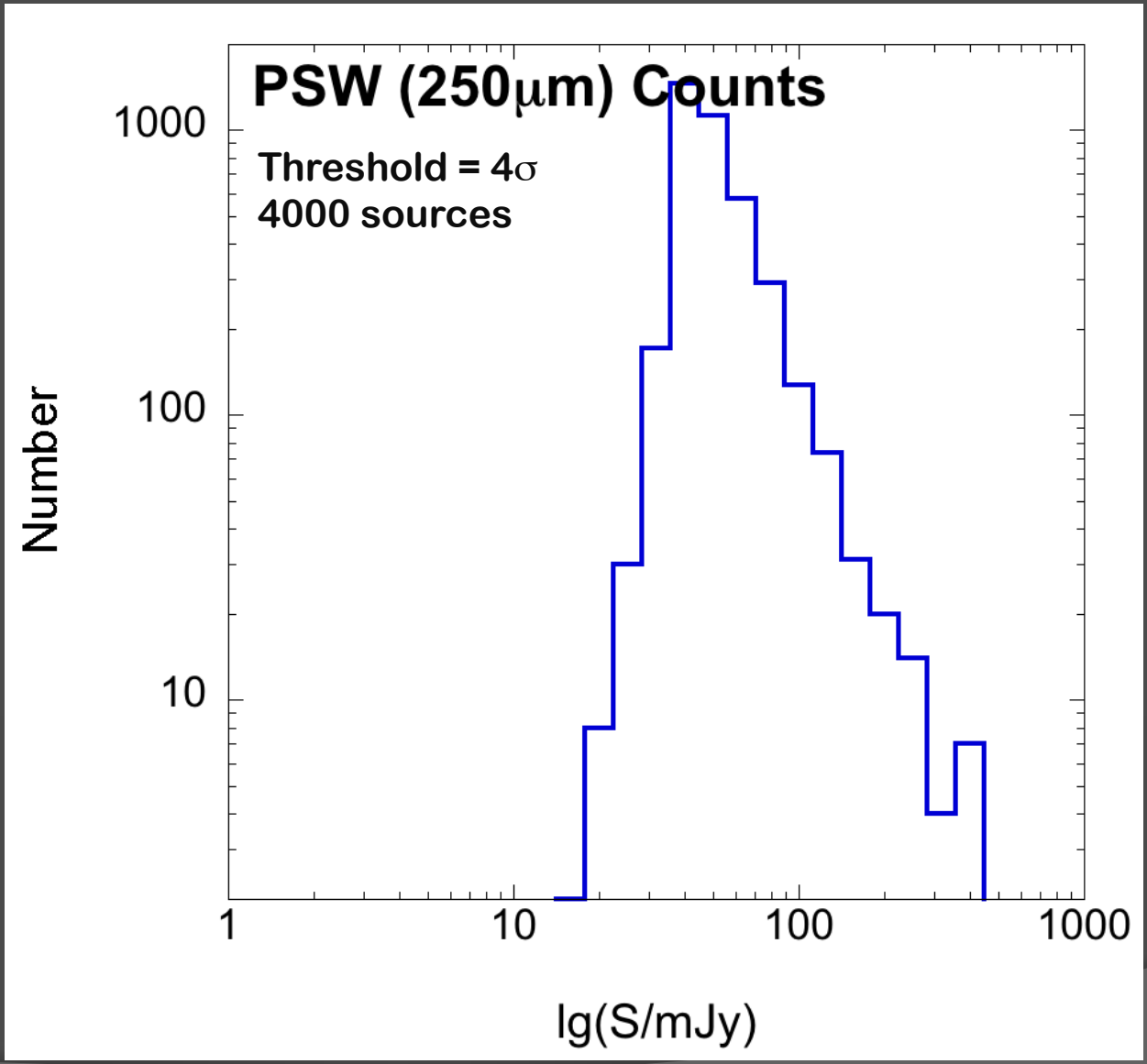
Compare: SUSSEXtractor, Timeline Fitter, DAOphot, Aperture Photometry.
Example Eyeballing of individual sources in the map (map flux = brightest pixel)

RA	DEC	x	y	Flux {mJy}				
Deg	Deg	[pix]	[pix]	Map	SXT	DAO	TLF	Aper
265.57018	66.89953	2205.653	1441.181	188.3	194.6	268.3	202.3	296.6
271.06914	65.49963	897.398	566.223	117.2	125.0	136.0	122.7	144.1
267.30718	67.30522	1786.656	1661.015	119.0	124.0	132.3	122.2	128.7
266.5586	66.27028	1994.104	1049.370	165.3	191.5	163.5	177.3	166.3
272.64538	66.18792	522.699	990.503	97.4	110.7	141.5	106.8	142.6
273.34553	67.01495	379.747	1494.252	57.7	57.1	65.1	59.9	79.1
272.66645	67.03968	539.372	1501.410	65.3	59.7	58.5	57.6	65.3
271.6397	66.08995	764.695	923.423	69.9	66.7	83.2	76.9	86.1
268.95141	66.15592	1417.755	959.985	62.0	37.8	71.5	49.0	88.7
271.24652	66.50884	865.291	1172.532	57.2	52.3	62.6	57.2	65.3
270.21794	65.97917	1110.2	851.86	33.6	32.4	24.4	32.7	35.6
268.85747	65.90314	1443.33	808.72	44.1	34.3	24.4	35.7	16.7
272.7704	65.95643	486.282	853.02	37.8	35.0	24.4	36.0	25.5
271.01647	66.04702	915.822	894.47	38	32.3	24.4	26.8	32.7
269.04627	66.66677	1390.04	1266.1	38.1	36.0	24.4	31.5	34.9
269.05768	66.15069	1392.03	956.43	38.5	44.0	24.5	33.1	25.3
271.10206	65.864	893.045	785.01	30.5	36.4	24.5	24.7	40.7
273.50742	65.95163	306.079	859.14	30.9	40.9	24.5	34.9	13.5
271.55516	65.74836	780.166	717.97	39.2	38.0	24.5	31.9	23.3
270.40078	66.2902	1066.72	1038.7	30.9	33.4	24.6	39.63	32
272.82992	65.68793	464.454	692.67	43.2	40.5	24.627	40.6	21.7

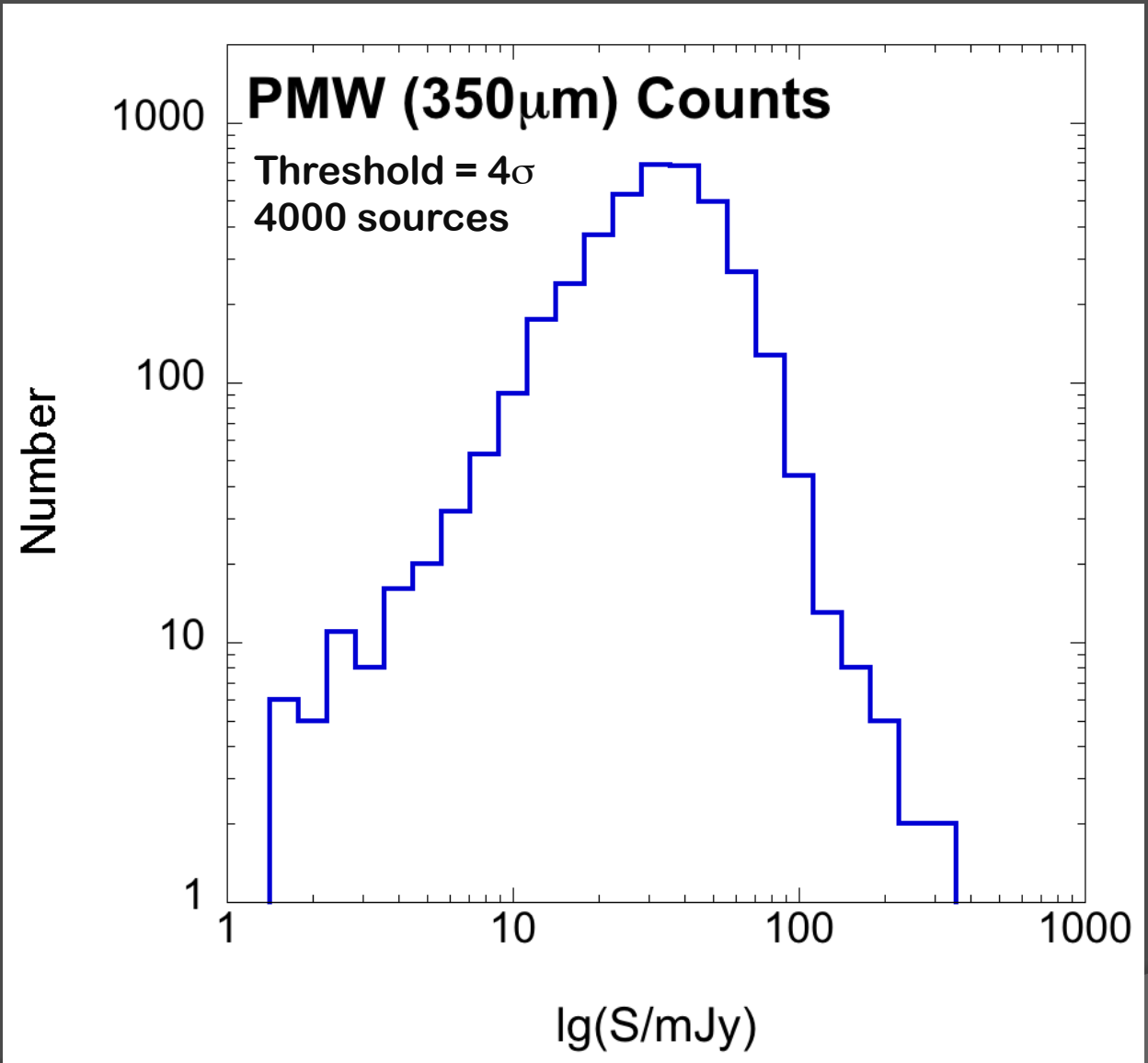
Conclude that on balance SUSSEXtractor provides most robust flux over widest flux range

OT2 NEP
Source Number Histogram
and
Colours

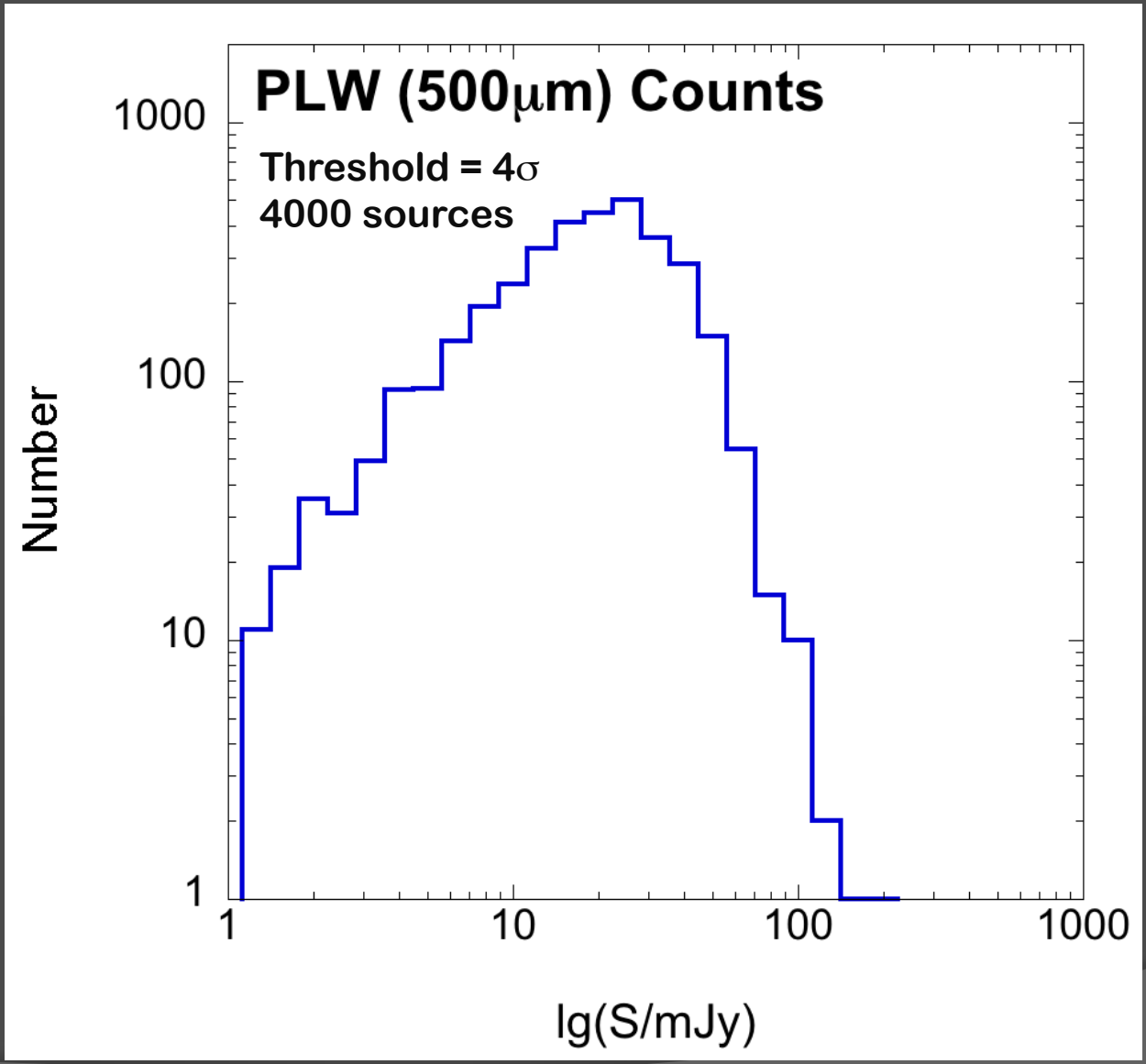
Source Histogram: PSW Band



Source Histogram: PMW Band

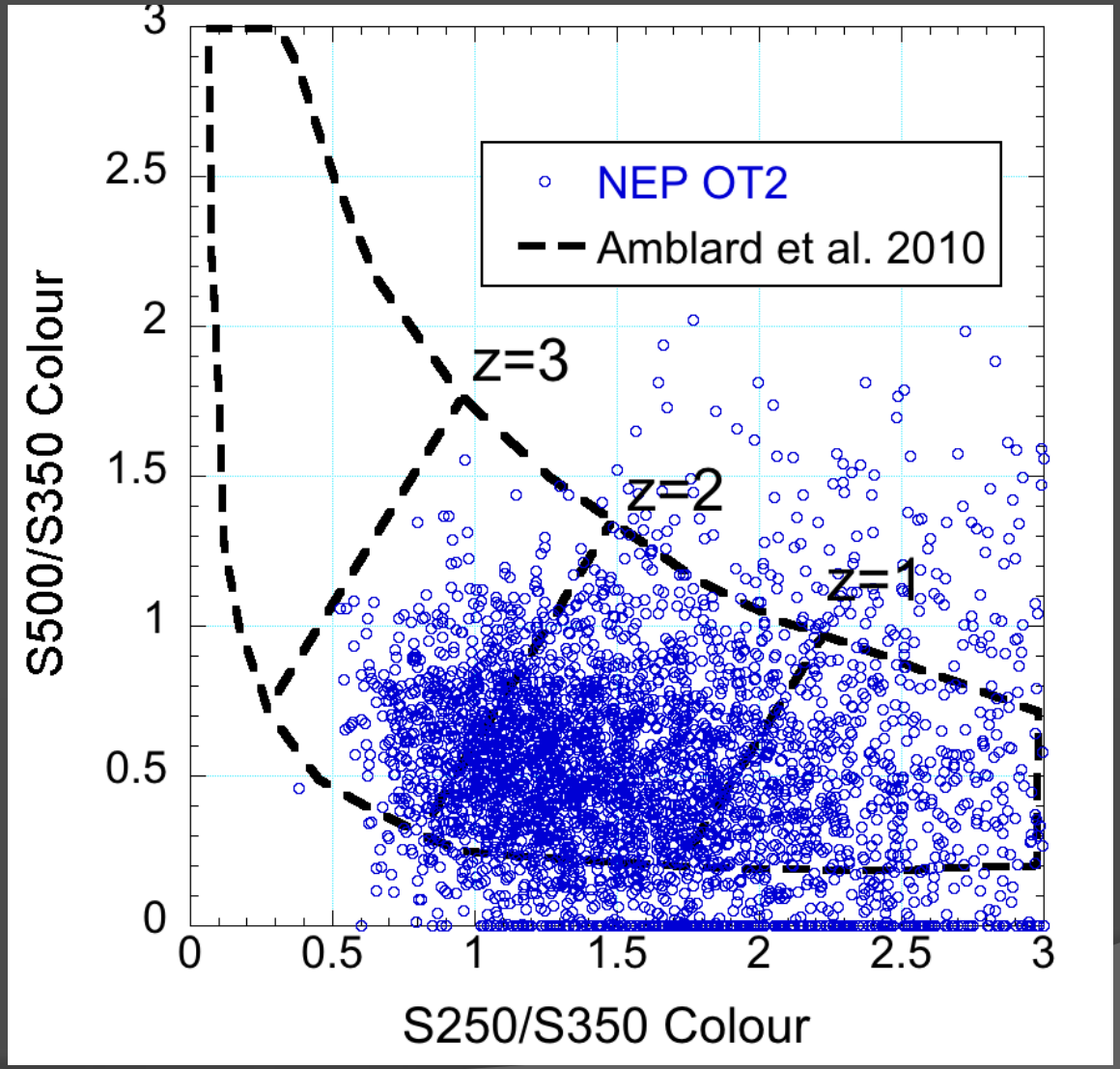


Source Histogram: PLW Band



Colour – Colour Plot

Comparison with simulations presented in Amblard et al. 2010

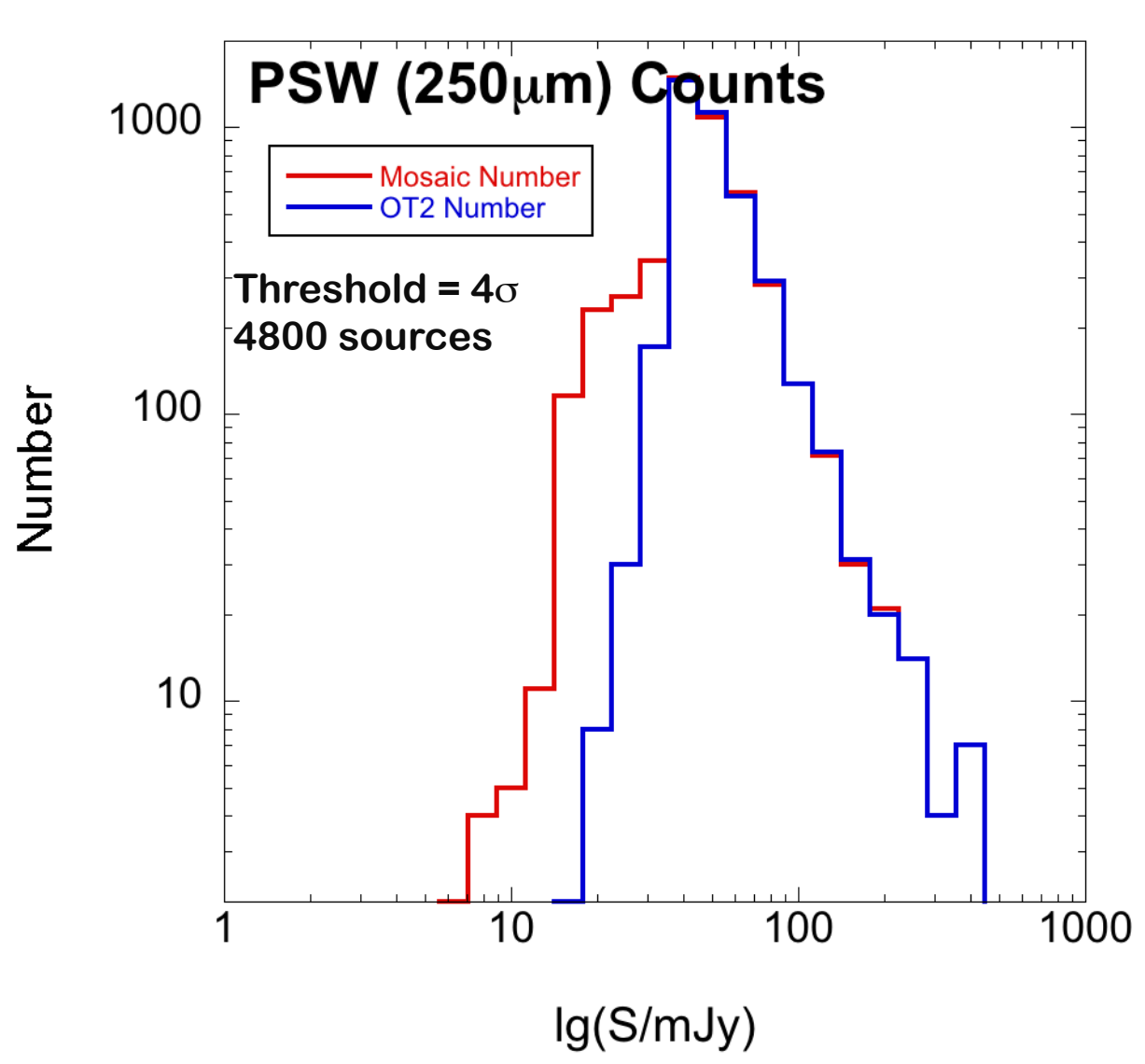


NEP All Maps Mosaic Source Number Histogram and Colours

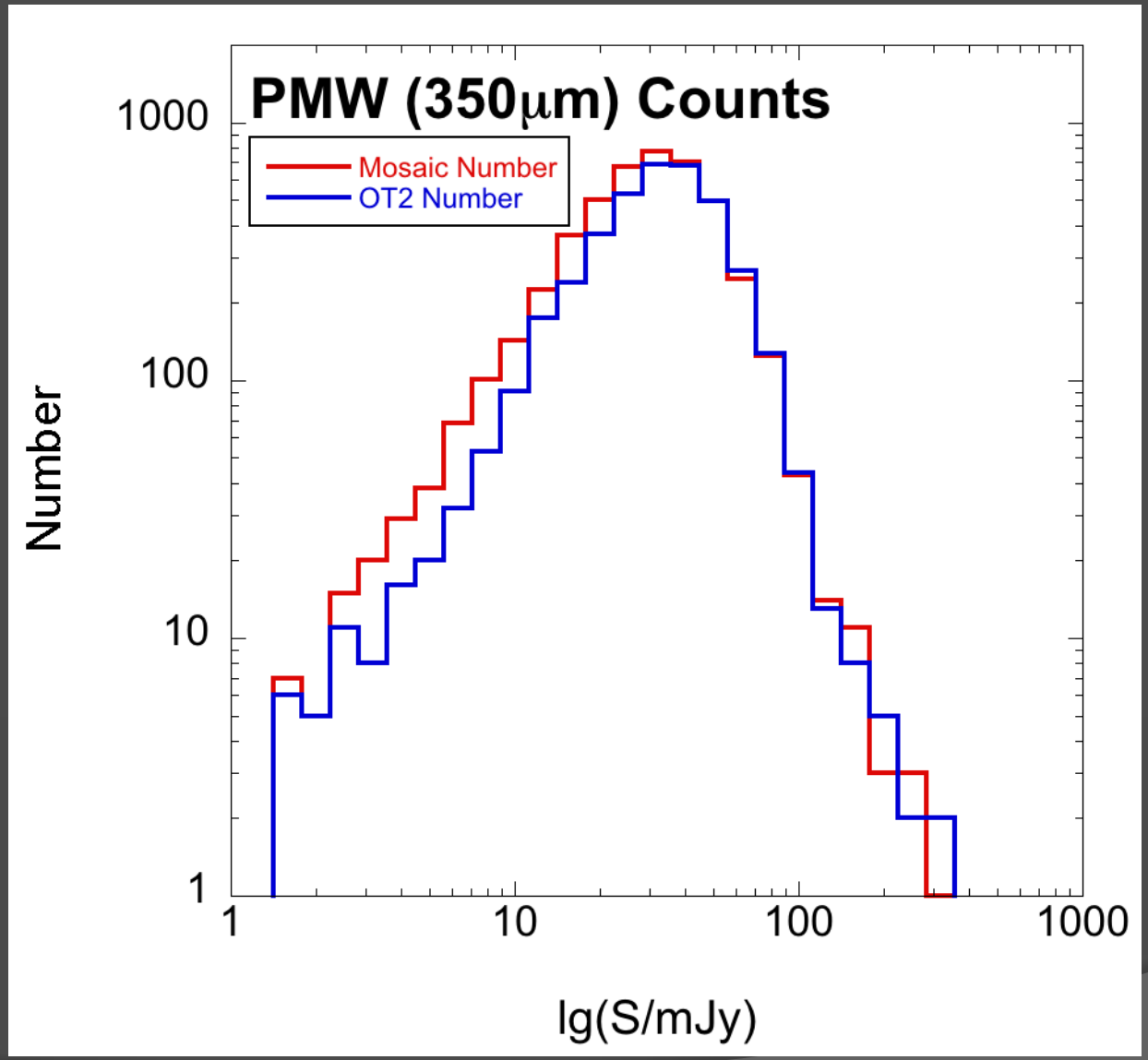
Results for Mosaic of all NEP Observations

Name	OD	obsid	time	Size	rep	Sensitivity (mJy)		
			(s)	(arcmin)		PSW	PMW	PLW
OT2	1023	1342239959	22178	160x160	1	9.0	7.5	10.8
PV-N	77	1342180954	983	20x20	1	9.0	7.5	10.8
PV-B	77	1342180957	983	20x20	1	32.2	24.0	28.1
GT	226	1342188590	4820	30 x 30	3	5.2	4.3	6.2

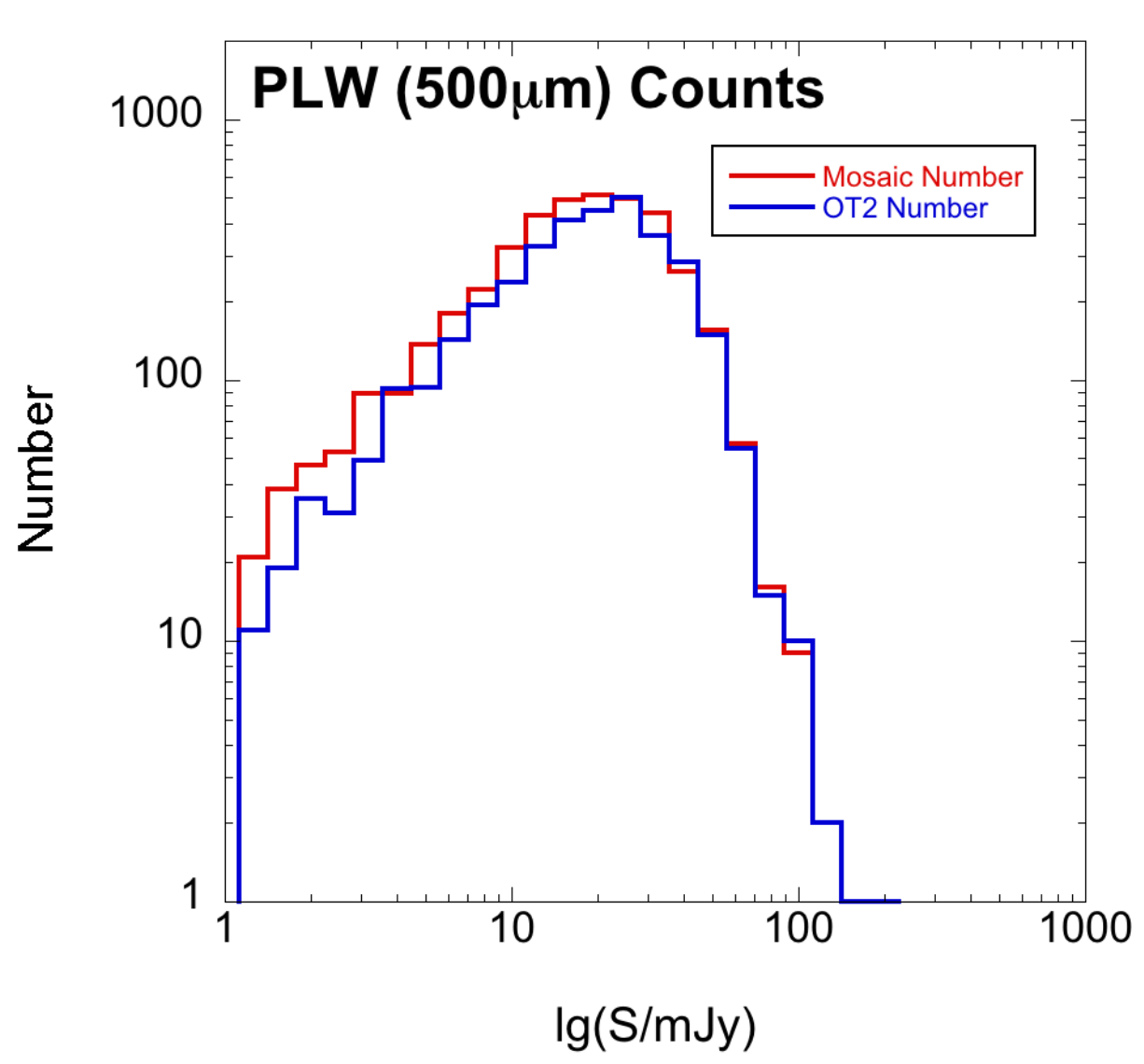
Source Histogram: PSW Band



Source Histogram: PMW Band

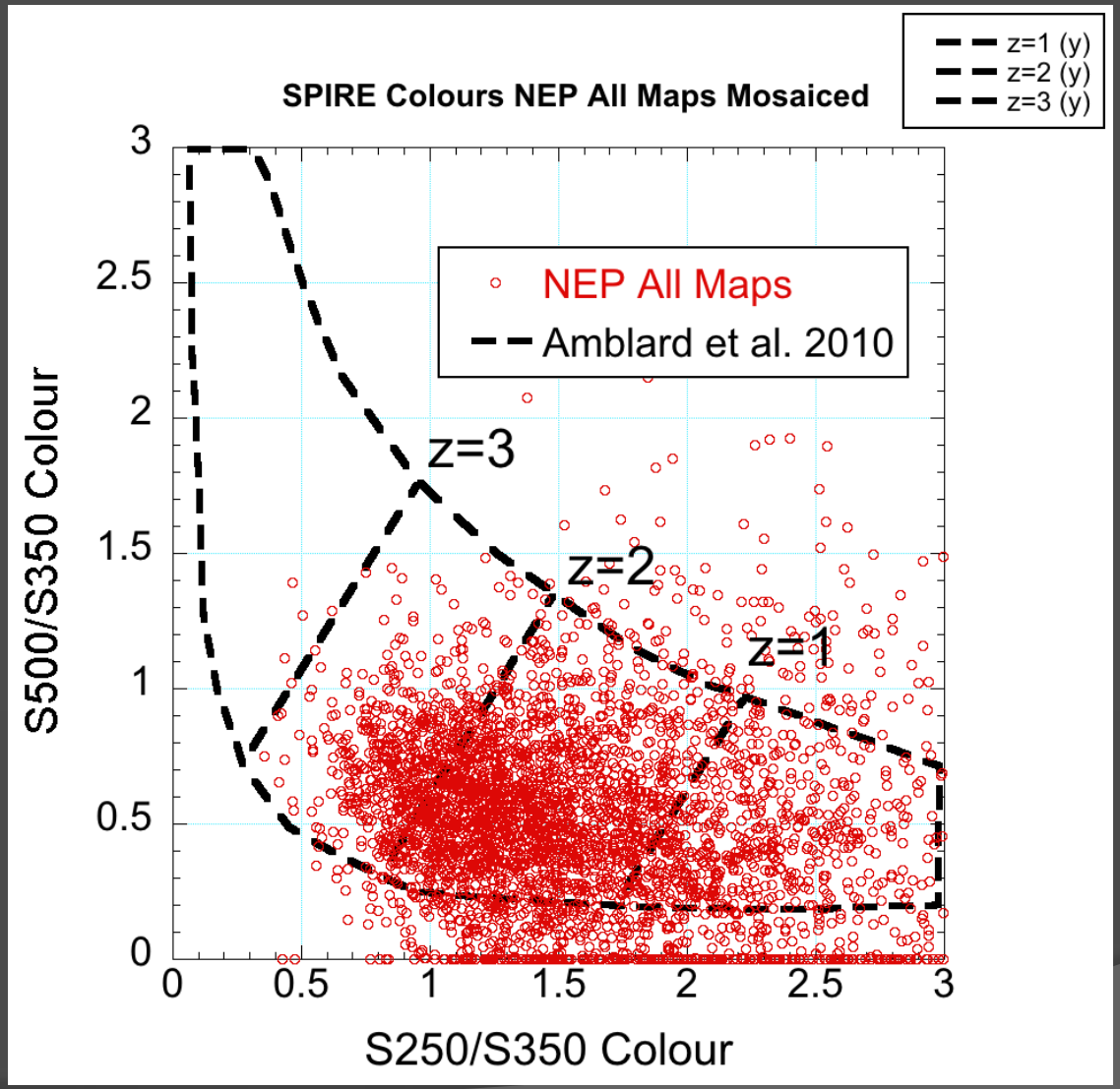


Source Histogram: PLW Band



Colour – Colour Plot

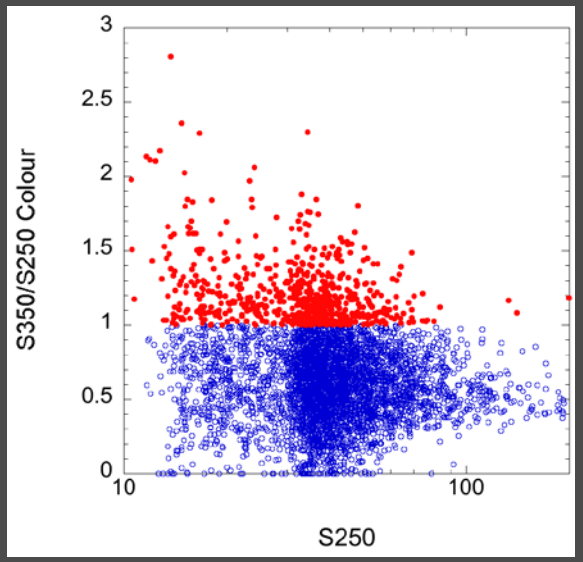
Comparison with simulations presented in Amblard et al. 2010

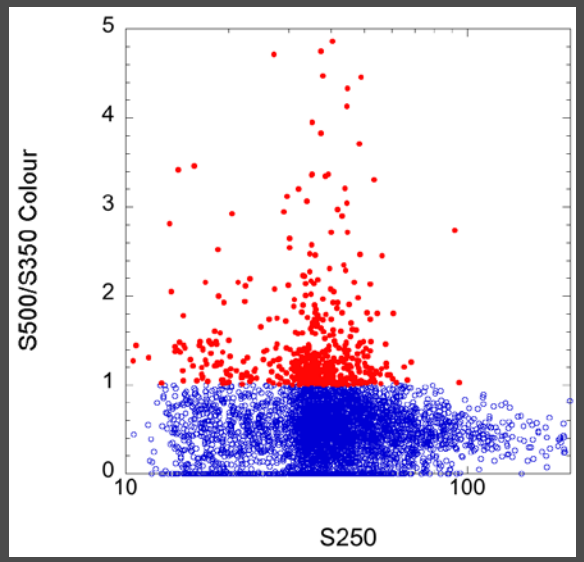


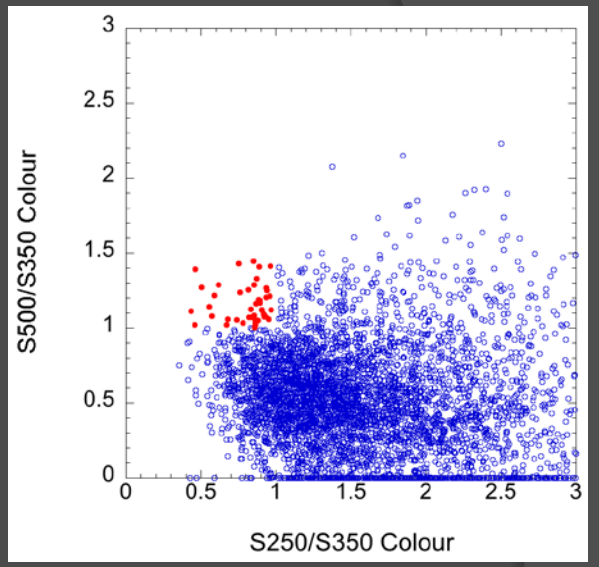
Colour Selection Plots

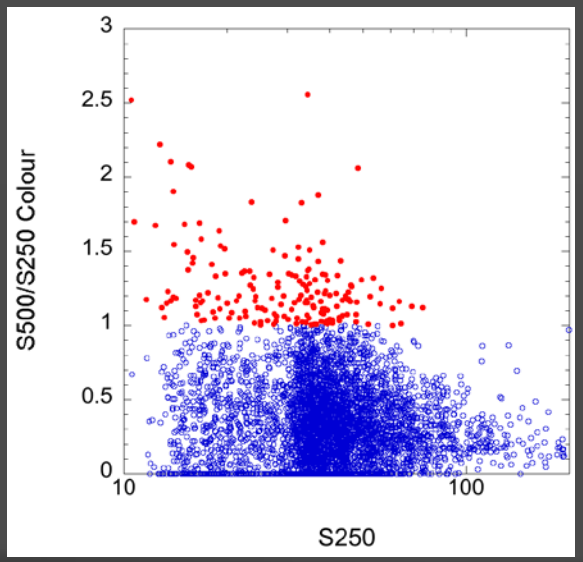
Colour Selection of High Redshift Sources

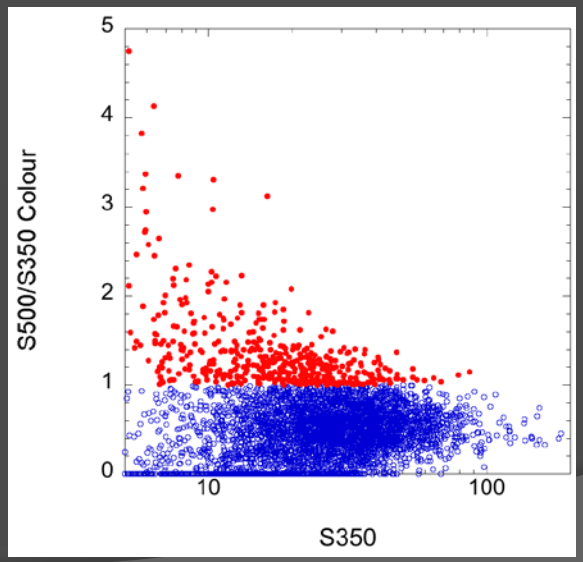
High Redshift K-Corrections produces S500 > S350 > S250

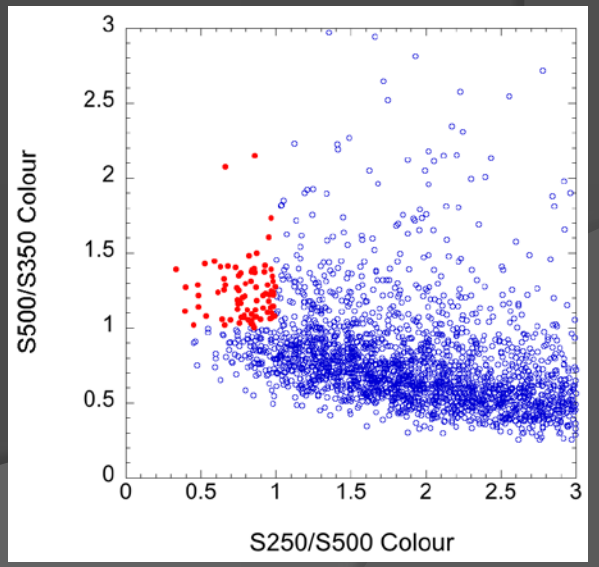






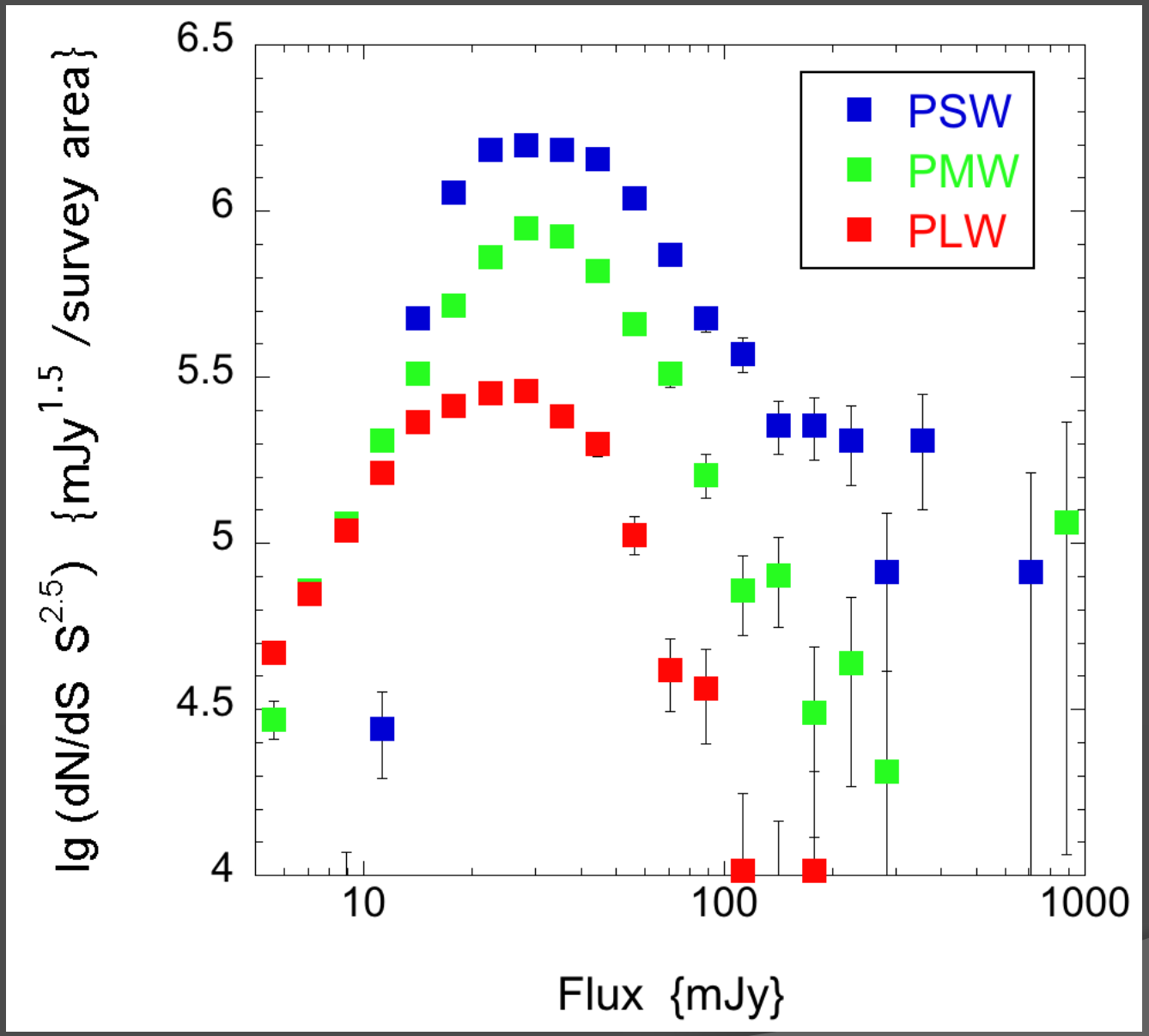






Source Counts

Source Counts



Survey area:
PSW
3246469 pixels
Pixel scale 6''
9.018 sq.deg

PMW
1174549 pixels
Pixel scale 10''
9.063 sq.deg

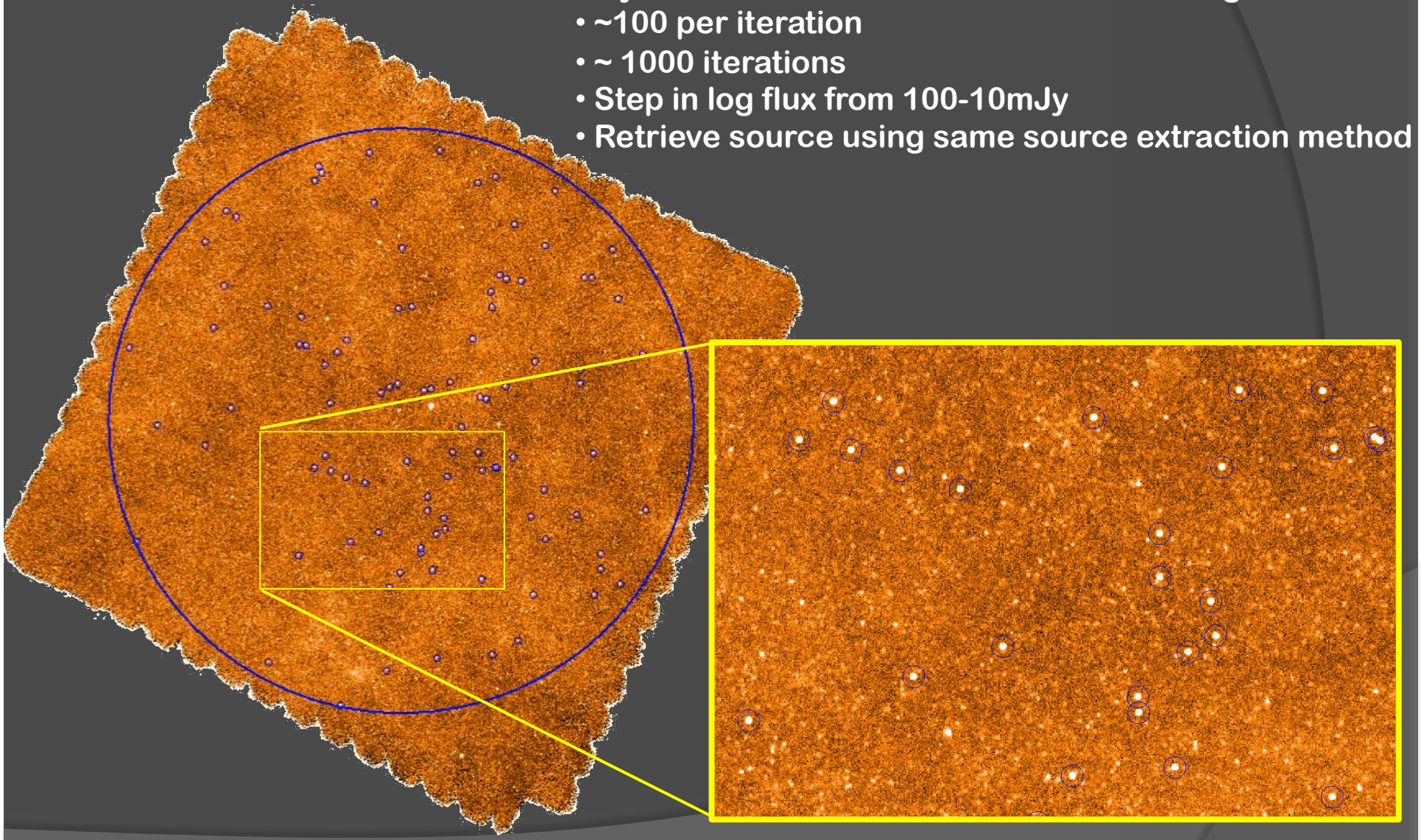
PLW
596737 pixels
Pixel scale 14''
9.0247 sq.deg

Completeness and Reliability

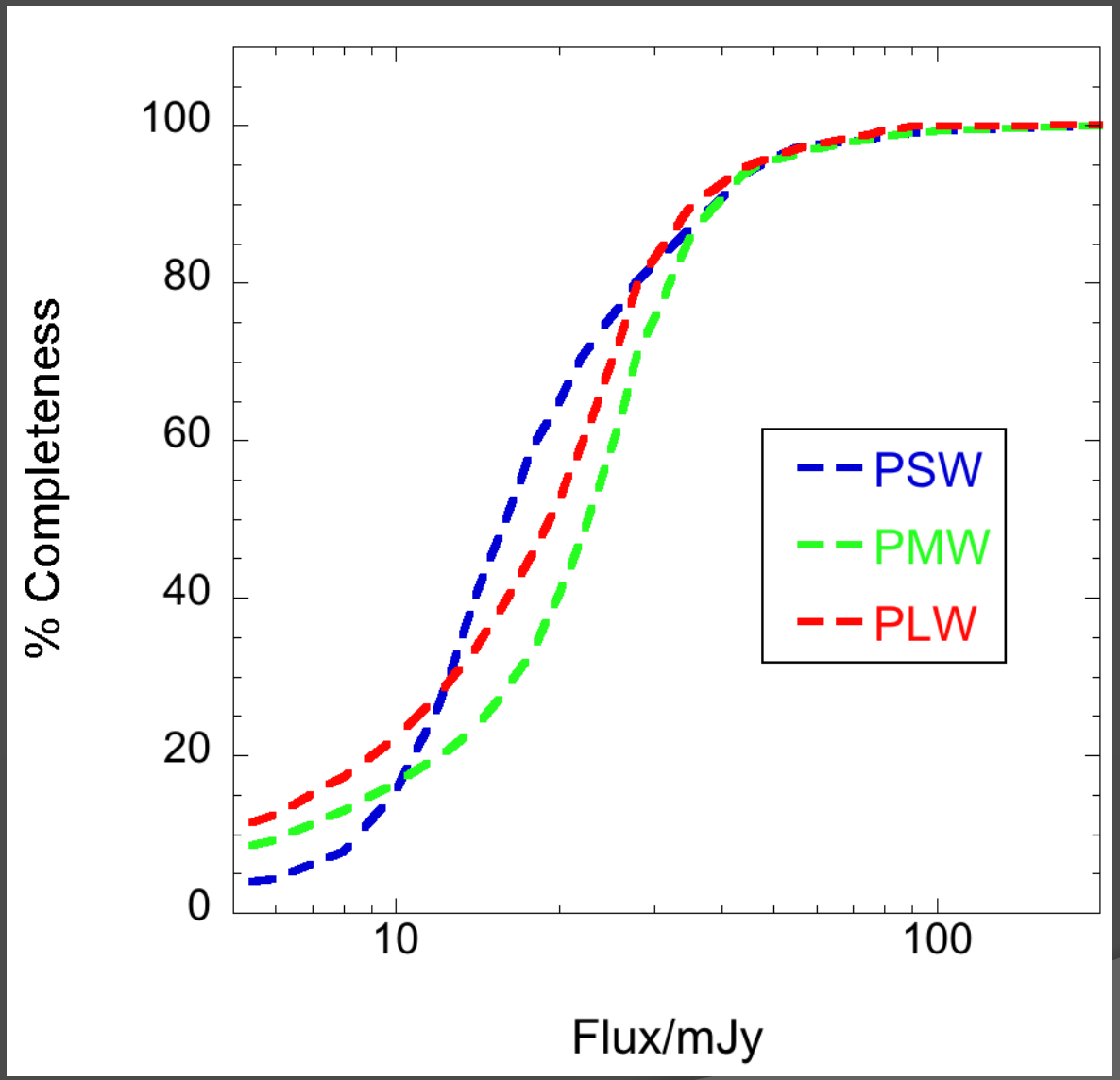
Completeness

Completeness Correction

- Inject artificial Gaussian sources into image
- ~100 per iteration
- ~ 1000 iterations
- Step in log flux from 100-10mJy
- Retrieve source using same source extraction method



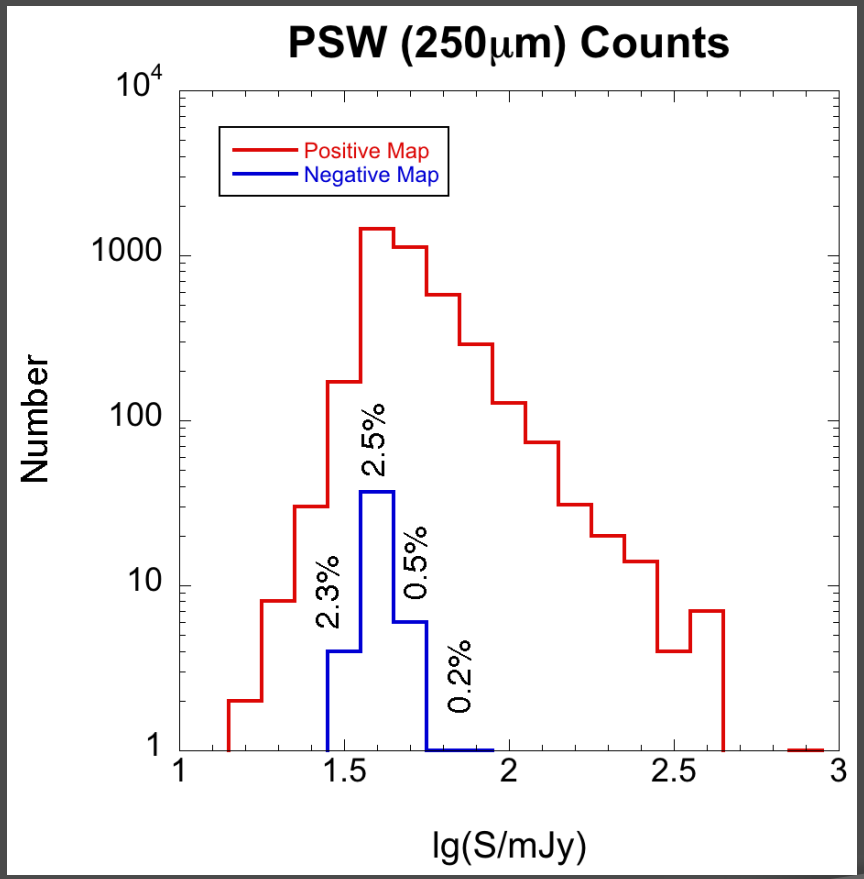
Completeness



Reliability

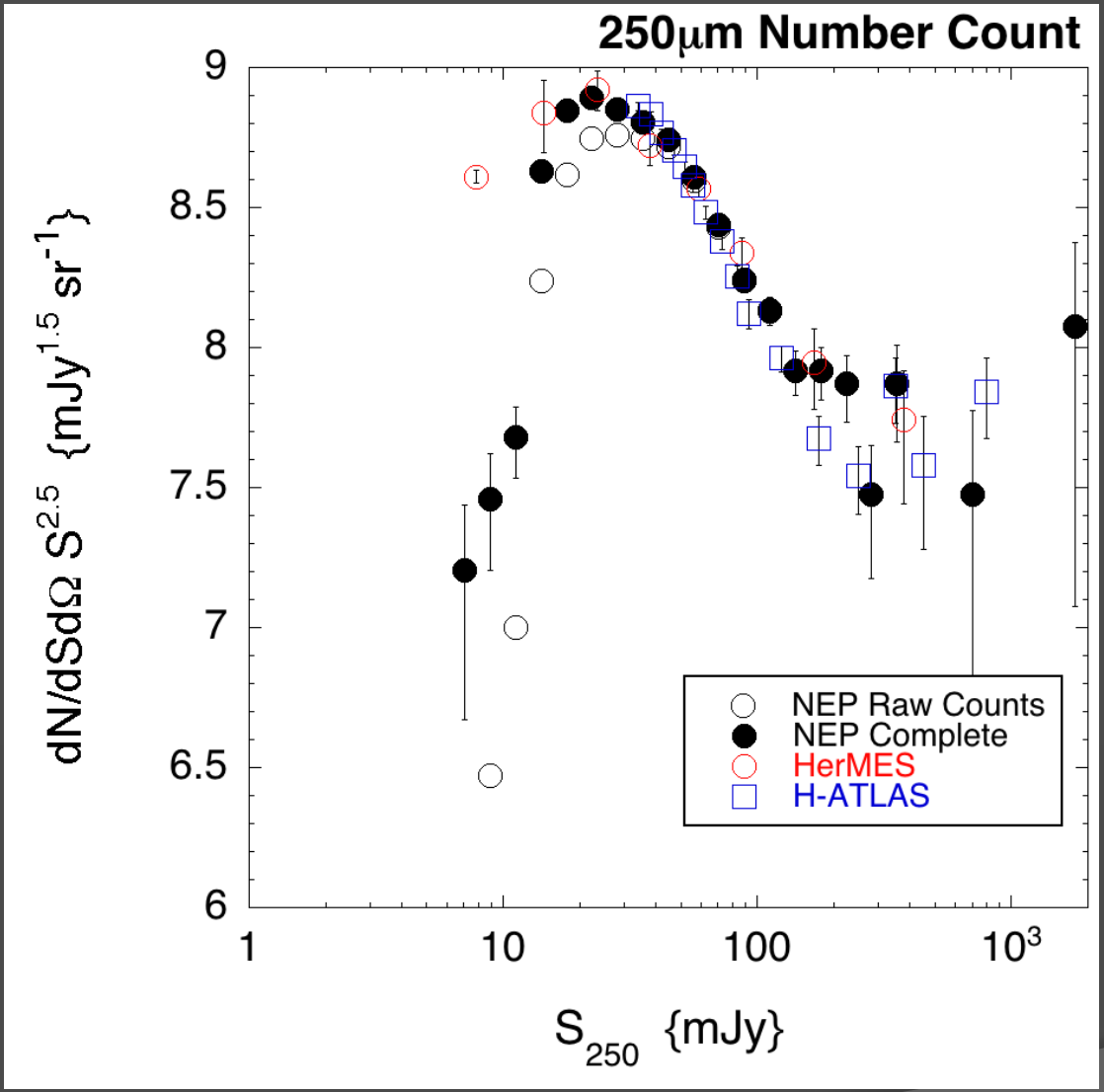
Reliability estimated by performing source extraction and photometry on the negative maps (i.e. maps multiplied by -1)

- **PSW map find a total of 48 sources over the entire map**
- **Reliability always > 97.7 %**



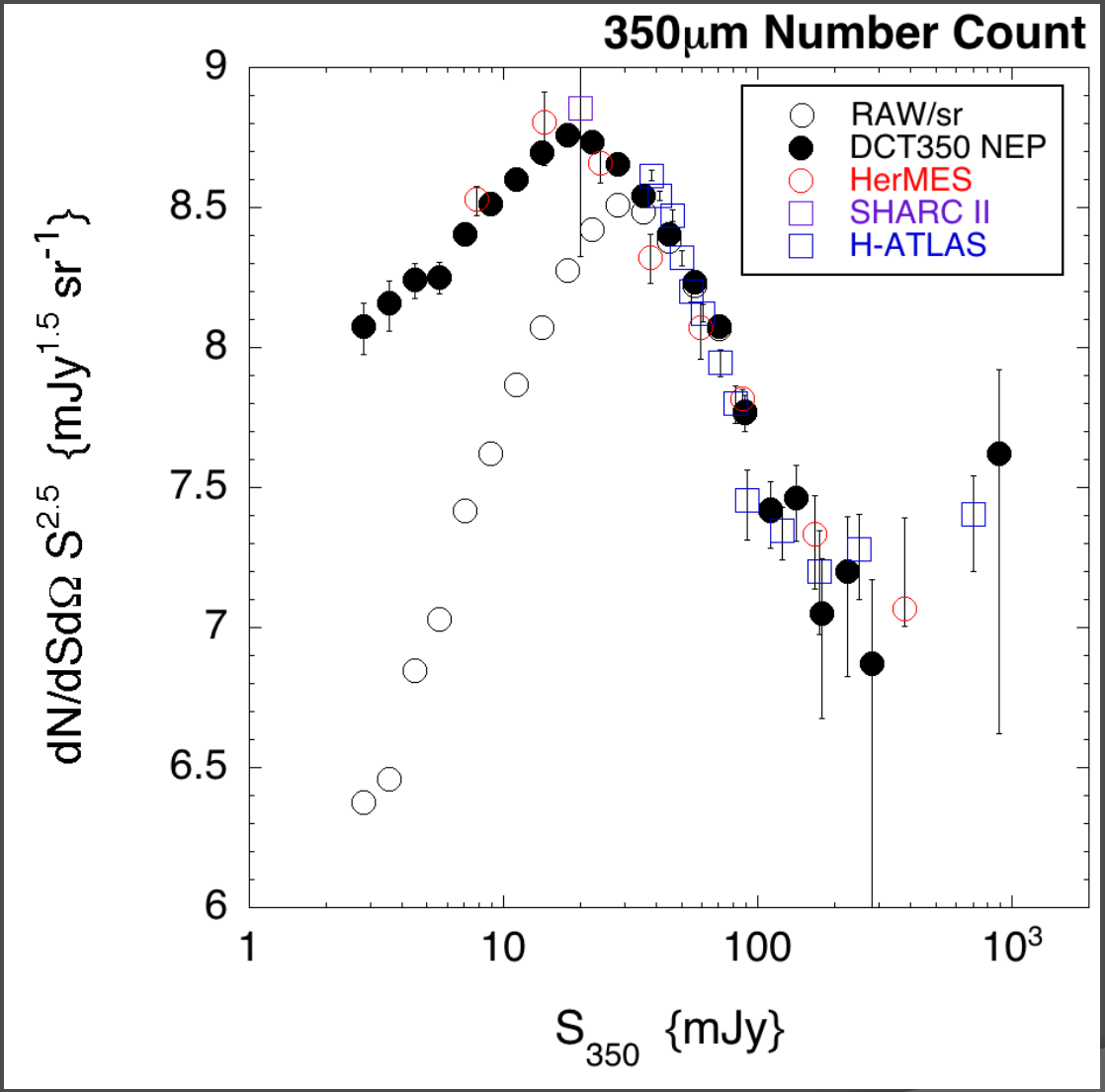
Comparison with other Source Counts

Source Counts



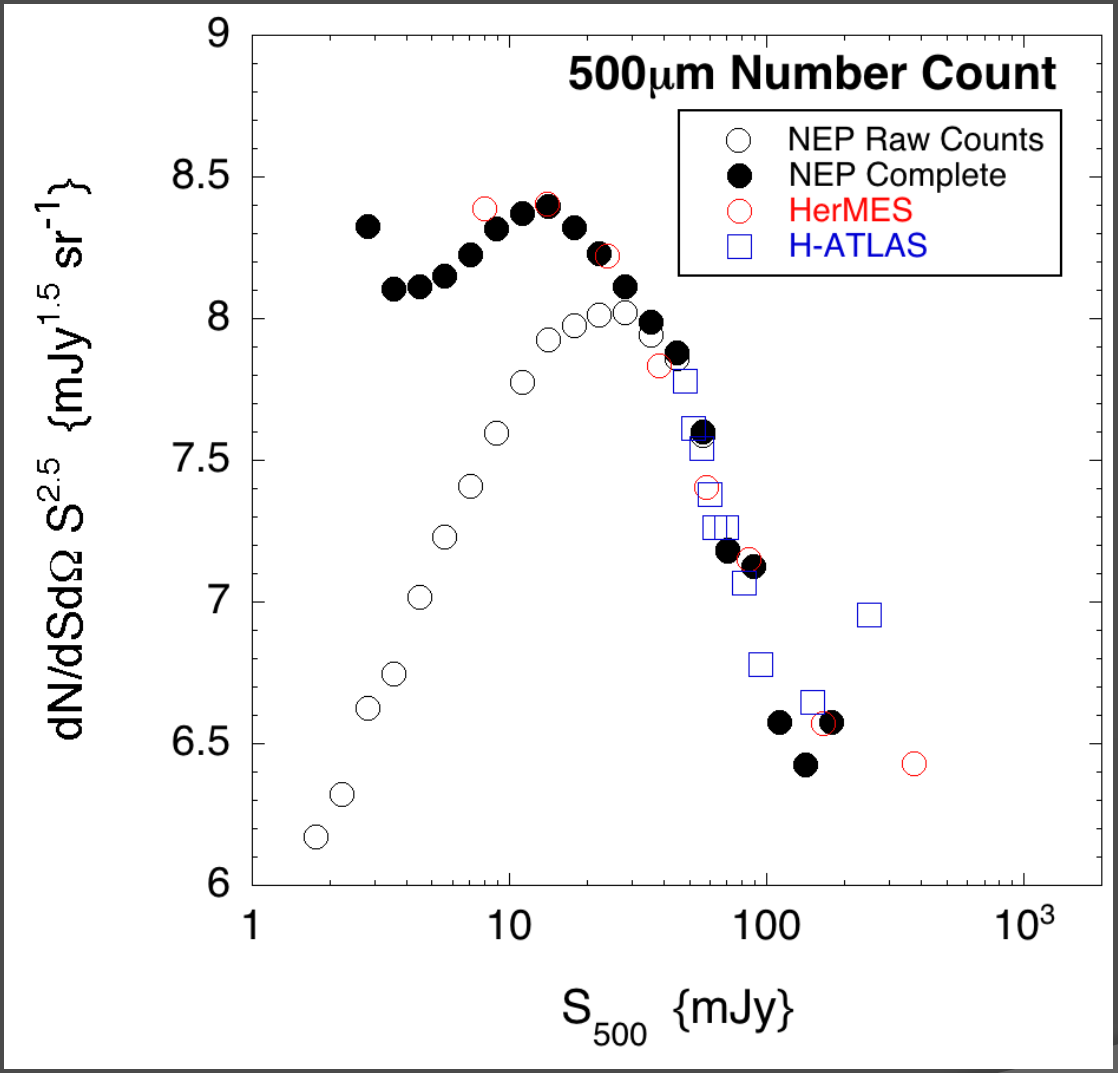
Completeness Level:
80%: 28mJy
50%: 16mJy

Source Counts



Completeness Level:
80%: 31mJy
50%: 23mJy

Source Counts



Completeness Level:
80%: 28mJy
50%: 19mJy

Future Work

Future Work

1. Compare our results with galaxy evolution models
2. Produce draft data reduction and counts paper
3. If required: produce separate catalogues using independent extractions using 250, 350, 500um maps
4. Compare with AKARI map
5. Compare with PACS map/catalogues (See initial work on PACS presentation)