Noise characterization of PACS photometer mini-maps processed with JScanam

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Change Record

Version	Date	Changes	Remarks
Issue 0.2	March 20, 2017	first 70 and 160 µm results	first draft for ICC internal discussion
Issue 1.0	June 27, 2018	all 70, 100, and 160 µm test cases including output pixel sizes used in calibration analysis	final version

Reference Documents

[RD1]	Noise characterization of high-pass filtered PACS photometer mini-maps PICC-MA-TN-014, Issue 2.0

Contents

1 Introduction

We investigate the noise properties of L2.5 mini-maps for point source photometry processed with JScanam (Graciá-Carpio et al. 2015, arXiv:1512.03252v1 [astro-ph.IM]) and how they vary depending on

a) the mapping parameter **pixfrac** (ratio of drop size to input pixel size used for the drizzling algorithm [c.f. Fruchter, A.S. & Hook, R.N., PASP, 114,144] employed within the photProject mapper), and

b) the **output pixel size (outpix)** in the final map.

We compare the noise measured by us in the intensity maps with the standard deviation (stddev) values in the stddev map product created by the PACS pipeline.

Furthermore, we compare the results with the noise values of high-pass filtered (HPF) mini-maps [RD1] for the same OBSIDs. For HPF maps a noise model has been worked out by Popesso et al. (2012, arXiv:1211.4257v1 [astro-ph.IM]) and implemented in the PACS pipeline to create error maps that represent the true level of noise in the associated HPF intensity maps (see [RD1]). In particular, the effects of noise correlation, that artificially lower the noise in the intensity maps, have been quantified and correction factors have been derived to provide the user with the true uncertainties in the intensity maps. For JScanam maps no such systematic noise model based on establishing a cross-correlation matrix has been worked out. In this study, we therefore attempt to determine empirical correlated noise correction factor for JScanam maps under the assumption that the final corrected noise value is the same for HPF and JScanam maps.

For that study two pairs of mini-maps on the intermediate bright standard star β Gem, OBSIDs 1342242770+1342242771 (only 100 µm analysis) and 1342242772+1342242773 (70 µm and 160 µm analysis) (cf. Table 1), were processed with the ipipe mapper script "JScanam" and combined to the L2.5 product with the photProject task for the combination of mapping parameters as listed in Table 2. The used HIPE version was 14.2.0, equivalent to build number 14.0.3597. For details of the data processing, please refer to the PACS data reduction guide photometry.

Table 1: Properties of the mini-maps. The 160 µm maps of OBSIDs 1342242770 and 1342242771 are not used in the analysis presented in this report.

OBSID	λ (µm)	scan speed ("/s)	orientation (^{o} wrt. S/C y-axis)	# scan legs	leg length (')	leg separation (")
1342242770	100+160	20	70	10	3	4
1342242771	100+160	20	110	10	3	4
1342242772	70+160	20	70	10	3	4
1342242773	70+160	20	110	10	3	4

2 Analysis overview

2.1 Noise level of the intensity maps

A representative 1-σ noise level per pixel depending on the mapping parameter combination of pixfrac and outpix, $\sigma_{\rm pix}(\rm pixfrac, outpix)$, of the L2.5 intensity maps is derived in two ways:

1) The standard deviation is determined in two rectangular boxes located in source-free and clean areas of the map close to the central position with the source. A mean $\sigma_{\rm mean} = \frac{\sigma_{\rm box1}+\sigma_{\rm box2}}{2.}$ is determined for further analysis.

2) A flux histogram is constructed for all output pixels of the image map, where the corresponding coverage map indicates that $cover_{\rm pix} \gtrsim \frac{1}{2}\ cover_{\rm max}$. A Gauss fit is performed to the histogram but restricted

Table 2: Combination of mapping parameters used for the study. The combinations high-lighted in bold face are used in the Standard Product Generation (SPG). The combinations in italics were typical for the PACS photometric flux calibration analysis.

pixfrac	output pixel size
blue (70 µm) filter	
0.1	1.″1
0.1	**1.″6**
0.1	2.″4
0.1	3.″2
0.5	1.″6
0.5	2.″4
0.5	3.″2
1.0	*1.″1*
1.0	1.″6
1.0	2.″4
1.0	3.″2
green (100 µm) filter	
pixfrac	output pixel size
0.1	1.″4
0.1	**1.″6**
0.1	2.″4
0.1	3.″2
0.5	1.″6
1.0	*1.″4*
1.0	1.″6
1.0	2.″4
1.0	3.″2
red (160 µm) filter	
pixfrac	output pixel size
0.1	2.″1
0.1	**3.″2**
0.1	4.″8
0.1	6.″4
0.5	3.″2
0.5	4.″8
0.5	6.″4
1.0	*2.″1*
1.0	3.″2
1.0	4.″8
1.0	6.″4

to the part with fluxes below the flux bin associated with the peak of the histogram, which is a good approximation of the mean background level. In this way we ensure that the derived σ_{hist} represents the noise of the background level only and is not contaminated by flux of faint sources. (In fact, to optimize the quality of the fit, typically about 10 histogram bins to the right of the peak of the histogram are included in the fit).

For a photometric measurement, the noise inside the measurement aperture must be determined from the noise per pixel $\sigma_{\mathrm{pix}}(\mathrm{pixfrac}, \mathrm{outpix})$. This is given by

$$\sigma_{\mathrm{aperture}} = \sqrt{N_{\mathrm{outpixinaper}}} \times \sigma_{\mathrm{pix}}(\mathrm{pixfrac}, \mathrm{outpix}) \quad (1)$$

with $N_{outpixinaper}$ being the number of output pixels inside the measurement aperture.

2.2 Noise level derived from standard deviation maps

The noise from the associated standard deviation maps is determined as median and mean inside the same boxes used in method (1) for the image maps.

2.3 Correlated noise correction factors for JScanam maps

For the determination of correlated noise correction factors for JScanam map parameter combinations pixfrac and outpix, $f_{\rm corr}^{\rm JS}(\rm pixfrac, outpix)$, we use the following relation:

$$f_{\rm corr}^{\rm JS}(\rm pixfrac, outpix) = \frac{< \sigma_{\rm aperture,corr} >^{\rm ref}_{\rm wmHPF}}{\sigma^{JS}_{\rm aperture}(\rm pixfrac, outpix)}, \tag{2}$$

where $< \sigma_{\rm aperture,corr} >^{\rm ref}_{\rm wmHPF}$ is a weighted mean (wm) reference noise from high-pass filtered maps corrected for noise correlation and $\sigma^{JS}_{\rm aperture}(\rm pixfrac, outpix)$ is the noise inside the measurement aperture as defined in Eq. 1. This approach is justified, since both HPF and JScanam mappers use the photProject task for the map projection. The best suited reference values for each filter appear to be the weighted means from a variety of map parameter combinations, as determined in [RD1], sections 6.8, 7.8, and 8.8, respectively.

The standard high-pass filter radius used for mini-maps in the standard product generation (SPG) is relatively compact (with values of 15 for 70 and 100 µm, and 25 for 160 µm). However, when selecting suitable reference values from [RD1] for the use in Eq. 2, it turned out that the weighted mean values of the smoother high-pass filter (larger HPF radius, i.e. HPF radius = 30 for 70 and 100 µm and HPF radius = 50 for 160 µm, see [RD1] for a definition) appear to be better matched.

For the 160 µm filter, there would be two combinations, where the correlated noise correction factors $f_{\rm corr}^{\rm JS}(\rm pixfrac, outpix)$ would be smaller than 1.0, if the weighted means of the smaller HPF radius 25 were used as reference noise value. It appears un-plausible that for some JScanam map parameter combinations the final noise would be smaller than measured (i.e. a reduction of noise by correlated noise correction), while for others the correlated noise correction would increase the final noise as expected.

Also, according to Popesso et al. (2012, arXiv:1211.4257v1 [astro-ph.IM]), the projection in the drizzle method implemented in photProject is related to a correlated noise factor $f_{\rm projection}$

$$f_{\rm projection} = \begin{cases} \frac{r}{1-\frac{1}{3r}} & \text{for} \quad r \geq 1 \\ \frac{1}{1-\frac{r}{3}} & \text{for} \quad r \leq 1 \end{cases} \tag{3}$$

where r is the ratio of the drop size and the ouput pixel size. $f_{\rm projection}$ therefore gives a lower boundary limit for $f_{\rm corr}^{\rm JS}$(pixfrac,outpix), in particular for pixfrac = 1.0. We list $f_{\rm projection}$ in Table 3 for the pixfrac and output pixel size combinations used in our analysis. Taking these numbers as lower limit references, then also for the 70 and 100 µm filters the weighted means of the smoother HPF radius = 30 give the more consistent results.

A possible explanation for this behaviour lies in the iterative application of the $\frac{1}{f}$-noise reduction by employing a multi-spatial-scale approach in the JScanam processing. Hence, also noise correlation over larger scales than the standard HPF window may, to a certain extent, be woven into the final JScanam maps. In this regard, JScanam compares better to a milder HPF filtering in case of the HPF algorithm. The reference noise values $< \sigma_{\rm aperture,corr} >^{\rm ref}_{\rm wmHPF}$ for each PACS filter applied in Eq. 2 are listed in Table 4.

Table 3: Calculated noise correction factors $f_{projection}$ due to the projection in the drizzle method implemented in photProject as the lower limit of the final f^{JS}_{corr}(pixfrac,outpix) according to Eq. 3. Drop size is the product of pixfrac and input detector pixel size, which is 3.″2 at 70 and 100 µm and 6.″4 at 160 µm.

70 and 100 µm filter						
		output pixel size				
pixfrac	drop size (")	1.1 (")	1.4 (")	1.6 (")	2.4 (")	3.2 (")
0.1	0.32	1.107	1.083	1.071	1.047	1.035
0.5	1.60	1.887	1.613	1.500	1.286	1.200
1.0	3.20	3.286	2.676	2.400	1.778	1.500
160 µm filter						
		output pixel size				
pixfrac	drop size (")	2.1 (")		3.2 (")	4.8 (")	6.4 (")
0.1	0.64	1.113		1.071	1.047	1.035
0.5	3.20	1.951		1.500	1.286	1.200
1.0	6.40	3.422		2.400	1.778	1.500

Table 4: Reference noise values $<\sigma_{aperture,corr}>^{ref}_{wmHPF}$ from high-pass-filtered (HPF) and correlated noise corrected maps. The weighted means of the 2 combinations with HPF = 30 at 70 and 100 µm and the 2 combinations with HPF = 50 at 160 µm are used (cf. [RD1]).

filter (µm)	$<\sigma_{aperture,corr}>^{ref}_{wmHPF}$ (mJy)
70	1.29±0.02
100	1.51±0.005
160	3.27±0.05

3 Analysis of 70μm maps

3.1 70 μm: Pixfrac 0.1, Pixsize 1.″1

3.1.1 L 2.5 OBSIDs 1342242772+1342242773

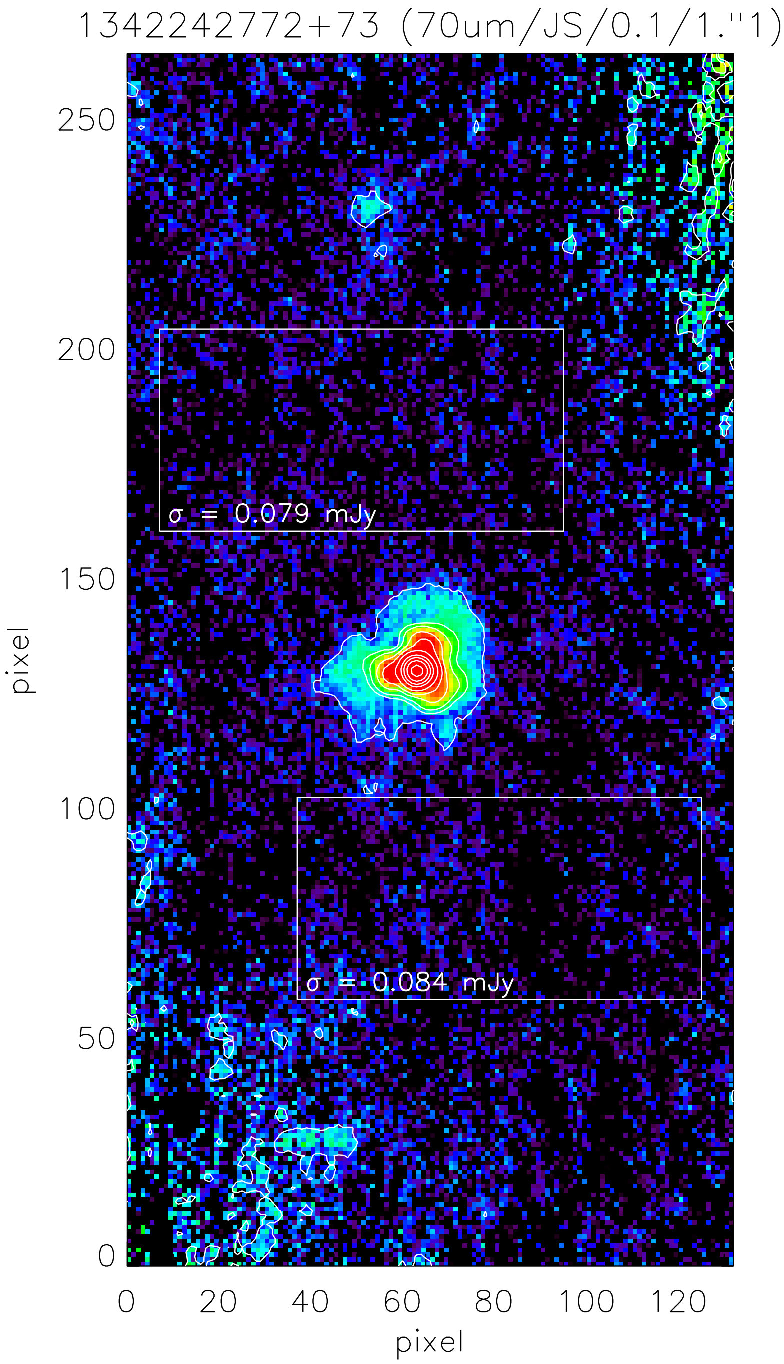

Figure 1: 70 μm L2.5 combined JScanam map for OBSIDs 1342242772+73 with pixfrac 0.1 and output pixel size of 1.″1. The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

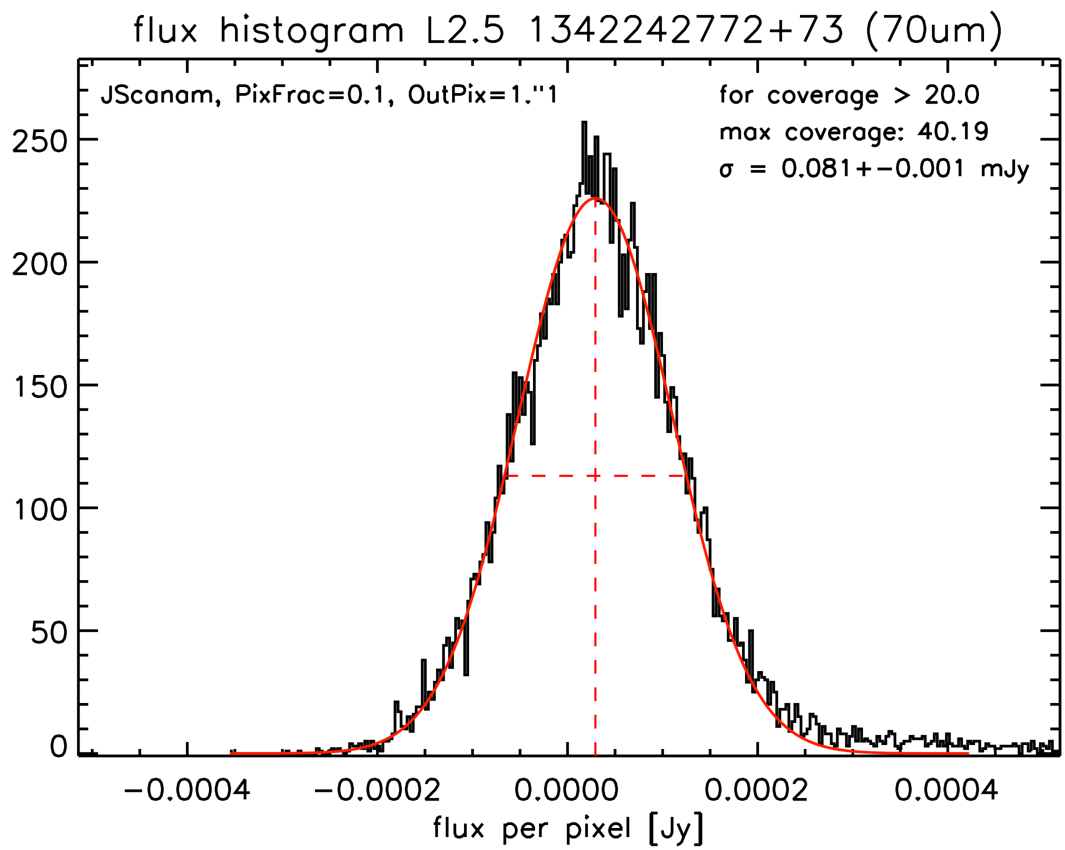

Figure 2: Noise determination for the 70 µm coadded L2.5 map of OBSIDs 1342242772+73 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\;\sigma_{\rm hist}$).

3.2 70 µm: Pixfrac 0.1, Pixsize 1.″6

3.2.1 L 2.5 OBSIDs 1342242772+1342242773

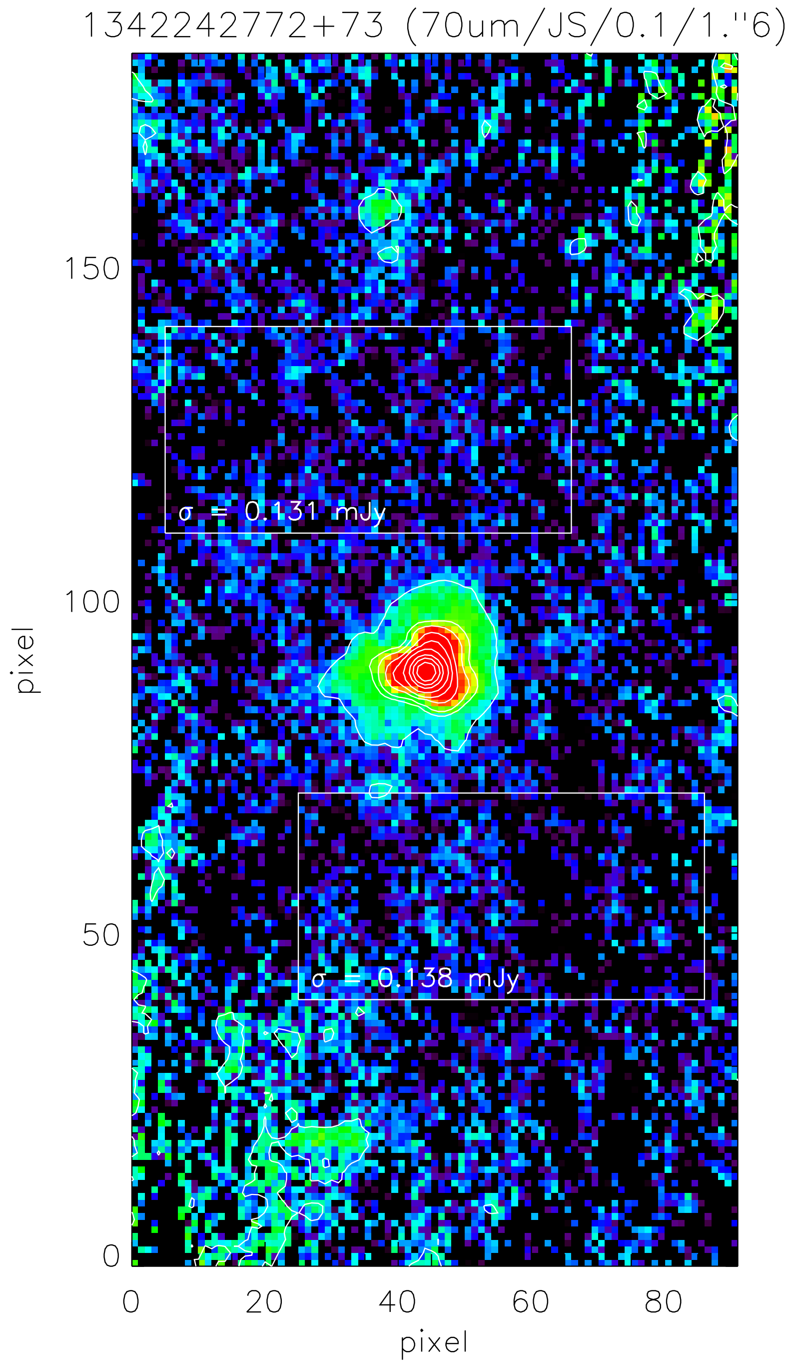

Figure 3: 70 µm L2.5 combined JScanam map for OBSIDs 1342242772+73 with pixfrac 0.1 and output pixel size of 1.″6 (SPG product parameter set). The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

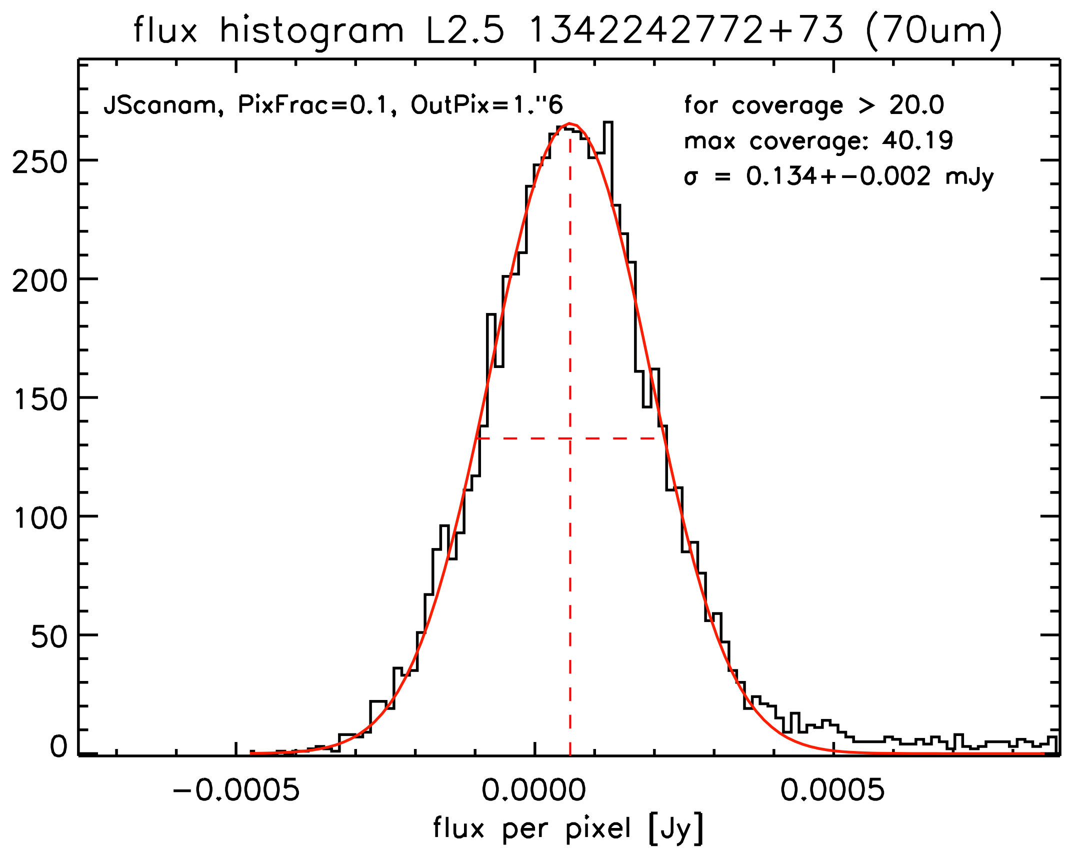

Figure 4: Noise determination for the 70 μm coadded L2.5 map of OBSIDs 1342242772+73 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\;\sigma_{\rm hist}$).

3.3 70 µm: Pixfrac 0.1, Pixsize 2.″4

3.3.1 L 2.5 OBSIDs 1342242772+1342242773

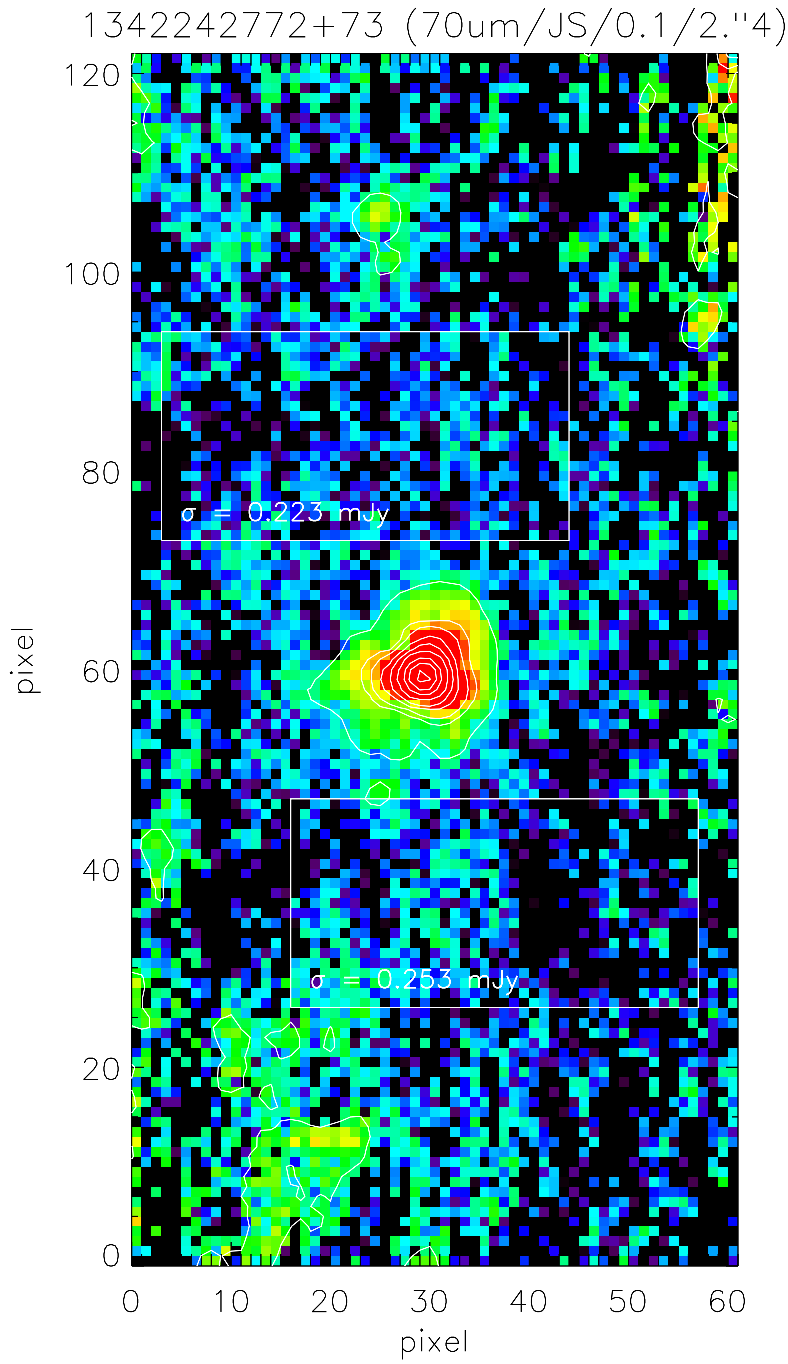

Figure 5: 70 µm L2.5 combined JScanam map for OBSIDs 1342242772+73 with pixfrac 0.1 and output pixel size of 2.″4. The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

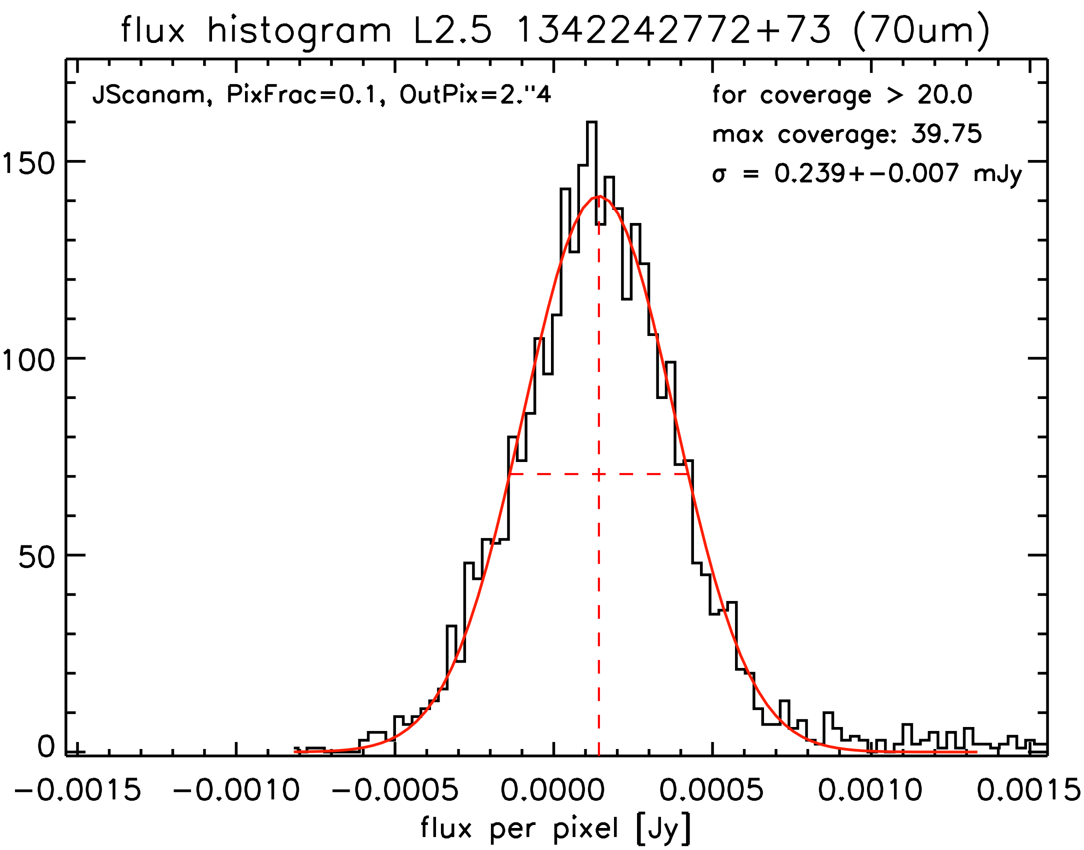

Figure 6: Noise determination for the 70 µm coadded L2.5 map of OBSIDs 1342242772+73 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\,\sigma_{\rm hist}$).

3.4 70 µm: Pixfrac 0.1, Pixsize 3.″2

3.4.1 L 2.5 OBSIDs 1342242772+1342242773

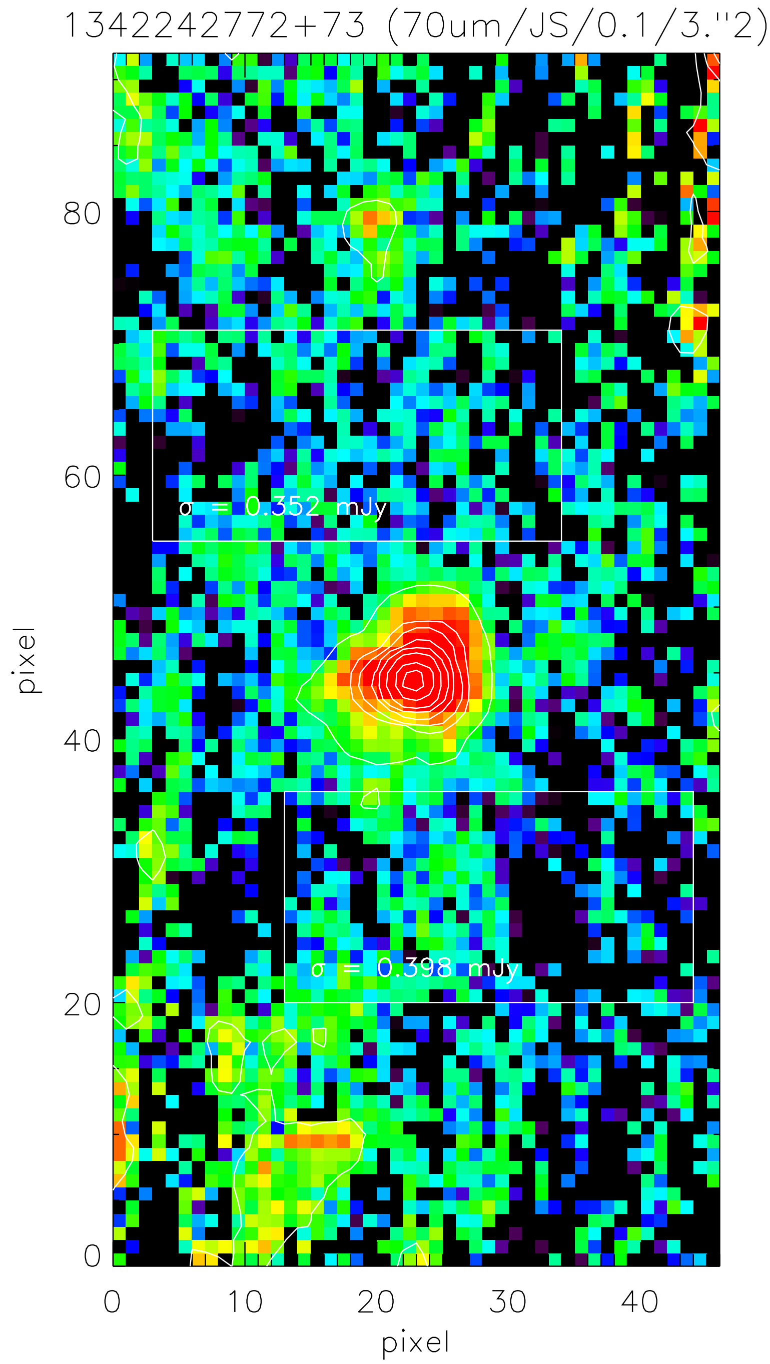

Figure 7: 70 µm L2.5 combined JScanam map for OBSIDs 1342242772+73 with pixfrac 0.1 and output pixel size of 3.″2. The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

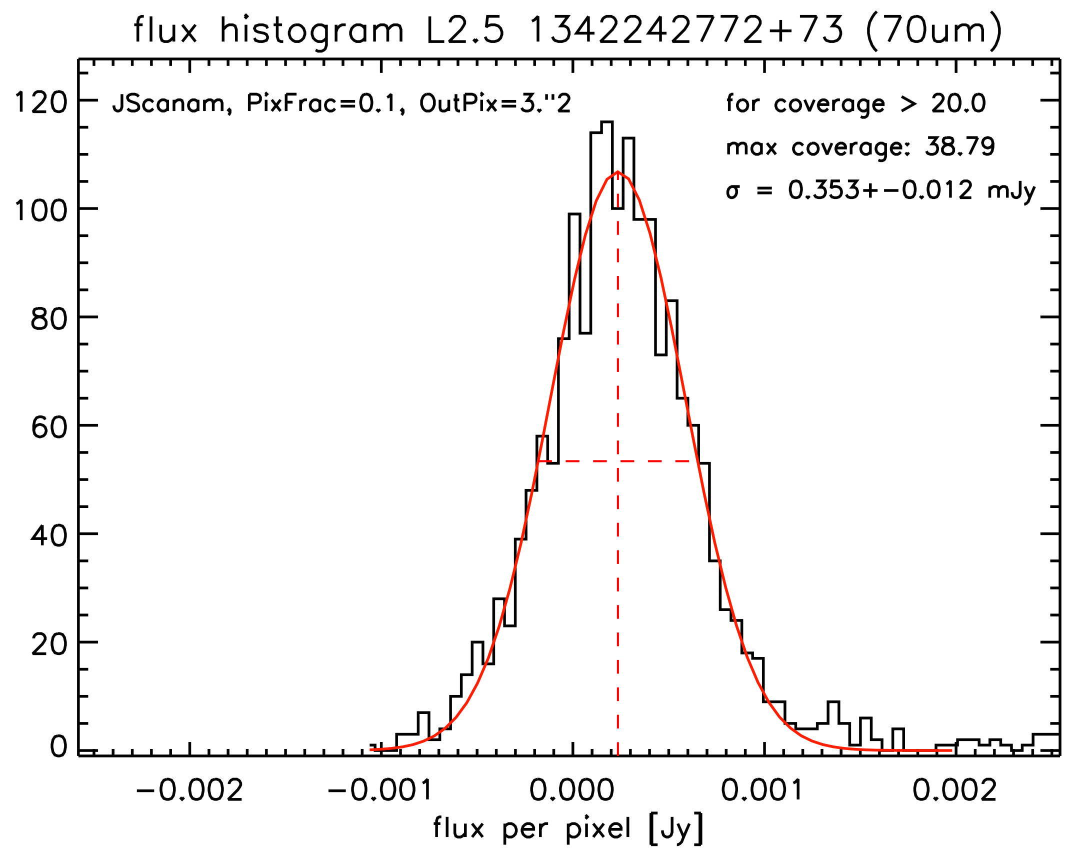

Figure 8: Noise determination for the 70 μm coadded L2.5 map of OBSIDs 1342242772+73 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\,\sigma_{\rm hist}$).

3.5 70 µm: Pixfrac 0.5, Pixsize 1.″6

3.5.1 L 2.5 OBSIDs 1342242772+1342242773

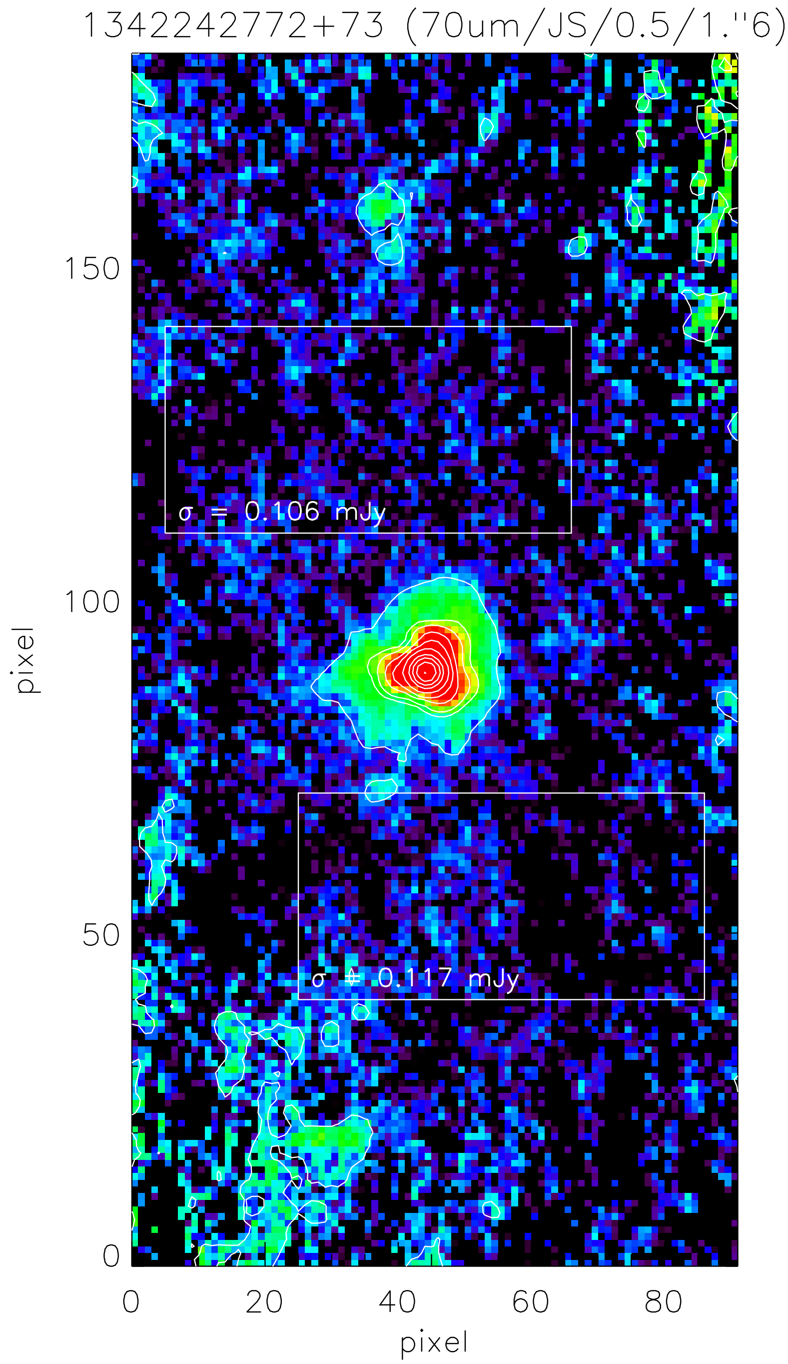

Figure 9: 70 µm L2.5 combined JScanam map for OBSIDs 1342242772+73 with pixfrac 0.5 and output pixel size of 1.″6. The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

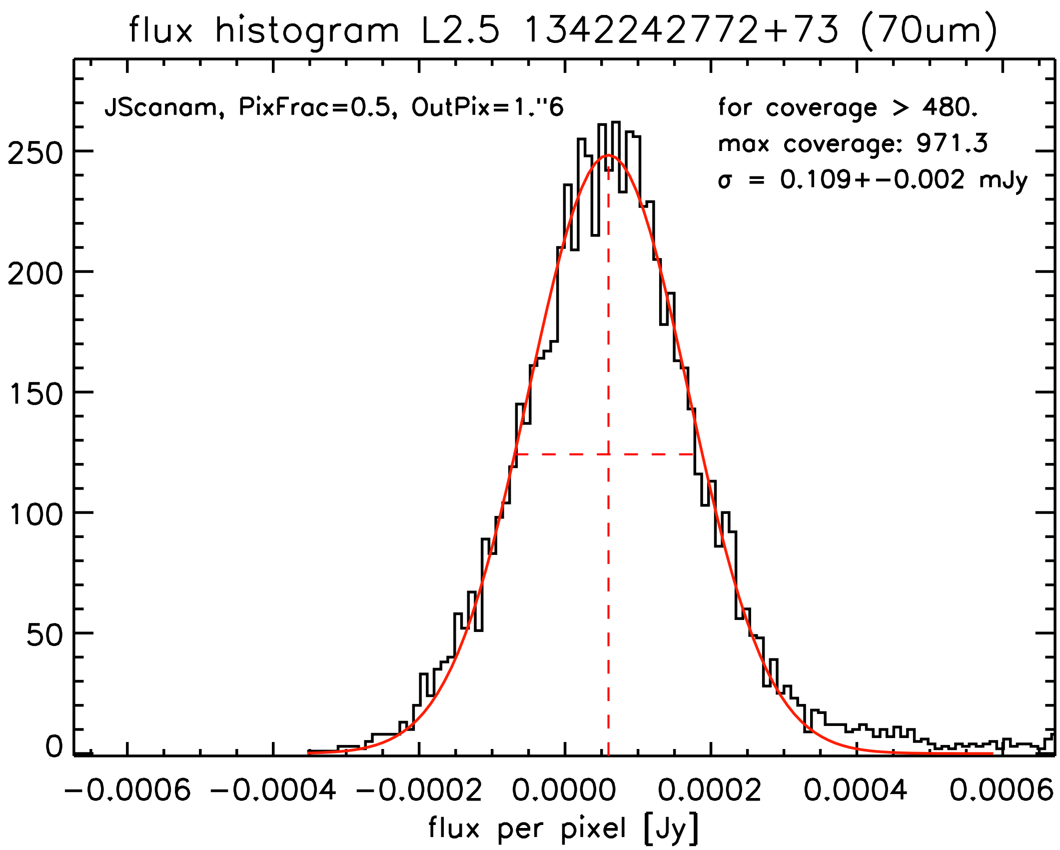

Figure 10: Noise determination for the 70 µm coadded L2.5 map of OBSIDs 1342242772+73 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\;\sigma_{\rm hist}$).

3.6 70 µm: Pixfrac 0.5, Pixsize 2.″4

3.6.1 L 2.5 OBSIDs 1342242772+1342242773

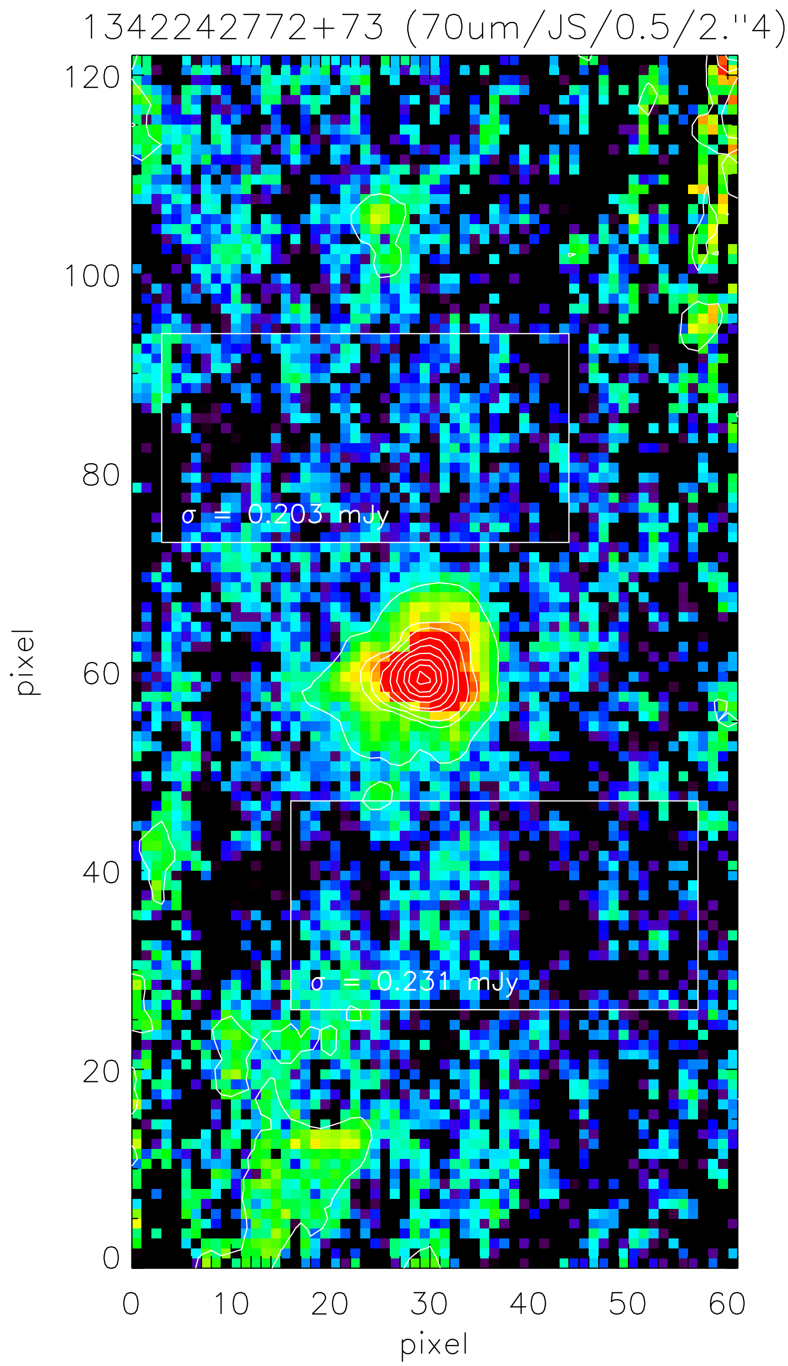

Figure 11: 70 µm L2.5 combined JScanam map for OBSIDs 1342242772+73 with pixfrac 0.5 and output pixel size of 2.″4. The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

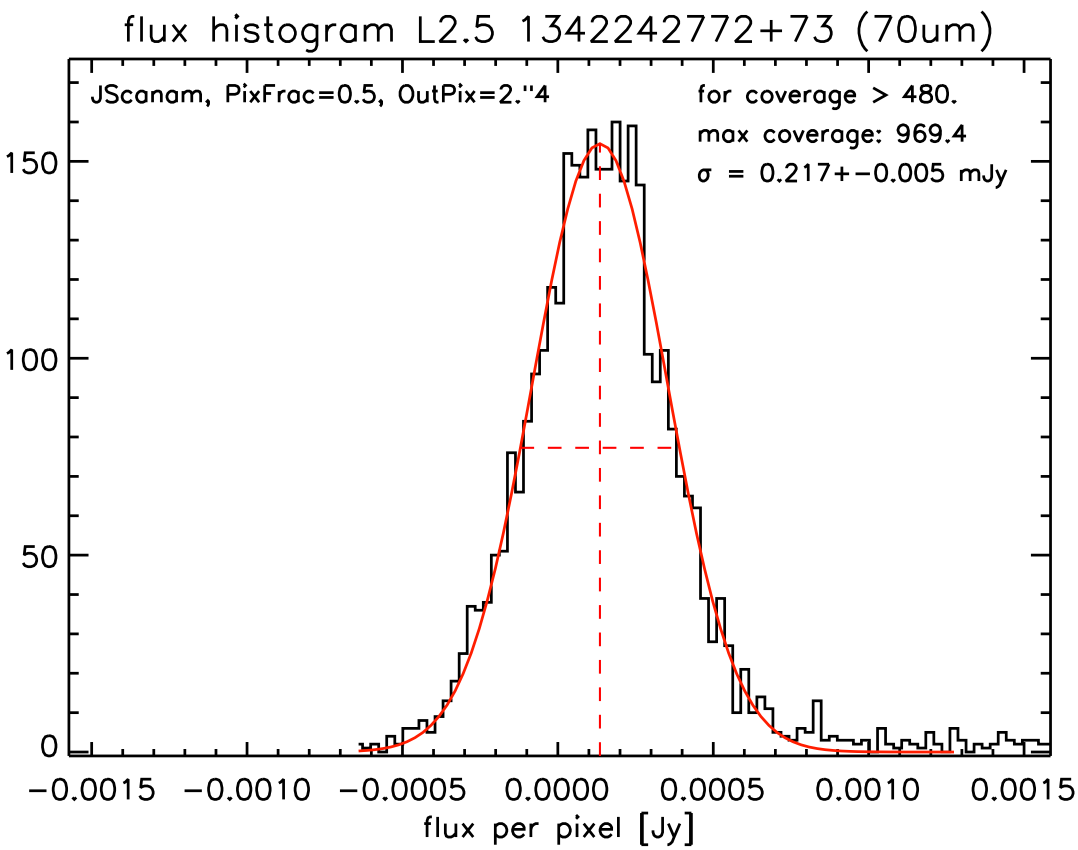

Figure 12: Noise determination for the 70 µm coadded L2.5 map of OBSIDs 1342242772+73 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\;\sigma_{\rm hist}$).

3.7 70 µm: Pixfrac 0.5, Pixsize 3.″2

3.7.1 L 2.5 OBSIDs 1342242772+1342242773

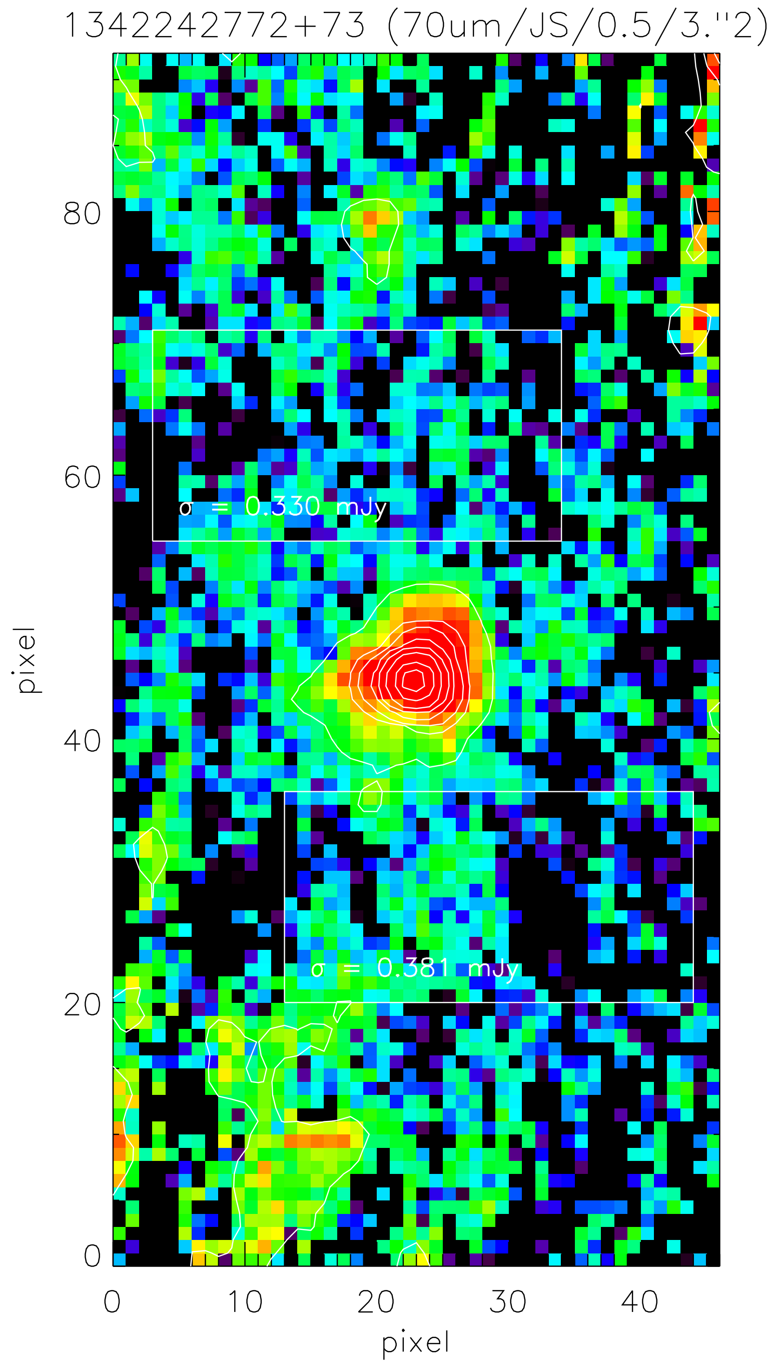

Figure 13: 70 µm L2.5 combined JScanam map for OBSIDs 1342242772+73 with pixfrac 0.5 and output pixel size of 3.″2. The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

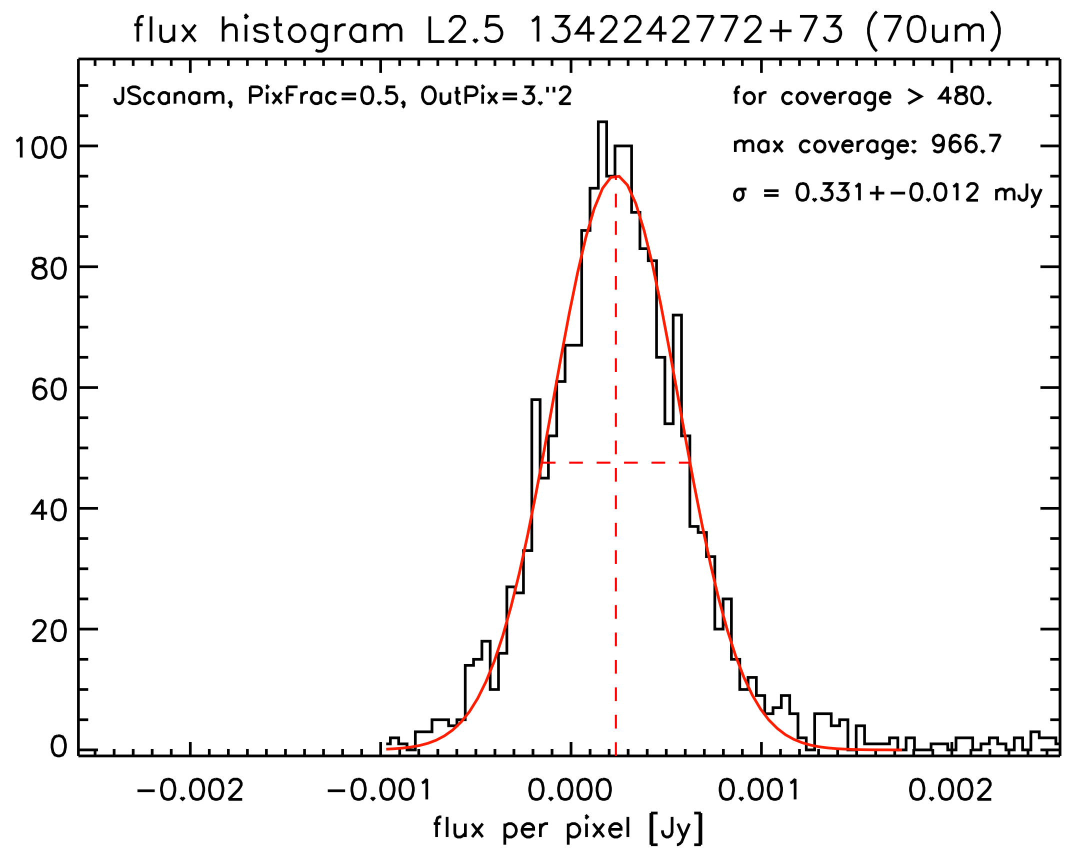

Figure 14: Noise determination for the 70 µm coadded L2.5 map of OBSIDs 1342242772+73 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\;\sigma_{\mathrm{hist}}$).

3.8 70 µm: Pixfrac 1.0, Pixsize 1.″1

3.8.1 L 2.5 OBSIDs 1342242772+1342242773

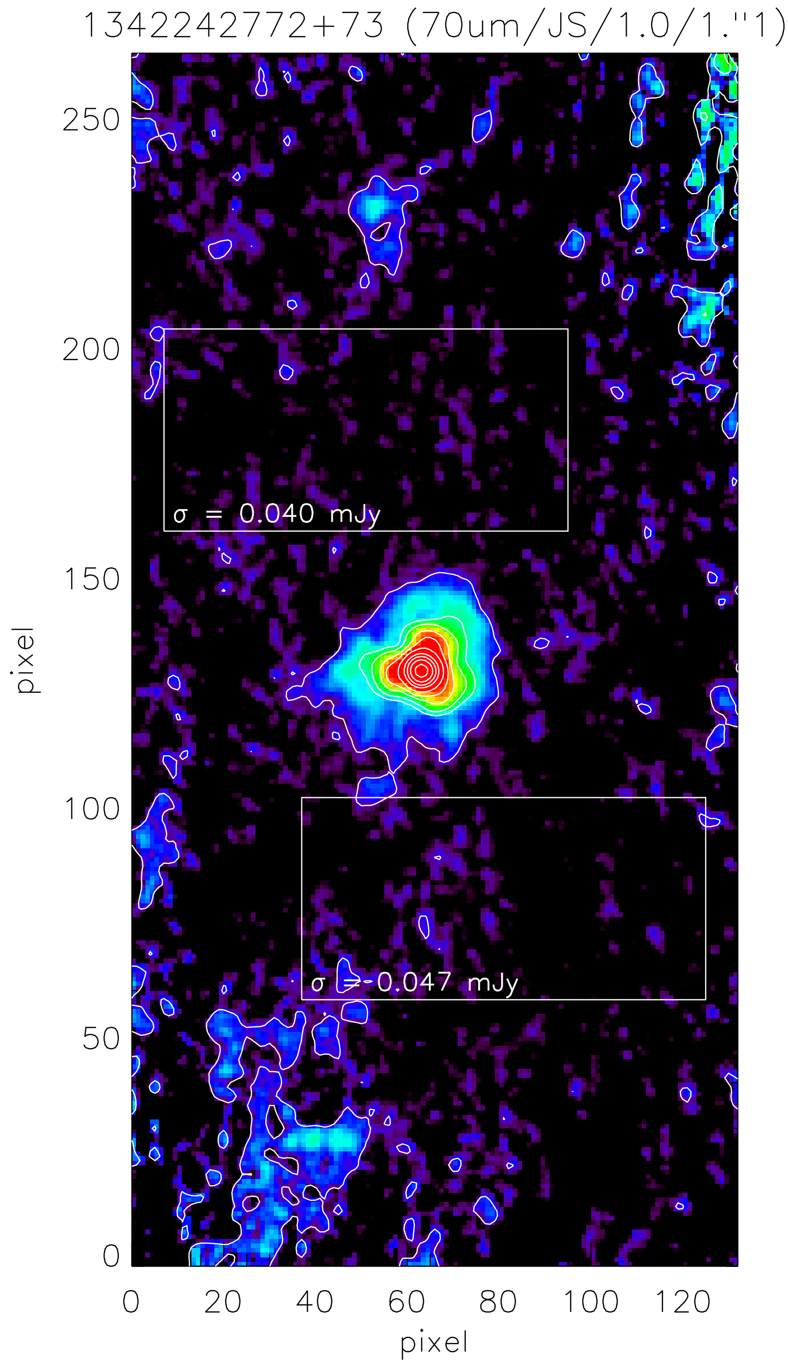

Figure 15: 70 µm L2.5 combined JScanam map for OBSIDs 1342242772+73 with pixfrac 1.0 and output pixel size of 1.″1. The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

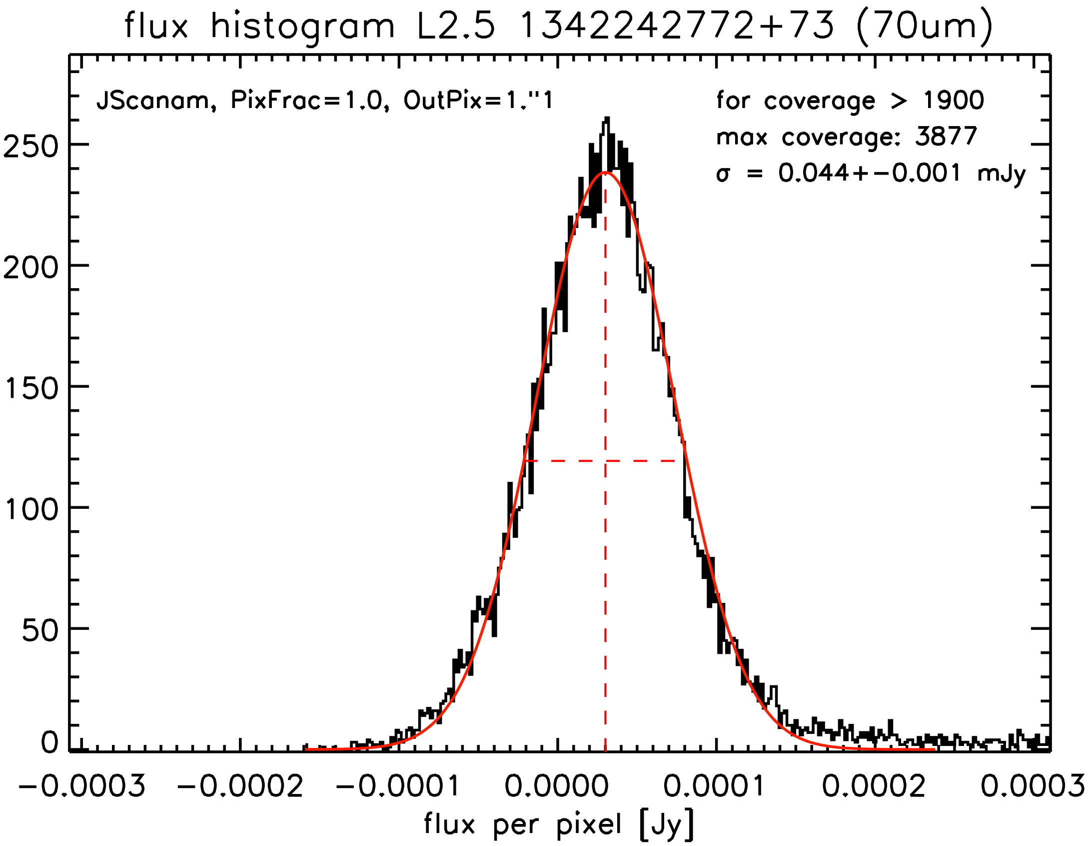

Figure 16: Noise determination for the 70 μm coadded L2.5 map of OBSIDs 1342242772+73 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\;\sigma_{\rm hist}$).

3.9 70 µm: Pixfrac 1.0, Pixsize 1.″6

3.9.1 L 2.5 OBSIDs 1342242772+1342242773

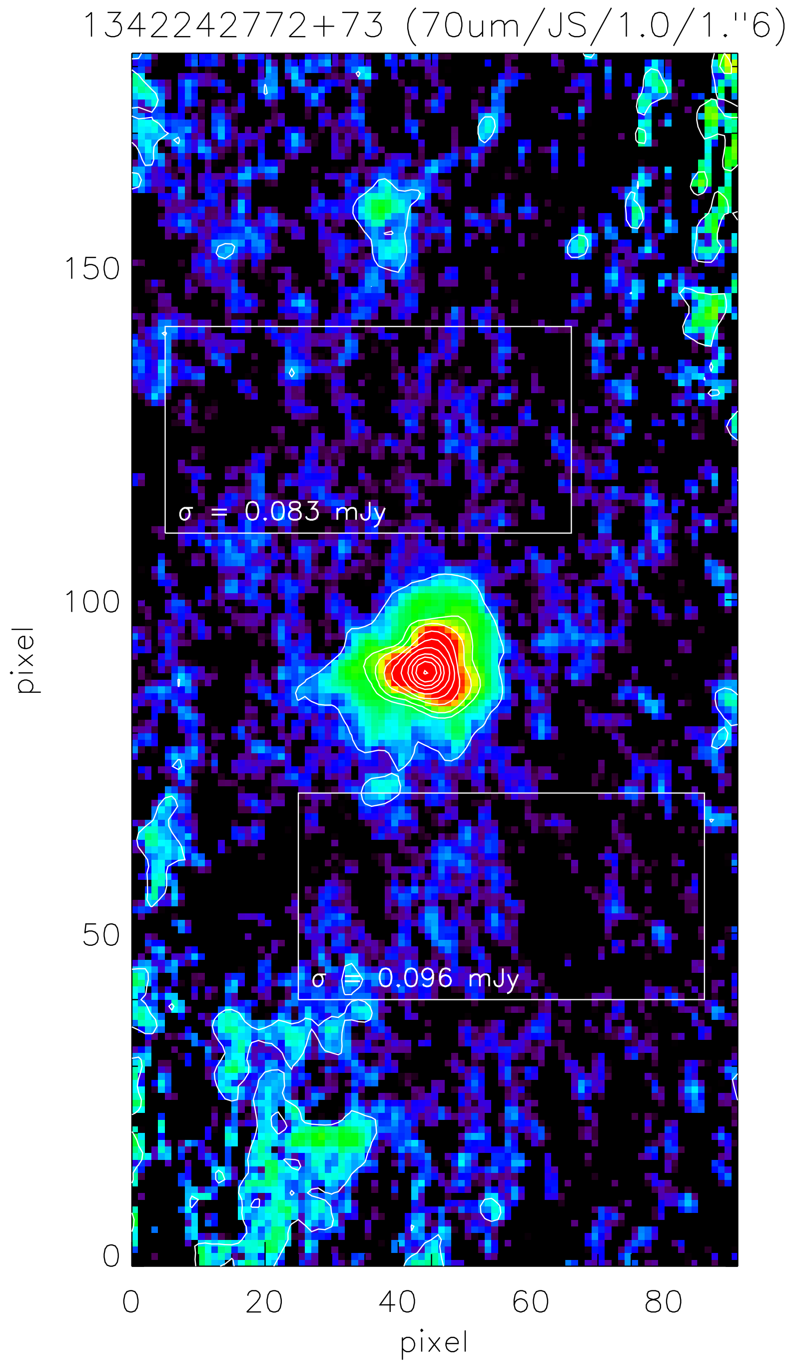

Figure 17: 70 µm L2.5 combined JScanam map for OBSIDs 1342242772+73 with pixfrac 1.0 and output pixel size of 1.″6. The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

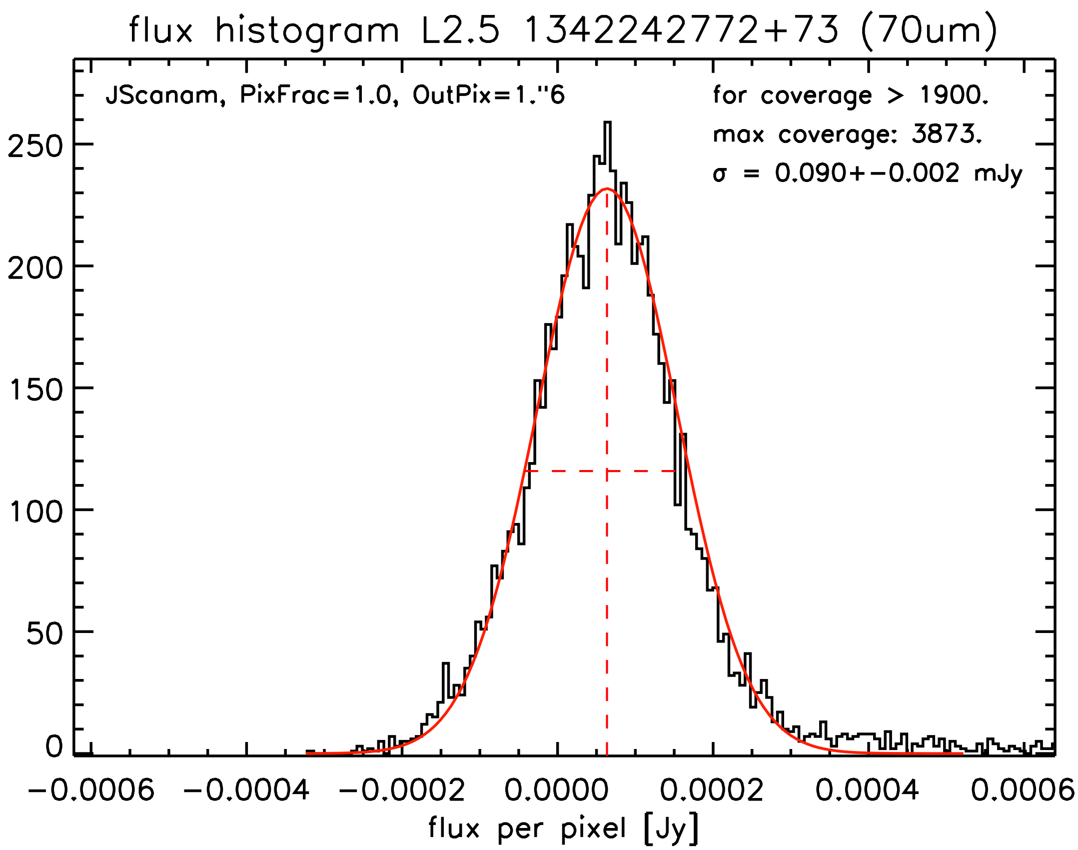

Figure 18: Noise determination for the 70 µm coadded L2.5 map of OBSIDs 1342242772+73 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\;\sigma_{\rm hist}$).

3.10 70 µm: Pixfrac 1.0, Pixsize 2.″4

3.10.1 L 2.5 OBSIDs 1342242772+1342242773

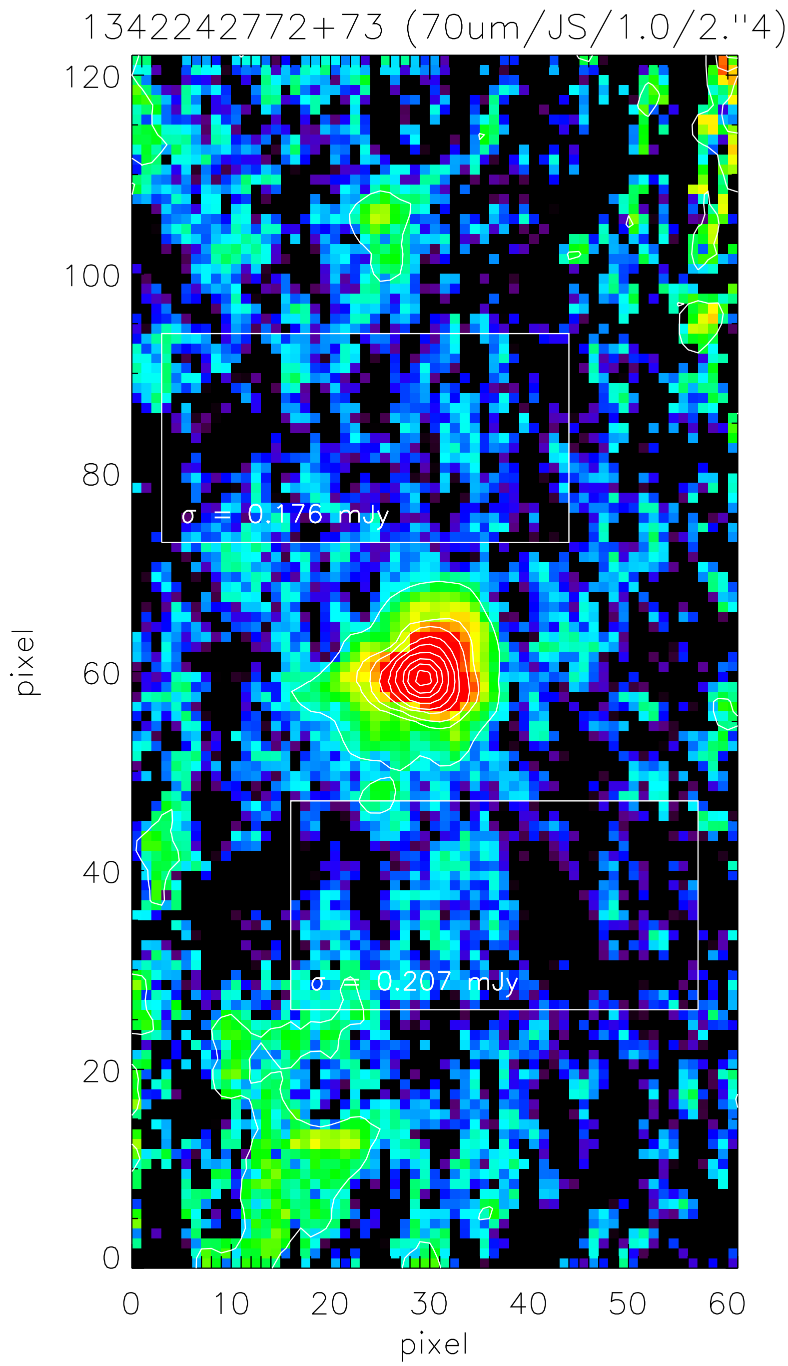

Figure 19: 70 µm L2.5 combined JScanam map for OBSIDs 1342242772+73 with pixfrac 1.0 and output pixel size of 2.″4. The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

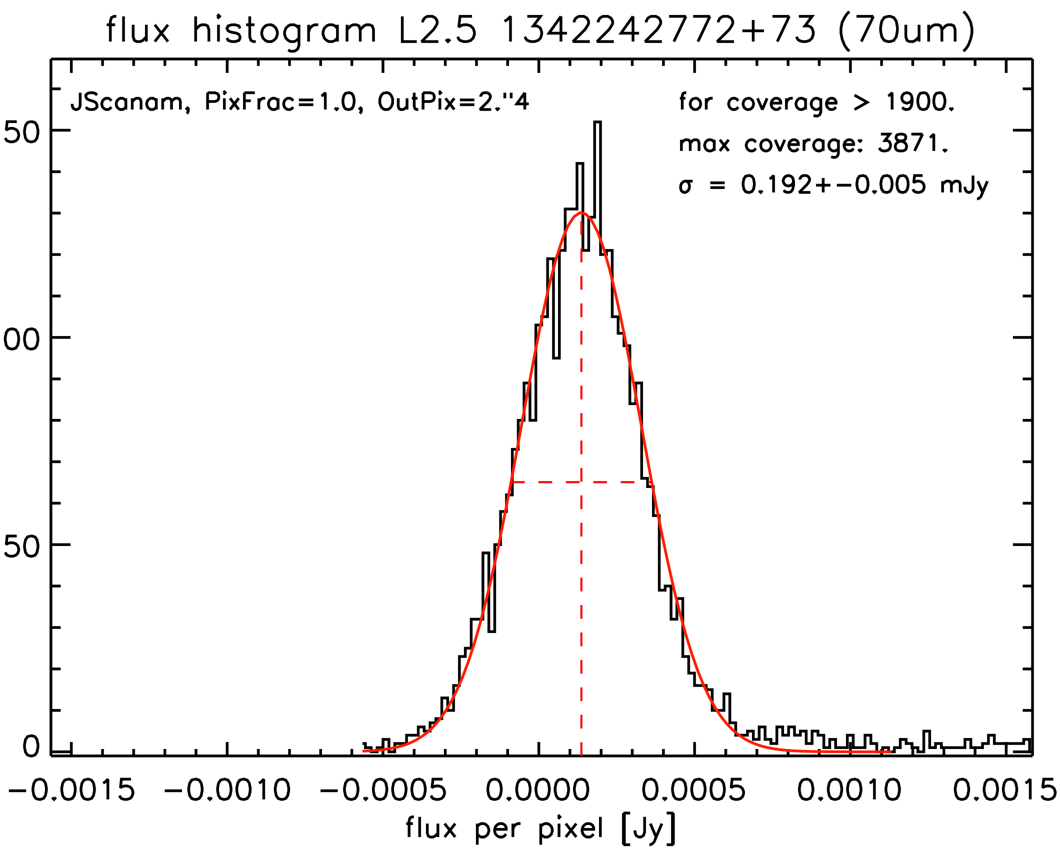

Figure 20: Noise determination for the 70 µm coadded L2.5 map of OBSIDs 1342242772+73 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\,\sigma_{\rm hist}$).

3.11 70 µm: Pixfrac 1.0, Pixsize 3.″2

3.11.1 L 2.5 OBSIDs 1342242772+1342242773

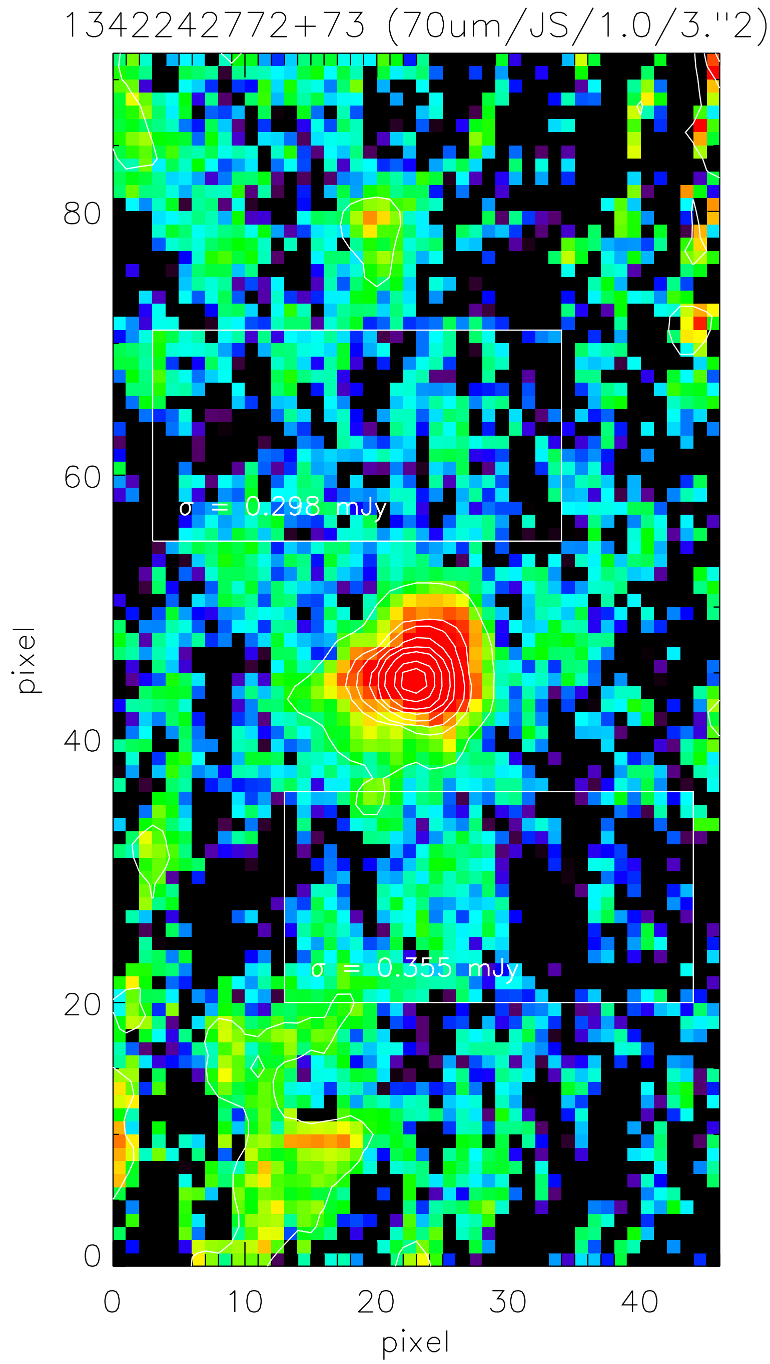

Figure 21: 70 µm L2.5 combined JScanam map for OBSIDs 1342242772+73 with pixfrac 1.0 and output pixel size of 3.″2. The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

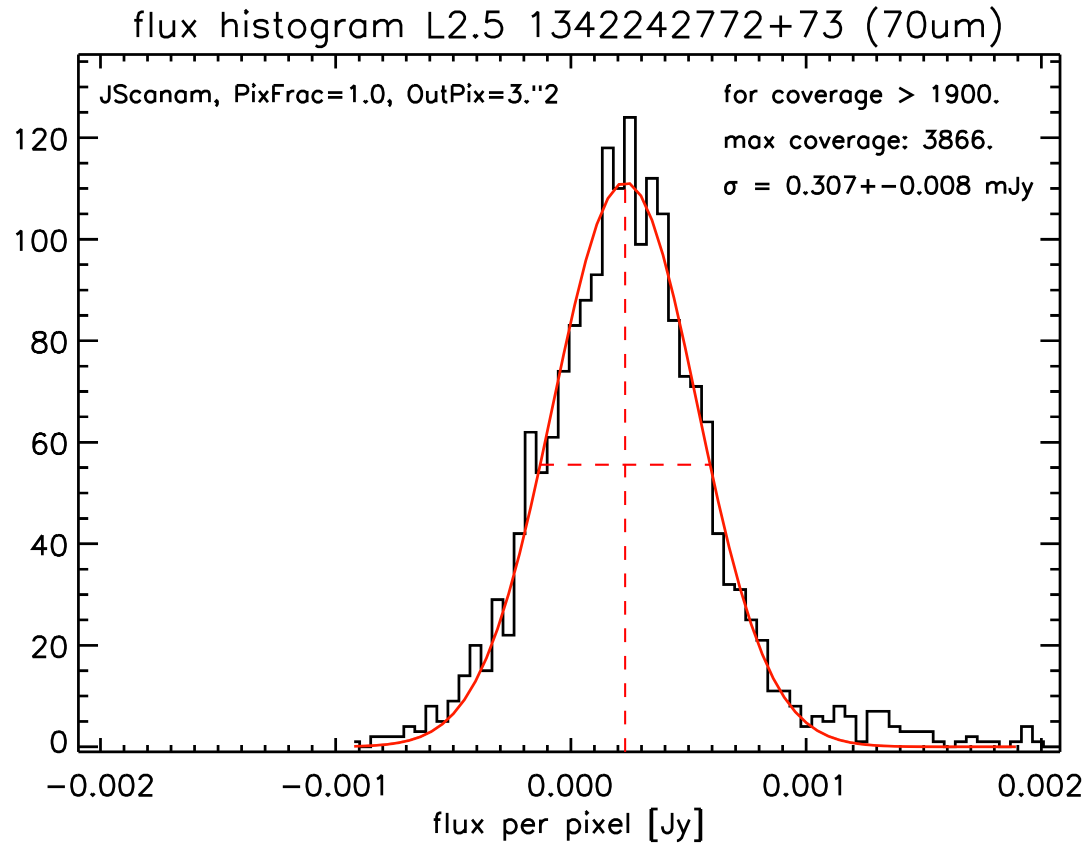

Figure 22: Noise determination for the 70 μm coadded L2.5 map of OBSIDs 1342242772+73 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\;\sigma_{\rm hist}$).

4 Analysis of 100μm maps

4.1 100 µm: Pixfrac 0.1, Pixsize 1.″4

4.1.1 L 2.5 OBSIDs 1342242770+1342242771

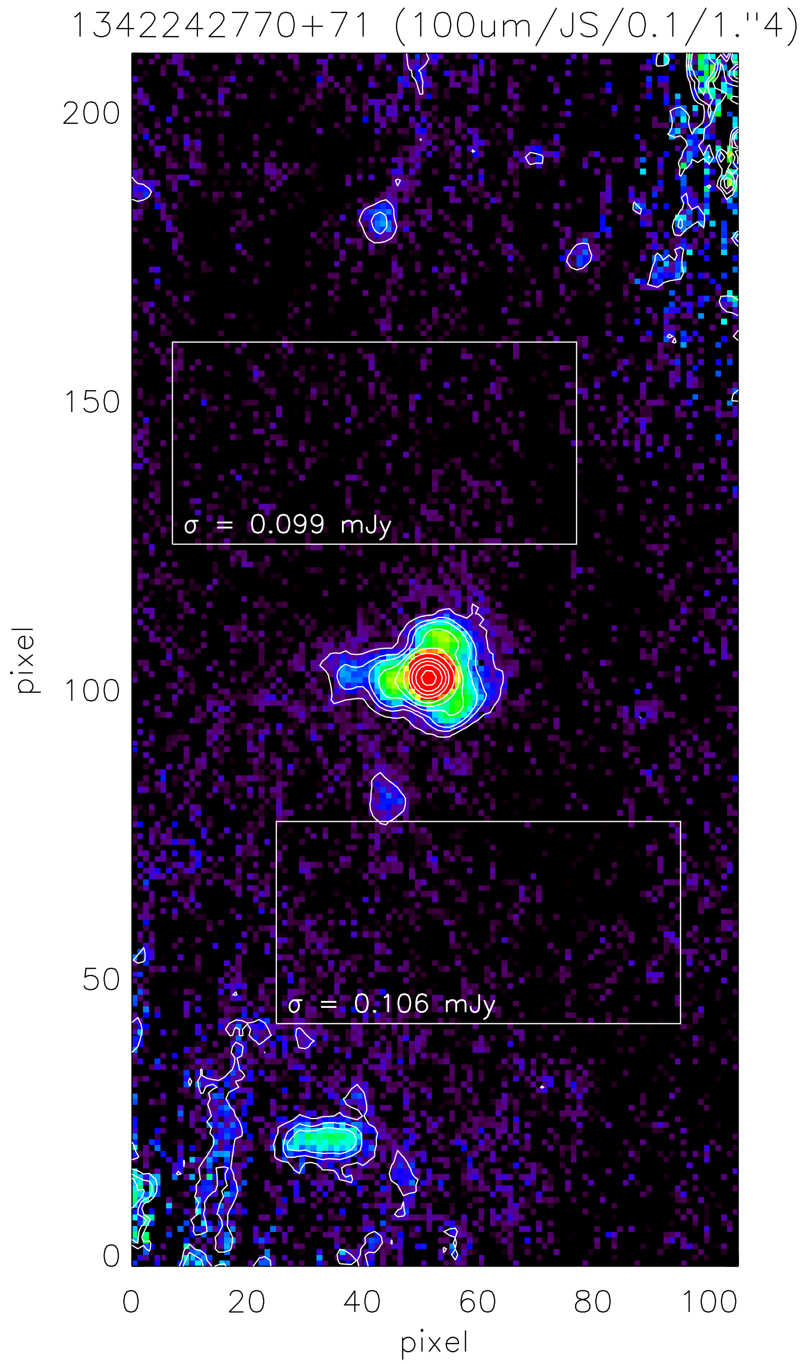

Figure 23: 100 µm L2.5 combined JScanam map for OBSIDs 1342242770+71 with pixfrac 0.1 and output pixel size of 1.″4. The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

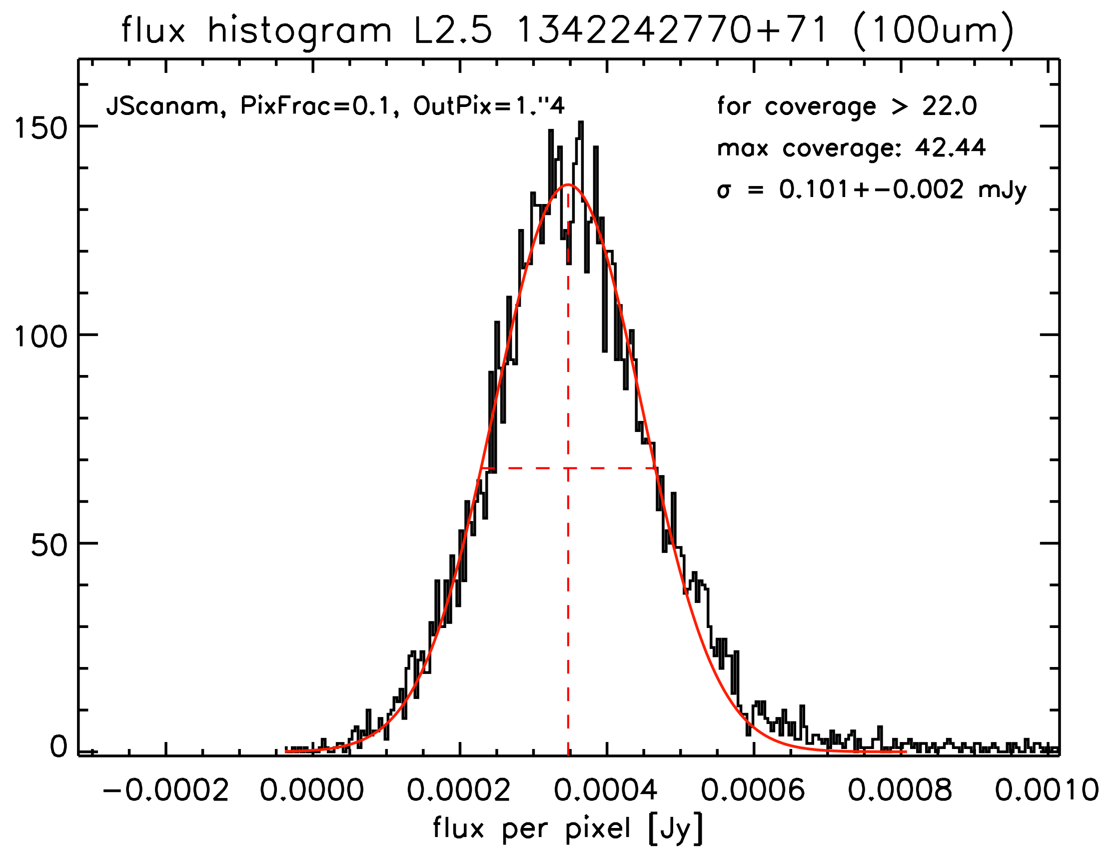

Figure 24: Noise determination for the 100 µm coadded L2.5 map of OBSIDs 1342242770+71 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\,\sigma_{\rm hist}$).

4.2 100 µm: Pixfrac 0.1, Pixsize 1.″6

4.2.1 L 2.5 OBSIDs 1342242770+1342242771

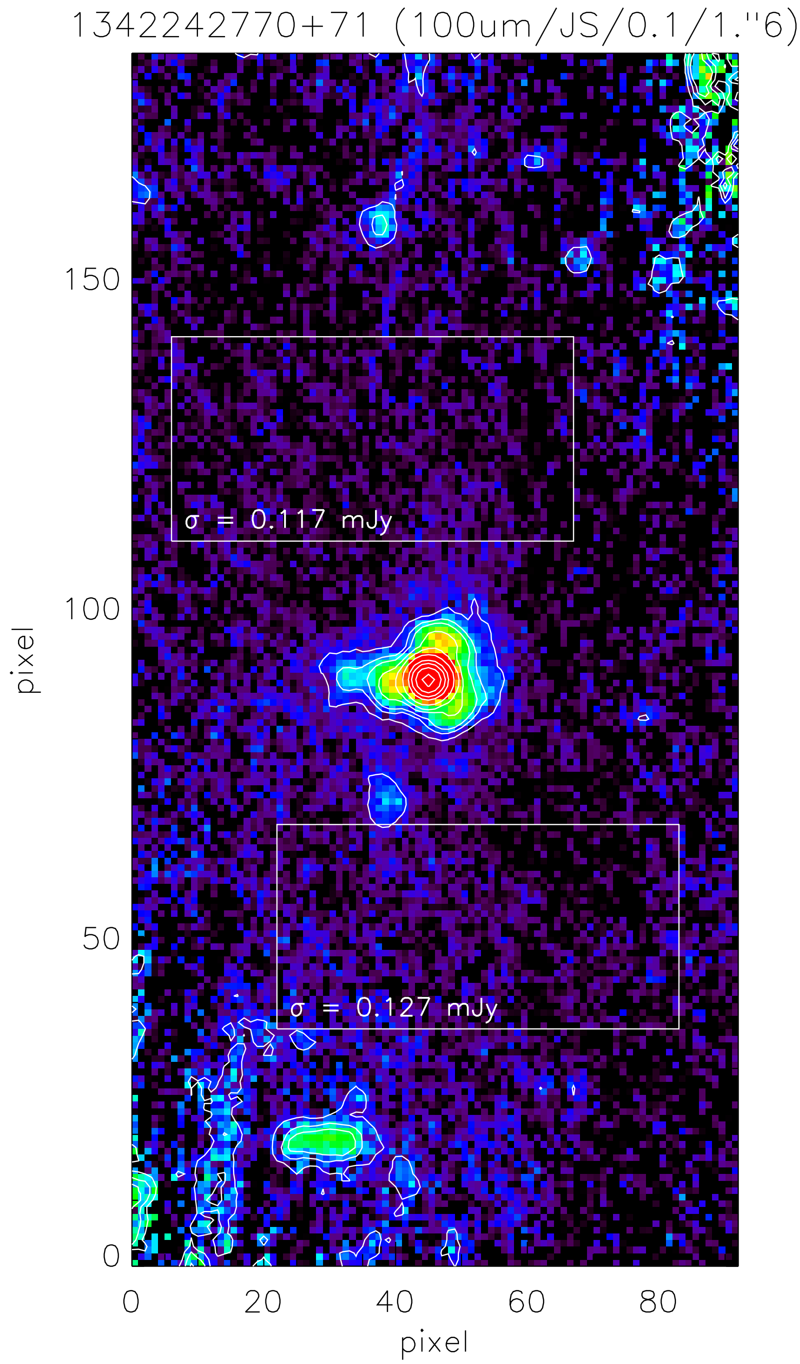

Figure 25: 100 µm L2.5 combined JScanam map for OBSIDs 1342242770+71 with pixfrac 0.1 and output pixel size of 1.″6 (SPG product parameter set). The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

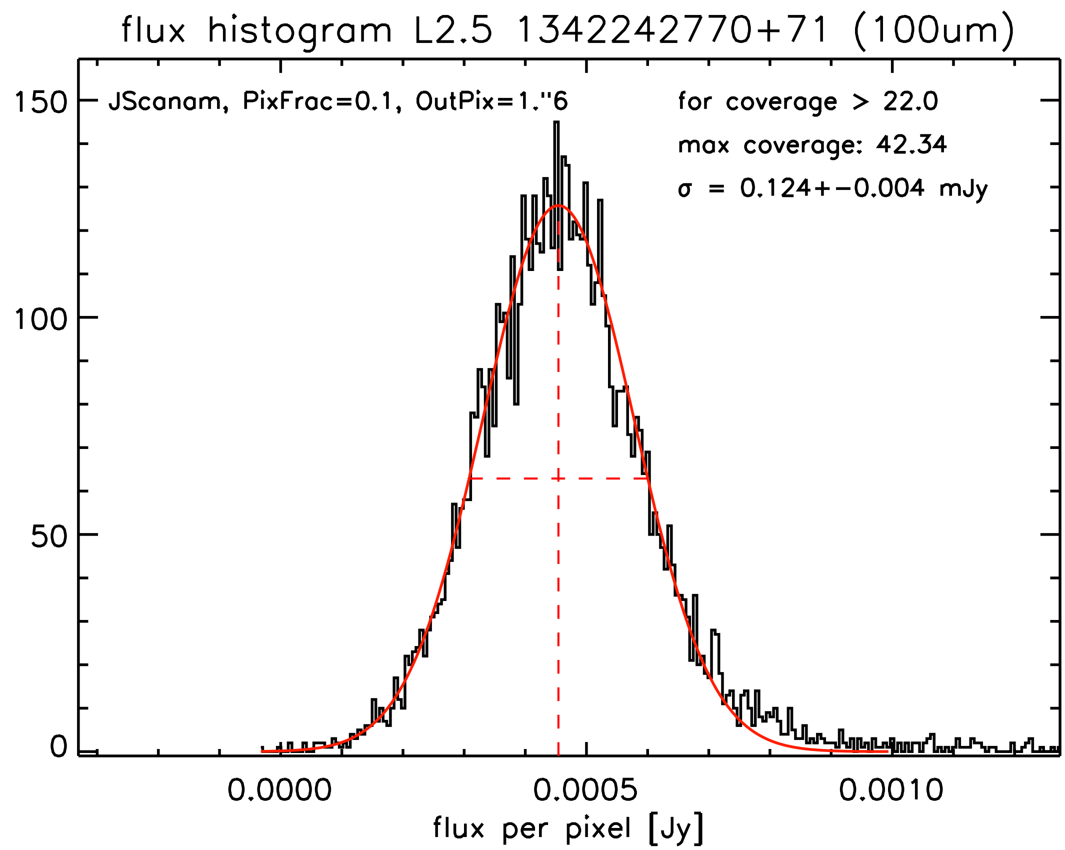

Figure 26: Noise determination for the 100 µm coadded L2.5 map of OBSIDs 1342242770+71 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\;\sigma_{\rm hist}$).

4.3 100 µm: Pixfrac 0.1, Pixsize 2.″4

4.3.1 L 2.5 OBSIDs 1342242770+1342242771

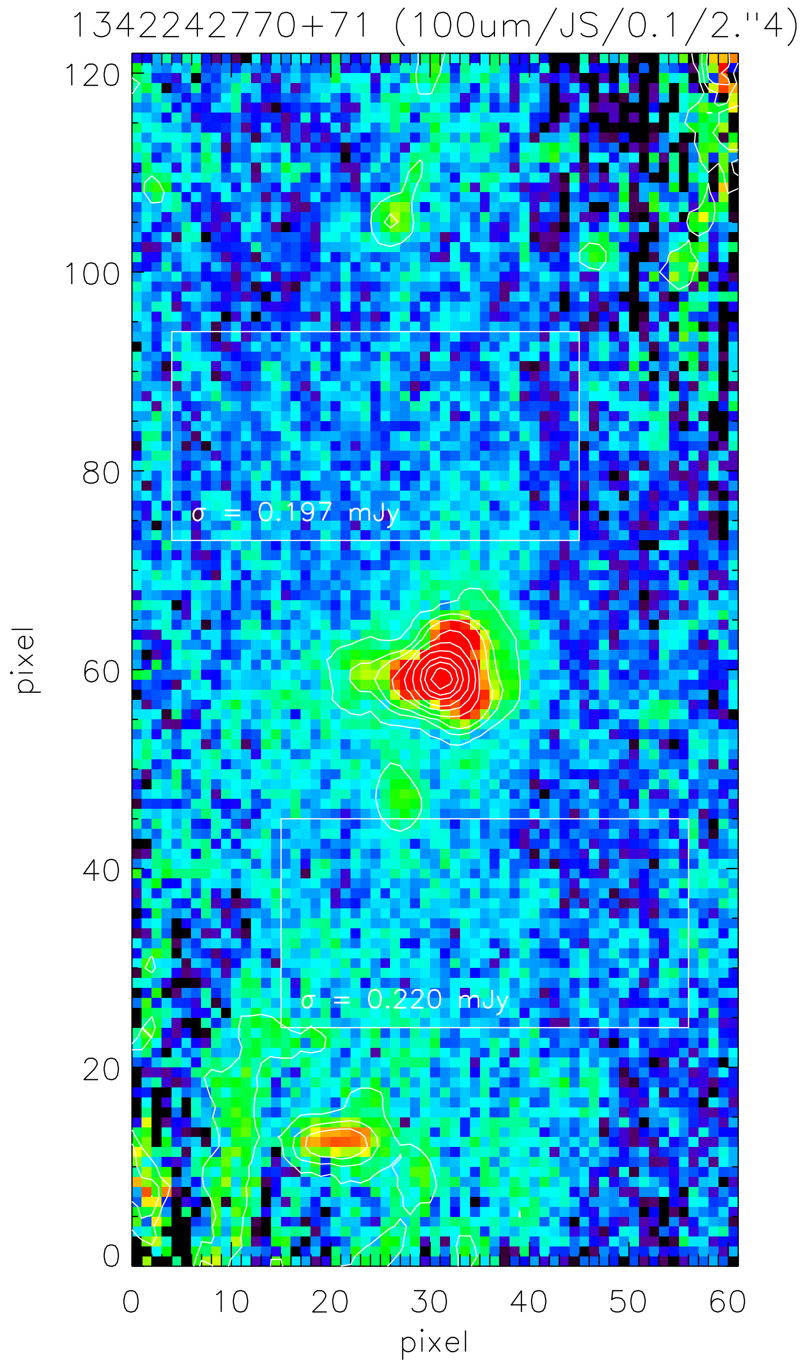

Figure 27: 100 µm L2.5 combined JScanam map for OBSIDs 1342242770+71 with pixfrac 0.1 and output pixel size of 2.″4 (SPG product parameter set). The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

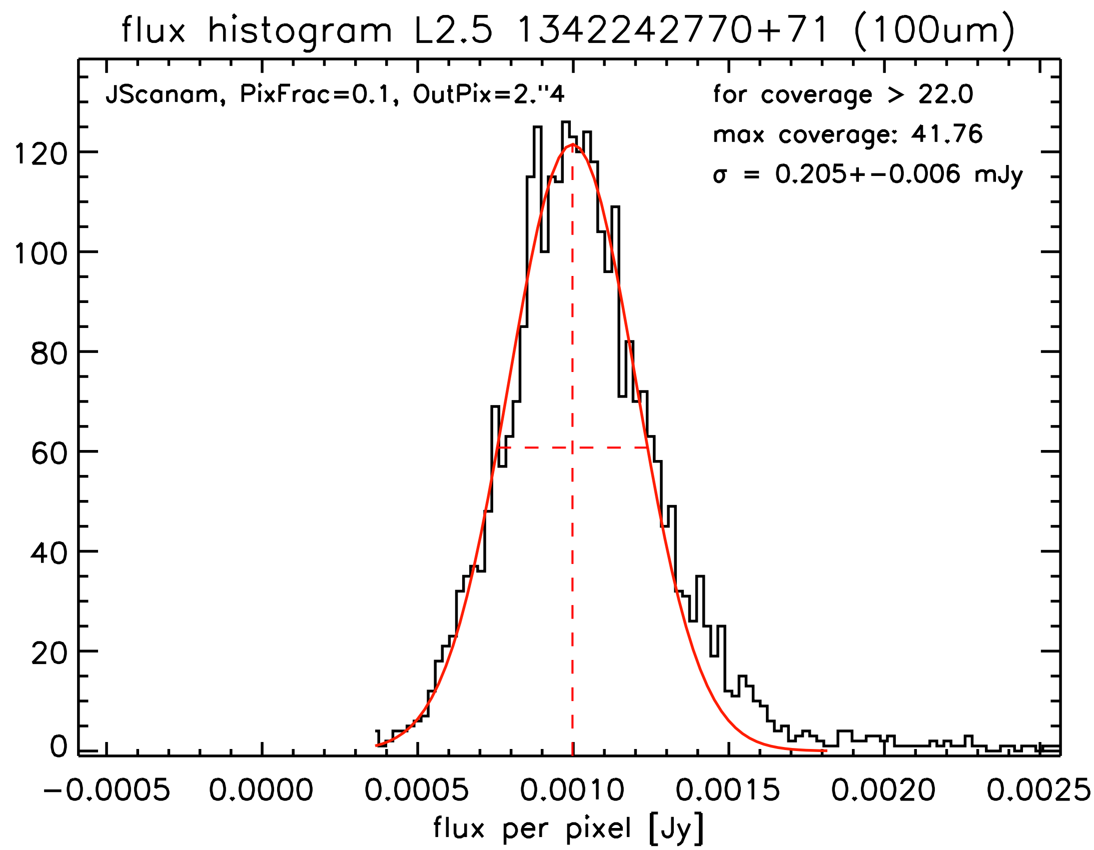

Figure 28: Noise determination for the 100 µm coadded L2.5 map of OBSIDs 1342242770+71 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\;\sigma_{\rm hist}$).

4.4 100 µm: Pixfrac 0.1, Pixsize 3.″2

4.4.1 L 2.5 OBSIDs 1342242770+1342242771

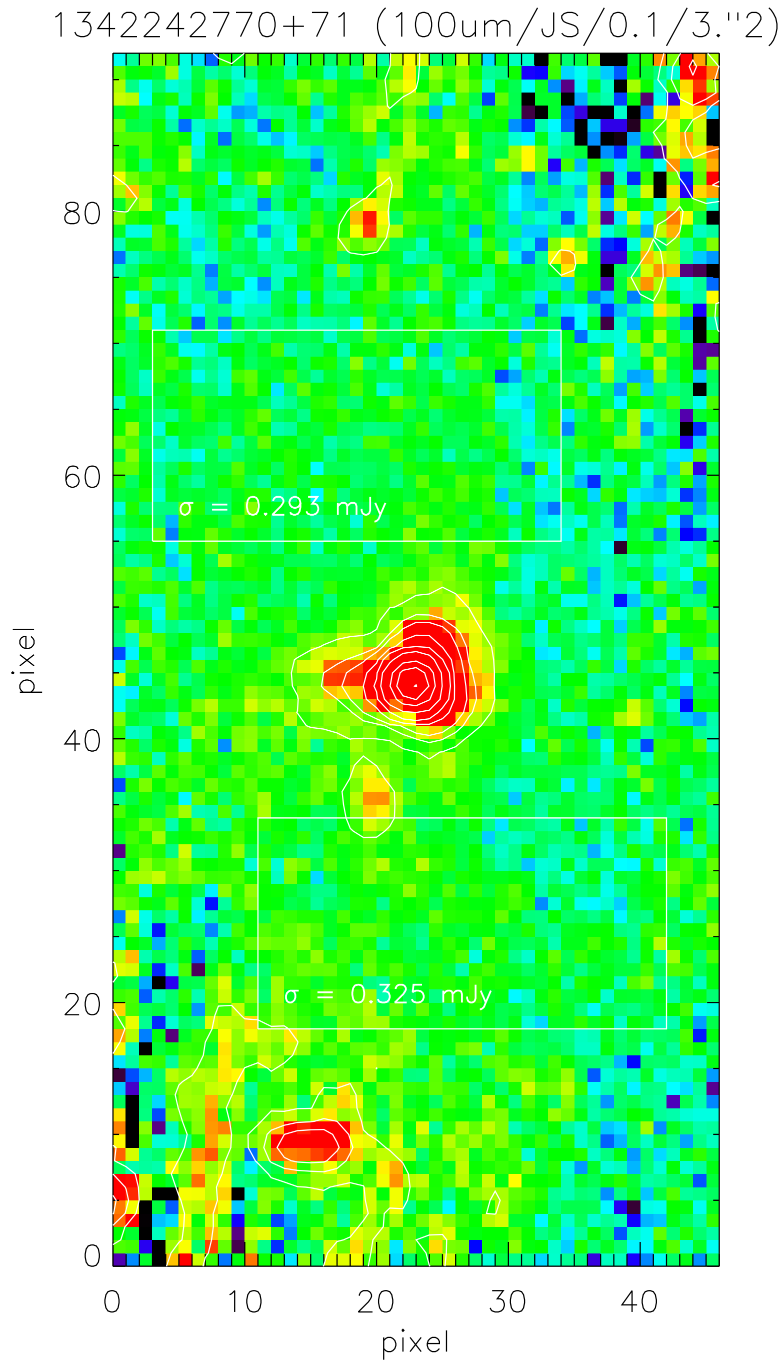

Figure 29: 100 µm L2.5 combined JScanam map for OBSIDs 1342242770+71 with pixfrac 0.1 and output pixel size of 3.″2 (SPG product parameter set). The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

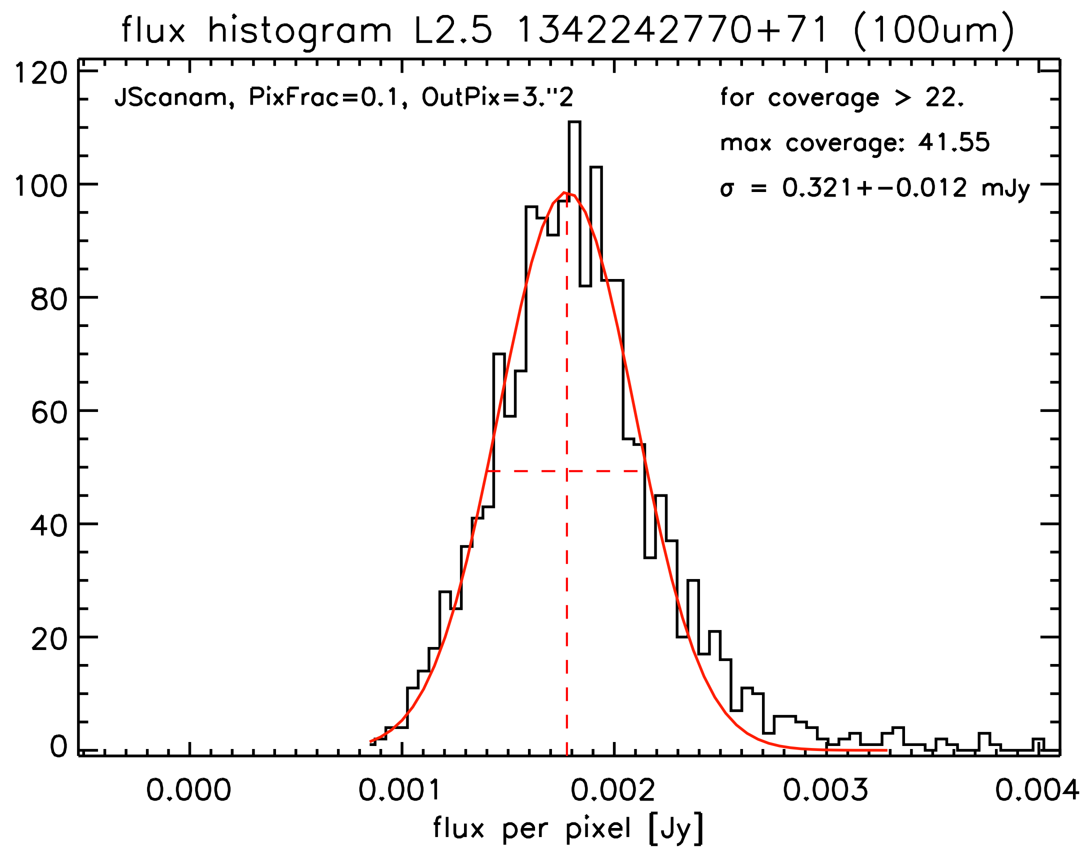

Figure 30: Noise determination for the 100 μm coadded L2.5 map of OBSIDs 1342242770+71 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\;\sigma_{\mathrm{hist}}$).

4.5 100 µm: Pixfrac 0.5, Pixsize 1.″6

4.5.1 L 2.5 OBSIDs 1342242770+1342242771

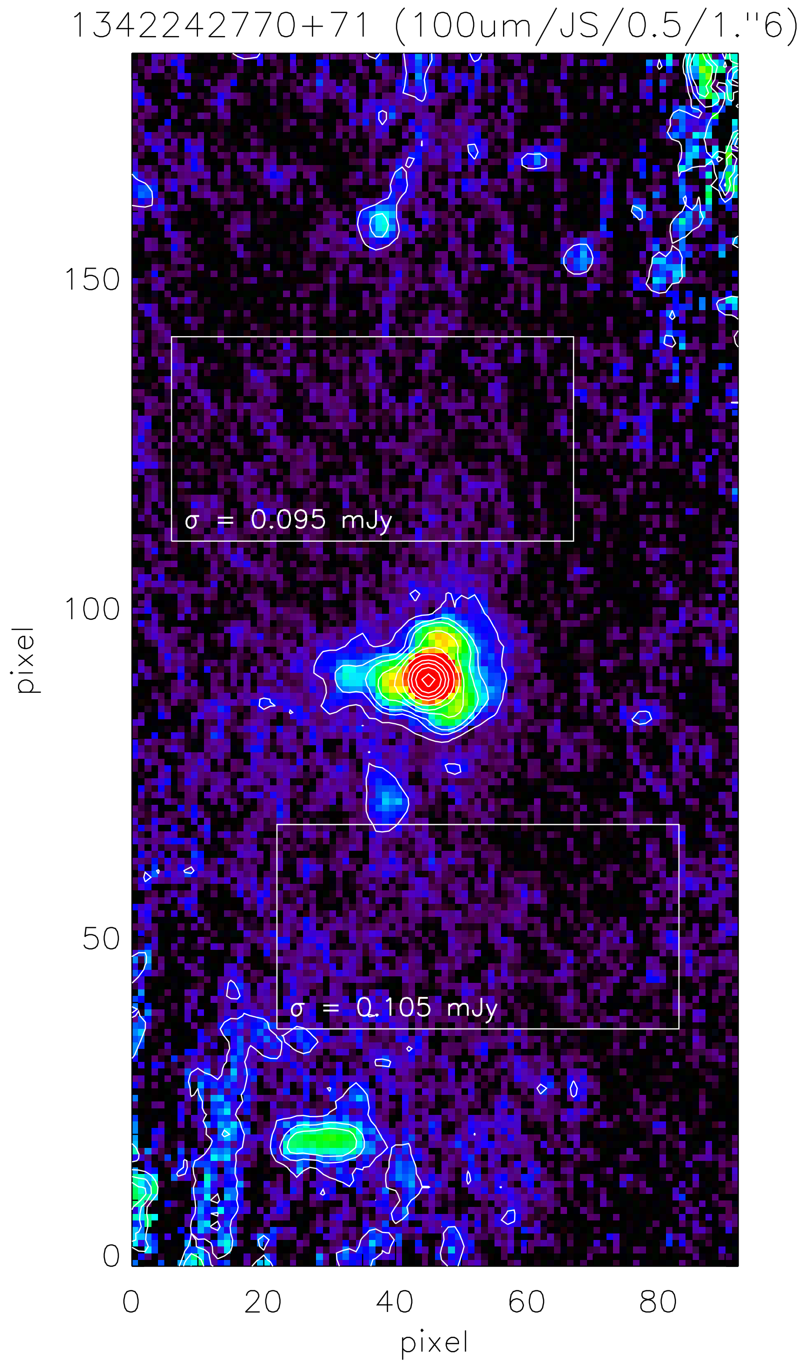

Figure 31: 100 µm L2.5 combined JScanam map for OBSIDs 1342242770+71 with pixfrac 0.5 and output pixel size of 1.″6. The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

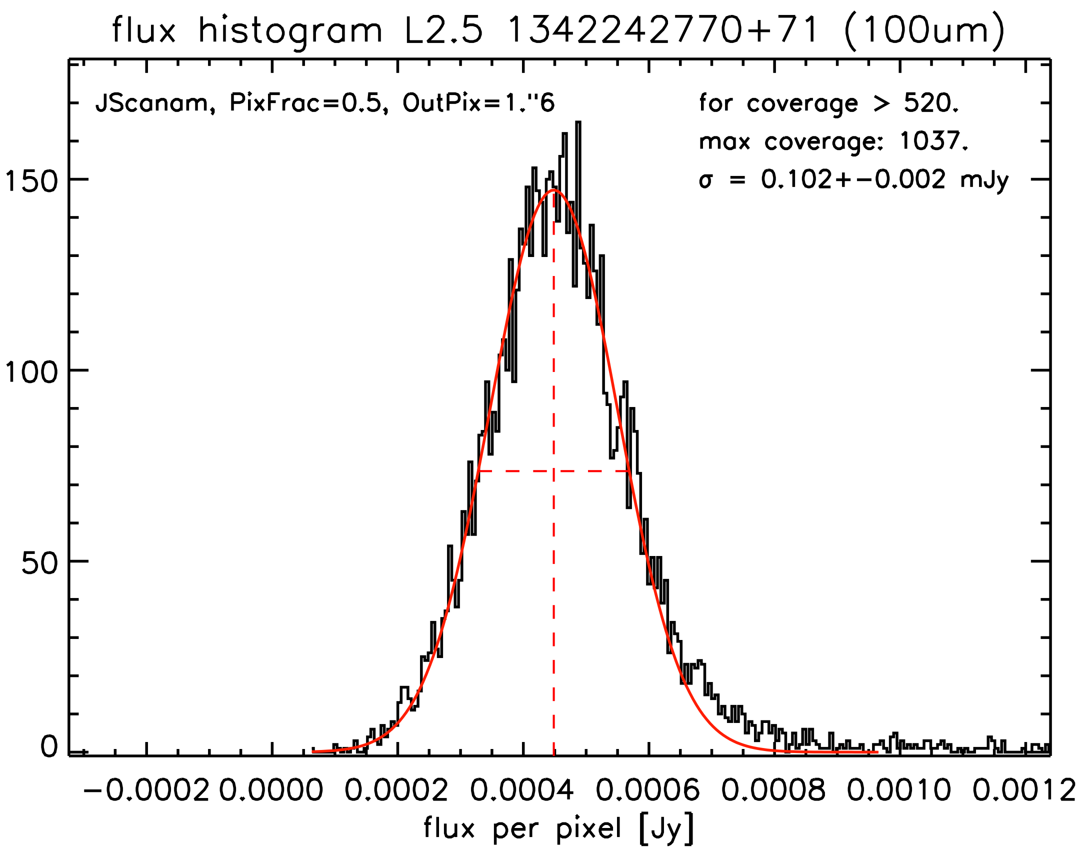

Figure 32: Noise determination for the 100 µm coadded L2.5 map of OBSIDs 1342242770+71 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\;\sigma_{\rm hist}$).

4.6 100 μm: Pixfrac 0.5, Pixsize 2.″4

4.6.1 L 2.5 OBSIDs 1342242770+1342242771

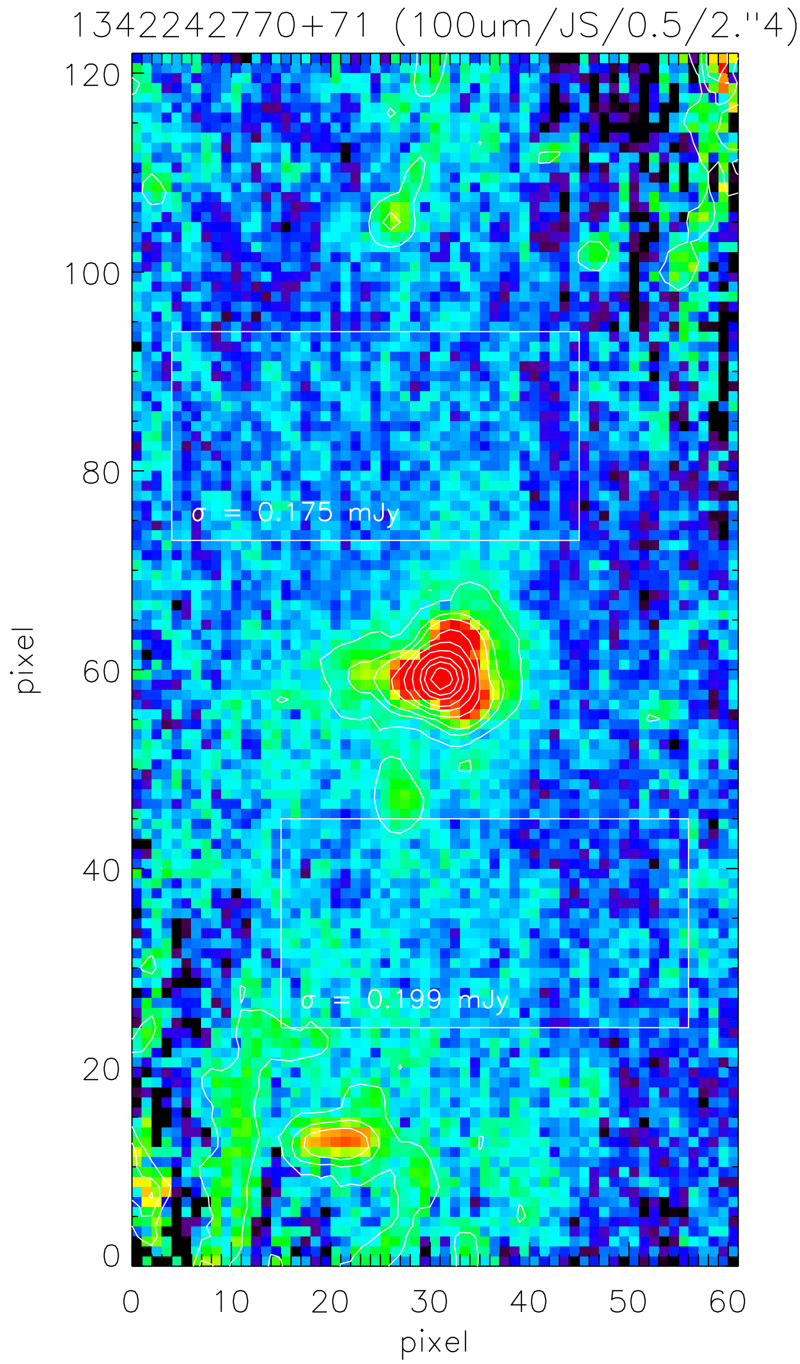

Figure 33: 100 μm L2.5 combined JScanam map for OBSIDs 1342242770+71 with pixfrac 0.5 and output pixel size of 2.″4 (SPG product parameter set). The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

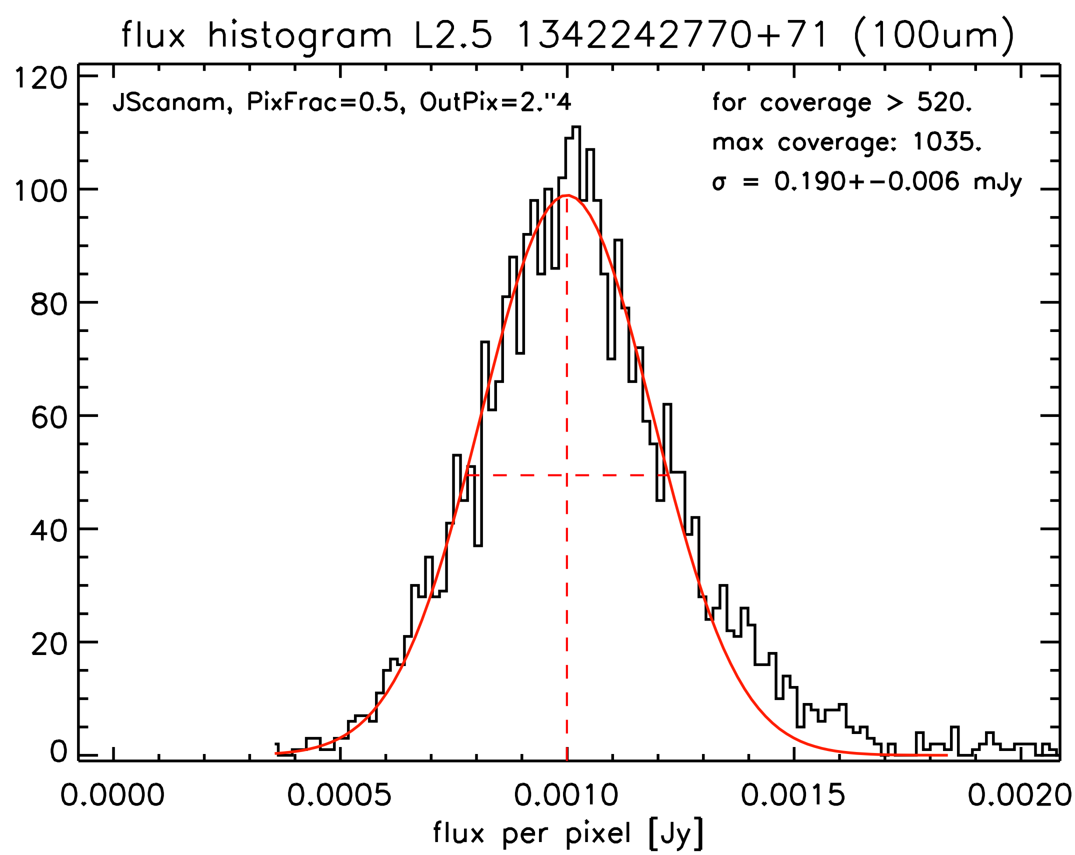

Figure 34: Noise determination for the 100 µm coadded L2.5 map of OBSIDs 1342242770+71 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\ \sigma_{\rm hist}$).

4.7 100 µm: Pixfrac 0.5, Pixsize 3.″2

4.7.1 L 2.5 OBSIDs 1342242770+1342242771

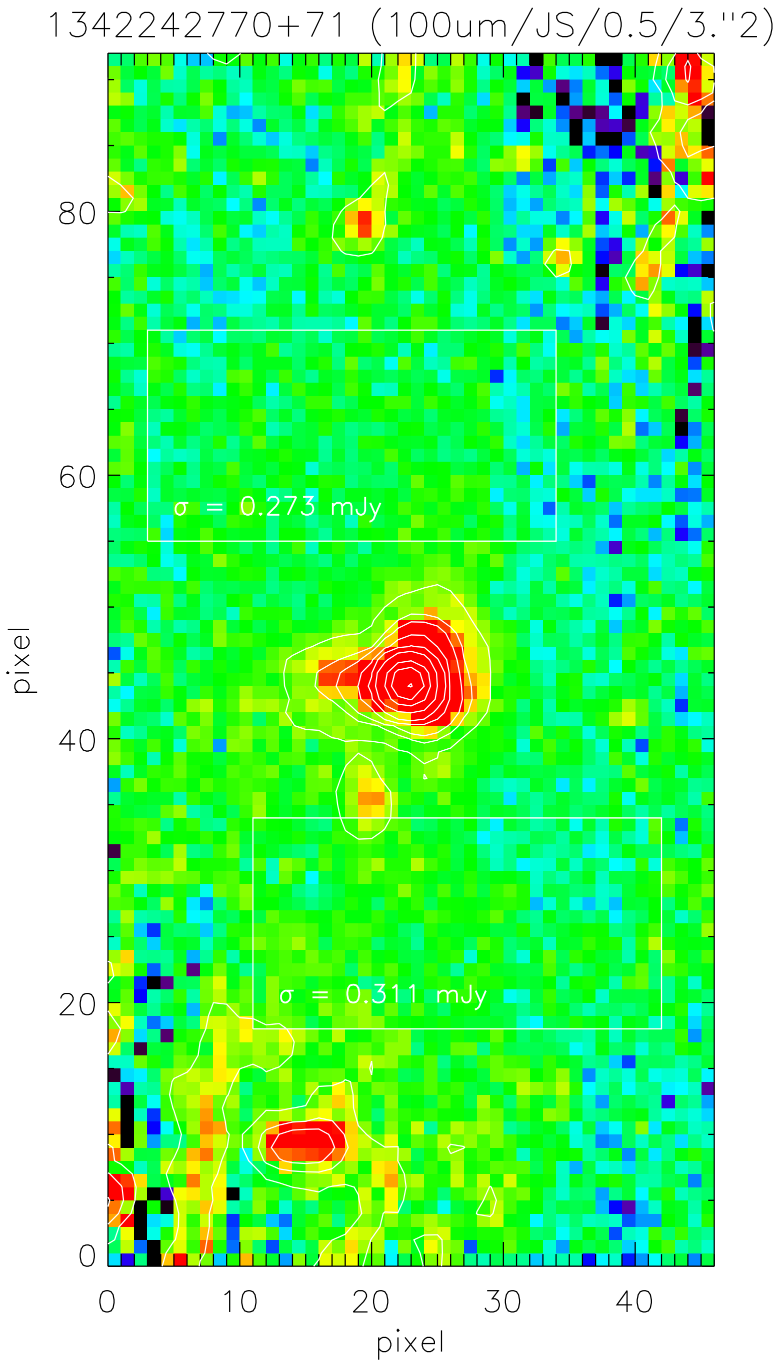

Figure 35: 100 µm L2.5 combined JScanam map for OBSIDs 1342242770+71 with pixfrac 0.5 and output pixel size of 3.″2. The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

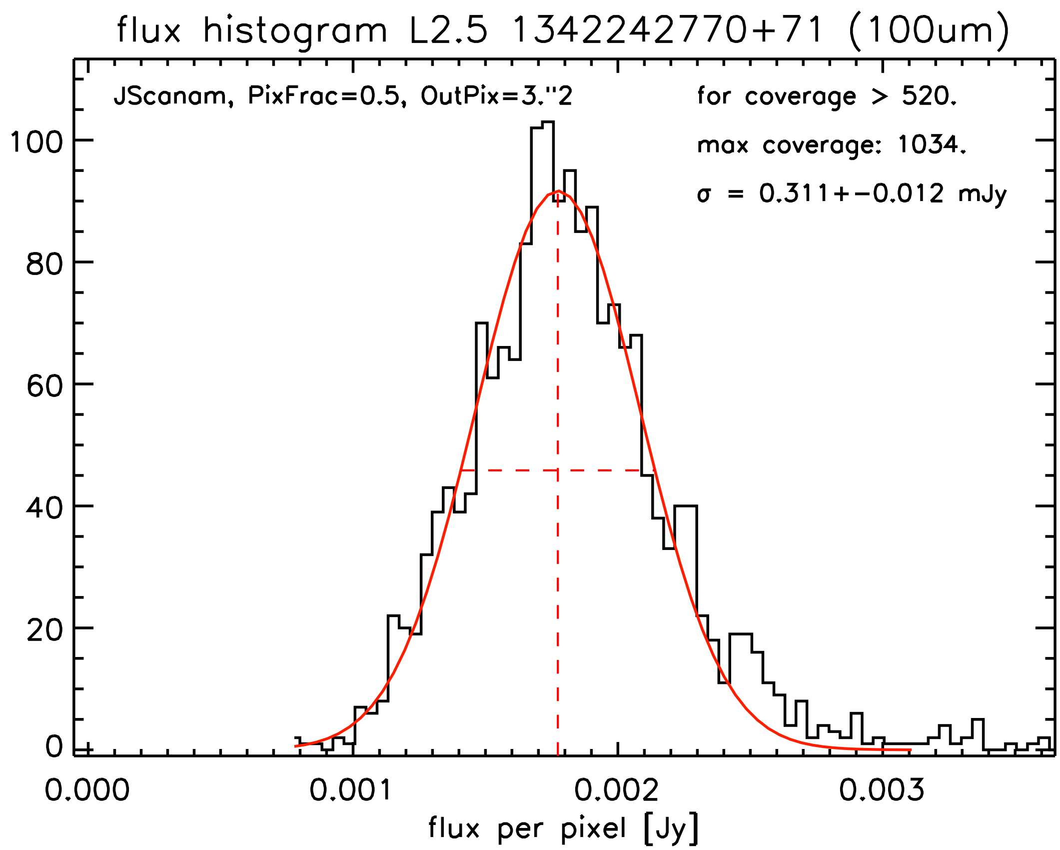

Figure 36: Noise determination for the 100 µm coadded L2.5 map of OBSIDs 1342242770+71 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\;\sigma_{\rm hist}$).

4.8 100 µm: Pixfrac 1.0, Pixsize 1.″4

4.8.1 L 2.5 OBSIDs 1342242770+1342242771

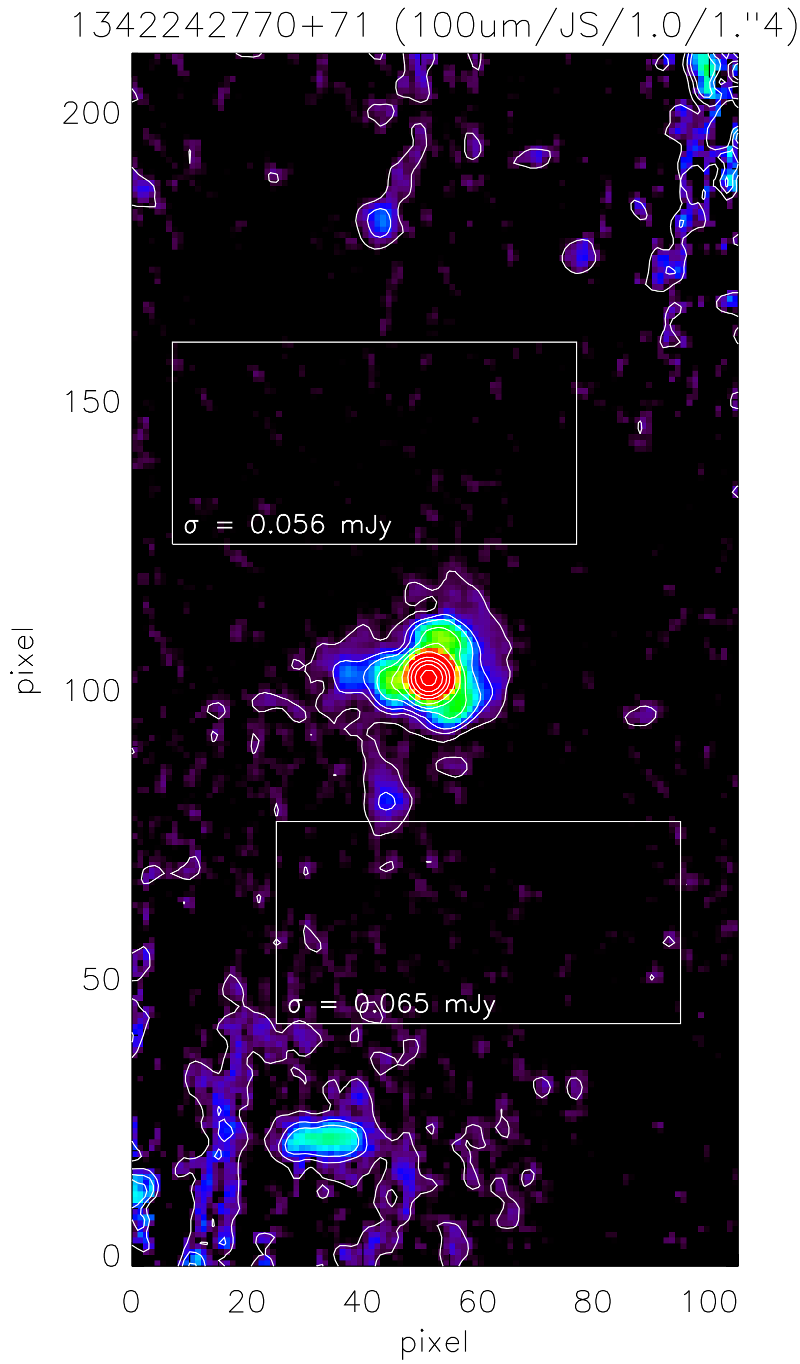

Figure 37: 100 µm L2.5 combined JScanam map for OBSIDs 1342242770+71 with pixfrac 1.0 and output pixel size of 1.″4. The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

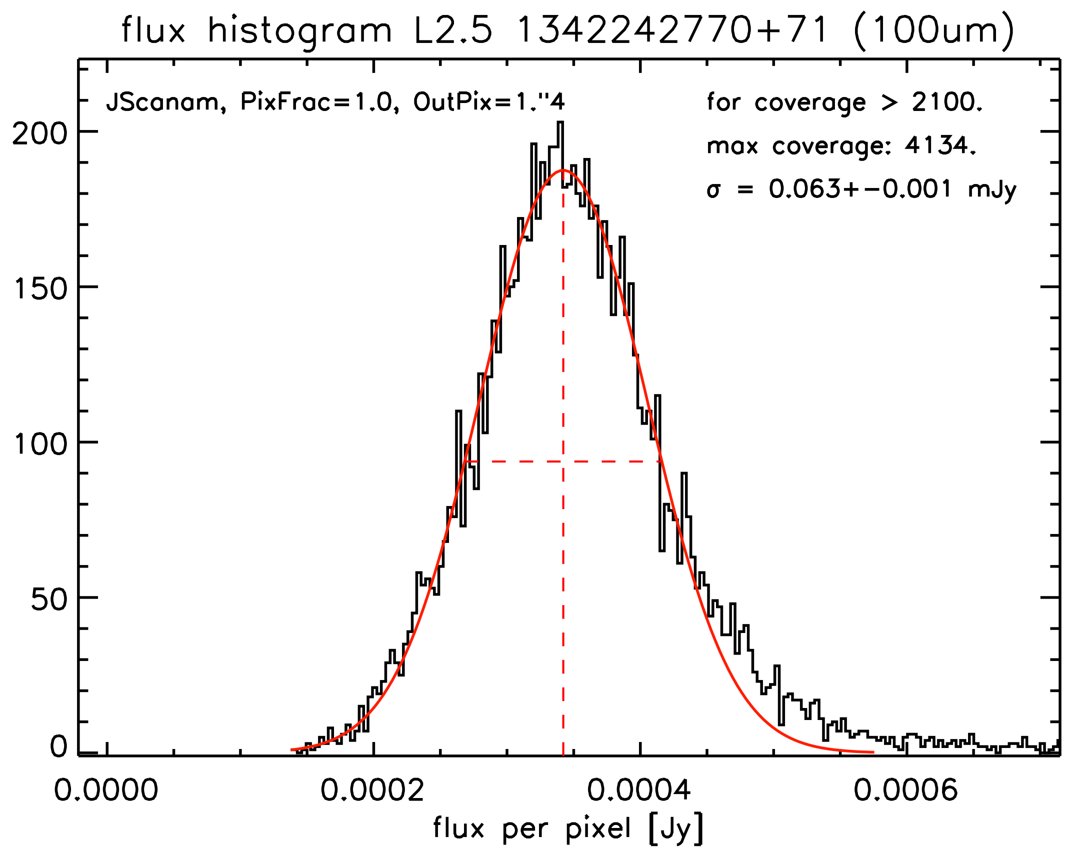

Figure 38: Noise determination for the 100 μm coadded L2.5 map of OBSIDs 1342242770+71 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\;\sigma_{\rm hist}$).

4.9 100 μm: Pixfrac 1.0, Pixsize 1.″6

4.9.1 L 2.5 OBSIDs 1342242770+1342242771

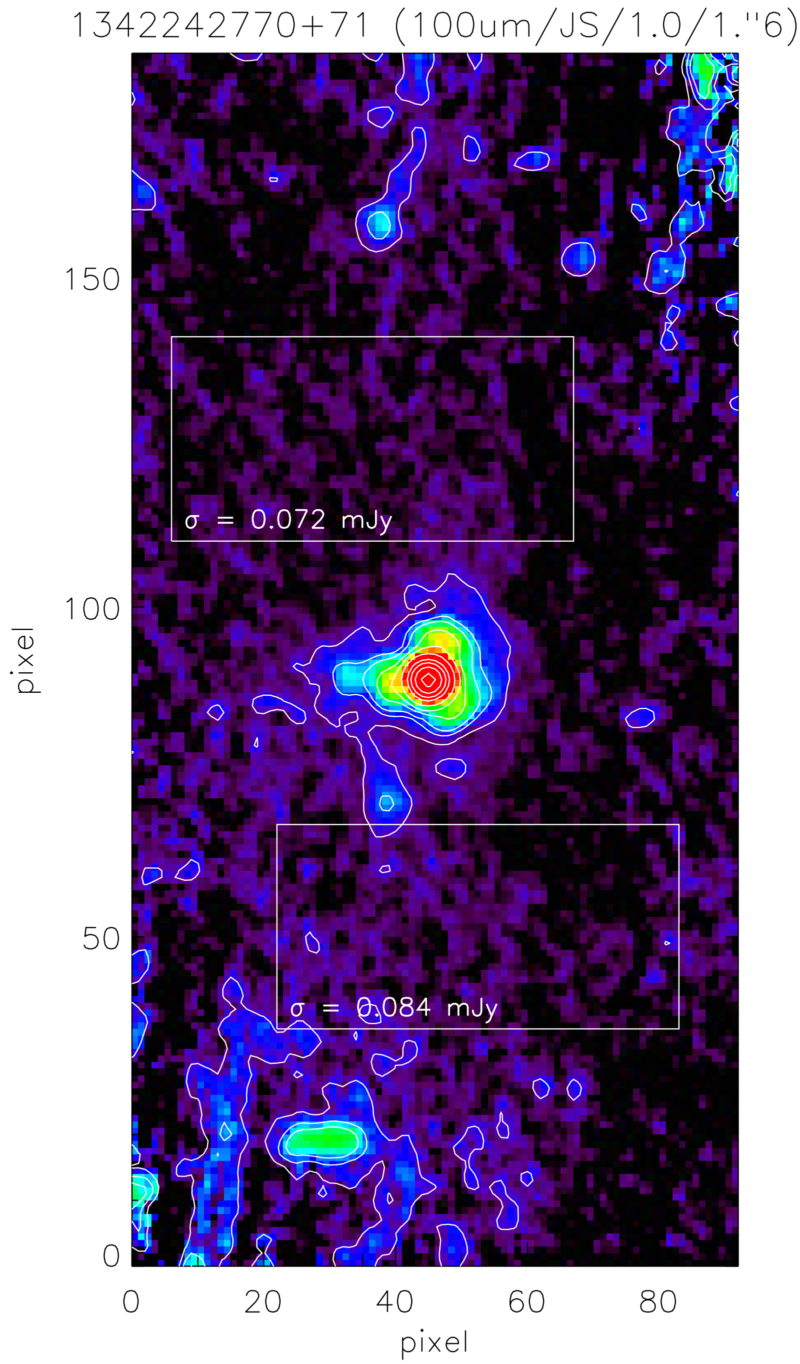

Figure 39: 100 μm L2.5 combined JScanam map for OBSIDs 1342242770+71 with pixfrac 1.0 and output pixel size of 1.″6. The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

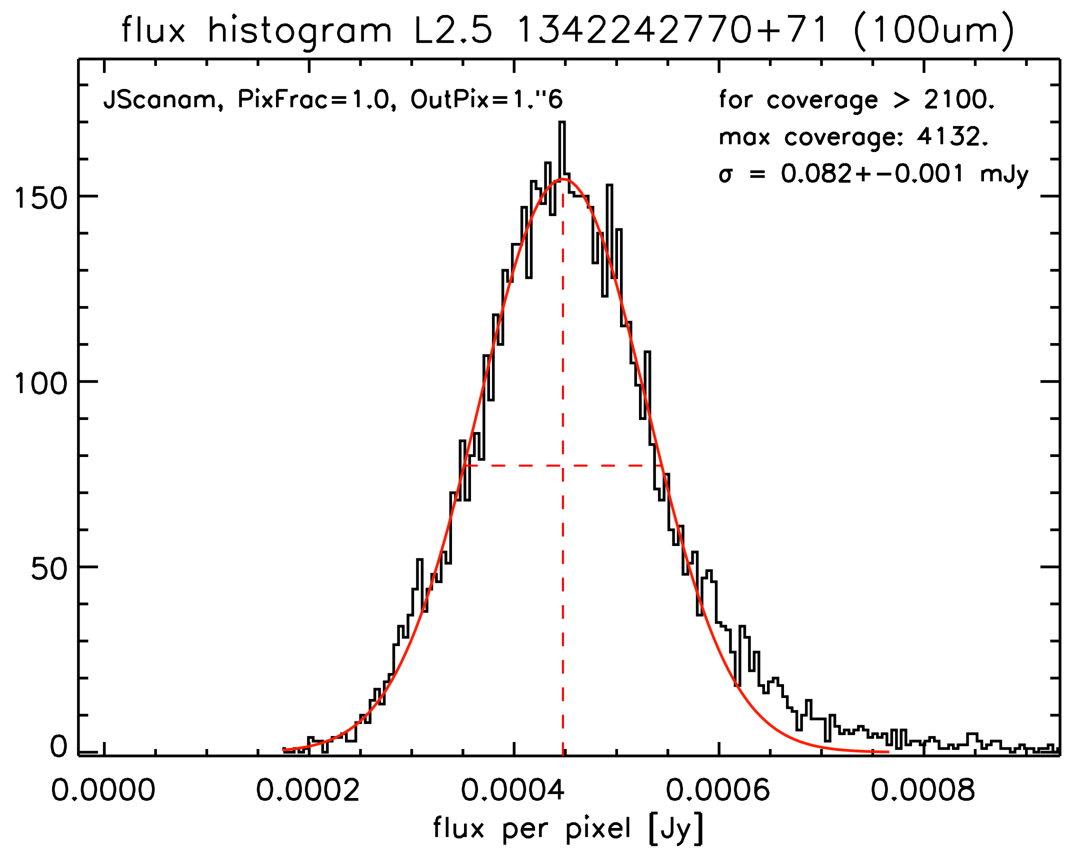

Figure 40: Noise determination for the 100 µm coadded L2.5 map of OBSIDs 1342242770+71 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\;\sigma_{\mathrm{hist}}$).

4.10 100 µm: Pixfrac 1.0, Pixsize 2.″4

4.10.1 L 2.5 OBSIDs 1342242770+1342242771

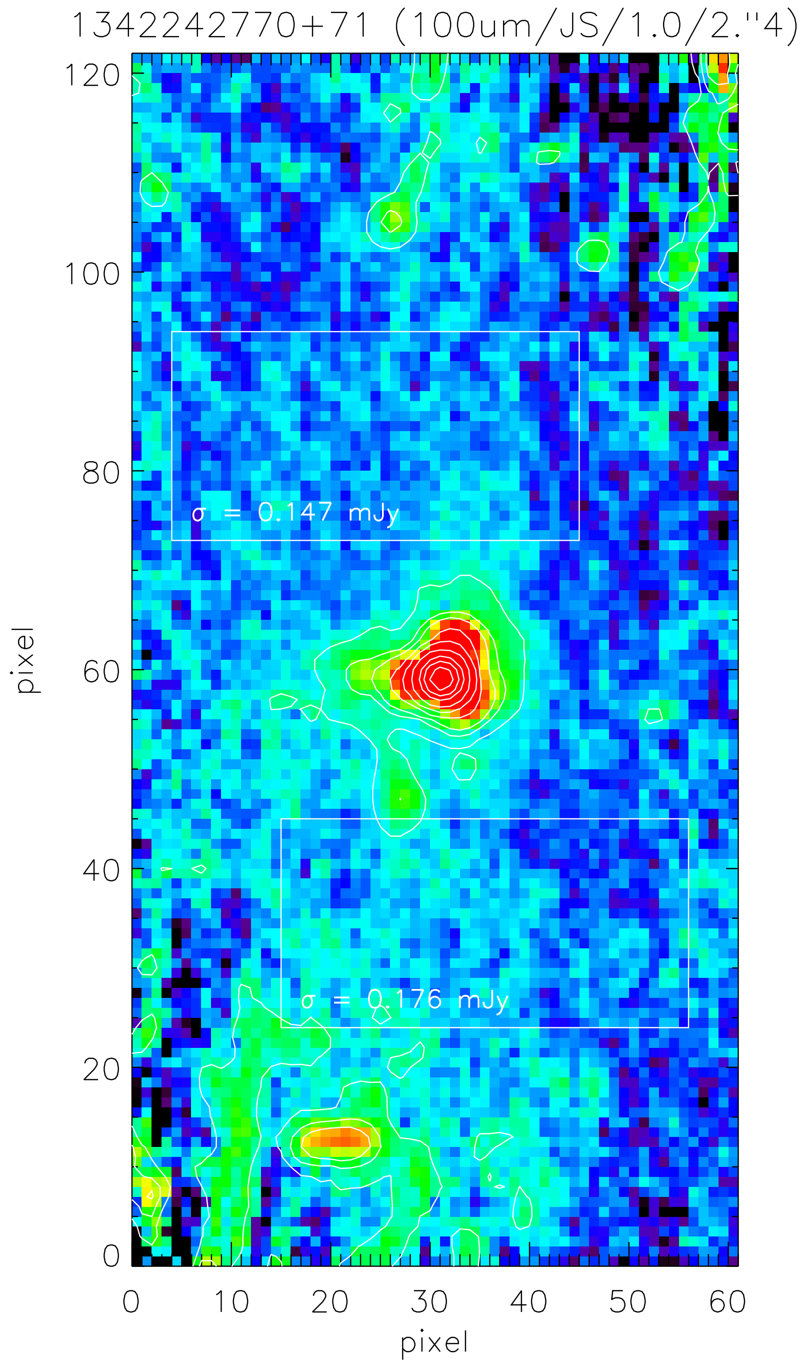

Figure 41: 100 µm L2.5 combined JScanam map for OBSIDs 1342242770+71 with pixfrac 1.0 and output pixel size of 2.″4. The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

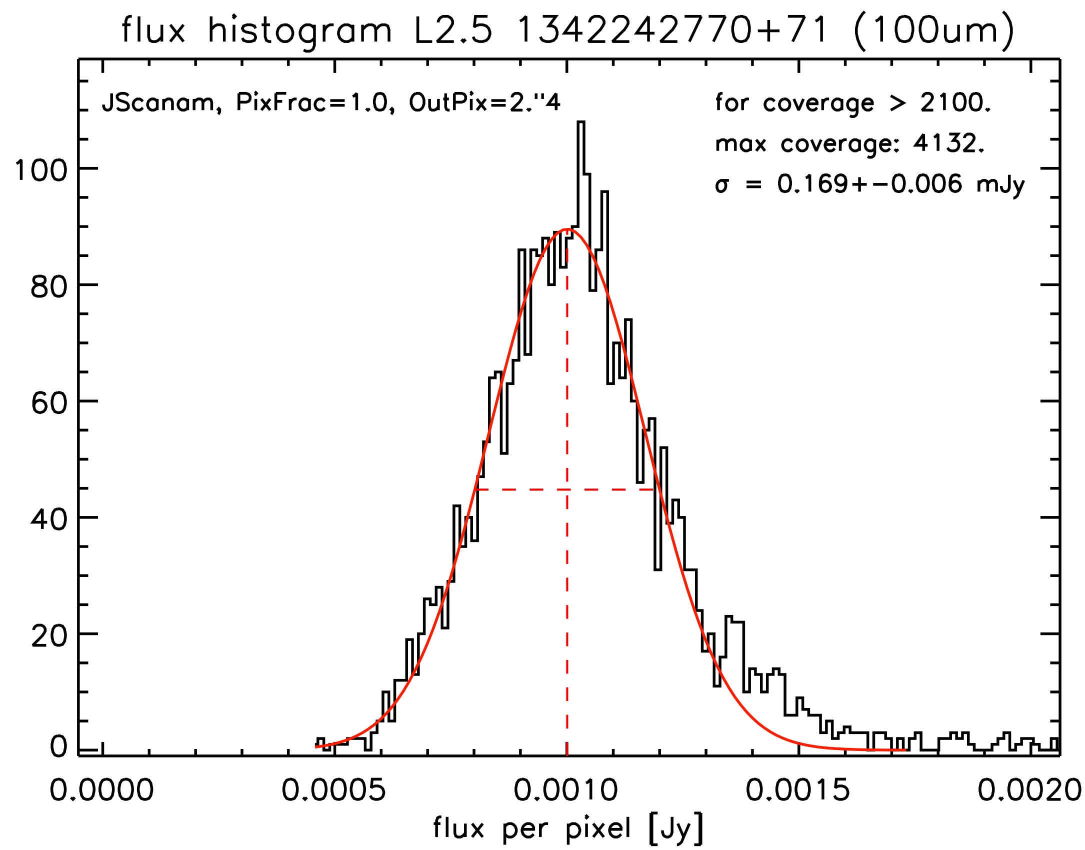

Figure 42: Noise determination for the 100 µm coadded L2.5 map of OBSIDs 1342242770+71 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\;\sigma_{\mathrm{hist}}$).

4.11 100 µm: Pixfrac 1.0, Pixsize 3.″2

4.11.1 L 2.5 OBSIDs 1342242770+1342242771

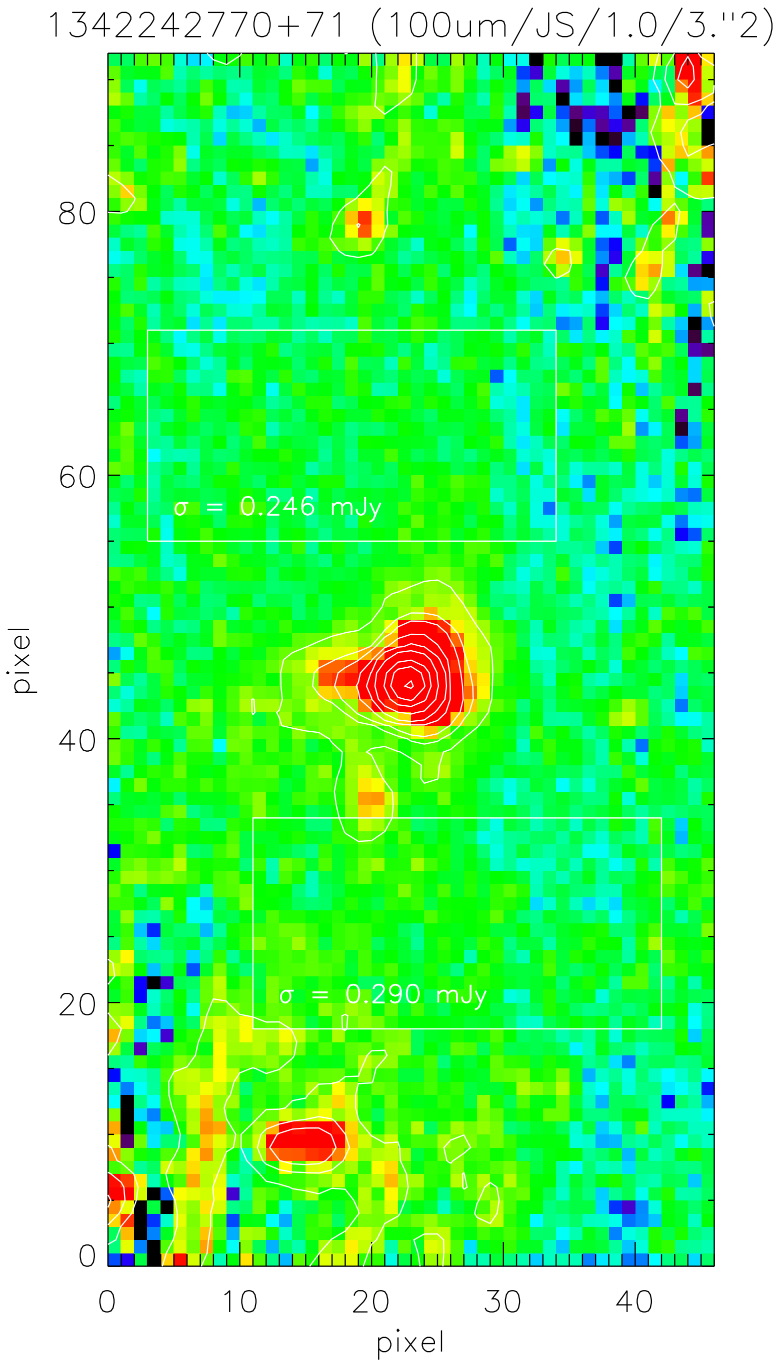

Figure 43: 100 µm L2.5 combined JScanam map for OBSIDs 1342242770+71 with pixfrac 1.0 and output pixel size of 3.″2. The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

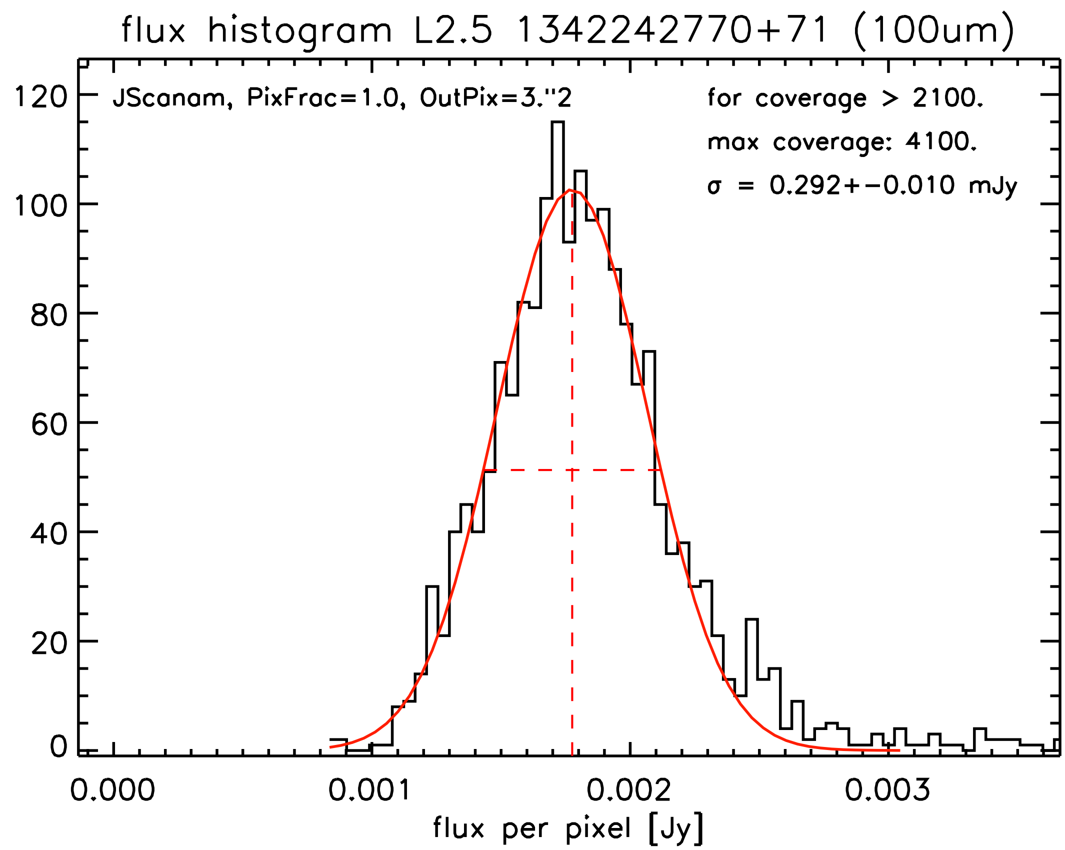

Figure 44: Noise determination for the 100 μm coadded L2.5 map of OBSIDs 1342242770+71 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\;\sigma_{\rm hist}$).

5 Analysis of 160μm maps

5.1 160 µm: Pixfrac 0.1, Pixsize 2.″1

5.1.1 L 2.5 OBSIDs 1342242772+1342242773

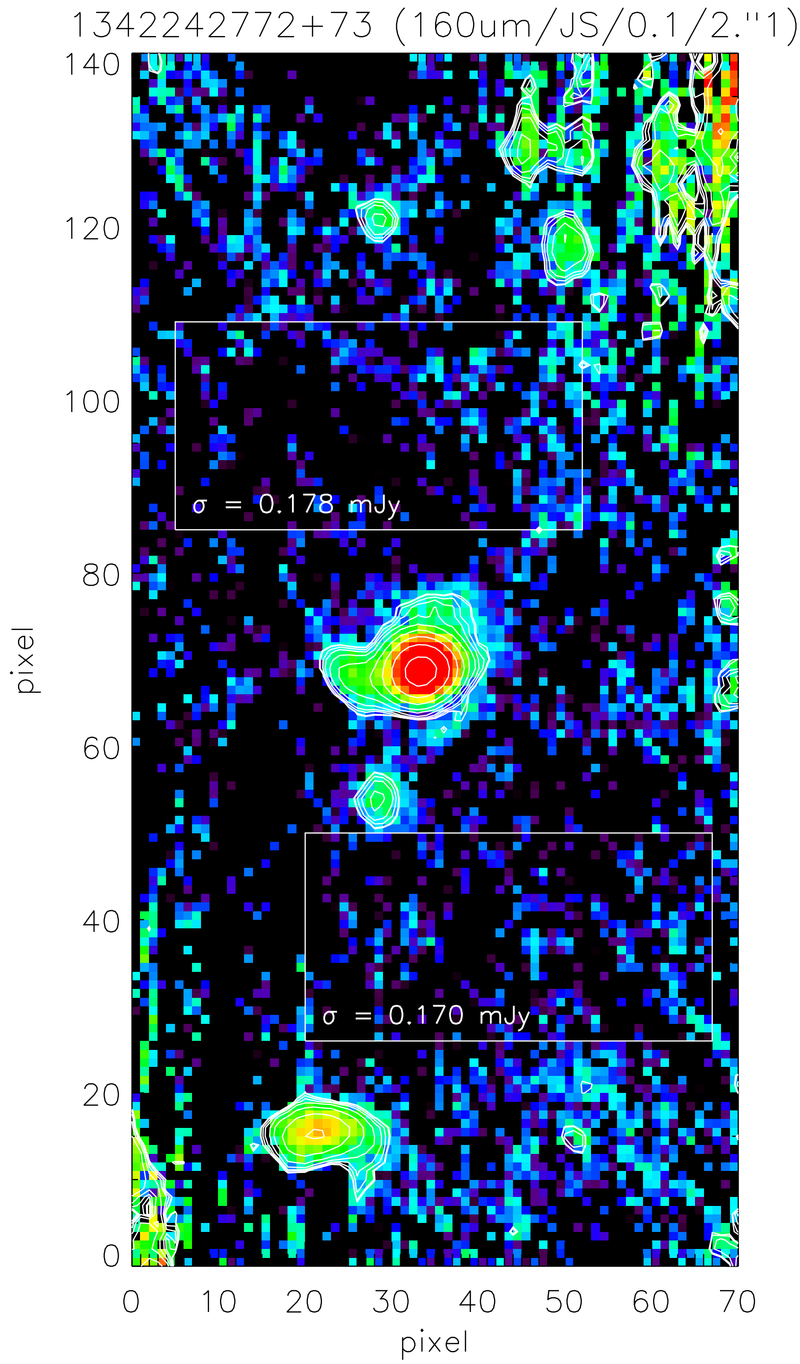

Figure 45: 160 µm L2.5 combined JScanam map for OBSIDs 1342242772+73 with pixfrac 0.1 and output pixel size of 2.″1. The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

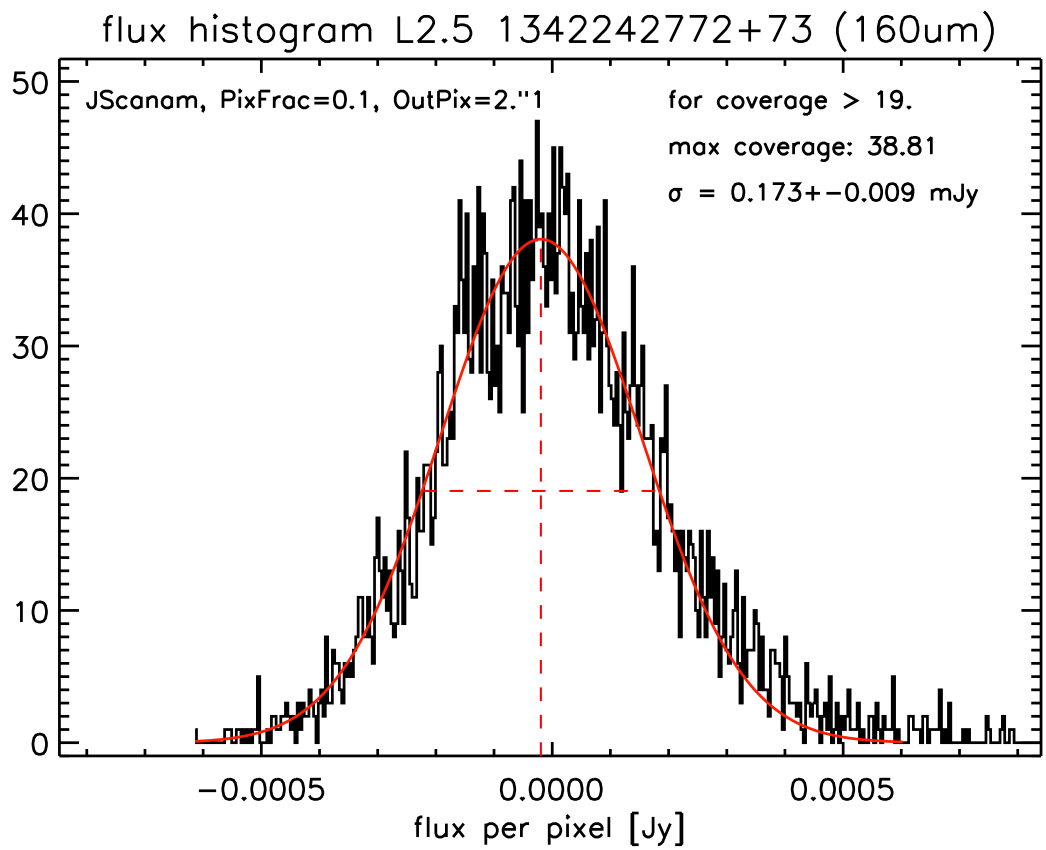

Figure 46: Noise determination for the 160 μm coadded L2.5 map of OBSIDs 1342242772+73 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\;\sigma_{\rm hist}$).

5.2 160 µm: Pixfrac 0.1, Pixsize 3.″2

5.2.1 L 2.5 OBSIDs 1342242772+1342242773

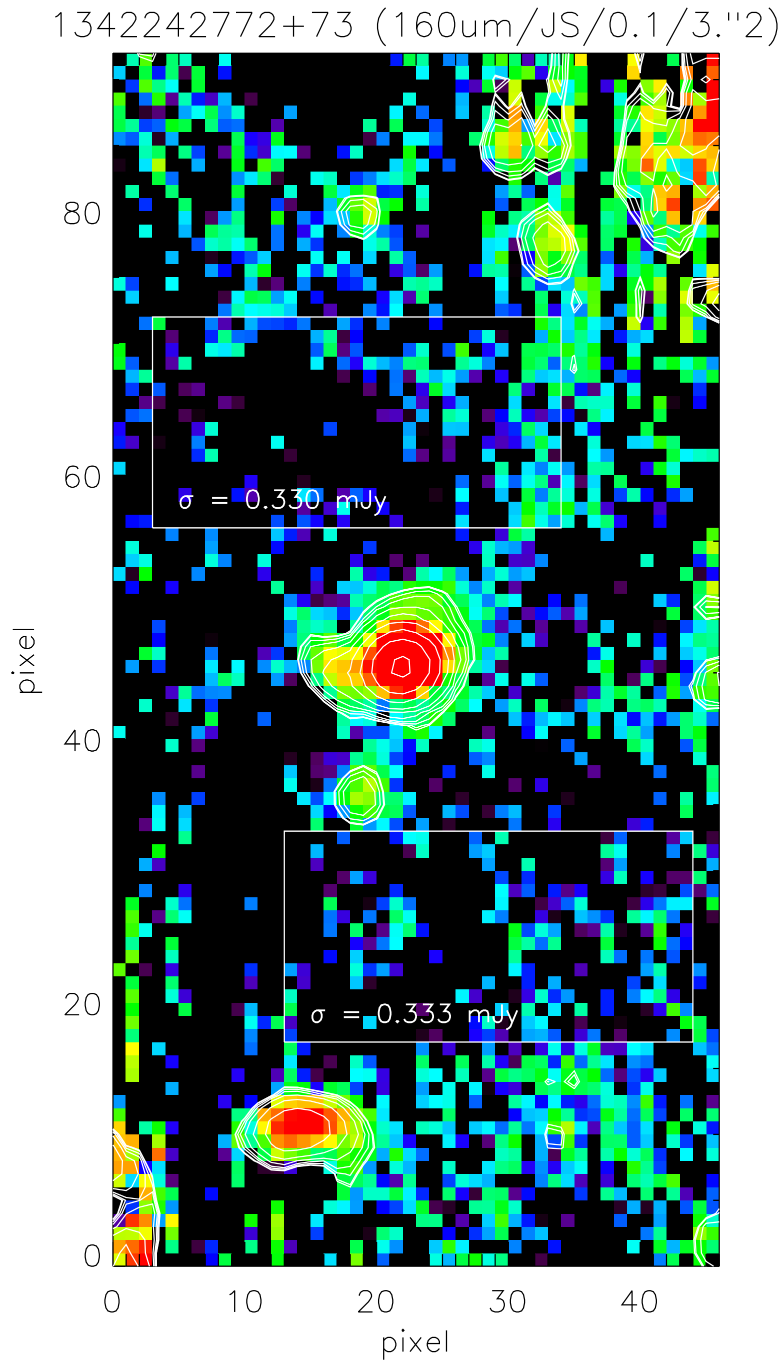

Figure 47: 160 µm L2.5 combined JScanam map for OBSIDs 1342242772+73 with pixfrac 0.1 and output pixel size of 3.″2 (SPG product parameter set). The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

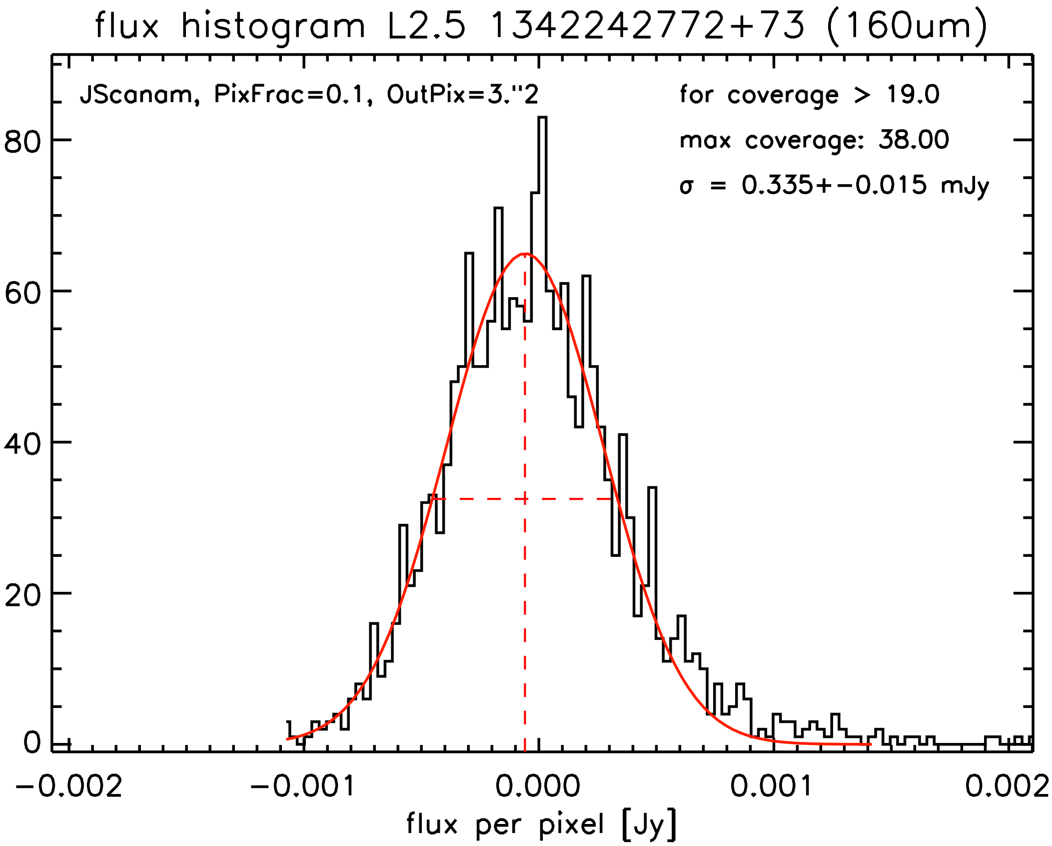

Figure 48: Noise determination for the 160 µm coadded L2.5 map of OBSIDs 1342242772+73 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\ \sigma_{\rm hist}$).

5.3 160 µm: Pixfrac 0.1, Pixsize 4.″8

5.3.1 L 2.5 OBSIDs 1342242772+1342242773

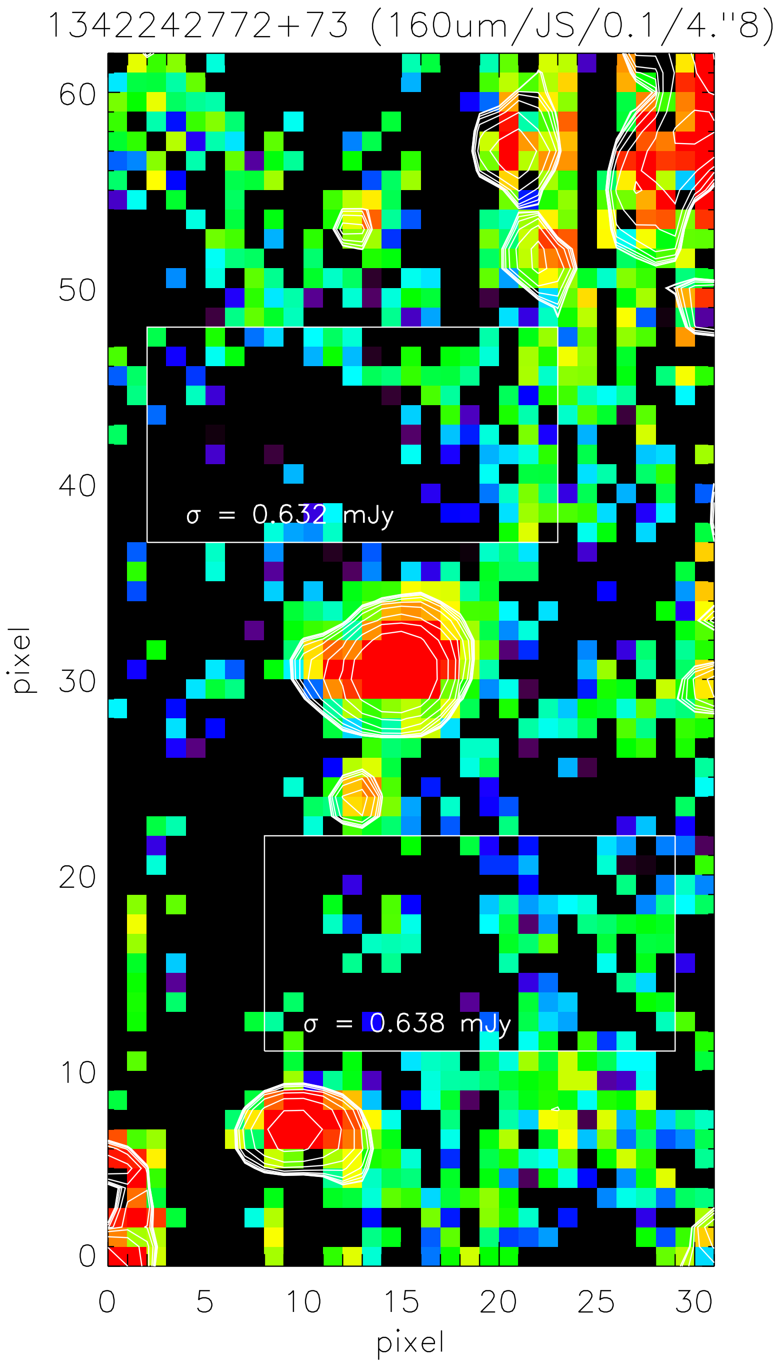

Figure 49: 160 µm L2.5 combined JScanam map for OBSIDs 1342242772+73 with pixfrac 0.1 and output pixel size of 4.″8. The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

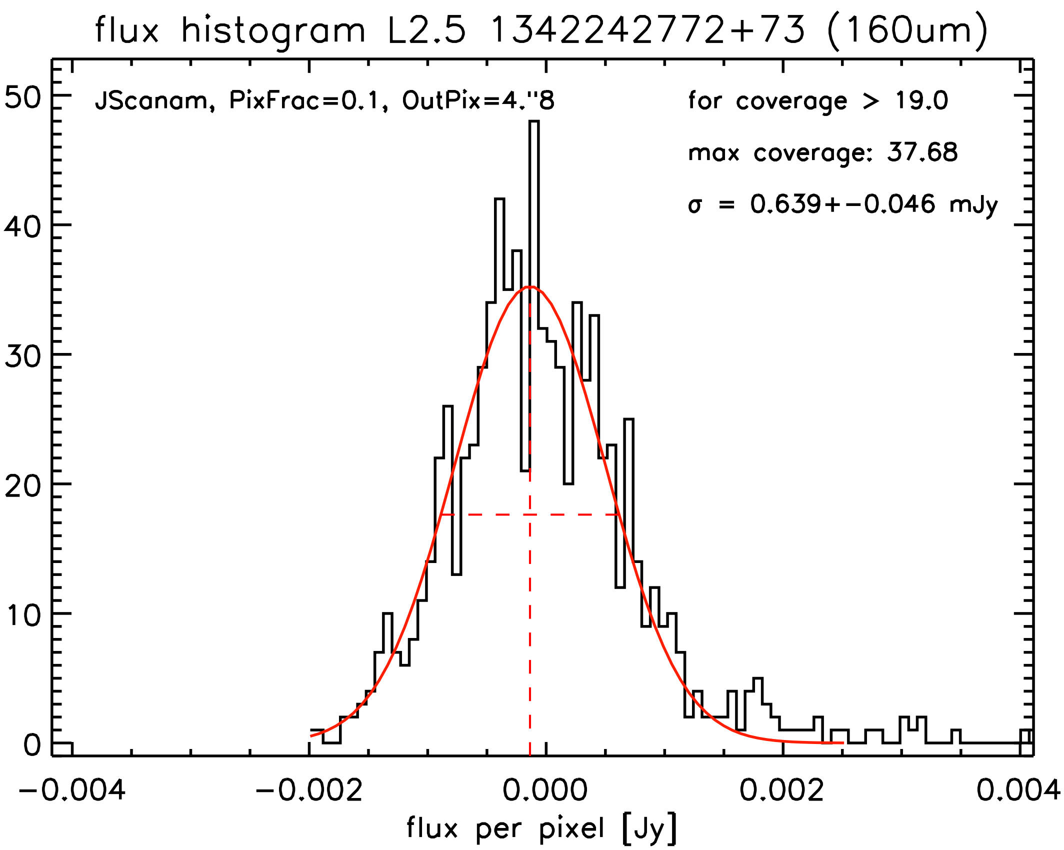

Figure 50: Noise determination for the 160 μm coadded L2.5 map of OBSIDs 1342242772+73 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\;\sigma_{\rm hist}$).

5.4 160 µm: Pixfrac 0.1, Pixsize 6.″4

5.4.1 L 2.5 OBSIDs 1342242772+1342242773

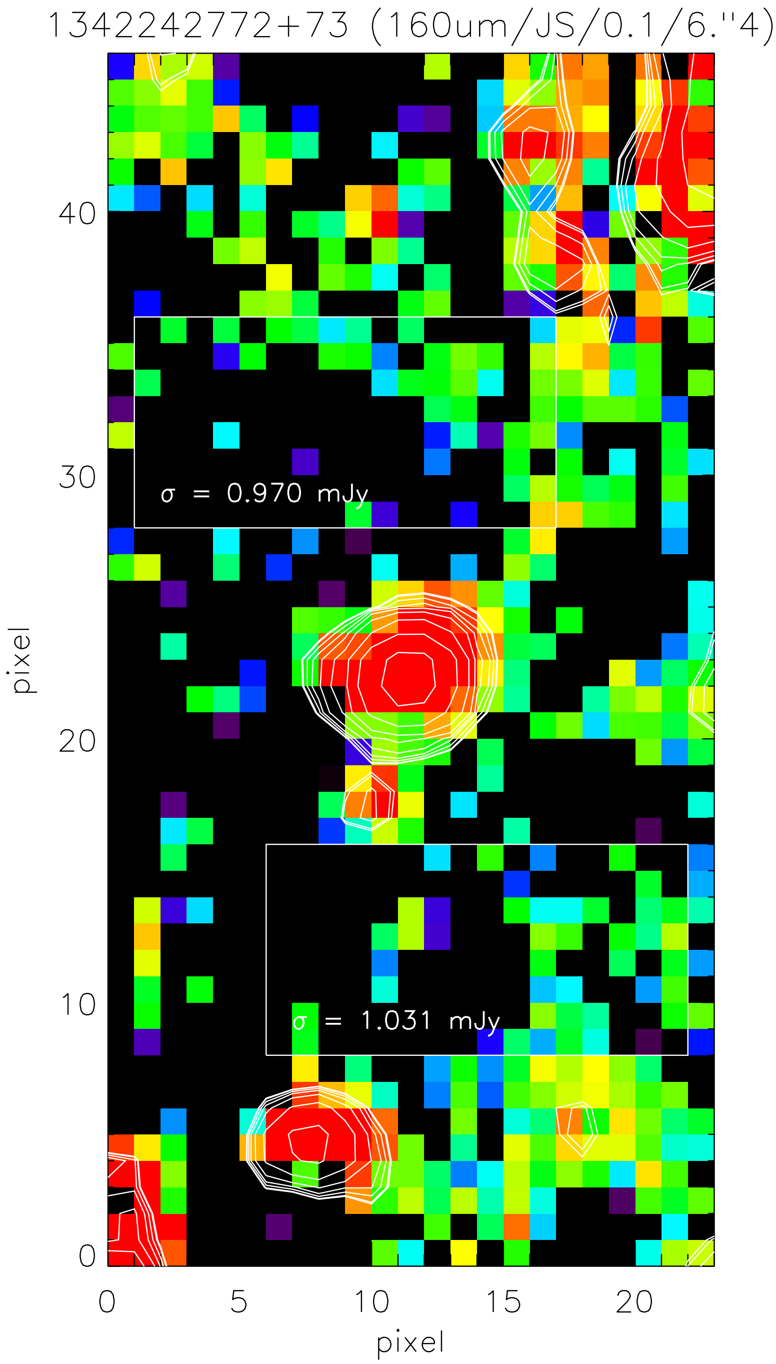

Figure 51: 160 µm L2.5 combined JScanam map for OBSIDs 1342242772+73 with pixfrac 0.1 and output pixel size of 6.″4. The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

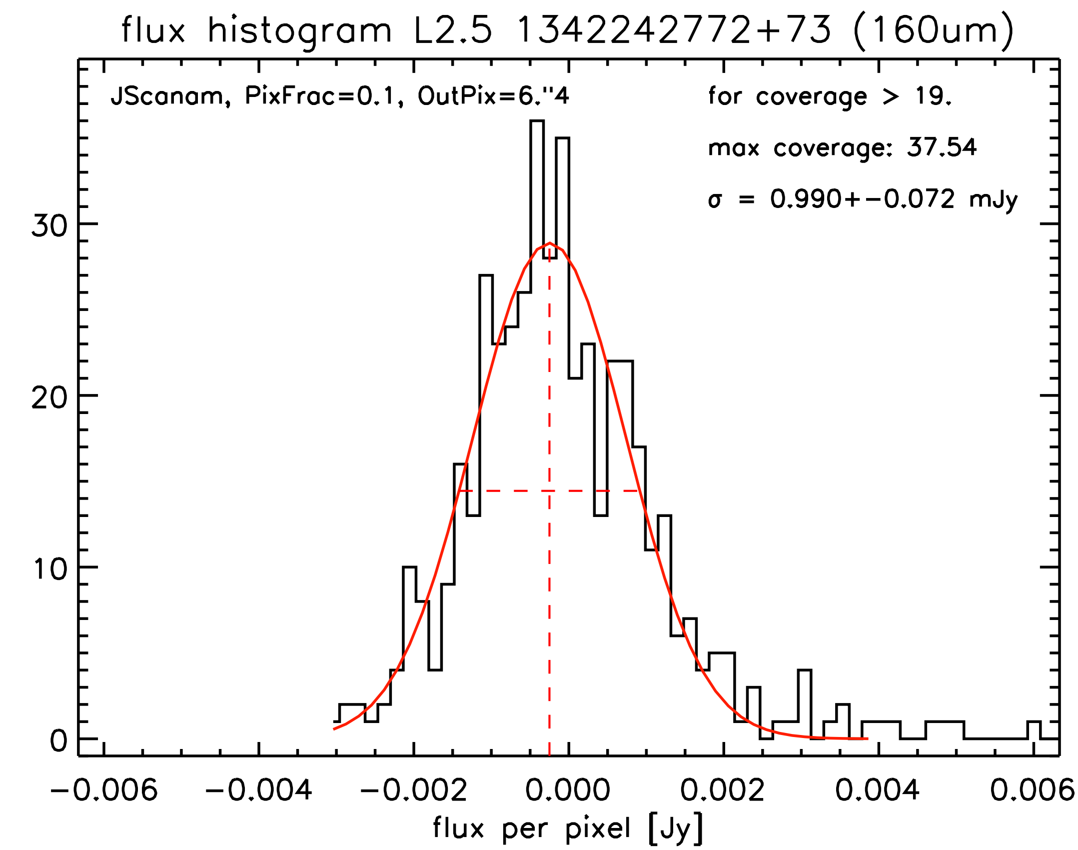

Figure 52: Noise determination for the 160 µm coadded L2.5 map of OBSIDs 1342242772+73 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\;\sigma_{\rm hist}$).

5.5 160 µm: Pixfrac 0.5, Pixsize 3.″2

5.5.1 L 2.5 OBSIDs 1342242772+1342242773

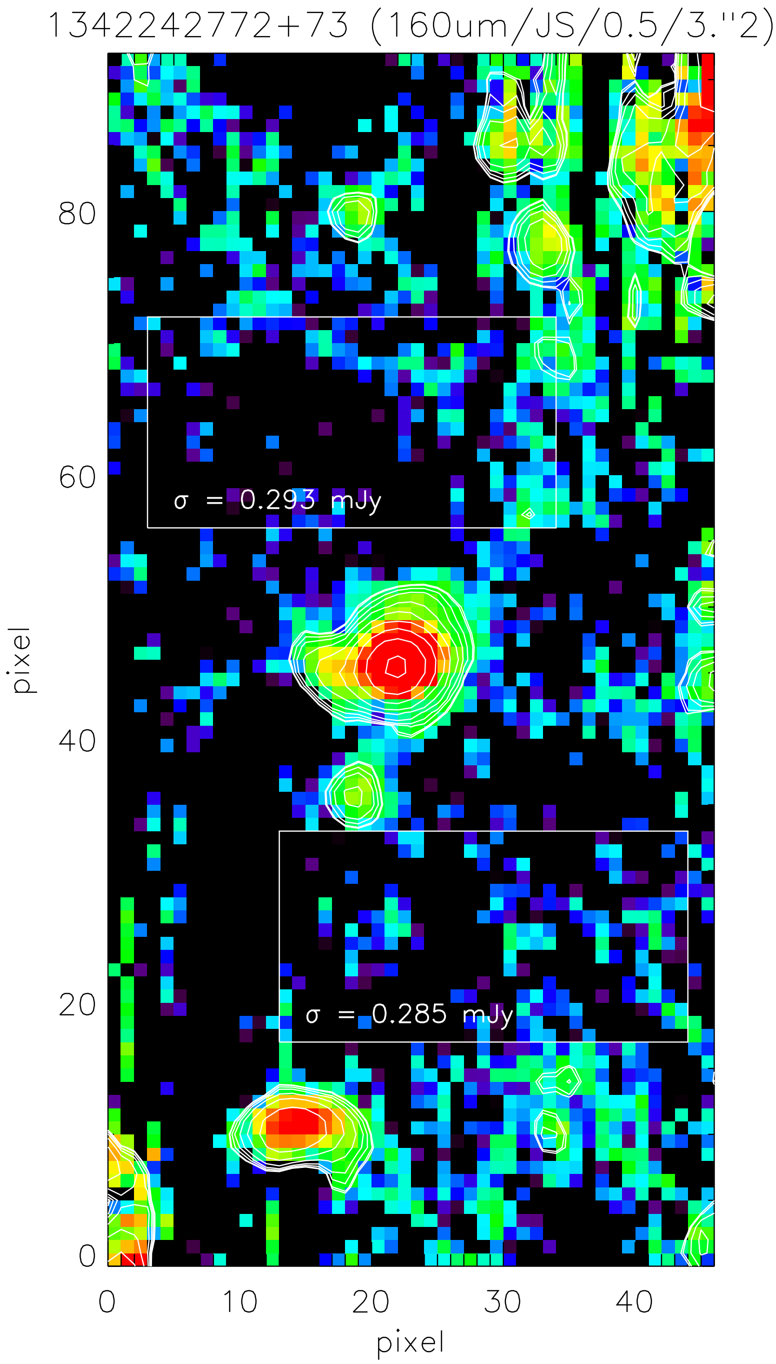

Figure 53: 160 µm L2.5 combined JScanam map for OBSIDs 1342242772+73 with pixfrac 0.5 and output pixel size of 3.″2. The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

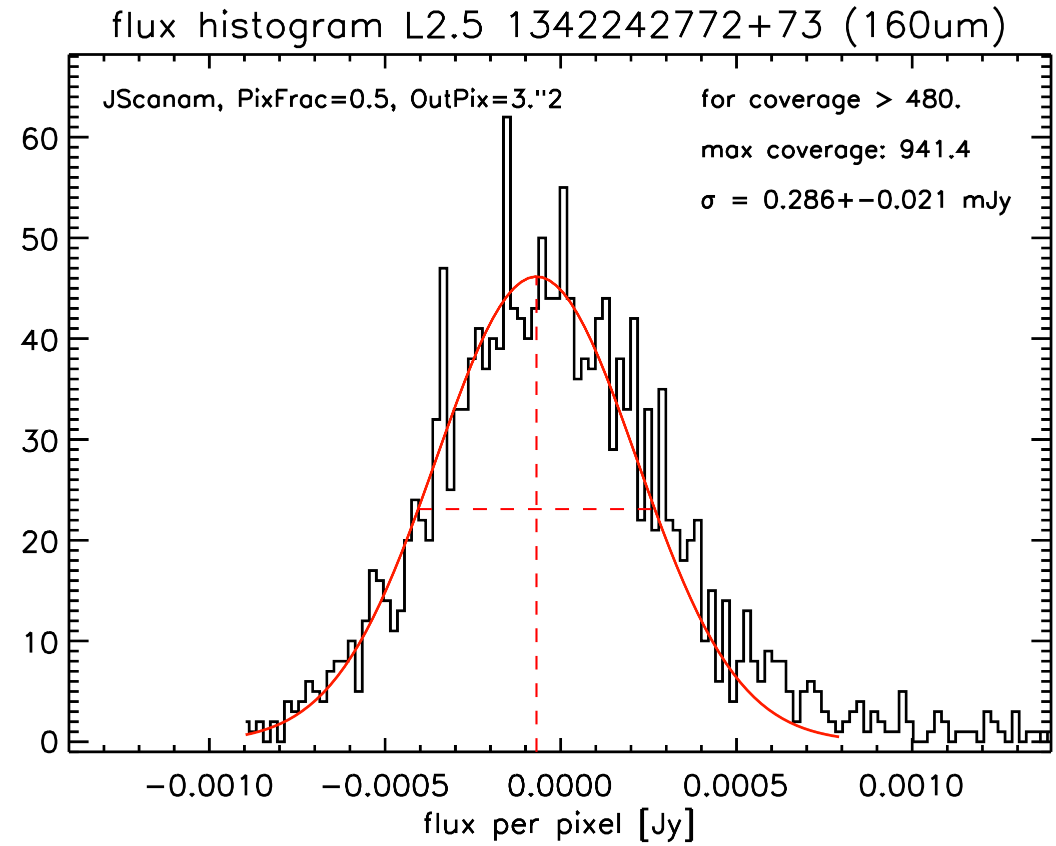

Figure 54: Noise determination for the 160 μm coadded L2.5 map of OBSIDs 1342242772+73 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\;\sigma_{\rm hist}$).

5.6 160 µm: Pixfrac 0.5, Pixsize 4.″8

5.6.1 L 2.5 OBSIDs 1342242772+1342242773

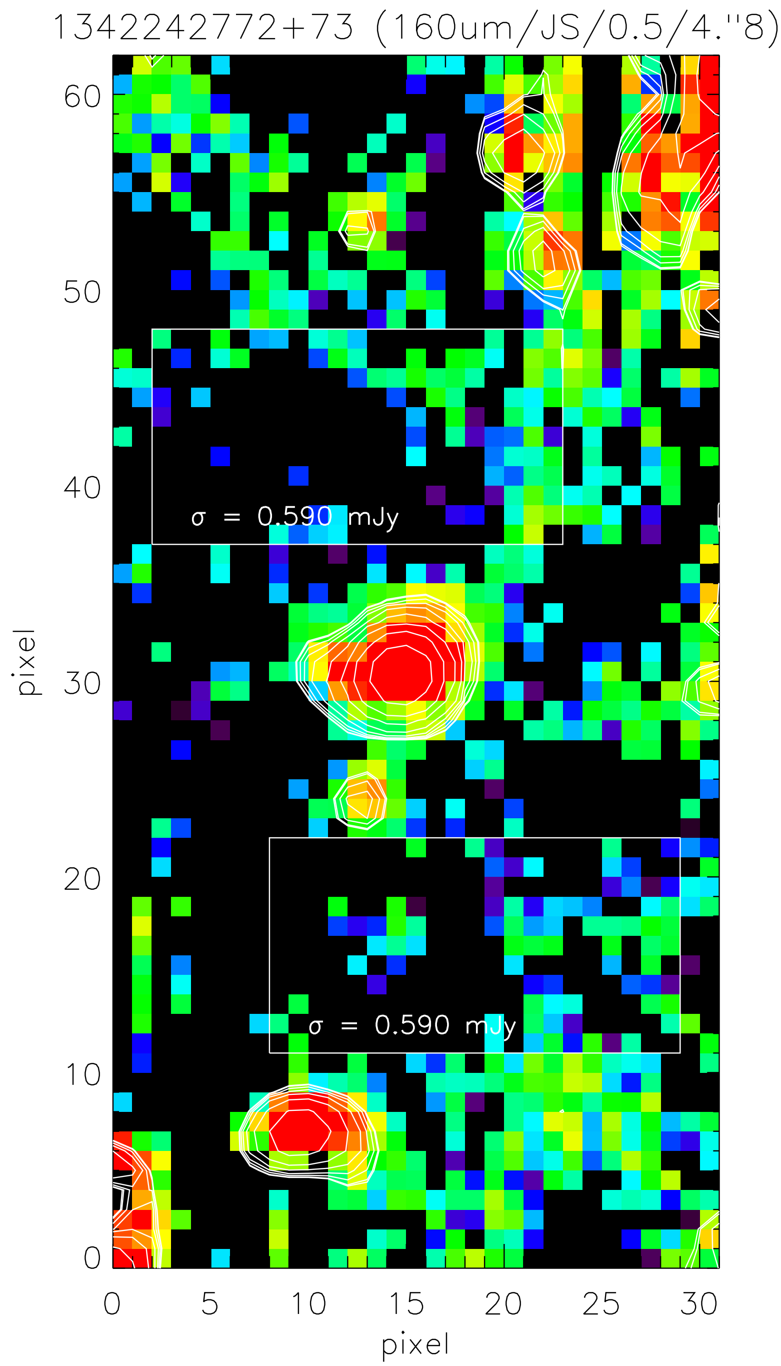

Figure 55: 160 µm L2.5 combined JScanam map for OBSIDs 1342242772+73 with pixfrac 0.5 and output pixel size of 4.″8. The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

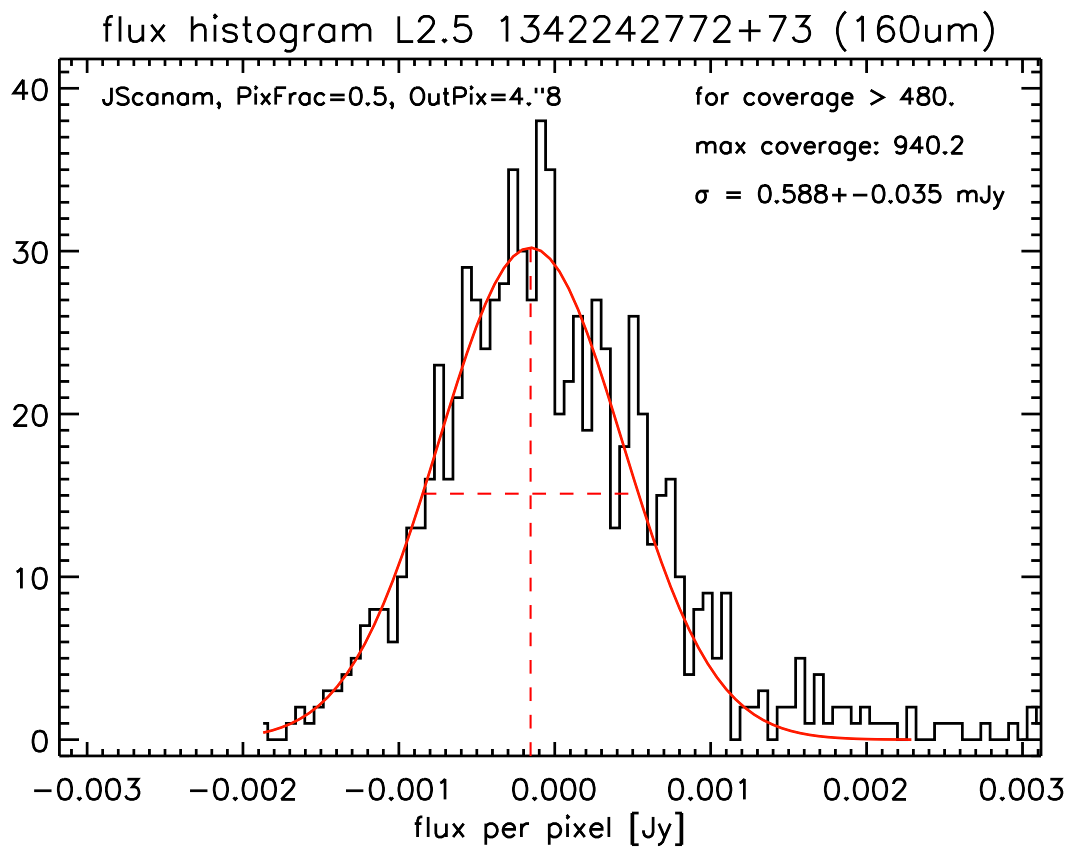

Figure 56: Noise determination for the 160 μm coadded L2.5 map of OBSIDs 1342242772+73 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\;\sigma_{\rm hist}$).

5.7 160 µm: Pixfrac 0.5, Pixsize 6.″4

5.7.1 L 2.5 OBSIDs 1342242772+1342242773

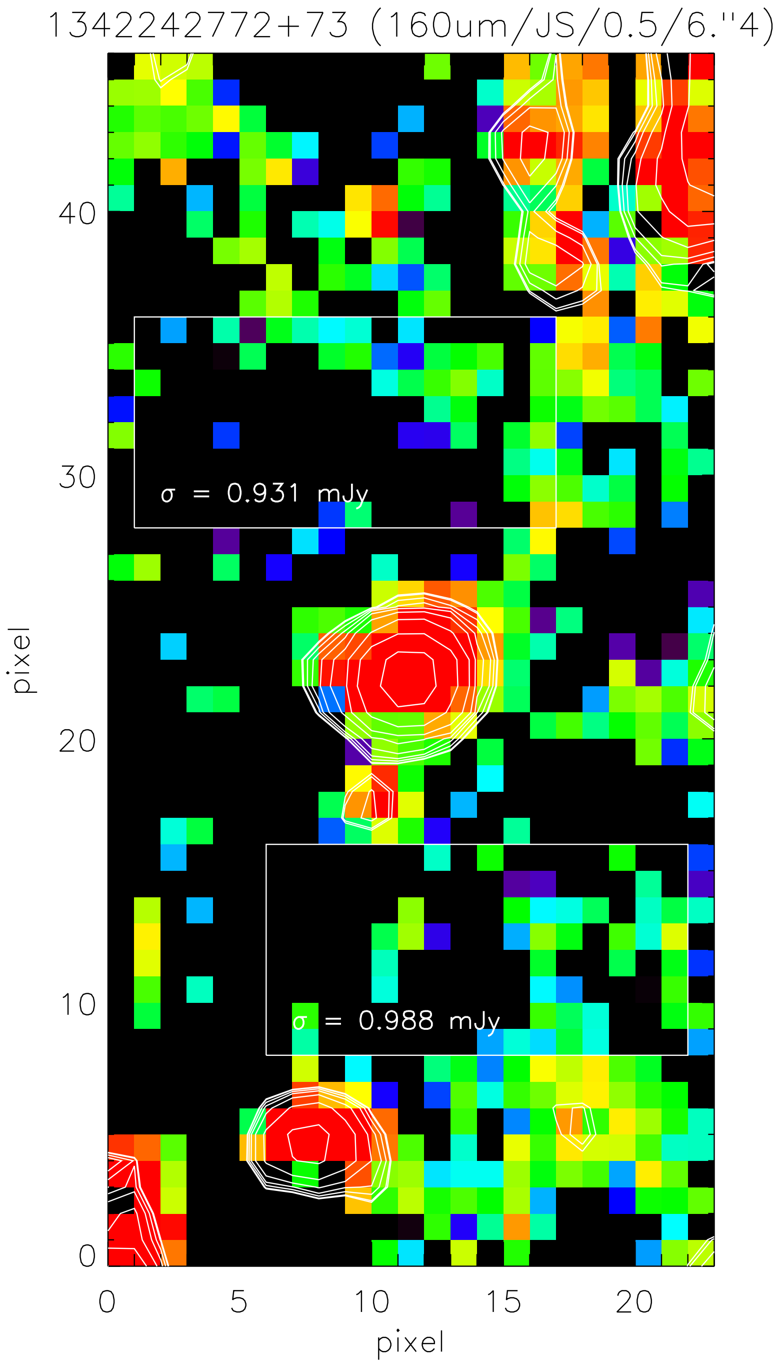

Figure 57: 160 µm L2.5 combined JScanam map for OBSIDs 1342242772+73 with pixfrac 0.5 and output pixel size of 6.″4. The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

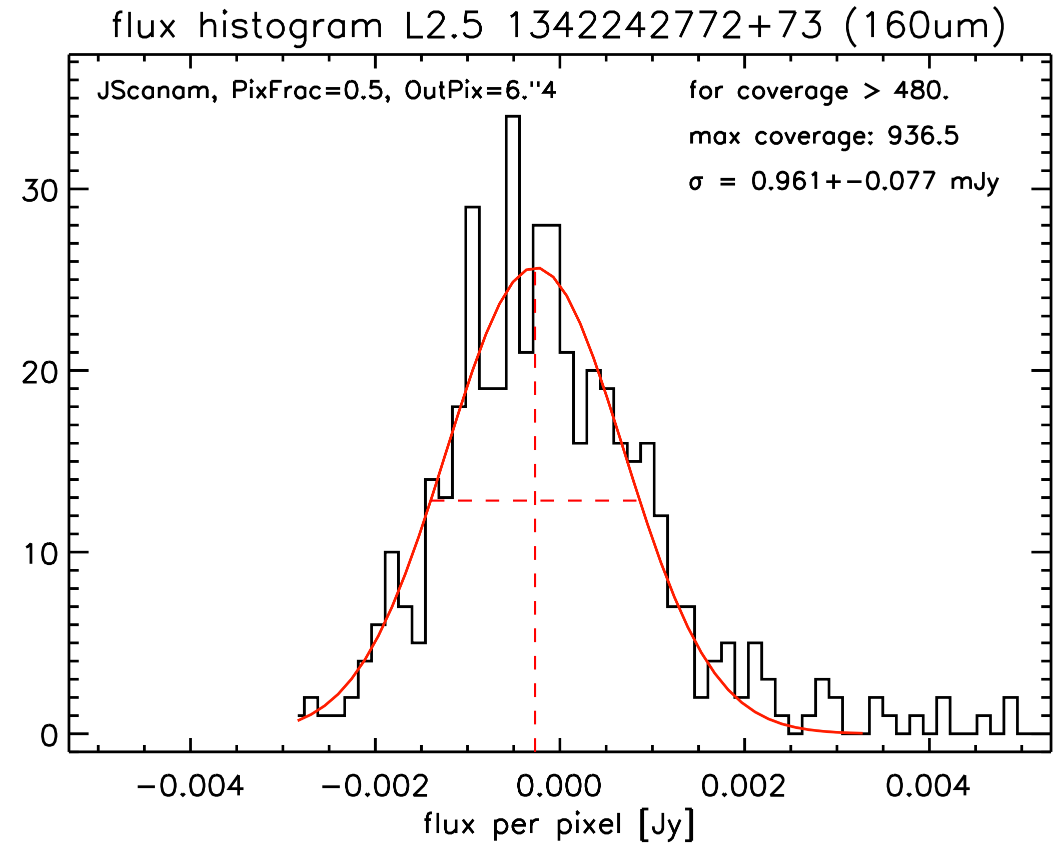

Figure 58: Noise determination for the 160 µm coadded L2.5 map of OBSIDs 1342242772+73 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\,\sigma_{\rm hist}$).

5.8 160 µm: Pixfrac 1.0, Pixsize 2.″1

5.8.1 L 2.5 OBSIDs 1342242772+1342242773

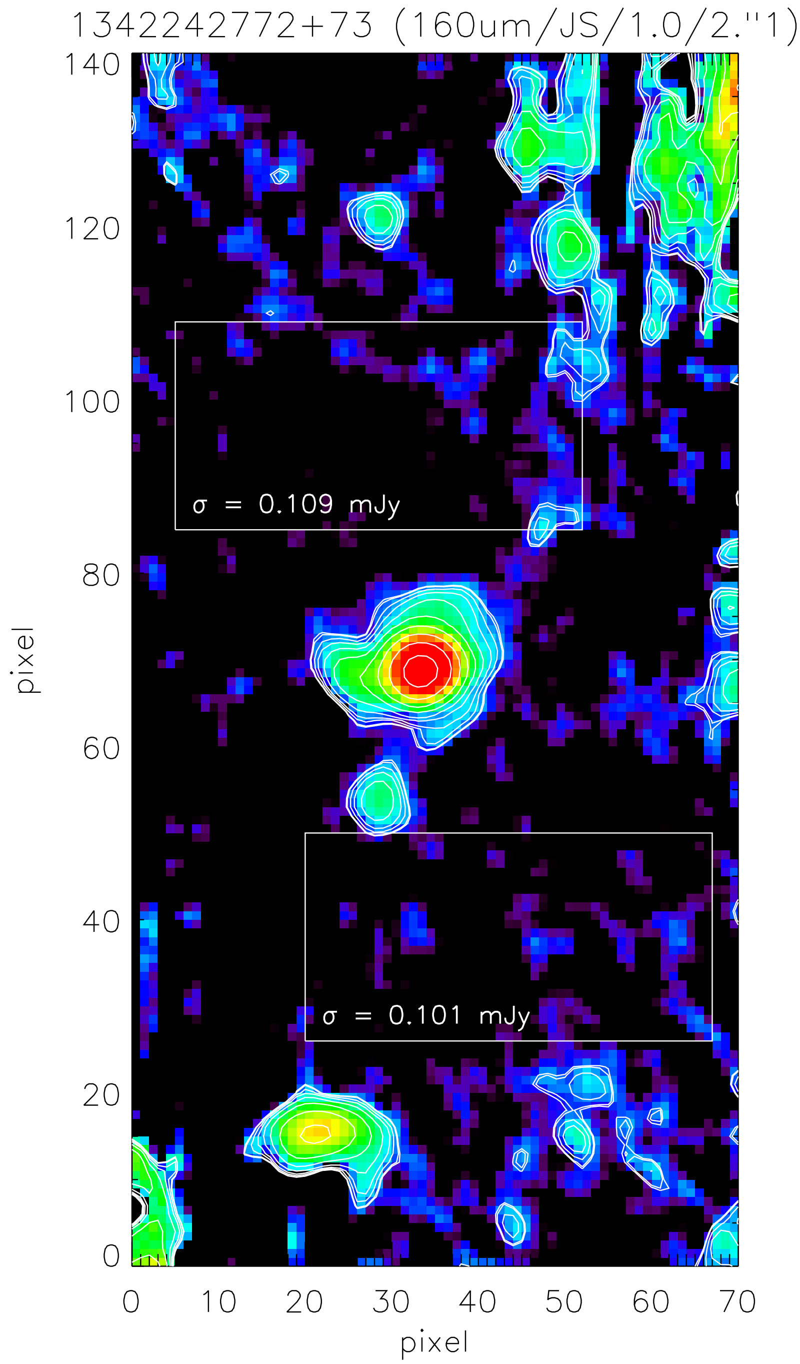

Figure 59: 160 µm L2.5 combined JScanam map for OBSIDs 1342242772+73 with pixfrac 1.0 and output pixel size of 2.″1. The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

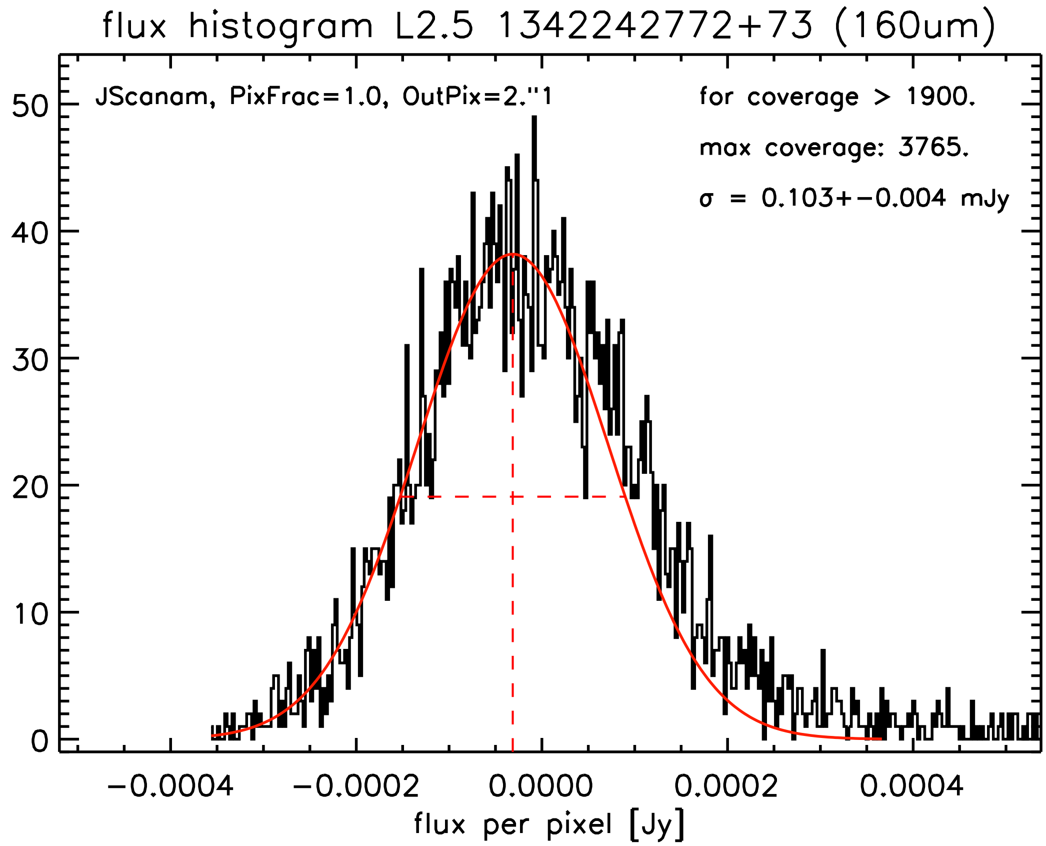

Figure 60: Noise determination for the 160 µm coadded L2.5 map of OBSIDs 1342242772+73 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\;\sigma_{\rm hist}$).

5.9 160 μm: Pixfrac 1.0, Pixsize 3.″2

5.9.1 L 2.5 OBSIDs 1342242772+1342242773

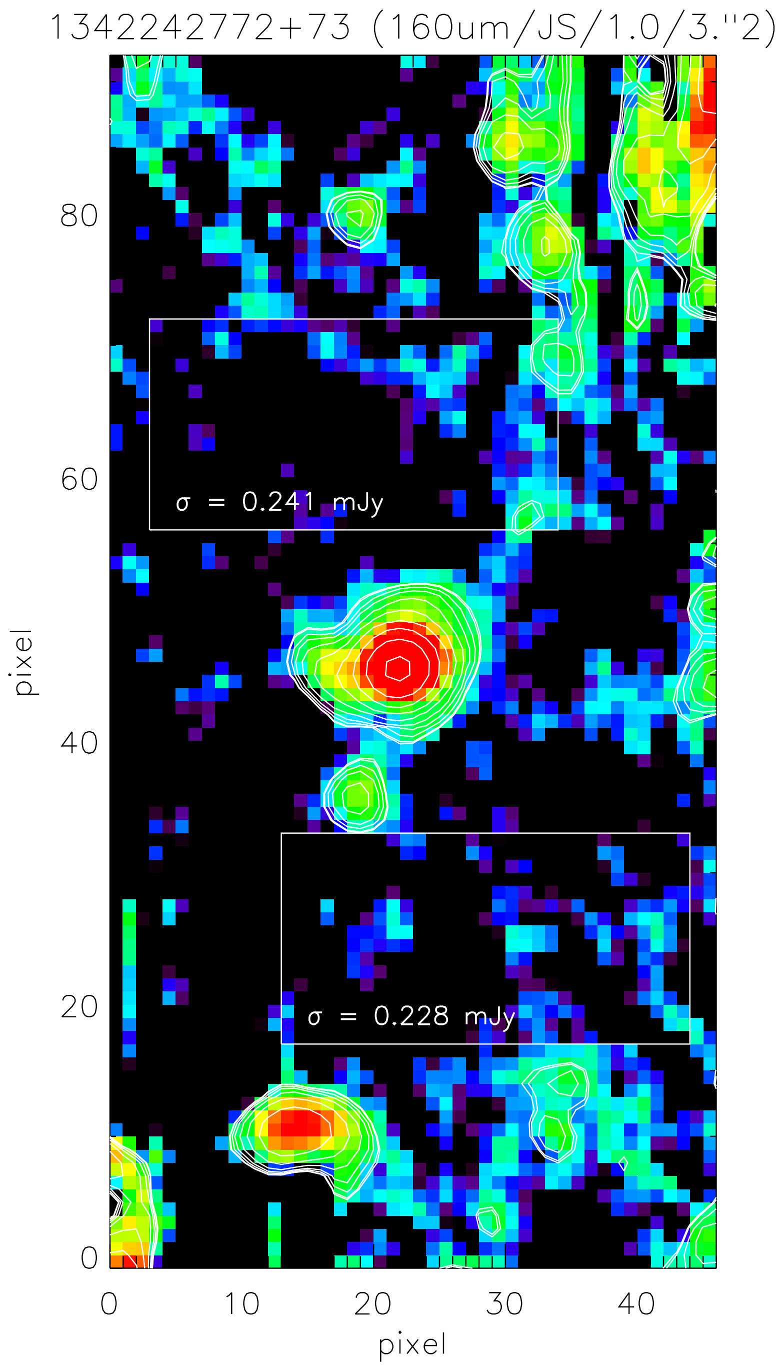

Figure 61: 160 μm L2.5 combined JScanam map for OBSIDs 1342242772+73 with pixfrac 1.0 and output pixel size of 3.″2. The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

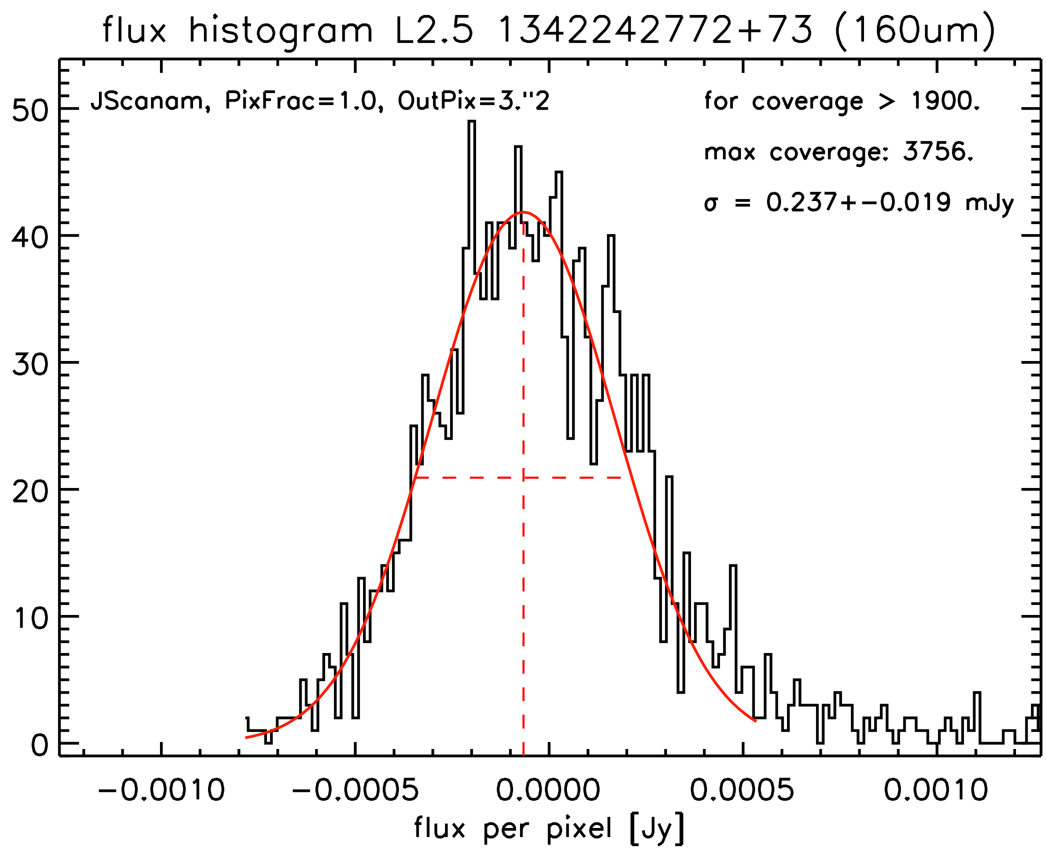

Figure 62: Noise determination for the 160 μm coadded L2.5 map of OBSIDs 1342242772+73 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\ \sigma_{\rm hist}$).

5.10 160 µm: Pixfrac 1.0, Pixsize 4.″8

5.10.1 L 2.5 OBSIDs 1342242772+1342242773

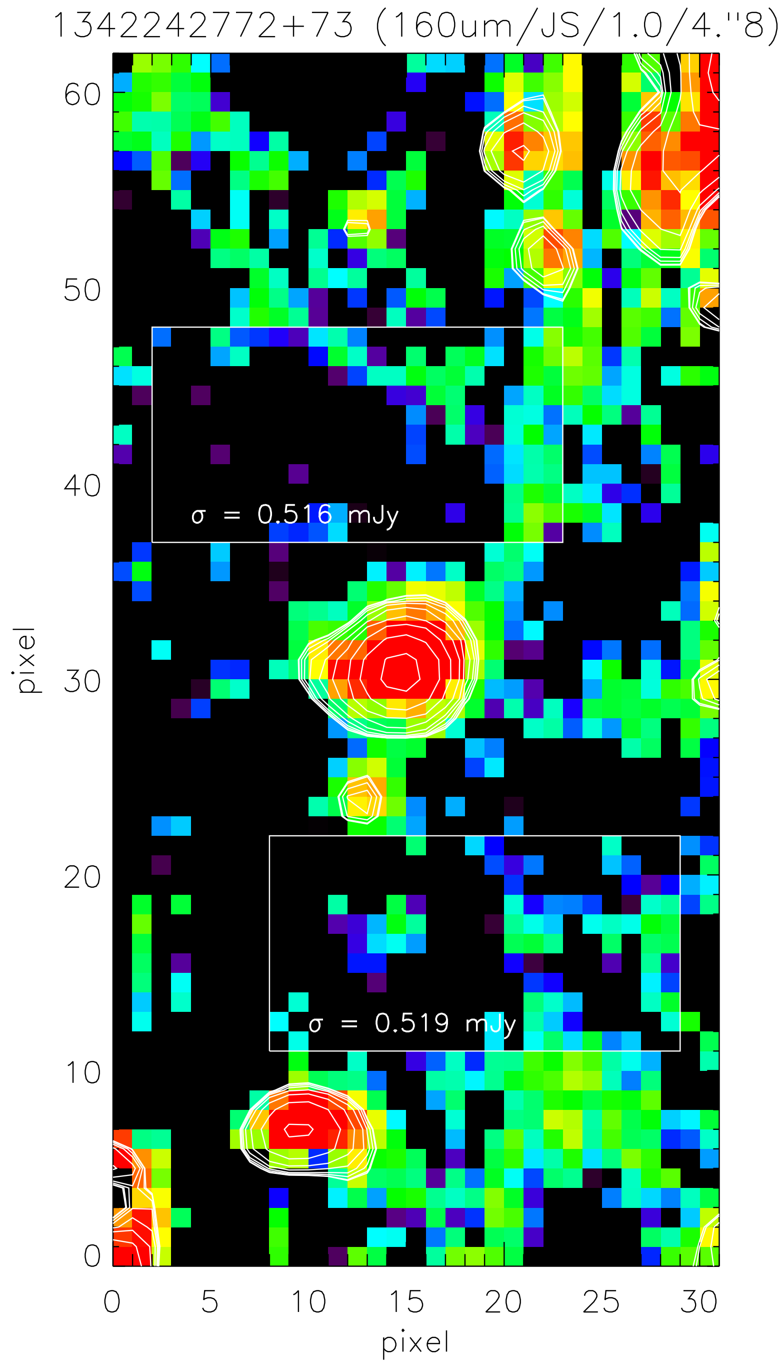

Figure 63: 160 µm L2.5 combined JScanam map for OBSIDs 1342242772+73 with pixfrac 1.0 and output pixel size of 4.″8. The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

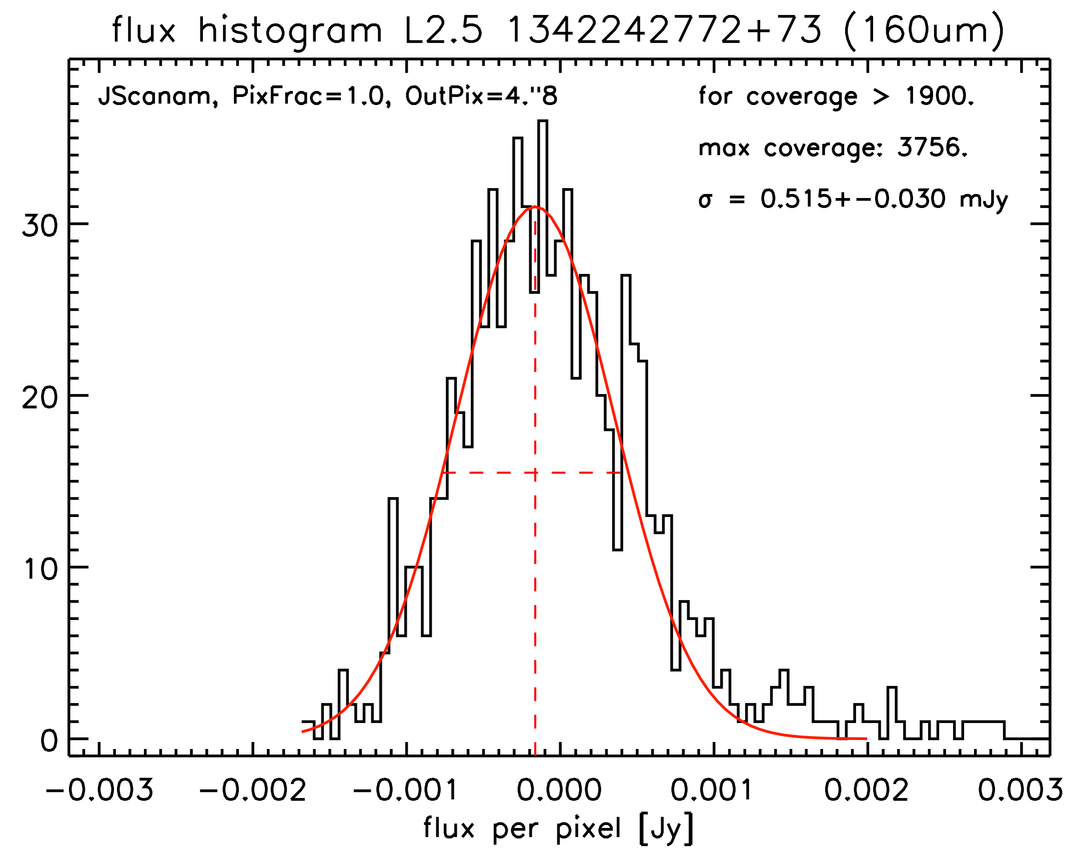

Figure 64: Noise determination for the 160 µm coadded L2.5 map of OBSIDs 1342242772+73 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\,\sigma_{\rm hist}$).

5.11 160 µm: Pixfrac 1.0, Pixsize 6.″4

5.11.1 L 2.5 OBSIDs 1342242772+1342242773

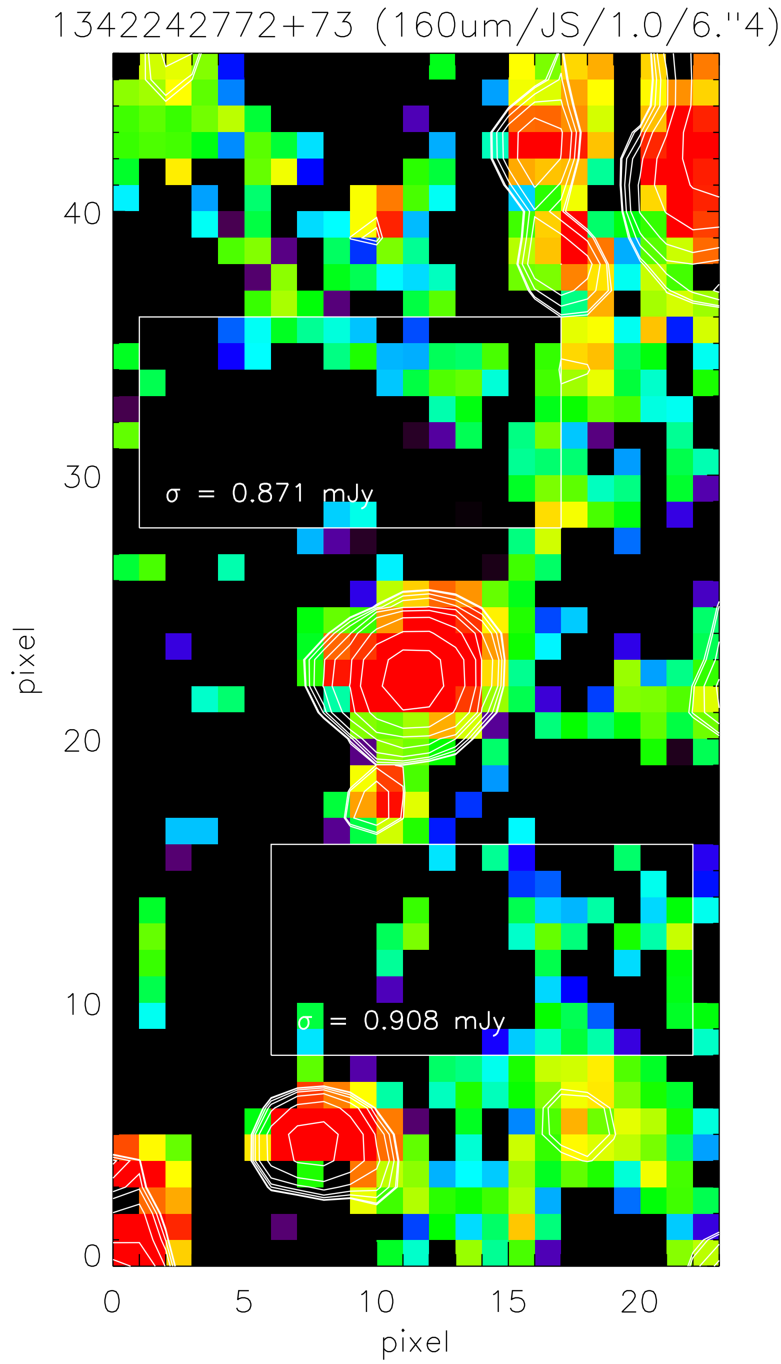

Figure 65: 160 µm L2.5 combined JScanam map for OBSIDs 1342242772+73 with pixfrac 1.0 and output pixel size of 6.″4. The two background fields for noise determination are outlined by the white boxes and the respective σ is indicated.

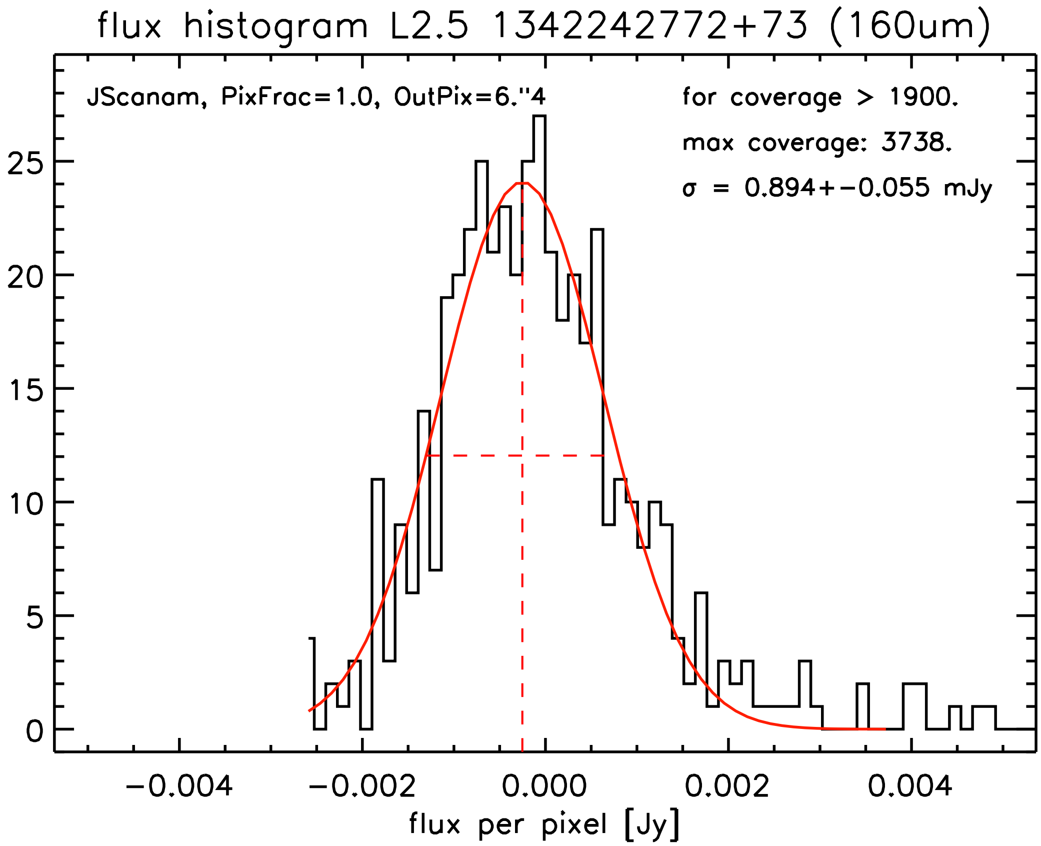

Figure 66: Noise determination for the 160 µm coadded L2.5 map of OBSIDs 1342242772+73 with the histogram method (only the flux distribution around the background level is shown). The red curve represents the Gauss fit. The vertical red dashed line indicates the position of the average background level. The horizontal red dotted line indicates the FWHM ($= 2\sqrt{2\,ln\,2}\,\sigma_{\rm hist}$).

6 Results for 70 µm maps

6.1 Measurement of flux standard deviation in source-free areas

Table 5 lists the measured noise of the background as determined in two source-free areas per map.

Table 5: Measurement of flux standard deviation at 70 µm in source-free areas for the co-added L2.5 product, IDs 1342242772 and 1342242773. The position of the boxes is indicated in Figs. 1 through 21. Note, that the cut levels for all 70µm map displays are identical. The combination high-lighted in bold face is used in the Standard Product Generation (SPG). The combination in italics was typical for the PACS photometric flux calibration analysis.

pixfrac/outpix	box size	L2.5 ID 1342242772+73		
		$\sigma_{\rm box1}$	$\sigma_{\rm box2}$	$\sigma_{\rm mean}$
	(pixels)	(mJy)	(mJy)	(mJy)
0.1 / 1.″1	88×44	0.079	0.084	0.082
0.1 / 1.″6	61×31	0.131	0.138	0.135
0.1 / 2.″4	41×21	0.223	0.253	0.238
0.1 / 3.″2	31×16	0.352	0.398	0.375
0.5 / 1.″6	61×31	0.106	0.117	0.111
0.5 / 2.″4	41×21	0.203	0.231	0.217
0.5 / 3.″2	31×16	0.330	0.381	0.355
1.1 / 1.″1	88×44	0.040	0.047	0.043
1.0 / 1.″6	61×31	0.083	0.096	0.089
1.0 / 2.″4	41×21	0.176	0.207	0.191
1.0 / 3.″2	31×16	0.298	0.355	0.326

There is a systematic variation of the measured noise in the image maps depending on the selection of the mapping parameters. The behaviour is quite similar to that of high pass filtered maps, which is due to the fact that both processing methods apply the PhotProject algorithm.

1) For identical *outpix* the noise decreases with increasing *pixfrac*, which is due to the drop size covering more output pixels and hence correlating the noise in a pixel cluster.

2) The noise increases with increasing *outpix* size, because there is more flux in each output pixel and hence also the amplitude increases.

3) The noise in the JScanam map areas is higher than in the identical HPF map areas with HPF radius 15. The factor is 1.13–1.24 for *outpix* size 1.″1, 1.20–1.26 for *outpix* size 1.″6, 1.28–1.30 for *outpix* size 2.″4, and 1.47–1.56 for *outpix* size 3.″2.

4) Also the asymmetry in flux standard deviation between both areas is higher for the JScanam processing than for the HPF processing. It increases with increasing *outpix* size and explains partly the non-constant noise ratio factor.

6.2 Measurement of flux standard deviation by histogram method

Table 6 lists the noise values in the image maps determined with the histogram and Gauss fit method, including the uncertainty of the fit.

Table 6: Measurement of flux standard deviation at 70 µm with the histogram method for the co-added L2.5 product, IDs 1342242772 and 1342242773. The coverage threshold used to determine σ_{hist} and the maximum coverage for each map are listed. The combination high-lighted in bold face is used in the Standard Product Generation (SPG). The combination in italics was typical for the PACS photometric flux calibration analysis.

pixfrac/outpix	L2.5 ID 1342242772+73		
	σ_{hist} (mJy)	coverage >	$\mathrm{cover}_{\mathrm{max}}$
0.1 / 1.″1	0.081±0.001	20	40.85
0.1 / 1.″6	0.134±0.002	20	40.19
0.1 / 2.″4	0.239±0.007	20	39.75
0.1 / 3.″2	0.353±0.012	20	38.79
0.5 / 1.″6	0.109±0.002	480	971.3
0.5 / 2.″4	0.217±0.005	480	969.4
0.5 / 3.″2	0.331±0.012	480	966.7
1.0 / 1.″1	0.044±0.001	1900	3877
1.0 / 1.″6	0.090±0.002	1900	3873
1.0 / 2.″4	0.192±0.005	1900	3871
1.0 / 3.″2	0.307±0.008	1900	3866

The derived noise values in Table 6 are quite similar to the values found for the source free areas, cf. Table 5, which indicates that the coverage range of the source free areas is above the threshold used for the histogram method. This is indeed the case as exemplary shown in Fig. 67 for the SPG mapping parameter combination 0.1 / 1.″6. Therefore, a consistent behaviour as described in Sect. 6.1 is found.

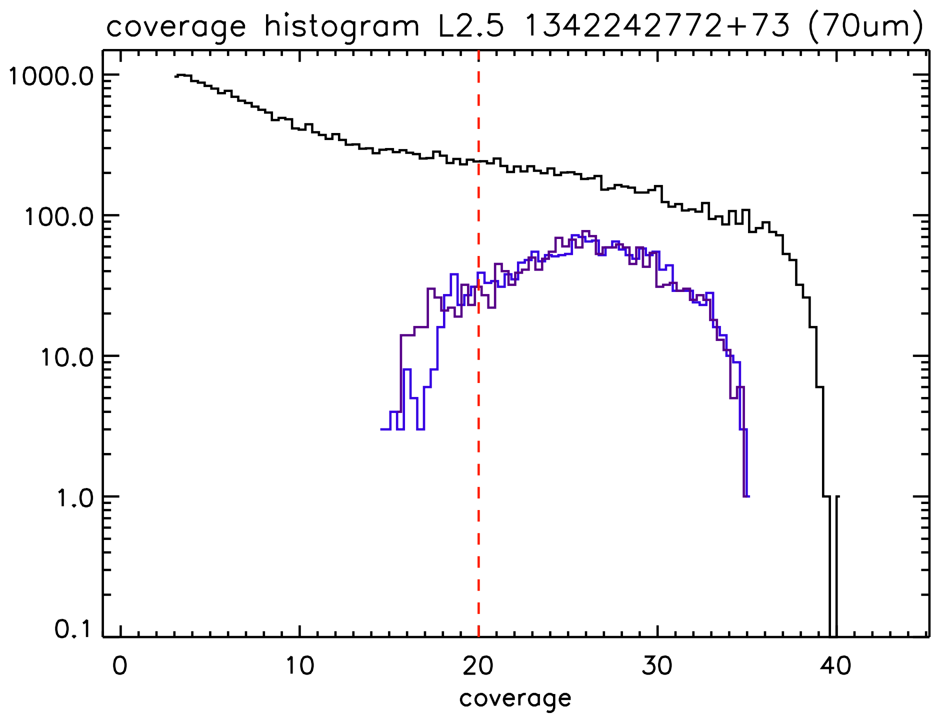

Figure 67: Histogram of the distribution of coverage for the L2.5 product with the SPG mapping parameter combination 15 / 0.1 / 1.″6 (black, all values below a coverage value of 3.0 are cut). The red dashed line indicates the coverage threshold used in the noise analysis. The dark blue and violet histograms give the coverage distribution inside the source-free noise measurement areas 1 and 2, respectively. The corresponding image map is shown in Fig. 3.

6.3 Determination of mean flux standard deviation from associated standard deviation map

Table 7 lists the mean noise per pixel as determined from the associated standard deviation map inside the same box area as for the image map.

Table 7: Determination of mean flux standard deviation at 70 µm inside the same box area as for the image maps in Figs. 1 through 21. $\frac{\sigma_{\rm mean,boxn}}{\sigma_{\rm ima,boxn}}$ is the ratio of the noise from the standard deviation map and the image map.

pixfrac/outpix	box size	L2.5 ID 1342242772+73					
	(pixels)	$\sigma_{\rm med,box1}$ (mJy)	$\sigma_{\rm mean,box1}$ (mJy)	$\frac{\sigma_{\rm mean,box1}}{\sigma_{\rm ima,box1}}$	$\sigma_{\rm med,box2}$ (mJy)	$\sigma_{\rm mean,box2}$ (mJy)	$\frac{\sigma_{\rm mean,box2}}{\sigma_{\rm ima,box2}}$
0.1 / 1.″1	88×44	0.078	0.079±0.008	1.00	0.080	0.082±0.011	0.98
0.1 / 1.″6	61×31	0.113	0.115±0.011	0.88	0.117	0.119±0.015	0.86
0.1 / 2.″4	41×21	0.170	0.173±0.016	0.78	0.177	0.180±0.023	0.71
0.1 / 3.″2	31×16	0.228	0.232±0.022	0.66	0.233	0.239±0.030	0.60
0.5 / 1.″6	61×31	0.114	0.115±0.011	1.08	0.117	0.119±0.015	1.02
0.5 / 2.″4	41×21	0.171	0.173±0.016	0.85	0.176	0.180±0.023	0.78
0.5 / 3.″2	31×16	0.228	0.232±0.022	0.70	0.233	0.239±0.030	0.63
1.0 / 1.″1	88×44	0.032	0.032±0.003	0.80	0.032	0.033±0.004	0.70
1.0 / 1.″6	61×31	0.067	0.068±0.006	0.82	0.069	0.070±0.009	0.73
1.0 / 2.″4	41×21	0.150	0.152±0.014	0.86	0.155	0.158±0.020	0.76
1.0 / 3.″2	31×16	0.229	0.232±0.021	0.78	0.233	0.239±0.030	0.67

1) The standard deviation maps give reasonable noise per pixel values in the order of 60–110% of the image maps.

2) The standard deviation maps reflect the asymmetry of the noise between the two measurement areas, but not as pronounced as the image maps.

3) For *outpix* size of 3.″2, there is hardly any difference for the noise values derived from the stdev maps between all *pixfrac* values 0.1, 0.5 and 1.0. For smaller *outpix* sizes 2.″4 and 1.″6 the noise values are identical for *pixfrac* 0.1 and 0.5 for the same *outpix* size, while the *pixfrac* 1.0 values are smaller. This looks suspicious, since the image maps show a clear difference with the trends as described in the summary of Sect. 6.1. We discuss this finding in more detail in the general part of Section 9 (Conclusions).

6.4 Final photometric noise values and determination of correlated noise correction factors

The correlated noise correction factors for 70 µm JScanam maps are determined according to Eq. 2 with the 70 µm reference noise $< \sigma_{\mathrm{aperture,corr}} >^{\mathrm{ref}}_{\mathrm{wmHPF}}$ $(70\,\mu m)$ value from Table 4. For the calculation we have to derive the noise in the standard aperture with radius 5.″6 according to Eq. 1. Table 8 lists the derived $\mathrm{f}^{\mathrm{JS}}_{\mathrm{corr}}$ values. The uncertainty of the $\mathrm{f}^{\mathrm{JS}}_{\mathrm{corr}}$ values is in the order of 3–5%.

Table 8: Noise per measurement aperture $\sigma_{\mathrm{aperture,corr}}$ at 70 µm (aperture radius of 5.″6) and determination of correlated noise correction factor for JScanam maps by comparison with the corrected aperture noise of HPF=30 maps. The combination high-lighted in bold face is used in the Standard Product Generation (SPG). The combination in italics was typical for the PACS photometric flux calibration analysis.

pixfrac/outpix	$\sigma^{JS}_{\mathrm{pix}}$ (mJy/pix)	$\mathrm{N}_{\mathrm{outpixinaper}}$	$\sigma^{JS}_{\mathrm{aperture}}$ (mJy)	$< \sigma_{\mathrm{aperture,corr}} >^{\mathrm{ref}}_{\mathrm{wmHPF30}}$ (mJy)	$\mathrm{f}^{\mathrm{JS}}_{\mathrm{corr}}$
0.1 / 1.″1	0.081±0.001	81.4	0.731±0.013	1.29±0.02	1.765±0.059
0.1 / 1.″6	0.134±0.003	38.5	0.831±0.019	1.29±0.02	1.552±0.060
0.1 / 2.″4	0.239±0.007	17.1	0.988±0.029	1.29±0.02	1.305±0.059
0.1 / 3.″2	0.353±0.012	9.6	1.094±0.037	1.29±0.02	1.179±0.058
0.5 / 1.″6	0.109±0.002	38.5	0.676±0.012	1.29±0.02	1.907±0.064
0.5 / 2.″4	0.217±0.005	17.1	0.897±0.021	1.29±0.02	1.438±0.056
0.5 / 3.″2	0.331±0.012	9.6	1.026±0.037	1.29±0.02	1.258±0.065
1.0 / 1.″1	0.044±0.001	81.4	0.397±0.009	1.29±0.02	3.250±0.124
1.0 / 1.″6	0.090±0.002	38.5	0.558±0.012	1.29±0.02	2.310±0.086
1.0 / 2.″4	0.192±0.005	17.1	0.794±0.021	1.29±0.02	1.625±0.068
1.0 / 3.″2	0.307±0.008	9.6	0.951±0.025	1.29±0.02	1.356±0.057

7 Results for 100 µm maps

7.1 Measurement of flux standard deviation in source-free areas

Table 9 lists the measured noise of the background as determined in two source-free areas per map.

Table 9: Measurement of flux standard deviation at 100 µm in source-free areas for the co-added L2.5 product, IDs 1342242770 and 1342242771. The position of the boxes is indicated in Figs. 23 through 43. Note, that the cut levels for all 100 µm map displays are identical. The combination high-lighted in bold face is used in the Standard Product Generation (SPG). The combination in italics was typical for the PACS photometric flux calibration analysis.

pixfrac/outpix	box size	L2.5 ID 1342242770+71		
		$\sigma_{\rm box1}$	$\sigma_{\rm box2}$	$\sigma_{\rm mean}$
	(pixels)	(mJy)	(mJy)	(mJy)
0.1 / 1.″4	70×35	0.099	0.106	0.103
0.1 / 1.″6	61×31	0.117	0.127	0.122
0.1 / 2.″4	41×21	0.197	0.220	0.209
0.1 / 3.″2	31×16	0.293	0.325	0.309
0.5 / 1.″6	61×31	0.095	0.105	0.100
0.5 / 2.″4	41×21	0.175	0.199	0.187
0.5 / 3.″2	31×16	0.273	0.311	0.292
1.0 / 1.″4	70×35	0.056	0.065	0.061
1.0 / 1.″6	61×31	0.072	0.084	0.078
1.0 / 2.″4	41×21	0.147	0.176	0.161
1.0 / 3.″2	31×16	0.246	0.290	0.268

There is a systematic variation of the measured noise in the image maps depending on the selection of the mapping parameters. The behaviour is quite similar to that of high pass filtered maps, which is due to the fact that both processing methods apply the PhotProject algorithm.

1) For identical *outpix* the noise decreases with increasing *pixfrac*, which is due to the drop size covering more output pixels and hence correlating the noise in a pixel cluster.

2) The noise increases with increasing *outpix* size, because there is more flux in each output pixel and hence also the amplitude increases.

3) The noise in the JScanam map areas is higher than in the identical HPF map areas with HPF radius 15. The factor is 1.24–1.39 for *outpix* size 1.″4, 1.24–1.28 for *outpix* size 1.″6, 1.31 for *outpix* size 2.″4, and 1.43–1.50 for *outpix* size 3.″2.

4) Also the asymmetry in flux standard deviation between both areas is higher for the JScanam processing than for the HPF processing. It increases with increasing *outpix* size and explains partly the non-constant noise ratio factor.

7.2 Measurement of flux standard deviation by histogram method

Table 10 lists the noise values in the image maps determined with the histogram and Gauss fit method, including the uncertainty of the fit.

Table 10: Measurement of flux standard deviation at 100 µm with the histogram method for the co-added L2.5 product, IDs 1342242770 and 1342242771. The coverage threshold used to determine σ_{hist} and the maximum coverage for each map are listed. The combination high-lighted in bold face is used in the Standard Product Generation (SPG). The combination in italics was typical for the PACS photometric flux calibration analysis.

pixfrac/outpix	L2.5 ID 1342242770+71		
	σ_{hist} (mJy)	coverage >	$\text{cover}_{\text{max}}$
0.1 / 1.″4	0.101±0.002	22	42.44
0.1 / 1.″6	0.124±0.004	22	42.34
0.1 / 2.″4	0.205±0.006	22	41.76
0.1 / 3.″2	0.321±0.012	22	41.55
0.5 / 1.″6	0.102±0.002	520	1037
0.5 / 2.″4	0.190±0.006	520	1035
0.5 / 3.″2	0.311±0.012	520	1034
1.0 / 1.″4	0.063±0.001	2100	4134
1.0 / 1.″6	0.082±0.001	2100	4132
1.0 / 2.″4	0.169±0.006	2100	4132
1.0 / 3.″2	0.292±0.010	2100	4130

The derived noise values in Table 10 are quite similar to the values found for the source free areas, cf. Table 9, which indicates that the coverage range of the source free areas is above the threshold used for the histogram method. This is indeed the case as exemplary shown in Fig. 68 for the SPG mapping parameter combination 0.1 / 1.″6. Therefore, a consistent behaviour as described in Sect. 7.1 is found.

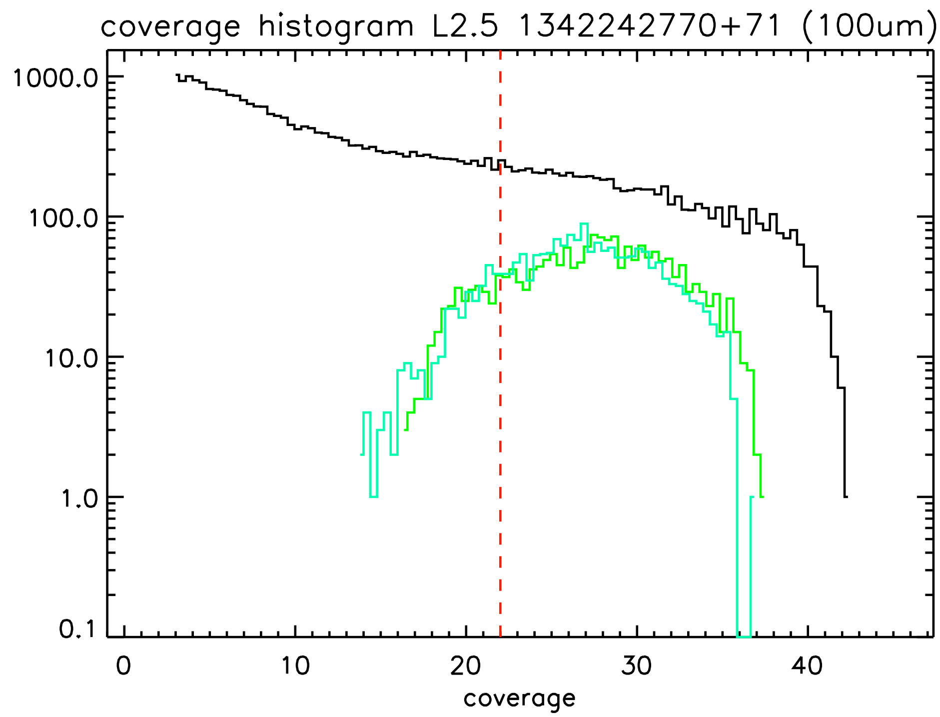

Figure 68: Histogram of the distribution of coverage for the L2.5 product with the SPG mapping parameter combination 15 / 0.1 / 1.″6 (black, all values below a coverage value of 3.0 are cut). The red dashed line indicates the coverage threshold used in the noise analysis. The dark and light green histograms give the coverage distribution inside the source-free noise measurement areas 1 and 2, respectively. The corresponding image map is shown in Fig. 25.

7.3 Determination of mean flux standard deviation from associated standard deviation map

Table 11 lists the mean noise per pixel as determined from the associated standard deviation map inside the same box area as for the image map.

Table 11: Determination of mean flux standard deviation at 100 μm inside the same box area as for the image maps in Figs. 23 through 43. $\frac{\sigma_{\rm mean,boxn}}{\sigma_{\rm ima,boxn}}$ is the ratio of the noise from the standard deviation map and the image map.

pixfrac/outpix	box size	L2.5 ID 1342242770+71					
	(pixels)	$\sigma_{\rm med,box1}$ (mJy)	$\sigma_{\rm mean,box1}$ (mJy)	$\frac{\sigma_{\rm mean,box1}}{\sigma_{\rm ima,box1}}$	$\sigma_{\rm med,box2}$ (mJy)	$\sigma_{\rm mean,box2}$ (mJy)	$\frac{\sigma_{\rm mean,box2}}{\sigma_{\rm ima,box2}}$
0.1 / 1.″4	70×35	0.093	0.094±0.009	0.95	0.097	0.100±0.013	0.94
0.1 / 1.″6	61×31	0.107	0.108±0.010	0.92	0.112	0.114±0.015	0.90
0.1 / 2.″4	41×21	0.161	0.163±0.015	0.83	0.168	0.172±0.023	0.78
0.1 / 3.″2	31×16	0.216	0.218±0.021	0.74	0.223	0.229±0.030	0.70
0.5 / 1.″6	61×31	0.107	0.108±0.010	1.14	0.112	0.114±0.015	1.09
0.5 / 2.″4	41×21	0.161	0.163±0.015	0.93	0.173	0.172±0.023	0.86
0.5 / 3.″2	31×16	0.216	0.218±0.020	0.80	0.223	0.229±0.030	0.74
1.0 / 1.″4	70×35	0.048	0.049±0.004	0.88	0.050	0.051±0.007	0.78
1.0 / 1.″6	61×31	0.063	0.064±0.006	0.89	0.066	0.067±0.009	0.80
1.0 / 2.″4	41×21	0.142	0.144±0.013	0.98	0.154	0.151±0.021	0.86
1.0 / 3.″2	31×16	0.215	0.218±0.020	0.89	0.223	0.229±0.030	0.79

1) The standard deviation maps give reasonable noise per pixel values in the order of 70–114% of the image maps.

2) The standard deviation maps reflect the asymmetry of the noise between the two measurement areas, but not as pronounced as the image maps.

3) For *outpix* size of 3.″2, there is hardly any difference for the noise values derived from the stdev maps between all *pixfrac* values 0.1, 0.5 and 1.0. For smaller *outpix* sizes 2.″4 and 1.″6 the noise values are identical for *pixfrac* 0.1 and 0.5 for the same *outpix* size, while the *pixfrac* 1.0 values are smaller. This looks suspicious, since the image maps show a clear difference with the trends as described in the summary of Sect. 7.1. We discuss this finding in more detail in the general part of Section 9 (Conclusions).

7.4 Final photometric noise values and determination of correlated noise correction factors

The correlated noise correction factors for 100 µm JScanam maps are determined according to Eq. 2 with the 100 µm reference noise $<\sigma_{\mathrm{aperture,corr}}>^{\mathrm{ref}}_{\mathrm{wmHPF}}$ $(100\,\mu m)$ value from Table 4. For the calculation we have to derive the noise in the standard aperture with radius 6.″8 according to Eq. 1. Table 12 lists the derived $\mathrm{f}^{\mathrm{JS}}_{\mathrm{corr}}$ values. The uncertainty of the $\mathrm{f}^{\mathrm{JS}}_{\mathrm{corr}}$ values is in the order of 1.5–4%.

Table 12: Noise per measurement aperture $\sigma_{\mathrm{aperture,corr}}$ at 100 µm (aperture radius of 6.″8) and determination of correlated noise correction factor for JScanam maps by comparison with the corrected aperture noise of HPF maps. The combination high-lighted in bold face is used in the Standard Product Generation (SPG). The combination in italics was typical for the PACS photometric flux calibration analysis.

pixfrac/outpix	$\sigma^{JS}_{\mathrm{pix}}$ (mJy/pix)	$\mathrm{N}_{\mathrm{outpixinaper}}$	$\sigma^{JS}_{\mathrm{aperture}}$ (mJy)	$<\sigma_{\mathrm{aperture,corr}}>^{\mathrm{ref}}_{\mathrm{wmHPF30}}$ (mJy)	$\mathrm{f}^{\mathrm{JS}}_{\mathrm{corr}}$
0.1 / 1.″4	0.101±0.002	74.1	0.869±0.017	1.51±0.005	1.737±0.040
0.1 / 1.″6	0.124±0.004	56.7	0.934±0.030	1.51±0.005	1.617±0.057
0.1 / 2.″4	0.205±0.006	25.2	1.029±0.030	1.51±0.005	1.467±0.048
0.1 / 3.″2	0.321±0.012	14.2	1.210±0.045	1.51±0.005	1.248±0.051
0.5 / 1.″6	0.102±0.002	56.7	0.768±0.015	1.51±0.005	1.966±0.045
0.5 / 2.″4	0.190±0.006	25.2	0.954±0.030	1.51±0.005	1.583±0.055
0.5 / 3.″2	0.311±0.012	14.2	1.172±0.045	1.51±0.005	1.289±0.054
1.0 / 1.″4	0.061±0.001	74.1	0.525±0.009	1.51±0.005	2.876±0.059
1.0 / 1.″6	0.082±0.001	56.7	0.618±0.008	1.51±0.005	2.446±0.040
1.0 / 2.″4	0.169±0.006	25.2	0.848±0.030	1.51±0.005	1.780±0.069
1.0 / 3.″2	0.292±0.010	14.2	1.100±0.038	1.51±0.005	1.372±0.052

8 Results for 160 µm maps

8.1 Measurement of flux standard deviation in source-free areas

Table 13 lists the measured noise of the background as determined in two source-free areas per map.

Table 13: Measurement of flux standard deviation at 160 µm in source-free areas for the co-added L2.5 product, IDs 1342242772 and 1342242773. The position of the boxes is indicated in Figs. 45 through 65. Note, that the cut levels for all 160µm map displays are identical. The combination high-lighted in bold face is used in the Standard Product Generation (SPG).

pixfrac/outpix	box size	L2.5 ID 1342242772+73		
		$\sigma_{\rm box1}$	$\sigma_{\rm box2}$	$\sigma_{\rm mean}$
	(pixels)	(mJy)	(mJy)	(mJy)
0.1 / 2.″1	47×24	0.178	0.170	0.174
0.1 / 3.″2	31×16	0.330	0.333	0.332
0.1 / 4.″8	21×11	0.632	0.638	0.635
0.1 / 6.″4	16×8	0.970	1.031	1.000
0.5 / 3.″2	31×16	0.293	0.285	0.289
0.5 / 4.″8	21×11	0.590	0.590	0.590
0.5 / 6.″4	16×8	0.931	0.988	0.960
1.0 / 2.″1	47×24	0.109	0.101	0.105
1.0 / 3.″2	31×16	0.241	0.228	0.235
1.0 / 4.″8	21×11	0.516	0.519	0.518
1.0 / 6.″4	16×8	0.871	0.908	0.890

There is a systematic variation of the measured noise in the image maps depending on the selection of the mapping parameters. The behaviour is quite similar to that of high pass filtered maps, which is due to the fact that both processing methods apply the PhotProject algorithm.

1) For identical *outpix* the noise decreases with increasing *pixfrac*, which is due to the drop size covering more output pixels and hence correlating the noise in a pixel cluster.

2) The noise increases with increasing *outpix* size, because there is more flux in each output pixel and hence also the amplitude increases.

3) The noise in the JScanam map areas is higher than in the identical HPF map areas with HPF radius 25. The factor is 1.25–1.33 for *outpix* size 2.″1, 1.46–1.55 for *outpix* size 3.″2, 1.63–1.68 for *outpix* size 4.″8, and 1.78–1.82 for *outpix* size 6.″4.

4) The asymmetry in flux standard deviation between both areas increases with increasing *outpix* size and explains partly the non-constant noise ratio factor.

8.2 Measurement of flux standard deviation by histogram method

Table 14 lists the noise values in the image maps determined with the histogram and Gauss fit method, including the uncertainty of the fit.

Table 14: Measurement of flux standard deviation at 160 µm with the histogram method for the co-added L2.5 product, IDs 1342242772 and 1342242773. The coverage threshold used to determine $\sigma_{\rm hist}$ and the maximum coverage for each map are listed. The combination high-lighted in bold face is used in the Standard Product Generation (SPG).

pixfrac/outpix	L2.5 ID 1342242772+73		
	$\sigma_{\rm hist}$ (mJy)	coverage >	$\text{cover}_{\rm max}$
0.1 / 2.″1	0.173±0.009	19.0	38.81
0.1 / 3.″2	0.335±0.015	19.0	38.00
0.1 / 4.″8	0.639±0.046	19.0	37.68
0.1 / 6.″4	0.990±0.072	19.0	37.54
0.5 / 3.″2	0.286±0.021	480	941.4
0.5 / 4.″8	0.588±0.035	480	940.2
0.5 / 6.″4	0.961±0.077	480	936.5
1.0 / 2.″1	0.103±0.004	1900	3765
1.0 / 3.″2	0.237±0.019	1900	3756
1.0 / 4.″8	0.515±0.030	1900	3754
1.0 / 6.″4	0.894±0.055	1900	3738

The derived noise values in Table 14 are quite similar to the values found for the source free areas, cf. Table 13, which indicates that the coverage range of the source free areas is above the threshold used for the histogram method. This is indeed the case as exemplary shown in Fig. 69 for the SPG mapping parameter combination 0.1 / 3.″2. Therefore, a consistent behaviour as described in Sect. 8.1 is found.

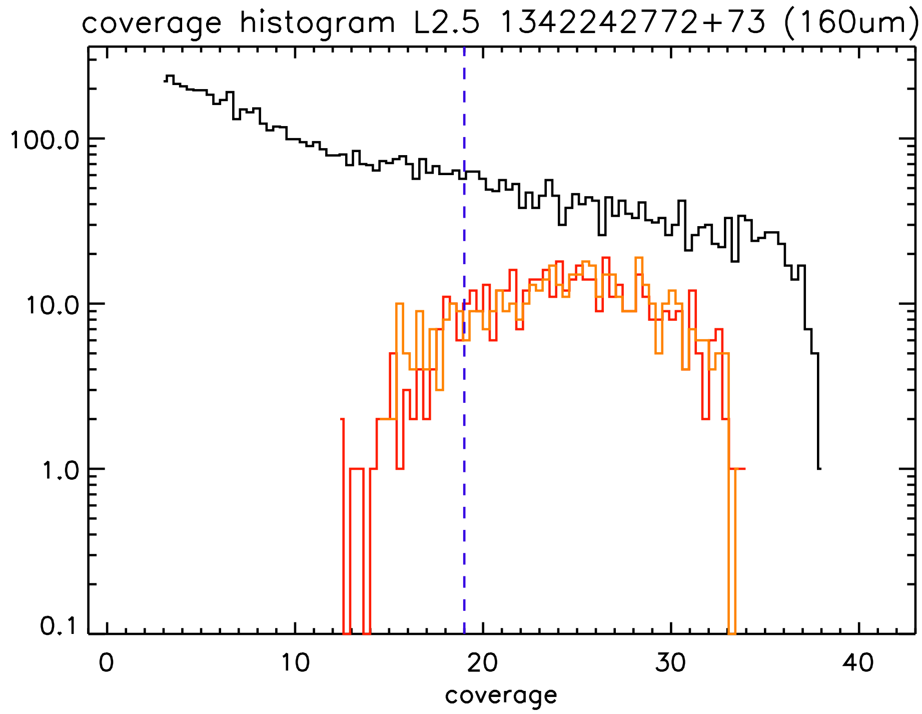

Figure 69: Histogram of the distribution of coverage for the L2.5 product with the SPG mapping parameter combination 0.1 / 3.″2 (black, all values below a coverage value of 3.0 are cut). The blue dashed line indicates the coverage threshold used in the noise analysis. The red and orange histograms give the coverage distribution inside the source-free noise measurement areas 1 and 2, respectively.

8.3 Determination of mean flux standard deviation from associated standard deviation map

Table 15 lists the mean noise per pixel as determined from the associated standard deviation map inside the same box area as for the image map.

Table 15: Determination of mean flux standard deviation at 160 µm inside the same box area as for the image maps in Figs. 45 through 65. $\frac{\sigma_{\rm mean,boxn}}{\sigma_{\rm ima,boxn}}$ is the ratio of the noise from the standard deviation map and the image map.

pixfrac/outpix	box size (pixels)	L2.5 ID 1342242772+73 $\sigma_{\rm med,box1}$ (mJy)	$\sigma_{\rm mean,box1}$ (mJy)	$\frac{\sigma_{\rm mean,box1}}{\sigma_{\rm ima,box1}}$	$\sigma_{\rm med,box2}$ (mJy)	$\sigma_{\rm mean,box2}$ (mJy)	$\frac{\sigma_{\rm mean,box2}}{\sigma_{\rm ima,box2}}$
0.1 / 2.″1	47×24	0.145	0.147±0.018	0.83	0.147	0.149±0.018	0.88
0.1 / 3.″2	31×16	0.219	0.224±0.025	0.68	0.225	0.229±0.026	0.69
0.1 / 4.″8	21×11	0.329	0.335±0.036	0.53	0.341	0.347±0.041	0.54
0.1 / 6.″4	16×8	0.446	0.454±0.051	0.47	0.456	0.464±0.057	0.45
0.5 / 3.″2	31×16	0.220	0.224±0.025	0.76	0.225	0.229±0.025	0.80
0.5 / 4.″8	21×11	0.329	0.335±0.036	0.57	0.341	0.347±0.041	0.59
0.5 / 6.″4	16×8	0.446	0.454±0.050	0.49	0.457	0.464±0.056	0.47
1.0 / 2.″1	47×24	0.054	0.055±0.006	0.50	0.055	0.055±0.006	0.54
1.0 / 3.″2	31×16	0.124	0.127±0.013	0.53	0.127	0.129±0.014	0.57
1.0 / 4.″8	21×11	0.279	0.284±0.030	0.55	0.289	0.294±0.034	0.57
1.0 / 6.″4	16×8	0.446	0.454±0.050	0.52	0.457	0.465±0.056	0.51

1) The standard deviation maps give reasonable noise per pixel values in the order of 45–88% of the image maps.

2) The standard deviation maps reflect the asymmetry of the noise between the two measurement areas, but not as pronounced as the image maps.

3) For *outpix* size of 6.″4, there is hardly any difference for the noise values derived from the stdev maps between all *pixfrac* values 0.1, 0.5 and 1.0. For smaller *outpix* sizes 4.″8 and 3.″2 the noise values are identical for *pixfrac* 0.1 and 0.5 for the same *outpix* size, while the *pixfrac* 1.0 values are smaller. This looks suspicious, since the image maps show a clear difference with the trends as described in the summary of Sect. 8.1. We discuss this finding in more detail in the general part of Section 9 (Conclusions).

8.4 Final photometric noise values and determination of correlated noise correction factors

The correlated noise correction factors for 160 µm JScanam maps are determined according to Eq. 2 with the 160 µm reference noise $< \sigma_{\mathrm{aperture,corr}} >^{\mathrm{ref}}_{\mathrm{wmHPF}}$ $(160\,\mu m)$ value from Table 4. For the calculation we have to derive the noise in the standard aperture with radius 10.″7 according to Eq. 1. Table 16 lists the derived $\mathrm{f}^{\mathrm{JS}}_{\mathrm{corr}}$ values. The uncertainty of the $\mathrm{f}^{\mathrm{JS}}_{\mathrm{corr}}$ values is in the order of 5–10%.

Table 16: Noise per measurement aperture $\sigma_{\mathrm{aperture,corr}}$ at 160 µm (aperture radius of 10.″7) and determination of correlated noise correction factor for JScanam maps by comparison with the corrected aperture noise of HPF maps. The combination high-lighted in bold face is used in the Standard Product Generation (SPG). The combination in italics was typical for the PACS photometric flux calibration analysis.

pixfrac/outpix	$\sigma^{JS}_{\mathrm{pix}}$ (mJy/pix)	$\mathrm{N}_{\mathrm{outpixinaper}}$	$\sigma^{JS}_{\mathrm{aperture}}$ (mJy)	$< \sigma_{\mathrm{aperture,corr}} >^{\mathrm{ref}}_{\mathrm{wmHPF50}}$ (mJy)	$\mathrm{f}^{\mathrm{JS}}_{\mathrm{corr}}$
0.1 / 2.″1	0.173±0.009	81.6	1.563±0.081	3.27±0.05	2.093±0.135
0.1 / 3.″2	0.335±0.015	35.1	1.985±0.089	3.27±0.05	1.648±0.099
0.1 / 4.″8	0.639±0.046	15.6	2.524±0.182	3.27±0.05	1.296±0.114
0.1 / 6.″4	0.990±0.072	8.8	2.937±0.214	3.27±0.05	1.114±0.099
0.5 / 3.″2	0.286±0.021	35.1	1.694±0.124	3.27±0.05	1.930±0.172
0.5 / 4.″8	0.588±0.035	15.6	2.322±0.138	3.27±0.05	1.408±0.106
0.5 / 6.″4	0.961±0.077	8.8	2.851±0.228	3.27±0.05	1.147±0.110
1.0 / 2.″1	0.103±0.004	81.6	0.930±0.036	3.27±0.05	3.515±0.190
1.0 / 3.″2	0.237±0.019	35.1	1.404±0.113	3.27±0.05	2.329±0.225
1.0 / 4.″8	0.515±0.030	15.6	2.034±0.119	3.27±0.05	1.608±0.119
1.0 / 6.″4	0.894±0.055	8.8	2.652±0.163	3.27±0.05	1.233±0.095

9 Conclusions

The systematic study (with different mapping parameters pixfrac and output pixel size) of a JScanam processed L2.5 composite of two mini-scan maps gave the following results:

1) JScanam processed maps show a similar behaviour of noise characteristics depending on *pixfrac* and *outpix* parameters as HPF processed maps. This is because both processing methods make use of the PhotProject algorithm.

2) We find that noise values derived from the standard deviation maps contained in the JScanam map product are in most cases identical among different *pixfrac* values for the same *outpix* size (cf. Tables 5, 9 and 13). For the parameter combinations analyzed in our study, there seems to be only a difference in the noise value with *pixfrac*, if the ratio of drop size (*pixfrac* $\times$ native detector pixel size) to *outpix* size changes from less equal 1 to greater than 1. The systematic trend of the noise level with *pixfrac* found for the noise analysis of the image maps is not reflected in the standard deviation maps. This kind of simplification is a common feature of the standard deviation map production in PhotProject, since it is also found for stdev maps associated with high pass filter processing (we verified that for a number of test cases investigated in [RD1]). Since the PACS software is frozen since end of 2016, it was not possible for us anymore to trigger an investigation of the code. However, neglecting the trend of the noise level with *pixfrac* introduces in most cases an uncertainty in the order of 5–20%. We can conclude, that the standard deviation maps give a reasonable estimate of the noise, as will be shown quantitatively for each filter below.

For 70µm maps:

1) The measured noise per pixel in JScanam processed maps is between 13 and 56% higher than in HPF processed maps with the standard HPF radius 15.

2) The standard deviation map of the JScanam L2.5 product gives representative noise per pixel values, which are in most cases at the 0.60–1.08 level of the noise measured inside the same area of the image map.

3) We derived correlated noise correction factors f_{corr}^{JS} under the assumption that the final noise corrected for correlation effects is the same for the HPF=30 and JScanam maps inside the standard aperture with 5.″6 radius.

For 100µm maps:

1) The measured noise per pixel in JScanam processed maps is between 24 and 50% higher than in HPF processed maps with the standard HPF radius 15.

2) The standard deviation map of the JScanam L2.5 product gives representative noise per pixel values, which are in most cases at the 0.70–1.14 level of the noise measured inside the same area of the image map.

3) We derived correlated noise correction factors f_{corr}^{JS} under the assumption that the final noise corrected for correlation effects is the same for the HPF=30 and JScanam maps inside the standard aperture with 6.″8 radius.

For 160µm maps:

1) The measured noise per pixel in JScanam processed maps is between 25 and 82% higher than in HPF processed maps with the standard HPF radius 25.

2) The standard deviation map of the JScanam L2.5 product gives representative noise per pixel values, which are in most cases at the 0.45–0.88 level of the noise measured inside the same area of the image map.

3) We derived correlated noise correction factors f_{corr}^{JS} under the assumption that the final noise corrected for correlation effects is the same for the HPF=50 and JScanam maps inside the standard aperture with 10.″7 radius.

For convenience all f_{corr}^{JS} values are summarized in Table 17.

Table 17: Correlated noise correction factors f_{corr}^{JS} for JScanam map parameter combinations.

pixfrac/outpix	f_{corr}^{JS}
70 µm filter	
0.1 / 1.″1	1.77±0.06
0.1 / 1.″6	1.55±0.06
0.1 / 2.″4	1.31±0.06
0.1 / 3.″2	1.18±0.06
0.5 / 1.″6	1.91±0.06
0.5 / 2.″4	1.44±0.06
0.5 / 3.″2	1.26±0.07
1.0 / 1.″1	3.25±0.12
1.0 / 1.″6	2.31±0.09
1.0 / 2.″4	1.63±0.07
1.0 / 3.″2	1.36±0.06
100 µm filter	
0.1 / 1.″4	1.74±0.04
0.1 / 1.″6	1.62±0.06
0.1 / 2.″4	1.47±0.05
0.1 / 3.″2	1.25±0.05
0.5 / 1.″6	1.97±0.05
0.5 / 2.″4	1.58±0.06
0.5 / 3.″2	1.29±0.05
1.0 / 1.″4	2.88±0.06
1.0 / 1.″6	2.45±0.04
1.0 / 2.″4	1.78±0.07
1.0 / 3.″2	1.37±0.05
160 µm filter	
0.1 / 2.″1	2.09±0.14
0.1 / 3.″2	1.65±0.10
0.1 / 4.″8	1.30±0.11
0.1 / 6.″4	1.11±0.10
0.5 / 3.″2	1.93±0.17
0.5 / 4.″8	1.41±0.11
0.5 / 6.″4	1.15±0.11
1.0 / 2.″1	3.52±0.19
1.0 / 3.″2	2.33±0.23
1.0 / 4.″8	1.61±0.12
1.0 / 6.″4	1.23±0.10