Superdeblending Manual

December 22, 2015

Contents

1 Abstract

This is the manual for the super-deblending photometry. We describe our method and procedures at each wavelength band, and record the latest notes and unsolved issues.

Hints: black text are our method and procedures, blue text are notes, and red text are unsolved issues.

2 Band 100

2.1 SED fitting before band 100

The SED fitting at this step includes these bands:

- K_s
- IRAC 3.6, 4.5, 5.8, 8.0
- IRS PUI 16, MIPS 24
- VLA 1.4 GHz (hereafter radio)

The SED fitting uses the following 3 parameters for better fitting of the SEDs:

- Type_AGN: radio loud AGN, $(f_{radio} - f_{SED}) > 3 \times \sqrt{\sigma^2_{f_{radio}} + \sigma^2_{f_{SED}}}$
- Type_SED: pure starburst, $SFR_{SED} > 6 \times SFR_{MS}$
- Type_FIR: high FIR S/N ratio, $\sqrt{SNR^2_{100} + \cdots + SNR^2_{1160}} > 10$

But at this step, we do not have any prior information about these Type_ parameters. Therefore, we run a trial SED fitting without any Type_ parameter, and use the output to do the Type_AGN and Type_SED classifications:

• Type_AGN: 85 out of 3306 sources are classified as radio loud AGN, for which we will not fit their radio data points.

• Type_SED: 46 out of 3306 sources are classified as pure starburst (hereafter SB), for which we will use only SB type SED templates.

• Type_SED: 1011 out of 3306 sources are classified as pure main-sequence (hereafter MS), for which we will use only MS type SED templates.

Applying these Type_ parameters, we run the SED fitting again, and use the results for the next step SED prediction. Additionally, we update the Type_ parameters, but do not repeat a third fitting for now.

- Type_AGN: 205 out of 3306 radio AGNs.
- Type_SED: 41 out of 3306 pure SB.
- Type_SED: 891 out of 3306 pure MS.

∘ Comparing to the trial step SED fitting: applying Type_AGN leads to lower SED best fitting SFR and S/N ratio for some radio AGNs, therefore their Type_SED changed from pure MS to unclassified.

∘ Code update: 2015-12: introduced a new parameter Type_FIR, but this parameter is not determined from SED fitting results but the galfit photometry results. This parameter will be used since the SED fitting before band 160, but not current step before band 100.

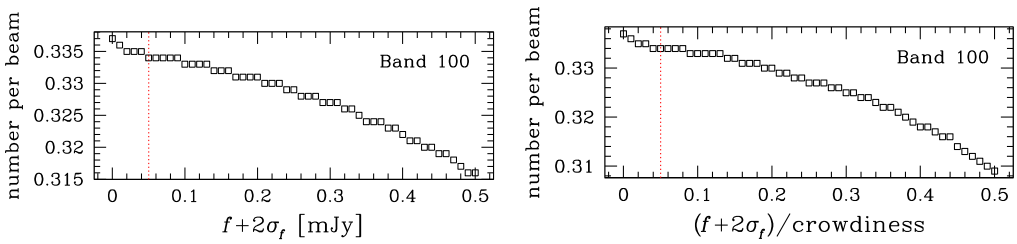
2.2 SED prediction for band 100

We use SED best fitting flux and uncertainty at band 100 as the predicted values to flag faint sources. We set a $(f+2\sigma_f)$ cut f_{cut}, so that brighter or larger uncertainty sources will be kept while fainter and better constrained sources will be flagged and subtracted. A Type_FIT parameter is determined for each source from the SED best fitting results:

- Type_FIT: fit at current band, $(f_{SED} + 2\sigma_{f_{SED}}) > f_{cut}$

○ TODO: 2015-12: I'm thinking about a crowdiness-dependent way to flag sources, so that if a source is relatively isolated, we can use a lower f_{cut} which tends to keep it for fitting, while a source is in a relatively blended environment, we can use a higher f_{cut} so that it tends to be flagged out. The inequation thus becomes $(f_{SED}+2\sigma_{f_{SED}})/crowdiness \geq f_{cut}$.

By varying f_{cut}, we can flag out different number of faint sources, and the number of source kept for photometry fitting will also change. We plot the number density of sources kept for fitting as a function of f_{cut}, with the number density normalized by the PSF area: $A_{\mathrm{PSF}} = \pi/(4\ln 2) \cdot \mathrm{FWHM}^2$:



We decide a $f_{cut} = 0.05$.

- Type_FIT=1: 3280 out of 3306 to fit.
- Type_FIT=0: 26 out of 3306 flagged out.

○ TODO: 2015-12: If crowdiness is used for the flagging $(f_{SED}+2\sigma_{f_{SED}})/crowdiness \geq f_{cut}$, then we have 28 out of 3306 flagged out, i.e. two more faint sources: ID 14834 (spec-z 0.202) and 13732 (spec-z 0.079). I have checked that 13732 has a very nearby source 13731, whose old version SED had a bad χ^2, i.e. 100 and 160 measurements were too low while 250 was much higher than the SED best fit. The new flagging will flag out 13732 since band 100, therefore will likely lead to much better SED of 13731.

2.3 Faint flux subtraction at band 100

We use the SED flux of the flagged faint sources to construct a PSF-modeled image, then subtract it from the original observed image. Using the faint-sources-subtracted image, we perform prior source fitting photometry in the next step.

○ Note: Remember to set Xback=0 and fbias=0 while doing the faint-source subtraction.

2.4 Galfit photometry at band 100

We use supermongo code + galfit software to do the prior source fitting photometry.

We directly use the sky background value from the result of PEP project. (TODO: Confirm?) But because we use Monte-Carlo simulation to correct flux bias and flux uncertainty in a sophisticated way, the choice of sky background value during the photometry will have very little bias to our final measurements.

We correct astrometry when needed. For the PACS 100 and 160 images from PEP project, no astrometry needs to be corrected. (TODO: Confirm?)

But for PACS 100 and 160 images, the flux measurements need high-pass filtering correction:

- If $f_{24} > 60$ and $S/N_{24} > 3$, we multiply a factor $\times 1.12$ to the measured flux, otherwise $\times 1.19$.
  - ○ Note: See "AGN_N.sm".
  - ○ Note: Flux bias: Previously we were using a constant flux bias at band 100, 160 and 1160, while a non-linear σ_f-dependent flux bias at band 250, 350 and 500. Now we decide to fully use Monte-Carlo simulation to derive non-linear correction recipes for flux bias correction. See next part.

2.5 Monte-Carlo simulation at band 100

We simulate one source at each time, and add its PSF-modeled image to the real observed image. Then all sources not flagged out (Type_FIT=1) are fitted together with the simulated source, and we record the recovered flux and flux uncertainty for the simulated source. The simulated flux, or the input flux S_{in}, are compared to the recovered flux, or the output flux S_{out} and the recovered flux uncertainty $\sigma_{S_{out}}$.

We repeat the procedure 6000 times, so that we have 6000 pairs of S_{in}, S_{out}, and $\sigma_{S_{out}}$. Statistical analyses are in the following section.

2.6 Flux bias and flux uncertainty correction

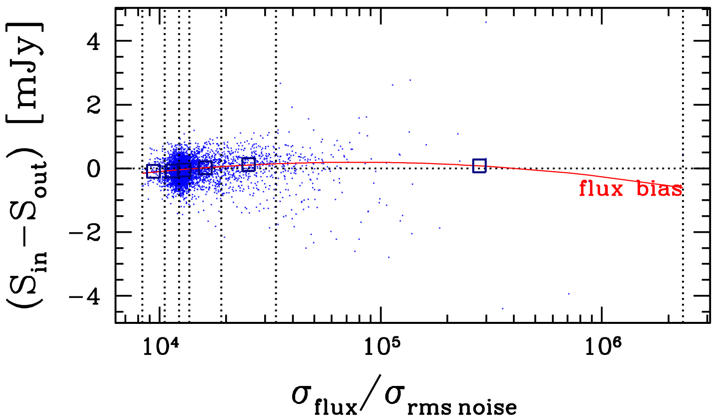
In one aspect, statistically, the differences between S_{in} and S_{out} should have a mean of 0. Any non-zero mean of the differences $\langle (S_{in} - S_{out}) \rangle$ is indicating that there have flux bias in the photometry procedure.

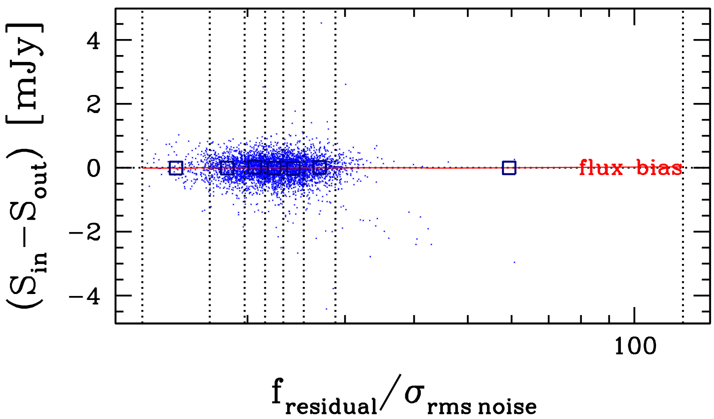
In another aspect, statistically, the flux uncertainty $\sigma_{S_{out}}$ should be consistent with the dispersion of $(S_{in} - S_{out})$. In another word, $(S_{in} - S_{out})/\sigma_{S_{out}}$ should have a shape of Gaussian distribution and a dispersion (Gaussian width $\sigma_{Gaussian}$) of 1.0.

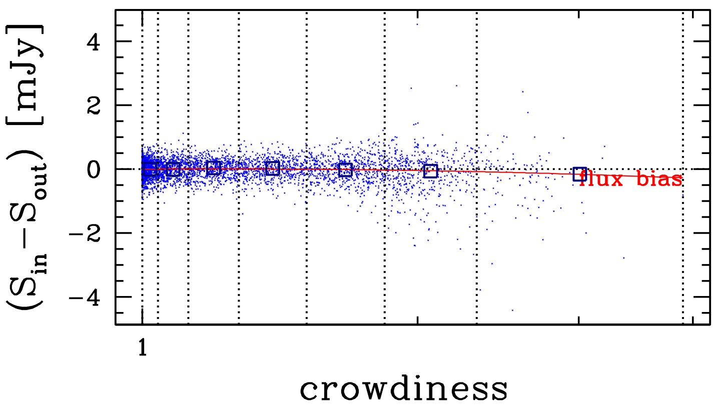
Based on the above two criterion, we can correct both S_{out} and $\sigma_{S_{out}}$. In the simplest way, we can derive a constant flux bias by taking the mean (TODO: or median?) $S_{bias} = \langle (S_{in} - S_{out}) \rangle$, and derive a constant flux uncertainty factor by taking the dispersion $corr_{\sigma_{S_{out}}} = \sigma_{((S_{in}-S_{out})/\sigma_{S_{out}})}$. However, after the simplest corrections, we find that $\sigma_{S_{out}}$ are still not good enough to match the input and output flux $(S_{in} - S_{out})$ in some individual cases, where the simulated sources either have very high $\sigma_{S_{out}}$, or left over imperfect residual, or are in too crowd fields.

Therefore, more sophisticated recipes are analyzed here. (TODO: descriptions.)

(TODO: I put 100 flux bias correction plots here:)



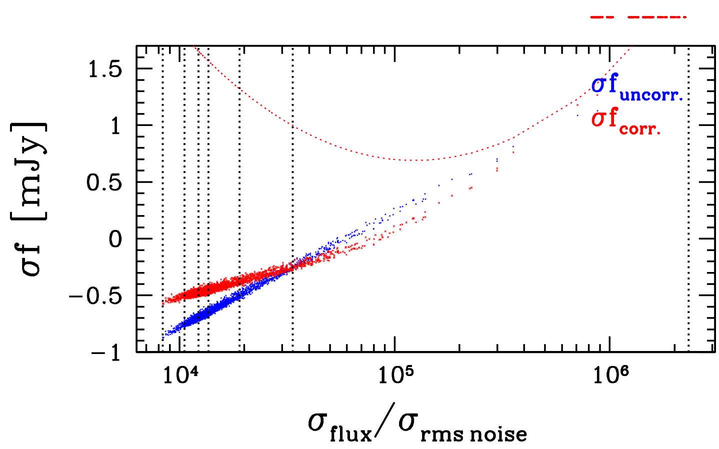


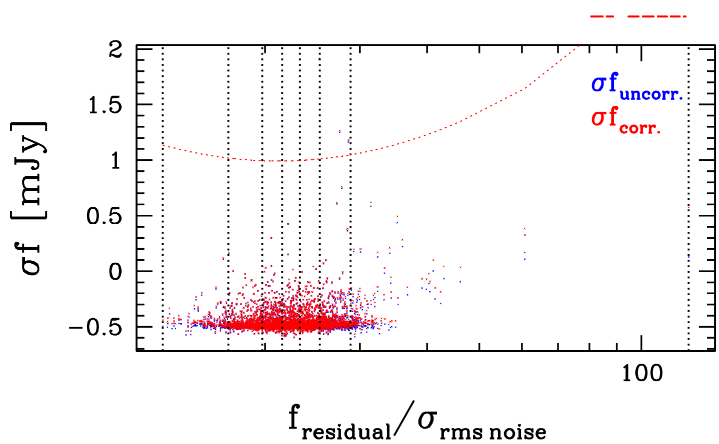


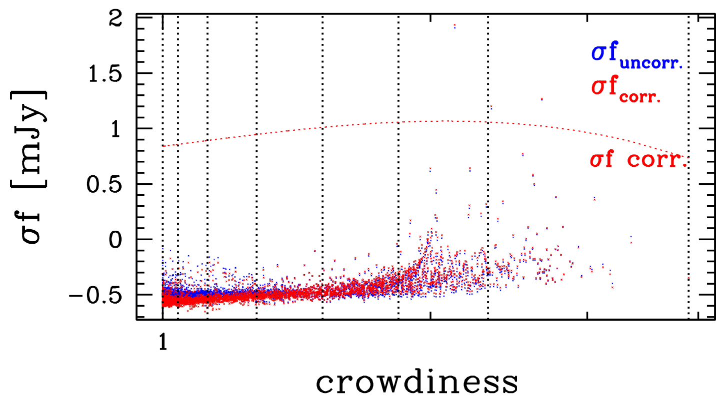
∘ Note: Flux bias corrections: In the plots, the blue data points are uncorrected, while the red ones are corrected. The dashed curve is the flux bias values, which are around 0. A lower than 0 flux bias means that we correct flux bias to be smaller, vice versa.

∘ Note: Flux bias corrections: Seems the flux bias are very small at band 100. Slightly non-linear trend can be found correlating to $\sigma_{flux}/\sigma_{rms\,noise}$.

(TODO: I put 100 flux uncertianty correction plots here:)







∘ Note: Flux uncertainty corrections: In the plots, the blue data points are uncorrected, while the red ones are corrected. The dashed curve is the correction factor values, which are around 1. A lower than 1 corr. factor means that we correct flux uncertainty to be smaller, vice versa.

◦ Note: Flux uncertainty corrections: Seems performing well. The correlation of $\sigma f corr.$ correction factor with $f_{residual}$ is not as prominent as the other two parameters, but it might have stronger correlation at longer wavelength bands.

3 Band 160

3.1 SED fitting before band 160

At this step, we have obtained new flux measurements and flux uncertainty are band 100. Therefore the SED fitting at this step includes:

- K_s
- IRAC 3.6, 4.5, 5.8, 8.0
- IRS PUI 16, MIPS 24
- PACS 100 $^{new!}$
- VLA 1.4 GHz (hereafter radio)

The SED fitting needs the aforementioned 3 parameters to be determined in prior:

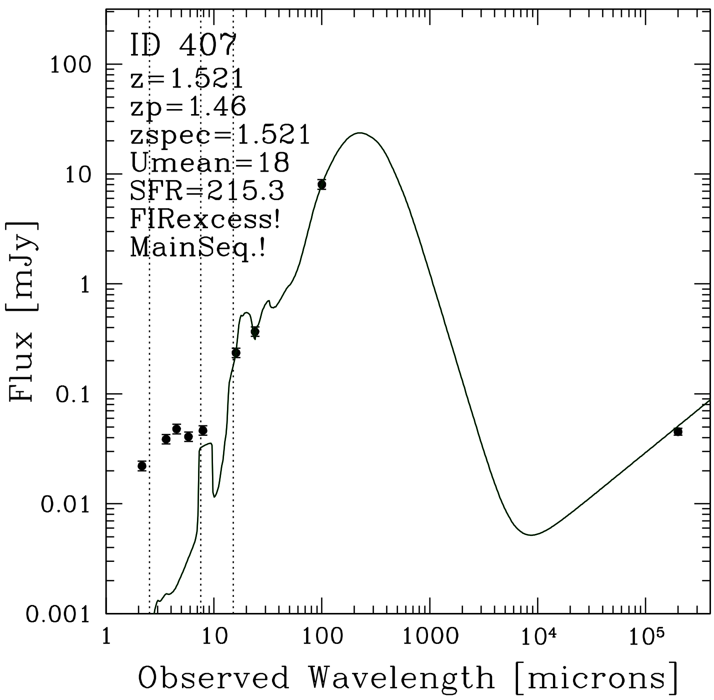
- Type_AGN
- Type_SED
- Type_FIR

We have already obtained Type_AGN and Type_SED through the SED fitting at band 100, but the Type_FIR needs band 100 flux measurements, therefore are determined now:

- Type_FIR=1: $SNR_{100} \geq 10$: fit only FIR data points (i.e. only 100 at this step).
- Type_FIR=1: $SNR_{100} < 10$: fit all data points (but radio depends on Type_AGN).

◦ DONE: 2015-12: Implement SED fitting code, if Type_FIR=1, set all non-FIR bands uncertainty to be 10^{10}, but show their data points in the SED fitting plot. Following is an example of the new SED fitting.

◦ TODO: 2015-12: This might be too stringent. We might use ≥ 5 as a limit, which should be enough to consider the IR as detected by itself.



◦ DONE: 2015-12: Found bug in flux residual measuring, which affects the band 100 simulation step. I have redone from that step.

◦ TODO: 2015-12-21: Found bug in reading the SED prediction file, which affects the band 100 photometry step. I have to redo from that step ···

4 Band 250

5 Band 350

6 Band 500

7 Band 1160