Superdeblending Manual

(GOODS-North)

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1 Abstract

This is the manual for the super-deblending photometry for deep fields. The aim is to solve the severe source blending problem caused by the large point spread functions (PSFs) in far-infrared (FIR) images, and to reach a deepest detection depth. For example, *Herschel* SPIRE images which cover FIR 250μm to 500μm have PSFs' full width half maximum (FWHM) as large as 30-40arcsec. In comparison, the *Spitzer* IRAC images have PSFs' FWHM as small as 1.66-1.98arcsec, and *HST* images have even smaller PSFs.

Instead of blindly detecting sources in the FIR images, we use the prior source information from IRAC catalog (from GOODS-Spitzer project; PI: M. Dickinson). Most galaxies located inside the deep fields can therefore be considered here, unless they are very low-z and too faint to be detected at IRAC, or they are very high-z and have very low stellar mass.

Our method is using redshift- and main-sequence-dependent SED fittings to constraint the number of sources to fit at each FIR band. Therefore the SED fitting is an important part of our work. Another important parts are the galfit photometry, and Monte-Carlo simulation.

In Section 2, we present our flow chart of processes at each FIR band, starting from the initial catalog and image. A summary table is also presented to show the status of processing in Section 3. In the next sections, the details of the processes at each FIR band are listed.

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

2 Flow Chart

Figure 1: Flow Chart of "Super-deblending" Processes at One FIR Band.
The order of processes are: Initial Catalog → SED → predict → subtract → galfit → residual → simulation → statistical corrections → final catalog and SED.

3 Processing Status

Band	SED 1	Predict 2	Subtract 3	Galfit 4	Residual 5	Galsim 6	Correct 7	Final 8
100	[5.1] [Done]	[5.2] [Done]	[5.3] [Done]	[5.4] [Done]	[5.5] [Done]	[5.6] [Done]	[5.8] [Done]	[??] [Done]
160	[6.1] [Done]	[6.2] [Done]	[6.3] [Done]	[6.4] [Done]	[6.5] [Done]	[6.6] [Done]	[6.8] [Done]	[??] [Done]
250	[7.1] [Done]	[7.2] [Done]	[7.3] [Done]	[7.4] [Done]	[7.5] [Done]	[7.6] [Done]	[7.8] [Done]	[??] [Done]
350	[8.1] [Done]	[8.2] [Done]	[8.3] [Done]	[8.4] [Done]	[8.5] [Done]	[8.6] [Done]	[8.8] [Done]	[??] [Done]
500	[9.1] [Done]	[9.2] [Done]	[9.3] [Done]	[9.4] [Done]	[9.5] [Done]	[9.6] [Done]	[9.8] [Done]	[??] [Done]
1160	[10.1] [Done]	[10.2] [Done]	[10.3] [Done]	[10.4] [Done]	[10.5] [Done]	[10.6] [Done]	[10.8] [Done]	[??] [Done]
850	[11.1] [Done]	[11.2] [Done]	[11.3] [Done]	[11.4] [Done]	[11.5] [Done]	[11.6] [Done]	[11.8] [Done]	[??] [Done]

Table 1: Processing Status

4 Current Results

Band	Instrument	PSF arcsec	N_{fit}	$N^{fit}_{S/N>3}$	$N^{add.}_{S/N>3}$	$1\sigma^{sim}$ mJy	$1\sigma^{det.}$ mJy
$24\mu m$	Spitzer/MIPS	5.7	19437	3056	0	6.336e-3	5.165e-3
$20cm$	VLA	$\sim$1.7	19437	1328	0	3.838e-3	2.744e-3
$16\mu m$	Spitzer/IRS/PUI	3.6	3306	1335	0	7.684	7.681
$100\mu m$	Herschel/PACS	7.2	3294	1178	0	0.30	0.315
$160\mu m$	Herschel/PACS	12.0	3137	1153	18	0.70	0.681
$250\mu m$	Herschel/SPIRE	18.2	1540	668	13	1.77	1.571
$350\mu m$	Herschel/SPIRE	24.9	966	292	10	2.20	2.072
$500\mu m$	Herschel/SPIRE	36.3	470	125	17	2.48	2.570
$1160\mu m$	AzTEC+MAMBO	19.5	515	43	11	0.66	0.661

Table 2: Current results. N_{fit} is number of sources being fit at each band. $N^{fit}_{S/N>3}$ is the number of signal-to-noise larger than 3 (i.e. detected) catalog sources which are chosen to be fit at each band. $N^{add.}_{S/N>3}$ is the number of detected additional sources which are chosen from residual image rather than from our 24+radio catalog. $1\sigma^{sim}$ is the one sigma noise derived from Monte-Carlo simulation. $1\sigma^{det.}$ is the one sigma detection limit computed as the median of the flux error of detected sources at each band. TODO: Maybe obsolete 2017-01-04.

5 Band 100

5.1 SED fitting before band 100

We use the redshift- and main-sequence-dependent SED fitting as an important tool to constraint the number of sources to fit at each FIR band. At band 100, we do the SED fitting the first time.

The SED fitting is based on the two-component dust SED templates from Draine & Li (2007), the evolution of galaxies' SEDs found in Magdis et al. (2012), and the latest evolution track of SEDs' $\langle U \rangle$ parameter in Sargent et al. (2014) and Béthermin et al. (2015).

By integrating the stellar component using BC03 templates, and AGN component using Mullaney et al. (2011) templates, as well as the radio component using radio-FIR correlation (e.g. Ivison et al. 2010), we can fit a panchromatic SED from K band all the way to radio band.

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 constraining parameters:

- Type_AGN: radio loud AGN

  defined as: $(f_{radio} - f_{SED}) > 3 \times \sqrt{\sigma^2_{f_{radio}} + \sigma^2_{f_{SED}}}$
- Type_SED: pure starburst type

  defined as: $(\log_{10} SFR_{SED} - \log_{10} SFR_{MS}) > 0.6\, dex$
- Type_FIR: very good FIR detection

  defined as: $\sqrt{SNR^2_{100} + SNR^2_{160} + \cdots + SNR^2_{1160}} > 5$

But at this step, we do not have any prior information about these Type_XXX parameters. Therefore, we run an initial pass SED fitting without any Type_XXX parameter.

We use these commands to run the SED fitting at current step:

```
cd Galsed_Initial/
rm coo_*.txt coo_*.log
./do_GalsedRunqsub \
-catalog "RadioOwenMIPS24_priors_v5_20151201_BeforeBand100.txt"
./do_GalsedRunqsub \
-catalog "RadioOwenMIPS24_priors_v5_20151201_BeforeBand100.txt" -postparallel
```

Then we use the output results to do the Type_AGN and Type_SED classifications.

We use these commands to do the Type_AGN and Type_SED parameter classifications at

current step:

```
cd Galsed_Initial/
cd do_Type_AGN/
sm <<< "macro read do_Type_AGN.sm do_Type_AGN"
cp coo_AGN.txt coo_AGN.log ../
cd ../
cd do_Type_SED/
sm <<< "macro read do_Type_SED.sm do_Type_SED"
cp coo_SED.txt coo_SED.log ../
cd ../
```

The number of radio loud AGN sources and pure starburst sources are listed as follows:

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

○ Done: 2016-01: Found severe bug in do_Type_SED.sm! We were using the inequation "(lgSFR-msSFR-lg(1.73)>0.6)", where lgSFR is our SED best fitting SFR in log space and in Chabrier IMF, and msSFR is the main sequence SFR in log space computed with our stellar mass in Salpeter IMF. A factor of 1.73 is applied to convert the IMFs, but it should be "(lgSFR-msSFR+lg(1.73)>0.6)". This bug leads to much smaller number of SB type sources. Need to correct in the next time processes! Done: 2016-02.

Applying these Type_XXX parameters, we run a second pass SED fitting with these commands:

```
cd Galsed_BeforeBand100/
cp ../Galsed_Initial/coo_*.* .
./do_GalsedRunqsub \
-catalog "RadioOwenMIPS24_priors_v5_20151201_BeforeBand100.txt"
./do_GalsedRunqsub \
-catalog "RadioOwenMIPS24_priors_v5_20151201_BeforeBand100.txt" -postparallel
```

After the second pass SED fitting, we update the Type_XXX parameters:

```
cd Galsed_BeforeBand100/
cd do_Type_AGN/
sm <<< "macro read do_Type_AGN.sm do_Type_AGN"
cp coo_AGN.txt coo_AGN.log ../
cd ../
cd do_Type_SED/
sm <<< "macro read do_Type_SED.sm do_Type_SED"
cp coo_SED.txt coo_SED.log ../
cd ../
```

The new number of radio loud AGN sources and pure starburst sources are listed as follows:

- Type_AGN: 205 radio AGNs, 3306 in total.
- Type_SED: 41 pure SB, 891 pure MS, 3306 in total.

○ NOTE: 2015-12: Comparing to the initial pass 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.

○ 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.

5.2 SED prediction for band 100

Before the galfit photometry at each band, we use our parameter-dependent SED fitting to predict the flux at current band. Based on the SED prediction, we decide whether some very faint sources should be excluded from the fitting.

Considering both the SED predicted flux and the uncertainty derived from the χ^2 distribution, some sources are highly likely having a very faint flux at current band, and are smaller than the detection depth estimated from simulation analysis.

Therefore, we define a cutting value f_{cut} for the combined flux and uncertainty item $(f + 2\sigma_f)$ at each band. Sources with $(f + 2\sigma_f)$ larger than f_{cut} will be kept for the next step galfit photometry, while fainter and better constrained sources will be excluded from the fitting.

A Type_FIT parameter is determined for each source from the SED best fitting results:

- Type_FIT: fit at current band, $(f_{SED} + 2\sigma_{f_{SED}}) > f_{cut}$
- OBSOLETE: 2016-01:
  Type_FIT: fit at current band, $(f_{SED} + 2\sigma_{f_{SED}})/crowdiness > f_{cut}$ $^{obsolete!}$

○ NOTE: 2015-12: dzliu: 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 $(f_{SED} + 2\sigma_{f_{SED}})/crowdiness \geq f_{cut}$.

○ NOTE: 2015-12: dzliu: The "crowdiness" property of a prior source is the sum of the Gaussian-type weights of all surrounding sources including the source itself:
$crowdiness_i = \sum_{j=1}^{N} e^{-4\ln 2\cdot\left((\mathrm{RA}_j-\mathrm{RA}_i)^2+(\mathrm{Dec}_j-\mathrm{Dec}_i)^2\right)/(\mathrm{FWHM})^2}$.

○ NOTE: 2015-12: dzliu: I have computed the "crowdiness" values using this equation, and with proper FWHM values as recorded in "goFine.sm" and "astroPhot.sm". Note that the computations before were normalized to arbitary value and were not using proper FWHM at each band.

With different f_{cut}, the number of faint sources that are flagged out changes, and the number of sources kept for fitting also changes as a function of f_{cut}. Dividing the number of sources by the PSF beam area: $A_{\mathrm{PSF}} = \pi/(4\ln 2)\cdot \mathrm{FWHM}^2$, the density of sources for fitting (ρ_{fit}) can

be derived. We decide the best f_{cut} value by ensuring that ρ_{fit} is not larger than 1 source per beam, so that the photometry performance can be improved.

Figure 2: Number of sources kept for fitting per PSF beam area (ρ_{fit}) as a function of different f_{cut} at band 100. ρ_{fit} is small at band 100, therefore even without flagging out any sources, the photometry performance can still be good. But we still decide to set a very low f_{cut} to flag out a few sources that are predicted to be too faint or in too crowd environment.

We use a $f_{cut} = 0.30$ at band 100, then run the following code to compute how many sources to fit and the rest to be excluded from fitting.

```
cd Galsed_BeforeBand100
./do_Type_FIT.sh
# 2016-02-12 23:43:28 CST
band: 100
fcut: 0.3028   # mJy # the cutting value of f+2df
fsig: 0.3028   # mJy # the 1-sigma detection limit
Total source number: 3306
Fitting source number: 3294
Subtract source number: 12
```

OBSOLETE: 2016-03:

We use a $f_{cut} = 0.05$ at band 100, which leads to:

- Type_FIT: 3278 out of 3306 sources will be used as prior sources at band 100, while 28 out of 3306 sources are flagged out, including ID 14834 and 13731.
- OBSOLETE: 2015-12:

  Type_FIT: 3280 out of 3306 sources will be used as prior sources at band 100, while 26 out of 3306 sources are flagged out, which will be not used as prior sources but whose flux will be subtracted from the observed image. $^{obsolete!}$

  - NOTE: 2015-12: dzliu: 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.

◦ NOTE: 2015-12: dzliu: Now we use $(f_{SED} + 2\sigma_{f_{SED}})/crowdiness > f_{cut}$ as the criterion to flag out too faint sources.

◦ NOTE: 2016-01: edaddi: We either not use crowdiness in the process of selecting sources, or we use it guided by simulations, verifying how crowdiness affects the noise, and keeping into account that trend, which is non linear. From the manual it seems it is also weak, at 100um, dunno the other bands. The non-linear dependence might change among bands… might be hard to properly implement this. Certainly quicker to go back to previous way, but the idea to keep into account crowdiness was good, anyway.

◦ Note: 2016-01: dzliu: do_Type_FIT.sm will not use crowdiness to flag faint sources for now.

5.3 Faint flux subtraction at band 100

We also decide to subtract the contribution of faint sources that are not going to be fit to the original observed image. Which is, we run galfit to generate a faint source model image, using their SED predicted flux, then run IRAF imarith to subtract the faint source model image from the original observed image at current band.

The commands used for creating faint source model image and then the image subtraction are:

```
ssh -X planer # login
qsub -IX -l walltime=24:00:00 # start qsub environment
source /dsm/upgal/data/dliu/Superdeblending/Softwares/SETUP
cd /dsm/upgal/data/$USER/Superdeblending/GOODSN/Galfit_Band100/
./do_Galsub 100 201601 \
-catalog "RadioOwenMIPS24_priors_v6_24.txt" \
-fitsname "pgh_goodsn_green_Map_v1.0_sci_DL.fits" \
-sedpredict "SED_predictions_100_201601.txt"
exit # end qsub environment
exit # logout
```

The figure below shows the original observed image, the faint source model image, and the faint source subtracted image from left to right at current band.

TODO: Faint-source subtraction screen-shot at band 100.

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.

5.4 Galfit photometry at band 100

We use the following command to run supermongo code + galfit software for the prior source fitting photometry.

```
ssh -X planer # login
#
# step 1. divide image into box regions
#
qsub -IX -l walltime=24:00:00 # start qsub environment
source '/dsm/upgal/data/dliu/Superdeblending/Softwares/SETUP'
cd /dsm/upgal/data/$USER/Superdeblending/GOODSN/Galfit_Band100/
do_Galfit "100" "201601" \
-catalog "RadioOwenMIPS24_priors_v6_24.txt" \
-fitsname "pgh_goodsn_green_Map_v1.0_sci_subfaintDL.fits" \
-sedpredict "SED_predictions_100_201601.txt"
exit # end qsub environment
#
# step 2. run galfit for all box regions
#
cd boxgalfit/
do_GalfitRunqsub
cd ../
#
# step 3. combine all fitted results in box regions
#
qsub -IX -l walltime=24:00:00 # start qsub environment
source '/dsm/upgal/data/dliu/Superdeblending/Softwares/SETUP'
cd /dsm/upgal/data/$USER/Superdeblending/GOODSN/Galfit_Band100/
do_Galfit "100" "201601" \
-catalog "RadioOwenMIPS24_priors_v6_24.txt" \
-fitsname "pgh_goodsn_green_Map_v1.0_sci_subfaintDL.fits" \
-sedpredict "SED_predictions_100_201601.txt" -postparallel
exit # end qsub environment
#
# end
#
exit # logout
```

We use the sky background value based on previous simulation results (define Xback XXX in goFine.sm).

We correct astrometry when needed (goSimu.sm). For the PACS 100 and 160 images from PEP project, no additional astrometry needs to be corrected.

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.
  - Note: Sky background: we have verified that median input minus measured very close to zero.

○ Confirmed: For the PACS 100 and 160 images from PEP project, no additional astrometry needs to be corrected.

5.5 Residual image at band 100

We found no obvious additional source from the residual image of band 100.

5.6 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.

The commands for running the simulations are:

```
ssh -X planer # login
#
# step 1. divide image into box regions
#
qsub -IX -l walltime=24:00:00 # start qsub environment
source '/dsm/upgal/data/dliu/Superdeblending/Softwares/SETUP'
cd /dsm/upgal/data/$USER/Superdeblending/GOODSN/Galsim_100/
do_Galsim "100" "201601" -mag0 6 -mag1 10 \
-catalog "RadioOwenMIPS24_priors_v6_24.txt" \
-fitsname "pgh_goodsn_green_Map_v1.0_sci_subfaintDL.fits" \
-sedpredict "SED_predictions_100_201601.txt"
exit # end qsub environment
#
# step 2. run galfit for all box regions
#
cd boxgalsim/
do_GalsimRunqsub
cd ../
#
# step 3. combine all fitted results in box regions
#
qsub -IX -l walltime=24:00:00 # start qsub environment
source '/dsm/upgal/data/dliu/Superdeblending/Softwares/SETUP'
cd /dsm/upgal/data/$USER/Superdeblending/GOODSN/Galfit_Band100/
do_Galsim "100" "201601" -mag0 6 -mag1 10 \
-catalog "RadioOwenMIPS24_priors_v6_24.txt" \
-fitsname "pgh_goodsn_green_Map_v1.0_sci_subfaintDL.fits" \
-sedpredict "SED_predictions_100_201601.txt" -postparallel
exit # end qsub environment
#
```

```
# end
#
exit # logout
```

5.7 Flux bias and flux error analyses

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 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.)

Figure 3: Band 100 flux bias correction plots.

○ 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 $\sigma_{flux}/\sigma_{rms\,noise}$.

Figure 4: Band 100 histogram of simulated source flux before and after each step correction.

Figure 5: Band 100 flux uncertainty correction plots.

○ 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.

Figure 6: Band 100 histogram of flux error before and after each step correction.

5.8 Flux bias and flux error correction

Now we apply the 3-step correction recipe to real measurements.

```
sm
macro read run_simu_stats_v8.sm run_simu_stats_v8 100
```

6 Band 160

6.1 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 uses the 3 aforementioned parameters, two of which have already been determined in the step ??:

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

The 3rd parameter is Type_FIR, which defines whether the SED will use only FIR (100-1160) data points or not. At this step, the Type_FIR parameter needs band 100 flux measurements to determine:

- Type_FIR: If $SNR_{100} \geq 5$, we fit only FIR data points (i.e. only 100 at this step). While $SNR_{100} < 5$, we fit all data points (but radio depends on Type_AGN).

  ◦ DONE: 2015-12: Implement SED fitting code, that when Type_FIR=1, we mask the non-FIR data points by setting the uncertainty values to 10^{10}, but we still show their measured data points in the SED fitting plot.

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

Following are two examples of Type_FIR=1 SEDs:

Figure 7: Left: results at 2016-01, the SED fitting before galfit photometry at band 160. Right: results at 2016-03, the final SED fitting.

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

○ DONE: 2015-12-21: Found bug in reading the SED prediction file, which affects the band 100 photometry step. I have redone from that step.

○ DONE: 2015-12-22: Found bug in supermongo! The supermongo on planer produces different SED best fitting PDF plots, but consistent SED best fitting text files. This is likely because the supermongo on planer was compiled with "float" type, while on my local PC it was compiled with "double" type. Now I have recompiled supermongo on planer, and the new plots look consistent. The SED best fitting text files seem consistent with my PC results, so no need to redo text files. Therefore, we must follow the same compiling procedure for supermongo as listed in Section C.

6.2 SED prediction for band 160

```
cd Galsed_BeforeBand160
./do_Type_FIT.sh
# 2016-02-16 19:49:05 CST
band: 160
fcut: 1.1   # mJy # the cutting value of f+2df
fsig: 0.7   # mJy # the 1-sigma detection limit
Total source number: 3306
Fitting source number: 3137
Subtract source number: 169
```

With the best fitting flux at 160um, we can determine which sources to fit and band 160 and which to be flagged out and subtracted:

Figure 8: Number of sources kept for fitting per PSF beam area (ρ_{fit}) as a function of different f_{cut} at band 160. ρ_{fit} is small at band 160, but we still decide to set a very low f_{cut} to flag out a few sources that are predicted to be too faint or in too crowd environment.

• Type_FIT: $(f_{SED,160}+2\sigma_{f_{SED,160}}/crowdiness) \geq 0.80$, 2904 sources will be fit while 402 sources be flagged out.

6.3 Faint flux subtraction at band 160

We use the SED flux of the flagged faint sources to construct a PSF-modeled image, then subtract it from the original observed image.

```
./do_Galsub 160 201512 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand160.txt \
-fitsname pgh_goodsn_red_Map_v1.0_sci_DL.fits \
-sedpredict SED_predictions_160_201512.txt
```

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.

6.4 Galfit photometry at band 160

```
./do_Galfit 160 201512 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand160.txt \
-fitsname pgh_goodsn_red_Map_v1.0_sci_subfaintDL.fits \
-sedpredict SED_predictions_160_201512.txt
# then run scripts in parallel
cd boxgalfit; do_GalfitRunqsub
cd ..
# then run postparallel process
./do_Galfit 160 201512 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand160.txt \
```

```
-fitsname pgh_goodsn_red_Map_v1.0_sci_subfaintDL.fits \
-sedpredict SED_predictions_160_201512.txt \
-postparallel
```

```
./do_Galfit 160 201512 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand160.txt \
-fitsname pgh_goodsn_red_Map_v1.0_sci_subfaintDL.fits \
-sedpredict SED_predictions_160_201512.txt \
-vary
# then run scripts in parallel
cd boxgalfit_vary; do_GalfitRunqsub
cd ..
# then run postparallel process
./do_Galfit 160 201512 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand160.txt \
-fitsname pgh_goodsn_red_Map_v1.0_sci_subfaintDL.fits \
-sedpredict SED_predictions_160_201512.txt \
-vary -postparallel
```

6.5 Residual image at band 160

```
cd run_sextractor_160/
idl -e 'do_SExtract_Mask, \
FitsFile="FIT_goodsn_160_Map_201512.fits", \
RmsFile="pgh_goodsn_red_Map_v1.0_rms_DL.fits"'
vim default.sex # set sigma thresholds
sex SExtractor_Signal.fits
# then write additional residual source catalog
# with supermongo code do_sextract_result.sm
gedit do_sextract_result.sm
...
define band 160
set catalog = {"RadioOwenMIPS24_priors_v6_20151221_BeforeBand160.txt"}
set rmsfits24 = {"n_mips_1_s1_v0_37_rms_ED.fits"}
set catalogadd = {"Residual_priors_v6_Band160.txt"}
...
print $(catalogadd) '%-9.0f %12.7f %12.7f %9g\n' \
{_id _ra _de zp_X f24 df24 f16 df16 f100 df100 \
radio eradio _fch1 _dfch1 _fch2 _dfch2 _fch3 _dfch3 _fch4 _dfch4 \
KtotX MassX distX spezX zq source distz idz goodArea}
...
macro read do_sextract_result.sm go
```

(TODO: Put Residual Images Here!)

Then run a second pass 6.4:

```
./do_Galfit 160 201512 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand160.txt \
-catalog-add Residual_priors_v6_Band160.txt \ # new!
-fitsname pgh_goodsn_red_Map_v1.0_sci_subfaintDL.fits \
-sedpredict SED_predictions_160_201512.txt
```

```
# then run scripts in parallel
cd boxgalfit; do_GalfitRunqsub
cd ..
# then run postparallel process
./do_Galfit 160 201512 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand160.txt \
-catalog-add Residual_priors_v6_Band160.txt \ # new!
-fitsname pgh_goodsn_red_Map_v1.0_sci_subfaintDL.fits \
-sedpredict SED_predictions_160_201512.txt \
-postparallel
```

6.6 Monte-Carlo simulation at band 160

```
# first estimate simulating flux or magnitude range
sm
load astroPhot.sm
convert_flux2mag goodsn 160 0.40 1.0 # 1σ 0.43mJy mag=9
convert_flux2mag goodsn 160 12.0 1.0 # 30σ 12mJy mag=5.2
# then run simulation code
./do_Galsim 160 20151201 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand160.txt \
-fitsname pgh_goodsn_red_Map_v1.0_sci_subfaintDL.fits \
-sedpredict SED_predictions_160_201512.txt \
-fitincl \
-mag0 5.2 -mag1 9 -nsim 6000
```

6.7 Flux bias and flux error analyses

Figure 9: Band 160 flux bias correction plots.

Figure 10: Band 160 histogram of flux.

Figure 11: Band 160 flux uncertainty correction plots.

Figure 12: Band 160 histogram of flux error before and after each step correction.

6.8 Flux bias and flux uncertainty correction

```
macro read run_simu_stats_v8.sm run_simu_stats_v8 160
```

6.9 Update catalog with the measurements of band 160

```
gedit run_simu_stats_v8.sm
define imax 160
define xdate_galsed 201512
```

```
define xdate_galfit 201512
define xdate_galsim 20151201
define xpath_galsed "Galsed_BeforeBand"$imax""
define xpath_galfit "Galfit_Band"$imax"_Pass2"
define xpath_galsim "Galsim_Band"$imax""
set old_catalog = {"RadioOwenMIPS24_priors_v6_20151221_BeforeBand160.txt"}
set new_catalog = {"RadioOwenMIPS24_priors_v6_20151221_BeforeBand250.txt"} \
# found fres -- simu.fits[2] error in previous data, \
# now corrected to [3]. redone Galsim statistics.
set add_catalog = {"Residual_priors_v6_Band160.txt"}
sm
macro read run_update_catalog_v6.sm run_update_catalog_v6
```

7 Band 250

7.1 SED fitting before band 250

Firstly, we use the Type_AGN and Type_SED determined in 6.1:

- Type_AGN: more radio loud AGNs now. Numbers TODO.
- Type_SED: more MS now. Numbers TODO.

Then we determine Type_FIR with the latest 160 measurements:

- Type_FIR: $\sqrt{SNR_{100}^2 + SNR_{160}^2} \geq 5$: 940 out of 3320 sources will be fit with only FIR data points. This includes 1 additional residual source.

Then, do not forget to append zeros to coo_AGN and coo_SED files for those additional residual sources! Here we have 14 of them, and we set all of their Type_AGN and Type_SED to 0, because they do not have radio data point, nor stellar mass measurement.

7.2 SED prediction for band 250

```
cd Galsed_BeforeBand250
./do_Type_FIT.sh
# 2016-02-20 18:59:07 CST
band: 250
fcut: 5.2   # mJy # the cutting value of f+2df
fsig: 1.77   # mJy # the 1-sigma detection limit
Total source number: 3306
Fitting source number: 1540
Fitting source number (SED prediction selection): 1184
Fitting source number (previous band S/N selection): 1152
Subtract source number: 1766
```

Figure 13: Number of sources kept for fitting per PSF beam area (ρ_{fit}) as a function of different f_{cut} at band 250.

7.3 Faint flux subtraction at band 250

We use the SED flux of the flagged faint sources to construct a PSF-modeled image, then subtract it from the original observed image.

```
./do_Galsub 250 201512 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand250.txt \
-fitsname spire250_ima_3p6_v0_100615.fits \
-sedpredict SED_predictions_250_201512.txt
```

Figure 14: Faint-source subtraction step at band 250. From left to right: original image, faint-source model image, and faint-source-subtracted 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.

7.4 Galfit photometry at band 250

```
./do_Galfit 250 201512 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand250.txt \
-fitsname spire250_ima_3p6_v0_100615_subfaintDL.fits \
-sedpredict SED_predictions_250_201512.txt
# then run scripts in parallel
cd boxgalfit; do_GalfitRunqsub
cd ..
# then run postparallel process
./do_Galfit 250 201512 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand250.txt \
-fitsname spire250_ima_3p6_v0_100615_subfaintDL.fits \
-sedpredict SED_predictions_250_201512.txt \
-postparallel
```

7.5 Residual image at band 250

```
cd run_sextractor_250/
idl -e 'do_SExtract_Mask, \
FitsFile="FIT_goodsn_250_Map_201512.fits", \
RmsFile="spire250_rms_3p6_v0_100615.fits"'
vim default.sex # set sigma thresholds
sex SExtractor_Signal.fits
# then write additional residual source catalog
# with supermongo code do_sextract_result.sm
gedit do_sextract_result.sm
...
define band 250
```

```
set catalog = {"RadioOwenMIPS24_priors_v6_20151221_BeforeBand250.txt"}
set rmsfits24 = {"n_mips_1_s1_v0_37_rms_ED.fits"}
set catalogadd = {"Residual_priors_v6_Band250.txt"}
...
print $(catalogadd) '%-9.0f %12.7f %12.7f %9g\n' \
{_id _ra _de zp_X f24 df24 f16 df16 f100 df100 f160 df160 \
radio eradio _fch1 _dfch1 _fch2 _dfch2 _fch3 _dfch3 _fch4 _dfch4 \
KtotX MassX distX spezX zq source distz idz goodArea}
...
macro read do_sextract_result.sm go
```

(TODO: Put Residual Images Here!)

Then run a second pass 7.4:

```
./do_Galfit 250 201512 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand250.txt \
-catalog-add Residual_priors_v6_Band250.txt \ # new!
-fitsname spire250_ima_3p6_v0_100615_subfaintDL.fits \
-sedpredict SED_predictions_250_201512.txt
# then run scripts in parallel
cd boxgalfit; do_GalfitRunqsub
cd ..
# then run postparallel process
./do_Galfit 250 201512 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand250.txt \
-catalog-add Residual_priors_v6_Band250.txt \ # new!
-fitsname spire250_ima_3p6_v0_100615_subfaintDL.fits \
-sedpredict SED_predictions_250_201512.txt \
-postparallel
```

7.6 Monte-Carlo simulation at band 250

```
# first estimate simulating flux or magnitude range
sm
load astroPhot.sm
convert_flux2mag goodsn 250 1.90 1.0 # 250um 1-sigma 1.98mJy -> mag=3.069
convert_flux2mag goodsn 250 57.0 1.0 # -> mag=-0.62
# then run the simulation code
./do_Galsim 250 20151201 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand250.txt \
-fitsname spire250_ima_3p6_v0_100615_subfaintDL.fits \
-sedpredict SED_predictions_250_201512.txt \
-fitincl -mag0 -0.62 -mag1 3.07 -nsim 6000
./do_Galsim 250 20151201 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand250.txt \
-fitsname spire250_ima_3p6_v0_100615_subfaintDL.fits \
-sedpredict SED_predictions_250_201512.txt \
-fitincl -mag0 -0.62 -mag1 3.07 -nsim 6000 \
-postparallel
```

7.7 Flux bias and flux error analyses

Figure 15: Band 250 flux bias correction plots.

Figure 16: Band 250 histogram of simulated source flux before and after each step correction.

Figure 17: Band 250 flux uncertainty correction plots.

Figure 18: Band 250 histogram of flux error before and after each step correction.

7.8 Flux bias and flux uncertainty correction

```
gedit run_simu_stats_v8.sm
sm
macro read run_simu_stats_v8.sm run_simu_stats_v8 250
```

7.9 Update catalog with new corrected measurements

```
gedit run_update_catalog_v6.sm
define xdate_galsed 201512
define xdate_galfit 201512
define xdate_galsim 20151201
define xpath_galsed "Galsed_BeforeBand"$imax""
define xpath_galfit "Galfit_Band"$imax"_Pass2"
define xpath_galsim "Galsim_Band"$imax""
set old_catalog = {"RadioOwenMIPS24_priors_v6_20151221_BeforeBand250.txt"}
set new_catalog = {"RadioOwenMIPS24_priors_v6_20151221_BeforeBand350.txt"}
set add_catalog = {"Residual_priors_v6_Band250.txt"}
sm
macro read run_update_catalog_v6.sm run_update_catalog_v6 250
```

8 Band 350

8.1 SED fitting before band 350

Firstly, we use the Type_AGN and Type_SED determined in 7.1:

- Type_AGN: more radio loud AGNs now. Numbers TODO.
- Type_SED: more MS now. Numbers TODO.
  - Note: do not forget to append zeros for additional sources found in the residual image of 250.

Then we determine Type_FIR with the latest 250 measurements:

- Type_FIR: $\sqrt{SNR_{100}^2 + SNR_{160}^2 + SNR_{250}^2} \geq 5$: 1047 out of 3334 sources will be fit with only FIR data points. This includes the additional residual sources found on 160 and 250 residual images.

Run SED fitting code on planer:

```
scp Galsed_BeforeBand350_BeforeFitting_20151223.tar.gz \
dliu@hubble.extra.cea.fr:/dsm/upgal/data/dliu/daddi_goodsn_2015/
cd /dsm/upgal/data/dliu/daddi_goodsn_2015/Galsed_BeforeBand350/
./do_GalsedRunqsub
```

8.2 SED prediction for band 350

```
cd Galsed_BeforeBand350
./do_Type_FIT.sh
# 2016-02-23 01:01:08 CST
band: 350
fcut: 8.6   # mJy # the cutting value of f+2df
fsig: 2.2   # mJy # the 1-sigma detection limit
Total source number: 3306
Fitting source number: 841
Fitting source number (SED prediction selection): 444
Fitting source number (previous band S/N selection): 669
Subtract source number: 2465
```

Figure 19: Number of sources kept for fitting per PSF beam area (ρ_{fit}) as a function of different f_{cut} at band 350.

8.3 Faint flux subtraction at band 350

We use the SED flux of the flagged faint sources to construct a PSF-modeled image, then subtract it from the original observed image.

```
./do_Galsub 350 201512 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand350.txt \
-fitsname spire350_ima_4p8_v0_100615.fits \
-sedpredict SED_predictions_350_201512.txt
```

Figure 20: Faint-source subtraction step at band 350. From left to right: original image, faint-source model image, and faint-source-subtracted 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.

8.4 Galfit photometry at band 350

```
./do_Galfit 350 201512 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand350.txt \
-fitsname spire350_ima_4p8_v0_100615_subfaintDL.fits \
-sedpredict SED_predictions_350_201512.txt
# then run scripts in parallel
cd boxgalfit; do_GalfitRunqsub
cd ..
# then run postparallel process
./do_Galfit 350 201512 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand350.txt \
-fitsname spire350_ima_4p8_v0_100615_subfaintDL.fits \
-sedpredict SED_predictions_350_201512.txt \
```

```
-postparallel
```

8.5 Residual image at band 350

```
cd run_sextractor_350/
idl -e 'do_SExtract_Mask, \
FitsFile="FIT_goodsn_350_Map_201512.fits", \
RmsFile="spire350_rms_4p8_v0_100615.fits"'
vim default.sex # set sigma thresholds
sex SExtractor_Signal.fits
# then write additional residual source catalog
# with supermongo code do_sextract_result.sm
gedit do_sextract_result.sm
...
define band 350
set catalog = {"RadioOwenMIPS24_priors_v6_20151221_BeforeBand350.txt"}
set rmsfits24 = {"n_mips_1_s1_v0_37_rms_ED.fits"}
set catalogadd = {"Residual_priors_v6_Band350.txt"}
...
print $(catalogadd) '%-9.0f %12.7f %12.7f %9g\n' \
{_id _ra _de zp_X f24 df24 f16 df16 f100 df100 f160 df160 f250 df250 \
radio eradio _fch1 _dfch1 _fch2 _dfch2 _fch3 _dfch3 _fch4 _dfch4 \
KtotX MassX distX spezX zq source distz idz goodArea}
...
macro read do_sextract_result.sm go
```

(TODO: Put Residual Images Here!)

Then run a second pass 8.4:

```
./do_Galfit 350 201512 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand350.txt \
-catalog-add Residual_priors_v6_Band350.txt \ # new!
-fitsname spire350_ima_4p8_v0_100615_subfaintDL.fits \
-sedpredict SED_predictions_350_201512.txt
# then run scripts in parallel
cd boxgalfit; do_GalfitRunqsub
cd ..
# then run postparallel process
./do_Galfit 350 201512 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand350.txt \
-catalog-add Residual_priors_v6_Band350.txt \ # new!
-fitsname spire350_ima_4p8_v0_100615_subfaintDL.fits \
-sedpredict SED_predictions_350_201512.txt \
-postparallel
```

8.6 Monte-Carlo simulation at band 350

8.7 Flux bias and flux error analyses

Figure 21: Band 350 flux bias correction plots.

Figure 22: Band 350 histogram of simulated source flux before and after each step correction.

Figure 23: Band 350 flux uncertainty correction plots.

Figure 24: Band 350 histogram of flux error before and after each step correction.

8.8 Flux bias and flux uncertainty correction

```
gedit run_simu_stats_v8.sm
sm
macro read run_simu_stats_v8.sm run_simu_stats_v8 350
```

9 Band 500

9.1 SED fitting before band 500

Firstly, we use the Type_AGN and Type_SED determined in 8.1:

- Type_AGN: Numbers TODO.
- Type_SED: Numbers TODO.
  - Note: do not forget to append zeros for additional sources found in the residual image of 350.

Then we determine Type_FIR with the latest 350 measurements:

- Type_FIR: $\sqrt{SNR_{100}^2 + SNR_{160}^2 + SNR_{250}^2 + SNR_{350}^2} \geq 5$: 1092 out of 3361 sources will be fit with only FIR data points.

9.2 SED prediction for band 500

```
cd Galsed_BeforeBand500
./do_Type_FIT.sh
# 2016-02-25 03:47:14 CST
band: 500
fcut: 7.44   # mJy # the cutting value of f+2df
fsig: 2.48   # mJy # the 1-sigma detection limit
Total source number: 3306
Fitting source number: 470
Fitting source number (SED prediction selection): 284
Fitting source number (previous band S/N selection): 292
Subtract source number: 2836
```

Figure 25: Number of sources kept for fitting per PSF beam area (ρ_{fit}) as a function of different f_{cut} at band 500.

9.3 Faint flux subtraction at band 500

We use the SED flux of the flagged faint sources to construct a PSF-modeled image, then subtract it from the original observed image.

```
./do_Galsub 500 201512 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand500.txt \
-fitsname spire500_ima_7p2_v0_100615.fits \
-sedpredict SED_predictions_500_201512.txt
```

Figure 26: Faint-source subtraction step at band 500. From left to right: original image, faint-source model image, and faint-source-subtracted 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.

9.4 Galfit photometry at band 500

```
./do_Galfit 500 201512 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand500.txt \
-fitsname spire500_ima_7p2_v0_100615_subfaintDL.fits \
-sedpredict SED_predictions_500_201512.txt
# then run scripts in parallel
cd boxgalfit; do_GalfitRunqsub
cd ..
# then run postparallel process
./do_Galfit 500 201512 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand500.txt \
-fitsname spire500_ima_7p2_v0_100615_subfaintDL.fits \
-sedpredict SED_predictions_500_201512.txt \
-postparallel
```

9.5 Residual image at band 500

```
cd run_sextractor_500/
idl -e 'do_SExtract_Mask, \
FitsFile="FIT_goodsn_500_Map_201512.fits", \
RmsFile="spire500_rms_7p2_v0_100615.fits"'
vim default.sex # set sigma thresholds
sex SExtractor_Signal.fits
# then write additional residual source catalog
# with supermongo code do_sextract_result.sm
gedit do_sextract_result.sm
...
define band 500
```

```
set catalog = {"RadioOwenMIPS24_priors_v6_20151221_BeforeBand500.txt"}
set rmsfits24 = {"n_mips_1_s1_v0_37_rms_ED.fits"}
set catalogadd = {"Residual_priors_v6_Band500.txt"}
...
print $(catalogadd) '%-9.0f %12.7f %12.7f %9g\n' \
{_id _ra _de zp_X f24 df24 f16 df16 f100 df100 \
f160 df160 f250 df250 f350 df350 radio eradio \
_fch1 _dfch1 _fch2 _dfch2 _fch3 _dfch3 _fch4 _dfch4 \
KtotX MassX distX spezX zq source distz idz goodArea}
...
macro read do_sextract_result.sm go
```

(TODO: Put Residual Images Here!)

Then run a second pass 9.4:

```
./do_Galfit 500 201512 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand500.txt \
-catalog-add Residual_priors_v6_Band500.txt \ # new!
-fitsname spire500_ima_7p2_v0_100615_subfaintDL.fits \
-sedpredict SED_predictions_500_201512.txt
# then run scripts in parallel
cd boxgalfit; do_GalfitRunqsub
cd ..
# then run postparallel process
./do_Galfit 500 201512 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand500.txt \
-catalog-add Residual_priors_v6_Band500.txt \ # new!
-fitsname spire500_ima_7p2_v0_100615_subfaintDL.fits \
-sedpredict SED_predictions_500_201512.txt \
-postparallel
```

9.6 Monte-Carlo simulation at band 500

9.7 Flux bias and flux error analyses

Figure 27: Band 500 flux bias correction plots:

Figure 28: Band 500 histogram of simulated source flux before and after each step correction.

Figure 29: Band 500 flux uncertainty correction plots:

Figure 30: Band 500 flux uncertainty histograms:

9.8 Flux bias and flux uncertainty correction

```
gedit run_simu_stats_v8.sm
sm
macro read run_simu_stats_v8.sm run_simu_stats_v8 500
```

10 Band 1160

10.1 SED fitting before band 1160

Firstly, we use the Type_AGN and Type_SED determined in 9.1:

- Type_AGN: Numbers TODO.
- Type_SED: Numbers TODO.
  - Note: do not forget to append zeros for additional sources found in the residual image of 500.

Then we determine Type_FIR with the latest 500 measurements:

- Type_FIR: $\sqrt{SNR_{100}^2 + SNR_{160}^2 + SNR_{250}^2 + SNR_{350}^2 + SNR_{500}^2} \geq 5$: 1114 out of 3386 sources will be fit with only FIR data points.

10.2 SED prediction for band 1160

```
cd Galsed_BeforeBand1160
./do_Type_FIT.sh
#
# 2016-02-25 12:40:15 CST
band: 1160
fcut: 0.66   # mJy # the cutting value of f+2df
fsig: 0.66   # mJy # the 1-sigma detection limit
Total source number: 3306
Fitting source number: 515
Fitting source number (SED prediction selection): 475
Fitting source number (previous band S/N selection): 125
Subtract source number: 2791
```

Figure 31: Number of sources kept for fitting per PSF beam area (ρ_{fit}) as a function of different f_{cut} at band 1160.

10.3 Faint flux subtraction at band 1160

We use the SED flux of the flagged faint sources to construct a PSF-modeled image, then subtract it from the original observed image.

```
./do_Galsub 1160 201512 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand1160.txt \
-fitsname combined_maw0_4_azw0_5_sig_astro.fits \
-sedpredict SED_predictions_1160_201512.txt
```

Figure 32: Faint-source subtraction step at band 1160. From left to right: original image, faint-source model image, and faint-source-subtracted 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.

10.4 Galfit photometry at band 1160

```
./do_Galfit 1160 201512 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand1160.txt \
-fitsname combined_maw0_4_azw0_5_sig_subfaintDL.fits \
-sedpredict SED_predictions_1160_201512.txt
# then run scripts in parallel
cd boxgalfit; do_GalfitRunqsub255
cd ..
# then run postparallel process
./do_Galfit 1160 201512 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand1160.txt \
-fitsname combined_maw0_4_azw0_5_sig_subfaintDL.fits \
-sedpredict SED_predictions_1160_201512.txt \
-postparallel
```

10.5 Residual image at band 1160

```
cd run_sextractor_1160/
idl -e 'do_SExtract_Mask, \
FitsFile="FIT_goodsn_1160_Map_201512.fits", \
RmsFile="combined_maw0_4_azw0_5_rms.fits"'
vim default.sex # set sigma thresholds
sex SExtractor_Signal.fits
# then write additional residual source catalog
# with supermongo code do_sextract_result.sm
gedit do_sextract_result.sm
...
define band 1160
```

```
set catalog = {"RadioOwenMIPS24_priors_v6_20151221_BeforeBand1160.txt"}
set rmsfits24 = {"n_mips_1_s1_v0_37_rms_ED.fits"}
set catalogadd = {"Residual_priors_v6_Band1160.txt"}
...
print $(catalogadd) '%-9.0f %12.7f %12.7f %9g\n' \
{_id _ra _de zp_X f24 df24 f16 df16 f100 df100 f160 \
df160 f250 df250 f350 df350 f500 df500 radio eradio \
_fch1 _dfch1 _fch2 _dfch2 _fch3 _dfch3 _fch4 _dfch4 \
KtotX MassX distX spezX zq source distz idz goodArea}
...
macro read do_sextract_result.sm go
```

(TODO: Put Residual Images Here!)

Then run a second pass 10.4:

```
./do_Galfit 1160 201512 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand1160.txt \
-catalog-add Residual_priors_v6_Band1160.txt \ # new!
-fitsname combined_maw0_4_azw0_5_sig_subfaintDL.fits \
-sedpredict SED_predictions_1160_201512.txt
# then run scripts in parallel
cd boxgalfit; do_GalfitRunqsub255
cd ..
# then run postparallel process
./do_Galfit 1160 201512 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand1160.txt \
-catalog-add Residual_priors_v6_Band1160.txt \ # new!
-fitsname combined_maw0_4_azw0_5_sig_subfaintDL.fits \
-sedpredict SED_predictions_1160_201512.txt \
-postparallel
```

10.6 Monte-Carlo simulation at band 1160

```
# run this to prepare galfit fitting files
./do_Galsim 1160 20151201 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand1160.txt \
-catalog-add Residual_priors_v6_Band1160.txt \
-fitsname combined_maw0_4_azw0_5_sig_subfaintDL.fits \
-sedpredict SED_predictions_1160_201512.txt \
-fitincl -fitadds -mag0 -6.69 -mag1 -3.55 -nsim 6000
# then run the galfit fitting in parallel mode
cd boxgalsim; do_GalsimRunqsub255; cd ..
# then run postparallel process
./do_Galsim 1160 20151201 \
-catalog RadioOwenMIPS24_priors_v6_20151221_BeforeBand1160.txt \
-catalog-add Residual_priors_v6_Band1160.txt \
-fitsname combined_maw0_4_azw0_5_sig_subfaintDL.fits \
-sedpredict SED_predictions_1160_201512.txt \
-fitincl -fitadds -mag0 -6.69 -mag1 -3.55 -nsim 6000 \
-postparallel
```

10.7 Flux bias and flux error analyses

Figure 33: Band 1160 flux bias correction plots:

Figure 34: Band 1160 flux uncertainty correction plots:

Figure 35: Band 1160 histogram of simulated source flux before and after each step correction.

Figure 36: Band 1160 flux uncertainty histograms:

10.8 Flux bias and flux uncertainty correction

```
gedit run_simu_stats_v8.sm
sm
macro read run_simu_stats_v8.sm run_simu_stats_v8 1160
```

11 Band 850

!new 20160719

11.1 SED fitting before band 850

We directly use *Galsed_AfterBand1160*.

Then we determine Type_FIR, Type_SED, Type_AGN.

```
cd Galsed_AfterBand1160
./do_Type_AGN.sh \
-catalog RadioOwenMIPS24_priors_dzliu_20160128_Band1160.txt -sedresults ResLMT*.txt
# below are outputs
2016-07-20 02:44:04
Writting to coo_AGN.txt!
We have 266 out of 3306 sources classified as radio loud AGN.
Successfully output to coo_AGN.txt!
Please use the output file coo_AGN.txt in the next time SED fitting!
```

```
cd Galsed_AfterBand1160
./do_Type_SED.sh \
-catalog RadioOwenMIPS24_priors_dzliu_20160128_Band1160.txt -sedresults ResLMT*.txt
# below are outputs
2016-07-20 02:45:09
Writting to coo_SED.txt!
We have 215 out of 3306 sources classified as pure starburst.
We have 1273 out of 3306 sources classified as pure mainsequence.
We have 1818 out of 3306 sources unable to be classified.
Successfully output to coo_SED.txt!
Please use the output file coo_SED.txt in the next time SED fitting!
```

```
cd Galsed_AfterBand1160
./do_Type_FIR.sh \
-catalog RadioOwenMIPS24_priors_dzliu_20160128_Band1160.txt
# below are outputs
2016-07-20 02:45:47
Writting to coo_FIR.txt!
We have 1172 out of 3306 sources to fit with FIR data points only.
Successfully output to coo_FIR.txt!
Please use the output file coo_FIR.txt for the following SED fitting!
```

11.2 SED prediction for band 850

```
cd Galsed_AfterBand1160
./do_Type_FIT.sh -band 850 -fcut 2.0 \
-catalog RadioOwenMIPS24_priors_dzliu_20160128_Band1160.txt -sedresults ResLMT*.txt
# 2016-07-20 03:07:53 CST
band: 850
fcut: 2   # mJy # the cutting value of f+2df
```

```
fsig: 2   # mJy # the 1-sigma detection limit
Total source number: 3306
Fitting source number: 372
Fitting source number (SED prediction selection): 372
Fitting source number (previous band S/N selection): 0
Subtract source number: 2934
```

Figure 37: Number of sources kept for fitting per PSF beam area (ρ_{fit}) as a function of different f_{cut} at band 850.

11.3 Faint flux subtraction at band 850

We use the SED flux of the flagged faint sources to construct a PSF-modeled image, then subtract it from the original observed image.

```
do_Superdeblending -field goodsn -band 850 -date 201607 -step Galfit_Band850 -catalog-input Galsed_Afte
```

```
do_Galsub 850 20160719 \
          -catalog RadioOwenMIPS24_priors_dzliu_20160128_Band1160.txt \
          -fitsname S2CLS_GOODSN_MF_FLUX_DR1_subfaintDL.fits \
          -fitsname-sci S2CLS_GOODSN_MF_FLUX_DR1 \
          -fitsname-rms S2CLS_GOODSN_MF_RMS_DR1 \
          -fitsname-psf S2CLS_SCUBA2_850um_dzliu_DoubleGaussian_PSF \
          -sedpredict SED_predictions_850.txt
```

Figure 38: Faint-source subtraction step at band 850. From left to right: original image, faint-source model image, and faint-source-subtracted 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.

11.4 Galfit photometry at band 850

```
do_Galfit 850 20160719 \
          -catalog RadioOwenMIPS24_priors_dzliu_20160128_Band1160.txt \
          -sedpredict SED_predictions_850.txt \
          -fitsname S2CLS_GOODSN_MF_FLUX_DR1_subfaintDL.fits \
          -fitsname-sci S2CLS_GOODSN_MF_FLUX_DR1 \
          -fitsname-rms S2CLS_GOODSN_MF_RMS_DR1 \
          -fitsname-psf S2CLS_SCUBA2_850um_dzliu_DoubleGaussian_PSF \
          -parallel

cd boxgalfit;
do_GalfitRunqsub;
cd ..

do_Galfit 850 20160719 \
          -catalog RadioOwenMIPS24_priors_dzliu_20160128_Band1160.txt \
          -sedpredict SED_predictions_850.txt \
          -fitsname S2CLS_GOODSN_MF_FLUX_DR1_subfaintDL.fits \
          -fitsname-sci S2CLS_GOODSN_MF_FLUX_DR1 \
          -fitsname-rms S2CLS_GOODSN_MF_RMS_DR1 \
          -fitsname-psf S2CLS_SCUBA2_850um_dzliu_DoubleGaussian_PSF \
          -postparallel
```

11.5 Residual image at band 850

```
cp -r /home/dzliu/Cloud/Github/DeepFields.SuperDeblending/Softwares/Galfit_Template_v20160225/run_sextra
cp -r /home/dzliu/Cloud/Github/DeepFields.SuperDeblending/Softwares/Galfit_Template_v20160225/run_sextra
./run_sextractor.sh -band 850 \
```

```
                    -catalog-output Residual_priors_850.txt \
                    -fitresults-map FIT_goodsn_850_Map_20160719_vary.fits \
                    -rms-map S2CLS_GOODSN_MF_RMS_DR1.fits \
                    -detect-thresh 3.5 \
                    -detect-minarea 2
```

(DONE: Put Residual Images Here!)

Figure 39: First-pass residual image at band 850. From left to right: original image, fitted model image, and the residual image.

Then run a second pass 11.4 to re-fit the additional sources:

```
#########################################################################
# Run galsub to subtract faint sources which are excluded from fitting #
#########################################################################
do_Galsub 850 20160719 \
          -catalog RadioOwenMIPS24_priors_dzliu_20160128_Band1160.txt \
          -fitsname S2CLS_GOODSN_MF_FLUX_DR1_subfaintDL.fits \
          -fitsname-sci S2CLS_GOODSN_MF_FLUX_DR1 \
          -fitsname-rms S2CLS_GOODSN_MF_RMS_DR1 \
          -fitsname-psf S2CLS_SCUBA2_850um_dzliu_DoubleGaussian_PSF \
          -sedpredict SED_predictions_850.txt

#############################################################
# Run galfit with input catalog and source position fixed #
#############################################################
do_Galfit 850 20160719 \
          -catalog RadioOwenMIPS24_priors_dzliu_20160128_Band1160.txt \
          -sedpredict SED_predictions_850.txt \
          -fitsname S2CLS_GOODSN_MF_FLUX_DR1_subfaintDL.fits \
          -fitsname-sci S2CLS_GOODSN_MF_FLUX_DR1 \
          -fitsname-rms S2CLS_GOODSN_MF_RMS_DR1 \
          -fitsname-psf S2CLS_SCUBA2_850um_dzliu_DoubleGaussian_PSF \
          -catalog-add Residual_priors_850.txt \
          -parallel

cd boxgalfit;
do_GalfitRunqsub;
cd ..

do_Galfit 850 20160719 \
```

```
          -catalog RadioOwenMIPS24_priors_dzliu_20160128_Band1160.txt \
          -sedpredict SED_predictions_850.txt \
          -fitsname S2CLS_GOODSN_MF_FLUX_DR1_subfaintDL.fits \
          -fitsname-sci S2CLS_GOODSN_MF_FLUX_DR1 \
          -fitsname-rms S2CLS_GOODSN_MF_RMS_DR1 \
          -fitsname-psf S2CLS_SCUBA2_850um_dzliu_DoubleGaussian_PSF \
          -catalog-add Residual_priors_850.txt \
          -postparallel

##############################################################
# Run galfit again allowing bright source position to vary #
##############################################################
do_Galfit 850 20160719 \
          -catalog RadioOwenMIPS24_priors_dzliu_20160128_Band1160.txt \
          -sedpredict SED_predictions_850.txt \
          -fitsname S2CLS_GOODSN_MF_FLUX_DR1_subfaintDL.fits \
          -fitsname-sci S2CLS_GOODSN_MF_FLUX_DR1 \
          -fitsname-rms S2CLS_GOODSN_MF_RMS_DR1 \
          -fitsname-psf S2CLS_SCUBA2_850um_dzliu_DoubleGaussian_PSF \
          -catalog-add Residual_priors_850.txt \
          -vary -parallel

cd boxgalfit_vary;
do_GalfitRunqsub;
cd ..

do_Galfit 850 20160719 \
          -catalog RadioOwenMIPS24_priors_dzliu_20160128_Band1160.txt \
          -sedpredict SED_predictions_850.txt \
          -fitsname S2CLS_GOODSN_MF_FLUX_DR1_subfaintDL.fits \
          -fitsname-sci S2CLS_GOODSN_MF_FLUX_DR1 \
          -fitsname-rms S2CLS_GOODSN_MF_RMS_DR1 \
          -fitsname-psf S2CLS_SCUBA2_850um_dzliu_DoubleGaussian_PSF \
          -catalog-add Residual_priors_850.txt \
          -vary -postparallel
```

Now we check the new residual image.

Figure 40: The second-pass residual image at band 850, with additional sources re-fitted. From left to right: original image, fitted model image, and the residual image.

11.6 Monte-Carlo simulation at band 850

```
do_Galsim 850 20160812 \
-catalog RadioOwenMIPS24_priors_dzliu_20160128_Band1160.txt \
-sedpredict SED_predictions_850.txt \
-fitsname S2CLS_GOODSN_MF_FLUX_DR1_subfaintDL.fits \
-fitsname-sci S2CLS_GOODSN_MF_FLUX_DR1 \
-fitsname-rms S2CLS_GOODSN_MF_RMS_DR1 \
-fitsname-psf S2CLS_SCUBA2_850um_dzliu_DoubleGaussian_PSF \
-catalog-add Residual_priors_850.txt \
-mag0 -4.0 -mag1 0.0 \
-parallel

cd boxgalsim;
do_GalsimRunqsub;
cd ..

do_Galsim 850 20160812 \
-catalog RadioOwenMIPS24_priors_dzliu_20160128_Band1160.txt \
-sedpredict SED_predictions_850.txt \
-fitsname S2CLS_GOODSN_MF_FLUX_DR1_subfaintDL.fits \
-fitsname-sci S2CLS_GOODSN_MF_FLUX_DR1 \
-fitsname-rms S2CLS_GOODSN_MF_RMS_DR1 \
-fitsname-psf S2CLS_SCUBA2_850um_dzliu_DoubleGaussian_PSF \
-catalog-add Residual_priors_850.txt \
-mag0 -4.0 -mag1 0.0 \
-postparallel
```

TODO: vary

11.7 Flux bias and flux error analyses

```
gedit run_simu_stats_v8.sm
echo "macro read run_simu_stats_v8.sm run_simu_stats_v8 850 20160812" | sm
```

Figure 41: Band 850 flux bias correction plots:

Figure 42: Band 850 histogram of simulated source flux before and after each step correction.

Figure 43: Band 850 flux uncertainty correction plots:

Figure 44: Band 850 flux uncertainty histograms:

11.8 Flux bias and flux uncertainty correction

```
gedit run_simu_stats_v8.sm
gedit goFine.sm
echo "macro read goFine.sm R_MIPS850_E" | sm
```

11.9 Update catalog

```
echo "macro read run_update_catalog_v7.sm run_update_catalog_v7 850" | sm
```

A Appendix

B Setup softwares in planer

```
IRAF
supermongo
galfit
sextractor
ds9
XPA # http://ds9.si.edu/site/XPA.html
wcstools # http://tdc-www.harvard.edu/software/wcstools/wcstools-3.9.2.tar.gz
others #
```

C Setup supermongo in planer

Here are the code for configuring, compiling and installing supermongo:

```
cd /dsm/upgal/data/dliu/Software/sm2_4_30/
./set_opts
We can help you configure things for which the defaults are usually OK
Do you want to do so? [n|y|list] y
Choose data type for vectors, "float" or "double"? [float] double
Choose length of longest macro [10000] 50000
Choose length for string-valued-vectors' elements [40] 80
Top level path to install things? [/usr/local] /dsm/upgal/data/dliu/supermongo
vim src/options.h
:d7
:wq
make
make install
cd
cd /home/dliu/.local/lib/sm/macro
rsyncdir /usr/local/lib/sm/macro \
dliu@hubble.extra.cea.fr:/dsm/upgal/data/dliu/supermongo/lib/sm/macro "*.sm"
It should be OK now!
echo PATH=/home/dliu/.local/bin:$PATH
type sm
# Note:
# additionally, if sm does not work,
# try to modify "/home/dliu/.local/lib/sm/.sm"
```

D Discussed Issues

D.1 SED prediction versus galfit measurement issue

Date: 2015-12-02

Because we highly rely on the SED prediction to decide which sources to fit and which to subtract, the accuracy of SED prediction is important and any underlying bias should be well understood. We compare the galfit measured flux and the SED predicted flux before the galfit photometry for the sources that are fitted at each band, i.e. a f_galfit v.s. f_predict diagram, to find out underlying bias.

D.2 Spec-z from various literature issue

Date: 2015-09-25

Date: 2016-01-15

Wirth et al. 2015 Keck MOSFIRE $z \sim 2$ spec-z survey. We have cross-matched their catalog with our 24+radio catalog, and got 55 matched sources with quality flag ≥ 2.5. Note that their quality flag $= 2.0$ means "Degenerate redshift, does not match z phot", $= 2.5$ means "Degenerate redshift, but matches z phot", $= 3.0$ means "Secure redshift (P >95%)", $= 4.0$ means "Very secure redshift (P >99%)". In which, 18 are new spec-z sources and a significant part of them are at and above redshift 2, while 37 are duplicated spec-z sources. TODO: compare the agreements of Wirth2015 spec-z and our previous spec-z for 37 duplicated spec-z sources.

Kriek et al. 2015 Keck MOSFIRE high-z spec-z survey. We have cross-matched their catalog with the GOODS-Spitzer IRAC 19437 catalog, and got 102 matched sources with their $z_{MOSFIRE} > 0$ ($z_{MOSFIRE} = -1$ means unreliable). As to our 24+radio 3306 catalog, we got about 22 new spec-z sources. TODO: compare the agreements of Wirth2015 spec-z and our previous spec-z for the duplicated spec-z sources.

D.3 Stellar mass from various literature issue

Date: 2015-12-31

In this work, we use the stellar mass from: Pannella et al. and 3DHST project. Discrepancies exist between the two catalogs, besides, some of our IRAC catalog sources are not covered in any of them. Therefore, we need to decide when to use which value. Here are our selection functions:

```
# massP    -- Stellar mass from Pannella, in Salpeter IMF
# mass3D   -- Stellar mass from 3DHST, in Salpeter IMF
# zp_P     -- photo-z from Pannella
# zp_3D    -- photo-z from 3DHST
# spez3D   -- spec-z from 3DHST
# spez     -- spec-z from various redshift survey camp
# MassX    -- our choice of stellar mass
```

```
# zp_X     -- our choice of photo-z
# spezX    -- our choice of spec-z
set MassX = (MassX-massP)<-1 && \
            abs(zp_P-zp_X)/(1+zp_X)<.2 ? \
            massP : MassX
set MassX = spez3D>0 && \
            abs(zp_X-spez3D)/(1+(zp_X+spez3D)/2)>.2 && \
            (abs(zp_X-zp_P)/(1+(zp_X+zp_P)/2)<.25 && zp_P>0) ? \
            massP : MassX
set MassX = spez3D>0 && \
            abs(zp_X-spez3D)/(1+(zp_X+spez3D)/2)>.2 && \
            !(abs(zp_X-zp_P)/(1+(zp_X+zp_P)/2)<.25 && zp_P>0) ? \
            -1 : MassX
```

D.4 Radio galfit output error got zero value issue

Date: 2016-01-07

When the source has very small errors, i.e. < 0.001, then our galfit code will lose the precision and only give zeros. Therefore we set an S/N upper limit for all sources:

```
sm
set e20cm = e20cm>0.05 ? e20cm : 0.05
```

D.5 Selecting prior sources for fitting issue

D.5.1 The "SED-Prediction" criterion

In order to reduce prior sources and improve the highly blended photometry at FIR bands, we use the SED best-fitting fluxes and flux errors for all the IRAC/MIPS sources to select part of them as the prior sources for the galfit fitting. To account for the uncertainty of SED fitting result, which contains the uncertainties of measured data points and the variation of SED template properties, we use the SED best-fitting flux plus 2 times the SED flux error (i.e. $f + 2\sigma_f$) item as the "SED-Prediction" criterion, and decide a "cutting flux" (f_{cut}) at each FIR band. If $f + 2\sigma_f > f_{cut}$, then we select this source for fitting. On the contrary, we exclude the source from fitting, and subtract its flux model from the original observed image.

Here are some discussions we had.

Date: 2016-01-07

Do we include stellar and AGN components during prediction phases? —- Yes. Now new fit_engine.sm code has been updated. We can do the multi-component fitting now.

Do we use crowdiness linearly to weight the SED predicted flux for prior source selection? —- No, we must provide simulation-based crowdiness weighting functions if we use crowdiness. Make the $(S_{in} - S_{out})$ v.s. $crowdiness$ diagram with simulation data points and derive functions from binned statistics.

Do we enlarge U range so as to derive better U values for at least GN20 at $z = 4.05$? —- Not in SED prediction phase. In final stage.

D.5.2 The "Previous-Detection" criterion

Date: 2016-01-07

Do we apply the following criterion when selecting prior sources to fit: if a source has more than 3σ detection at previous FIR band (i.e. $24\mu m$ to $1160\mu m$), then we fit it at current band, ignoring its SED flux criterion? —- This is being tested.

i.e. do we always fit a previous band detected ($S/N > 3$) source?

We are doing the tests now. (TODO)

At band 100, we first run galfit with the full 24+radio catalog sources.

Date: 2016-02-18

We have tested the source detections at band 100 and 160.

```
100um detection number 1178
160um detection number 1159
100um detected but not at 160um 293
160um detected but not at 100um 274 (because of good radio constraint)
160um detected and also at 100um 885
```

D.5.3 Historical figures of selecting prior sources for fitting

Date: 2016-02-29

Historical plots of selecting prior sources for fitting. Here are 3 versions of the figures.

- First is the Dec. 2014 version, when we were using old SED fitting, which has imperfect SED prediction versus galfit measurement issue, and has imperfect simulation-based correction recipes. We were not considering the effect of clustering/crowdiness.

• Then the second version is the Dec. 2015 version, with the new 3-step simulation-based flux & flux error correction recipes, and with new SED fitting algorithm. But I was trying considering the effect of the crowding of sources. Therefore I tried dividing the SED predicted flux item by the "crowdiness" parameter when selecting prior sources for fitting.

number per beam
0.335
0.33
0.325
Band 100
f_{cut}=0.05
N_{cut}=28
N_{fit}=3278
ρ_{fit}=0.33
0
0.1
0.2
0.3
$(f+2\sigma_f)$/crowdiness

number per beam
0.8
0.6
0.4
Band 160
f_{cut}=0.80
N_{cut}=402
N_{fit}=2904
ρ_{fit}=0.82
0
0.5
1
1.5
2
2.5
$(f+2\sigma_f)$/crowdiness

number per beam
2
1.5
1
0.5
Band 250
f_{cut}=1.63
N_{cut}=1792
N_{fit}=1528
ρ_{fit}=1.00
0
2
4
6
$(f+2\sigma_f)$/crowdiness

• Then the third version is the Jan. 2016 version, with new simulation-based flux & flux error correction recipes, and with newer SED fitting algorithms (with Type_FIR, i.e. $S/N_{FIR\,bands} > 3$, and with stellar & AGN component). Due to the complexity of implementing "crowdiness"-dependent fitting sources selection, we will not use the simple method of dividing "crowdiness" parameter for now. Instead, we applied another discussed criterion, i.e.

if a source is detected at previous FIR band (e.g. $160\mu m$), we always select it for fitting at current FIR band (i.e. $250\mu m$). With the application of this so-called "Previous-Detection" criterion, on the other hand, we must reduce the sources selected by the "SED-Prediction" criterion, so that the mean number density of sources in fitting does not largely exceed 1 per beam, which ensures a non-blending fitting. The third version of figures are presented below.

Band 100
f_{cut}=0.3028 mJy
$1\sigma_f$=0.3028 mJy
ρ_{beam}
Number
$f+2\sigma_f$ [mJy]
Band 160
f_{cut}=1.1 mJy
$1\bar{\sigma}_f$=0.7 mJy
ρ_{beam}
Number
$f+2\sigma_f$ [mJy]
Band 250
$1\bar{\sigma}_f$=1.77 mJy
f_{cut}=5.2 mJy
ρ_{beam}
Number
$f+2\sigma_f$ [mJy]
Band 350
$1\bar{\sigma}_f$=2.2 mJy
f_{cut}=8.6 mJy
ρ_{beam}
Number
$f+2\sigma_f$ [mJy]

D.6 GN20, GN20.2a and GN20.2b source position issue

Date: 2016-01-07

GN20.2a is actually corresponding to 2 HST sources.

Date: 2016-01-28

We now use slightly tuned positions for GN20.2a and GN20.2b, based on their actual IRAC and VLA positions.

D.7 Residual source issue

Date: 2016-01-07 We should check the detection of all added residual sources to see whether we are using a too low detection limit or extracting too many fake sources.

Date: 2016-02-29 Now we are doing two-step galfit-fitting to ensure that all the additional sources we added can be detected.

Date: 2016-02-29

```
Band 100 number of additional sources fitted: 0
Band 160 number of additional sources fitted: 29
Band 160 number of additional sources detected: 18
Band 250 number of additional sources fitted: 136
Band 250 number of additional sources detected: 26
Band 350 number of additional sources fitted: 97
Band 350 number of additional sources detected: 20
Band 500 number of additional sources fitted: 39
Band 500 number of additional sources detected: 7
Band 1160 number of additional sources fitted: 68
Band 1160 number of additional sources detected: 8
```