SSC Bandmerge Test Results

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1. Basic Algorithm:

A detailed description of the SSC bandmerge module is available in the Bandmerging User's guide, available on the SSC website. The module can work on up to 7 different bands. The basic source matching algorithm is based on the positional match in a reference pixel coordinate system, in which sources in different bands have the same (x, y) coordinates. The positional χ^2 between a pair of (x, y) positions is calculated using the followingequation:

$$\chi^2 = \frac{\sigma_y^2(x_1 - x_2)^2 + \sigma_x^2(y_1 - y_2)^2 - 2\sigma_{xy}^2(x_1 - x_2)(y_1 - y_2)}{\sigma_x^2\sigma_y^2 - \sigma_{xy}^2\sigma_{xy}^2}$$

with

$$\sigma_x^2 = \sigma_{x_1}^2 + \sigma_{x_2}^2$$

$$\sigma_y^2 = \sigma_{y_1}^2 + \sigma_{y_2}^2$$

$$\sigma_{xy} = |\sigma_{x_1y_1}|\sigma_{x_1y_1} + |(\sigma_{x_2y_2})|\sigma_{x_2y_2}$$

The basic method in dealing with the multiple matches between two different bands is to choose the source pair with the smallest χ^2 value. In the case of merging more than two bands, additional steps are implemented in the code to check the validity of each matching between any pair of sources.

2. Bandmerging the Data from Four IRAC Channels

The bandmerging of the four IRAC band data is somewhat easier in the sense that the pixel size is the same for all four bands. In the example shown in this section, we used the SSC code APEX to first mosaic the images, then to extract source fluxes, and finally bandmerge the source lists at the four wavelengths.

The mosaic pixel size is chosen to be half of the original pixel size, *i.e.* $0.6''$ per pixel. The data used for this test are the simulated images based on the luminosity functions by Xu et al. (2001, ApJ, 562,179). The data simulate the depths and coverage of the SWIRE observations. The subset of the data we used for the test covers a total area of 0.5×0.5 sq. deg. The IRAC channel 1 data has the highest source density, reaching about 51000 over 0.25 sq. deg. to the 1.5σ SNR limit, whereas in the same area and at the same depth, the IRAC channel 4 has only about 8500 sources. This shows that the number of sources with all four band detections is much smaller than the total number of detections in channel 1.

We used the SSC bandmerge module, setting the χ^2 criteria of 36.0 in the source matching. We found that the difference in the source centroid measured in different bands is far more significant than their positional errors could account for. It is necessary to introduce an additional positional uncertainty in each band-pair. This is done with the band-pair registration uncertainty file that is input to the bandmerge code. The values used are roughly what we expect to use on the real data, $\sim$0.2 in both x and y directions and the cross term is zero.

Figure 1 $-$ 3 illustrate the results of bandmerging two bands (IRAC 1 and IRAC 2), three bands (IRAC 1 + IRAC 2 + IRAC 3) and four bands, respectively. In Figure 1, the top and bottom panels show small sections of IRAC channel 1 and channel 2 images, with the bandmerged sources marked in red circles. Figure 2 in three panels shows the sections of the images of IRAC channel 1, 2 and 3, with the bandmerged sources marked in blue circles. It is obvious that many sources in Channel 1 are not detected in IRAC channel 3. Similarly, in Figure 3 the green circles represent the sources detected in *all* four IRAC bands.

3. Bandmerging the MIPS 24 and 70 Data

Again, the MIPS images are simulated using the same model as in the simulated IRAC data. The depth and areal coverage is similar to what the actual SWIRE observations will be. Here the MIPS 24 and 70 micron images cover the same pointing region as the simulated IRAC data, over roughly 0.5×0.5 sq. deg. Using a similar approach as what we did with IRAC data, we resample the MIPS 24 and 70 micron images to a pixel size of $1.225''$, and do the source detections on the mosaiced images with this finer pixel grid; however, the profile-fitted fluxes are measured in the original individual images. The source lists from the two bands are generated using APEX. The sources have the same (x, y) coordinates, and are ready for input to the SSC bandmerge module.

Similar to the IRAC result described above, we found that the source centroid in each band is sufficiently different that it is necessary to have additional positional registration uncertainties when running the SSC bandmerge module. For MIPS 24 and 70 data, we set the x and y sigma uncertainties for the band-pair registration to 0.5. This uncertainties are additive to the positional uncertainties measured from the images.

Figure 4 shows the bandmerging result between MIPS 24 and 70 micron. The MIPS 70 mosaiced image is resampled to the same pixel size, $1.225''$ as the mosaiced MIPS 24 micron image. The red circles mark the bandmerged source list. It is apparent that the MIPS 70 micron has a much larger beam and single large sources are resolved into multiple sources in the MIPS 24 micron band.

4. Merging the IRAC and MIPS Six Bands (excluding MIPS 160 band)

In order to merge the sources from all six bands, we adopt the approach in which we will resample all IRAC and MIPS images to a common pixel size, so that their source lists will have the same (x, y) coordinates. In the test case, we choose the pixel size of $1.2''$, the size of the original IRAC pixel size. The MIPS 24 and 70 micron images are resampled to this finer pixel grid (MIPS 24 pixel size is $2.45''$, MIPS 70 micron pixel size is $9.9''$, and MIPS 160 micron pixel size is $15.8''$). In this test, we exclude the MIPS 160 micron images to simplify the bandmerge process.

We found that resampling the coarse MIPS pixels to a finer grid helps to deblend very close sources using the SSC source extraction module APEX. All APEX parameters are tuned to detect sources on the mosaiced images with the $1.2''$ size pixel, then extract the source fluxes using the original input images.

Figure 5 shows in 6 panels the subsections of images from the 6 bands, from IRAC 3.5 to MIPS 70 micron. Each panel is labeled with the name of the wave-band, and the green circles mark the sources output from the SSC bandmerge module which are detected in all 6 bands.

5. Remaining Issues:

This is an preliminary report on the bandmerge tests. Many additional tests are planned. For example, we are working on incorporating MIPS 160 micron data, and will include the test results in the next report. There are several remaining issues which should be explored:

1. Optimal source extraction parameters: using a small mosaic pixel size seems to improve APEX's deblending. However, this also produces false detections around bright objects. Fine tuning the extraction parameters in APEX would help in producing a cleaner source list before bandmerging. This would be particularly relevant once we have the real data.
2. What kind of source lists should be input to bandmerge? When we generate source lists for bandmerge, we need to decide how deep and reliable our source list in each band is. This will define the source extraction parameters. We could either fine-tune the parameters so that the source list for each band independently achieves a certain completeness and reliability, then perform the bandmerge; or we could allow the source lists in all bands to reach faint limits so that we have higher completeness, and use the bandmerging as the final check of the source reliability. These two approaches are very different. Some tests should be done to decide their merits.
3. The simulated images do not have any band-pair registration uncertainties. This will not be true when we have the real data. A certain amount of positional uncertainties need to be added to the positional errors whenwe bandmerge the real data.
4. The current SSC bandmerge is based only on positional match. Additional flux matching criteria could be implemented in order to improve the reliability.