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Band Merging of *Spitzer* Detections in the SWIRE Fields

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Abstract. The *Spitzer* Wide-area Infra-Red Extragalactic (SWIRE) Survey has imaged 49 deg^2 of high-Galactic-latitude sky in seven infrared bands spanning wavelengths from 3.6 μm to 160 μm, with beam sizes ranging from about $2''$ to $40''$. Lists of extracted sources from the individual bands are merged using the *Spitzer* band merging software. Positions and their uncertainties are used to identify possible band-to-band matches, then decision theory is applied to choose a best match. We present our assessment of band merging reliability based on analysis of the random match rate, and we discuss our application of constraints of multi-band detections and proximity to produce reliable catalogs. We examine the crucial role played by positional uncertainties for extractions made with SExtractor and with *Spitzer's* Astronomical Point-source EXtraction (APEX) software.

1. The *Spitzer*/SWIRE Band Merging Challenge

The SWIRE survey is relatively shallow, with about two minutes of integration time per point in the mid-infrared, and less time at the longest bands. The challenge in making catalogs of galaxies from these data is twofold. First, the resolution of the sources varies greatly owing to *Spitzer's* small (85 cm) primary mirror diameter. Second, the sensitivity to galaxies is highest in the shortest two bands and lowest in the longest bands, due mainly to the near absence of background in the 3.6 μm and 4.5 μm channels, as well as differences in detector technology. The result is large variations in source density and resolution with wavelength (Table 1).

Table 1. Characteristics of the seven SWIRE imaging bands.

	Ch1	Ch2	Ch3	Ch4	24	70	160
Nominal Wavelength, μm	3.6	4.5	5.8	8.0	24	70	160
Resolution, arcsec	2	2	2	2	6	17	40
Source density, arcmin^{-2}	14.9	10.85	2.31	1.55	3.97	0.21	0.078
Beams per source	77	100	500	740	32	76	37
Ch1 sources per beam	0.013	0.013	0.013	0.013	0.12	0.94	5.2

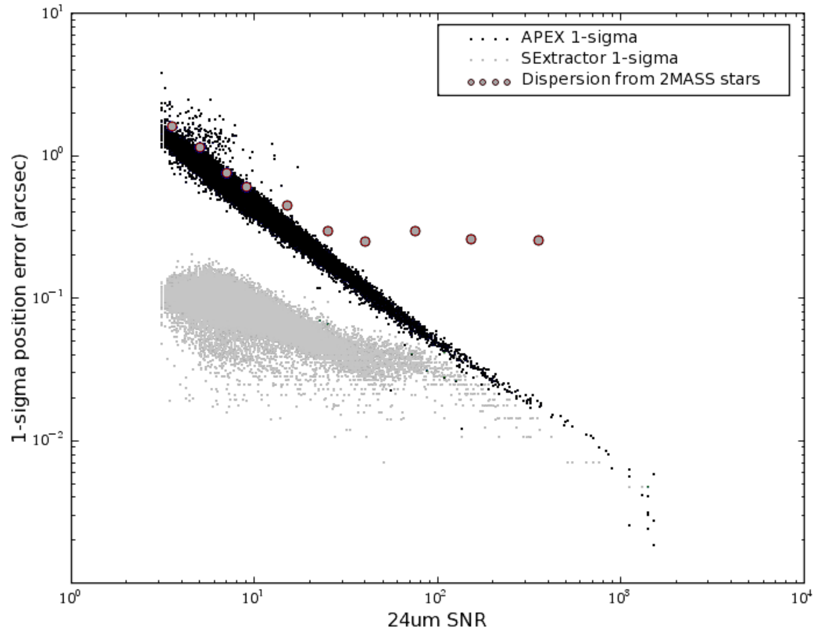

Figure 1. Comparison of 1-σ positional errors from SExtractor (light gray) and APEX (black). The balls show the measured dispersion between 2MASS stars and their corresponding 24 μm extractions.

2. Merging of the 4 IRAC Bands + MIPS-24

For the merging of the four IRAC bands and the MIPS-24 band, we have been using the *Spitzer* band merge program. For each merger seed-candidate combination, 20 in this case, a χ^2 statistic is constructed from the distance between the sources and their position uncertainties. When a seed has more than one candidate passing the χ^2 threshold, confusion is indicated. After all 20 combinations have been matched, the best merge is determined by following the steps of simple confusion processing, inconsistent chain breaking, excess linkage rejection, and position refinement (more information is available on the *Spitzer* website at `http://ssc.spitzer.caltech.edu`).

Positional uncertainties play a crucial role in this process. Our IRAC extractions are made using SExtractor (Bertin & Arnouts 1996), which estimates position errors, but these are significantly underestimated compared to the actual separation of e.g. 3.6 μm-to-4.5 μm merges. The SWIRE MIPS extractions, by contrast, were made using the *Spitzer* APEX PRF-fitting source extractor (Makovoz & Marleau 2005). This extraction makes use of an uncertainty image and, when the uncertainty is properly characterized, the resulting positional uncertainties accurately reflect the positional accuracy estimated from astrometric 2MASS sources (Figure 1). Since the SExtractor position uncertainties are underestimated for the IRAC bands, a global uncertainty value ranging from $0\farcs2$ to $0\farcs4$ is combined in quadrature into the calculation of the positional χ^2 for these bands. Similarly, as shown in Figure 1, a global value of $0\farcs25$ must be added for MIPS-24 for the brighter sources. Thus the merging between IRAC bands is virtually independent of flux or SNR, but merging of MIPS-24 to IRAC depends on the 24 μm SNR.

Utility programs (Laher & Fowler 2007) have been developed to adjust positional uncertainties for bandmerging. These utilities have been used to modify uncertainties for the completeness and reliability analysis discussed in Section 4.

3. Merging of 70 μm and 160 μm Sources

Although the *Spitzer* band merge program is capable of merging all seven *Spitzer* bands, we have taken a different approach. The band merge software outputs only a single match even where multiple candidates (confusion) are indicated. SWIRE instead flags primary and secondary matches, so that multiple shorter-wavelength sources may point to the same 70 μm or 160 μm source. We match 24 μm sources to 70 μm sources within a 6″ radius. Where multiple sources fall within this radius, we select a primary match based on the brighter of the two closest sources. The other matches are flagged as secondary. A similar procedure is followed for 160 μm except that a 12″ aperture is used. Only sources matching a 24 μm source brighter than 0.3 milliJy are considered reliable.

4. Band Merging Completeness & Reliability

The reliability of IRAC Ch 1 to MIPS-24 band merges has been assessed using two types of Monte Carlo simulations. In the first type, for each MIPS-24 source, we have "cloned" one IRAC Ch 1 source and one Ch 2 source with the positions randomly adjusted according to the position uncertainties. Next, the remaining IRAC Ch 1 and Ch 2 sources are added as background with random positions. Then band merge is run on the five bands. In the second simulation only random IRAC Ch1 sources are merged with the 24 μm list. Completeness and reliability are scored by counting correct and incorrect merges. The results for the first case are shown in Figure 2.

The overall reliability depends on the true fraction of MIPS-24 sources that are expected to have a real detection in IRAC Ch1. For the totally random case, about 8% of MIPS-24 sources pick up a false match. Assuming 90% of 24 μm sources have a true match and 10% do not, then the overall reliability from this simulation at low SNR is 0.9*0.981 + 0.1*0.920 = 0.975 overall, and 0.992 for unconfused sources.

5. Summary

The band merging of *Spitzer* sources in the SWIRE survey is complicated by the large beamsizes at long wavelengths and the high source density at the shortest wavelengths. The band merging process for the shorter wavelengths is based on a positional χ^2 calculation in which positional uncertainties play a crucial role. The APEX PRF-fitting extractor produces realistic uncertainties for low SNR detections.

The 70 μm and 160 μm bands are merged by matching in a fixed radius with the intermediate 24 μm band. Where there is more than one potential match,

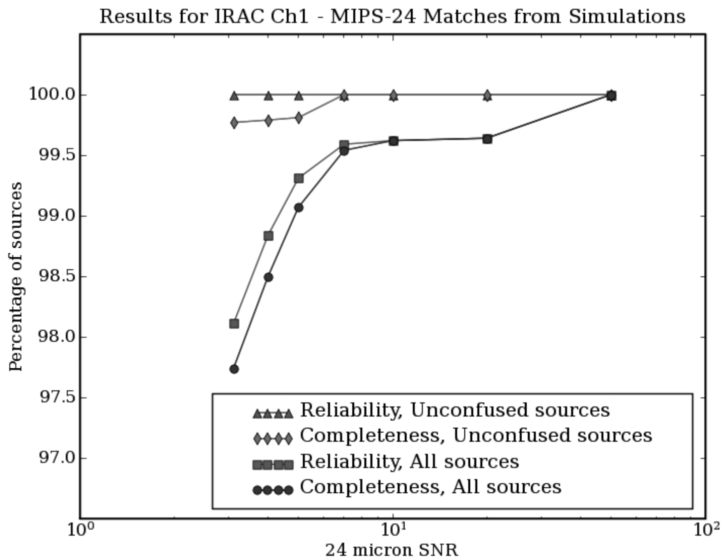

Figure 2. Completeness and reliability results for simulations in which all 24 μm sources have a simulated true match in IRAC Channels 1 & 2. Unconfused sources are those having no more than one match candidate that passed the position χ^2 threshold.

the brighter of the two closest sources is selected. Only those sources matching a 24 μm source of brightness > 0.3 milliJy are considered reliable. Simulations of the merging of the IRAC bands and MIPS-24 indicate a reliability of about 0.975 for all merges and a reliability of 0.992 for unconfused sources.

References

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