The SAGE-SMC Data Description: Delivery 1
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Contents

1. Executive Summary

This document describes the first SAGE-SMC delivery that includes:

- SAGESMCcatalogIRAC_EP1, the v1.0 IRAC catalogs containing Epoch 1 only data bandmerged with All-Sky 2MASS and 6X2MASS
- SAGESMCarchiveIRAC_EP1, the v1.0 IRAC archives containing Epoch 1 only data bandmerged with All-Sky 2MASS and 6X2MASS
- FITS images containing information about the time of observation for a given SAGE IRAC source
- SAGESMCcatalogMIPS24_EP1, the Epoch 1 only MIPS 24 μm catalogs
- SAGESMCfullMIPS24_EP1, the Epoch 1 only MIPS 24 μm full lists

This document provides a brief overview of the project and data processing, as well as the guidance of how to use the source lists to meet the user's scientific needs. A summary of the point source lists can be found in Table 1. A guide to contents of the SAGESMC catalog and archive/full list columns is provided.

Table 1. SAGE-SMC Point Source Lists

Source List Title	No. of Sources	Wavelengths (μm)	Content
SAGESMCcatalogIRAC_EP1	Epoch 1: ∼1.23 million	1.24, 1.66, 2.16 (2MASS or 6X2MASS) 3.6, 4.5, 5.8, 8.0 (IRAC)	IRAC catalog containing Epoch 1 only sources with 0.6 and 12 s frame photometry bandmerged with 2MASS and 6X2MASS; high reliability emphasized. Faint limits[a] for Epoch 1 are 17.6, 17.0, 14.6, & 13.6 mag for IRAC 3.6, 4.5, 5.8, & 8.0 μm
SAGESMCarchiveIRAC_EP1	Epoch 1: ∼1.28 million	1.24, 1.66, 2.16 (2MASS or 6X2MASS) 3.6, 4.5, 5.8, 8.0 (IRAC)	IRAC archive containing Epoch 1 only sources with 0.6 and 12 s frame photometry bandmerged with 2MASS and 6X2MASS; includes more sources and more source fluxes (fewer nulled wavelengths), see §3.3. Faint limits[a] for Epoch 1 are 17.7, 17.1, 14.7, and 14.1 mag for IRAC 3.6, 4.5, 5.8, and 8.0 μm, respectively.
SAGESMCcatalogMIPS24_EP1	Epoch 1: ∼16,000;	24	MIPS 24 μm catalog containing Epoch 1 only sources; high reliability emphasized. To assure high reliability, stringent criteria were applied to the source list extracted from the 24 μm Epoch 1 image AOR mosaics. Faint limit is ∼10 mag.

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Table 1 – Continued

Source List Title	No. of Sources	Wavelengths (μm)	Content
SAGESMCfullMIPS24_EP1	Epoch 1: ∼67,000	24	MIPS 24 μm full list containing *all* sources extracted from the 24 μm Epoch 1 image AOR mosaics. Faint limit is ∼12 mag.

[a] The IRAC 'faint limit' is defined as the point where 99% of IRAC sources (with a non-NULL entry for that IRAC band) are brighter than that quoted faint limit.

2. Overview of the *Spitzer* SAGE-SMC Survey

The SAGE-SMC project is a Cycle 4 legacy program on the *Spitzer* Space Telescope, entitled, " SAGE-SMC: Surveying the Agents of Galaxy Evolution in the Tidally-Disrupted, Low-Metallicity Small Magellanic Cloud", with Karl Gordon (STScI) as the PI. The project overview and initial results are described in a paper by Gordon et al. (2010, in prep). The main characteristics of the survey are listed in Table 2. The SMC was mapped at two different epochs dubbed Epochs 1 and 2 separated by 3 (IRAC) and 9 (MIPS) months,as this provides a 90-degree roll angle in the orientation of the detectors, which optimally removes the "striping" artifacts in MIPS and artifacts along columns and rows in the IRAC image data. In addition, these two epochs are useful constraints of source variability expected for evolved stars and some young stellar objects (YSOs). Note, the predicted sensitivities for the complete survey are listed in Table 2 are for the whole survey, whereas the single epoch catalogs use only half of the data and thus have less sensitivity. Note, not all sources in the SAGE catalog belong to the SMC.

Table 2. Principal Characteristics for SAGE-SMC Survey: *Spitzer* program ID 40245

Characteristic	IRAC Value	MIPS Value
Nominal Center Point	RA(J2000): $1^{h}\ 27^{m}\ 09^{s}$	
	Dec(J2000): -74° 02′ 26″	
Survey area	∼30 □°	∼30 □°
AOR size, # AORs	1.1° × 1.1°, 29	25′ × 4°, 21/24
Total time (hrs)	178.1	112.8
λ (μm)	3.6, 4.5, 5.8, and 8.0	24, 70, and 160
Pixel size at λ	1.″2, 1.″2, 1.″2, 1.″2	2.″5, 9.″8, 15.″9
Angular resolution at λ	1.″7, 1.″7, 1.″9, 2.″0	6″, 18″, 40″
Exposure time/pixel at λ (s)	43, 43, 43, 43	60, 30, 6
Expected final faint limits[a] (mJy)	0.013, 0.012, 0.066, 0.070	0.6, 35, 280
Expected final faint limits[a] (mag)	18.3, 17.9, 15.6, 14.9	11.3, 4.4, 0.6
Saturation limits (Jy) at λ	1.1, 1.1, 7.4, 4.0	4.1, 23, 3
Saturation limits (mag) at λ	6.0, 5.5, 3.0, 3.0	0.60, -3.7, -3.2
Epoch 1	Jun 12-19, 2008	Sep 15-23, 2007
Epoch 2	Sep 17-25, 2008	Jun 25-28, 2008

[a]The IRAC/MIPS 'faint limit' is defined as the point where 99% of the sources (with a non-NULL entry) are brigther than the quoted faint limit.

3. IRAC Epoch 1 Catalog and Archive

3.1. Brief Overview

The SAGE-SMC IRAC Epoch 1 only (EP1) Catalog is a more highly reliable list of 1.23 million sources, and the Archive is a more complete list both in number of sources (at 1.28 million) and flux measurements at each wavelength (less nulling of fluxes). The main differences between the Catalog and Archive are 1) fluxes brighter than a threshold that marks a nonlinear regime are nulled (removed) in the Catalog; 2) sources within 2″ of another are culled (removed) from the Catalog, whereas the Archive allows sources as close as 0.″5 from another; 3) sources within the PSF profile of a saturated source are culled from the Catalog but not the Archive; and 4) the Catalog has higher signal-to-noise thresholds and slightly more stringent acceptance criteria. Users who want a more "bullet-proof" list and don't want to have to get as familiar with the source quality flags, or who will be doing the kind of analysis that does not allow for manual inspection of very many source Spectral Energy Distributions (SEDs), should use the Catalog. Users who want more complete SEDs and source lists, and are willing to invest time to understand the source quality flags, can make use of the Archive. This allows the use of upper limits for fluxes that are nearly saturated, more data points at lower signal-to-noise, more sources in crowded regions, and more sources in the wings of saturated sources. Using the source quality flag, these sources can be identified and should be more carefully inspected to verify their quality. Both Archive and Catalog users can improve the quality of their data by paying attention to the source quality flag, as well as other diagnostic information such as the close source flag (see Appendix B).

The Epoch 1 observations are described in §2 and Table 2. The single-epoch point source lists were extracted from IRAC Epoch 1 single frame images processed with the SSC pipeline version S18.0.2 using a modified version of DAOPHOT (Stetson 1987) to perform the PSF fitting. The array-location-dependent photometric corrections[1] were applied to the source lists. The Wisconsin IRAC pipeline, which was originally developed to process the GLIMPSE data (Benjamin et al. 2003), is described by the GLIMPSE pipeline documents[2]. This pipeline was modified for the SAGE-LMC/SAGE-SMC projects to handle the high dynamic range (HDR) data and longer exposure times. Details for the SAGE-LMC IRAC processing can be found in Meixner et al. (2006). Here we summarize the bandmerging process and the criteria for selection of the point sources in the catalog (SAGESMCcatalogIRAC_EP1) and

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[1]http://ssc.spitzer.caltech.edu/irac/locationcolor/

[2]http://www.astro.wisc.edu/glimpse/docs.html

the archive (SAGESMCarchiveIRAC_EP1) after the sources are extracted from the images.

3.2. Bandmerging to Produce Epoch 1 Source Lists

The point source lists are merged at two stages using a modified version of the SSC bandmerger[3]. Before the first stage, source detections with signal-to-noise (S/N) less than 3 are culled. During the first stage, or in-band merge, all detections at a single wavelength are combined using position, S/N and flux to match the sources. The 0.6 second flux is included if the signal-to-noise is greater than (5,5,5,7) and the magnitudes are brighter than (12,11,9,9), for the four IRAC bands [3.6],[4.5],[5.8], and [8.0], respectively. This prevents Malmquist bias for the 0.6 second data from affecting the results. The 12 second flux is included if the magnitude is fainter than the saturation limit of (9.5, 9.0, 6.5, 6.5) for the four IRAC bands [3.6], [4.5], [5.8], and [8.0], respectively. When both criteria are met, the 0.6 and 12 second fluxes are combined, weighted by the propagated errors. Fluxes of sources within $1.''6$ in the IRAC frame are combined together or "lumped" into one flux.

The second stage, or cross-band merge, combines all wavelengths for a given source position using only position as a criterion in order to avoid source color effects. Cross-band lumping is done with a $1.''6$ radius. Position migration can still occur in the bandmerging process which results in a small number of sources that have sources within $1.''6$ of it. In the cross-band merge stage we also merge with a combined All-Sky 2MASS (Skrutskie et al. 2006) and 6X2MASS point source list (Cutri et al. 2003, Appendix 3) and details on how that combined list was made can be found in Appendix A. Note that we only propagate a subset of the 2MASS quality flags and information, and users should refer to the original 2MASS and 6X2MASS catalogs available through IRSA for full information. We include the unique numeric identifier assigned by the 2MASS project "cntr" (TmassCntr in the SAGESMCcatalogIRAC_EP1 and SAGESMCarchiveIRAC_EP1) to allow this cross-referencing. All the sources with TmassCntr $>$ 15E+08 come from the 6X2MASS catalog, and the sources with TmassCntr $<$ 15E+08 are from the All-Sky 2MASS catalog. The original 6X2MASS TmassCntr was not unique compared with the 2MASS All-Sky TmassCntr. To insure uniqueness we added 15E+08 to the original 6X2MASS TmassCntr.

[3]http://ssc.spitzer.caltech.edu/postbcd/bandmerge.html

3.3. Epoch 1 Catalog and Archive Criteria

Our source list criteria have been developed to ensure that each source is a legitimate astronomical source (*culling* criteria) and that the fluxes reported for the IRAC bands are of high quality (*nulling* fluxes if they do not meet quality standards).

3.3.1. Culling Criteria - is it a real source?

The IRAC single epoch source lists were produced from photometry on individual BCD frames. The 12 second exposures suffer from cosmic rays. For this reason, stringent selection criteria were developed to limit false sources. To ensure high reliability of the final point-source Catalog (SAGESMCcatalogIRAC_EP1) by minimizing the number of false sources, we adopt the following selection criteria: Given M detections out of N possible observations (see Appendix B.4), we require that M/N $\geq$ 0.6 in one band (the selection band), and M/N $\geq$ 0.32 in an adjacent band (the confirming band), with a S/N $>$ 5, 5, 5, 7 for IRAC bands [3.6], [4.5], [5.8] and [8.0], respectively. The 2MASS K_s band is counted as a detection. As an example, a source is typically observed twice at 0.6 second and twice at 12 seconds for a total of four possible observations in each band. Such a source detected three times in band [3.6] with S/N $>$ 5, and twice in band [4.5] with S/N $>$ 5 would be included in both the Catalog and Archive. For a typical source, extracted from 2 $\times$ 12 sec frametime images, the minimum detection criterion (M/N $\geq$ 0.32) amounts to being detected twice in one band (usually band 1 or 2) and once in an adjacent band. Thus, we sometimes refer to this as the 2+1 criterion. In our source selection process, we don't allow fluxes in bands with hot or dead pixels within 3 pixels of source center, those in wings of saturated stars, and/or those within 3 pixels of the frame edge. Sources are also culled when they are too close to another source because this neighboring source could influence the flux for the source: We use the Archive list to search for near neighbors, and cull from the Catalog sources within $2''$

For the Archive (SAGESMCarchiveIRAC_EP1), the culling criteria are less stringent. The M/N and S/N criteria are the same as for the Catalog to limit false sources caused by cosmic rays. The close source criteria is relaxed: Sources are removed from the Archive if there are neighboring Archive sources within $0\farcs5$ of the source.

3.3.2. Nulling Criteria - ensuring high quality fluxes

A source may be reliably detected in two bands (usually [3.6] or [4.5]) but have questionable flux in another (usually [5.8] or [8.0]). To ensure high quality fluxes for each source, a flux/magnitude entry for a band in the *Catalog* will be nulled, i.e. removed, for any of the four following reasons: 1) the source is brighter than the 0.6 sec. saturation magnitude limits, 6.0, 5.5, 3.0, 3.0, for IRAC bands [3.6], [4.5], [5.8] and [8.0], respectively; 2) the source location is flagged as coincident with a bad pixel; 3) the S/N is less than [6, 6, 6, 10] for IRAC bands [3.6], [4.5], [5.8] and [8.0], respectively in order to mitigate Malmquist bias; 4) for 12-second only data, if $M < 2$ or M/N is less than 0.6 in order to mitigate faint cosmic ray detections. Note that in HDR mode, data from one epoch (N=4: 2×12 sec observations and 2×0.6 sec observations) having a result with N=2 is not uncommon. Bright sources are only measurable in the 0.6 sec data and faint sources are only measurable in the 12 sec data. Only stars in the intermediate range of brightness will have useful detections in both the 0.6 and 12 sec images. If all fluxes for a source are nulled, the source is removed from the catalog.

For the *Archive*, the nulling criteria are less stringent. The magnitude is nulled if the S/N is less than 5 in that band. For photometry with 12 second only data, if $M/N < 0.3$ the magnitude is nulled.

The actual null values for the fields in the entry for a source are given in Table 3.

Characteristics of the Epoch 1 only source lists are summarized in Table 1. Since the selection (or culling) criteria are fairly similar between the Catalog and Archive, the total number of sources is not that different (1.23 million vs 1.28 million in Epoch 1). However, the Catalog sources have more fluxes nulled. So, for example, a given source may appear in both the Catalog and Archive but have flux at 2 wavelengths in the Catalog and 4 wavelengths in the Archive.

3.4. Time of Observation Information for each IRAC Source

The time of observation for any given SAGE-SMC IRAC source is a complex question. SAGE-SMC IRAC sources have been bandmerged from multiple imaged frames. Each area of the sky was observed at least 2 times for each epoch, and at each observing time (0.6 and 12 second in HDR mode) in the 4 IRAC bands. The [3.6] and [5.8] bands see a different area of the sky as the [4.5] and [8.0] bands during an observation. Thus a SAGE-SMC source with entries in all 4 bands will consist of measurements made from several different times. Since SAGE-SMC was observed in HDR mode, each area of the sky was observed a minimum of 4 times, and in overlap areas the number can rise to more than 10 unique observations for some limited strips of data. Because of this complication we have provided time-of-observation information in a broad sense. We provide FITS images that display the earliest and latest observational times for any given area observed by SAGE-SMC for each of the 4 IRAC channels. The FITS files are in units of minutes and correspond to the number of minutes after Julian Date 2453400.5. The epoch 1 filenames are smc1.b*.begintime.frms.fits and smc1.b*.endtime.frms.fits, where * = 1,2,3 and 4 for IRAC bands 1 through 4. In this fashion, any SAGE-SMC source with a given RA and Dec can be cross referenced with these FITS files to determine the time period within which those results were taken by epoch and by channel. We also provide an IDL program (get_smc_jd.pro) which shows how to use these timestamp FITS files.

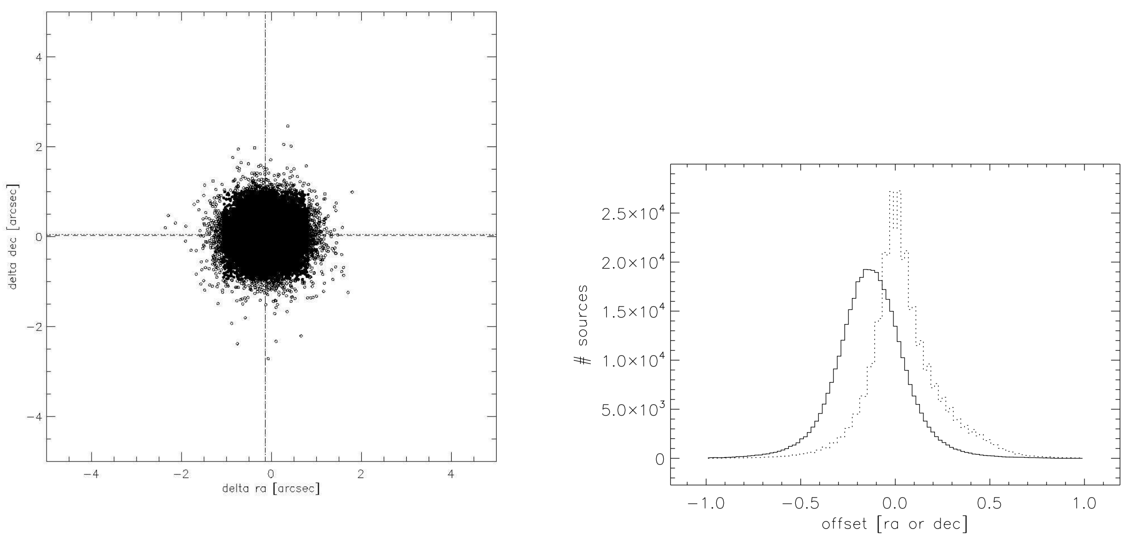

Fig. 1.— The scatter plot of the position difference between 400,000 Epoch 1 sources (from SAGESMCcatalogIRAC_EP1) and their corresponding 2MASS or 6X2MASS catalog positions is shown on the left. On the right, the histogram quantifies the offsets between the list and shows that the average is within the anticipated precision of 0.″3.

3.5. Data Quality Checks

In this section, we describe some quality checks performed on the single- epoch source lists, including astrometry, photometric precision, photometric accuracy, and completeness.

3.5.1. Astrometry

The IRAC catalog astrometry is referenced to the All-Sky 2MASS astrometry through cross matching of the IRAC and All-Sky 2MASS frames. The absolute uncertainty in the 2MASS astrometry is typically $0\farcs3$ (1σ). We determine the astrometric quality of the single epoch Catalogs and Archives (SAGESMCcatalogIRAC_EP1 and SAGESMCarchiveIRAC_EP1) by cross checking its positions against the All-Sky 2MASS/6X2MASS catalogs. Note that sources with 2MASS associates have SAGE-SMC positions that are in part derived from the 2MASS position.

In Figure 1, we plot the histogram showing the offsets between the Catalog Epoch 1 positions and the corresponding All-Sky 2MASS or 6X2MASS positions in 0.05 arcsecond bins. For Epoch 1, the peak of the histogram is within the anticipated precision of $0\farcs3$.

3.5.2. Precision and Accuracy of the Photometry

Figure 2 shows the photometric uncertainty for Epoch 1. There is a jump in uncertainties at the brighter magnitudes, e.g. 9.5 at 3.6 μm, which shows the boundary between the 0.6 and 12 second photometry (with the shorter exposure having larger errors).

The reliability of the flux uncertainties was studied by comparing the quoted error (dFi) with the root mean square (RMS) of the measurements (Fi_rms). For the single frame photometry single epoch source lists, Bands 2 & 4 showed the largest discrepancy. The formal band 2 uncertainties have been decreased 30%, band 3 uncertainties increased 10% and band 4 uncertainties have been increased 35%. Band 1 uncertainties were not changed.

To assure that our photometric calibration is uniform across the large area observed by SAGE-SMC, and between different AORs, epochs, and wavelengths, we compare our photometry to a network of absolute stellar calibrators custom-built for SAGE. These are 53 A0-A5V or K0-M2III stars selected from SIMBAD; their surface density within the SAGE-SMC area is approximately 3 stars per square degree. The techniques used to produce the complete UV to mid-IR absolute spectra are described by Cohen et al. (2003a).

Figure 3 shows the excellent agreement between the SAGE-SMC magnitudes and the predicted magnitudes of the calibration stars for the epoch 1 IRAC data. Uncertainties in both the extracted magnitudes and those predicted were added in quadrature to produce the plotted error bars. Magnitude differences are much smaller than the one-sigma errors of our photometry. The ensemble averaged differences and standard deviations in the four IRAC bands between SAGE-SMC and the predicted magnitudes are 0.010 ± 0.062, 0.024 ± 0.060,

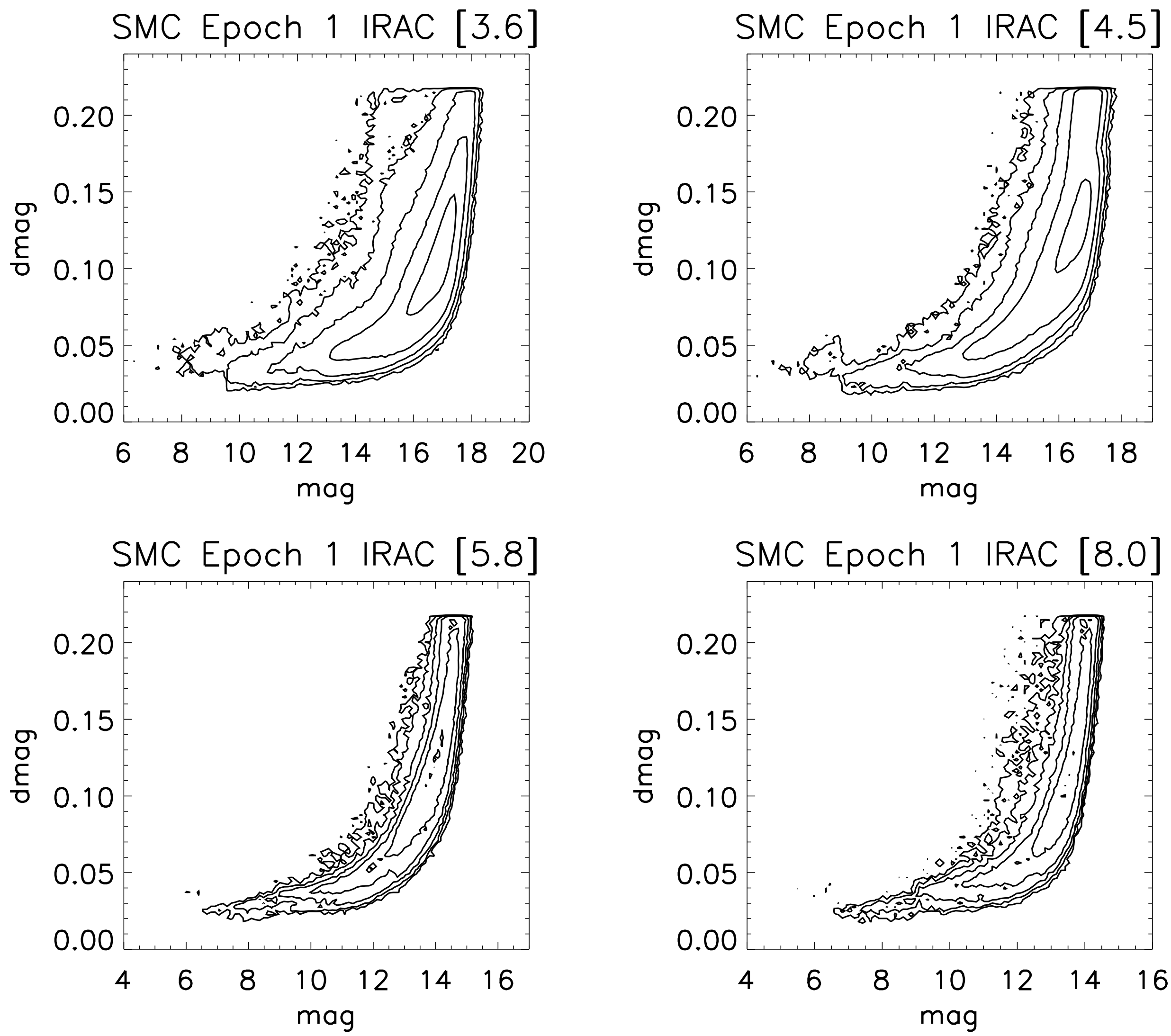

Fig. 2.— Magnitude uncertainty vs. magnitude for each IRAC band in Epoch 1 included in the SAGESMCarchiveIRAC_EP1. Contours show the density of the sources. The lack of data above dmag of .22 is caused by the criterion that archive data have signal to noise ratios of 5 or better.

-0.002±0.060, -0.018±0.052, for bands 1 through 4, respectively for Epoch 1. The number of calibrators per channel varies due to saturation and varies per epoch due to slight coverage differences. For Epoch 1 SAGE-SMC data, the numbers were 31, 40, 52 and 53 flux calibrators for IRAC [3.6], [4.5], [5.8], and [8.0] respectively.

The basis for calibration is identical for 2MASS (Cohen et al. 2003b) and IRAC (Cohen et al. 2003a), with absolute zero points (expressed in Jy for zero magnitude) for 2MASS J,

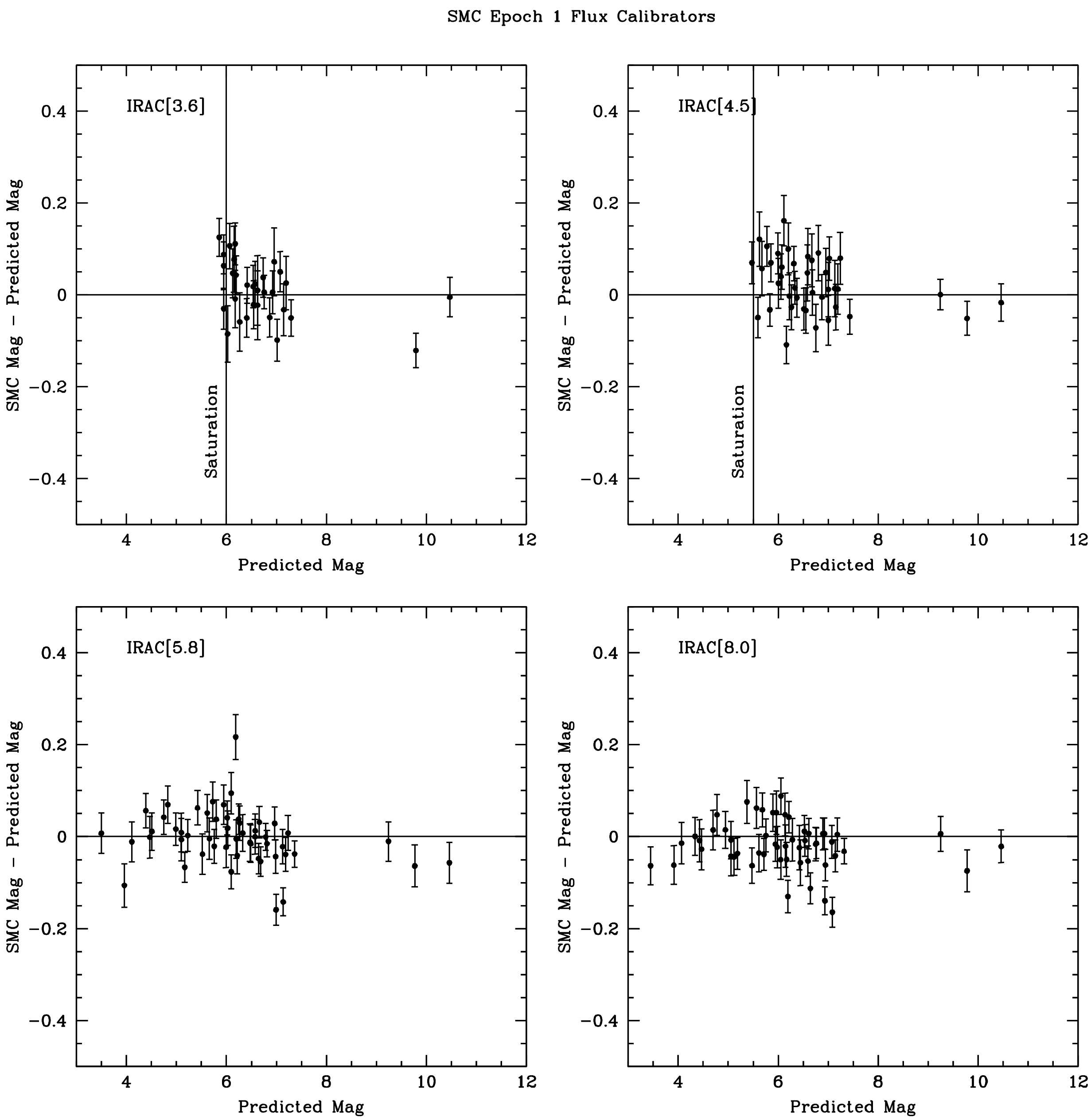

Fig. 3.— Plots demonstrating the quality of the SAGE magnitude measurements in the SAGESMCarchiveIRAC_EP1 for Epoch1. SAGE-SMC magnitudes are compared to predictions for 31 to 53 calibration stars for each IRAC band. Error bars are the root sum of the squares of the errors of both extracted and predicted magnitudes for each star.

H, K_s and the IRAC bands (3.6, 4.5, 5.8, and 8.0 μm) of 1594.0, 1024.0, 666.7, 280.9, 179.7, 115.0, 64.13 Jy, respectively. These zero points are tied to the Midcourse Space eXperiment's

(MSX) absolute calibration which has an accuracy of ±1.1% (Price et al. 2004). The method employed to produce the SAGE-SMC network of calibrators is identical to that used to create the suite of standards at the North Ecliptic Pole (Cohen et al. 2003a) from which the IRAC primary calibrators were selected (Reach et al. 2005).

3.5.3. Completeness

The SAGESMCarchiveIRAC_EP1 and SAGESMCcatalogIRAC_EP1 have been designed for reliability, not completeness. We do not run a thorough completeness test of the source lists. In Figure 4 we compare the number counts per magnitude bin of sources in the SAGESMCarchiveIRAC_EP1 with the SAGESMCcatalogIRAC_EP1. These plots show that the Epoch 1 lists are mostly complete down to 16.0, 15.5, 13.0 and 12.0 in IRAC bands [3.6], [4.5], [5.8], and [8.0] respectively with the big drop-offs at 17.0, 16.5, 14.0 and 13.5 for bands 1 through 4, respectively. Completeness is also a function of background level which is more variable for IRAC [5.8] and [8.0].

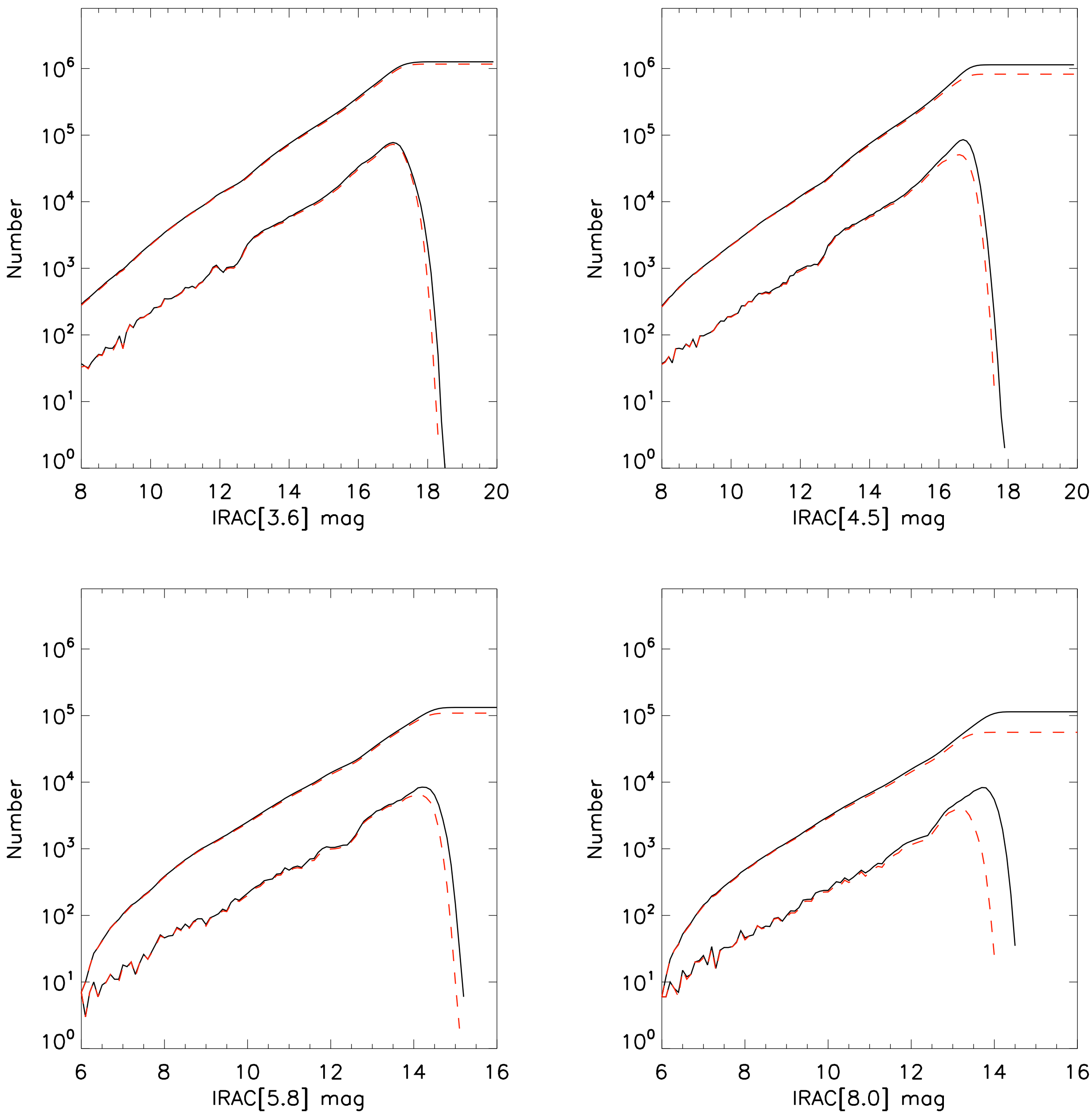

Fig. 4.— Comparison of the SAGESMCarchiveIRAC_EP1 source counts (solid black line) with the SAGESMCcatalogIRAC_EP1 source counts (dashed red line). The lower two lines in each panel show the differential number counts while the upper two lines in each panel show the cumulative total number counts.

4. MIPS 24 μm Epoch 1 Full and Catalog Lists

The point source lists presented in this document were extracted from the Epoch 1 images for MIPS 24 μm. The Arizona MIPS team pipeline, MIPS Data Analysis Tool v3.06 (DAT; Gordon et al. 2005) and customized post-processing scripts were used to do the processing and mosaicing of the individual images. The details for the SAGE-SMC MIPS Epoch 1 data processing can be found in Meixner et al. (2006) and Gordon et al. (2010, in prep). Here we summarize the criteria for selection of the point sources to be in the full and catalog list after the sources are extracted from the images. Then we describe the quality of the various lists.

4.1. 24 μm Full List and Catalog Criteria

The MIPS source lists were extracted using StarFinder (Diolaiti et al. 2000) on the Epoch 1 image AOR mosaics for MIPS 24 μm. The extraction was done using a model PSF and setting the acceptable source parameters to be $>2\sigma$ and a correlation >0.80. The source lists for the individual AORs were merged into single epoch source lists averaging the sources which were detected in multiple AORs. This produced a large list of sources (called 'full lists'). The reliability of sources was nonuniform over SMC and extensive tests were carried out to identify criteria which could be used to create a high reliability catalog for each epoch. To be included in each single epoch catalog, each 24 μm source has to meet a number of criteria. The source had to be nearly point like with a correlation value >0.89. This removed approximately 2/3 of the entries in the single epoch source lists. In regions where there is a significant structure in the surrounding region (identified as having a $\sigma > 0.25$ in a 120$''$ width square box), the source had to have a correlation value >0.91. This requirement removed a small number of sources (∼70). Finally, all sources had to have signal-to-noise (S/N) values >5. The S/N used was that estimated from the StarFinder code using the mosaic uncertainty image added in quadrature with an 0.6% error due to the background subtraction. This removed ∼700 sources. The final Epoch 1 catalogs (SAGESMCcatalogMIPS24_EP1) likely have a few remaining unreliable sources, but we estimate this to be at the less than 1% level.

We also deliver the MIPS 24 μm Full List (SAGESMCfullMIPS24_EP1). This source list contains ALL the sources extracted from the mosaics, thus a user should be aware that it contains spurious sources. The full list may be useful to search for the potential 24 μm counterparts to known sources. Inspection of the 24 μm counterparts could be done by inspecting the 24 μm image and by analyzing the spectral energy distribution of the source.

4.2. Data Quality Checks

4.2.1. Astrometry

The astrometry of the SAGESMCcatalogMIPS24_EP1 sources are referenced to the IRAC Single Frame Epoch 1 by using a bright 8 μm source list for the astrometric framework of the MIPS 24 μm catalog. The corrections required to register the MIPS 24 μm catalog to the bright 8 μm catalog are $\sim 1''$. This is not unexpected as the nominal pointing accuracy of Spitzer is $\sim 1''$. As the IRAC observations have already been registered to 2MASS sources, this results in the MIPS 24 μm sources being registered to the 2MASS coordinate system as well.

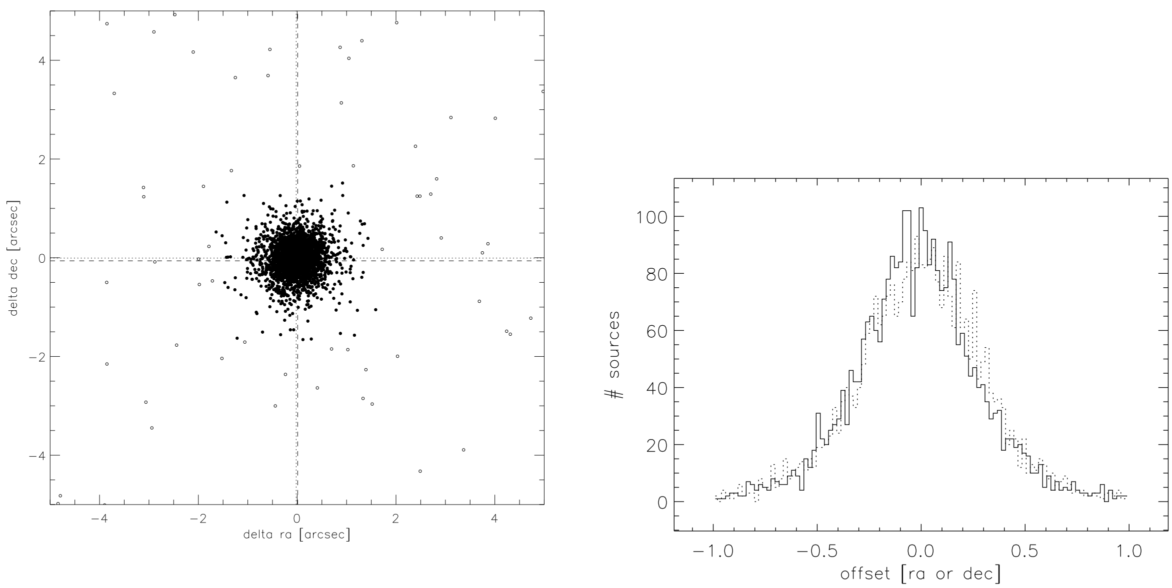

Fig. 5.— The left plot shows the scatter plot of the sources matching between the bright IRAC 8 μm and the MIPS 24 μm sources within $5''$. The histogram plot quantifies the offsets between these two lists and show that the average is very near zero for both ra and dec.

Histograms showing the offsets between the registered MIPS 24 μm and the bright IRAC 8 μm list reveals the average offsets sharply peaked at zero as expected (Figure 5).

4.2.2. Precision and Accuracy of the Photometry

Figure 6 shows the photometric uncertainties of the MIPS 24 μm Catalog (SAGESMCcatalogMIPS24_EP1). The behavior of the uncertainties as a function of magnitude is

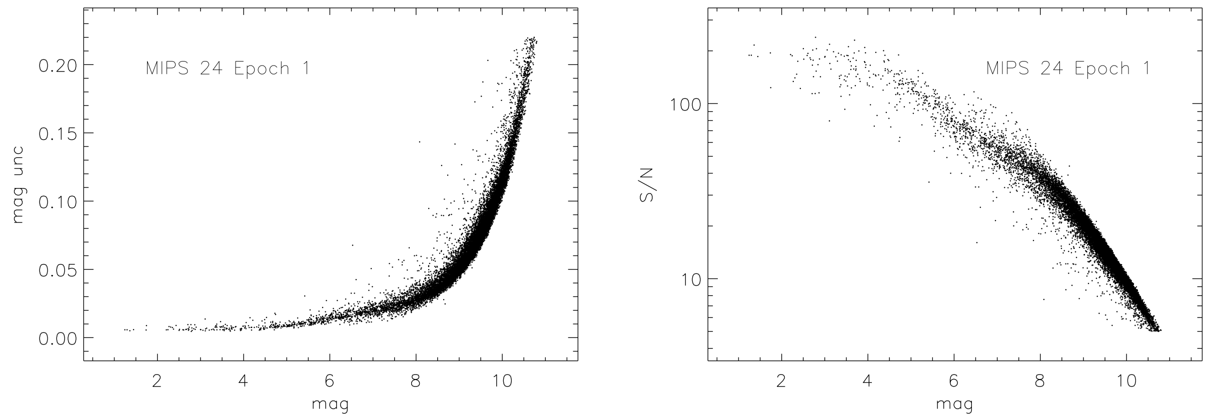

Fig. 6.— The uncertainty in magnitudes is plotted versus magnitude for the full MIPS 24 μm catalog in the left plot. The right plot shows the S/N versus magnitude for the same catalog.

as expected. The scatter in the uncertainties at the same magnitude is due to the large variations in the background (extended) emission across the SMC.

The absolute photometry accuracy of the MIPS fluxes is 2% at 24 μm (Engelbracht et al. 2007), 5% at 70 μm (Gordon et al. 2007), and 12% at 160 μm (Stansberry et al. 2007). The zero points for the MIPS 24, 70, and 160 μm magnitudes are 7.17, 0.778, and 0.160 Jy (Rieke et al. 2008). As an independent check on the measured MIPS 24 μm magnitudes, we compared the SAGE-SMC magnitudes to the predicted MIPS 24 μm magnitudes of calibration stars in the SAGE-SMC fields (Figure 7). This checks that the extraction of point source fluxes from the images has not introduced systematic errors. The average offset is 0.050 mag for Epoch 1. The expected offset is 0.029 mag due to small differences between the Cohen et al. (2003a) and Rieke et al. (2008) photometric systems. The good agreement seen between the measured and expected differences provides confidence that the extraction of the MIPS 24 μm sources provides accurate photometry.

4.2.3. Completeness

We have not conducted full completeness tests for the MIPS catalogs. Full completeness tests require extensive false source tests which have yet to be carried out. The overall completeness can be estimated by examining the flux histogram of the catalog sources. Figure 8 shows the histograms for all the MIPS catalogs. The full source list and the high reliability catalog histograms are shown. From the catalog histograms it can be seen that

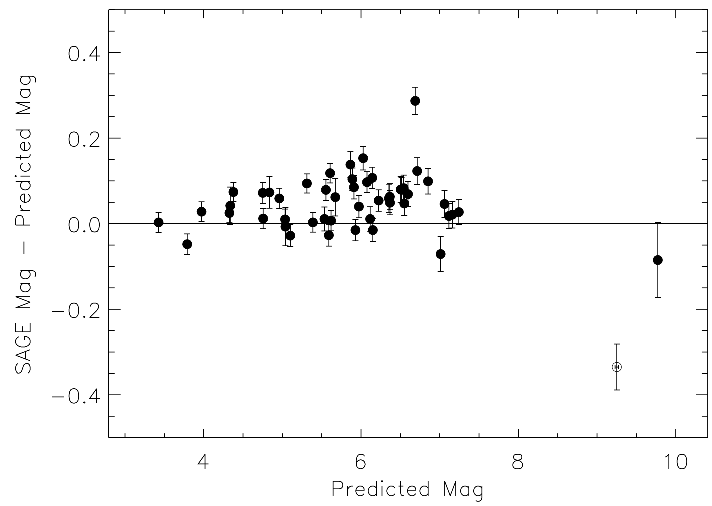

Fig. 7.— The difference between the measured SAGE magnitude and the predicted magnitude for the Cohen et al. (2003a) calibration stars in the SAGE-SMC catalog is shown. The solid line is at zero. The expected offset is 0.029 mag and the observed is 0.05 mag Epoch 1. The predicted magnitudes are based on techniques by Cohen et al. (2003a).

the catalogs are complete to a little above 1 mJy (24 μm). Given the large variations in the extended emission in the SMC, the completeness limit will vary significantly over the SMC. The number quoted above is for the faintest, least crowded regions in the SMC.

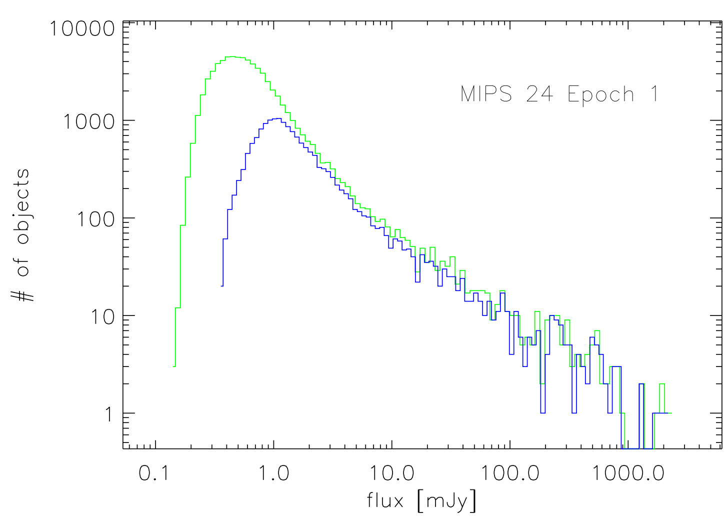

Fig. 8.— The flux histograms for the full source lists (green) as well as the high reliability catalogs (blue) is shown.

Another measure of the reliability of a catalog is the histogram of the nearest neighbor distances. Figure 9 shows this histogram for the full source lists and the catalogs. The full source lists clearly include a number of spurious sources given the large peaks at close separations. These peaks are not seen in the catalog histograms confirming that they are highly reliable (at least in the context of nearest neighbors).

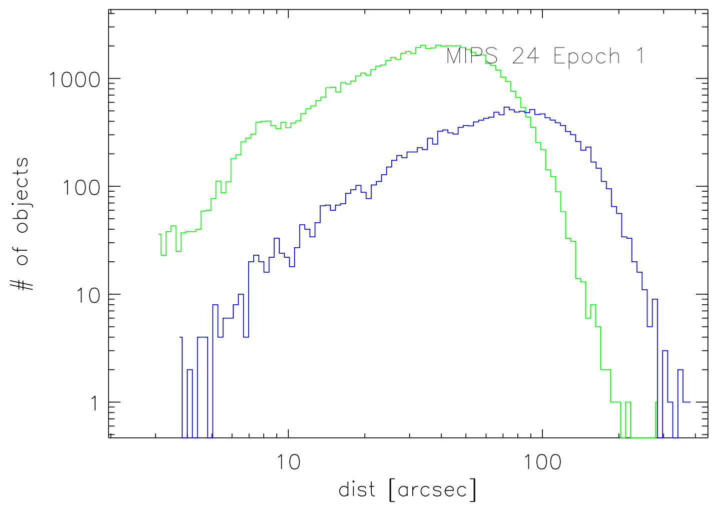

Fig. 9.— The nearest neighbor histogram of the full source lists (green) and catalogs (blue) is plotted.

A. APPENDIX A - Bandmerging with the 2MASS All Sky and 6X Point Source Catalogs

The IRAC data were bandmerged with a combination of the 2MASS All-Sky Point Source Catalog and the 2MASS 6X Deep Point Source Catalog.

- How the 2MASS All-Sky + 6X2MASS were combined

  The 6X2MASS catalog is deeper than the original All-Sky catalog, but contains only direct pipeline extractions from 2MASS imaging, whereas the All-Sky has been supplemented at the bright end with more sophisticated photometry. Thus, the most scientifically robust catalog should use the original All-Sky for bright sources, the 6X2MASS for faint sources, and possibly a combination at intermediate fluxes. In order to maintain maximum tracability back to the 2MASS catalog, we chose to use either the 6X or the All-Sky bandmerged source, and not to mix photometry from the different catalogs in different bands.

  Sources that lie in regions scanned more than once or in overlap regions may have multiple independent detections. One unique observation is selected for inclusion in the 6X2MASS catalog. We followed the procedure outlined in the 2MASS documentation of choosing the source furthest from its tile boundary (see www.ipac.caltech.edu/2mass/releases/allsky/doc/seca3_6d.html for more details). We first removed sources within 2″ from the 6X2MASS catalog. To the best of our knowledge this results in a catalog consistent with the 2MASS documentation.

  For each source we determined the reddest measurement (e.g. for a source with a K_s detection we use the K_s magnitude. For a source with K_s upper limit and H detection we use the H magnitude). We then constructed a list consisting of:

  – any source in the All-Sky with reddest magnitude (redband) <13
  – any source in the 6X with redband >15
  – any source in either the All-Sky or the 6X with 13 < redband < 15 and no source in the other list within 5″
  – any source with a match from the other list within 5″, choosing the source with better photometric quality flag in the reddest band.

  All the sources with TmassCntr > 15E+08 come from the 6X2MASS catalog, and the sources with TmassCntr < 15E+08 are from the All-Sky 2MASS catalog. The original 6X2MASS TmassCntr was not unique compared with the 2MASS All-Sky TmassCntr. To insure uniqueness we added 15E+08 to the original 6X2MASS TmassCntr.

- We include a 2MASS match if the source has a photometric quality flag of A, B, C or D for the K_s band, or a quality flag of A or B in the H band (see Appendix B.5.2 for the definition of the photometric quality flag). The 2MASS combined catalog contains a large number of sources without K_s detections because 2MASS is more sensitive at shorter wavelengths, and the majority of sources in the Galaxy have the "blue" infrared colors of main-sequence stars. We found that in crowded regions, sources with questionable 2MASS photometry (according to their photometric quality flag) in J and/or H, and no detection in K_s, usually led to incorrect associations with IRAC. In fact, comparison of the SAGE and 2MASS sensitivity limits makes it clear that a source with reasonable astrophysical colors, good IRAC photometry, good J photometry, and only upper limits at K_s, is highly unlikely. Thus we performed a (very conservative) selection on the 2MASS catalog, removing sources with worse than A photometric quality in J, worse than C in H, AND worse than E in K_s.

B. APPENDIX B - IRAC Catalog and Archive Formats

Table 3 describes the columns in the single epoch Catalog and Archive source lists (SAGESMCcatalogIRAC_EP1 and SAGESMCarchiveIRAC_EP1) including the data format and null values. Note that:

- The fields in the Catalog and the fields in the Archive are the same. Data is delivered in IPAC Table format.

- Where NULL values are not legal, NO is entered in the column. Otherwise, the null value is given.

Selected columns are discussed in detail in the following subsections.

B.1. Designation

The format of the source designations is 'SSTISAGE1A JHHMMSS.SS±DDMMSS.S' and 'SSTISAGE1C JHHMMSS.SS±DDMMSS.S' for the SAGE-SMC IRAC Catalogs and Archives, respectively, where

SST = Spitzer Space Telescope
I = IRAC

SAGE = SAGE-SMC Survey projects
0 = Epoch 0; **1** = Epoch 1; **2** = Epoch 2
C = highly reliable Catalog
A = more complete Archive
J = 2000.0 epoch
HHMMSS.SS = Right ascension (hr, min, sec) of source
±**DDMMSS.S** = Declination (deg, min, sec) of source

B.2. Close Source Flag

The Close Source Flag is set when a source in the Archive is within $3\farcs0$ of another Archive source. It was found that the magnitudes of sources closer than about $2\farcs0$ from each other are not as reliably extracted and bandmerged. Therefore, a source that is within $2\farcs0$ of an Archive source is culled from the Catalog. The Archive allows sources to be up to $0\farcs5$ from each other before culling. The Close Source Flag can have values from 0 to 6, with the following definitions:

0 no sources in the Archive within $3\farcs0$ of the source
1 sources in the Archive between $2\farcs5$ and $3\farcs0$ of the source
2 sources in the Archive between $2\farcs0$ and $2\farcs5$ of the source
3 sources in the Archive between $1\farcs5$ and $2\farcs0$ of the source
4 sources in the Archive between $1\farcs0$ and $1\farcs5$ of the source
5 sources in the Archive between $0\farcs5$ and $1\farcs0$ of the source
6 sources in the Archive within $0\farcs5$ of the source.

Table 3. IRAC Catalog and Archive Formats-Single Epoch Source Lists

Col.	Name	Description	Data	Format	Null
1	globalSourceID	Unique identifier	I*4	i10	NO
2	sourceCatalog	Identifier for source catalog	ASCII	a8	NO
3	epoch	Identifier for the epoch of the observations of the source	ASCII	a16	NO
4	designation	Source name Archive: SSTISAGE1A JHHMMSS.SS±DDMMSS.S Catalog: SSTISAGE1C JHHMMSS.SS±DDMMSS.S	ASCII	a32	NO
5	TmassCntr	cntr from 2MASS Point Source Catalog	I*4	i10	0
6	TmassDesignation	2mass source name	ASCII	a32	null
7	ra	Right Ascension, J2000 (deg)	R*8	f11.6	NO
8	dec	Declination, J2000 (deg)	R*8	f11.6	NO
9	dra	Error in Right Ascension ($''$) dra is in units of arcseconds, so to convert to seconds of time, multiply by cos(dec)/15.	R*8	f4.1	NO
10	ddec	Error in Declination ($''$)	R*8	f4.1	NO
11	closeFlag	Close source flag	I*2	i3	NO
12-25	magi, dmagi	Magnitude from from J,H,K (i=1-3) and each IRAC band (i=4-7) and 1σ error (mag)	R*4	7(f7.3,f7.3)	99.999,99.999
26-39	fi,dfi	Fluxes and 1σ error in each band i, i=1-7 (mJy)	R*4	14(e11.3)	-999.9,-999.9
40-43	rms_fi	rms dev. of individual detections from fi (i=4-7), (mJy)	R*4	4(e11.3)	-999.9
44-47	skyi	Local sky bkg. for band i flux (i=4-7), (MJy/sr)	R*4	4(e11.3)	-999.9
48-54	sni	Signal/Noise for band i flux (i=1-7)	R*4	7(f6.2)	-9.99
55-58	srcdensi	Local source density for band i object (i=4-7), (#/sq')	R*4	4(f5.1)	-9.9
59-62	mi	Number of detections for band i (i=4-7)	I*2	4(i3)	NO
63-66	ni	Possible number of detections for band i (i=4-7)	I*2	4(i3)	NO
67-73	sqfi	Source Quality Flag for band i flux (i=1-7)	I*4	7(i10)	-9
74-77	mflagi	Flux calc method flag for band i flux (i=4-7)	I*2	4(i3)	-9
78	versionNo	Version number assigned by IRAC pipeline team	R*4	f6.2	NO
79	versionDate	Date catalog was produced in the following format, "mon dd yyyy", "Dec 5 2007"	ASCII	a12	NO
80	cx	x of unit vector on the unit sphere for ra,dec of this source	R*4	f30.20	NO
81	cy	y of unit vector on the unit sphere for ra,dec of this source	R*4	f30.20	NO
82	cz	z of unit vector on the unit sphere for ra,dec of this source	R*4	f30.20	NO
83	htmID	The Hierchical Triangular Mesh partition computed at index level 20 in which this source lies	I*4	i20	NO

B.3. Local Source Density

If a band's flux was derived from single frame photometry, a local source density (number of sources per square arcmin) was measured as follows: The individual IRAC frame is divided into a 3×3 grid, each of the nine cells being $1'.71 \times 1'.71$. A source density is calculated for each cell (number of sources per arcmin^2), and is assigned to each source in that cell.

B.4. M and N (number of actual detections, number of possible detections)

For fluxes derived from single frame photometry:

M = All detections used in the final flux calculation. Detections can be thrown out by exposure time (when combining 0.6 and 12 second data, for example), or because they have bad SQF flags. Detections are also thrown out at the beginning of bandmerging for sensitivity or saturation reasons. If *any* detections without bad flags went into the final flux, then only those good detections are counted. If all detections had bad flags, then all are counted, and the final source will have some bad quality flags also. Bad in this context is 8=hot/dead pixel and 30=edge (see Appendix B.5 for SQF details).

N = All frames containing the position of the combined source in this band (*not* including the edge of the frame, within 3 pixels) for which the exposure time was used in the final flux. As for M, if *any* good detections are used, we only count the good detections, but if they're all bad we count all of them and set flags in the final source. For sources not detected in a band, the position of the final cross-band merged source is used for calculating N.

B.5. Source Quality Flag (SQF)

The Source Quality Flag (SQF) is generated from SSC-provided masks and the SAGE-SMC pipeline during point source extraction on individual IRAC frames and bandmerging. Each source quality flag is a binary number allowing combinations of flags (bits) in the same number. Flags are set if an artifact (e.g., a hot or dead pixel) occurs near the core of a source - i.e. within 3 pixels. A non-zero SQF will in most cases decrease the reliability of the source. Some of the bits, such as the DAOPHOT tweaks (see Appendix B.5.1), will not compromise the source's reliability, but have likely increased the uncertainty assigned to the source flux. If just one IRAC detection has the condition requiring a bit to be set in the SQF, then the bit is set even if the other detections did not have this condition. Sources with hot or dead pixels within 3 pixels of source center (bit 8), those in wings of saturated stars (bit 20), and those within 3 pixels of the frame edge (bit 30) were used in the culling to produce the Catalog. Table 4 gives the Source Quality Flag bits and the origin of the flag (SSC or SAGE-SMC pipeline). Each of the 7 bands has its own Source Quality Flag. For the cross-band confusion flag and the cross-band merge lumping flag, when the condition is met for one of the bands, the bit is set for all the source's bands.

B.5.1. IRAC Source Quality Flag

Information is gathered from the SSC IRAC bad pixel mask (pmask), SSC bad data mask (dmask) and the SAGE IRAC pipeline for the Source Quality Flag. For more information about the IRAC pmask and dmask, see
http://ssc.spitzer.caltech.edu/irac/products/pmask.html
and
http://ssc.spitzer.caltech.edu/irac/products/bcd_dmask.html

The value of the SQF is $\sum 2^{(bit-1)}$. For example, a source with bits 1 and 4 set will have SQF = $2^0 + 2^3 = 9$. If the SQF is 0, the source has no detected issues. A detailed description of the bits is given below.

bit
1 - poor pixels in dark current
This bit is set when a source is within 3 pixels of a pixel identified in the SSC IRAC pmask as having poor dark current response (bits 7 and 10 in the pmask).
2 - flat field questionable
If a pixel is flagged in the SSC IRAC dmask as flat field applied using questionable value (bit 7) or flat field could not be applied (bit 8), a source within 3 pixels of these pixels will have this bit set.
3 - latent image
This flag comes from the latent image flag (bit 5) from the dmask. The SSC pipeline predicts the positions of possible latent images due to previously observed bright sources.
7 - muxbleed correction applied (bands 1 & 2)
This bit is set if the source was within 3 pixels of a pixel that had a muxbleed correction applied.
8 - hot, dead or otherwise unacceptable pixel
Hot, dead or unacceptable pixels are identified in the IRAC pmask as having an unacceptable response to light (bits 8, 9 and 14 in the IRAC pmask). After inspecting IRAC frames, we have added bit 12 to the pmask to flag additional pixels we found to be bad. Also considered bad pixels are ones flagged as bad or missing in bit 11 and 14 in the IRAC dmask. SQF bit

Table 4. Source Quality Flag bits

SQF bit	Description	Origin
1	poor pixels in dark current	SSC pmask
2	flat field questionable	SSC dmask
3	latent image	SSC dmask
3	persistence (p)	2MASS
4	photometric confusion (c)	2MASS
7	muxbleed correction applied	SAGE
8	hot, dead or otherwise unacceptable pixel	SSC pmask,dmask,SAGE
9	muxbleed corr. applied is $>3\sigma$ above bkg	SAGE
9	electronic stripe (s)	2MASS
10	DAOPHOT tweak positive	SAGE
11	DAOPHOT tweak negative	SAGE
13	confusion in in-band merge	SAGE
14	confusion in cross-band merge (IRAC)	SAGE
14	confusion in cross-band merge (2MASS)	SAGE
15	column pulldown corrected	SAGE
16	banding corrected	SAGE
19	data predicted to saturate	SAGE
20	saturated star wing region	SAGE
20	diffraction spike (d)	2MASS
21	pre-lumping in in-band merge	SAGE
22	post-lumping in cross-band merge (IRAC)	SAGE
22	post-lumping in cross-band merge (2MASS)	SAGE
23	photometric quality flag	2MASS
24	photometric quality flag	2MASS
25	photometric quality flag	2MASS
30	within three pixels of edge of frame	SAGE

8 is set if a source is within 3 pixels of any of these bad pixels. Bands with this bit set are not counted during the source selection process (see Section 3.5)

9 - muxbleed correction $>3\sigma$ above the background (bands 1 & 2)

This bit is set if the source was within 3 pixels of a pixel where there was a muxbleed correction applied which is $> 3\sigma$ above the background.

10 - DAOPHOT tweak positive

11 - DAOPHOT tweak negative

Bits 10 and 11 correspond to an iterative photometric step (tweaking). Photometry is initially performed by DAOPHOT/ALLSTAR using PSF fitting. This photometric step produces a list of sources, their positions and brightnesses, as well as a residual image of those sources removed from the input image. By flattening the residual image (smoothing it and then subtracting the smoothed image from the residual image) and then performing small aperture photometry at the location of each of the extracted sources, it is possible to determine if the extracted source was over or under subtracted due to any local complex variable background or the undersampled PSF. SQF bit 10 refers to sources that were initially under-subtracted. From the aperture photometry a positive flux correction was applied to the DAOPHOT/ALLSTAR extraction value (source was brightened via aperture photometry as compared to the initial PSF fitted DAOPHOT/ALLSTAR photometry). SQF bit 11 refers to sources that were initially over-subtracted. Using aperture photometry, a negative flux correction was applied to the DAOPHOT/ALLSTAR extraction value (source was dimmed via aperture photometry as compared to the initial PSF fitted DAOPHOT/ALLSTAR photometry). Sources with both SQF bits 10 and 11 set imply 1) the source was initially under-subtracted, but the aperture photometry over- corrected and thus a second aperture correction was applied or 2) multiple observations in a band consisted of at least one observation with a positive tweak and another observation with a negative tweak.

13 - confusion in in-band merge

14 - confusion in cross-band merge

These bits are set during the bandmerging process. The bandmerger reports, for each source and band, the number of merge candidates it considers in each of the other bands. If the number of candidates is greater than 2, then the bandmerger had to resolve the choice based on examination of the different band-pair combinations and position (and flux in-band) χ^2 differences between candidates. If the number of candidates is greater than 1, the confusion flag is set for all bands.

15 - column pulldown corrected (bands 1 & 2)

This bit is set if the source is within 3 pixels of a column pulldown corrected pixel.

16 - banding corrected (bands 3 & 4)

This bit is set if the source is within 3 pixels of a banding corrected pixel.

19 - data predicted to saturate

This bit is set when a source is within 3 pixels of a pixel identified in the dmask as being saturated (bit 10 in the dmask). The SAGE IRAC pipeline runs a saturated pixel estimator and sets bit 10 in the dmask. This program finds clusters of high-valued pixels. The cluster size and high pixel value are tuned so that extracted photometry above the IRAC non-linear (near-saturation) limits are flagged as saturated. Before photometry is done on an IRAC frame, these pixels are masked.

20 - saturated star wing region

False sources can be extracted in the wings of saturated sources. This bit is set if the source is within a PSF-shaped region (with a 24-pixel radius) surrounding a saturated source determined from bit 10 in the dmask. Bands with this bit set are not counted during the source selection process (see Section 3.3)

21 - pre-lumping in in-band merge

Sources in the same IRAC frame within a radius of 1.6 arcsec are merged into one source (weighted mean position and flux) before bandmerging. This is potentially a case in which the source is incompletely extracted in the first IRAC frame and a second source extracted on the second IRAC frame. Or it could be a marginally resolvable double source. This bit is set for the band if sources have been lumped for that band.

22 - post-lumping in cross-band merge

This bit is set if the source is a result of sources that were lumped in the cross-band merge step for all bands. Cross-band lumping is done with a 1.6 arcsec radius. For example, say there are two sources within 1.6 arcsec of each other. One source has data in bands 1 and 4 and the other has data in bands 2 and 3. These two sources will be lumped into one source with data in all 4 bands.

30 - within three pixels of edge of frame

Sources within three pixels of the edge of the IRAC frame are flagged since it is likely to be too close to the edge of the frame for accurate photometry to be done. Bands with this bit set are not counted during the source selection process (see Section 3.3)

B.5.2. 2MASS Source Quality Flag

For the 2MASS bands, the following contamination and confusion (cc) flags from the 2MASS All Sky + 6X2MASS Point Source Catalog are mapped into bits 3, 4, 9 and 20 of the Source Quality Flag. For more information about the cc flags, see
http://www.ipac.caltech.edu/2mass/release/All-Sky/doc/sec2_2a.html#cc_flag.
Three Source Quality Flag bits (23, 24, 25) provide the 2MASS photometric quality flag information, whose possible values are (from worst to best) X, U, F, E, D, C, B, and A (see http://pegasus.phast.umass.edu/ipac_wget/releases/All-Sky/doc/sec1_6b.html#phqual.)
Users should consult the 2MASS PSC documentation for the complete information about the source, including all of their source quality flags.

bit

3 - "p" persistence

Source may be contaminated by a latent image left by a nearby bright star.

4 - "c" photometric confusion

Source photometry is biased by a nearby star that has contaminated the background estimation.

9 - "s" electronic stripe

Source measurement may be contaminated by a stripe from a nearby bright star.

14 - confusion in cross-band merge

This bit is set during the bandmerging process. The bandmerger reports, for each source and band, the number of merge candidates it considered in each of the other bands. If the number of candidates is greater than 2, then the bandmerger had to resolve the choice based on examination of the different band-pair combinations and position χ^2 differences between candidates. If the number of candidates is greater than 1, the confusion flag is set for all bands.

20 - "d" diffraction spike confusion

Source may be contaminated by a diffraction spike from a nearby star.

22 - post-lumping in cross-band merge

This bit is set for all bands (IRAC and 2MASS) if the source is a result of sources that were lumped in the cross-band merge step. Cross-band lumping is done with a 1.6 arcsec radius.

23 - Photometric quality flag

24 - Photometric quality flag

25 - Photometric quality flag

Table 5. 2MASS Source Quality Flag

2MASS "ph" Flag =>	SQF bits 23, 24, 25	value
X	0, 0, 0	0
U	1, 0, 0	4194304
F	0, 1, 0	8388608
E	1, 1, 0	12582912
D	0, 0, 1	16777216
C	1, 0, 1	20971520
B	0, 1, 1	25165824
A	1, 1, 1	29360128

In Table 5:

X - There is a detection at this location, but no valid brightness estimate can be extracted using any algorithm.

U - Upper limit on magnitude. Source is not detected in this band or it is detected, but not resolved in a consistent fashion with other bands.

F - This category includes sources where a reliable estimate of the photometric error could not be determined.

E - This category includes detections where the goodness-of-fit quality of the profile-fit photometry was very poor, or detections where psf fit photometry did not converge and an aperture magnitude is reported, or detections where the number of frames was too small in relation to the number of frames in which a detection was geometrically possible.

D - Detections in any brightness regime where valid measurements were made with no [jhk]_snr or [jhk]_cmsig requirement.

C - Detections in any brightness regime where valid measurements were made with [jhk]_snr>5 AND [jhk]_cmsig<0.21714.

B - Detections in any brightness regime where valid measurements were made with [jhk]_snr>7 AND [jhk]_cmsig<0.15510.

A - Detections in any brightness regime where valid measurements were made with [jhk]_snr>10 AND [jhk]_cmsig<0.10857.

B.5.3. Key to Bit Values

This section describes how to determine the bit values of a Source Quality Flag.

bt = bit in SQF
value = $\sum 2^{(bt-1)}$

bit values:
bt 1 => 1; 2 => 2; 3 => 4; 4 => 8; 5 => 16; 6 => 32; 7 => 64; 8 => 128 bt 9 => 256; 10 => 512; 11 => 1024; 12 => 2048; 13 => 4096; 14 => 8192; 15 => 16384; bt 16 => 32768; 17 => 65536; 18 => 131072; 19 => 262144; 20 => 524288; bt 21 => 1048576; 22 => 2097152; 23 => 4194304; 24 => 8388608; 25 => 16777216; 30 => 536870912

For example, say the Source Quality Flags are 29360128 for the 2MASS J and H bands and 29360136 for the K_s band. This translates to bits 23, 24 and 25 being set for J & H, which is the photometric quality A flag from the 2MASS PSC. For K_s, bits 4, 23, 24 and 25 are set, meaning the "c" photometric confusion flag was set and the photometric quality flag is A. Say IRAC band 1 has a SQF of 16384. This means bit 15 has been set which means the source is within three pixels of a column pulldown corrected area.

B.6. Flux Calculation Method Flag

The flux calculation method flag (MF) indicates by bit, for single frame photometry, whether a given exposure time was present, and whether that exposure time was used in the final flux.

Table 6.

ft	present		used	
	bit	(value)	bit	(value)
0.6	1	(1)	2	(2)
1.2	3	(4)	4	(8)
2	5	(16)	6	(32)
12	7	(64)	8	(128)
30	9	(256)	10	(512)
100	11	(1024)	12	(2048)

For example, if 0.6 and 12 sec data were present, but only the 12 sec data were used, then bits 1 and 7 will be set (fluxes present) and bit 8 will be set (12 sec used) and the MF will be $2^0 + 2^6 + 2^7 = 1 + 64 + 128 = 193$ (see Table 6). Note that, in practice, MF of 193 is rarely assigned because some detections are thrown out at the beginning of bandmerging because of sensitivity or saturation issues (see Sect 3.2).

For SAGE 12/0.6 sec HDR mode, the relevant numbers work out to be
  3 - short exp data used, long exp data absent
  67 - short used, long present but unused
  192 - long exp used, short absent
  193 - long exp used, short present but unused
  195 - both long and short present and used

B.7. An Example of a Line of Text for SAGESMCcatalogIRAC/SAGESMCarchiveIRAC

Here is an example of a line of text for the Single Frame Photometry Catalog (83 columns)

```
globalSourceID sourceCatalog epoch designation TmassCntr TmassDesignation ra dec
dra ddec closeFlag magJ dmagJ magH dmagH magK dmagK mag3_6 dmag3_6 mag4_5 dmag4_5
```

Table 7. The Example Line from SAGESMCcatalogIRAC

Parameter	Value	Description
globalSourceID ..	998751	Unique identifier
sourceCatalog ...	iracc	Identifier for source catalog
epoch	epoch 1	Identifier for epoch of source
designation	SSTISAGE1C J001138.93-730821.6	source name
TmassCntr	1302207582	2MASS cntr from 2MASS PSC
TmassDesignation	00113891-7308213	2MASS designation from 2MASS PSC
ra, dec	2.912212 -73.13936	RA and Dec in degrees
dra, ddec	0.3 0.3	Error in RA and Dec in arcsec
	...	dra is in units of arcseconds,
	...	so to convert to seconds of
	...	time, multiply by cos(dec)/15.
closeFlag	0	Close source flag
mag	9.06 8.771 8.741 8.612 8.671 8.691 8.667	Magnitudes [JHK, Bands 1-4]
dmag	0.03 0.047 0.021 0.046 0.047 0.031 0.041	mag uncertainties [JHK, Bands 1-4]
flux	378.9 317.6 212.6 100.9 61.09 38.4 21.89	Fluxes (mJy) JHK and Bands 1-4
dflux	10.47 13.75 4.112 4.26 2.619 1.11 0.821	Flux uncertainties (mJy) [JHK, Bands 1-4]
rms_f	1.97 0 1.023 0	rms_flux (mJy) [Bands 1-4]
sky	0.159 0.22 0.381 -1.17	Sky Bkg (MJy/sr) [Bands 1-4]
S/N	36.19 23.1 51.7 23.69 23.33 34.6 26.66	Signal to Noise [J,H,K,Bands 1-4]
srcDensity	26.1 15.8 18.2 25.4	Local Source Density [Bands 1-4]
m	2 1 4 2	Number of detections [Bands 1-4]
n	2 1 4 2	Number of poss detections [Bands 1-4]
sqf	29360128 29360128 29360128 16896 512 0 32768	Source Quality Flag [J,H,K,Bands 1-4]
mf	67 67 195 195	Flux Calculation Method Flag [Bands 1-4]
versionNo	1	Catalog version number assigned by
....	...	IRAC pipeline team
versionDate	Aug 22 2008	Date catalog was produced
	...	in the following format,
	...	"month day year"
cx	0.289670252805673	x of unit vector to this source
cy	0.0147359612863192	y of unit vector to this source
cz	-0.957013059516152	z of unit vector to this source
htmID	9120518099590	20-deep HTM ID of this source

```
mag5_8 dmag5_8 mag8_0 dmag8_0 fluxJ dfluxJ fluxH dfluxH fluxK dfluxK flux3_6 dflux3_6
flux4_5 dflux4_5 flux5_8 dflux5_8 flux8_0 dflux8_0 rms_f3_6 rms_f4_5 rms_f5_8
rms_f8_0 sky3_6 sky4_5 sky5_8 sky8_0 SNJ SNH SNK SN3_6 SN4_5 SN5_8 SN8_0 srcDensity3_6
srcDensity4_5 srcDensity5_8 srcDensity8_0 m3_6 m4_5 m5_8 m8_0 n3_6 n4_5 n5_8 n8_0
sqfJ sqfH sqfK sqf3_6 sqf4_5 sqf5_8 sqf8_0 mf3_6 mf4_5 mf5_8 mf8_0 versionNo versionDate
cx cy cz htmID
998751 iracc epoch 1 SSTISAGE1C J001138.93-730821.6 1302207582 00113891-7308213
2.912212 -73.13936 0.3 0.3 0 9.06 0.03 8.771 0.047 8.741 0.021 8.612 0.046 8.671
0.047 8.691 0.031 8.667 0.041 378.9 10.47 317.6 13.75 212.6 4.112 100.9 4.26 61.09
2.619 38.4 1.11 21.89 0.821 1.97 0 1.023 0 0.159 0.22 0.381 -1.17 36.19 23.1 51.7
23.69 23.33 34.6 26.66 26.1 15.8 18.2 25.4 2 1 4 2 2 1 4 2 29360128 29360128 29360128
16896 512 0 32768 67 67 195 195 1 Aug 22 2008 0.289670252805673 0.0147359612863192
-0.957013059516152 9120518099590
```

Table 7 shows the same line from SAGESMCcatalogIRAC_EP1 with the detailed description of the individual columns. SAGESMCarchiveIRAC_EP1 contains the same columns with the sourceCatalog column set to 'iraca'.

C. APPENDIX C - MIPS 24 μm Catalog Formats

C.1. An Example of a Line of Text for SAGESMCcatalogMIPS24/SAGESMCfullMIPS24

Here is an example of a line of text for the Catalog (29 columns; see also Table 8)

```
globalSourceID sourceCatalog epoch designation ra dec dra ddec conf24 mag24 dmag24
flux24 dflux24 sky24 SN24 flag24 correlation24 mmmSkymode24 mmmSigma24 mmmSkew24
mmmNsky24 averageCoverage24 AORNumber24 versionNo versionDate cx cy cz htmID
8599426 mips24c epoch 1 SSTM1SAGE1 J005842.86-722716.7 14.678583 -72.454647 0.03
0.03 0 1.245 0.005753 2278 12.07 21.09 188.73 0 0.983 0.3386 0.2088 0.06842 2179
10.92 22818048 1.2 Oct 22 2009 0.291621719172991 0.0763890274596602 -0.953478625555055
9120229586620
```

The detailed description of the individual columns and the data format can be found in Table 9. The MIPS 24 μm Full List (SAGESMCfullMIPS24_EP1) contains the same columns as the MIPS 24 μm Catalog (SAGESMCcatalogMIPS24_EP1). However, for the full list the 'sourceCatalog' column is set to 'mips24f'.

Table 8. SAGESMCcatalogMIPS24 and SAGESMCfullMIPS24 Format

Col.	Name	Description	Data	Format	Null
1	globalSourceID . . .	Unique identification number of each source in the catalog	I*4	i10	NO
2	sourceCatalog	Character string identifier for source catalog	ASCII	a8	NO
3	epoch	Character string identifier for the epoch of the observation of the source	ASCII	a16	NO

Continued on Next Page. . .

Table 8 – Continued

Col.	Name	Description	Data	Format	Null
4	designation	SAGE source designation name	ASCII	a32	NO
5	ra	Right ascension, J2000 (deg)	R*8	f11.6	NO
6	dec	Declination, J2000 (deg)	R*8	f11.6	NO
7	dra	Error in Right Ascension ($''$)	R*8	f4.1	NO
8	ddec	Error in Declination ($''$)	R*8	f4.1	NO
9	conf24	Confusion Flag for band 24,	I*2		-9
	....	currently unused			
10	flux24	24μm flux (mJy)	R*8	e11.3	-999.9
11	dflux24	24μm 1σ error (mJy)	R*8	e11.3	-999.9
12	mag24	24μm magnitude	R*8	f7.3	-999.9
13	dmag24	24μm 1σ error	R*8	f7.3	-999.9
14	sky24	Local Sky Bkg. for band 24 (MJy/sr)	R*4	e11.3	-999.9
15	SN24	Signal/Noise for band 24	R*4	f6.2	-9.99
16	flag24	The flag currently refers to how many times a source was observed by different AORs in a single epoch. Is it was observed more than once, the reported flux is the average of the multiple observations. If flag24 = 0, then it was only measured in 1 AOR. If it is > 1 (it will never be 1), then that is the number.	I*2		-9
17	correlation24	Correlation describes how like the input PSF each point source is	R*8	e11.3	-999.9
18	mmmSkymode24 . .	Scalar giving estimated mode of the sky values. Sky is determined in a 49x49 square pixel (1 pixel = 2$''$.49) region surrounding the source in the residual image (all sources subtracted).	R*8	f11.6	NO

Continued on Next Page. . .

Table 8 – Continued

Col.	Name	Description	Data	Format	Null
19	mmmSigma24	Scalar giving standard deviation of the peak in the sky histogram. If for some reason it is impossible to derive skymode, then SIGMA = -1.	R*8	f11.6	NO
20	mmmSkew24	Scalar giving skewness of the peak in the sky histogram	R*8	f11.6	NO
21	mmmNsky24	number of points used to determine the sky values for mmmSkymode24, mmmSigma24 and mmmSkew24	R*8	f11.6	NO
22	averageCoverage24	The average coverage (no. of independent observations per pixel) in a 49×49 square pixel (1 pixel = 2.″49) region centered on the source.	R*8	f11.6	NO
23	AORNumber24 ...	Request key for the 1st AOR within which the source appears	I*4	i10	NO
24	versionNo	Version number assigned by MIPS pipeline team	R*4	f6.2	NO
25	versionDate	Date catalog was produced in the following format, "mon dd yyyy", "Dec 5 2007"	ASCII	a12	NO
26	cx	× of unit vector on the unit sphere for ra,dec of this source	R*8	f30.20	NO
27	cy	y of unit vector on the unit sphere for ra,dec of this source	R*8	f30.20	NO
28	cz	z of unit vector on the unit sphere for ra,dec of this source	R*8	f30.20	NO
29	htmID	The Hierchical Triangular Mesh partition computed at index level 20 in which this source lies	I*4	i20	NO

Table 9. The Example Line from SAGESMCcatalogMIPS24

Parameter	Value
globalSourceID . .	8599426
sourceCatalog	mips24c
epoch	epoch 1
designation	SSTM1SAGE1 J005842.86-722716.7
ra, dec	14.678583 -72.454647
dra, ddec	0.03 0.03
conf24	0
mag24, dmag24 . . .	1.245 0.005753
flux24, dflux24	2278 12.07
sky24	21.09
SN24	188.73
flag24	0
correlation24	0.983
mmmSkymode24 .	0.3386
mmmSigma24 . . .	0.2088
mmmSkew24	0.06842
mmmNsky24	2179
averageCoverage24	10.92
AORNumber24 . . .	22818048
versionNo	1.2
versionDate	Oct 22 2009
cx	0.291621719172991
cy	0.0763890274596602
cz	-0.953478625555055
htmID	9120229586620

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