The SAGE-SMC Data Description: Delivery 3
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Contents

1. Executive Summary

This document describes the full SAGE-SMC value-added data products. Many of these data products were delivered in the SAGE-SMC data delivery 2 and are described here for completeness. The full list of value-added data products is:

Point Source Catalogs and Archives

- SAGESMCcatalogIRAC, the IRAC v1.5 Single Frame + Mosaic Photometry Catalog combining Epochs 1 & 2 and S^3MC data bandmerged with All-Sky 2MASS and 6X2MASS. *This is the highest quality SAGE-SMC Catalog*, deeper than previously delivered single epoch catalogs that used only half of the data.

- SAGESMCarchiveIRAC, the IRAC v1.5 Single Frame + Mosaic Photometry Archive combining Epochs 1 & 2 and S^3MC data bandmerged with All-Sky 2MASS and 6X2MASS. This highest quality SAGE-SMC archive is approximately one magnitude deeper than previously delivered single epoch archives.

- SAGESMCcatalogIRAC_EP0_EP1_EP2, the v1.0 IRAC catalog containing epoch 0, 1, & 2 data bandmerged with All-Sky 2MASS and 6X2MASS (epochs 1 & 2 are from SAGE-SMC observations, while epoch 0 is from S^3MC observations)

- SAGESMCarchiveIRAC_EP0_EP1_EP2, the v1.0 IRAC archive containing epoch 0, 1, & 2 data bandmerged with All-Sky 2MASS and 6X2MASS

- SAGESMCcatalogMIPS24, the epoch 0, 1, & 2 MIPS 24 μm catalog

- SAGESMCfullMIPS24, the epoch 0, 1, & 2 MIPS 24 μm full list

- SAGESMCcatalogMIPS70 & SAGESMCcatalogMIPS160, the combined epoch MIPS 70 and 160 μm catalog lists extracted from the combined mosaics that include all the SAGE-SMC epoch 1 & 2 and S^3MC data

- SAGESMCfullMIPS70 & SAGESMCfullMIPS160, the combined epoch MIPS 70 and 160 μm full lists extracted from the combined mosaics that include all the SAGE-SMC epoch 1 & 2 and S^3MC data

IRAC and MIPS Images

- IRAC 3.6, 4.5, 5.8, and 8.0 μm $10^\circ \times 6^\circ$, $2''$ pixel mosaics and mosaics of residual images combining SAGE-SMC epoch 1 & 2 and S^3MC data

- IRAC 3.6, 4.5, 5.8, and 8.0 μm $10^\circ \times 6^\circ$, $1.2''$ pixel mosaics and mosaics of residual images combining SAGE-SMC epoch 1 & 2 and S^{3}MC data

- fits images containing information about the time of observation for a given SAGE-SMC IRAC source in the single epoch source lists

- MIPS 24, 70, and 160 μm combined mosaics of the entire SMC that include all the SAGE-SMC epoch 1 & 2 and S^{3}MC data

- MIPS 24, 70, and 160 μm residual images where the point sources have been subtracted.

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 and the images in Table 2. A guide to contents of the SAGE-SMC 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	∼2.0 million	1.24, 1.66, 2.16 (2MASS or 6X2MASS) 3.6, 4.5, 5.8, 8.0 (IRAC)	IRAC Single Frame + Mosaic Photometry Catalog: a combination of mosaic photometry source list extracted from the combined Epoch 1, Epoch 2 and S^3MC 12 second frametime mosaics with all-epochs single frame source list, bandmerged with 2MASS or 6X2MASS. High reliability emphasized. Faint limits[b] are 18.3, 17.7, 15.7, and 14.5 for IRAC 3.6, 4.5, 5.8, 8.0 μm, respectively. **This is the best SAGE-SMC IRAC Catalog**; see §3 for a usage recommendation.
SAGESMCarchiveIRAC	∼2.2 million	1.24, 1.66, 2.16 (2MASS or 6X2MASS) 3.6, 4.5, 5.8, 8.0 (IRAC)	IRAC Single Frame + Mosaic Photometry Archive: a combination of mosaic photometry source list extracted from the combined Epoch 1, Epoch 2 and S^3MC 12 second frametime mosaics with all-epochs single frame source list, bandmerged with 2MASS or 6X2MASS. Includes more sources and more source fluxes (fewer nulled wavelengths), see §5.2. Faint limits[b] for both epochs are 18.5, 18.1, 16.2, and 15.4 mag for IRAC 3.6, 4.5,

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Table 1 – Continued

Source List Title	No. of Sources	Wavelengths (μm)	Content
			5.8, and 8.0 μm, respectively. **This is the best SAGE-SMC IRAC Archive**; see §3 for a usage recommendation.
SAGESMCcatalogIRAC_EP0_EP1_EP2	Epoch 0: ~217,000 Epoch 1: ~1.23 million Epoch 2: ~1.13 million	1.24, 1.66, 2.16 (2MASS or 6X2MASS) 3.6, 4.5, 5.8, 8.0 (IRAC)	IRAC catalog containing Epoch 0, 1 & 2 only sources with 0.6 and 12 s frame photometry bandmerged with 2MASS and 6X2MASS; high reliability emphasized. Faint limits[a] are 17.6, 17.0, 14.6, & 13.6 mag for IRAC 3.6, 4.5, 5.8, & 8.0 μm
SAGESMCarchiveIRAC_EP0_EP1_EP2	Epoch 0: ~273,000 Epoch 1: ~1.28 million Epoch 2: ~1.17 million	1.24, 1.66, 2.16 (2MASS or 6X2MASS) 3.6, 4.5, 5.8, 8.0 (IRAC)	IRAC archive containing Epoch 0, 1 & 2 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 §4.2. Faint limits[a] 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	Epoch 0: ~5,600; Epochs 1 & 2:	24	MIPS 24 μm catalog containing Epoch 0, 1, & 2 only sources; high reliability emphasized. To assure high reliability, stringent

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Table 1 – Continued

Source List Title	No. of Sources	Wavelengths (μm)	Content
	∼16,500		criteria were applied to the source list extracted from the 24 μm image AOR mosaics. Faint limit is ∼10 mag.
SAGESMCfullMIPS24	Epoch 0: ∼18,000 Epochs 1 & 2: ∼67,000	24	MIPS 24 μm full list containing *all* sources extracted from the 24 μm image AOR mosaics. Faint limit is ∼12 mag.
SAGESMCcatalogMIPS70	Epoch C[b]: ∼1000	70	MIPS 70 μm catalog based on the combined Epoch 0, 1 and Epoch 2 data. To assure high reliability, stringent criteria were applied to the source list extracted from the 70 μm full mosaic. The faint limit is 3.4 mag.
SAGESMCfullMIPS70	Epoch C[b]: ∼6100	70	MIPS 70 μm full list based on the combined Epoch 0, 1, and 2 data. It contains *all* the sources extracted from the 70 μm full mosaic. The faint limit is 4.4 mag. This is a list of sources with lower reliability than the catalog.
SAGESMCcatalogMIPS160	Epoch C[b]:	160	MIPS 160 μm catalog based on the

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Table 1 – Continued

Source List Title	No. of Sources	Wavelengths (μm)	Content
	$\sim$130		combined Epoch 0, 1, and 2 data. To assure high reliability, stringent criteria were applied to the source list extracted from the 160 μm full mosaic. The faint limit is -0.6 mag.
SAGESMCfullMIPS160	Epoch C[b]: $\sim$1000	160	MIPS 160 μm full list based on the combined Epoch 0, 1, and 2 data. It contains *all* the sources extracted from the 160 μm full mosaic. The faint limit is 0.6 mag. This is a list of sources with lower reliability than the catalog.

[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.

[b] Epoch C data is the combined SAGE-SMC Epoch 1 & 2 data and S^3MC Epoch 0 data.

Table 2. SAGE-SMC Images

Image	Pixel Size (″)	Description
SAGE_SMC_IRAC*_2_mosaic.fits .... SAGE_SMC_IRAC*_2_resid.fits	2.0	IRAC 10° × 6°, 2″ pixel mosaic and residual images combining Epochs 0, 1, & 2 12 second frametime data for each IRAC band (* = 3.6, 4.5, 5.8, 8.0).
SAGE_SMC_IRAC*_1.2_mosaic.fits .... SAGE_SMC_IRAC*_1.2_resid.fits	1.2	IRAC 10° × 6°, 1.2″ pixel mosaic and residual images combining Epochs 0, 1, & 2 12 second frametime data for each IRAC band (* = 3.6, 4.5, 5.8, 8.0).
SAGE_SMC_IRAC∗_E?.earliest_obstime.fits SAGE_SMC_IRAC∗_E?.latest_obstime.fits	2.0	Fits images that display the earliest and latest observational times for any given area observed by SAGE for each of the SAGE-SMC Epochs (? = 0,1,2) and for each of the 4 IRAC channels (*=3.6,4.5,5.8,8.0). Image units are minutes, corresponding to the number of minutes past Julian Date 2453400.5. See Section 4.3 for details.

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Table 2 – Continued

Image	Pixel Size (″)	Description
SAGE_SMC_MIPS24_E012.fits .... SAGE_SMC_MIPS24_E012_wt.fits	2.49	MIPS 24 μm full mosaic combining Epochs 0, 1, and 2 data. Not on the IRAC/MIPS common projection. Optimizes coverage versus file size
SAGE_SMC_MIPS24_E012_resid.fits		Point source subtracted image.
SAGE_SMC_MIPS70_E012.fits .... SAGE_SMC_MIPS70_E012_wt.fits	4.80	MIPS 70 μm full mosaic combining Epoch 0, 1, and 2 data (*E012.fits) and a weight map (*E012_wt.fits).
SAGE_SMC_MIPS70_E012_resid.fits		Point source subtracted image.
SAGE_SMC_MIPS160_E012.fits .... SAGE_SMC_MIPS160_E012_wt.fits	15.6	MIPS 160 μm full mosaic combining Epochs 0, 1, and 2 data (*E012.fits) and a weight map (*E012_wt.fits).
SAGE_SMC_MIPS160_E012_resid.fits		Point source subtracted image.

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. (2011, AJ, submitted). The main characteristics of the survey are listed in Table 3. 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). The IRAC and MIPS observations from the S^3MC pathfinder survey of the inner 3 sq. deg. of the SMC (PI: Bolatto, which we refer to as epoch 0) have been reduced using the same software. The S^3MC data were included in the SAGE-SMC delivery to provide consistently reduced catalogs and the deepest mosaics possible. Note, the predicted sensitivities for the complete survey are listed in Table 3 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.

3. Brief Overview of the IRAC Source Lists and their Usage

There are several SAGE-SMC IRAC source lists, detailed in Table 1:
1. Single frame + mosaic photometry (SMP), Catalog and Archive
2. Epoch 1 only (EP1), Epoch 2 only (EP2), and Epoch 0 (S^3MC) only (EP0) single frame photometry, Catalog and Archive

Most users will want to use the single frame + mosaic photometry (SMP) catalog or archive, described in §5. The Catalog is a more highly reliable list of 2.0 million sources, and the Archive is a more complete list both in number of sources (at 2.2 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 (e.g., number of detections in various bands, §5.2) . Users who want a more "bullet-proof" list and don't want to have to get as familiar with the source quality

Table 3. 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
Faint limits[a] (mJy)	0.0112, 0.0103, 0.0381, 0.0444	0.6, 35, 280
Faint limits[a] (mag)	18.5, 18.1, 16.2, 15.4	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 0	May 7-9, 2005	Nov 6-8, 2004
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 brighter than the quoted faint limit.

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 and close fulls flag (see Appendix B).

Users interested in variability of sources will want to make use of the EP0, EP1 and EP2 source lists. These contain fewer sources (1.23 million in the EP1 Catalog, and 1.28 million in the EP1 Archive) than the SMP lists for 3 reasons: 1) they are based on single-frame photometry so each frame is effectively 1/4 (or less, in the region of overlap with S^3MC) the integration time of the mosaic image, 2) they have half as much total integration time on each sky position, and 3) photometry is done on the frames without cosmic ray removal. Therefore we had to use much more stringent source-selection criteria (§4.2) which has the side effect of removing some real sources in addition to cosmic rays. For the mosaic photometry lists, cosmic rays were removed in the mosaic-process, before photometry.

4. IRAC Single Epoch Catalogs and Archives

The single Epoch observations are described in §2 and Table 3. The single-epoch point source lists were extracted from IRAC single frame images processed with Spitzer Science Center (SSC) pipeline version S14.0 and later using a modified version of DAOPHOT (Stetson 1987) to perform the PSF fitting. The array-location-dependent photometric corrections[a] 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[b]. 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 catalogs (SAGESMCcatalogIRAC_EP0_EP1_EP2) and the archives (SAGESMCarchiveIRAC_EP0_EP1_EP2) after the sources are extracted from the images.

4.1. Bandmerging to Produce Single Epoch Source Lists

The point source lists are merged at two stages using a modified version of the SSC bandmerger[c]. 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

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

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

[c]http://ssc.spitzer.caltech.edu/dataanalysistools/tools/bandmerge/

0.6 and 12 second fluxes are averaged, 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. 2008, 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_EP0_EP1_EP2 and SAGESMCarchiveIRAC_EP0_EP1_EP2) 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.

4.2. Single Epoch 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).

4.2.1. 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_EP0_EP1_EP2) by minimizing the number of false sources, we adopt the following selection criteria: Given M detections out of N possible observations (see Appendix B.5), 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 2×12 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_EP0_EP1_EP2), 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 $0''.5$ of the source.

4.2.2. 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 4.

Characteristics of the single Epoch 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 (e.g. 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.

4.3. 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. S^3MC had on average twelve visits on the sky. 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 and S^3MC 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. 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.

5. IRAC Single Frame + Mosaic Photometry Catalog and Archive

The Single Frame + Mosaic Photometry (SMP) Catalog (SAGESMCcatalogIRAC) and Archive (SAGESMCarchiveIRAC) are a combination of mosaic photometry and the single frame photometry Epoch 0+1+2 source lists. Epoch 0+1+2 source lists were derived from doing photometry on individual IRAC frames, then doing an error-weighted average of those results for each band. For each SAGE epoch there were two 12 sec frames and two 0.6 sec frames. Potentially, a result for one band could be an average of 4 (or more if in overlap areas) detections. The number of actual detections (M) and number of possible detections (N) are part of each source entry. For the all-epoch source lists (Epoch 0+1+2), all the possible frames were used in the bandmerging to produce the fluxes. The mosaic photometry was done on the 12 second frametime mosaiced images (mosaics of combined Epoch 0, 1 and 2) which have been cleaned of most of the instrument artifacts, including cosmic rays (CRs) (which are abundant in the single frames). Stray light areas are also removed from the mosaics but are in the single IRAC frames. Then, the mosaic photometry results were merged with the epochs 0+1+2 single frame photometry results and the combined All-SKY 2MASS and 6X2MASS Point Source Catalogs (PSC; see Appendix A). A source entry can have fluxes for the IRAC bands that can come from photometry either on single IRAC frames or mosaic images. For example band 1 and 2 fluxes can come from single frame photometry and band 3 and 4 fluxes can be derived from mosaic photometry. Generally, single frame photometry was used for the brighter sources, and mosaic photometry was used at the fainter end. The Flux Calculation Method Flag (MF) for each band tells you from which data (single frame or mosaic) the flux was taken. This flag is explained in detail in Appendix B.7.

5.1. Bandmerging to Produce Single Frame + Mosaic Photometry Source Lists

Before the in-band merge stage (merging at a single wavelength), source detections with S/N less than 3 are removed, both in the single frame and mosaic photometry. For the single frame photometry (epochs 0+1+2) 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. 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. For the single frame photometry data, all detections at a single wavelength are combined using position, signal-to-noise and flux to match the sources. The single frame photometry flux is compared to the mosaic photometry result for that band. The following are the criteria that were used in the in-band bandmerging of the single frame and mosaic photometry. In cases where there were both mosaic and single frame photometry results:

Band1, use mosaic data if mos_mag > 15.0, or SingleFrm_dmag > 0.1,

Band2, use mosaic data if mos_mag > 15.0, or SingleFrm_dmag > 0.1,
Band3, use mosaic data if mos_mag > 13.0, or SingleFrm_dmag > 0.1,
Band4, use mosaic data if mos_mag > 12.0, or SingleFrm_dmag > 0.1,

where mos_mag is the mosaic photometry magnitude and SingleFrm_dmag is the single frame photometry magnitude uncertainty. Effectively this means that fainter mosaic data are more reliable, and single frame data with large uncertainties (dmag > 0.1 mag corresponds roughly to S/N less than 10) are less reliable, provided the mosaic result has a better error.

Source lists from the combined mosaic and single frame photometry are hybrid lists. For bright sources, multiple single-frame extractions using PSF fitting on native images (no rotation, no translation) should provide a more reliable result. However for the fainter sources, mosaiced images will produce much more reliable and deeper results. We chose not to use mosaic results for all brightness levels for the following reason: SAGE SMC data were taken in primarily two epochs with a position angle rotation between those two epochs of roughly 90°. The mosaic image of all-epoch SAGE SMC data therefore produces an image that, when closely scrutinized, reveals bright sources with variable PSFs. The PSFs for all 4 IRAC bands are highly structured. When one looks at the coverage map for any given location in the SAGE field of view (FOV), that position may be covered by non-equal number of frames for each epoch, and thus the PSF will be highly variable across the entire SAGE FOV. Producing a varying PSF for any given location in the SAGE FOV was not an option in our photometry pipeline processing. For this reason doing PSF fitting on the all-epoch SAGE mosaic image does not produce the best result for the bright end of the SAGE source lists. However, for the faint sources, where the flux is primarily identified in the more uniform core of the PSF, PSF fitting is reliable and well suited for extending the source lists to a fainter limit.

The cross-band merging combines all wavelengths, whether from single frame or mosaic photometry, for a given source position using only position information (not signal-to-noise or flux as in the in-band merge stage) as a criterion in order to avoid source color effects. Cross-band lumping is done with a 1."6 radius. Position migration can occur in the bandmerging process which results in a small number of sources that are positioned just within 1."6 of another source at the end of the process. 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. 2008; details on how that combined list was made can be found in Appendix A).

5.2. Single Frame + Mosaic Photometry Catalog and Archive Criteria

5.2.1. Culling Criteria - is it a real source?

The more stringent M/N criteria used in the single epoch, single frame photometry source lists (see §4.2.1) have been relaxed since we don't need to worry as much about false sources due to cosmic rays in the single frame + mosaic photometry (SMP) source lists.

For the *Catalog*, we require M/N ≥ 0.32 in adjacent bands for fluxes derived from mosaic photometry only or a mix of mosaic and single frame photometry. The 2MASS K_s band can be counted as a detection. Note that for mosaic photometry only, by definition, the possible number of observations N equals the actual detections M, which is equal to 1. A typical case would be that band 1 is derived from single-frame all-epoch photometry. N is typically 4, so we require M $\geq$ 2 in this band. If band 2 is derived from mosaic photometry, M=N=1, so M/N=1; and thus our source selection criteria is met. In addition, we require that one band (the selection band) must have S/N $\geq$ 5,5,5,7 for bands 1 through 4 respectively. The second band (the confirming band) must have S/N $>$ 5. Thus in our example, the S/N must be greater than 5 in both bands 1 and 2.

If all the fluxes are derived from single-frame photometry, then the source selection criteria from the single-epoch Catalog (§4.2.1) apply. A small percentage of sources ($<$ 2%) have only single-frame photometry in all measured bands, but an example would be a source with a magnitude of 12 at bands 1-3 and no detection in band 4. The selection criteria from §4.2.1 applies.

To weed out some suspect data, for bands 3 and 4 only: If 0.6 sec data was used and M = 1 and N $>$ 3, then we do not use that data as a confirming band in the culling. This case suggests that we have likely extracted a band 3/4 cosmic ray (a bright source that comes from 0.6 sec data should really be detected every time. If not, it's likely either a cosmic ray or it's saturated and highly unreliable).

Close source flag culling is the same as for the single epoch photometry lists. For the Catalog, sources are culled if an Archive source is within $2\farcs0$ of the source.

The culling criteria for the *Archive* is the same as for the Catalog, except the selection bands do not need to be adjacent. Close source flag culling is the same as for the single epoch photometry lists. For the Archive, sources are culled if an Archive source is within $0\farcs5$ of the source.

5.2.2. *Nulling Criteria - ensuring high quality fluxes*

The nulling (removal of poor quality fluxes) of individual magnitudes is different for the Catalog and Archive. For the Catalog, we null at higher S/N threshholds and require that if mosaic photometry was used for a particular band, then the single frame photometry result (extracted flux) must be present. This is intended to weed out the lower-reliability faint end of the particular band. If all fluxes for a source are nulled, the source is removed from the source list.

Bands with S/N $<$ 6,6,6,10 for bands 1, 2, 3 and 4 respectively are nulled for the *Catalog*. The flux is nulled if the method flag indicates ($>$ 12353 but $<$ 16384) the mosaic photometry was lumped with the single frame photometry in the in-band merge, indicating severe confusion. The flux is nulled if the method flag is 12288, which means the mosaic data was present and used but there was no single frame photometry result present (no flux extracted or the flux had a S/N $<$ 3). The band 3 or 4 flux is nulled if its method flag is 3, 67 or 4099 (0.6 sec data used) and M=1, with N $>$ 3 (likely a cosmic ray). See Appendix B.7 for details about the Flux Calculation Method Flag.

If the flux in a band was derived from single-frame photometry, then the nulling criteria described in §4.2.2 also apply here.

For the *Archive*, the nulling criteria are the same as for the Catalog except that the S/N limits are 5,5,5,5 for bands 1, 2, 3 and 4 respectively; and we don't null on method flag 12288, to allow for fainter detections in the Archive.

The actual null values for the various fields in the SMP entry for a source are given in Table 5.

5.3. Adding Sources to the Single Frame + Mosaic Photometry Source Lists

One complication in the choice to produce a hybrid source list–using single frame photometry for the brighter sources and mosaic photometry for the fainter sources–was in the behavior of our pipeline bandmerging software, especially with regard to variable stars. To optimize proper source identification in the bandmerging process, flux is used as a discriminant when merging the data within any given IRAC band (the in-band merge). This is useful when source confusion is an issue, which is the case over a large area of the SMC. When combining results from multiple images into one average result, if two stars of different brightness are physically close (within the matching radius for source matching) the bandmerger will combine the brighter measurements into one source and the fainter into another.

In single epoch data, when the multiple exposures are all taken at roughly the same time, this approach is an improvement over a purely positional matching routine in confused regions. However, in multiple epoch data, this method breaks down for the small percentage of sources that are variable. By comparing the Epoch 1 and Epoch 2 sourcelists we discovered these sources which were missing from the automated pipeline bandmerging process for the SMP (single frame + mosaic photometry) source lists. To correct for this, 1870 sources were manually added to the SMP Archive source list, and 1777 sources were manually added to the SMP Catalog source list. Roughly 1/4 of these are possibly variable, and 3/4 are sources that were inadvertently excluded due to their positions being on the boundary of bandmerger grid cells (the bandmerging is done in 1/3 x 1/3 degree grid cells since the overall SAGE coverage is too large to bandmerge at one time). In our final SAGE SMP source lists, we identify the sources that were initially excluded by the automatic pipeline process and then manually inserted by a bit in the Flux Calculation Method Flag, bit 15 (see Appendix B.7).

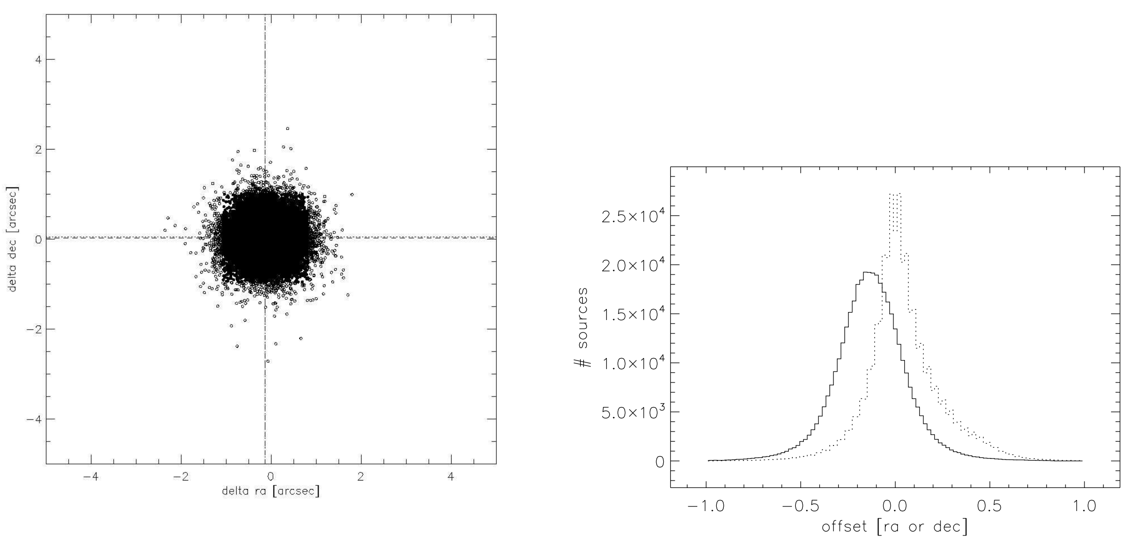

Fig. 1.— The scatter plot of the position difference between 400,000 Epoch 1 sources (from SAGESMCcatalogIRAC_EP0_EP1_EP2) and their corresponding 2MASS or 6X2MASS catalog positions is shown on the left. On the right, the histogram quantifies the offsets between the list and shows that the average is within the anticipated precision of 0."3.

6. IRAC Data Quality Checks

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

6.1. 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 $0.''3$ (1σ). We determine the astrometric quality of the single epoch Catalogs and Archives (SAGESMCcatalogIRAC_EP0_EP1_EP2 and SAGESMCarchiveIRAC_EP0_EP1_EP2) 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. The peak of the histograms are within the anticipated precision of $0.''3$. The other two epochs show similar characteristics for their offsets.

6.2. Precision and Accuracy of the Photometry

Figures 2, 3 and 4 show the photometric uncertainty for Epochs 1, 2 and 0, respectively. 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).

Figure 5 shows the photometric uncertainty due to the extraction for the SMP (single frame + mosaic photometry) source list.

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. A similar analysis was done on the single frame + mosaic photometry source lists. The band 3 uncertainties were increased 10% and the band 4 uncertainties were increased 35%.

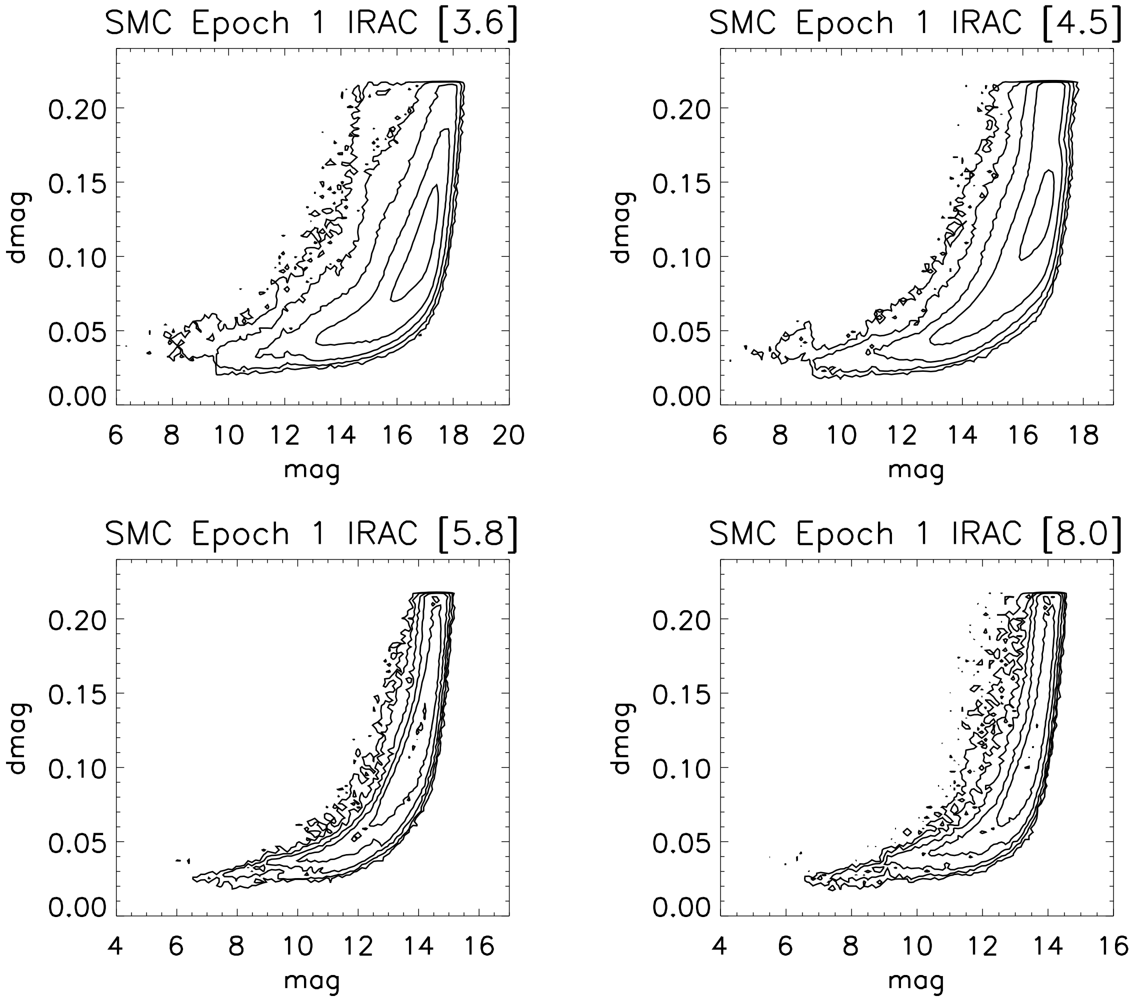

Fig. 2.— Magnitude uncertainty vs. magnitude for each IRAC band in Epoch 1 included in the SAGESMCarchiveIRAC_EP0_EP1_EP2. Contours show the density of the sources. The lack of data above dmag of .22 is caused by the criterion that archive data have signal to noise ratios of 5 or better.

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-SMC (Figure 6). 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).

Figures 7, 8, and 9 show the excellent agreement between the SAGE-SMC magnitudes

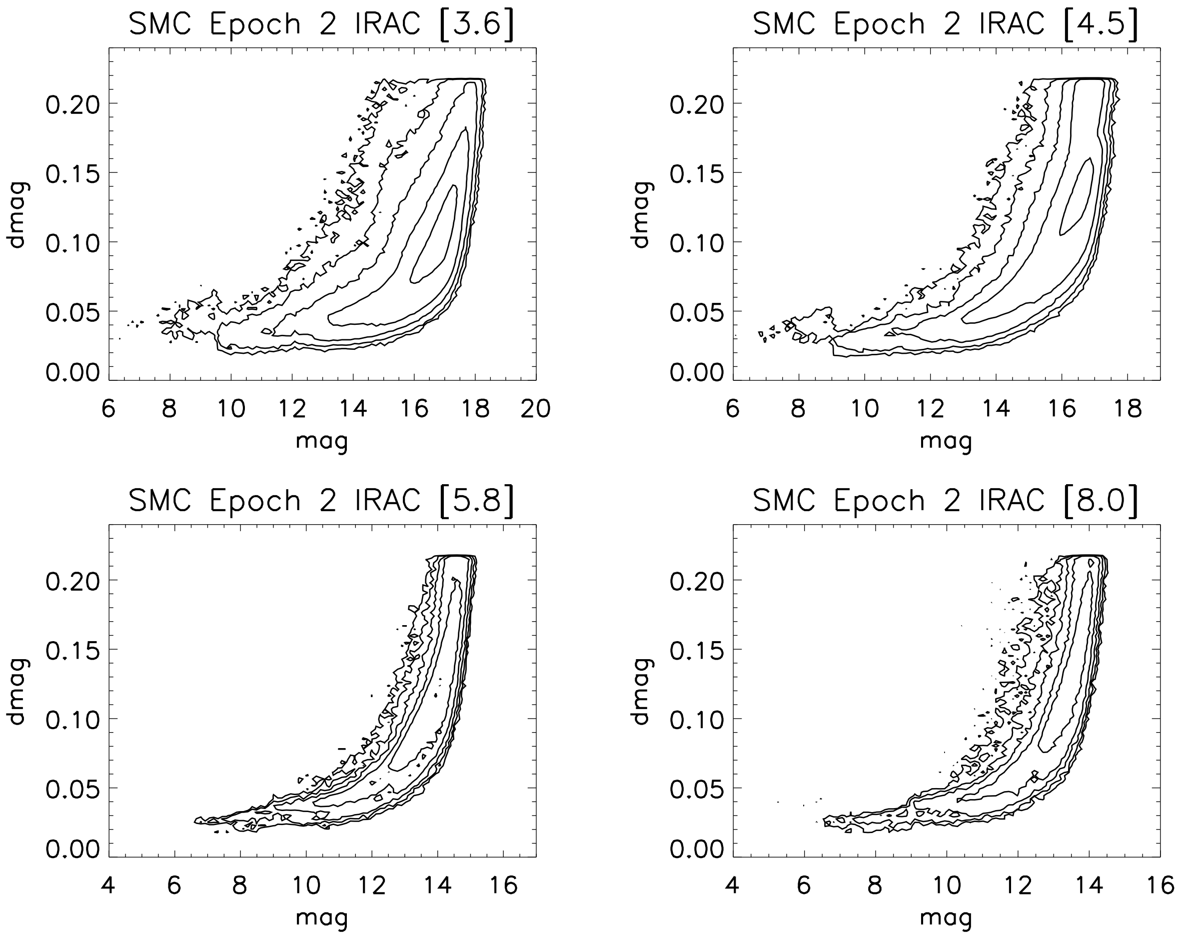

Fig. 3.— Same as Figure 2 for the Epoch 2 data.

and the predicted magnitudes of the calibration stars for the epochs 1, 2 and 0 IRAC data respectively. 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, -0.002±0.060, -0.018±0.052, for bands 1 through 4, respectively for Epoch 1. For Epoch 2 the averaged differences and standard deviations are 0.003±0.062, 0.025±0.060, -0.002±0.049, -0.004±0.044, for bands 1 through 4, respectively.

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. For Epoch 2 there were 28, 35, 48 and 47 flux calibrators for bands 1 through 4 respectively.

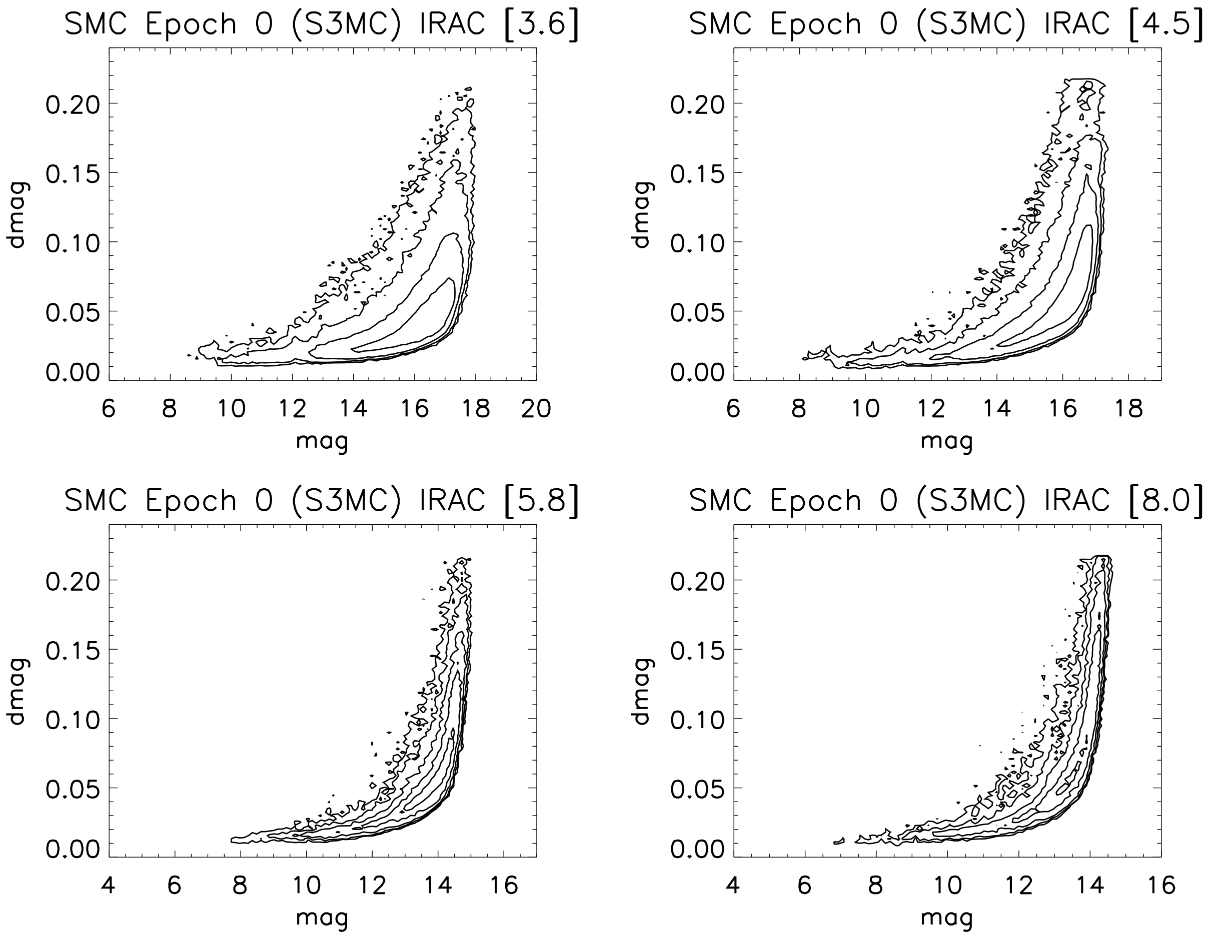

Fig. 4.— Same as Figure 2 for the Epoch 0 data.

The comparison of the SMP (single frame + mosaic photometry) data to the SAGE flux calibrators is shown in Figure 10. The ensemble averaged differences and standard deviations in the four IRAC bands between the SAGE-SMC SMP and the predicted magnitudes are 0.003±0.055, 0.022±0.060, -0.005±0.051, -0.012±0.050, for bands 1 through 4, respectively. The number of calibrators per channel varies due to saturation and it was 32, 41, 52, and 52 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, 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

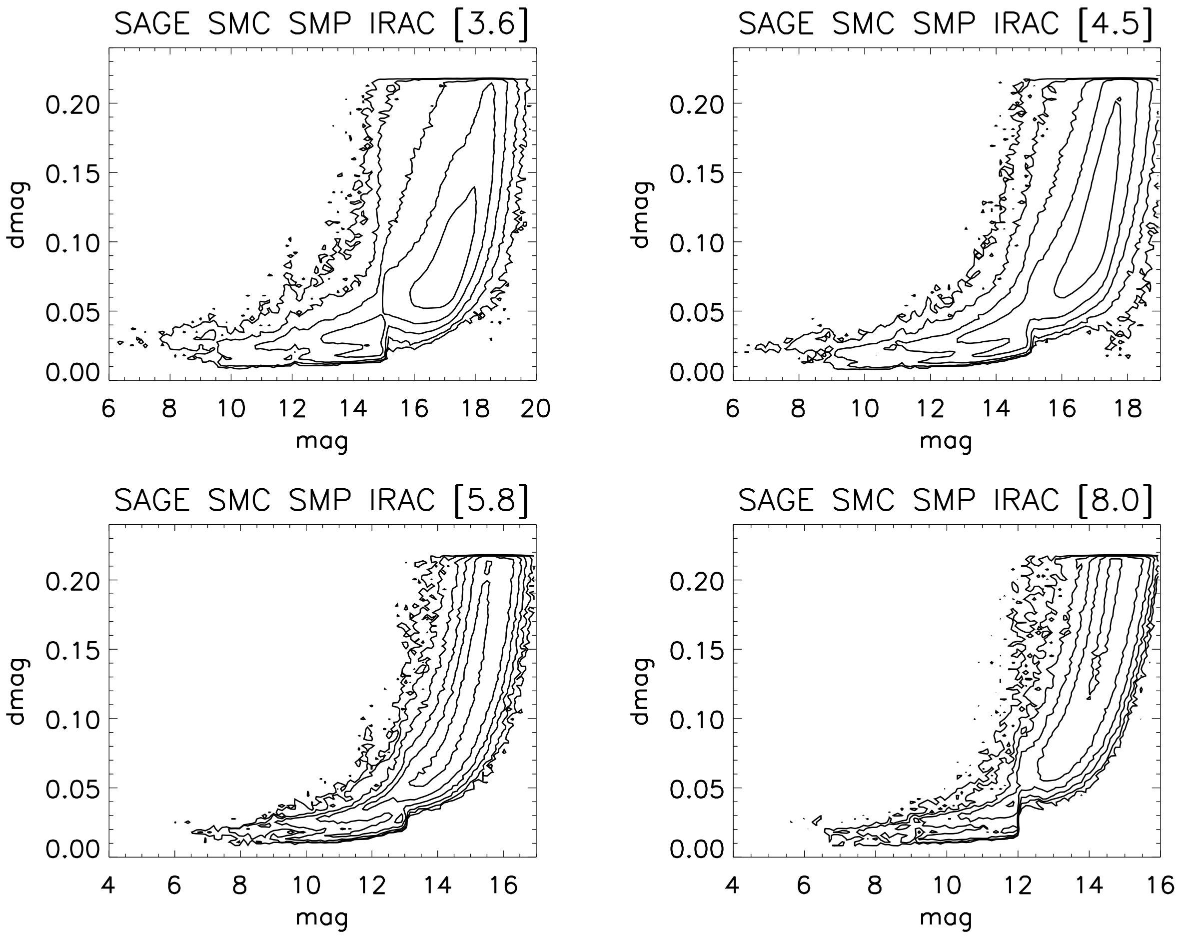

Fig. 5.— Magnitude uncertainty vs. magnitude for each IRAC band in SAGESMCarchiveIRAC (single frame + mosaic photometry). Contours are used to show the density of the sources. The lack of data above dmag of 0.22 is caused by the criterion that archive data have signal to noise ratios of 5 or better. There are two apparent 'discontinuities' in these contour plots. The discontinuity on the bright end is due to the larger uncertainties of the shorter 0.6 sec exposure times. The second discontinuity at the fainter end of each band (noticeable in bands 1 and 2 at mag=15, band 3 at mag=13, and noticeable in band 4 at mag=12) is due to the fact that at these fainter magnitudes we are primarily using mosaic photometry which produces slightly smaller dmag uncertainties.

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).

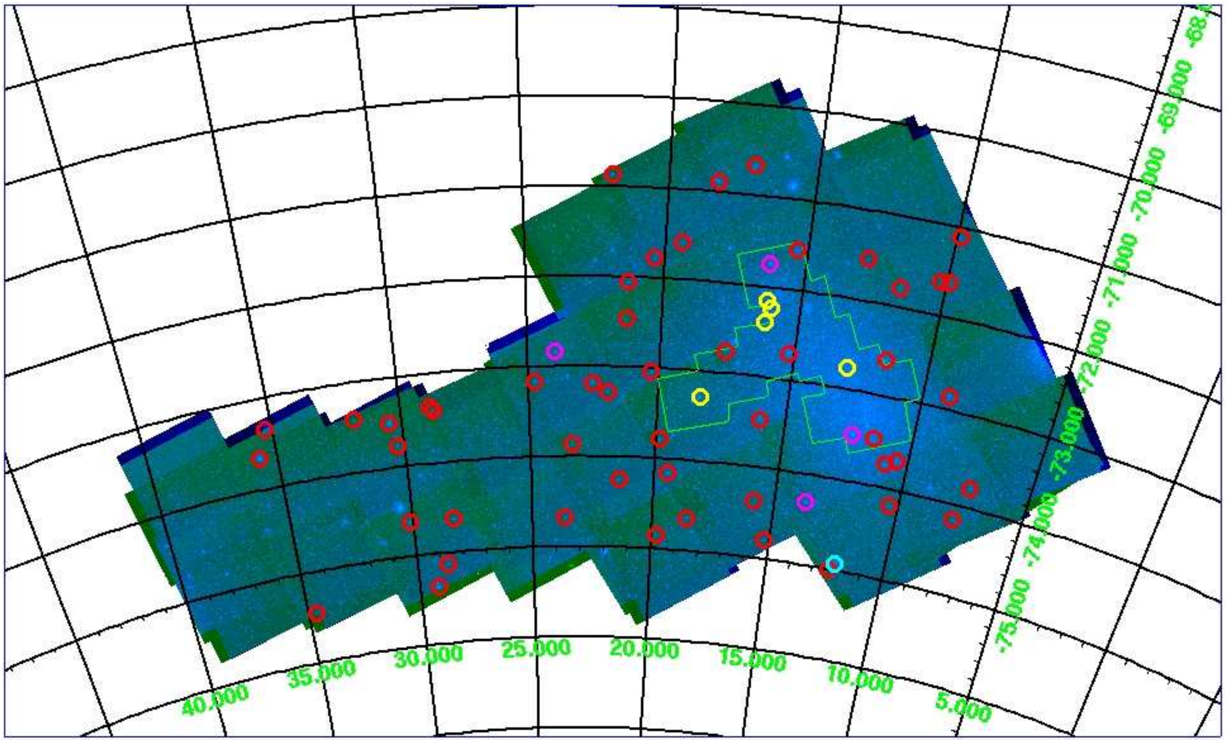

Fig. 6.— An IRAC image of the combined Epoch1 and Epoch2 observed area of SAGE-SMC. Overplotted in colored circles are 60 of Martin Cohen's flux calibrators. Of these 60 potential calibrators, 1 saturates in all 4 bands (cyan) , 4 (magenta) suffered some confusion in the bandmerging step and 5 (yellow) of the calibrators are from a catalog that has produced less reliable results and therefore not used in our analysis (Martin Cohen, private communication). Also outlined in green is the S^{3}MC region.

6.3. Completeness

The single epoch source lists (SAGESMCcatalogIRAC_EP0_EP1_EP2 and SAGESMCarchiveIRAC_EP0_EP1_EP2) have been designed for reliability, not completeness. For this release of the data, we do not run a thorough completeness test of the catalogs. Instead, as a gauge of its completeness, we compare the number counts per magnitude bin of sources between the SAGESMCarchiveIRAC_EP0_EP1_EP2 and the SAGESMCcatalogIRAC_EP0_EP1_EP2 with source counts based on the cleaner and deeper combined SMP source lists (SAGESMCcatalogIRAC and SAGESMCarchiveIRAC) for the entire SAGE area (see Figures 11 and 12). These plots show that the Epoch 1 Archive is mostly complete down to 16.5, 16.5, 14.0 and 13.5 (16.0, 16.0, 13.5 and 12.5 in the Catalog) in IRAC bands [3.6],[4.5],[5.8],[8.0] respectively, with the big drop-offs at 17.0, 17.0, 14.5 and 14.0 for bands 1

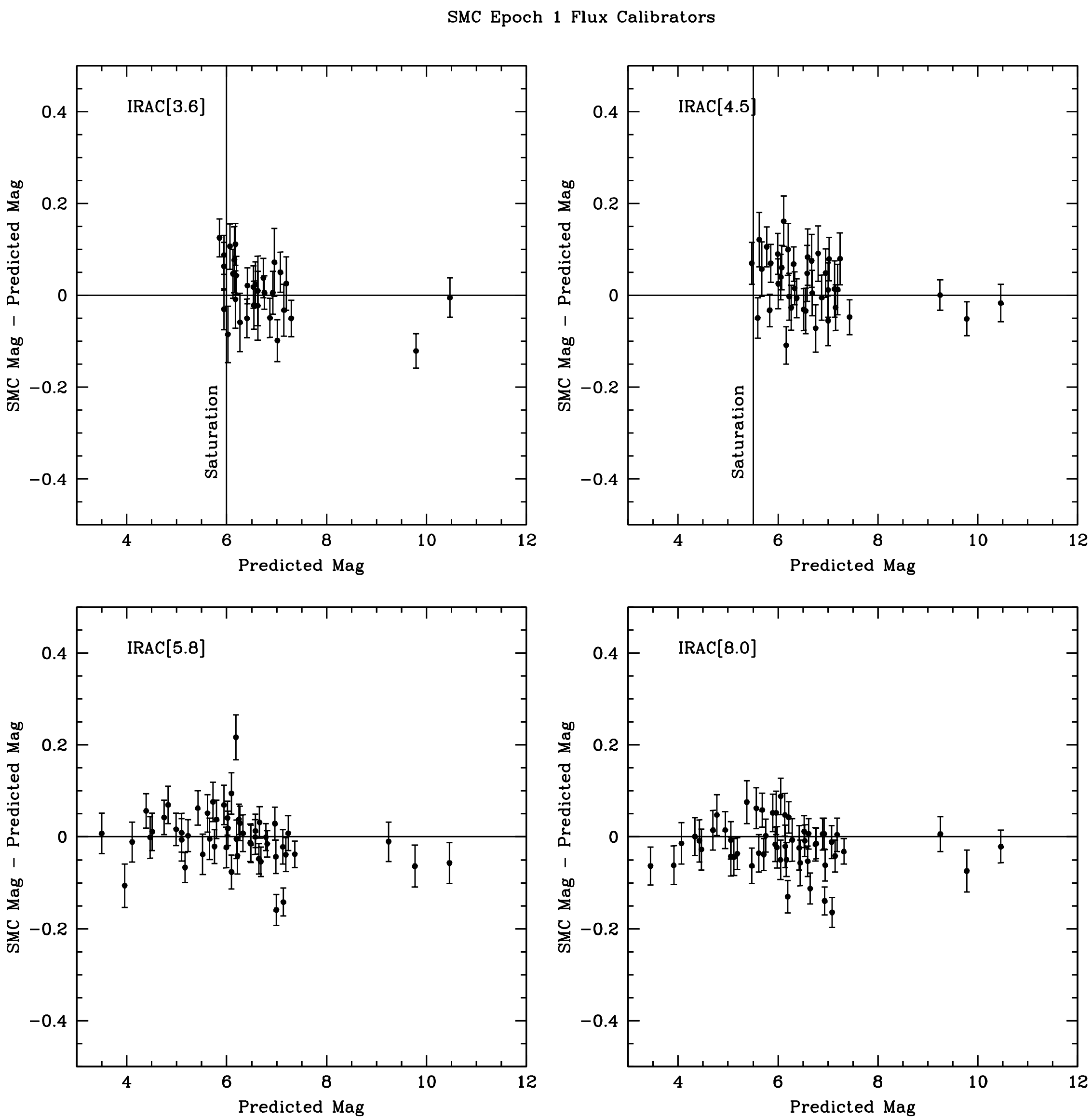

Fig. 7.— Plots demonstrating the quality of the SAGE magnitude measurements in the SAGESMCarchiveIRAC_EP0_EP1_EP2 for Epoch1. SAGE-SMC magnitudes are compared to predictions for 31 to 53 calibration stars for each IRAC band. Error bars are the root sum of the squares of the errors of both extracted and predicted magnitudes for each star.

through 4, respectively. Divergence from the 'truth' list (obtained from mosaic photometry) occurs at the fainter magnitudes, due to our stringent source-selection criteria that removes real sources in addition to cosmic rays (§4.2.1). In addition, completeness is a function of background level which is more variable for IRAC [5.8] and [8.0]. Figures 11 and 12 show that the SMP source lists extend the Archive and Catalog respectively about 1 magnitude

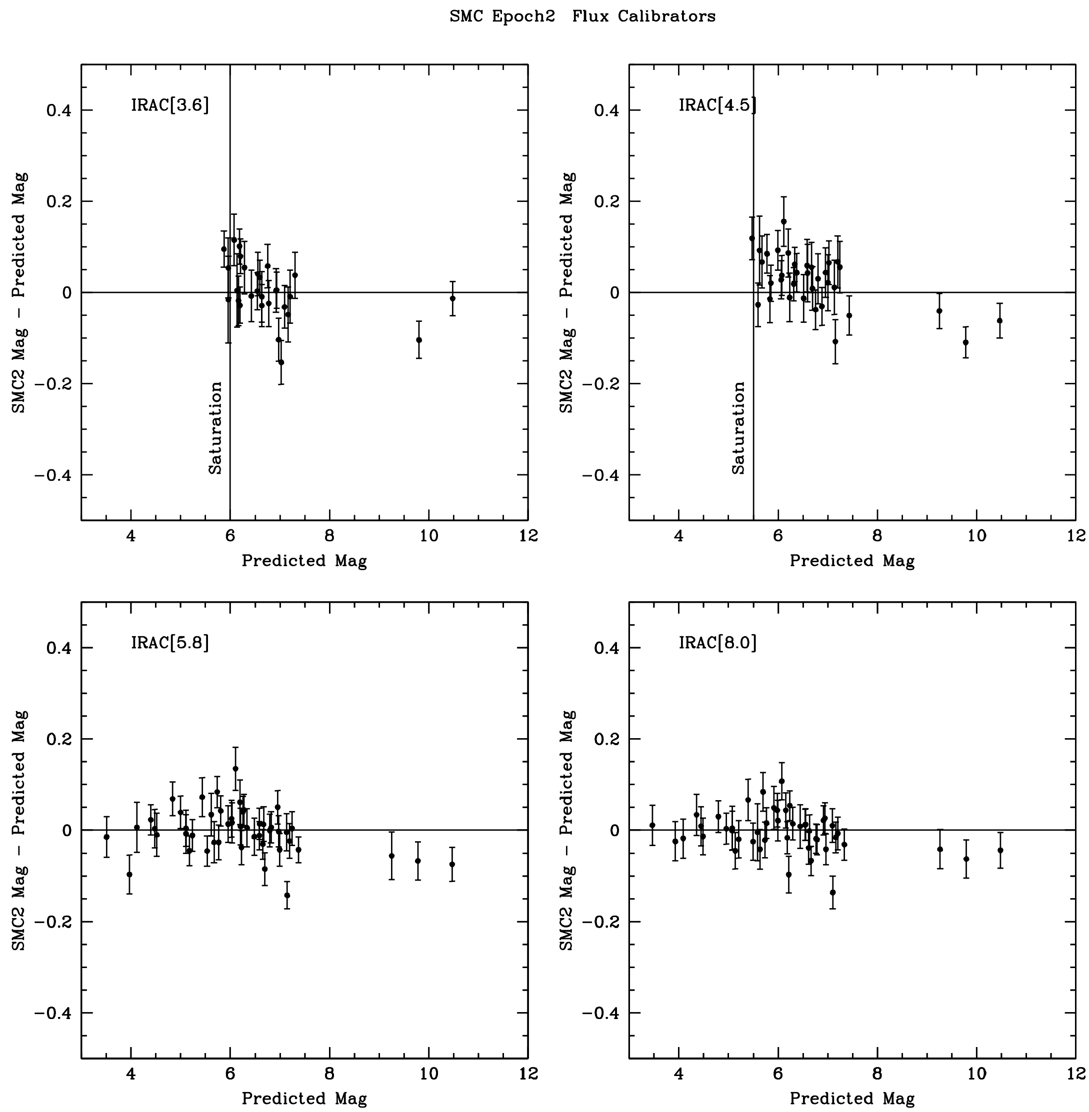

Fig. 8.— Same as Figure 7 for the Epoch 2 data

deeper than the single-frame source lists.

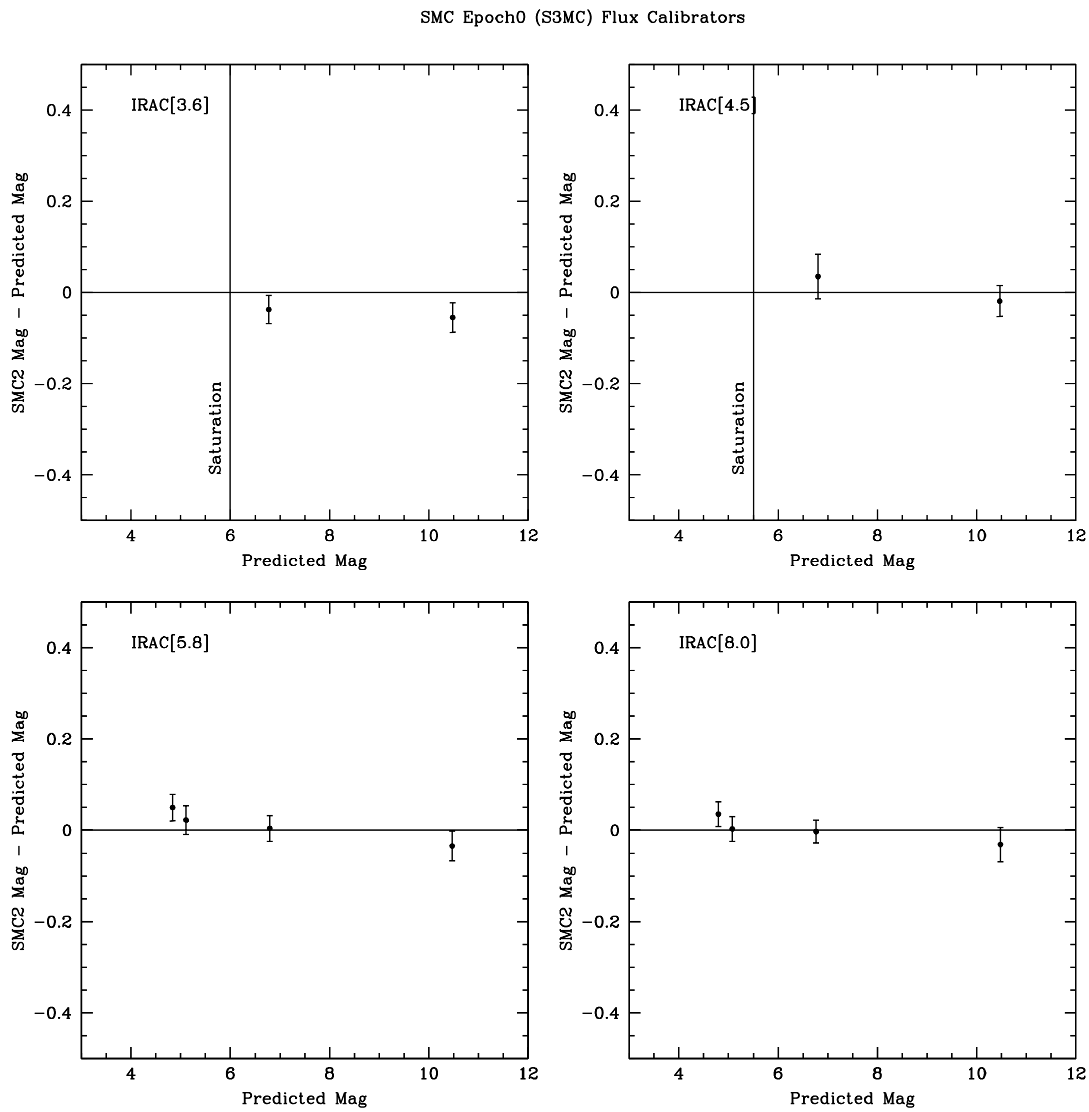

Fig. 9.— Same as Figure 7 for the Epoch 0 data

6.4. Comparison of S^{3}MC (Bolatto et al. 2007) versus SAGE-SMC point source lists of S^{3}MC data

Within the observed SAGE-SMC region is the S^{3}MC subregion. This region contains 6 of the 53 primary flux calibrators. Initial processing of the S^{3}MC data by the SAGE-SMC IRAC pipeline produced results that showed systematic offsets between the S^{3}MC catalog (Bolatto et al. 2007) in bands 3 and 4. Figure 9 shows the comparison of the SAGE-SMC processing of the S^3MC data versus these 6 calibrators. It should be noted for reasons of location and saturation, there are only 2 valid calibrators for bands 1 and 2 and 4 calibrators for bands 3 and 4. However, all data points tend to confirm that the SAGE-SMC IRAC pipeline processing appears to have no systematic offsets from the predicted magnitudes (at least down to 11th magnitude, the faintest calibrators).

Figure 13 compares the matched sources between the SAGE-SMC Epoch1 data and the SAGE-SMC IRAC pipeline processing of the S^3MC data. There is no offset in magnitudes. The degree of scatter, especially at the brighter magnitudes, is quite possibly a display of the extent of variables in these two data sets. There are no systematic offsets; since the SMC data agree well with the SMC flux calibrators, we conclude that the SAGE-SMC processing of the S^3MC data is well calibrated.

Figure 14 is a plot of the Bolatto et al. S^3MC catalog magnitudes compared to the SAGE-SMC Epoch1 Archive magnitudes. Since the SMC Archive magnitudes compare well to the Cohen flux calibrators, any offsets seen here is evidence that the Bolatto catalog magnitudes have additional systematic errors. Plotted in red are Bolatto data with magnitude uncertainties greater than 0.1. For IRAC[3.6] the Bolatto magnitudes with these uncertainties appear to suffer some additional systematic error.

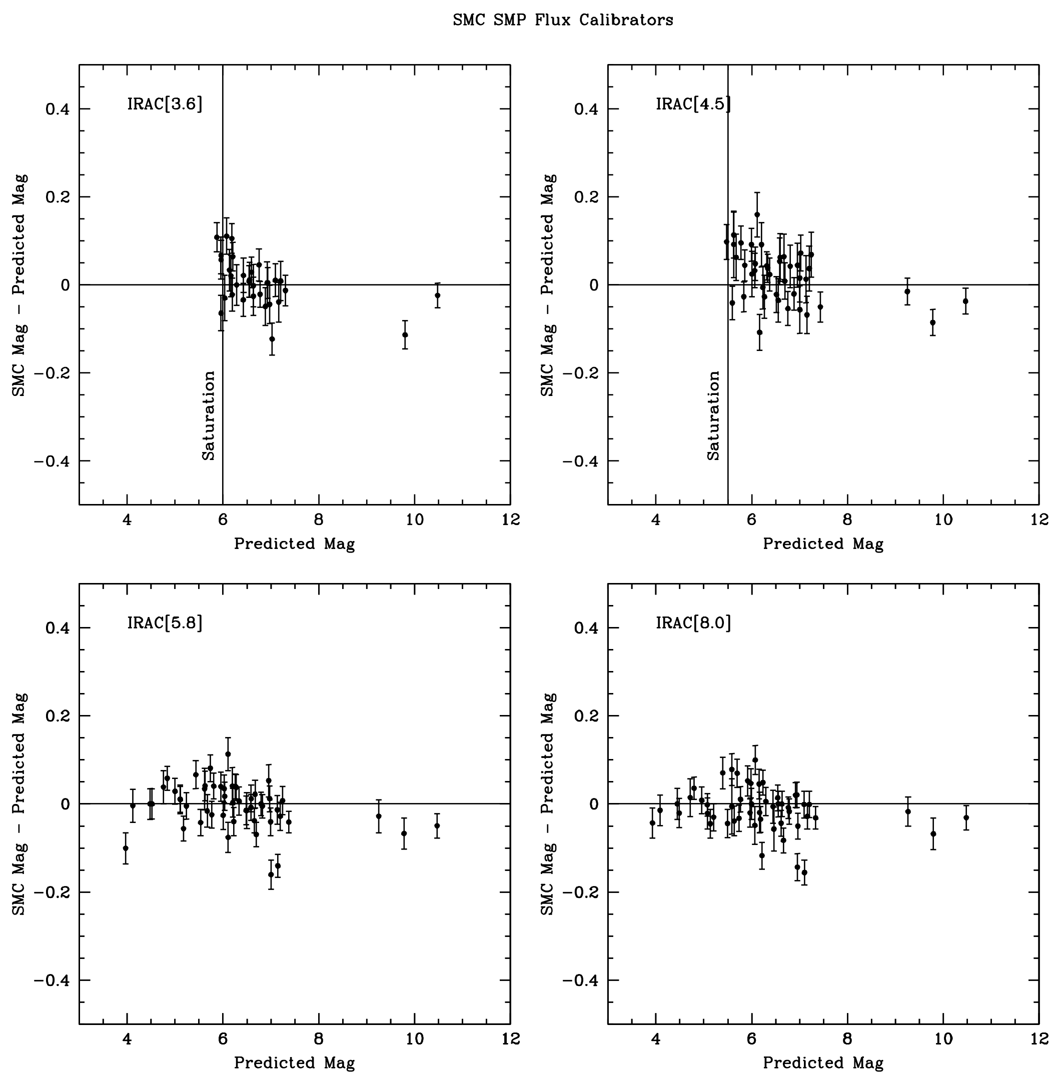

Fig. 10.— Same as Figure 7 for the single frame + mosaic photometry source list (SAGESMCarchiveIRAC).

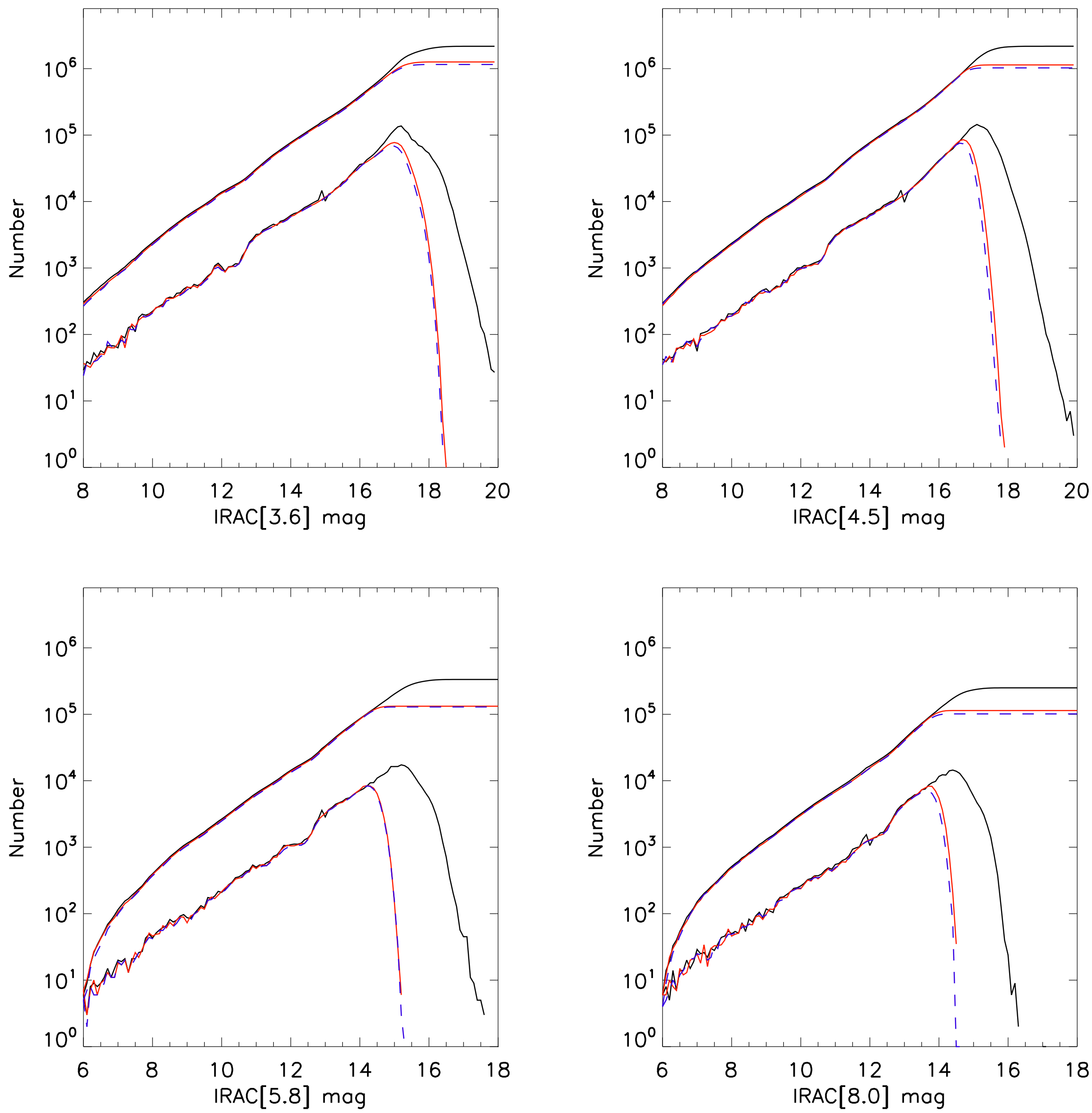

Fig. 11.— Comparison of the Epoch 1 (red lines) and 2 (blue dashed lines) Archive source counts with the SMP photometry Archive counts (black lines) for the entire SAGE-SMC survey. The upper curves in each panel are the cumulative plots while the lower curves are the differential number counts.

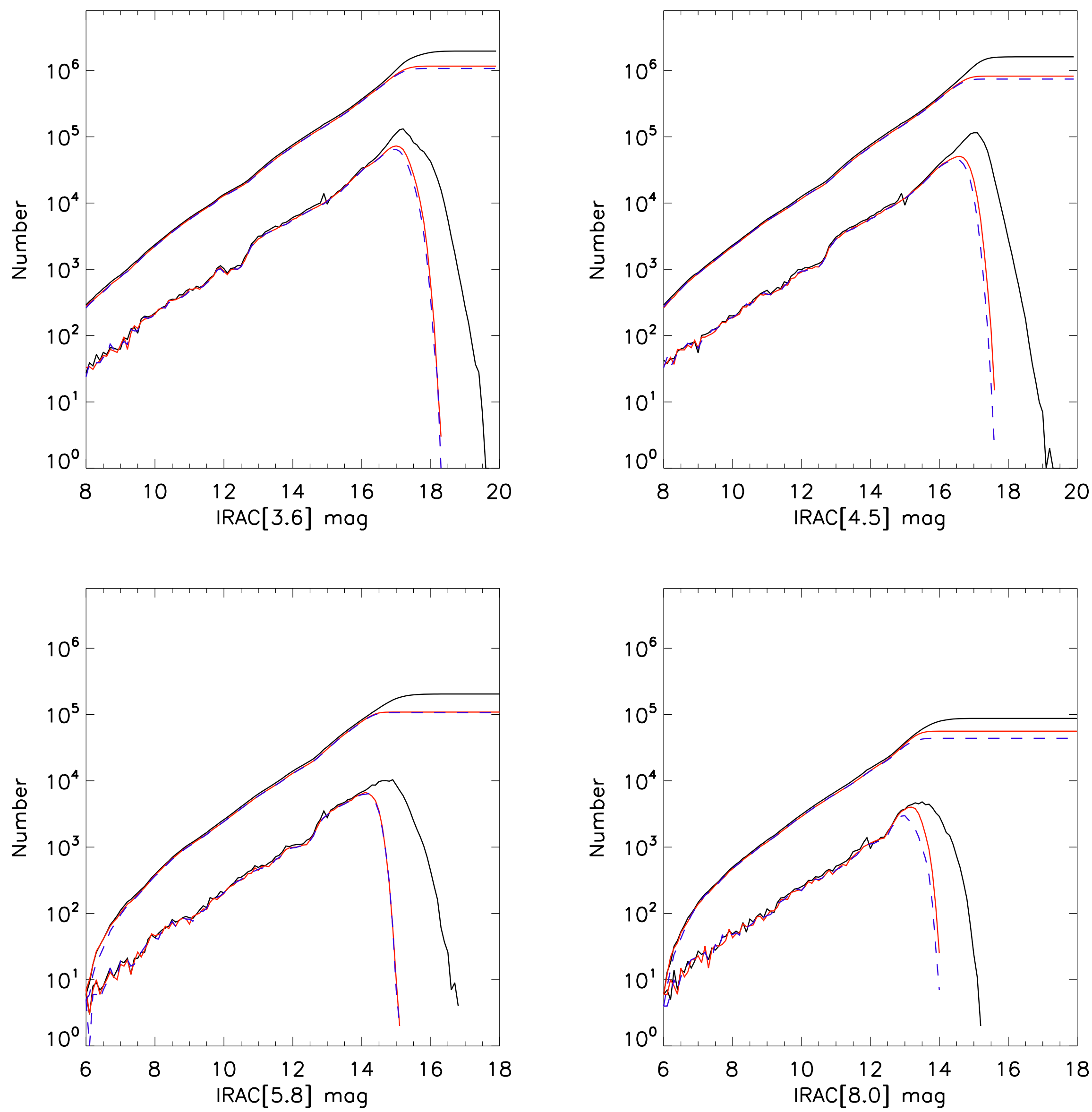

Fig. 12.— Same as Fig. 11 except for the Catalog. Note the main difference seen between the Archive and the Catalog is in band 4 where our S/N threshold for the Catalog is higher.

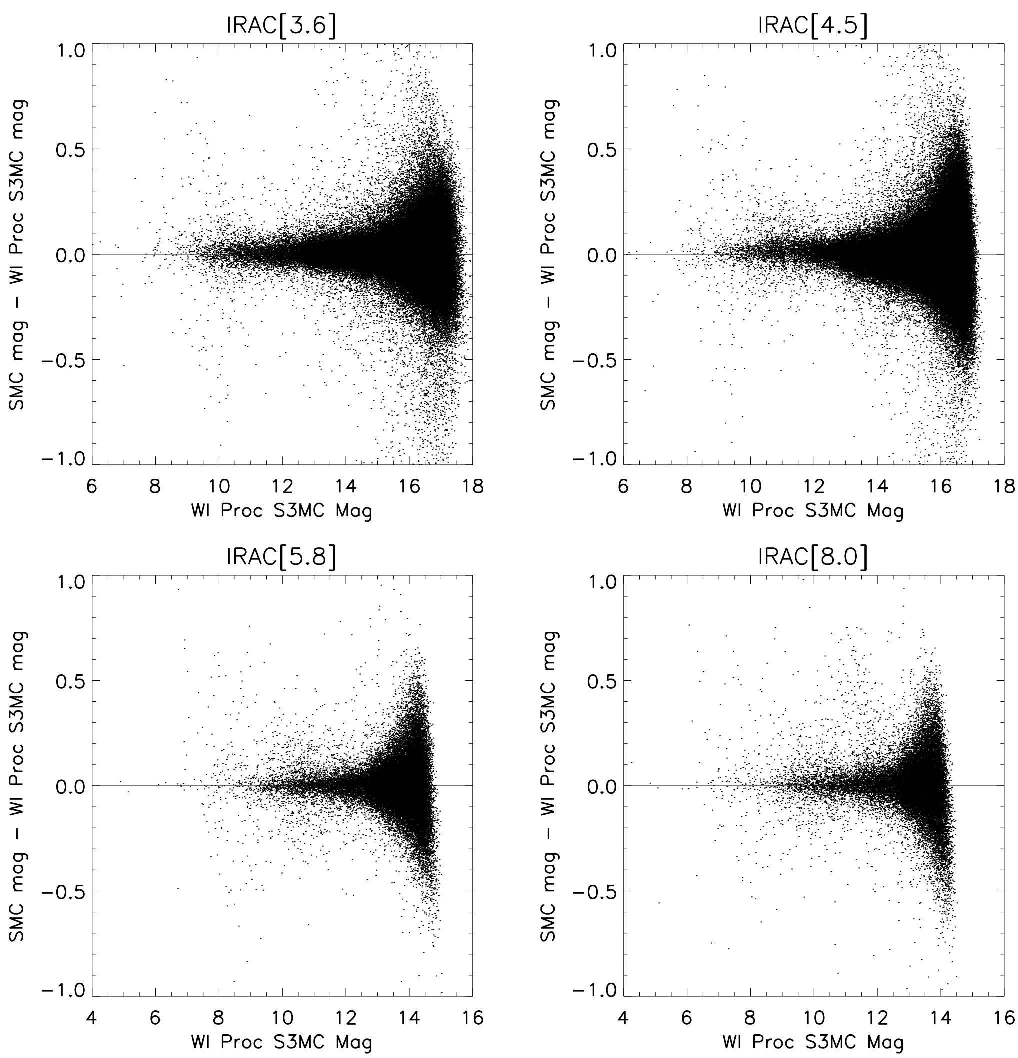

Fig. 13.— Comparison of the SAGE-SMC Epoch 1 Archive and the SAGE-SMC pipeline processed S^3MC magnitudes. There are no systematic offsets between the two datasets.

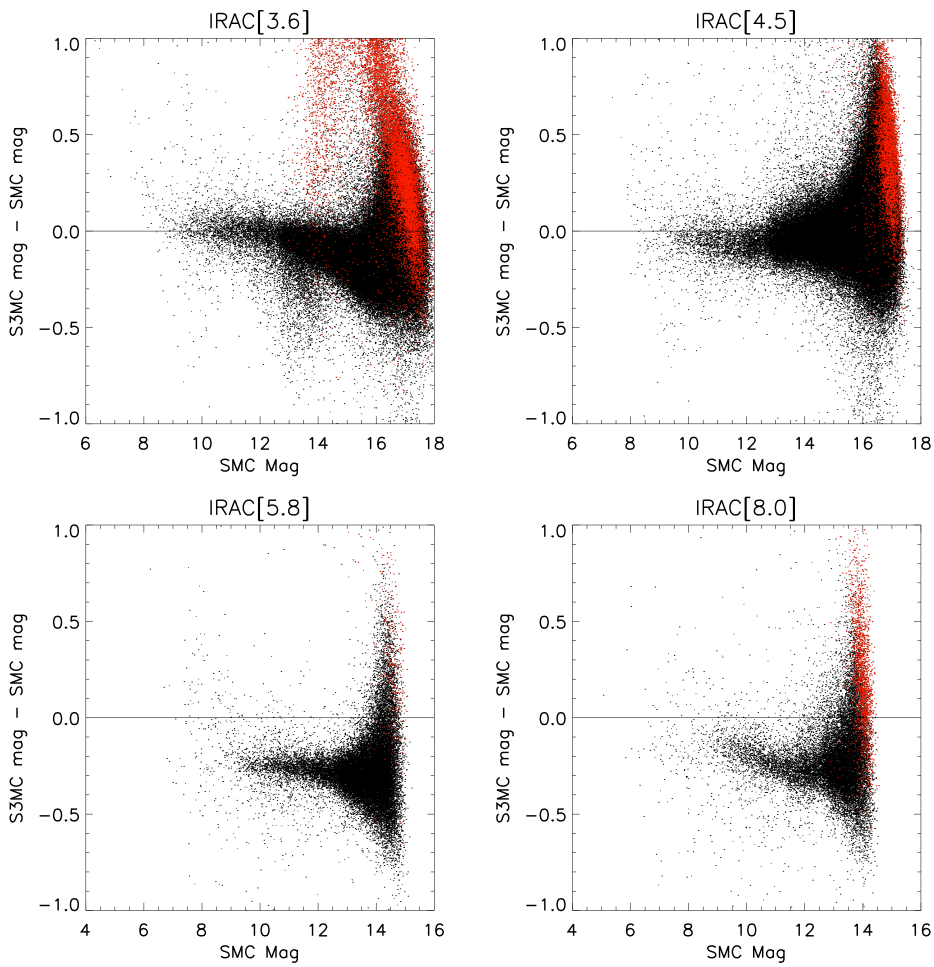

Fig. 14.— Comparison of the Bolatto et al. processed S^3MC magnitudes compared to the SAGE-SMC Epoch 1 Archive magnitudes. Plotted in red are the Bolatto data with magnitude uncertainties greater than 0.1.

7. IRAC Images

7.1. Description of IRAC Images

IRAC images of the entire SAGE-SMC region are provided for each of the four bands at 2.0″ and 1.2″ pixel scales. Both regular image and residual image (point sources removed) mosaics are provided for the 10°× 6° images. Figure 15 shows a 4-color image of the 2″ pixel SAGE SMC region.

These images were made from IRAC Basic Calibrated Data (BCD) frames using SSC pipeline version S14.0 and later processing. The mosaics contain data from all the epochs (0+1+2). The 12 second frametime (FT) IRAC frames were mosaicked using the v3.0 Montage[d] package. The mosaic images conserve surface brightness in the original images; the units are MJy/sr. The images are 32-bit IEEE floating point single extension FITS formatted files. The images have a common projection center: RA=21.78°, Dec=-74.04°. World Coordinate System (WCS) keywords are standard (CTYPE, CRPIX, CRVAL, CD matrix keywords) with an equatorial projection (RA-TAN,DEC-TAN Calabretta and Greisen 2002). Pixels that have no flux estimate have the value NaN. The FITS headers contain relevant information from both the SSC pipeline processing and the IRAC processing. See Appendix D for an example of a FITS header.

7.2. Image Processing

The zodiacal light was subtracted from each IRAC frame. Several image artifacts (described in Hora et al. (2004) and the IRAC Data Handbook[e]) are corrected in the SAGE IRAC pipeline. We correct for column pulldown[f] in bands 1 & 2, using an algorithm written by Lexi Moustakas (GOODS team) and modified by us to handle variable backgrounds. We correct for muxbleed[g] in bands 1 & 2 using a modified version of the IRAC Bright Source

[d]http://montage.ipac.caltech.edu/

[e]http://ssc.spitzer.caltech.edu/irac/iracinstrumenthandbook/

[f]Column pulldown is a reduction in intensity of the columns in which bright sources are found in Bands 1 and 2. See *Spitzer* Observer's Manual (SOM) at http://ssc.spitzer.caltech.edu/files/spitzer/som8.0.pdf.

[g]The multiplexer bleed effect is a series of bright pixels along the horizontal direction on both sides of a bright source in Bands 1 and 2

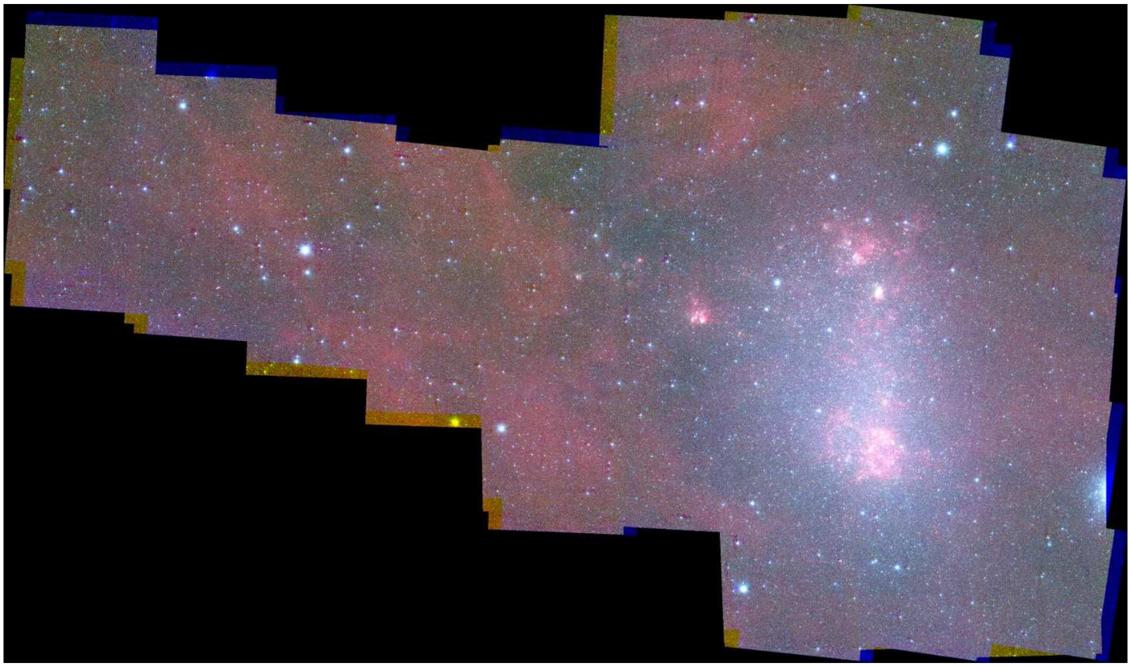

Fig. 15.— IRAC 4-color image of the SAGE SMC region made from the 2″ pixel mosaics. Note that this image is rotated with respect to Fig. 6.

Artifact Corrector[h]. We correct for banding[i] in band 3 by using an algorithm fitting each incidence of banding individually and in band 4 using an exponential function. Hot, dead, and missing pixels are masked. Outlier masking (e.g. cosmic rays, stray light from bright sources outside the field of view) was done using IRACproc (Schuster et al 2006). Visual inspection was done on higher resolution 0.6″ pixel mosaics. The instrument artifacts found by the visual inspection (such as stray light and low or high columns and rows) were removed. Also, latent images from bright sources were removed when possible. Note that some instrument artifacts near the edge of coverage cannot be removed without causing gaps in the images, because of little or no redundancy of coverage. If there are areas of overlapping image artifacts that cause a gap in coverage, we do not mask that area. Because of the two epoch observing strategy (see Section 2) the artifacts along rows and columns (e.g. banding, muxbleed, column pulldown) are mitigated. See SSC's IRAC image features web site[j] for more information about the detector artifacts.

[h]http://ssc.spitzer.caltech.edu/dataanalysistools/tools/contributed/irac/iracartifact/

[i]Banding refers to streaks that appear in the rows and columns radiating away from bright sources in Bands 3 and 4. See the SOM.

[j]http://ssc.spitzer.caltech.edu/irac/features

We use the Montage[k] package v3.0 to mosaic and project to equatorial coordinates. We match instrumental background variations between the images using Montage's level background correction algorithm [l]. Instrument artifacts such as full array pull-up, first frame effect and frame pull-down are mostly removed from the images. The gradient introduced during the background matching process was removed in the full mosaic images using the method described in Appendix E.

7.3. Residual Images

The residual images (images with point sources removed) were produced by running DAOPHOT on the 12 second FT BCD frames. We use a modified version of DAOPHOT (Stetson 1987) as our point source extractor, performing Point Spread Function (PSF) fitting on individual IRAC frames. The residual images are used in an iterative process reassessing the photometric calculations (referred to as "tweaking"), which has been shown to substantially improve the flux estimates in complex background regions[m]. The $10^\circ \times 6^\circ$ residual images are mosaics from the individual frame residuals. Thus, if a source is extracted in some but not all frames it will show up in these images as a source (although its brightness will be reduced because it is being averaged with images where the source was extracted). Sources may not be extracted for a variety of reasons, mainly due to cosmic ray contamination, saturation/non-linearity limits and along the frame edges. Bands 1 and 2 residuals are always a bit worse than bands 3 and 4 because bands 1 and 2 have the more under-sampled PSFs. Sources along ridges and on complex background regions may be slightly over-extracted. Close doubles are sometimes extracted as a single source. In these cases the residual usually looks like a dark bar between two brighter lobes. Because we use 12 second FT images, sources that saturate at this frametime will remain in the residual images even though they may have been extracted and removed for the 0.6 sec FT data.

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[k]http://montage.ipac.caltech.edu/;Montage is funded by the National Aeronautics and Space Administration's Earth Science Technology Office, Computation Technologies Project, under Cooperative Agreement Number NCC5-626 between NASA and the California Institute of Technology. Montage is maintained by the NASA/IPAC Infrared Science Archive.

[l]http://montage.ipac.caltech.edu/docs/algorithms.html#background

[m]see Figure 1 of Babler 2006 at http://www.astro.wisc.edu/glimpse/glimpse_photometry_v1.0.pdf

8. MIPS Full and Catalog Lists

The point source lists presented in this document were extracted from the single epoch images for MIPS 24 μm and from the combined epoch 0+1+2 images for MIPS 70 and 160 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 (including a re-reduction of the epoch 0 data). The details for the SAGE-SMC MIPS data processing can be found in Meixner et al. (2006) and Gordon et al. (2011, AJ, submitted). 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.

8.1. 24 μm Full List and Catalog Criteria

The MIPS source lists were extracted using StarFinder (Diolaiti et al. 2000) on the single Epoch 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 ($\sim$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 $\sim$700 sources. The final single epoch catalogs (SAGESMCcatalogMIPS24) 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). 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.

8.2. 70 and 160 μm Full List and Catalog Criteria

The MIPS 70 and 160 μm point source lists were created using the combined Epoch 0+1+2 images. The combination of all the epochs into a single mosaic was required due to the low redundancy of the SAGE observations at these wavelengths (especially MIPS 160 μm). The StarFinder criteria were the same as described above for the MIPS 24 μm full lists. The full 70 μm and 160 μm source lists containing all the sources extracted from the mosaics are included in SAGESMCfullMIPS70 and SAGESMCfullMIPS160, respectively. The criteria for inclusion in the catalog list (SAGESMCcatalogMIPS70 and SAGESMCcatalogMIPS160) is also the same as for the MIPS 24 μm Catalog (SAGESMCcatalogMIPS24).

8.3. Data Quality Checks

8.3.1. Astrometry

The astrometry of the SAGESMCcatalogMIPS24 sources are referenced to the IRAC Single Frame Epochs 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.

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 16).

8.3.2. Precision and Accuracy of the Photometry

Figure 17 shows the photometric uncertainties of the MIPS 24 μm Catalogs (SAGESMCcatalogMIPS24) and Figure 18 shows the same for the MIPS 70 and 160 μm catalogs (SAGESMCcatalogMIPS70 and SAGESMCcatalogMIPS160). The behavior of the uncertainties as a function of magnitude is 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).

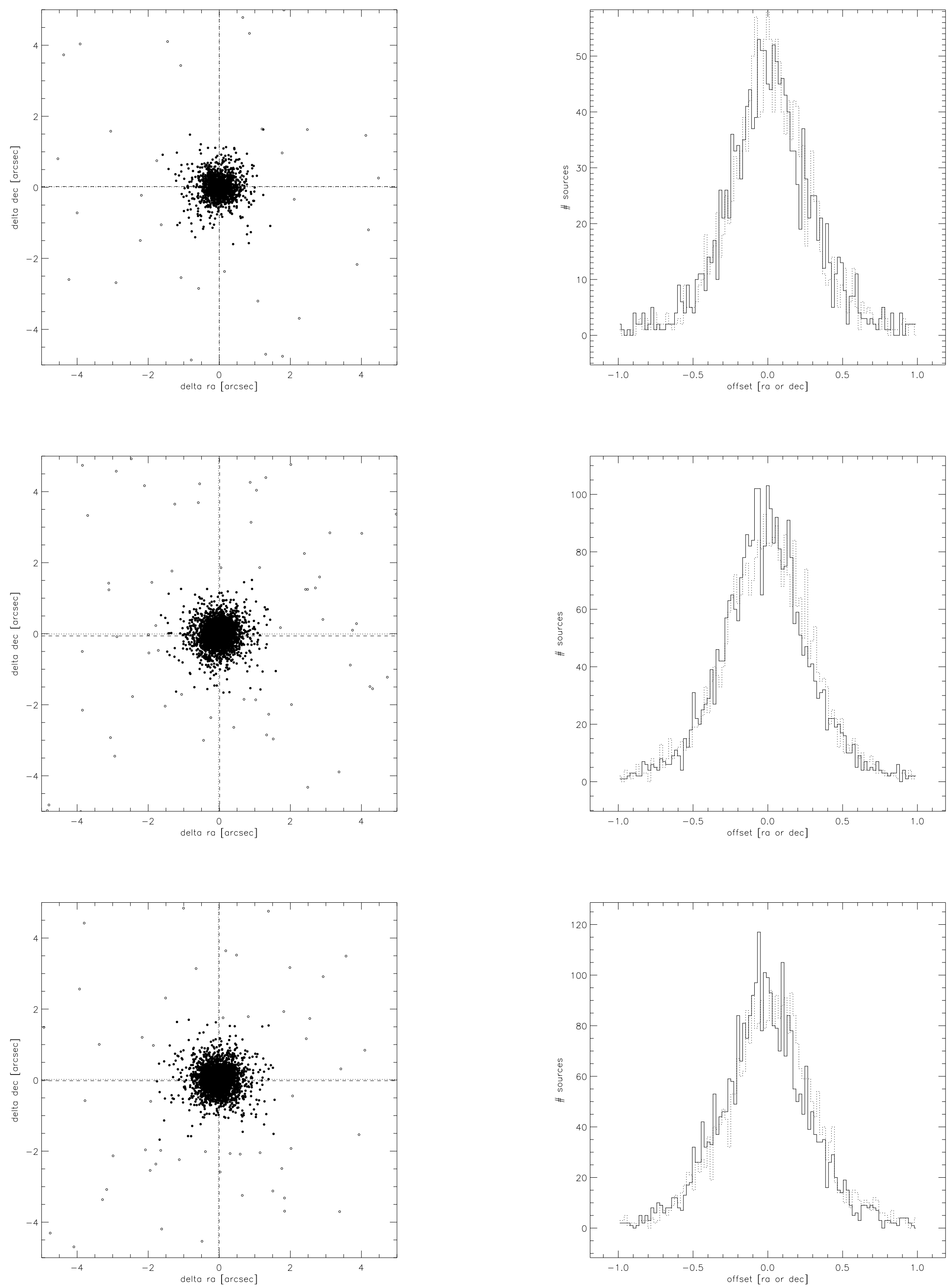

Fig. 16.— The left plot shows the scatter plot of the sources matching between the bright IRAC 8 μm and the MIPS 24 μm sources within 5″ for epoch 0 (top), epoch 1 (middle), and epoch 2 (bottom). The histogram plot quantifies the offsets between these two lists and show that the average is very near zero for both ra and dec.

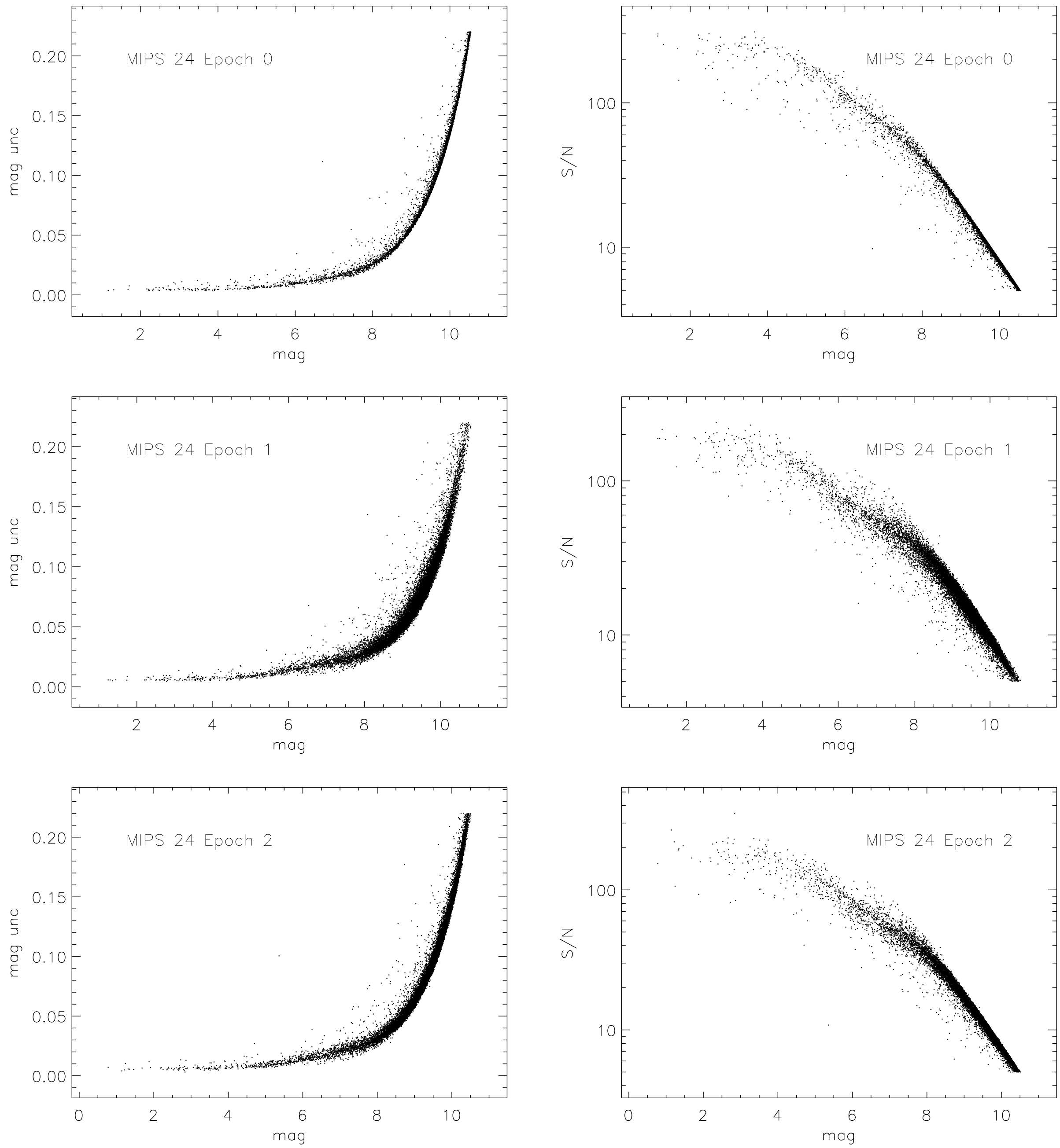

Fig. 17.— The uncertainty in magnitudes is plotted versus magnitude for the full MIPS 24 μm catalog in the left plot. The right plot shows the S/N versus magnitude for the same catalog.

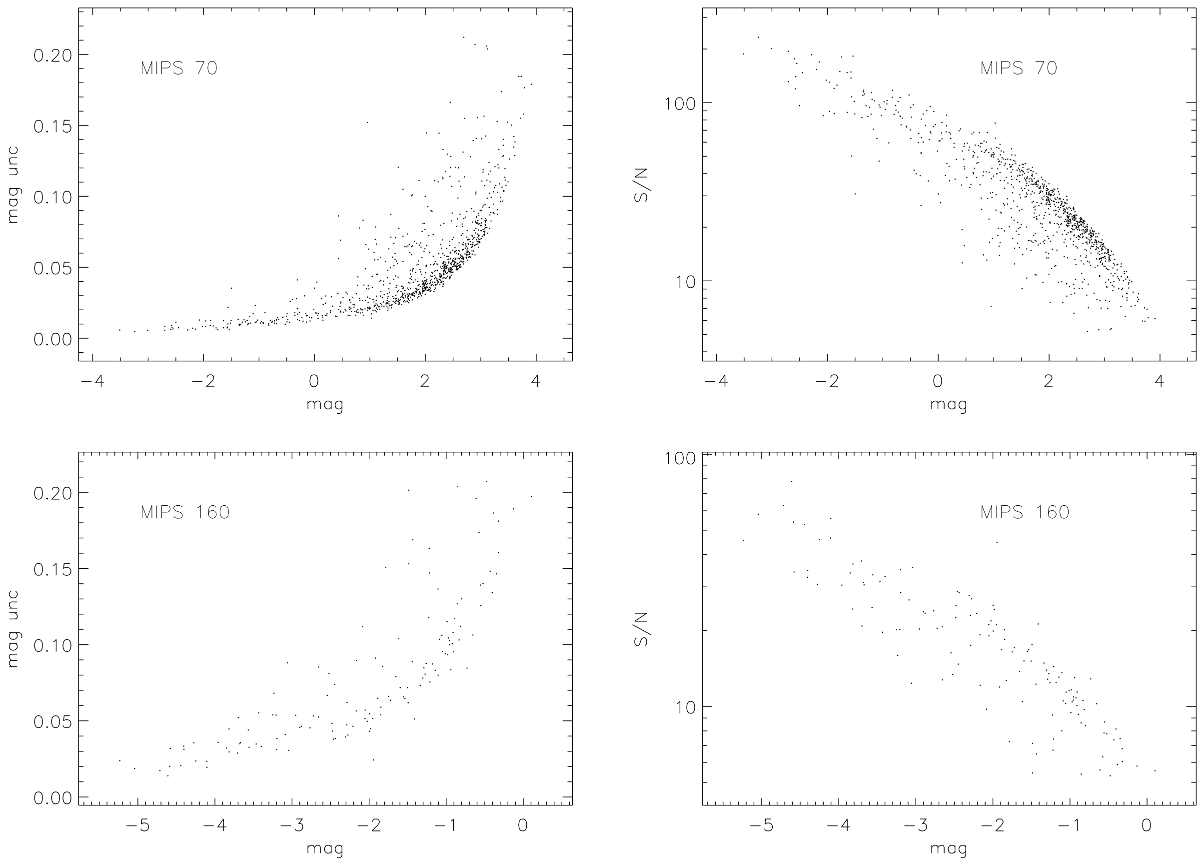

Fig. 18.— The uncertainty in magnitudes is plotted versus magnitude for the MIPS 70 and 160 μm catalogs on the left. The right plots show the S/N versus magnitude for the same catalogs.

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 19). 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.

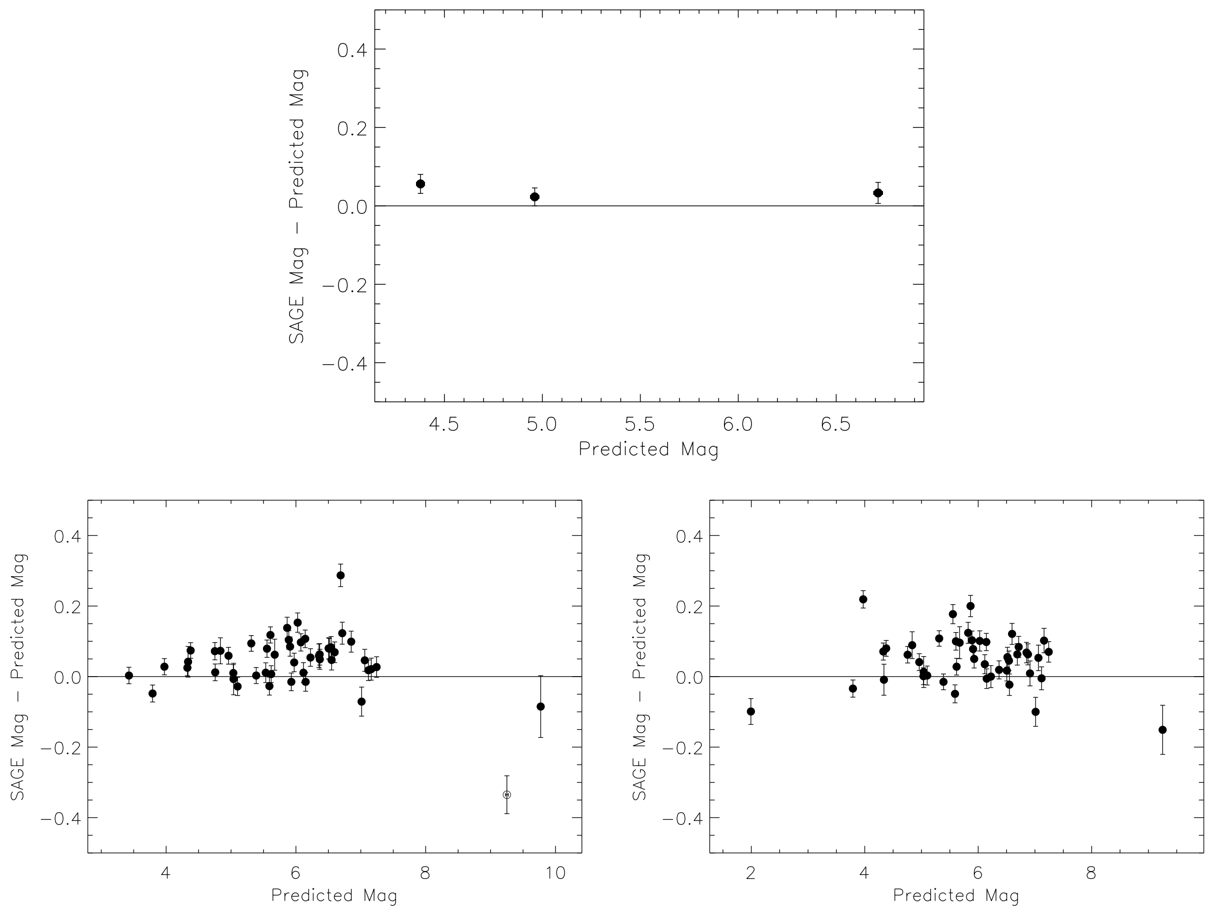

Fig. 19.— The difference between the measured SAGE magnitude and the predicted magnitude for the Cohen et al. (2003a) calibration stars in the SAGE-SMC catalog is shown. The solid line is at zero. The expected offset is 0.029 mag and the observed is 0.04 for Epoch 0 (top) and 0.05 mag Epochs 1 (bottom left) & 2 (bottom right). The predicted magnitudes are based on techniques by Cohen et al. (2003a).

8.3.3. 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 20 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 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.

Another measure of the reliability of a catalog is the histogram of the nearest neighbor distances. Figure 21 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).

8.4. Comparison to S^3MC Photometry

The MIPS 24 & 70 μm photometry determined from the S^3MC observations (epoch 0) using the SAGE-SMC pipeline was compared to that published by the S^3MC collaboration (Bolatto et al. 2007) and found to be consistent within the expected changes in calibrations. For MIPS 24 μm the average S^3MC/SAGE-SMC flux ratio is 1.015 for the nearly 10,000 sources were found in both the S^3MC and SAGE-SMC epoch 0 catalogs. The 1.5% lower SAGE-SMC MIPS24 fluxes are as expected and likely due to the extra steps taken in the SAGE-SMC pipeline to reduce instrumental artifacts (Engelbracht et al. 2007). For MIPS 70 μm, the average S^3MC/SAGE-SMC flux ratio is 0.913 for the nearly 1,800 sources were found in both the S^3MC and SAGE-SMC epoch 0 catalogs. The $\sim$9% higher SAGE-SMC MIPS70 fluxes are expected given that the SAGE-SMC pipeline used the revised 70 μm calibration factor that is 11% higher than the preliminary calibration factor used for the S^3MC reductions (Gordon et al. 2007).

9. MIPS Images

The MIPS 24, 70, & 160 μm mosaics of the whole SMC were created by combining over 100,000 individual images per band into single mosiacs. Given the large number of images, this was especially challenging for the MIPS 24 μm data requiring different steps between

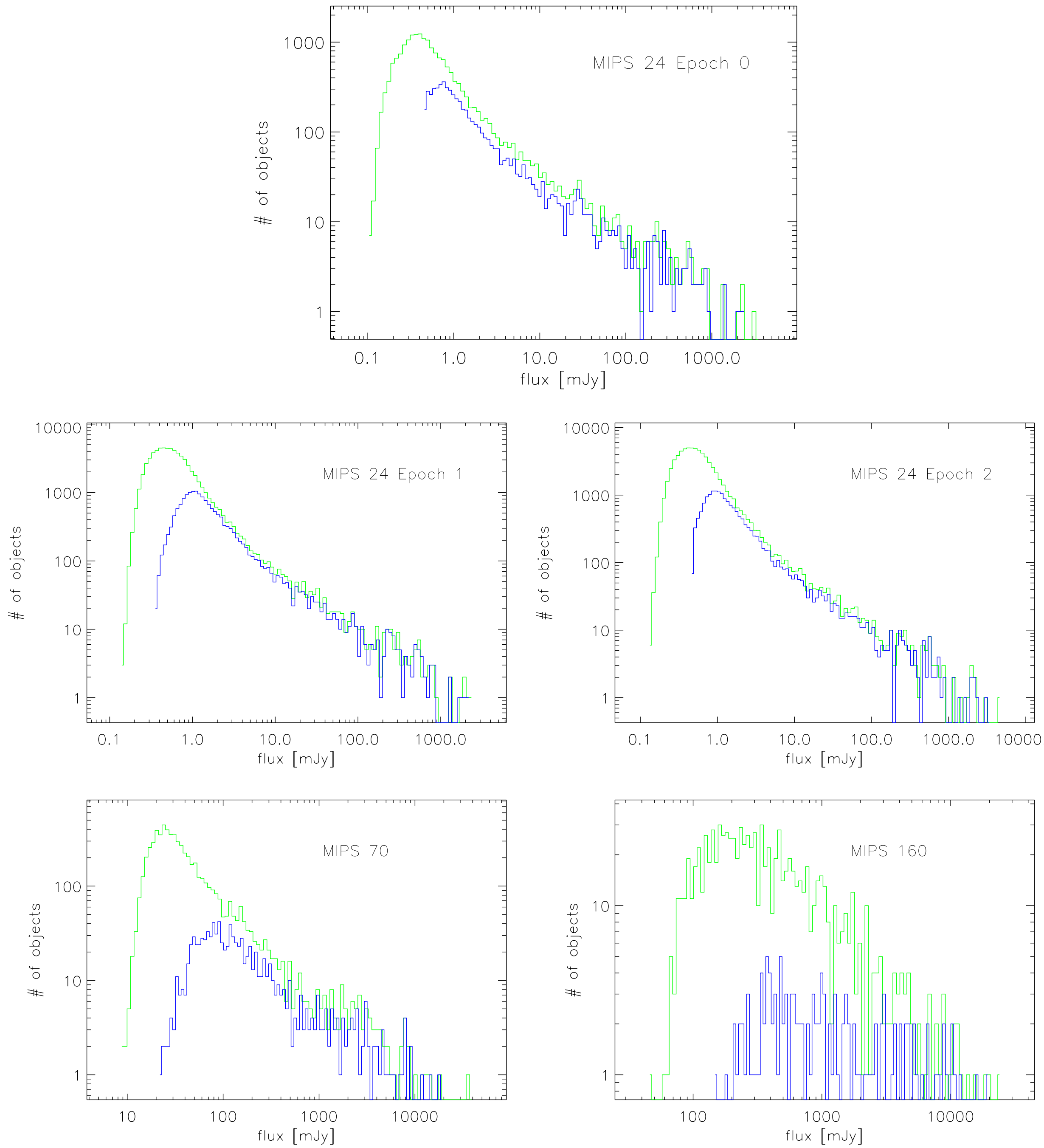

Fig. 20.— The flux histograms for the full source lists (green) as well as the high reliability catalogs (blue) is shown.

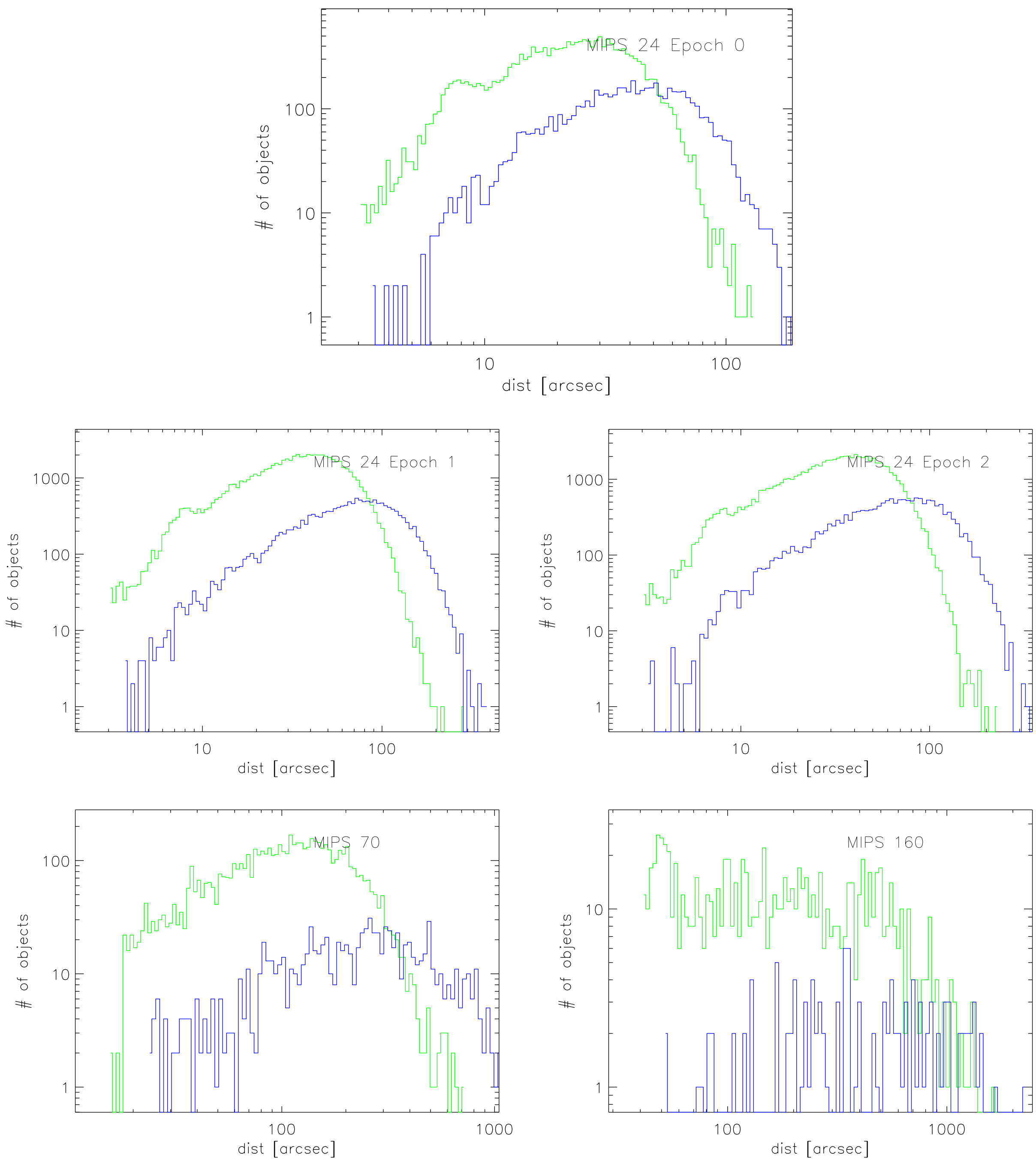

Fig. 21.— The nearest neighbor histogram of the full source lists (green) and catalogs (blue) is plotted.

the 24 μm and 70/160 μm data. Figure 22 shows a 3-color MIPS image of the SAGE-SMC region.

The delivered SMC images were background subtracted at 24 & 70 μm, but *not* background subtracted at 160 μm.

The processing of the individual AORs was done as described in the previous section.

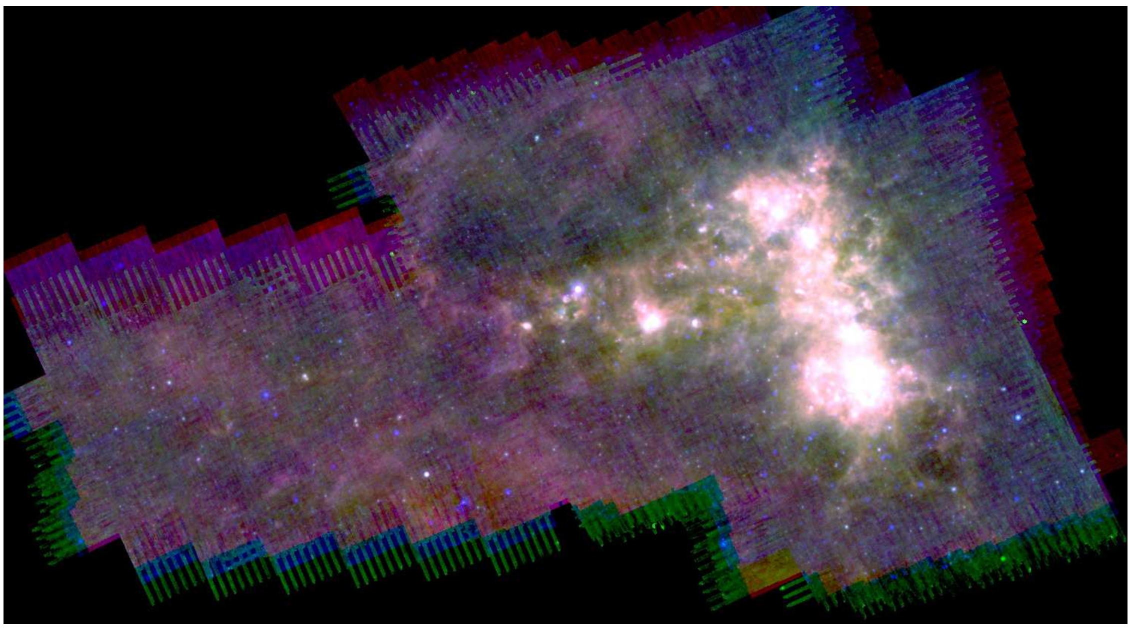

Fig. 22.— A MIPS 3-color image of the SAGE SMC region is shown.

9.1. MIPS 24 μm Images

The MIPS 24 μm mosaics are delivered as the combined epoch 0, 1, and 2 full mosaics of the SMC.

The combined epoch mosaics were created using the combination of the MIPS DAT and Montage programs. The individual AOR mosaics were created using the MIPS DAT. The zodiacal dust emission contributes significantly to the 24 μm band. The zodiacal dust emission is time variable and was removed from the epoch 1 & 2 observations as part of the data reduction using a low order polynomial fit to the data at then ends of each scan leg (devoid of emission from the SMC itself). For the epoch 0 (S^3MC) observations, it was not possible to use off-SMC regions to remove the zodiacal dust emission given that most of the S^3MC observations never got off the SMC. As a result, an intermediate epoch 1+2 mosaic was used as a reference to determine the value to correct each individual epoch 0 image. A single number was subtracted from each epoch 0 image resulting a epoch 0 mosaic that had levels consistent with the epoch 1+2 mosaic allowing for the epoch 0, 1, & 2 images to combined into a final single mosaic.

9.2. MIPS 70 & 160 μm Images

The MIPS 70 & 160 μm mosaics were created using the MIPS DAT and represent the combination of all epochs of data. The individual epoch mosaics exhibit significant residual instrumental signatures (70 μm) or excessive cosmic rays (160 μm). This was expected as these observations have lower redundancy than the 24 μm data and suffer from larger residual instrumental signatures.

The MIPS 70 μm epoch 1 & 2 data were corrected for residual instrumental signatures on a pixel-by-pixel basis using a low order polynomial fit to the data outside of the SMC. This step also effectively removes the background emission measured in the regions outside of the SMC. For the epoch 0 (S^3MC) data, it was not possible to use off-SMC regions to remove the zodiacal dust emission given that most of the S^3MC observations never got off the SMC. As a result, an intermediate epoch 1+2 mosaic was used as a reference to determine the baseline correction for each 70 μm pixel as a function of time. The difference between the epoch 0 data and the values in the epoch 1+2 mosaic was fit with a low order polynomial for each pixel in each AOR. The resulting low order polynomial fits describes the baseline drifts and was removed from the epoch 0 data on a pixel-by-pixel basis. The resulting epoch 0 70 μm mosaic had levels consistent with the epoch 1+2 mosaic allowing for the epoch 0, 1, & 2 images to combined into a final single mosaic.

The MIPS 160 μm data did not require a correction for residual instrumental signatures allowing for the epoch 0, 1, & 2 data to be simply combined to create the final combined epoch mosaic. Thus, the final full SMC 160 μm image is not background subtracted. The background subtraction at 160 μm is not simple as the dominant background source at this wavelength is the complex Milky Way cirrus which is not well approximated by a plane.

9.3. MIPS Residual Images

Residual images of the SMC in each band were computed by subtracting a scaled point spread function (PSF)from each point source found in the delivered image mosaics, using the software "StarFinder". The PSF was constructed as described by (Engelbracht et al.

2007), Gordon et al. (2007), and Stansberry et al. (2007), i.e., by computing an oversampled model PSF using the "Tiny Tim/SIRTF" software (v1.1), convolving it with a square kernel slightly larger than a detector pixel, and resampling it to the resolution of the observation it is to be compared to. We further modified the PSF by averaging two copies of it, each rotated to match one epoch of the full SMC map. This procedure improves the matching of the PSF to the sources in the map, but does not perfectly match the PSF in the outer parts of the map (where the spacecraft rotated $\sim$1 degree/day) and matches even less well in the core of the map (where the epoch 0 data, the S^3MC survey, was combined with the new data). Nevertheless, the subtraction procedure typically resulted in residual sources a few percent of their original brightness.

10. Acknowledgements and References

The SAGE-SMC survey was proposed by a creative team of scientists listed in the SAGE-SMC overview paper (Gordon et al. 2011, AJ, submitted). At the core of the SAGE-SMC team are three data centers at which the Spitzer data are processed and distributed.

- IRAC pipeline based at the University of Wisconsin: Barbara Whitney (lead/Univ. of Wisconsin;SSI), Marilyn Meade (Univ. of Wisconsin), Brian Babler (Univ. of Wisconsin), Remy Indebetouw (Univ. of Virginia), Joe Hora (Harvard/CfA), Steve Bracker (Univ. of Wisconsin), Thomas Robitaille (Harvard/CfA)
- MIPS pipeline based at the University of Arizona: Charles Engelbracht (Univ. of Arizona/lead), Karl Gordon (STScI), Miwa Block (Univ. of Arizona), Karl Misselt (Univ. of Arizona), Steve Bracker (Univ. of Wisconsin)
- SAGE Database based at STScI: Margaret Meixner (STScI/lead), Bernie Shiao (STScI), Marta Sewiło (JHU)

Bernie Shiao of STScI was instrumental in setting up the SAGE-SMC database. This work was funded by NASA Spitzer grants to STScI and other SAGE-SMC institutions. Support from the SSC was critical to the success of the SAGE-SMC project.

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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

This preprint was prepared with the AAS LaTeX macros v5.2.

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.6.2 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 4 describes the columns in the single epoch Catalog and Archive source lists (SAGESMCcatalogIRAC_EP0_EP1_EP2 and SAGESMCarchiveIRAC_EP0_EP1_EP2) including the data format and null values. Table 5 describes the columns in the SMP (single frame + mosaic) Catalog and Archive source lists (SAGESMCcatalogIRAC and SAGESMCarchiveIRAC). There is one extra column in the SMP source lists, which is the close Fulls flag (see Appendix B.3). 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 (S^3MC); **1** = Epoch 1; **2** = Epoch 2; **M** = Single frame + mosaic photometry
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$''$.0 of another Archive source. It was found that the magnitudes of sources closer than about 2$''$.0 from each other are not as reliably extracted and bandmerged. Therefore, a source that is within 2$''$.0 of an Archive source is culled from the Catalog. The Archive allows sources to be up to 0$''$.5 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.″0 of the source

1 sources in the Archive between 2.″5 and 3.″0 of the source

2 sources in the Archive between 2.″0 and 2.″5 of the source

3 sources in the Archive between 1.″5 and 2.″0 of the source

4 sources in the Archive between 1.″0 and 1.″5 of the source

5 sources in the Archive between 0.″5 and 1.″0 of the source

6 sources in the Archive within 0.″5 of the source.

B.3. Close Fulls Flag

The Close Fulls Flag has been added to the entry of the SMP source lists (it is not in the single epoch, single frame photometry source lists). The "Fulls list" is a list of all the detections that come out of the bandmerger before any source list criteria are applied. "Something" was extracted at the given position, which may affect the photometry of a nearby source. Since there are many more sources at the faint end of the mosaic photometry, there are more detections that may effect the photometry at the faint flux end. We do not use this flag for any culling; it is for information only. The Close Fulls Flag is set when a source in the "Fulls List" is within 3.″0 of the Catalog or Archive source. It has the same values as the close source flag, except it uses the Fulls list instead of the Archive as the nearest neighbor source list.

0 no sources in the Fulls list within 3.″0 of the source

1 sources in the Fulls list between 2.″5 and 3.″0 of the source

2 sources in the Fulls list between 2.″0 and 2.″5 of the source

3 sources in the Fulls list between 1.″5 and 2.″0 of the source

4 sources in the Fulls list between 1.″0 and 1.″5 of the source

5 sources in the Fulls list between 0.″5 and 1.″0 of the source

6 sources in the Fulls list within 0.″5 of the source.

Table 4.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

Table 5.IRAC Catalog and Archive Formats-Single Frame + Mosaic Photometry 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: SSTISAGEMA JHHMMSS.SS±DDMMSS.S Catalog: SSTISAGEMC 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	closeFullFlag	Close fulls flag	I*2	i3	NO
13-26	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
27-40	fi,dfi	Fluxes and 1σ error in each band i, i=1-7 (mJy)	R*4	14(e11.3)	-999.9,-999.9
41-44	rms_fi	rms dev. of individual detections from fi (i=4-7), (mJy)	R*4	4(e11.3)	-999.9
45-48	skyi	Local sky bkg. for band i flux (i=4-7), (MJy/sr)	R*4	4(e11.3)	-999.9
49-55	sni	Signal/Noise for band i flux (i=1-7)	R*4	7(f6.2)	-9.99
56-59	srcdensi	Local source density for band i object (i=4-7), (#/sq')	R*4	4(f5.1)	-9.9
60-63	mi	Number of detections for band i (i=4-7)	I*2	4(i3)	NO
64-67	ni	Possible number of detections for band i (i=4-7)	I*2	4(i3)	NO
68-74	sqfi	Source Quality Flag for band i flux (i=1-7)	I*4	7(i10)	-9
75-78	mflagi	Flux calc method flag for band i flux (i=4-7)	I*2	4(i3)	-9
79	versionNo	Version number assigned by IRAC pipeline team	R*4	f6.2	NO
80	versionDate	Date catalog was produced in the following format, "mon dd yyyy", "Dec 5 2007"	ASCII	a12	NO
81	cx	x of unit vector on the unit sphere for ra,dec of this source	R*4	f30.20	NO
82	cy	y of unit vector on the unit sphere for ra,dec of this source	R*4	f30.20	NO
83	cz	z of unit vector on the unit sphere for ra,dec of this source	R*4	f30.20	NO
84	htmID	The Hierchical Triangular Mesh partition computed at index level 20 in which this source lies	I*4	i20	NO

B.4. 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.5. 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.6 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.6. 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.6.1), 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 6 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.

Some SQF bits were carried over from the single frame photometry to the single frame + mosaic photometry source lists, namely bits 3 (latent), 7 (muxbleed), 9 ($>3\sigma$ muxbleed), 15 (column pulldown), 16 (banding), and 20 (saturated star wing area). Bits 10 (DAOPHOT tweak positive) and 11 (DAOPHOT tweak negative) can come from either the mosaic photometry or the single frame photometry.

There are three possible SQF styles:

1) Mosaic entry, flux calculation method flag = 12288 (mosaic only data, no single frame data). This data will only have SQF of mosaic tweaking and the bandmerging SQFs (bits 21 and higher). Mosaic photometry entries in this case should have only the following SQF bits:
10 (tweak positive) From Mosaic photometry cat file
11 (tweak negative) From Mosaic photometry cat file
21 (pre-lumping in-band merge) From bandmerging step
22 (post-lumping cross-band merge) From bandmerging step

2) Mosaic entry, flux calculation method flag of 12352 and 12353 indicates single frame photometry present. The SQF will be a mix of single frame SQF and the mosaic photometry tweak bits as well as the bandmerging SQFs (bits 21 and higher). Mosaic photometry entries should have only the following SQF bits:
3 (latent bit) From Single frame photometry database entry
7 (muxbleed) From Single frame photometry database entry
9 ($>3\sigma$ muxbleed) From Single frame photometry database entry
10 (tweak positive) From Mosaic photometry cat file
11 (tweak negative) From Mosaic photometry cat file
15 (col pulldown) From Single frame photometry database entry
16 (banding) From Single frame photometry database entry
20 (satwing) From Single frame photometry database entry
21 (pre-lumping in-band merge) From bandmerging step
22 (post-lumping cross-band merge) From bandmerging step
24 (in-band merge confusion) From bandmerging step

3) Single Frame entry - contains all Single Frame SQF values as well as the bandmerging

SQFs (bits 21 and higher). The entries can have all the SQF bits listed in Table 6 except bit 24.

B.6.1. 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/calibrationfiles/pmask/
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 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 4.2)
9 - muxbleed correction > 3σ above the background (bands 1 & 2)

Table 6.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	in-band merge confusion with mosaic photometry	SAGE
24	photometric quality flag	2MASS
25	photometric quality flag	2MASS
30	within three pixels of edge of frame	SAGE

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 4.2)

21 - pre-lumping in in-band merge

Sources in the same IRAC frame within a radius of 1.6″ 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″ 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.

24 - confusion in in-band merge with mosaic photometry

This bit is set during the in-band bandmerging process. The bandmerger finds the nearest mosaic photometry source neighbor for each single frame photometry source. Then it finds the nearest single frame photometry source to each mosaic photometry source. If those two sources are pointing at each other, then it tries to merge, according to the flux criteria (see Sect 5.1). Otherwise, it decides things are confused, keeps just the single frame photometry flux, and sets this bit.

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 4.2)

B.6.2. 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″ radius.

23 - Photometric quality flag

24 - Photometric quality flag

25 - Photometric quality flag

Table 7.2MASS 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 7:

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.6.3. 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.7. 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. If a mosaic photometry result is present for the source's flux in a given band, bit 13 is set. If a band's flux was derived from mosaic photometry, bit 14 is set. Bit 15 is set if the source is an "addBack" source (see Sect 5.3).

Table 8.

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)
mosaic	13	(4096)	14	(8192)
addBack	15	(16384)		

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 8). 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 4.1).

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

4099 - 0.6 sec data, mosaic photometry data present
4163 - 0.6 sec data, 12 sec and mosaic present
4288 - 12 sec data, mosaic present
4291 - 12 sec and 0.6 sec data, mosaic present
12288 - mosaic photometry only, present and used
12352 - mosaic photometry present and used, 12 sec present
12353 - mosaic photometry present and used, 0.6 and 12 sec present
>16384 - an addBack source

Table 9.The Example Line from SAGESMCcatalogIRAC

Parameter	Value	Description
globalSourceID ..	15367695	Unique identifier
sourceCatalog ...	iracc	Identifier for source catalog
epoch	SMP	Identifier for epoch of source
designation	SSTISAGEMC J001138.95-730821.6	source name
TmassCntr	1302207582	2MASS cntr from 2MASS PSC
TmassDesignation	00113891-7308213	2MASS designation from 2MASS PSC
ra, dec	2.912304 -73.139360	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
closeFullFlag	0	Close fulls flag
mag	9.060 8.771 8.741 8.611 8.691 8.691 8.662	Magnitudes [JHK, Bands 1-4]
dmag	0.030 0.047 0.021 0.046 0.037 0.031 0.031	mag uncertainties [JHK, Bands 1-4]
flux	378.900 317.600 212.600 101.000 60.000 38.400 22.000	Fluxes (mJy) JHK and Bands 1-4
dflux	10.470 13.750 4.112 4.260 2.051 1.11 0.622	Flux uncertainties (mJy) [JHK, Bands 1-4]
rms_f	1.393 1.246 1.023 0.396	rms_flux (mJy) [Bands 1-4]
sky	0.159 0.267 0.381 -0.728	Sky Bkg (MJy/sr) [Bands 1-4]
S/N	36.19 23.10 51.70 23.71 29.25 34.56 35.35	Signal to Noise [J,H,K,Bands 1-4]
srcDensity	26.1 13.4 18.2 25.4	Local Source Density [Bands 1-4]
m	2 2 4 4	Number of detections [Bands 1-4]
n	2 2 4 4	Number of poss detections [Bands 1-4]
sqf	29360128 29360128 29360128 16896 16896 0 32768	Source Quality Flag [J,H,K,Bands 1-4]
mf	4099 4099 4291 4291	Flux Calculation Method Flag [Bands 1-4]
versionNo	1.5	Catalog version number assigned by
....	...	IRAC pipeline team
versionDate	Mar 8 2011	Date catalog was produced
	...	in the following format,
	...	"month day year"
cx	0.28967022914372349000	x of unit vector to this source
cy	0.01473642641066859000	y of unit vector to this source
cz	-0.95701305951615191000	z of unit vector to this source
htmID	9120518099590	20-deep HTM ID of this source

B.8. An Example of a Line of Text for

SAGESMCcatalogIRAC/SAGESMCarchiveIRAC

Here is an example of a line of text for the Single Frame + Mosaic Photometry Catalog (84 columns)

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

15367695 iracc SMP SSTISAGEMC J001138.95-730821.6 1302207582 00113891-7308213
2.912304 -73.139360 0.3 0.3 0 0 9.060 0.030 8.7710.047 8.741 0.021
8.611 0.046 8.691 0.037 8.691 0.031 8.662 0.031 378.900 10.470 317.600 13.750
212.600 4.112 101.000 4.260 60.000 2.051 38.400 1.111 22.000 0.622
1.393 1.246 1.023 0.396 0.159 0.267 0.381 -0.728 36.19 23.10 51.70
23.71 29.25 34.56 35.35 26.1 13.4 18.2 25.4 2 2 4 4 2 2 4 4
29360128 29360128 29360128 16896 16896 0 32768 4099 4099 4291 4291
1.50 Mar 8 2011 0.28967022914372349000 0.01473642641066859000 0
-0.95701305951615191000 9120518099590

Table 9 shows the same line from SAGESMCcatalogIRAC with the detailed description of the individual columns. SAGESMCarchiveIRAC 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 10)

```
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 10. 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 10. SAGESMCcatalogMIPS24 and SAGESMC-fullMIPS24 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
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, currently unused	I*2		-9
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	I*2		-9

Continued on Next Page...

Table 10 – Continued

Col.	Name	Description	Data	Format	Null
		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.			
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
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

Continued on Next Page...

Table 10 – Continued

Col.	Name	Description	Data	Format	Null
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 11. 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

D. APPENDIX D - IRAC FITS File Header

Here is an example of the IRAC FITS file header for an IRAC 10°x 6° 2″ pixel mosaic, SAGE_SMC_IRAC3.6_2_mosaic.fits:

```
SIMPLE  =                    T / Written by IDL:  Thu Oct 29 17:33:35 2009
BITPIX  =                  -32 / array data type
NAXIS   =                    2 / number of array dimensions
NAXIS1  =                17704
NAXIS2  =                10371
COMMENT   FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT   and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
COMMENT --------------------
COMMENT Pointing Information
COMMENT --------------------
CTYPE1  = 'RA---TAN'           /Projection Type
CTYPE2  = 'DEC--TAN'           /Projection Type
EQUINOX =                 2000
CRVAL1  =        21.7849724910 /[Deg] Right Ascension at reference pixel
CRVAL2  =       -74.0405036320 /[Deg] Declination at reference pixel
CRPIX1  =              8852.50 /Reference pixel for x-position
CRPIX2  =              5186.00 /Reference pixel for y-position
CD1_1   = -0.0004730333736654825
CD1_2   = 0.0002913441310565927
CD2_1   = 0.0002913441310565927
CD2_2   = 0.0004730333736654825
RA      =              21.7850 /[Deg] Right ascension at mosaic center
DEC     =             -74.0405 /[Deg] Declination at mosaic center
COMMENT --------------------
TELESCOP= 'SPITZER '           /Telescope
INSTRUME= 'IRAC    '           /Instrument ID
ORIGIN  = 'UW Astronomy Dept'  /Installation where FITS file written
CREATOR = 'IRAC Pipeline'      /SW that created this FITS file
CREATOR1= 'S14.0 and later'    /SSC pipeline that created the BCD
MOSAICER= 'Montage V3.0'       /SW that originally created the Mosaic Image
FILENAME= 'SAGE_SMC_IRAC3.6_2_mosaic' /Name of this file
FILETYPE= 'mosaic  '           /Calibrated image(mosaic)/residual image(resid)
```

```
CHNLNUM =                    1 /1 digit Instrument Channel Number
DATE    = '2009-10-29T17:29:45' /file creation date (YYYY-MM-DDThh:mm:ss UTC)
COMMENT --------------------
BUNIT   = 'MJy/sr  '           /Units of image data
GAIN    =              3.30000 /e/DN conversion
PIXSCAL1=              2.00000 /[arcsec/pixel] pixel scale for axis 1
PIXSCAL2=              2.00000 /[arcsec/pixel] pixel scale for axis 2
OLDPIXSC=              1.22100 /[arcsec/pixel] pixel scale of single IRAC frame
NIMAGES =                26724 /Number of Frames in Mosaic
COMMENT --------------------
COMMENT Proposal Information
COMMENT --------------------
OBSERVR1= 'Karl Gordon'        /Observer Name
OBSVRID1=                   49 /Observer ID of Principal Investigator
PROCYCL1=                    7 /Proposal Cycle
PROGID1 =                40245 /Program ID
PROTITL1= 'SAGE-SMC:Surveying the Agents of Galaxy Evolution in the Tidally-Di'
PROGCAT1=                   27 /Program Category
OBSERVR2= 'Alberto Bolatto'    /Observer Name
OBSVRID2=                  413 /Observer ID of Principal Investigator
PROCYCL2=                    4 /Proposal Cycle
PROGID2 =                 3316 /Program ID
PROTITL2= 'The Small Magellanic Cloud: A Template for the Primitive Interstella'
PROGCAT2=                   30 /Program Category
COMMENT -----------------------------
COMMENT Time and Exposure Information
COMMENT -----------------------------
FRAMTIME=              12.0000 /[sec] Time spent integrating each BCD frame
EXPTIME =              10.4000 /[sec] Effective integration time each BCD frame
COMMENT DN per pixel=flux(photons/sec/pixel)/gain*EXPTIME
NEXPOSUR=                    4 /Typical number of exposures
COMMENT Total DN per pixel=flux(photons/sec/pixel)/gain*EXPTIME*NEXPOSUR
COMMENT Total integration time for the mosaic = EXPTIME * NEXPOSUR
AFOWLNUM=                    8 /Fowler number
COMMENT -----------------------------
COMMENT AORKEYS/ADS Ident Information
COMMENT -----------------------------
AOR001  = '0022827776'         /AORKEYS used in this mosaic
```

```
AOR002  = '0022828032'         /AORKEYS used in this mosaic
AOR003  = '0022828288'         /AORKEYS used in this mosaic
AOR004  = '0022828544'         /AORKEYS used in this mosaic
AOR005  = '0022829056'         /AORKEYS used in this mosaic
AOR006  = '0022829312'         /AORKEYS used in this mosaic
AOR007  = '0022829568'         /AORKEYS used in this mosaic
AOR008  = '0022829824'         /AORKEYS used in this mosaic
AOR009  = '0022830080'         /AORKEYS used in this mosaic
AOR010  = '0022830336'         /AORKEYS used in this mosaic
.
.
          AORKEY information for AORs 11 through 60
.
.
AOR061  = '0010741504'         /AORKEYS used in this mosaic
AOR062  = '0010741760'         /AORKEYS used in this mosaic
AOR063  = '0010742016'         /AORKEYS used in this mosaic
AOR064  = '0010742272'         /AORKEYS used in this mosaic
AOR065  = '0010742528'         /AORKEYS used in this mosaic
AOR066  = '0010742784'         /AORKEYS used in this mosaic
AOR067  = '0010743040'         /AORKEYS used in this mosaic
AOR068  = '0012206336'         /AORKEYS used in this mosaic
DSID001 = 'ads/sa.spitzer#0022827776' /Data Set Identification for ADS/journals
DSID002 = 'ads/sa.spitzer#0022828032' /Data Set Identification for ADS/journals
DSID003 = 'ads/sa.spitzer#0022828288' /Data Set Identification for ADS/journals
DSID004 = 'ads/sa.spitzer#0022828544' /Data Set Identification for ADS/journals
DSID005 = 'ads/sa.spitzer#0022829056' /Data Set Identification for ADS/journals
DSID006 = 'ads/sa.spitzer#0022829312' /Data Set Identification for ADS/journals
DSID007 = 'ads/sa.spitzer#0022829568' /Data Set Identification for ADS/journals
DSID008 = 'ads/sa.spitzer#0022829824' /Data Set Identification for ADS/journals
DSID009 = 'ads/sa.spitzer#0022830080' /Data Set Identification for ADS/journals
DSID010 = 'ads/sa.spitzer#0022830336' /Data Set Identification for ADS/journals
.
.
          Data Set Identification for IDS 11 through 60
.
.
DSID061 = 'ads/sa.spitzer#0010741504' /Data Set Identification for ADS/journals
```

```
DSID062 = 'ads/sa.spitzer#0010741760' /Data Set Identification for ADS/journals
DSID063 = 'ads/sa.spitzer#0010742016' /Data Set Identification for ADS/journals
DSID064 = 'ads/sa.spitzer#0010742272' /Data Set Identification for ADS/journals
DSID065 = 'ads/sa.spitzer#0010742528' /Data Set Identification for ADS/journals
DSID066 = 'ads/sa.spitzer#0010742784' /Data Set Identification for ADS/journals
DSID067 = 'ads/sa.spitzer#0010743040' /Data Set Identification for ADS/journals
DSID068 = 'ads/sa.spitzer#0012206336' /Data Set Identification for ADS/journals
END
```

E. APPENDIX E - Gradient Corrected IRAC 10°x 6°Images

The observing strategy for the SAGE project was to divide the SAGE SMC IRAC area into 29 tiles, or Astronomical Observing Requests (AORs) for each of the two epochs. One SAGE AOR was $1.1^{\circ} \times 1.1^{\circ}$, made up of 14 x 28 IRAC frames, with half-array steps, similar to the strategy for SAGE-LMC. See Meixner et al 2006 for more details of the mapping strategy. To produce the background matched and gradient corrected SAGE images, each individual AOR was mosaicked (with background matching) using Montage v3.0. For each AOR, the corrections.tbl file giving the corrections used by Montage to match the backgrounds was then converted to a table of corrections as a function of position in the AOR mosaic. This was used to find the correction at each pixel position in the AOR mosaic using a smoothing radial basis function interpolation. This 'smoothed correction map' was compared to the original corrections, and outliers were rejected from the original table. A new smoothed map was produced, and this procedure was repeated several times, to ensure that no outliers affected the smoothed map. The final background correction map obtained thus represented the incorrect fit applied by Montage, and this correction map was then subtracted from the AOR mosaic. The rejection of outliers was necessary, as these outliers correspond to desirable corrections rather than large-scale corrections.

For band 3, a number of problems meant that the procedure to make mosaics for individual AORs was more complex. The original background matched mosaics were found to include severe gradients and a grid-like pattern. It was found that this was caused by a strong residual gradient in the BCD frames that was consistent over the AORs. This was removed by computing the median of the median-subtracted BCD frames (ignoring the first 40 BCD frames). The median frame was then subtracted from all BCD frames in that AOR. For 18 of the 58 AORs this was not sufficient to remove the gradient and grid-like pattern completely. For these AORs, the above procedure was done for each set of 28 consecutive

BCDs (except for the first set which only included 27 frames as the first frame was removed from the start). Thus, for each of these AORs, 14 separate median frames were computed. Finally, the 14 first frames were removed for each AOR in band 3 due to remaining first-frame effect issues.

The background matching procedure can introduce large-scale gradients that have to be corrected for. In each AOR, the Montage correction for each BCD frame as a function of position was fitted by a smooth function using RBF interpolation, and the smooth function was then subtracted from the AOR mosaic.

In the case of the band 3 mosaics, it was found that the distribution of corrections minus the smooth correction was bimodal. In most cases, around half the frames deviated from the smooth function by approximately +0.1 MJy/sr, while in the remaining cases, half the frames deviated from the smooth function by -0.1 MJy/sr. This random offset of +/- 0.1 MJy/sr caused the correction map to be noisy, which was problematic for the gradient correction.

Investigating this revealed that the median level in band 3 BCD frames is strongly dependent on the inter-frame delay time, and the offsets are predictable. For the S^{3}MC mosaics, the following corrections were *subtracted* from the BCD frames:

```
INTRFDLY < 0.5         -0.629 MJy/sr
0.5 < INTRFDLY < 0.9   -0.184 MJy/sr
0.9 < INTRFDLY < 1.3   -0.016 MJy/sr
1.3 < INTRFDLY < 1.7    0.183 MJy/sr
1.7 < INTRFDLY < 2.1    0.410 MJy/sr
2.1 < INTRFDLY         -0.208 MJy/sr
```

For the remaining mosaics, the following corrections were *subtracted* from the BCD frames:

```
INTRFDLY < 0.5         -0.571 MJy/sr
0.5 < INTRFDLY < 0.9   -0.341 MJy/sr
0.9 < INTRFDLY < 1.3   -0.105 MJy/sr
1.3 < INTRFDLY < 1.7    0.062 MJy/sr
1.7 < INTRFDLY < 2.1    0.125 MJy/sr
2.1 < INTRFDLY         -0.283 MJy/sr
```

A final problem with the Band 3 AORs was that the median level in the BCD frames was found to increase with time in some AORs, following a power law p(x) = a * x ** b

+ c where x was the original frame number in the AOR, and b < 1, such that the rise was rapid at the start and slowed down at later times. However, this residual time-dependent variation was enough to affect the background matching correction applied later, so a power law was fitted to the corrections and subtracted for each AOR. This was done only for three AORs for the S^3MC mosaics, and was done for all other AORs *except* 7 AORs.

The next step was to mosaic all the AORs together for each epoch to produce the $10° \times 6°$ images. Background matching was used to remove differences in the levels of different AOR frames. Once again, large-scale gradients were removed by producing smoothed correction maps and subtracting these from the mosaics. At 5.8 μm , a number of AOR mosaics were offset from the majority of AOR mosaics, and therefore had a significantly different offset correction applied. These were ignored when calculating the smoothed correction map, as these correspond to desirable corrections, rather than undesirable large-scale gradients.

For each band, the combined $10° \times 6°$ mosaic was produced by averaging the $10° \times 6°$ mosaics for the three separate epochs. NaN pixels were ignored in the averages; so for pixels where one epoch had a NaN value, the flux for the other epoch was used. Throughout the process, a number of BCD frames were found to cause problems and were removed.

The AORs were mosaicked together for each epoch using background matching, first with equal weights. This was done to determine the offset between the different AORs. A custom program was then used to combine together the AORs into single-epoch and all-epoch AORs using these offsets, and weighting each pixel by the number of BCDs covering that position in each AOR (which is equivalent to the weights that would be used if all the BCDs were mosaicked together from the start).

For a description of the gradient correction procedure used for the SAGE LMC images, see Appendix E of the SAGE Data Products Description (September 2009) at http://data.spitzer.caltech.edu/popular/sage/20090922_enhanced/documents/SAGEDataProductsDescription_Sep09.pdf