Deep GLIMPSE Data Description

Deep GLIMPSE: Exploring the Far Side of the Galaxy

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1 Quick Start

The Deep GLIMPSE project provides mid-infrared coverage of the Far Outer Galaxy as it warps above and below the Galactic plane looking towards the Galactic center. We survey the following regions: longitudes 25°< l < 65°, 0°< b <+2.7° and 265°< l < 350°, -2°< b <+0.1°(see Figure 1). The data have been processed by the Wisconsin GLIMPSE IRAC pipeline. For those who are familiar with Galactic Legacy Infrared Mid-Plane Survey Extraordinaire (GLIMPSE) data, Deep GLIMPSE data products are very similar. There are two types of source lists: a high reliability point source Catalog and a more complete point source Archive. The other main product is the set of mosaicked images. Deep GLIMPSE is a Spitzer "Warm Mission" program. After the cryogen depletion in May 2009, the observatory is operating using only IRAC's 3.6 and 4.5 μm channels.

This Deep GLIMPSE data release contains images from l=264.6°to 300.05°. Previously released Deep GLIMPSE images were l=24.6°to 65.3°and l=299.95°to 350.3°. All of the Deep GLIMPSE images have now been released. This completes the Deep GLIMPSE data delivery to IRSA.

All of the Deep GLIMPSE source lists have been delivered to IRSA. The entire Deep GLIMPSE source list totals 38,279,639 Catalog sources and 63,522,165 Archive sources. The source lists are a result of doing photometry on each IRAC frame, averaging all detections of a single band (in band-merge), then doing the merging of all wavelengths, including 2MASS J,H, and K_s, at a given position on the sky (cross-band merge).

GLIMPSE, GLIMPSEII, GLIMPSE3D, Vela-Carina, GLIMPSE360 and Deep GLIMPSE data products are available at the Infrared Science Archive (IRSA)

- irsa.ipac.caltech.edu/data/SPITZER/GLIMPSE/

Useful websites for the analysis of these data provided by the GLIMPSE team are the Web Infrared Tool Shed (WITS) and the Young Stellar Objects (YSO) Grid and Fitter

- WITS – dustem.astro.umd.edu/
- YSO Model Fitter – caravan.astro.wisc.edu/protostars/ and http://sedfitter.readthedocs.org/

2 Deep GLIMPSE Survey and Data Products Overview

2.1 Project Overview

Deep GLIMPSE is the sixth in a series of large area projects to map regions of the Galactic plane using the Spitzer Space Telescope (SST; Werner et al. 2004) Infrared Array Camera (IRAC) (Fazio et al. 2004). Deep GLIMPSE is a Warm Mission Spitzer Cycle 8 Exploration Science Program (PIDs 80074 and 80253) that mapped 125 degrees of longitude of the Far Side of the Galaxy. Warm Mission Spitzer has two IRAC bands, centered at approximately 3.6 and 4.5 μm. The Galactic longitudes covered by Deep GLIMPSE are l=265°-350°and 25°-65°. The latitude width is about 2.1° (see Figure 1). The latitude center follows the Galactic warp at a Galactocentric distance of 13 kpc to survey the Far Outer Galaxy (Binney & Merrifield 1998; Levine et al. 2006). Table 1 shows the Deep GLIMPSE areas and the dates of observation for each longitude segment.

Deep GLIMPSE overlapped some of the original GLIMPSE (including the Observing Strategy Validation (OSV) area near RCW49), GLIMPSE3D, Vela-Carina and GLIMPSE360 surveys. Deep GLIMPSE has three visits on each sky position with 0.6 and 12 second frametime High Dynamic Range (HDR) exposures providing a large dynamic range of sensitivity, exceeding both GLIMPSE and the Wide-field Infrared Survey Explorer (WISE-Wright et al. 2010; see Table 2). This differs from many of the previous GLIMPSE surveys which are 2-3 visit 2-sec frametime exposures (OSV was ten 2-sec FT exposures), though is similar to GLIMPSE360, SMOG and Cygnus-X. The survey strategy of three HDR visits on each sky position increases the dynamic range over GLIMPSE, GLIMPSE3D and Vela-Carina by a factor of 13 on the faint end and 3 on the bright end. 57% of the Deep GLIMPSE observations were mapped by previous Spitzer Galactic Plane surveys GLIMPSE, GLIMPSE3D, Vela-Carina, and GLIMPSE360. 35% of the Deep GLIMPSE area overlaps with GLIMPSE; 12% overlaps with Vela-Carina; 9% overlaps with GLIMPSE3D and 1% overlaps with GLIMPSE360. Approximately 43% of the Deep GLIMPSE observations were of areas not previously observed. Table 3 summarizes the approximate coverages, wavelengths observed, integration times, and observation dates for the larger Galactic plane projects.

The Deep GLIMPSE data were processed by the Wisconsin GLIMPSE IRAC pipeline. The Deep GLIMPSE Survey produces enhanced data products in the form of a point source Catalog, a point source Archive, and mosaicked images. See Benjamin et al. (2003), Churchwell et al. (2009) and the GLIMPSE web site (www.astro.wisc.edu/glimpse/) for more description of the GLIMPSE projects and pipeline processing. We have processed the SMOG and Cygnus-X data to provide consistency with our other GLIMPSE products. These teams are providing source lists as well. See the Cygnus-X website[1] for more information on their data delivery.

This document describes the data products from the Deep GLIMPSE survey. The organization of this document is as follows: §2 gives an overview of the Deep GLIMPSE survey and data products, §3 describes the data processing; §4 discusses the quality checks and validation of the source lists; §5 shows comparisons of Deep GLIMPSE photometry to previous Galactic plane datasets; §6 provides a detailed description of the data products; and §7 describes the format. Appendix A gives details about the Source Quality Flag. This document contains numerous acronyms, a glossary of which is given at the end.

[1] www.cfa.harvard.edu/cygnusX/data.html

Table 1. Observation Dates for the Deep GLIMPSE Survey

observation dates[a]	longitude segment longitude range (deg)	approximate latitude range (deg)
20120528-0530	264.7 to 270.3	-2.4 to -0.8
20130218-0221	269.8 to 274.1	-2.4 to -0.8
20130304-0310[c]	273.9 to 281.1	-2.4 to -0.8
20120311-0315[b]	280.8 to 288.1	-2.3 to -0.7
20120320-0323	287.8 to 295.0	-2.3 to -0.6
20120330-0405	294.8 to 302.1	-2.2 to -0.5
20120408-0414	301.9 to 309.1	-2.1 to -0.4
20120420-0422	308.8 to 316.0	-2.0 to -0.3
20120428-0503	315.7 to 323.2	-1.9 to -0.2
20120510-0513	322.7 to 330.2	-1.8 to -0.1
20121017-1023	329.8 to 335.2	-2.2 to +0.3
20121023-1029	334.8 to 340.2	-2.2 to +0.3
20121030-1104	339.8 to 345.2	-2.2 to +0.3
20121106-1113	344.8 to 350.2	-2.2 to +0.3
20121113-1122	24.8 to 30.0	+0.4 to +2.8
20120605-0609	29.4 to 34.8	-0.1 to +2.1
20121116-1125	34.3 to 39.7	+0.1 to +2.2
20121125-1201	39.3 to 44.7	+0.3 to +2.4
20121201-1207	44.3 to 49.7	+0.5 to +2.6
20121207-1213	49.3 to 54.7	+0.6 to +2.7
20121213-1219	54.3 to 59.7	+0.7 to +2.8
20121220-1224	59.3 to 65.1	+0.8 to +2.9

[a] dates in YearMoDa

[b] first Deep GLIMPSE observation

[c] last Deep GLIMPSE observation

Table 2. Sensitivity Limits in mJy (magnitudes in parentheses)

Project	3.6 μm Lower	3.6 μm Upper	4.5 μm Lower	4.5 μm Upper
Deep GLIMPSE[a]	0.021 (17.8)	1100 (6.0)	0.022 (17.3)	1100 (5.5)
WISE[b]	0.06 (16.8)	110 (8.6)	0.10 (15.6)	60 (8.6)
GLIMPSE	0.20 (15.4)	440 (7.0)	0.20 (14.9)	450 (6.5)

[a] Based on 3 visits of 0.6 & 12 second HDR frames, photometry done on individual frames

[b]WISE central wavelengths are 3.3 and 4.7 μm.

Table 3. Deep GLIMPSE and Similar Spitzer Galactic Plane Surveys

Survey	Coverage	Approx. Area	IRAC Bands	Exp. Time	Date Obs	Reference
Deep GLIMPSE	l = 265°–350°, b=-2°–+0.1° l = 25°–65°, b= 0°–+2.7°	208 sq. deg.	[3.6],[4.5]	3 × 10.4 s	Mar 2012-Mar 2013	Whitney et al. (2011)
GLIMPSE I	10°< $|l|$ <65°; $|b|$ < 1°	220 sq. deg.	[3.6],[4.5],[5.8],[8.0]	2 × 1.2 s	Mar-Nov 2004	Churchwell et al. (2009)
GLIMPSE II	$|l|$ < 10°; $|b|$ <1.5° [a]	54 sq. deg.	[3.6],[4.5],[5.8],[8.0]	3 × 1.2 s[b]	Sep 2005;Apr 2006	Churchwell et al. (2009)
GLIMPSE 3D	< $|l|$ < 31°;$|b|$ > 1°[a]	120 sq. deg.	[3.6],[4.5],[5.8],[8.0]	3(2) × 1.2 s[c]	Sep 2006-May 2007	Churchwell et al. (2009)
Vela-Carina	l=255°–295°; b ≈ -1.5°–+1.5°[a]	86 sq. deg.	[3.6],[4.5],[5.8],[8.0]	2 × 1.2 s	Jan-Jul 2008	Zasowski et al. (2009)
GLIMPSE 360	l=65°–76°,82°–102°,109°–265° $|b|$ < 3°[a]	511 sq. deg.	[3.6],[4.5]	3 × 10.4 s	Sep 2009-Dec 2012	Whitney et al. (2008)
SMOG	l=102°–109°; b= 0°–3°	21 sq. deg.	[3.6],[4.5],[5.8],[8.0]	4 × 10.4 s	Jan-Feb 2009	Carey et al. (2008)
Cygnus-X	l= 76°–82°; b = -2.3°–+4.1°[a]	24 sq. deg.	[3.6],[4.5],[5.8],[8.0]	3 × 10.4 s	Nov 2007;Aug,Nov 2008	Hora et al. (2007)

[a]Irregular region; see survey documentation for details. [b]GLIMPSE II data products include the *Spitzer* Galactic Center survey (S. Stolovy; PID=3677) which has five visits. [c]Some portions of GLIMPSE 3D use two visits and others have three.

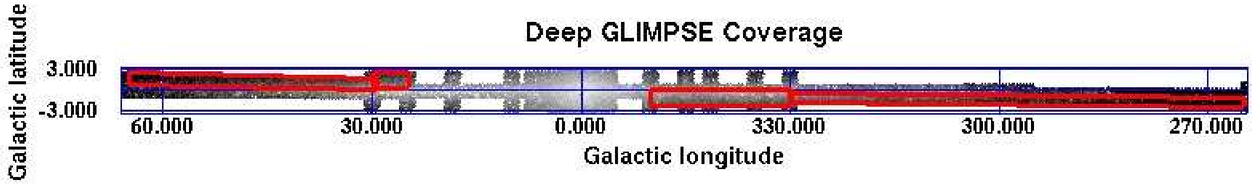

Figure 1: The Deep GLIMPSE area outlined in red is overlayed over the GLIMPSE, II, 3D and Vela-Carina areal coverages.

2.2 Data Products Overview

The Deep GLIMPSE enhanced data products consist of a highly reliable Point Source Catalog (GLMDPC), a more complete Point Source Archive (GLMDPA), and mosaic images covering the survey area. Also provided to the astronomical community are web tools for modeling infrared data. The websites for these data products are given in §1 of this document. The enhanced data products are:

1. The Deep GLIMPSE Catalog (GLMDPC, or the "Catalog") consists of the highest reliability point sources. See §3.4 for a discussion of the Catalog criteria. Figure 2 shows the number of Deep GLIMPSE Catalog sources as a function of magnitude for the two IRAC bands. For each IRAC band the Catalog provides fluxes (with uncertainties), positions (with uncertainties), the areal density of local point sources, the local sky brightness, and a flag that provides information on source quality and known anomalies present in the data. Sources were band-merged with the Two Micron All Sky Survey Point Source Catalog (2MASS; Skrutskie et al. 2006). 2MASS provides images at similar resolution to IRAC, in the J (1.25 μm), H (1.65 μm), and K$_s$ (2.17 μm) bands. For each source with a 2MASS counterpart, the GLMDPC also includes the 2MASS designation, counter (a unique identification number), fluxes, signal-to-noise, and a modified source quality flag. For some applications, users will want to refer back to the 2MASS Point Source Catalog for a more complete listing of source information. The Deep GLIMPSE Catalog format is ASCII, using the IPAC Tables convention (irsa.ipac.caltech.edu/applications/DDGEN/Doc/ipac_tbl.html).

2. The Deep GLIMPSE Archive (GLMDPA or the "Archive") consists of point sources with less stringent selection critera than the Catalog (§3.4). The information provided is in the same format as the Catalog. The number of Archive sources as a function of magnitude for each IRAC band is shown in Figure 3. The Catalog is a subset of the Archive, but the entries for a particular source might not be the same due to additional nulling of magnitudes in the Catalog because of the more stringent requirements (§3.4).

3. The Deep GLIMPSE Image Atlas comprises mosaicked images for each band, each covering e.g. $3.1^\circ \times 2.4^\circ$with $1.2''$ pixels. These are 32-bit IEEE floating point single extension FITS formatted images covering the survey area. These images are in units of surface brightness MJy/sr. Mosaics of each band are also made for smaller e.g. $1.1^\circ \times 1.1^\circ$ areas, with a pixel size of $0.6''$. The $1.2''$ pixel mosaics are provided with and without background matching and gradient correction. The background matching and gradient correction process (§3.1) may be removing real sky variations so we provide these images *in addition* to the images that do

not have the background matching. Also included are quicklook 3-color jpeg images (IRAC [3.6], IRAC [4.5] and IRAC [8.0] (or WISE [12] if IRAC [8.0] did not observe that area)) of the same size as the FITS images.

4. The Web Infrared Tool Shed (WITS) is a web interface to a collection of models of IR spectra of dusty envelopes and photodissociation regions (PDRs), updated for IRAC and MIPS band passes. WITS is described in detail in §5.3 of the GLIMPSE360 document[2].

5. The YSO Model Grid and Fitter is a web-based home of a large grid of 200730 YSO model spectral energy distributions (SEDs). The 2-D YSO radiation transfer models of YSOs producing SEDs span a large range of evolutionary stages and stellar masses. The model grid browser allows users to examine SED variations as a function of a range of physical parameters. An online fitting tool fits input data using the grid of model SEDs. The Grid and Fitter are described in §5.4 of the GLIMPSE360 document.

3 Pipeline Processing

3.1 Image Processing

Image processing steps for photometry include masking hot, dead, and missing data pixels (using SSC supplied flags). Pixels associated with saturated stars are masked using an algorithm generated by GLIMPSE; this algorithm finds most of the saturated stars. Pixels within a PSF-shaped region (with a 24-pixel radius) of a saturated source are flagged. Several image artifacts (described in Hora et al (2004) and the IRAC Data Handbook[3]) are corrected for in the GLIMPSE pipeline. A description of the Spitzer Warm Mission IRAC image features is found at irsa.ipac.caltech.edu/data/SPITZER/docs/irac/warmfeatures/. We correct for column pulldown[4] in bands [3.6] & [4.5], using an algorithm written by Matt Ashby and Joe Hora of the IRAC instrument team [5] and modified by GLIMPSE to handle variable backgrounds. There is no muxbleed effect in the Warm Mission IRAC frames.

Image processing for the mosaic image products include the column pulldown correction mentioned above. Hot, dead, and missing pixels are masked. Outlier masking (e.g. cosmic rays, stray light from bright sources outside the field of view; rmask) was done using IRACproc (Schuster et al 2006). The instrument artifacts found by visual inspection of the higher resolution $0.6''$ mosaics were removed. Latent images from bright sources are removed when possible. If there are areas of overlapping image artifacts that cause a gap in coverage, we do not mask that area. Latent images can repeat (particularly along rows and columns) and remain in the images because masking them would cause gaps in coverage. See SSC's IRAC image features web sites[6], [7] and the IRAC Data Handbook for more information about the detector artifacts. We use the Montage[8] package v3.0 to mosaic and project to Galactic coordinates.

[2]http://www.astro.wisc.edu/glimpse/glimpse360_dataprod_v1.5.pdf

[3]irsa.ipac.caltech.edu/data/SPITZER/docs/irac/iracinstrumenthandbook

[4]Column pulldown is a reduction in intensity of the columns in which bright sources are found in bands [3.6] and [4.5]. See Warm *Spitzer* Observers Manual (Warm SOM) at ssc.spitzer.caltech.edu/warmmission/propkit/som/.

[5]irsa.ipac.caltech.edu/data/SPITZER/docs/dataanalysistools/tools/contributed/irac/fixpulldown/

[6]irsa.ipac.caltech.edu/data/SPITZER/docs/irac/features/

[7]irsa.ipac.caltech.edu/data/SPITZER/docs/irac/warmfeatures/

[8]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

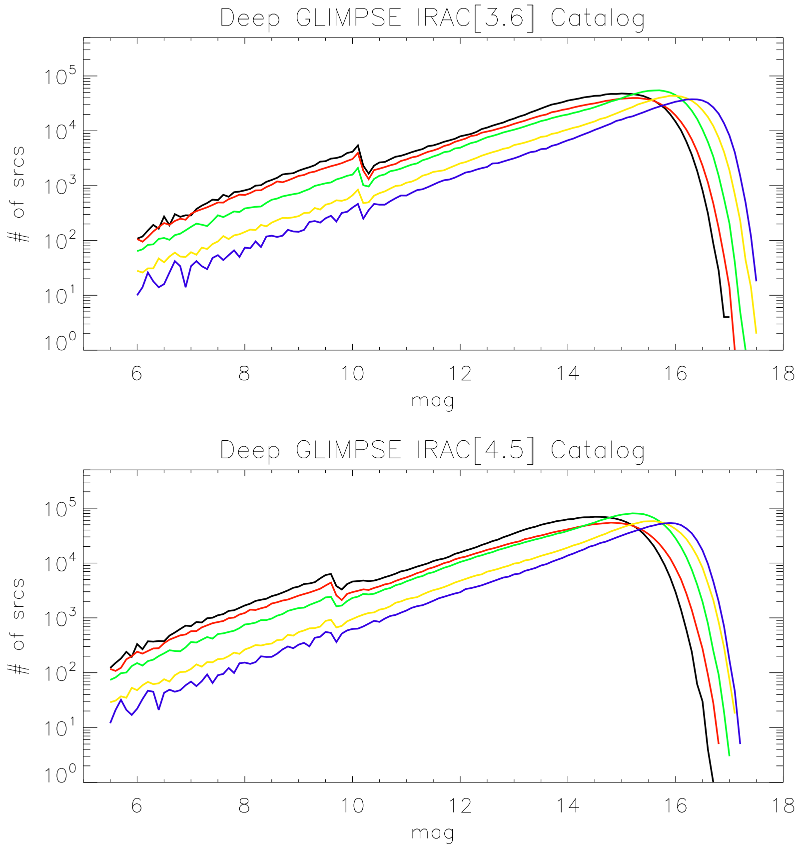

Figure 2: Deep GLIMPSE Catalog source counts versus magnitude for IRAC [3.6] & [4.5]. Deep GLIMPSE data from l=344°-346° are plotted in the black line. Data from l=334°-336° and 24°-26° are plotted in the red line. Data from l=314°-316° and 44°-46° are plotted in the green line. Data from l=294°-296° and 64°-66° are plotted in the yellow line and data from l=274°-276° are plotted in the blue line. The glitch in the [3.6] plot at 10.25 and the [4.5] plot at 9.6 are at the boundary where either the 0.6 sec FT data or the 12 sec FT data are used for photometry (see §3.3). The discontinuity at the frametime boundary is caused by the more stringent criteria used for the Catalog for sources near saturated sources. The 12 second FT data produces more saturated locations causing fewer Catalog sources. This effect disappears for the Archive lists (see Figure 3). This plot shows the increase in source counts as one approaches the Inner Galaxy as well as a falloff in completeness.

We match instrumental background variations between the IRAC frames using Montage's level background correction algorithm[9]. Instrument artifacts such as full array pull-up, frame pull-down and offsets between AORs are mostly removed from the images. In the background matching process, Montage introduces unwanted large-scale gradients. Our gradient correction algorithm finds the large-scale gradients by taking the corrections table produced by Montage and creating a smoothed version to eliminate small-scale corrections. This is done by using a Radial Basis Function interpolation with a smoothing factor of 1000. We then find the difference between the corrections

between NASA and the California Institute of Technology. Montage is maintained by the NASA/IPAC Infrared Science Archive.

[9]montage.ipac.caltech.edu/docs/algorithms.html#background

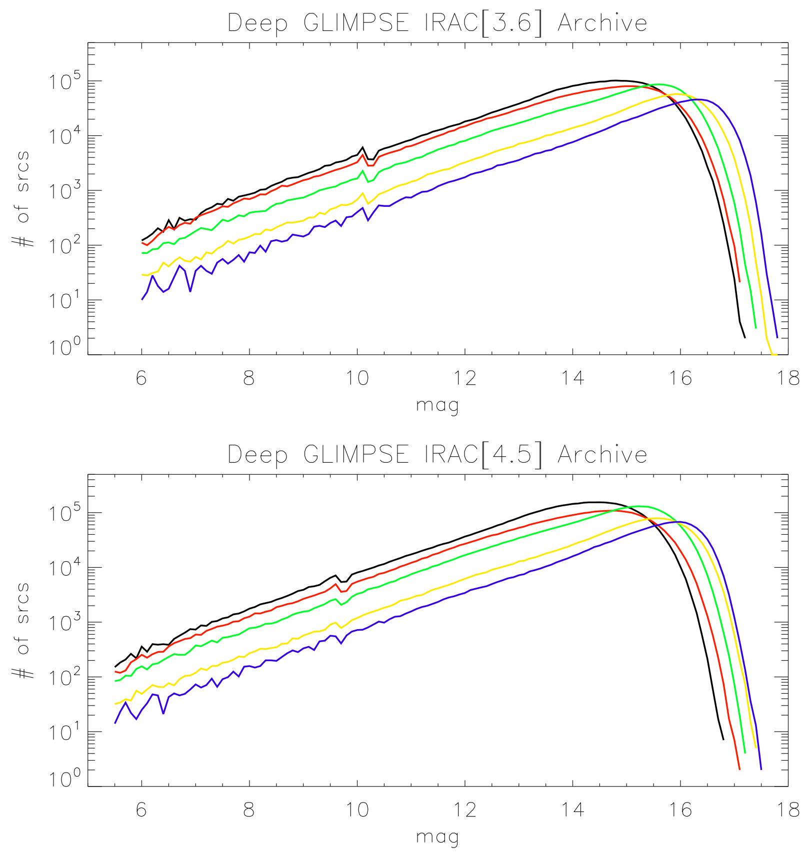

Figure 3: Same as Figure 2 except these are Deep GLIMPSE Archive source counts versus magnitude for the various longitude ranges. No vertical discontinuity is seen at the frametime boundary due to the less stringent Archive criteria (see §3.4).

and the smoothed corrections, find the standard deviation of this difference, then reject all points which deviate by more than 5 sigma. A new smoothed correction map is computed and the process is repeated until no points are rejected (typically 10 iterations). Once this is complete, a final correction map is computed and removed from the image, thus undoing the large-scale gradients introduced by Montage. The background matching and gradient correction may be removing real sky variations so we provide these images *in addition* to the images that do not have the background matching.

3.2 Photometry

We use a modified version of DAOPHOT (Stetson 1987) as our point source extractor, performing Point Spread Function (PSF) fitting on individual IRAC frames. We repeat the photometry calculations on the residual (point-source removed) images (referred to as "tweaking" in Table 6), which has been shown to substantially improve the flux estimates in complex background regions. More details about the photometry steps can be found at www.astro.wisc.edu/glimpse/glimpse_photometry_v1.0.pdf. The warm mission array-location-dependent photometric corrections[10] were applied to the source lists.

3.3 Bandmerging to Produce Source Lists

The point source lists are merged at two stages using a modified version of the SSC bandmerger[11]. 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) and the magnitudes are brighter than (10.25, 9.6) for the two IRAC bands [3.6] and [4.5], 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 (10.25, 9.6) for the IRAC bands [3.6] and [4.5], respectively. Fluxes of sources within $1\farcs6$ 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 $1\farcs6$ radius. Position migration can still occur in the bandmerging process which results in a small number of sources that are within $1\farcs6$ of another source. In the cross-band merge stage we also merge with the All-Sky 2MASS (Skrutskie et al 2006) point source list. Note that we only propagate a subset of the 2MASS quality flags and information, and users should refer to the original 2MASS catalog available through IRSA for full information. We include the unique numeric identifier assigned by the 2MASS project "cntr" (tmasscntr in the Deep GLIMPSE source lists) to allow this cross-referencing.

3.4 Source Selection for Catalog and Archive

Now we describe the selection criteria for the Catalog and Archive once photometry and bandmerging have been completed. These criteria were established to produce high reliability single frame photometry where the abundance of cosmic rays can contribute to false sources.

The Catalog is a more reliable list of sources, and the Archive is a more complete list both in number of sources 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 $2.0''$ of another are culled (removed) from the Catalog, whereas the Archive allows sources as close as $0\farcs5$ 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) . Users who want a more "bullet-proof" list and don't want to have to get as familiar with the source quality flags, or who will be doing the kind of analysis that does not allow for manual inspection of very many source Spectral Energy Distributions (SEDs), should use the Catalog. Users who want more complete SEDs and source lists, and are willing to invest time to understand the source quality flags, can make use of the Archive. This allows the use of lower 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

[10] section 3.5 of http://irsa.ipac.caltech.edu/data/SPITZER/docs/irac/warmfeatures/

[11] ssc.spitzer.caltech.edu/dataanalysistools/tools/bandmerge/

to the source quality flag (§6.1.6 and Appendix A), as well as other diagnostic information such as the close source flag (see §6.1.6).

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

3.4.1 Culling Criteria - is it a real source?

The IRAC 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 (GLMDPC) by minimizing the number of false sources, we adopt the following selection criteria: Given M detections out of N possible observations (see §6.1.5), 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 $S/N > 5$ for IRAC bands [3.6] and [4.5]. The 2MASS K_s band is counted as a detection. As an example, a source is typically observed three times at 0.6 second frametime and three times at 12 second frametime for a total of six possible observations in each band. Such a source detected four 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 3×12 sec frametime images, the minimum detection criterion ($M/N \geq 0.32$) amounts to being detected twice in one band 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 (GLMDPA), 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.

3.4.2 Nulling Criteria - ensuring high quality fluxes

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 and 5.5 for IRAC bands [3.6] and [4.5], respectively; 2) the source location is flagged as coincident with a bad pixel; 3) the S/N is less than 6 for IRAC bands [3.6] and [4.5] 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. 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 8.

Since the selection (or culling) criteria are fairly similar between the Catalog and Archive, the total number of sources is not that different. However, the Catalog sources have more fluxes nulled.

4 Quality Checks and Source List Validation

We summarize here analysis used to validate the Catalog and Archive point source lists. Additional information can be found in documents at www.astro.wisc.edu/glimpse/docs.html. A study of completeness in all the GLIMPSEs point source lists can be found in Kobulnicky et al. 2013.

4.1 Astrometric Accuracy

Sources bright enough to have 2MASS associations are typically within 0.3″ of the corresponding 2MASS position, as discussed in §6.1.3. Figure 4 shows a comparison of Deep GLIMPSE source positions to the 2MASS PSC positions, in 0.02″ bins, for a ten degree longitude, two degree wide latitude area in the Deep GLIMPSE survey. The peak of the plot is at 0.1″ and the majority of the sources have positional differences less than 0.3″ , similar to previous GLIMPSE source lists. Fainter Deep GLIMPSE sources are likely to have larger errors due to poorer centroiding.

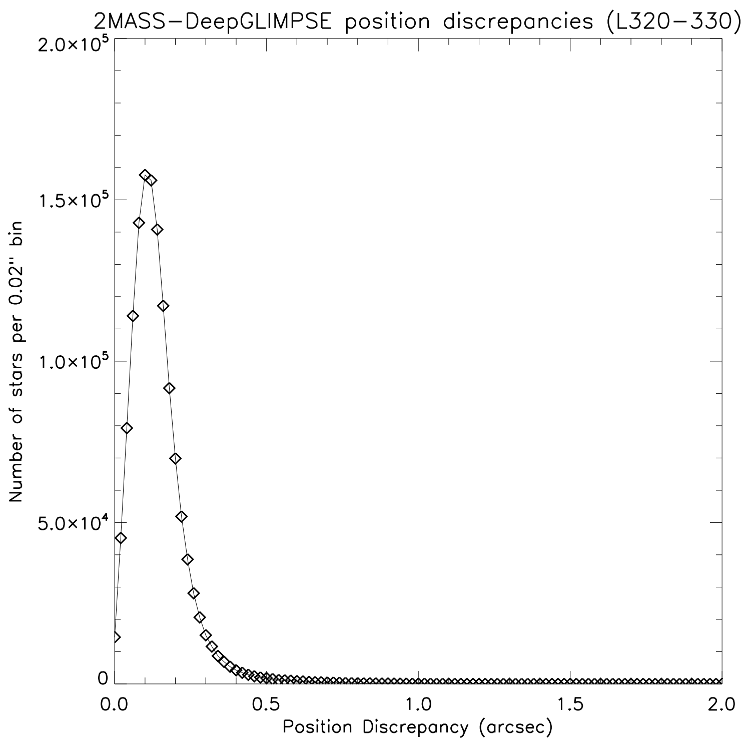

Figure 4: Comparison of Deep GLIMPSE source positions to their corresponding 2MASS PSC positions from sources from longitudes between 320°and 330° and latitudes from about -1.8° to -0.1°. The astrometric discrepancy plotted is the angular separation in arcseconds between the Deep GLIMPSE position and the 2MASS position. Note that sources with 2MASS associates have Deep GLIMPSE positions that are in part derived from the 2MASS position. Thus this is not a comparison of a pure IRAC-only position with the 2MASS position.

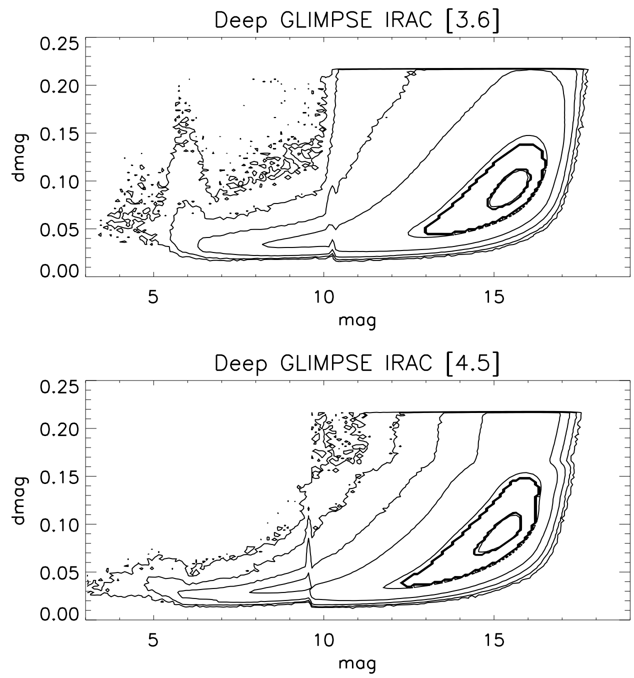

Figure 5: Magnitude uncertainty vs. magnitude for each IRAC band included in the Deep GLIMPSE Archive for the entire survey area. Contours show the density of sources. The lack of data above dmag of 0.22 is caused by the criterion that Archive data have signal to noise ratios of 5 or better. The "bump" at [3.6]=10.25 and [4.5]=9.6 is the boundary where the 0.6 sec frametime data are used for brighter sources and the 12 sec frametime data are used for fainter sources.

4.2 Precision and Accuracy of the Photometry

Figure 5 shows the photometric uncertainty for the entire Deep GLIMPSE survey region. There is a jump in uncertainties at the brighter magnitudes which shows the boundary between the 0.6 and 12 sec frametime photometry (with shorter exposures having larger errors).

The reliability of the flux uncertainities was studied by comparing the quoted error (dFi) with the root mean square (RMS) of the measurements (Fi_rms) for thousands of sources in a given flux range; if a large fraction of the sources have intrinsic variability, this method will produce an upper limit to the uncertainties. The DAOPHOT output uncertainties include a PSF fitting component, photon noise, read noise, and goodness of flat fielding; the strength of each component is not perfectly determined. Based on our comparison to the RMS of the measurements, we have decreased our photometry uncertainties produced by DAOPHOT by 5% in the [3.6] band and 35% in the [4.5] band.

Photometric accuracy was further verified by comparison with 45 flux calibrators distributed in the Deep GLIMPSE survey region. The flux predictions were supplied by Martin Cohen. These calibrators span a range of fluxes in each IRAC band. The techniques used to produce the flux predictions are described in Cohen et al. (2003). Our analysis is applied on the calibrators fainter than the saturation limit that are extracted without confusion. Figure 6 shows the agreement between the Deep GLIMPSE magnitudes and the predicted magnitudes. Uncertainties in both the extracted and predicted magnitudes were added in quadrature to produce the plotted error bars.

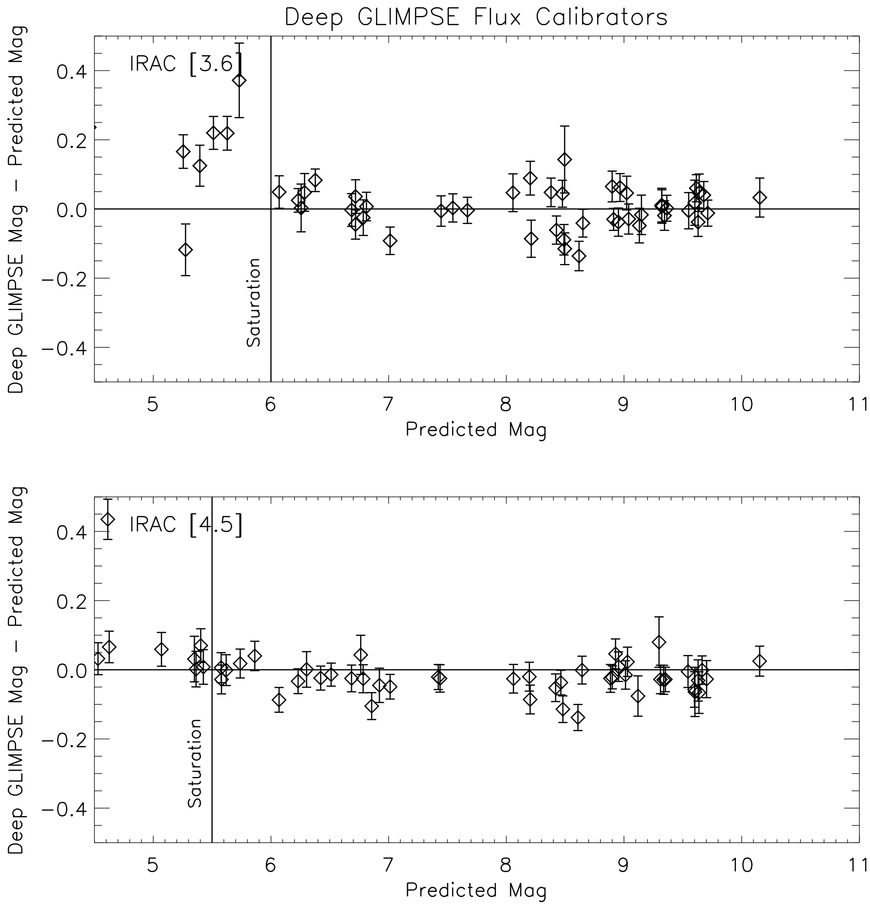

Figure 6: Comparison of Deep GLIMPSE flux calibrators to predictions provided by Martin Cohen for each IRAC band. Error bars are the root-sum-of-squares of the errors of both the extracted and predicted magnitudes for each source. The vertical lines are the best estimates of the saturation limits.

Table 4 gives details about the number of flux calibrators used for each band (which can vary due to saturation and partial coverage on the survey boundaries), average differences (Deep GLIMPSE magnitude minus the predicted magnitude), and RMS errors.

Table 4. Comparison of Flux Calibrators to Predicted Magnitudes

Band (μm)	[3.6]	[4.5]
No. Flux calibrators	45	45
Ave. [Observed-Predicted] mag	0.001711	-0.025333
RMS error	0.055541	0.042226

4.3 Color-Color and Color-Magnitude Plots

Color-color and color-magnitude plots were made of the Catalog and Archive files (in approximately $2^{\circ} \times 2^{\circ}$ regions). An example set of color-color and color-magnitude plots is shown in Figures 7

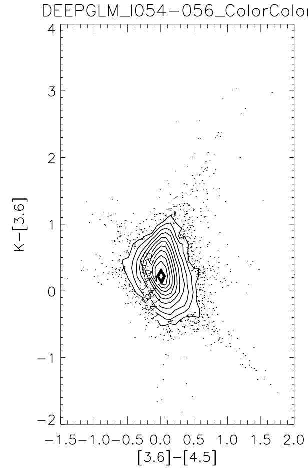

Figure 7: Color-color plot of the region $l = 54° - 56°$ and $b = +0.7°\ to + 2.8°$ for sources in the Archive. 10 contours are evenly spaced between log(# sources/mag^2)=2.0 and the log of maximum number of sources per square magnitude. The contours are labeled with the log of the number of sources per square magnitude. Outside of the lowest contour, the positions of individual sources are plotted.

& 8, respectively. The color-color plots generally show a peak near 0 color due to main sequence and giant stars. The outliers in Figure 7 (the points) comprise 0.4% of the sources. Sources with these unusual colors usually either have intrinsic color variations due to e.g., dust scattering or emission; or have poor flux extractions. The color-magnitude plots can be used to show the limiting magnitudes where the flux uncertainties become large and the colors begin to show large deviations. This is not significant in Figure 8 which demonstrates that our fluxes are accurate at the faint end. Postscript files of the color-color and color-magnitude plots for source lists for each set of 2 degrees of longitude in the entire Deep GLIMPSE survey are available from the Deep GLIMPSE web site (www.astro.wisc.edu/glimpse/deepglimpse/ColorColor/ and www.astro.wisc.edu/glimpse/deepglimpse/ColorMag/).

4.4 Other checks

Spot checks include inspection of residual images to verify proper point source extraction; overplotting the positions of the sources in the Catalogs and Archives on mosaic images; and plotting Spectral Energy Distributions (SEDs) of several sources. In addition to these and other tests described in previous documents, our source lists have been extensively tested by users analyzing the data on evolved stars, YSOs, and other sources throughout the Galaxy and the Magellanic Clouds (GLIMPSE, SAGE-LMC, SAGE-SMC).

5 Comparison of Deep GLIMPSE photometry to previous GLIMPSE datasets

The spatial overlap between the original GLIMPSE surveys and the Deep GLIMPSE survey allows us to examine photometric and positional accuracy, and to search for variable and high proper

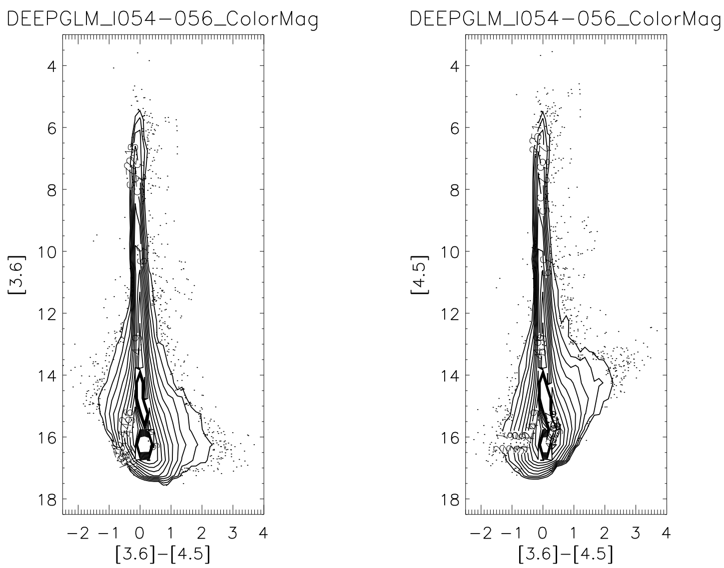

Figure 8: Same as Figure 7 except that these are Color-magnitude plots.

motion sources.

In section 4.2 we displayed the good agreement between the Deep GLIMPSE flux values and the predicted values from Martin Cohen's calibration sources. However the Cohen flux calibrators were small in number (45 in the Deep GLIMPSE survey), and limited in magnitude range between the saturation limit of Deep GLIMPSE observations (see Table 2) and roughly 10th magnitude. The significant spatial overlap between the Deep GLIMPSE observations and previous GLIMPSE survey projects gives us an opportunity to assess the degree of systematic variation in flux determination beyond the limited magnitude range of the absolute flux calibrators. The overlapping GLIMPSE projects have a variety of observing methods: specifically, the early GLIMPSE projects (OSV, GLIMPSE, GLIMPSEII (2 epochs), GLIMPSE3D (2 epochs), and processed projects of Vela-Carina and Carina (Smith et al. 2010)) were observed during the cryogenic mission with 2 second frametime exposures; other Galactic plane surveys processed by the GLIMPSE pipeline (Cygnus-X, SMOG) were cryogenic and HDR mode (0.6 second and 12 second frametime data); and during the post-cryogenic warm mission period, GLIMPSE360 and Deep GLIMPSE observations were done in HDR mode. Because of these exposure time differences and temperature (cryo versus warm) differences, we can assess the systematic variations between these observing modes.

For this discussion we emphasize the Deep GLIMPSE comparison although a suite of comparisons exist between other projects, and we include more than just the Deep GLIMPSE comparisons in Figure 9. First, we determined the areas of overlap of Deep GLIMPSE observations with other GLIMPSE style projects processed by the GLIMPSE pipeline. For areas of overlap, initial source matching was done between the Archive source lists for each project, using a matching radius of 1.5 arcseconds. Localized positional offsets were determined from the matched source lists. These offsets are typically less than 0.5 arcseconds but clearly show a pattern consistent with individual AOR observational tracks (see Figure 10). Using these improved relative positions, matching was redone at a matching radius of 1.0". Matched sources were binned together by magnitude range from 4th to 18th magitude with a bin width of 0.01 magnitudes for each IRAC band, and average magnitude differences were calculated for each bin. For Figure 9 we further averaged bins down to

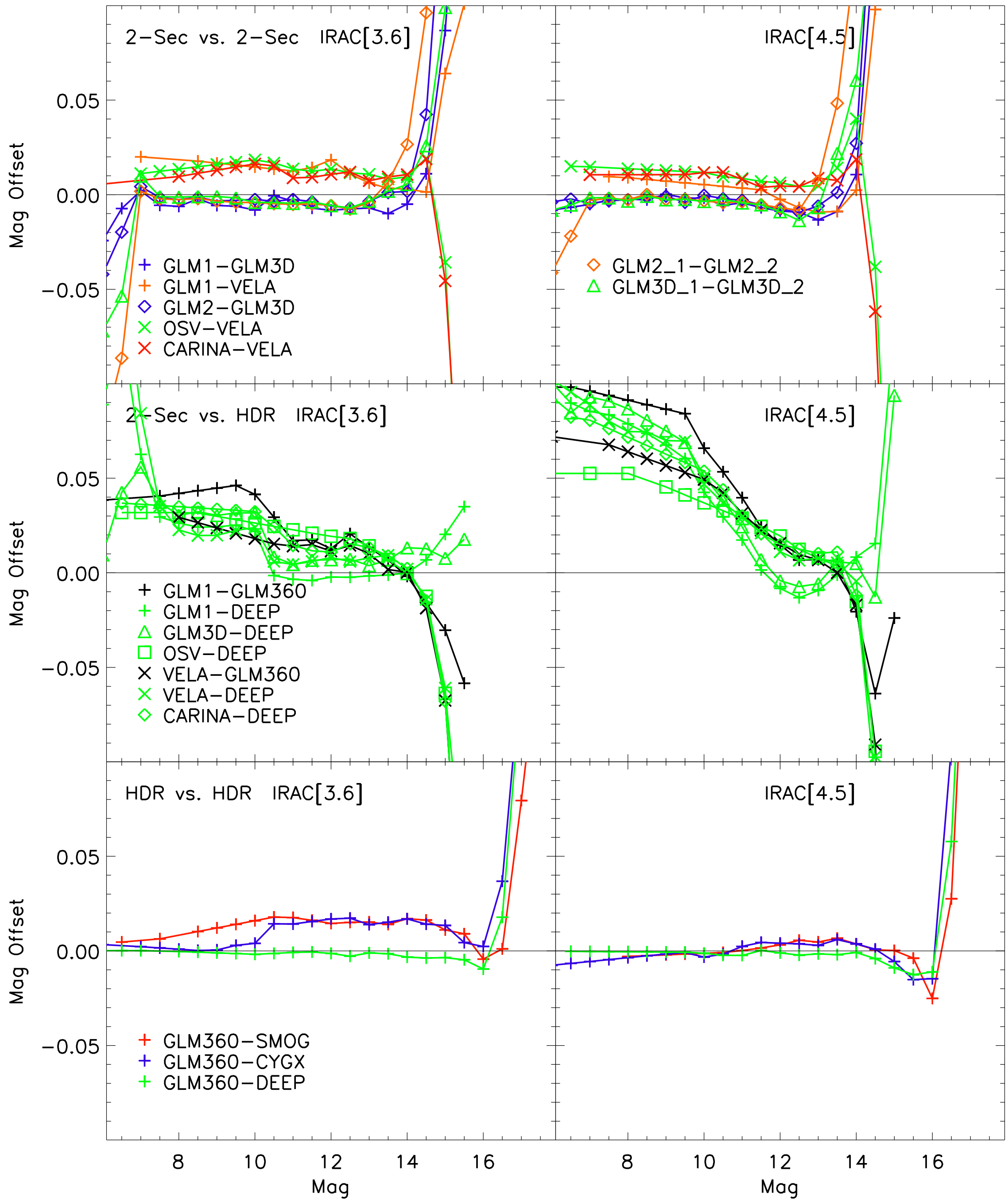

Figure 9: Comparison of photometry from several GLIMPSE datasets

0.5 mag widths for plotting clarity. In Figure 9 we plot the results, including only the IRAC[3.6] and IRAC[4.5] bands, since Deep GLIMPSE is restricted to post-cryo mission data (no IRAC[5.8]

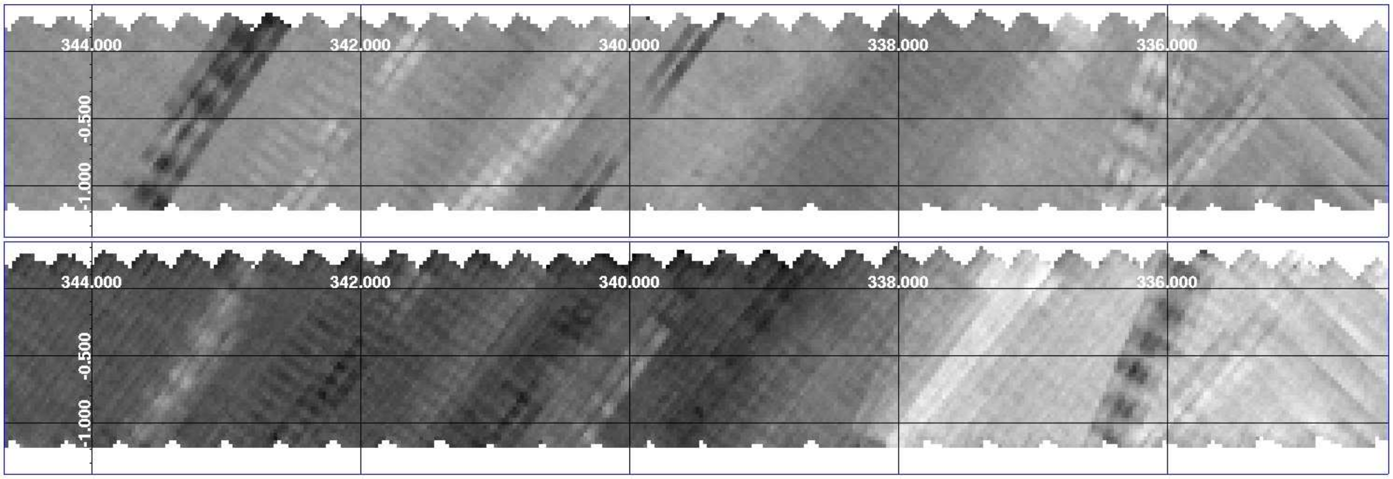

Figure 10: Representative example of systematic positional offsets for an area of overlap between the Deep GLIMPSE and GLIMPSE projects at L=340°, the top panel shows delta L position between the two projects while the bottom panel shows the delta B positions. The offsets are typically less than 0.5 arcseconds, but one can see systematic shifts that correlate to specific individual AORs. Linear gray scale from -0.6 to 0.6 (arcsecond offset between GLIMPSE and Deep GLIMPSE projects) black to white.

or IRAC[8.0]). For broader interpretation, we also plot some early GLIMPSE projects relative to non Deep GLIMPSE data.

We now discuss several results from Figure 9. First, for cryo mission two second data compared to other cryo mission two second data (top panels), the flux measurements are consistent: GLIMPSE vs GLIMPSE3D, GLIMPSEII vs GLIMPSE3D, multi-epoch GLIMPSEII and GLIMPSE3D all agree across a broad magnitude range to within 0.01 mags; only at the extreme brightness ranges (saturation and faint limit) do they start to deviate. We see also that individual projects such as Vela-Carina may show a systematic offset (about 0.02 mags), but it is constant across that same large magnitude range (seen in the top row of Figure 9).

Second, as the Fig. 9 middle panels show, the cryogenic two second frametime data (OSV, GLIMPSE, GLIMPSE3D, Vela-Carina and Carina) compared to warm mission HDR mode data (GLIMPSE360 and Deep GLIMPSE) show more structure in the magnitude comparisons. There is a break in the curves around 10th mag that corresponds to the transition between HDR mode 0.6 second data and the 12 second data. For IRAC[3.6] data, the comparisons are generally flat above and below this transition point with the exception again being at the extreme ends where saturation and the faint limit dominate. For the IRAC[4.5] data, the structure above and below the HDR transition magnitude is much more sloped, with peak to peak differences from roughly 6th mag to 14th mag at nearly 0.1 magnitudes. This slope is not seen in the absolute flux comparison in Sect 4.2 for two basic reasons: First, the absolute flux calibrators are 10th magnitude and brighter (which is the bright HDR data only). Typically in this range of 6-10th mag the change in mag offset is a few hundredths; there are not enough absolute calibrators to resolve that degree of change (see Figure 6). Also, Figure 6 does not show an absolute offset comparable to 0.06-0.08 mags. This is explained by the fact that for Deep GLIMPSE the systematic offset for IRAC[4.5] relative to the flux calibrators is -0.025 (see Table 4). However for GLIMPSE, which contained 140 absolute calibrators, that offset was +0.045 (see http://www.astro.wisc.edu/glimpse/glimpse1_dataprod_v2.0.pdf). Thus the relative GLIMPSE-Deep GLIMPSE difference would be 0.07 (0.045 minus -0.025) as seen in Figure 9.

Finally, the bottom panels of Figure 9 show that for warm mission HDR data comparisons (GLIMPSE360 and Deep GLIMPSE), agreement between project magnitudes is consistent and flat across the broad magnitude range. However when comparing warm mission HDR data (GLIMPSE360 and Deep GLIMPSE) and cryogenic mission HDR data (CYGX and SMOG), a difference is present in the IRAC[3.6] data and less so for the IRAC[4.5]. Most of the difference in the IRAC[3.6] data is seen in the longer 12 second frametime HDR data (faint data with magnitudes greater than 10th).

Figure 9 shows that care must be given when attempting to compare the magnitudes of one GLIMPSE project source list with another, especially if the two projects are not both of the same frametime or not both of the same pre/post cryo mission. However, comparisons are possible if one first accounts for 1) local positional offsets (for matching sources) and 2) systematic magnitude offsets which are specific and unique to projects and IRAC band. Although the user can approximate a magnitude offset from Figure 9, better localized offset values can be derived specifically for targeted areas (provided there are sufficient numbers of matched sources). For the GLIMPSE processing, we empirically derived point source functions (PSFs) for each IRAC band and observing mode. These different PSFs likely account for some of the systematic differences seen in Figure 9.

6 Data Products Description

6.1 Catalog and Archive Fields and Flags

Each entry in the Deep GLIMPSE Catalog and Archive has the following information:

designation	SSTGLMDPC GLLL.llll±BB.bbbb, SSTGLMDPA GLLL.llll±BB.bbbb
2MASS PSC names	2MASS designation, 2MASS counter
position	l, b, dl, db, ra, dec, dra, ddec
flux	mag_i, $dmag_i$, F_i, dF_i, F_i_rms (IRAC)
	mag_t, $dmag_t$, F_t, dF_t (2MASS)
diagnostic	sky_i, SN_i, $srcdens_i$, # detections M_i out of N_i possible (IRAC)
	SN_t (2MASS)
flags	Close Source Flag, Source Quality Flag (SQF_i), Flux Method Flag (MF_i) (IRAC)
	Source Quality Flag (SQF_t) (2MASS)

where i is the IRAC wavelength number (IRAC bands 3.6, 4.5, 5.8 and 8.0 μm) and t is the 2MASS wavelength band (J, H, K_s). For the Deep GLIMPSE Warm Mission data, bands [5.8] and [8.0] fields are always nulled since no data were taken at those wavelengths. We keep the same format as the previous GLIMPSE source lists.

Details of the fields are as follows:

6.1.1 Designation

This is the object designation or "name" as specified by the IAU recommendations on source nomenclature. It is derived from the coordinates of the source, where G denotes Galactic coordinates, LLL.llll is the Galactic longitude in degrees, and ±BB.bbbb is the Galactic latitude in degrees. The coordinates are preceded by the acronym SSTGLMDPC (Deep GLIMPSE Catalog) or SSTGLMDPA (Deep GLIMPSE Archive).

6.1.2 2MASS PSC information

The 2MASS designation is the source designation for objects in the 2MASS All-Sky Release Point Source Catalog. It is a sexagesimal, equatorial position-based source name of the form hhmmssss±ddmmsss, where hhmmssss is the right ascension (J2000) coordinate of the source in hours, minutes and seconds, and ±ddmmsss is the declination (degrees, minutes, seconds). The 2MASS counter is a unique identification number for the 2MASS PSC source. See www.ipac.caltech.edu/2mass/releases/allsky/doc/sec2_2a.html for more information about these fields.

6.1.3 Position

The position is given in both Galactic (l, b) and equatorial (α, δ) J2000 coordinates, along with estimated uncertainties. The pointing accuracy is $1''$ (Werner et al. 2004). The SSC pipeline does pointing refinement[12] of the images based on comparison with the 2MASS Point Source Catalog, whose absolute accuracy is typically $< 0.2''$ (Cutri et al. 2005). After applying the SSC geometric distortion corrections and updating to the 2MASS positions, the GLIMPSE point source accuracy is typically $\sim 0.3''$ absolute accuracy, limited by undersampling of the point-spread function. The position uncertainties are calculated by the bandmerger based on the uncertainties of individual detections, propagated through the calculation of the weighted mean position. Sources with 2MASS associates have positions in part derived from the 2MASS position.

6.1.4 Flux

For each IRAC band i = 3.6 and 4.5 μm and, when available 2MASS band t = J, H, and K_s, the fluxes are expressed in magnitudes (mag_i, mag_t) and in mJy (F_i, F_t). Each IRAC flux is the error-weighted average of all independent detections of a source. The 2MASS magnitudes and uncertainties are from the 2MASS All-Sky Release Point Source Catalog. They are the j_m, j_msigcom, h_m, h_msigcom, and k_m, k_msigcom columns from the 2MASS PSC. The zeropoints for converting from flux to magnitude are from Reach et al (2005) for the IRAC bands and Cohen et al. 2003 for 2MASS and given in Table 5.

Table 5. Zeropoints for Flux to Magnitude Conversion

Band	J	H	K_s	[3.6]	[4.5]	[5.8]	[8.0]
Zeropoints (Jy)	1594	1024	666.7	280.9	179.7	115.0	64.13

The IRAC flux/magnitude uncertainties (dF_i; $d\mathrm{mag}_i$) are computed during the photometry stage and take into account photon noise, readnoise, goodness of flat fielding, and PSF fitting (Stetson 1987).

[12] irsa.ipac.caltech.edu/data/SPITZER/docs/irac/iracinstrumenthandbook/50/#_Toc296497447

The rms deviation (F_i_rms) of the individual detections from the final flux of each source is provided. The F_rms is calculated as follows: F_rms=$\sqrt{\sum(F_j - <F>)^2/M}$ where j is an individual IRAC frame, $<F>$ is the average Flux, and M is the number of detections.

6.1.5 Diagnostics

The associated flux diagnostics are a local background level (sky_i) ($i = 3.6$ and 4.5 μm) in MJy/sr, a Signal/Noise (SN_i), a local source density (srcdens_i) (number of sources per square arcmin), and number of times (M_i) a source was detected out of a calculated possible number (N_i). The Signal/Noise is the flux (F_i) divided by the flux uncertainty (dF_i). The Signal/Noise for the 2MASS fluxes (SN_t) have been taken from the 2MASS PSC (the j_snr, h_snr and k_snr columns). The local source density is measured as follows: The individual IRAC frame is divided into a 3×3 grid, each of the nine cells being 1.71′ x 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. The local source density can be used to assess the confusion in a given region, along with the internal reliability. M_i and N_i can be used to estimate reliability. N_i is calculated based on the areal coverage of each observed frame; due to overlaps some areas are observed more often per band.

Detections (M) can be thrown out by exposure time (when combining 0.6 and 12 second frametime 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 §6.1.6 and Appendix A for SQF details). N is 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.

6.1.6 Flags

There are three types of flags: the Close Source Flag, the Source Quality Flag and the Flux Calculation Method Flag. The Close Source Flag is set if there are Archive sources that are within 3″ of the source. The Source Quality Flag provides a measure of the quality of the point source extraction and bandmerging. The Flux Calculation Method Flag describes how the final Catalog/Archive flux was determined.

• The Close Source Flag is set when a source in the Archive is within 3.0″ of the source. It was found that the magnitudes of a source with nearby sources closer than about 2″ are not reliably extracted and bandmerged. A source that has Archive sources within 2.0″ of the source are *culled* from the Catalog. A source that has Archive sources within 0.5″ of the source are *culled* from the Archive. The flag is defined as follows:

0=no Archive source within 3.0″ of source
1=Archive sources between 2.5″ and 3.0″ of source
2=Archive sources between 2.0″ and 2.5″ of source
3=Archive sources between 1.5″ and 2.0″ of source

4=Archive sources between $1.0''$ and $1.5''$ of source
5=Archive sources between $0.5''$ and $1.0''$ of source
6=Archive sources within $0.5''$ of source

• The Source Quality Flag (SQF) is generated from SSC-provided masks and the GLIMPSE 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, will not compromise the source's reliability, but has 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) are culled from the Catalog.

Table 6 gives the Source Quality Flag bits and origin of the flag (SSC or GLIMPSE pipeline). Each of the 5 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.

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 problems. More information about these flags and a bit value key can be found in Appendix A.

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
8	hot, dead or otherwise unacceptable pixel	SSC pmask,dmask,GLIMPSE
9	electronic stripe (s)	2MASS
10	DAOPHOT tweak positive	GLIMPSE
11	DAOPHOT tweak negative	GLIMPSE
13	confusion in in-band merge	GLIMPSE
14	confusion in cross-band merge (IRAC)	GLIMPSE
14	confusion in cross-band merge (2MASS)	GLIMPSE
15	column pulldown corrected	GLIMPSE
19	data predicted to saturate	GLIMPSE
20	saturated star wing region	GLIMPSE
20	diffraction spike (d)	2MASS
21	pre-lumping in in-band merge	GLIMPSE
22	post-lumping in cross-band merge (IRAC)	GLIMPSE
22	post-lumping in cross-band merge (2MASS)	GLIMPSE
23	photometry quality flag	2MASS
24	photometry quality flag	2MASS
25	photometry quality flag	2MASS
30	within three pixels of edge of frame	GLIMPSE

Table 6. Source Quality Flag (SQF) Bits

• Flux calculation Method Flag (MF_i). The flux calculation method flag indicates by bit whether a given frametime was present, and whether that frametime was used in the final flux. Table 7 defines the values for this flag: value= $2^{(present\_bit-1)} + 2^{(used\_bit-1)}$

Table 7. Flux Calculation Method Flag (MF)

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

For example, if 0.6 and 12 sec frametime 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 7). 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 (§3.3).

For Deep GLIMPSE 12/0.6 sec frametime 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

6.2 Deep GLIMPSE Image Atlas

Using the Montage package, the IRAC images are mosaicked into rectangular tiles that cover the surveyed region. The units are MJy/sr and the coordinates are Galactic. The mosaic images conserve surface brightness in the original images. We provide 1.2″ pixel mosaics as well as higher resolution 0.6″ pixel mosaics. We provide larger (e.g. 3.1°×2.1°, 3.1°×2.4°, 3.1°×2.6°, 3.1°×2.7°, 3.1°×2.8°, 3.1°×3.0°, and 3.1°×3.1°) FITS files with a pixel size of 1.2″ , with and without background matching and gradient correction, for an overview look that covers the full latitude range of the Deep GLIMPSE areas. The background matching and gradient removal may be removing real sky variations so we provide these images *in addition* to the 1.2″ pixel images that do not have the background matching. The angular sizes of the higher resolution tiles (pixel size of 0.6″) are 1.1°×0.7°, 1.1°×0.8°, 1.1°×0.9°, 1.1°×1.0°and 1.1°×1.1°. Three tiles span the latitude range of the areas. World Coordinate System (WCS) keywords are standard (CTYPE, CRPIX, CRVAL, CD matrix keywords) with a Galactic projection (GLON-CAR, GLAT-CAR; Calabretta and Greisen 2002). See (§7.2) for an example of a FITS header. The mosaicked images are 32-bit IEEE floating point single-extension FITS formatted images. For a quick-look of the mosaics, we provide 3-color jpeg files (IRAC [3.6], [4.5] and IRAC [8.0] (or WISE [12] if IRAC [8.0] did not observe that area) for each area covered by the FITS files. These are rebinned to much lower resolution to make the files small. Some artifacts remain in the images since removing them would cause gaps in coverage. Appendix C of the GLIMPSE360 data description document[13] gives examples of some of the artifacts that still may be found in the Deep GLIMPSE images. Note that with the higher backgrounds of the Inner Galaxy regions that Deep GLIMPSE observed, these image artifacts are not nearly as noticeable as they are for the lower background Outer Galaxy GLIMPSE360 areas. Since the WISE [12] images have been included in our 3-color jpegs, Appendix C also gives examples of some of the more noticeable artifacts that appear in the WISE [12] images.

7 Product Formats

7.1 Catalog and Archive

• The Catalog and Archive are broken into 2° (longitude) x 2° (latitude) areas for the Deep GLIMPSE Survey. The Catalog and Archive files are in IPAC Table Format. Filenames are GLMDEEPC_llmin-lmax.tbl and GLMDEEPA_llmin-lmax.tbl, for the Catalog and Archive respectively (e.g. GLMDEEPC_l054-056.tbl, GLMDEEPA_l054-056.tbl, GLMDEEPC_l056-058.tbl, GLMDEEPA_l056-058.tbl, etc.) The entries are sorted by increasing Galactic longitude within each file.

[13] http://www.astro.wisc.edu/glimpse/glimpse360_dataprod_v1.5.pdf

An example of a GLMDPC entry is

SSTGLMDPC G054.7760+02.2374 19243076+2024280 1339867377 54.776087 2.237445 0.3 0.3
291.128168 20.407784 0.3 0.3 0 13.422 0.027 12.231 0.025 11.872 0.025
11.588 0.129 12.057 0.054 99.999 99.999 99.999 99.999
6.819E+00 1.696E-01 1.312E+01 3.021E-01 1.189E+01 2.737E-01
6.508E+00 7.722E-01 2.702E+00 1.342E-01 -9.999E+02 -9.999E+02 -9.999E+02 -9.999E+02
7.054E-02 9.422E-01 -9.999E+02 -9.999E+02 2.720E-01 2.060E-01 -9.999E+02 -9.999E+02
40.21 43.43 43.43 8.43 20.13 -9.99 -9.99 111.0 86.5 -9.9 -9.9
3 6 0 0 3 6 0 0 29368320 29368320 29368320 9216 5632 -9 -9 192 192 -9 -9

Table 8 gives all of the available fields per source. Table 9 shows how to decode the above entry into these fields. All fields associated with IRAC bands [5.8] and [8.0] have been nulled for the Warm Mission Deep GLIMPSE survey.

- Each source in both the Catalog and Archive has the entries given below.

Table 8. Fields in the Catalog and Archive

Column	Name	Description	Units	Data Type	Format	Nulls OK? or Value
1	designation	Catalog (SSTGLMDPC GLLL.llll±BB.bbbb) Archive (SSTGLMDPA GLLL.llll±BB.bbbb)	-	ASCII	A26	No
2	tmass_desig	2MASS PSC designation	-	ASCII	A16	null
3	tmass_cntr	2MASS counter (unique identification number)	-	I*4	I10	0
4	l	Galactic longitude	deg	R*8	F11.6	No
5	b	Galactic latitude	deg	R*8	F11.6	No
6	dl	Uncertainty in Gal. longitude	arcsec	R*8	F7.1	No
7	db	Uncertainty in Gal. latitude	arcsec	R*8	F7.1	No
8	ra	Right ascension (J2000)	deg	R*8	F11.6	No
9	dec	Declination (J2000)	deg	R*8	F11.6	No
10	dra	Uncertainty in right ascension	arcsec	R*8	F7.1	No
11	ddec	Uncertainty in declination	arcsec	R*8	F7.1	No
12	csf	Close source flag	-	I*2	I4	No
13–18	mag_t,$dmag_t$	Magnitudes & 1σ uncertainty in t=J,H,K_s bands	mag	R*4	6F7.3	99.999,99.999
19–26	mag_i,$dmag_i$	Magnitudes & 1σ uncertainty in IRAC band i	mag	R*4	8F7.3	99.999,99.999
27–32	F_t,dF_t	Fluxes & 1σ uncertainty in t=J,H,K_s bands	mJy	R*4	6E11.3	-999.9,-999.9
33–40	F_i,dF_i	Fluxes & 1σ uncertainty in IRAC band i	mJy	R*4	8E11.3	-999.9,-999.9
41–44	F_i_rms	RMS dev. of individual detections from F_i	mJy	R*4	4E11.3	-999.9
45–48	sky_i	Local sky bkg. for IRAC band i flux	MJy/sr	R*4	4E11.3	-999.9
49–51	SN_t	Signal/Noise for bands t=J,H,K_s	-	R*4	3F7.2	-9.99
52–55	SN_i	Signal/Noise for IRAC band i flux	-	R*4	4F7.2	-9.99
56–59	$srcdens_i$	Local source density for IRAC band i object	no./sq $'$	R*4	4F9.1	-9.9
60–63	M_i	Number of detections for IRAC band i	-	I*2	4I6	No
64–67	N_i	Number of possible detections for IRAC band i	-	I*2	4I6	No
68–70	SQF_t	Source Quality Flag for t=J,H,K_s flux	-	I*4	3I11	-9
71–74	SQF_i	Source Quality Flag for IRAC band i flux	-	I*4	4I11	-9
75–78	MF_i	Flux calc method flag for IRAC band i flux	-	I*2	4I6	-9

Table 9. Example of Catalog/Archive Entry

designation	SSTGLMDPC G054.7760+02.2374	Name
tmass_desig	19243076+2024280	2MASS designation
tmass_cntr	1339867377	2MASS counter
l,b	54.776087 2.237445	Galactic Coordinates (deg)
dl,db	0.3 0.3	Uncertainty in Gal. Coordinates (arcsec)
ra,dec	291.128168 20.407784	RA and Dec (J2000.0) (deg)
dra,ddec	0.3 0.3	Uncertainty in RA and Dec (arcsec)
csf	0	Close source flag
mag,dmag	13.422 12.231 11.872	Magnitudes (2MASS J,H,K_s) (mag)
	0.027 0.025 0.025	Uncertainties (2MASS) (mag)
mag,dmag	11.588 12.057 99.999 99.999	Magnitudes (IRAC 3.6,4.5,5.8,8.0 μm) (mag)
	0.129 0.054 99.999 99.999	Uncertainties (IRAC) (mag)
F,dF	6.819E+00 1.312E+01 1.189E+01	2MASS Fluxes (mJy)
	1.696E-01 3.021E-01 2.737E-01	Uncertainties in 2MASS fluxes (mJy)
F,dF	6.508E+00 2.702E+00 -9.999E+02 -9.999E+02	IRAC Fluxes (mJy)
	7.722E-01 1.342E-01 -9.999E+02 -9.999E+02	Uncertainties in IRAC fluxes (mJy)
F_rms	7.054E-02 9.422E-01 -9.999E+02 -9.999E+02	RMS_flux (mJy) (IRAC)
sky	2.720E-01 2.060E-01 -9.999E+02 -9.999E+02	Sky Bkg (MJy/sr) (IRAC)
SN	40.21 43.43 43.43	Signal to Noise (2MASS)
SN	8.43 20.13 -9.99 -9.99	Signal to Noise (IRAC)
srcdens	111.0 86.5 -9.9 -9.9	Local Source Density (IRAC) (#/sq arcmin)
M	3 6 0 0	Number of detections (IRAC)
N	3 6 0 0	Number of possible detections (IRAC)
SQF	29368320 29368320 29368320	Source Quality Flag (2MASS)
SQF	9216 5632 -9 -9	Source Quality Flag (IRAC)
MF	192 192 -9 -9	Flux Calculation Method Flag (IRAC)

7.2 Deep GLIMPSE Image Atlas

The mosaicked images for each IRAC band are standard 32-bit IEEE floating point single-extension FITS files in Galactic coordinates. Pixels that have no flux estimate have the value NaN. The FITS headers contain relevant information from both the SSC pipeline processing and the GLIMPSE processing such as IRAC frames included in the mosaicked image and coordinate information.

We provide native resolution images (1.2″ pixels) (e.g. 3.1°x 2.4° mosaic FITS files) for each band, along with low resolution 3-color jpegs. Other mosaics are 3.1°×2.1°, 3.1°×2.6°, 3.1°×2.7°, 3.1°×2.8°, 3.1°×3.0°, and 3.1°×3.1°. Filenames are GLM_*lcbc*_mosaic_I*ch*.fits, where *lc* and *bc* are the Galactic longitude and latitude of the center of the mosaic image, I denotes IRAC, and *ch* is the IRAC instrument channel number (1=[3.6] and 2=[4.5]). For example, GLM_05400+0170_mosaic_I1.fits is a 3.1°x 2.4° IRAC channel 1 [3.6] mosaic centered on l=54.00°, b=+1.70°. We provide low-resolution 3-color jpeg images for each area, combining IRAC [3.6] and [4.5] and IRAC [8.0] (or WISE [12] if IRAC [8.0] did not observe that area) to be used for quick-look purposes. The filename for this jpeg file is similar to the mosaic FITS file: e.g. GLM_05400+0170_mosaic_3.1x2.4.jpg. We also provide the background matched and gradient corrected 1.2″ pixel mosaics and 3-color jpegs. The background matched and gradient corrected image filenames have "corr_" pre-pended to the filename (e.g. corr_GLM_05400+0170_mosaic_I1.fits). This comment line is added to the FITS header for these images:

```
COMMENT Background Matched, Gradient Corrected
```

The angular sizes of the higher resolution (0.6″ pixels) tiles are 1.1°×0.7°, 1.1°×0.8°, 1.1°×0.9°, 1.1°×1.0°and 1.1°×1.1°. Three tiles span the latitude range of the areas. There are three mosaics per 1.1 degree Galactic longitude interval with 0.05° overlap between mosaics. The filenames are similar to the other FITS and jpeg images: e.g. GLM_34650-0185_mosaic_I2.fits, GLM_34650-0185.jpg.

Here is an example of the FITS header for the 3.1°x 2.4° GLM_05400+0170_mosaic_I2.fits:

```
--------------------------------- extension 0 ---------------------------------
SIMPLE  =                    T / file does conform to FITS standard
BITPIX  =                  -32 / number of bits per data pixel
NAXIS   =                    2 / number of data axes
NAXIS1  =                 9300 / length of data axis 1
NAXIS2  =                 7200 / length of data axis 2
COMMENT   FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT   and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
TELESCOP= 'SPITZER '           / Telescope
INSTRUME= 'IRAC    '           / Instrument ID
ORIGIN  = 'UW Astronomy Dept'  / Installation where FITS file written
CREATOR = 'GLIMPSE Pipeline'   / SW that created this FITS file
CREATOR1= 'S19.1.0 '           / SSC pipeline that created the BCD
PIPEVERS= '1v04    '           / GLIMPSE pipeline version
MOSAICER= 'Montage V3.0'       / SW that originally created the Mosaic Image
FILENAME= 'GLM_05400+0170_mosaic_I2.fits' / Name of associated fits file
PROJECT = 'DEEPGLL '           / Project ID
FILETYPE= 'mosaic  '           / Calibrated image(mosaic)/residual image(resid)
CHNLNUM =                    2 / 1 digit Instrument Channel Number
DATE    = '2013-02-22T02:13:16' / file creation date (YYYY-MM-DDThh:mm:ss UTC)
COMMENT --------------------
COMMENT Proposal Information
COMMENT --------------------
OBSRVR  = 'Barbara Whitney'    / Observer Name
OBSRVRID=                31113 / Observer ID of Principal Investigator
PROCYCLE=                   11 / Proposal Cycle
PROGID  =                80074 / Program ID
PROTITLE= 'Deep GLIMPSE: Exploring the Fa' / Program Title
PROGCAT =                   30 / Program Category
COMMENT ----------------------------
COMMENT Time and Exposure Information
COMMENT ----------------------------
SAMPTIME=                  0.2 / [sec] Sample integration time
FRAMTIME=                 12.0 / [sec] Time spent integrating each BCD frame
EXPTIME =                 10.4 / [sec] Effective integration time each BCD frame
COMMENT DN per pixel=flux(photons/sec/pixel)/gain*EXPTIME
NEXPOSUR=                    3 / Typical number of exposures
COMMENT Total integration time for the mosaic = EXPTIME * NEXPOSUR
COMMENT Total DN per pixel=flux(photons/sec/pixel)/gain*EXPTIME*NEXPOSUR
AFOWLNUM=                    8 / Fowler number
COMMENT --------------------
```

```
COMMENT Pointing Information
COMMENT --------------------
CRPIX1  =            4650.5000 / Reference pixel for x-position
CRPIX2  =            3600.5000 / Reference pixel for y-position
CTYPE1  = 'GLON-CAR'           / Projection Type
CTYPE2  = 'GLAT-CAR'           / Projection Type
CRVAL1  =          54.00000000 / [Deg] Galactic Longtitude at reference pixel
CRVAL2  =           1.70000005 / [Deg] Galactic Latitude at reference pixel
EQUINOX =               2000.0 / Equinox for celestial coordinate system
DELTA-X =           3.09999990 / [Deg] size of image in axis 1
DELTA-Y =           2.40000010 / [Deg] size of image in axis 2
BORDER  =           0.00000000 / [Deg] mosaic grid border
CD1_1   =      -3.33333330E-04
CD1_2   =       0.00000000E+00
CD2_1   =       0.00000000E+00
CD2_2   =       3.33333330E-04
PIXSCAL1=                1.200 / [arcsec/pixel] pixel scale for axis 1
PIXSCAL2=                1.200 / [arcsec/pixel] pixel scale for axis 2
OLDPIXSC=                1.213 / [arcsec/pixel] pixel scale of single IRAC frame
RA      =         291.24176025 / [Deg] Right ascension at mosaic center
DEC     =          19.47021294 / [Deg] Declination at mosaic center
COMMENT ----------------------
COMMENT Photometry Information
COMMENT ----------------------
BUNIT   = 'MJy/sr  '           / Units of image data
GAIN    =                  3.7 / e/DN conversion
JY2DN   =          2047105.000 / Average Jy to DN Conversion
ETIMEAVE=              10.4000 / [sec] Average exposure time for the BCD frames
PA_AVE  =                88.72 / [deg] Average position angle
ZODY_EST=              0.18241 / [Mjy/sr] Average ZODY_EST
ZODY_AVE=              0.01574 / [Mjy/sr] Average ZODY_EST-SKYDRKZB
COMMENT Flux conversion (FLUXCONV) for this mosaic =
COMMENT Average of FLXC from each frame*(old pixel scale/new pixel scale)**2
FLUXCONV=          0.150100082 / Average MJy/sr to DN/s Conversion
COMMENT -----------------------------
COMMENT AORKEYS/ADS Ident Information
COMMENT -----------------------------
AOR001  = '0045909760'         / AORKEYS used in this mosaic
AOR002  = '0045906432'         / AORKEYS used in this mosaic
AOR003  = '0045918976'         / AORKEYS used in this mosaic
AOR004  = '0045916672'         / AORKEYS used in this mosaic
AOR005  = '0045914624'         / AORKEYS used in this mosaic
AOR006  = '0045906944'         / AORKEYS used in this mosaic
AOR007  = '0045912576'         / AORKEYS used in this mosaic
AOR008  = '0045923072'         / AORKEYS used in this mosaic
AOR009  = '0045949696'         / AORKEYS used in this mosaic
AOR010  = '0045908224'         / AORKEYS used in this mosaic
AOR011  = '0045919744'         / AORKEYS used in this mosaic
```

```
AOR012  = '0045917440'         / AORKEYS used in this mosaic
AOR013  = '0045904384'         / AORKEYS used in this mosaic
AOR014  = '0045933824'         / AORKEYS used in this mosaic
AOR015  = '0045906688'         / AORKEYS used in this mosaic
AOR016  = '0045934336'         / AORKEYS used in this mosaic
AOR017  = '0045952512'         / AORKEYS used in this mosaic
AOR018  = '0045907712'         / AORKEYS used in this mosaic
AOR019  = '0045942272'         / AORKEYS used in this mosaic
AOR020  = '0045916416'         / AORKEYS used in this mosaic
AOR021  = '0045948160'         / AORKEYS used in this mosaic
AOR022  = '0045932032'         / AORKEYS used in this mosaic
DSID001 = 'ads/sa.spitzer#0045909760' / Data Set Identification for ADS/journals
DSID002 = 'ads/sa.spitzer#0045906432' / Data Set Identification for ADS/journals
DSID003 = 'ads/sa.spitzer#0045918976' / Data Set Identification for ADS/journals
DSID004 = 'ads/sa.spitzer#0045916672' / Data Set Identification for ADS/journals
DSID005 = 'ads/sa.spitzer#0045914624' / Data Set Identification for ADS/journals
DSID006 = 'ads/sa.spitzer#0045906944' / Data Set Identification for ADS/journals
DSID007 = 'ads/sa.spitzer#0045912576' / Data Set Identification for ADS/journals
DSID008 = 'ads/sa.spitzer#0045923072' / Data Set Identification for ADS/journals
DSID009 = 'ads/sa.spitzer#0045949696' / Data Set Identification for ADS/journals
DSID010 = 'ads/sa.spitzer#0045908224' / Data Set Identification for ADS/journals
DSID011 = 'ads/sa.spitzer#0045919744' / Data Set Identification for ADS/journals
DSID012 = 'ads/sa.spitzer#0045917440' / Data Set Identification for ADS/journals
DSID013 = 'ads/sa.spitzer#0045904384' / Data Set Identification for ADS/journals
DSID014 = 'ads/sa.spitzer#0045933824' / Data Set Identification for ADS/journals
DSID015 = 'ads/sa.spitzer#0045906688' / Data Set Identification for ADS/journals
DSID016 = 'ads/sa.spitzer#0045934336' / Data Set Identification for ADS/journals
DSID017 = 'ads/sa.spitzer#0045952512' / Data Set Identification for ADS/journals
DSID018 = 'ads/sa.spitzer#0045907712' / Data Set Identification for ADS/journals
DSID019 = 'ads/sa.spitzer#0045942272' / Data Set Identification for ADS/journals
DSID020 = 'ads/sa.spitzer#0045916416' / Data Set Identification for ADS/journals
DSID021 = 'ads/sa.spitzer#0045948160' / Data Set Identification for ADS/journals
DSID022 = 'ads/sa.spitzer#0045932032' / Data Set Identification for ADS/journals
NIMAGES =                 3280 / Number of IRAC Frames in Mosaic
```

In addition to the FITS header information given above, the associated ASCII .hdr file includes information about each IRAC frame used in the mosaic image. For example, GLM_05400+0170_mosaic_I2.hdr includes:

```
COMMENT ----------------------------------------
COMMENT Info on Individual Frames in Mosaic
COMMENT ----------------------------------------
IRFR0001= 'SPITZER_I2_0045909760_0253_0000_01_levbflx.fits' / IRAC frame
DOBS0001= '2012-12-09T09:01:32.734' / Date & time at frame start
MOBS0001=      56270.375000000 / MJD (days) at frame start
RACE0001=           290.653503 / [Deg] Right ascension at reference pixel
```

```
DECC0001=            18.156101 / [Deg] Declination at reference pixel
PANG0001=                90.07 / [deg] Position angle for this image
FLXC0001=              0.14690 / Flux conversion for this image
ZODE0001=              0.18068 / [MJy/sr] ZODY_EST for this image
ZODY0001=              0.01403 / [MJy/sr] ZODY_EST-SKYDRKZB for this image
IRFR0002= 'SPITZER_I2_0045909760_0275_0000_01_levbflx.fits' / IRAC frame
DOBS0002= '2012-12-09T09:05:58.539' / Date & time at frame start
MOBS0002=      56270.378906250 / MJD (days) at frame start
RACE0002=           290.967407 / [Deg] Right ascension at reference pixel
DECC0002=            18.157227 / [Deg] Declination at reference pixel
PANG0002=                90.17 / [deg] Position angle for this image
FLXC0002=              0.14690 / Flux conversion for this image
ZODE0002=              0.17998 / [MJy/sr] ZODY_EST for this image
ZODY0002=              0.01332 / [MJy/sr] ZODY_EST-SKYDRKZB for this image
.
.       Information on the IRAC frame: filename, date of observation, central
.       position, position angle, flux convert and zodiacal light for
.       frames 3 through 3278
.
IRFR3279= 'SPITZER_I2_0045948160_0083_0000_01_levbflx.fits' / IRAC frame
DOBS3279= '2012-12-13T08:55:48.644' / Date & time at frame start
MOBS3279=      56274.371093750 / MJD (days) at frame start
RACE3279=           291.508881 / [Deg] Right ascension at reference pixel
DECC3279=            20.258051 / [Deg] Declination at reference pixel
PANG3279=                88.16 / [deg] Position angle for this image
FLXC3279=              0.14690 / Flux conversion for this image
ZODE3279=              0.18275 / [MJy/sr] ZODY_EST for this image
ZODY3279=              0.01610 / [MJy/sr] ZODY_EST-SKYDRKZB for this image
IRFR3280= 'SPITZER_I2_0045942272_0115_0000_01_levbflx.fits' / IRAC frame
DOBS3280= '2012-12-10T20:25:36.582' / Date & time at frame start
MOBS3280=      56271.851562500 / MJD (days) at frame start
RACE3280=           290.427368 / [Deg] Right ascension at reference pixel
DECC3280=            18.949663 / [Deg] Declination at reference pixel
PANG3280=                89.19 / [deg] Position angle for this image
FLXC3280=              0.14690 / Flux conversion for this image
ZODE3280=              0.18265 / [MJy/sr] ZODY_EST for this image
ZODY3280=              0.01599 / [MJy/sr] ZODY_EST-SKYDRKZB for this image
```

8 APPENDIX A - Source Quality Flag Bit Descriptions

A.1 IRAC Source Quality Flag

Information is gathered from the SSC IRAC bad pixel mask (pmask), SSC bad data mask (dmask) and the GLIMPSE IRAC pipeline for the Source Quality Flag. Table 6 lists the bits and the origin of the flag (SSC or GLIMPSE pipeline). See ssc.spitzer.caltech.edu/irac/products/pmask.html and ssc.spitzer.caltech.edu/irac/products/bcd_dmask.html for more information about the IRAC pmask and dmask.

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.

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). 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. Sources with this bit set are culled from the Catalog.

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 consisting 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 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 (and flux in-band) χ^2 differences between candidates. If the number of candidates is greater than 1, the confusion flag is set.

15 column pulldown corrected ([3.6] and [4.5] bands)
This bit is set if the source is within 3 pixels of a column pulldown corrected pixel.

19 data predicted to saturate
This bit is set when a source is within 3 pixels of a pixel identified in the SSC IRAC dmask as being saturated (bit 10 in the dmask). GLIMPSE runs a saturated pixel predicter 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 sources above the IRAC 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. See Figure 11 for an example of the shapes of the saturated star wing areas flagged by this bit. Sources with this bit set are culled from the Catalog.

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 one IRAC frame and a second source extracted on another 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. Cross-band lumping is done with a 1.6″ radius. For example, say there are two sources within 1.6″ of each other. One source has data in bands K_s and [3.6] and the other has data in band [4.5]. These two sources will be lumped into one source with data in two IRAC bands.

30 within three pixels of edge of frame
Sources within three pixels of the edge of the IRAC frame are flagged since it is likely to be too close to the edge of the frame for accurate photometry to be done. Sources with this bit set are culled from the Catalog.

A.2 2MASS Source Quality Flag

For the 2MASS bands, the following contamination and confusion (cc) flags from the 2MASS All-Sky 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
www.ipac.caltech.edu/2mass/releases/allsky/doc/sec2_2a.html#cc_flag. 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

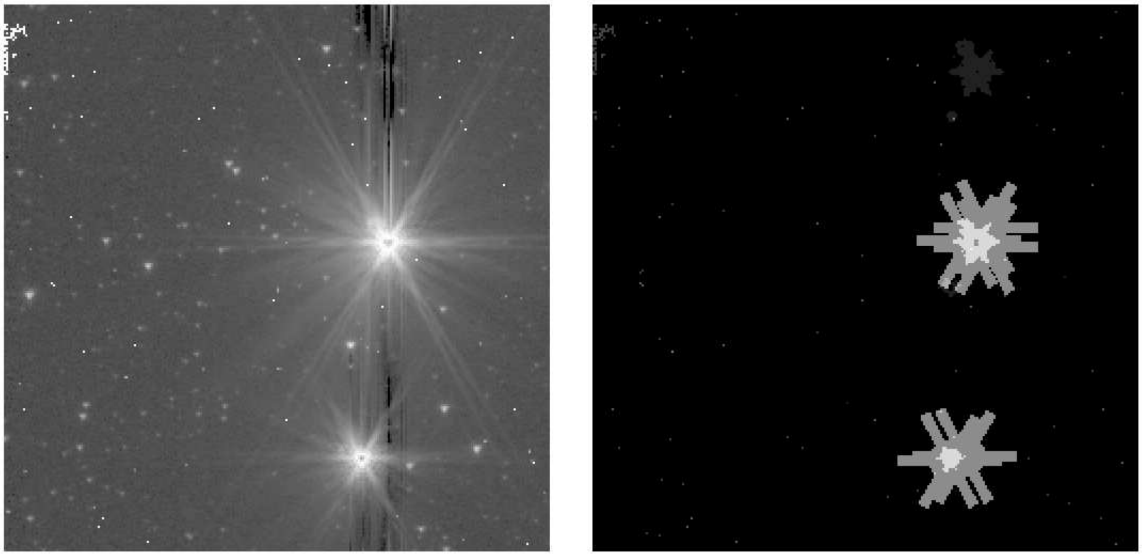

Figure 11: The [3.6] GLIMPSE360 IRAC frame (AOR 32845568, exposure 141) is on the left; the flags for that frame are shown on the right. The PSF-shaped areas around the bright sources correspond to SQF bit 20. Latent images are flagged at the top of the image, above the bright source. Various small dots are hot, dead or bad pixels (SQF bit 8). Bits in the SQF will have been set for sources within 3 pixels of any of the bad pixels.

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.

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

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

where

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.3 Key to Bit Values

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

bt = bit in sqf
value = $2^{(bit-1)}$ i.e. bit 3 corresponds to 2^2=4

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, the Source Quality Flags in the example in Table 9 are 29368320 for the 2MASS J, H and K_s bands. This translates to bits 23, 24 and 25 being set, which is the photometric quality

A flag from the 2MASS PSC. Also bit 14 is set which means confusion in the cross-band merge. IRAC [3.6] has a SQF of 9216. This means bits 11 and 14 were set which means tweaking was done in the source extraction and the source and there is confusion in the cross-band merge step. IRAC [4.5] SQF is 5632. This means bits 10 and 11 have been set which means the tweaking has been done in the source extraction. Bit 13 was also set which means confusion in the in-band merge.

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GLOSSARY

2MASS	Two Micron All Sky Survey
BCD	Basic Calibrated Data, released by the SSC
Cygnus-X	CYGX-A Spitzer Legacy Survey of the Cygnus-X Complex
dmask	A data quality mask supplied by the SSC for the BCD
GLIMPSE	Galactic Legacy Infrared Midplane Survey Extraordinaire
GLMDPC	Deep GLIMPSE Point Source Catalog
GLMDPA	Deep GLIMPSE Point Source Archive
HDR	High Dynamic Range
IPAC	Infrared Processing and Analysis Center
IRAC	*Spitzer* Infrared Array Camera
IRS	*Spitzer* Infrared Spectrometer
IRSA	InfraRed Science Archive
MF	Method Flag used to indicate exposure times included in the flux
MIPS	*Spitzer* Multiband Imaging Photometer
OSV	Observing Strategy Validation
pmask	A bad pixel mask supplied by the SSC for the BCD
PSF	Point Spread Function
rmask	Outlier (radiation hit) mask
SMOG	Spitzer Mapping of the Outer Galaxy
SOM	*Spitzer* Observer's Manual
SSC	*Spitzer* Science Center
SED	Spectral energy distribution
SQF	Source Quality Flag
SST	*Spitzer* Space Telescope
YSO	Young Stellar Object
WISE	Wide-field Infrared Survey Explorer
WITS	Web Infrared Tool Shed, for data analysis