GLIMPSEI - v2.0 Data Release

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Version 2.0
May 11, 2007

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1 Quick Start

GLIMPSEI and GLIMPSEII data products are available at the Spitzer Science Center (SSC) (see http://ssc.spitzer.caltech.edu/legacy/glimpsehistory.html) and the Infrared Science Archive (IRSA) (e.g. http://irsa.ipac.caltech.edu/data/SPITZER/). For scientists who want to immediately use the GLIMPSEI data, §2.1 briefly describes the survey and data products; and §6 describes the source list entries and the images. The Web Infrared Tool Shed (WITS) is located at http://dustem.astro.umd.edu. The Young Stellar Objects (YSO) Grid and Fitter can be found at http://caravan.astro.wisc.edu/protostars/.

2 Overview

2.1 GLIMPSEI Survey and Data Products

The Galactic Legacy Infrared Mid-Plane Survey Extraordinaire (GLIMPSEI)[1], using the *Spitzer* Space Telescope (SST) (Werner et al. 2004) Infrared Array Camera (IRAC) (Fazio et al. 2004) surveyed approximately 220 square degrees of the Galactic plane, covering a latitude range of $\pm 1°$, and a longitude range of $|l| = 10° - 65°$, plus the Observation Strategy Validation (OSV) region at l=284°. IRAC has four bands, centered at approximately 3.6, 4.5, 5.8 and 8.0 μm respectively. We will refer to them as bands 1 - 4 in this document. The observations consisted of two 1.2 second integrations at each position, for a total of over 77,000 pointings and ~310,000 IRAC frames in 400 hours total survey time. The survey is producing approximately 266 Giga Bytes (GB) of data in

[1] Although originally known as GLIMPSE, we will use the acronym GLIMPSEI to avoid confusion between it, GLIMPSEII and GLIMPSE-3D

the form of a point source Catalog, a point source Archive, and mosaicked images. See Benjamin et al. (2003) and the GLIMPSE web site (www.astro.wisc.edu/glimpse/) for more description of the GLIMPSEI project.

This document describes the data products from the GLIMPSEI Survey, specifically the v2.0 data products delivered in early 2007. The organization of this document is as follows: §2 gives an overview of the GLIMPSEI survey and data products, §3 briefly describes the data processing; §4 discusses the validation of the source lists; §5 provides a detailed description of the data products; and §6 describes the format. Appendix A discusses the differences between the GLIMPSEI v2.0 and v1.0 data products, and Appendix B gives details about the Source Quality Flag. This document contains numerous acronyms, a glossary of which is given at the end.

The GLIMPSEI enhanced data products consist of a highly reliable Point Source Catalog (GLMIC), a more complete Point Source Archive (GLMIA), and mosaic images covering the survey area. Also provided to the astronomical community are web tools for modeling infrared data. The enhanced data products are:

1. The GLIMPSEI Catalog (GLMIC, or the "Catalog"), consisting of point sources whose selection criteria (§3.2) are determined by the requirement that the reliability be $\geq$99.5%. Figure 1 shows the number of GLIMPSEI (and GLIMPSEII) Catalog sources as a function of magnitude for each IRAC band and various longitudes. This figure shows there is a range of limiting magnitudes depending on whether the source is in a sparsely populated or low background region or in a region of high diffuse background or high source density. The photometric uncertainty is typically < 0.2 mag. 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 any anomalies present in the data. Sources were bandmerged 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. The 2MASS information we include from the 2MASS PSC is designation, counter (a unique identification number), fluxes, signal-to-noise, and a limited source quality flag. Users should refer back to the 2MASS Point Source Catalog for the complete 2MASS information about the source. The GLIMPSEI Catalog format is ASCII, using the IPAC Tables convention (irsa.ipac.caltech.edu/applications/DDGEN/Doc/ipac_tbl.html). The v2.0 Catalog occupies $\sim$21 GB of storage, and contains $\sim$ 31 million sources.

2. The GLIMPSEI Archive (GLMIA or the "Archive"), consisting of point sources with a signal-to-noise > 5 in at least one band and less stringent selection critera than the Catalog (§3.2). The photometric uncertainty is typically < 0.3 mag. The information provided is in the same format as the Catalog. The number of GLIMPSEI v2.0 Archive sources as a function of magnitude for each IRAC band in various longitude regions (with differing background levels and source density) is shown in Figure 2. The Archive occupies $\sim$ 34 GB of storage, and contains about 49 million sources. The GLIMPSEI Catalog is a subset of the Archive, but note that 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 (§3.2).

3. The GLIMPSEI Image Atlas. Mosaicked Images for each band, each covering $1.1^\circ \times 0.8^\circ$. 1344 of these 32-bit IEEE floating point single extension FITS formatted images cover the entire survey area. These images, in units of surface brightness MJy/sr, occupy $\sim$170 GB of disk space, with a pixel size of $0.6''$. Mosaics of each band are made for larger $3.1^\circ \times 2.4^\circ$ areas,

with a pixel size of 1.2″ . There are 164 of these 3.1°×2.4° mosaics, totalling ∼ 42 GB. Also included are quicklook 3-color jpeg images of the same size as the FITS images.

4. The Web Infrared Tool Shed (WITS), 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.

5. The YSO Model Grid and Fitter, a web-based home of a large grid of YSO model spectral energy distributions (SEDs). To date, 20073 YSO radiation transfer models of YSOs, each at ten viewing angles, spanning a large range of evolutionary stages and stellar masses have been computed. The model grid browser allows users to examine SED variations as a function of a range of physical parameters. The fitting tool will fit input SED data from the grid of model SEDs.

GLIMPSEI source lists and mosaics are served by the SSC (see http://ssc.spitzer.caltech.edu/legacy/) and IRSA (http://irsa.ipac.caltech.edu/data/SPITZER/). The Web Infrared Tool Shed is located at the University of Maryland (http://dustem.astro.umd.edu) and the YSO Grid and Fitter is served by the University of Wisconsin (http://caravan.astro.wisc.edu/protostars/).

2.2 v1.0 Data Release

v1.0 source lists for the entire GLIMPSEI survey region derived from data from SSC pipeline processing versions S10.5 and earlier were delivered to the SSC in April 2005. Image delivery was completed in August 2006. See the GLIMPSEI Data Products Description v1.5 (http://www.astro.wisc.edu/glimpse/docs.html) for more information about the v1.0 data. www.astro.wisc.edu/glimpse/glimpsedata.html gives the links to the location of the GLIMPSEI v1.0 data products at the SSC.

2.3 v2.0 Data Release

The v2.0 data products consist of point source Catalogs and Archives and mosaic images for the entire survey region. The v2.0 data products incorporate improvements in the SSC processing and the Wisconsin IRAC pipeline and include small amounts of new data taken to fill gaps in survey coverage. As in the v1.0 processing, photometry is performed on individual IRAC frames using a modified version of DAOPHOT (Stetson 1987) and combined in the bandmerger stage to produce the source lists. For the v2.0 data release, we are also providing 2MASS fluxes with the IRAC data, when available. We don't provide 2MASS sources that lack an IRAC counterpart. We did not attempt to match instrumental background variations between the images during the mosaic stage but plan to for the v3.0 mosaics.

Our v2.0 processing uses SSC pipeline processing version S13.2 (corrected for jailbar) and later, which has improved pointing refinement to 2MASS positions and a new flux calibration as discussed in Reach et al. 2005.

The Wisconsin IRAC pipeline enhancements for the v2.0 processing include: muxbleed correction; better banding correction for band 3; more information included in the source quality flag; combining of sources within 2″ in the in-band and cross-band merging (to lessen flux sharing between close sources); photometric correction applied (a function of position of the source in the frame); and a close source flag implemented (set if a nearby Archive source is within 3″).

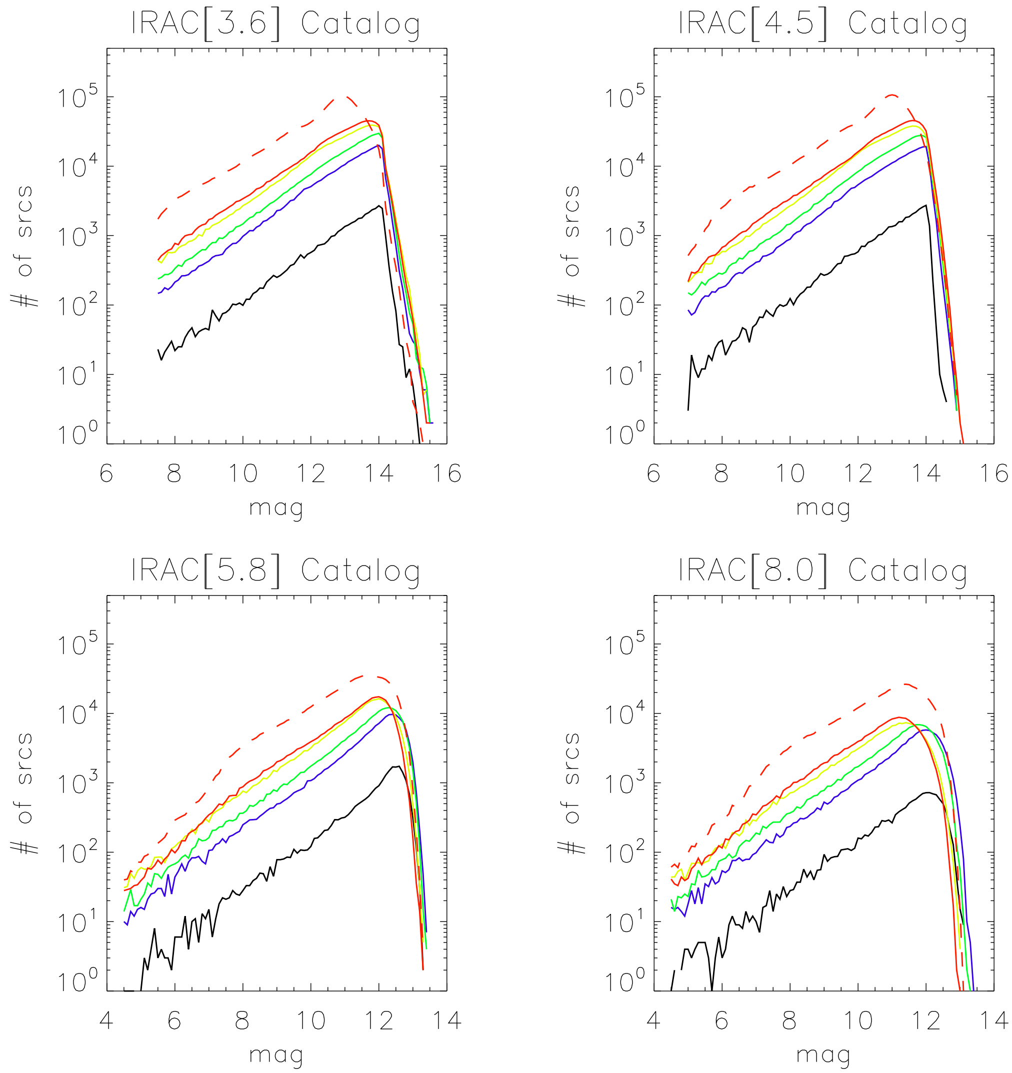


Figure 1: GLIMPSEI and GLIMPSEII Catalog source counts versus magnitude. GLIMPSEI Observation Strategy Validation (OSV) data (galactic longitude approximately l=284°) is plotted in the solid black line. 1 degree of GLIMPSEI data from $|l| = 55.5°$ is plotted in the solid blue line, 1 degree of GLIMPSEI data from $|l| = 40.5°$ is plotted in the solid green line, 1 degree of GLIMPSEI data from $|l| = 25.5°$ is plotted in the solid yellow line, 1 degree of GLIMPSEII data from $|l| = 9.5°$ is plotted in the solid red line, and ± 1 degree of GLIMPSEII data at l = 0° is plotted in the dashed red line. This plot shows both the increase in source counts as one approaches the Galactic center as well as the falloff of completeness as one approaches the Galactic center.

Appendix A gives more details about the differences between the v2.0 and v1.0 processing of the GLIMPSEI data products.

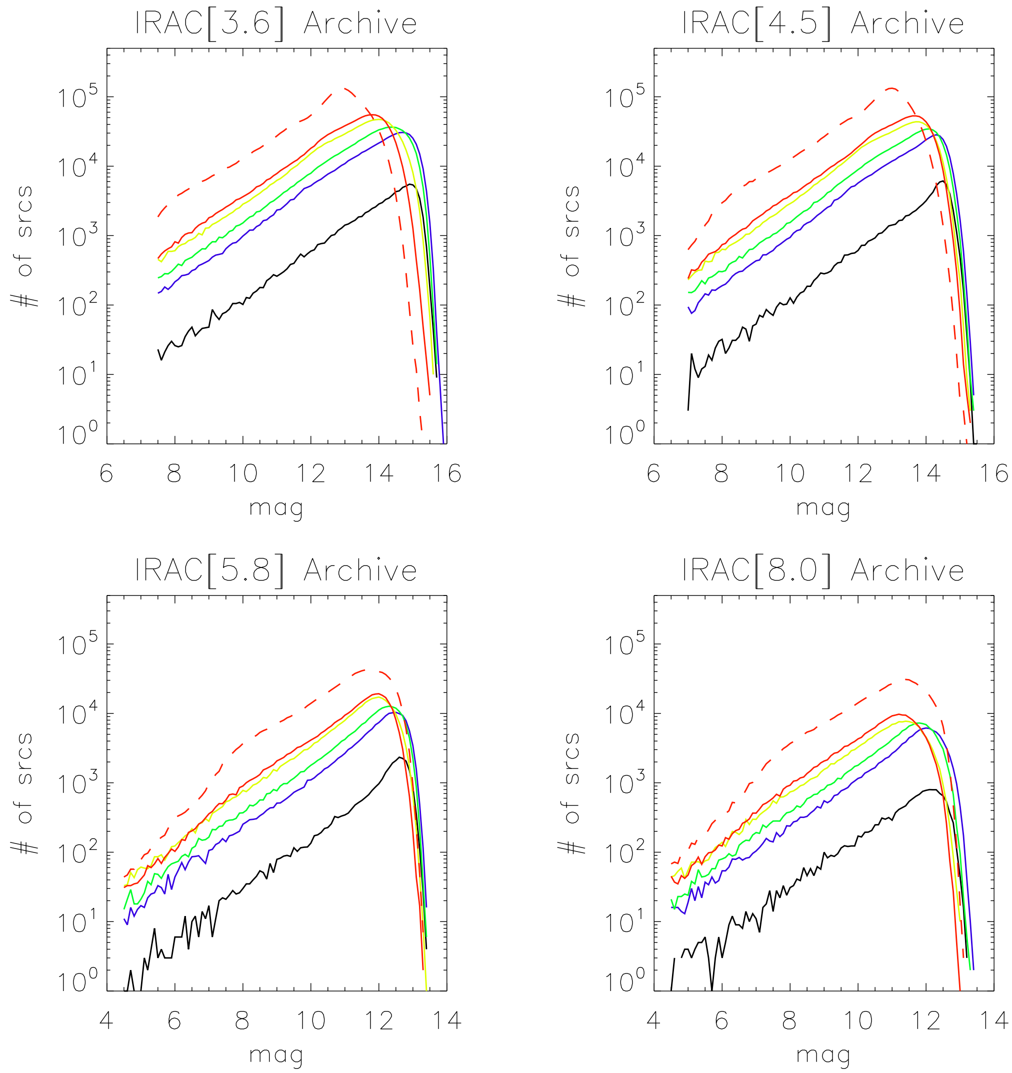


Figure 2: Same as Figure 1 except these are GLIMPSEI and GLIMPSEII Archive source counts versus magnitude for various longitude ranges.

2.4 v3.0 Data Products - Background Matched Mosaic Images

In the v3.0 mosaic images, we match instrumental background variations between the images. Instrument artifacts (Hora et el. 2004; IRAC Data Handbook[2]) such as full array pull-up, first frame effect and frame pull-down are mostly removed from the images. We will do this for the 3.1°x 2.4° images. This processing may be removing real sky variations so we provide these images *in addition* to the v2.0 3.1°x 2.4° images that do not have the background matching. We expect to deliver the v3.0 mosaics in summer 2007.

[2]http://ssc.spitzer.caltech.edu/irac/dh/

2.5 Complementary Datasets

Numerous complementary datasets will increase the scientific impact of the GLIMPSE survey. 2MASS provides imaging at similar resolution to IRAC, in the J (1.25 μm), H (1.65 μm), and K_s (2.17 μm) bands. The Midcourse Space Experiment (MSX) (Price et al. 2001) also observed the Galactic plane in several mid-IR wavebands (from 4.2 to 26 μm) with $18''$ resolution at 8 μm. The following additional datasets can be accessed by the astronomical community through links from the GLIMPSE web site (www.astro.wisc.edu/glimpse/complementary.html):

1. Arecibo and Green Bank Telescope (GBT) surveys of IR-color selected H II Regions in the GLIMPSE survey region: a dataset that resolves distance ambiguities to massive star formation regions. This dataset includes > 100 objects and can be found on the GLIMPSE web site.

2. Milky Way Galactic Ring Survey (GRS) (www.bu.edu/galacticring), a Boston University and Five College Radio Astronomy Observatory collaboration, is a large-scale ^{13}CO line survey of the inner Galaxy between longitudes 18° and 52°.

3. The International Galactic Plane Survey (www.ras.ucalgary.ca/IGPS) is an H I 21-cm survey of the disk of the Milky Way. This survey provides data cubes of the H I spectral line emission with resolution of $1'$ and one km/s over the entire area of the GLIMPSE survey.

4. The Coordinated Radio and Infrared Survey for High-Mass Star Formation (CORNISH) (www.ast.leeds.ac.uk/Cornish/index.html) Very Large Array (VLA) 6 cm continuum survey of much of the GLIMPSE area is well underway. CORNISH has a spatial resolution of $\sim 1''$ and a sensitivity of $\sim$1 mJy, very similar to that of IRAC.

3 Pipeline Processing

3.1 Image Processing, Photometry, and Bandmerging

The GLIMPSE Pipeline Description document (GPD)[3] will describe in detail the GLIMPSE (GLIMPSEI, GLIMPSEII, GLIMPSE-3D) pipeline processing, including photometry and bandmerging to produce source lists. We note here some steps that are relevant to the final data products. 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) are corrected for in the GLIMPSE pipeline. We correct for column pulldown[4] in bands 1 & 2, using an algorithm written by Lexi Moustakas (GOODS team) and modified by GLIMPSE to handle variable backgrounds. We correct for muxbleed[5] in bands 1 & 2 using a modified version of the IRAC Bright Source

[3] will be found at http://www.astro.wisc.edu/glimpse/docs.html

[4] 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/documents/som/.

[5] 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

Artifact Corrector[6]. We correct for banding[7] in band 3 by using an algorithm fitting each incidence of banding individually and band 4 using an exponential function.

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 4), which has been shown to improve the flux estimates in complex background regions substantially. Cosmic rays are removed from the source list based on an algorithm that operates on the residual images. More details about the photometry steps can be found at http://www.astro.wisc.edu/glimpse/glimpse_photometry_v1.0.pdf. The array-location-dependent photometric corrections[8] were applied to the v2.0 source lists.

Prior to the bandmerge stage, we cull all IRAC sources with signal-to-noise less than 3. As a result, no IRAC sources in the Catalog or Archive will have signal-to-noise less than 3 in any band. We use the SSC-supplied bandmerger[9] (modified by the GLIMPSE team) in two stages, first to combine all detections of the same source in the same band (in-band merge), and then to cross-correlate detections in different bands (cross-band merge). Signal-to-noise and flux information is used as well as position during the in-band merge, but only position is used for the cross-band merge (to avoid any systematic effects dependent on source color). Fluxes of sources within $2''$ in the IRAC frame are combined together or "lumped" into one flux during the in-band merge to lessen flux splitting. Cross-band lumping is done with a $2''$ radius. Position migration can occur in the bandmerging process which results in a small number of sources that have sources within $2''$ of it. Sources from the 2MASS All-Sky Point Source Catalog are merged with the IRAC fluxes in the cross-band merge stage only if it has a K_s detection.

Image processing for the mosaic image products include the column pulldown, muxbleed and banding corrections mentioned above. Hot, dead, and missing pixels are masked. The SSC mosaicer MOPEX[10] is run to obtain the outlier mask (rmask; generally due to cosmic rays). Both the dual outlier bit and the temporal bit of the rmask are masked during the mosaicing. Stray light from bright sources outside the field of view scatters onto the detector and can appear in the images. To remove them, we use the SSC IRAC Stray Light Masker[11] modified to use the IRAC magnitudes from the GLIMPSEI source lists to predict the positions of the stray light. It creates a mask (smask) for each input IRAC frame. About 90% of the stray light areas are found by the SSC Stray Light Masker. Most of the remaining stray light areas are removed by visual inspection. Artifacts that have only single-frame coverage (outside the nominal latitude range of $\pm 1^\circ$) are left in the mosaic. If there are areas of overlapping image artifacts that cause a gap in coverage, we do not mask that area. In bands 3 and 4 stray light areas can repeat (particularly along rows) and remain in the images because masking them would cause gaps in coverage. See SSC's IRAC image features web site[12] and the IRAC Data Handbook for more information about the detector artifacts. See also the GLIMPSE IRAC Instrument Artifact Gallery (http://www.astro.wisc.edu/glimpse/glimpse_artifact_gallery_v1.0.pdf) which gives examples of artifacts in the GLIMPSEI images that are corrected for and examples of artifacts that remain in the

[6]http://spider.ipac.caltech.edu/staff/carey/irac_artifacts

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

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

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

[10]http://ssc.spitzer.caltech.edu/postbcd/

[11]http://ssc.spitzer.caltech.edu/irac/straylight/

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

GLIMPSEI images. We use the Montage[13] package v2.2 to mosaic and project to Galactic coordinates. We use Montage's background correction algorithm[14], with the "level" option, to produce the background matched v3.0 mosaics.

3.2 Source Selection for Catalog and Archive

Now we describe the selection criteria for the Catalog and Archive once photometry and bandmerging have been completed.

Catalog

To satisfy the requirement that the Catalog be ≥99.5% reliable, it was determined from simulated data and study of the Observation Strategy Validation (OSV) data that a source must be detected at least twice in one band and at least once in an adjacent band for the general GLIMPSEI observing strategy of two visits on the sky, described in detail in the GLIMPSE Quality Assurance (GQA) document (http://www.astro.wisc.edu/glimpse/GQA-master.pdf). We call this the "2+1" criterion. The 2MASS K_s magnitude, when present, is used for the "2+1" criterion for IRAC band 1. To allow for the more general case of M detections out of N possible observations, we require that $M/N \geq 0.6$ in one band and $M/N \geq 0.4$ in an adjacent band.

In the two bands that satisfy the 2+1 criterion, only sources with flux greater than 0.6 mJy (<14.2 mag), 0.4 mJy (<14.1 mag), 2 mJy (<11.9 mag), and 10 mJy (<9.5 mag) in bands 1 through 4, respectively, are allowed in the Catalog. Similarly, the bright limit flux is 439 mJy (7 mag), 450 mJy (6.5 mag), 2930 mJy (4 mag) and 1590 mJy (4 mag) for bands 1 through 4, respectively, to remove sources at nonlinear response levels. (See §5.1 for the zeropoints used for converting from flux to magnitude.) The signal-to-noise in the band with the two detections satisfying the 2+1 criterion is required to be greater than 5. Sources with hot or dead pixels within 3 pixels of source center, those in wings of saturated stars, and those within 3 pixels of the frame edge are culled from the Catalog.

Once a source satisfies the 2+1 criterion, the requirements for the other 2 bands of the same source are less stringent. Flux values above the bright limit flux are nulled, but values below the low-limit flux are allowed. Signal-to-noise <5 (down to a lower limit of 3) is allowed. Bands with hot or dead pixels and in wings of saturated stars are nulled, but those within 3 pixels of the frame edge are allowed.

Finally, sources are removed from the Catalog if there are Archive sources within 2″ of the source, because we found that the neighboring source could influence the flux extraction for that source.

Archive

Requirements for source selection in the Archive are less stringent than for the Catalog. Therefore the Archive is less reliable than the Catalog but more complete. We require $M/N \geq 0.6$ in one band or $M/N \geq 0.4$ in any two bands. For a typical source observed two times, this translates to a detection twice in one band or once in two bands. The 2MASS K_s magnitude is allowed in the "1+1" criterion. We require that the signal-to-noise be greater than 5 in the band or bands used

[13]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.

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

for source selection. The lower limit of the signal-to-noise for all bands is 3. Sources are removed from the Archive if there are neighboring Archive sources within $0.5''$ of the source. There are no further culls, leaving it to the user to cull or null based on values of the fluxes and flags (described in §5.1).

4 Source List Validation

We summarize here analysis used to validate the Catalog and Archive point source lists. The GLIMPSE Quality Assurance document describes the GLIMPSEI v1.0 data validation in more detail. Much of it also applies to the GLIMPSEI v2.0 data.

4.1 False sources/Asteroids

Verification of our source selection criteria (§3.2) was done with a Reliability study of the GLIMPSEI OSV data. See http://www.astro.wisc.edu/glimpse/cr_manuscript.pdf (Reliability and Completeness for the GLIMPSE Survey), http://www.astro.wisc.edu/glimpse/val.20040130.pdf (Observation Strategy Validation Report), and http://www.astro.wisc.edu/glimpse/addendum4.pdf (Addendum to the Validation Report). One cause of false sources in the source lists is imperfect muxbleed correction leaving faint point-like sources every four pixels along a row from a bright source in bands 1 and 2. We estimate about 90% of the muxbleed has been corrected by the Bright Source Artifact Corrector but the muxbleed remaining in the images can cause false sources. Most of the muxbleed sources have signal-to-noise less than 5 and do not make it into the source lists. Very few false sources due to muxbleed are found in high background areas (e.g. in the inner Galaxy). We estimate that $< 0.04\%$ of the Catalog sources may be due to muxbleed. We estimate that $<$ 0.2% of the Archive sources may be due to muxbleed because of our less stringent selection criteria. The false detections due to muxbleed will be in only bands 1 and 2. An additional cause of false detections in the Archive occurs in regions surrounding saturated stars where the GLIMPSE source extractor may find false sources in the wings of the PSF. These sources are culled from the Catalog but only flagged in the Archive. Our source selection criteria remove the vast majority of other potential false detections, such as cosmic rays and stray light. In addition, our photometry iteration on residual images reduces false source detections in variable backgrounds caused by both real sky variations as well as instrumental artifacts such as banding, stray light, muxbleed, and column pulldown.

Asteroid detection in the GLIMPSEI source lists will generally be limited to the Archive. Due to the observation strategy and source list criteria, nearly all asteroids should be culled from the Catalog. This is a result of the 2+1 criteria which requires detections in adjacent IRAC bands. Since the IRAC detector observes simultaneously bands 1 and 3 in one location on the sky and bands 2 and 4 at an offset location on the sky, asteroids will generally be limited to having only two bands of data which are not adjacent. In the case that an asteroid is observed in a frame for bands 1 and 3, it will not be imaged in bands 2 and 4 (since those bands are positionally offset from bands 1 and 3) until the AOR has progressed long enough to have positioned the IRAC band 2 and 4 detectors at the same area of sky. This is usually a sufficiently long period of time that the asteroid has moved far enough from its earlier position that the asteroid's band 2 and 4 detections are at a unique position compared to its bands 1 and 3 position. Thus, Catalog criteria of 2+1 fails. However, the less stringent 1+1 Archive criteria can still be met and asteroids are usually

2 unique entries in the Archive: one entry having band 1 and 3 data and the second entry (at a slightly different position) with band 2 and 4 data.

4.2 Astrometric Accuracy

Sources bright enough to have 2MASS associations are typically within 0.3″ of the corresponding 2MASS position, as discussed in §5.1. Figure 3 shows a comparison of GLIMPSEI source positions to the 2MASS PSC positions, in 0.05″ bins, for a one degree longitude, two degree latitude area in the GLIMPSEI survey. The peak of the plot is at 0.2″ and the majority of the sources have positional differences less than 0.3″ , similar to the GLIMPSEI v1.0 source lists. Fainter GLIMPSEI sources are likely to have larger errors due to poorer centroiding. See Section VII of the GQA for a more detailed discussion of positional accuracy.

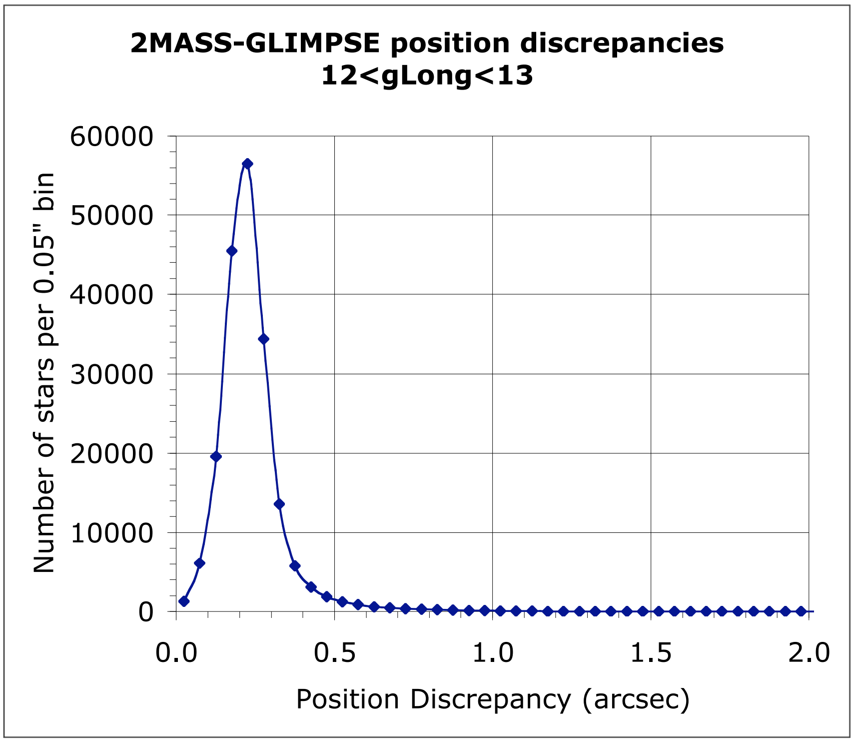


Figure 3: Comparison of GLIMPSEI source positions to their corresponding 2MASS PSC positions from sources of longitudes between 12 and 13 degrees and latitudes ± 1 degrees. The astrometric discrepancy plotted is the angular separation in arcseconds between the GLIMPSEI position and the 2MASS position. Note that sources with 2MASS associates have GLIMPSEI 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.

4.3 Photometric Accuracy

Photometric accuracy was originally verified with simulated images consisting of known point source fluxes placed on residual images (IRAC images with point sources removed giving realistic backgrounds). The point source accuracy depends on background level. A table of photometric accuracy as a function of background level is given in the Addendum to the GLIMPSE Validation Report (http://www.astro.wisc.edu/glimpse/addendum4.pdf). For average background levels, the photometric accuracy is $\leq 0.2^m$ at magnitudes brighter than $\sim 14, \sim 12, \sim 10.5, \sim 9.0$ for bands 1 - 4 respectively.

Our goal was to achieve point source photometry accuracy of ≤0.2 mag. Table 1 shows a summary of the fraction of sources in both the Catalog and Archive that achieve this level. Band 3 shows a higher percentage of sources with photometric accuracy >0.2 mag, probably due to its lower sensitivity. Band 2 shows a higher percentage of sources with photometric accuracy >0.2 mag compared to band 1, most likely due to our selection criteria (§3.2). For the Catalog, band 1 is almost always the band with the "2" in our "2+1" criteria. The signal-to-noise for the band with 2 detections is required to be greater than 5. Therefore a smaller percentage of band 1 sources with photometric accuracy >0.2 mag will be in the Catalog. Similarly, the Archive requires two detections in any band. The two detections are often band 1 detections with the signal-to-noise required to be greater than 5.

Table 1. Photometric Accuracy of the GLIMPSEI Sources

Band (μm)	[3.6]	[4.5]	[5.8]	[8.0]
Catalog				
No. with error >0.2 mag	246861	3546719	2917697	1069064
Total number of entries	30985240	30476282	12377561	7309529
% with errors >0.2 mag	0.8	11.6	23.6	14.6
Archive				
No. with error >0.2 mag	1152849	10488841	3429636	1232235
Total number of entries	48410563	40847634	13227218	7817077
% with errors >0.2 mag	2.4	25.7	25.9	15.8

Photometric accuracy was further verified by comparison with more than 250 flux calibrators distributed throughout the GLIMPSEI survey region. The flux predictions were supplied by Martin Cohen. These calibrators span a wide range of fluxes in each IRAC band. The techniques used to produce the flux predictions are described in Cohen et al. (2003). Figure 4 shows the agreement between the GLIMPSEI magnitudes and the predicted magnitudes. Uncertainties in both the extracted and predicted magnitudes were added in quadrature to produce the plotted error bars. Figure 4 shows that there do not appear to be any large systematic errors related to, e.g. flux levels or spectral type. Table 2 gives details about the number of flux calibrators used for each band (varies due to saturation and partial coverage on the survey boundaries), average differences (GLIMPSEI magnitude minus the predicted magnitude), and RMS errors.

Table 2. Comparison of Flux Calibrators to Predicted Magnitudes

Band (μm)	[3.6]	[4.5]	[5.8]	[8.0]
No. Flux calibrators	123	140	245	242
Ave. [Observed-Predicted] mag	0.024244	0.045229	0.013086	-0.000269
RMS error	0.071454	0.058485	0.049828	0.055844

Although Figure 4 shows a degree of scatter (typically 0.05 mags, see "RMS error" in Table 2), this seems reasonable when compared to the plotted errors in Figure 4. The exception may be IRAC band 4 where the plotted errors appear to be a bit small. Error assessment is being studied by

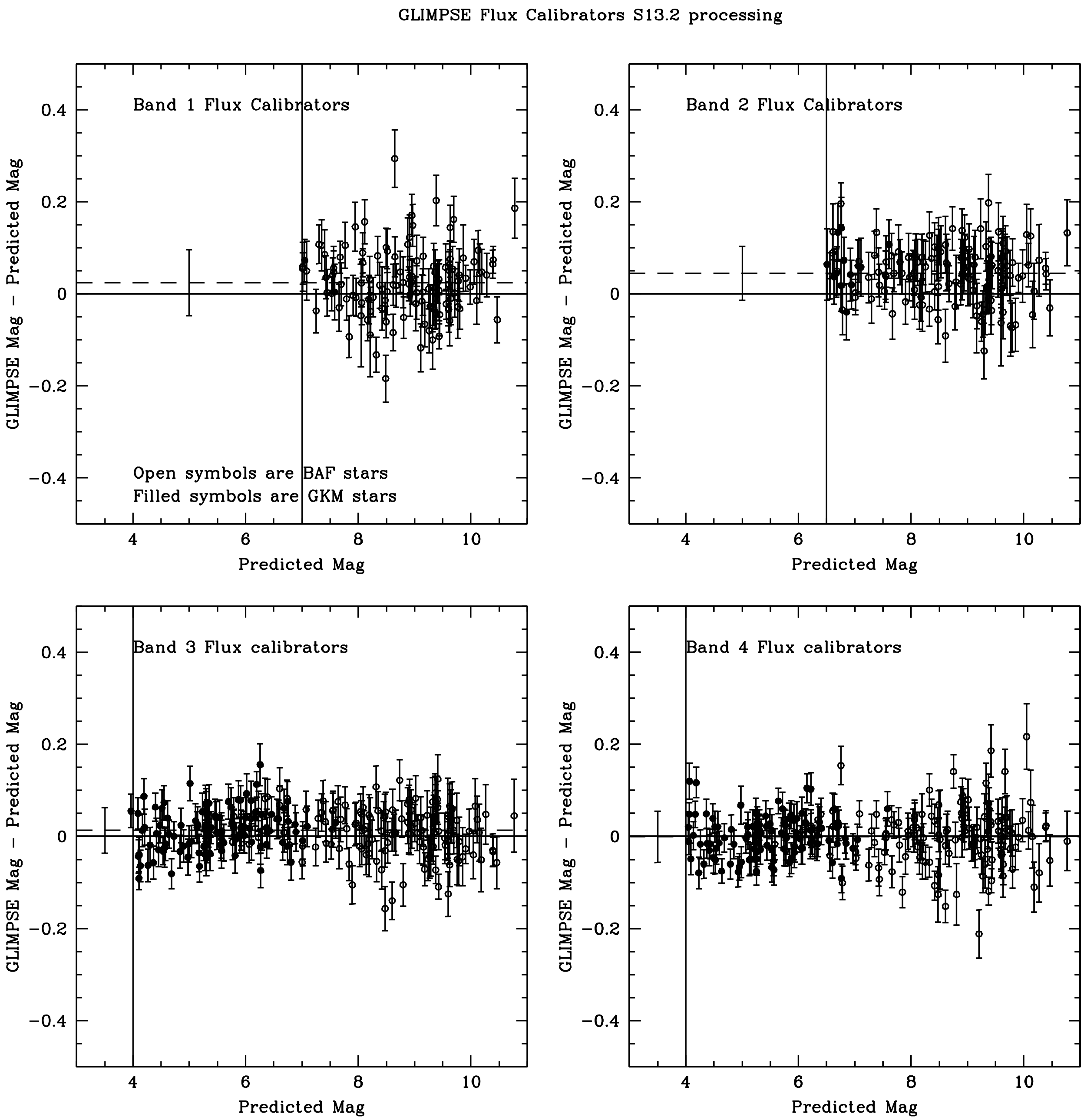


Figure 4: Comparison of GLIMPSEI flux calibrators to predictions provided by Martin Cohen for each IRAC band. Error bars are the root-sum-of-squares of the errors of both the extracted and predicted magnitudes for each source. The vertical lines are the best estimates of the saturation limits. Filled circles are spectral types B, A, and F; open circles are spectral types G,K, and M. No discernible spectral type dependence is seen in these data. The left most error bar in each of the 4 panels shows the RMS of the GLIMPSEI mag - Predicted mag. The dashed line represents the average GLIMPSEI mag - Predicted mag.

comparing the quoted error (dF_i) with the RMS of the error (F_i_rms). From initial studies bands 2 and 4 appear to be the most systematically off. Band 2 errors appear to be systematically too large by about 10%. Band 4 errors are too small. Empirically the band 4 error *correction* appears to be related to the background level as well as the quoted error. The average band 4 error correction is around +20%, (i.e. df_b4'=df_b4*1.2) but ranges from about 0.8 to 2.0. Likewise there may be small corrections for bands 1 and 3. No corrections have been applied to the data, but we will make recommendations for corrections when our study is completed.

4.4 Color-Color and Color-Magnitude Plots

Color-color and color-magnitude plots were made of each Catalog and Archive Table (in approximately $1^\circ \times 2^\circ$ regions). An example set of color-color and color-magnitude plots is shown in Figures 5 and 6, respectively. The color-color plots generally show a peak near 0 color due to main sequence and giant stars, and a red tail corresponding to the large variety of stars with circumstellar dust and possibly galaxies. The color-magnitude plots can be used to show the limiting magnitudes where the flux errors become large and the colors begin to show large deviations. This is not apparent in Figure 6 which demonstrates that our fluxes are accurate at the faint end. Postscript files of the color-color and color-magnitude plots for each degree of longitude in the GLIMPSEI survey are available from the GLIMPSE web site (http://www.astro.wisc.edu/glimpse/v2.0/ColorColor/ and http://www.astro.wisc.edu/glimpse/v2.0/ColorMag/).

4.5 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. The l=13°-14°, l=43°-44° and l=300°-301° Catalogs and Archives were run through our SED grid and fitter (§5.4, Robitaille et al. 2006, 2007). using a large grid of stellar atmosphere models. Four data points were required for the fit. About >98% (Archive) and >99% (Catalog) of the sources were well-fit within the χ^2 per datapoint < 3 and are therefore likely valid data. The remaining <1% (Catalog) and <2% (Archive) sources were examined individually and we found that about 1/2 to 2/3 of the sources have a datapoint that is questionable (due to bad or mismatched IRAC or 2MASS fluxes, or variability between IRAC and 2MASS; Robitaille et al. 2007, submitted). The rest are real sources not well fit by stellar atmospheres, e.g. dusty Young Stellar Objects and evolved stars. As another sanity check, the values of the Source Quality Flag were plotted as a function of source position. No obvious problems were apparent.

5 Data Products Description

5.1 Catalog and Archive Fields and Flags

Each entry in the GLIMPSEI v2.0 Catalog and Archive has the following information:

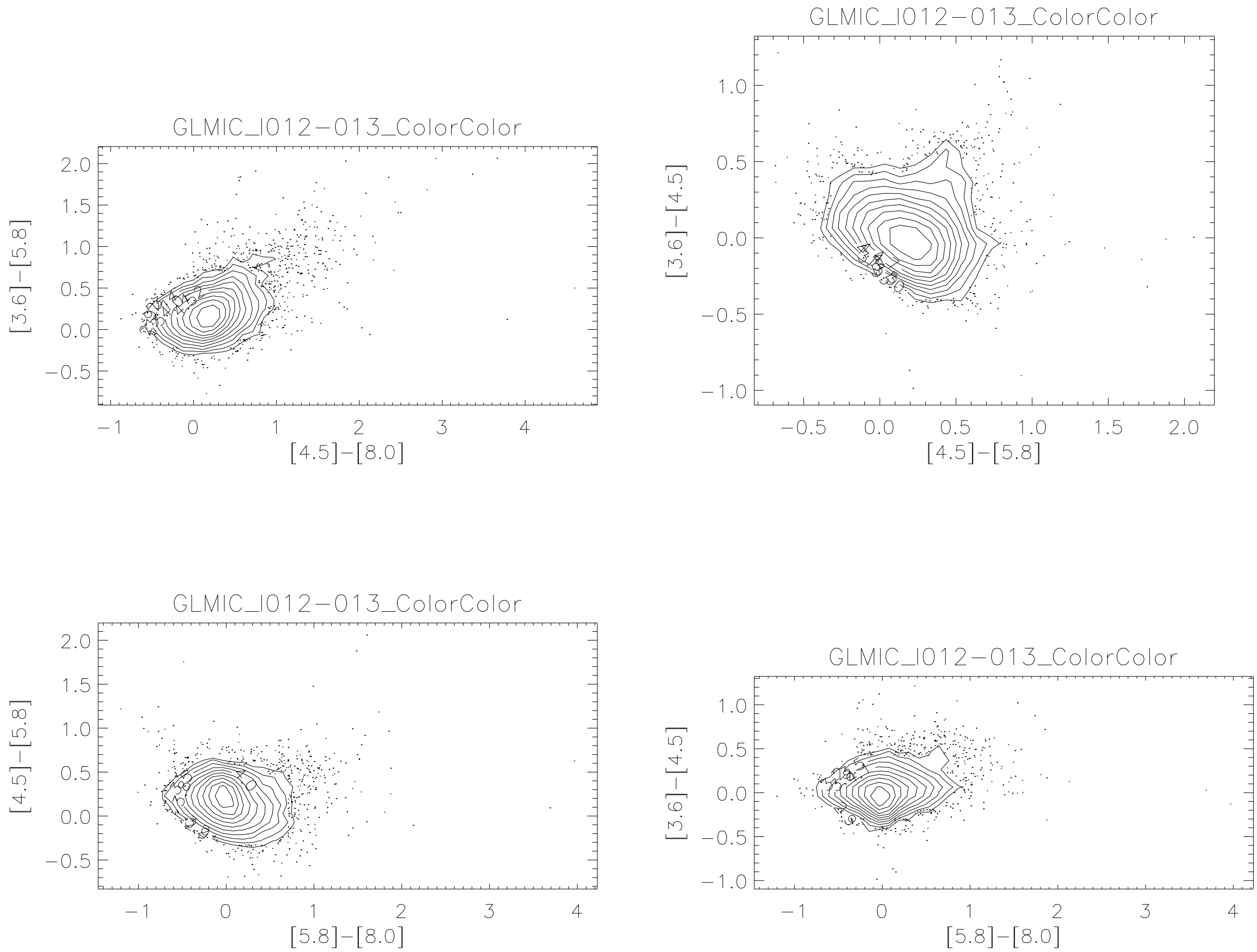


Figure 5: Color-color plots of the region $l = 12 - 13°$ and $|b| < 1°$ for sources in the Catalog. 10 contours are evenly spaced between log(# sources/mag^2)=2.0 and the log of maximum number of sources per square magnitude. The contours are labeled with the log of the number of sources per square magnitude. Outside of the lowest contour, the positions of individual sources are plotted.

designation	SSTGLMC GLLL.llll±BB.bbbb, SSTGLMA 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 1 - 4) (3.6 μm, 4.5 μm, 5.6 μm and 8.0 μm) and t is the 2MASS wavelength band (J, H, K$_s$). Details of the fields are as follows:

Designation

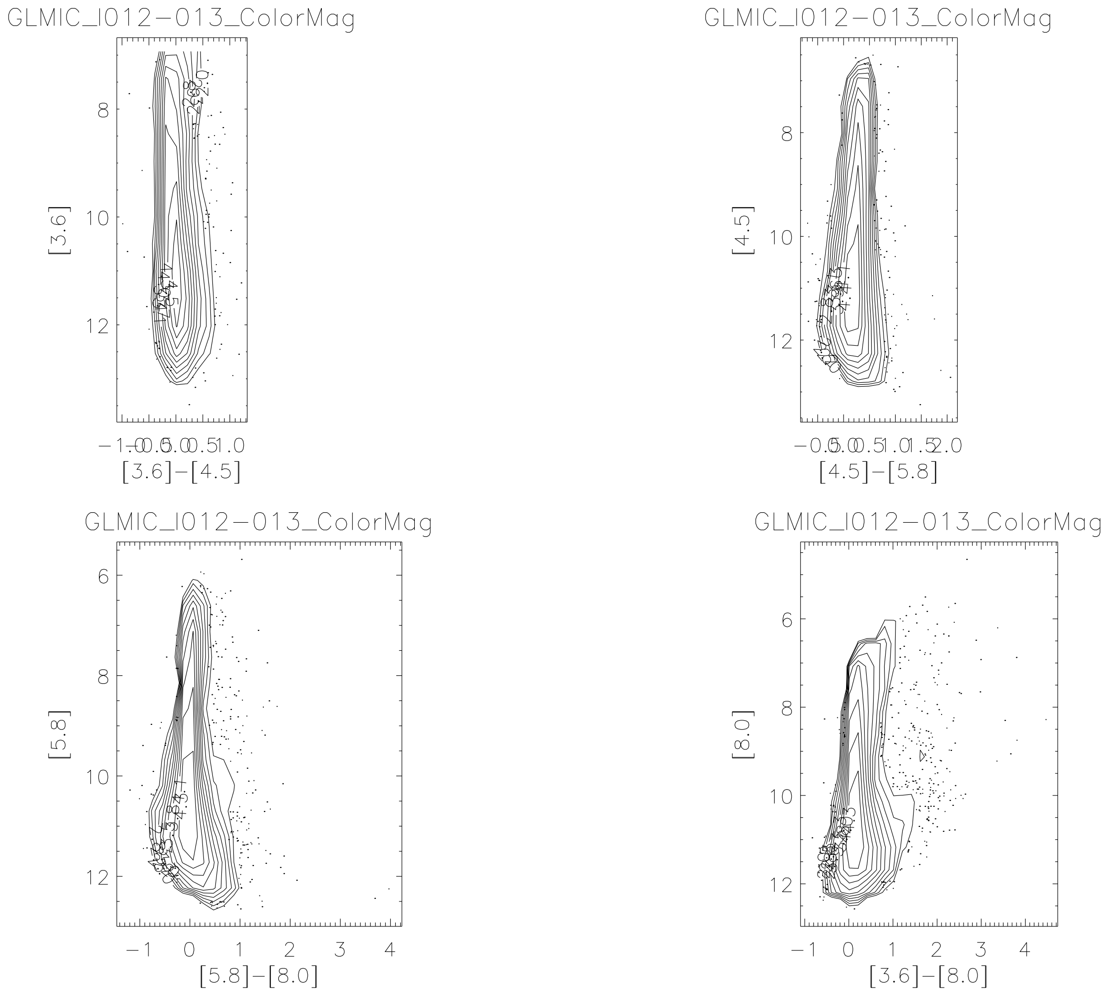


Figure 6: Color-magnitude plots of the region $l = 12 - 13°$ and $|b| < 1°$ for sources in the Catalog. 10 contours are evenly spaced between log(# sources/mag^2)=2.0 and the log of the maximum number of sources per square magnitude. The contours are labeled with the log of the number of sources per square magnitude. Outside of the lowest contour, the positions of individual sources are plotted.

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 SSTGLMC (GLIMPSEI Catalog) or SSTGLMA (GLIMPSEI Archive).

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 http://pegasus.phast.umass.edu/ipac_wget/releases/allsky/doc/sec2_2a.html for more information about these fields.

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[15] 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 GLIMPSEI 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.

Flux

For each IRAC band i = 3.6, 4.5, 5.6, and 8.0 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 for the S13.2 and later SSC processing versions are from Reach et al (2005) for the IRAC bands and Cohen et al. 2003 for 2MASS and given in Table 3.

Table 3. 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; $dmag_i$) are computed during the photometry stage and take into account photon noise, readnoise, goodness of flat fielding, and PSF fitting (Stetson 1987). Magnitude uncertainties are typically <0.2 mag for the Catalog and < 0.3 mag for the Archive. The uncertainties are smaller in bands 1 and 2 than bands 3 and 4 due to lower backgrounds in bands 1 & 2 and the lower sensitivity of the band 3 detector. Table 1 shows the percentages of sources meeting the 0.2 mag accuracy criterion.

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.

Diagnostics

The associated flux diagnostics are a local background level (sky_i) (i = 3.6, 4.5, 5.6, and 8.0 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 local background, an output of DAOPHOT, is provided because high backgrounds were shown to affect the reliability of IRAS sources, and for IRAC as well (especially bands 3 and 4) (see the GQA document). However, the effects may not be easily characterizable in the quoted error. The

[15] http://ssc.spitzer.caltech.edu/postbcd/pointingrefine.html

Signal/Noise is the flux (F_i) divided by the flux error (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 than twice per band.

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 (see Section VIII of the GQA) 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 $\sim$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. We are continuing to study the effects of various SQF bits on data quality.

Table 4 shows the SQF sequence for the GLIMPSEI v2.0 data release. The stray light flag has been implemented for this data release. We have determined that false sources from such regions do not make it into the Catalog due to our 2+1 source selection criterion (§3.2). In addition, our photometry algorithm was modified substantially to find sources in high background regions that gives it the ability to find sources in stray light and banded regions as well, increasing the photometric uncertainties accordingly.

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 B.

Table 4. Source Quality Flag (SQF) Bits

SQF bit	Description	Origin
1	poor pixels in dark current	SSC pmask
2	flat field questionable	SSC dmask
3	latent image[a]	SSC dmask
3	persistence (p)	2MASS
4	photometric confusion (c)	2MASS
7	muxbleed correction applied	GLIMPSE
8	hot, dead or otherwise unacceptable pixel	SSC pmask,dmask,GLIMPSE
9	muxbleed correction applied is $> 3\sigma$ above bkg	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
16	banding corrected	GLIMPSE
17	stray light	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	GLIMPSE
30	within three pixels of edge of frame	GLIMPSE

[a]Due to the short exposure time and high sky backgrounds in the GLIMPSEI fields, we have not seen evidence for latent sources in the images, even though they are flagged via an automatic algorithm in SSC's processing.

• 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 5 defines the values for this flag: value= $2^{(present\_bit-1)} + 2^{(used\_bit-1)}$

Table 5. Flux Calculation Method Flag (MF)

exp (sec)	present bit	used bit
0.6	1	2
2	3	4
12	5	6
30	7	8
100	9	10

This flag is more useful for High Dynamic Range (HDR) mode data which has two frametimes, one of which is not necessarily used (i.e. the 12 second frametime data is not used for the very bright sources). For the 2 second frametime of the GLIMPSEI survey, the method flag always equals 12 ($2^2 + 2^3$).

5.2 GLIMPSEI Image Atlas

The IRAC images are mosaicked using the Montage[16] package 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. The angular size of each tile is $1.1^\circ \times 0.8^\circ$. Three tiles span the latitude range of the survey ($\pm 1.15^\circ$) and 112 span the longitude range (including the OSV region), giving a total of 336 mosaic images in each band to cover the survey region. The pixel size is $0.6''$, smaller than the native IRAC pixel size of $1.2''$. 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 (§6.2) for an example of a FITS header. The mosaicked images are 32-bit IEEE floating point single-extension FITS formatted images and require about 170 GB. We also provide $3.1^\circ \times 2.4^\circ$ FITS files with a pixel size of $1.2''$ for an overview look that covers the full latitude range of GLIMPSEI. There are 164 of these $3.1^\circ \times 2.4^\circ$ mosaics, totalling $\sim$ 42 GB. For a quick-look of the mosaics, we provide 3-color jpeg files (bands 1, 2 and 4) for each area covered by the FITS files. These are rebinned to much lower resolution to make the files small. Note that outside the latitudes of $\pm 1^\circ$ we do not necessarily have full coverage in all four IRAC bands. This can be seen in the jpeg files.

5.3 Web Infrared Tool Shed

The Web Infrared Tool Shed (WITS) (dustem.astro.umd.edu) contains two toolboxes: the Dust Infrared Toolbox (DIRT) and the PhotoDissociation Region Toolbox (PDRT). The toolboxes provide extensive databases of circumstellar shell emission models and PDR emission models. Users input data and retrieve best fit models. DIRT output includes central source and dust shell parameters. PDRT output consists of gas density, temperature, incident UV field and IR line intensities.

Legacy Tools include, for DIRT, a retrievable database of SEDs convolved with IRAC bands, an IRAC specific input GUI (Graphic User Interface), and an extended model base containing embedded high mass stars and low luminosity protostars with and without illumination by an external field. It also includes models with alternate grain models including ice mantles.

Spitzer enhancements to PDRT consist of PDR lines (Si II, Fe II, H_2) useful for Infrared Spectrograph (IRS) observations and interpretation of IRAC PDR emission.

DIRT is based on the radiation transfer code of Wolfire and Cassinelli (1986) that calculates the passage of stellar radiation through a spherical dust envelope. The web interface to DIRT is a JAVA applet which accesses a catalog of pre-run spectral energy distributions. There are currently about 400,000 models on-line. Users can display models with various properties including:

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

Table 6. Ranges of the DIRT Tool

Parameters	Current values	*Spitzer* enhancements
The gas density power law:	0, -0.5, -1.0, -1.5, -2.0	
Stellar Luminosity (L_0):	10,30,50,100,....5×10^5	1e-5,3e-5,5e-5,....1
Effective temperature (K):	3e3,5e3,1e4,3e4,4e4	1e3,1.5e3,2e3,2.5e3,3e3
Outer Shell Radius (cm):	1e14,3e14,5e14,....5e18	1e11,3e11,5e11....5e15
Inner Shell Radius (cm):	1e13 to Outer Radius/10	1e11 to Outer Radius/10
A_V through Shell:	1,3,5,10,....5e3	1,3,5,10,....5e2

The models are displayed in an interactive plot window showing flux versus frequency for a series of models with increasing A_V. Users can change scale, color code models, axes, etc. Users can input observations with error bars and beam sizes and run a χ^2 fit to find the best model. The best fit is overlayed with observations and error bars. Additional details are displayed including the run of gas density and gas temperature, the run of grain temperatures, emitted intensity across model source at various wavelengths, and flux versus beam size for a beam centered on the source at various wavelengths. Flux and source size are scaled to input distance. A *Spitzer* specific interface accepts IRAC and MIPS data input. Models are retrievable and displayed in IRAC band integrated quantities. Model space is searched for the best fit from the input IRAC observations. For each band, plots show model flux versus wavelength (μm) and model surface brightness versus source size ($''$).

PDRT is based on the photodissociation region code of Tielens and Hollenbach 1985 and updated by Wolfire, Tielens, and Hollenbach 1990, Kaufman et al. 1999, and Kaufman et al. 2006. The interface to PDRT allows users to input three or more spectral line observations, with errors, and χ^2 contour plots are generated showing the best fit model parameters to their data set. The output model parameters are the incident ultraviolet radiation field, the gas density, and the gas temperature. In addition, several predicted line intensities are given that match the best fit model. Current lines include the dominant coolants of PDRs including [C II] 158 μm, [O I] 63 μm, and CO (J=1-0), plus several weaker lines that are also observable e.g., [O I] 145 μm, and [C I] 370 μm and 610 μm. Updates to the on-line models include [Si II] 35 μm and [Fe II] 26 μm, H_2 0-0S(0) 28.2 μm, 0-0S(1) 17.0 μm, and 0-0S(2) 12.3 μm, all observable by *Spitzer* IRS. Model results are given for local ISM abundances and for abundances a factor of 3 times higher. These emission lines along with IRAC maps of PDRs may be used to constrain the PDR properties including the distribution and abundance of polycyclic aromatic hydrocarbons (PAHs), as well as the efficiency of grain photoelectric heating.

5.4 YSO Grid and Fitter

To help interpret the many thousands of newly discovered Young Stellar Objects (YSOs) observed by the *Spitzer Space Telescope*, we have developed a tool to fit their Spectral Energy Distributions (SEDs) from a large grid of model SEDs produced by a 2-D radiation transfer code (Robitaille et al. 2006, 2007). Each model includes a central star that illuminates and heats a disk and a rotationally-flattened infalling envelope with bipolar cavities (Whitney et al. 2003a,b, 2004). Our grid includes a reasonably wide range of envelope and disk parameter values at each stellar age and mass to simulate a variety of evolutionary stages. For example, an early stage source is expected to have a high envelope infall rate and narrow bipolar cavities, whereas a later stage source may just have a disk without an envelope; but we allow for a large range of variation in each.

We have made the model YSO grid and SED fitting tool publicly available (http://caravan.astro.wisc.edu/protostars). Our website contains a browser that allows users to examine SEDs from each model for a range of viewing angles and apertures. Various components of each model SED can be viewed, including for example the flux originating from the central star, disk, or envelope, as shown in Figure 7. We have found the grid very useful for exploring how the SED of a YSO is affected by various parameters (e.g. Robitaille et al 2006). Also available on the website are files containing the fluxes in specific filters, e.g. IRAC or MIPS, for all models. Figure 7 shows how these files can be used to produce color-color plots for comparison to data.

Another main section on the website is an interface for our SED fitting tool. The fitting tool uses linear regression to quantify how well each model fits a given set of data. How well a parameter is constrained is determined directly from the range of parameter values for the well-fit SEDs. The online interface to this tool allows users to enter fluxes or magnitudes in specific filters (e.g. IRAC or MIPS), or fluxes at specific wavelengths (e.g. IRS fluxes). Figure 8 shows an example of fits to the SED of the T Tauri star AA Tau using fluxes specified in broadband filters; and to the SED of a massive embedded source, G10.62-0.38, including IRS data. Both figures were generated from the web server.

A new grid of models, including imaging, will be produced in 2007-2008. Feedback is appreciated, and can be made through a form on the website.

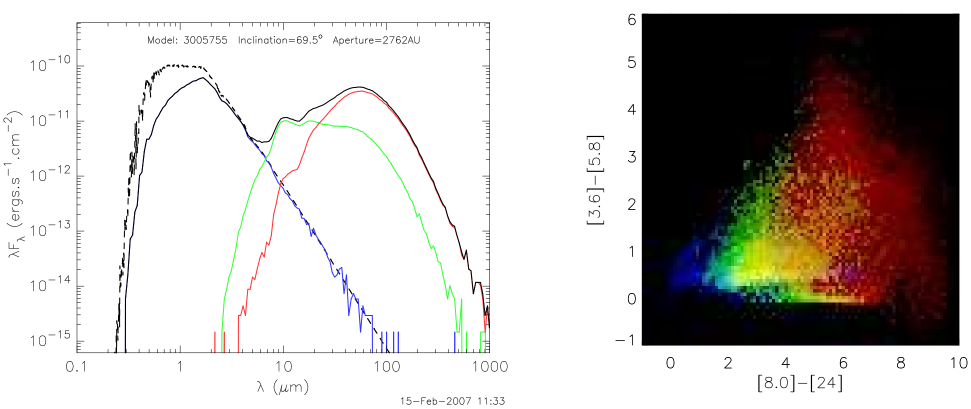
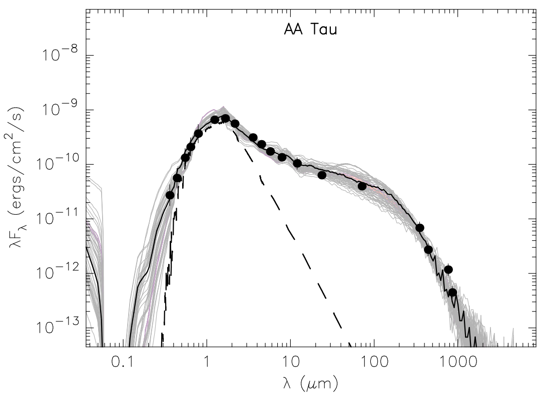


Figure 7: *Left:* A model SED downloaded from the grid browser. The lines show the total spectrum (black), the unextincted stellar atmosphere (dotted line), and flux that originated in the disk (green), envelope (red), and star (blue). *Right:* A color-color diagram produced from the model grid for a star formation region at a distance of 5 kpc. Three stages of evolution are shown in true-color (red: embedded stage, green: optically thick disk stage, blue: optically thin disk). The colors blend in regions occupied by multiple evolutionary stages.



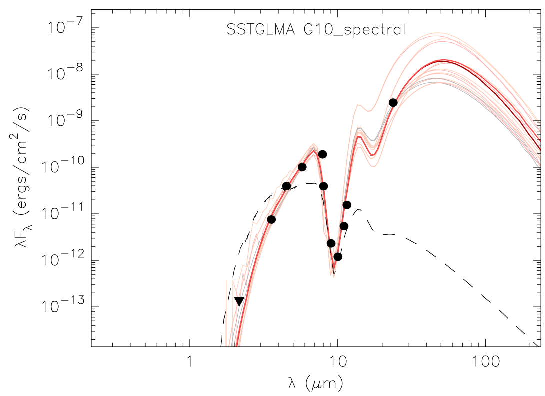


Figure 8: *Left:* Model SED fits (grey lines) to broadband photometry of AA Tau. *Right:* Model fits (colors indicate different apertures) to broadband photometry and a few IRS points for G10.62-0.38. The dashed line shows the extincted input stellar atmosphere.

5.5 Complementary Datasets

Arecibo/GBT: More than 100 IR-color selected H II regions have been observed with the Arecibo 300m and NRAO Green Bank Telescope in the H110α and H_2CO ($1_{10}-1_{11}$) lines to resolve distance ambiguities. The H110α line determines the kinematic distance and the H_2CO ($1_{10}-1_{11}$) absorption line resolves the near-far distance ambiguity. In 2001 this technique was applied as a pilot project at Arecibo to 20 Ultra-Compact (UC) H II regions. Distances were successfully determined for 19 sources (Araya et al. 2002). In 2002 H110α was detected toward 45 UC H II regions and the near-far distance ambiguity resolved for 35 objects; ten were found to lie near the tangent point (Watson et al. 2003). H110α and H_2CO ($1_{10} - 1_{11}$) data have been obtained for an additional 72 compact HII regions using the NRAO GBT telescope.

GRS: Astronomers from Boston University and Five College Radio Astronomy Observatory are collaborating on a ^{13}CO Galactic Ring Survey (Jackson et al. 2006)(www.bu.edu/galacticring). This survey is cataloging molecular clouds and cloud cores, establishing kinematic distances to many clouds and YSOs, determine their sizes, luminosities, and distributions, and determining the distribution of molecular gas in the inner Milky Way, especially that of the 5 kpc ring. Compared with previous molecular line surveys of the inner Galaxy, the GRS offers excellent sensitivity (<0.4 K), higher spectral resolution (0.2 km s^{-1}), comparable or better angular resolution (46$''$) and sampling (22$''$), and the use of ^{13}CO (1-0), a better column density tracer than the commonly observed ^{12}CO (1-0) line.

IGPS: The GLIMPSE survey is complemented by data from the International Galactic Plane Survey, a collaboration of radio astronomers in the US, Canada, and Australia to map the Milky Way disk in the HI 21-cm line (www.ras.ucalgary.ca/IGPS). This survey provides data cubes of the H I spectral line emission with resolution of 1$'$ and one km/s over the entire area of the GLIMPSE survey. It also provides continuum maps of the Stokes *I, Q, U*, and *V* emission. The radio data is valuable for measuring unreddened emission from H II regions, and the H I absorption spectra will help resolve distance ambiguities to many of our sources.

VLA: The Coordinated Radio and Infrared Survey for High-Mass Star Formation (CORNISH) 6 cm VLA survey of the GLIMPSE region is underway. CORNISH has a spatial resolution of $\sim 1.2''$ and a sensitivity of ∼1 mJy (VLA B-configuration). This survey will cover the longitude range l= -20° to

66°, b < |1|°. It will image SNRs, HIIs, PNs and galaxies. Cross-correlation of GLIMPSE mid-Infrared sources with radio sources is expected to provide deeper insight into the physics of many classes of objects in the disk of our Galaxy. See http://www.ast.leeds.ac.uk/Cornish/index.html for more details.

6 Product Formats

6.1 Catalog and Archive

• The Catalog and Archive are broken into 1° (longitude) x 2.3° (latitude) areas for the GLIMPSEI Survey. 115 Catalog files and 115 Archive files have been delivered for the entire survey region and the Observation Strategy Validation area. Each Catalog 1°x 2.3° area has about a third of a million sources and each Archive area has around a half million sources. The Catalog and Archive files are in IPAC Table Format. Filenames are GLMIC_llmin.tbl and GLMIA_llmin.tbl, for the Catalog and Archive respectively (e.g. GLMIC_l306.tbl, GLMIC_l307.tbl, GLMIA_l306.tbl, GLMIA_l307.tbl, etc.) The entries are sorted by increasing Galactic longitude within each file. Due to the nature of the survey mapping, there are areas outside of the nominal GLIMPSEI survey region that were observed. There is a small amount of IRAC coverage from l=9.8° to 10°, l=65°-65.3°, l=294.8°-295°, and l=350°-350.3°. Also we provide whatever sources that were detected from $|b|$ =1.0°to 1.15°.

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

Table 7. Fields in the Catalog and Archive

Column	Name	Description	Units	Data Type	Format	Nulls OK? or Value
1	designation	Catalog (SSTGLMC GLLL.llll±BB.bbbb) Archive (SSTGLMA 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 error in t=J,H,K_s bands	mag	R*4	6F7.3	99.999,99.999
19–26	mag_i,$dmag_i$	Magnitudes & 1σ error in IRAC band i	mag	R*4	8F7.3	99.999,99.999
27–32	F_t,dF_t	Fluxes & 1σ error in t=J,H,K_s bands	mJy	R*4	6E11.3	-999.9,-999.9
33–40	F_i,dF_i	Fluxes & 1σ error 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

• Example of GLMIC entry:

SSTGLMC G056.0001-00.6235 19374305+2006172 1245819487 56.000161 -0.623589 0.3 0.3
294.429402 20.104790 0.3 0.3 0 14.045 0.053 12.942 0.065 12.565 0.033
12.405 0.065 12.355 0.116 12.098 0.099 12.181 0.132
3.841E+00 1.875E-01 6.816E+00 4.080E-01 6.280E+00 1.909E-01
3.066E+00 1.835E-01 2.053E+00 2.186E-01 1.665E+00 1.514E-01 8.601E-01 1.043E-01
2.631E-01 8.076E-02 2.244E-02 3.963E-02 9.690E-01 7.490E-01 3.949E+00 1.125E+01
20.49 16.70 32.90 16.71 9.39 10.99 8.25 55.3 36.4 13.0 14.4
2 2 2 2 2 2 2 2 8 8 8 0 16384 0 0 12 12 12 12

The columns in this example are described in Table 8.

Table 8. Example of Catalog/Archive Entry

designation	SSTGLMC G056.0001-00.6235	Name
tmass_desig	19374305+2006172	2MASS designation
tmass_cntr	1245819487	2MASS counter
l,b	56.000161 -0.623589	Galactic Coordinates (deg)
dl,db	0.3 0.3	Uncertainty in Gal. Coordinates (arcsec)
ra,dec	294.429402 20.104790	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	14.045 12.942 12.565	Magnitudes (2MASS J,H,K_s) (mag)
	0.053 0.065 0.033	Uncertainties (2MASS) (mag)
mag,dmag	12.405 12.355 12.098 12.181	Magnitudes (IRAC bands 1-4) (mag)
	0.065 0.116 0.099 0.132	Uncertainties (IRAC) (mag)
F,dF	3.841E+00 6.816E+00 6.280E+00	2MASS Fluxes (mJy)
	1.875E-01 4.080E-01 1.909E-01	Uncertainties in 2MASS fluxes (mJy)
F,dF	3.066E+00 2.053E+00 1.665E+00 8.601E-01	IRAC Fluxes (mJy)
	1.835E-01 2.186E-01 1.514E-01 1.043E-01	Uncertainties in IRAC fluxes (mJy)
F_rms	2.631E-01 8.076E-02 2.244E-02 3.963E-02	RMS_flux (mJy) (IRAC)
sky	9.690E-01 7.490E-01 3.949E+00 1.125E+01	Sky Bkg (MJy/sr) (IRAC)
SN	20.49 16.70 32.90	Signal to Noise (2MASS)
SN	16.71 9.39 10.99 8.25	Signal to Noise (IRAC)
srcdens	55.3 36.4 13.0 14.4	Local Source Density (IRAC) (#/sq arcmin)
M	2 2 2 2	Number of detections (IRAC)
N	2 2 2 2	Number of possible detections (IRAC)
SQF	8 8 8	Source Quality Flag (2MASS)
SQF	0 16384 0 0	Source Quality Flag (IRAC)
MF	12 12 12 12	Flux Calculation Method Flag (IRAC)

6.2 GLIMPSEI 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.

The mosaic images are each 1.1°x 0.8° (6640 x 4840 0.6″ pixels). Each file is about 128 Megabytes in size. There are three mosaics per one degree galactic longitude interval with 0.05° overlap between mosaics. For example, for the Galactic longitude of 308°, the centers of the three mosaics are (308.5°, +0.75°), (308.5°, 0.0°), and (308.5°, -0.75°). The longitude range is 307.95° to 309.05° for each of the three mosaics. The latitude ranges are 0.35° to 1.15°, -0.40° to +0.40°, and -1.15° to -0.35°. 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 channel number. For example, GLM_30850+075_mosaic_I1.fits is a 1.1°x 0.8° IRAC channel 1 mosaic centered on l=308.50°, b=0.75°. We provide low-resolution 3-color jpeg images for each 1.1°x 0.8° area, combining bands 1, 2, and 4 to be used for quick-look purposes. The filename for this jpeg file is similar to the mosaic FITS file: e.g. GLM_30850+0075.jpg. We also provide 3.1°x 2.4° mosaic FITS files (9320 x 7220 1.2″ pixels) for each band, along with low resolution 3-color jpegs. Each mosaic is about 270 Megabytes in size. The filenames are similar to the other FITS and jpeg images: e.g. GLM_02700+0000_mosaic_I1.fits, GLM_02700+0000_3x2.jpg.

Here is an example of the FITS header for the 1.1°x 0.8° GLM_30850+0000_mosaic_I1.fits:

```
SIMPLE  =                    T / file does conform to FITS standard
```

```
BITPIX  =                  -32 / number of bits per data pixel
NAXIS   =                    2 / number of data axes
NAXIS1  =                 6640 / length of data axis 1
NAXIS2  =                 4840 / 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= 'S13.2.0 '           / SSC pipeline that created the BCD
PIPEVERS= '1v04    '           / GLIMPSE pipeline version
MOSAICER= 'Montage V2.2'       / SW that originally created the Mosaic Image
FILENAME= 'GLM_30850+0000_mosaic_I1.fits' / Name of associated fits file
PROJECT = 'FSURVEY '           / Project ID
FILETYPE= 'mosaic  '           / Calibrated image(mosaic)/residual image(resid)
CHNLNUM =                    1 / 1 digit Instrument Channel Number
DATE    = '2006-08-27T21:06:33' / file creation date (YYYY-MM-DDThh:mm:ss UTC)
COMMENT --------------------
COMMENT Proposal Information
COMMENT --------------------
OBSRVR  = 'Ed Churchwell'      / Observer Name
OBSRVRID=                   90 / Observer ID of Principal Investigator
PROCYCLE=                    2 / Proposal Cycle
PROGID  =                  190 / Program ID
PROTITLE= 'The SIRTF Galactic Plane Surve' / Program Title
PROGCAT =                   27 / Program Category
COMMENT ----------------------------
COMMENT Time and Exposure Information
COMMENT ----------------------------
SAMPTIME=                  0.2 / [sec] Sample integration time
FRAMTIME=                  2.0 / [sec] Time spent integrating (whole array)
EXPTIME =                  1.2 / [sec] Effective integration time per pixel
COMMENT DN per pixel=flux(photons/sec/pixel)/gain*EXPTIME
AFOWLNUM=                    4 / Fowler number
COMMENT --------------------
COMMENT Pointing Information
COMMENT --------------------
CRPIX1  =            3320.5000 / Reference pixel for x-position
CRPIX2  =            2420.5000 / Reference pixel for y-position
CTYPE1  = 'GLON-CAR'           / Projection Type
CTYPE2  = 'GLAT-CAR'           / Projection Type
CRVAL1  =         308.50000000 / [Deg] Galactic Longtitude at reference pixel
CRVAL2  =           0.00000000 / [Deg] Galactic Latitude at reference pixel
EQUINOX =               2000.0 / Equinox for celestial coordinate system
DELTA-X =           1.10666668 / [Deg] size of image in axis 1
DELTA-Y =           0.80666667 / [Deg] size of image in axis 2
BORDER  =           0.00333333 / [Deg] mosaic grid border
```

```
CD1_1   =      -1.66666665E-04
CD1_2   =       0.00000000E+00
CD2_1   =       0.00000000E+00
CD2_2   =       1.66666665E-04
PIXSCAL1=                0.600 / [arcsec/pixel] pixel scale for axis 1
PIXSCAL2=                0.600 / [arcsec/pixel] pixel scale for axis 2
OLDPIXSC=                1.221 / [arcsec/pixel] pixel scale of single IRAC frame
RA      =         204.92752075 / [Deg] Right ascension at mosaic center
DEC     =         -62.34874344 / [Deg] Declination at mosaic center
COMMENT ----------------------
COMMENT Photometry Information
COMMENT ----------------------
BUNIT   = 'MJy/sr  '           / Units of image data
GAIN    =                  3.3 / e/DN conversion
JY2DN   =           314754.031 / Average Jy to DN Conversion
ETIMEAVE=               1.2000 / [sec] Average exposure time
PA_AVE  =               -39.85 / [deg] Average position angle
ZODY_AVE=             -0.00317 / [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=          0.450565249 / Average MJy/sr to DN/s Conversion
COMMENT -----------------------------
COMMENT AORKEYS/ADS Ident Information
COMMENT -----------------------------
AOR001  = '0009229056'         / AORKEYS used in this mosaic
AOR002  = '0009230848'         / AORKEYS used in this mosaic
AOR003  = '0009228544'         / AORKEYS used in this mosaic
AOR004  = '0009235200'         / AORKEYS used in this mosaic
AOR005  = '0009233664'         / AORKEYS used in this mosaic
DSID001 = 'ads/sa.spitzer#0009229056' / Data Set Identification for ADS/journals
DSID002 = 'ads/sa.spitzer#0009230848' / Data Set Identification for ADS/journals
DSID003 = 'ads/sa.spitzer#0009228544' / Data Set Identification for ADS/journals
DSID004 = 'ads/sa.spitzer#0009235200' / Data Set Identification for ADS/journals
DSID005 = 'ads/sa.spitzer#0009233664' / Data Set Identification for ADS/journals
NIMAGES =                  341 / 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_30850+0000_mosaic_I1.hdr includes:

```
COMMENT ----------------------------------------
COMMENT Info on Individual Frames in Mosaic
COMMENT ----------------------------------------
IRFR0001= 'SPITZER_I1_0009229056_0027_0000_03_levbflx.fits' / IRAC frame
DOBS0001= '2004-03-10T06:25:08.534' / Date & time at frame start
```

```
MOBS0001=      53074.265625000 / MJD (days) at frame start
RACE0001=           203.723312 / [Deg] Right ascension at reference pixel
DECC0001=           -62.349380 / [Deg] Declination at reference pixel
PANG0001=               -38.73 / [deg] Position angle for this image
FLXC0001=              0.10880 / Flux conversion for this image
ZODY0001=             -0.00343 / [MJy/sr] ZODY_EST-SKYDRKZB for this image
IRFR0002= 'SPITZER_I1_0009229056_0033_0000_03_levbflx.fits' / IRAC frame
DOBS0002= '2004-03-10T06:26:52.534' / Date & time at frame start
MOBS0002=      53074.269531250 / MJD (days) at frame start
RACE0002=           204.055511 / [Deg] Right ascension at reference pixel
DECC0002=           -62.538837 / [Deg] Declination at reference pixel
PANG0002=               -39.03 / [deg] Position angle for this image
FLXC0002=              0.10880 / Flux conversion for this image
ZODY0002=             -0.00342 / [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 339
.
IRFR0340= 'SPITZER_I1_0009235200_0030_0000_03_levbflx.fits' / IRAC frame
DOBS0340= '2004-03-10T08:53:56.826' / Date & time at frame start
MOBS0340=      53074.371093750 / MJD (days) at frame start
RACE0340=           205.460785 / [Deg] Right ascension at reference pixel
DECC0340=           -62.307793 / [Deg] Declination at reference pixel
PANG0340=               -40.38 / [deg] Position angle for this image
FLXC0340=              0.10880 / Flux conversion for this image
ZODY0340=             -0.00304 / [MJy/sr] ZODY_EST-SKYDRKZB for this image
IRFR0341= 'SPITZER_I1_0009235200_0019_0000_03_levbflx.fits' / IRAC frame
DOBS0341= '2004-03-10T08:50:46.029' / Date & time at frame start
MOBS0341=      53074.367187500 / MJD (days) at frame start
RACE0341=           204.842224 / [Deg] Right ascension at reference pixel
DECC0341=           -61.966595 / [Deg] Declination at reference pixel
PANG0341=               -39.84 / [deg] Position angle for this image
FLXC0341=              0.10880 / Flux conversion for this image
ZODY0341=             -0.00307 / [MJy/sr] ZODY_EST-SKYDRKZB for this image
```

6.3 Web Infrared Tool Shed

The output from PDRT is in the form of contour plots in FITS, postscript, or GIF format. Pre-generated diagnostic plots as well as plots with observation overlays can be downloaded directly from the web interface. The model output from DIRT can be downloaded as ASCII tables directly from the web interface.

6.4 YSO Grid and Fitter

Models from the YSO grid are available as ASCII SEDs and postscript plots. In addition, the ASCII input files are available for each model, if the user wishes to run our publicly available radiation transfer code. Fitter fluxes from all the models are available in ASCII format. Results from the SED fitter are in the form of postscript files.

7 APPENDIX A - Improvements/Fixes in the v2.0 Data Products

A.1 Main improvements in the SSC processing versions S13.2 and later

The GLIMPSEI version 1.0 data release used data processed by SSC pipeline versions S9.5.0, S10.0.1, S10.0.3 and S10.5.0. The v2.0 data products uses SSC pipeline processing versions S13.2 and later. The S13.2 and later processings have two important improvements. First, the absolute flux calibration has been updated to reflect the results described in the IRAC calibration paper (Reach et al. 2005). Second, "super-boresight" pointing refinement was implemented, improving the pointing accuracy for bands 3 and 4 as well as removing positional offsets between the IRAC channels. Better positions result in crisper mosaics and more accurate bandmerging of sources. Other improvements in SSC processing S13.2 include new linearity corrections for band 3 and using a "super-skyflat" for the flat fielding. The dark drift correction, which removes vertical striping (jailbar effect) in the data, was applied to only band 3 in the S13.2 processing but it was later found that the dark drift correction was needed for the other three bands. SSC processing version S14.0 rectified this problem. We applied a jailbar correction[17] to bands 1, 2 and 4 frames if they were processed by the S13.2 pipeline. See the IRAC pipeline history log at http://ssc.spitzer.caltech.edu/archanaly/plhistory/irac.html for more details about the SSC processing versions.

A.2 Improvements/Fixes in the GLIMPSEI processing affecting *mosaic images*

Muxbleed and Banding corrections
In the v1.0 processing, we did not apply a muxbleed correction but did apply banding corrections for bands 3 and 4. The GLIMPSEI v2.0 pipeline processing applied a muxbleed correction and a better banding correction for band 3. The muxbleed correction improved about 90% of the pixels affected by muxbleed. The quality of the mosaic images is improved by the mitigation of these instrument artifacts.

Zodiacal light problem
There was a zodiacal light subtraction problem for GLIMPSEI v1.0 images for l=350° through 295° (-10° through -65°). We subtracted the zodiacal light background from the frames incorrectly. Our pipeline calculated a zodiacal light background, based on Ned Wright's model (Wright 1998), as modified by Mark Wolfire. We subtracted that value from each IRAC frame. But part of the *Spitzer* Space Telescope's processing is to subtract a DARK from the BCD frame. Included in that DARK is a zodi component. Starting with S10.0 processing, the zodi component of the DARK was in the FITS header as SKYDRKZB. SSC calculates its own zodiacal light value (ZODY_EST). What we should have done is subtract (ZODY_EST - SKYDRKZB) from the image. The result is we had oversubtracted the zodi. This has a smaller affect on the images because of our high backgrounds. This was fixed for the v1.0 l=10° through 65° mosaics and in the v2.0 processing.

[17] http://ssc.spitzer.caltech.edu/irac/jailbar/

Addition of an associated .hdr file; Keywords Changes in the FITS Header
The v1.0 mosaic FITS file header included information about each IRAC frame, as well as other standard information (pointing, photometry) found in a FITS header. This made the FITS header very large. We removed the information about the IRAC frames (filename, date of observation, etc.) from the FITS header and created an associated ASCII .hdr file containing that information as well as all the keywords in the FITS header. The keywords EQUINOX, DELTA-X, DELTA-Y, PA_AVE, and ZODY_AVE were added to the FITS header. Keywords RACEnnnn, DECCnnnn, PANGnnnn (central position and position angle) were added to the information given for each IRAC frame, found in the .hdr file. The keyword SEGNAME was removed from the FITS header. See §6.2 for an example of the v2.0 FITS header and the associated .hdr file.

A.3 Improvements/Fixes in the v2.0 processing affecting the *source lists*

Muxbleed and Banding corrections
Applying a muxbleed correction results in fewer false sources detected. The better banding correction for band 3 provides a more uniform background for the source extraction.

Zodiacal light subtraction problem fixed
The over-subtraction of the zodiacal light in the v1.0 data release, discussed above, doesn't affect the photometry but the local sky background value given in the source lists is affected by this problem for all entries in the v1.0 source lists.

Source extraction improvements
The GLIMPSEI v2.0 photometry contains several improvements over the initial GLIMPSEI photometry. SSC BCD images have the estimated zodical light subtracted from it. This fact was not taken into account in determining the appropriate 3-sigma detection level for the initial GLIMPSEI photometry. Reprocessed photometry takes this into account and produces source lists that are less prone to false detections. Initial GLIMPSEI photometry was done using point source functions (PSFs) that were empirically derived from a single image containing several well sampled point sources. The PSFs were determined for several IRAC campaigns containing GLIMPSEI data and determined to be stable. For GLIMPSEI v2.0 processing photometry, a single PSF (per band) comprised from a composite of many well sampled point sources was used. Also for bands 3 and 4 that suffer electronic bandwidth effects (a decaying brightness every 4th pixel from the brightest point sources), the effects of the electronic bandwidth pixels were mitigated to improve the overall PSF for those two bands.

2MASS J, H, and K$_s$ fluxes delivered, when available, with the IRAC data
We provided only the IRAC magnitudes in our version 1.0 source lists. In the version 2.0 release we have bandmerged the IRAC data with the 2MASS All-Sky Point Source Catalog. If a 2MASS source is found to be associated with the IRAC source, in addition to the IRAC information we provide 2MASS identification names, fluxes, signal-to-noise and a limited Source Quality Flag. The user can refer back to the 2MASS PSC using the 2MASS identification for the complete information about the source.

Close Source Flag Implemented
The Confusion Flag in the v1.0 source lists had not been implemented. In the v2.0 data release this flag is renamed the Close Source Flag and is set when a source in the Archive is within 3.0$''$ of the source. It was found (see Section VIII of the GQA) that the magnitudes of a source with nearby sources closer than about 2$''$ are not reliably extracted and bandmerged. See §5.1 for details about this flag. We cull sources from the Archive and Catalog based on this flag. We have found it one of

the most useful improvements to our source lists as it removes problematic objects from our lists.

More Information Included in the Source Quality Flag
Sources within 3 pixels of a stray light area or a muxbleed corrected region are now flagged in the Source Quality Flag. See Table 4 and Appendix B for more details.

Improved Saturated Star Wing Shape
In the v1.0 data release we had a circular mask with a width of 24 pixels surrounding each saturated source. Sources within 3 pixels of these areas were culled from the Catalog. For the v2.0 release we have a PSF-shaped region which more accurately reflects the area affected by the diffraction spikes of the saturated source. Thus fewer sources are culled from the Catalog.

Photometric Correction as a Function of Position of the Source in the IRAC frame
The v1.0 source lists did not have this correction applied. SSC recommends that this correction be applied to give an improvement of up to 10% peak-to-peak in the flux calibration. The effect is lower with the half-step observing strategy of GLIMPSEI.
See http://ssc.spitzer.caltech.edu/irac/locationcolor/ for more details about this correction.

In-band and cross-band lumping of sources
Sources in the same IRAC frame within a radius of $2.0''$ are merged into one source before band-merging. Cross-band lumping is also done with a $2.0''$ radius. In the v1.0 source lists there was limited in-band lumping and no cross-band lumping. In-band and cross-band lumping was implemented for the v2.0 source lists. This was done to reduce the instances of flux splitting and multiple sources. Bits were added to the Source Quality Flag to track which data have been lumped. See the discussion of bits 21 and 22 in Appendix B for more details.

Source list criteria modifications
We consider the 2MASS K_s magnitude a detection (a "1") in our source list criteria. In the "2+1" Catalog criteria, K_s is used with band 1 to determine if it is a source worthy of the Catalog (see §3.2). In the "1+1" Archive criteria, K_s is used with any band to determine if it is a source to be included in the Archive. For band 2, the faint flux limit (used for the Catalog) was changed from the more conservative 0.6 mJy in the v1.0 source lists to the original result, 0.4 mJy (see Section V of the GLIMPSE Quality Assurance Document http://www.astro.wisc.edu/sirtf/GQA-master.pdf).

Flux Calculation Method Flag Changed
Since we upgraded our pipeline to process HDR mode data which has two exposure times, we changed the definition of this flag to track which frametimes were used in the final flux. It is not that useful for GLIMPSEI which has a frametime of 2 secs. This value should always be 12.

Miscellaneous changes/fixes
Other changes to the v2.0 processing are: we do not null out M & N (defined in §5.1) when there is no flux in the band (i.e. the flux has been nulled), since they still contain useful information. F_i_rms was in the wrong units in our v1.0 source lists. It is now in the proper units (mJy). We truncate the source designation, as per IAU standards, instead of rounding. The longitude position for large galactic longitudes had a "stair stepping" problem where the last digit to the right of the decimal place was incorrect. This has been fixed (it was a 32-bit/64-bit issue).

8 APPENDIX B - Source Quality Flag Bit Descriptions

B.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 4 lists the bits and the origin of the flag (SSC or GLIMPSE pipeline). See http://ssc.spitzer.caltech.edu/irac/products/pmask.html and http://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. Due to the short exposure times (two seconds) and high sky backgrounds in the GLIMPSEI survey we have not seen latent images in the data, even though they are flagged.

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

9 muxbleed correction $> 3\sigma$ above the background (bands 1 & 2)
This bit is set if the source was within 3 pixels of a pixel where there was a muxbleed correction applied which is $> 3\sigma$ above the background.

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

negative flux correction was applied to the DAOPHOT/ALLSTAR extraction value (source was dimmed via aperture photometry as compared to the initial PSF fitted DAOPHOT/ALLSTAR photometry). Sources with both SQF bits 10 and 11 set imply 1) the source was initially under-subtracted, but the aperture photometry over- corrected and thus a second aperture correction was applied or 2) multiple observations in a band 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 (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.

17 stray light area
This bit is set if the source is within 3 pixels of an area of stray light as identified in the GLIMPSE smask file.

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 9 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 2.0″ 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 (GLIMPSEI is nominally a 2-visit survey). 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 2.0″ radius. For example, say there are two sources within 2.0″ of each other. One source has data in bands 1 and 4 and the other has data in bands 2 and 3. These two sources will be lumped into one source with data in all 4 bands.

30 within three pixels of edge of frame
Sources within three pixels of the edge of the IRAC frame are flagged since it is likely to be too

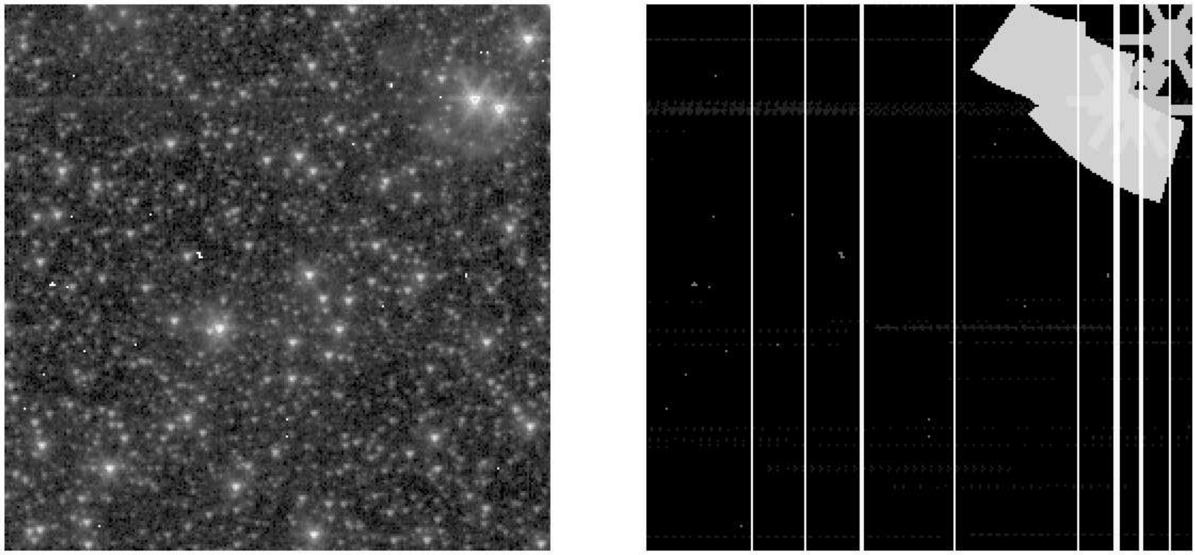


Figure 9: The band 1 IRAC frame (AOR 12110848, exposure 11) is on the left (corrections were applied for muxbleed and column pulldown); the flags for that frame are shown on the right. Stray light masks (SQF bit 17) are seen in the upper right hand corner of the frame. The PSF-shaped areas around the bright sources correspond to SQF bit 20. The vertical lines correspond to where the frame was corrected for column pulldown (SQF bit 15). The horizontal dots show which pixels were corrected for muxbleed (SQF bits 7 and/or 9). 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 these areas.

close to the edge of the frame for accurate photometry to be done. Sources with this bit set are culled from the Catalog.

B.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
http://www.ipac.caltech.edu/2mass/release/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

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.

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 => 104857; 22 => 2097152; 30 => 536870912

For example, the Source Quality Flags in the example in Table 8 are 8 for all three 2MASS bands. This translates to bit 4 being set, which is the photometric confusion flag from the 2MASS PSC. IRAC band 2 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.

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GLOSSARY

2MASS	Two Micron All Sky Survey
BCD	Basic Calibrated Data, released by the SSC
CORNISH	Coordinated Radio and Infrared Survey for High-Mass Star Formation
DIRT	Dust Infrared Toolbox, for data analysis
dmask	A data quality mask supplied by the SSC for the BCD
GBT	Green Bank Telescope (100 m)
GLIMPSE	Galactic Legacy Infrared Midplane Survey Extraordinaire
GLMIC	GLIMPSEI Point Source Catalog
GLMIA	GLIMPSEI Point Source Archive
GPD	GLIMPSE Pipeline Description
GQA	GLIMPSE Quality Assurance
GRS	Galactic Ring Survey (^{13}CO)
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
MSX	Midcourse Space Experiment
NRAO	National Radio Astronomy Observatory
OSV	Observation Strategy Validation
PDR	Photodissociation Region
PDRT	PhotoDissociation Region Toolbox, for data analysis
pmask	A bad pixel mask supplied by the SSC for the BCD
PSF	Point Spread Function
rmask	Outlier (radiation hit) mask
SOM	*Spitzer* Observer's Manual
SSC	*Spitzer* Science Center
SED	Spectral energy distribution
SQF	Source Quality Flag
SST	*Spitzer* Space Telescope
smask	Stray light mask
TBD	To Be Determined
VLA	Very Large Array
YSO	Young Stellar Object
WITS	Web Infrared Tool Shed, for data analysis