GLIMPSEII - v2.0 Data Release

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1 Quick Start

The GLIMPSEI, GLIMPSEII and GLIMPSE3D data products consist of source lists and mosaiced images. There are three types of source lists: a high reliability point source Catalog, a more complete point source Archive and a "More Reliable" point source Archive for the single visit data. The v2.0 GLIMPSEII data products include all epochs of the GLIMPSEII survey region, including the Galactic center data from the General Observer (GO) program GALCEN (PI: Stolovy), as well as GLIMPSEI data at the boundary of the surveys (at l=10° and l=350°). Data products also include single epoch source lists for scientists interested in variables. (These single epoch source lists do not include data from the Galactic center area nor do they include GLIMPSEI data at the l=10 deg and 350 deg boundaries.) These data products are available at the Spitzer Science Center (SSC) and will be available at the Infrared Science Archive (IRSA).

- SSC – http://ssc.spitzer.caltech.edu/legacy/glimpsehistory.html
- IRSA – http://irsa.ipac.caltech.edu/data/SPITZER/

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

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

For scientists who want to immediately use the GLIMPSEII data, §2.1 briefly describes the survey and data products; and §5 describes the source list entries and the images. Based on an error analysis study, we recommend increasing the band 1 uncertainties by 10%, the band 3 uncertainties by 15% and the band 4 uncertainties by 35%. We recommend leaving the band 2 uncertainties as quoted. These corrections typically increase the band 1, 3 and 4 uncertainties by 0.01 magnitudes, < 0.03 magnitudes and < 0.05 magnitudes respectively (see §3.2).

2 GLIMPSEII Survey and Data Products

2.1 Survey Overview

The Galactic Legacy Infrared Midplane 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. 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 GLIMPSEI survey covered a latitude range of $\pm 1°$, and a longitude range of $|l| = 10° - 65°$ (Benjamin et al. 2003). GLIMPSEII imaged longitudes $\pm 10°$ of the central region of the Galaxy. The latitude coverage is $\pm 1°$ from $|l| = 10° to\ 5°$, $\pm 1.5°$ from $|l| = 5° to\ 2°$, and $\pm 2°$ from $|l| = 2° to\ 0°$. GLIMPSEII coverage excludes the Galactic center region l=$\pm$1°, b=$\pm$0.75° observed by the GALCEN GO program (PID=3677). Figure 1 shows the GLIMPSEII coverage. GLIMPSEII had two-epoch coverage for a total of three visits on the sky. The observations consisted of two 1.2 second integrations at each position in the first epoch of data taking (September 2005) and a single 1.2 second integration at each position six months later (April 2006). See Benjamin et al. (2003), Churchwell et al. (2009) and the GLIMPSE web site (www.astro.wisc.edu/glimpse/) for more description of the GLIMPSEII project.

This document describes the data products from the GLIMPSEII Survey. The v2.0 source lists and mosaics include data from all epochs of the GLIMPSEII survey area, the areas overlapping with GLIMPSEI at l=10°and l=350°and the GALCEN GO program data. There are also source lists for each epoch of data (no GLIMPSEI or GALCEN data included). For the epoch 2 single visit data, we produce a "More Reliable" Archive instead of a Catalog (since the Catalog requires two detections in one IRAC band). The v3.5 mosaics have been background and boundary matched (§2.4.2). The organization of this document is as follows: §2 gives an overview of the GLIMPSEII survey and data products; §3 discusses the validation of the source lists; §4 provides a detailed description of the data products; §5 describes the format; and Appendix A gives details about the Source Quality Flag. Since the data processing for these data is very similar to the previous GLIMPSE programs, this description is not repeated here. Please see §3 of the GLIMPSEI v2.0 Data Release document (http://www.astro.wisc.edu/glimpse/glimpse1_dataprod_v2.0.pdf, hereafter GLI Doc) for this discussion.

The differences between the GLIMPSEI v2.0 and GLIMPSEII v2.0 processing are:

- The 2MASS photometric quality flag is now included in our Source Quality Flag (SQF) (see Table 4 and Appendix A).
- The criteria for including a 2MASS source were changed. In GLIMPSEI v2.0 processing, a GLIMPSE source would match to a 2MASS source only when the 2MASS source had a good K_s band measurement (photometric quality of "A"). This left out some sources that were K_s band "drop-outs" but detected in J and H bands. For the GLIMPSEII processing, we include a 2MASS match if the source has a photometric quality flag of A, B, C or D for the K_s band, or a quality flag of A or B in the H band.

This document contains numerous acronyms, a glossary of which is given at the end.

[1]Although originally known as GLIMPSE, we will use the acronym GLIMPSEI to avoid confusion between it, GLIMPSEII and GLIMPSE3D

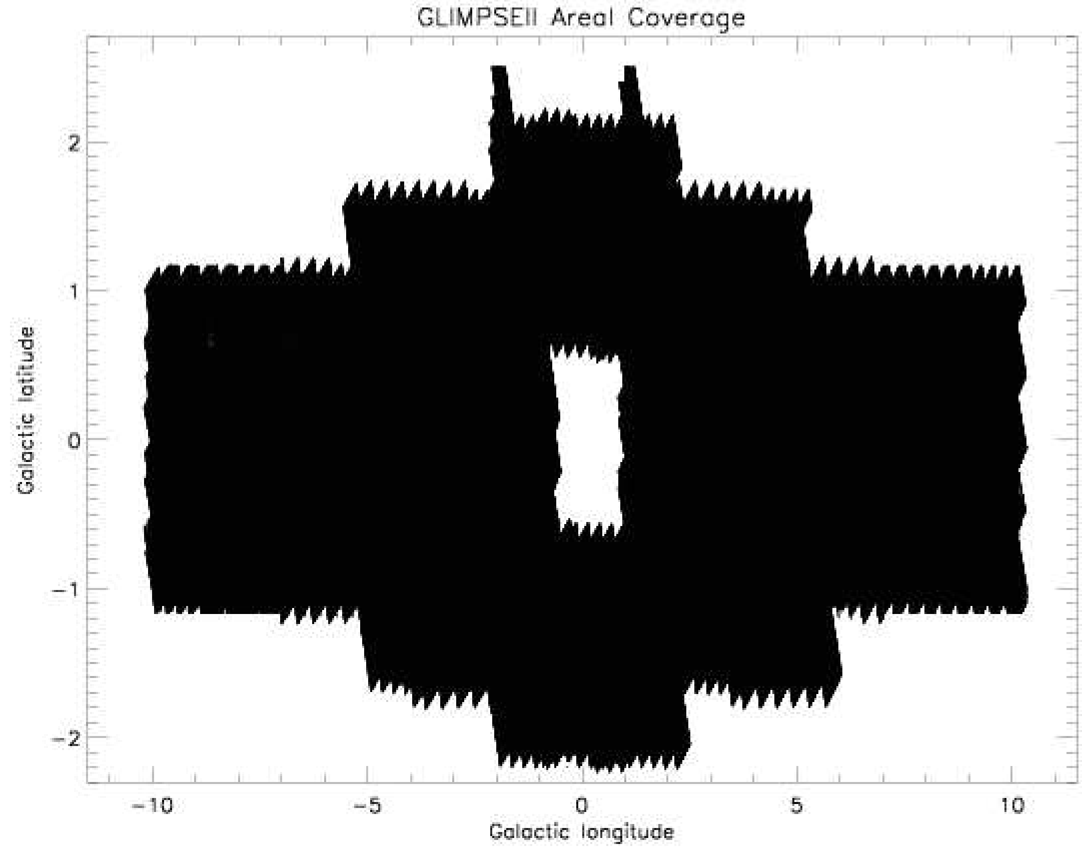

Figure 1: GLIMPSEII areal coverage of the inner Galactic plane.

2.2 Data Products Overview

The GLIMPSEII enhanced data products consist of a highly reliable Point Source Catalog (GLMIIC), a more complete Point Source Archive (GLMIIA), a More Reliable Point Source Archive (GLMIIMRA) and mosaic images covering the survey area. The enhanced data products are:

1. The GLIMPSEII Catalog (GLMIIC, or the "Catalog") consists of the highest reliability point sources. The sources in the Catalog must be detected at least twice in one IRAC band and at least once in an adjacent band, a "2+1" criterion, where the "1" can include the 2MASS K_s band. Based on considerations detailed in §3.2 of the GLI Data Release Document, this yields a GLIMPSEII Catalog with a reliability greater than 99.5%; that is, only five sources in a thousand are expected to be spurious. Figure 2 (dashed lines) shows the number of Catalog sources as a function of magnitude for each IRAC band. 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), providing 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 format of the Catalog is ASCII, using the IPAC Tables convention (http://irsa.ipac.caltech.edu/applications/DDGEN/Doc/ipac_tbl.html).

2. The GLIMPSEII Archive (GLMIIA or the "Archive") consists of point sources with a signal to noise > 5 in at least one band and less stringent selection critera than the Catalog (§3.2 of the GLI Doc). The photometric uncertainty is typically < 0.3 mag. The information provided is in the same format as the Catalog. The number of Archive sources as a function of magnitude for each IRAC band is shown in Figure 2 (solid lines). The 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 in the GLI Doc).

3. The GLIMPSEII More Reliable Archive (GLMIIMRA) consists of higher reliability point sources than the Archive. It was produced for the single visit epoch 2 only source lists to provide a higher reliability source list than the Archive. No highly reliable Catalog is produced for this dataset since it requires a source be detected twice in one band. The sources in the More Reliable Archive have the same stringent criteria as the Catalog except two detections are not required in a single band. Two detections in adjacent bands are required (the "1" can include the 2MASS K_s band); for example one detection in band 1 and one detection in band 2. See §3.2 in the GLI Doc for details about the source list criteria.

4. The GLIMPSEII Image Atlas consists of mosaicked images of all epochs for each band, each covering $1.1^\circ \times 0.8^\circ$, $1.1^\circ \times 1.2^\circ$, or $1.1^\circ \times 1.6^\circ$, depending on the latitude coverage. These are 32-bit IEEE floating point single extension FITS formatted images covering the entire survey area and projected in Galactic coordinates. These images, in units of surface brightness MJy/sr, have a pixel size of $0.6''$. Mosaics of each band are made for larger ($3.1^\circ \times 2.4^\circ$, $3.1^\circ \times 3.45^\circ$, or $3.1^\circ \times 4.5^\circ$) areas, with a pixel size of $1.2''$. $1.2''$ pixel mosaics are provided, with and without background and boundary matching. Also included are quicklook 3-color jpeg images of the same size as the FITS images.

5. 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. WITS is described in detail in §5.3 in the GLI Doc.

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

2.3 v1.0 Data Release

v1.0 data products, consisting of a point source Catalog and Archive and mosaics for the entire GLIMPSEII survey region using the epoch 1 data taken in September 2005 and processed with SSC pipeline version S12.4, were delivered to the Spitzer Science Center in May 2007. See the GLIMPSEII Data Products Description v1.1 (http://www.astro.wisc.edu/glimpse/glimpse2_dataprod_v1.1.pdf)

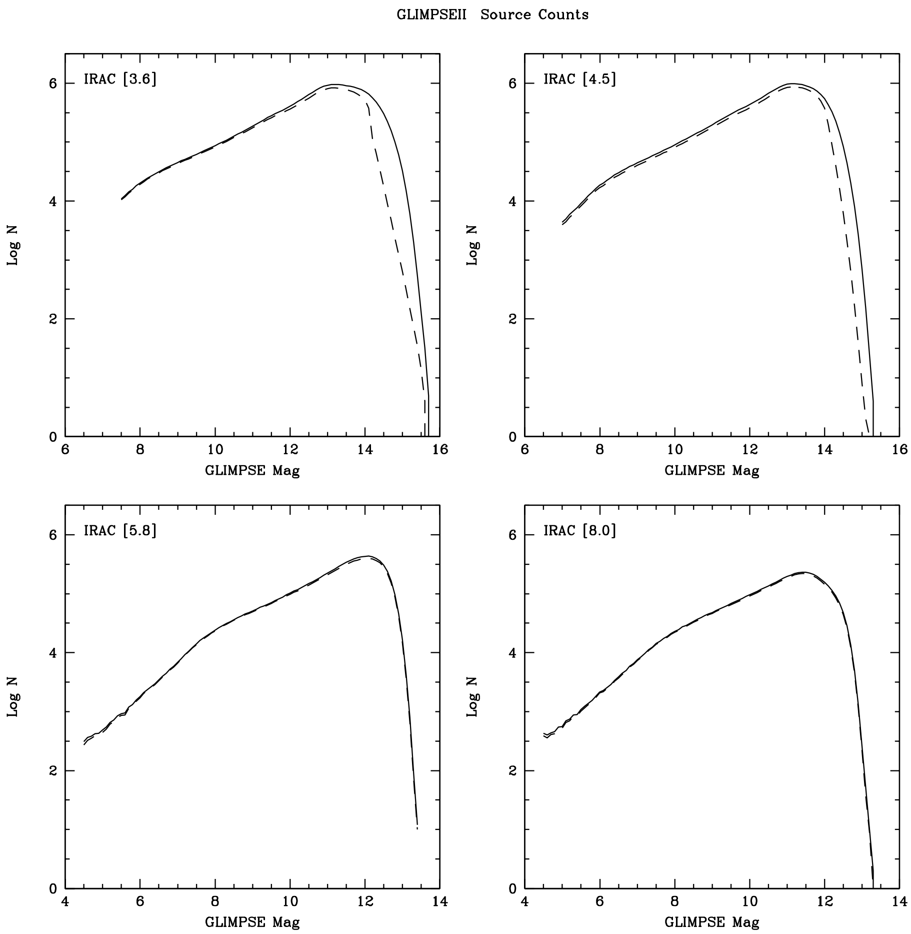

Figure 2: GLIMPSEII source counts versus magnitude. Plotted is the logarithm of the source counts in the GLIMPSEII Catalog (dashed lines) and Archive (solid lines) binned every 0.1 magnitudes. Each of the 4 bands is plotted, showing the effective limiting magnitude for each band. The band 1 & 2 distributions are very similar since most sources that make it into the Archive or Catalog have data in those bands. Sources from the entire GLIMPSEII region were used in these plots.

for more information about the v1.0 data release. The v1.0 data products have been superceded by the v2.0 data products.

2.4 v2.0 Data Release

2.4.1 v2.0 Data Products

The v2.0 data products described here consist of point source Catalogs and Archives and mosaic images for the entire GLIMPSEII survey region including the GALCEN data and GLIMPSEI data at the boundary of the surveys (at l=10° and l=350°). There are also single epoch GLIMPSEII data only source lists. The v2.0 data products incorporate improvements in the SSC processing and the Wisconsin IRAC pipeline and include both epochs of the GLIMPSEII survey plus small amounts of new data taken to fill gaps in survey coverage due to missing or bad frames. As in the v1.0 processing, photometry is performed on individual IRAC frames using a modified version of DAOPHOT (Stetson 1987, Babler 2006[2]) and combined in the bandmerger stage to produce the source lists. We use the SSC-supplied bandmerger[3] (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). Since flux information is used in the in-band merge, some variable sources are *excluded* in the source lists from multi-epoch observations. We provide single epoch source lists for those who wish to study variables. We provide 2MASS fluxes with the IRAC data, when available. We don't provide 2MASS sources that lack an IRAC counterpart.

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: 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); and photometric correction[4] applied (a function of location of the source in the frame). For the outlier masking of the images, we used the IRAC post-BCD processing software "IRACproc" developed by Mike Schuster, Massimo Marengo and Brian Patten at the Smithsonian Astrophysical Observatory (Schuster et al. 2006).

Appendix A in the GLI Doc gives more details about the differences between the v2.0 and v1.0 processing.

2.4.2 v3.5 Images - Background and Boundary Matched $1.2''$ pixel Mosaics

In the v3.5 mosaic images, we match instrumental background variations between the images. Instrument artifacts (Hora et el. 2004; IRAC Data Handbook[5]) such as full array pull-up, first frame effect and frame pull-down are mostly removed from these images. We do this only for the larger (3.1°x 2.4°, 3.1°x 3.45°, and 3.1°x 4.5°) $1.2''$ pixel images. This processing may be removing real sky variations so we provide these images *in addition* to the v2.0 $1.2''$ pixel images that do not have the background matching. The processing done to produce the v3.5 mosaics is described in §4.2.

2.5 Data Delivery Schedule

Documentation is provided with each data delivery.

```
Winter 2009
  v2.0 source lists and mosaics of the subarray mode data

November 2009
```

[2]http://www/astro.wisc.edu/glimpse/glimpse_photometry_v1.0.pdf
[3]http://ssc.spitzer.caltech.edu/postbcd/bandmerge.html
[4]http://ssc.spitzer.caltech.edu/irac/locationcolor/
[5]http://ssc.spitzer.caltech.edu/irac/dh/

```
  v2.0 epoch 2 only source lists, to be used for variable stars and
    asteroid hunting.

December 2008
  v2.0 epoch 1 only source lists, to be used for variable stars and
    asteroid hunting.

January 2008 - SUPERCEDES v1.0 source lists and images
  v2.0 source lists, mosaics and 3-color jpgs - derived from all GLIMPSEII epochs +
    Galactic center + GLIMPSEI at boundaries
    19 million Catalog sources, 24 million Archive sources, 0.6" and 1.2" pixel
    mosaics.  1.2" pixel mosaics (3.1x2.4 deg, 3.1x3.45 deg, 3.1x4.5 deg) with and
    without background and boundary matching

May 2007 (delivered) SUPERCEDED
  v1.0 mosaics and 3-color jpgs
   the remaining images for the rest of the GLIMPSEII survey from data taken
   in September 2005 and processed by SSC pipeline version S12.4.
    1.1x1.2 deg 0.6" pixel mosaics for l=5,4,3,354,355,356 deg (72 fits files)
    1.1x1.6 deg 0.6" pixel mosaics for l=2,1,0,359,358,357 deg (72 fits files)
    3.1x3.45 deg 1.2" pixel mosaics centered at l=6,354 deg  (8 fits files)
    3.1x4.5 deg 1.2" pixel mosaics of l=0,3,357        (12 fits files)
  *NOTE* Re-delivery of mosaics delivered in January 2007, with a slightly updated
    fits header (see the README file accompanying the data files for the details):
    1.1x0.8 deg 0.6" pixel mosaics for l=6,7,8,9,350,351,352,353 deg (96 fits files)
    3.1x2.4 deg 1.2" pixel mosaics centered at l=9,351 deg    (8 fits files)

January 2007 (delivered) SUPERCEDED
  derived from data taken in September 2005 (epoch 1) with S12.4 SSC processing
  v1.0 source lists - point source Archive and Catalog, IRAC+2MASS
       (about 16 million Catalog sources, 21 million Archive sources)
  v1.0 mosaics and 3-color jpgs
      1.1x0.8 deg 0.6" pixel mosaics - for 8 degrees of longitude
           (l=6 through 9 deg; l=350 through 353 deg)- 96 fits files
      3.1x2.4 deg 1.2" pixel mosaics  (centered at l=9 and 351 deg)- 8 fits files
```

3 Quality Checks and Source List Validation

This section describes some of the checks we have made on the quality of the Catalog and Archive point source lists. Many of the checks for this data were also performed as part of GLIMPSE. Additional information can be found in the following documents:

- *GLIMPSE Quality Assurance (GQA) document*: http://www.astro.wisc.edu/glimpse/GQA-master.pdf
- *Reliability and Completeness for GLIMPSE*: http://www.astro.wisc.edu/glimpse/cr_manuscript.pdf

- *Observation Strategy Validation Report*: http://www.astro.wisc.edu/glimpse/val.20040130.pdf
- *Addendum to the Validation Report*: http://www.astro.wisc.edu/glimpse/addendum4.pdf

These documents describe the GLIMPSEI data validation and the results of a reliability study using GLIMPSEI Observation Strategy Validation (OSV) data to develop source selection criteria. Additional details are given in §3.2 and §4.1 of the GLI Doc.

3.1 Astrometric Accuracy

Sources bright enough to have 2MASS associations are typically within $0.3''$ of the corresponding 2MASS position, as discussed in §4.1. Figure 3 shows a comparison of GLIMPSEII source positions to the 2MASS PSC positions, in $0.05''$ bins, for a one degree longitude, 4 degrees of latitude area in the GLIMPSEII survey. The peak of the plot is at $0.15''$ and the majority of the sources have positional differences less than $0.3''$. Fainter 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.

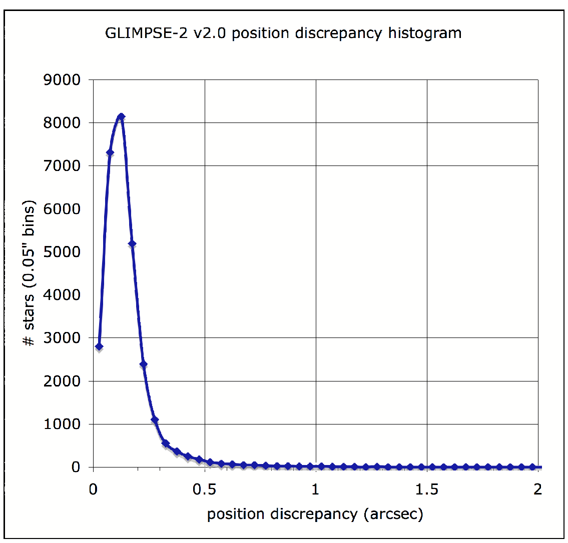

Figure 3: Comparison of GLIMPSEII source positions to their corresponding 2MASS PSC positions from sources of longitudes between 1 and 2 degrees and latitudes ± 2 degrees. The astrometric discrepancy plotted is the absolute angular separation in arcseconds between the GLIMPSEII position and the 2MASS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

3.2 Photometric Accuracy

Photometric accuracy for GLIMPSEI was 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, most likely due to its lower sensitivity. Band 2 shows a higher percentage of sources with photometric accuracy >0.2 mag compared to band 1. This is a result of our selection criteria (§3.2 in the GLI Doc). 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 v2.0 GLIMPSEII All Epoch Sources

Band (μm)	[3.6]	[4.5]	[5.8]	[8.0]
Catalog				
No. with error >0.2 mag	168218	1454090	1719676	633963
Total number of entries	18924851	18745750	8309644	5047446
% with errors >0.2 mag	0.89	7.76	20.69	12.56
Archive				
No. with error >0.2 mag	388614	2901379	1941926	701857
Total number of entries	24012388	22495127	8906797	5341078
% with errors >0.2 mag	1.62	12.90	21.80	13.14

Photometric accuracy was further verified by comparison with 100 flux calibrators distributed throughout the GLIMPSEII 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 GLIMPSEII magnitudes and the predicted magnitudes. Uncertainties in both the extracted and predicted magnitudes were added in quadrature to produce the plotted error bars. Table 2 gives details about the number of flux calibrators used for each band (varies due to saturation), average differences (GLIMPSEII 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	45	47	90	87
Ave. [Observed-Predicted] mag	-0.020	-0.016	0.005	-0.007
RMS error	0.079	0.092	0.086	0.078

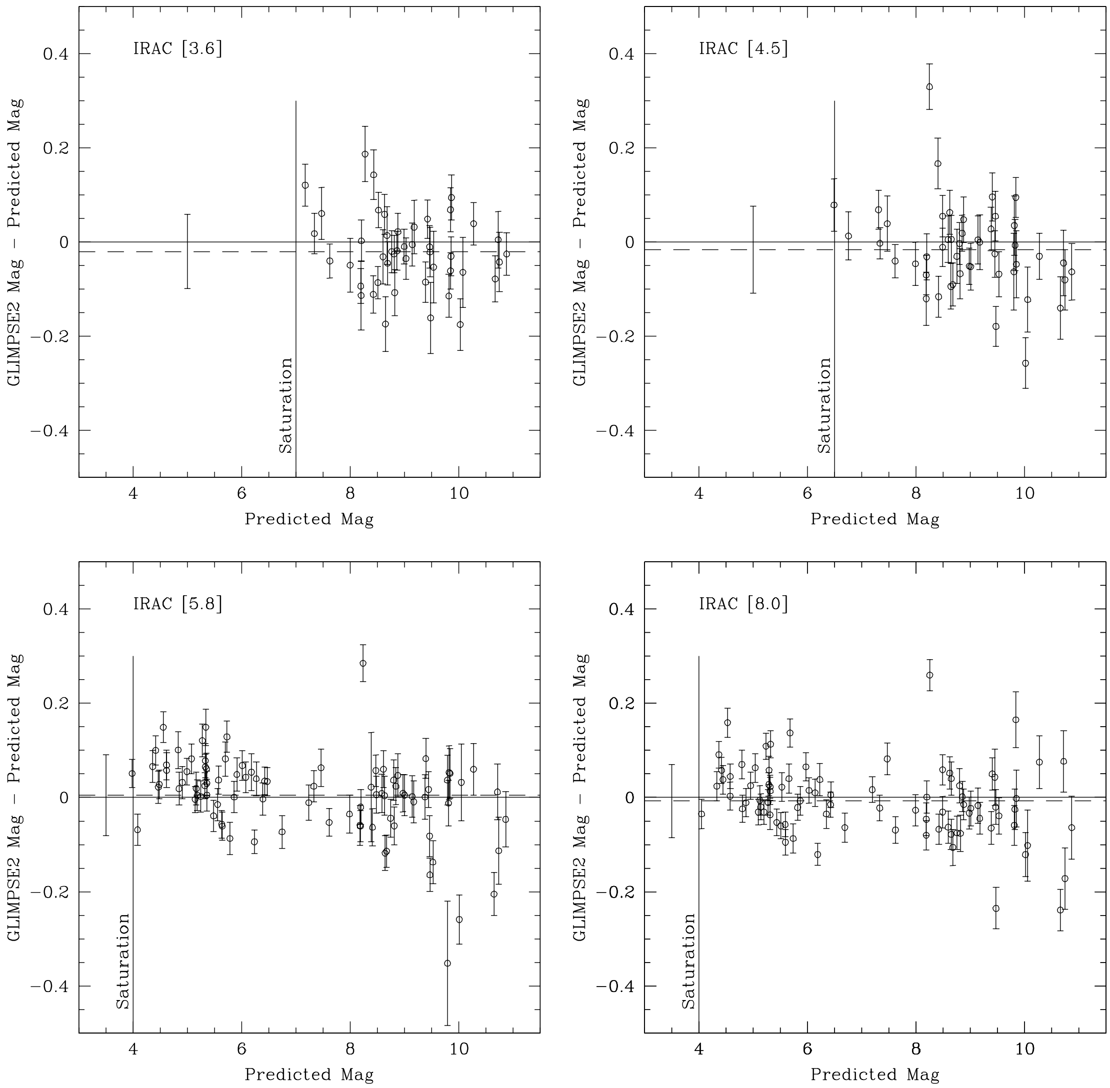

Figure 4: Comparison of GLIMPSEII flux calibrators to predictions provided by Martin Cohen for each IRAC band. Error bars are the root-sum-of-squares of the errors of both the extracted and predicted magnitudes for each source. The vertical lines are the best estimates of the saturation limits. The dashed line indicates the average difference between the GLIMPSEII magnitude and the predicted magnitude. The error bar farthest to the left is the corresponding RMS of the data points.

Uncertainty assessment is being done by comparing the quoted uncertainty (dF_i) with the RMS of the uncertainty (F_i_rms). From our studies, the uncertainties for bands 1, 3 and 4 all appear to be statistically too small with band 4 being the worst. Band 2 uncertainties appear to be slightly too large. Empirically the best correction appears to be related to the diffuse background level. However a simple percentage increase to the uncertainties seems adequate. At this time we would recommend increasing the band 1 uncertainties by 10%, the band 3 uncertainties by 15% and the band 4 uncertainties by 35%. We recommend leaving the band 2 uncertainties as quoted. These corrections typically increase the band 1 uncertainties by 0.01 magnitudes, the band 3 uncertainties

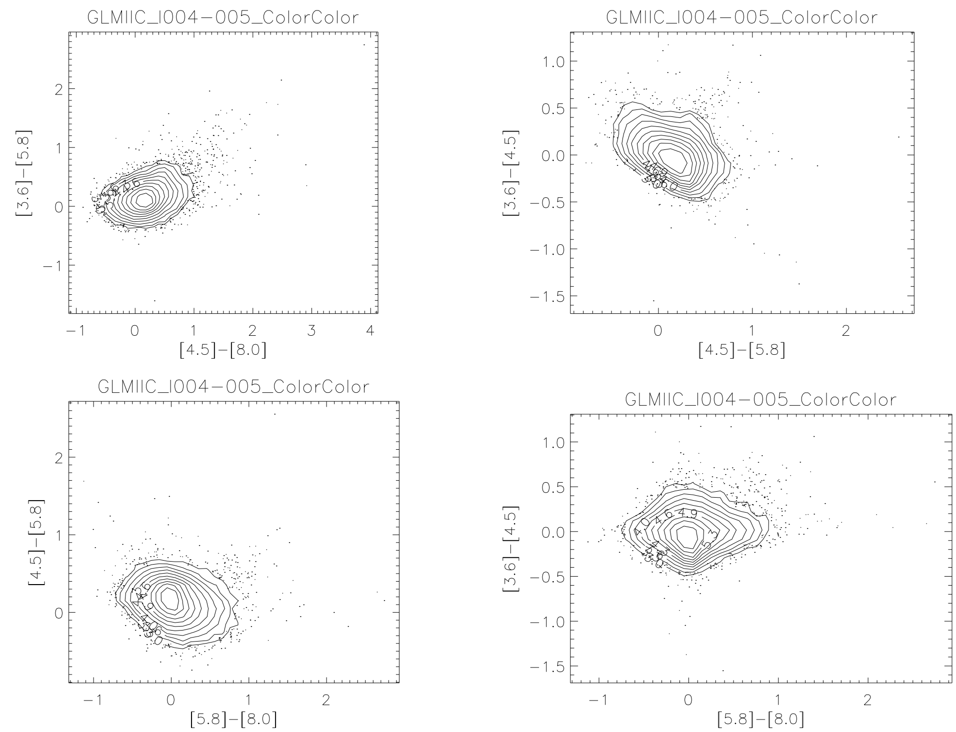

Figure 5: Color-color plots of the region $l = 4 - 5^\circ$ and $|b| < 1.55^\circ$ for sources in the Catalog. 10 contours are evenly spaced between log(# sources/mag^2)=2.0 and the log of maximum number of sources per square magnitude. The contours are labelled with the log of the number of sources per square magnitude. Outside of the lowest contour, the positions of individual sources are plotted.

by less than 0.03 magnitudes and the band 4 uncertainties by less than 0.05 magnitudes.

3.3 Color-Color and Color-Magnitude Plots

Color-color and color-magnitude plots were made of each Catalog, Archive and More Reliable Archive (in approximately $1^\circ \times 2 - 4^\circ$ 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. Postscript files of the color-color and color-magnitude plots for each degree of longitude in the GLIMPSEII survey are available from the GLIMPSE web site (http://www.astro.wisc.edu/glimpse/glimpse2/v2.0/ColorColor/ and http://www.astro.wisc.edu/glimpse/glimpse2/v2.0/ColorMag/).

3.4 Other checks

Spot checks include inspection of residual images to verify proper point source extraction; overplotting the positions of the sources in the Catalogs and Archives on mosaic images; and plotting Spectral Energy Distributions (SEDs) of several sources. The l=0°-1° and l=4°-5° Catalogs and

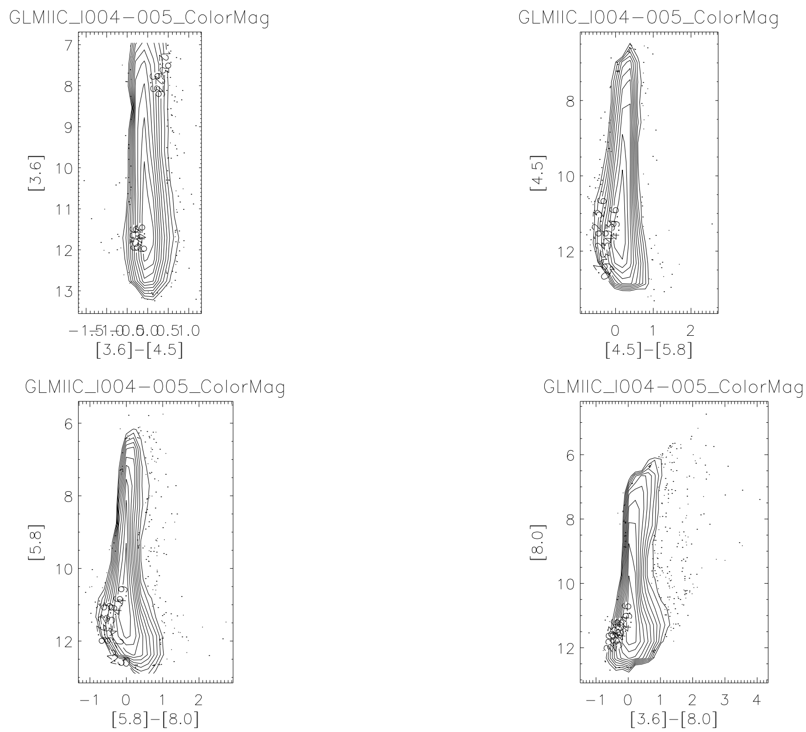

Figure 6: Color-magnitude plots of the region $l = 4 - 5°$ and $|b| < 1.55°$ for sources in the Catalog. 10 contours are evenly spaced between log(# sources/mag^2)=2.0 and the log of the maximum number of sources per square magnitude. The contours are labelled with the log of the number of sources per square magnitude. Outside of the lowest contour, the positions of individual sources are plotted.

Archives were run through our SED grid and fitter (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 mis-matched IRAC or 2MASS fluxes, or variability between IRAC and 2MASS). The rest are real sources not well fit by stellar atmosphere models, e.g. dusty Young Stellar Objects and evolved stars.

3.5 Comparison of the GLIMPSEII pipeline processing of the GALCEN data with the GALCEN Team's source list

We compared the source lists from our processing of the GALCEN observations with the GALCEN Team's source list (Ramirez et al. 2008). This is a comparison of two independent source extraction methods on the same IRAC data and is useful for improving photometric accuracy and error analysis. The results of this study can be found at
http://www.astro.wisc.edu/glimpse/glm2_galcen_comparison.pdf. The difficulty of performing photometry in such a challenging field should not be underestimated. Our conclusions are summarized as follows:

- There is general agreement in a limited magnitude range for each of the 4 IRAC channels at a level of about 10% uncertainty (which is much greater than the combined uncertainties of the two catalogs). These ranges are approximately magnitudes 7.5 to 10.5 for band 1, 6.5 to 10.5 for band 2, 6.0 to 10.0 for band 3, and 8.0 to 10.0 for band 4. Fainter than these limits we see systematic offsets between the two catalogs that are greater than 10% which get progressively worse. For brighter magnitudes in bands 1 and 4, we also see offsets greater than 10%.

- We believe the GALCEN uncertainties are too small. We cannot account for systematic magnitude offsets between the GALCEN and GLIMPSEII magnitudes for data in the magnitude range of 4 through 8 where GLIMPSEII flux calibrators show GLIMPSEII magnitudes to be in good agreement with predictions. Since GLIMPSEII has access to a greater set of independently determined flux calibrators and the GLIMPSEII magnitudes for those calibrators do not show any evidence of a systematic offset, we suspect that the SSC PRFs that GALCEN used may be responsible for the observed offsets. It has recently been determined that the PRF's provided by SSC for IRAC source extraction are not ideal due to the undersampled nature of the IRAC point spread function (see: http://ssc.spitzer.caltech.edu/postbcd/mopex.html). It is likely that the lower uncertainties in the mopex PRF flux estimate published in the GALCEN survey are linked to these non-ideal PRFs. SSC is working to better characterize the IRAC PRF for future use with improved versions of mopex.

- Inspection of GLIMPSEII residual images (images with the sources subtracted from the image) shows no indication of improper or systematic extraction problems. GLIMPSEII extracts more sources than does GALCEN. GLIMPSEII systematically finds sources to fainter limits. With a greater number of sources extracted from the GLIMPSEII images, the resultant GLIMPSEII background values are systematically lower than the GALCEN background values for extracted sources.

4 Data Products Description

Here we provide information on the fields and flags recorded for each point source provided in the Catalog and Archive. More detailed information on the file formats for the Catalog and Archive, as well as mosaics, can be found in the following section.

4.1 Catalog and Archive Fields and Flags

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

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, 5.8 μm and 8.0 μm) and t is the 2MASS wavelength band (J, H, K_s). Details of the fields are as follows:

Designation

This is the object designation or "name" as specified by the IAU recommendations on source nomenclature. It is derived from the coordinates of the source, where G denotes Galactic coordinates, LLL.llll is the Galactic longitude in degrees, and ±BB.bbbb is the Galactic latitude in degrees. The coordinates are preceded by the acronym SSTGLMC (GLIMPSEII Catalog and More Reliable Archive) or SSTGLMA (GLIMPSEII 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[6] 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 GLIMPSEII 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, 5.8, 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 errors 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 version 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

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

1987). Magnitude uncertainties are estimated to be <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, 5.8, 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 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 section. 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 three times 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 second source in the Archive is within $3.0''$ of the source. It was found (see §VIII of the GQA) that the magnitude 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, after point source extraction on individual IRAC frames. 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 some cases decrease the reliability of the source. Some of the bits, such as the DAOPHOT tweaks, will not compromise the source's reliability, and has likely increased the error assigned to the source flux. If just one of the IRAC detections 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. Bands with hot or dead pixels within 3 pixels of source center (bit 8), those in wings of saturated stars (bit 20), and those within 3 pixels of the frame edge (bit 30) were not counted during the source selection process (see §3.2 in the GLI Doc). Each of the seven bands has its own SQF. For the cross-band confusion flag and the cross-band merge lumping flag, when the condition is met for one of the bands, the bit is set for all the source's bands.

Table 4 shows the SQF sequence for the GLIMPSEII v2.0 data release. We have determined that false sources from regions such as stray light do not make it into the Catalog due to our 2+1 source selection criterion (§3.2 in the GLI Doc). In addition, our photometry algorithm has been 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 issues. More information about these flags and a bit value key can be found in Appendix A.

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
22	post-lumping in cross-band merge	2MASS
23	photometric quality flag	2MASS
24	photometric quality flag	2MASS
25	photometric quality flag	2MASS
30	within three pixels of edge of frame	GLIMPSE

[a]Due to the short exposure time and high sky backgrounds in the GLIMPSEII 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
1.2	3	4
2	5	6
12	7	8
30	9	10
100	11	12

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 GLIMPSE surveys, the method flag equals 48 (2^4 + 2^5).

4.2 GLIMPSEII Image Atlas

The IRAC images are mosaicked into rectangular tiles that cover the surveyed region using the Montage[7] v3.0 package. The units are MJy/sr and the coordinates are Galactic. The mosaic images conserve surface brightness in the original images. We provide 1.2″ pixel mosaics as well as higher resolution 0.6″ pixel mosaics. The angular size of each higher resolution tile is 1.1°×0.8°, 1.1°×1.2°, and 1.1°×1.6°, depending on the latitude range covered for the particular longitude. Three tiles span the latitude range of the survey and ∼20 span the longitude range, giving a total of ∼60 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 (§5.2) for an example of a FITS header. The mosaicked images are 32-bit IEEE floating point single-extension FITS formatted images. We also provide larger (3.1°×2.4°, 3.1°×3.45°, and 3.1°×4.5°) FITS files with a pixel size of 1.2″ for an overview look that covers the full latitude range of GLIMPSEII, both with (v3.5) and without (v2.0) background and boundary matching. Seven tiles per band cover the survey region. There are 28×2 (with and without background matching) of these 1.2″ pixel mosaics. 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 nominal survey coverage we do not necessarily have full coverage in all four IRAC bands. This can be seen in the jpeg files.

The background and boundary matching may be removing real sky variations so we provide these images *in addition* to the v2.0 1.2″ pixel images that do not have the background matching. The v3.5 background and boundary matched mosaics are processed using the following procedure:

- v3.0 Background matched
  For the larger (3.1°×2.4°, 3.1°×3.45°, and 3.1°×4.5°) 1.2″ pixel mosaic images, we match instrumental background variations between the 5x5 arcmin IRAC BCD frames using the Montage mosaicing package. Instrument artifacts (see the IRAC Data Handbook) such as full array pull-up, first frame effect and frame pull-down are mostly removed from the images. We use the "level" option in the Montage mBgModel module (http://montage.ipac.caltech.edu/docs/mBgModel.html) to produce the background matched mosaics. See http://montage.ipac.caltech.edu/docs/algorithms.html#background for a discussion of the background modeling. This produces the v3.0 1.2″ pixel background matched mosaics.

- v3.5 Background and Boundary matched
  We further match across boundaries of the v3.0 1.2″ pixel mosaics (3.1°×2.4°, 3.1°×3.45°, and 3.1°×4.5°) using the non- background matched v2.0 1.2″ pixel mosaics as a guide. This helps to insure a more consistent background level across the v3.5 1.2″ pixel mosaics.

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

Here are the essential steps in producing the boundary corrected images. Note that the 1.2″ pixel mosaics overlap by 320 pixels.

```
1)  Create a difference image of bkg_corrected (v3.0) to non-bkg_corrected
    (v2.0) images.
2a) For each row in the difference image, determine the median of first 320
    pixels.
 b) Fit a 4th order polynomial curve to these median values.
3a) Determine median of last 320 pixels of each row.
 b) Fit a 4th order polynomial curve to those median values.
4)  Initialize a correction image.  The values of the first column
    of that image is the polynomial curve determined in step 2b.
    The values of the last column of the correction image is the
    polynomial curve determined in step 3b.
5)  For each row in the correction image interpolate a linear correction
    from the value in the first column to the value in the last column.
6)  This is the correction image.  Subtracting the correction image
    from the (v3.0) bkg_corrected image produces the new improved (v3.5)
    background_and_boundary corrected image.
```

5 Product Formats

5.1 Catalog, Archive and More Reliable Archive

• The Catalog, Archive and More Reliable Archive are broken into 1° (longitude) x 2.3-4° (latitude) areas for the GLIMPSEII Survey. Three sets (all epoch, epoch 1 only, epoch 2 only) of 22 Catalog (or More Reliable Archive) files and 22 Archive files were delivered for the entire survey region. The Catalog and Archive files are in IPAC Table Format (http://irsa.ipac.caltech.edu/applications/DDGEN/Doc/ipac_tbl.html). Filenames are v2.0_GLMIIC_llmin.tbl and v2.0_GLMIIA_llmin.tbl, for the Catalog and Archive respectively (e.g. v2.0_GLMIIC_l006.tbl, v2.0_GLMIIC_l007.tbl, v2.0_GLMIIA_l006.tbl, v2.0_GLMIIA_l007.tbl, etc.) For the single epoch source lists, the file names are e.g. v2.0_epoch1_GLMIIC_006.tbl, v2.0_epoch2_GLMIIMRA_354.tbl. The entries are sorted by increasing Galactic longitude within each file. Due to the nature of the survey mapping, there are areas that were observed with latitudes outside of the nominal GLIMPSEII survey region. Source lists are provided for those areas.

There is a small amount of IRAC coverage from l=9.8° to 10.3° and l=349.8° to 350.2° where there was overlap between the GLIMPSEII and GLIMPSEI surveys. All epoch source lists in these areas use data from both the GLIMPSEII and GLIMPSEI surveys. In the overlap between the GLIMPSEII and GALCEN data, both datasets are used to produce the all epoch source lists.

An example of a Catalog entry is

SSTGLMC G004.0000-00.9893 17583907-2559569 173833910 4.000045 -0.989381 0.3 0.3
269.662836 -25.999180 0.3 0.3 0 14.126 0.062 12.361 0.054 11.665 0.035
11.074 0.049 11.067 0.058 11.007 0.064 11.034 0.052
3.565E+00 2.036E-01 1.164E+01 5.788E-01 1.439E+01 4.637E-01

1.045E+01 4.706E-01 6.725E+00 3.585E-01 4.550E+00 2.672E-01 2.474E+00 1.196E-01
4.132E-01 1.953E-01 3.303E-01 4.199E-01 3.227E+00 2.050E+00 8.740E+00 3.144E+01
17.51 20.11 31.02 22.20 18.76 17.03 20.69 126.0 108.0 33.6 25.4
3 4 3 4 3 4 3 4 25165824 29360128 29360128 0 0 0 1024 48 48 48 48

Table 6 gives all of the available fields per source. Table 7 shows how to decode the above entry into these fields.

Table 6. 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 dra is in units of arcseconds, so to convert to seconds of time, multiply by cos(dec)/15.	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

Table 7. Example of Catalog/Archive Entry on Previous page

designation	SSTGLMC G004.0000-00.9893	Name
tmass_desig	17583907-2559569	2MASS designation
tmass_cntr	173833910	2MASS counter
l,b	4.000045 -0.989381	Galactic Coordinates (deg)
dl,db	0.3 0.3	Uncertainty in Gal. Coordinates (arcsec)
ra,dec	269.662836 -25.999180	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	14.126 12.361 11.665	Magnitudes (2MASS J,H,K_s) (mag)
	0.062 0.054 0.035	Uncertainties (2MASS) (mag)
mag,dmag	11.074 11.067 11.007 11.034	Magnitudes (IRAC bands 1-4) (mag)
	0.049 0.058 0.064 0.052	Uncertainties (IRAC) (mag)
F,dF	3.565E+00 1.164E+01 1.439E+01	2MASS Fluxes (mJy)
	2.036E-01 5.788E-01 4.637E-01	Uncertainties in 2MASS fluxes (mJy)
F,dF	1.045E+01 6.725E+00 4.550E+00 2.474E+00	IRAC Fluxes (mJy)
	4.706E-01 3.585E-01 2.672E-01 1.196E-01	Uncertainties in IRAC fluxes (mJy)
F_rms	4.132E-01 1.953E-01 3.303E-01 4.199E-01	RMS_flux (mJy) (IRAC)
sky	3.227E+00 2.050E+00 8.740E+00 3.144E+01	Sky Bkg (MJy/sr) (IRAC)
SN	17.51 20.11 31.02	Signal to Noise (2MASS)
SN	22.20 18.76 17.03 20.69	Signal to Noise (IRAC)
srcdens	126.0 108.0 33.6 25.4	Local Source Density (IRAC) (#/sq arcmin)
M	3 4 3 4	Number of detections (IRAC)
N	3 4 3 4	Number of possible detections (IRAC)
SQF	25165824 29360128 29360128	Source Quality Flag (2MASS)
SQF	0 0 0 1024	Source Quality Flag (IRAC)
MF	48 48 48 48	Flux Calculation Method Flag (IRAC)

5.2 GLIMPSEII 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 0.6″ pixel mosaic images are each 1.1°x 0.8°, 1.1°x 1.2°, and 1.1°x 1.6°, depending on the latitude coverage. The 1.1°x 0.8° mosaics are 128 Megabytes in size. The 1.1°x 1.2° mosaics are 192 Megabytes in size and the 1.1°x 1.6° mosaics are 255 MB. There are three mosaics per one degree galactic longitude interval with 0.05° overlap in longitude between mosaics. For example, for the Galactic longitude of 8°, the centers of the three mosaics will be (8.5°, +0.75°), (8.5°, 0.0°), and (8.5°, -0.75°). The longitude range is 7.95° to 9.05° 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°, also overlapping by 0.05°. 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_00850+0075_mosaic_I1.fits is a 1.1°x 0.8° IRAC channel 1 mosaic centered on l=8.50°, b=0.75°. We provide low-resolution 3-color jpeg images for each 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_00850+0000.jpg We provide larger (3.1°x 2.4°, 3.1°x 3.45°and 3.1°x 4.5°) mosaic FITS files (1.2″ pixels) for each band, along with low resolution 3-color jpegs. Each 3.1°x 2.4° mosaic is about 269 Megabytes in size. The 3.1°x 3.45° mosaic is 388 Megabytes in size and the 3.1°x 4.5° mosaic is 504 Megabytes. The filenames are similar to the other FITS and jpeg images: e.g. GLM_00900+0000_mosaic_I1.fits, GLM_00900+0000_3.1x2.4.jpg. We also provide the background and boundary matched 1.2″ pixel mosaics.

Here is an example of the FITS header for a 1.1°x 0.8° file, GLM_00850+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= 'S14.0.0 '           / SSC pipeline that created the BCD
PIPEVERS= '1v04    '           / GLIMPSE pipeline version
MOSAICER= 'Montage V3.0'       / SW that originally created the Mosaic Image
FILENAME= 'GLM_00850+0000_mosaic_I1.fits' / Name of associated fits file
PROJECT = 'FGLIMPSEIIC'        / Project ID
FILETYPE= 'mosaic  '           / Calibrated image(mosaic)/residual image(resid)
CHNLNUM =                    1 / 1 digit Instrument Channel Number
DATE    = '2007-07-14T17:18:58' / 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=                    5 / Proposal Cycle
PROGID  =                20201 / Program ID
PROTITLE= 'GLIMPSE II: Imaging the Centra' / Program Title
PROGCAT =                   30 / Program Category
COMMENT -----------------------------
COMMENT Time and Exposure Information
COMMENT -----------------------------
SAMPTIME=                  0.2 / [sec] Sample integration time
FRAMTIME=                  2.0 / [sec] Time spent integrating each BCD frame
EXPTIME =                  1.2 / [sec] Effective integration time each BCD frame
COMMENT DN per pixel=flux(photons/sec/pixel)/gain*EXPTIME
NEXPOSUR=                    3 / Typical number of exposures
COMMENT Total integration time for the mosaic = EXPTIME * NEXPOSUR
COMMENT Total DN per pixel=flux(photons/sec/pixel)/gain*EXPTIME*NEXPOSUR
AFOWLNUM=                    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  =           8.50000000 / [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      =         271.15618896 / [Deg] Right ascension at mosaic center
DEC     =         -21.59907150 / [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 for the BCD frames
PA_AVE  =                27.56 / [deg] Average position angle
ZODY_EST=              0.12927 / [Mjy/sr] Average ZODY_EST
ZODY_AVE=              0.08929 / [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  = '0014347776'         / AORKEYS used in this mosaic
AOR002  = '0014347520'         / AORKEYS used in this mosaic
AOR003  = '0014348032'         / AORKEYS used in this mosaic
AOR004  = '0014347264'         / AORKEYS used in this mosaic
AOR005  = '0014347008'         / AORKEYS used in this mosaic
AOR006  = '0014317568'         / AORKEYS used in this mosaic
AOR007  = '0014317824'         / AORKEYS used in this mosaic
AOR008  = '0014317312'         / AORKEYS used in this mosaic
AOR009  = '0014318080'         / AORKEYS used in this mosaic
AOR010  = '0014317056'         / AORKEYS used in this mosaic
AOR011  = '0017055232'         / AORKEYS used in this mosaic
DSID001 = 'ads/sa.spitzer#0014347776' / Data Set Identification for ADS/journals
DSID002 = 'ads/sa.spitzer#0014347520' / Data Set Identification for ADS/journals
DSID003 = 'ads/sa.spitzer#0014348032' / Data Set Identification for ADS/journals
DSID004 = 'ads/sa.spitzer#0014347264' / Data Set Identification for ADS/journals
DSID005 = 'ads/sa.spitzer#0014347008' / Data Set Identification for ADS/journals
```

```
DSID006 = 'ads/sa.spitzer#0014317568' / Data Set Identification for ADS/journals
DSID007 = 'ads/sa.spitzer#0014317824' / Data Set Identification for ADS/journals
DSID008 = 'ads/sa.spitzer#0014317312' / Data Set Identification for ADS/journals
DSID009 = 'ads/sa.spitzer#0014318080' / Data Set Identification for ADS/journals
DSID010 = 'ads/sa.spitzer#0014317056' / Data Set Identification for ADS/journals
DSID011 = 'ads/sa.spitzer#0017055232' / Data Set Identification for ADS/journals
NIMAGES =                  509 / 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_00850+0000_mosaic_I1.hdr includes:

```
COMMENT -----------------------------------------
COMMENT Info on Individual Frames in Mosaic
COMMENT -----------------------------------------
IRFR0001= 'SPITZER_I1_0014347776_0036_0000_02_levbflx.fits' / IRAC frame
DOBS0001= '2005-09-22T02:11:08.440' / Date & time at frame start
MOBS0001=      53635.089843750 / MJD (days) at frame start
RACE0001=           271.269257 / [Deg] Right ascension at reference pixel
DECC0001=           -21.016459 / [Deg] Declination at reference pixel
PANG0001=                89.95 / [deg] Position angle for this image
FLXC0001=              0.10880 / Flux conversion for this image
ZODE0001=              0.12599 / [MJy/sr] ZODY_EST for this image
ZODY0001=              0.09029 / [MJy/sr] ZODY_EST-SKYDRKZB for this image
IRFR0002= 'SPITZER_I1_0014347520_0164_0000_02_levbflx.fits' / IRAC frame
DOBS0002= '2005-09-22T01:40:39.453' / Date & time at frame start
MOBS0002=      53635.070312500 / MJD (days) at frame start
RACE0002=           270.983002 / [Deg] Right ascension at reference pixel
DECC0002=           -21.509216 / [Deg] Declination at reference pixel
PANG0002=                89.98 / [deg] Position angle for this image
FLXC0002=              0.10880 / Flux conversion for this image
ZODE0002=              0.12757 / [MJy/sr] ZODY_EST for this image
ZODY0002=              0.09186 / [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 508
.

IRFR0509= 'SPITZER_I1_0017055232_0001_0000_01_levbflx.fits' / IRAC frame
DOBS0509= '2006-04-27T10:06:51.845' / Date & time at frame start
MOBS0509=      53852.421875000 / MJD (days) at frame start
RACE0509=           271.322235 / [Deg] Right ascension at reference pixel
DECC0509=           -21.016941 / [Deg] Declination at reference pixel
PANG0509=               -91.82 / [deg] Position angle for this image
FLXC0509=              0.10880 / Flux conversion for this image
```

```
ZODE0509=              0.13437 / [MJy/sr] ZODY_EST for this image
ZODY0509=              0.08623 / [MJy/sr] ZODY_EST-SKYDRKZB for this image
```

6 APPENDIX A - Source Quality Flag Bit Descriptions

A.1 IRAC Source Quality Flag

Information is gathered from the SSC IRAC bad pixel mask (pmask), SSC bad data mask (dmask) and the GLIMPSE IRAC pipeline for the Source Quality Flag. Table 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. See §3 in the GLI Doc for a description of the instrument artifacts referred to below.

bit
1 poor pixels in dark current
This bit is set when a source is within 3 pixels of a pixel identified in the SSC IRAC pmask as having poor dark current response (bits 7 and 10 in the pmask).

2 flat field questionable
If a pixel is flagged in the SSC IRAC dmask as flat field applied using questionable value (bit 7) or flat field could not be applied (bit 8), a source within 3 pixels of these pixels will have this bit set.

3 latent image
This flag comes from the latent image flag (bit 5) from the dmask. The SSC pipeline predicts the positions of possible latent images due to previously observed bright sources. Due to the short exposure times (two seconds) and high sky backgrounds in the GLIMPSEII 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. Bands with this bit set are not counted during the source selection process (see §3.2 in the GLI Doc).

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. See Figure 7 for an example of the shapes of the saturated star wing areas flagged by this bit. Bands with this bit set are not counted during the source selection process (see §3.2 in the GLI Doc).

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. Or it could be a marginally resolvable double source. This bit is set for the band if sources

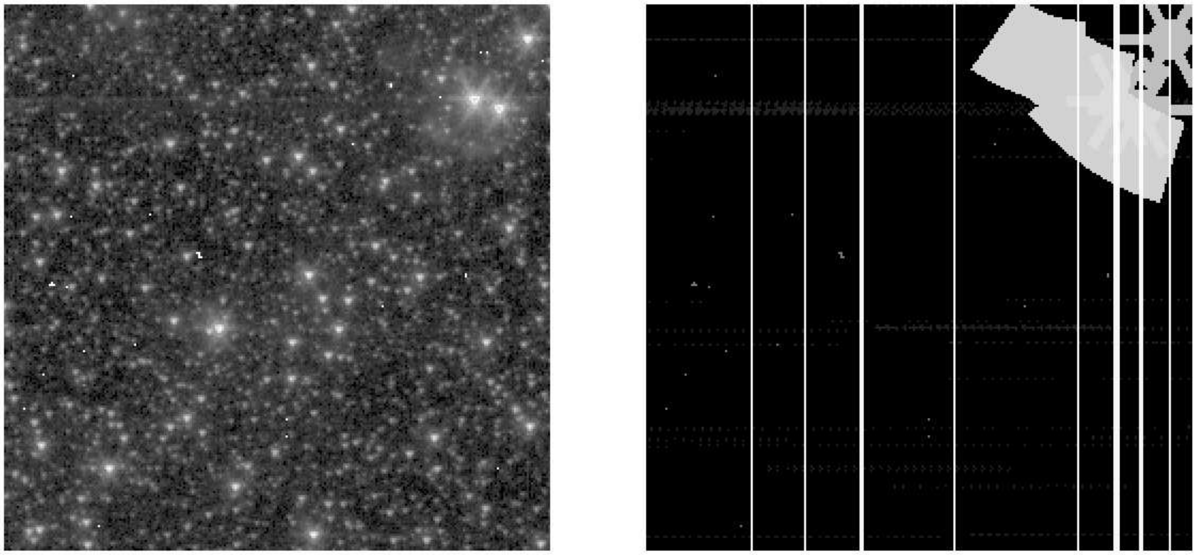

Figure 7: The band 1 (GLIMPSEI) IRAC frame (AOR 12110848, exposure 11) is on the left (corrections were applied for muxbleed and column pulldown); the flags for that frame are shown on the right. Stray light masks (SQF bit 17) are seen in the upper right hand corner of the frame. The PSF-shaped areas 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.

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 close to the edge of the frame for accurate photometry to be done. Bands with this bit set are not counted during the source selection process (see §3.2 in the GLI Doc).

A.2 2MASS Source Quality Flag

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

Users should consult the 2MASS PSC documentation for the complete information about the source, including all of their source quality flags.

bit
3 "p" persistence
Source may be contaminated by a latent image left by a nearby bright star.

4 "c" photometric confusion
Source photometry is biased by a nearby star that has contaminated the background estimation.

9 "s" electronic stripe
Source measurement may be contaminated by a stripe from a nearby bright star.

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

20 "d" diffraction spike confusion
Source may be contaminated by a diffraction spike from a nearby star.

22 post-lumping in cross-band merge
This bit is set for all bands (IRAC and 2MASS) if the source is a result of sources that were lumped in the cross-band merge step. Cross-band lumping is done with a 2.0 arcsec radius.

23 Photometric quality flag
24 Photometric quality flag
25 Photometric quality flag

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

  where

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

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

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

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

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

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

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

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

A.3 Key to Bit Values

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

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

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

For example, the Source Quality Flags in the example in Table 7 are 25165824 for the 2MASS J band and 29360128 for the H and K_s band. This translates to bits 23, 24 and 25 being set for H & K_s, which is the photometric quality A flag from the 2MASS PSC. For J, bits 24 and 25 are set, the photometric quality B flag. IRAC band 4 has a SQF of 1024. This means bit 11 has been set (the DAOPHOT tweak negative bit).

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GLOSSARY

2MASS	Two Micron All Sky Survey
BCD	Basic Calibrated Data, released by the SSC
dmask	A data quality mask supplied by the SSC for the BCD
GALCEN	Galactic Center Guest Observer program PID 3677, PI Susan Stolovy
GLIMPSE	Galactic Legacy Infrared Midplane Survey Extraordinaire
GLMIIC	GLIMPSEII Point Source Catalog
GLMIIA	GLIMPSEII Point Source Archive
GLMIIMRA	GLIMPSEII Point Source More Reliable Archive
GQA	GLIMPSE Quality Assurance
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 method of weighting fluxes
MIPS	*Spitzer* Multiband Imaging Photometer
OSV	Observation Strategy Validation
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
YSO	Young Stellar Object
WITS	Web Infrared Tool Shed, for data analysis