The ISOCAM GT Survey of Selected Areas in the Galactic Plane

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Abstract. Seven fields in the inner Galactic plane were imaged by the Infrared Space Observatory's camera ISOCAM between April and September 1996 with the objective to observe the large scale properties of the Galaxy. Between 134 and 194 point sources were extracted at 15.0 μm in the $11.6 \times 11.6\,\mathrm{arcmin}^2$ fields, and between 182 and 289 objects at 9.6 μm. The limiting flux for completeness is approximately 10 mJy. For most of the areas there is a good correlation between the observed source counts and the numbers predicted with a multiwavelength model (SKY), originally built to replicate the IRAS 12- and 25-μm point source sky.
At specific Galactic longitudes, however, significantly more sources were detected with ISOCAM than predicted. These discrepancies enable us to probe the mid-infrared populations of the molecular ring and the bulge. Colour histograms are presented as other indicators of the nature of any populations potentially missing from the model.

1 INTRODUCTION

The determination of the spatial distribution of stars in our Galaxy is a problem with a long history. A fundamental difficulty in this "classical" stellar statistics is the extinction of star light caused by interstellar dust which limits star counts at visible wavelengths to relatively high Galactic latitudes or small windows near the plane. As this extinction decreases with increasing wavelength, radio and infrared observations were used in order to investigate the Galactic structure at large distances and close to the Galactic plane. These wavelengths, however, probe different Galactic constituents than the visible: Whereas the latter is dominated by ordinary stars, the radio directly traces the distribution of gas, and the mid-infrared preferentially detects dust

heated by nearby stellar objects. From these observations it was inferred that our Galaxy is a mildly barred spiral.
Detailed characterizations of the global distribution of stars in our Galaxy were studied by using plausible models of the near- and mid-infrared sky. Earlier surveys in the near-infrared, however, suffered either from too low sensitivities or from too coarse resolution to accurately model the structure of the Galaxy. This drawback will be met with the *DE*ep *N*ear *I*nfrared *S*urvey DENIS ([6]) and the 2 *M*icron *A*ll *S*ky *S*urvey 2MASS ([2]). At mid-infrared wavelengths our knowledge is mainly based on star counts from the IRAS Point Source Catalog, but unfortunately IRAS data products are often confusion limited along the Galactic plane. This "confusion" degraded IRAS' detection limit over much of the inner plane to fluxes of 1 Jy or greater. Therefore, only the most luminous of stars in the Galactic plane could be detected at large distances by IRAS, biasing the sample.
With the observations discussed in this paper it was possible to check the validity of models for the mid-infrared point source sky at lower fluxes. We chose for the comparison between observation and theory a modified version of the SKY model ([13], [4], [5]). The authors built an ab initio statistical model of the point source sky and tested it extensively against IRAS source counts. [3] extended the model's synthetic spectral library from 2.0 to 35.0 μm. This range covers in particular the ISOCAM filters LW3 and LW7 that were used in our observations.

2 OBSERVATIONS AND DATA PROCESSING

The observing strategy consisted of sampling a number of critical positions in the Galactic plane with ISOCAM raster scans. The positions of the fields analyzed are given in Table 1.

Table 1. Central positions of the rasters in the GPSURVEY program

OSN	latitude b	longitude l	Revolution number
1	$-0.^{\circ}1$	$+5.^{\circ}2$	148
2	$+0.^{\circ}3$	$+15.^{\circ}9$	148
3	$+0.^{\circ}6$	$+28.^{\circ}1$	152
4	$+0.^{\circ}3$	$-28.^{\circ}8$	273
5	$0.^{\circ}0$	$-15.^{\circ}7$	289
6	$+0.^{\circ}1$	$-6.^{\circ}0$	391
7	$+3.^{\circ}1$	$0.^{\circ}0$	301

Each raster consisted of 6×6 images, separated by 100 arcsec in spacecraft y- and z-axis. This way we covered an area of 135 arcmin^2 in an observation of two hours duration. The images were taken with the Astronomical Observation Template CAM01 using filters LW3 and LW7. They cover the wavelength ranges 12-18 μm and 8.5-10.7 μm, respectively. The pixel field of view was 6 arcsec.
The starting point of the data processing was Auto Analysis Results from pipeline version 7. For the extraction of point sources we used an algorithm developed for the ISOGAL project ([1]), an observing program with a similar observing strategy as GPSURVEY ([10]). It contains inter alia corrections for the distortion of the ISOCAM field of view and for transient effects. Spot-checks of the lists produced were then carried out with the ISOCAM Interactive Analysis software ([12]) in order to test the reliability of the source extraction. In each field we detected more sources in filter LW7 than in filter LW3, as expected because of the shorter wavelength. Therefore it was possible to check the completeness of the LW3 source list by means of cross-identification with LW7. We found for 86 % of the sources stronger than 10 mJy in LW3 a counterpart in LW7, hence the source extraction worked in a satisfactory way down to that flux level.

3 RESULTS

Figs. 1 and 2 show the comparison between the ISOCAM observations and the SKY 5 model for all fields that were observed in the Galactic Plane. For observations sequence numbers (OSN's) 1, 3, 4 and 5 we find excellent agreement. OSN 7 samples mainly the bulge population and is not further discussed in this paper (first results from an analysis of ISOCAM data taken in the inner Galactic Bulge can be found in [11]). For OSN's 2 and 6 we find significantly more sources in filter LW7 than the model predicted; at OSN 2 there is also an excess of sources in filter LW3.
For the comparison with the model we only used the inner 64 arcmin^2 of each GPSURVEY field, where 80 percent of the area has been observed in 4 different raster positions. This way we increased the reliability of the source detection and created a dataset with rather homogeneous signal to noise ratio. We considered only sources with fluxes above 10 mJy, hence the lower limit of our survey is at least five times the rms noise. This is the minimum needed to derive a sound number–flux-density relationship ([8]). For fluxes above several hundred mJy the number of sources found is too small to allow reliable statements on their distribution. Besides, the GPSURVEY fields had to be chosen away from bright sources in order to avoid saturation of the detectors, hence objects with very high fluxes might be systematically underrepresented in our samples. The source densities in our fields range between 3600 and 5200 deg^{-2} for LW3 and between 4900 and 7700 deg^{-2} for LW7; this is not far from the formal confusion limit of 8000 deg^{-2} at 15 μm ([9]).

Fig. 3 gives the colour histograms for the fields that were observed in the Galactic Plane. The observed source colours agree with the model only at the largest distances from the Galactic Center that we observed. Further towards the interior we find more sources with colour indices [9.6]-[15] $\approx$ 1 than the model predicts.

4 CONCLUSIONS

We extended the range of fluxes S for source counts N in the mid-infrared by two orders of magnitude compared to what was known from IRAS. Because of the high sensitivity and spatial resolution provided by ISOCAM, it became possible to check the predictions in the SKY 5 model for the flux range 10-300 mJy.
From a comparison of the source lists for the two different filters we conclude that we have reached a high level of completeness in the LW3 filter down to 10 mJy. This is in good agreement with the limit found in the ISOGAL fields which were observed with a similar strategy. As the sensitivity of the camera in LW7 is rather similar to the one in LW3, we assume that the completeness limit in this filter is $\approx$ 10 mJy as well. This is borne out by the log N, log S slopes which are smooth and essentially constant to this flux limit.
The comparison of the observed source counts with the SKY model showed discrepancies at $l = -6\overset{\circ}{.}0$ and $l = 15\overset{\circ}{.}9$. From the colour indices of the excess stars observed we conclude that they must be late type giants: K, M or AGB stars. This finding supports a stick-like bar with a half-length of about 4 kpc in the inner Galaxy more than a ring ([7]).
Extinction does not affect the source counts strongly, even in filter LW7 which is centered on the "Silicate band" at 9.7 μm. The distribution of stars in a two colour diagram generated with observations at 6.8, 9.6 and 15 μm at $l = -6\overset{\circ}{.}0$ in the Galactic plane suggests an extinction of half a magnitude in LW7. This means that extinction is negligible in LW3 for all the directions probed with this survey.

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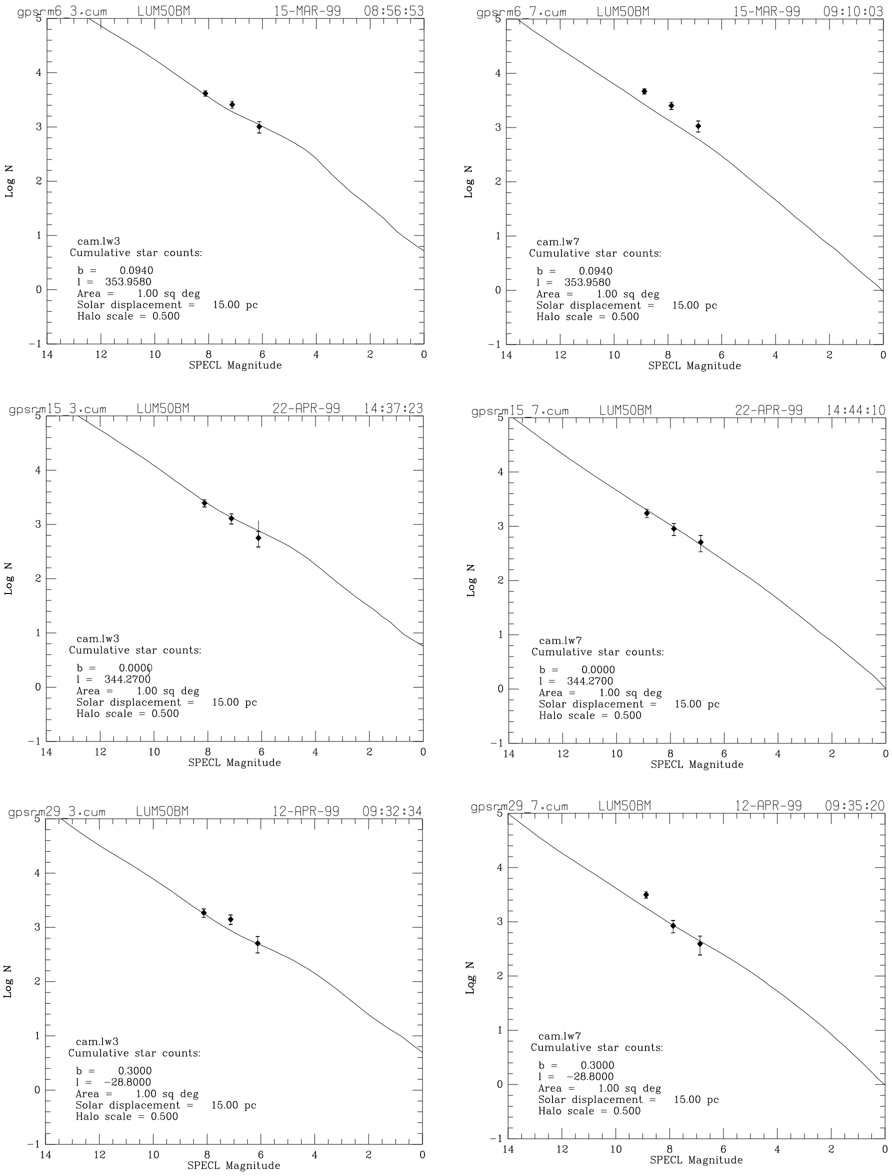

Fig. 1. Comparison of SKY 5 predictions and GPSURVEY observed cumulative star counts at the positions observed at negative longitudes in the Galactic Plane. Poisson error bars are shown, appropriate to the actual number of sources observed in each bin. Diamonds, observed star counts; solid line, total model prediction.

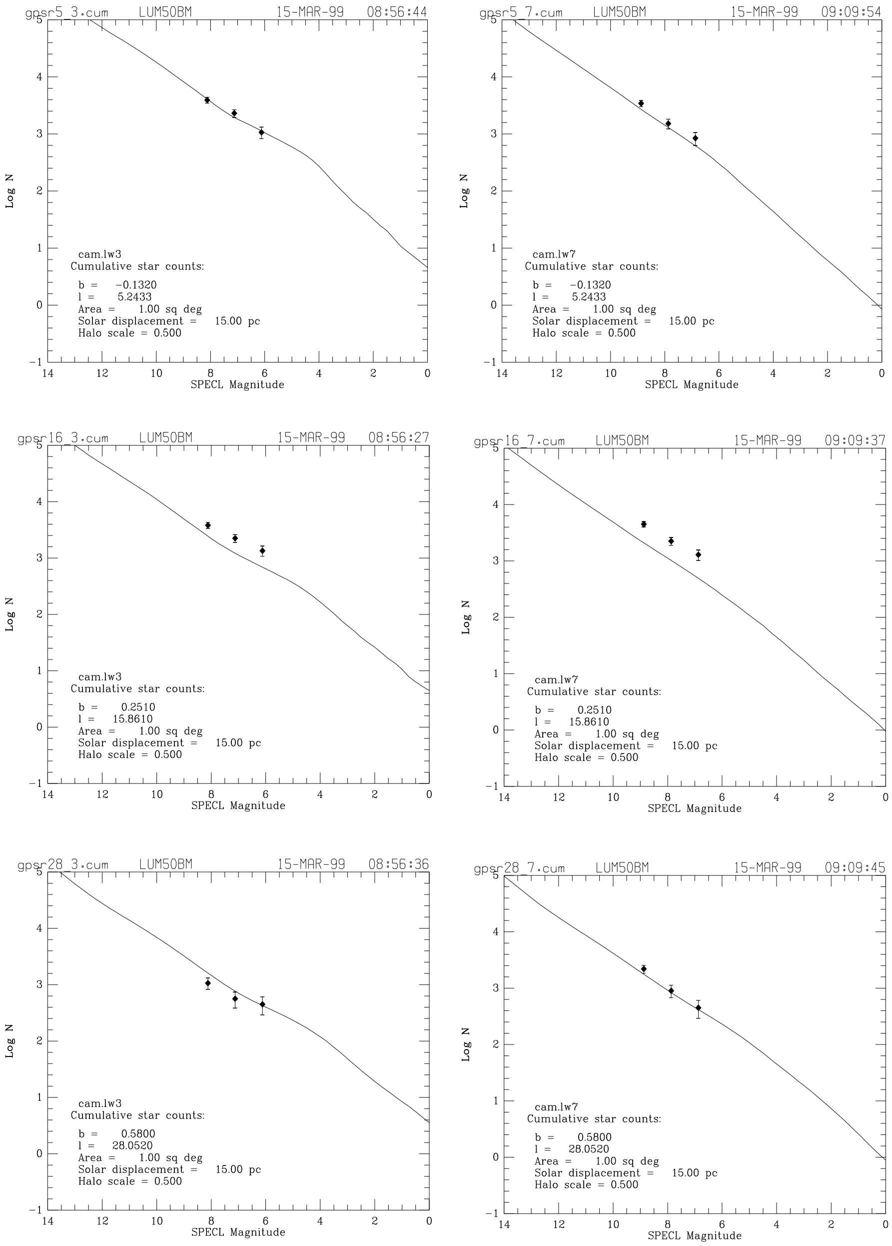

Fig. 2. Comparison of SKY 5 predictions and GPSURVEY observed cumulative star counts as in Fig. 1, but for positive Galactic longitudes.

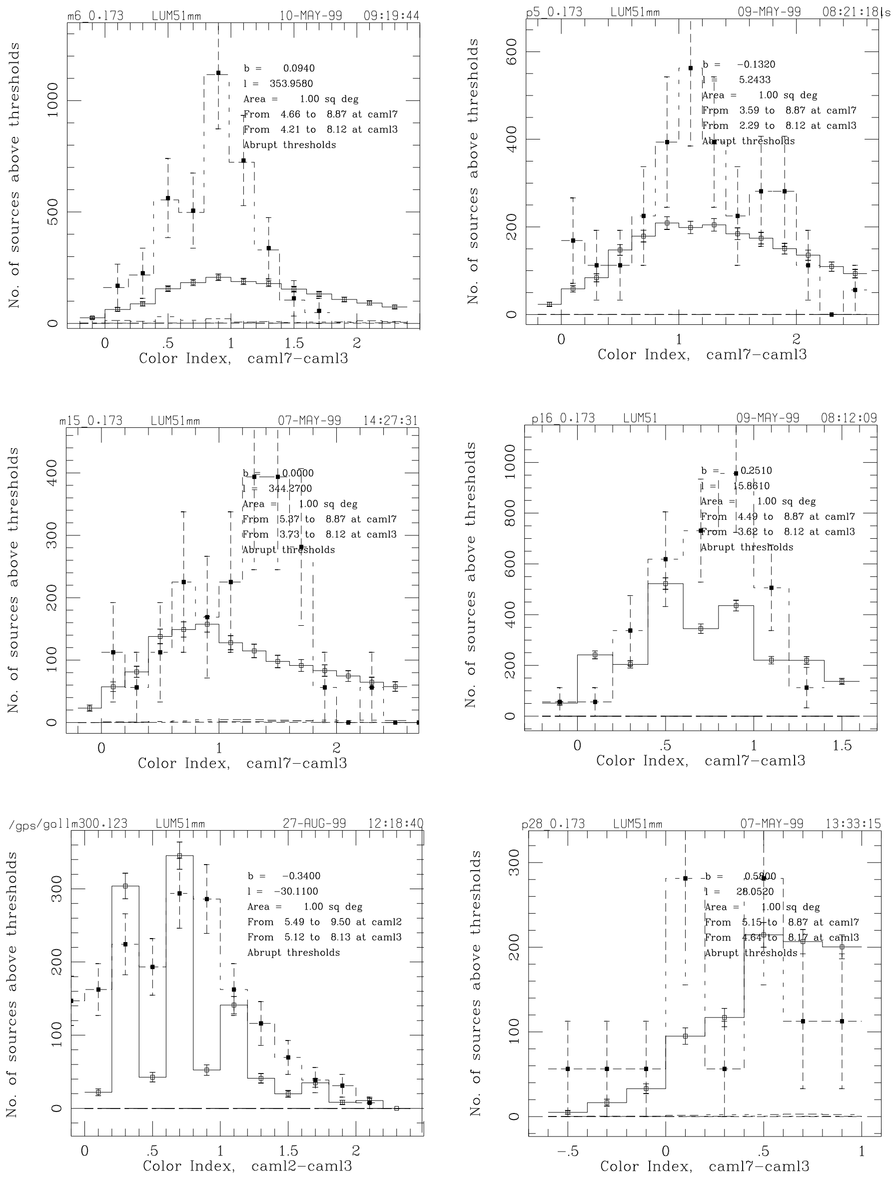

Fig. 3. [9.6]-[15] colour histograms for the fields observed in the Galactic Plane ([6.8]-[15] for $l = -30°$). Solid line, total model prediction; short dashed, observed number of point sources.