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ATLASGAL - The APEX Telescope Large Area Survey of the Galaxy at 870 μm

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ABSTRACT

Context. Thanks to its excellent 5100 m high site in Chajnantor, the Atacama Pathfinder Experiment (APEX) systematically explores the southern sky at submillimeter wavelengths, both in continuum and in spectral line emission. Studying continuum emission from interstellar dust is essential to locate the highest density regions in the interstellar medium, and to derive their masses, column densities, density structures, and larger scale morphologies. In particular, the early stages of (massive) star formation are still quite mysterious: only small samples of high-mass proto-stellar or young stellar objects have been studied in detail so far.

Aims. Our goal is to produce a large scale, systematic database of massive pre- and proto-stellar clumps in the Galaxy, in order to better understand how and under what conditions star formation takes place. Only a systematic survey of the Galactic Plane can provide the statistical basis for unbiased studies. A well characterized sample of Galactic star-forming sites will deliver an evolutionary sequence and a mass function of high-mass star-forming clumps. Such a systematic survey at submillimeter wavelengths also represents a pioneering work in preparation for Herschel and ALMA.

Methods. The APEX telescope is ideally located to observe the inner Milky Way. The recently commissioned Large APEX Bolometer Camera (LABOCA) is a 295-element bolometer array observing at 870 μm, with a beam of 19.″2. Taking advantage of its large field of view (11.′4) and excellent sensitivity, we have started an unbiased survey of the whole Galactic Plane accessible to APEX, with a typical noise level of 50–70 mJy/beam: the APEX Telescope Large Area Survey of the Galaxy (ATLASGAL).

Results. As a first step, we have covered ~95 deg^2 of the Galactic Plane. These data reveal ~6000 compact sources brighter than 0.25 Jy, or 63 sources per square degree, as well as extended structures, many of them filamentary. About two thirds of the compact sources have no bright infrared counterpart, and some of them are likely to correspond to the precursors of (high-mass) proto-stars or proto-clusters. Other compact sources harbor hot cores, compact HII regions or young embedded clusters, thus tracing more evolved stages after star formation has occurred. Assuming a typical distance of 5 kpc, most sources are clumps smaller than 1 pc with masses from a few 10 to a few 100 $M_\odot$. In this first introductory paper, we show preliminary results from these ongoing observations, and discuss the mid- and long-term perspectives of the survey.

Key words. Surveys — Submillimeter — ISM: structure — Dust, extinction — Stars: formation — Galaxy: disk

1. Introduction

Dust continuum emission in the (sub)millimeter (submm) range is one of the best tracers of the earliest phases of star formation since it is directly probing the dense interstellar material from which the stars form. Trying to understand the formation and early evolution of stars is an important field of modern astrophysics (see the recent review of McKee & Ostriker 2007, and references therein).

Over the past two decades, a large amount of theoretical effort has been aimed at constraining the early stages of the formation of isolated low mass (solar-like) stars. Still, today two quite different pictures are being maintained. On the one hand, a collapse picture has emerged whose "long" time scales are determined by ambipolar diffusion (Shu et al. 1987; Adams et al. 1987). On the other, a scenario is advocated in which the star formation rate is governed by supersonic turbulence (Mac Low & Klessen 2004). Many recent observational campaigns have contributed crucial data and in particular sys-

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tematic (sub)millimeter surveys of nearby star forming regions, such as Chamaeleon, Perseus and Ophiuchus, have resulted in the detection of many prestellar and proto-stellar condensations (André et al. 2000; Ward-Thompson et al. 2007). They allow determination of the dense core mass spectrum down to sub-stellar masses, and investigation of its relationship to the Initial Mass Function (Motte et al. 1998; Gahm et al. 2002; Hatchell et al. 2005).

High-mass star formation is even less constrained (e.g. Zinnecker & Yorke 2007; Beuther et al. 2007, for recent reviews) and there is controversy on the issue of how such stars attain their final masses: driven by turbulence (McKee & Tan 2003) on the one hand and competitive accretion (e.g. Bonnell et al. 2004) on the other. Since high-mass stars seem to form mostly in clusters (along with many more lower-mass stars), it is fundamental to have a good estimate of the mass distribution of cluster forming clumps in the Giant Molecular Clouds (GMCs) they are part of. This exactly is one of the major goals of the present effort.

A cardinal reason for the many open questions concerning high-mass star formation is the fact that the relevant time-scales are short (McKee & Tan 2002), implying low number statistics in finding stars in a given evolutionary state. Moreover, high-mass stars are rare. This implies that regions in which they form are generally at large distances, which leads to the basic problem that such objects are difficult to identify. For instance, little is known so far about the Galactic molecular ring, a few kpc distant from us, and where most of the star formation is presently taking place (e.g. Bronfman et al. 2000).

While various samples of high-mass proto-stellar objects have been defined based on various criteria, such as maser emission (e.g., Walsh et al. 1997; Pestalozzi et al. 2005) and infrared (IR) colors (Palla et al. 1991; Molinari et al. 1996; Sridharan et al. 2002; Lumsden et al. 2002; Robitaille et al. 2008), an *unbiased* sample has not yet been assembled. In the past two decades, much effort has focused on follow-up studies of bright IR sources detected by the Infrared Astronomy Satellite (IRAS) and showing far-infrared (FIR) colors typical of ultra-compact HII regions (Wood & Churchwell 1989), e.g. in high-density molecular tracers (Bronfman et al. 1996; Molinari et al. 1996) or in dust continuum emission (Faúndez et al. 2004), or in maser emission (e.g. Palla et al. 1993; Beuther et al. 2002). While some of these studies revealed a few massive cold cores in the neighborhood of the central compact HII region (e.g. Garay et al. 2004), they were mostly biased against the earliest, possibly coldest phases of massive star formation.

Alternatively, dense condensations in Infrared Dark Clouds (IRDCs, see Simon et al. 2006, for a recent compilation) are promising hunting grounds for the initial stages of high-mass star formation (e.g. Rathborne et al. 2006; see also the recent reviews by Menten et al. 2005; Wyrowski 2008). IRDCs appear in absorption by dust even at mid-infrared wavelengths against the diffuse emission of the Galactic Plane and trace high column densities. However, IRDCs get increasingly difficult to identify the further away they are, and the relative contributions by foreground and background emission may be difficult to estimate. Also massive dust condensations are not all infrared dark clouds. For example the two most massive condensations (with masses of 200 and 800 $M_\odot$ at a distance of 1.3 kpc) observed at 870 μm in the photo-dissociation region (PDR) bordering the RCW 120 HII region (Deharveng et al. 2009) are not detected as IRDCs at 8 or 24 μm. They are hidden, at these wavelengths, by the bright emission of the adjacent foreground PDR.

Cold dust absorbing the IR radiation also shows thermal emission in the submm regime. This grey body emission is generally optically thin and, thus, an excellent tracer of the dust mass and, by inference, total mass of the emitting cloud. Therefore, observations in the submm continuum are complementary to the IR extinction techniques. Given the short time-scales for the formation of high-mass stars, all early formation stages will still be associated with strong dust continuum emission, allowing a systematic study of a large range of evolutionary phases.

Recently, several groups have performed large scale mapping of molecular complexes in the (sub)millimeter continuum. Using the Submillimetre Common User Bolometer Array (SCUBA) instrument, Johnstone et al. (2004) have mapped 4 deg^2 of the Ophiuchus star-forming cloud, and Hatchell et al. (2005) have covered 3 deg^2 of the Perseus molecular cloud. Complementary to the Spitzer "Cores to Disks" legacy project (Evans et al. 2003), Enoch et al. (2006) have mapped 7.5 deg^2 covering the Perseus cloud, and Young et al. (2006) have mapped nearly 11 deg^2 covering Ophiucus, both using the BOLOCAM instrument at 1.1 mm.

In the field of high-mass star formation, Moore et al. (2007) have covered 0.9 deg^2 of the W3 giant molecular cloud with SCUBA. Going to larger scale, Motte et al. (2007) used the MAMBO instrument to obtain a complete dust continuum map of the molecular complex associated with the Cygnus X region. From this 3 deg^2 map, they could derive some statistically significant results on the characteristics (e.g. mass, density, outflow power, mid-IR flux) and lifetimes of different evolutionary phases of high-mass star formation. In particular, no high-mass analog of pre-stellar dense cores was found by this study, hinting at a short lifetime for the earliest phases of dense cores in which high-mass stars are being formed. An unbiased survey of the complete Galactic Plane will allow us to put much stronger constraints on this stage of high-mass star formation.

On an excellent 5100 m high site and at a latitude of -23°, the 12 m diameter APEX telescope (Güsten et al. 2006a,b) is ideally located to make sensitive observations of the two inner quadrants of the Galactic Plane. A consortium led by the Max Planck Institute für Radioastronomie (MPIfR) in Bonn, involving scientists from the Max Planck Institute für Astronomie in Heidelberg and from the ESO and Chilean communities has embarked on the APEX Telescope Large Area Survey of the Galaxy (ATLASGAL). This project aims at a systematic survey of the inner Galactic Plane, mapping several 100 deg^2 with a uniform sensitivity. In this paper, we present the first data taken and analyzed. The observing strategy and data reduction are described in § 2 and § 3. First preliminary results are discussed in §4. Finally, we discuss longer term perspectives in §5.

2. Observations

Observations of continuum emission from interstellar dust at (sub)millimeter wavelengths are best made with sensitive broadband bolometer detectors. Modern (sub)millimeter bolometer development started in the mid 1980s with single pixel element instruments, with a resolution, i.e. diffraction limited FWHM beam size, of 11″ for the IRAM 30 m telescope at 1.2 mm and 19″ for the James Clerk Maxwell Telescope (JCMT) at 1.1 mm. Since then, arrays with more and more elements have been developed and deployed to telescopes. Modern arrays of bolometers have hundreds of elements: 384 for the Nyquist-sampled Submillimeter High-Angular Resolution Camera 2 (SHARC II, Dowell et al. 2003), and 295 for the Large APEX Bolometer Camera (LABOCA), which has recently been deployed at the

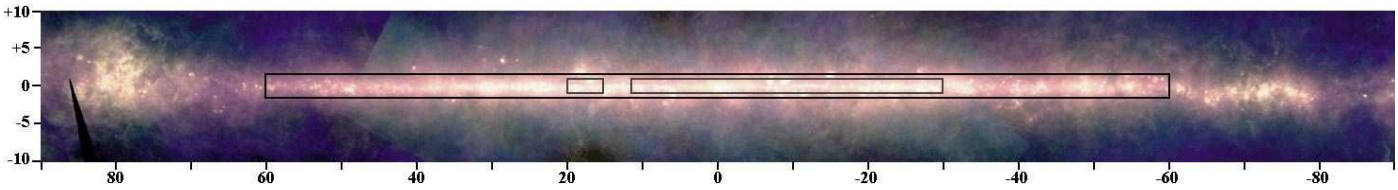


Fig. 1. Coverage of the ATLASGAL observations overlaid on an IRAS false color image (12 μm in blue, 60 μm in green and 100 μm in red). This image covers ±90° in galactic longitude, and ±10° in latitude. The long frame shows the area that we plan to cover until the end of 2009: ±60° in l and ±1.5° in b. The smaller frames inside delineate the area that was observed in 2007 (see also Fig. 3).

APEX telescope (Siringo et al. 2007, 2009). With a field of view of 11.′4, and a single pixel sensitivity (noise equivalent flux density, NEFD) in the range 40–70 mJy $s^{1/2}$, LABOCA is currently the most powerful bolometer array for large scale mapping operational on a ground-based telescope.

The ATLASGAL observations are carried out at the APEX 12 m submm antenna, which is a modified copy of the VERTEX prototype antenna for the Atacama Large Millimeter Array (ALMA). The antenna has an improved surface accuracy of 15 μm rms, i.e. better than ALMA specifications. Two additional Nasmyth cabins allow several receivers to be ready for use. The LABOCA instrument is an array made of 295 bolometers arranged in an hexagonal pattern, with two-beam spacing between bolometers (Siringo et al. 2009). It is located at the Cassegrain focus, where it has an effective field of view of 11.′4 in diameter. Small variations in the beam shape are seen within the field of view, but should not affect the data (see Siringo et al. 2009, for a discussion of these effets). Its bandpass is centered at 870 μm (frequency 345 GHz), with a bandwidth of 60 GHz. The beam at this wavelength has been measured to have a width of 19.″2 FWHM. The number of usable bolometers at the end of the reduction, after flagging the noisy ones and the ones not responding (Sect. 3) is usually between 250 and 260.

In the present paper, we will focus on the data acquired in 2007, which cover 95 deg^2: $-30° \leq l \leq +11.5°$ and $+15° \leq l \leq +21°$, with $|b| \leq 1°$ (Fig. 1), at a one-σ sensitivity of 50 to 70 mJy/beam. For comparison, the 9-year lifetime of the SCUBA instrument resulted in a total of 29.3 deg^2 mapped at 850 μm (Di Francesco et al. 2008). A single observation consists in an on-the-fly map, 2° long and 1° wide, with 1.′5 steps between individual lines, resulting in fully sampled maps covering 2 deg^2. The scanning speed used is 3′/s. This fast scanning allows to perform observations in total power mode, i.e. without chopping. Each map crosses the Galactic Plane with a ±15° position angle with respect to the galactic latitude axis. Two consecutive maps are spaced by 0.5° along the Galactic Plane, with a 30° difference in position angle (Fig. 2). Thus, each position on the sky is observed in two independent maps, with different position angles, greatly reducing many systematic effects (e.g. striping in the scanning direction).

In the longer term, we are planning to extend the coverage to ±60° in longitude and ±1.5° in latitude (Fig. 1), with the same sensitivity of 50 mJy/beam. An ESO large programme has recently been approved to conduct these observations, which will require a total of 430 hours, including all overheads, to cover 360 deg^2. The observing time will be shared with 45 hours from Chile, 225 hours from the Max-Planck-Society (MPG) and 160 hours from ESO, spanning four semesters in 2008–2009.

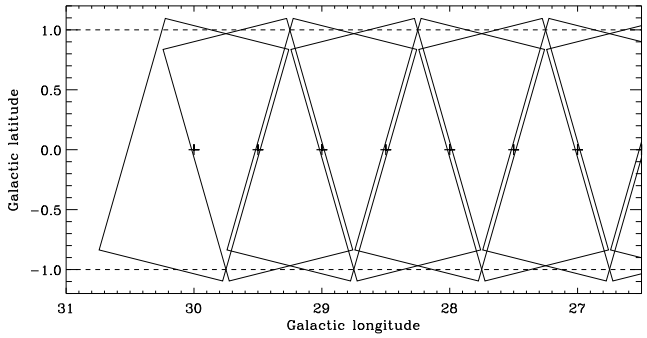


Fig. 2. Mapping strategy: each rectangular frame represents a single map. The plus symbols show the maps centers. A position angle of 15° with respect to the galactic axis was chosen. Two neighboring maps are observed with position angles of +15° and −15°, respectively.

3. Data reduction and source extraction

The raw data are recorded in MB-FITS (Multi-Beam FITS) format by the FITS writer, which is part of the APEX Control System (APECS, Muders et al. 2006). These data were processed using the BOlometer array data Analysis package (BOA; Schuller et al. in prep.), which was specifically developed as part of the LABOCA project to reduce data obtained with bolometers at the APEX telescope. The reduction steps involved in the processing of the ATLASGAL data are described in the next subsections.

3.1. First step: from raw data to 2 deg^2 maps

Each single observation is processed and calibrated in order to build a map covering 2 deg^2. The data are calibrated by applying an opacity correction, as determined from skydips observed typically every two hours (see Siringo et al. 2009, for more details). In addition, the flux calibration is regularly (every hour) checked against primary calibrators (the planets Mars, Neptune and Uranus) or secondary calibrators (bright Galactic sources, for which the fluxes at 870 μm were measured during the commissioning of LABOCA). If any discrepancy is found between the opacity-corrected flux of a calibrator and its expected flux, then the correction factor required to get the expected flux is also applied to the science data. Given the uncertainties on the fluxes of the planets themselves, we estimate that, alltogether, the typical calibration accuracy should be better than 15%. Pointing scans are also observed on bright sources every hour; the pointing rms is typically of order 4″.

The reduction steps are as follows:

– flagging bad pixels (not responding, or not seeing the sky)
– correlated noise removal (see below for details)

– flagging noisy pixels
– despiking
– low frequency filtering (see below)
– first order baseline on the full time stream
– building a map, using natural weighting: each data point has a weight 1/rms^2, where rms is the standard deviation of each pixel

The main source of noise in the submm is variable atmospheric emission (sky noise) which varies slowly with typical amplitudes of several 100 Jy. Fortunately, this sky noise is highly correlated between bolometers. For each integration, the correlated noise is computed as the median value of all normalized signals. It is removed in successive steps: as a first step the median between all bolometers is computed, then between pixels connected to the same amplifier box (groups of 60 to 80 pixels); finally, the correlated signal is computed for groups of 20 to 25 pixels sharing the same read-out cable. A consequence of this processing is that uniformly extended emission is filtered out, since there is no way to distinguish extended astronomical signal seen by all bolometers from correlated (e.g. atmospheric) noise. The strongest effect occurs when computing the correlated noise in groups of pixels: these groups typically cover $\sim 1\farcm5 \times 5'$ on the array, and since the correlated noise is computed as the median value of the signals, any emission that is seen by more than half the bolometers in a given group is subtracted. Thus, *uniform* emission on scales larger than $\sim 2\farcm5$ is filtered out.

Another low frequency filtering is performed, in order to reduce the effects of the slow instrumental drifts which are not correlated between bolometers. This filtering is performed in the Fourier domain, and applies to frequencies below 0.2 Hz, which, given the scanning speed of 3′/s, translates to spatial scales above 15′, i.e. larger than the LABOCA field of view. Therefore, this step should not affect extended emission that has not already been filtered out by the correlated noise removal.

This reduction is optimized for recovering compact sources with a good signal-to-noise. Alternatively, the data can be reduced without subtracting all components of correlated noise, which allows one to recover more extended emission, but results in an increased noise level in the final maps.

3.2. Second step: using a source model

The data processed in the first step are then combined by groups of three maps: for each position l_0, the maps centered at l_0, $l_0 + 0.5^\circ$ and $l_0 - 0.5^\circ$ are computed and co-added to get a two-fold coverage on the central 1×2 deg^2 area (see Fig. 2). This combined map is then used as a source model to mask the data in the time streams which correspond to positions in the map where the emission is above some given threshold. The full reduction is then performed again, involving the same processing steps as described in the previous section, with somewhat less conservative parameters for despiking and correlated noise removal. During this step, data points that correspond to strong emission in the model map are masked for the various computations (baseline removal, despiking, subtraction of correlated noise), but the results of these computations are also applied to the masked data.

Finally, another iteration is performed, this time *subtracting* the source model (resulting from the previous step) from the raw data. In this case, all data-points are used for the computations, and processing steps that may affect strong sources (e.g. despiking) can be performed with only little caution, since most of the real emission has been subtracted from the signals. Before adding the source model back into the reduced data, weights are computed using sliding windows along the time-streams. The weight affected to each data-point is 1/rms^2, where rms is the standard deviation in a given pixel computed for 50 data-points. The net effect of these iterations with source model is to reduce the negative artifacts that appear around strong sources in the first reduction step and to recover some fraction of the flux of bright objects that was lost in that step. The final flux uncertainty for compact sources should be lower than 15% (Sect. 3.1), as also confirmed by hundreds of measurements of primary and secondary calibrators (Siringo et al. 2009).

When building maps with two pixels per beam, the final noise level obtained from individual observations is generally in the 70–100 mJy/beam range. In the combined maps, the rms is then 50–70 mJy/beam in overlapping regions. The combined maps covering continuously -30° to $+12^\circ$ in longitude are shown in Fig. 3, and example zooms are shown in Fig. 4.

3.3. Compact source extraction

A preliminary extraction of compact sources was done using the SExtractor programme (Bertin & Arnouts 1996). The extraction was done in two steps: first, the peaks are detected on signal-to-noise ratio maps; then, SExtractor is used to compute the sources peak positions and fluxes, as well as their sizes. Since we were only interested in compact sources to build this first catalog, one constraint used was that the ratio of major to minor axes should be lesser than 4. Details on the method and the complete catalog itself will be published in a forthcoming paper (Contreras et al. in prep).

This source extraction resulted in ∼6000 objects with peak fluxes above 250 mJy/beam, over the 95 deg^2 mapped. The average source density is thus 63 sources per square degree, but the sources' distribution is highly non-uniform (Fig. 5). The source sizes range from one LABOCA beam (19″) to about 8 beams (150″). We note that the filtering of uniform emission on spatial scales larger than $2\farcm5$ (Sect. 3.1) should not prevent extraction of sources with larger FWHM, as long as they are reasonably compact, i.e. with a profile close to a Gaussian shape; however their fluxes would be severely underestimated.

Assuming a typical distance of 5 kpc, which roughly corresponds to the molecular ring, the 19″ resolution translates to ∼0.5 pc. The LABOCA data are therefore sensitive to molecular clumps, following the terminology of Williams et al. (2000, see also Motte & Hennebelle 2009), where dense cores have typical sizes ∼0.1 pc and are embedded in pc-scale clumps, themselves being part of >10 pc GMCs. The sources distribution is strongly peaked toward the Galactic Plane, as seen in Fig. 5, and in particular in the direction of the Galactic Center, with an excess of sources toward negative latitudes. Within the central few degrees, sources show an excess at positive longitudes. Other peaks in longitude are visible in Fig. 5 in the direction of the Norma arm ($-30^\circ \leq l \leq -20^\circ$), and around $l = -8^\circ$, which corresponds to the NGC6334/NGC6357 star forming complexes.

As seen in Fig. 5, the latitude distribution of compact sources peaks at $b = -0.09^\circ$, which is significantly below zero. This effect is seen in all ranges of longitudes. We suspect this is due to the Sun being slightly above the Galactic Plane, but this effect requires more study. The reason for the asymmetry in longitude within the few central degrees is unclear, but is certainly real, as can be seen also in Fig. 3. Interestingly, the distribution of compact sources seen with Spitzer at 24 μm shows an excess toward *negative* longitudes (Hinz et al. 2008). While no clear explanation is found, Hinz et al. (2008) suggest that this could reflect the actual distribution of infrared sources near the Galactic Center,

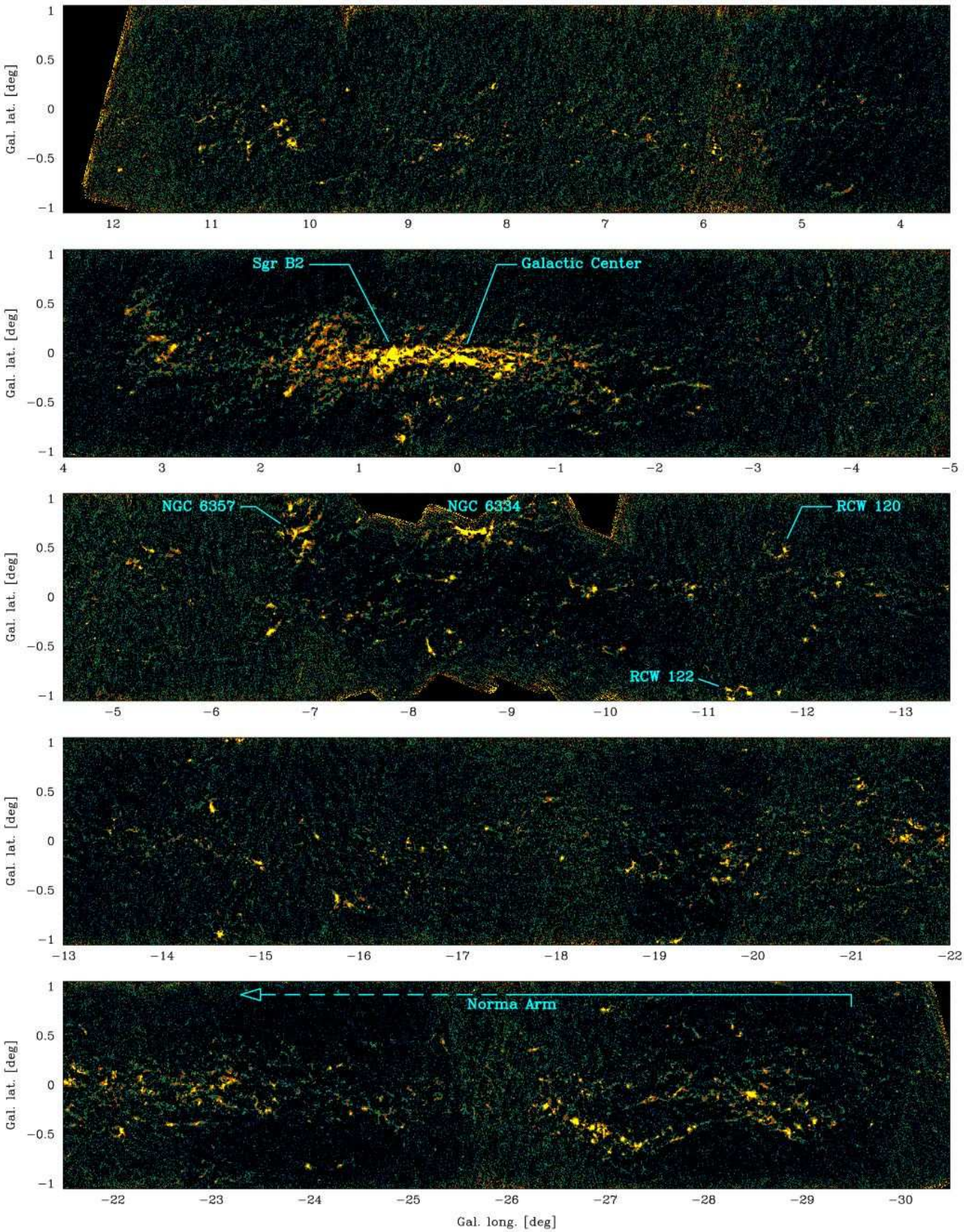


Fig. 3. Combined maps showing 84 deg^2 of the ATLASGAL data obtained in 2007, at 870 μm with a resolution of 19″. The color scale is logarithmic between 0.05 and 1.0 Jy/beam. The rms is of order 50 to 70 mJy/beam in most parts of these maps. A few known regions are labeled in the maps. See also Fig. 4.

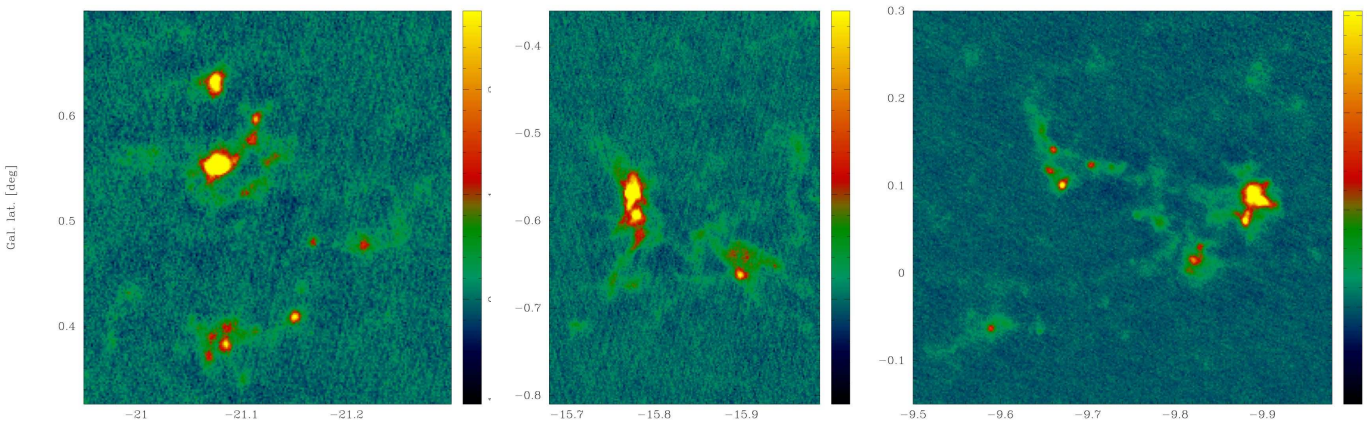


Fig. 4. Zooms into selected regions. These maps are projected with three pixels per beam, resulting in a pixel r.m.s. between 80 and 130 mJy/beam. All maps are shown in linear scale, calibrated to Jy/beam. The color scale has been chosen to highlight the negative artifacts, but doesn't cover the full range of fluxes in these images: the brightest peaks are, from left to right, 18.6, 17.2 and 7.2 Jy/beam; the most negative pixels are at -0.49, -0.54 and -0.43 Jy/beam, respectively.

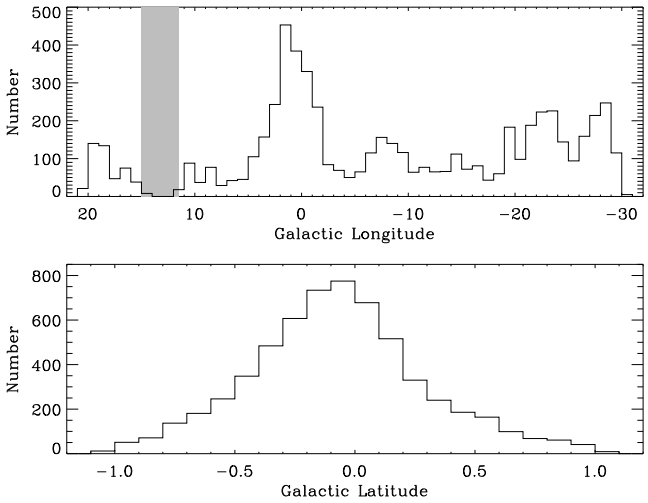


Fig. 5. Distribution of the 6000 compact sources in Galactic longitude (top, with 1° bins) and latitude (bottom, with 0.1° bins). Note that the longitude range +11.5° to +15° is not covered by the present data.

if more molecular clouds are present at positive longitudes, hiding the compact IR sources, which would be consistent with the distribution that we observe in the submm.

4. First results

The large scale maps in Fig. 3 clearly show a variety of submillimeter sources from bright compact objects to faint extended regions on the arcmin scale, to long filaments up to nearly the degree scale. The survey is very rich, and a wealth of new results is expected. To give a flavor of these and to illustrate how a complete view of the Galactic star formation activity will be achieved from ATLASGAL, we present here a first analysis and some first results for a typical 1° wide slice, around $l = 19°$ (Fig. 6). This region shows a reasonably rich population of sources, and is also representative of regions with several cloud complexes at different distances. We also selected this region because it is covered by the Galactic Ring Survey (GRS, Jackson et al. 2006), which provides good quality CO data that we use to discuss the association with large scale molecular clouds.

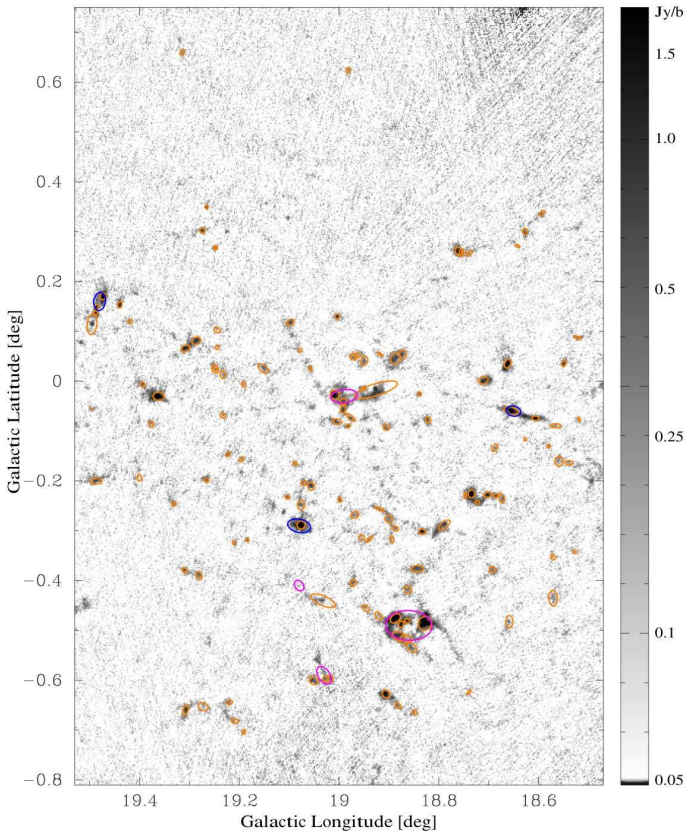


Fig. 6. Example combined map covering 1×1.5 deg^2, shown in logarithmic scale. The pixel scale is one third of the beam and the standard deviation between pixels in empty regions of the maps is typically 90 mJy/beam. The brightest peak is at 6.2 Jy/beam. The 128 compact sources extracted in this region are shown with orange ellipses, with sizes and position angles as measured with SExtractor (Sect. 3.3). Ultra-compact HII regions discussed at the end of Sect. 4.2 are shown with blue ellipses; compact and classical HII regions are indicated with magenta ellipses.

4.1. Compact sources and extended emission at $l = 19°$

In a number of galactic directions, there is submillimeter emission virtually everywhere in the Galactic Plane. The region shown in Fig. 6 at $l = 19°$ is one of these. From our preliminary source extraction, we find 128 compact sources with peak fluxes above 0.25 Jy/beam in this 1×2 deg^2 slice (no source is detected outside the $|b| \leq 0.75°$ range shown in Fig. 6), in perfect agreement with the average 63 extracted sources per square degree. Only 16 of these sources have a probable known counterpart in the SIMBAD database (infrared, millimeter or radio source within a 10″ search radius), which means that more than 80% have not yet been studied. Some of them certainly have counterparts in the new infrared surveys observed with Spitzer (see e.g. Fig. 14); associations between ATLASGAL and Spitzer data will be addressed elsewhere.

As can be seen in Fig. 6, most of the compact sources are actually embedded in more extended emission of a few arcmin extent. Many of these features appear filamentary and could correspond to over-densities within giant molecular clouds, in which even denser clumps are forming. That small groups of clumps belong to one single molecular complex is sometimes confirmed by informations on their kinematics, as discussed in the next section.

4.2. Coherent complexes and distance determination

Toward the inner Galactic Plane, the detected sources can be at any distance. *A priori* any direction of the Plane could contain sources at distances distributed over a significant range of values, except for some peculiar lines of sight, like the Galactic Center (GC), where most sources are probably concentrated close to the GC itself. In other directions, one expects to find over-densities of objects at particular distances, corresponding to the Galactic arms, particularly in the molecular ring region, but a wide range of distances is allowed.

Distance determination in the Galaxy is a difficult issue. The kinematic distances can be obtained thanks to molecular line follow-ups. We have started systematic observations of the compact ATLASGAL sources in NH_3 with the Effelsberg 100 m telescope (Wienen et al. in prep.) for the northern part of the plane, and in many molecular lines observed simultaneously with the MOPRA 22 m telescope (Wyrowski et al. in prep.) for the southern part. The NH_3 lines were detected for nearly all targeted sources, showing various line widths and shapes, and usually with only one velocity component (see examples in Fig. 7). This is expected since NH_3 is a high density tracer, which is detectable only for the dense cores also seen with LABOCA.

Twenty-four of the total 278 sources observed so far in NH_3 are located in the region shown in Fig. 6. The distribution of measured V_{LSR} is shown in Fig. 8. Interestingly, the velocities are not spread over the whole allowed range, but are mostly gathered in very few coherent groups. In addition, these groups are also spatially coherent (see Fig. 8 top). We can conclude that the ATLASGAL emission is dominated by few bright complexes at specific distances. In the $l = 19°$ region, 15 out of 24 ATLASGAL compact sources detected in NH_3 have a velocity between 60 and 66 km s^{-1}. Such a complex would be at a distance of 4 or 12 kpc depending whether the near or the far solution for the kinematic distance is correct. In addition to this clear velocity component, two sources are at rather low velocities around 20 km s^{-1}, a few are between 35 and 50 km s^{-1} and two are at 80 and 81 km s^{-1} respectively.

In order to further study the spatial distribution of these velocity components, we have used the ^{13}CO(1–0) data from the GRS to identify the molecular complexes associated with these velocities (Fig. 9). In addition, using an extinction map obtained from the 2MASS catalog (Bontemps, priv. com.), it is possible to recognize that some of these complexes actually account for the detected extinction and are therefore most probably at their near kinematic distance. This is the case for the 36 to 52 km s^{-1} complex, and for a small part of the ∼20 km s^{-1} clouds (dashed line arc around (19.35, 0.05) in Fig. 9). The main complex at 65 km s^{-1} is more complicated: parts of this complex are associated with peaks of extinction, but other parts correspond to very low extinction. Nevertheless, this might indicate that it is also at the near distance. In addition, this complex appears quite extended at 8 μm and 870 μm, which again favors the near distance solution. The full extent of the ^{13}CO emission, spanning about 0.9° in latitude, corresponds to 70 pc at a distance of 4.5 kpc, typical of GMC dimensions.

Finally, we note that a large part of the ∼20 km s^{-1} component is a string of compact CO clouds which are not associated with any feature in the extinction map. They are therefore most probably complexes at their far distance, i.e. of the order 14 kpc. The source at $(l, b) = (18.76, 0.26)$ coincides with a very compact object in the GLIMPSE (Benjamin et al. 2003) image (Fig. 10), also consistent with a far distance solution.

Additional constraints can be obtained from absorption lines toward HII regions (e.g. Sewilo et al. 2004; Anderson & Bania 2009). Anderson & Bania (2009) list seven HII regions with distance determination in the range $18.5° \leq l \leq 19.5°$: three ultracompact and four compact/classical regions. All three ultracompact and three out of the four compact regions have clear

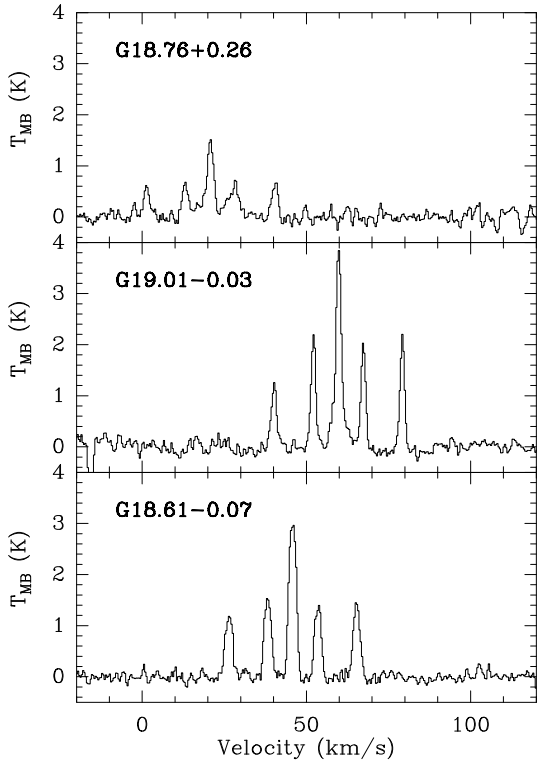


Fig. 7. Example spectra in NH_3 (1,1) transition for three sources located in the region shown in Fig. 6. G18.76+0.26 is probably at a distance of ∼14 kpc, while G19.01-0.03 and G18.61-0.07 are probably at 4.3 and 3.7 kpc, respectively.

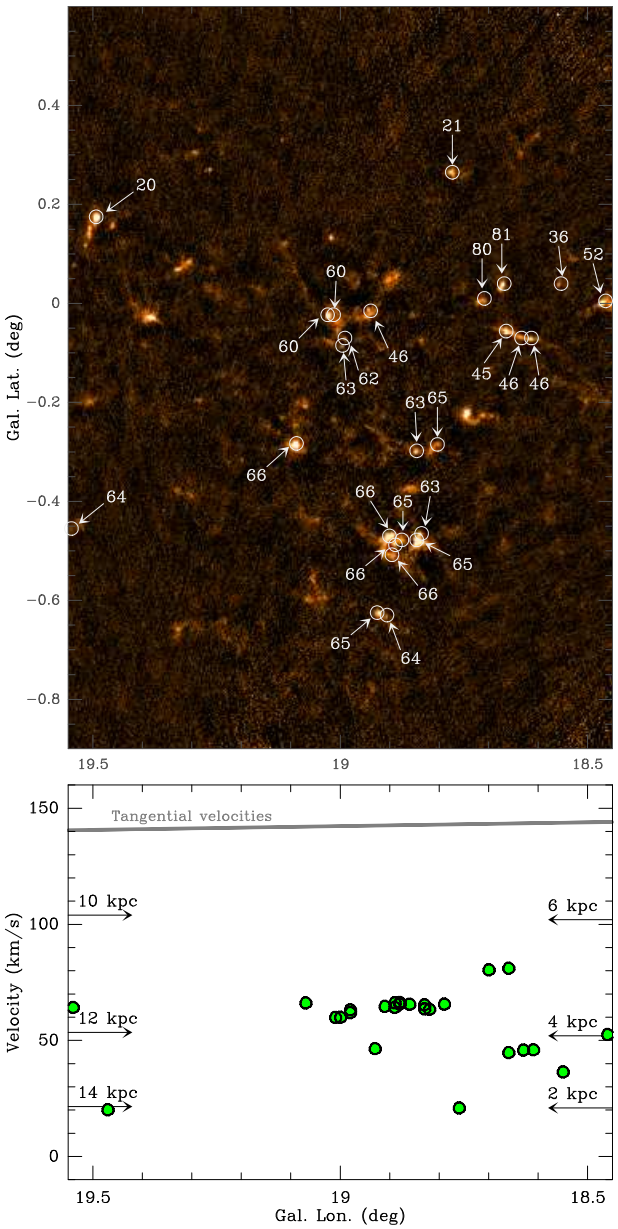


Fig. 8. *Top*: LSR velocities (in km s^{-1}) derived from NH_3 spectra are indicated next to the sources visible in the ATLASGAL map. *Bottom*: the measured LSR velocities are plotted against Galactic longitude. Kinematic distances derived using the Galactic rotation model of Brand & Blitz (1993) are indicated on the right for the near distance solution, and on the left for the far solution. The thick line near 140 km s^{-1} shows the maximal expected velocity, which corresponds to the tangential point for a circular orbit with a radius ~2.7 kpc around the GC.

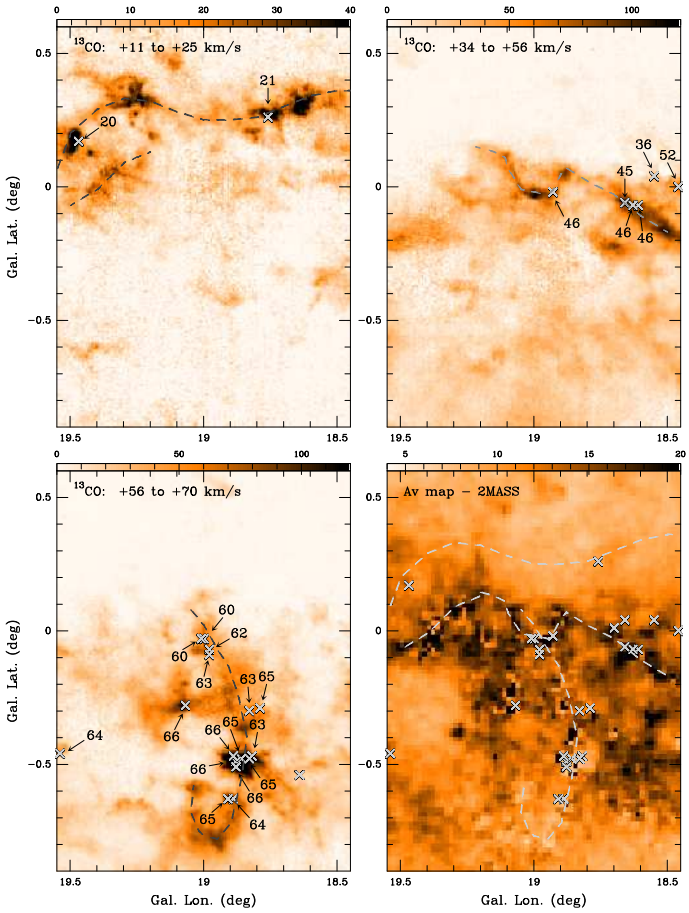


Fig. 9. Integrated ^{13}CO(1–0) intensity over different ranges of velocities, shown in the top-left corner of each panel, from the GRS data. The color scale is shown on top of each panel, in units of K km s^{-1}. LSR velocities of ATLASGAL sources derived from the NH_3 spectra are indicated. *Bottom right*: extinction map derived from the 2MASS catalog. The color scale corresponds to magnitudes of visual extinction. In all panels, dashed lines outline structures that seem connected together.

counterpart in ATLASGAL (Fig. 6). Except for C18.95-0.02, which shows several components in the ^{13}CO spectrum, and C19.04-0.43, that we did not observe in NH_3, there is a good agreement between the LSR velocities derived from radio recombination lines, ^{13}CO(1–0) and NH_3 transitions. Finally, results from, both, Sewilo et al. (2004) and Anderson & Bania (2009) generally agree with our conclusions for the objects located in the test field, with the +65 km s^{-1} complex being at the near distance, and the +20 km s^{-1} clump G19.47+0.17 being at the far distance. However, in a few cases, properly interpreting absorption lines remains difficult: Sewilo et al. (2004) and Anderson & Bania (2009) conclude with a far distance solution for U18.66-0.06, but all three ATLASGAL sources that we observed in NH_3 (with v_{LSR} ~ +45 km s^{-1}) follow an IRDC nicely detected in GLIMPSE (Figs. 10 and 14), which favors a near distance. Discussion of all individual sources goes beyond the scope of the present paper, and will be addressed elsewhere.

4.3. Mass estimates

Dust emission is generally optically thin in the submm continuum. Therefore, following Hildebrand (1983), the total mass in a core is directly proportional to the total flux density F_ν, integrated over the source:

$$M = \frac{d^2 F_\nu R}{B_\nu(T_D)\,\kappa_\nu} \quad (1)$$

where d is the distance to the source, R is the gas-to-dust mass ratio, B_ν is the Planck function for a dust temperature T_D, and κ_ν is the dust absorption coefficient. The beam averaged column

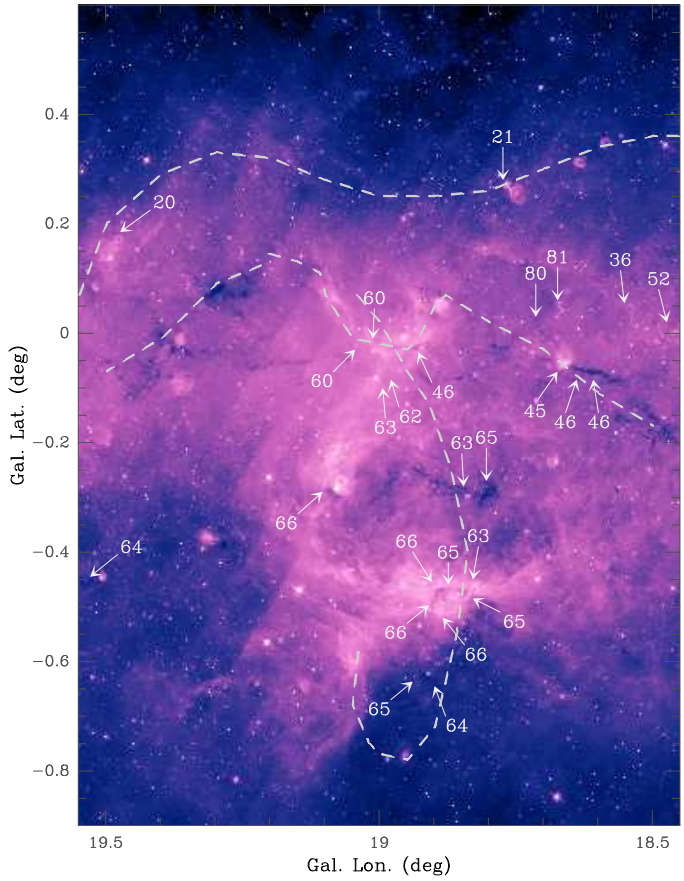


Fig. 10. 8 μm map of the region shown in Fig. 6 from the GLIMPSE survey. LSR velocities derived from NH_3 data are indicated.

density, which does not depend on the distance, can also be computed with:

$$N_{H_2} = \frac{F_\nu R}{B_\nu(T_D)\,\Omega\,\kappa_\nu\,\mu\,m_H} \quad (2)$$

where Ω is the beam solid angle, μ is the mean molecular weight of the interstellar medium, which we take equal to 2.8, and m_H is the mass of an hydrogen atom. Assuming a gas-to-dust mass ratio of 100, and $\kappa_\nu = 1.85$ cm^2 g^{-1} (interpolated to 870 μm from Table 1, Col. 5 of Ossenkopf & Henning 1994), our survey is sensitive to cold cores with typical masses in the range ~100 $M_\odot$ at 8 kpc to below 1 $M_\odot$ at 500 pc (Fig. 11). The 5-σ limit of 0.25 Jy/beam corresponds to column densities in the range 3.6×10^{21} cm^{-2} for $T_D = 30$ K to 2.0×10^{22} cm^{-2} for $T_D = 10$ K, equivalent to visual extinctions of 4 mag to 21 mag, respectively (using the conversion factor from Frerking et al. 1982).

These computations assume that the emission at 870 μm is optically thin. For the brightest source detected so far (Sgr B2(N), with a peak flux at 170 Jy/beam), we compute the beam-averaged optical depth using:

$$\tau_{870} = -ln\left[1 - \frac{F_\nu}{\Omega B_\nu(T)}\right] \quad (3)$$

This gives an optical depth $\tau \leq 0.31$ for a temperature $T \geq 25$ K. Therefore, the optically thin assumption should be correct, even for the brightest sources.

Using the distances as estimated in Sect. 4.2, we have calculated the masses of the clumps located around $l = +19°$

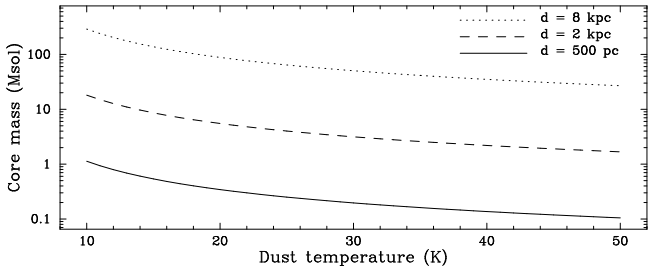


Fig. 11. Total gas plus dust masses in a core with 250 mJy integrated flux density at 870 μm (5-σ detection limit) as a function of dust temperature, for three typical distances: 500 pc (full line), 2 kpc (dashed line) and 8 kpc (dotted line).

(Fig. 8); the results are summarized in Table 1. In a few cases, the SExtractor program, used to extract compact sources from the full survey (Sect. 3.3), does not extract well sources that appear blended. Therefore, we have fitted 2D-Gaussian profiles to the 24 sources observed in NH_3 in order to measure their fluxes and sizes. Special care was taken to separate blended sources; results of these fits are: source positions, sizes (minor and major axis FWHM), peak and integrated fluxes.

Table 1 gives: sources names (based on Galactic coordinates); equatorial coordinates and sizes, measured from Gaussian fits on the 870 μm image; LSR velocities measured with the NH_3(1,1) transition; corresponding Galactocentric radius, as well as near and far kinematic distances; peak and integrated fluxes at 870 μm; kinetic temperatures, computed from the NH_3(1,1) and (2,2) measurements (Wienen et al., in prep.). Finally, masses for the near and far distances are computed, using the integrated 870 μm fluxes and the kinetic temperatures.

These computations assume that the 870 μm fluxes detected with LABOCA only originate in thermal emission from the dust. From spectral line surveys it is known that molecular lines might contribute a significant amount of flux to the emission detected by broadband bolometers. Groesbeck (1995) estimated from line surveys in the 345 GHz atmospheric window that lines can contribute up to 60% of the flux. This extreme value was found for the Orion hot core, which is peculiar due to a large contribution from wide SO_2 lines (Schilke et al. 1997). The relative contribution from CO(3–2) lines alone will only be relevant for extreme outflow sources with little dust continuum. From a quantitative analysis of the relative CO contribution in the bright massive star forming region G327.3-0.6, observed recently with the APEX telescope in CO (Wyrowski et al. 2006), we found the contribution to be insignificant towards the compact hot core but going up to 20% for the bright, extended photon dominated region to the north of the hot core. In summary, hot molecular cores, strong outflow sources and bright photon dominated regions will have a flux contribution from line emission larger than the typical 15% calibration uncertainty (Sect. 3.1) of the continuum observations. Line follow-up observations in the mm/submm with APEX of bright sources found with ATLASGAL will help to put stronger constraints on line flux contribution.

Another source of contamination could come from free-free emission, when an HII region has already been formed. The contribution from free-free at 345 GHz should however be low compared to the thermal emission from dust. As an example, Motte et al. (2003) have estimated the contribution from free-free emission at 1.3 mm in the compact fragments found within the W43 massive star-forming region, which harbors a giant HII region. In most cases, the free-free emission accounts for

Table 1. Observed and derived parameters for the 24 sources located in the region shown in Fig. 6 and observed in NH_3 lines. When the distance ambiguity could be solved, the preferred distance and mass are shown in boldface.

Source	RA (J2000)	Dec (J2000)	Size	v_{LSR}	R_G	D_{near}	D_{far}	F_{peak}	F_{int}	T_{kin}	$N(H_2)$	M_{near}	M_{far}
			″	km/s	kpc	kpc	kpc	Jy/b.	Jy	K	(1)	$M_\odot$	$M_\odot$
G18.55+0.04	18 24 37.85	-12 45 14.8	36×24	36.3	5.6	3.1	13.0	0.92	2.8	21.0	2.1	140	2380
G18.61–0.07	18 25 08.42	-12 45 21.6	38×26	45.8	5.2	**3.7**	12.5	1.70	5.7	32.7(2)	2.2	**210**	2490
G18.63–0.07	18 25 09.84	-12 44 07.5	53×21	45.7	5.2	**3.6**	12.5	0.96	3.6	14.7	3.9	**420**	5010
G18.65–0.06	18 25 10.63	-12 42 24.1	43×25	44.6	5.2	**3.7**	12.5	2.25	8.1	18.3	6.4	**680**	7940
G18.66+0.04	18 24 50.98	-12 39 20.8	36×24	80.9	4.0	5.2	10.9	2.10	6.3	22.4	4.5	780	3510
G18.70+0.00	18 25 02.38	-12 38 12.6	46×34	80.3	4.0	5.1	11.0	0.84	4.5	14.8	3.4	1030	4770
G18.76+0.26	18 24 13.27	-12 27 44.6	59×42	20.8	6.6	2.0	**14.1**	1.14	9.7	15.8	4.1	320	**15090**
G18.79–0.29	18 26 15.53	-12 41 36.2	40×34	65.5	4.4	**4.5**	11.6	0.94	4.3	14.4	4.0	**830**	5360
G18.83–0.30	18 26 23.70	-12 39 38.9	37×28	63.5	4.6	**4.4**	11.7	1.35	4.8	-(3)	5.3	**800**	5610
G18.83–0.47	18 26 59.34	-12 44 46.5	34×32	63.3	4.5	**4.5**	11.6	1.50	5.7	18.9	4.1	**680**	4600
G18.83–0.49	18 27 03.57	-12 45 06.5	58×25	65.2	4.5	**4.5**	11.6	1.34	6.7	20.8	3.2	**720**	4640
G18.86–0.48	18 27 06.20	-12 43 09.3	38×23	65.4	4.4	**4.6**	11.5	0.73	2.1	18.8	2.0	**270**	1710
G18.88–0.49	18 27 09.21	-12 42 35.1	38×25	65.5	4.5	**4.5**	11.6	1.11	3.5	22.4	2.4	**340**	2210
G18.88–0.51	18 27 15.13	-12 42 54.6	52×29	66.2	4.4	**4.6**	11.5	0.62	3.2	23.6	1.2	**290**	1840
G18.89–0.47	18 27 07.82	-12 41 38.0	64×34	66.1	4.4	**4.6**	11.5	3.39	25.4	25.9	5.9	**2040**	12840
G18.89–0.64	18 27 43.46	-12 45 48.5	28×22	64.1	4.5	**4.5**	11.6	0.58	1.2	20.0	1.5	**130**	880
G18.91–0.63	18 27 43.55	-12 44 51.0	50×43	64.5	4.5	**4.5**	11.6	1.51	11.1	17.1	4.8	**1560**	10340
G18.93–0.01	18 25 32.35	-12 26 41.4	27×25	46.3	5.1	3.7	12.4	1.33	3.1	29.3	2.0	140	1530
G18.98–0.07	18 25 51.06	-12 25 42.5	26×18	61.8	4.6	**4.4**	11.7	0.82	1.3	20.4	2.0	**140**	960
G18.98–0.09	18 25 55.22	-12 25 50.3	30×19	63.0	4.5	**4.4**	11.6	0.64	1.3	20.7	1.5	**130**	900
G19.01–0.03	18 25 44.61	-12 22 42.0	40×34	59.8	4.7	**4.3**	11.8	2.18	10.1	19.5	5.7	**1070**	8000
G19.01–0.03	18 25 44.61	-12 22 42.0	40×34	59.8	4.7	**4.3**	11.8	2.18	10.1	20.7	5.2	**970**	7300
G19.08–0.29	18 26 48.77	-12 26 20.7	39×37	66.0	4.6	**4.3**	11.7	4.28	21.4	24.2	8.2	**1700**	12330
G19.47+0.17	18 25 54.50	-11 52 34.4	33×24	20.0	6.6	2.0	**14.0**	6.53	18.0	23.4	13.1	330	**15510**

Notes: (1) Unit of $N(H_2)$ is 10^{22} cm^{-2}
(2) This source was also observed in NH_3 by Sridharan et al. (2005), with a better signal-to-noise ratio. We therefore use the kinetic temperature derived by this study rather than our own data for this source.
(3) Only the (1,1) transition of NH_3 is detected at this position, so that no kinetic temperature could be derived. A temperature of 15 K has been assumed to compute masses and column density for this source.

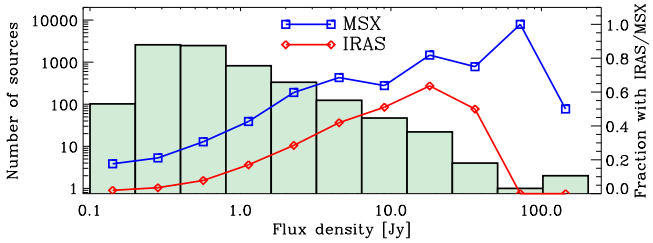


Fig. 12. Distribution of peak fluxes for the compact sources extracted in the data observed in 2007, shown in logarithmic scale. Fractions of sources associated with IRAS or MSX sources within a 30″ search radius are indicated, using the scale shown in the right hand side.

≤40% at 1.3 mm, with one extreme case where this fraction reaches 70%. Assuming a flat spectrum for free-free (optically thin case), and $F_\nu \propto \nu^{3.5}$ for the dust emission (i.e. a dust emissivity $\beta = 1.5$), scaling from 240 GHz to 345 GHz yields a 20% fraction coming from free-free emission at the LABOCA wavelength. In conclusion, the contribution from free-free should be mostly negligible, and even in the most extreme cases it should not exceed 20%.

4.4. Nature of the sources

Since dust emission in the submm is optically thin, the LABOCA observations are sensitive to all kinds of objects containing dust, which can range from cold dense clumps within clouds to more evolved proto-stars centrally heated. We have systematically searched for infrared counterparts to our preliminary catalog of 6000 sources in the IRAS Point Source Catalog (Beichman et al. 1988) and in the Midcourse Space Experiment (MSX, Price et al. 2001) data, using a search radius of 30″ (more details will be given in Contreras et al. in prep.). Only ∼10% of the submm compact sources can be associated with an IRAS point source, and ∼32% have a possible MSX counterpart (Fig. 12). In contrast, two thirds do not have a mid- or far-infrared counterpart in the IRAS/MSX catalogs, and could correspond to the coldest stage of star formation, prior to the birth of a massive proto-star. This fraction is similar to the results found by Motte et al. (2007) for the Cygnus-X region. However, with the superior sensitivity of the Spitzer GLIMPSE and MIPSGAL (Carey et al. 2005) surveys, weaker mid-IR sources are found to be associated with many of the MSX-dark compact submm clumps. Sources with IRAS associations generally correspond to later stages of star formation, e.g. hot molecular cores, compact HII regions or young embedded star clusters.

One should note that in some bright, complex star-forming regions, due to crowding and blending, even strong infrared sources do not fulfill the point source selection criteria and, consequently, are not included in the IRAS/MSX catalogs. An extreme example is seen in the histogram of Fig. 12, where the brightest source in the survey, SgrB2(N), is counted as a source without IRAS/MSX association.

High-contrast IRDCs are easily picked up by ATLASGAL. These clouds can have various shapes, from compact cores to filamentary morphologies of 1–5 arcmin in size. As an example, our demonstration field contains the already well-investigated IRDC G19.30+0.07 (Carey et al. 1998). In Fig. 13 we show

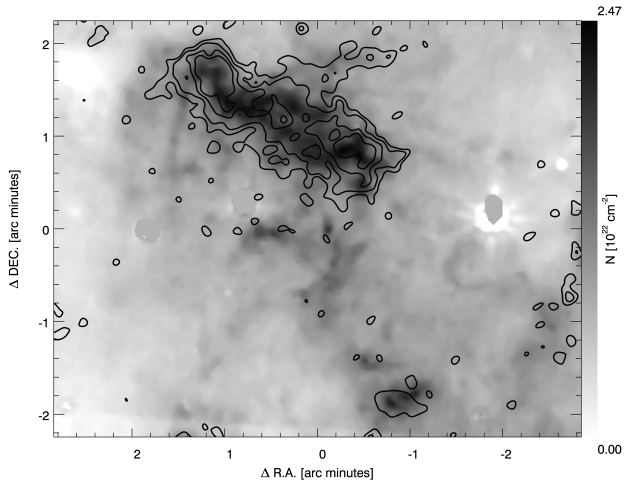


Fig. 13. Column density map of the IRDC G19.30+0.07, contained in the $l = 19°$ demonstration field. The map is derived from 8 μm extinction values measured in the corresponding Spitzer/GLIMPSE map. The ATLASGAL emission at 870 μm is overlaid in contours. The map center is at $\alpha = 18^h\,25^m\,53.94^s$, $\delta = -12°\,05'43.9''$ (J2000), or $l = 19.2771°$, $b = +0.0703°$.

a column density map of this IRDC, based on an extinction map derived from GLIMPSE 8 μm data. The $R_V = 5.5$ extinction law of Weingartner & Draine (2001) has been used. Further details of this approach are described in a forthcoming publication (Vasyunina et al. 2009). Overlaid as contours are the ATLASGAL 870 μm emission data. There is a good agreement of the morphologies especially for the high column density center of the IRDC. With an adopted distance of 2.38 kpc, roughly 260 $M_\odot$ are collected in this clump. IRDCs are considered to be a good hunting ground for the earliest phases of star formation, and ATLASGAL is expected to reveal a considerable fraction of them as sub-mm emission sources.

Some sources seen in the submm may also correspond to *low-mass* star formation at small distances. However, our survey is sensitive to 1 $M_\odot$ dense clumps up to a distance of ~1 kpc only (Eq. (1)). In addition, nearby regions of star formation are likely to be located off the Galactic Plane, outside the area covered by ATLASGAL. Therefore, low-mass star forming clumps are not expected to be a dominant population in our data.

A small fraction of sources detected in the submm may not be related with star formation. This include: late evolved stars with circumstellar envelopes, planetary nebulae, (nuclei of) external galaxies and quasars. However, we estimate the contamination by such classes of objects to be negligible. For instance, following the method outlined by Anglada et al. (1998, Appendix), the number of background sources per arcmin^2 with flux densities at 5 GHz above S is:

$$N(arcmin^{-2}) = 0.011 \times S\,(mJy)^{-0.75} \quad (4)$$

Then, assuming that the flux density scales with frequency as $S \propto \nu^{-0.7}$, one gets, for $\nu = 345$ GHz, 0.10 source above 150 mJy per square degree, or about 10 background sources in the 95 deg^2 discussed here. The extrapolation from 5 GHz to 345 GHz is quite uncertain, but this shows nevertheless that the number of such background sources must be very low.

Another estimate can be derived from deep field surveys in the submm. Integrating the differential submm source counts from the SCUBA Half-Degree Extragalactic Survey at 850 μm (SHADES, Coppin et al. 2006, their Eq. 12 and Table 7), yields 1×10^{-3} sources per square degree with flux densities above 150 mJy, or 0.1 source above this limit in our surveyed area. Thus, we don't expect to detect any high redshift object in our data.

The situation with late evolved stars may be more complex. As an example, the red supergiant VY CMa, which is one of the brightest sources at IR wavelengths and is ~1.5 kpc distant, has a flux density of 1.5 Jy at 870 μm, as measured with LABOCA. Therefore, this object could be seen up to a distance of 3.5 kpc with our survey sensitivity. Less extreme or more distant objects of similar nature will most likely fall below our detection limits, but we cannot exclude having a small fraction of supergiants and extreme late evolved stars in our data. It will be possible to identify such objects from their colors at other wavelengths, e.g. in the Spitzer surveys (Robitaille et al. 2008).

5. Perspectives

5.1. An unbiased survey

This survey will provide the first unbiased database of Galactic sources at submm wavelengths, covering the inner 120° of the Galaxy in a systematic fashion. Since dust emission in the submm is optically thin, it scales directly with the mass of material (assuming a constant temperature) and leads to the detection of all proto-stellar objects or pre-stellar clumps and cores. With a 5-σ detection limit of 250 mJy/beam, this survey will be complete for proto-stellar cores down to ~10 $M_\odot$ at 2 kpc, or ~50 $M_\odot$ at 5 kpc (Fig. 11). In addition, the data will allow the investigation of the structure of molecular complexes at various scales, from their lower-intensity filaments to higher-density star-forming regions.

The systematic nature of this survey will also allow a complete census of extreme sources in the inner Galaxy, such as the high-mass star forming regions W49 or W51. With our sensitivity, we should detect at a 10-σ level sources on the far side of the Galaxy, 25 kpc away, down to about 1500 $M_\odot$.

The unbiased nature of this database is of crucial importance in order to build good samples of objects for all types of follow-up projects based on a safe statistic. This is especially true in the context of ALMA (see also Sect. 5.5 below), which will explore exactly the same part of the sky as APEX in the (sub)mm range.

5.2. Evolutionary stages of high-mass star formation

This database will contain a large number of high-mass clouds with submm emission not associated with developed star formation (as traced in the infrared surveys), which are expected to correspond to the earliest phases of the formation of the richest clusters of the Galaxy. Since high-mass proto-stars are rare (Motte et al. 2007), such large scale surveys are required to get large statistics for the different stages of massive star formation. Thus, the data will allow for a determination of a basic evolutionary sequence for high-mass star formation.

Another topic that can be addressed with these data is the importance of triggered star formation, that can be assessed by identifying the second generation stars at the edges of HII regions (e.g. Deharveng et al. 2005) and supernova remnants. Especially in the context of high-mass star formation, the relative importance of triggering relative to spontaneous star formation is still an open question.

5.3. Distances and Galactic structure

Dust emission makes the connection between star forming regions seen in the IR/radio and molecular clouds seen in CO, e.g. in the Galactic Ring Survey, by tracing the highest column density features: compact sources and filaments. With the help of extinction maps and of absorption lines toward HII regions (Sewilo et al. 2004), the near/far ambiguity of kinematic distances can be solved to get the proper distances for a large fraction of ATLASGAL sources (Sect. 4.2). This will therefore help improving our 3D view of the Galaxy. Such data will also allow us to discover new coherent star formation complexes up to distances of a few kpc. Finally, these data will allow us to compare the star formation processes at different locations, in the spiral arms and inter-arm regions, and between the different arms.

5.4. Ancillary data

The region that we plan to map covers the same area as the GLIMPSE and MIPSGAL surveys (e.g. Fig. 14). It will also be mapped with PACS and SPIRE for the approved Hi-GAL (the Herschel infrared Galactic Plane Survey; Molinari et al.) open-time Herschel key project. The ATLASGAL data will thus be cross-correlated with similar large scale Galactic surveys at other wavelengths, in the near- to far-infrared range, for example with the J, H, K UKIDSS Galactic Plane Survey (Lucas et al. 2008), providing spectral energy distributions from ~1 to 870 μm. The LABOCA data at 870 μm are crucial to estimate the total amount of dust along the line of sight. Combining data from APEX, Spitzer and Herschel will provide an extraordinary new database of the Galactic Plane from the near-IR to the millimeter, at a spatial resolution $\lesssim$30″.

We will also correlate our data with existing radio surveys in the centimeter range: the NRAO VLA Sky Survey (NVSS, Condon et al. 1998), the Multi-Array Galactic Plane Imaging Survey (MAGPIS, Helfand et al. 2006), the Sydney University Molonglo Sky Survey (SUMSS, Mauch et al. 2003), and the Co-Ordinated Radio 'N' Infrared Survey for High-mass star formation (CORNISH)[1]. Particularly interesting will be comparison with surveys in radio continuum and maser emission that will be possible with the Expanded Very Large Array and the Australia Telescope Compact Array in the near future (Menten 2007). Existing or upcoming molecular line databases include those resulting from the multi-beam CH_3OH maser Galactic Plane survey (Green et al. 2007) and from surveys, e.g. in the CS or ^{13}CO molecules (e.g. Bronfman et al. 1996; Urquhart et al. 2007). Combining ATLASGAL with the IR to cm data will allow us to establish a solid picture of the star formation evolutionary stages and their associated time-scales.

Several bolometer arrays are expected to be installed at APEX in the near future, including the Submillimetre APEX Bolometer Camera (SABOCA), a 37-element array observing at 350 μm, with a beam of 7.″7. Our team plans to complement the 870 μm data with targeted observations at 350 μm, covering limited areas of a few arcmin extent, in order to constraint the dust emissivity and to resolve bright sources in crowded regions. The 870 μm survey might also be extended in surface (going toward the outer Galactic Plane), or in a small part of the Galactic Plane in depth (20 mJy/beam rms or less).

A similar survey of the northern Galactic Plane ($l \geq -10°$) has been started with the BOLOCAM instrument at the Caltech Submillimeter Observatory (CSO), at a wavelength of 1.1 mm (Drosback et al. 2008), with a 27″ resolution. The northern Galactic Plane will also be mapped with the SCUBA-2 instrument at 450 and 850 μm, with resolutions of 8″ and 15″, respectively. In particular, as part of the SCUBA-2 "All-Sky" Survey (SASSY, Thompson et al. 2007), a 10° wide strip covering $|b| \leq 5°$ over the part of the Galactic Plane accessible from Hawaii will be observed at 850 μm with a one-σ sensitivity of 30 mJy/beam, comparable to the ATLASGAL survey. In addition, the JCMT Galactic Plane Survey plans to cover much deeper the area $+10° \leq l \leq 65°$, $|b| \leq 1°$, at both 450 and 850 μm. Combining data from these large scale surveys will provide data at three different wavelengths in the Rayleigh-Jeans part of the dust emission spectrum, thus allowing us to study, among others, the dust emissivity, related to the composition of the dust.

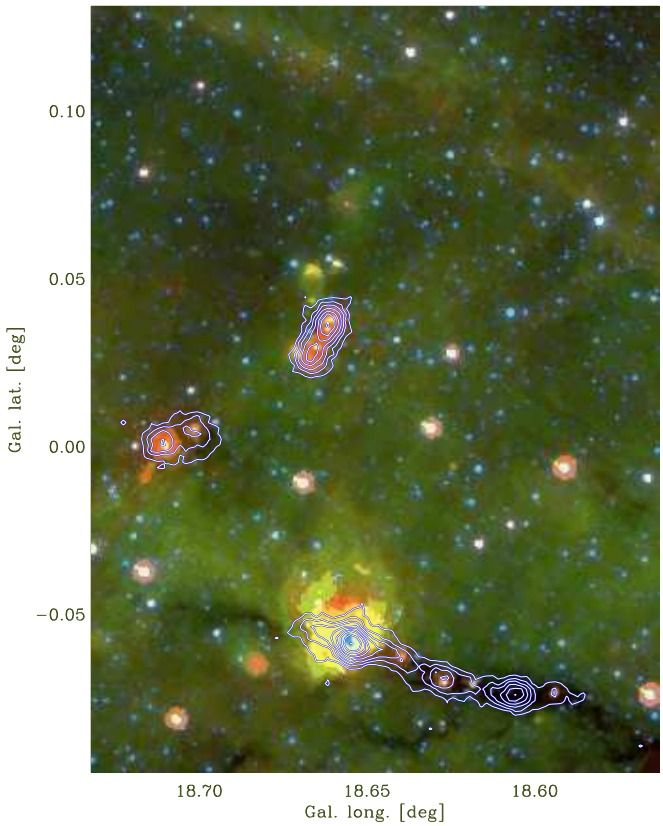


Fig. 14. Three color image from Spitzer surveys: GLIMPSE 4.5 μm in blue (mostly tracing stars) and 8 μm in green (mostly PAH emission), MIPSGAL 24 μm in red, with 870 μm emission overlaid in contours.

5.5. Legacy value

The raw data will be available to outside users through the ESO archive[2] one year after the end of each observing period. We also plan to make the reduced combined maps available to the community; in addition a compact source catalog (including associations with surveys at other wavelengths) and a catalog of extended objects will be published upon completion. These will be available from a public web site[3]. This project will thus have a high legacy value, providing well characterized samples

[1] http://www.ast.leeds.ac.uk/Cornish/index.html

[2] http://archive.eso.org/wdb/wdb/eso/apex/form

[3] http://www.mpifr-bonn.mpg.de/div/atlasgal/

of targets to address in details many questions of astrophysics. Calibrated maps built from the data observed in 2007 and discussed in the present paper are expected to be available online, both on the ESO archive and on the ATLASGAL public website, by Summer 2009.

The observations that we have planned should be completed by the end of 2009, i.e. when the Herschel observatory is expected to deliver its first science data. Our team will be involved in the investigation of systematic associations between the ATLASGAL sources and Herschel products. In particular, members of the consortium are leading the key projects HOBYS (the Herschel imaging survey of OB Young Stellar objects; Motte, Zavagno, Bontemps et al.) and Hi-GAL.

The first ALMA antennas should also be available for early science soon after completion of our survey. This will be the perfect time for conducting follow-ups of carefully selected targets at an unprecedent spatial resolution. The ATLASGAL catalog will provide ALMA with more than 10^4 compact sources, including hot cores, high-mass proto-stellar objects and cold prestellar cores. All sorts of molecular lines will be available to study the sources' chemistry, or to search for signatures of infall or outflows for example. Thus, ATLASGAL is expected to trigger numerous follow-up studies to characterize the detected sources in terms of their excitation and chemistry. ATLASGAL will also provide the James Webb Space Telescope (JWST) with samples of well characterized targets, and these future facilities will allow one to study the inner workings of the star formation process on small scales. This survey is therefore an essential pathfinder for Herschel, ALMA and the JWST.

In addition to the new findings in the realm of high-mass star formation, the survey will tell us on larger scale details about the structure and mass distribution in our Galaxy and will help us to connect our knowledge of local star formation with star formation in external galaxies, where high-mass stars are the only ones we see.

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