

# Hi-GAL as a favourite starting point for ALMA studies

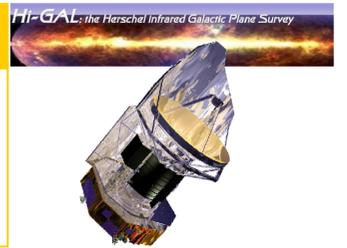


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## Abstract

Hi-GAL is a Herschel Open Time Key Project aiming to survey a 2°-wide stripe of Galactic Plane at five wavelengths between 70 and 500  $\mu\text{m}$ . Once completed, this large survey will give a map of the dust distribution and temperature in the inner Galactic plane with an unprecedented spatial resolution and dynamic range. During its initial phase of operation, Herschel observed eight 2° x 2° tiles of Hi-GAL, significantly increasing the number of far-Infrared known compact sources. In particular, sources that were once discovered as dark clouds in front of bright backgrounds (infrared dark clouds) are now revealed as bright objects and easily recognised. The SEDs of these objects show differences that are not easy to interpret, as many of these are the result of probably more than one source. The extraordinary spatial resolution provided by ALMA will allow us to better describe these objects, and to characterise them in a statistically significant way, both in continuum emission as well as spectroscopically.



## The Hi-GAL survey

Hi-GAL (Herschel infrared Galactic plane survey) uses PACS and SPIRE to image the Galactic plane ( $|\ell| < 60^\circ$ ,  $|b| < 1^\circ$ ) in five photometric bands (70, 160, 250, 350, and 500  $\mu\text{m}$ , then with a diffraction-limited 4-40" spatial resolution) at 60"/s satellite scanning speed. Hi-GAL exploits a combination of Herschel wavelength coverage, sensitivity, mapping strategy and speed to deliver, in a single and homogeneous dataset, the ultimate census of temperature, luminosity, mass and spectral energy distributions of star forming regions and cold ISM structures in all the environments of the Galactic ecosystem, at unprecedented resolutions. To extract compact sources from maps, our group developed both a detection algorithm searching for local maxima in the 2<sup>nd</sup>-derivative maps, and a photometry algorithm fitting the source intensity profile with an elliptical Gaussian, even multiple in case of crowding (Molinari et al., in prep.). After band merging, the SEDs of the clumps are built and analysed to derive their physical properties (Molinari et al. 2010, Elia et al. 2010).

## The IRDCs

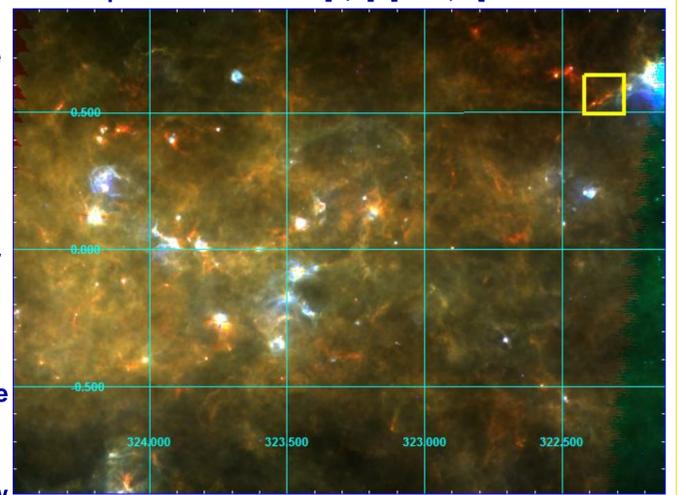
The InfraRed Dark Clouds (IRDCs hereafter) are identified as dark extinction features seen in silhouette against the bright Galactic plane in NIR/MIR observations, showing a big variety of shapes, from filamentary to nearly spherical. A catalog of these objects, based on GLIMPSE maps at 8  $\mu\text{m}$ , has been compiled by Peretto & Fuller (2009). IRDCs are characterized by cold temperatures and high densities ( $T < 25$  K,  $d_H > 10^5$   $\text{cm}^{-3}$ , see e.g. Egan et al. 1998, Carey et al. 1998, 2000), typical sizes in the range 1-10 pc and masses in the range  $10^2$ - $10^4$   $M_\odot$ . They are therefore reservoirs of cold, dense molecular gas, most likely still containing the initial conditions of star formation. In particular, physical conditions of IRDCs fulfill the requirements for the formation of clusters and massive stars (McKee & Tan 2003).

Unlike their NIR/MIR appearance, IRDCs appear as bright regions in the sub-mm SPIRE maps (see Peretto et al. 2010). They also have a complex internal structure, with embedded clumps (Simon et al. 2006, Battersby et al. 2010). In Hi-GAL maps, these clumps appear as compact sources that we are able to extract, providing the most complete and homogeneous sample of targets for ALMA observations of clumps in IRDCs.

## The $\ell=323^\circ$ field of Hi-GAL

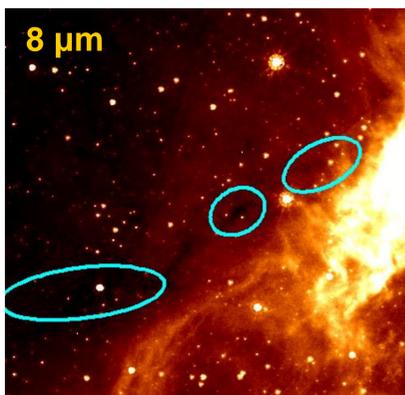
The portion of the Galactic plane centered on  $[\ell, b]=[323^\circ, 0^\circ]$  is one of the first Hi-GAL fields imaged during the initial phase of operation of Herschel.

APEX  $\text{C}^{18}\text{O}(2-1)$  spectra have also been observed for tens of sources in this field, to derive the kinematic distance and the physical conditions of the gas. Here we show

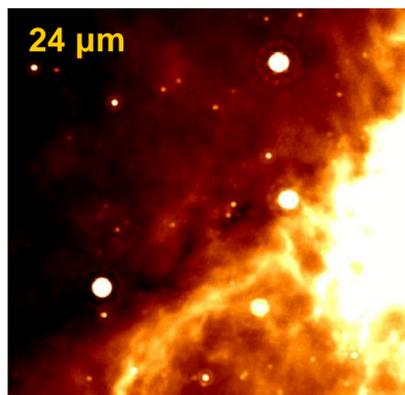


a RGB (70/160/350  $\mu\text{m}$ ) composite image of this field. The yellow box encompasses the area expanded and shown in the images below.

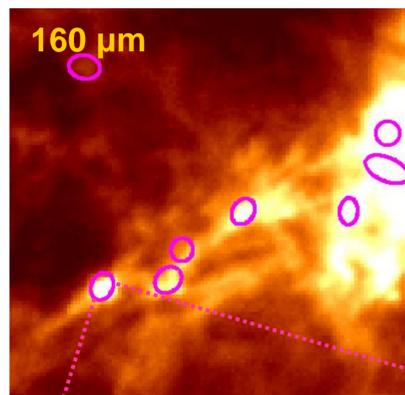
## Examples of IRDCs in $\ell=323^\circ$ : dark clouds are not dark in the FIR/sub-mm!



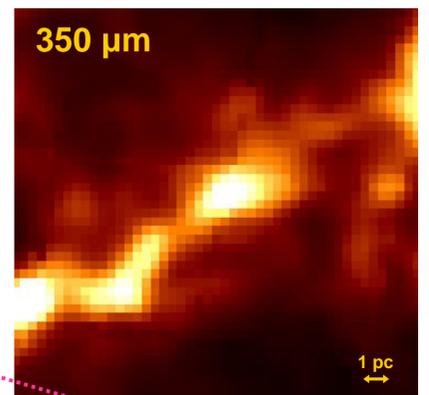
8  $\mu\text{m}$   
GLIMPSE image of the area in the yellow box of the previous figure. The estimated positions and sizes of the IRDCs of the Peretto & Fueller (2009) catalog are shown.



24  $\mu\text{m}$   
MIPSGAL image of the same field as the previous image. The IRDCs still appear as dark features superposed on a brighter background.



160  $\mu\text{m}$   
Hi-GAL (PACS) image: IRDCs are revealed in emission. Compact sources (magenta ellipses, inside and outside IRDCs) are found and extracted by our algorithm.



350  $\mu\text{m}$   
Hi-GAL (SPIRE) image: the clumps of the IRDCs turn out to be the brightest sources seen in the sub-mm. The size corresponding to 1 pc in the sky at  $d=10$  kpc is reported.

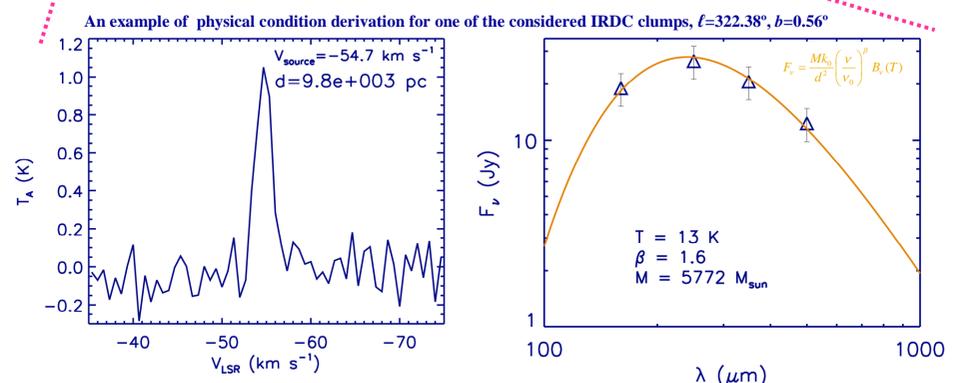
## Observing IRDC clumps with ALMA

The ALMA Early Science phase will have, as minimum requirements, at least 16 12-m antennas fully commissioned; bands 3, 6, 7, 9 on all antennas (from 84 to 720 GHz); a maximum baseline of 250 m (max resolution: 2.8" @ 84 GHz, 0.3" @ 720 GHz).

Mapping the IRDCs with these spatial resolutions both in the continuum and in line emission will allow us to investigate the internal structures of their densest parts, also in cases of relatively far distances. In our  $\ell=323^\circ$  example tile, at 10 kpc, 2" correspond to about 0.1 pc in the sky, sufficient to recognize sub-structures as pre- and proto-stellar cores. A better knowledge of cloud fragmentation (scales, masses) is crucial to state whether massive stars are preferentially formed in IRDCs.

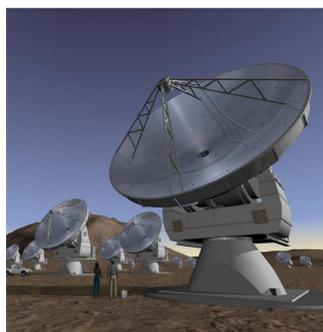
Furthermore, the choice of opportune tracers of high-density environments ( $\rho = 10^5$   $\text{cm}^{-3}$ ), (as, for example,  $\text{H}^{13}\text{CO}^+$ ,  $\text{H}_2\text{CO}$ ,  $\text{CH}_3\text{OH}$ , etc.) will provide, for IRDC clump and cores, *i*) a deep inspection of the structure of density and velocity field of the gas with unprecedented spatial and spectral resolution, *ii*) the chance to make comparisons with the existing models of chemical evolution of clumps and cores, through the quantitative analysis of molecular composition, freeze out (e.g. Aikawa et al. 2005), abundance ratios (e.g. Suzuki et al. 1992), etc.

In conclusion, the extraordinary characteristics of ALMA represent the natural complement of the huge amount of information about IRDCs provided by Hi-GAL.



An example of physical condition derivation for one of the considered IRDC clumps,  $\ell=322.38^\circ$ ,  $b=0.56^\circ$   
APEX  $\text{C}^{18}\text{O}(2-1)$  spectrum of a dense clump indicated in the 160  $\mu\text{m}$  frame. The peak  $V_{\text{LSR}}$  and the corresponding kinematic distance, based on a Galactic rotation model, are given.

PACS+SPIRE spectral energy distribution of the considered clump. Best grey-body fit is plotted in orange, and the estimated physical properties (temperature, dust opacity exponent and mass) are displayed.



## References

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