Mapping the column density and dust temperature structure of IRDCs with *Herschel*

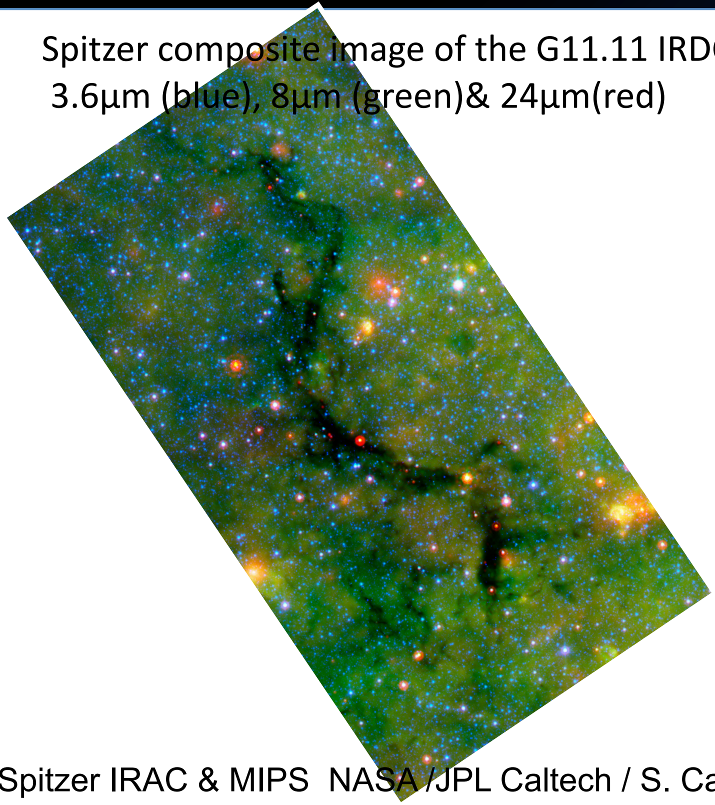
N. Peretto[1,2], G.A. Fuller[2], R. Plume[3], L. Anderson, J. Bally, C. Battersby, M. Beltran, J. Kirk, C. Lenfestey, D. Marshall, P. Martin, S. Molinari, L. Montier, F. Motte, I. Ristorcelli, J.A. Rodon, H. Smith, D. Ward-Thompson
and the Hi-GAL consortium

1, CEA Saclay, France
2, Jodrell Bank Centre for Astrophysics, Manchester, UK
3, University of Calgary, Canada

IRDCs in the Galaxy

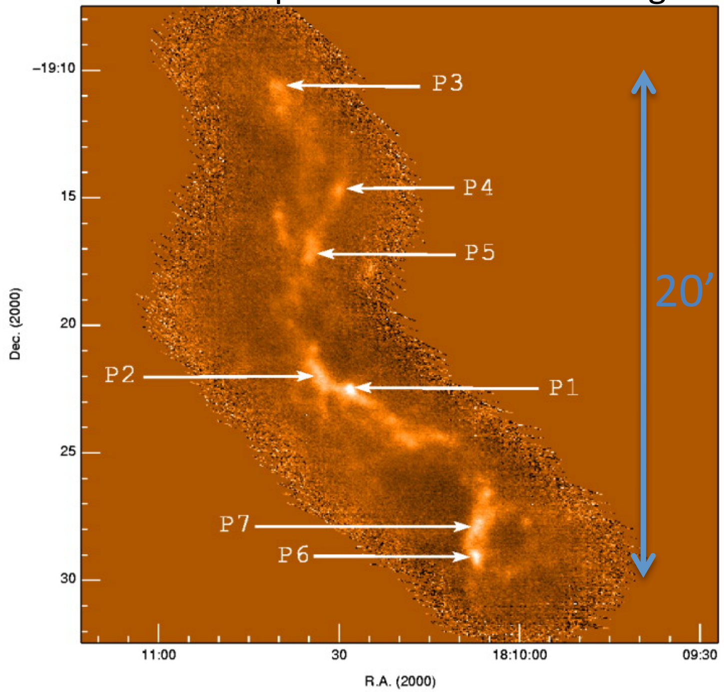
Infrared dark clouds (IRDCs) are dense molecular clouds seen in silhouette against the mid-IR emission of the galactic plane (Perault et al. 1996; Carey et al. 2000; Teyssier et al. 2002; Simon et al. 2006; Rathborne et al. 2006)

Spitzer composite image of the G11.11 IRDC
3.6µm (blue), 8µm (green)& 24µm(red)



Spitzer IRAC & MIPS NASA /JPL Caltech / S. Carey

SCUBA 850µm dust continuum image

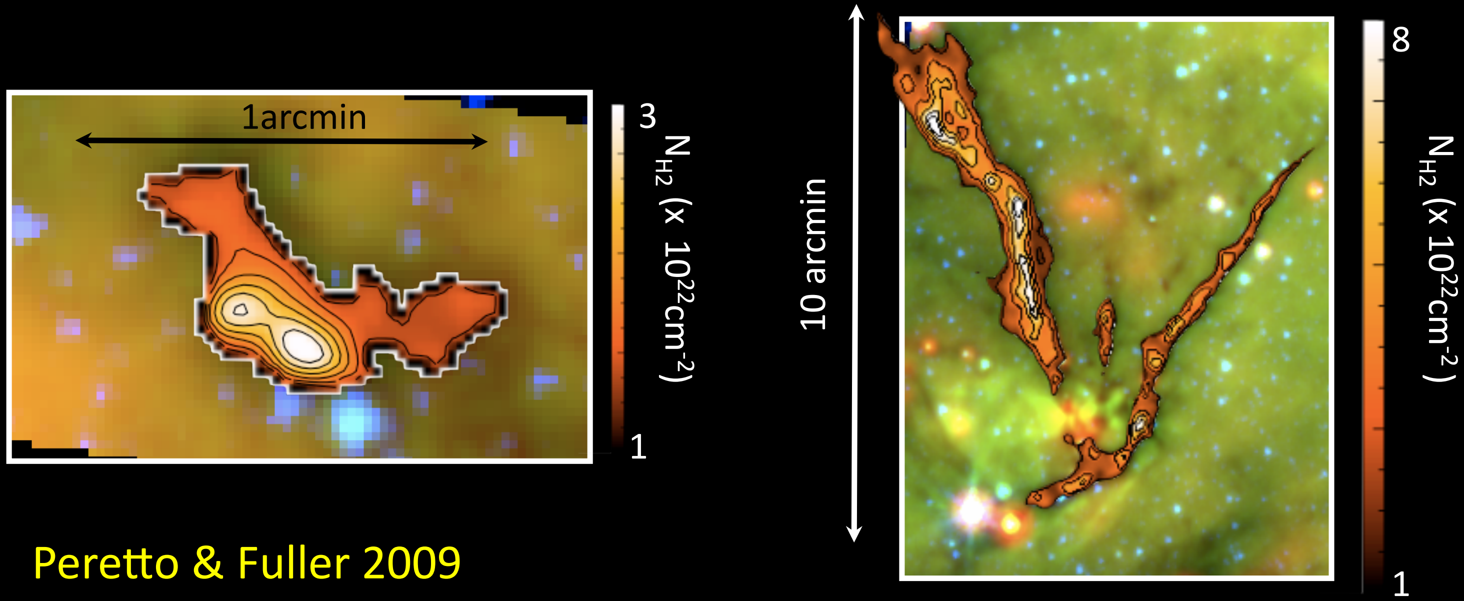


Johnstone et al . 2003

Cold structures, little star formation activity, therefore they likely contain the imprints of the initial conditions of star formation: Very important objects to study

IRDCs in the Galaxy

Using the Spitzer GLIMPSE/MISPGAL data Peretto & Fuller (2009) constructed a catalogue of ~ 11000 IRDCs in the inner part of the galactic plane



Peretto & Fuller 2009

Extinction provides no access to temperature information and some bias in the column density measurements

We need Herschel to measure dust temperature within IRDCs and get a global picture of their column density structure and star formation activity

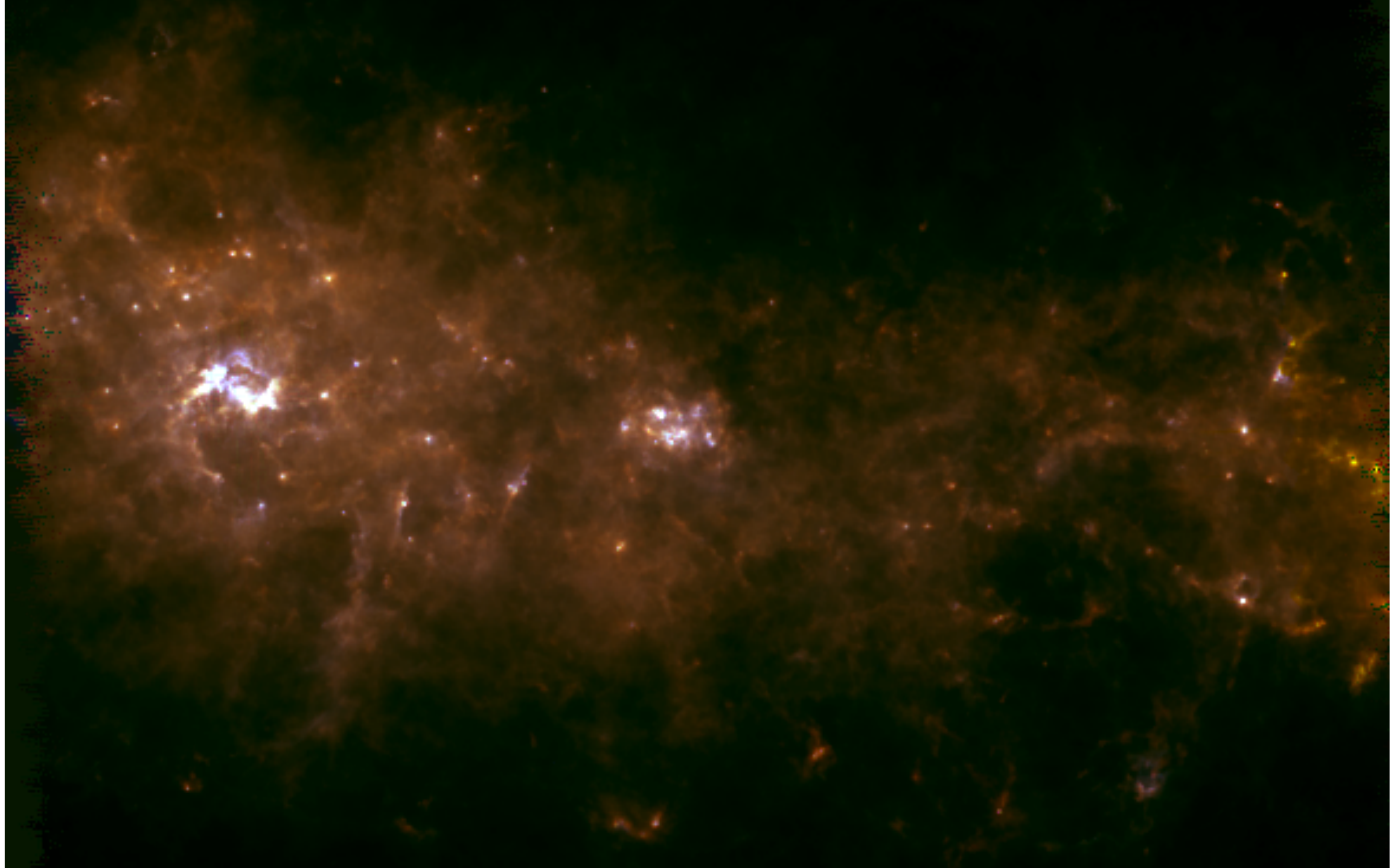
Hi-GAL SDP data

Hi-GAL: Galactic plane survey with Herschel PACS/SPIRE covers similar area as the GLIMPSE/ MIPSGAL Spitzer galactic plane surveys. PACS/SPIRE parallel mode observations (70/160/250/350/500 micron) Two Science Demonstration Phase fields: l=30 and l=59

- 450 IRDCS in Peretto & Fuller catalog in HIGAL SDP fields

- Important to notice: The extended diffuse emission is everywhere and has to be taken into account when looking at the emission properties of cold objects

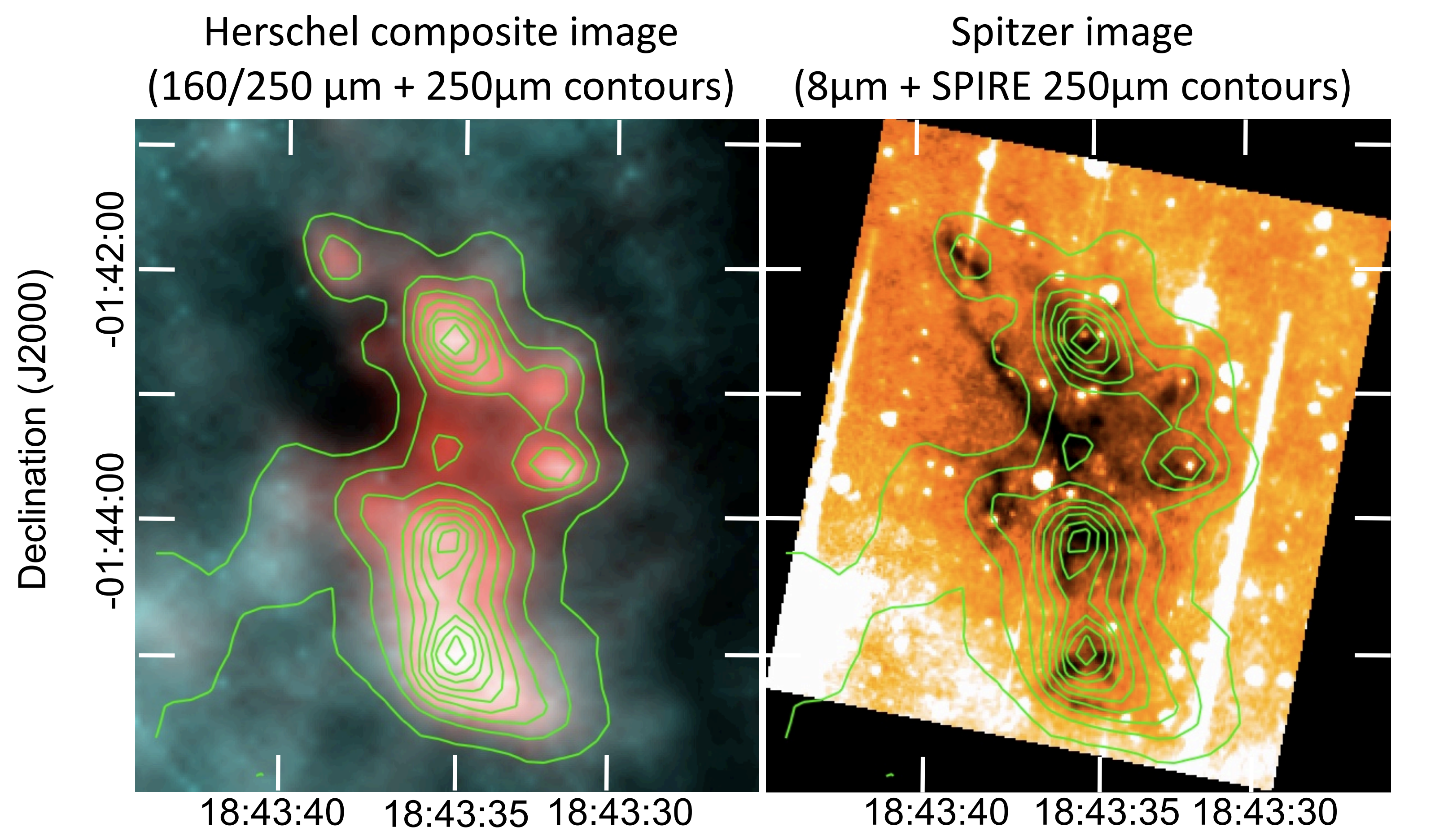
Hi-GAL l=30: A slice of the Milky Way as seen with Herschel



Herschel composite image PACS/SPIRE (160/250/350micron)

Hi-GAL SDP data

Spitzer IRDCs seen with Herschel



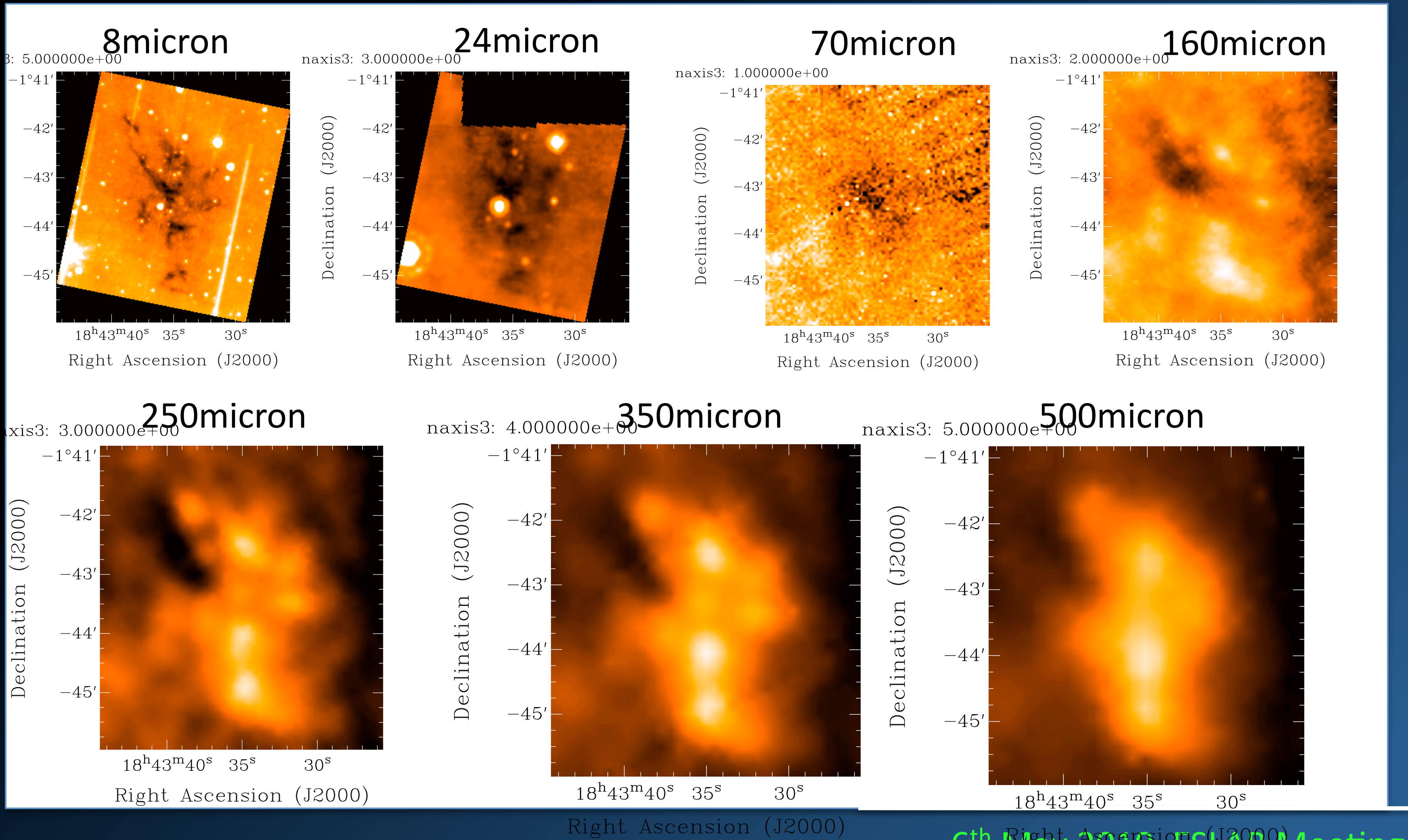
Peretto et al. (2010)

Determining the Background

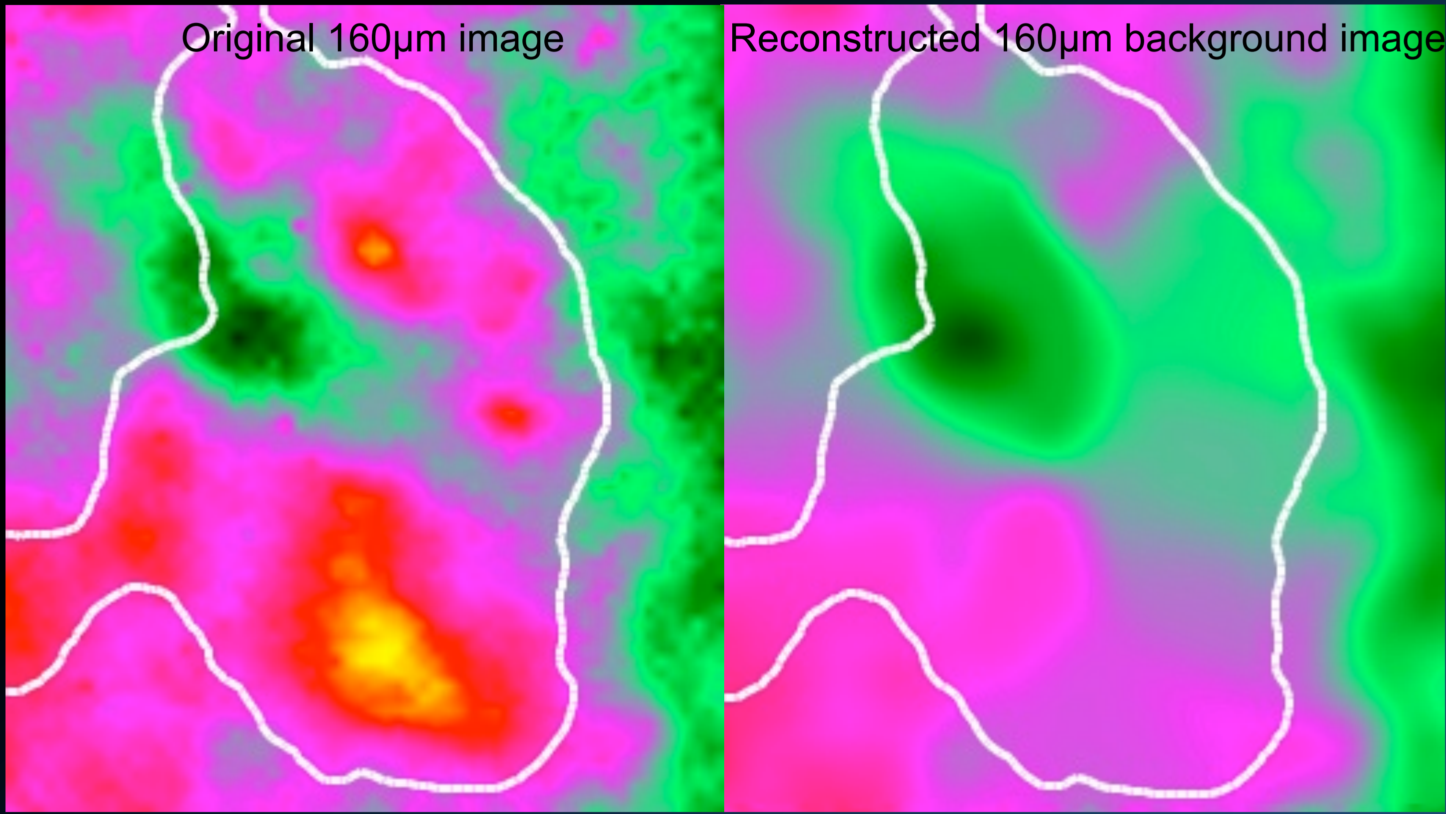
optically thin approximation:

$$I_\nu = B_\nu(T_d^{IRDC}) \times \tau_\nu^{IRDC} + I_\nu^{bg}$$

- 500 micron data used to determine the boundary between background and IRDC

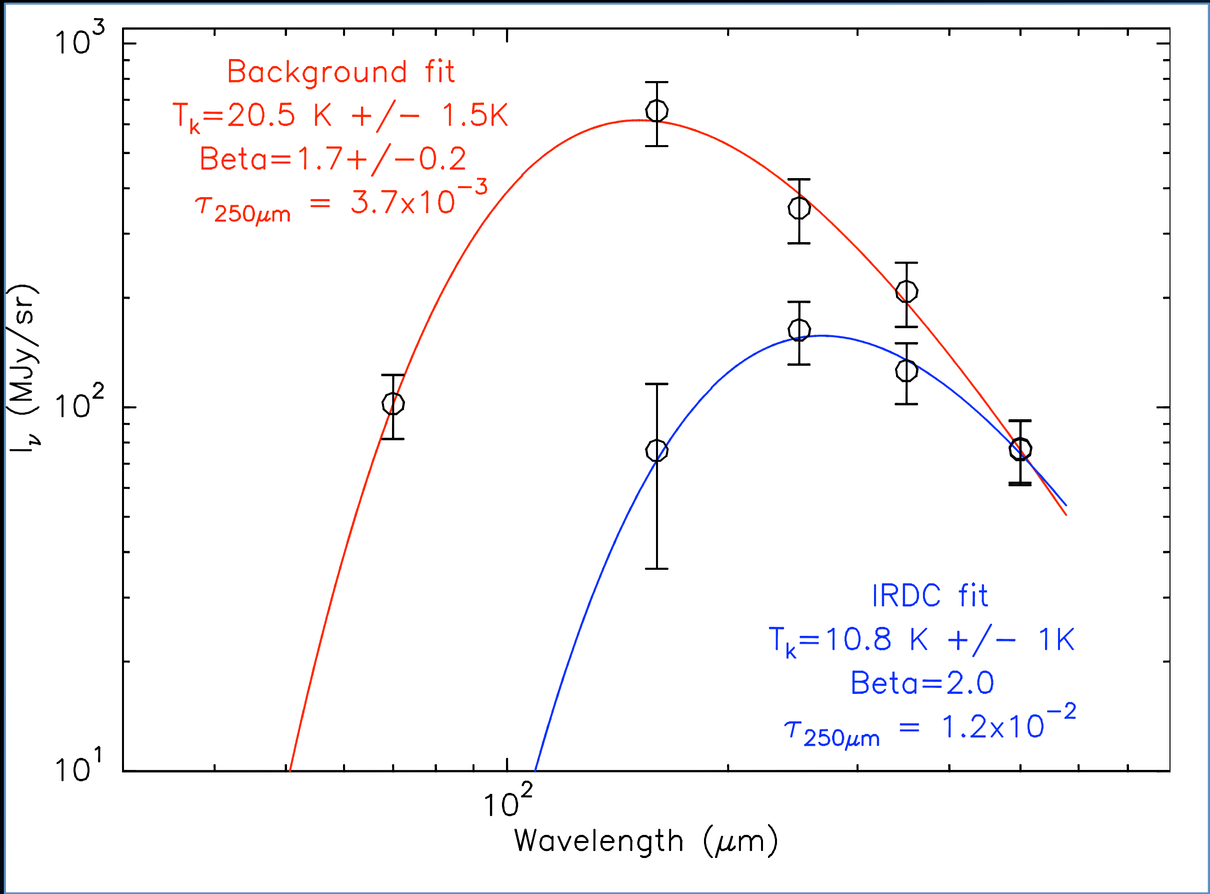


Background consideration



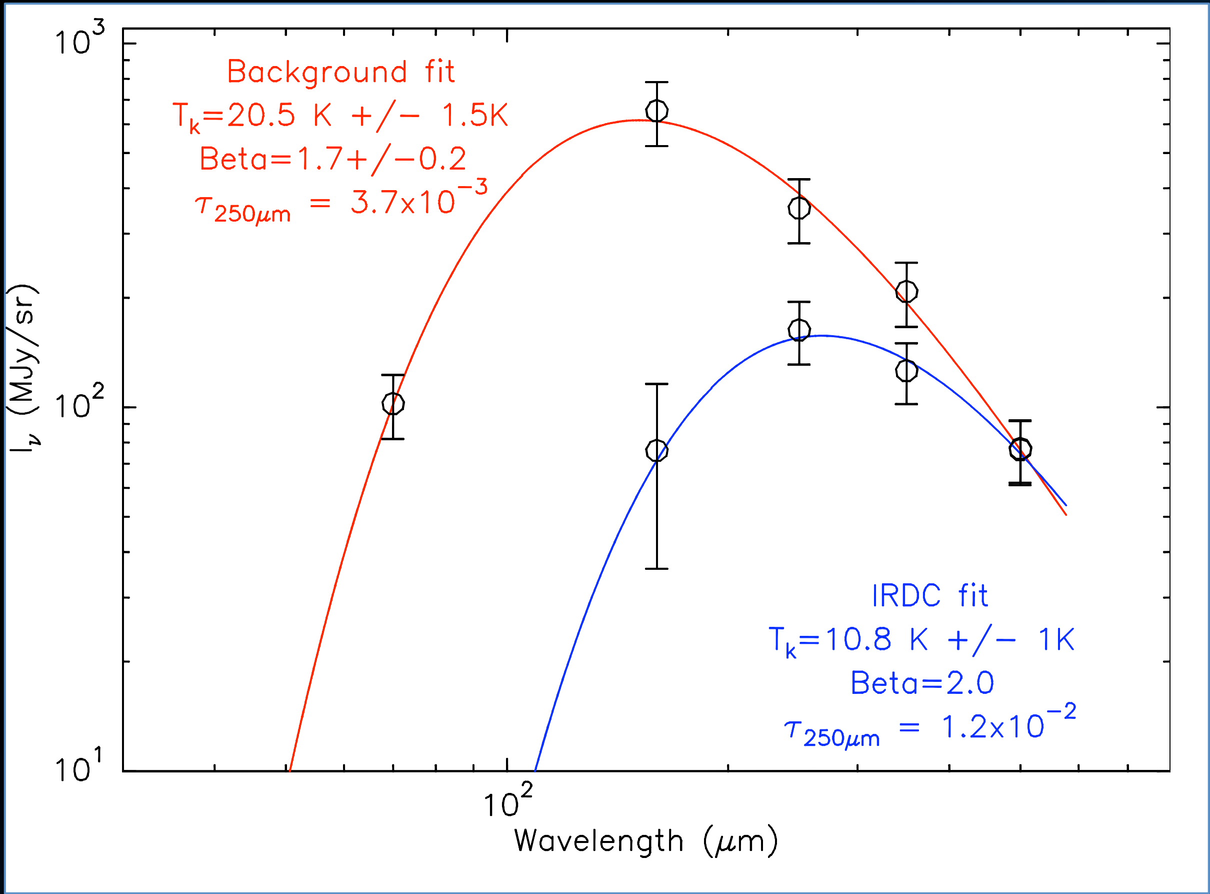
Reconstruct background images by interpolation of background only pixels at the positions of the IRDC pixels

SED of background



- SED of background images fitted to determine the properties of dust responsible for background
- 5 data points (70 to 500 micron) allow constraint of τ, T and β.
- T_{bg} ~ 20 to 30 K (consistent with Bernard 2010)
- β = 1.6 to 2.3 (consistent with Boulanger 1996)

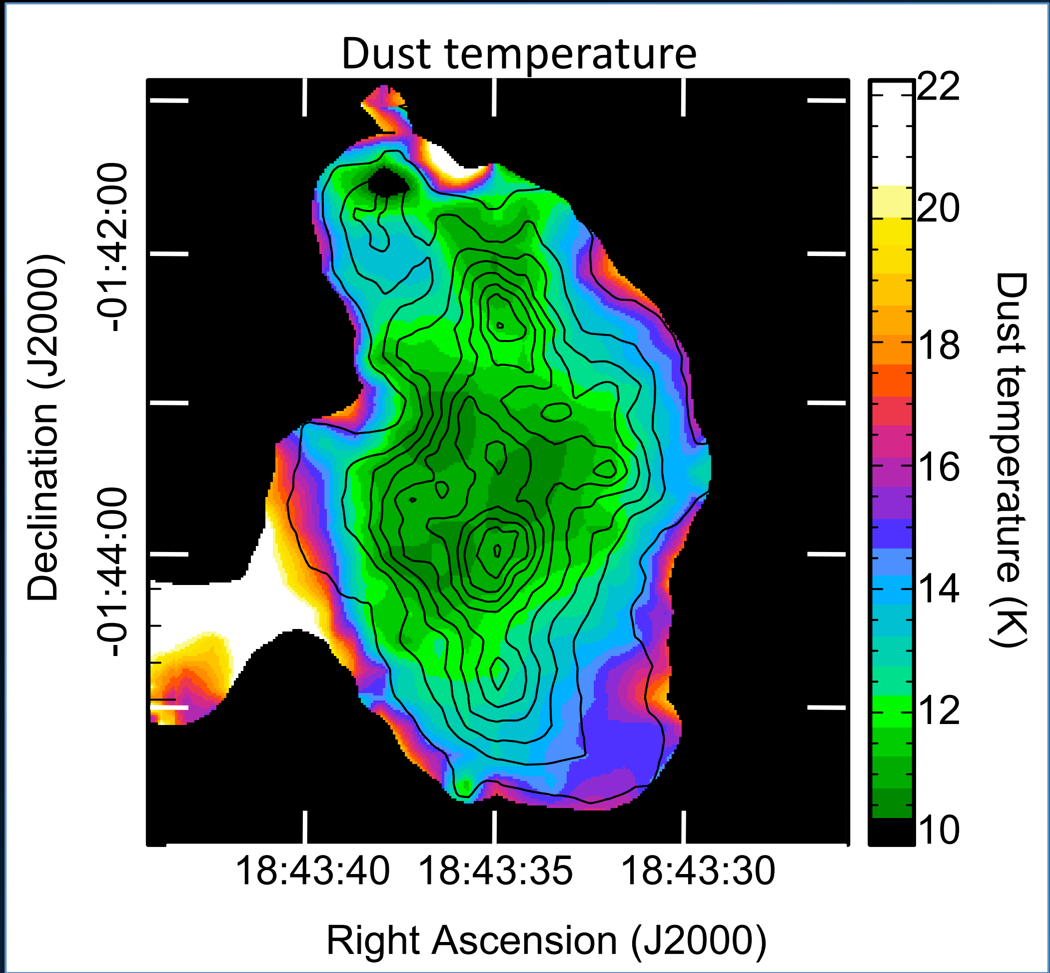
SED in IRDC



- reconstructed background images provide I_{bg} for each pixel in IRDC
- τ and T for each pixel determined by minimizing χ^2 between observed fluxes and those from the equation
- excluded 70 micron data point since 70 micron is often seen in absorption
- smoothed other points to 36” resolution
- with only 4 data points we cannot constrain β, so fix β = 2

Dust temperature and column density structure of IRDCs

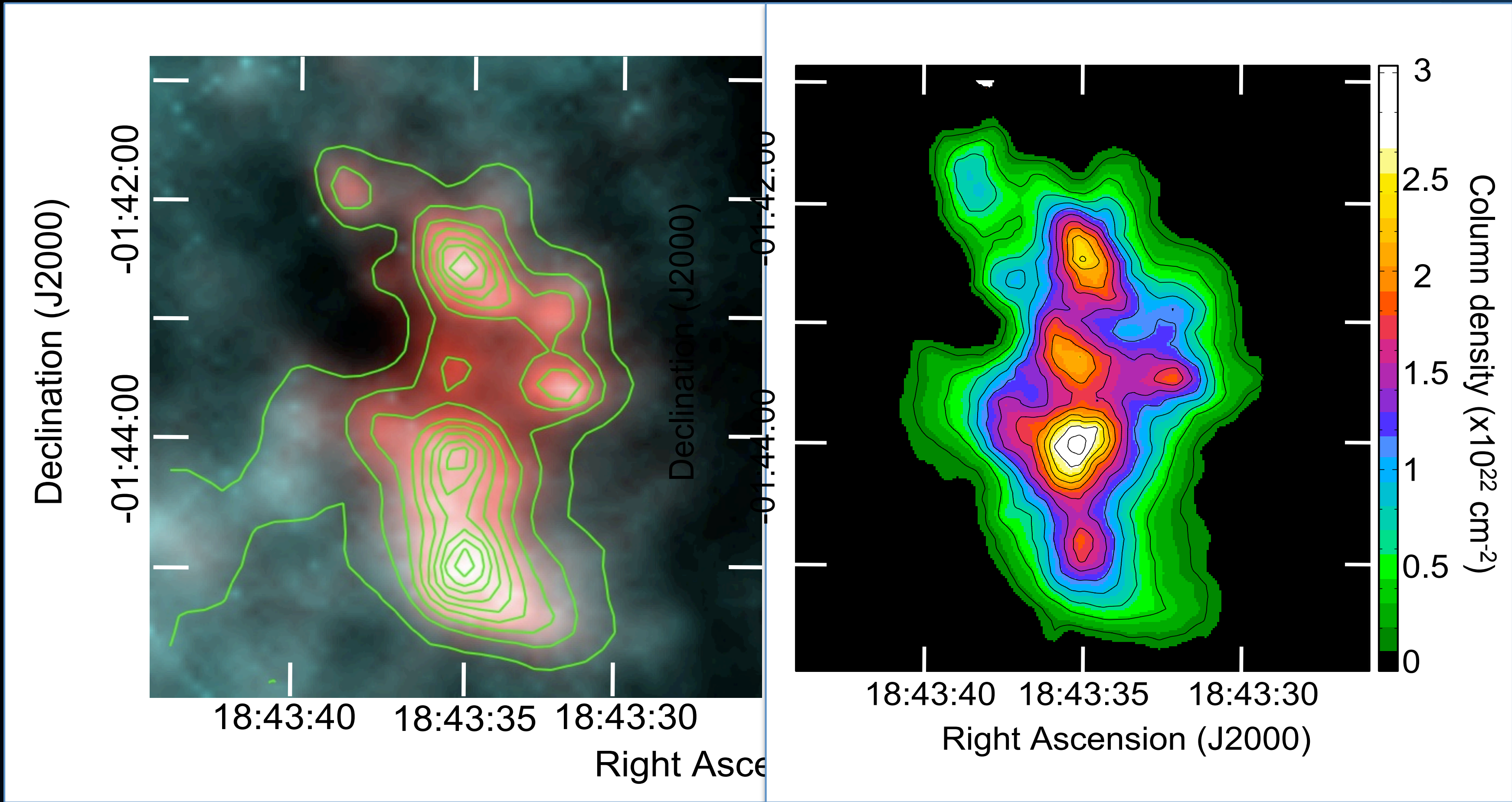
Construct the column density maps and dust temperature maps of IRDCs



- Temperature is not uniform (20-30 K in background gas to 10 K in centre)
- suggests that IRDCs form from warm (20 – 30K) gas and then cool down down to ~ 10K
- T gradient form at the earliest stages (before protostar forms)

Peretto et al. (2010)

Dust temperature and column density structure of IRDCs

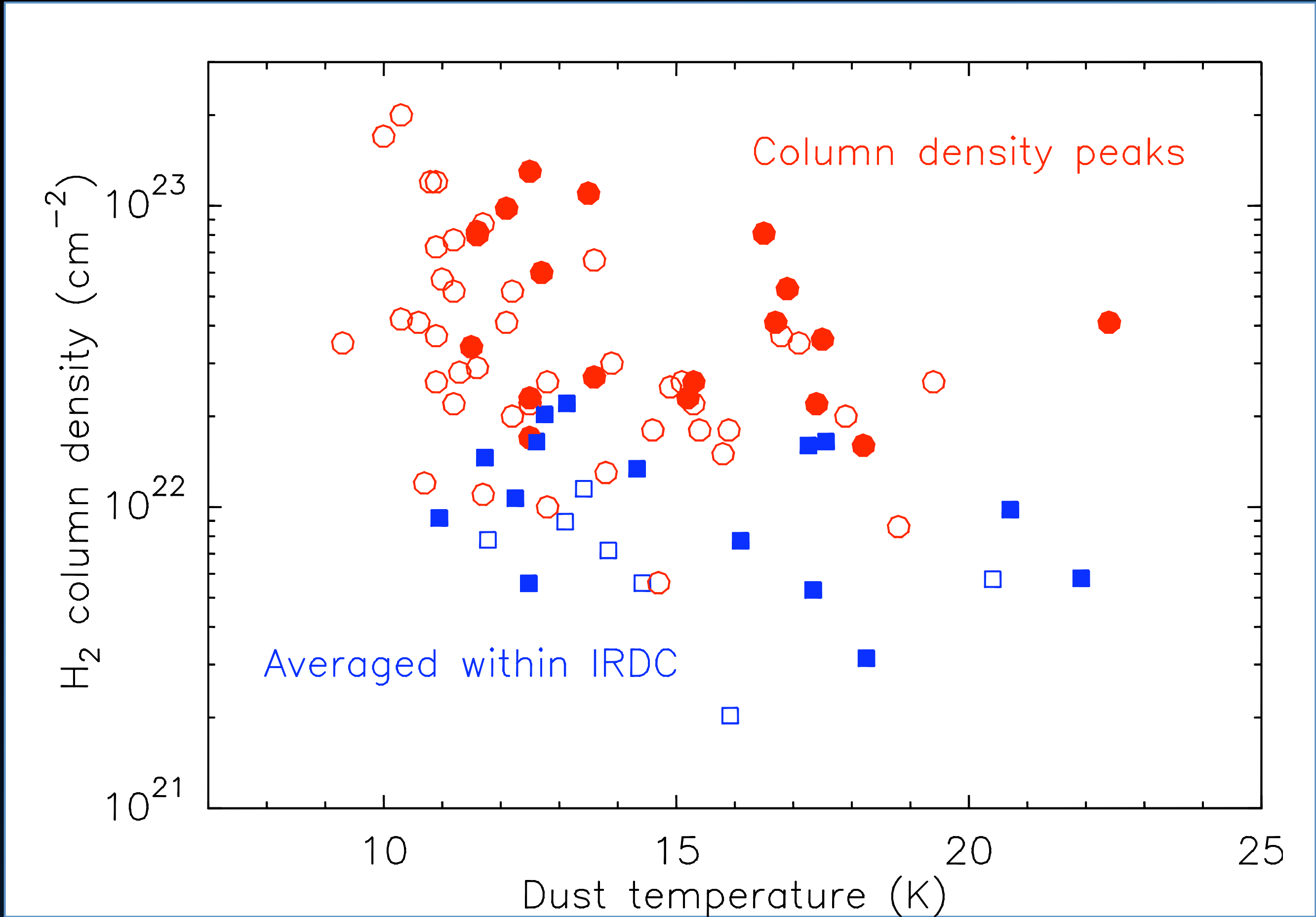


- Submm continuum does not necessarily directly trace column density structure

Peretto et al. (2010)

Dust temperature and column density structure of IRDCs

selected 22 IRDCs (out of the 450) all large enough to contain at least one, 500 micron beam



- The ones showing 70micron sources (filled) are likely forming massive stars / clusters
- Some starless column density peaks reaches $10^{23} cm^{-2}$ – progenitors of massive stars ?

Peretto et al. (2010)

Conclusions

We developed a method to analyze the dust temperature and column density structure of IRDCs as seen in the Hi-GAL open time key project. Based on the analysis of 22 large IRDCs located in the SDP fields, we can draw the following conclusions:

- IRDCs have non uniform dust temperature, decreasing in some cases by 15K from edge to center

- IRDC column density structure could be significantly different from what is seen directly on a single submm wavelength image – Temperature information is crucial

- Based on the extrapolation of the linear correlation found by Dunham et al. (2008) between 70micron flux and bolometric luminosity ,we suggest that IRDCs with embedded 70micron sources are forming massive stars/clusters

- Some high column density peaks, with no evidence of star formation activity are found – These are excellent candidates to be the progenitors of massive stars. Over the full Hi-GAL dataset we expect to find few hundreds of such objects