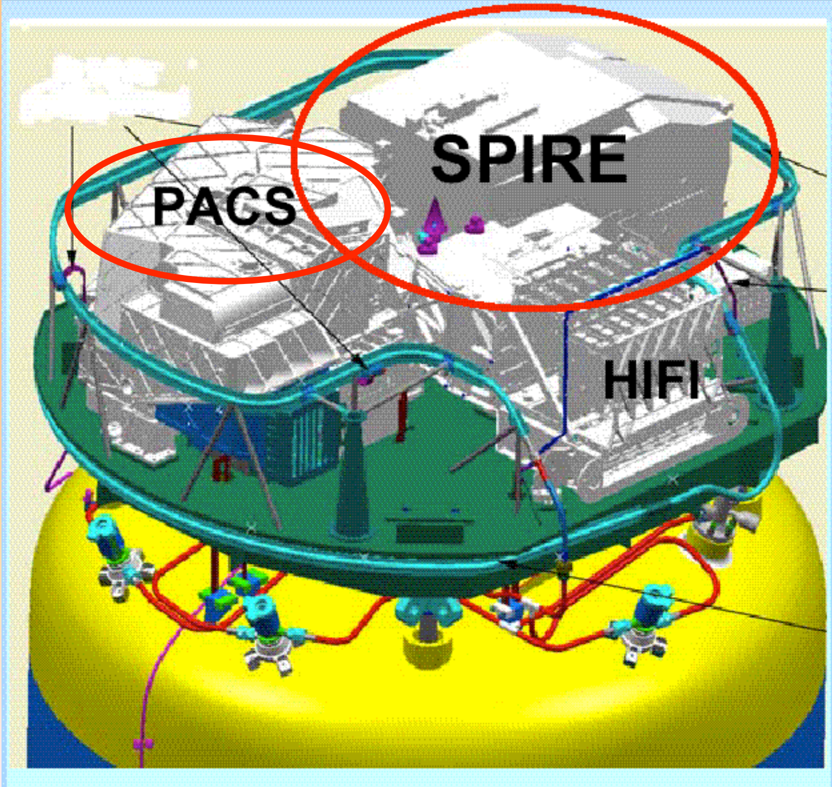
Herschel SPIRE/PACS Star Formation Key Projects

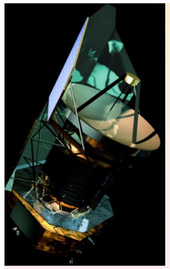
Philippe André, CEA/SAp Saclay

Herschel : Major Far-IR & Submm Space Observatory (ESA 'cornerstone') 3.5 m telescope

Launch : 2008

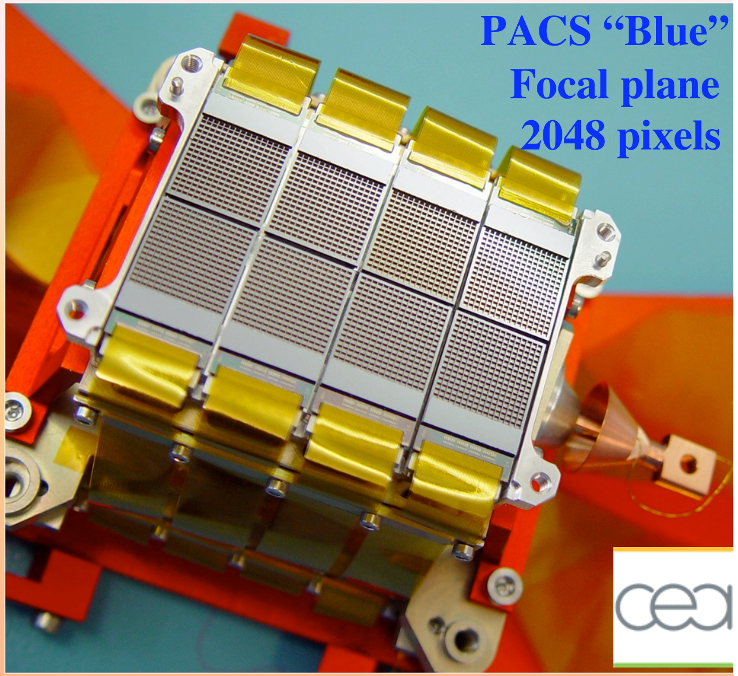
Payload instruments





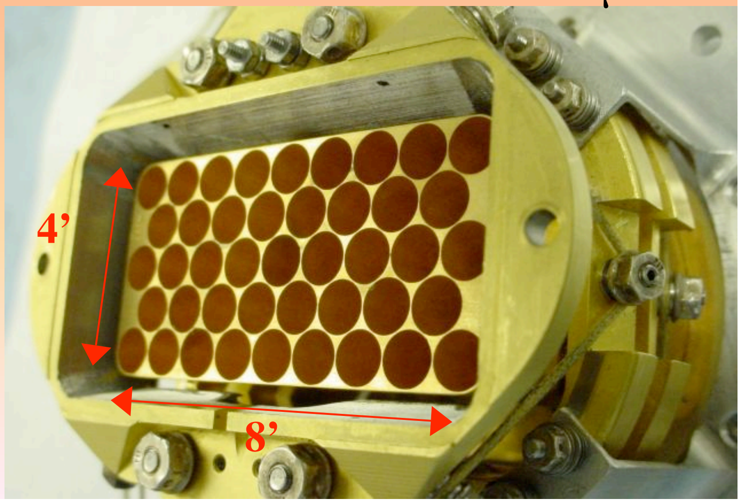
Herschel imaging instruments

- **PACS - Photodetector Array Camera and Spectrometer**
  - PI: Albrecht Poglitsch, MPE, Garching, Germany
  - imaging photometry in 2 bands simultaneously: **75 or 110 μm and 170 μm**
  - 2 filled bolometer arrays (64x32 and 32x16 pixels) --> full beam sampling over **3.5'x1.75' field of view**
  - **Angular resolution: 6.4" (blue) and 12.8" (red)** HPBW
  - **Expected sensitivity: ~ 3 mJy/beam** (5σ, 1hr)
  - Integral-field line spectroscopy from 57 to 210 μm



- **SPIRE - Spectral and Photometric Imaging Receiver**
  - PI: Matt Griffin, Cardiff University, UK
  - 3-band imaging bolometer array: **250, 360, 520 μm** (simultaneous)
  - **8'x4' field of view** (2Fλ feedhorns - cf. SCUBA)
  - **Angular resolution: 18", 25", 36"** (HPBW)
  - **Expected sensitivity: ~ 3-10 mJy/beam** (5σ, 1hr)
  - Spectro-imaging FTS from 200 to 670 μm

SPIRE 43 detectors @ 520 μm



Overview of Herschel SPIRE/PACS SF Key Projects

• ***Probing the origin of the stellar IMF*** (**Gould Belt** survey)
Coordinators: Ph. André (CEA/Saclay) and P. Saraceno (IFSI/Rome)
Wide-field (~150 deg^2) photometric imaging of nearby (d < 0.5 kpc) molecular clouds **460 hr of GT (SPIRE+PACS consortium)**

• ***The birth of high-mass stars*** (**OB star formation** survey)
Coordinators: F. Motte (CEA/Saclay), A. Zavagno, and S. Bontemps
Multi-band imaging survey of high-mass star-forming complexes at intermediate (d < 3 kpc) distances **125 hr of GT**

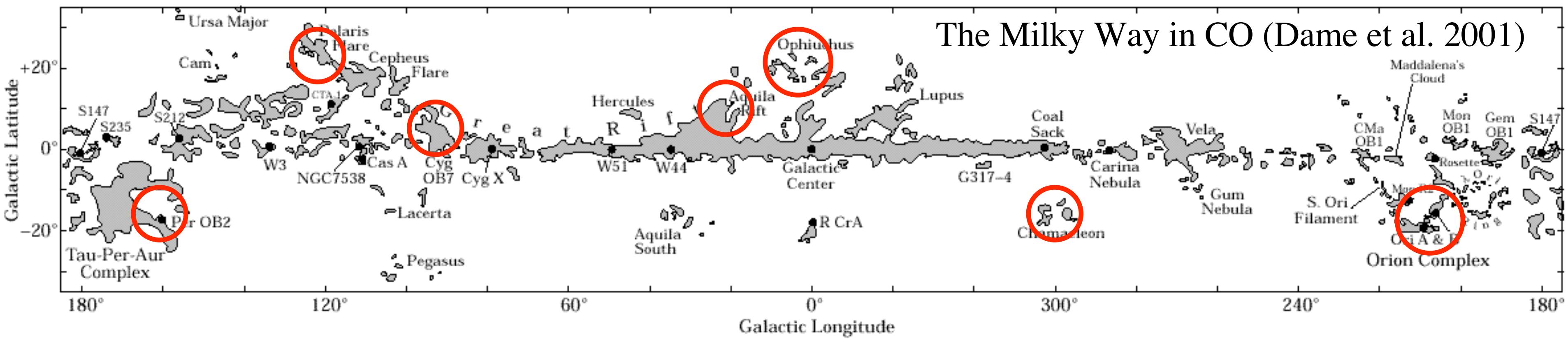
• ***The earliest phases of low- to high-mass star formation***
Coordinators: Th. Henning & O. Krause (MPIA/Heidelberg)
Detailed, small-scale mapping of individual objects **118 hr of GT**

• ***Herschel Infrared Galactic Plane Survey*** ***(HIGAL)***
Coordinator: S. Molinari (IFSI/Rome) **Open Time KP**

Scientific Motivation for the Gould Belt Survey

Key questions on the earliest phases of star formation:

- What determines the distribution of stellar masses = the IMF ?
- What generates prestellar cores and what governs their evolution to protostars and proto-brown dwarfs ?
- Timescale of core/star formation ? Slow, quasi-static process or fast, dynamic process ?



The Milky Way in CO (Dame et al. 2001)

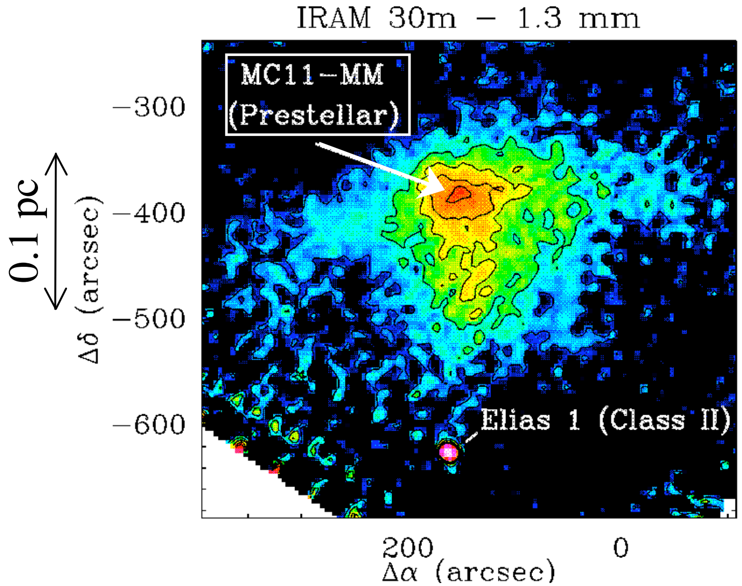
Prestellar Cores (t < 0)

The progenitors of protostars

→

Class 0 protostars (t > 0)

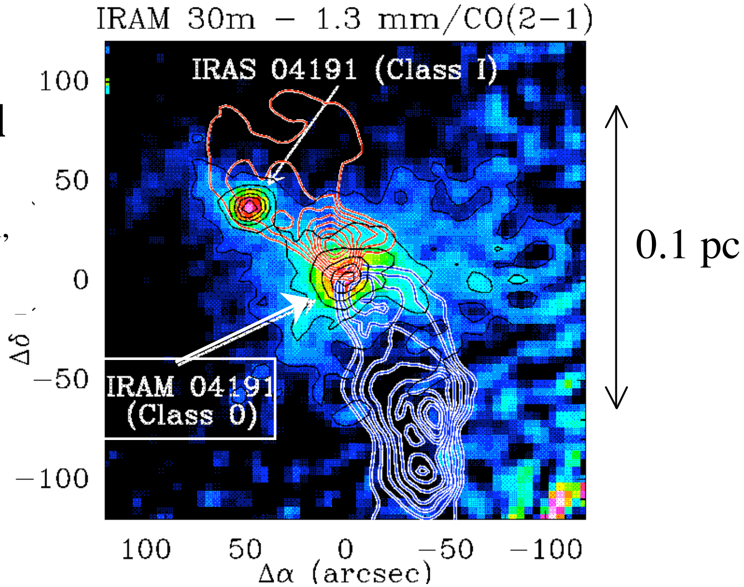
Protostars in the build-up phase



Representative of the collapse initial conditions
(cf. André, Ward-Thompson, Barsony 2000 PPIV)

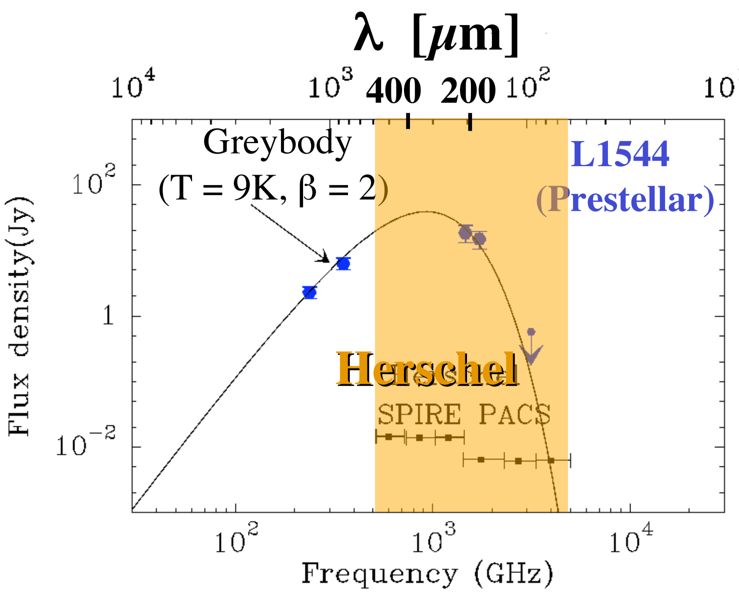
Sizes: ~ 0.01 pc to ~ 0.1 pc

Resolved by *Herschel* up to ~ 0.5 kpc



Gravitationally bound ($M \sim M_{VIR}$, $M_* = 0$)

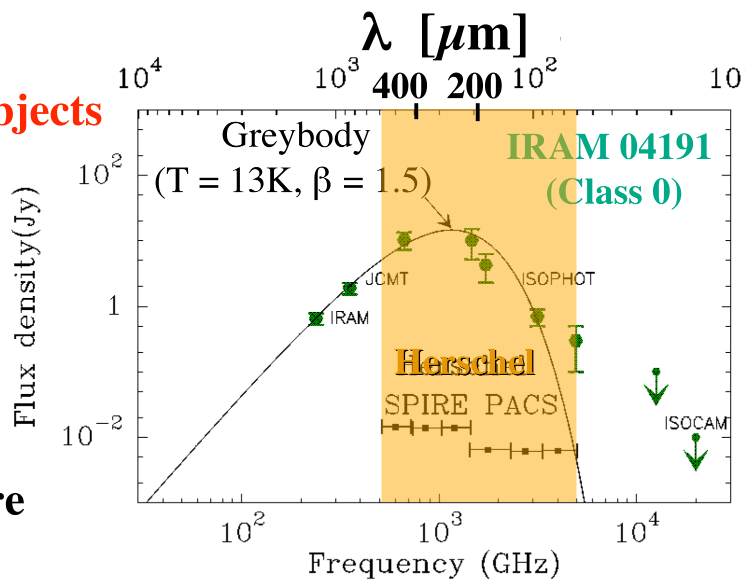
Massive envelopes ($M_{env} > M_*$)



Submm-only objects

↓

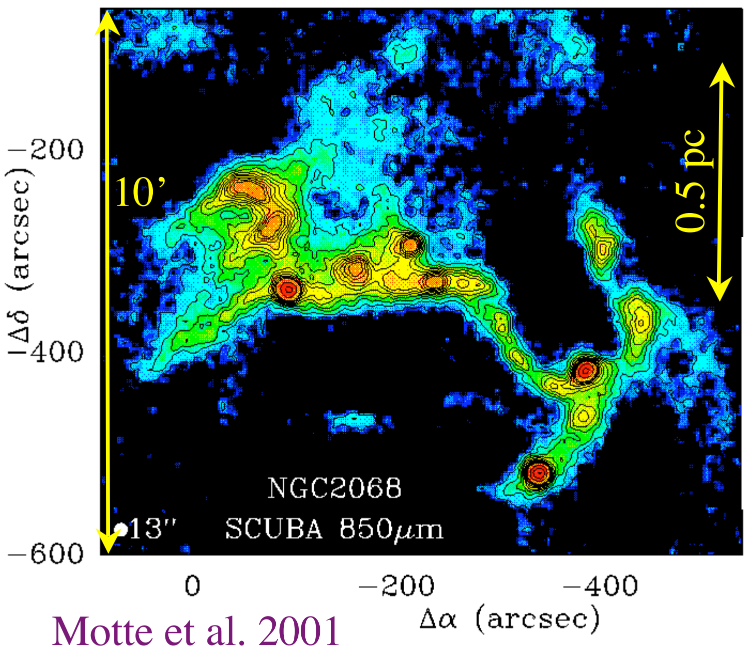
***Herschel* bands essential**
for **luminosity** and **temperature** determinations



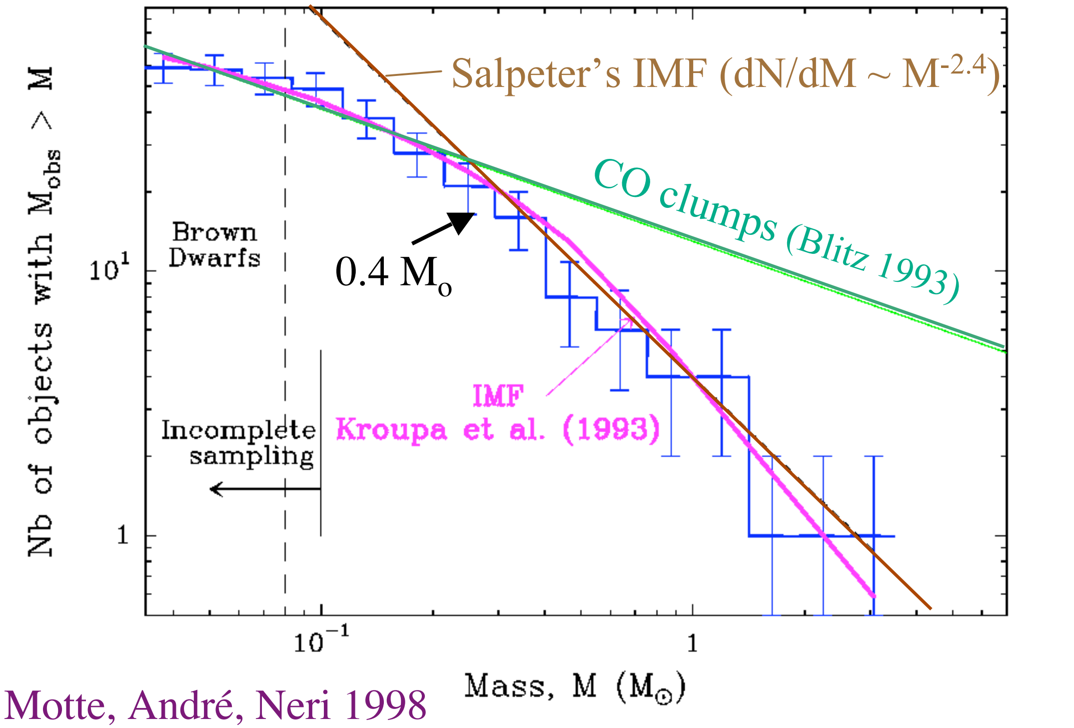
Importance of complete surveys of these early stages

➜ The prestellar core mass function resembles the IMF

NGC2068 (d = 410 pc) à 850 µm



Motte et al. 2001



Motte, André, Neri 1998

➜ IMF partly determined by fragmentation at prestellar stage

<u>Problems</u>: Small-number statistics, incompleteness at low-mass end

\+ Current mass estimates assume constant dust properties

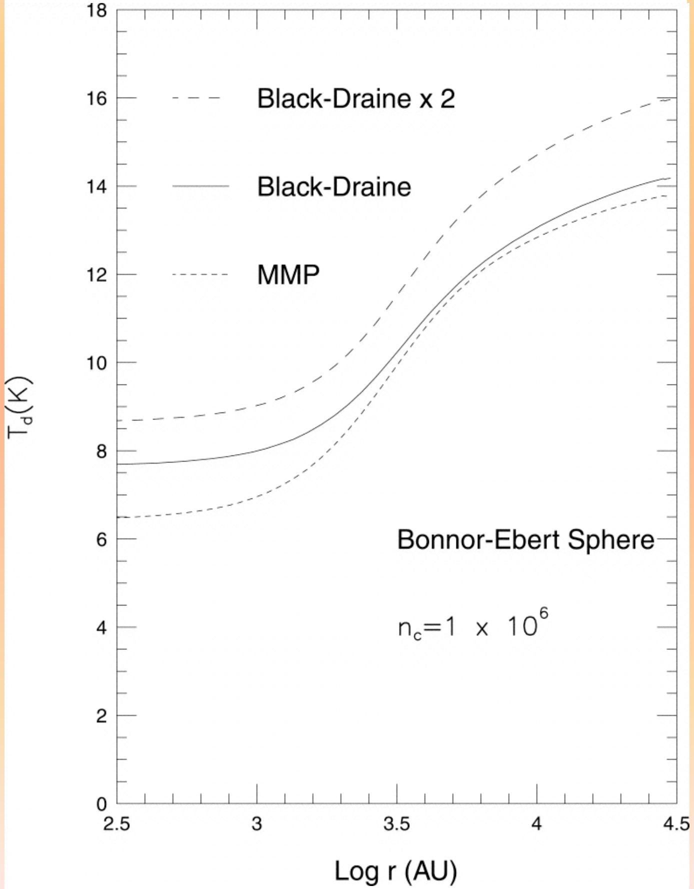
➜ *Herschel* needed to confirm/extend conclusion toward low masses

Importance of direct determinations of the dust properties

- Current mass estimates assume constant dust properties (T_{dust} , κ_{dust})
- But both T_{dust} and κ_{dust} are uncertain and may vary from object to object

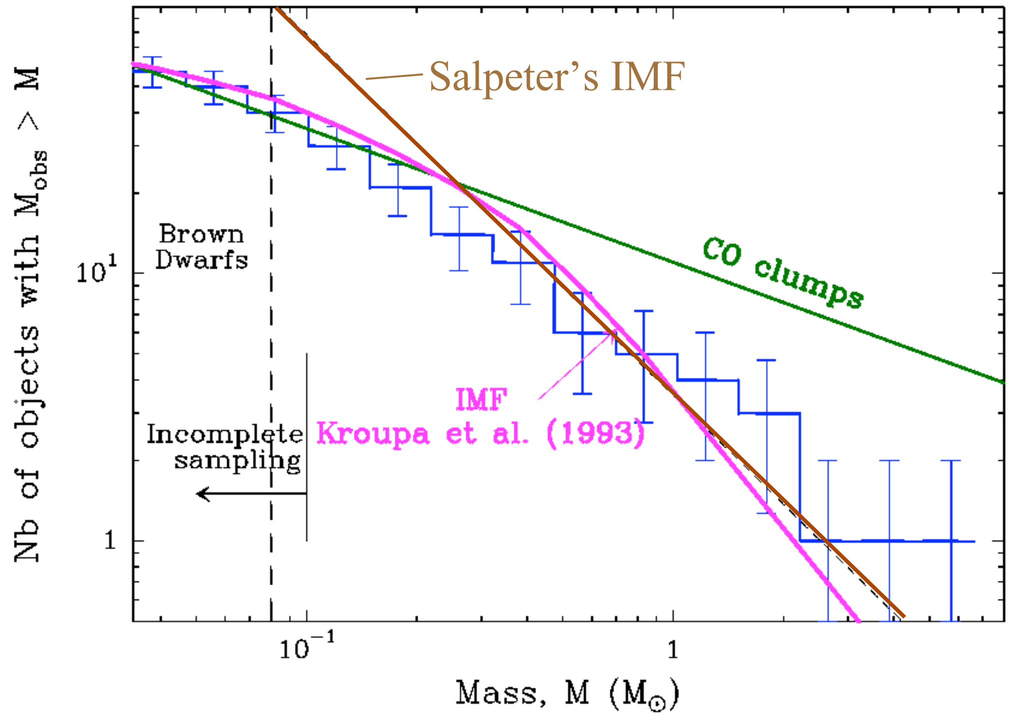
Expectations: T_{dust} ↘ and κ_{dust} ↗ in the core interiors as N_{H2} (or A_V) ↗

Expected Core Temperature Profile



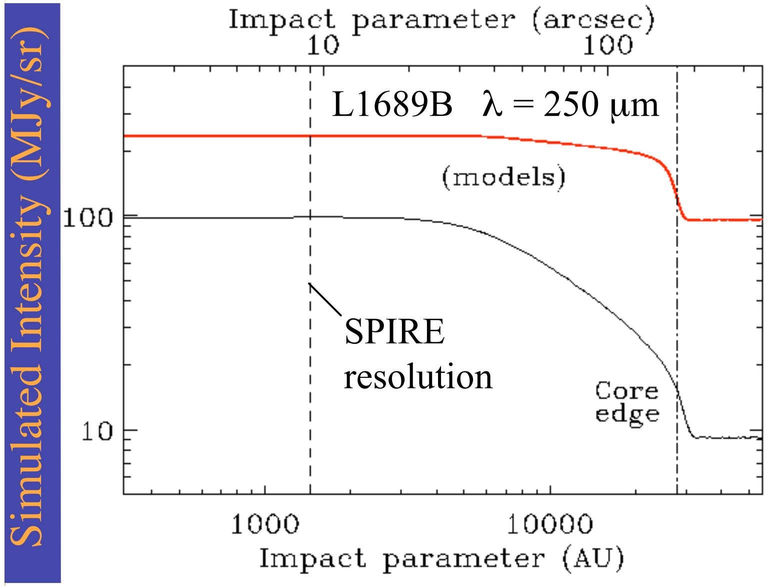
Evans et al. 2001

Mass spectrum of ρ Oph prestellar condensations assuming a distribution of dust temperatures



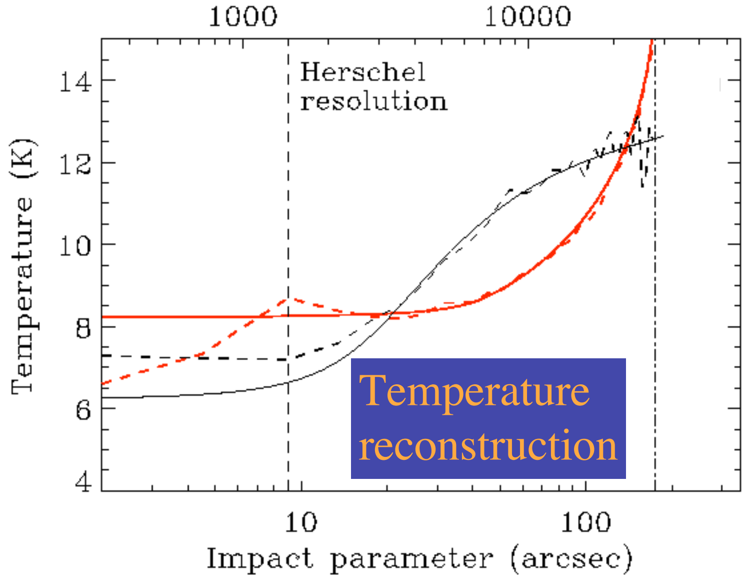
➜ Direct temperature measurements with Herschel are crucially needed

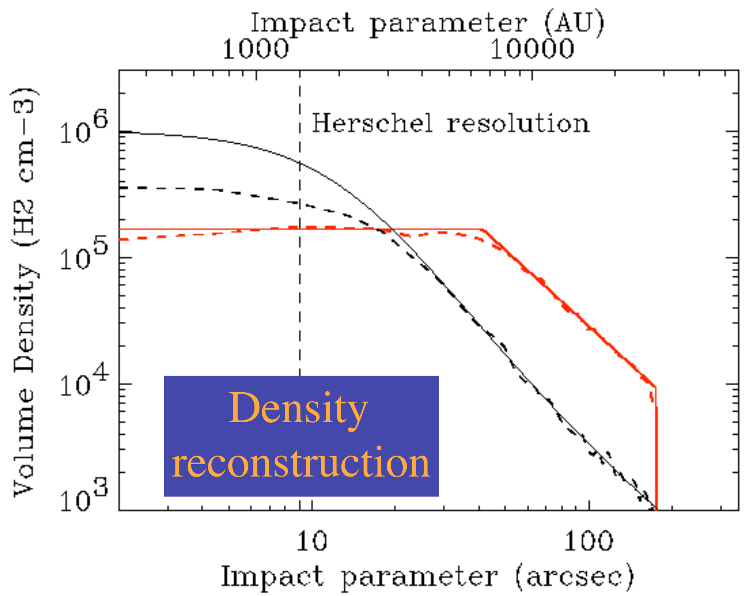
With SPIRE+PACS: Simultaneous determination of the temperature and column density profiles



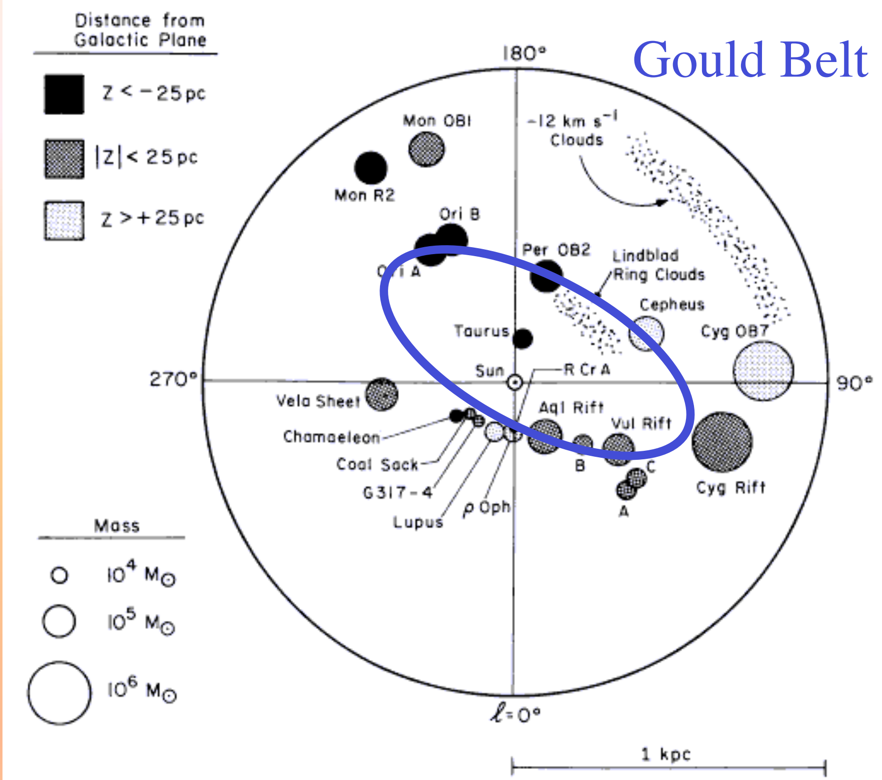
Multi-band mapping with Herschel
+ ground-based (sub)mm telescopes

5 Herschel Bands (110-500 µ) + 850 + 1250µm
+
Assumption on 3D core geometry
↓
Reconstructed Core Structure





Herschel Photometric Survey of the Gould Belt



<u>An *Herschel* GT Key Project</u>:

- SPIRE 250-500 μm survey of ~ 160 deg^2 in both active and quiescent nearby (d < 0.5kpc) molecular clouds, including densest ($A_v > 3$) part of Gould belt
- PACS 110-170 μm imaging of ~ 60 deg^2 : representative, selected areas including nearby protoclusters and isolated dense cores
- Sensitivity (5σ): $A_v \sim 1$ ~ cirrus confusion

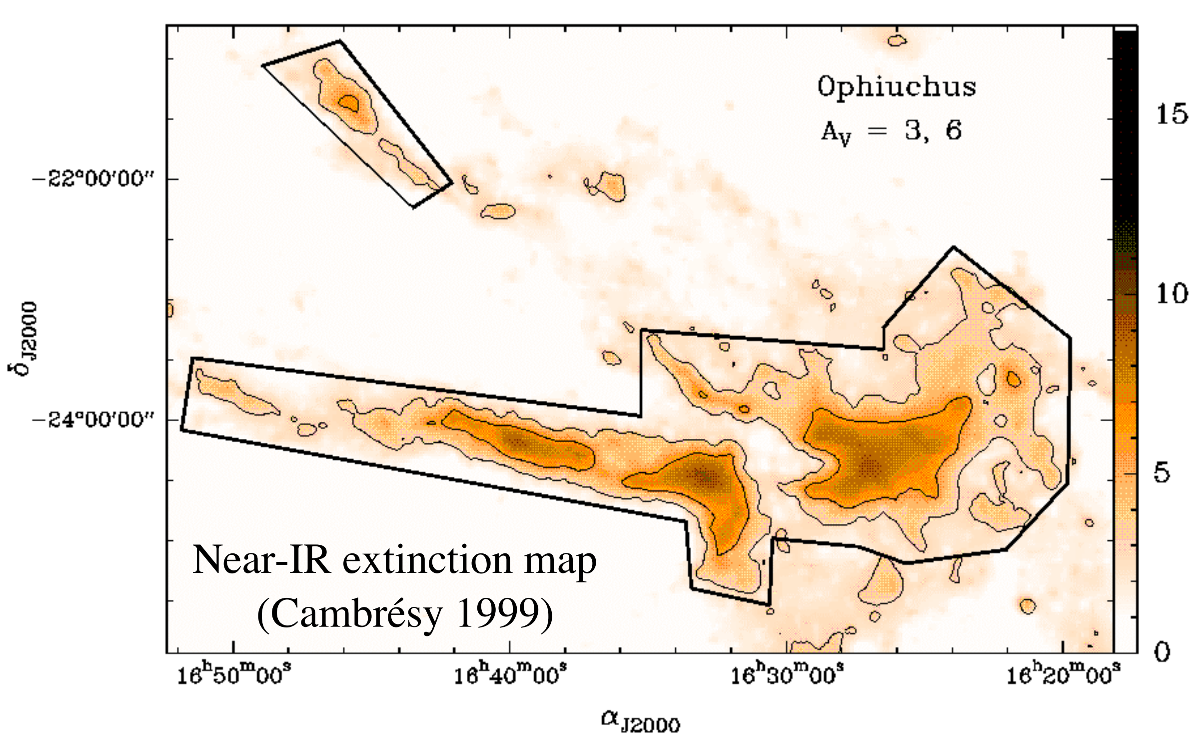
<u>Expected immediate outcome of the survey:</u>

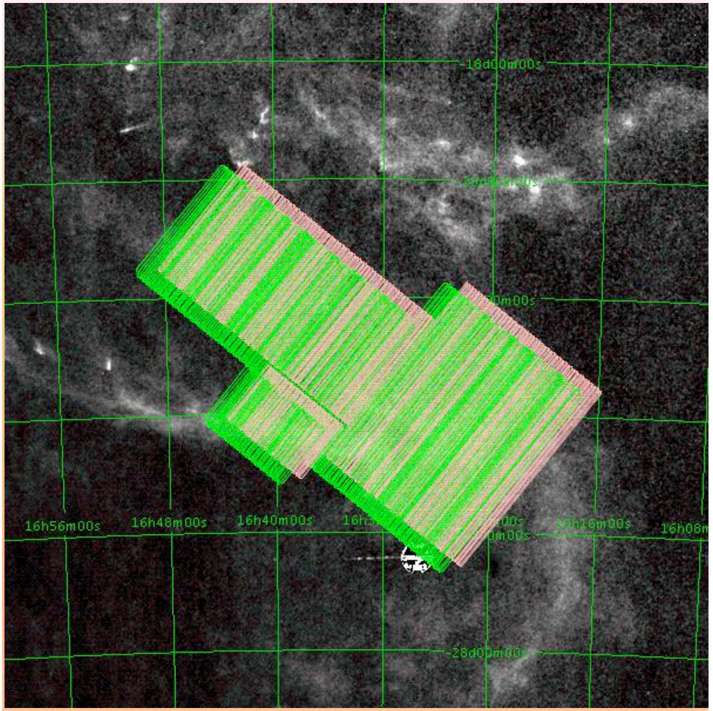
- A few hundred Class 0 protostars and a few thousand prestellar condensations with well-characterized temperatures, luminosities, masses (+ profiles in many cases)

➜ Good sampling of the prestellar core mass function from the substellar to the intermediate-mass regime; lifetimes as a function of mass, density, environment

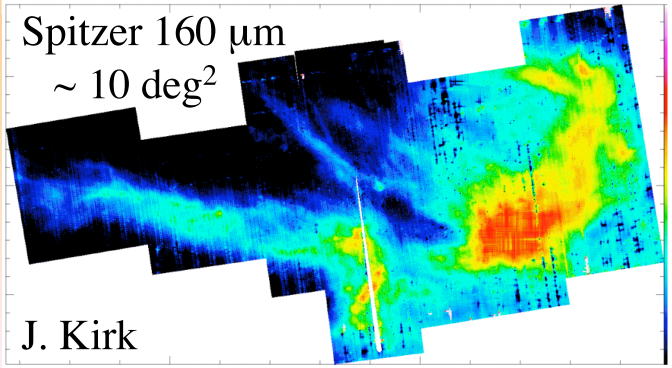
➜ Unique database for follow-up kinematical/multiplicity studies with ALMA

Careful definition of the target fields using near-IR extinction maps





N. Evans' Spitzer c2d project



--> ~ 17 deg^2 in scan-map mode with SPIRE

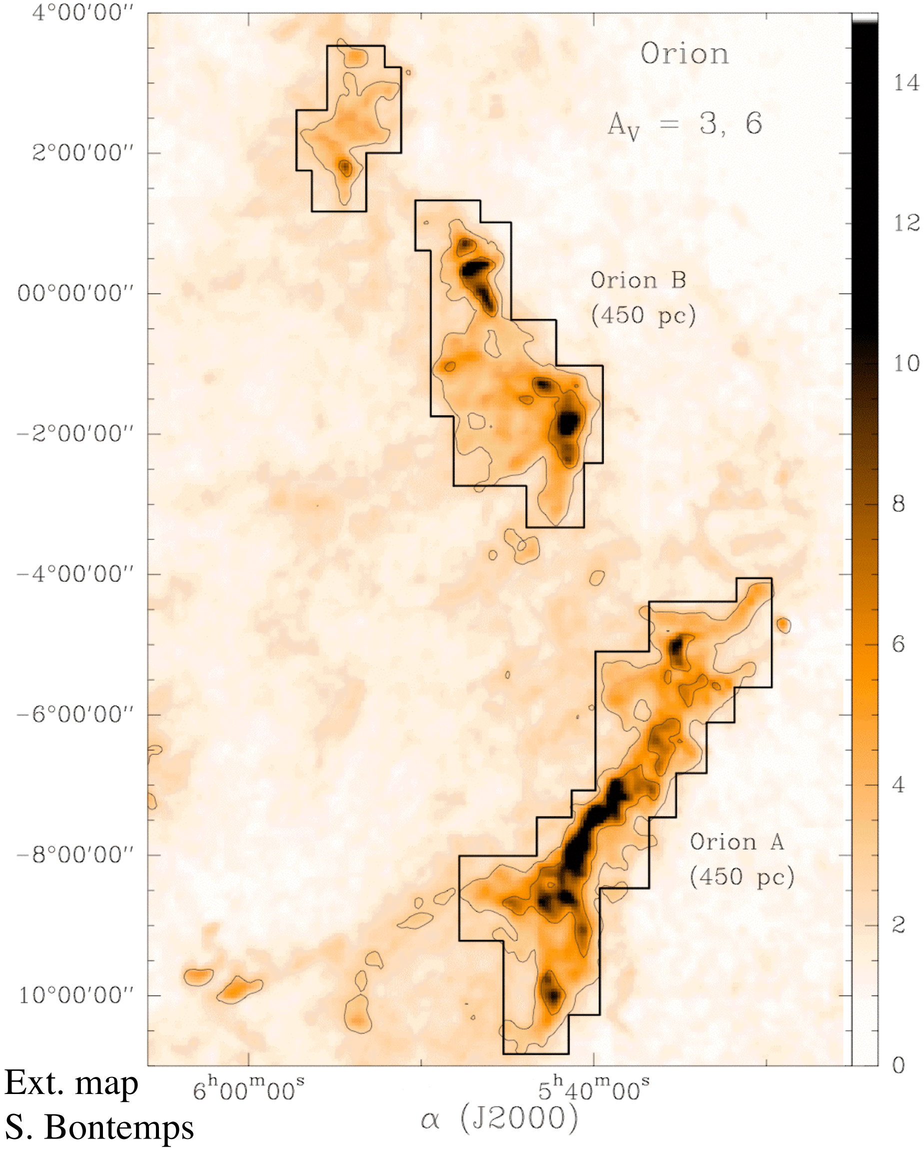
Sensitivity level ~ cirrus confusion noise:

$\sigma_{250} \sim 20$ mJy x $(B_{100}/55\text{MJy/sr})^{1.5}$

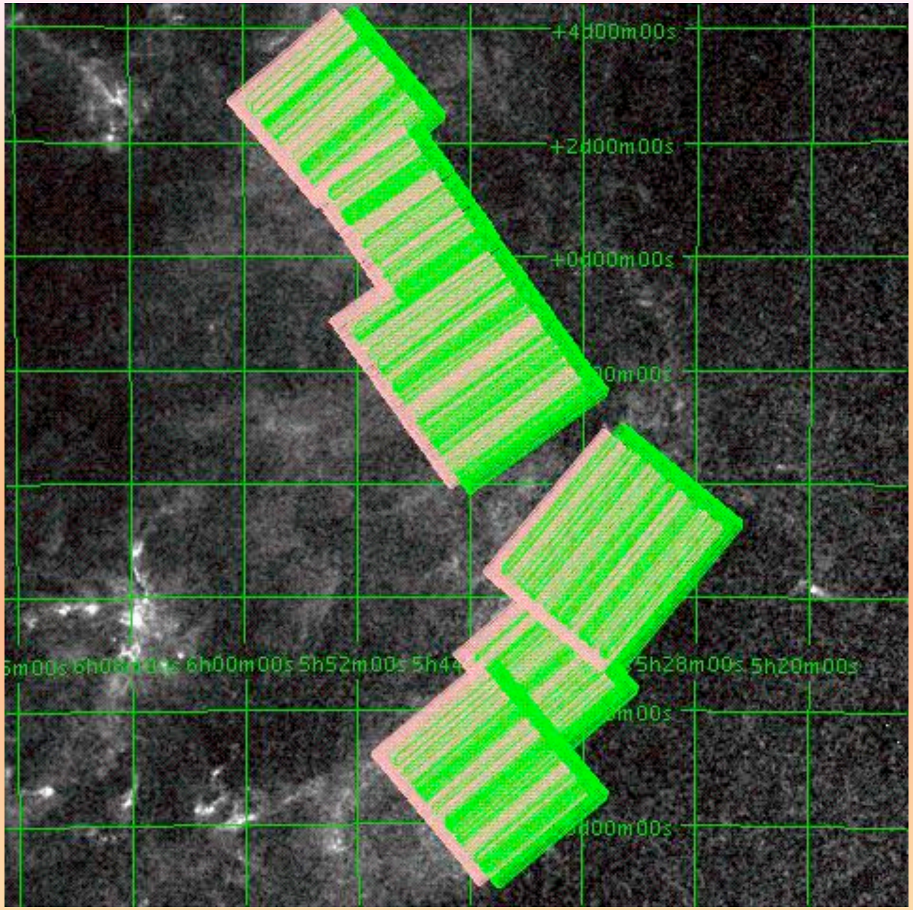
Corresponding column density level: $A_V \sim 1$ (5σ)

Near-IR extinction map with preliminary SPIRE survey field

Orion A/B complex



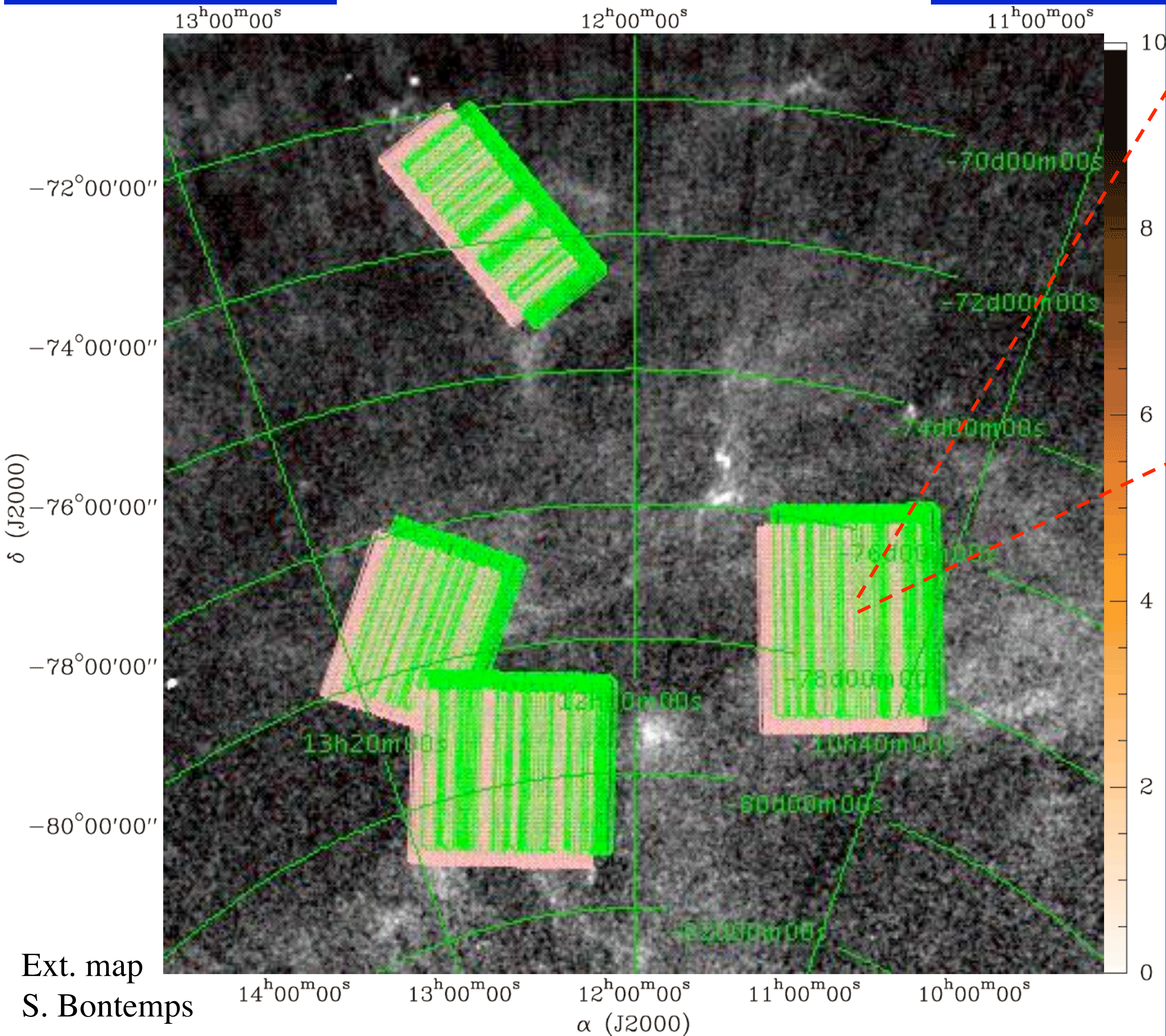
Ext. map
S. Bontemps



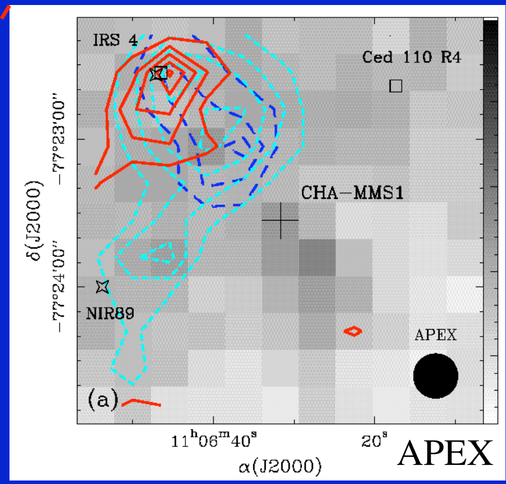
→ ~ 30 ~ 15+15 deg^2 in scan-map mode with SPIRE

Sensitivity ~ 10 mJy (< cirrus noise)

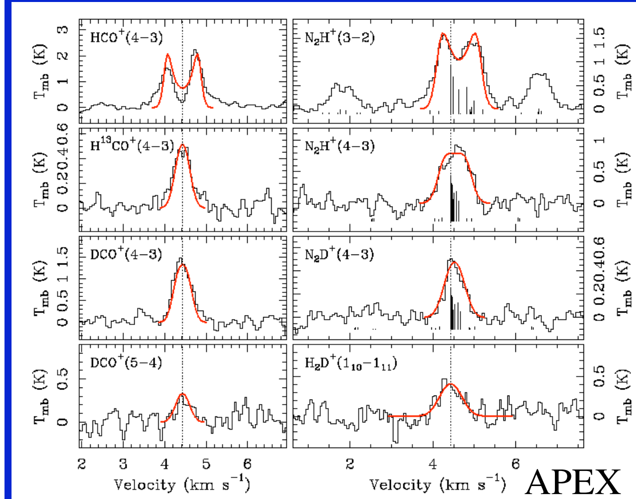
Chamaeleon + Musca clouds



Ext. map
S. Bontemps



Cha-MMS1 (Reipurth et al. 1996
Belloche et al. 2006)



→ ~ 15 deg^2 to rms$_{250}$ ~ 10 mJy/beam in scan-map mode with Herschel-SPIRE

Estimated cirrus confusion noise: σ_{250} ~ 5 mJy x (B_{100}/20MJy/sr)$^{1.5}$