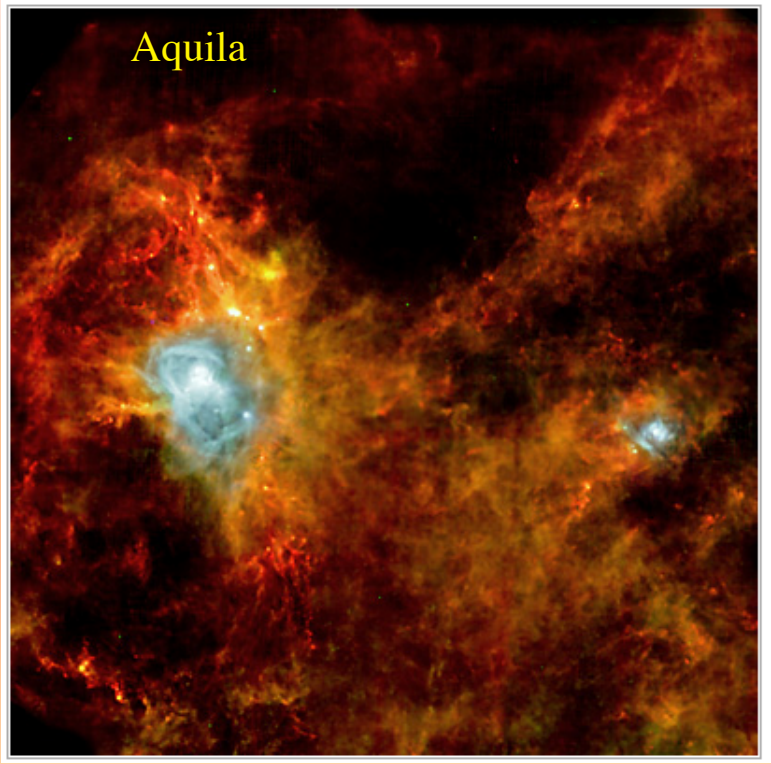
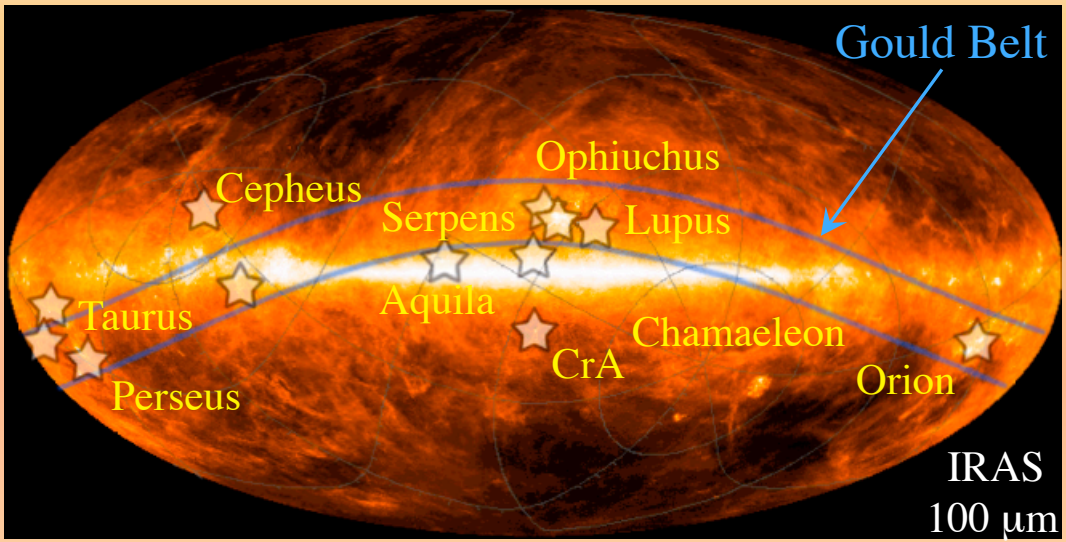
Initial Results from the Gould Belt Survey

Philippe André, CEA/SAp Saclay

on behalf of the Gould Belt Consortium



http://starformation-herschel.iap.fr/gouldbelt/



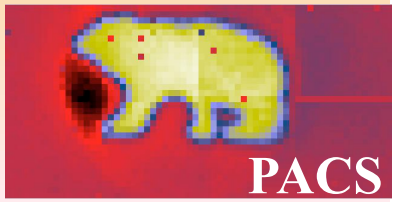
cf. http://oshi.esa.int

Main groups : SPIRE SAG 3 (e.g. Cardiff)

CEA Saclay, IFSI Rome & INAF Arcetri

OAMP Marseille, KU Leuven, MPIA Heidelberg

+ ESA HSC



Gould Belt KP Consortium

Main groups : SPIRE SAG 3

(eg. **P. Saraceno**, D. Ward-Thompson, J.Kirk,
S. Bontemps, V. Konyves,
J. Di Francesco, C. Wilson, P. Martin,
A. Abergel, G. White, M. Griffin,
G. Olofsson, M. Huang, H. Roussel)

PACS Institutes

- **CEA Saclay** (F. Motte, A. Menshchikov, N. Schneider, V. Minier)
- **IFSI Rome** (eg. **P. Saraceno**, S. Molinari) & **INAF Arcetri** (eg. L. Testi)
- **OAMP Marseille** (A. Zavagno, J.P. Baluteau, D. Russeil)
- **KU Leuven** (P. Royer, J. Blommaert & C. Waelkens)

MPIA Heidelberg (eg. T. Henning, R. Launhardt)

+ ESA HSC (eg. B. Merin, R. Vavrek)

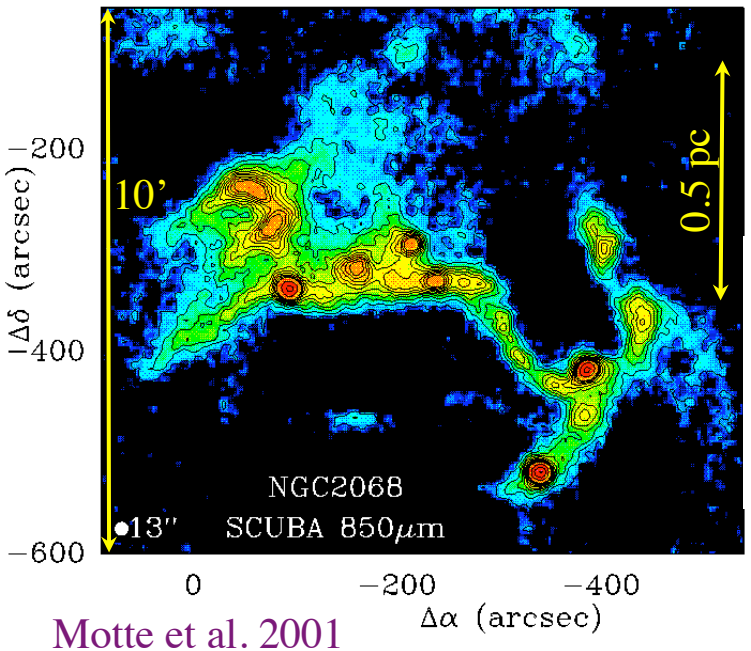
Scientific Motivation for the Gould Belt Survey

Key questions on the earliest phases of star formation:

- What determines the distribution of stellar masses = the IMF ? Clarify the link between the prestellar CMF and 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 ?

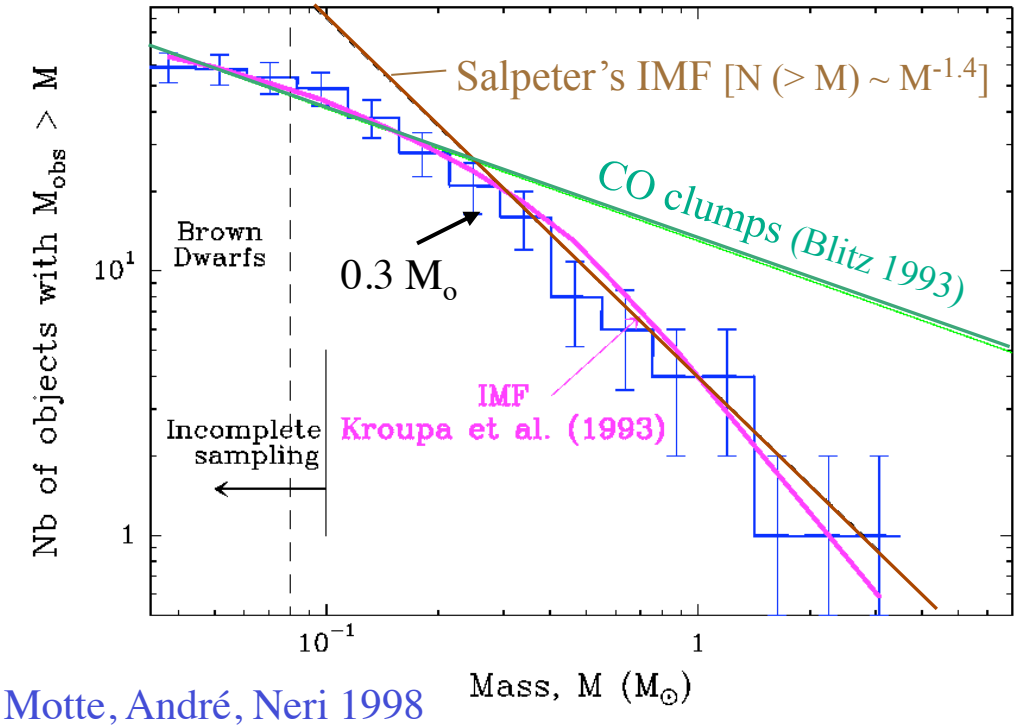
The prestellar core mass function (CMF) resembles the IMF

NGC2068 at 850 μm



Motte et al. 2001

Mass Spectrum of ρ Oph Prestellar Condensations



Motte, André, Neri 1998

→ **The IMF is at least partly determined by pre-collapse cloud fragmentation** (~ 0.1 - 5 $M_\odot$)

• **Limitations:** Small-number statistics, incompleteness at low-mass end (?) + assume constant dust properties

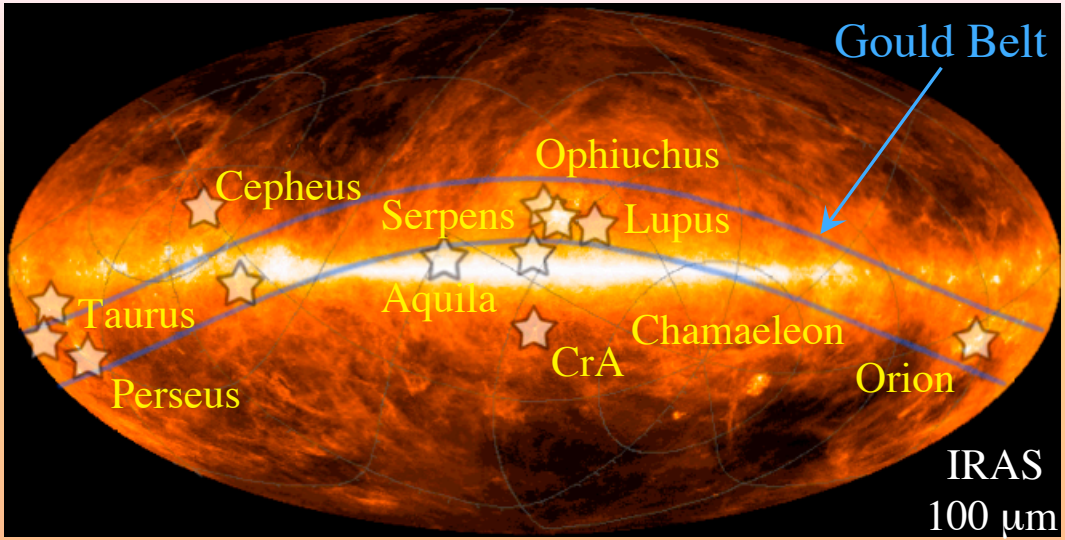
→ ***Herschel*** **needed to confirm/extend conclusions toward lower/higher masses**

See also: Testi & Sargent 1998;
Johnstone et al. 2001;
Stanke et al. 2006; Alves et al. 2007
Nutter & Ward-Thompson 2007

And for massive cores:
Beuther & Schilke 2004;
Reid & Wilson 2006

A wide-field *Herschel* survey of nearby clouds (d < 500 pc)

~ 461 hr of GT ~ 160 deg^2 with SPIRE/PACS



Herschel **~ 3 orders of magnitude faster than SCUBA**

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

- ~ 350 Class 0 protostars and ~ 3500 prestellar cores with well-characterized temperatures, luminosities, masses (+ profiles in many cases)
- Expect up to ~ 300 pre-brown dwarfs with M_{core} ~ 0.01-0.08 M_o in Ophiuchus, Taurus, Pipe, Polaris, Lupus, Coal Sack, Chamaeleon, Corona Australis

➜ Good sampling of the core mass function down to the substellar regime

Gould Belt Science Demonstration Observations

- SPIRE/PACS parallel-mode (60''/sec) mapping of ~ 9 deg^2 field in the **Aquila star-forming complex** (high background, cluster-forming)

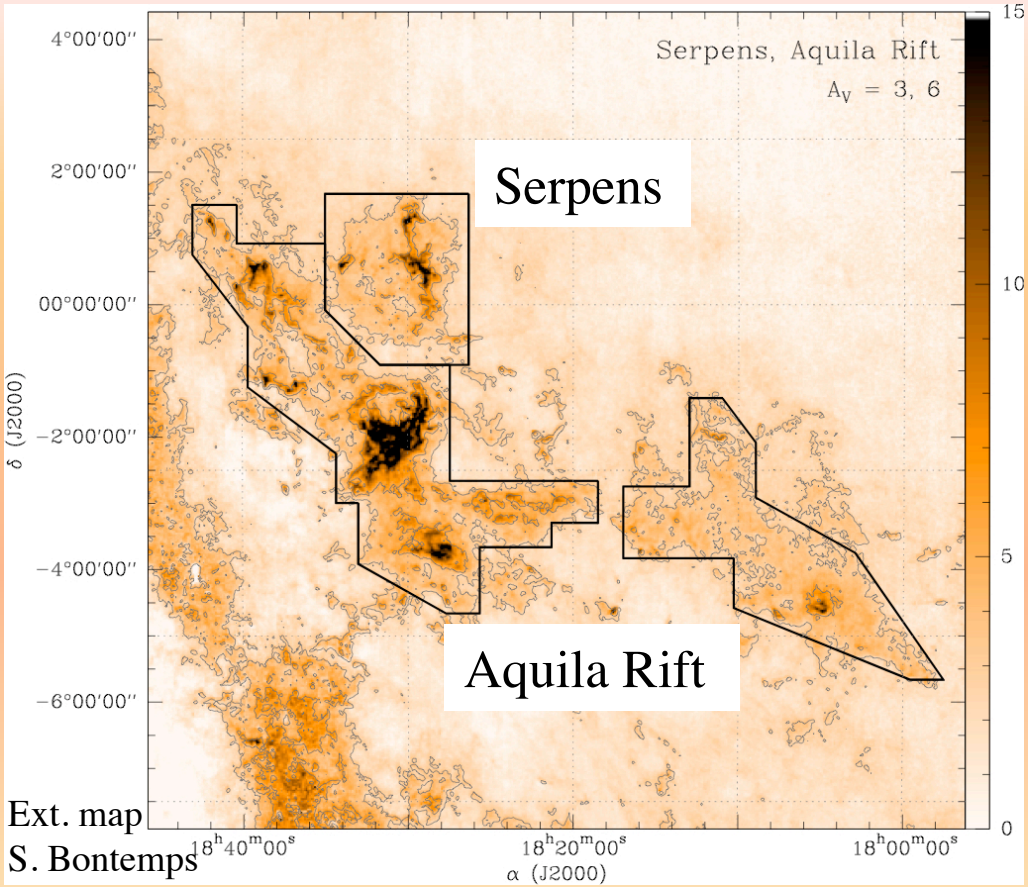
- SPIRE/PACS parallel-mode (60''/sec) mapping of ~ 6 deg^2 field + PACS-only (20''/sec) mapping of ~ 1 deg^2 field toward **Polaris 'cirrus' cloud** (very low background)

- Total duration of SDP observations: ~ 24 hr (~ 5% of entire survey)

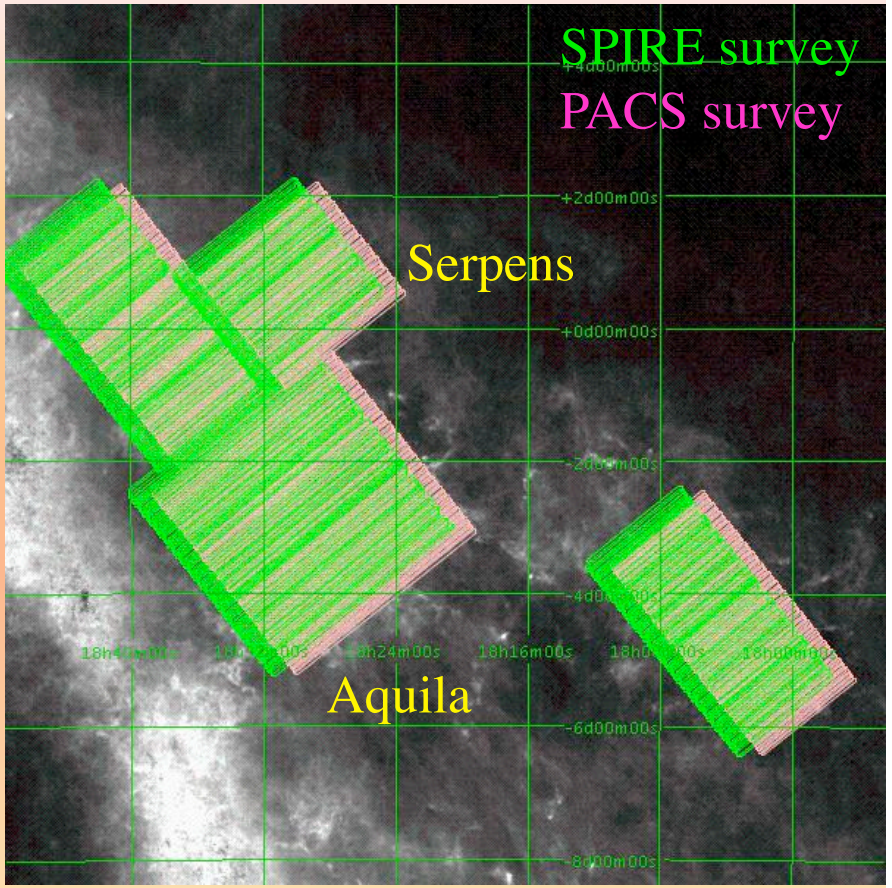
Data reduction: N. Schneider for SPIRE
V. Konyves for PACS
Thanks to M. Sauvage, B. Ali, B. Altieri

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

(See http://starformation-herschel.iap.fr/gouldbelt/ for all fields)

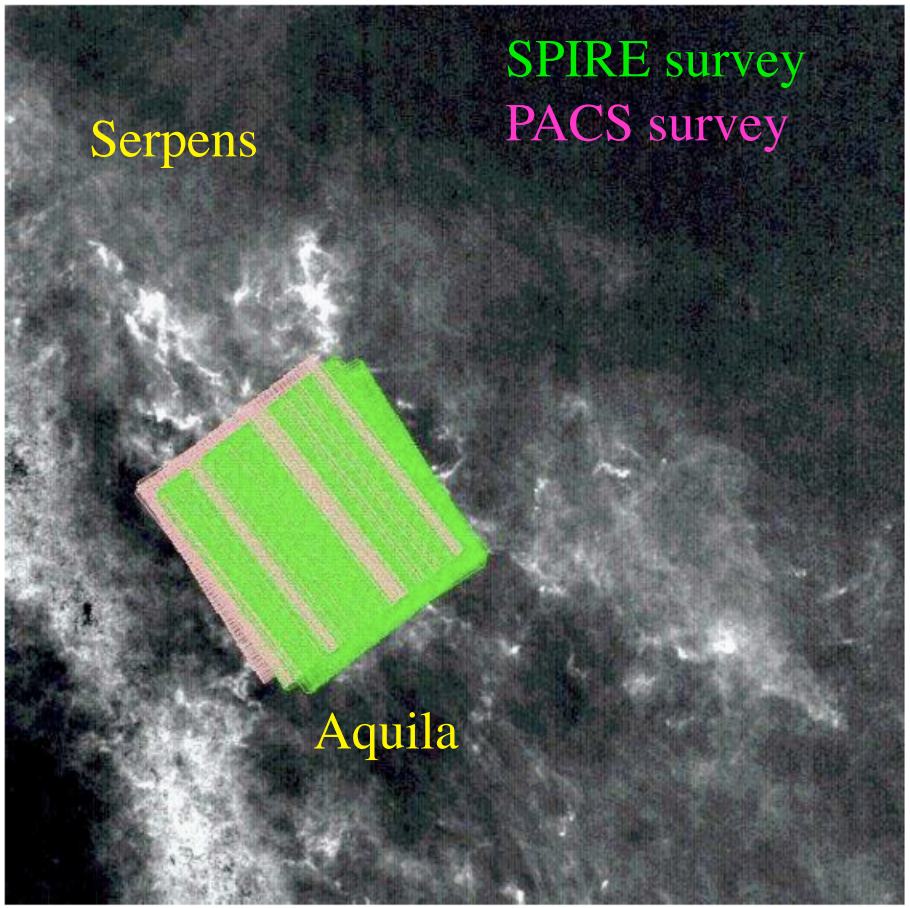


Ext. map
S. Bontemps

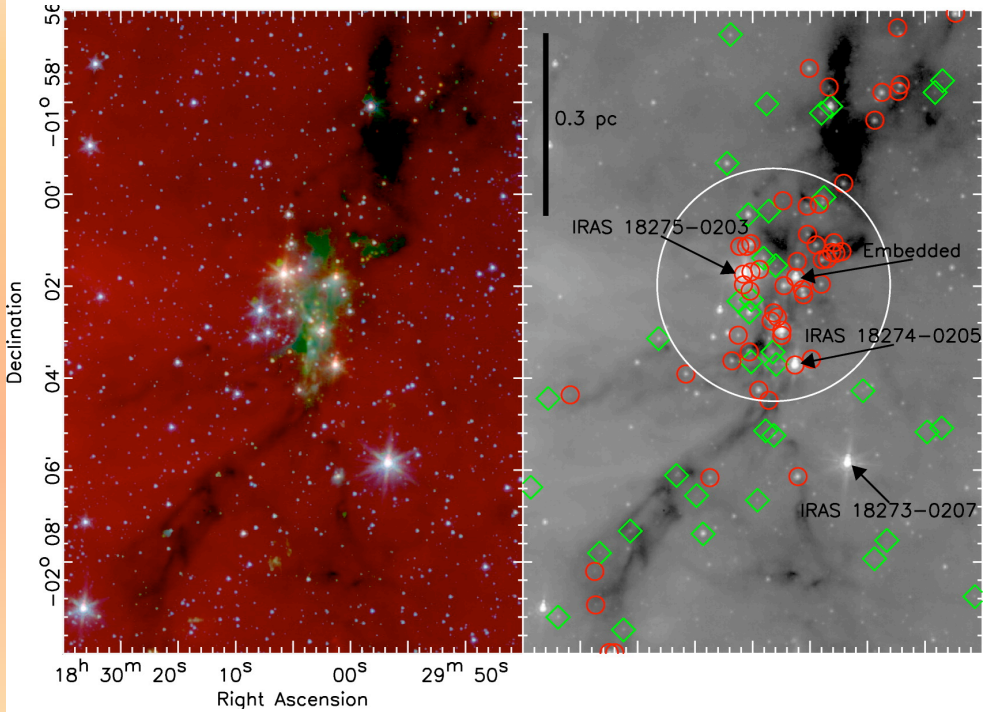


~ 23 deg^2 @ 60”/sec with SPIRE/PACS //
~ 7.5 deg^2 @ 20”/sec with PACS only
Sensitivity ~ 10 mJy/beam (<< cirrus noise)

Observations of Aquila during Science Demonstration Phase on 24 October 2009

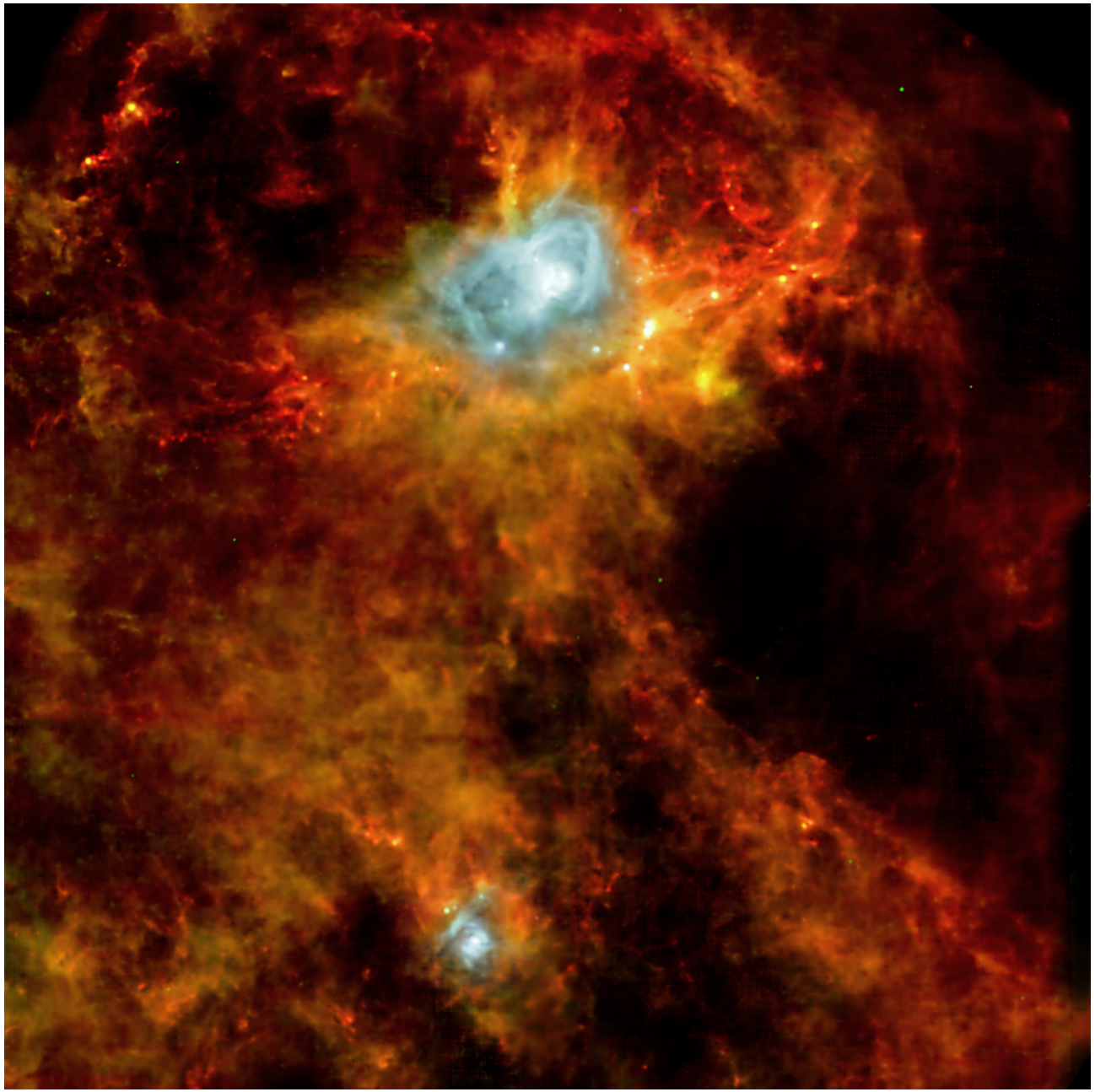


The Serpens-South/Aquila protocluster with *Spitzer*



Gutermuth et al. 2008

“First image” from the Gould Belt Survey



24 Oct 2009

Aquila star-forming cloud (~ 3 deg x 3 deg)

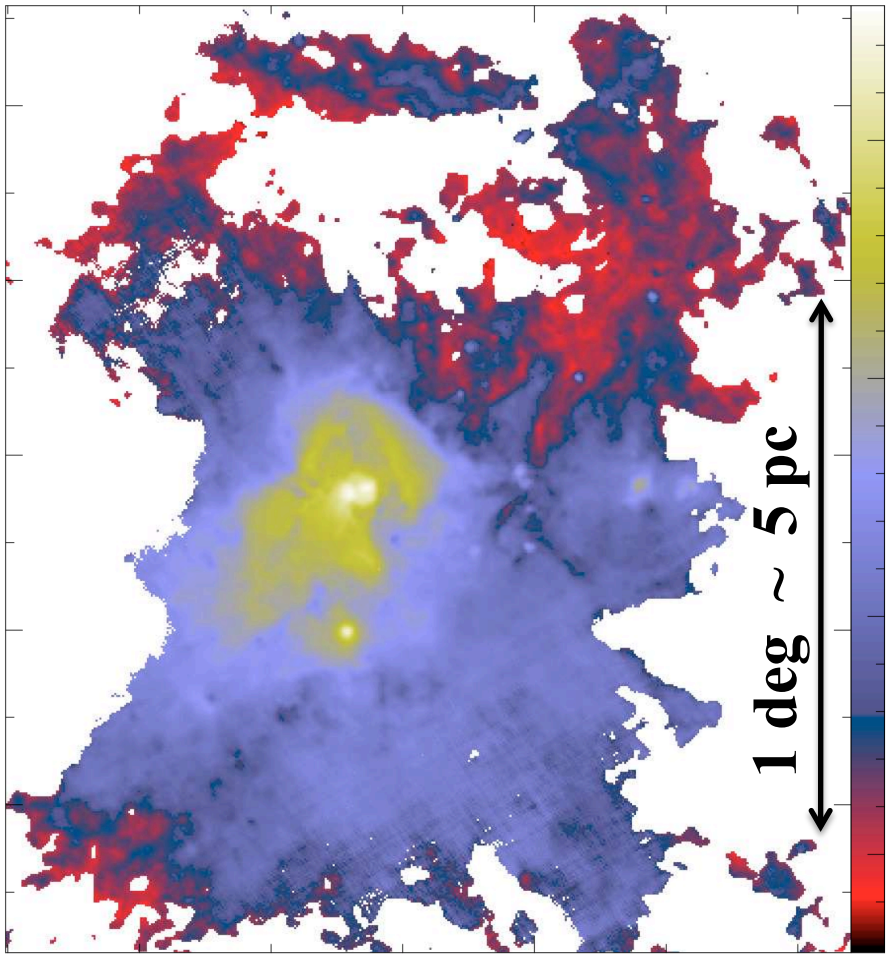
Red : SPIRE 500 μm
Green : PACS 160 μm
Blue : PACS 70 μm

15 nearby SF regions like this mapped in the entire GB Key Programme

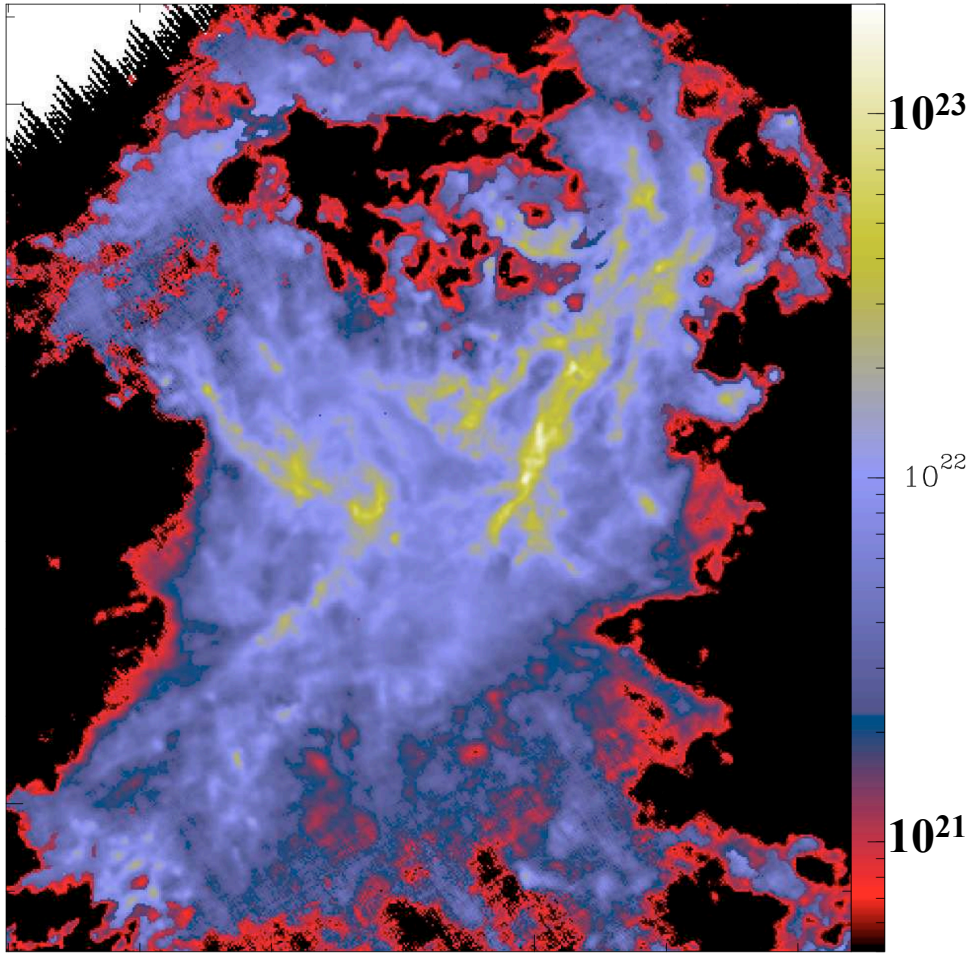
cf. http://oshi.esa.int

Revealing the structure of one of the nearest infrared dark clouds (Aquila Main: d ≲ 300 pc)

Herschel (SPIRE+PACS)
Dust temperature map (K)



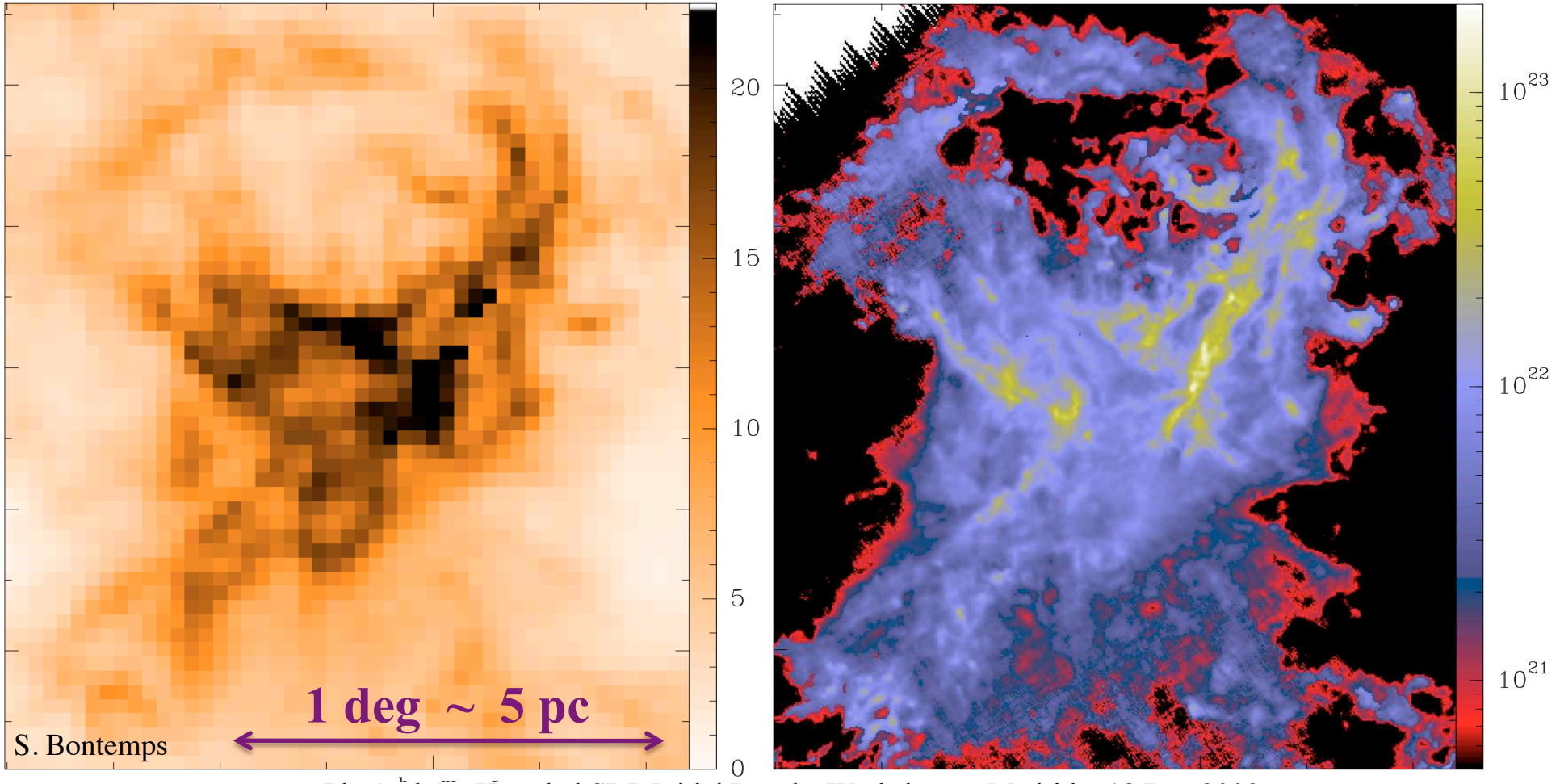
Herschel (SPIRE+PACS)
Column density map (H_2/cm^{-2})



Revealing the structure of one of the nearest infrared dark clouds (Aquila Main: d ≲ 300 pc)

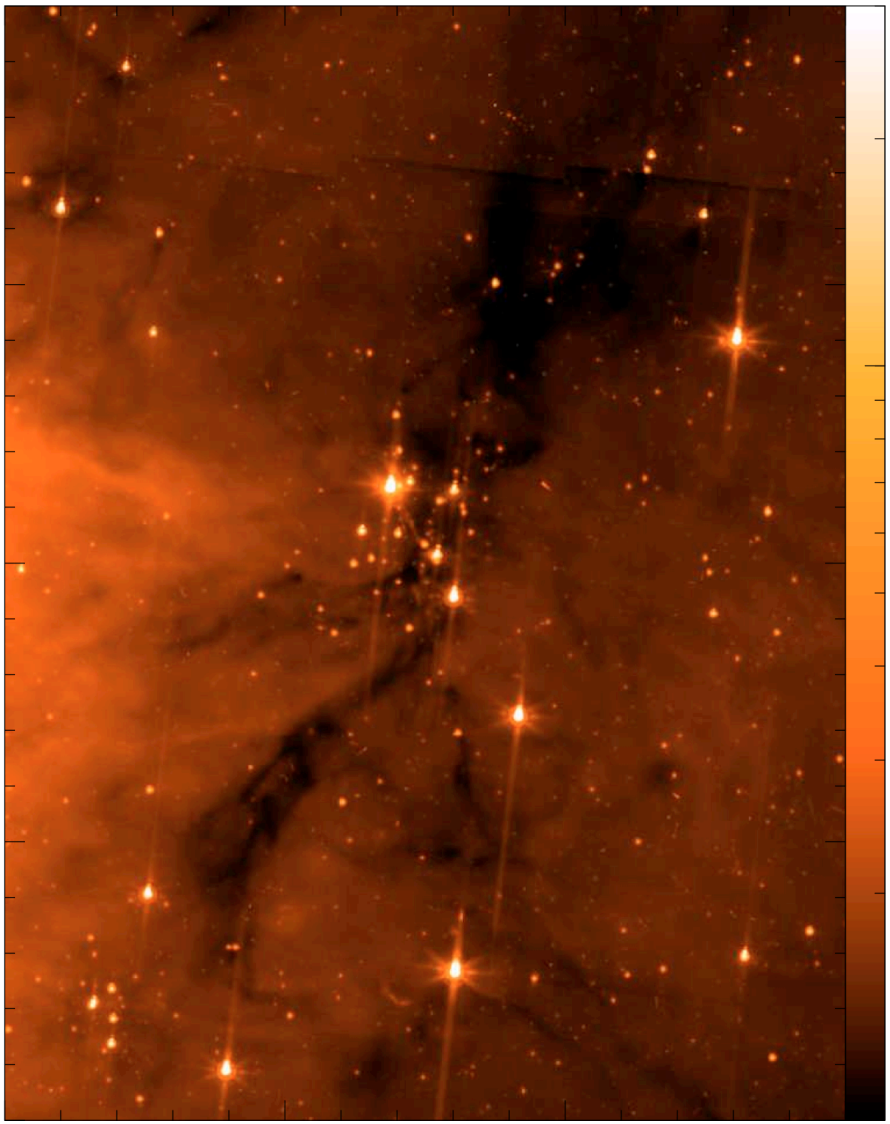
2MASS Near-infrared Extinction map (A_V)

Herschel (SPIRE+PACS) Column density map

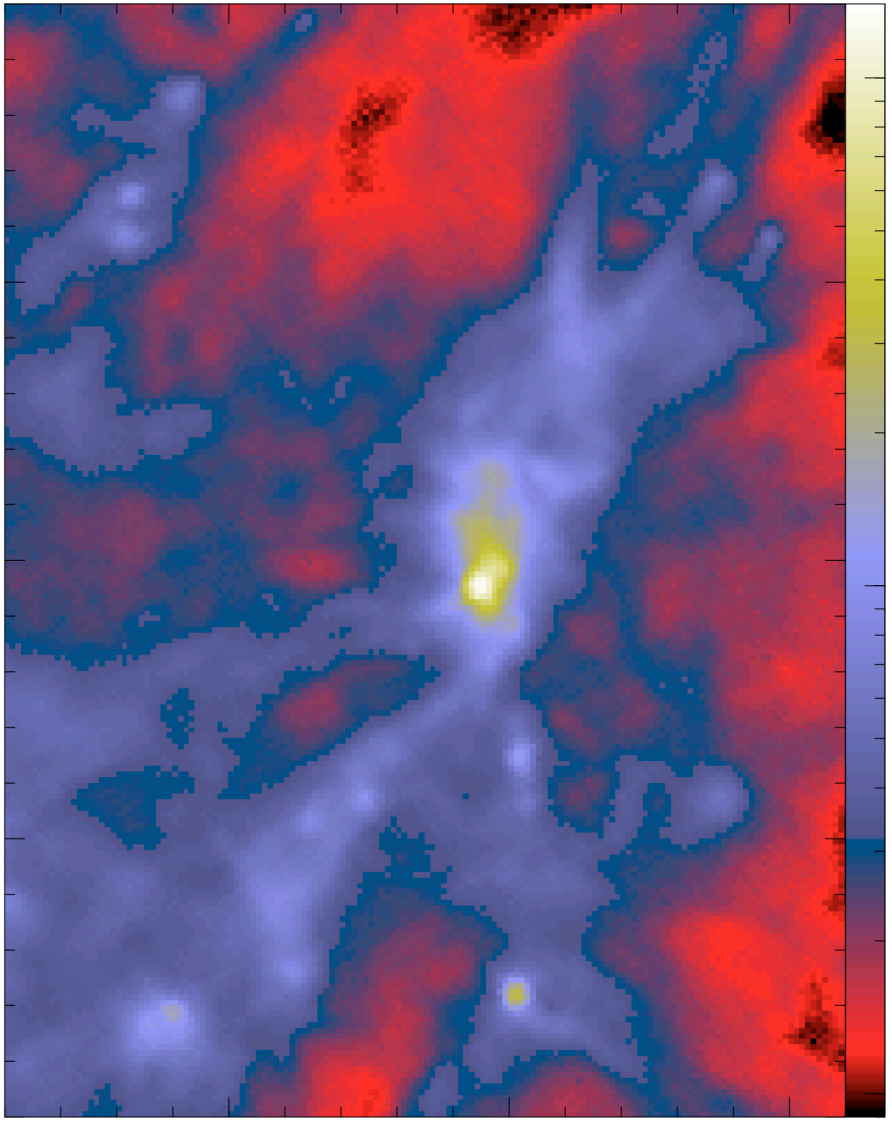


Aquila dark filament: A star cluster in the making

***Spitzer*/IRAC 8 μm**



***Herschel*/SPIRE 250 μm**



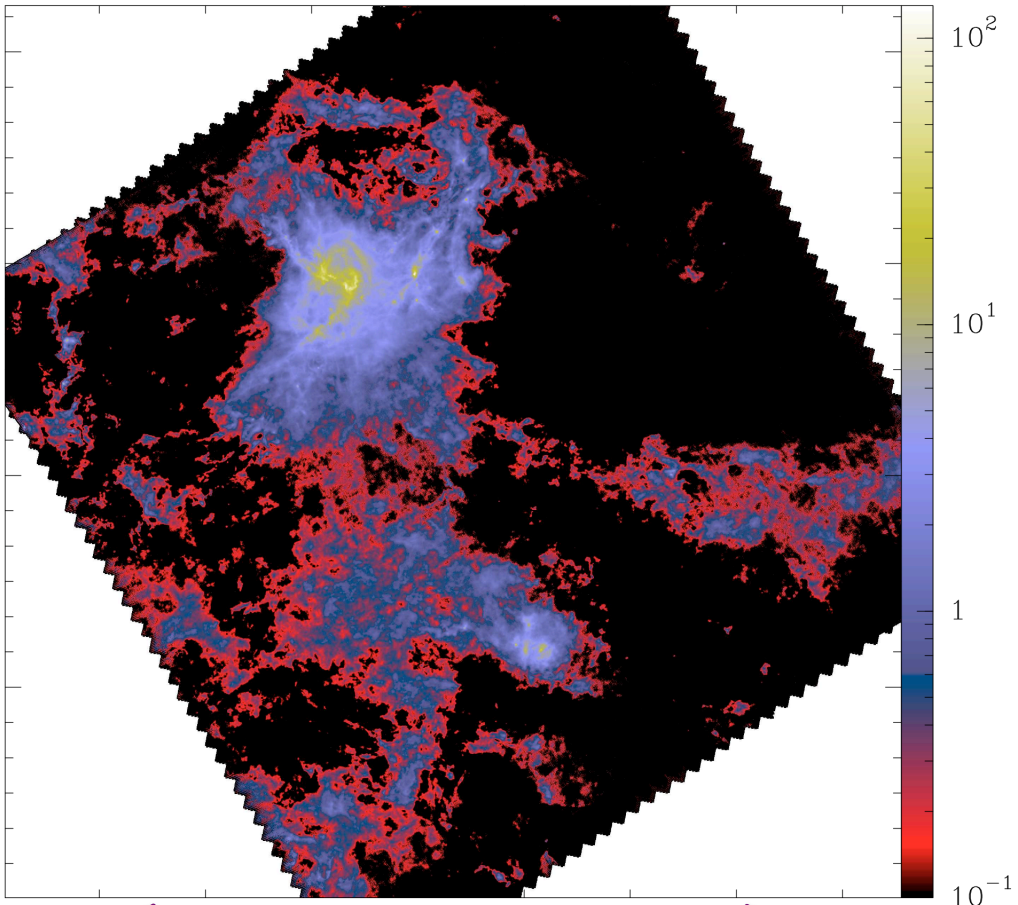
Aquila: `Compact' Source Extraction

(using "getsources" – A. Menshchikov)

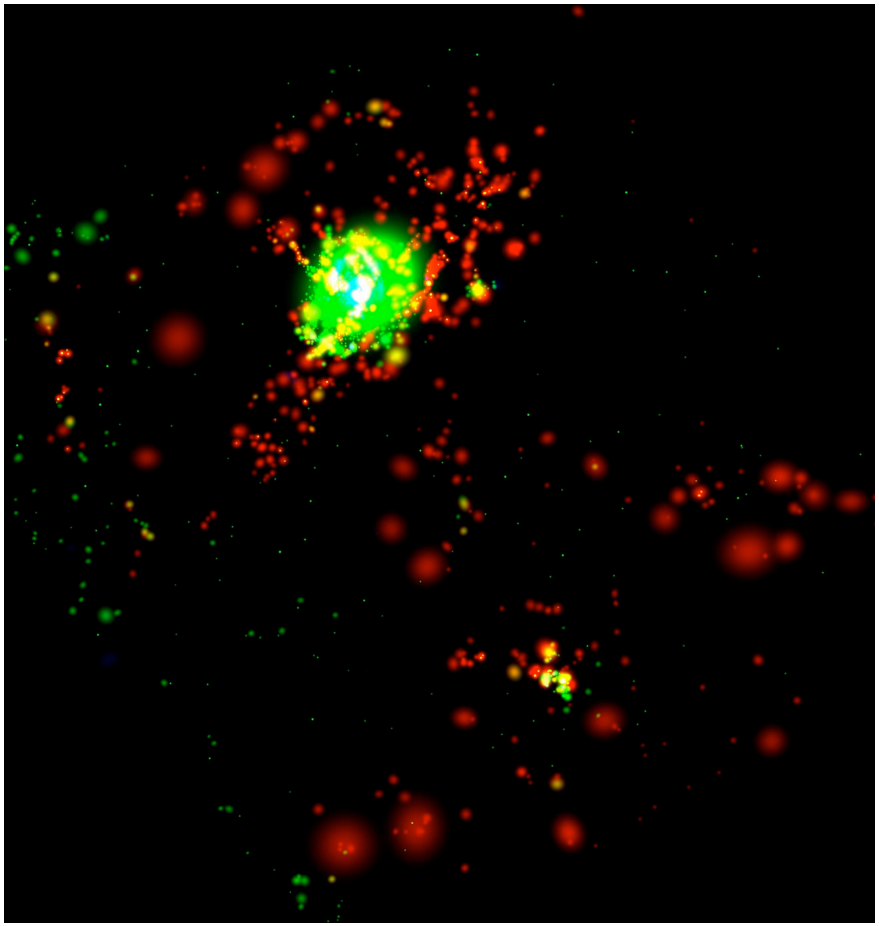
Herschel/SPIRE 250 μm map

~ 700 starless
~ 300 YSOs

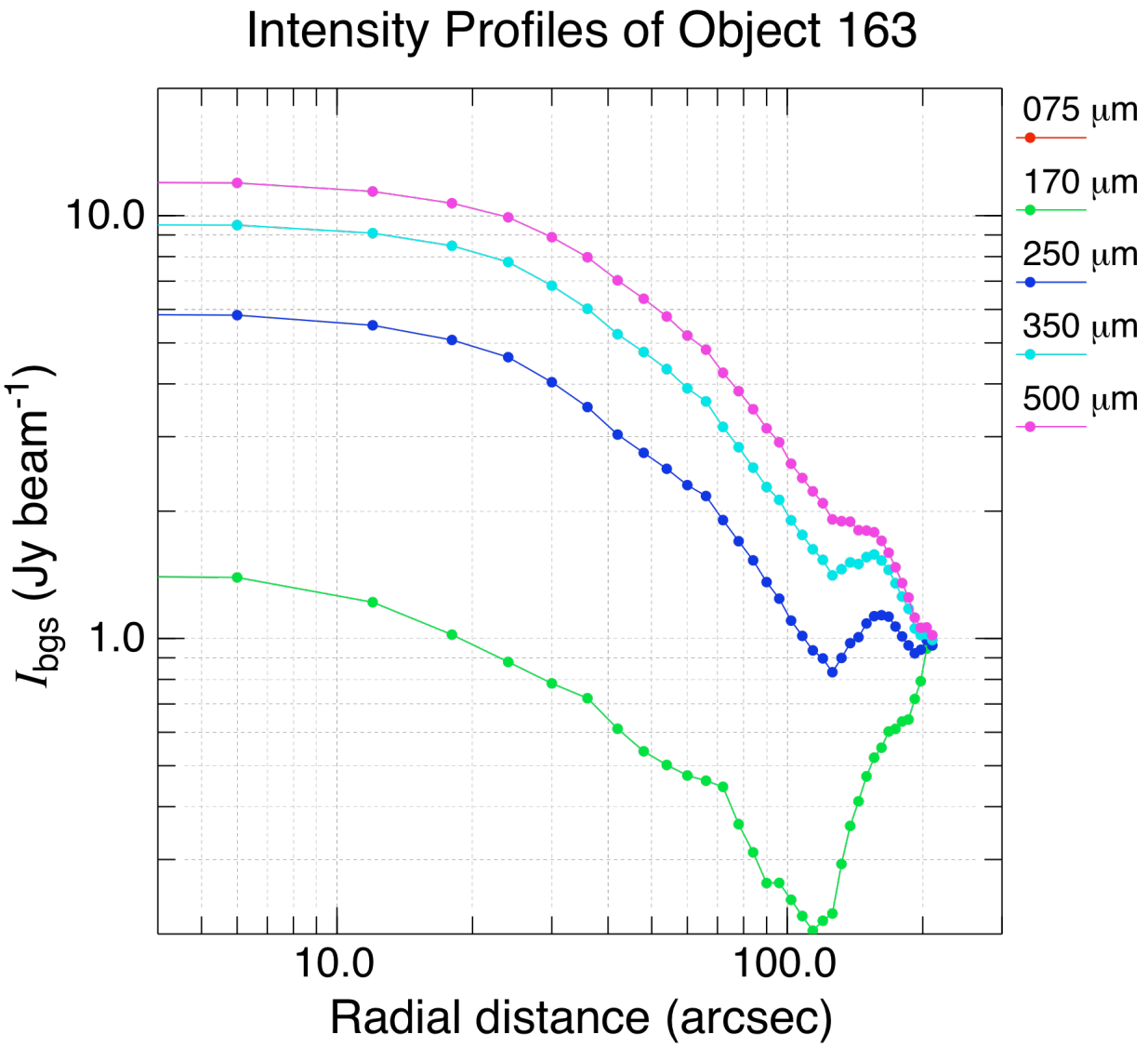
Spatial distribution of extracted cores



3 deg ~ 15 pc



75/170/500 μm composite image

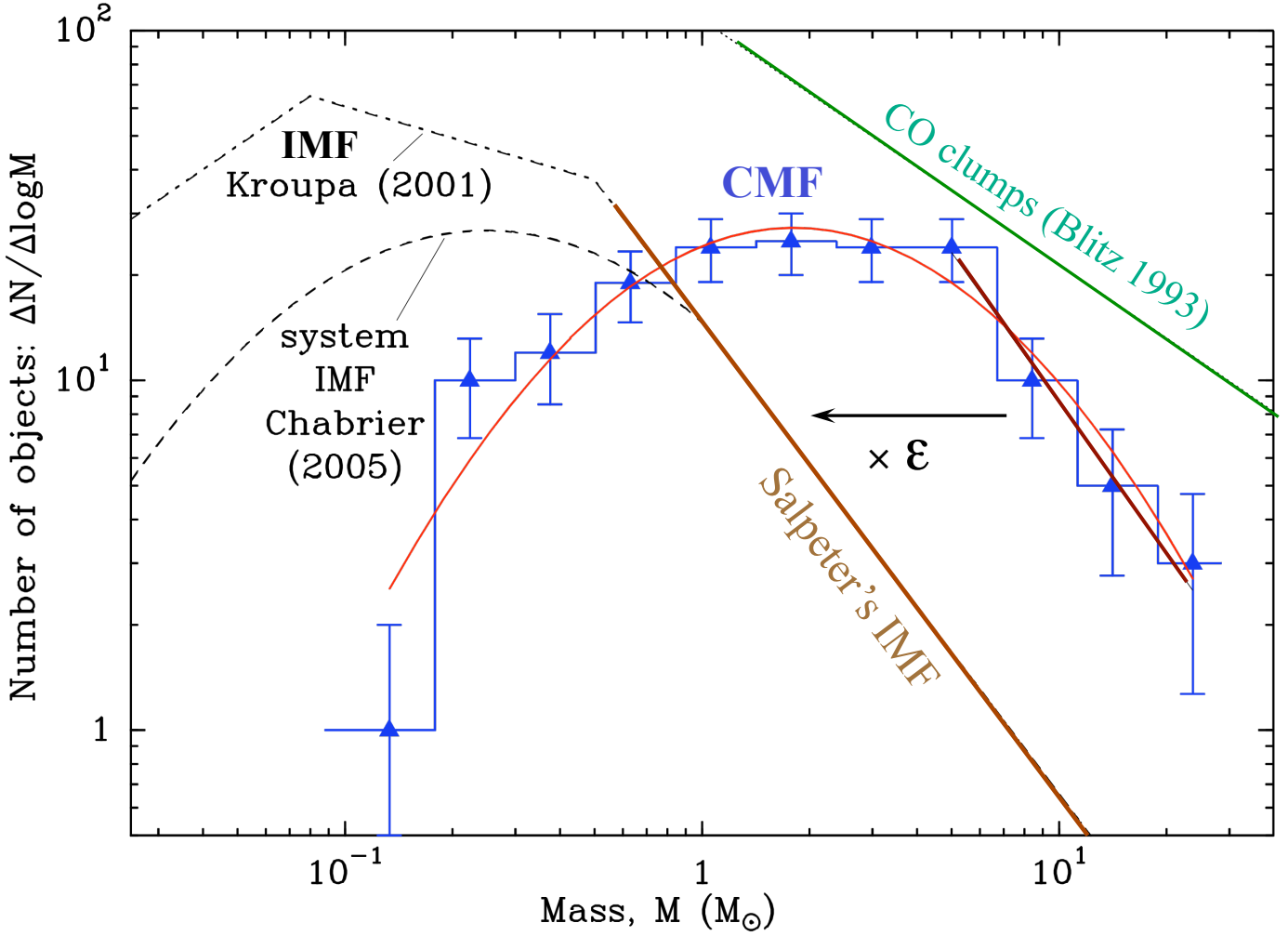

Intensity Profiles of Object 163
075 μm
170 μm
250 μm
350 μm
500 μm
10.0
1.0
I_{bgs} (Jy beam^{-1})
10.0
100.0
Radial distance (arcsec)

Probing the link between the prestellar CMF and the IMF

In Aquila main body, 162 *Herschel* cores with no *Spitzer* 24 μm nor PACS 70 μm emission --> starless

Red curve: Lognormal fit to *Herschel* CMF

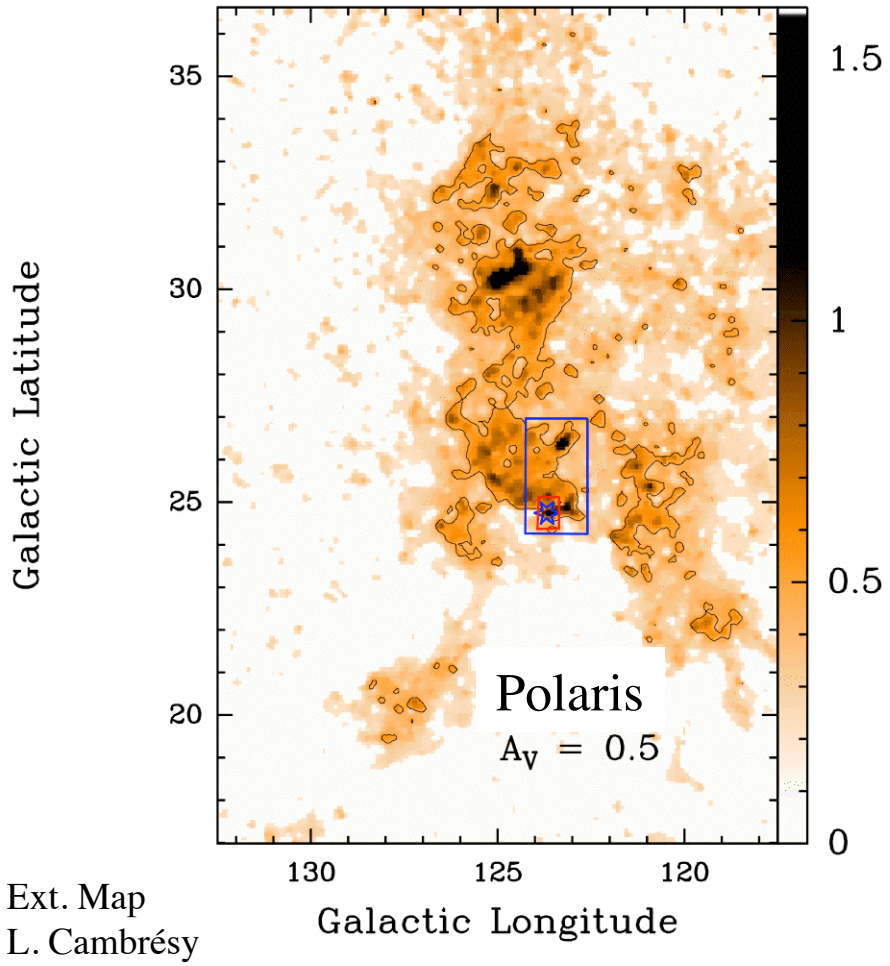
Preliminary Prestellar Core Mass Function (CMF) in Aquila Main



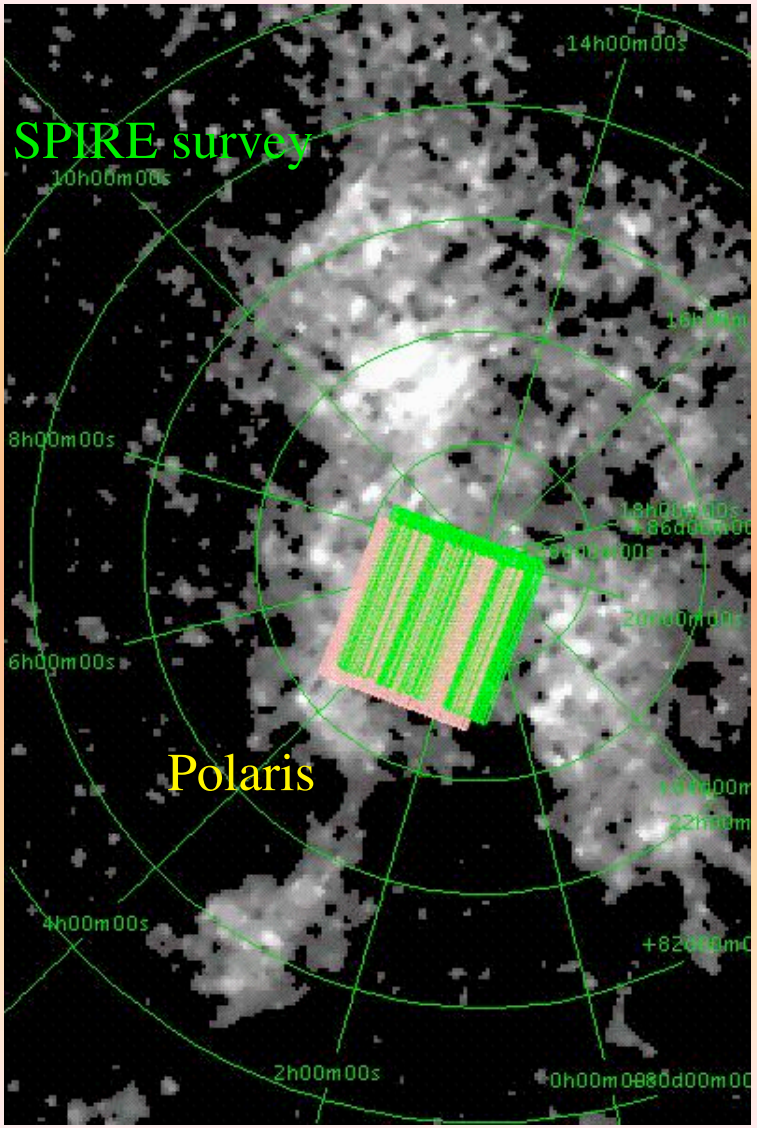
→ Confirms good (~ one-to-one) correspondence between core mass and system mass $M_* = \varepsilon M_{core}$ with $\varepsilon \sim 0.2$ in Aquila (?)

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

(See http://starformation-herschel.iap.fr/gouldbelt/ for all fields)



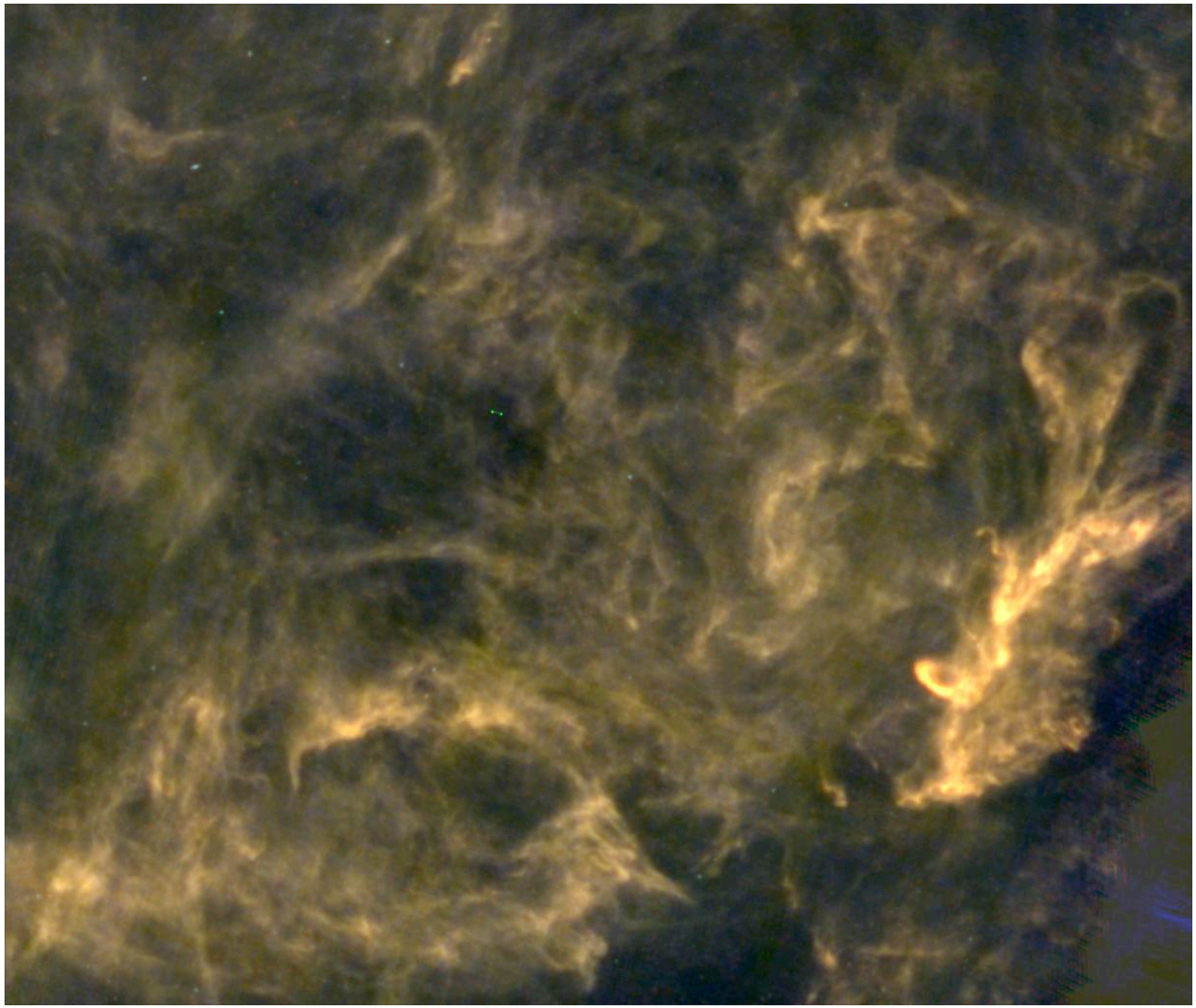
Ext. Map
L. Cambrésy



~ 6 deg^2 @ 60”/sec with SPIRE/PACS //
~ 1 deg^2 @ 20”/sec with PACS only

Parallel-mode imaging of the Polaris cloud

23 Oct 2009

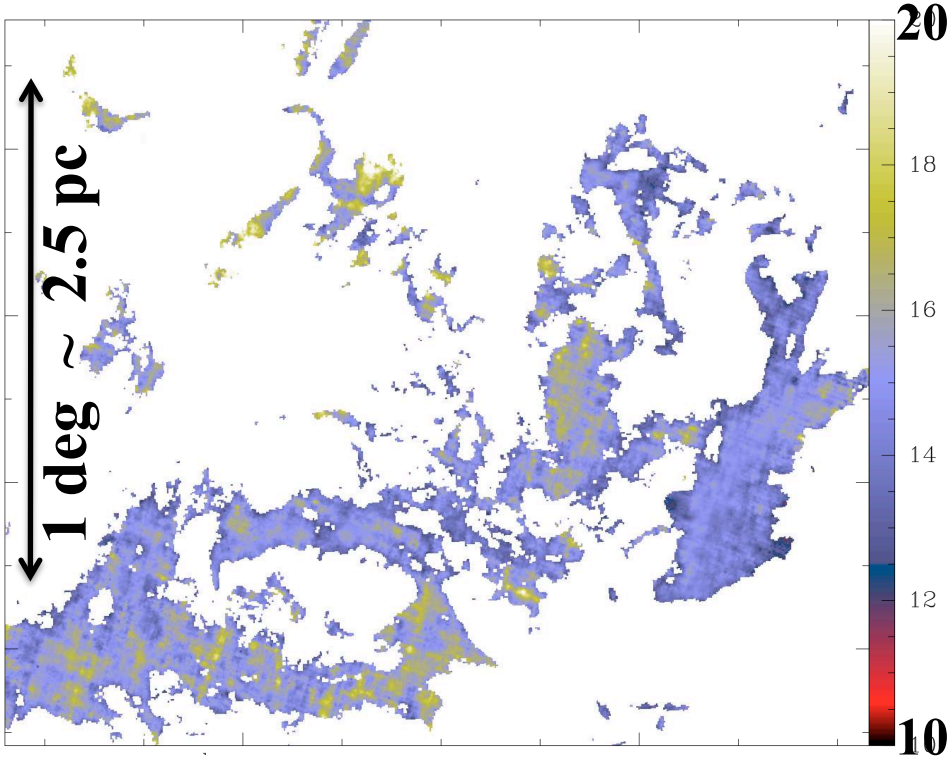


Red : SPIRE 500 μm
Green : SPIRE 250 μm
Blue : PACS 160 μm

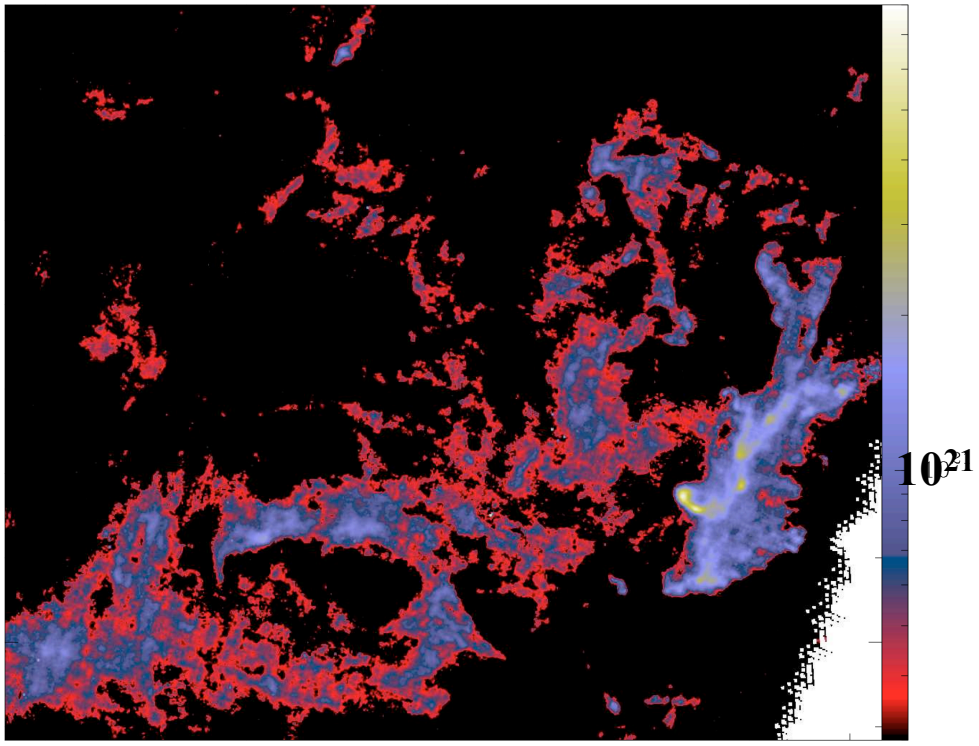
~ 6 deg^2 field of common interest to SPIRE SAGs 3 & 4
(cf. A. Abergel's talk)

Revealing the structure of the cold ISM prior to any star formation (Polaris: d ~ 150 pc)

Herschel (SPIRE+PACS)
Dust temperature map (K)

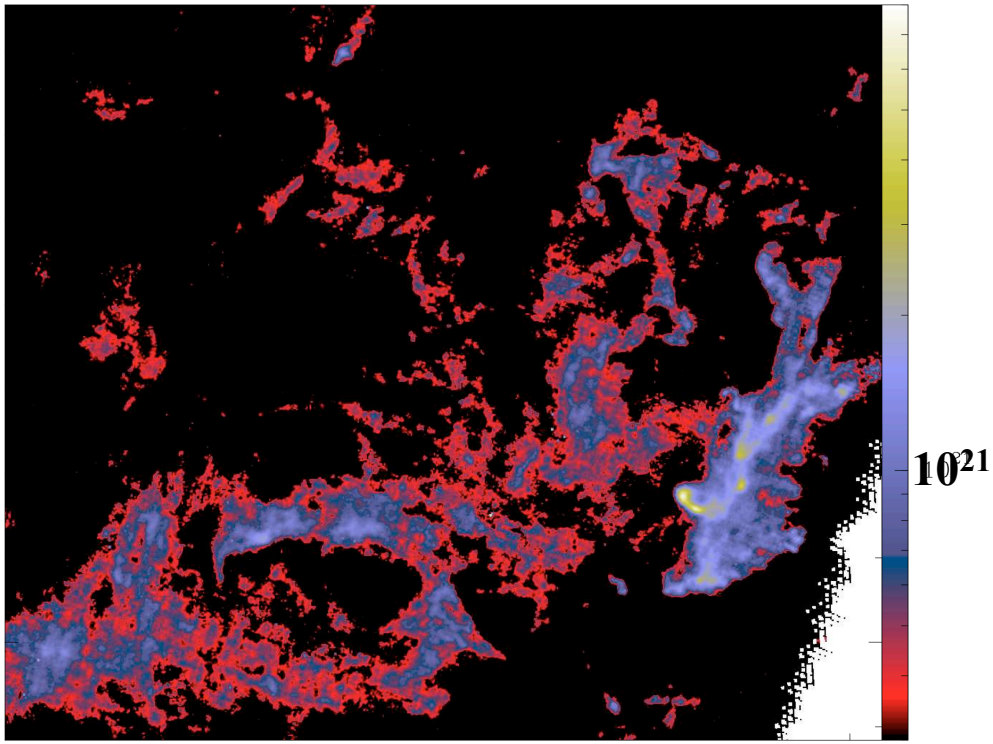


Herschel (SPIRE+PACS)
Column density map (H_2/cm^{-2})

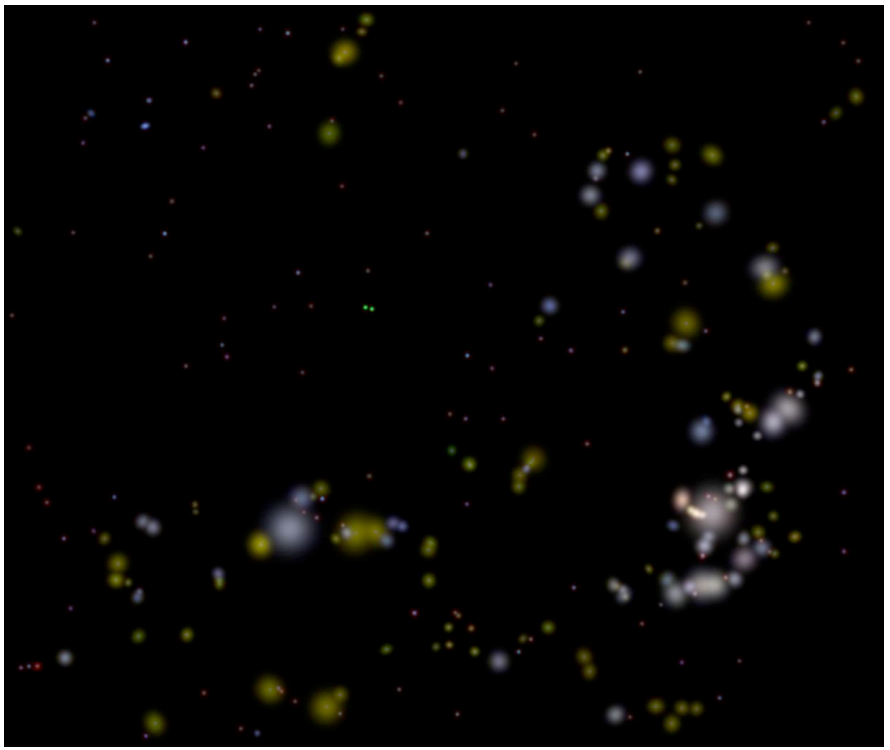


Polaris: `Compact' Source Extraction
(using "getsources" – A. Menshchikov)

Herschel (SPIRE+PACS)
Column density map (H_2/cm^{-2})

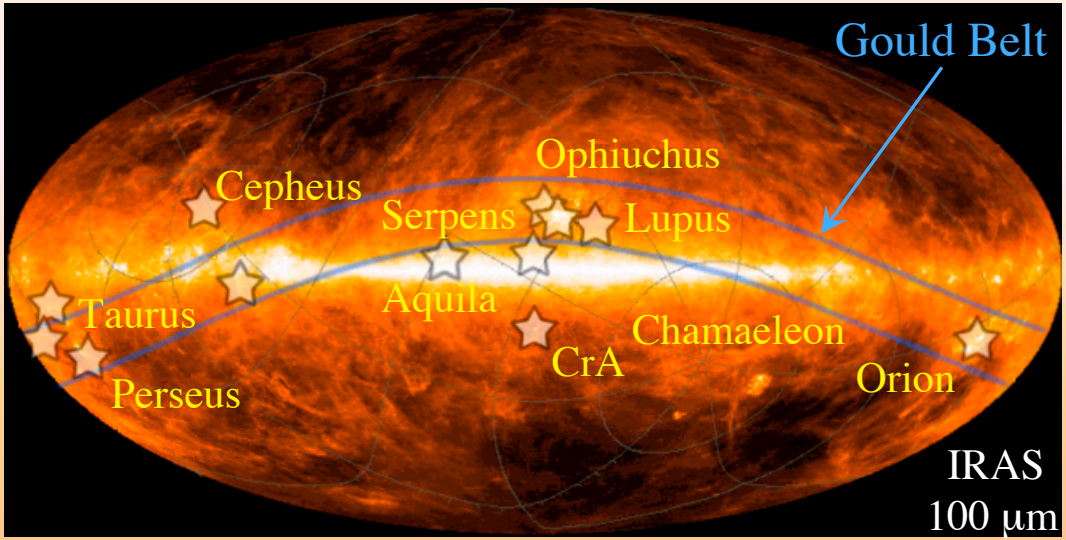


Spatial distribution of
~ 700 extracted sources
(all starless)



170/250/500 μm composite image

Conclusions



The SDP results are extremely promising; exceed expectations !

The *Herschel* Gould Belt survey at λ ~ 75-500 μm will soon provide complete samples of prestellar cores and young protostars down to the substellar regime.

➜ Major step forward in our understanding of the early stages of SF

➜ Unique database for follow-up studies with ALMA & IRAM

THANKS TO ESA HSC + SPIRE & PACS ICCs