

Initial Highlights from the Gould Belt Survey

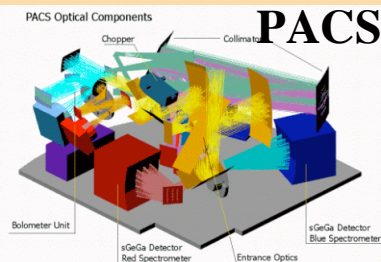
Philippe André, CEA/SAp Saclay

A.Men'shchikov, S.Bontemps, V. Könyves, F. Motte, N. Schneider, P. Didelon, V. Minier, P. Saraceno, D.Ward-Thompson, J. Di Francesco, G. White, S. Molinari, L. Testi, A. Abergel, M. Griffin, T. Henning, P. Royer, B. Merin, R. Vavrek, M. Attard, D. Arzoumanian, C.D. Wilson, P. Martin, and the Gould Belt KP Consortium

Main groups : SPIRE SAG 3

(eg. J.Kirk, M. Huang, G. Olofsson)

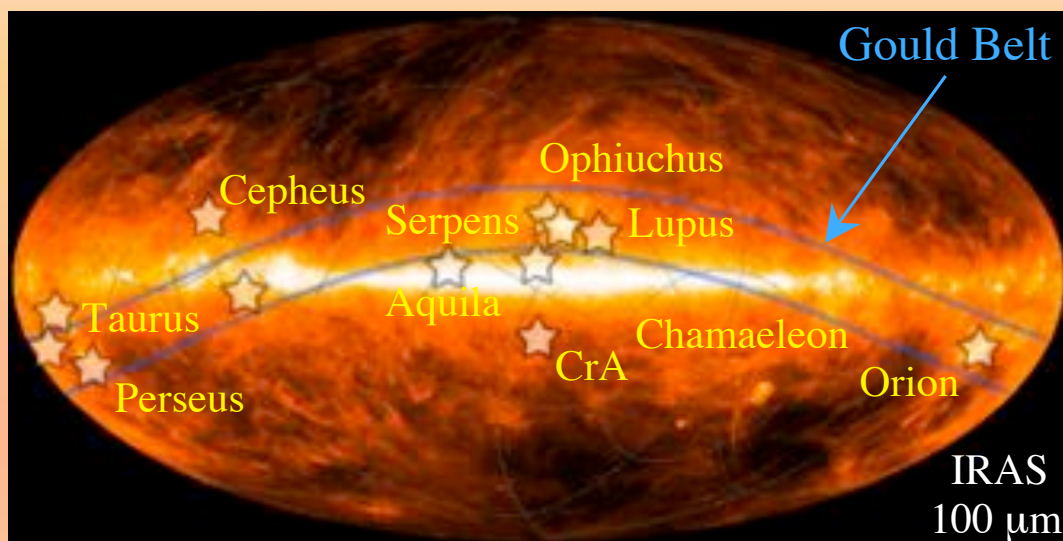
PACS Institutes { **CEA Saclay, IFSI Rome & INAF Arcetri**
OAMP Marseille (A. Zavagno)
KU Leuven (J. Blommaert & C. Waelkens)
MPIA Heidelberg (O. Krause, R. Launhardt)
+ ESA HSC



The *Herschel* Gould Belt Survey

[http://gouldbelt-herschel.cea.fr/](http://gouldbelt-herschel cea.fr/)

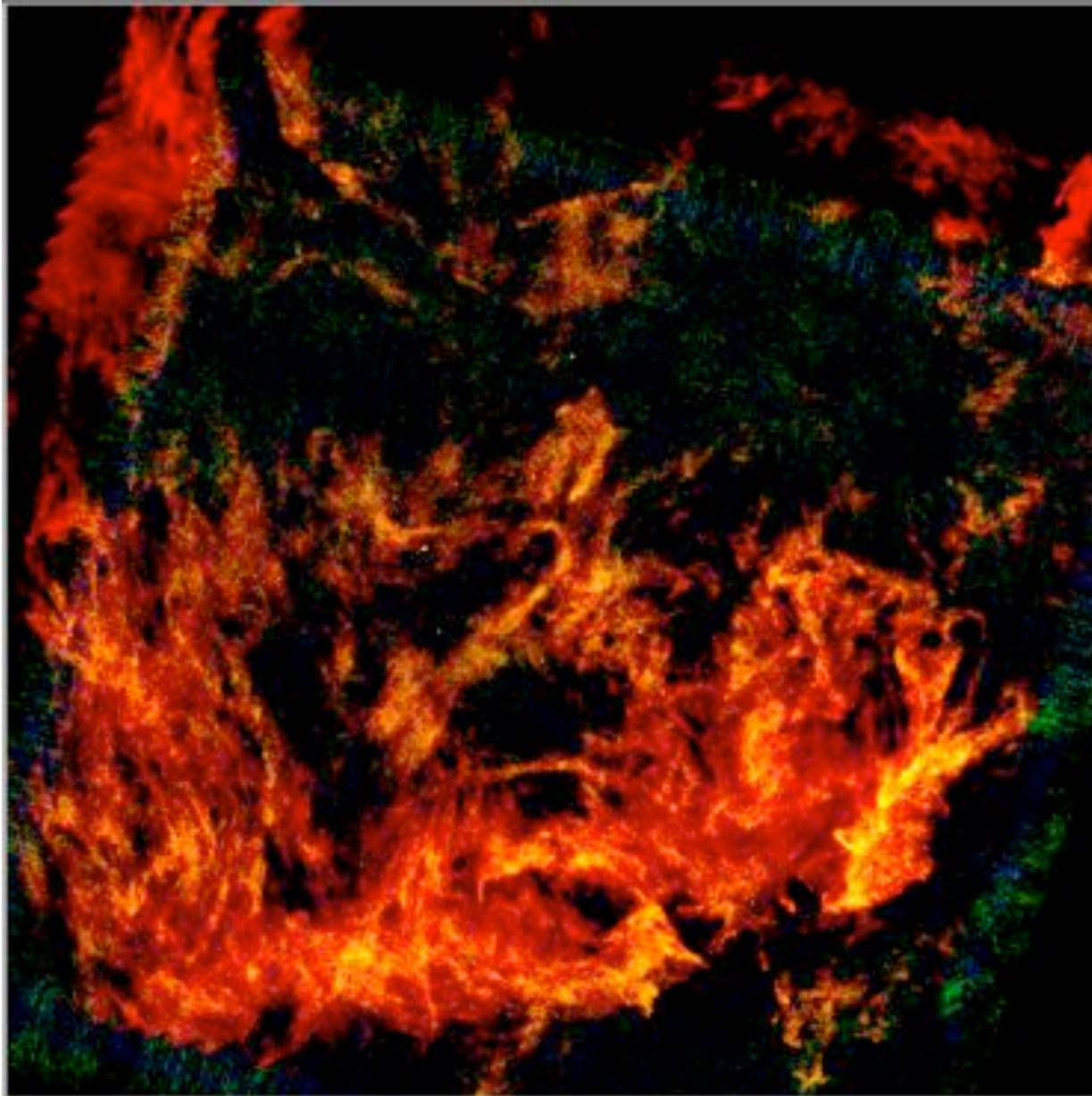
SPIRE/PACS 70-500 μm imaging of the bulk of nearby ($d < 0.5$ kpc) molecular clouds (~ 160 deg²), mostly located in Gould's Belt.



Motivation: Key issues on the early stages 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 ?

“First images” from the Gould Belt Survey



1) **Polaris
translucent cloud**
(d ~ 150 pc)

23 Oct 2009

Red : SPIRE 500 μm

Green : SPIRE 250 μm

Blue : PACS 160 μm

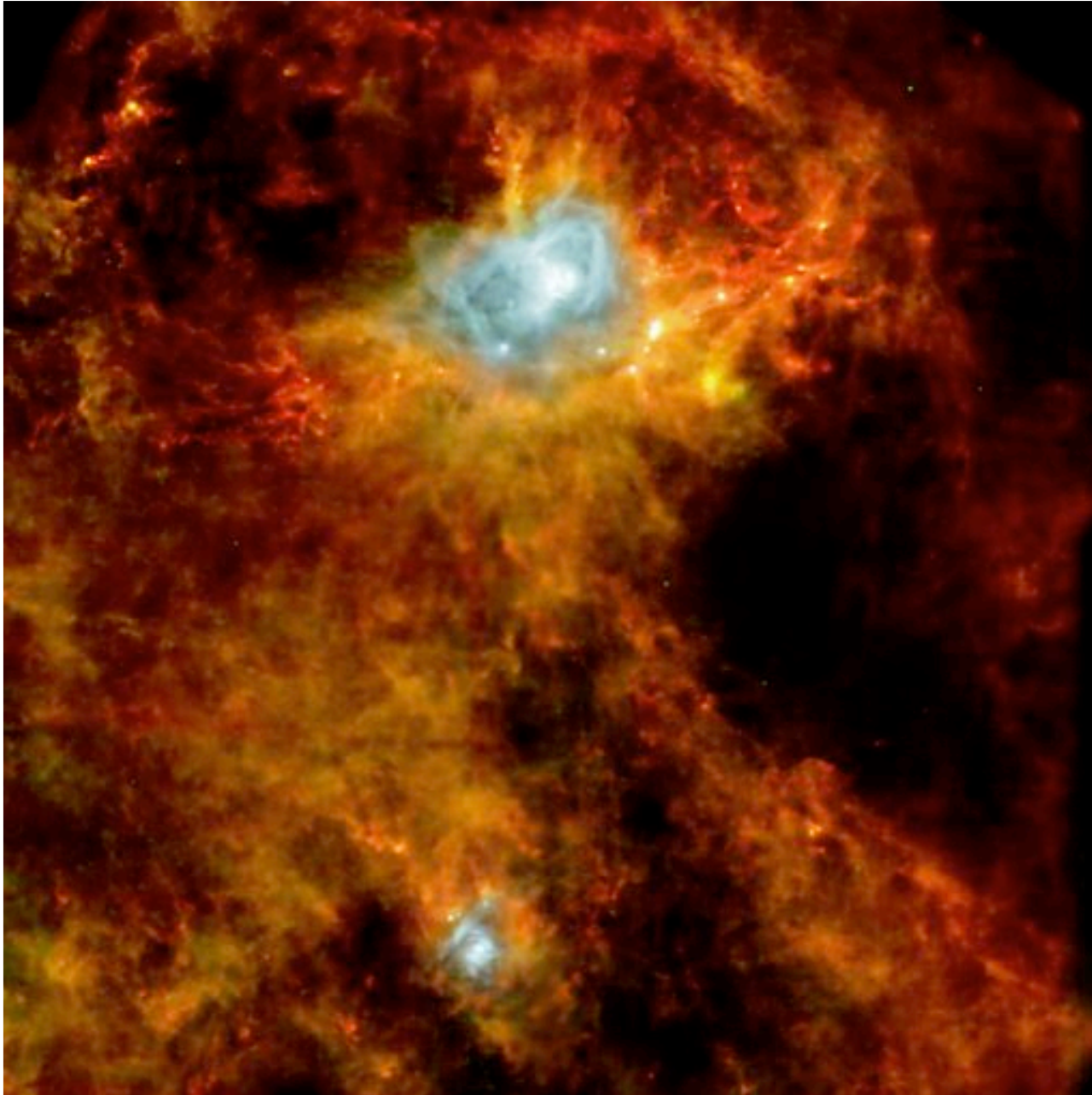
~ 7 deg² field

Ward-Thompson et al. 2010

Miville-Deschênes et al. 2010

A&A special issue

“First images” from the Gould Belt Survey



2) **Aquila Rift
star-forming
cloud (d ~ 260 pc)**

24 Oct 2009

cf. <http://oshi.esa.int>

Red : SPIRE 500 μm

Green : SPIRE 160 μm

Blue : PACS 70 μm

**~ 3.3 deg x 3.3 deg
field**

Könyves et al. 2010

Bontemps et al. 2010

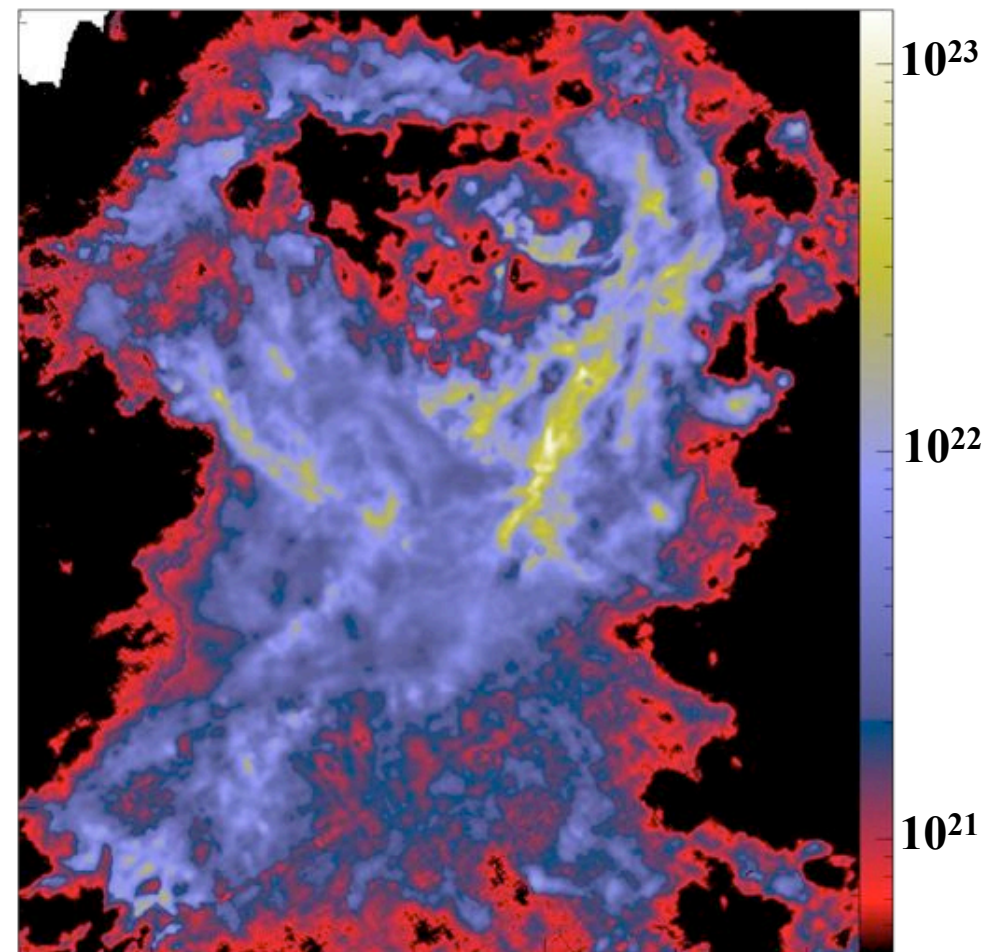
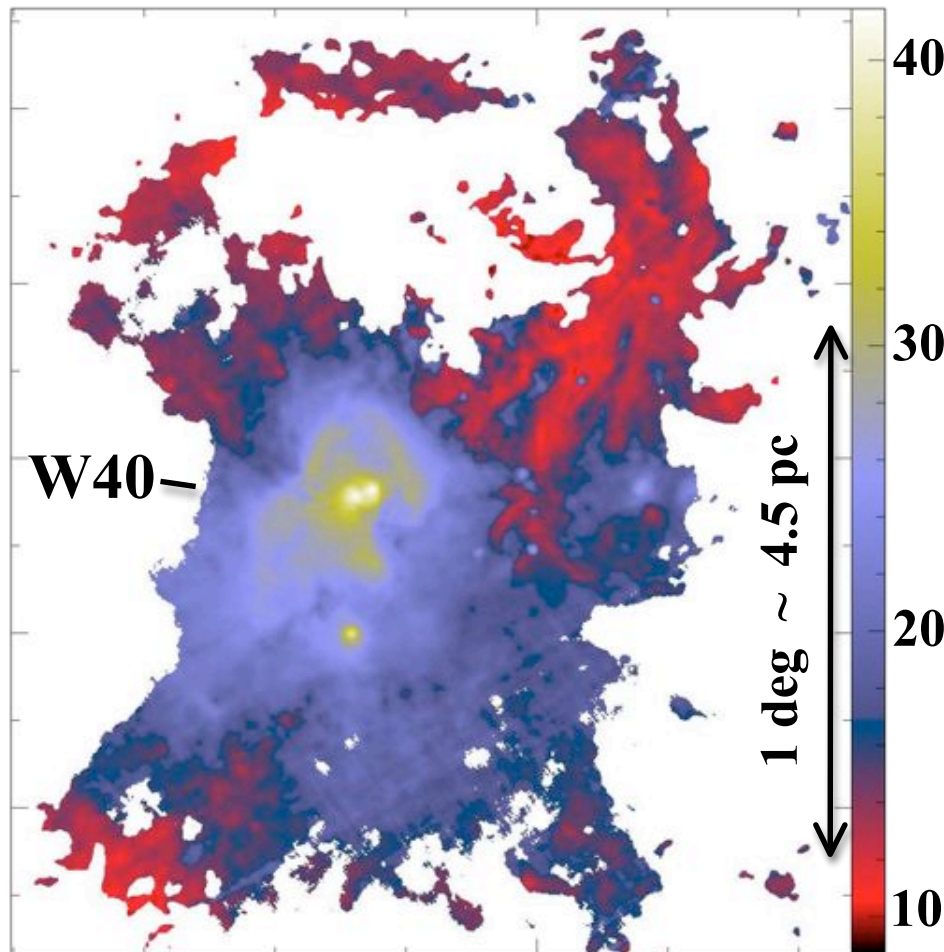
André et al. 2010

A&A special issue

Revealing the structure of one of the nearest infrared dark clouds (Aquila Main: $d \sim 260$ pc)

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

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

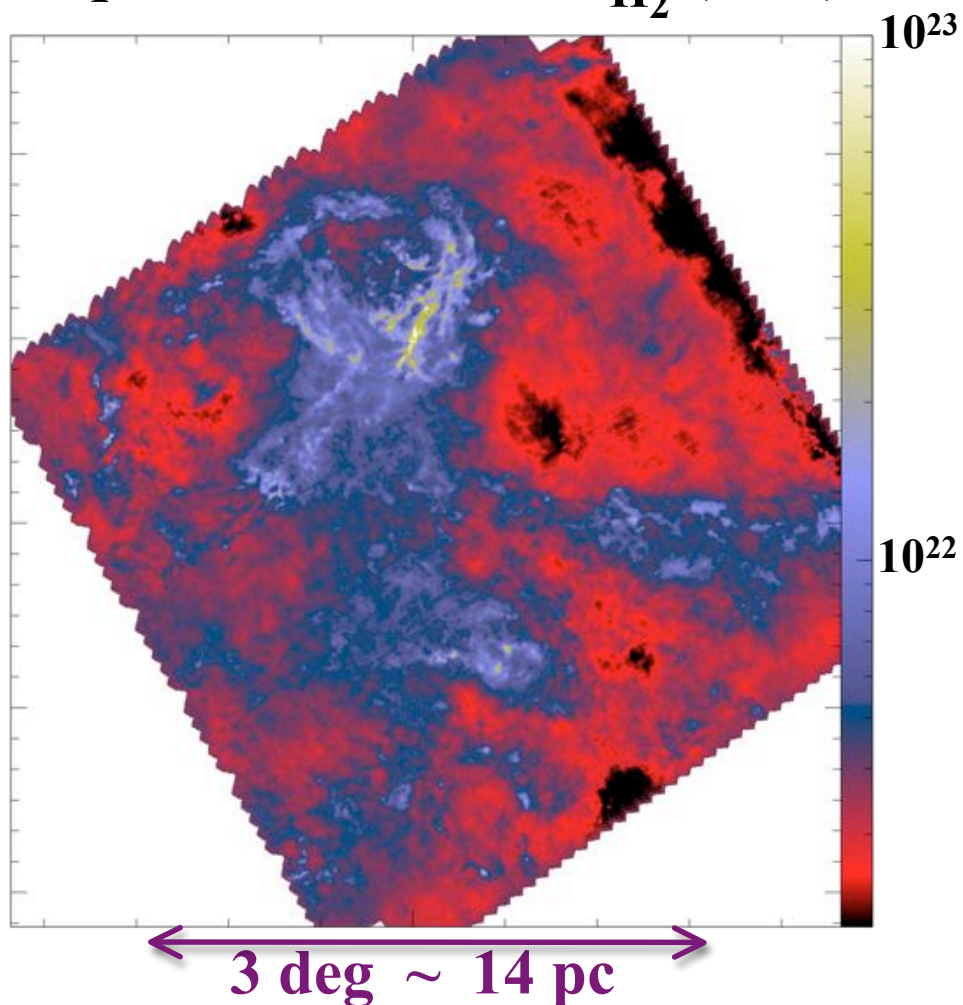


Aquila: 'Compact' Source Extraction

(using "getsources" – A. Mennshchikov et al. 2010)

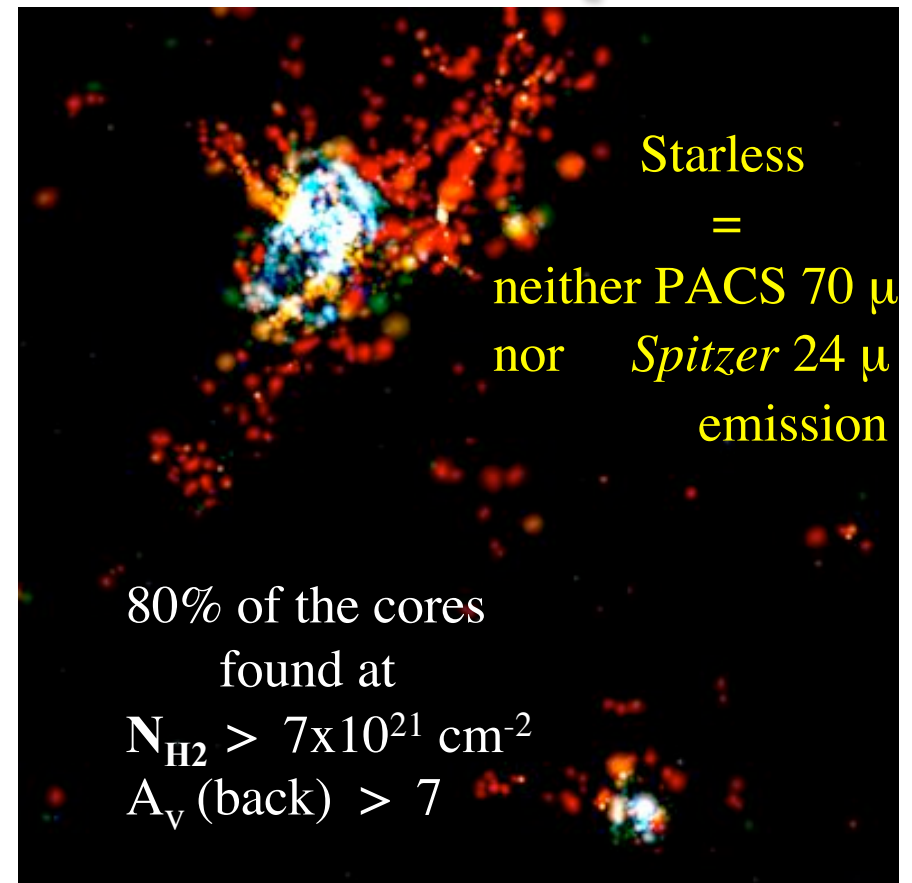
Herschel (SPIRE+PACS)

Aquila entire field: N_{H_2} (cm^{-2})



Spatial distribution of extracted cores

541 starless
201 YSOs



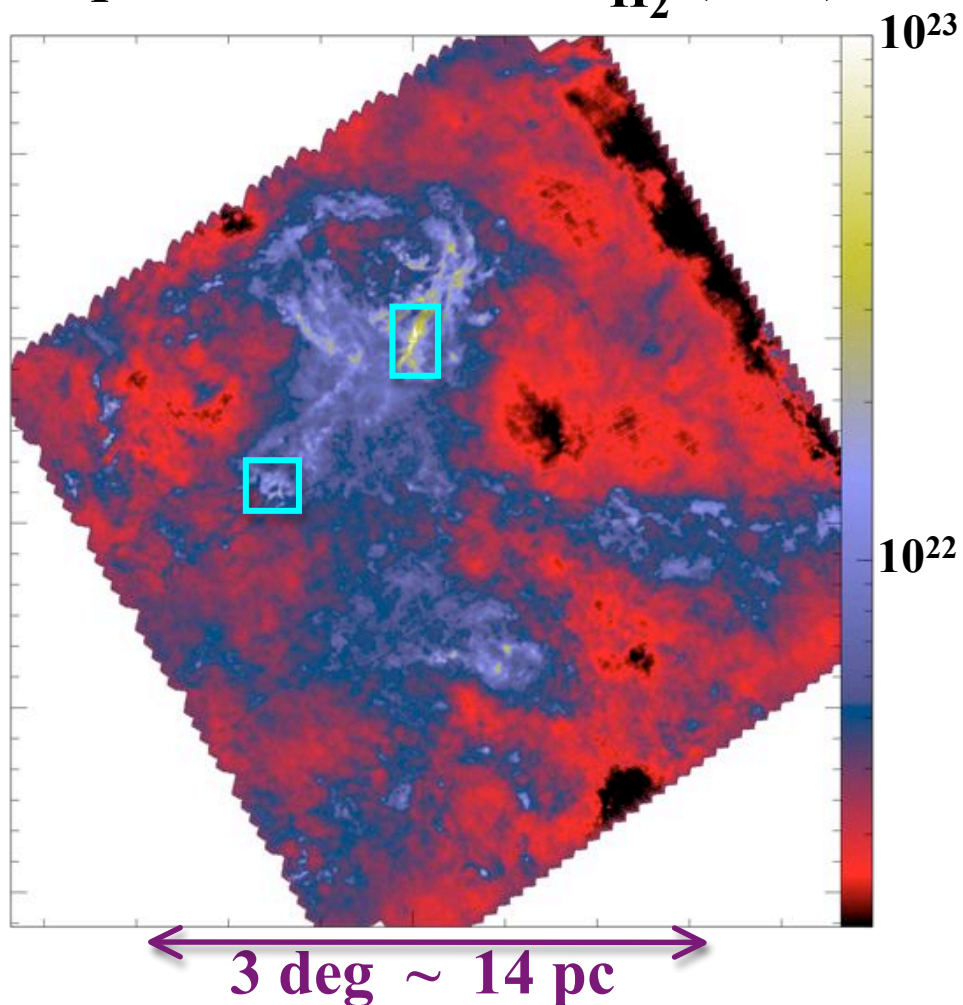
70/160/500 μm composite image

Aquila: 'Compact' Source Extraction

(using "getsources" – A. Mennshchikov et al. 2010)

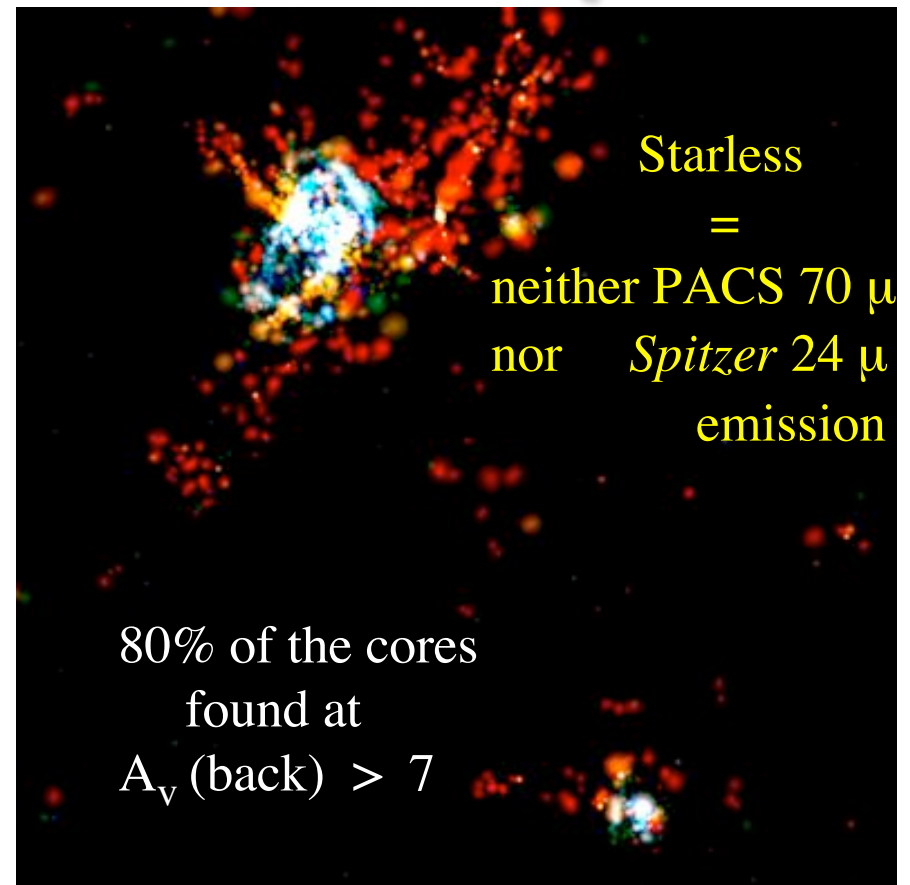
Herschel (SPIRE+PACS)

Aquila entire field: N_{H_2} (cm^{-2})



Spatial distribution of extracted cores

- 541 starless
- 201 YSOs

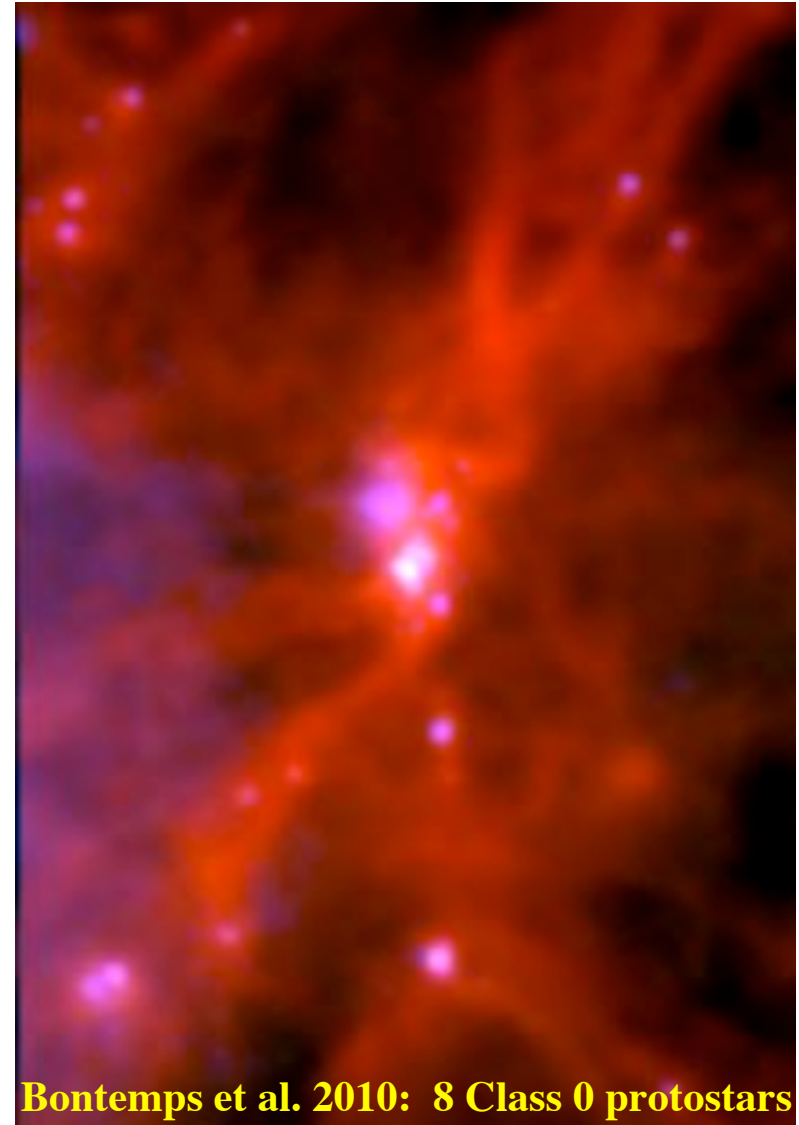
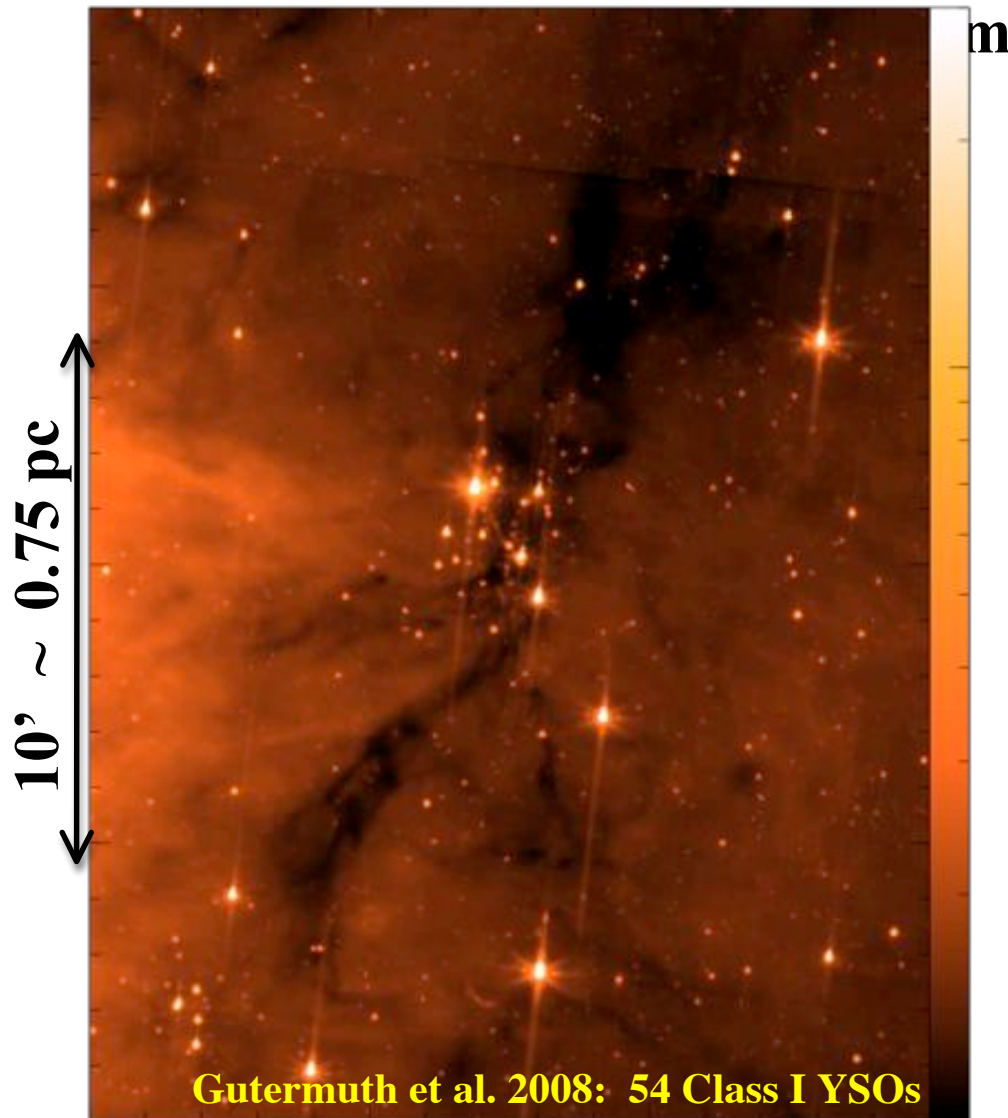


70/160/500 μm composite image

Aquila/Serpens-South dark filament: A rich protocluster in the making

Spitzer/IRAC 8 μm

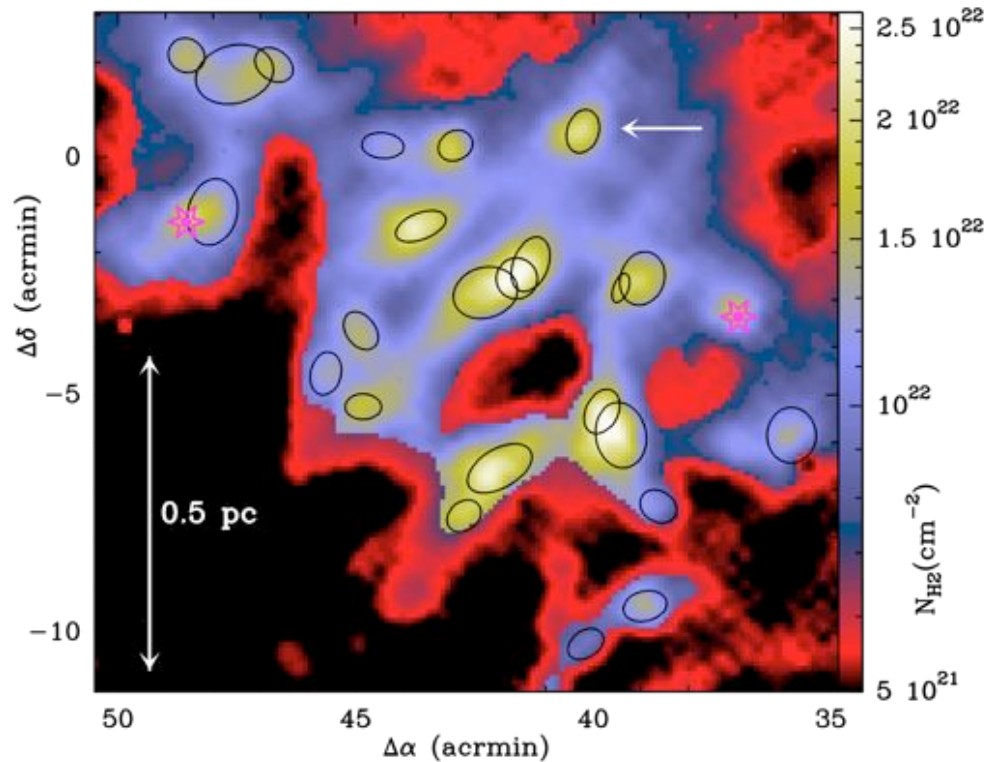
SPIRE 250 μm + PACS 160/70 μm



A group of starless cores in Aquila-East

Herschel (SPIRE+PACS)

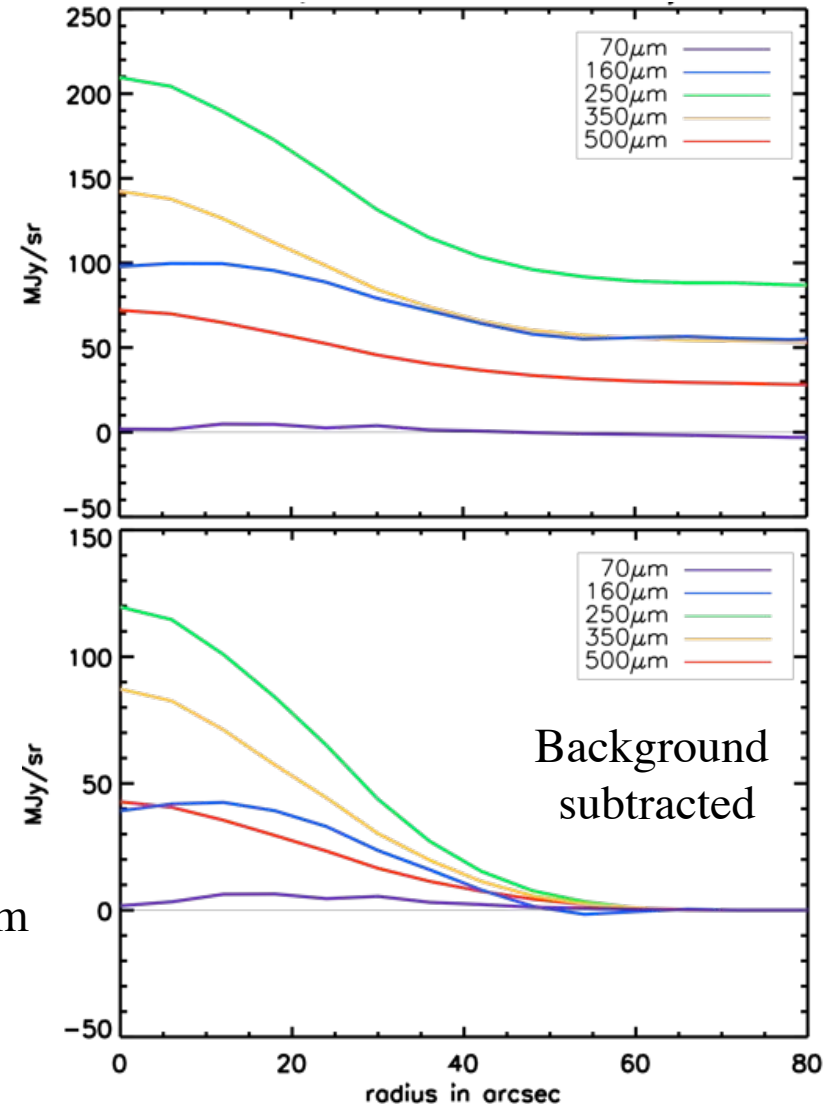
N_{H_2} map (cm^{-2})



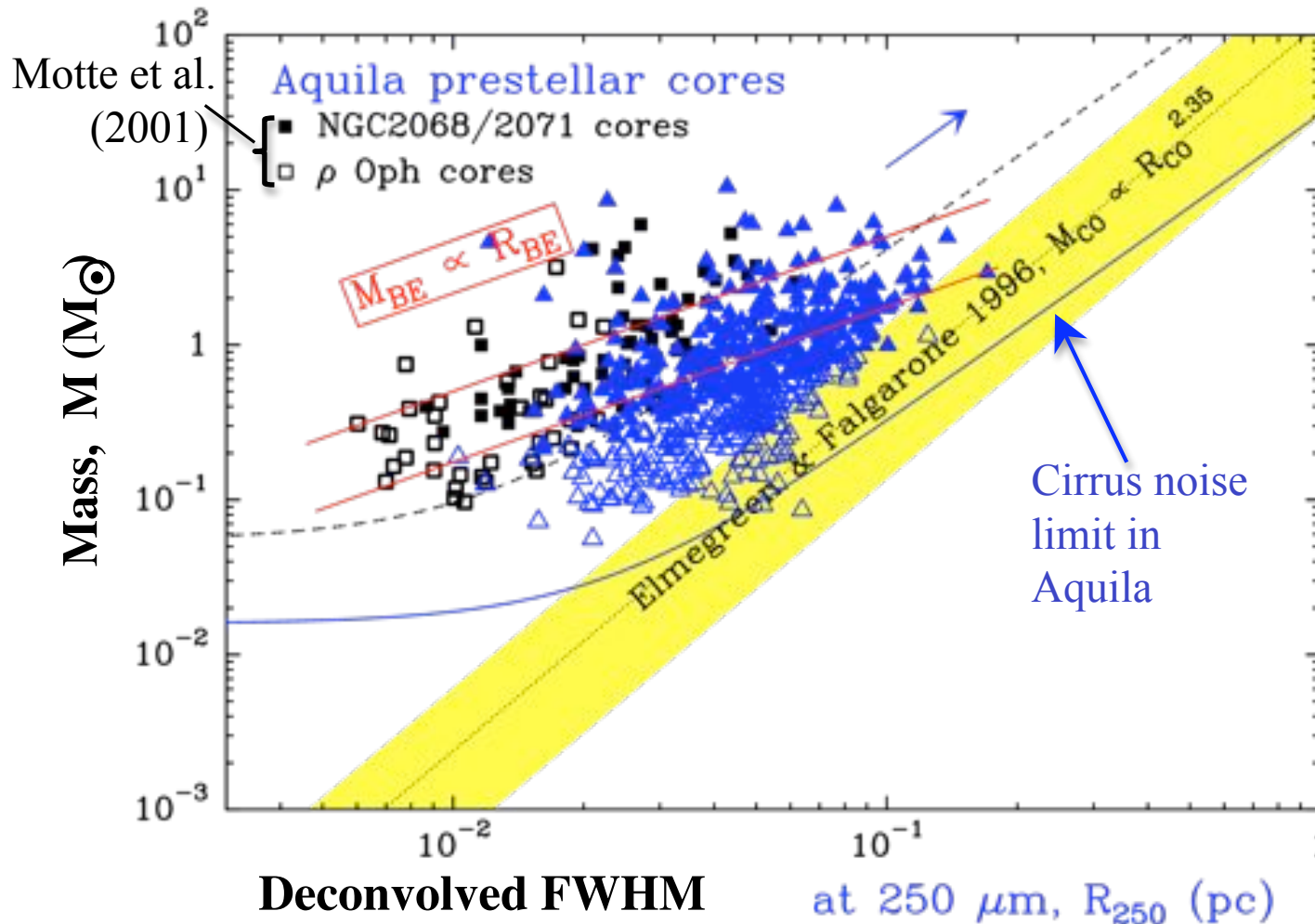
{ Ellipses: FWHM sizes of 24 starless cores at 250 μm
 Stars (\star): Two candidate Class 0 protostars

Könyves et al. 2010, A&A special issue

Radial intensity profiles



Most of the Aquila starless cores are bound



➤ Likely prestellar in nature

Könyves et al. 2010

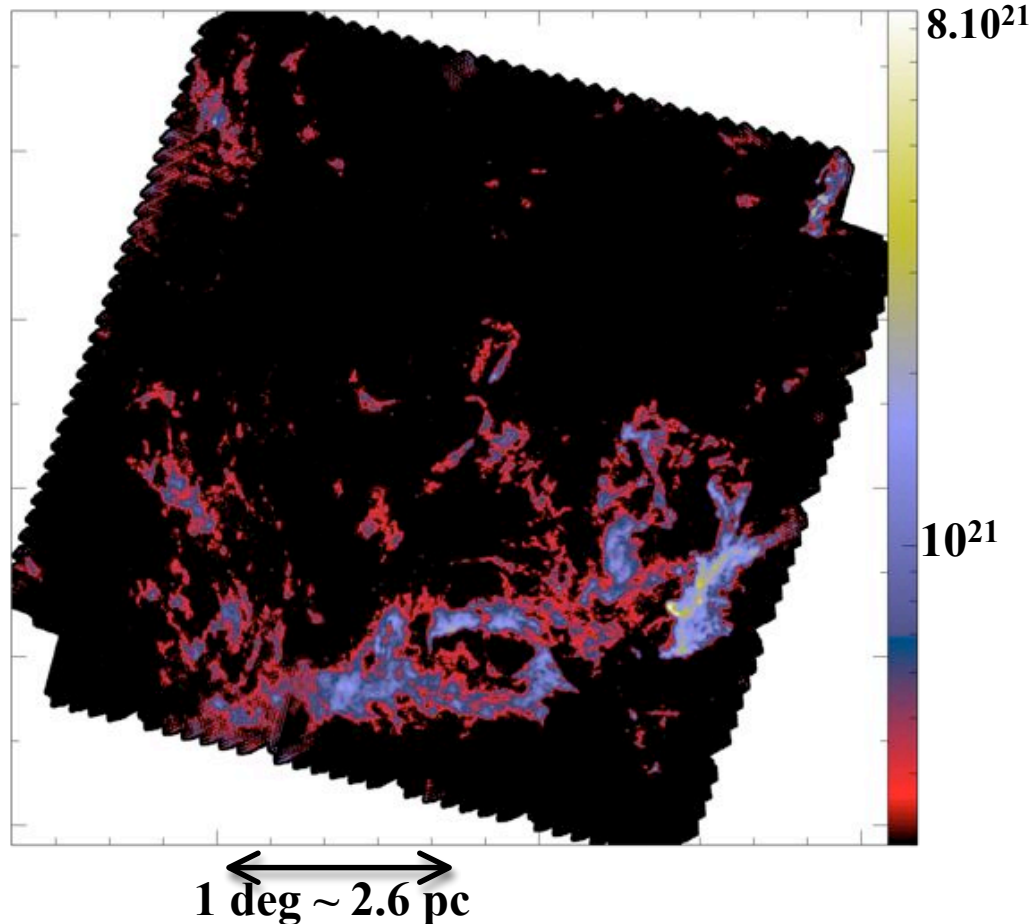
Talk by V. Könyves on Thursday

- Location in mass vs. size diagram, consistent with BE spheroids
- High degree of concentration: $N_{\text{H}_2}^{\text{peak}} / \langle N_{\text{H}_2} \rangle \sim 4$ on average
- Median column density contrast over the background ~ 1.5

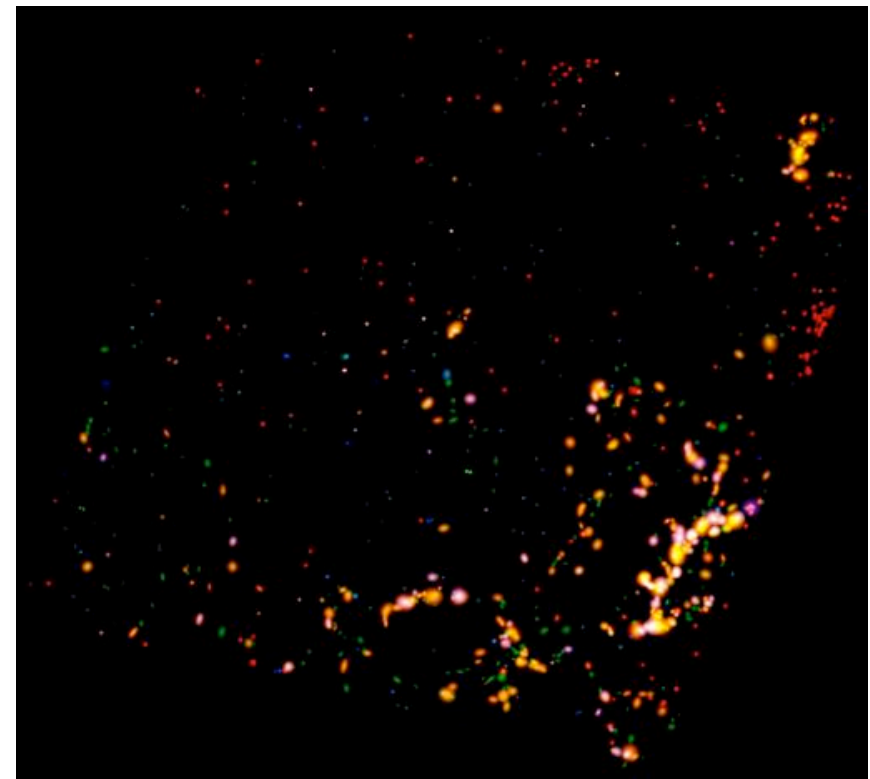
Polaris: `Compact' Source Extraction

(using “getsources” – A. Mennschikov et al. 2010)

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

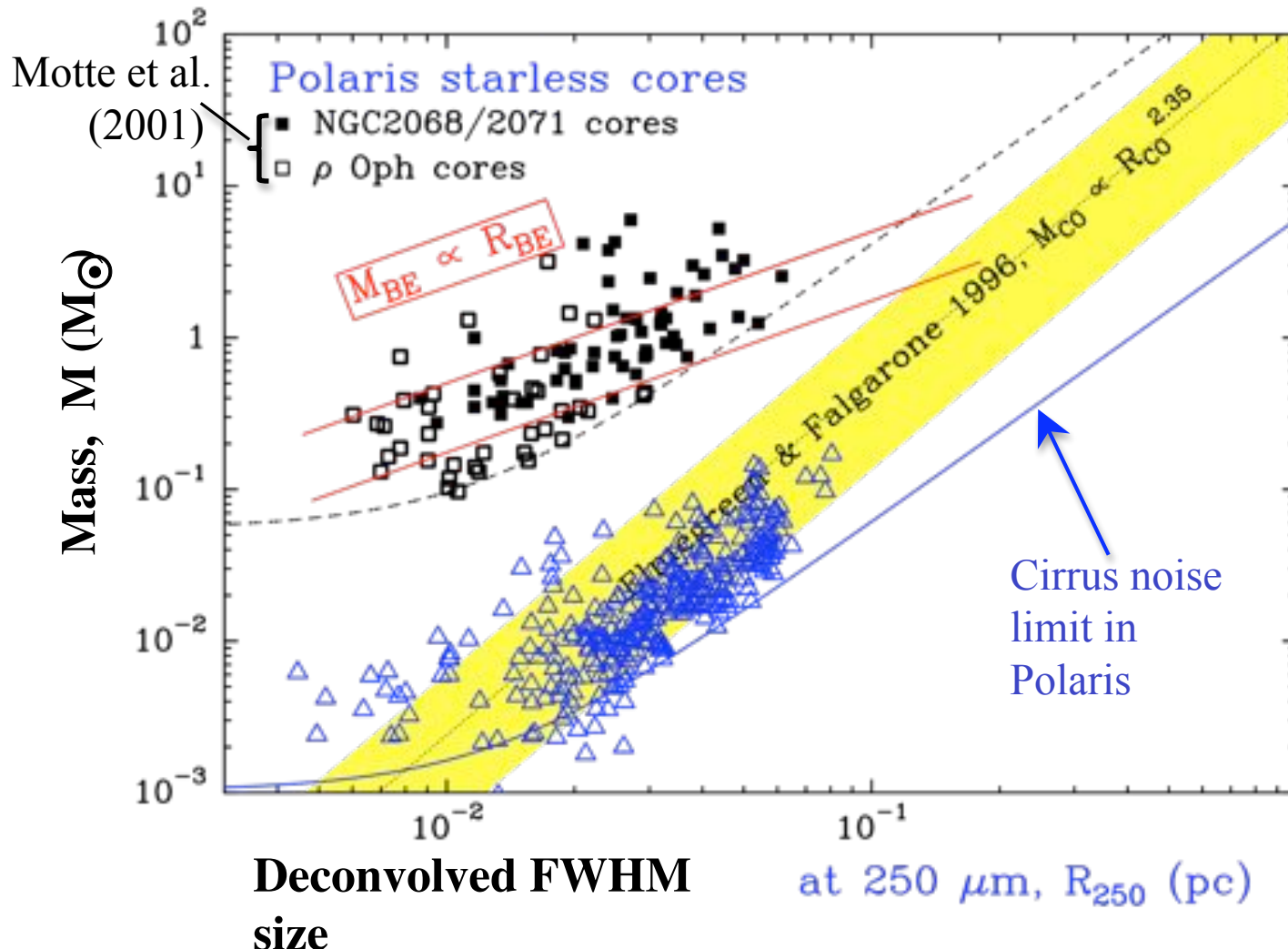


Spatial distribution of
~ 300 extracted cores
(all starless) + galaxies (!)



160/250/500 μm composite image

Most of the Polaris starless cores are unbound



➤ not (yet ?) prestellar

André et al. 2010
Ward-Thompson et al. 2010

Talk by D. Ward-Thompson on Wednesday

➤ Location in mass vs. size diagram: 2 orders of magnitude below the density of self-gravitating Bonnor-Ebert isothermal spheres

Confirming the link between the prestellar CMF & the IMF

Könyves et al. 2010

André et al. 2010

A&A special issue

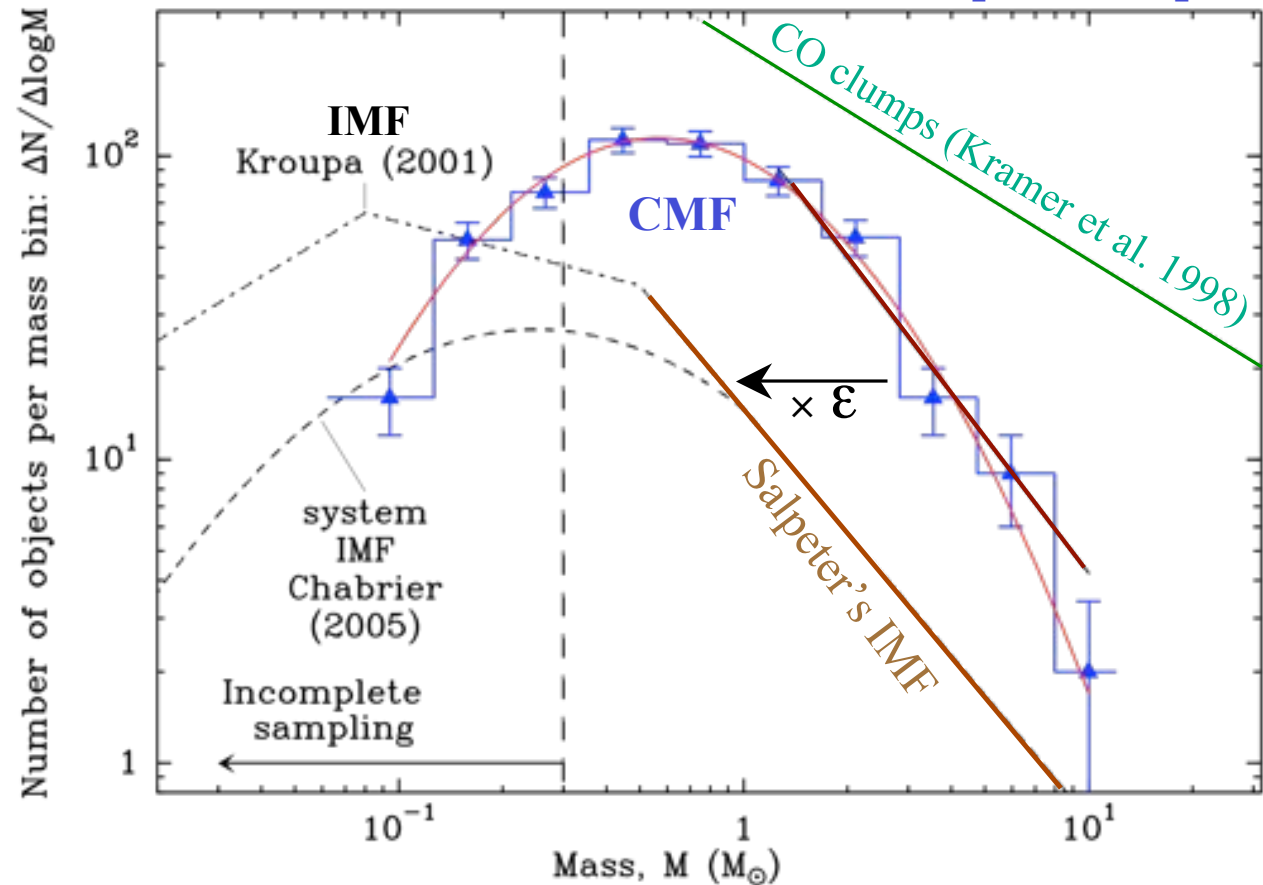
341-541 prestellar
cores in Aquila

Factor $\sim 2-9$ better
statistics than earlier
studies:

e.g. Motte, André, Neri
1998; Johnstone et al. 2000;
Beuther & Schilke 2004;
Stanke et al. 2006; Enoch et
al. 2006; Alves et al. 2007;
Nutter & Ward-Thompson

07

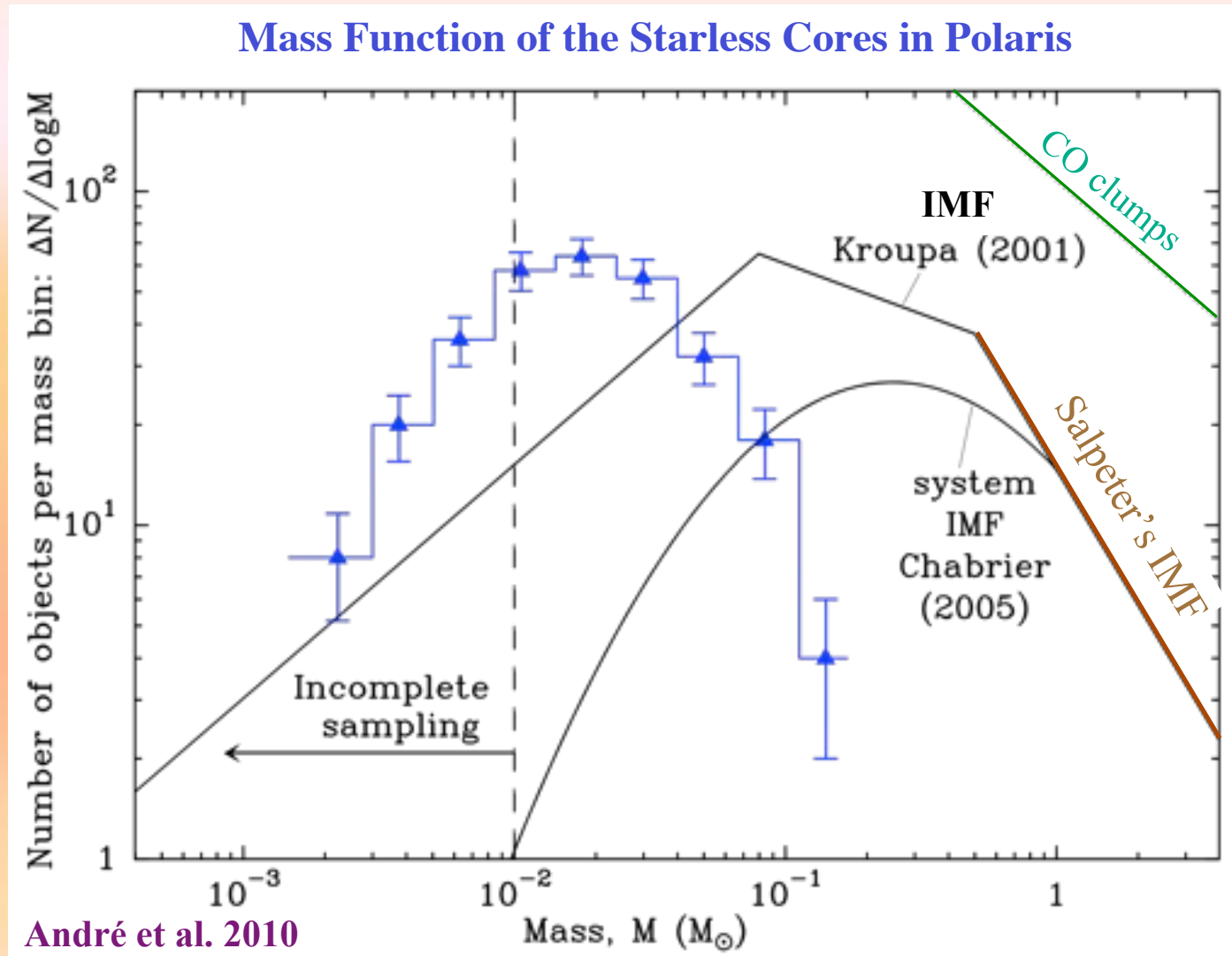
Prestellar Core Mass Function (CMF) in Aquila Complex



➤ Good (\sim one-to-one) correspondence between core mass and system mass: $M_* = \epsilon M_{\text{core}}$ with $\epsilon \sim 0.2-0.4$ in Aquila

➤ The IMF is at least partly determined by pre-collapse cloud fragmentation (cf. models by Padoan & Nordlund 2002, Hennebelle & Chabrier 2008)

The Polaris starless cores are not massive enough to form stars



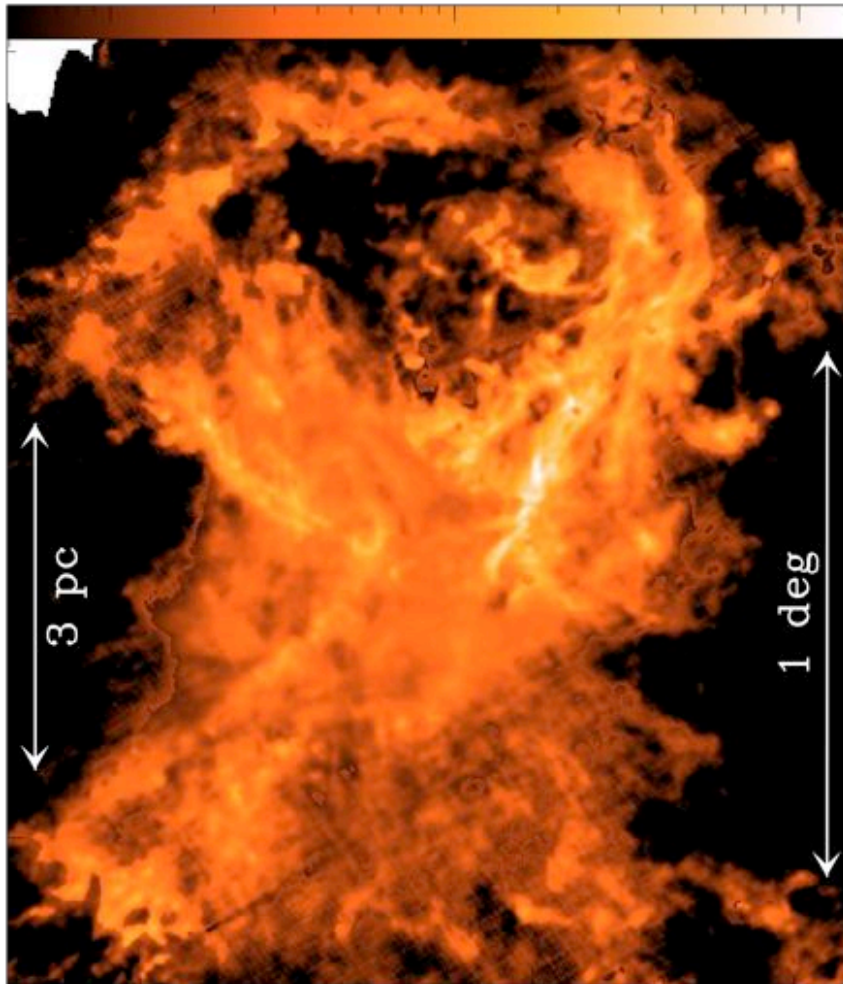
The mass function of Polaris starless cores peaks at $\sim 0.02 M_{\odot}$ i.e., \sim one order of magnitude below the peak of the stellar IMF

Prestellar cores form out of a filamentary background

Herschel (SPIRE+PACS)

Column density map (H_2/cm^2)

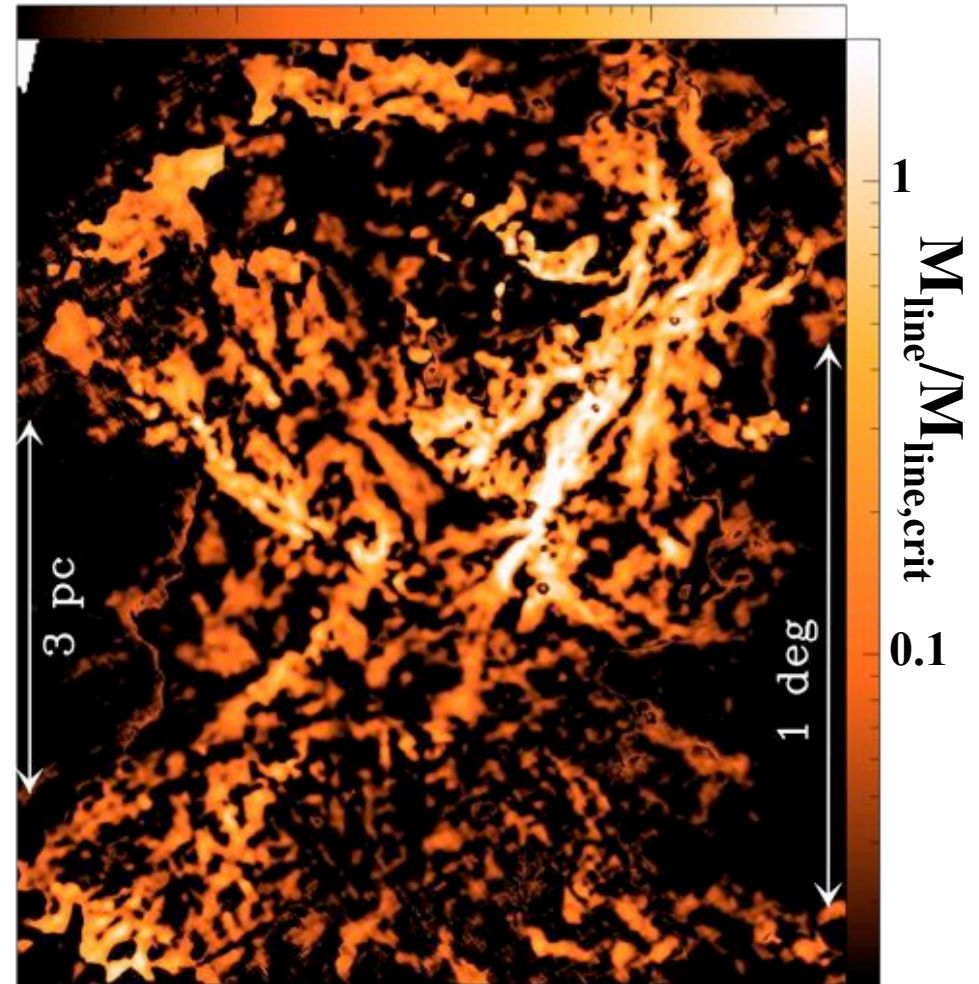
10^{21} 10^{22} 10^{23}



Curvelet component of

column density map (H_2/cm^2)

10^{21} 10^{22}

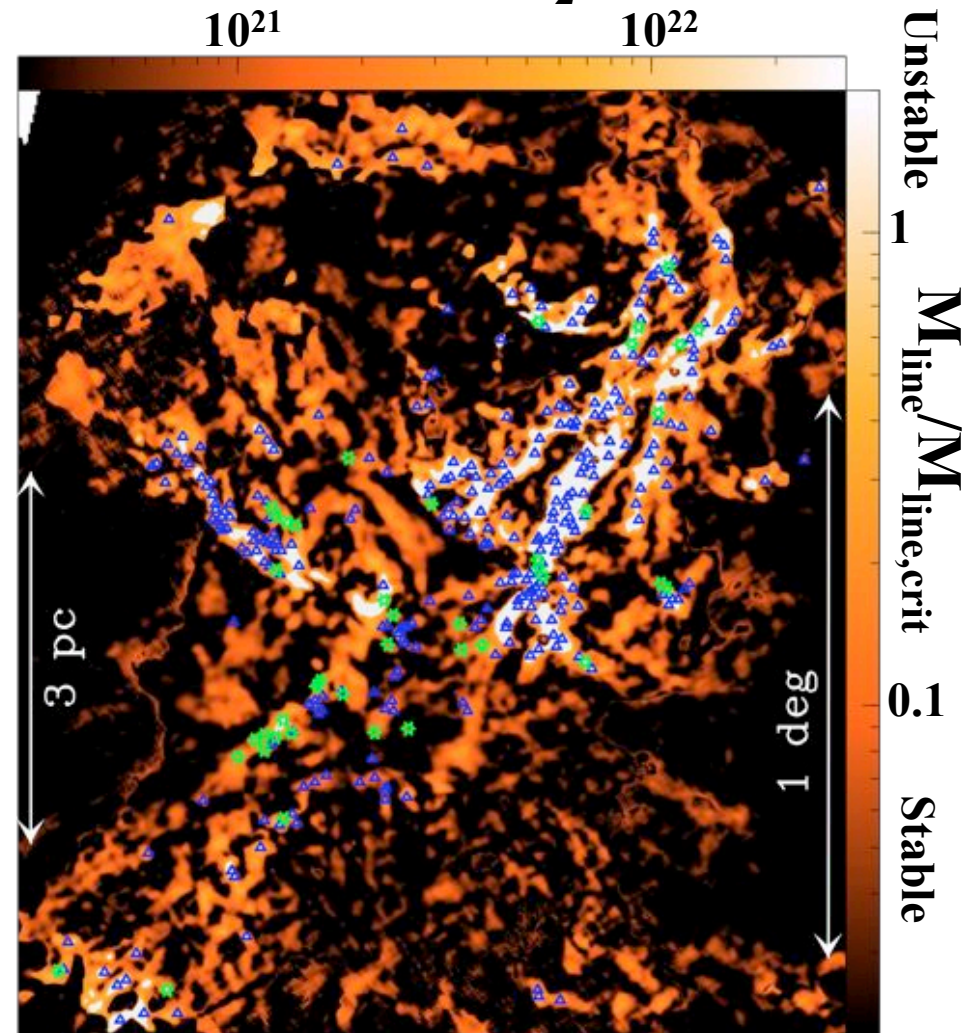
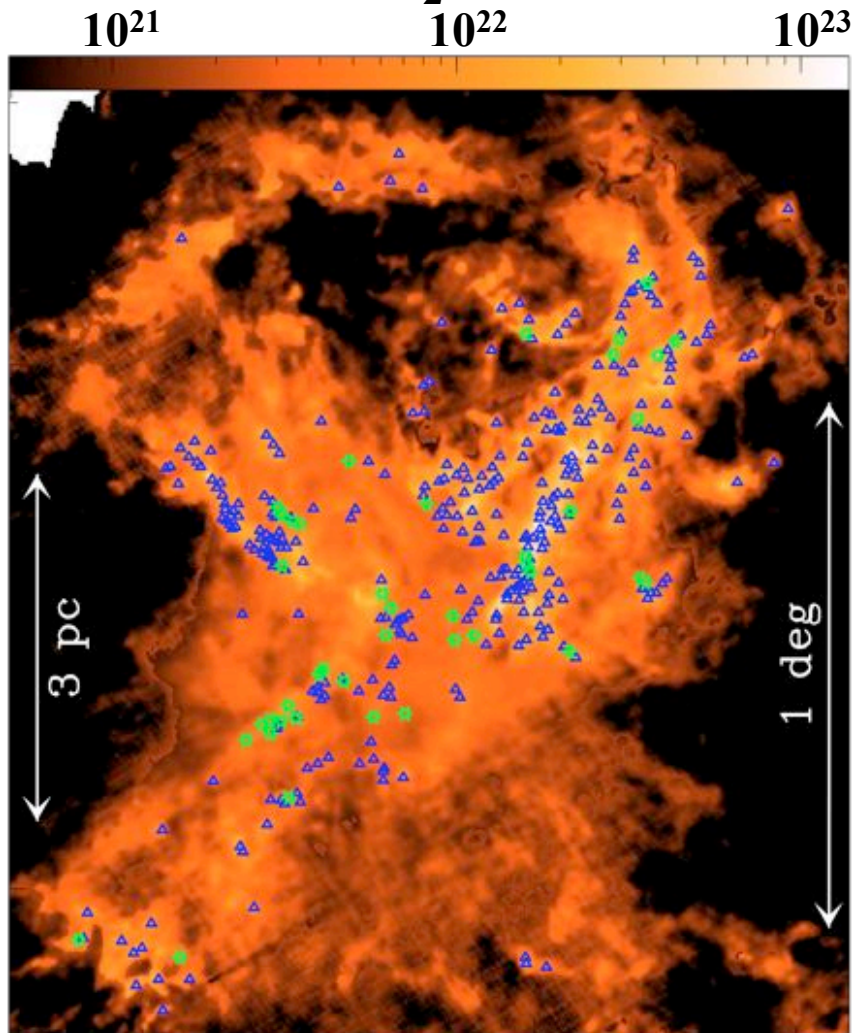


Prestellar cores form out of a filamentary background

★ : Class 0 protostars △ : Prestellar cores - 80% found at $A_V(\text{back}) > 7$

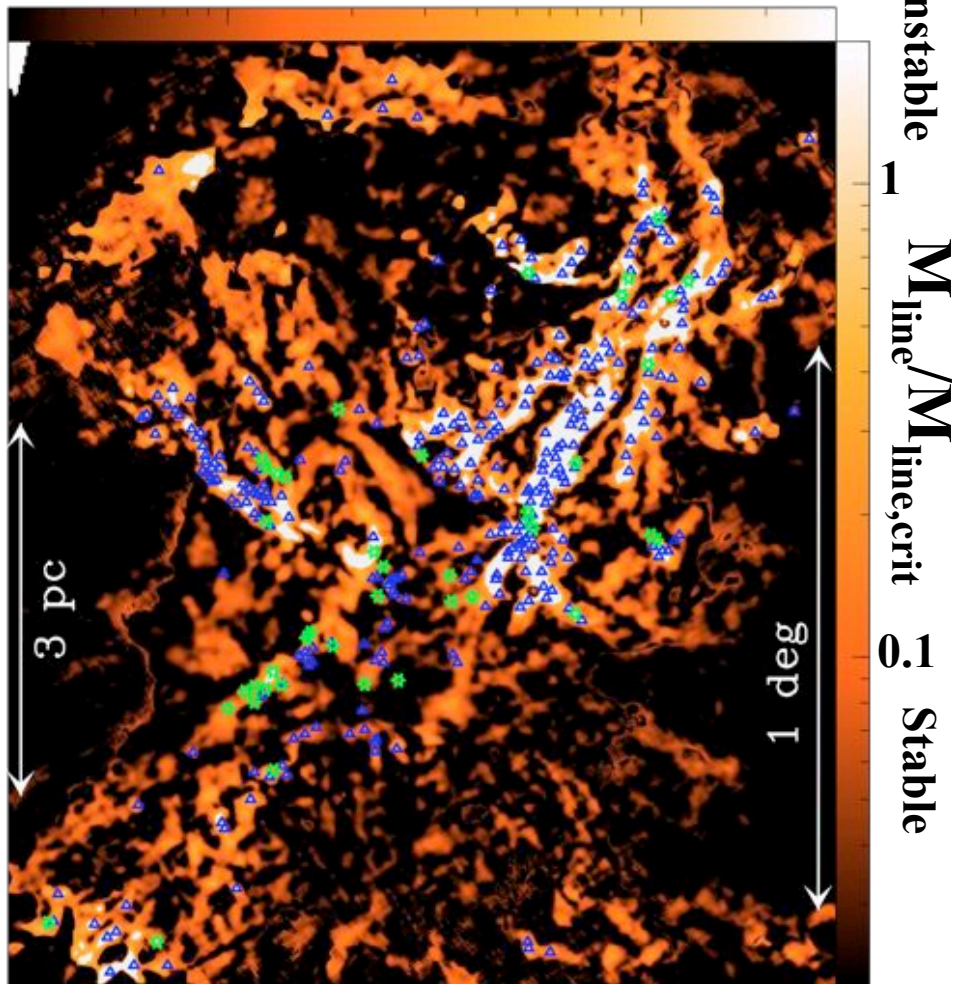
Aquila N_{H_2} map (cm^{-2})

Aquila curvlet N_{H_2} map (cm^{-2})



Only the densest filaments are gravitationally unstable and contain prestellar cores (Δ)

Aquila curvelet N_{H_2} map (cm^{-2})



André et al. 2010, A&A special issue

➤ The gravitational instability of filaments is controlled by the value of their mass per unit length M_{line} (cf. Ostriker 1964, Inutsuka & Miyama 1997):

- unstable if $M_{\text{line}} > M_{\text{line,crit}}$
- stable if $M_{\text{line}} < M_{\text{line,crit}}$
- $M_{\text{line,crit}} = c_s^2/G \sim 15 M_{\odot}/\text{pc}$ for $T = 10\text{K}$

➤ Simple estimate:

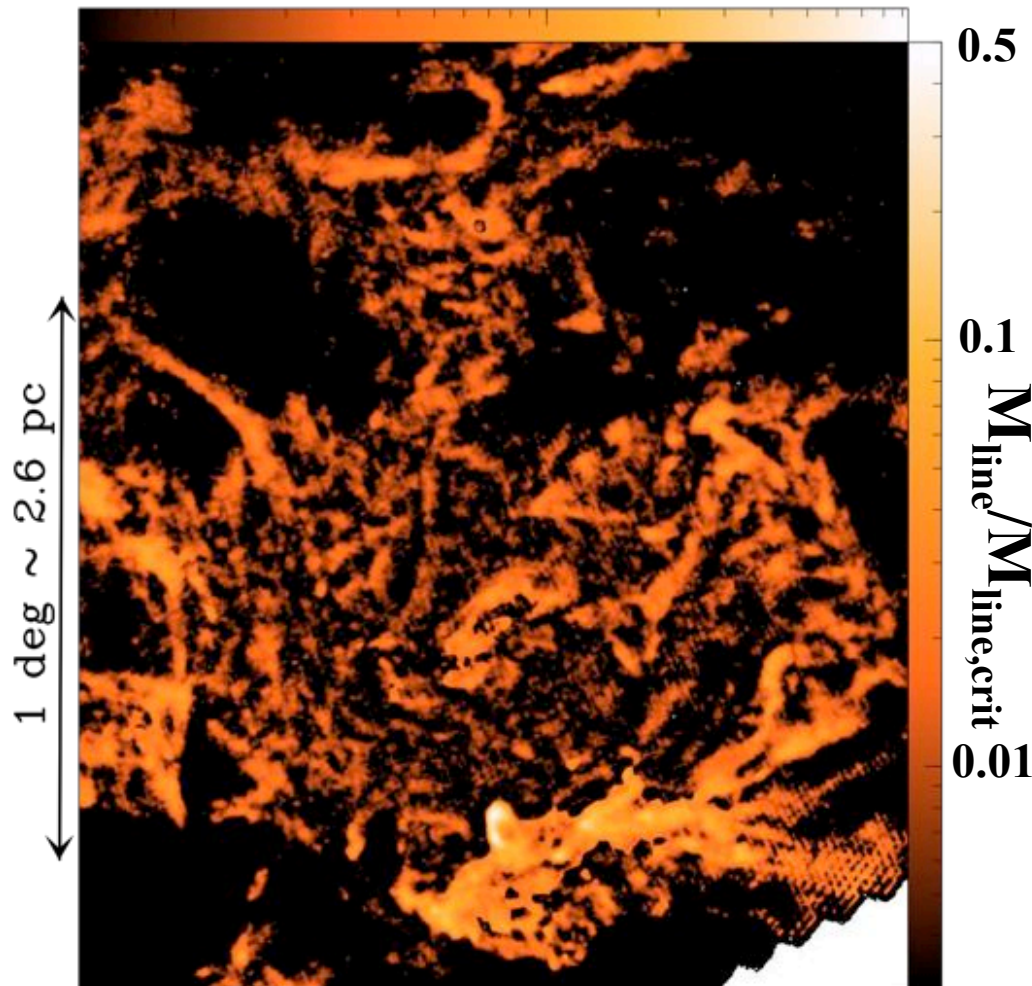
$M_{\text{line}} \propto N_{\text{H}_2} \times \text{Width}$ Unstable filaments highlighted in white in the N_{H_2} map

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

Polaris curvlet N_{H_2} map (cm^{-2})

10^{20}

10^{21}



André et al. 2010, A&A special issue

No prestellar cores (yet ?) in Polaris

- Filaments are already widespread prior to star formation
- The maximum value of $M_{\text{line}}/M_{\text{line,crit}}$ observed in the Polaris filaments is ~ 0.5
- The Polaris filaments are gravitationally stable and unable to form prestellar cores and protostars at present

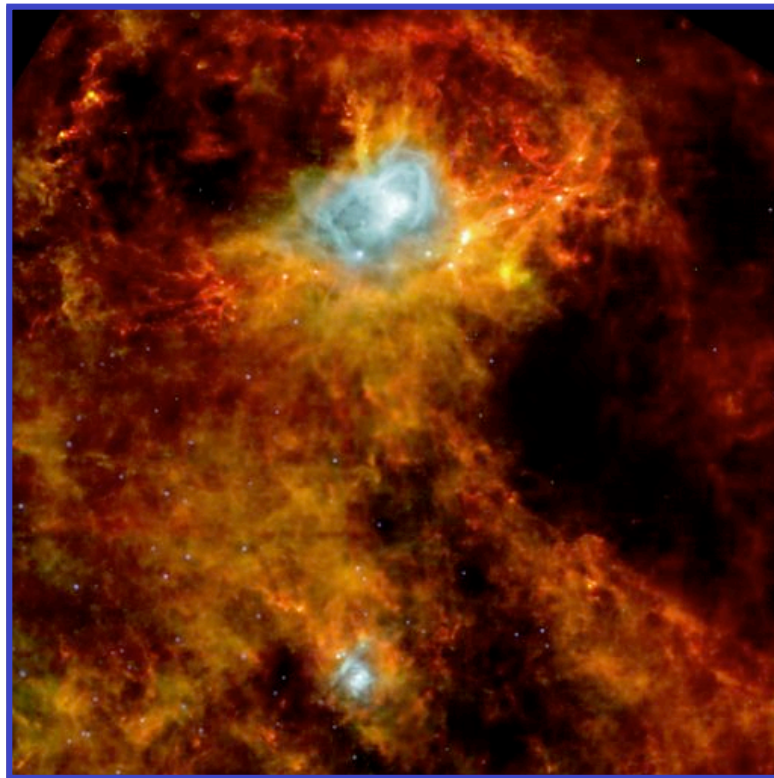
Filaments permeate the ISM on all scales

Herschel

SPIRE 500 μm

+

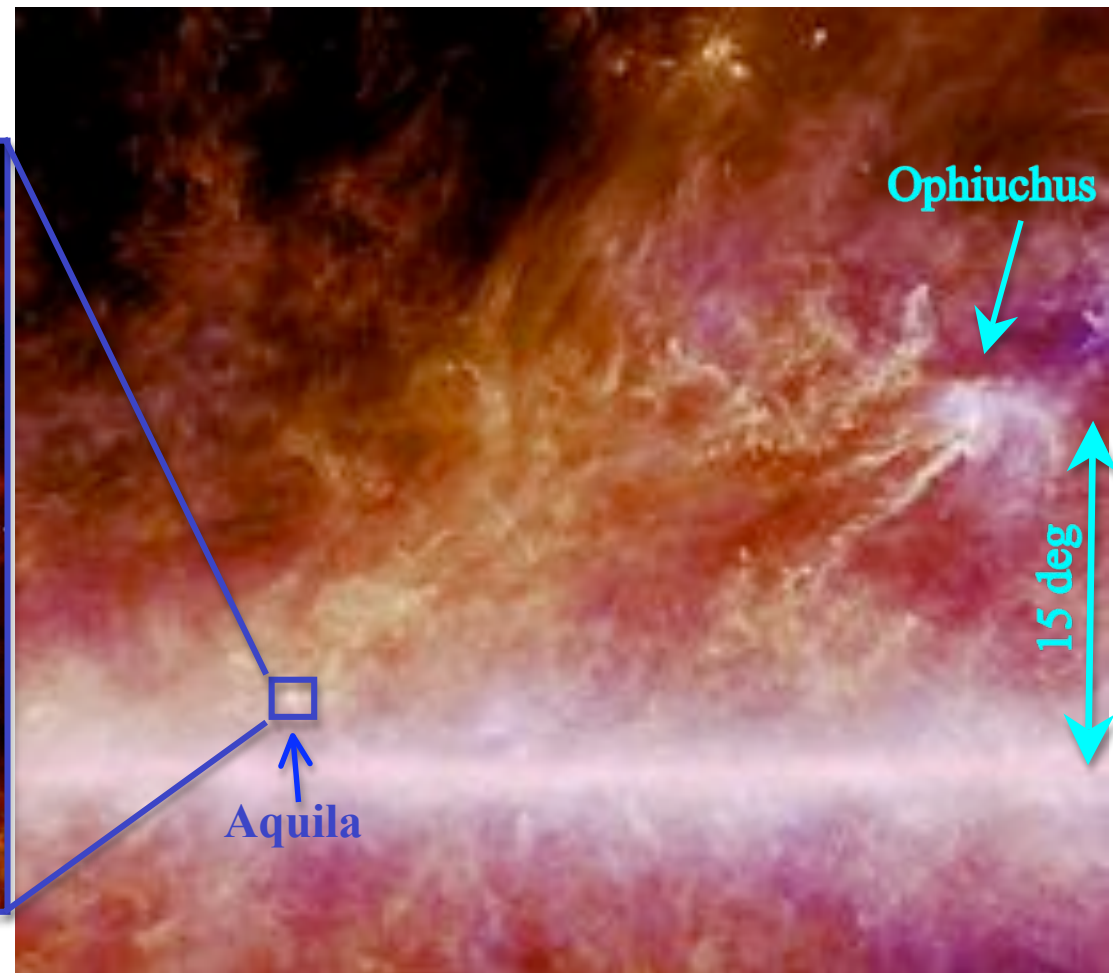
PACS 160/70 μm



ESA and the Gould Belt KP

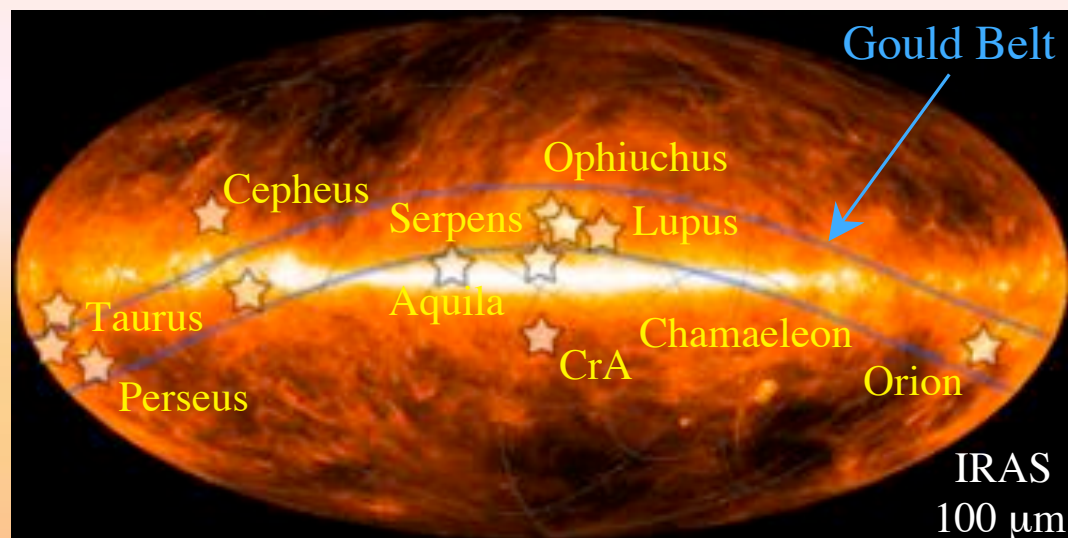
Planck

HFI 540/350 μm + IRAS 100 μm



ESA and the HFI Consortium

Conclusions



Our first results are extremely promising; exceed expectations !

- Confirm the close link between the prestellar CMF and the IMF
- Suggest an **observationally-driven scenario of core formation**:
 - 1) Filaments form first in the cold ISM, possibly as a result of interstellar MHD turbulence;
 - 2) The densest filaments then fragment into prestellar cores via gravitational instability.

MANY THANKS TO ESA HSC + SPIRE & PACS ICCs