Herschel PACS/SPIRE map of Aquila (Gould Belt survey)

Vera Könyves

Lab. AIM, Paris-Saclay – IAS/Orsay, France

Ph. André, A. Men'shchikov, N. Schneider, S. Bontemps, D. Arzoumanian, N. Peretto, P. Didelon, P. Palmeirim, F. Motte, A. Roy, A. Maury, and the SPIRE SAG3 cons.

Prestellar cores in Aquila observed by the Herschel Gould Belt survey

The Universe Explored by Herschel, ESTEC, Oct., 2013

HERSCHEL Gould Belt survey (HGBS)

Herschel Gould Belt Key Program (André et al. 2010)

- wide-field submm continuum survey with SPIRE/PACS
- 461 hrs of GT
- in nearby star-forming cloud complexes ($d \leq 500$ pc) of the Gould Belt
- probes **the origin of the stellar masses**

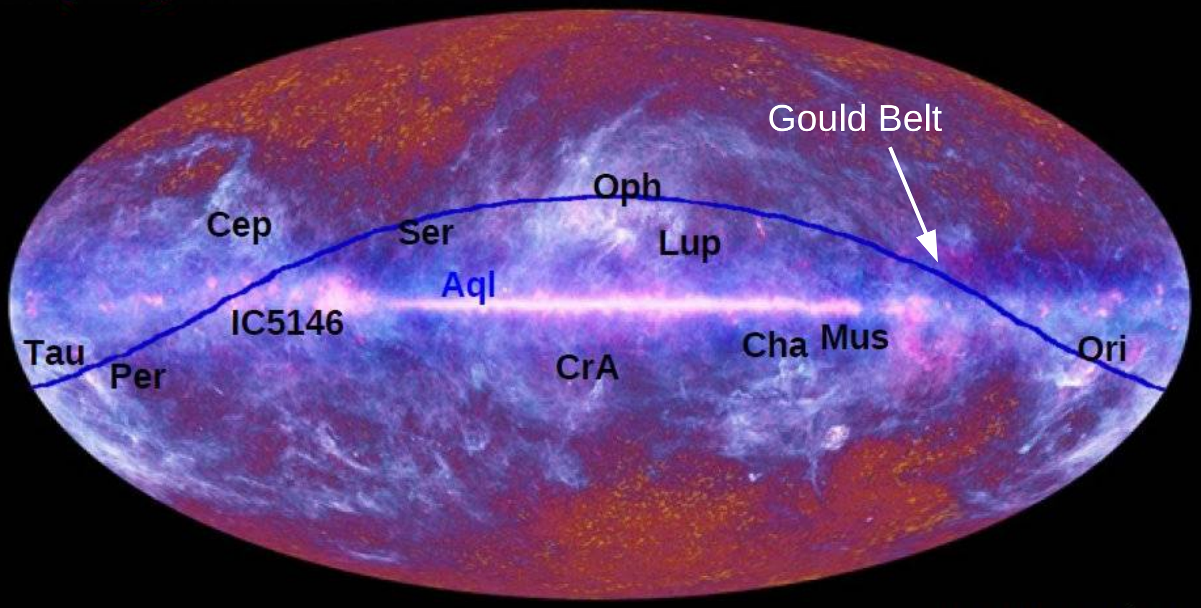
Scientific motivations, goals:

⇨ Link between the prestellar CMF and the stellar IMF ?

⇨ Provide a complete census of prestellar cores and protostars

⇨ Unravel the core formation mechanisms

http://gouldbelt-herschel.cea.fr



PLANCK HFI/LFI

Observations

- ♣ **SPIRE/PACS parallel-mode of *Herschel*.**
- ♣ Two orthogonal scan maps, 1 repetition, taken with 60''sec^{-1} scanning speed.

Data reduction

SPIRE 250/350/500 µm (N. Schneider):

- ♦ HIPE v.10 SPIRE Destriper pipeline for data processing and map making.

PACS 70/160 µm (V. Könyves):

- ♦ HIPE v.10 for data processing; Scanamorphos (Roussel, 2013) for map-making.

SPIRE/PACS map-making benchmark

- ♠ Joint efforts of SPIRE/PACS ICCs, map-makers, Herschel Key Program repres.
- ♠ Map-making tests and benchmarks including: photProject, madMap, SPIRE pipeline (Naive, Destriper), Scanamorphos, JScanamorphos, Sanepic, Tamasis, Unimap, +high-res. methods (HiRes, Supreme).
- ♠ Results of this benchmark will become public soon.

DERIVING T_d, N_{H2} MAPS

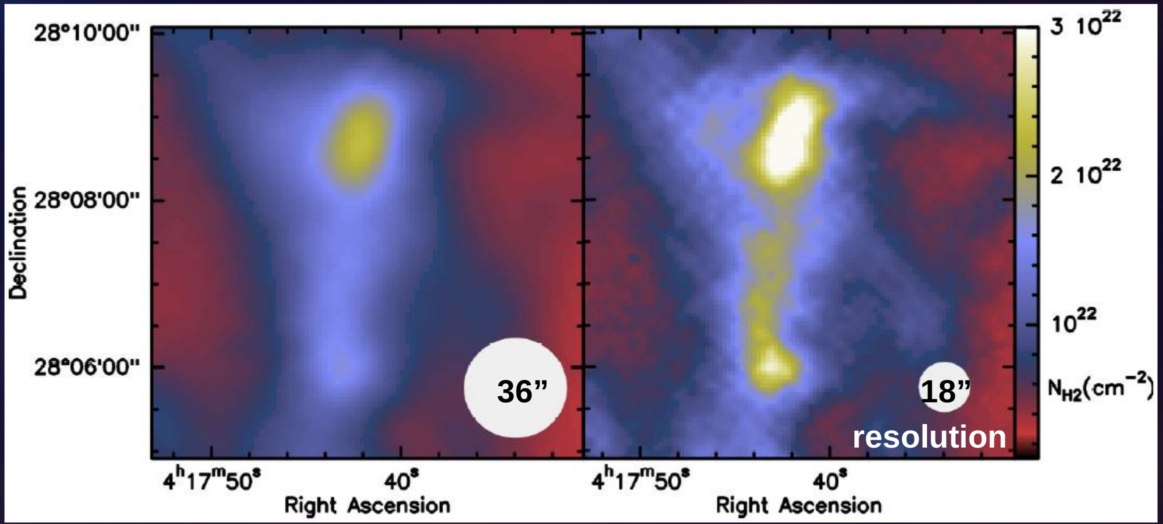
Dust temperature (T_d) and column density (N_{H2}) maps

- ♥ Using smoothed (36.9″) maps of 160-250-350-500 μm; Planck offsets added (Bernard et al. 2010).
- ♥ Pixel-by-pixel SED fitting with a greybody: $I_\nu = B_\nu(T_d)\kappa_\nu\Sigma$
  - Assumption: single-temperature dust optically thin emission
  - Dust emissivity index $\beta = 2$ (cf. Hildebrand, 1983)
- ♥ Weighting by calibration uncertainties (20%-160 μm, 15%-SPIRE bands)

⇨ $N_{H2} = \Sigma / \mu_{H2} m_H$

Deriving high-resolution (18.2”) column density maps (see Palmeirim et al. 2013):

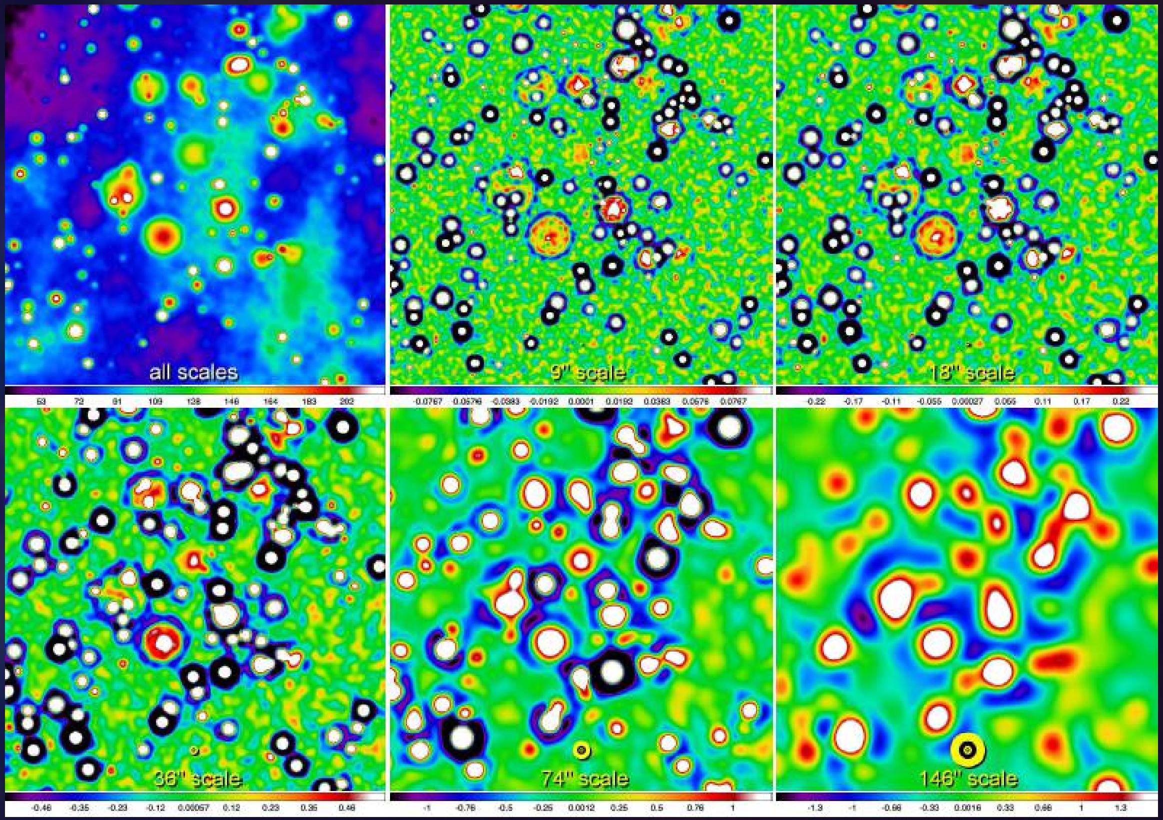
- ♣ Using the concept of multi-scale decomposition (Starck et al. 2004)
- ♣ Small scales are successively added up from 250 to 500 μm while conserving spectral informations from longer wavelengths.



Source extraction with *getsources*

Getsources: multi-scale, multi-wavelength source finding algorithm (Men'shchikov et al. 2012).

The method analyzes fine spatial decompositions of original images



Source extraction in two steps:

- Detection phase:
  - Cores: 160, 250, 350, 500 μm maps, high-resolution column density image.
  - Protostars/YSOs: 70 mu image.
- Measurement phase:
  - Cores: orig., bg-subtr. 70, 160, 250, 350, 500 μm maps, and the high-res. column density image
  - Protostars/YSOs: same as for cores.

Source selection/classification

♠ Using both the core & protostellar extraction results we distinguish candidates of:

- dense cores
- YSOs/protostars
- starless cores
- embedded protostars

♠ We set combinations of selection criteria based on:

- Significance
- S/N ratio
- peak/total flux
- source size/elongation

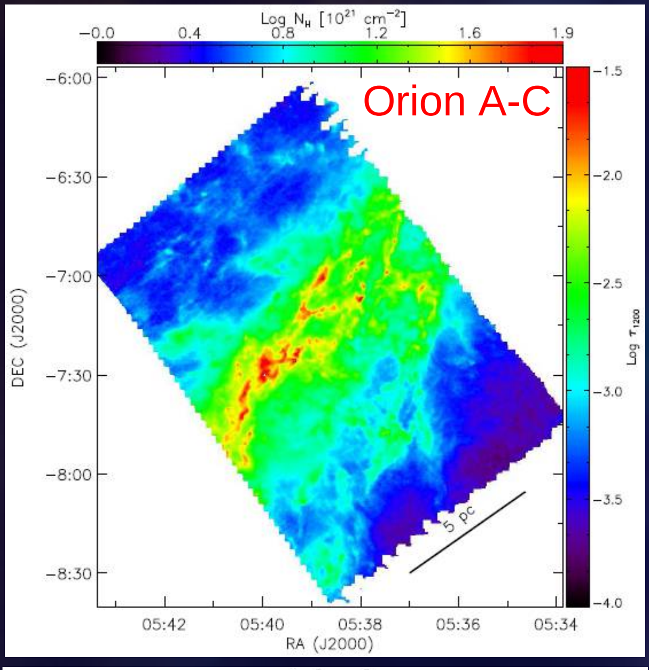
Eg.: • YSOs: detected in emission above 5σ level at 70 μm

• Starless cores: undetected in emission (or detected in absorption) at 70 μm.

♣ Similar SED fitting procedure (as for the T_d, N_{H2} maps) was employed to estimate the core properties from integrated flux densities by *getsources* (*d*=260 pc).

⇨ Estimated **mass uncertainty is a factor of ~2**, mainly due to κ_ν.

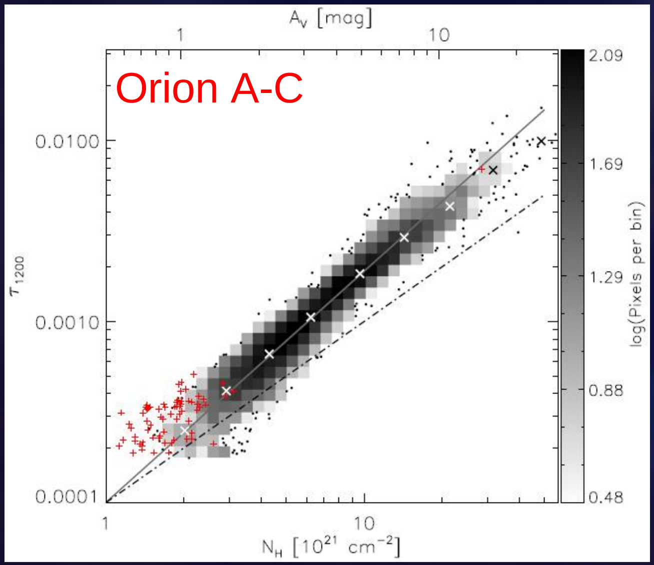
Improving the accuracy of mass estimates (1)



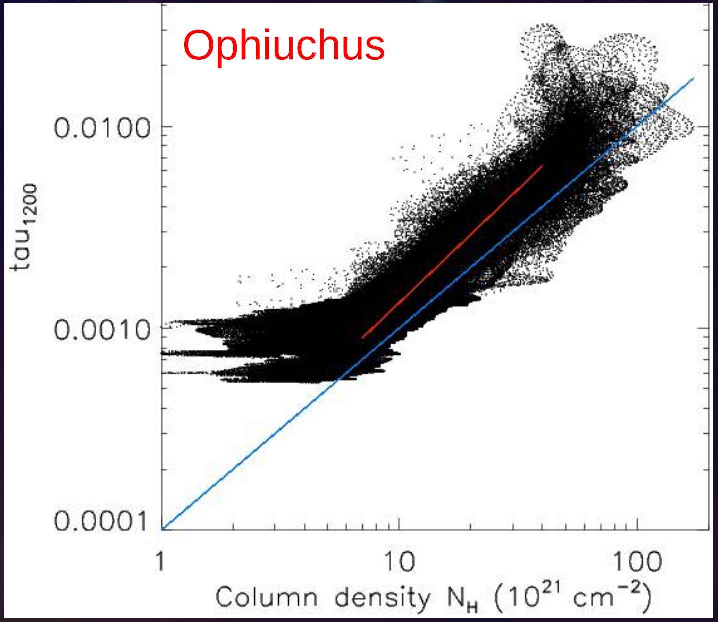
Dust opacity changes with (column) density!

In Orion A-C optical depth, τ, (from *Herschel* data) is well correlated with N_H (from 2MASS color excess).

Roy et al. (2013) found: $\kappa_\lambda \propto N_{H2}^{\ 0.28}$

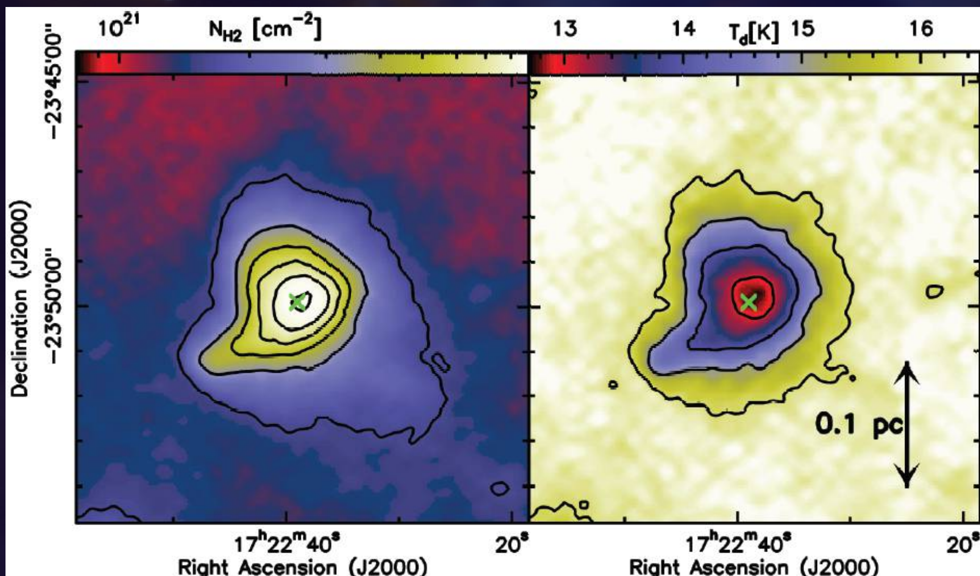


Könyves et al., in prep. / b

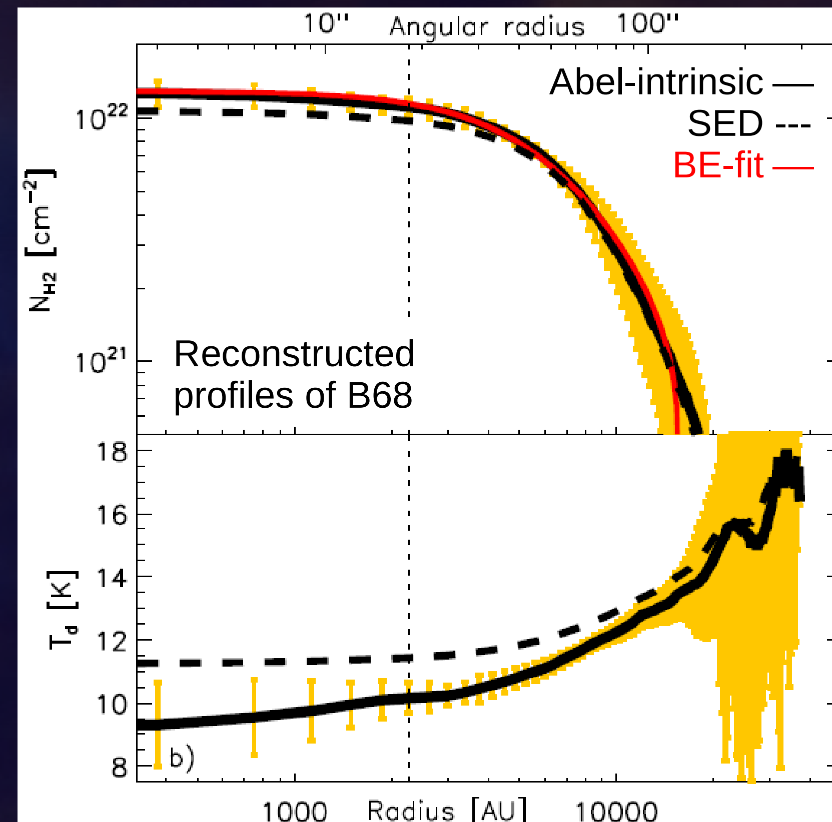


CORE PHYSICAL PROPERTIES – MASS ACCURACY

Improving the accuracy of mass estimates (2)



B68: N_{H2} and T_d maps derived from grey-body fitting of 160-500 μm HGBS data.



N_{H2} and T_d profile reconstruction based on Abel transformation technique (Roy et al., subm.)

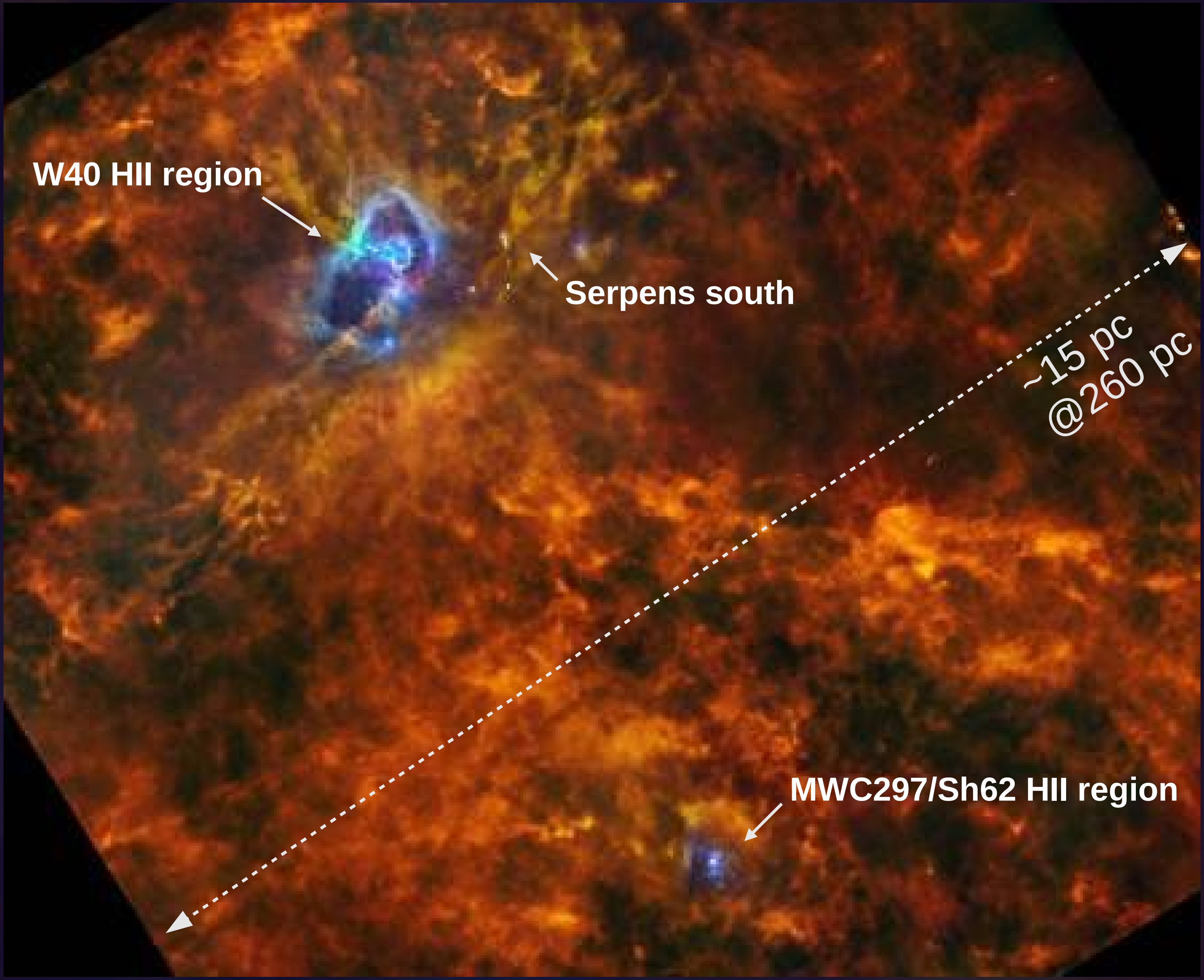
session B: poster 67 !

⇨ Corrects the effect of line-of-sight temperature variations on the total mass derivation.

⇨ We can improve mass determination for a subset of cores in the near future.

HGBS: THE AQUILA CLOUD COMPLEX

RGB COMPOSITE

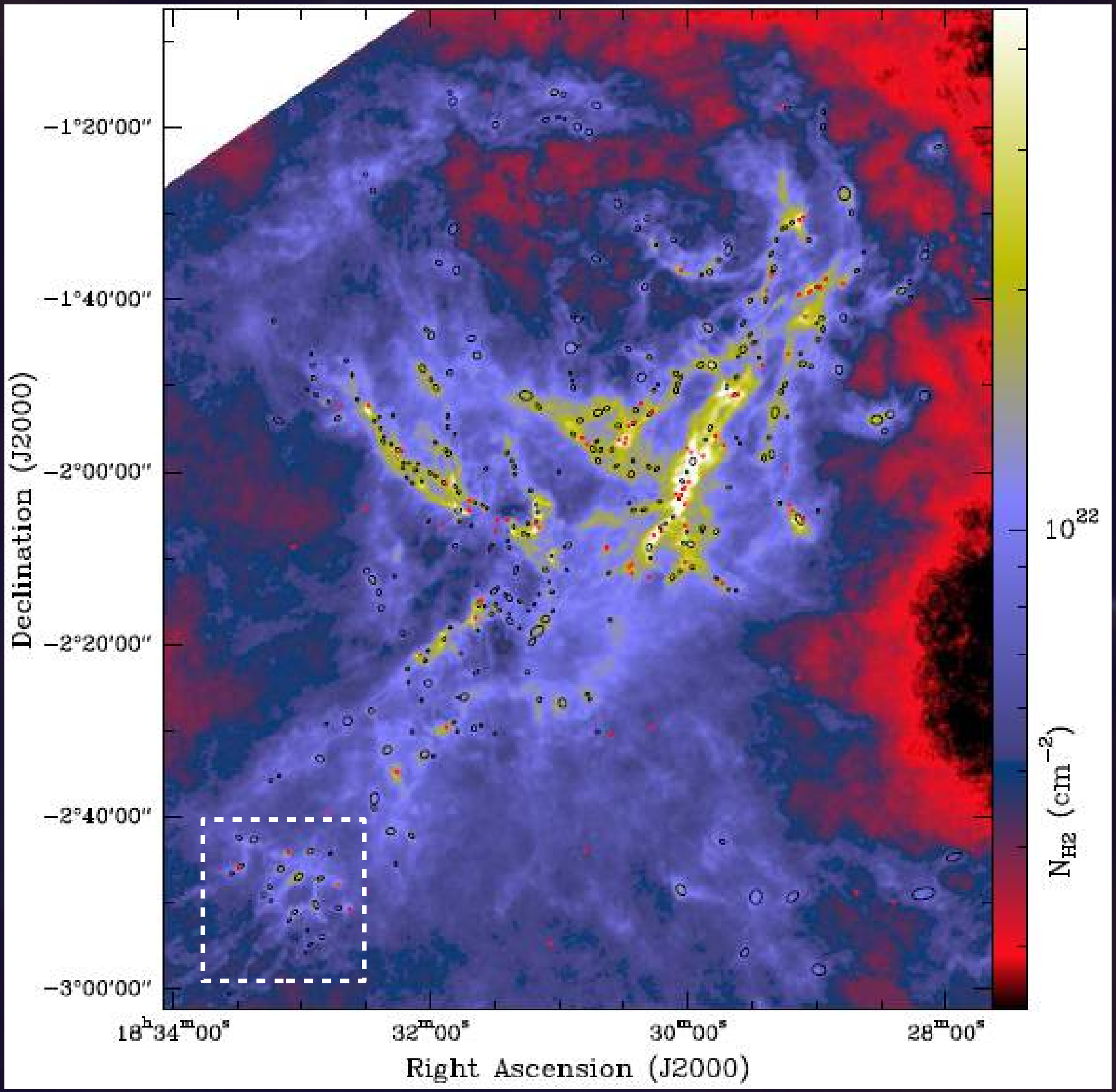


R-250 µm
G-160 µm
B- 70 µm

André et al. 2010
Könyves et al. 2010
Bontemps et al. 2010
Men'shchikov et al. 2010
Maury et al. 2011

HGBS: AQUILA

SOURCES IN THE AQUILA MAIN PART



Aquila -entire- field
(~10 deg^2)**:**

~ 600 starless cores (O)
~ 400 prestellar cores (70 %)
~ 200 protostars (O)

Background: high-res. column density map
(Planck offsets added)

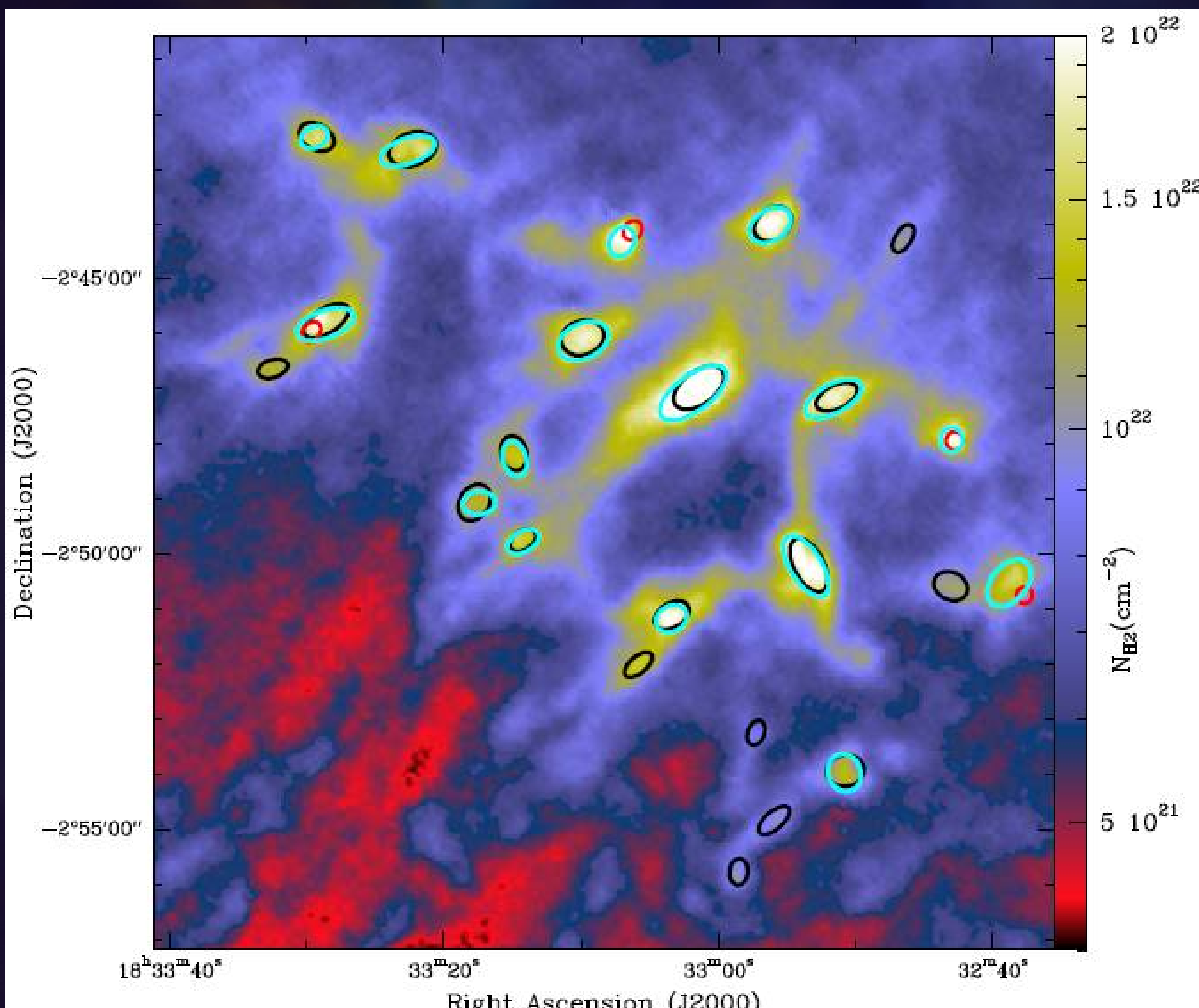
André et al. 2010
Könyves et al. 2010
Bontemps et al. 2010
Maury et al. 2011

HGBS: AQUILA

CLOSE UP VIEW OF EXTRACTED SOURCES

Part of the HGBS source extraction procedure: running an other source finder code (than *getsources*) ⇨ generate robustness flag

For Aquila cores we ran **CSAR** (Cardiff Sourcefinding AlgoRithm, Kirk et al. 2013), on the column density map.



A core:

- local column density peak
- simple (convex) shape
- no substructure at Herschel resol.
- potential single star-forming entity

Column density image zoom of starless cores and protostars.

Black - *Getsourcses* starless cores
Red - *Getsources* protostars
Green - CSAR sources

HGBS: AQUILA

THE CORE CATALOG

http://gouldbelt-herschel.cea.fr/archives

Legacy of the *Herschel* Gould Belt survey

Products:

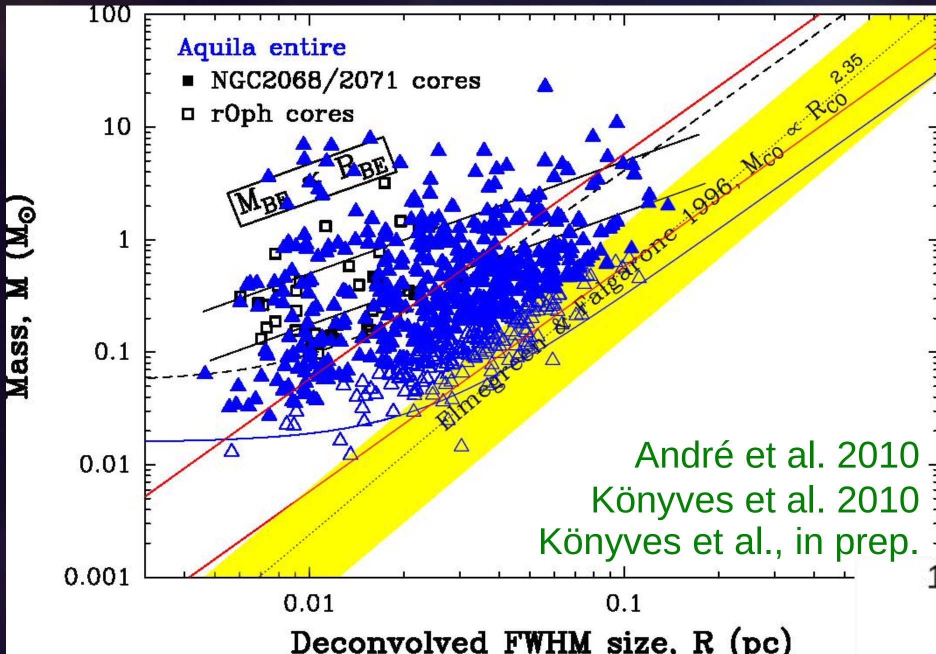
- Level-2.5 maps at 70/160/250/350/500 μm
- Catalogues of observed/derived properties of cores and protostars.

Herschel Gould Belt Survey SPIRE/PACS core catalog of the AQUILA region

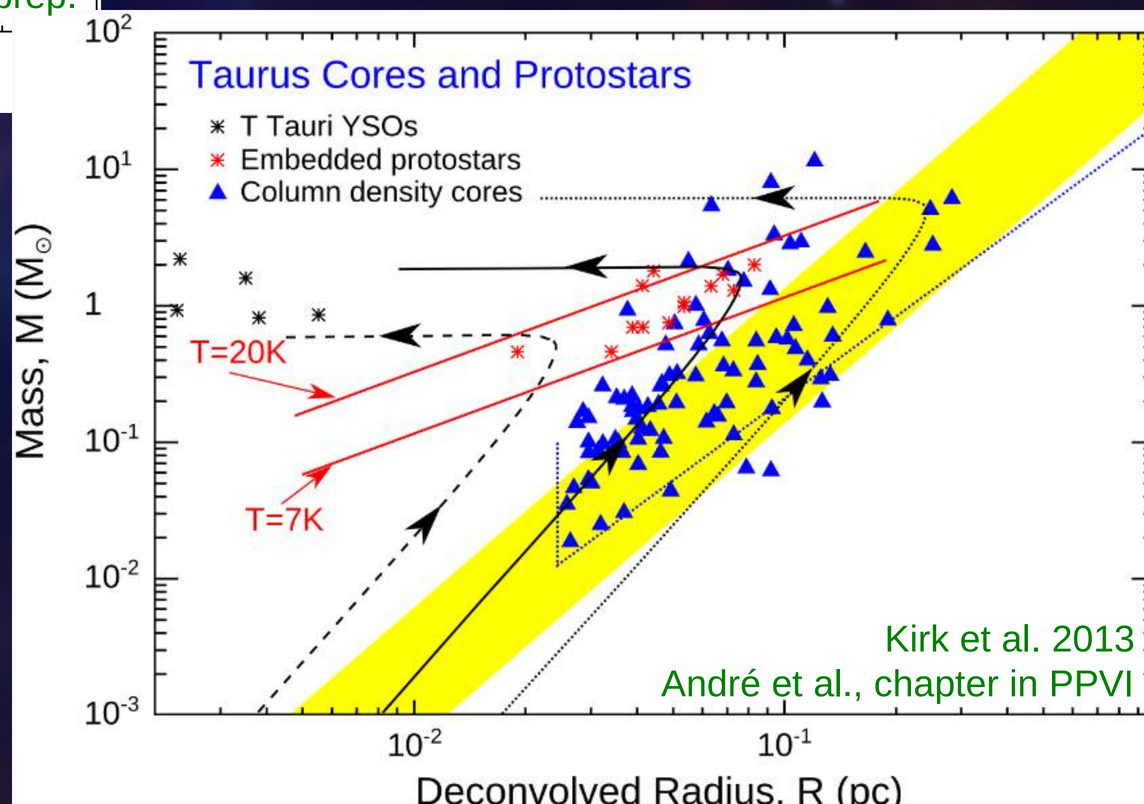
name	α	δ	sig_{070}	fxp_{070}	$fxperr_{070}$	ctr_{070}	fxt_{070}	$fxterr_{070}$	$afwhm_{070}$	$bfwhm_{070}$	pa_{070}	sig_{160}	fxp_{160}	$fxperr_{160}$	classification	looks	COMMENTS
	deg	deg		Jy/beam	Jy/beam		Jy	Jy	arcsec	arcsec	deg		Jy/beam	Jy/beam			
aql1	277.51726	-2.05163	1.623E+03	1.789E+01	1.898E-01	1	6.608E+01	2.751E-01	16.2	9.9	27.6	3.748E+03	1.491E+02	2.853E+00	protostellar		
aql2	277.03841	-3.80277	3.577E+02	5.762E+00	2.238E-02	1	1.096E+01	3.898E-02	12.0	10.5	18.5	1.279E+03	4.191E+01	2.038E-01	prestellar		
aql3	277.51017	-2.04661	2.287E+01	1.850E+00	1.988E-01	1	7.382E+00	2.709E-01	19.3	9.5	119.2	6.733E+02	4.907E+01	3.838E+00	prestellar		
aql4	277.28475	-1.51301	5.085E+02	6.750E+00	2.358E-02	1	1.031E+01	4.328E-02	11.4	11.2	40.2	9.598E+02	3.402E+01	1.237E-01	prestellar		
aql5	277.28051	-3.72333	4.209E+01	7.086E-01	1.763E-02	1	8.727E-01	2.998E-02	11.1	9.3	135.7	2.694E+02	9.047E+00	8.300E-02	prestellar		
aql6	277.50627	-2.17374	2.278E+03	3.676E+01	2.035E-02	1	5.741E+01	3.658E-02	11.6	10.9	71.0	1.398E+03	5.160E+01	2.852E-01	prestellar		
aql7	277.26508	-1.65083	3.528E+01	4.343E-01	1.746E-02	1	1.315E+00	2.554E-02	15.4	9.6	93.1	2.849E+02	9.169E+00	8.577E-02	prestellar		

HGBS: AQUILA

MASS-SIZE DIAGRAM

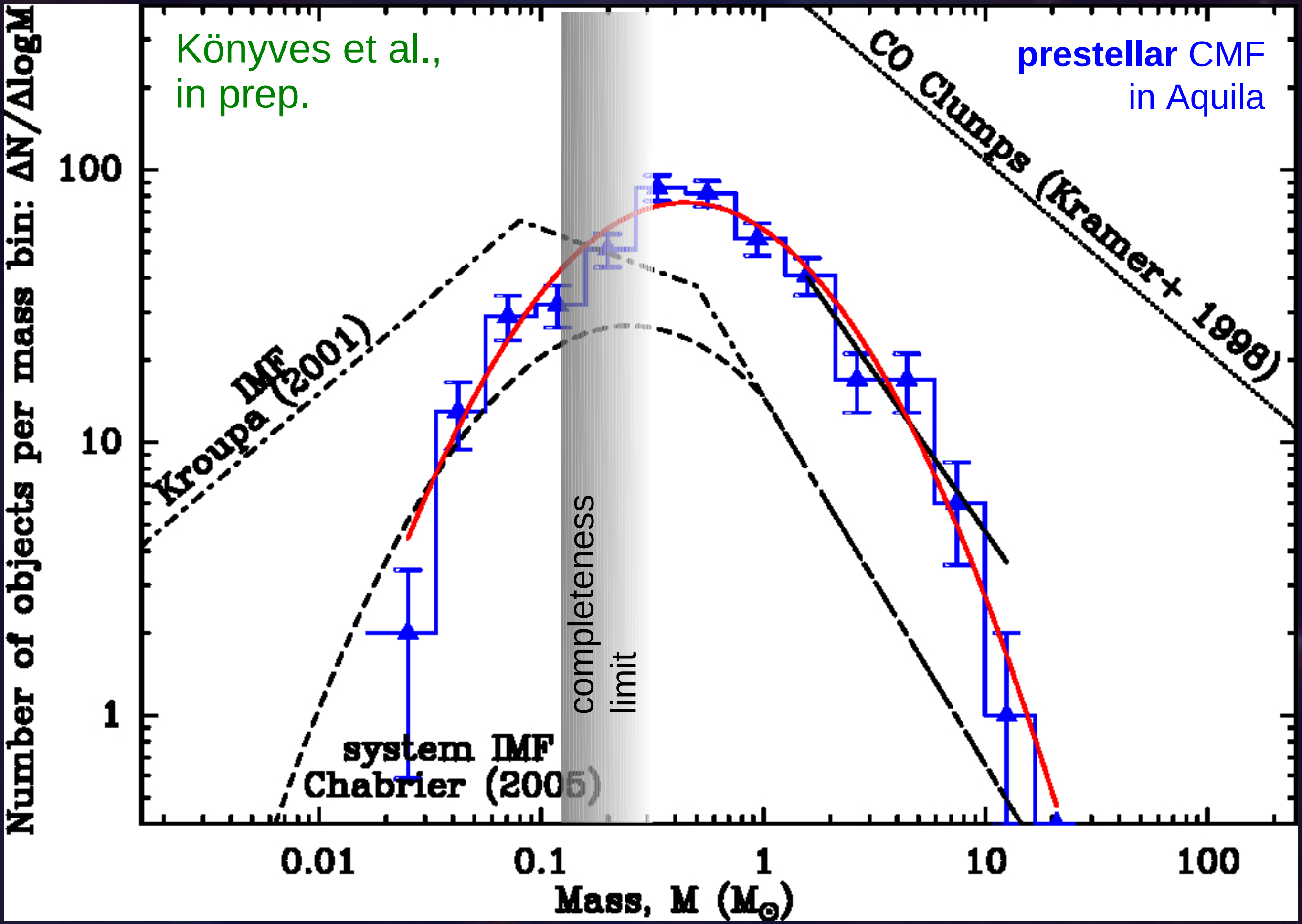


Aquila: Mass vs. size diagram comparing the locations of ~400 candidate prestellar cores (▲), and the rest of starless cores (△) (André et al. 2010, Könyves et al. 2010).



Taurus: mass-size diagram appears to serve as an evolutionary diagram (André et al., chapter in PPVI).

CORE MASS FUNCTION (CMF)



Lognormal fit peaks at ~ 0.4–0.6 $M_\odot$

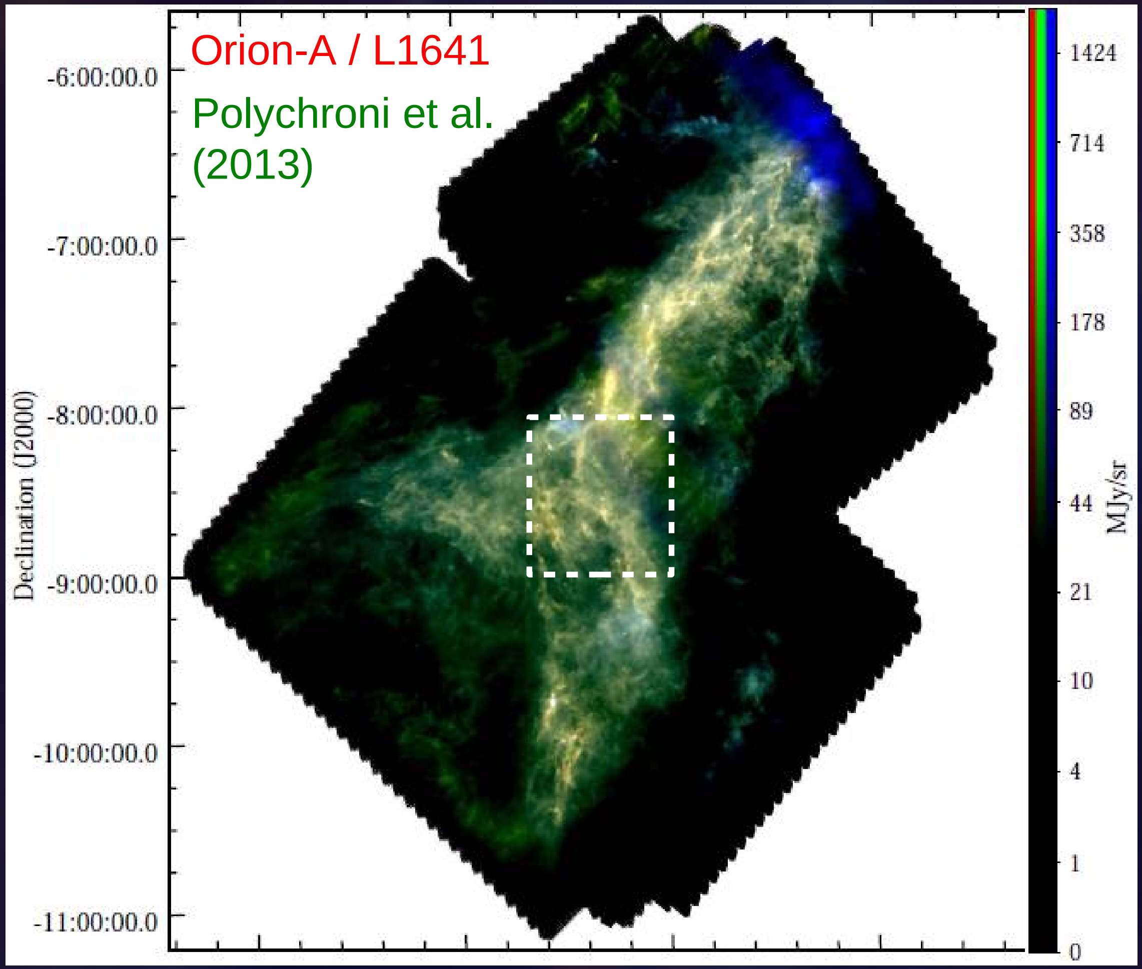
fitted power-law: $dN/d\log M \propto M^{-1.16\pm0.26}$

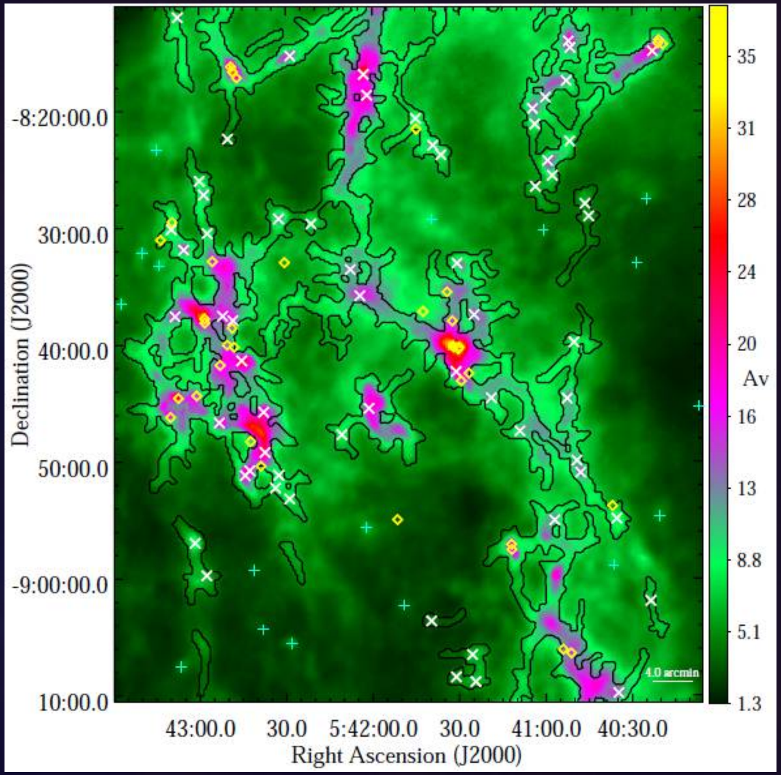
André et al. 2010
Könyves et al. 2010

Differential mass function of ~400 prestellar cores in the entire Aquila field.

HGBS: (ORION-A/L1641)

CORE MASS FUNCTION (CMF)



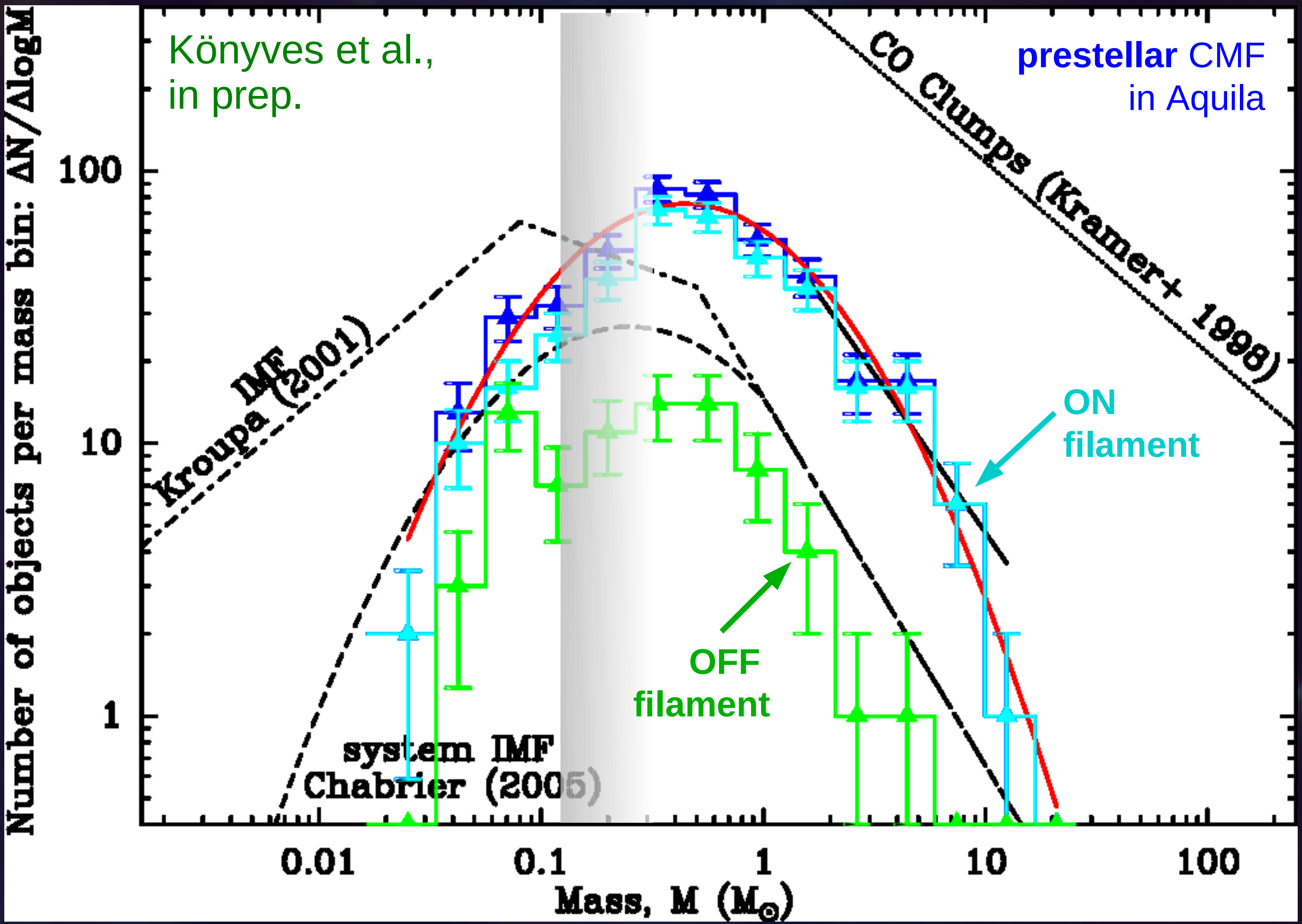


x : prestellar cores ON filament

+: prestellar cores OFF filament

In Orion-A / L1641 Polychroni et al. (2013) found that prestellar cores sitting ON filaments seem to be more massive than the OFF-filament ones.

CORE MASS FUNCTION (CMF)



Differential mass function of ~400 prestellar cores in the entire Aquila field

Lognormal fit peaks at ~ 0.4–0.6 $M_{\odot}$

fitted power-law:
$dN/d\log M \propto M^{-1.16\pm0.26}$

André et al. 2010
Könyves et al. 2010

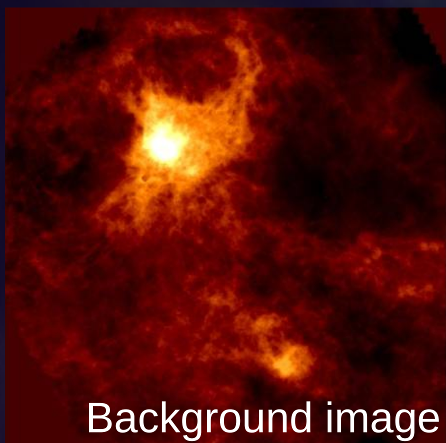
In Aquila, the prestellar cores with ON-filament positions do not show strong evidence of being more massive.

⇨ This feature can be environment dependent...

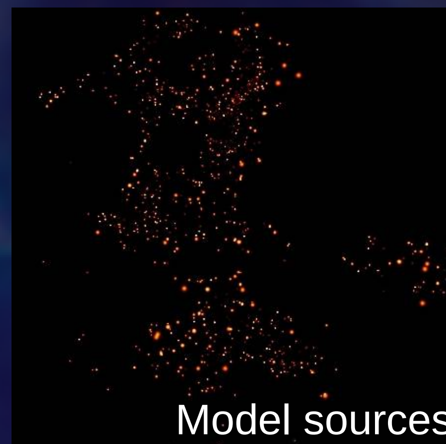
HGBS: AQUILA

COMPLETENESS LIMIT

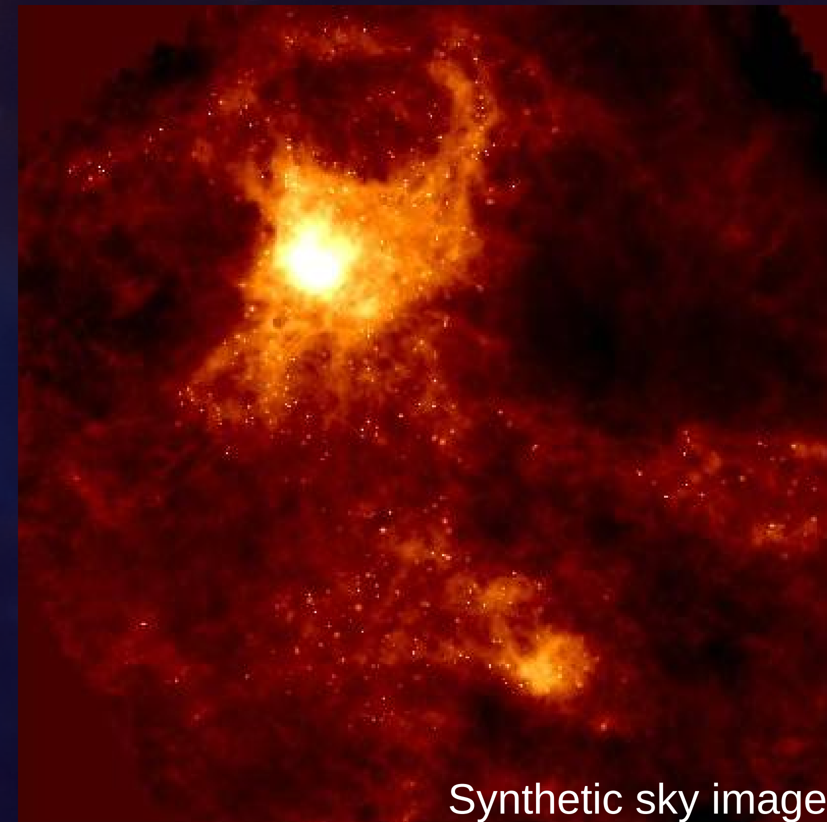
Source completeness is background dependent!

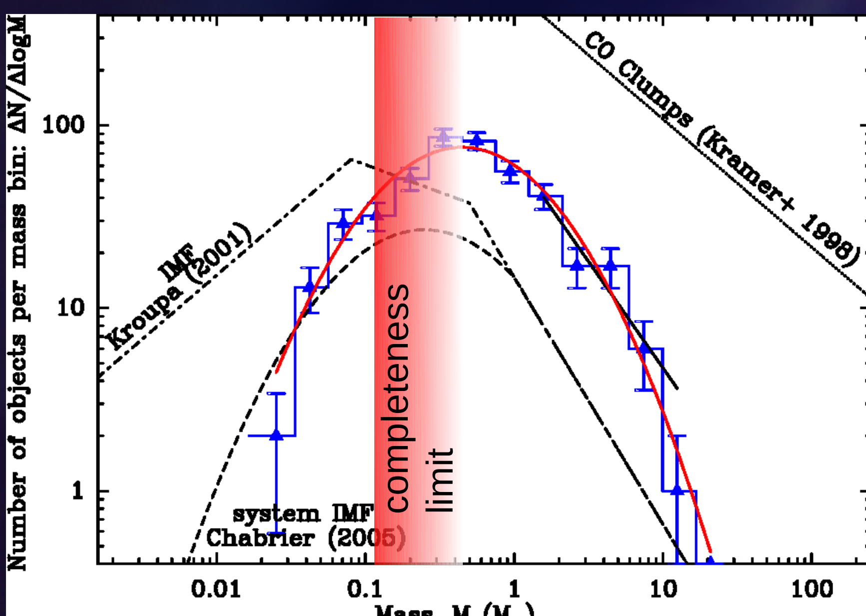


+



=





- ♥ Conservative completeness limit of prestelar cores: ~0.3 $M_\odot$

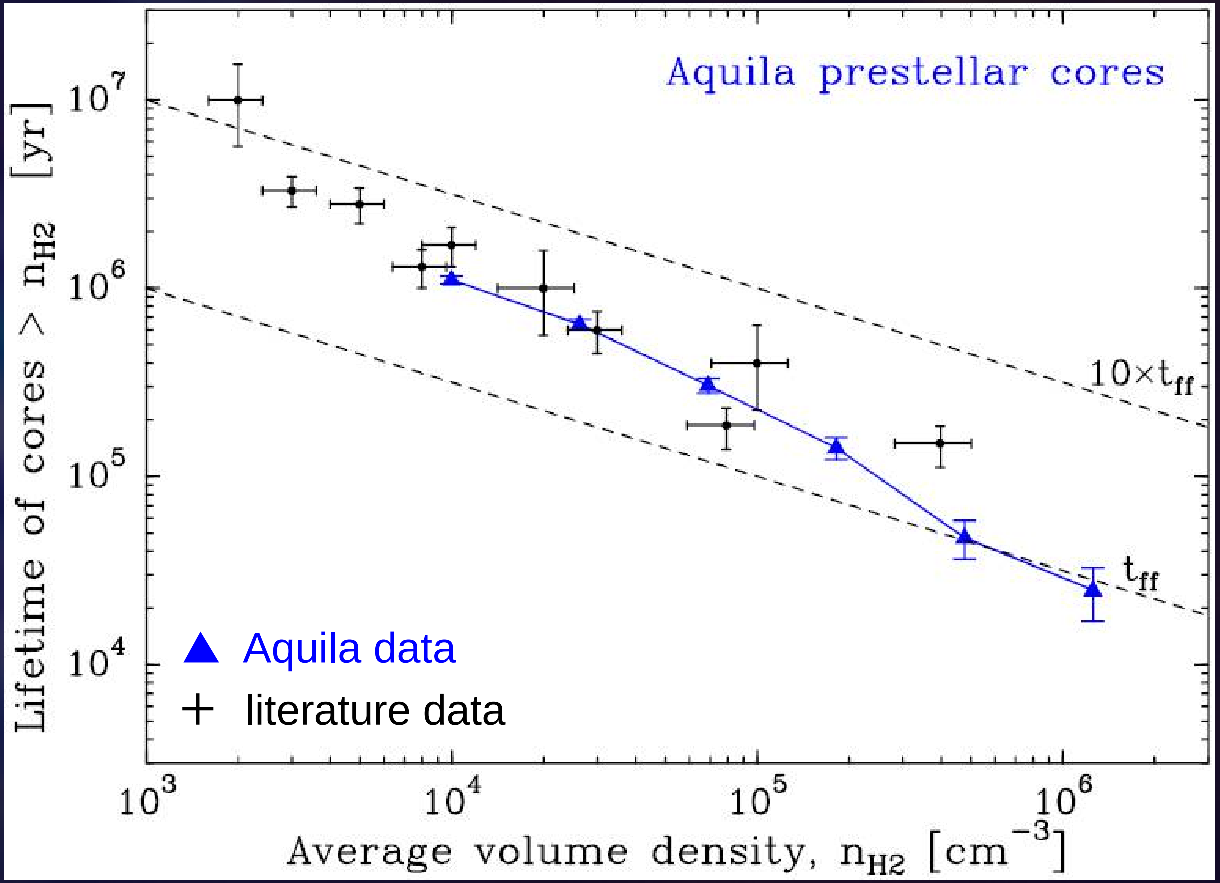
Könyves et al. 2010, Könyves et al., in prep.

Core lifetime estimates

Based on number ratios:

- ~400 *Herschel* prestellar cores (t ~ 1 Myr)
- ~200 *Herschel* Class0/ClassI protostars (t ~ 0.5 Myr)
- ~800 *Spitzer* (Class II, YSOs) (t ~ 2 Myr, Evans et al. 2009)

Könyves et al., in prep.



Jessop & Ward-Thompson 2000, André et al., chapter in PPVI.

Estimates of Aquila core lifetimes lie between two “extreme” timescale evolutionary models.

Literature estimates for observed core timescales of various data-sets gave similar constraints (Jessop & Ward-Thompson 2000, Ward-Thompson et al. 2007, references therein).

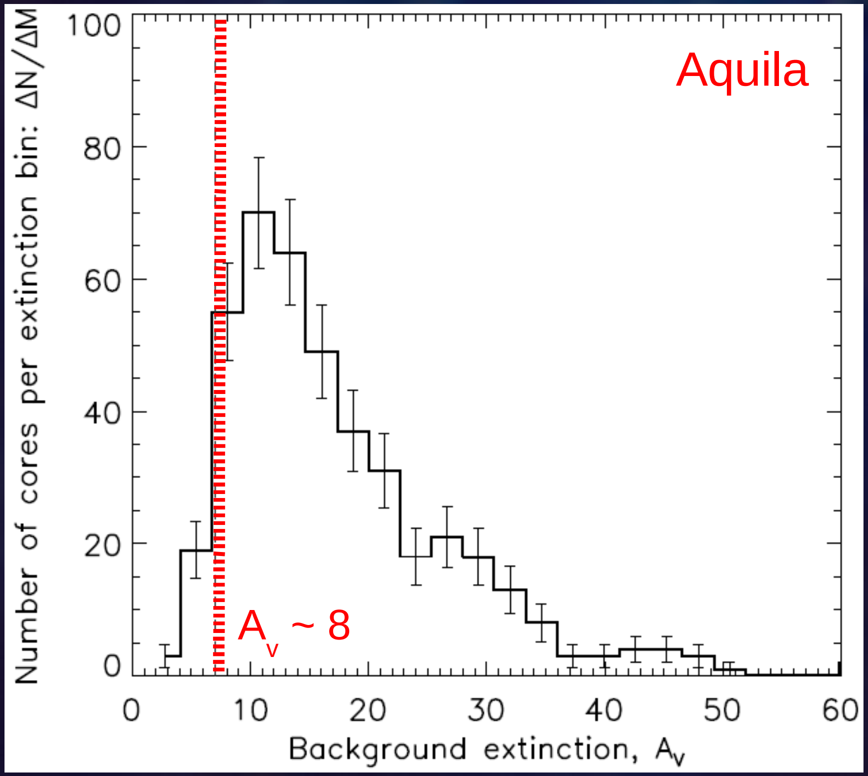
HGBS: AQUILA

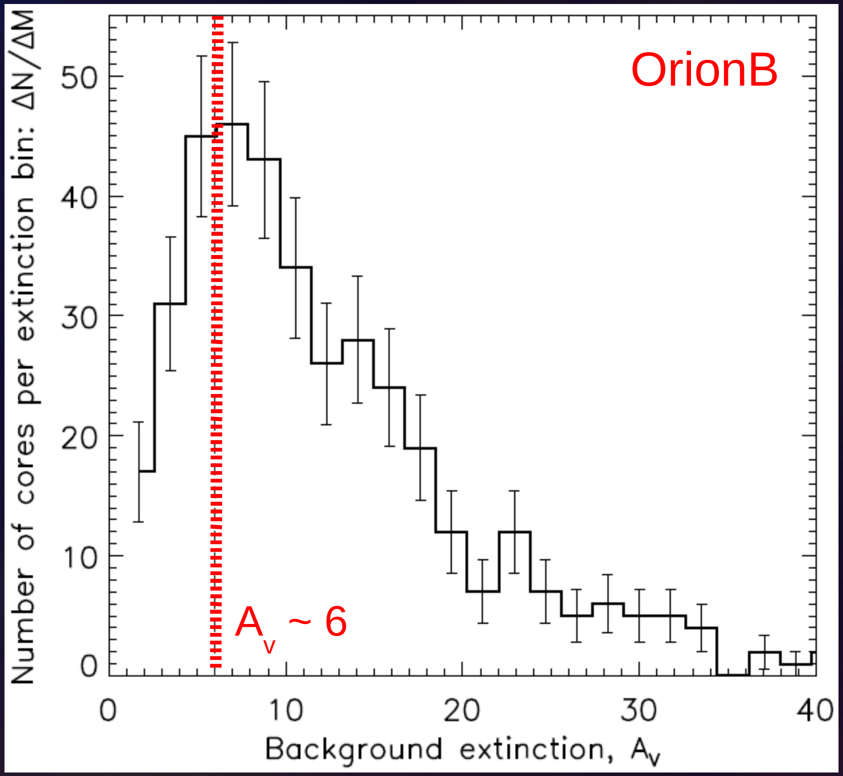
CORE/STAR FORMATION THRESHOLD?

Strong evidence of a column density “threshold” for the formation of prestellar cores in Aquila

In Aquila, ~ 90% of the *Herschel* prestellar cores are found above
$A_v \sim 8 \Leftrightarrow \Sigma \sim 150\ M_\odot\ pc^{-2}$

Distribution of background cloud column densities (or A_V) 'behind' the prestellar cores.





André et al. 2011, IAU270 (arXiv:1309.7762), Könyves et al., in prep.

Thank You!