Fragmentation in Hi-GAL clumps

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ALMA Cycle 2 Proposal

Fragmentation in Hi-GAL clumps

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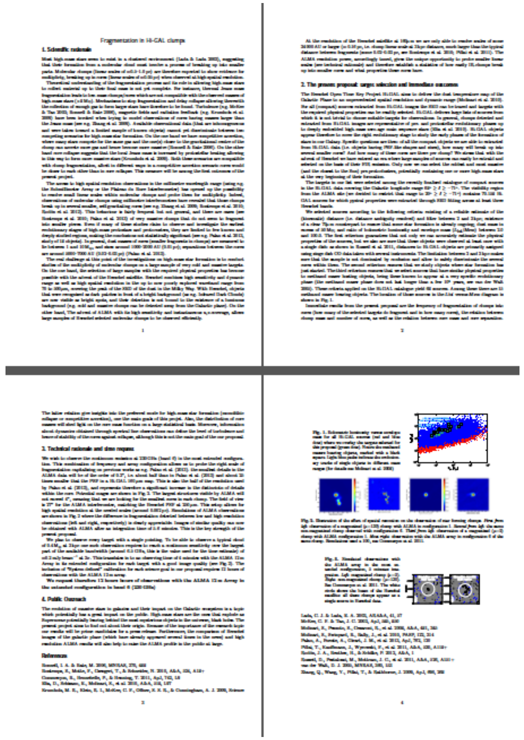
Busquet, G., Palau, A., Elia, D., Commerçon, B., Molinari, S., Testi, L., Pezzuto, S., Olmi, L.



In short:

We asked to observe 68 Hi-GAL objects in the continuum at 230 GHz in the most extended configuration, for studying fragmentation in the high-mass star formation case.

It was assigned priority grade C (filler project), but not observed yet

High-mass star formation ($M > 10\ M_{\odot}$):

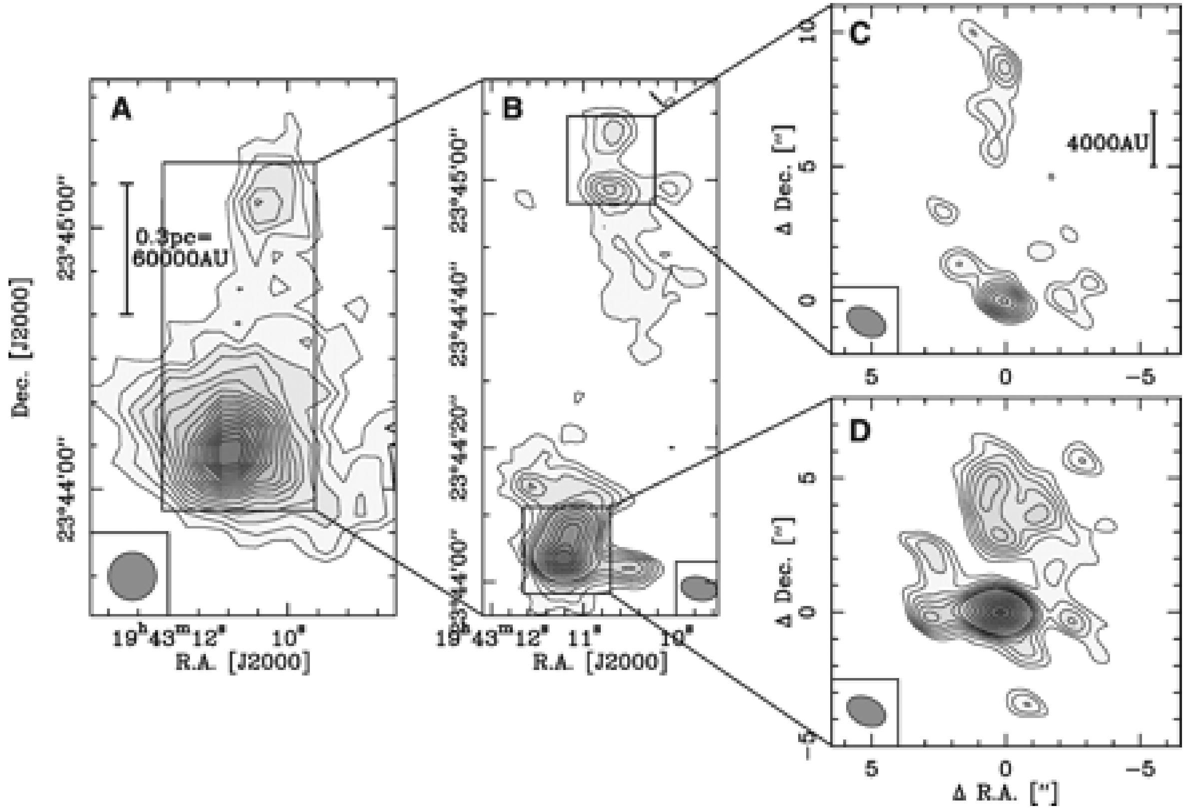
To achieve a full theoretical understanding of massive star formation is an important goal of contemporary Astrophysics.

Two scenarios (core accretion and competitive accretion) are invoked at present to explain how massive star can form.

In particular, does fragmentation (which determines the final mass distribution) proceed always in the same way?

Studies of single regions (e.g. Cygnus X, Bontemps+ 2011, four different regions ad d < 3 kpc, Palau+ 2013) already exist.
Now statistics must be increased!

Cloud FRAGMENTATION develops with time, but at a given time a different degree of fragmentation can be observed, depending on <u>RESOLUTION</u>



IRAM 30m 1.2mm PdBI 3mm PdBI 1.3mm

Beuther & Schilke, 2004

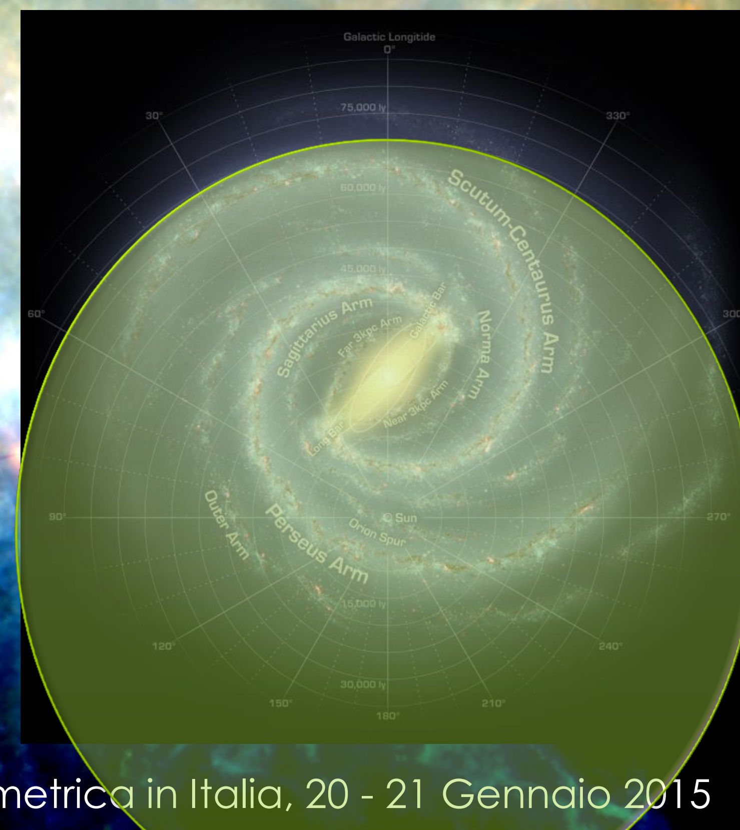
Hi-GAL as a mine of candidate ALMA targets…

P.I. Sergio Molinari, INAF-IAPS, Italy

The entire Plane was covered: Simultaneous 5-bands (70-160-250-350-500 μm) continuum mapping of 720 sq. deg. of the Galactic Plane (|b|≤1°)

With almost 900 hours observing time is the largest OPEN TIME Herschel KP

Galaxy-wide Census, Luminosity, Mass and SED of dust structures at all scales from massive YSOs to Spiral Arms



Hi-GAL as a mine of candidate ALMA targets…

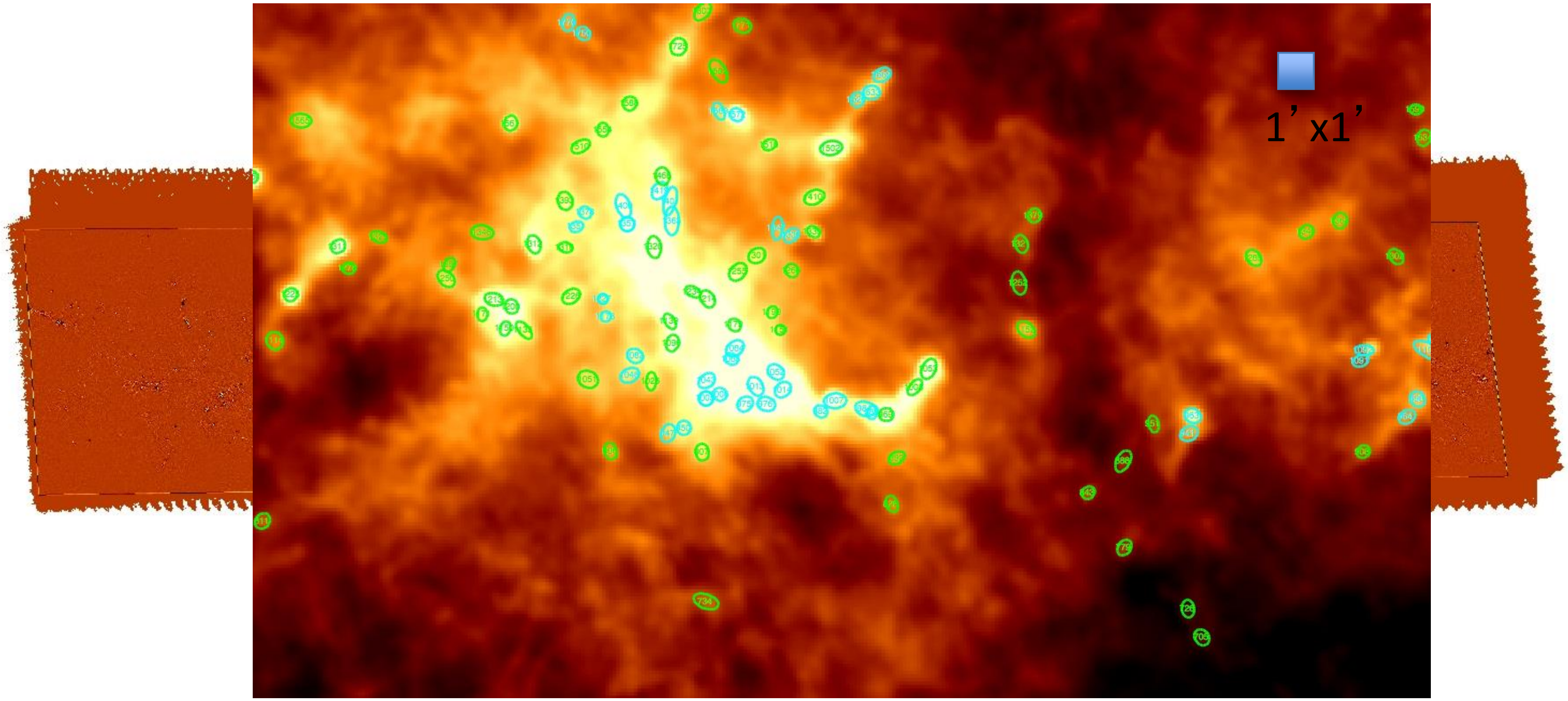
- First-generation Photometric Catalogues created using CuTEx package (Molinari+ 2010, 2011) for the inner Galaxy (-71° ≤ l ≤ 67°)

- Naïve band-merging produces a catalogue of **519400** entries (Molinari+ 2014, in prep)

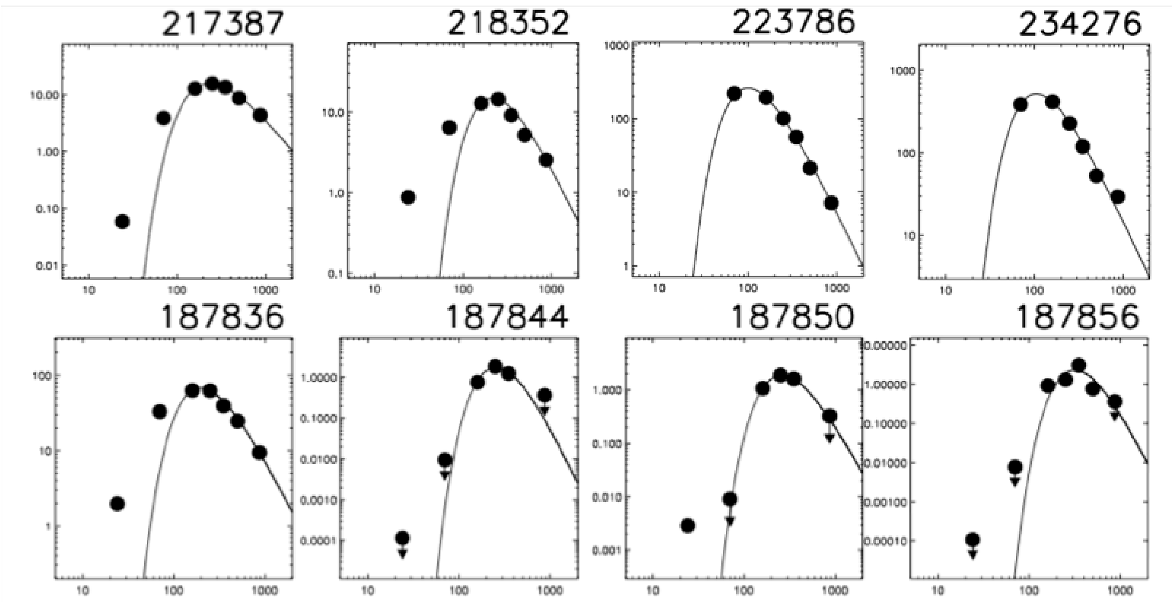
- Clump catalogue downselected filtering "nice" SEDs with at least three adjacent counterparts in the 160-500 μm range yields **99083** entries.

Band	$N_{sources}$
PACS-70μm	122 971
PACS-160μm	292 051
SPIRE-250μm	280 258
SPIRE-350μm	161 855
SPIRE-500μm	85 880

How to extract the compact sources: CuTEx example

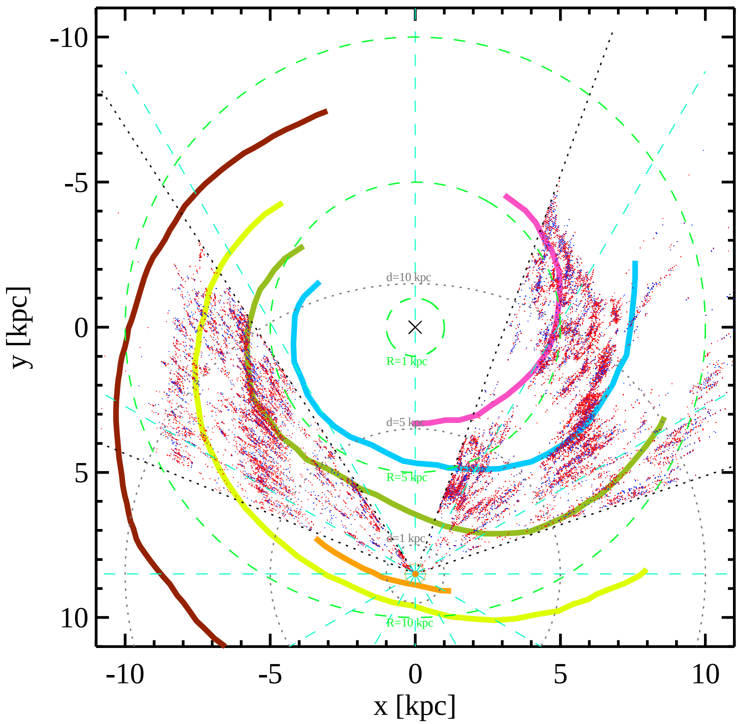


Hi-GAL is statistics: Huge output…

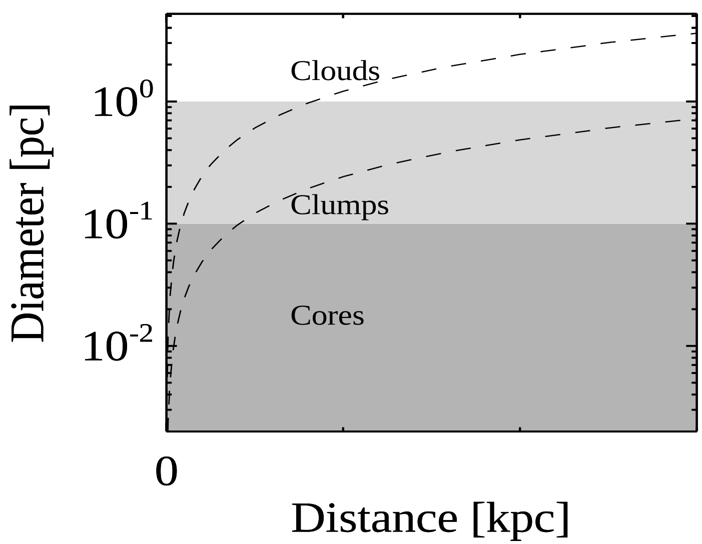


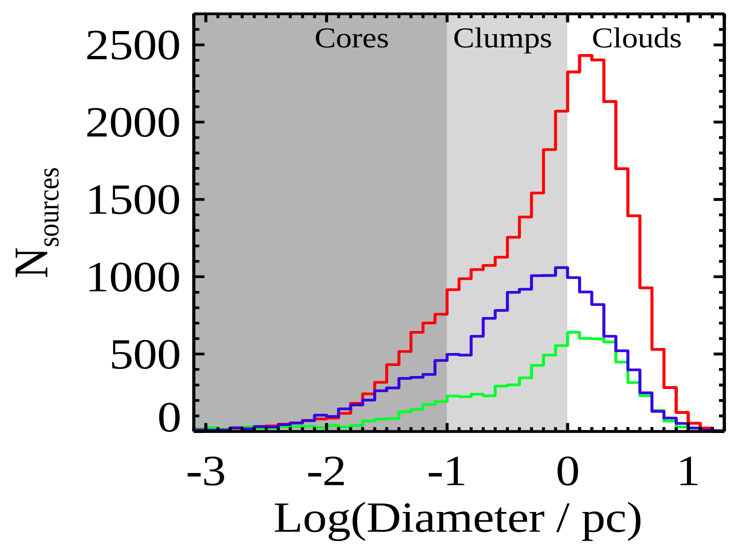
For the 99083 inner Galaxy sources with counterparts in at least three bands, we expand SED coverage with ATLASGAL, BGPS, MIPSGAL, WISE, MSX

Elia+ 2014, in prep



A first set of kinematic distance estimates (with different levels of reliability) has been carried out excluding -1° < *l* < 14°, yielding *T*, *L*, *M* and size, for **56656** sources

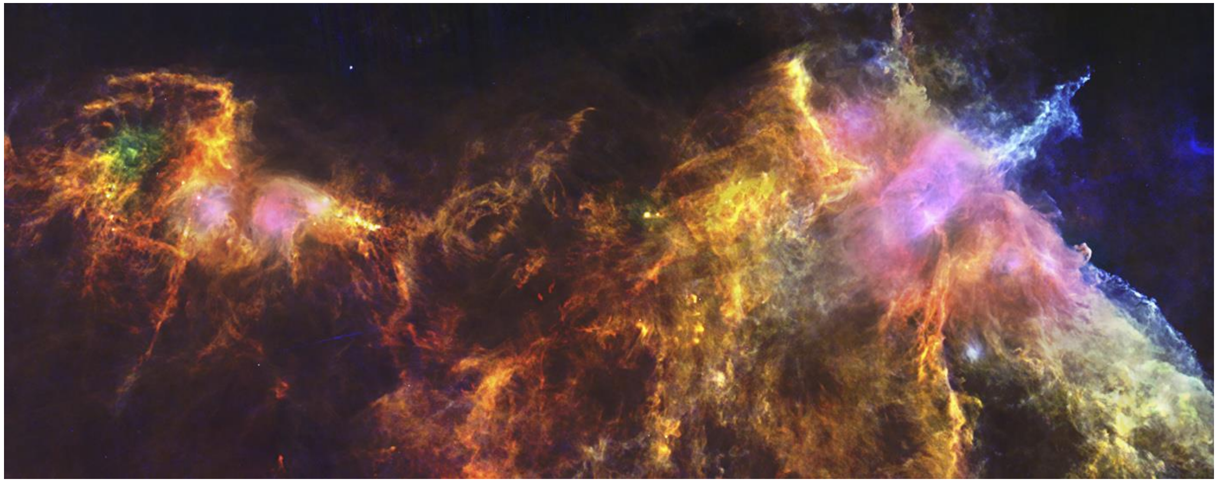




The keyword is… RESOLUTION

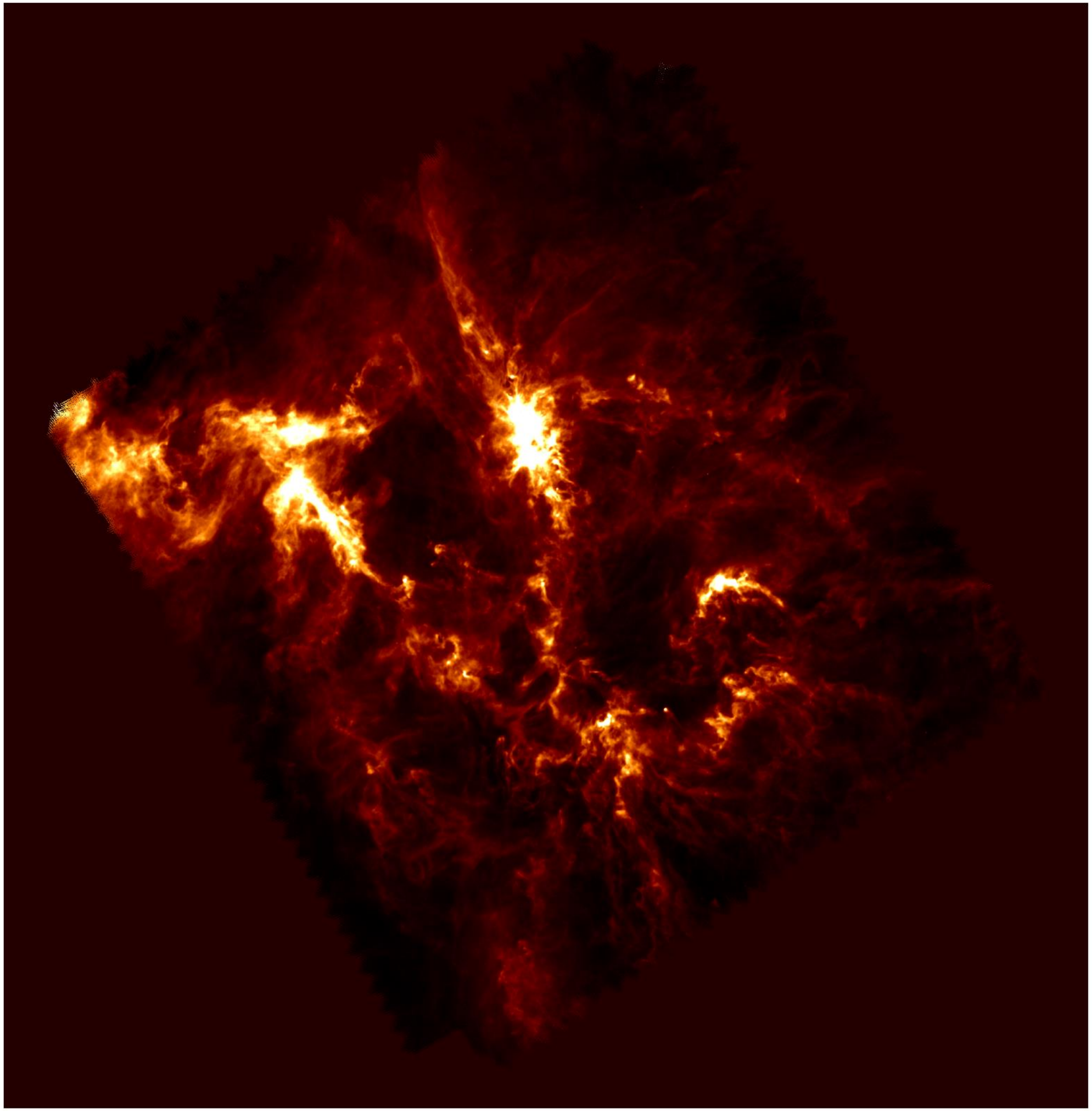
It is necessary to carry out follow-up observations at mm interferometers, but it is also interesting to “move away” the maps of near star-forming regions to typical distances of Hi-GAL sources, and see what remains…

Herschel Gould Belt survey maps can suit us fine!



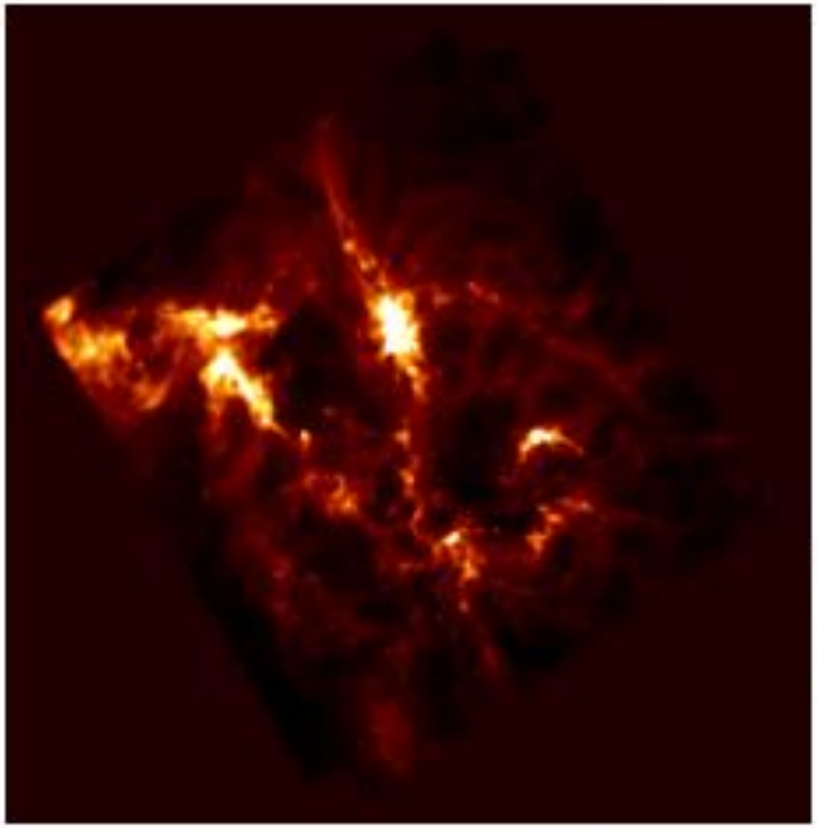
Perseus

d = 235 pc



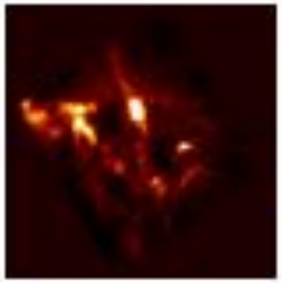
Perseus cloud "moved away"

d = 1 kpc

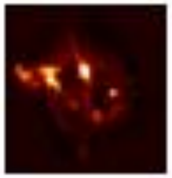


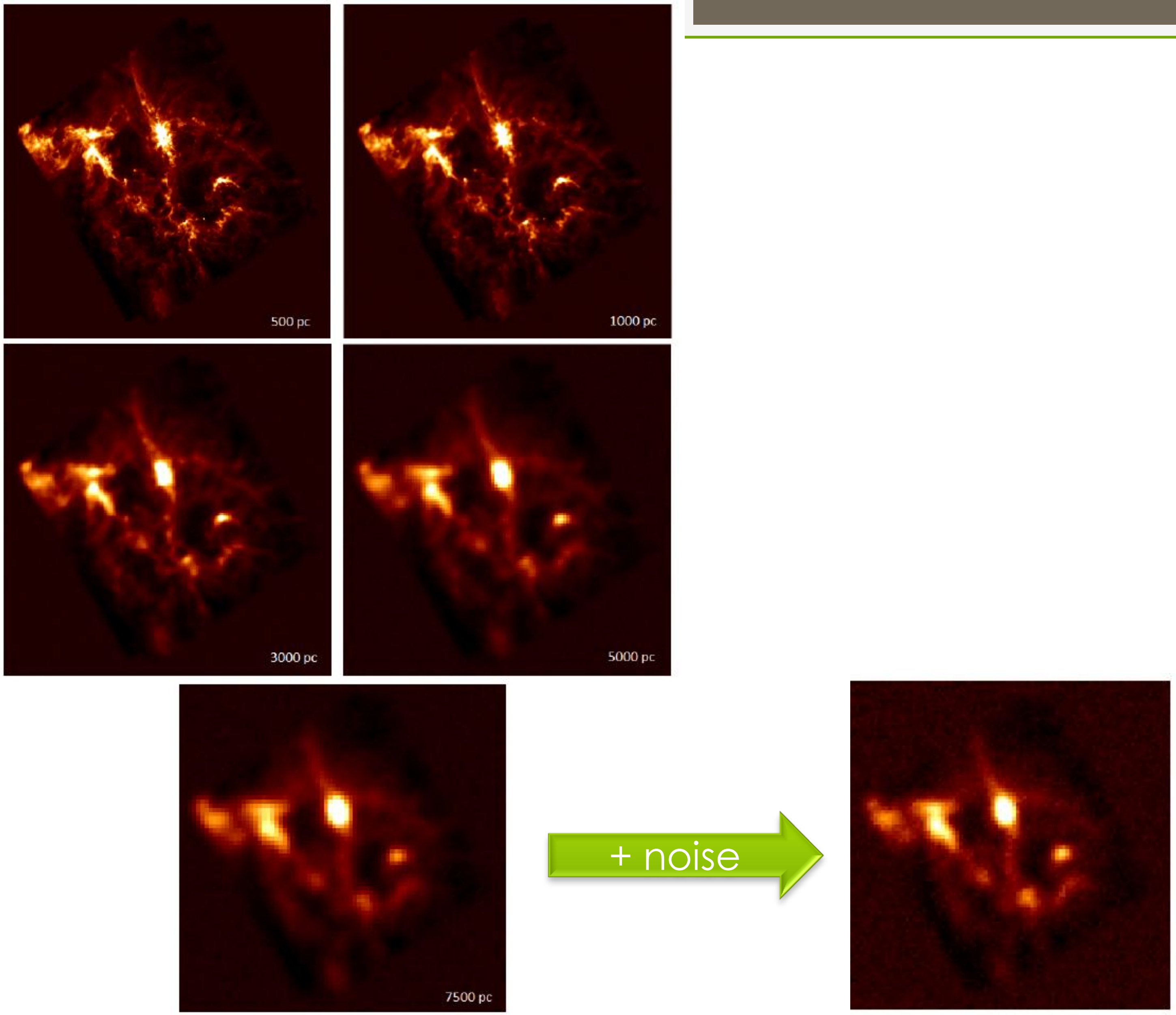
- The maps are regridded according to the simulated distance
- A new convolution with the Herschel beam is performed
- A new instrumental noise is simulated and added

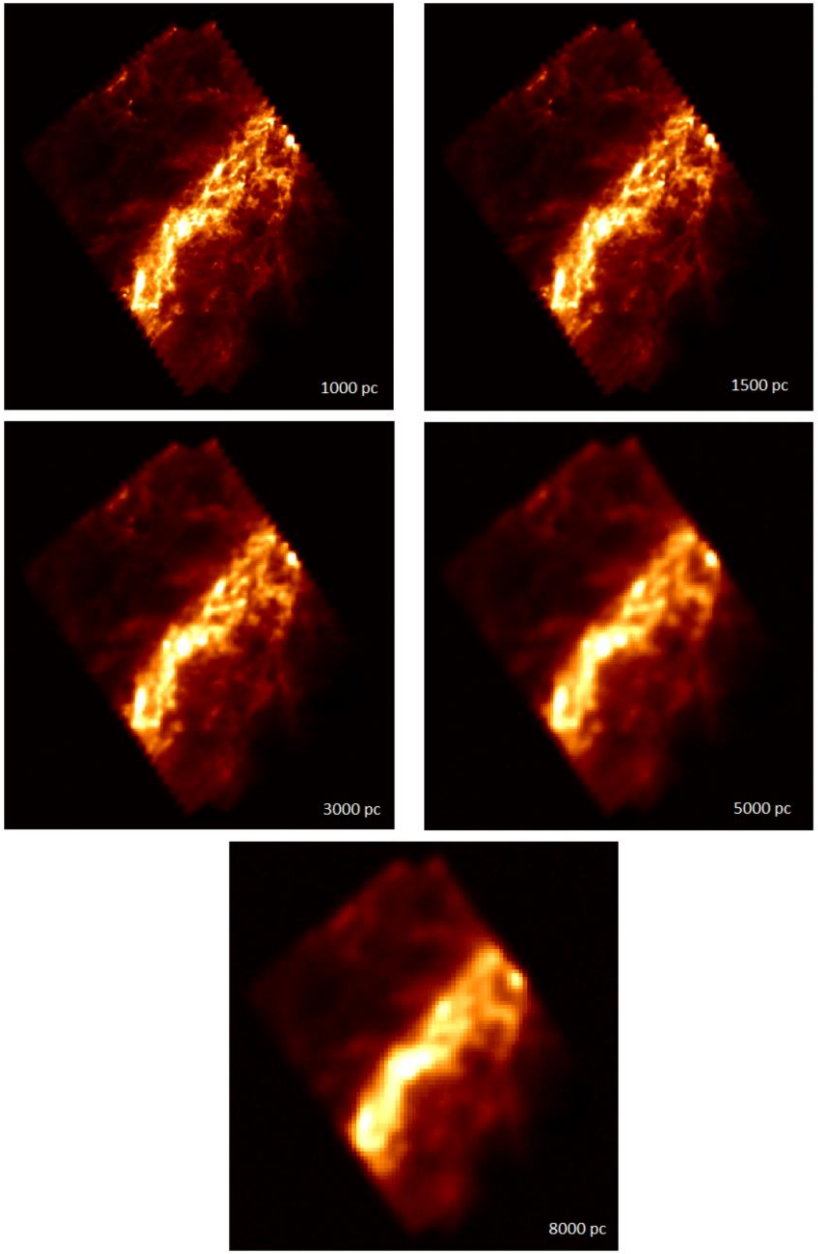
d = 3 kpc



d = 5 kpc

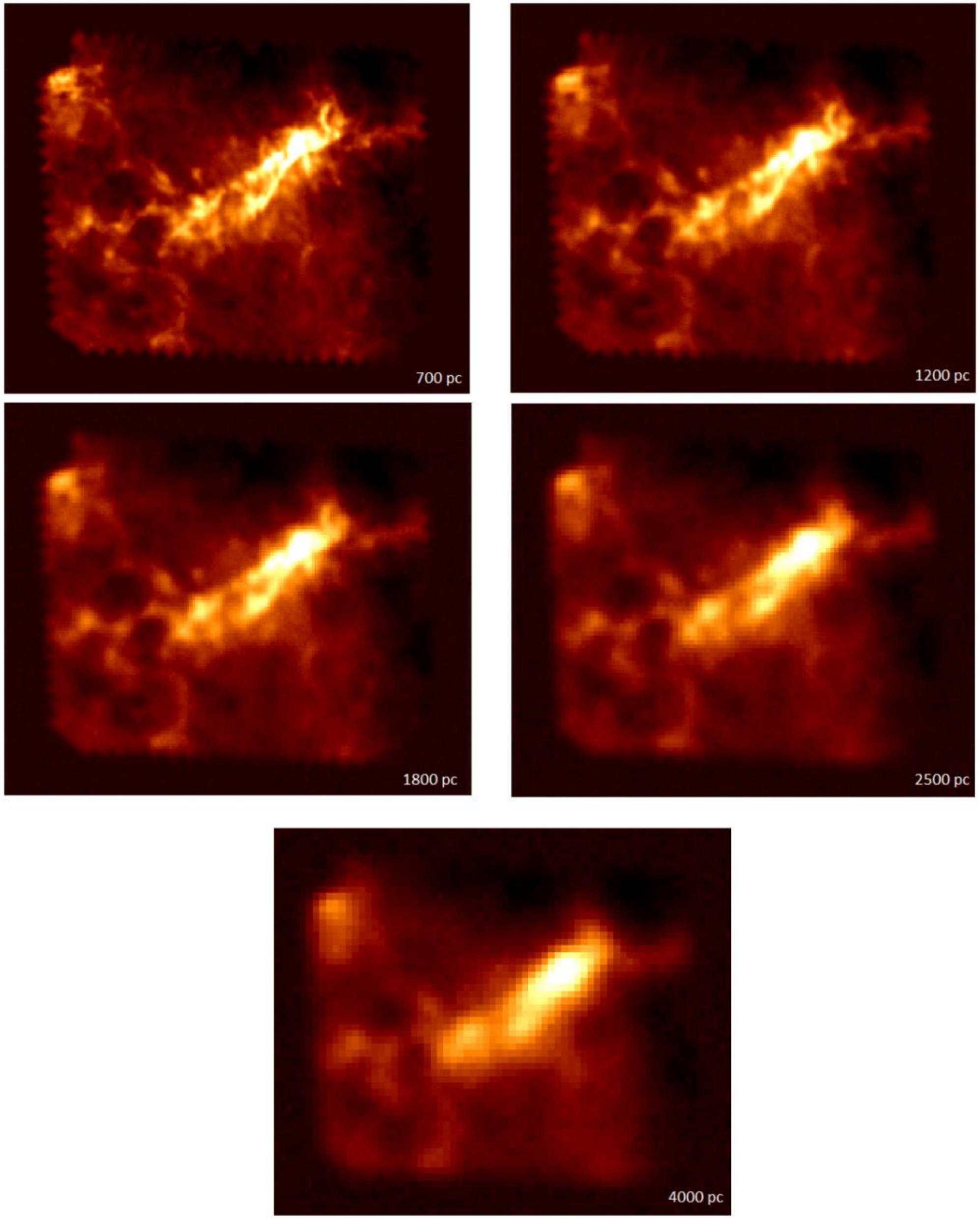



500 pc
1000 pc
3000 pc
5000 pc
7500 pc
+ noise



Orion A

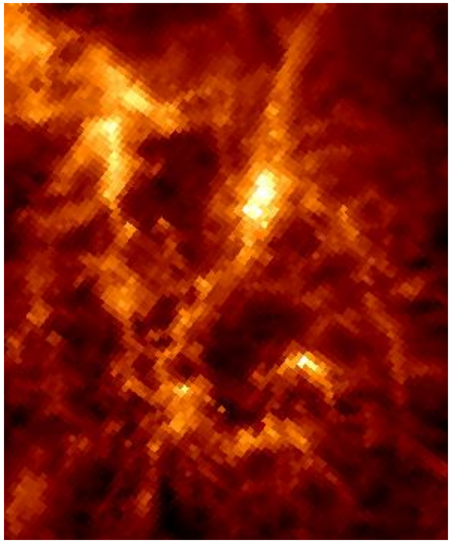
d = 415 pc

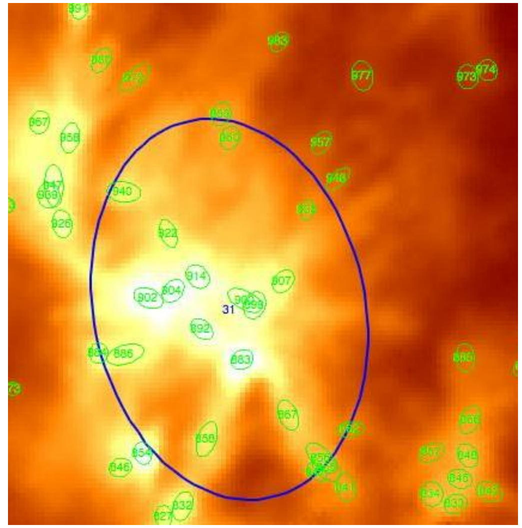


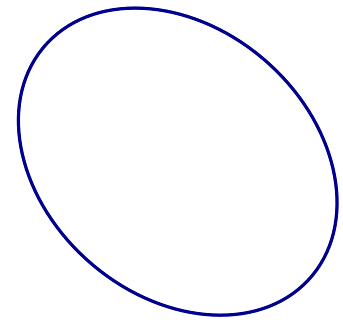
Lupus III

d = 200 pc

d = 5 kpc

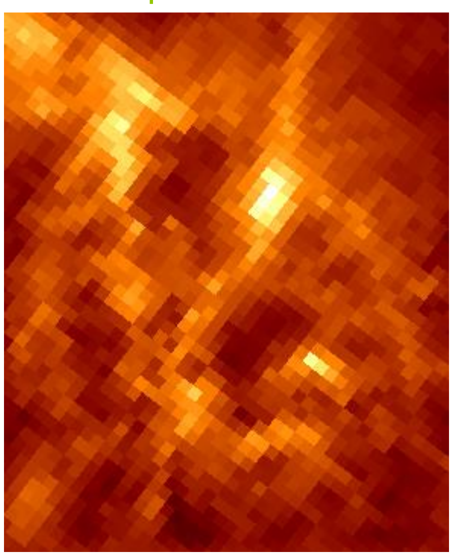


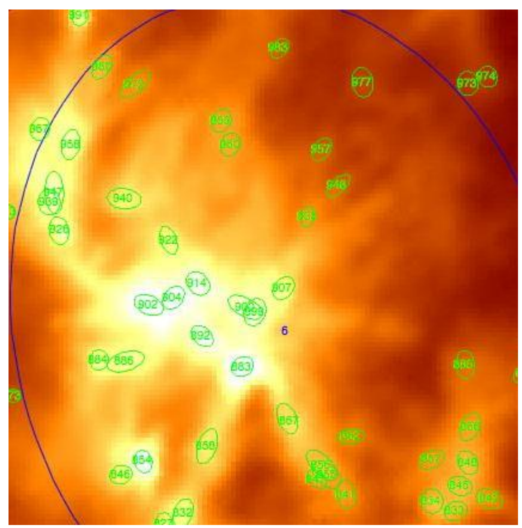




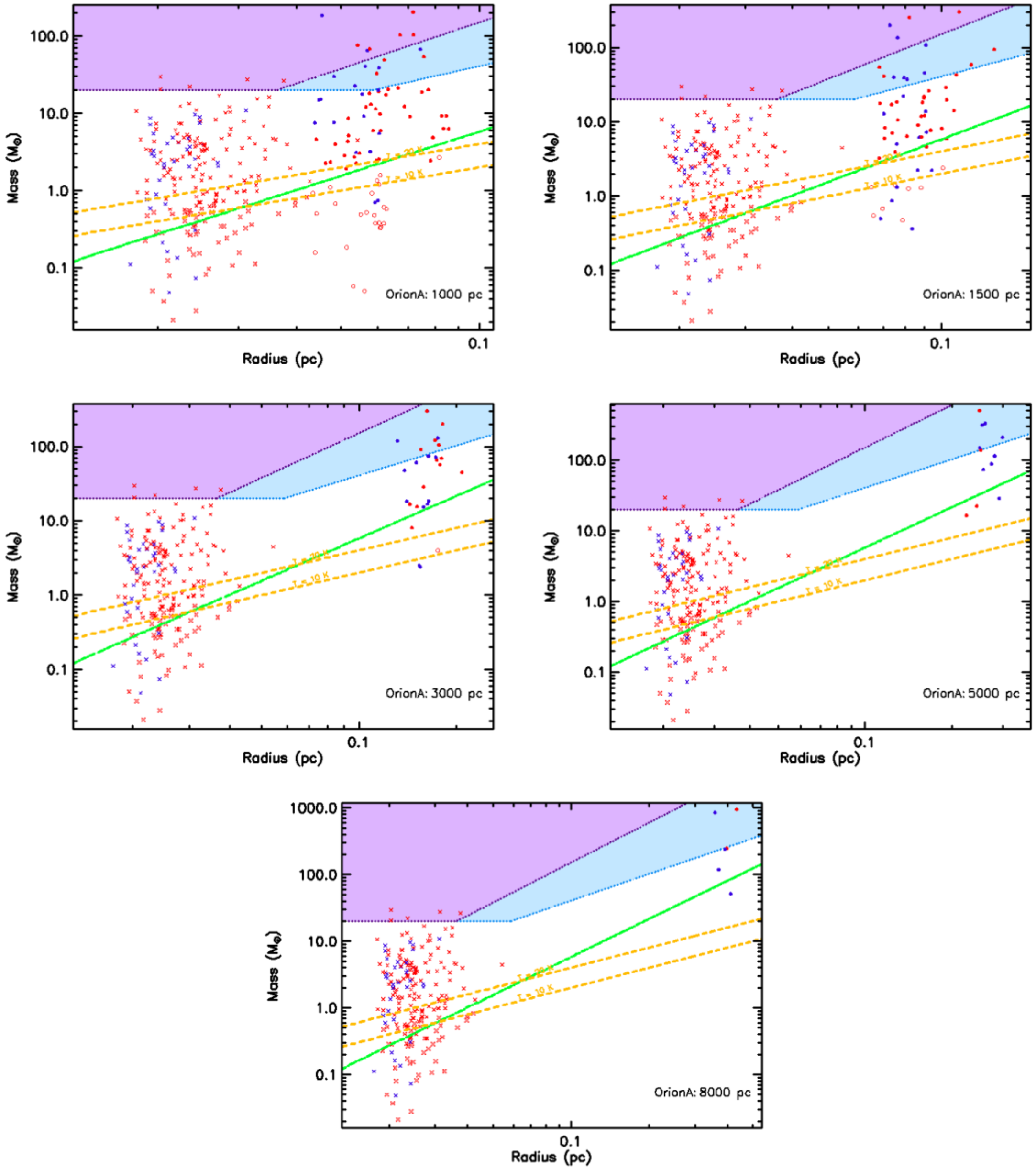
Single source detected in the Herschel “moved away” map

d = 10 kpc





Sources detected n the original Herschel map



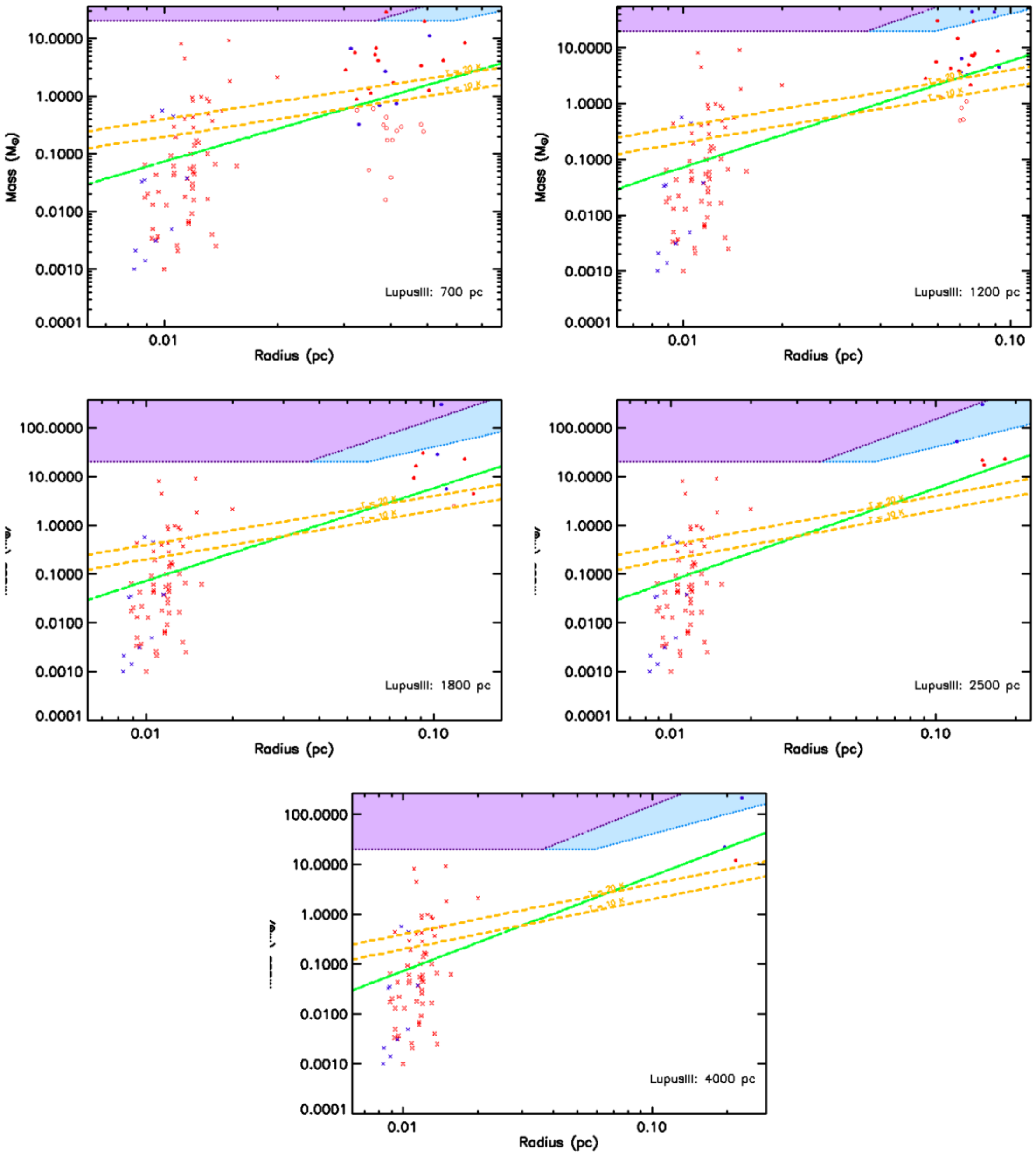
Orion A

M vs *r* relation

Krumholz & McKee 2008

Kauffmann & Pillai 2011

Larson 1981



Lupus III

M vs *r* relation

The ALMA proposal 2013.1.01193.S

Aims:

- Rate of occurrence of fragmentation
  (how many of the selected targets do fragment and in how many cores)
- Relation between clump mass and number of cores
- Relation between clump mass and core separation
  (monolithic collapse vs competitive accretion)

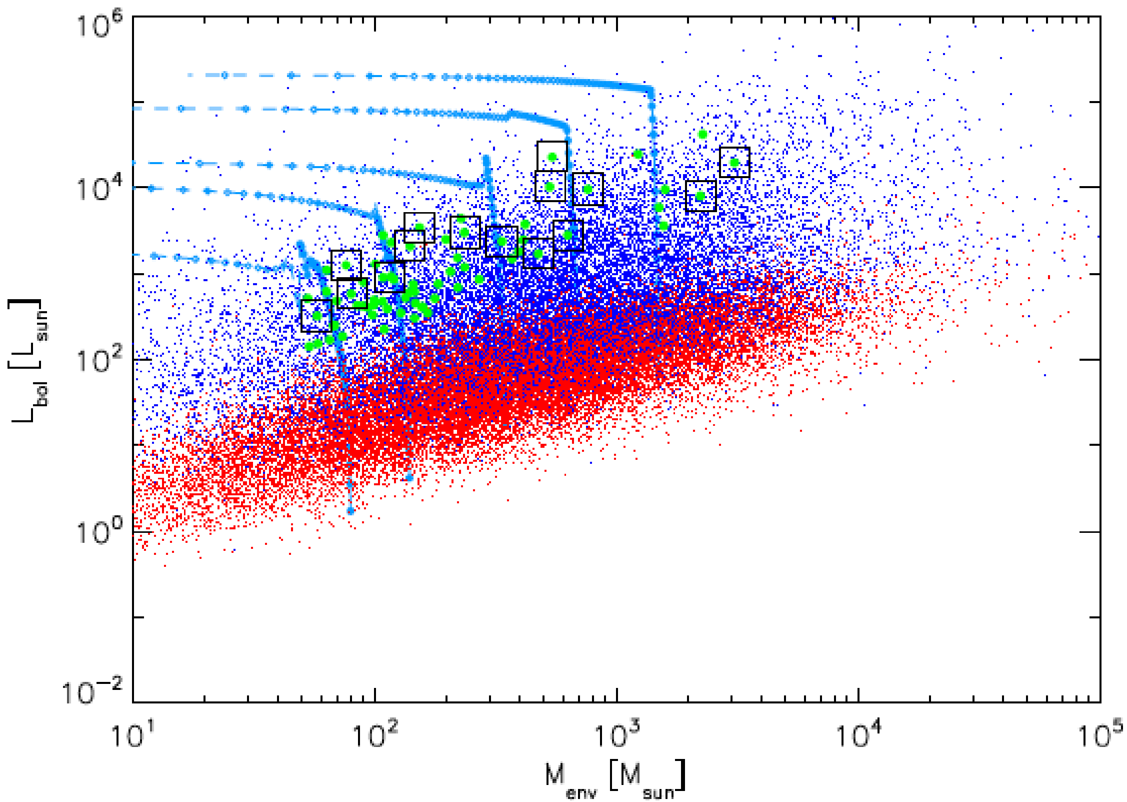
…and also:

- To build a large statistics of masses for building CMFs

Applied filters

Sources were required:

1. To be visible from the ALMA site ($-71° \leq l \leq 20°$)
2. To be already provided with a kinematic distance estimate (therefore to have been already observed in CO)
3. To be in the distance range $2 < d$ [kpc] < 3
4. To have a 70 μm counterpart (i.e. to be considered protostellar)
5. To have $M > 50\ M_{\odot}$
6. To have $2 < L_{bol}/M_{env}$ [$L_{\odot}/M_{\odot}$] < 100



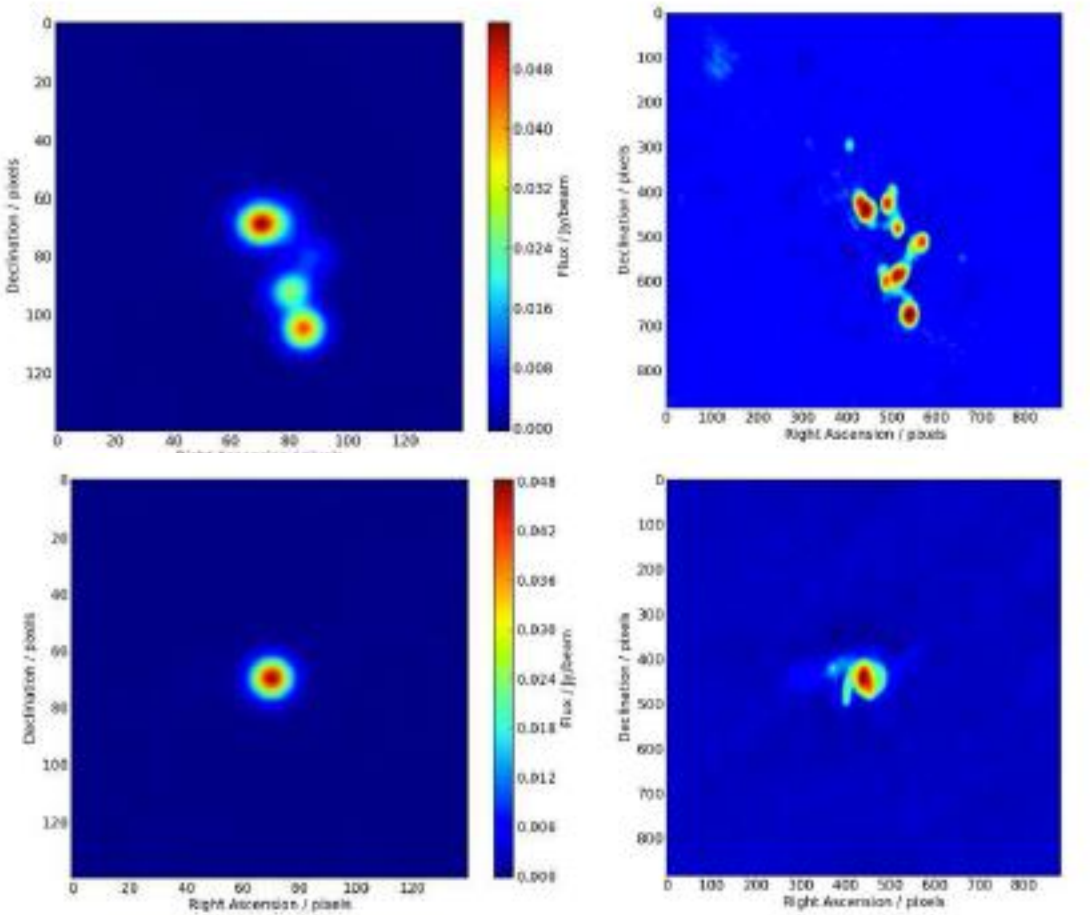
68 targets were selected in this way, 15 of which host methanol masers (the criterion 6 ensures that the other ones are in a similar evolutionary stage).

12 hrs of total observing time were asked.

Today the Hi-GAL sources fulfilling the same criteria would be 164

The most compact configuration:
max baseline
of ~ 160 m

The most extended configuration:
max baseline
of ~1.5 km
in Band 3,4,6,7



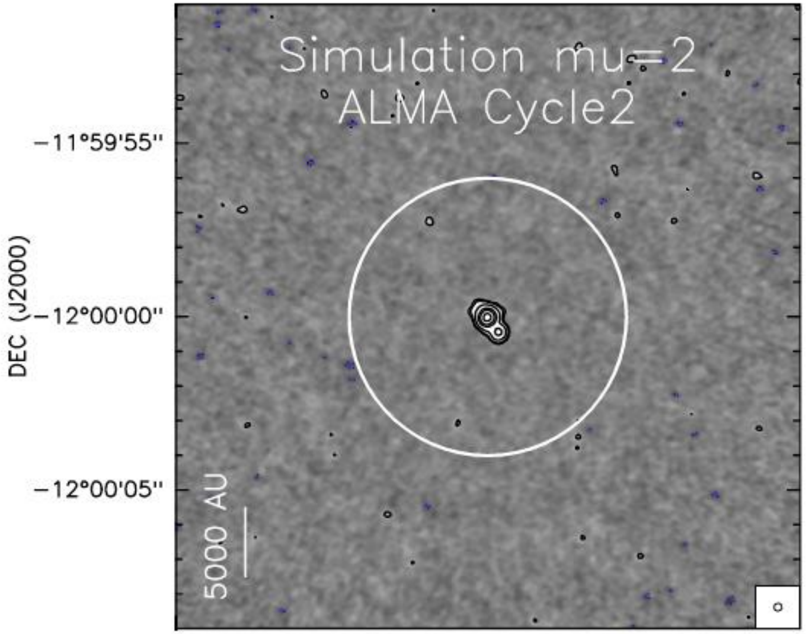
Non-magnetized
(μ = 130)

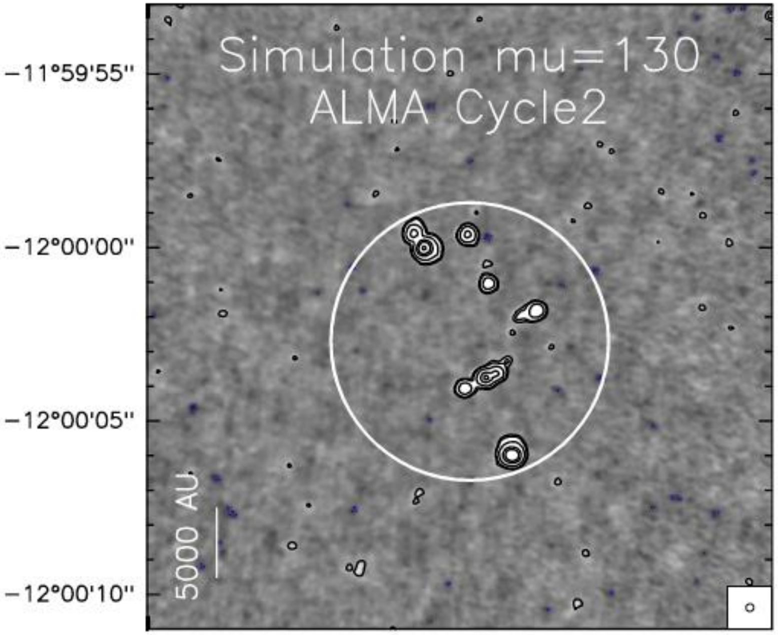
Magnetized
(μ = 2)

Simulations a the most extended configuration:
0.4 M at 3 kpc correspond to
0.2 mJy/beam at 3σ, reached in t_{int} ~ 5 min

Magnetized
(μ = 2)

Non-magnetized
(μ = 130)





Both cases would turn out to be unresolved by Herschel-PACS @ 70 μm

In conclusion…

The Hi-GAL catalog represents a huge reservoir of candidates for studying high mass star formation with ALMA, finally providing a meaningful statistics.

Meanwhile, to do the inverse process (to move Herschel maps to distances larger than the original one) can be helpful, e.g. for better identifying ALMA candidates…