AS-ALMA

The importance of high angular resolution to understand the formation of massive stars

D. Russeil, J. Tigé, A. Zavagno + HOBYS consortium

LAM - Université d'Aix-Marseille - CNRS

The Context

The massive star formation problem !

Radiation pressure => stop further accretion !

The monolithic collapse of a massive cloud fragment supported by supersonic turbulent pressure (e.g. Mc Kee & Tan, 2002)

A high accretion rate expected !

-> Increasing accretion rate in turbulent cores, accretion via disks, escape of radiation through wind-blown cavitities ...
(e.g. Yorke and Sonnhalter 2002, Krumholz and Tan 2003 , Krumholz et al. 2005 ...)

Or new views:

- The coalescence scenario : high (~10^8 pc^{-3}) protostellar/stellar density of a forming cluster + collisions and merging (e.g. Bonnel et al. 1998)

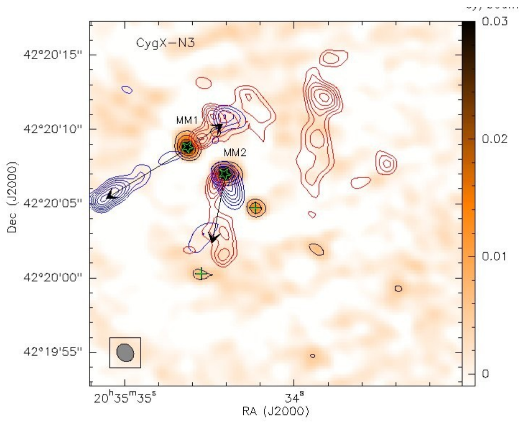
- The competitive accretion in a clustered environment (Bonnel et al. 2004)

Observations: search, find and study
the earliest phase of the massive star-formation

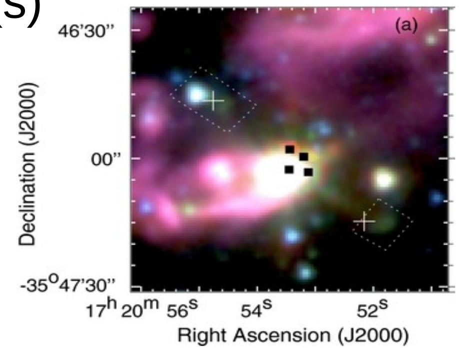
<u>**Observationnal Evolutionnary sequence**</u>:

1) High mass starless core --> no activity

2) High mass core harboring accretion/outflow
--> Molecular lines (SiO, HCO^+, CO, ...)



3) High mass protostellar object --> HII region/radio source, Maser, Spitzer-IRAC YSOs, 24µm and/or 70 µm point source(s)



Spitzer three-color composite image
3.6, 4.5, and 5.8 (blue, green, red)

4) Final stars --> classical OB stars + HII region

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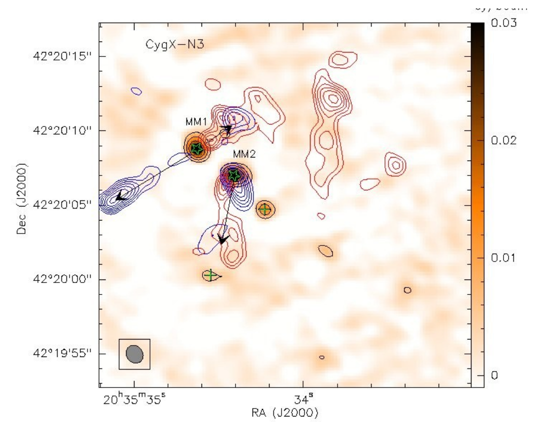

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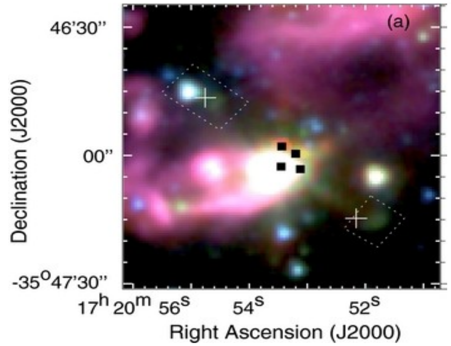

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The data

The Herschel HOBYS survey

- Target all molecular cloud complexes forming OB-type stars at dSun < 3 kpc
- Wide-field PACS/SPIRE imagings (70, 160, 250, 350, 500 μm) with 20''/sec

HPBW = 6''-36.9'' @ 0.7-3 kpc -> down to 0.03-0.2 pc dense cores

⇒ census of intermediate- to high-mass protostars

⇒ link between cloud structure and (high-mass) SF

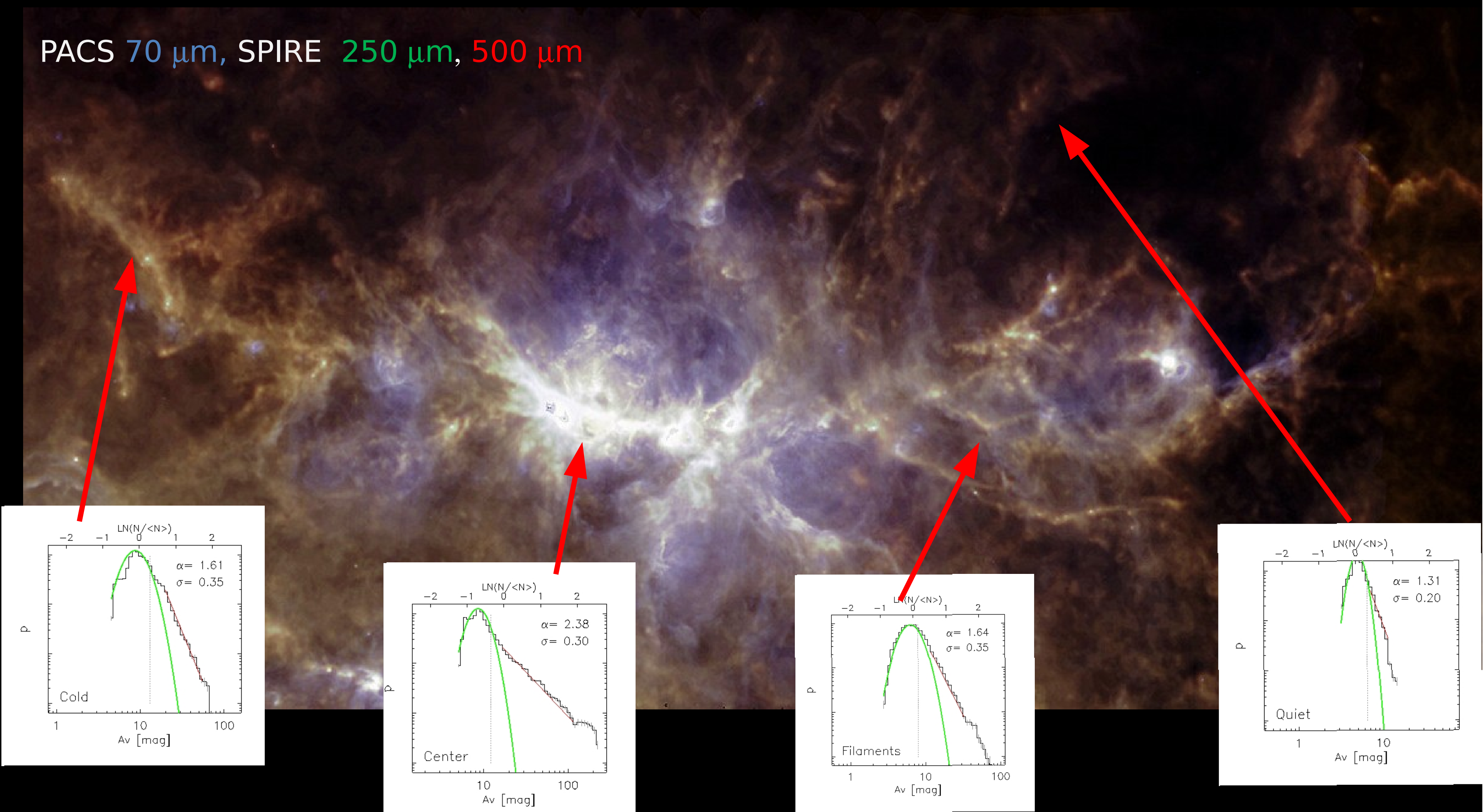
⇒ feedback effects

- Complementary to other *Herschel* KPs:
  - high-mass dense cores (small and isolated clouds) - EPOS (Krause et al.)
  - low-mass cores (~0.02 pc) – HGBS, Cold Cores and HOPS survey (André et al.; Juvela, Ristorcelli et al.; Megeath et al.)
  - protoclusters (~1 pc clumps) - Hi-GAL (Molinari et al.)

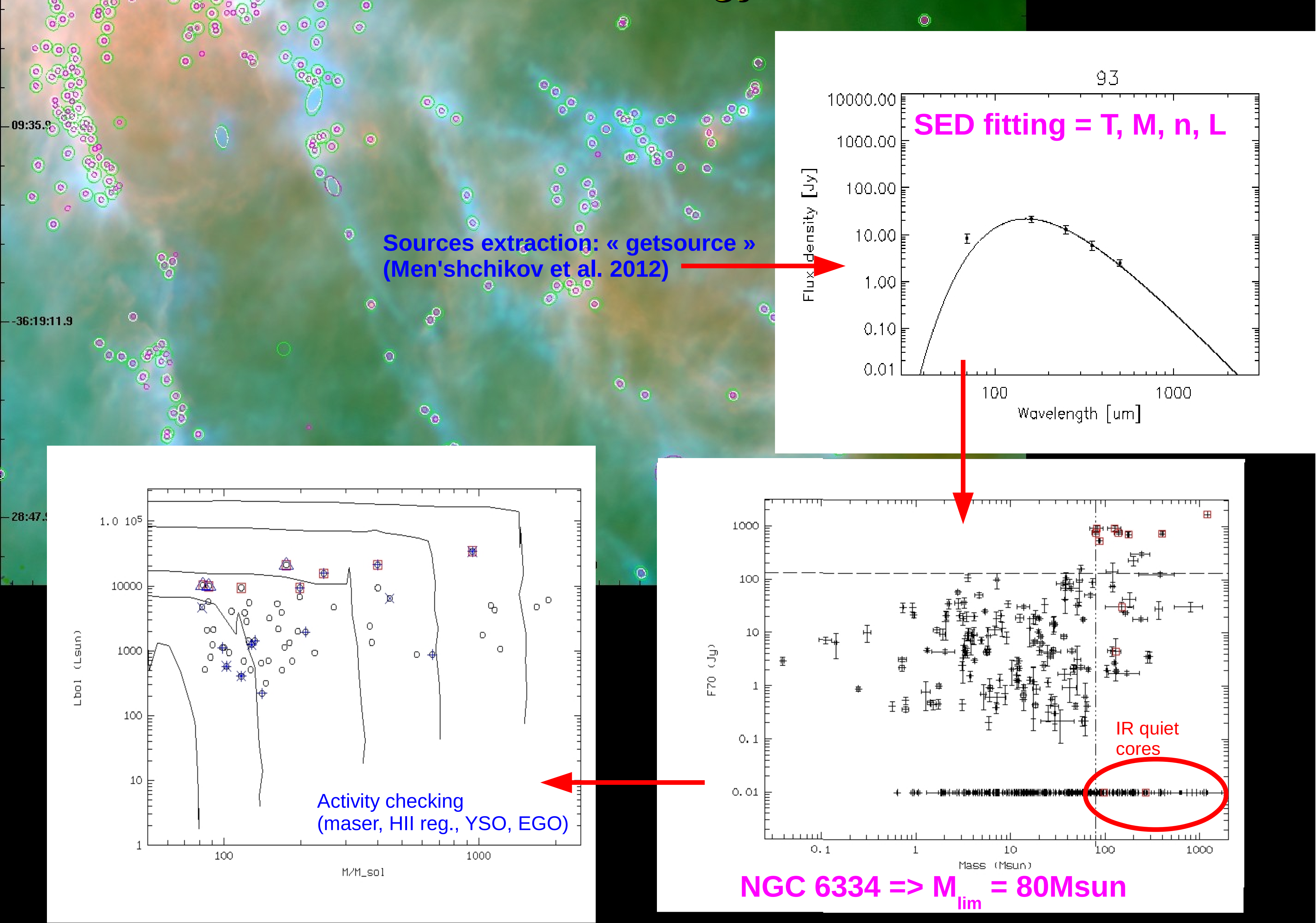
Massive star formation in NGC6334
(d ~ 1.7 kpc – core size 0.05 – 0.3 pc)

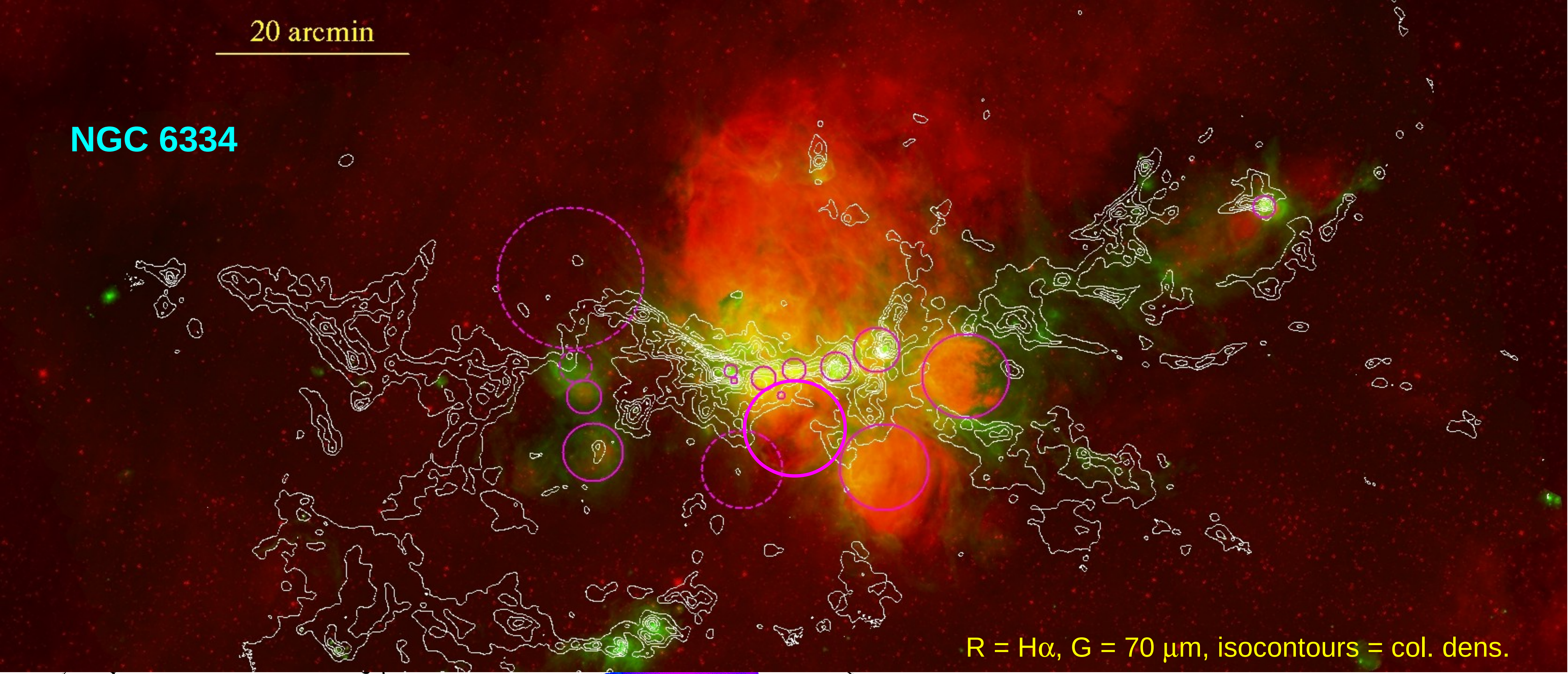
- Study of the earliest phase of the massive stars formation: Tigé et al. in preparation

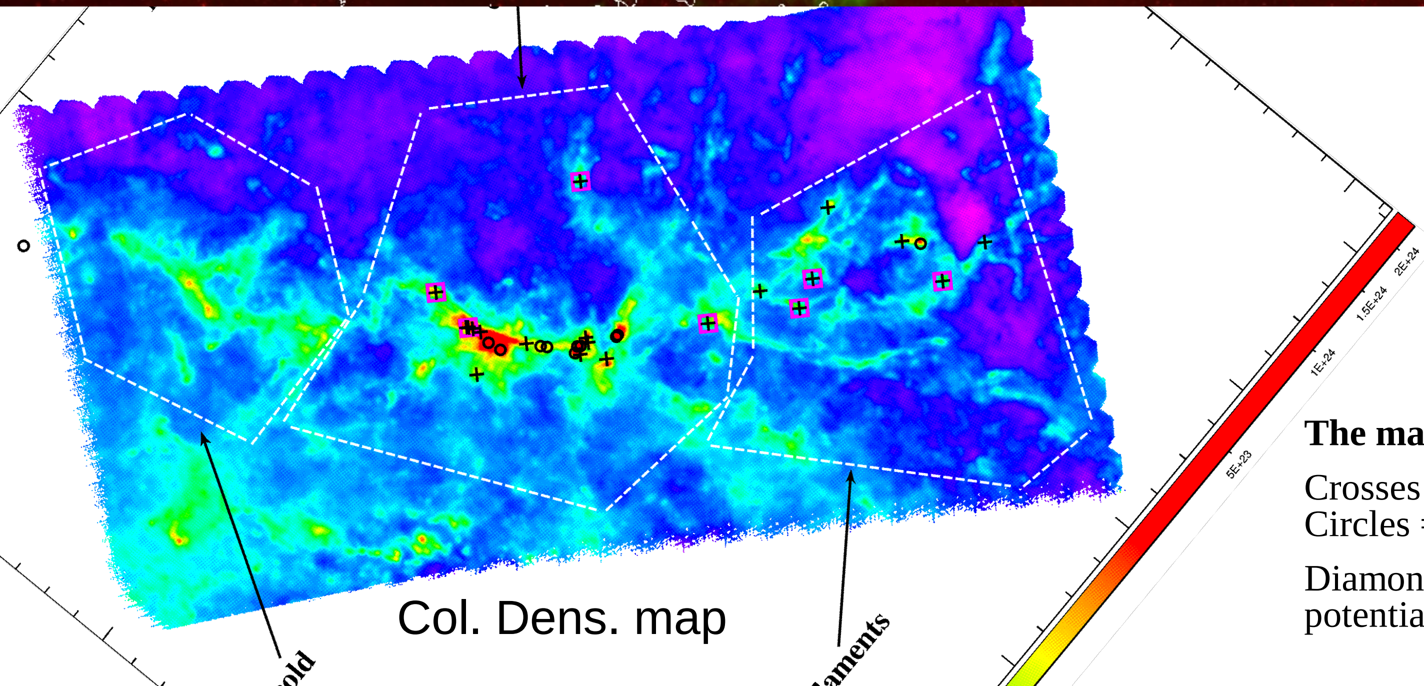
- Study of the filamentary structures: Probability density function
=> different evolutionnary status across the region (Russeil et al. 2013)



Selection strategy







Circles = radio sources / HII reg.
Dashed circles = SNR ?

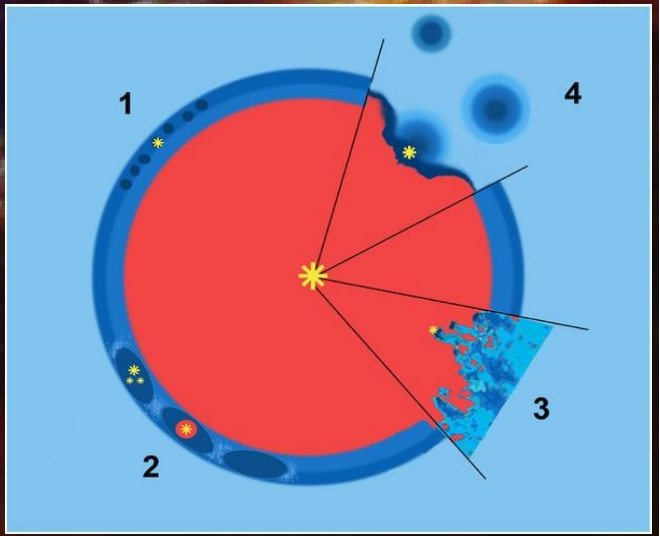
See J. Tigé for details

The massive dense cores (M ≥ 80 M⊙)

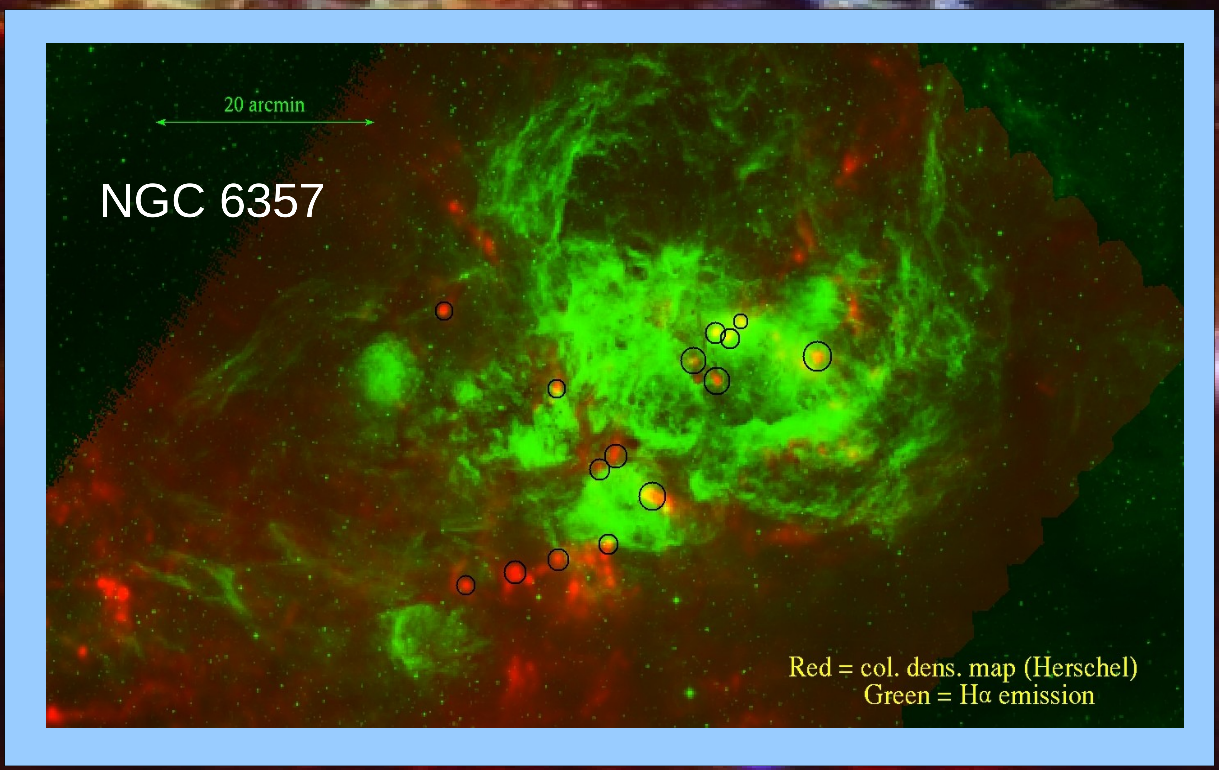
Crosses = F70μm < 132 Jy
Circles = F70μm ≥ 132 Jy

Diamonds = quiescent massive dense cores, potential progenitors of high mass stars

- Massive dense cores: in filaments/ridges + HII region border
- Few massive starless cores
- Importance of the HII regions: trigerred star-formation
- Comparison with MDCs in NGC 6357 powered by Pismis 24



Deharveng et al. 2010

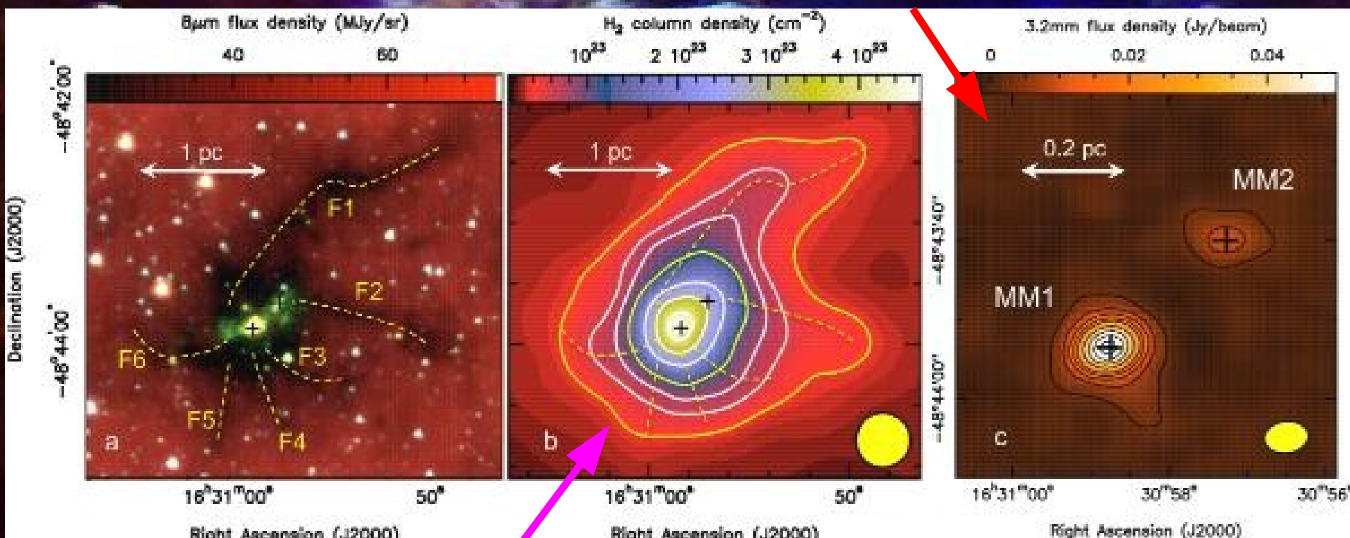



Why high spatial
resolution ?

Fragmentation and local kinematics

Peretto et al. 2013
IRDC SDC335

Two cores identified from **ALMA 3.2 mm dust continuum** emission.



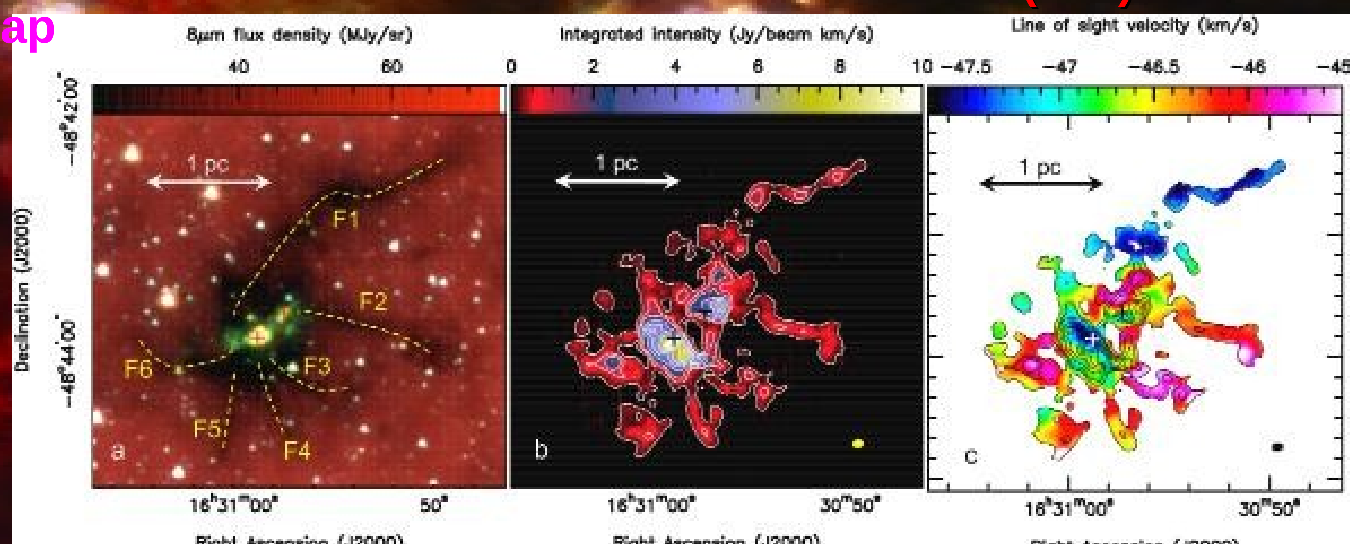
+ CMF – IMF link

+ systemic velocity
+ line width
+ core stability
+ rotation ?

Herschel col. Dens. map

ALMA N2H+(1−0)

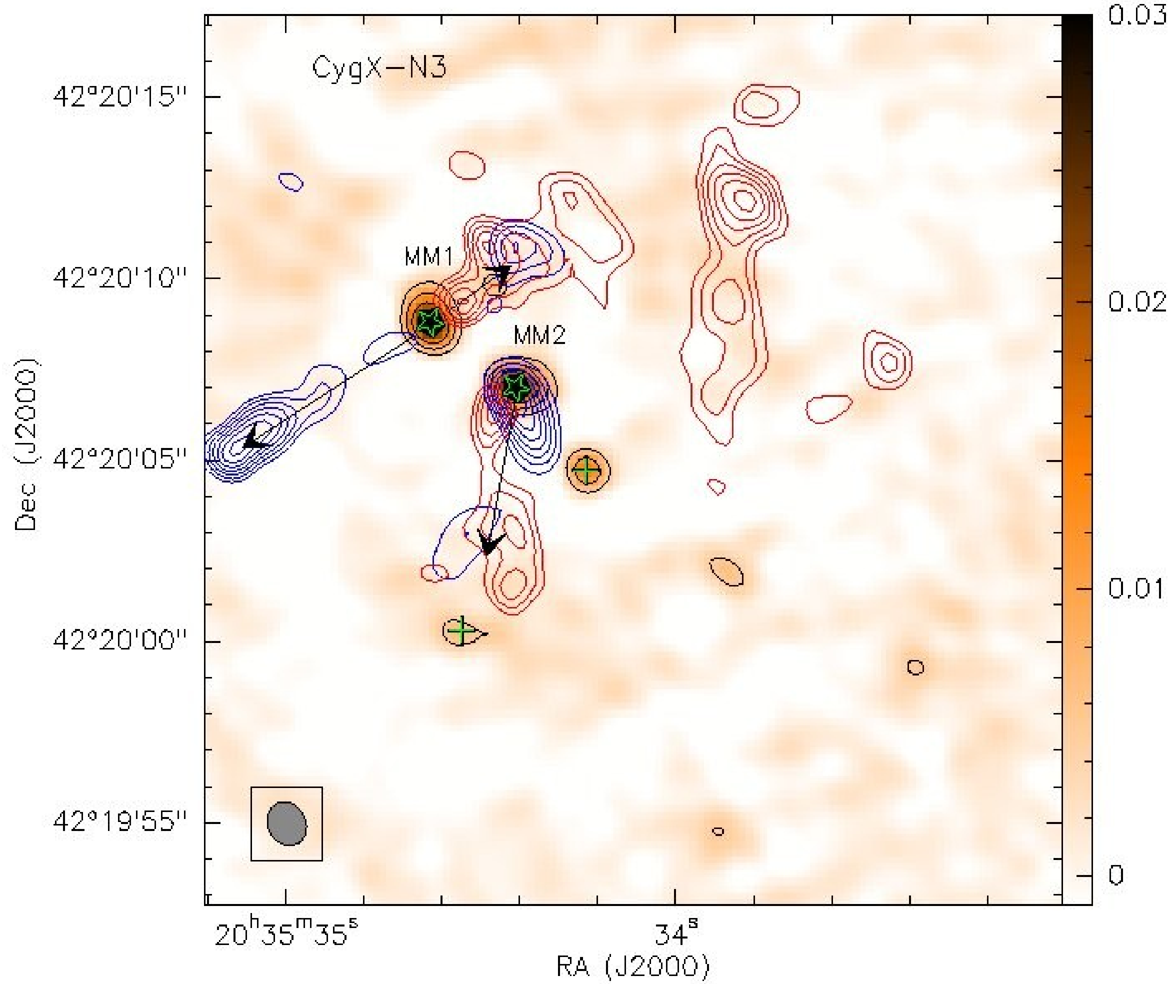
Feeding of the core
by filaments



Outflows : identification and characterisation

Duarte-Cabral et al. 2013
MDCs in Cygnus X

PdBI 1.2mm continuum and CO line

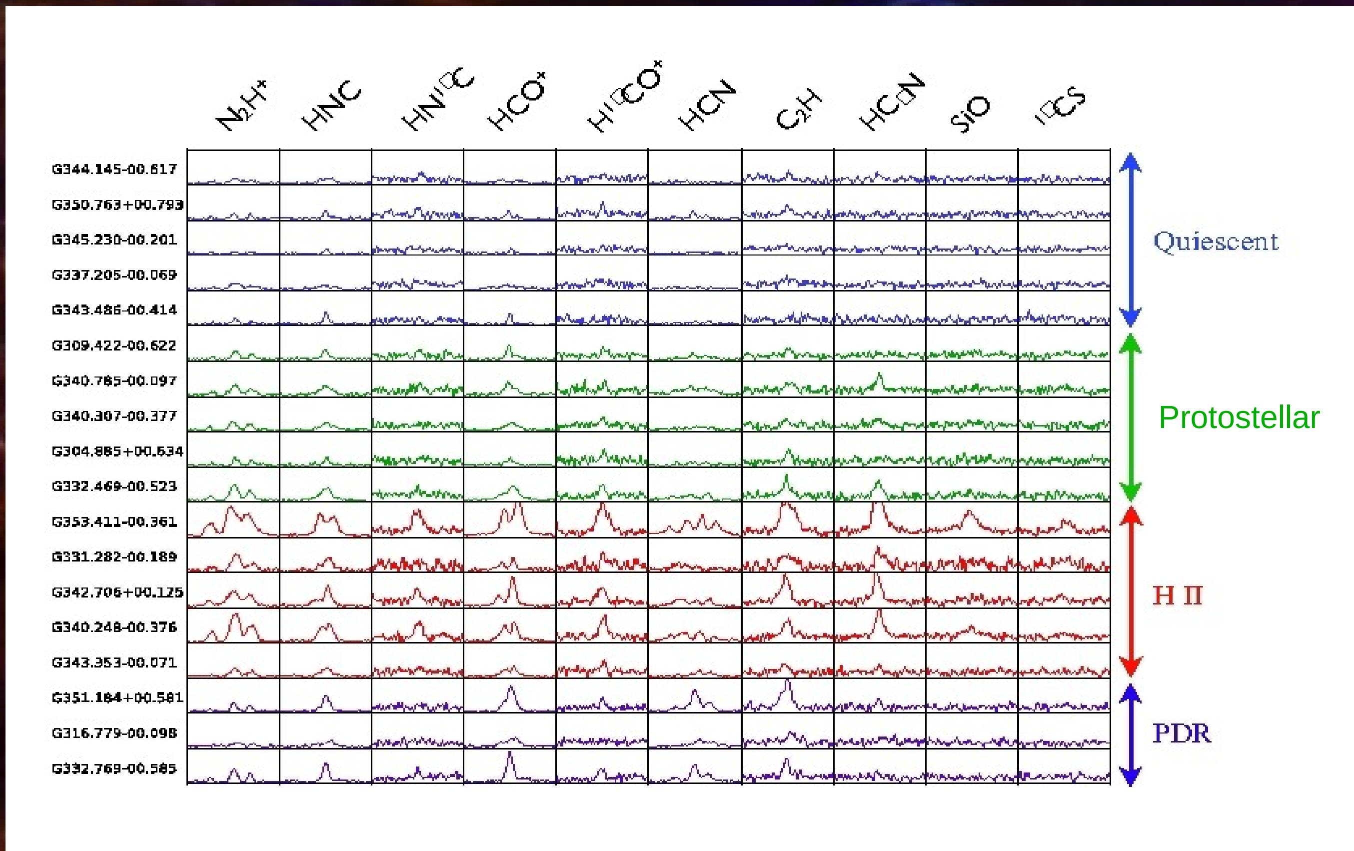


$$F_{co} \propto \dot{M}\, acc$$

Fco = momentum flux = Msun km/s yr^{-1}

Chemical composition

Foster et al. 2013



H_2O, Herschel obs.

=> good tracer of high-mass protostellar environment (accretion/outflow)

=> line profile change with time

NH_2D, Pillai et al. 2011

=> good tracer of cold and dense gas

=> destroyed in protostellar cores

Chemical abundance => core evolution

Conclusions

- HOBYS regions:
  - Both south and north -> ALMA + PdBi
  - Already existing low resolution molecular data (MOPRA, MALT90)
    - -> general kinematic

- Galactic plane HiGAL survey:
  - Selection of massive dense clumps on Galactic scale
  - Arm-inter-arm, inner-outer disk

- Caracterisation of the massive dense cores:

  -> A « large number » for statistic

  -> Different location in our Galaxy

  -> Different environment (HII regions, filaments)

  -> Different evolutionnary stage