Impact of ionization compression on star formation

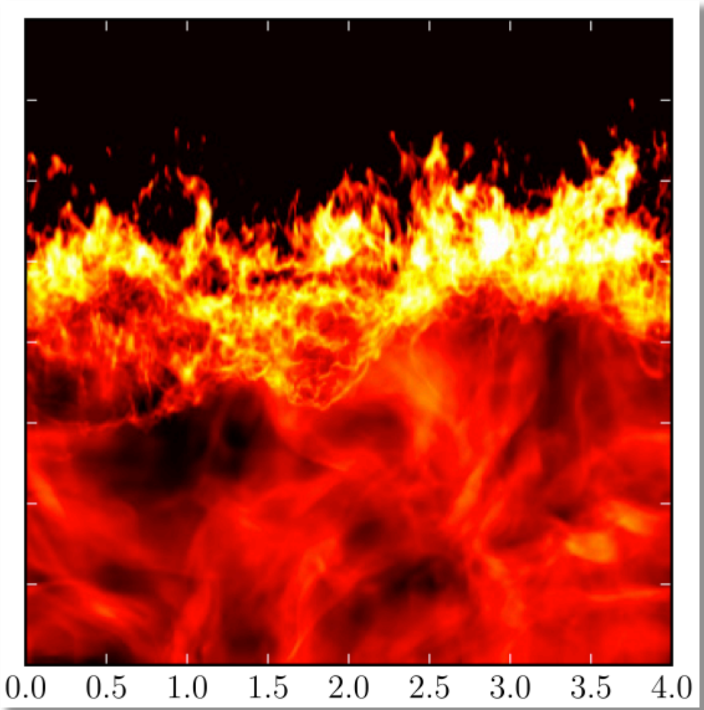
P. Tremblin, N. Schneider, V. Minier, F. Motte, E. Audit (CEA Saclay)
+ HOBYS Key program
(Herschel imaging survey of OB Young Stellar object)

- How do feedback processes regulate star formation?
- Do they trigger the formation of new stars?
- Is it important to take it into account to understand the IMF?

- Here feedback is ionization from massive stars
- But most of the results can be generalized for any kind of feedback

- What is ionization and compression from ionization ?

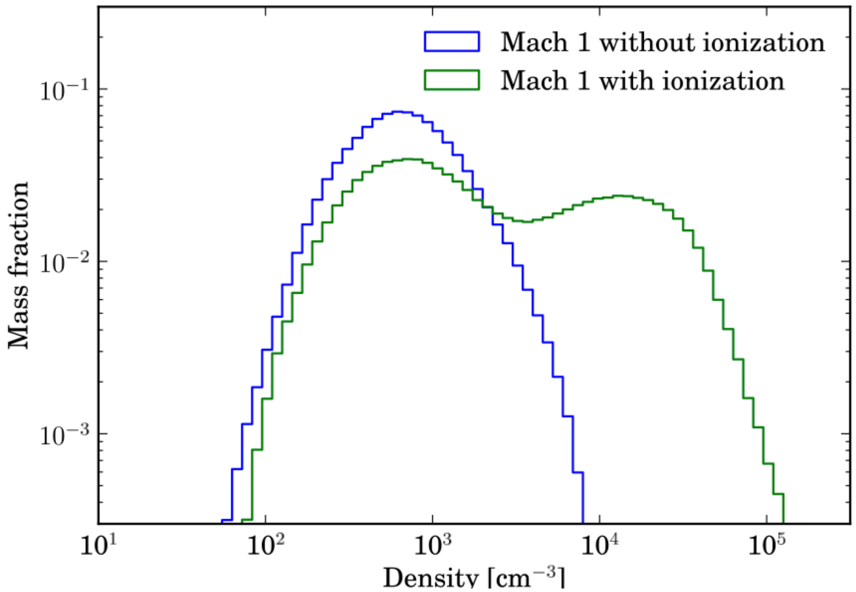
Eagle Nebula (Hill et al. 2012) HOBYS

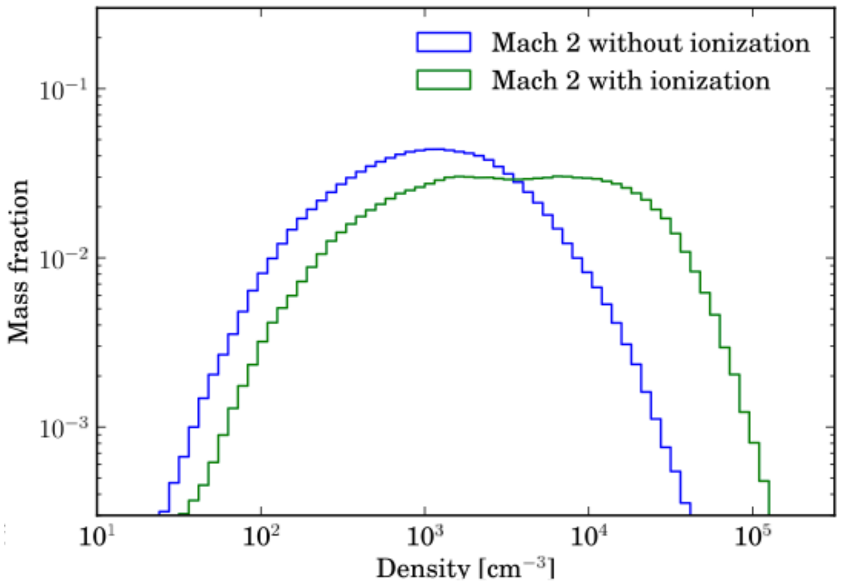


Turbulent-ionized simulation (Tremblin et al. 2012)
HERACLES code

Other examples:
- Previous talk by A. Zavagno, NGC6334 D. Russeil P68
- RCW36 bipolar nebula V. Minier P78

➢ How do we see the compression from ionization ?





Turbulent-ionized simulation (no gravity)
(Tremblin et al. 2012)

➢ Double-peaked or enlarged PDF of the gas

- What is the shape of the second component ?

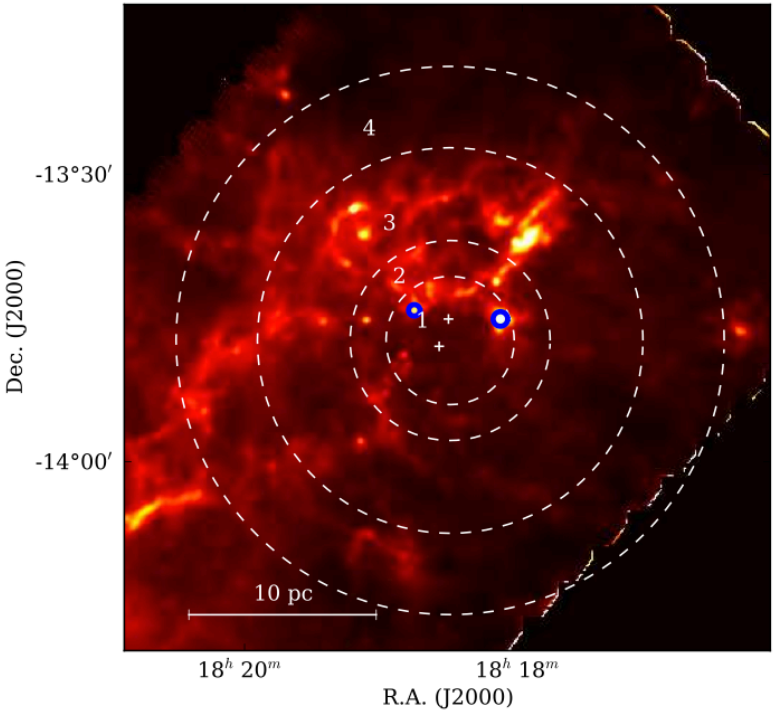
  - If the turbulence is important in the compressed layer: lognormal shifted at higher densities by the square of the Mach number of the driven shock

  - If the turbulence is low in the compressed layer: it is homogeneous and you expect a power-law profile in the PDF (similar to the power-law in a PDF of a spherical collapsing clump)

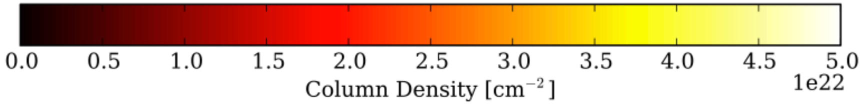
Unperturbed turbulent cloud	Compressed layer	Influence of gravity
Lognormal at low column densities	Lognormal (turbulent) or Power-law (homogeneous)	Power-law at highest column densities

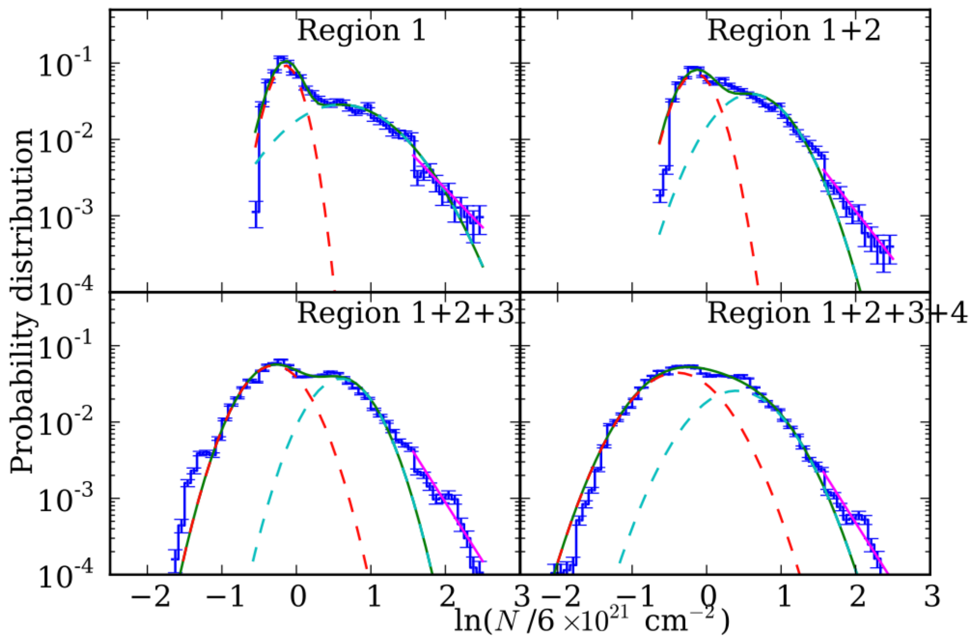
More details about column density PDF in the previous talk by N. Schneider

- ➢ Do we see it in observations ? Herschel column densities



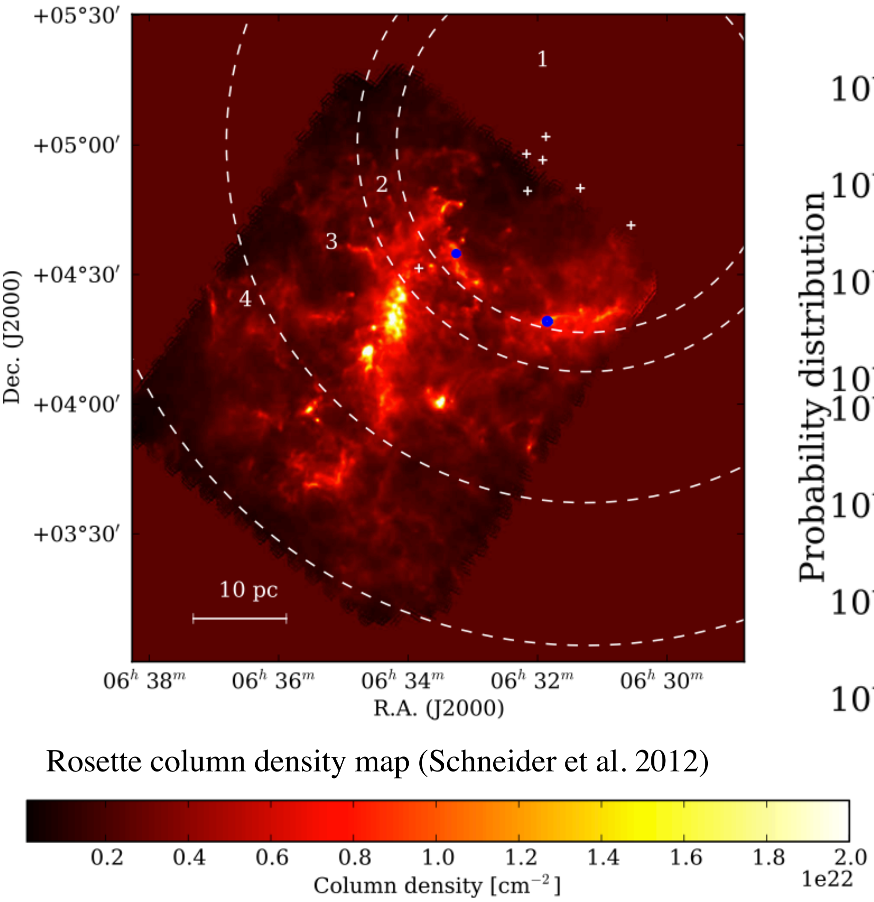
M16 column density map (Hill et al. 2012)



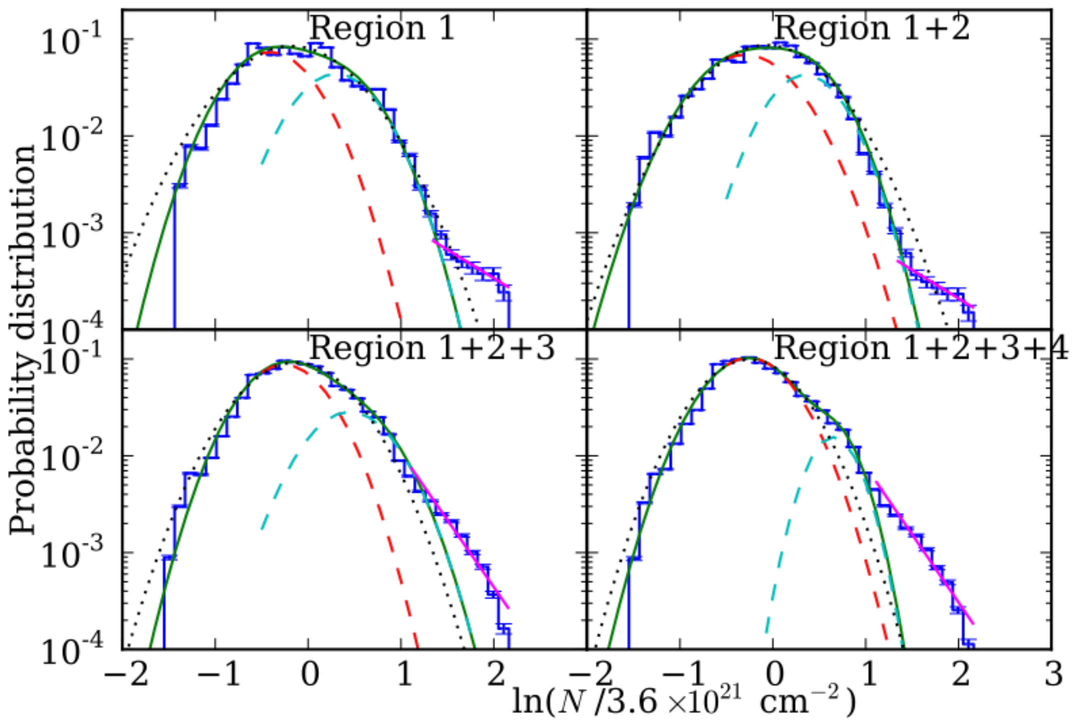


Tremblin et al (submitted)

➢ Is a two-lognormal fit better than a single one for enlarged distribution ?



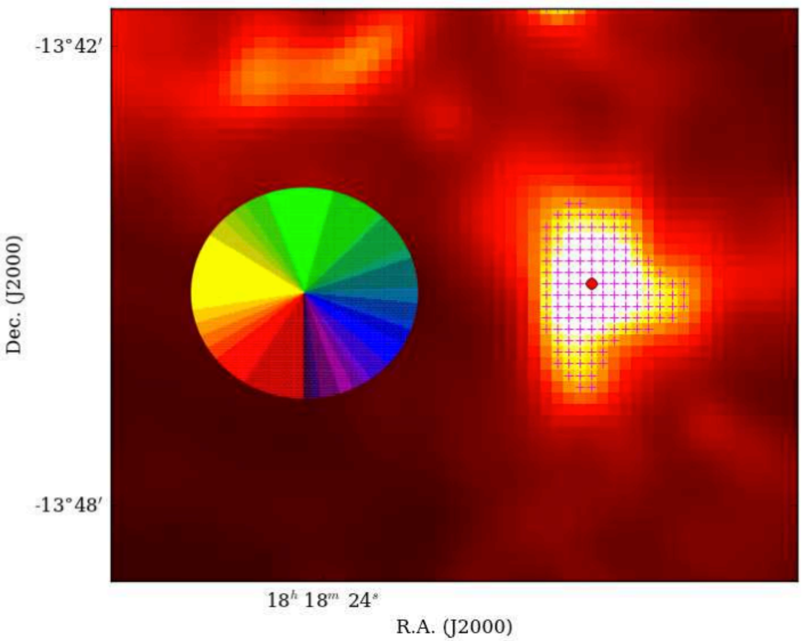
Rosette column density map (Schneider et al. 2012)



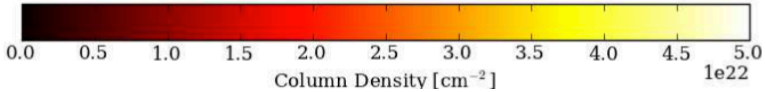
Tremblin et al (submitted)

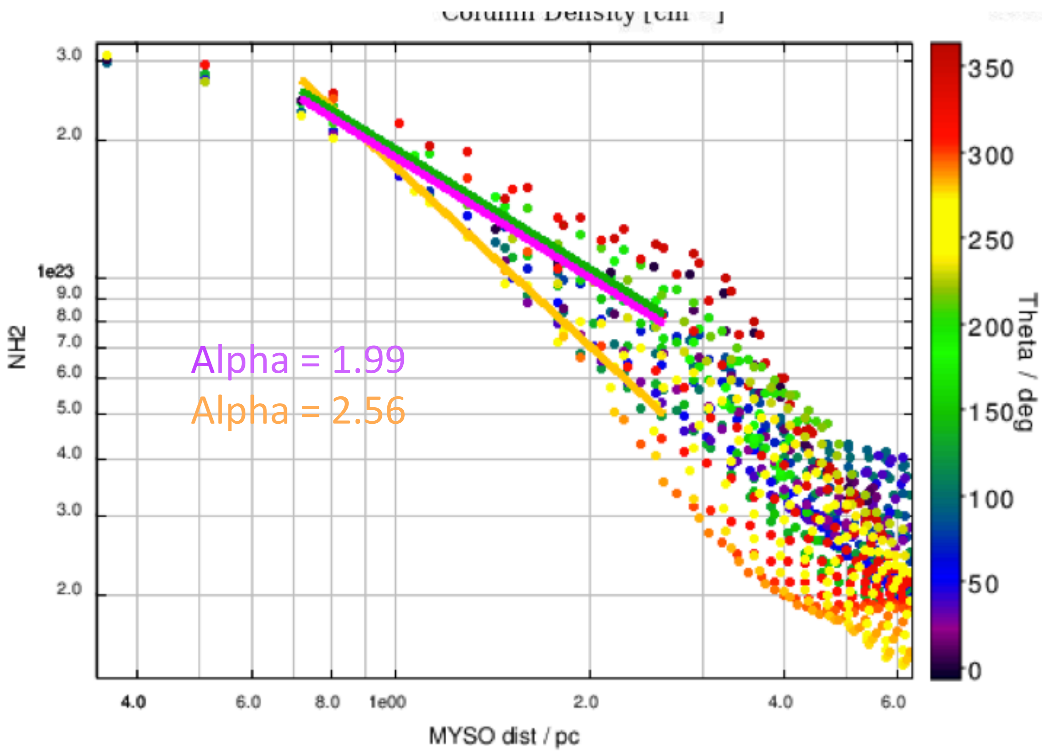
- Also small scale compression !

Steeper radial profile: distinguish between forced-fall and free-fall collapse

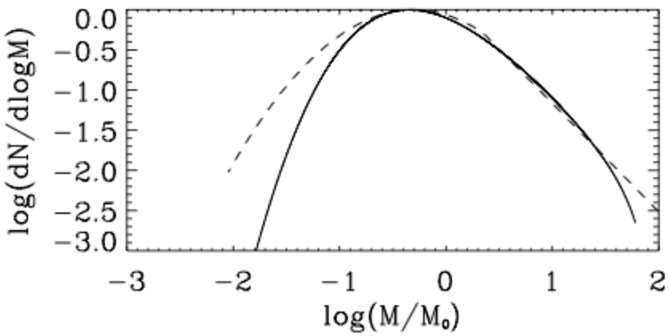


Massive YSO in M16



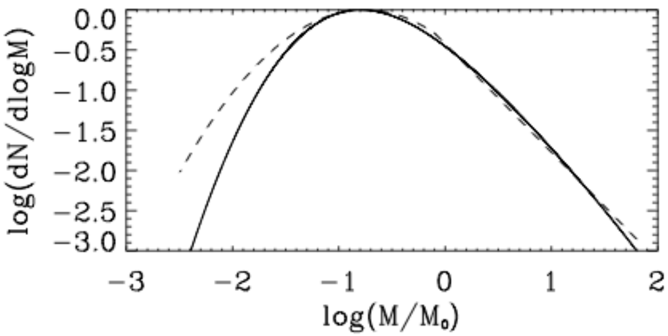


See also Russeil et al. 2013

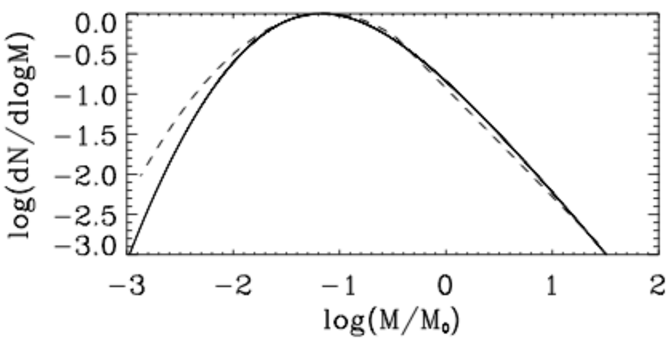


Mach 6

- ➢ Important for the understanding of star formation and the IMF?

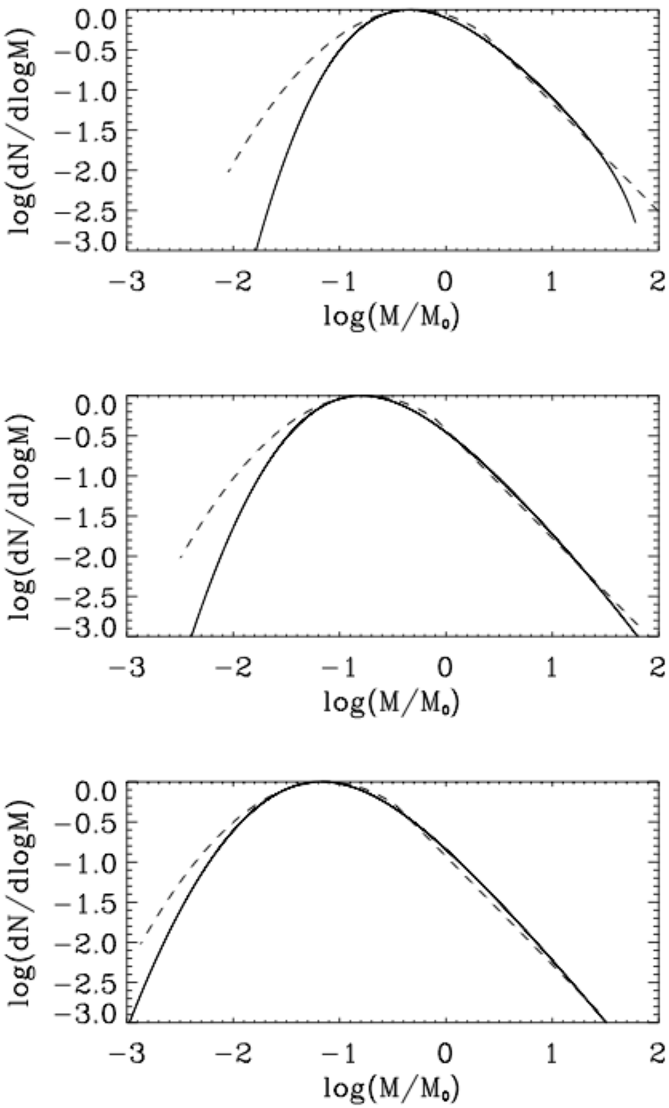


Mach 12



Mach 25

Hennebelle & Chabrier 2008



Mach 6

Mach 12

Mach 25

Hennebelle & Chabrier 2008

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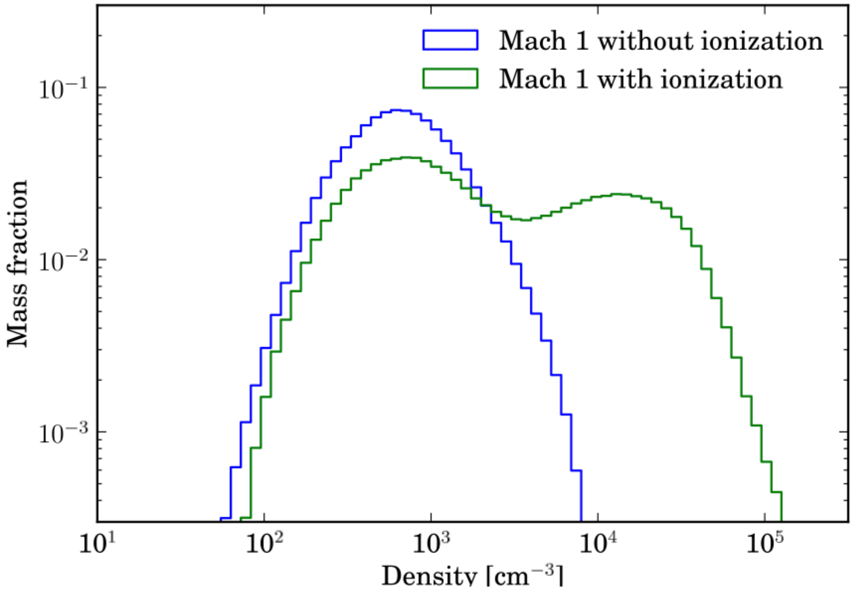
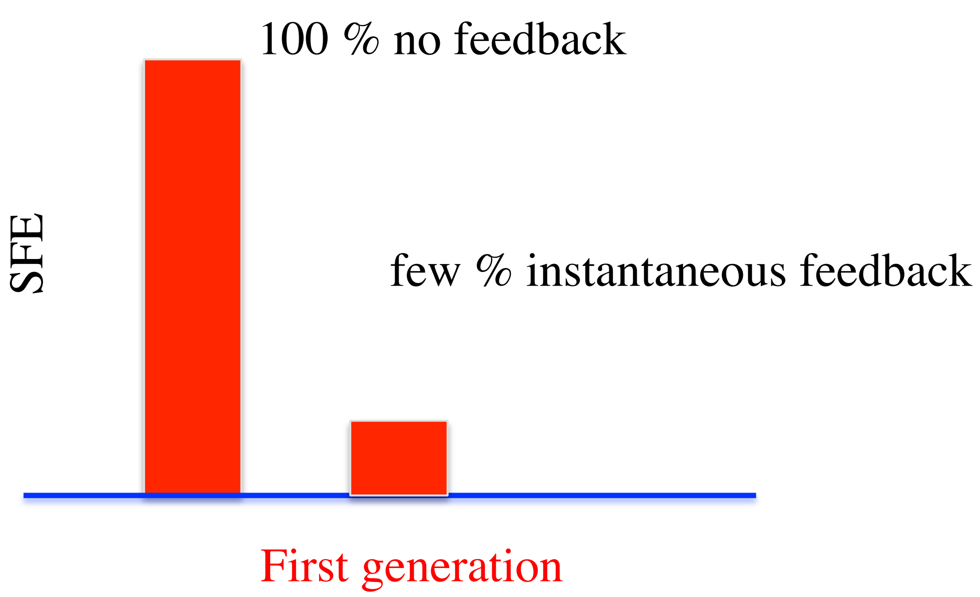


- Feedback compression can enlarge PDF while keeping a realistic turbulent level for the cloud

➢ Regulation of star formation, Positive or negative feedback ?

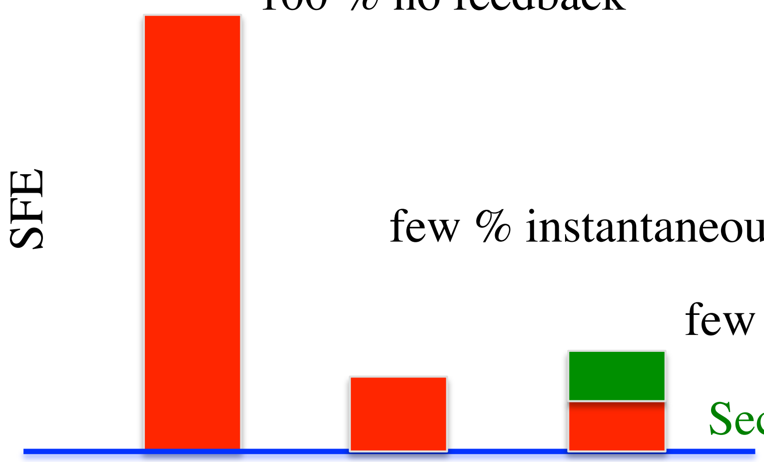
Large-scale message : you need feedback to remove your gas and stop star formation



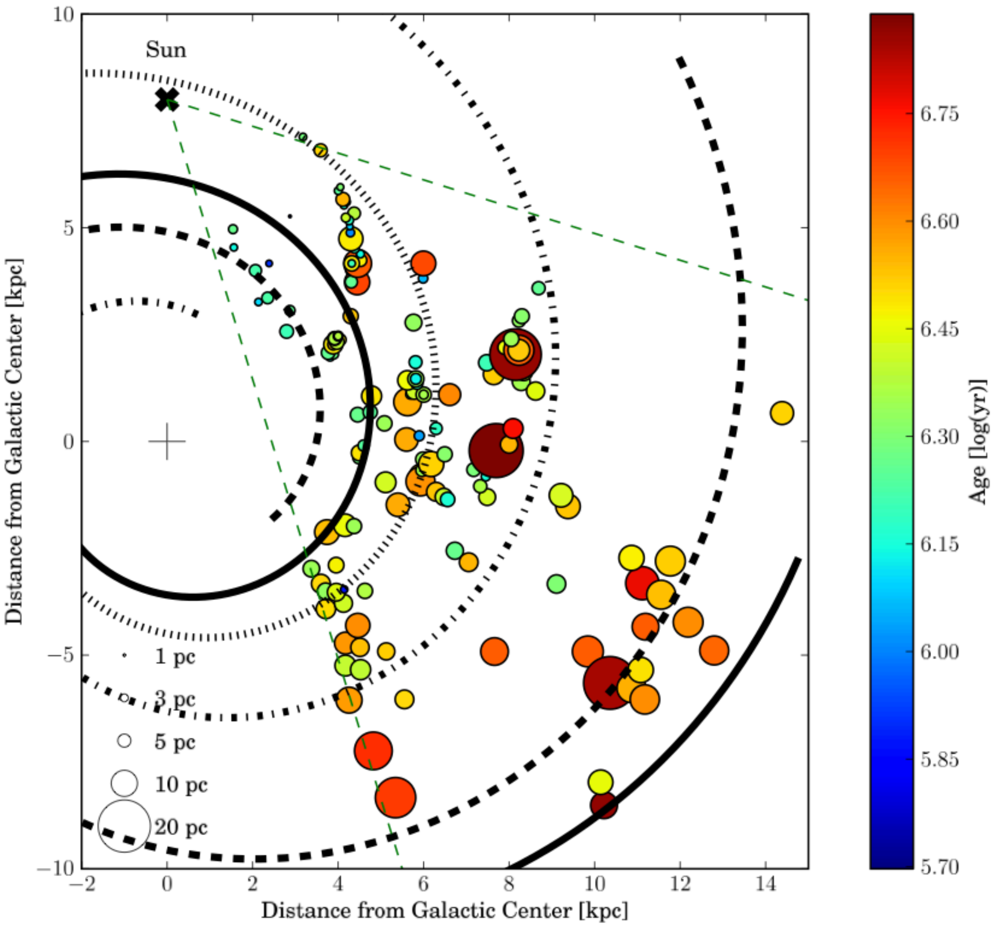
- Star formation efficiency (SFE), Positive or negative feedback ?

BUT you cannot do that instantaneously:

the dynamical time of HII regions is similar to the lifetime of molecular clouds, which implies ionization compression and a second generation of star formation



Up to 30 % of massive YSOs at the edge of ionized bubbles (Thompson et al. 2012)



- Most of galactic high-mass star-forming regions are far away
- Need to be understood to link galactic and extra-galactic star formation

HII regions from hrds survey (Anderson et al 2011), age estimates from simulations, Tremblin et al in prep

- Summary

- Ionization compresses molecular clouds and can be identified in PDFs as a second lognormal (or power-law if homogeneous compressed layer) or enlarged distribution (if the initial turbulence is high).

- Compression is also seen on radial profiles of clumps allowing to distinguish free-fall collapse and forced-fall collapse:
  steep radial profile $r^{-\mathrm{alpha}}$ with alpha > 2 (around 2.5)

- While the bubble expands and halt star formation in the ionized regions it forms a second generation of stars in a compressed layer. This second generation could be of importance to get a correct IMF with realistic Mach numbers in gravo-turbulent theories.

- Thanks to Herschel we can study nearby high-mass star-forming regions, a mandatory first step to link galactic and extra-galactic star formation.