FRIGG : From Intermediate Galactic scales to self-Gravitating cores

Zooming-in on star formation regions

--Spinning the clouds--

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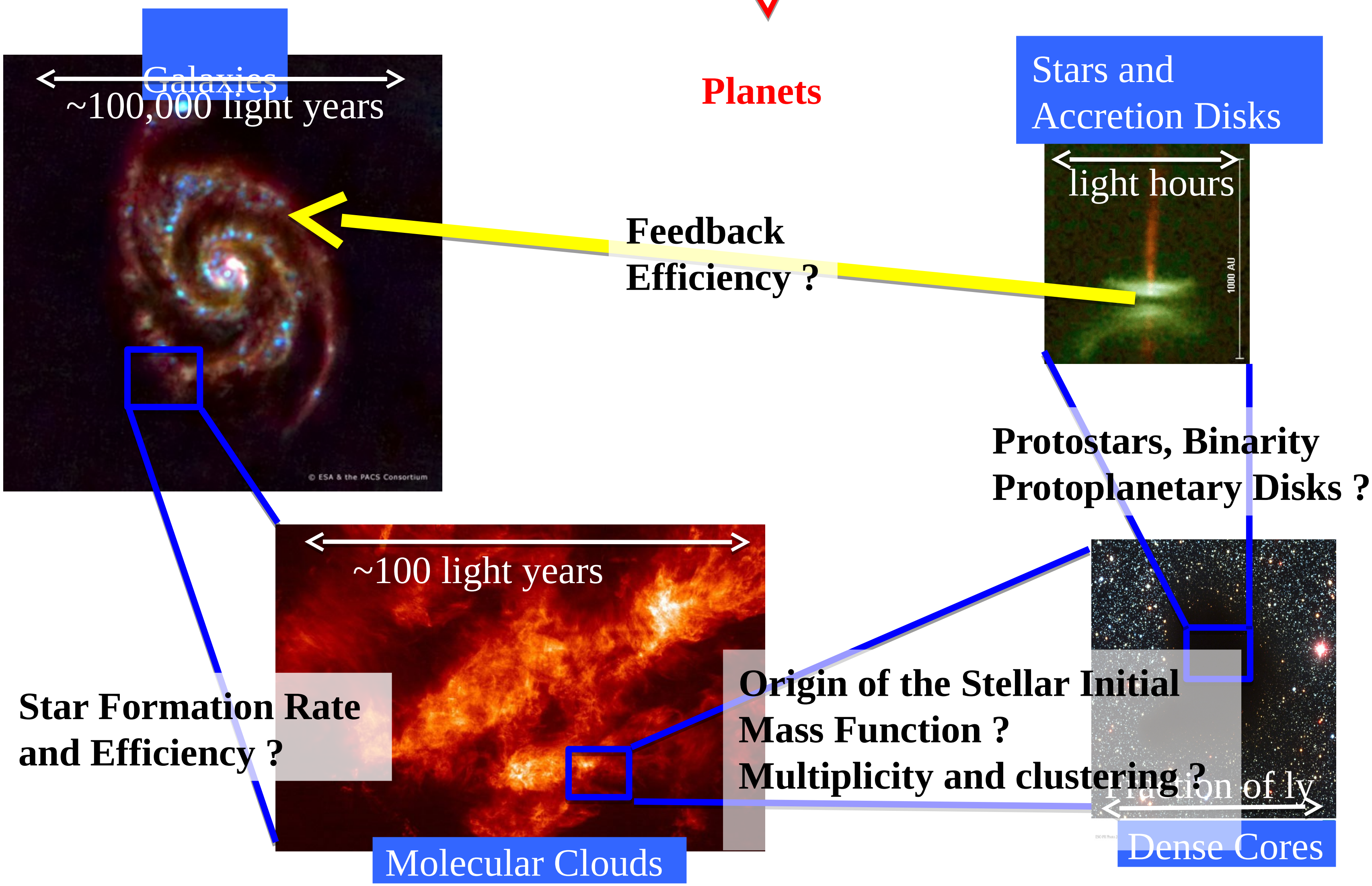
Large Scale Structures

Interstellar Cycle and Star Formation



Motivation :

et a “self-consistent” description from scales of a few 100 pc
ypical intermediate galactic scales) to less than 0.1 pc, the scale of the dense co

nimum ingredients:
A stratified disc
A self-regulated ISM

Investigating feedback at molecular cloud scales: HII and SN

-SN : uniform medium and MC => dependence on environment

Investigating their effects at kpc scale: Self-regulated models

-low resolution, setup and caveats

-high resolution, some statistics

Zooming-in: preliminary statistics

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Total momentum injected by a supernova onto the ISM
Uniform Medium

(e.g. Sedov 1959, Cioffi et al. 1988, Blondin et al. 1998)

10^{51} erg

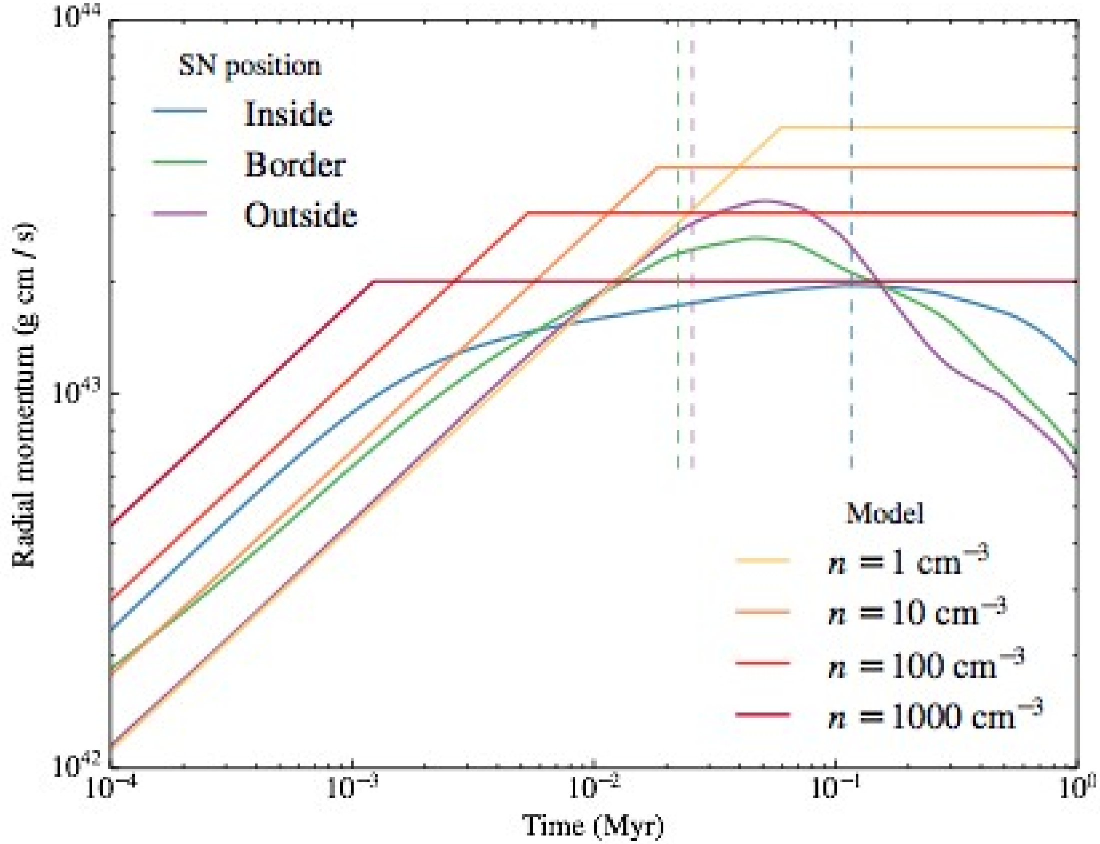
1/50 yr in the MW

First phase:
adiabatic expansion

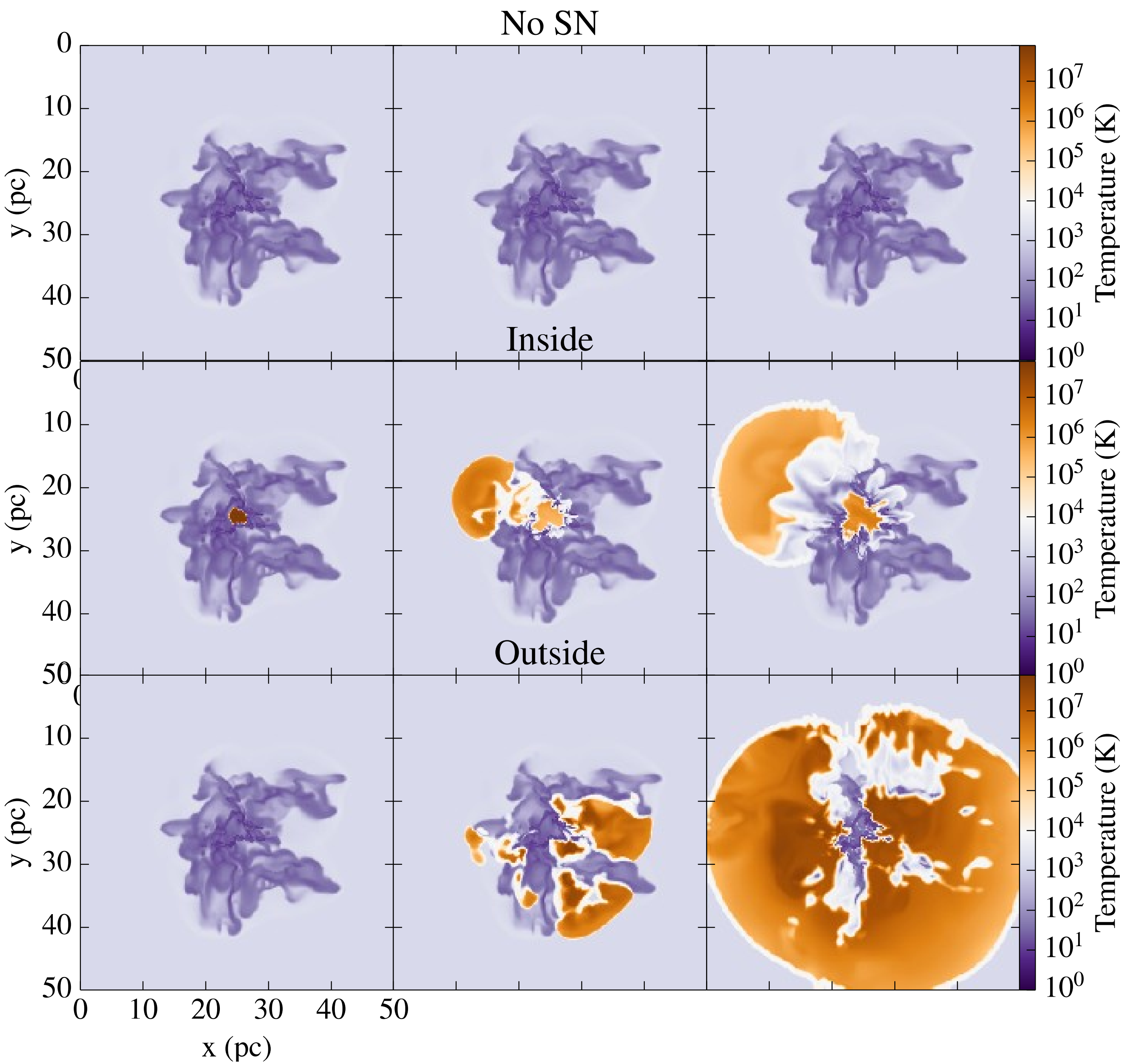
Sedov phase: $r_i(t) = 1.77 n^{1/5} E_{51}^{4/5} t_4^{3/5}$

Second phase:
radiative lost in the shell

Third phase:
Momentum driven phase

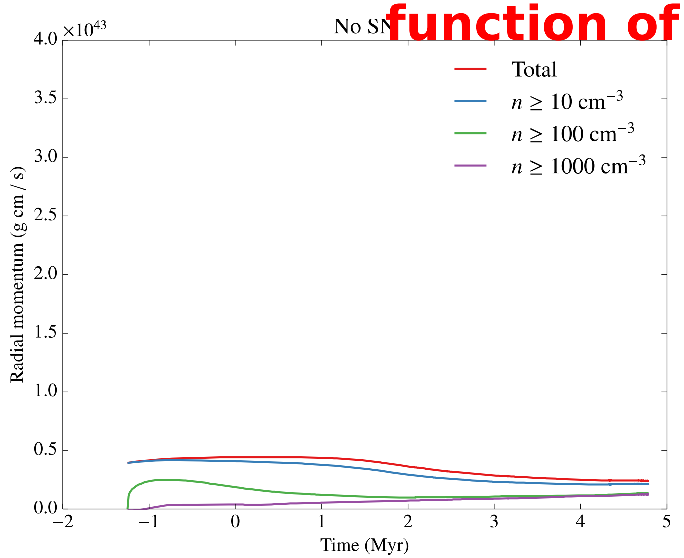


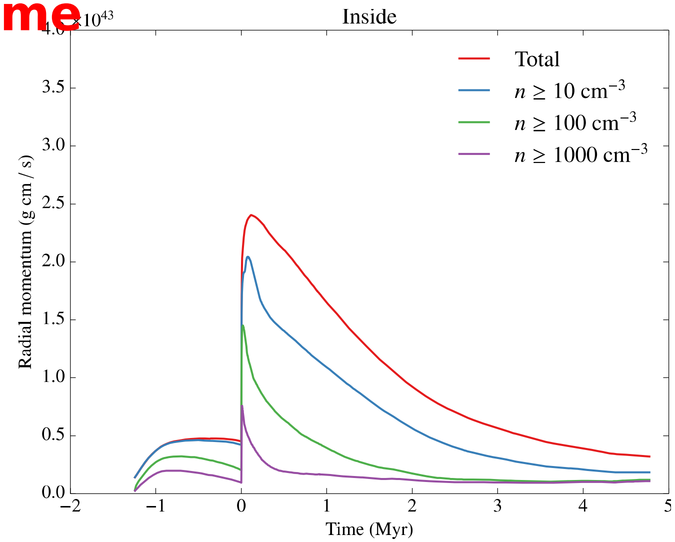
Iffrig & H 2015



Iffrig & H 2015

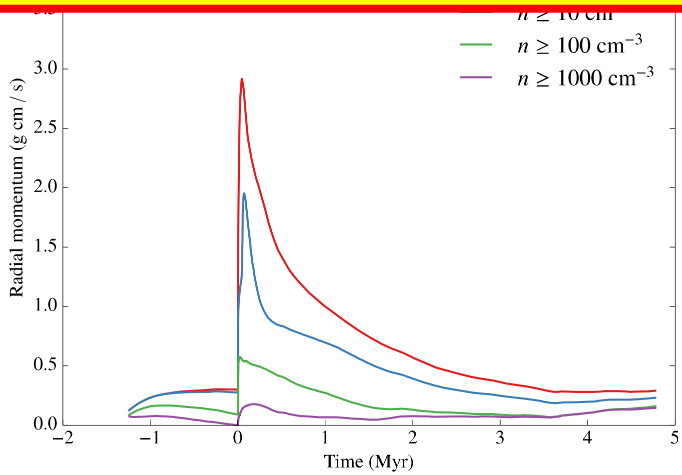
Momentum injected in gas above various density thresholds as a function of time

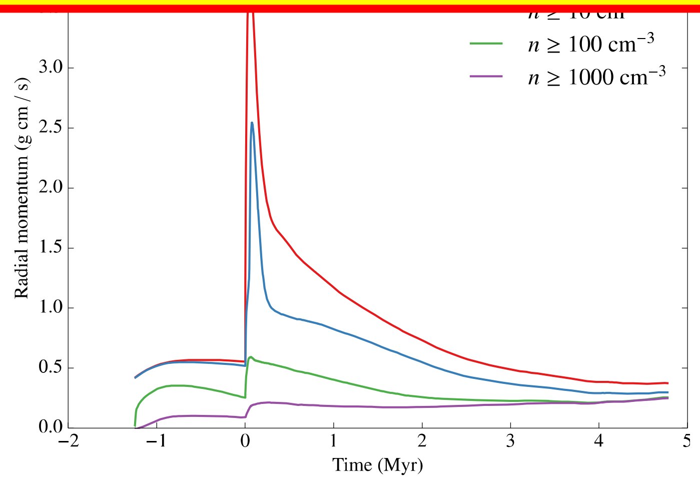




pernova efficiency depends on their location !

- Need to know well enough the history of the massive stars





Iffrig & H 2015

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Zooming-in: preliminary statistics

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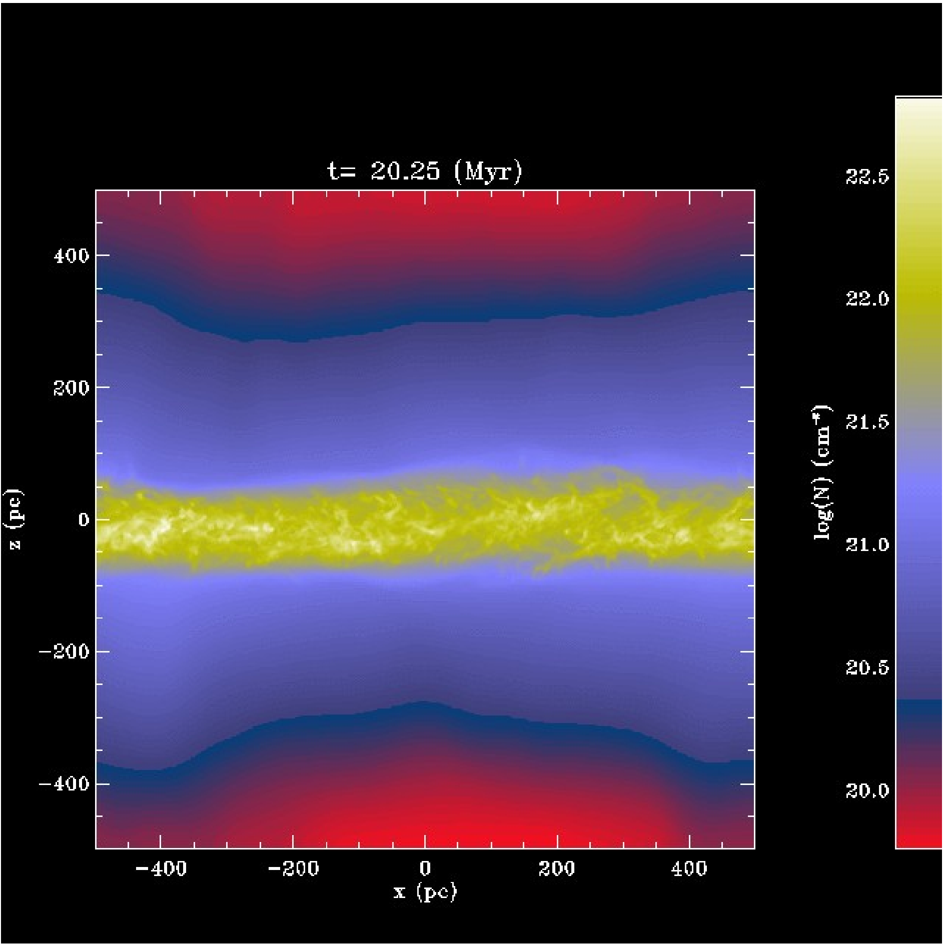
Supernovae regulated ISM (from few 100 pc to 1kpc)

Slyz et al. 2005, de Avillez & Breitschwerdt 2005,2007, Joung & MacLow 2006, Hill et al. 2012, Kim et al. 2011, Hennebelle & Iffrig 2014, Gatto et al. 2014)

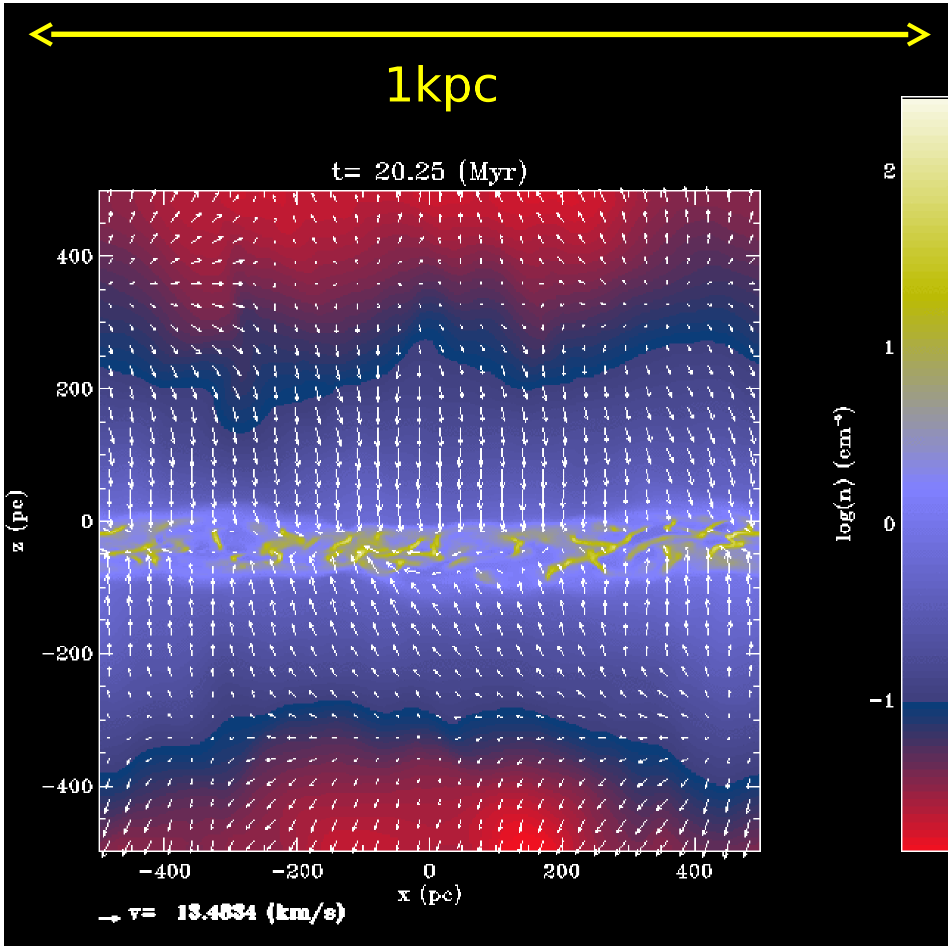
External gravitational field (due to stars and DM), multi-phase ISM, self-gravity, magnetic field

Supernovae explosions (different schemes)

Column density



density



issue of Injection of supernovae in galactic scale sim

energy and/or momentum are damped in a sphere of 12pc or radii

nt distributions:

rate is imposed
correlation at all with the gas
elation with the density peaks

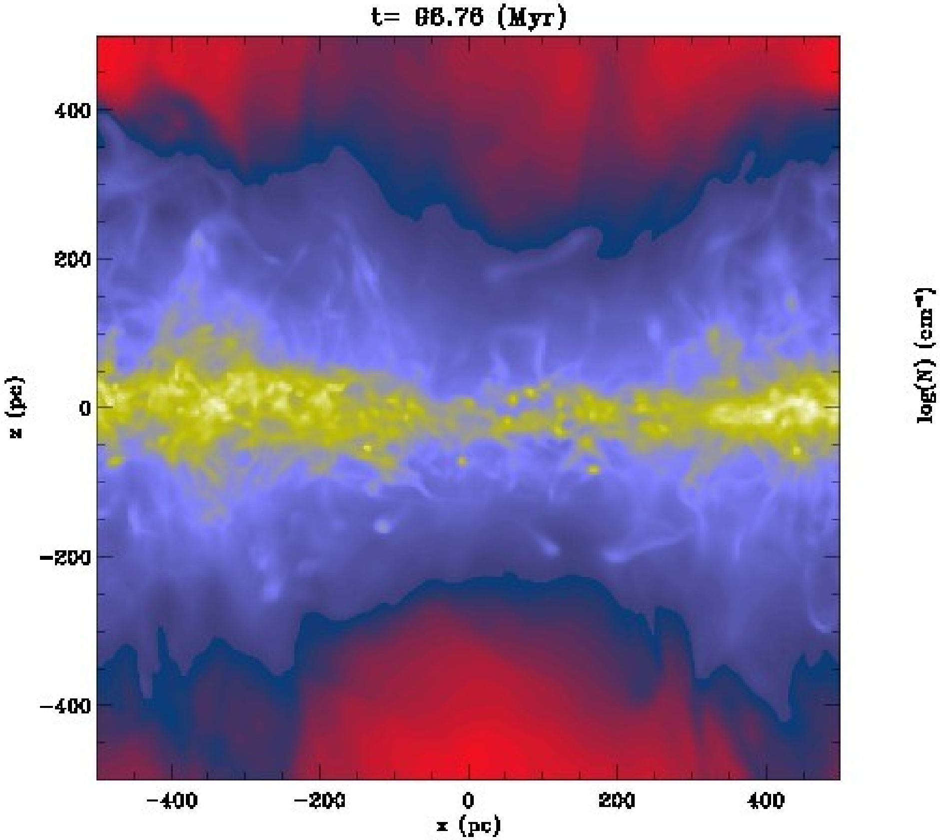
nes a sink particle accretes 120 Ms of gas, a supernova explodes
ernovae are distributed randomly within a sphere of 10 pc around the sin
ernovae are distributed randomly within a shell between 10 and 20 pc (s

H & Iffrig 2014

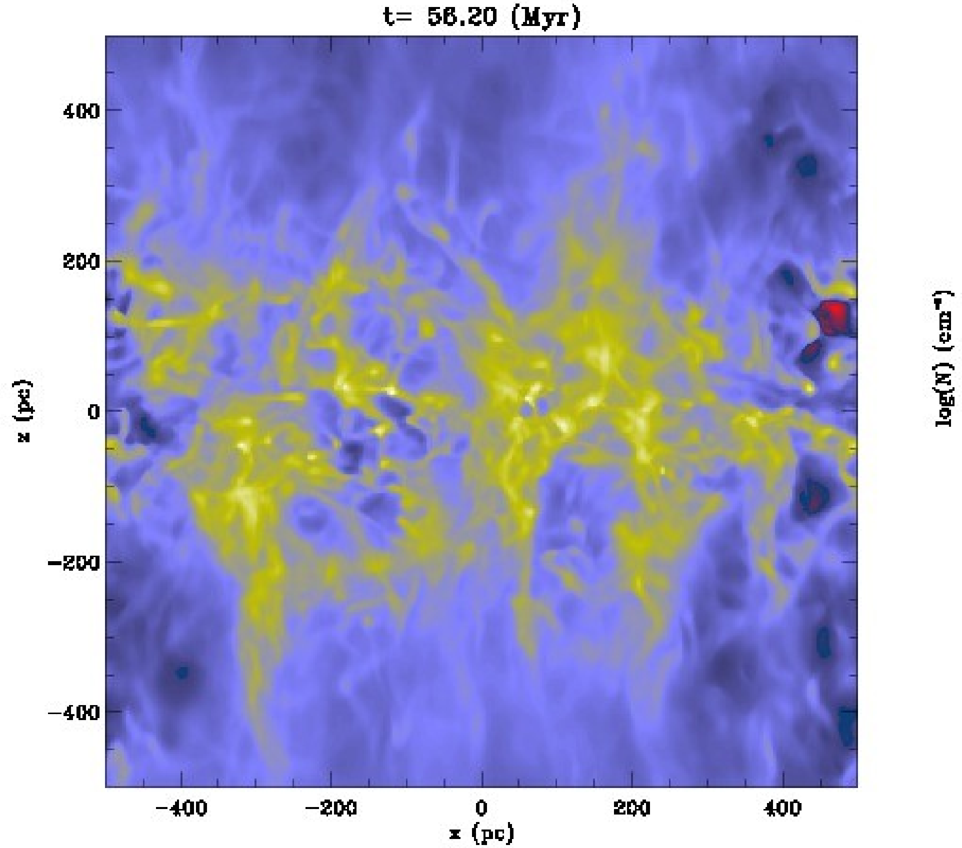
ferent answers depending on how exactly are the supernovae in

(see also Gatto et al. 2014)

Supernovae (sphere of 16 pc around the sink)



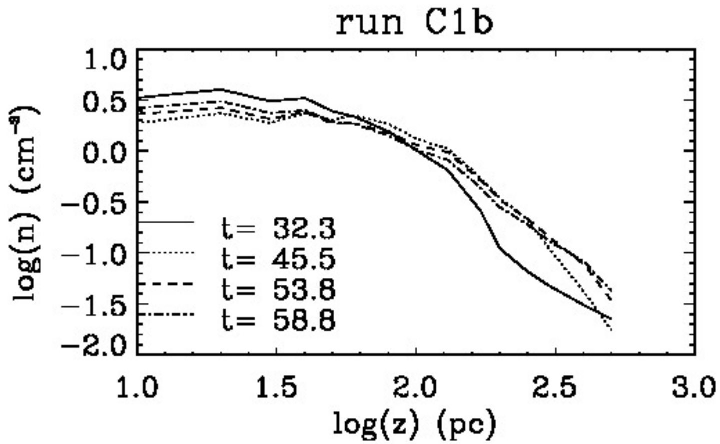
Supernovae (shell of 16 pc around the sin



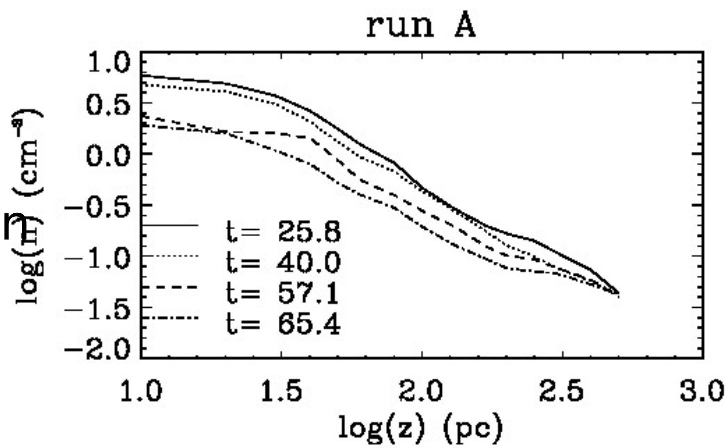
H & Iffrig 2014

he results depend a lot on the way supernovae are being introdu

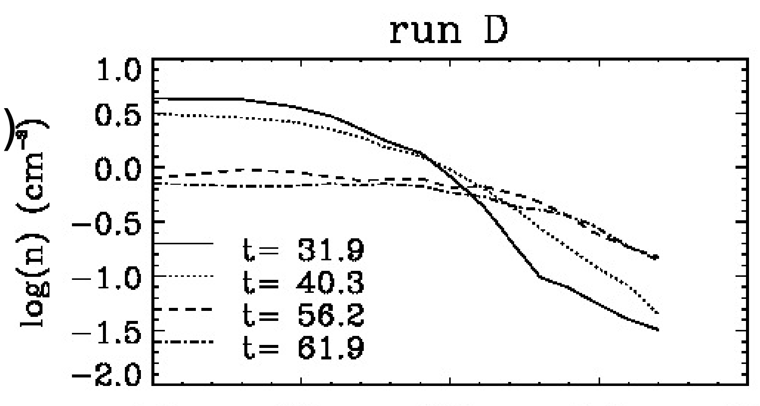
Supernovae (ref)



Supernovae
fix rated
no spatial correlation



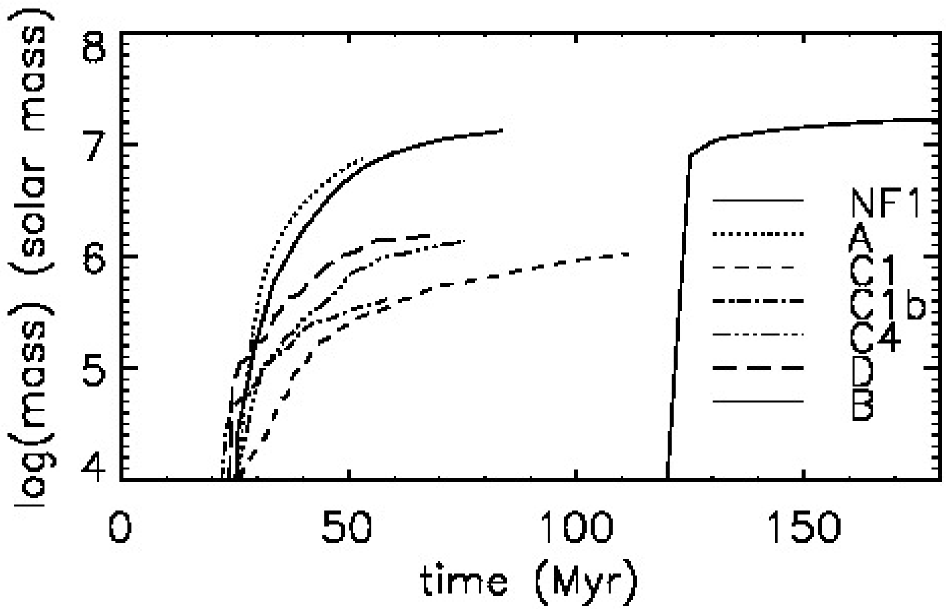
Supernovae (shell)



H & Iffrig 2014

Star formation rate: very sensitive to the supernovae scheme

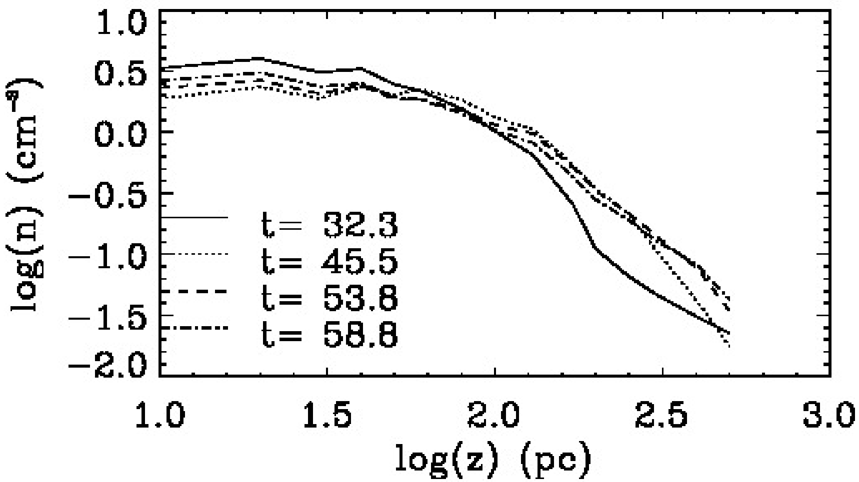
SFR for
various supernovae
schemes



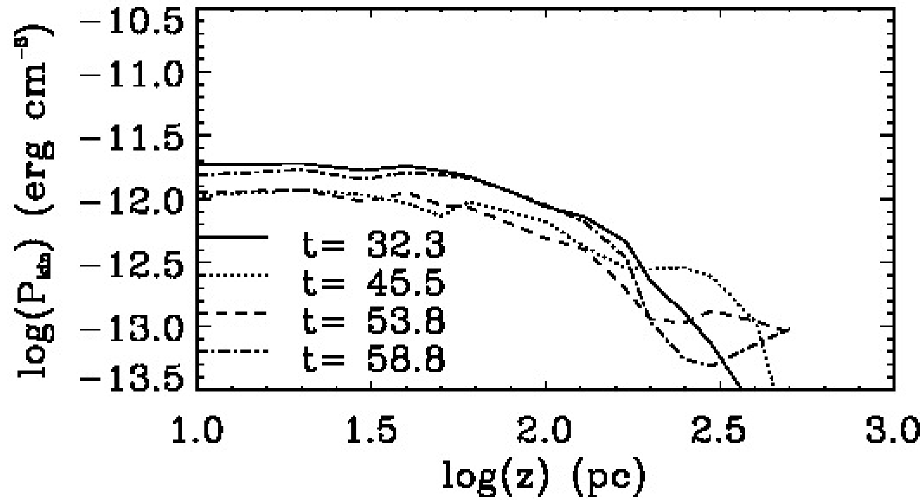
H & Iffrig 2014

ty profile of the galactic disk and pressure (turbulent, magnetic,

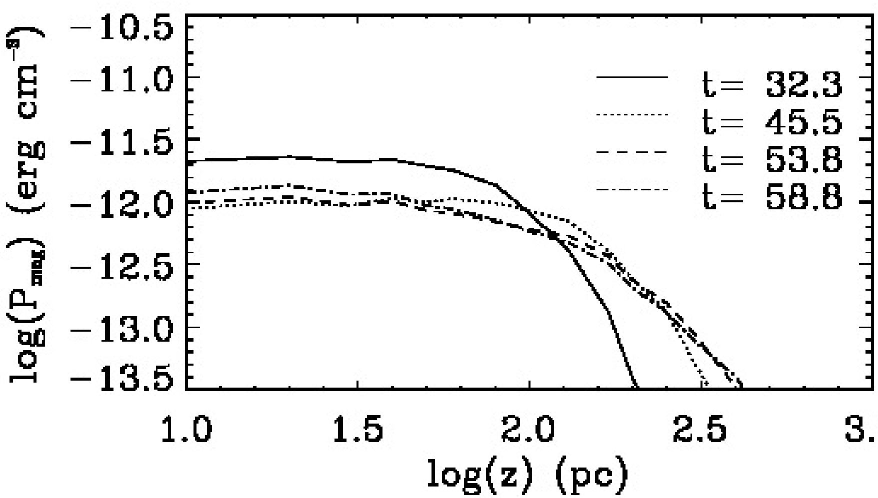
Density vs z



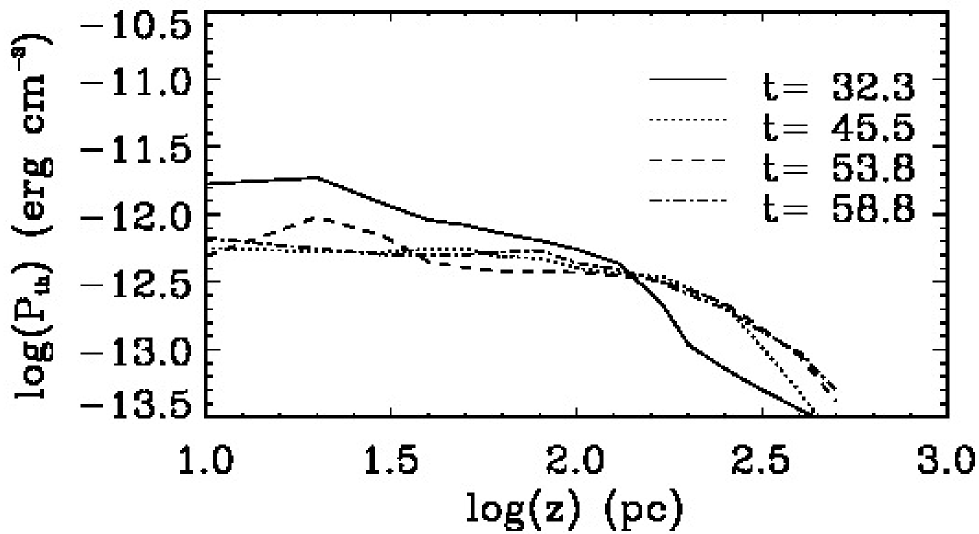
Kinetic pressure vs z



Magnetic pressure vs z



Thermal pressure vs z



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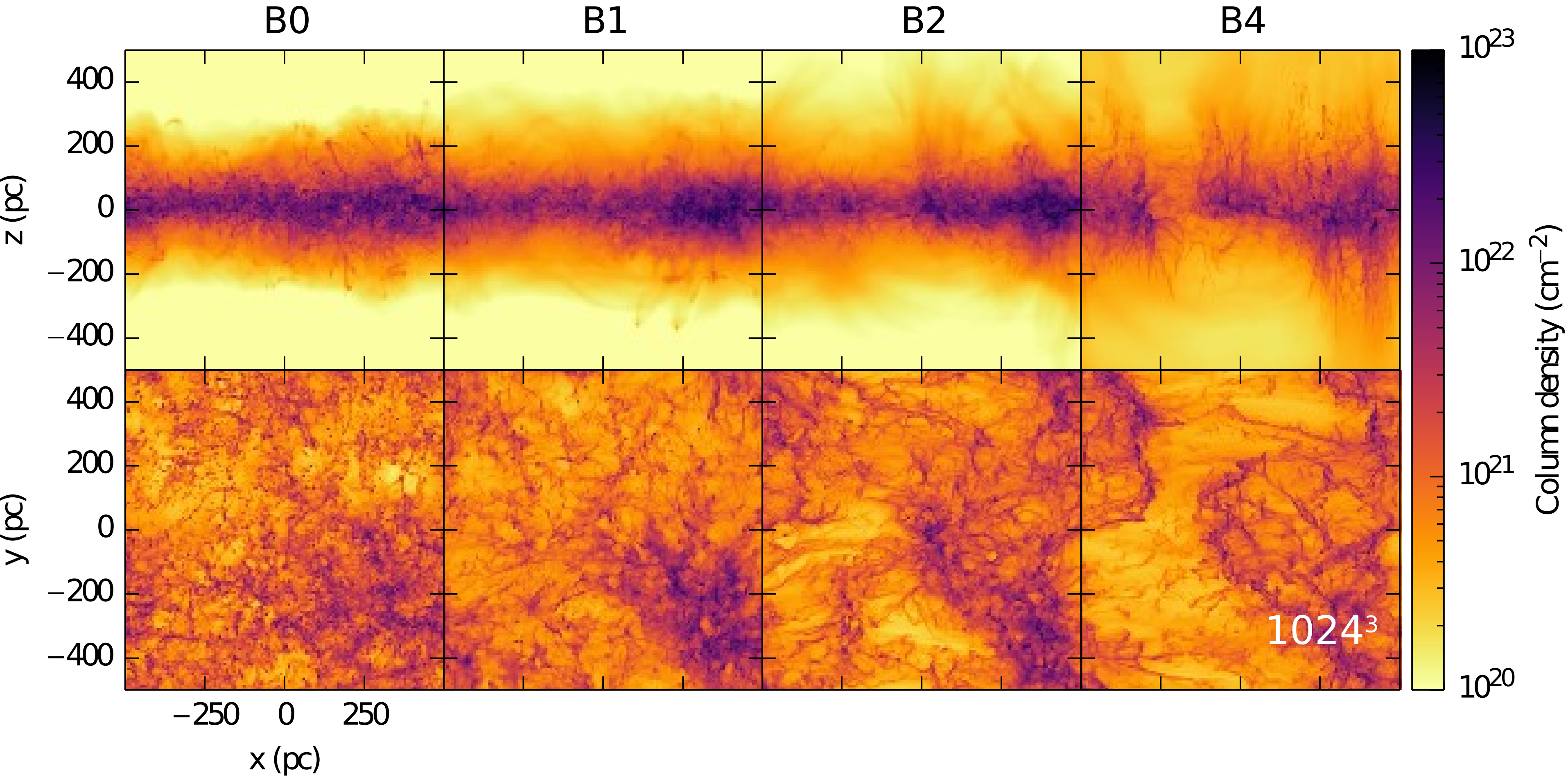
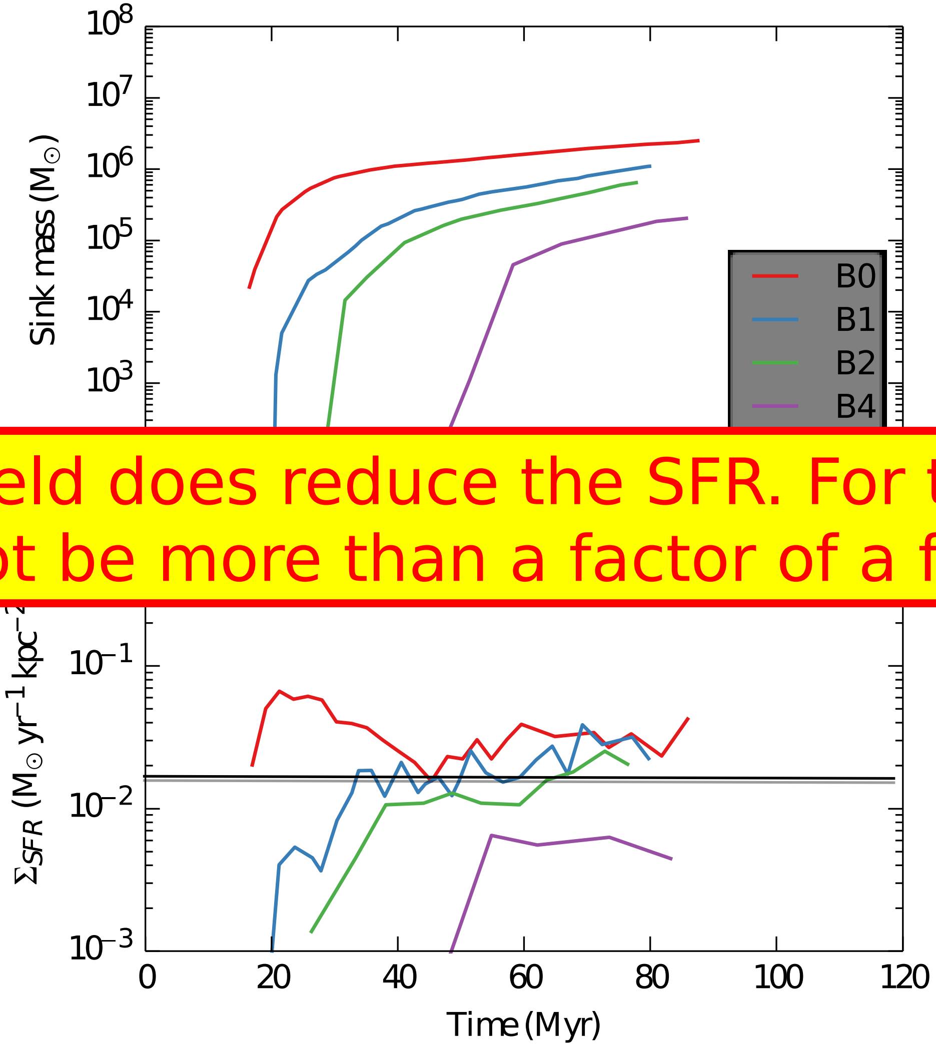
High resolution simulations
(B=0, 2.5, 5 and 10 μG)



Iffrig&H in prep

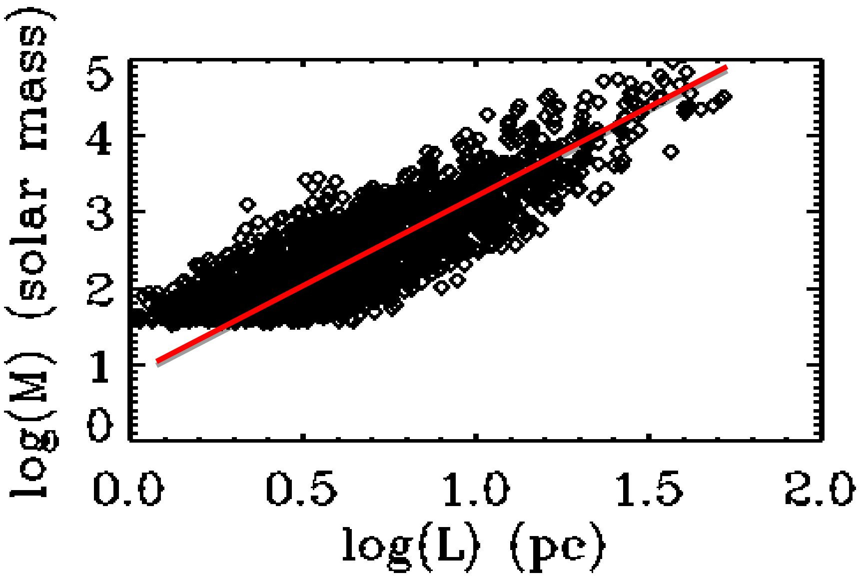
Star formation rate as a function of time (B=0, 2.5, 5 and 10 μG)

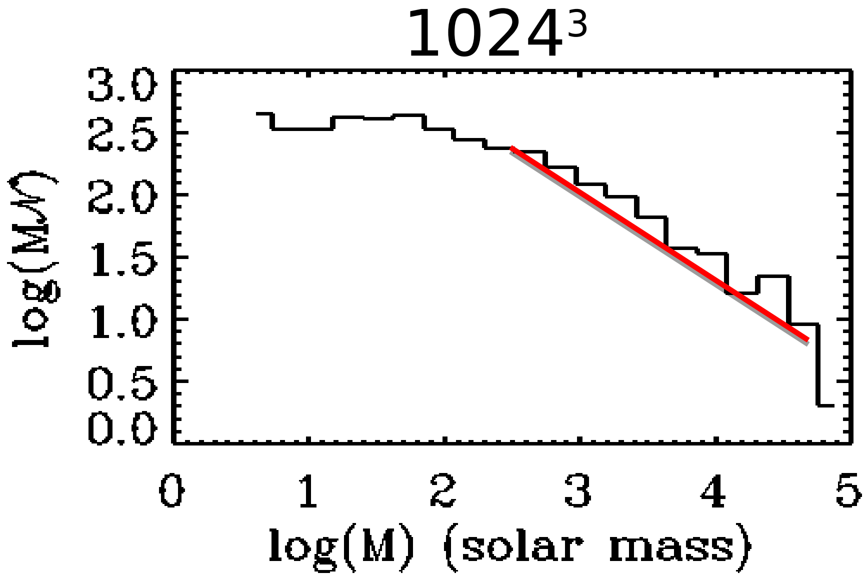


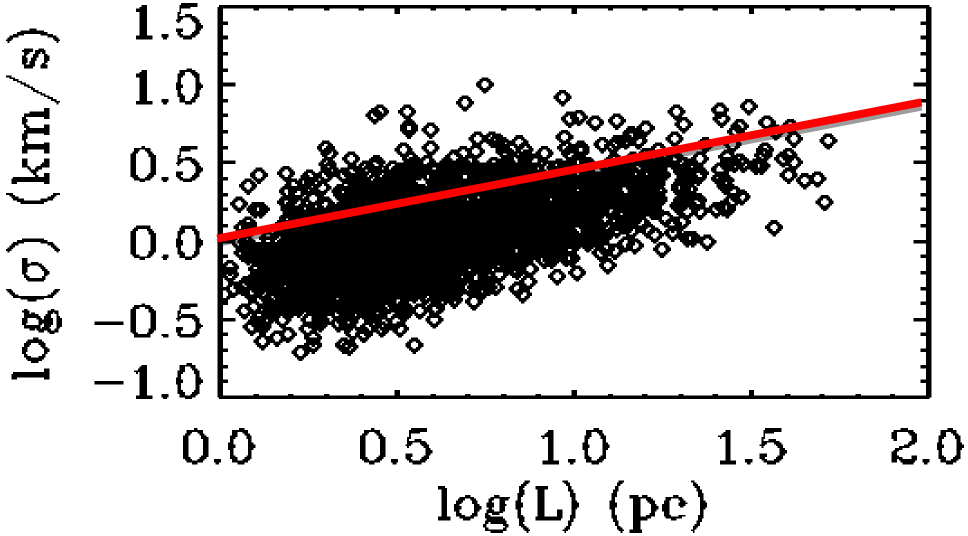
Magnetic field does reduce the SFR. For typical values this may not be more than a factor of a few.

Clump properties

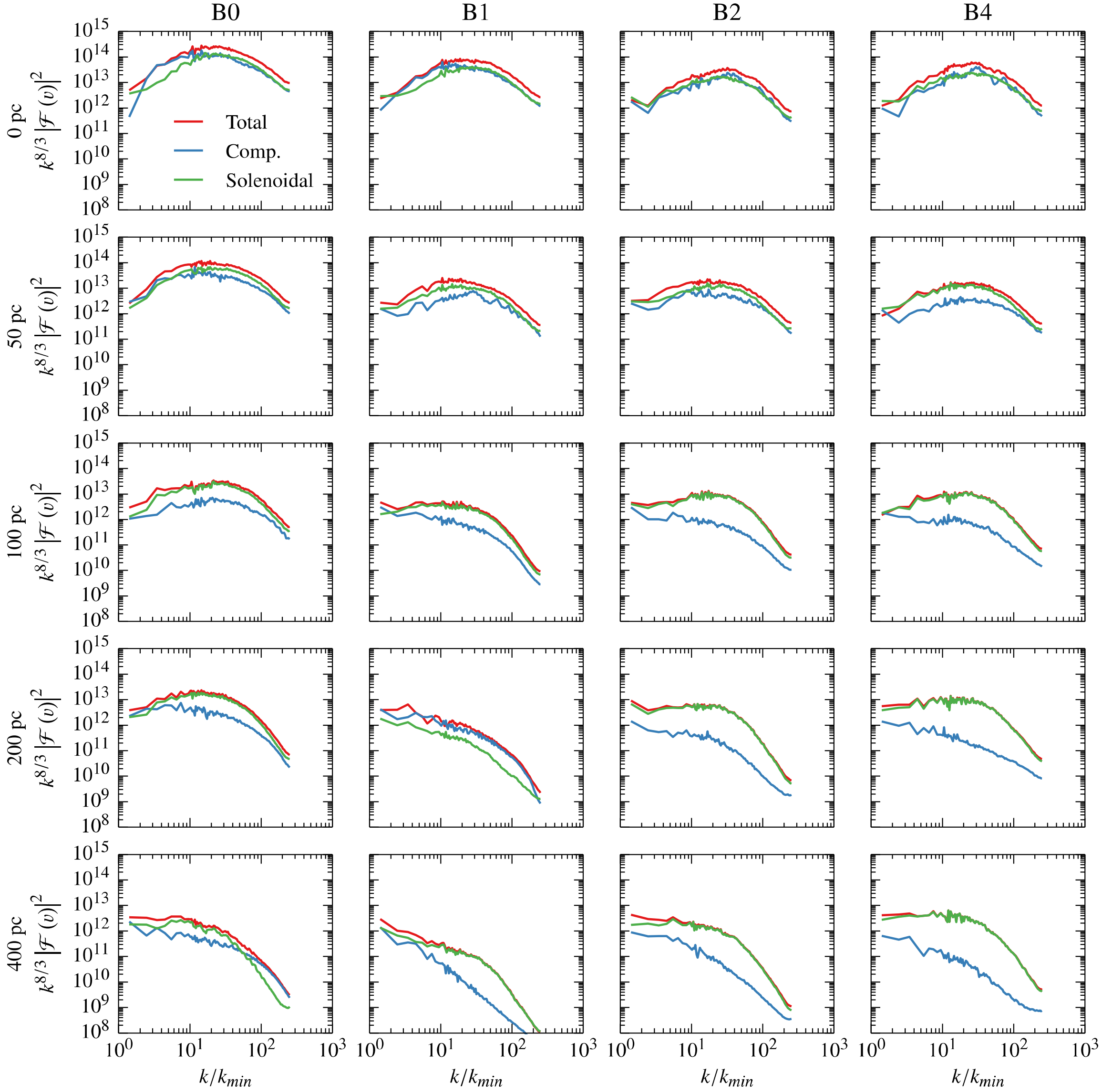
B=2.5 μG, density threshold 50 cm^{-3}: mass spectrum, mass-size







verspectra of the velocity field at different altitude for 4 magnetisations (0, 2.5, 5



Compressible modes dominating in the equatorial plane
Compressible mode amplitude quickly decreases with altitude and magnetisation

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Zooming-in: preliminary statistics

Strategy adopted for the zooming technique

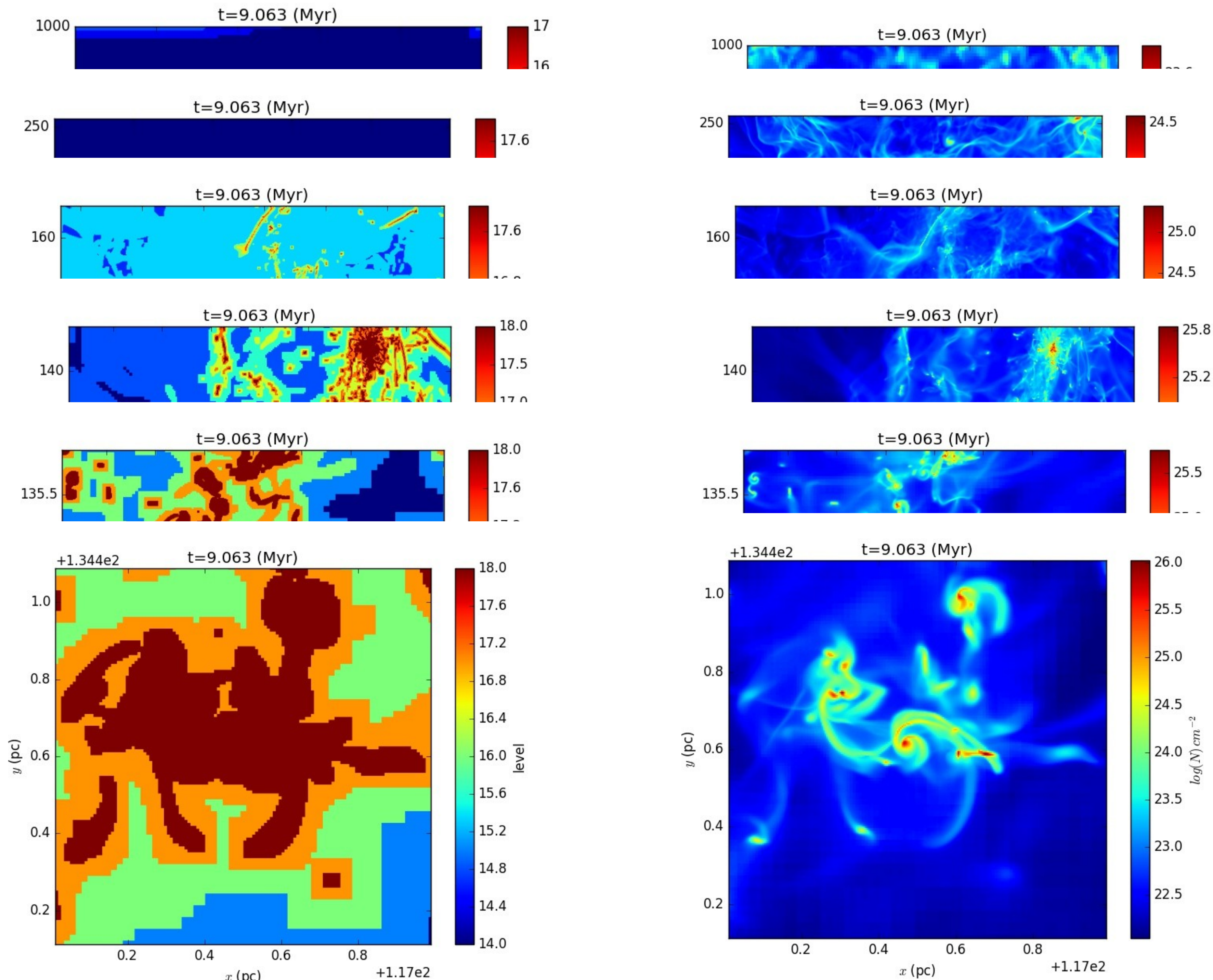
-start with unigrid stratified box regulated by supernovae

⇒ First difficulty : sink particles should not be used (too big when zooming)
⇒ Correlate SN with peak density – impose a star formation rate

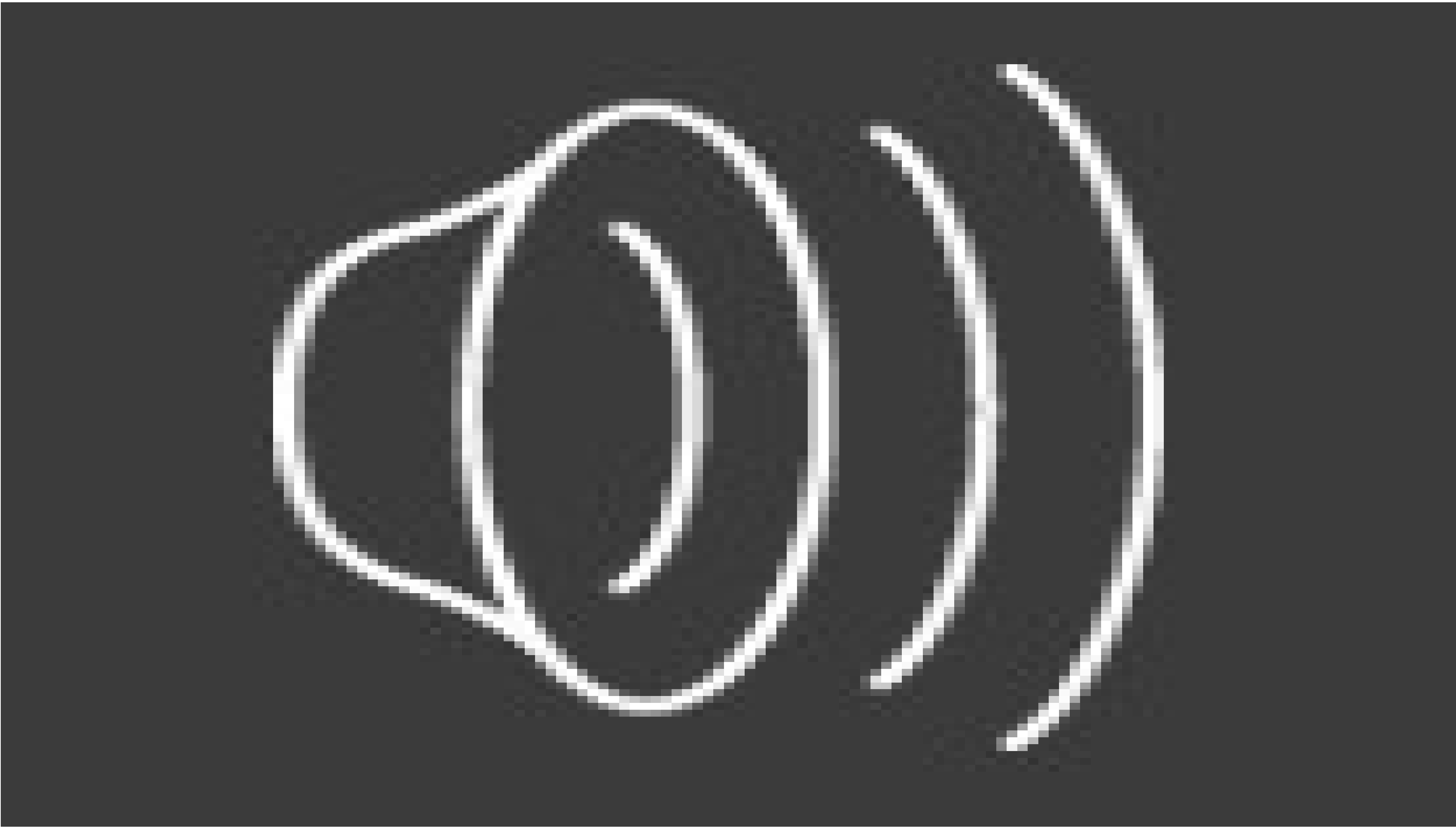
-want to get proper turbulent fluctuations : uniform resolution grids
⇒ Refine on concentric cubes with UNIFORM resolution
⇒ Do a few timesteps after each refinement (to let the grid relaxing) and load balance

-Can do unigrid refinement up to some levels (typically 14) if one wants to cover a sufficiently large regions (of 100 pc)
⇒ Finish the last levels with Jeans refinement (from 14 to 18)

-timesteps very small when feedback is used : far too small when refinement is used
⇒ Stop the SN feedback when start refinement, let relax a bit before refinement starts

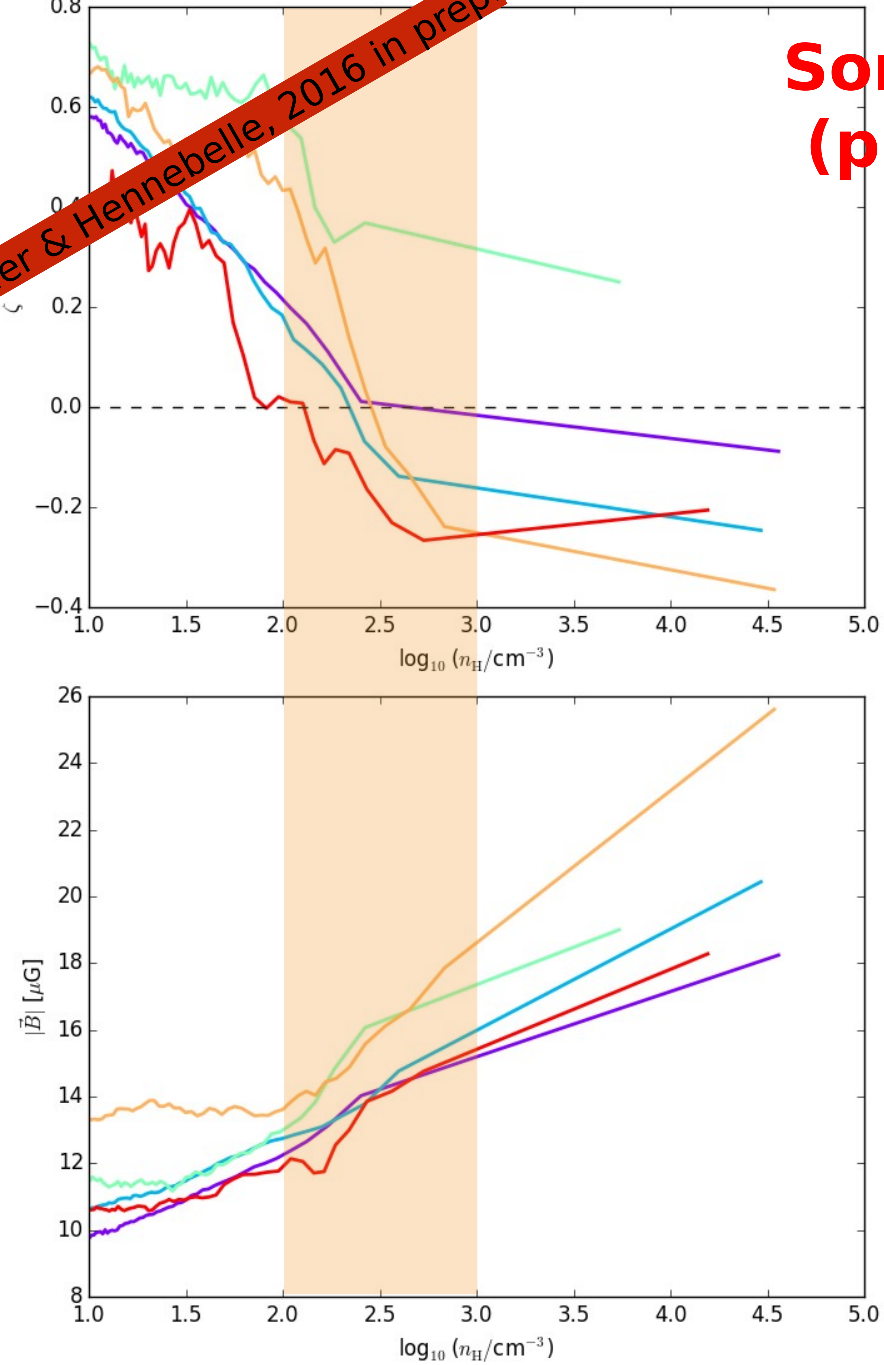


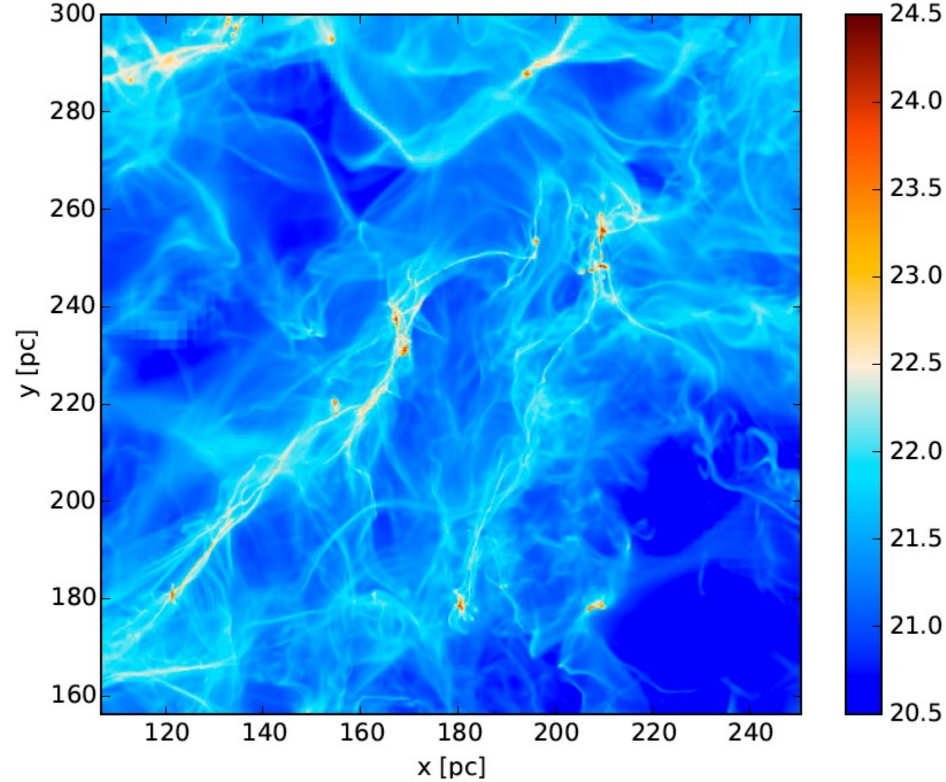
t=9.063 (Myr)
1000
17
16
250
17.6
160
17.6
140
18.0
17.5
17.0
135.5
18.0
17.6
+1.344e2
1.0
0.8
0.6
0.4
0.2
y (pc)
0.2
0.4
0.6
0.8
x (pc)
+1.17e2
18.0
17.6
17.2
16.8
16.4
16.0
15.6
15.2
14.8
14.4
14.0
level
24.5
25.0
25.8
25.2
25.5
26.0
24.0
23.5
23.0
22.5
$log(N)\,cm^{-2}$



Some statistics of the diffuse (preliminary)

Soler & Hennebelle, 2016 in prep.





Goal: comparison with PLANCK statistic

Extracting the dense cores

We use the HOP algorithm

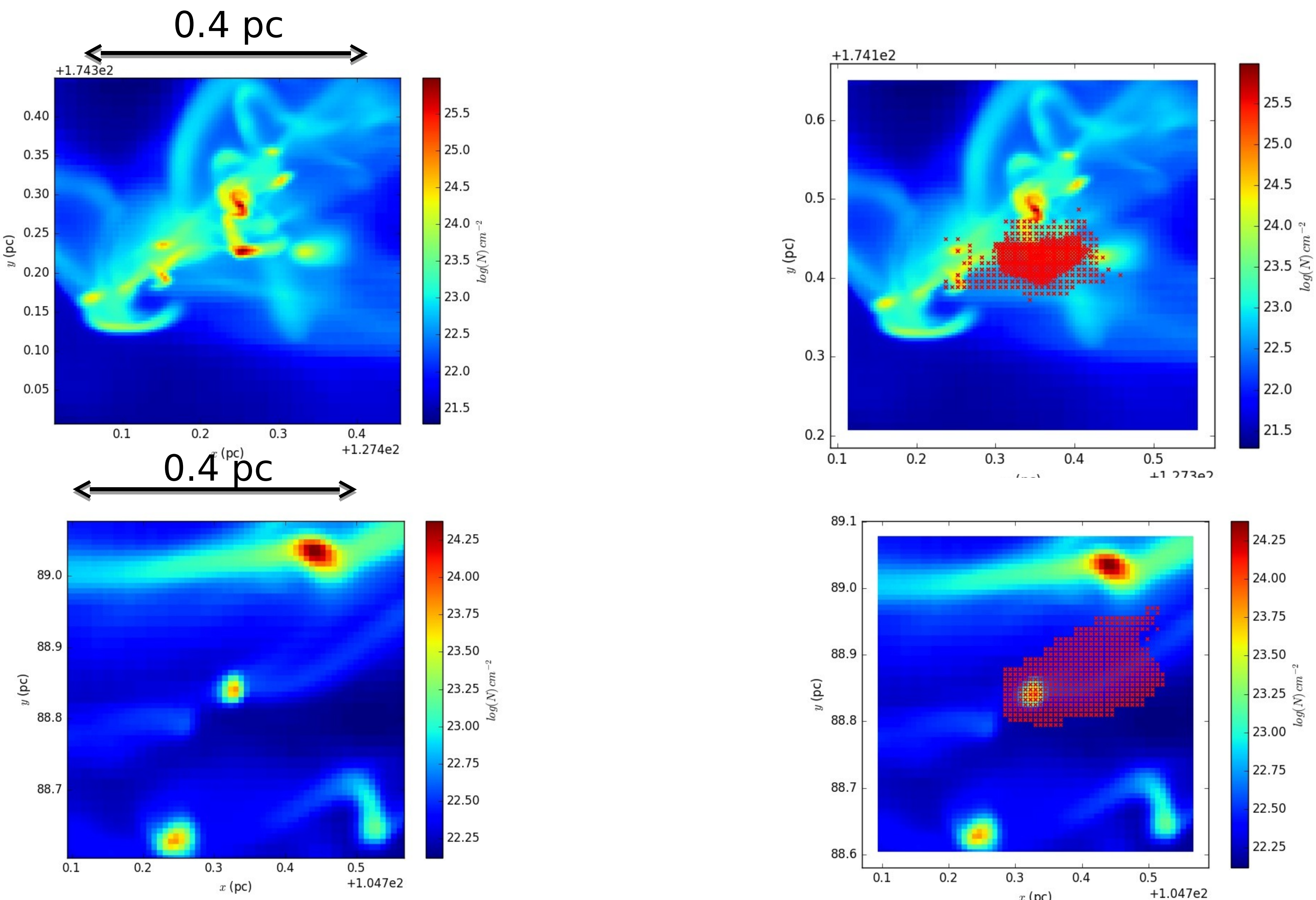
Select cells with density above some thresholds (1000 cc) and at least at level

We provide to HOP the density of these cells

We obtain the GROUP (based on local maxima and saddle points)

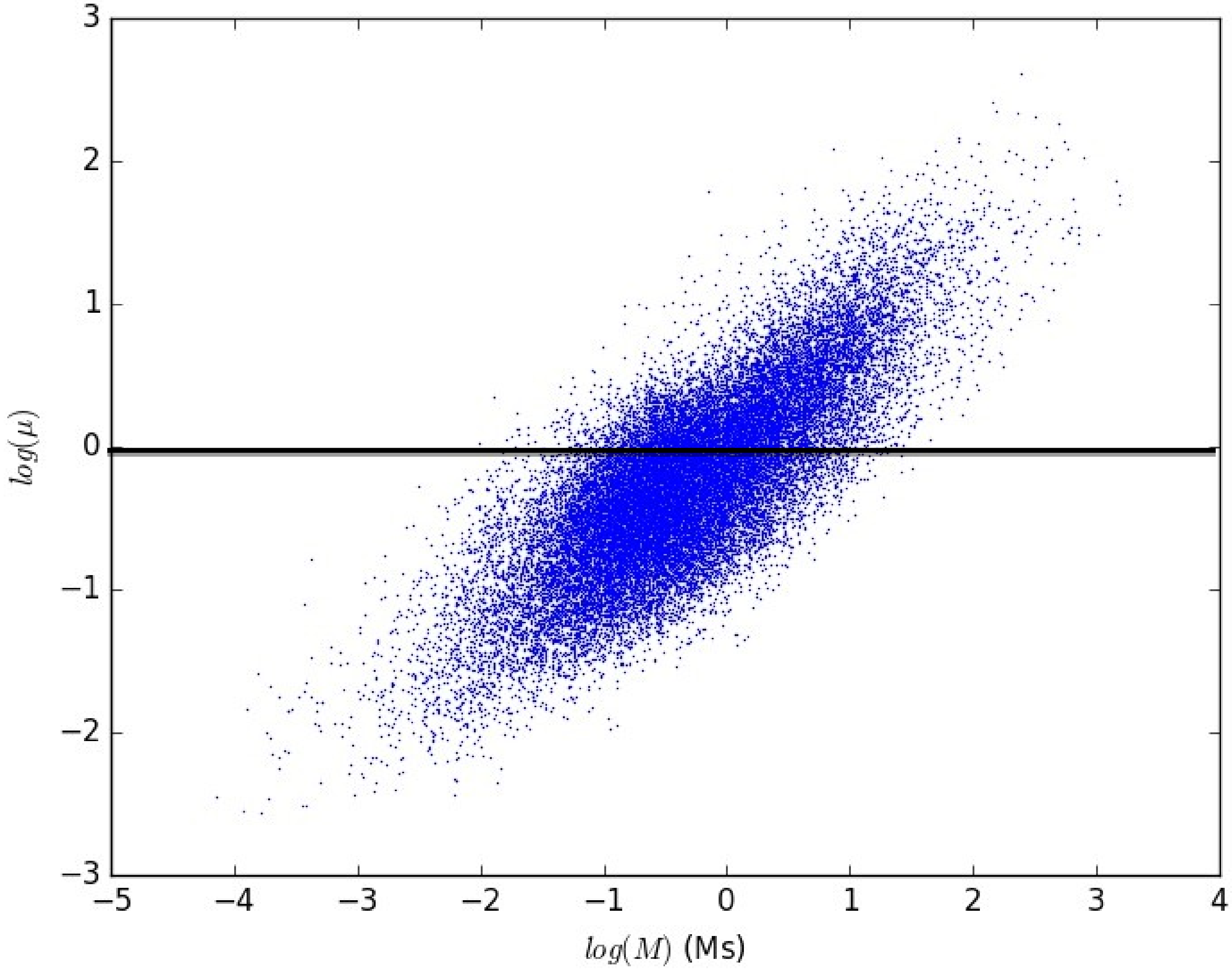
We do not regroup

Extracting the dense cores



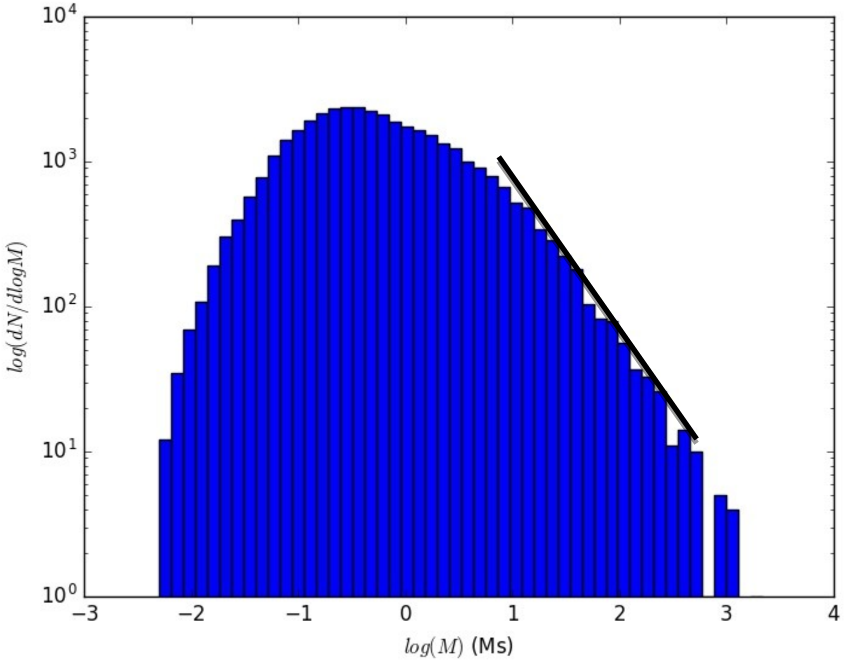
Some statistics of the dense cores (preliminary)

Mass to flux over critical mass to flux ratio distribution

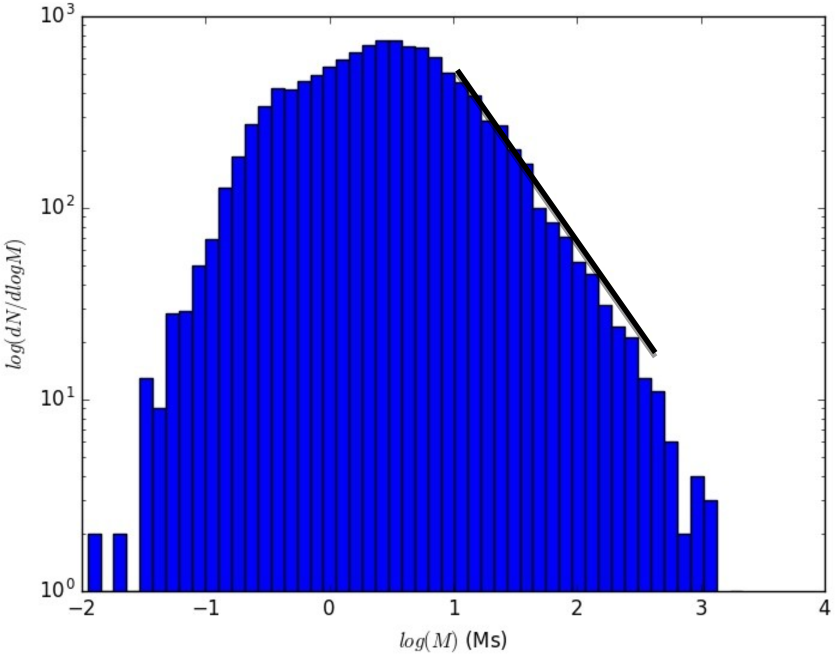


Some statistics of the dense cores (preliminary)

Mass spectrum (all “cores”)



Mass spectrum
(only supercritical “cores”)



Conclusions

Feedback is not only delivering momentum/energy, it is also when and where
Supernovae do not do much when exploding outside MC

Many uncertainties regarding its exact influence and how it should be implemented
⇒ hugely difficult: multi-scale and complex stellar physics

Under some favorable assumptions regarding the assumptions for SN, can reproduce many properties of the observed ISM (e.g. Larson relations) and SFR

Magnetic field certainly reduces the SFR. Are we more magnetized that we think ?