Stellar feedback processes in kiloparsec-scale numerical simulations of the ISM: a real challenge

Olivier Iffrig
with Patrick Hennebelle, Sam Geen

Astrophysics division, CEA Saclay

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Introduction

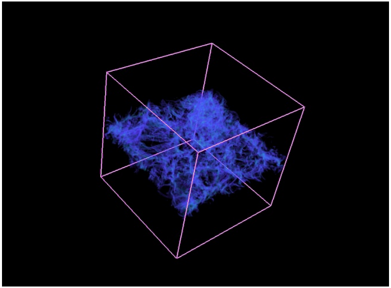
Physical context

Goal

- Self-consistent feedback models to simulate star formation

Scales

- Kiloparsec box
- $< 4\,\mathrm{pc}$ resolution



Physical processes

- Turbulence
- Magnetic field
- Gravity (stars + DM, self-gravity)
- Star formation
- Feedback

Numerical setup

The code

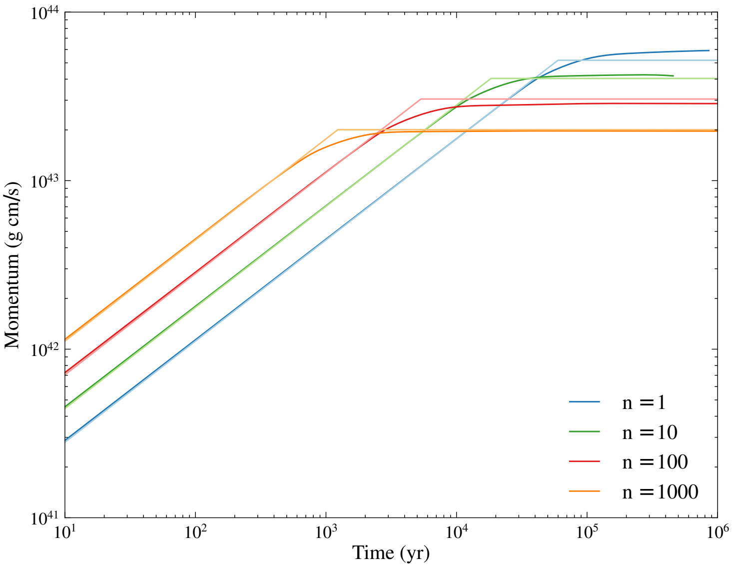
- RAMSES (Teyssier, A & A, 2002, Fromang et al., A & A, 2006)
- MHD, self-gravity (+ galactic potential), cooling
- Sink particles for star formation and feedback source

Simulations

- Stratified conditions: gaussian $n(z)$, $B_x(z)$
- Initial turbulent velocity field
- Sink particles: massive star every 120 $M_\odot$
- Feedback models: supernovae, H_{II} regions

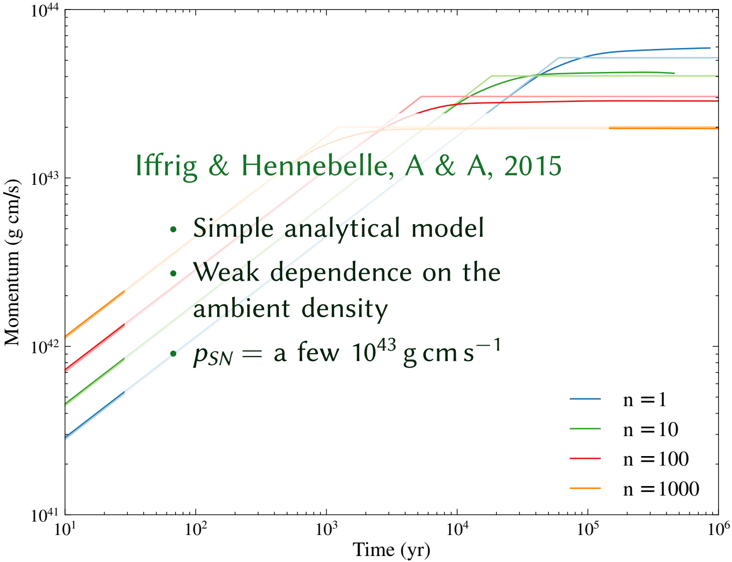
Supernovae

The model



Momentum (g cm/s)
Time (yr)
10^{44}
10^{43}
10^{42}
10^{41}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
n = 1
n = 10
n = 100
n = 1000

The model



Iffrig & Hennebelle, A & A, 2015

- Simple analytical model
- Weak dependence on the ambient density
- p_{SN} = a few $10^{43}\,\mathrm{g\,cm\,s^{-1}}$

Implementation

Hennebelle & Iffrig, A & A, 2014

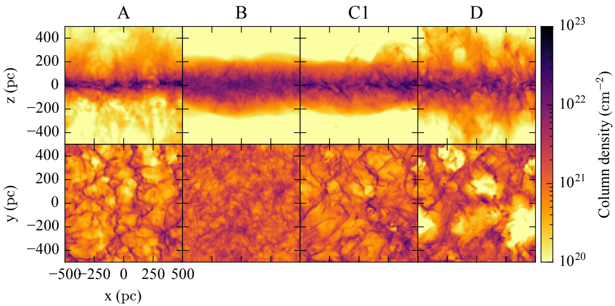
Schemes

- Fixed rate
  - A Random position
  - B Densest region
- Star formation events
  - C Within 10 pc around the sink
  - D Between 10 and 20 pc around the sink

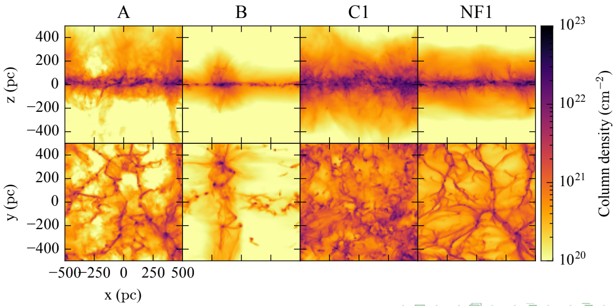
The problem

- Big variability!

40 Myr



First stars + 40 Myr



Simulations

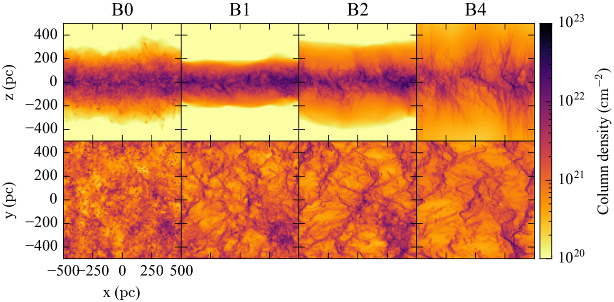
We chose the most “realistic” scheme

- One supernova for every $120\,M_\odot$ accreted
- Location within 10 pc around the sink
- 2 values of momentum: 10^{43} (cheaper!) and $4 \times 10^{43}\,\mathrm{g\,cm\,s^{-1}}$
- Magnetic field: 0, 2.5, 5, and 10 μG in the midplane

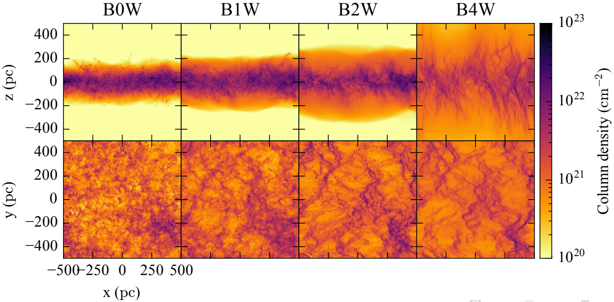
Feedback in ISM simulations

Olivier Iffrig

40 Myr, $p_{SN} = 4 \times 10^{43}$ g cm s^{-1}



40 Myr, $p_{SN} = 10^{43}$ g cm s^{-1}



H_{II} regions

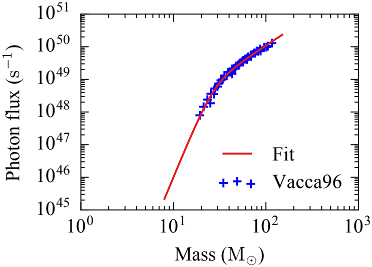
The models

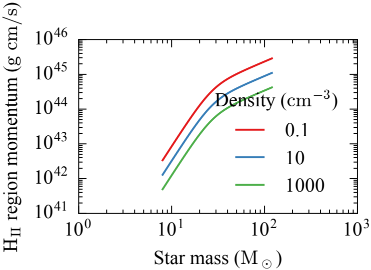
Photon flux

- Fit of Vacca et al., ApJ, 1996

H_{II} region momentum

- Analytical model: Geen et al., MNRAS, 2015





Implementation

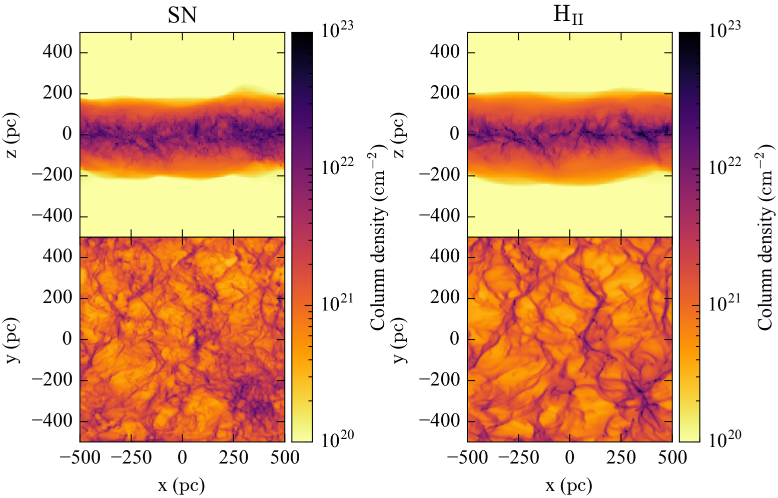
Based on sinks

- Create a stellar object every 120 $M_\odot$ accreted
- Draw a random mass from an IMF $8\,M_\odot \leq M \leq 120\,M_\odot$
- Compute a lifetime for this mass (fit of Woosley et al., RvMP, 2002, Claret, A & A, 2004)
- Compute a photon flux

2 variants

- Put H_{II} region momentum
- Radiative transfer simulations (RAMSES-RT, Rosdahl et al., MNRAS, 2013)
- Both with or without a supernova at end of life

Simulations



Conclusion

Conclusion

What we have

- Supernova feedback
- H_{II} region kinetic model
- H_{II} regions with radiative transfer

What's next

- H_{II} region parameter study
- High-resolution simulations
- Other feedback sources (protostellar jets, ...)
- In-detail study of the interactions

Thanks for your attention!