Can stars regulate star formation ?

Noé Brucy
Patrick Hennebelle
Cédric Colling
AIM - CEA Saclay

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Star formation, a pure gravitational process ?

Estimating the Star Formation Rate (SFR)

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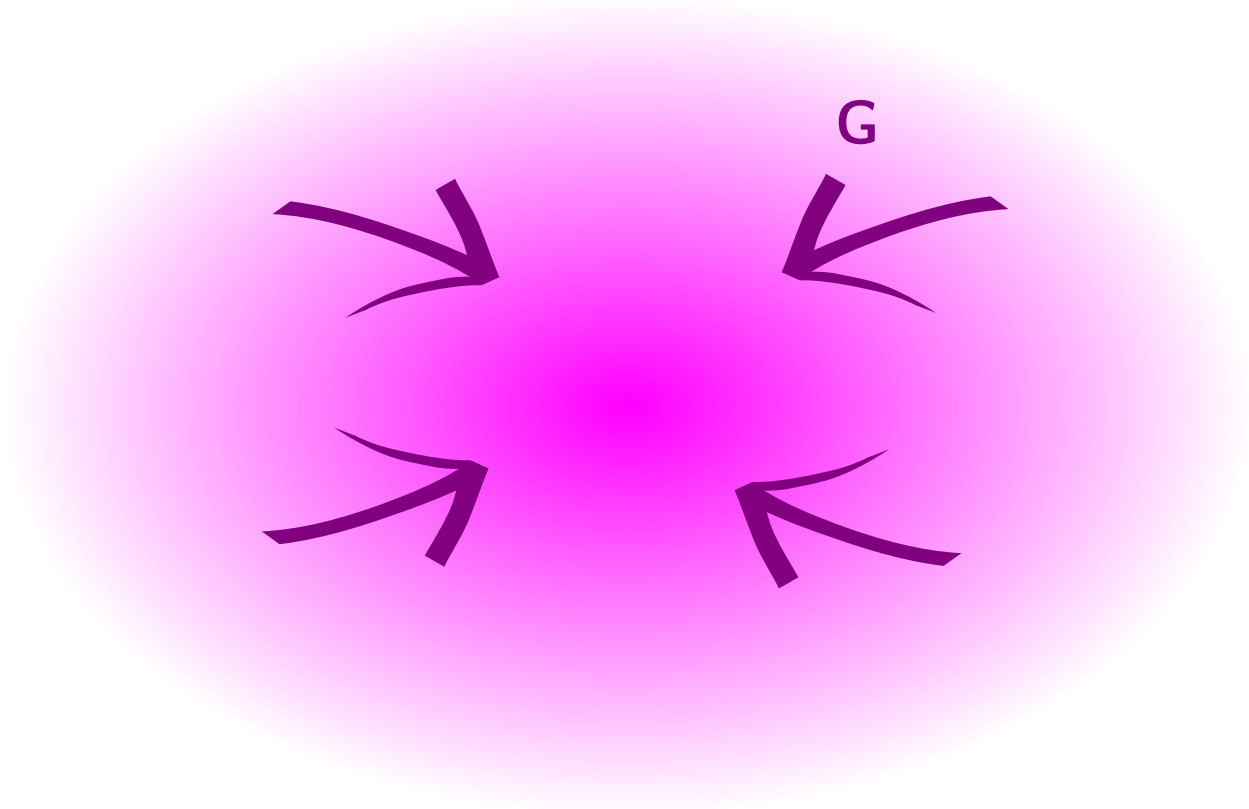

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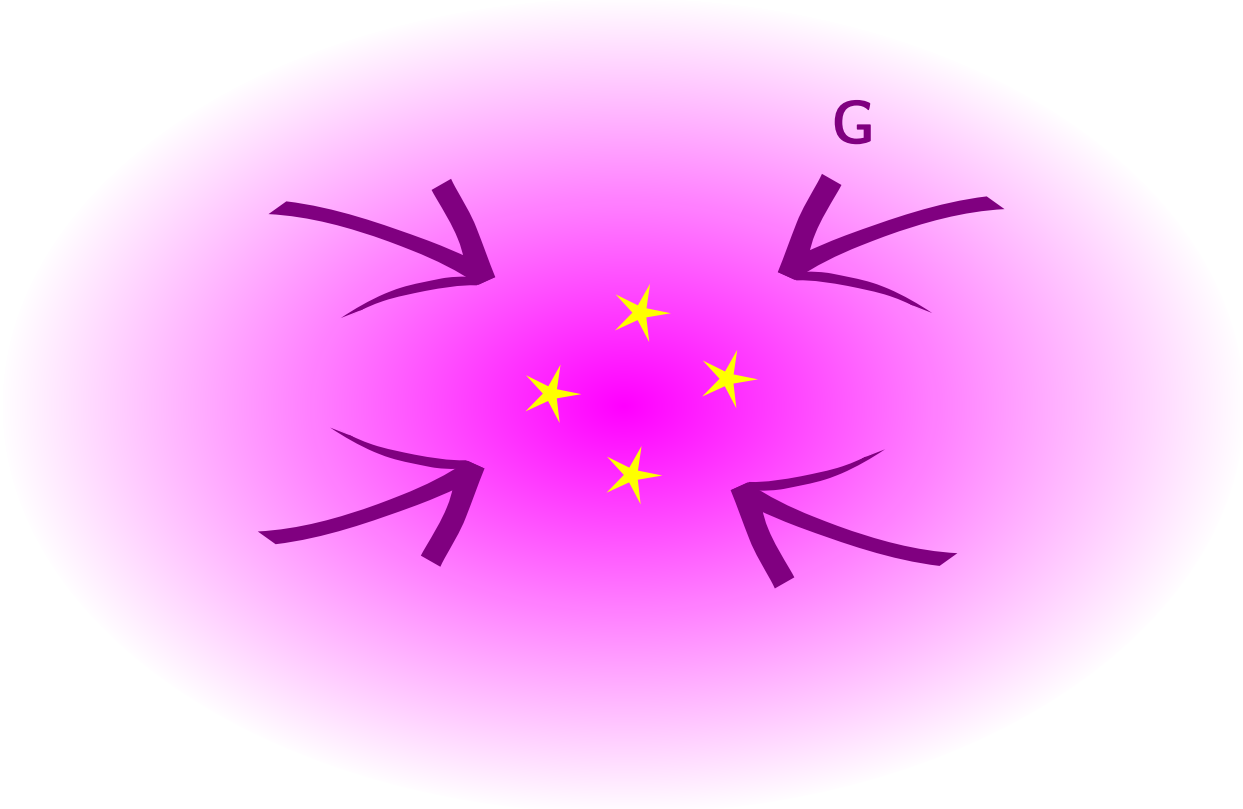

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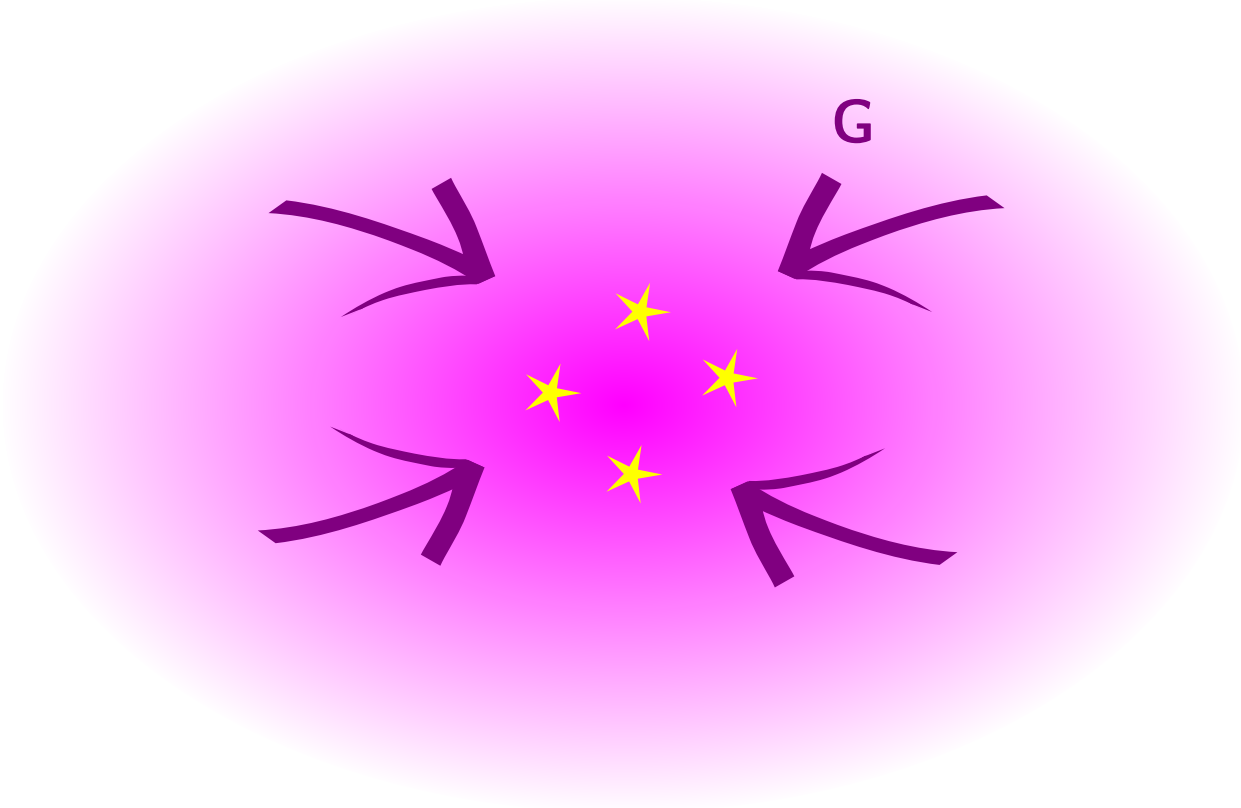

$$SFR_{\mathrm{grav}} \approx \frac{M_{\mathrm{cloud}}}{t_{\mathrm{free-fall}}} \approx 460\ \mathrm{M}_{\odot} \cdot \mathrm{yr}^{-1}$$

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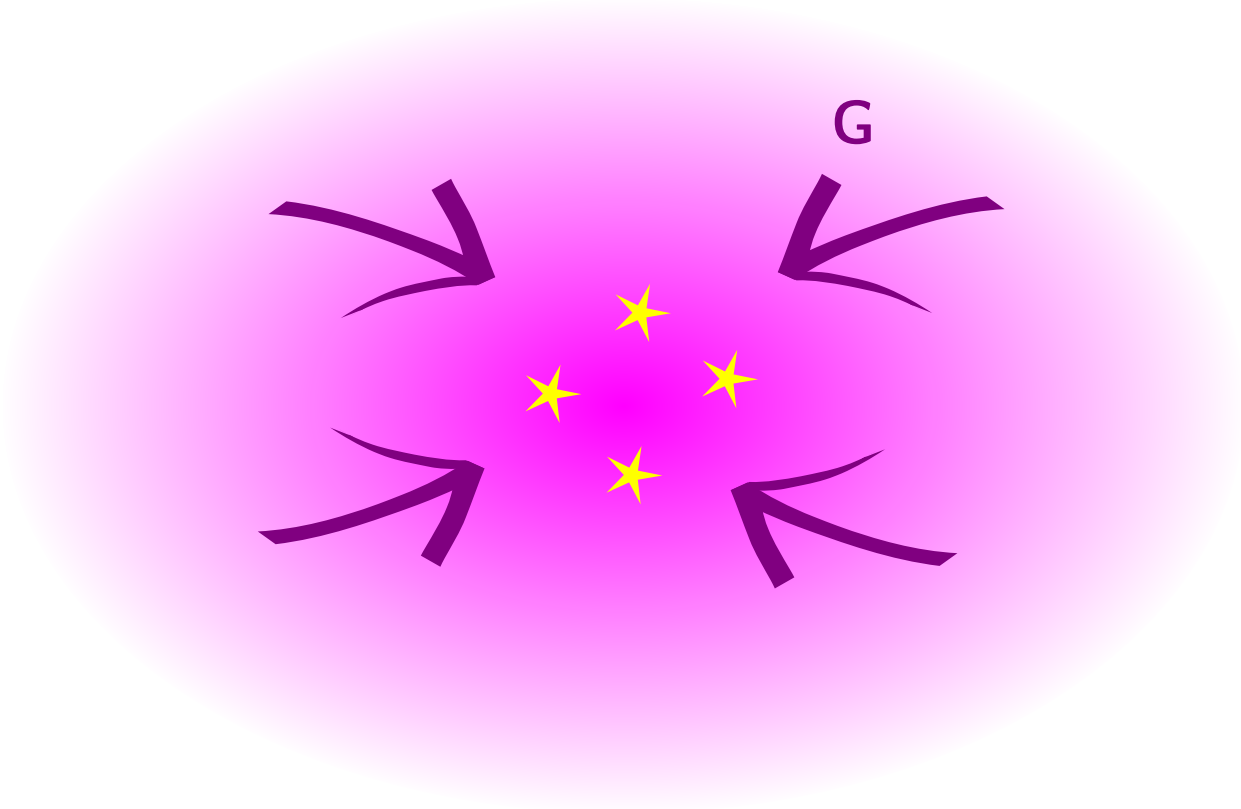
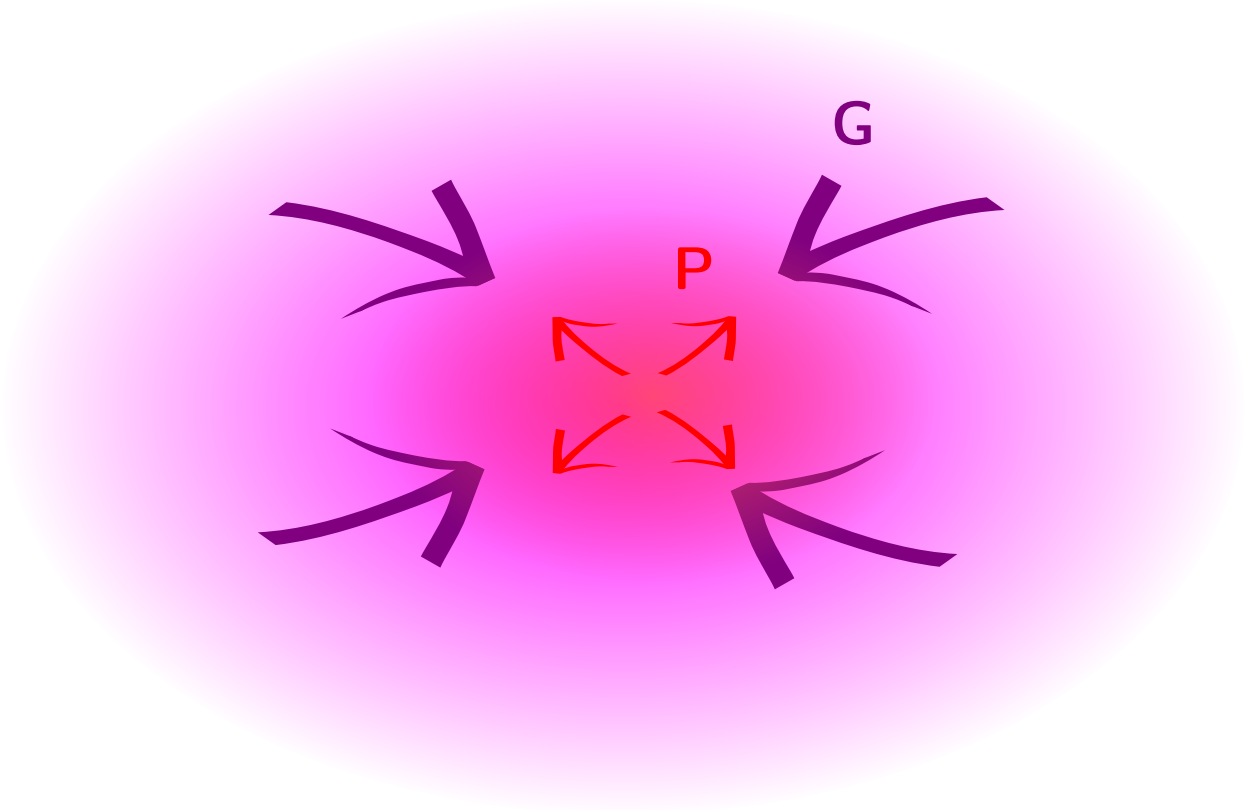


$$SFR_{\mathrm{grav}} \approx \frac{M_{\mathrm{cloud}}}{t_{\mathrm{free-fall}}} \approx 460\ \mathrm{M}_{\odot} \cdot \mathrm{yr}^{-1} \gg SFR_{\mathrm{obs}} \approx 2\ \mathrm{M}_{\odot} \cdot \mathrm{yr}^{-1}$$

Quenching star formation

Estimating the Star Formation Rate (SFR)



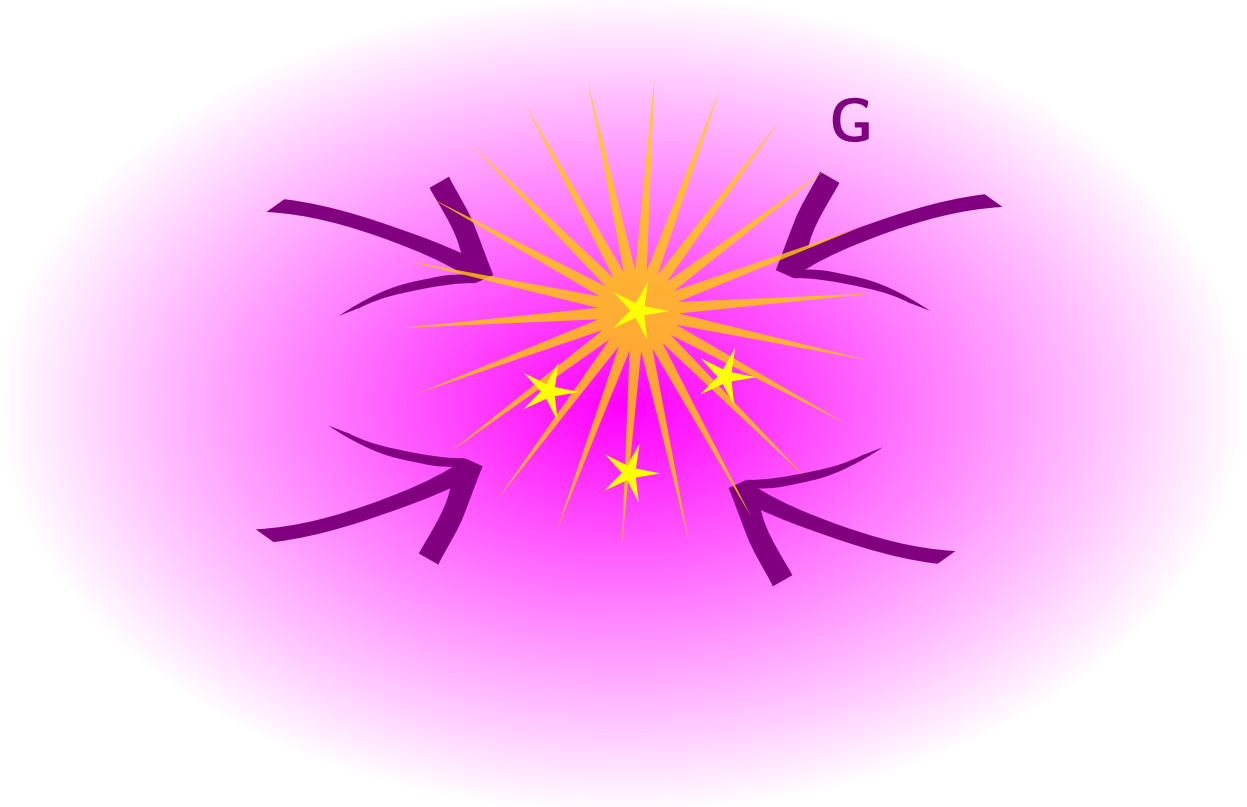
Thermal pressure

Stellar Feedbacks

Turbulence

Quenching star formation

Estimating the Star Formation Rate (SFR)



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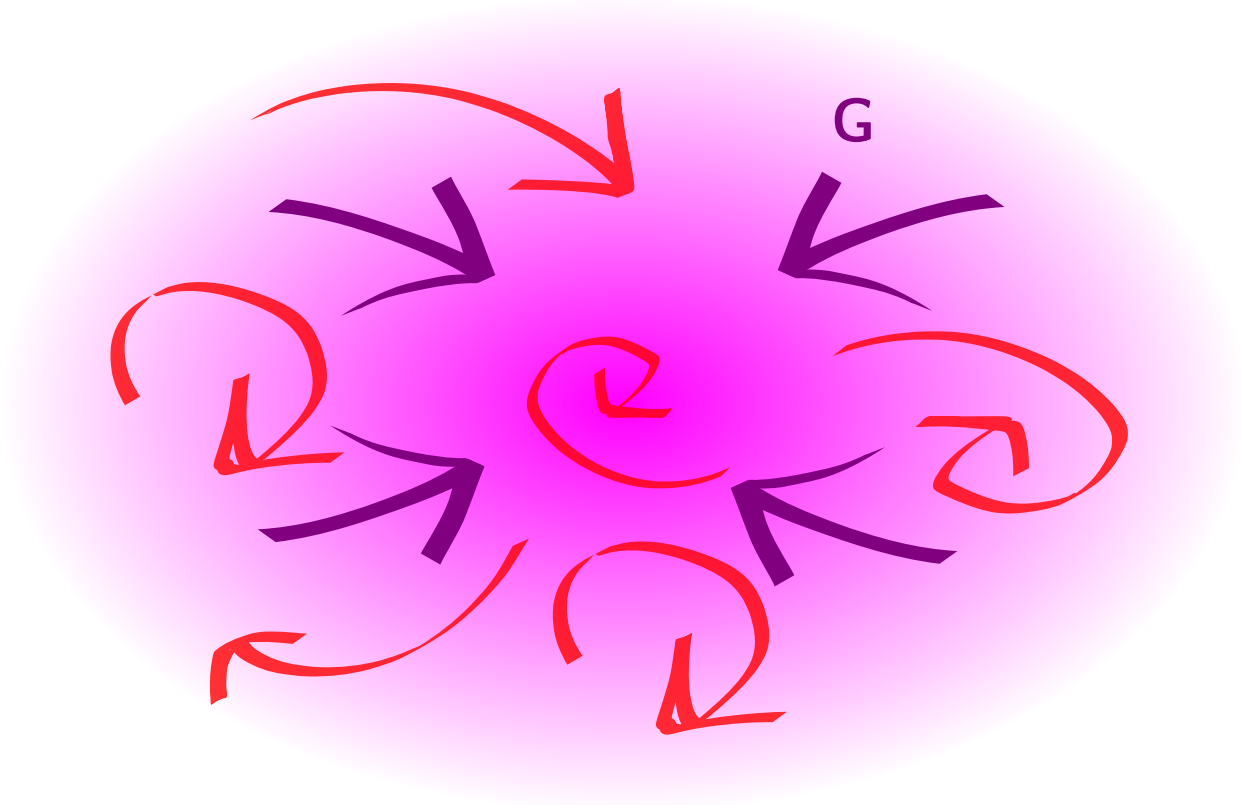


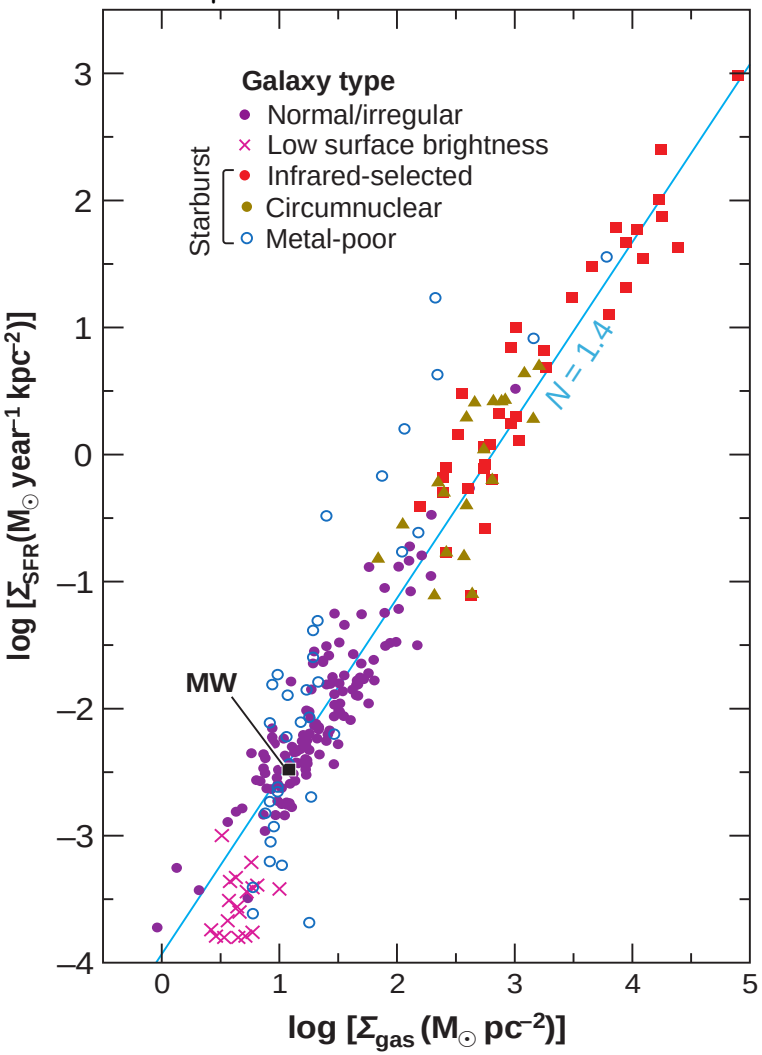
Thermal pressure

Stellar Feedbacks

Turbulence

The Schmidt-Kennicutt law

Kennicutt+2012



Relation between

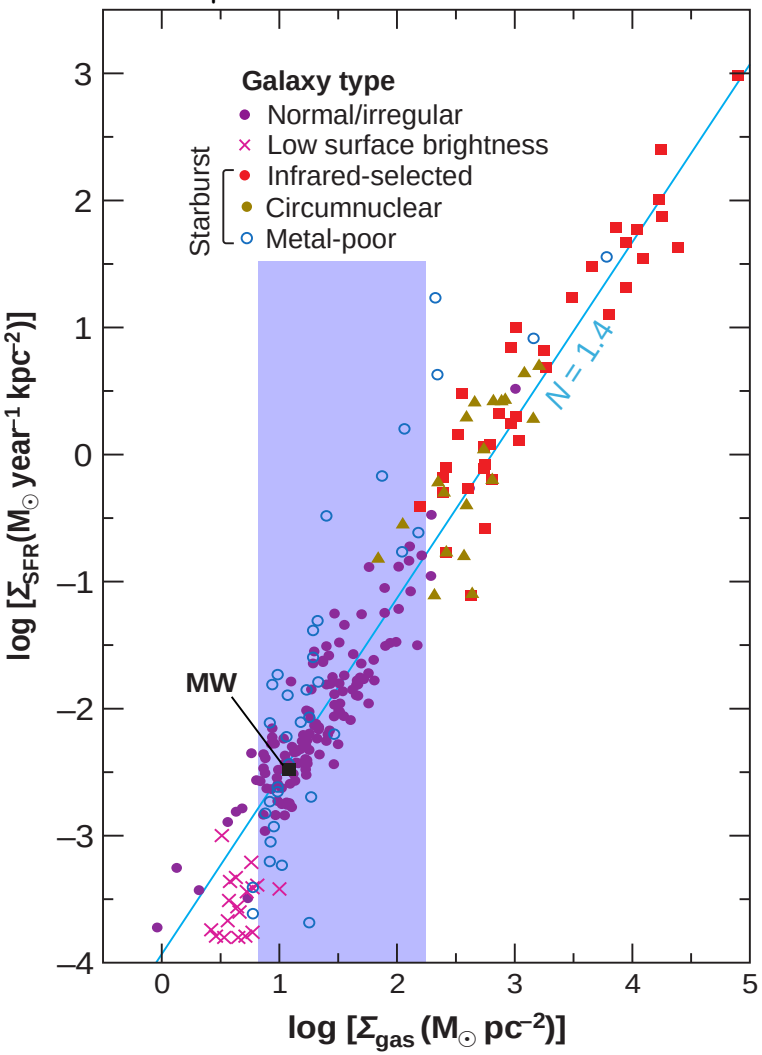
$\Sigma_{\rm SFR}$ Surface density of SFR

$\Sigma_{\rm gas}$ Surface density of gas

$$\Sigma_{\rm SFR} \propto \Sigma_{\rm gas}^{1.4}$$

The Schmidt-Kennicutt law

Kennicutt+2012



Relation between

$\Sigma_{\rm SFR}$ Surface density of SFR

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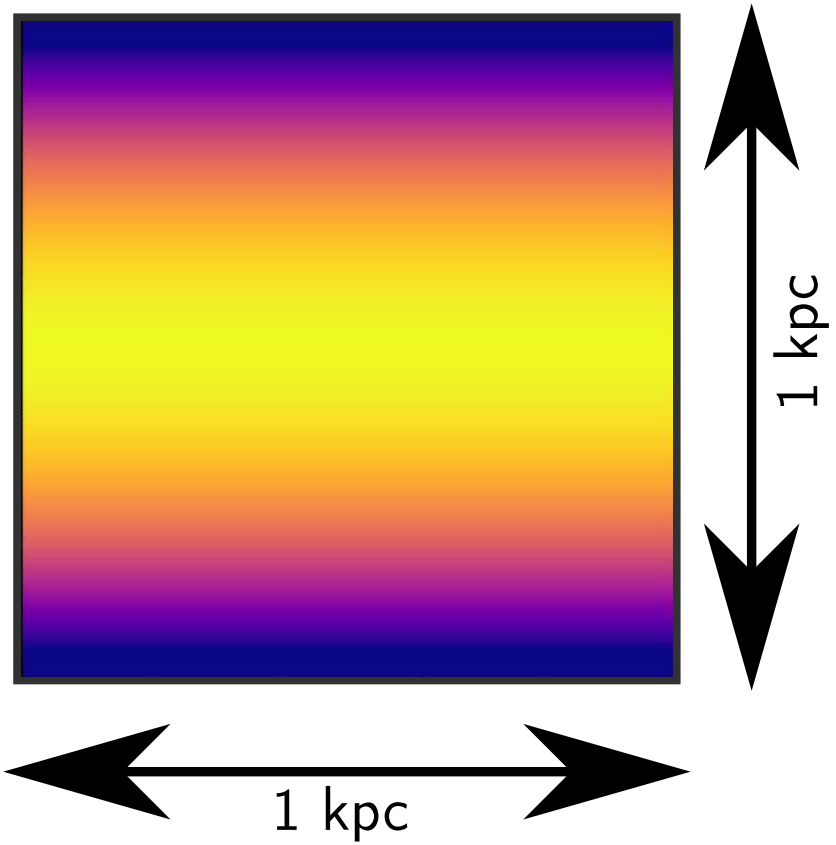
$$\Sigma_{\rm SFR} \propto \Sigma_{\rm gas}^{1.4}$$

Our study

- Dominating quenching processes explaining this law ?
- **Numerical investigation**

Putting a galaxy into a (numerical) box



MHD simulations with Ramses

- 1 kpc^3 region of a galactic disk
- Physics of the interstellar medium (cooling / heating)
- Star formation: density threshold

Tested quenching processes

1. Stellar feedbacks:
   - HII Region
   - UV heating
   - Supernovae
2. Large scale turbulent driving

Star formation self-regulation

Description of the feedback models

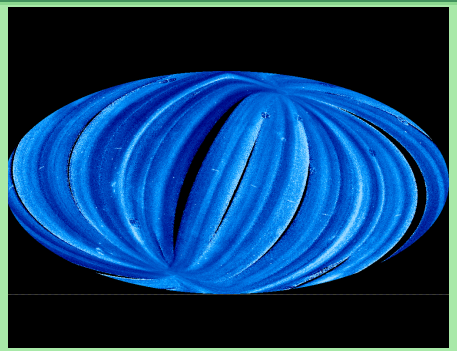
HII regions

Expanding ionized bubble of hydrogen, with a shock.

Model

Expansion computed via radiative transfert.

Far Ultra Violet



Energetic UV photons can go trough the gas and heat it.

Model

Uniform heating of the gas, proportional to the SFR.

Supernovae

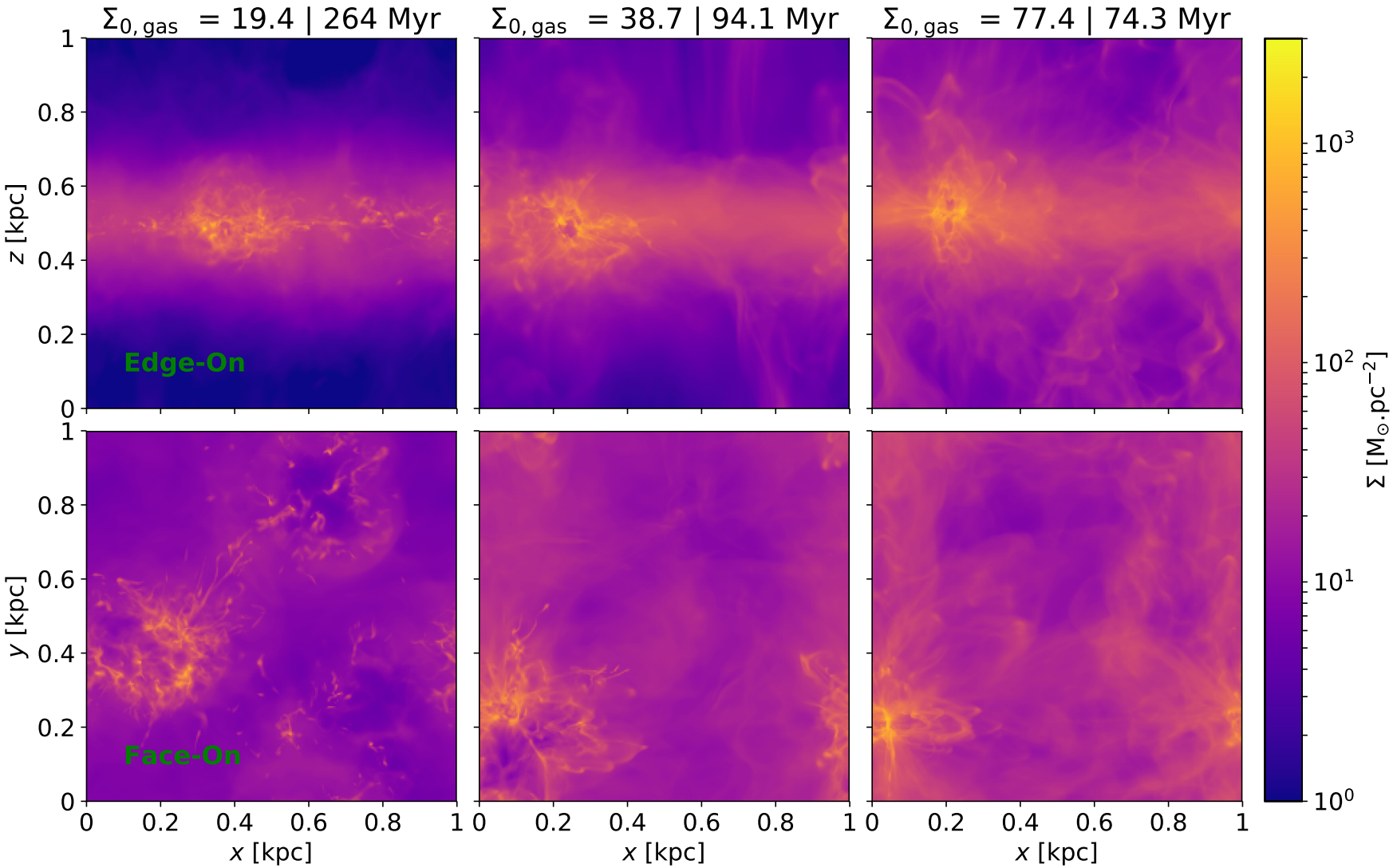
End of life of massive stars, injects $10^{51}\mathrm{erg}$ in the ISM.

Model

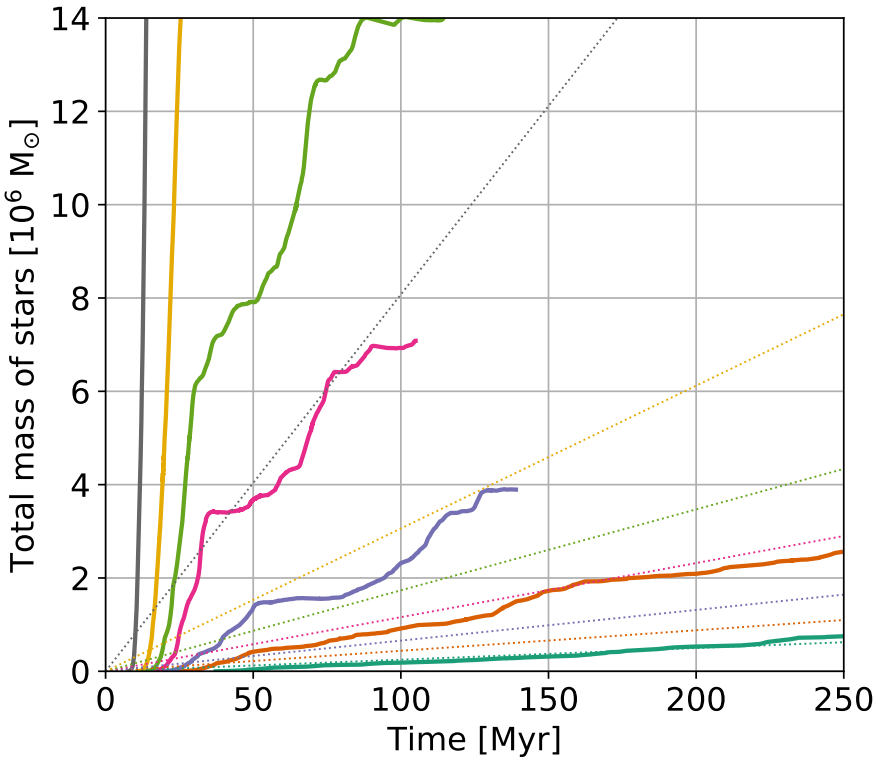
Stellar object with random motion that eventually inject momentum.

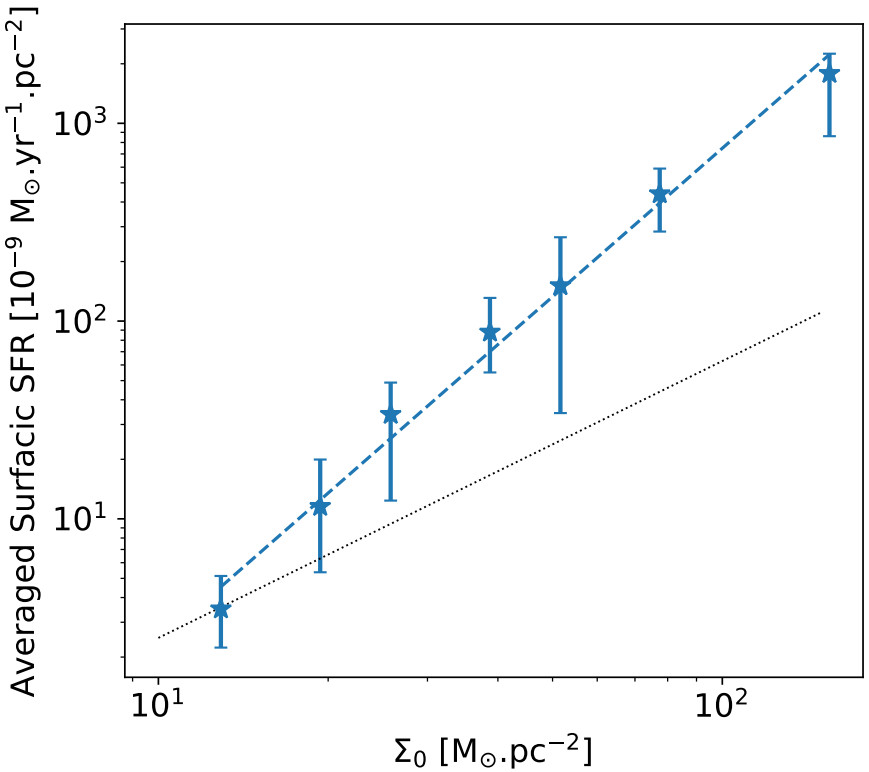
Star formation self regulation

Column density maps



Star formation self regulation

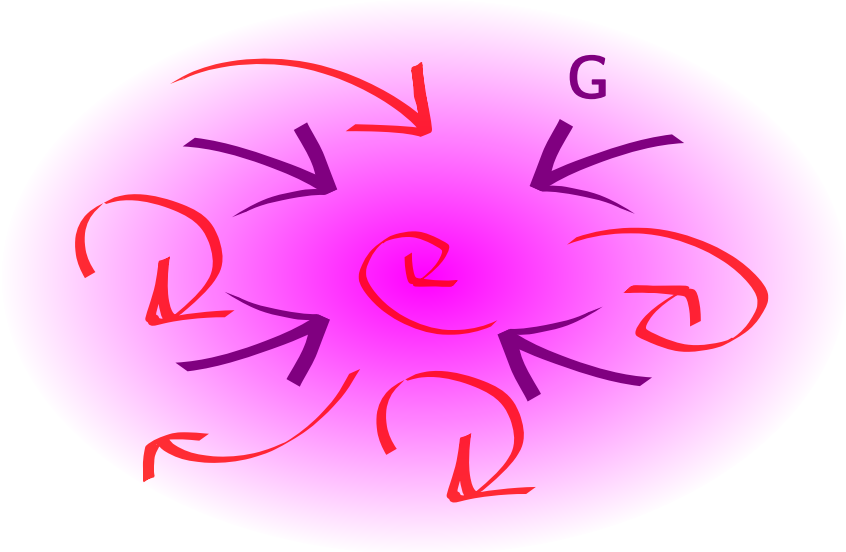




$\Sigma_{0,\mathrm{gas}}$ = 12.9
$\Sigma_{0,\mathrm{gas}}$ = 19.4
$\Sigma_{0,\mathrm{gas}}$ = 25.8
$\Sigma_{0,\mathrm{gas}}$ = 38.7
$\Sigma_{0,\mathrm{gas}}$ = 51.6
$\Sigma_{0,\mathrm{gas}}$ = 77.4
$\Sigma_{0,\mathrm{gas}}$ = 155

Stellar feedback only
Power-law fit with index 2.5
N = 1.4 (Kennicutt)

The influence of larger-scale dynamics: turbulent driving



Turbulence from galactic dynamics

- Spirals, mass transfert $\rightarrow$ turbulence
- Expected injected power: $P_{\rm inj} \propto \Sigma_{\rm gas}^{2.5}$

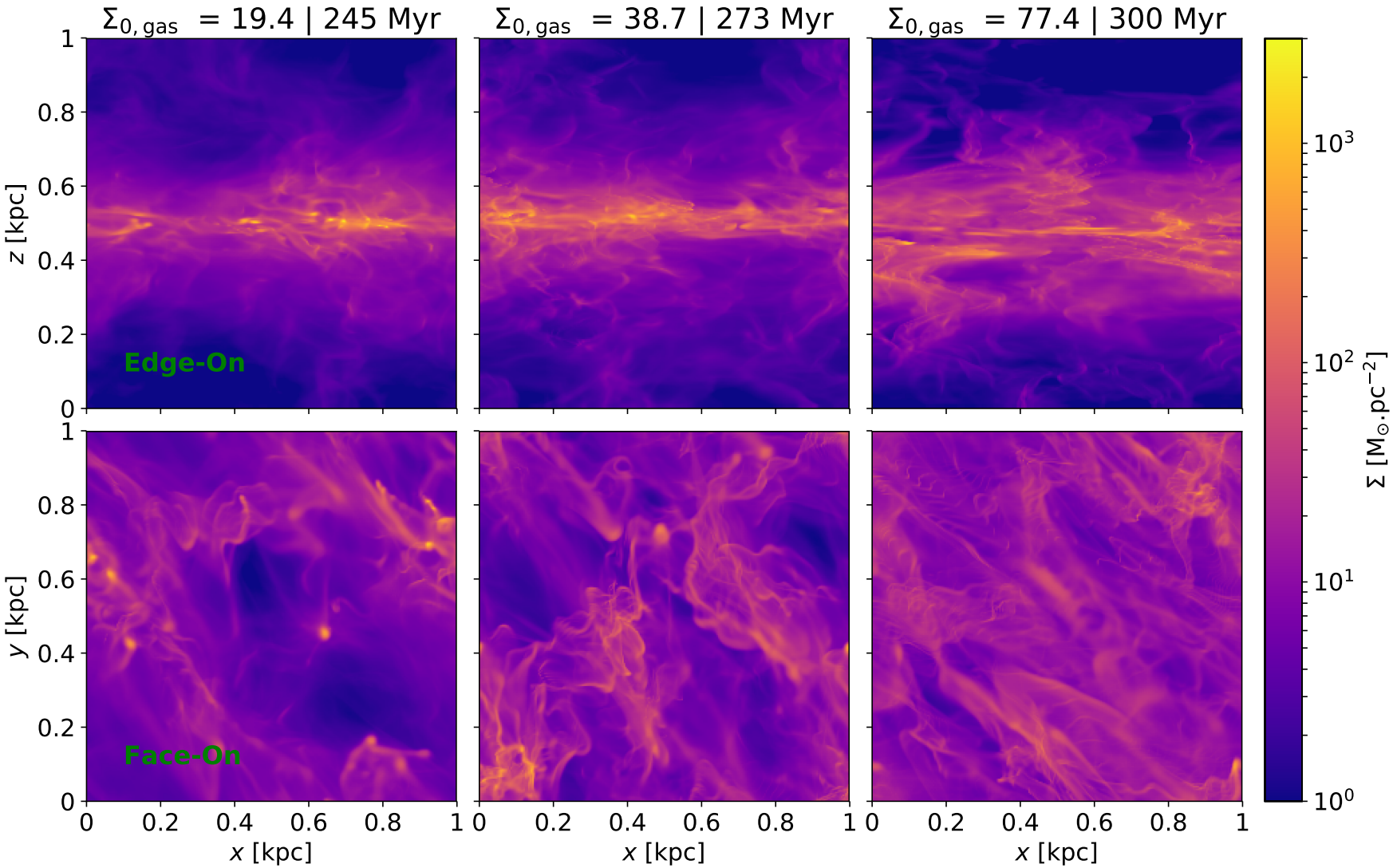
Model

An extra 2D force is added to generate random motion.
Two sets of simulations:

- $P_{\rm inj} \propto \Sigma_{\rm gas}^{2.5}$
- $P_{\rm inj} \propto \Sigma_{\rm gas}^{4}$

Effects of turbulence driving

Column density maps



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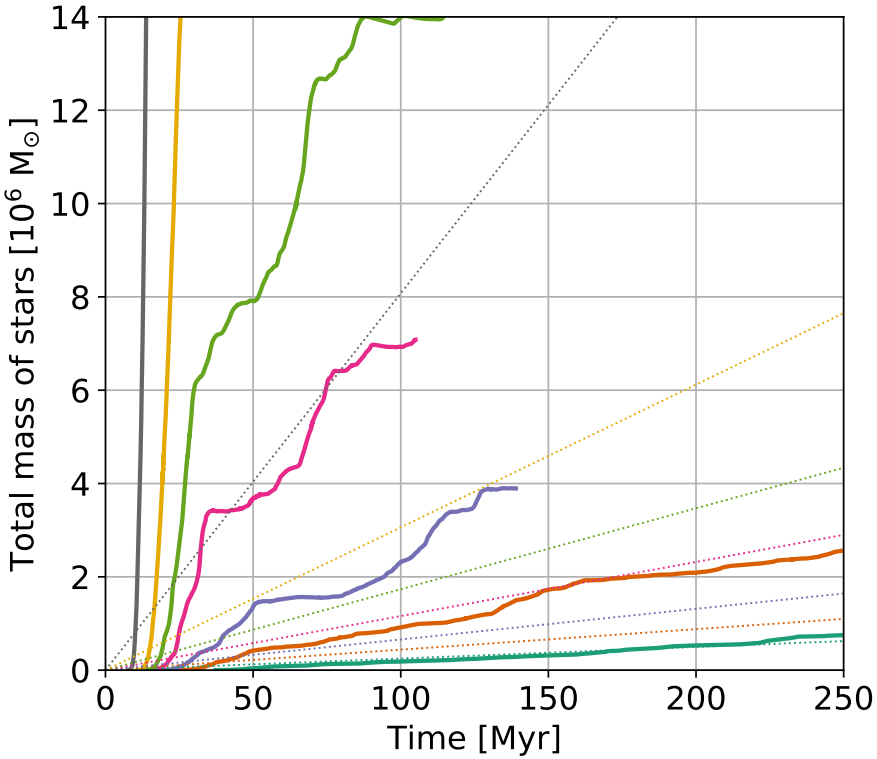

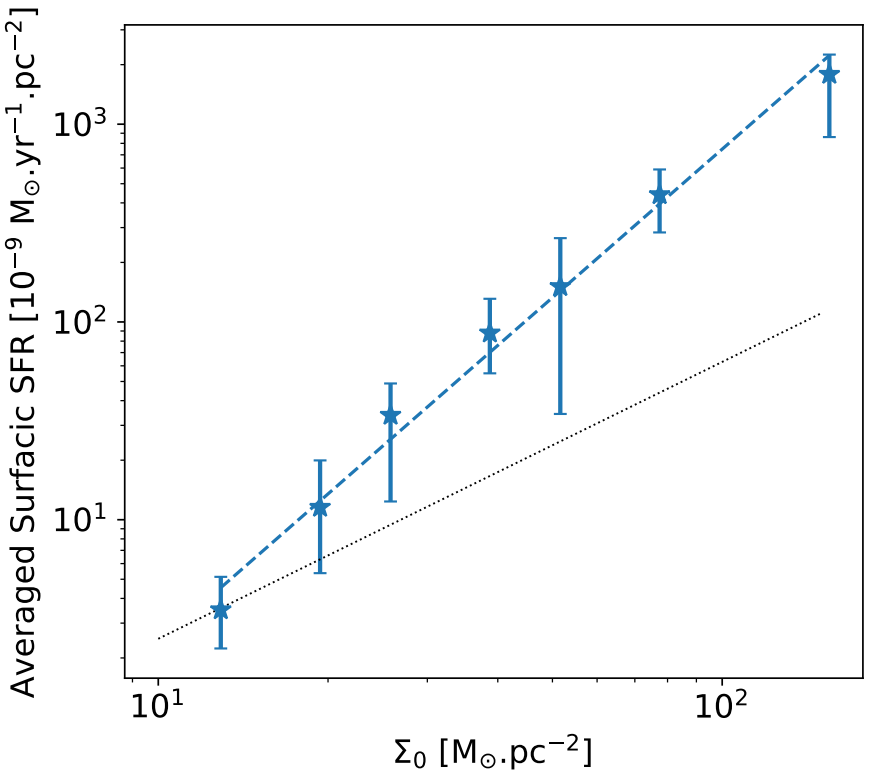

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Power-law fit with index 2.5
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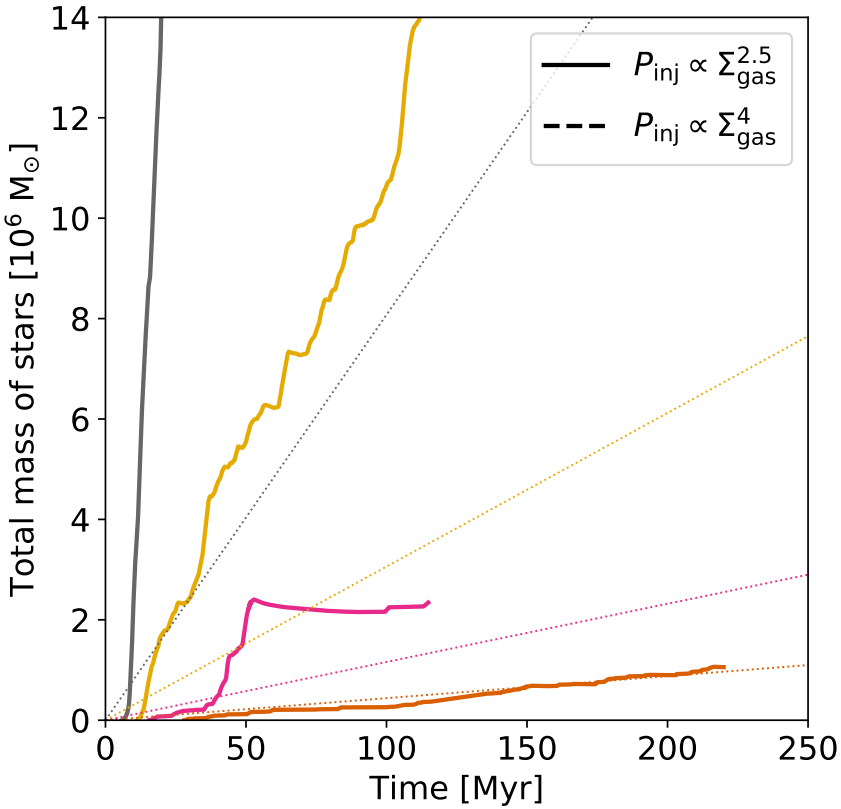
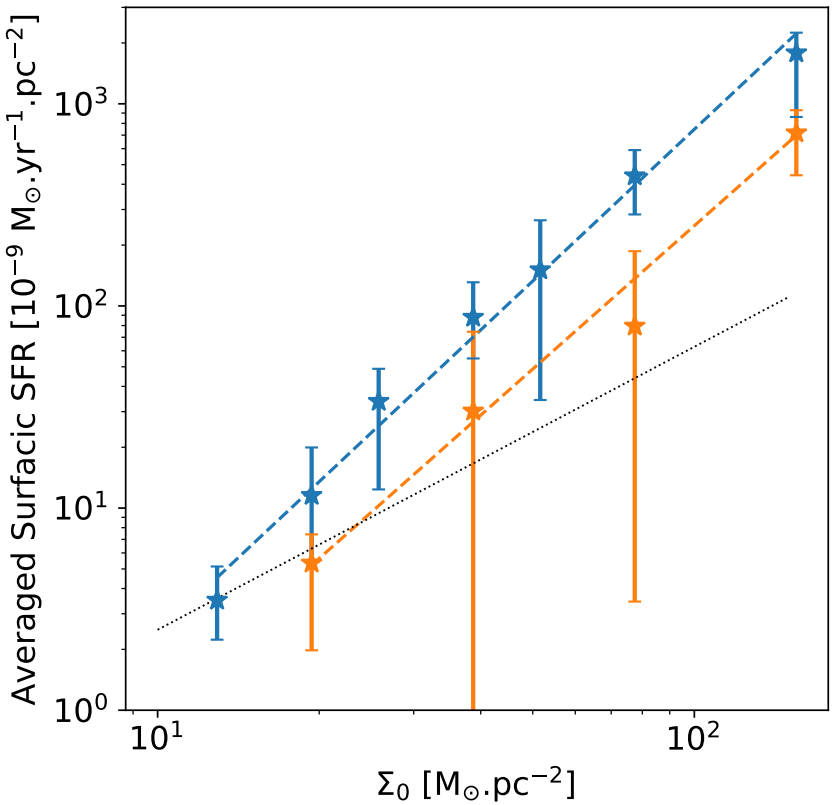
Without turbulence

Effects of turbulence driving





$\Sigma_{0,gas}$ = 19.4 $\Sigma_{0,gas}$ = 77.4
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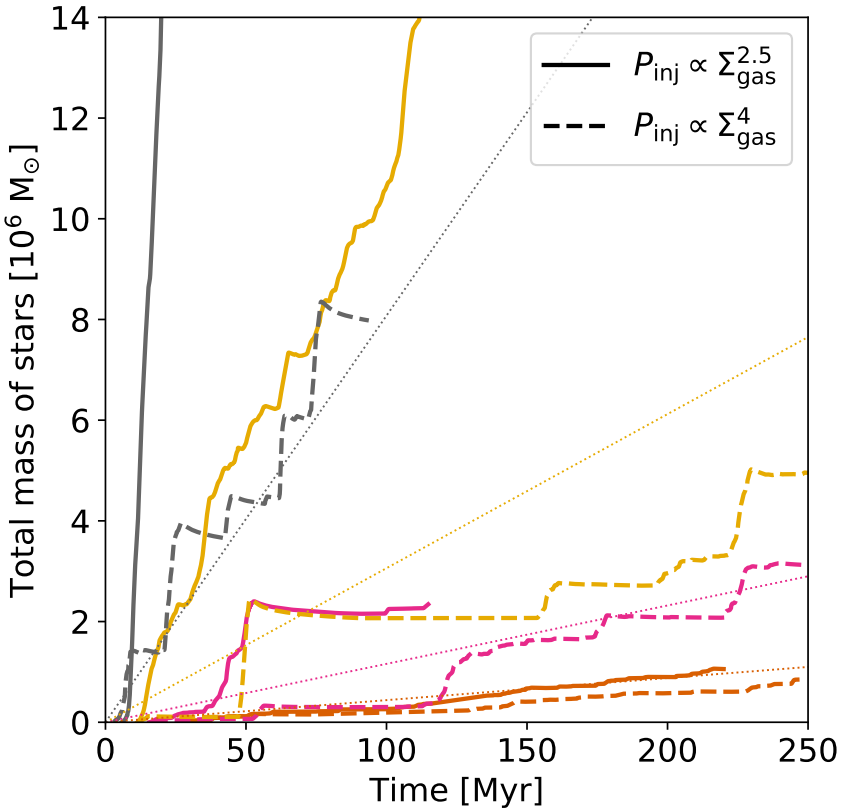
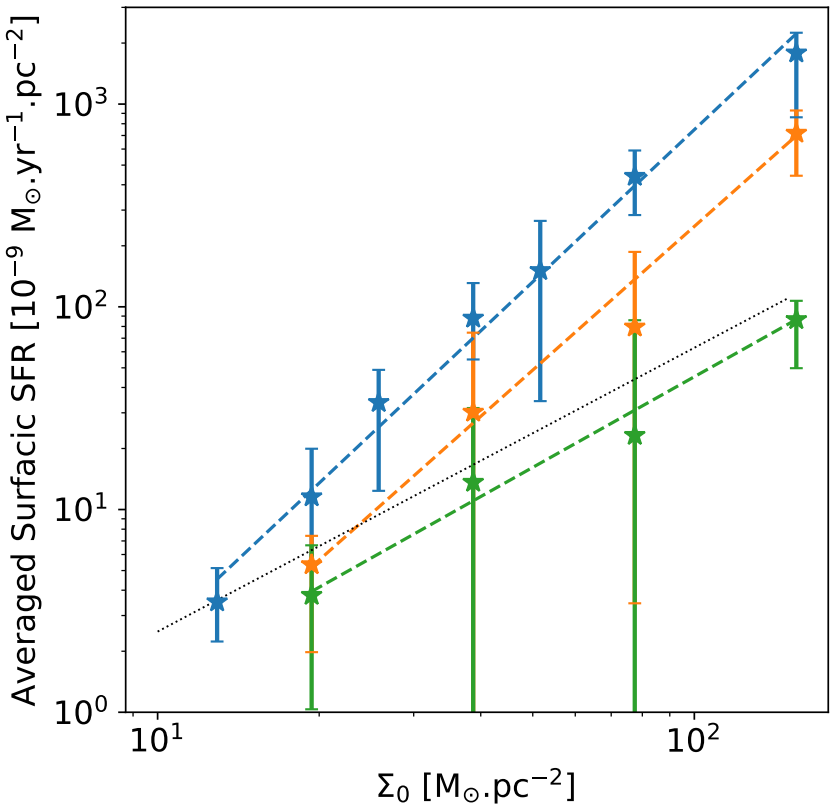
Power-law fit with index 2.5
Power-law fit with index 2.4
Power-law fit with index 1.5
N = 1.4 (Kennicutt)
No driving
$P_{inj} \propto \Sigma_{gas}^{2.5}$
$P_{inj} \propto \Sigma_{gas}^{4}$

Without turbulence , $P_{inj} \propto \Sigma_{gas}^{2.5}$

Effects of turbulence driving





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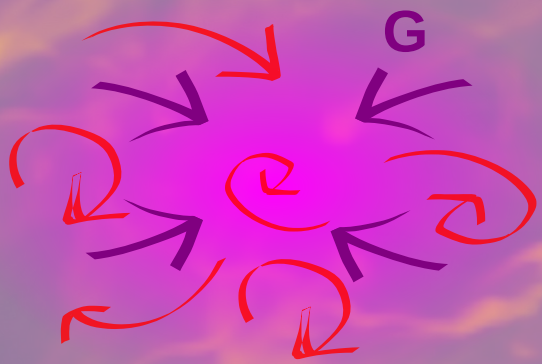
Power-law fit with index 2.4
Power-law fit with index 1.5
N = 1.4 (Kennicutt)
No driving
$P_{inj} \propto \Sigma_{gas}^{2.5}$
$P_{inj} \propto \Sigma_{gas}^{4}$

Without turbulence , $P_{inj} \propto \Sigma_{gas}^{2.5}$, $P_{inj} \propto \Sigma_{gas}^{4}$

Conclusions

1. *Stellar feedback alone cannot explain the Schimdt-Kennicutt Law.*

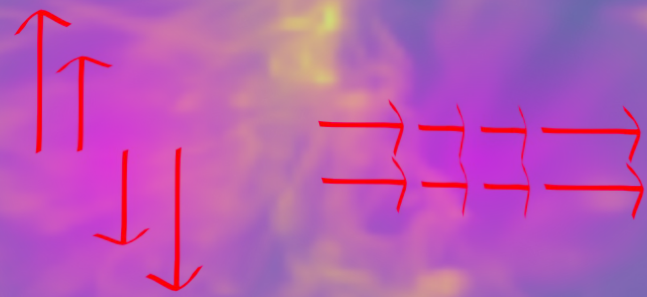
2. *Turbulent driving can reduce the SFR enough.*



3. *But the required energy is too high.*

Future work

A. *Test different kind of turbulence.*



B. *Galaxy-scale simulations to have better constraints on turbulence.*