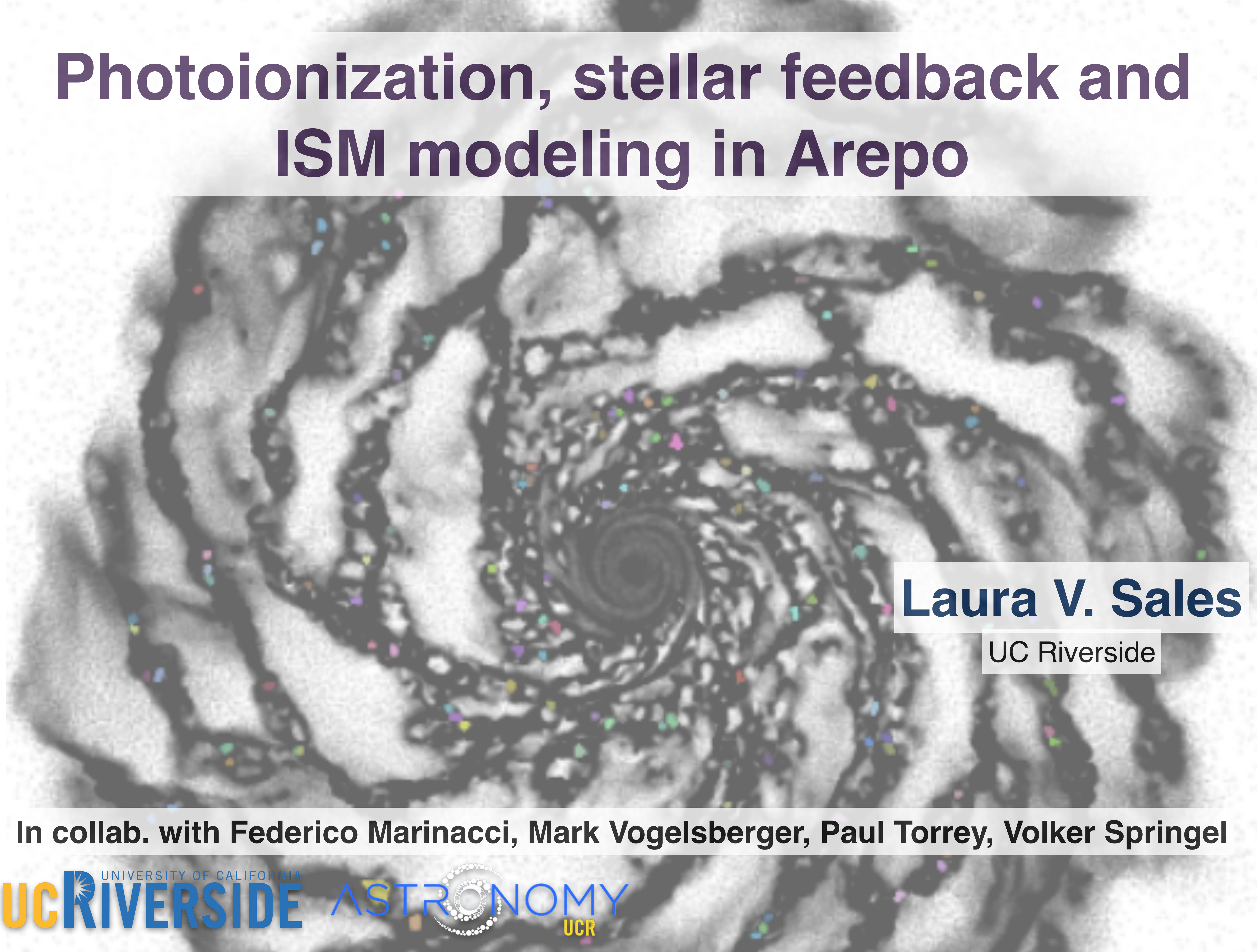
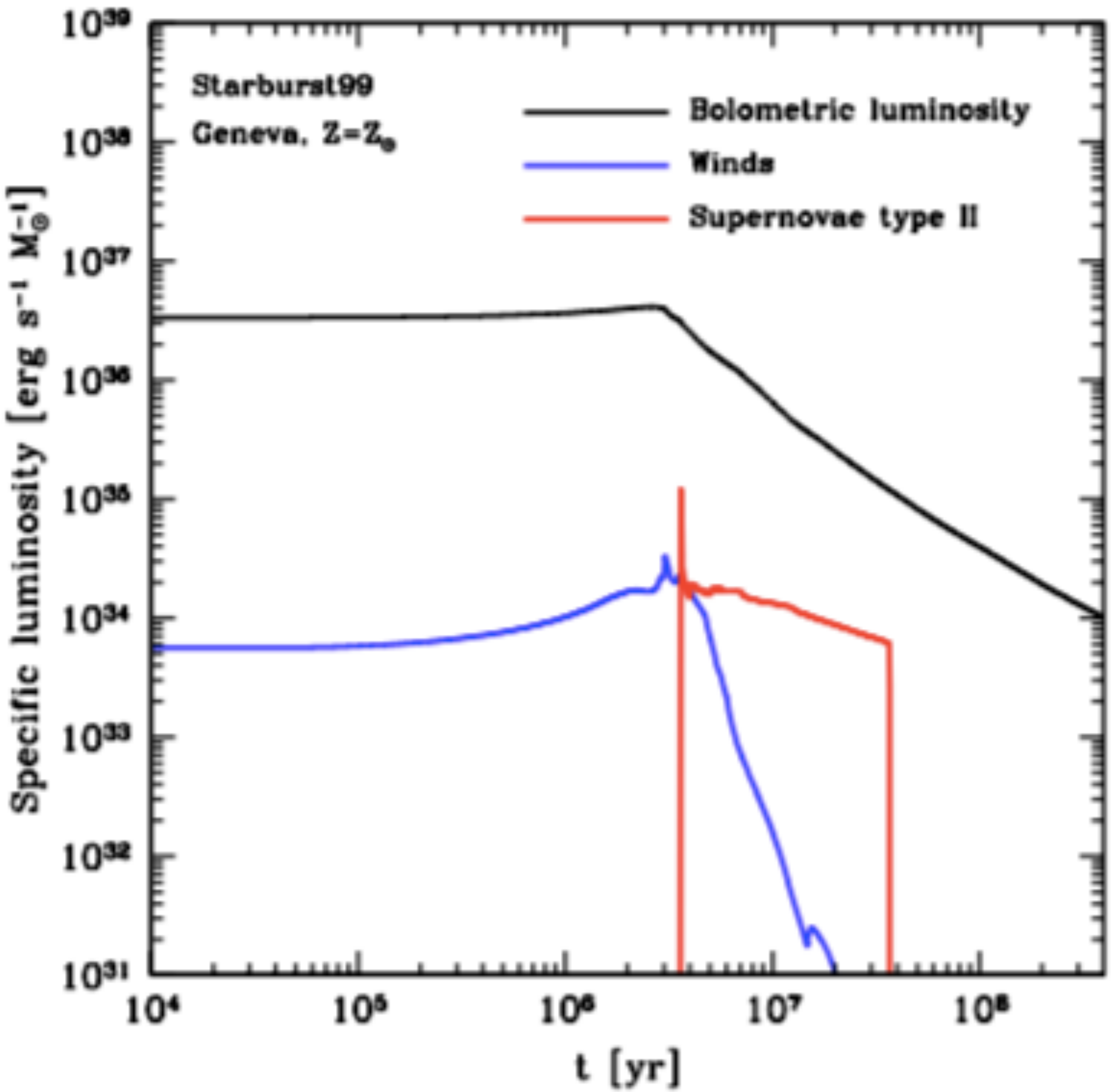


Photoionization, stellar feedback and ISM modeling in Arepo

Laura V. Sales
UC Riverside

In collab. with Federico Marinacci, Mark Vogelsberger, Paul Torrey, Volker Springel



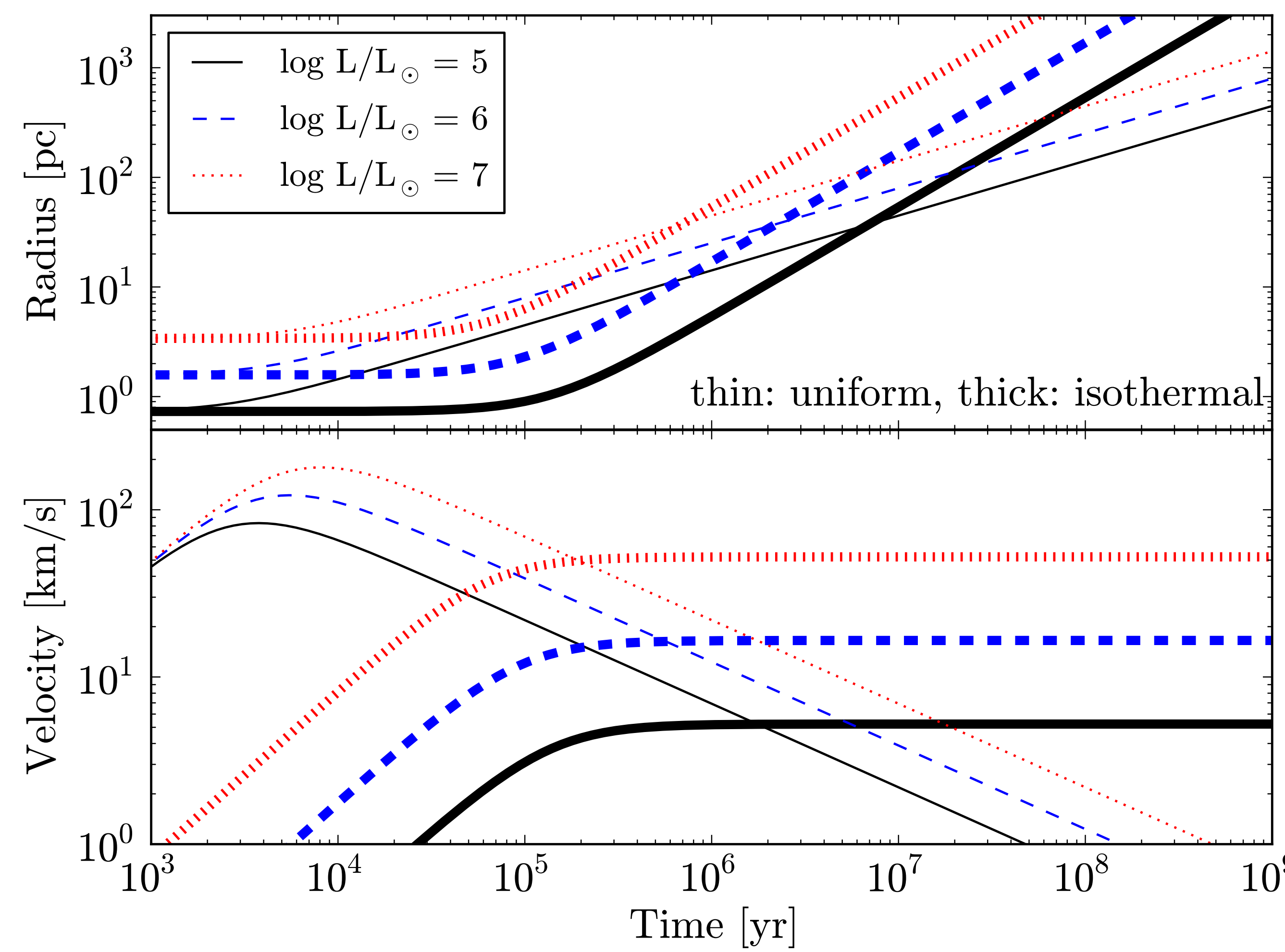
Agertz et al. 2013

Photoionization and Radiation Pressure

$$\frac{dP}{dt} = -\frac{GM(r)M_{\rm gas}(r)}{r^2} + \frac{L}{c}.$$

$$v(t) = \frac{Lt}{cM_{\rm shell}} = \frac{Lt}{c}\left[4\pi \int_0^r r'^2 \rho(r') dr'\right]^{-1}$$

(Wise et al. 2012)



Absorption of photons from young stars photoionizes the gas but also impartes momentum. How important can this process be?

Murray et al. , Hopkins et al. , Wise et al., Kimm et al., Ceverino et al., ...

Cloud 1

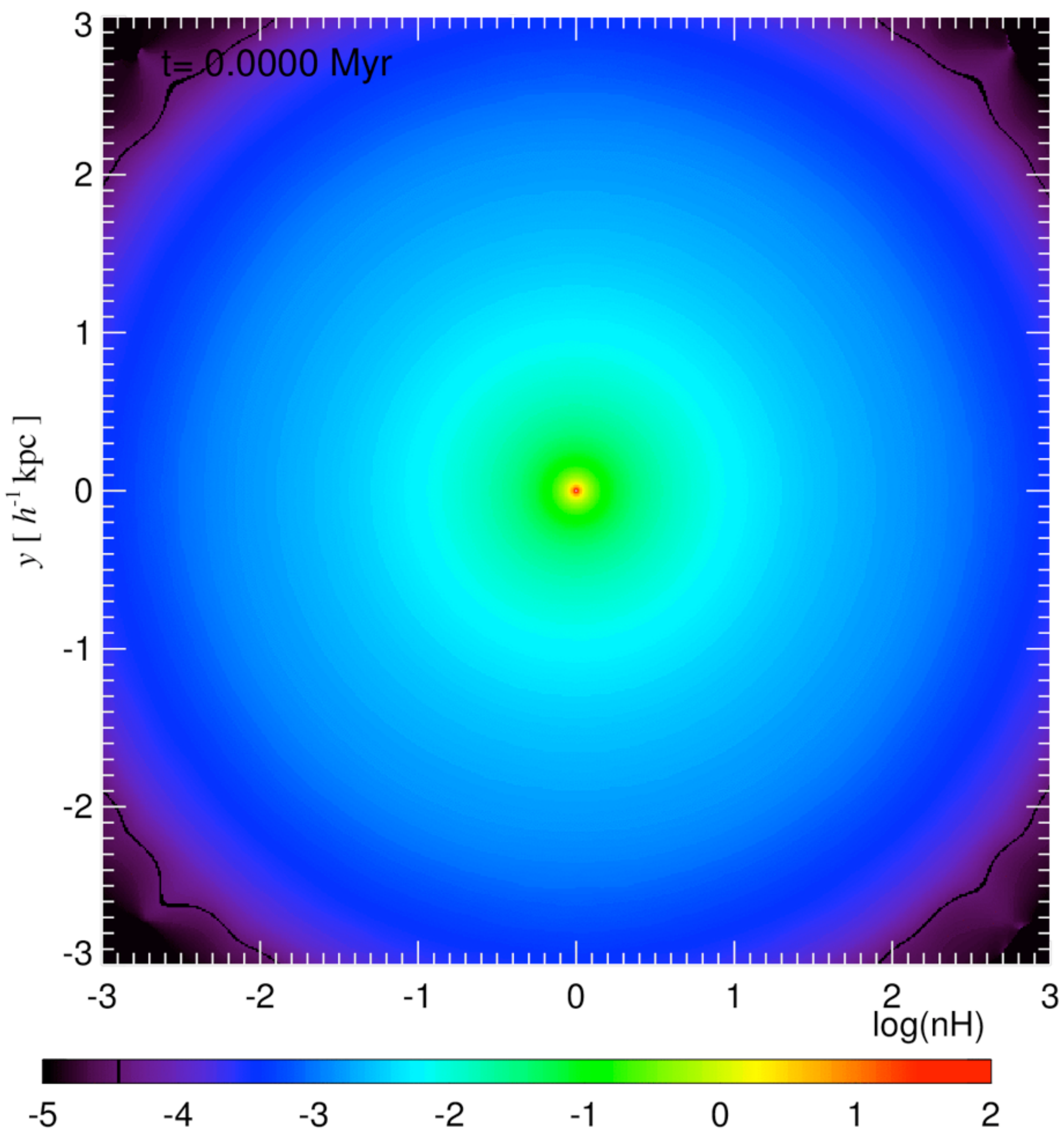
$M \sim 2 \times 10^6\ M_{sun}$

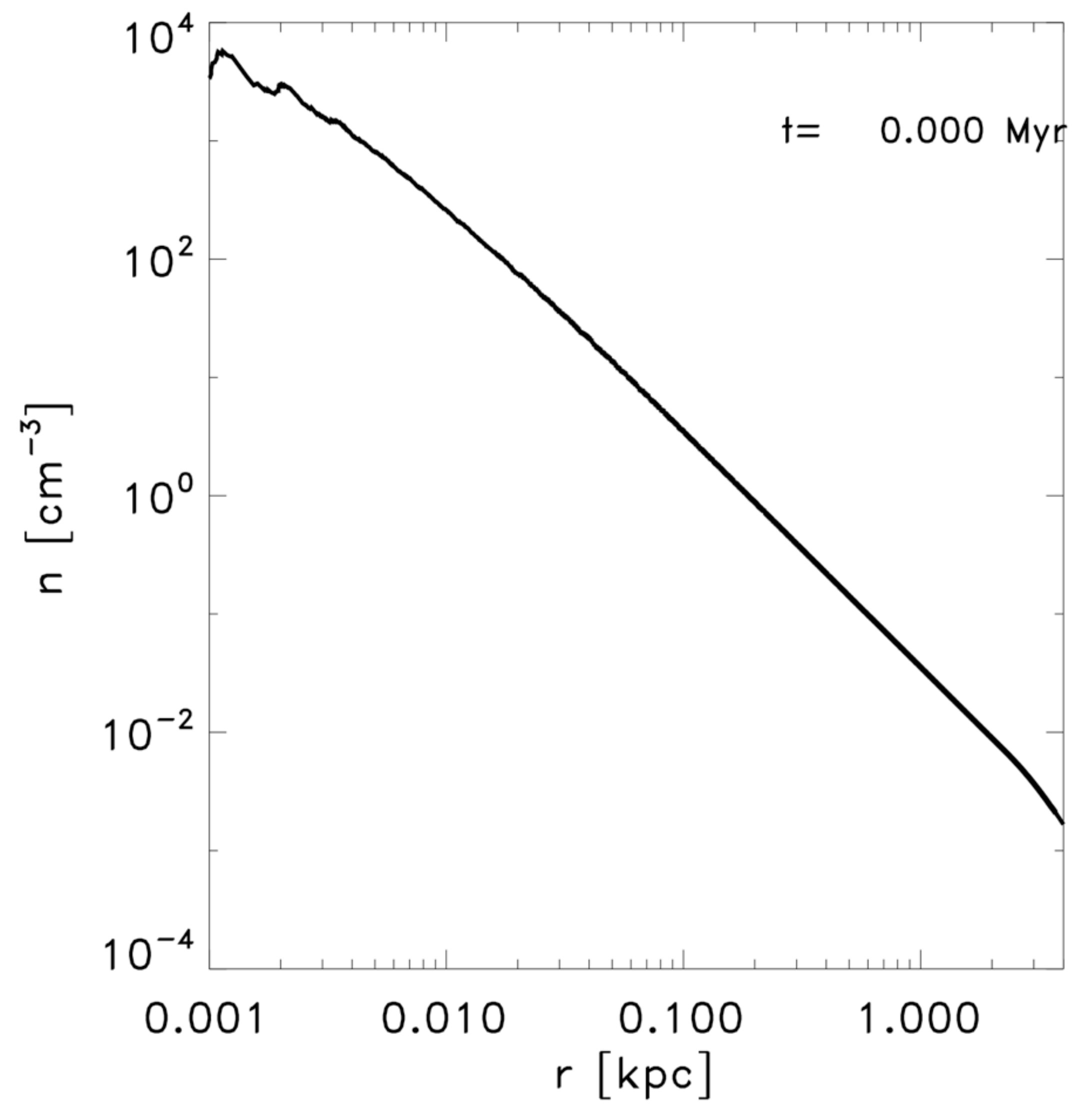
$R = 3$ kpc

$T_0 \sim 500$ K

$L = 10^6\ L_{sun}$

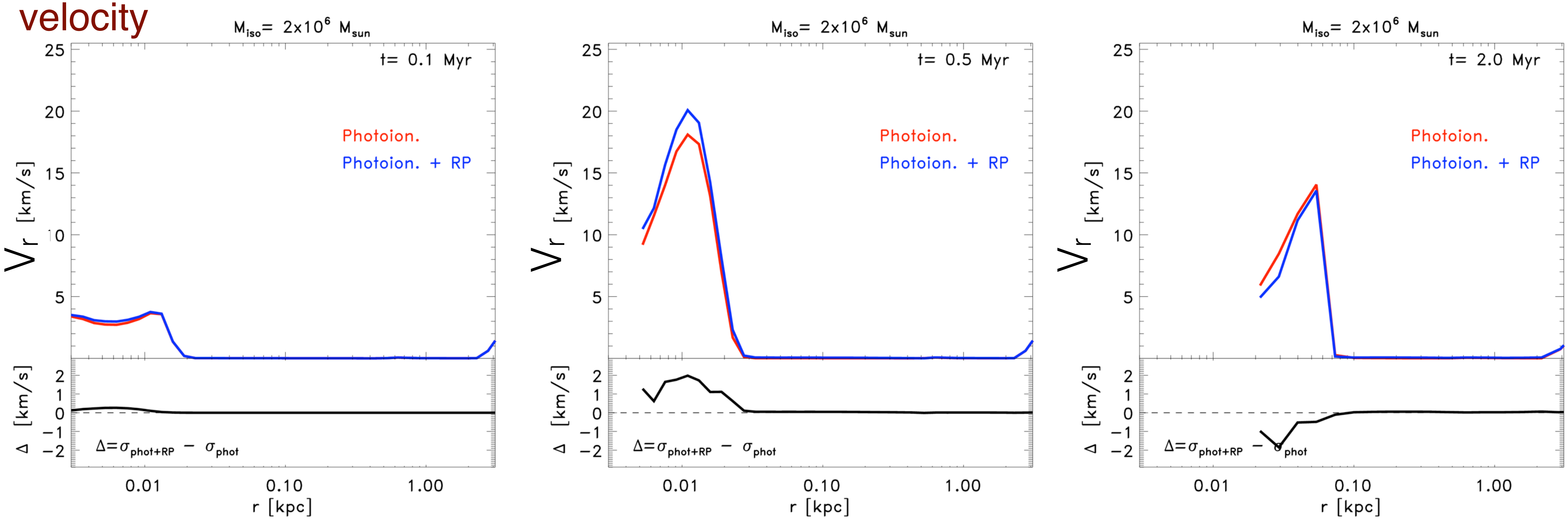
Idealized radiative transfer experiments with Arepo



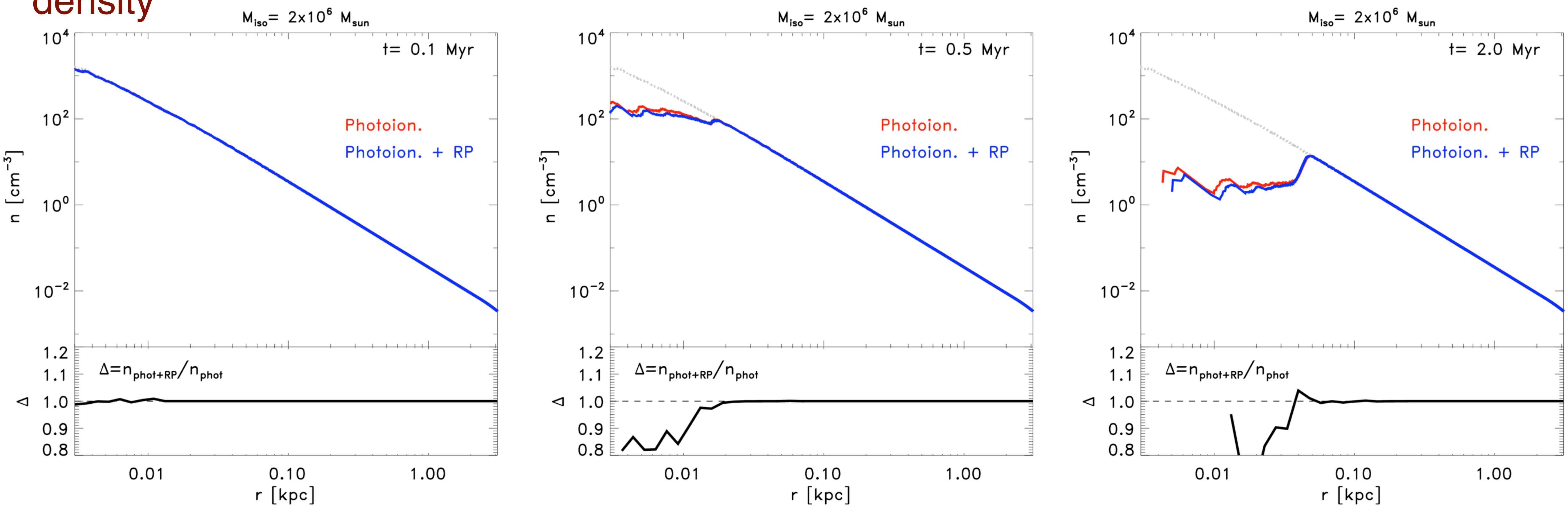


Sales et al. 2014

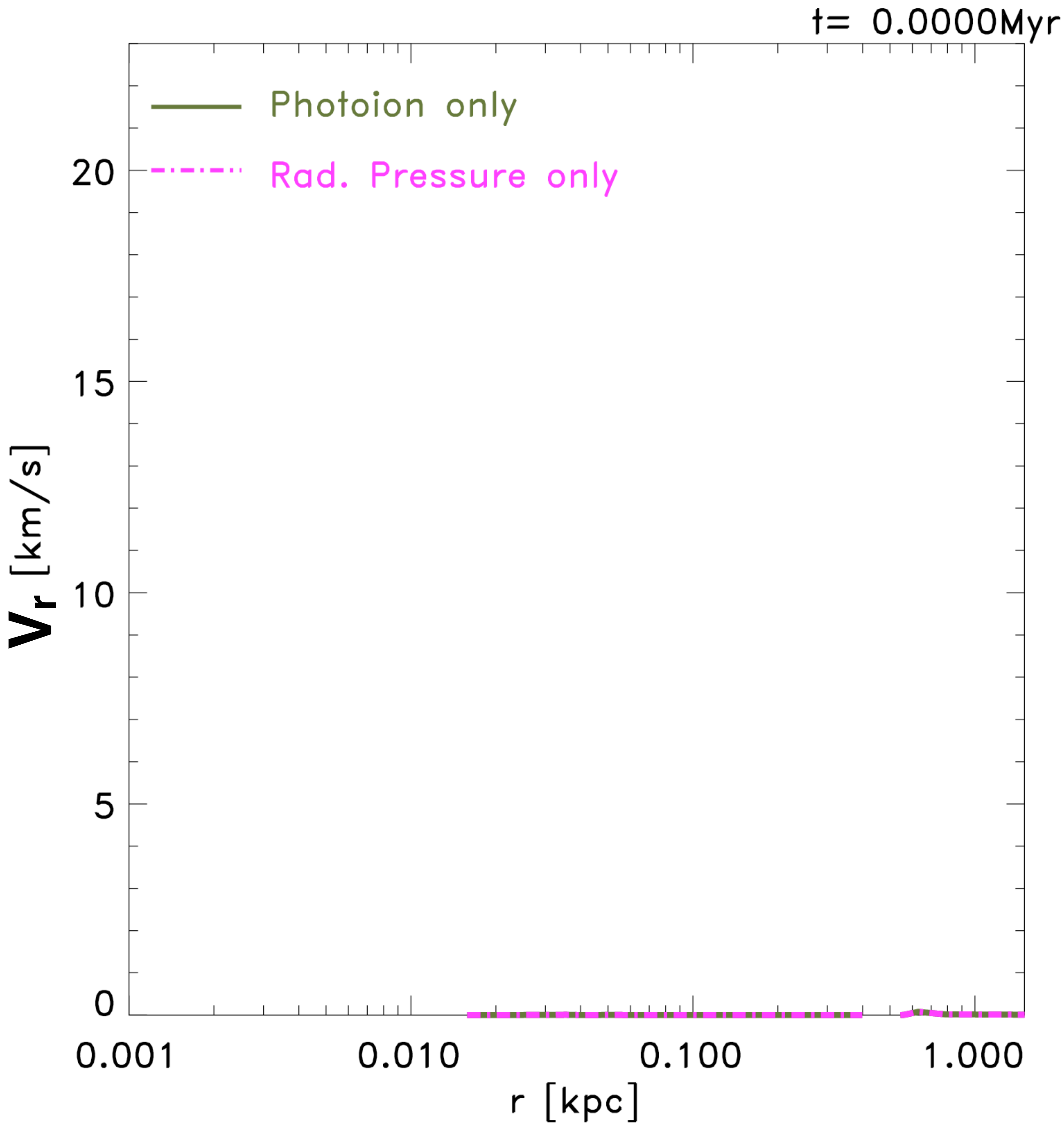
velocity



density



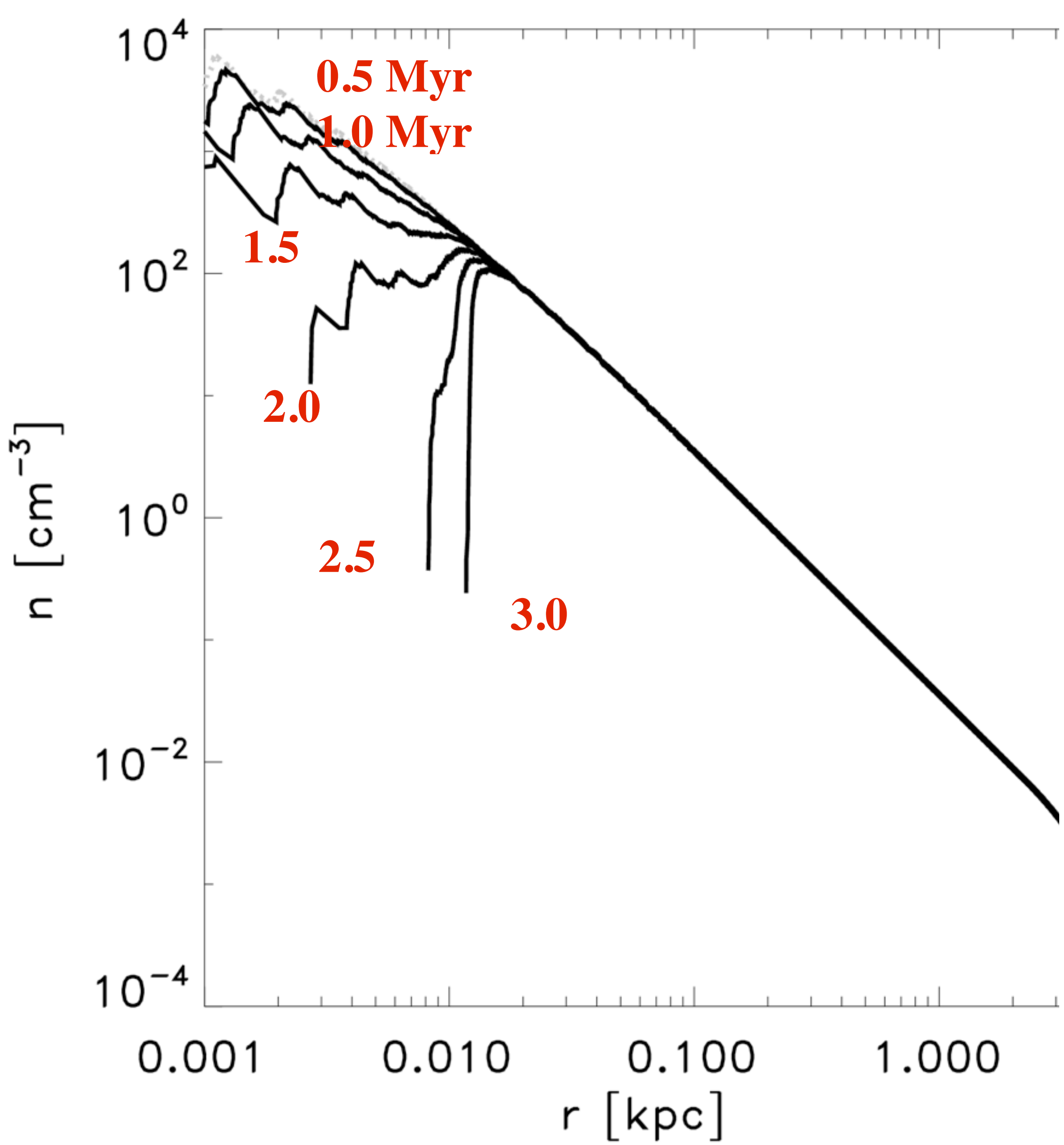
Sales et al. 2014



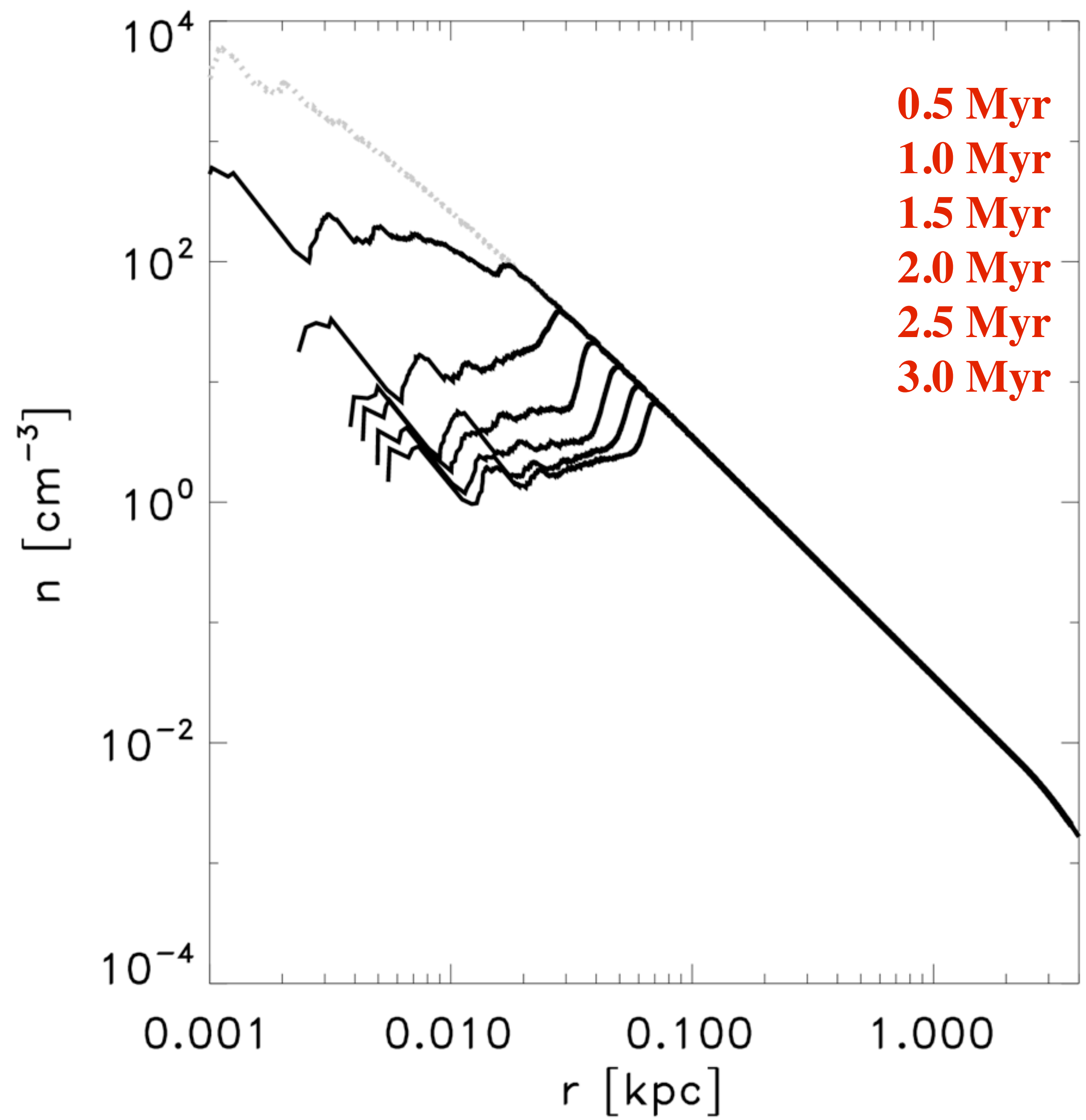
Sales et al. 2014

RP has the capability, but is slower than photoionization

Radiation. Pressure



Photoionization



Sales et al. 2014

(see also Walch et al. 2012, Rosdahl et al. 2015, Raskutti et al. 2017,Haid et al. 2018)

New ISM treatment in Arepo

Marinacci, Sales, Vogelsberger, Torrey, et al. , in prep.

Gravity

Gravitational forces are calculated using a Tree-PM scheme. Long range forces = particle-mesh / short scale = oct-tree

Heating/Cooling

Cooling: gas allowed to cool down to low temperature ~10K via low-temperature metal line, fine-structure and molecular cooling processes, fit to CLOUDY tables.

Heating: Cosmic ray and photoelectric heating.

(modelling follows Hopkins et al. 2018)

Stellar Feedback

Supernova

Energy + momentum

$$p_{\rm SN} = M_{\rm SN} v_{\rm SN} = \sqrt{2 E_{\rm SN} M_{\rm SN}}$$

$$E_{\rm SN,tot} = f_{\rm SN} E_{51} (N_{\rm SNII} + N_{\rm SNIa})$$

Boost for unresolved Sedov-Taylor phase:

$$r_{\rm cool} = 28 {\rm pc}\, E_{51}^{0.29} \langle n \rangle^{-0.43} (Z/Z_\odot + 0.01)^{-0.18}$$

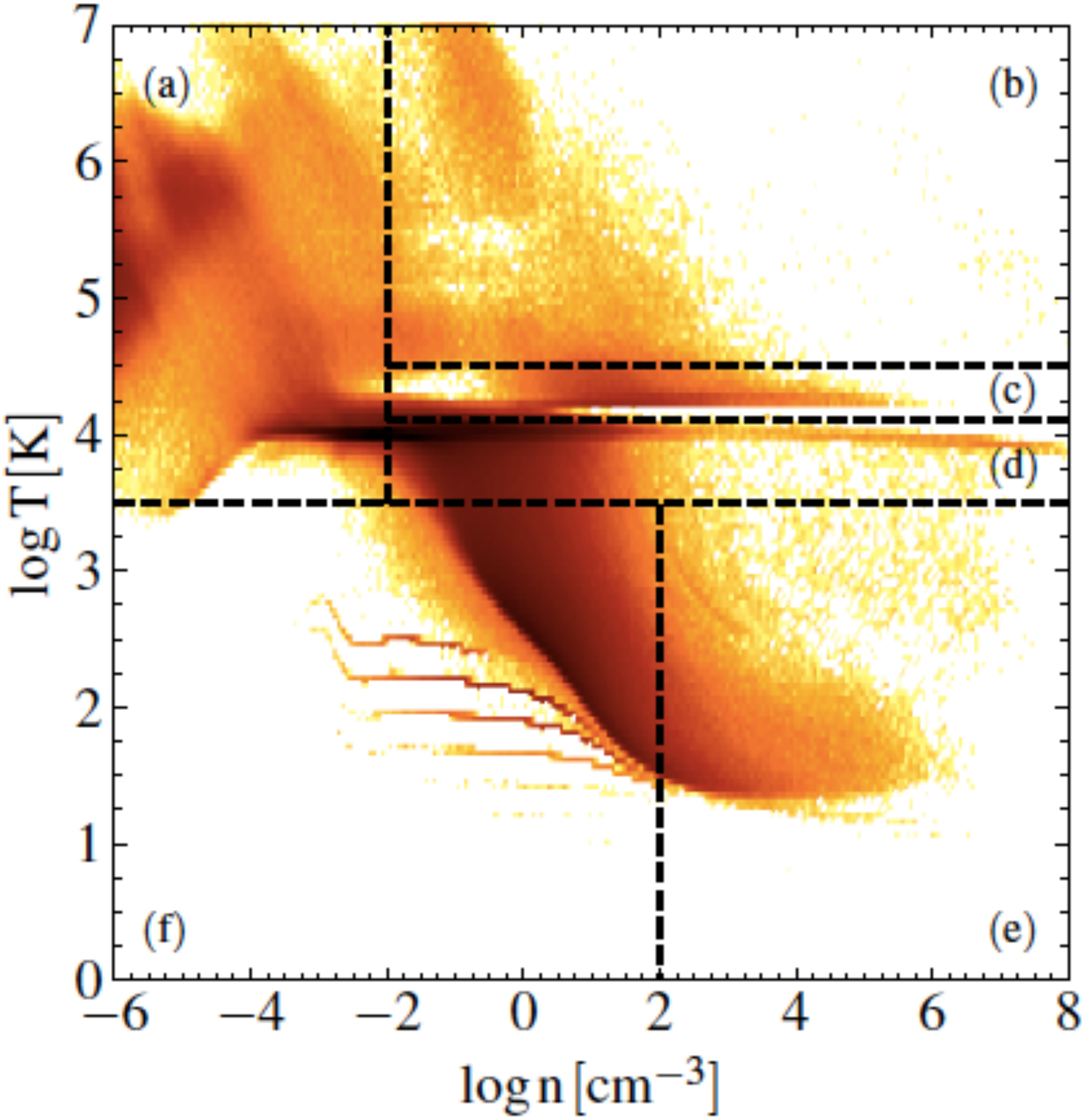
Photoionization + Radiation pressure

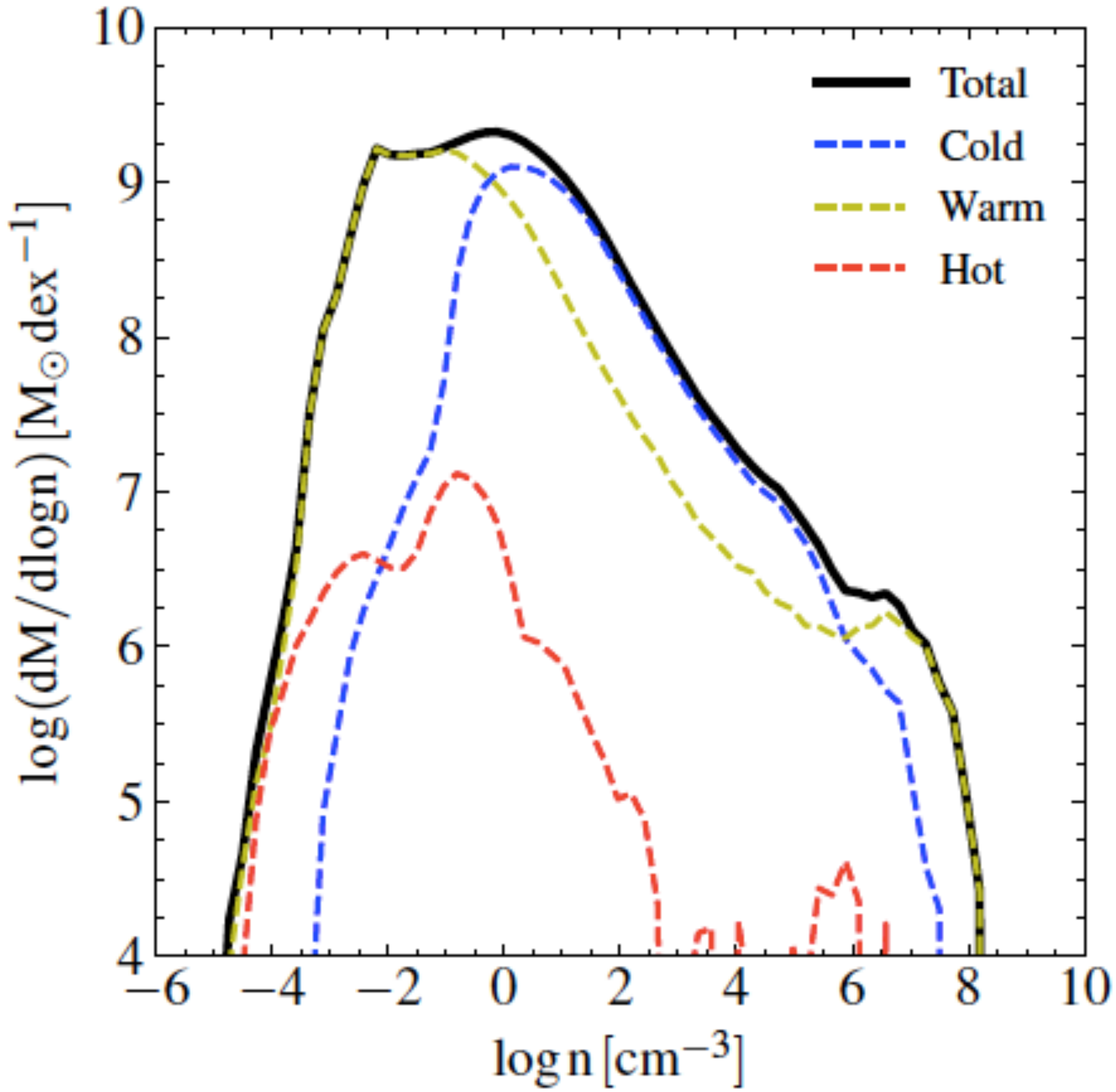
Stochastic heating + momentum within kernel

$$r_{\rm strom,s} = \left(\frac{3 N_\star}{4\pi \alpha_{\rm rec} \langle n_{\rm H}^2 \rangle} \right)^{1/3}$$

$$\Delta p = \frac{L_\star}{c} (1 + \tau_{\rm IR}) \Delta t$$

Resolving the multi-phase nature of gas in Arepo

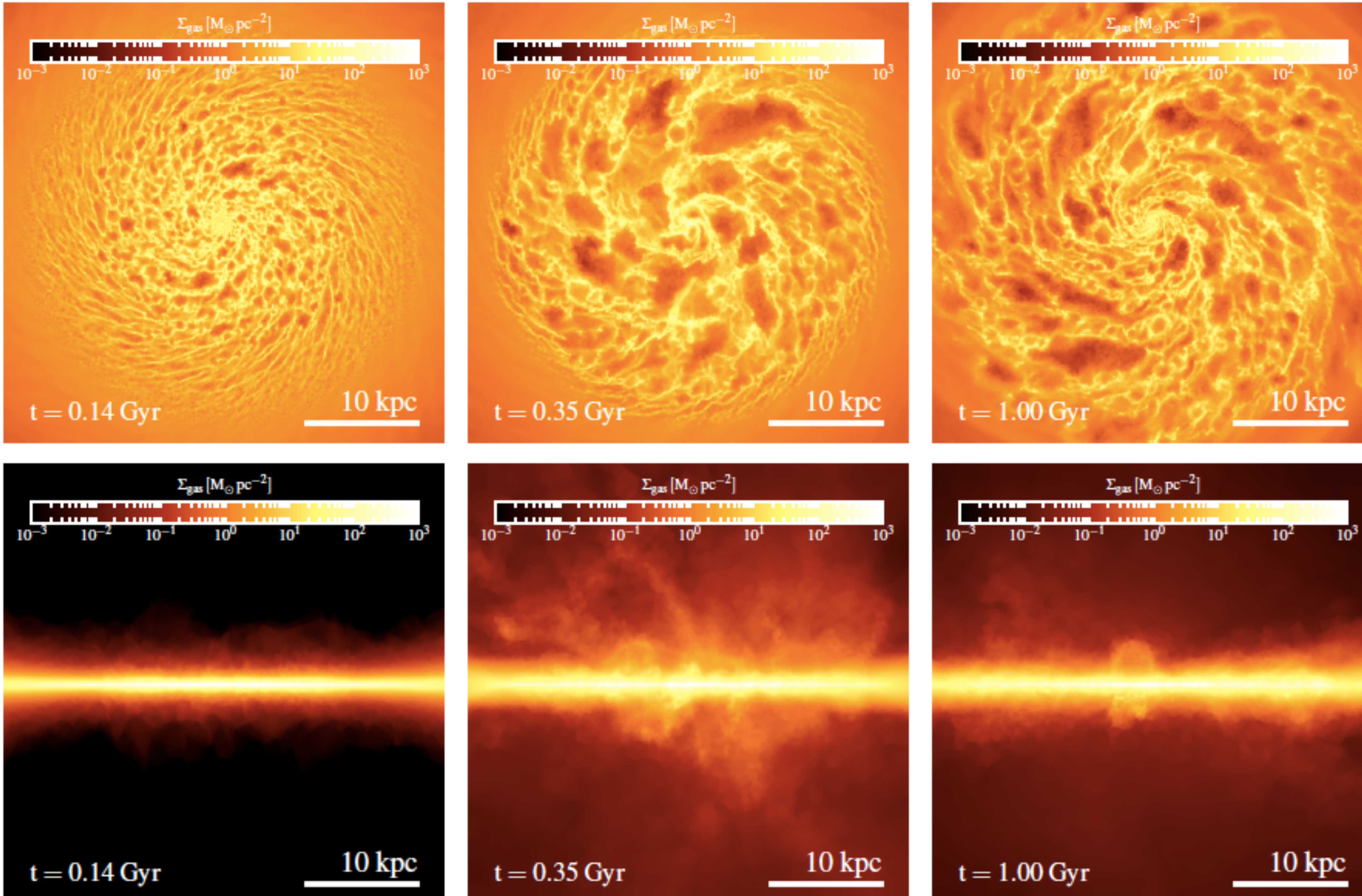




Marinacci, Sales, Vogelsberger, Torrey, et al. , in prep.

Photoionization, stellar feedback and ISM modeling

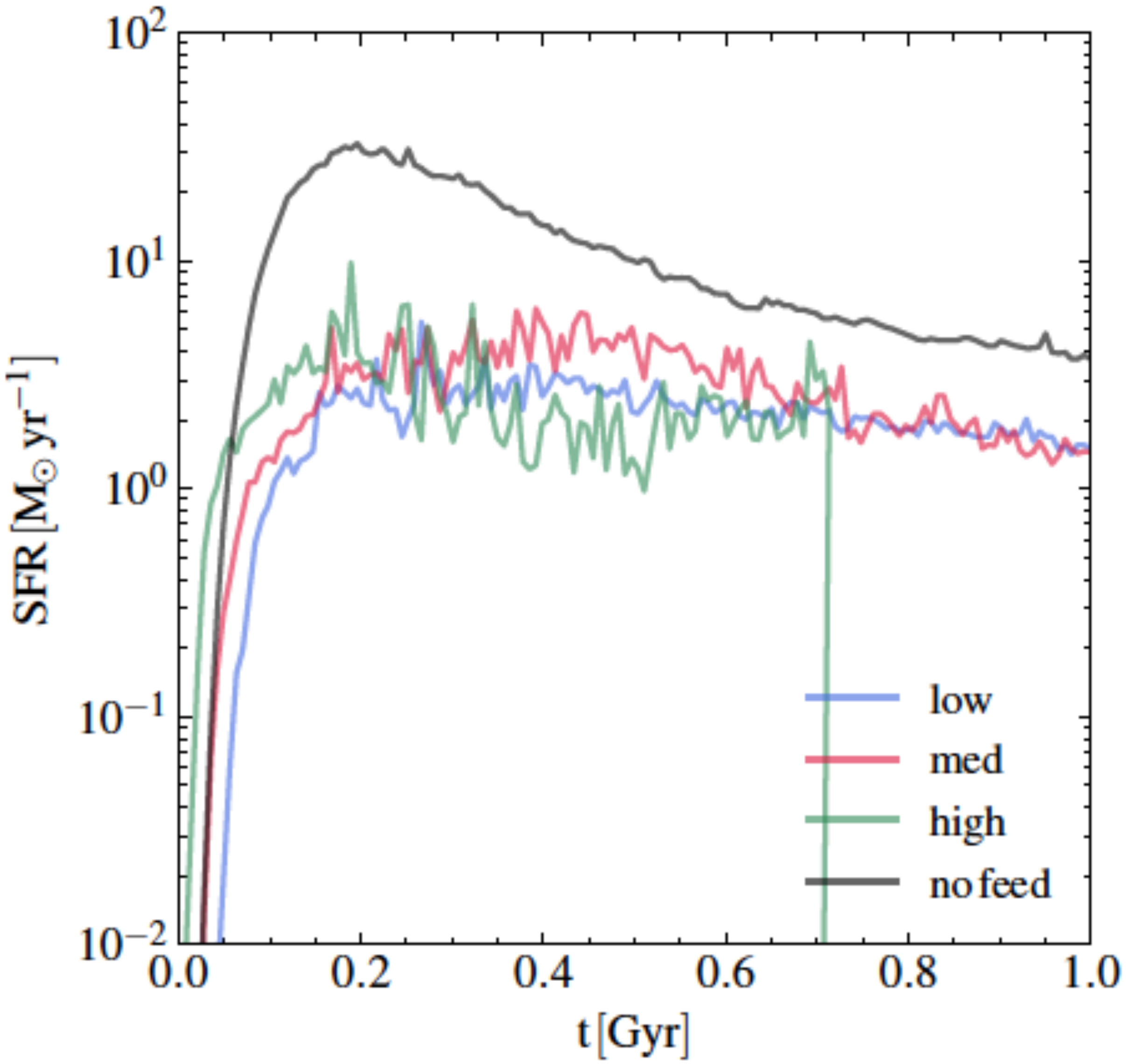
Laura V. Sales



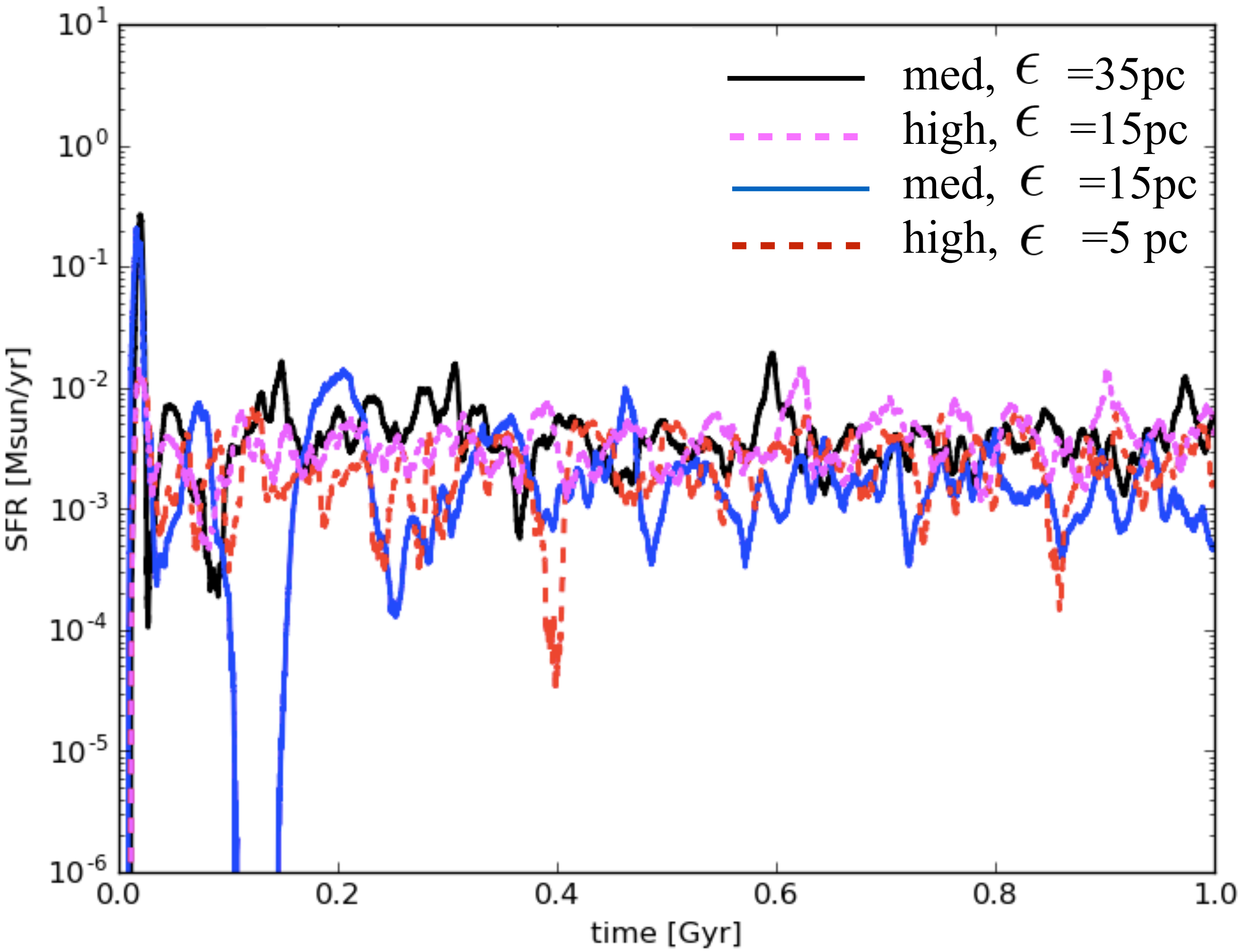
Marinacci, Sales, Vogelsberger, Torrey, et al. , in prep.

Self-regulation of star formation

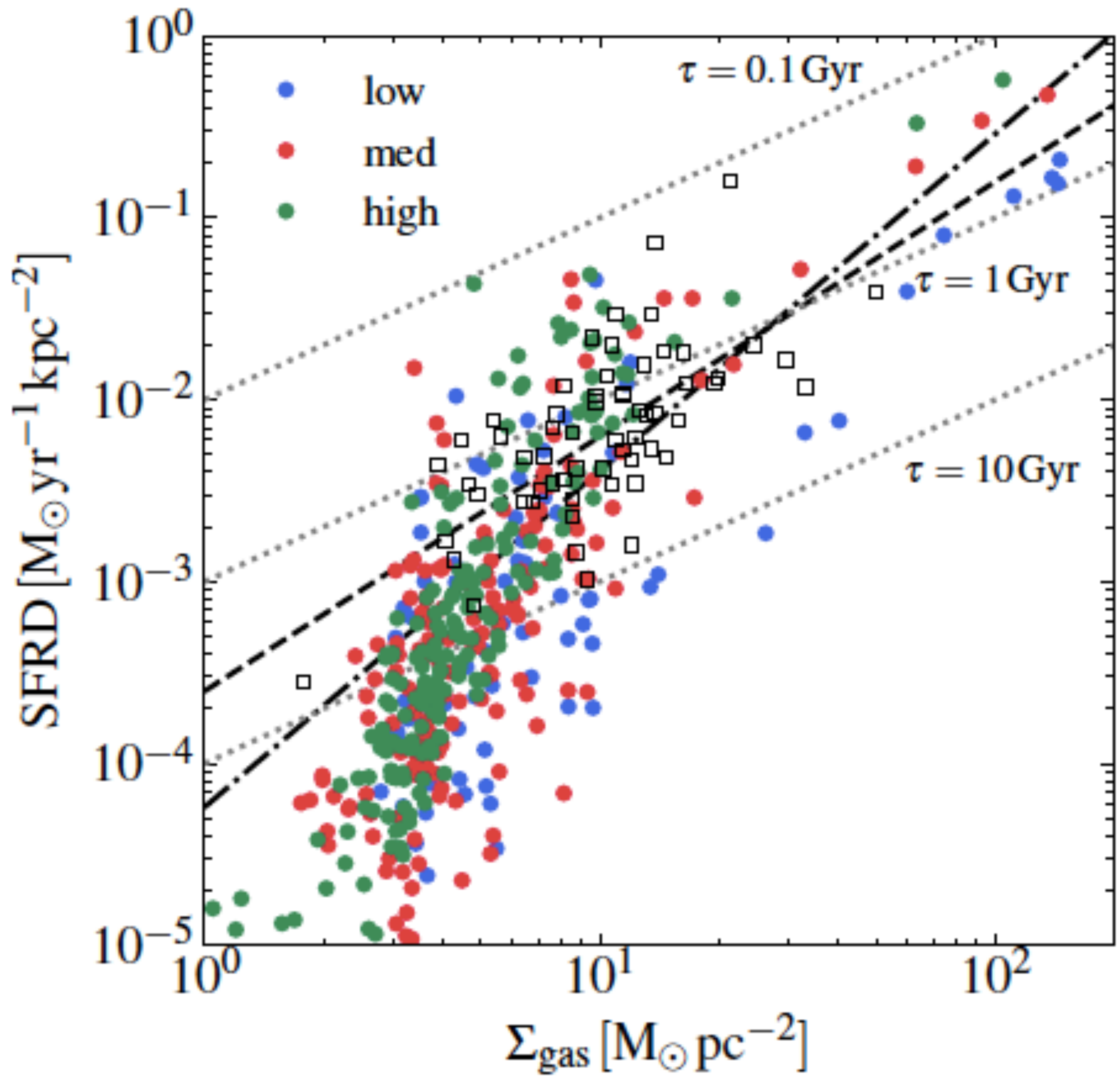
MW disk



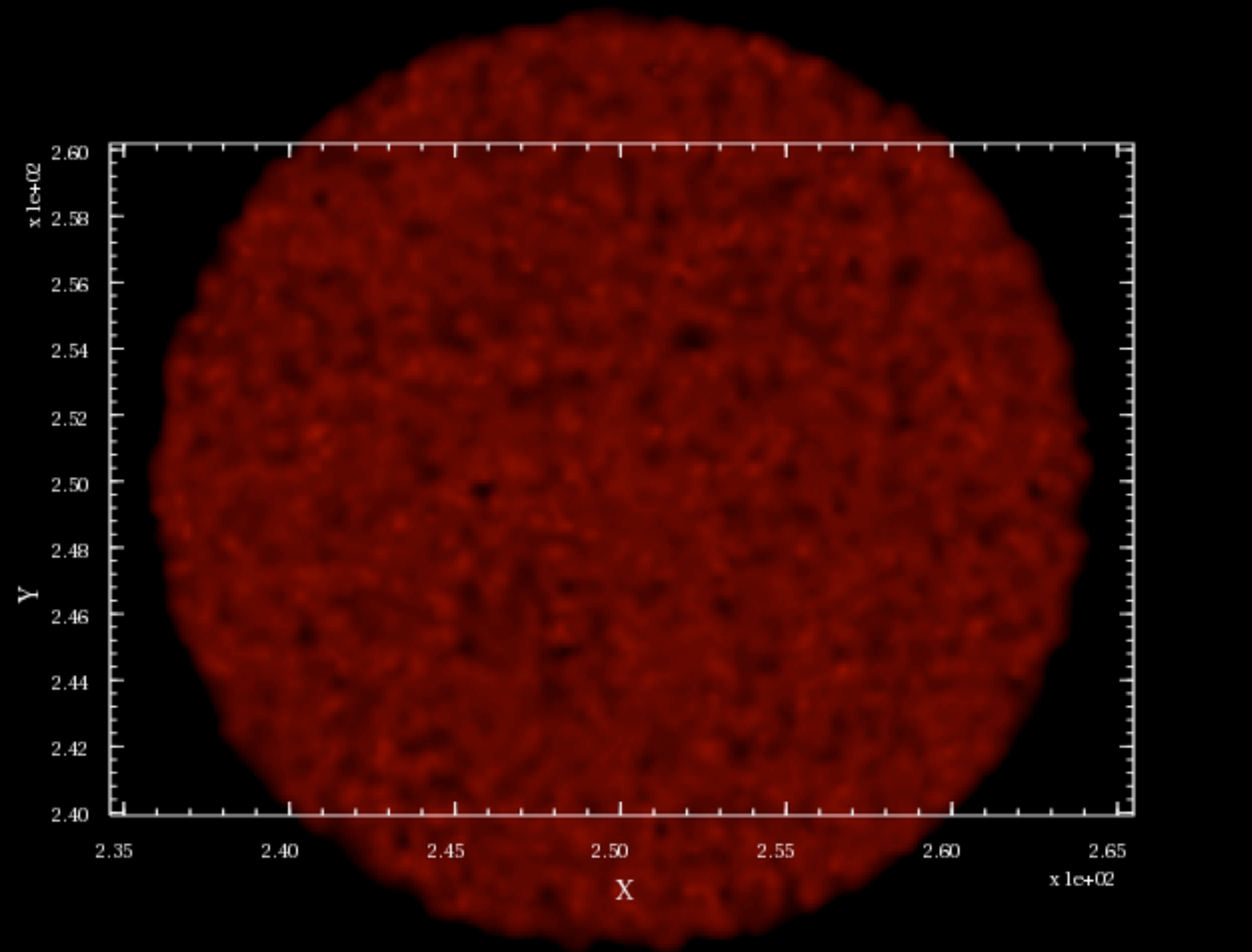
Dwarf galaxy

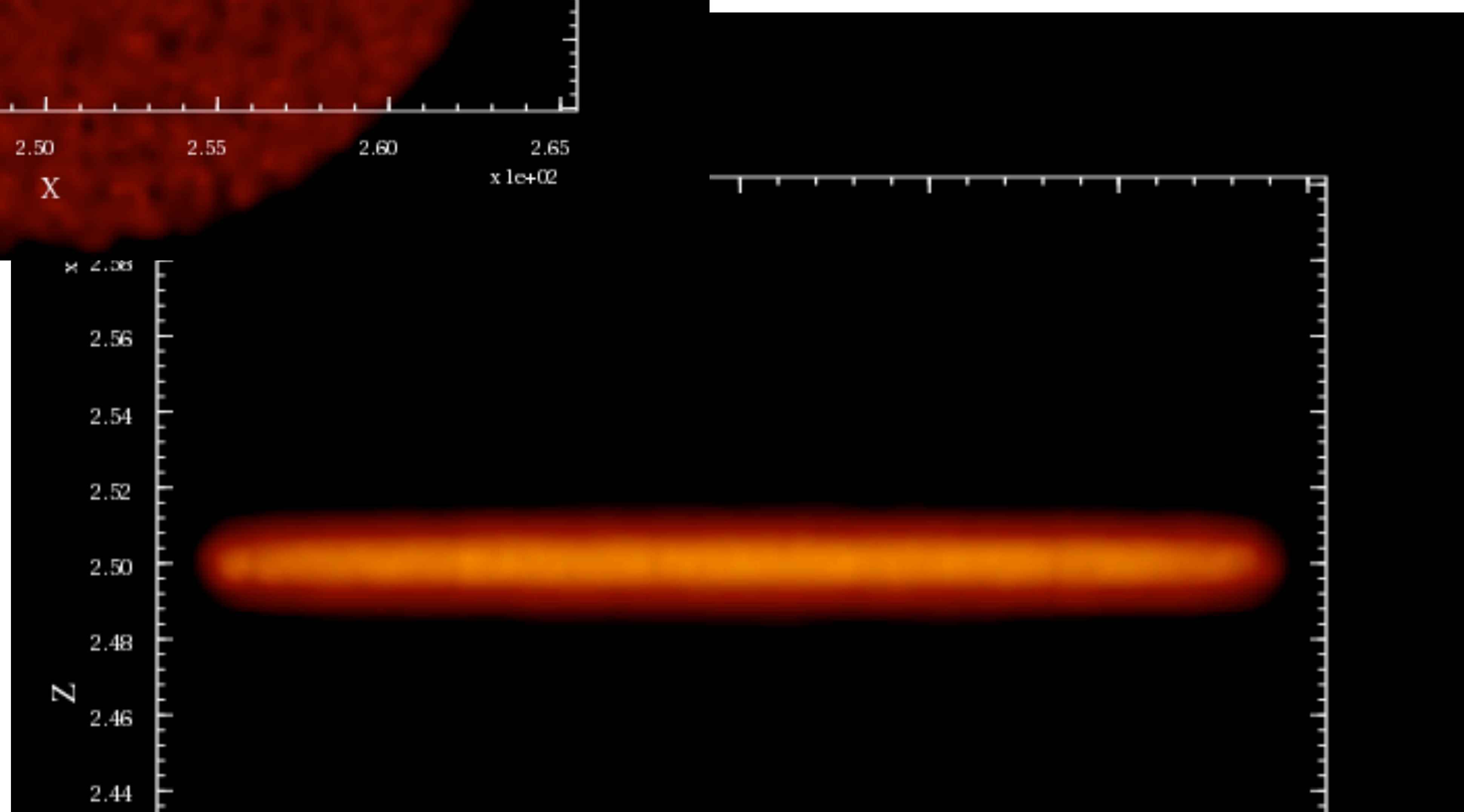


Marinacci, Sales, Vogelsberger, Torrey, et al. , in prep.

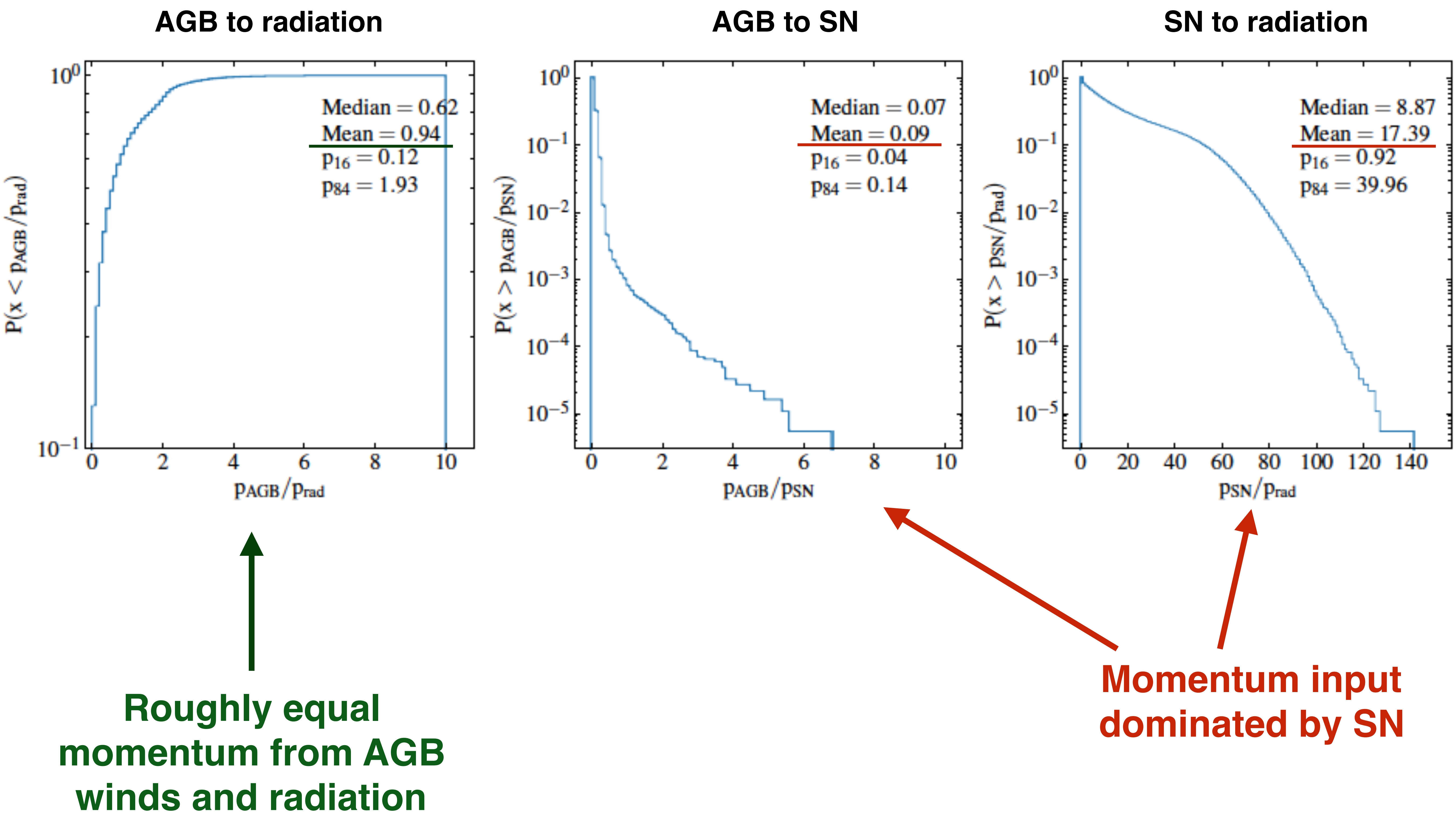


low
med
high
τ = 0.1 Gyr
τ = 1 Gyr
τ = 10 Gyr
SFRD [M⊙ yr⁻¹ kpc⁻²]
Σgas [M⊙ pc⁻²]
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
10^0
10^1
10^2


x 1e+02
2.60
2.58
2.56
2.54
2.52
2.50
2.48
Y
2.46
2.44
2.42
2.40
2.35
2.40
2.45
2.50
2.55
2.60
2.65
x 1e+02
X


2.56
2.54
2.52
2.50
2.48
Z
2.46
2.44

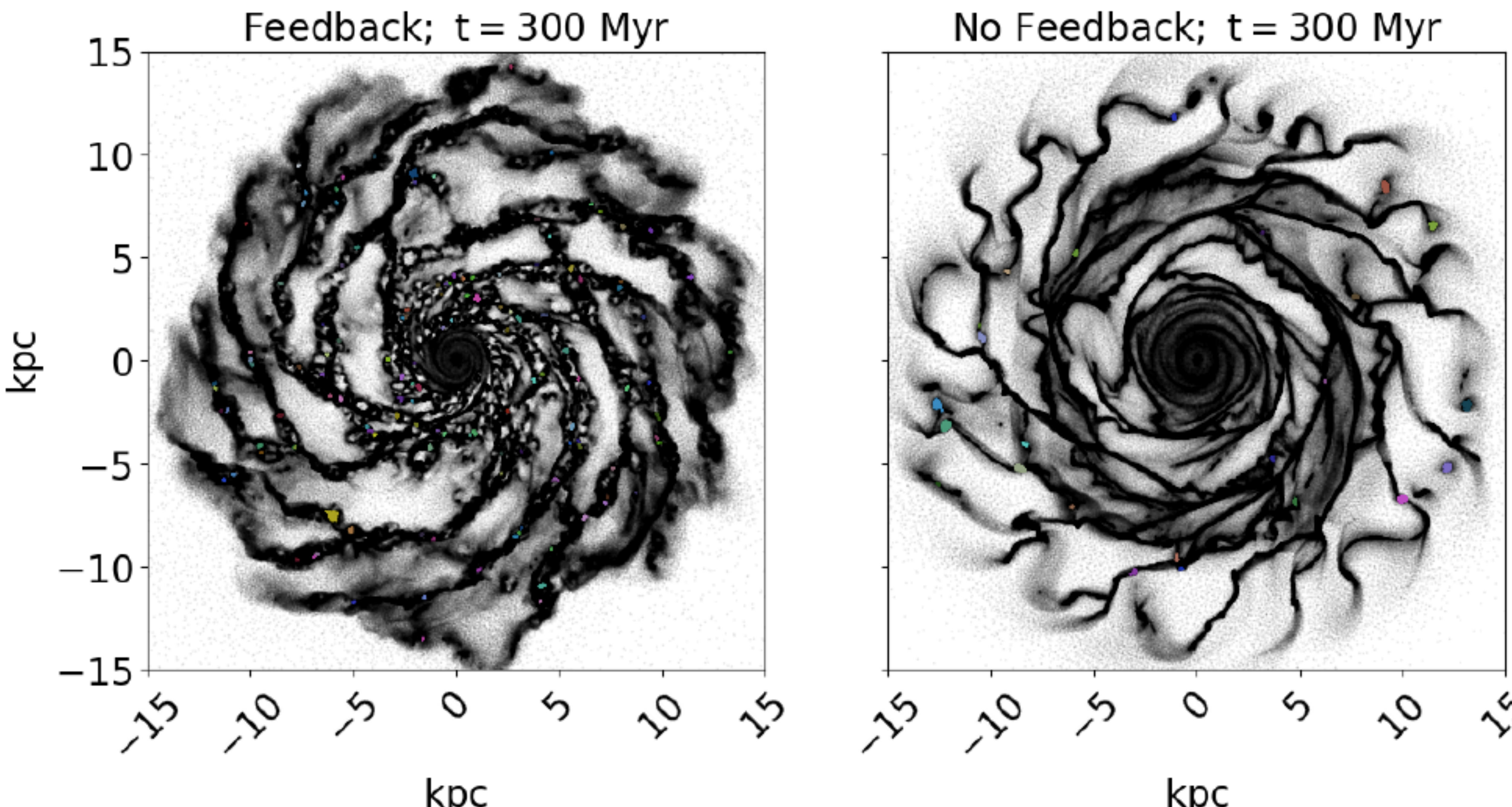
Momentum budget in MW-like disk



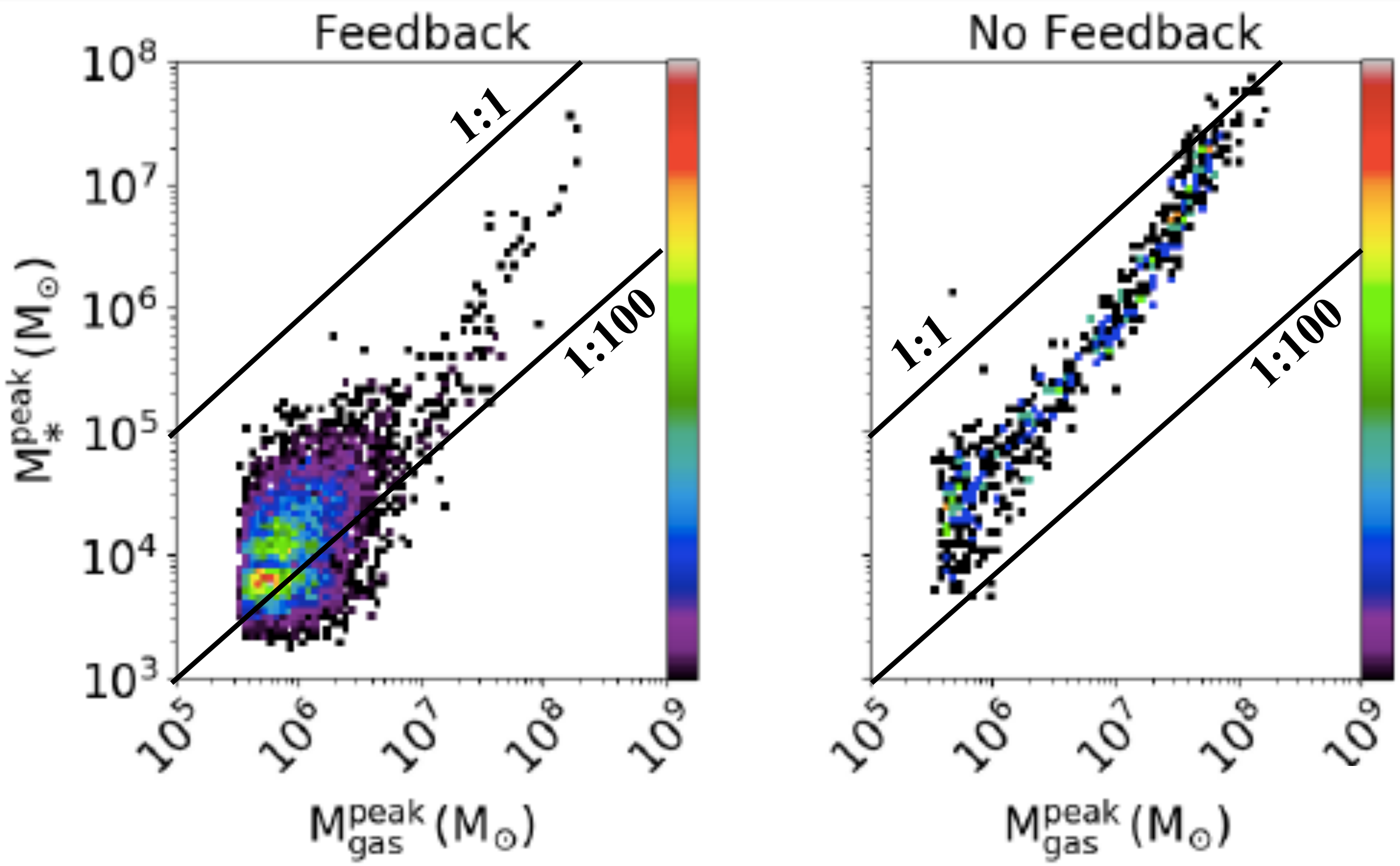
Marinacci, Sales, Vogelsberger, Torrey, et al. , in prep.

Properties of gas clouds

Feedback fragments the ISM with more and smaller clouds than no-feedback runs



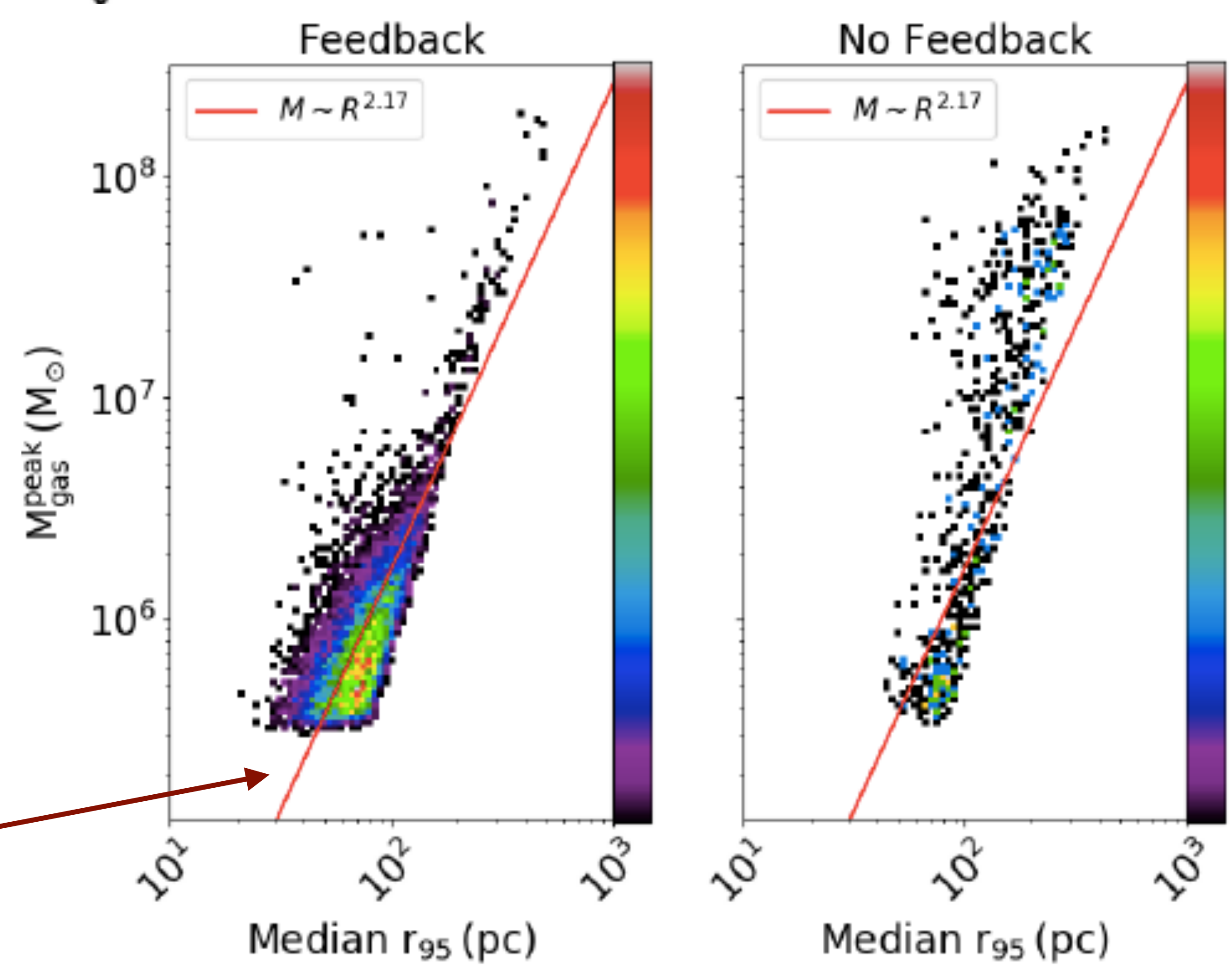
Hicks, Sales, Marinacci, Vogelsberger, et al., in-prep



Properties of gas clouds

Lower SF efficiency in clouds with feedback

Reasonable mass-size relation for clouds

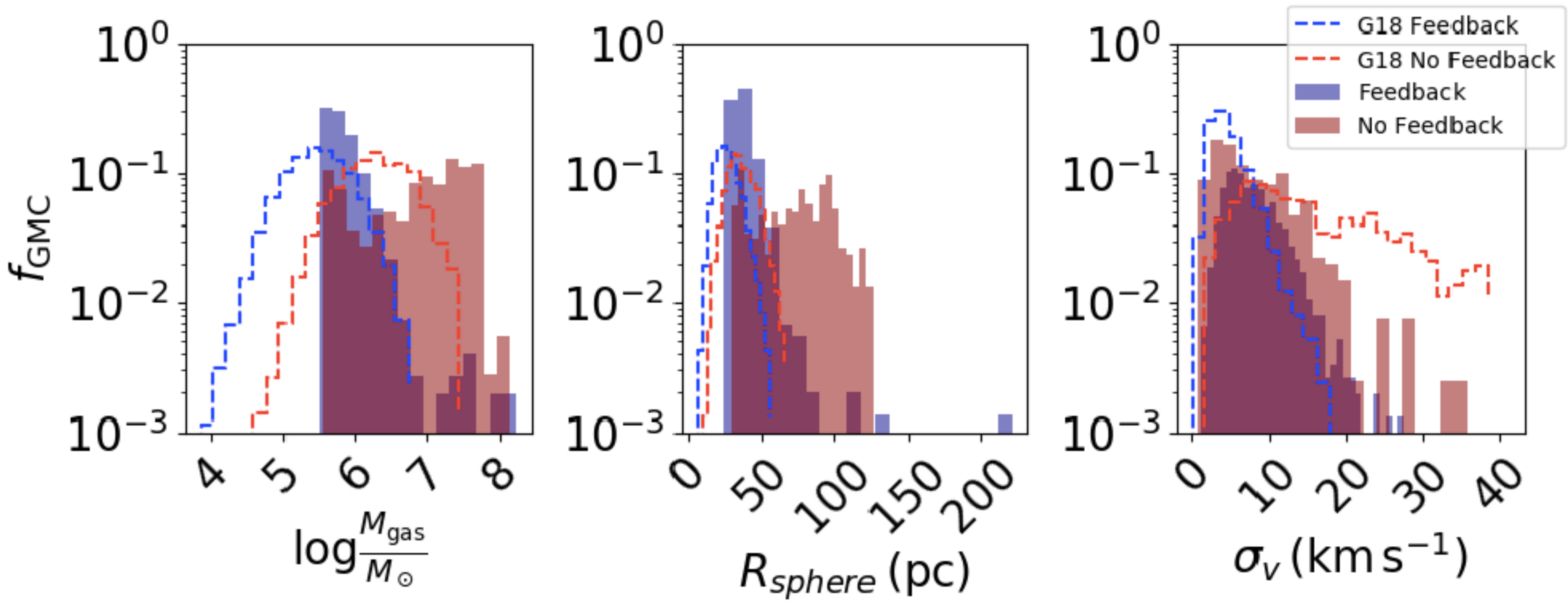


Observed MW-relation

Hicks, Sales, Marinacci, Vogelsberger, et al., in-prep

Properties of gas clouds

Feedback allows for lower mass, smaller radius and σ_v ~5-10 km/s



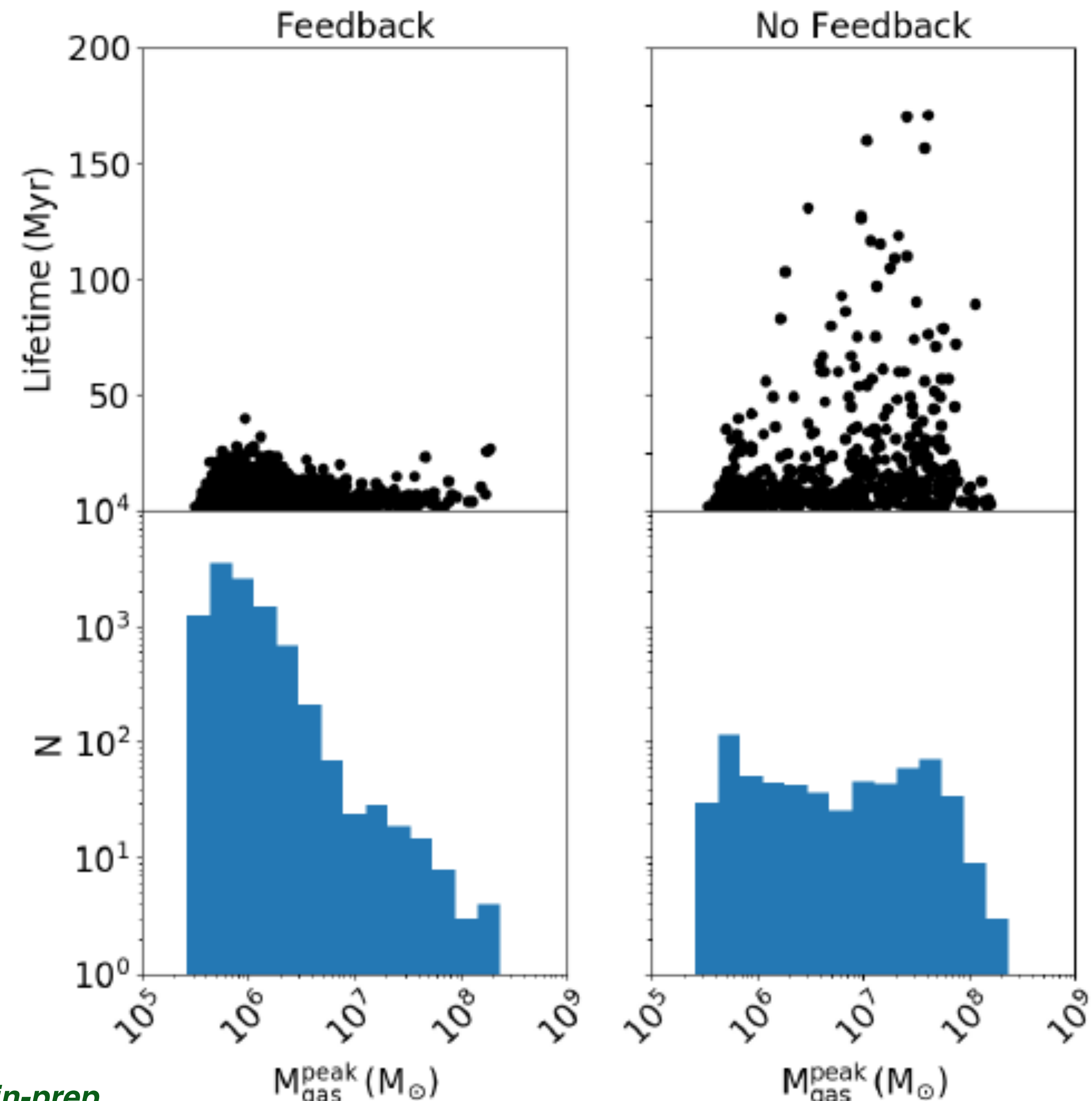
Good agreement with Grisdale et al. 2018 using RAMSES

Hicks, Sales, Marinacci, Vogelsberger, et al., in-prep

Properties of gas clouds

- Survival time of clouds is shorter in feedback runs

- Massive clouds dissolve more quickly



Hicks, Sales, Marinacci, Vogelsberger, et al., in-prep

Summary

- Photoionization quickly propagates into the cold ISM and might weaken the effect of radiation pressure compared to idealized models

- Radiative feedback from young stars is important to achieve self-regulation in star formation, but is subdominant in terms of momentum input and outflows in MW and dwarf models.

- ISM models including SN and radiative feedback establish a multi-phase gas distribution. Gas clouds are less massive, smaller radius and with lower efficiency to form stars. Properties agree to first order with observed MW clouds.

- Results should be compared with full radiative transfer runs