Discussion: Stellar feedback in the ISM

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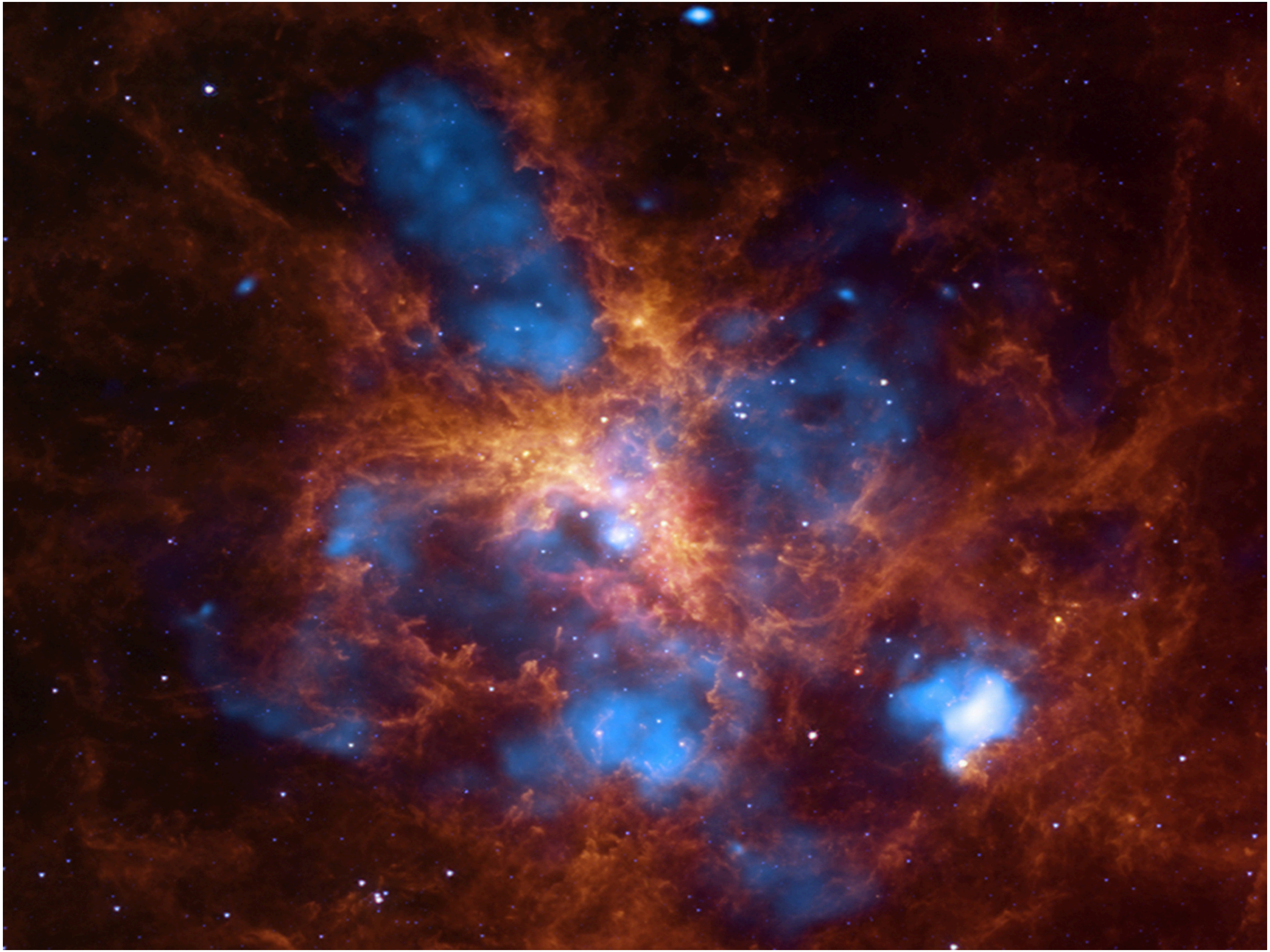
6.9.2018

www.astro.uni-koeln.de/silcc



Open Questions

Physics: The role of

- magnetic fields?
- non-ionizing radiation (PE heating)?
- more energetic radiation
- (Xrays / Cosmics Rays)?
- radiation pressure?
- the dust model?
- ISM sub-structure / source environment?
- stellar evolution, dynamics, multiplicity?

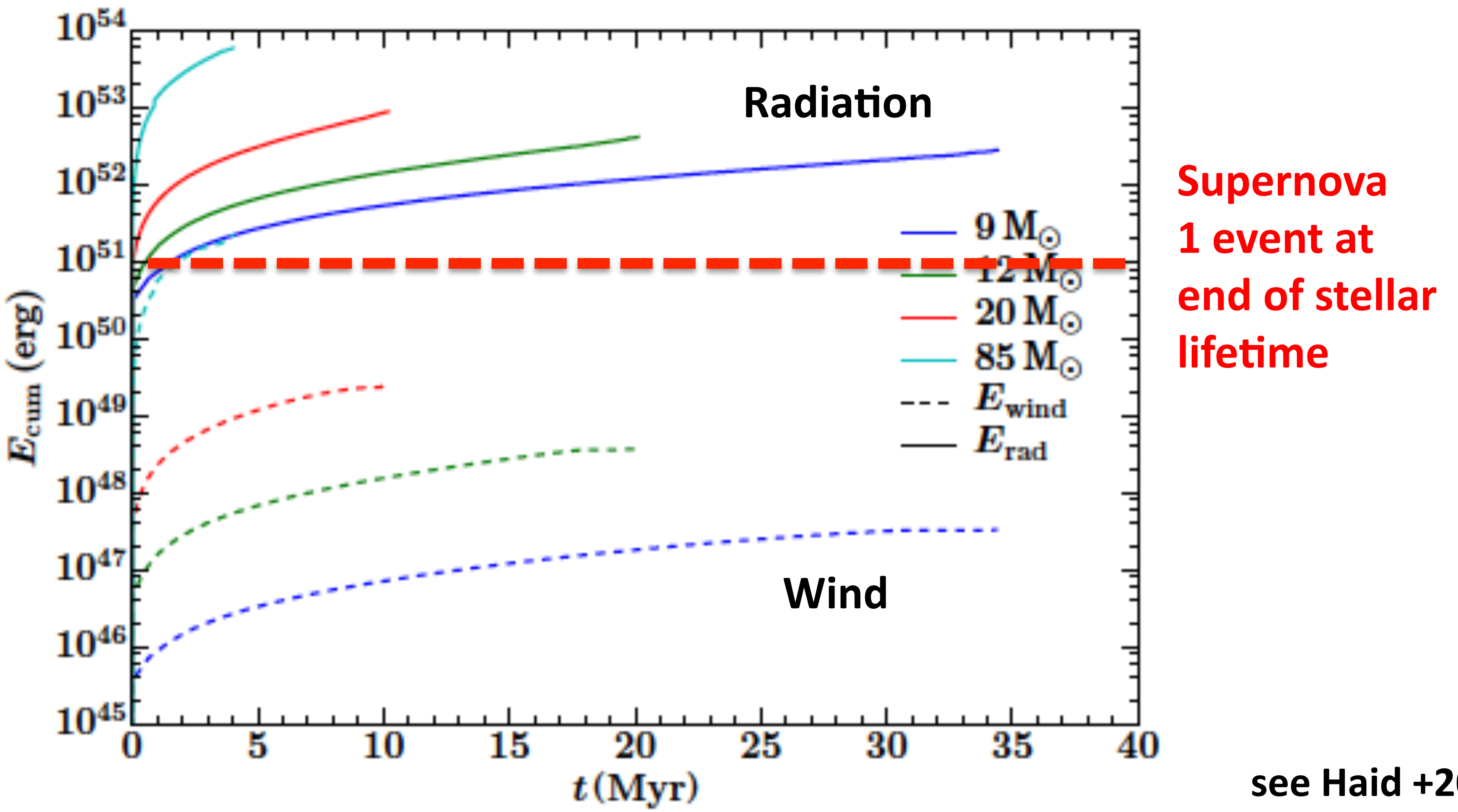
Numerics:

- numerical resolution??
- governing equations: e.g. FLD / reduced speed of light RT etc.; ideal MHD; Cosmic Ray transport ?
- numerical discretization / order of the scheme / time integration / AMR and adaptive time stepping

In the context of:

- What are the escape fractions of radiation and winds from dense clouds?
- Metal enrichment?
- Gas cycle driving and wind structure?

Energy input:
Stellar winds, ionizing radiation and Supernovae:
How is this energy coupled to the ISM?



see Haid +2018
(submitted)

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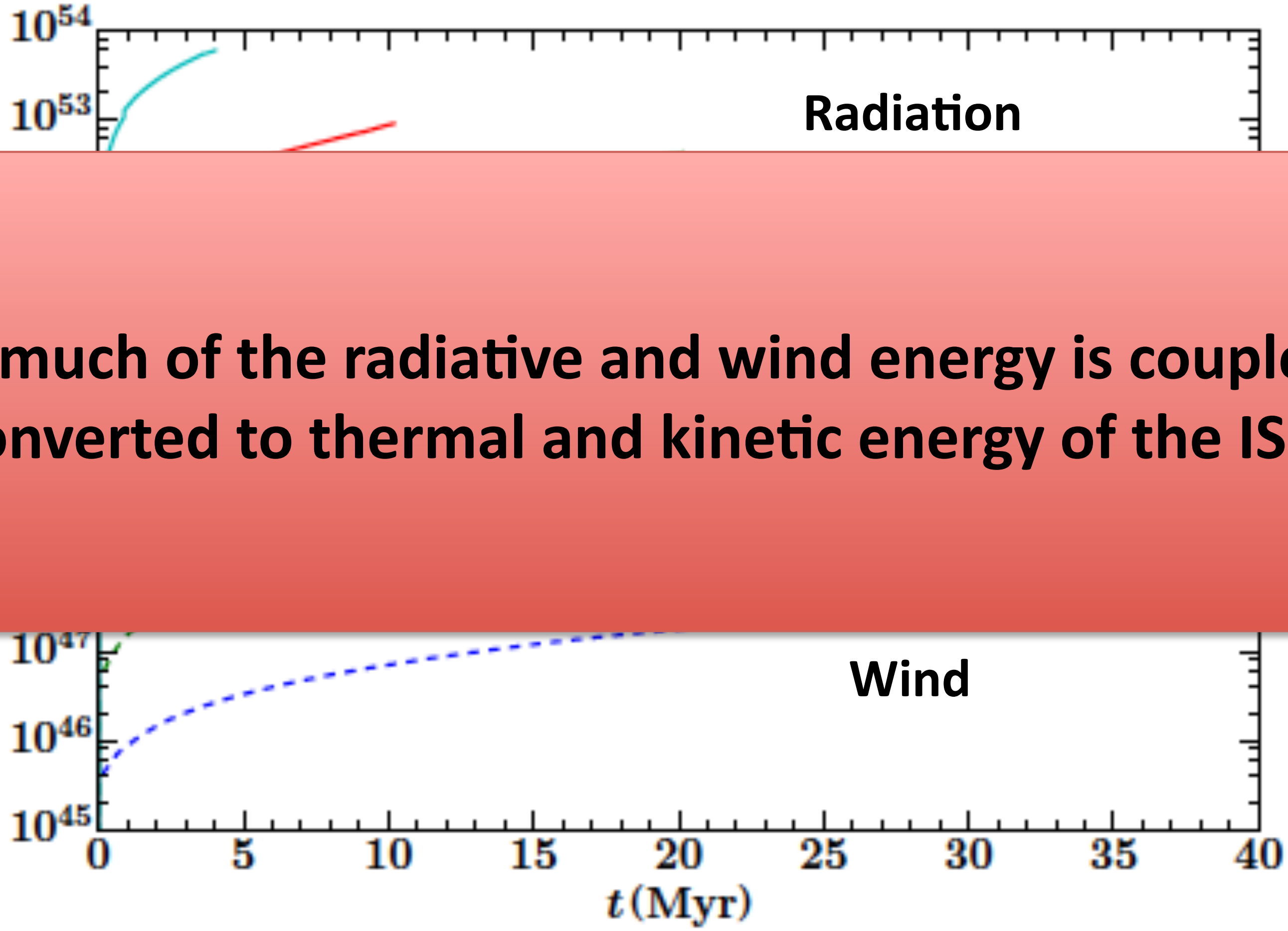


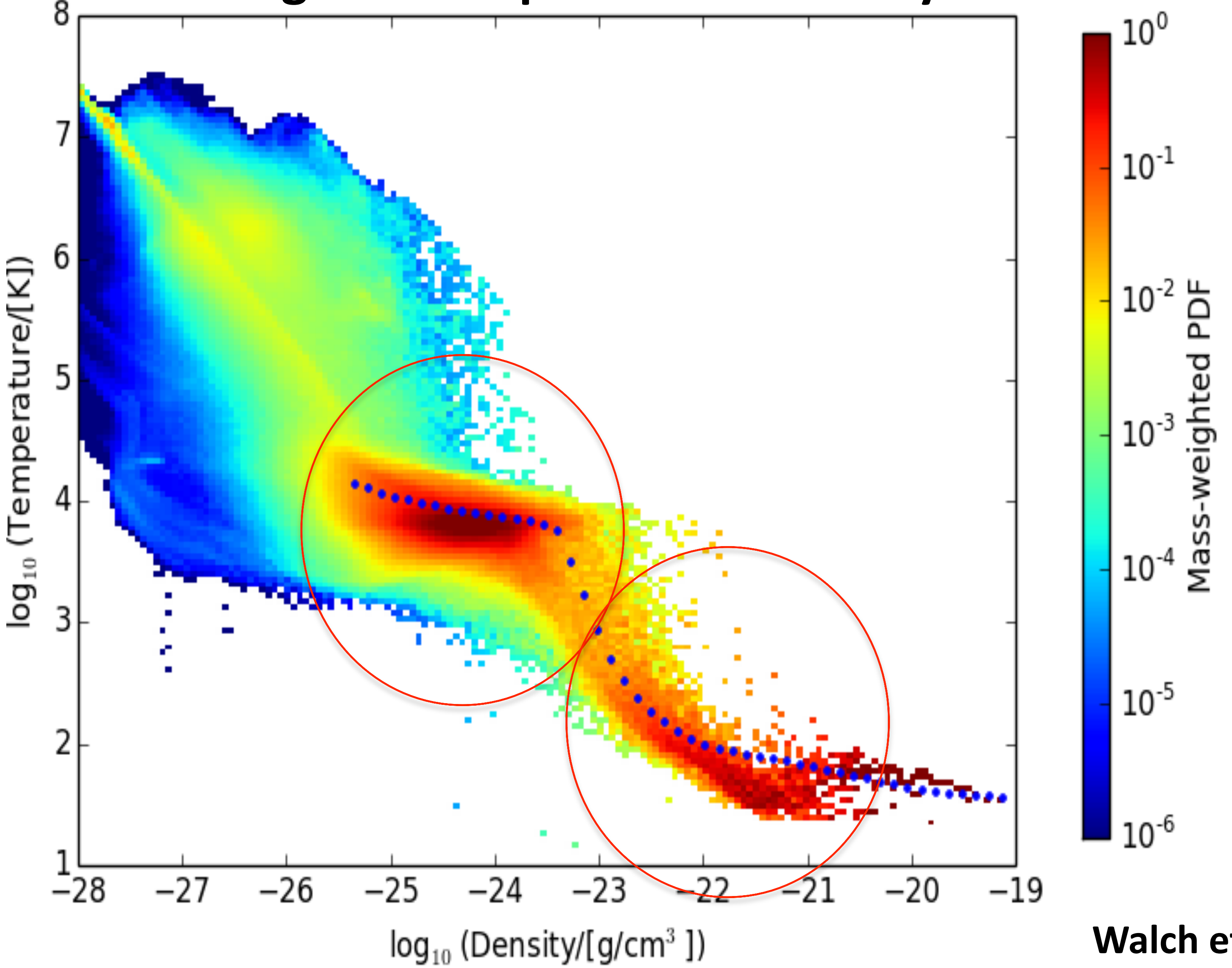
How much of the radiative and wind energy is coupled, i.e. converted to thermal and kinetic energy of the ISM?

see Haid +2018 (submitted)

The SILCC project (www.astro.uni-koeln.de/silcc):

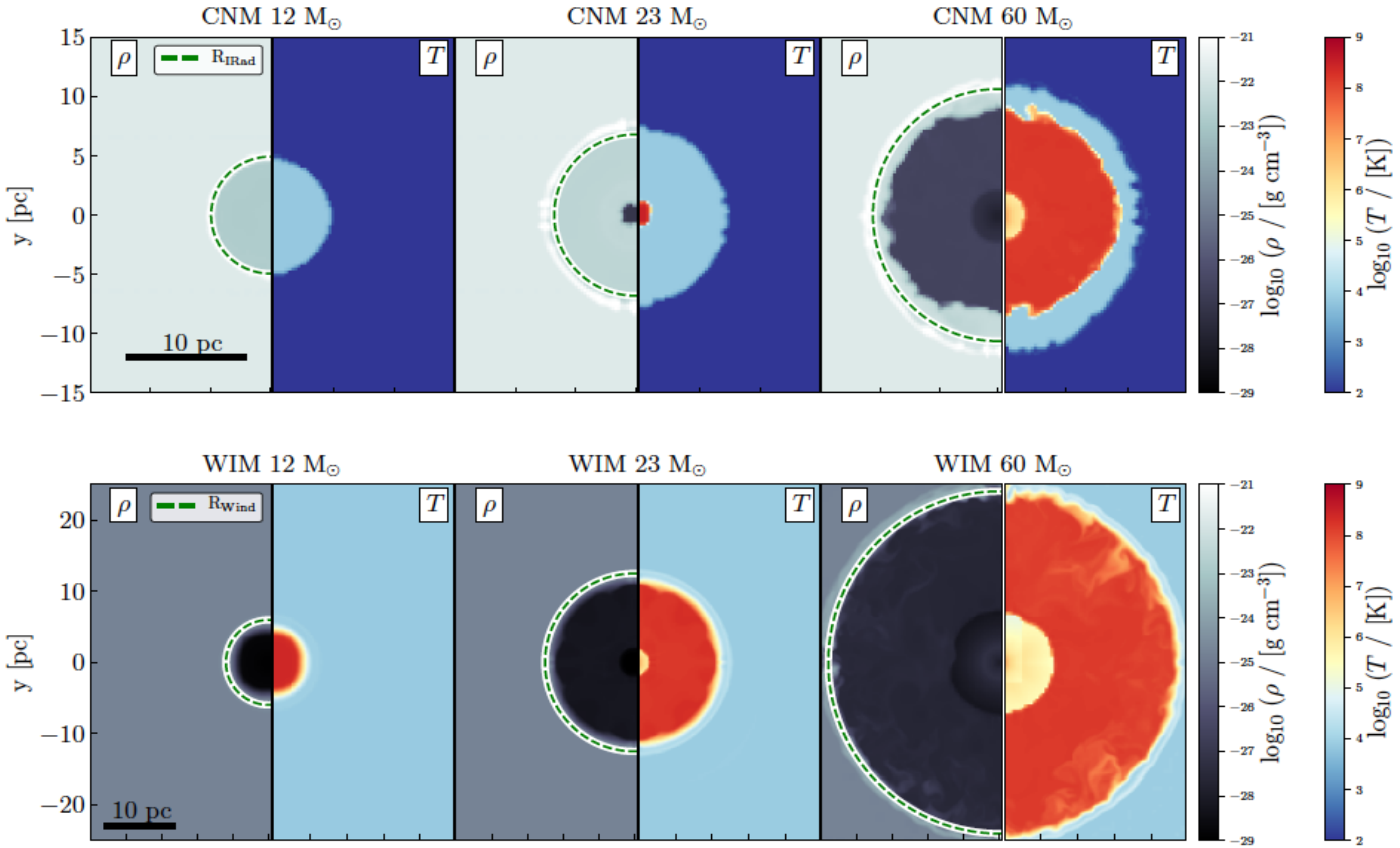
Typical mass distribution in the multi-phase ISM in a star forming galactic disk

Mass-weighted temperature – density PDF



Walch et al. (2015)

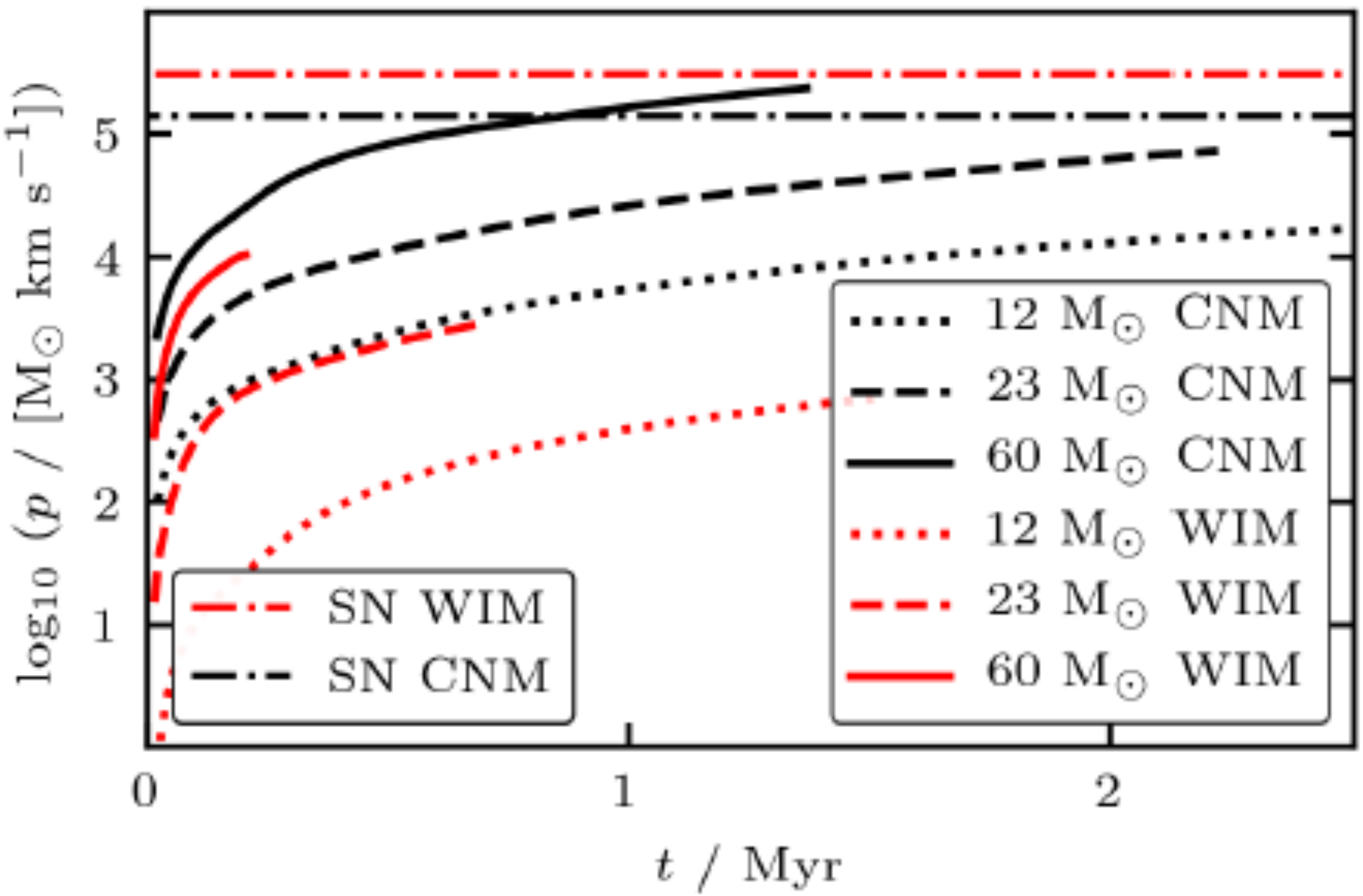
How is this energy coupled to the ISM?
Stellar winds vs. ionizing radiation:
Simulations with FLASH + TreeRay + Chemical Network



CNM: T=20 K, n=100 cm^{-3}; **WIM: T=10^4 K, n=0.1 cm^{-3}**

Haid et al. (2018)

Momentum input:
Stellar winds, ionizing radiation and Supernovae:
Coupling of radiation is inefficient…



Supernova 1 event at end of stellar lifetime

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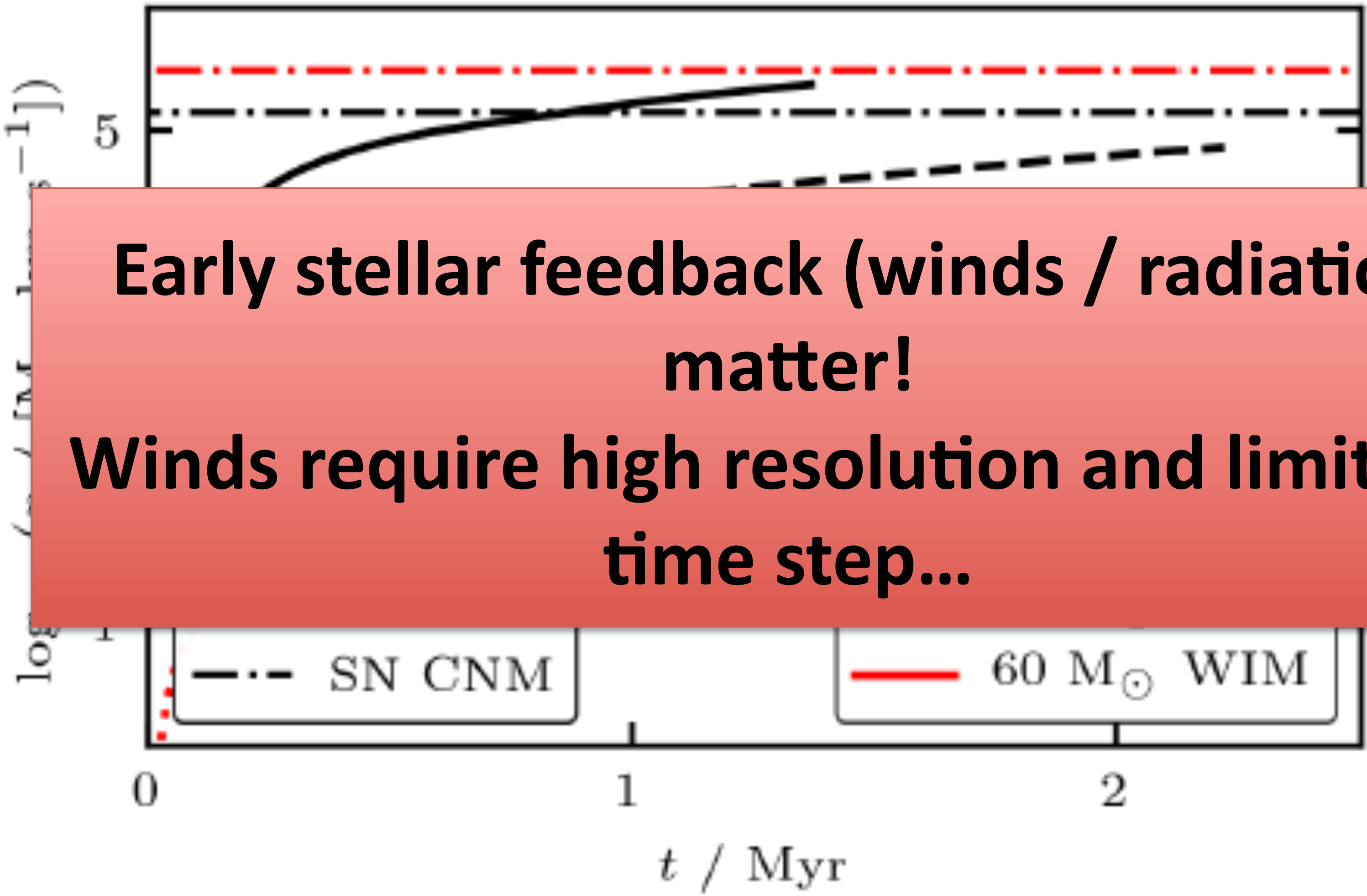


Supernova
1 event at
end of stellar
etime

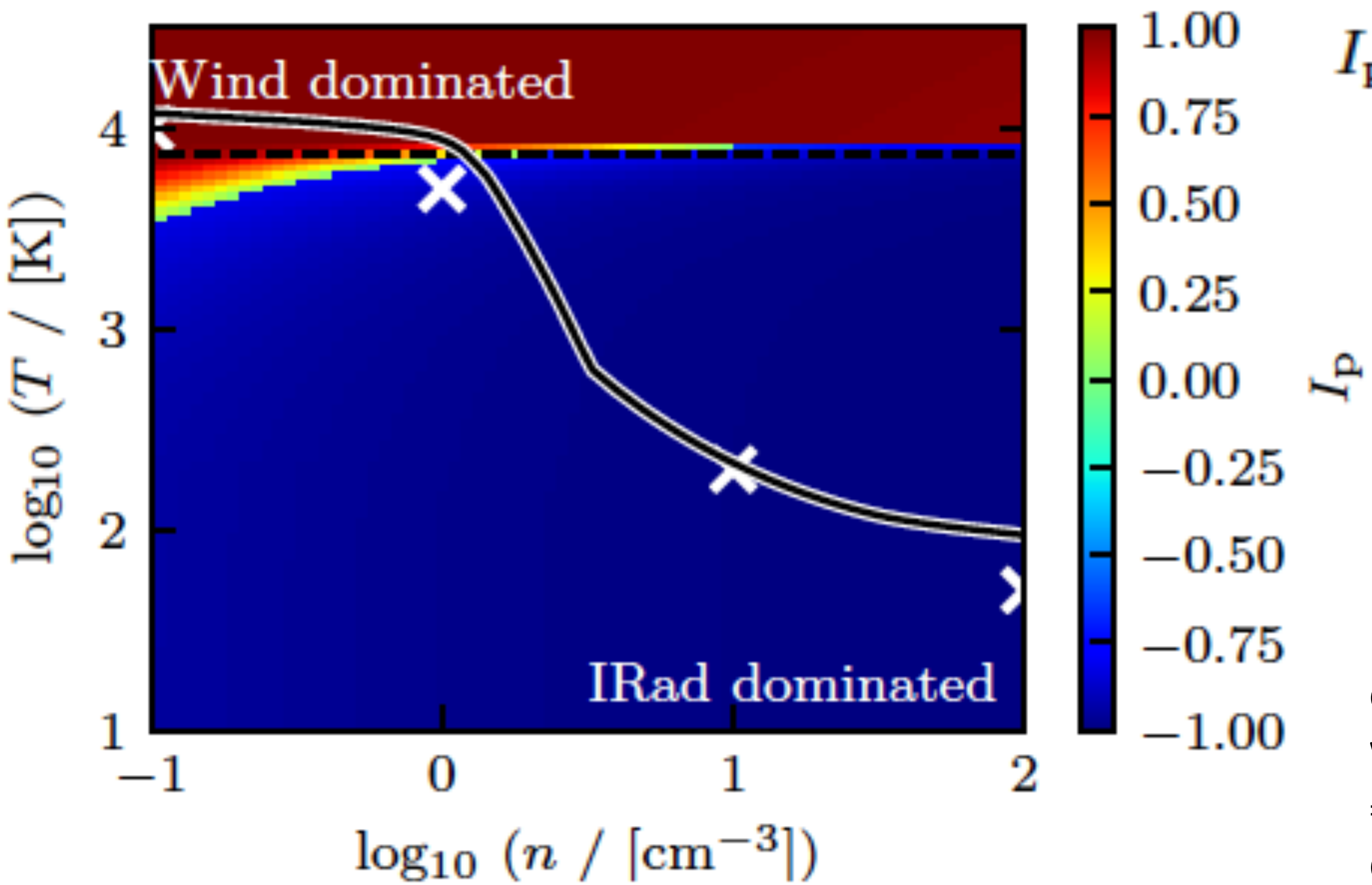
Early stellar feedback (winds / radiation) matter!

Winds require high resolution and limit the time step…

CNM: T=20 K, n=100 cm^{-3}; WIM: T=10^4 K, n=0.1 cm^{-3}

Haid et al. (2018)

Momentum input:
Stellar winds vs. ionizing radiation:
Environment matters!



$$I_\mathrm{p} \equiv \frac{p_\mathrm{Wind} - p_\mathrm{IRad}}{p_\mathrm{Wind} + p_\mathrm{IRad}}$$

Relative impact of wind and radiation

Here: for 23 $M_\odot$ star

Radiation does not couple in low density/ warm ambient medium ⇒stellar winds become dominant there!

CNM: T=20 K, n=100 cm^{-3}; WIM: T=10^4 K, n=0.1 cm^{-3}

Haid et al. (2018)

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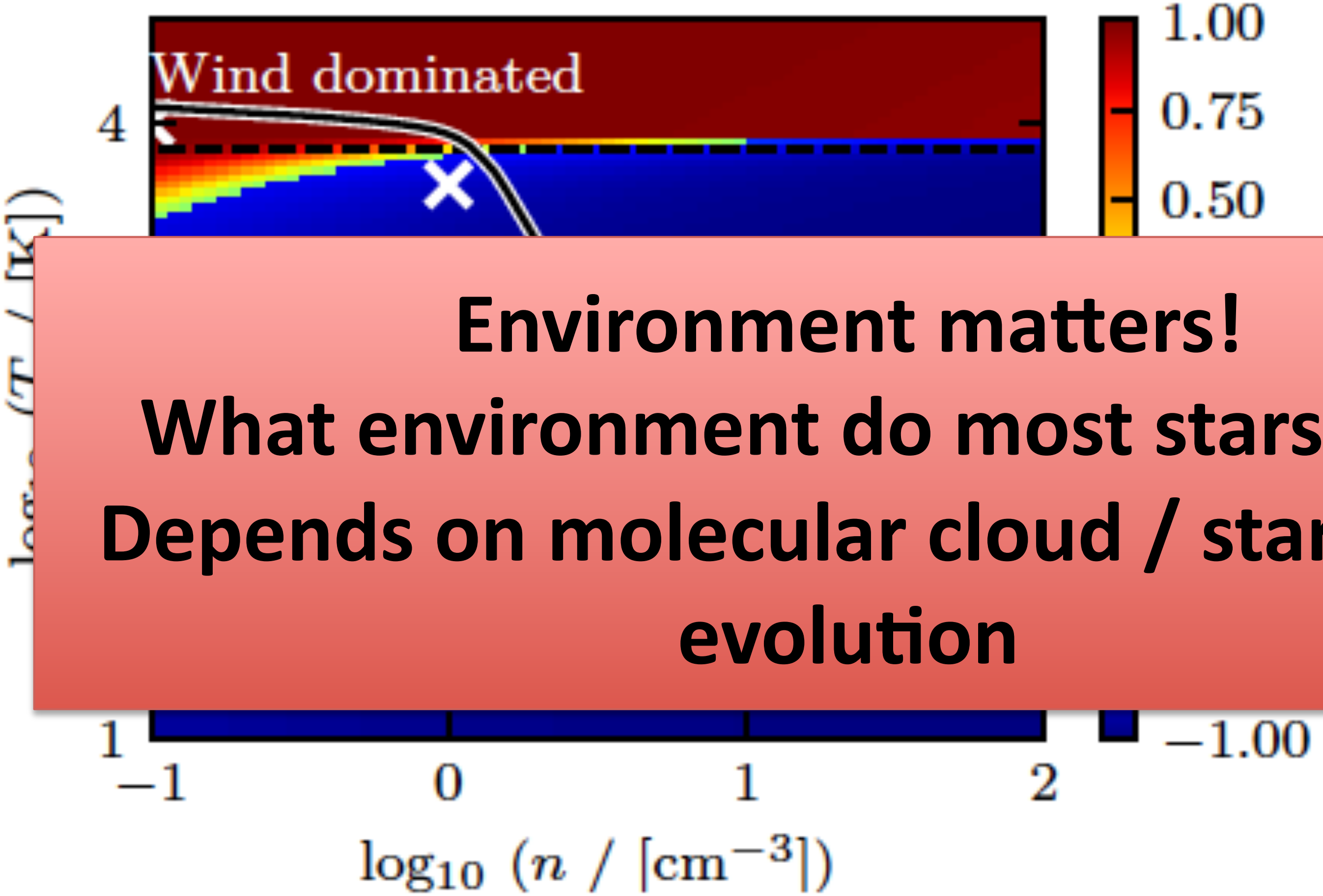

$$I_p \equiv \frac{p_{\mathrm{Wind}} - p_{\mathrm{IRad}}}{p_{\mathrm{Wind}} + p_{\mathrm{IRad}}}$$

Environment matters!
What environment do most stars sit in?
Depends on molecular cloud / star cluster evolution

pact of
adiation

3 M$_\odot$ star

es not
density/
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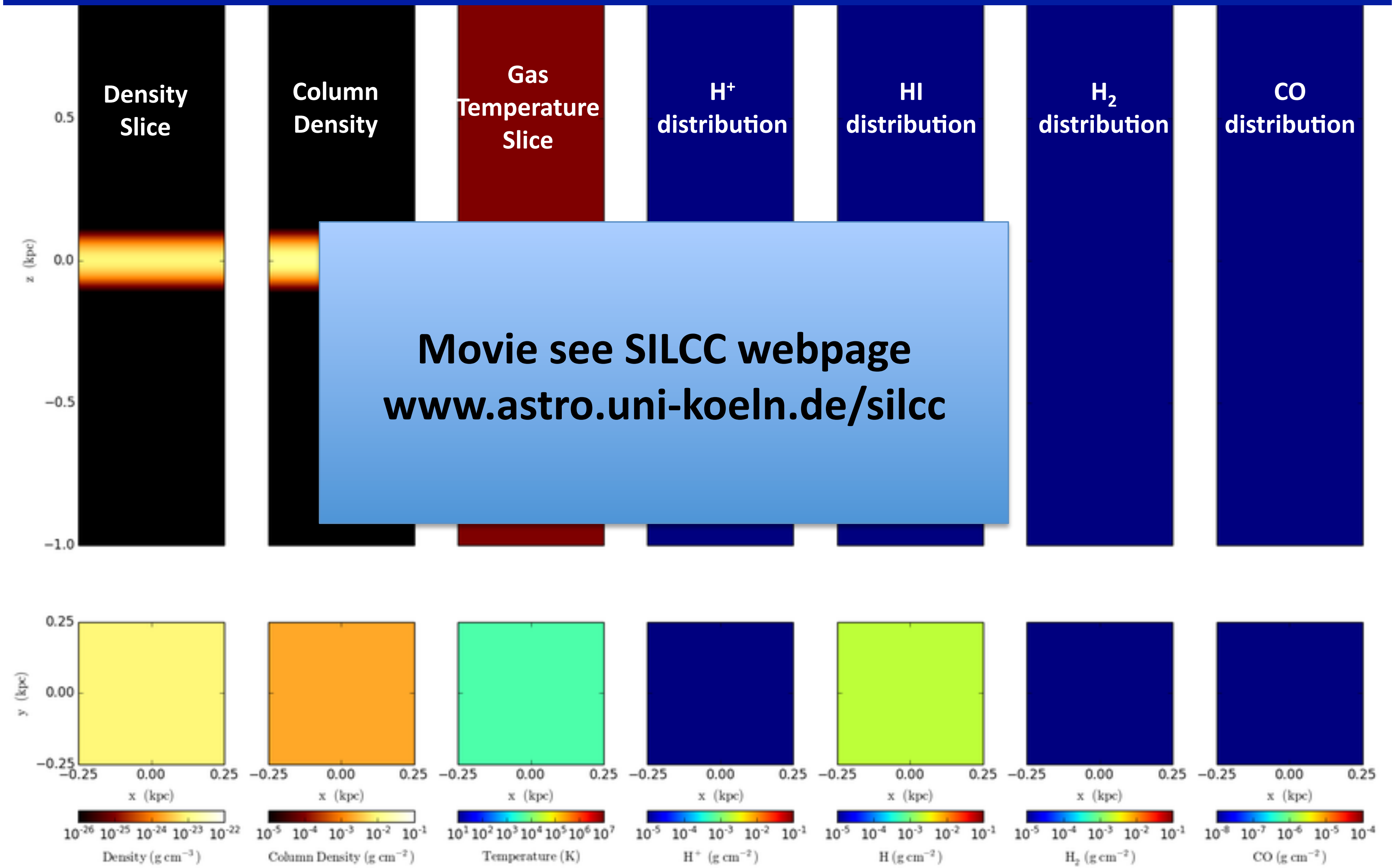
⇒stellar winds become dominant there!

CNM: T=20 K, n=100 cm^{-3}; WIM: T=10^4 K, n=0.1 cm^{-3}

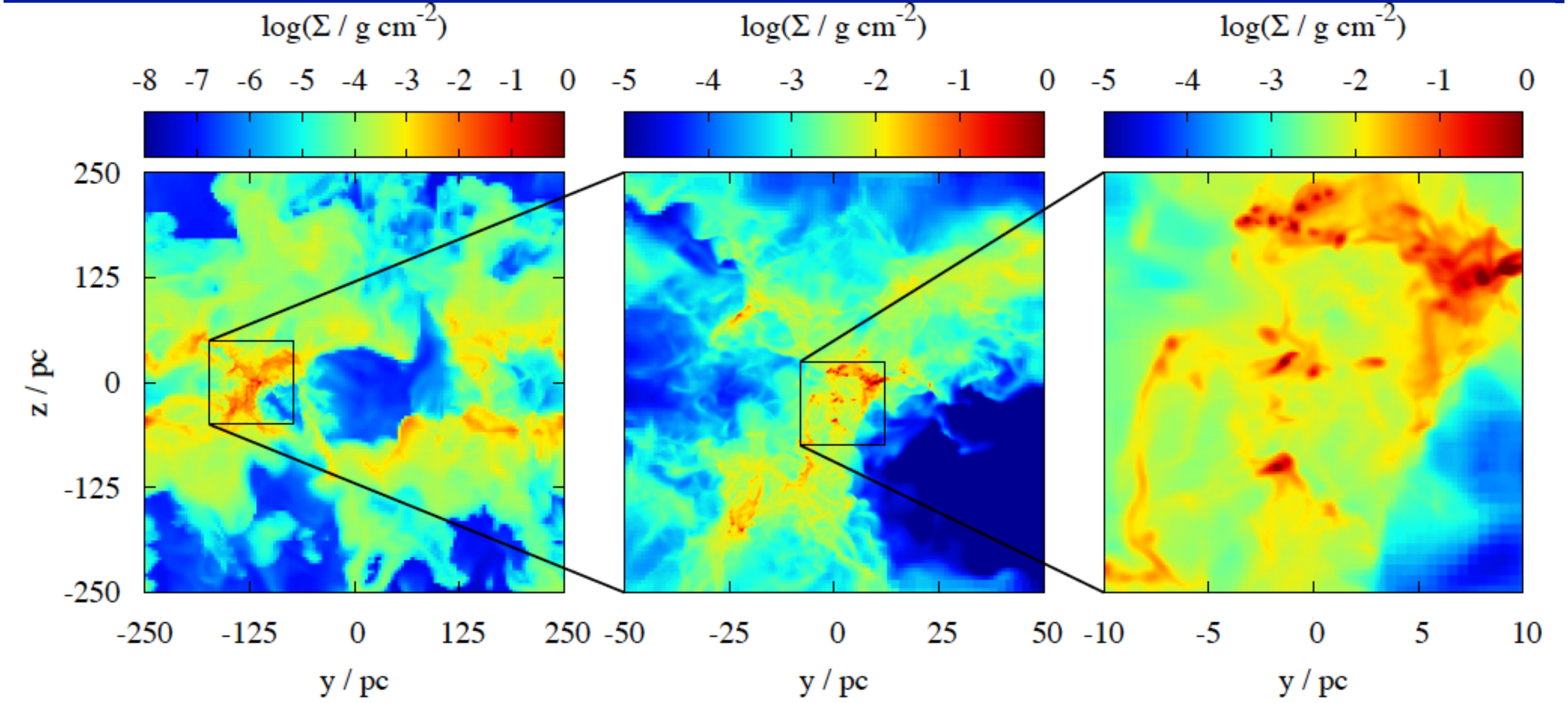
Haid et al. (2018)

SILCC simulations of Gatto, Walch +2017: including star cluster formation and feedback (stellar winds + supernovae)



Movie see SILCC webpage
www.astro.uni-koeln.de/silcc

SILCC-ZOOM:
Galactic zoom-in calculations:

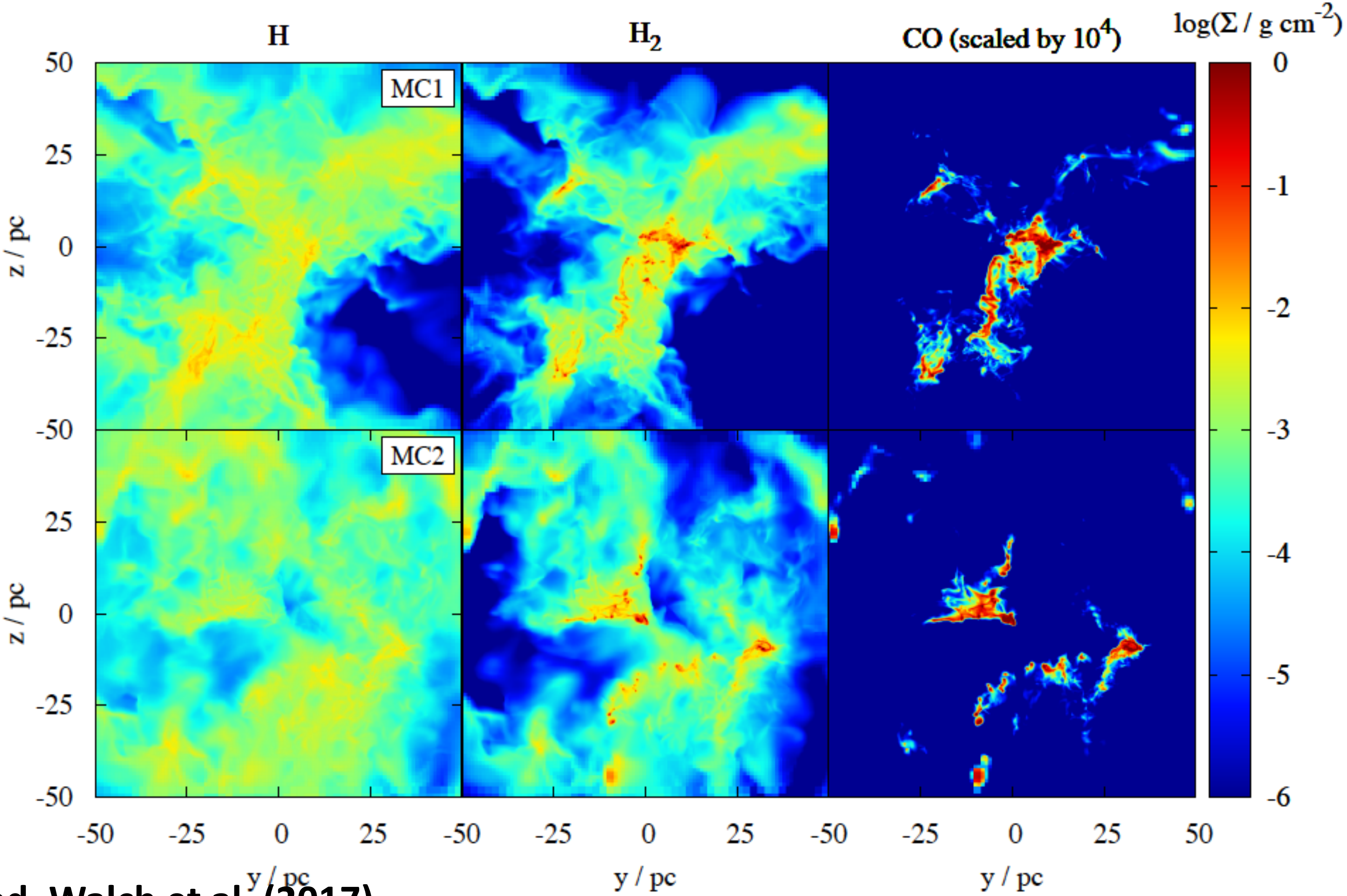


=> pick a cloud from SILCC

=> resolve down to 0.1 pc but keep galactic environment

Seifried, Walch et al. (2017)

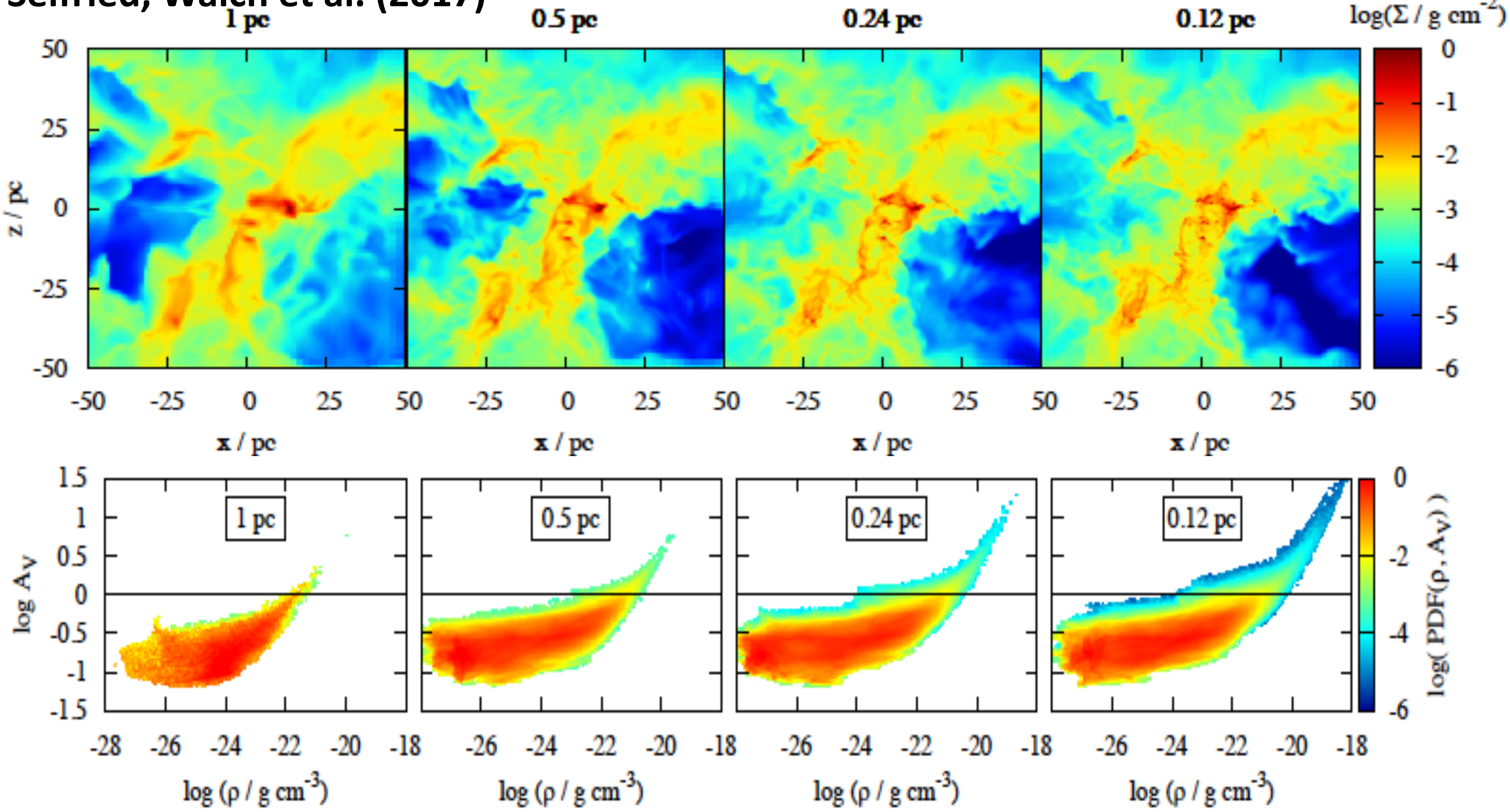
Zoom-in calculations for 2 clouds: Column density in HI, H_2, and CO



Seifried, Walch et al. (2017)

Molecular cloud 1 at different maximum resolution (t=5 Myr)

Seifried, Walch et al. (2017)



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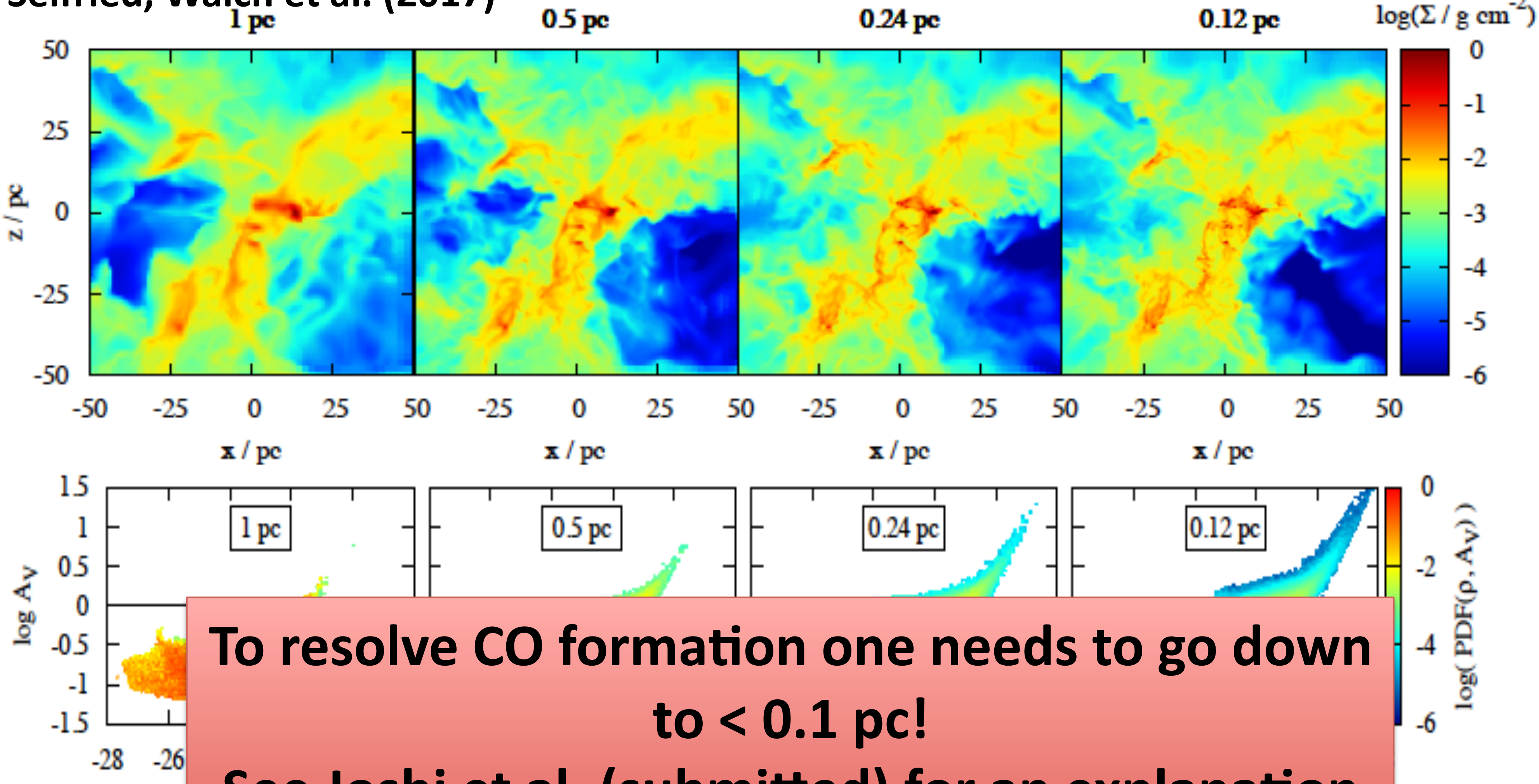
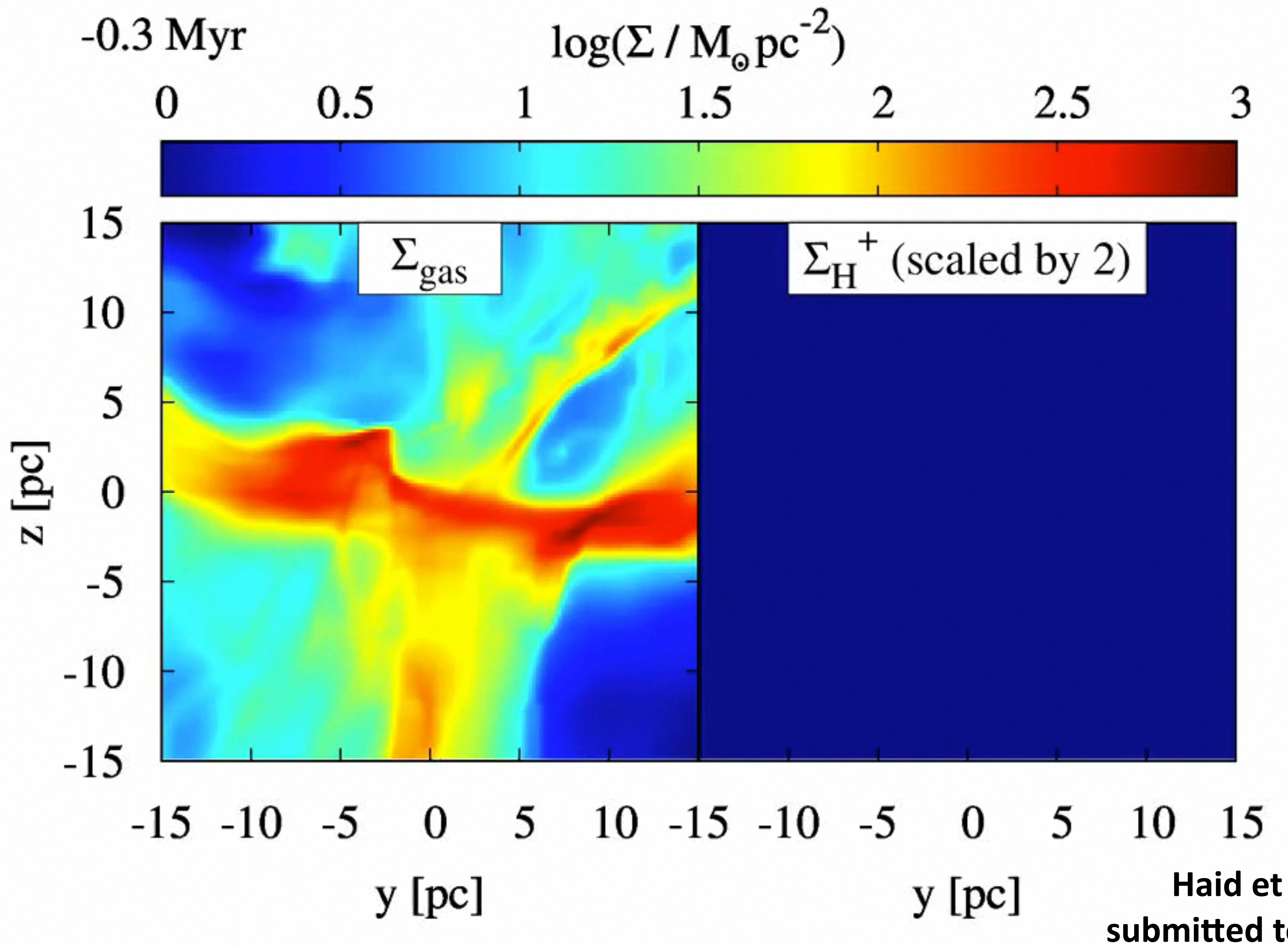


To resolve CO formation one needs to go down to < 0.1 pc!
See Joshi et al. (submitted) for an explanation of this resolution criterion!

The molecular cloud “thunderstorm”: Flickering HII regions - highly variable ionization fraction



Haid et al., 2018, submitted to MNRAS

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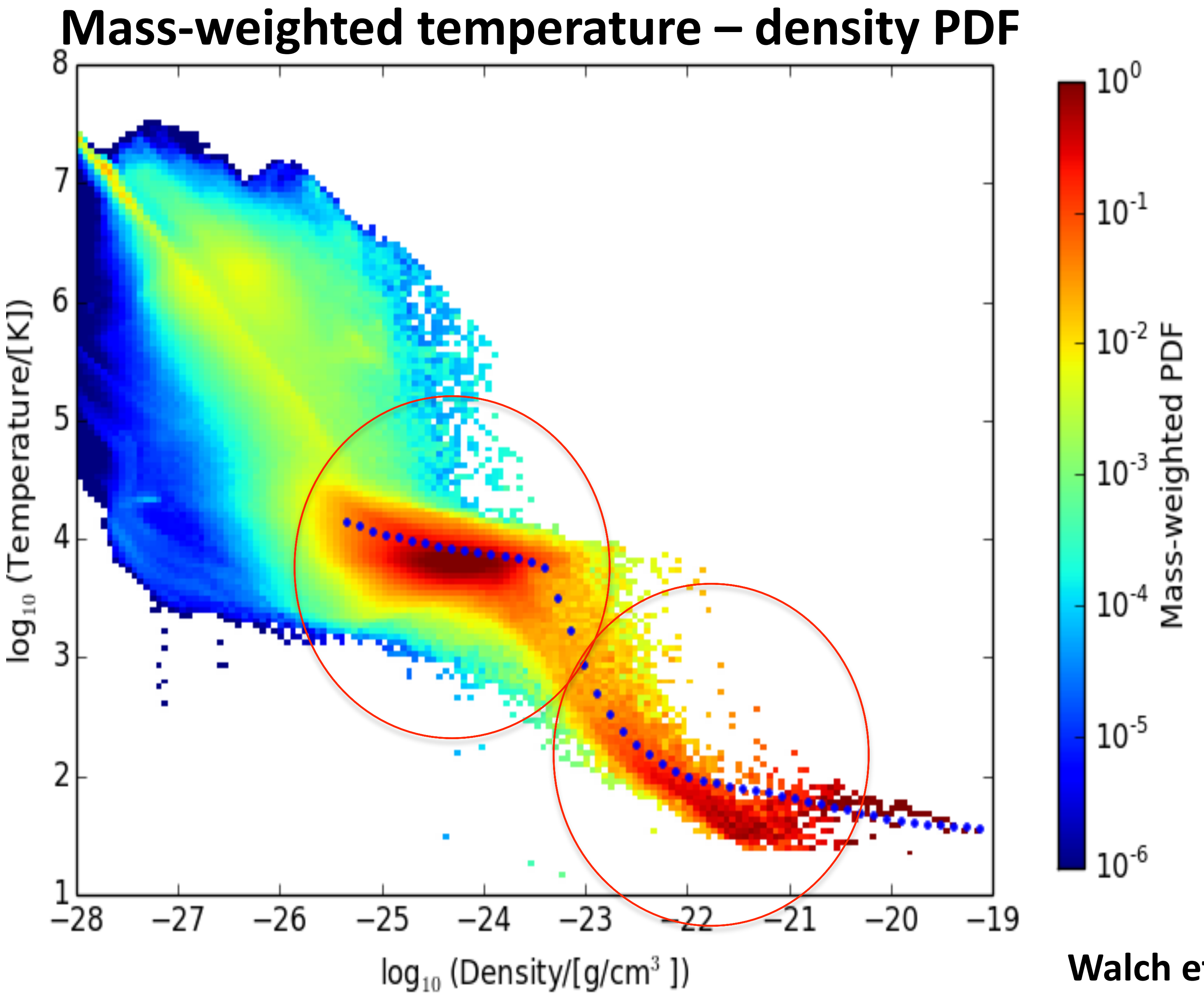

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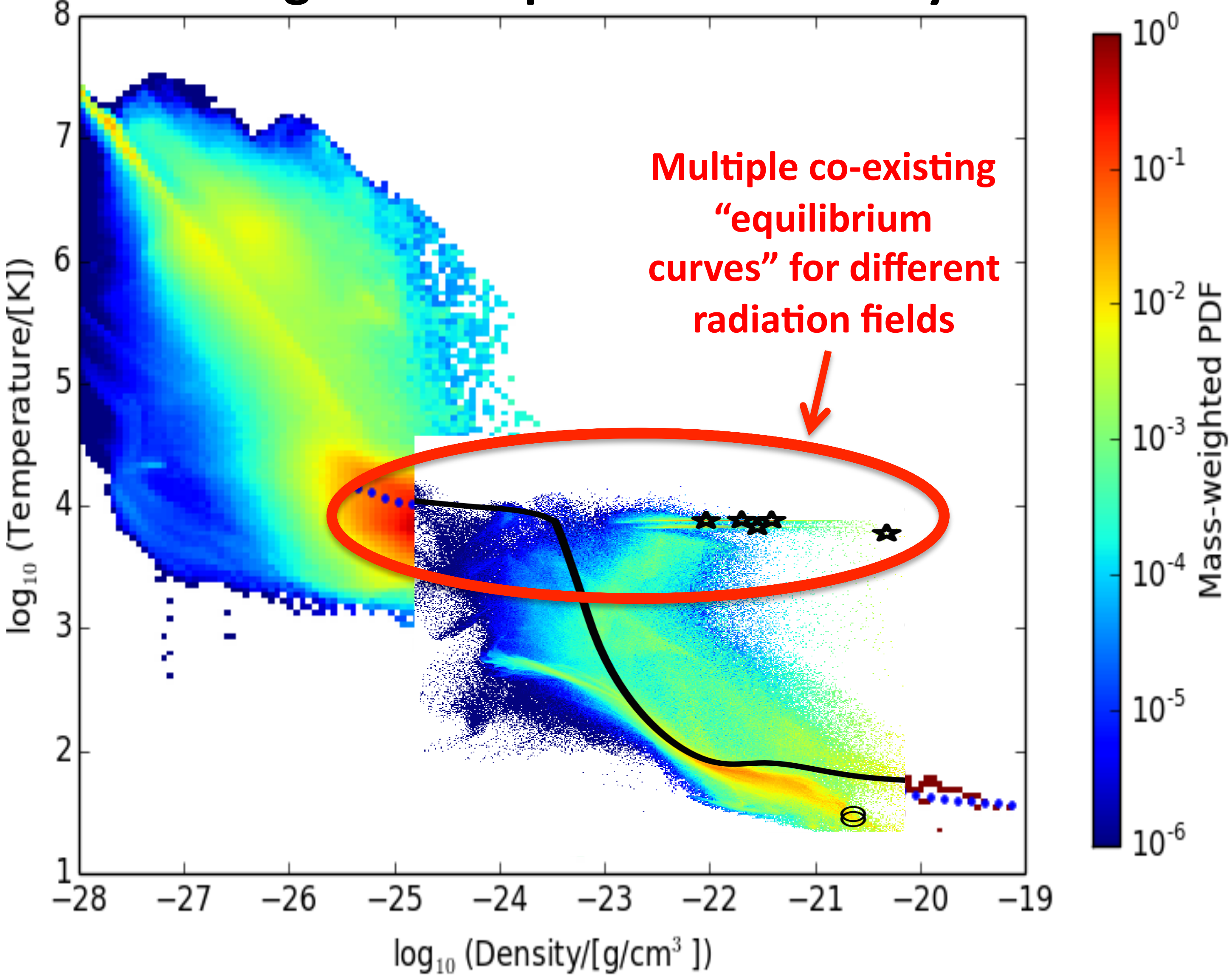
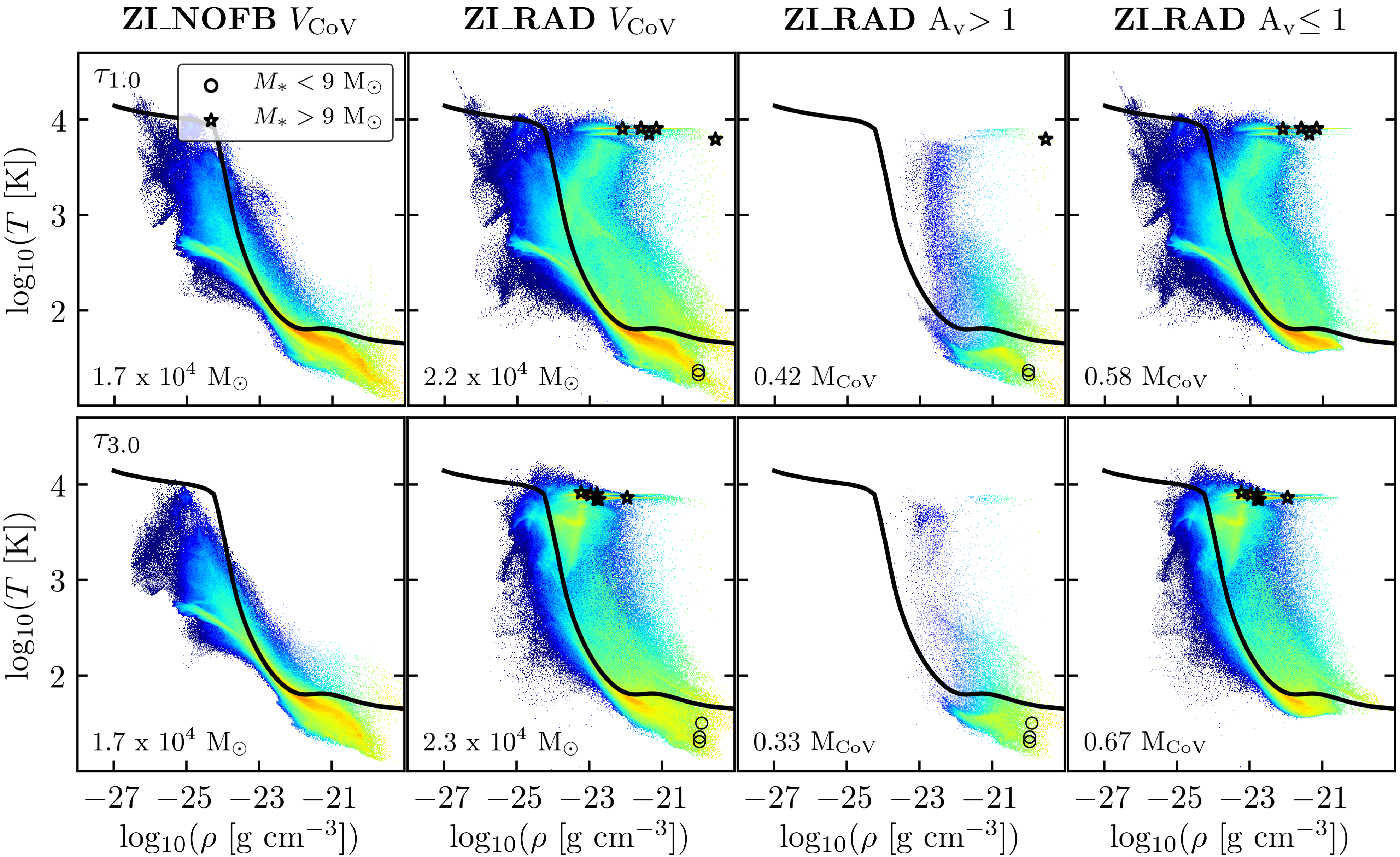


With radiative feedback, gas is pushed above the standard equilibrium curve!



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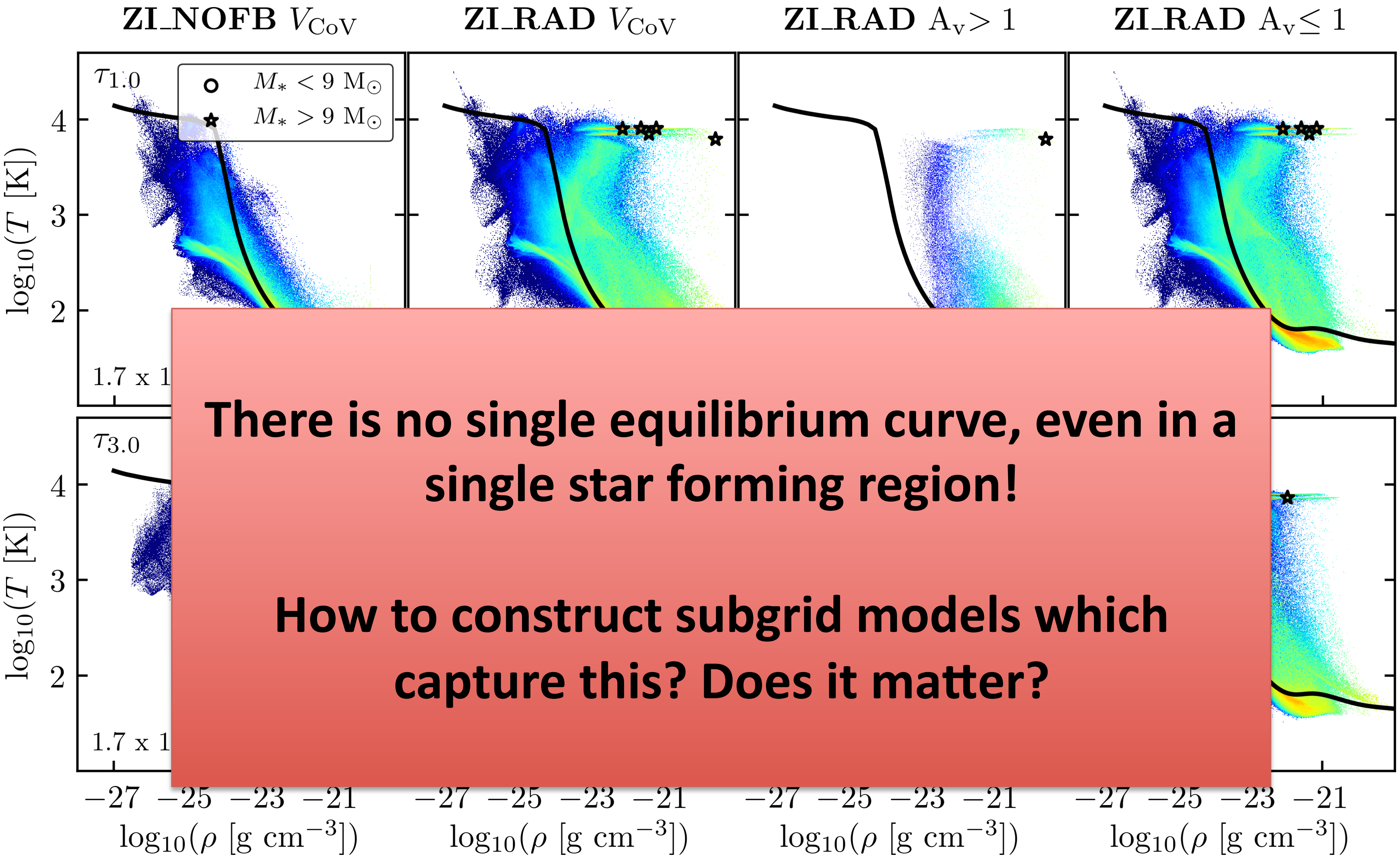
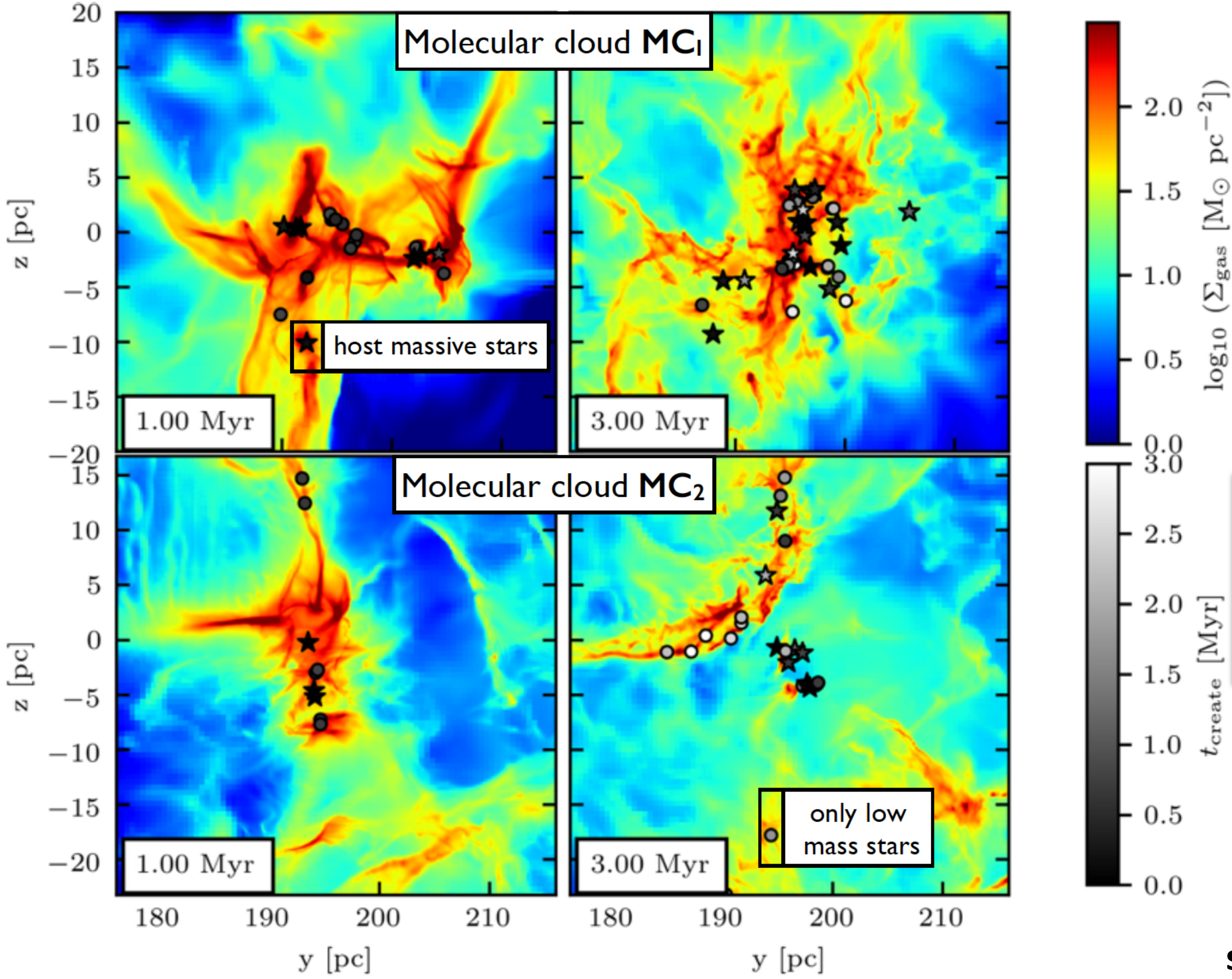


There is no single equilibrium curve, even in a single star forming region!

How to construct subgrid models which capture this? Does it matter?

Why clouds react differently to a comparable energy input in the form of ionizing radiation?



Study evolution of two clouds with comparable initial and star forming properties (Mass, size, virial parameter, luminosity input and SFE)

MC1 stays compact
MC2 is dispersed

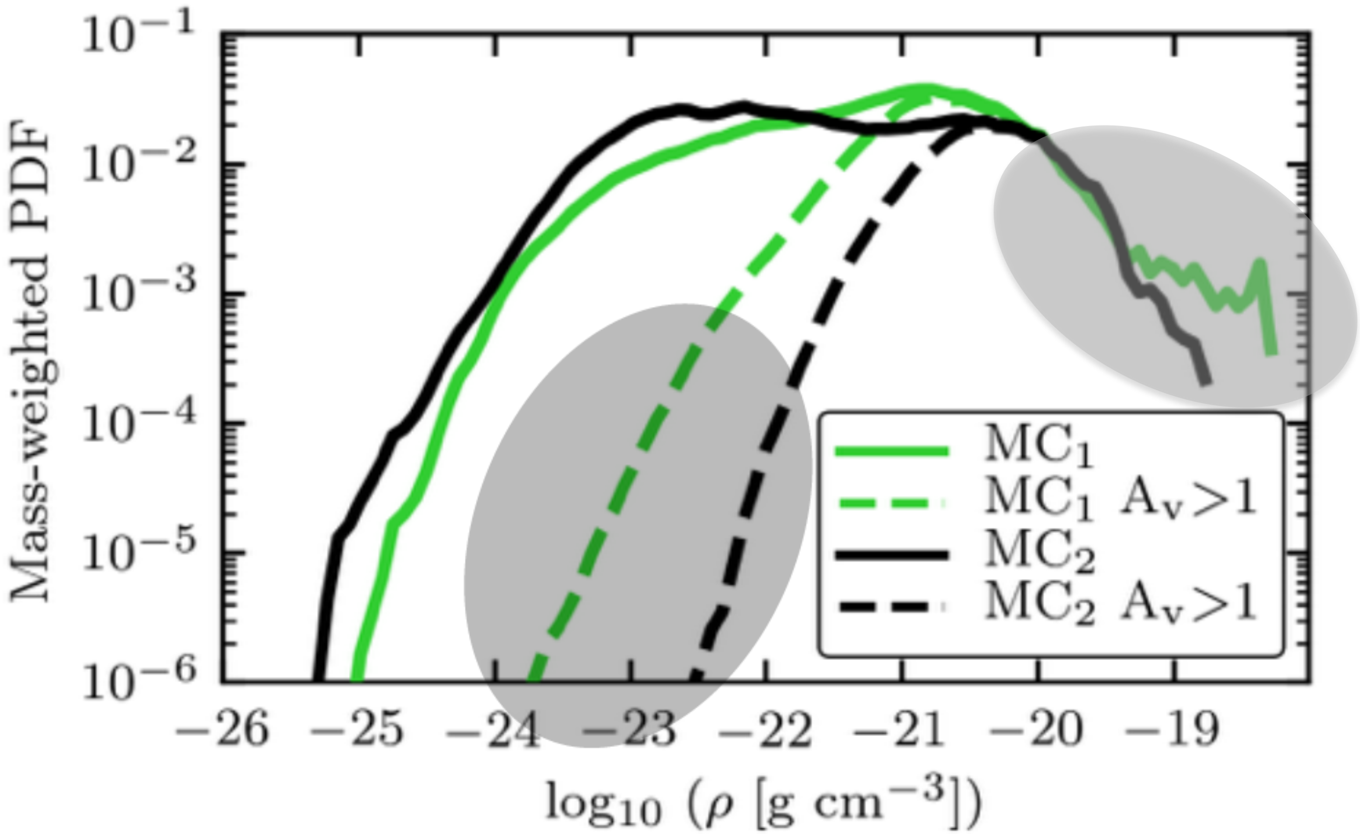
Why?

Haid et al., 2018, submitted to MNRAS

Why clouds react differently to a comparable energy input in the form of ionizing radiation?

Density distribution of the total gas ▬▬▬

Density distribution of shielded gas ▬ ▬ ▬



MC1 stays compact
MC2 is dispersed

Because…
MC1 contains more well shielded gas!

MC2 is dispersed more easily!

Haid et al., 2018, submitted to MNRAS

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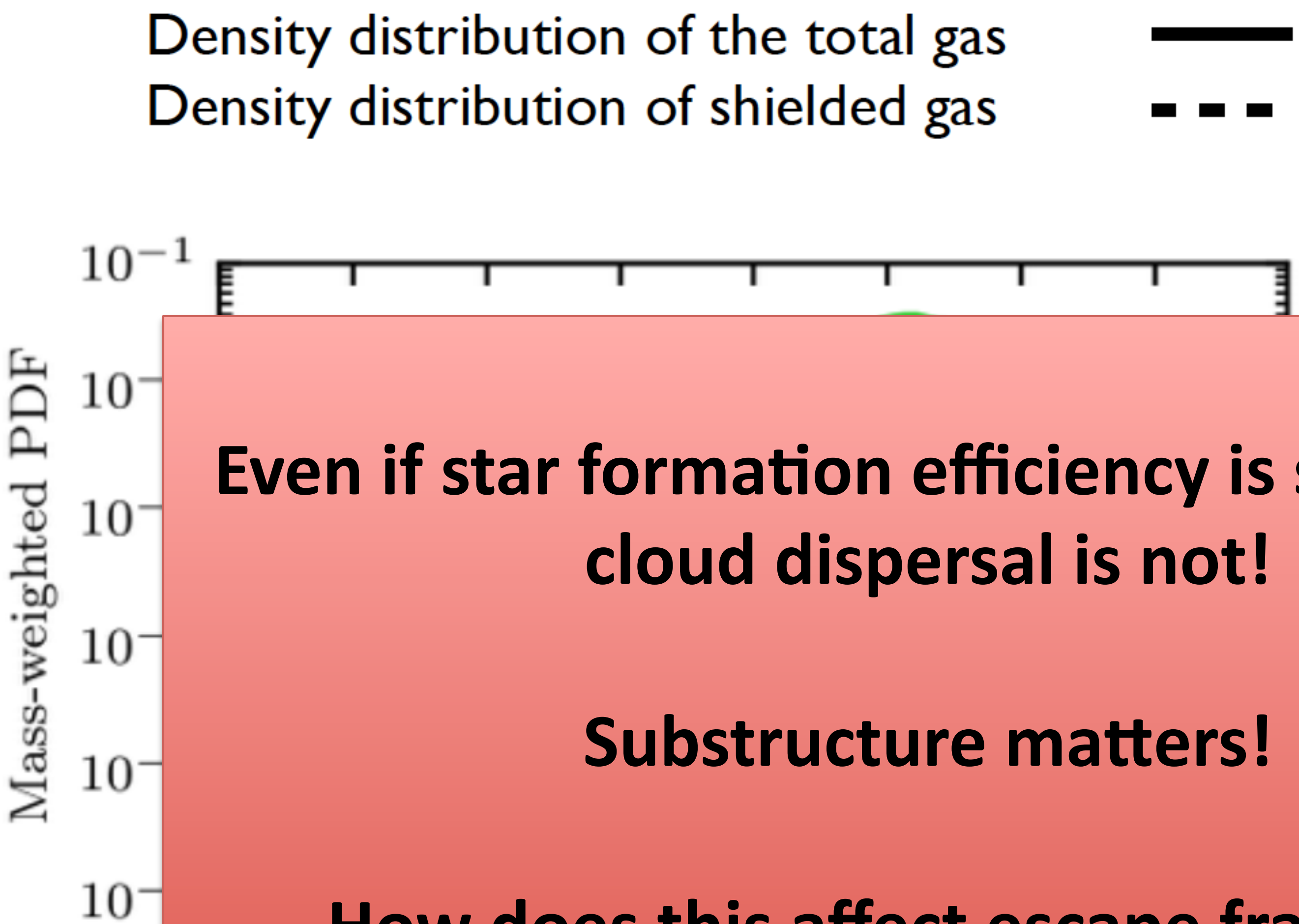

MC1 stays compact
rsed
..
more
l gas!
rsed
ly!

Even if star formation efficiency is similar, the cloud dispersal is not!

Substructure matters!

How does this affect escape fractions?

Haid et al., 2018,
submitted to MNRAS

Open Questions

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