The RIGEL project:

Simulating dwarf galaxies with feedback from individual stars and radiative transfer at 1 $M_\odot$ resolution

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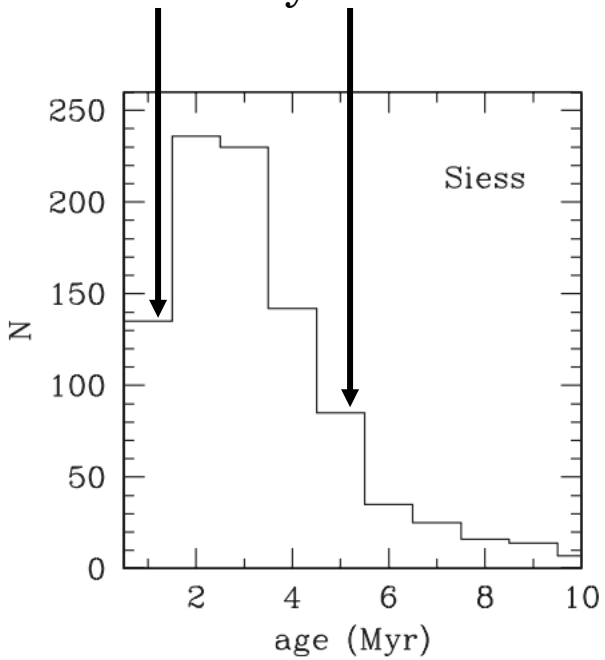
Radiative feedback disperse molecular clouds on a short time scale of ~1.5 Myr prior to the SN explosion

Observed star cluster formation / molecular cloud disruption time scale is very short

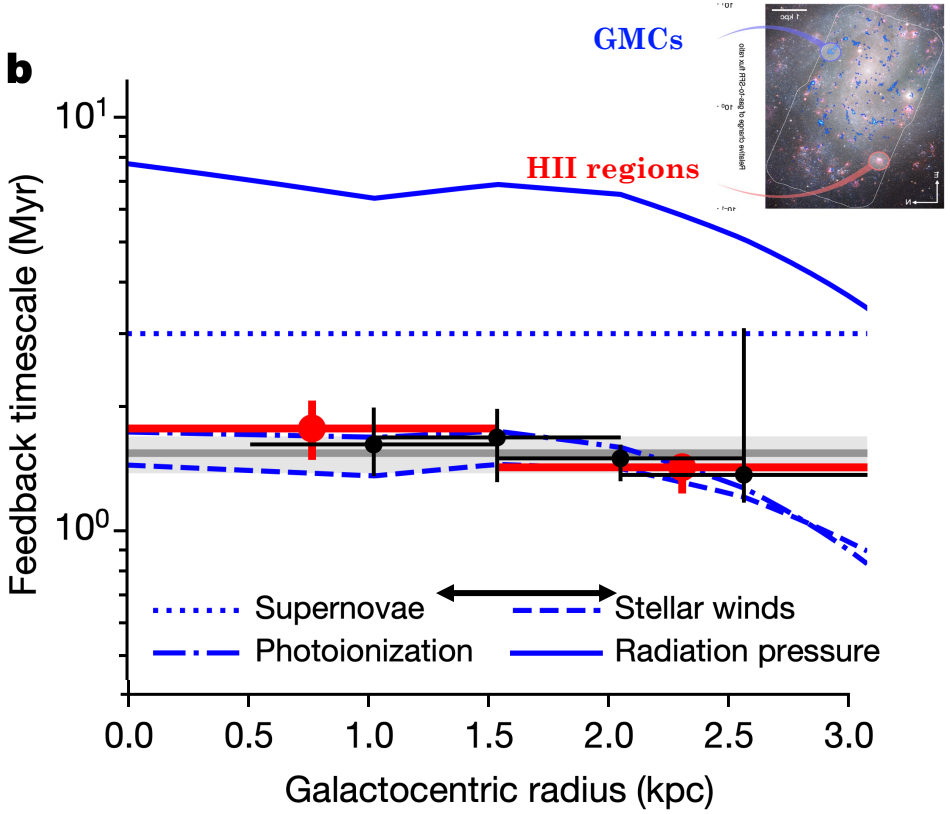
NGC 602 < 5 Myr young cluster in SMC, probably no SN yet (HST/ACS)

Age spread of ONC cluster (t_{80}) < 4 Myr

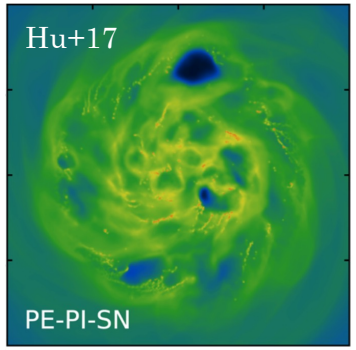


Hartmann+12

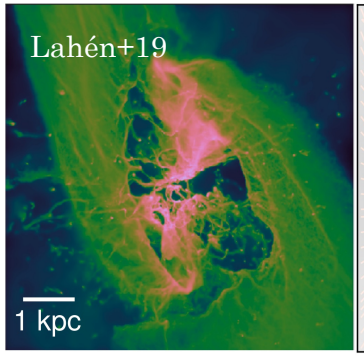
Feedback timescale in spiral galaxies is 1.5 Myr (Kruijssen+19)

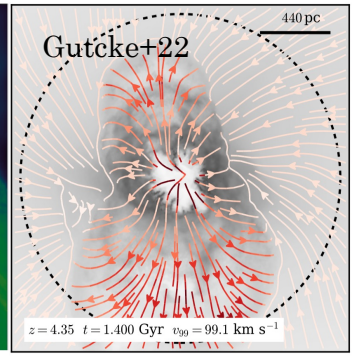


However, simulating radiation feedback with resolved star-forming regions is still very challenging



Radiative transfer is usually not solved explicitly in most simulations





Strömgren Mass

$$M_{\rm S} \approx 3.25\, Q_{48} n_3^{-1} \alpha_0^{-1}\, {\rm M}_\odot\,.$$

Timescale

$$t_{\rm rec} = \frac{1}{\alpha_{\rm B} n_{\rm H}} \approx 122.3\, n_3^{-1} \alpha_0^{-1}\, {\rm yr}\,.$$

Q_{48} ionizing photon rate / 10^{48}/s

Maximum density to resolve the Strömgren sphere

$$n_{\rm H} \lesssim 32\,{\rm cm}^{-3} \left(\frac{\mathcal{R}_i}{10}\right)^{-1} \left(\frac{M_{\rm cell}}{10\,{\rm M}_\odot}\right)^{-1} Q_{48}\,.$$

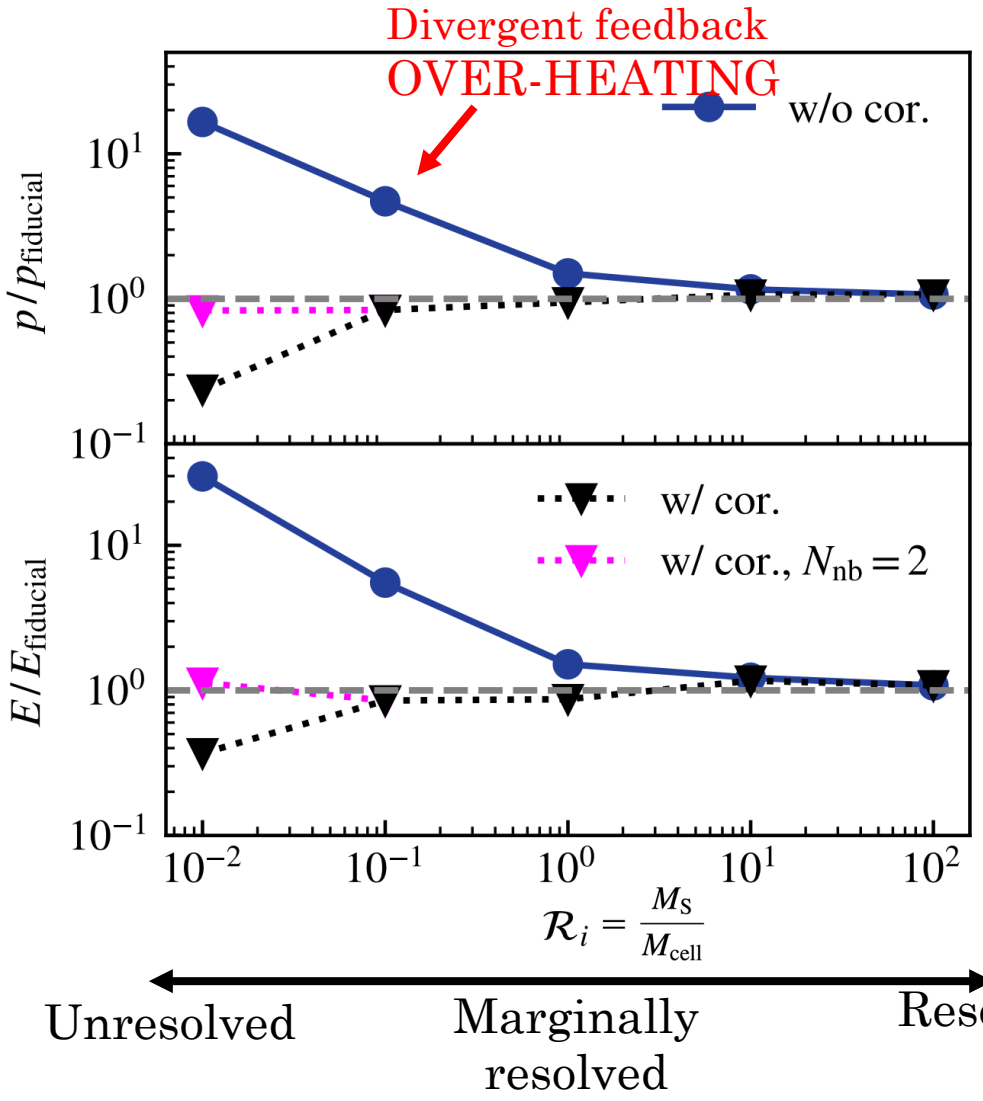
Resolution $\mathcal{R}_i = \frac{M_{\rm S}}{M_{\rm cell}}$

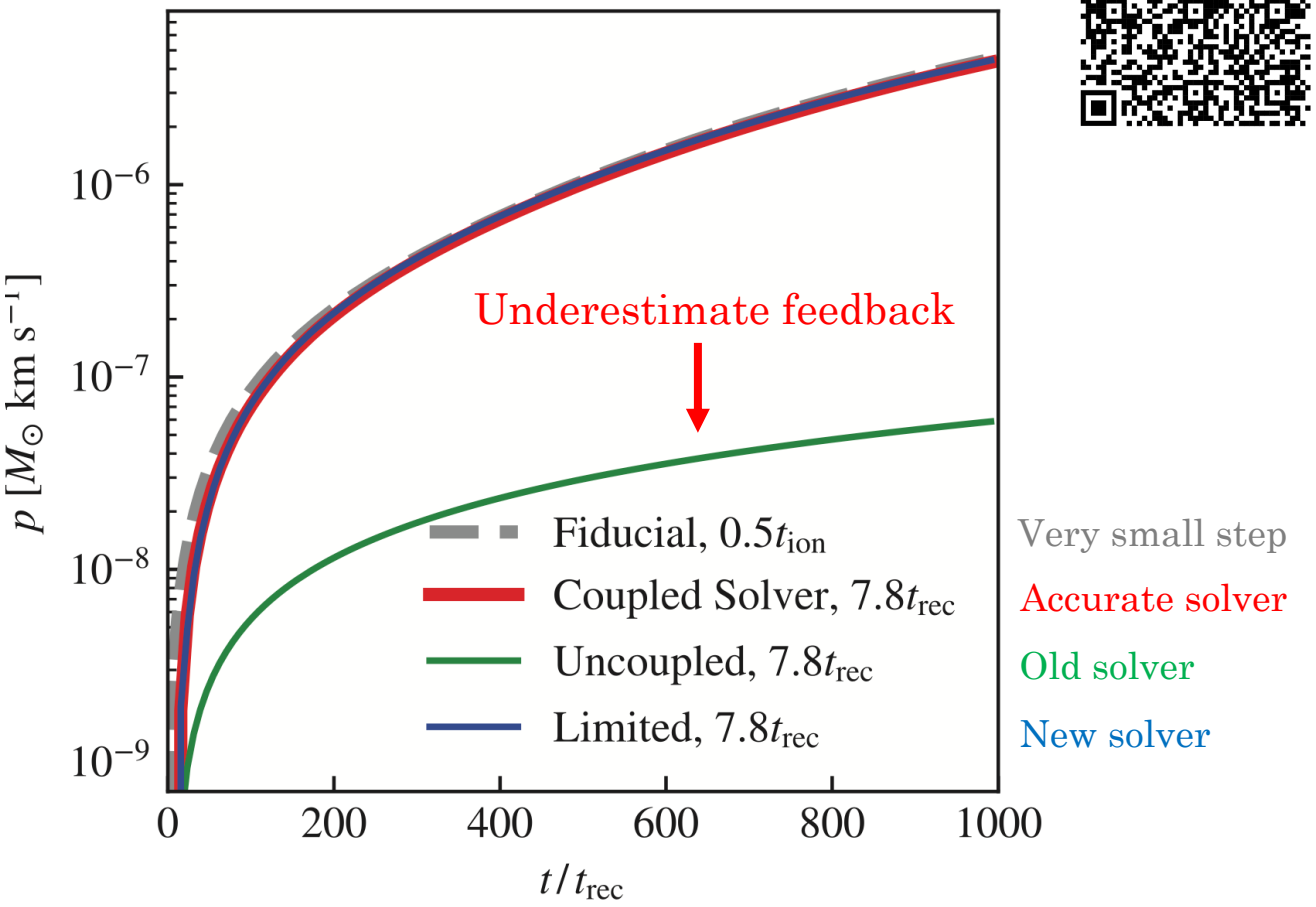
Deng et al. 2024, MNRAS

However, simulating radiation feedback with resolved star-forming regions is still very challenging

Reasons and solutions check here

Convergence across large spatial (and temporal) resolution range (Deng et al. 2024, MNRAS)





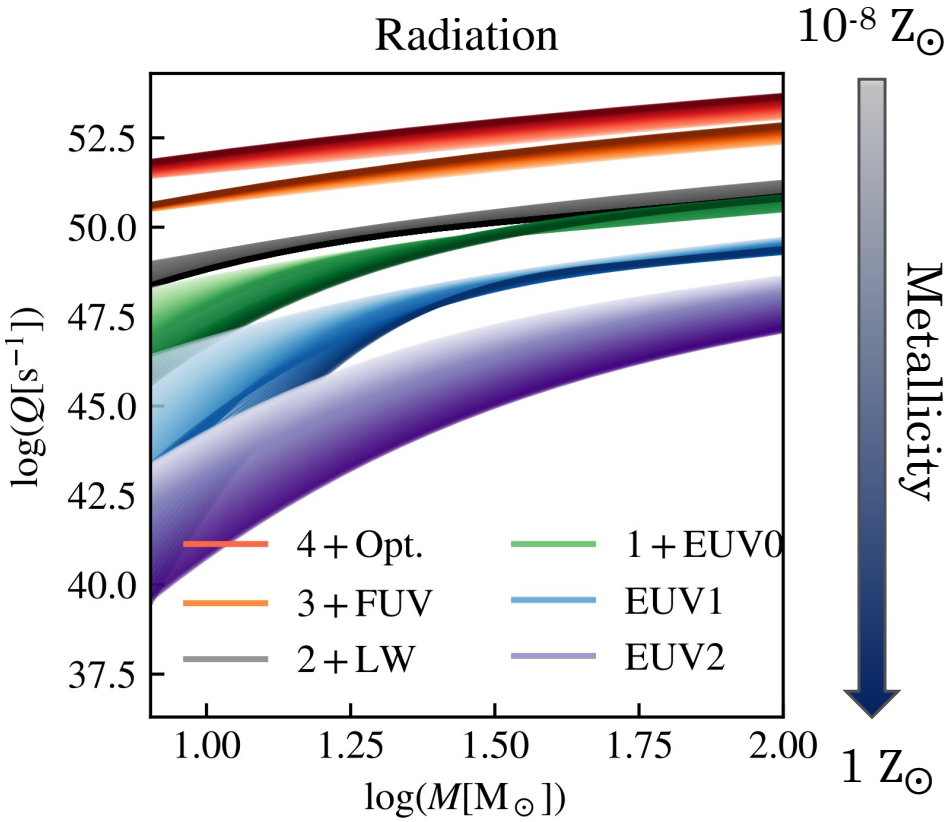
Very small step

Accurate solver

Old solver

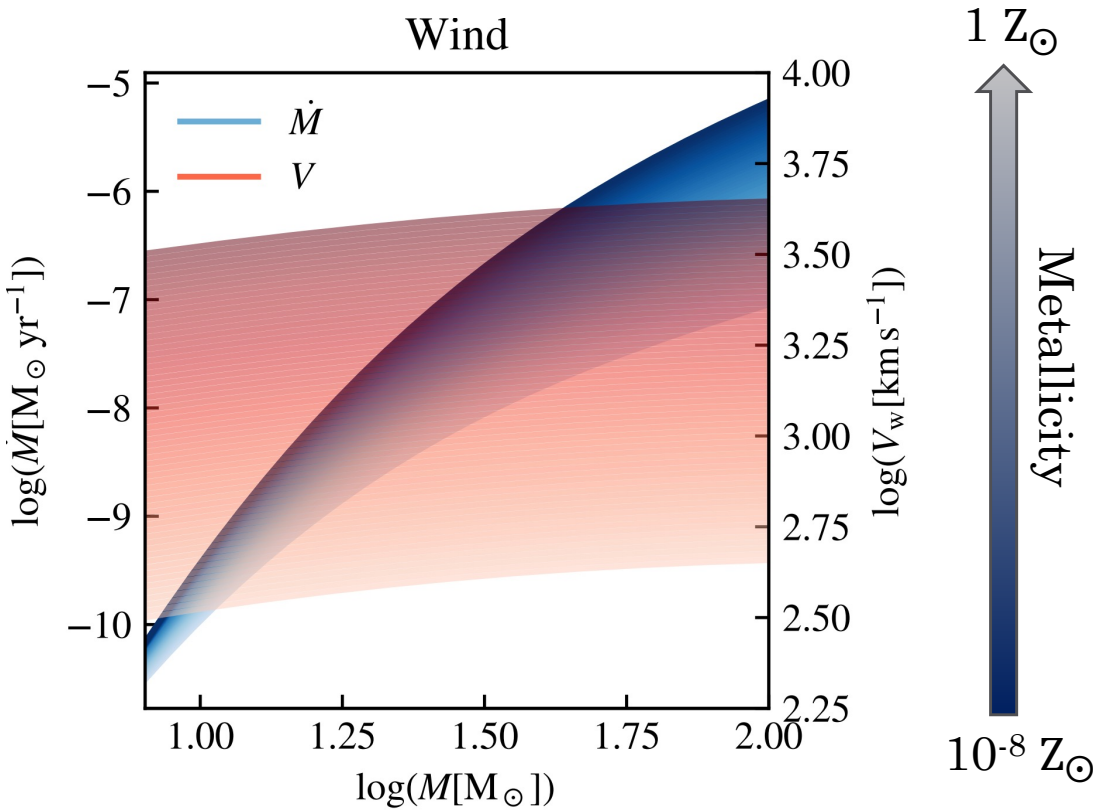
New solver

Metallicity dependency of stellar feedback budget



IR: 0.1-1 eV
Opt.: 1-5.8 eV
FUV: 5.8-11.2 eV
LW: 11.2-13.6 eV
EUV0: 13.6-24.6 eV
EUV1: 24.6-54.4 eV
EUV2: >54.4 eV

Reference:
Lanz & Hubeny 03,
Schaerer 02,
Tanikawa+20 (black-body),
Gessey-Jone+22;

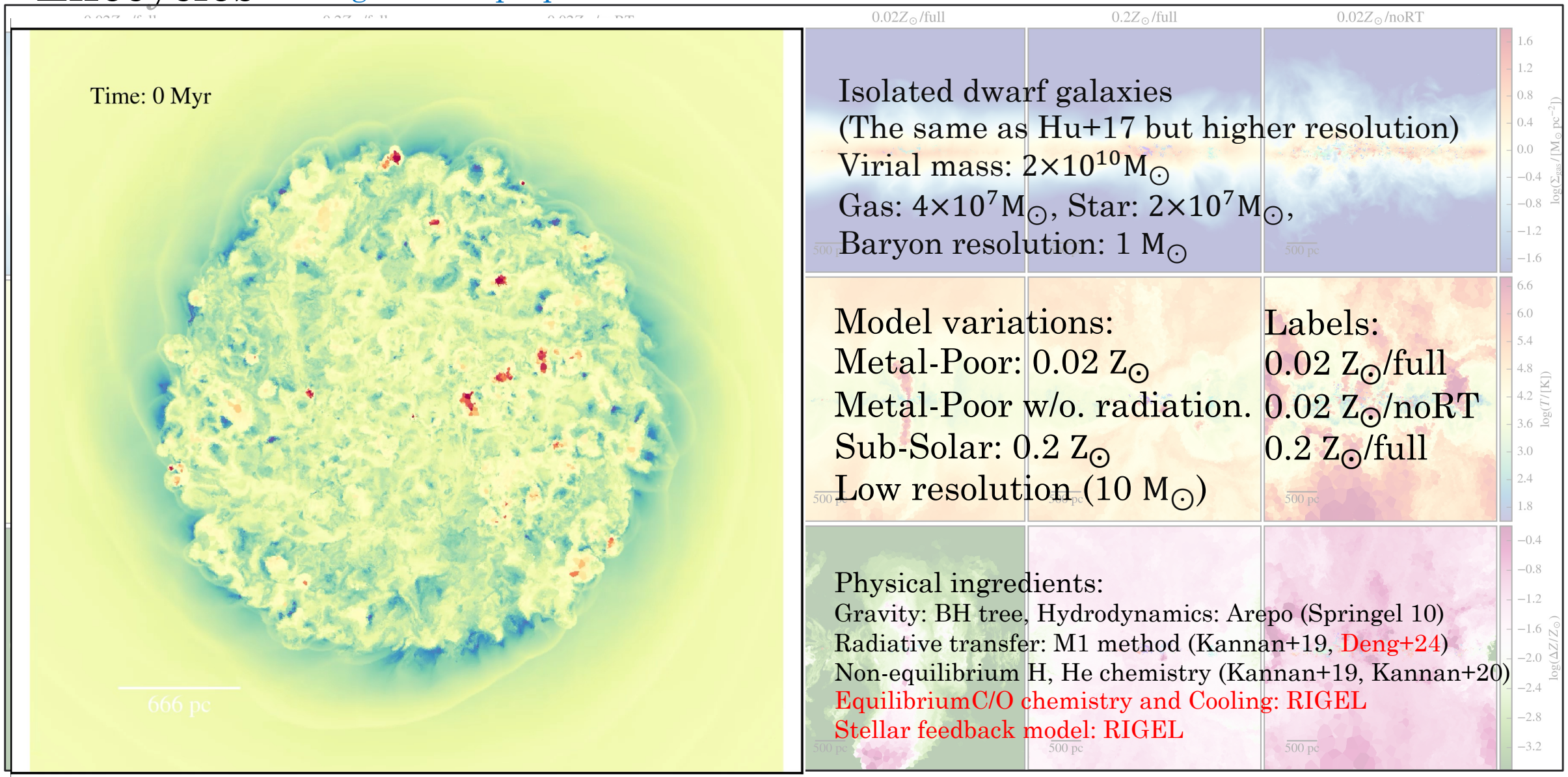


Reference:
Vink & Sander 21, Vink+01

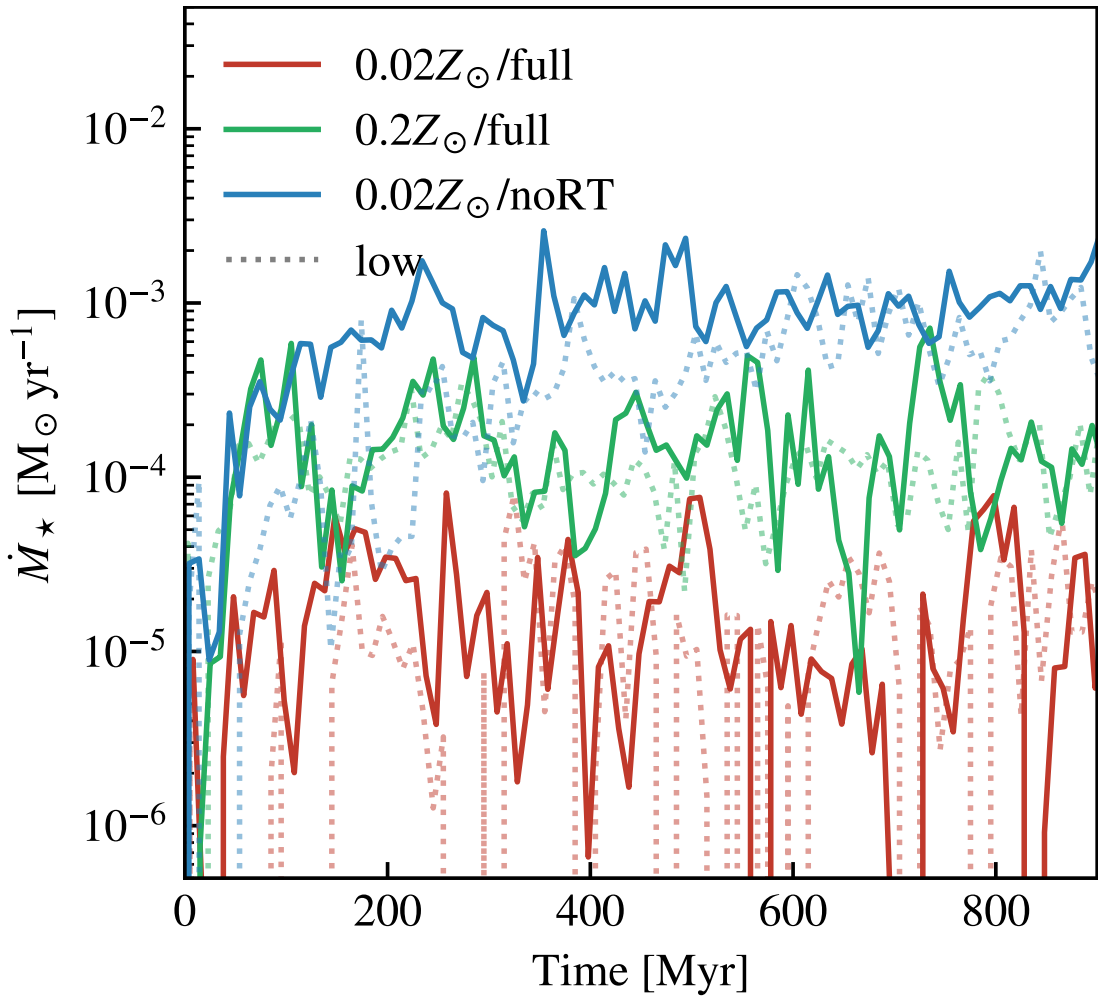
Order of magnitude differences, important for cosmological simulations evolving from primordial to present-day

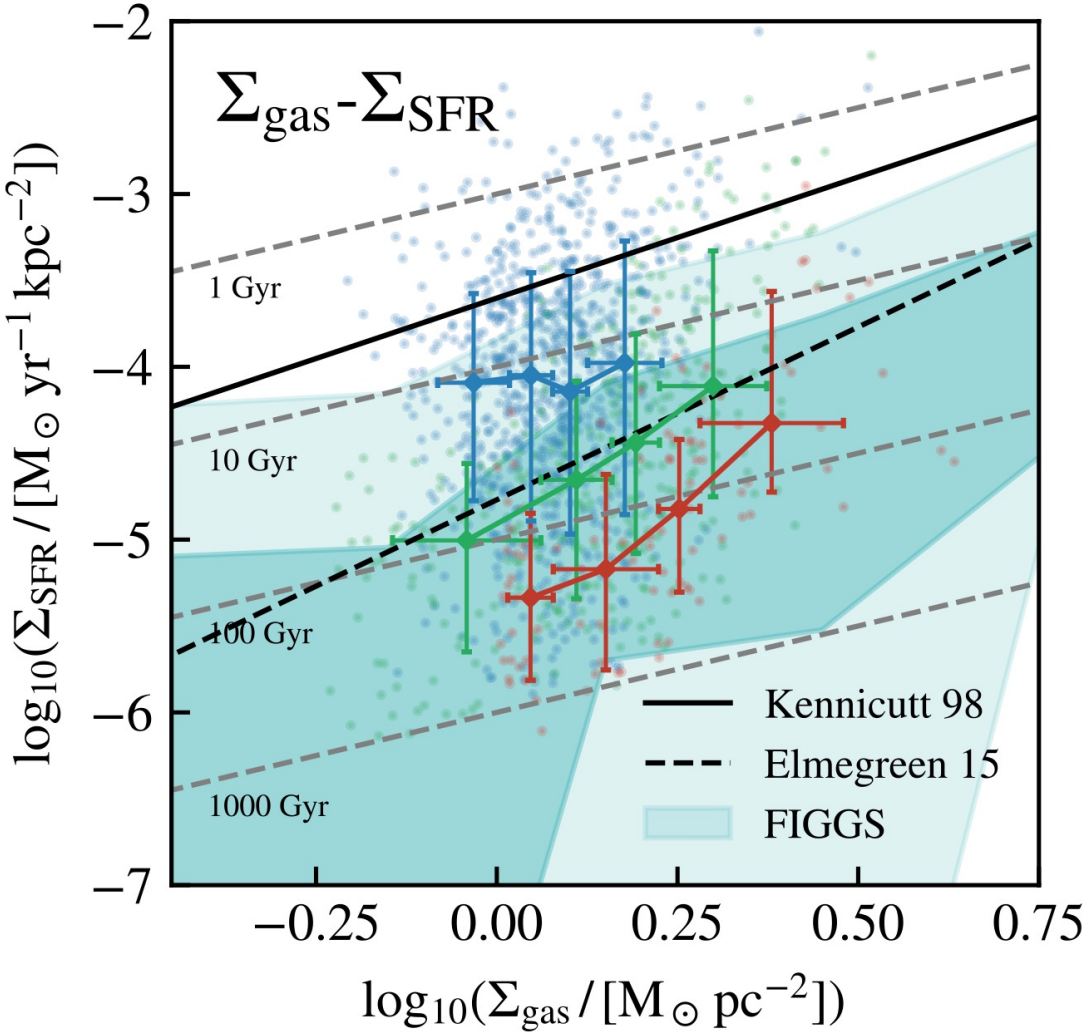
RIGEL: Realistic Ism modeling in Galaxy Evolution and Lifecycles

Deng et al. in prep.

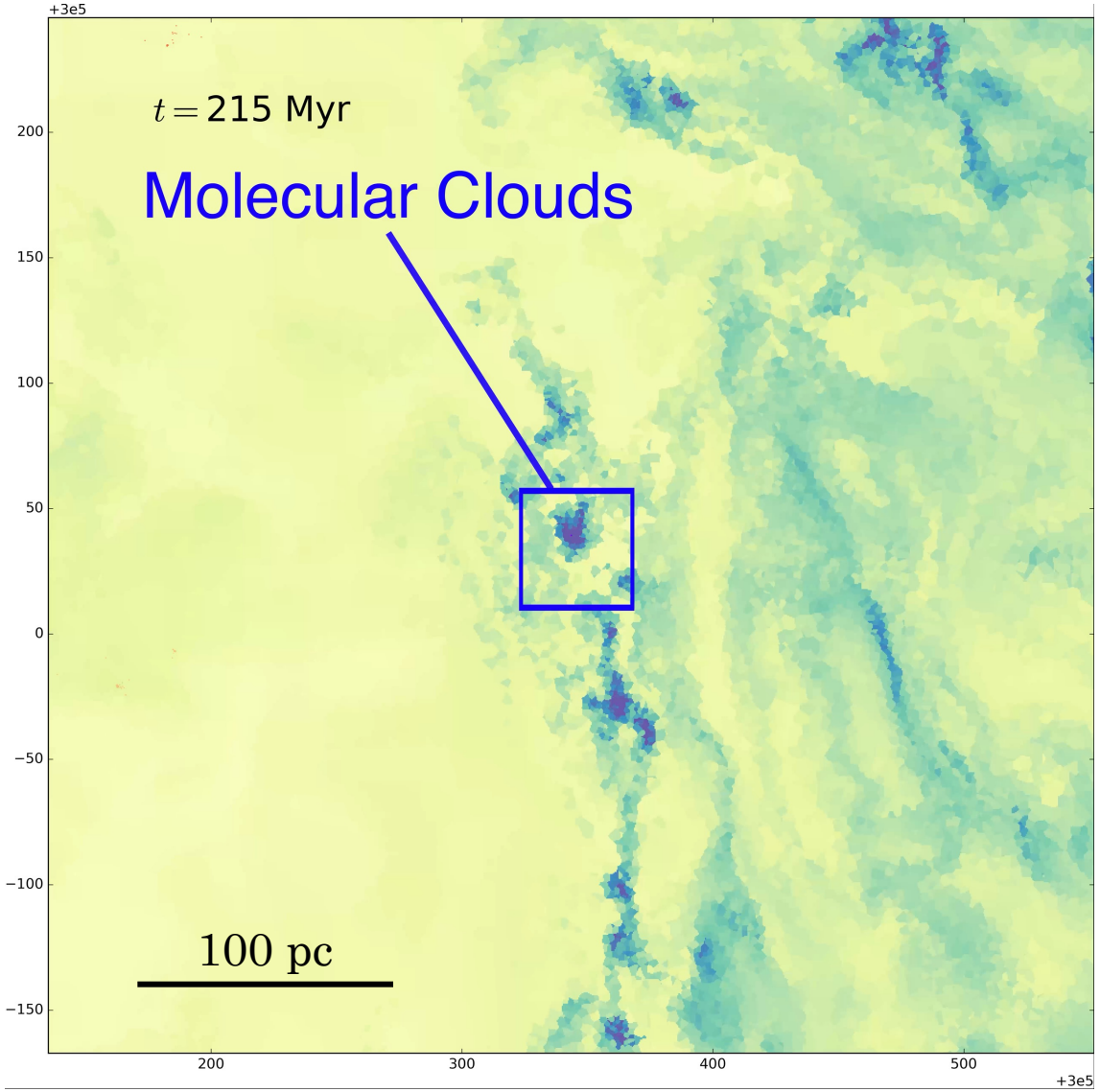


Star formation and Kennicutt-Schmidt relation



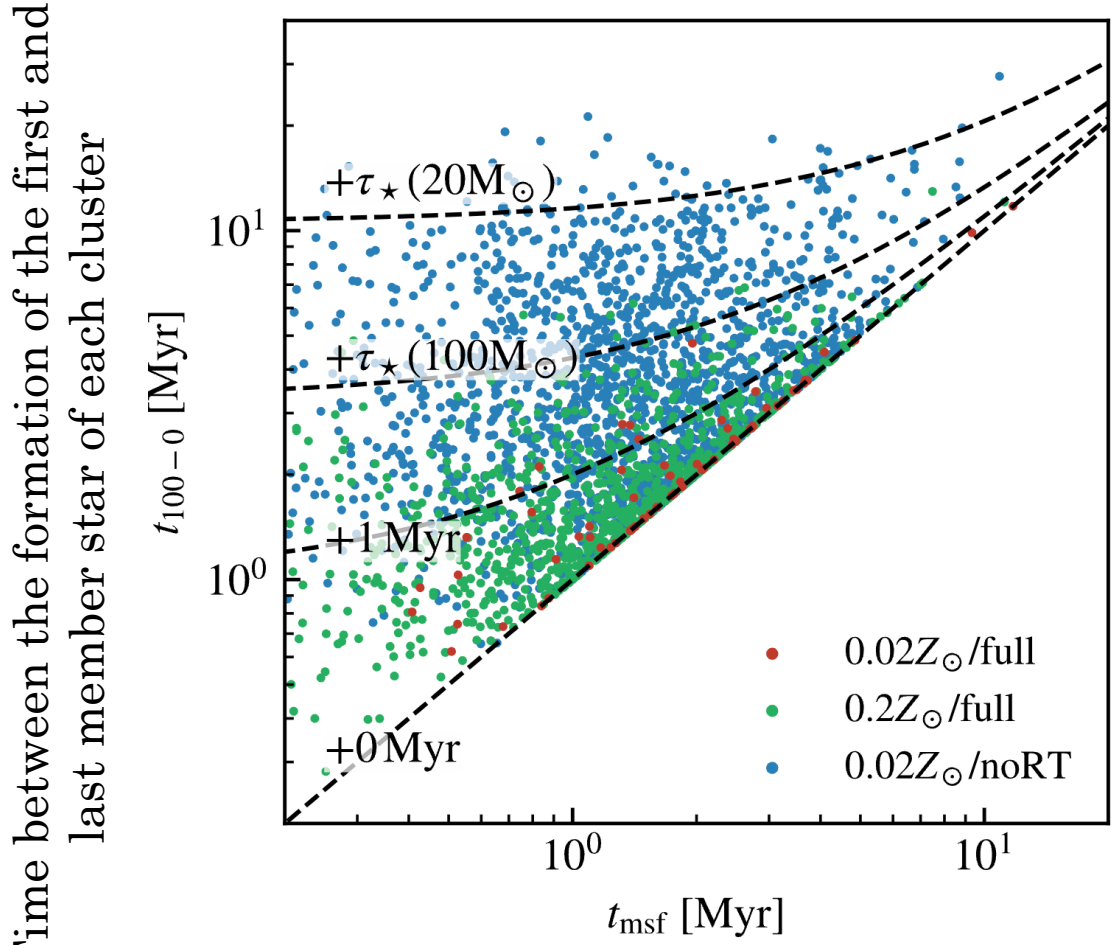


Isolate dwarf galaxy: How does radiative feedback play its role



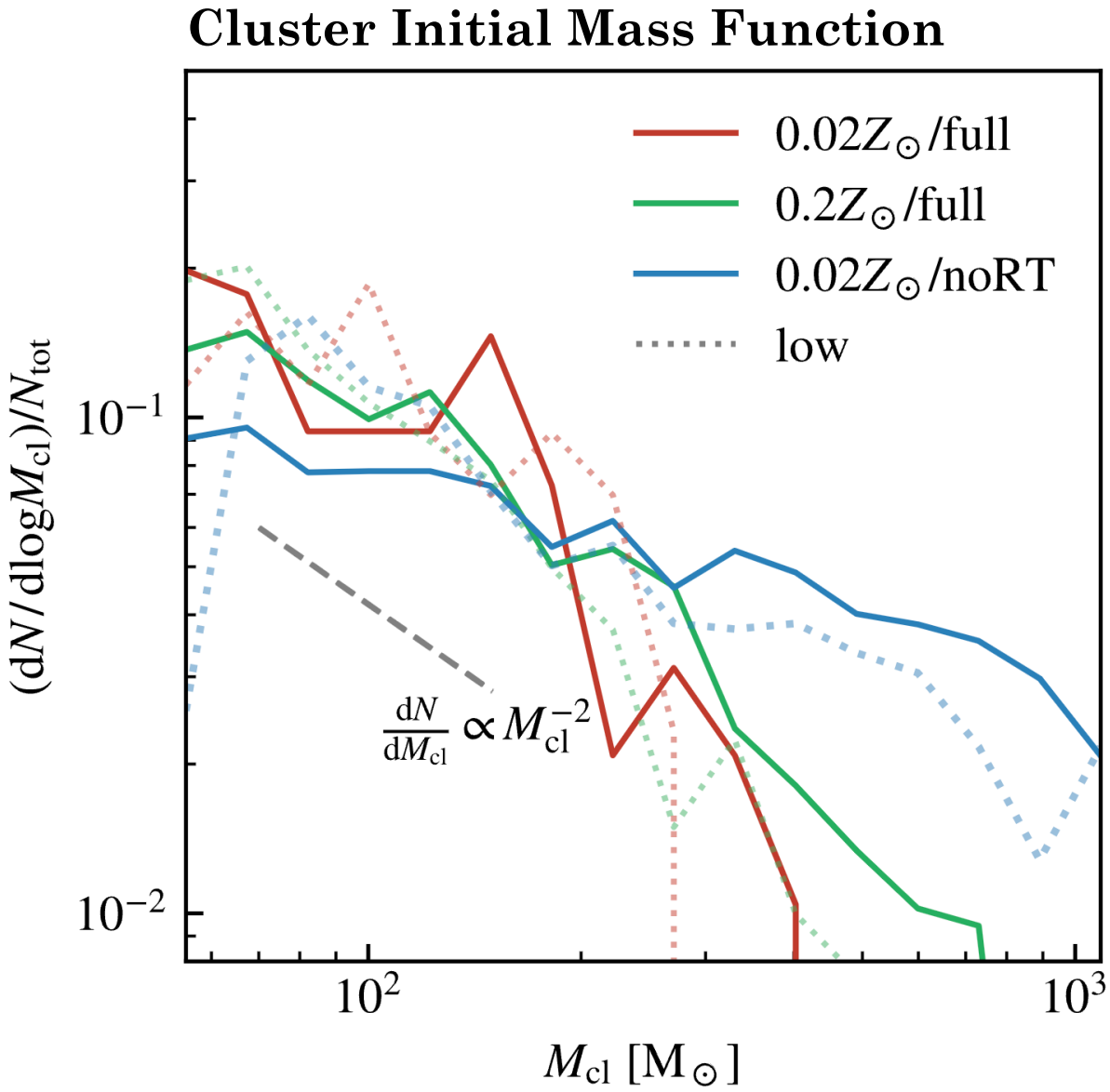
Temperature slice from the 0.02 $Z_\odot$/full galaxy

Low-mass star clusters stop increasing mass far before the first SN explosion



Formation time of the first massive star in each cluster

Isolate dwarf galaxy: How does radiative feedback play its role



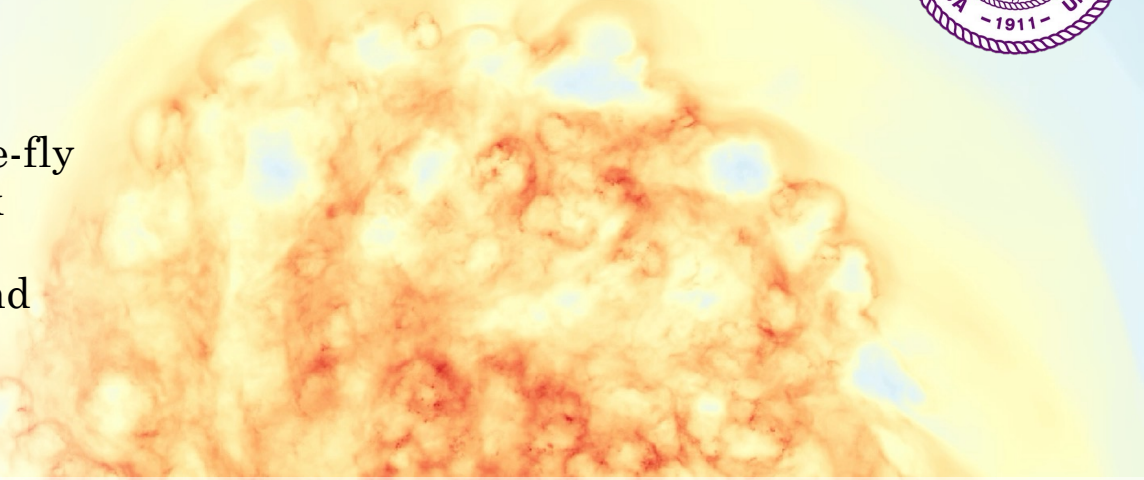
Power-law fitting (bootstrap)

Model	slope	std
0.02 $Z_\odot$/full	2.40	0.13
0.2 $Z_\odot$/full	2.07	0.02
0.02$Z_\odot$/noRT	1.63	0.03

Prohibit the formation of massive star clusters

Summary and
Ongoing projects with RIGEL

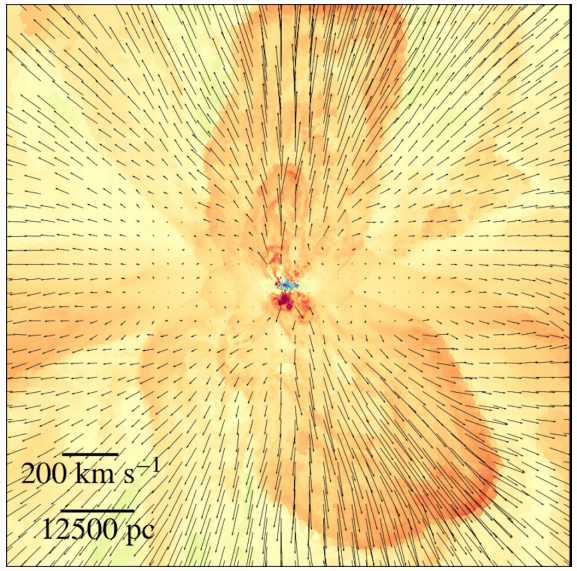
RIGEL
Realistic **I**sm modeling in **G**alaxy **E**volution and **L**ifecycles



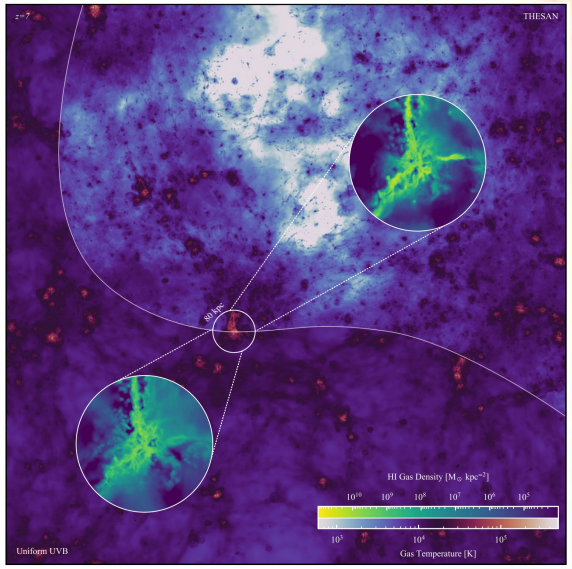
1. The RIGEL model: a self-consistently model of the interstellar medium (ISM) in dwarf galaxies with on-the-fly RT, individual massive stars, and Z-dependent feedback

2. Tested this model with an isolate dwarf galaxy and found that radiative feedback is important to prohibit the formation of massive star cluster and shaping the mass function steep at the high mass end.

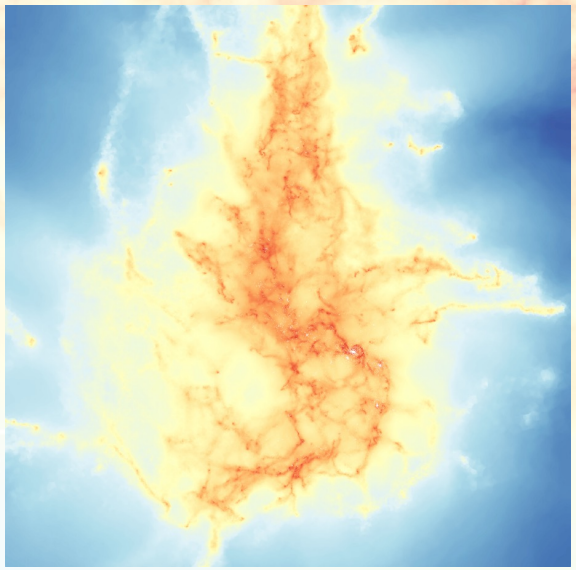
Outflow and SN clustering
in
Isolated Dwarf galaxies



Zoom-in
Simuluations of
Dwarf galaxies in THESAN



GMC-scale
cluster formation with
yields of binaries



Central Molecular
Zone of
our Milky Way