Launching of hot gas outflow by disc-wide supernova explosions

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SNe explosions & gas transfer: observations

M82

NGC891

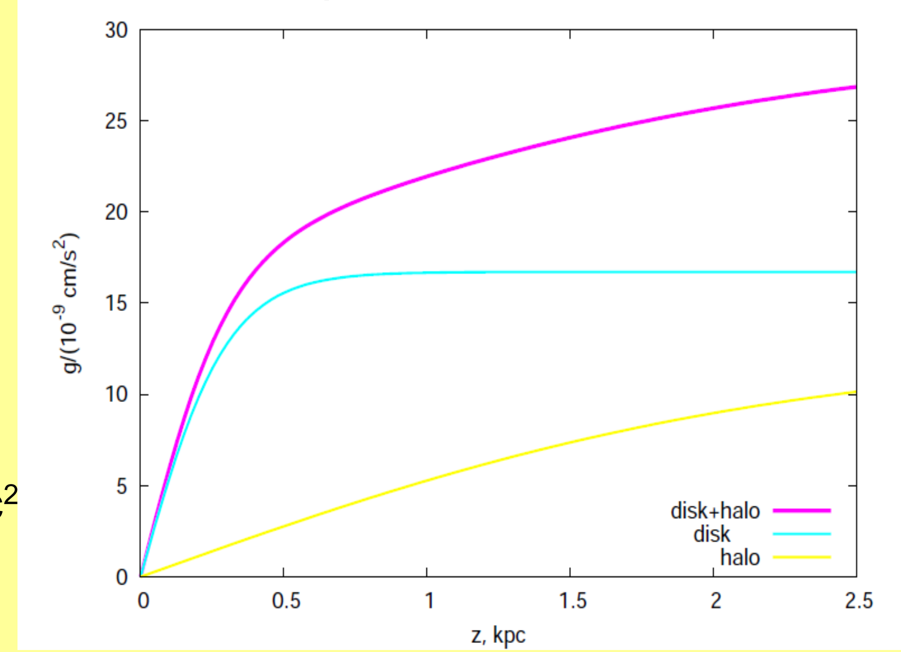
local starformation bursts → elevation of gas over the disk plane

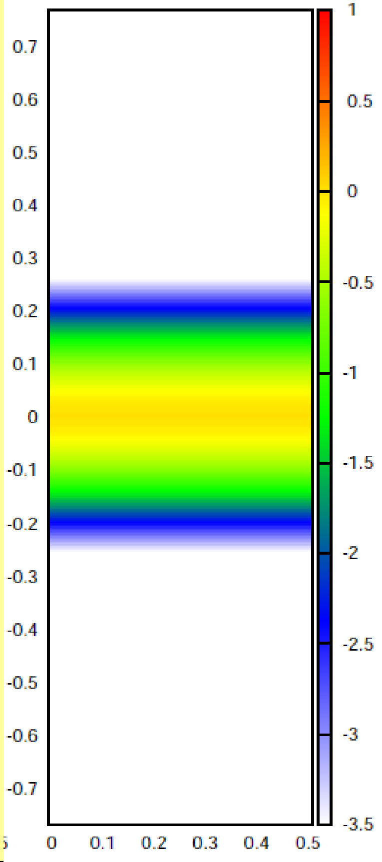
powerful starformation bursts → galactic winds

how is a gas transported from the disk to large heights?

gas in the gravitational potential (stellar disk + dark halo)

Galactic disk
stellar disk:
scale height 300 pc
distance from the center 3 kpc





stellar $\Sigma \sim 180\ M_{sun}/pc^2$

gaseous $\Sigma \sim 3.5\text{-}10\ M_{sun}/pc^2$

($n \sim 1 - 3\ cm^{-3}$)

the gaseous disk is in dynamical and thermal equilibrium

T in the disk ~ 9000 K ↔ heating 6e-24 erg/s for [Z/H] = 0

SNe

scale height ~ 0.5 of the gaseous scale height

uniformly distributed in the disk

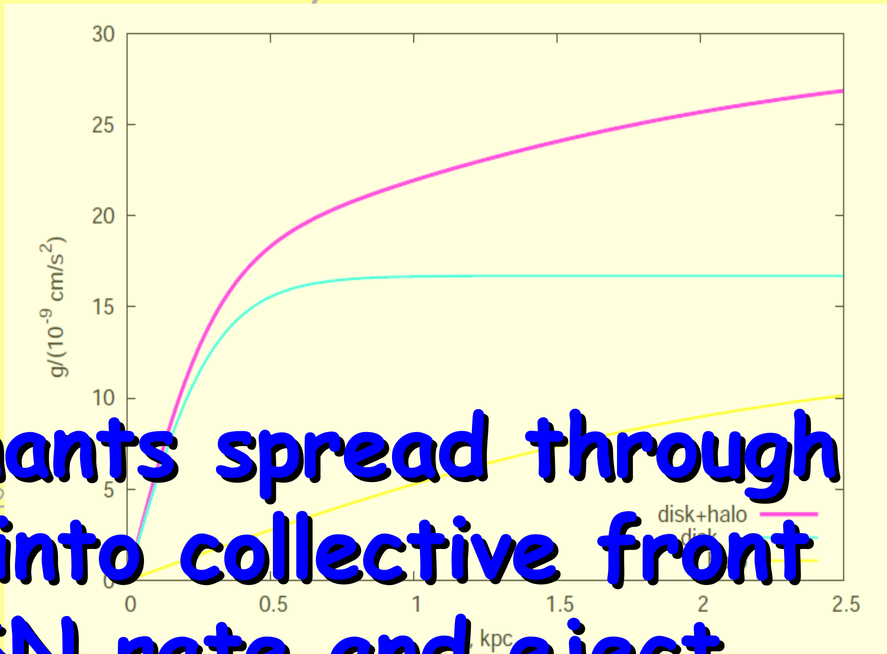
volume explosion rate: 1.9e-14 ... 1.9e-12 $pc^{-3}\ yr^{-1}$

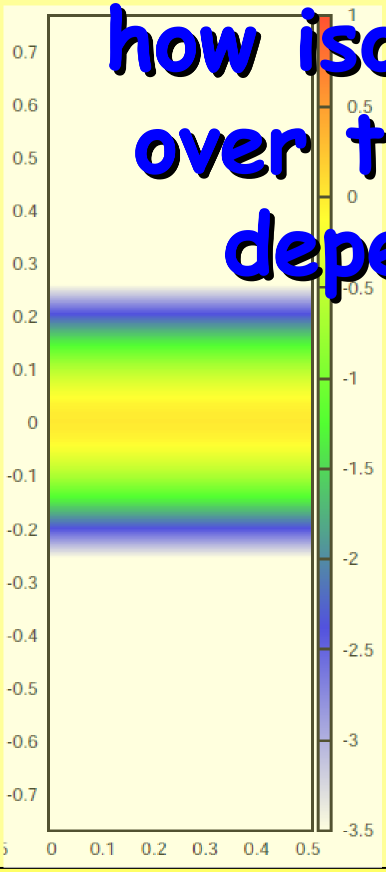
or SF surface density rate: 6e-4 ... 6e-2 Msun $yr^{-1}\ kpc^{-2}$

3D gas dynamics + cooling/heating

gas in the gravitational potential (stellar disk + dark halo)

Galactic disk
stellar disk:
 scale height 300 pc
 distance from the center 3 kpc





how isolated SN remnants spread through over the disc merge into collective front depending on the SN rate and eject interstellar gas into haloes

stellar Σ ~ … M_{sun}/pc^2
gaseous Σ ~ 3.5-10 M_{sun}/pc^2
(n ~ 1 … cm^{-3})

the gaseous disk is in dynamical and thermal equilibrium
T in the disk ~ [illegible] K, heating 6e-[illegible] erg/s for [Z/H] = 0

SNe
 scale height ~ 0.5 of the gaseous scale height
 uniformly distributed in the disk
 volume explosion rate: 1.9e-14 ... 1.9e-12 pc^{-3} yr^{-1}
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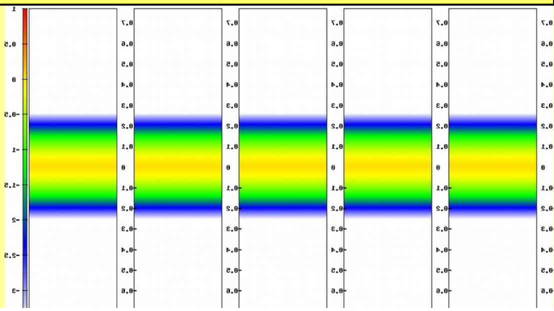
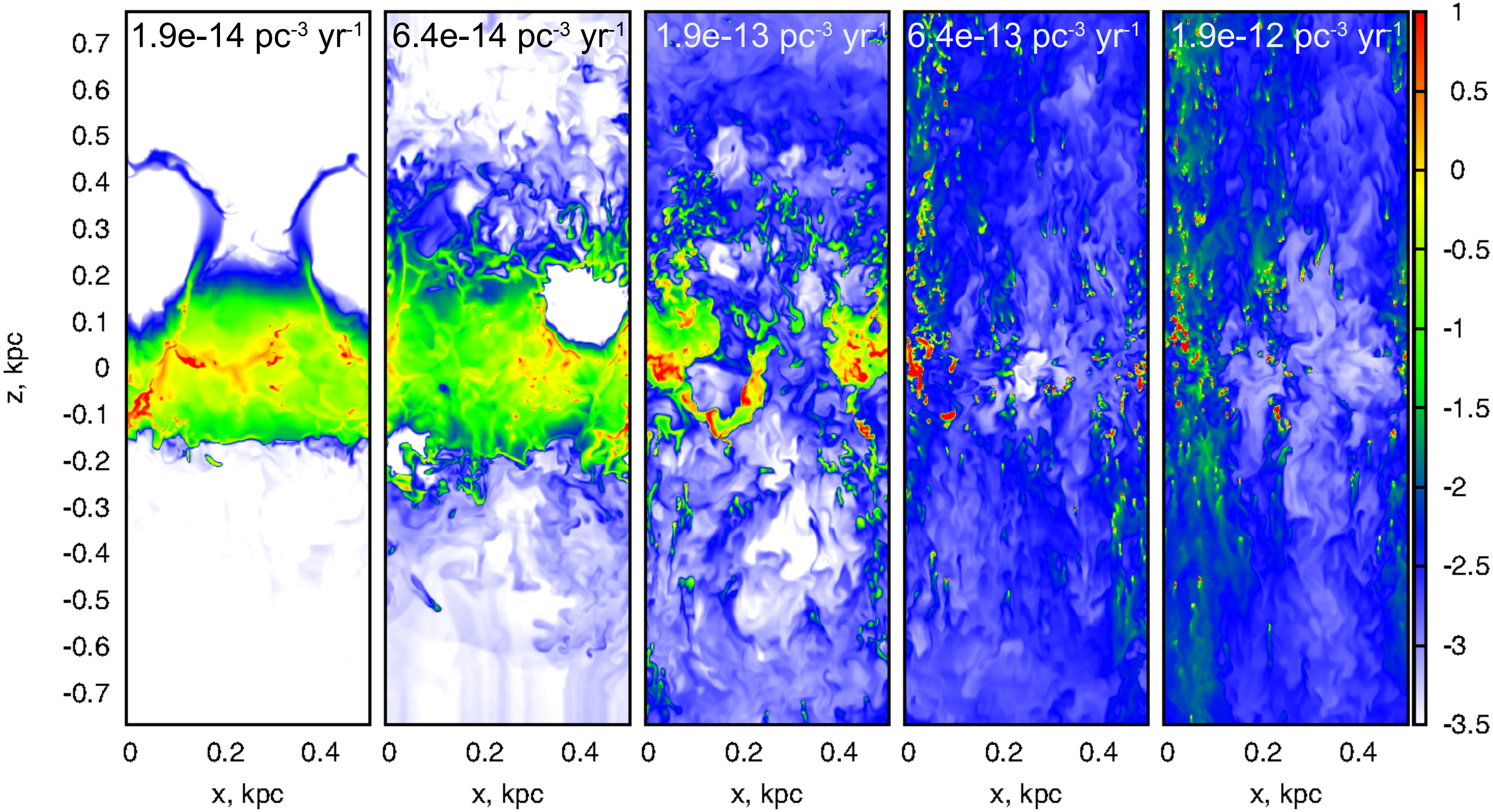
3D gas dynamics + cooling/heating

2D slices: gas number density at y = 0.25 kpc

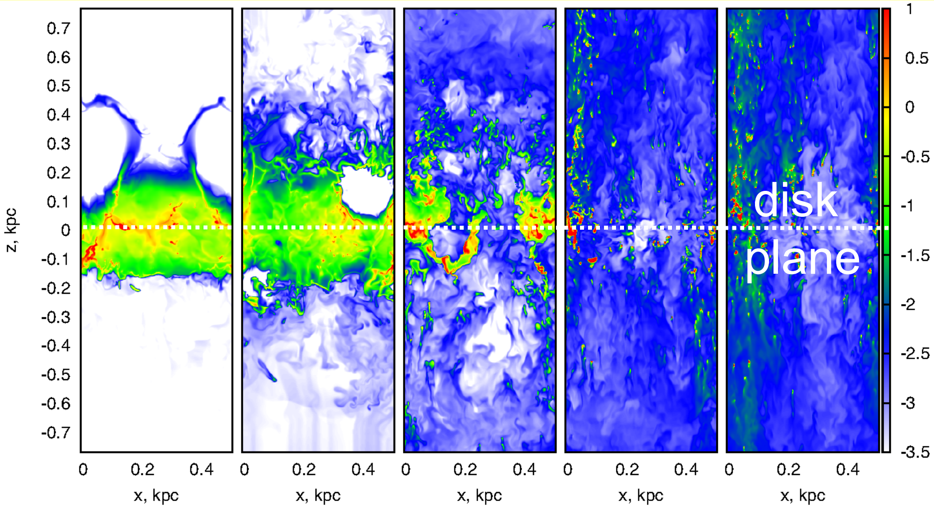


t = 30 Myr

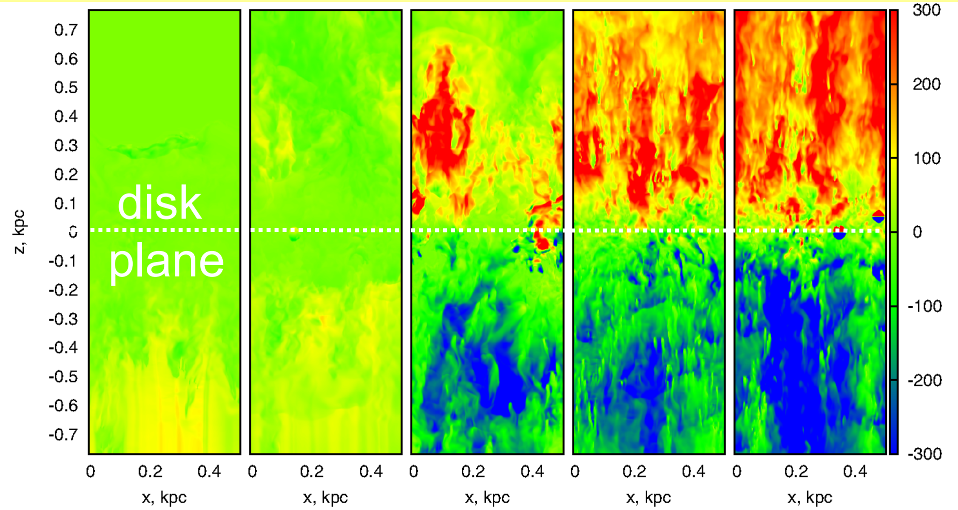


mass-averaged velocity

number density



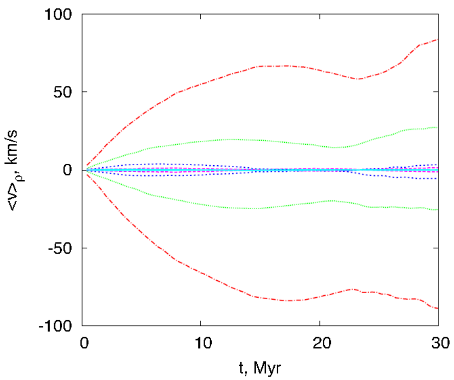
velocity along vertical direction - v_z



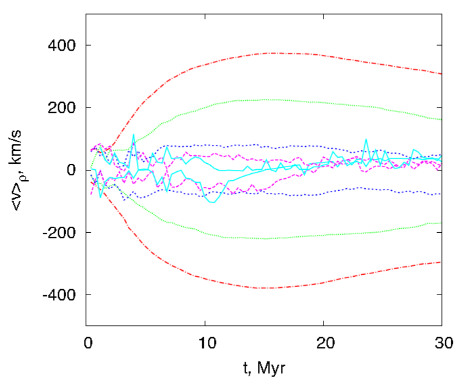
1.9e-14 6.4e-14 1.9e-13 6.4e-13 1.9e-12 $pc^{-3}\ yr^{-1}$

mass-averaged velocity above/below the disk plane

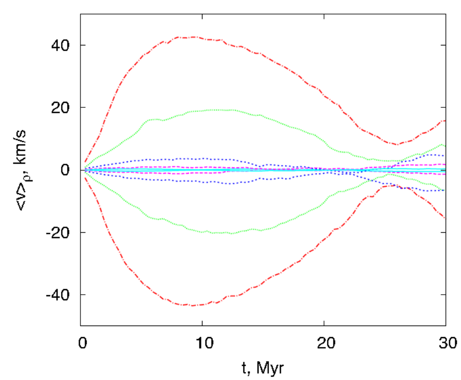
all T



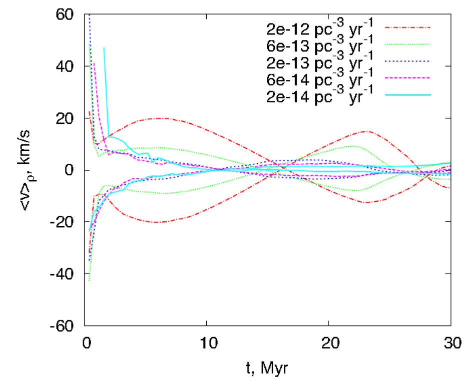
T > 1e5 K



1e3 K < T < 1e5 K



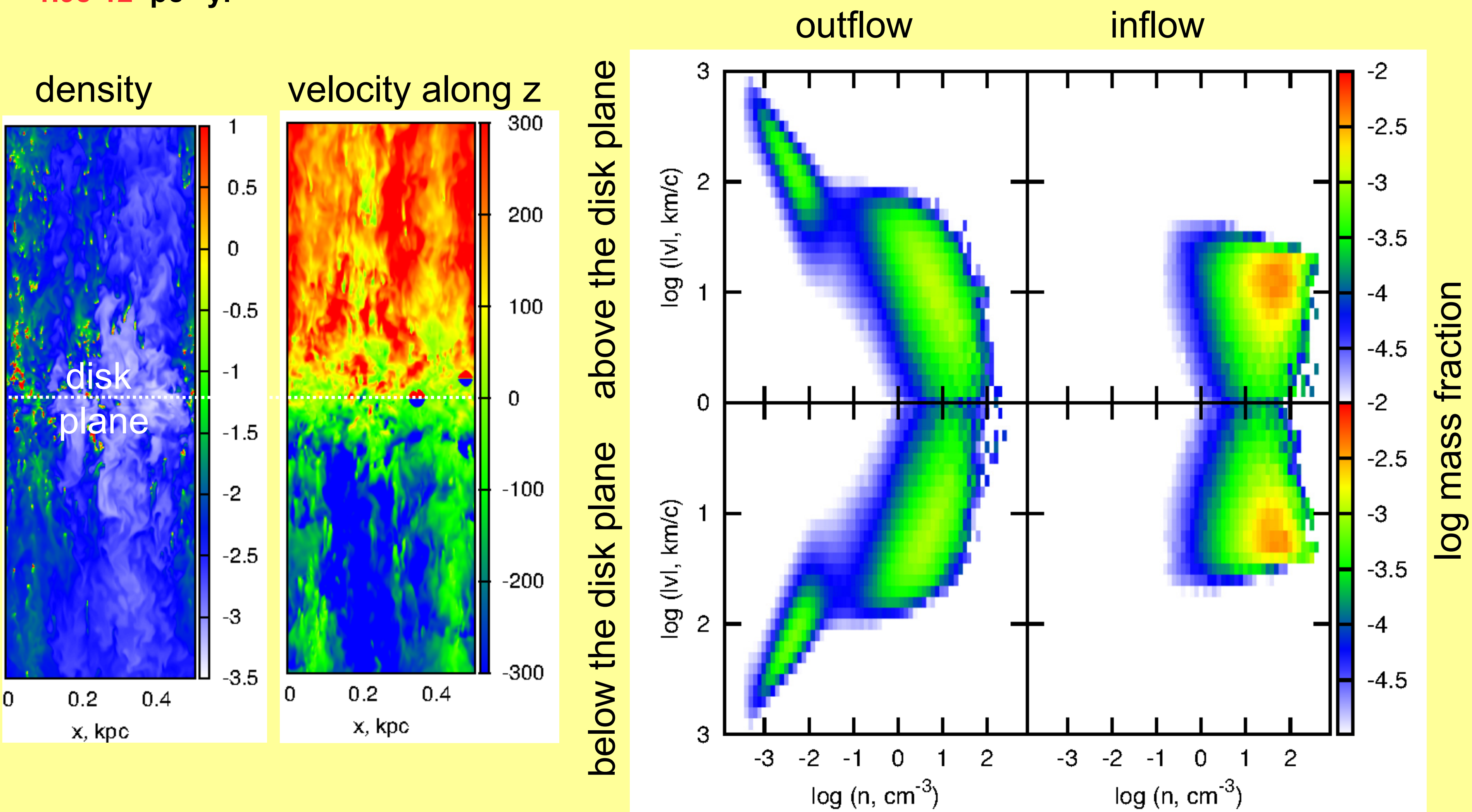
T < 1e3 K



EV etal 2019

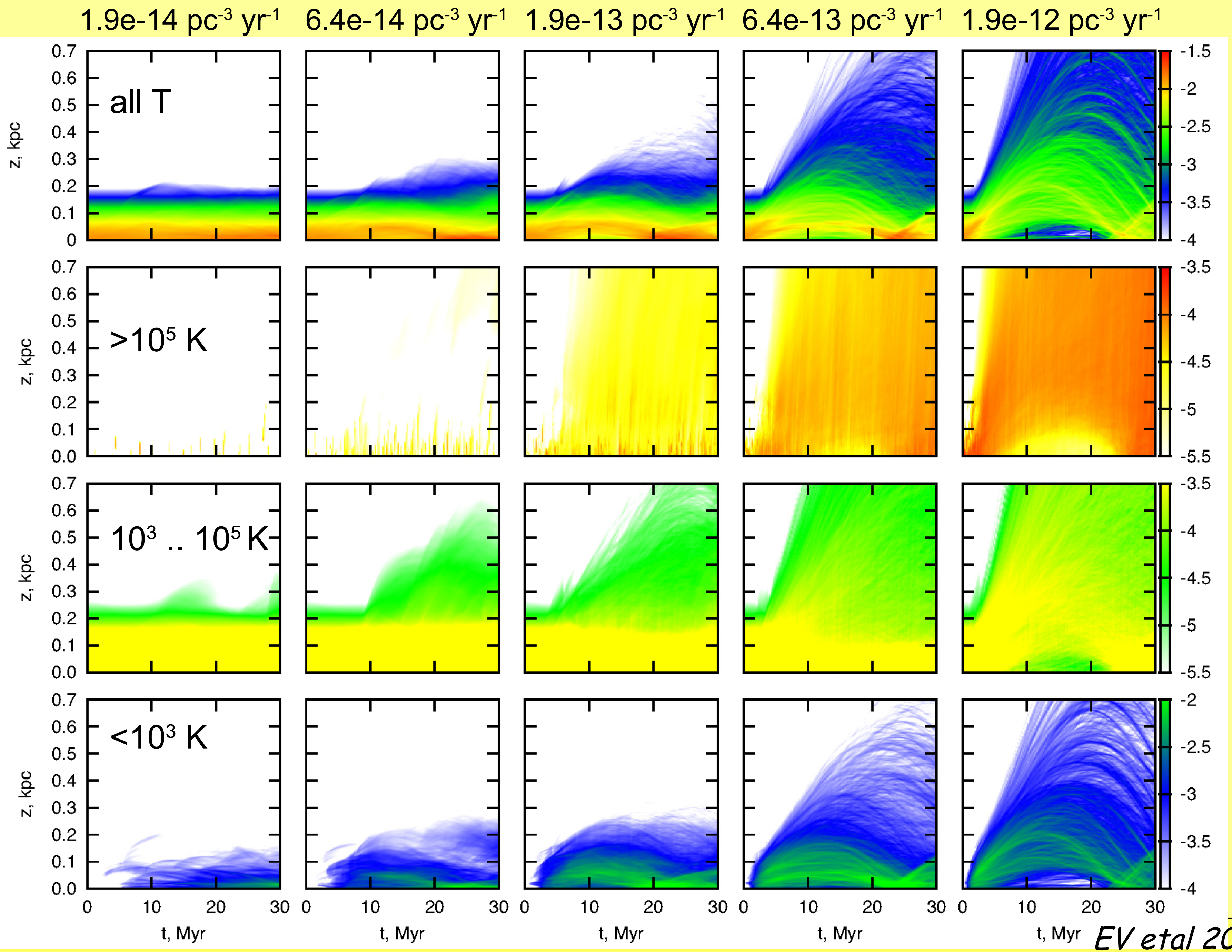
inflow-outflow

1.9e-12 pc^{-3} yr^{-1}



EV etal 2019

fraction of gas mass at a given height: evolution

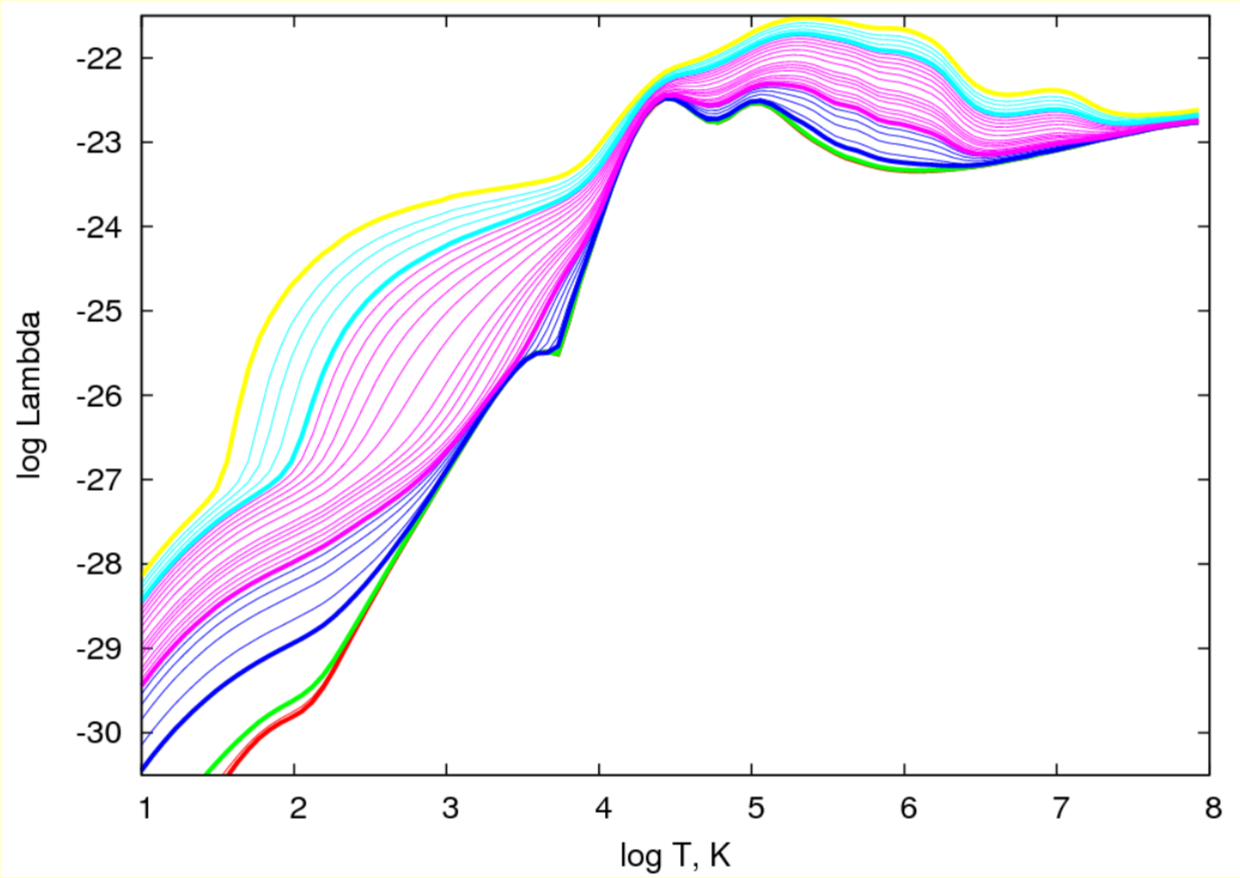


EV etal 2019

each SN injects metals

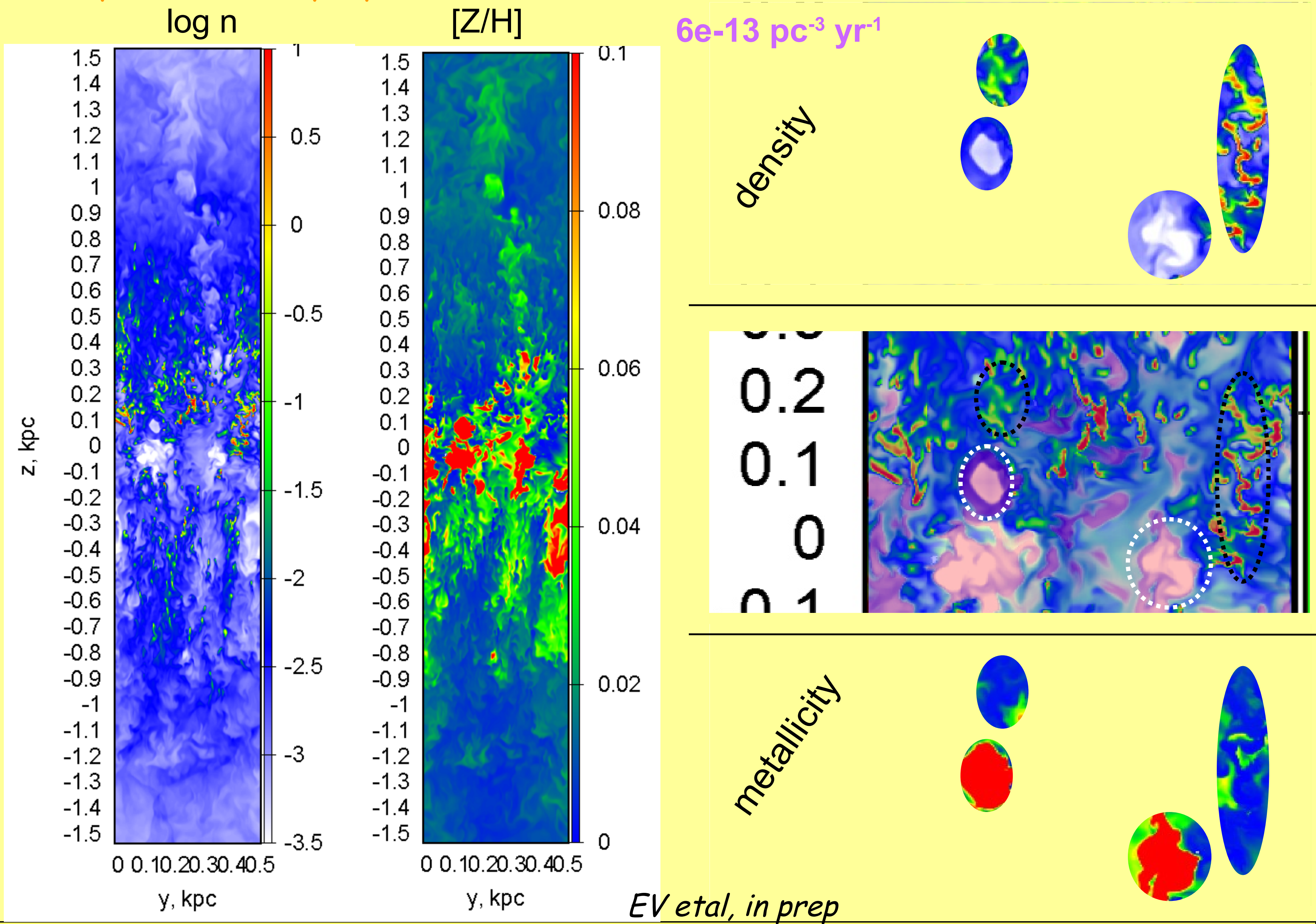
gas is enriched by «new» metals

detailed cooling rates



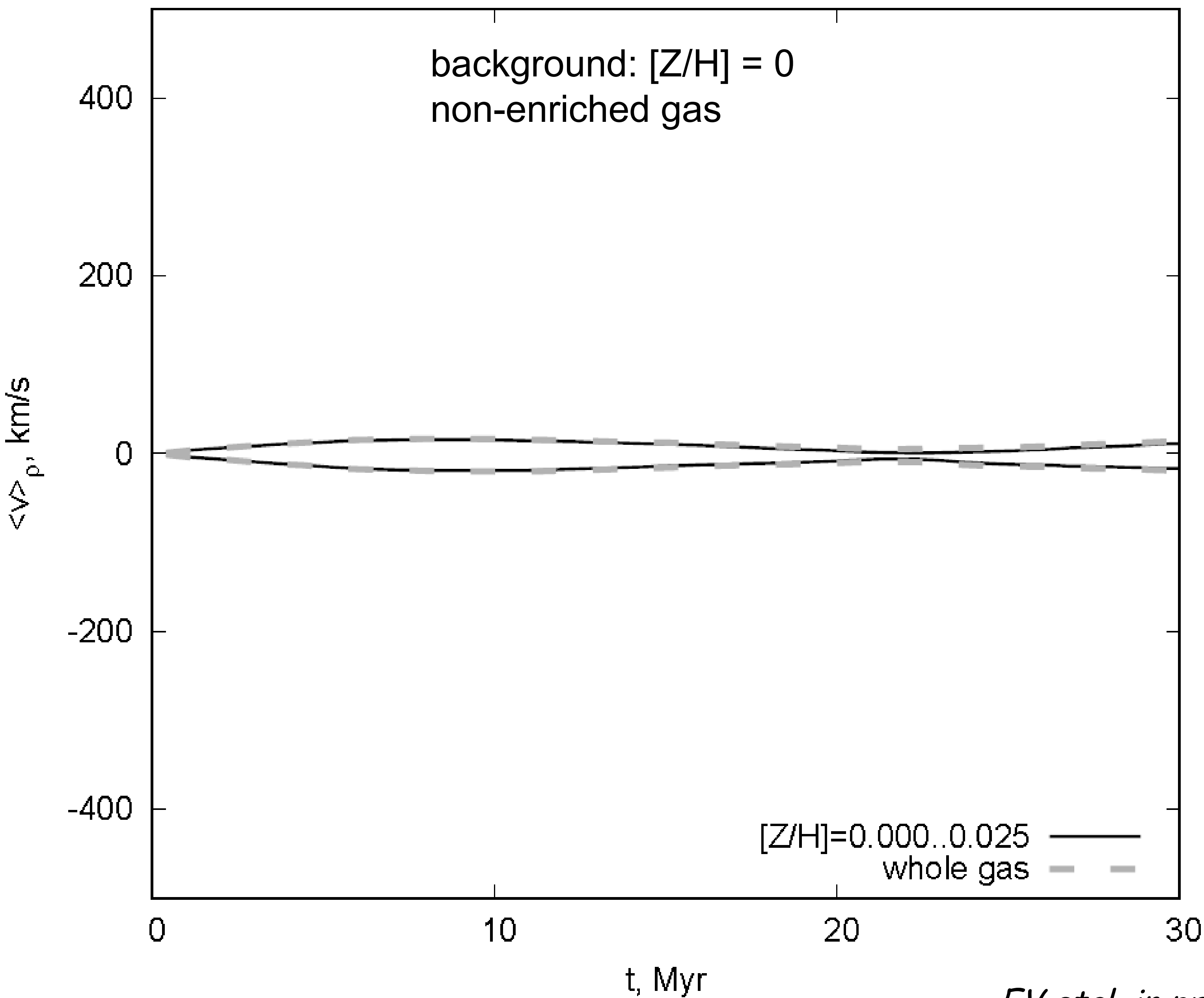
EV 2013

density — metallicity: spatial distribution



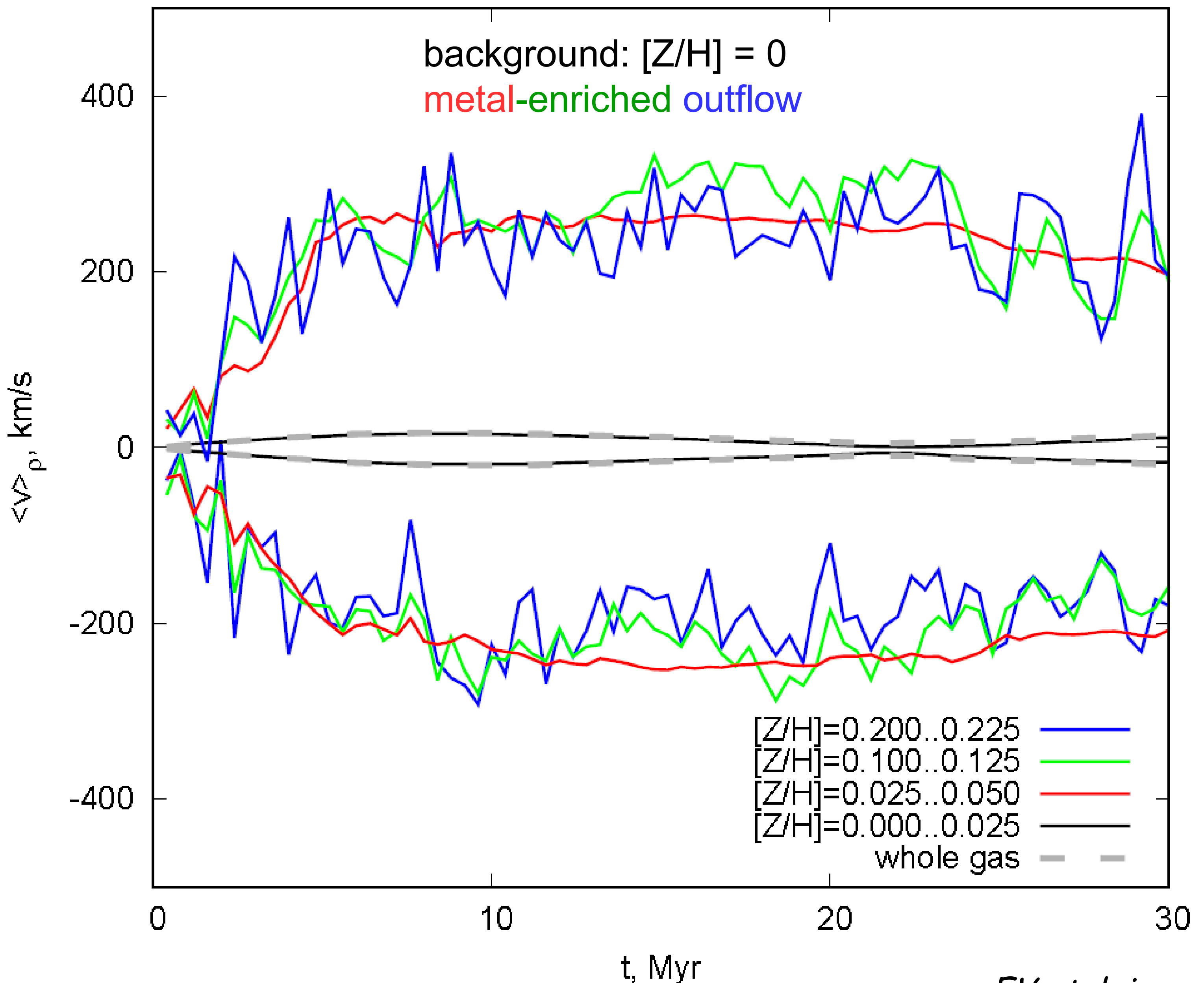
EV etal, in prep

mass-averaged velocity



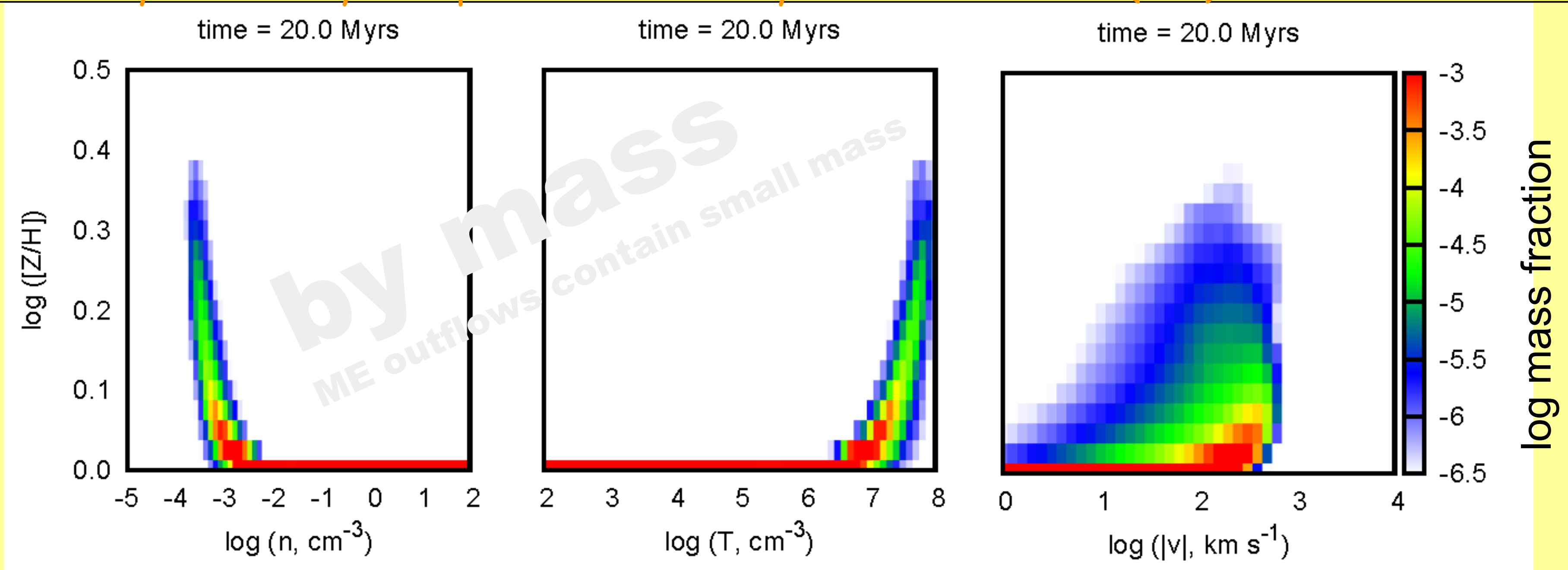
EV etal, in prep

mass-averaged velocity

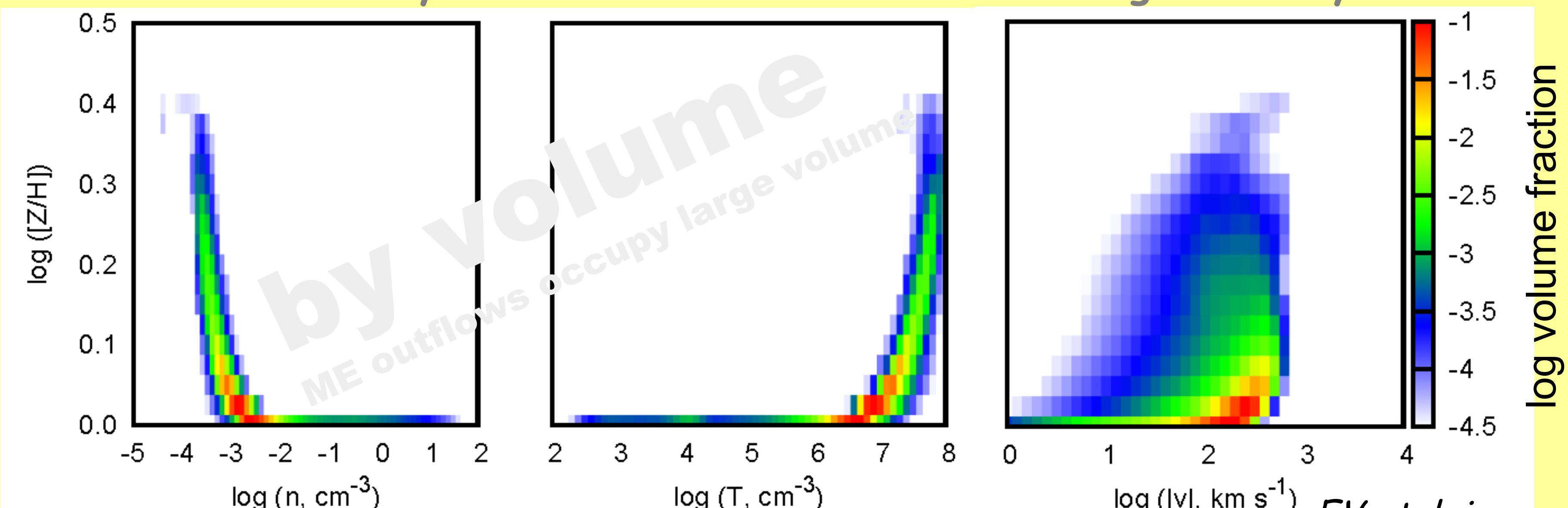


EV etal, in prep

metallicity — density/temperature/velocity: metal-enriched (ME) outflows



outflows are low-density & hot & high-velocity & ME



EV etal, in prep

two flows are formed due to high SNe activity (>1e-13 pc^{-3} yr^{-1}): high-velocity ($|v| \geq 70$ km s^{-1}) hot diffuse gas along with low-velocity ($|v| \leq 70$ km s^{-1}) dense gas moving outwards, and counter flowing low-velocity ($|v| \leq 70$ km s^{-1}) dense clumps moving inwards

the major part by mass is enclosed in cold fragments (T<1e3 K), whose volume covering factor is less <0.1%

a significant part (by mass) of newly injected metals is locked in hot low-density gas moved outwards with high velocity: $|v| > 100$ km s^{-1}

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Thank you!!!

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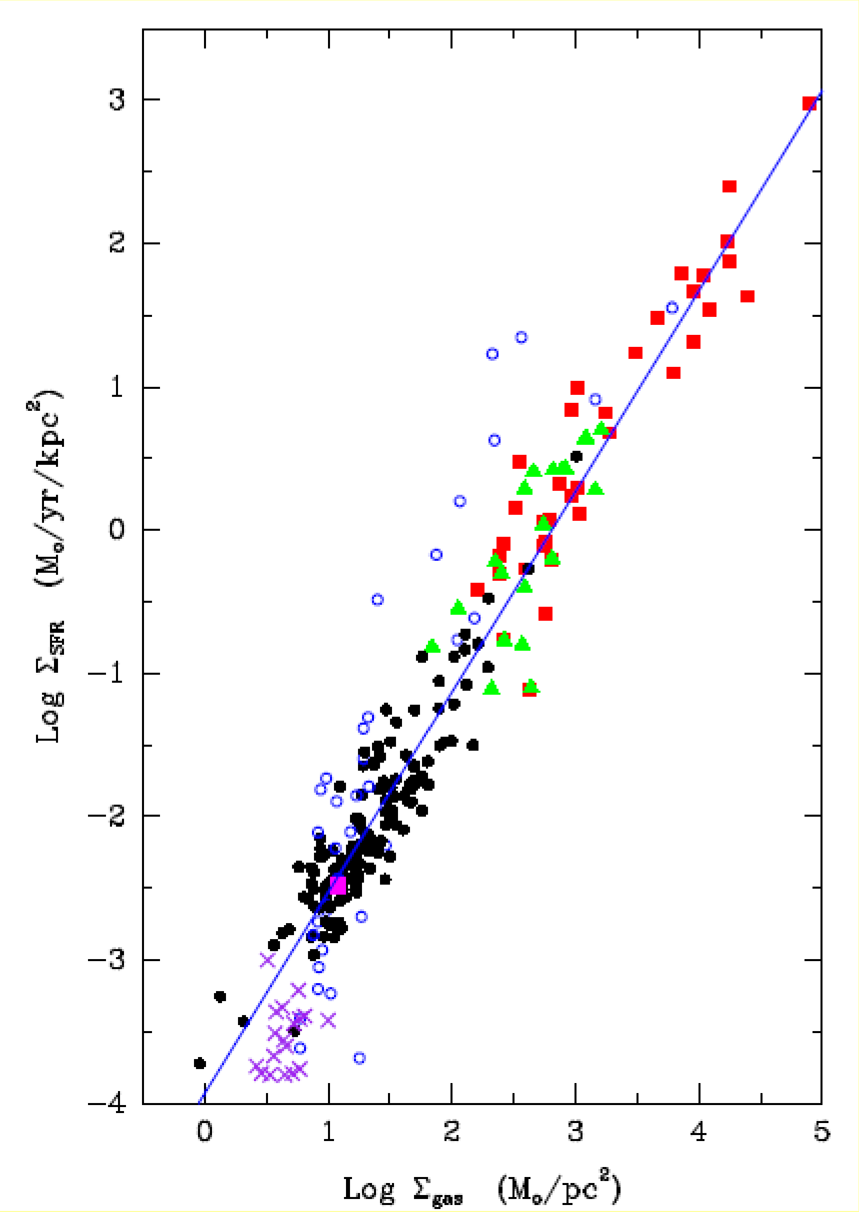
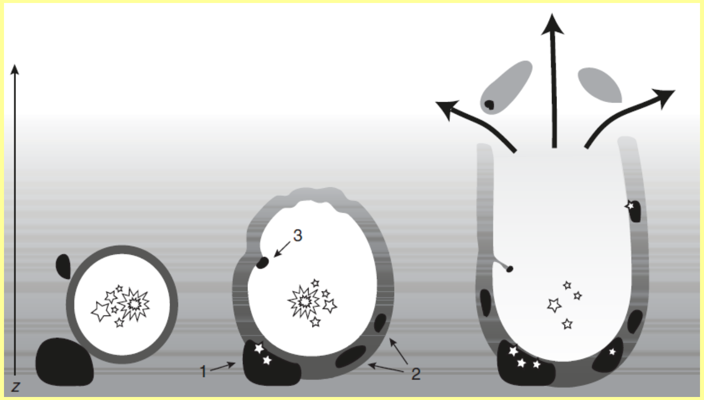
SF at large scales: Kennicutt-Schmidt relation



Kennicutt & Evans 2012

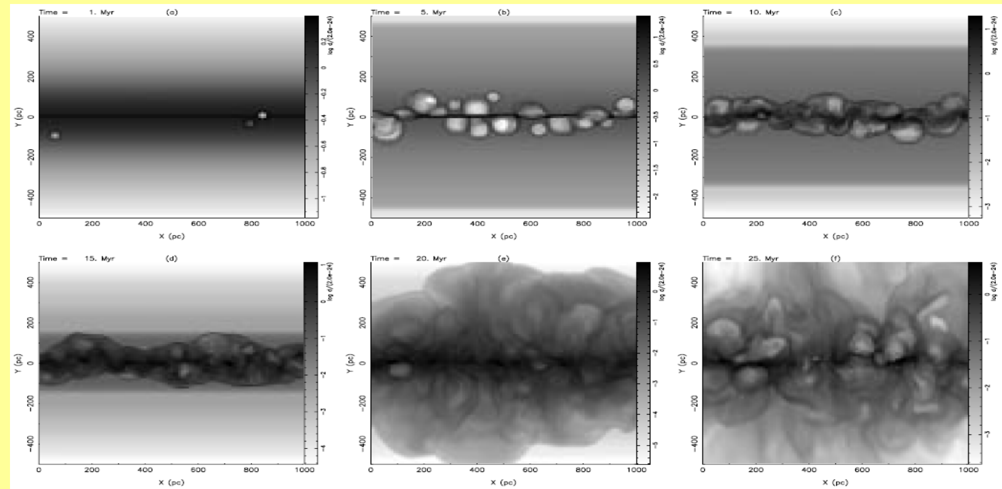
SNe explosions and gas transport: models

superbubbles



Kovalenko & Shchekinov 1985
Kolenik & Silich 1986
Tomisaka & Ikeuchi 1986
McLow & McCray 1988, 1989
Bisnovatyi-Kogan etal 1989
Shustov 1989
Norman & Ikeuchi 1989
Igumenshchev etal 1990
…

multiple SNe



Avillez 2000
Avillez & Breitschwerdt 2005-2012
Hill etal 2012
EV etal 2015, 2017
Walsch etal 2016
Li etal 2017
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