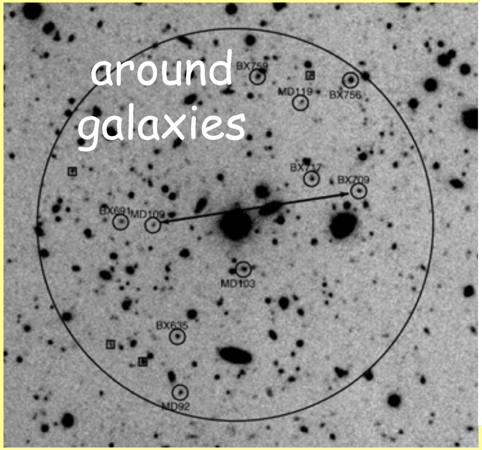
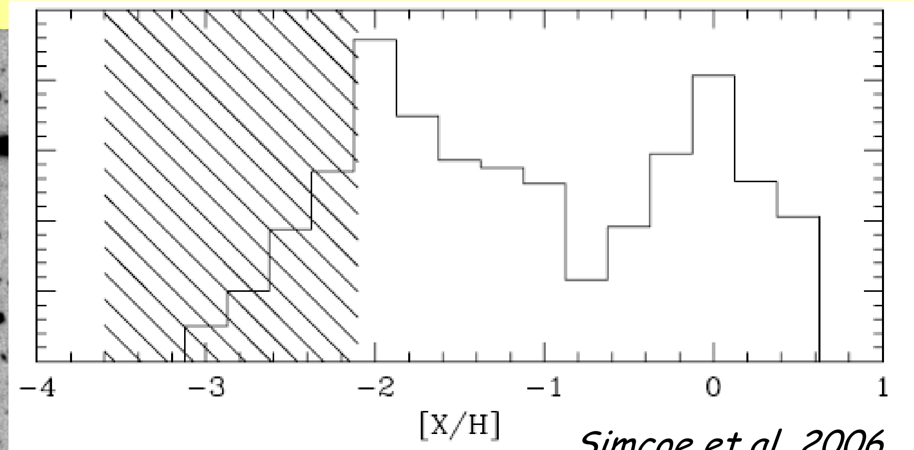
Mixing of metals ejected by a supernova into the ISM

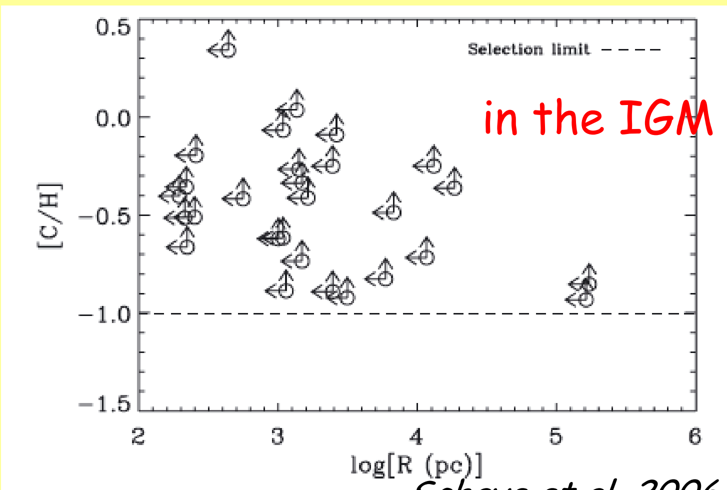
evgenii vasiliev

southern federal university
rostov-on-don



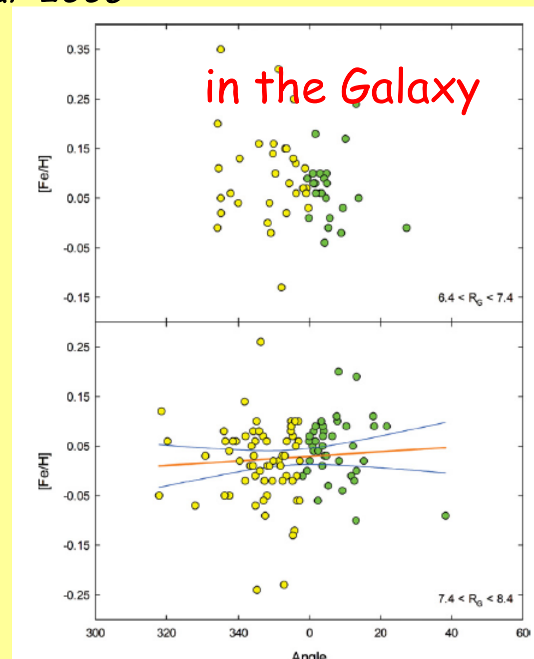


Simcoe et al 2006



Schaye et al 2006

metal inhomogeneities in …



Luck et al 2012

mixing in cloudy medium:

a) around first stars,

b) the two-phase ISM

first stars in minihalo: HII zone

minihalo $M=10^7 M_{sun}$,
z = 12 – 3-sigma peaks

collapse of baryons
until $n \sim 10^8$ cm^{-3}
in the central part

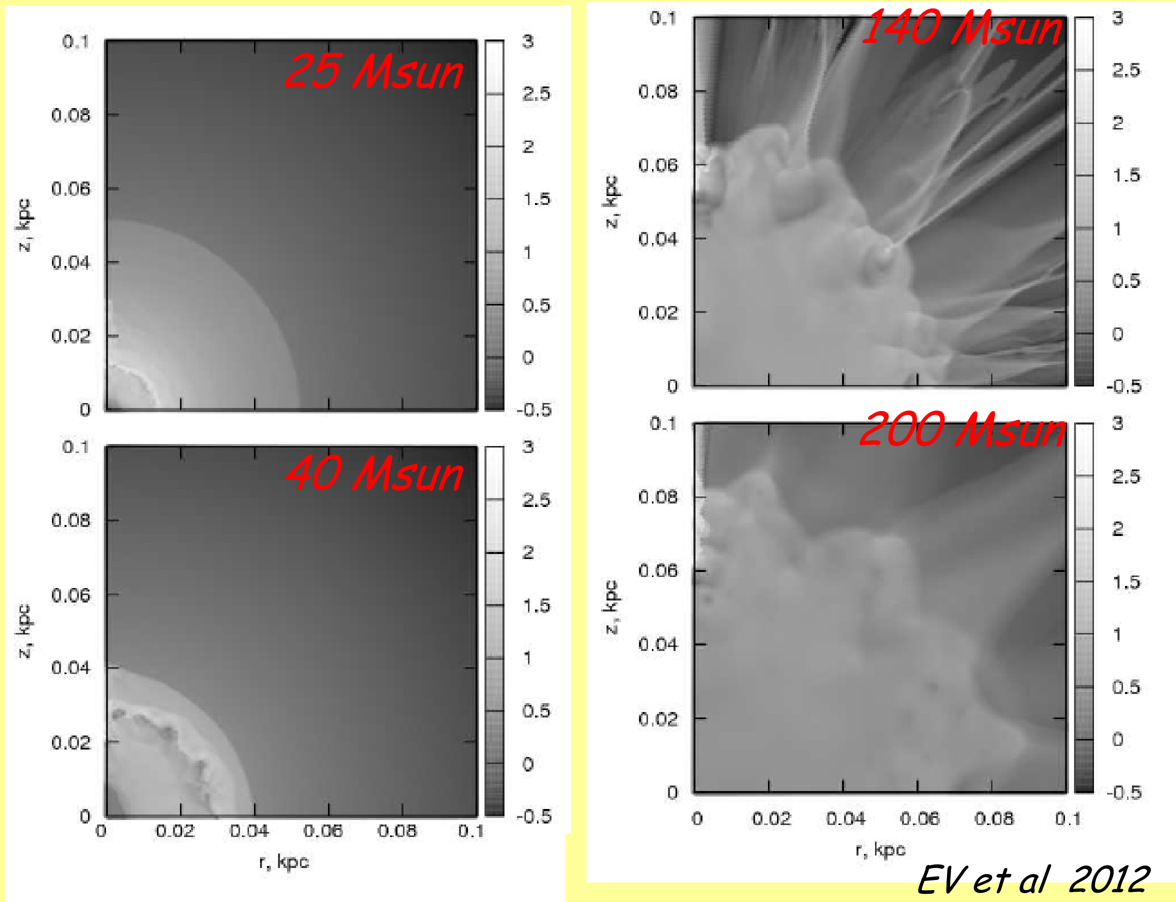
a birth of first star

HII zone evolution

2.5D gas dynamics
+ NEQ primordial chemistry
+ ray-tracing RT

flat (Burkert) DM profile

HII zone: pre-supernova density distribution



EV et al 2012

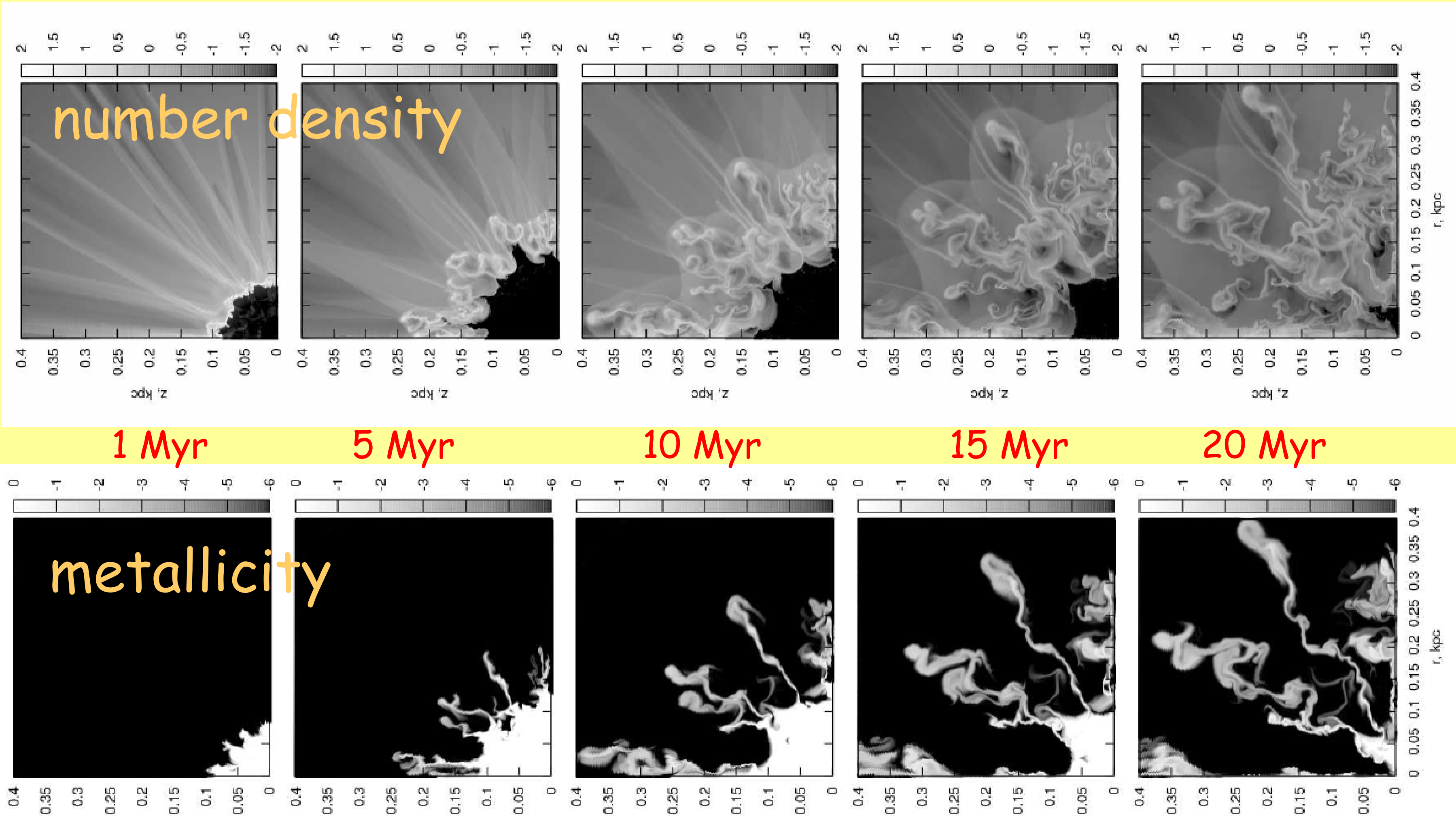
M_{star}	M_{ej}	M_{met}	E_{SN}
25	~ 21	~ 2.1	10^{51}
40	~ 34	~ 8.2	3×10^{52}
140	~ 140	~ 63	10^{52}
200	~ 200	~ 98.5	5×10^{52}

Woosley & Weaver 1995

Heger & Woosley 2002

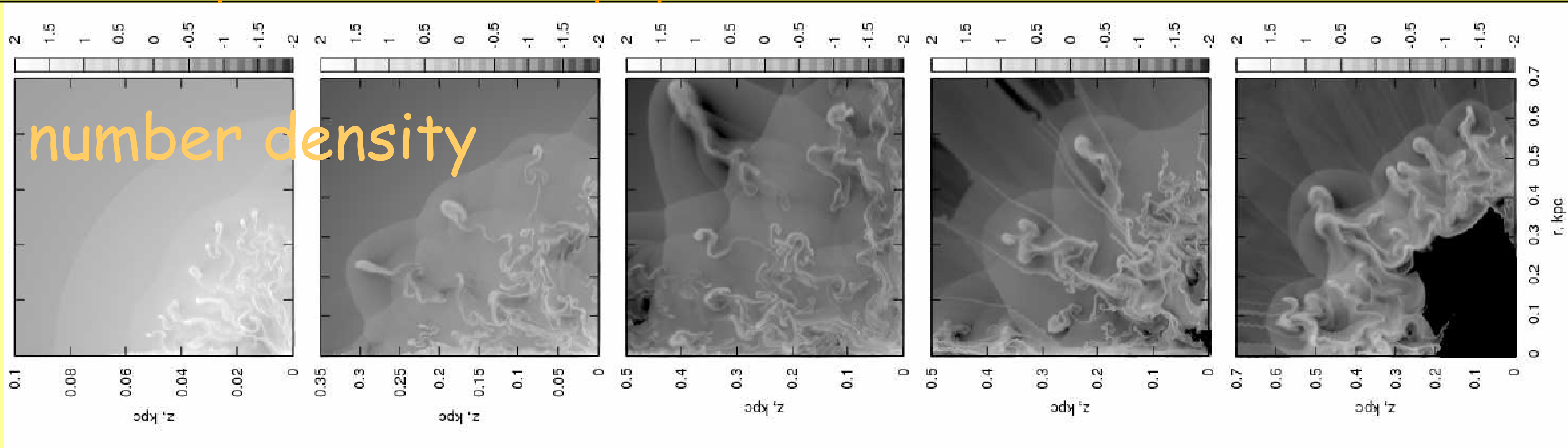
140 Msun, 10^{52} erg

EV et al 2012



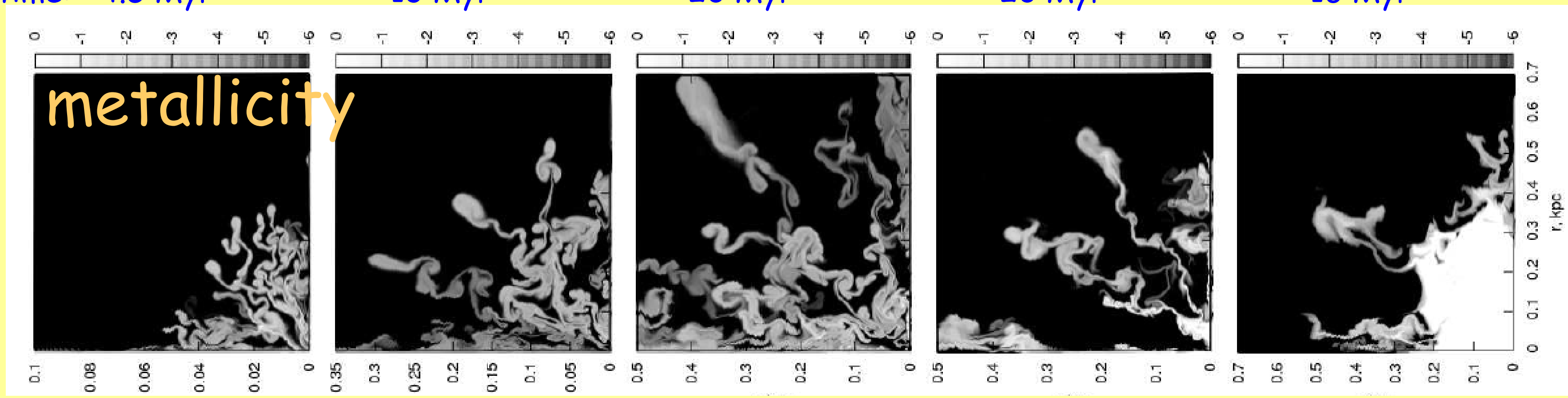
re-collapse

first SN: dependence on stellar properties



Mstar, E_{SN}: 25, 10^{51} | 25, 10^{52} | 40, 3×10^{52} | 140, 10^{52} | 200, 5×10^{52}

time: 4.5 Myr | 13 Myr | 20 Myr | 20 Myr | 16 Myr

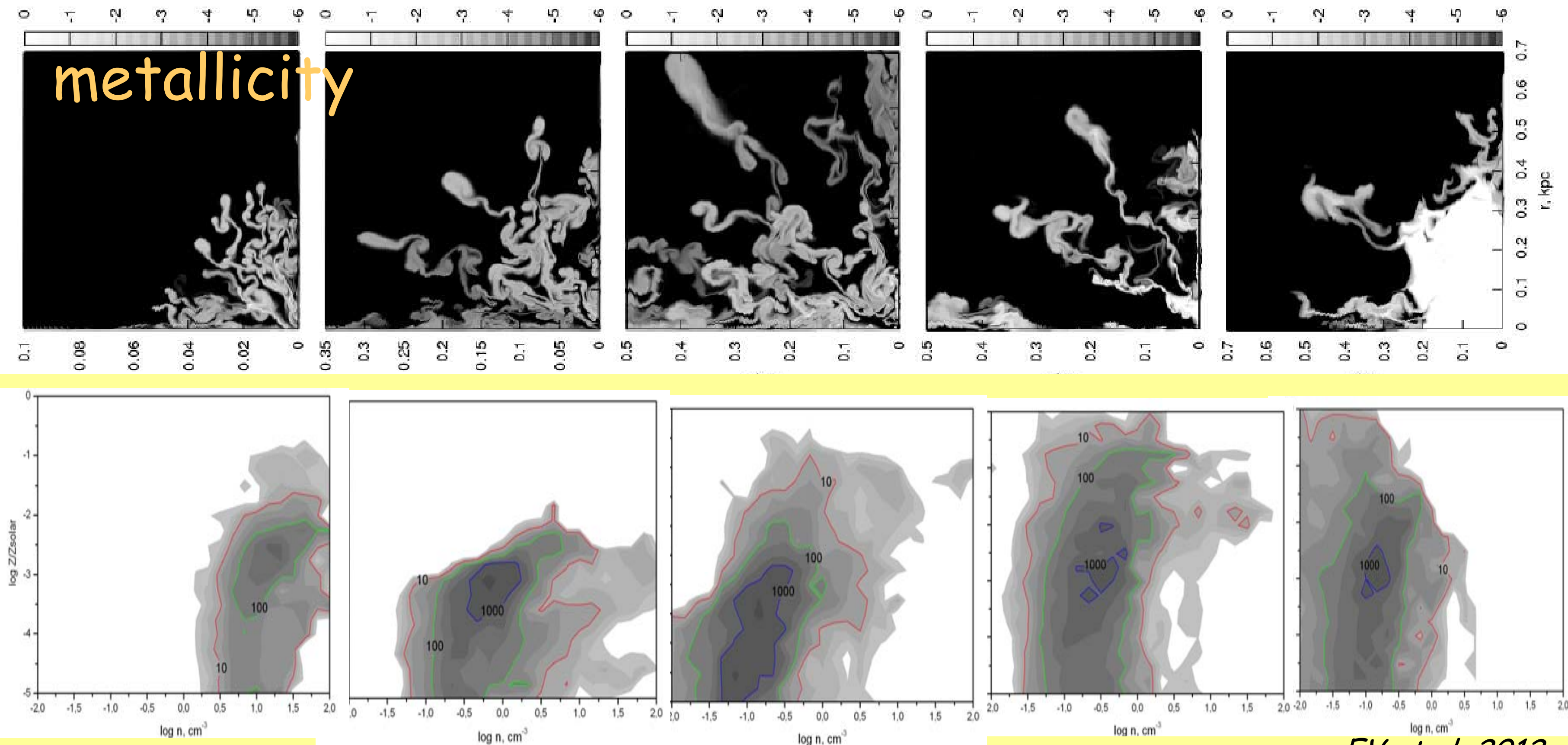


EV et al 2012

first SN: metallicity-density

Mstar, E_{SN}: 25, 10^{51} | 25, 10^{52} | 40, 3×10^{52} | 140, 10^{52} | 200, 5×10^{52}

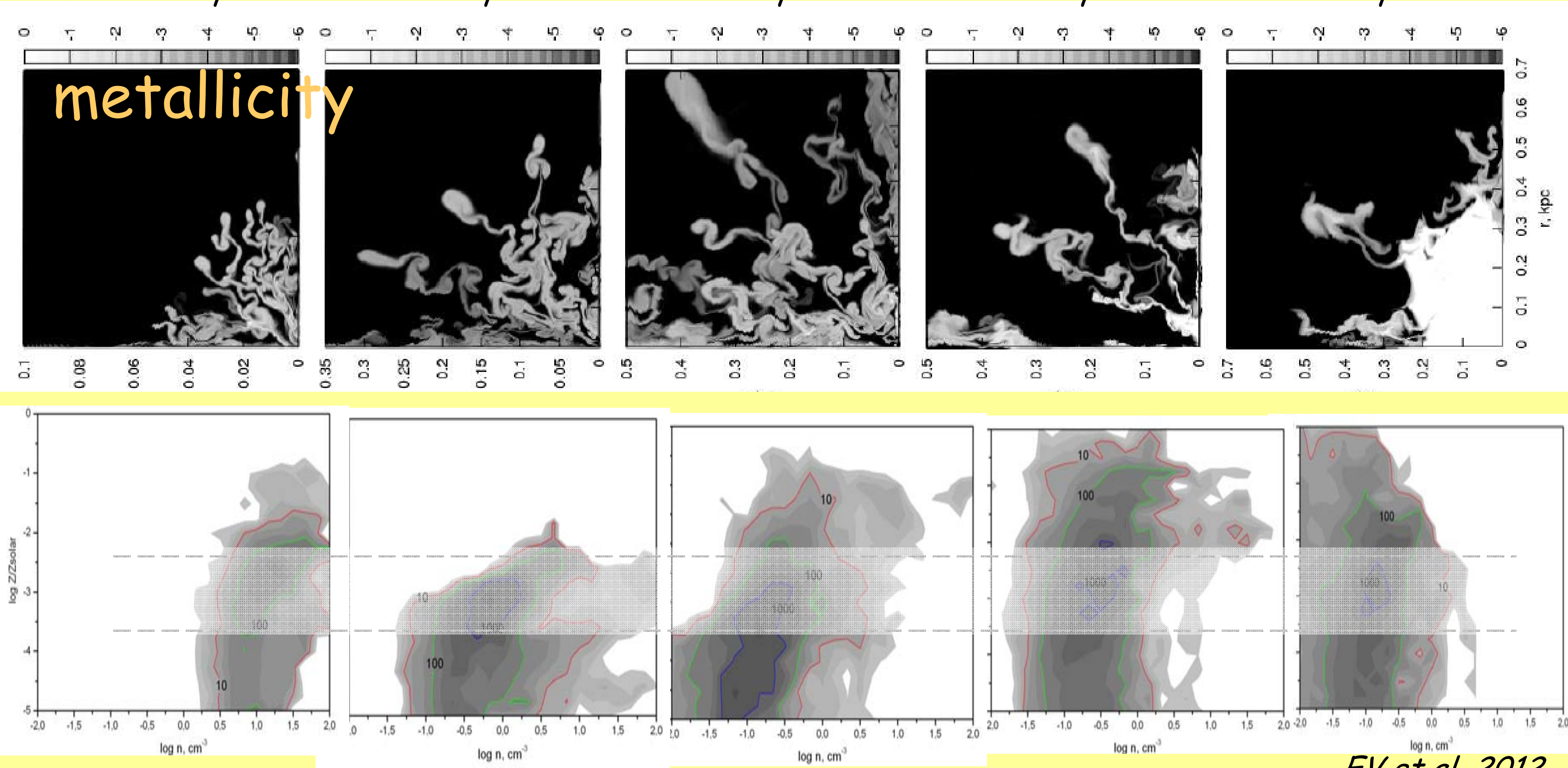
time: 4.5 Myr | 13 Myr | 20 Myr | 20 Myr | 16 Myr



EV et al 2012

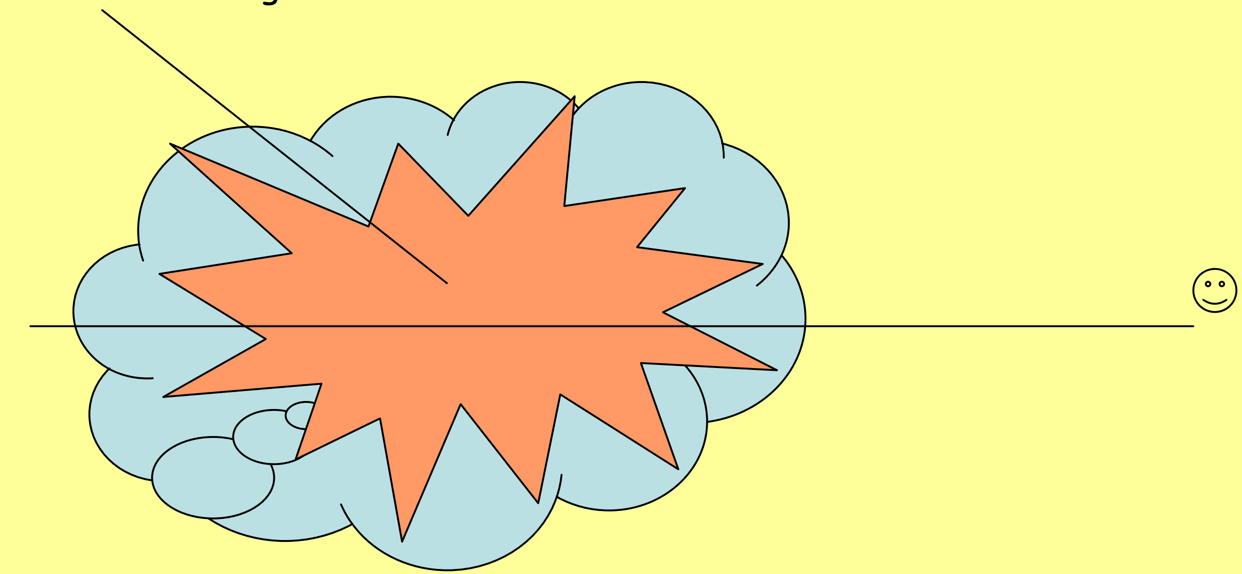
first SN: metallicity-density

Mstar, E_{SN}:	25, 10^{51}	25, 10^{52}	40, 3×10^{52}	140, 10^{52}	200, 5×10^{52}
time:	4.5 Myr	13 Myr	20 Myr	20 Myr	16 Myr



EV et al 2012

maximum of gaseous mass - $[Z/Z_{sun}] \sim -3$



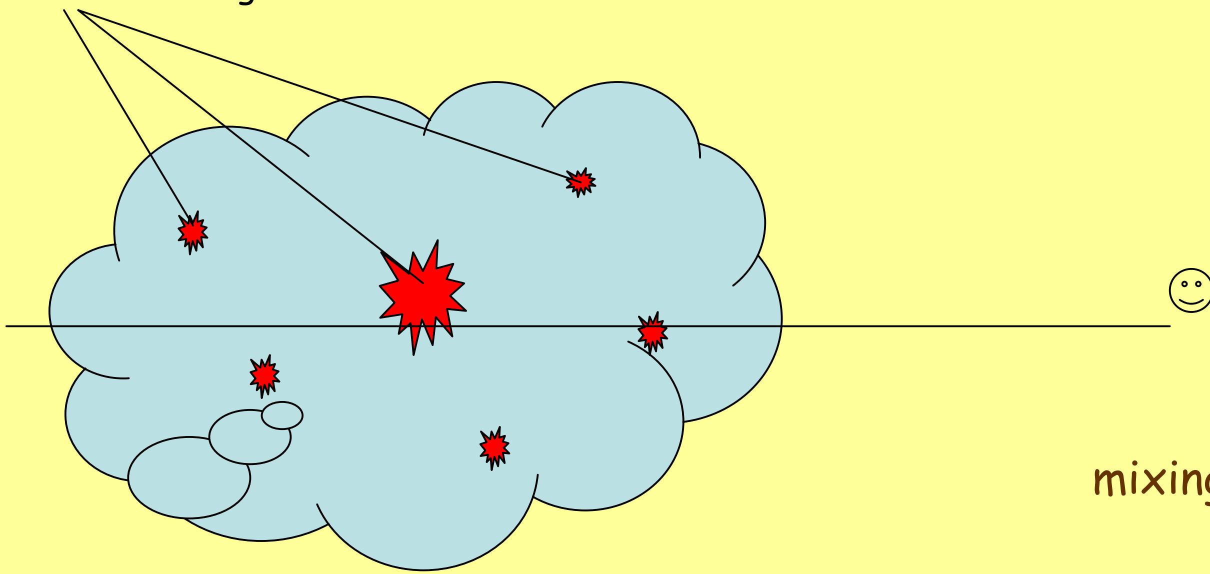
mixing efficiency f ~ 1

average metallicity

$Z \sim M_{metals}/M_{gas}$

mixing efficiency

metal enriched gas



mixing efficiency f ~ 1

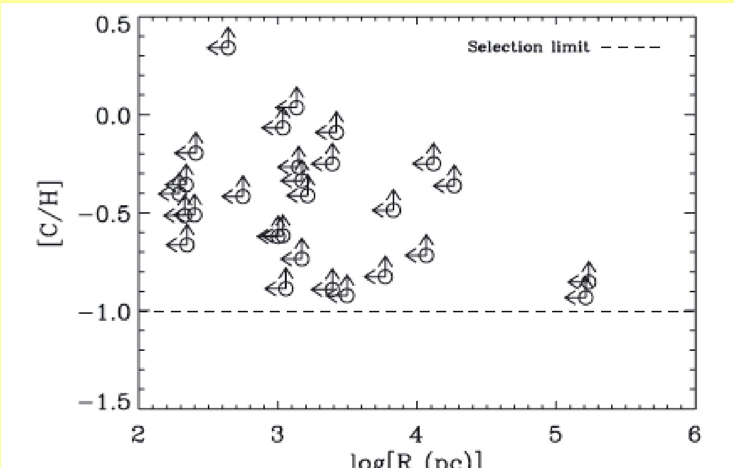
average metallicity

$Z \sim M_{metals}/M_{gas}$

mixing efficiency f<<1

average metallicity
$Z \sim M_{metals} \,/\, M_{gas} \,/\, f$

f ~ 0.01

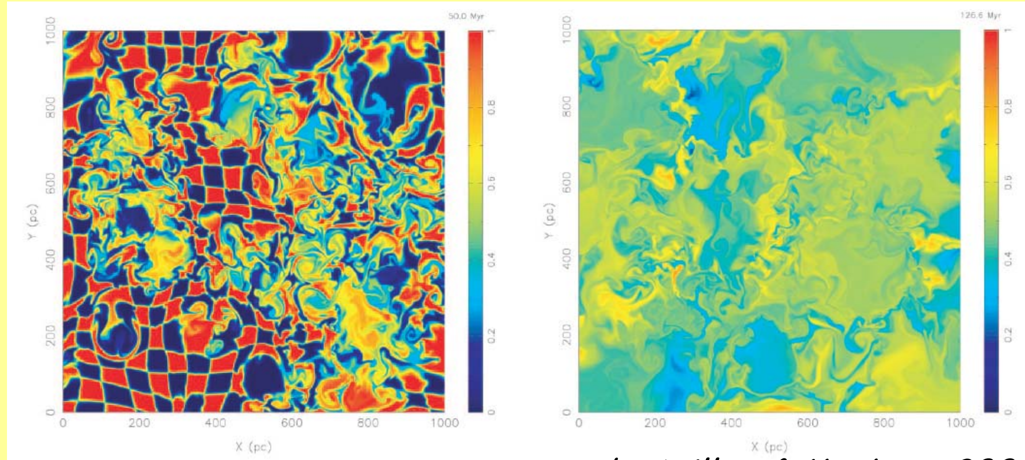


Schaye et al 2006

along LOS – rarely and small gaseous pockets with enhanced metallicity

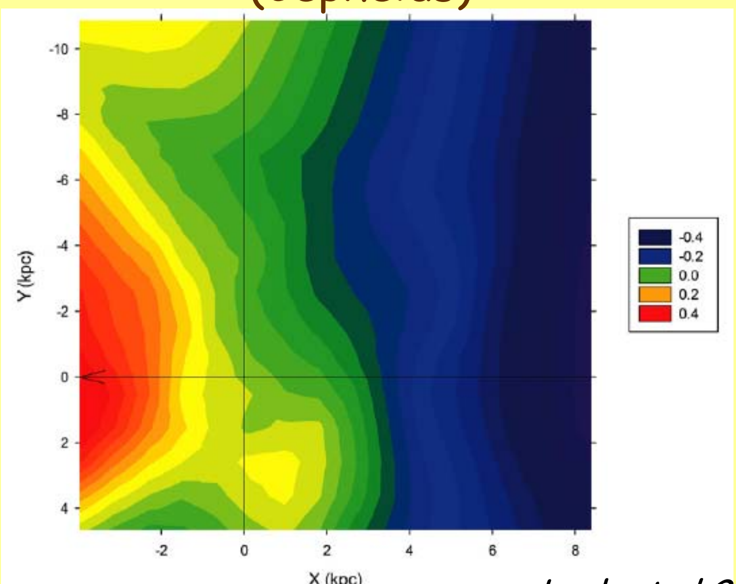
mixing metals in the ISM

timescale for complete mixing
~350 Myr for the Galactic
SN rate



de Avillez & MacLow 2002

map of the [Fe/H]
(Cepheids)



Luck et al 2012

many explosions in massive galaxies
more efficient mixing

a few explosions in dwarf galaxies
less efficient mixing

SN in two-phase ISM: evolution

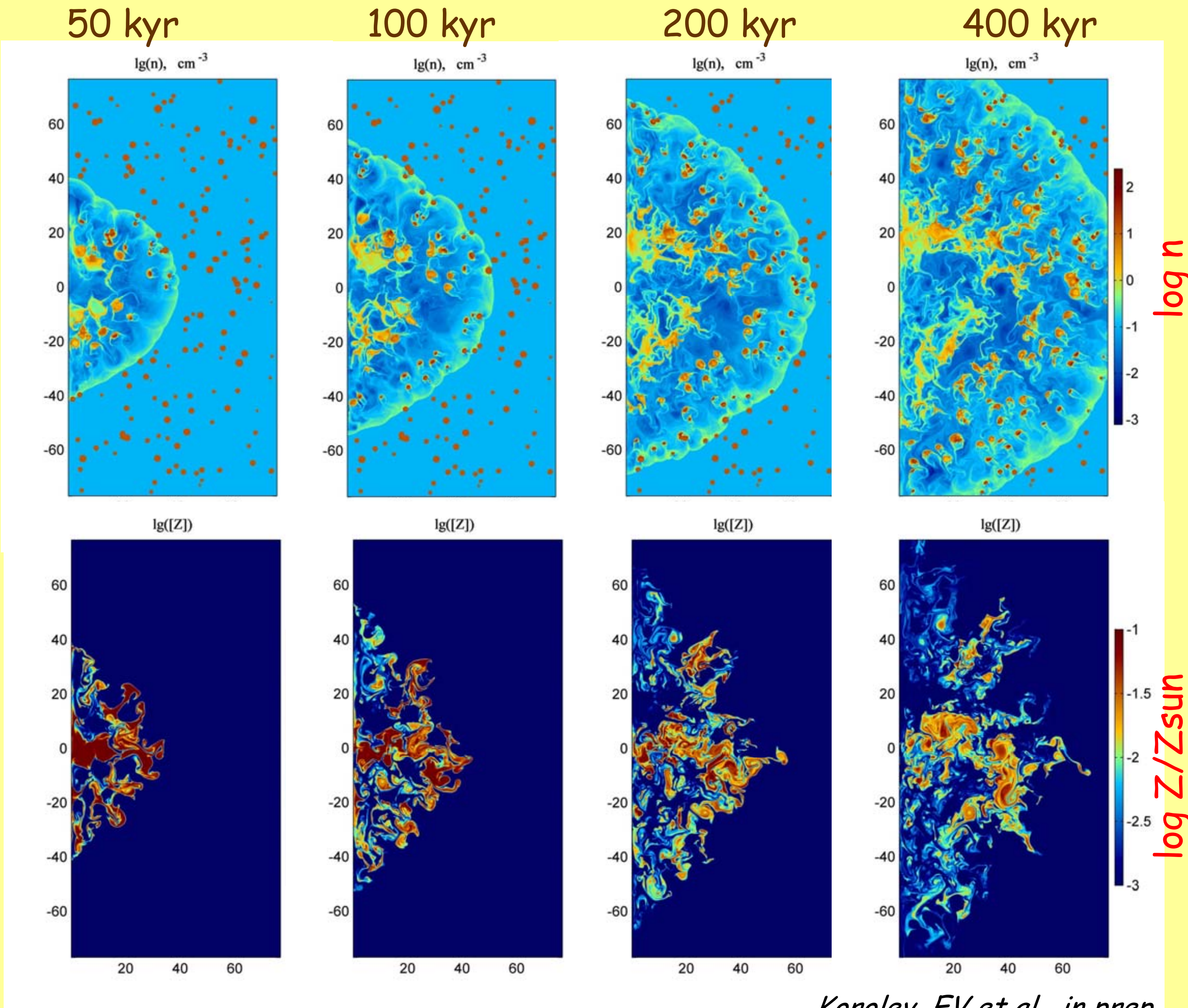
2.5 gas dynamics + cooling curve (20 points on Z)

SN explosion 10^{51} erg

$[Z_{clouds}] = [Z_{medium}] = -3$

two-phase medium

~100 & 10^4 K



Korolev, EV et al , in prep

SN in two-phase ISM: covering factor

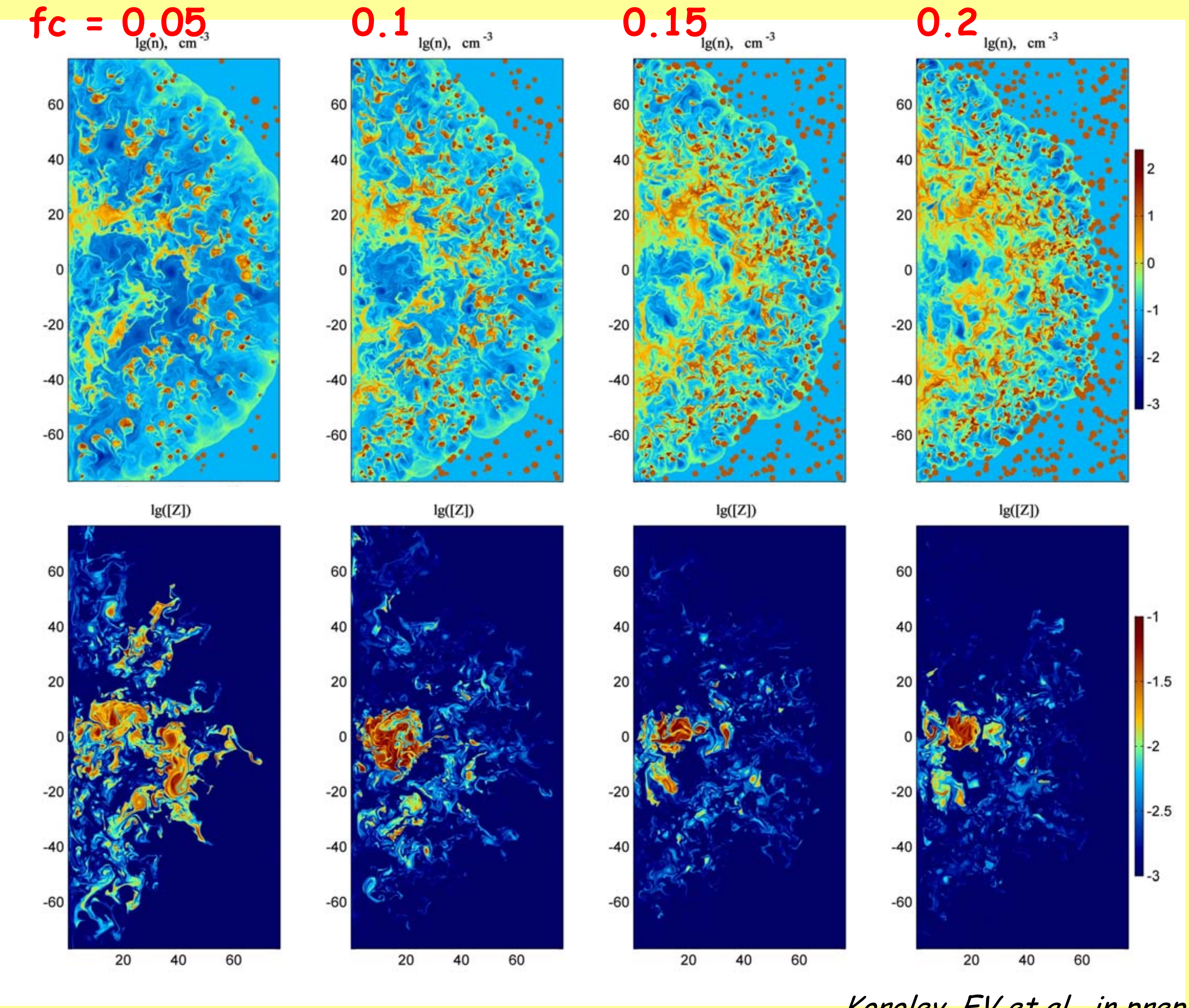
400 kyr

fc

volume factor

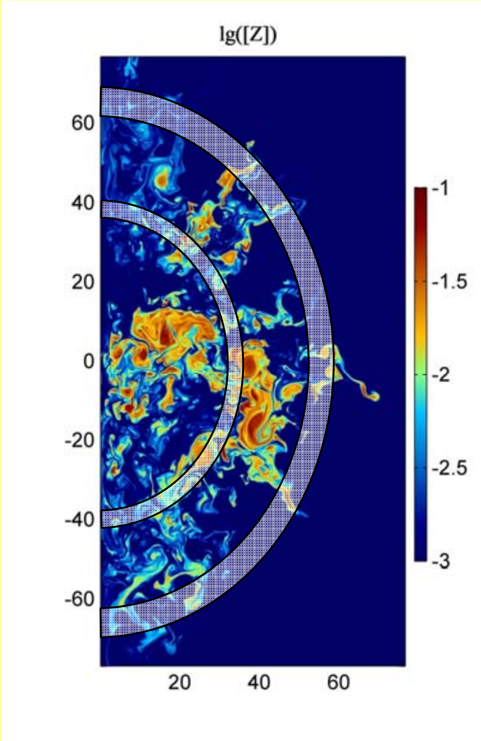
higher fc

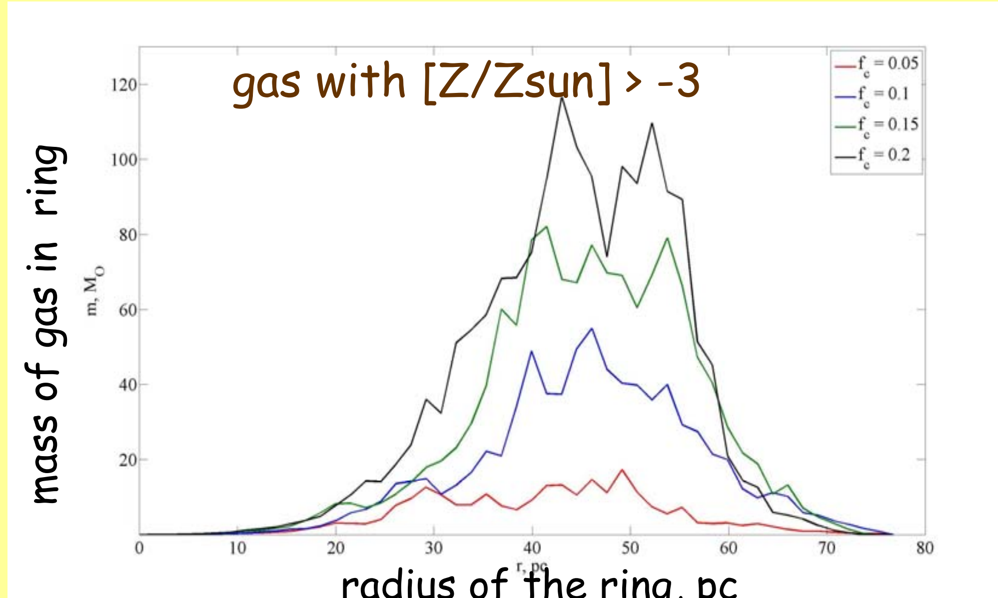
smaller volume occupied by SN metals



Korolev, EV et al , in prep

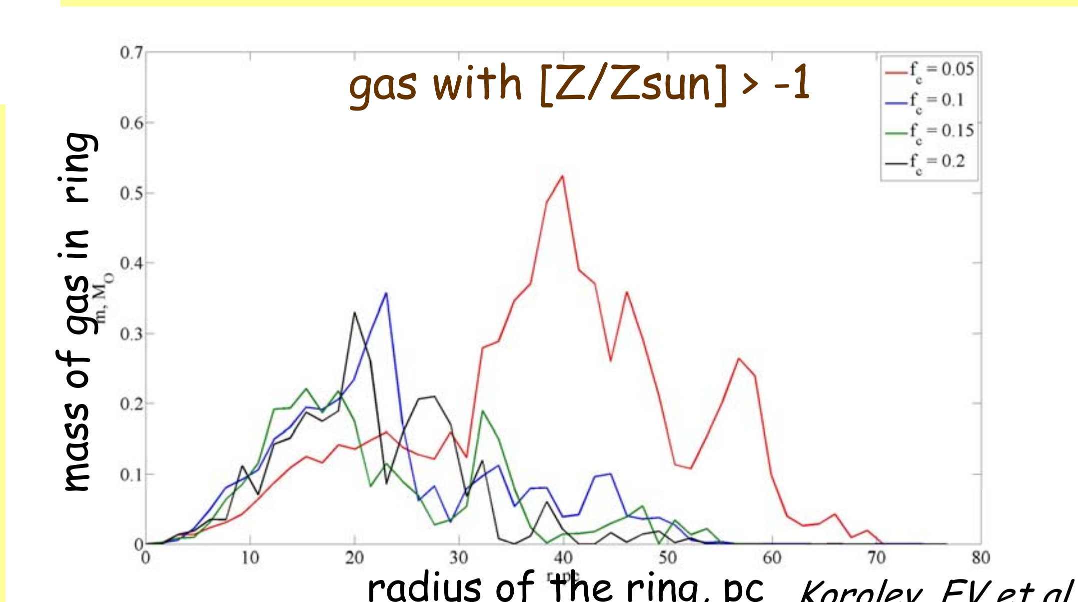
SN in two-phase ISM: metal-enriched gas





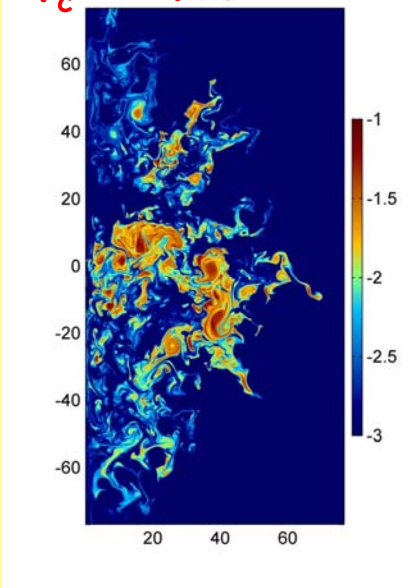
higher f_c

larger mass & lower metallicity of enriched gas

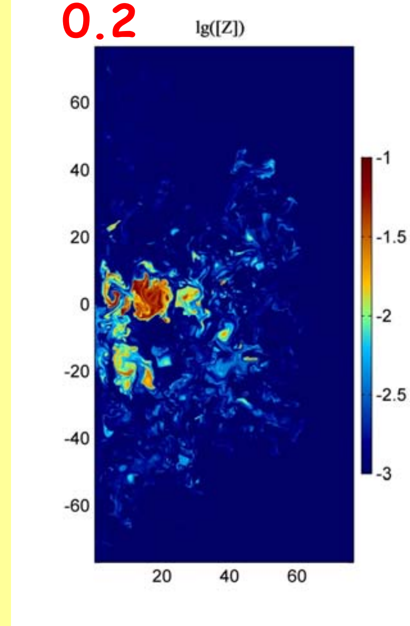


Korolev, EV et al , in prep

f_c = 0.05

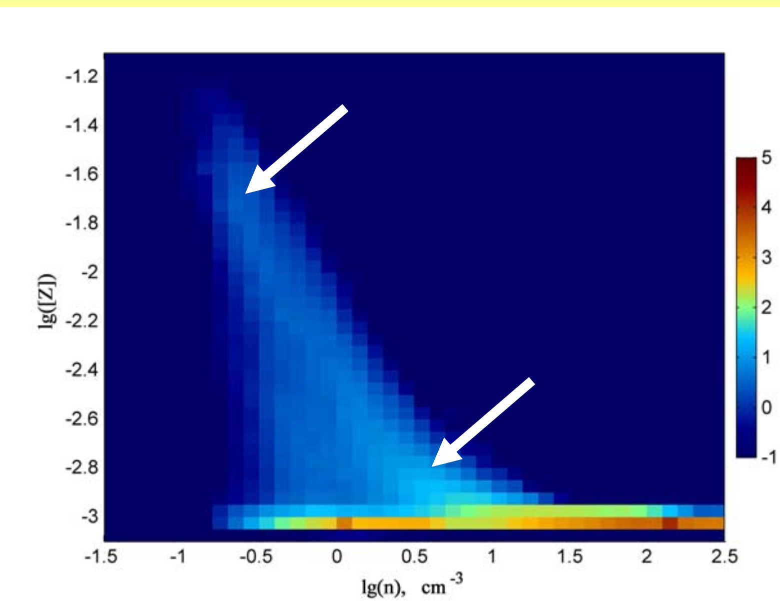


0.2

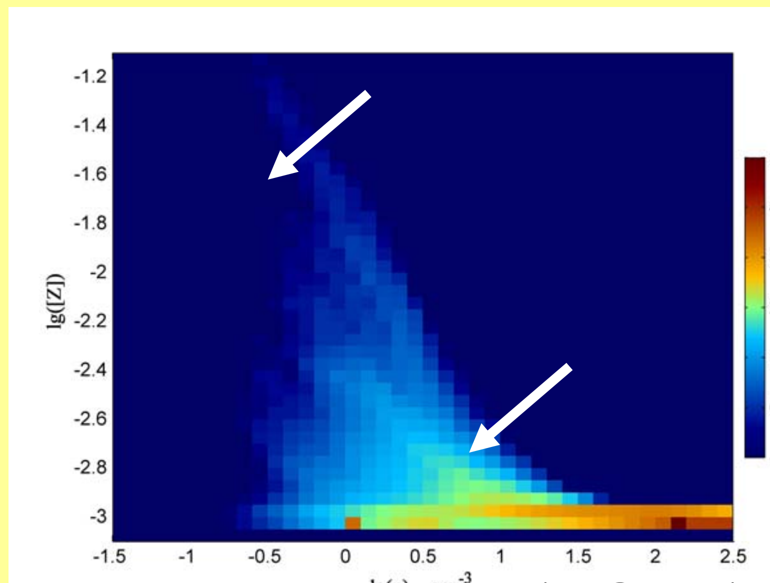


higher f_c

larger mass & lower metallicity **& higher density** of enriched gas



log Mgas



log Mgas

Korolev, EV et al , in prep

mixing metals in first minihalos is inefficient

major part of a gas has [Z/Zsun] ~ -3

significant part has higher Z

influence on further SF

mixing metals becomes more efficient in mass-loaded flows

mixing takes place in smaller volume

compact pockets of enriched gas

high-Z absorption systems