Star Formation in the Galactic Context

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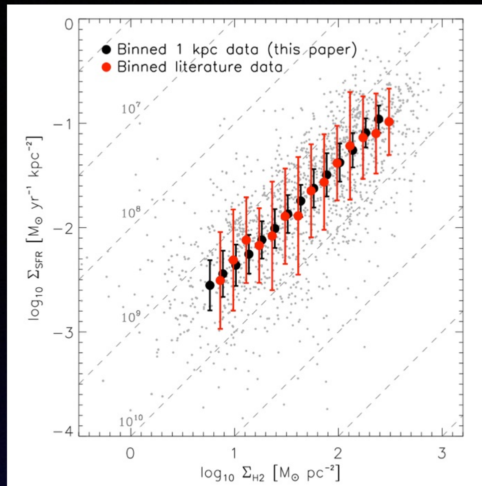
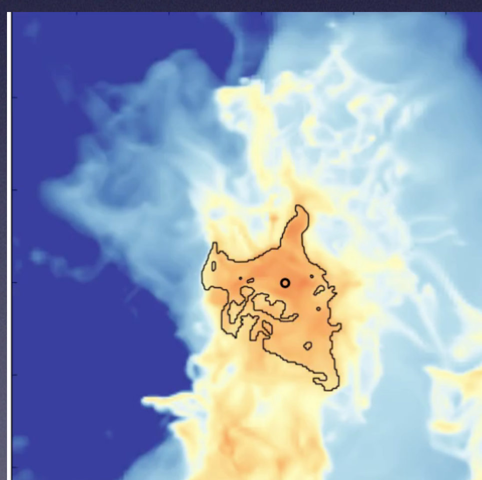
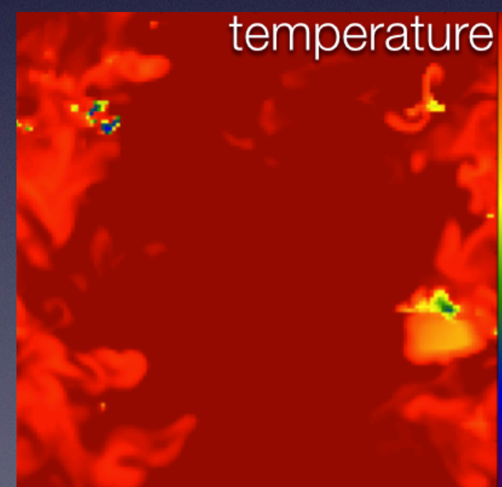


H_2: necessity or tracer?

Modern analogues of high-*z* galaxies?



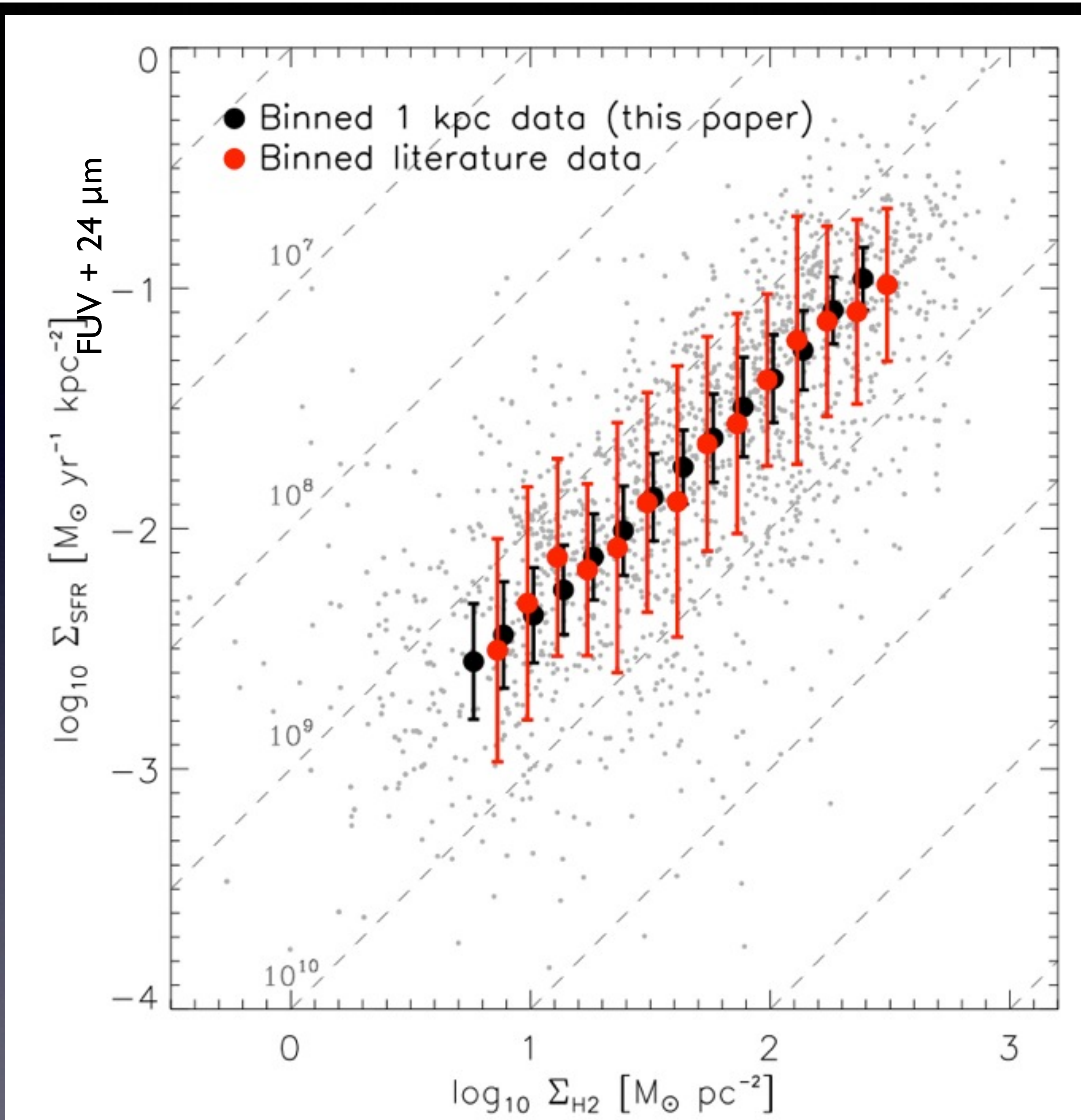
Does SN feedback determine SF efficiency?



How does SN placement and rate matter?

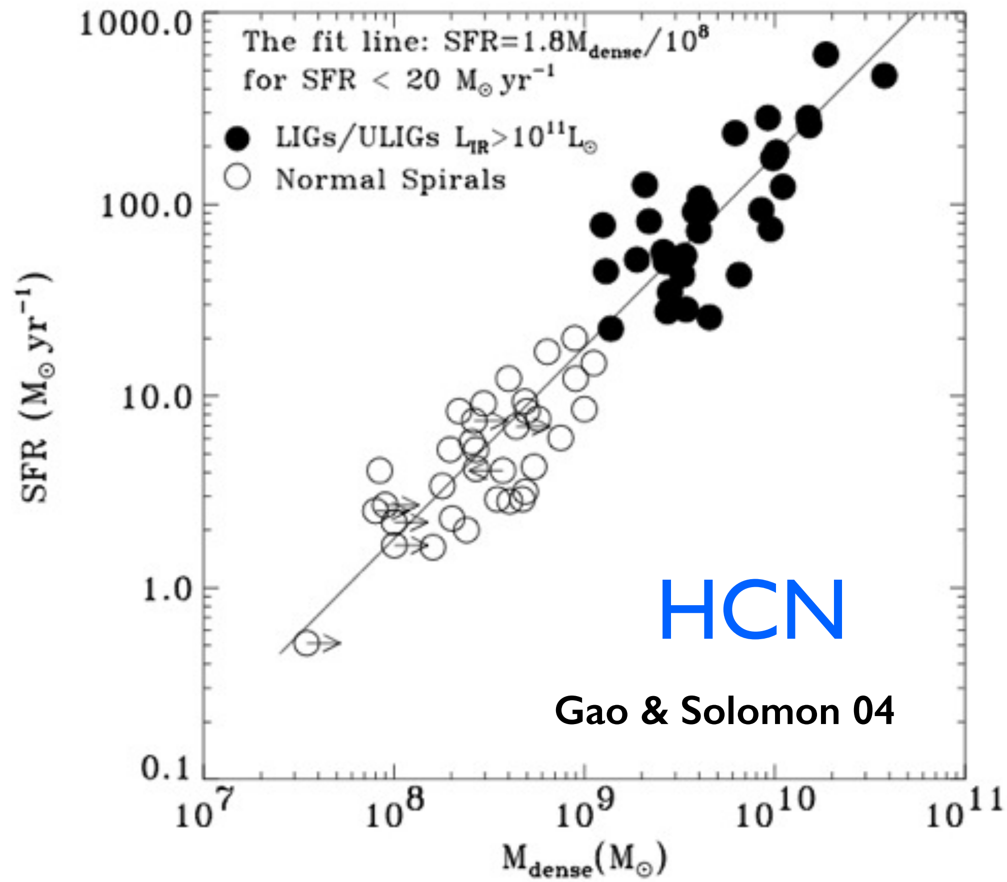
Star formation rate density correlates with H_2 surface density.

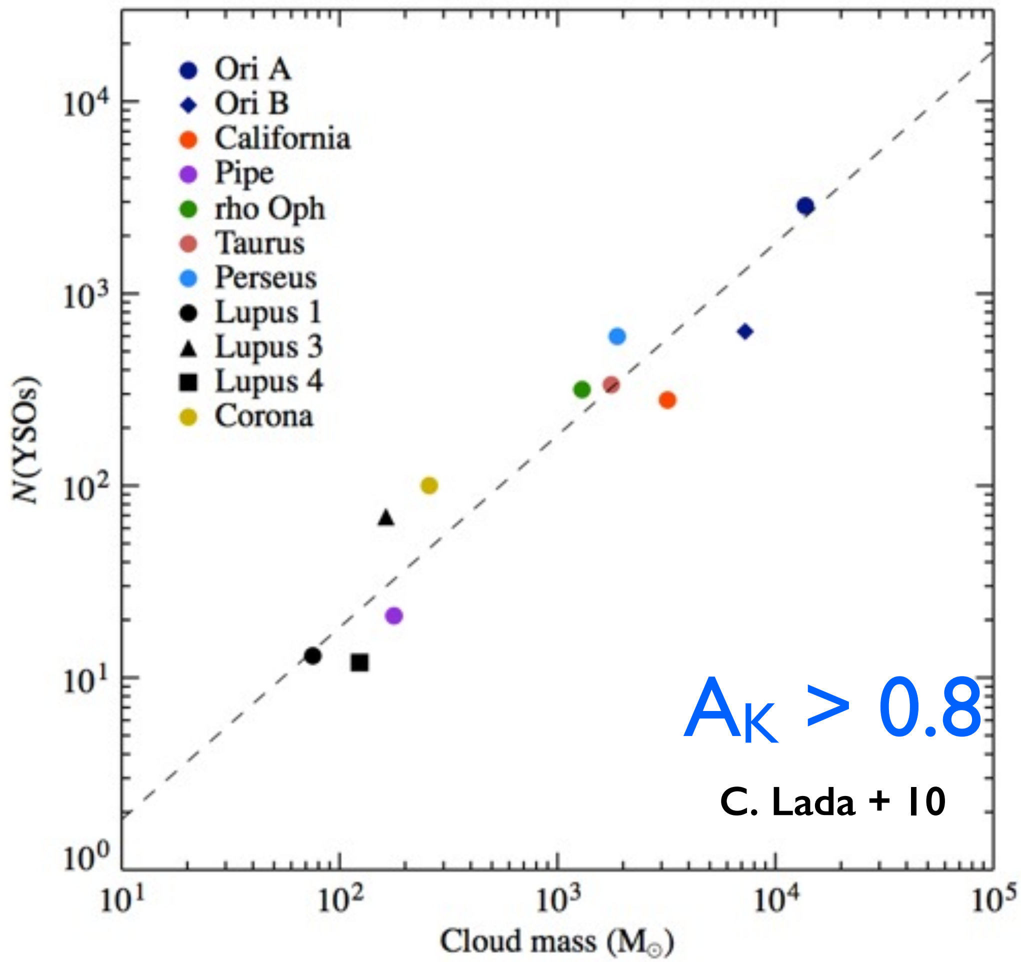
Does correlation imply causation?



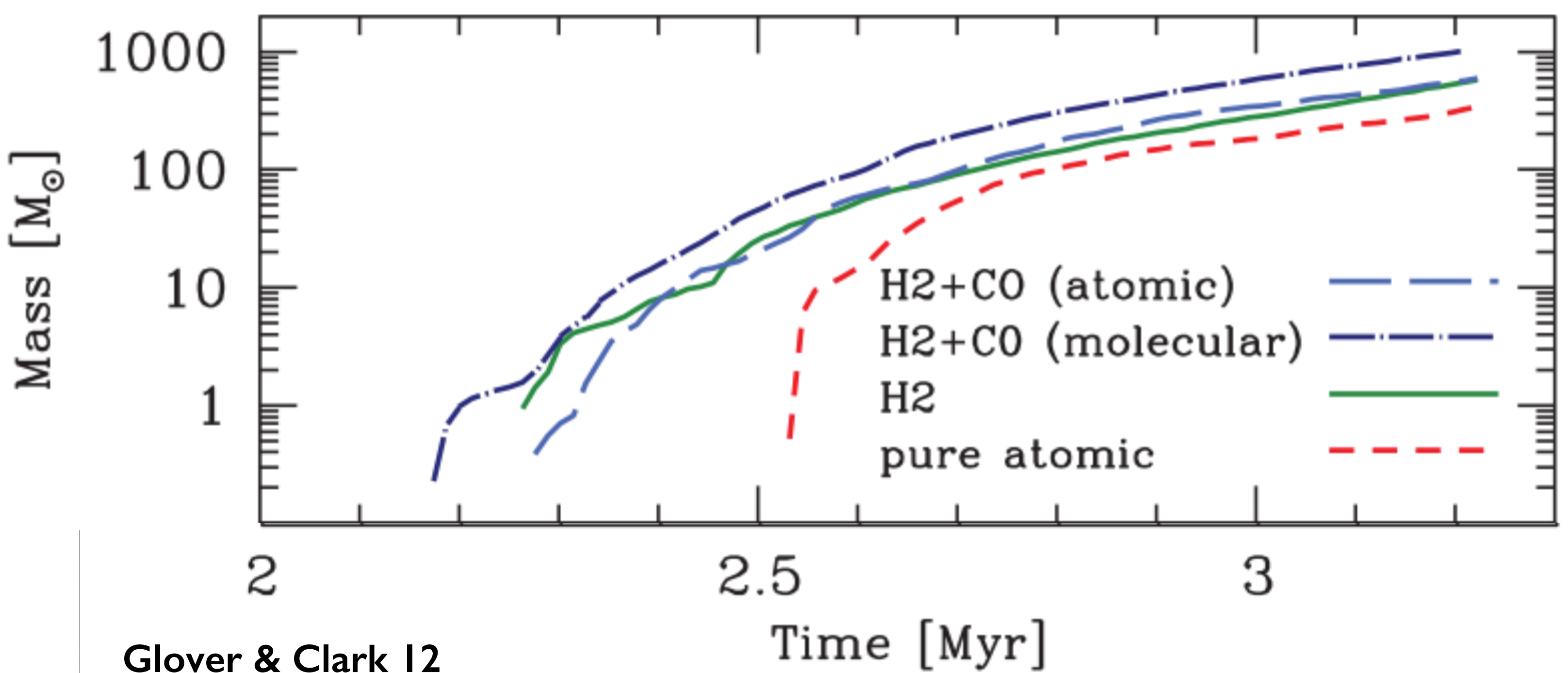
Bigiel + 11; also see Rownd & Young 99, Wong & Blitz 02, Bigiel + 08, Leroy + 08

Alternatives: HCN, $A_K > 0.8$





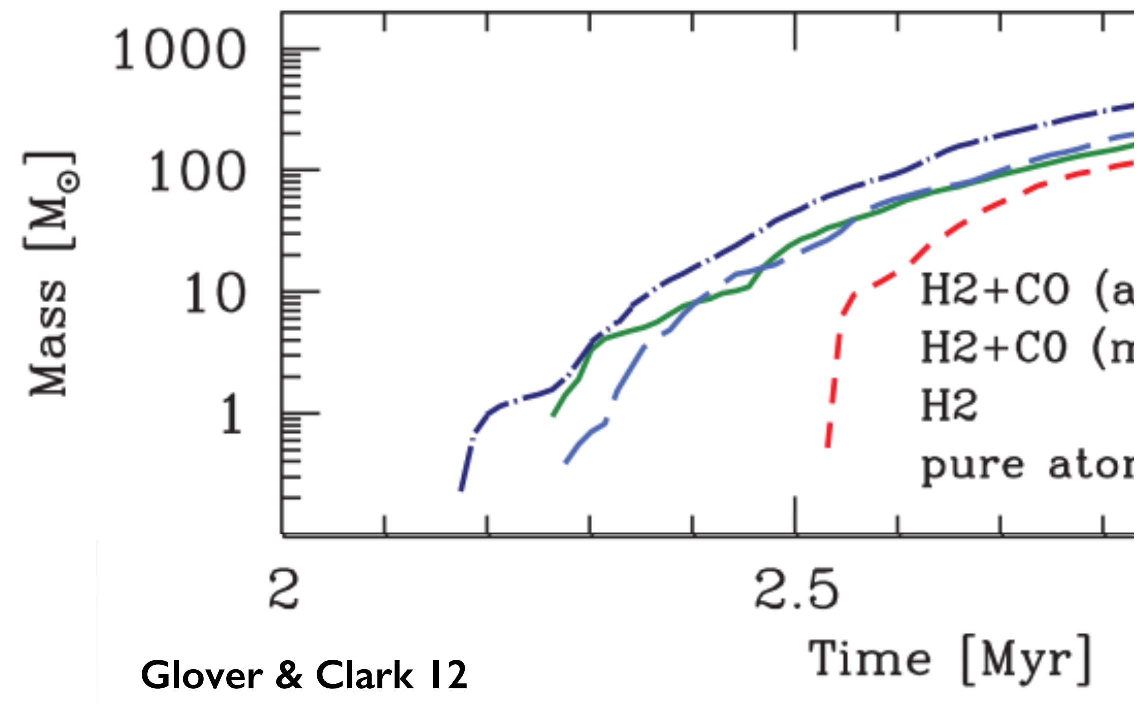
Other measurements of high density gas correlate equally well.



Glover & Clark 12

also see Krumholz + 11

Molecules do not control [modern] star formation.

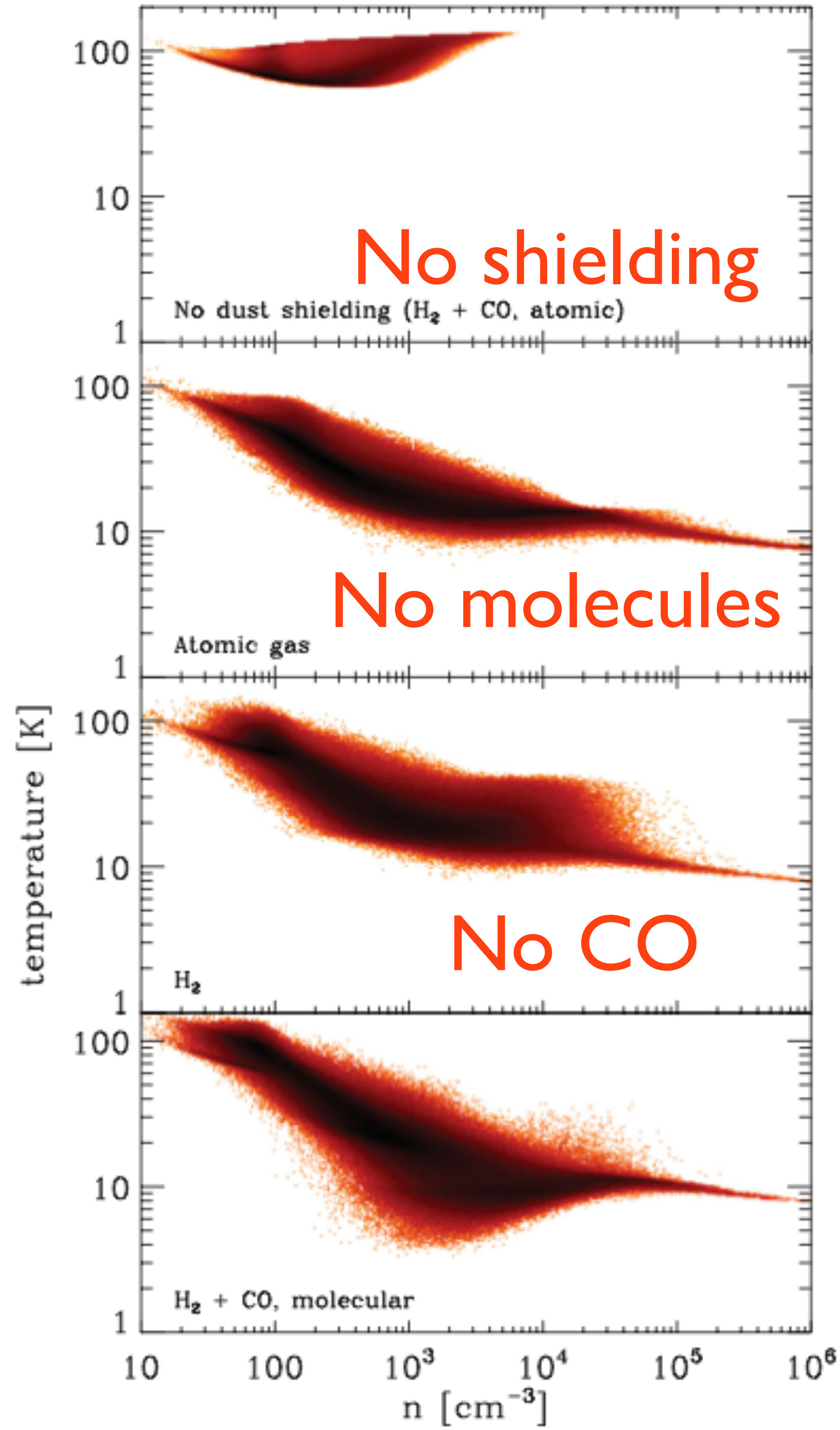


Glover & Clark 12

also see Krumholz + 11

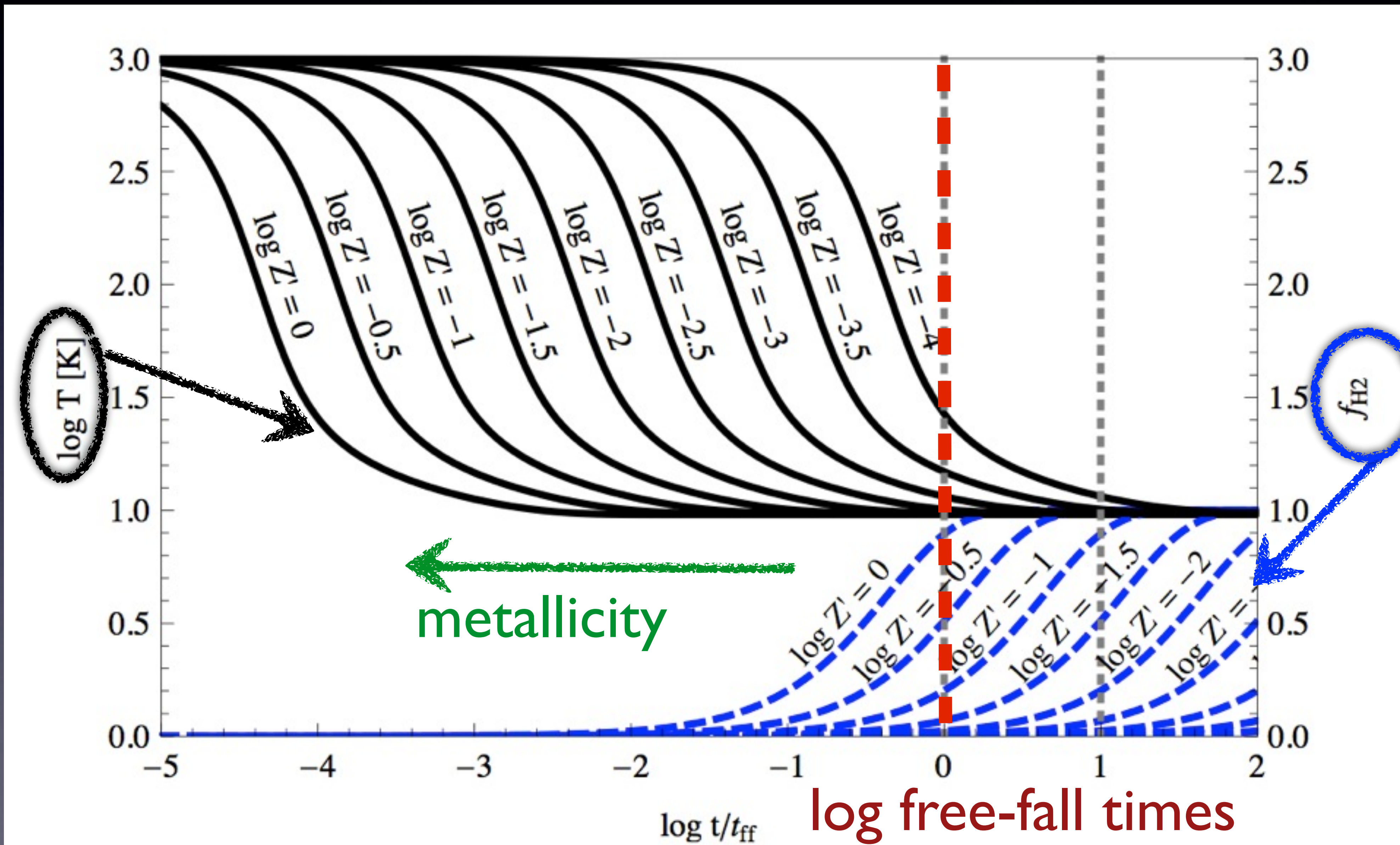
Molecules do not control [modern] star formation.

Rather dust shielding from photoelectric heating does.

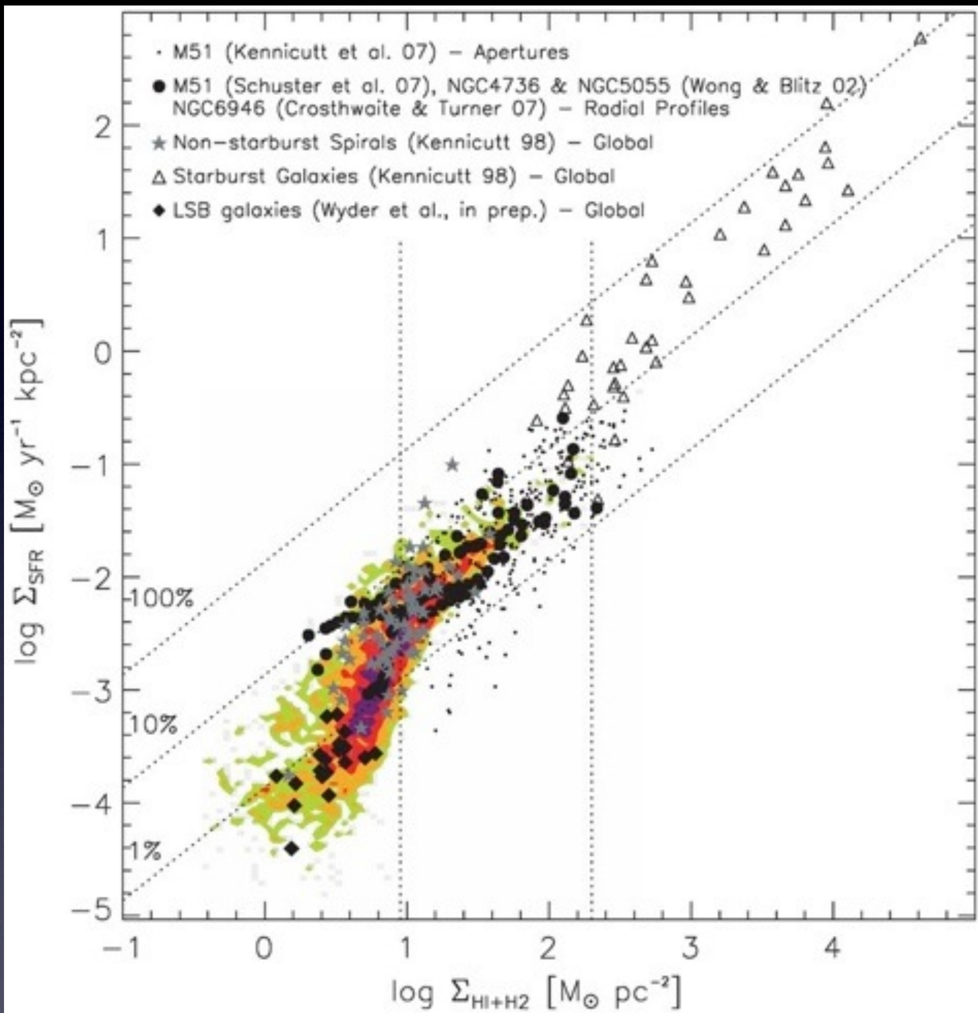


Cooling occurs faster than H_2 formation. At low metallicity, collapse occurs faster as well.

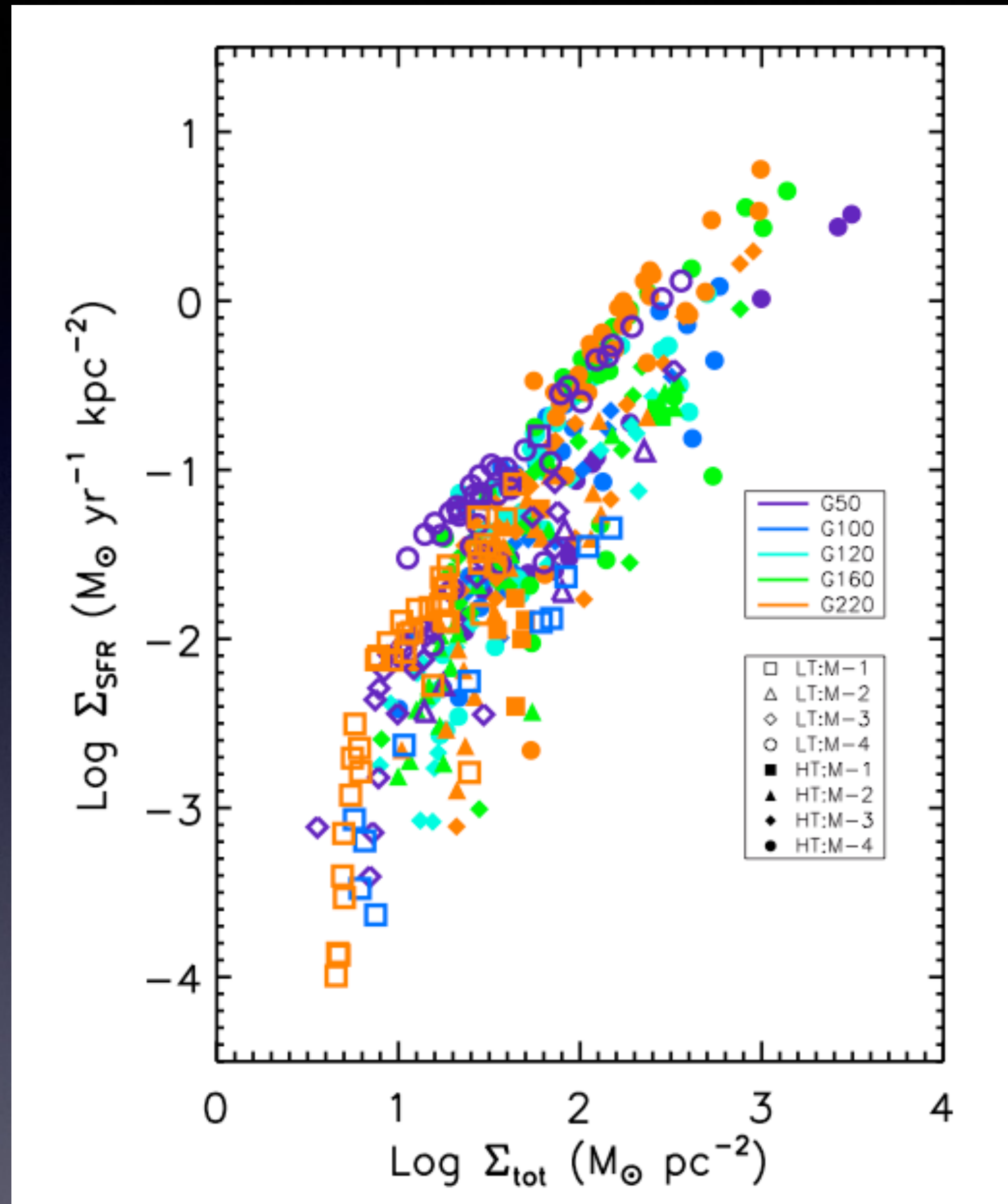
Krumholz 12



GI predicts threshold seen at low surface density



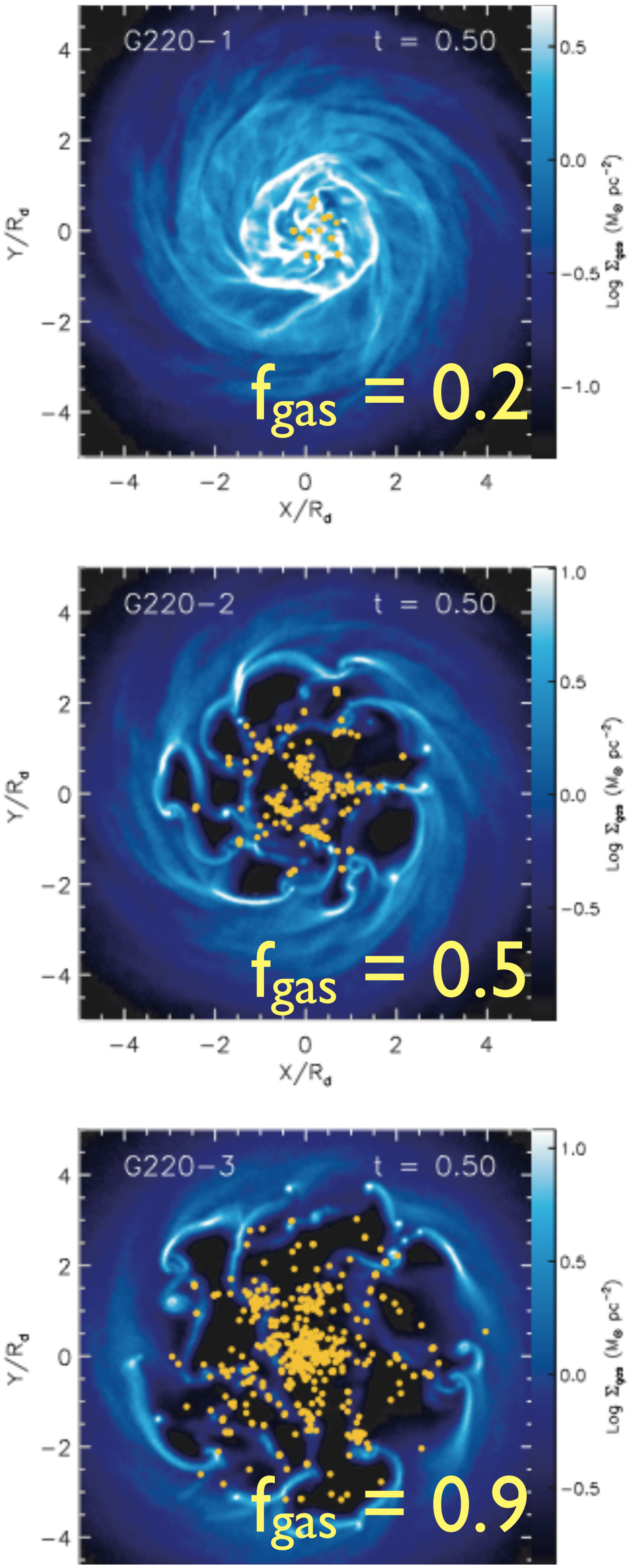
Bigiel + 08



Li, Mac Low & Klessen 06

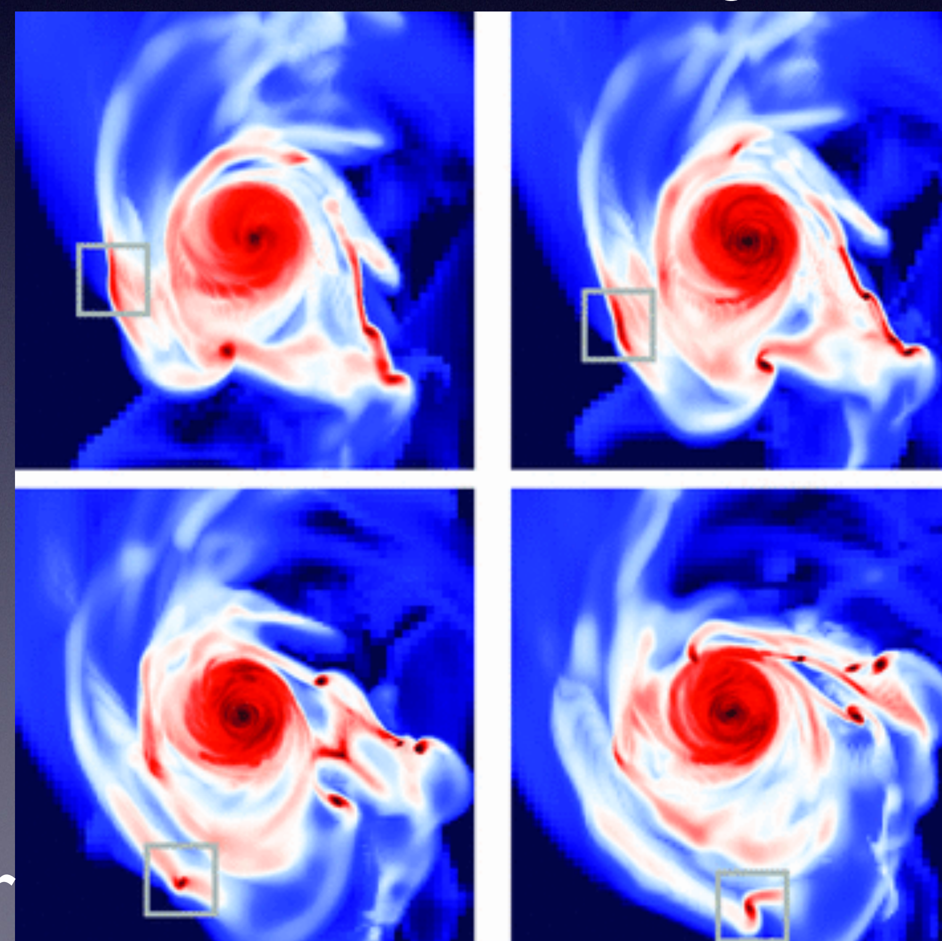
(also Kravtsov 03)

Li, Mac Low, Klessen 05



Gravitational instability drives clump formation and rapid star formation in gas-rich disks

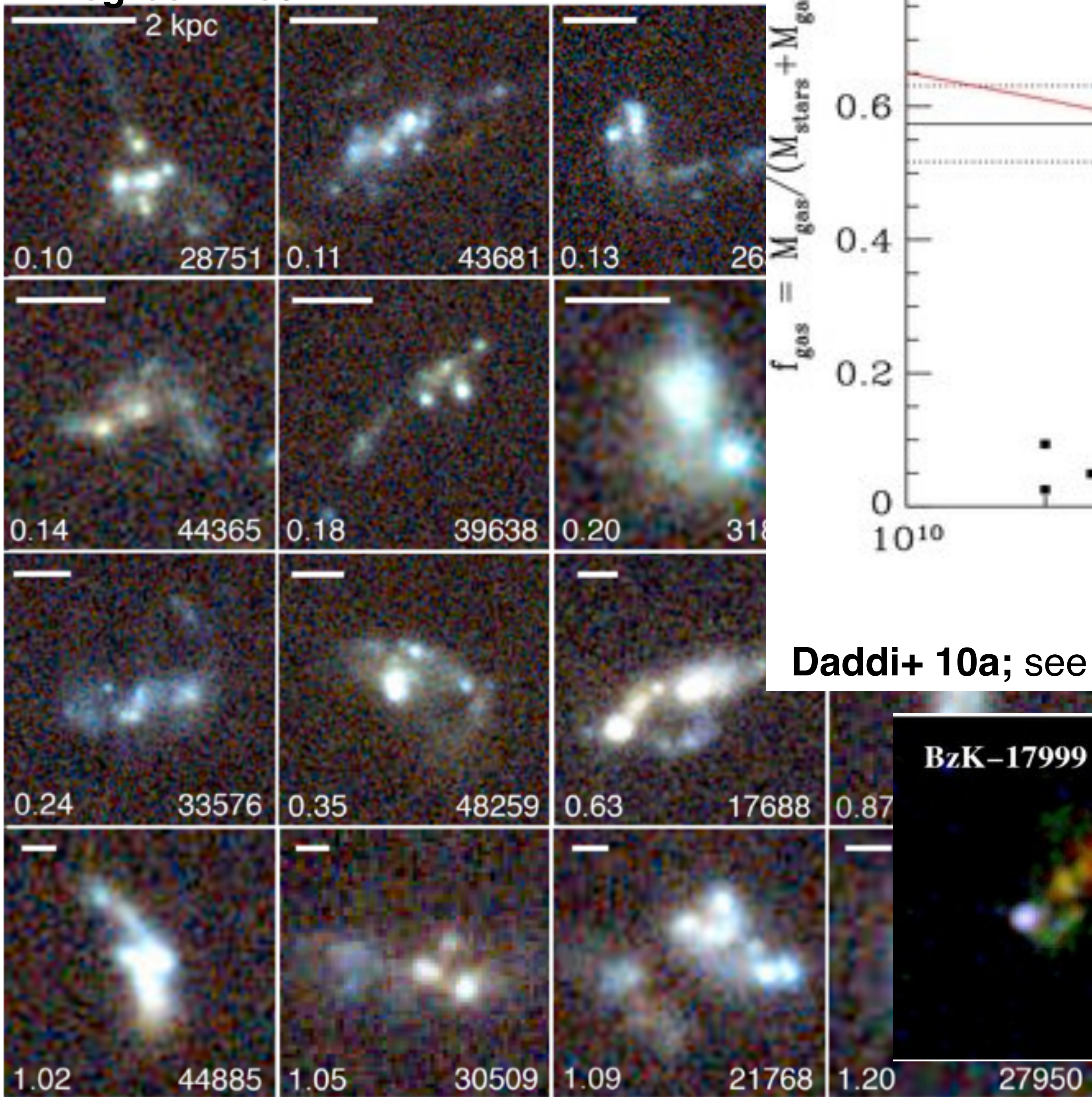
Agertz + 09

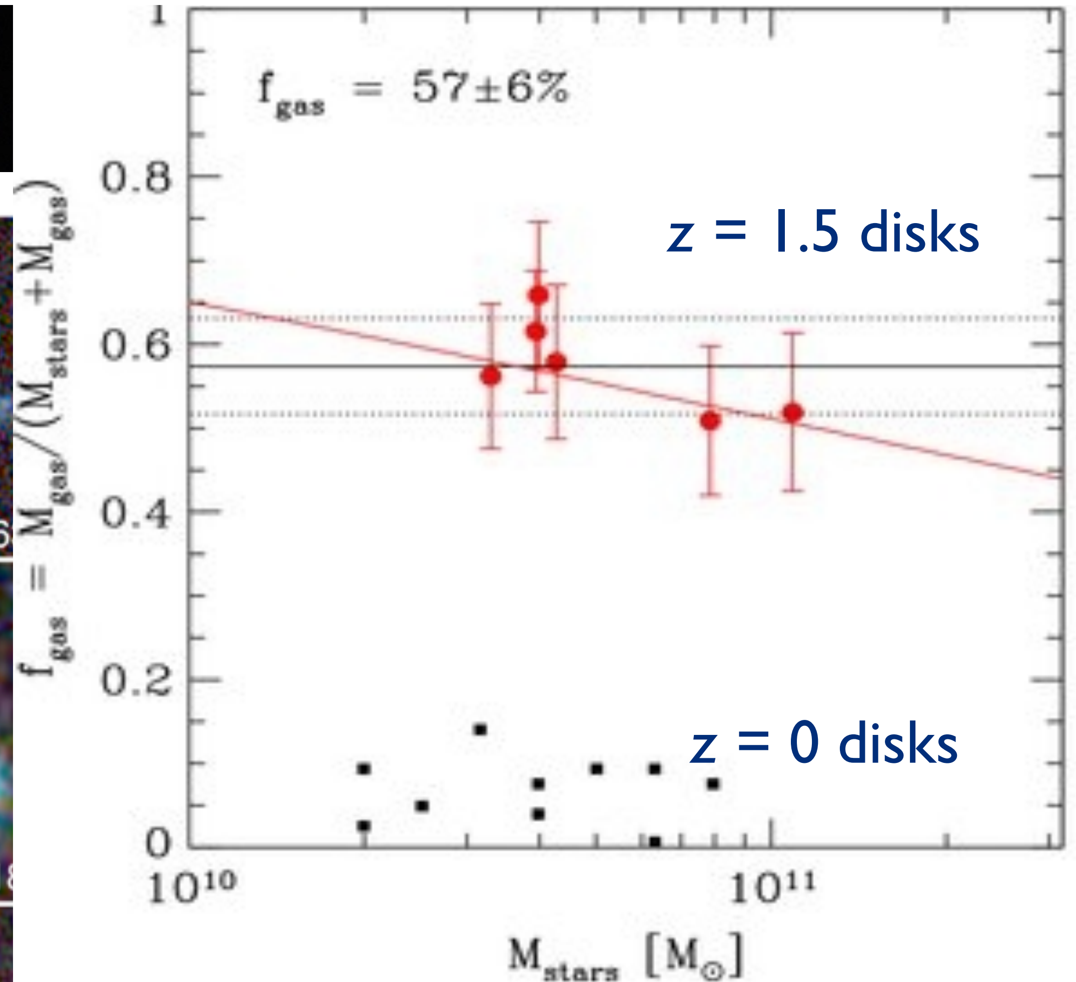


AMR shows similar behavior

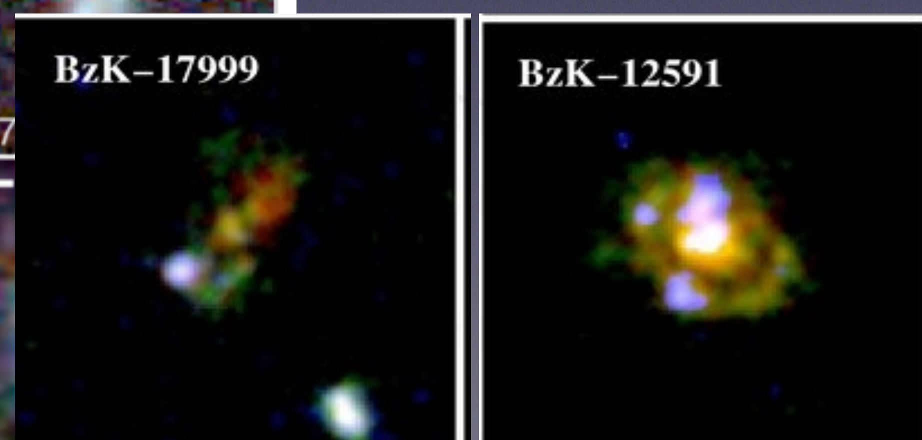
Violent disk instability
(see Dekel+09, Agertz+09)

Elmegreen + 09

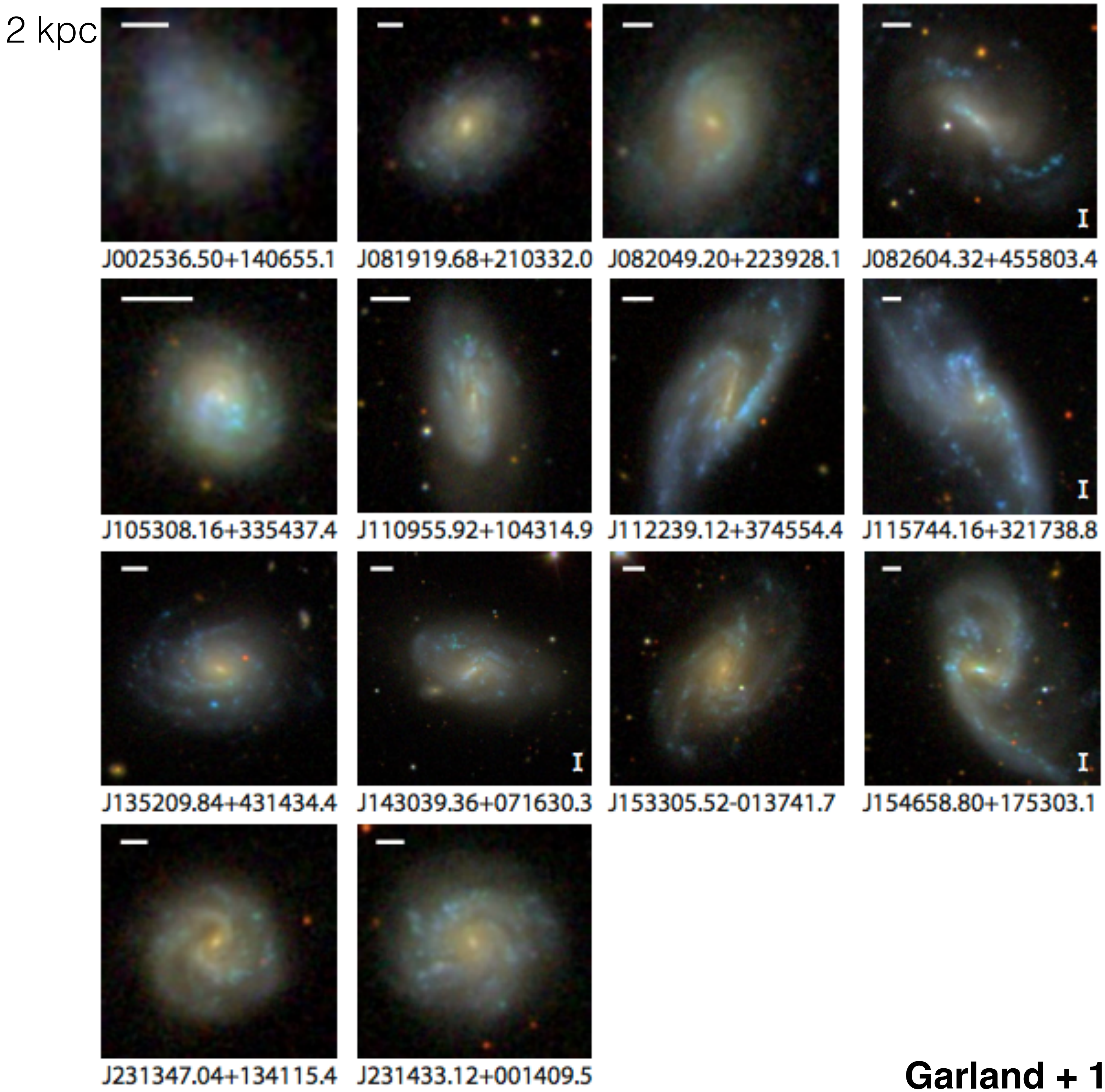




Daddi+ 10a; see also Daddi + 08, Tacconi+ 10



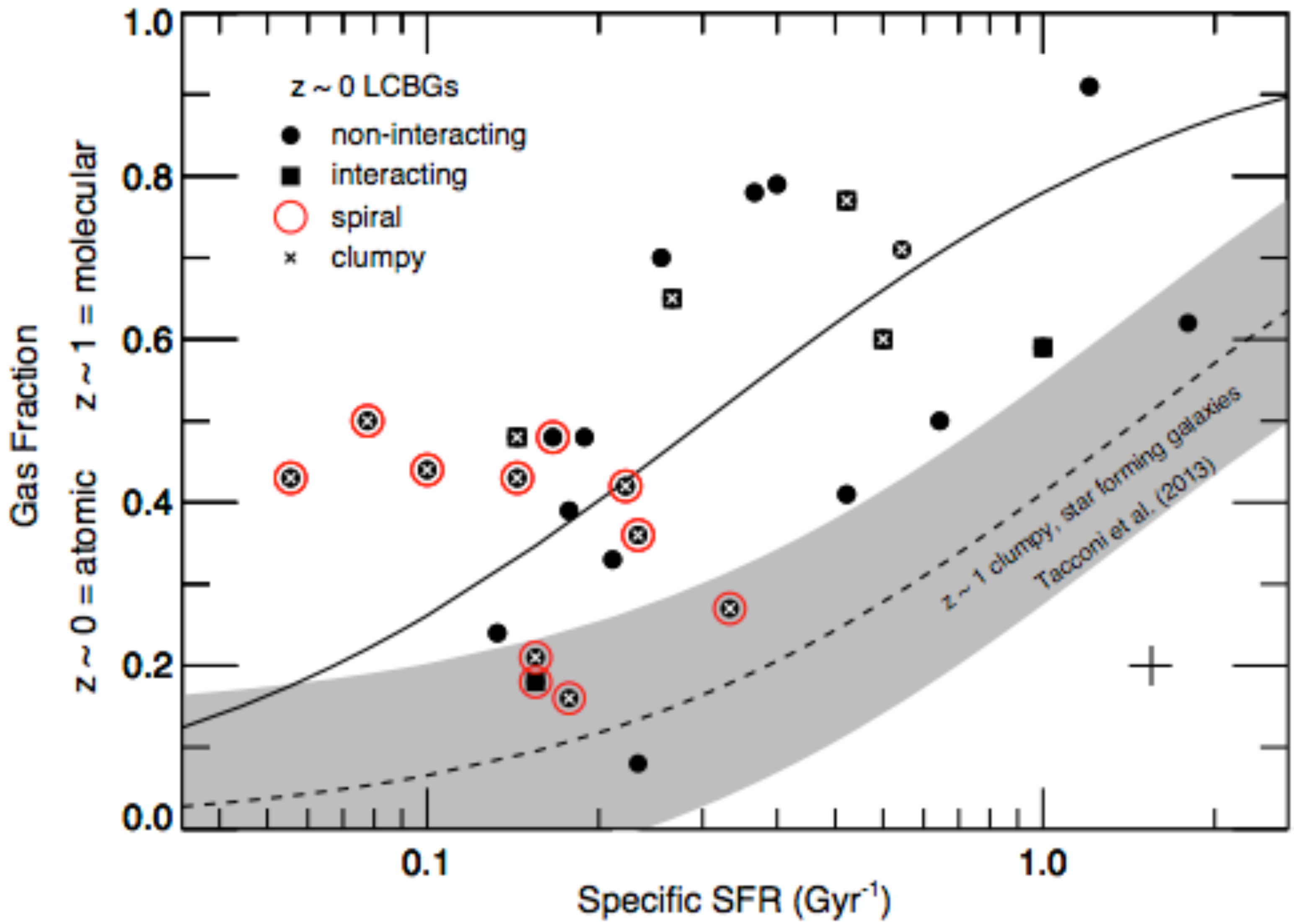
Luminous compact blue galaxies often turn out to be gas-rich local examples of similar behavior.

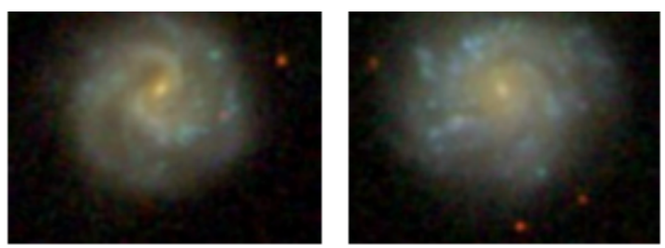


Garland + 15

Fig. 2.— Color-combined SDSS images of the 14 local LCBGs classified as clumpy. A range

Luminous compact blue galaxies often turn out to be gas-rich local examples of similar behavior.

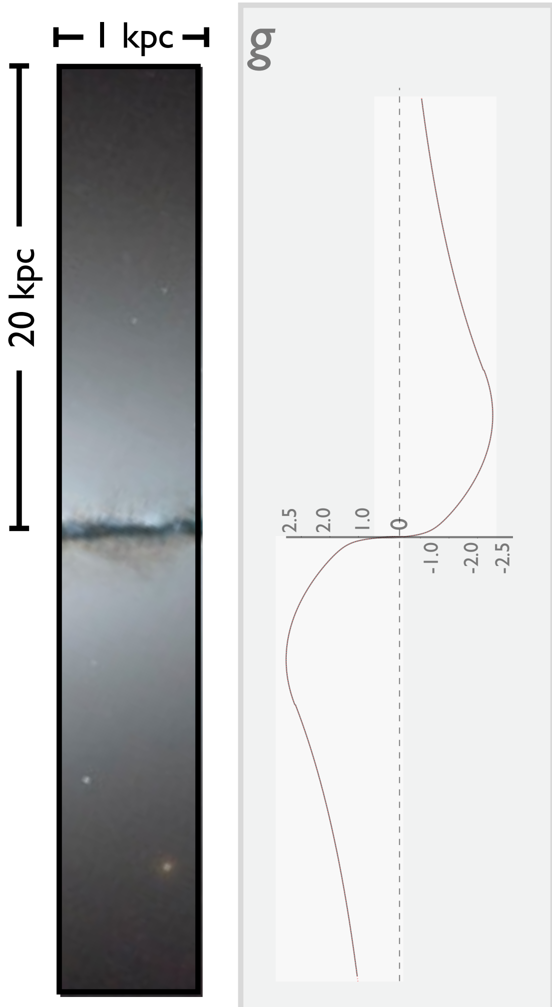


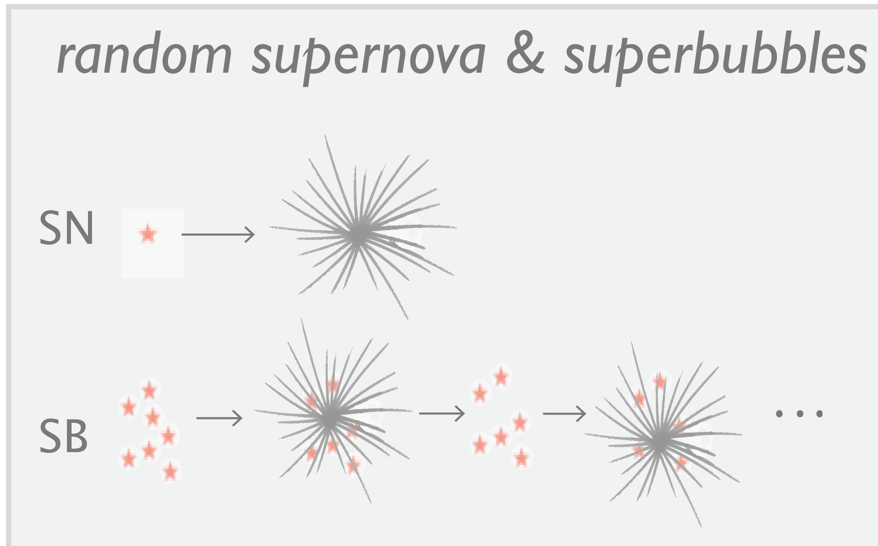


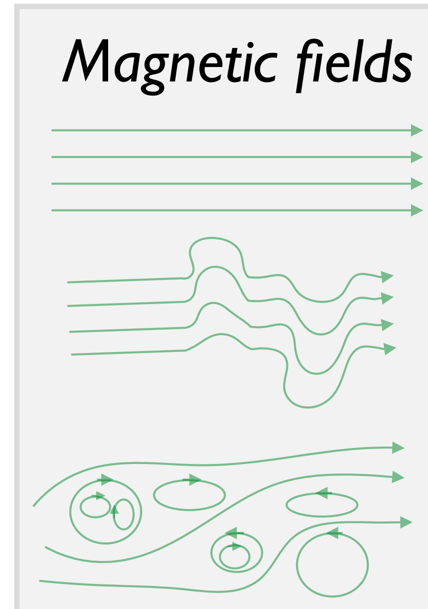
Garland + 15

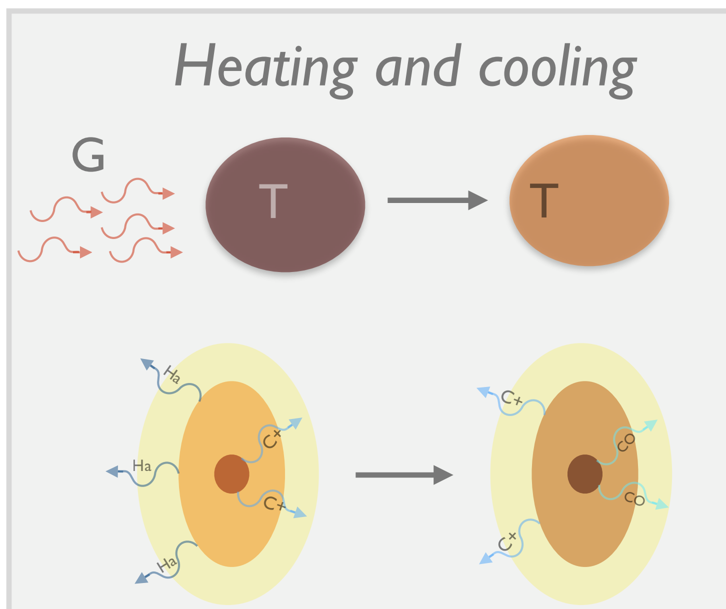
Fig. 2.— Color-combined SDSS images of the 14 local LCBGs classified as clumpy. A range

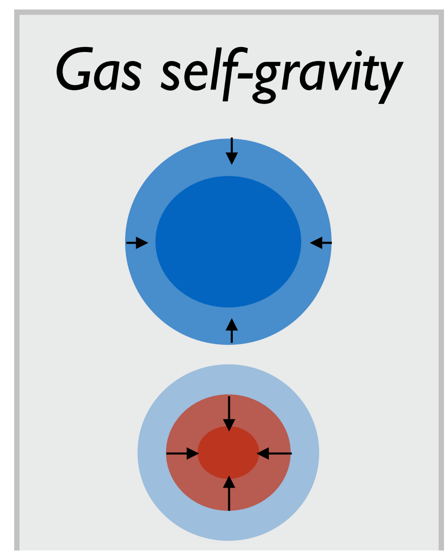
Physics included.







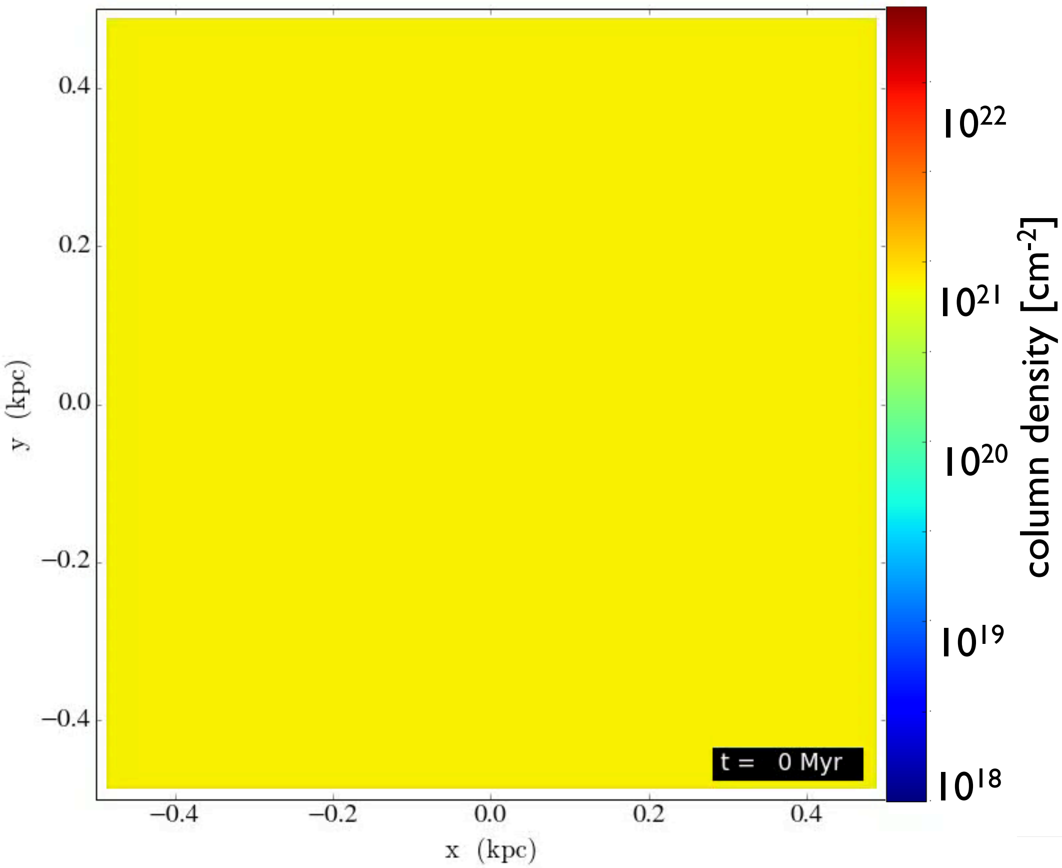


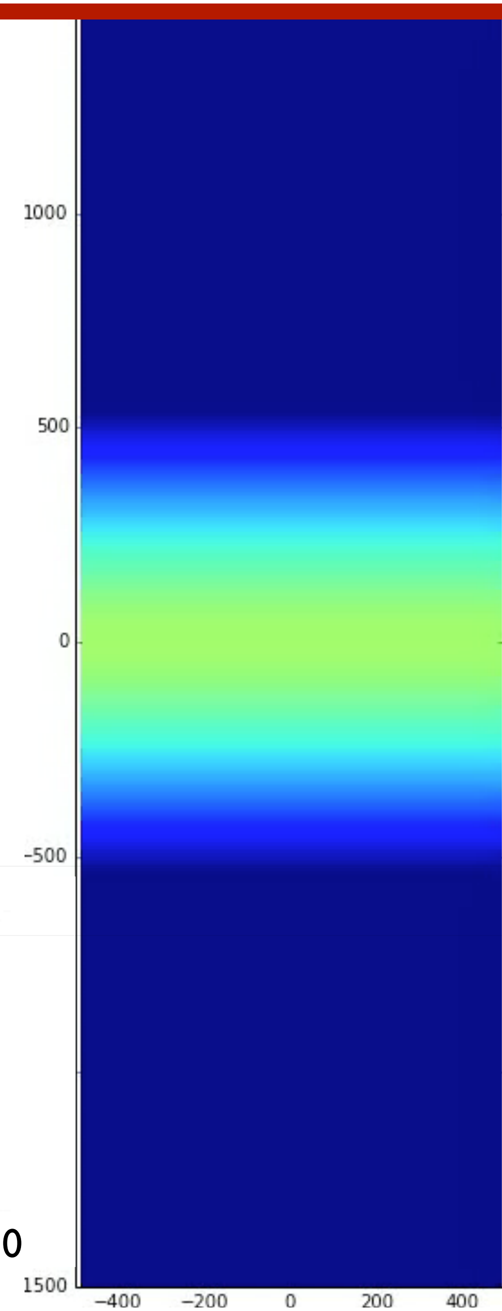


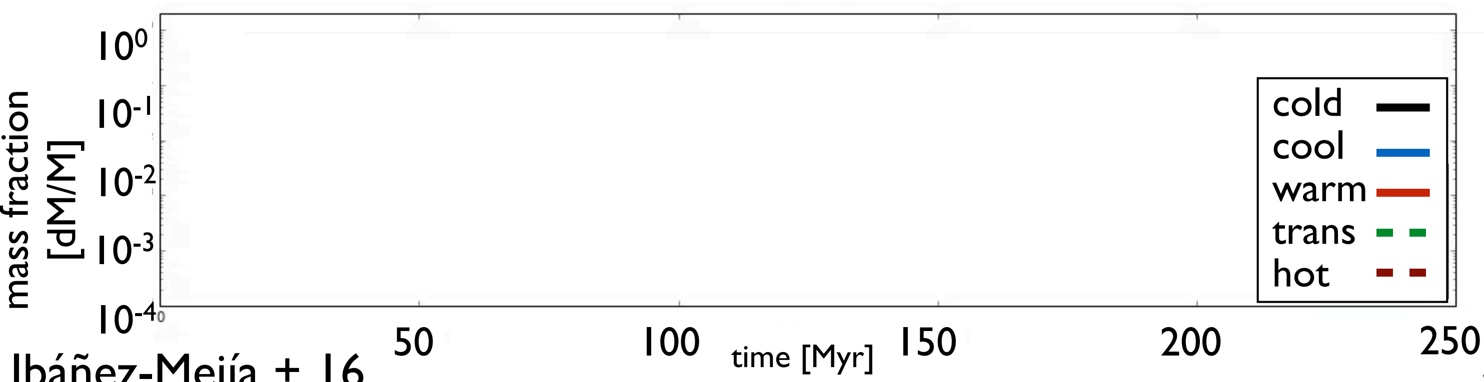
Ibáñez-Mejía + 16

Included at late times

Non-self-gravitating evolution.

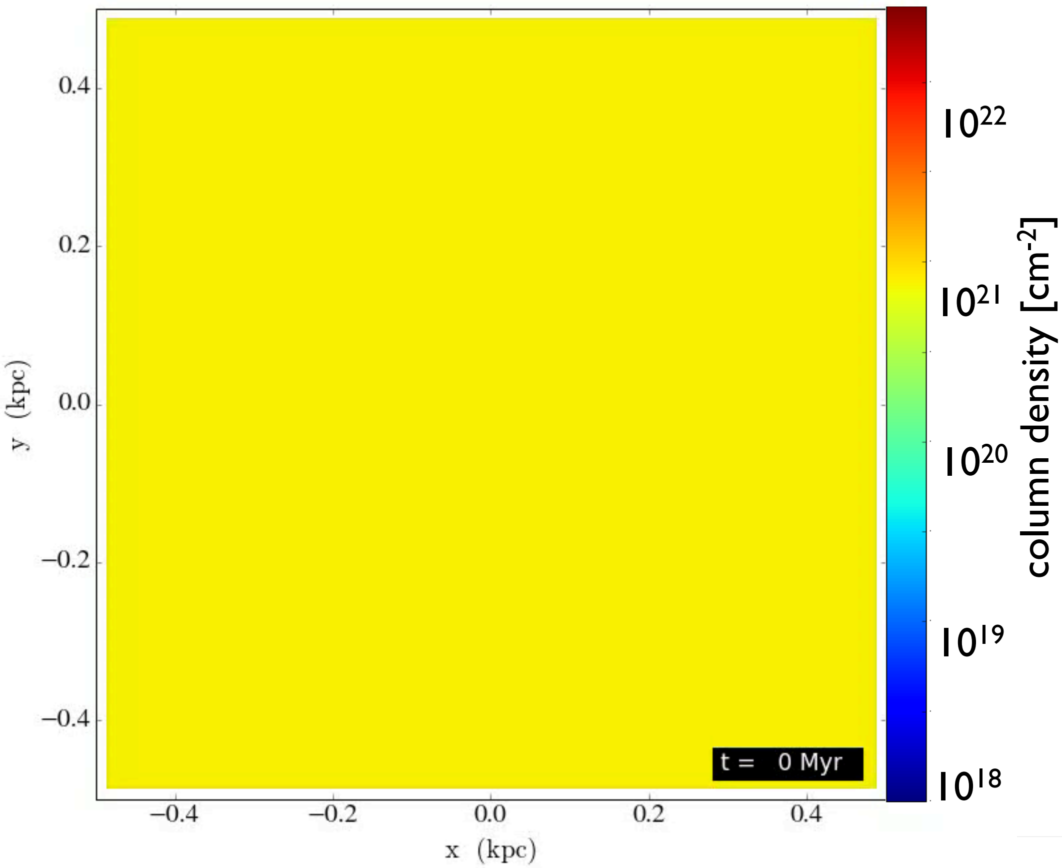


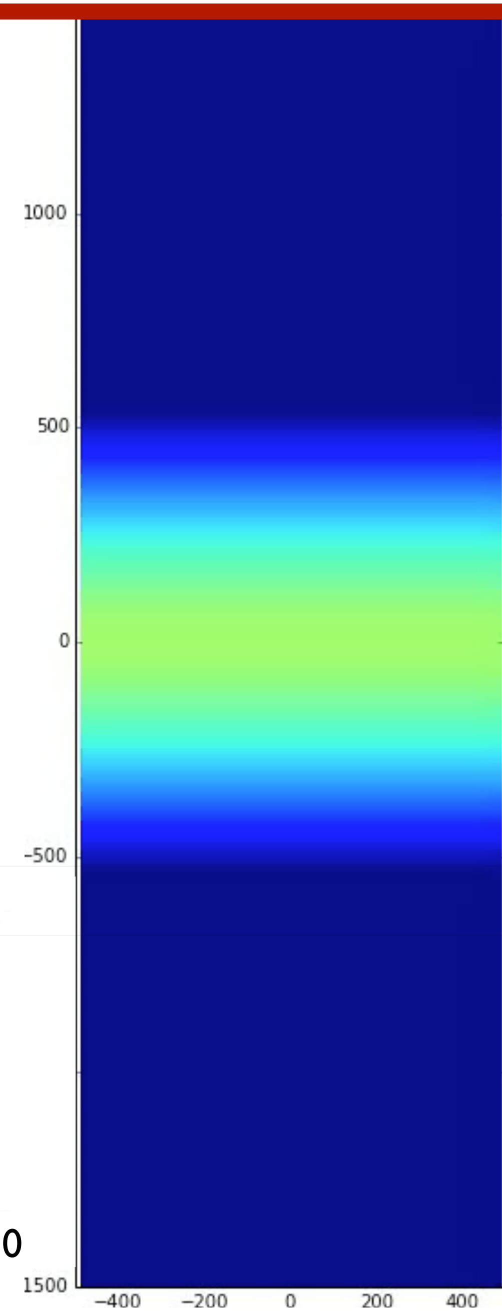


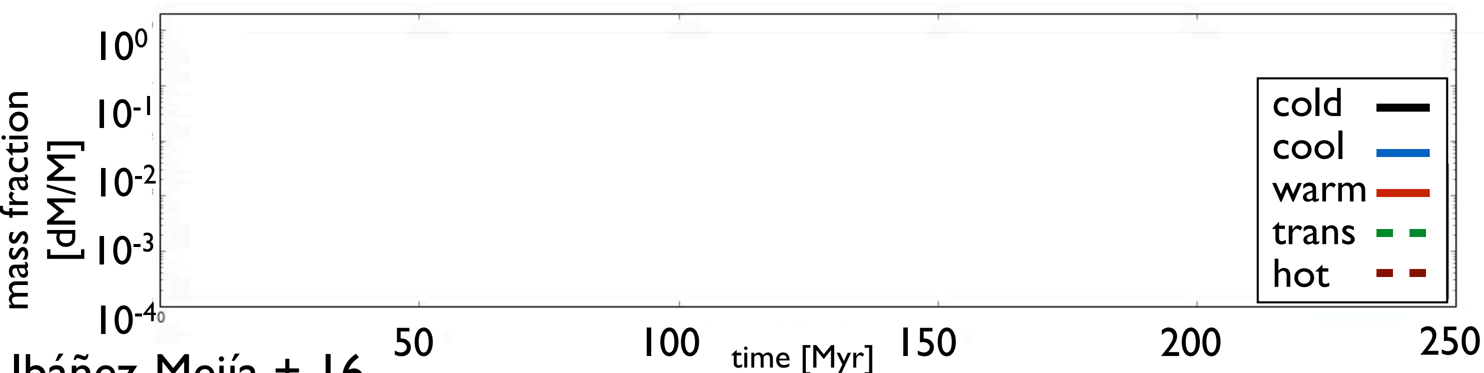


Ibáñez-Mejía + 16

Non-self-gravitating evolution.







Ibáñez-Mejía + 16

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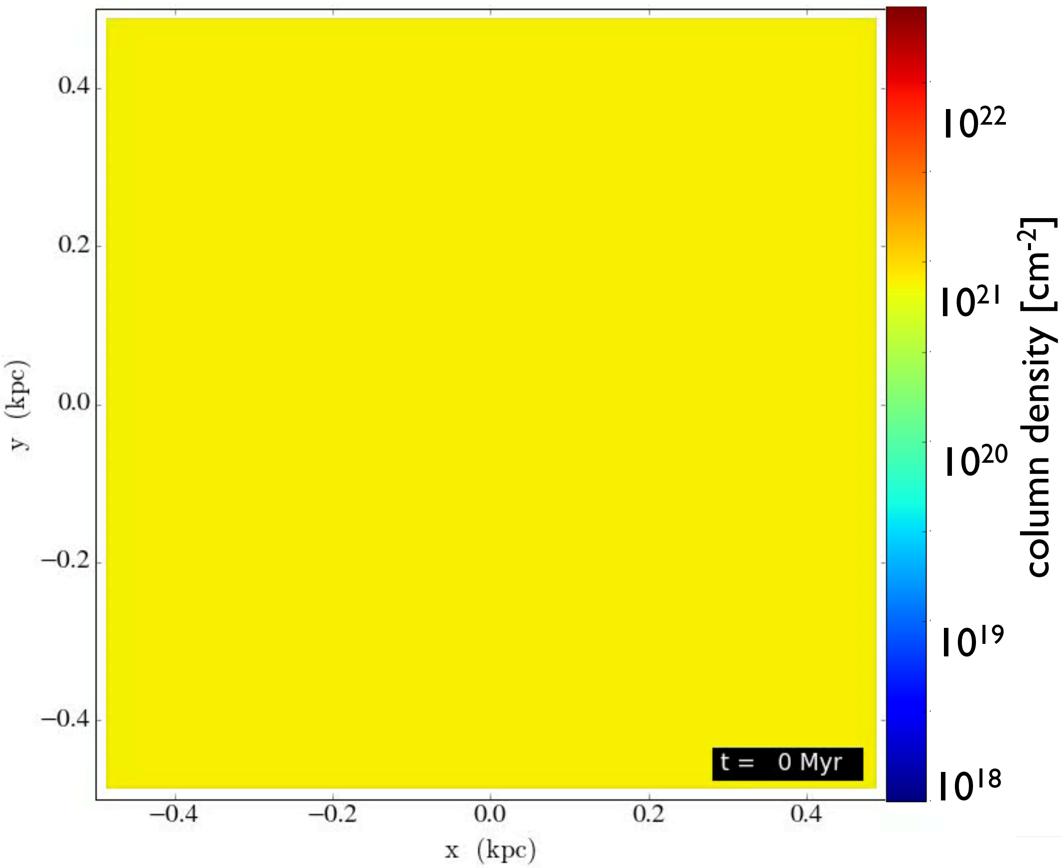
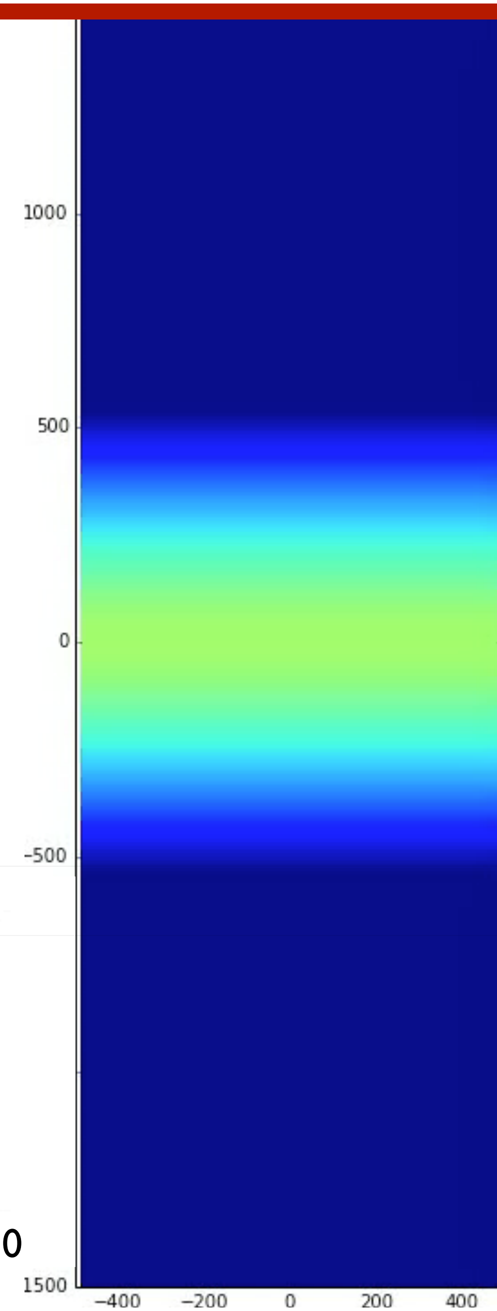
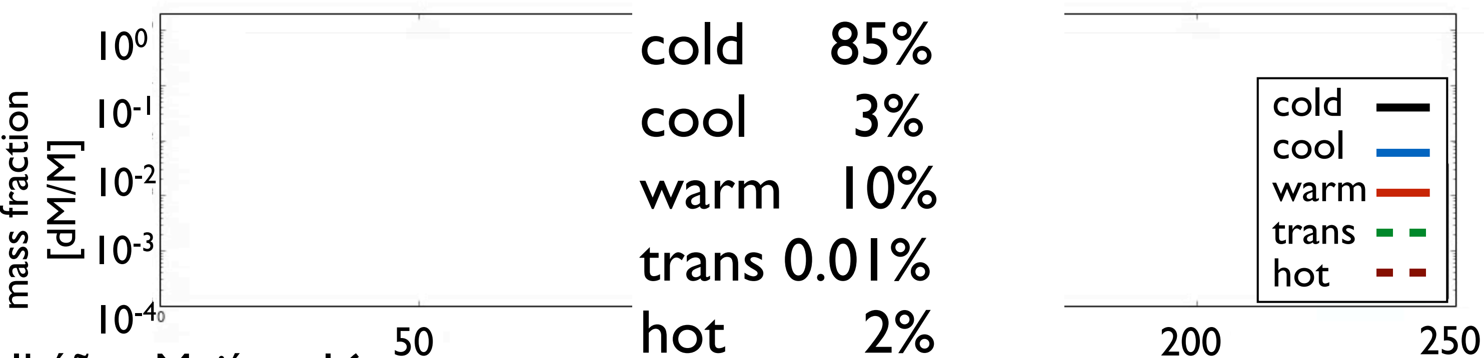


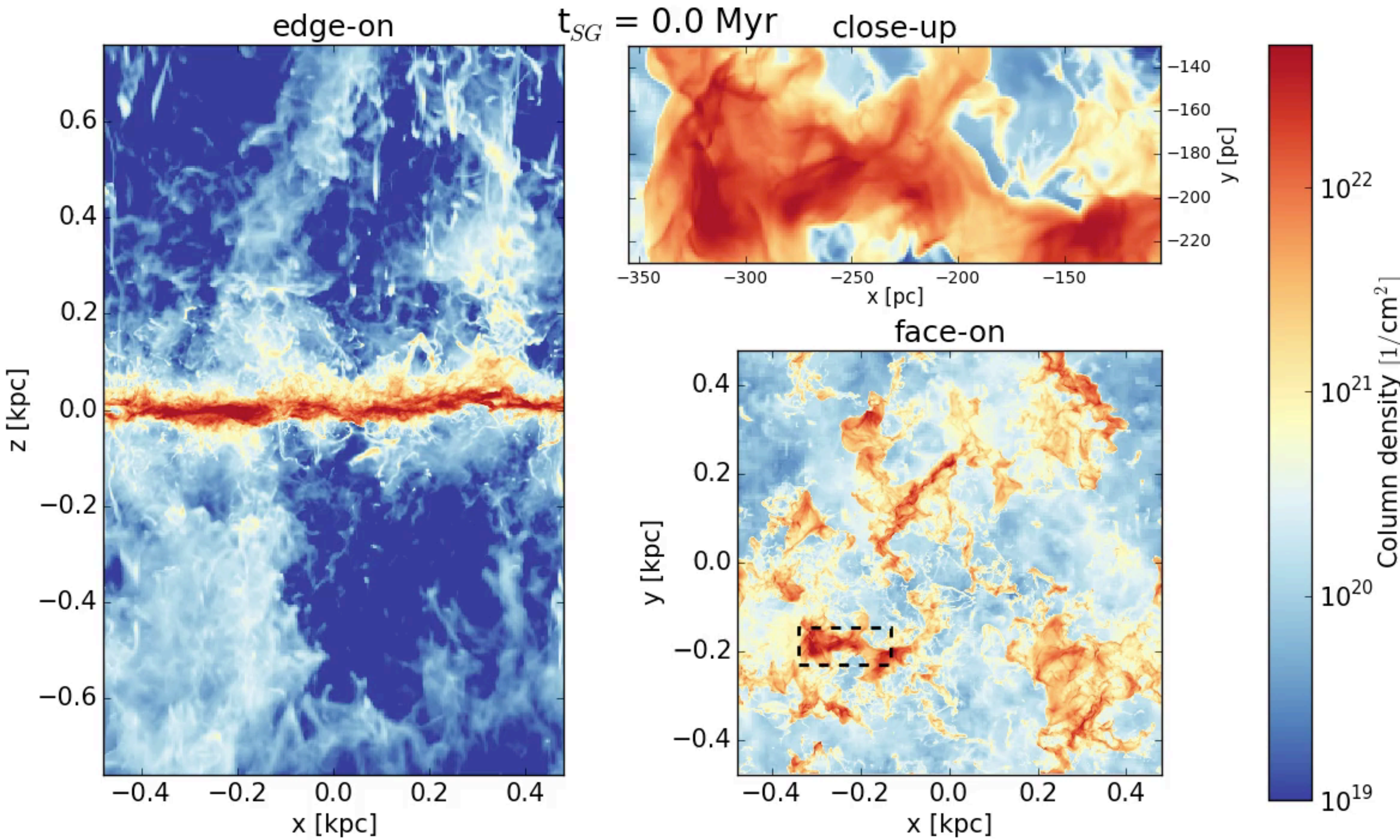




cold	85%
cool	3%
warm	10%
trans	0.01%
hot	2%

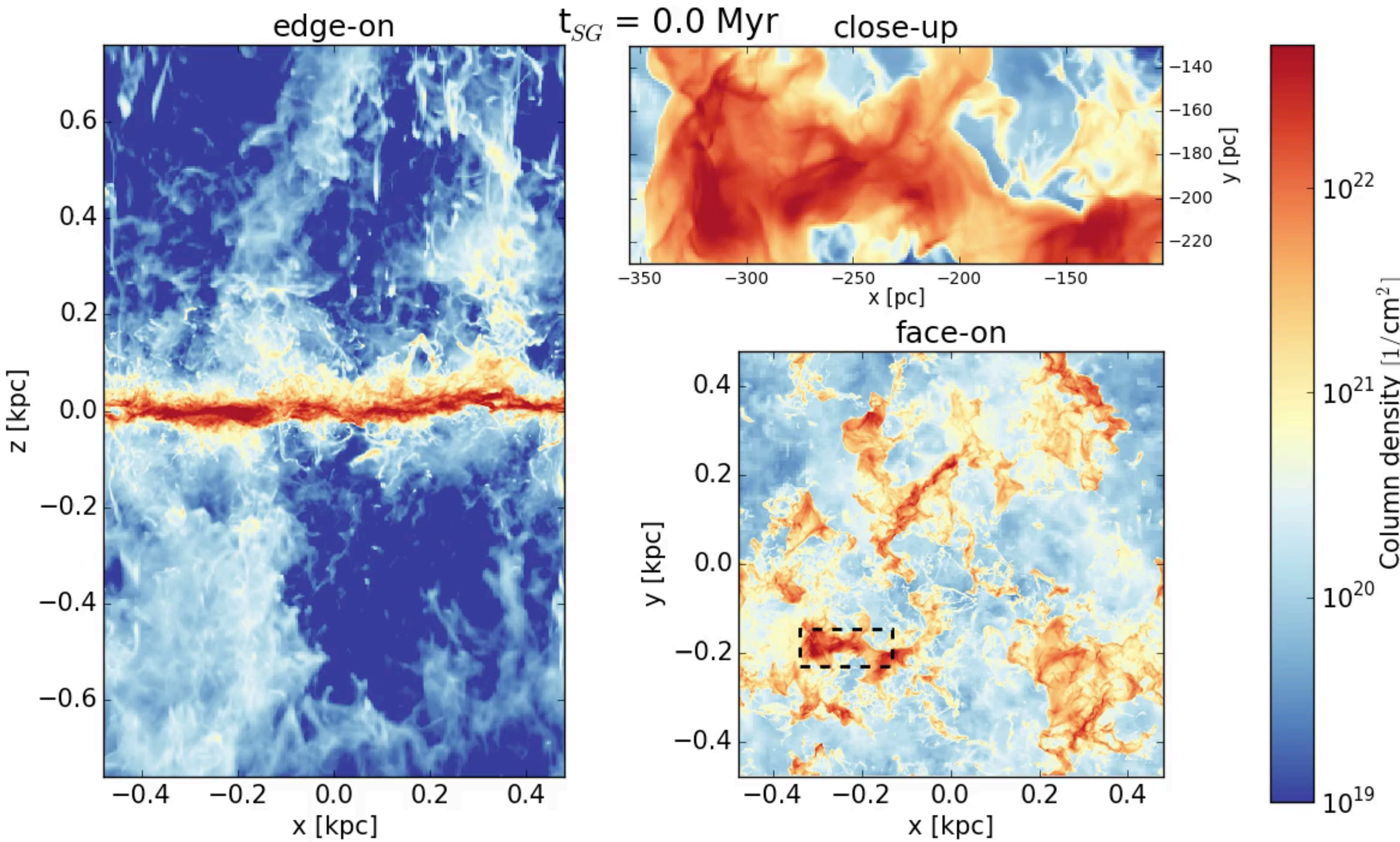
Ibáñez-Mejía + 16

Self-gravitating evolution

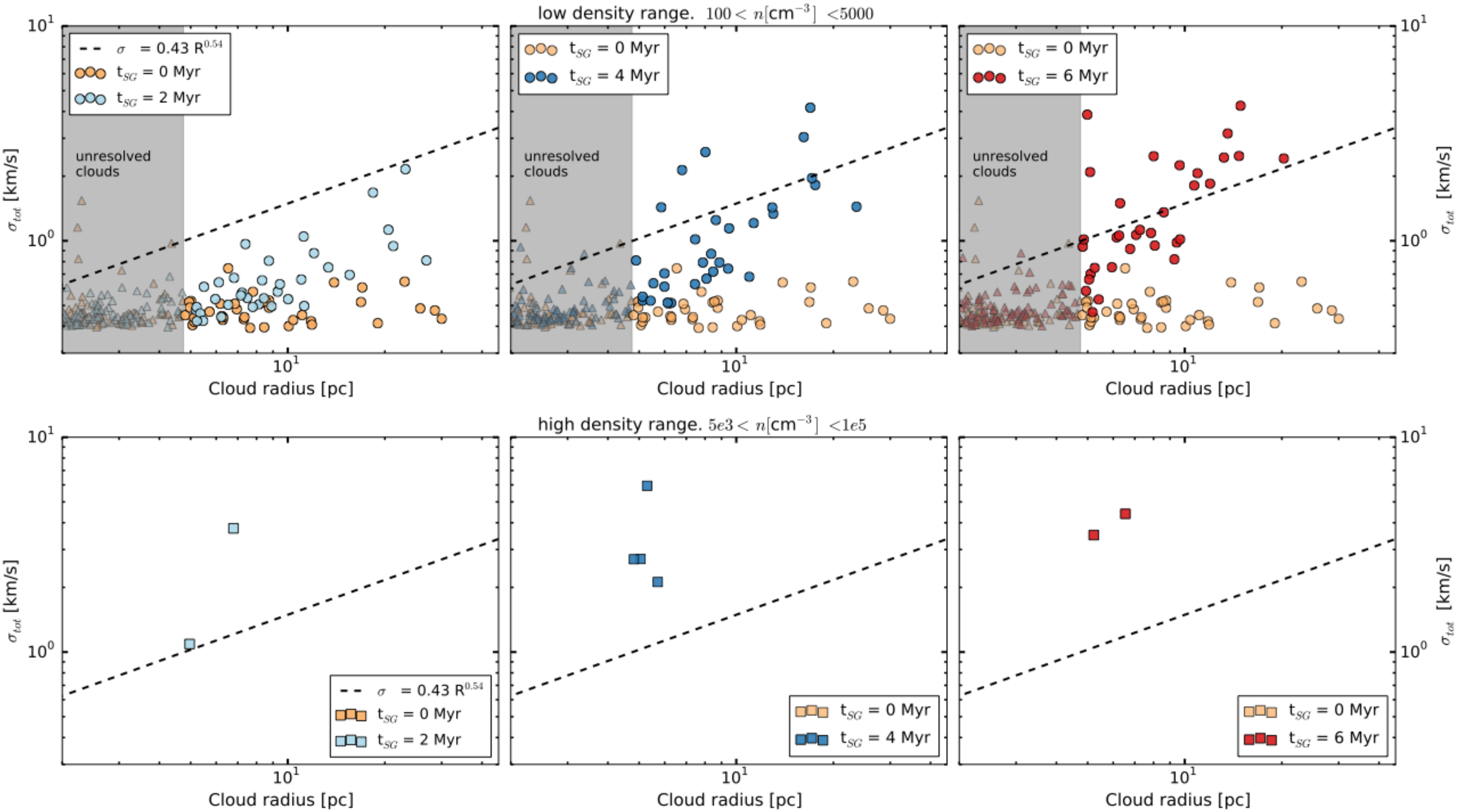


Ibáñez-Mejía + 16

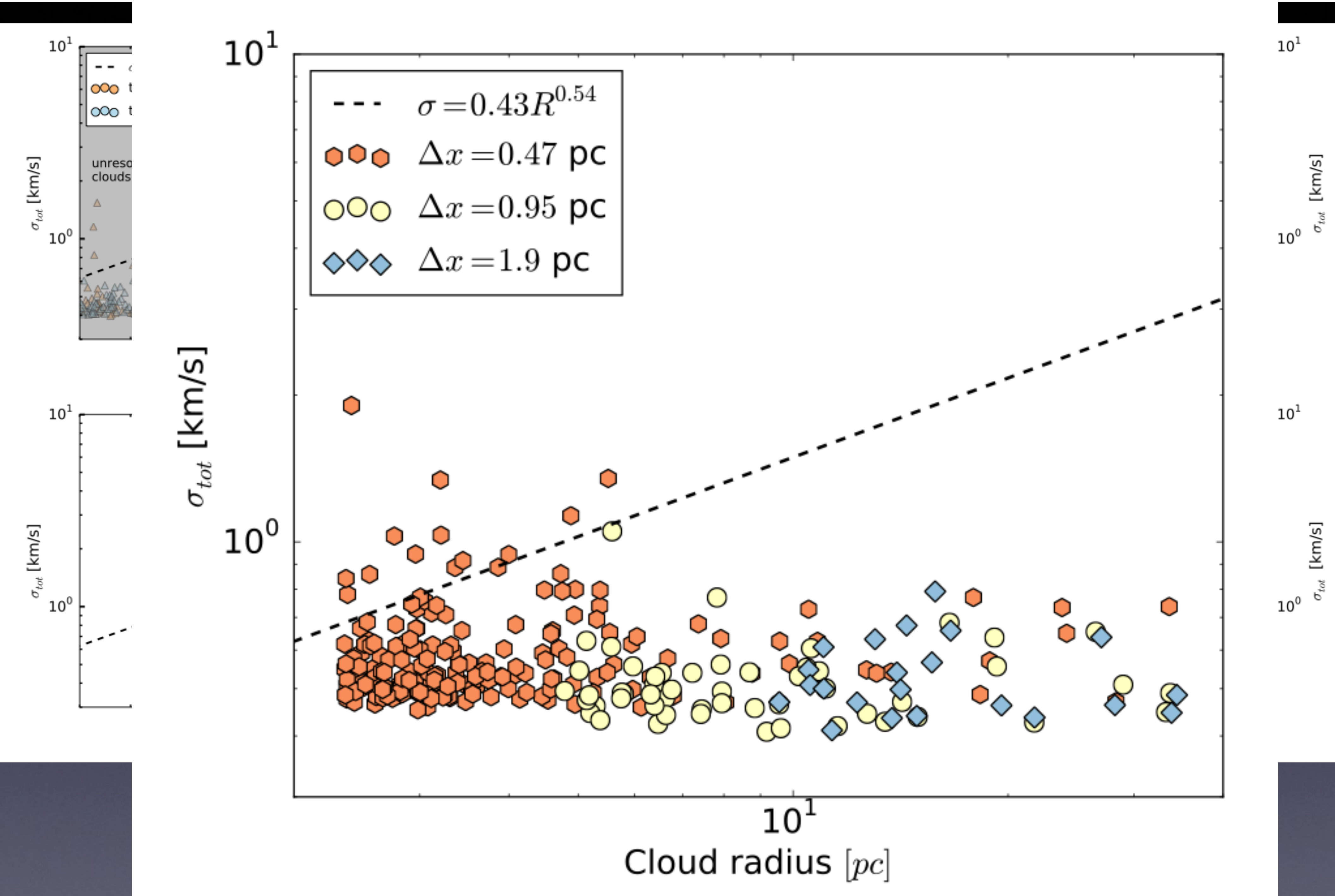
Self-gravitating evolution



Ibáñez-Mejía + 16

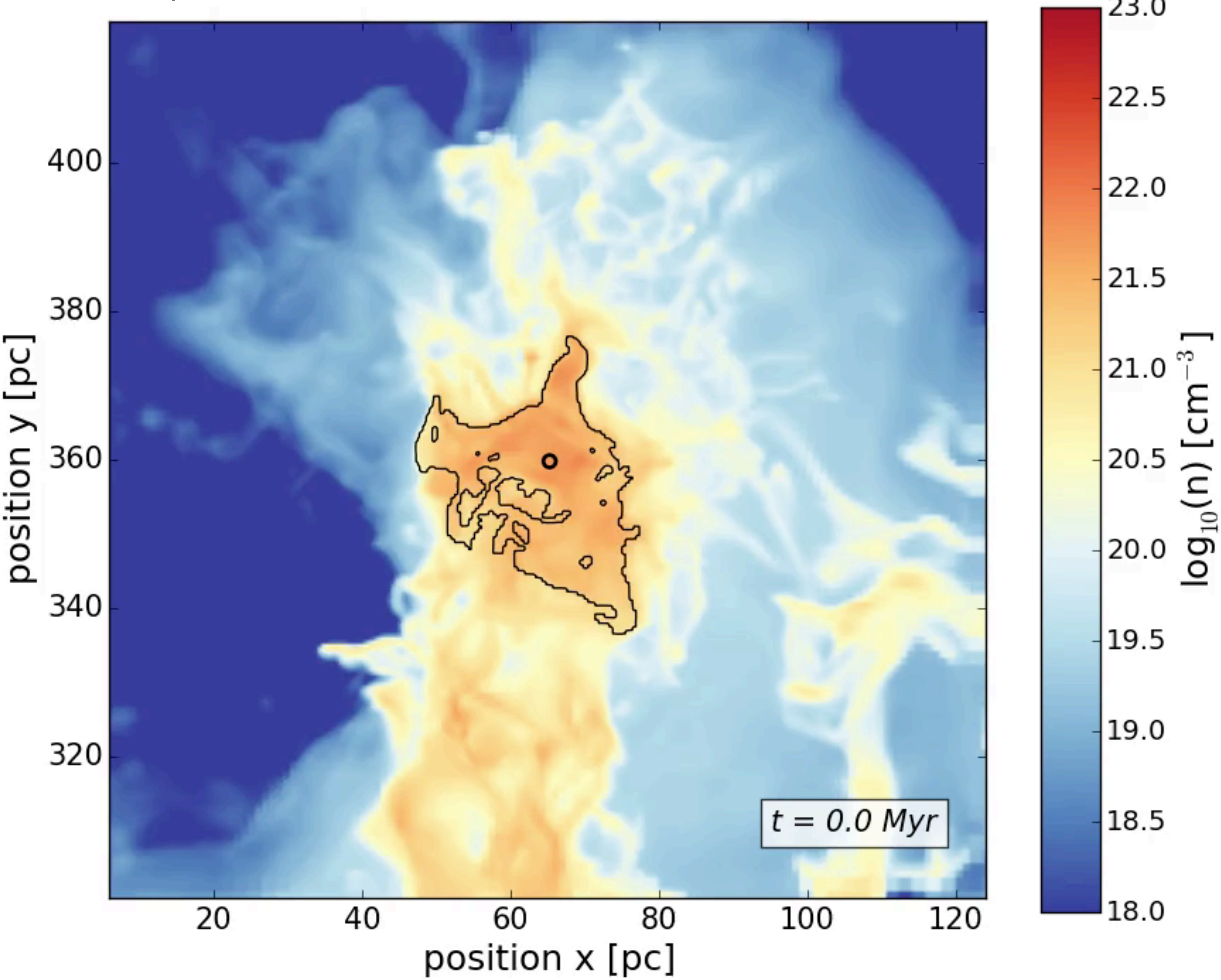


Ibáñez-Mejía + 16



Ibáñez-Mejía + 16

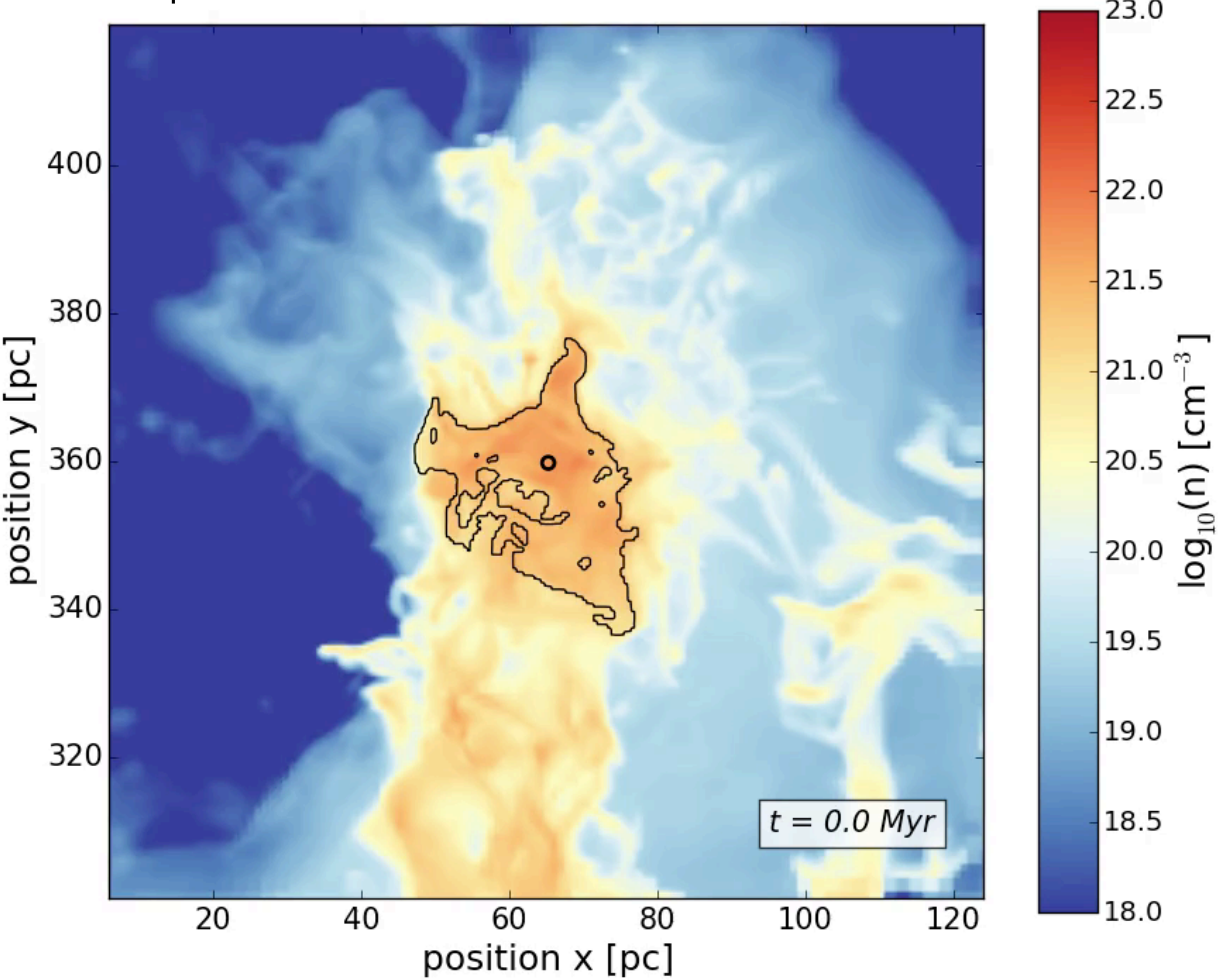
Δx = 0.12 pc



Ibáñez-Mejía + 16b

M8e3

Δx = 0.12 pc



Ibáñez-Mejía + 16b

M8e3

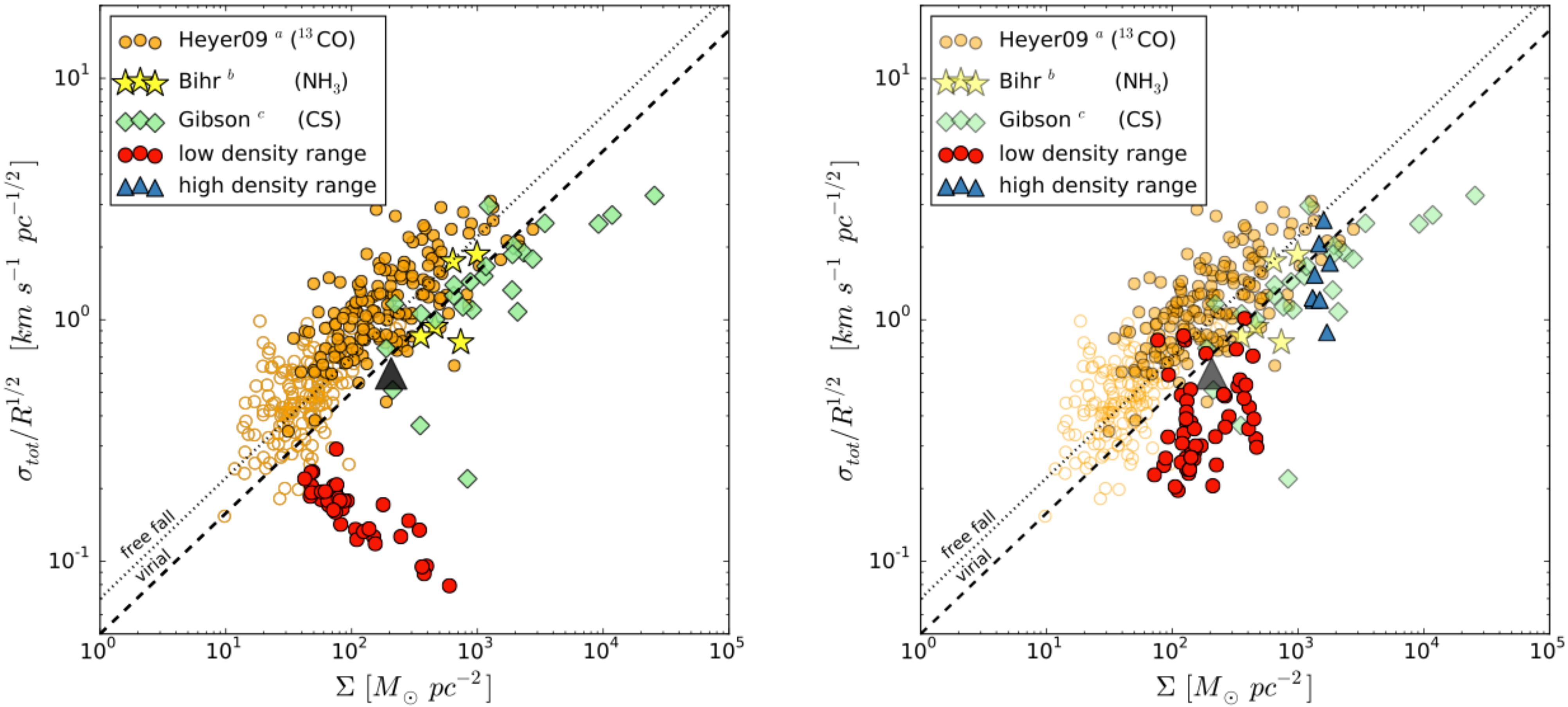


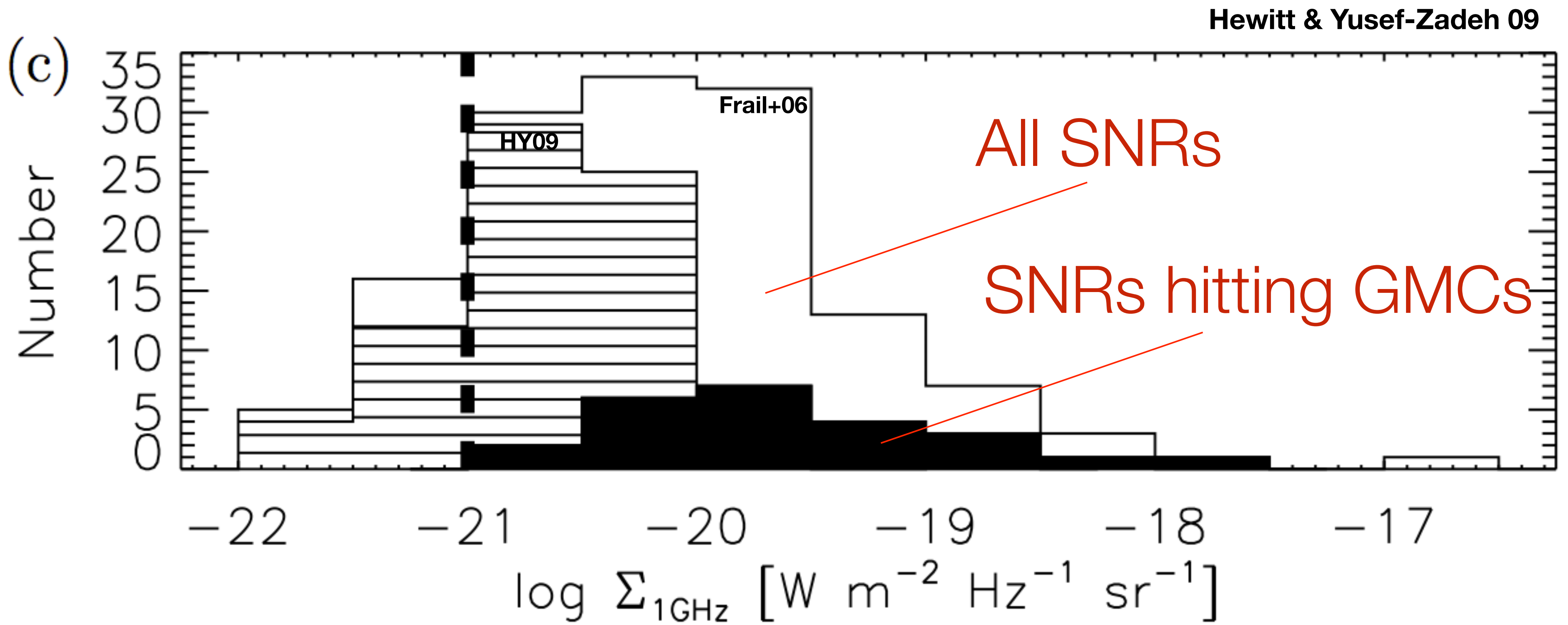
Figure 10. Velocity dispersion-radius-surface density ($\sigma - R - \Sigma$) scaling relation for observations and simulations of MCs, clumps, and cores in the Galaxy. Both plots show (orange open and filled circles) observations in ^{13}CO reported by Heyer et al. (2009); (light green diamonds) Galactic infrared-dark clouds observed in CS (Gibson et al. 2009); and (yellow stars) infrared dark clouds observed with NH_3 (Bihr et al. 2015). The black triangle shows the constant value of the column density reported by Solomon et al. (1987) in their size-density relation. The left plot shows the simulated objects **captured by the** low (red circles) and high (blue triangles) density ranges at $t_{SG} = 0$. The right plot contains the evolved population of simulated clouds and clumps for low (red circles) and high (blue triangles) density ranges. Clumps are always denoted with triangles because they are lower limits for the velocity dispersion, upper limits for the cloud radius **and the surface density.** The dashed and dotted lines correspond to the relation $\sigma/R^{1/2} \propto \Sigma^{1/2}$, where the dashed line corresponds to the velocity dispersion for a uniform spherical cloud in virial equilibrium and the dotted line the apparent velocity dispersion for a cloud in free-fall collapse.

Ibáñez-Mejía + 16

Accretion drives Larson's size-velocity relation. Turbulence drives the scatter.

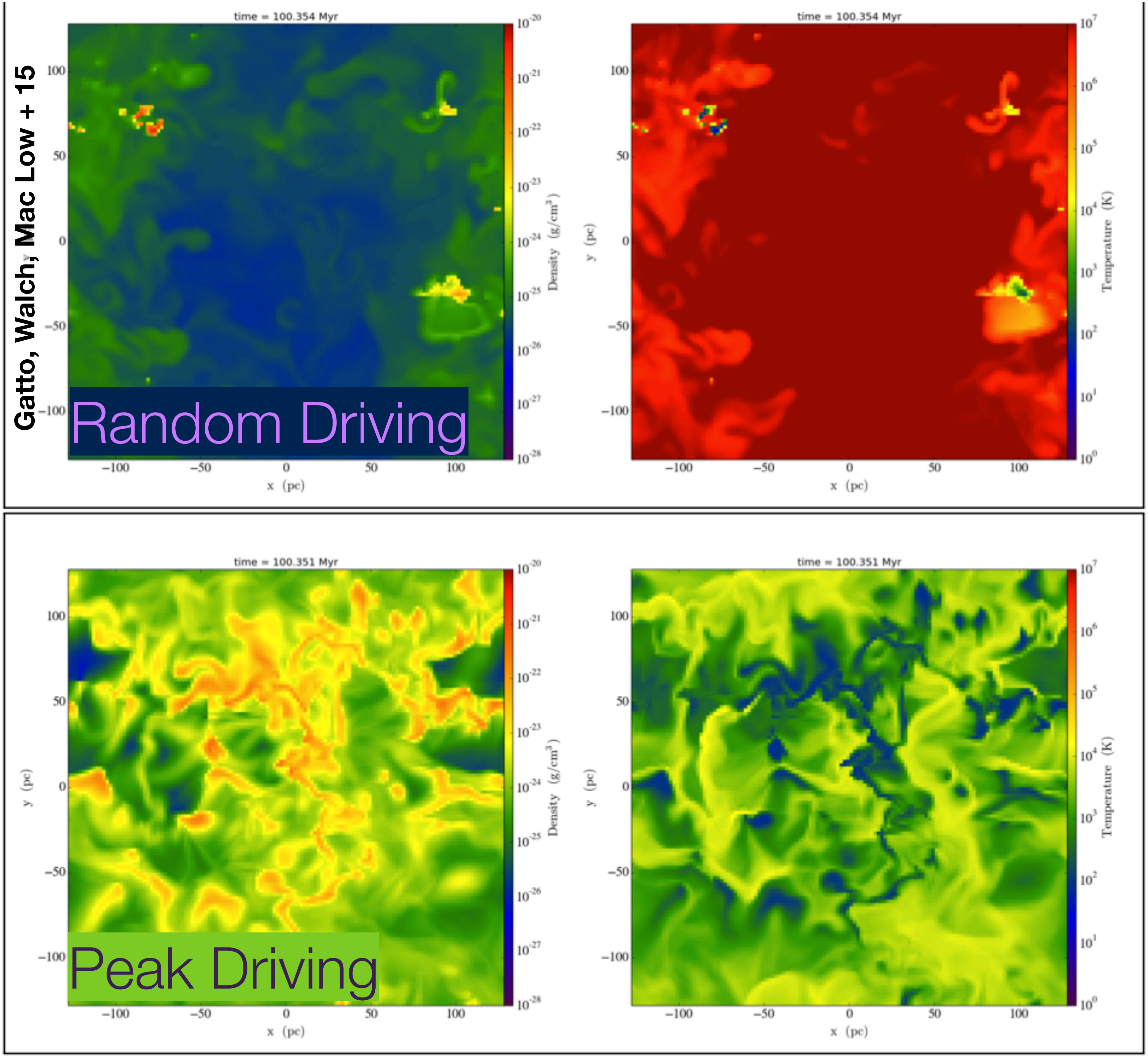
Molecular clouds appear to form quickly by gravitational instability and begin forming stars just as quickly.

This leaves open the question of why star formation remains inefficient. Rapid feedback, which we are now working on simulating, must be important.



Only 10% of identified SNRs interact with molecular gas (traced here by OH maser emission, but also seen with TeV γ-ray emission by Fukui+ 03)

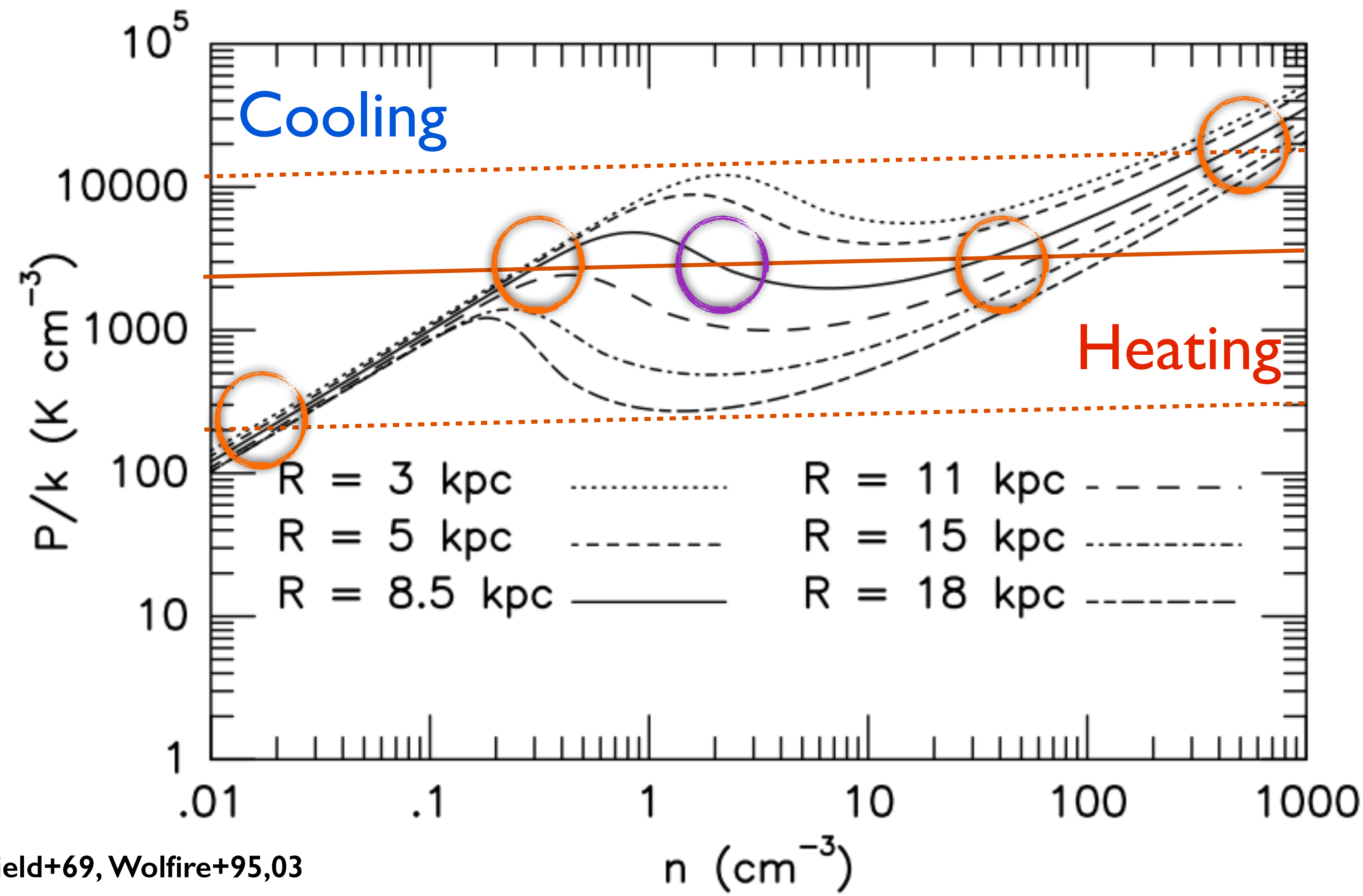
Many more SNRs are hidden in superbubbles (e.g. Chu & Mac Low 90)



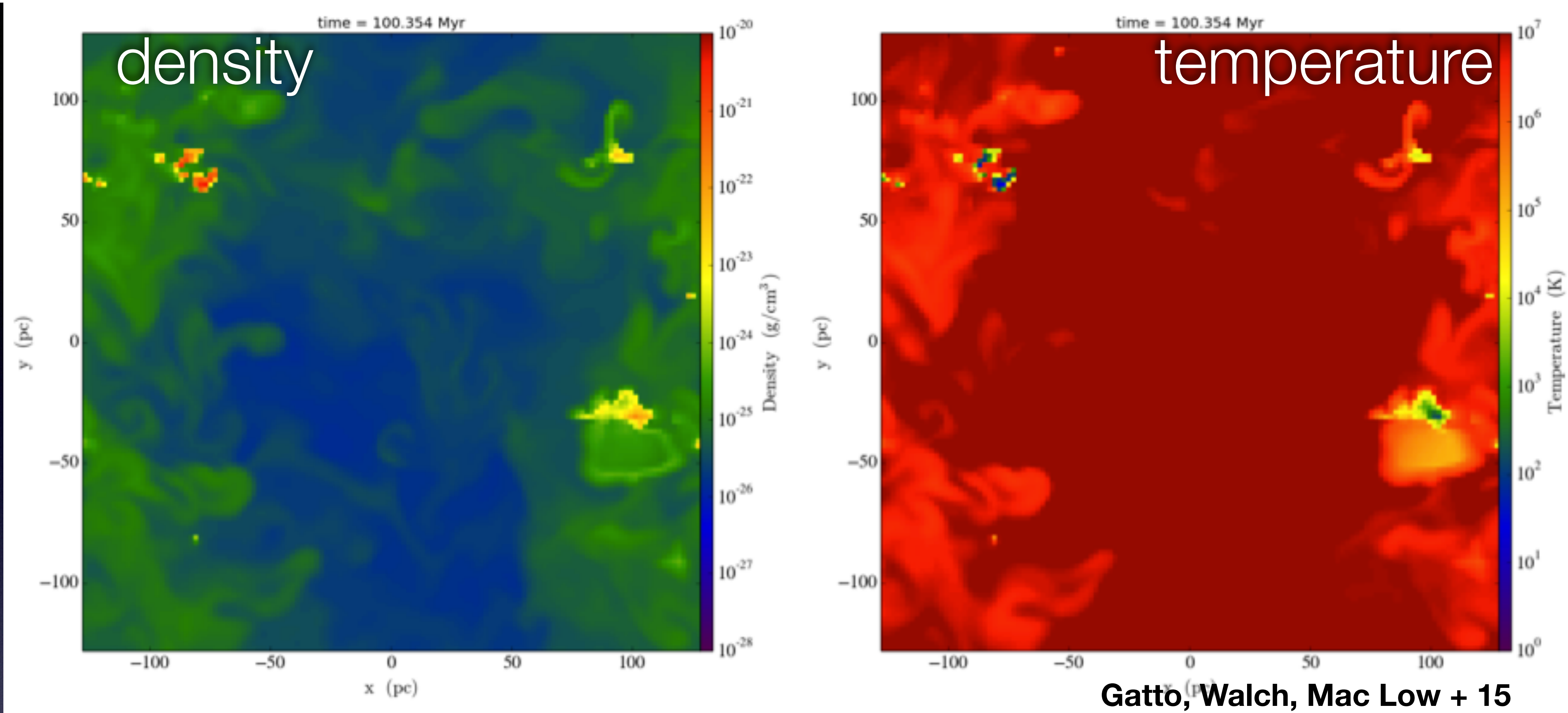
Also seen by comparing
Joung & Mac Low 06
to
Avillez & Breitschwerdt 04

see *Miao Li* talk as well (and Li+15)

Thermal equilibrium between FUV stellar heating and radiative cooling can result in a two phase medium



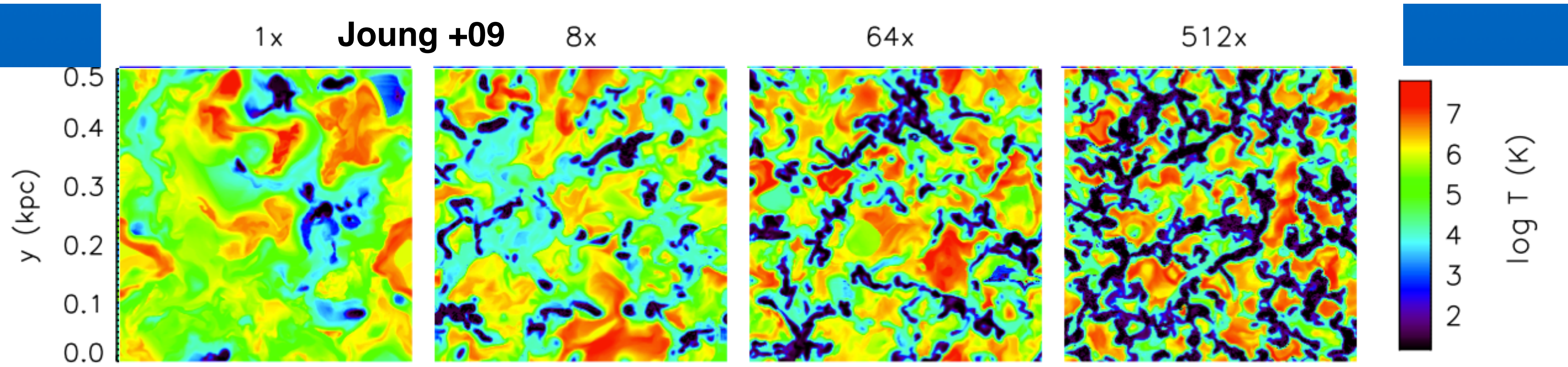
Field+69, Wolfire+95,03



Example of a high-pressure simulation with all mass in tiny, dense, clumps.

Pure cold phase has huge volume filling factor of hot gas, leading to thermal runaway from supernova heating (Gatto + 15, Miao Li + 15)

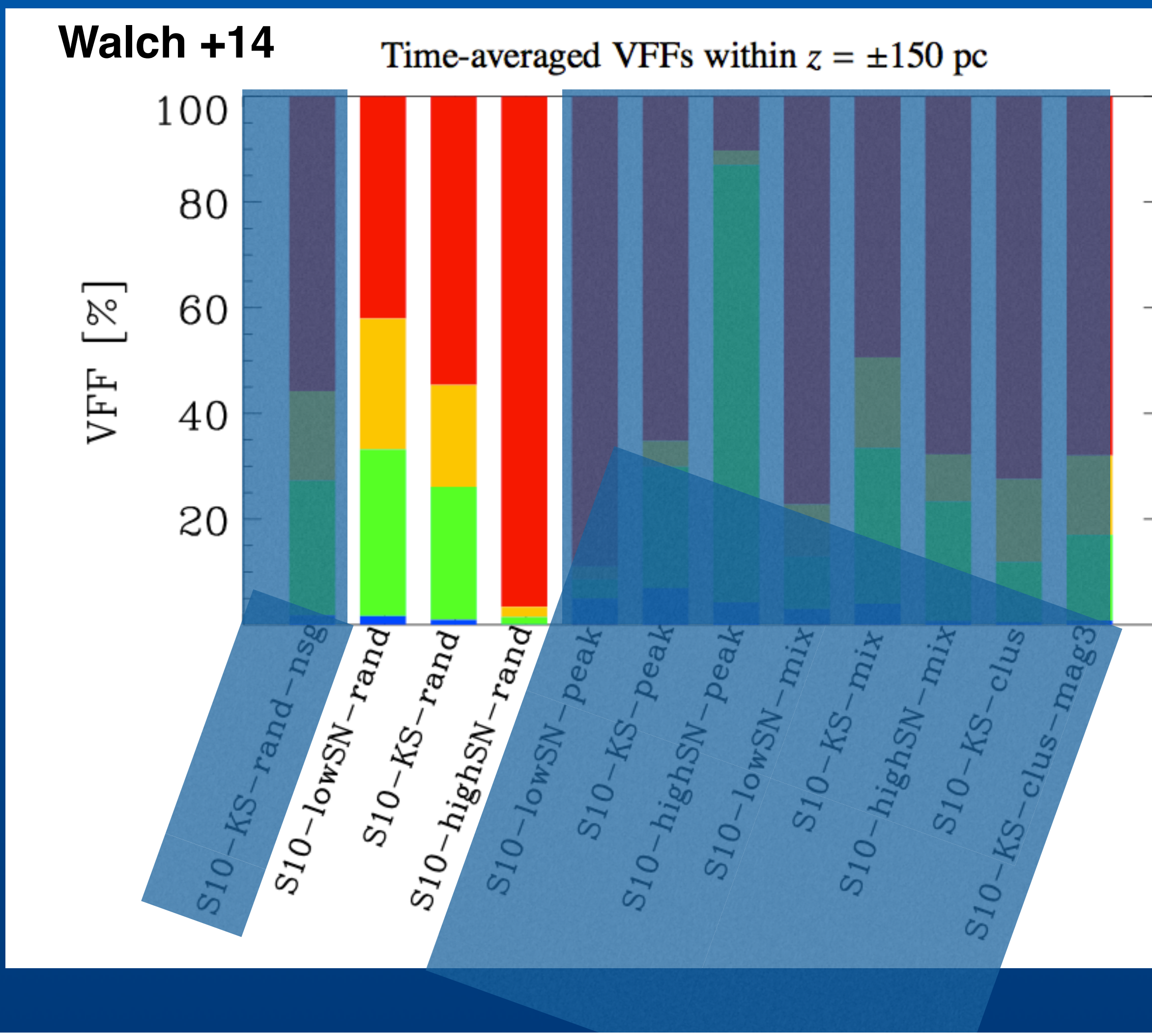
Massive, gas rich, high-pressure, molecular disks might be in this phase (Hill + 16, in prep)

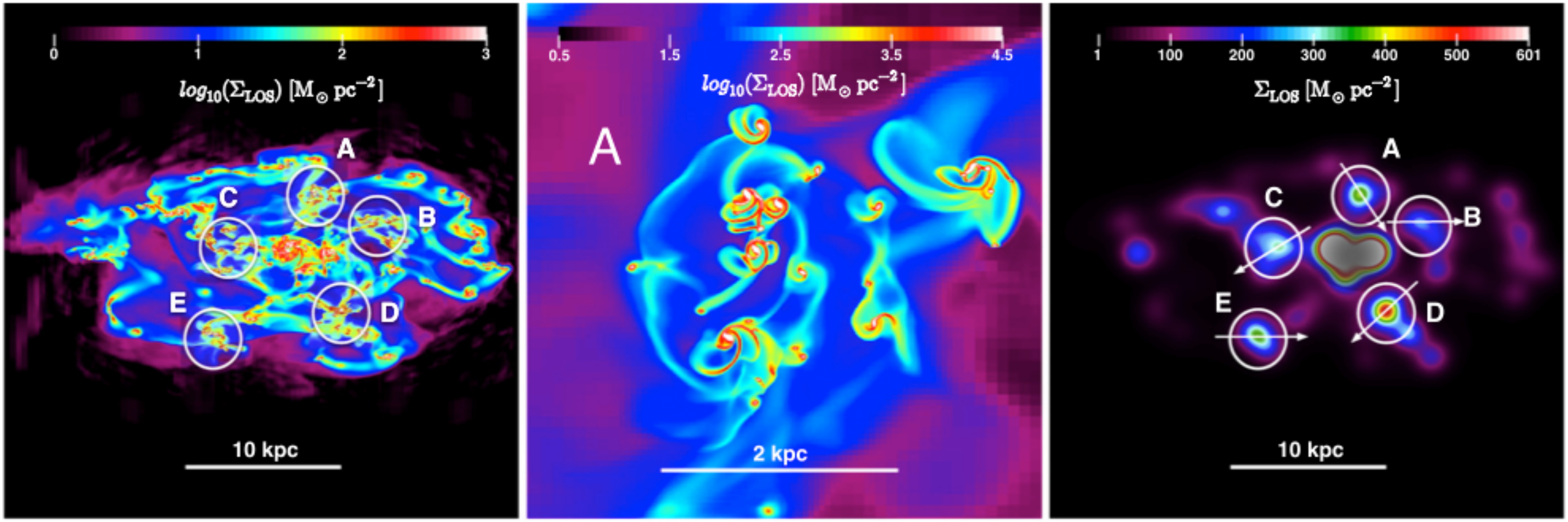


Following the Kennicutt-Schmidt relation results in three-phase ISM,

but

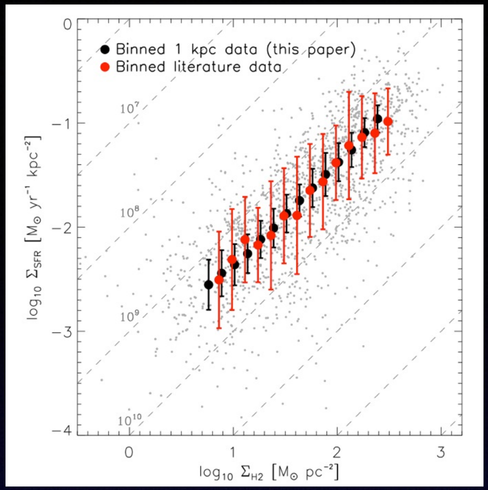
increasing SN rate (= SFR) by factor of three leads to thermal runaway and a cold ISM filled with hot gas.





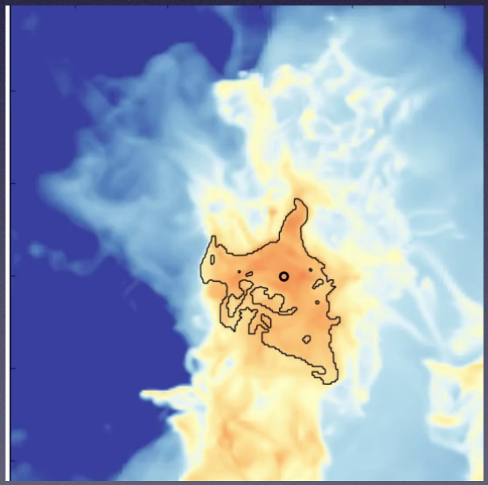
(a) Gas surface density (b) Zoom onto cluster A (c) Gas surface density beam smeared

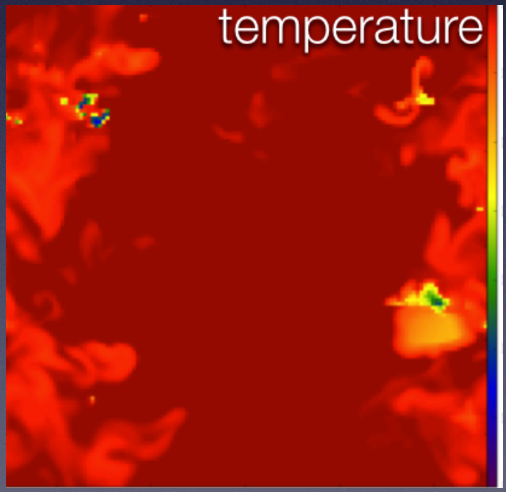
Massive clumps likely to have hierarchical substructure so they are better thought of as clump clusters, again with low filling factor of cold, dense gas.



H_2: tracer if metals present

LCBGs analogues of high-*z* galaxies





Clouds collapse hierarchically: SFE from feedback?

SN placement and rate can determine phases.