Formation of the first massive star clusters

and their feedback on galaxies at z > 3

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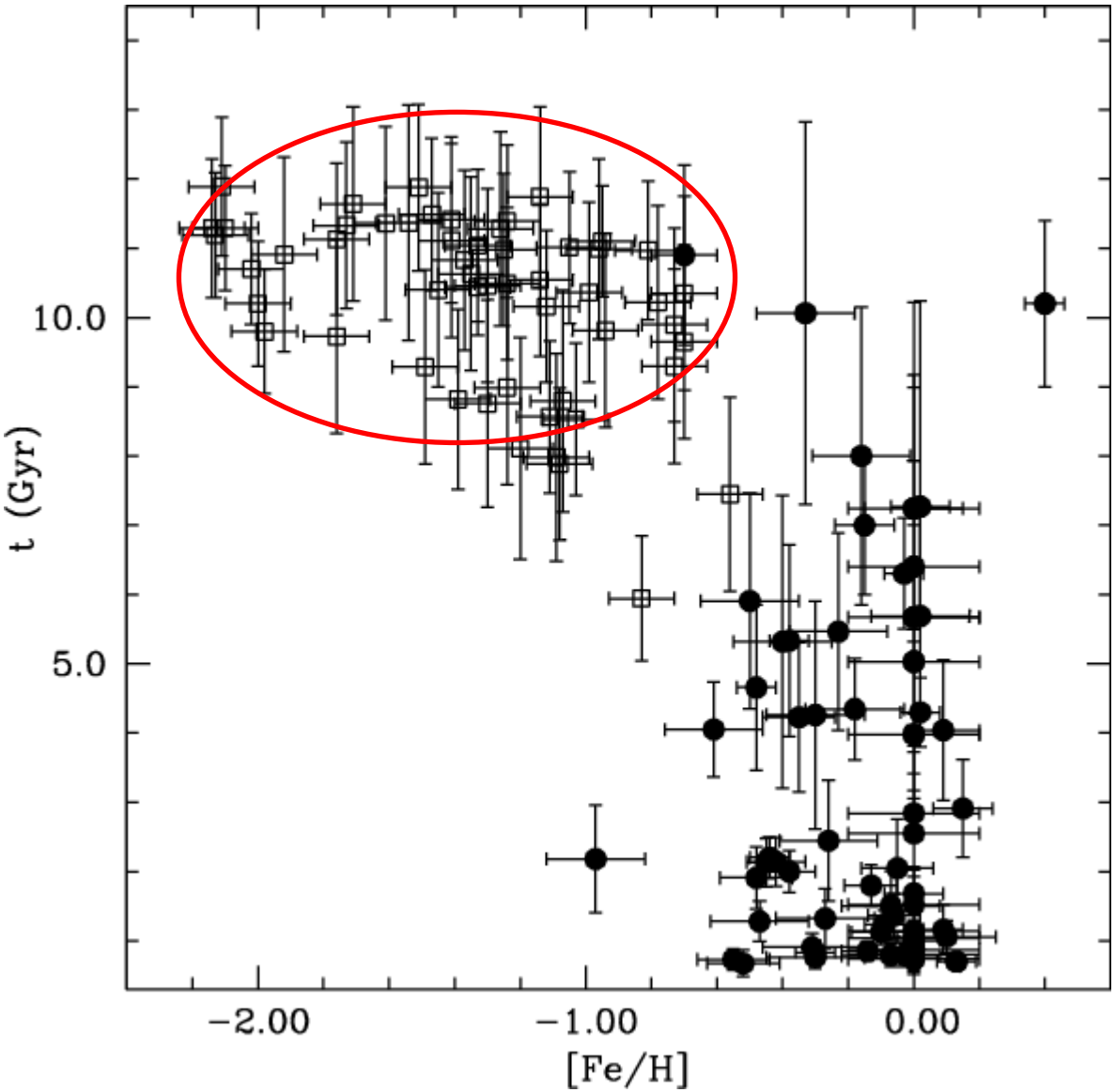
every old cluster was young sometime

~~how ?~~

when ?

where ?

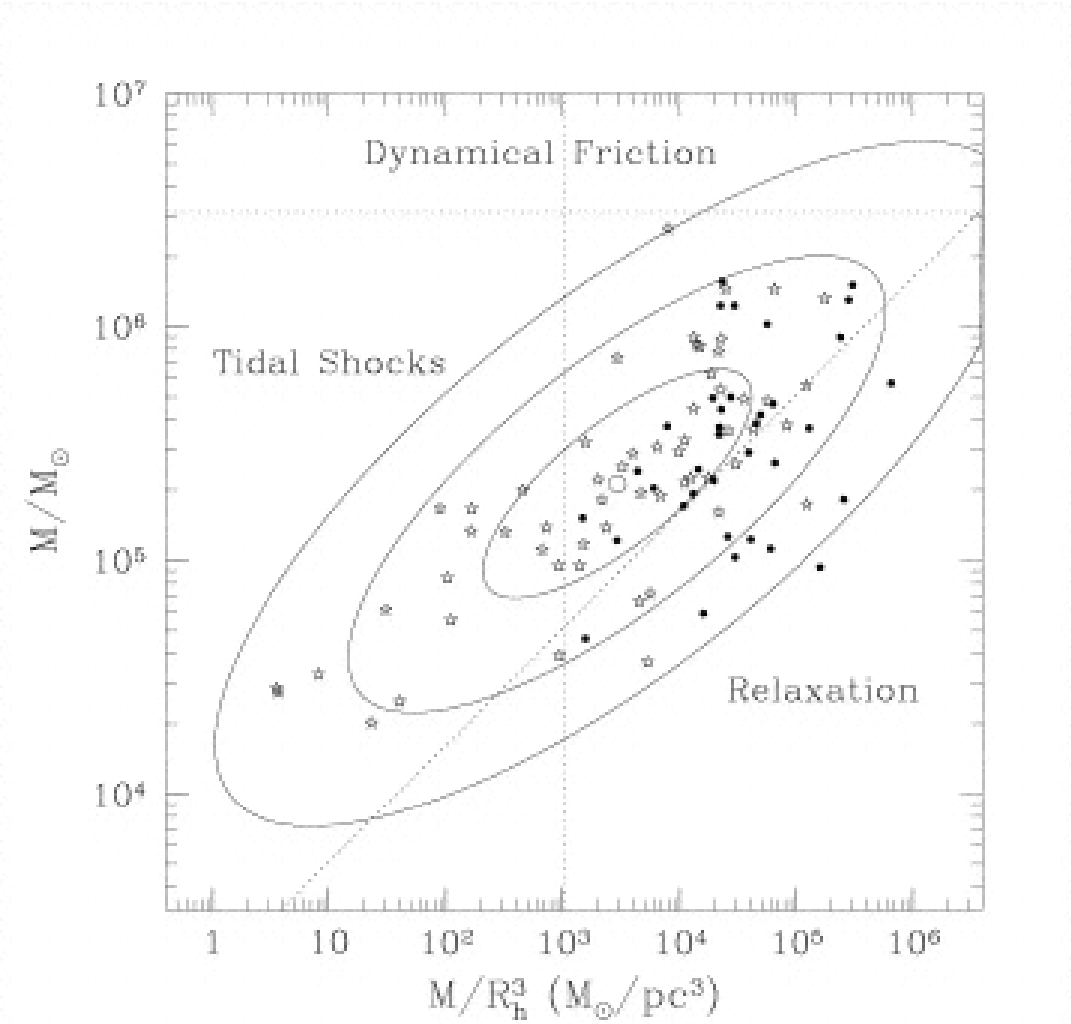
globular clusters are old and low (but non-zero) metallicity



Percival & Salaris

globular clusters are dense

mass



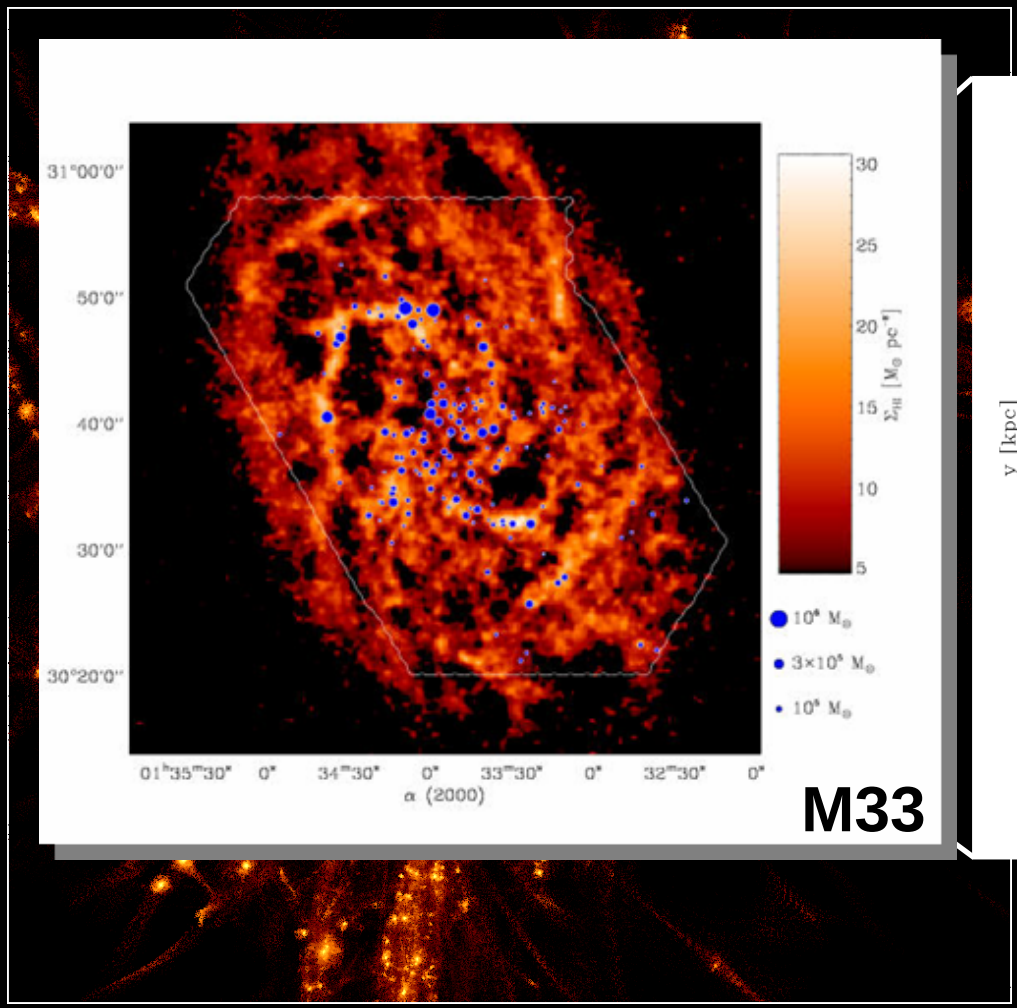
Average density at half-light radius ~ 10^2 – 10^5 $M_\odot$ pc^{-3}

The Monoceros R2 Molecular Cloud Complex

Two Micron All Sky Survey
– Southern Facility –
2MASS Atlas Image Mosaic

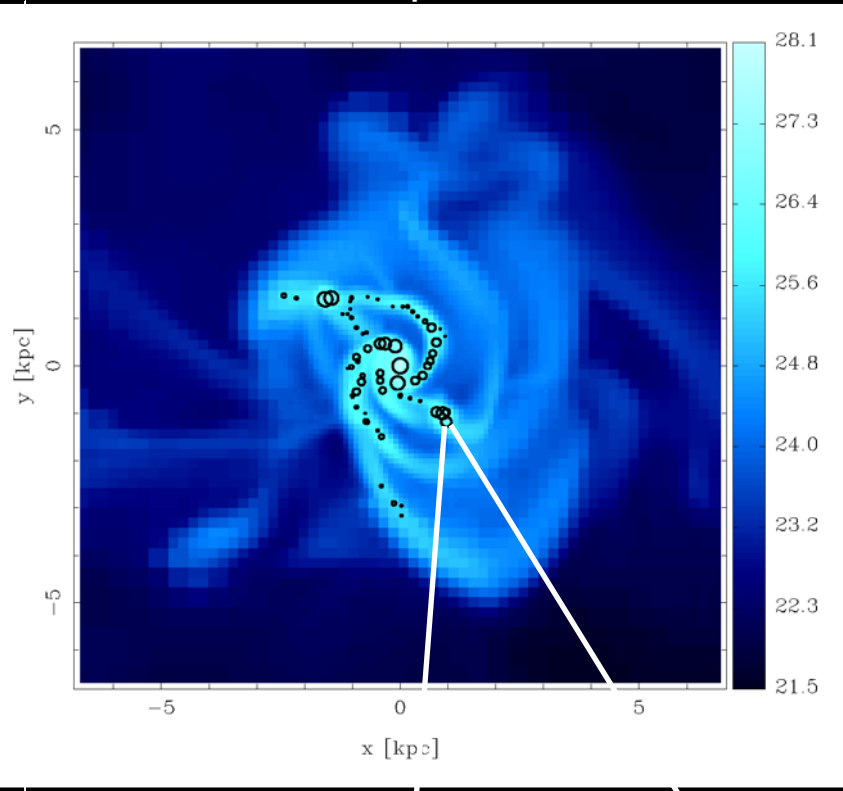
Infrared Processing and Analysis Center & University of Massachusetts

Use hydrodynamic simulations to find molecular clouds



300 kpc (physical)

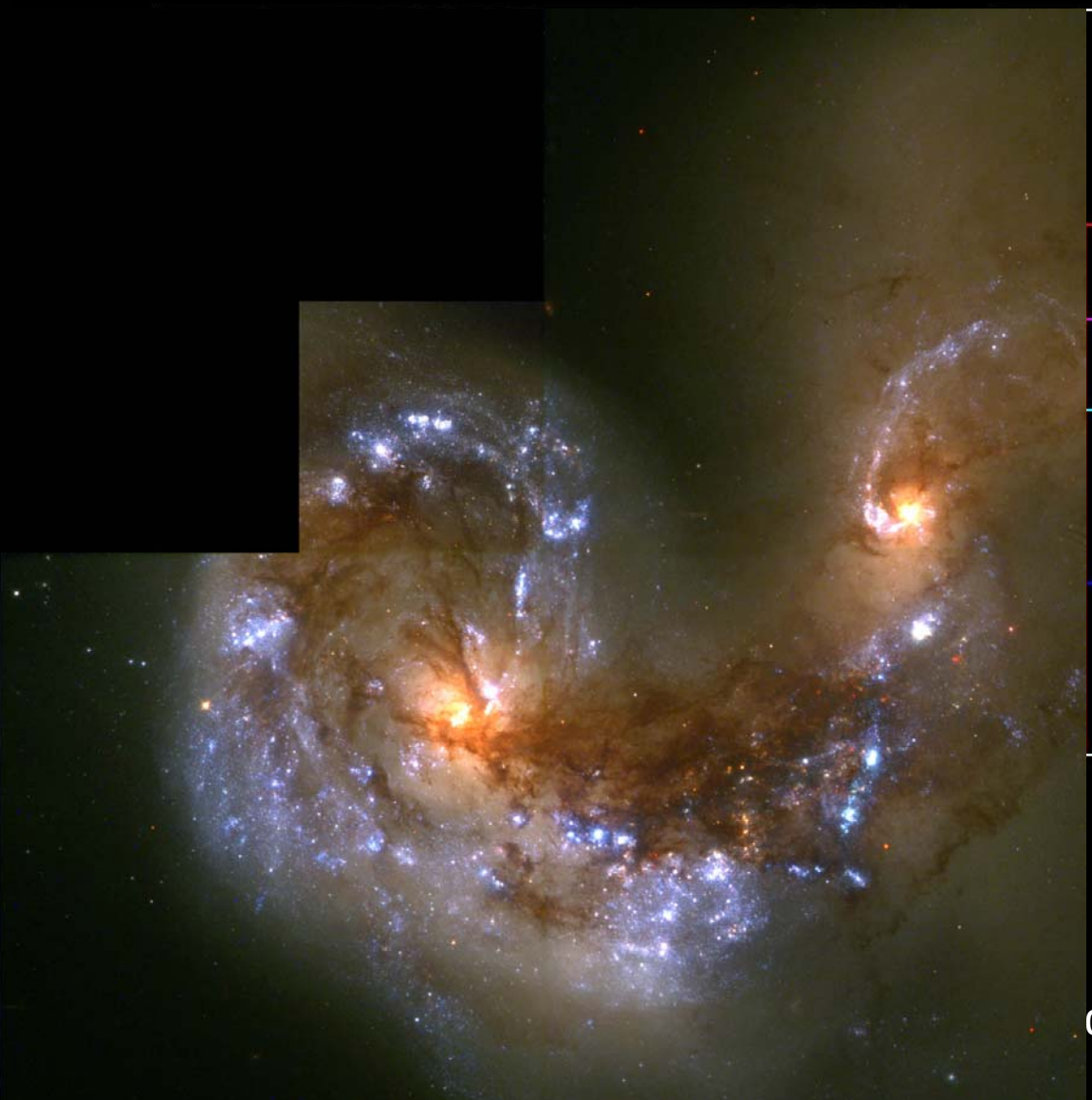
14 kpc

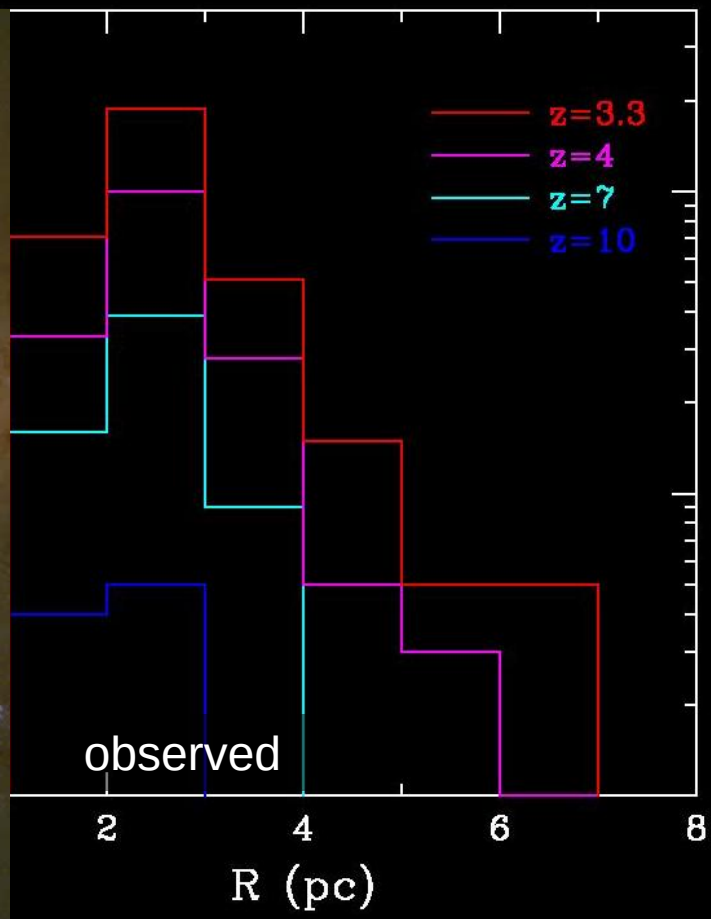


20 pc

Kravtsov & OG (2005)

Masses and sizes of model GCs are in excellent agreement with the observations of young clusters



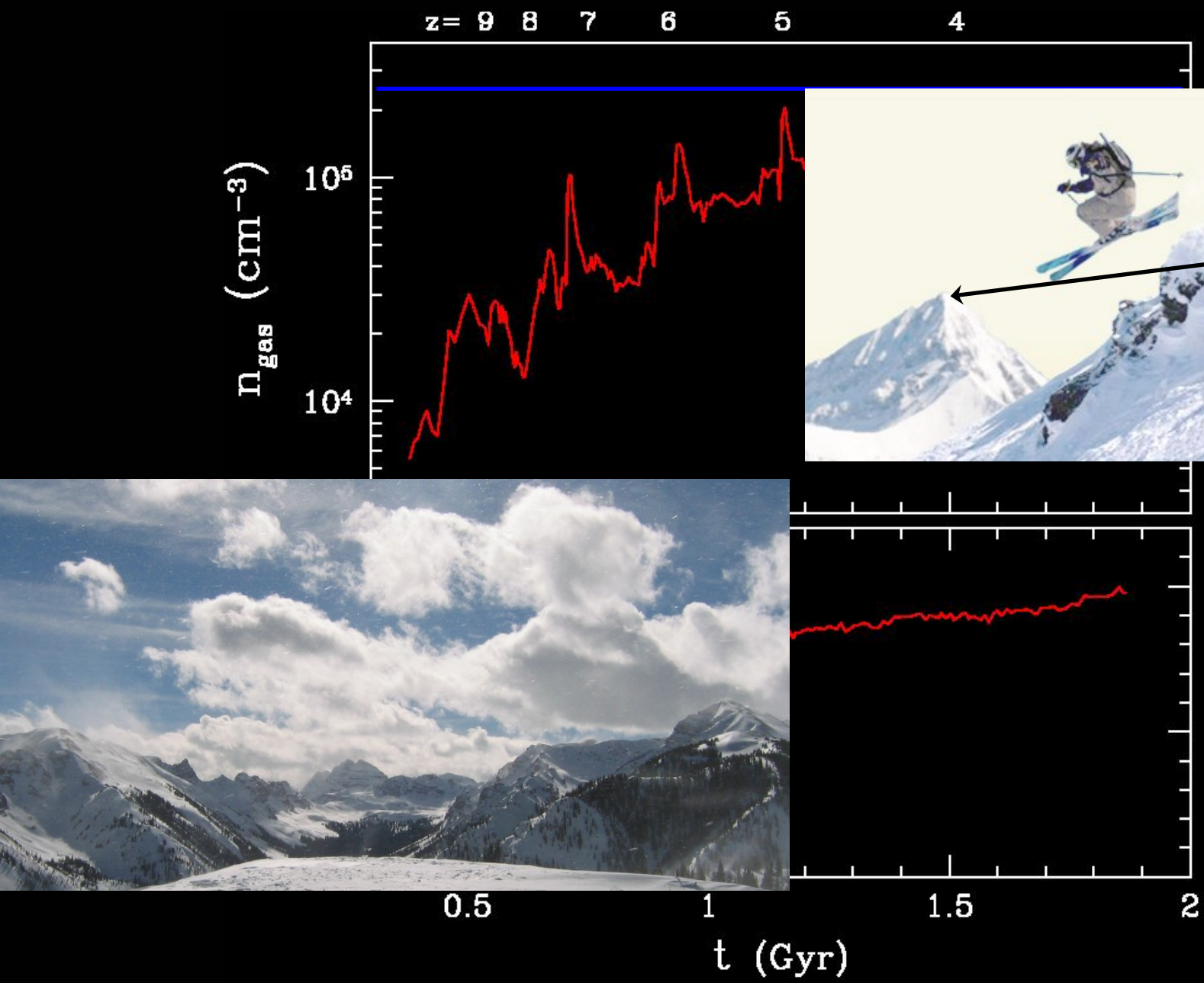


d by a given epoch)

young star clusters in the Galaxy form in self-gravitating cores of molecular clouds with $\rho_{gas} > 10^4\ M_\odot\ pc^{-3}$

these cores contain only a few % of the H_2 mass $\Rightarrow$ globular clusters probe the highest peaks of the density field

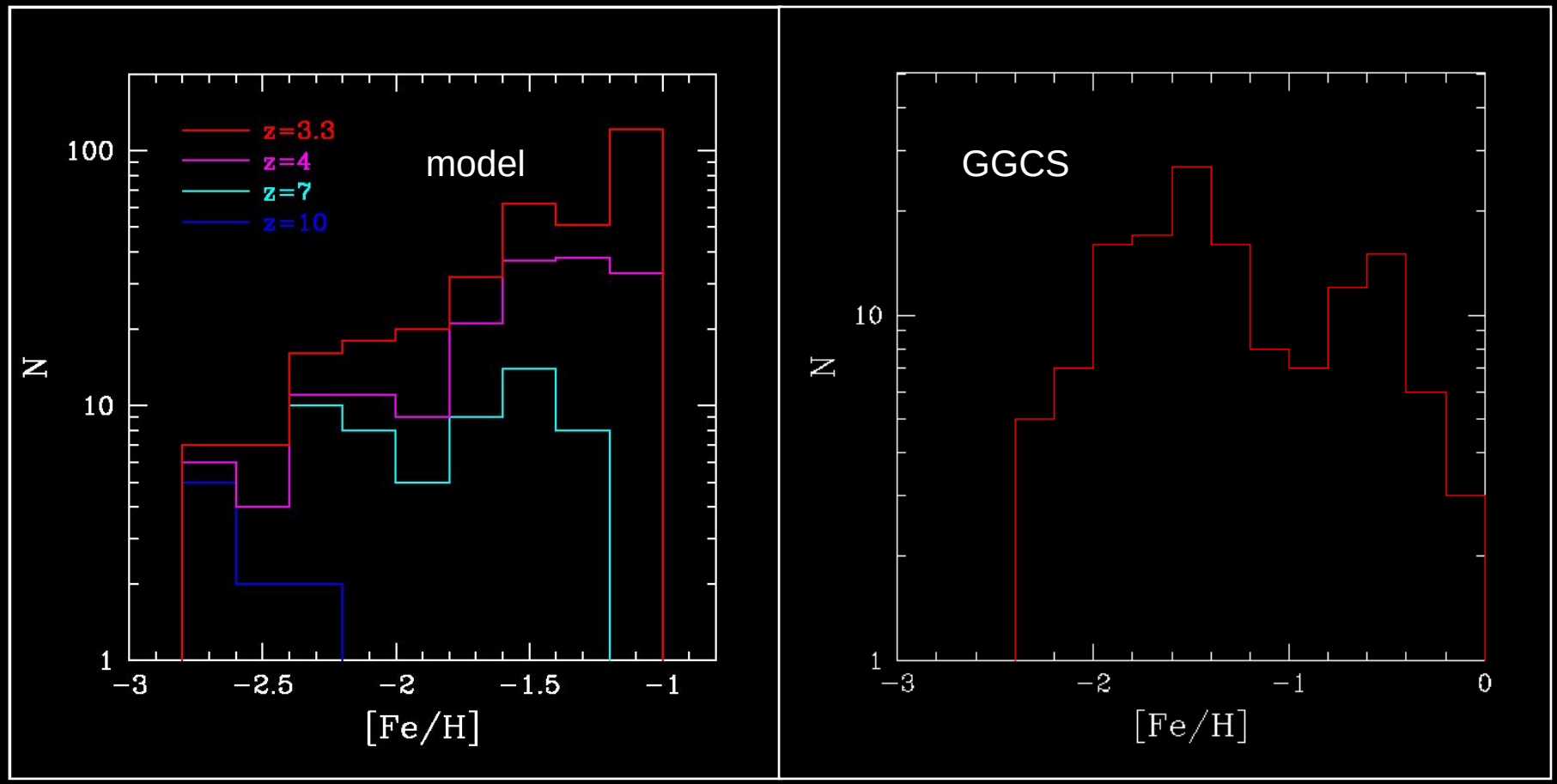
Globular clusters at redshifts above 3 or 4 ?



peak of global SF

density!

metallicities at z > 3 are barely high enough for blue GCs

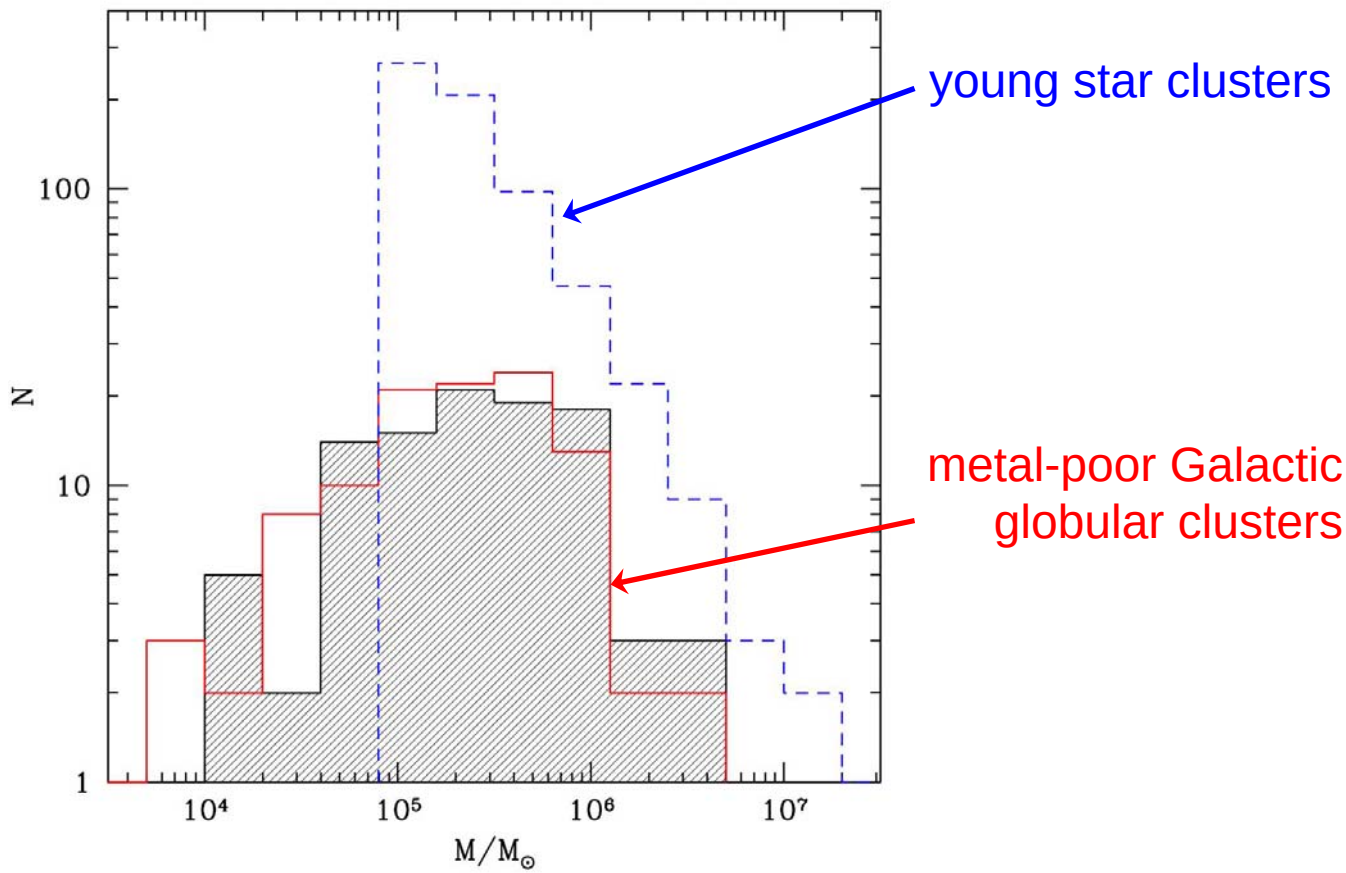


large range of metallicities of GCs formed at the same epoch: up to two orders of magnitude

Dynamical evolution removes most low-mass clusters

Jose Prieto & OG (2007)

Stellar evolution + relaxation + tidal shocks

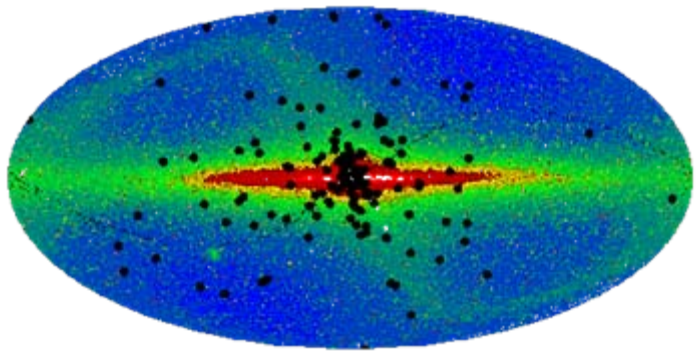


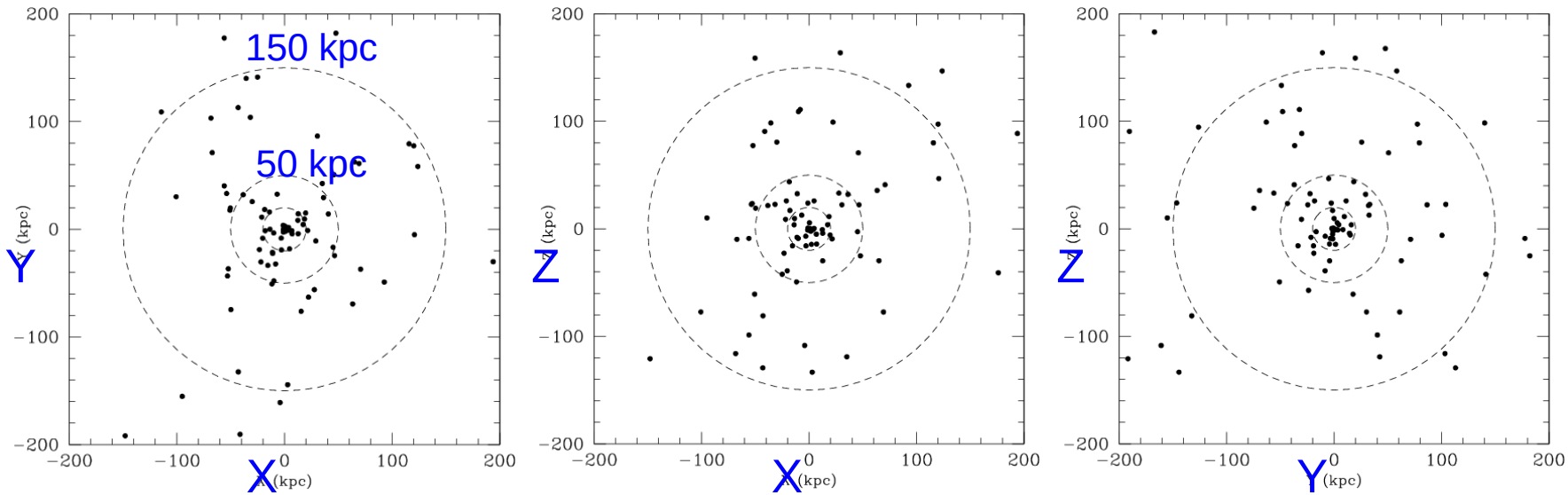
final/initial mass = 0.46 final/initial number = 0.16

Mergers of host galaxies of GCs result in a spheroidal distribution of the overall GC system *now*

number density is consistent with a power-law, slope ≈ –2.7

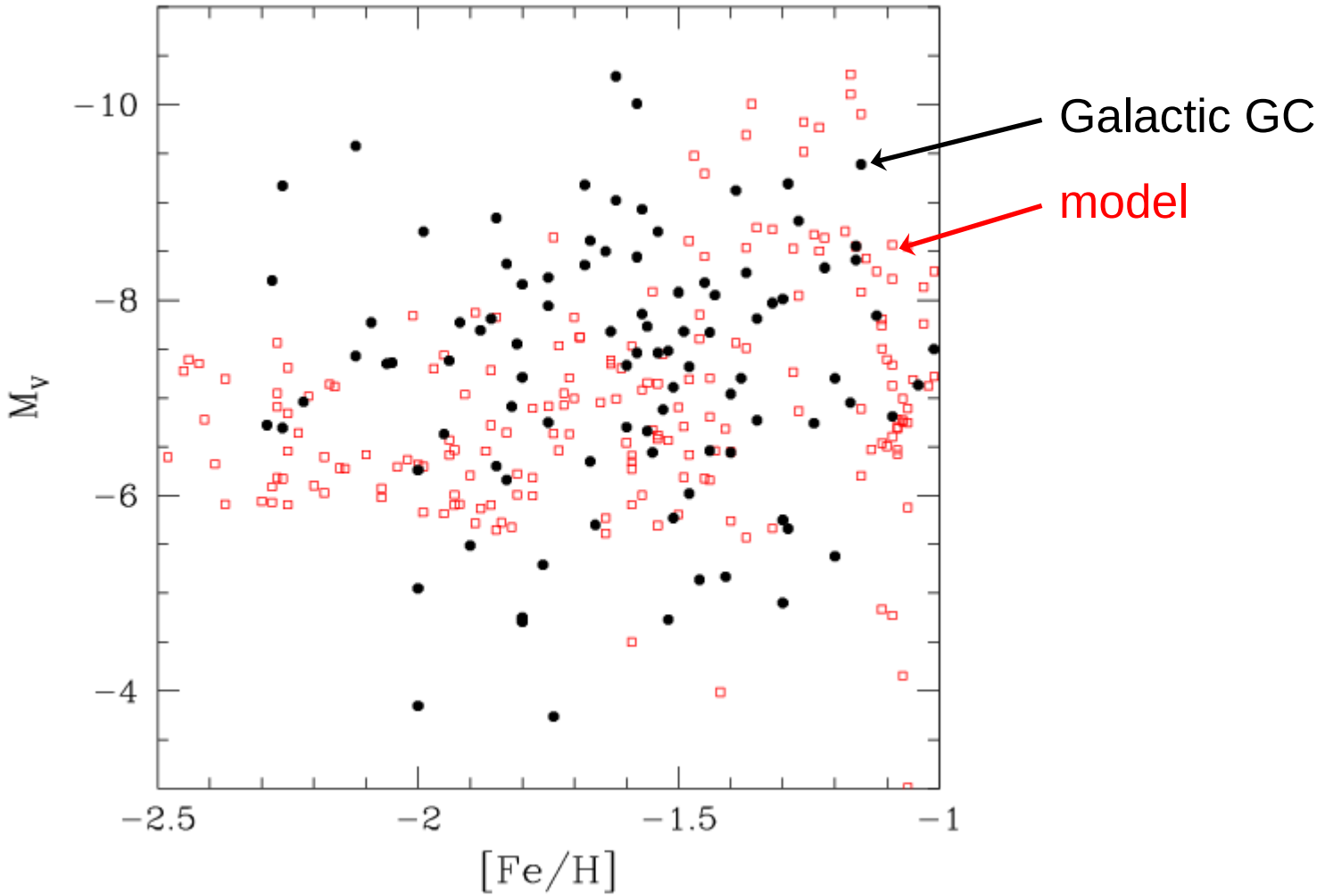
(observed ≈ – 3)





Luminosity-metallicity distribution is also ok

Sasha Muratov & OG, in prep.



Feedback of young star clusters on their host galaxies

Young clusters for 5 Myr after formation have ionizing luminosity $\lambda L_\lambda \sim 10^8\ L_\odot$ ($\sim 10^7\ L_\odot$ for 10 Myr)

Luminous O and B stars ionize and heat the high density regions of parent molecular cloud. Subsequent supernovae expand into the reduced density, partially ionized medium $\Rightarrow$ superbubbles

$$M_{\text{all GC}} \sim 3\ 10^6\ M_\odot\ (M_{\text{halo}}/10^{11} M_\odot) \sim 3\ 10^6\ M_\odot\ (M_{\text{bar}}/10^{10} M_\odot)$$

Young GCs can be directly detected in Lyα searches (for low [Fe/H] not much absorption by local dust)

– analogs of local super-starburst regions [Roderik Overzier talk]

Most massive clusters contain most massive stars:

- Likely sites for gamma-ray bursts and hypernovae
- Intermediate-mass black holes (gas accretion may lead to mini-quasars)