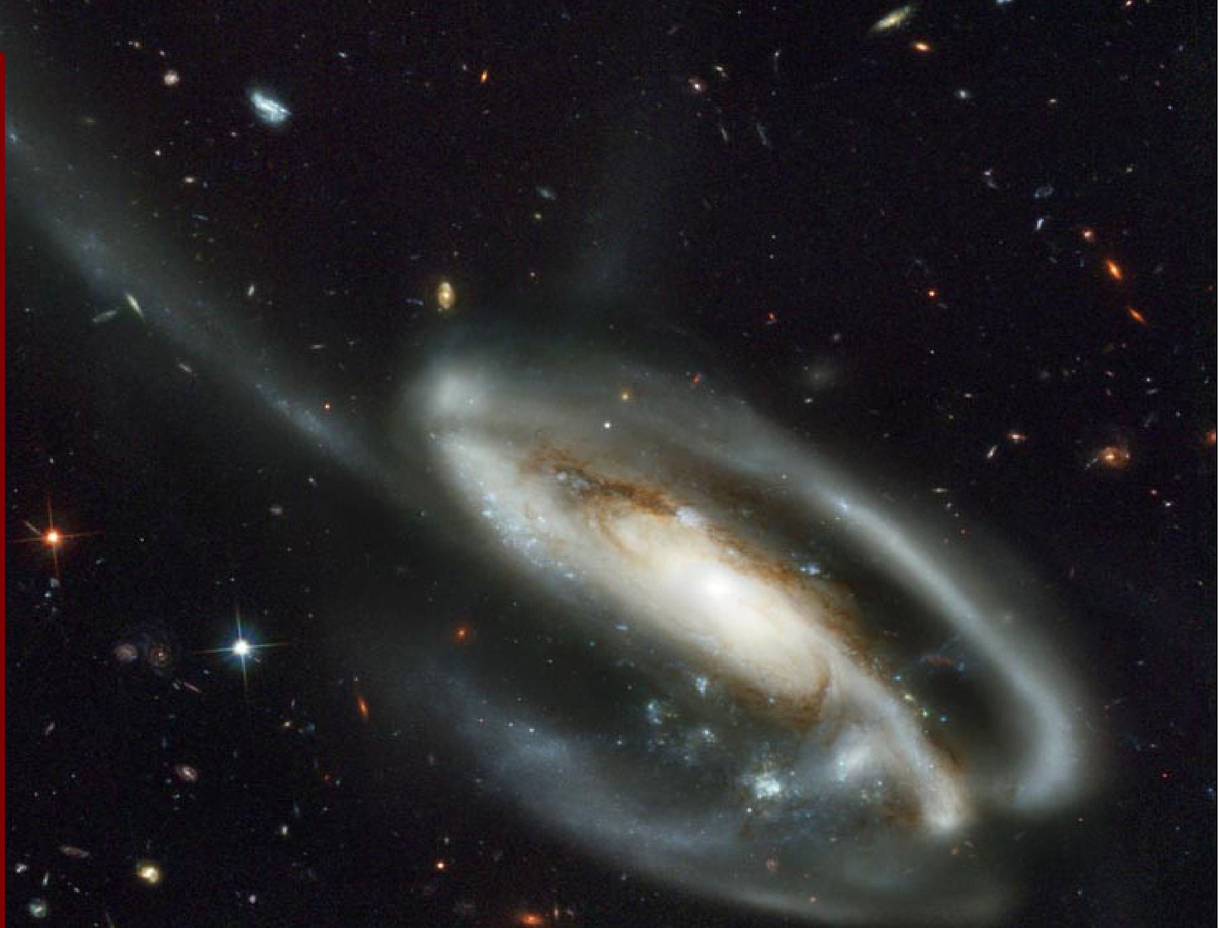
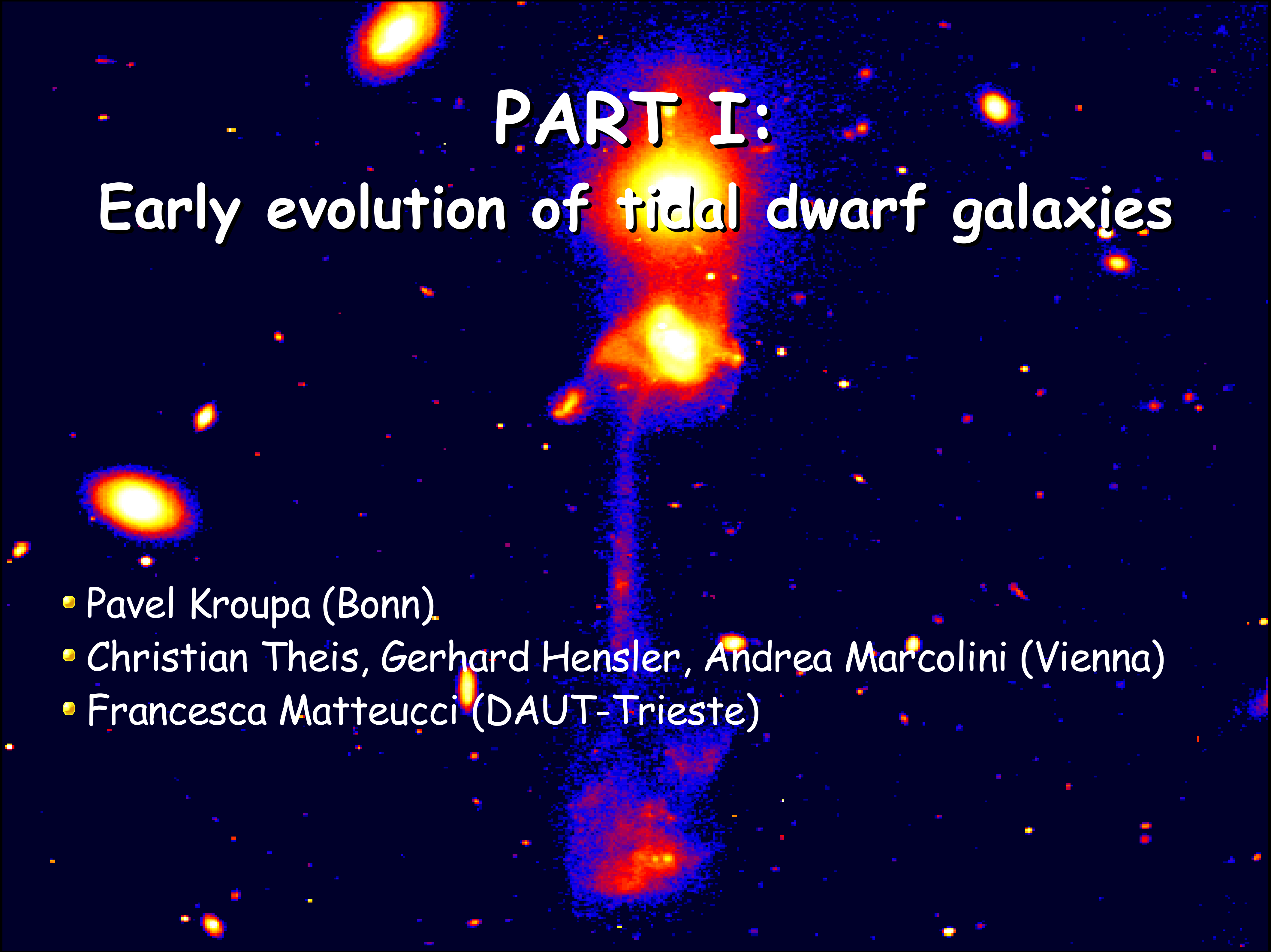
Early evolution of tidal dwarf galaxies

OATS-DAUT Seminar

Trieste, 22 / 11 / 2006

+ self-enrichment of globular clusters




PART I:
Early evolution of tidal dwarf galaxies
Pavel Kroupa (Bonn)
Christian Theis, Gerhard Hensler, Andrea Marcolini (Vienna)
Francesca Matteucci (DAUT-Trieste)

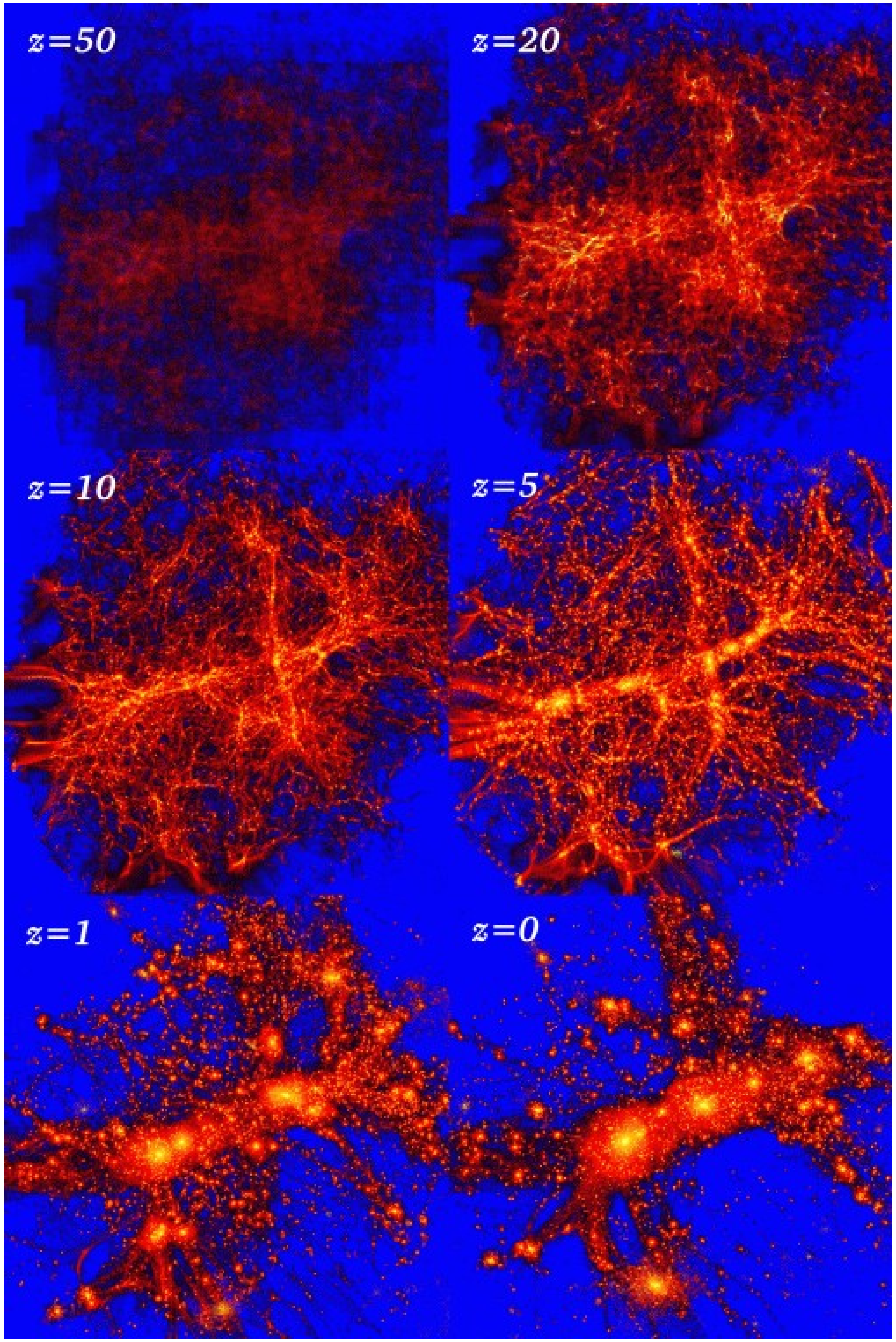
PART I:

Early evolution of tidal dwarf galaxies

outline:

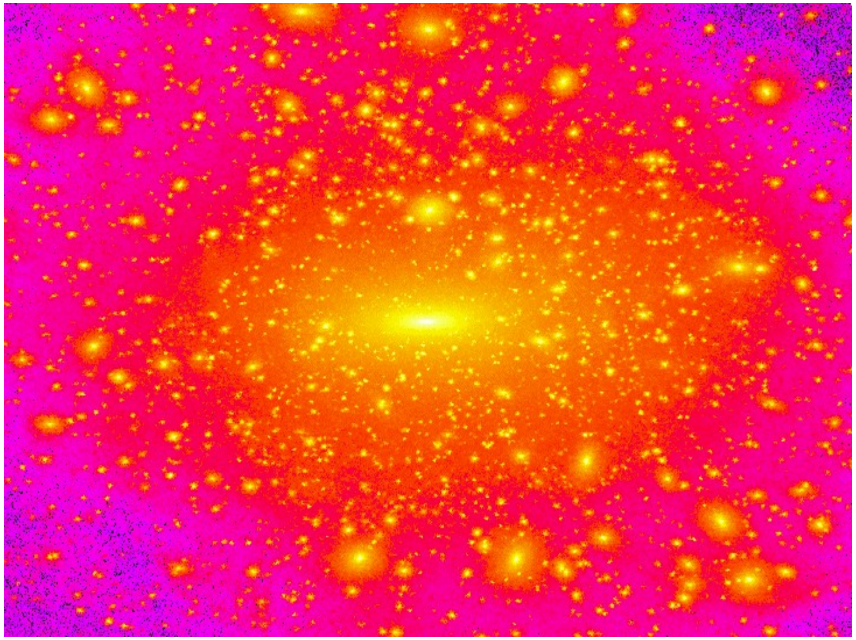
- The astrophysical context
- Investigation method
- Preliminary results

The hierarchical buildup of a Milky Way halo

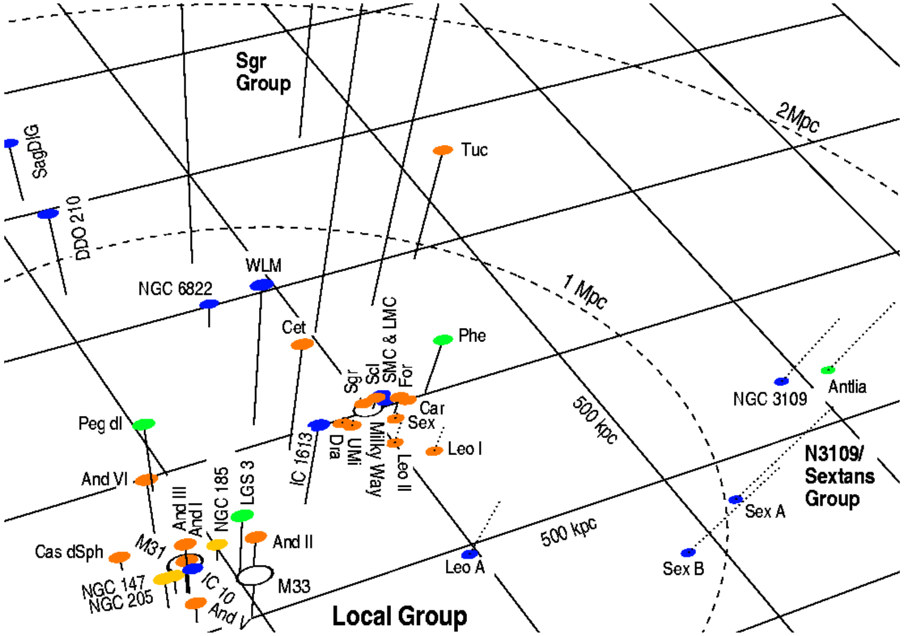


(from Ben Moore's web site www.nbody.net)

The "missing satellites" problem

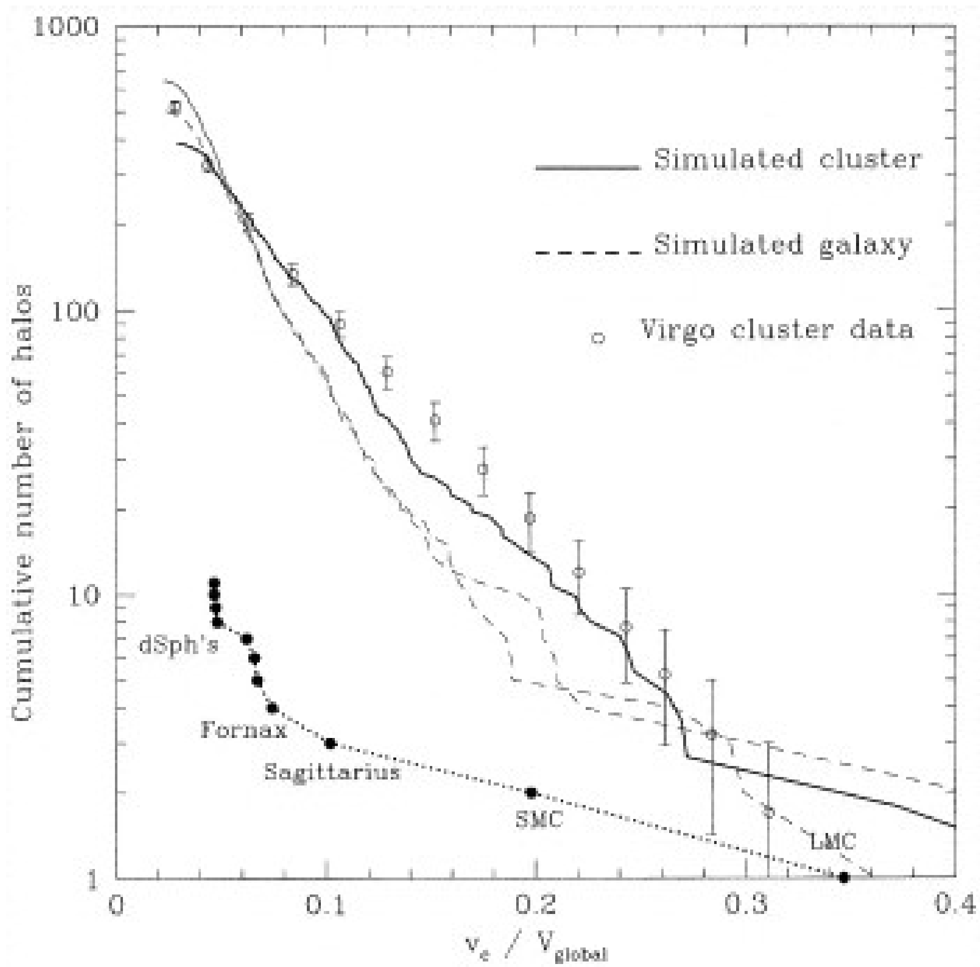


Ben Moore web site



Grebel (2000)

The "missing satellites" problem

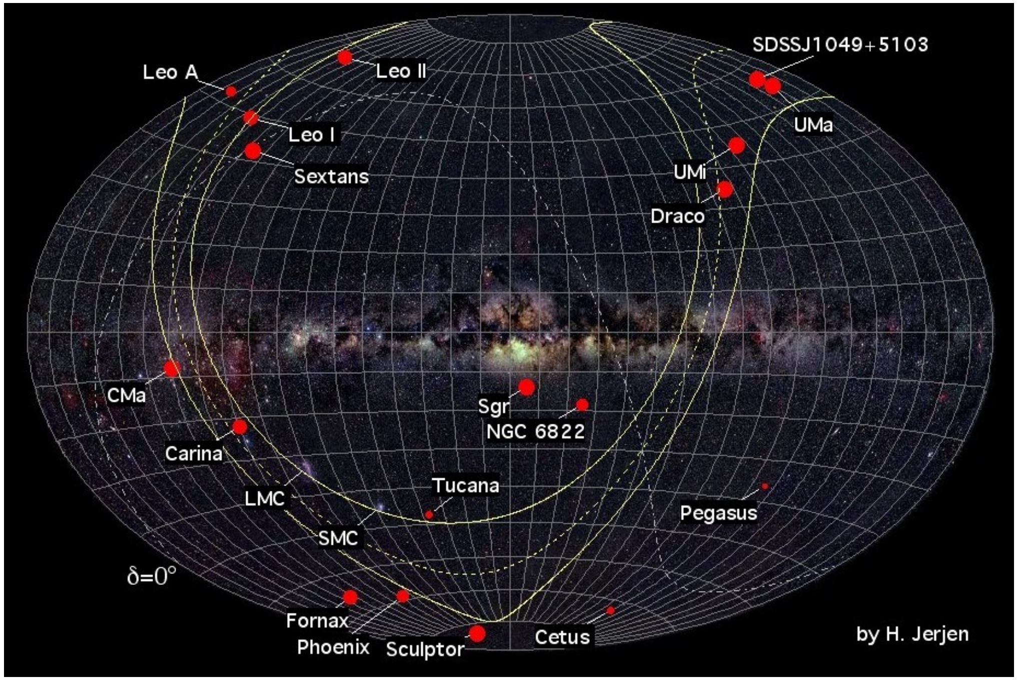


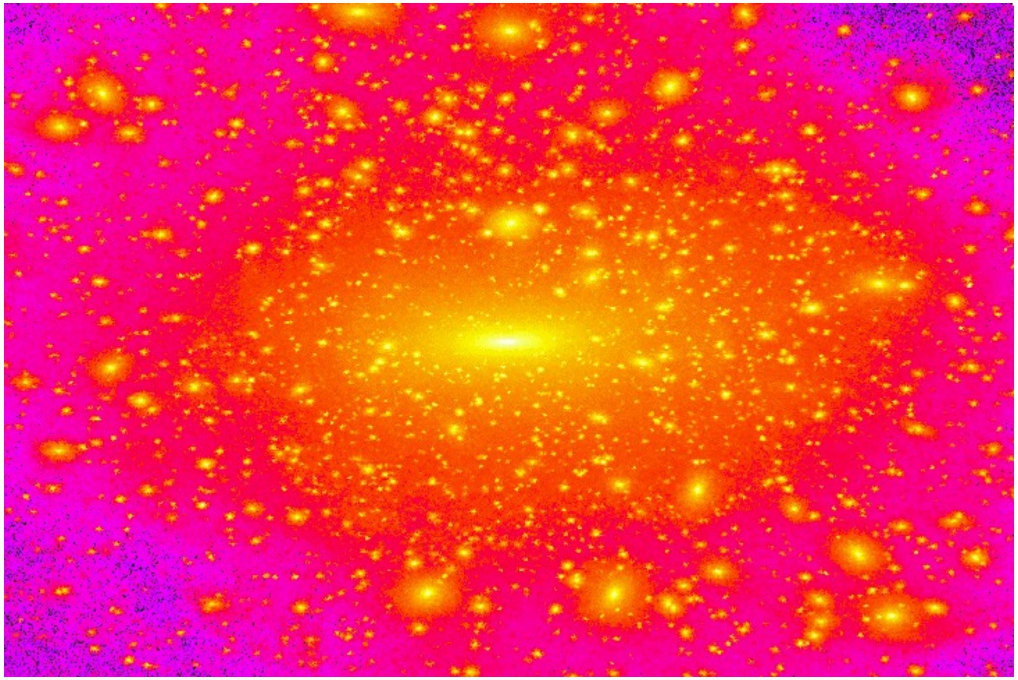
Moore et al. (1999)

The "missing satellites" problem possible solutions

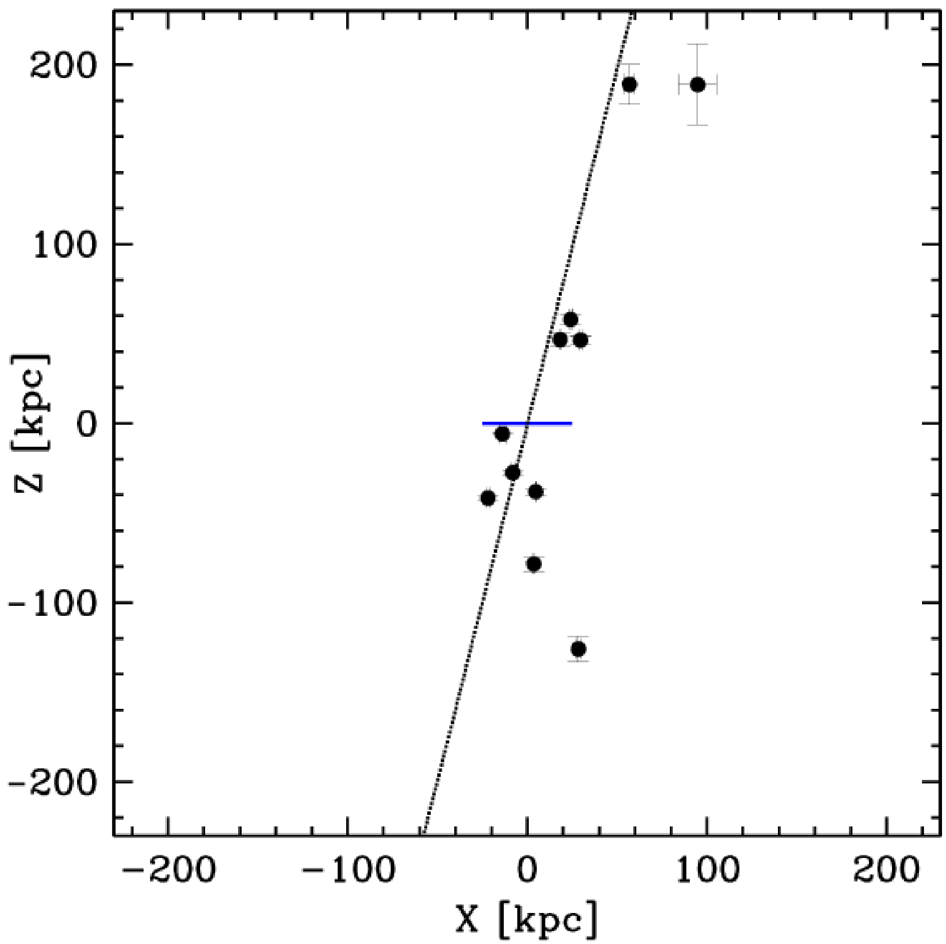
- Gas is held/captured only by the 11 most massive CDM sub-halos (Stoehr et al. 2002)
- Ionization from UV radiation prevents gas accretion in most of the DM halos (Gnedin 2000) and/or can photoevaporate gas (Shaviv & Dekel 2003)
- Tidal interactions reduce drastically the masses and the circular velocities of sub-halos (Kravtsov et al. 2004)
- Some satellite can be identified with the high-velocity clouds surrounding the Milky Way (Klypin et al. 1999)

The "missing satellites" problem is not the only one..





The "missing satellites" problem is not the only one..



Kroupa et al. (2005)

The “Durham Pancake” solution

Libeskind et al. et al. (2005)

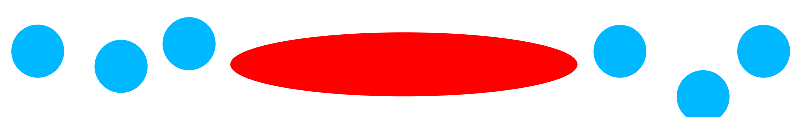
The major axis of the satellite distribution is co-aligned to that of the host DM halo

but..

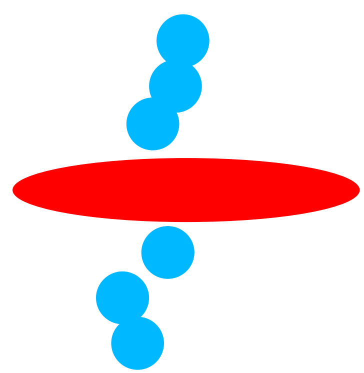
The major axis of the host DM halo should be coplanar to the Galactic disk

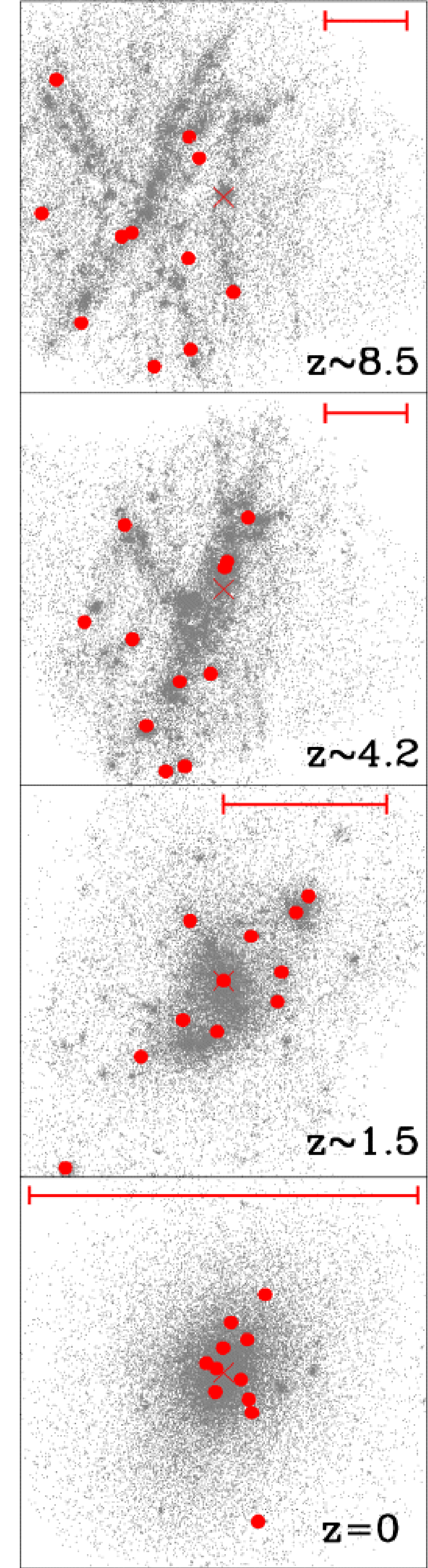
Okamoto et al. et al. (2005)

thus



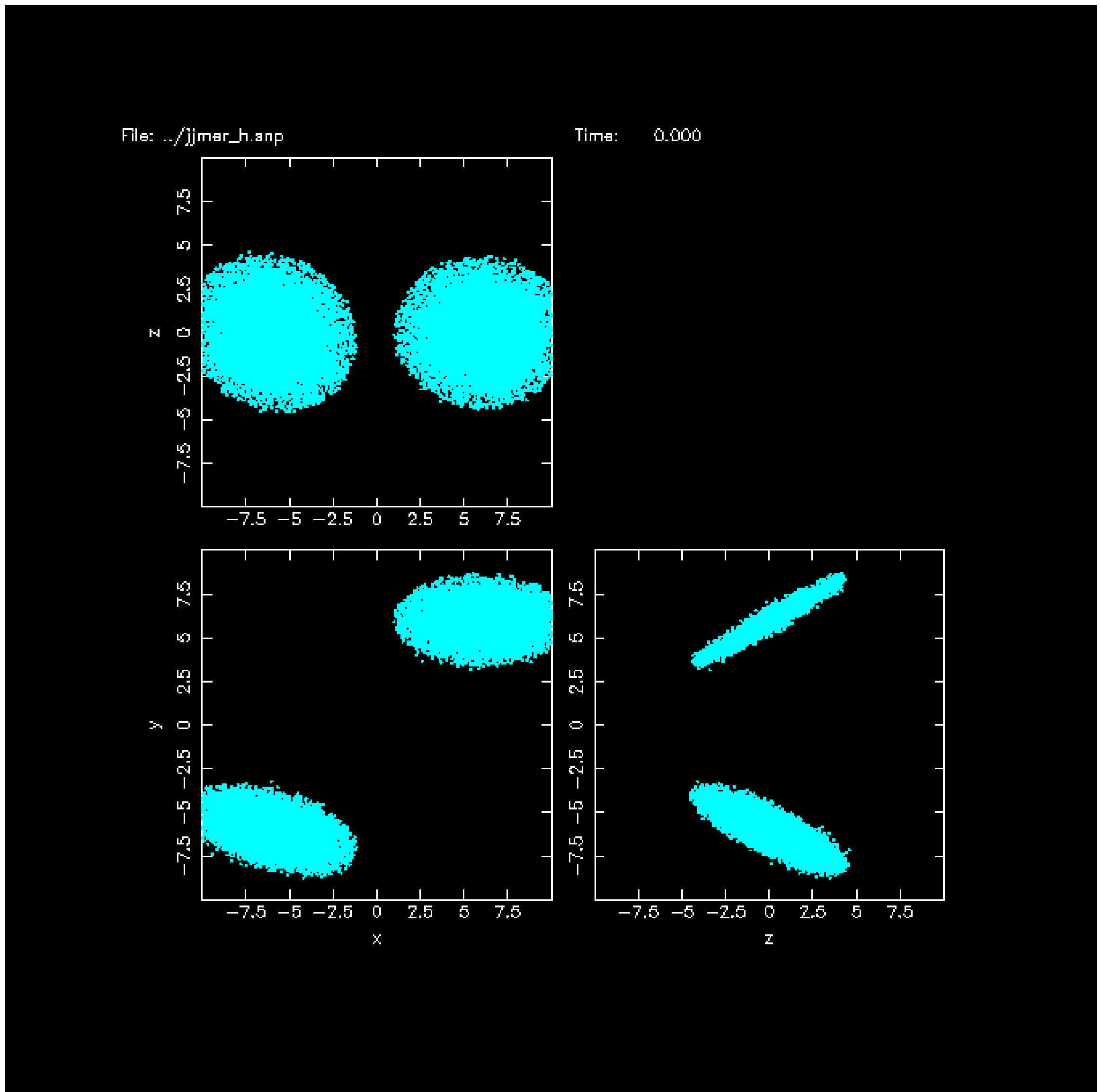
and not





The Milky Way satellites look like they are causally connected.. what if they are originated in

tidal streams?



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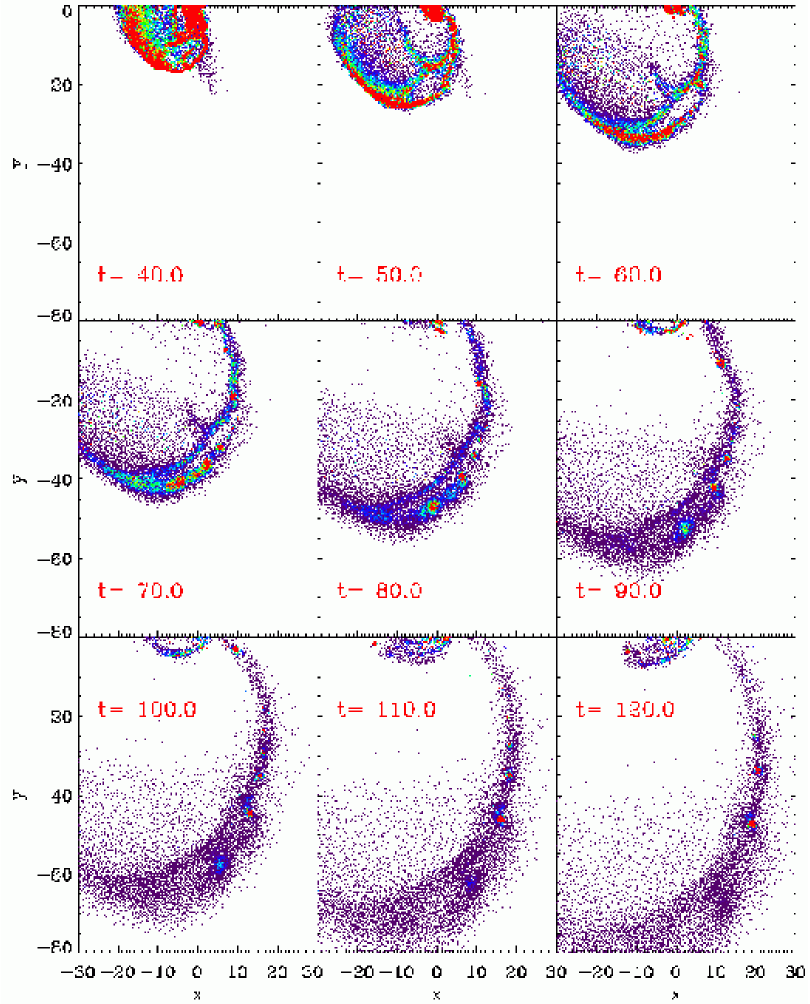

Wetzstein et al. (2006)

The Milky Way satellites look like they are causally connected.. what if they are originated in

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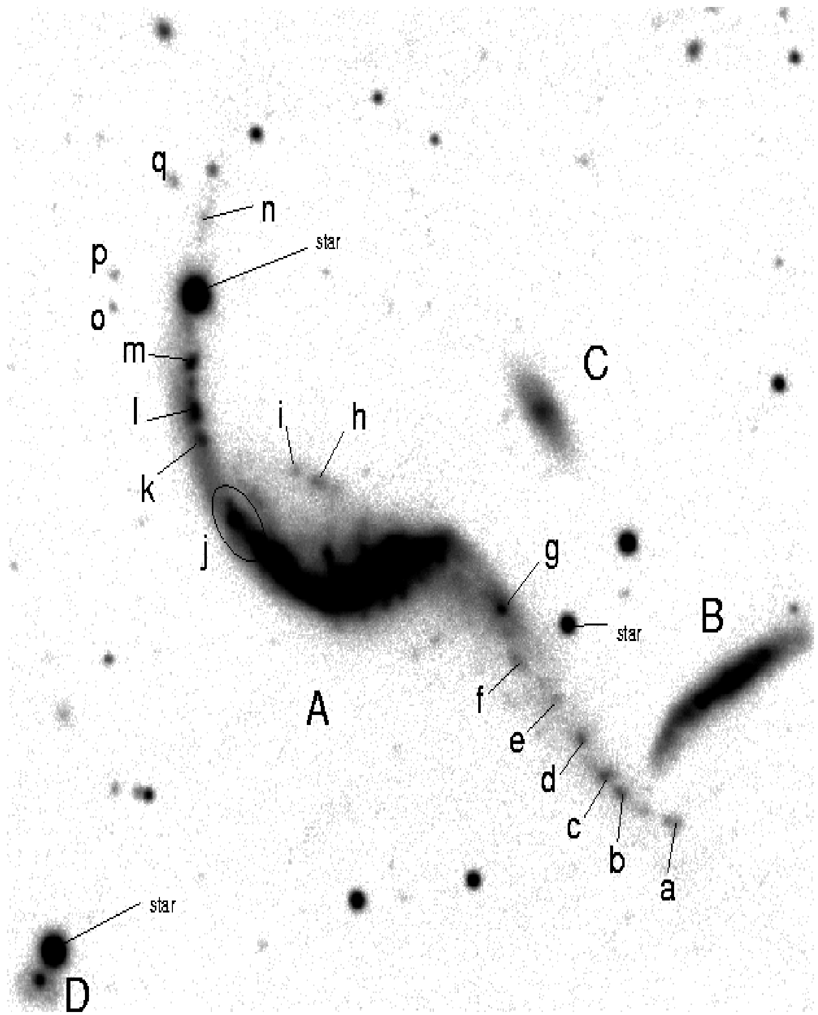


Weilbacher et al. (2005)

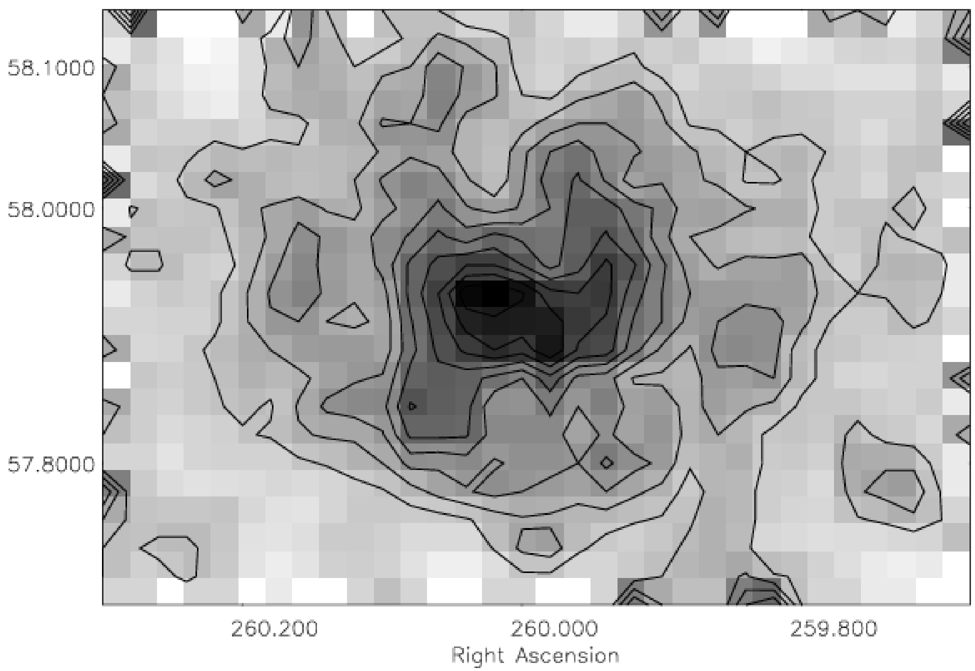
..but tidal dwarf galaxies are baryon dominated!

(Barnes & Hernquist 1992)

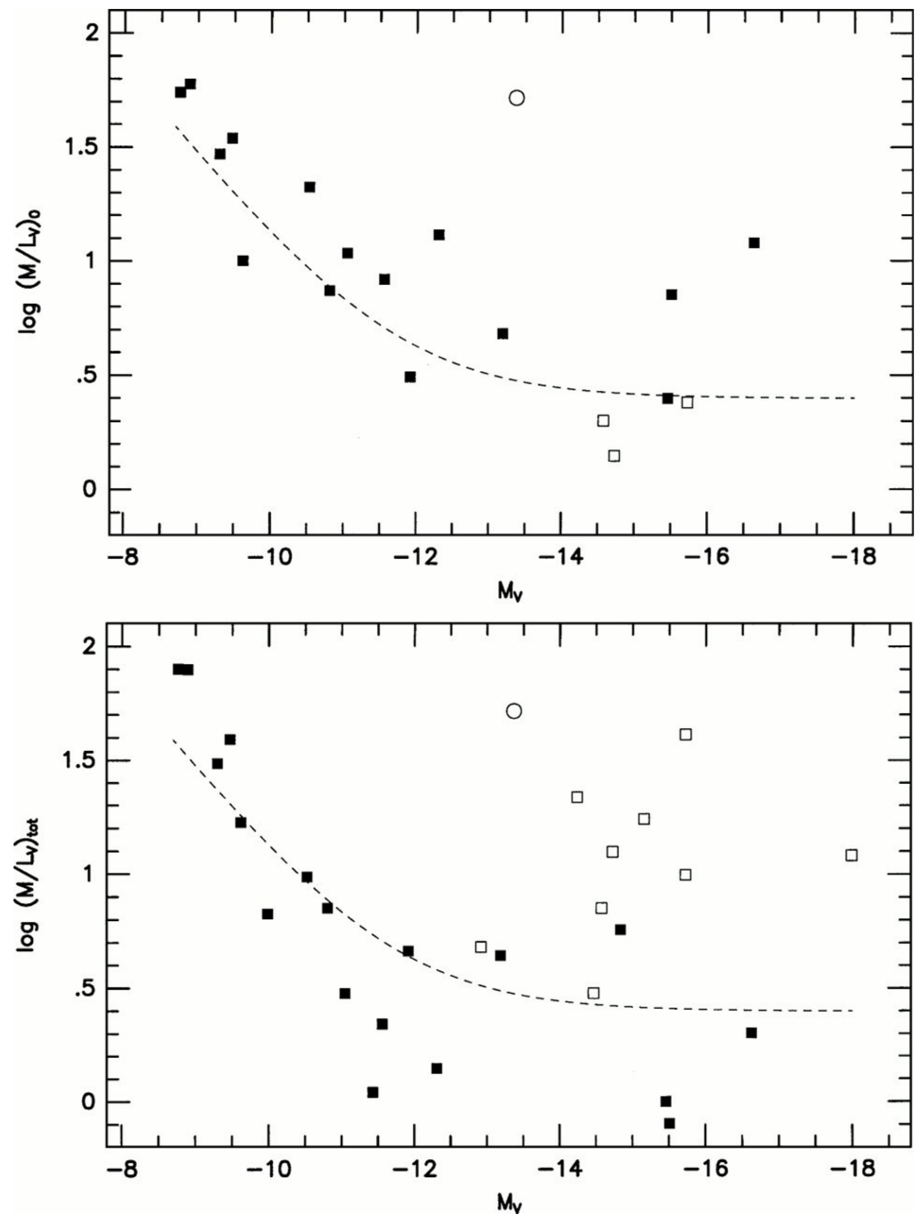
then how to explain this?

(Mateo 1998)

Isophotes of Draco



(Cioni & Habing 2005)



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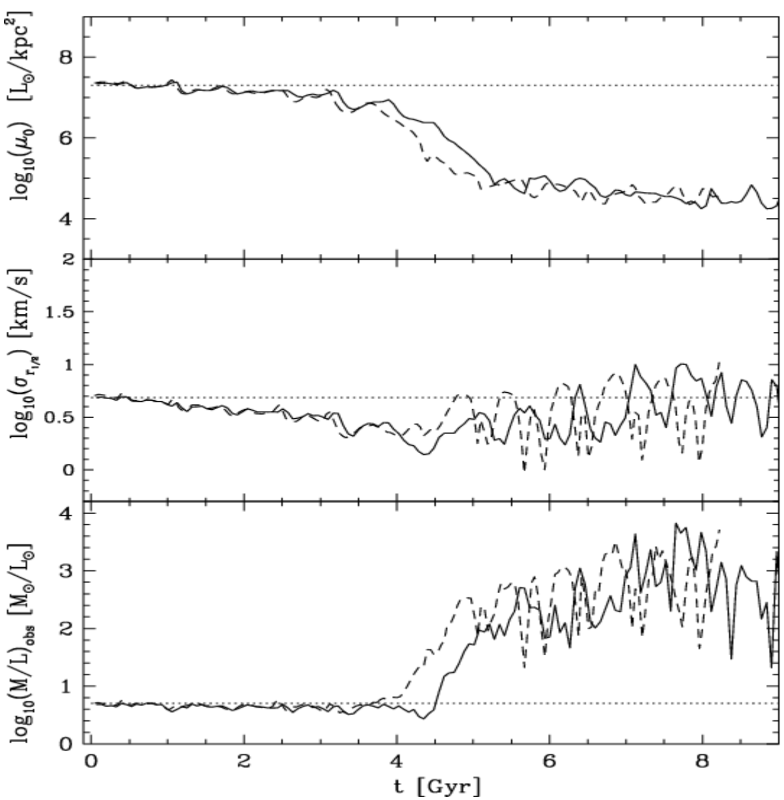
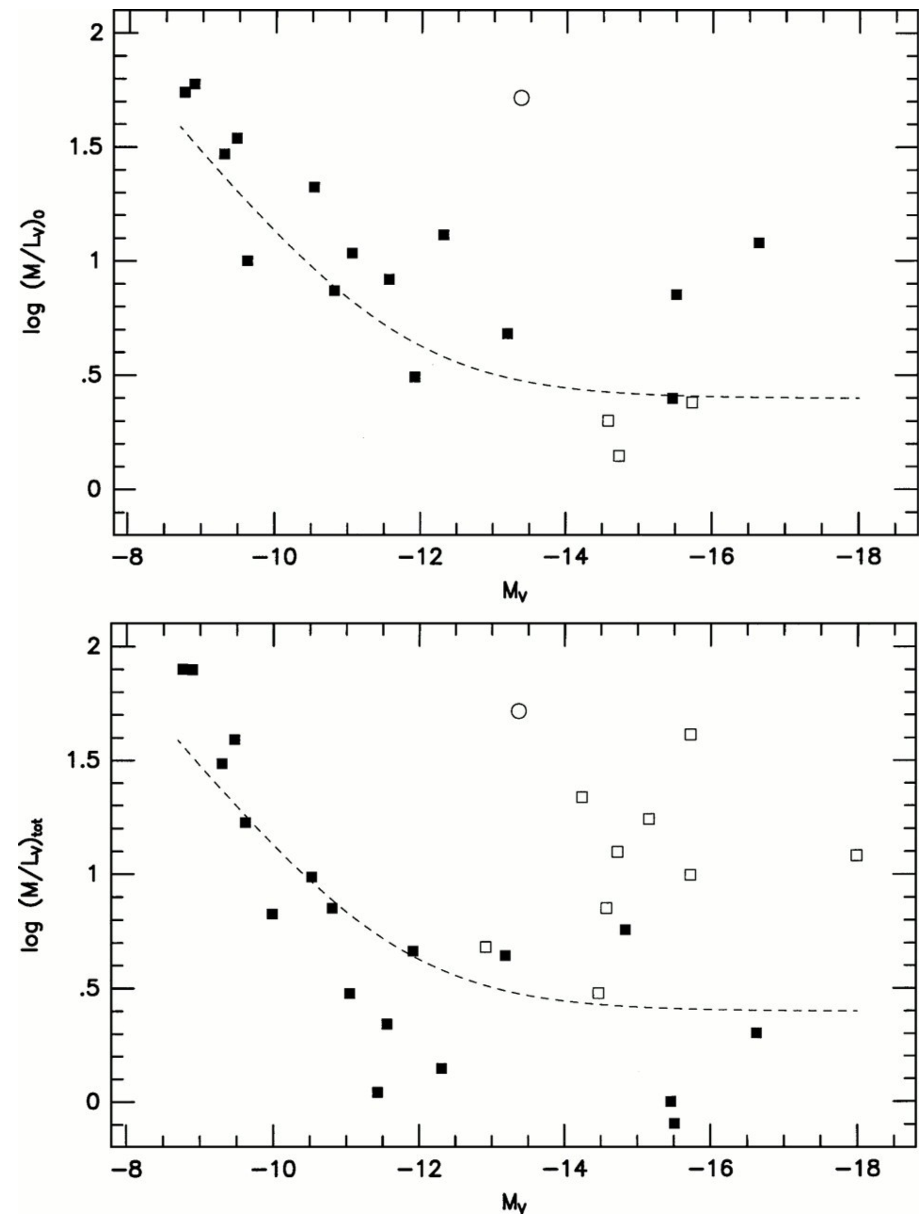
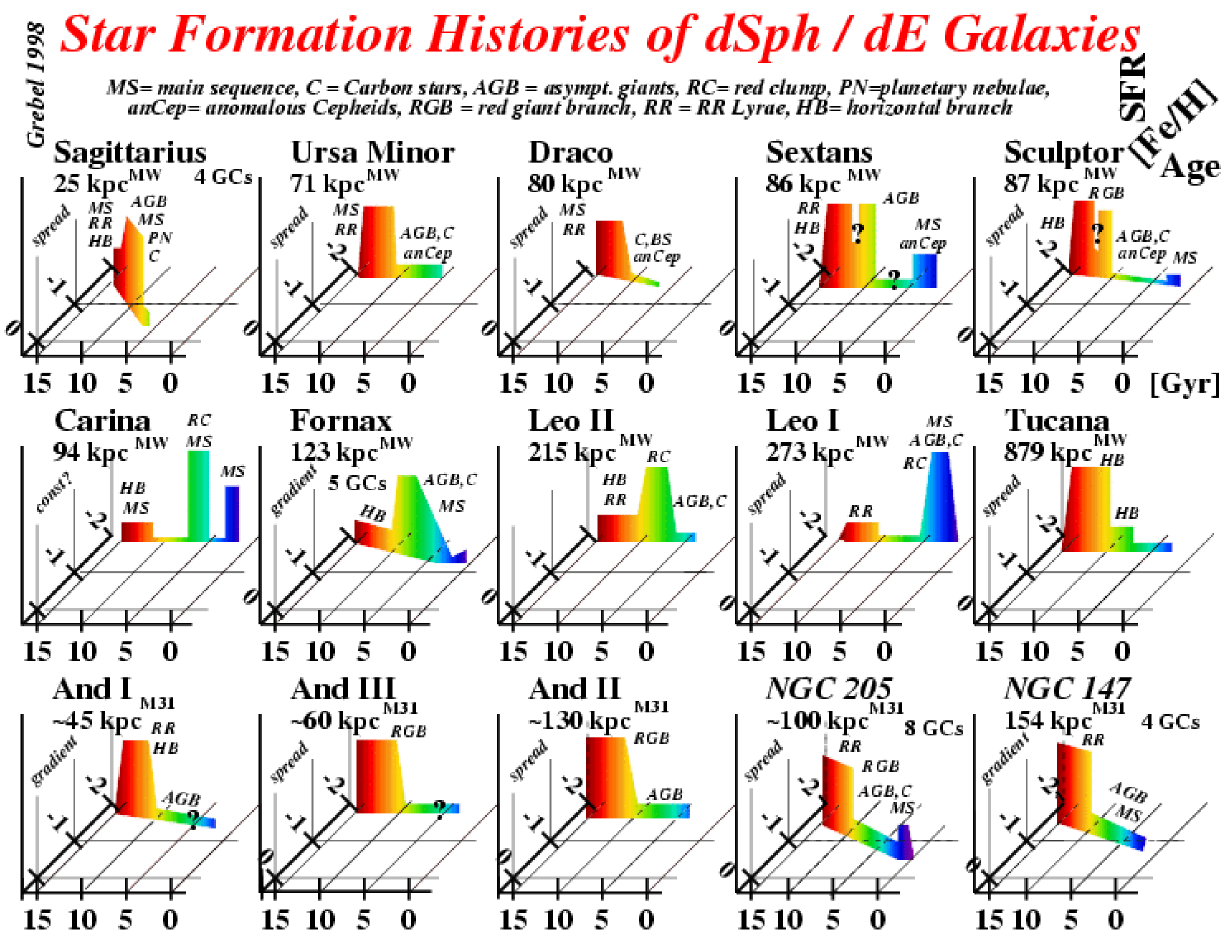


(Klessen & Kroupa 1997)



My problem:

tidal dwarf galaxies are not dark-matter dominated.. how can they survive the feedback of SNe and stellar winds and form stars for some Gyrs?



Grebel (1998)

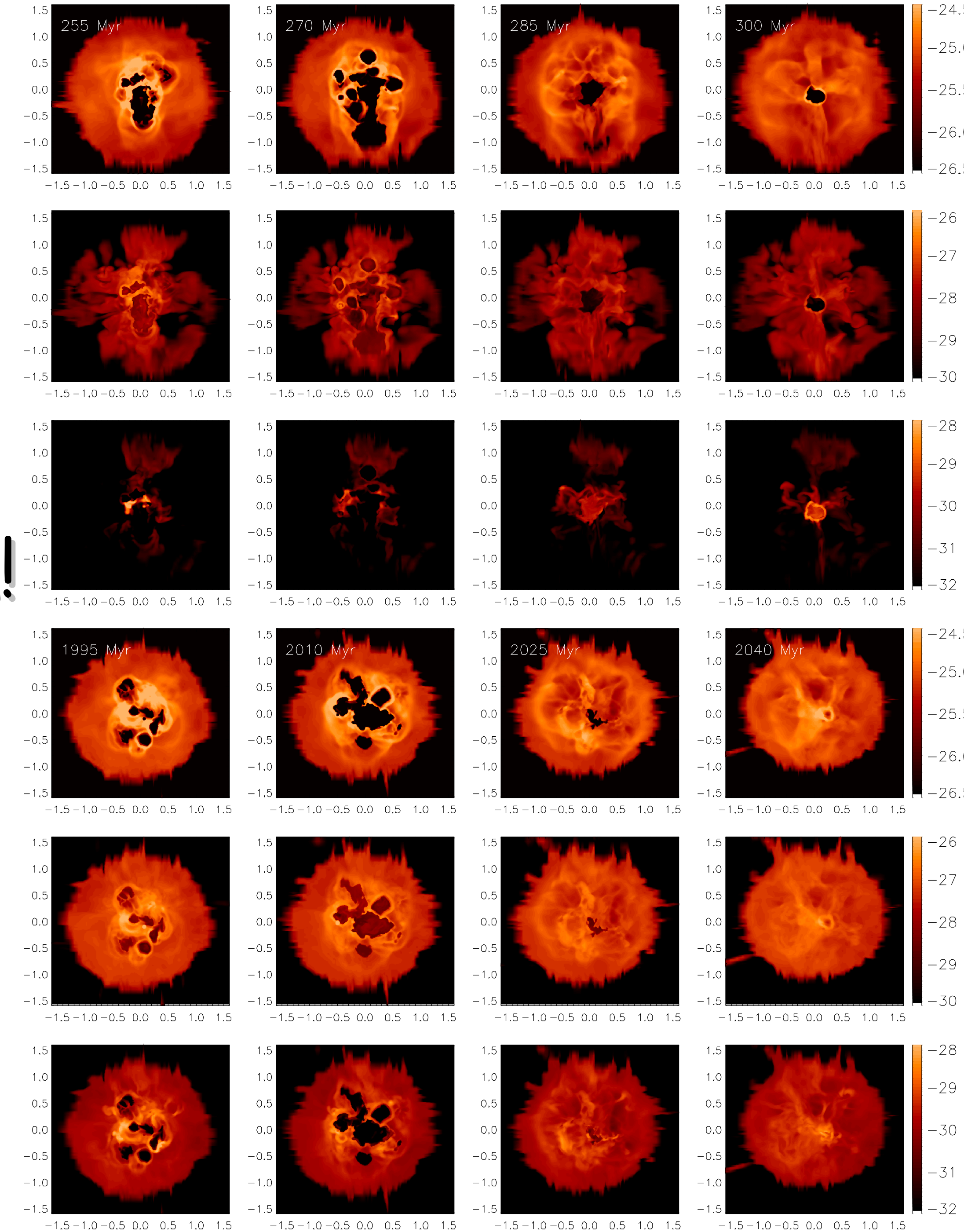
How to solve the problem?

Hydrodynamical simulations: let's check whether a DM-poor proto-galaxy can sustain the feedback of the ongoing star formation for long enough

Previous results

(Marcolini, D'Ercole, Brighenti & SR 2006)

..but this was with DM! It is possible to reproduce similar results without DM?



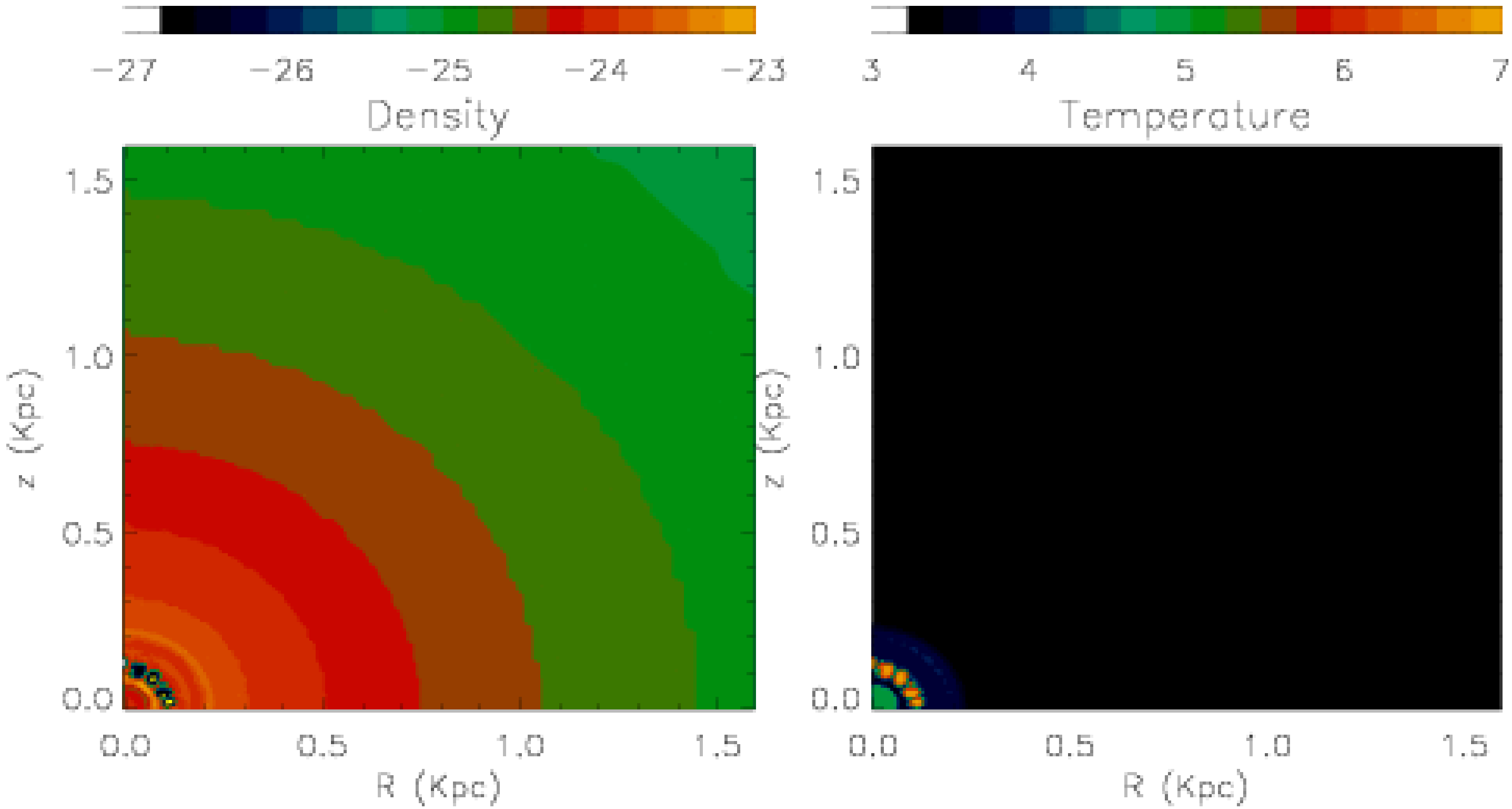
The model:

- 2-D hydrodynamical models in cylindrical coordinates
- Self-gravity
- Star formation depending on the thermodynamical properties of the ISM
- Each "stellar population" (all the stars born within intervals of 1 or 5 Myr) is treated separately and its feedback is followed consistently
- (Metallicity-dependent) luminosities from stellar winds are considered
- Fully treatment of the chemical evolution of the ISM and of the stellar components
- Metallicity-dependent cooling function
- Environmental effects

The "reference" model:

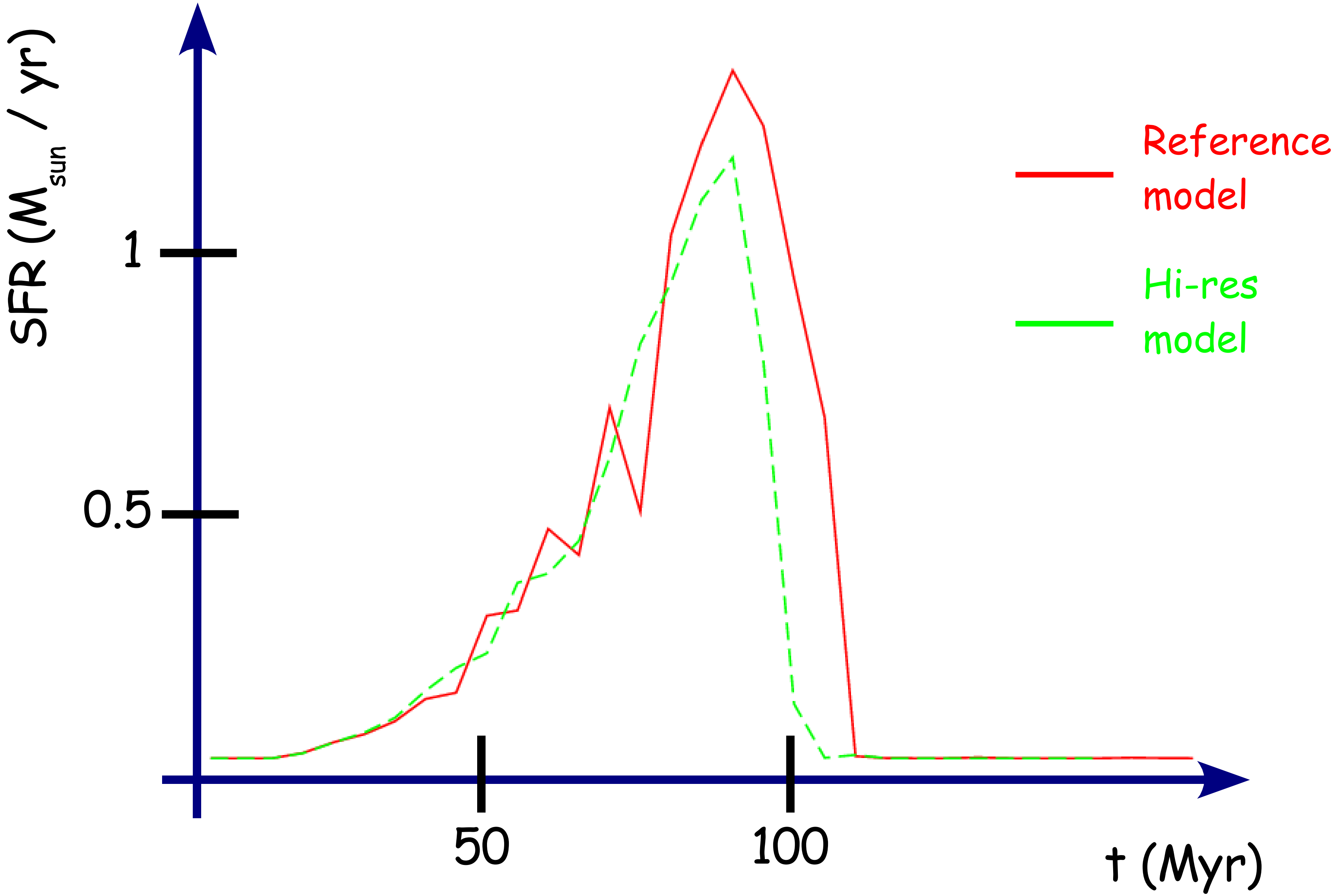
- No stellar dynamics (the stars remain where they are born)
- Linear Schmidt star formation law with a temperature threshold of 10^4 K.
- Efficiency of star formation: 0.2
- Initial density profile $\rho = \frac{\rho_0}{1+(r/r_0)^2}$ with r_0 = 500 pc.
- Initial mass $4 * 10^8$ M_{sun}
- The galaxy is isolated
- It has no rotation

Dynamical evolution of the "reference" model

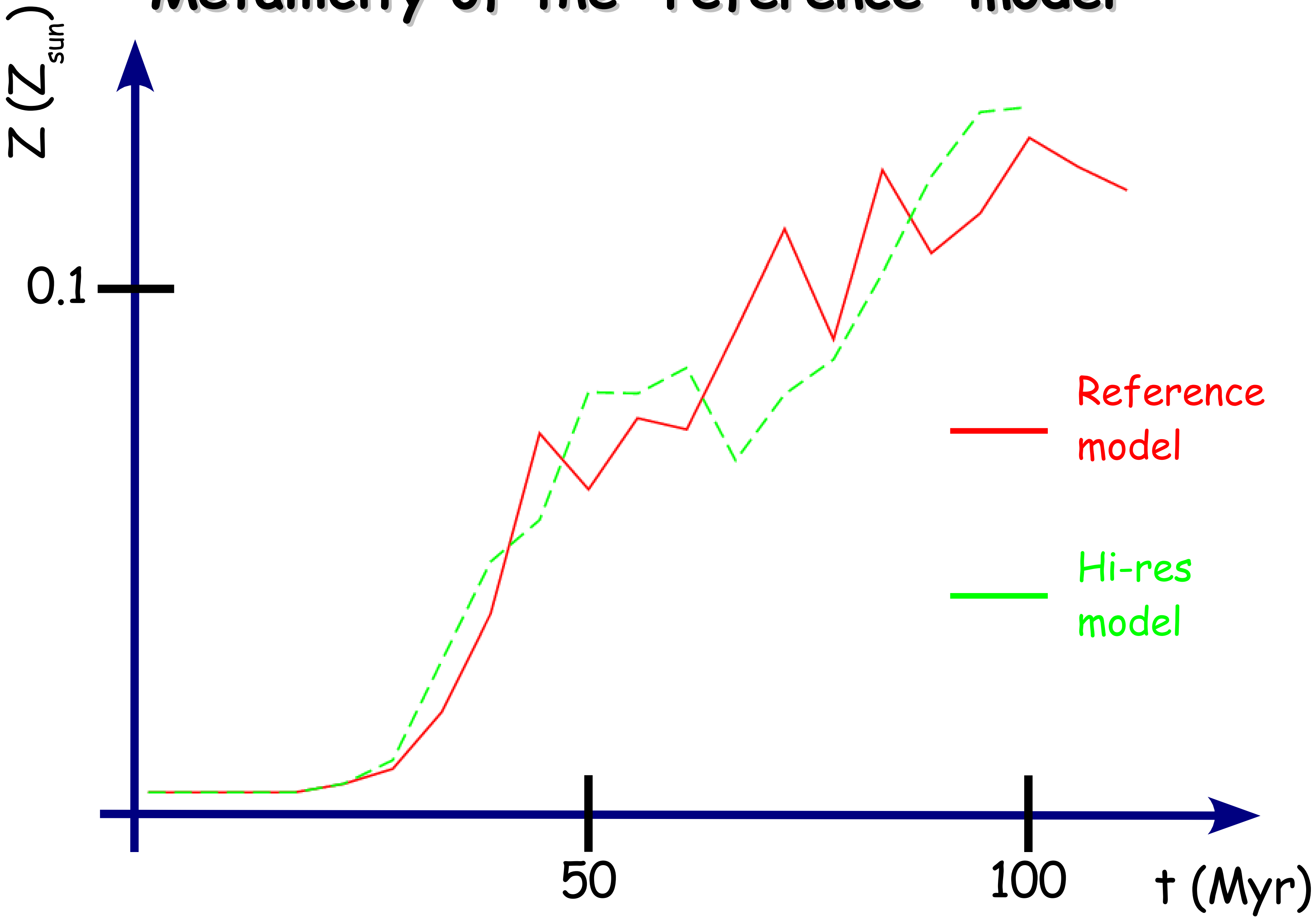


Final time: 120 Myr

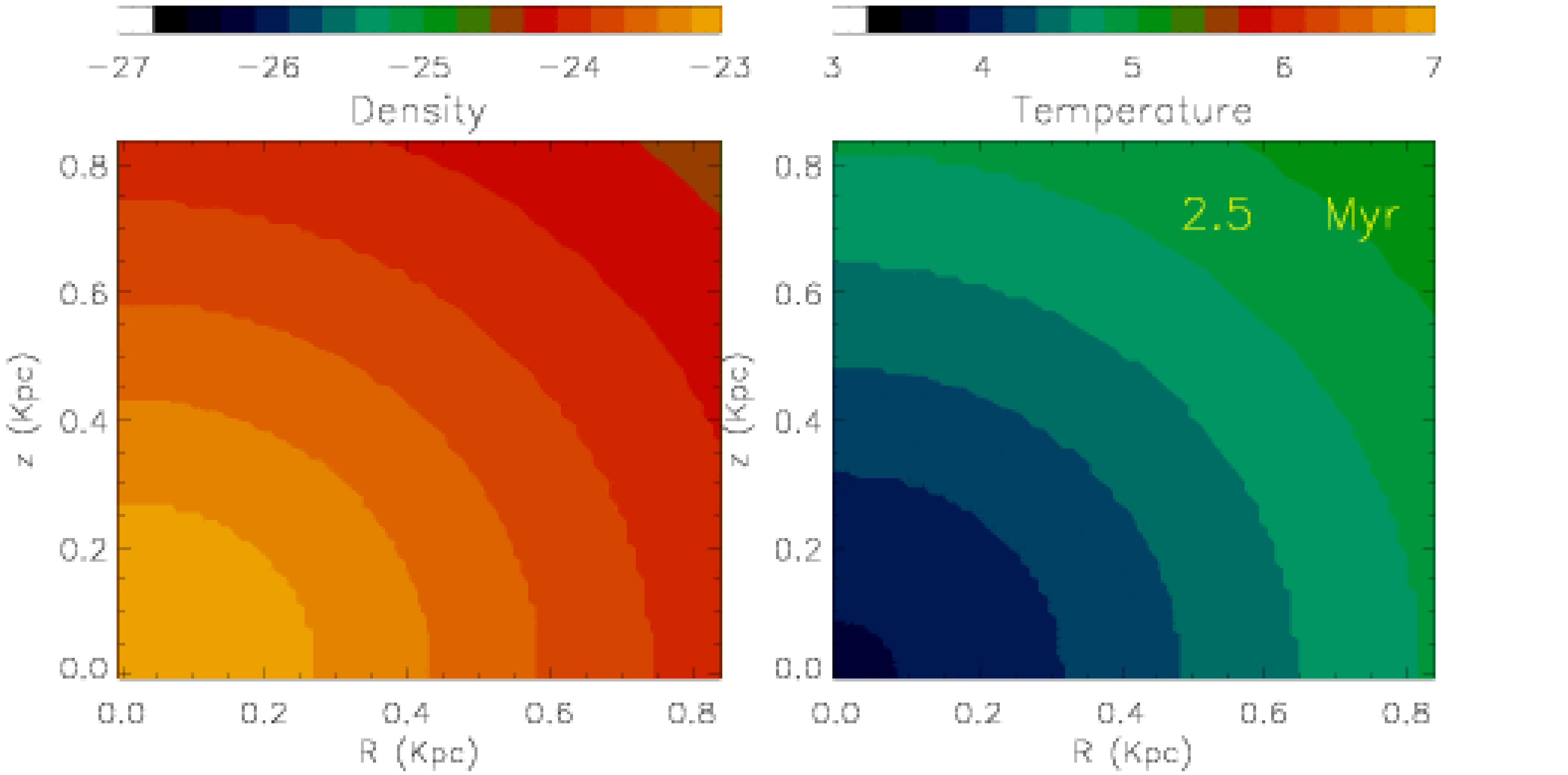
Star formation of the “reference” model



Metallicity of the “reference” model



Star formation efficiency 0.1



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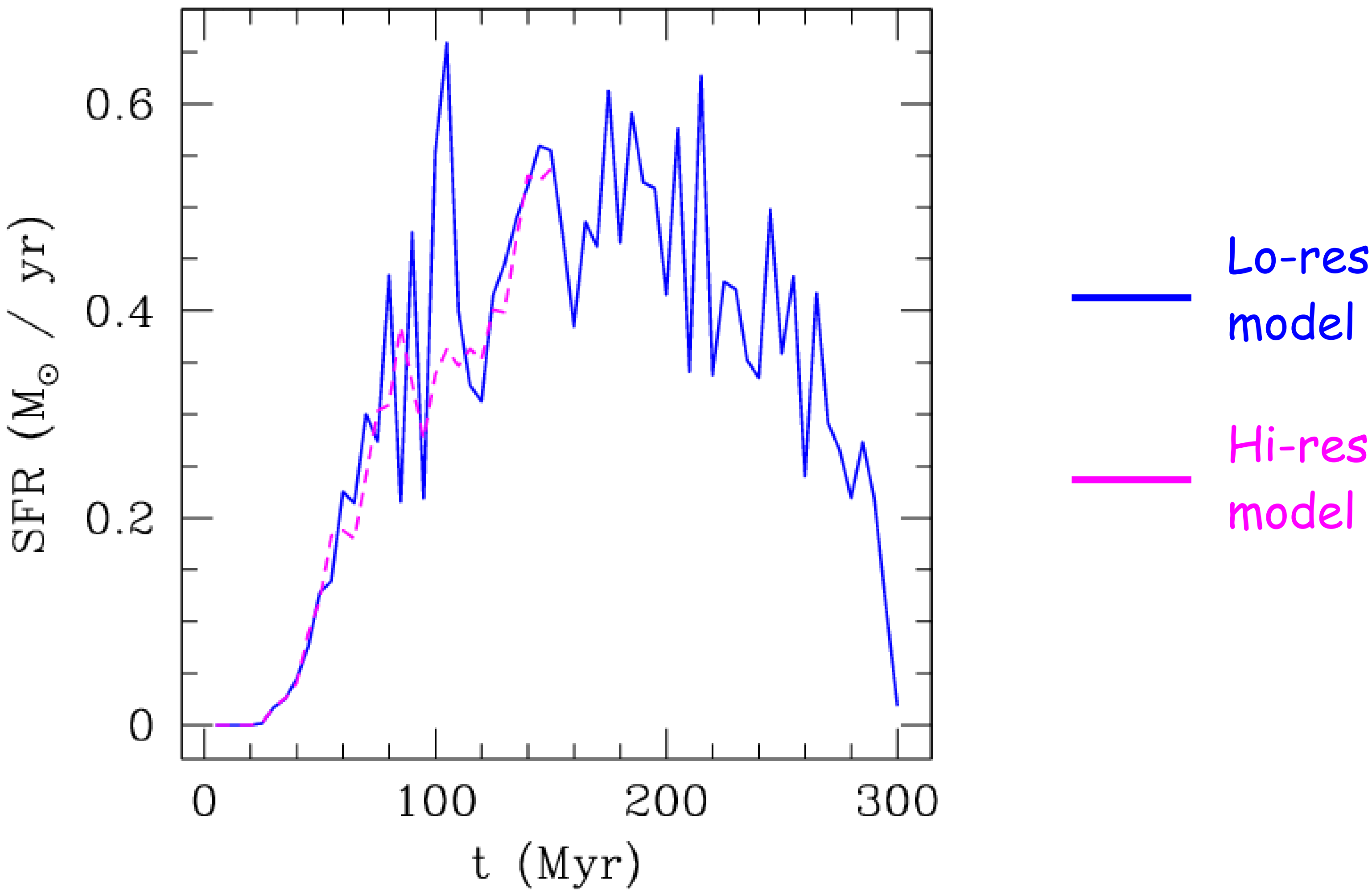

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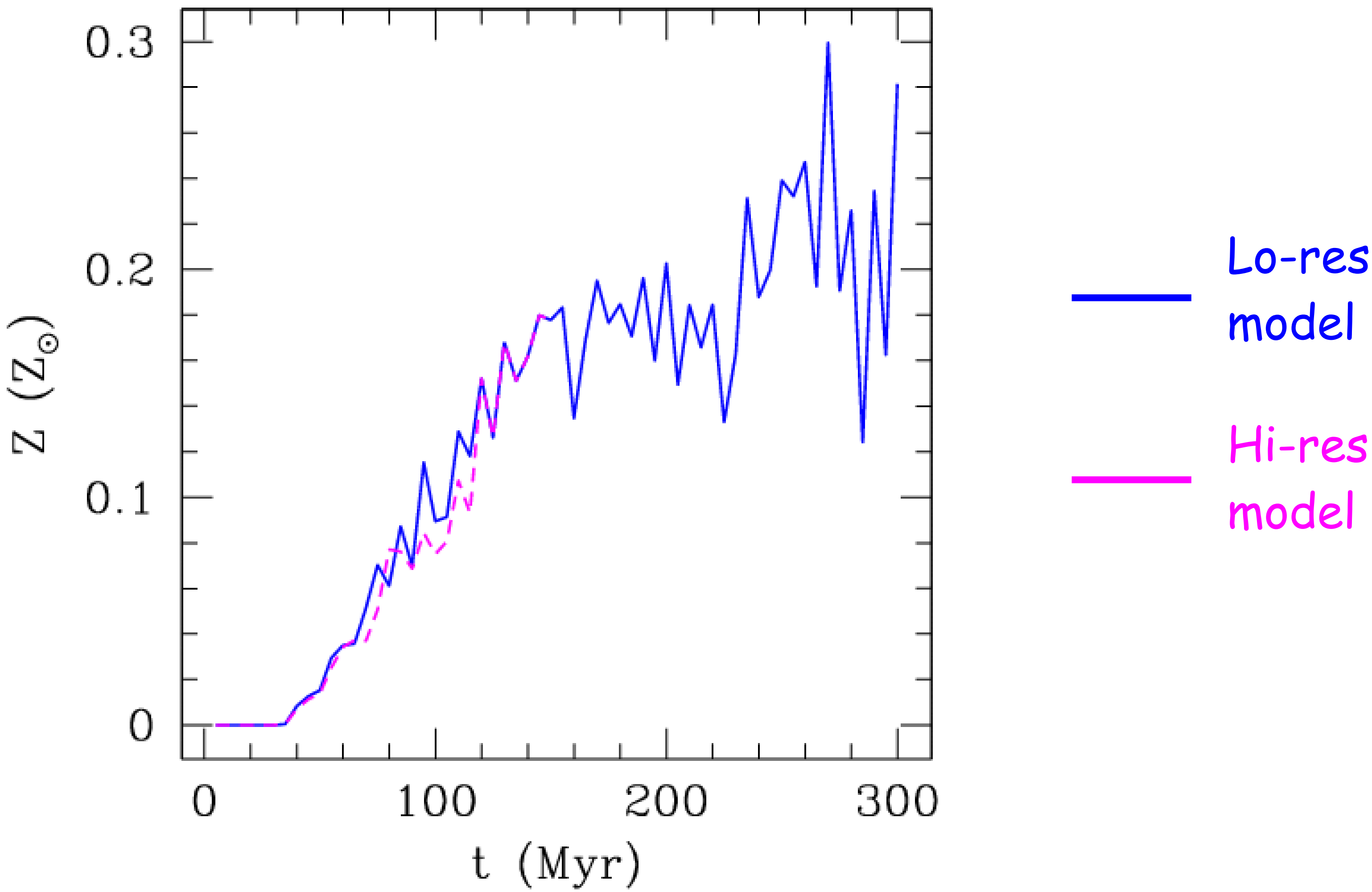

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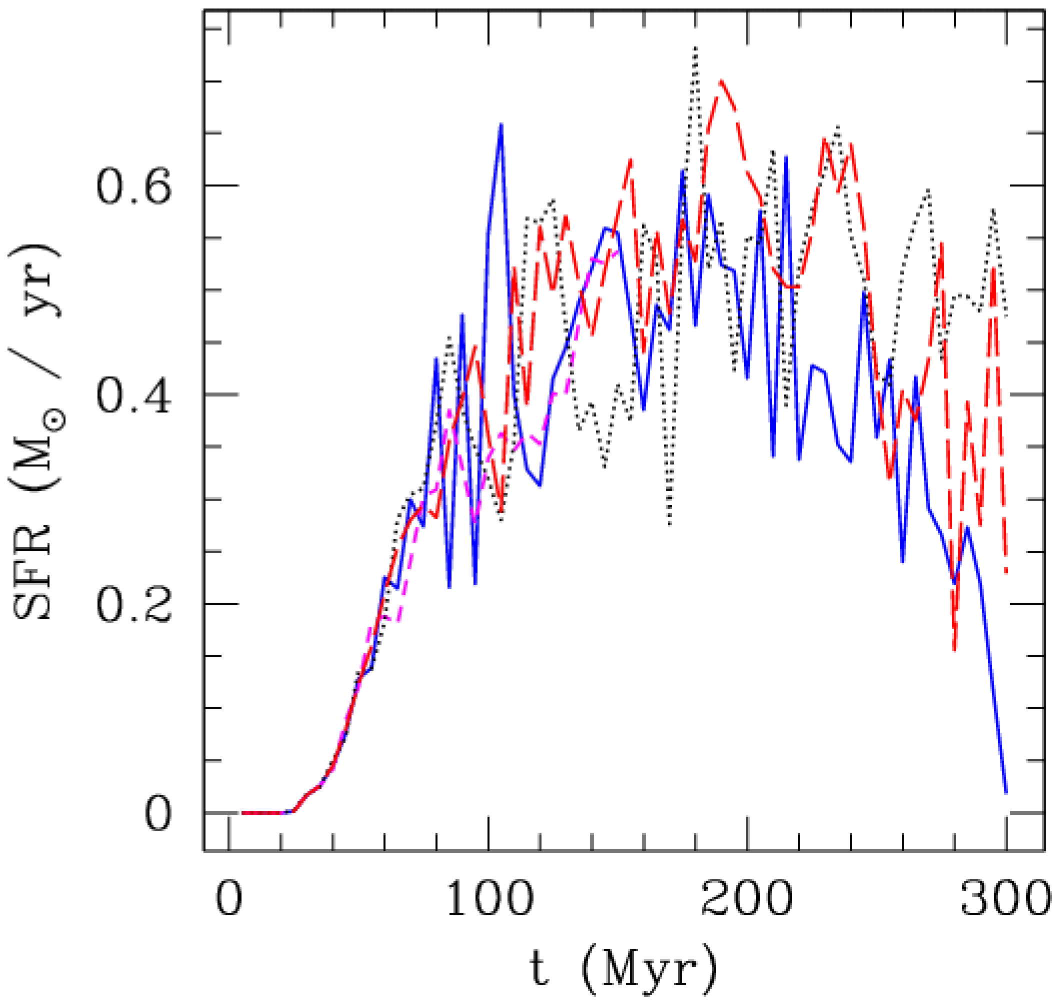
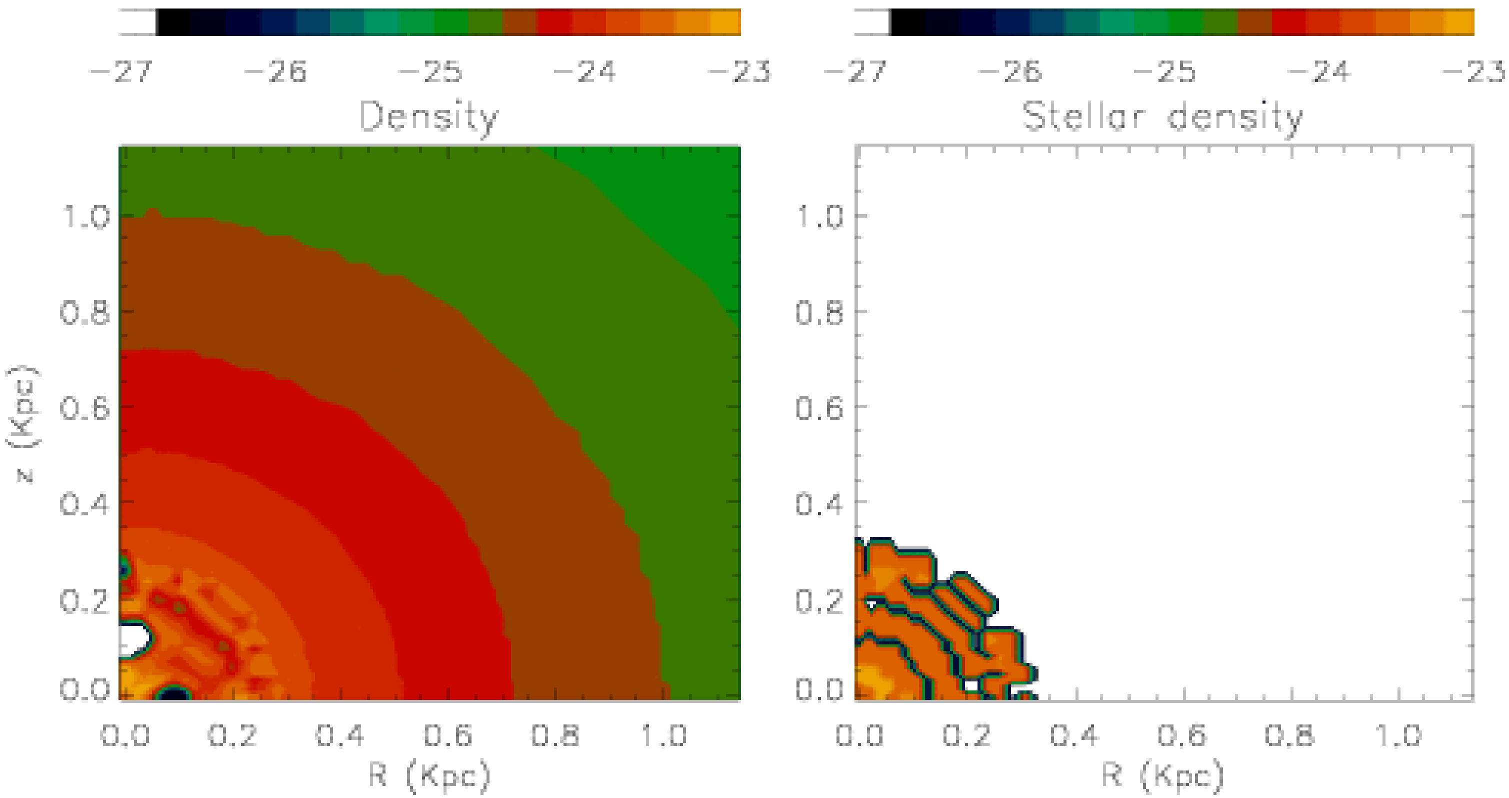


no stellar winds

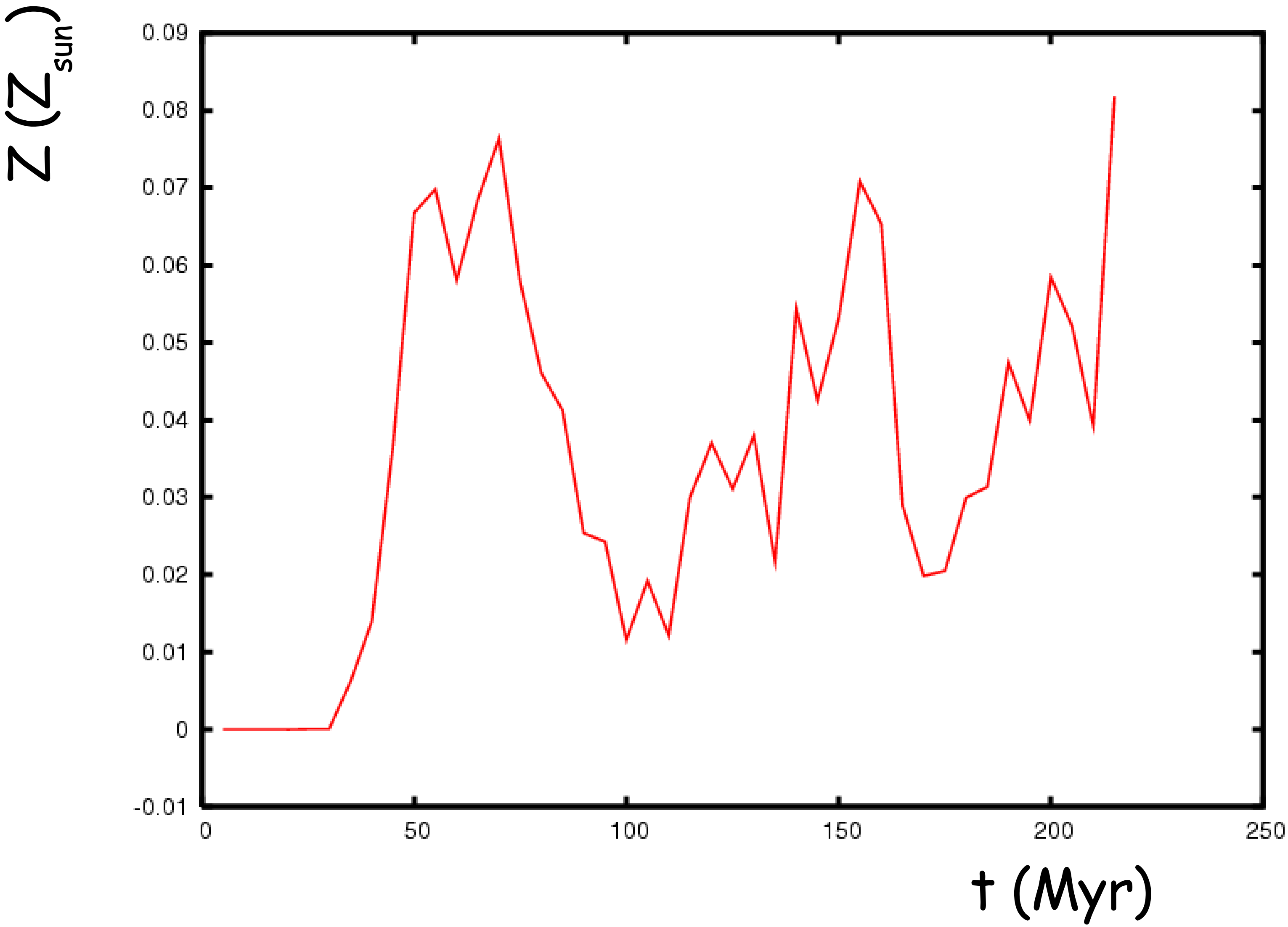
temperature threshold 5000 K

Asymmetric model



Final time: 220 Myr

Asymmetric model

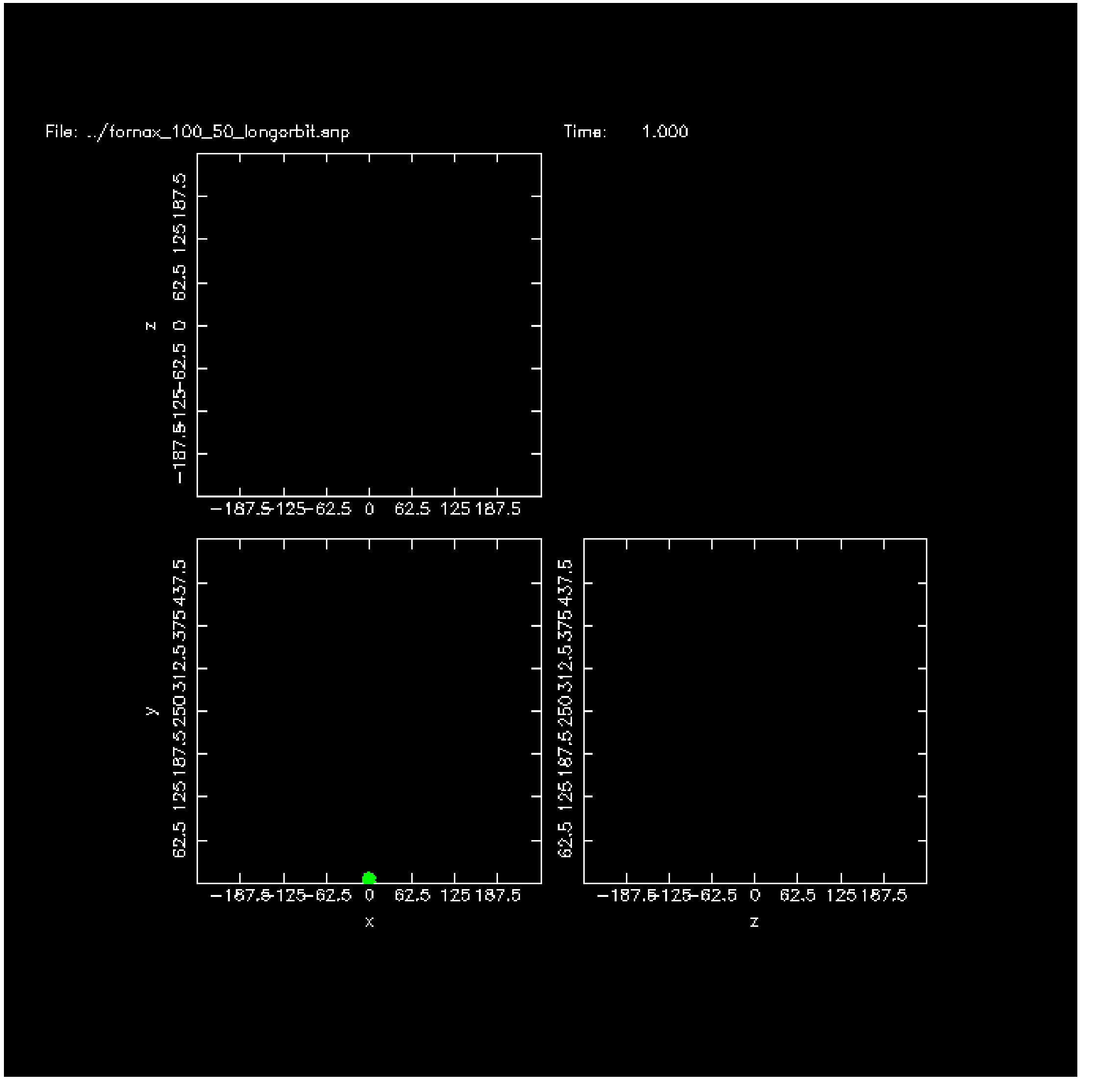


The future:

- Explore more in detail the results and expand the parameter space.
- Consistent dynamics of the stellar component (work in progress)
- Constant infall of gas, coming from the stream (work in progress)

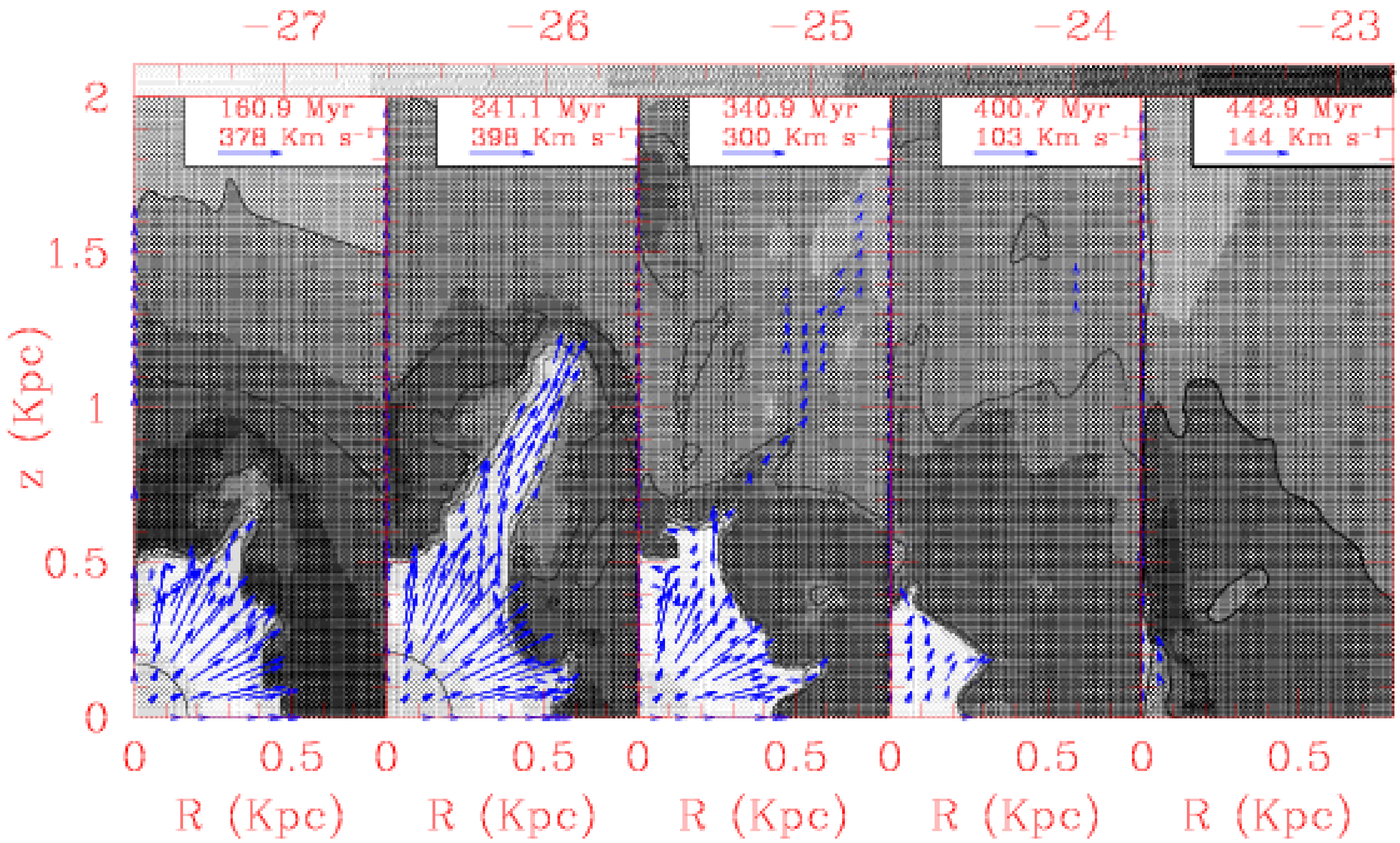
The future:

- Models with reliable interactions between the dwarf galaxy and a perturbing giant galaxy



The future:

- Long-term evolution of the models



SR & Hensler (2006)

The future:

- Long-term evolution of the models

Model	M_g (10^8 M_{sun})	SF duration (Myr)	SF rate (M_{sun} yr^{-1})	Refilling time-scale
LS	1	25	0.5	415 Myr
LL	1	200	0.05	600 Myr
HS	1.8	25	0.5	125 Myr
HL	1.8	200	0.05	200 Myr

SR & Hensler (2006)

Conclusions:

- Not necessarily dwarf galaxies without dark matter are quickly destroyed.
- Not necessarily galactic winds quench completely the star formation
- The future is interesting


PART II:
Self-enrichment in globular clusters
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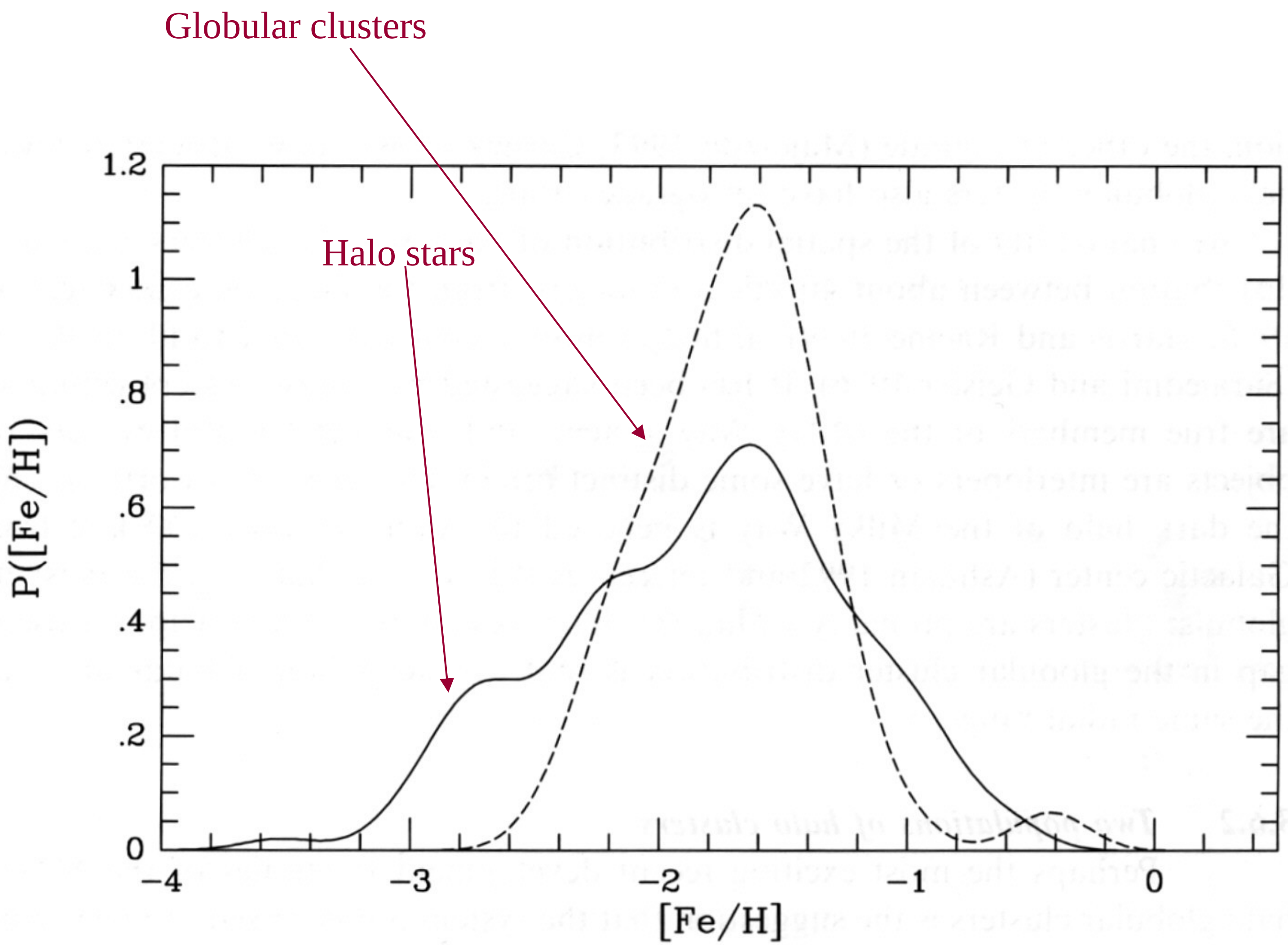
Francesca Matteucci (DAUT)
Annibale D'Ercole, Eugenio Carretta, Angela Bragaglia (INAF-OA Bologna),
Franca D'Antona, Paolo Ventura (INAF-OA Roma)

PART II:
Self-enrichment in globular clusters

outline:

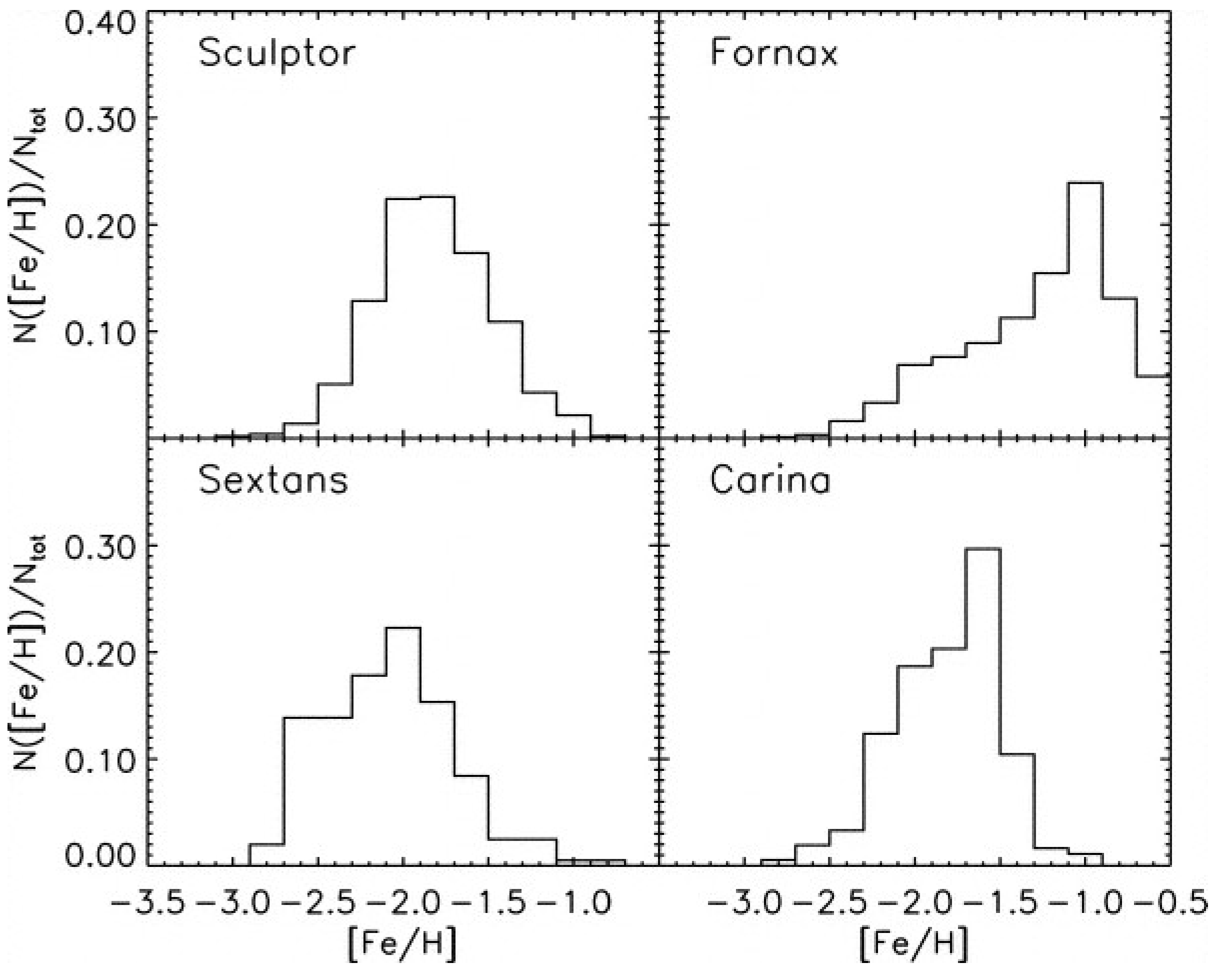
- The astrophysical context
- Investigation method
- Preliminary results

Comparing the globular cluster system with halo stars. The metallicity distribution



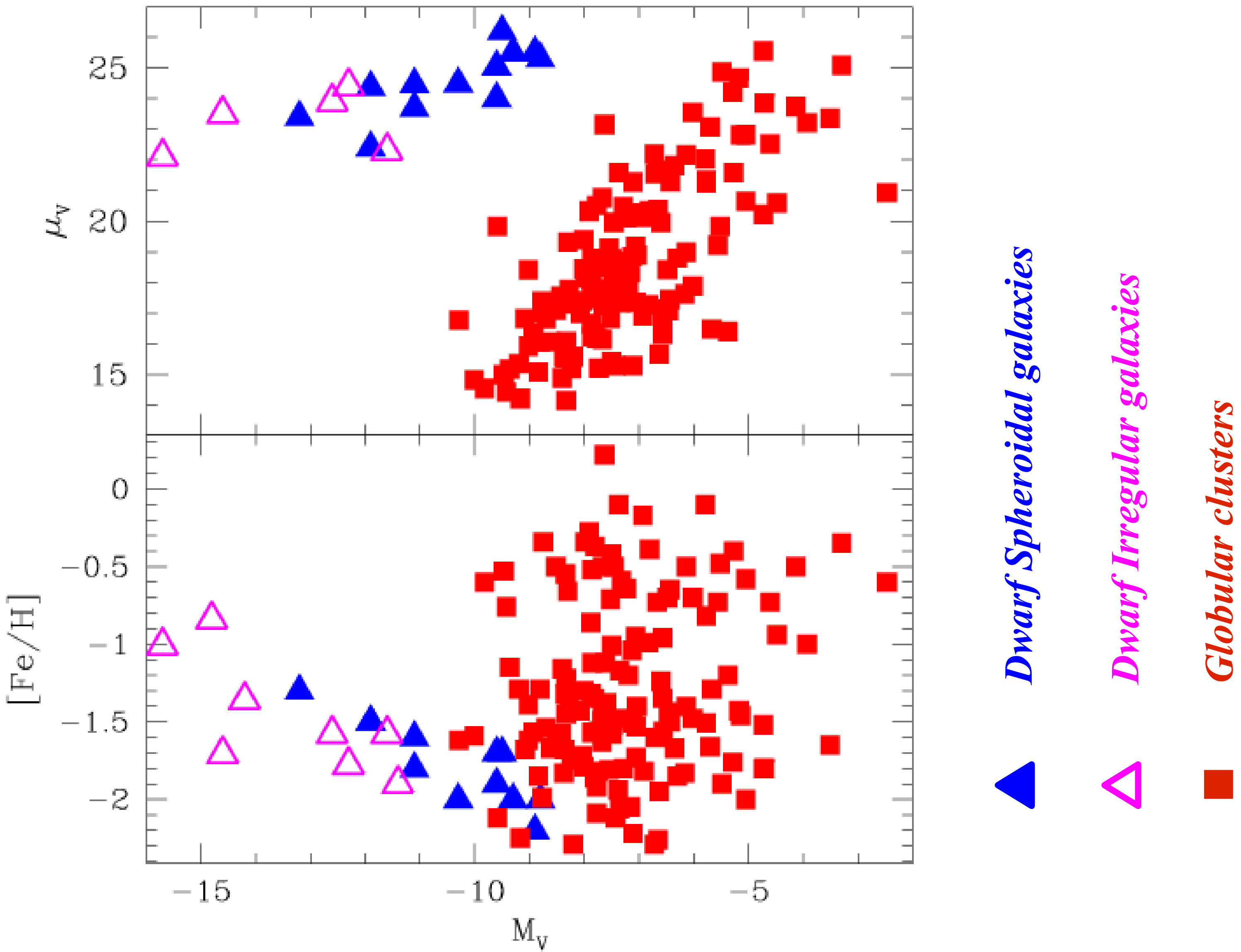
Ashman & Zepf (1998)

Comparing the globular cluster system with dwarf spheroidals. The metallicity distribution

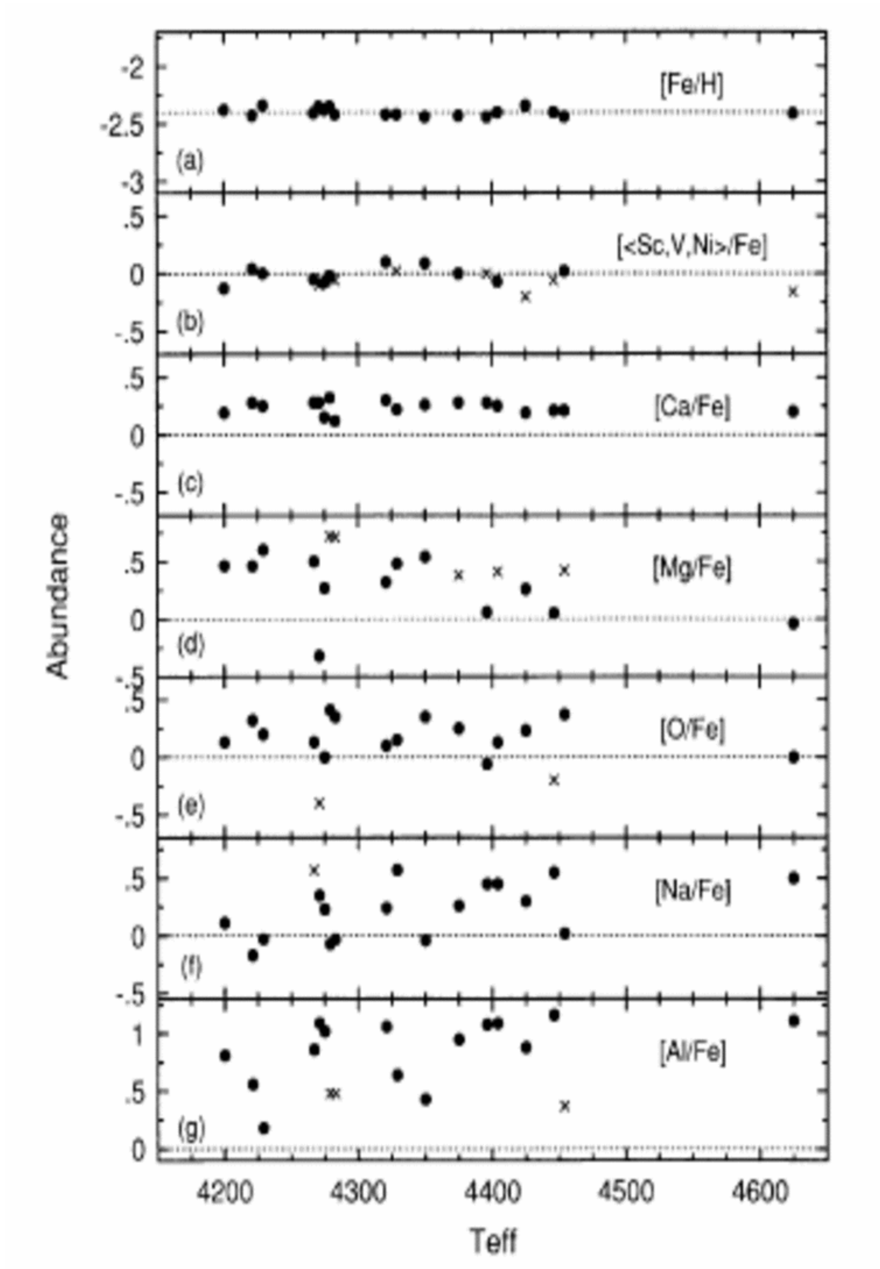


Helmi et al. (2006)

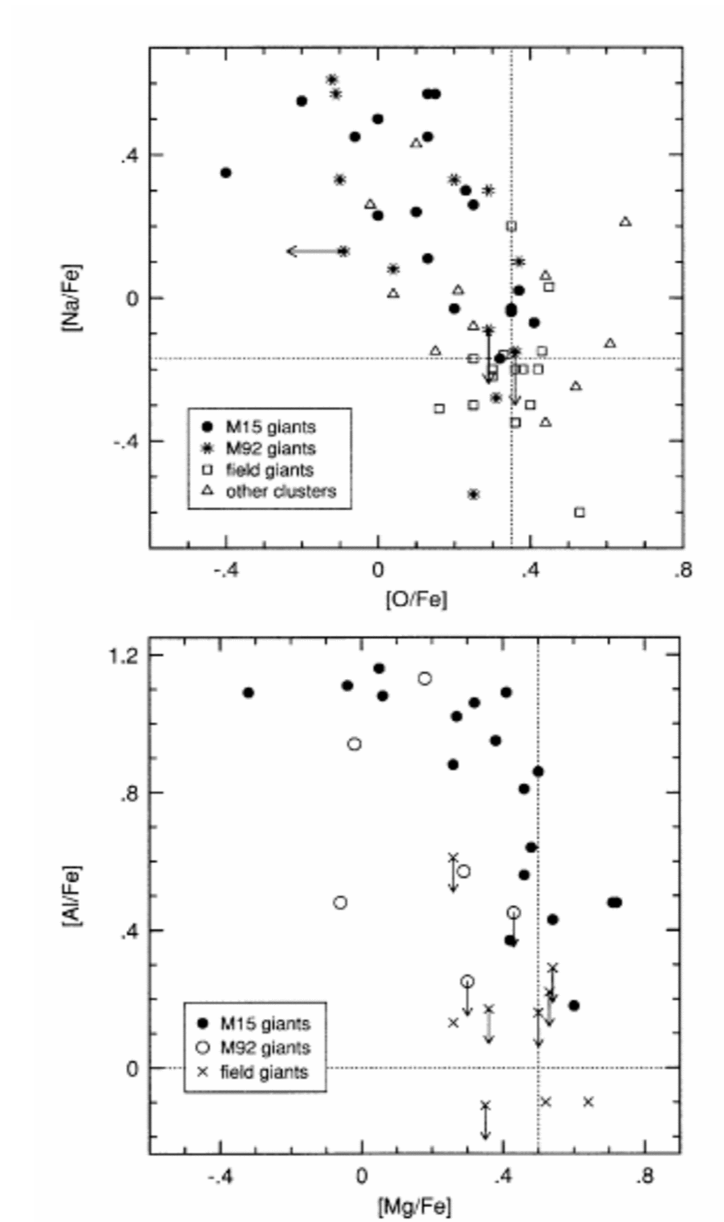
Comparing the globular cluster system with dwarf spheroidals. The metallicity distribution



The metallicity distribution function within globular clusters. Giant stars in M15



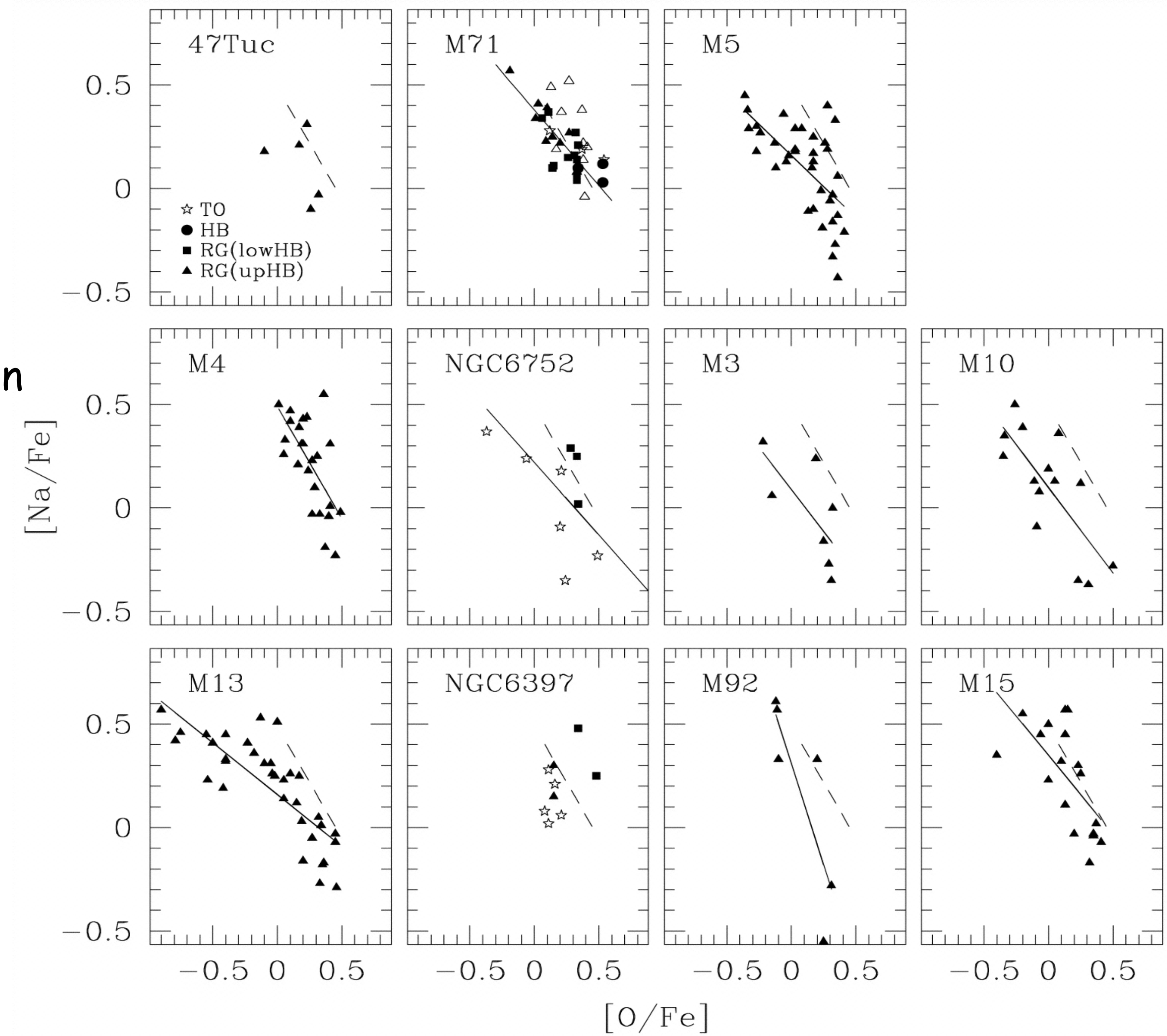
Abundances and abundance ratios of M15 giants (Sneden et al. 1997)



Na/O and Mg/Al anticorrelations in *GC* giants (Sneden et al. 1997)

The metallicity distribution function within globular clusters

The Na/O anticorrelation is observed in almost all the Globular Clusters surveyed!



(Ramirez & Cohen 2001)

The metallicity distribution function within globular clusters: possible explanations?

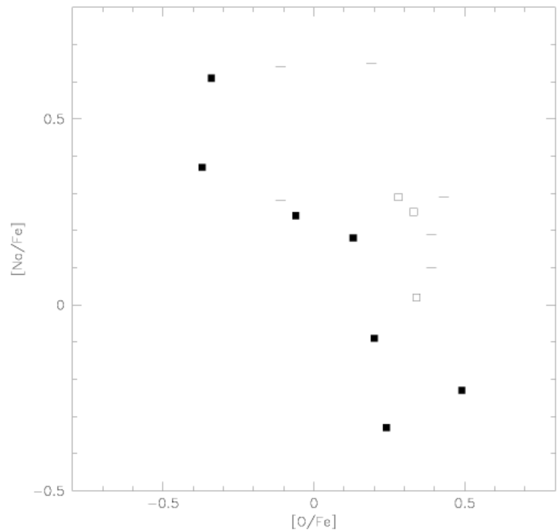
- **Internal processes.** Circulation within the radiative zone between the base of the convective envelope and the CNO burning shell can connect the surface of a star with the region responsible for nuclear processing. The circulation could be the result of stellar rotation which drives meridional current.

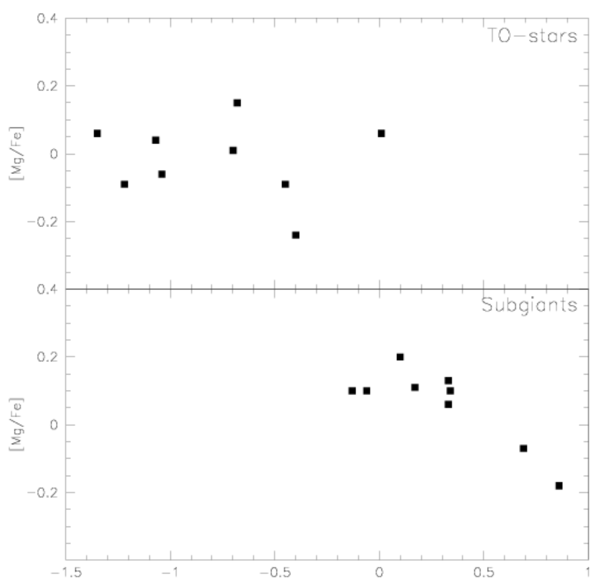
Deep within the CNO-burning shell the rates for proton capture on ^{16}O and ^{22}Ne are approximately the same. So, if material from the envelope were mixed deep into the CNO shell, O would be depleted and Na enhanced.

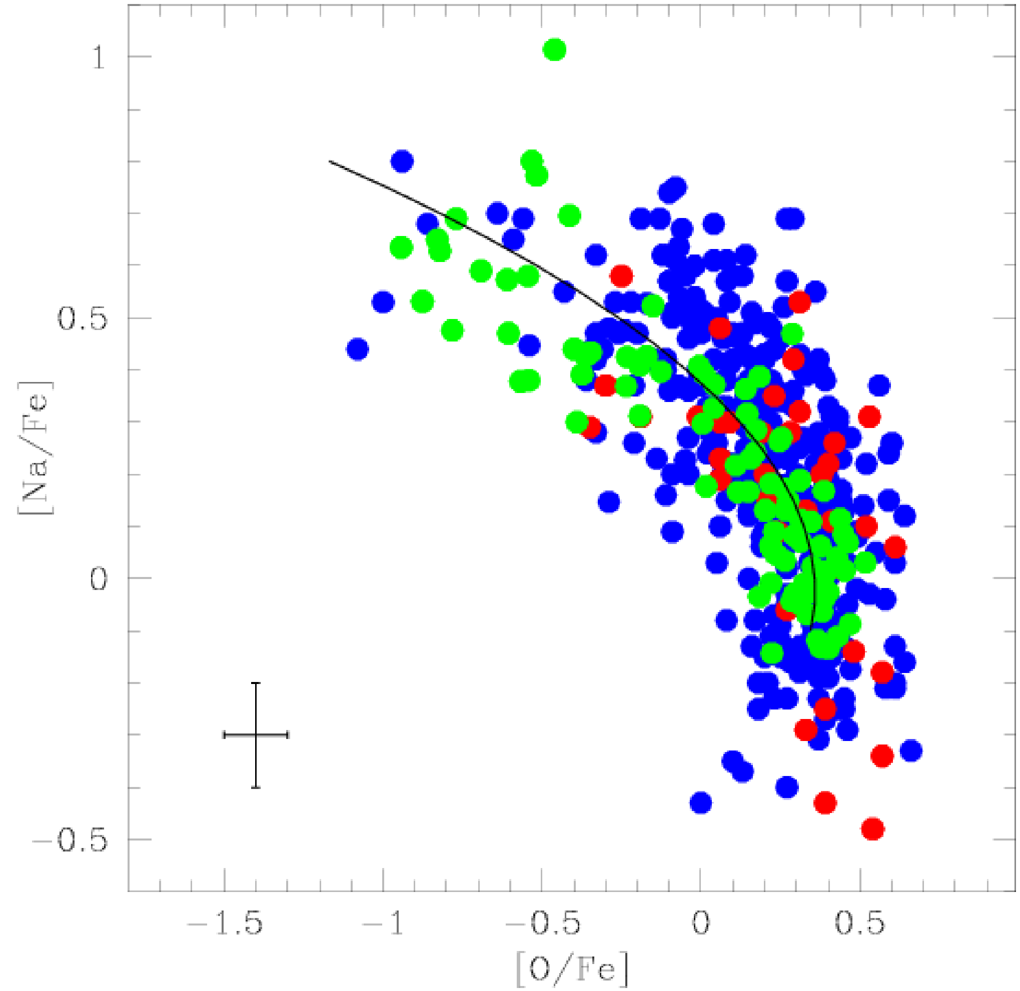
- **External processes.** The peculiar abundances of Na or Al are due to accretion to the surface of the stars from a polluting companion or to pre-enrichment of the proto-cluster gas.

The anticorrelations in unevolved stars; problem solved!

Na/O and Mg/Al anticorrelation in unevolved stars of NGC6752 (Gratton et al. 2001)

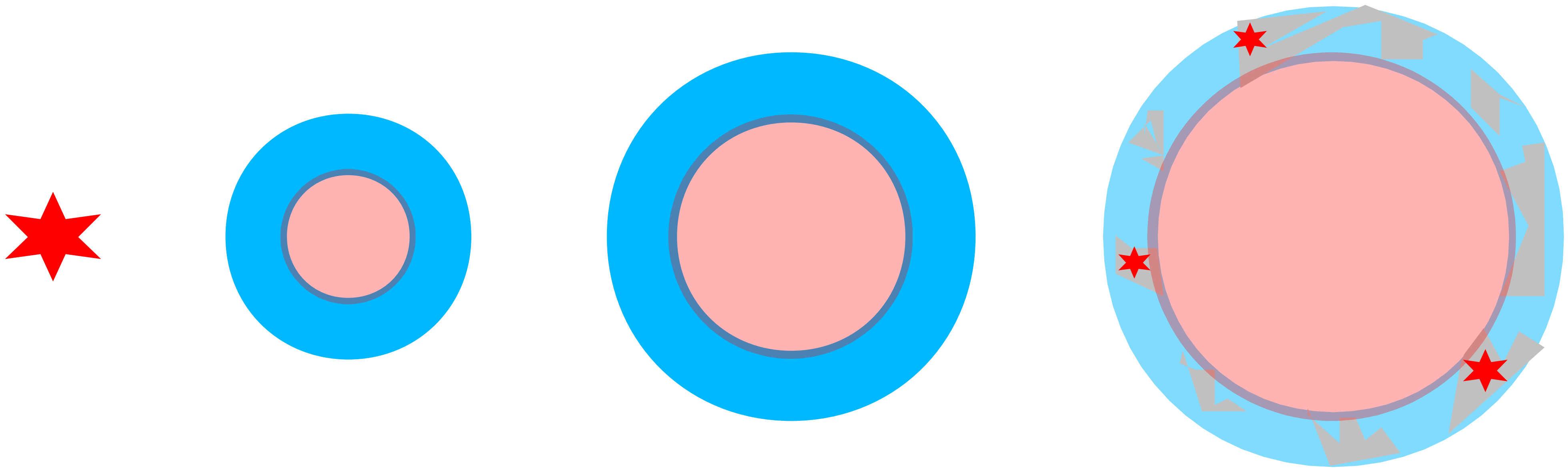






Na/O anticorrelation in NGC2808 (green points) in RGB stars (blue points) and unevolved stars (red points) of other Gcs (Carretta et al. 2005)

Which stars are responsible for the self-pollution? A single hypernova or a bunch of massive stars?



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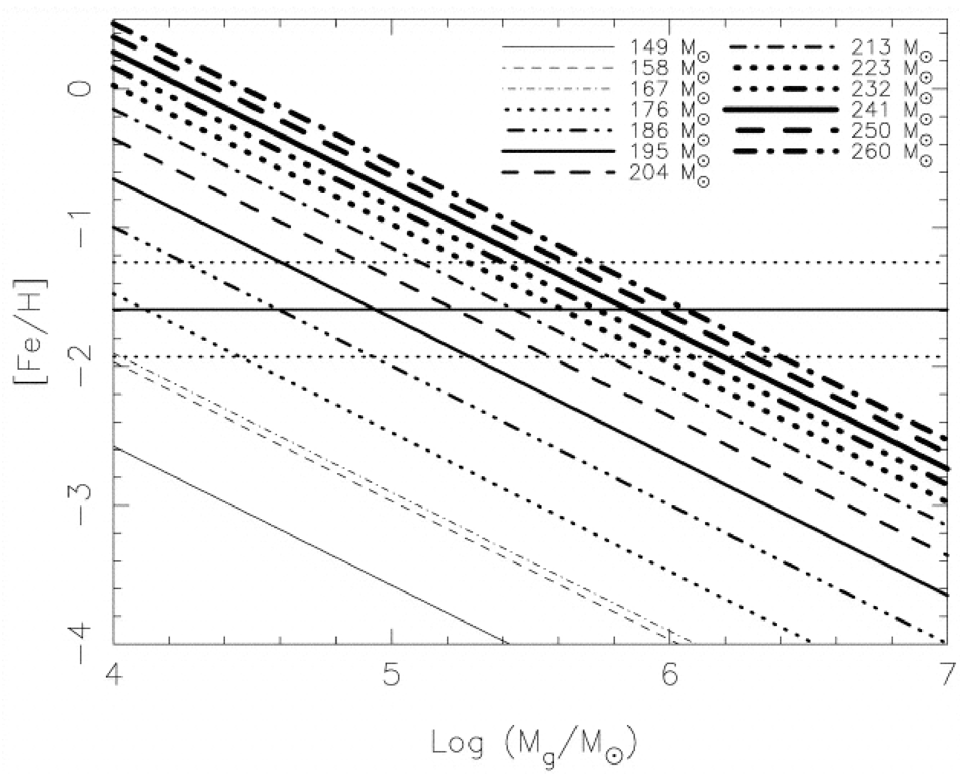
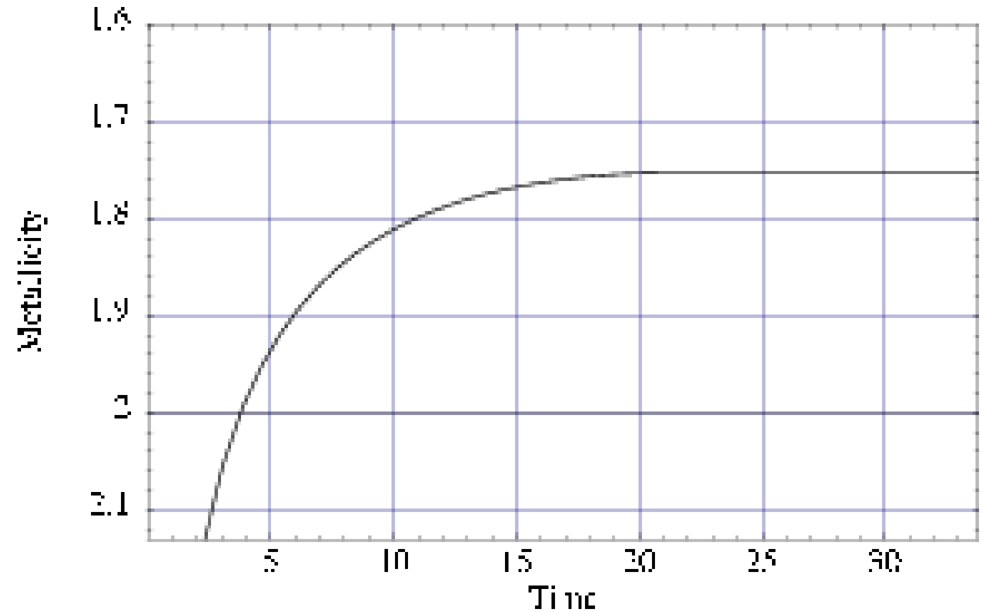
Hypernova



Beasley et al. (2003)

Superbubble



Parmentier et al. (1999)

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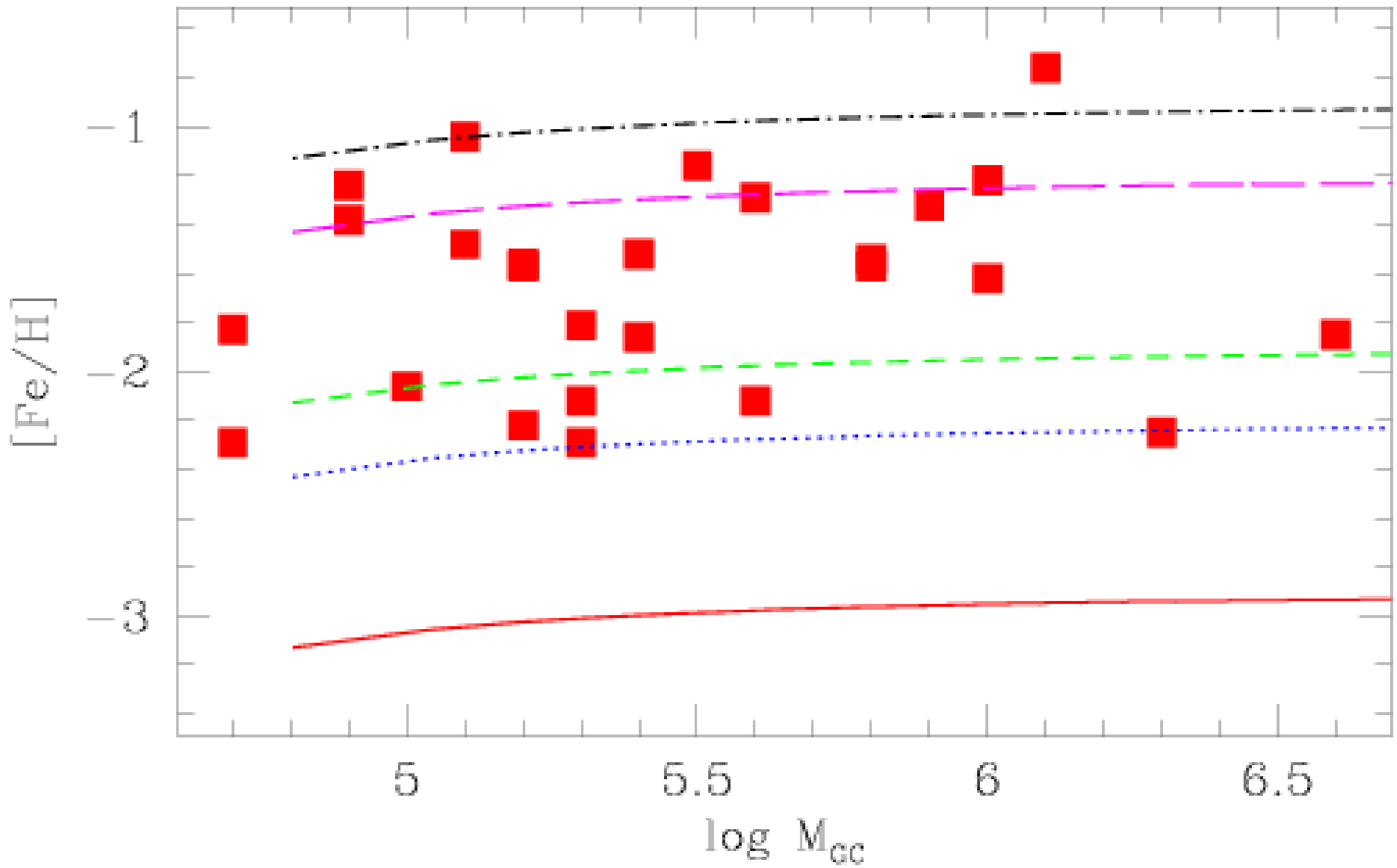
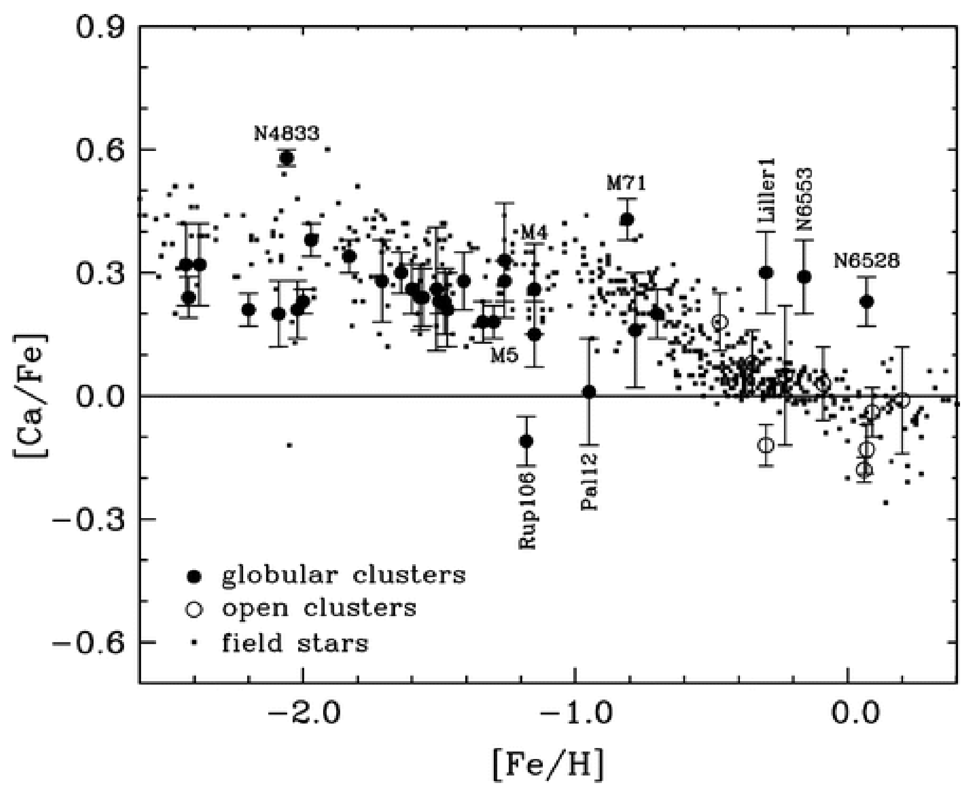


SR & Danziger (2005)

Mass-metallicity relations for GC models having different mixing efficiencies: from 0.01 to 1

..but how can these models explain the observed Na/O and Mg/Al anticorrelations?
If this mechanism is responsible of the spread in light elements, should not it produce also a spread in Fe?

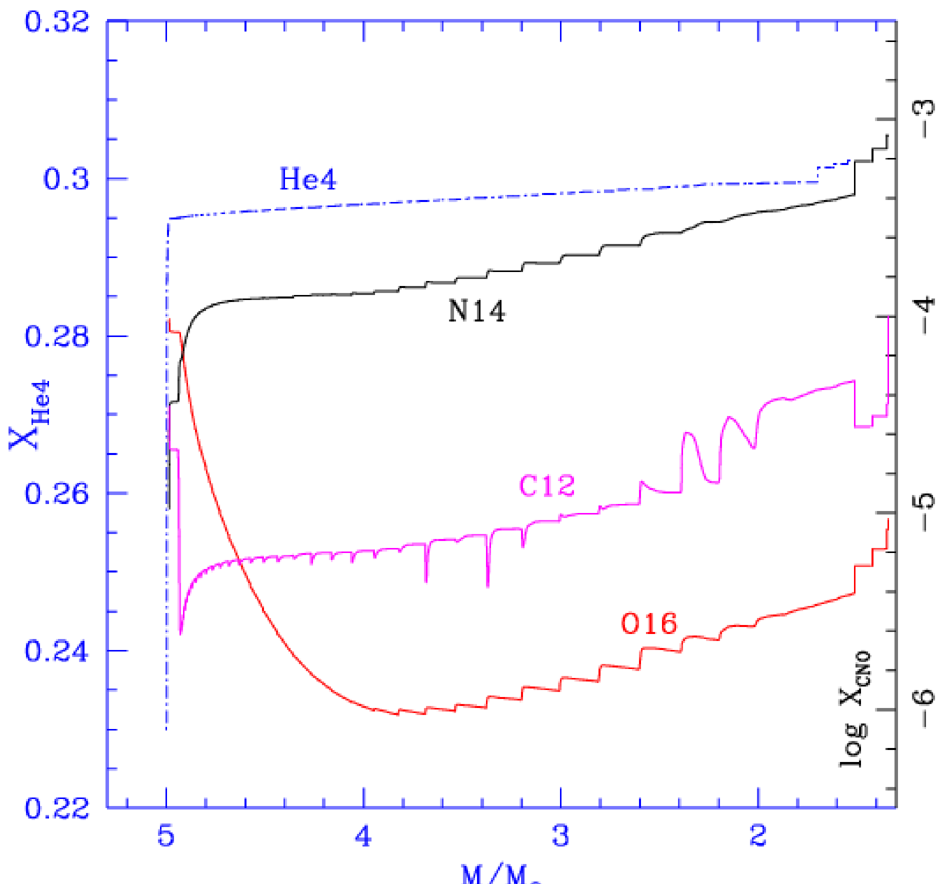
These models can explain the [Fe/H] threshold and the generally enhanced [alpha/Fe]
BUT NOT
the spread in light elements!



Gratton et al. (2004)

Which stars are responsible of the self-pollution? Intermediate-mass stars between 4 and 7 M_{sun}?

These stars can produce the right amounts of Na and Al. They do not produce significant amounts of iron-peak elements, therefore they do not contradict the observed iron uniformity



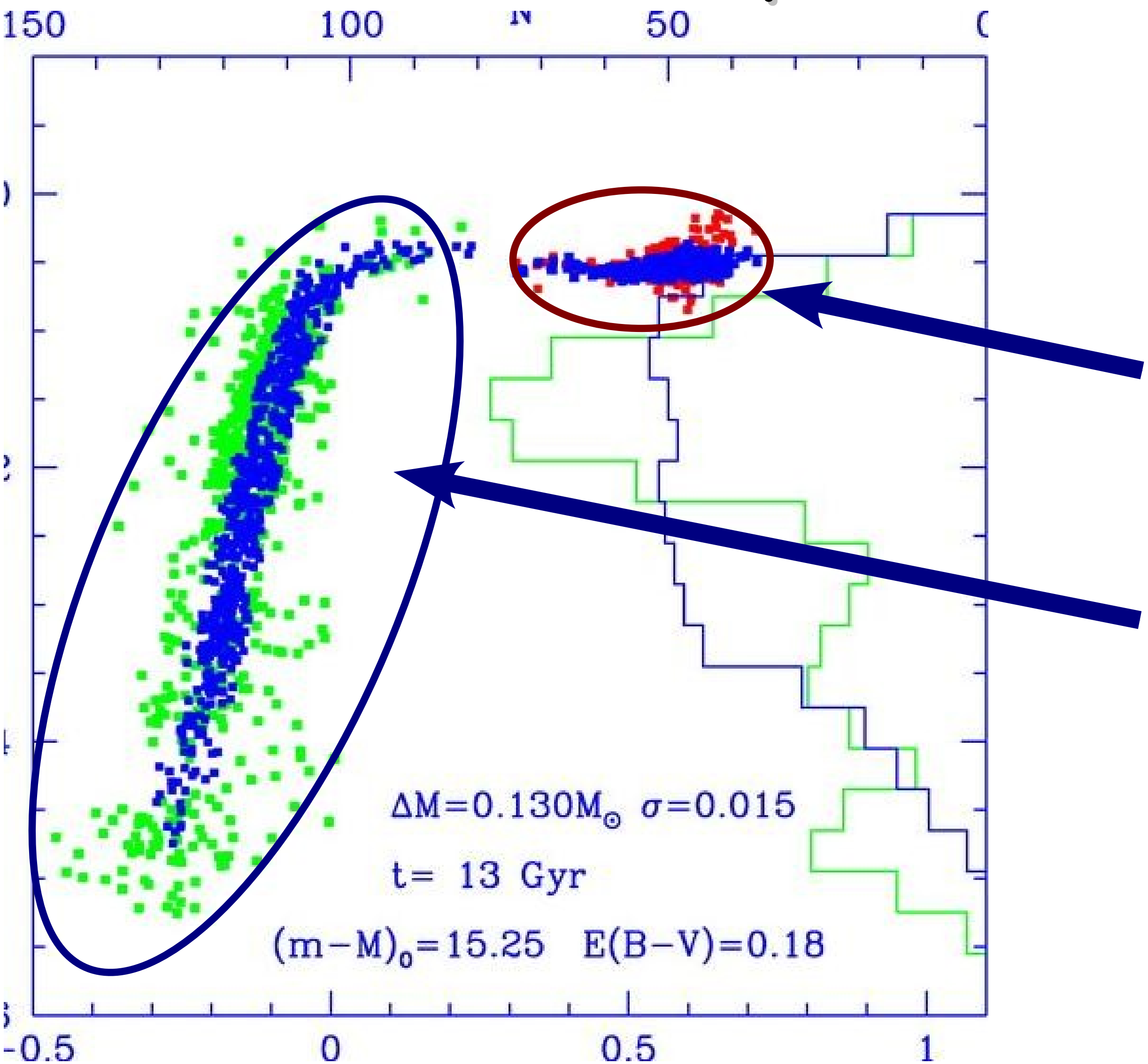
Ventura & D'Antona 2005

Evolution of a 5 M_{sun} star.

The C and N enhancement and the O depletion are associated with a He enrichment from Y=0.23 to Y=0.3.

➡ self-pollution from AGB stars should be associated with a large spread in He

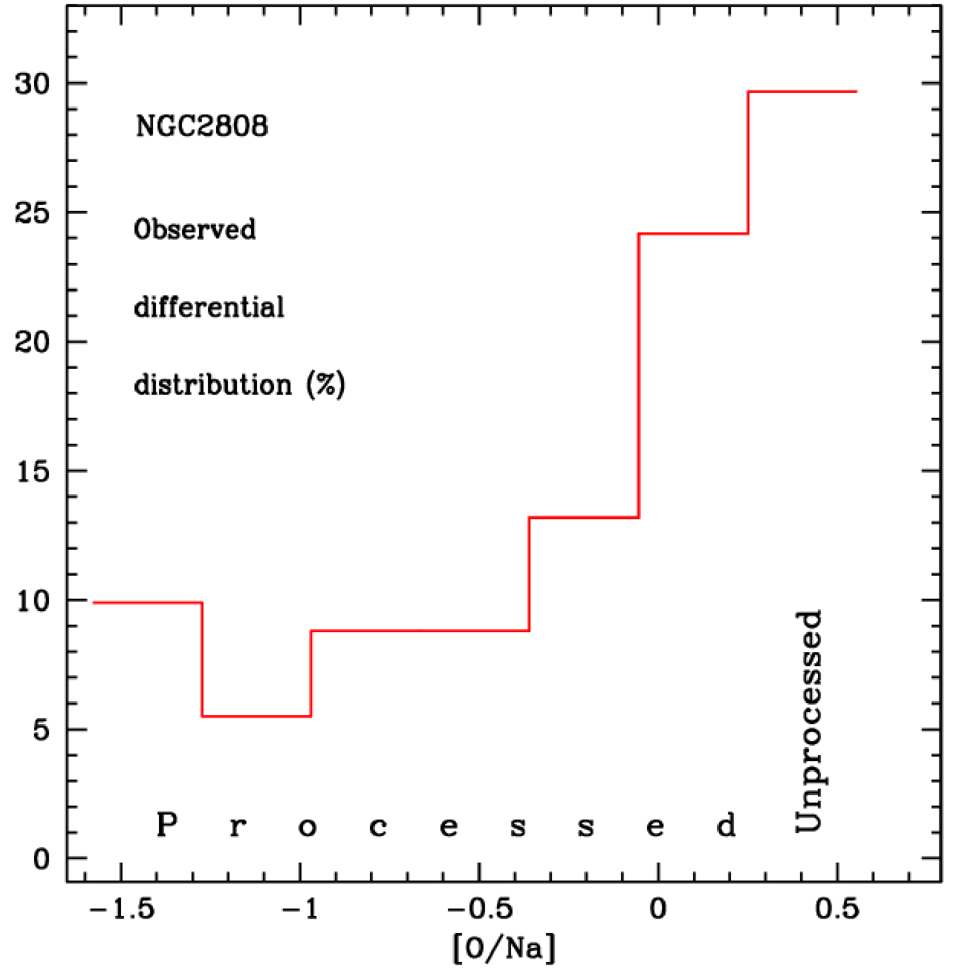
Example: NGC2808



Horizontal branch of NGC2808. According to the calculation of D'Antona & Caloi (2004), **this part** of the disgram (red plume) is characterized by stars with uniform, almost primordial He abundance (Y=0.24) whereas **this part** (blue tail) has a larger spread of helium (from Y=0.26 to Y=0.32).
According to their prediction the blue tail stars have been polluted from winds of intermediate-mass stars with a large range in masses.

D'Antona & Caloi 2004. Red and green: Observations; blue: predictions of the model

Example: NGC2808



Prantzos & Charbonnel (2006)

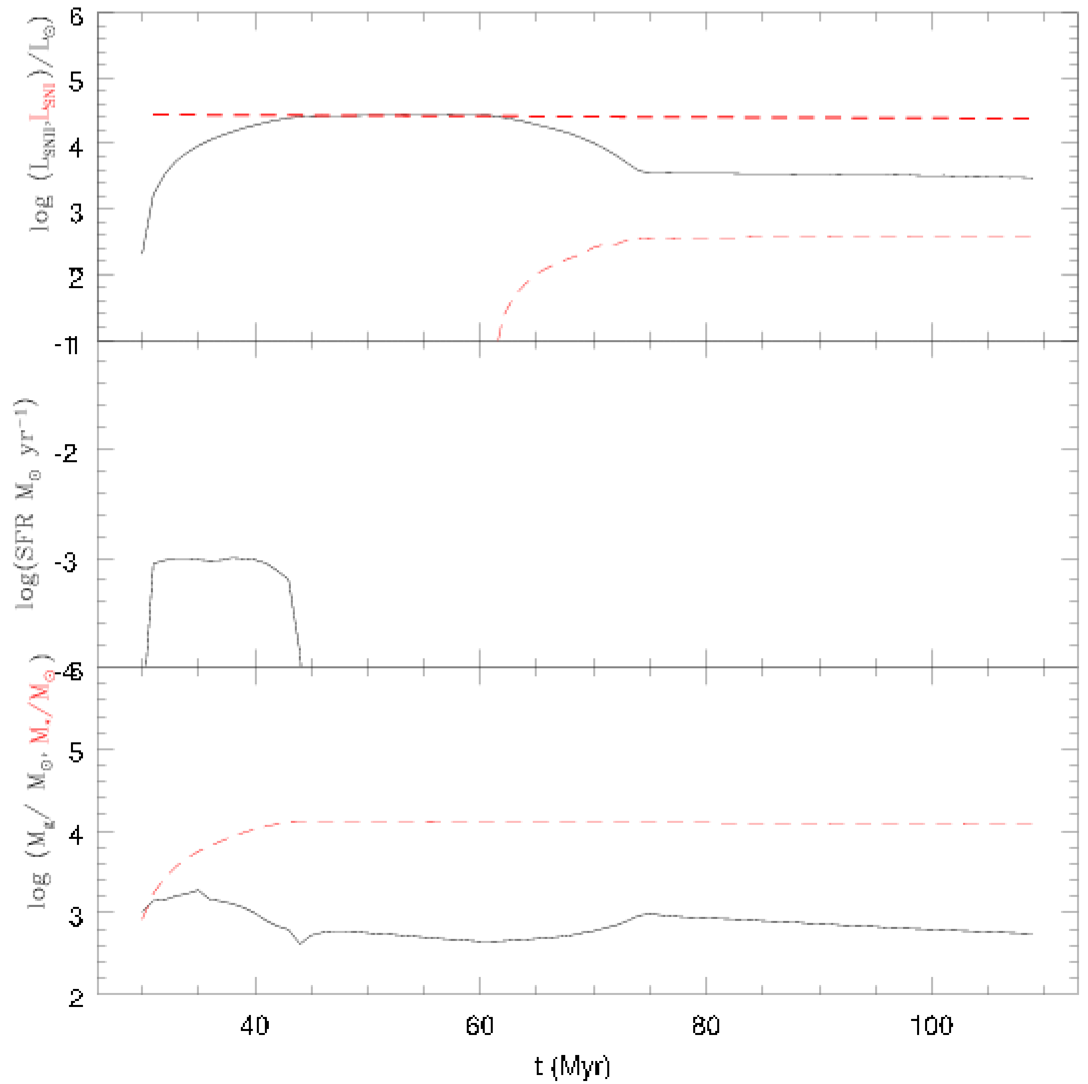
Only 30% of the stars in NGC2808 reflect the pristine composition. The others are polluted.

1-D modelling

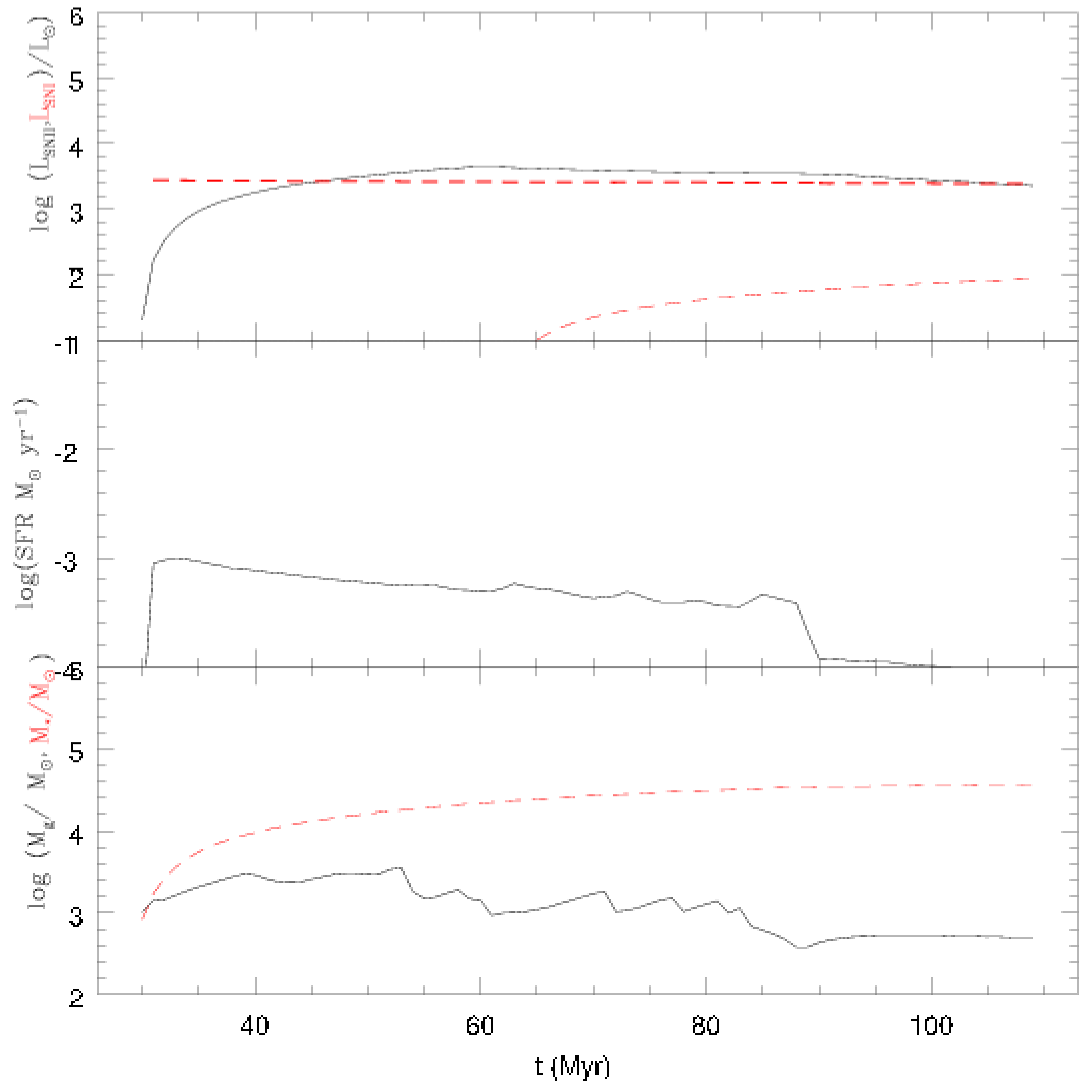
We assume that 10^6 M_{sun} of stars are formed in the first generation.

We assume that the SNeII of the first generation are able to get rid of all the pristine gas. We follow the evolution of the ejecta in order to see how many stars can they form.

1-D modelling



1-D modelling



Conclusions:

- Not necessarily star formation in globular clusters occurs in a single instantaneous burst
- The future is interesting