The Origin and Fate of the dSph galaxies

Their dynamical and chemical evolution

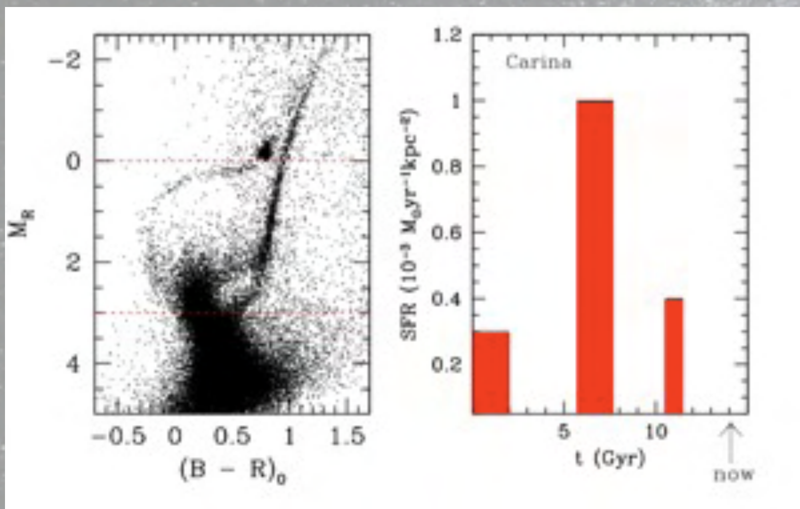
P JABLONKA

&

DARTeam : Y. Revaz E. Tolstoy V. Hill M. Irwin M. Shetrone A. Helmi K. Venn G. Battaglia B. Letarte M. Tafelmeyer_ E. Starkenburg

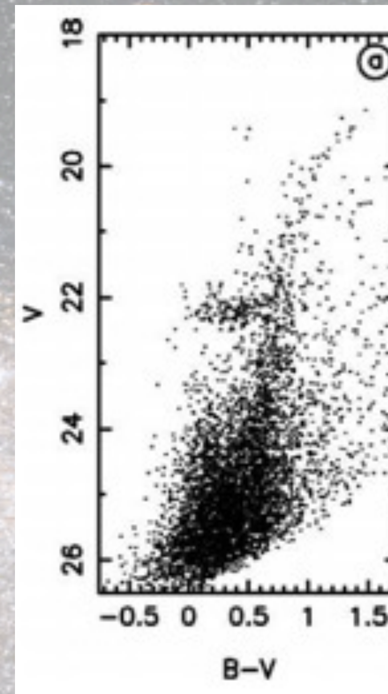
Motivation

THE CARINA DWARF SPHEROIDAL GALAXY,

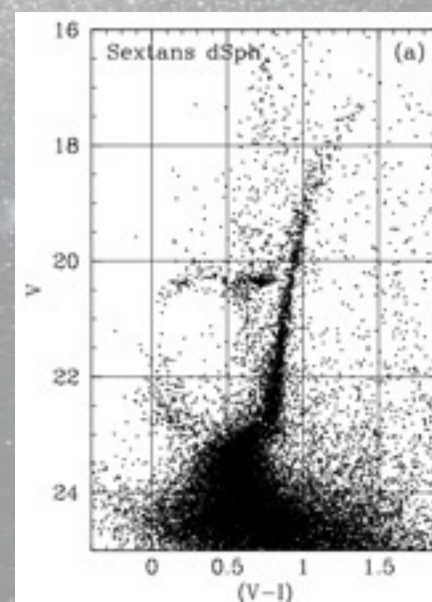


Tolstoy Hill Tosi 2009

CANES VENATICI I DWARF GALAXY,
Martin et al. 2008



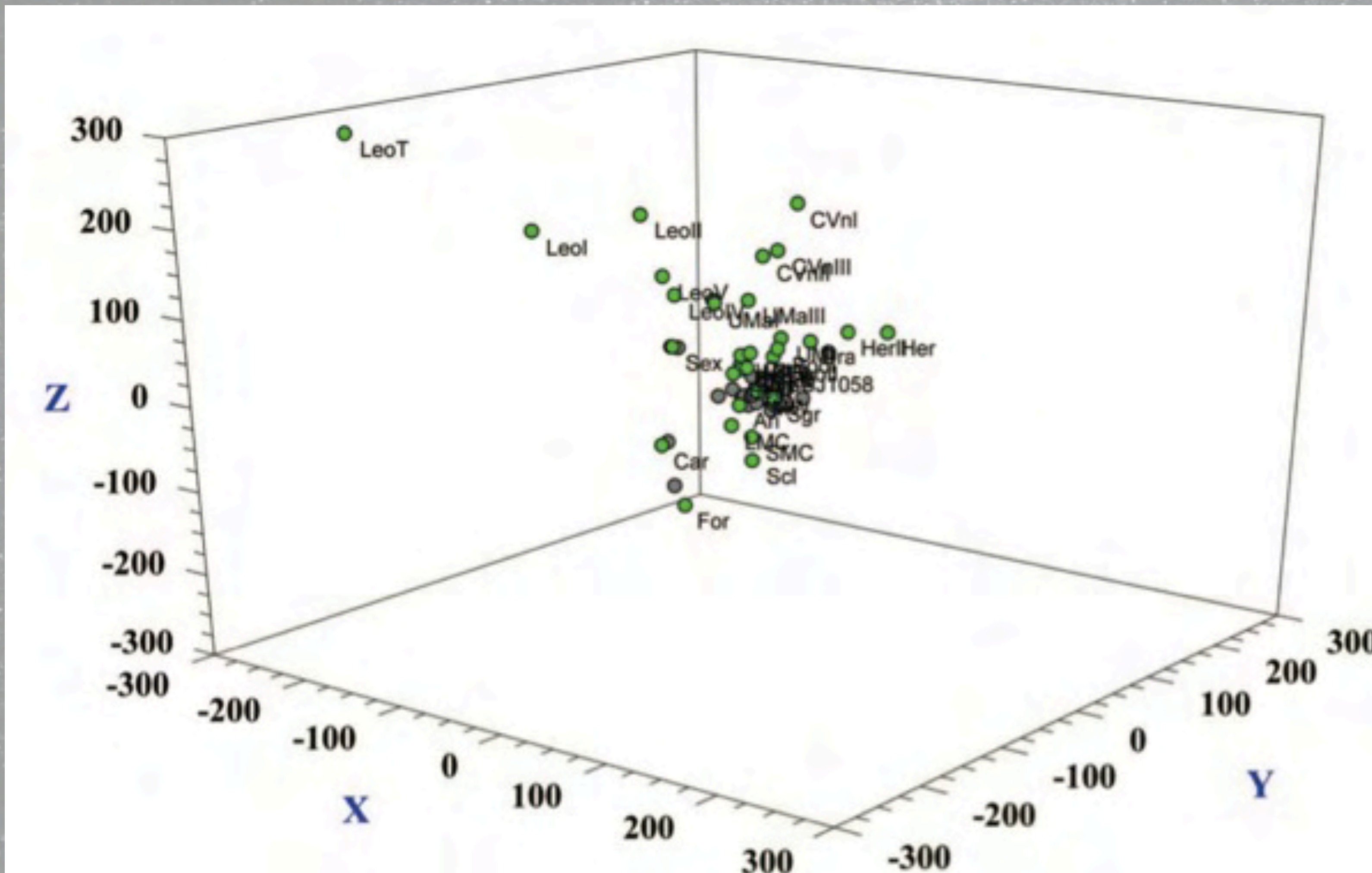
THE SEXTANS DWARF SPHEROIDAL GALAXY,
Lee et al. 2003



A large variety of star formation histories

Motivation

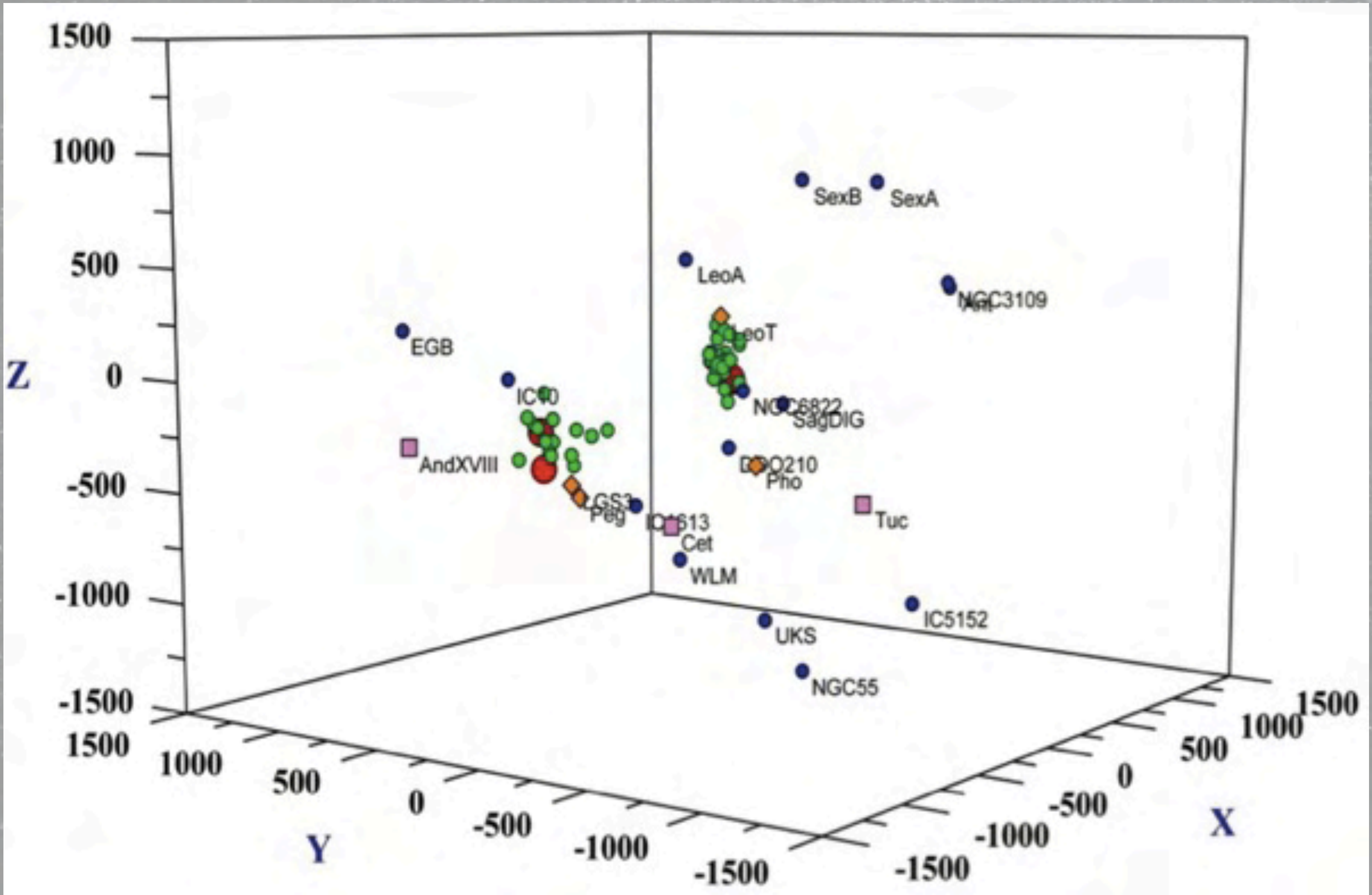
dSphs are clustered around massive galaxies



Mateo 2008

Motivation

dSphs are interior to Transition systems, interior to dIrrs



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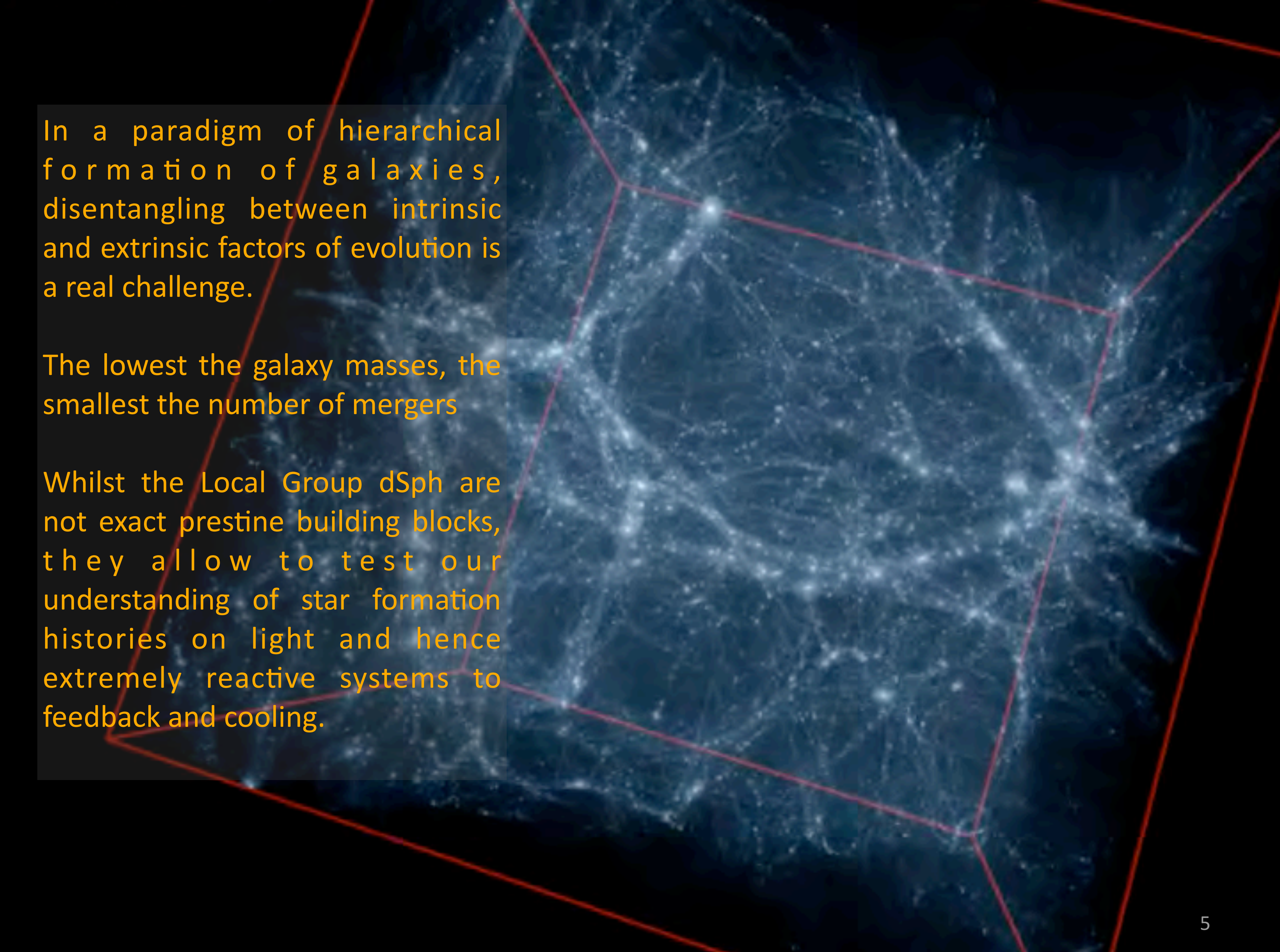

In a paradigm of hierarchical formation of galaxies, disentangling between intrinsic and extrinsic factors of evolution is a real challenge.

The lowest the galaxy masses, the smallest the number of mergers

Whilst the Local Group dSph are not exact prestine building blocks, they allow to test our understanding of star formation histories on light and hence extremely reactive systems to feedback and cooling.

From a $2Mpc/h^3$ pure DM simulation
134’217’728 particles
Resolution 150pc/h, 4.5 10^4Msun

Selection of 150 Local-Group dSph-like haloes with masses between 10^8 and 10^9 Msun

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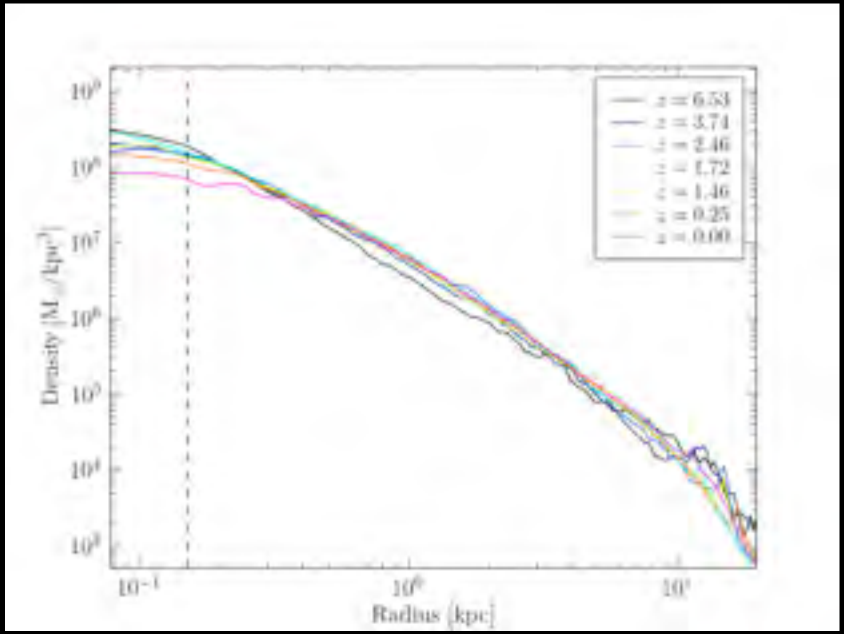

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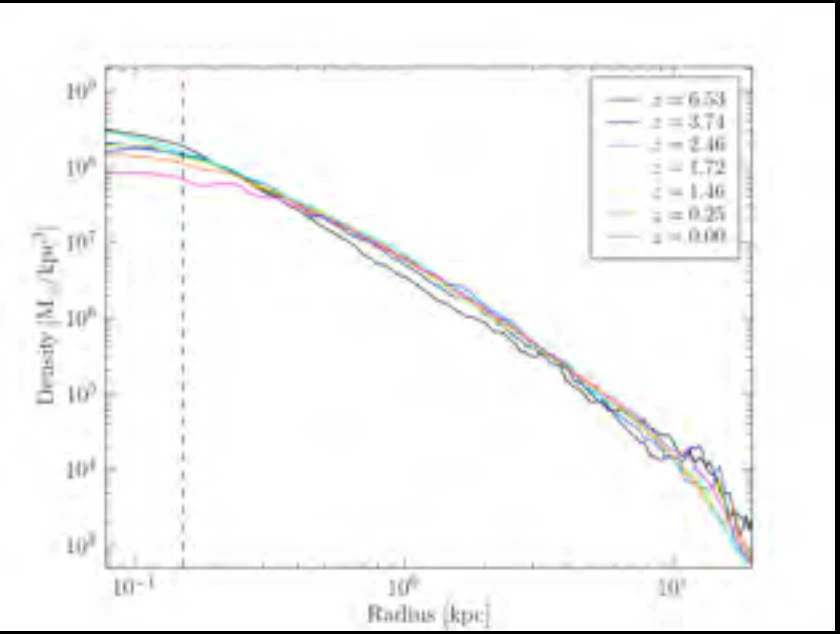

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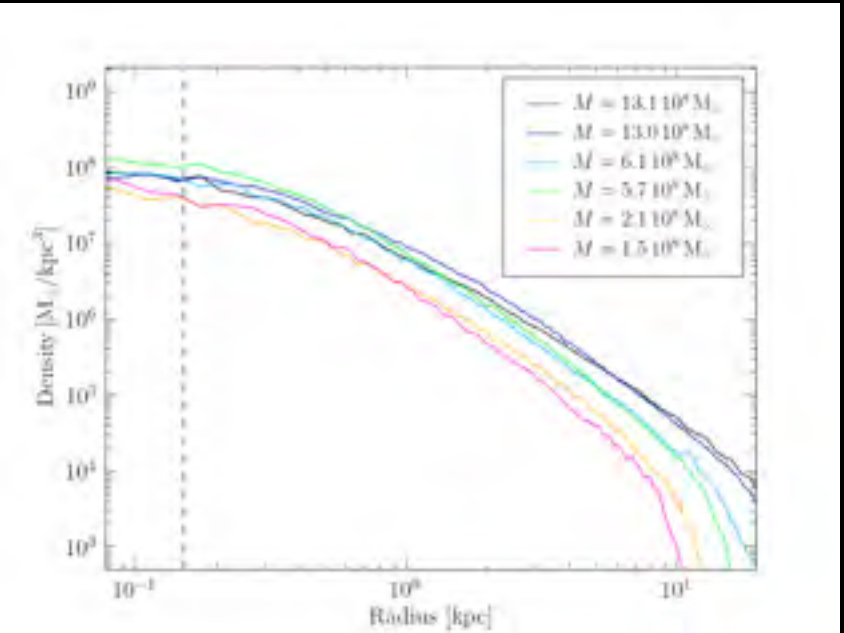
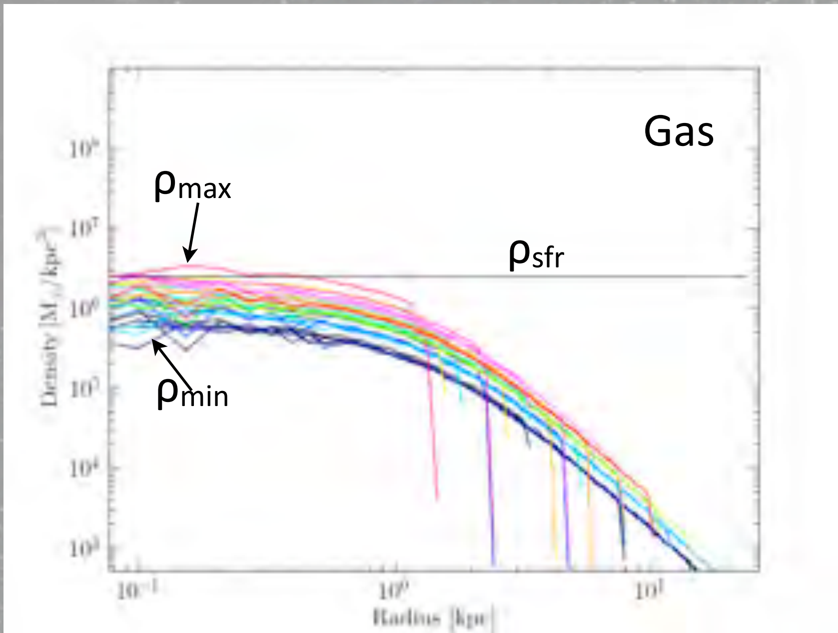
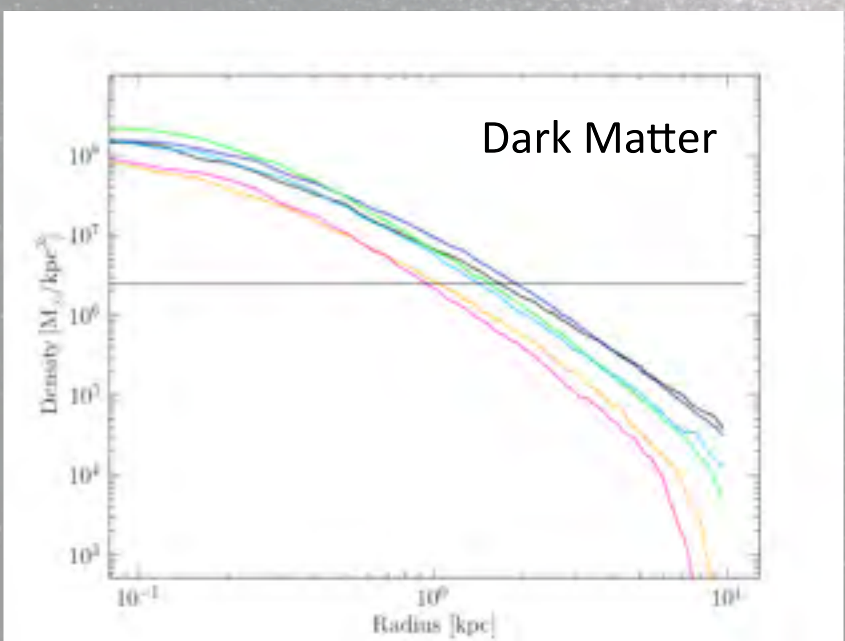




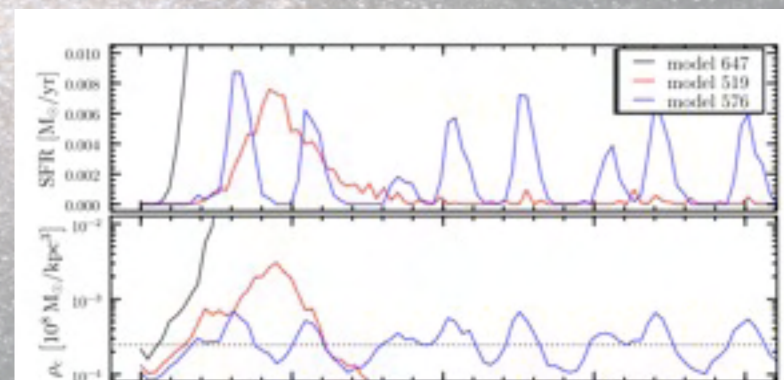


General Features from chemo-dynamics:

The gas density plays a key role in the onset of star formation

✦Systems must form stars ⇒ρ_{min}

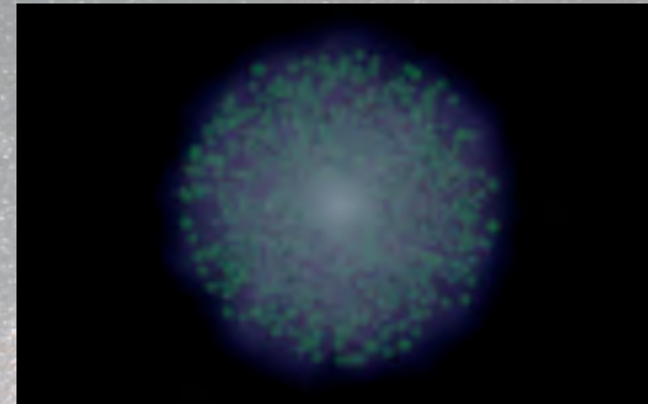
✦ Systems should not collapse ⇒ρ_{max}



Revaz et al. 2009

WMAP cosmology ⇒ Baryonic Fraction (15%)

Initial conditions



Dark matter + primordial gas
Pseudo isothermal or
NFW + Burkert spheres

Code Revaz & Jablonka 2010

<u>Skeleton</u>:

- ✦ Gadget-2
  - *Hydro= SPH*
  - *Gravity = Tree*

<u>Inserted physics:</u>

- ✦ Star formation $$\frac{d\rho_g}{dt} = -\frac{d\rho_*}{dt} = -\frac{c_*\rho_g}{t_g}$$
- ✦ SNII, SNIa nucleosynthesis
- ✦ Stellar lifetime=f(Z)
- ✦ Thermal feedback + blast
- ✦ Cooling function =f(Z)

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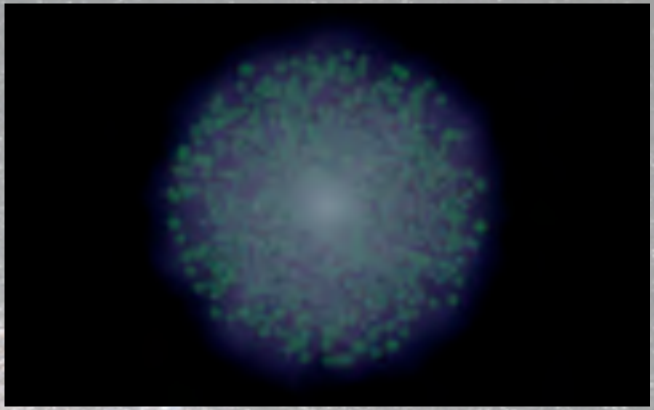

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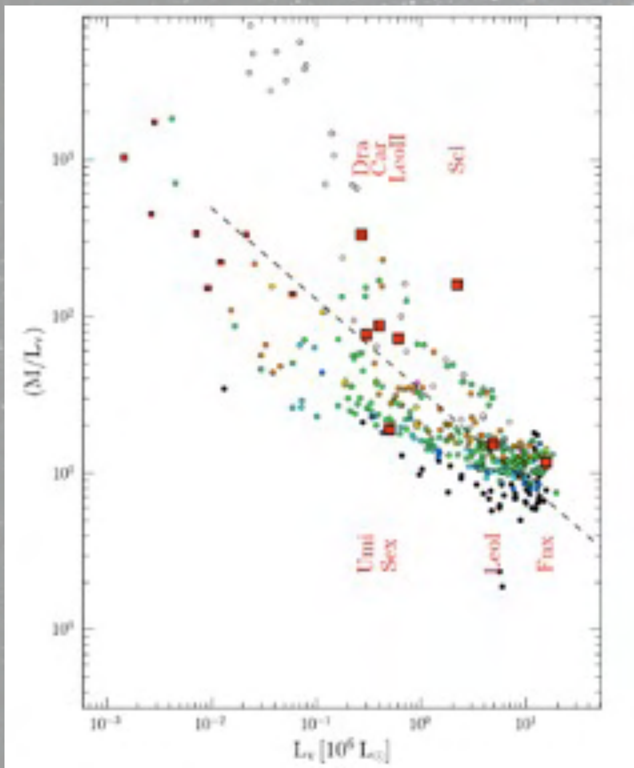
419 simulations from 0 to 14Gyr
Spatial resolution down to 12pc ($4x10^6$ particles)
All parameters investigated C_*, ρ, M_i, E_{SN}
but also convergence, energy conservation etc.

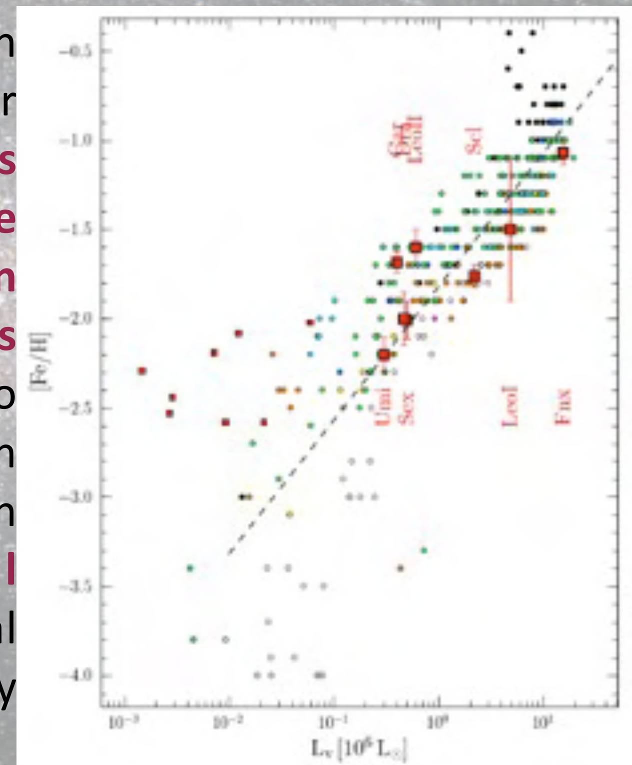
Global Relations

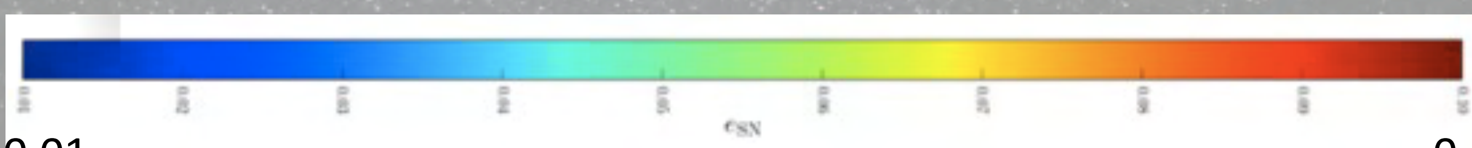
Massive stars end their lives as core-collapse SNe and deposit typically **E_{SN} ~10^{51}** ergs in the form of kinetic energy of the ejecta. Initially the SN ejecta expands freely into the wind-blown cavity and later **interacts with the shell** produced previously by the winds, generating various shocks, e.g., transmitted and reflected shocks. Most of the explosion energy is thermalized via such shocks. The supernova remnant begins to lose a significant fraction of thermal energy via radiative cooling. **The final energy budget** deposited into the surrounding medium in the forms of thermal, kinetic, and radiative energy **depends on the size and structure** of the preexisting **wind bubble** as well as on the **ambient ISM**.

Global Relations



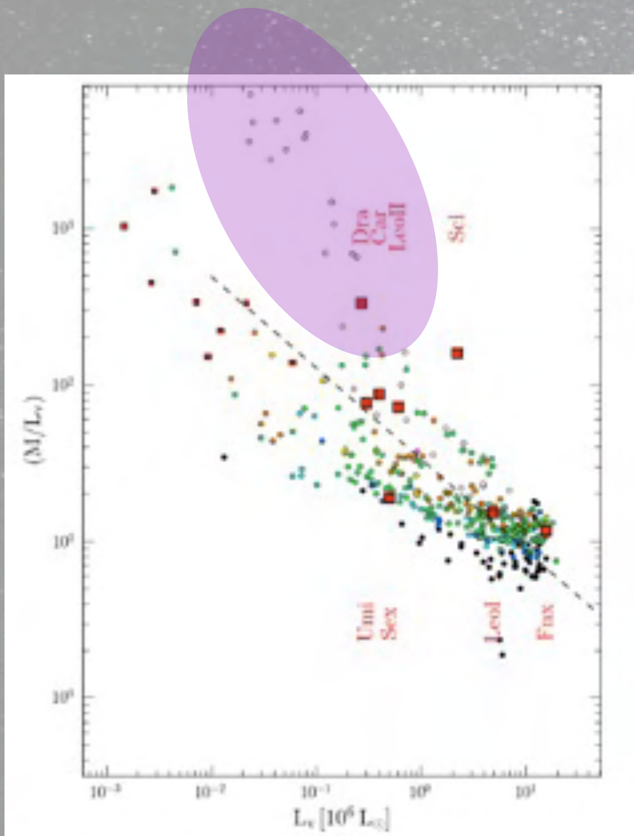
Although **SN feedback** is an important ingredient for galaxy formation, it **occurs typically on length and time scales much smaller than grid spacings and time steps of numerical simulations.** So such subgrid physics is often treated through **phenomenological prescriptions** in numerical simulations for galaxy formation





Efficiency of the super novae feedback energy

Global Relations



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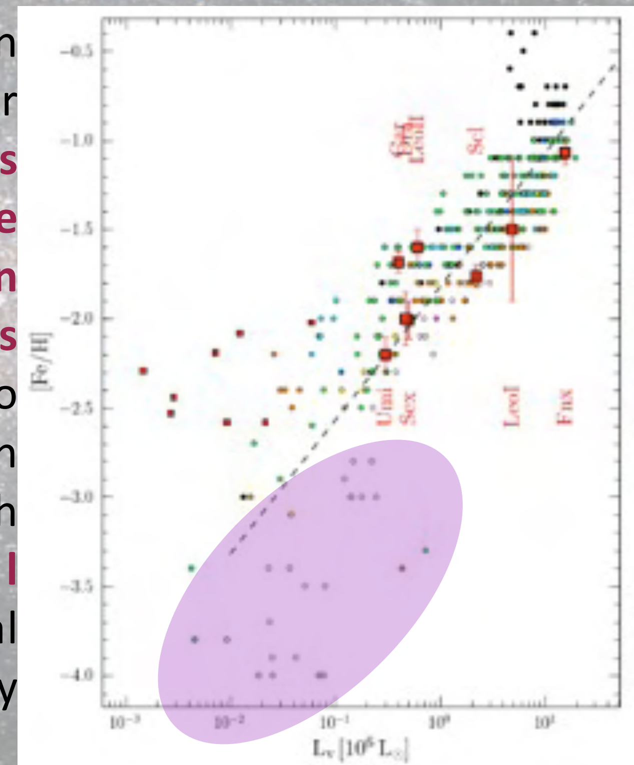

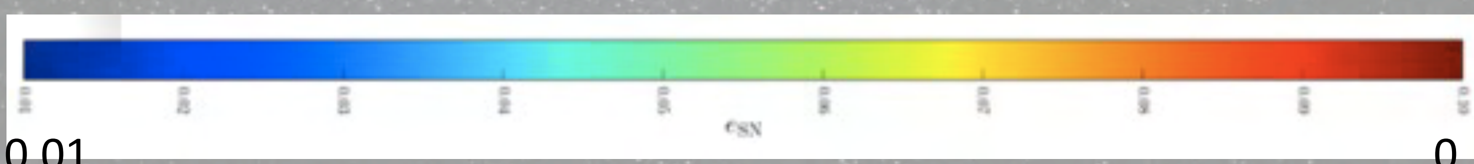

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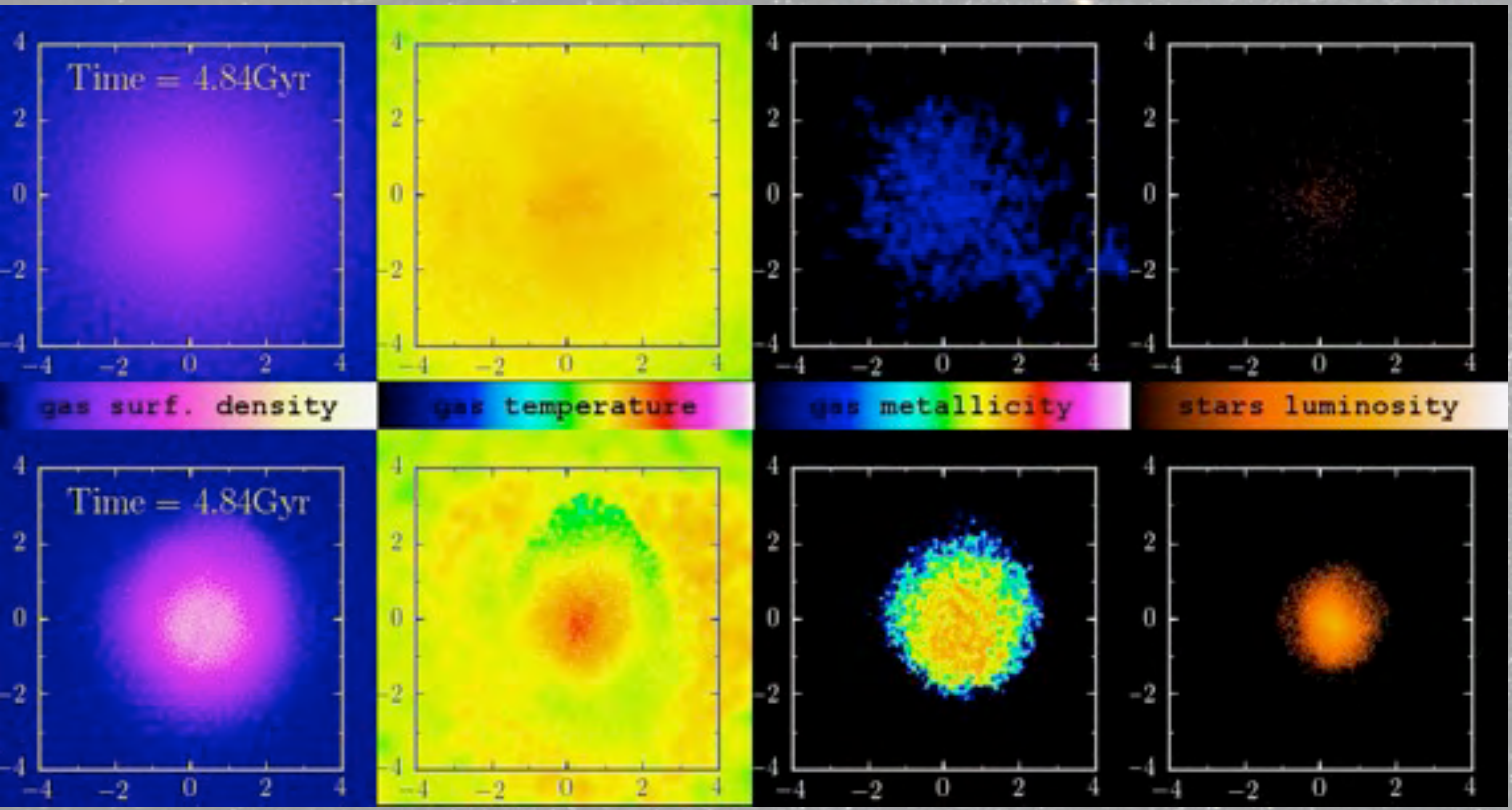


100% efficiency
ε=1

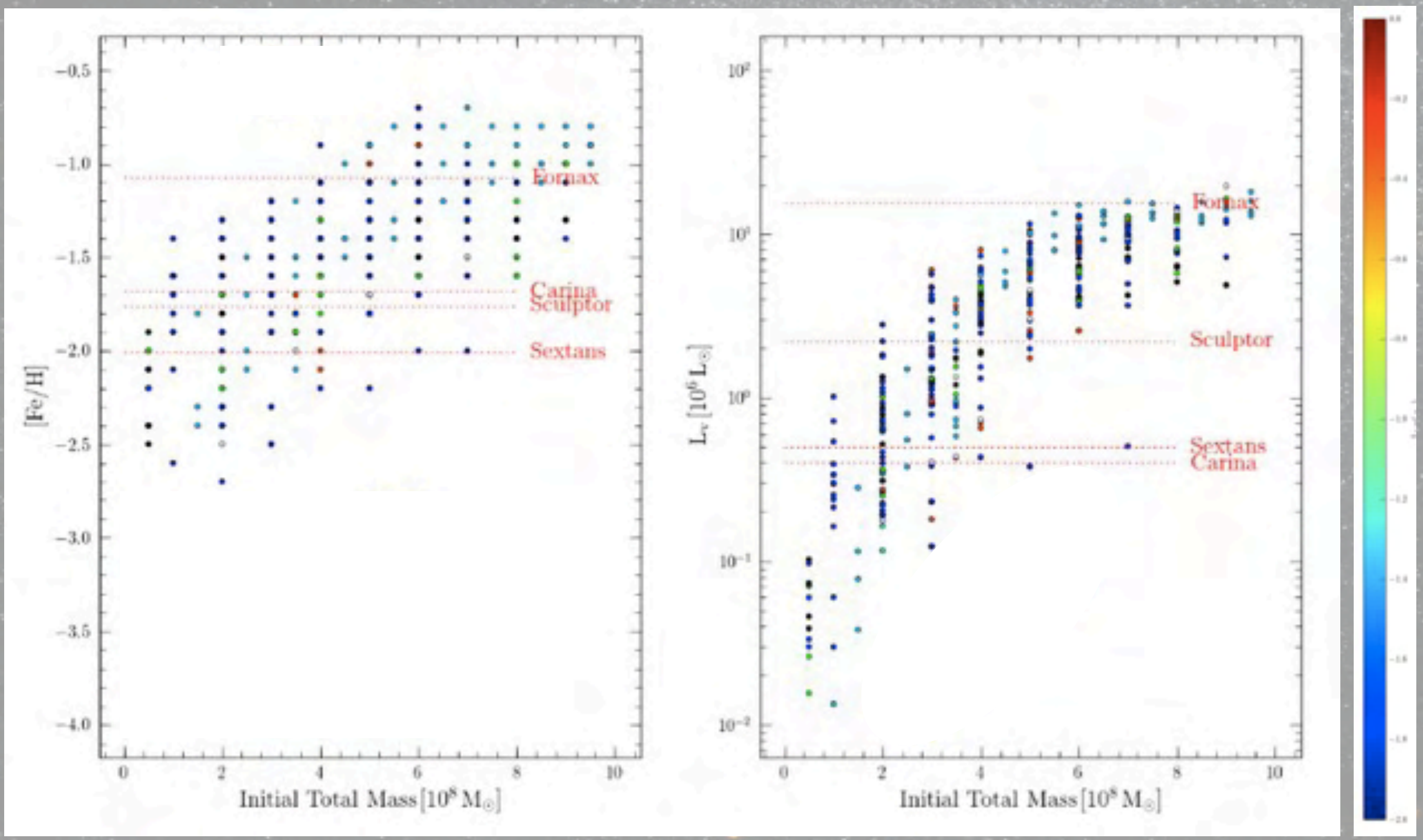
1% efficiency
ε=0.01

✦To allow chemical enrichment, ε must be below 10%

✦Contrary to the classical «naive» picture, there is no strong wind, the gas is kept around the system - Different modes of chemical enrichement of the ISM (including Archimede forces on hot bubbles)

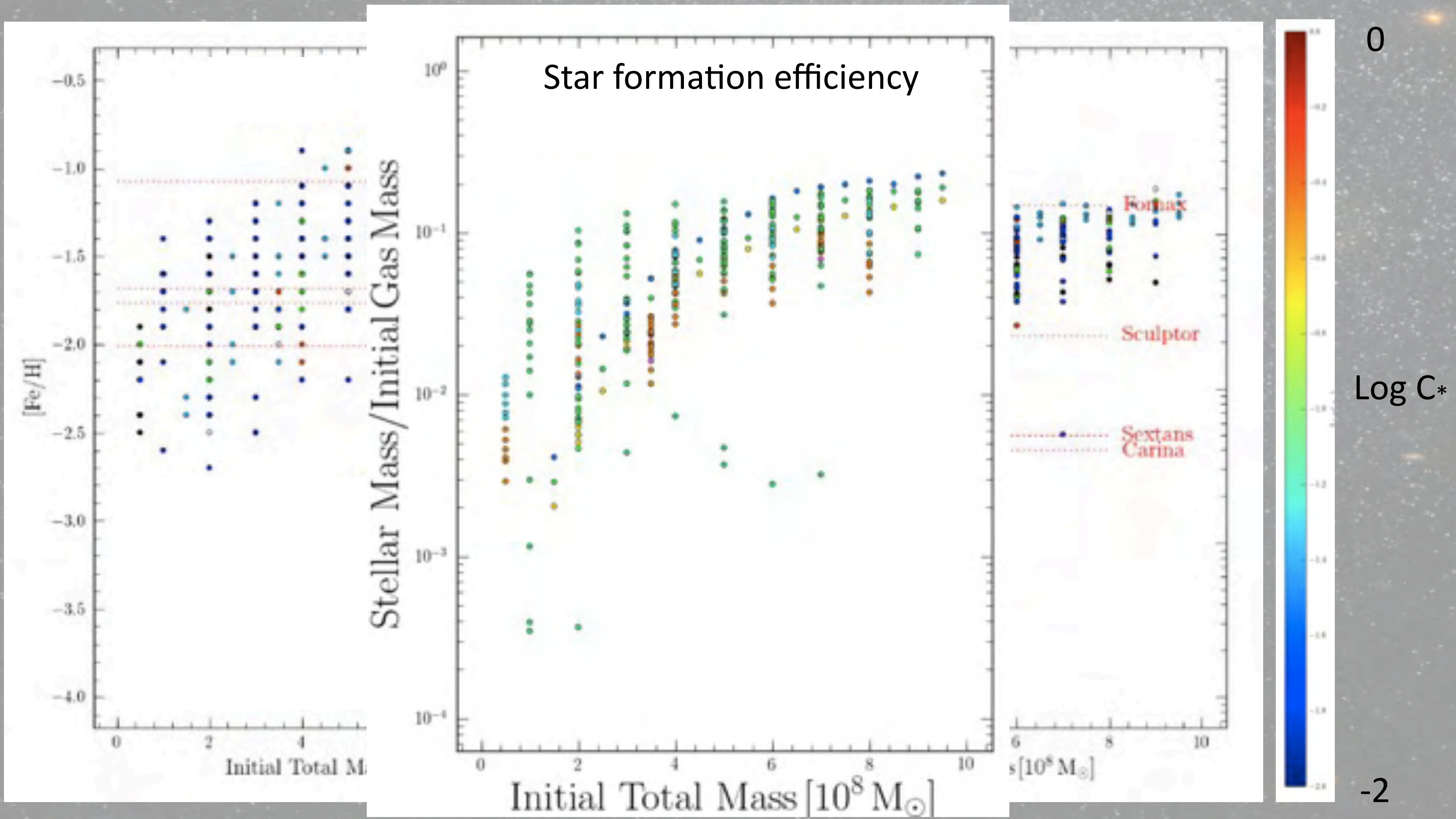
✦

Global Relations



Initial Galaxy Mass = Dark Matter + Gas in cosmological baryonic fraction

Global Relations

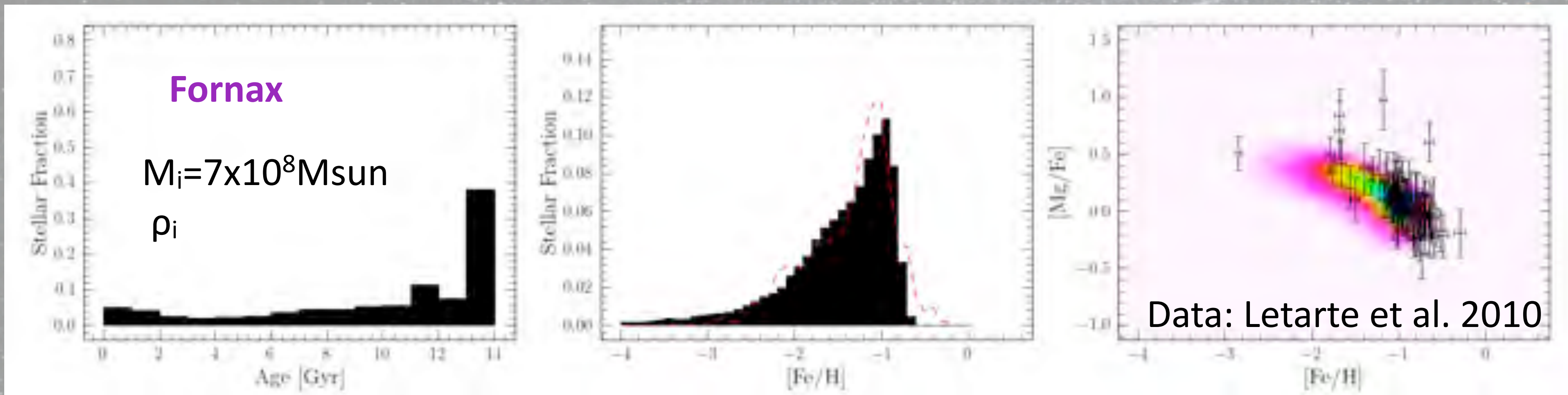


Initial Galaxy Mass = Dark Matter + Gas in cosmological baryonic fraction

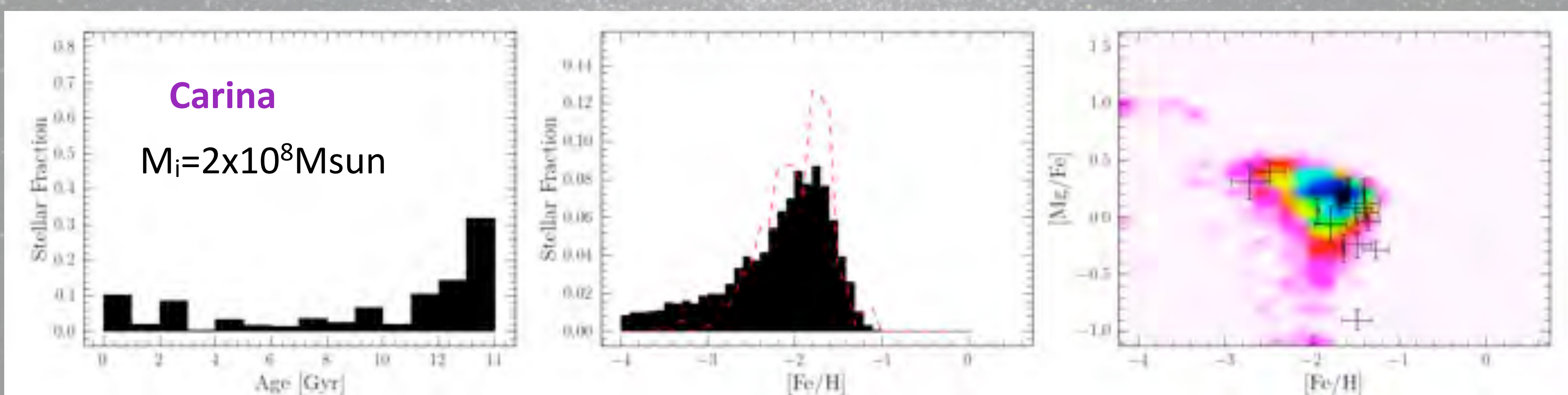
Abundance Ratios

One single set of parameters
Initial condition, ε, c_* etc ..

AGES [Fe/H] [Mg/Fe]



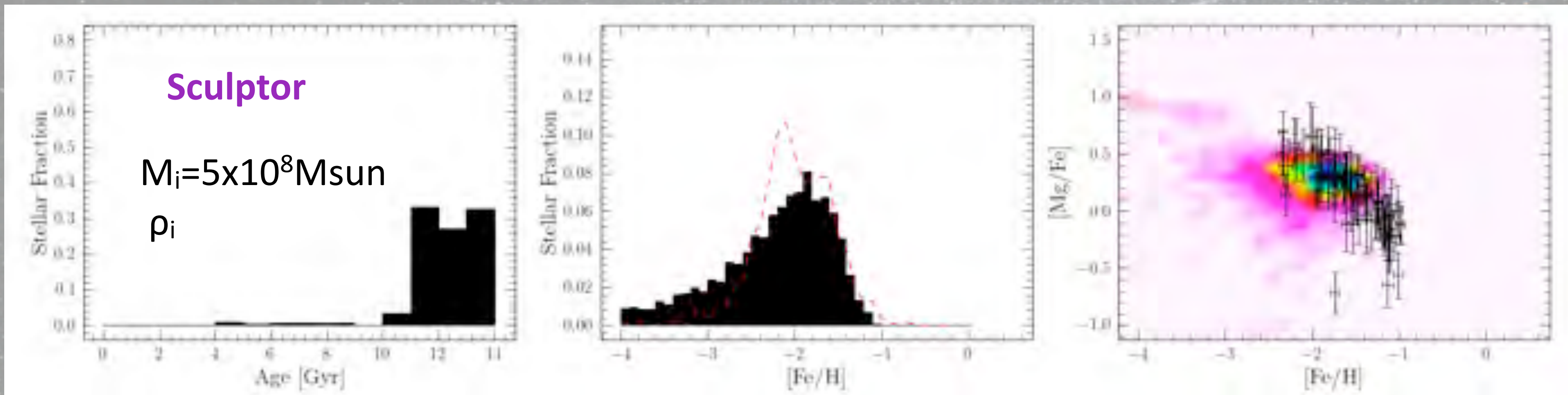
Feedback efficiency ε=0.05

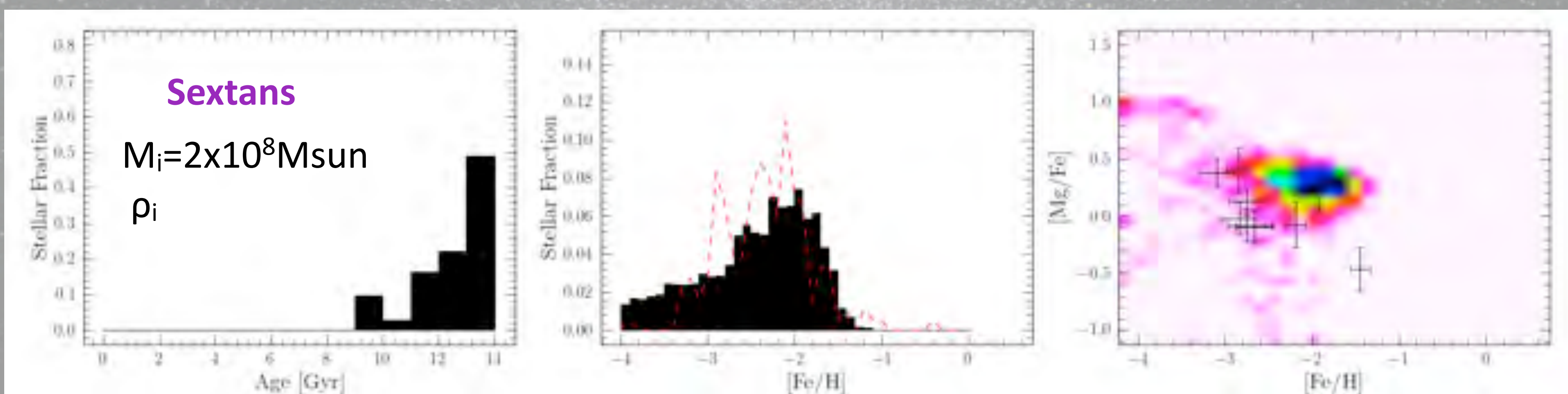


Data : Koch et al. 2008

Abundance Ratios

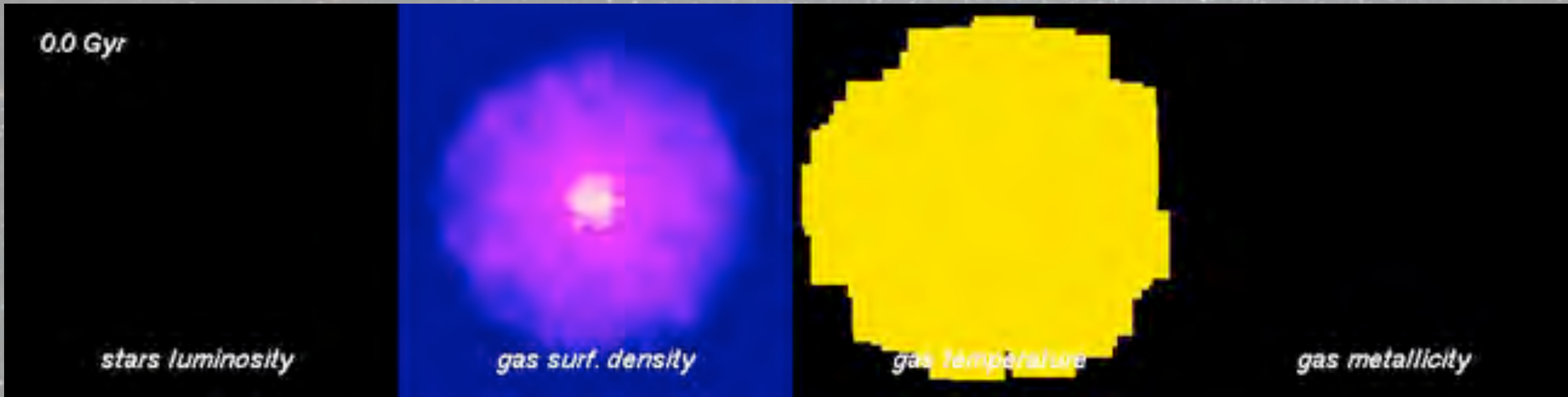
Data: Hill et al. in prep

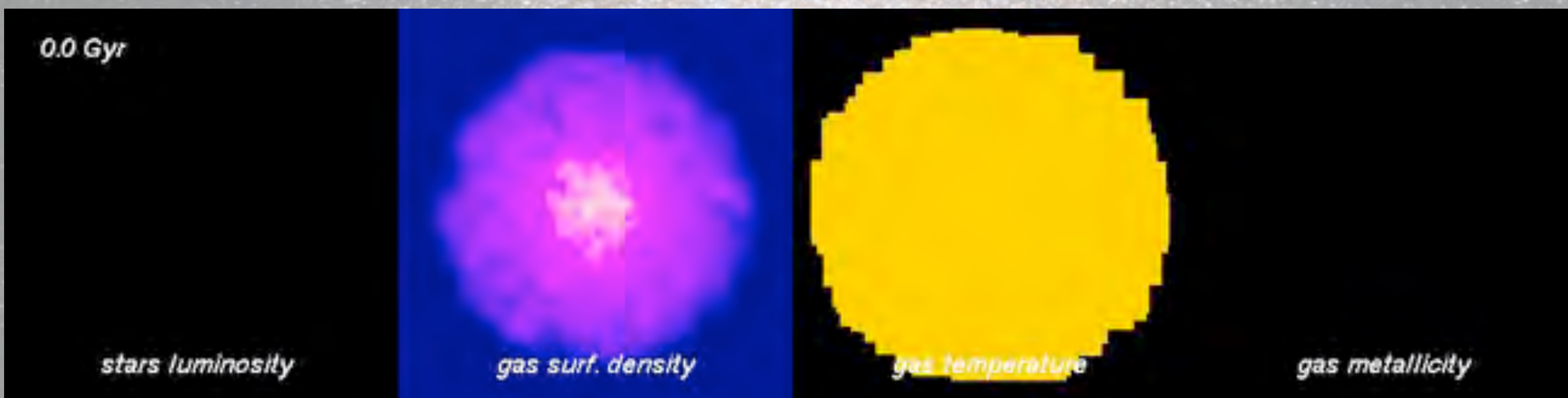




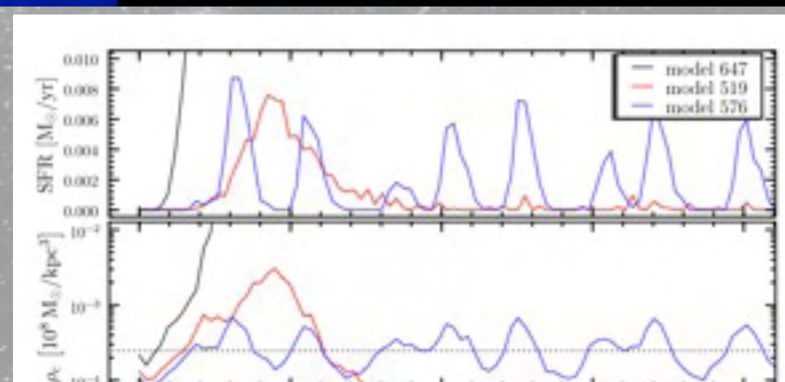
Data: Shetrone et et al. , Aoki et al 2009

Low Mass (Carina)





High Mass (Fornax)



Summary

✦ **NATURE** The variety of star formation histories among Local Group dSph (**discontinuous to continuous star formation**) can be reproduced in a single framework in which

☞ **the initial total mass (and density)**

and

☞ **the efficiency of the SN explosions**

play the primary role

via heating and cooling processes

✦ **NURTURE** The chemodynamical simulations in isolation provide clear evidence for a role of interaction in the dSph evolution

☞ **remaining gas in all simulated systems at 14Gyr**

and

☞ **no intrinsic process to stop star formation**

GAIA

Motivation

Gas removal : if the tidal force affects the HI, it should also affect the stars

Tidal tails ?

Fornax : Putman et al. 1998 *YES* in the HI

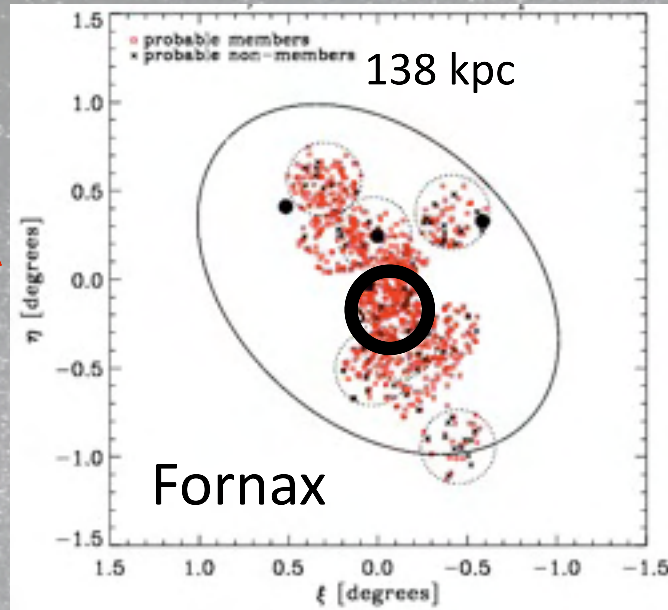
Coleman et al 2005 *YES* (*> Rt)

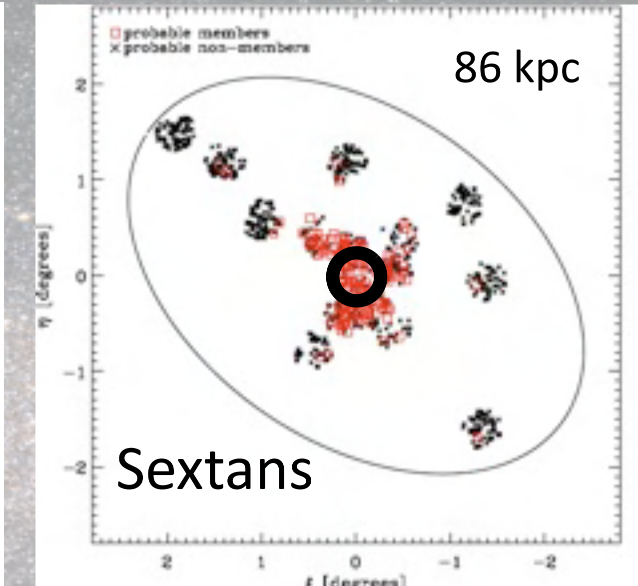
Sculptor : Walcher et al 2003 *YES*

Coleman et al 2005 *NO*

Motivation

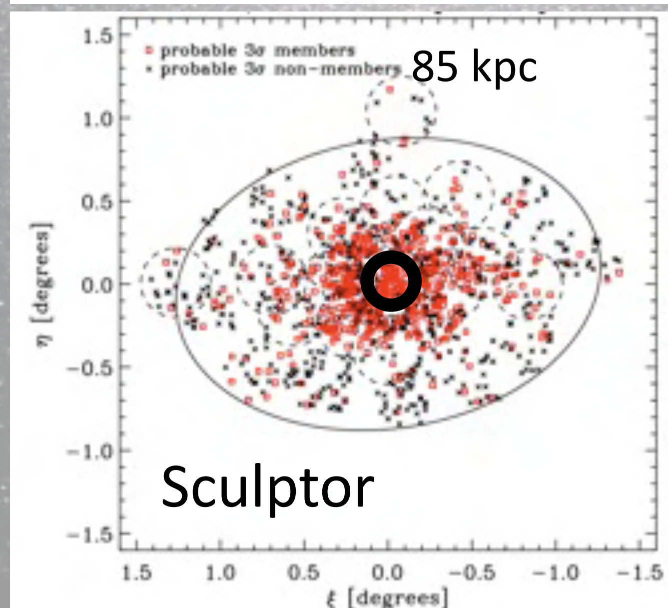
DART





566 LR stars @ V< 18.9
of which only 72 with HR

355 stars @ V>18.9
None with HR spectro

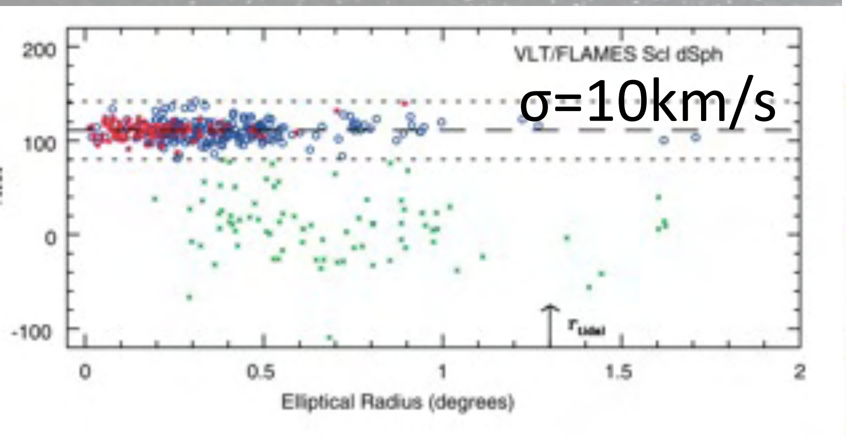


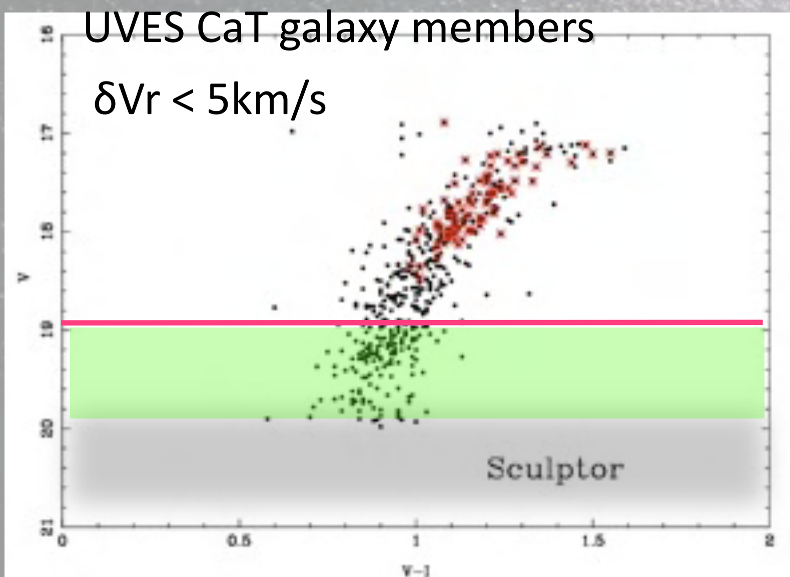
290 LR stars @ V< 18.9
of which only 89
with HR

348 stars @ V>18.9
None with HR spectro

- ✦HR restricted to galaxy centers, latest generations of stars
- ✦LR cover wider area but still not statistical coverage to tidal R

Route to Membership





GAIA

Astrometry

	V mag	EOM Performance [µas]	Specification
B1V	< 10.0	10.7	< 7
	15.0	30.0	< 25
	20.0	390.3	< 300
G2V	< 10.0	10.4	< 7
	15.0	27.8	< 24
	20.0	344.1	< 300
M6V	< 10.0	10.4	< 7
	15.0	10.3	< 12
	20.0	110.4	< 100

End of mission astrometry performances

Spectroscopy

	V mag	EOM Performance [km/sec]	Specification
B1V	7.0	0.5	< 1
	12.0	8.1	< 15
G2V	13.0	0.6	< 1
	16.5	14.1	< 15
K1IIIMP	13.5	0.6	< 1
	17.0	15.6	< 15

End of mission radial velocity spectrometry performances

Prusti 2010 (Gaia meeting)

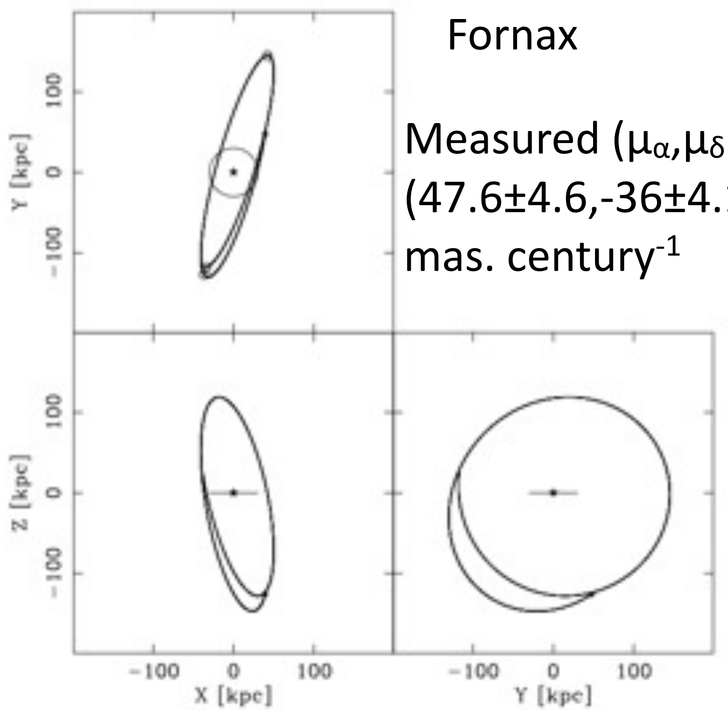
Proper motions

Individual star motions
Global galaxy motion
Galaxy mass

⇨ Relative motions

Fornax

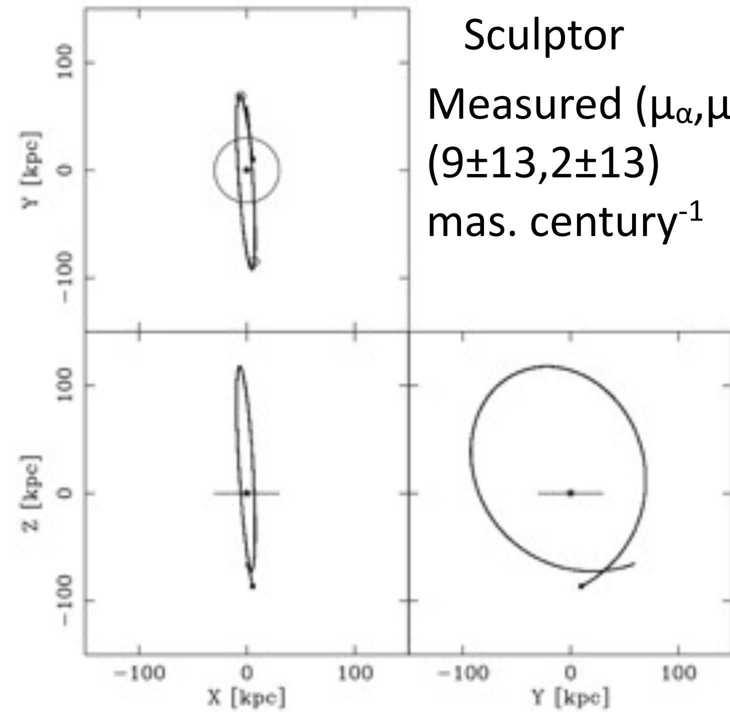
Measured (μ_α,μ_δ)= $(47.6\pm4.6,-36\pm4.1)$ mas. century^{-1}



Piatek et al. 2007

Sculptor

Measured (μ_α,μ_δ)= $(9\pm13,2\pm13)$ mas. century^{-1}



Piatek et al. 2006

Mean «individual» error ~30 mas. century^{-1}

Summary

✦GAIA offers a unique spatial coverage for all LG dSph, largely improving on the present situation.

✦Membership will definitely be derived from RELATIVE proper motions (rather than from radial velocities, halo/dSph systems)-

✦HR Spectroscopic follow-up will then be necessary to derive abundances, at last giving access at the chemical evolution of the full galaxies