Laying outside the law. The case of the brightest galaxies in the Universe

Noelia Jiménez ,

Postdoc fellow at University of Trieste

National University of La Plata

Barcelona, ICE, 2013

Universidad Nacional de La Plata

Astrofísica Numérica

CONICET

MARIE CURIE ACTIONS

CosmoComp

SEVENTH FRAMEWORK PROGRAMME

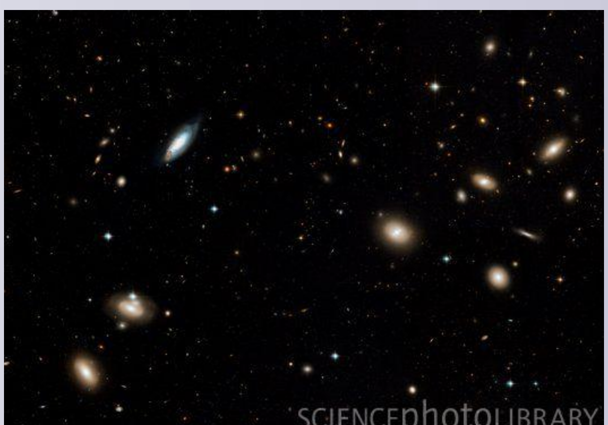
Clusters of galaxies

Virgo cluster

Abell 1689

Perseo cluster

Coma cluster

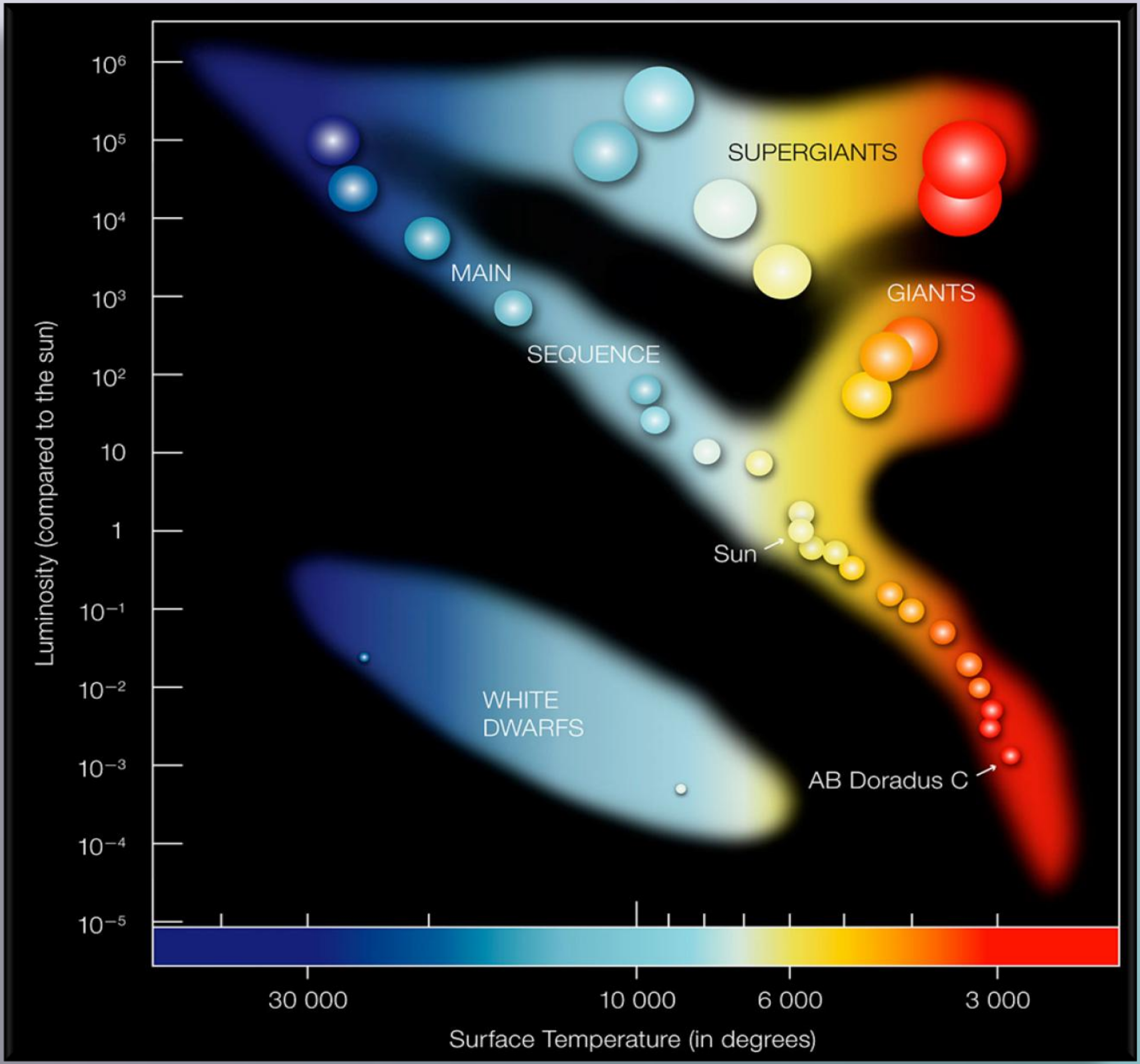


Deep field SDSS

H-R diagram

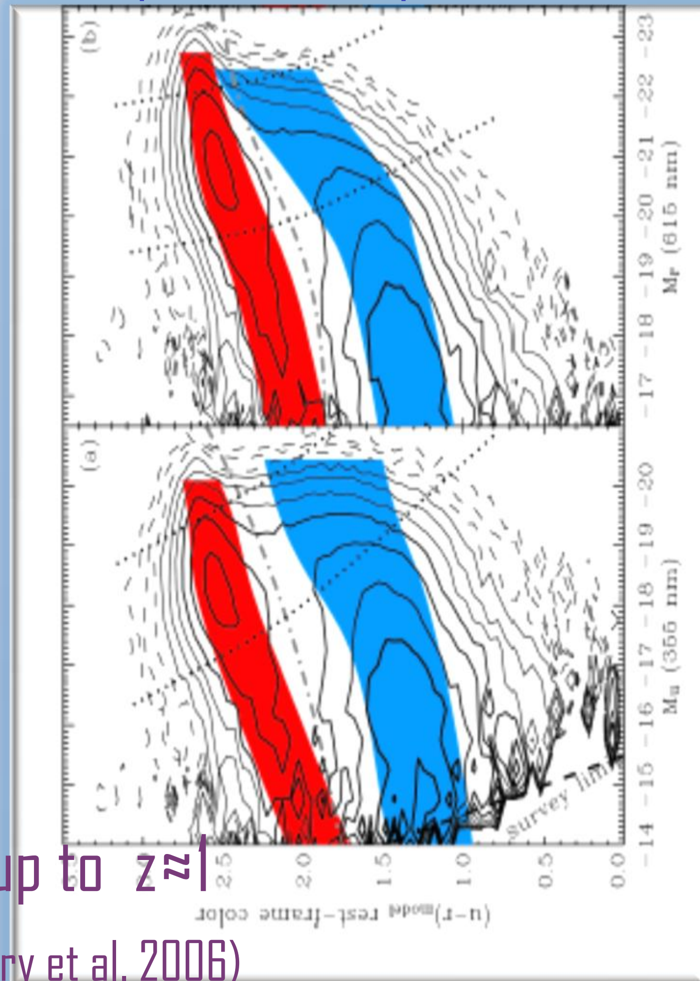
Hertzsprung (1873-1967)

Russell (1877-1957)



Scaling relations: the colour-magnitude relation

Showing two different properties of the galaxies as their lumonisity (or magnitudes) against their colours we obtain a distrution of points in the plane not uniform



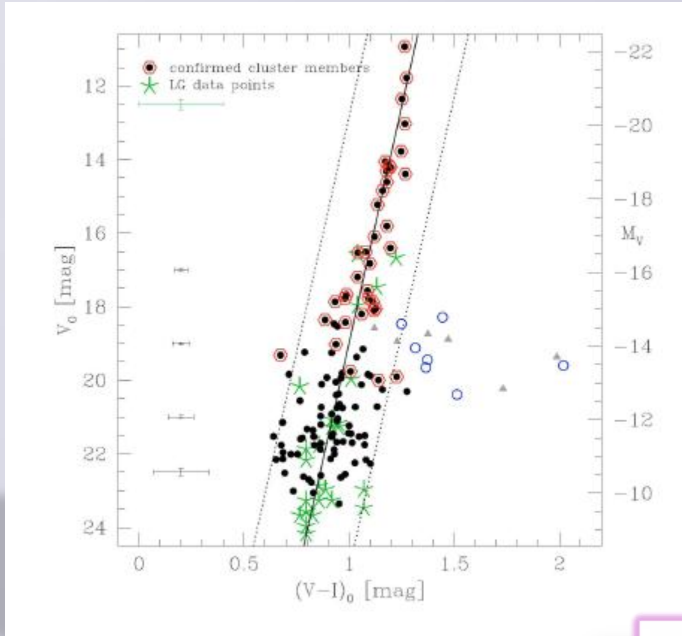
(Baldry 2006): SDSS, galaxias a z < 0.1

- **"red sequence"**
- **"blue cloud"**

Bimodalilty in colours is present up to z≈1

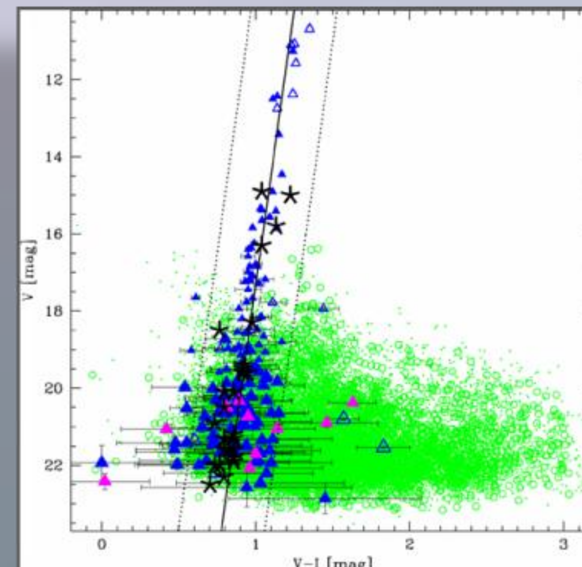
(Strateva et al. 2001; Blanton et al. 2003; Baldry et al. 2006)

The Colour-Magnitud Relation (CMR):

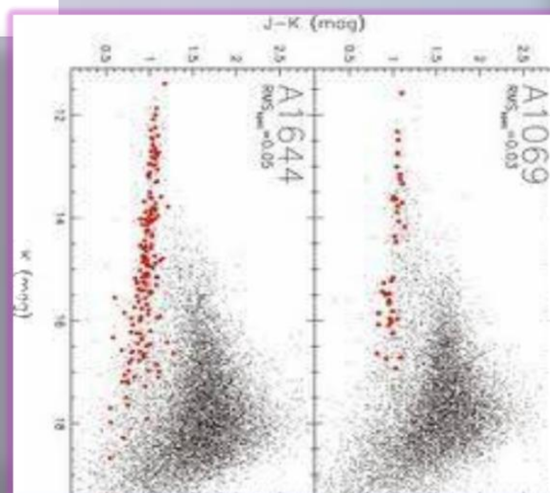


Hydra I cluster (Misgeld et al. 2008)

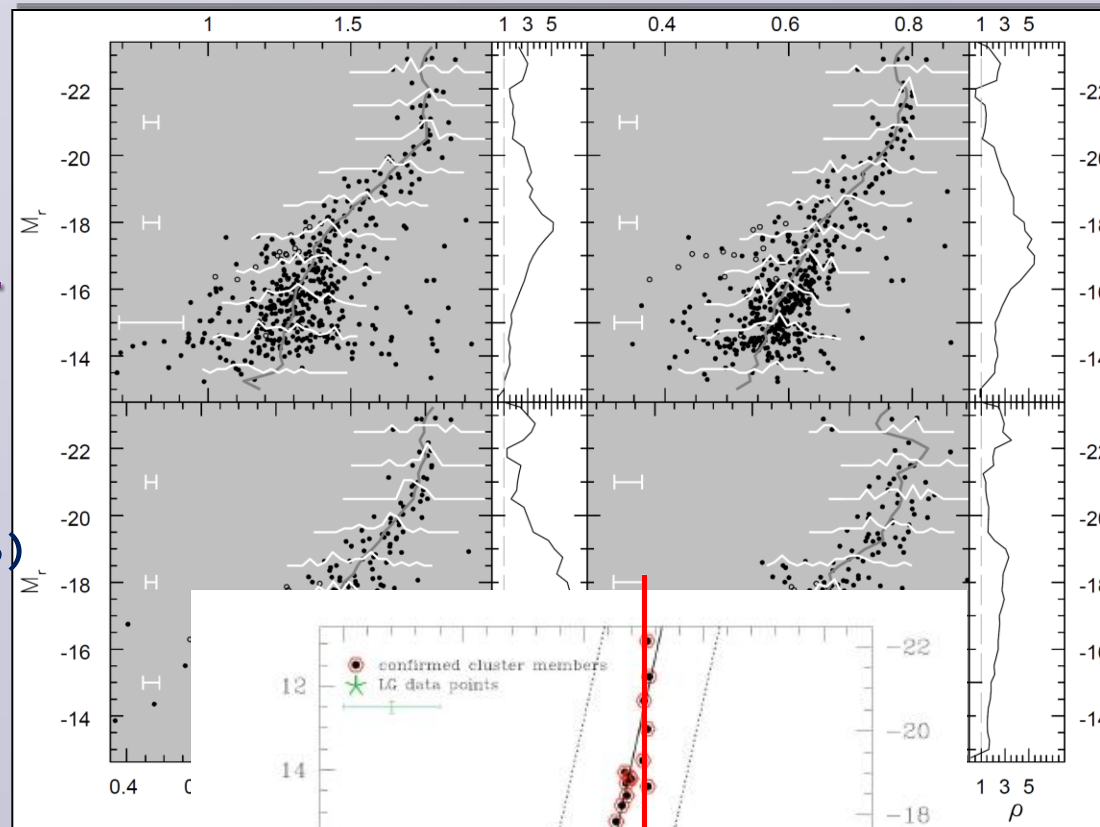
Fornax cluster
Hilker et al. (2003)



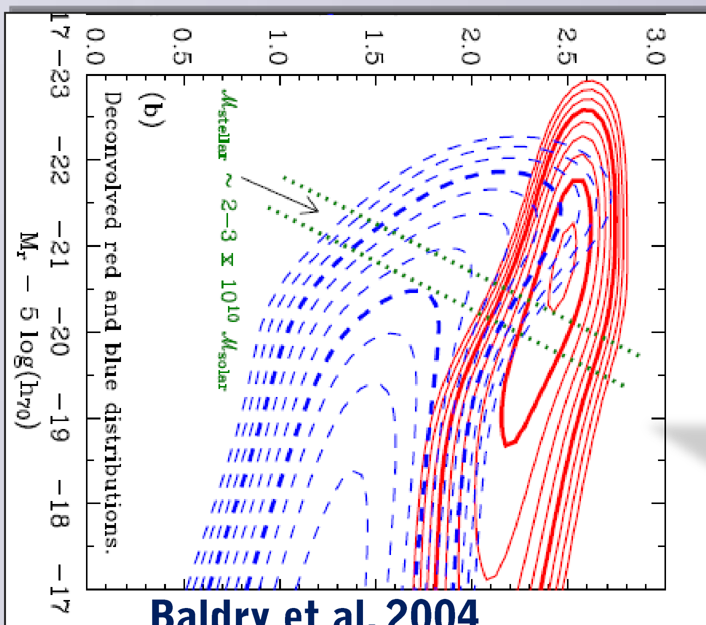
Abell 1644, 1069



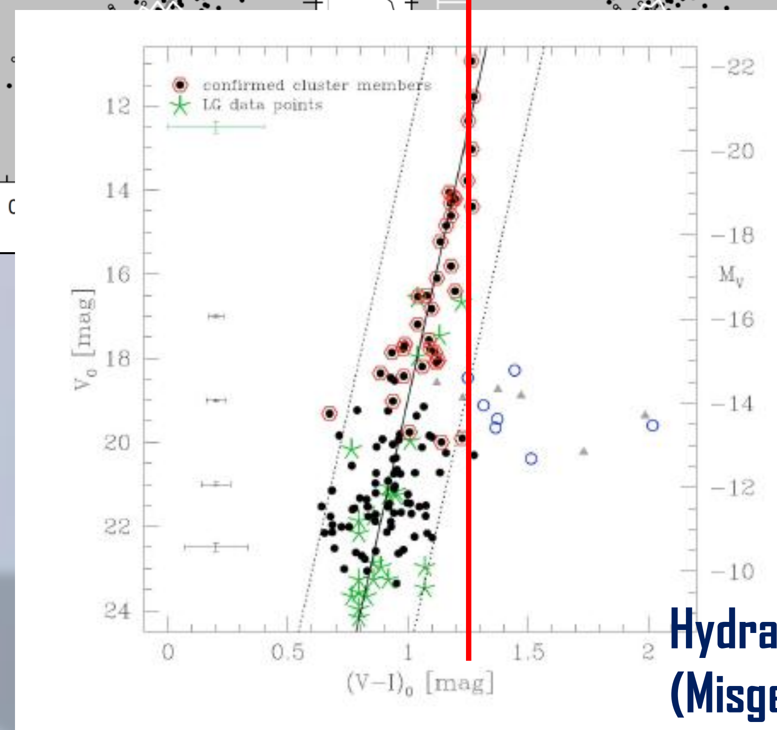
There is evidence of the break in Vaucoleurs et al. (1961), Tremonti et al. (2004), Baldry et al. (2004), Ferrarese et al. (2006), Boselli et al. (2008), Metcalfe, Godwin & Peach (1994)



Virgo cluster (SDSS)
Janz & Lisker 2009



Baldry et al. 2004 (SDSS)



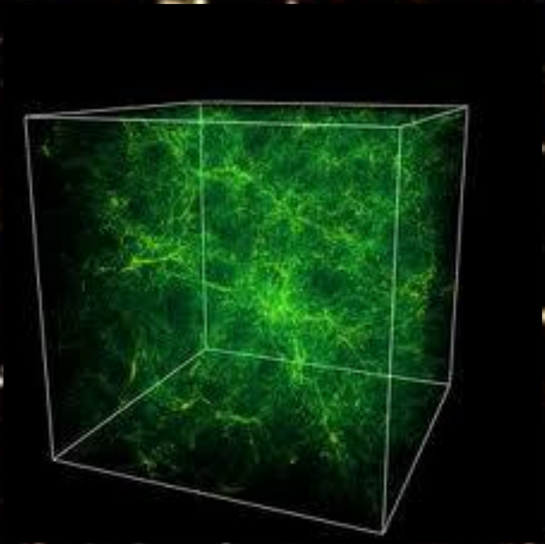
Hydra I cluster (Misgeld et al. 2008)

Motivation:

The CMR constitutes an excelent tool to constrain galaxy formation models since galactic evoution is evidenced through the relation

- What are the physical processes involved in the development of the CMR of cluster galaxies?

- How can we explain the behavior of the bright end?

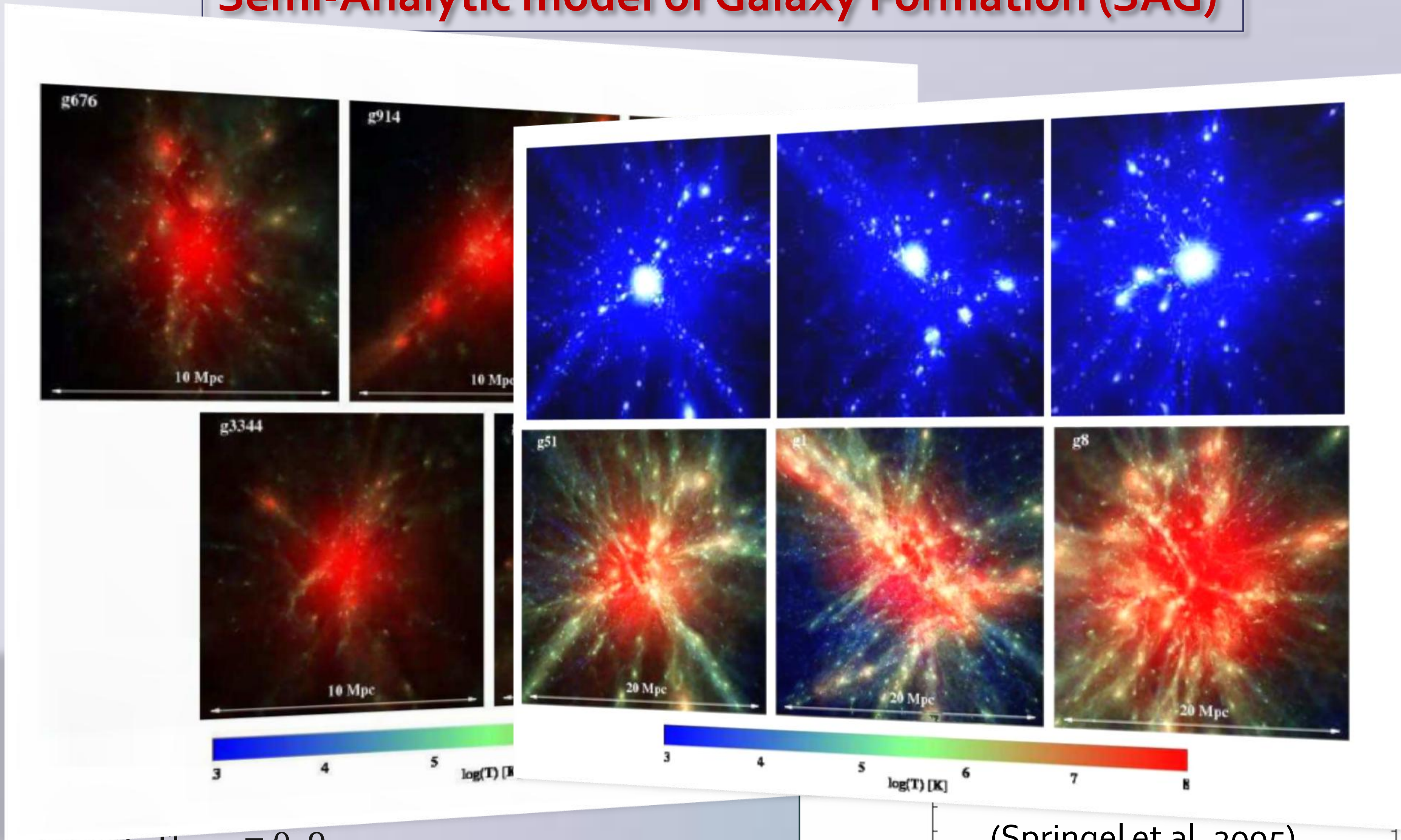


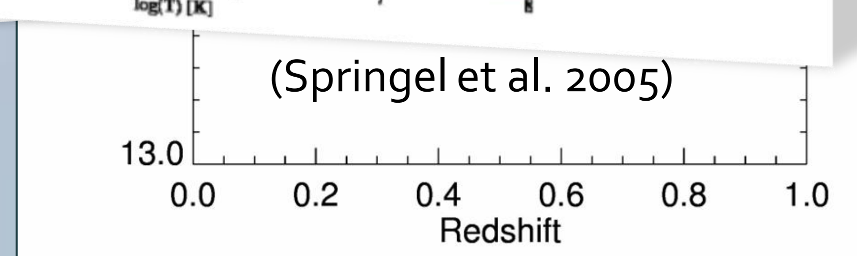
Hybrid Model of Galaxy Formation

N-body Simualtions

Semi-analytical model of galaxy Formation (SAG)

Semi-Analytic model of Galaxy Formation (SAG)





$\Gamma = 0.21,\ \sigma_8 = 0.9$

$H_0 = 100\ \mathrm{km\ s^{-1}\ Mpc^{-1}},\ h = 0.7$

Semi-analytical model of galaxy formation

$$M_{\rm hot} = \Omega_b M_{\rm vir} - \sum_i \left(M^{(i)}_{\rm star} + M^{(i)}_{\rm cold} + M^{(i)}_{\rm BH}\right)$$

$$t_{\rm cool}(r) = \frac{3}{2}\frac{kT\rho_g(r)}{\mu m_p n_e^2(r)\Lambda(T,Z)}$$

$$\frac{dM_{\rm cool}}{dt} = 4\pi r^2 \ldots {\rm ol} \frac{dr_{\rm cool}}{dt}$$

$$\ldots \frac{M_{\rm cold}}{t_{\rm dyn}}$$

$$\Delta M_{\rm reheat} = \frac{4}{3}\varepsilon \frac{\eta_{\rm SNCC} E_{\rm SNCC}}{V_{\rm vir}^2} \Delta M \ldots$$

HOT GAS

COLD GAS

The model is calibrated to reproduce simultnaneously several galactic properties as the LF, the MBH, the CMR, morpholgy ratios, etc

SN FEEDBACK

AGN FEEDBACK

Metals:

Low mass stars — Marigo (2001)

SN CC — Portinari et al. (1998)

SN Ia — SD (Lia et al. 2002); Iwamoto et al. (1999)

SAG (Lagos, Cora & Padilla, 2008)

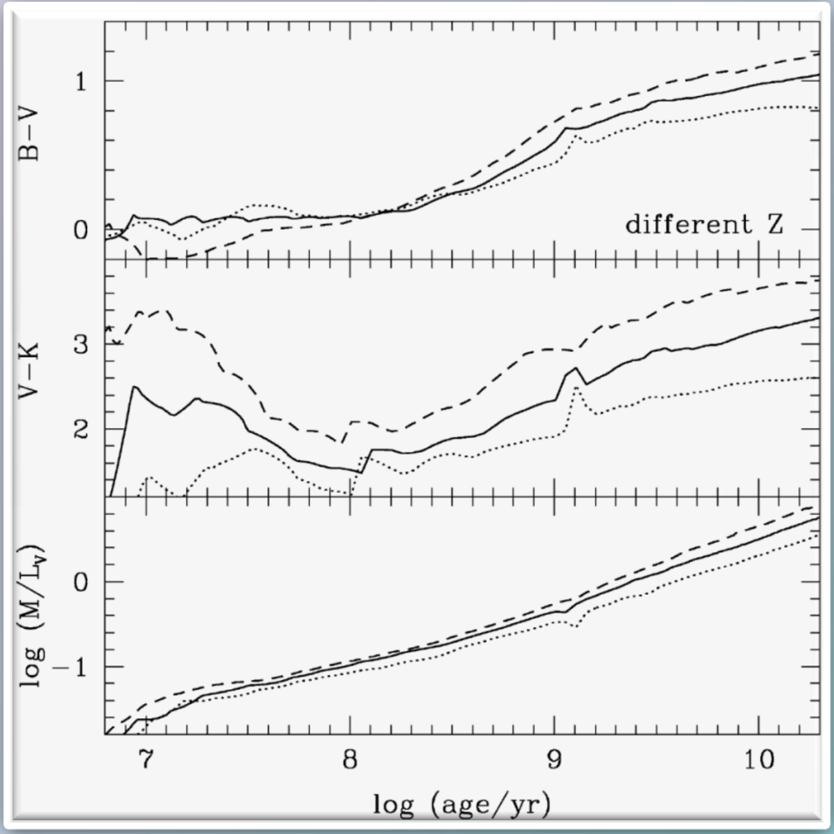
Lifetime of stars: Padovani & Matteucci (1993)

Spectoscopic properties of galaxies are calculated using evolutionary models of synthetic stellar populations to estimate the spectral energy distribution (SED) of single stellar populations (SSP) within the galaxies .

We use the model of Bruzual (2007). Magnitudes are given in the system of Johnson Morgan (U,B,V,K,R,I) and the SDSS bands u,g,r,i,z.

We can choose to select galaxies according to :

- metallicity
- morphology
- SSFR



Evolution of colours and mass-to-light ratios of SSP at different SSP´s metallicities

Red-sequence galaxies are those redder than

$$\langle U - V \rangle = 1.15 - 0.31\, z - 0.08\,(M_V - 5\log h + 20)$$

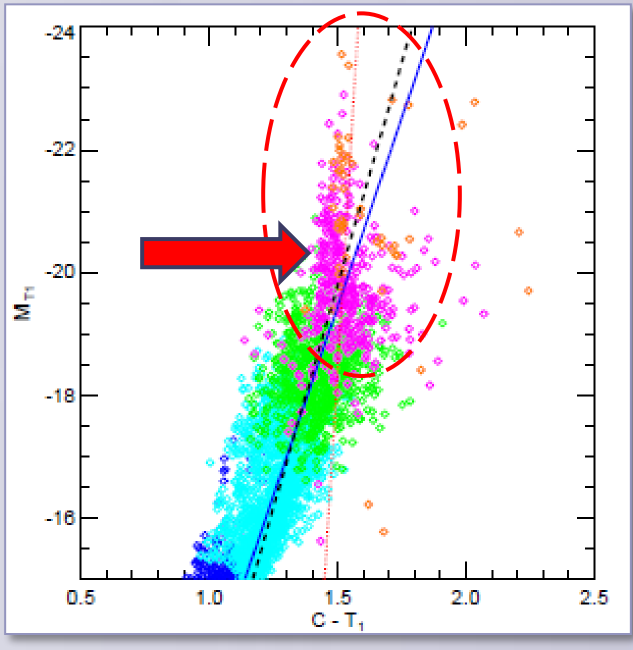
Bell et al. (2004)

We adopt z = 0 to obtain simulated CMRs at the present epoch and compare them with observed ones.

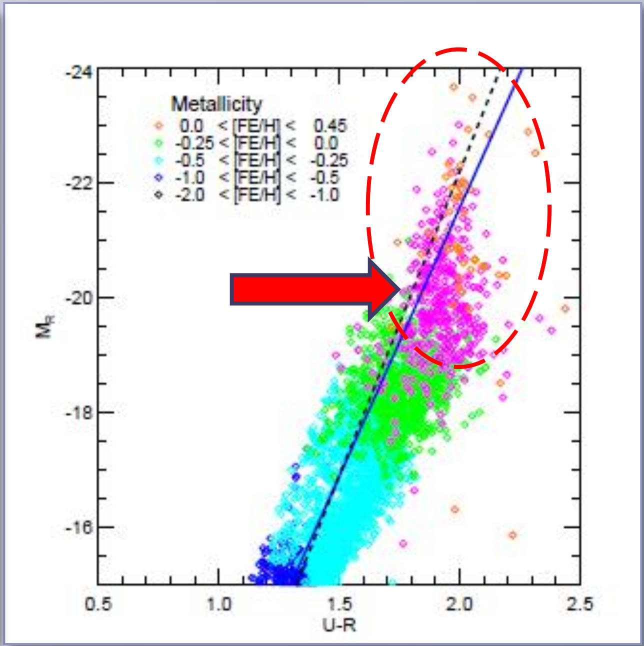
$M_{break} \approx -20$

$M_* \sim 10^{10} M_0$

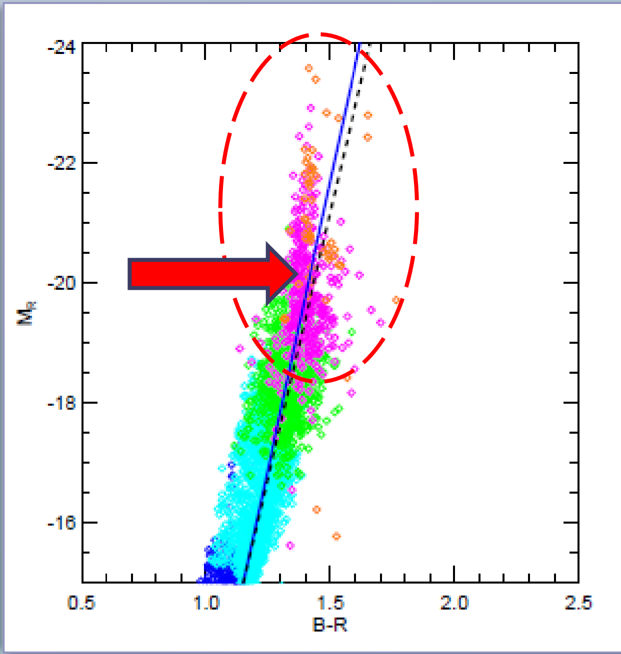
T_1 vs. $(C - T_1)$

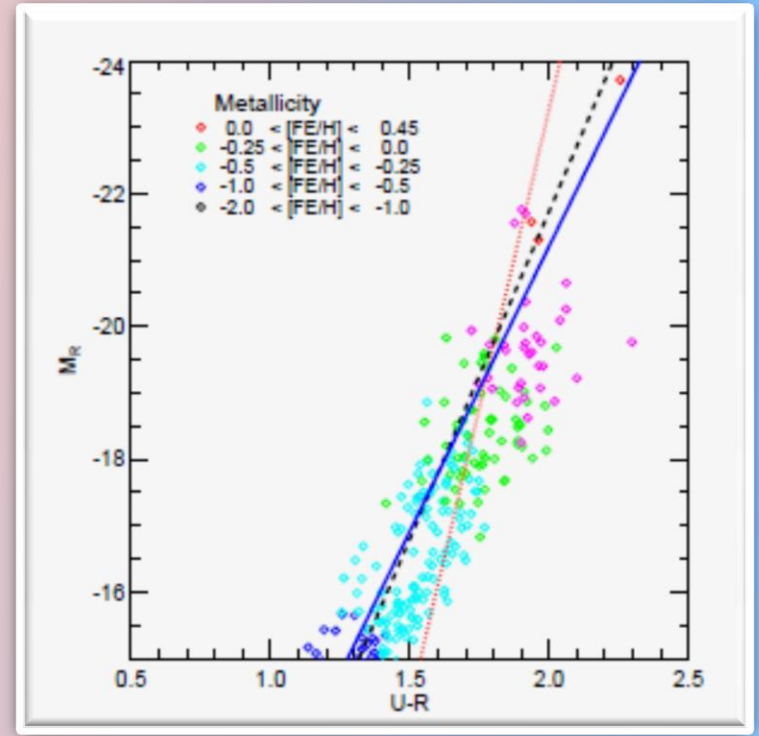


R vs. (U – R)



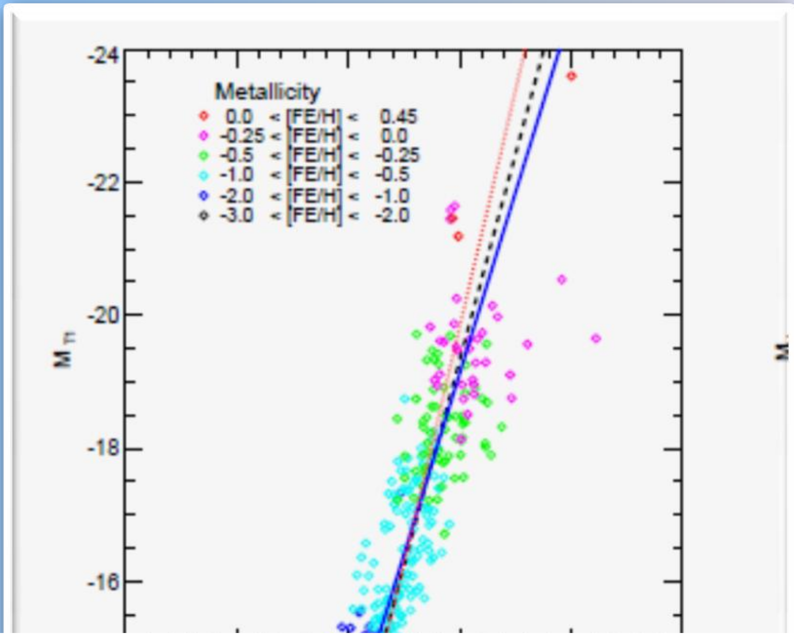
R vs. (B – R)





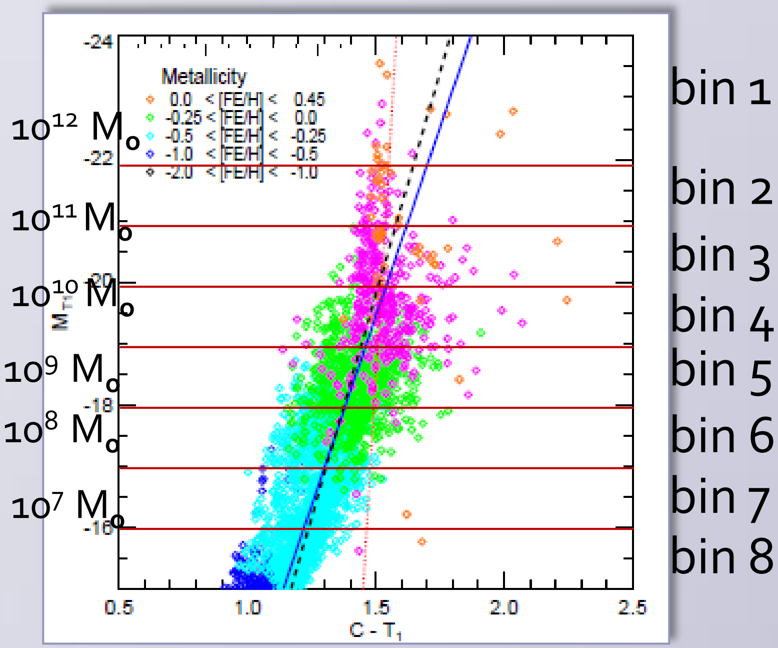
The CMR of C14 clusters has not enough bright galaxies to define the relation and the break

U vs. (U-R)



The CMR seems universal; can be found in gropus, clusters and field galaxies (vg. Lopéz Cruz et al. 2004, Hogg et al. 2004, McIntosh et al. 2005, Scott et al. 2009, Martínez et al. 2009)

Galaxy Metallicities



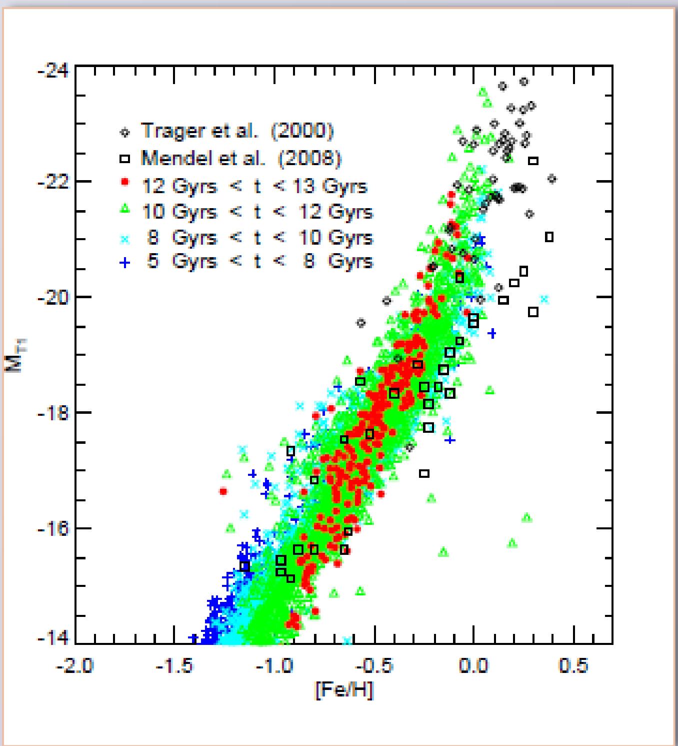
Galaxies in the **bright end** are:

- the **most massive** galaxies (bins 1,2 and 3)
- the **most metal rich** ones with [Fe/H] > −0.25 up to 0.45

Along the CMR galaxies become fainter, bluer and less chemically enriched: **mass-metallicity relation**.

The more luminous (massive) galaxies have deep potential wells, capable of retaining the metals released by stellar evolution.

Luminosity-Metallicity Relation



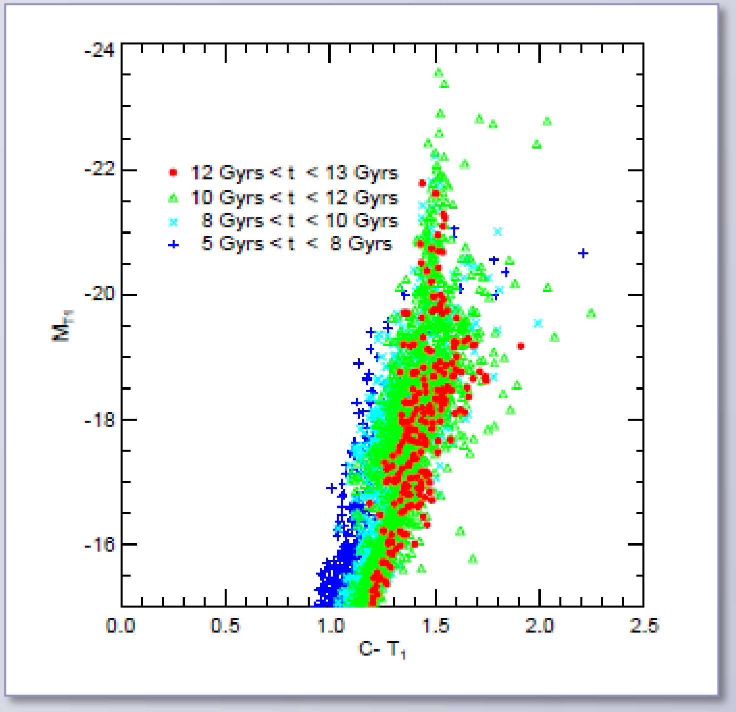
Clear **correlation** between age and metallicity for the least luminous galaxies ($M_{T_1} > -16$)

Brighter galaxies in this relation show **ages** and **metallicity** **<u>anticorrelated</u>**, in agremeent with Gallazzi et al. (2006) for galaxies in the SDSS at fixed velocity dispersion.

Very good agreement between simulated values and the observed samples of Trager et al. (2000) and Mendel et al. (2008)

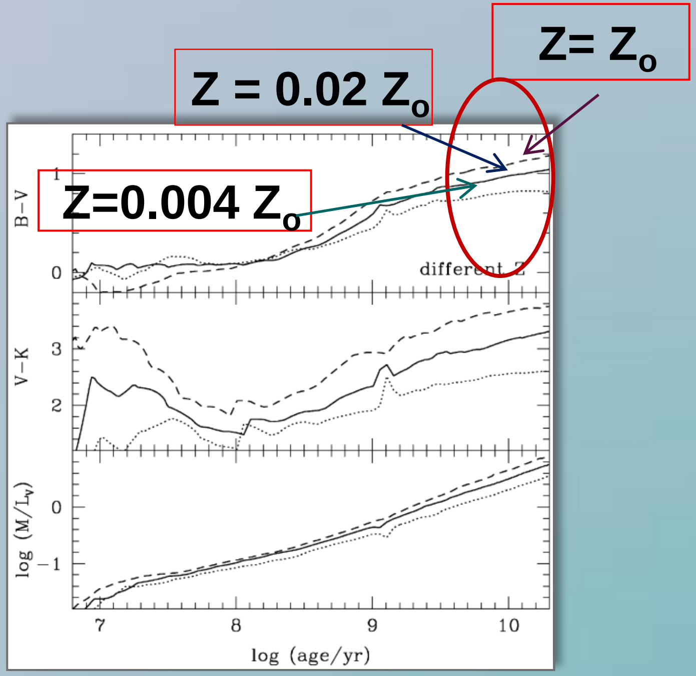
It supports the use of the **chemical history** of galaxies as a tool to help understand the development of the CMR and its special feature at the **bright end.**

Age distribution in the CMR

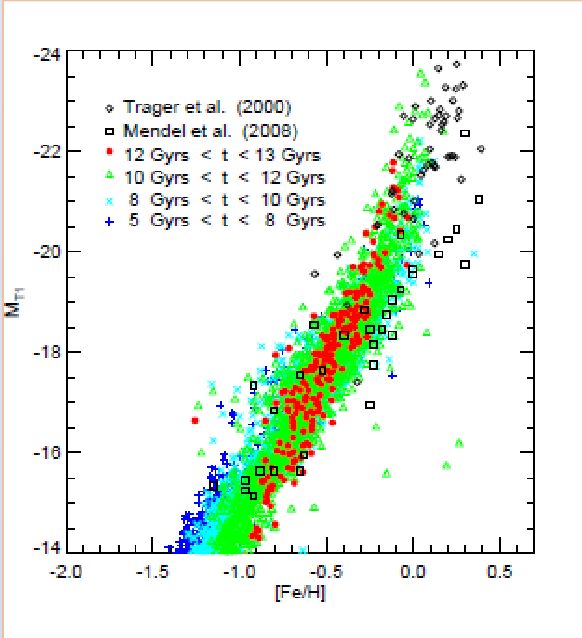


Most galaxies in the bright end of our simulated CMR share very similar ages (1.0×10^{10} yr $< t <$ 1.2×10^{10} yr).

Evolution of colours of SSP with different metallicities (BC03)

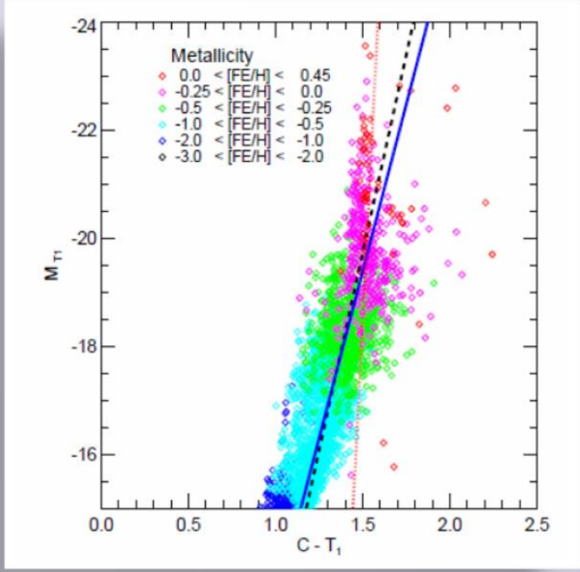


The effect of age differences on the final colours of galaxies in the bright end of the CMR is completely **negligible** (Bruzual & Charlot 2003)



- A clear correlation between age and metallicity is present for the least luminous bins ($M_{T1} > -16$).

- But the brightest galaxies show the opposite trend: **anticorrelation**, in agreement with observations by Gallazzi et al. (2006)



This anticorrelation might explain the modest **scatter** of the bright end of the CMR , characterized by a negligible spread in age (Trager el at. 2006)

CMR development: physical processes involved

We track the evolution of the **masses** and **metallicities** of the stars added to each galaxy by different processes:

- quiescent SF
- starbursts during **mergers** and **disk instability** events

} **"stars" component**

- stellar **mass accreted** from satellite galaxies during mergers

} **"sat" component**

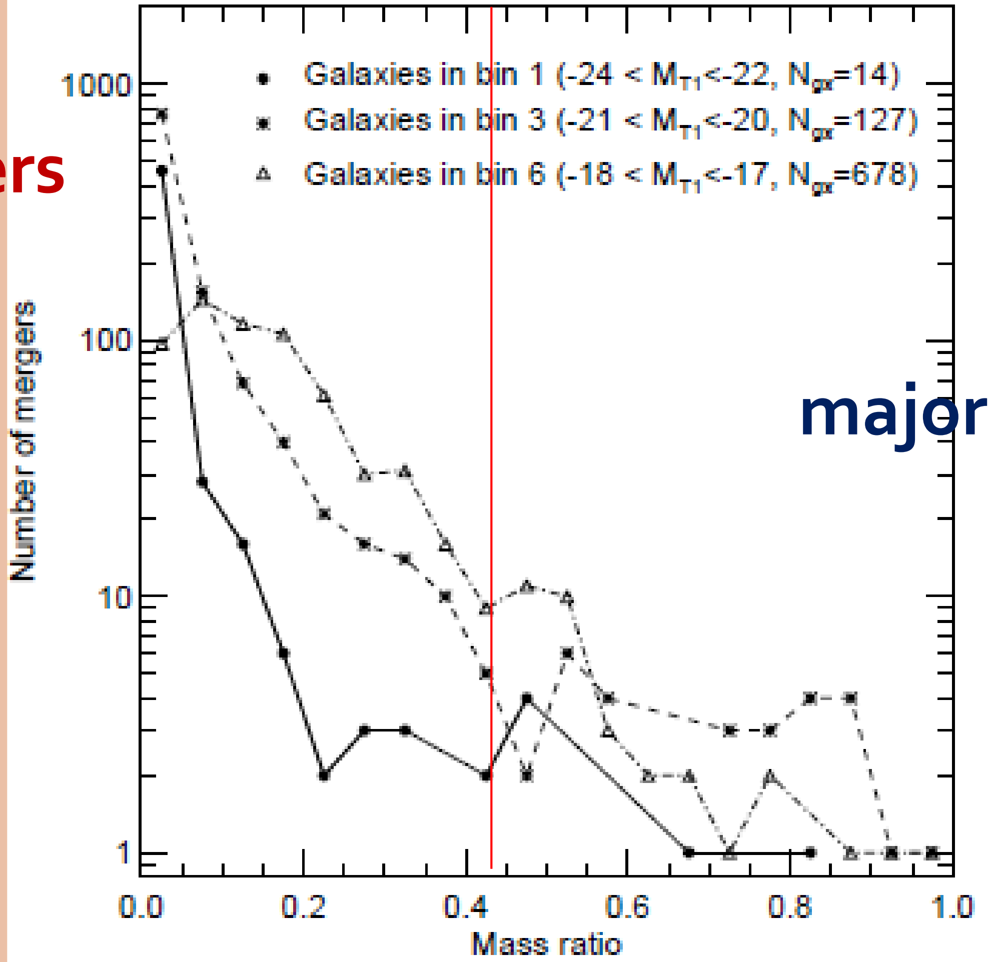
Mergers in the model

We define:

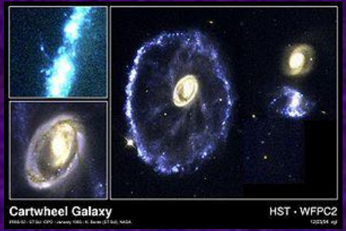
- **minor merger** $\frac{M_{\mathrm{sat}}}{M_{\mathrm{central}}} < 0.3$
  - if $\frac{M^{\mathrm{central}}_{\mathrm{ColdGas}}}{M^{\mathrm{central}}_{\mathrm{disc}}} > f_{\mathrm{gas,minor}} (= 0.6)$
    - **minor wet merger**
  - **minor dry merger**
- **major merger** $\frac{M_{\mathrm{sat}}}{M_{\mathrm{central}}} \geq 0.3$
  - if $\frac{M^{\mathrm{central}}_{\mathrm{ColdGas}}}{M^{\mathrm{central}}_{\mathrm{disc}}} > f_{\mathrm{gas,major}} (= 0.4)$
    - **major wet merger**
  - **major dry merger**

Number of mergers

minor mergers

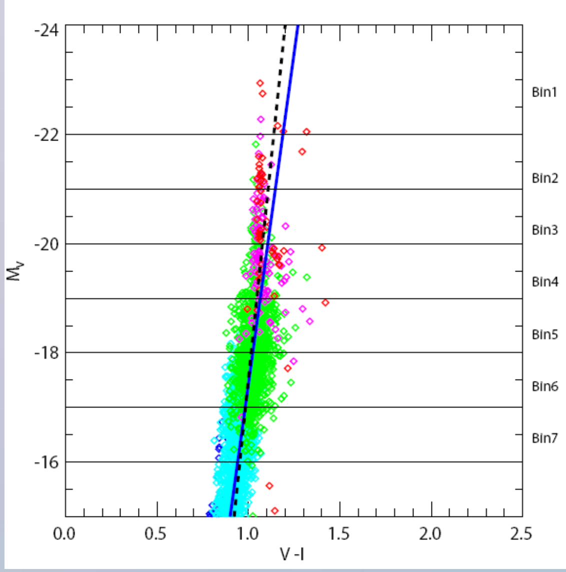


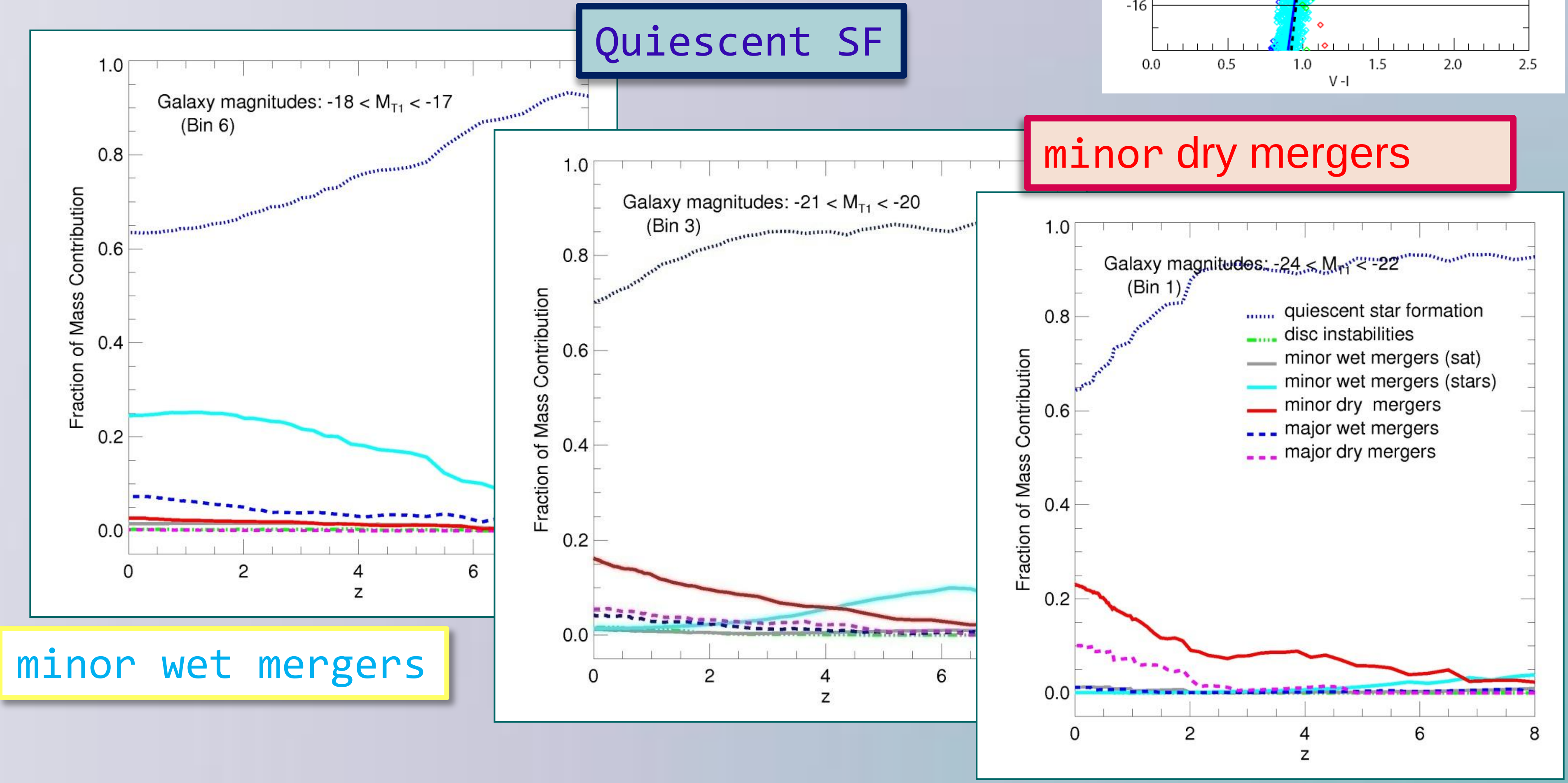
major mergers



Evolution of stellar mass fractions

Evolution with redshift of the accumulated stellar mass contributions from the different processes, within different magnitudes bins.

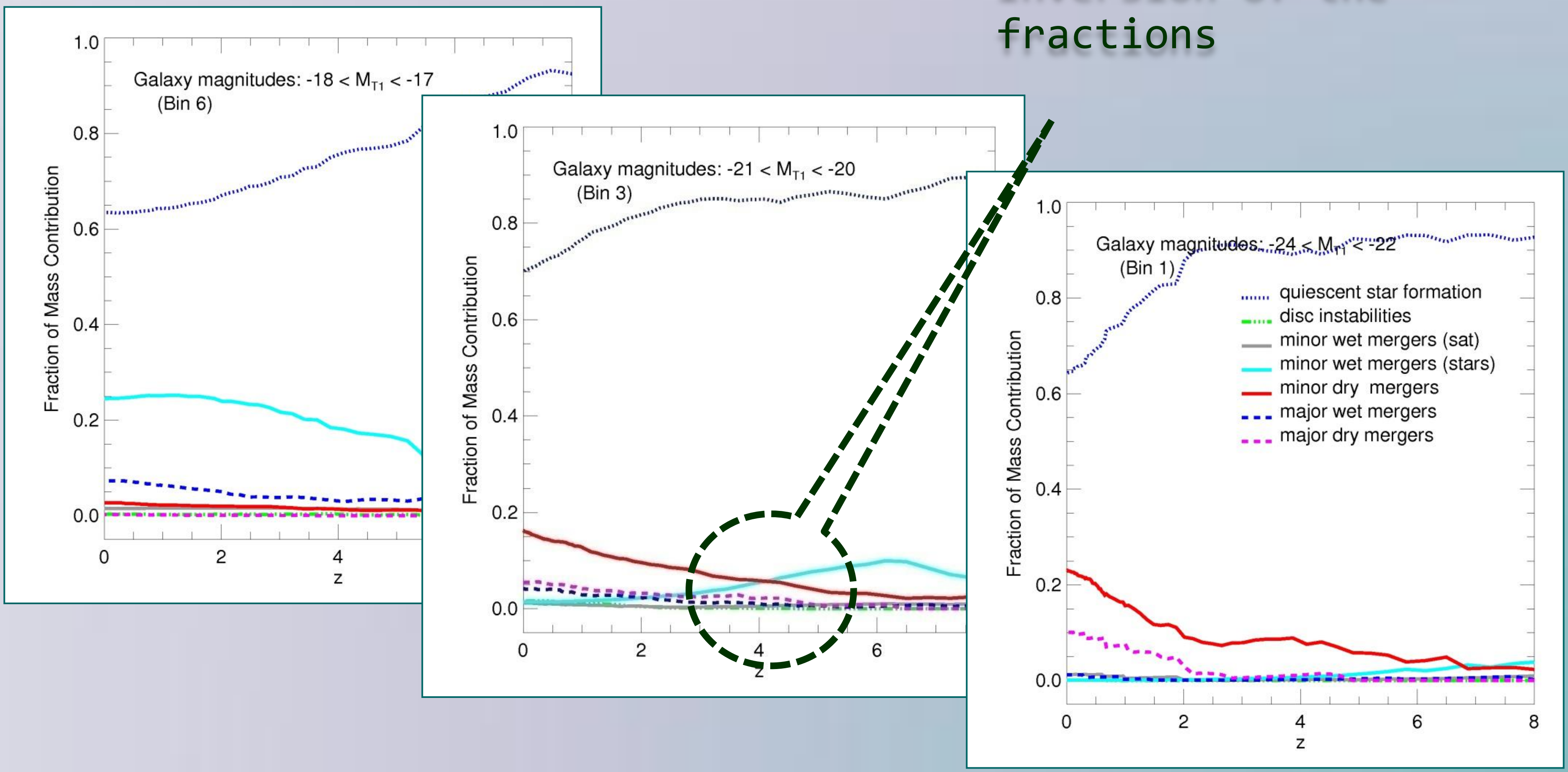




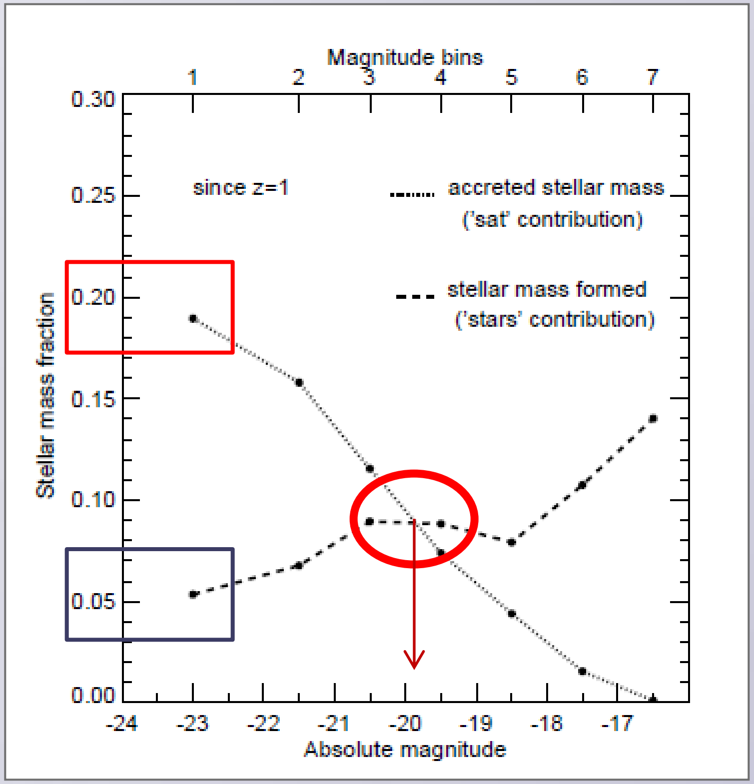
Evolution of stellar mass fractions

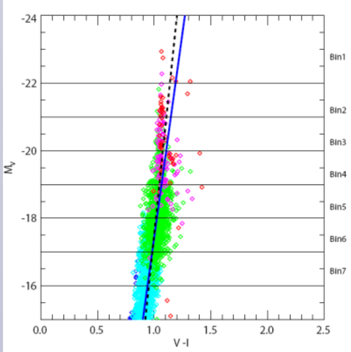
Quiescent SF is the dominant process it decreases monotonically with redshift as the cold gas reservoir ineach galaxy is exhausted

Inversion of the fractions



Accumulated Mass Fractions since z=1





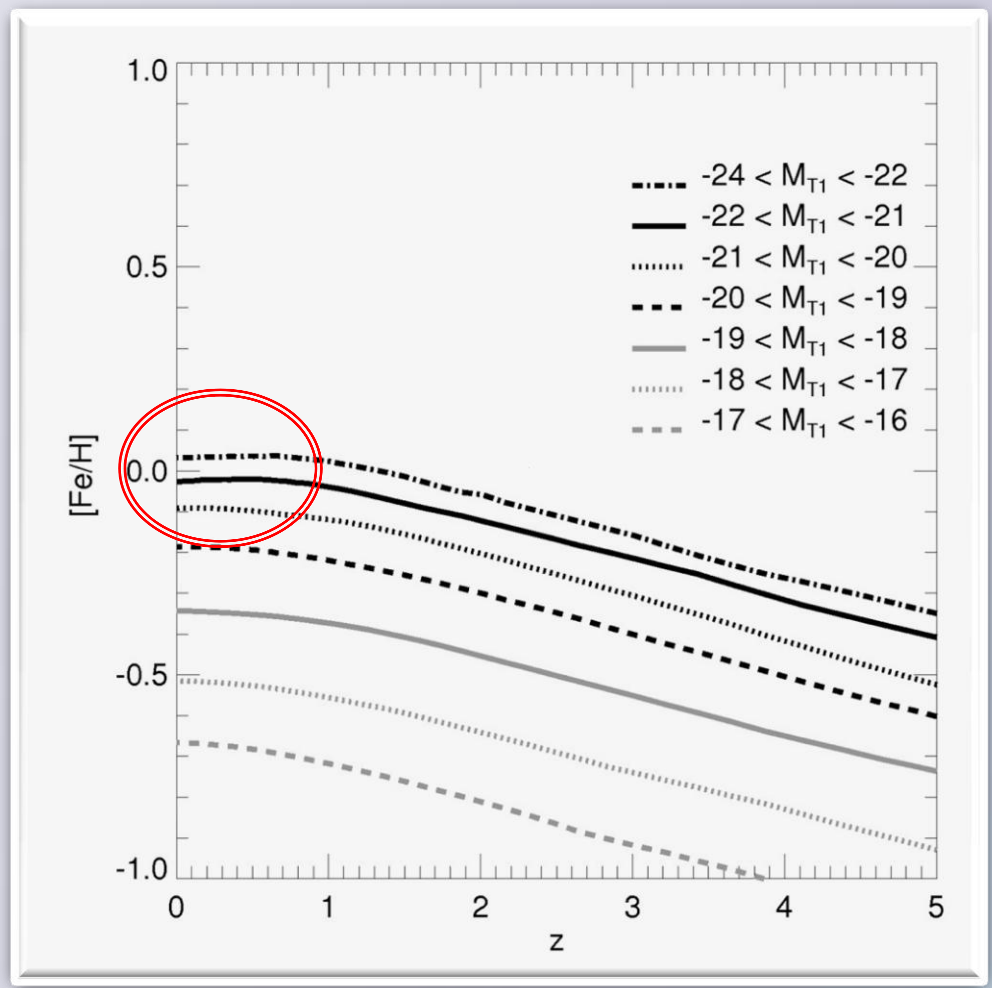
Mass fractions:
Normalized with the total stellar mass at z = 0 within a given magnitude bin.

Dependence with magnitude bins of the mass fractions of the stellar mass given by **new formed stars** and **accreted stars** (regardless of the processes that contribute to them)

contributions of 'stars' and 'sat' comp. cross each other at the break magnitude $M_{T1} = -20$

≈ 20 % of the mass of galaxies in the **bright end** arises from **satellites accreted** since z = 1, **with very few stars being formed in situ!**

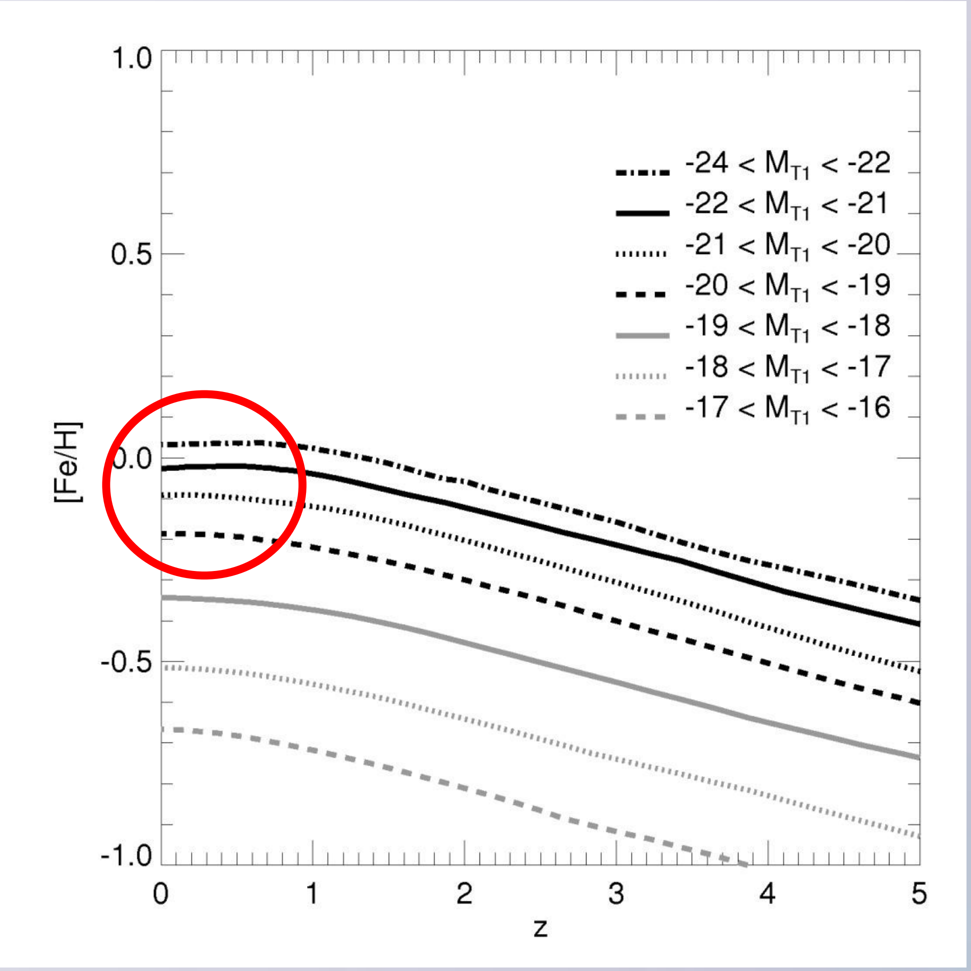
Galaxy metallicities



Evolution of the mean value of the stellar iron abundance of galaxies that at z = 0, within a given range of mag.

Galaxies in the **bright end** ($M_{T_1} > -20$) reach metallicity values within a narrower range (≈ 0.15 dex) than the rest of the galaxy population.

Directly linked with the **similar colours** that characterize these gx. making them depart form the general trend of the CMR.

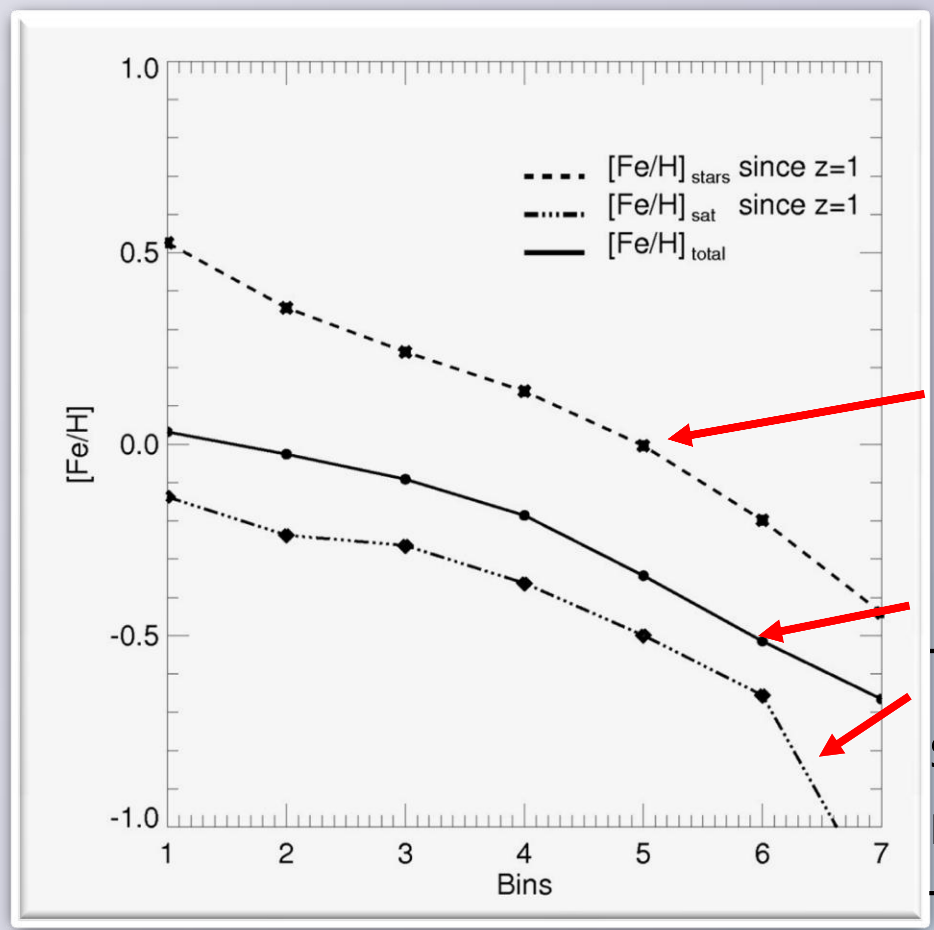


These chemical abundances seem to
be in place since z = 1.

Supported by observations of high redshift clusters, which show that the <u>slope and scatter in the CMR</u> for morphologically selected ETGs show little or no evidence of evolution out to z ≈ 1.2
(Blakeslee et al. 2003;
Mei et al. 2006;
Jaff, et al. 2010).

Metallicity of the stellar mass contributed since z = 1

90% of the stellar mass formed and added by mergers since z = 1 is still alive at z = 0, determining the metallicity and colour of galaxies in the CMR at the present epoch.



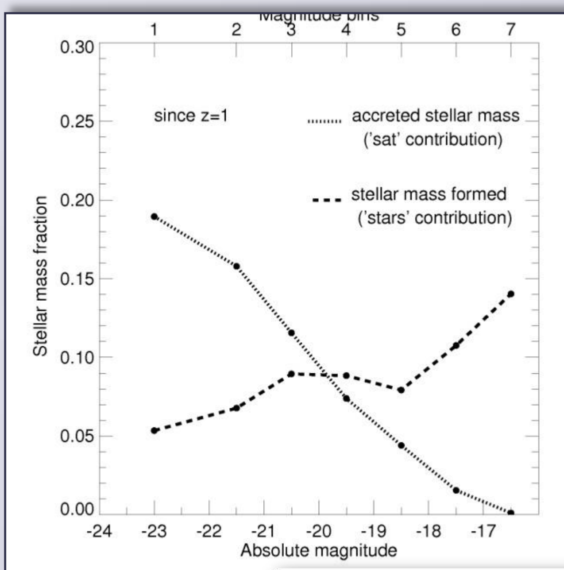
Average metallicity of:

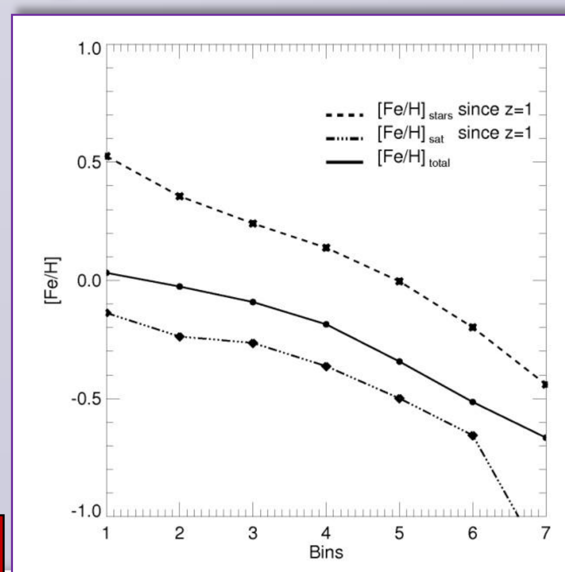
The mass contributed by the stars formed since z = 1, but the SF processes are very low.

The stellar mass at z = 0.

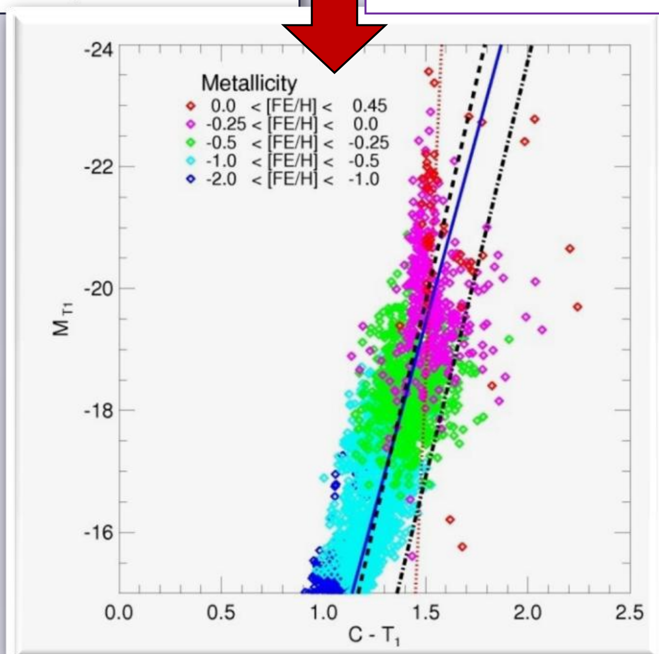
The stars already present in the satellites accreted since z = 1, represent an apprecible fraction of the galaxy mass at z=0, but can not increase the total metallicity.

Detachment of bright end: effect of dry mergers





Dry mergers help to **increase the mass** of gx in the **bright end** **without** considerably **affecting metallicities**.



Upper limit in **the metallicity fixes their colour**, <u>being bluer than expected</u> if SF from highly chemically enriched gas were relevant in their final evolution.

Thanks for your attention!