Element abundance ratios and star formation quenching in satellite and central galaxies

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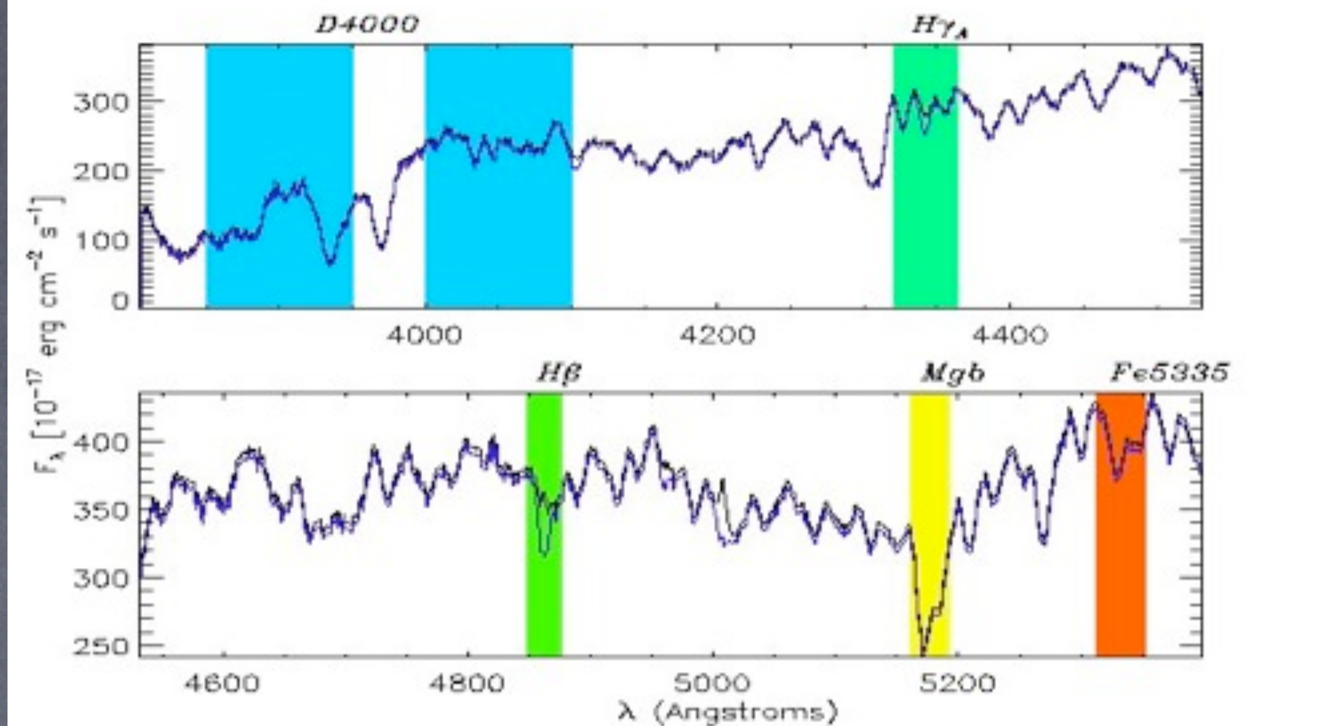
EGEE2014, Bologna, 18/9/2014

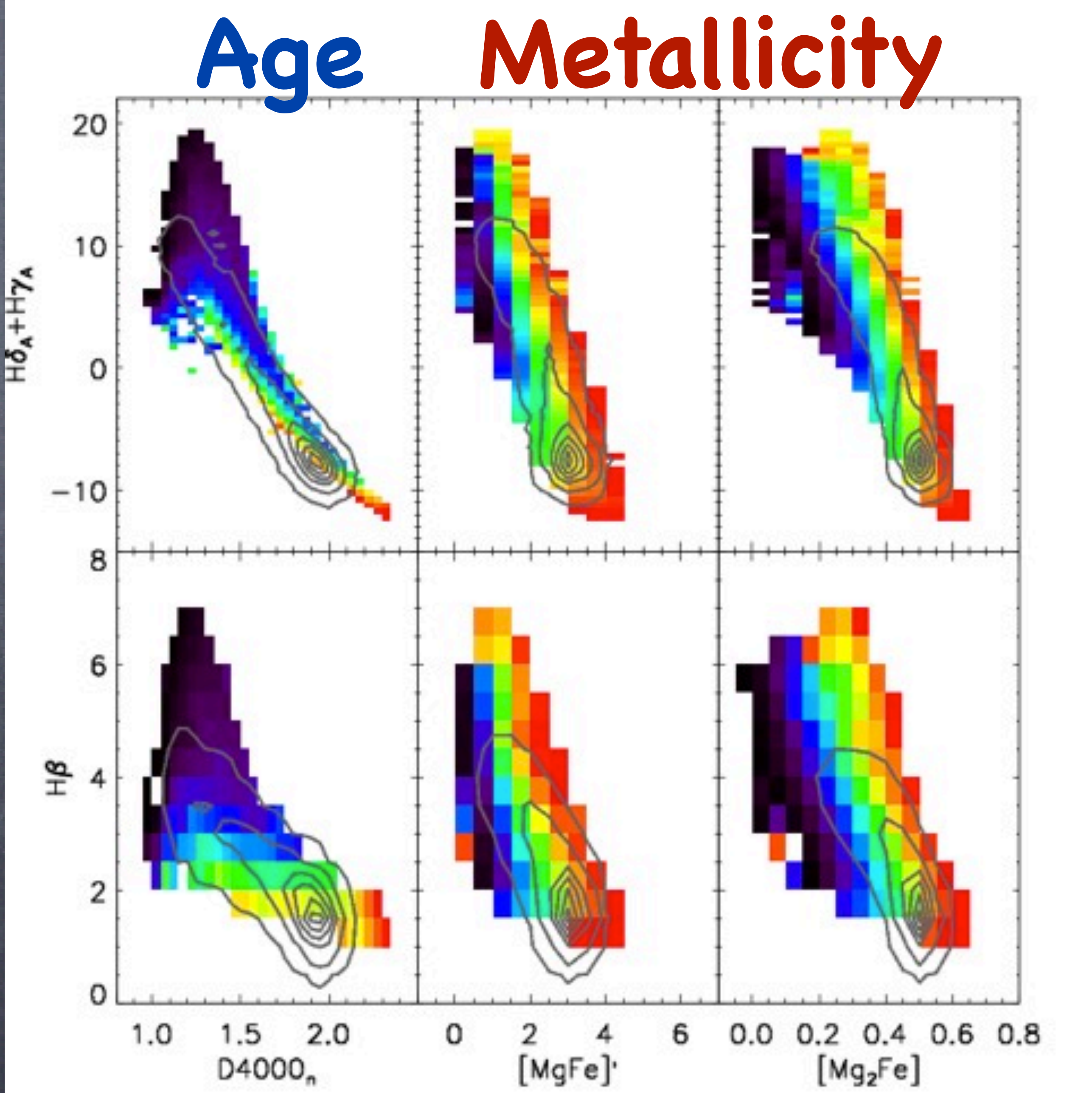
Introduction

- Several galaxy properties are known to vary with environment (morphology, SFR, color, quiescent fraction)
- Stellar population properties (light-weighted age, metallicity, element abundance ratio) as tracers of past star formation activity and chemical enrichment
- Disentangle a specific environmental dependence from that induced by the dominant dependence on galaxy mass
- Distinguish "satellite" galaxies from equally-massive "central" galaxies
- Do we see an imprint of a different evolutionary path between centrals and satellites?

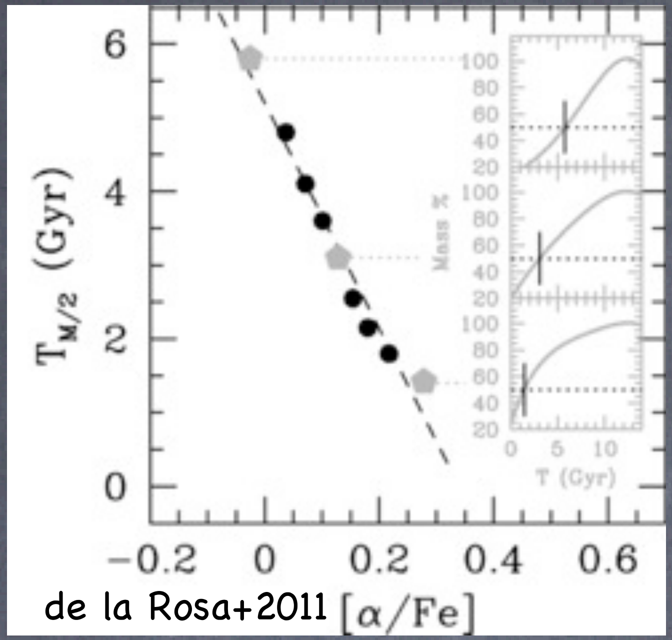
Stellar population parameters

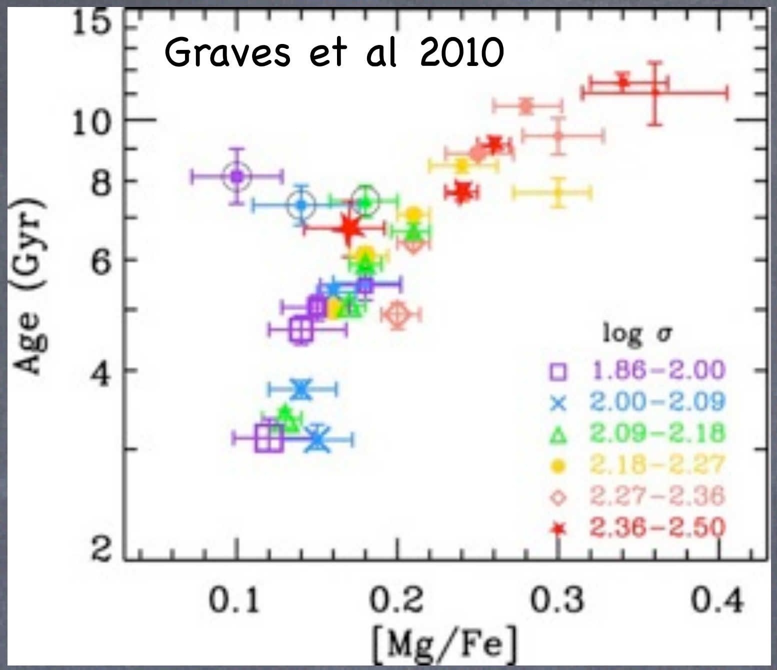


- Optimal set of absorption features independent of element abundance ratio: **D4000, Hβ, Hγ+Hδ, [Mg_2Fe], [MgFe]'**
- MONTE CARLO LIBRARY OF COMPLEX SFH: exponential SFH + random burst; metallicity fixed for each model (i.e. no chemical evolution) - based on BC03
- build full probability density function of **LUMINOSITY-WEIGHTED AGE AND STELLAR METALLICITY**
- Application to SDSS DR7 galaxies of any type and SF activity at $0.05<z<0.2$



[α/Fe] : relative effective yields of SNII and SNIa products -> indicator of galaxy SF timescale





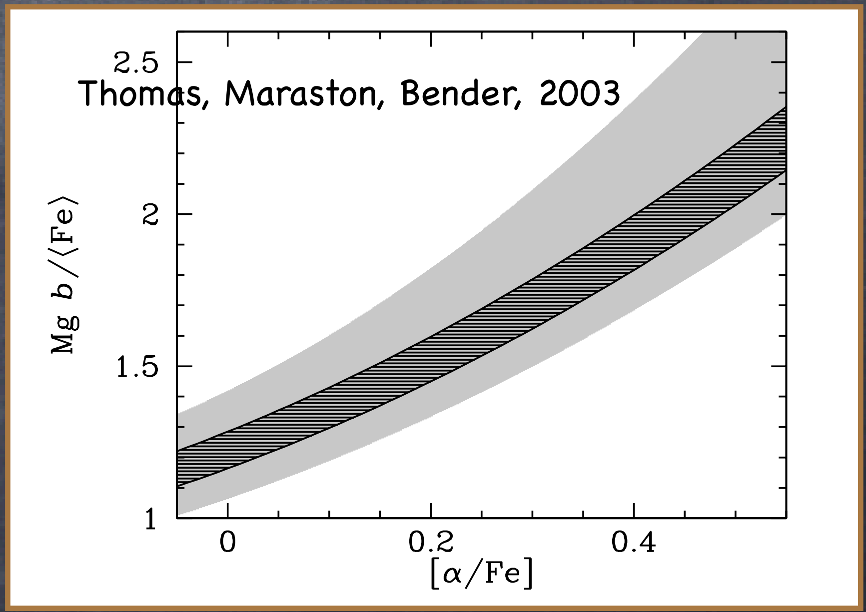
also Gallazzi et al 2006

- Relative strength of **Mg and Fe indices** gives indication on the α/Fe

- Difference between the observed **Mgb/<Fe>** and the one of the solar-scaled model that best fits α/Fe-independent features

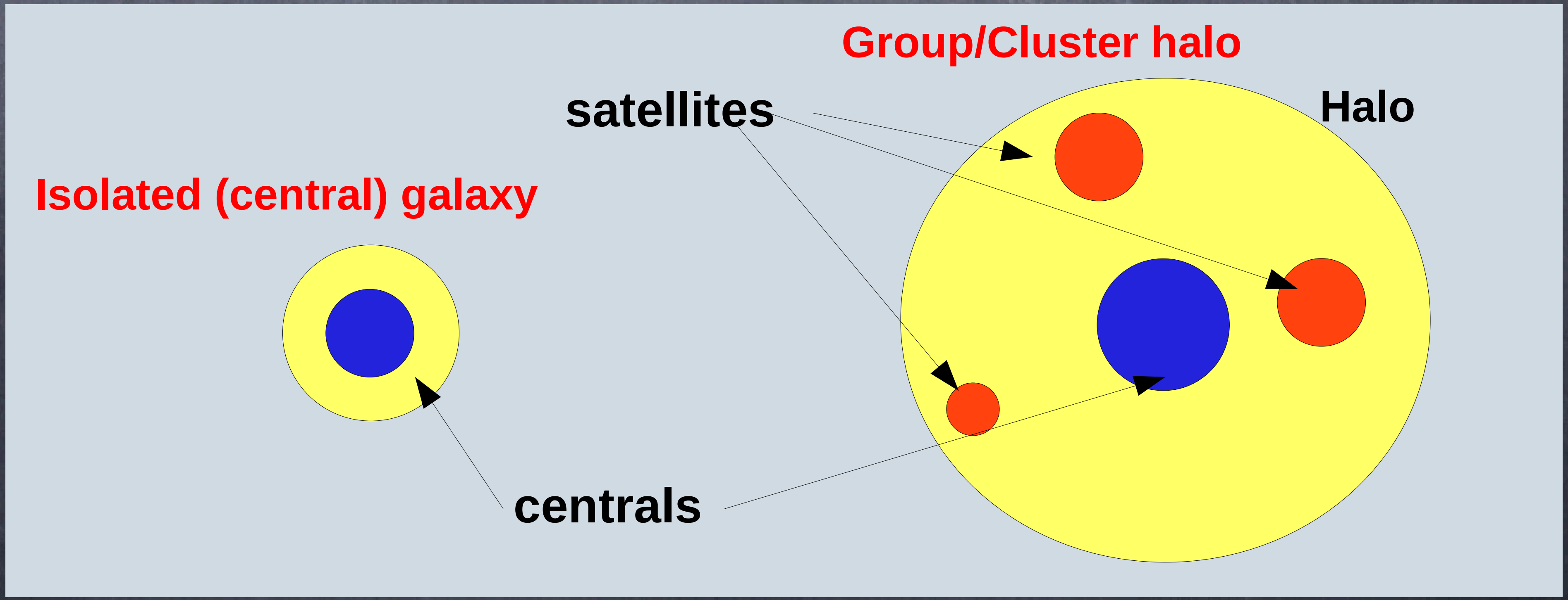
$$\Delta(Mg_b/\langle Fe\rangle) = (Mg_b/\langle Fe\rangle)_{obs} - (Mg_b/\langle Fe\rangle)_{model}$$

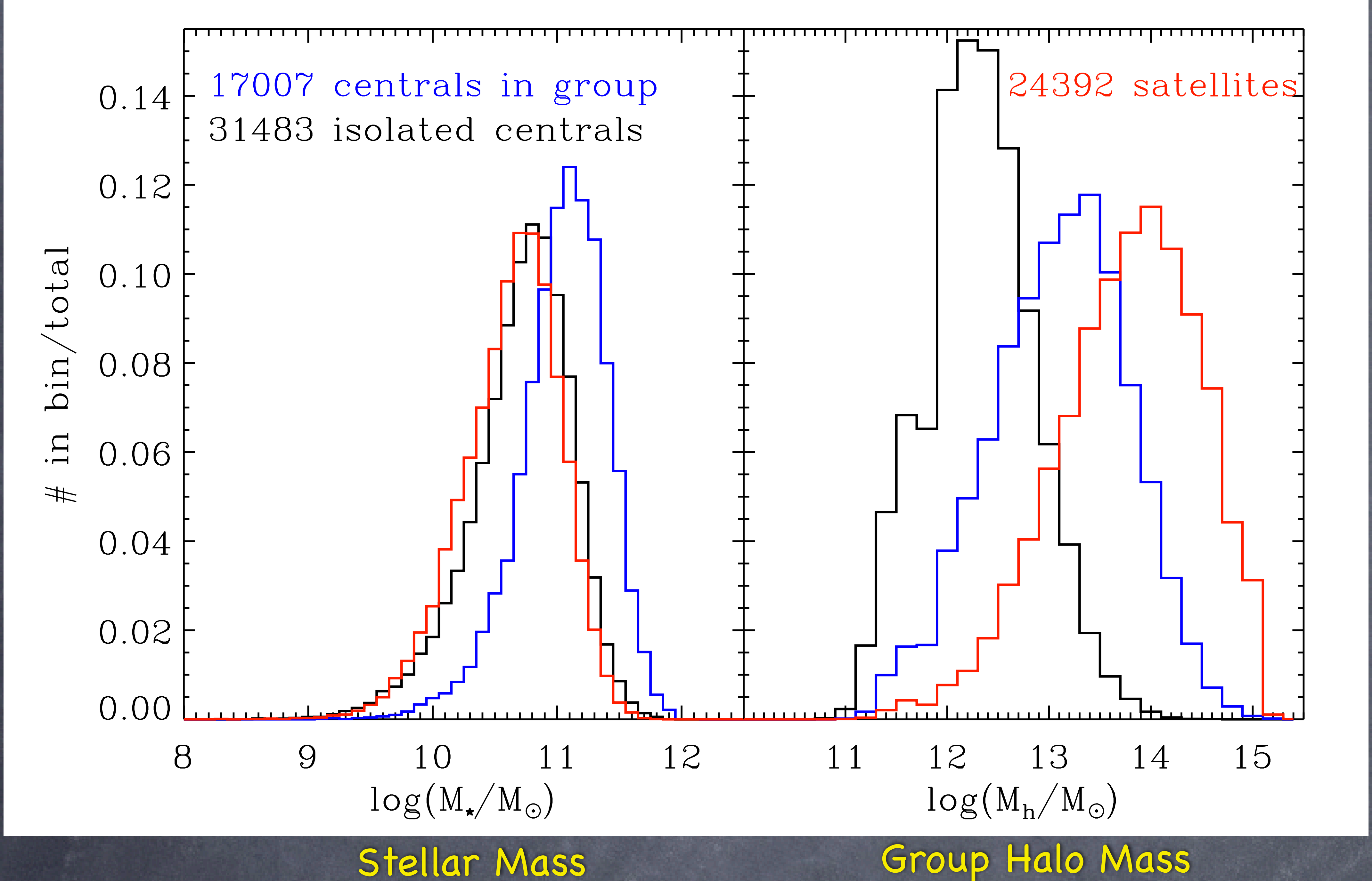
- $\Delta(Mg_b/\langle Fe\rangle) \rightarrow$ [α/Fe] : calibrated with the Thomas+03,+10 models (proportionality largely independent of age and metallicity; similar calibration with Coelho+07 models)



Definition of environment

- SDSS DR7 group catalog (Yang+07): identify centers of potential groups with FoF; iterative procedure to define group mass and size and group membership; halo mass estimated from the ranking of the characteristic mass
- CENTRALS: sitting at the center of a dark matter halo either as dominant galaxy in a group or as isolated galaxy
- SATELLITES: accreted into a larger halo and orbiting as a satellite
- Stellar populations scaling relations as a function of group hierarchy and of group halo mass

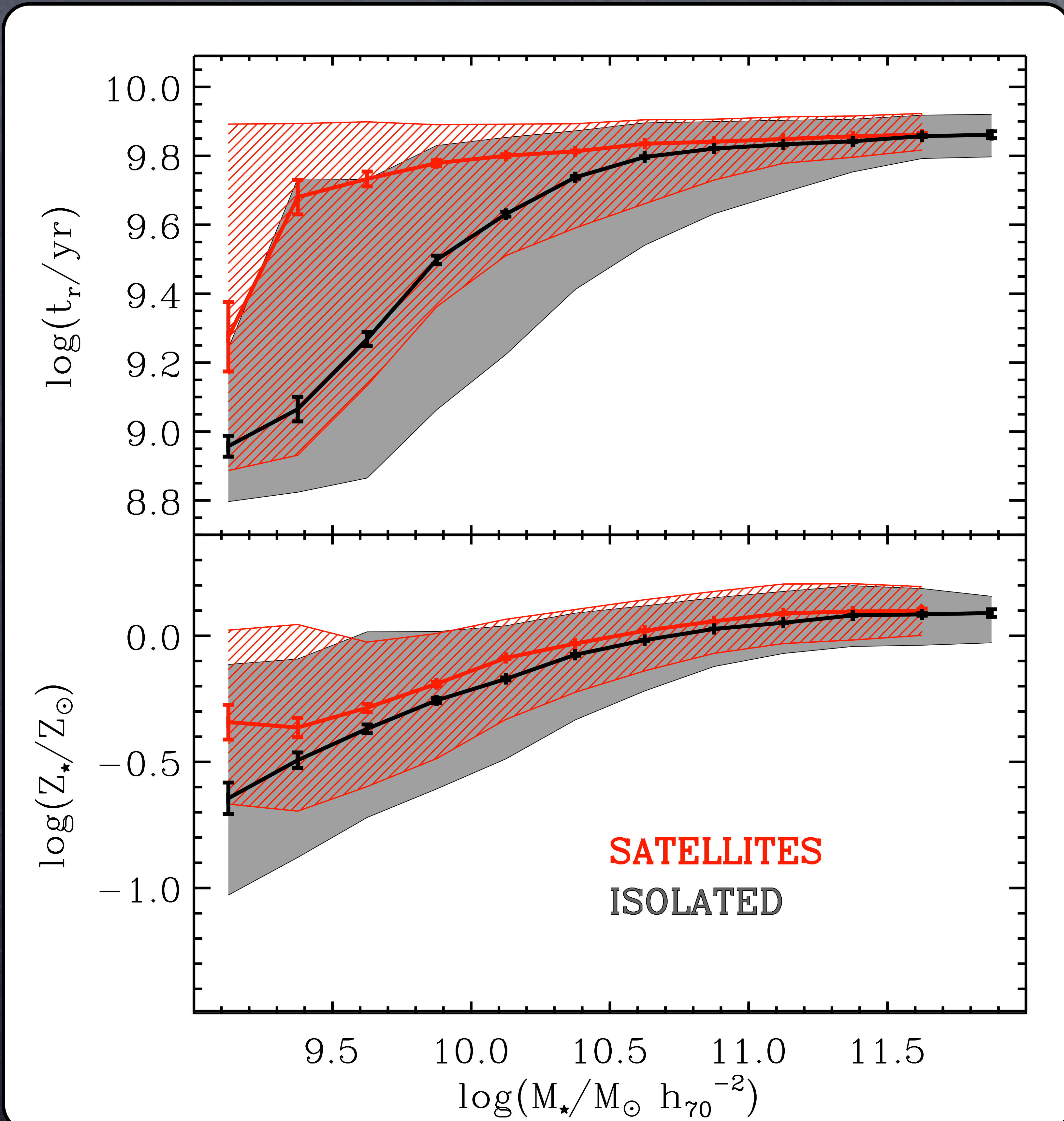




SDSS DR7 group catalog + stellar populations catalog; $0.01<z<0.2$, $r<17.77$, $S/N>20$

Gallazzi et al 2014, in prep.

All galaxy types

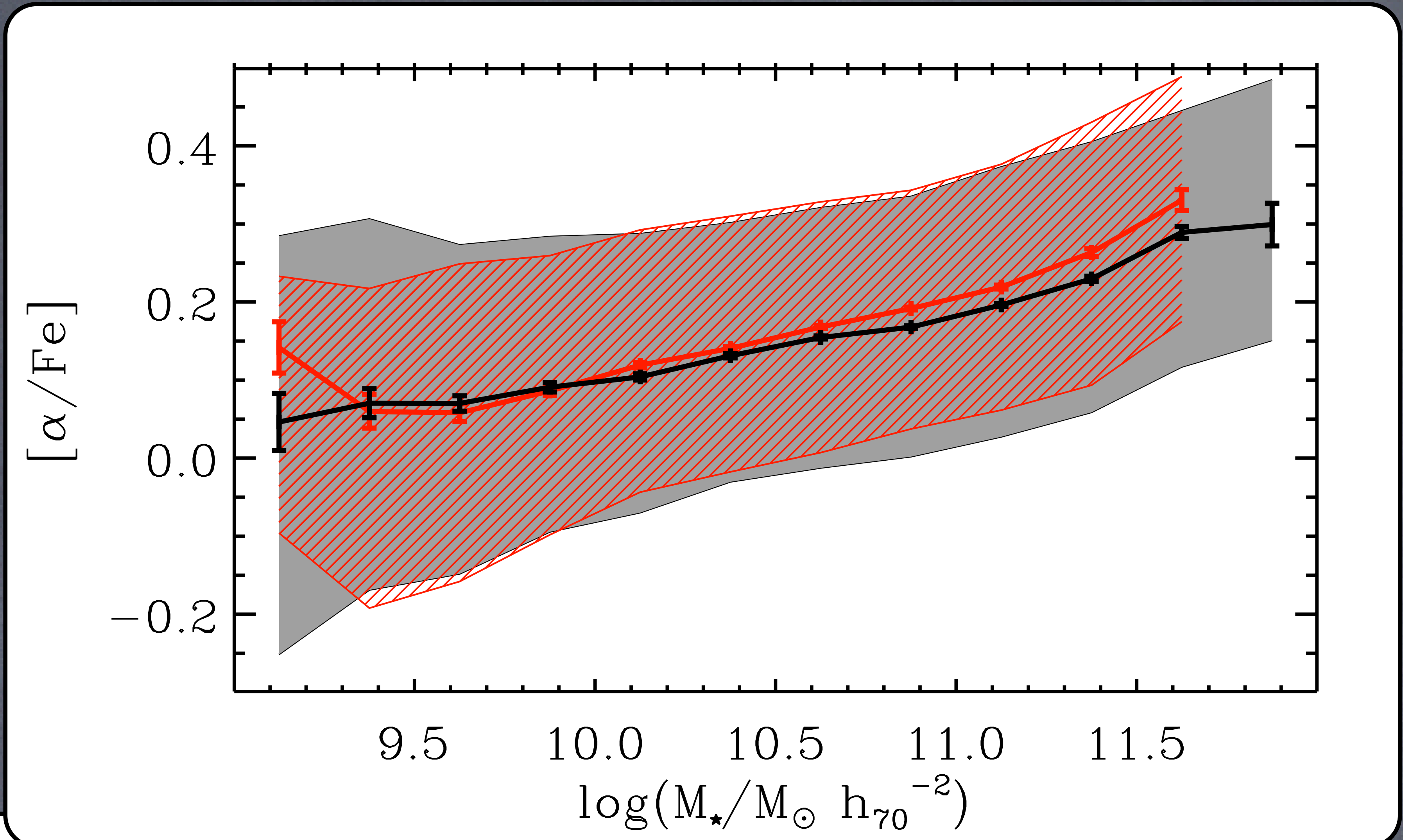


Stellar Mass

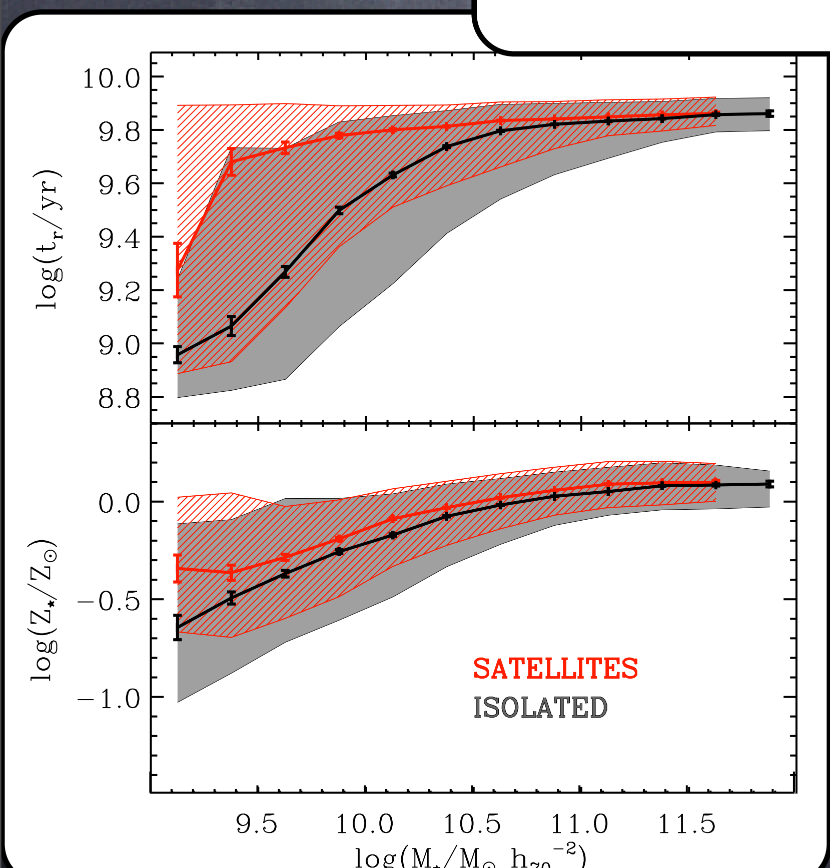
- **At a given stellar mass, satellites are older and more metal-rich than isolated central galaxies**, with increasing difference below $3x10^{10}M_{\odot}$
- At nearly all mass lack of young, metal-poor galaxies among satellites; at masses $<6x10^{10}M_{\odot}$ excess of old, metal-rich galaxies among satellites

Pasquali et al 2010
Gallazzi et al 2014, in prep.

All galaxy types



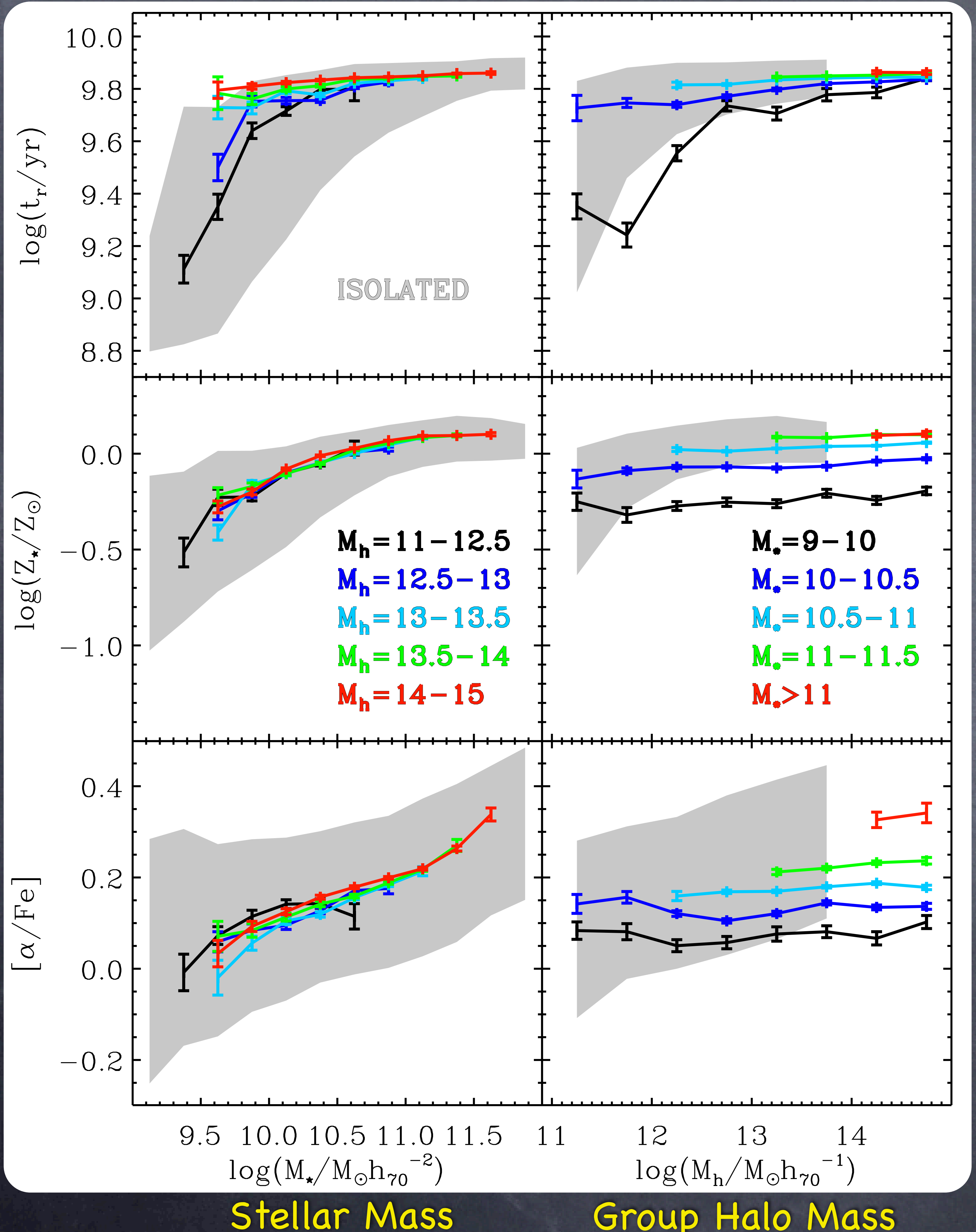
Stellar Mass



At fixed stellar mass Satellite galaxies are only slightly more α-enhanced than isolated galaxies

not more than ~500Myr difference in "half-mass time" (using de la Rosa et al 2011 relation)

Gallazzi et al 2014, in prep.

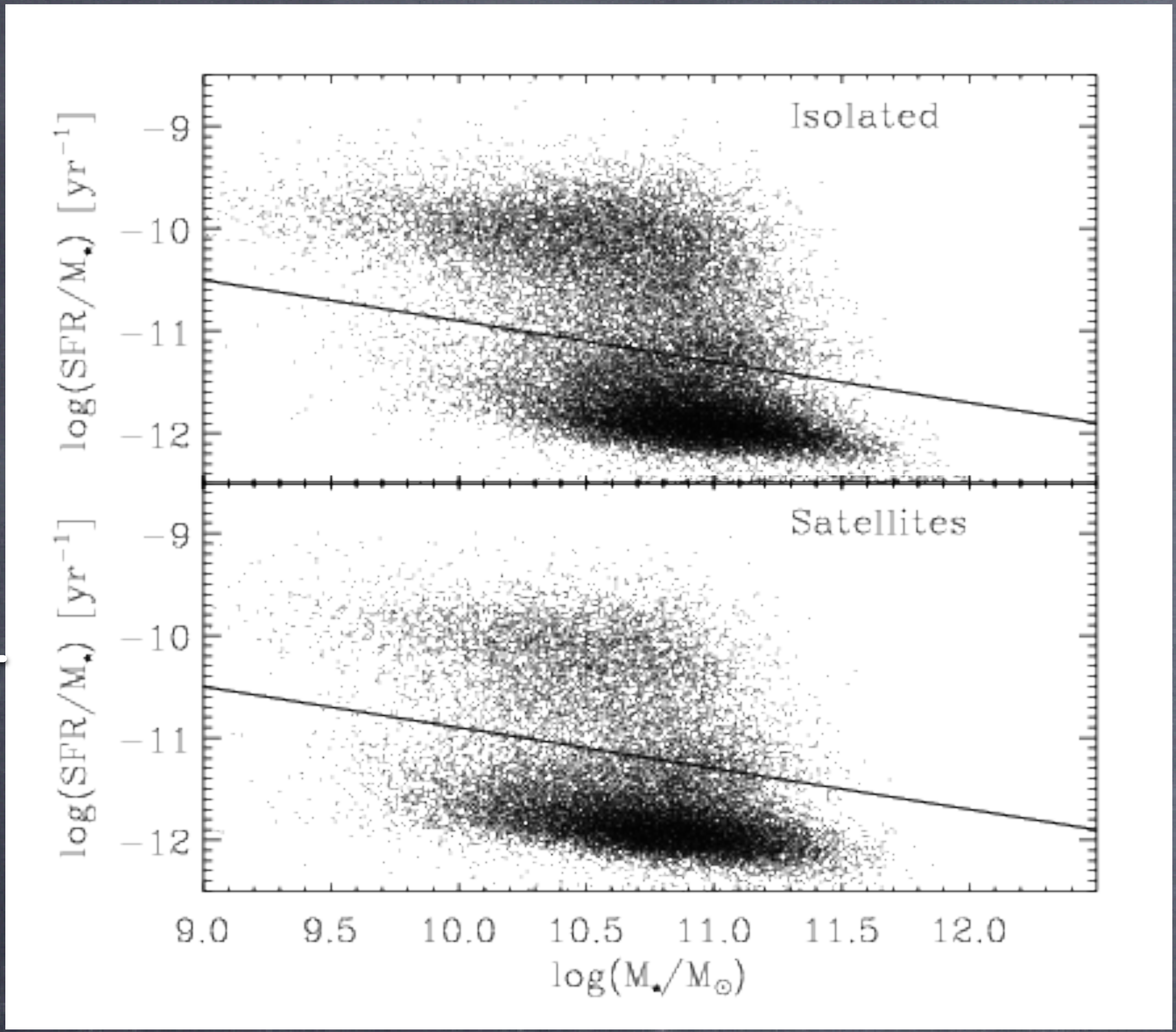


- $M_* > 3\times10^{10} M_\odot$: satellites are coeval to centrals, nearly independent of halo mass
- $M_* < 3\times10^{10} M_\odot$:
  - ages of satellites increase with the mass of the halo in which they reside
  - quenching of SF at infall; galaxies in more massive groups were accreted earlier

See also Pasquali et al 2010

- [α/Fe] of satellites is set by the galaxy stellar mass, almost independently of halo mass
- environmental quenching happens significantly after bulk of SF occurs

Gallazzi et al 2014, in prep.



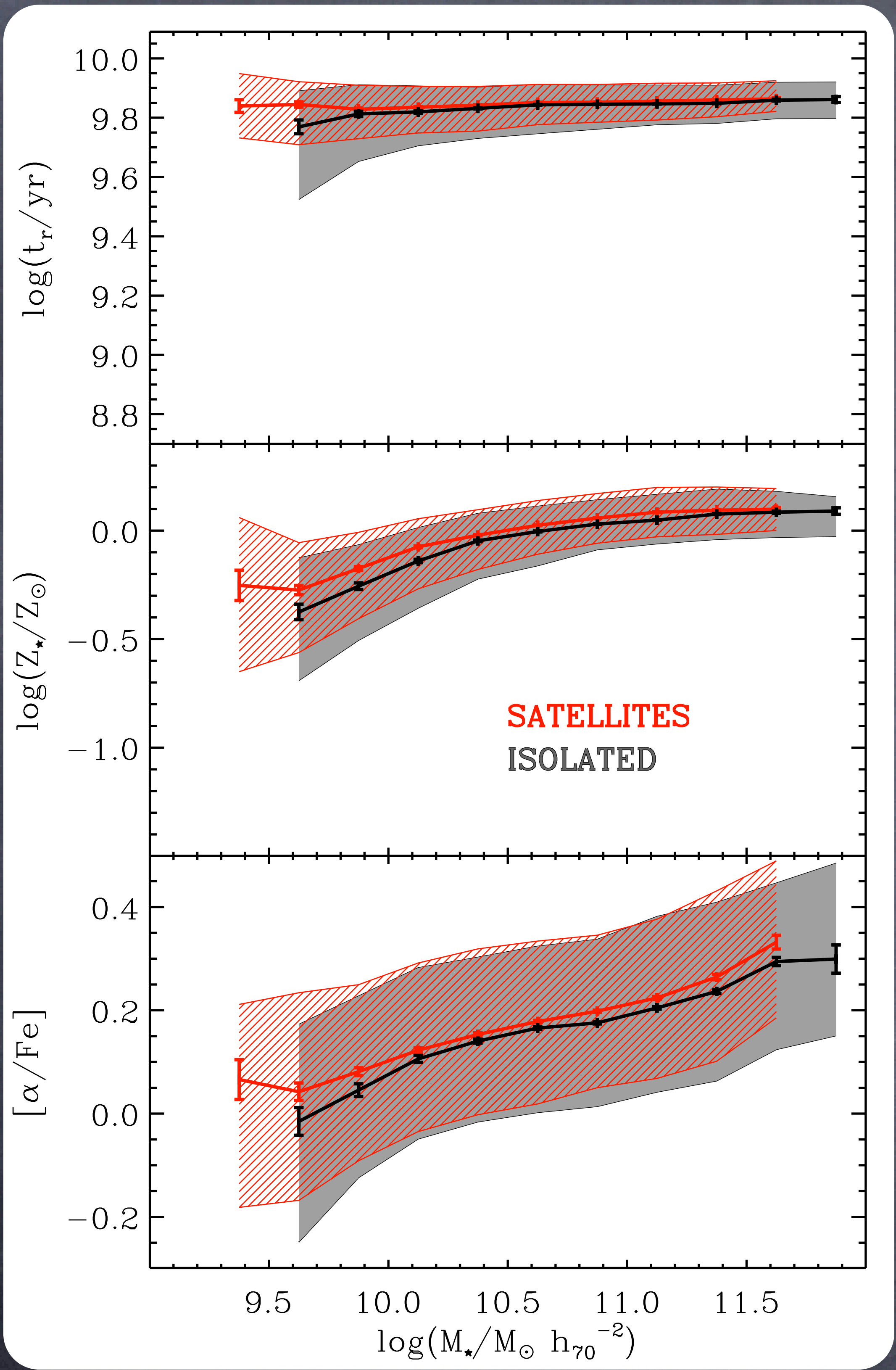
Specific SFR

Stellar Mass

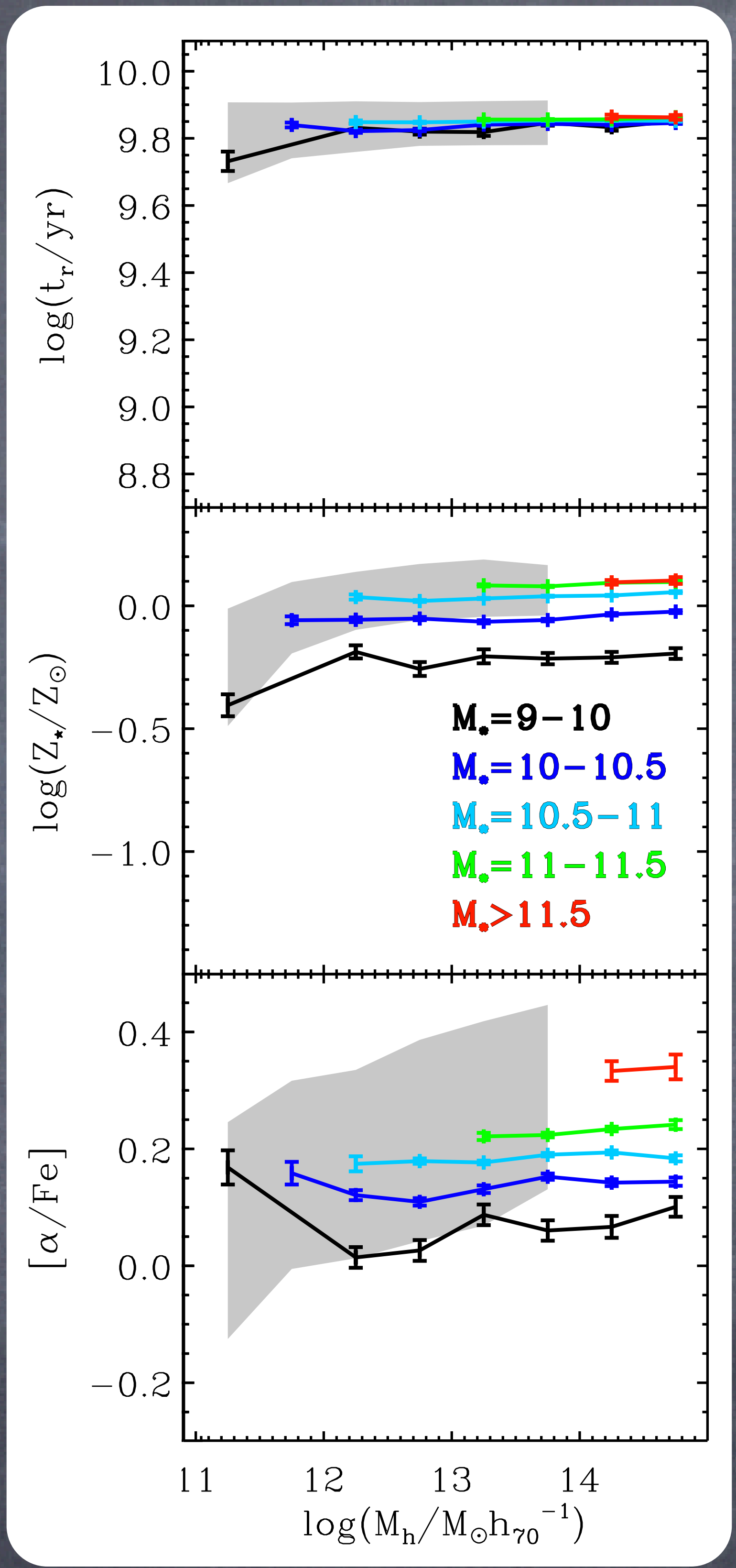
26% star-forming satellites
40% star-forming isolated

Do the differences reflect just a difference fraction of quiescent and star-forming galaxies?
Do quiescent and star-forming satellites separately differ from their isolated analogs?

Quiescent galaxies



Stellar Mass

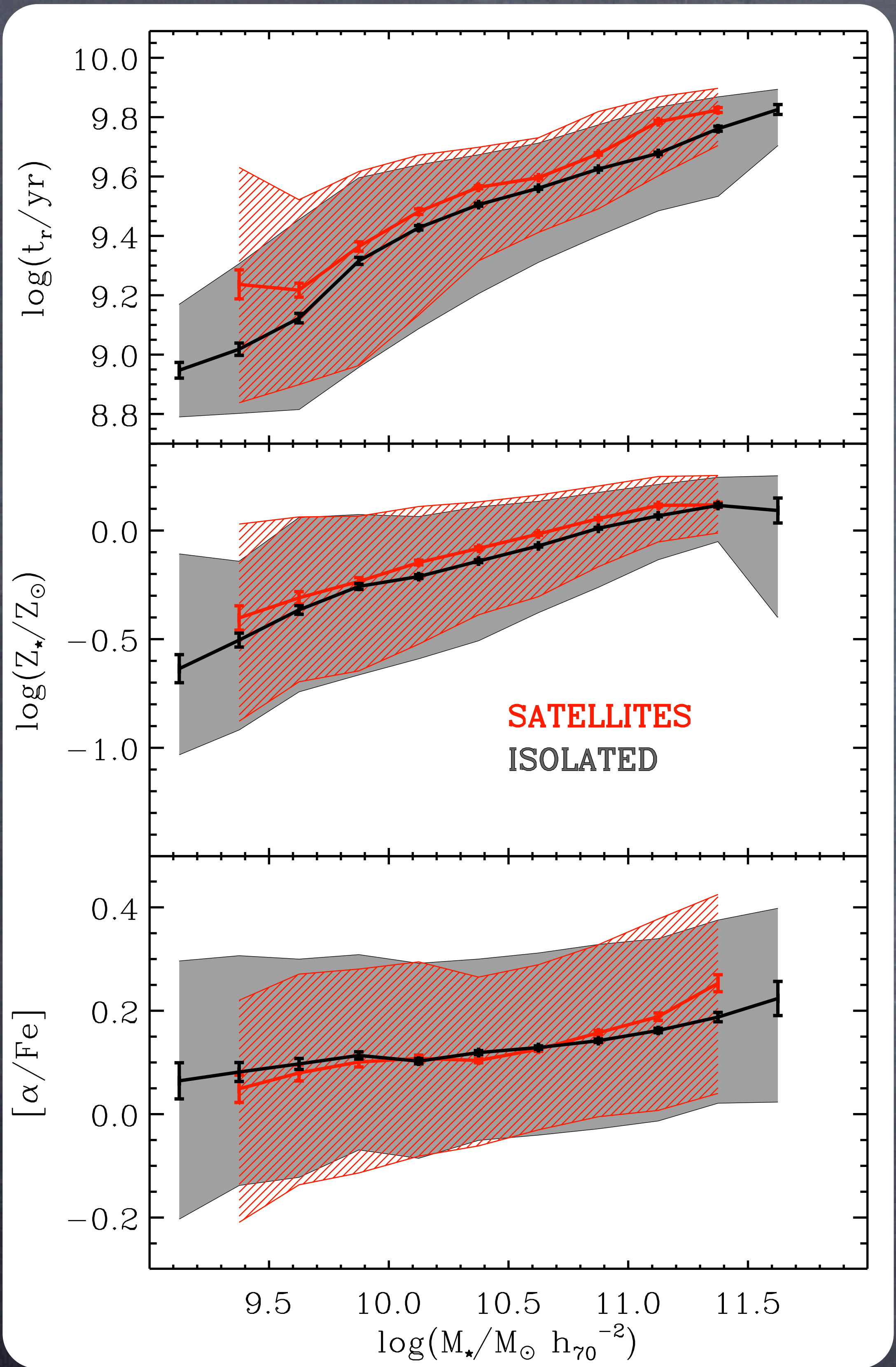


Group Halo Mass

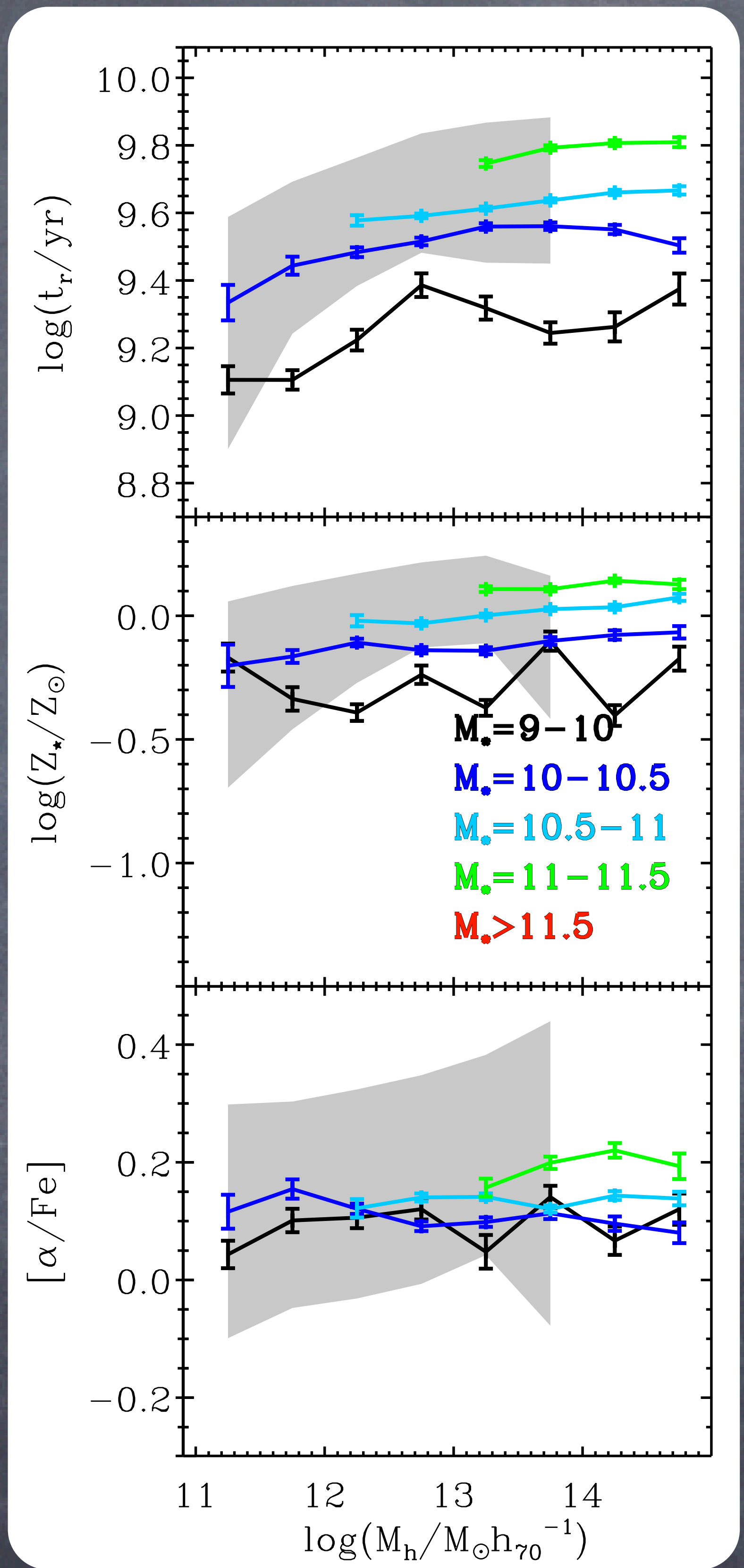
Satellites are uniformly old, small difference in metallicity and [α/Fe] wrt to isolated

-> Epoch and timescale of quenching influenced by environment but with almost no dependence on halo mass

Star-forming galaxies



Stellar Mass



Group Halo Mass

At fixed mass star-forming satellites are slightly older and metal-richer than isolated with mild increase with halo mass

-> Gradual suppression of SF on timescales long enough not to alter [α/Fe]

Summary and thoughts

- Massive ($M_* > 3x10^{10} M_\odot$) or quiescent satellites: **early formation epoch** (as isolated galaxies); [α/Fe] primarily driven by galaxy mass (internal efficiency); influence of environment seen in the **slightly higher [α/Fe] -> quenching timescales shorter by at most ~500Gyr ...quenched before being accreted?** (see also Wetzel et al 2013)
- Low-mass or star-forming satellites **older and slightly more metal-rich than equally massive isolated centrals** → gas strangulation and/or stripping that quenches supply of cold gas for star-formation; also explains the higher gas metallicities by preventing inflows of metal-poor gas from the outskirts
  - Differences in age correlate with halo mass: consistent with quenching induced by the environment at the time of infall and **higher redshift of infall for those satellites that reside today in more massive groups/clusters**
  - Generally low [α/Fe] and no dependence on halo mass: continued SF
- **Timescale of SF, as traced by [α/Fe], depends only on stellar mass, equally for isolated and satellites:** The overall timescale of quenching is long enough for SF to continue and process SN products according to internal efficiency
- consistent with a **delayed-then-rapid quenching scenario** (Wetzel et al 2013): star-formation continues for 2-4Gyr before quenching on <1Gyr timescale; timescale only dependent on galaxy mass (shorter at higher masses)