Using concentrated star-formation to study environmental quenching in EAGLE simulation

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UNLOCKING THE UNIVERSE,
INSPIRING THE FUTURE

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EAGLE (Evolution and Assembly of GaLaxies and their Environments) simulation suite

It consists of a collection of cosmological hydrodynamical simulations on galaxy evolution with different resolutions, cosmological volumes and subgrid models.

'Friends-of-Friends'(FoF) algorithm define halos; SUBFIND algorithm define subhaloes within the FoF halo; contain particles with the lowest value of the gravitational potential are classified as the centrals, while the rest are classified as satellites.

Cluster-EAGLE

The galaxy cluster zoom hydrodynamical simulations

- Spatial distribution of SF in the EAGLE galaxies comparing with SAMI observations (C-index)
- What will effect the C-index? (How long has the galaxies been a satellite, radii)
- With EAGLE, how the sSFR, C-index change with lookback-time?
- Further more, how does SF quenching act at different redshift?

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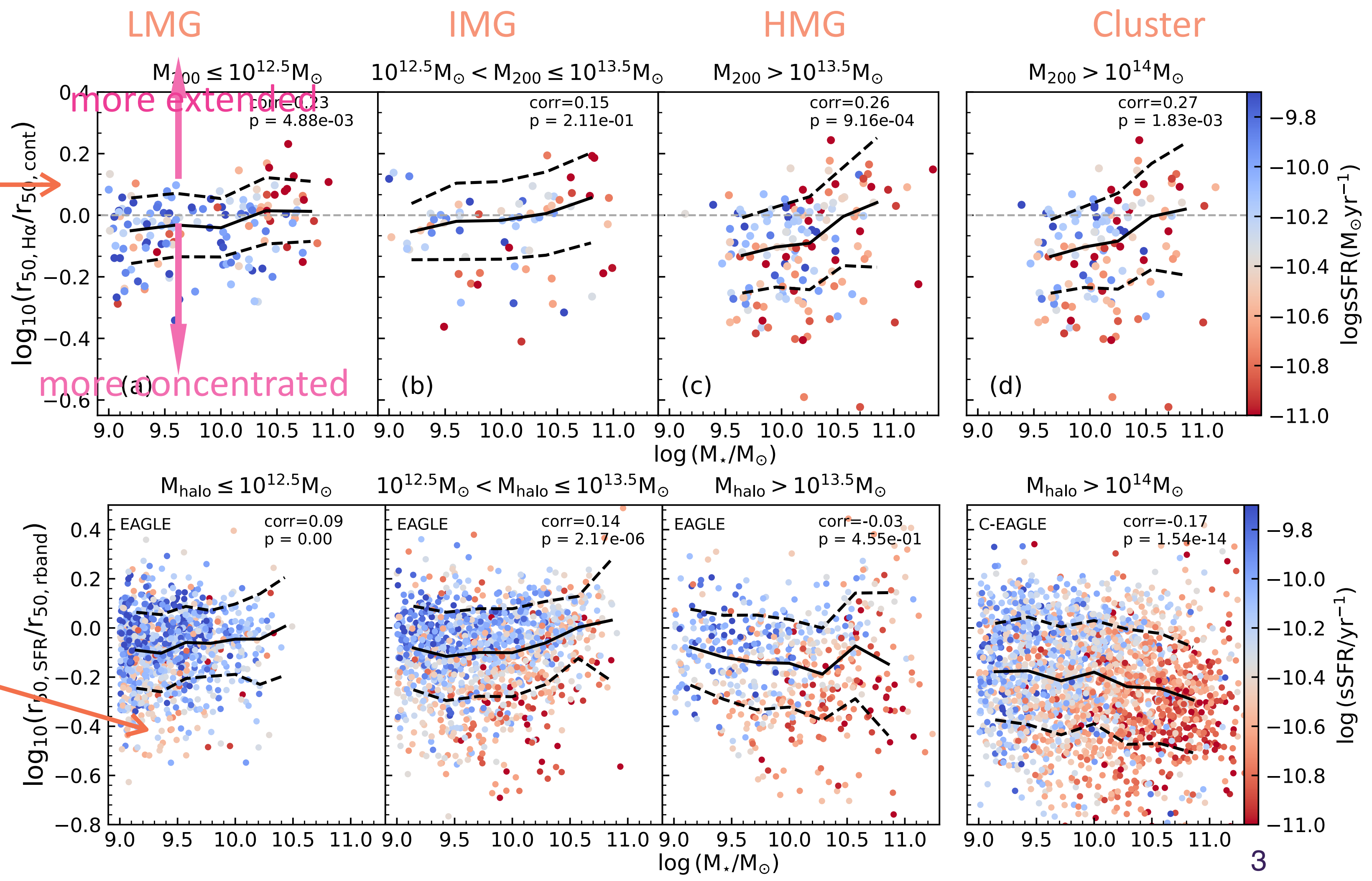
Distribution of SF in the galaxies:

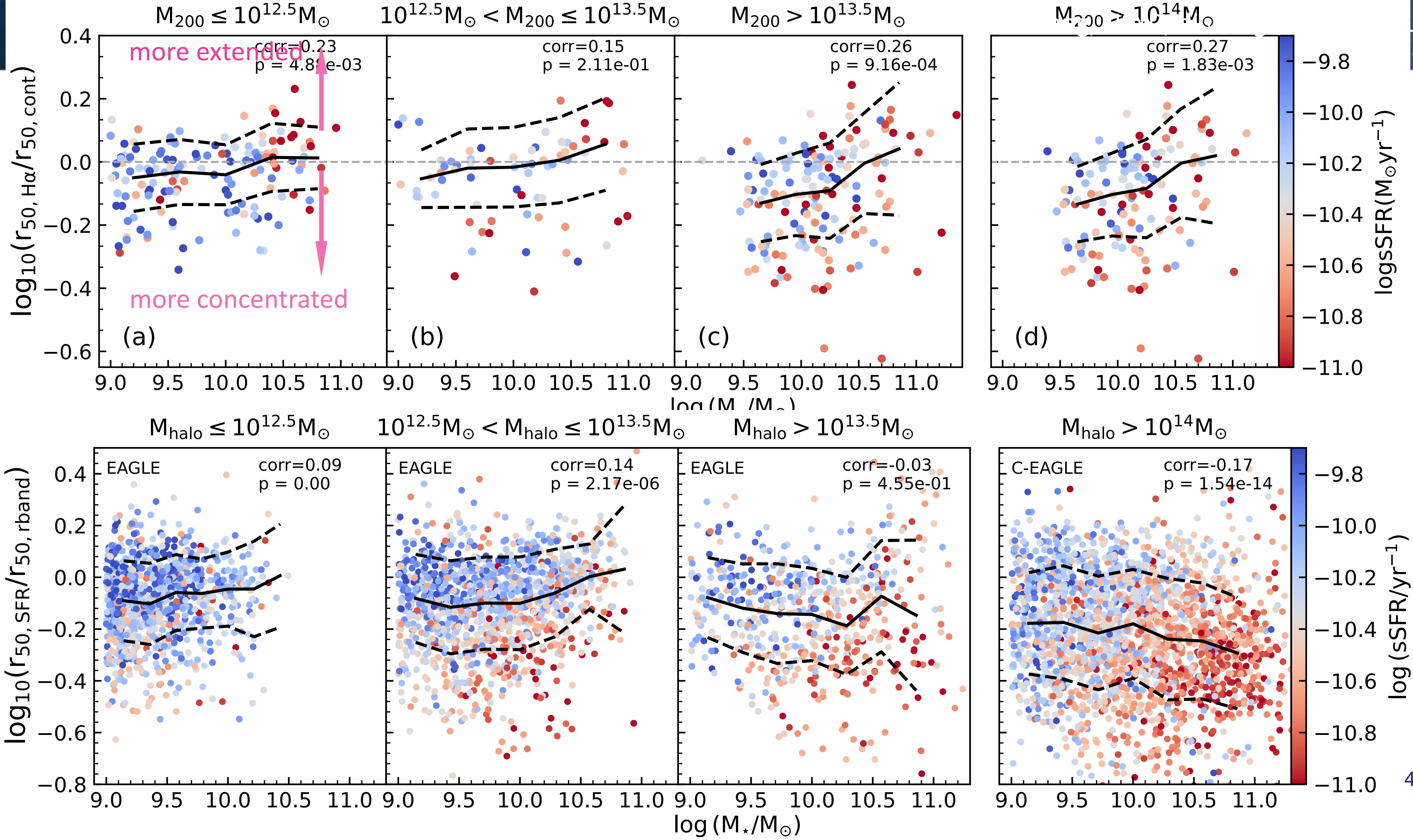
- Concentration index (C-index):

SAMI: log10(r50,Hα/r50,cont), which compares the extent of ongoing star formation to previous star formation. (Schaefer 2017, 2019)

EAGLE/C-EAGLE: log10(r50,SFR/r50,rband) from gas/stellar particles. (only include particles within 1.4r_e in the disc, 0.5r_e in height considering the aperture affect in SAMI). At z=0.

regular galaxy : C-index ≥ -0.2
SF-concentrated galaxy: C-index < -0.2





M200 ≤ 10^12.5 M⊙
10^12.5 M⊙ < M200 ≤ 10^13.5 M⊙
M200 > 10^13.5 M⊙
M200 > 10^14 M⊙
more extended
more concentrated
corr=0.23
p = 4.88e-03
corr=0.15
p = 2.11e-01
corr=0.26
p = 9.16e-04
corr=0.27
p = 1.83e-03
(a)
(b)
(c)
(d)
log10(r50, Hα/r50, cont)
logsSFR(M⊙yr−1)
Mhalo ≤ 10^12.5 M⊙
10^12.5 M⊙ < Mhalo ≤ 10^13.5 M⊙
Mhalo > 10^13.5 M⊙
Mhalo > 10^14 M⊙
EAGLE
corr=0.09
p = 0.00
EAGLE
corr=0.14
p = 2.17e-06
EAGLE
corr=-0.03
p = 4.55e-01
C-EAGLE
corr=-0.17
p = 1.54e-14
log10(r50, SFR/r50, rband)
log (sSFR/yr−1)
log (M⋆/M⊙)

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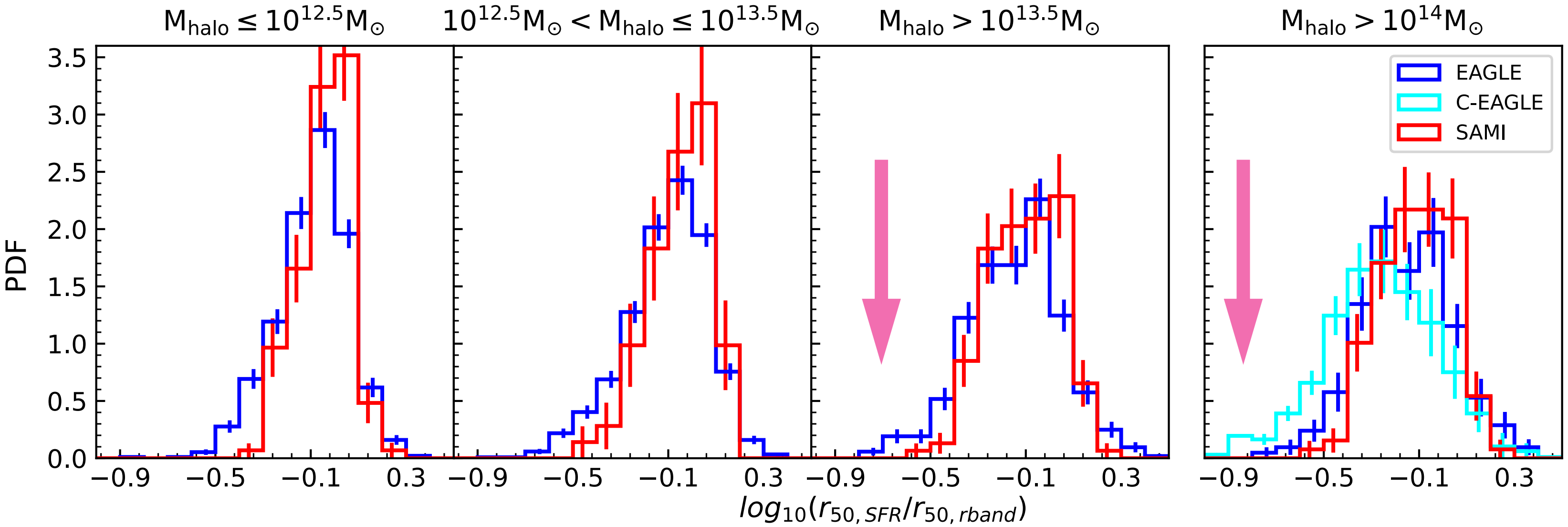
Normalized Histogram of C-index



With SAMI survey, we see galaxies in denser regions tend to have lower C-index, the fraction of SF-concentrated galaxies is increasing with greater halo masses. (Wang2022)

Sum1:
We can use C-index in EAGLE simulation for selecting galaxies that are currently undergoing "outside- in "quenching process.
We see a similar trend with EAGLE galaxies compared with SAMI observations at z=0.

Fraction of SF-concentrated galaxy with binary distribution

regular galaxy : C-index ≥ -0.2
SF-concentrated galaxy: C-index < -0.2

Fraction	LMG	IMG	HMG	C-EAGLE
SAMI	10±3%	14±4%	29±4%	29±4%
EAGLE	21±2%	27±1%	40±2%	51±3%

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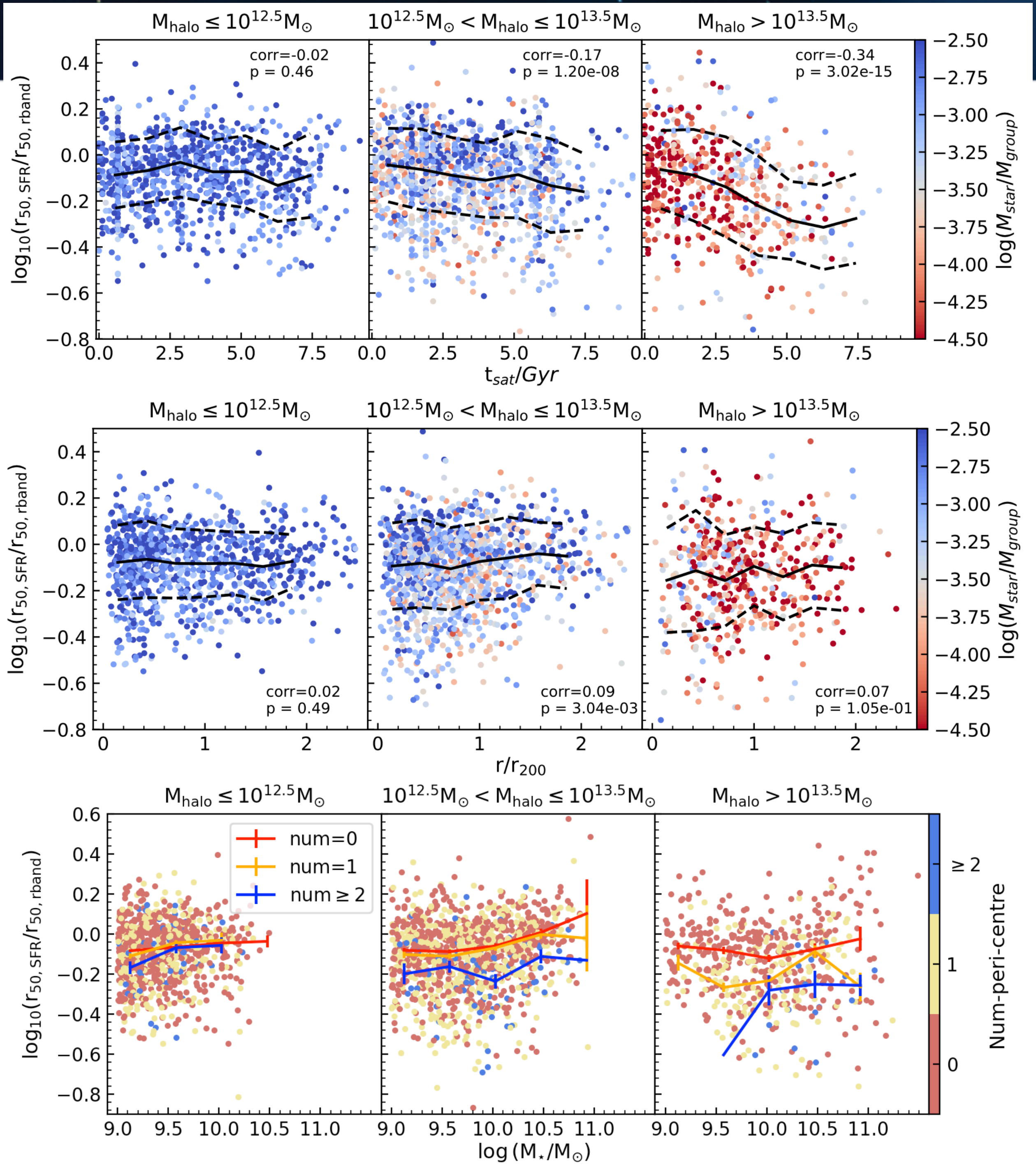
What will effect the C-index in different halo masses?

- T_sat: the lookback-time when satellites falled into the current host halo
- Radii: satellite current radii normalised by r200
- N_pricentre: how many times the galaxy passes through the group centre

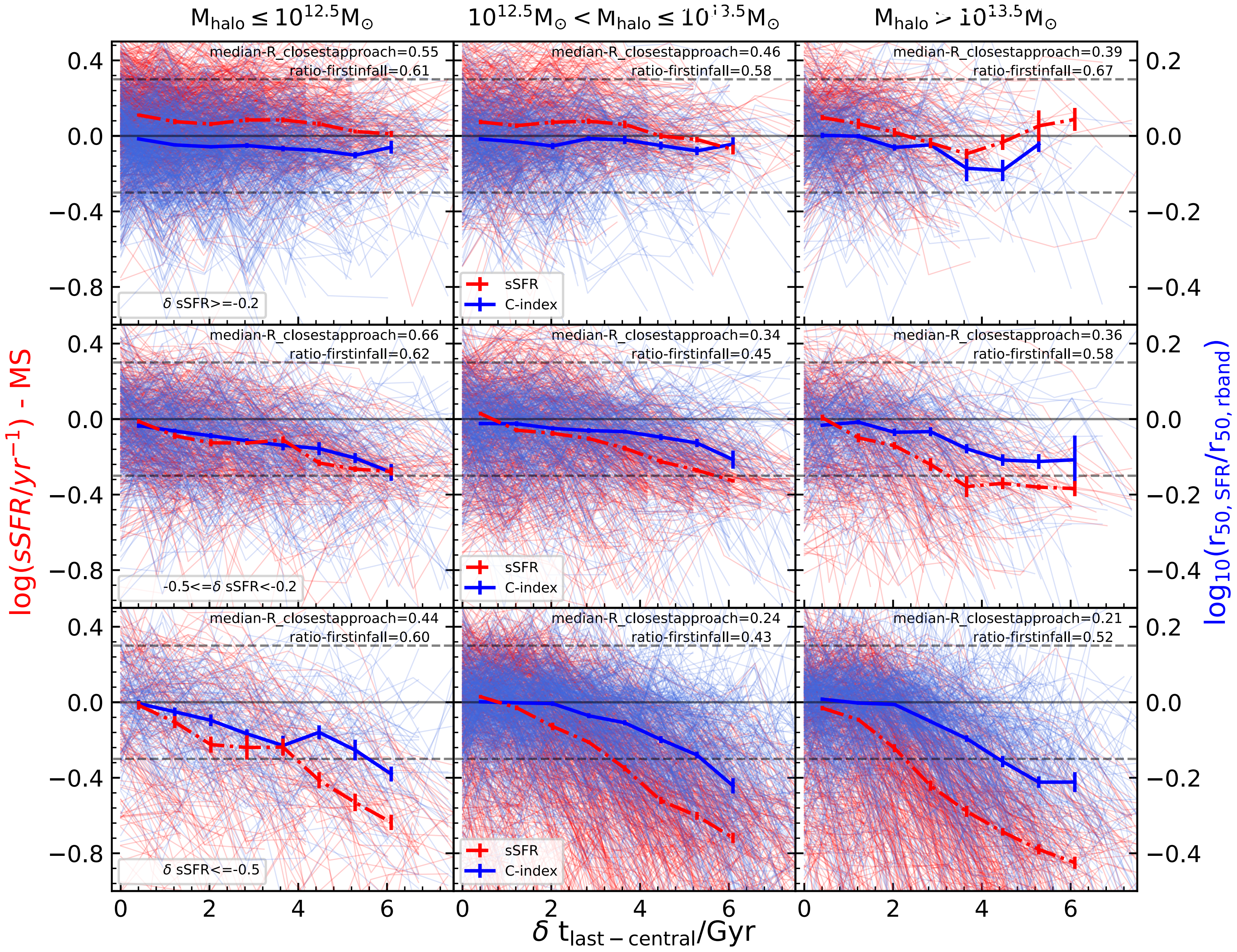
Sum2:
C-index is a better calibration of how long the satellite has fallen into the current host than the radius
Orbit is important during the environmental quenching process as greater N_pricentre have more concentrated star-formation



SSFR, C-index time Profile

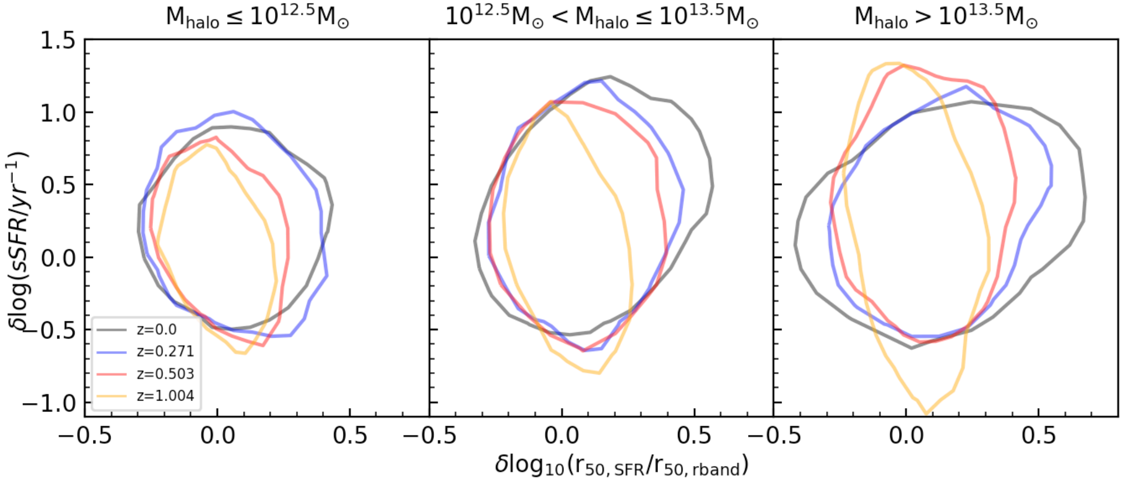
- T_lastcentral: the lookback-time when when the galaxy was a central; delta T_lastcentral = 0, means galaxies just been noticed as satellites
- sSFR, C-index at 20 snapshot from z=0 to 20.
- sSFR-MS bin: ≥-0.2, -0.2 to -0.5, <-0.5 (top to bottom)
- R_closetapproach: the closest radii that satellites approach the host centre
- First_infall: N-pricentre = 0

Sum3:
EAGLE supports sSFR take shorter times to drop off the MS in HMGs; denser environments are more efficient in stripping gas in the discs;
R-closest_approach and ratio of first-infallers are corresponding to the row difference



SF quenching at different redshift

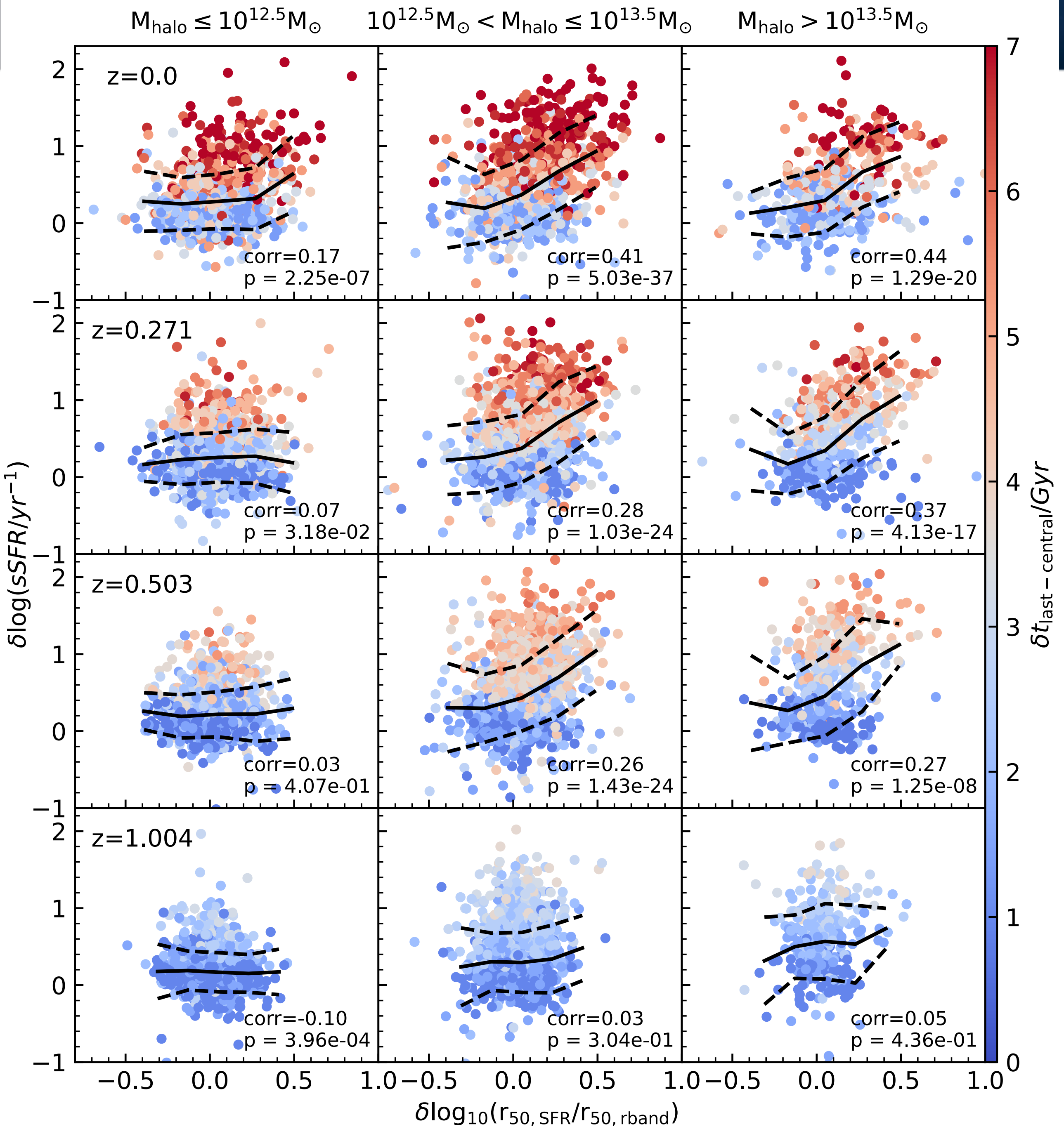
- T_lastcentral: the lookback-time when when the galaxy was a central; delta T_lastcentral = 0, means galaxies just been noticed as satellites
- delta sSFR: sSFR_lastcentral - sSFR_refshift
- delta C-index: C-index_lastcentral - C-index_redshift



Sum4:

At z=0, a positive correlation between delta sSFR and delta C-index, longer delta t_lastcentral cause greater differences

At higher redshift, the delta sSFR is large without delta C-index change, might be caused by at high redshift, galaxies are more tend to be clumpy and disturbed (Elmegreen2005,Nelson2013)



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SF quenching at different redshift

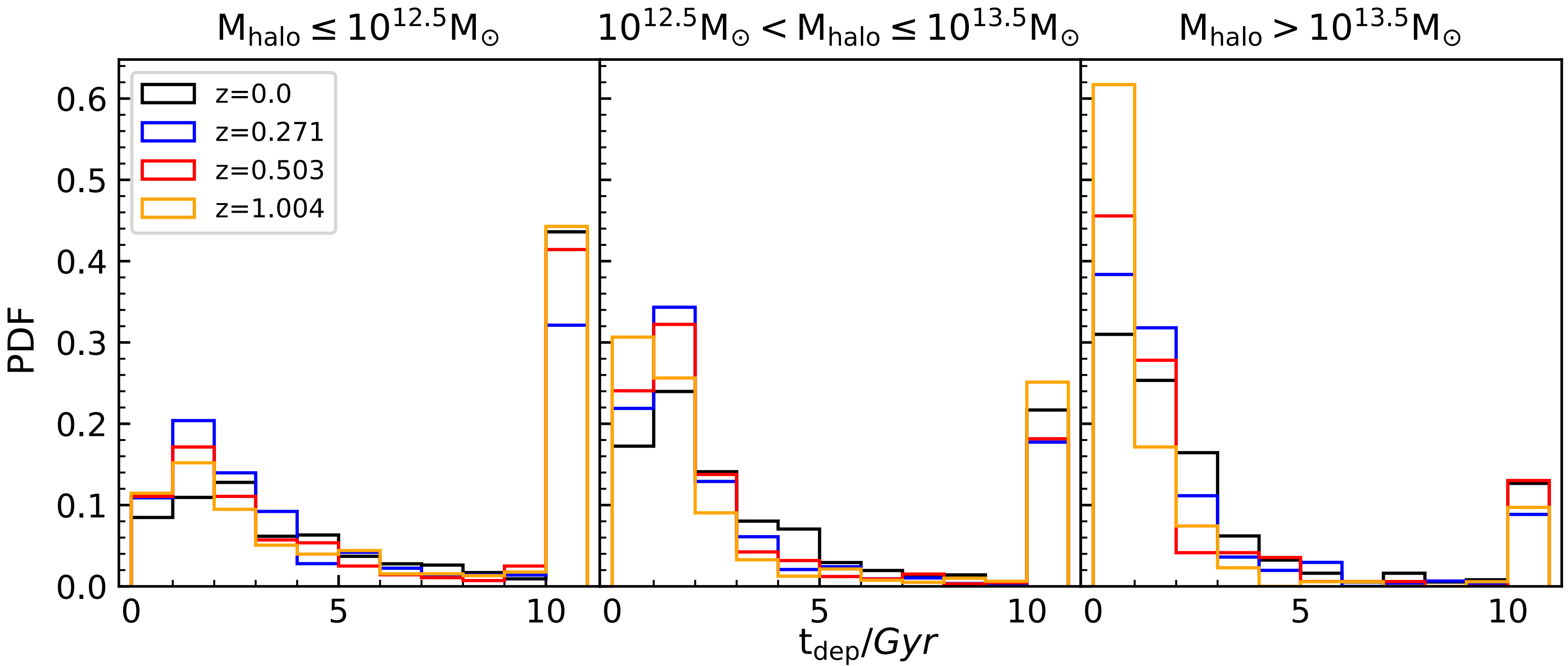
- T_dep: assuming that ISM inflow, outflow, and SFRs remain constant, how long does it take to deplete gas in a galaxy completely

$$t_{\rm dep} = \Delta t = \frac{M_{\rm ISM,t}}{\dot{M}_{\rm in,t} - \dot{M}_{\rm out,t} - \dot{M}_{\star,t}}.$$

(a)net growing or maintaining their ISM reservoir, t dep ≥10Gyr;

(b)slowly depleting their ISM reservoir, 1.5 Gyr < t dep < 10 Gyr;

(c)rapidly depleting their ISM reservoir, t dep ≤ 1.5 Gyr;



Sum5:

We find that satellites at z = 1 display very short depletion timescales < 1 Gyr; too short to imprint a clear signal of outside-in quenching in the form of C-index variations.

At $z \lesssim 0.5$, however, the population of galaxies undergoing delayed-then-rapid quenching (i.e. those with depletion times ≳ 5 Gyr) become very common, allowing the C-index to trace the way outside-in quenching happens

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Conclusion:

- We can use C-index in EAGLE simulation for selecting galaxies that are currently undergoing quenching process. We see similar trend with EAGLE galaxies comparing with SAMI observations at z=0. It's likely that ram-pressure strips gas in the discs, which will lead to lower C-index.
- C-index is a better calibration of how long the satellite has fallen into the current host than the radius. Orbit is important during the environmental quenching process as galaxies with greater N_pricentre have more concentrated star-formation
- EAGLE supports sSFR take shorter times to drop off the MS in HMGs; denser environments are more efficient in stripping gas in the discs;
- At z=0, a positive correlation between delta sSFR and delta C-index, longer delta t_lastcentral cause greater differences. SF quenching acts differently at different redshift

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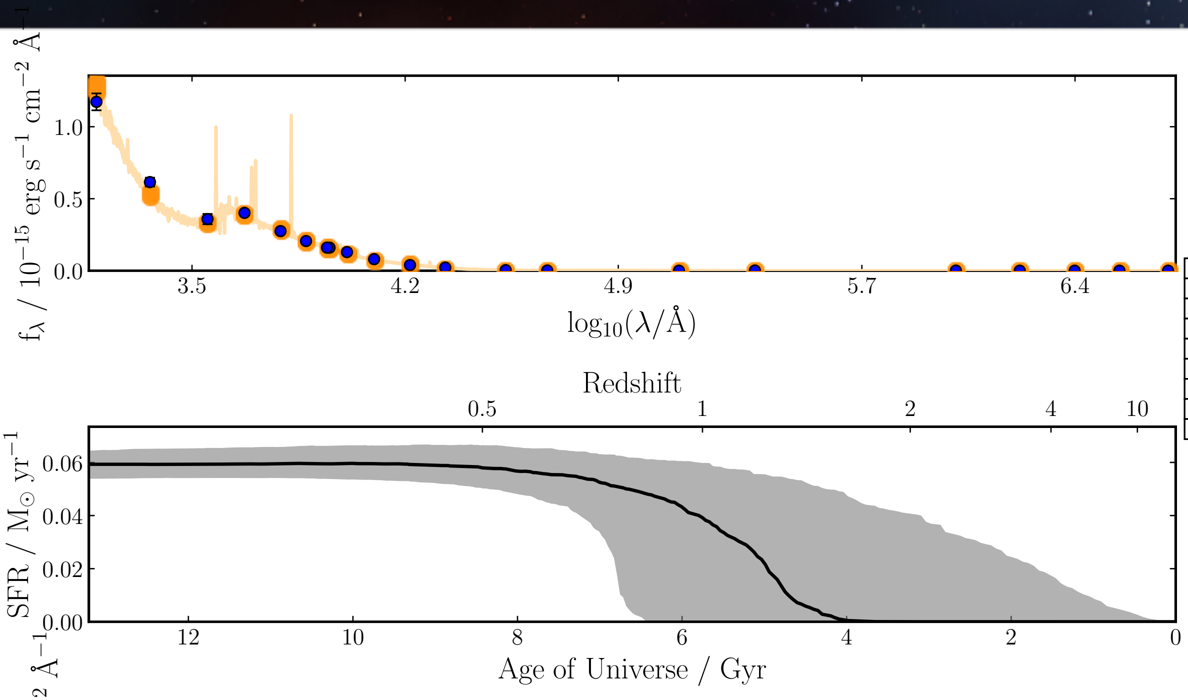
Bagpipes:

2.4. *Double power law*

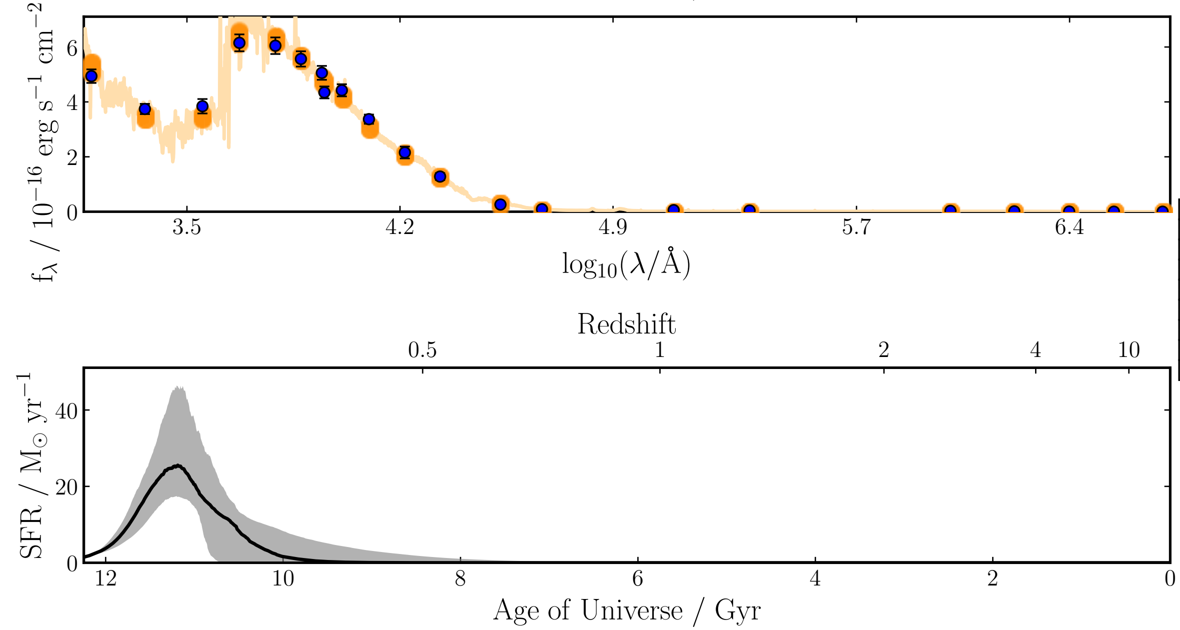
The double-power-law (DPL) function introduces another free parameter in order to separate the rising and declining phases of the SFH, which are modelled by two separate power-law slopes. This function has been shown to provide a good description of the redshift evolution of the cosmic SFRD (Behroozi et al. 2013; Gladders et al. 2013), as well as producing good fits to SFHs from simulations (e.g. Pacifici et al. 2016; Diemer et al. 2017; Carnall et al. 2018). The functional form is

$$\mathrm{SFR}(t) \propto \left[\left(\frac{t}{\tau} \right)^{\alpha} + \left(\frac{t}{\tau} \right)^{-\beta} \right]^{-1} \quad (4)$$

where α is the falling slope, β is the rising slope and τ is related to (but not the same as) the peak time. The priors reported in Table 1 are based on those used by Carnall et al. (2018).

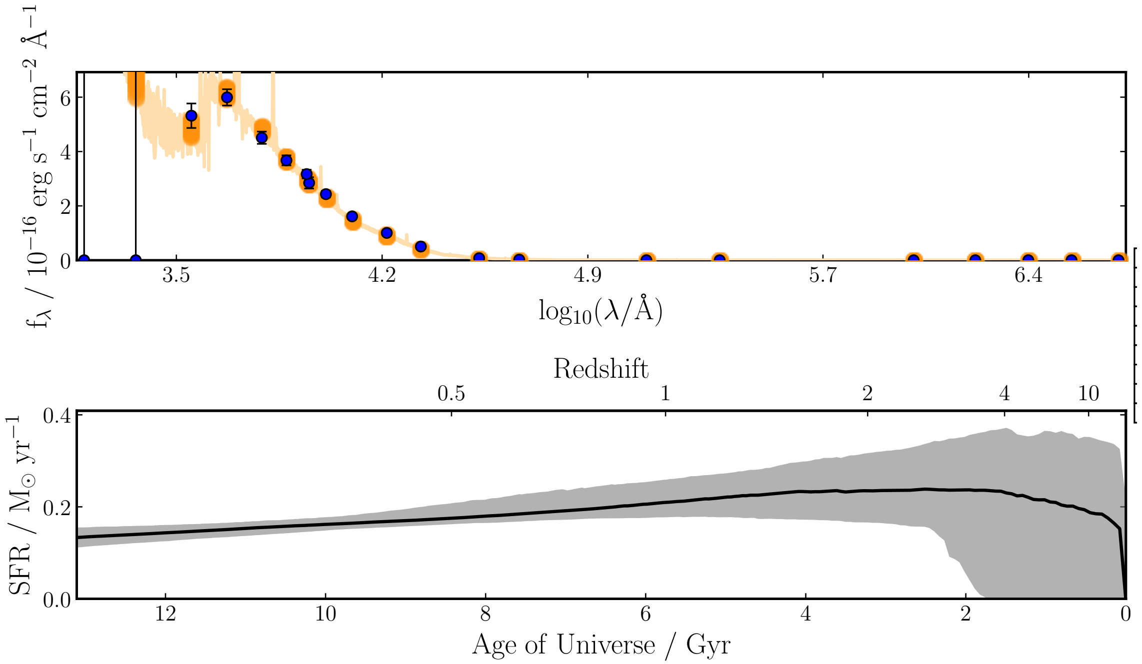


CATID	184834
z	0.01863
Mstar	8.35
$log_{10}(r_{50,H\alpha}/r_{50,cont})$	-0.0860752
$\log(sSFR/yr^{-1})$	-9.69833813
****	****
z_bag	0.01865
Mstar	8.36925
sSFR	-9.59896

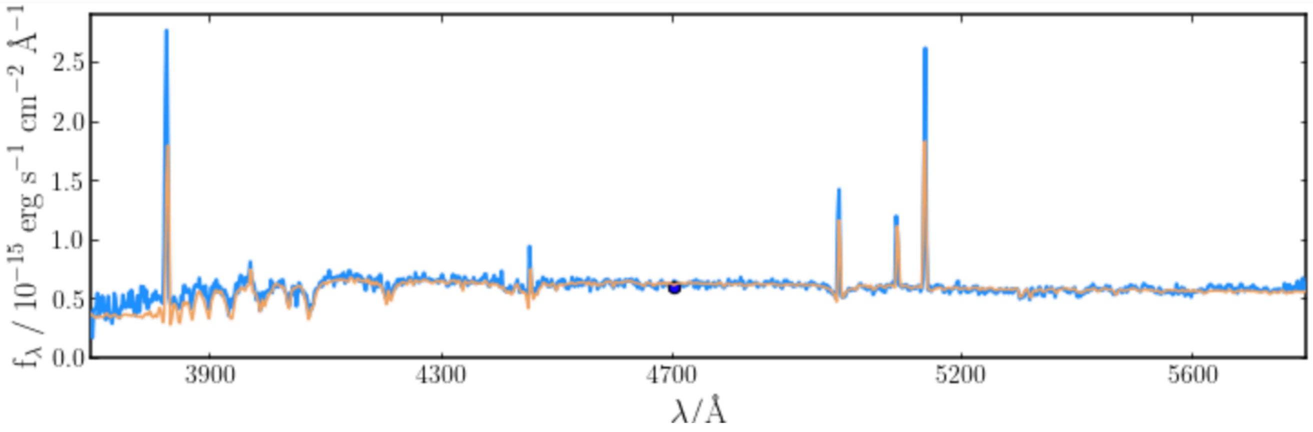


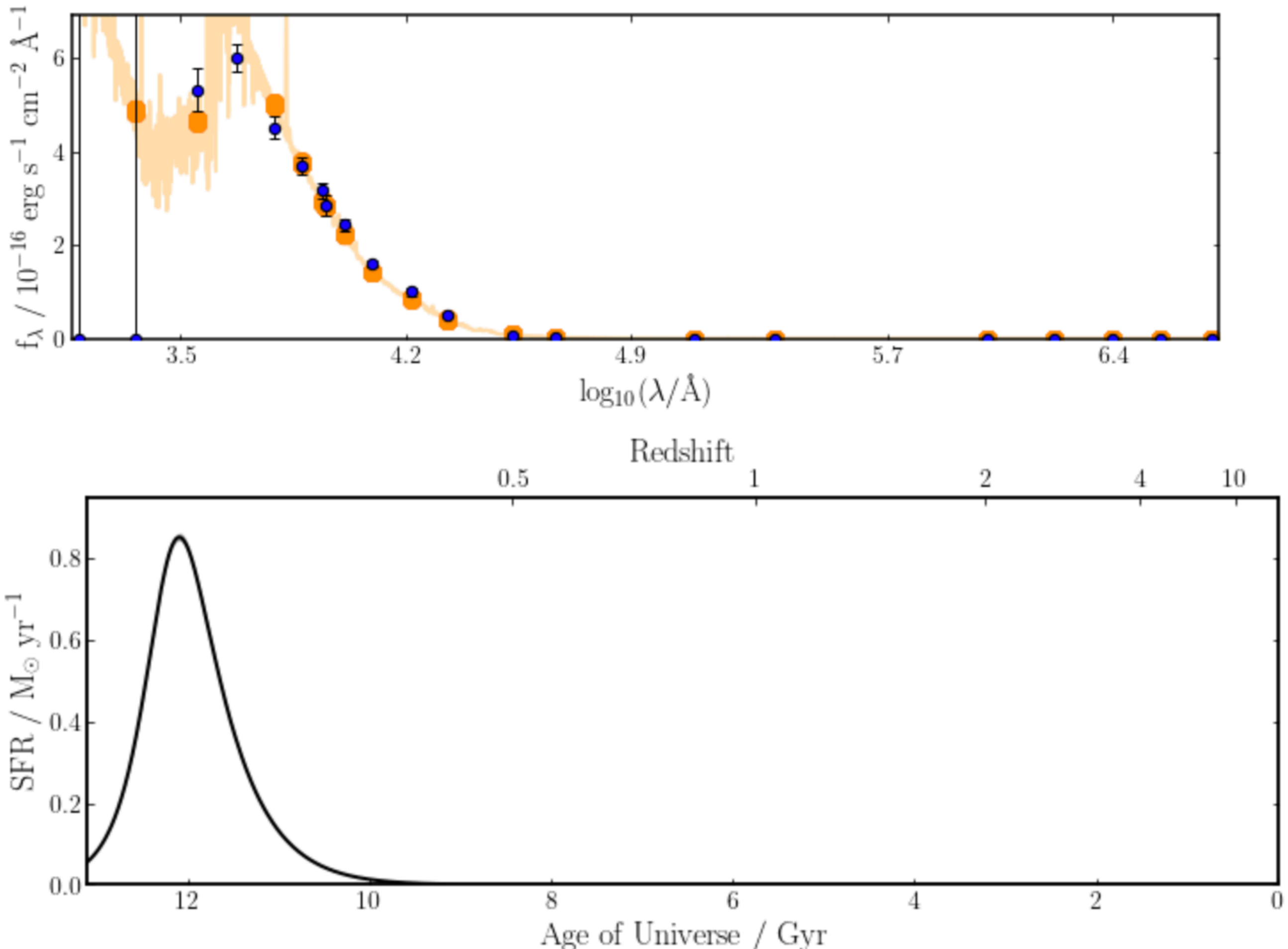
CATID	7206
z	0.09339
Mstar	10.48
$log_{10}(r_{50,H\alpha}/r_{50,cont})$	0.09725285
$\log(sSFR/yr^{-1})$	-10.262522
****	****
z_bag	0.09338
Mstar	10.28542
sSFR	-10.03351

Bagpipes:



CATID	107594
z	0.02619
Mstar	8.93
$log_{10}(r_{50,H\alpha}/r_{50,cont})$	-0.03053852
$\log(sSFR/yr^{-1})$	-9.83495988
****	****
z_bag	0.02617
Mstar	9.07683
sSFR	-9.95289





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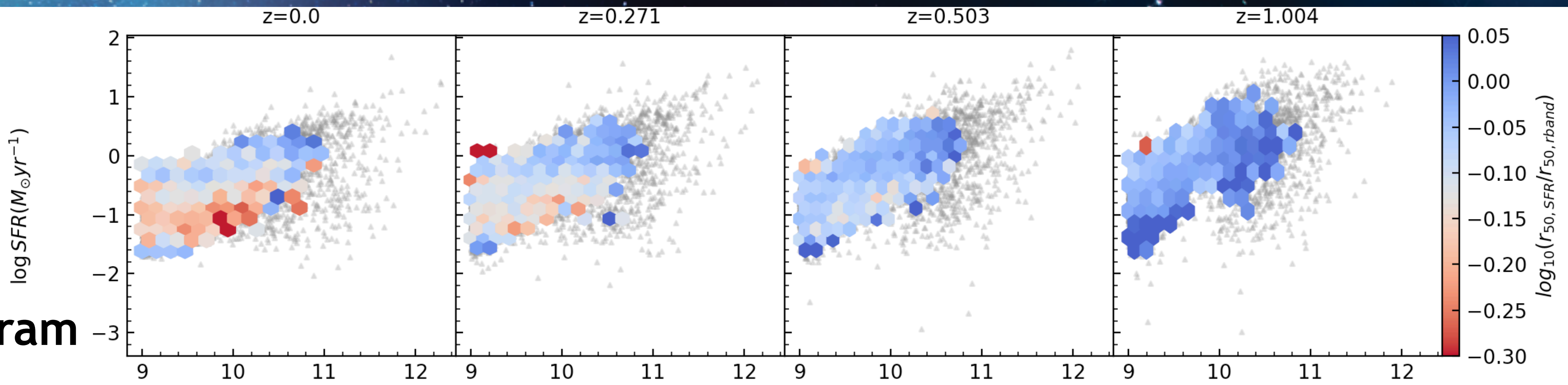
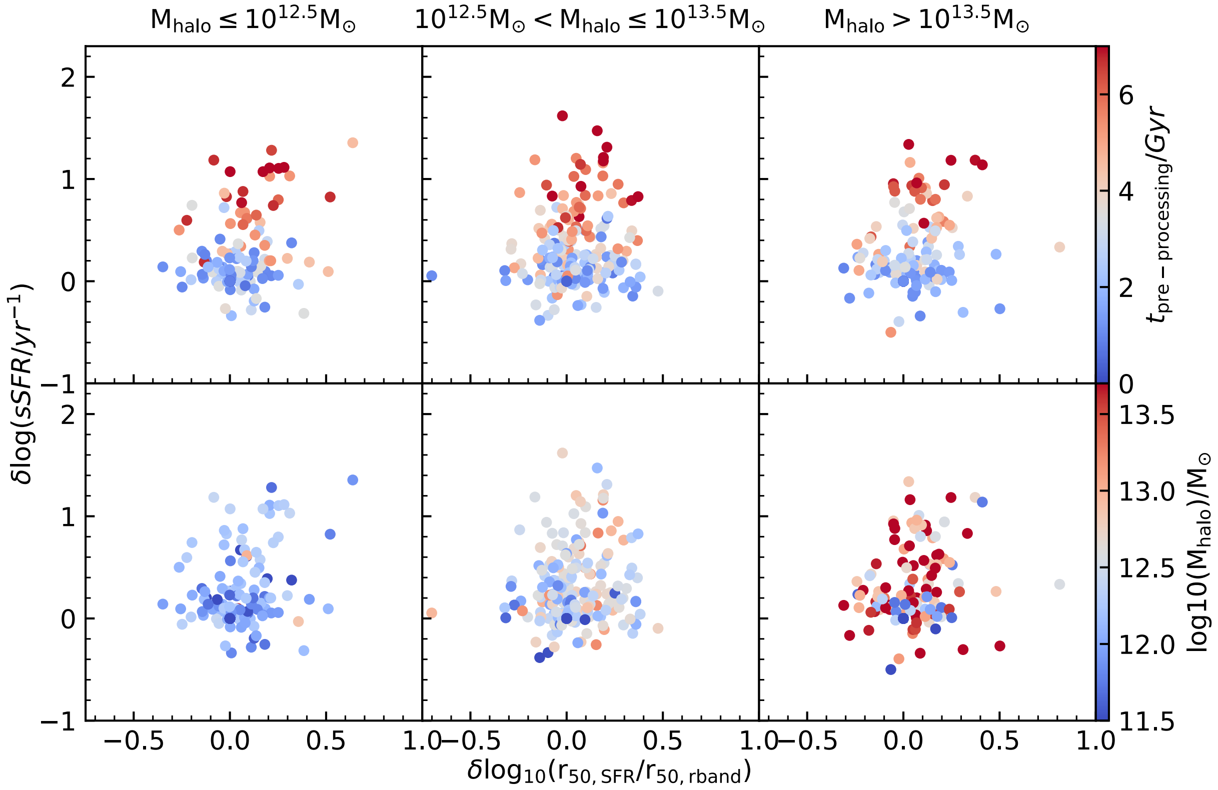


SFR-Mass diagram



support group pre-processing