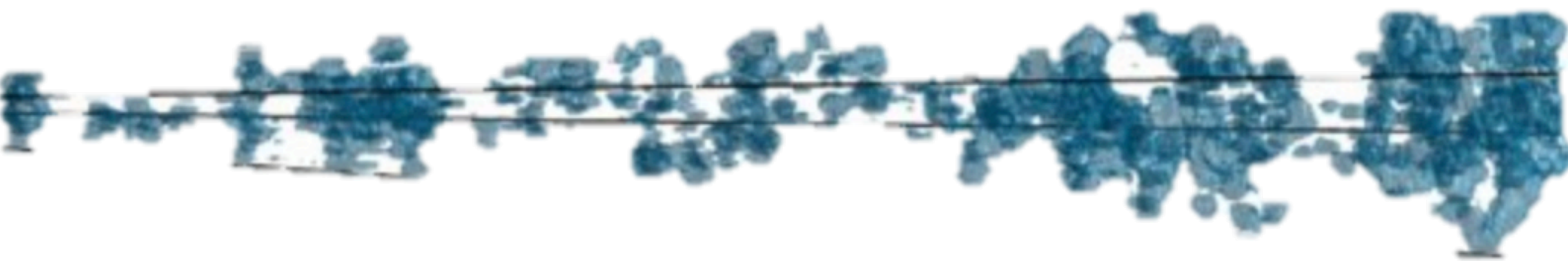
Environmental quenching disentangled: centrals, satellites, and galactic conformity

Katarina Kovač, ETH Zürich

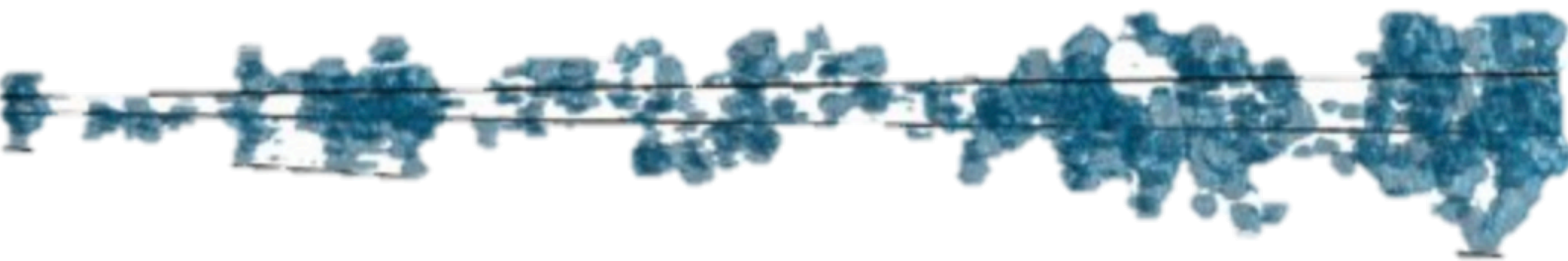
Collaborators: Simon Lilly, Christian Knobel, Yingjie Peng, Joanna Woo, Aseem Paranjape, Will Hartley, Isha Pahwa



Overview

- Quenching of star formation in different environments over $0<z<0.7$: focus on the role of centrals and satellites and galactic conformity
- Data: 1) DR7 SDSS with ~200,000 galaxies with $r<17$ at $z\approx 0$

  2) final zCOSMOS-bright ($i < 22.5$) data set; about 17,000 galaxies with reliable redshift in $0<z<1$
- Empirical approach – finding the relations in the data
- Given the associated uncertainties, our statements should be understood as approximations to physical reality, rather than physically exact formulae

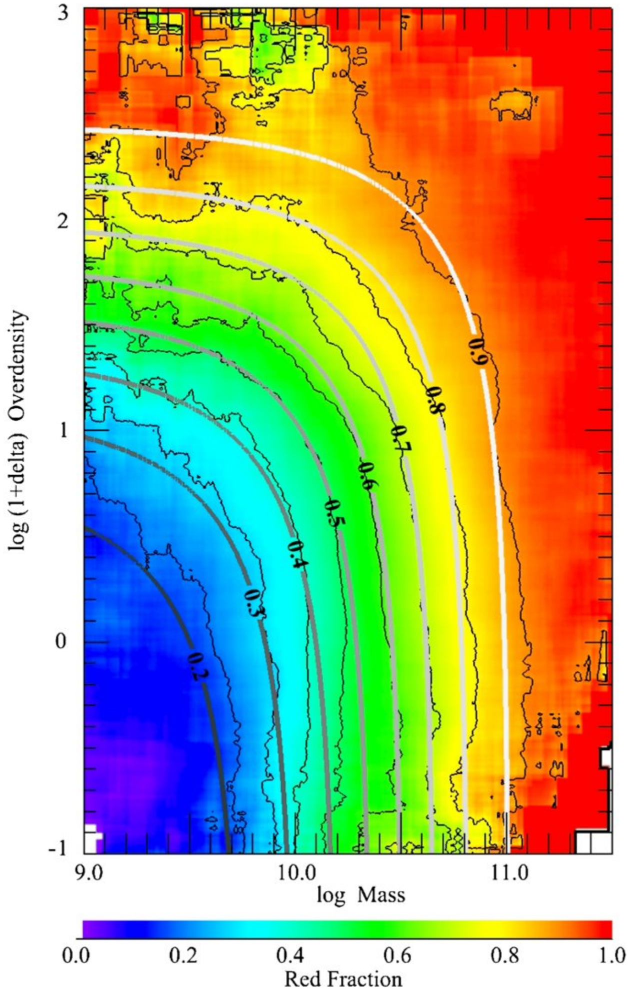


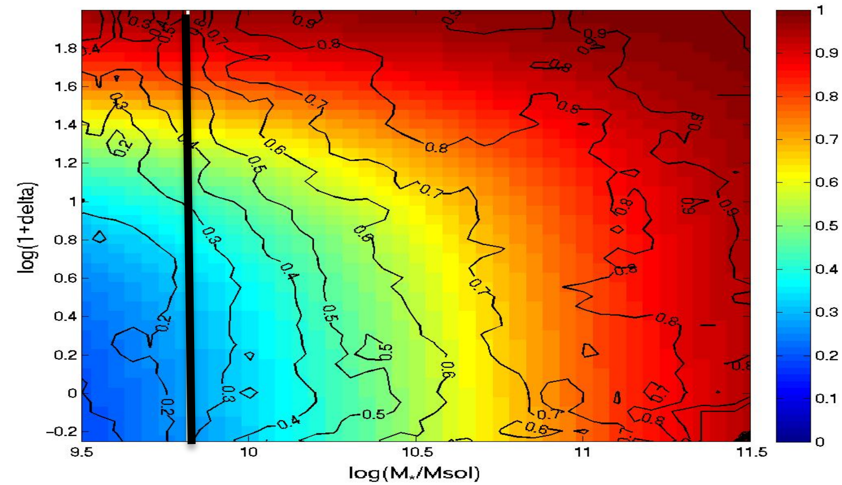
Differential effect of stellar mass and environment in 0<z<0.7

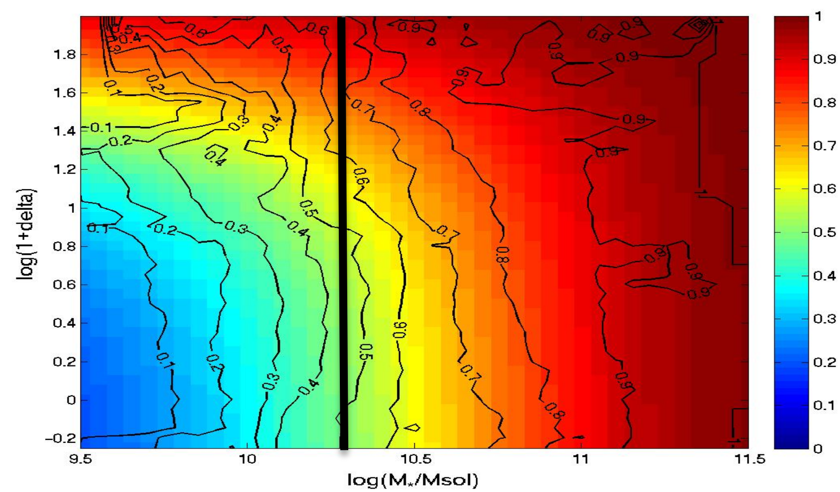
f_red(δ,M*) = 1 – exp[(-((δ/p1)^p2) – ((M*/p3)^p4)] = $\varepsilon_m(M_*) + \varepsilon_\rho(\delta) - \varepsilon_m(M_*)\varepsilon_\rho(\delta)$

(Baldry et al. 2006, see also Peng et al. 2010)

Peng, Lilly, Kovač et al. 2010



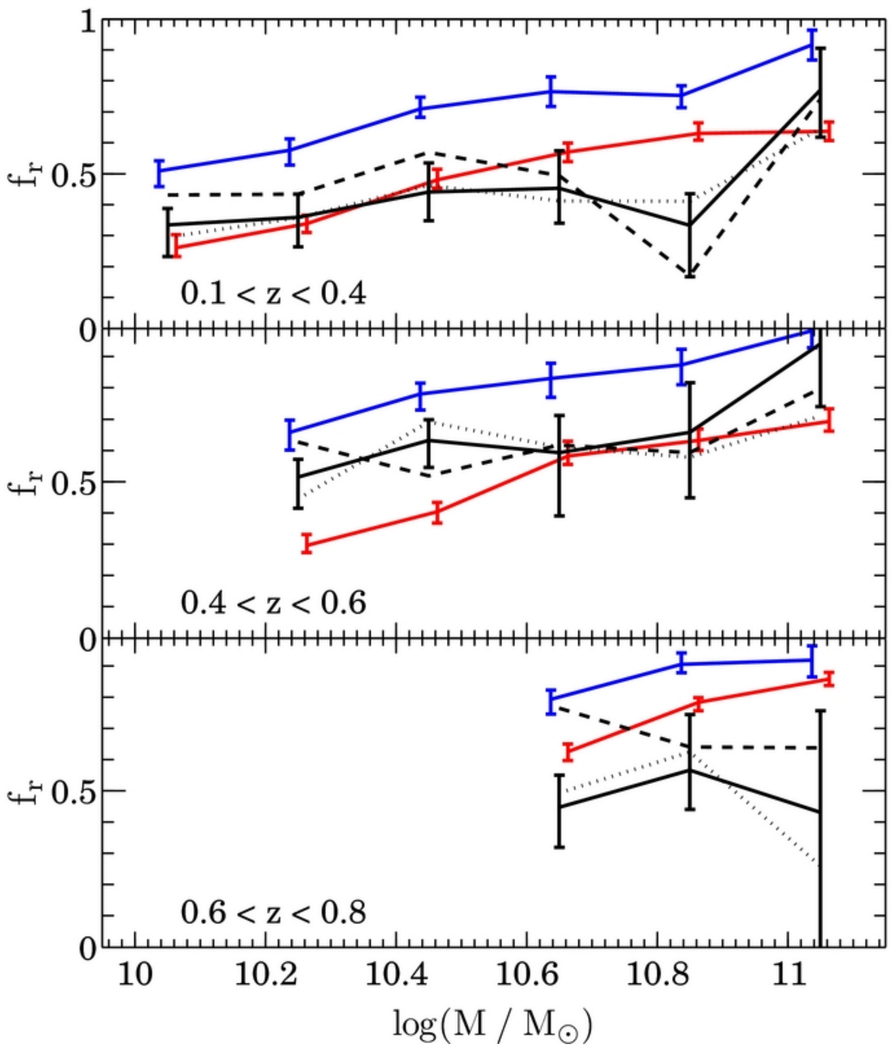




Kovač et al. 2014

Separability holds to a good degree at least up to z<0.7; possible cross-term within the errors

Central/satellite dichotomy: satellite quenching f(mass) at 0.1<z<0.8



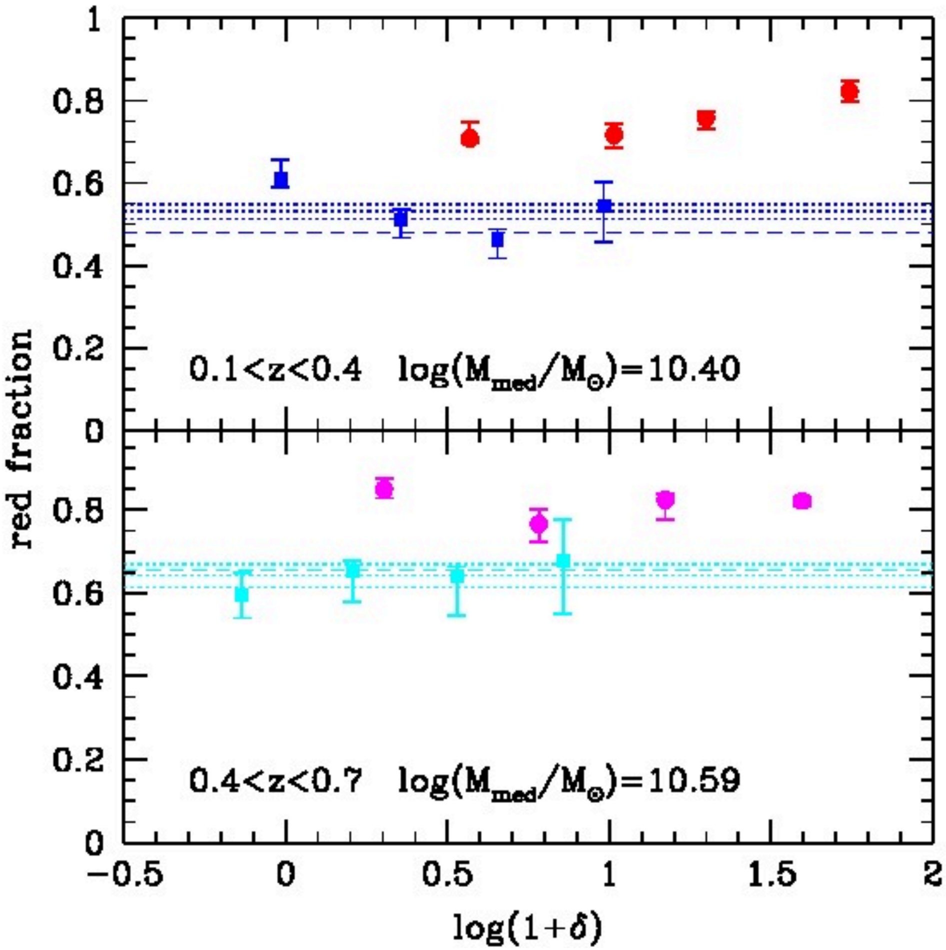
Knobel, Lilly, Kovač, et al. 2013

High-fidelity 20k zCOSMOS catalogue (Knobel et al. 2012)

$\varepsilon_{sat}(m) = [f_{r,sat}(m) - f_{r,cen}(m)]/[f_{b,cen}(m)]$

Satellite quenching: constant at all masses, mirroring z~0 SDSS results; no evolution with redshift

Fraction of red centrals and satellites as a function of local environment in 0.1<z<0.7



Analysis in the mass-matched samples to obtain reliable results

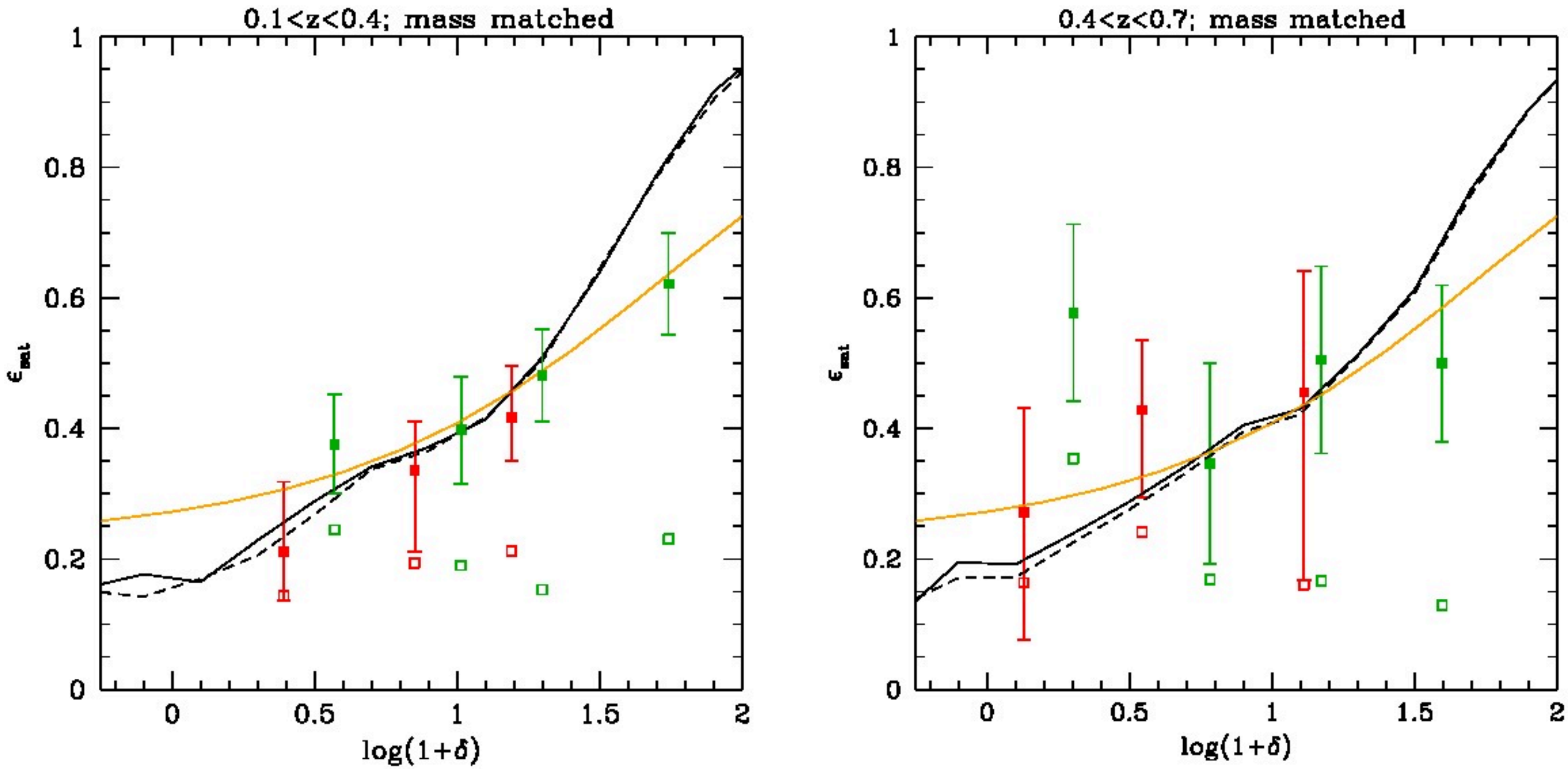
Centrals consistent with being independent of δ, i.e. fr,cen is consistent with ε_m (>95%) where f_red = $\varepsilon_m + \varepsilon_\rho - \varepsilon_m \varepsilon_\rho$

Red fraction of satellites require some additional form of quenching in addition to ε_m

Kovač et al. 2014

Central/satellite dichotomy: satellite quenching f(δ)

$$\varepsilon_{sat}(M_*,\delta) = [f_{r,sat}(M_*,\delta) - f_{r,cen}(M_*,\delta)]/[f_{b,cen}(M_*,\delta)]$$

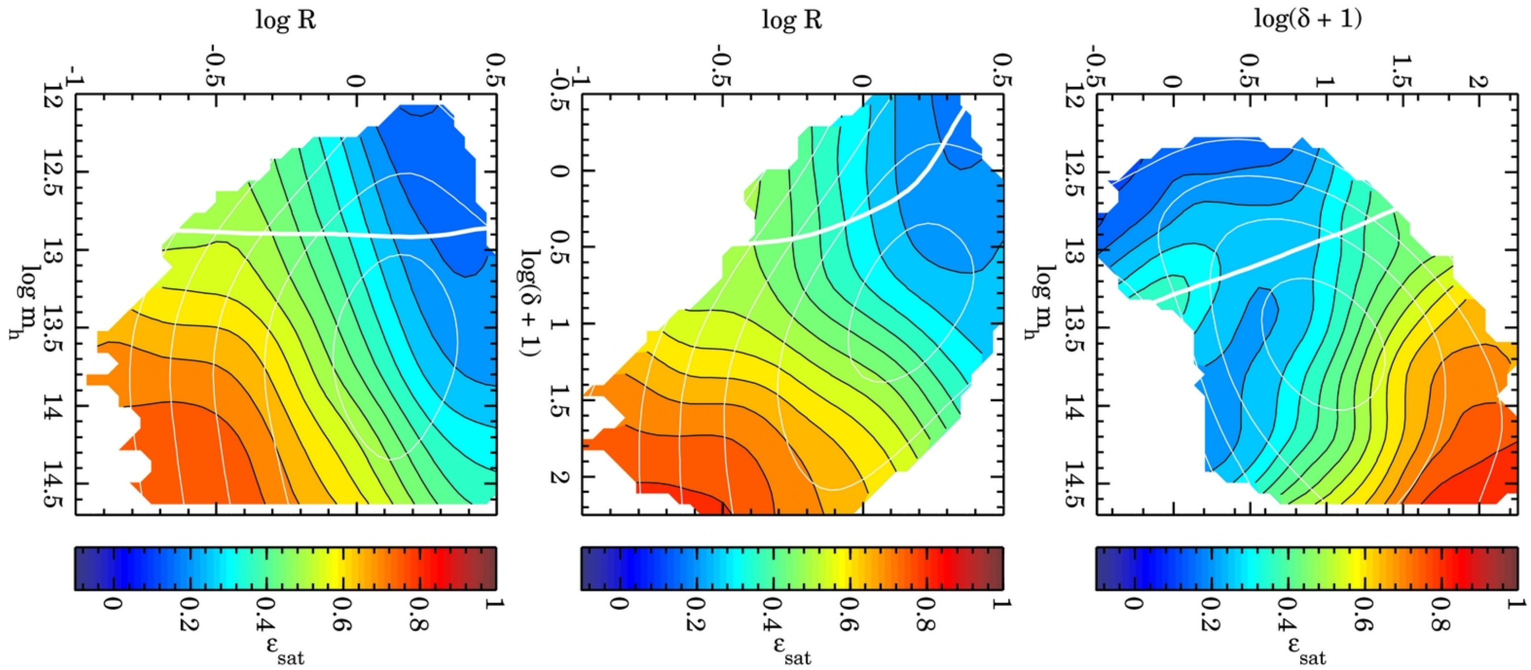


Satellite quenching: consistent with ε_ρ/fsat(, when centrals are not dependent on environment; mirroring the z~0 SDSS (Peng et al. 2012) results

Satellites are the major drivers of the overall observed environmental differences up to z~0.7

Kovač et al. 2014

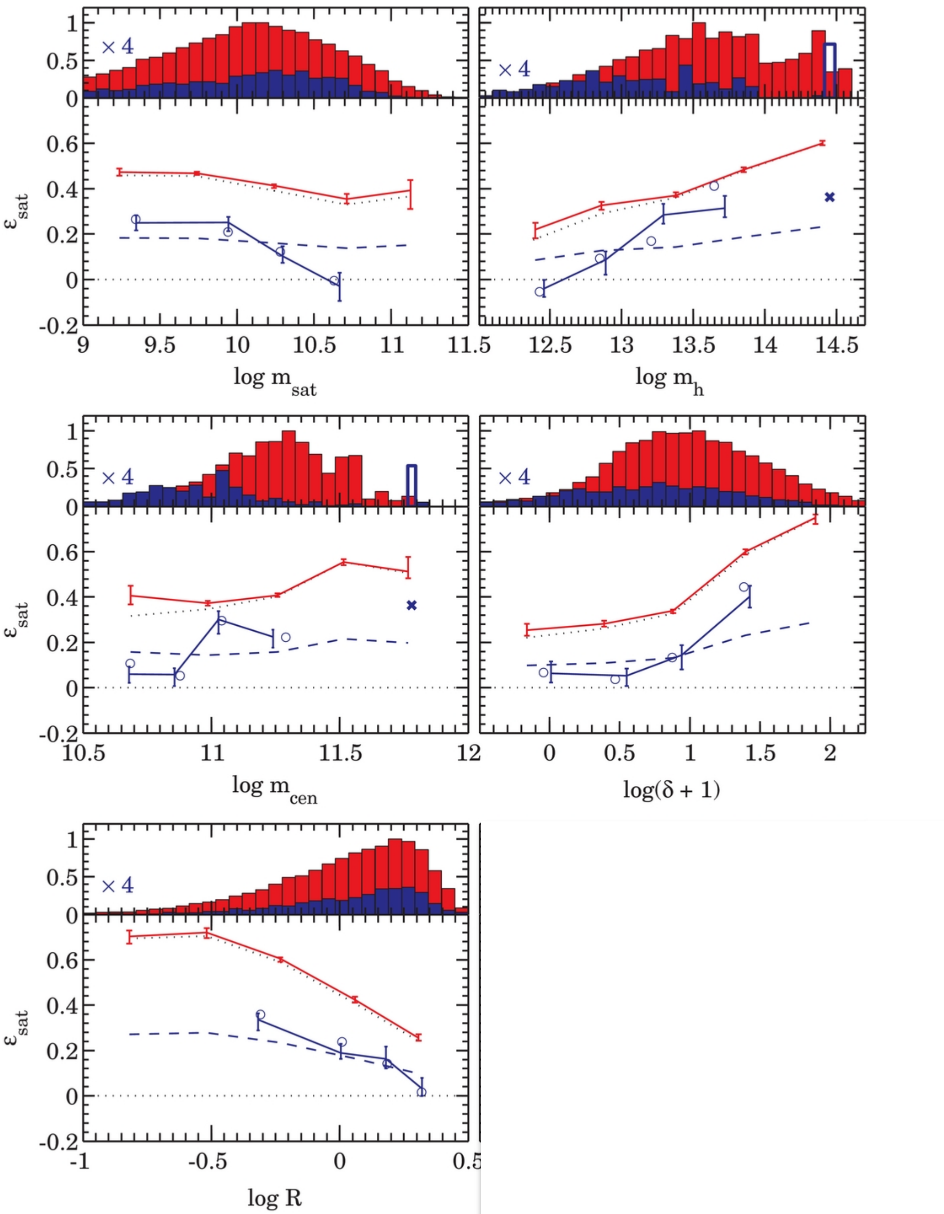
Satellite quenching efficiency (z=0) as function of environmental parameters



All of these environmental parameters are important in satellite quenching.

Knobel, Lilly, Woo, Kovač 2014

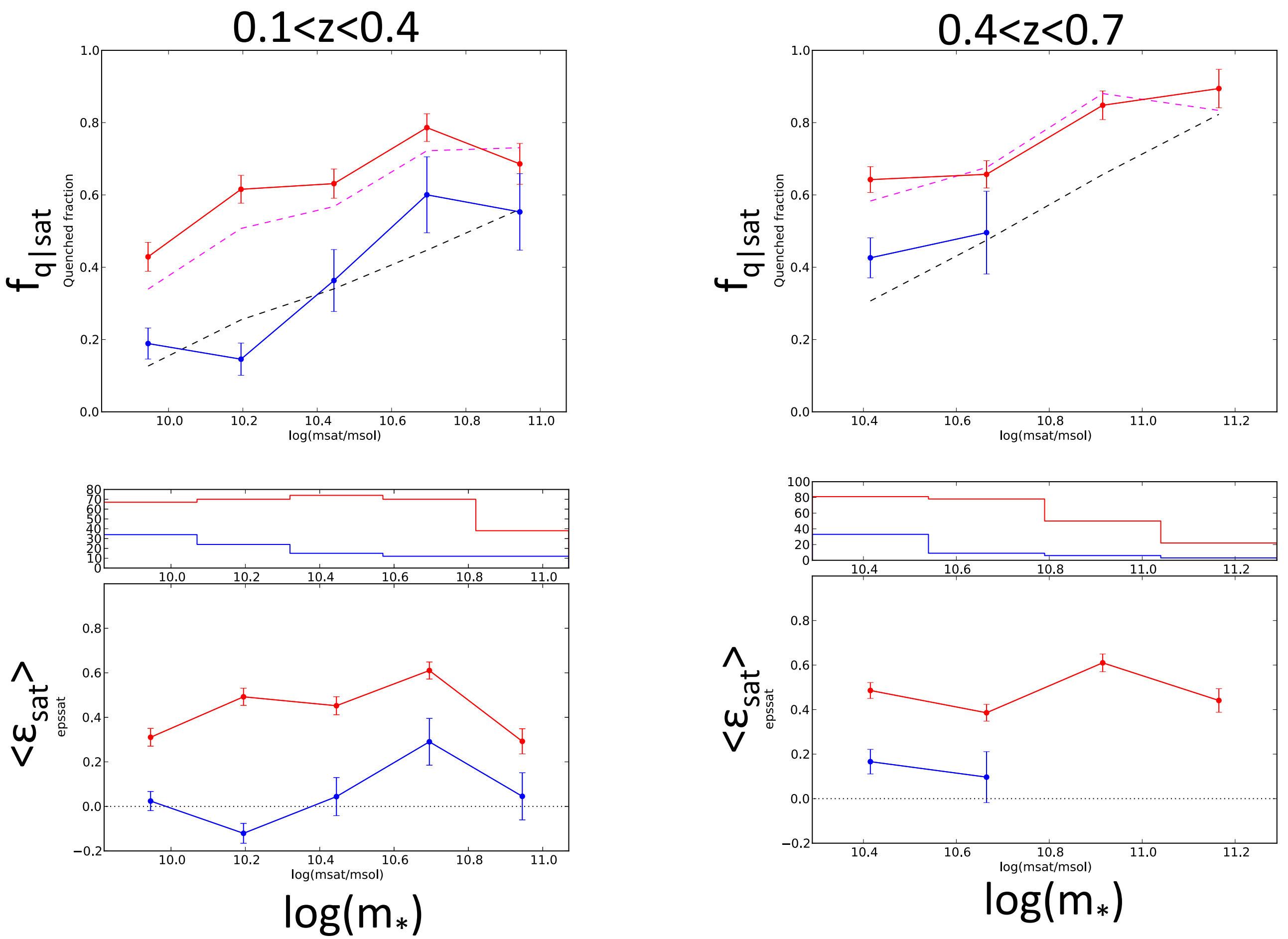
Satellites are the major drivers of the overall observed environmental effects … but … properties of satellites depend on properties of their central



- Satellites of quenched centrals ~2.5 times more likely to be quenched than satellites of star-forming centrals
- Signal vary in similar way with the environmental parameters for satellites of both quenched and star-forming centrals
- Existence of some “hidden variable” shared by the centrals and satellites in the same group

Knobel, Lilly, Woo, Kovač 2014

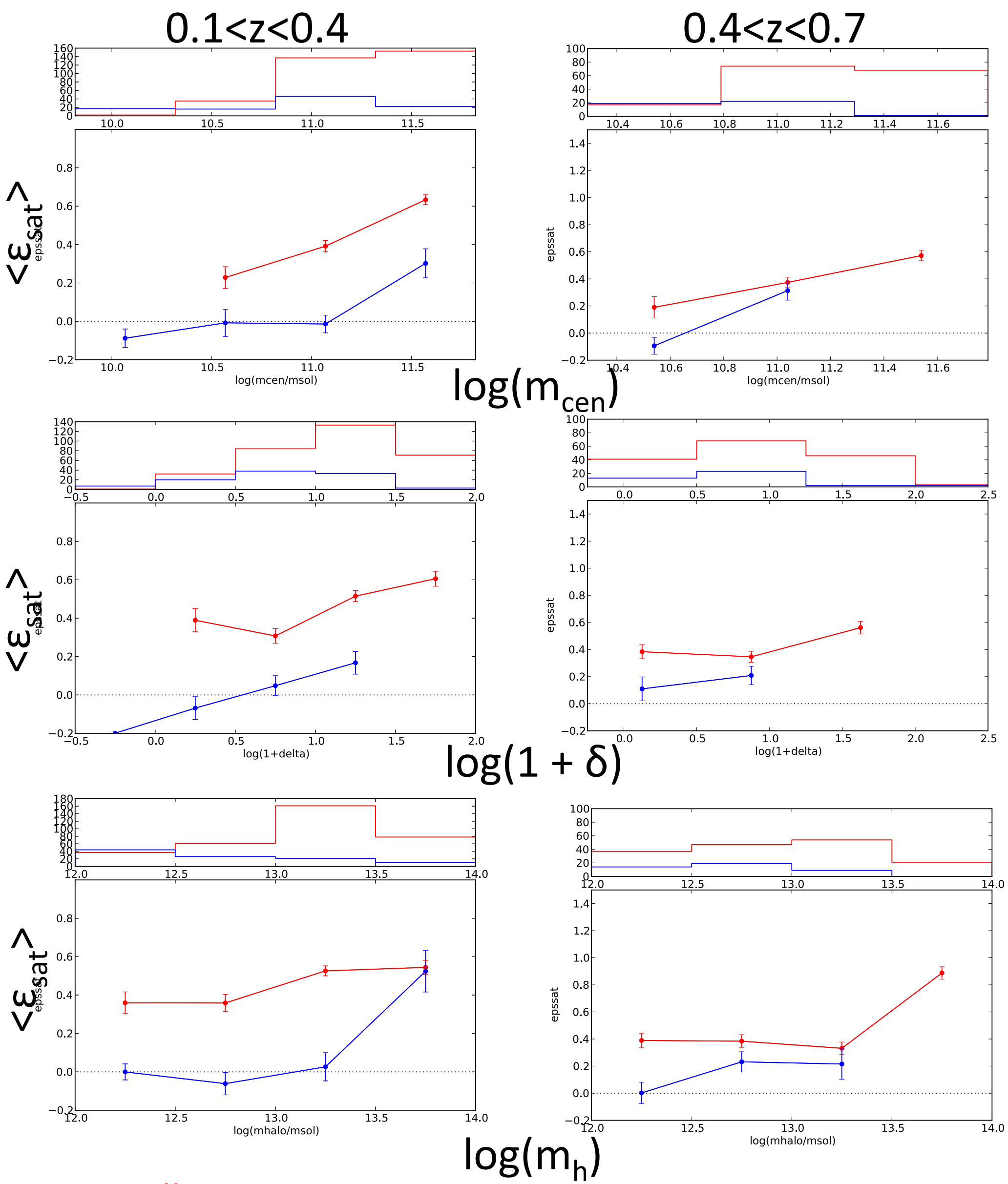
Conformity at z>0



Satellites of quenched centrals are more likely to be quenched than satellites of star-forming centrals up to z~0.7

Kovač K.+, in prep.

Conformity at z>0



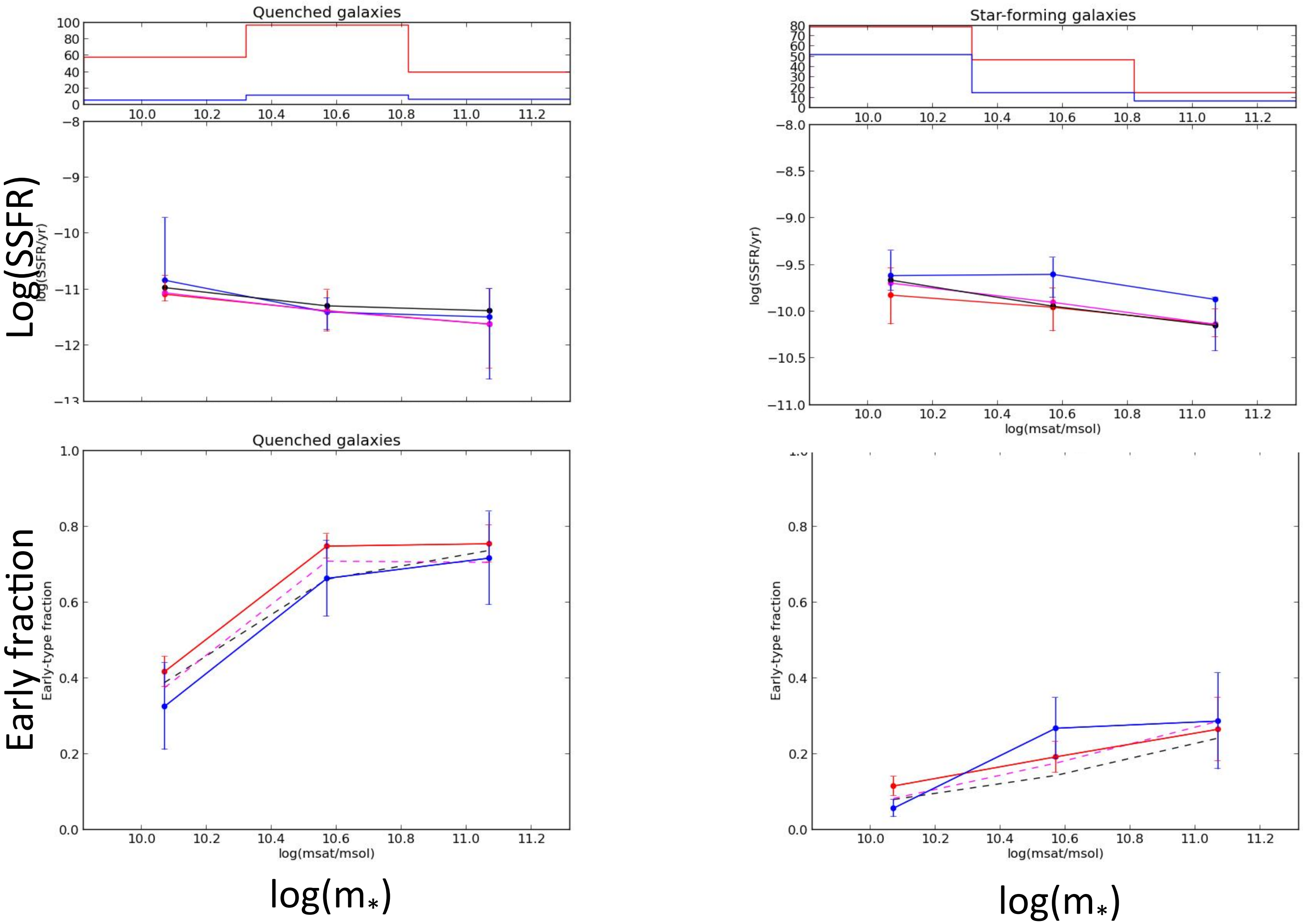
Existence of some "hidden variable" shared by the centrals and satellites in the same group:

1) physical but difficult to observe (hot gas, entropy etc),
2) physical but almost unobservable (i.e. assembly bias)
3) errors in the parameters

Caution: slopes are unconstrained

Kovač K.+, in prep.

Conformity at 0.1<z<0.4

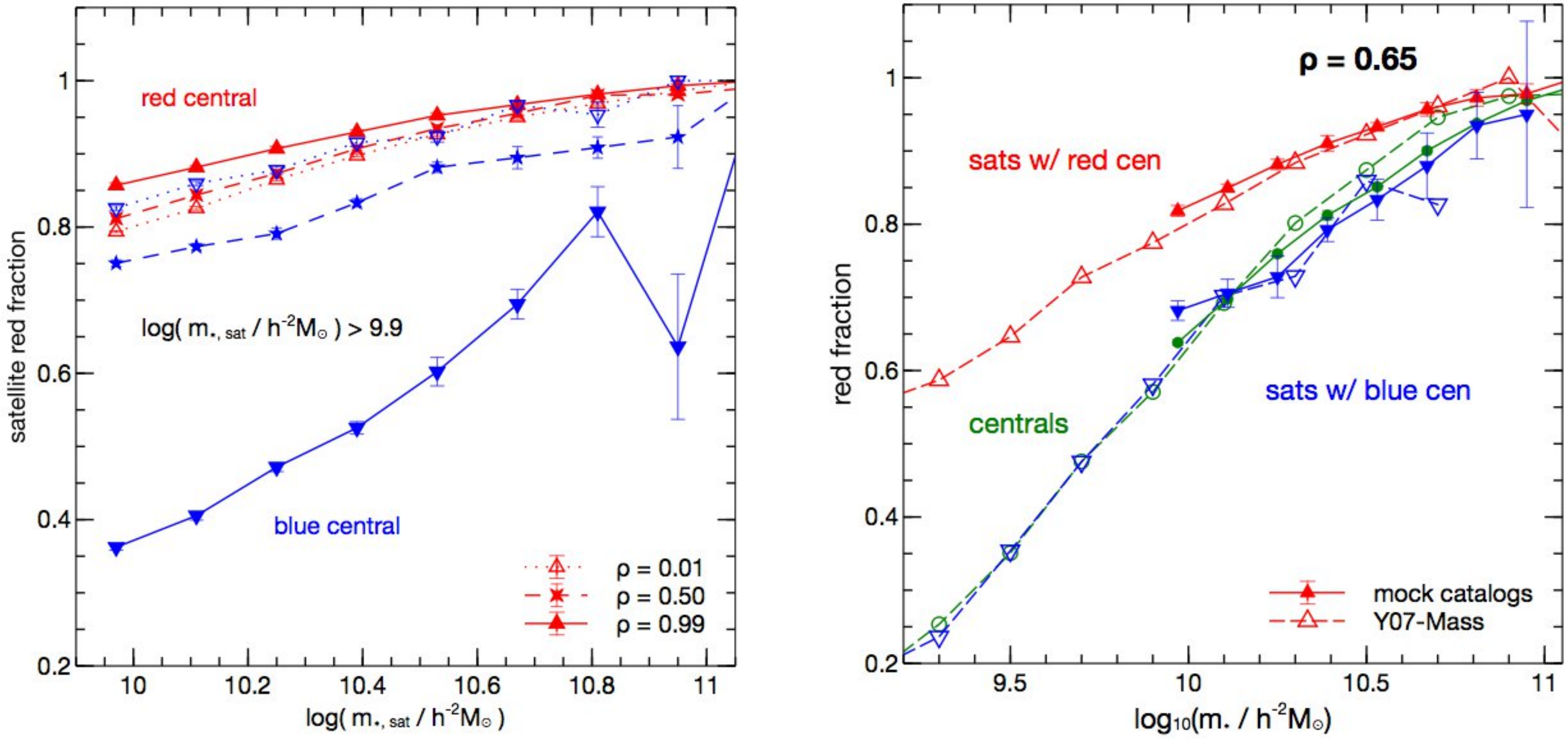


Kovač K.+, in prep.

No difference in the SSFR/morphological fractions for quenched and SF galaxies in the groups with different types of central

A Tunable Halo Model of Galactic Conformity

$$p(\text{red}|s) = (1 - \rho)\, p(\text{red}) + \rho\, \Theta(s - s_{red})$$



Correlation between the galaxy colour and the concentration of a parent halo can explain the conformity-like effects.

Mocks with ρ = 0.65 closely resemble the SDSS results.

Paranjape, Kovač, Hartley, Pahwa 2015

Conclusions

1) Red fraction in 0<z<0.7 appears to be separable in mass and environment, suggesting the existence of the two independent quenching mechanisms: mass quenching and environmental quenching

2) Red fraction of satellites requires additional quenching mechanism in addition to the mass quenching: at the same mass and overdensity, satellites are redder; satellite quenching efficiency can explain majority of the overall environmental effects at least up to z=0.7

3) Satellites of quenched centrals are few times more likely to be quenched than satellites of star-forming centrals, indicating the existence of some “hidden variable” shared by the centrals and satellites in the same group

4) Our modified HOD framework which correlates galaxy colours with the concentration of the parent halo, can explain conformity-like-effects; it makes the older, more concentrated haloes at fixed mass preferentially host quenched galaxies