Quenching the star formation in galaxies up to large clustercentric distances

Marina Trevisan
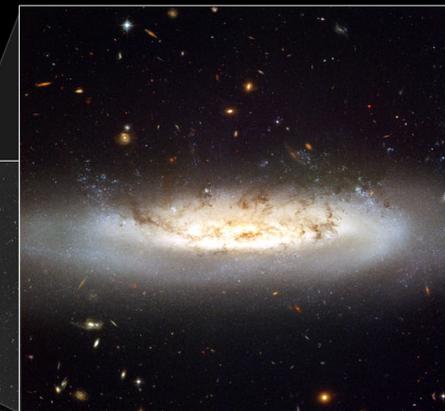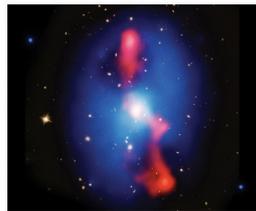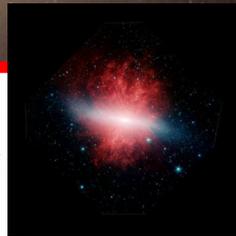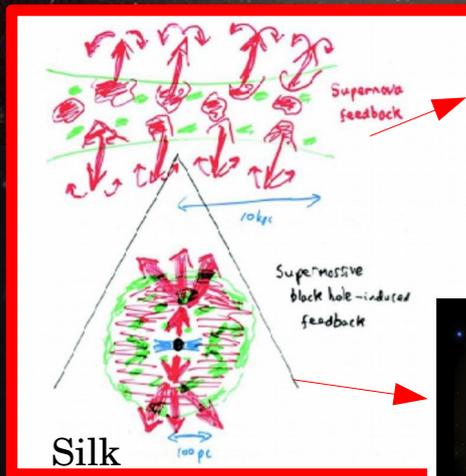
Gary Mamon, Diego Stalder

Quenching star formation

- " self quenching "
  (Peng et al. 2010)

- **Environmental quenching**
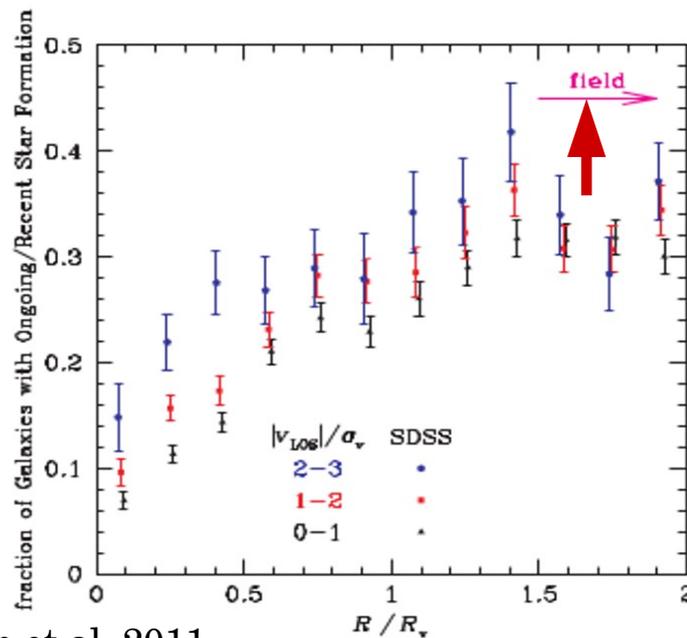 - Mergers
  - Tidal stripping
  - Harassment
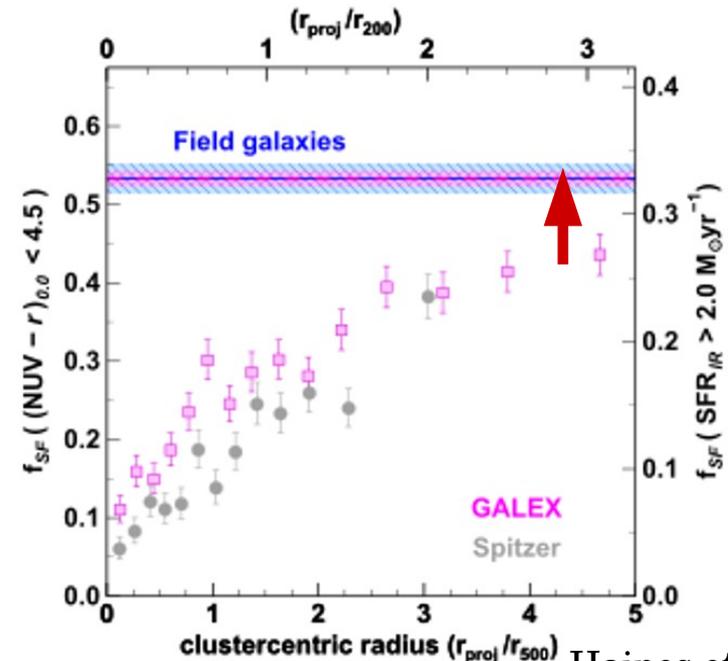 - Ram-pressure
  - Starvation
  - ....

Silk

NGC4522 galaxy
in relation to its host cluster,
the Virgo Cluster

Quenching star formation: where?

- *How far from the cluster center do we see quenched galaxies?*

Mahajan et al. 2011

Haines et al. 2015

- *Pre-processing in small groups/ filaments?*
(e.g. simulations by Bahé et al. 2013)

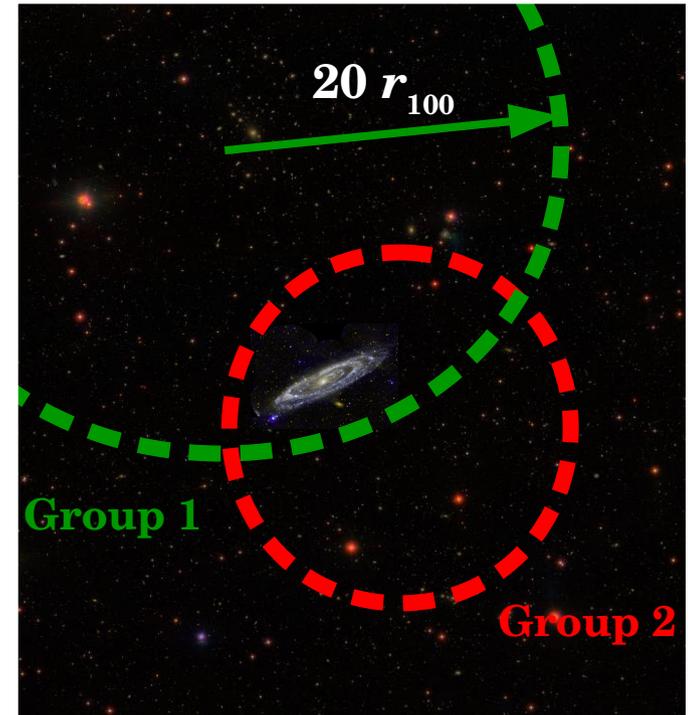- *Backsplash galaxies? (Mahajan et al. 2011)*

Galaxies in and around groups

- Groups and clusters selected from Yang et al. (2007) catalog (updated version)
  - $0.015 < z < 0.10$, $13.5 < \log M_{halo} < 15.0$
  - Galaxy absolute magnitudes < -20.4

- Assignment scheme to select galaxies up to 20 r_{100}:
  - R > r_{100}: z-space distance
  - R < r_{100}: density contrast

NFW profile

$$P_M(R, \Delta z) = \frac{H_0}{c} \frac{\Sigma(R)}{\bar{\rho}} p(\Delta z)$$

Gaussian

→ 1842 groups, ~128 000 galaxies

20 r_{100}

Group 1

Group 2

Assignment scheme

Fraction of star forming galaxies

- f_{SF} as a function of $M_{star,gal}$, $M_{halo,group}$, R / r_{vir} :

→ **Logistic regression**

= generalized linear model when the response variable follows the Bernoulli distribution: {0, 1}, *i.e., either the galaxy is star forming or it is not.*

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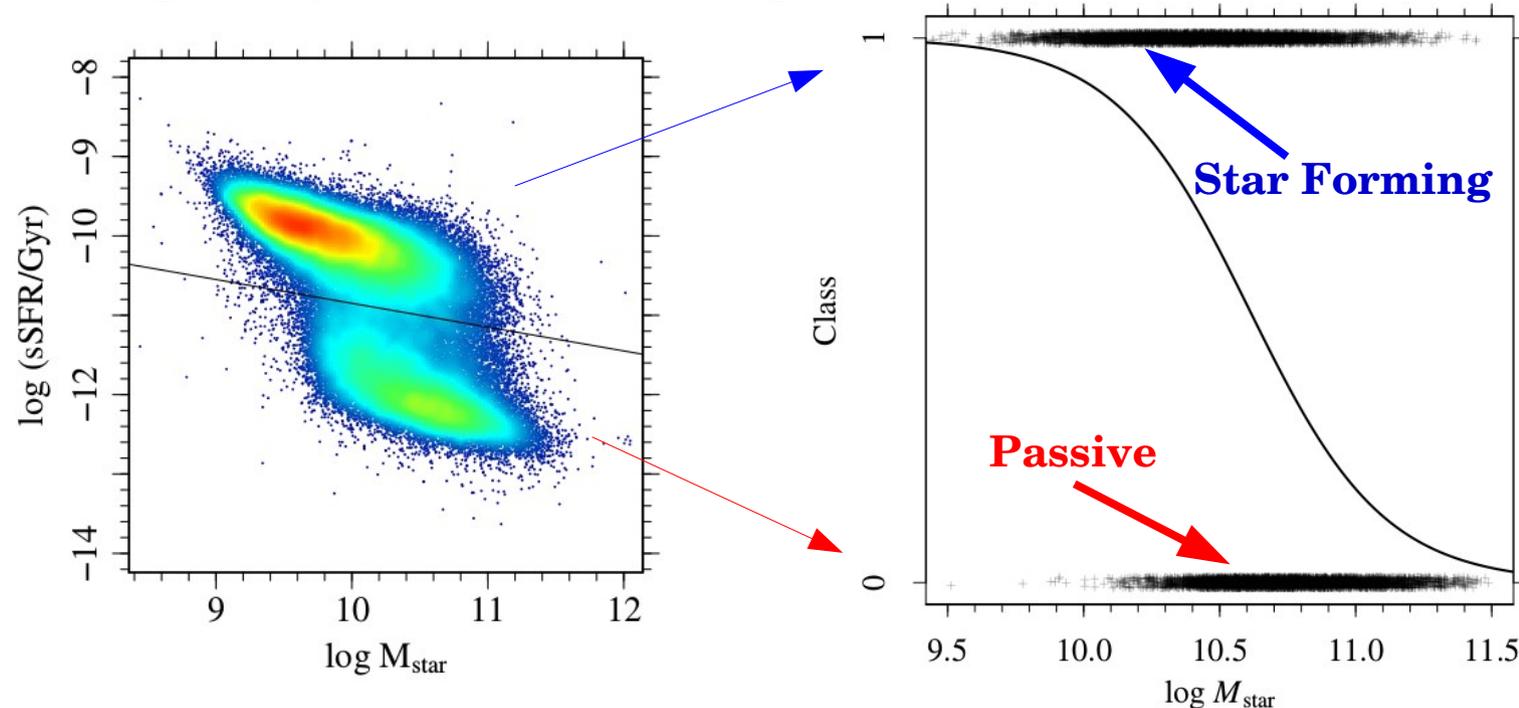 *i.e., either the galaxy is star forming or it is not.*

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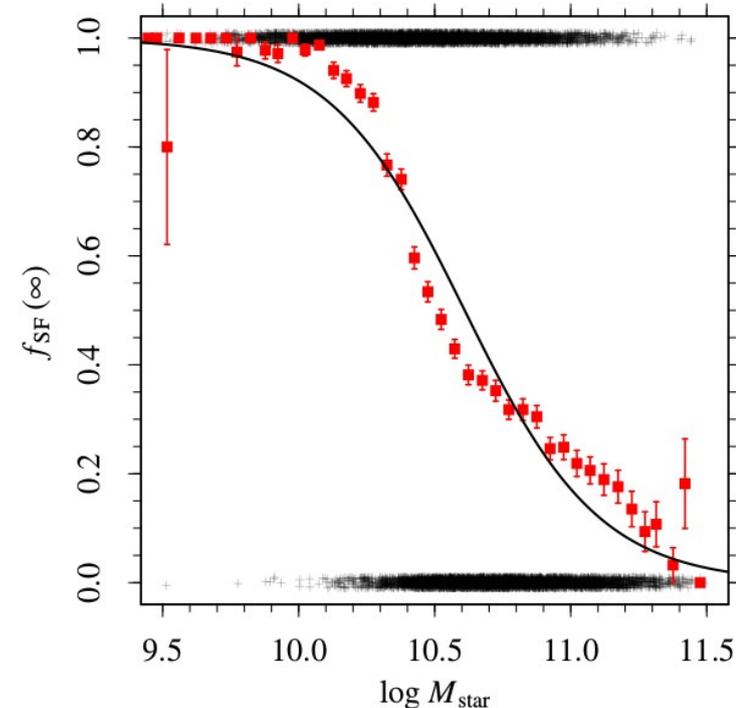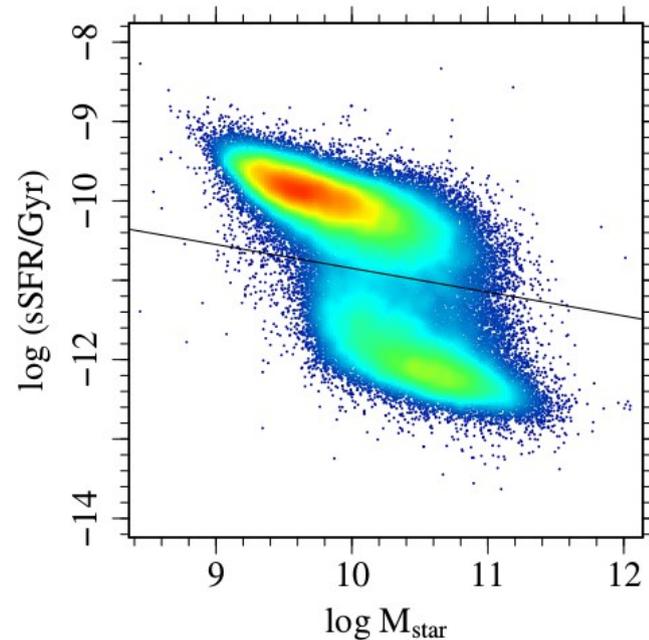 *i.e., either the galaxy is star forming or it is not.*

  - Linear predictor
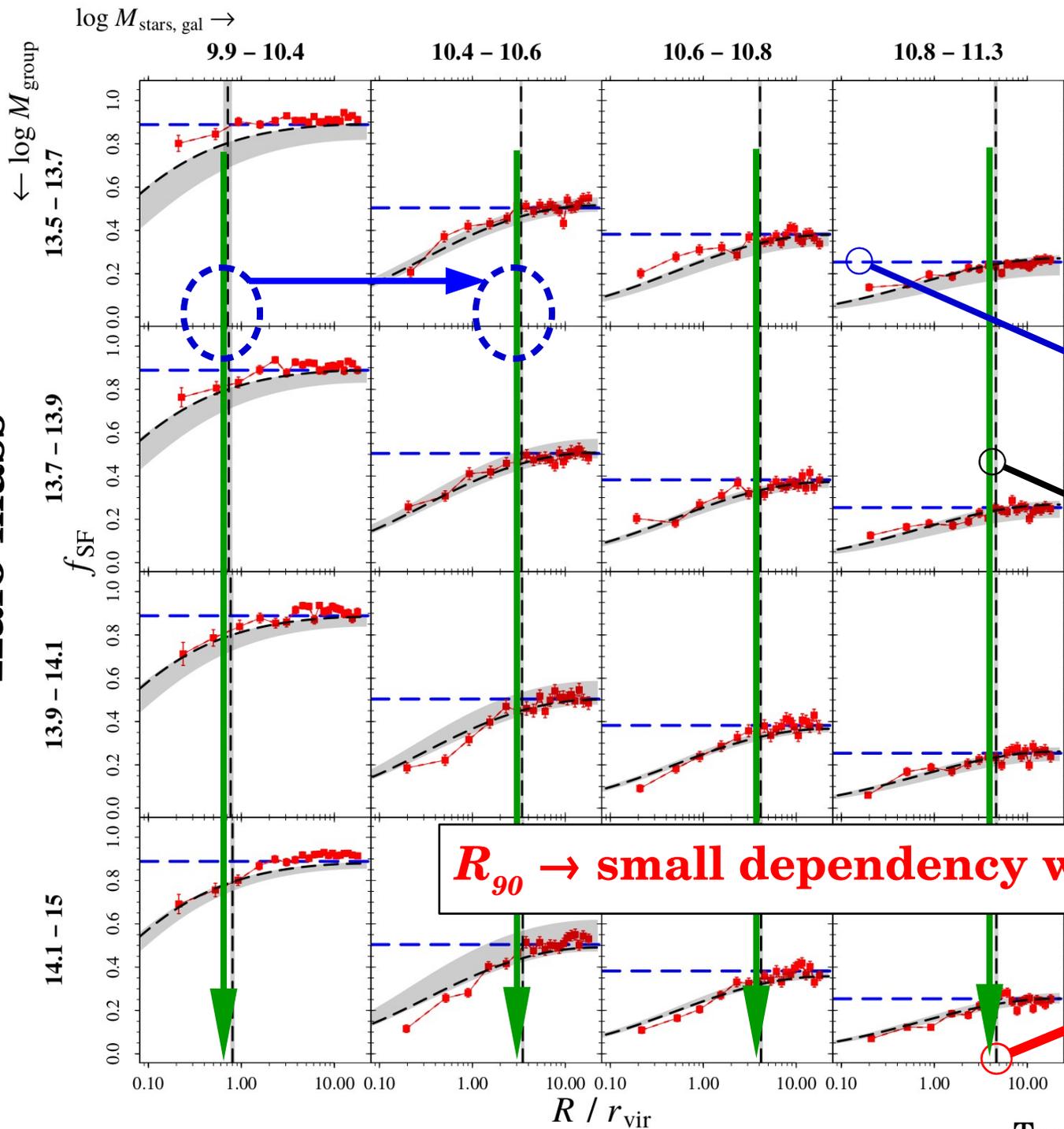 $$\mathbf{X}\,\beta = \beta_1 + \beta_2 \log M_h + \beta_3 \log M_s + \beta_4 \log(R/r_{vir}) + \dots$$

  - Link function
    $$\mathbf{X}\,\beta = \ln\left[\, f_{SF} / (1 - f_{SF}) \,\right] \quad \rightarrow \quad \boxed{f_{SF} = 1 / [1 + \exp(\mathbf{X}\,\beta)]}$$

Stellar mass ⟶

$\log M_{\text{stars, gal}} \rightarrow$

| 9.9 – 10.4 | 10.4 – 10.6 | 10.6 – 10.8 | 10.8 – 11.3 |

$\leftarrow \log M_{\text{group}}$

Halo mass

13.5 – 13.7
13.7 – 13.9
13.9 – 14.1
14.1 – 15

f_{SF}

R / r_{vir}

Fraction of star forming galaxies

Field galaxies

"quenching radius"
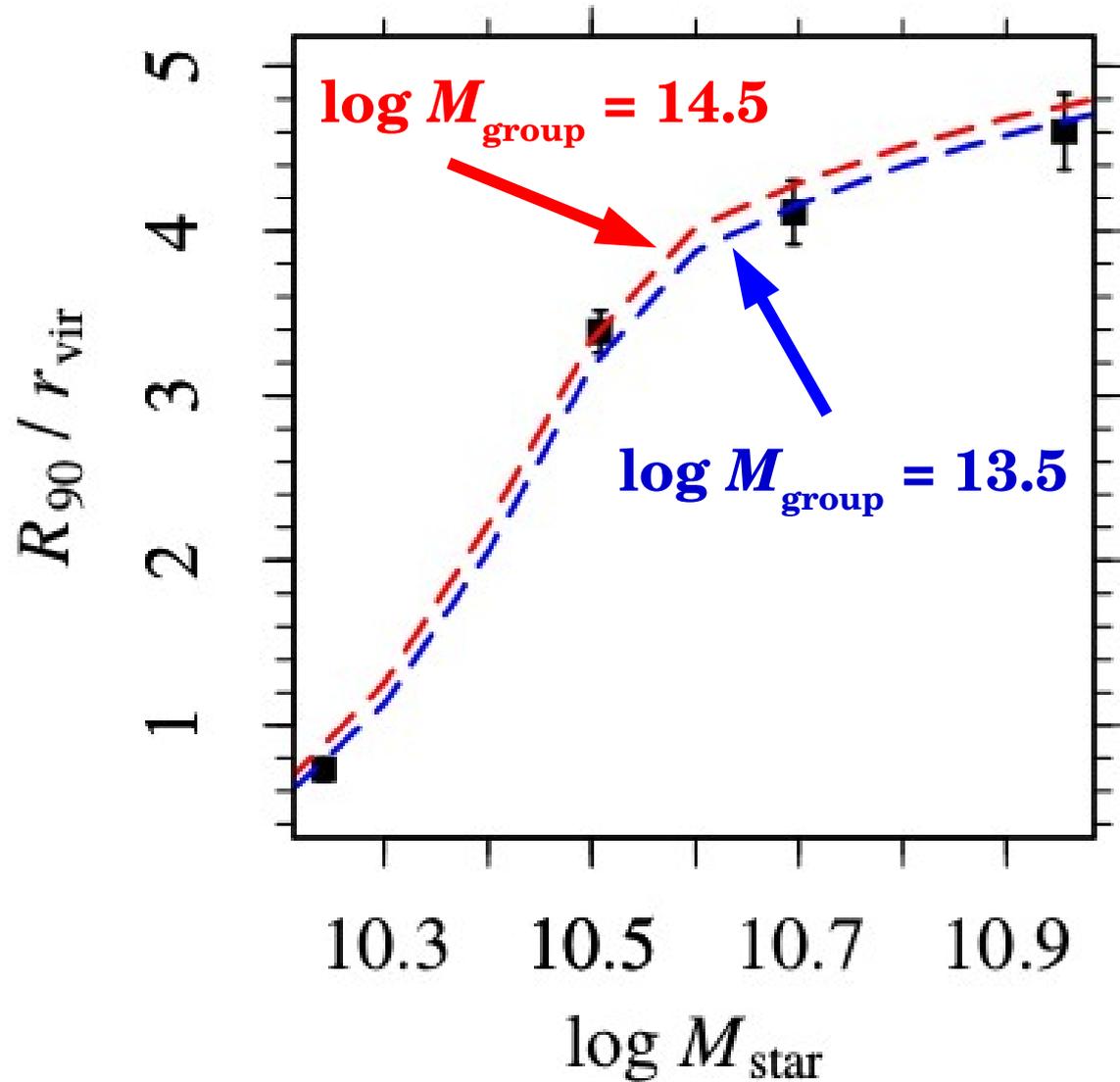$R_{90} = R(f_{\text{SF}} = 0.9\, f_{\infty})$

$R_{90} \rightarrow$ **small dependency with** $\log M_{\text{group}}$

$\sim 5\, r_{\text{vir}}$ **!!**

Trevisan, Mamon & Stalder, in prep.

"Quenching radius"

$$R_{90} = R(f_{SF} = 0.9\, f_\infty)$$

log M_{group} = 14.5

log M_{group} = 13.5

$R_{90}\,/\,r_{vir}$

log M_{star}

Pre-processing in small groups?

- The effect of halos with 12.5 < log M_{halo} < 13.5:

  → *Change in the mass threshold for assignment*
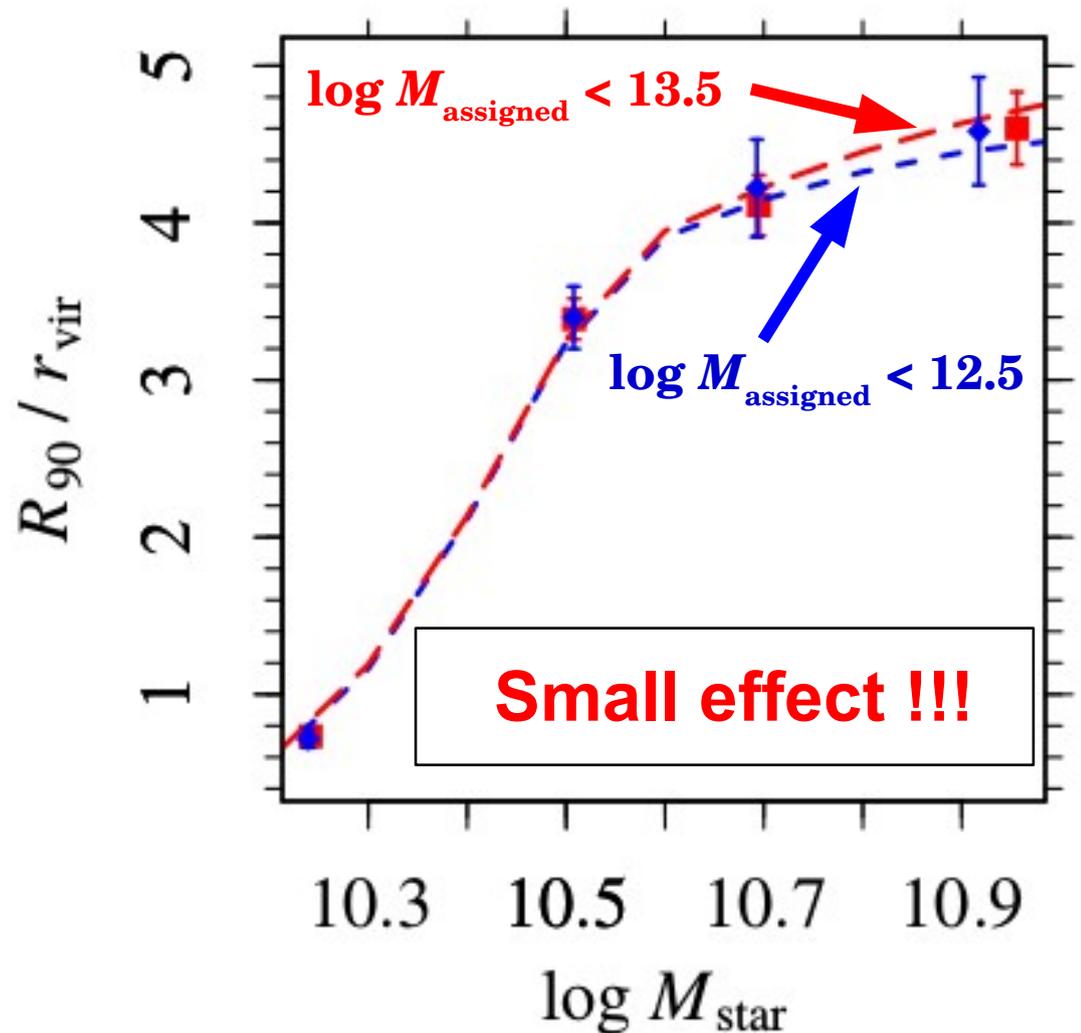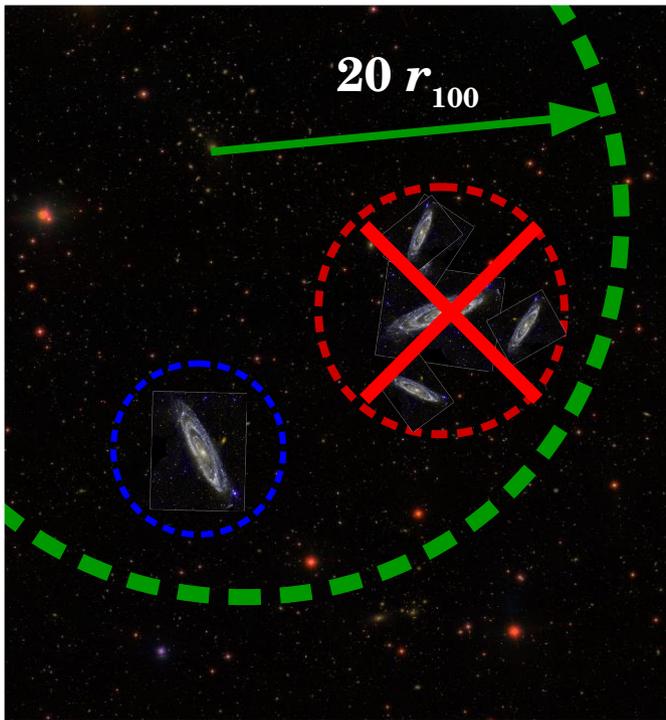
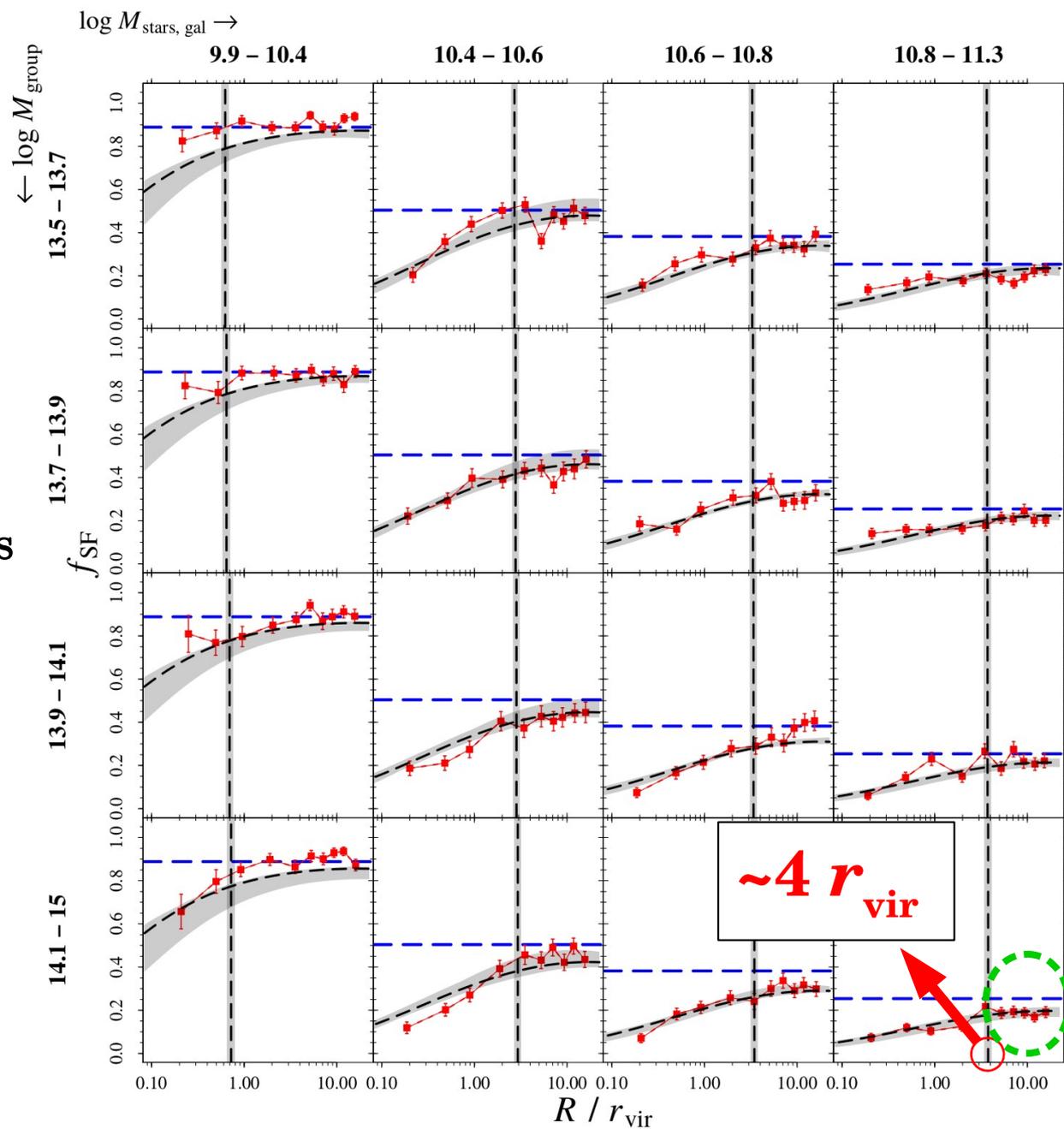# Pre-processing along filaments?

Galaxies *close* to filaments:

D < 1.4 Mpc from filaments
with L > 10^{11} L_{Sun}/h^2

Catalogue of filaments from Tempel et al. 2014

~4 r_{vir}

$\log M_{stars,\ gal} \rightarrow$

$\leftarrow \log M_{group}$

9.9 – 10.4   10.4 – 10.6   10.6 – 10.8   10.8 – 11.3

13.5 – 13.7

13.7 – 13.9

13.9 – 14.1

14.1 – 15
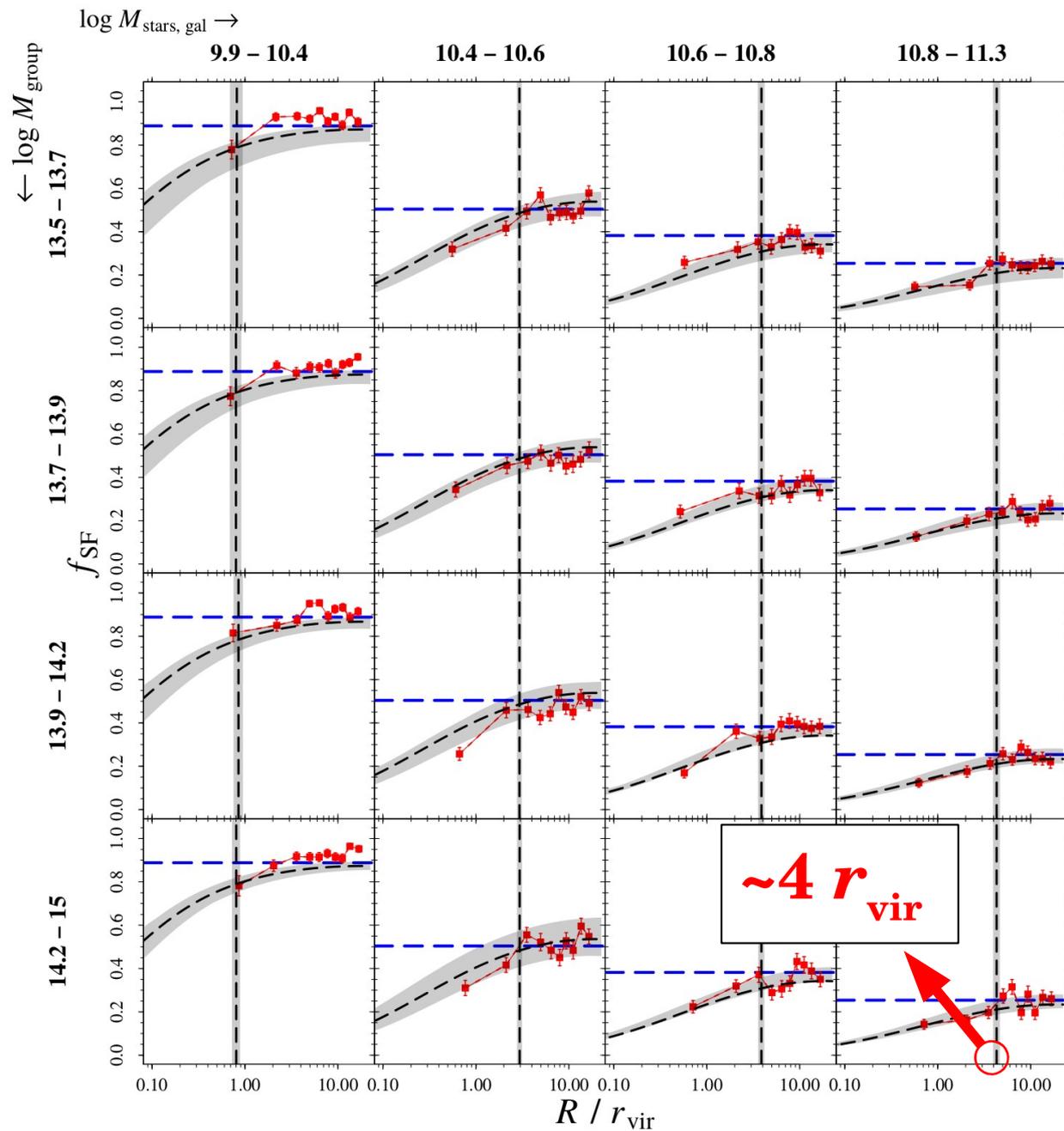
f_{SF}

$R\ /\ r_{vir}$

Pre-processing along filaments?

Galaxies *far* from filaments:

d > 20 Mpc from filaments
with L > 5 10^{10} L$_{sun}$/h^2

OR

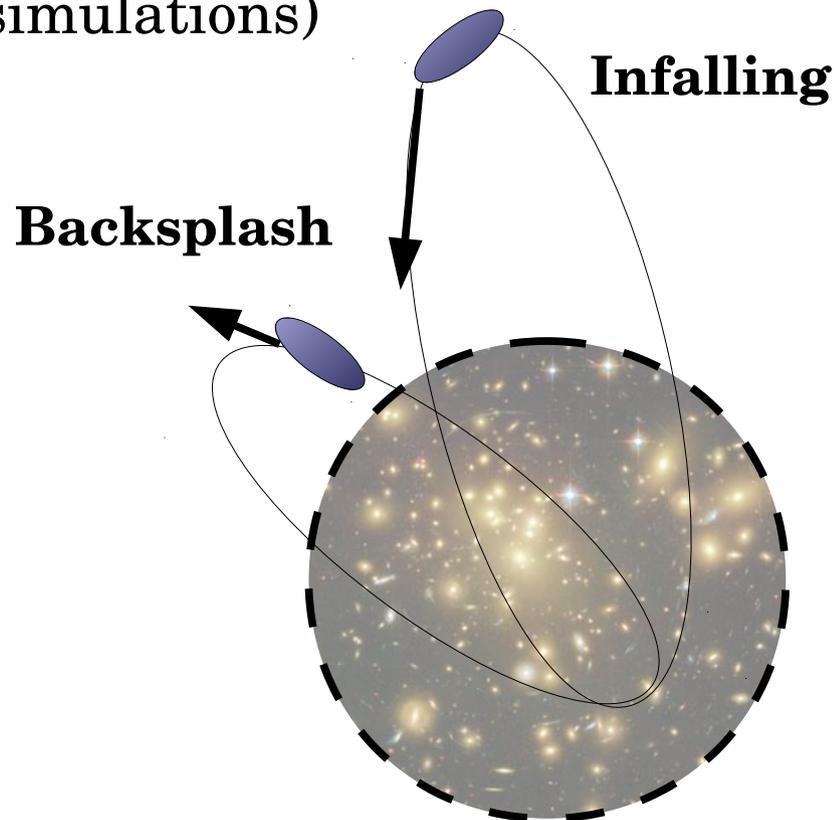close to "faint" filaments
(L < 5 10^{10} L$_{Sun}$/h^2)

~4 r$_{vir}$

Backsplash galaxies?

- Galaxies can bounce out of cluster up to:
  - Mamon+04: **1 - 2.5 r_{vir}**, depending on method (toy model or simulations)
  - Gill+05: **2.5 r_{vir}** (following subhalo orbits)
  - Sales+07ab, Ludlow+09: **> 3.5 r_{vir}** (based on hydro cosmo simulations)

Infalling

Backsplash

Summary

- Radius where f_{sf} reaches 90% of f_{sf} in the field, R_{90}:

    → **strong dependency with galaxy log M_{star}**

    → **independent of group log M_{halo}**

- $f_{sf} < 0.9\, f_{sf,\,field}$ up to ~ 5 r_{vir}

    → **f_{sf} converges to $f_{sf,\,field}$ at even larger distances (~8 r_{vir})**

- Pre-processing in small groups?
    - It seems that it is not the case, at least in groups with
        $12.5 < \log M_{halo} < 13.5$
    - *Pre-processing in even smaller groups (log $M_{halo} < 12.5$)?*

- Pre-processing in filaments?
    - Maybe part of the effect, but not all (trends for galaxies far from filaments have similar R_{90})

- *Backsplash galaxies? Galaxy conformity on large scales (or "two-halo conformity", Hearin & Watson 2013, Hearin+14)? Assembly bias?*