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Satellite quenching was not important for z~1 clusters: most quenching occurred during infall.

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ABSTRACT
We quantify the relative importance of environmental quenching versus pre-processing in $z \sim 1$ clusters by analysing the infalling galaxy population in the outskirts of 15 galaxy clusters at $0.8 < z < 1.4$ drawn from the GOGREEN and GCLASS surveys. We find significant differences between the infalling galaxies and a control sample; in particular, an excess of massive quiescent galaxies in the infalling region. These massive infalling galaxies likely

Выборка далеких скоплений

2.1 The GOGREEN and GCLASS cluster surveys

We use data from the first public data release (DR1) of the Gemini Observations of Galaxies in Rich Early ENvironments (GOGREEN) and Gemini CLuster Astrophysics Spectroscopic Survey (GCLASS) surveys[1] (Muzzin et al. 2012; Balogh et al. 2017, 2021), which contains photometric and spectroscopic data for 26 clusters and groups with redshifts between 0.85 and 1.50, and masses of at least $M_{200} \sim 10^{13} M_{\odot}$. Three of these clusters were discovered using the Sunyaev-Zeldovich effect (Sunyaev & Zeldovich 1970) with the South Pole Telescope (SPT) (Foley et al. 2011; Stalder et al. 2013; Sifón et al. 2016), whilst 14 were discovered using the red-sequence galaxy selection method as part of the Spitzer Adaptation of the Red-Sequence Cluster Survey (SpARCS; Wilson et al. 2009b,a; Muzzin et al. 2009), and nine groups in the COSMOS field were selected based on diffuse X-ray emission implying a well established intragroup medium (Finoguenov et al. 2010, 2007; George et al. 2011).

In this work, we only use the most massive clusters in the sample with intrinsic velocity dispersions $\sigma > 500$km/s, which have dynamical masses of $> 10^{14}$M$_{\odot}$. We make this selection because

Name	RA (J2000)	Dec (J2000)	Redshift	σ (km/s)	R_{200} (Mpc)
SpARCS0034	8.675	-43.132	0.867	700	0.58
SpARCS0036	9.188	-44.181	0.869	750	1.06
SpARCS1613	243.311	56.825	0.871	1350	1.54
SpARCS1047	161.889	57.687	0.956	660	0.91
SpARCS0215	33.850	-3.726	1.004	640	0.88
SpARCS1051	162.797	58.301	1.035	689	0.84
SPT0546	86.640	-53.761	1.067	977	1.15
SPT2106	316.519	-58.741	1.131	1055	1.21
SpARCS1616	244.172	55.753	1.156	782	0.92
SpARCS1634	248.654	40.364	1.177	715	0.85
SpARCS1638	249.715	40.645	1.196	564	0.73
SPT0205	31.451	-58.480	1.323	678	0.85
SpARCS0219	34.931	-5.525	1.325	810	0.9*
SpARCS0035	8.957	-43.207	1.335	840	0.90
SpARCS0335	53.765	-29.482	1.368	542	0.69

Table 1. The 15 clusters from the GOGREEN and GCLASS samples that are used in this work. Column 4 provides the redshift of the cluster. Columns 5 and 6 provide the intrinsic velocity dispersion and radius in proper Mpc from Biviano et al. (2021), except for the cluster marked with * where we estimated the radius from σ provided by GOGREEN DR1.

Разбили галактики на членов скоплений, падающих туда и в поле

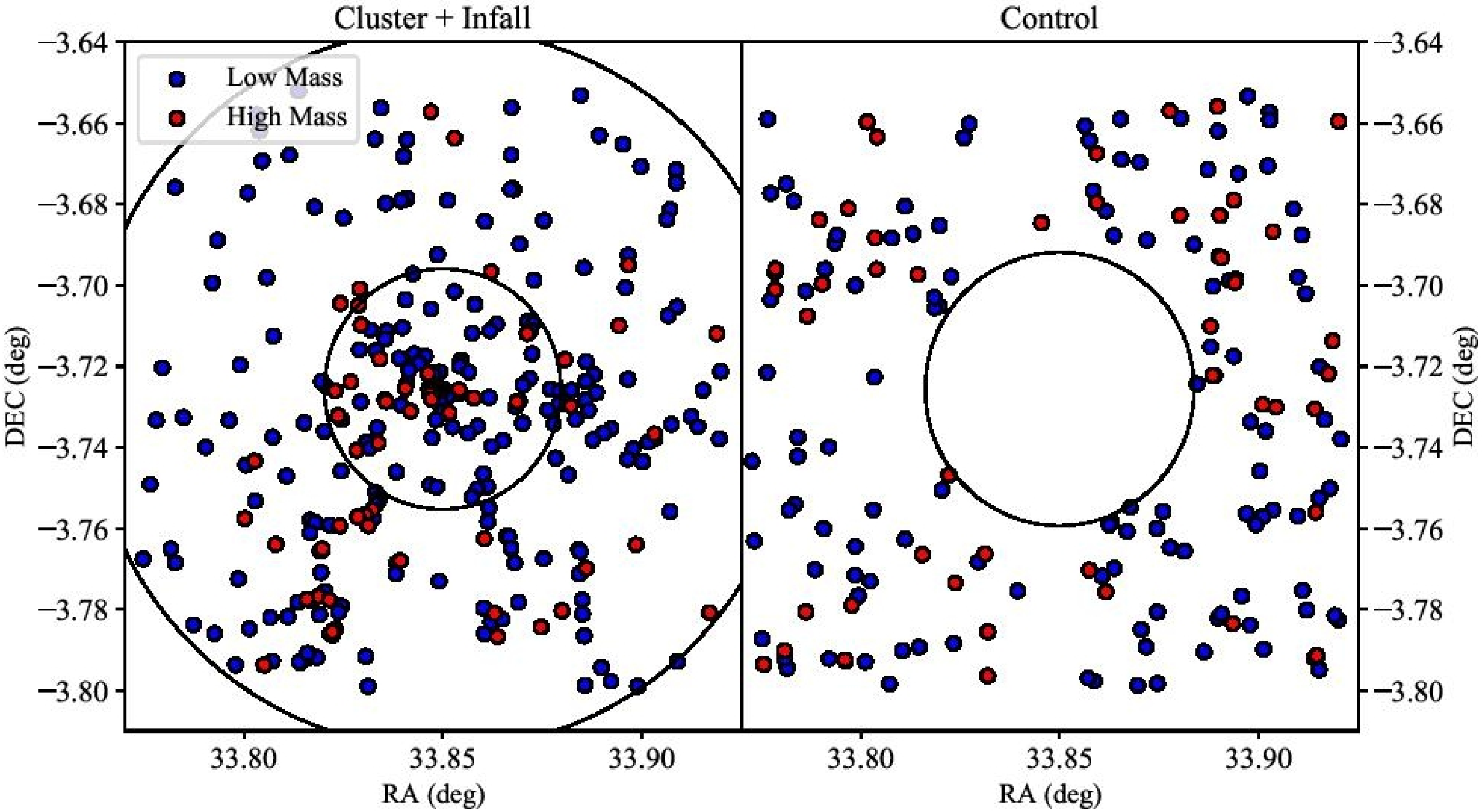
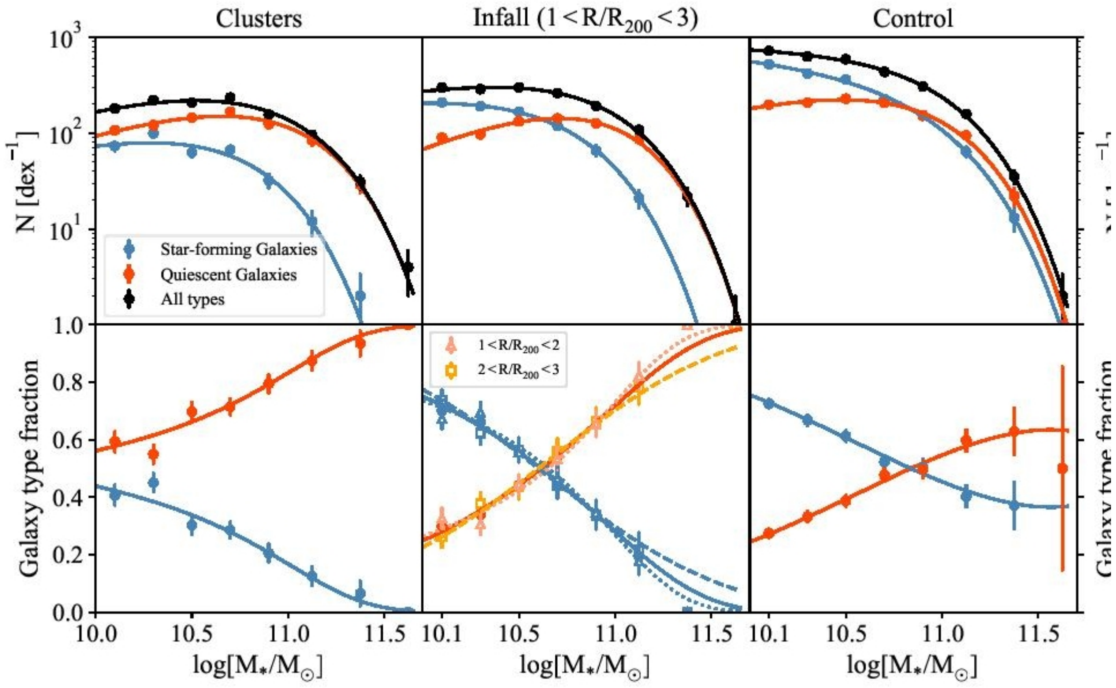


Figure 1. Positions of galaxies in our cluster and infall samples (left panel) and control sample (right panel) within the SpARCS215 field. Blue points mark the positions of lower mass galaxies with $9.75 < \log(M_*/M_\odot) < 10.8$. Red points locate galaxies with $\log(M_*/M_\odot) > 10.8$. In the left panel the inner circle marks the R_{200} boundary. Galaxies within the circle (and $|\Delta z|/(1+z) < 0.08$) are classified as cluster members. The outer circle marks $3R_{200}$: infall galaxies lie between the inner and outer circle (and $|\Delta z|/(1+z) < 0.08$). The circle in the right panel marks 1 Mpc from the BCG. The control galaxies are distributed outside this circle with redshifts in the range $0.15 < |\Delta z|/(1+z) < 0.3$.

Статистика набирается

an example cluster, SpARCS0215, in Figure 1. In total, the cluster galaxy sample contains 1113 members, the infall galaxy sample contains 1442 members, whilst the control sample contains 2632 members to a mass limit of 10^{10} $M_{\odot}$.

Распределение галактик по массам: в поле больше «карликов»



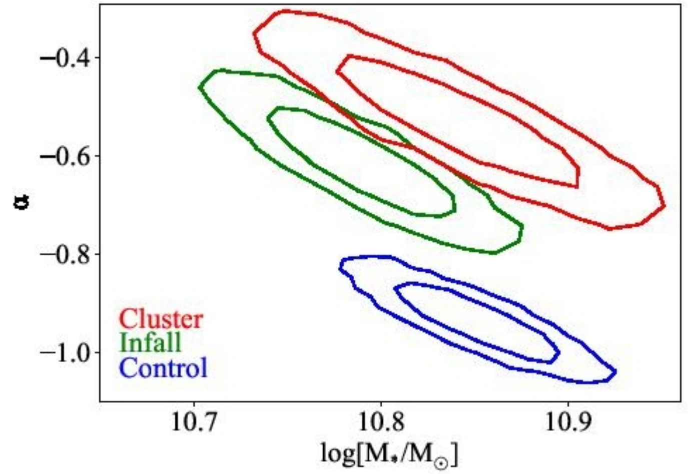


Figure 3. The most likely characteristic mass, M_*, and low mass slope, α for the cluster (red), infall (green) and control (bue) samples. The contours mark 1 and 2σ for each population. The low mass slope of the control sample differs by more than 2σ meaning both the cluster and infall samples have top-heavy stellar mass functions.

Механизм quenching'а в скоплениях не зависит от массы!

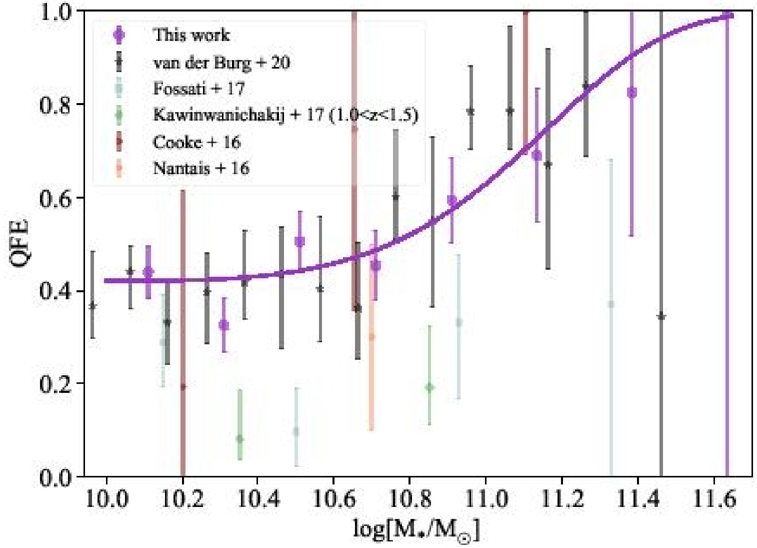


Figure 4. The excess of quiescent galaxies in the cluster compared to the control (purple points and solid line). We find a favourable comparison to literature results of a similar redshift and cluster mass: van der Burg et al. (2020) (black), Nantais et al. (2016) (pink) Fossati et al. (2017) (blue), Kawinwanichakij et al. (2017) (green), and Cooke et al. (2016) (dark pink) data. QFE = 0 occurs when there are no excess quenched galaxies in the cluster within the mass bin, whereas QFE = 1 occurs when all the star-forming galaxies in a mass bin are quenched in the cluster.

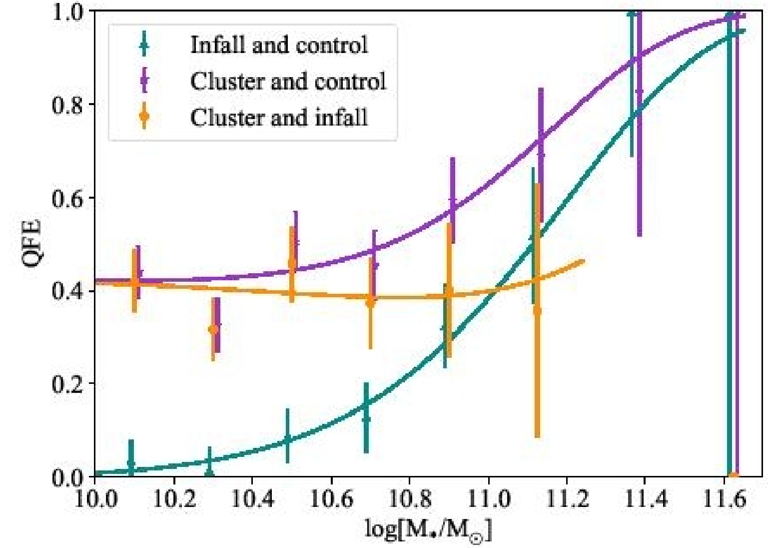


Figure 5. The orange data points show that the excess quiescent fraction in the cluster sample compared to the infall sample (QFE_{cl-inf}) is approximately constant across all stellar masses up to $10^{11.2}$ $M_\odot$. Above $10^{11.2}$ $M_\odot$ there are no excess of quiescent galaxies in the cluster compared to the infall therefore above this limit $QFE_{cl-inf} = 0$. The aquamarine data points show the excess quiescent fraction in the infall sample compared to the control sample ($QFE_{inf-con}$), which has a strong mass-dependency. The solid lines are obtained from the Schechter fits to the stellar mass functions rather than fits to the data points.

У «падающих» массивных галактик больше спутников…

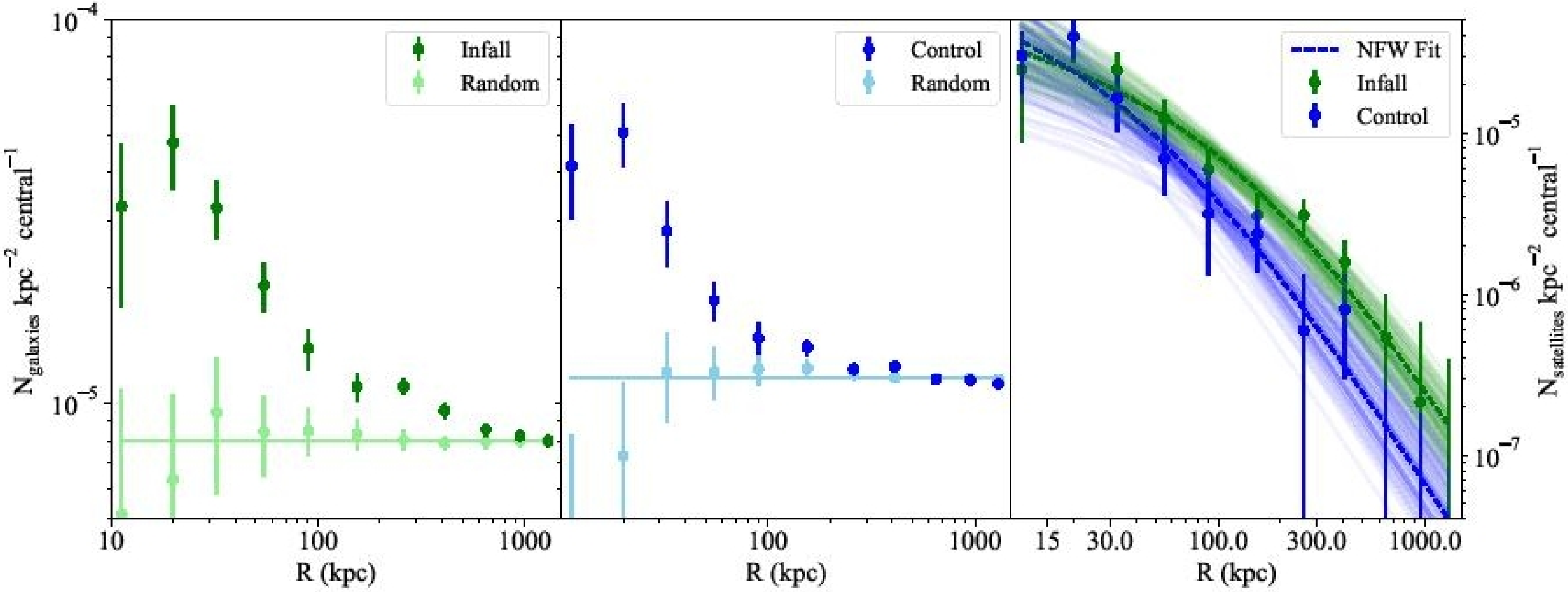


Figure 6. Number of (satellite) galaxies per area per central galaxy as a function of projected distance. The left panel displays, in dark green, the density of infall galaxies located in projected radial bins around $> 10^{10.8}$ $M_{\odot}$ galaxies in the infall sample. In light green we display the galaxy density in radial bins around random position in the infall region to measure the expected level of contamination; the solid line is the median. The middle panel displays a similar analysis as the left panel, but using control galaxies of $> 10^{10.8}$ $M_{\odot}$. Subtracting the contamination (straight solid lines) from the dark blue and green points results in the excess satellite galaxy density, which is shown in the right panel. The dashed lines are the most likely NFW fit to the satellite galaxy distributions, whilst the transparent lines are 2% of the samples from the MCMC chain selected by random.

…И темные гало (NFW) более протяженные

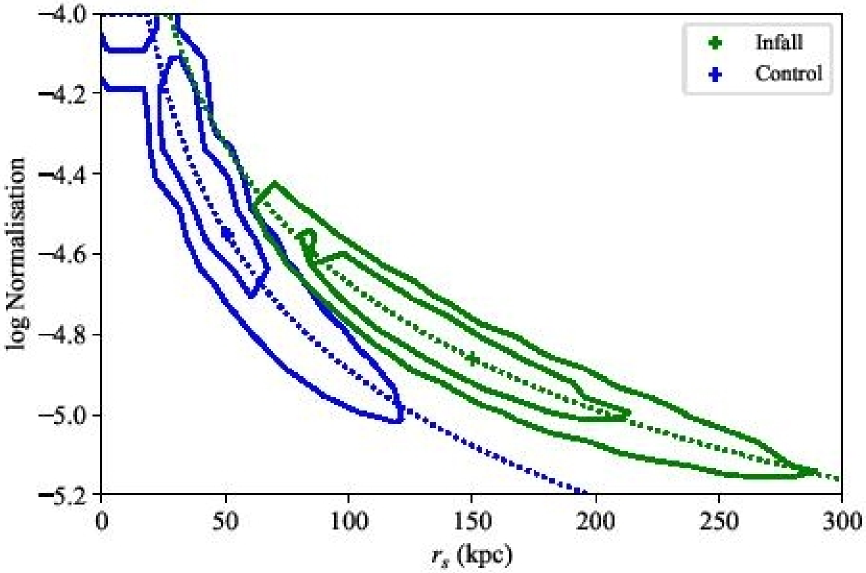
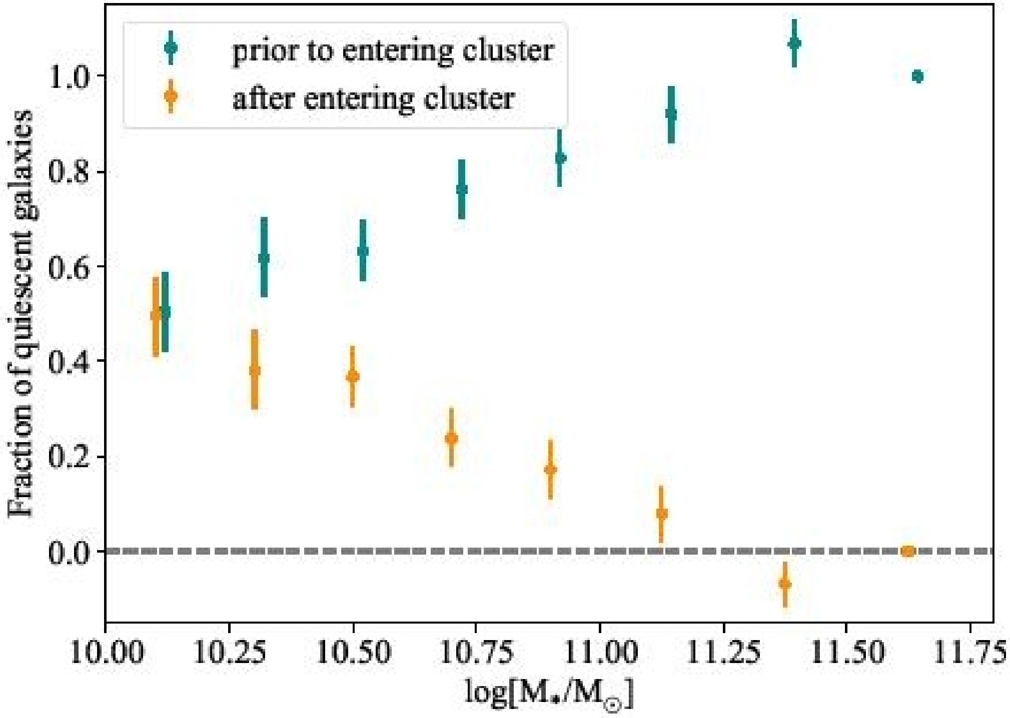


Figure 7. Distribution for the scale radius, r_S, and normalisation, n obtained from an MCMC analysis of the projected satellite galaxy distributions for the control sample (blue) and for the infall (green). Contours mark 50% and 80% significance and the dotted lines mark the region of constant integrated galaxy density consistent with the number of observed satellites in each sample.

Вывод: роль скоплений в остановке звездообразования мала, роль окружения - велика



Biasing: в плотных областях эволюция быстрее!