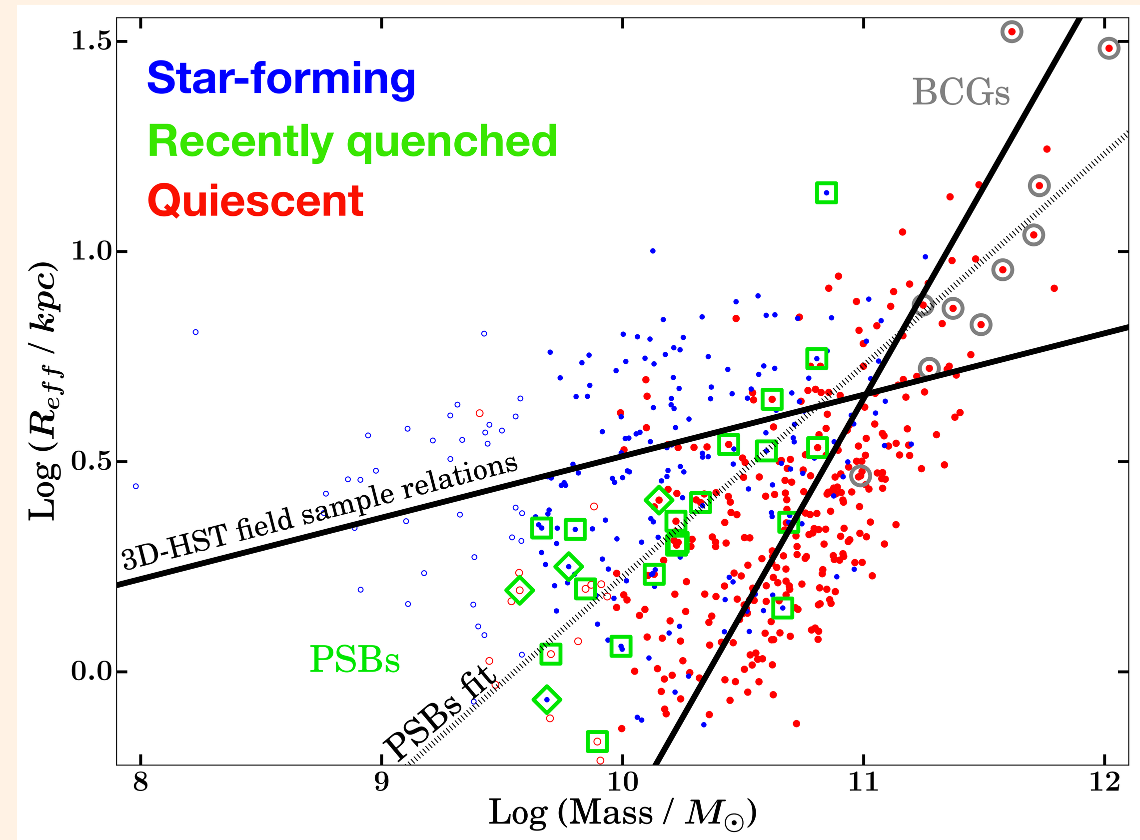
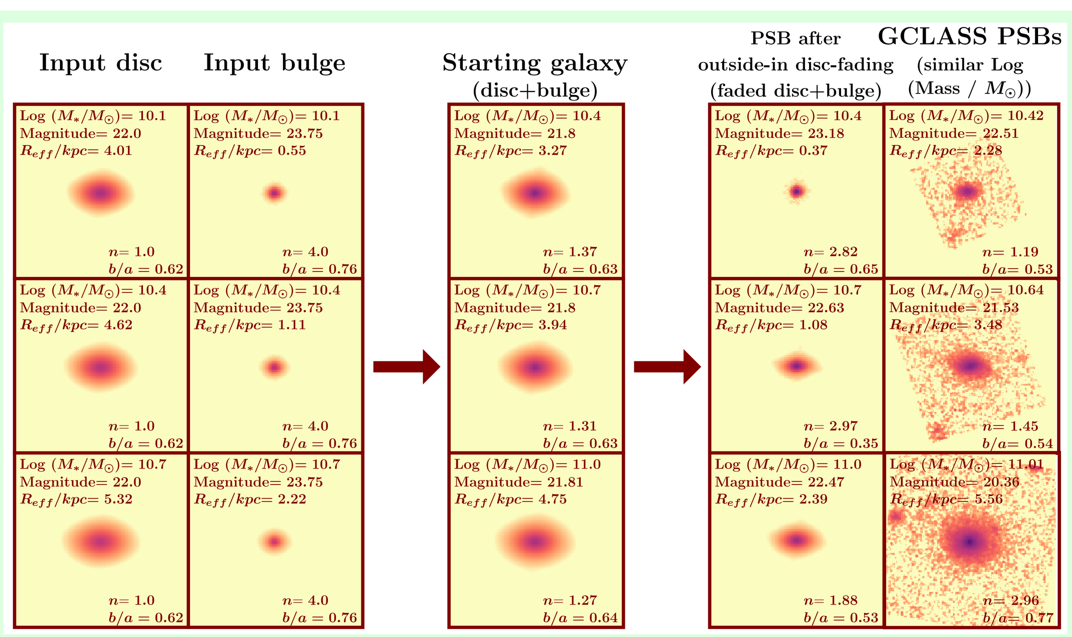
As the Universe ages, quiescent (not star-forming) galaxies grow more rapidly in size than stellar mass. The two leading explanations for this size growth are minor mergers (see second result for more info) and the addition of *recently* quenched galaxies to the quiescent population. Star-forming galaxies have larger sizes on average compared to quiescent galaxies. When they stop forming stars and quench, they join the quiescent population of galaxies at the large size end of the distribution. Therefore, *recently quenched galaxies should have larger sizes than quiescent galaxies on average*. Over time, the addition of recently quenched galaxies to the quiescent population should therefore induce an increase in the average size of quiescent galaxies.

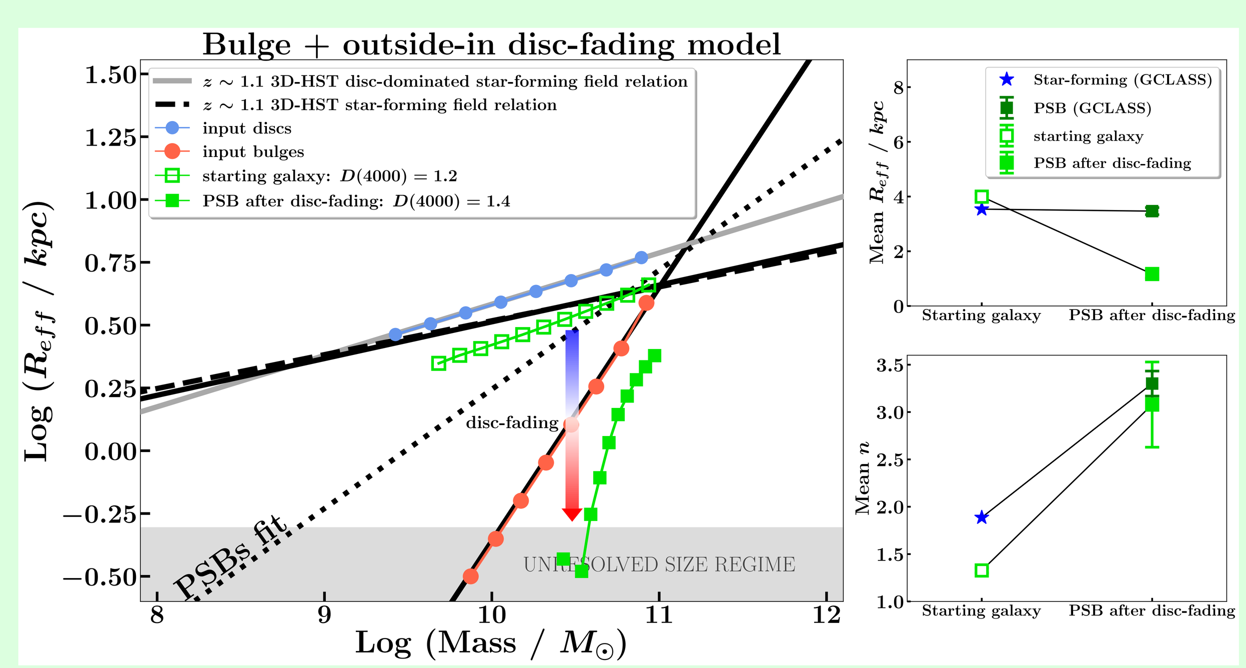
In Matharu et al., (2020), we found direct evidence for this process by studying the position of 23 spectroscopically identified recently quenched cluster galaxies on the mass—size plane (green markers in the plot to the right). **Recently quenched cluster galaxies follow a mass—size relation lying midway between the star-forming and quiescent field mass—size relations** (dotted line in the plot). This result confirmed that **the average size of quiescent galaxies does increase due to the quenching of star-forming galaxies as well as minor mergers** (see second result for more info). Go to the website below to find out more about this work.

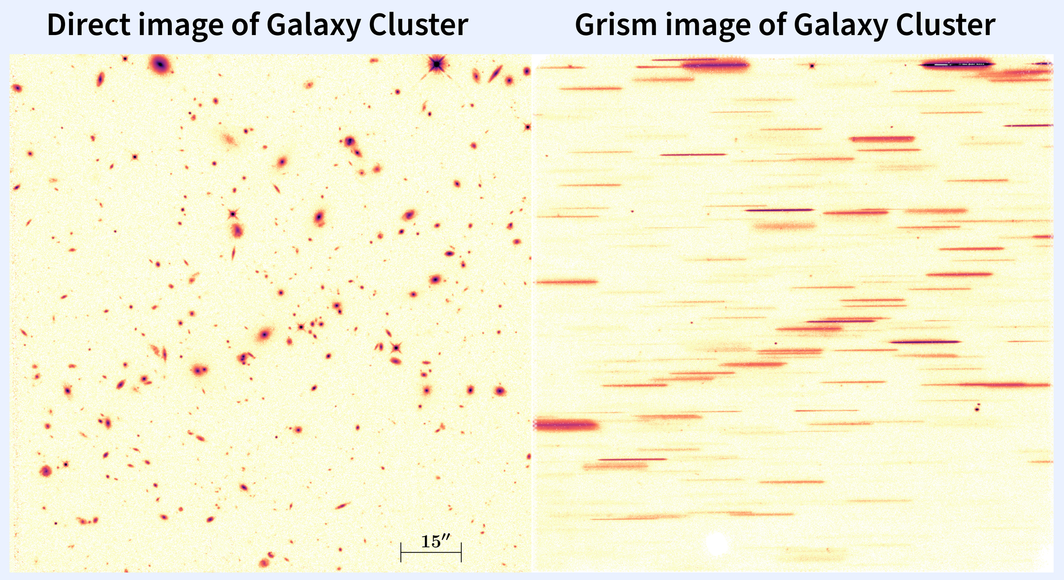




What is the physical process that causes the formation of recently quenched galaxies in clusters? Given the results we found about recently quenched cluster galaxies on the mass—size plane (see previous result for more info), **we tried to see if disc-fading could explain the mass—size relation of recently quenched cluster galaxies**. We **created model galaxies** (plot to the left) composed of a disc and bulge, then **faded the disc "outside-in" to replicate the way quenching proceeds in clusters**.

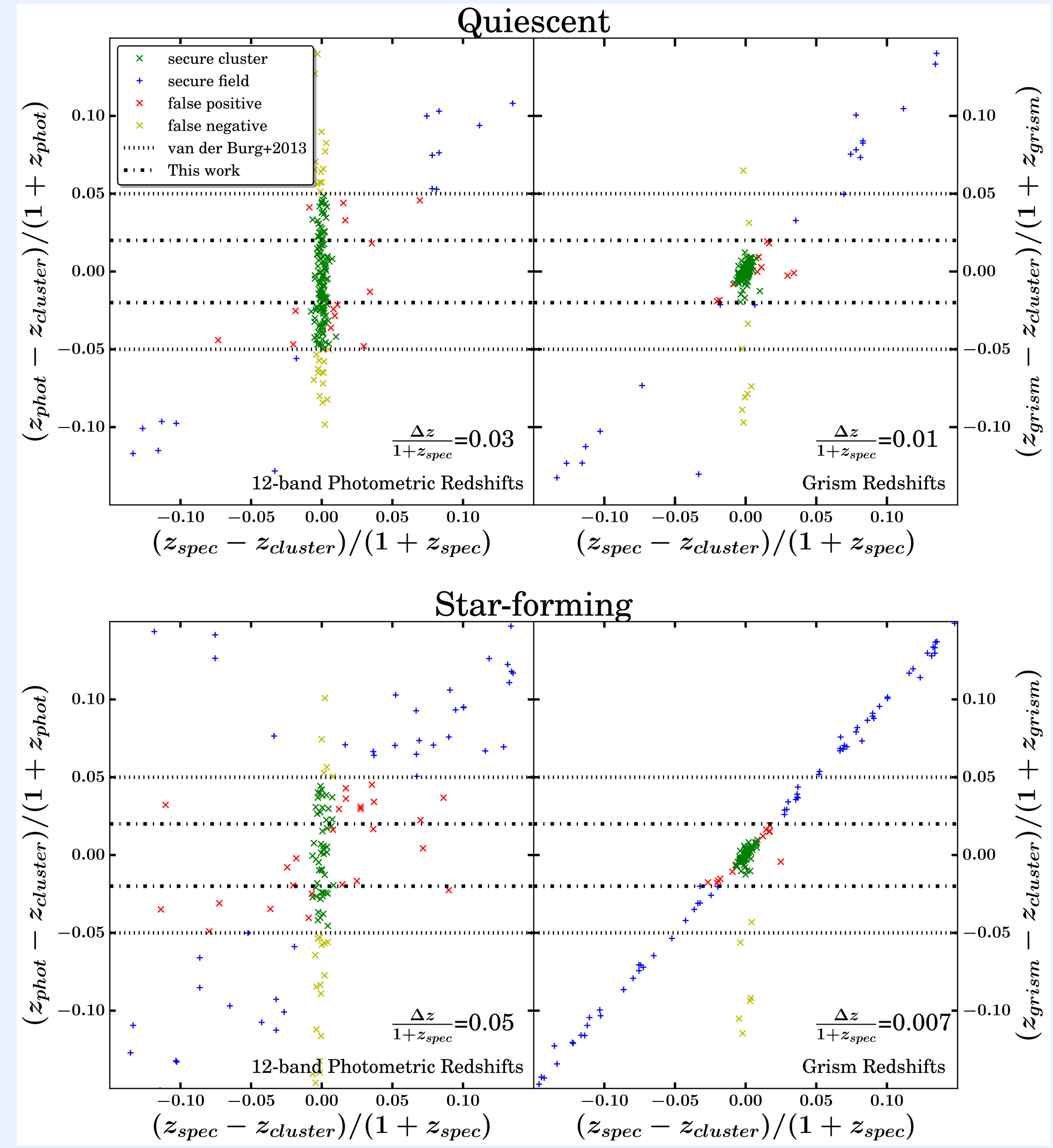
In Matharu et al., (2020), we found that **modeling a galaxy with a bulge+disc, and fading the disc from the "outside-in" can lead to the reduction in size and increase in bulge-dominance observed between star-forming and recently quenched cluster galaxies**. However, more sophisticated modeling will be required to fully reproduce the structural properties of the observed recently quenched cluster galaxies. Go to the website below to find out more about this work.





Slitless spectroscopy uses the combination of a diffraction grating and prism (a "grism") to create an image of a galaxy at every wavelength within some range. The image above on the left is an image of a Galaxy Cluster taken with the *Hubble Space Telescope* using a single filter. You can think of it as an image of the Galaxy Cluster at some fixed wavelength of light. The image to its right shows the grism spectra for the same Galaxy Cluster also obtained using the *Hubble Space Telescope*. You can see that grism spectra look like horizontal streaks. Each streak is actually images of the same galaxy at different wavelengths, very close together side-by-side with some overlap.

During my PhD, I found that **when space-based grism spectroscopy is combined with a sufficiently large amount of imaging using different coloured filters, it is almost as successful as conventional spectroscopy in identifying galaxies that are members of a cluster.** Usually, cluster members are identified using conventional spectroscopy which can be expensive to obtain. This result is best seen by the tight clustering of green crosses (secure cluster members) in the second column compared to the first column (no grism spectroscopy) of the plot to the right. Go to the website below to find out more about this work.

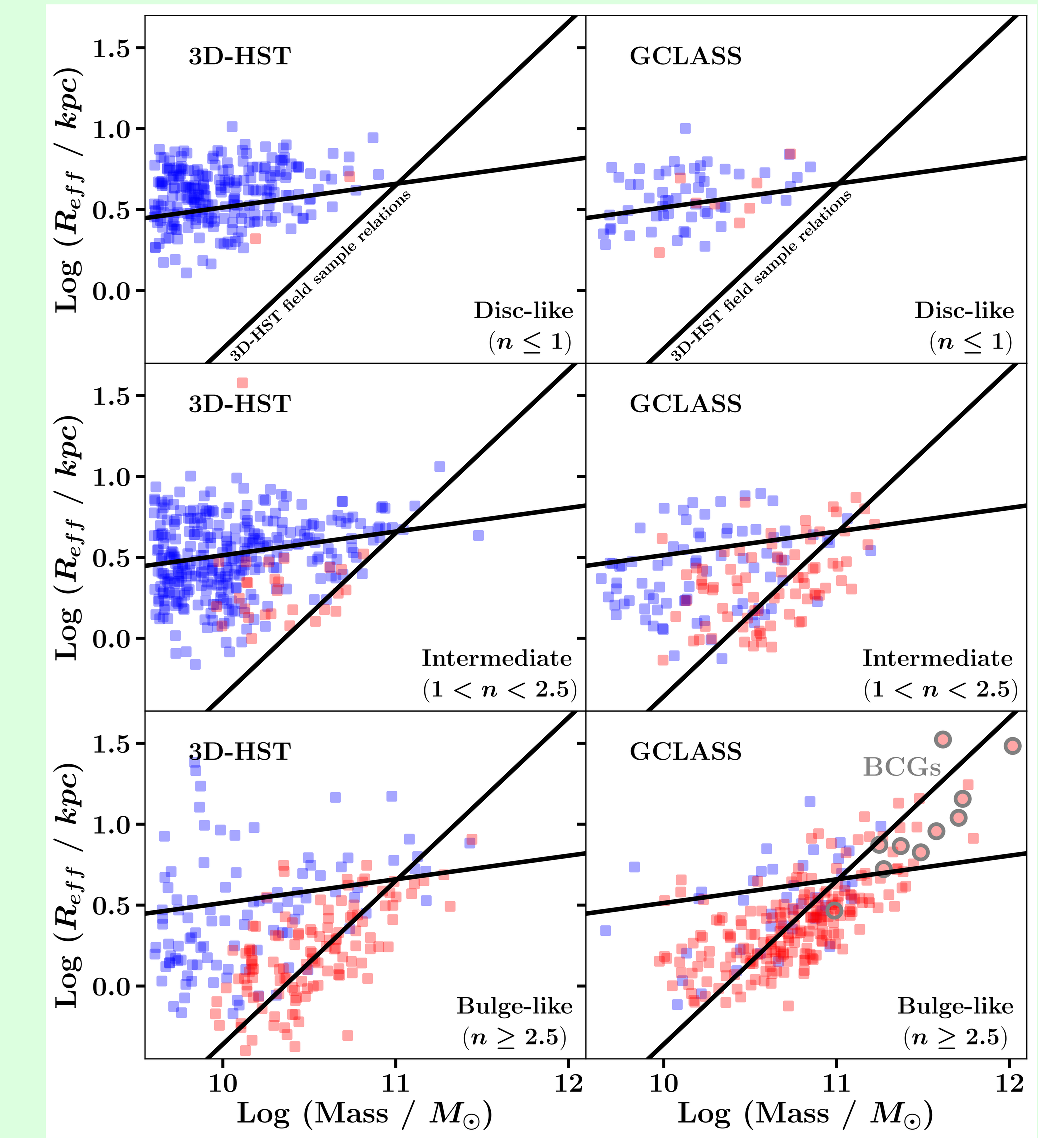


We have known for a while now that galaxies residing in clusters are redder in colour, less actively star-forming and more bulge-dominated than their counterparts in the field (small groups of galaxies). But so far, it has been difficult to pinpoint exactly why this is the case.

In Matharu et al., (2019), we tracked the morphology of both star-forming and quiescent (not star-forming) galaxies across the stellar mass—size plane, both in the field and cluster environments. In the figure on the right, the first column shows the results for the field and the second column shows the results for Galaxy Clusters. This experiment was conducted with galaxies residing at a time when the Universe was approximately 6 billion years old.

The first thing to notice is that both star-forming (blue points) and quiescent (red points) galaxies broadly follow the same mass—size relations in both environments for all three types of morphology. However, **there is clearly a larger fraction of quiescent intermediates and bulge-like galaxies in the clusters.** This excess population of quiescent intermediates and bulge-like galaxies indicates that the cluster environment is more efficient at quenching galaxies of their star formation than the field environment.

The increased efficiency in quenching intermediate-type galaxies may be directly responsible for the larger fraction of quiescent bulge-like galaxies in clusters, because the physical process could make the galaxy end up looking more bulge-like. This result suggests **there is a direct morphological consequence of environmental quenching**. Go to the website below to find out more about this work.



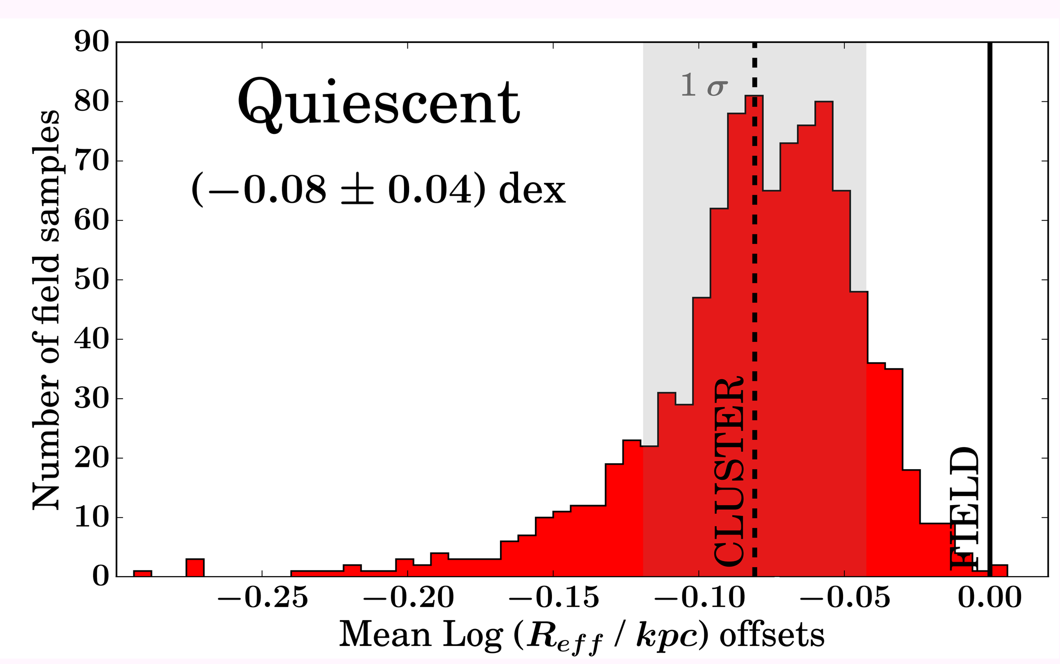
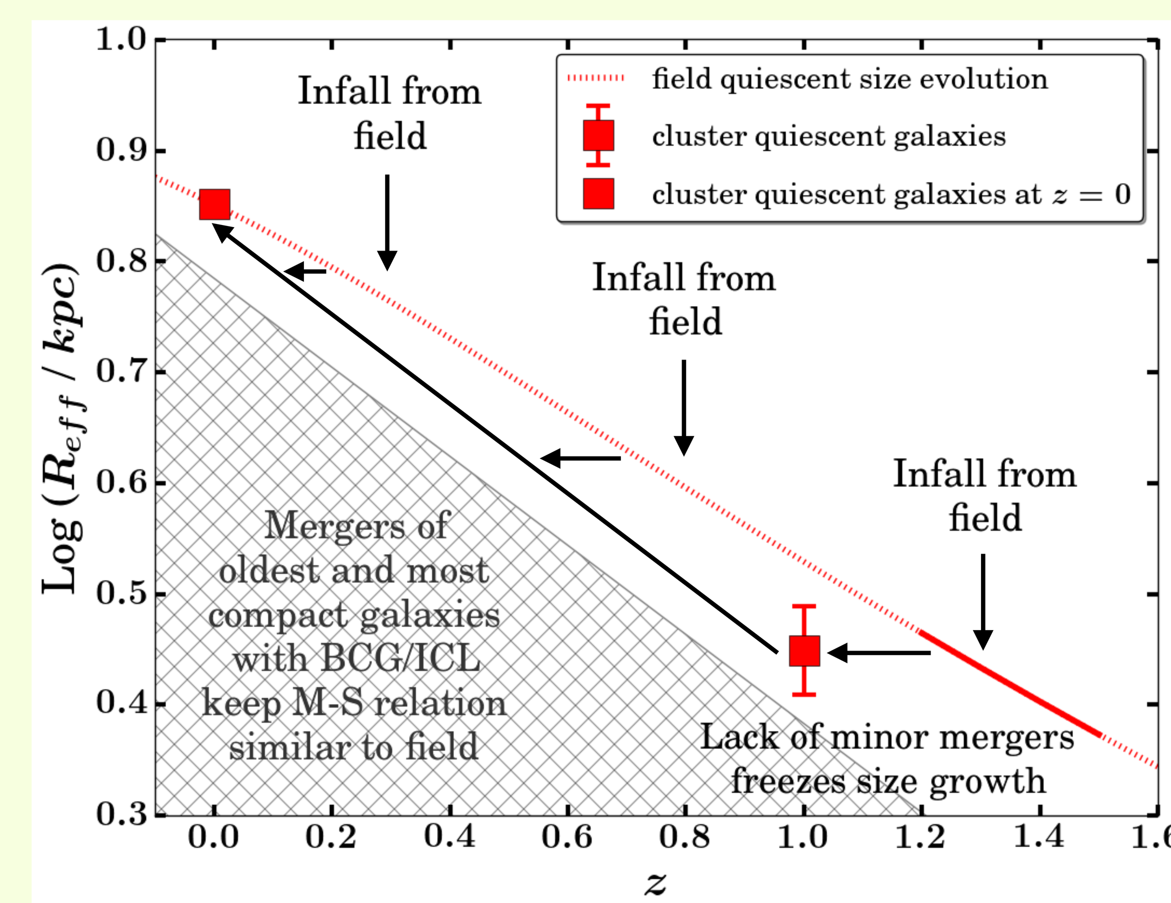


Figure Caption: R_{eff} is the half-light radius of a galaxy measured in kiloparsecs. The half-light radius is the radius within which half of the total light emitted by the galaxy is contained. 1 parsec = 3.086×10^{13} kilometres. Negative R_{eff} offsets indicate smaller sizes.

When star formation ceases in a galaxy (or is "quenched"), we refer to this galaxy as "quiescent". Today, the Universe is 13.7 billion years old. Since it reached an age of about 3.3 billion years, the amount of star formation occurring per unit time in a given volume of the Universe has been in continuous decline. This has led to a build-up of quiescent galaxies in the Universe.

Observations have shown that quiescent galaxies grow disproportionately more in size than stellar mass as the Universe ages. Many studies have argued that minor mergers (mergers between two galaxies that have very different stellar masses) are responsible for this size growth. To test this hypothesis, it is possible to use the cluster environment as a laboratory. Cluster galaxies have high peculiar velocities, making mergers between them rare. Since minor mergers are expected to increase galaxy size more than they do stellar mass, the most direct way to test this is to measure the stellar mass–size relations in both the cluster and field (small groups of relatively isolated galaxies) environments at a fixed point in time and compare them to see if there is a significant offset in size. If the predictions of minor mergers driving galaxy size growth are true, cluster galaxies should find themselves inhibited from size growth and will therefore be significantly *smaller* than field galaxies at fixed stellar mass. In Matharu et al., (2019), we conducted this experiment using cluster and field galaxies residing at a time when the Universe was approximately 6 billion years old. The plot to the left shows our main result: **quiescent cluster galaxies are smaller than quiescent field galaxies**. This result supports the case that minor mergers drive the rapid size growth we observe in quiescent *field* galaxies. You can find out more about this work by going to the website below.



As the Universe ages, quiescent (not star-forming) galaxies grow more rapidly in size than stellar mass (see second result for more info). Observations have shown that **if we compare the sizes of cluster and field quiescent galaxies in the present-day Universe, they are the same or very similar.** This is different from the result we found when the Universe was approximately 6 billion years old: quiescent cluster galaxies were found to be noticeably *smaller* than their field counterparts.

To explain the results in the present-day Universe, **cluster quiescent galaxies need to grow in size via some other route than minor mergers** (since these are rare in clusters — see second result for more info), **such that they can "catch up" with their field counterparts by the present day.** In Matharu et al., (2019), we presented a toy model which showed that **quiescent cluster galaxies could catch up with their field counterparts due to cluster-specific physical processes.** These physical processes would need to 1) destroy ~60% of the smallest, most compact galaxies in the cluster and 2) merge the remaining ~40% of compact galaxies with the galaxy at the centre of the cluster. Combined with the infall of younger, more larger galaxies from the field into the cluster over time, these processes could help explain why we observe no difference in the quiescent mass—size relation with environment in the present day Universe. To understand more about the plot to the left, go to the website below.