Compact star-forming galaxies preferentially quenched to become PSBs in z < 1 clusters

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DATA

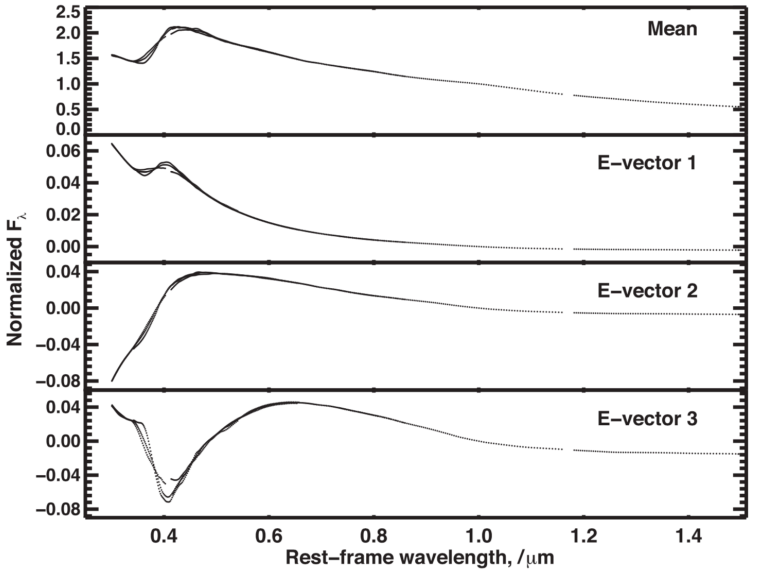
- 8th UDS: J=24.7, H=24.2, K=24.6
- Subaru XMM-Newton Deep Survey(SXDS): B=27.6, V=27.2, R=27.0, i=27.0, z=26.0
- Canada-France-Hawaii Telescope(CFHT): U=26.75
- Spitzer Legacy Program: [3.6]=24.2, [4.5]=24.0

- K<24.3 -> 95% completeness
- 23,398 galaxies at 0.5<z<1.0

- Photometric redshift, stellar mass
  - used the techniques in Simpson (2013).
  - *EAZY* photometric-redshift code
  - U, B, V, R, i′, z′, J, H, K, 3.6μm and 4.5μm photometry
  - Bruzual & Charlot (2003) stellar population synthesis models
  - Chabrier (2003) initial mass function.

Galaxy classification and sSFR

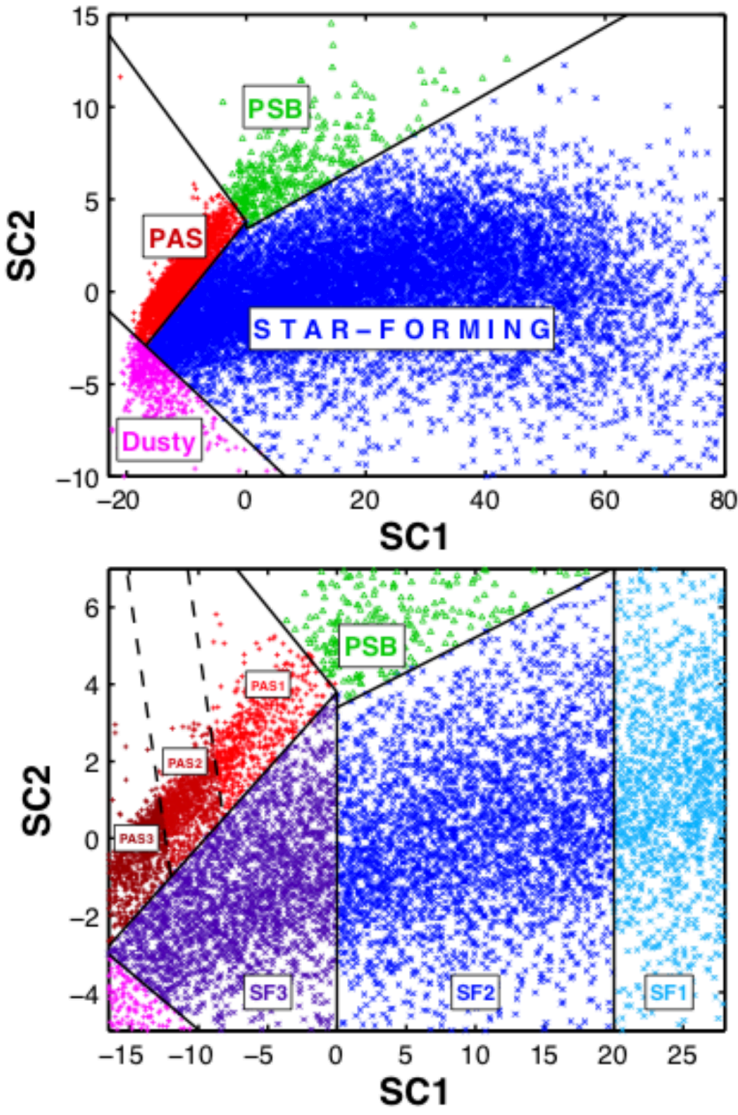
- Wild+2014
- PCA:
  - SC1: modifies the red-blue slope and traces the R-band weighted mean stellar age or SSFR.
  - SC2: the strength of the Balmer break and correlates with the fraction of the stellar mass formed in bursts during the last billion years, and also traces metallicity.
  - SC3: the shape of the SED around 4000Å and is used to break the degeneracy between metallicity and the fraction of the stellar mass formed during the last Gyr.
- SSFRs: supercolor method (Wild+16)



Classification

- SC-SC diagrams (SC1-SC2 and SC1-SC3)
- SF, PAS, PSB, metal-pool and dusty galaxies.
- SF: SF1, SF2, SF3

- SF1: 11,625
- SF2: 3,486
- SF3: 2,055
- PAS: 2,206
- PSB: 418

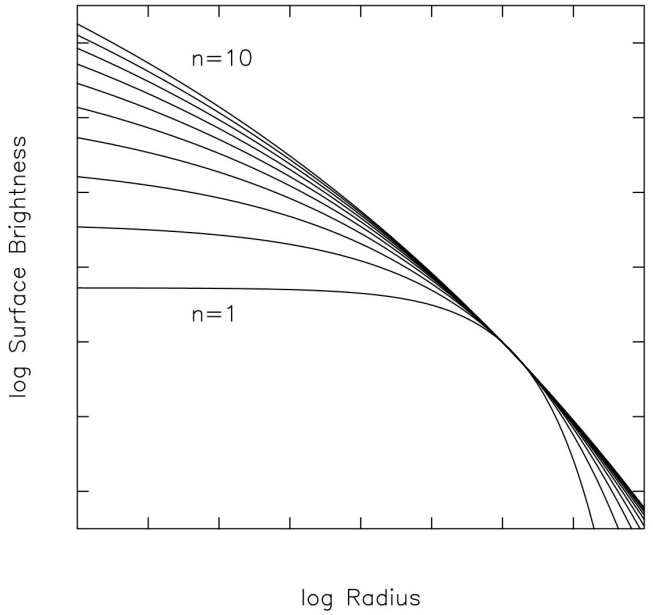


Cluster and field sample

- Friends-of-friends algorithm (Drawn from Socolovsky+2018)
  - Two linking distances: projected (d_{link}) and along the line of sight(z_{link}), detection threshold (N_{min})
  - The algorithm starts by selecting one galaxy at [*r*0,z0] from the catalogue that has not been assigned to any structure. All other galaxies fulfilling $|r0 - ri| \leq d_{link}$ and $|z0 - zi| \leq z_{link}$ are then designated as 'friends'.
  - The method is iterative and continues searching for friends of the friends until no remaining galaxy fulfils the conditions.
- K-band galaxy catalog of the UDS, $d_{link} = 1Mpc, z_{link} = 2.5\sigma_z\big(\sigma_z = 0.023(1+z)\big), N_{min} = 20$
- 37 galaxy overdensities (2,210)
- Filed (13,837):
  - Not associated with an overdensity
  - Follow the redshift distribution of the cluster sample

Galaxy size and Sersic index

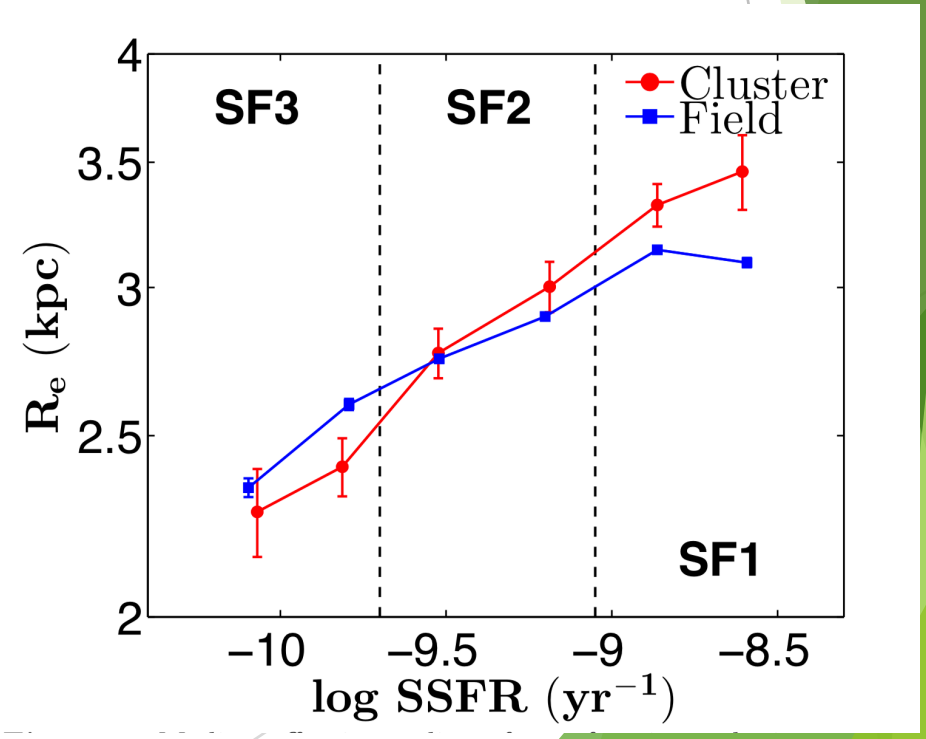
- Structural parameters:
  - effective radius, R_e
  - Sersic index, n
- K-band image from the UDS DR11
  - GALAPAGOS software
  - GALFIT
  - Reject poor fit ($\chi_\nu > 100$): 1.7%
  - Reject not converge to one solution: 7%



- 5421 (1453) SF, 1146 (307) PAS and 95 (26) PSB field (cluster) galaxies.

Size - sSFR

- R_e increase linearly with log sSFR
- Cluster galaxies with high sSFR have larger median R_e than their countparts
- Most of the galaxies with sSFR> $10^{-9.0}\ yr^{-1}$ belong to the population of SF1.



SF1: Size - sSFR

- In both environment galaxies increase in size for increasing stellar mass.
- SF1 galaxies in clusters are on average larger than in the field at all stellar masses.
- 3.4 σ discrepancy between the cluster and field environments.
- Unlike to be driven by an increase in the sSFR of a result of an interaction with the cluster environment.
- Dense environment affect the mass-size relation of young, highly star-forming galaxies.

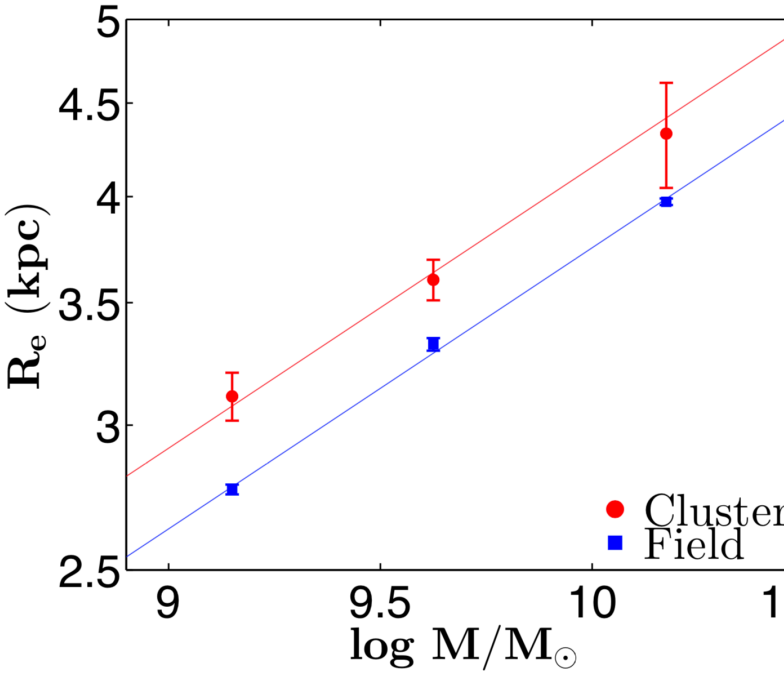
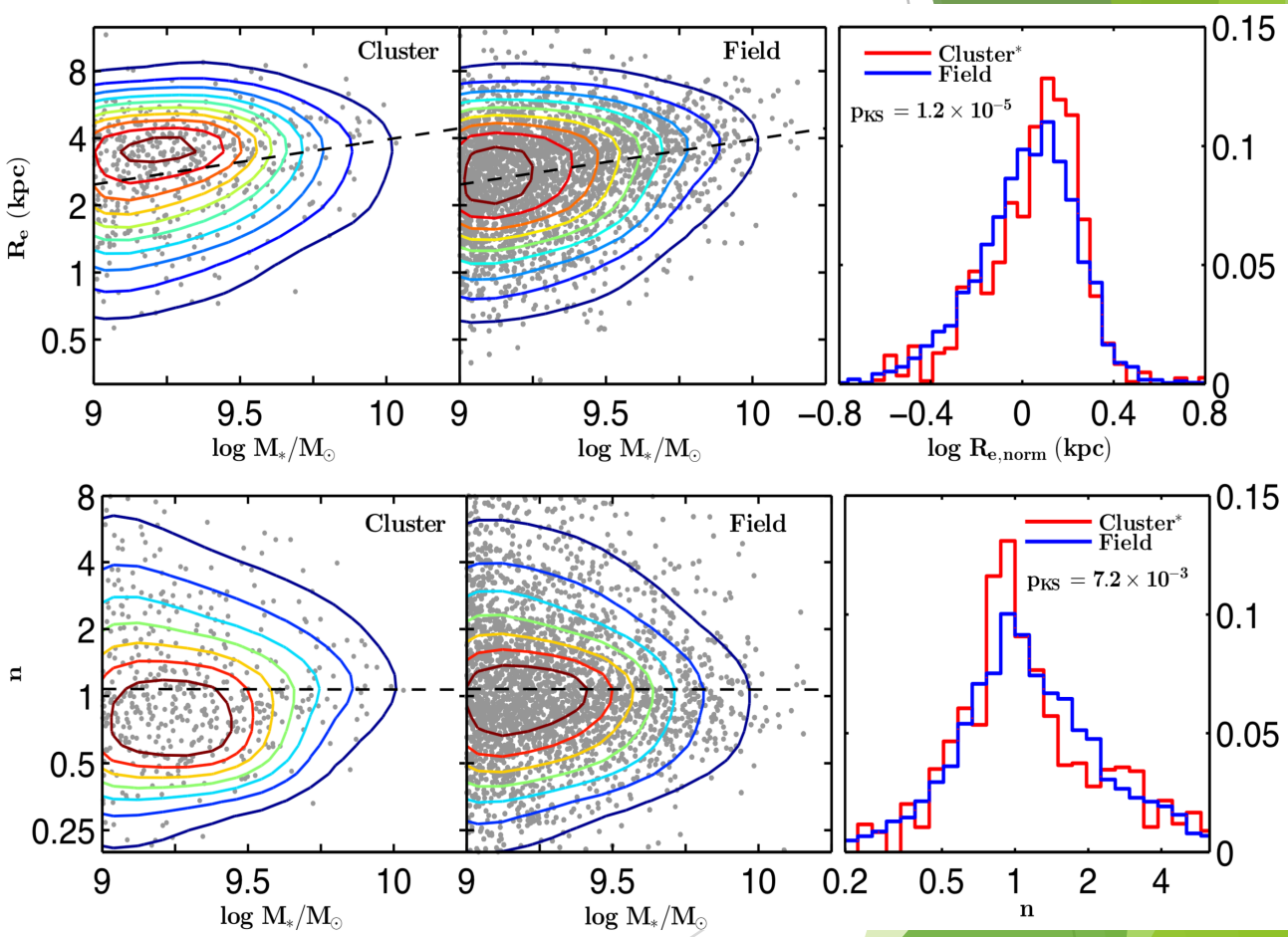


Figure 3. Stellar-mass–size relations of cluster (red) an (blue) high-SSFR galaxies (SF1 galaxies) at $0.5 < z < 1.$ errorbars correspond to the 1σ confidence intervals estima ing bootstrapping. We fit a linear model to each mass–size r (solid lines) in order to compare them. We find that clust galaxies are systematically 9% larger than their field counte at all masses.

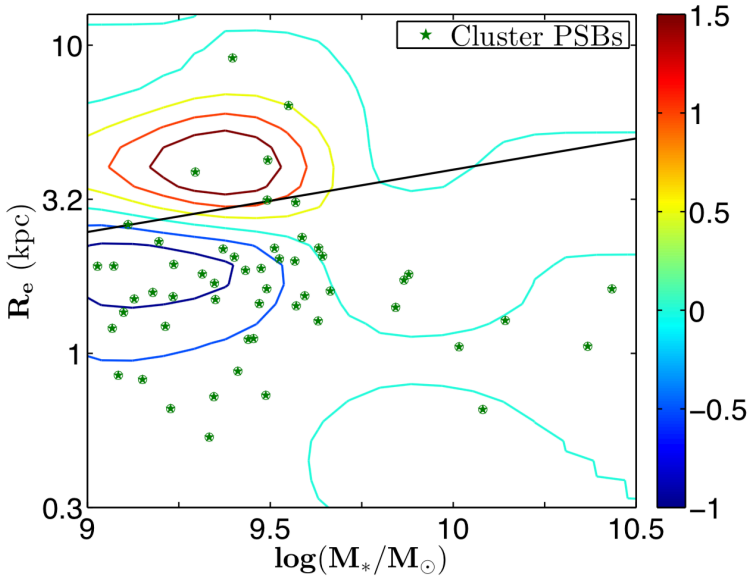
A lack of compact star-forming galaxies

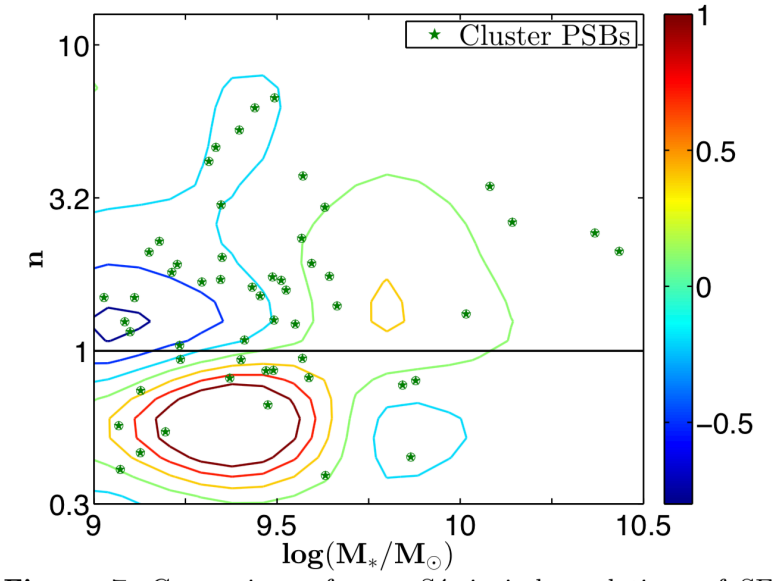
- The cluster distribution peaks above the field mass-size relation, larger sizes at the same stellar mass.
- Cluster distribution peaks at lower value of *n* than in the field.



The cluster post-starburst mass–size relation

- Most PSB are found below the SF1 mass-size relation
- Cluster PBSs typically have n ~ 1.5, partially maintain a disc-like nature
- Cluster PSBs and compact field SF1 galaxies are consistent with having the same n distribution.
- The compact SF1 galaxies undergo a gentle evolution to become PSBs in dense environment, without a significant structural transformation.





Discussion

- SF1 in cluster larger than SF1 in field, lack of SF1 galaxies with small R_e at a given stellar mass
  - Environment affect SF1 that R_e increases
  - Compact galaxies are being preferentially quenched in the cluster environment.

- Elliptical tend to be larger in high density environment:
- Harassment or dry merges in crowded environment
- But SF1 mainly star-forming disc with n~1
- Minor megers: enable the growth of the disc compont
- Major gas-rich merge: quenching them into compact PSB.

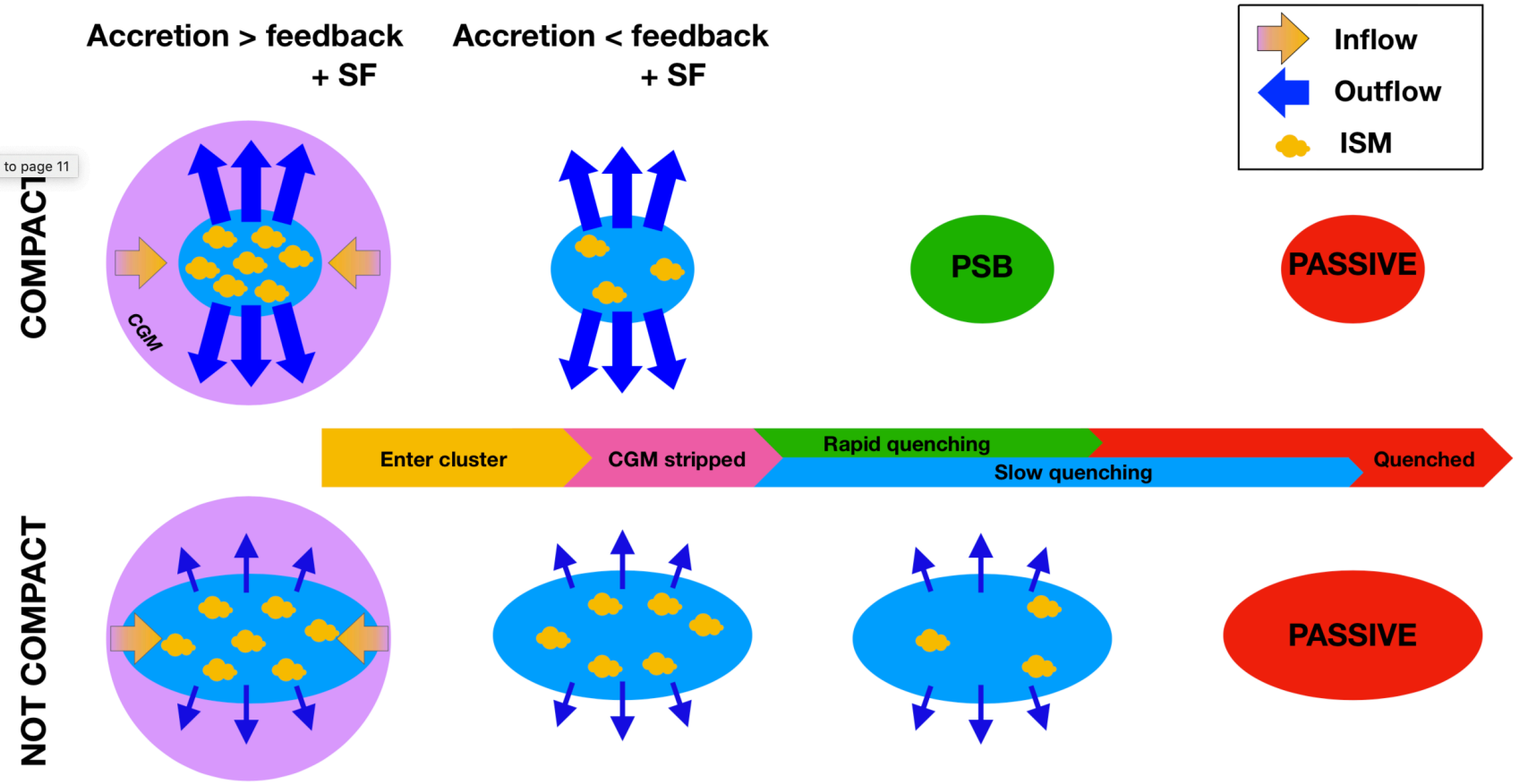
Environment affect SF1 that R_e increases?

- Weakness: sersic ~ 1.5
- Low n for a post-major merger scenario
- At z < 0.1, PSBs have high Sérsic index values and are thought to be major merger remnants that tend to reside in low-density environments

- PSBs are originated via some kind of gentle gas removal in galaxy cluster.
- minor mergers with dwarf galaxies that we cannot observe provide a feasible explanation

Compact galaxies are being preferentially quenched in the cluster environment?

- ram-pressure stripping and tidal interactions are expected to act more efficiently in more extended galaxies
- A combination of both internal and external mechanisms
- bathtub-type model: Star formation in a galaxy in regulated by the balance between gas inflows and outflows.
- Cold gas reservoir: interstellar medium ISM: corresponds to the dense gas within the disc, represents the instantaneous fuel for star formation
- Hot gas reservoir: circumgalactic medium CGM: extended halo of diffuse gas, too hot to collapse into stars but has the potential to cool down with time and feed the ISM through cold streams, long-term gas reservoir



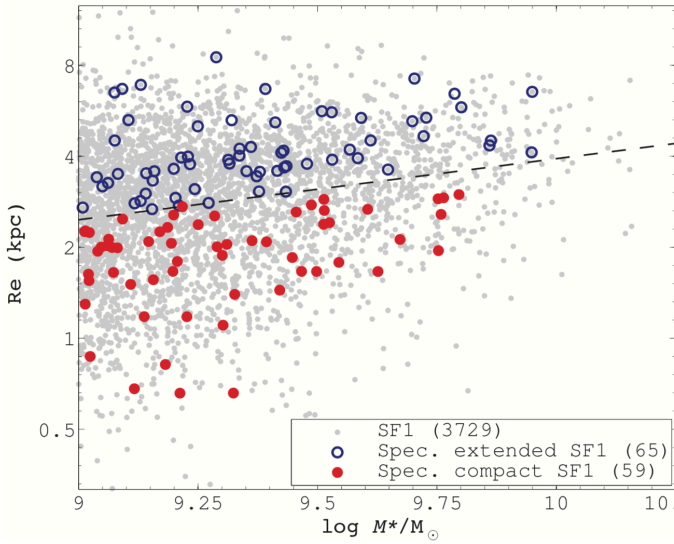
If galaxy becomes a satellite in cluster, CGM is stripped away via interaction with intracluster medium

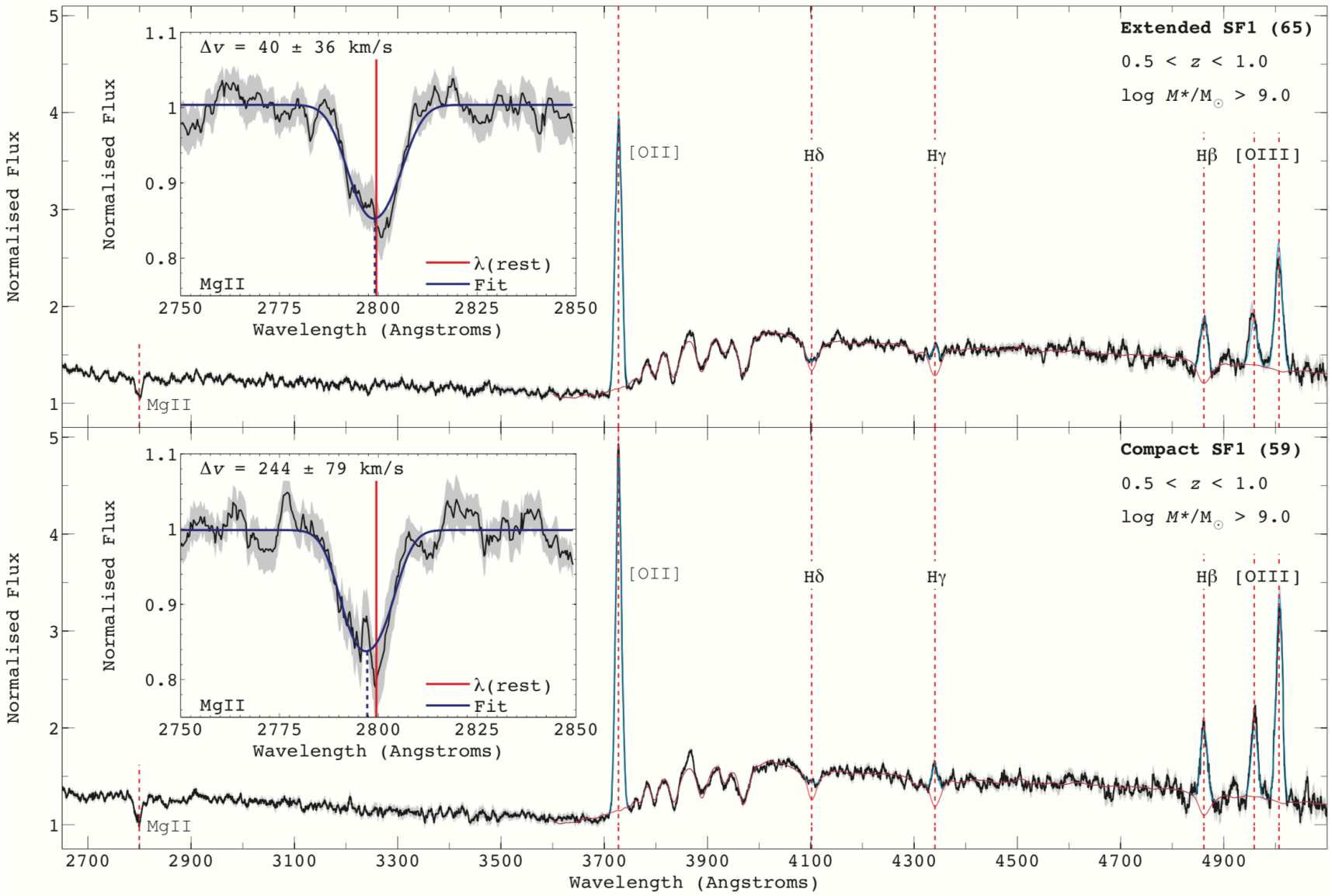
- highest SSFRs and/or strongest galactic outflows will deplete their cold gas reservoir faster and, consequently quenched
- Compact: may have stronger stellar-wind-driven outflows.
- Strength of super-wind $\propto \Sigma_{\mathrm{SFR}}$

- Compact: strong outflows
- Not compact: modest outflows, stay star-forming over longer timescales before run out of fuel. (“delayed-then-rapid” environmental quenching scenario)
- Environment quenching does not trigger significant structural evolution, PSBs are compact because they are the descendants of the compact SF1 galaxies.

Spectrum

- The strong stellar feedback in compact galaxies cause significant outflows which rapidly expel any remaining cold gas from the central region.
- Mg II absorption doublet : sensitive tracer of low-ionization interstellar gas
- The detection of a blue-shifted component to this absorption feature is generally indicative of galactic-scale outflows along the line-of-sight to the observer.
- Stack:
  - Red-optimised stack ($\lambda > 3500\text{Å}$):
  - Blue-optimised stack ($\lambda < 3700\text{Å}$):
- Mg II doublet:
  - Extended SF1s: well-centred, $\Delta v = 40 \pm 36\ km\ s^{-1}$
  - Compact SF1s: offset toward bluer wavelengths, $\Delta v = 244 \pm 79\ km\ s^{-1}$




Extended SF1 (65)
0.5 < z < 1.0
log M*/M⊙ > 9.0
Δv = 40 ± 36 km/s
Compact SF1 (59)
0.5 < z < 1.0
log M*/M⊙ > 9.0
Δv = 244 ± 79 km/s
[OII]
Hδ
Hγ
Hβ
[OIII]
MgII
λ(rest)
Fit
Normalised Flux
Wavelength (Angstroms)

- Strong galactic-scale outflows are commonplace in compact SF1 galaxies, but not a significant factor in the more extended SF1 galaxies.

- Extended galaxies: lack of strong outflows leads to galaxy retaining it cold gas disc and therefor the continuation of star formation.
- Compact galaxies: the stronger outflows present will quickly lead to the removal of the remaining clod gas disc, which would result in the rapid quenching of star formation and the subsequent evolution of these galaxies into cluster PSBs.

Conclusion

- Galaxies with high sSFR in the cluster environment are on average large than their counterparts in the field
- The difference in size is likely to be driven by a lack of compact SF1 galaxies in clusters. This suggests a preferential environmental quenching of the most compact galaxies. The missing compact SF1 galaxies had higher Sérsic index, n than typical SF1 galaxy in the field.
- The structural parameters of the missing compact SF1 galaxies are compatible with those of the cluster PSB population.
- Compact SF1s are the main progenitors of cluster PSBs, rather than the SF1 population as a whole. These galaxies are rapidly quenched and evolve into the PSB population with no significant structural evolutin.