VIPERS

VIMOS PUBLIC EXTRAGALACTIC REDSHIFT SURVEY

Hidden diversity of intermediate redshift galaxies

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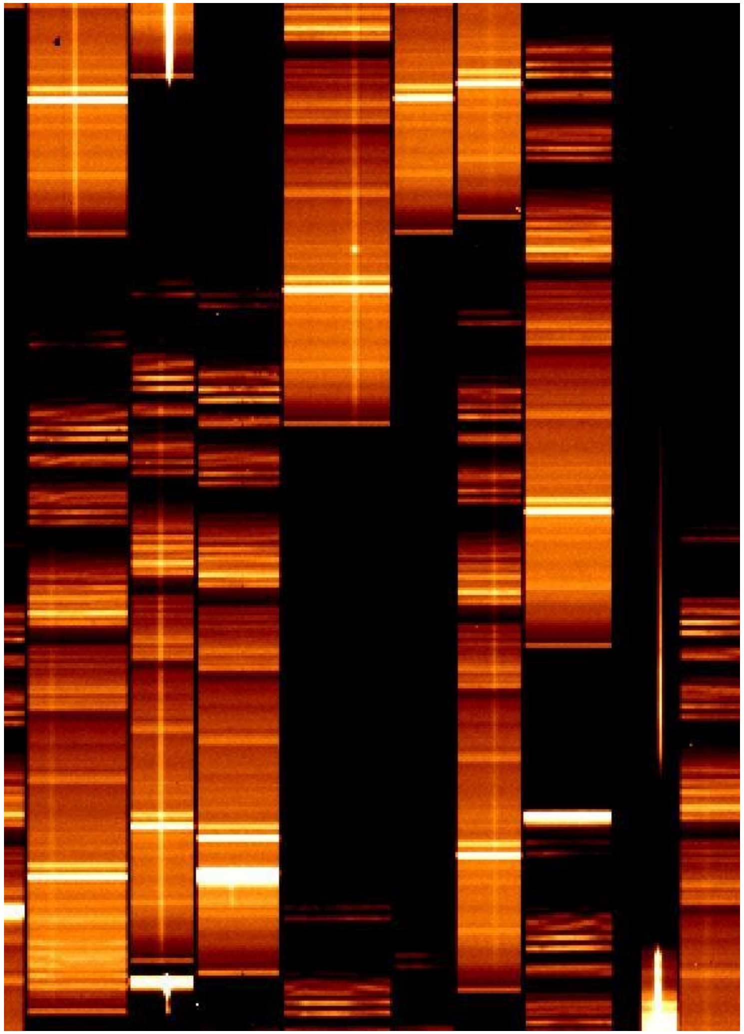
From galaxies to cosmology with large spectroscopic surveys, Marseille, 4-8 July 2022

Outline

- too short overview of the VIPERS project,
- classification if z~1 (and 0),
- sub-classes vs environment - a hint for different evolutionary paths.



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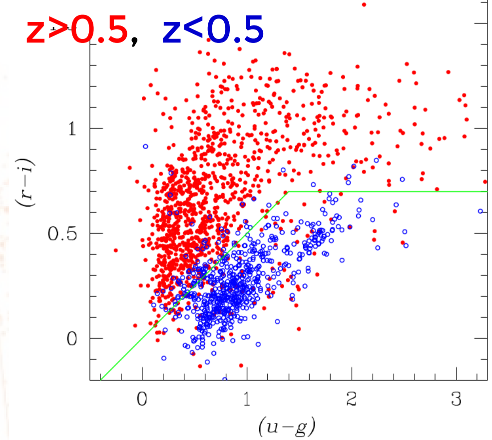
VIMOS PUBLIC EXTRAGALACTIC REDSHIFT SURVEY

the intermediate redshift equivalent of state-of-the-art local surveys

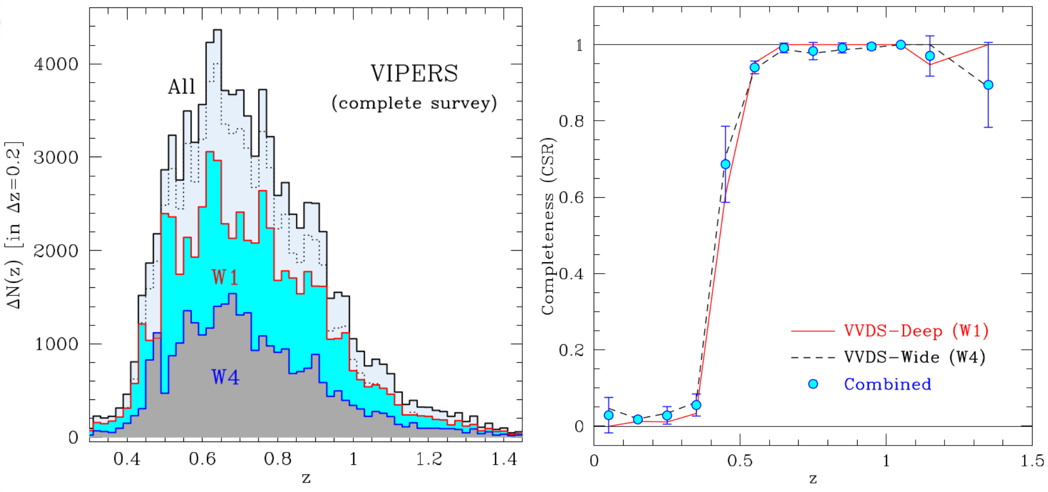
completed Large ESO Programme, (2008-2016, PI: L. Guzzo)

- designed to investigate the spatial distribution of galaxies at $z \sim 1$ (i<22.5, z>0.5 colour--colour pre-selection),
- built of W1 and 4 CFHTLS-Wide fields (23.5 deg^2),
- spec-z for nearly 90 000 (!) galaxies.

based on VVDS data:



Guzzo et al. 2014



Scodeggio et al. 2016, PDR-2

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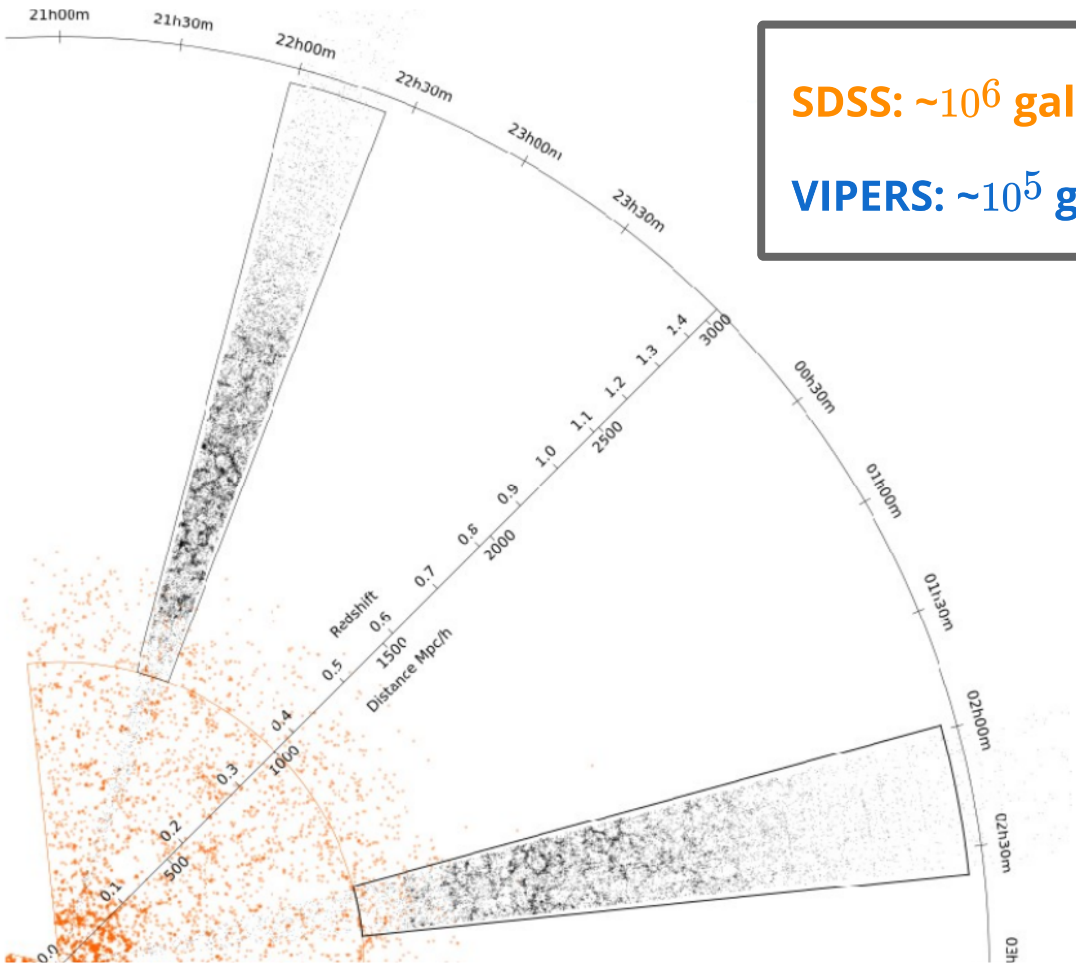
the intermediate redshift equivalent of state-of-the-art local surveys



SDSS: ~10^6 galaxies at 0.0 < z < 0.25,

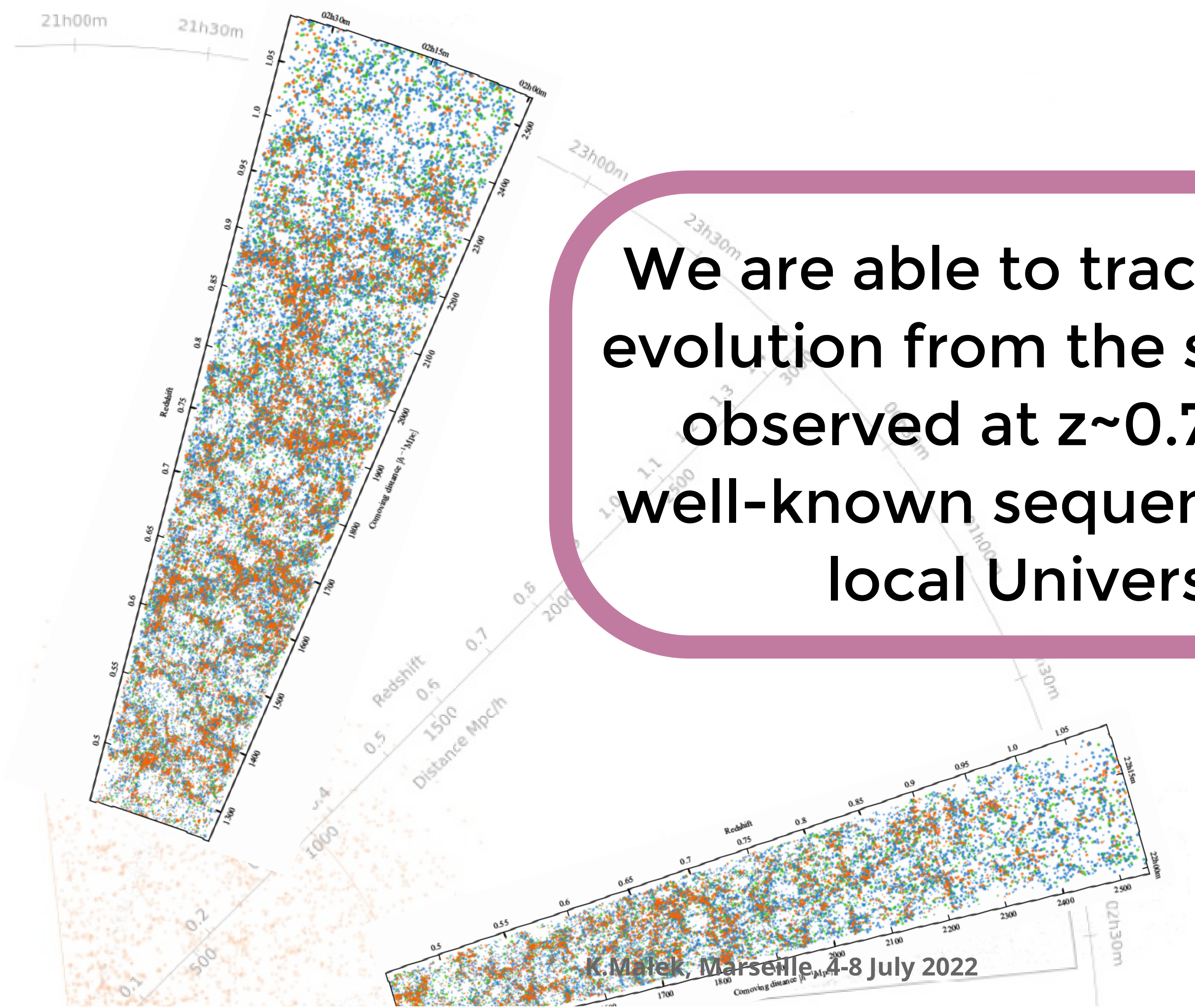
VIPERS: ~10^5 galaxies at 0.4 < z < 1.2

Guzzo et al. 2013,

Garilli et al. 2014,

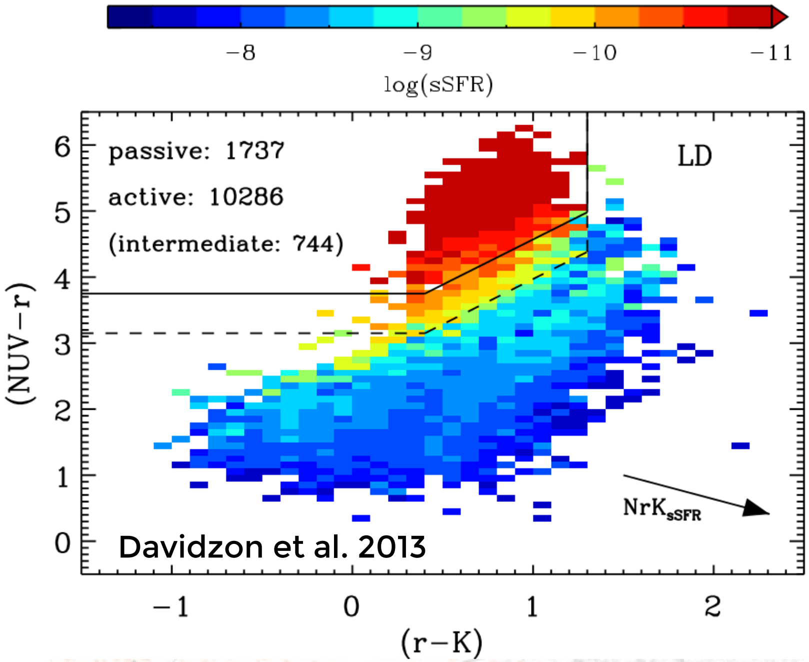
Scodeggio et al. 2018

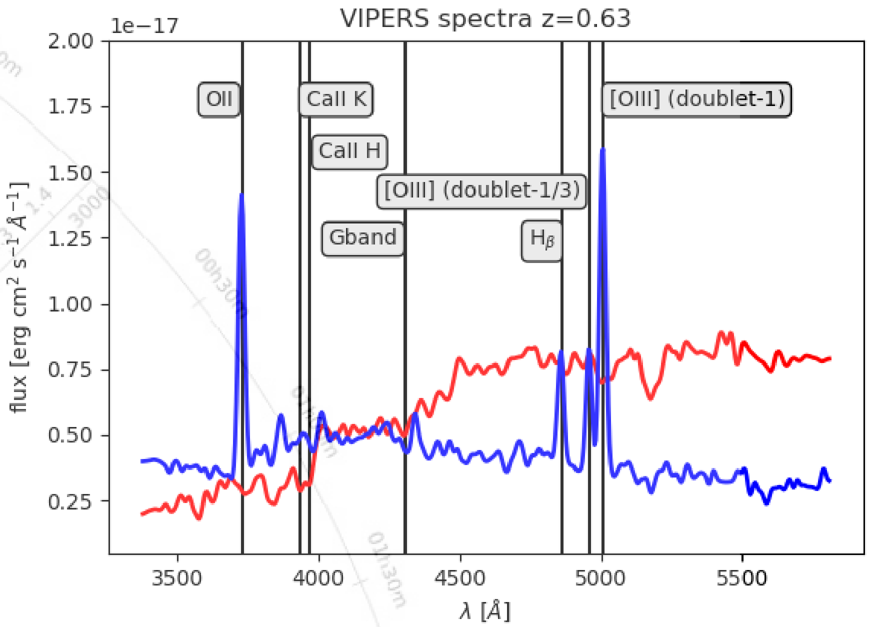
the intermediate redshift equivalent of state-of-the-art local surveys



We are able to trace the the evolution from the structures observed at z~0.7 to the well-known sequence in the local Universe.

The spectra were collected by **VIMOS** spectrograph (LR Red grism, λ: 5,500-9,500$\mathring{A}$, R~220).

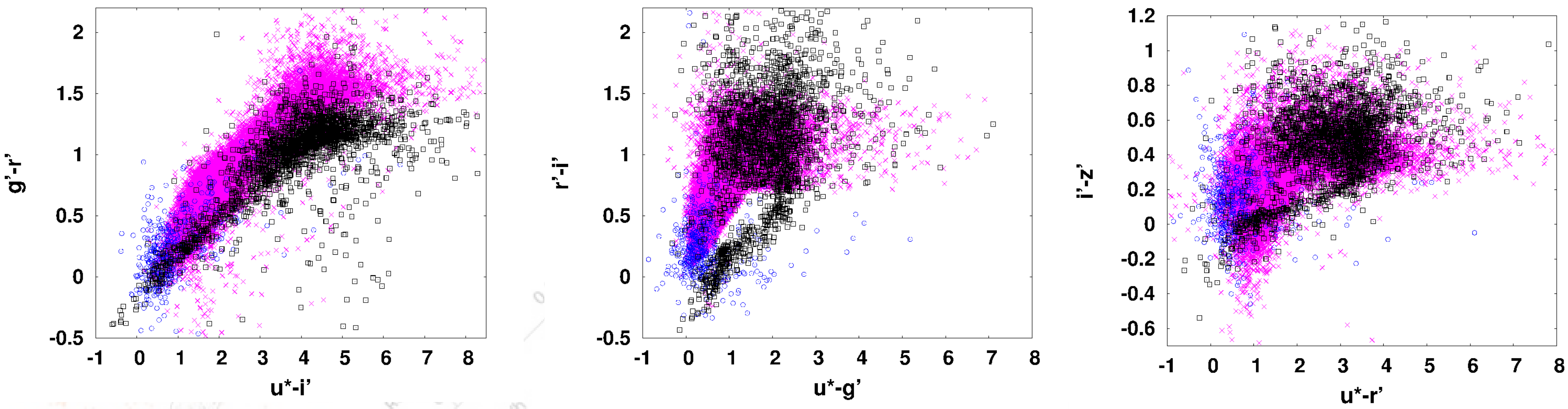




Classification if $z \sim 1$

classification if z~1, supervised

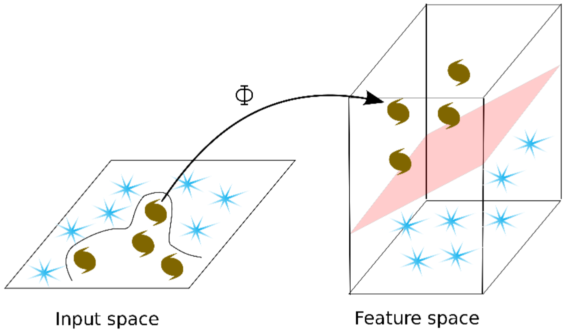
galaxies, AGNs, stars



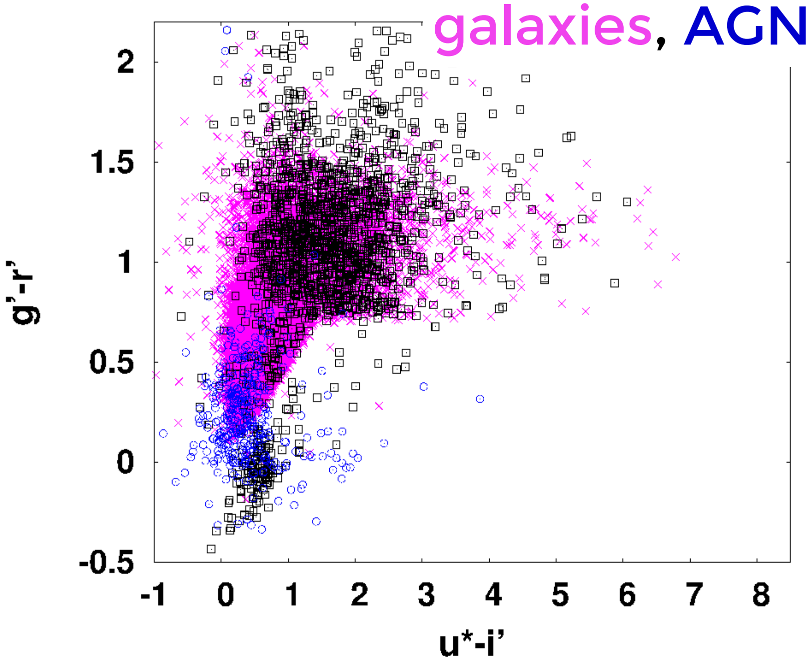
KM et al. 2013

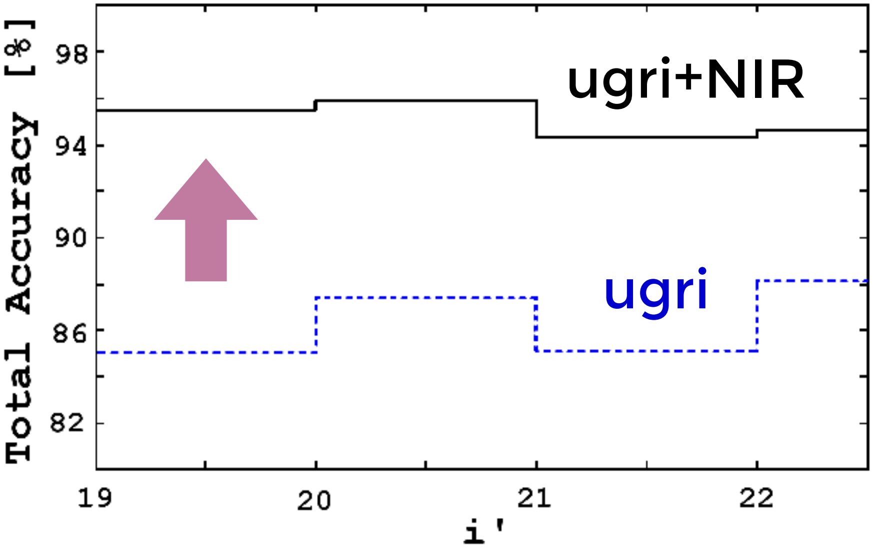
classification if z~1, supervised

KM+2013 - **Support Vector Machine (SVM)**, a supervised classifier applied for AGN/star/galaxy selection based on available photometry (ugriz+)



galaxies, AGNs, stars





KM et al. 2013

- Is the galaxy/star/AGN selection enough to trace evolutionary paths?

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- ☐ Can we divide *z*~1 galaxies into smaller subsamples (smaller than red/blue/green)?

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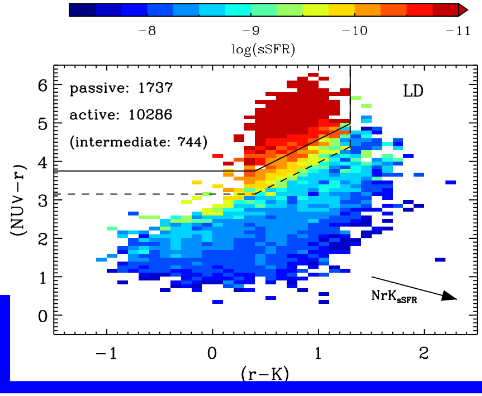
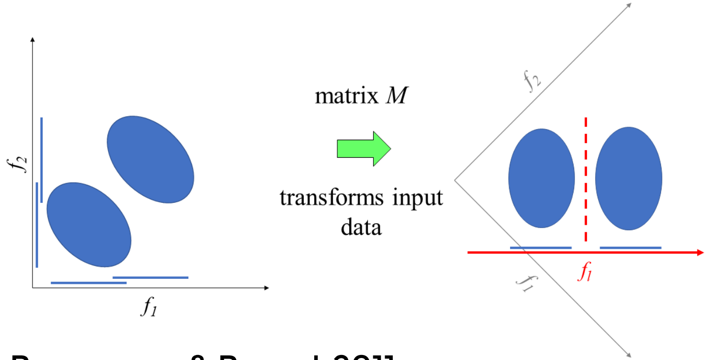
- ☑ Can we divide *z*~1 galaxies into smaller subsamples (smaller than red/blue/green)?

classification if z~1, unsupervised Fisher Expectation-Maximisation method

The bimodality in colour-colour space forces a similar division in a multi-dimensional space.



Davidzon et al. 2013

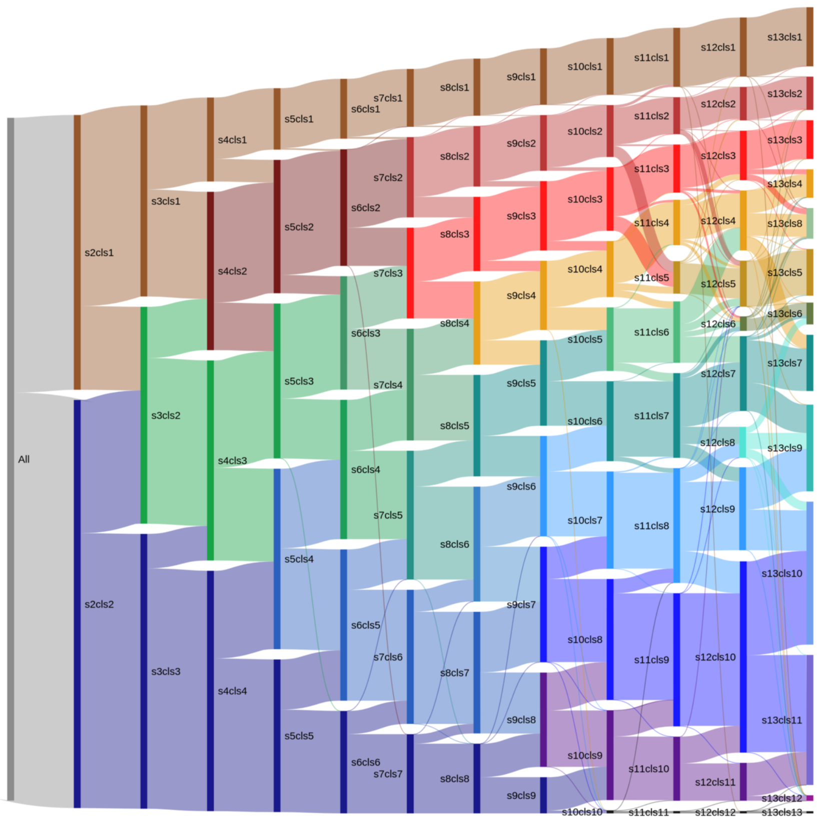


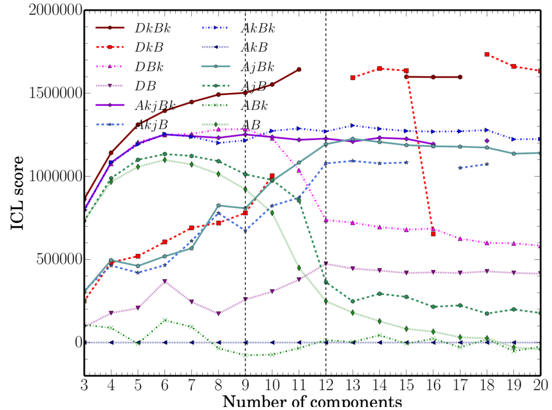
Bouveyron & Brunet 2011
Bouveyron et al. 2012

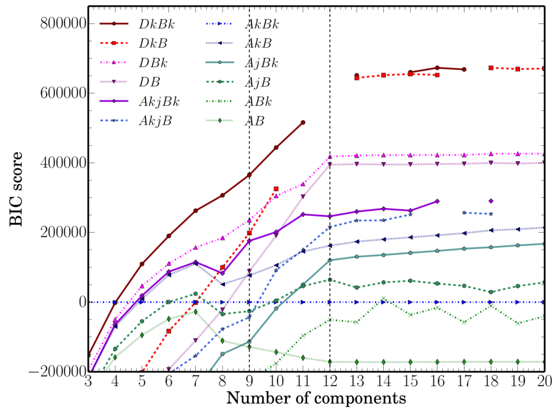
Unsupervised **Fisher Expectation-Maximisation** classification of VIPERS galaxies using a 13D feature space (rest-frame UV-optical-NIR colours, no direct spectroscopic information → zspec for absolute magnitudes).

classification if z~1, unsupervised Fisher Expectation-Maximisation method

How many galaxy populations can be blindly selected at z~1?

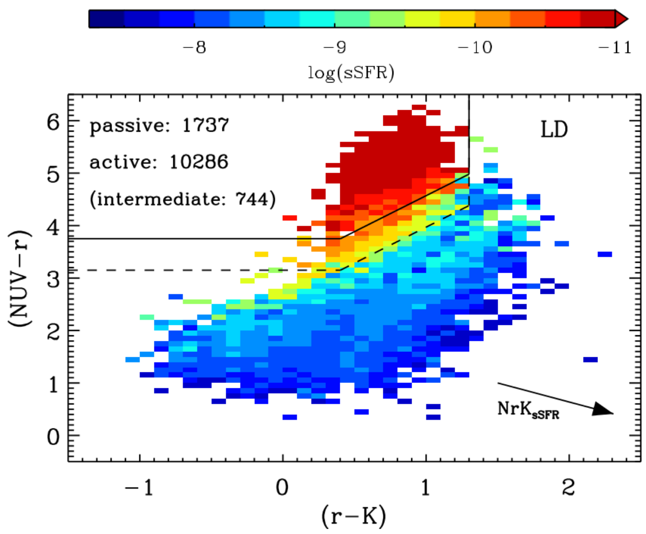




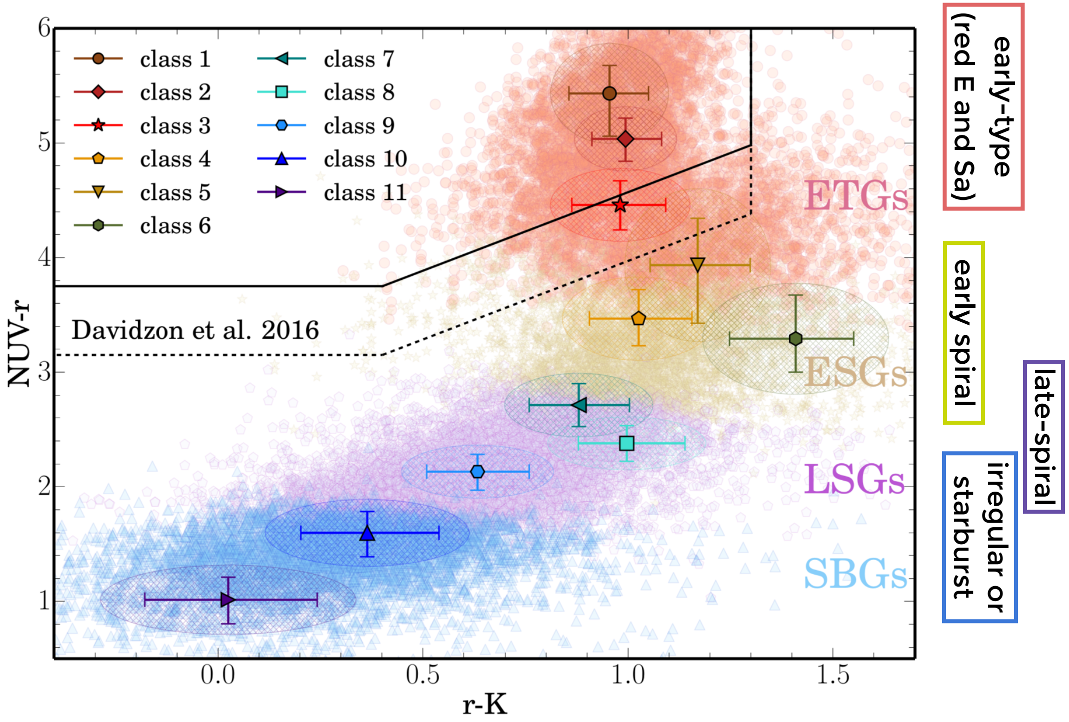


Siudek,KM,Pollo et al. 2013

11 subclasses well separated in a multidimensional photometric space.



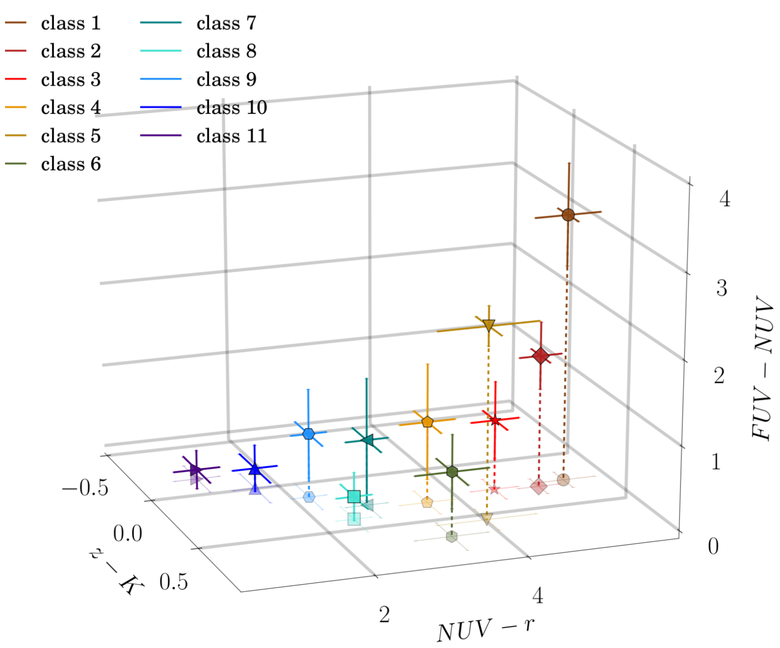
Davidzon et al. 2013

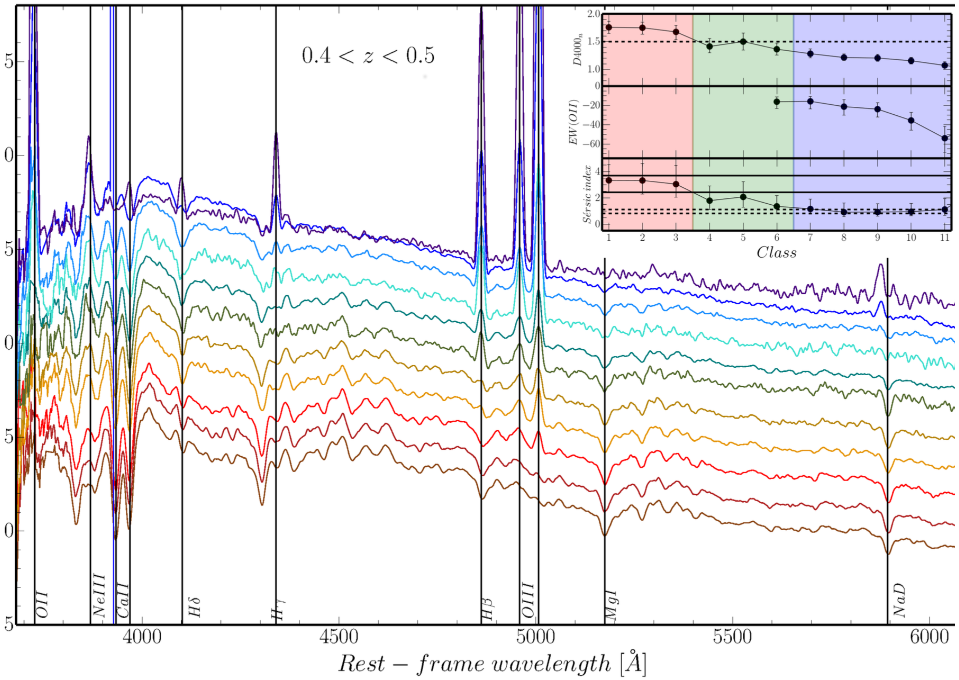


Siudek,KM,Pollo et al. 2018, but also Turner et al. 2021 for z~0

classification if z~1, unsupervised Fisher Expectation-Maximisation method

Eleven subclasses well separated in a multiD **PHOTOMETRIC** and **SPECTROSCOPIC** space





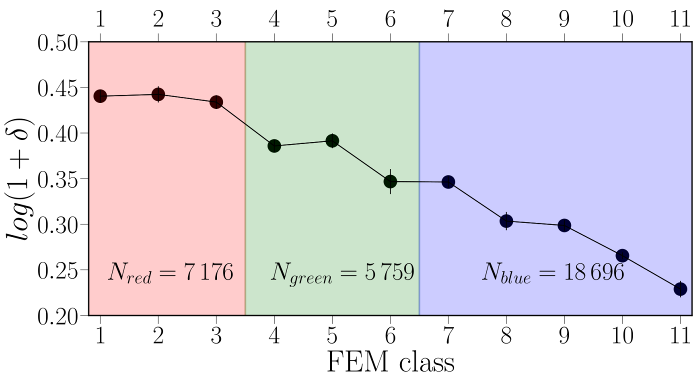
Siudek,KM,Pollo et al. 2018

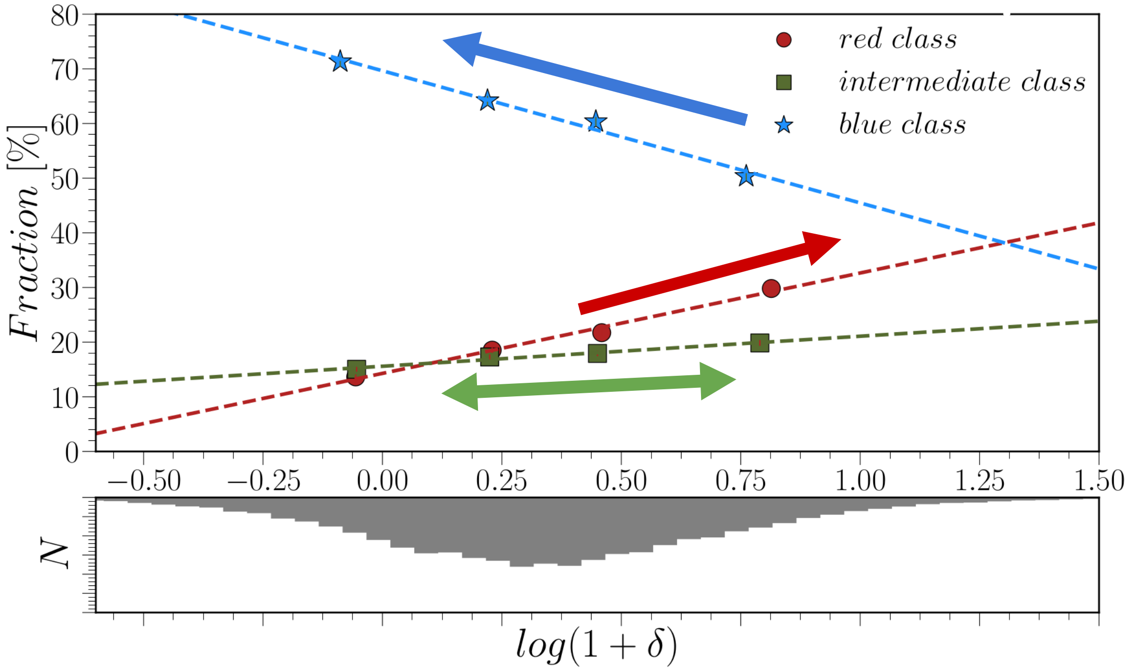
Subclasses of red/green/blue galaxies vs environment

Does the environment matter?

δ (local density contrast)
Cucciati et al. 2017):

- Volume-limited tracers $M_B < 20.4 - z$,
- cylinders (±1000km/s) and the radius (5th NN),
- scales between 2 and 6 Mpc/h.



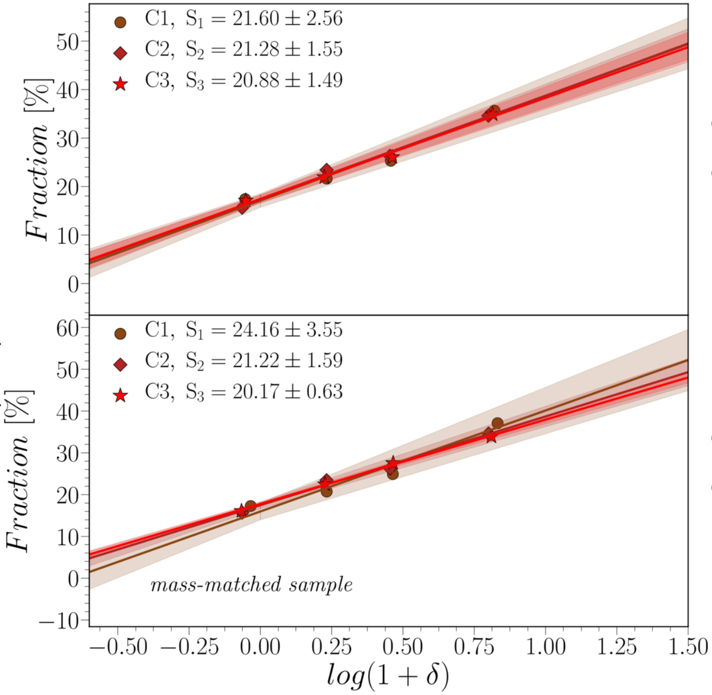


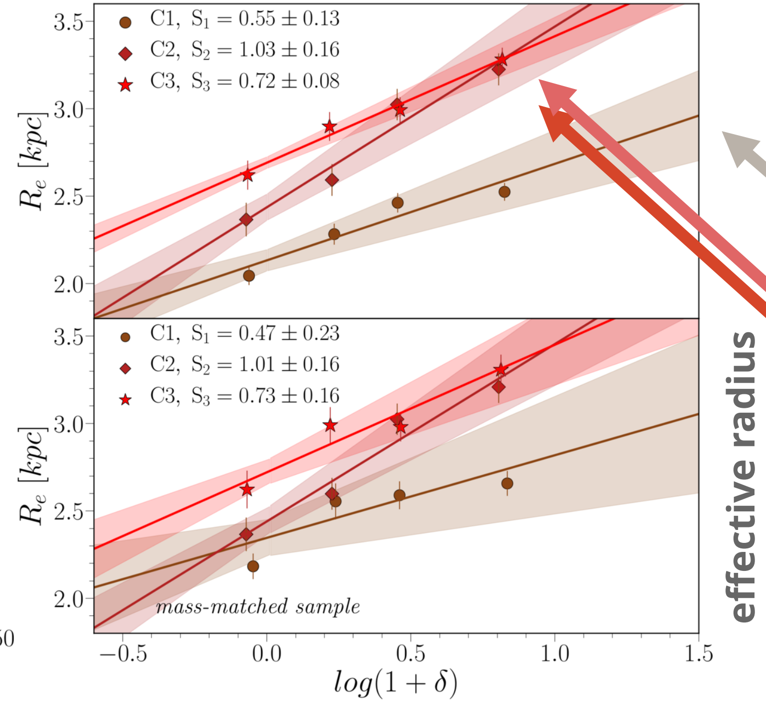
~32k galaxies involved in this study

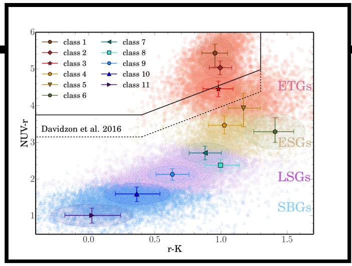
Siudek,KM,Pollo et al. 2022

Are all red subclasses similar?

Siudek,KM,Pollo et al. 2022







C1: compact independently or mass driven

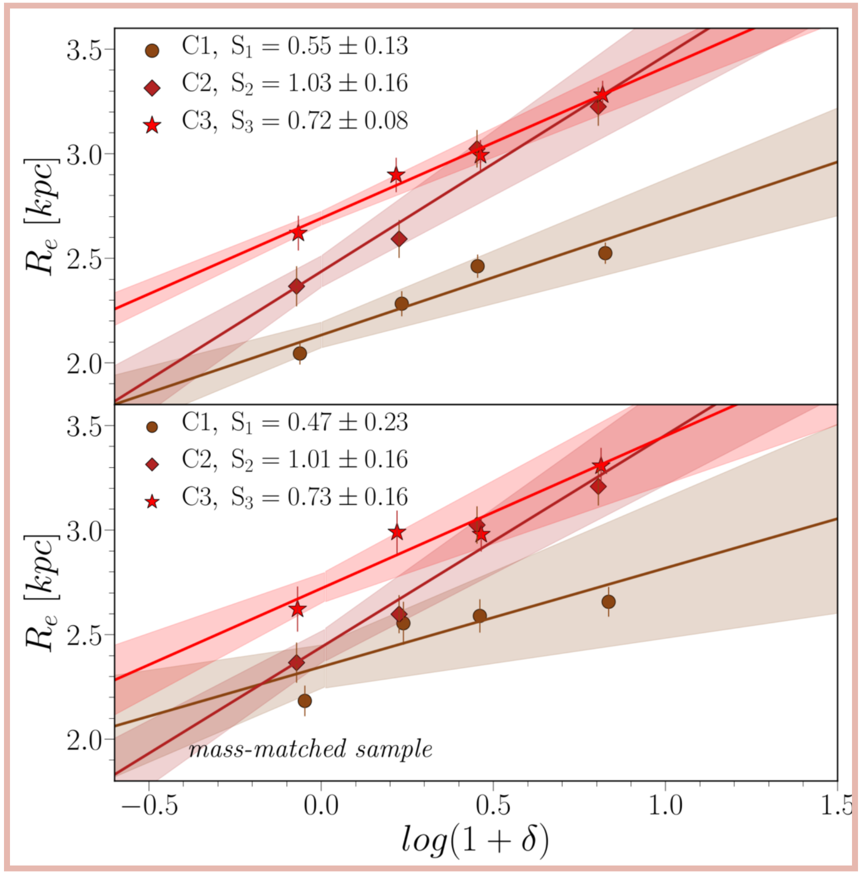
C2&C3 mass+enviroment-driven

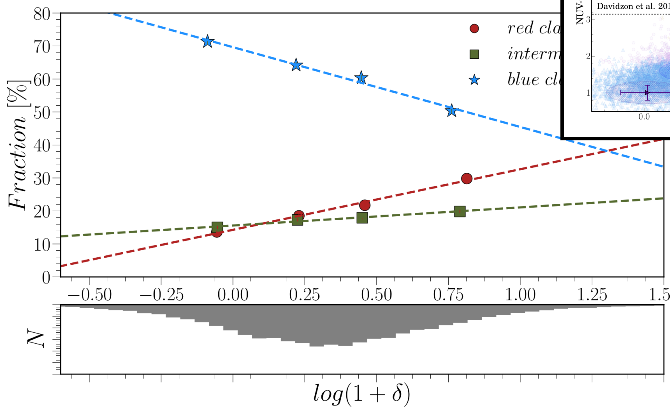
the same preference for denser environments, but:

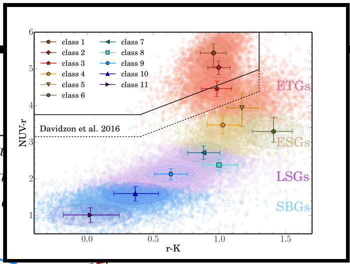
- their **sizes** differ and **correlate** with the local environment in different ways:
  - C3 suggests dry merger activity,
  - C1 quenched mostly as a result of internal processes.

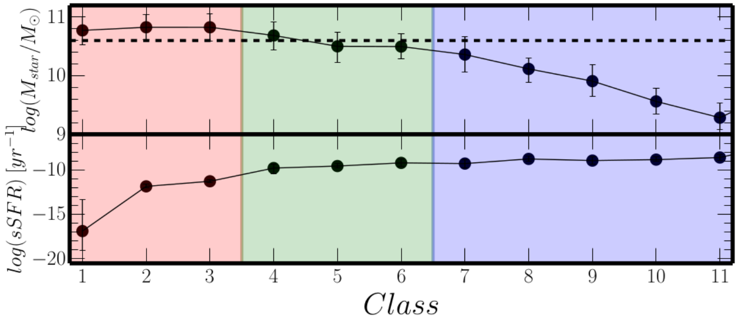
Are all red subclasses similar? NOT

Siudek,KM,Pollo et al. 2022



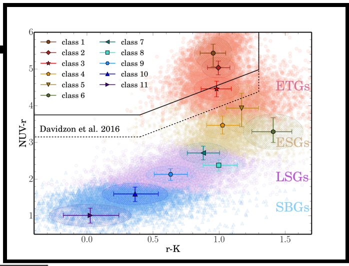




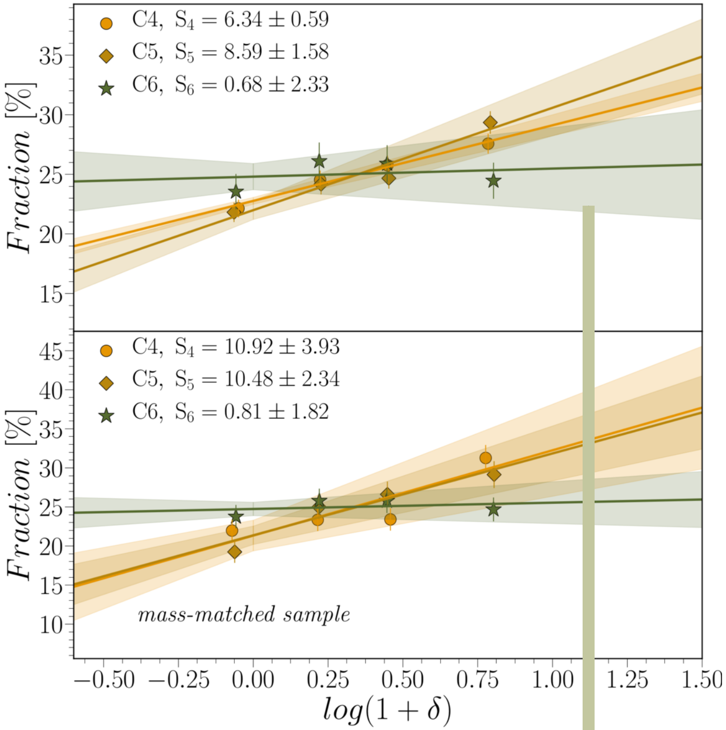


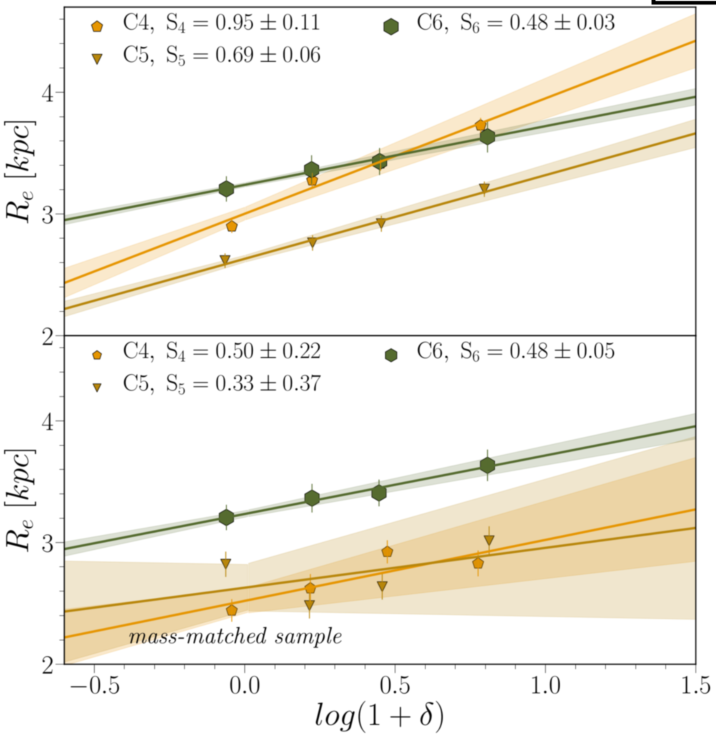
More about galaxies from C1/C2 classes you can find during Krzysztof Lisiecki talk (red nuggets at the intermediate *z*)

Are the green subclasses ~~similar~~ boring?



Siudek,KM,Pollo et al. 2022





only ~600 galaxies

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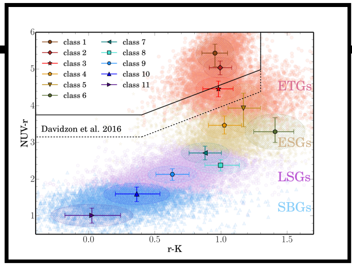
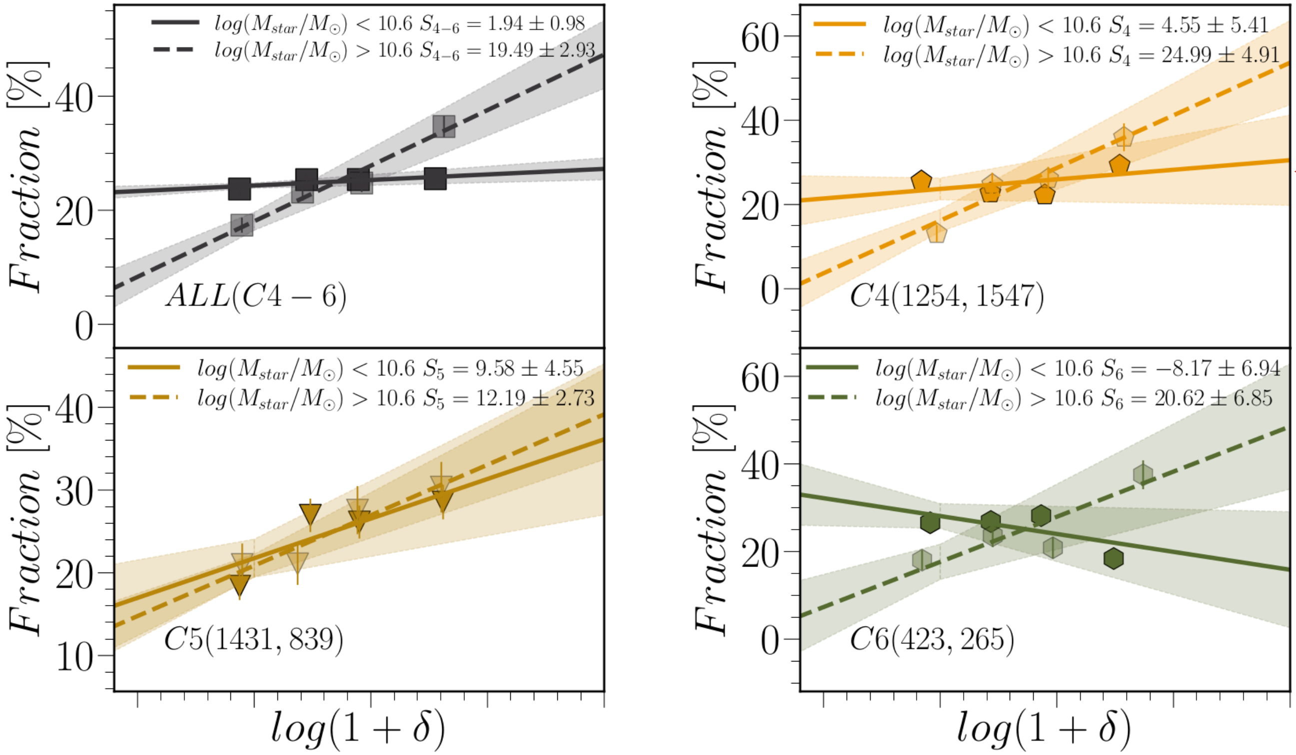
Are the green subclasses ~~similar~~ boring? NOT



Siudek,KM,Pollo et al. 2022



passive-like

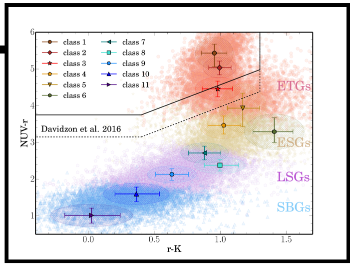
C4-C6:

low mass green galaxies behave like passive galaxies; high mass ones - are like active galaxies

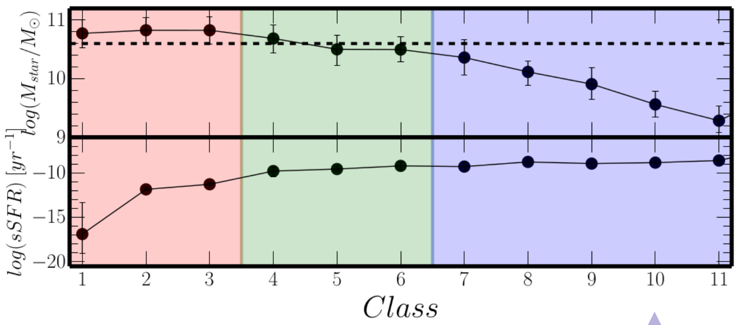
High-mass (log(Mstar/M)>10.6) green galaxies:

the positive fraction-density relation suggesting that environmental quenching is more important in the evolution of high-mass green galaxies.

Are all blue cloud galaxies similar?

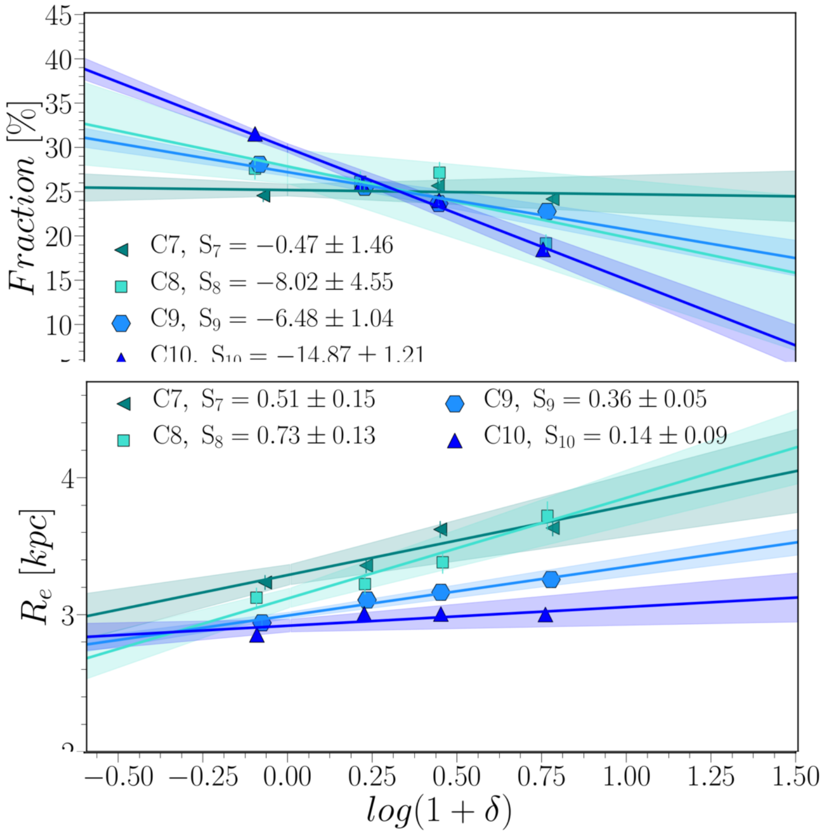


C10:
the smallest & the least massive follows the downsizing trend (slow accretion of surrounding gas)



~9200 galaxies

Siudek,KM,Pollo et al. 2022



The downsizing is driven mainly by class of the smallest and the least-massive galaxies (C10). The other blue subclasses may be a subject of a mixture of mass- & environment-driven evolution.

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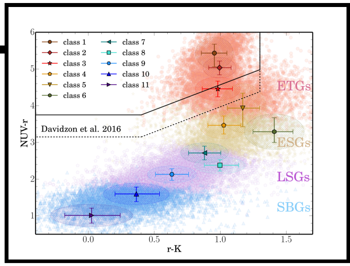
Are all blue cloud galaxies similar? Difficult to say ..



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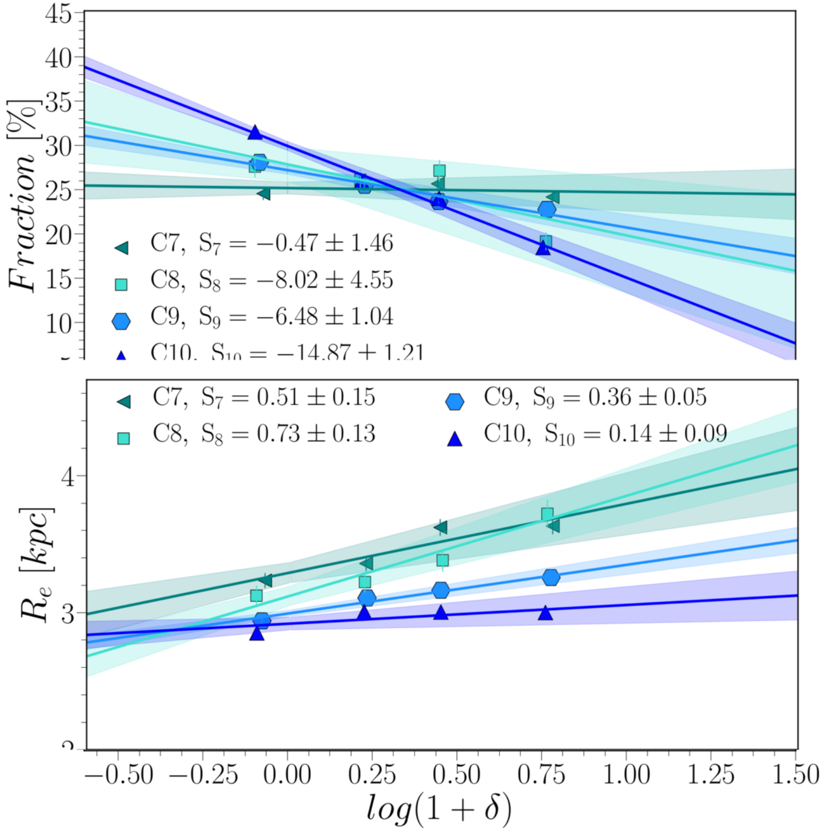
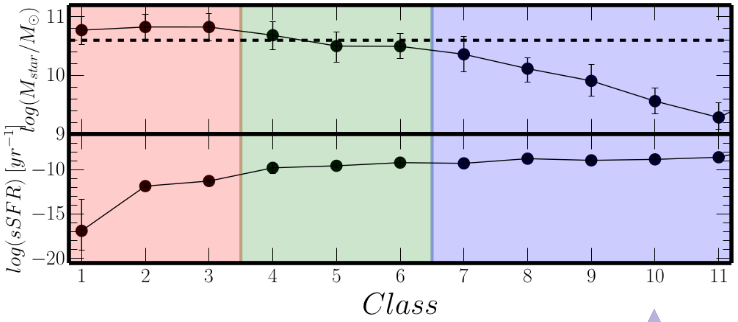
Siudek,KM,Pollo et al. 2022





~9200 galaxies

The downsizing is driven mainly by class of the smallest and the least-massive galaxies (C10). The other blue subclasses may be a subject of a mixture of mass- & environment-driven evolution.

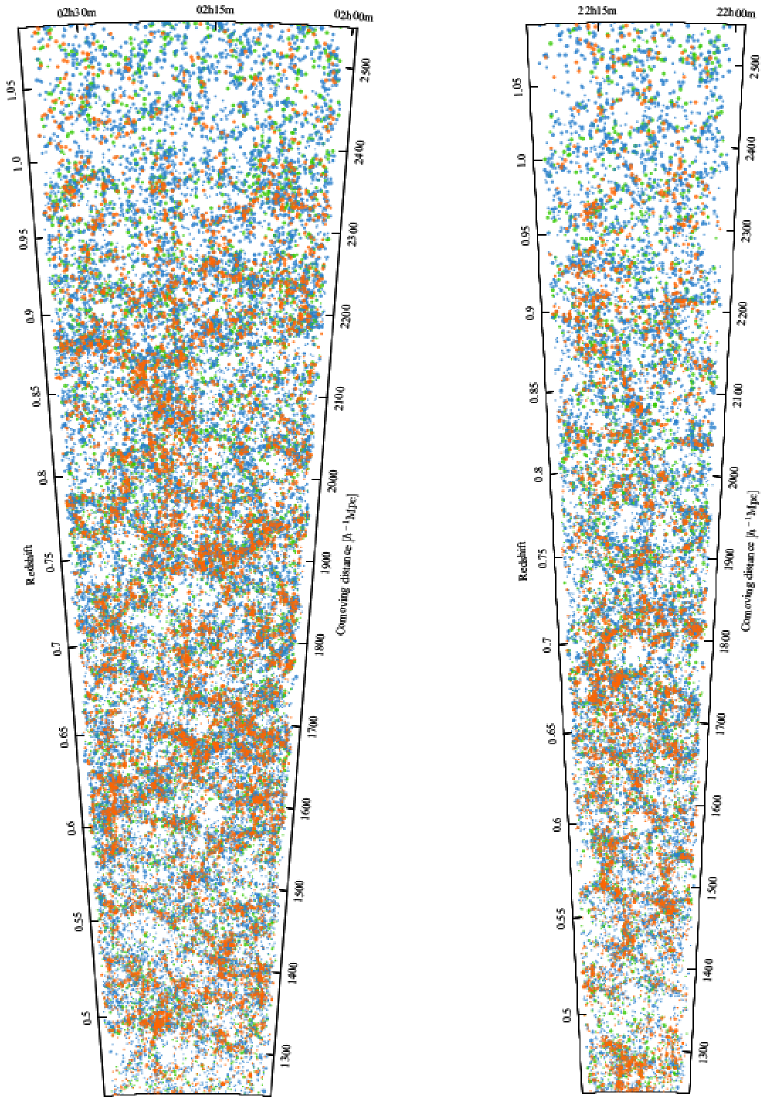
Does the environment matter? YES

Detailed FEM classification allows for deeper insight into the evolution-environment relations and environmental paths.

- **Red compact galaxies** are formed in-situ. Red large galaxies experienced merger processes,
- Strong dependence of **green galaxies** on the transition mass (for z~0.7 log(Mstar/M) = 10.6),
- The downsizing trend for **blue galaxies** is driven mostly by **one** blue subclass gathering the smallest and the least massive galaxies.

Siudek,KM,Pollo et al. 2022

Yes, the enviroment matters !



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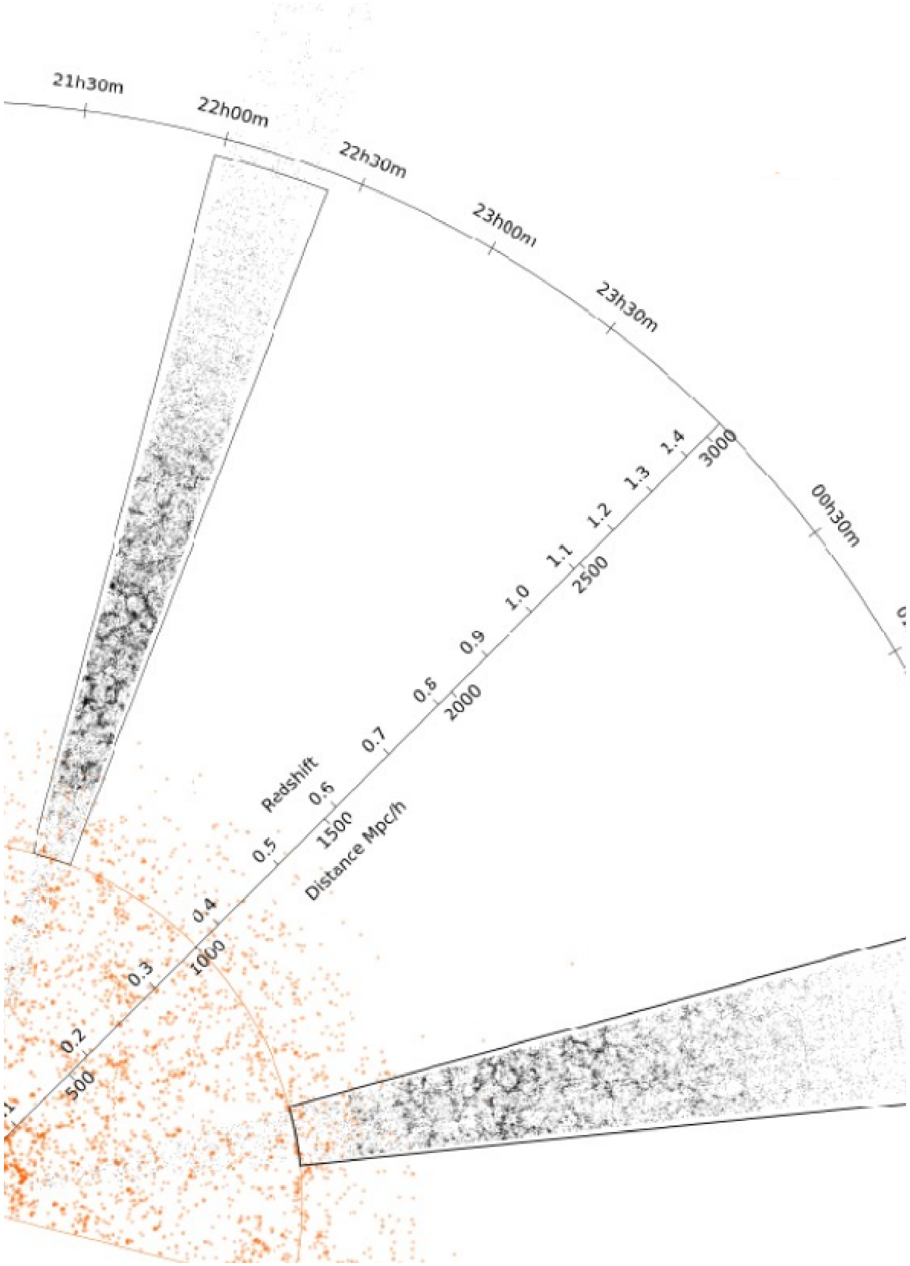
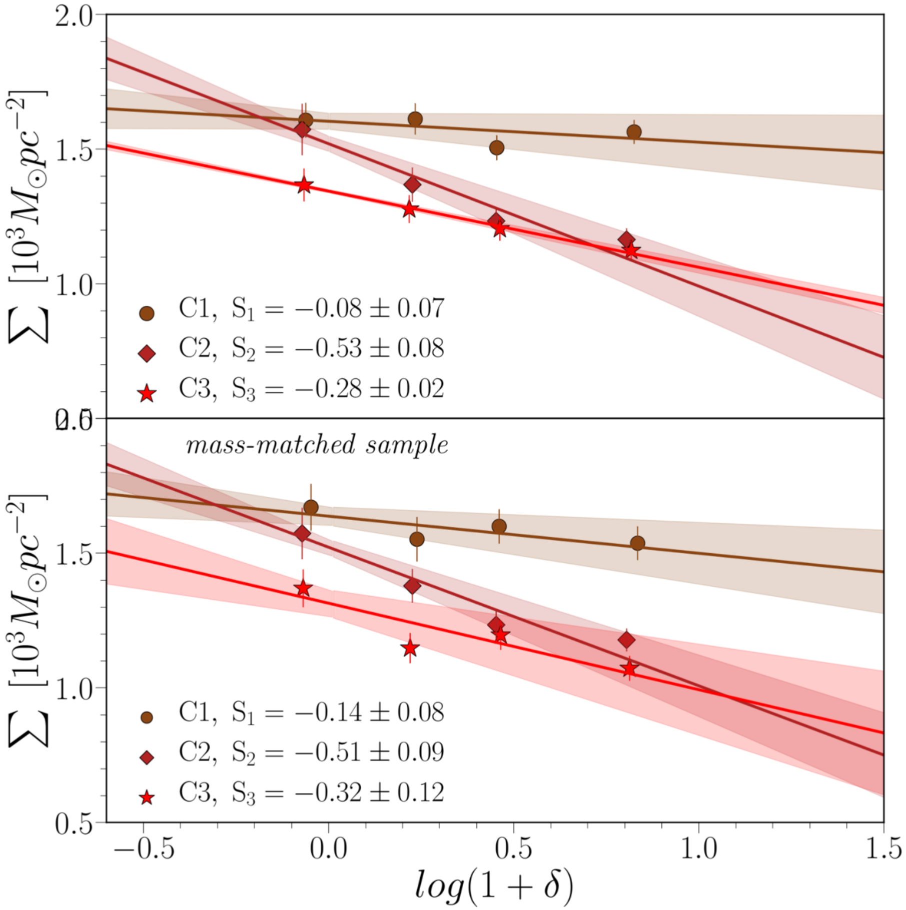
Thank you for your attention



main properties of the FEM classes

Cls	*N*	δ	log(sSFR)	log(M_{star})	R_e	*n*	*D*4000	*FUV−NUV*
C1	3061	$1.76^{+2.35}_{-1.18}$	$-16.88^{3.55}_{-2.16}$	$10.77^{0.21}_{-0.24}$	$2.38^{+1.33}_{-0.77}$	$3.37^{+1.19}_{-0.97}$	$1.76^{+0.10}_{-0.10}$	$3.16^{0.40}_{-0.45}$
C2	1637	$1.77^{+2.32}_{-1.11}$	$-11.85^{0.29}_{-0.14}$	$10.81^{0.21}_{-0.21}$	$2.91^{+1.36}_{-1.08}$	$3.29^{+1.31}_{-1.05}$	$1.74^{+0.10}_{-0.11}$	$1.60^{0.24}_{-0.22}$
C3	2478	$1.72^{+2.21}_{-1.17}$	$-11.28^{0.37}_{-0.16}$	$10.81^{0.23}_{-0.23}$	$3.00^{+1.29}_{-1.03}$	$3.02^{+1.49}_{-0.97}$	$1.67^{+0.12}_{-0.13}$	$0.83^{0.45}_{-0.27}$
C1–3	7176	$1.75^{+2.29}_{-1.16}$	$-11.99^{0.66}_{-4.45}$	$10.79^{0.22}_{-0.22}$	$2.68^{+1.39}_{-0.92}$	$3.25^{+1.32}_{-1.00}$	$1.73^{+0.10}_{-0.12}$	$1.74^{1.31}_{-0.70}$
C4	2801	$1.43^{+2.00}_{-1.02}$	$-9.73^{0.44}_{-0.63}$	$10.65^{0.22}_{-0.22}$	$3.37^{+1.16}_{-0.96}$	$1.76^{+1.08}_{-0.67}$	$1.41^{+0.14}_{-0.11}$	$1.02^{0.42}_{-0.58}$
C5	2270	$1.46^{+2.09}_{-1.09}$	$-9.57^{0.33}_{-0.17}$	$10.49^{0.22}_{-0.26}$	$2.90^{+1.12}_{-0.86}$	$2.03^{+1.17}_{-0.74}$	$1.49^{+0.16}_{-0.15}$	$2.28^{0.11}_{-0.28}$
C6	688	$1.22^{1.79}_{-0.93}$	$-9.21^{0.38}_{-0.35}$	$10.50^{0.21}_{-0.20}$	$3.77^{+1.26}_{-1.01}$	$1.35^{+0.85}_{-0.51}$	$1.36^{+0.11}_{-0.10}$	$0.71^{0.27}_{-0.45}$
C4–6	5759	$1.42^{2.00}_{-1.04}$	$-9.57^{0.36}_{-0.27}$	$10.57^{0.23}_{-0.24}$	$3.25^{+1.27}_{-0.98}$	$1.77^{+0.98}_{-0.66}$	$1.43^{+0.16}_{-0.12}$	$1.44^{0.80}_{-0.76}$
C7	3281	$1.22^{1.67}_{-0.96}$	$-9.23^{0.44}_{-0.49}$	$10.33^{0.29}_{-0.28}$	$3.48^{+1.19}_{-0.93}$	$1.11^{+0.72}_{-0.38}$	$1.28^{+0.08}_{-0.07}$	$0.79^{+0.55}_{-0.50}$
C8	1203	$1.01^{1.39}_{-0.85}$	$-8.77^{0.27}_{-0.29}$	$10.08^{0.20}_{-0.21}$	$3.32^{+0.93}_{-0.84}$	$0.89^{+0.66}_{-0.31}$	$1.22^{+0.06}_{-0.05}$	$0.21^{+0.16}_{-0.15}$
C9	3468	$0.99^{1.55}_{-0.83}$	$-8.94^{0.37}_{-0.38}$	$9.88^{0.25}_{-0.23}$	$3.11^{+1.09}_{-0.85}$	$0.90^{+0.62}_{-0.28}$	$1.21^{+0.06}_{-0.05}$	$0.78^{+0.28}_{-0.49}$
C10	9207	$0.84^{1.36}_{-0.77}$	$-8.87^{0.30}_{-0.19}$	$9.56^{0.20}_{-0.19}$	$2.96^{+0.90}_{-0.81}$	$0.92^{+0.60}_{-0.30}$	$1.16^{+0.06}_{-0.05}$	$0.21^{+0.26}_{-0.14}$
C11	1537	$0.69^{1.31}_{-0.71}$	$-8.76^{0.37}_{-0.21}$	$9.22^{0.17}_{-0.15}$	$2.51^{+0.96}_{-0.81}$	$1.10^{+0.80}_{-0.45}$	$1.08^{+0.07}_{-0.06}$	$0.07^{+0.19}_{-0.12}$
C7–11	18696	$0.93^{1.44}_{-0.81}$	$-8.93^{0.36}_{-0.29}$	$9.72^{0.34}_{-0.28}$	$3.06^{+0.99}_{-0.84}$	$0.94^{+0.56}_{-0.30}$	$1.18^{+0.07}_{-0.06}$	$0.30^{+0.47}_{-0.21}$


2.0
1.5
1.0
0.5
$\sum \; [10^3 M_\odot pc^{-2}]$
C1, $S_1 = -0.08 \pm 0.07$
C2, $S_2 = -0.53 \pm 0.08$
C3, $S_3 = -0.28 \pm 0.02$
mass-matched sample
C1, $S_1 = -0.14 \pm 0.08$
C2, $S_2 = -0.51 \pm 0.09$
C3, $S_3 = -0.32 \pm 0.12$
−0.5
0.0
0.5
1.0
1.5
$log(1 + \delta)$

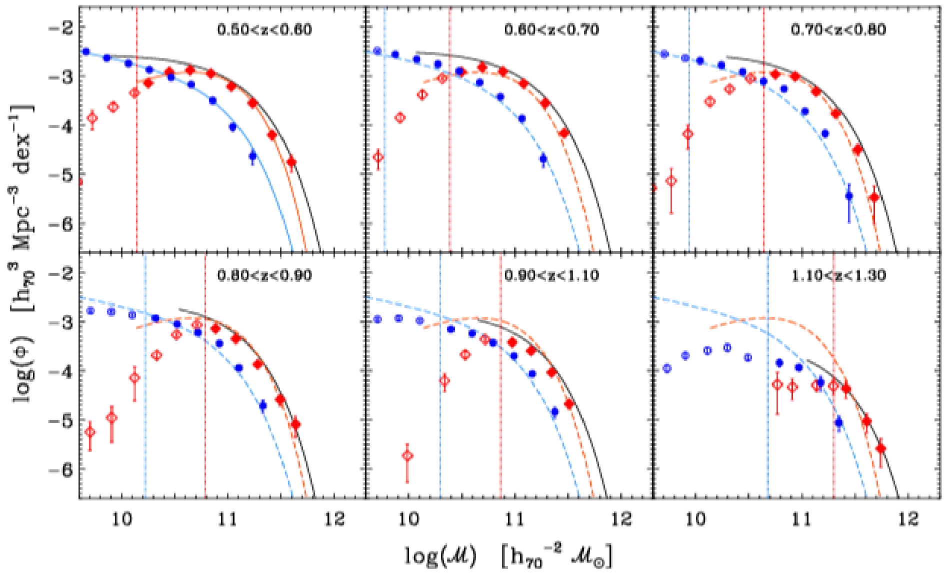
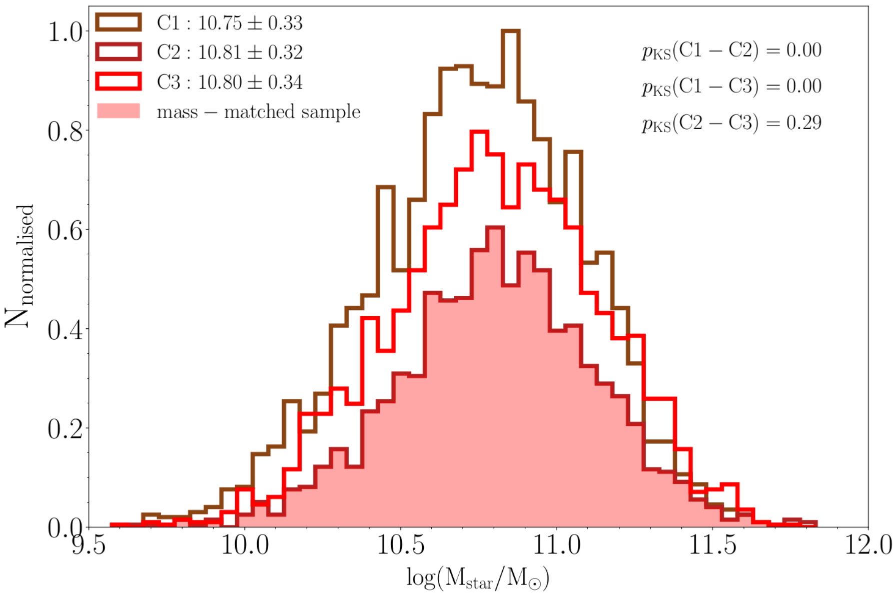
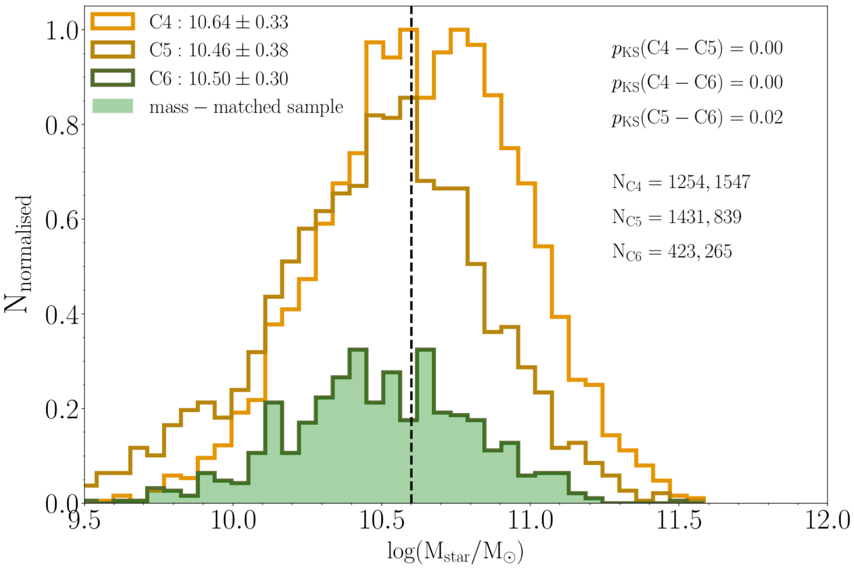
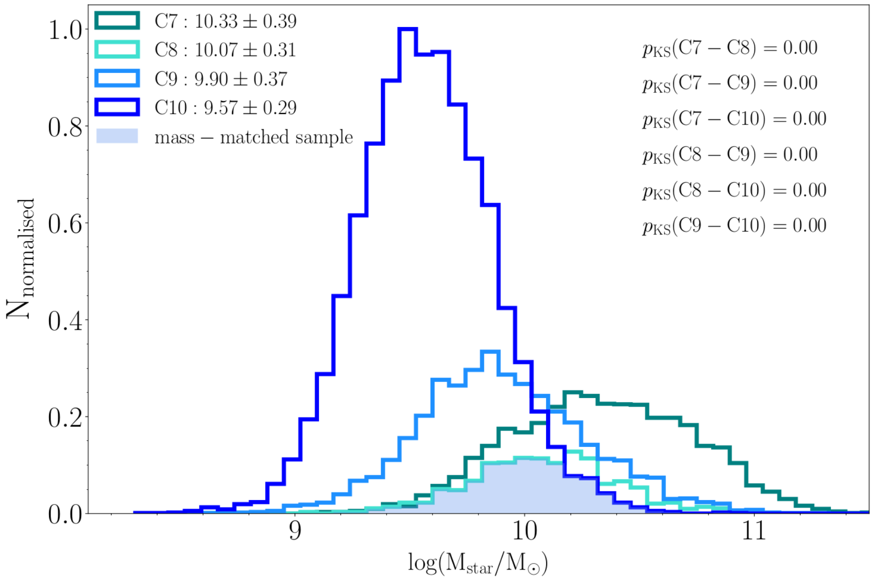


Fig. 12. Galaxy stellar mass functions of the blue and red populations in VIPERS, derived using the $1/V_{max}$. Symbols (circles and diamonds, respectively) are filled for data above the corresponding completeness limit $\mathcal{M}_{lim}$ (vertical lines) and empty below. Error bars account for Poisson noise alone. The Schechter fit of the two populations in the bin $0.5 < z < 0.6$ (solid blue and red lines) is reported for reference as a dashed line in the other panels. The solid black line in each panel gives the Schechter best fit to the whole VIPERS sample in that redshift bin.

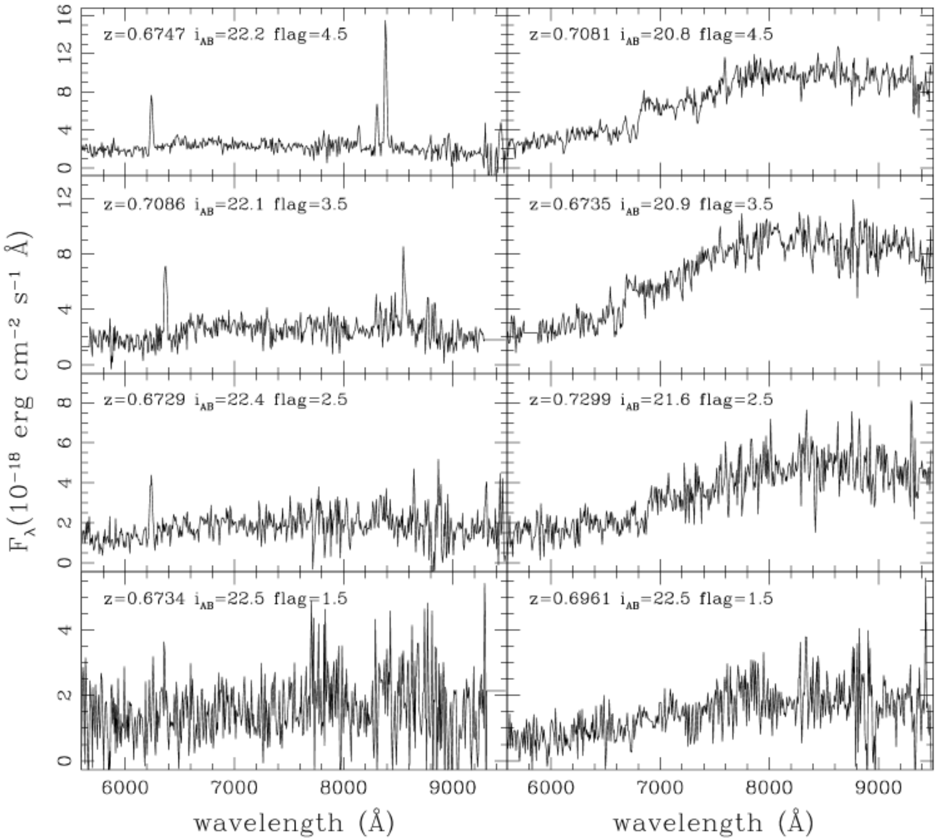
Davidzon et al. 2013

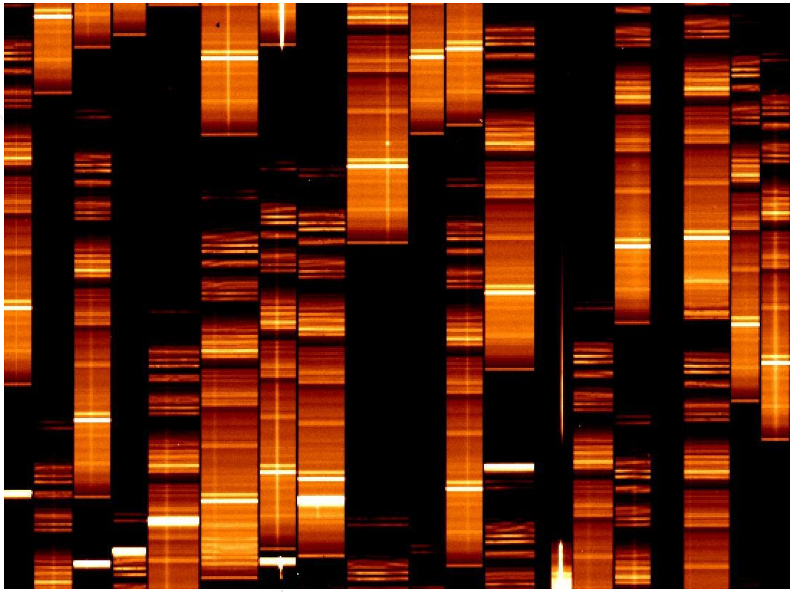

C1 : 10.75 ± 0.33
C2 : 10.81 ± 0.32
C3 : 10.80 ± 0.34
mass − matched sample
$p_{KS}(C1 - C2) = 0.00$
$p_{KS}(C1 - C3) = 0.00$
$p_{KS}(C2 - C3) = 0.29$
$N_{normalised}$
$\log(M_{star}/M_\odot)$


C4 : 10.64 ± 0.33
C5 : 10.46 ± 0.38
C6 : 10.50 ± 0.30
mass − matched sample
$p_{KS}(C4 - C5) = 0.00$
$p_{KS}(C4 - C6) = 0.00$
$p_{KS}(C5 - C6) = 0.02$
$N_{C4} = 1254, 1547$
$N_{C5} = 1431, 839$
$N_{C6} = 423, 265$
$N_{normalised}$
$\log(M_{star}/M_\odot)$


C7 : 10.33 ± 0.39
C8 : 10.07 ± 0.31
C9 : 9.90 ± 0.37
C10 : 9.57 ± 0.29
mass − matched sample
$p_{KS}(C7 - C8) = 0.00$
$p_{KS}(C7 - C9) = 0.00$
$p_{KS}(C7 - C10) = 0.00$
$p_{KS}(C8 - C9) = 0.00$
$p_{KS}(C8 - C10) = 0.00$
$p_{KS}(C9 - C10) = 0.00$
$N_{normalised}$
$\log(M_{star}/M_\odot)$

The spectra were collected by **VIMOS** spectrograph (LR Red grism, λ: 5,500-9,500 $\mathring{A}$, R~220).





Sccodeggio et al. 2016