Red nuggets of the almighty VIPERS

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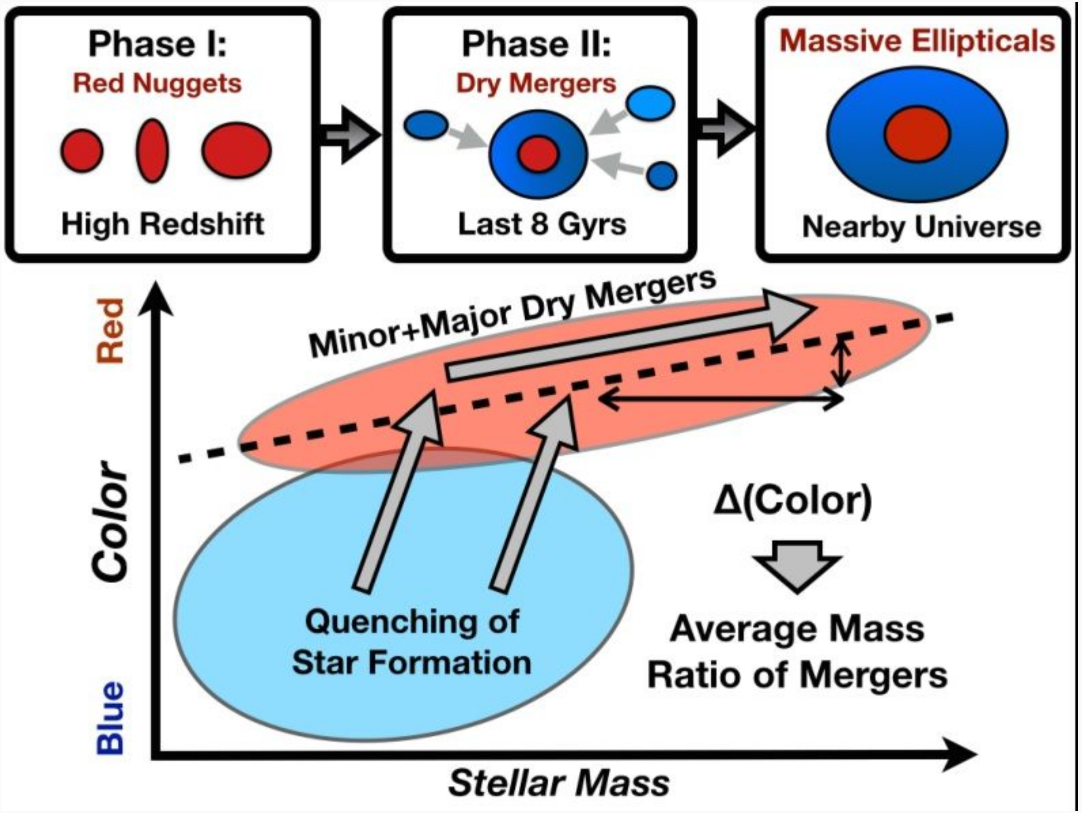
VIMOS PUBLIC EXTRAGALACTIC REDSHIFT SURVEY

NATIONAL SCIENCE CENTRE POLAND
NICOLAUS COPERNICUS UNIVERSITY IN TORUŃ
NATIONAL CENTRE FOR NUCLEAR RESEARCH ŚWIERK

What red nuggets really are?

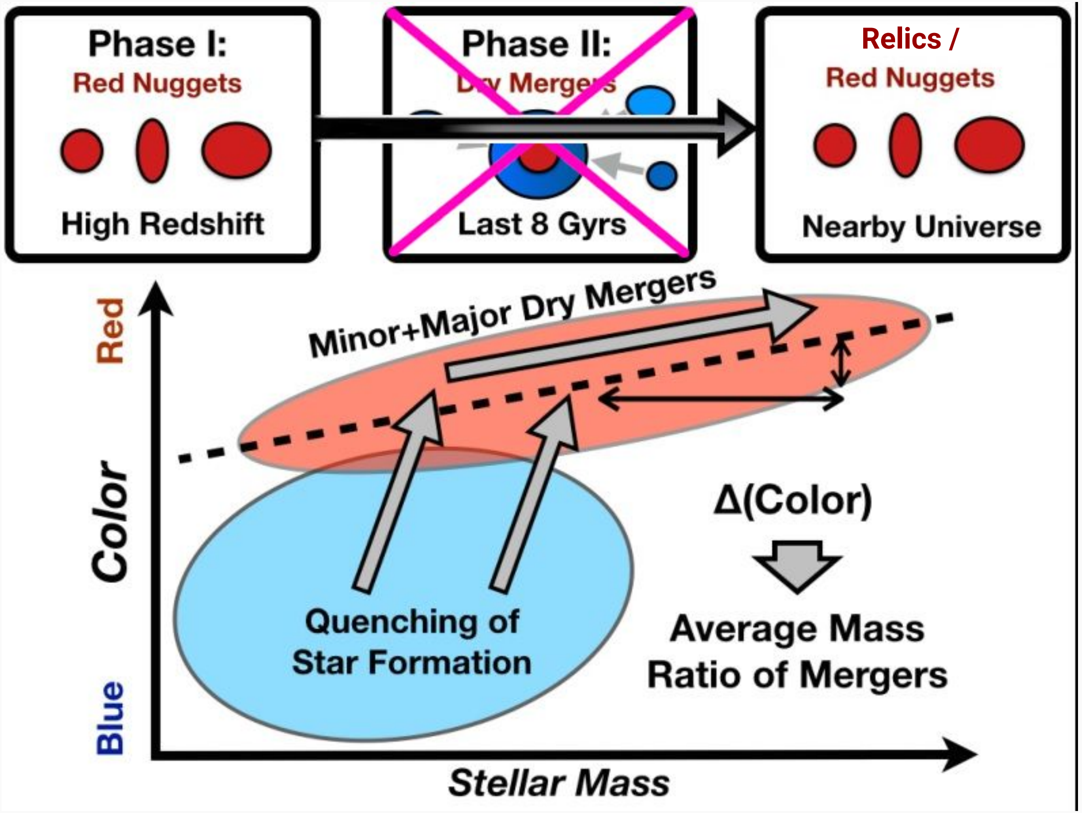
Red nuggets are a rare population of passive compact massive galaxies thought to be the first massive galaxies that formed in the Universe.



Source: Song Huang et. al 2016

What red nuggets really are?

But the mergers events are stochastic, so we can expect some of them in the local or at least closer Universe.

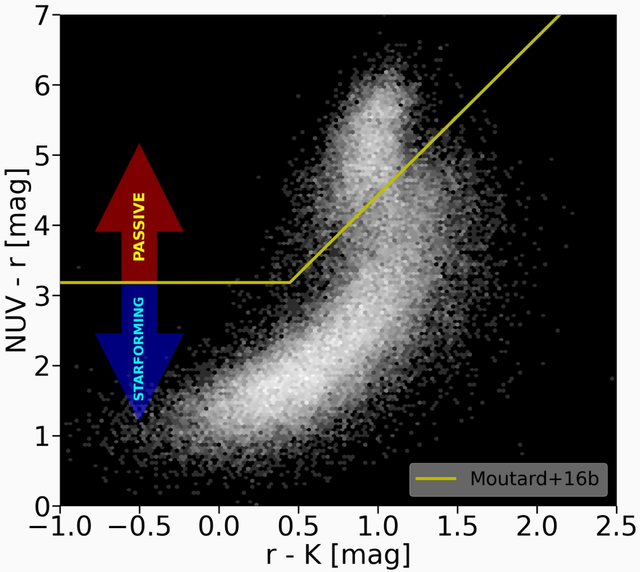


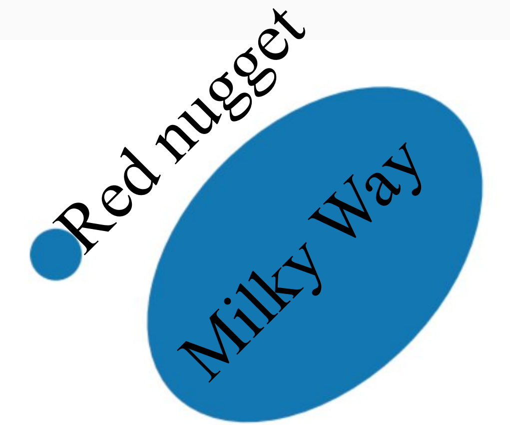
Source: Song Huang et. al 2016

Red nuggets: how to find them?

There are three things that determine red nugget:

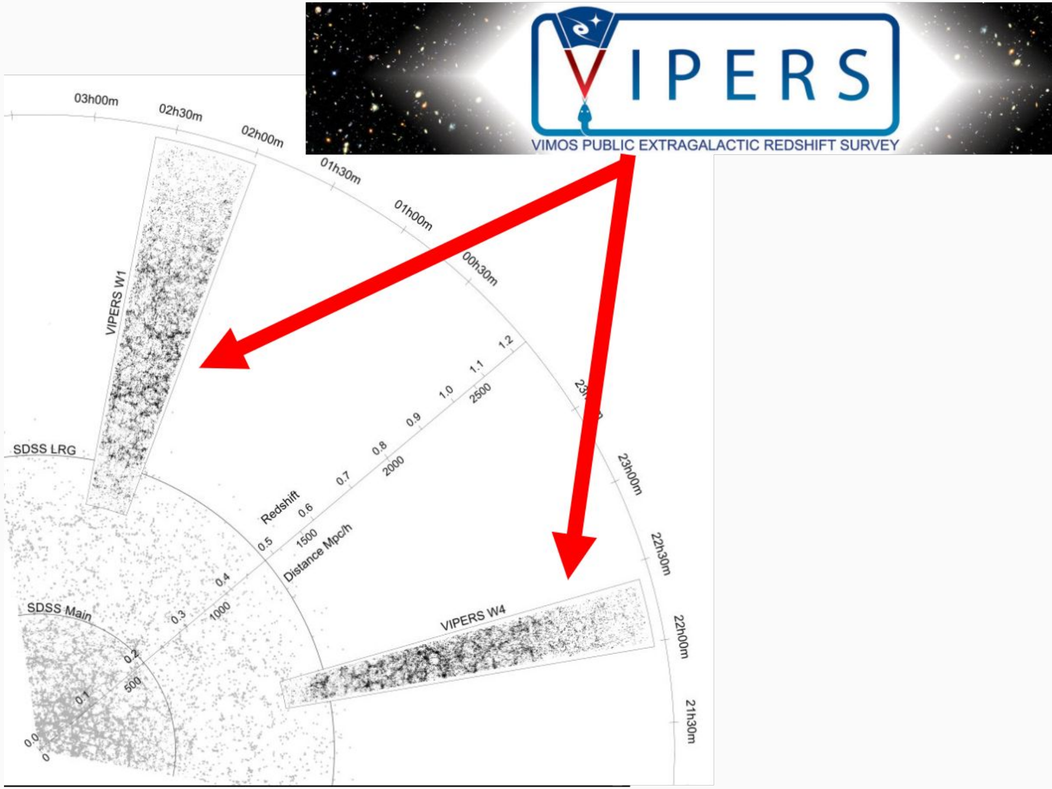
1. stellar mass higher than 10^{10}–10^{11} solar masses
2. size smaller than a few kpc
3. low star formation rate – passiveness





Almighty VIPERS: overview

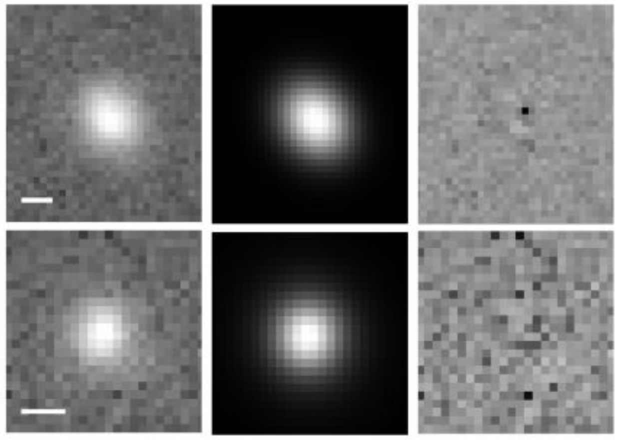
- ~90k spectroscopically measured galaxies;
- redshift range: 0.4 - 1.2;
- wavelength range: 450 - 950 nm;
- total area: 23.5 deg^2;

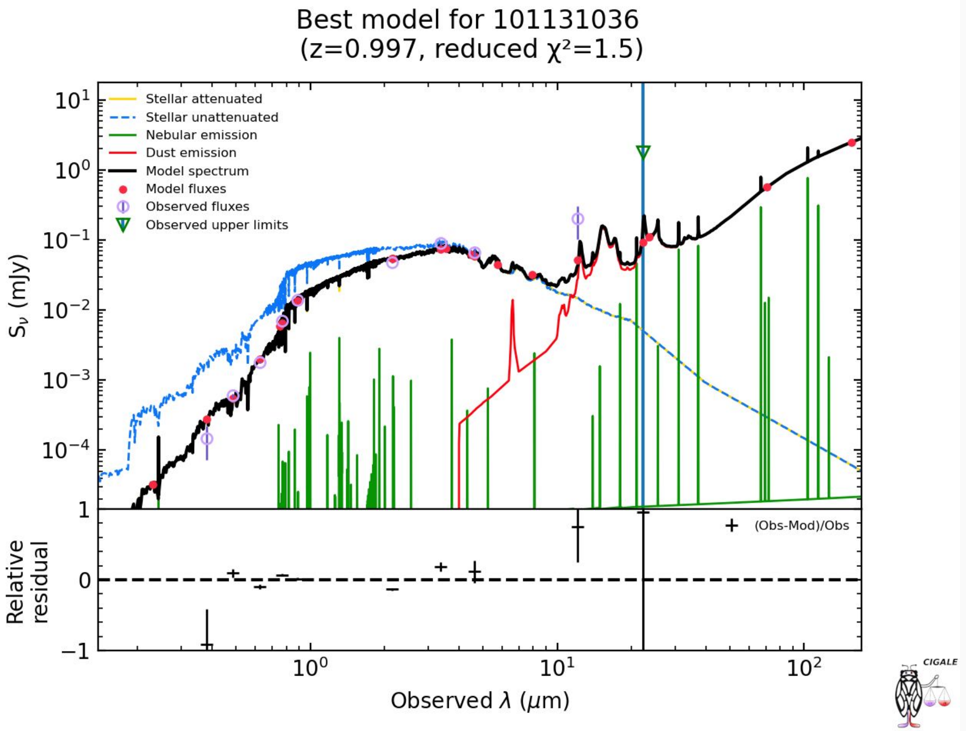


Almighty VIPERS: physical properties

To derive physical properties, in particular stellar masses and SFRs, we used the Code Investigating The Galaxy Emission (CIGALE).

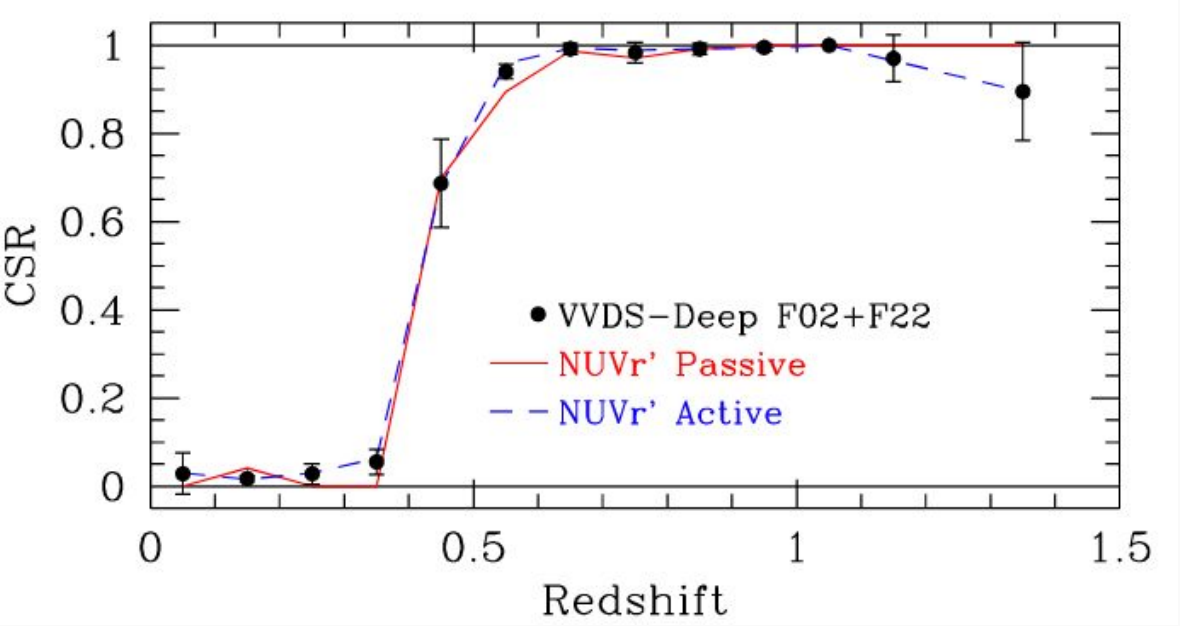
The morphological parameters were derived by Krywult et. al 2017.





Almighty VIPERS red nuggets selection: preselection

- 95% confidence in redshift estimation to ensure effective radii in kpc
- 0.5 < z < 1 to be complete in colour

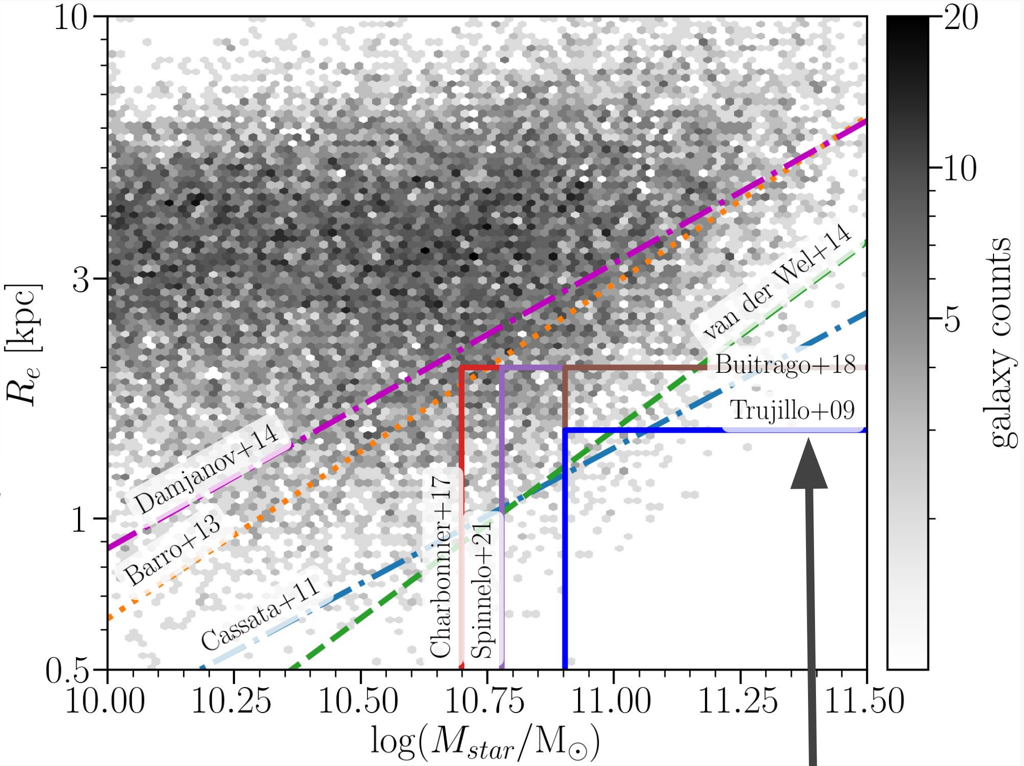


Fritz et al. 2014

Cut	Sample size
VIPERS database	91 507
$z_{flag} \in \{3, 4, 23, 24\}$	54 252
Redshift range $0.5 \leq z \leq 1$	44 145
R_e uncertainties	36 157

Almighty VIPERS red nuggets selection: compactness

As we wanted to be sure that we select only truly compact and massive sources, we decided to use one of the most restrictive criterion (Trujillo et. al 2009):



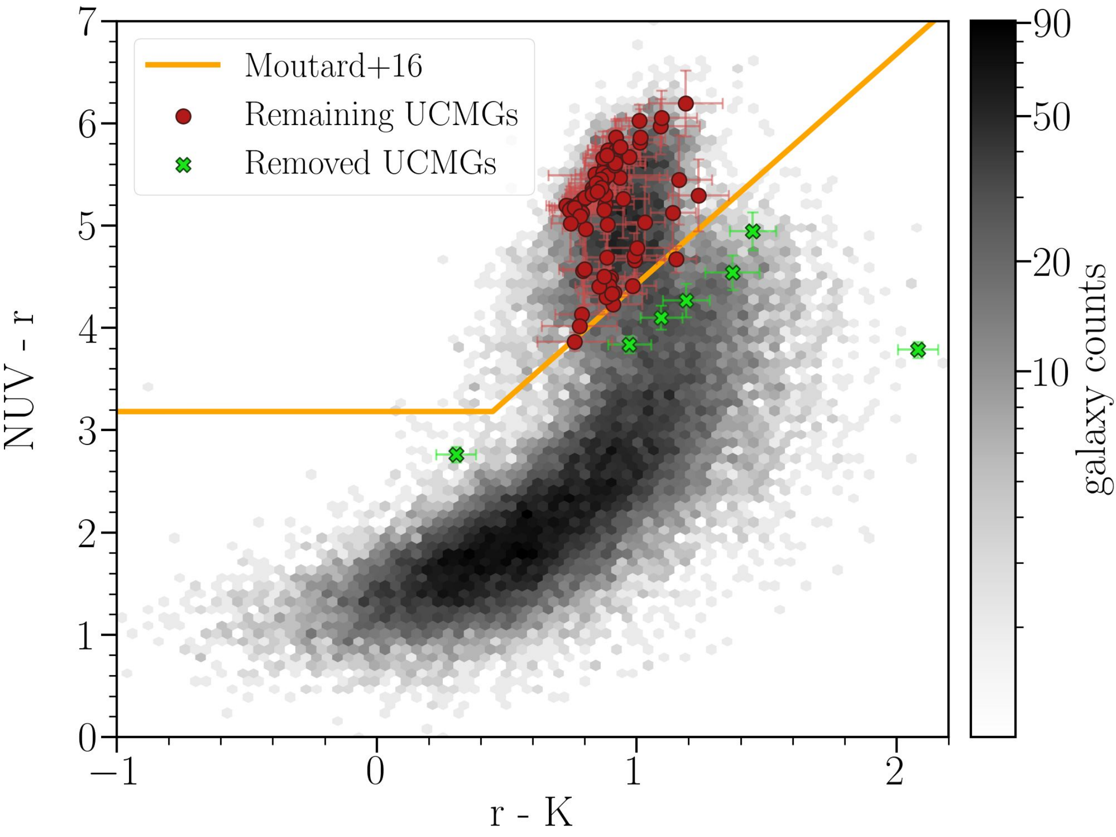
Reference	Number of sources
Damjanov et al. (2015)	4 347
Cassata et al. (2011) – compact	3 139
Barro et al. (2013)	3 083
van der Wel et al. (2014) – compact	1 801
Charbonnier et al. (2017)	1 061
Spiniello et al. (2021)	693
Buitrago et al. (2018)	277
Cassata et al. (2011) – ultracompact	250
van der Wel et al. (2014) – ultracompact	241
Trujillo et al. (2009)	86

$M_{star} > 8 \times 10^{10} M_{\odot}$ and $R_e < 1.5$ kpc

Almighty VIPERS red nuggets selection: passiveness

We performed multistage selection based on colours, emission lines, and visual check.

NUVrK diagram is widely used by VIPERS team to separate red and blue galaxy populations.



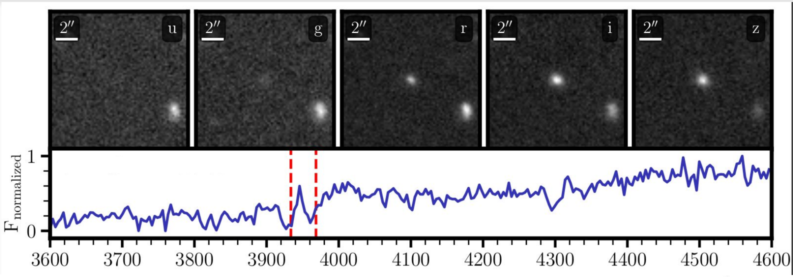
Lisiecki et al. submitted

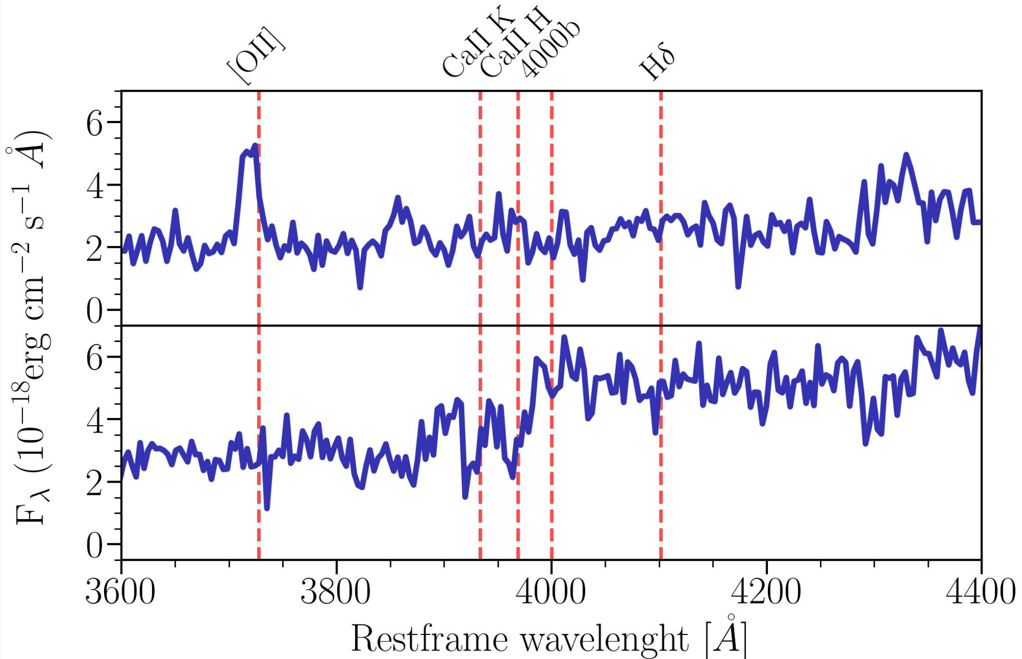
Almighty VIPERS red nuggets selection: passiveness II

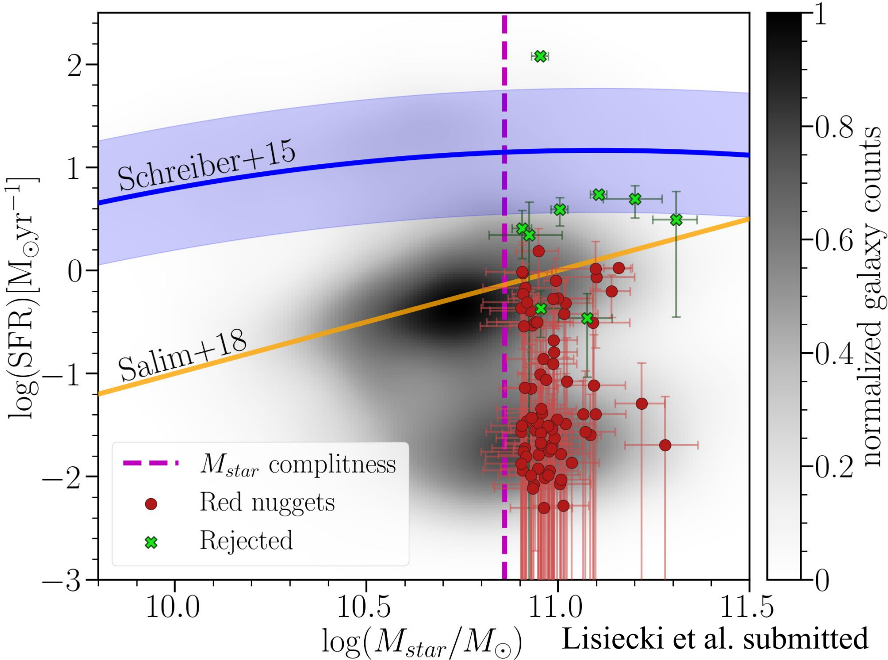
VIPERS red nugget →

Main sequence ↘

Passive/active spectra↓







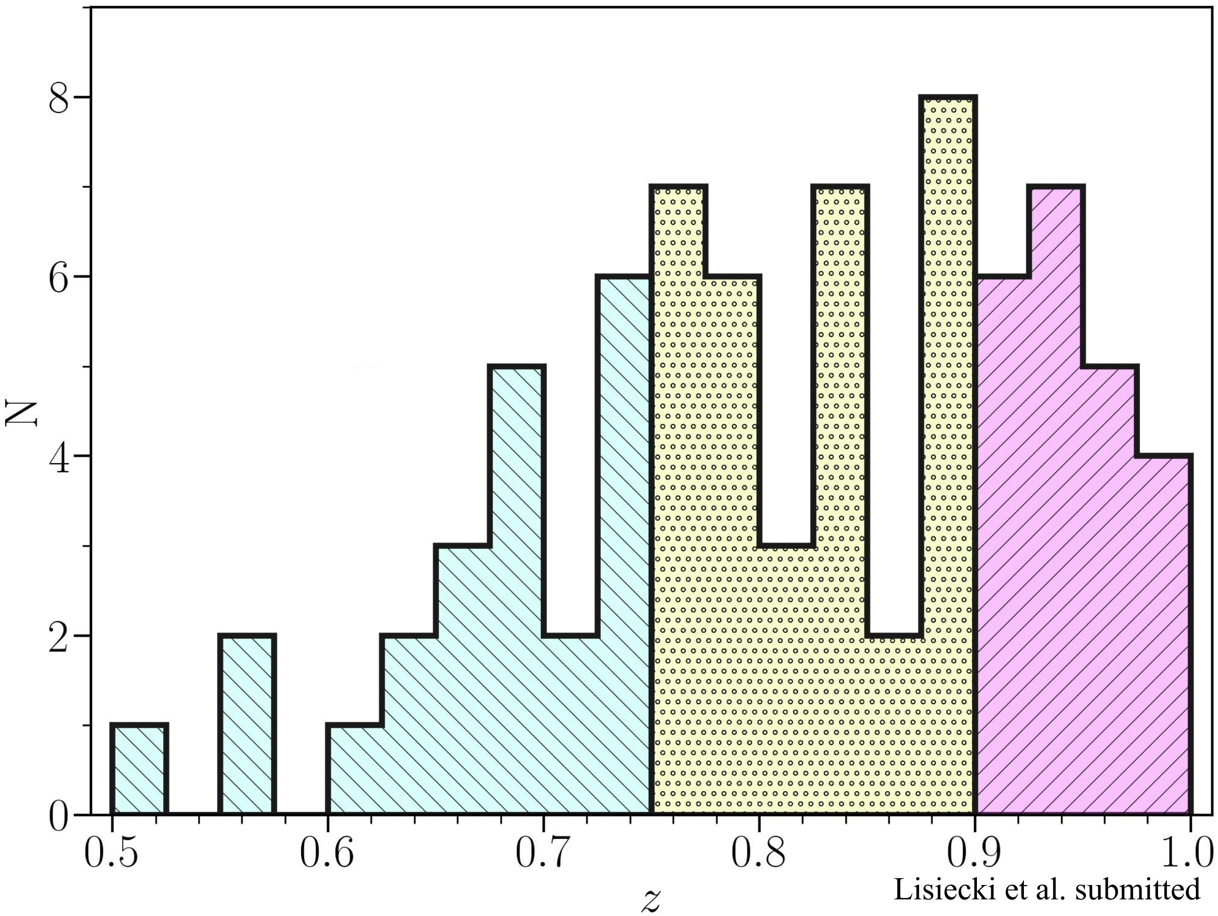
Lisiecki et al. submitted

Almighty VIPERS red nuggets catalogue

We established the first spectroscopic catalogue of red nuggets at z 0.5-1. In total 77 sources, which is the largest spec-z sample above z ~ 0.5.

Divided them into three redshift bins:

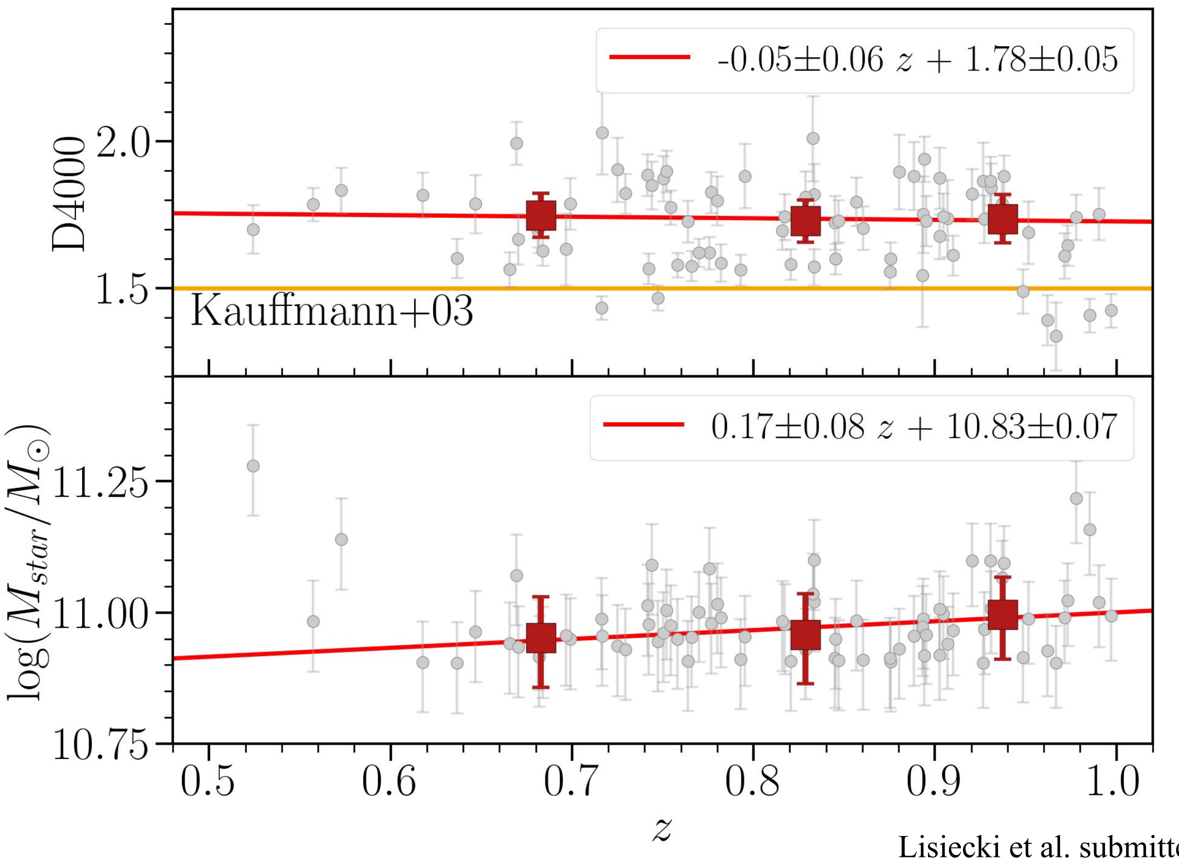
Redshift range	N
$0.50 \leq z \leq 0.75$	22
$0.75 < z \leq 0.90$	33
$0.90 < z \leq 1.00$	22
$0.50 \leq z \leq 1.00$	77



Lisiecki et al. submitted

Almighty VIPERS red nuggets catalogue: D4000 and masses

A few sources have D4000 at lower level than the passiveness limit proposed by Kauffmann et al. 2003, but this limit was found in the local Universe.



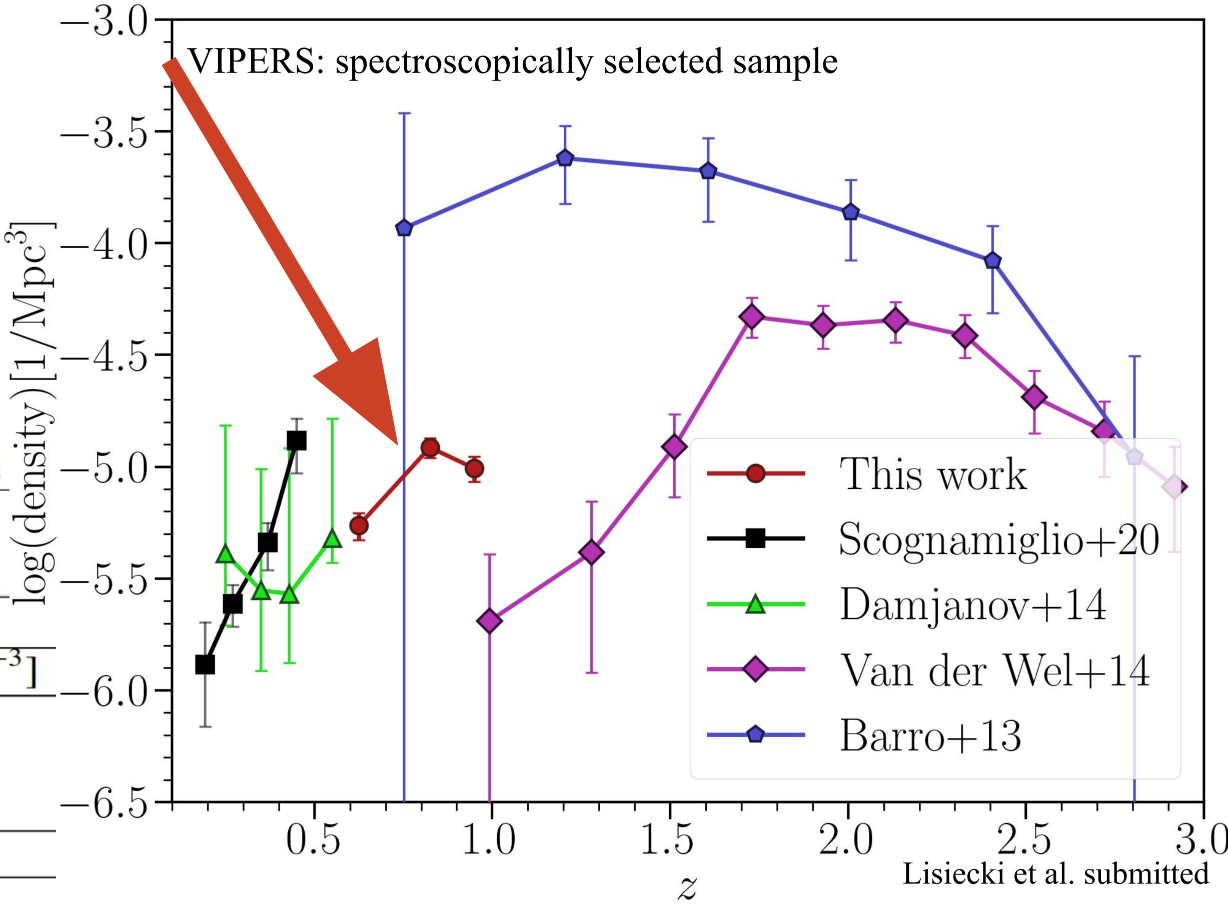
Lisiecki et al. submitted

Almighty VIPERS red nuggets catalogue: number densities

Calculated number densities per cubic comoving Mpc are in agreement with low-z measurements but not so much with high-z.

Reference	Number of sources
Barro et al. (2013)	3 083
van der Wel et al. (2014) – ultracompact	241
Tortora et al. (2016)	86

Redshift range	Number density [Mpc^{-3}]
$0.50 \leq z \leq 0.75$	5.46×10^{-6}
$0.75 < z \leq 0.90$	1.22×10^{-5}
$0.90 < z \leq 1.00$	9.82×10^{-6}
$0.50 \leq z \leq 1.00$	8.86×10^{-6}



Lisiecki et al. submitted

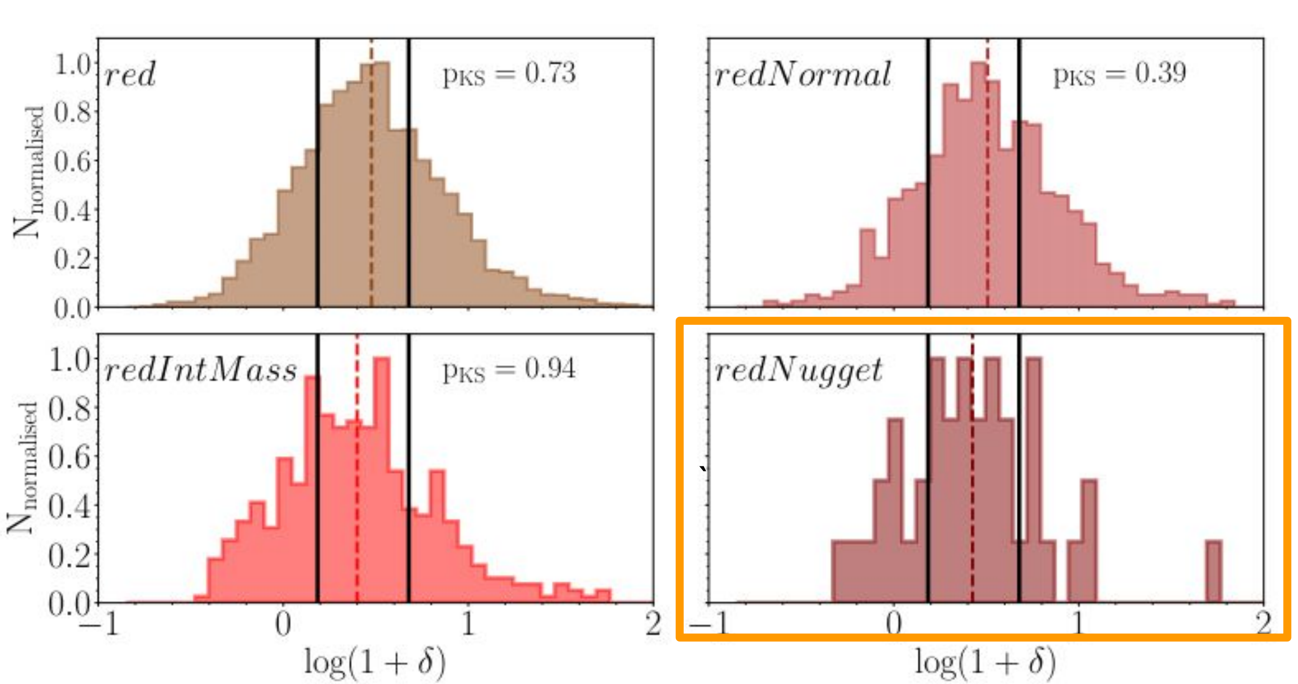
Almighty VIPERS red nuggets catalogue: environments

To characterize the environments of red nuggets, we generated three control samples.

All red VIPERS galaxies

Similar mass larger size

Similar size smaller mass



Red nuggets

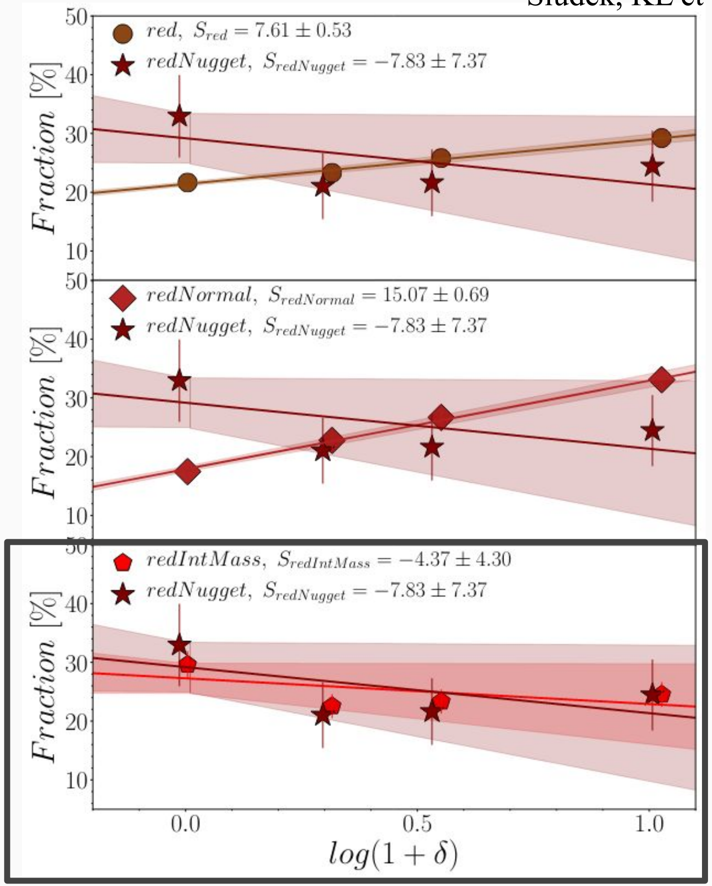
Siudek, KL et al. (almost) submitted

Siudek, KL et al. (almost) submitted

Red nuggets do not have environmental preferences.

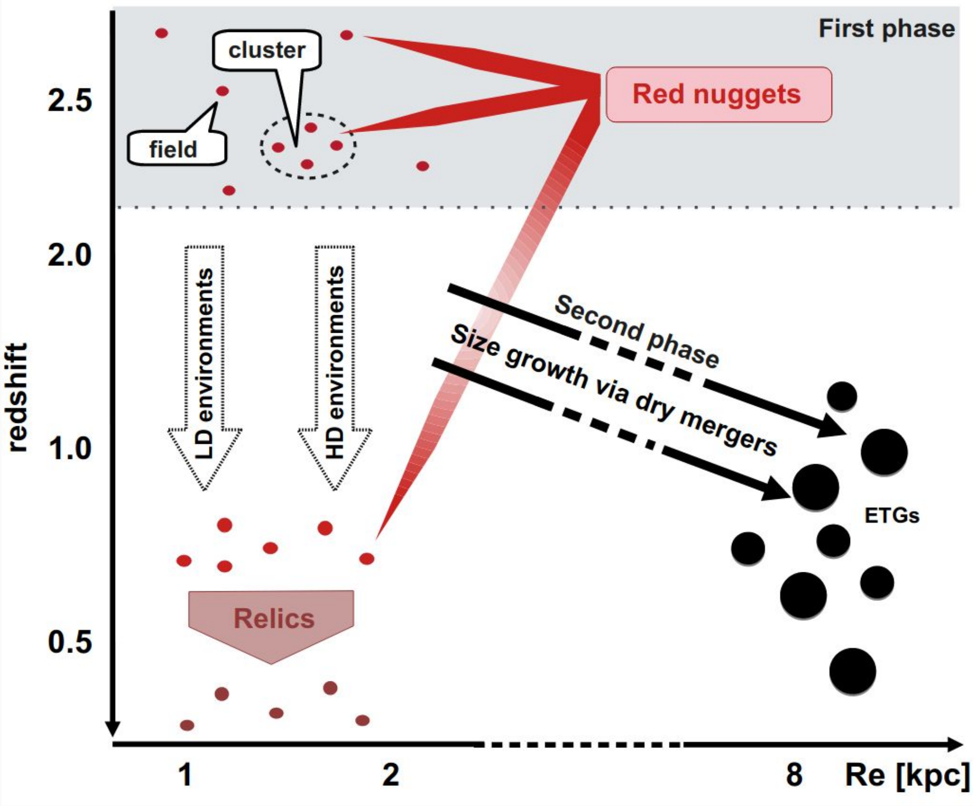
We found 11 red nuggets in low density and 10 in high density environment.

The most similar distribution can be found in sample with galaxies with similar sizes and lower masses.



Summary

- We found 77 spectroscopically selected red nuggets at intermediate redshift. It is the first catalogue of this kind.
- All of them are spectroscopically identified – unique for red nuggets
- Number densities are in good agreement – it is not trivial to compare due to the selection function
- We found no relation with the environment.



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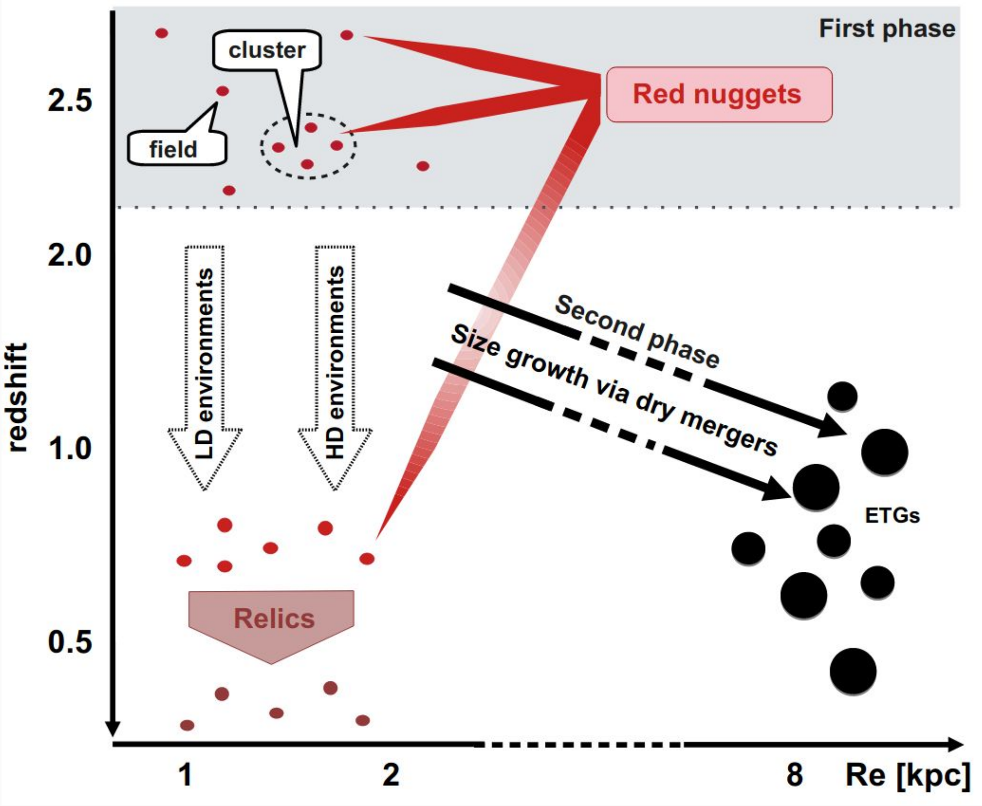
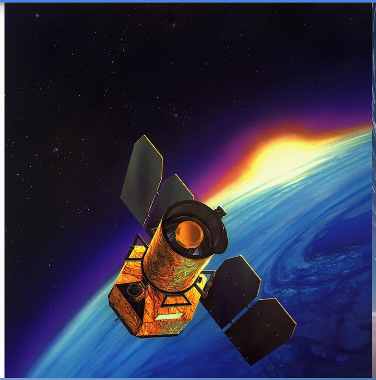


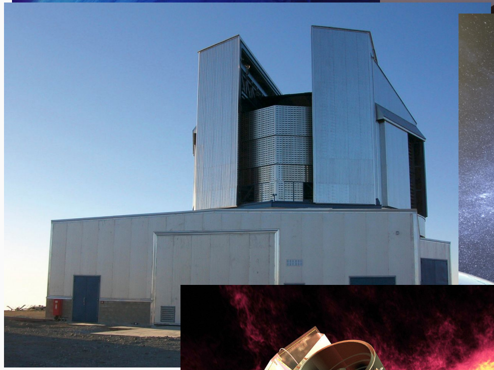
Thank you for your attention!

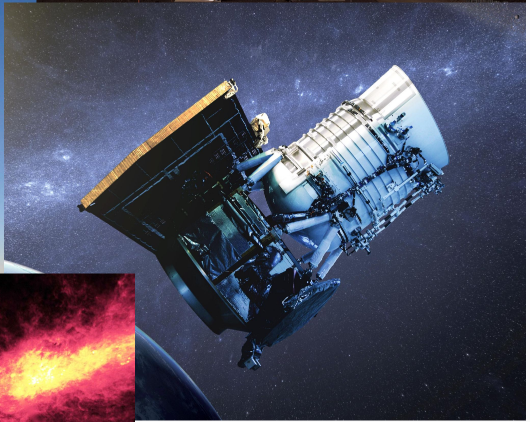
This work is supported by Polish National Science Centre
via grant UMO-2018/30/E/ST9/00082

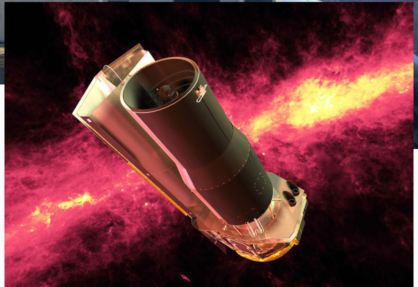
Almighty VIPERS: photometry

Telescope/ Instrument	Filter	λ_{mean} (μm)
GALEX	FUV	0.155
	NUV	0.234
CFHT/MegaCam	u	0.369
	g	0.482
	r	0.643
	i	0.772
	z	0.900
	iy	0.769
CFHT/Wircam	K_s	2.150
VISTA	K_{video}	2.158
WISE	W1	3.353
	W2	4.603
	W3	11.561
	W4	22.088
Spitzer/IRAC	I1	3.557
	I2	4.505
	I3	5.739
	I4	7.927
Spitzer/MIPS	24μm	23.843
	70μm	72.555
	160μm	157.000









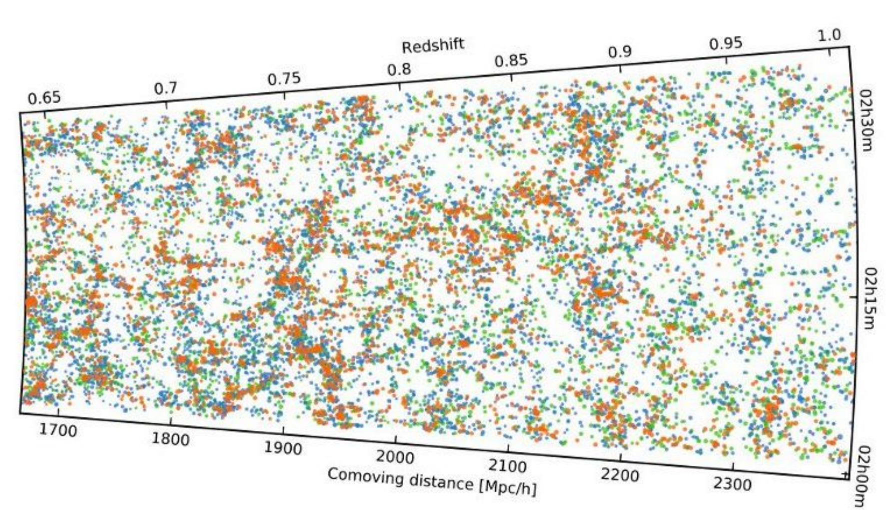
Almighty VIPERS: spectroscopy

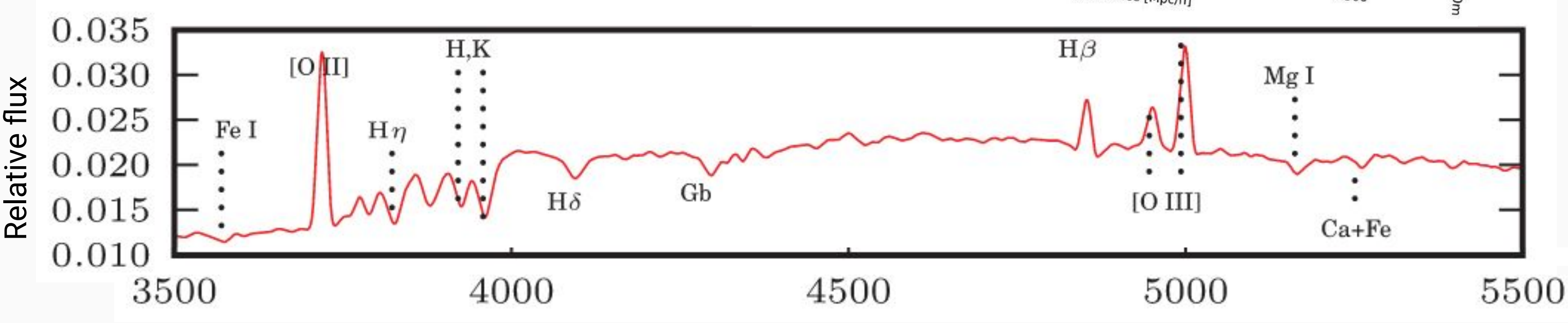
Spectroscopic redshifts with >95% confidence for 54 252 galaxies

Spectra restframe wavelength range:

z = 0.5 -> 3000 - 6300 A

z = 1.0 -> 2250 - 4750 A





Marchetti et al. 2013

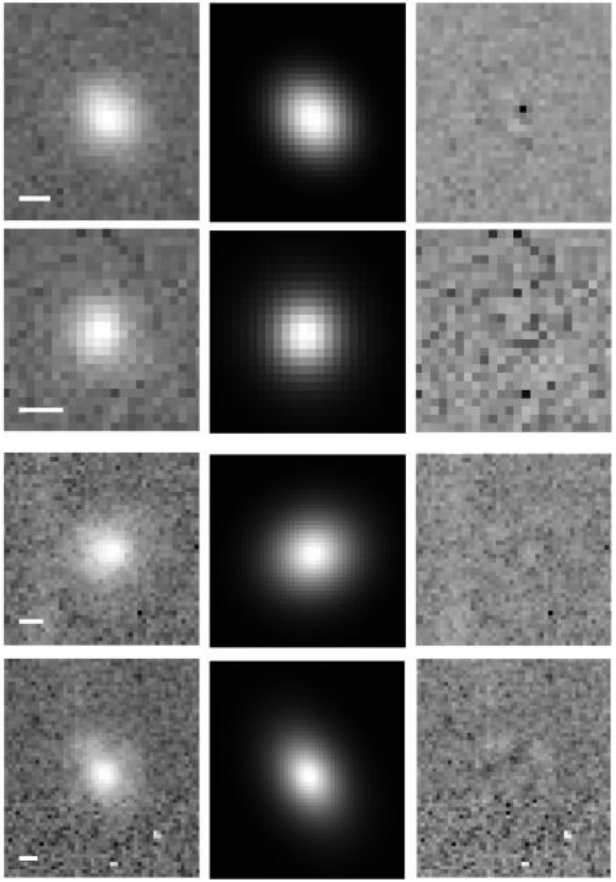
Almighty VIPERS: morphology

Half-light radii, Θ_e, was derived using GALFIT with Sersic profile:

$$I(r) = I_e \exp\left(-b_n\left[\left(\frac{r}{\theta_e}\right)^{1/n} - 1\right]\right)$$

In analysis we used circuralised half-light radii:

$$R_e = \theta_e \sqrt{b/a}$$



Krywult et al. 2017

Almighty VIPERS: morphology