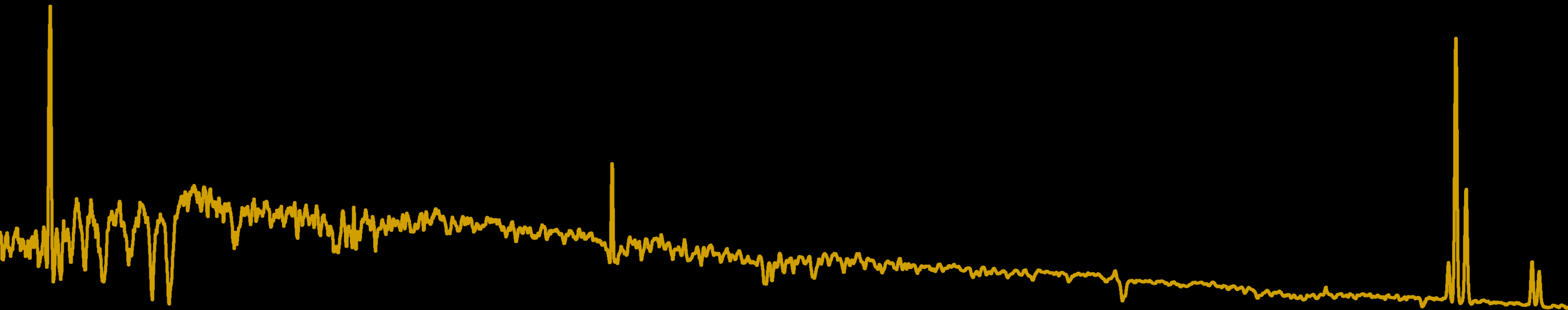

CATCHING GALAXIES IN THE ACT OF QUENCHING STAR FORMATION

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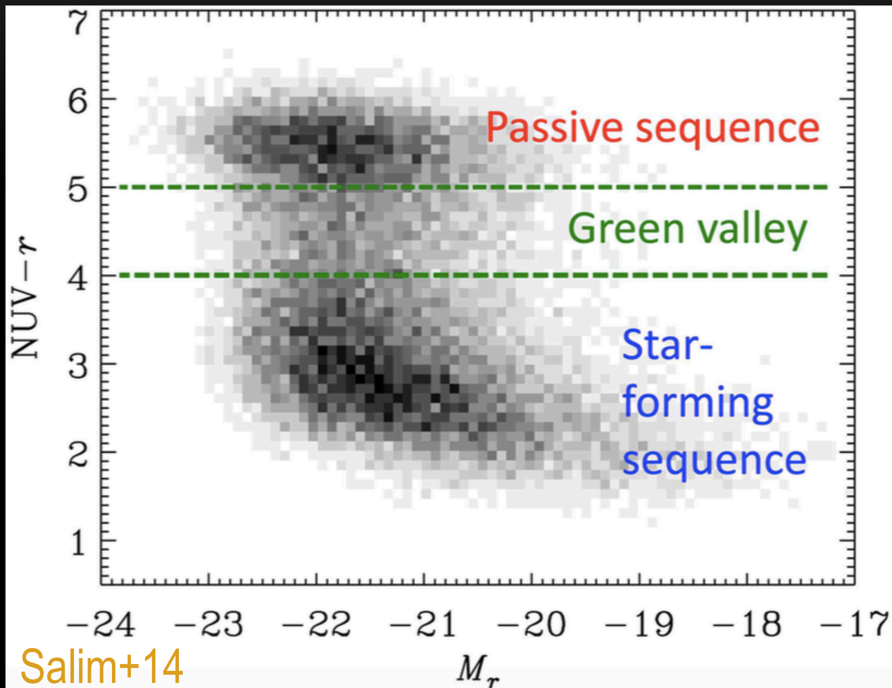
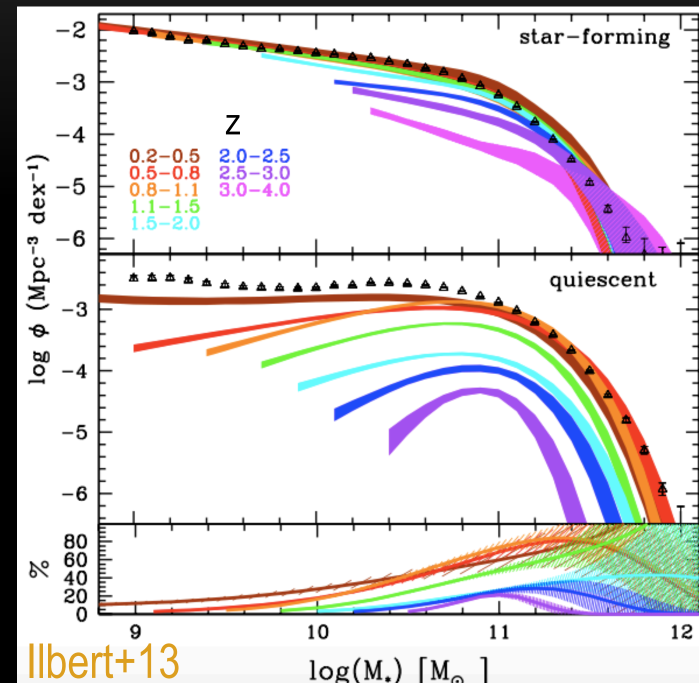
Firenze – November 15th 2017

Scientific Background

Colours-mass dichotomy



Growth of the red population



Expectations:

- migration toward the red sequence;
- morphological transformation;
- suppression of the star formation (SF);

SF QUENCHING

Previous Searches

- **Green valley galaxies (e.g. Schawinski+10, Salim+14)**:
  - predominance of bulge-dominated disk-galaxies,
  - lower sSFR towards redder colours.
- **Post-starburst galaxies E+K, A+K (e.g. Quintero+04, Poggianti+08):**
  - strong Balmer absorption (A stars domination),
  - disturbance due to gas-rich mergers,
  - supposed to have stopped SF 0.5-1 Gyr ago.
- **Young ETGs (e.g. McIntosh+14):**
  - ETGs not disturbed,
  - spectroscopically quiescent,
  - with young stellar population,
  - supposed to have stopped SF ~0.5 Gyr ago.

Quenching population is still elusive

Galaxies in the act of quenching star formation

Main driver: searching for galaxies just after the halt of the star formation (i.e. quenching)

Strength of our approach: Different from previous methods (post-starburst, green valley, ...), detect quenching galaxies right at the beginning of the quenching phase

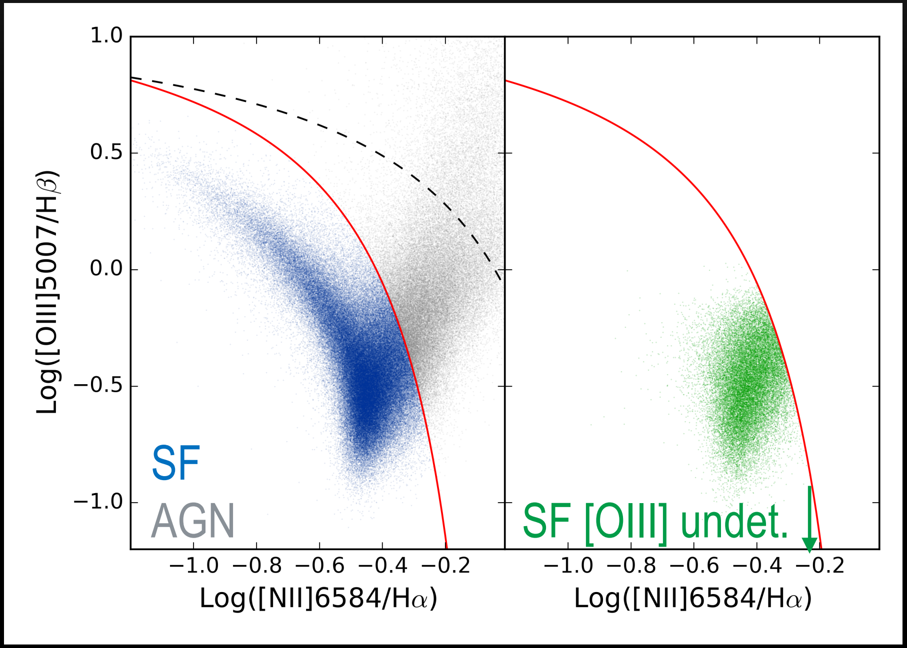
Sample: Sloan Digital Sky Survey – data release 8 (SDSS-DR8) - ~174.000 SF galaxies

Method: spectroscopic selection of ideal quenching candidates based on emission line ratios (high and low ionization lines, such as [OIII]λ5007 and Hα)

Sample selection

Criteria applied to the SDSS-DR8:

- EW(Hα, Hβ) < 0;
- S/N(Hα) ≥ 5;
- S/N(Hβ) ≥ 3;
- 0.04 ≤ z < 0.21.



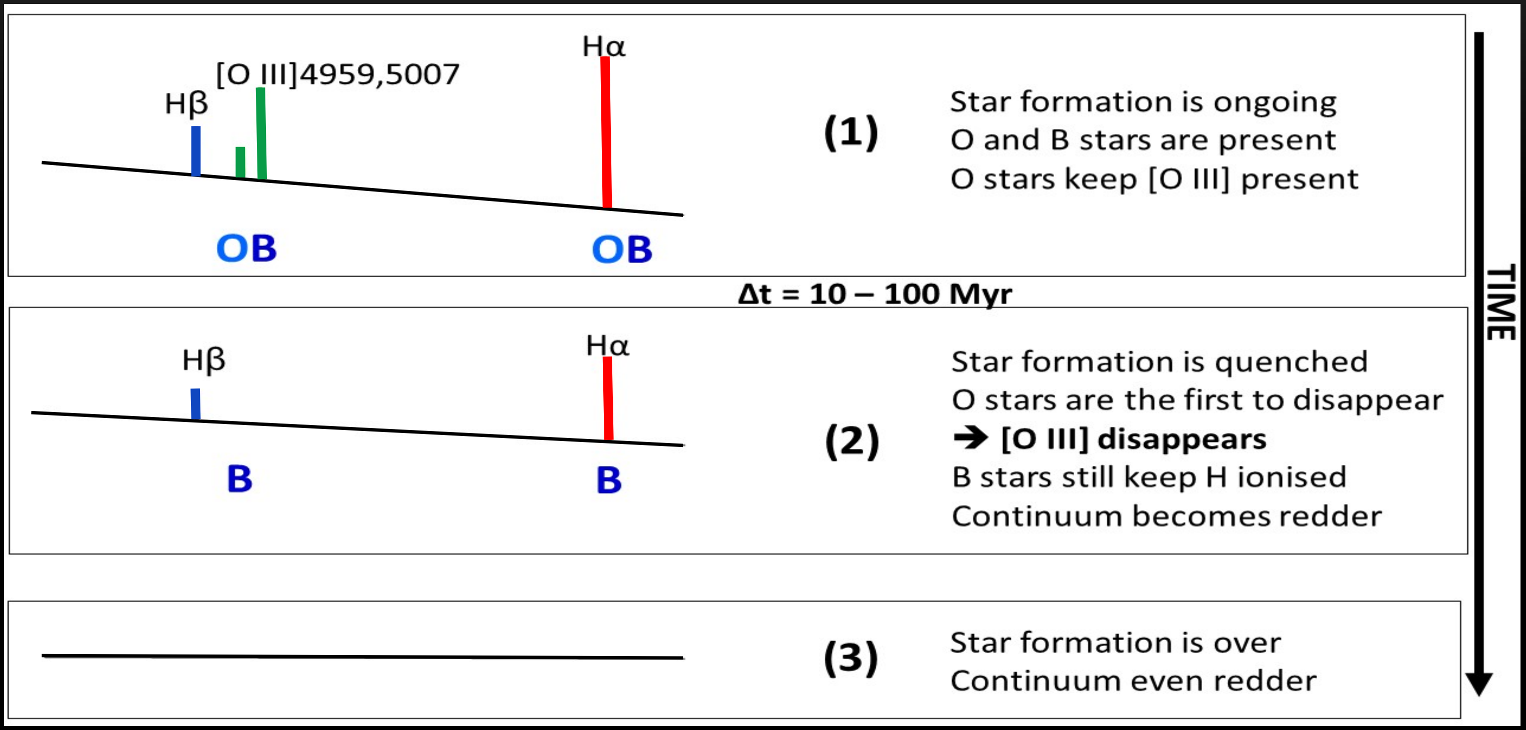
SF (~150.000)

SF [OIII] undetected (~26.000) → Search for quenching candidates

no-Hα (complementary sample)

Our Approach

See also **Citro**'s talk



[OIII]/Hα as ionization indicator

Galaxies with low [OIII] luminosity but with Hα could be qualified as Quenching candidates

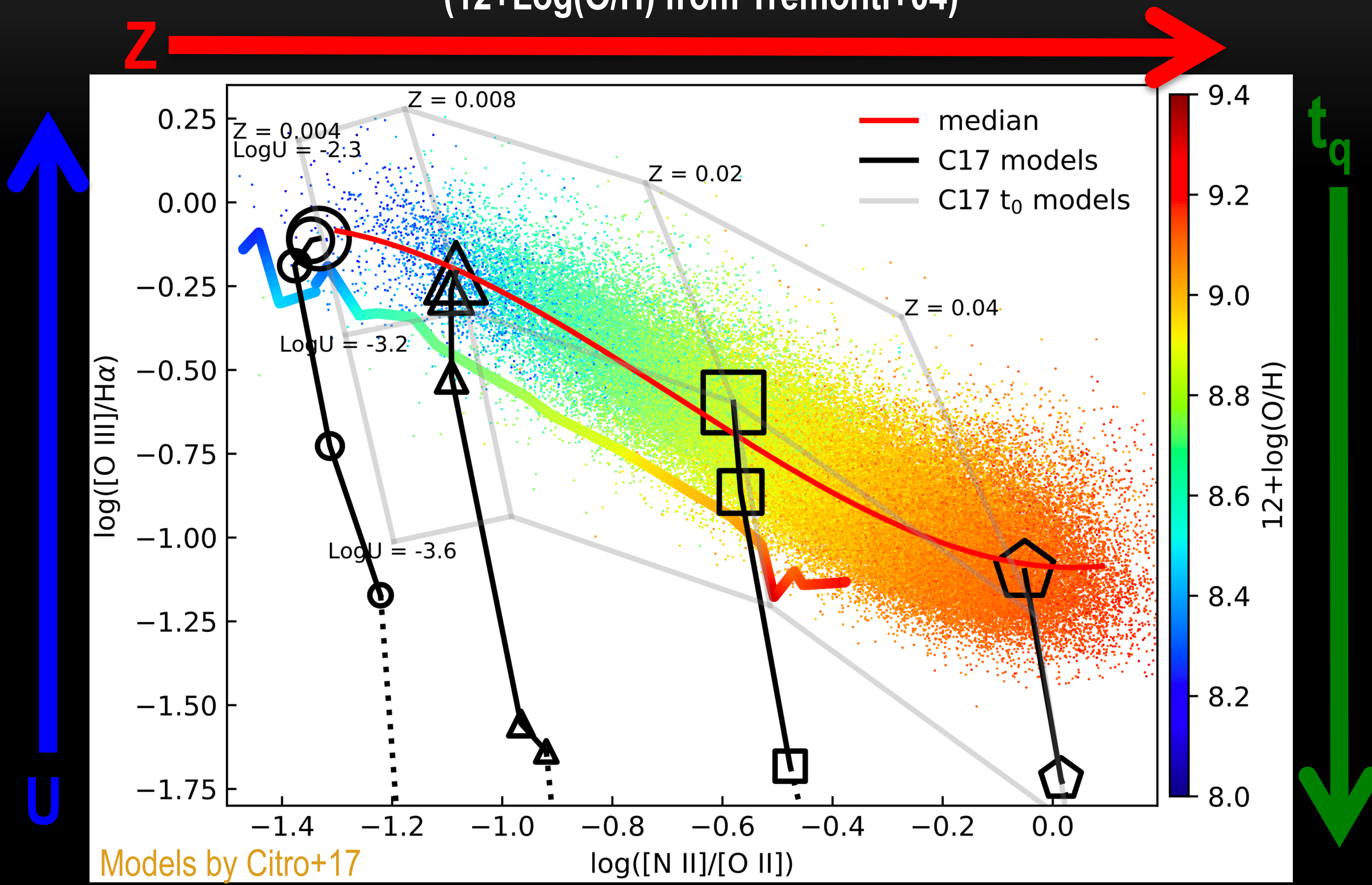
ionization – metallicity (U-Z) degeneracy!

An independent metallicity estimator is needed

Breaking the U-Z Degeneracy

[N II]λ6584/[O II]λ3727 ⟶ metallicity estimator

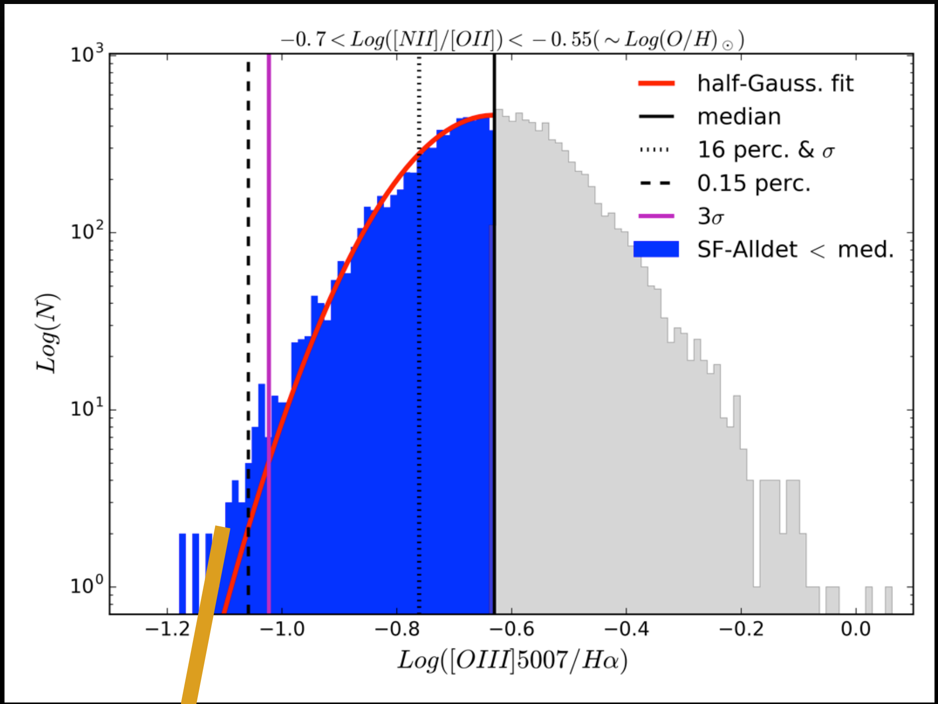
(12+Log(O/H) from Tremonti+04)

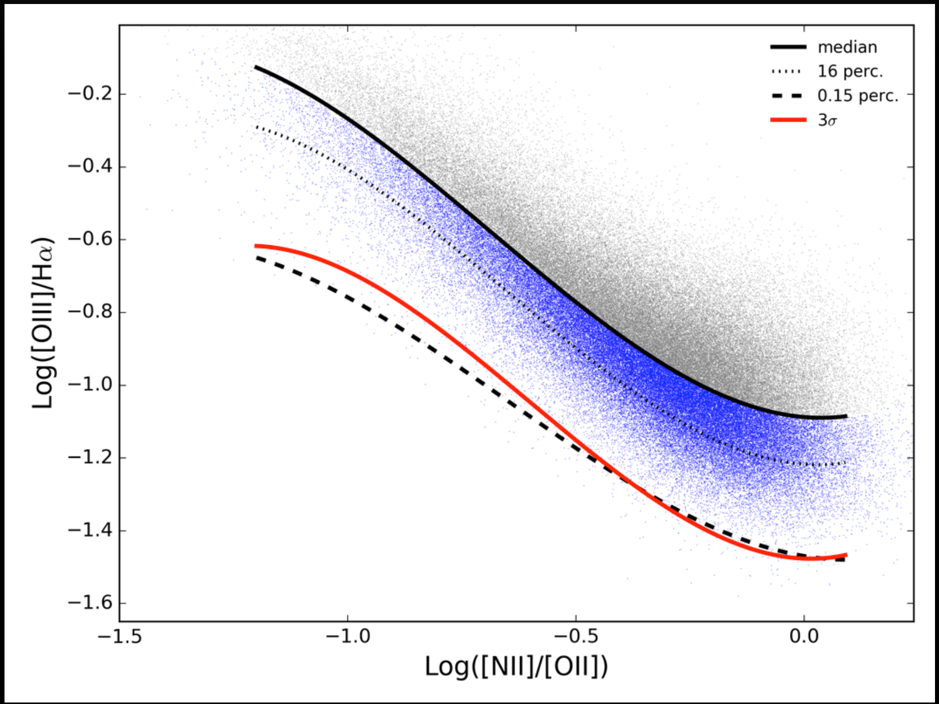


Breaking the U-Z Degeneracy

[N II]λ6584/[O II]λ3727 ⟶ metallicity estimator

(12+Log(O/H) from Tremonti+04)

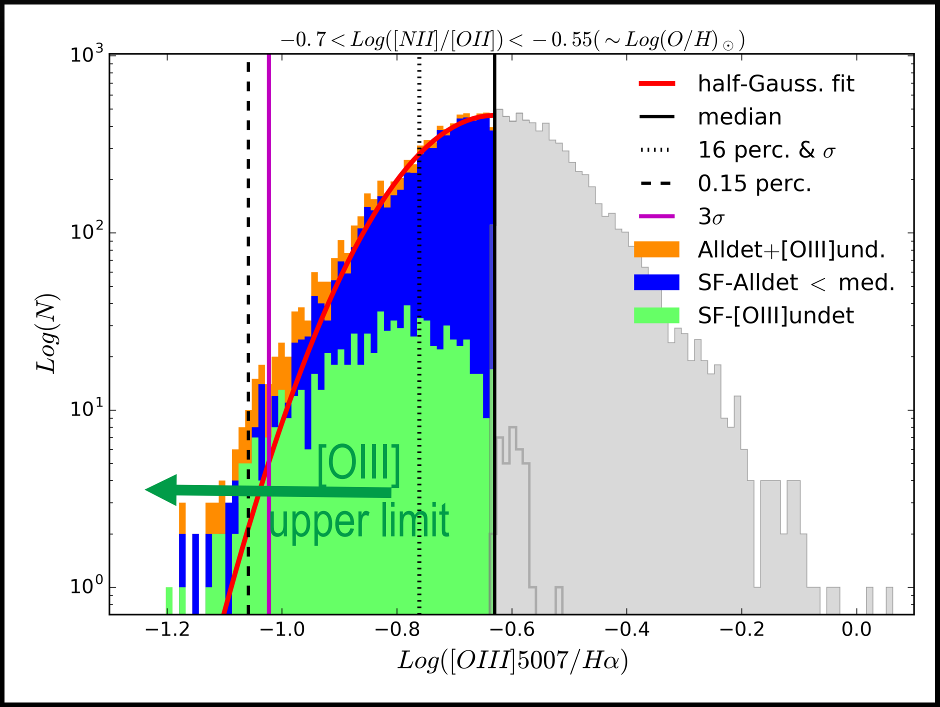


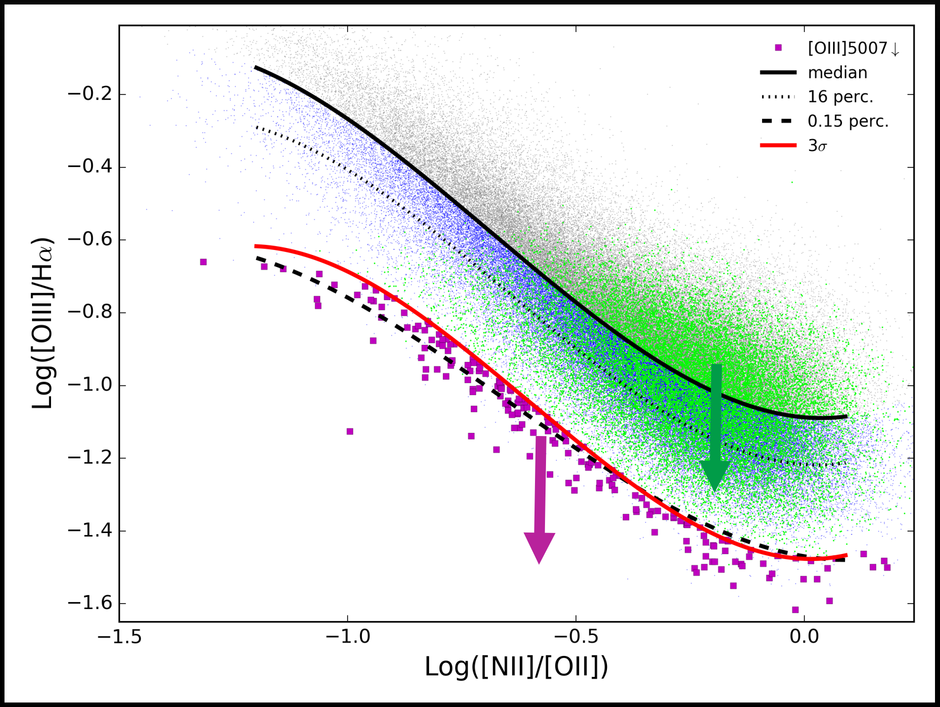


EXCESS

Breaking the U-Z Degeneracy

[N II]λ6584/[O II]λ3727 ⟶ metallicity estimator
(12+Log(O/H) from Tremonti+04)





QGs – A = 192

other line ratios were tested, such as [OIII]/Hβ - [NII]/[SII]

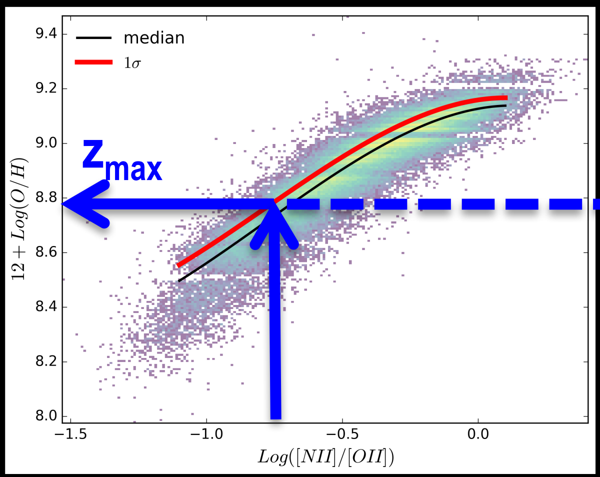
✔ no dust extinction, high redshift, agreement with former ratios ✗ [SII] weak

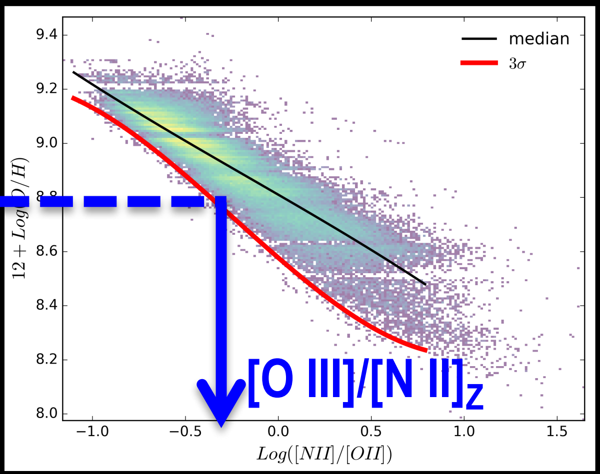
Complementary Method

[O III] weaker than the flux expected for the maximum metallicity:

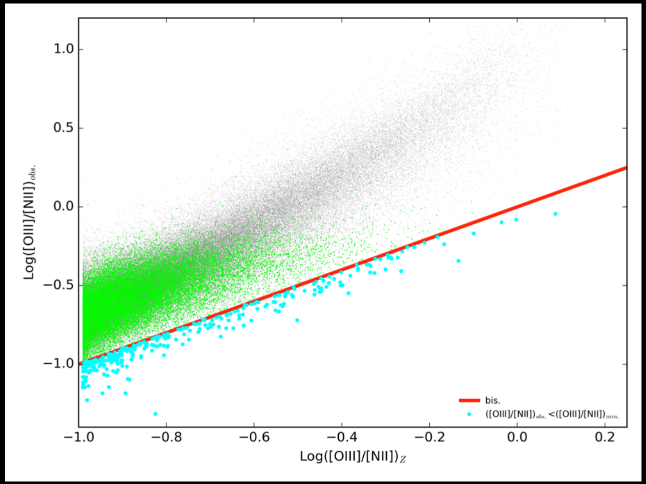
1) $Z_{max} = Z + 1\sigma$
- Z: from [N II]/[O II]-Z relation (Nagao+06);
-

2) $[O\,III]/[N\,II]_Z = [O\,III]/[N\,II](Z_{max}) - 3\sigma$
- $[O\,III]/[N\,II](Z_{max})$: from [O III]/[N II]-Z (Nagao+06);





3) $[O\,III]/[N\,II]_{obs} < [O\,III]/[N\,II]_Z$:

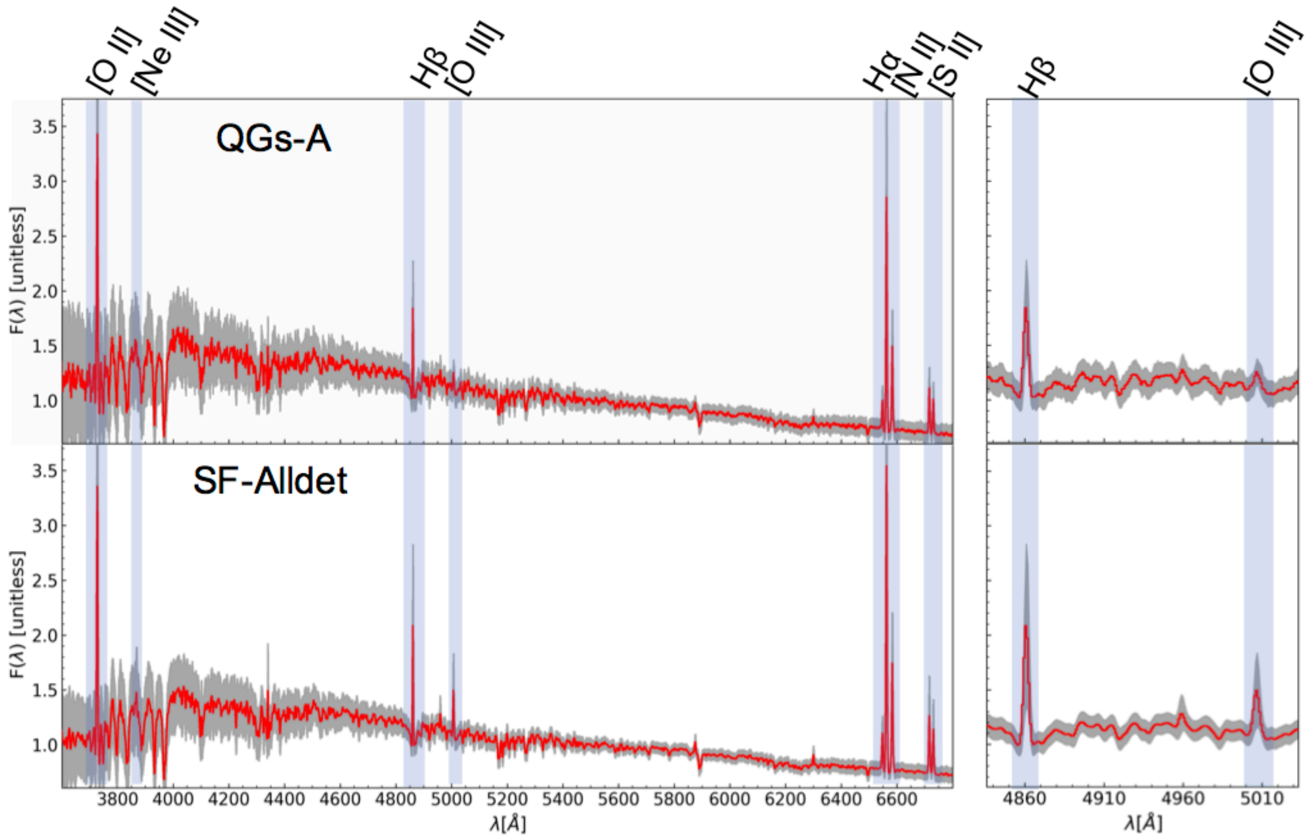


308 QGs - B:

The weakness of the [O III] is not statistically attributable to high metallicity

RESULTS

QGs stacked spectrum

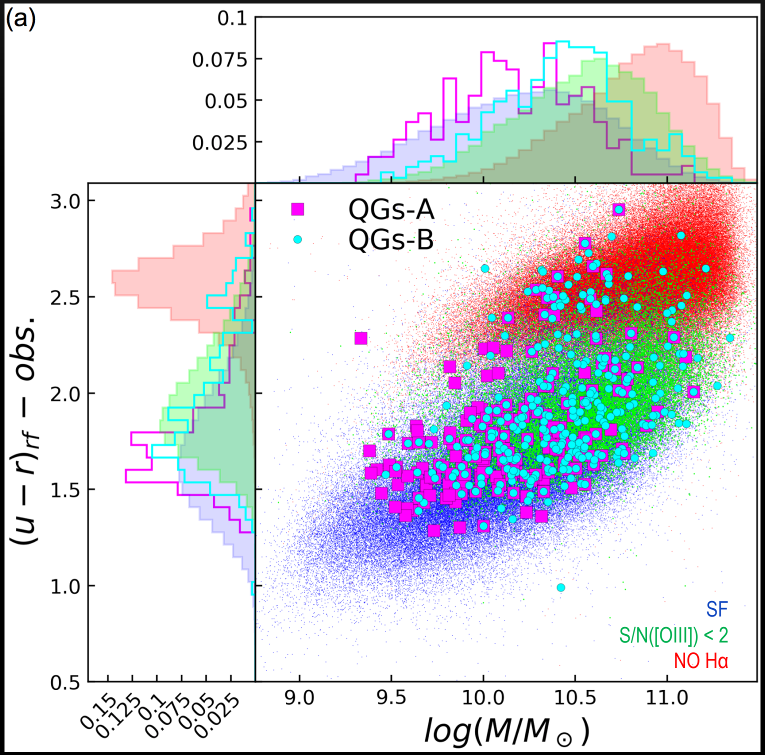


The stacked spectrum analysis confirms:

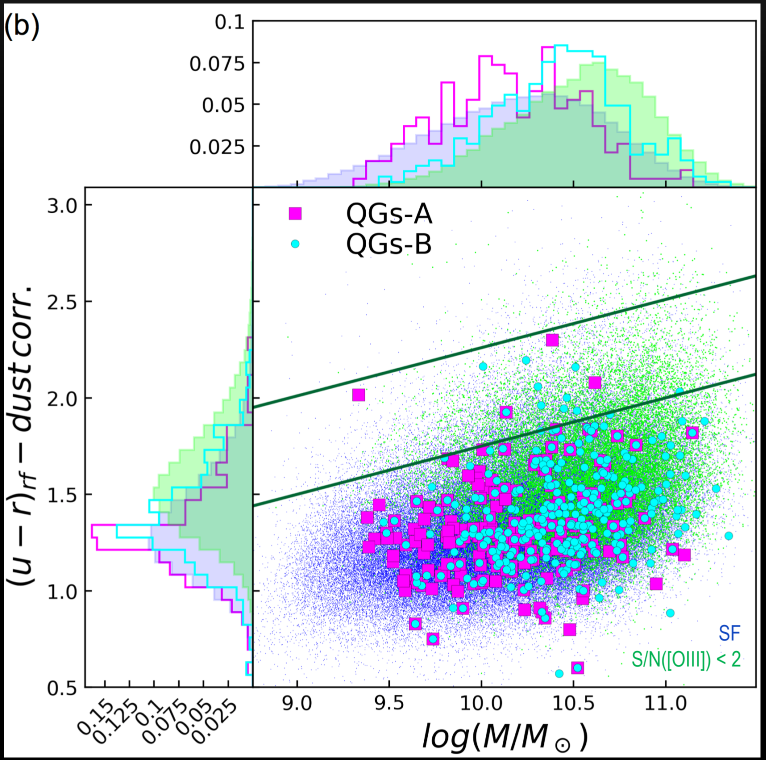
- Blue stellar continuum;
- lack of [O III];
- $F(H\alpha)_{QGs} \sim 0.8\ F(H\alpha)_{SF;}$
- $\log([O\ III]/H\alpha)_{QGs} \sim -1.34$ vs. $\log([O\ III]/H\alpha)_{SFs} \sim -0.92$.

Colours - mass

Dust uncorrected (u-r) vs mass



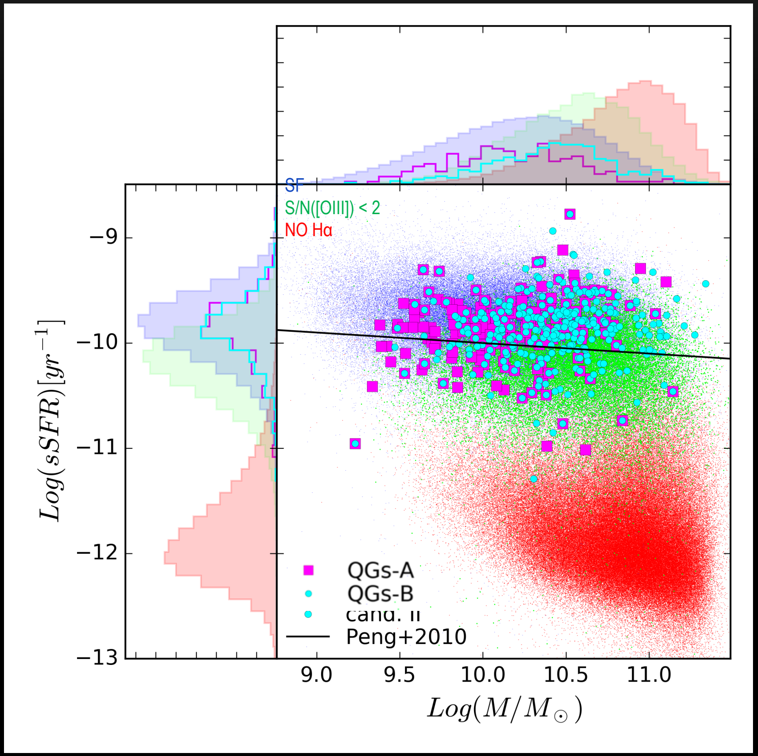
Dust corrected (u-r) vs mass



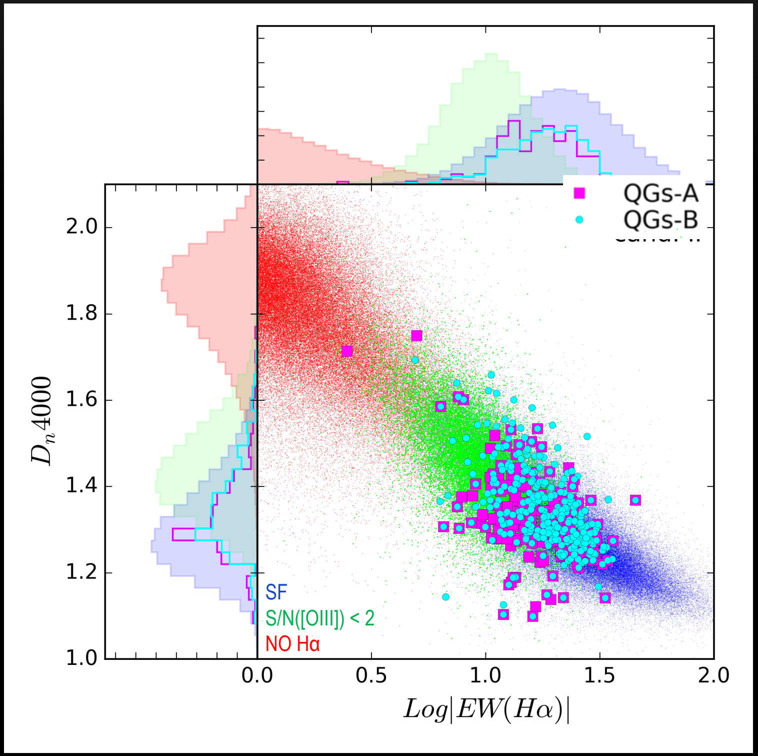
- The bulk of QGs are in the blue cloud;
- a few QGs are in the Green valley;
- masses of QGs over the range $9.8 \lesssim \log(M/M_\odot) \lesssim 10.6$ (16^{th} – 84^{th} perc.);
- no QGs and no quiescent galaxies with $\log(M/M_\odot) \lesssim 9.5$;
- quenching has not started yet for low-mass galaxies (i.e. Downsizing scenario)

SFR and spectral features

sSFR - mass



D_n4000 vs EW(Hα)

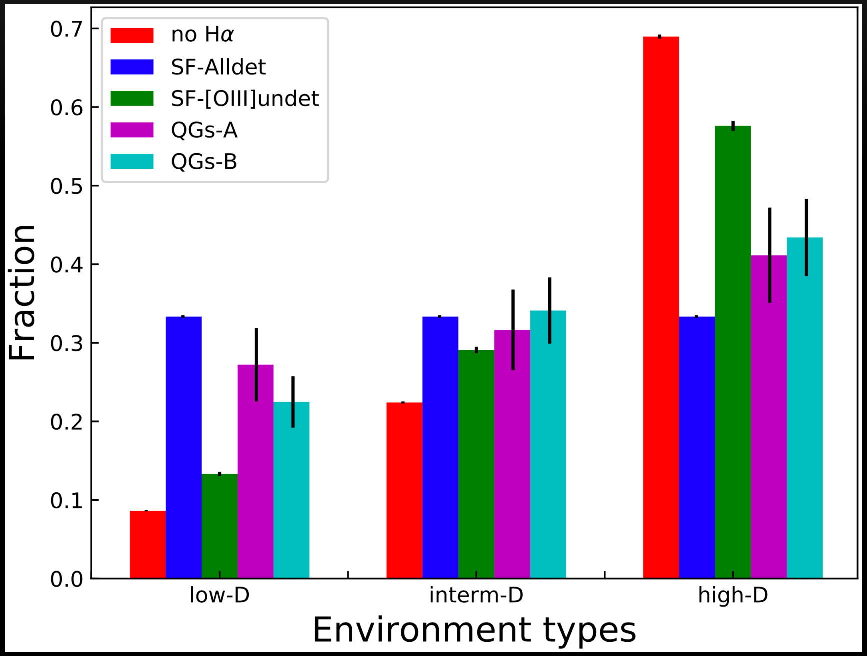


The most of our QGs:

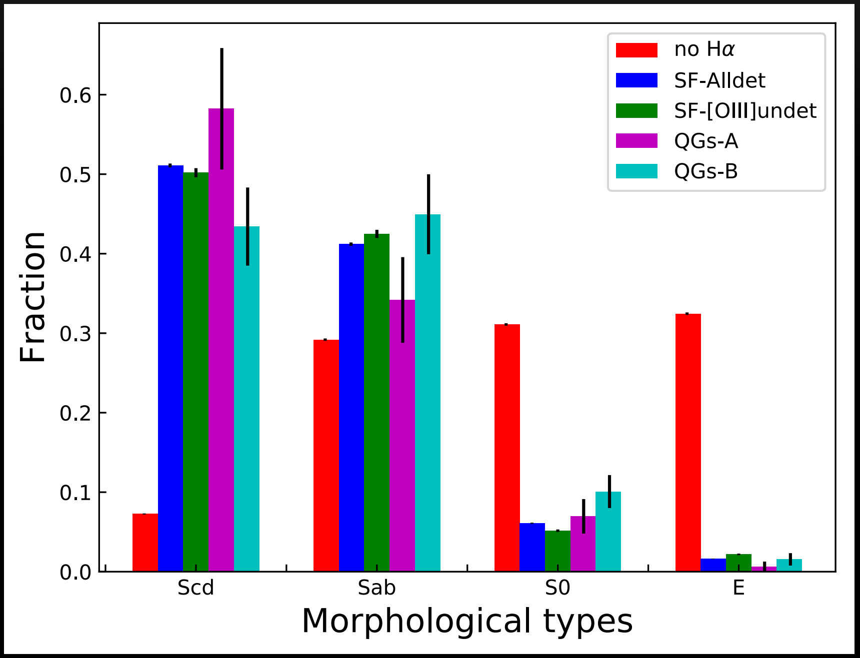
- show high sSFR (the Hα is kept strong by late O and early B stars);
- have EW(Hα) and D_n4000 intermediate between SF and quenched galaxies;
- have just stopped their star-formation;
- have a young/intermediate stellar population.

Environment and morphology

Environment types



Morphological types



- Excess of QGs in high density environments (42 ± 5% vs 33 ± 0.5% of SF);
- The QGs and SF have similar morphologies (no morphological transformation occurred yet).

Quenching timescale

Fraction of QGs observed:

$$Fr(QGs) = \frac{N(QGs\ A\text{-}B)}{N(SF)} = \frac{192 - 308}{174000} \approx 0.11 \sim 0.18\ \%$$

Quenching timescale:

$$T_Q = Fr(QGs) \times t_{doubling} = Fr(QGs) \times \sim 1/sSFR$$

$$T_Q \approx (0.11 \sim 0.18\ \%) \times (3 - 10\ \text{Gyrs}) \sim 3.3 - 18\ \text{Myrs}$$

e.g. Citro+17 models give $T_Q \sim 10$ Myrs

Summary

- Search for quenching galaxies in the SDSS-DR8 sample selected with lowest [O III]/Hα ratio (ionization indicator) not related to metallicity;
- found 192 - 380 QGs with two different methods;
- quenching timescales compatible with rapid quenching (T_Q~3-18 Myrs)
- mass ($9.5 < Log(M/M_{\odot}) < 11$) compatible with the growth of the red population;
- intermediate stellar population ages (from Dn4000 and EW(Hα));
- excess in dense environments and no morphological transformation.

Quai et al. (subm. MNRAS)

Next steps

In order to confirm the quenching status of our QGs candidates we need:

- to study a strategy to estimate the amount of cold gas in QG (CO maps – ALMA);
- integral field unit spectra of QGs (quenching spatial resolved);
- to measure the star formation history of the QGs from their spectra.

THANKS FOR YOUR ATTENTION

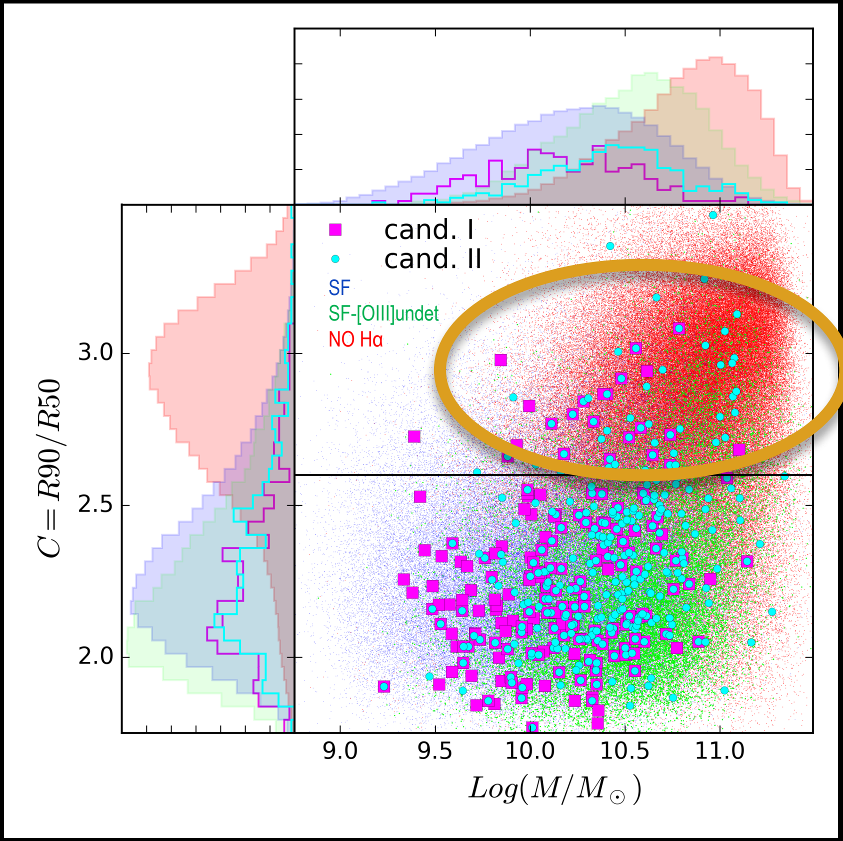
other materials

QGs morphologies

Migration toward the red sequence

+

morphological transformation

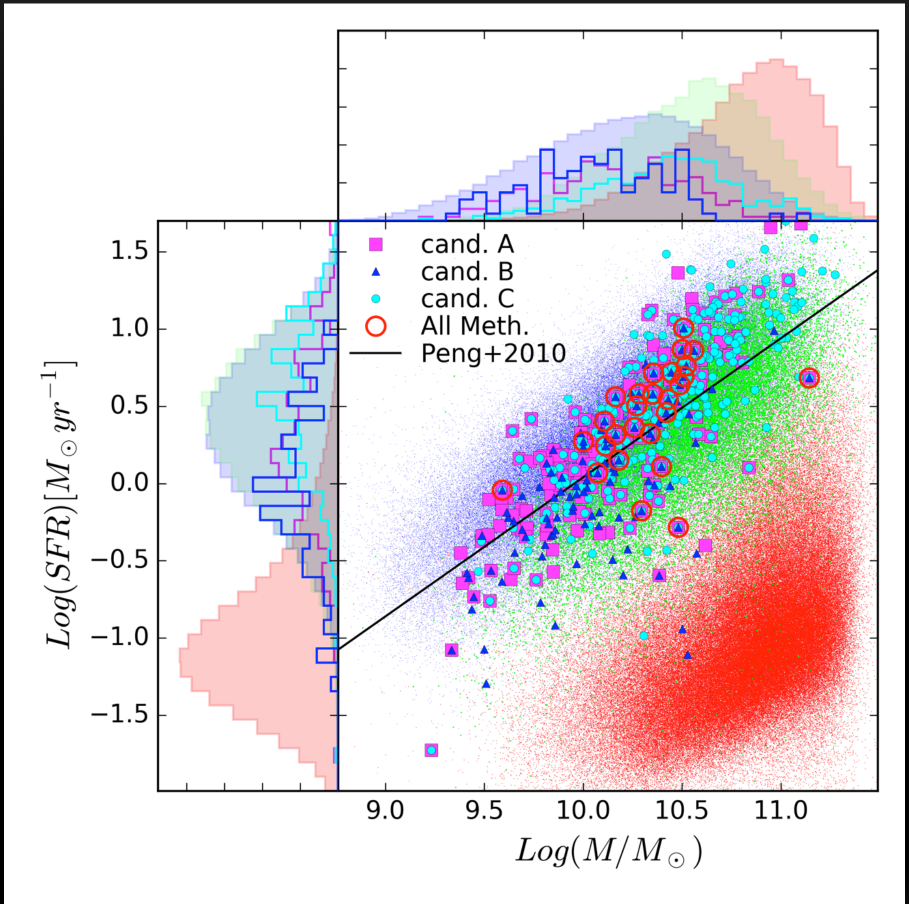


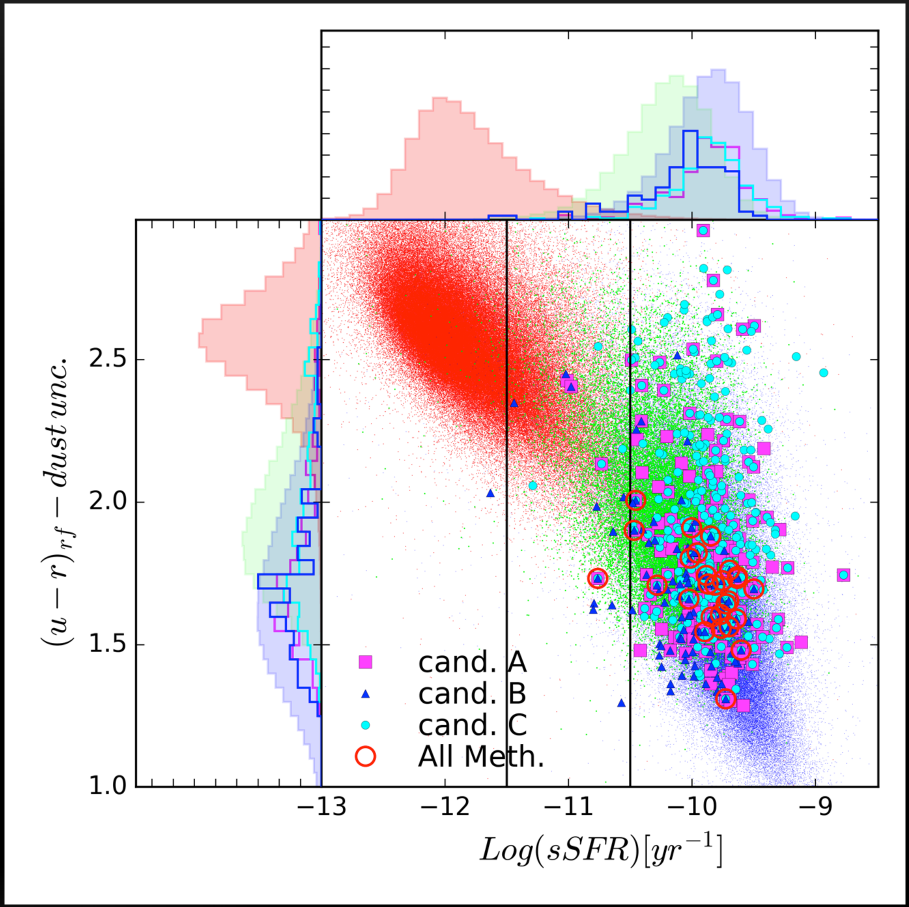
C > 2.6
typical ETGs
light concentration

Visual inspection of SDSS sample too uncertain for morphological analyses

Cross-matching with Meert+15 catalogue (work in progress)

SFR - mass


cand. A
cand. B
cand. C
All Meth.
Peng+2010
$Log(SFR)[M_\odot yr^{-1}]$
$Log(M/M_\odot)$
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
9.0
9.5
10.0
10.5
11.0


cand. A
cand. B
cand. C
All Meth.
$(u-r)_{rf} - dust\ unc.$
$Log(sSFR)[yr^{-1}]$
2.5
2.0
1.5
1.0
−13
−12
−11
−10
−9

QGs Size and aperture effects