(preliminary results on…)

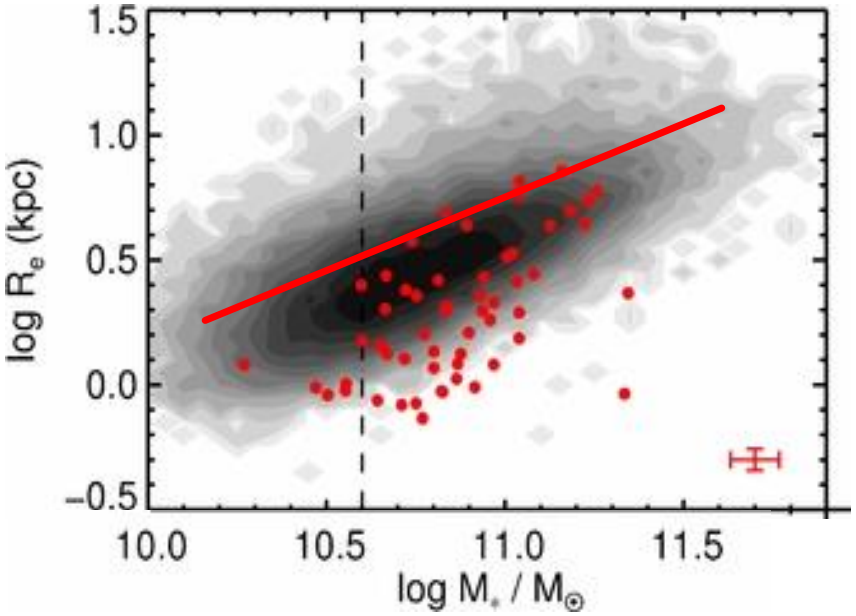
The build-up of dense and normal massive passive galaxies in VANDELS

ADRIANA GARGIULO, PAOLO FRANZETTI, BIANCA GARILLI & VANDELS TEAM

INAF – IASF MILANO

12 DICEMBRE - MILANO

THE STARTING POINT OF OUR ANALYSIS



Belli et al. 2016

At fixed stellar mass

1. local passive galaxies (PGs) have effective radii R_e which vary up to an order of magnidute

(or two orders of magnidute
in mean surface stellar mass density $\Sigma = M_* / (2 \pi R_e^2)$)

2. PGs at high redshift are smaller (i.e. denser) than local PGs.

In which way was build up the population of local MPGs?

IN & OUT STELLAR POPULATION PROPERTIES OF PGs AS A FUNCTION OF Σ

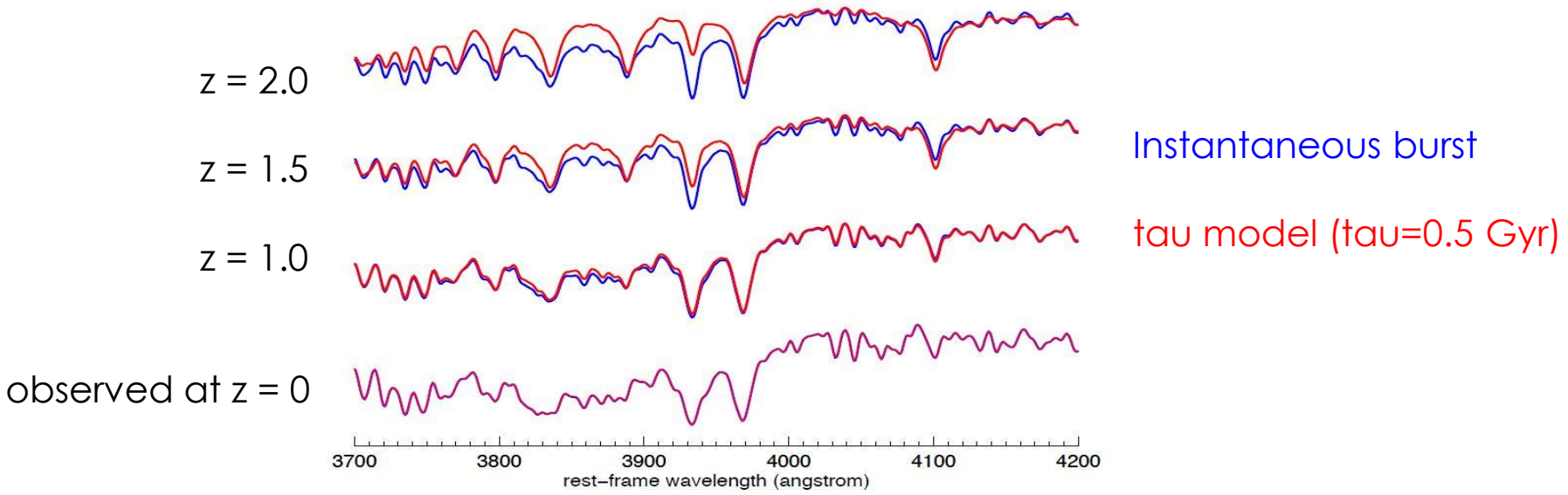
Reconstruct the star-formation history of PGs with different Σ

↓

Spatially resolved stellar population properties (e.g. age/metallicity) of PGs with different Σ *at the highest possible redshift*

IN & OUT STELLAR POPULATION PROPERTIES OF PGs AS A FUNCTION OF Σ

Why high-z observations?



PREVIOUS STUDIES:

Few works on spatially resolved stellar population properties of **individual** PGs at z ~ 1.5 from **photometry** (i.e. color gradients, see Gargiulo et al. 2011, 2012).

Only one work on in & out stellar population properties of PGs at z ~ 1.5 from **a stacked spectrum** (e.g. Gobat et al. 2016) → **Data do not allow to investigate trends with Σ and M_{star}**

PASSIVE GALAXIES IN VANDELS

A deep VIMOS survey of the CANDELS UDS and CDFS fields

~ 300 PGs (UVJ selected) with texp between 20h and 80h

THE SAMPLE

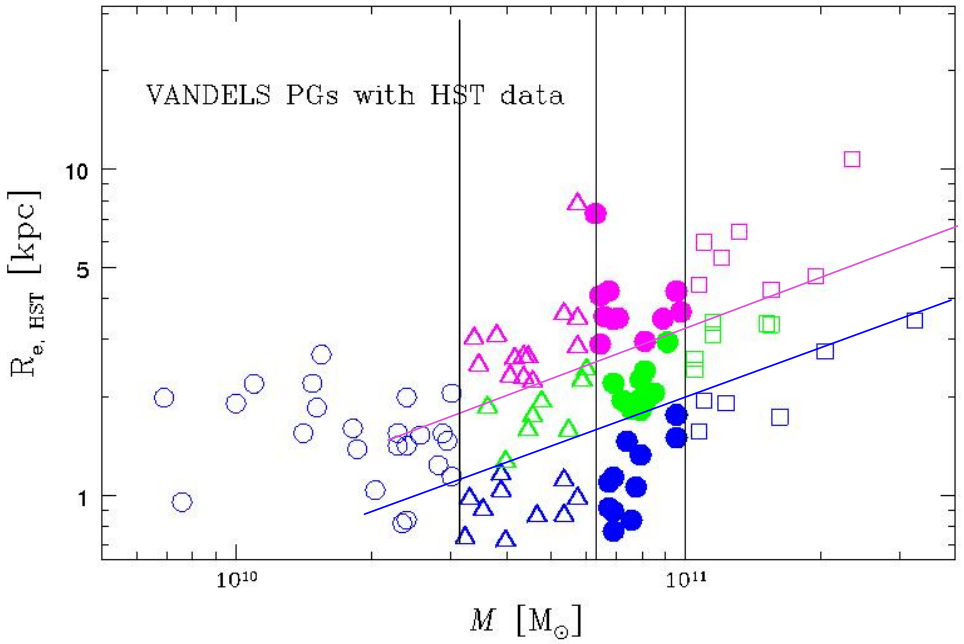
- HST data available → 119 gals
- reliable estimate of R_e (van der Wel et al.)
- three (SMALL) stellar mass bins

  $10.5 \leq \mathrm{Log}\ (M_{star}/M_{sun}) < 10.8$
  → to be checked – 31 gals

  $10.8 \leq \mathrm{Log}\ (M_{star}/M_{sun}) < 11.0$
  → 32 gals

  $\mathrm{Log}\ (M_{star}/M_{sun}) \geq 11.0$
  → 20 gals

- redshift range $1 < z < 1.6$



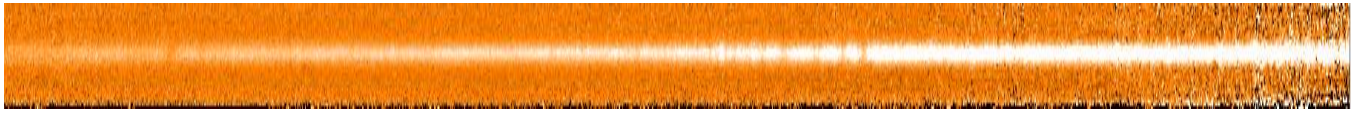
Three subsamples of
Normal ($\Sigma < 1500 M_{sun}$ pc^{-2}),
Intermediate ($1500 \leq \Sigma < 4000 M_{sun}$ pc^{-2}) and
Dense ($\Sigma \geq 4000 M_{sun}$ pc^{-2}) PGs

THE ROADMAP OF STACK PROCEDURE

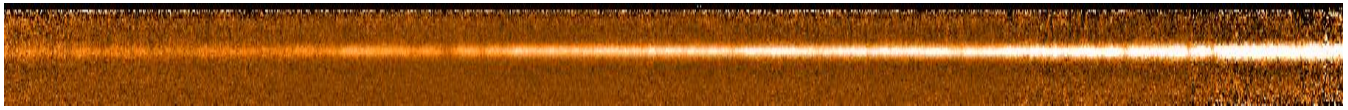
Starting point: 2D linearly resampled and λ calibrated spectra as produced by the EasyLife pipeline. Then, 2D spectra are:

- flux calibrated and corrected for galactic and atmospheric extinctions;
- redshifted to rest-frame;
- resampled to a common dispersion (the larger one);
- shifted along the spatial direction to match the peaks of all the various object profiles;
- rescaled to the same median flux in the 3000-3200 Å range;
- combined in a stacked spectrum (median).

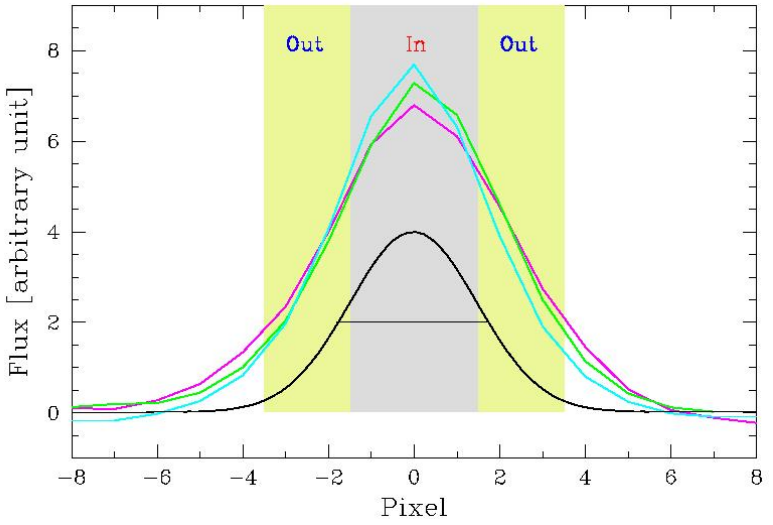
2D STACKED SPECTRUM OF NORMAL PGs



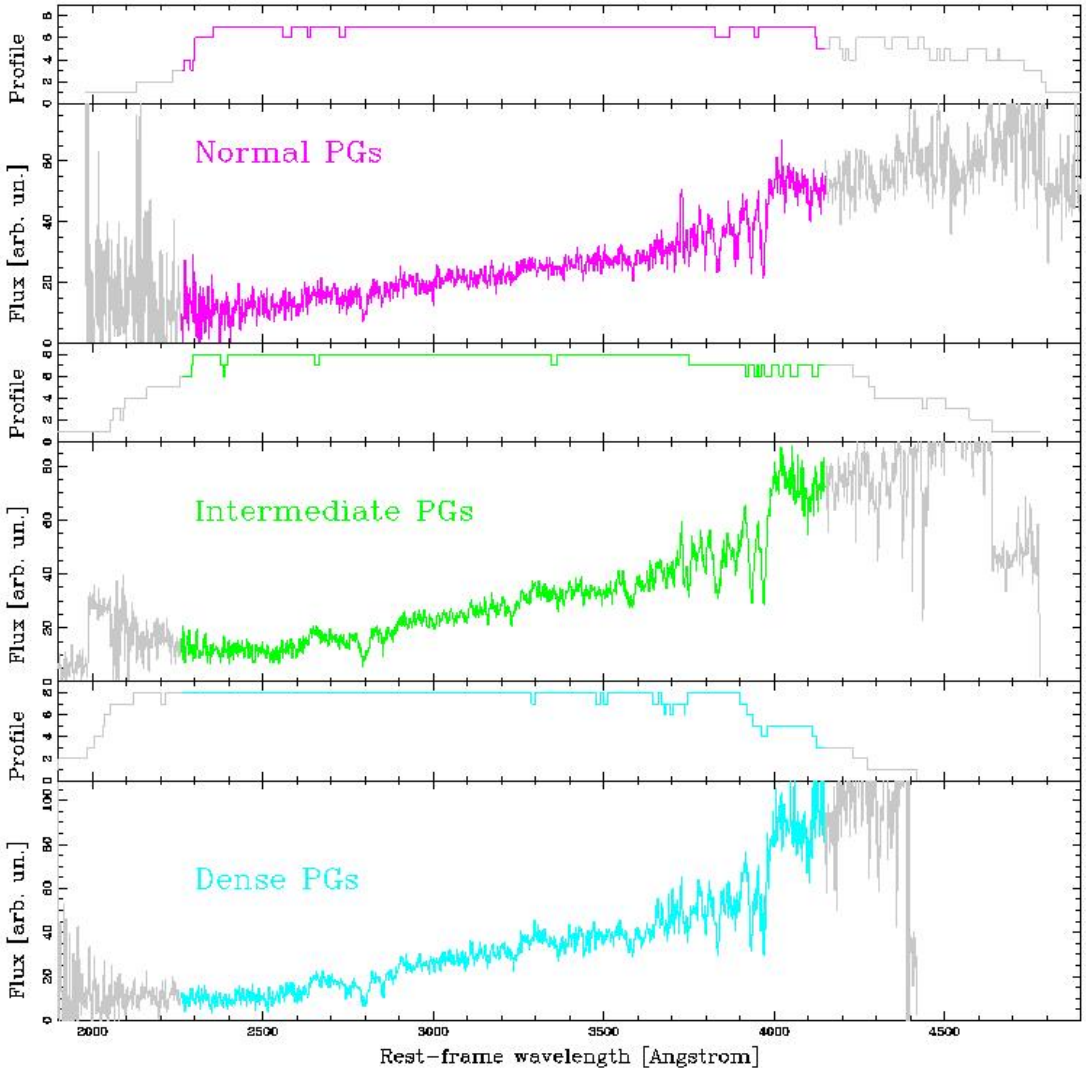
2D STACKED SPECTRUM OF DENSE PGs



EXTRACTION PROFILES OF STACKED SPECTRA



THE 1D STACKED SPECTRA



$10.8 \leq \mathrm{Log}\ (M_{star}/M_{sun}) < 11.0$

Stacked spectra of **Normal**, **Intermediate** and **Dense** PGs at z ~ 1.3

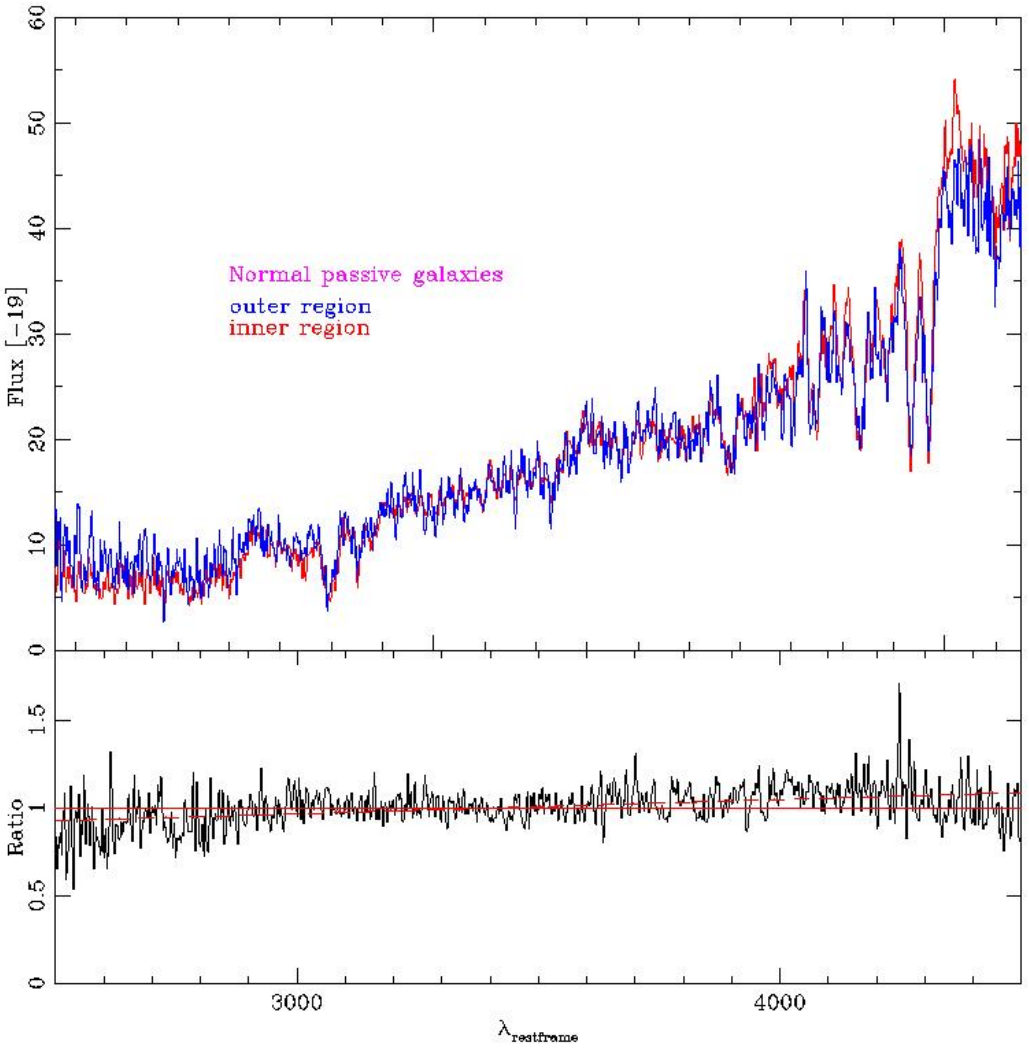
- equivalent total exposure time in each stack ~ 250-300h

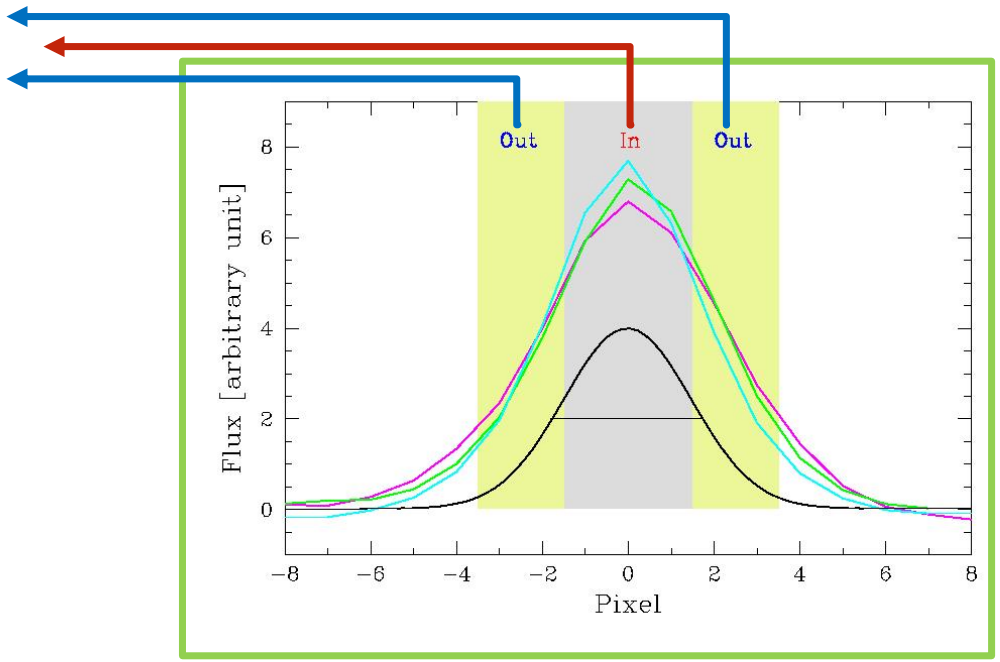
- rest-frame resolution 5.5Å

- common high-S/N wavelength range : 2260 – 4150Å

- $SFR_{OII\,line} < 2M_{sun}/yr \rightarrow sSFR \sim 10^{-11}\ yr^{-1}$

IN & OUT STELLAR POPULATION PROPERTIES OF PGs AS A FUNCTION OF Σ



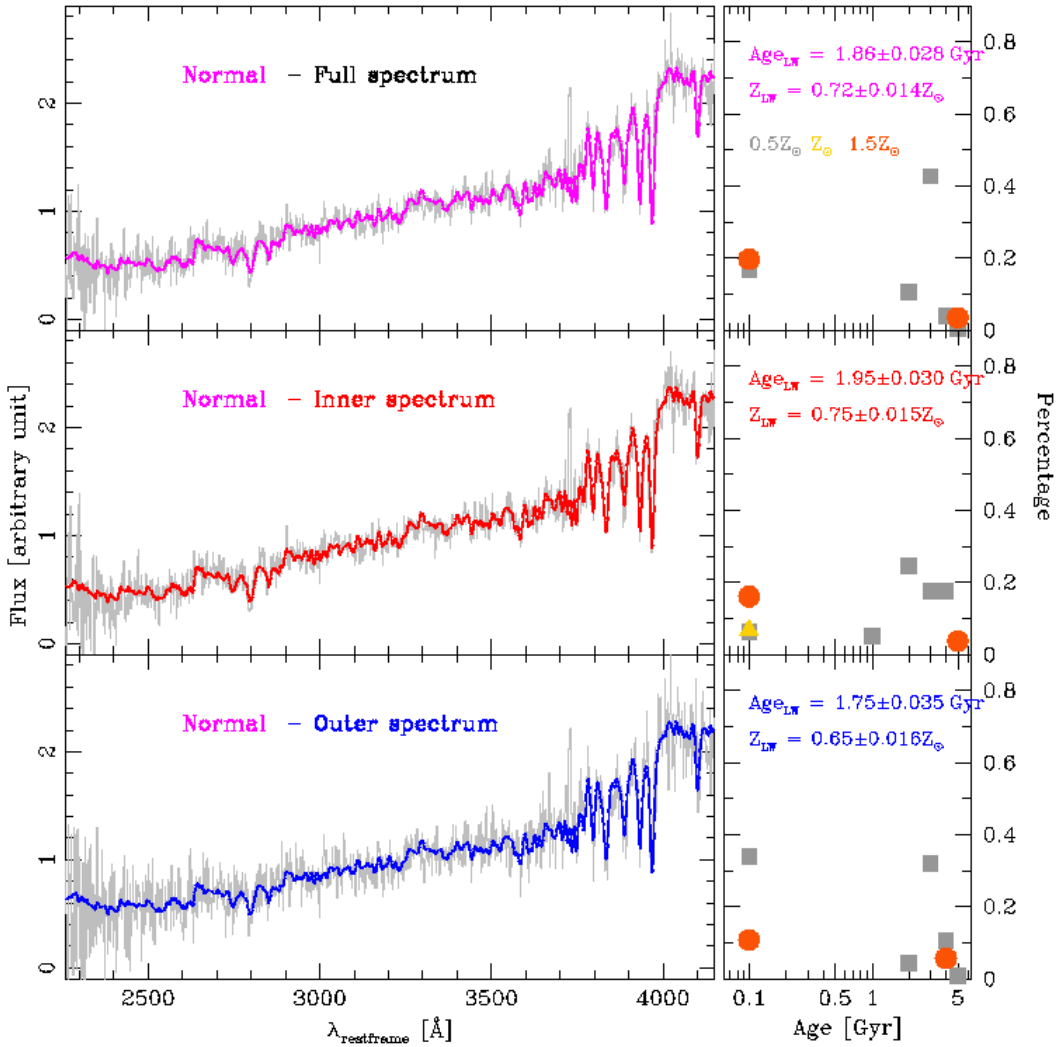


Extraction profile of stacked spectrum of **Normal**, **Intermediate** and **Dense** PGs

Mean FWHM of PSF ~ 0.7'' ~ 3px

NORMAL PGs: Central regions *redder* than outer regions

SPECTRAL FITTING: NORMAL PGs



(*Relative*) Age and Metallicity of the inner and outer regions of PGs from ***spectral fitting***

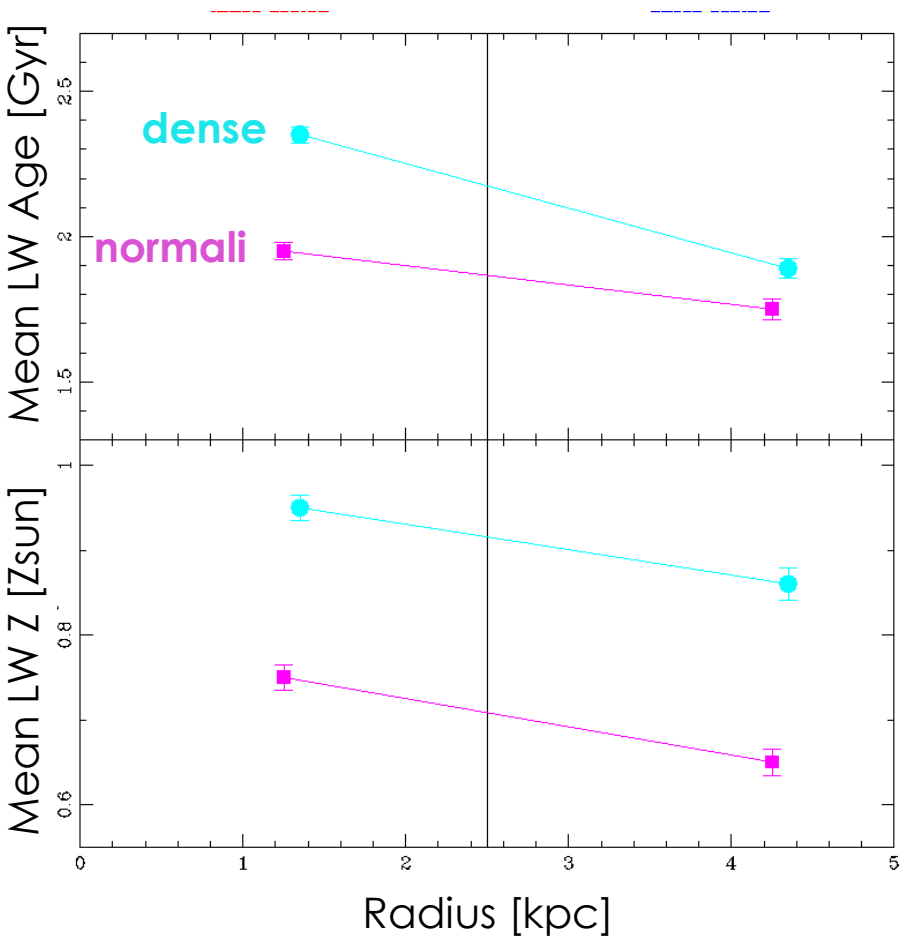
Starlight + Vazdekis models

$0.5\ Z_{sun}$, Z_{sun}, $1.5Z_{sun}$

0.1 – 5 Gry

Errors on parameters estimated with simulations

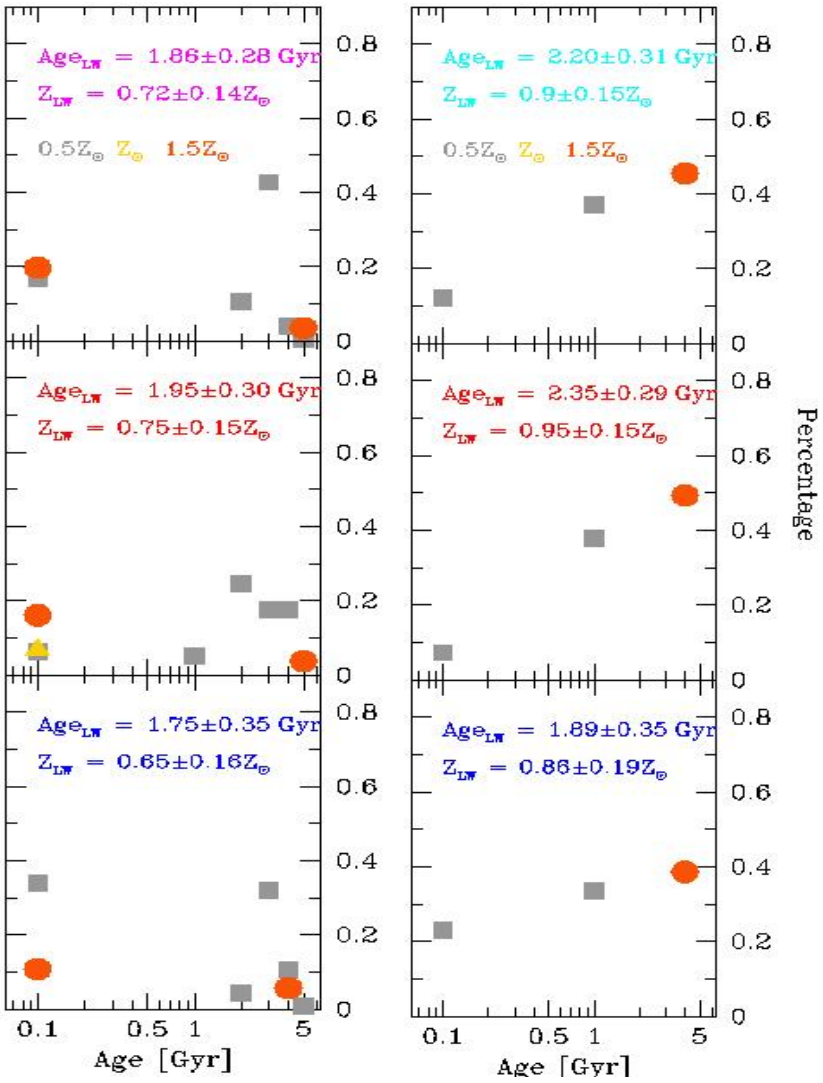
NORMAL VS. DENSE PGs : (PRELIMINARY) RESULTS



- Stellar population in the center of PGs older and more metal rich of stellar populations in the outskirts, independently of Σ;

- *At any radius*
stellar populations of **dense** PGs
older and more metal rich
than stellar populations of **normal** PGs

NORMAL VS. DENSE PGs : (PRELIMINARY) RESULTS

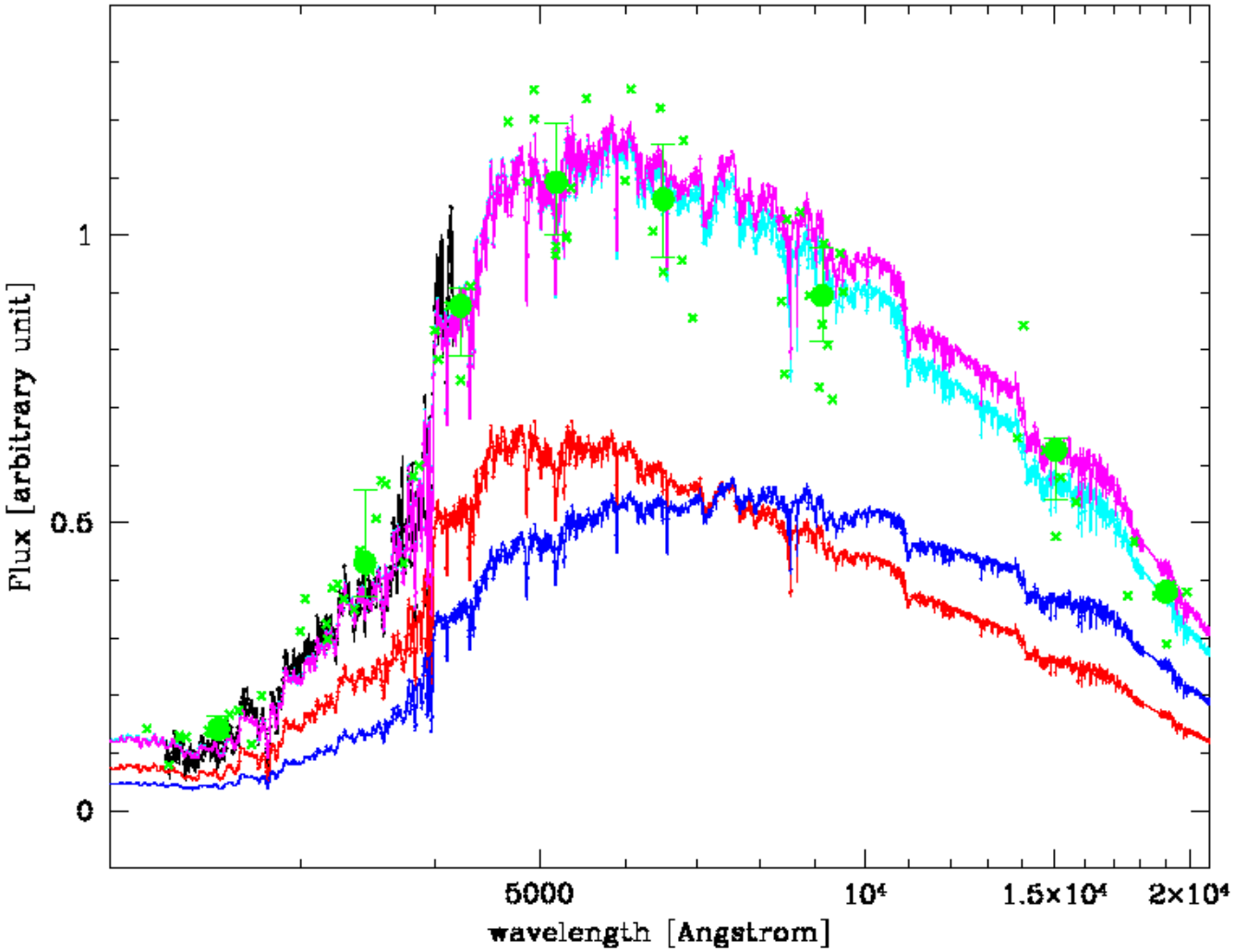


- SFH of PGs depends on Σ → **normal** PGs more jagged SFH than **dense** PGs.

…AND FUTURE STEPS

❖ VANDELS spectra have ‘’short’’ wavelength coverage (~2000 Å rest-frame) → add photometry;

SPECTRO + PHOTOMETRY

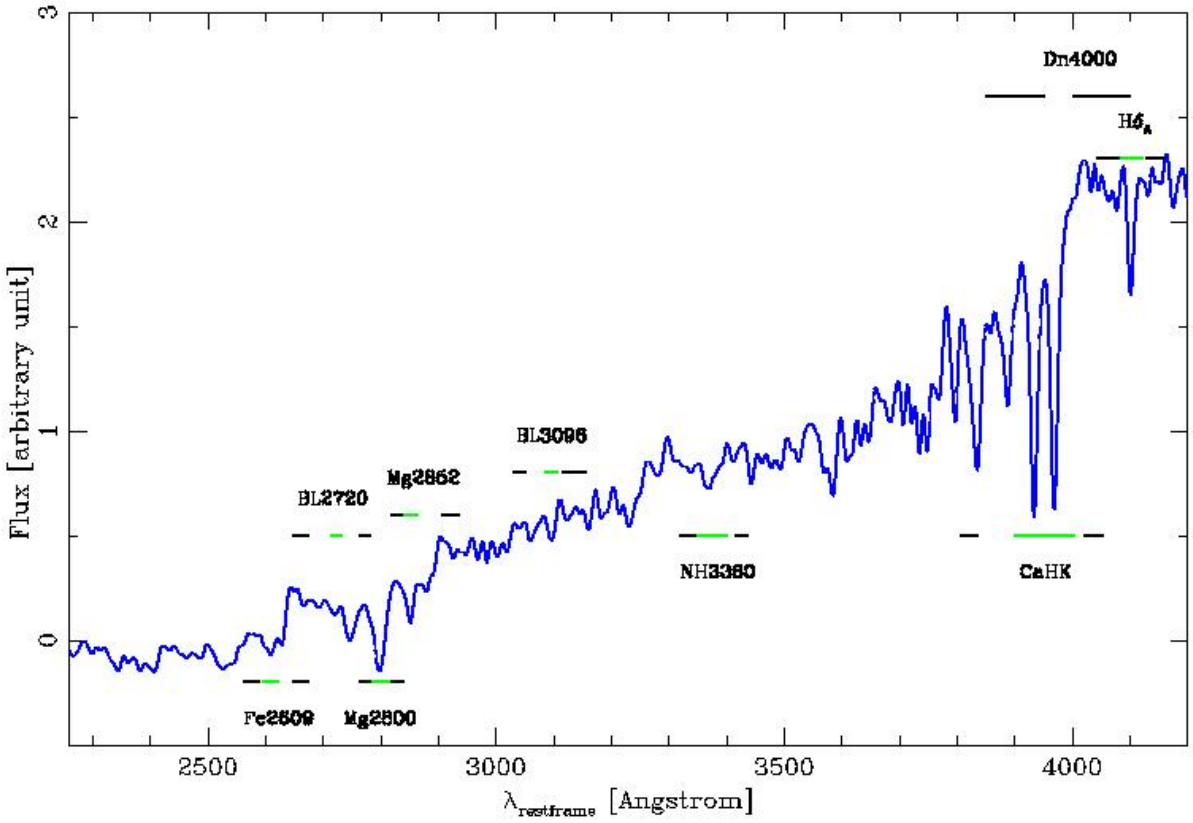


Best fit inner spec
Best fit outer spec
Sum best fit in + best fit ou
Best fit tot spec
Obs tot spec

…AND FUTURE STEPS

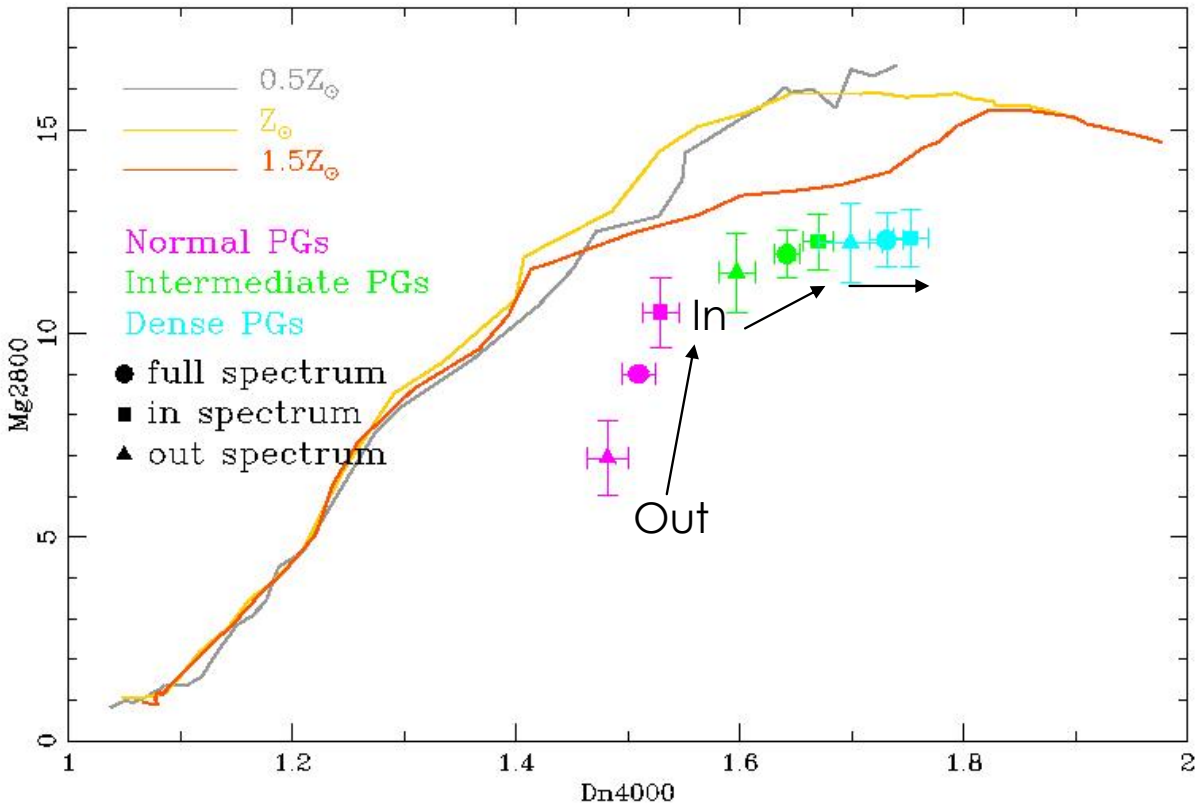
- VANDELS spectra have ''short'' wavelength coverage (~2000 Å rest-frame) → add photometry;
- Exploit the unplumed richness of UV spectral indices to look for (possible) indices combinations sensitive to age/met → very few works on this;

SPECTRAL INDICES



Lector software → Lick and Rose indices
+ D4000 (Balogh def.)

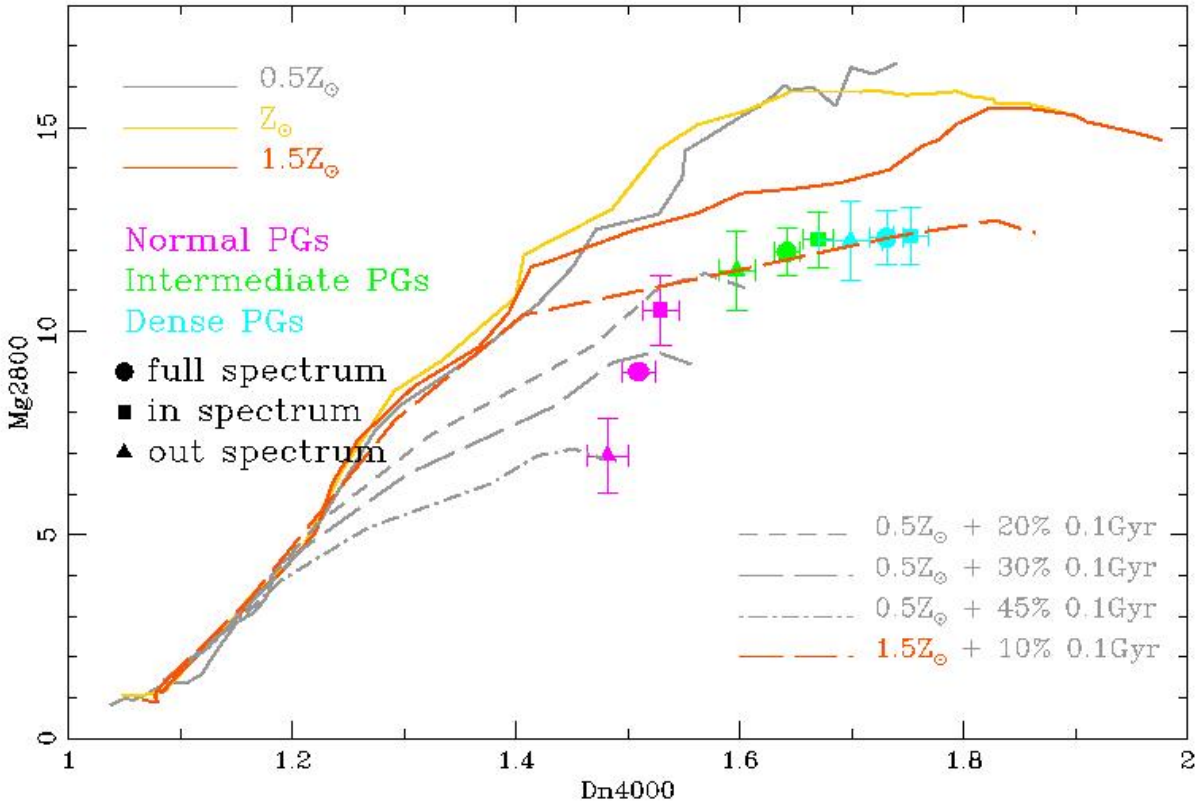
IN & OUT SPECTRAL INDICES



Simple Stellar Populations do not reproduce observed indices →

more complex star formation histories for **NORMAL**, **INTERMEDIATE** and **DENSE** PGs as derived from the fit of the whole spectrum

IN & OUT SPECTRAL INDICES



1. **normal** and **dense** PGs indices reproduced only considering young SSP contribution

2. The fraction of light coming from younger stars is higher for **normal** PGs than for **dense** PGs

3. Spectral indices of **dense** PGs can be reproduced only with models with higher Z than **normal** PGs

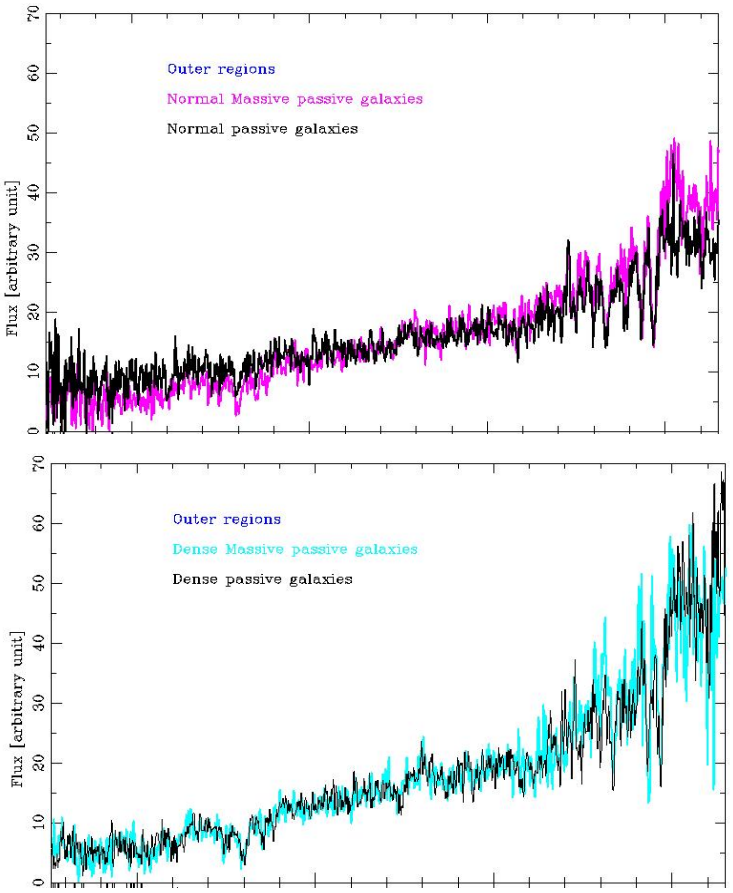
…AND FUTURE STEPS

- VANDELS spectra have ''short'' wavelength coverage (~2000 Å rest-frame) → add photometry;
- Exploit the unplumed richness of UV spectral indices to look for (possible) indices combinations sensitive to age/met → very few works on this;
- Repeate the same analysis for different stellar mass bin;

TRENDS WITH STELLAR MASS

Massive Passive Galaxies (MPGs) → Log (M_{star}/M_{sun}) ≥ 11.0

Normal MPGs redder (i.e. older/more metallic) than normal PGs *at any radius*
→ in line with age/met – mass relation



DENSE MPGs have spectra similar to PGs *at any radius*
→ mass assembly history of DENSE PGs is not mass dependent

THE FUTURE: MORE THAN JWST, MOSAIC @ E-ELT

VANDELS → pioneering work, but on stacked samples → 10 galaxies per stack

For analysis on single PGs at z ~ 1.5:

JWST

→ **NIRSpec IFU Spectroscopy**

→ can do it, but ~ 20h of integration time per galaxy → not feasible for large samples

MOSAIC @ E-ELT

→ High Definition Mode: NIR spectroscopy [0.8 – 1.8]μm + 10 IFU (2x2 arcsec) over 32 arcmin^2

→ tailored to fit the expected number density of PGs at z ~ 1.5 → we need it!

THE FUTURE: MORE THAN JWST, MOSAIC @ E-ELT

VANDELS → pioneering work, but on stacked samples → 10 galaxies per stack

For analysis on single PGs at z ~ 1.5:

JWST

→ **NIRSpec IFU Spectroscopy**

→ can do it, but ~ 20h of integration time per galaxy → not feasible for large samples

MOSAIC @ E-ELT

→ High Definition Mode: NIR spectroscopy [0.8 – 1.8]μm + 10 IFU (2x2 arcsec) over 32 arcmin^2

→ tailored to fit the expected number density of PGs at z ~ 1.5 → we need it!