***Science with multi-object spectrographs**: perspectives and opportunities for the Italian community*

Milano, 12-13 December 2018

VANDELS

A deep VIMOS survey of the CANDELS UDS and CDFS fields

An introduction to the survey and first results

Margherita Talia
University of Bologna
INAF-OAS

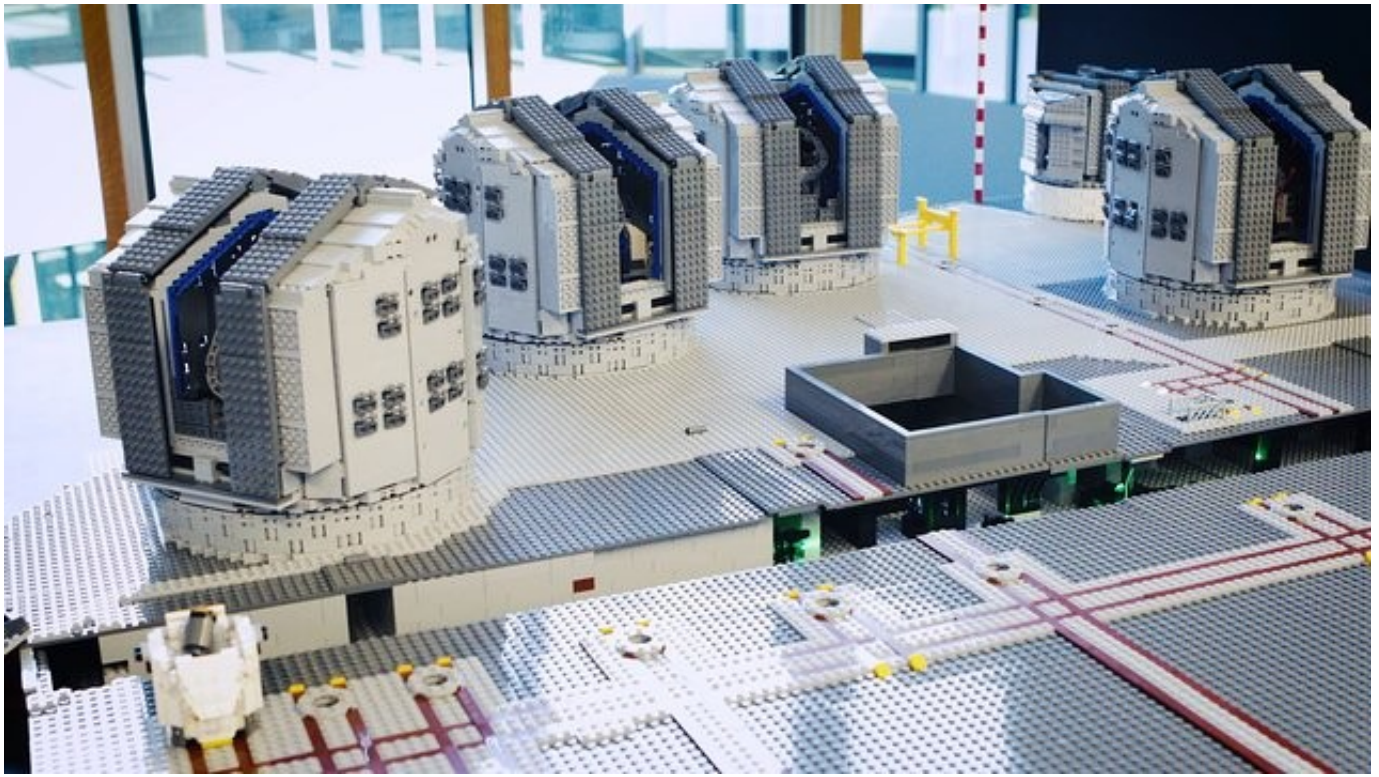


Image credits: ESO

Spectroscopic surveys

Key complement to multi-wavelength data:

- Redshifts validation (evolution of LF, MF, SFRD)
- Probe structures/overdensities and impact of environement

But also…

- Probe stellar populations properties
- Probe ISM: gas kinematics, chemical enrichment, interaction with IGM

…if deep enough!

Previous high-z spec. surveys in the CANDELS fields (not exhaustive list)

VUDS COSMOS+ECDFS (optical): ~7000 galaxies @ 2<z<6
3D-HST All CANDELS fields (near-IR): ~10,000 galaxies @ 1<z<3.5
MOSDEF COSMOS+AEGIS+GOODS-N (near-IR): ~1500 galaxies @ 1.4<z<3.8

…also **DEEP3, zCOSMOSdeep, UCR-DEIMOS, DEIMOS 10K, GMASS**...

McLure et al. 2018
Pentericci et al. 2018

ID card

Public survey: raw data immediately public

Target pre-selection: biased to very high-redshift
→ *85% of targets @ z>3*

VIMOS visitor time: > 1000 hours
→ *observations completed!*

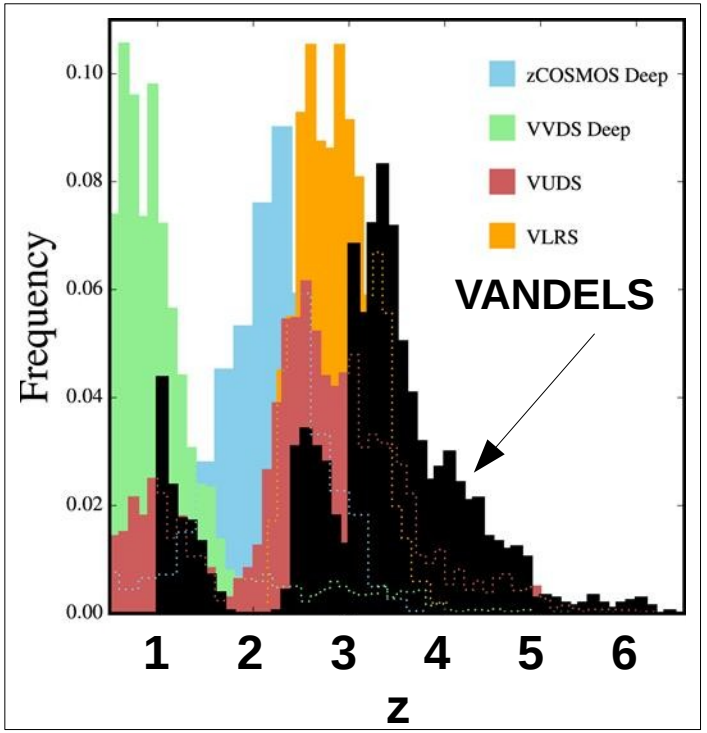
Wavelength coverage: ~4800 – 9800 Å
→ *UV range @ z>2*

Spectral resolution: ~600

Integration time: up to 80 hours per target

Area: 0.2 sq. degrees

Fields: CANDELS GOODS-S & UDS
→ *best available multi-wavelength data*



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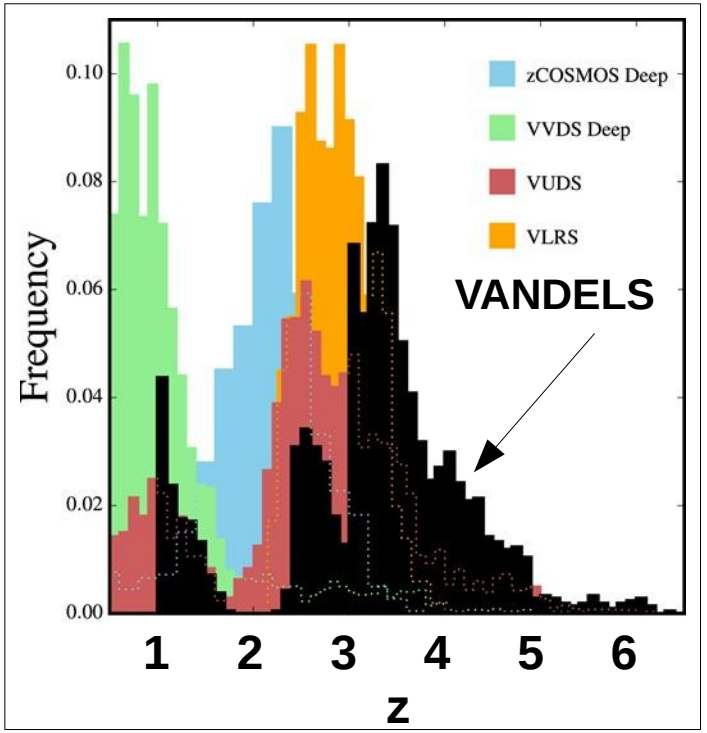

Legacy value to the high-z extra-galactic community

Not just a redshift survey!
Different science from previous VIMOS surveys

Motivation

Combine ultra-deep optical spectroscopy with near-IR grism spectroscopy and 0.3µm-4.5µm photometry to measure physical tracers of galaxy evolution:
age, mass, dust, SFR, outflows, stellar metallicity….

Sufficient **signal-to-noise** and **resolution** to measure physical properties from ***individual*** spectra, not only stacks.

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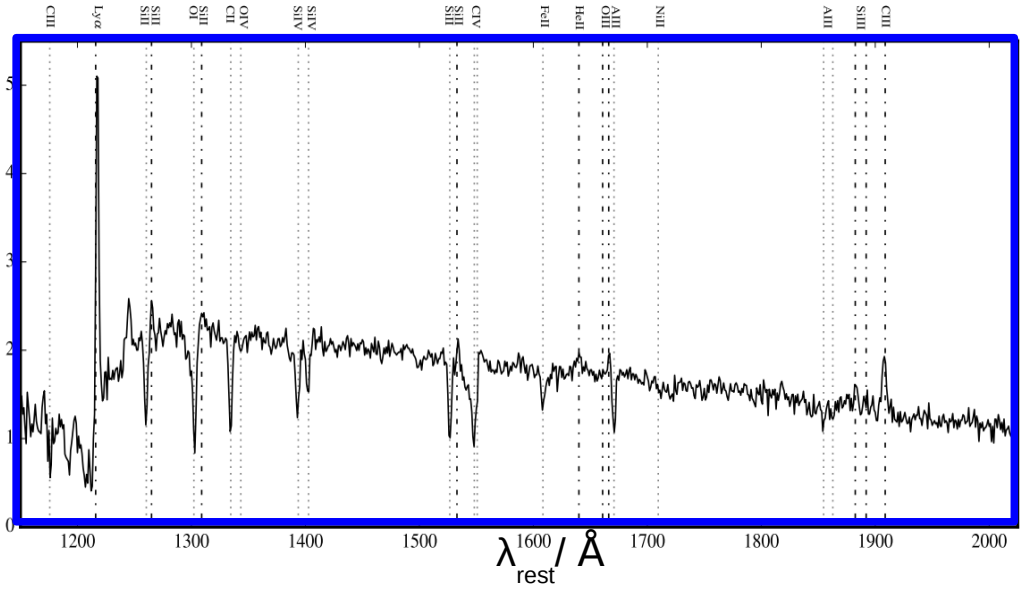
Primary Targets

Star-forming galaxies at $2.4<z<5.5$ ($H_{AB}<24$)

DR1 stacked spectra

McLure et al. 2018



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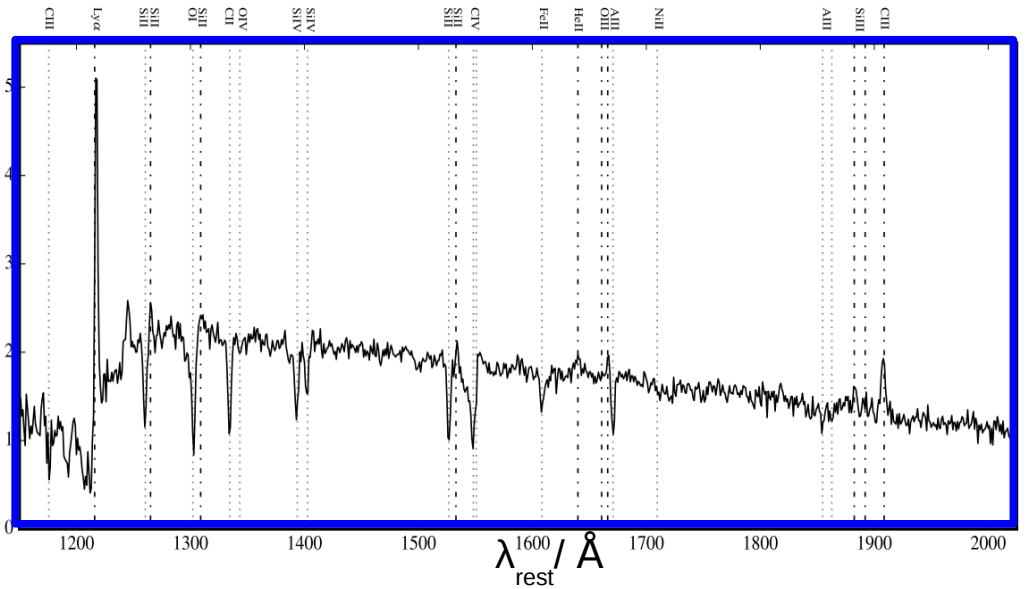

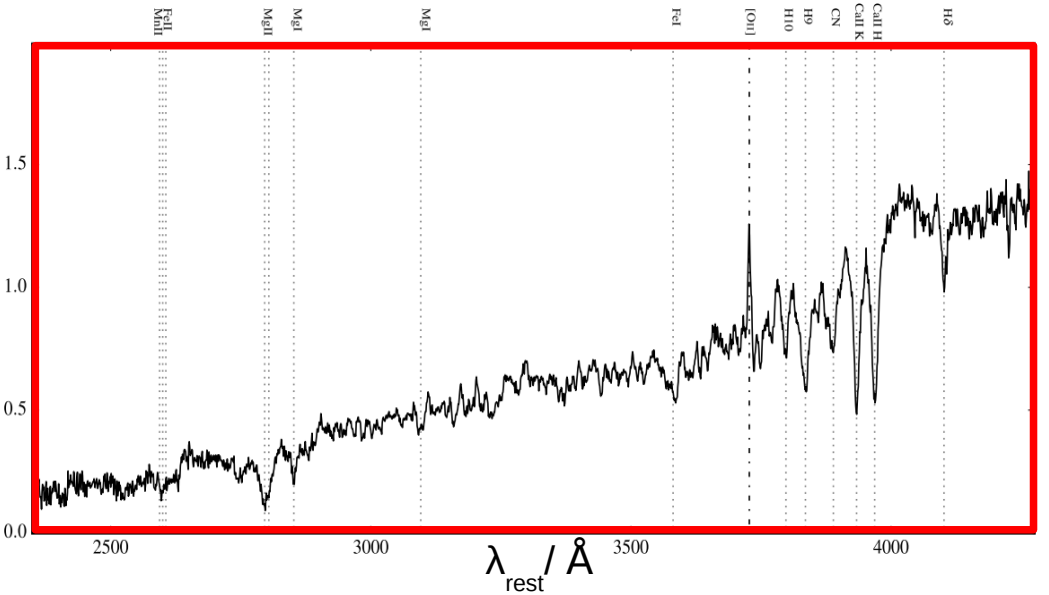

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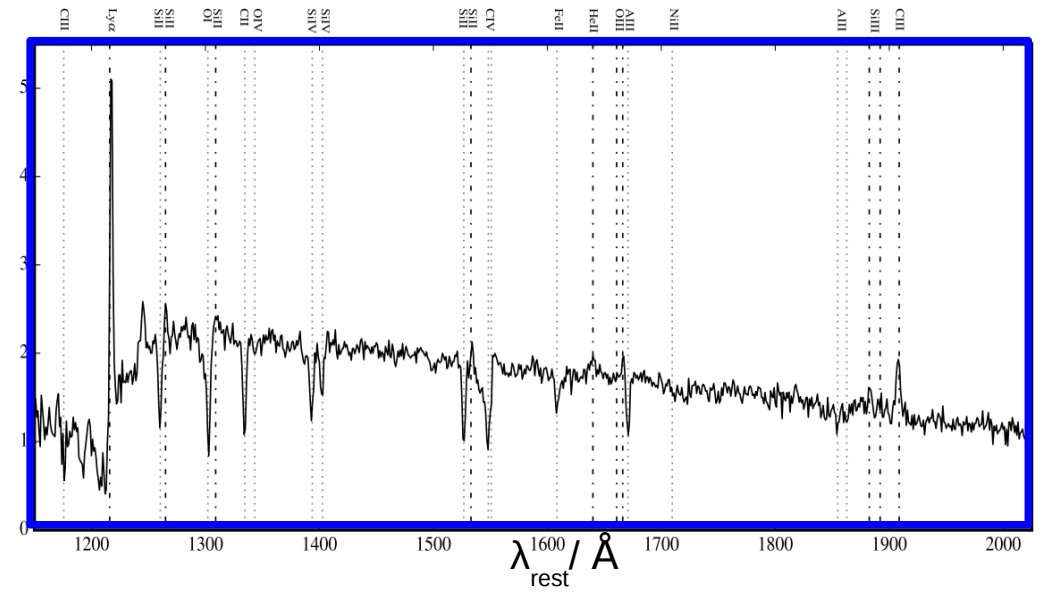
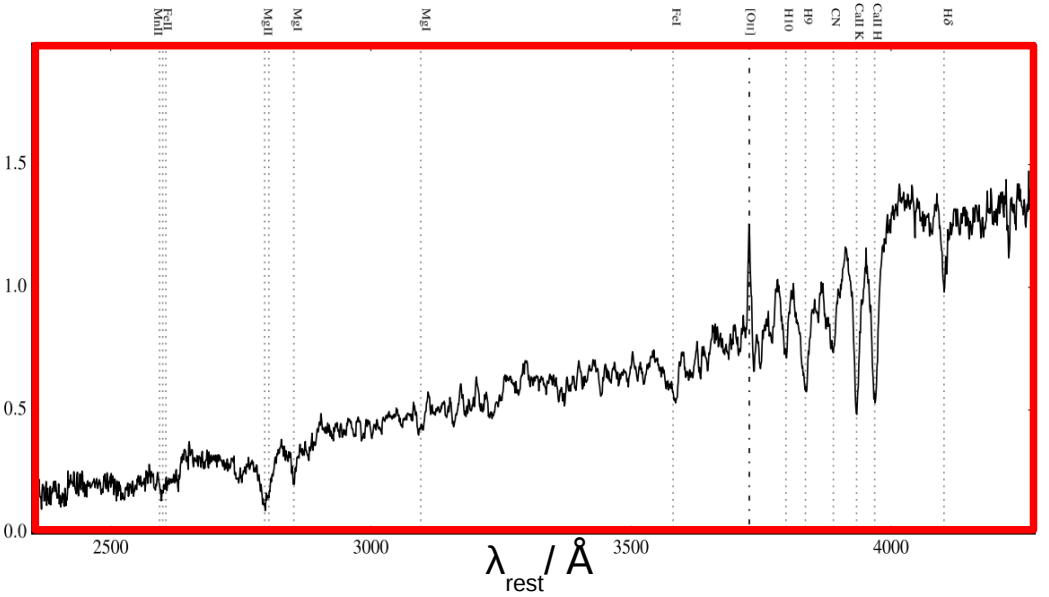
Lyman-break galaxies at $3.0<z<7.0$ ($H_{AB}<27$)

DR1 stacked spectra

McLure et al. 2018





Data release

WHAT?	WHEN?	WHERE?
Raw data	Immediate	ESO archive
Reduced spectra (1D – 2D) Redshift catalogue	Regular releases	ESO archive VANDELS database
Enhanced products	Final data release	ESO archive VANDELS database

Full details and database: **vandels.inaf.it**

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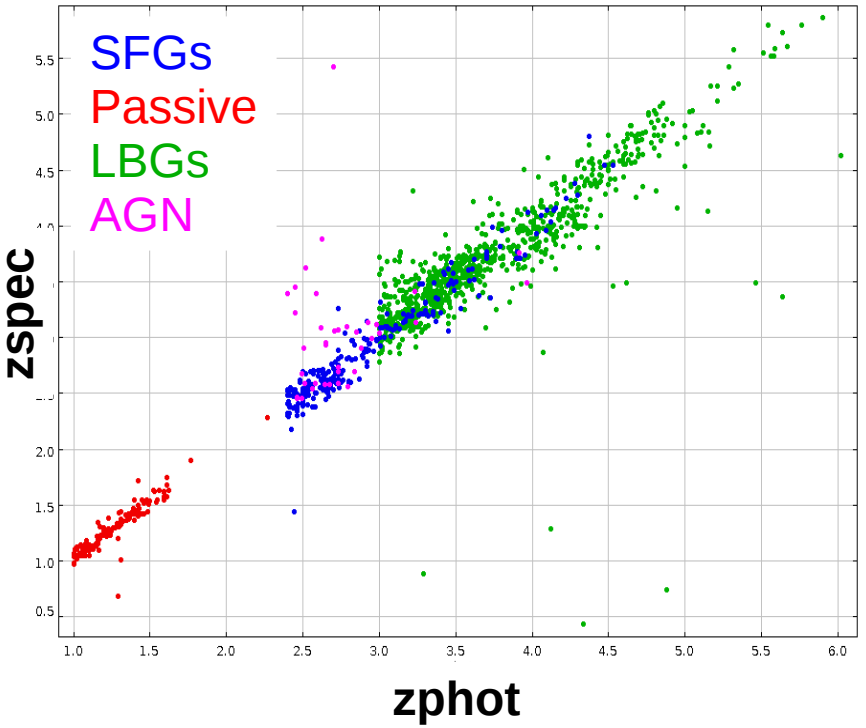
Second data release (DR2) available from 1st Oct. 2018



Excellent accuracy of the photometric redshifts

DR2: **1362 spectra**
1132 completed
217 spectra which received 80 hours integration time

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Enhanced products

- Final spectroscopic redshift catalogue
- Final combined photometric catalogue
- Basic stellar population parameters
- Catalogue of spectroscopic measurements

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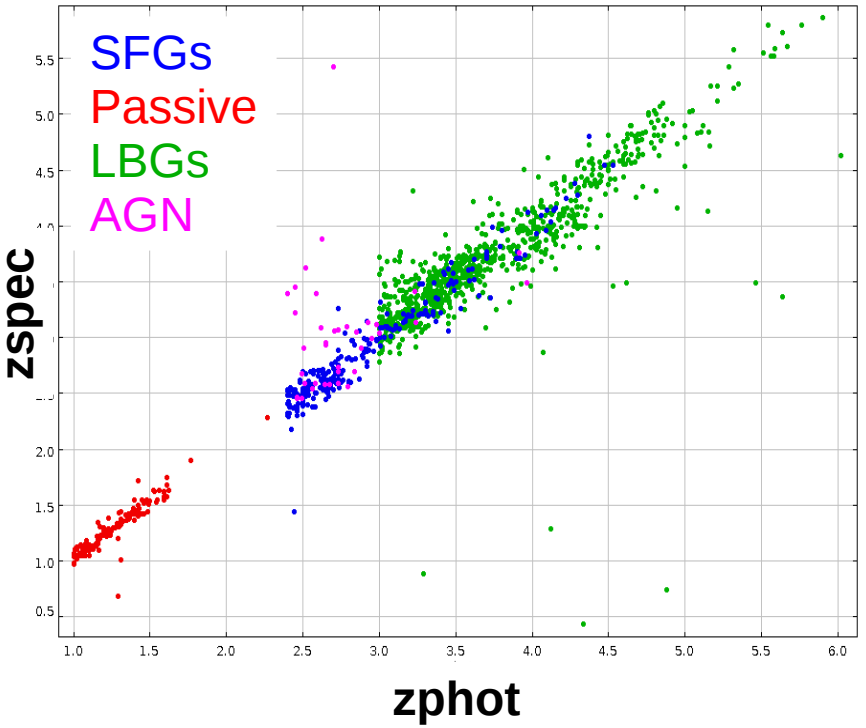

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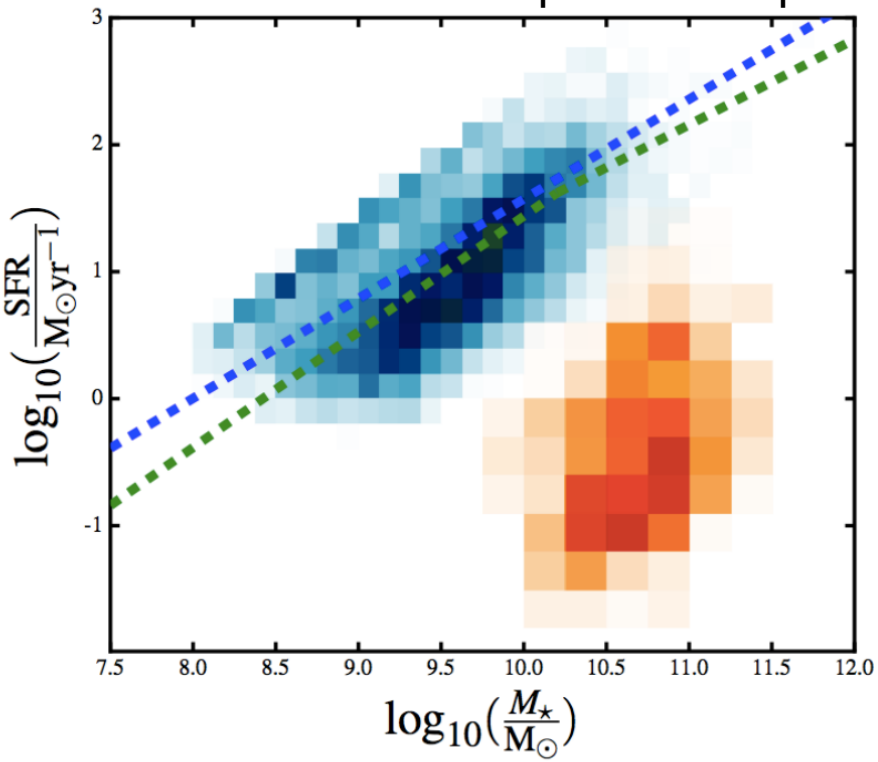
Science

Full VANDELS sample: >2100 targets
→ **star-forming population at 2.5<z<5.5**
and their **passive descendants at 1<z<2**

VANDELS parent sample



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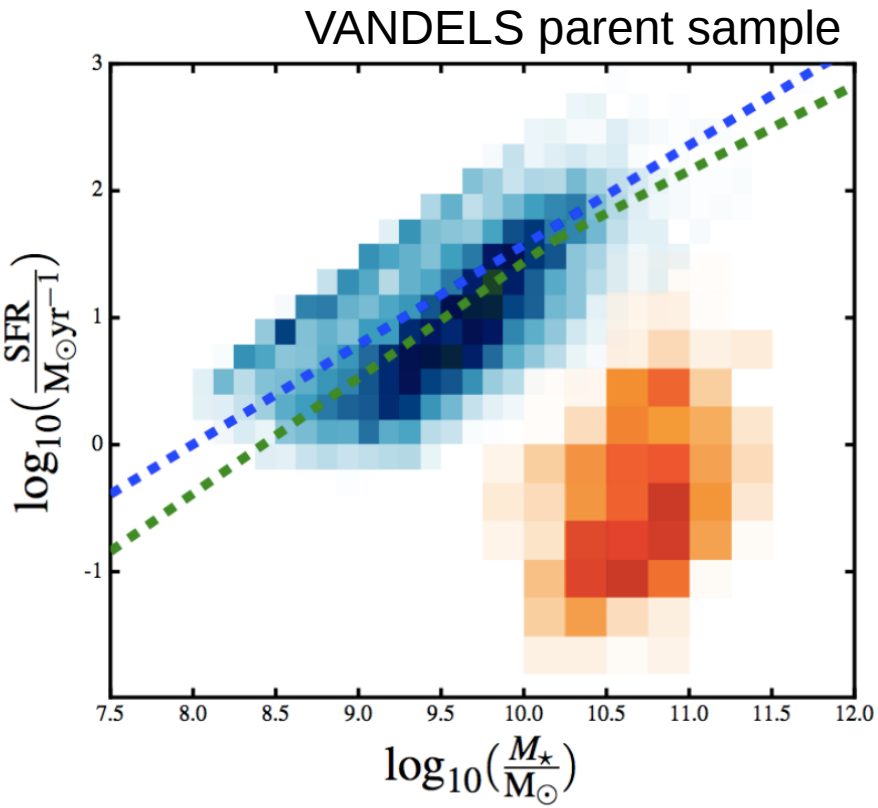

Exploiting the VANDELS dataset

- Constraints on metallicity, dust (*Cullen et al. 2018*), age of SFGs at z>2
- Massive galaxy assembly and quenching
- Outflow/inflow velocity measurements – feedback, build-up of mass-metallicity relation
- Impact of nebular line emission at high-z
- Unbiased measurement of Lya emitter fraction into epoch of reionization
- Comparison with physical properties of AGN and Herschel sources
- Excellent source of targets for JWST NIRSpec follow-up
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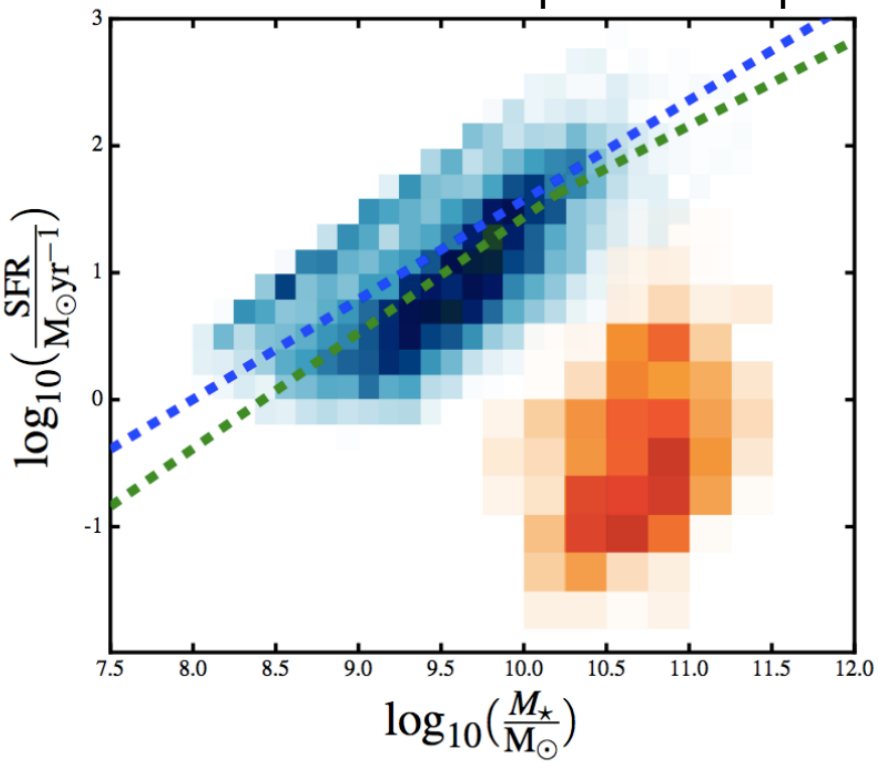

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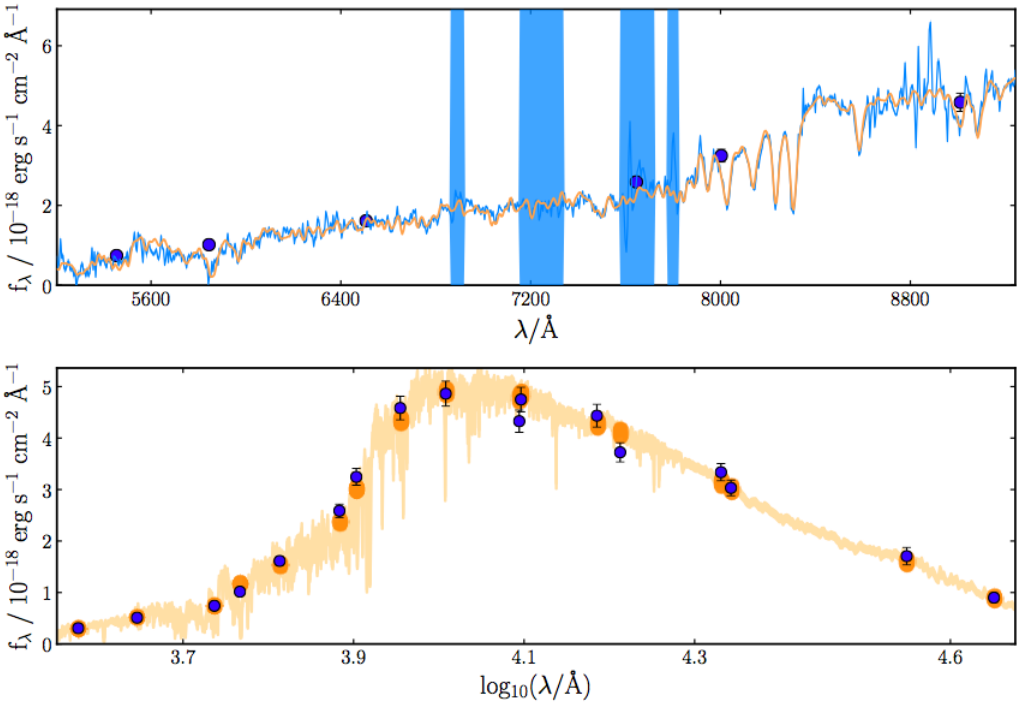
Topics of general interest → Working Groups

1. Spectroscopic measurements for the final data release (**coordinator M. Talia**)
2. Metallicity (coord. Amorin)
3. Spectrophotometric fitting (coord. McLure)
4. AGN properties (coord. A. Bongiorno)
5. Density field, proto-clusters, environment (coord. O. Cucciati)

Carnall et al.

Star formation histories and physical parameters
Passive galaxies



VANDELS DR2: 74 galaxies with
$1.0<z<1.3$ and $M_* > 10^{10.3}$ (mass complete)

BAGPIPES https://bagpipes.readthedocs.io

Bayesian Analysis of Galaxies for Physical Inference and Parameter EStimation

Complex physical model
(13 free parameters)

- Redshift
- Stellar mass
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Carnall et al.

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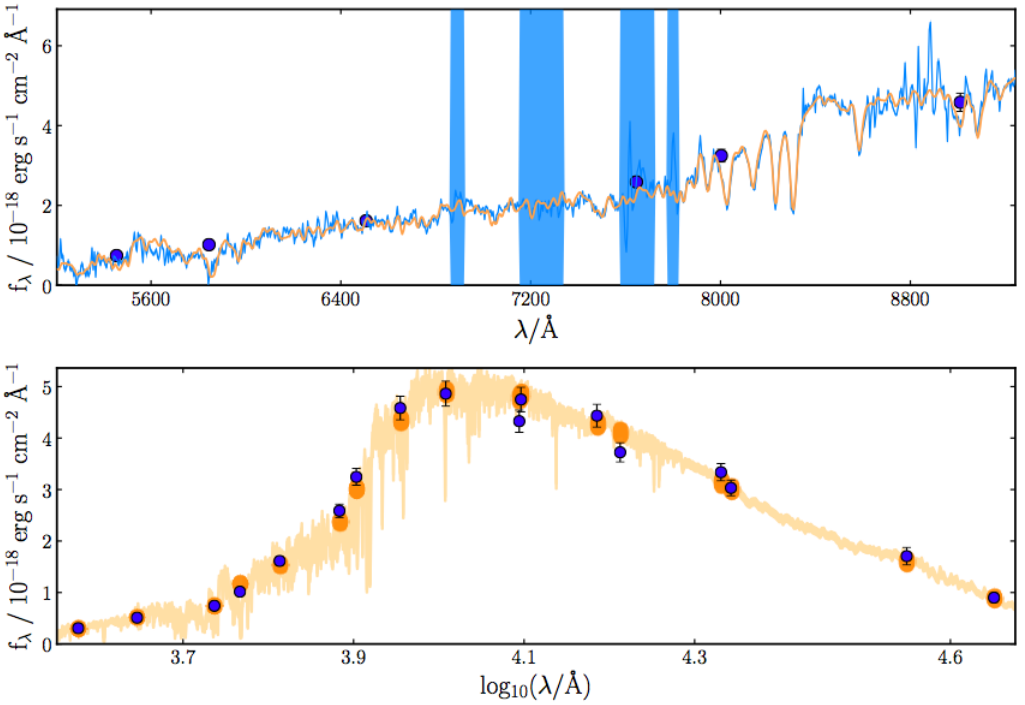

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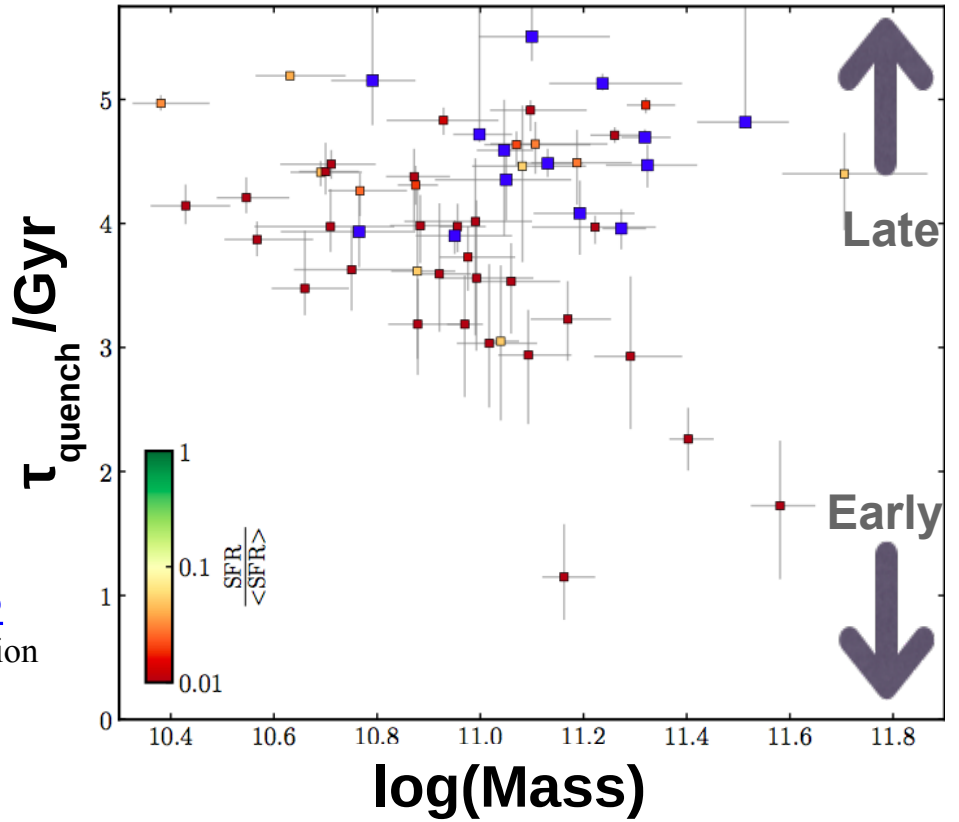

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- ...

- Most passive galaxies quenched earliest
- Those forming more stars are younger.
- OII emission primarily within younger, more star-forming galaxies

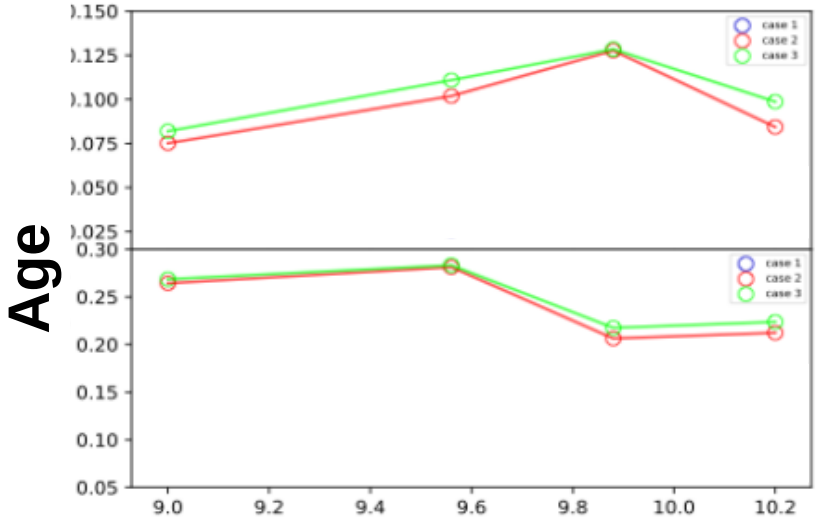
Citro, Pozzetti, Talia et al.

Star formation histories and physical parameters

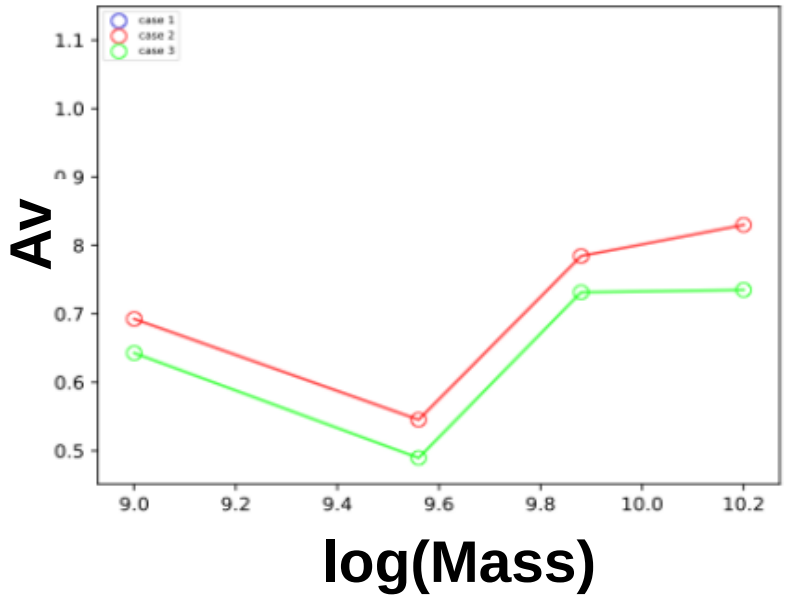
SFGs

Full spectral fitting
→ Starlight code (*Cid Fernandes+'07*)

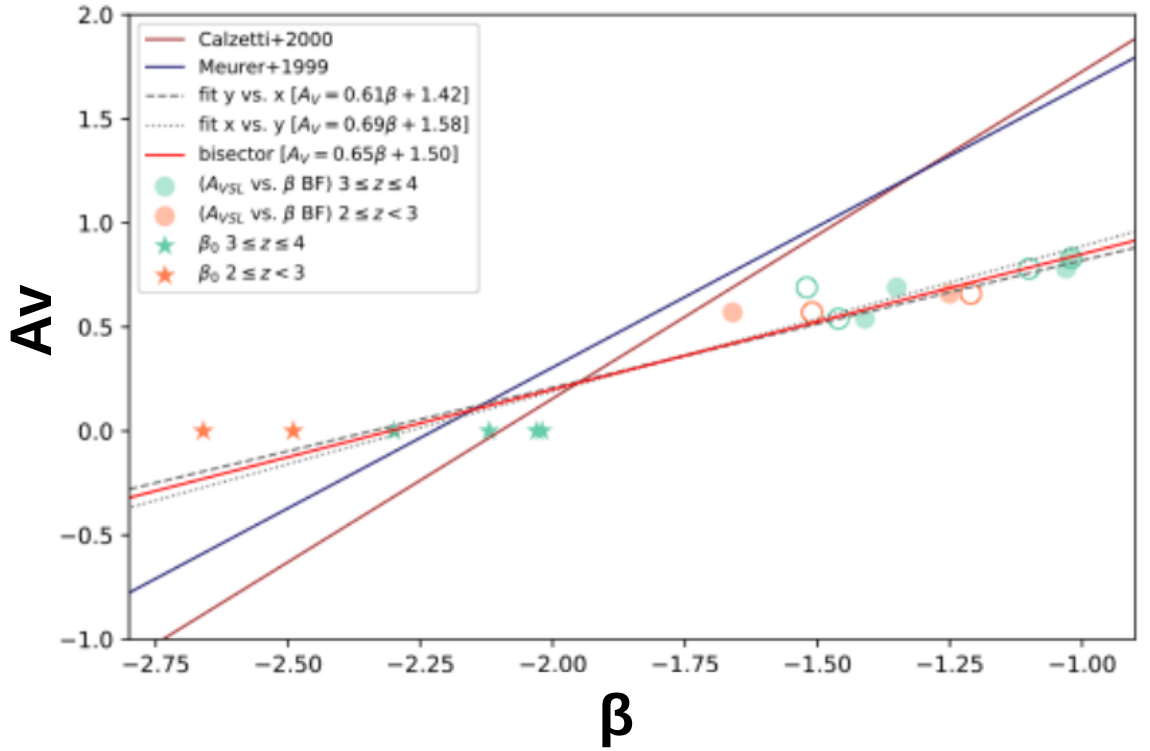
VANDELS DR2: 290 SFGs
with $2.0<z<4.0$ and $10^8 < M_* < 10^{11.5}$



More massive galaxies have larger dust extinctions. No clear trend with age or metallicity.

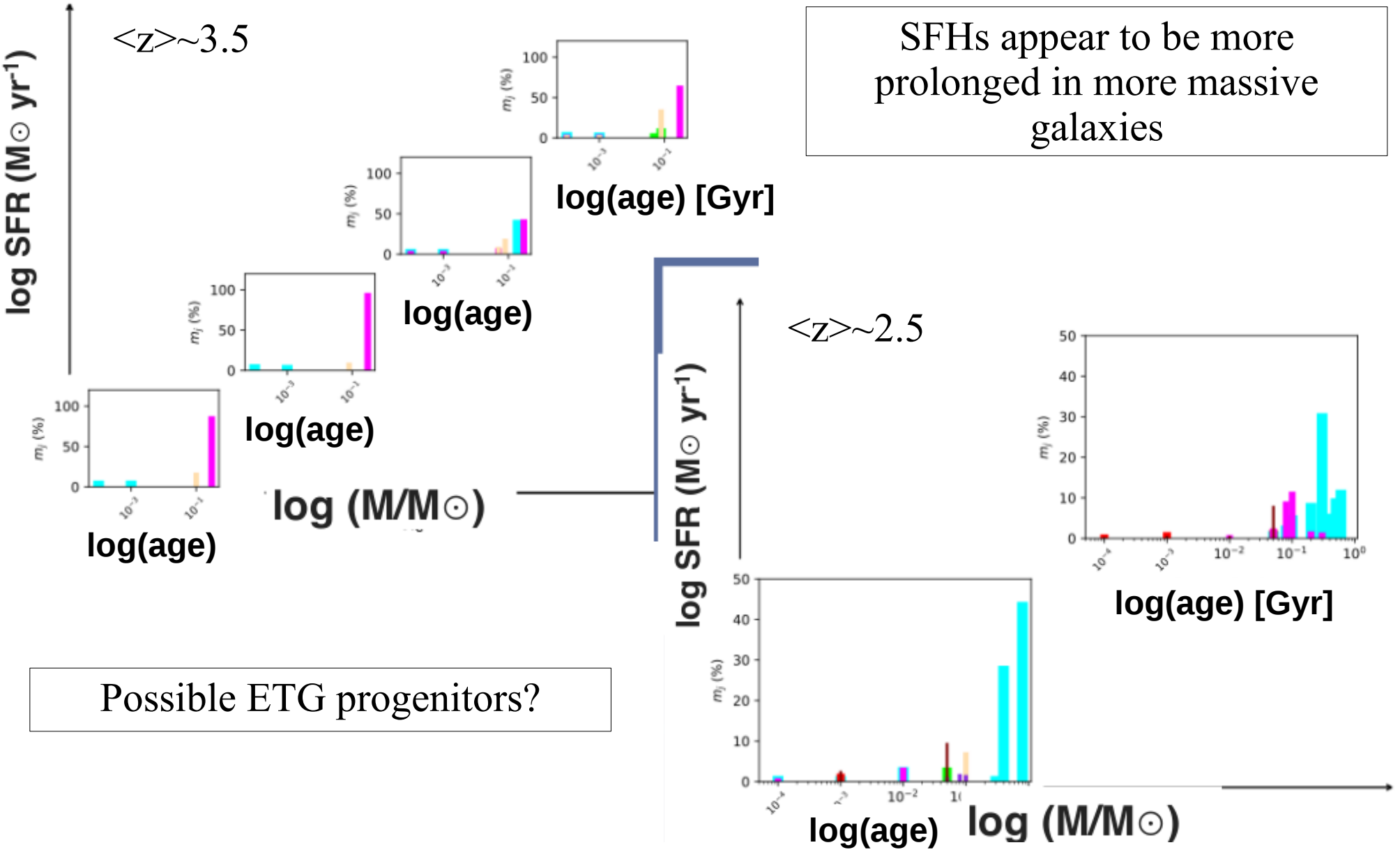


The Av-beta relation is flatter than Calzetti's and Meurer's



Citro, Pozzetti, Talia et al.

Star formation histories and physical parameters SFGs

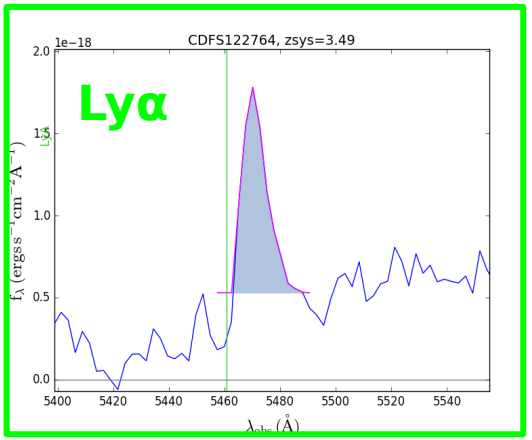


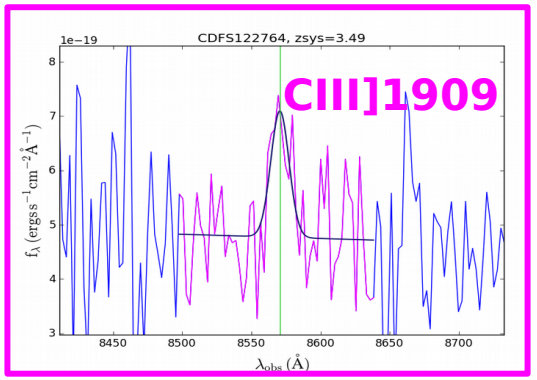
SFHs appear to be more prolonged in more massive galaxies

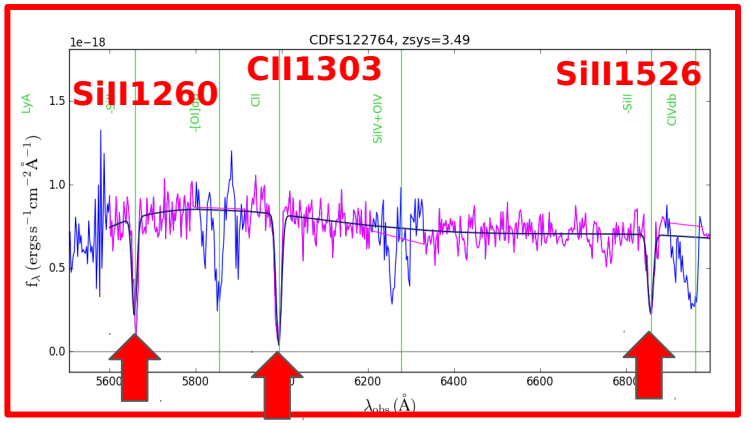
Possible ETG progenitors?

Marchi et al.

What's regulating the escape of Lyα photons in high redshift SFGs



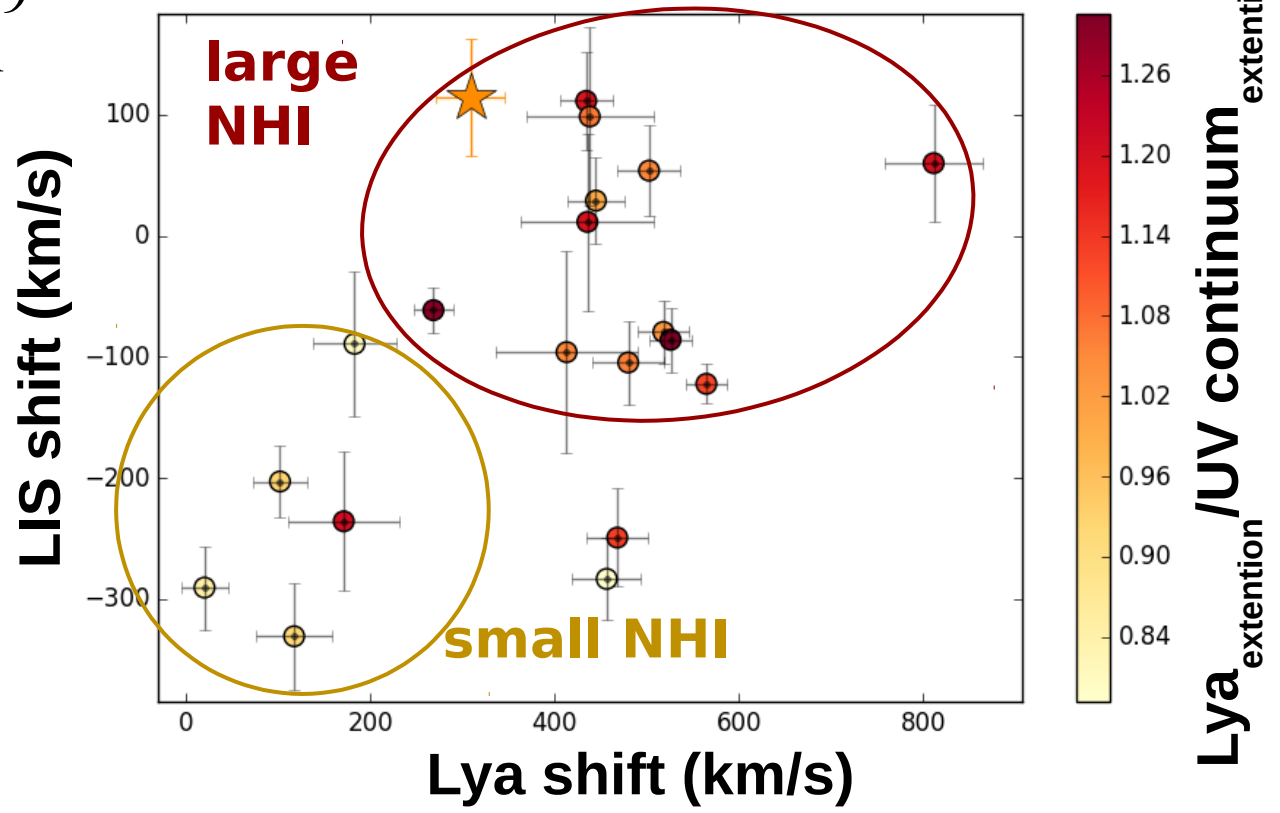




VANDELS DR2:

- 57 Lya emitters
- 3.0<z<4.5
- CIII]1909 emission

Correlation between IS and Lya velocity shifts



Consistent with predictions from the **shell model** (*e.g., Verhamme+'15*)

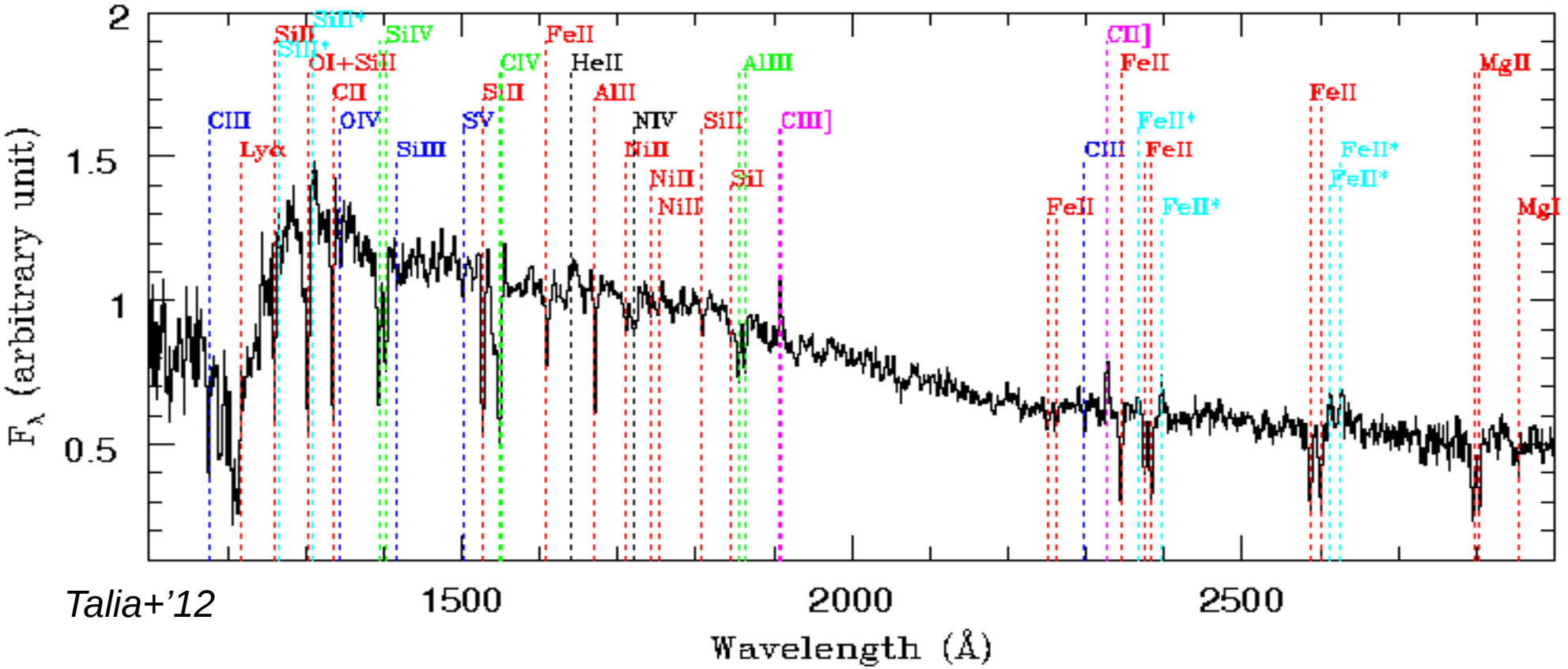
Talia, Citro, Cimatti, Pozzetti et al.

The inter-stellar medium (ISM) in SFGs: inferring outflow properties from UV absorption lines

Low/high-ionization absorption lines velocity offset:

~ - 100 km/s in SFGs up to z~4.6 *(e.g. Shapley+'03, Talia+'12, Cicone+'16)*

~ - 600-800 km/s in AGN *(e.g. Hainline+'11, Cimatti+'13, Talia+'17)*



Talia+'12

Low-ionization IS abs. lines

High-ionization IS abs. lines

Talia, Citro, Cimatti, Pozzetti et al.

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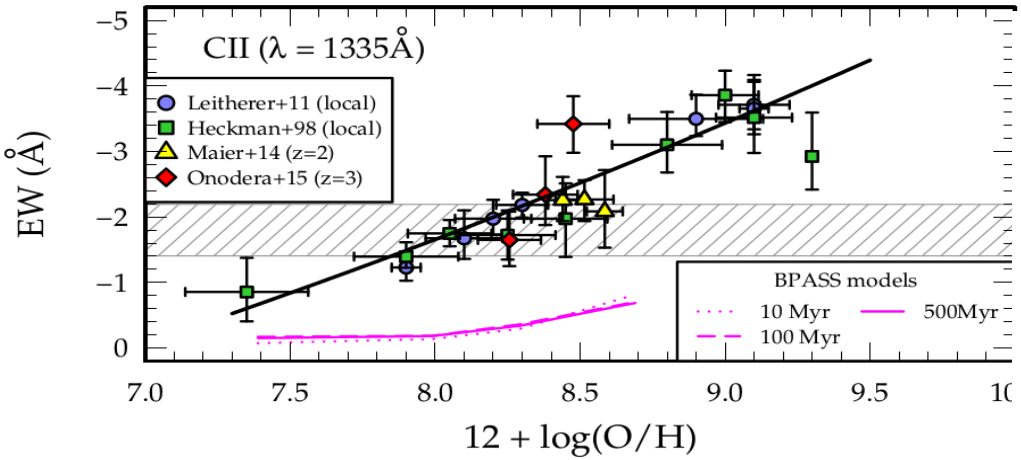
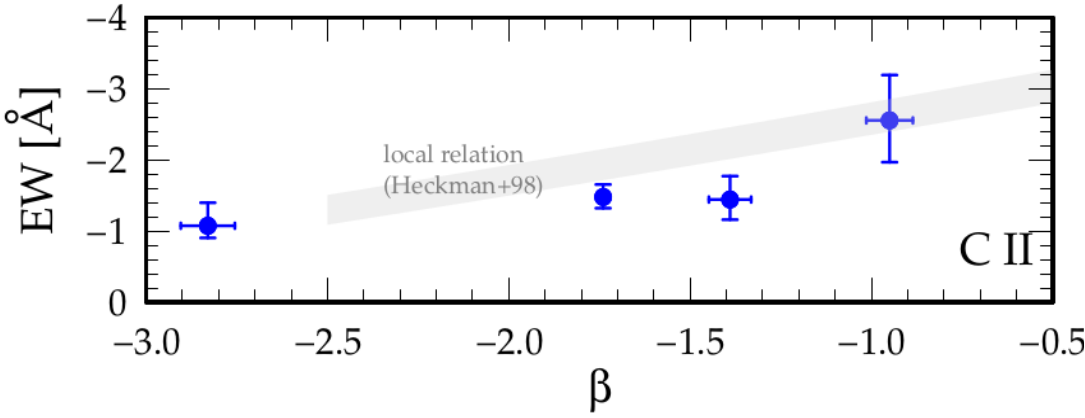
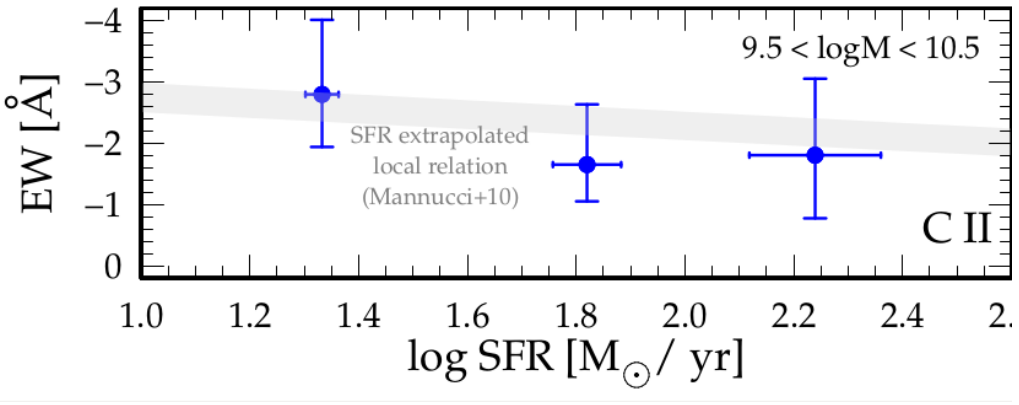
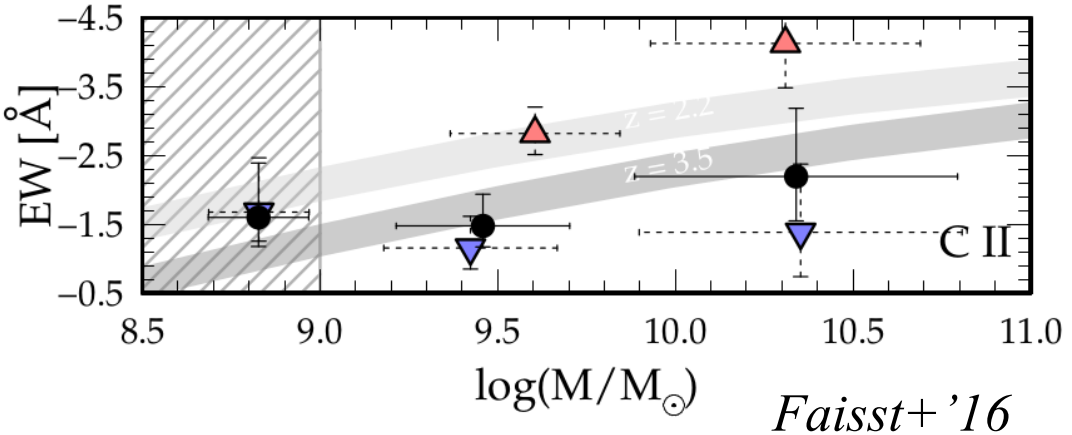
Correlation between gas and galaxy physical properties
(metallicity, SFR, stellar Mass…)

Which is the "driving" correlation?



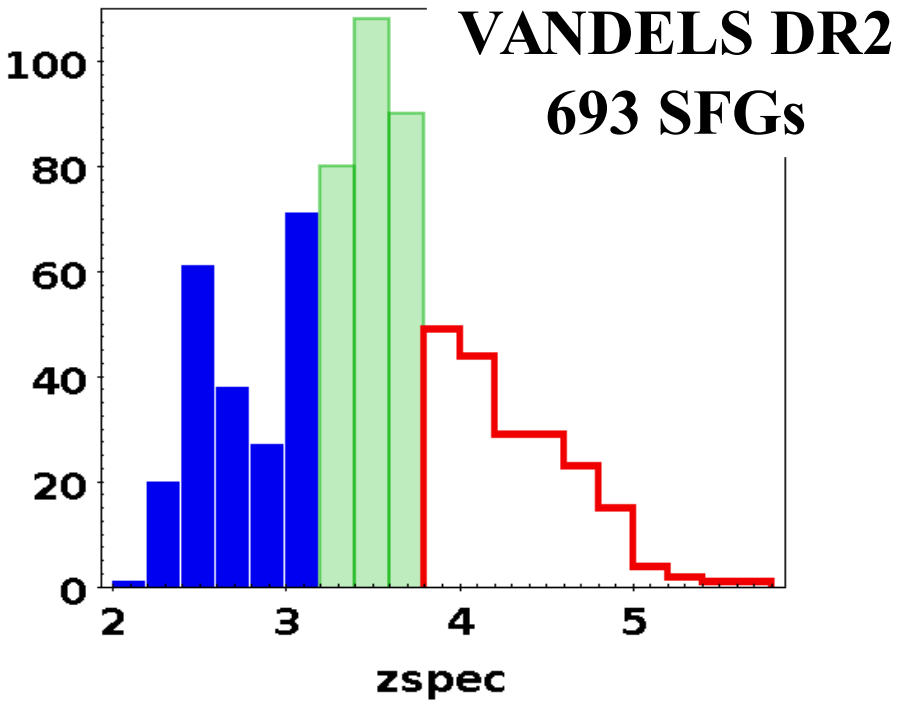


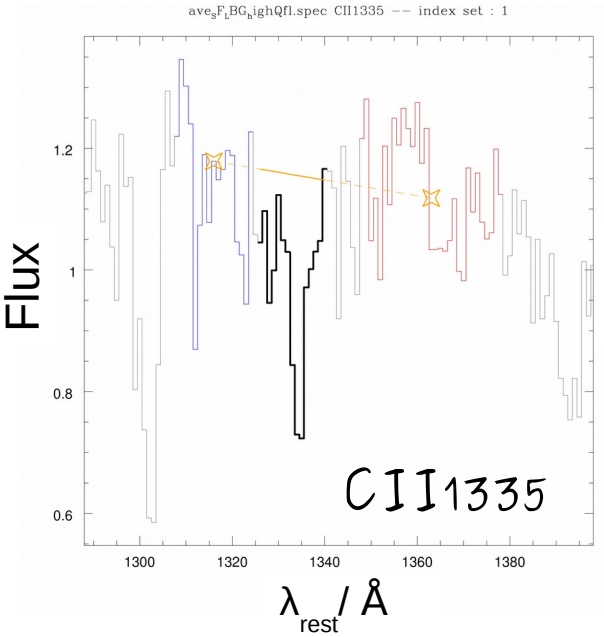


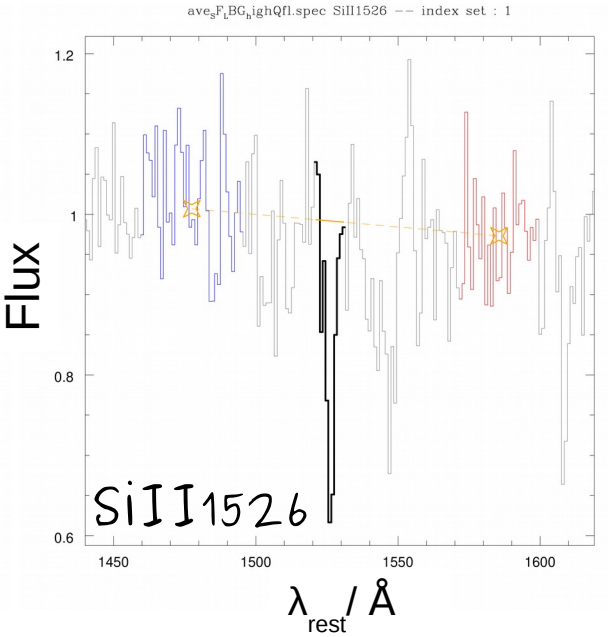


Faisst+'16

Talia, Citro, Cimatti, Pozzetti et al.







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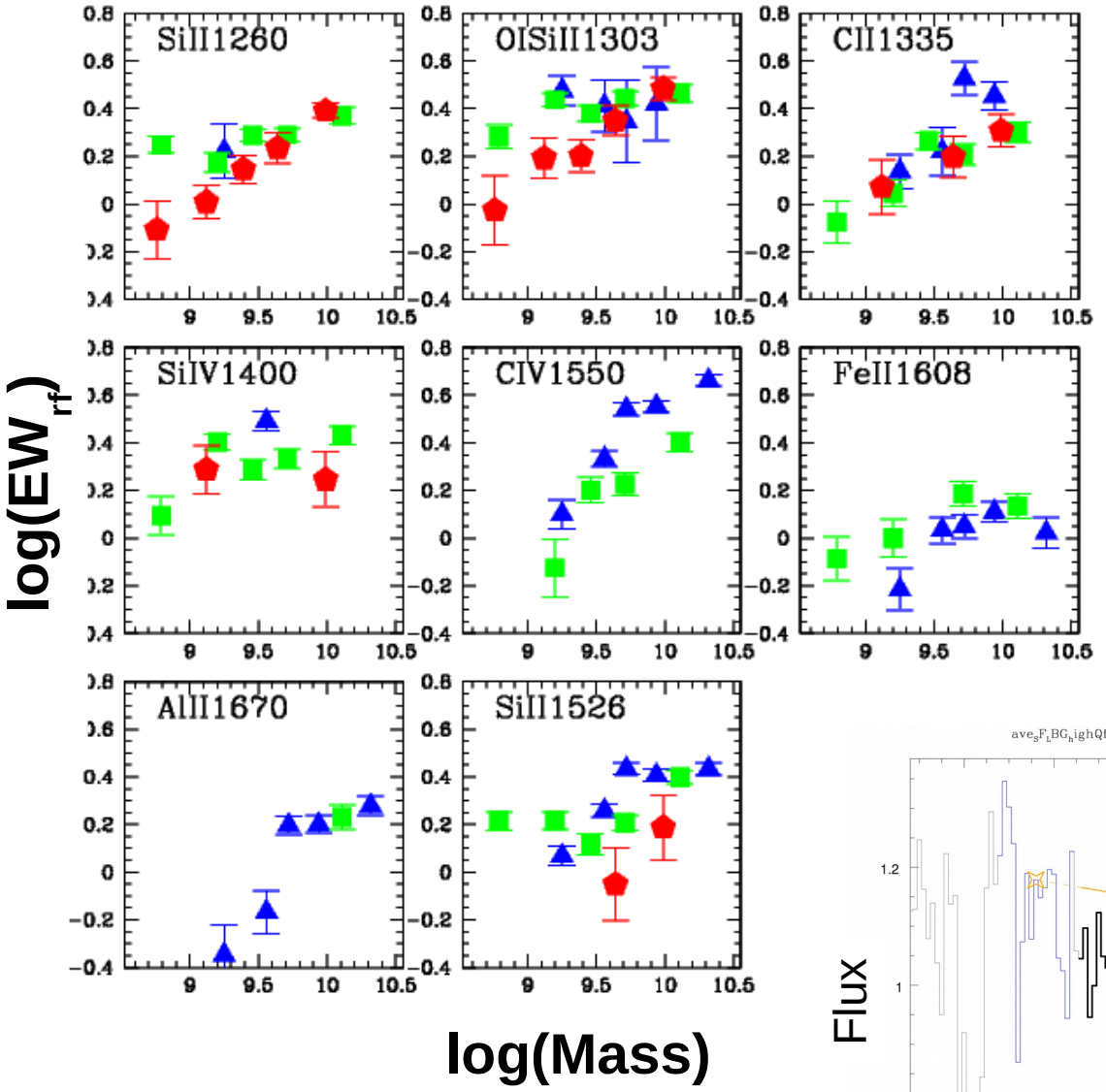

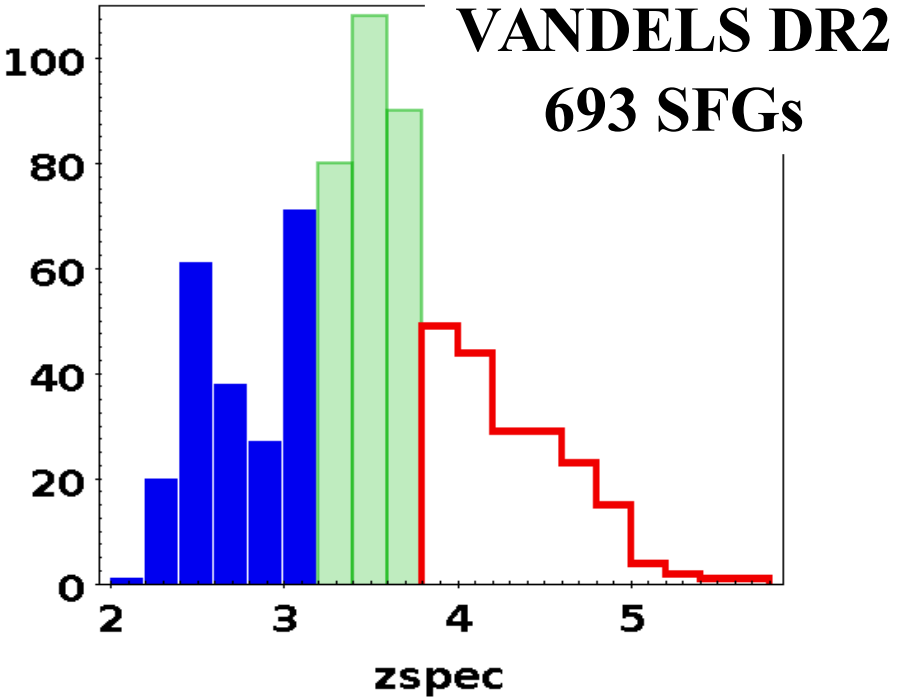

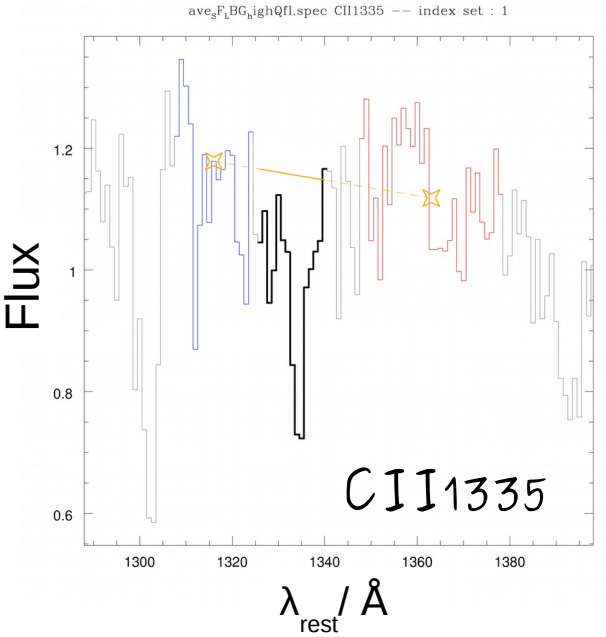

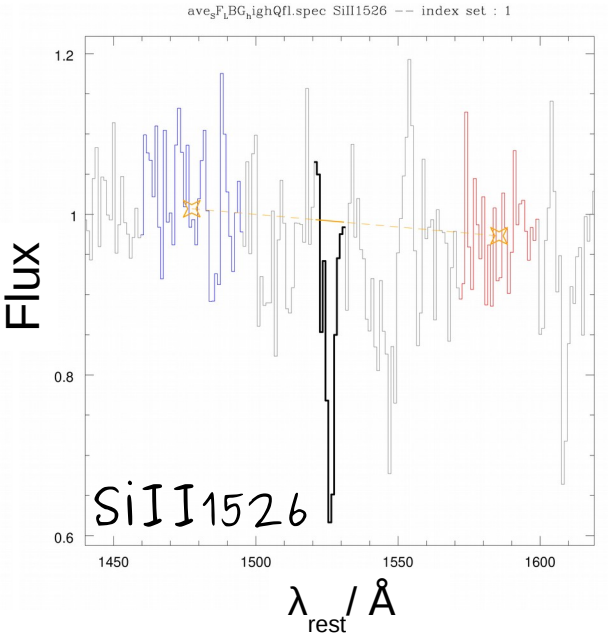

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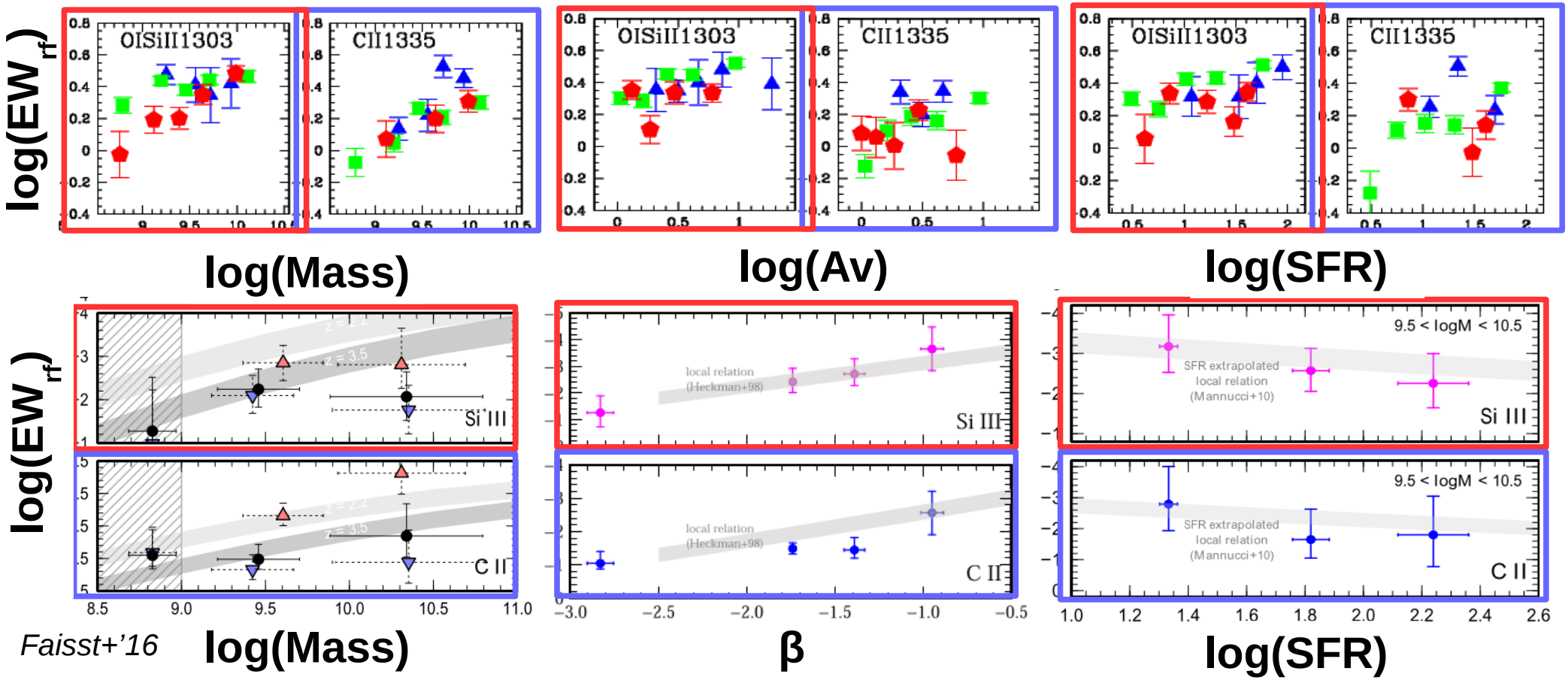
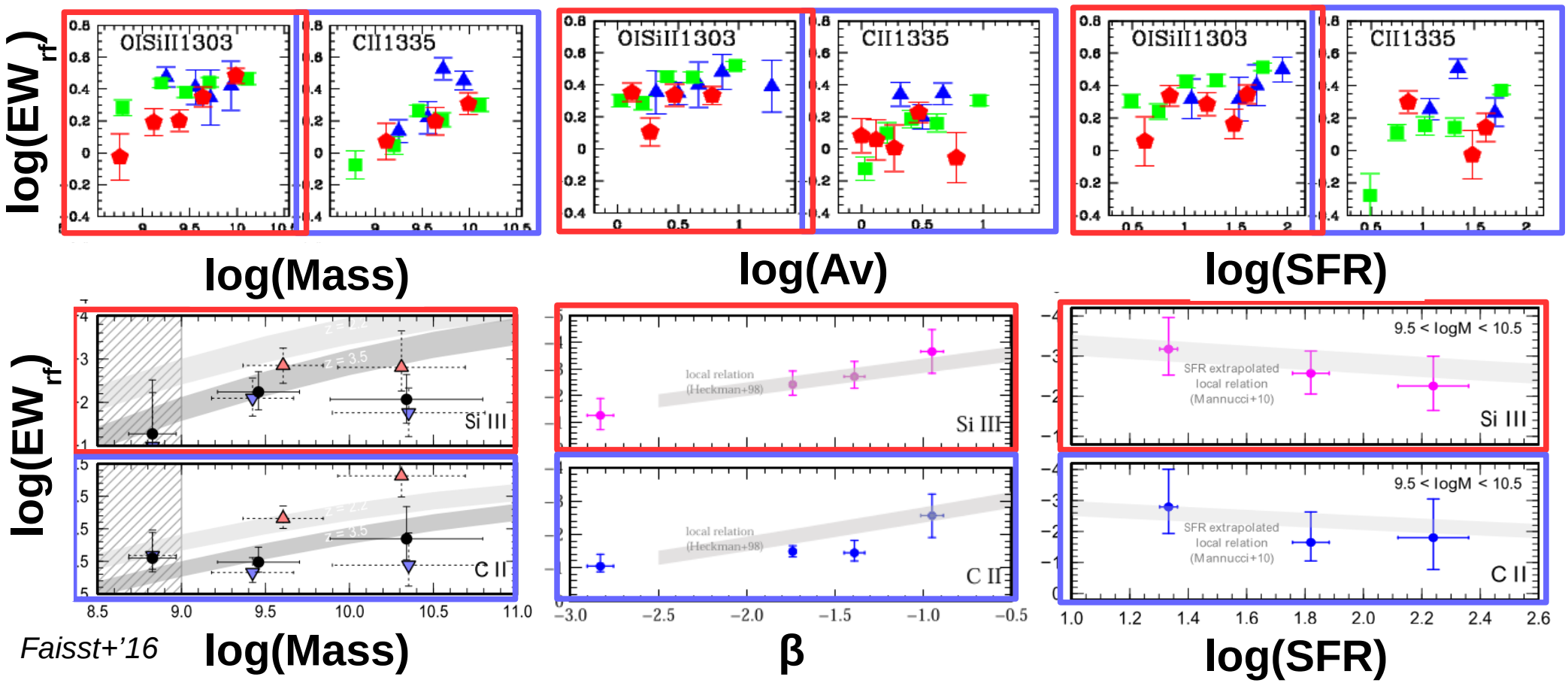


Faisst+'16

Clear trend with Mass, Av, SFR, but no redshift evolution between 2.5 and 5.0

Some tension with local Universe relation with SFR, if metallicity is "driving" the trends

Talia, Citro, Cimatti, Pozzetti et al.



ISM velocity shifts consistent with previous findings for SFGs
$\Delta v \sim -150$ km/s

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McLure et al. 2018
Pentericci et al. 2018

Summary

The powerful combination of **VANDELS ultra-deep spectra** and CANDELS multiwavelength photometry is crucial to explore the physical properties of high redshift galaxies

DR2 VANDELS reduced spectra (1D-2D) are already available from the ESO archive and the VANDELS database **vandels.inaf.it**

Enhanced products (spectroscopic measurements, stell. pop. parameters, photometric catalogues) will be made available in the final data release

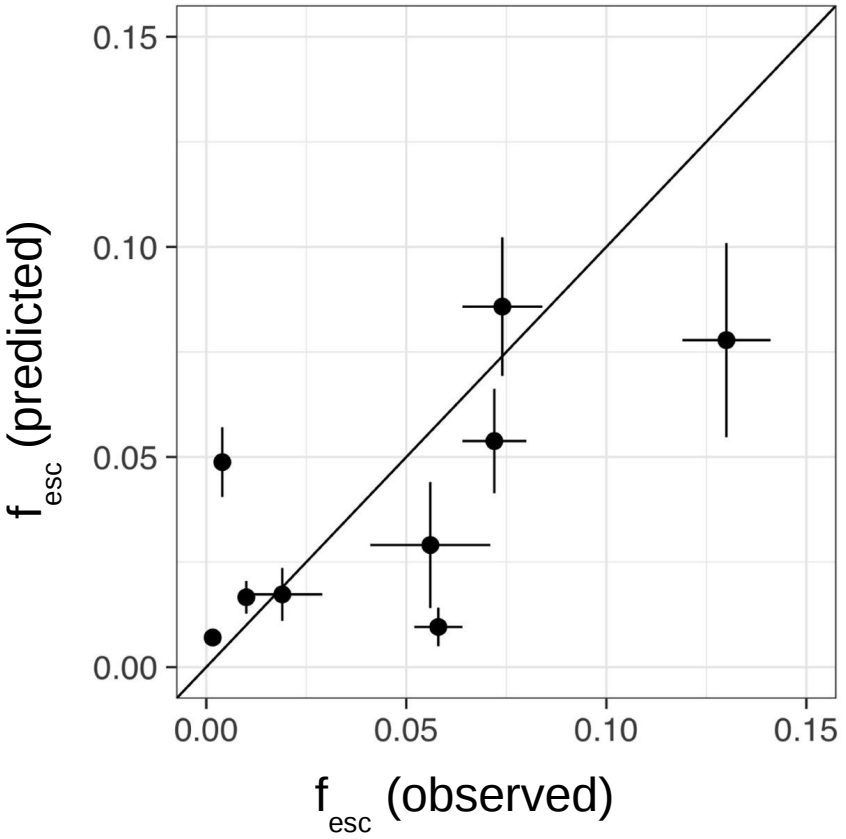
First science papers coming out soon!

Schaerer et al.

The ISM covering fraction and LyC escape of SFGs

Escape fraction of ionizing photons at high-z → indirect methods needed (large opacity of the IGM)

UV absorption lines
(Lyman series and SiII1190, SiII1260)
can be used to infer the LyC escape indirectly
(Gazagnes+'18, Chisholm+'18)

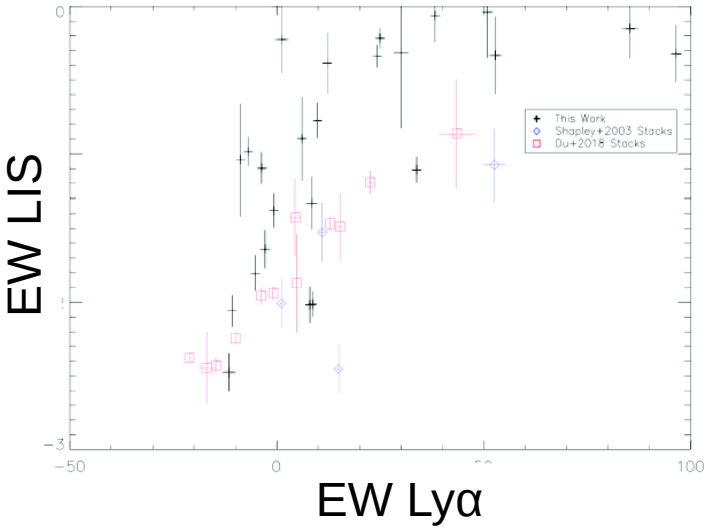


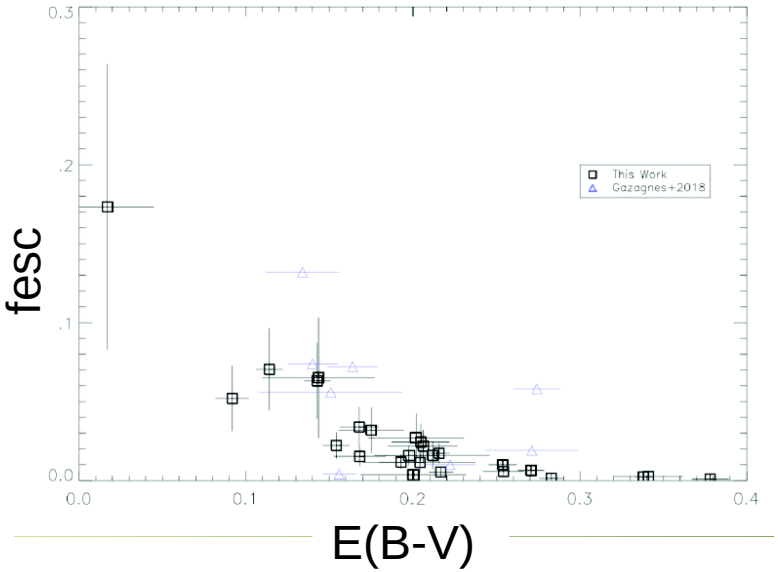
Consistent modelling of
continuum + lines + UV attenuation
is needed for accurate predictions

Apply to VANDELS

- Determine the Neutral gas properties and fesc(Lyc) as a function of galaxy physical parameters
- Find LyC emitter candidates

Preliminary fit on **50**
high SNR VANDELS spectra at z>3





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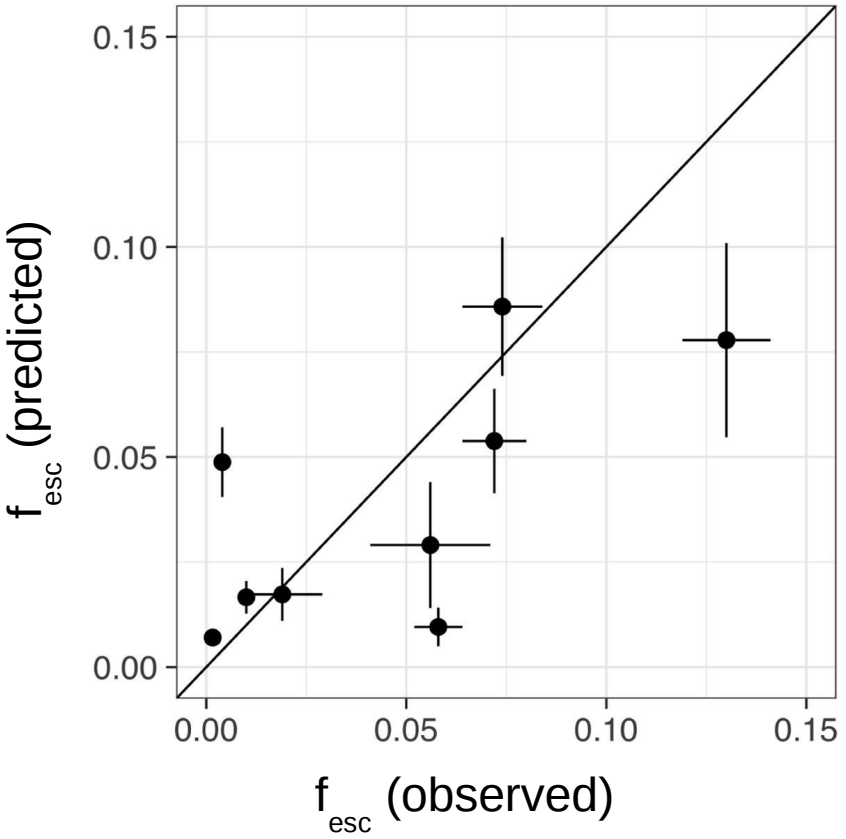

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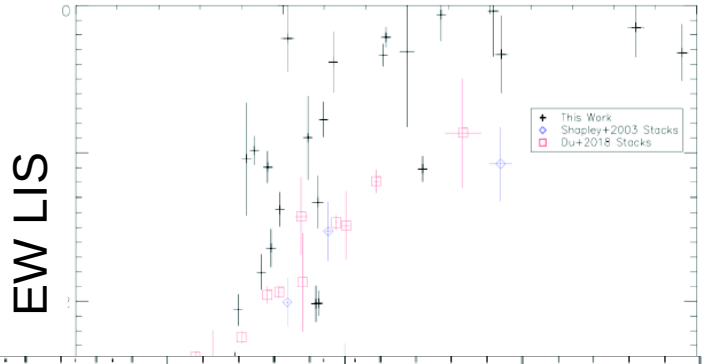

- Dete
  gas
  fesc
  of g
  para
- Finc
  cand