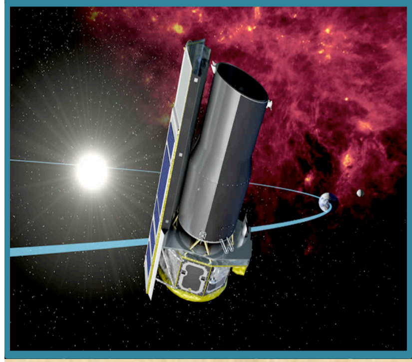
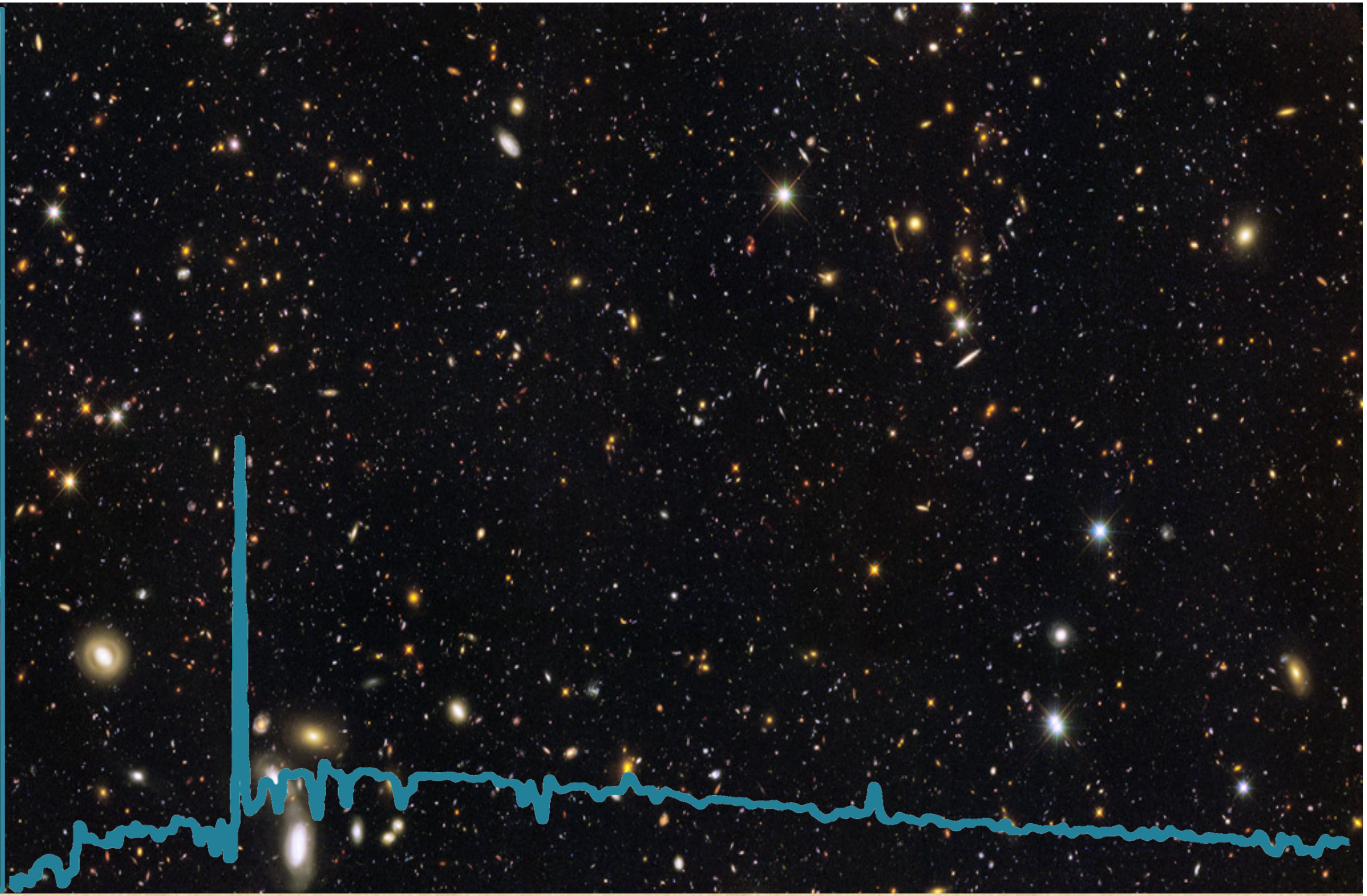




VANDELS

A deep VIMOS survey of the CANDELS UDS and CDFS fields

ESO public VIMOS spectroscopy survey of the UDS and CDFS fields

R. McLure & L. Pentericci

What is it?

- 912 hours of VIMOS visitor time: 2015-2018
- 20-80 hour integrations focused on z>3 star-forming galaxies
- Science goals: ages, masses, metallicities and outflows at high-z
- Raw data immediately public
- Regular releases of reduced data (DR1 in September 2017)
- Full details can be found at: vandels.inaf.it

VANDELS

A deep VIMOS survey of the CANDELS UDS and CDFS fields

ESO public VIMOS spectroscopy survey of the UDS and CDFS fields

R. McLure & L. Pentericci

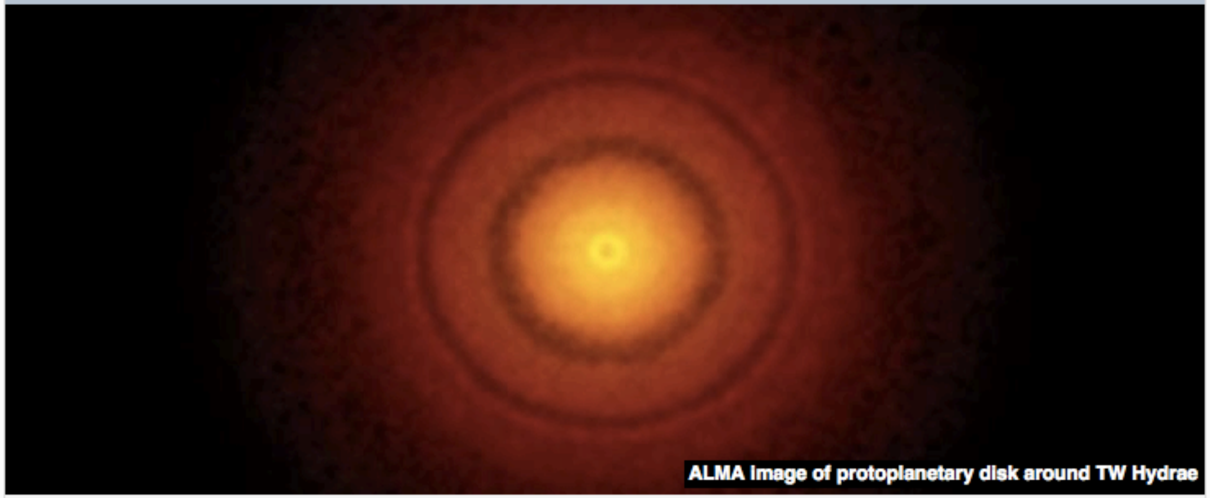
VANDELS: overview

Survey began observations in August 2015, first of ~~four~~ three observing seasons which ran from Aug – Jan of each year

European Southern Observatory

ESO Science Newsletter June 2016

16 Jun 2016



ALMA image of protoplanetary disk around TW Hydrae

This newsletter is a summary of recent ESO Science Announcement items. Follow the links or visit ESO Science Announcements to read more.

Science Announcements

VIMOS to be Decommissioned in 2018

16 Jun 2016:

The planning for the near future of the VLT instrumentation was discussed at the Scientific Technical Committee (STC) meeting in April 2016. With the return of CRIRES+ currently planned for the first quarter of 2018, a VLT Nasmyth focus needs

somewhat inconvenient…

VANDELS: overview

Proposal was focused on two key aspects:

- Legacy value to astronomy community
- Different science from previous VIMOS surveys (VUDS VVDS zCOSMOS VIPERS which were mainly redshift surveys)

Four key elements of VANDELS:

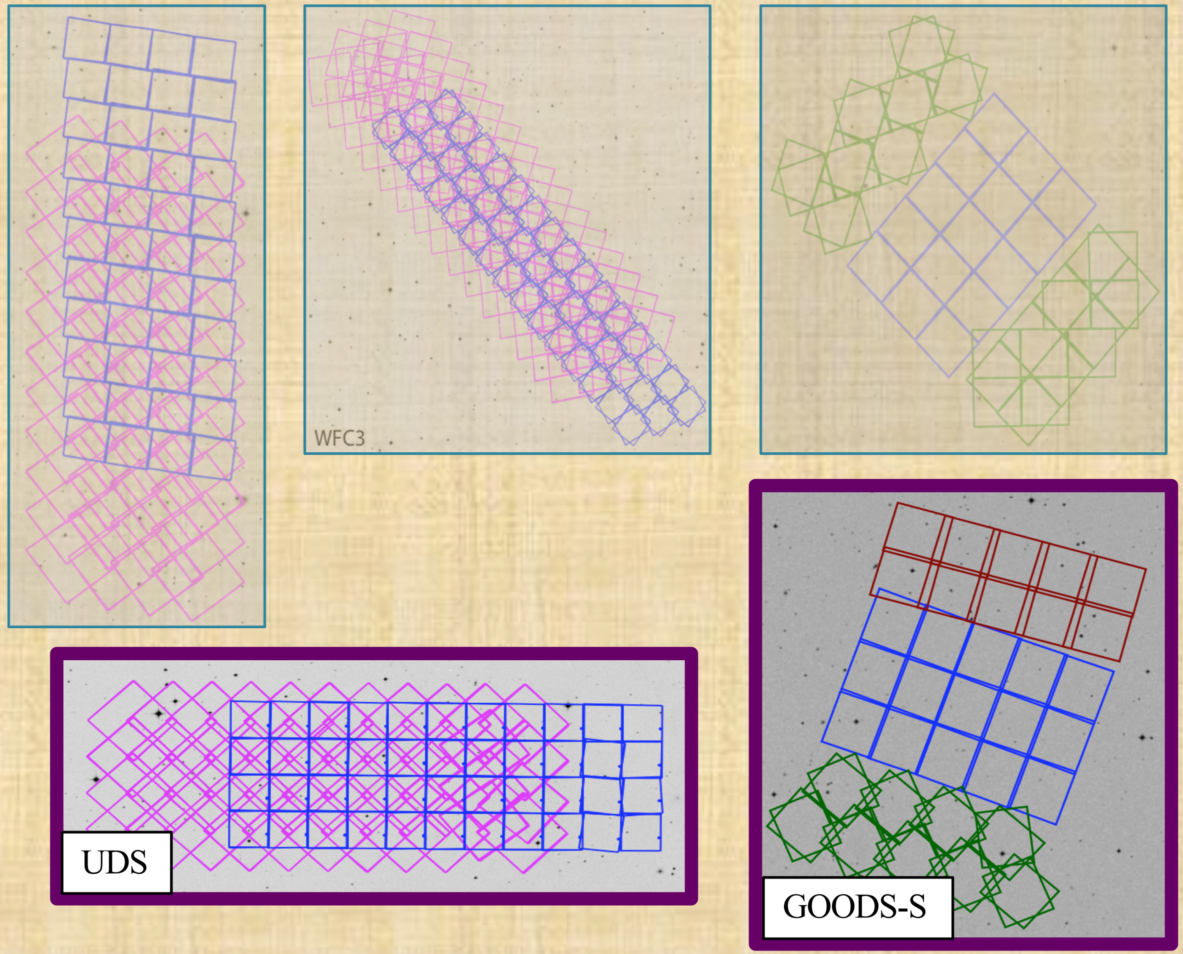
- Small area (0.2 sq. degrees), best available multi-wavelength data
- Ultra-long integrations, minimum 20 hours max 80 hours per source
- Medium resolution spectra (MR grism)
- Pre-selection biased to very high redshift (85% of targets at z>3)

VANDELS: survey fields

CANDELS

Cosmic Assembly Near-infrared Deep Extragalactic Legacy Survey

HST optical/near-IR imaging survey covering 0.2 square degrees split over 5 survey fields



VANDELS targets the two southern CANDELS fields, exploiting unrivalled 15+ band (0.3μm-4.5μm) photometry and near-IR grism spectra (3D-HST)

VANDELS: motivation

Primary Targets

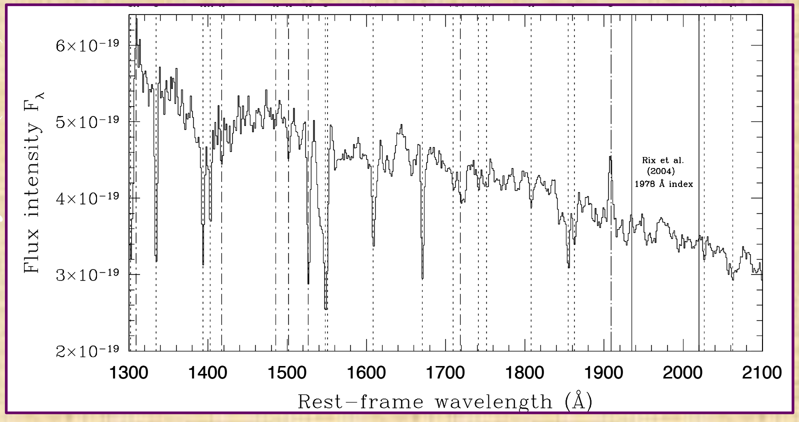
- Star-forming galaxies at $2.4<z<5.5$ ($H_{AB}<24$)
- Passive galaxies at $1.0<z<2.5$ ($H_{AB}<22.5$)
- Lyman-break galaxies at $3.0<z<7.0$ ($H_{AB}<27$)

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

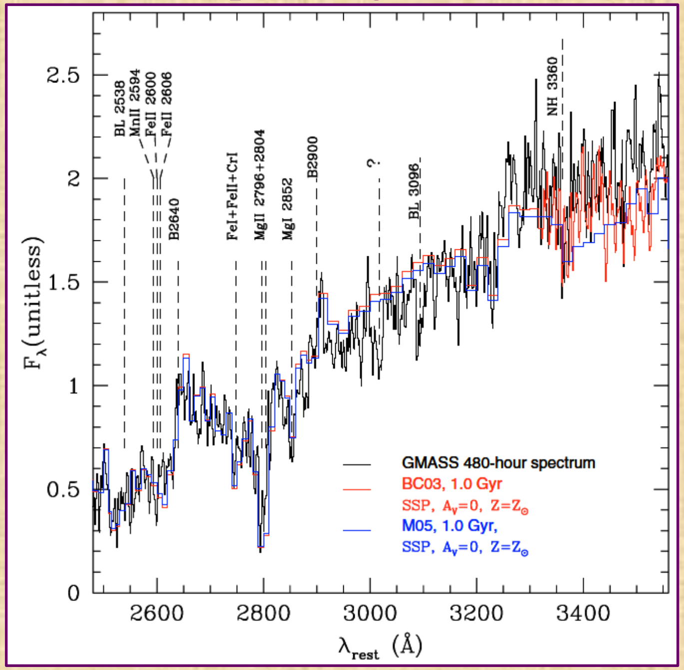
Provide sufficient signal-to-noise and resolution to measure physical properties from *individual* spectra as well as stacks

Absorption line

Halliday et al. (2008)

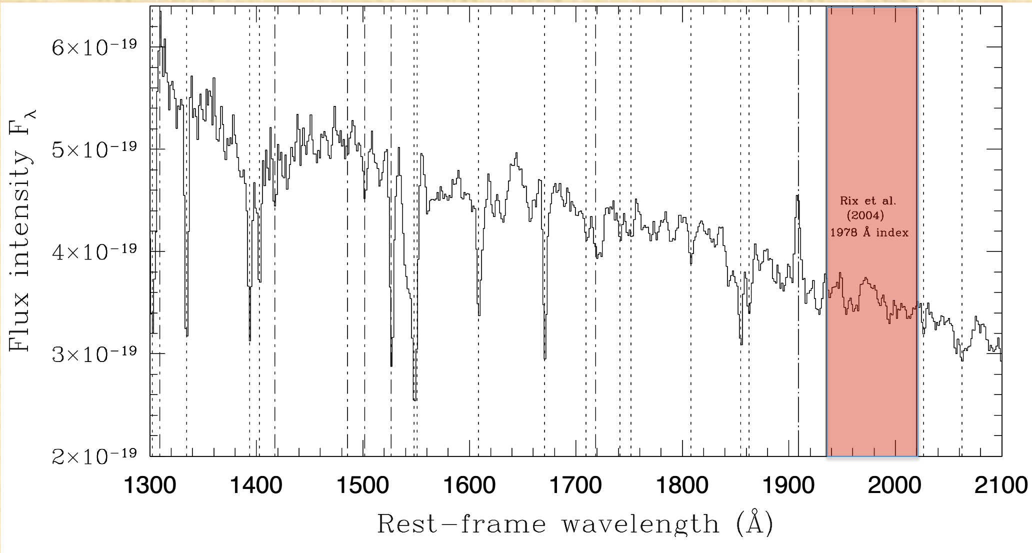


UV+optical age constraints



VANDELS: main science case

Primary science case is focused on determining physical properties of star-forming galaxies at $2.4<z<5.5$:



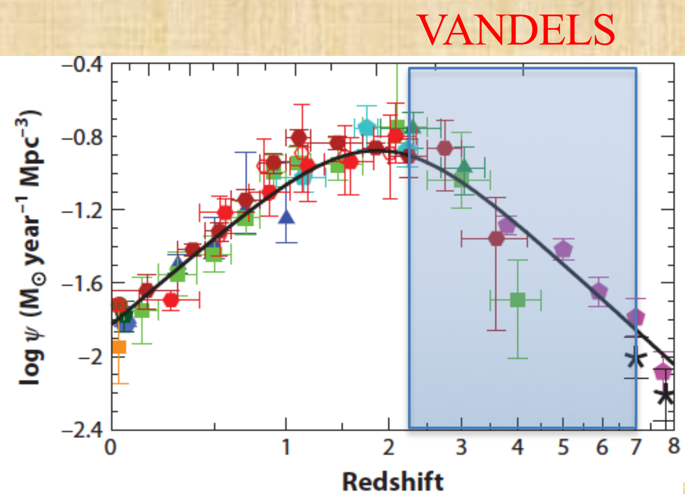
metals

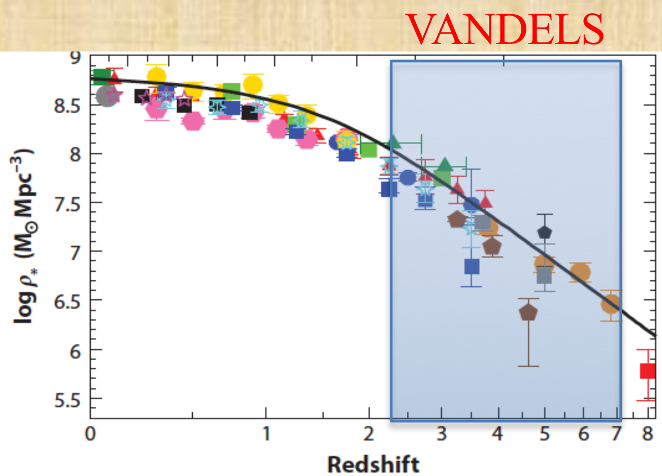
↓

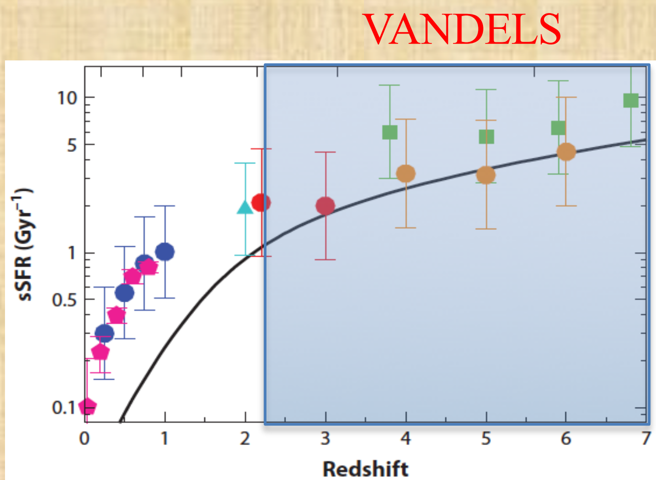
dust

↙ ↘

mass SFR



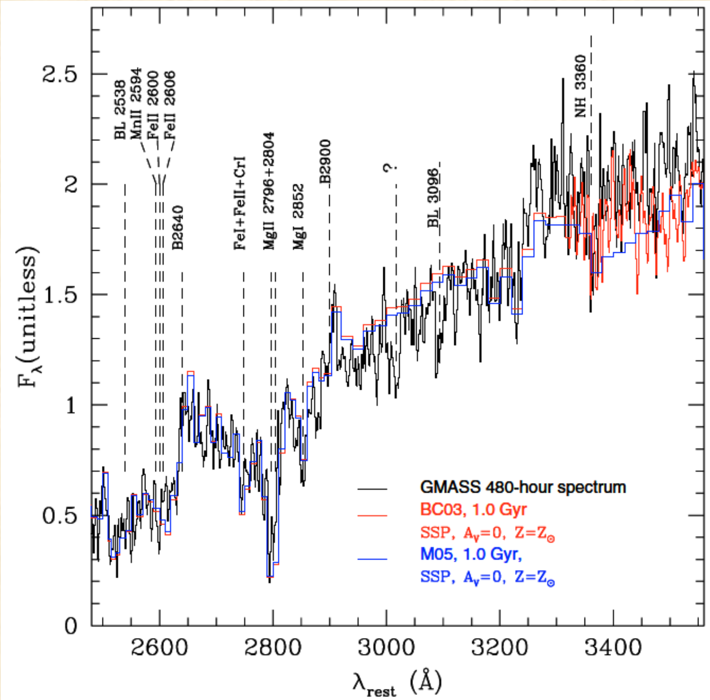




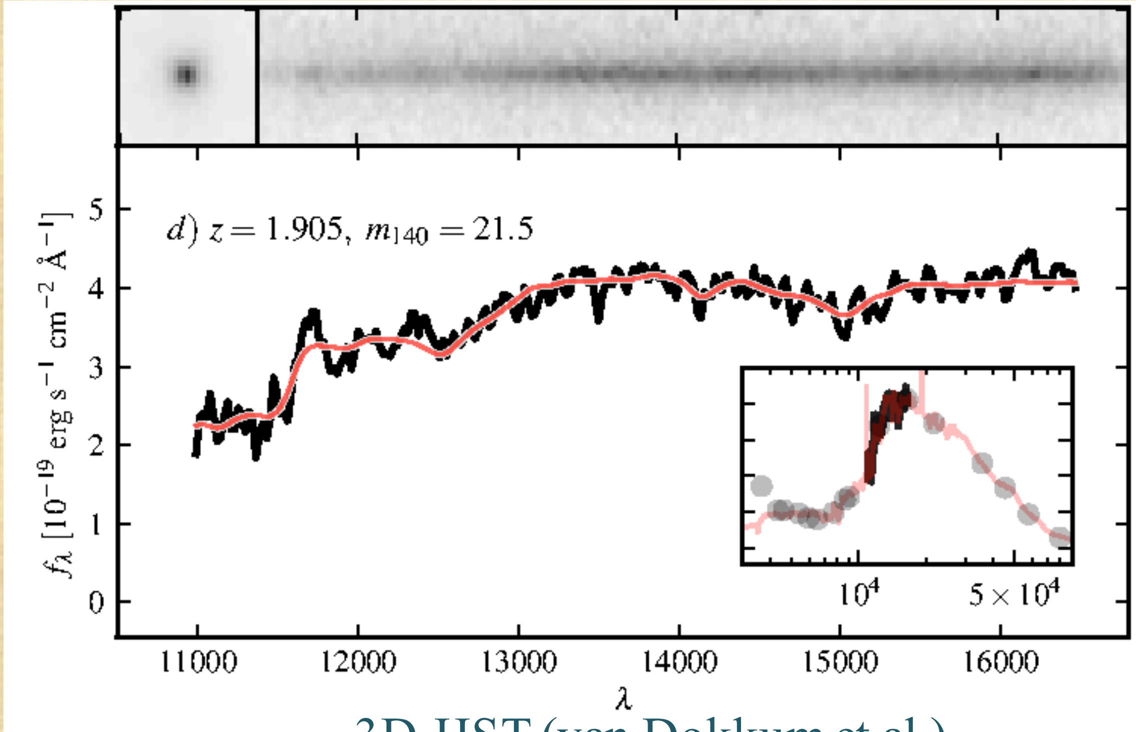
Madau & Dickinson (2014)

VANDELS: main science case

Primary science case : detailed investigation of the descendants of high-z star-formers: passive galaxies at 1.0<z<2.5



Cimatti et al. (2008)



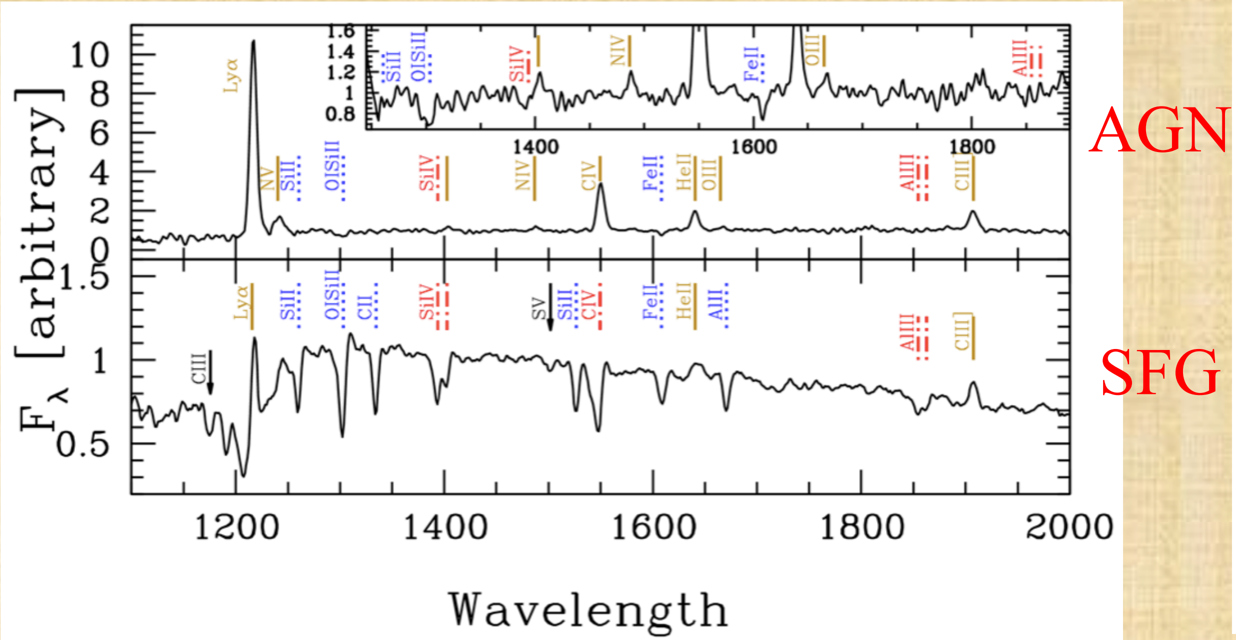
3D-HST (van Dokkum et al.)

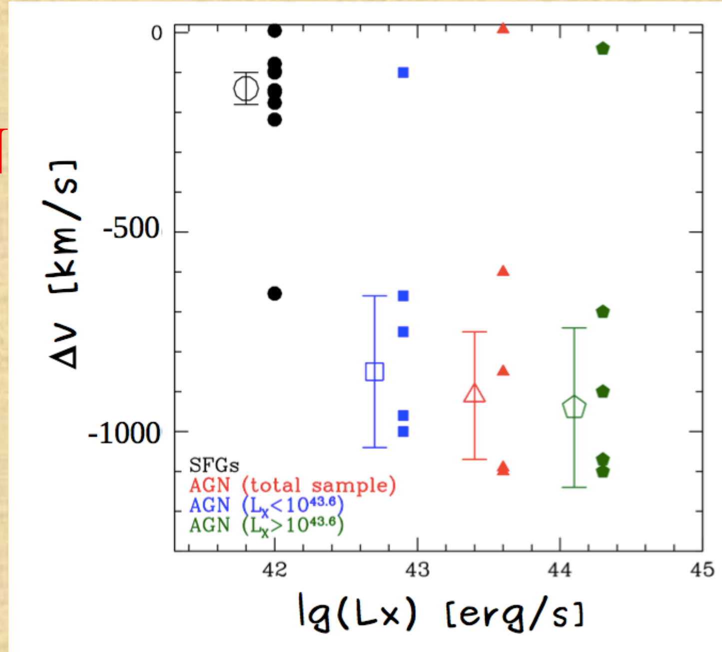
- Possible to constrain ages from UV breaks (2600/2800 Angs) and Balmer break from VANDELS spectra plus 3D-HST spectra plus photometry

- Full spectrophotometric fitting (photometry+spectra) offers prospect of delivering accurate stellar ages, masses and metallicities of massive quiescent galaxies at z~2

VANDELS: science case summary

- For star forming galaxies and AGN : outflow/inflow velocity measurements from emission and absorption lines – feedback, build-up of mass-metallicity relation



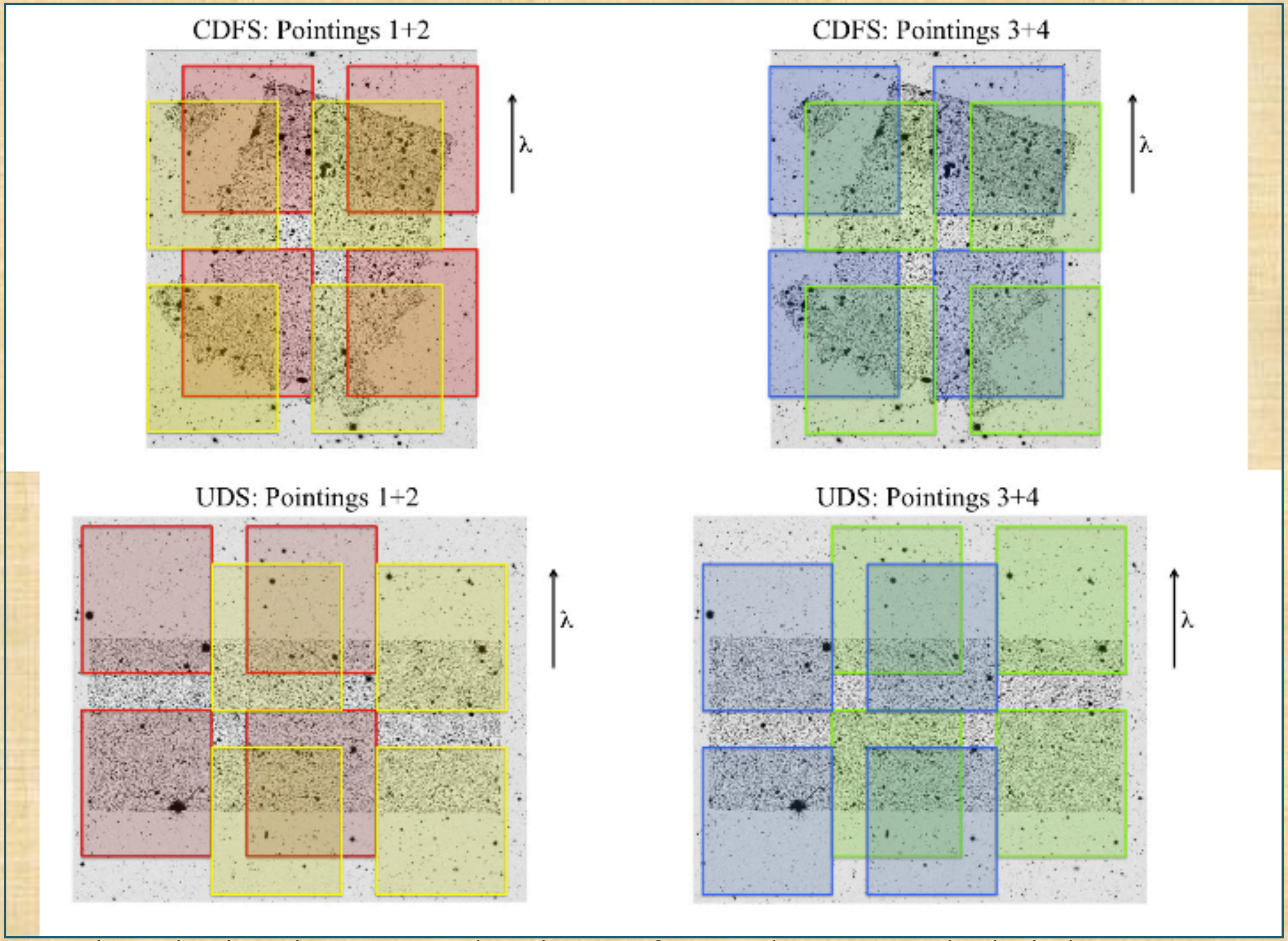


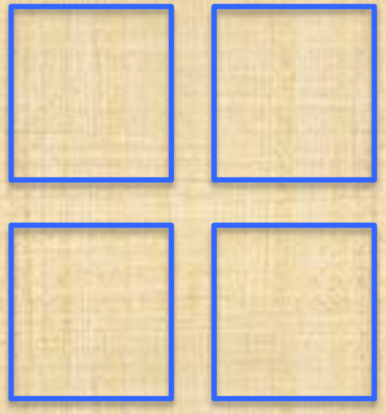
Talia+17

Additional science cases

- Quantify impact of nebular line emission at high redshift
- Unbiased measurement of Lyα emitter fraction into epoch of reionization
- Comparison with physical properties of AGN and Herschel sources

VANDELS: observations



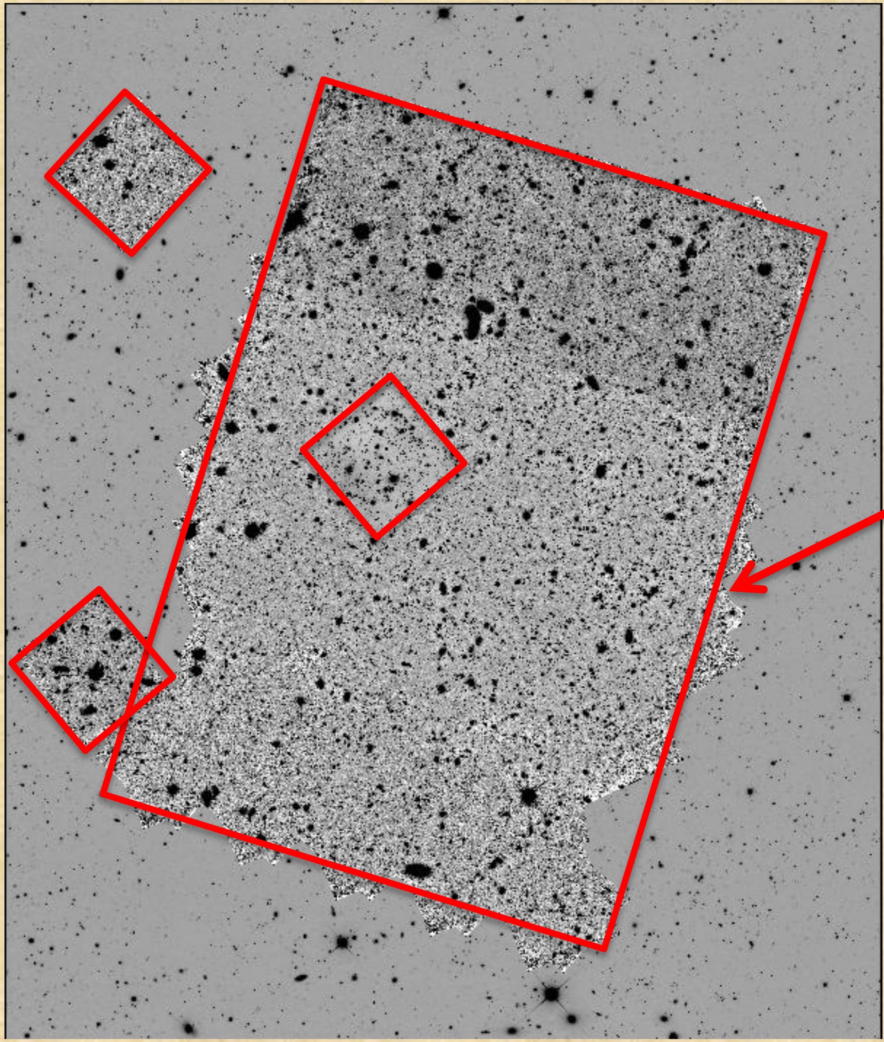


VIMOS FOOTPRINT

Each pointing is targeted 4 times, for 20 hours each: bright targets get 20 hours integration, faint targets get 80 hours. We aim at a S/N=15-20 per pixel for the brightest and S/N=10 for the faintest (SFG& Passive), S/N=3 on the continuum and line flux limit $2x10^{18}$ erg/s/cm^2 (5σ) for the faintest LBG

Improved photometric catalogues: CDFS

VANDELS exploits the multi-wavelength photometry in UDS and CDFS to do uniquely robust photometric redshift pre-selection….

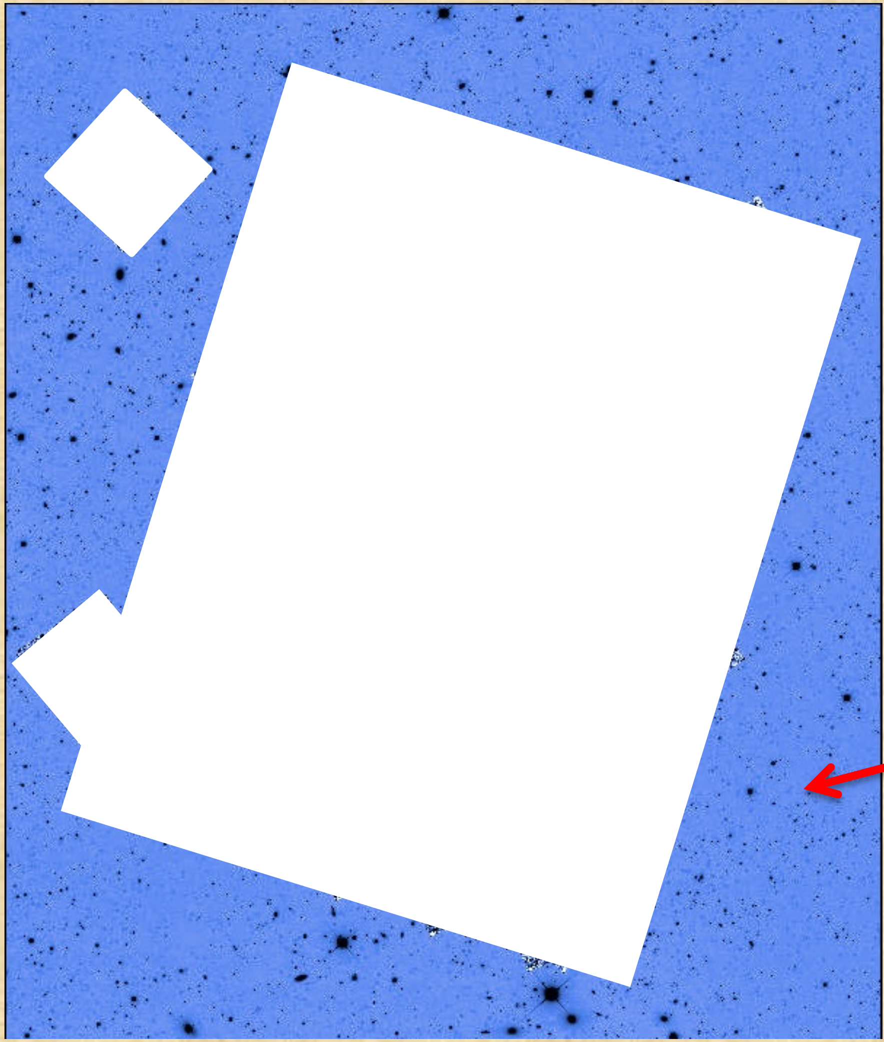


VANDELS CDFS FIELD

In area covered by CANDELS HST imaging use the Guo et al. (2013) TFIT catalogues featuring aperture matched, 14-band photometry 0.3-4.5μm

Improved photometric catalogues: CDFS

VANDELS exploits the multi-wavelength photometry in UDS and CDFS to do uniquely robust photometric redshift pre-selection….



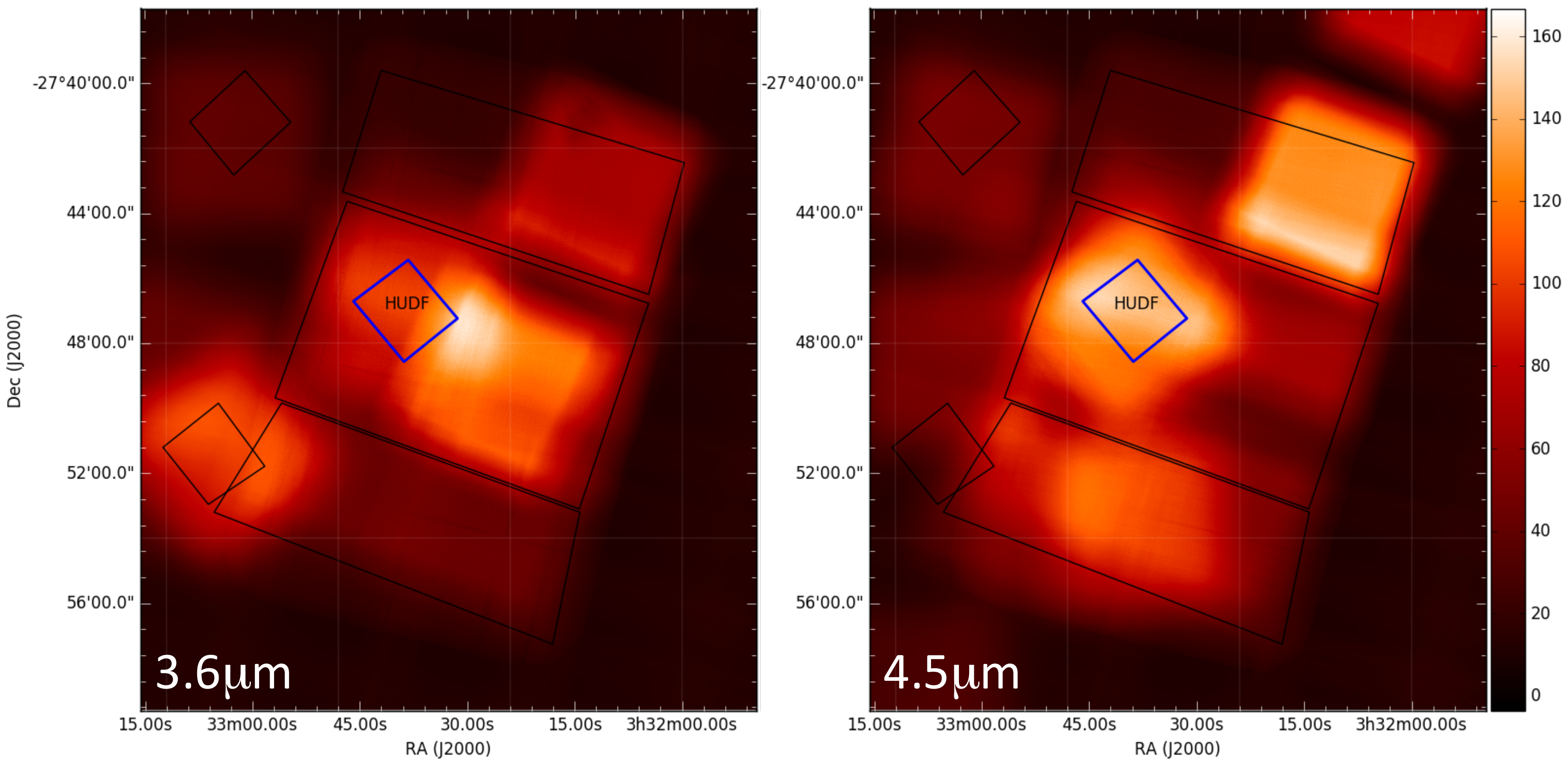
VANDELS CDFS FIELD

For extended CDFS region, Edinburgh VANDELS catalogue, utilizing a combination of 16-band photometry:

VIMOS U+R imaging
GEMS HST imaging in V_{606} and z_{850}
Subaru medium band imaging (7 bands)
J+K imaging from TENIS survey on CFHT
Y+H imaging from VISTA VIDEO survey
IRAC "supermap" of all CDFS Spitzer programmes

Improved photometric catalogues: CDFS

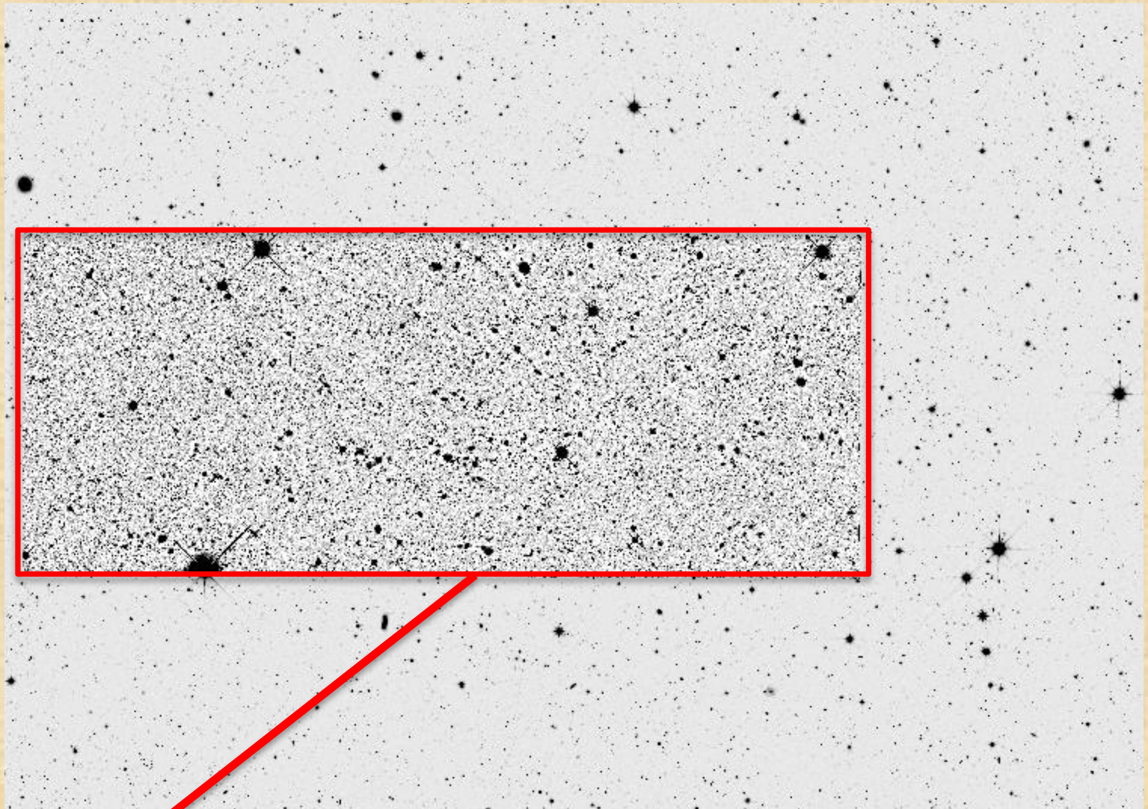
Key improvement is introduction of ultra-deep IRAC imaging over the wide-area footprint in the E-CDFS:



Combination of : GOODS+SIMPLE+SCANDELS+Fazio+Labbe

Improved photometric catalogues: UDS

VANDELS will exploit the multi-wavelength photometry in UDS and CDFS to do uniquely robust photometric redshift pre-selection….

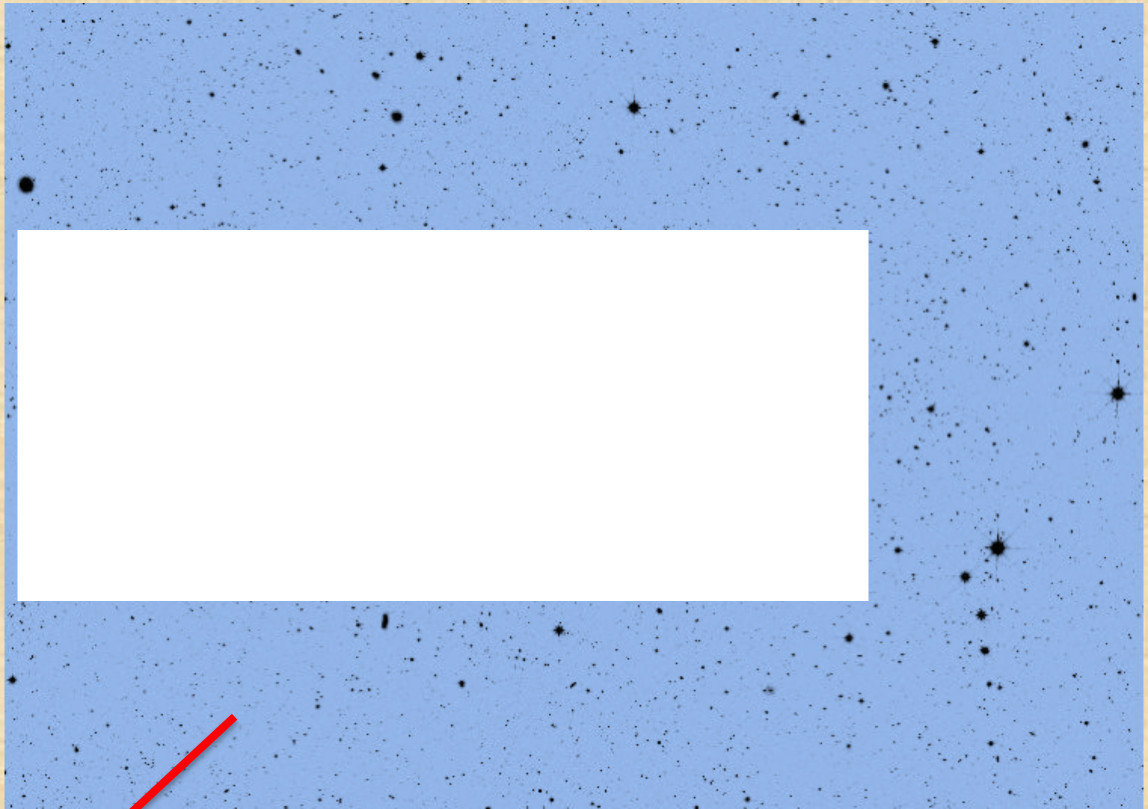


VANDELS UDS FIELD

Within CANDELS HST region, exploit Galametz et al. (2013) TFIT catalogue, which features 15-band aperture matched photometry covering 0.3-4.5μm

Improved photometric catalogues: UDS

VANDELS will exploit the multi-wavelength photometry in UDS and CDFS to do uniquely robust photometric redshift pre-selection….

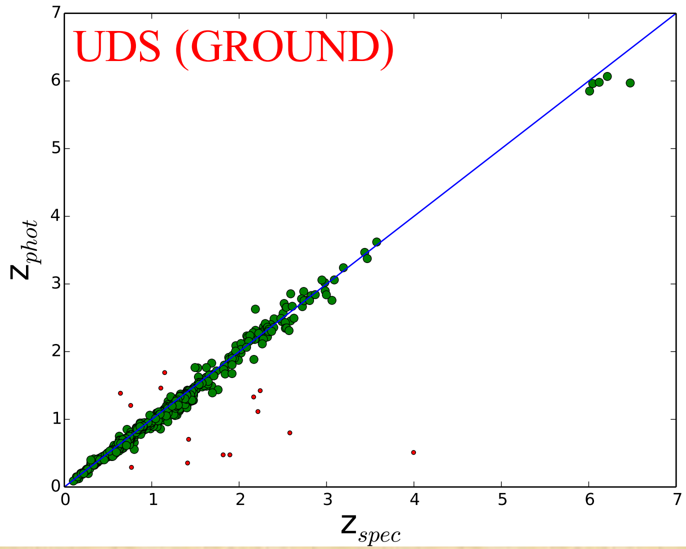


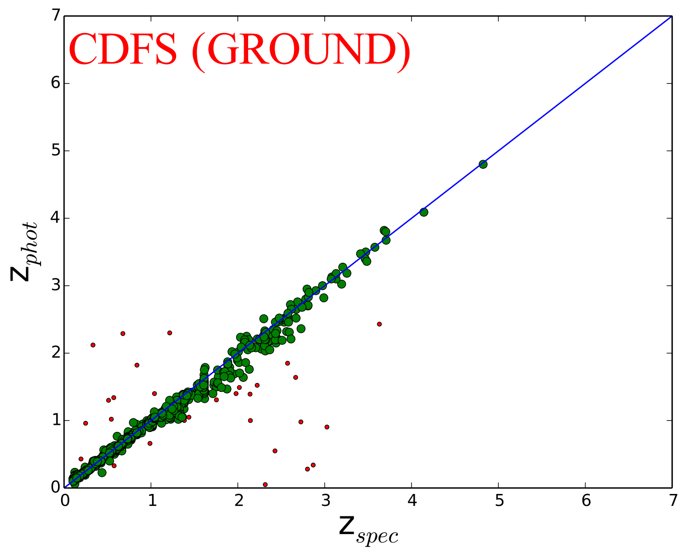
VANDELS UDS FIELD

Within extended UDS region, Edinburgh VANDELS catalogue using 13-band photometry: CFHT U-band, Subaru BVRizz$_{nb}$, VIDEO Y-band, JHK from UKIDSS UDS, IRAC from SEDS

VANDELS: photo-z pre-selection

VANDELS exploits the multi-wavelength photometry in UDS and CDFS to do uniquely robust photometric redshift pre-selection….





HST regions:

Official CANDELS photo-z catalogues (Dahlen et al. 2013)

WIDE regions:

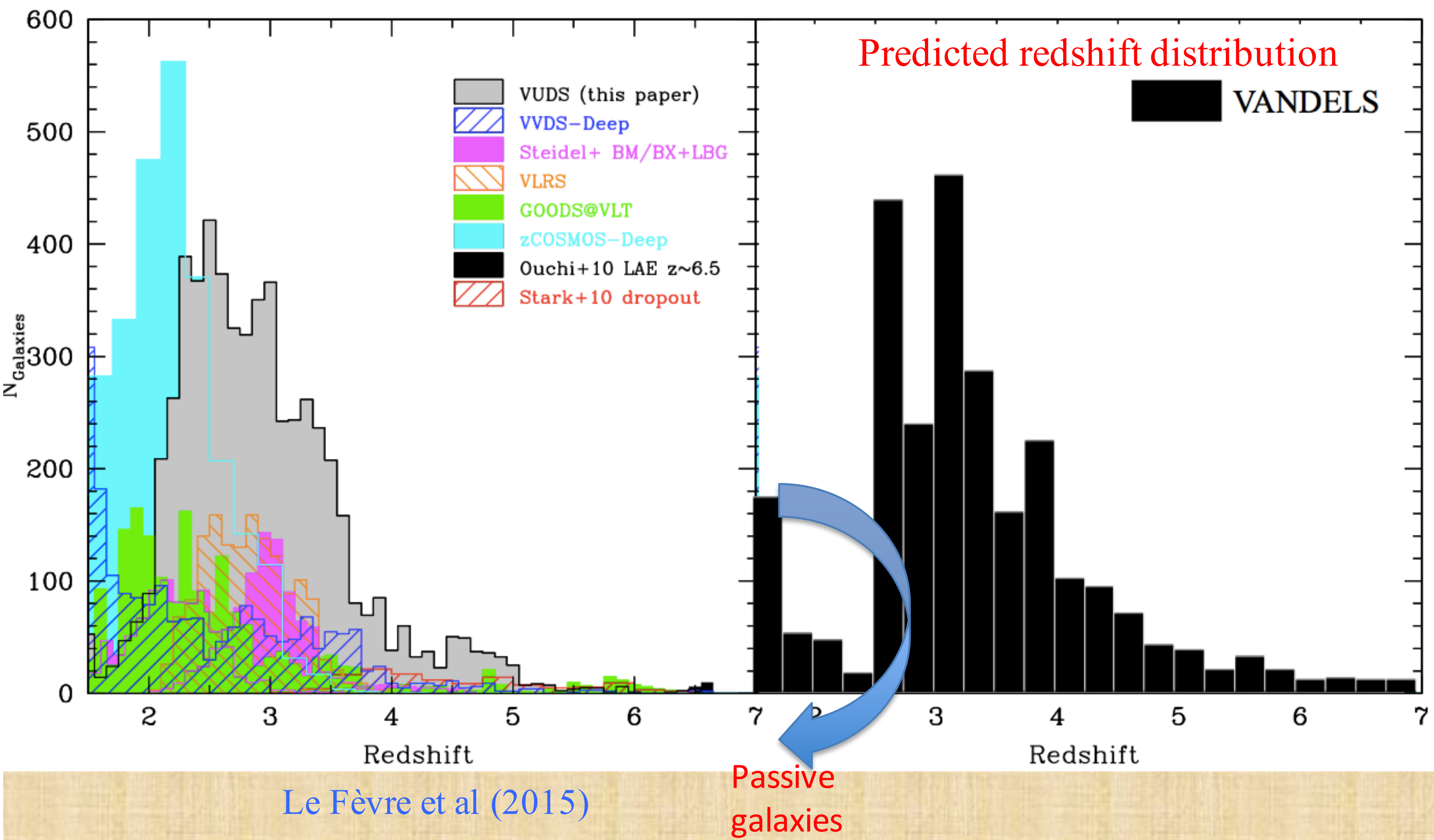
- Photo-z results based on new ground-based multi-wavelength photometry catalogues
- 14 independent photo-z runs (11 individuals)
- median photo-z results comparable with HST results

$$\sigma_{MAD}=0.017$$

outlier fraction < 2%

Realistic aim is for < 5% redshift interlopers

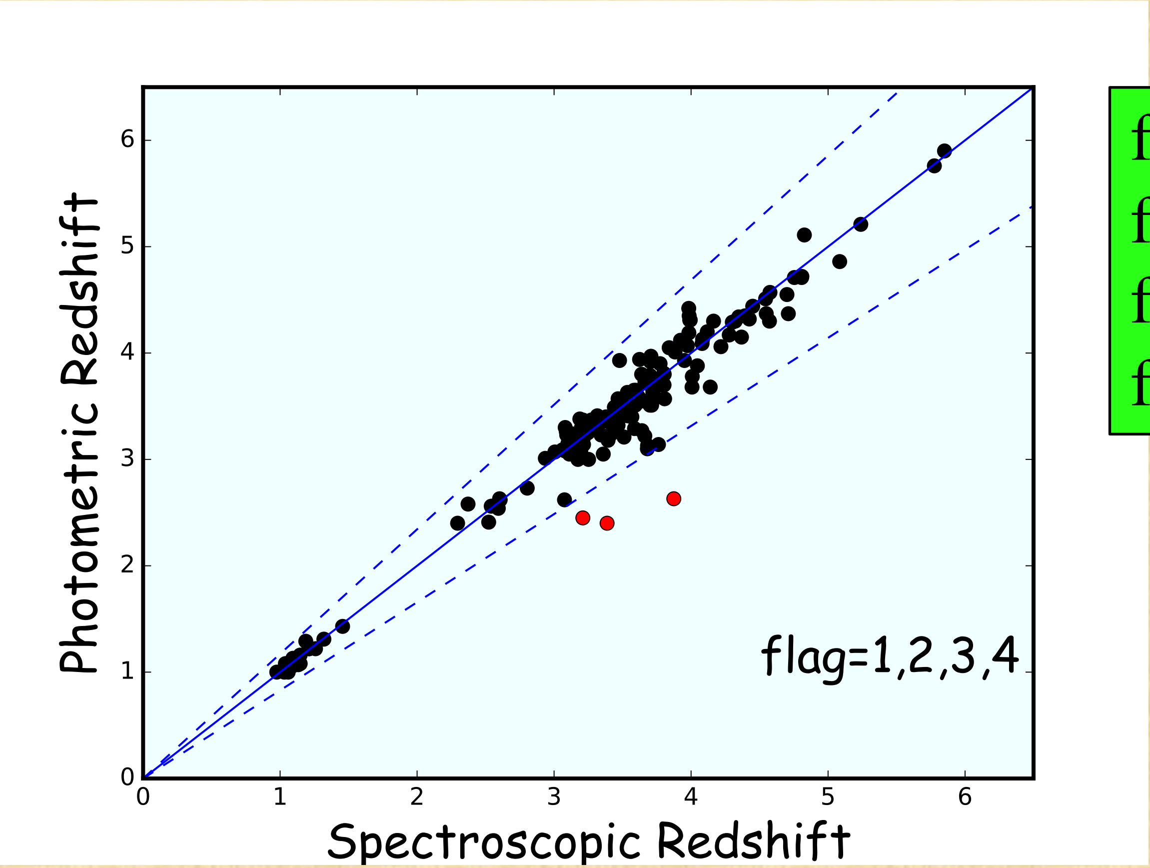
VANDELS: photo-z pre-selection



Le Fèvre et al (2015)

So, how well has selection worked?

Spectroscopic redshifts for ≈200 completed 20-hour targets from season one



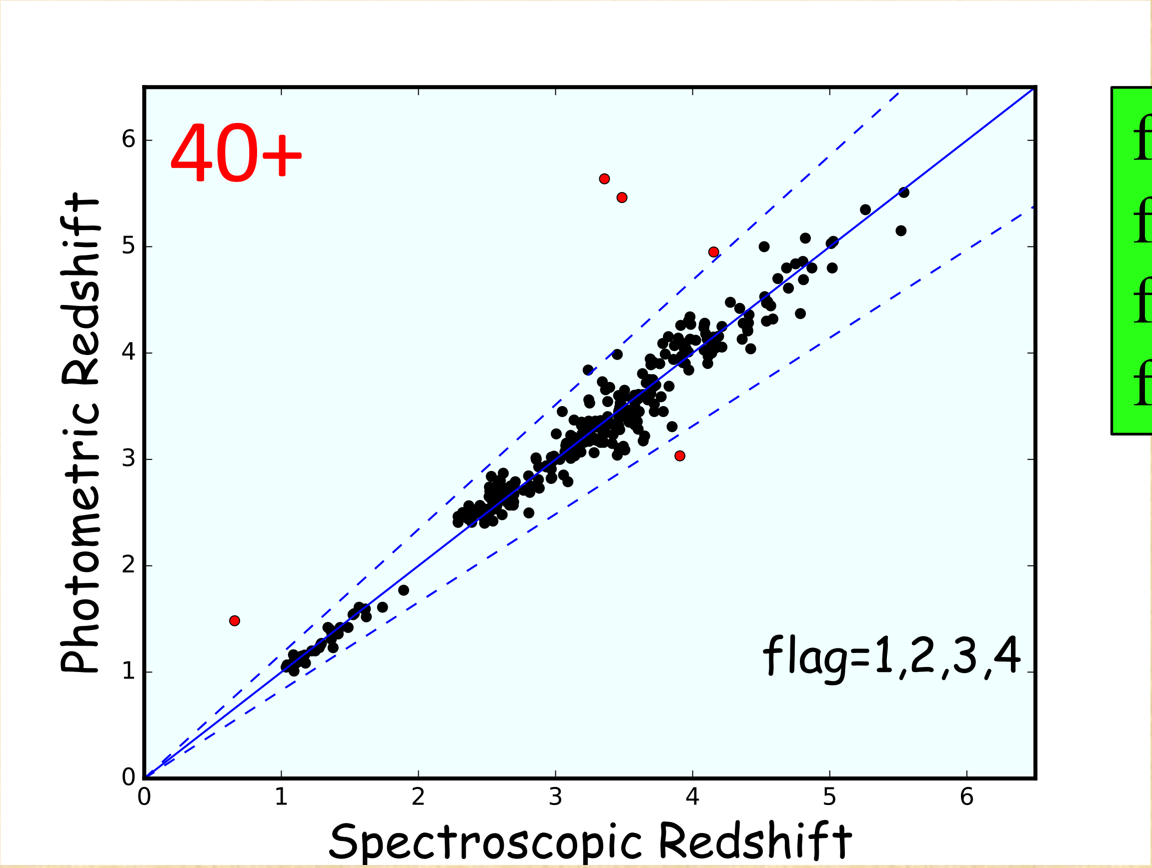
flag 1 = I want to believe
flag 2 = definitely maybe
flag 3 = solid
flag 4 = bullet proof

no outliers
$dz_{NMAD} = 0.025$

object classification + z_{phot} accuracy of 20hr targets was very good

So, how well has selection worked?

We now know what the selection accuracy looks like for the 40hr targets:



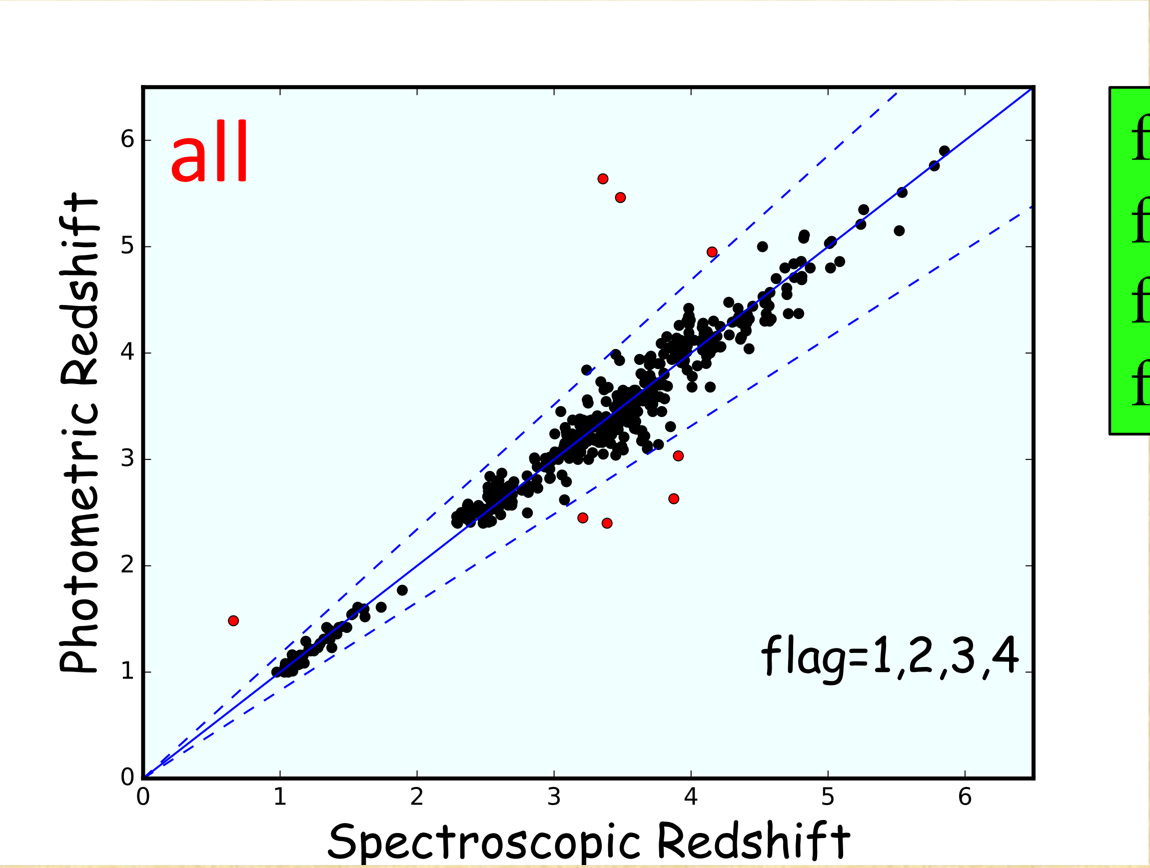
flag 1 = I want to believe
flag 2 = definitely maybe
flag 3 = solid
flag 4 = bullet proof

1% outliers
$dz_{NMAD} = 0.025$

object classification + z_{phot} accuracy of 40hr targets remains good

So, how well has selection worked?

We now know what the selection accuracy looks like for the 40hr targets:



flag 1 = I want to believe
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1% outliers
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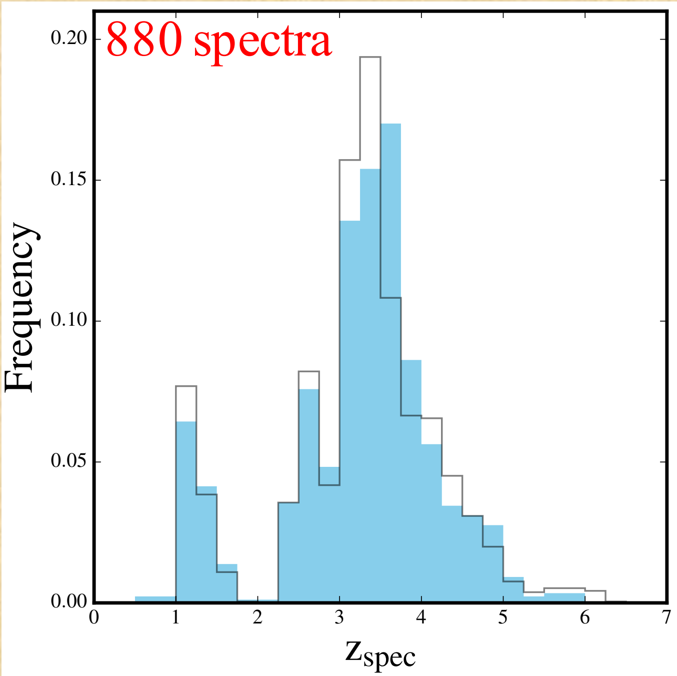
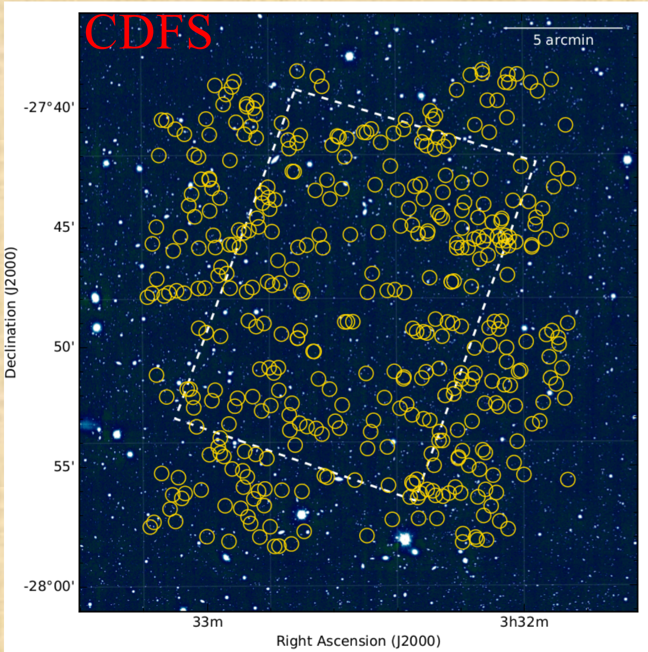
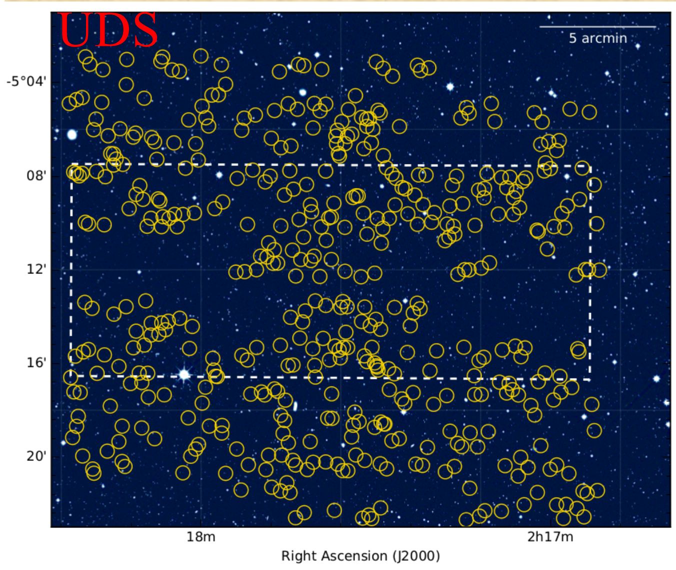
VANDELS data release one (DR1): September 2017







The data release includes the spectra for all galaxies for which the scheduled integration time was completed during season one. In addition, it includes the spectra for those galaxies for which the scheduled integration time was 50% complete at the end of season one (i.e. 20/40 hours and 40/80 hours).

The total number of spectra released is 879 (415 in CDFS and 464 in UDS)

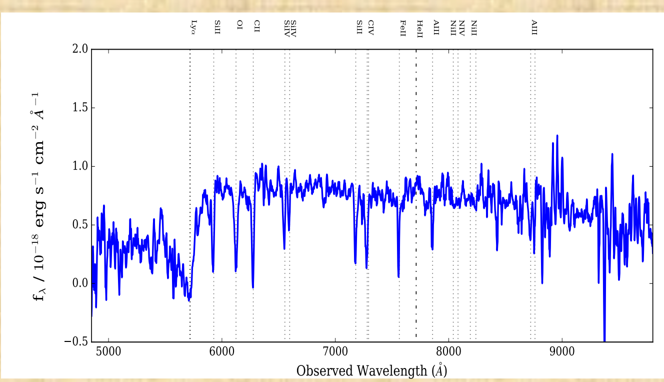
VANDELS data release one (DR1): September 2017

The data release consists of:

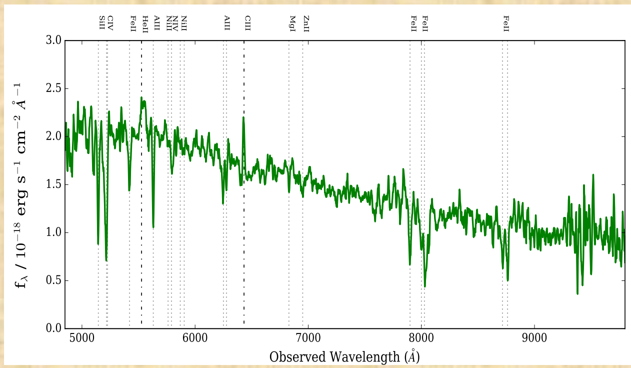
- Fully wavelength and flux calibrated 1D spectra for all 880 galaxies, along with the associated error spectrum and sky spectrum.
- Wavelength calibrated 2D spectra for all 880 galaxies.
- Catalogues listing the essential data associated with each galaxy including the spectroscopic redshift and its data quality flag

Data reduction was carried out by the IASF Milano Team lead by Bianca Garilli.

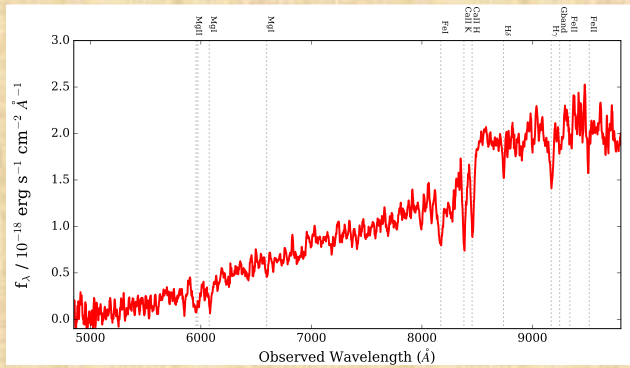
faint H_{AB}<27 star-forming galaxies at 3.0<z<7.0



bright H_{AB}<25 star-forming galaxies at 2.4<z<5.5



massive passive galaxies at 1.0<z<2.0



VANDELS data release one (DR1): September 2017

Distribution of spectroscopic redshift flag for DR1

- 0: No redshift could be assigned (set to Nan)
- 1: 50% probability to be correct
- 2: 75% probability to be correct
- 3: 95% probability to be correct
- 4: 100% probability to be correct
- 9: spectrum with a single emission line. The redshift given is the most probable given the observed continuum, it has a >80% probability to be correct.

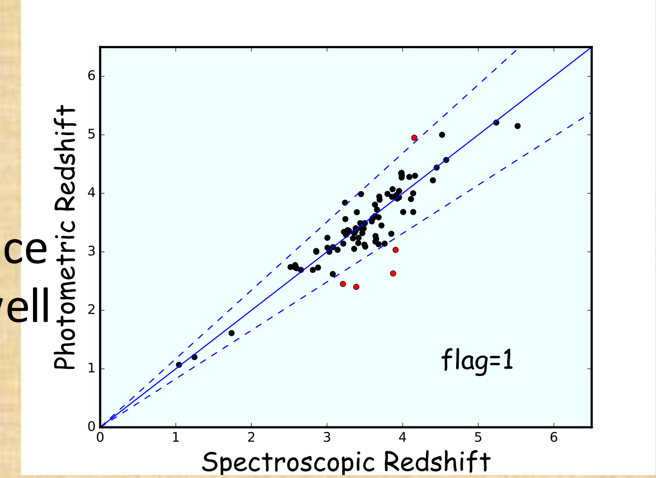
flag 0 =	5%
flag 1 =	16%
flag 2 =	16%
flag 3 =	21%
flag 4 =	37%
flag 9 =	5%-

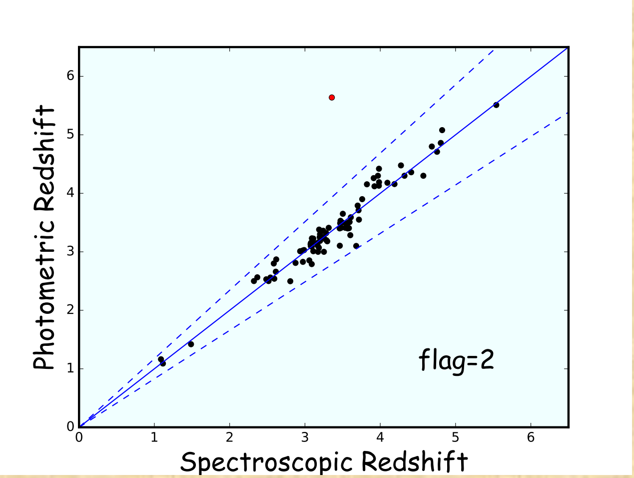
A dedicated team was set up within VANDELS to determine the spec-z.

Each spectrum is measured independently by >3 people

The typical accuracy of the spectroscopic redshift measurements is estimated to be +/-0.0005.

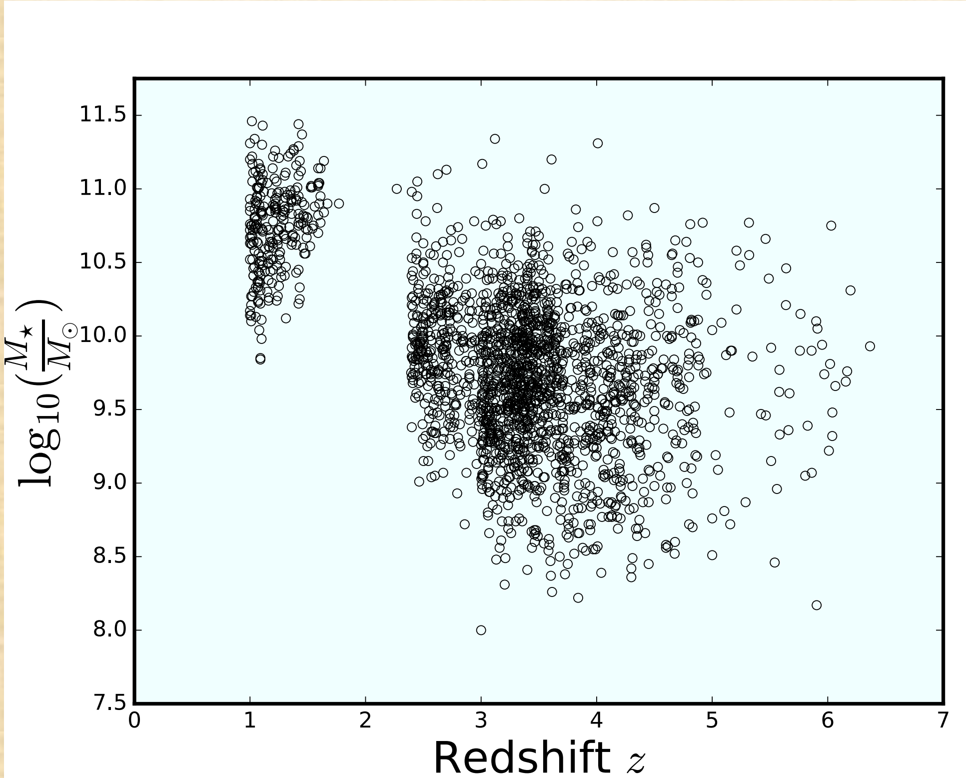
Looks like our flag allocation might be a bit conservative since even flag 1 and 2 agree very well with photo-z

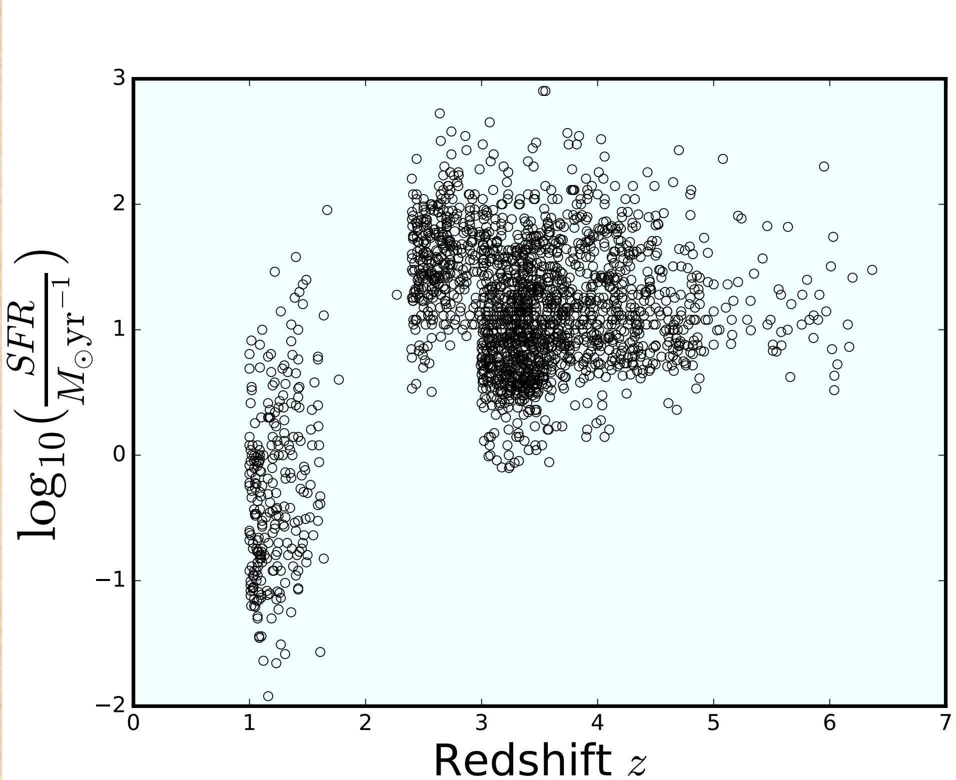




VANDELS: science

The full VANDELS sample consists of >2100 targets, designed to sample the star-forming population at 2.5<z<5.5 and their passive descendants at 1<z<2.



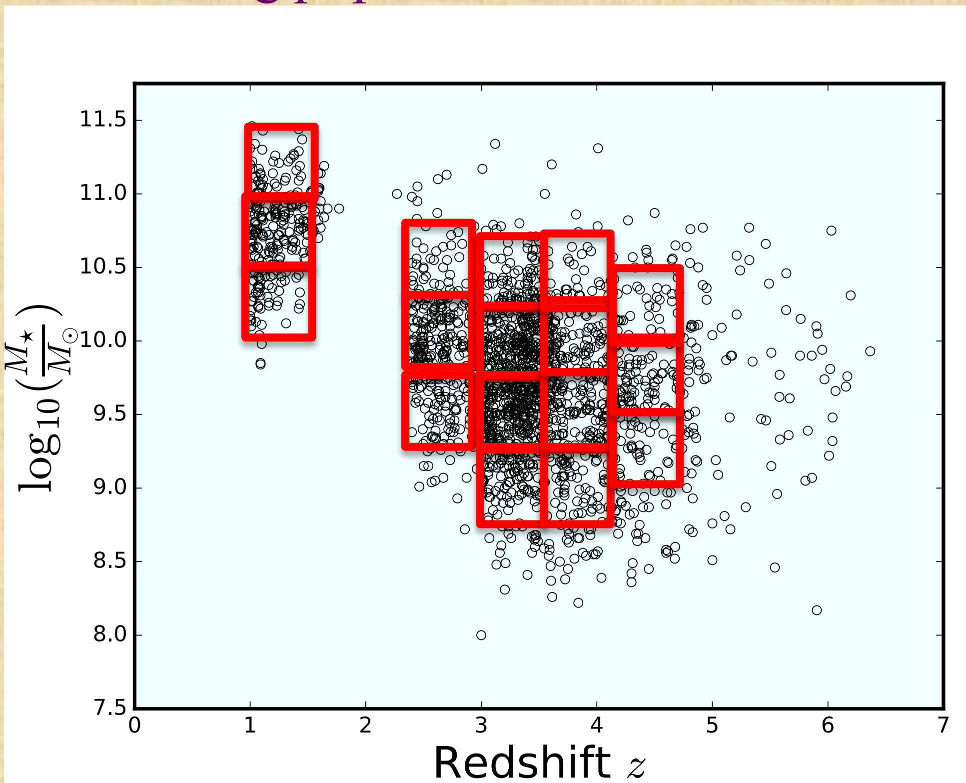


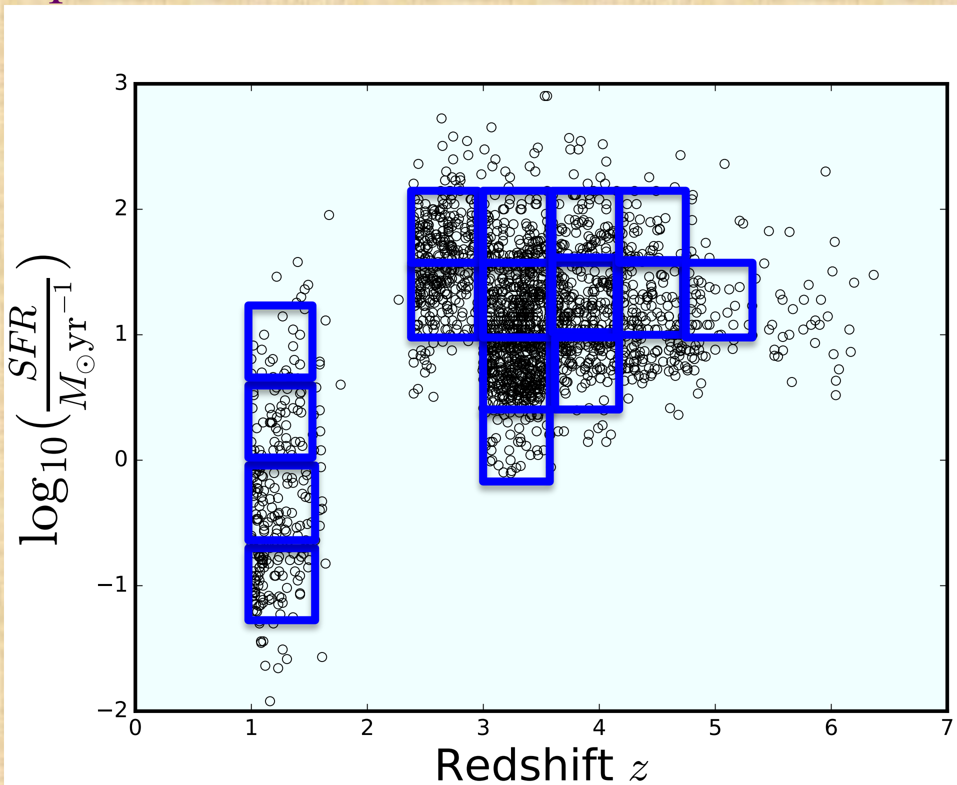
Final sample will span: 3 dex in stellar mass
4 dex in star formation rate

Provide good sampling of SF "main sequence" at 2.5<z<5.5

VANDELS: science

The full VANDELS sample consists of >2100 targets, designed to sample the star-forming population at 2.5<z<5.5 and their passive descendants at 1<z<2.

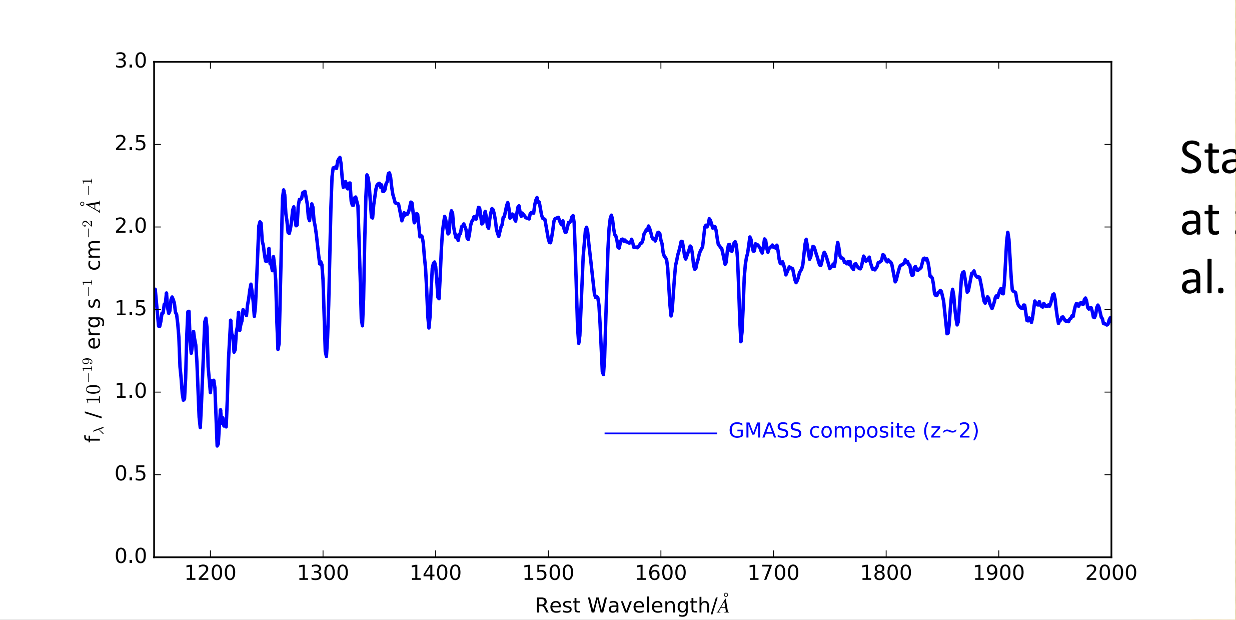




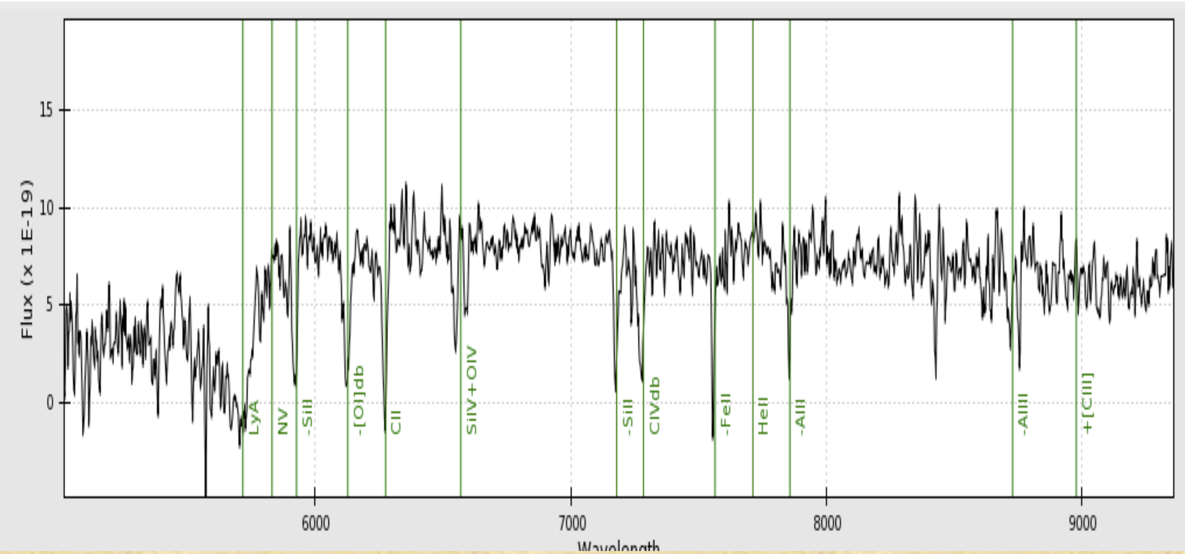
High SNR will allow detailed studies of individual targets, but clearly many opportunities to explore the properties of composite spectra as function of z, mass, metallicity, SFR….

VANDELS: initial results

Key science goal is to study the stellar metallicities of star-forming galaxies at 2.5<z<5.5: initial data of the season one look promising in this regard.



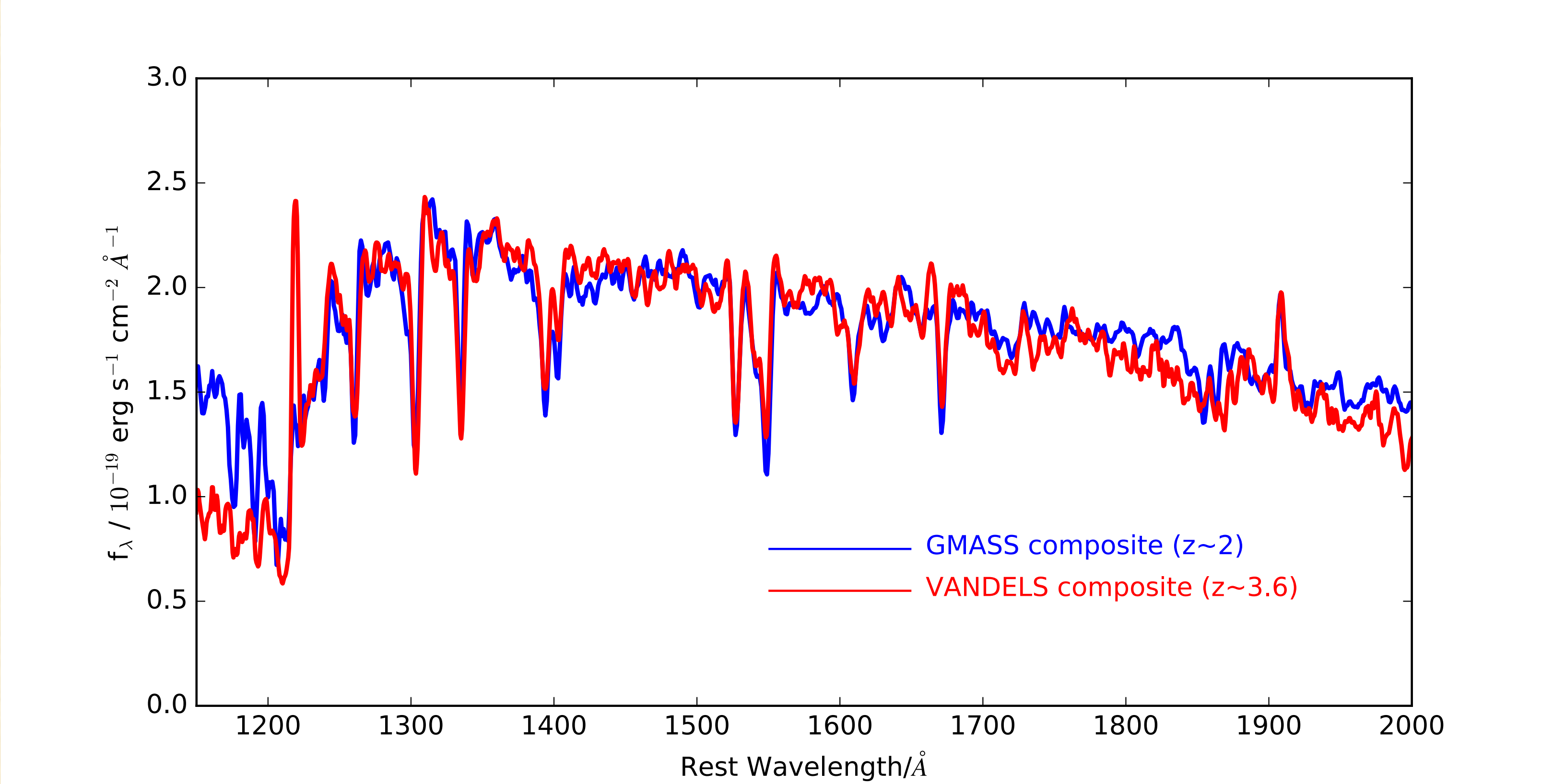
Stack of 75 star forming galaxies at z=2 from GMASS (Halliday et al. 2008)



Spectrum of a bright completed VANDELS source from season 1 observations

VANDELS: initial results

Key science goal is to study the stellar metallicities of star-forming galaxies at 2.5<z<5.5, initial data of the season one look promising in this regard.

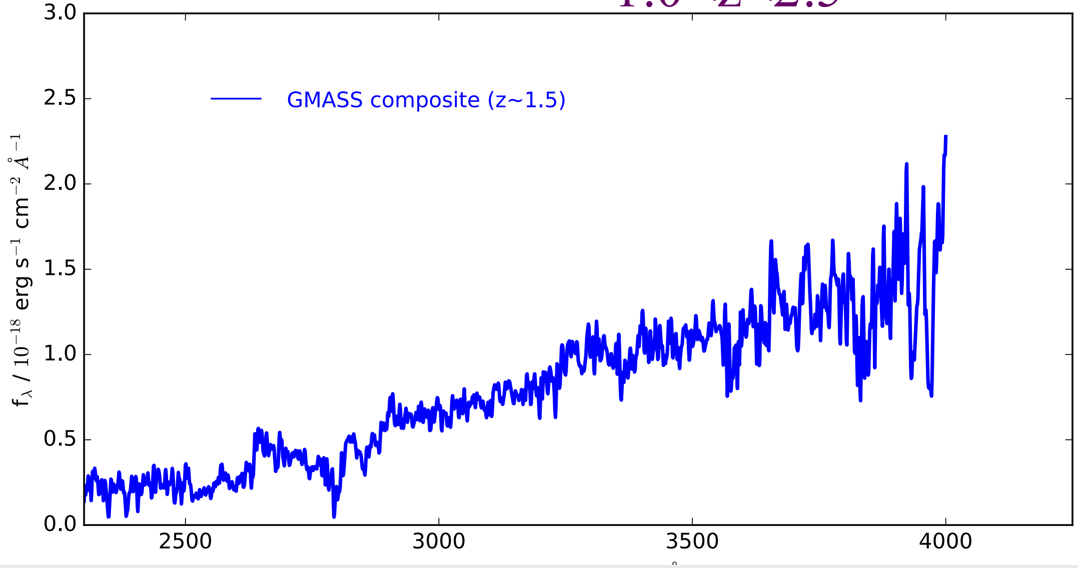


Median: $z=3.6$, $M^*{\sim}5\times10^9 M_\odot$, SFR~10 $M_\odot yr^{-1}$, sSFR~3 Gyr^{-1}

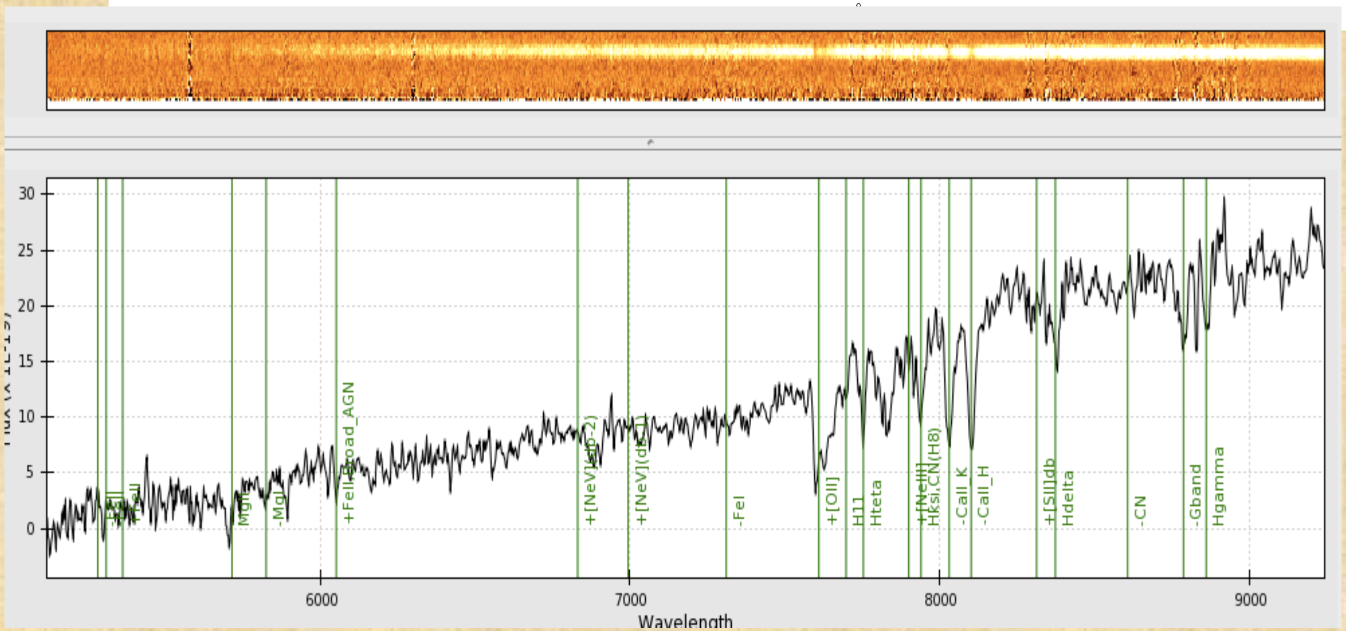
Rough stack of 50 LBGs in the redshift range 3.0<z<4.0. Final sample will contain ~1100 LBGs in this redshift range, allowing sub-division by redshift, mass, SFR…..

VANDELS: initial results

Key science goal is to study the stellar metallicities, ages, SFHs of passive galaxies at $1.0<z<2.5$



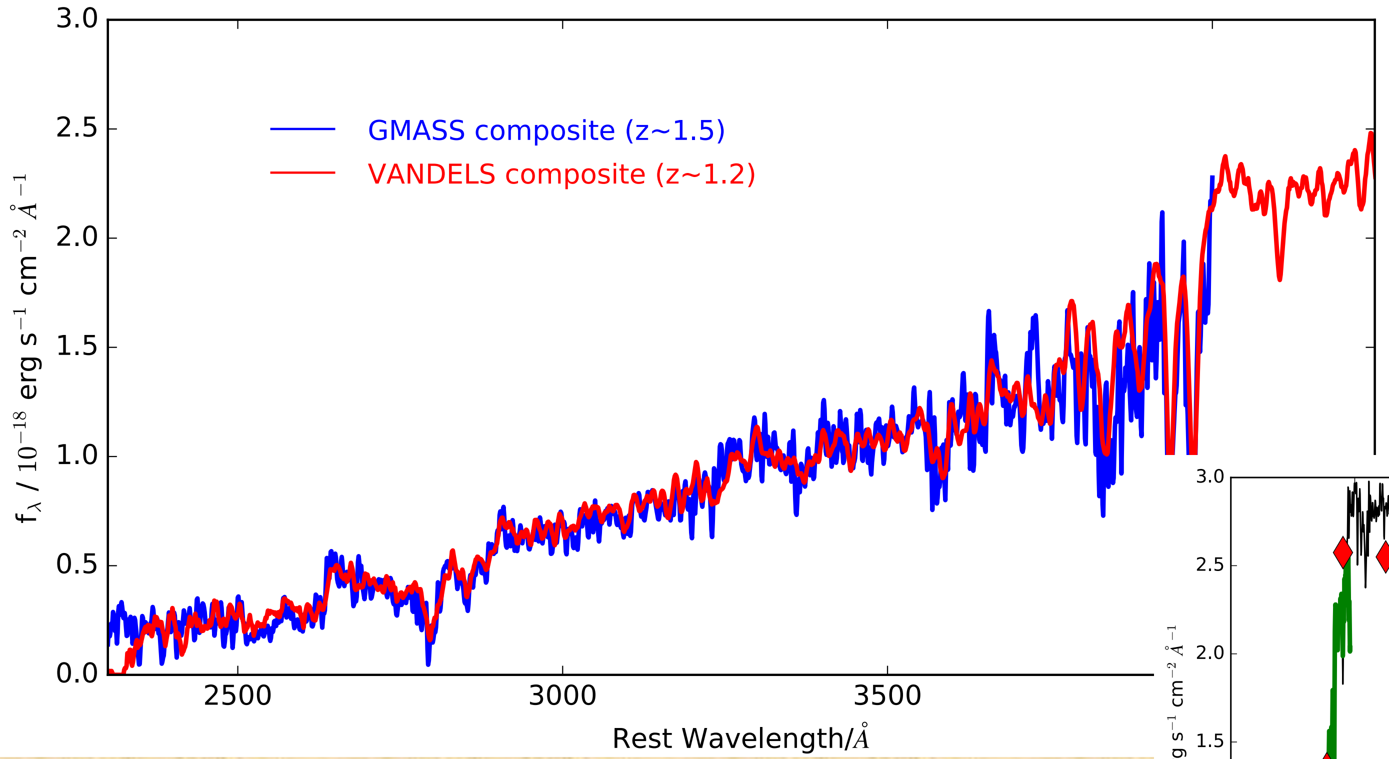
State of the arte: stack of early type galaxies at z=1.5 from GMASS (Cimatti et al. 2008)



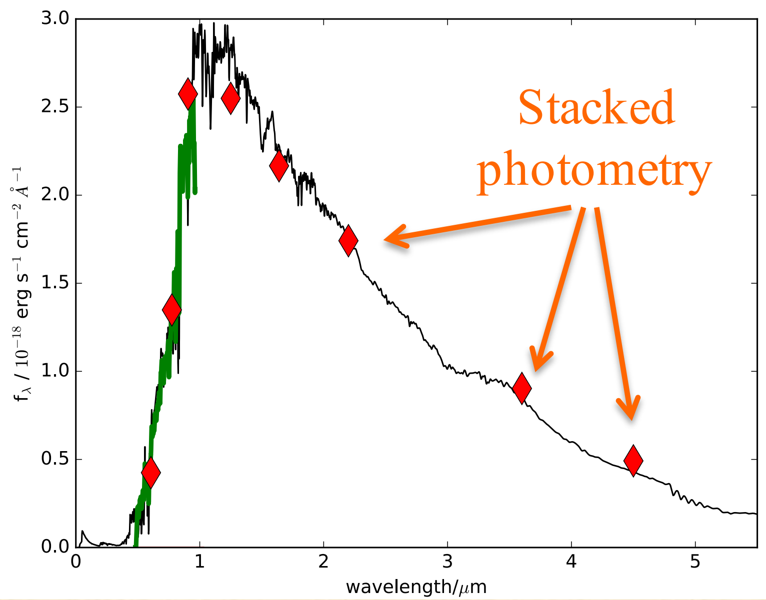
Spectrum of a bright passive galaxy from VANDELS season 1 oservations

VANDELS: initial results

Key science goal is to study the stellar metallicities, ages, SFHs of passive galaxies at 1.0<z<2.0. Again, initial stacks of the season one data look promising.



For slightly fainter objects we will derive stacks: this stack contains N=20 passive objects,



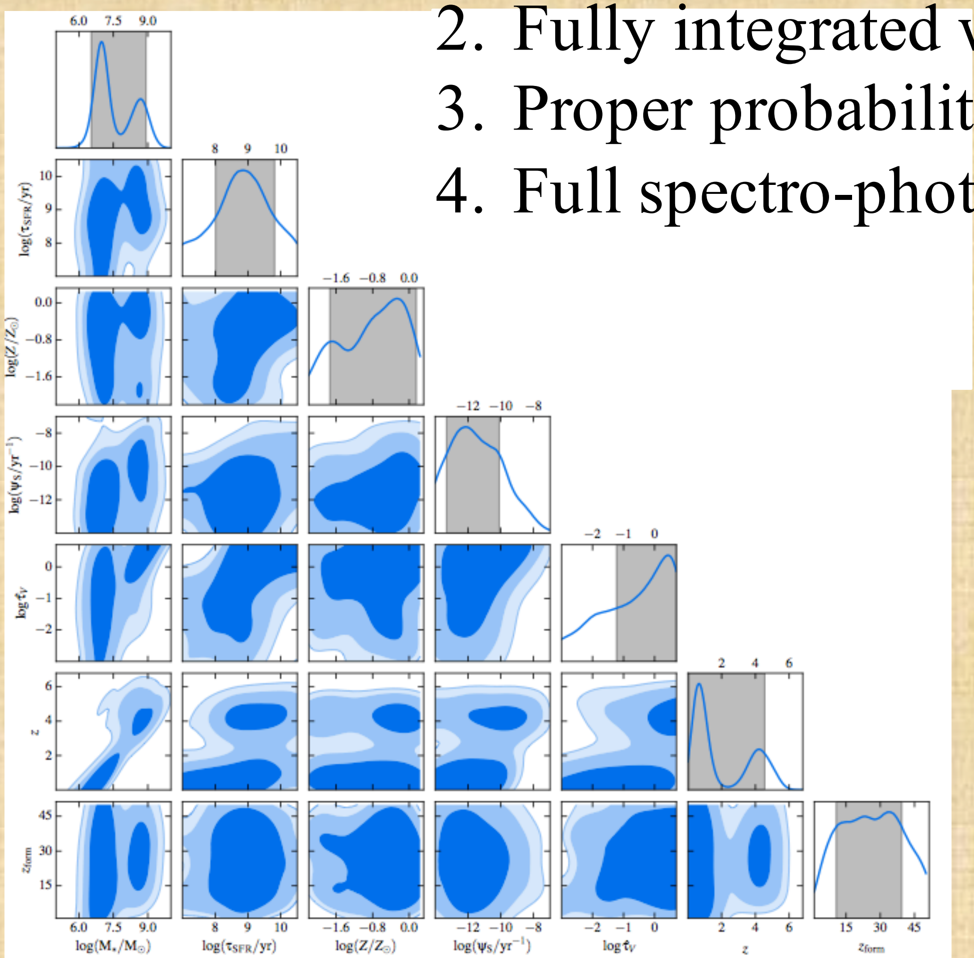
To fully exploit the data we clearly need to employ full spectro-photometric fitting:

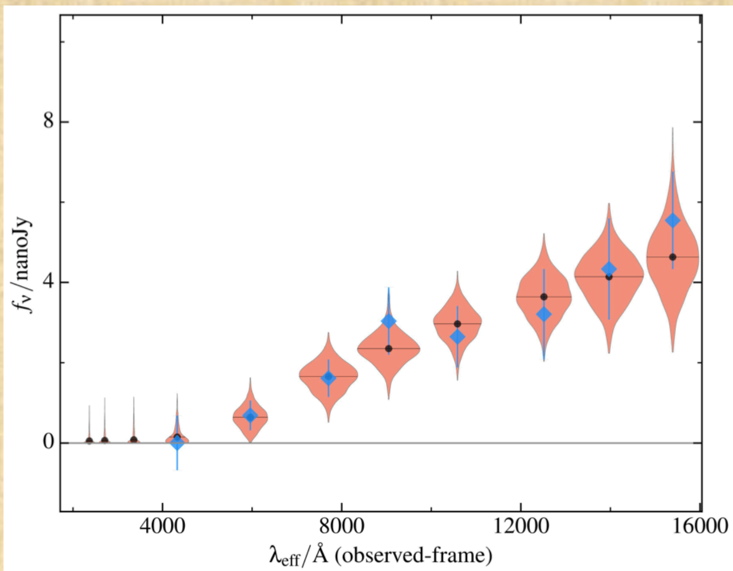
BEAGLE

(BayEsian Analysis of GaLaxy sEds)

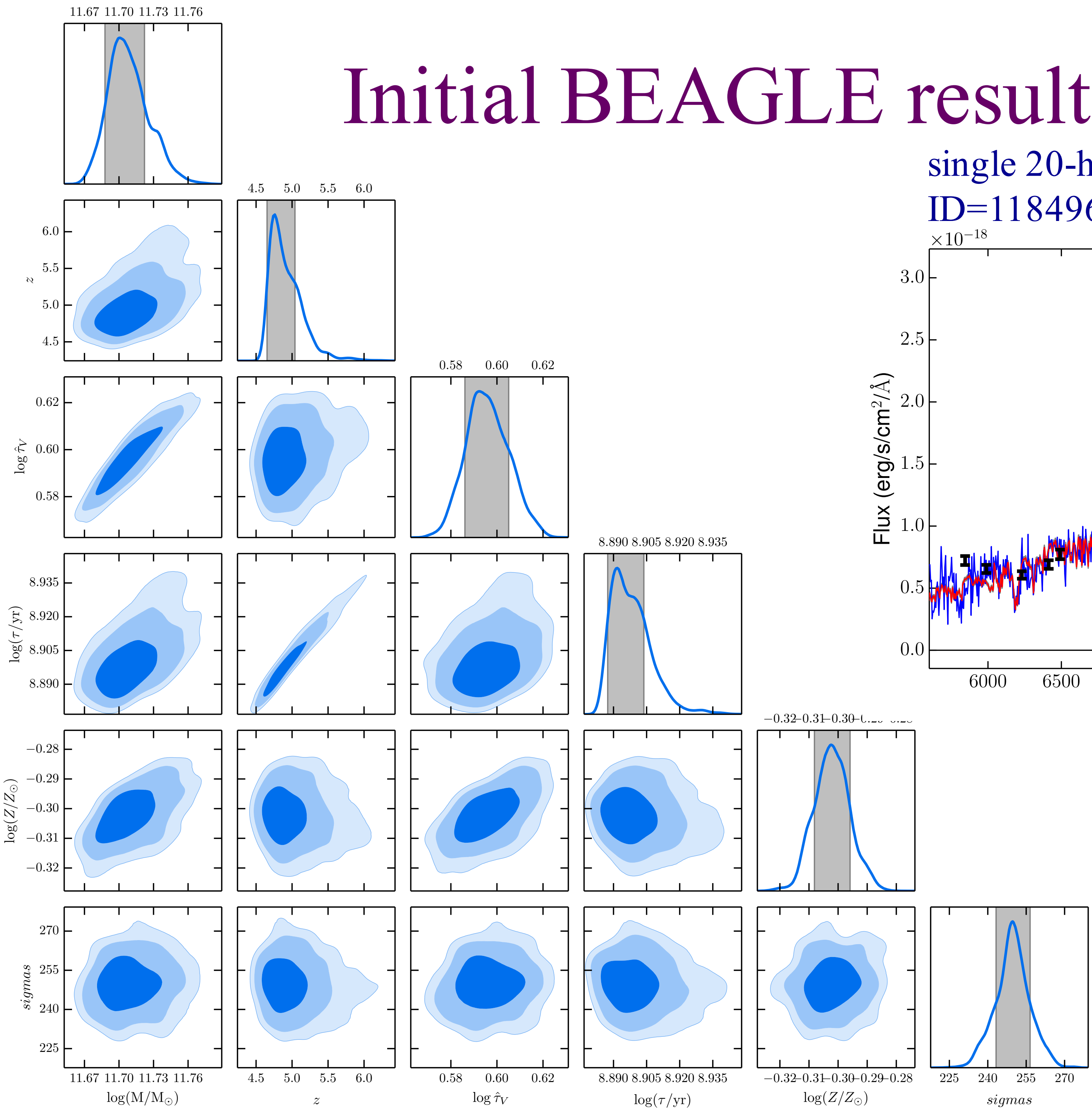
Chevallard & Charlot (2016)

1. CB15 stellar population models
2. Fully integrated with CLOUDY for nebular emission
3. Proper probability distributions for fitted parameters
4. Full spectro-photometric fitting

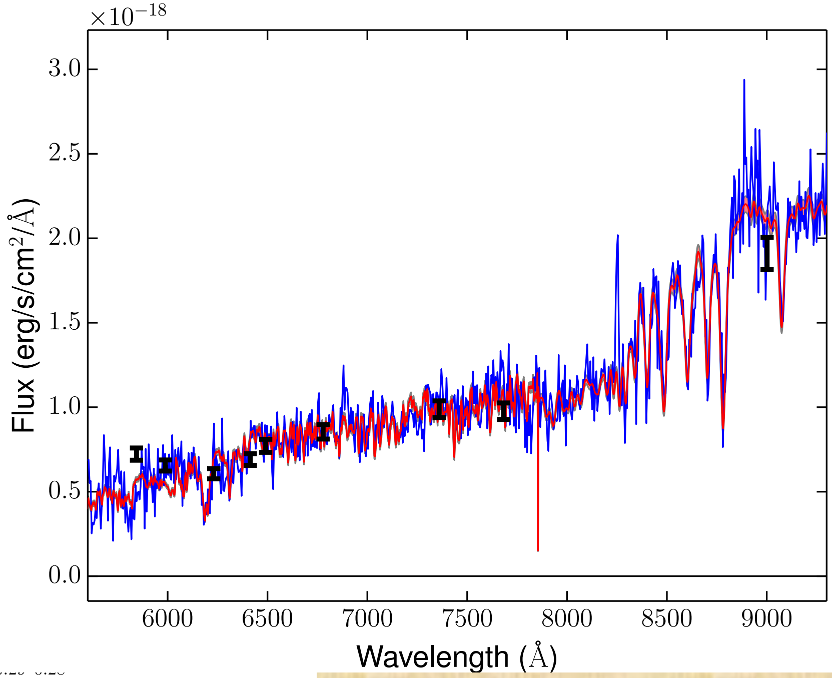




Initial BEAGLE results

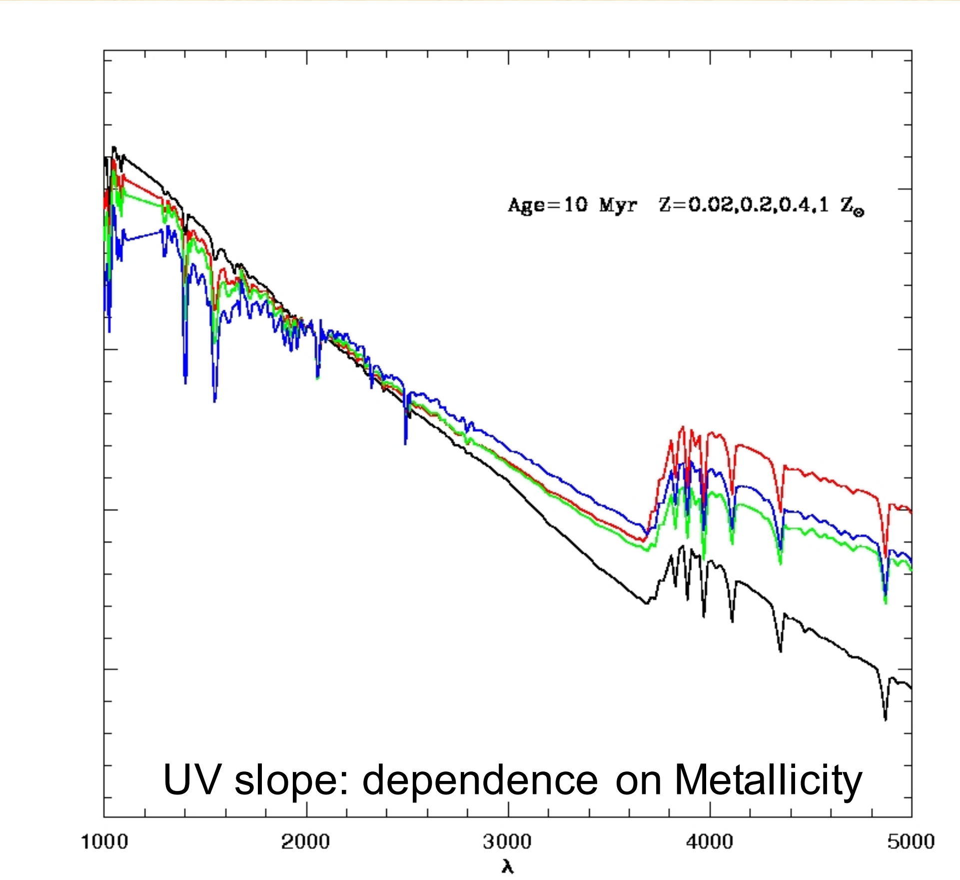


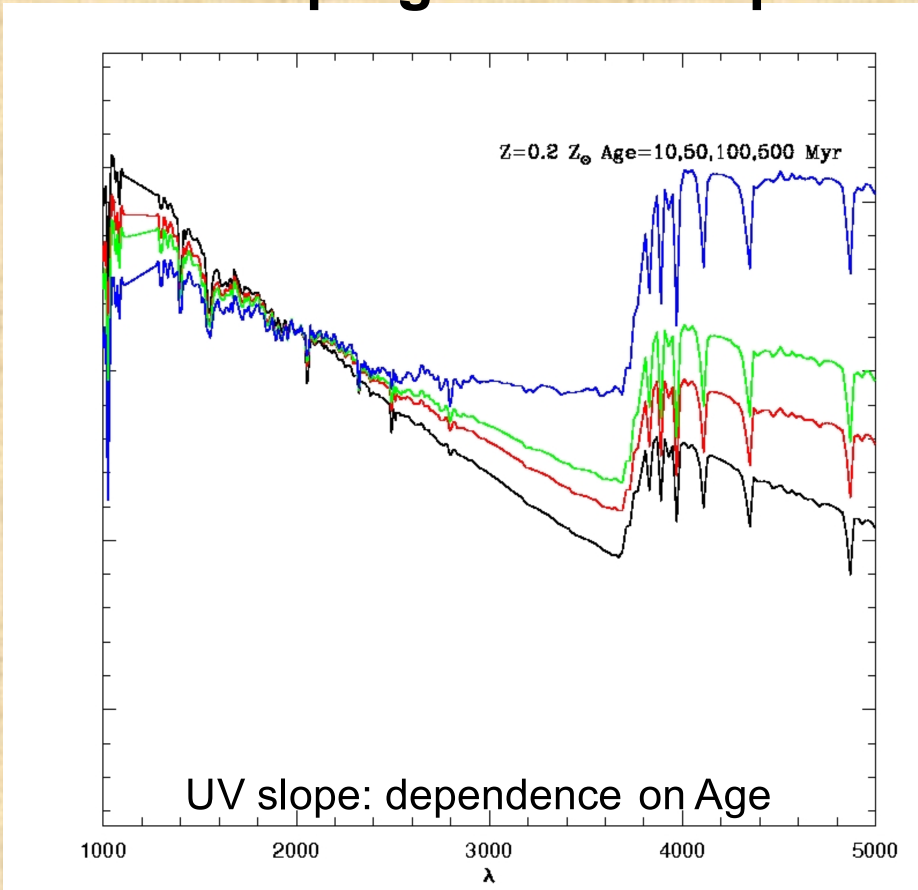
single 20-hr VANDELS spectrum
ID=118496 at z=1.2



Carnall et al work in progress

Dust/metallicity/age degeneracies shaping the UV slope





The UV slope is one of the most important observables at high-z, but we need both spectroscopic and photometric information to *understand* it and to *use it properly*.

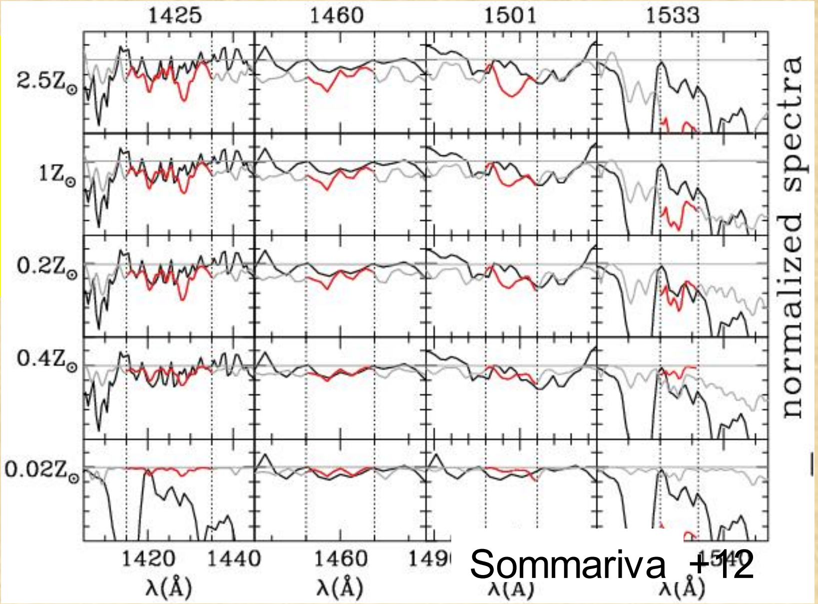
Exploiting the VANDELS sample we can:

1) accurately constrain LBG properties taking into account the effect of low metallicity: **need to revise upward extinction and SFRs (Castellano et al. 2014)**

2) disentangle the effect of metallicity, age and extinction on the UV slope

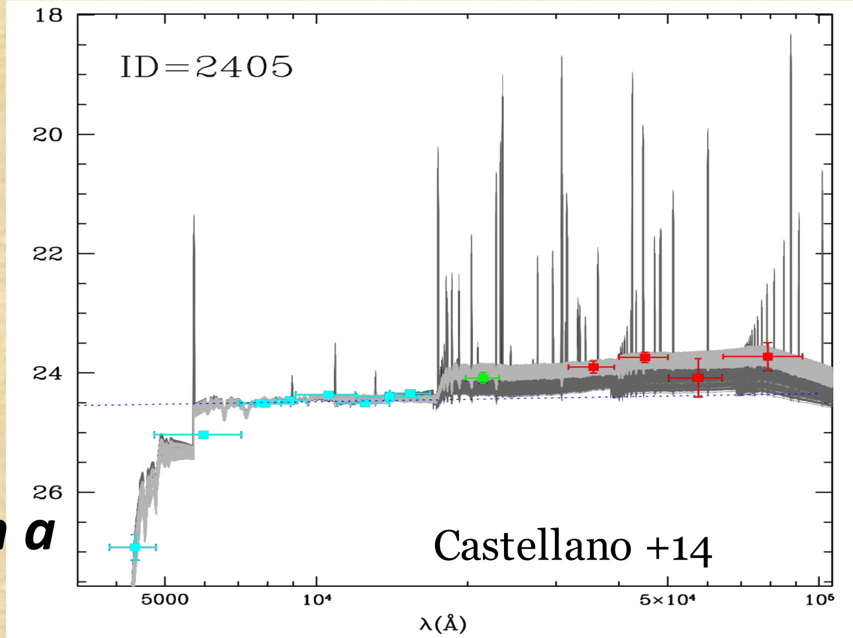
LBG properties taking into account the effect of low metallicity

“The SFR of z~3 LBGs with measured metallicity in CANDELS” (Castellano+14): exploratory work on the 14 “best” LBGs at z=3-4.



Stellar metallicity from UV absorption lines (as in Sommariva+12)
→ Sub-solar metallicity

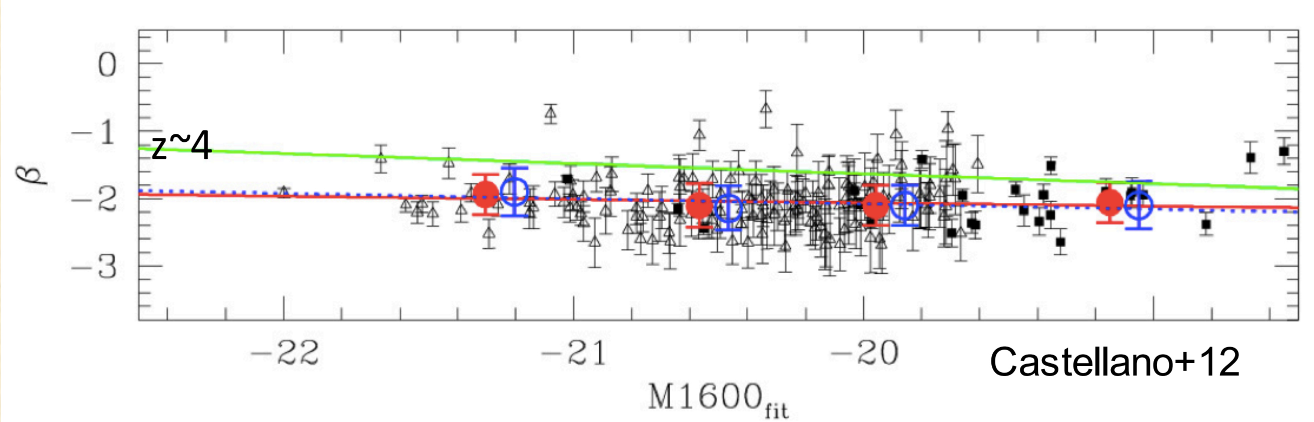
Balmer break sampled by ultra-deep K-band and IRAC
→ Young ages

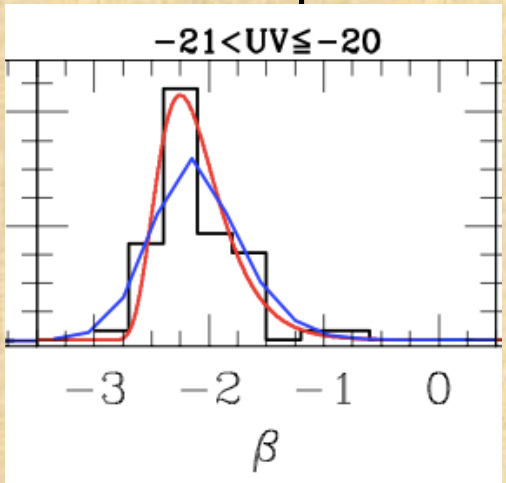


Result in a modified UV slope-extinction relation: $\mathbf{A_{1600}=5.32+1.99\beta}$

VANDELS enables tighter constraints from a much larger sample

Finding effects of metallicity, age and extinction on the UV slope

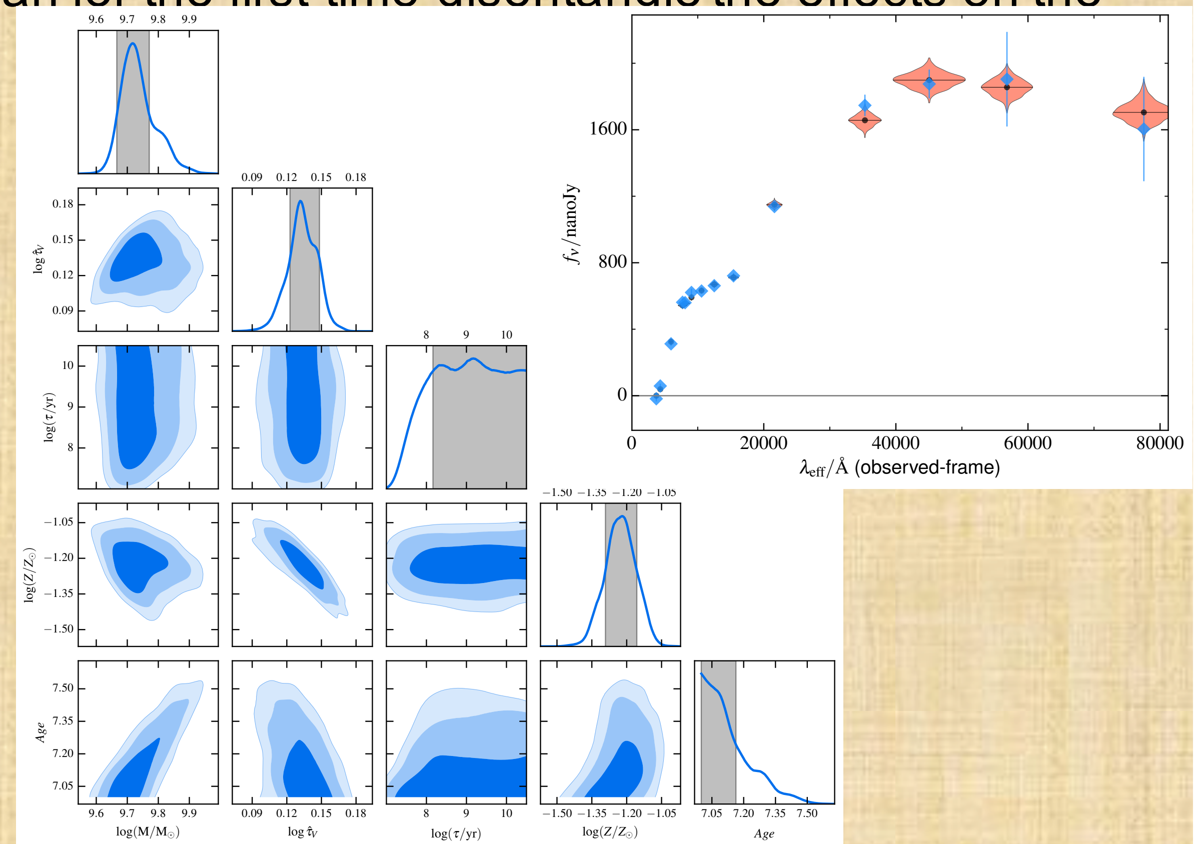




What is the impact of metallicity, age and extinction on the *average* UV slope (and *scatter*) at different redshifts? We can for the first time disentangle the effects on the UV slope thanks to VANDELS.

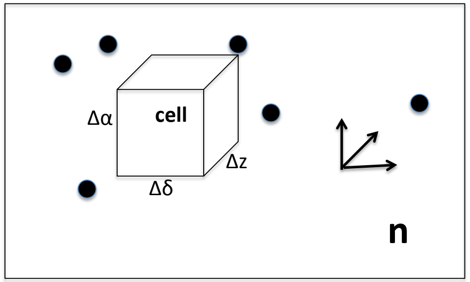
Currently testing BEAGLE code for the measurement of metallicity from tiny absorption features in the UV range (continuum definition is crucial!!)

(M. Castellano & Rome group in collaboration with J. Chevallard, S. Charlot)



Discovery of overdensities at z>2 in the season 1 and 2 VANDELS dataset
(Guaita, Pompei, Castellano, Pentericci in prep)

Code for environment: 3dv4 *(Trevese2007, Castellano2007, Salimbeni2008)*

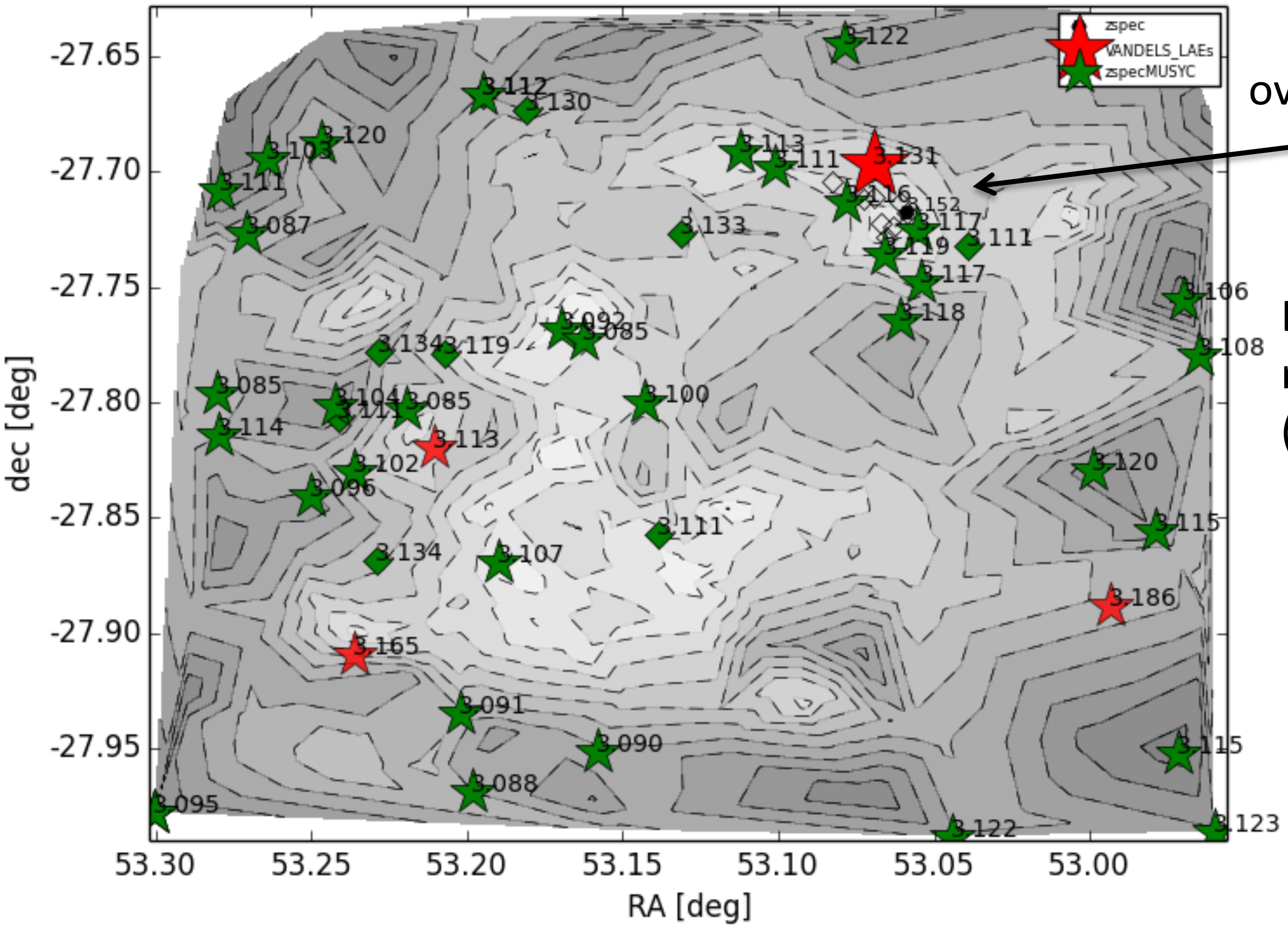


$V_n \Rightarrow \rho_{cell} = n/V_n$

Δz = 0.025 zphot
= 0.005 zspec
= 0.02 zphot+zspec

-> structure when ρ **>** $\langle\rho\rangle$ + TH σ

- estimation of local densities in the VANDELS fields
- identification of the position of VANDELS LAEs with respect to dense regions

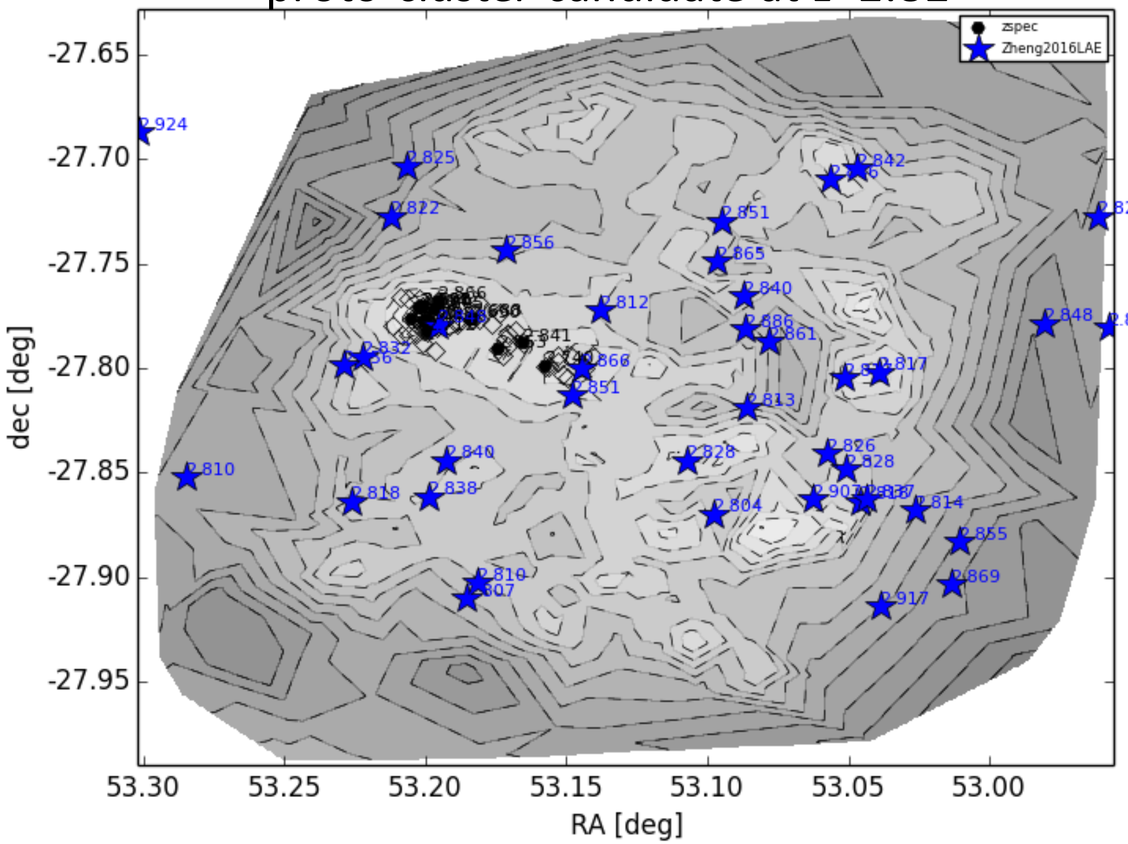


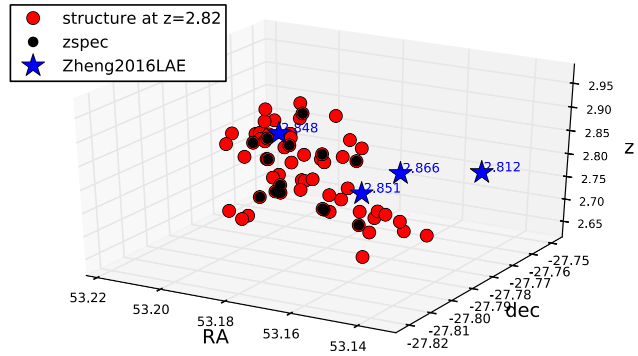
overdense structure at z=3.11

LAEs on the outskirts of the most dense regions
(ρ < $\langle\rho\rangle$ +1 σ)

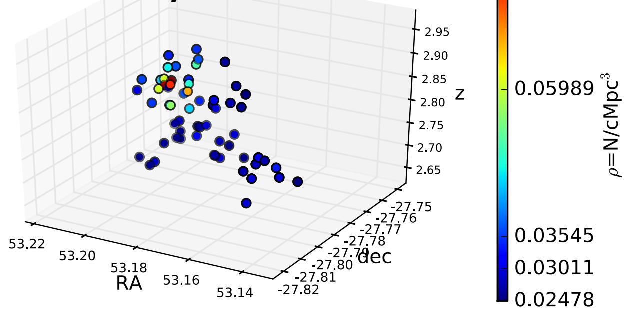
white-ish = higher density
darker=lower density

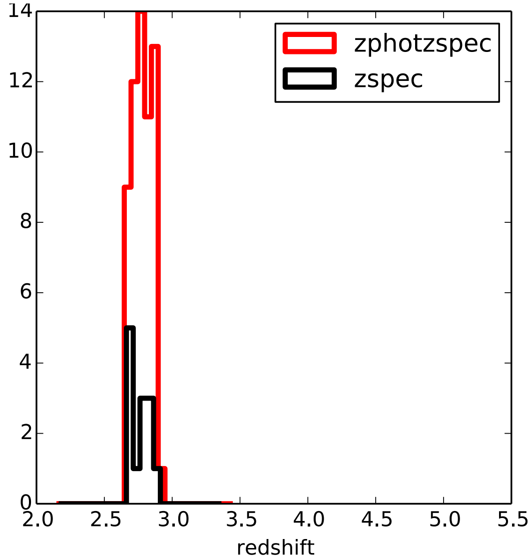
proto-cluster candidate at z=2.82



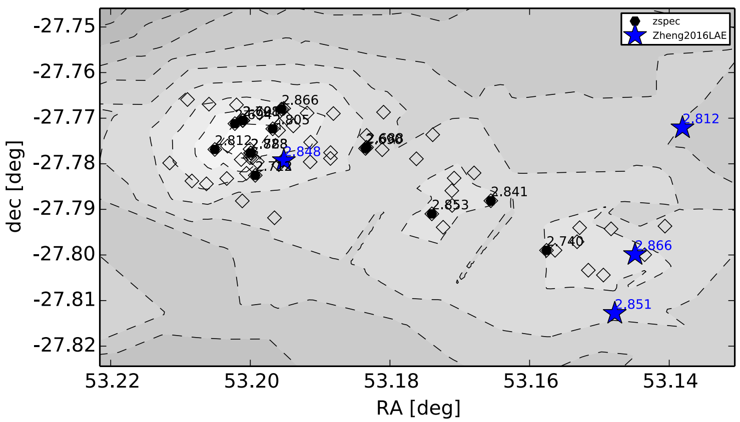


density scale

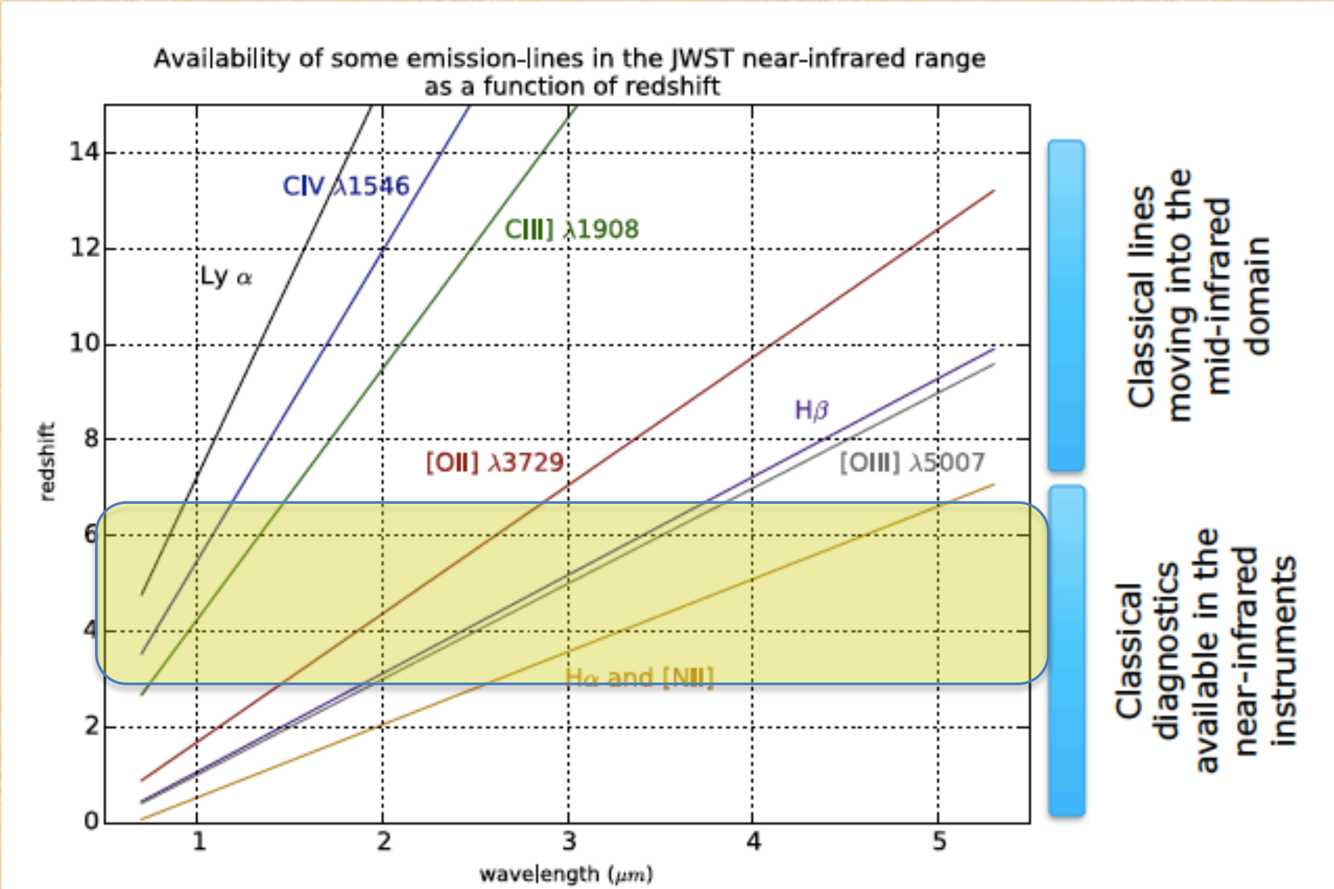




Interesting because
- most massive galaxies at the peak of the overdensity
- larger U-V color towards the outskirst
- red sequence starts to be delineated



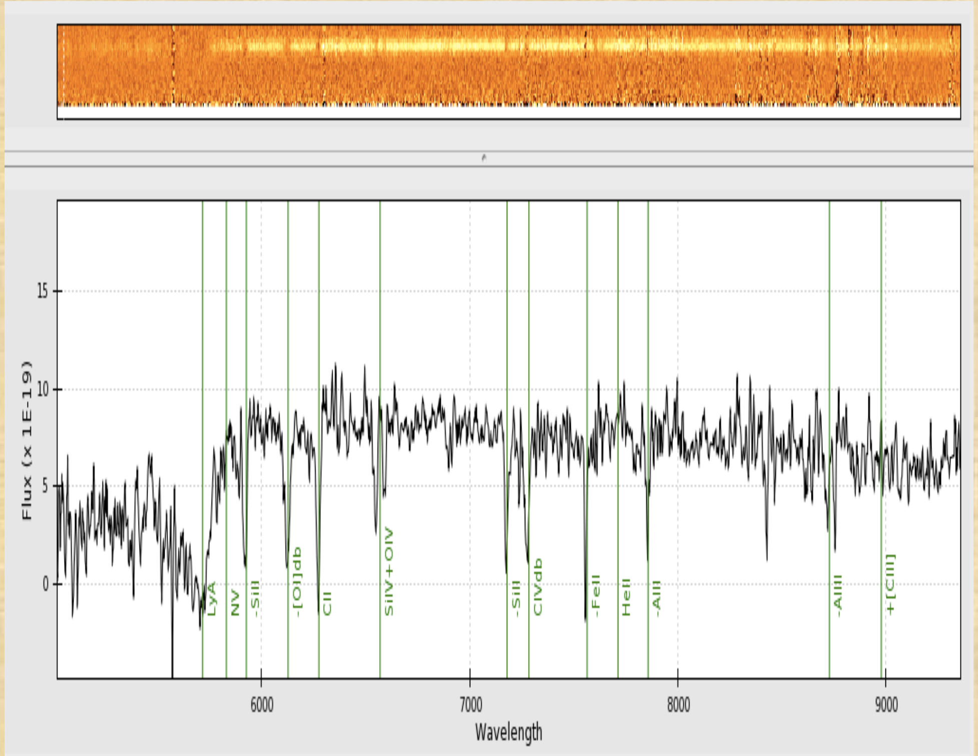
VANDELS targets will be ideal to follow up with JWST/NIRSPEC



For all our star forming galaxies @ 2.5<z<6.5 NIRSPEC will cover the following emission lines: CIII] [OII] Hβ [OIII] Hα [NII]

What can we learn from the combination of ultradeep VANDELS spectra and NIRSPEC

VANDELS:restframe UV



Lyα properties

EW, FWHM, spatial extent

ISM kinematics/Outflows

$\Delta v_{Ly\alpha} \Delta v_{LIS}$ Absorption line profiles

Stellar metallicity

F1370 F1425 (Leitherer), F1460

F1501 (Sommariva) F1978 (Rix)

LyC Properties

LyC flux detectable at 4<z<4.5

What can we learn from the combination of ultradeep VANDELS spectra and NIRSPEC

Star formation rates
(Balmer lines)

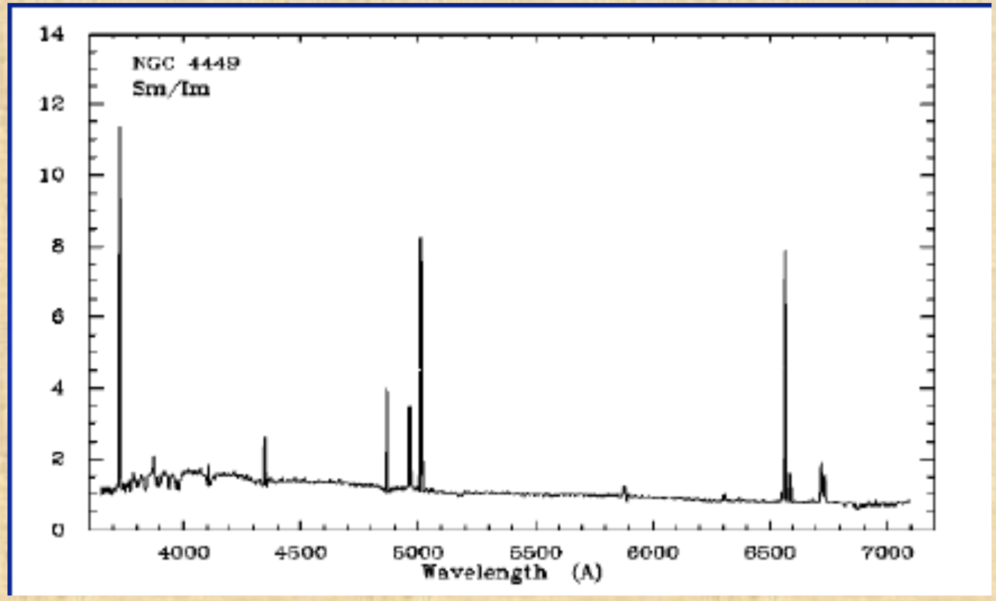
Dust extinction
(Hα/Hβ)

Gas metallicity
O3N2, R23 N2

Ionization parameter
[OIII]/[OII]

etc

NIRSPEC: restframe optical



What can we learn from the combination of ultradeep VANDELS spectra and NIRSPEC

Star formation rates
(Balmer lines)

Dust extinction
(Hα/Hβ)

Gas metallicity
O3N2, R23 N2

Ionization parameter
[OIII]/[OII]

etc

- Lyα escape vs dust/O32/
- Stellar metallicity vs gas metallicity
- Ouflows vs stellar mass
- Outflows vs SFR
- Lyα vs metalicity

.....and much more!!!!

Lyα properties
EW, FWHM, spatial extent

ISM kinematics/Outflows
$\Delta v_{Ly\alpha} \Delta v_{LIS}$ Absorption line profiles

Stellar metallicity
F1370 F1425 (Leitherer), F1460
F1501 (Sommariva) F1978 (Rix)

LyC Properties
LyC flux detectable at 4<z<4.5

Summary

- Currently working on data from season one and two
- Photo-z pre-selection working very well
- SNR of data as predicted, integrating down as $t^{0.5}$
- Initial modelling of composite spectra looks promising
- VANDELS targets will be ideal candidates for NIRSPEC observations
- ESO release of season one data is ready: keep an eye on the ESO pages!!

- More details can be found at: vandels.inaf.it

VANDELS

A deep VIMOS survey of the CANDELS UDS and CDFS fields

ESO public VIMOS spectroscopy survey of the UDS and CDFS fields

R. McLure & L. Pentericci