1 Title: VANDELS

A deep VIMOS survey of the CANDELS UDS and CDFS fields

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1.1 Abstract:(10 lines)

We propose a uniquely *deep* VLT spectroscopic survey of high-redshift galaxies, carefully designed to exploit the multi-wavelength imaging and near-IR grism spectroscopy available in the CANDELS UDS and CDFS fields. Our aim is to move beyond redshift acquisition, obtaining spectra with high enough signal-to-noise to derive metallicities and velocity offsets from absorption and emission lines, allowing a detailed investigation of the physics of galaxies in the early Universe. Using integration times set to obtain a constant S/N ($20 < t_{int} < 80$ hours), we will target: *a)* $2.5 < z < 5.5$ star-forming galaxies with $H_{\rm AB} \leq 24$ ($I_{AB} \leq 25$), *b)* $H_{AB} < 22.5$ passive galaxies at $1.5 < z < 2.5$; *c)* fainter ($H_{AB} \leq 27$) star-forming galaxies at $3.0 < z < 7.0$ and *d)* X-ray/radio selected AGN. Our strategy will deliver ≥ 2500 high signal-to-noise spectra within an area of $\simeq 0.2$ deg^2. Combining the proposed VIMOS spectroscopy with the best optical+nearIR+Spitzer imaging will produce a unique legacy dataset, capable of unveiling the physics underpinning high-redshift galaxy evolution.

2 Description of the survey: (Text: 3 pages, Figures: 2 pages)

2.1 Scientific rationale:

We propose to undertake a major ESO Public Spectroscopic Survey to perform the deepest ever spectroscopic study of the high-redshift Universe. Our proposed investment of ESO time is only merited, and our key scientific goals can only be realised, if this survey targets the fields with the very best multi-wavelength photometry and *Hubble Space Telescope (HST)* infrared+optical imaging. The CANDELS survey[1] (Co-PIs Faber & Ferguson) has recently completed its allocation of 902 HST orbits, delivering 0.25 deg^2 of deep WFC3 and ACS imaging over GOODS N+S, UDS, COSMOS & EGS (Grogin et al. 2011). Our proposed spectroscopic survey (VANDELS) aims to provide fundamental new insights into the processes of high-redshift galaxy evolution by obtaining repeated VIMOS observations of the CANDELS UDS and CDFS fields (see Fig. 1).

In addition to the quality of the available optical-nearIR data, our chosen survey fields are covered by ultra-deep *Spitzer* imaging (50 hrs per filter) from S-CANDELS (PI Fazio), providing the deepest available 3.6+4.5μm imaging on these angular scales ($\mathrm{m_{AB}} \simeq 26.5$ (5σ) at 3.6μm). Moreover, each field also features deep WFC3/IR grism spectroscopy from the public 3D-HST programme (Brammer et al. 2012). When combined with the deepest available $Y + K$ imaging provided by our large HAWK-I programme (Fontana et al. 2014), it is clear that the UDS/CDFS fields (and COSMOS, see Section 9.3) are now the key legacy fields for studying the high-redshift Universe. This proposal aims to fully capitalise on ESO's and ESA's existing investment by providing the ESO community with an unprecedented spectroscopic dataset for high-redshift galaxy evolution studies.

Our fundamental science goal is to move beyond simple redshift acquisition and obtain a spectroscopic dataset deep enough to study the *astrophysics* of high-redshift galaxy evolution. Consequently, we propose to target a large sample ($\simeq 900$) of $H_{\mathrm{AB}} \leq 24$ star-forming galaxies in the redshift range $2.5 < z < 5.5$ using photometric redshift pre-selection. Our adopted $H_{\mathrm{AB}} \leq 24$ magnitude limit ($S/N \geq 50$ in the CANDELS $H-$band imaging), which corresponds closely to a stellar-mass completeness limit of $M_\star \geq 5 \times 10^9\,\mathrm{M}_\odot$, is both pragmatic and scientifically motivated. Pragmatically, $\geq 90\%$ of $H_{\mathrm{AB}} \leq 24$ galaxies also have $I_{\mathrm{AB}} \leq 25$, meaning that we can provide robust *continuum* detections ($S/N \geq 10$ per pixel) in 20 hour integrations for the brightest objects ($I_{\mathrm{AB}} \leq 23.5$), increasing to 80 hours for the faintest $I_{\mathrm{AB}} \simeq 25$ galaxies. Scientifically, at this magnitude limit the existing 3D-HST ($1.1\mu\mathrm{m} < \lambda < 1.7\mu\mathrm{m}$) grism spectroscopy provides continuum detections with $S/N \geq 5$ per resolution element. Moreover, $H_{\mathrm{AB}} = 24$ is also the practical limit for extracting reliable morphological information from the available CANDELS HST imaging (e.g. Grogin et al. 2011; Bruce et al. 2012).

To study the descendants of our high-redshift star-forming galaxies, we also propose to target a complementary sample of massive ($H_{\mathrm{AB}} \leq 22.5$) *passive* galaxies at $1.5 < z < 2.5$, for which age/metallicity information from VIMOS can be combined with robust Balmer break measurements from 3D-HST grism spectroscopy. Finally, we also propose to extend our spectroscopic study to fainter magnitudes and higher redshifts by targeting faint ($H_{\mathrm{AB}} \leq 27$) Lyman-break galaxies (LBGs) and active galactic nuclei (AGN) at $3 < z < 7$. Our adopted strategy of repeated observations of each pointing, with on-source integrations of between 20 and 80 hours, will deliver a *minimum* of $\simeq 2560$ high signal-to-noise spectra over a total survey area of $\simeq 0.2\,\mathrm{deg}^2$. In Fig. 2 we show the expected VANDELS redshift distribution, estimated using the high-quality photometric redshifts available in UDS+CDFS, within the context of previous high-redshift spectroscopic surveys. In the next section we concentrate on describing the four science cases which are the main drivers of our survey design, before finishing with a brief discussion of the immense legacy value offered by VANDELS.

2.2 Objectives: Understanding the physics of high-redshift galaxy evolution

The luminosity function of star-forming galaxies at $2.5 < z < 8.0$ has now been determined to high accuracy, over two orders of magnitude in luminosity (e.g. McLure et al. 2013a; Bowler et al. 2014; Bouwens et al. 2014; Reddy & Steidel 2009). Consequently, the focus is now moving beyond basic demographics to understanding the physics of high-redshift galaxy evolution. Within this context, it is clear that the observational priorities

[1] http://candels.ucolick.org/

are accurate determinations of the form and evolution of the stellar mass function, star-formation rate density (SFRD), specific star-formation rate (sSFR) and the mass-metallicity relation at $z \geq 2.5$. However, all current studies are fundamentally undermined by interrelated and insidious uncertainties in stellar mass, metallicity, star-formation rate and dust attenuation. The main goal of this proposal is to circumvent many of these issues by providing, for the first time, spectra with high enough signal-to-noise and resolution to subject high-redshift galaxies to detailed absorption line studies.

Constraining the metallicity, dust and star-formation rate of $2.5 < z < 5.5$ galaxies
It has become increasingly clear that metallicity provides a powerful constraint on galaxy evolution because of its direct link to past star formation and sensitivity to interaction (inflow/outflow) with the IGM (e.g. Davé et al. 2011). Knowledge of the metallicity of stellar populations is also fundamental to achieve accurate estimates of both star-formation rates (and hence global SFRD) and dust extinction (e.g. Castellano et al. 2014). Indeed, the slope of the UV continuum, currently used as a proxy for dust extinction, is known to be a strong function of both metallicity and age (Rogers et al. 2014).

Our recent work has demonstrated that, given deep enough spectroscopy, this problem can be overcome using photospheric UV absorption lines (1370-1900Å) whose equivalent width is sensitive to metallicity and independent of other stellar parameters (Sommariva et al. 2012). By providing $\simeq 900$ spectra at $2.5 < z < 5.5$ with which to measure *stellar* metallicities, both individually and via stacking, the proposed observations offer the prospect of transforming our understanding of metallicity at high redshift (c.f. Halliday et al. 2008; Fig. 3). By combining absorption-line metallities with accurate stellar masses based on WFC3/IR+IRAC photometry, it will be possible, for the first time, to study the evolution of the stellar mass − *stellar* metallicity relation out to $z \simeq 5$ (c.f. Mannucci et al. 2010; Cullen et al. 2014).

The stellar mass function and star-formation histories at $z \geq 2.5$
Any viable model of high-redshift galaxy evolution must be able to simultaneously reproduce the evolution of both the SFRD and the stellar mass function. The key to addressing these issues is accurate spectral energy distribution (SED) fitting, including both the near-IR and mid-IR bands. This was the original motivation of the CANDELS survey and the resulting *HST* imaging dataset is currently unrivalled. However, current uncertainties in the estimates of stellar masses, SFRs and SFHs caused by the lack of spectroscopic redshifts, and the metallicity/dust degeneracy discussed above, make it impossible to exploit the full potential of CANDELS. Moreover, progress is further limited by the uncertain impact of nebular line emission (e.g. de Barros, Schaerer & Stark 2014), compounded by recent results which show that the equivalent widths of key nebular lines increase rapidly with redshift (Shim et al. 2011; Stark et al. 2013; Smit et al. 2014).

Our VIMOS programme will deliver a unique sample of $\simeq 2200$ spectroscopically-confirmed star-forming galaxies at $2.5 < z < 7.0$, with $\simeq 900$ bright enough to use for metallicity measurements. The spectroscopic redshifts alone will substantially improve the accuracy of stellar-mass estimates (e.g. Santini et al. 2012) and largely circumvent the nebular emission problem by allowing detailed SED fitting (in extreme cases *excluding* the photometric bands affected by strong nebular emission lines). Metallicity-constrained SED fitting will also remove degeneracies between metallicity and age, allowing us to derive the improved age measurements necessary to constrain evolutionary models. Our proposal will deliver a *spectroscopic* determination of the bright end of the evolving stellar mass function and SFRD with unprecedented accuracy, providing the benchmark dataset for future high-redshift galaxy evolution studies.

Massive galaxy assembly at $1.5 < z < 2.5$
A key component of this proposal is obtaining deep spectroscopy of $\simeq 300$ massive ($M_\star \geq 10^{10.5}\,\mathrm{M}_\odot$) *passive* galaxies at $1.5 < z < 2.5$. This population holds the key to understanding the quenching mechanisms responsible for producing the strong colour bi-modality observed at $z \leq 1$, together with the significant evolution in the number density, morphology and size of passive galaxies observed between $z = 2$ and the present day (e.g. Bruce et al. 2012; McLure et al. 2013b). For passive $z \simeq 2$ galaxies, VIMOS spectroscopy will provide the crucial rest-frame UV absorption-line information (e.g. MgUV, 2640Å/2900Å breaks, see Fig. 4) needed to complement Balmer break measurements from 3D-HST. Using the VIMOS+3D-HST spectra, it will be possible to break age/dust/metallicity degeneracies and deliver accurate stellar mass, dynamical mass, star-formation rate, metallicity and age measurements via full spectrophotometric SED fitting (e.g. McLure et al. 2013b).

Measuring galactic outflows at $1.5 < z < 4.5$

An additional goal of our proposal is to study outflows of interstellar gas. Recent work suggests that high-velocity outflows may be ubiquitous for star forming galaxies at $z > 1$, with mass outflow rates comparable to the rates of star formation (e.g. Weiner et al. 2009; Bradshaw et al. 2013). There is also evidence that very compact starbursts can produce extreme outflows with velocities in excess of 1000 km s^{-1}, yielding winds that were previously only thought possible from AGN activity (Diamond-Stanic et al. 2012). Such outflows may be playing a major role in the termination of star formation at high redshift and the build-up of the mass-metallicity relation.

The high signal-to-noise, rest-frame UV, spectra delivered by VANDELS for both *individual* and small-number stacks of star-forming galaxies at $2.5 < z < 4.5$ will allow accurate measurements of outflowing ISM velocities from high and low-ionization UV (1200Å-1700Å) interstellar absorption features (e.g. Shapley et al. 2003). At lower redshifts, $1.5 < z < 2.5$, it will be possible to exploit the strong Mg II (2800Å) interstellar aborption feature (e.g. Weiner et al. 2009; Bradshaw et al. 2013). Our key aim is to measure the outflow rate as a function of stellar mass, SFR, and galaxy morphology, to understand the impact of galactic outflows on star-formation at $z \geq 2$. Measuring the balance of inflow, outflow and star formation will enable us to test models for the evolving gas reservoir (e.g. Dayal, Ferrara & Dunlop 2012) and address the origins of the Fundamental Metallicity Relation (Mannucci et al. 2010). Finally, comparing the outflow velocities of star-forming galaxies with and without hidden AGN (as identified from X-ray emission) will allow the role of AGN feedback in quenching star formation and the build-up of the red sequence to be investigated (e.g. Cimatti et al. 2013).

Summary and legacy value

The immediate objective of the VANDELS survey is to obtain uniquely-deep (20-80 hour integrations), moderate-resolution, optical spectra ($0.48\mu m < \lambda < 1.0\mu m$) of ≥ 2500 galaxies in the CANDELS UDS and CDFS fields. In combination with the unparalleled multi-wavelength photometry available in these fields, the high signal-to-noise ($10-20$ per pixel) VANDELS spectra are primarily designed to yield accurate stellar metallicity, stellar age, gas outflow and stellar mass measurements for large, statistical, samples of star-forming galaxies at $2.5 < z < 7.0$. The fundamental goal of VANDELS is to provide spectra with sufficient signal-to-noise to investigate the *astrophysics* of high-redshift star-formation via the first detailed *absorption line* studies of well-defined samples of high-redshift galaxies.

The immense legacy value of the VANDELS survey is compelling: simply by providing spectra of relatively faint targets with unprecedentedly high signal-to-noise, VANDELS is guaranteed to open up new parameter space for investigating the physical properties of high-redshift galaxies. For example, VANDELS will fundamentally improve our knowledge of the statistics of Lyα emission in star-forming galaxies approaching the reionization epoch (e.g. Pentericci et al. 2011; Stark et al. 2011; Curtis-Lake et al. 2012; Cassata et al. 2014) and facilitate the identification of the progenitors of compact galaxies amongst star-forming galaxies at $z \geq 2.5$ (e.g. Williams et al. 2013). Finally, thanks to the large number of targets that can be allocated on each VIMOS mask, VANDELS will also facilitate the study of rarer bright systems such as *Herschel* detected galaxies and AGN. For these bright systems, the deep VANDELS spectroscopy will make it possible to assess their physical conditions (e.g. metallicities, ionizing fluxes and outflows signatures) and compare them with those of less active systems at the same redshifts.

The following table provides a summary of the different VANDELS sub-samples and the expected number of objects to be targeted for 20, 40 and 80 hour integrations:

TARGET TYPE	Selection	Science	N80	N40	N20	TOTAL
Star-forming $2.5 < z < 5.5$	$H < 24$	Metallicity/dust/outflows	335	350	195	880
Passive $1.5 < z < 2.5$	$H < 22.5$	SF quenching	210	60	30	300
Faint LBGs $3.0 < z < 7.0$	$H < 27$	Redshifts, LFs, Lyα fraction	95	820	365	1280
Faint AGN $3.0 < z < 5.0$	X-ray/Radio	Outflows, feedback	–	50	50	100
TOTAL			640	1280	640	2560

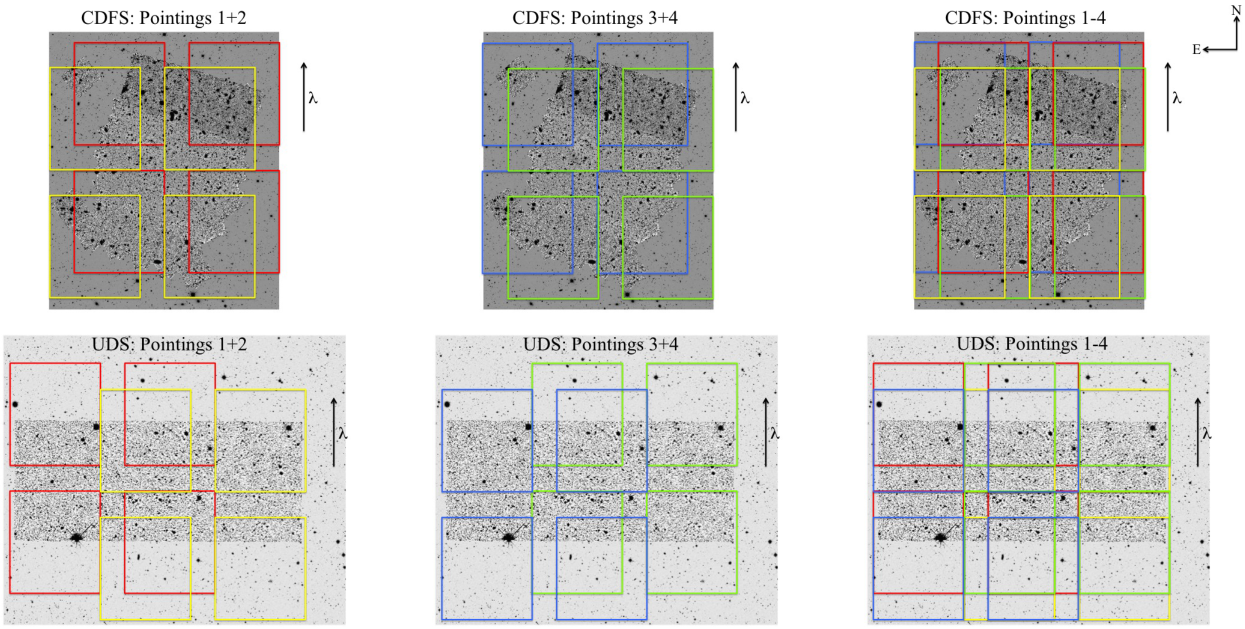

Figure 1: Layout of the proposed VANDELS pointings (4 in UDS and 4 in CDFS). In each figure the VIMOS quadrants of a given pointing are shown as a different colour, overlaid on a greyscale image showing the available *HST* $H-$band imaging (centre) and wider-area, ground-based, near-IR imaging. The total area covered by the 8 VIMOS pointings is $\simeq 0.2$ square degrees. The quality of the multi-wavelength data available over the wider UDS and E-CDFS fields is now excellent, and more than sufficient to select $H \leq 24$ targets over the full VANDELS footprint. The pointings are placed to ensure that each VIMOS quadrant always intersects the CANDELS *HST* imaging which, due to the high surface density of faint $z \geq 3$ galaxies, allows us to maximize the number of slits in the central *HST* area. The spectroscopic slits will be placed E-W on the sky, as recommended to minimize slit losses during long integrations on fields at these declinations (Sánchez-Janssen et al. 2014).

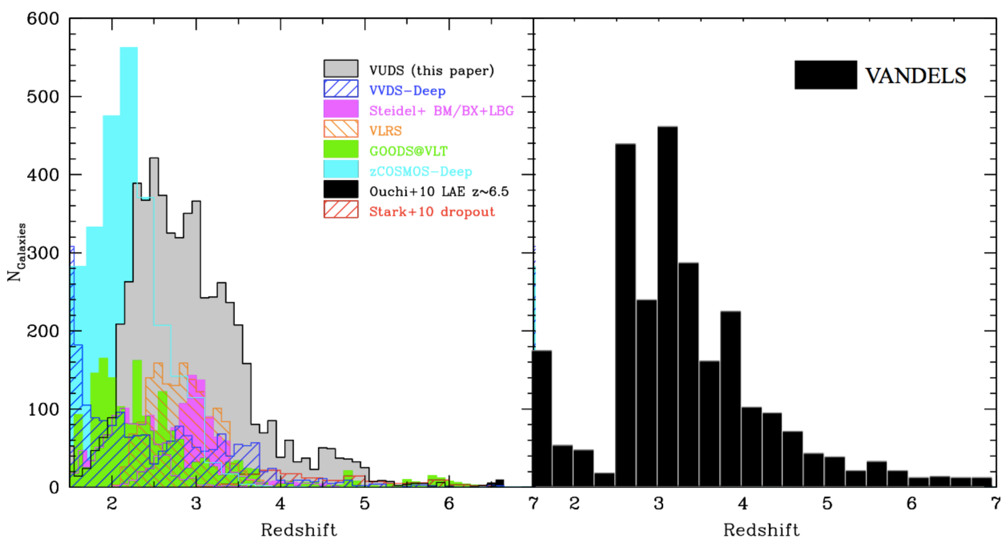

Figure 2: LHS: the redshift distribution of the VIMOS Ultra Deep Survey (VUDS) within the context of other notable spectroscopic surveys (Le Fèvre et al. 2014). It is clear that even VUDS has a redshift distribution which is strongly peaked at $z = 2.5 - 3$, with only a small fraction of galaxies at $z \geq 4$ and only 26 galaxies in total at $z \geq 5$. RHS: the expected redshift distribution of VANDELS, based on photometric redshifts derived from the multi-wavelength data available in the UDS and CDFS fields. The VANDELS selection function should ensure that $\simeq 20\%$ of the final sample are at $z \geq 4$, with $\simeq 200$ galaxies at $z \geq 5$.

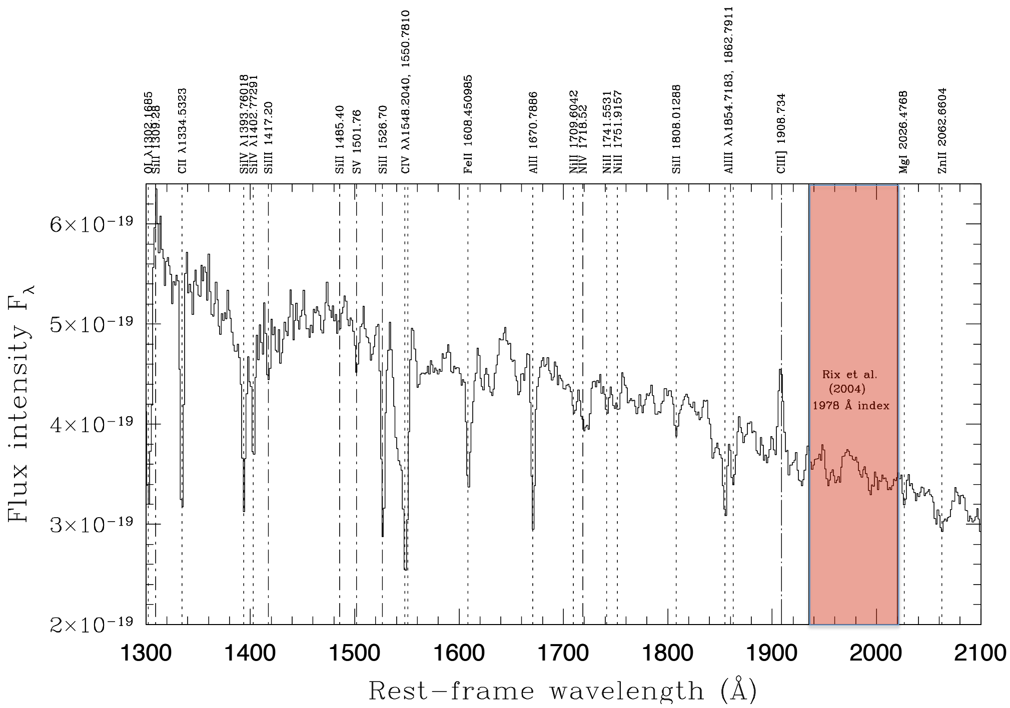

Figure 3: Stacked UV spectrum of 75 star-forming galaxies at $z \simeq 2$ observed as part of the GMASS survey (Halliday et al. 2008). This stacked spectrum has S/N$\simeq$ 100 and illustrates the wealth of information available from interstellar (dotted) and photospheric (dashed) absorption features. In red we have highlighted the so-called 1978-index (Rix et al. 2004), used by Halliday et al. to determine the stellar metallicity from the stack. The final VANDELS sample will contain $\simeq$ 900 spectra covering the rest-frame UV of star-forming galaxies at $z \geq 2.5$, each with $S/N \simeq 10 - 20$ per pixel. Consequently, using stacks of small numbers of objects, it will be possible to determine the average stellar metallicity as a function of redshift, stellar mass, SFR and age.

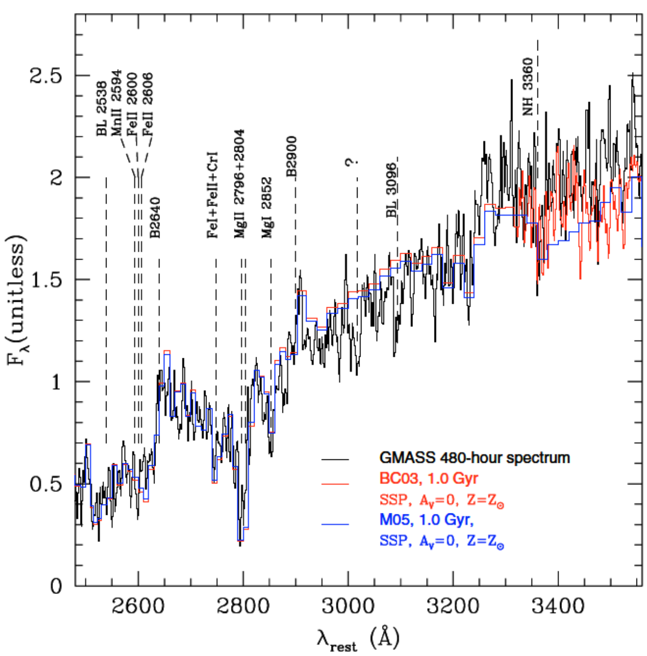

Figure 4: Stacked spectrum of 13 early-type galaxies at $\langle z \rangle = 1.6$ from GMASS (Cimatti et al. 2008), showing the crucial age-dependent information provided by deep spectroscopy of the Mg_{UV} region. The stacked GMASS spectrum has an equivalent exposure time of 480 hours and the same spectral resolution as the proposed VANDELS spectroscopy. The red and blue curves show 1 Gyr old model fits with solar metallicity BC03 and Maraston05 models respectively. VANDELS will provide stacked spectra of this quality for small (i.e. $\simeq$ 6 object) sub-samples.

3 Are there similar ongoing or planned surveys? (1 page)

ESO has a long standing tradition of allocating many hundreds of hours of service time observations to large spectroscopic surveys, many of which have made extensive use of the multi-plex capabilities of VIMOS: VVDS, GOODS, zCOSMOS, VUDS & VIPERS. The spectroscopic redshift distributions produced by these projects are shown in Fig. 2. Most of these previous VIMOS spectroscopic surveys are either long-completed (e.g. VVDS, GOODS & zCOSMOS), or primarily low-redshift cosmology experiments (i.e. VIPERS). However, it is clearly of interest to discuss our current VANDELS proposal within the context of the recently-completed VIMOS Ultra Deep Survey (VUDS; Le Fèvre et al. 2014).

The primary objective of VUDS was to obtain deep VIMOS spectroscopy for 10,000 ($I_{AB} \leq 25$) galaxies over an area of 1 square degree in three survey fields: COSMOS (8 pointings), VVDS-02 (5 pointings) & E-CDFS (3 pointings). The survey used a combination of photometric and colour pre-selection techniques to target galaxies in the redshift interval $2 < z \sim 6$, typically obtaining 14 hours of integration on each target with the low resolution red and blue grisms (i.e. LR_RED+LR_BLUE). The VUDS spectra therefore provide a total wavelength coverage of 3600Å$< \lambda <$ 9350Å at a spectral resolution of $180 < R < 210$ (Le Fèvre et al. 2014).

In terms of selection function, depth and spectral resolution it is clear that VANDELS is both complementary to VUDS and surpasses it. Although VUDS targeted objects in the redshift range $2 < z < 6$, it is clear from Fig. 2 that the majority of the spectroscopic redshifts are in the range $2 < z < 3$. Moreover, Fig. 2 also demonstrates that only a very small fraction of VUDS galaxies are at $z \geq 4$, with virtually no galaxies at $z \geq 5$ (26 in total, Le Fèvre et al. 2014). In contrast, the pre-selection we will employ for VANDLES is based on photometric redshift probability functions derived from high-quality multi-wavelength catalogues, which are already in place (Galametz et al. 2013; Guo et al. 2013), and will ensure that $\simeq 80\%$ of VANDELS targets are in the range $2.5 < z < 7.0$. Crucially, our pre-selection will allocate $\simeq 20\%$ of VANDELS slits to galaxies at $z \geq 4$ and will target $\simeq 200$ galaxies at $5.0 < z < 7.0$. It is therefore clear that VANDELS promises to open up new parameter space for detailed galaxy evolution studies at $z \simeq 4$ and beyond.

The minimum VANDELS exposure time is 20 hours of on-source integration, with 75% of the sample being allocated 40-80 hours of integration (c.f. 14 hours in VUDS). Moreover, our choice of the MR grism with the GG475 order sorting filter provides wavelength coverage out to 1.0μm (c.f. 0.935μm in VUDS), fully exploiting the red sensitivity of the upgraded VIMOS detectors and pushing our Lyα redshift limit to $z \simeq 7.1$. In addition to improved signal-to-noise, the factor of three improvement in spectral resolution provided by the MR grism is crucial for extracting accurate stellar metallicities, ages and outflow velocities from absorption features in the rest-frame UV. Moreover, the improved spectral resolution will lead to significant improvements in sky subtraction at $\lambda >$ 7500Å, which is vital for reliably measuring faint absorption/emission features at $z \geq 5$.

The final area in which VANDELS holds a significant advantage over previous spectroscopic surveys is in the quality of the multi-wavelength data available in the UDS+CDFS fields. The key advantages lie in the unparalleled CANDELS WFC3/IR imaging and the ultra-deep *Spitzer* data from the S-CANDELS survey. In addition to providing a significant improvement in the initial selection function, the availability of these data ensure that the majority of VANDELS spectra will be accompanied by detailed *HST* morphological information *and* accurate stellar masses.

4 Observing strategy: (1 page)

We propose to target the CDFS and UDS with four overlapping VIMOS pointings per field, designed to provide full coverage of the WFC3/IR imaging provided by CANDELS (see Fig. 1). We intend to design four VIMOS masks per pointing, observing each mask for 20 hours of on-source integration. The instrument set-up for all observations will be identical: MR grism+GG475 order sorting filter, 1″ slit widths and a minimum slit length of 6″. We intend to employ individual integrations of 1200s, using a three-point off-set pattern along the slit (i.e. +0.75″, 0.0″, −0.75″). Using this instrumental set-up, repeated simulations with VMMPS indicates that we can typically allocate 180 slits per mask (45 per VIMOS quadrant). The pointings (Fig. 1) are placed to ensure that each VIMOS quadrant always intersects the CANDELS *HST* imaging which, due to the high surface density of faint $z \geq 3$ galaxies, allows us to maximize the number of slits in the central *HST* area. To ensure that our slits can be placed with maximum accuracy we will require short $R-$band pre-imaging observations of all eight pointings to properly account for VIMOS focal plane distortions. Moreover, due to the extended red coverage provided by the MR grism, we will also require additional spectrophotometric standard observations designed to provide good signal-to-noise out to $\lambda \simeq 1\mu$m.

To accommodate the range of exposure times needed to meet our science goals we will pursue a nested slit allocation strategy, whereby objects requiring 80 hours of integration are retained on all four masks, those requiring 40 hours are included on two masks and those only requiring 20 hours integration appear on a single mask. The following table illustrates our slit-allocation for a single VIMOS quadrant over a series of four masks. The columns indicate the number of objects that would be observed for 80 (N80), 40 (N40) and 20 hours (N20):

Mask	N80	N40	N20	Total
1	20	20	5	
2	20	20	5	
3	20	20	5	
4	20	20	5	
no. of spectra	20	40	20	80

Using this nested strategy, each quadrant provides 20 objects which receive 80 hours of integration (retained on all 4 masks), 40 objects which receive 40 hours of integration (two sub-samples of 20) and 20 objects which receive 20 hours of integration (four sub-samples of 5).

Over our 8 VIMOS pointings we will therefore obtain a **total of 2560 spectra**, comprised of 640 (N80), 1280 (N40) and 640 (N20) targets. Uniquely, 75% of our targets will receive 40+ hours, with 25% receiving 80 hours.

Feasibility and scheduling
Here we evaluate the feasibility of scheduling VANDELS within a nominal ~ 3 year survey period in visitor mode. We explicitly assume that we require dark/grey time, photometric/clear sky conditions and $\leq 1''$ FWHM seeing. In addition to accounting for the frequency of poor seeing and non-photometric/clear conditions, we also assume that we will not observe either of our two fields when they are above an airmass of $sec z > 1.4$ and that visitor mode is impractical unless we can observe for 4+ hours per night. Moreover, in liaison with the ESO survey team, we have accounted for telescope downtime due to weather (10% in Oct, 5% in Sep, Nov & Dec) and technical faults (2.5%; Hammersley et al. 2013). Finally, we have used the P2PP3 software to calculate a conservative overhead estimate of 25% (including calibration).

Under these restrictions, we calculate that there are $\simeq$ 277 hours of actual *on-source science* observations available for VANDELS between 1st September and 21st December each year, with the majority $\simeq$ 166 hours available during Oct-Nov. These figures should be compared against our requirement for 640 hours of on-source science observations (8x80 hours). This leads to two potential scenarios for completing VANDELS within a $\simeq$ 3 year survey period. In both cases, the total number of visitor nights refers to the actual number of nights we would require a visiting astronomer at the telescope.

Scenario 1: VANDELS is allocated a flat distribution of the dark/grey time during Sep-Dec. In this scenario the survey could be completed in a 3-year period using a total of $\simeq$ **195 visitor nights** (including half nights). This requires VANDELS to be allocated $\simeq$ 77% of the available dark/grey time on UT3 over periods P94-P99.

Scenario 2: VANDELS is allocated $\simeq$100% of the dark/grey time available in Oct-Nov, when the UDS+CDFS fields are at their most observable from Paranal. In this scenario VANDELS could be completed over a $\simeq$ 3-year period (P94-P100) using a total of $\simeq$ **180 visitor nights**.

5 Instrumental setup & pre-imaging needs

The complete VANDELS survey consists of 8 overlapping VIMOS pointings (4 in UDS and 4 in CDFS), with 4 different masks being observed at each pointing. In total we therefore require 32 VIMOS masks and pre-imaging at 8 different pointings. Our pre-imaging requirements are independent of the survey schedule so, as an illustration, in the table we have assumed an observing schedule where all VANDELS observations are confined to Oct+Nov. In this scenario we would begin observing the VANDELS fields at the start of each even period (1st Oct), which means that the pre-imaging would have to be obtained in service mode at the end of the previous odd period (see Table in Section 6).

Periods (94-104)	grism/filter	total no. of masks	no. pre-images required	pre-imaging time (n)
P94	MR/GG475	8	2	0.2n
P96	MR/GG475	8	2	0.2n
P98	MR/GG475	8	2	0.2n
P100	MR/GG475	8	2	0.2n

6 Estimated observing time:

In the table below we have calculated our likely observing time requirement. In the first scenario we have assumed VANDELS is allocated $\simeq$ 77% of the dark/grey time on UT3 during Sep-Dec for 3 years (P94-P99). In the second scenario we have assumed VANDELS is allocated 100% of the dark/grey time on UT3 during Oct-Nov during periods P94, P96, P98 & P100. In both cases the nights listed in column 2 are the actual number of nights we expect to need an observer at the telescope in visitor mode (including half/part nights), and the conversion between nights and hours assumes 1 night = 8 hours. We have inserted an extra column to separate traditional observing overheads (estimated to be $\simeq$ 25%) from unavoidable time losses in visitor mode which would not be charged to service mode observations (i.e. fields visible for part nights, bad weather, poor seeing, cloud and technical downtime). Scenario one is less efficient than scenario two simply because of the greater number of half/part nights in Sep and Dec.

Scenario 1: Sep-Dec observing

Periods (94-104)	Total Time inc. all overheads (n)	Pre-imaging time (n)	Science exp. time (n)	Overheads time(n)	Vistor mode loss time (n)	Mean RA –	Moon –
P93	0.2n	0.1n	0.0n	0.1n	0.0n	03h	grey
P94	51n	0.0n	21.0n	5.3n	24.7n	03h	grey
P95	14.2n	0.1n	5.7n	1.5n	6.9n	03h	grey
P96	51n	0.0n	21.0n	5.3n	24.7n	03h	grey
P97	14.2n	0.1n	5.7n	1.5n	6.9n	03h	grey
P98	51n	0.0n	21.0n	5.3n	24.7n	03h	grey
P99	14n	0.0n	5.7n	1.4n	6.9n	03h	grey

Scenario 2: Oct-Nov observing

Periods (94-104)	Total Time inc. all overheads (n)	Pre-imaging time (n)	Science exp. time (n)	Overheads time(n)	Vistor mode loss time (n)	Mean RA –	Moon –
P93	0.2n	0.1n	0.0n	0.1n	0.0n	03h	grey
P94	45n	0.0n	20.0n	5.0n	20.0n	03h	grey
P95	0.2n	0.1n	0.0n	0.1n	0.0n	03h	grey
P96	45n	0.0n	20.0n	5.0n	20.0n	03h	grey
P97	0.2n	0.1n	0.0n	0.1n	0.0n	03h	grey
P98	45n	0.0n	20.0n	5.0n	20.0n	03h	grey
P99	0.2n	0.1n	0.0n	0.1n	0.0n	03h	grey
P100	45n	0.0n	20.0n	5.0n	20.0n	03h	grey

6.1 Time justification: (1 page)

To allow detailed (rest-frame UV) absorption-line studies of faint star-forming galaxies at $2.5 < z < 5.5$ we require robust *continuum* detections of individual objects at $I_{AB} \leq 24.5$ and in stacks of fainter objects. Specifically, as shown in Sommariva et al. (2012), we will require a continuum $S/N \simeq 10-20$ per pixel to reliably measure the most robust stellar metallicity indicators at $\lambda_{rest} = 1370 - 1501$Å. Moreover, with reference to Cimatti et al. (2008), for our passive galaxy sample at $1.5 < z < 2.5$ we require a high enough S/N to robustly detect the prominent UV breaks at $\lambda_{rest} = 2640$Å/2900Å and the other metal absorption lines (e.g. MgI λ2852, MgII λ2800, FeI and FeII) which together comprise the Mg_{UV} feature (Dunlop et al. 1996; Daddi et al. 2005). Crucially, it is the presence of the Mg_{UV} feature which confirms the lack of significant star formation over the last $\simeq 0.5$ Gyr. Finally, for the faint LBG component of our sample we require to reach $S/N = 3$ in the continuum or detect emission-line fluxes of $\simeq 1 - 2 \times 10^{-18}$ erg s^{-1} cm^{-2} at $S/N > 5$.

The instrument set-up for all our VIMOS MOS observations is identical: MR grism with the GG475 order sorting filter, providing wavelength coverage over the wavelength range 480-1000nm at a mean spectral resolution of $R \simeq 580$ (1″wide slits). Based on this observational set-up, we have used the on-line VIMOS ETC to calculate the continuum and line-flux sensitivity of our proposed observations. All calculations are based on a flat spectrum point-source input, and reflect the *average* observing conditions we expect in visitor mode (see Section 4):

- Sky conditions of 7 days from new moon (i.e. grey)
- Airmass=1.15
- Seeing 0.9″ FWHM

In the following table we report the signal-to-noise ratio we expect in the final extracted 1D spectra. Column one lists the input continuum apparent magnitude, while columns 2-4 list the final signal-to-noise ratio per pixel expected for 80, 40 and 20 hours of on-source integration. It should be noted that these numbers include a 2x2 binning of the final spectra in the spectral direction, which can be achieved without degrading the spectral resolution because of the oversampling of a projected 1″wide slit by the VIMOS detectors.

Continuum	S/N (80)	S/N (40)	S/N (20)
$I_{AB} = 25.0$	**10.8**	7.6	5.4
$I_{AB} = 24.5$	**17.1**	12.1	8.5
$I_{AB} = 24.0$	–	**19.1**	13.5
$I_{AB} = 23.5$	–	–	**21.2**

It can be seen that the desired *constant* SNR of $\simeq 20$ per pixel can be achieved in 20, 40 and 80 hours of integration for objects with $I_{AB} = 23.5, 24.0\,\&\,24.5$ respectively. Objects with $I_{AB} \simeq 25$ will need to be stacked in small sub-samples to reach the same SNR.

In addition to absorption-line studies, a key element of VANDELS is the ability to detect faint Lyα emission at $z \geq 3$. The following table reports the expected Lyα line-flux limits (/erg s^{-1} cm^{-2}) for the full integration time of 80 hours (both 10σ and 5σ limits). In the table, the relationship between line-flux limit and redshift reflects the varying VIMOS throughput and sky background as a function of wavelength (column 2). The line-flux limits assume a line with FWHM=10Å and are integrated over the line profile.

Redshift	Lyα Wavelength	10σ	5σ
z=3	4864Å	4.4E-18	2.2E-18
z=4	6080Å	2.0E-18	1.0E-18
z=5	7296Å	2.3E-18	1.2E-18
z=6	8512Å	4.8E-18	2.4E-18
z=7	9728Å	9.5E-18	4.8E-18

It should be noted that these line-flux limits correspond to spectral regions between strong sky lines. Limits within bad sky-line regions are expected to be a factor of two higher.

7 Data management plan: (3 pages)

Survey monitoring, managing, and data reduction will be centralised within the data reduction and management centre at INAF−IASF Milano. The full management of these operations will be achieved by adapting the *Easylife* system (Garilli et al. 2012, PASP, 124, 1232) to VANDELS needs.

A dedicated Survey Web Site will allow the whole community to follow the survey progress in terms of observations, data reduction and data products availability. The web site will also allow team members to retrieve raw or reduced data, and to upload further data products into the survey database. All survey related data, from the input photometric catalogues, to all spectroscopic data, will be made available through a dedicated database, with an available Web interface accessed from the Survey Web Site, along the lines of the ongoing VIPERS survey (see http://vipers.inaf.it).

The *Easylife* administrative layer, accessible via the Survey Web Site, will allow the survey status to be both monitored and managed, handling all survey management steps from the pre-imaging phase to the distribution of data reduction and redshift measurement tasks. A data presentation layer will be used to generate the live public Web pages of the VANDELS survey. Data ingestion, organisation and reduction tasks will be carried out via dedicated tools running on a dedicated machine. Finally, the results database (based on MySQL) will be accessed through a dedicated GUI. Access to these different layers is controlled via an administrative SQL-based database, which will keep track of the global status of the survey, the composition of the survey team, and of the data access privileges for the public and for the survey team. It will be structured to have different access levels: public and team restricted. Through the public level, the whole community will have access to the survey description and goals, and can inspect how the survey is advancing in terms of observations, reduction and data availability. The public level will also allow the community to connect to the database system, which will provide the reduced spectra together with catalogues of scientific information extracted from them. Through the team restricted level, each member of the team will be able to retrieve data products prior to public distribution for quality checks and analysis and upload their corresponding scientific measurements.

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7.1 Team members:

R. McLure	Co-PI	University of Edinburgh	UK
L. Pentericci	Co-PI	INAF, Rome	Italy
J. Dunlop	Management Group	University of Edinburgh	UK
A. Fontana	Management Group	INAF, Rome	Italy
K. Nandra	Management Group	MPE	Germany
D. Elbaz	Management Group	CEA	France
A. Cimatti	Management Group	University of Bologna	Italy
S. Finkelstein	Target selection	University of Texas	USA
A. Grazian	Target selection	INAF, Rome	Italy
R. Bowler	Target selection	University of Edinburgh	UK
M. Cirasuolo	Target selection	University of Edinburgh	UK
A. Iovino	Mask production	INAF, Brera	Italy
M. Nonino	Mask production	INAF, Trieste	Italy
O. Cucciati	Mask production	INAF, Bologna	Italy
A. Bongiorno	Mask production	INAF, Rome	Italy
E. Curtis-Lake	Observation supervision	University of Edinburgh	UK
M. Castellano	Observation supervision	INAF, Rome	Italy
J. Mendez-Abreu	Observation supervision	University of St. Andrews	UK
B. Garilli	Data reduction pipeline	IASF-Milano	Italy
M. Scodeggio	Data reduction pipeline	IASF-Milano	Italy
P. Franzetti	Survey handling web site	IASF-Milano	Italy
E. Vanzella	Data quality + redshift determination	INAF, Bologna	Italy
E. Marmol-Queralto	Data quality + redshift determination	University of Edinburgh	UK
F. Cullen	Data quality + redshift determination	University of Edinburgh	UK
I. Balestra	Data quality + redshift determination	INAF, Trieste	Italy
L. Guaita	Data quality + redshift determination	University of Stockholm	Sweden
P. Popesso	Data quality + redshift determination	MPE	Germany
K. Caputi	Data quality + redshift determination	Groningen	Netherlands
W. Hartley	Data quality + redshift determination	ETH	Switzerland
V. Sommariva	Enhanced data products	University of Bologna	Italy
G. Cresci	Enhanced data products	INAF, Arcetri	Italy
A. Mortlock	Enhanced data products	University of Edinburgh	UK
N. Bourne	Enhanced data products	University of Edinburgh	UK
R. Amorin	Enhanced data products	INAF, Rome	Italy
S. Charlot	Enhanced data products	IAP	France
M. Mignoli	Enhanced data products	INAF, Bologna	Italy

7.2 Detailed responsibilities of the team: (1 page)

The overall responsibility for both the successful execution of the survey and the distribution of the final data products to the community will be shared by McLure and Pentericci as VANDELS Co-PIs. Importantly, both McLure and Pentericci can guarantee $\geq 80\%$ research time over the full duration of the proposed VANDELS programme. The Co-PIs will be supported by the members of the VANDELS management group (Dunlop, Fontana, Nandra, Elbaz & Cimatti) who have been chosen on the basis of their multi-wavelength expertise and their previous experience in managing large ESO projects (e.g. GOODS, Ultra-VISTA, K20, GMASS & UDSz).

In order to ensure that the various tasks needed for the successful planning, execution, reduction and distribution of the VANDELS survey and dataset are carried out efficiently, we have constructed small teams to focus on specific tasks:

1. Target selection team
Members: S. Finkelstein • A. Grazian • R. Bowler • M. Cirasuolo
The members of this team will be responsible for producing robust target catalogues from the available multi-wavelength imaging in the UDS and CDFS fields to be used in VIMOS slit allocation. Together they will produce consolidated catalogues of potential targets based on independent measurements of the photometric redshift probability functions.

2. VIMOS mask production team
Members: A. Iovino • M. Nonino • O. Cucciati • A. Bongiorno
The members of this team will be responsible for the necessary VANDELS pre-imaging and using VMMPS to optimally allocate slits based on the information supplied by the target selection team.

3. Observing supervision team
Members: E. Curtis-Lake • M. Castellano • J. Mendez-Abreu
The members of this team will be responsible for constructing the OBs for VANDELS and the organisation and supervision of the visitor observing programme.

4. Data Reduction team
Members: B. Garilli • M. Scodeggio • P. Franzetti
The members of this team will be responsible for the full data-reduction process, taking the raw data and producing fully wavelength-calibrated and flux-calibrated 1D and 2D spectra using the VIPGI and Easylife software developed in IASF-Milano.

5. Data quality and redshift measurement team
Members: E. Vanzella • E. Marmol-Queralto • F. Cullen • I. Balestra • L. Guaita • P. Popesso • K. Caputi • W. Hartley
The members of this team will be responsible for monitoring the quality of the spectra as they are obtained. Subsequently, this team will be responsible for redshift determination using a combination of automated algorithms and detailed visual inspection.

6. Enhanced data products
Members: V. Sommariva • G. Cresci • A. Mortlock • N. Bourne • R. Amorin • S. Charlot • M. Mignoli
The members of this team will be responsible for the production and dissemination of value-added data products, in addition to the basic 1D+2D spectra and associated redshifts. These data products will include line flux and EW measurements, together with basic stellar-population parameters derived from SED fitting.

7.3 Data reduction plan: (1 page)

VANDELS data reduction will be performed with a fully-automated pipeline, starting from the raw data and flowing down to the wavelength- and flux-calibrated spectra. The pipeline is an updated version of the algorithms and dataflow from the original VIPGI system, fully described in Scodeggio et al. 2005, PASP, 117, 1284. The original VIPGI system has been used to reduce all the spectra from the VVDS (Le Fèvre et al. 2005, A&A, 439, 845 and Garilli et al. 2008, A&A, 486, 683), zCosmos (Lilly et al. 2007, ApJS, 172, 70), and VUDS surveys (Le Fèvre et al. 2014), while the updated system, called Easylife, has been used to reduce all the spectra from the ongoing VIPERS survey (Garilli 2014, A&A, 486, 683).

As a first step, in each raw frame the 2D dispersed spectrum for each slit is located and traced. Each spectrum is collapsed along the dispersion direction, and the object location computed. An inverse dispersion solution is computed for each slit making use of an arc calibration lamp, and further checked on the wavelength of prominent sky lines (if needed, a rigid offset is applied to the dispersion solution in order to bring the sky lines to their correct wavelengths). The algorithm used leads to a wavelength calibration uncertainty below 1/5 of a pixel for 97% of the spectra (see Garilli et al. 2014). Finally, a first sky subtraction is performed row by row, avoiding the region identified as the object.

The sky-subtracted 2D spectra are then resampled to a linear wavelength scale making use of the inverse dispersion solution, and packed together in a convenient data format. The different scientific exposures of each slit are registered and co-added, and a second background subtraction is performed repeating the procedure carried out before. Finally, 1D spectra are extracted applying the Horne extraction algorithm, and spectra are corrected for the instrument sensitivity function, as derived from spectrophotometric standard star observations.

To obtain an absolute flux calibration, correcting for slit losses and varying observing conditions, we will normalize observed spectral fluxes to the available photometry, convolving each spectrum with a photometric filter response function (normally the i filter) and deriving a normalisation factor between the spectrum and the photometric magnitude. Given a 2D spectrum, sky-subtraction residuals are computed and combined with the poissonian statistical error to build an error spectrum.

Formally the above recipes, in their original form, always end successfully, but this does not automatically mean that the results meet the degree of accuracy required to achieve the specific scientific goals. Consequently, in the transition from VIPGI to Easylife, we have added additional quality checks on spectra location, wavelength calibration, target detection rate, and general data quality, based on the mean PSF as measured from the reduced image, the measured sky brightness, and the object centring in the slit (see Garilli et al. 2012, PASP, 124, 1232, for more details). These additional checks are designed to ensure that the final reduction results are scientifically exploitable.

7.4 Expected data products: (2 pages)

In the following description we have split the VANDELS data products into basic and enhanced categories. The basic data products are those which could be regarded as the minimum required for a spectroscopic survey of this nature. The enhanced data products are those which the team is committed to delivering as an additional service to the community, and are designed to maximize the scientific productivity and legacy value of VANDELS. All data products listed here will be made available to the community in VO-compliant formats.

Basic Data Products

- **Final extracted one-dimensional (1D) spectra**

The final wavelength-calibrated and flux-calibrated 1D spectra for all objects targeted by VANDELS. In addition to flux calibration using spectrophotometric standards, the final flux calibration will be normalized to the multi-wavelength photometry available for each target.

- **Noise and sky spectra (1D)**

In addition to the final extracted spectra, 1D noise and sky spectra will be made available for each target.

- **Final stacked two-dimensional (2D) spectra**

The final wavelength-calibrated 2D spectrum for each target will be made available. The 2D spectra will be essential for confirming the reality of faint emission features and identifying potential emission-line velocity gradients.

- **Final spectroscopic redshift catalogue**

A final catalogue will be made available which contains the essential information for each VANDELS target: ID, RA, Dec, I-magnitude, H-magnitude, spectroscopic redshift and redshift quality flag. The redshift quality flag will be defined on the same system previously employed by the VVDS and zCOSMOS surveys.

Enhanced Data Products

- **VANDELS selection function**

We intend to make available all of the relevant information necessary to compute the VANDELS selection function. This information will allow the community to accurately calculate the completeness of the survey for their own scientific purposes.

- **Final combined spectroscopic redshift+photometric catalogue**

In addition to the final spectroscopic redshift information, this catalogue will feature aperture-matched optical+nearIR photometry for each target. Based on this information the community should be able to directly proceed to SED fitting using their preferred choice of software and templates.

- **Basic stellar population parameters**

Based on the final redshift+photometric catalogue we will release our own catalogue of basic stellar population parameters (e.g. stellar mass, age & reddening) derived by fitting standard templates (e.g. Bruzual & Charlot 2003 + Chabrier IMF) using publicly available SED-fitting codes (e.g. Le Phare).

- **Final catalogue of spectroscopic measurements**

In addition to the final spectroscopic redshift determinations, a catalogue will be made available to the community which contains line flux and equivalent width measurements (together with error estimates and data quality flags) for robustly detected emission/absorption features in each VANDELS spectrum.

7.5 General schedule of the project: (1 page)

Here we discuss the schedule of the observations, the data reduction process and the release of the basic and enhanced data products.

Observations

In Section 6 we presented two alternative scenarios for the scheduling of VANDELS in visitor mode, both of which assume that spectroscopic observations will commence on 1st Oct 2014 (start of P94).

The first scenario assumed that VANDELS was allocated $\simeq 77\%$ of the available dark/grey time on UT3 in Sep-Dec each year. According to this schedule we would require pre-imaging observations for the first VANDELS pointings in mid-late Aug 2014 (P93), with the first spectroscopic observations starting on 1st Oct 2014. The last spectroscopic observations would be taken in Sep 2017 (P99).

The second scenario assumed that VANDELS was allocated $\simeq 100\%$ of the available dark/grey on UT3 in Oct-Nov each year. As before, spectroscopic observations would begin on 1st Oct 2014 (start of P94), with a requirement for some pre-imaging at the end of P93. However, in the case, the final spectroscopic observations would be obtained in Nov 2017 (P100).

Data reduction and basic data products

Due to the RAs of our two target fields there will be a natural structure to the VANDELS programme, with spectroscopic observations finishing at the end of a given calendar year, before beginning again $\simeq 9$ months later the following Sep/Oct. Consequently, we propose a data release schedule whereby the basic data products (1D+2D reduced spectra and spectroscopic redshift catalogues) are made available to the community at the end of September each year, 9 months after the previous season's observations have been completed.

Based on their extensive experience of previous VIMOS surveys, the data reduction team in Milan are confident they can reduce the spectra for a given VANDELS observing season $\simeq 1$ month after the end of observations. Consequently, to meet our proposed data release schedule, the VANDELS team would face the manageable task of determining robust spectroscopic redshifts and quality flags for $\simeq 750$ spectra over an eight-month period.

Enhanced data products

The enhanced data products consist of catalogues providing the final spectroscopic redshift information, line flux/EW measurements, full aperture-matched optical-nearIR photometry and basic stellar population parameters derived from SED fitting. The VANDELS team would commit to releasing this information to the community one year after the final spectroscopic observations have been completed.

Summary

- Initial pre-imaging observations mid-late August 2014.
- Start of spectroscopic observations 1st October 2014.
- Annual release of basic data products, starting September 2015.
- End of spectroscopic observations Sep/Nov 2017 depending on schedule.
- Final release of enhanced data products, one year after final observations are completed.

8 Envisaged follow-up: (1 page)

The fields targeted by VANDELS are already two of the most complete, multi-wavelength survey fields in the sky. As a consequence, these fields already feature unique, largely publicly available, multi-wavelength datasets spanning the X-ray, UV, optical, nearIR, midIR, sub-mm and radio regimes. However, despite this, it is clear that the unique VANDELS spectroscopic dataset will immediately motivate a variety of further follow-up observations:

- **WFC3/IR imaging:** one of the key motivations of VANDELS is the prospect of obtaining ultra-deep spectroscopy for $z \geq 2$ galaxies for which deep optical-nearIR *HST* imaging is already available. However, it is anticipated that $\simeq 30\%$ of our spectroscopic slits will target galaxies lying outside the main CANDELS imaging footprint in UDS and CDFS. Consequently, in order to maximize the potential for morphological studies based on the VANDELS dataset, we would envisage applying for an additional $\simeq 100$ orbits of *HST* WFC3/IR imaging in the H_{160} filter to fully cover the VANDELS footprint in UDS and CDFS.

- **IFU spectroscopy:** the large number of ultra-deep optical spectra provided by VANDELS will clearly act as a major resource for follow-up IFU spectroscopy. The two obvious ESO instruments of choice for follow-up IFU observations are the KMOS near-IR spectrograph and the MUSE optical spectrograph (currently being commissioned). For KMOS observations, the VANDELS spectra can be used to identify spectroscopically confirmed galaxies at $z \geq 2$ which place luminous emission lines (i.e. Hα, O[III], O[II]) within suitable near-IR observing windows. Opclauraerating over a very similar wavelength range to the VANDELS spectra, obvious targets for IFU follow-up with MUSE (i.e. those with strong emission-line velocity gradients) can be selected from the VANDELS 2D spectra.

- **ALMA:** the southern position of both UDS and CDFS make them ideal survey fields for sub-mm and mm follow-up observations with ALMA. One of the key scientific questions that VANDELS will help to address is the evolution of star-formation and metallicity in galaxies at $z \geq 2$. However, in order to derive a complete picture it will be necessary to obtain dust mass and star-formation rate measurements at long wavelength, which can be now be provided by short, targeted, continuum observations with ALMA. Alternatively, a contiguous 1.2mm ALMA continuum mosaic of the HUDF has already been approved (PI Dunlop), and when ALMA is capable of making larger-area mosaics, the central CANDELS imaging areas of UDS+CDFS covered by VANDELS would be an obvious choice of location.

- **JWST:** if VANDELS is approved, it is likely that the VIMOS spectroscopic observations will be completed in 2017/18, shortly before the currently-scheduled launch date for JWST. High-redshift galaxies with spectroscopic redshifts provided by VANDELS would provide an excellent source of candidates for follow-up imaging and spectroscopy with JWST. As an example, high signal-to-noise (S/N≥ 10) spectra of the Balmer break region of typical $z \simeq 5$ galaxies targeted by VANDELS could be obtained with NIRSPEC in 1hr integrations. Moreover, longer-wavelength $\lambda \geq 6\mu$m imaging with MIRI could provide much more accurate measurements of the M/L ratio of high-redshift stellar populations than currently available from *Spitzer* IRAC imaging.

- **E-ELT:** given their location in two of the very best multi-wavelength survey fields observable from Paranal, $z \geq 3$ galaxies with high signal-to-noise ratio VANDELS spectra would be prime targets for initial high-redshift galaxy evolution studies with E-ELT. The two first-light instruments for E-ELT are an imager and IFU, both AO-fed and both operating in the near-IR. The photon gathering power and spatial resolution provided by E-ELT will facilitate studies of the rest-frame optical structure and dynamics of $z \geq 3$ galaxies well beyond the reach of current ground-based instrumentation.

9 Other remarks, if any: (1 page)

9.1 Strategic importance

We note that this proposal can be regarded as the culmination of a highly successful tradition of targeting deep ESO spectroscopy on the extragalactic survey fields which have received the largest investments of deep, high-resolution, HST imaging. This approach, so well demonstrated by GOODS, and then maintained via zCOSMOS, has proved highly successful in enabling the ESO community to maximise its scientific exploitation of ESA's investment in NASA's great observatories. It would be a mistake to regard this as simply the VLT following a strategy established by HST. On the contrary, many leading ESO astronomers, including key Co-Is on this proposal, have been instrumental in the development of the HST programmes and understand the enormous added value offered by VLT spectroscopy. This is especially true of CANDELS, where much of the imaging strategy has been driven by the key ESO Co-Is on this VLT proposal.

9.2 Visitor mode versus service mode

Starting with the initial call for letters of intent (LOI), it has been made clear that any potential ESO public spectroscopy programme will be observed in visitor mode. As a consequence, we have set out in detail the likely visitor mode requirements to complete VANDELS within a nominal $\simeq 3$ year survey period. However, it is clear from the calculations presented in Sections 4 & 6 that the decision to observe a survey of this nature in visitor mode is highly inefficient. This is simply unavoidable given that we have been instructed to focus on two fields at very similar RAs that, even at peak visibility, are not observable for full nights. In addition, in visitor mode, it is necessary to account for time losses due to bad weather, poor seeing, non photometric/clear sky conditions and technical downtime. Although we would be happy to execute the survey in visitor mode, it is clear that service mode would be more efficient in terms of both telescope and observer time.

However, if VANDELS is approved in visitor mode we are confident that we have sufficient numbers of potential observers within the VANDELS team to successfully staff the survey. The VANDELS survey consists of 79 Co-Is, of which 66 are from ESO member institutes. Realistically this means that we have a pool of ≥ 40 observers with which to staff the survey.

9.3 The COSMOS field

In the original VANDELS LOI, we proposed targeting the CANDELS fields in UDS, CDFS *and* COSMOS. Given that COSMOS features the same level of deep, multi-wavelength, HST and ground-based data as UDS+CDFS, it was an obvious choice as the third VANDELS field. However, following instructions from the PSS panel that the COSMOS field is reserved for a scientifically distinct survey, we have removed it from the survey plan submitted here.

The two Co-PIs of VANDELS have been in contact with A. van der Wel, the PI of the PSS proposal which was allocated the COSMOS field (but proposed COSMOS+CDFS at the LOI stage). Together we have agreed that should both surveys be approved, it would be beneficial to share half nights in Dec/Jan when both COSMOS and CDFS are observable. However, if only one survey can be approved it would seem sensible for ESO to lift the current RA restrictions to allow our team to observe COSMOS (or the other PSS team to observe CDFS). Observations in the COSMOS field would proceed in an identical fashion to those proposed here for UDS+CDFS, and would require a $< 50\%$ increase in time allocation due to increased observing efficiency.

9.4 Back-up programme

In visitor mode it is inevitable that perfectly useable telescope time will be lost because conditions do not meet our adopted seeing limit of $\leq 1''$ FWHM. In this situation we would observe masks targeting bright $i_{\rm AB} \leq 23.5$ galaxies as a back-up programme. Observations of this nature would clearly have important legacy value in the UDS, where spectroscopic coverage is comparatively poor. However, even in CDFS there are ≥ 1000 galaxies with $i_{\rm AB} \leq 23.5$ without spectroscopic redshifts.