1 ELVIS: Emission-Line galaxies with VISTA Survey

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1.1 Abstract:

Emission-line galaxies are essential for determining the star formation history of the Universe. Evolution of their abundance and properties over the history of the transparent Universe give crucial insight into the formation and evolution of galaxies. We here propose a Public narrow-band Survey for emission-line galaxies with VISTA, utilising the 1.18 μm narrow-band filter, provided by the DARK Cosmology Centre, Denmark. This survey will allow the discovery and analysis of a very large sample of Hα-emitters ($z = 0.8$), medium redshift [OIII]-, Hβ- and [OII]-emitters ($z = 1.4$, 1.4 and 2.2 respectively) and a significant sample of Lyα-emitters at very high redshift ($z = 8.8$). Hence, this survey will probe the density of star formation from the end of the dark ages to $z \approx 1$, when the star formation density started to decline. Whereas broadband surveys typically find the brightest and most massive systems, emission-line surveys probe more numerous, fainter, and less massive galaxies, making surveys for emission-line galaxies complementary to broad band surveys.

2 Description of the survey:

2.1 Scientific rationale:

Introduction

A promising way of detecting purely star-forming galaxies throughout the Universe is via surveys for emission-line galaxies. In our vicinity, we look for Hα emission, in the intermediate range we can target Hβ, [OIII] and [OII] and at high redshift Lyα. All of these emission lines are intimately linked to the star formation rate of the emitting galaxy. Studies of faint Hα- and Lyα-emitters show that almost all of them are powered by star formation, only a few contain AGN. We here propose a Public Survey that will give access to these lines, at redshifts ranging between $z \approx 0.8 - 8.8$ in two large fields of view with existing very deep multi-band data. This will provide excellent opportunities to study the star formation history of the Universe, as well as the star formation as a function of environment at different redshifts.

Clues to the evolution of our Universe from Emission-Line Galaxies.

Very high redshift

The success of narrow-band searches, focusing on Lyα, was predicted by Partridge & Peebles (1967) nearly 40 years ago. But it is only recently, with the advent of 8 m class telescopes, that larger samples of objects have been reported (e.g., Steidel et al., 2000; the LALA survey by Malhotra & Rhoads, 2002; the Building the Bridge survey by Fynbo et al., 2003; several Subaru surveys, e.g. Hayashino et al., 2004; and the surveys in the fields of radio galaxies by Venemans et al., 2005 and references therein). The selection method combines narrow-band (NB) imaging with observations in one or two broad-bands. Objects that are bright in the narrow-band image and comparatively faint or non-detected in the broad-band images are selected. The result is a list of candidate emission-line galaxies within a narrow redshift range, typically $\Delta z \approx 0.05$. Spectroscopic follow-up is necessary to exclude interlopers and spurious detections and to measure the precise redshifts. The confirmation rates for Lyα in the $z \sim 3$ surveys part of us have already carried out typically lie in the range 75 – 90% (Fynbo et al., 2001; Fynbo et al., 2003).

Several samples of Lyα-emitters between $z = 3 - 5.5$ have been reported to date (e.g., Steidel et al., 2000; Malhotra & Rhoads, 2002; Hayashino et al., 2004). At redshifts below $z \sim 2$, Lyα cannot be observed from the ground, hence it is not a useful tool at low redshifts. At redshifts larger than six, Lyα moves into the NIR and atmospheric OH-lines start to interfere. Therefore narrow-band imaging for Lyα at such redshifts is only feasible in certain redshift "windows" that are clean of OH-lines, such as $z = 6.58$, 6.89, 7.73, 8.22, 8.78 etc. To date, fifteen Lyα-emitters with redshifts above six have been published (Hu et al., 2002; Kodaira et al., 2003; Rhoads et al., 2004; Kurk et al., 2004; Stern et al., 2005 and Taniguchi et al., 2005) but none above redshift seven. Some attempts have been made to observe Lyα-emitters at redshift $z \sim 9$ (Willis & Courbin, 2005) but none are detected to date, most likely due to the small volumes probed.

Finding and studying a sample of Lyα-emitting galaxies at very high redshift ($z = 8.8$, proposed here) will give insights into key elements in cosmic history such as the epoch of reionisation, the evolution of the cosmic star formation rate density, and the evolution of galaxy clustering.

Reionisation Analysis of the Lyα emission line and comparisons between luminosity functions of Lyα-emitters at different redshifts will tell us when reionisation happened, or at a minimum place tighter constraints on the time of reionisation.

As we observe sources at high redshifts, we approach the time when the Universe was filled with fully neutral hydrogen. A not yet answered, highly interesting question is at what redshift the reionisation happened. It is widely believed that reionisation happened at redshifts $z \leq 10$, and recent results show that reionisation was almost complete at redshift $z \approx 6$. Several authors have argued that Lyα-emitting high-redshift galaxies may provide a tool to constrain the redshift of reionisation better (e.g. Miralda-Escudé, 1998; Miralda-Escudé & Rees, 1998; Haiman, 2002; Gnedin & Prada, 2004; Haiman & Cen, 2005). These authors show that absorption in the Gunn-Peterson trough may extend to the red side of the Lyα emission line and cause damping wings. Haiman (2002) and Haiman & Cen (2005) suggest that this damping will change the shape of the luminosity function of Lyα-emitters before and after reionisation. A comparison between luminosity functions at redshifts $z = 5.7$ and $z = 6.5$ was performed by Malhotra & Rhoads (2004) to test this prediction. They find no sign of reionisation and conclude that reionisation must be almost complete at $z = 6.5$.

With the observations proposed here, a sample of Lyα-emitters at redshifts $z = 8.72 - 8.82$ will be found. As outlined below we expect to detect a few times ten such galaxies. It will be possible to put some constraints on the luminosity function and hence also to infer information about the ionization state of the Universe at this redshift.

Galaxy formation at $z > 8$ How and when galaxies formed, as well as how they evolve are outstanding questions in cosmology. The direct observation of galaxies during their birth and first evolution at very high redshift will give new clues to answering these questions.

When did the first galaxies form? What amount of stars were formed and when? How did large scale structures form? These and more questions will be answered as larger samples of very high redshift sources are discovered and investigated. A few examples of observables are:

- **Number density of Lyα-emitters.** How many Lyα-emitters existed at a specific time? Taniguchi et al. (2005) study the number densities of several Lyα-surveys between $z \approx 3.4$ to 6.6 and find no evolution with comoving number density.
- **SFR and $\rho_{\rm SFR}$.** Observations at lower redshifts ($z \approx 3 - 4.5$) indicate that Lyα-emitters are moderately star-forming, dust free galaxies with little or no AGN content (e.g., Gawiser et al., 2006). Was the SFR different in this class of objects at very high redshift? These galaxies may be dominated by stars formed out of pristine gas with no, or extremely few metals. The inital mass function was very likely different for such stars, which would significantly alter the appearance of these galaxies (e.g., Schaerer, 2003).

Emission lines at intermediate or low redshift

Emission line galaxies at $z = 0.8$, 1.4 and 2.2 The narrow-band filter is also sensitive to lower redshift emission line galaxies with much higher surface density, namely Hα at $z = 0.80$, [OIII] at $z = 1.36$, Hβ at $z = 1.43$, and [OII] at $z = 2.17$. These redshifts span most of the time when the majority of the cosmic star formation occurred.

At intermediate redshifts, $z = 1.4$ and $z = 2.2$, Hβ, [OIII], and [OII] emitters can be detected. Hβ is a tracer of star formation, whereas [OIII] and [OII] are frequently used as tracers of AGN and Seyfert galaxies. The line profiles and ratios of these emission lines give information on the kinematics of the emitting gas, and of the properties of the AGN. (Heckman et al., 1981; Boroson, 2005; Gu et al., 2006). The forbidden oxygen lines are metallicity dependent, but also affected by AGN. Nevertheless, in particular [OII] is still a good tracer of star formation and hence we will have an interesting handle on the star formation density at $z = 2.16$, which is complementary to the broad-band surveys targeting similar redshifts (e.g., Adelberger et al. 2004). The expected density of intermediate redshift galaxies will probably be smaller than the density of Hα emitters because of the higher distance moduli and (on average) lower equivalent widths, even though the higher redshift increases the observed equivalent widths. We estimate that we will detect about an order of magnitude fewer such objects compared to Hα emitters.

Hα is a one of the best, direct tracers of the instantaneous star formation rate and it is particularly useful as it is relatively unaffected by metallicity and dust extinction. There have been many attempts to pin down the Hα luminosity function at redshifts close to $z = 1$, which is believed to be the peak of star formation in the Universe, but sample sizes are still small (e.g. Tresse et al. 2002; Doherty et al., 2006 - submitted; Hopkins et al. 2000; Yan et al 1999). A wealth of evidence for strong evolution in the SFR from redshift 0 to 1, by perhaps an order of magnitude (Hopkins, 2004 and refs therein) exists. However, many surveys are limited to the bright end of the luminosity function. It is therefore not entirely clear whether this evolution in global SFR is a property of galaxies with well above average SFRs, or whether it also extends to average SFR galaxies. The Hα luminosity of normal galaxies is well studied in the local universe. Comparing the full range of Hα luminosities at higher redshifts to those of local galaxies could therefore provide crucial insight into the evolution of the SFR. Another question recently posed is that of the apparent "downsizing" of star forming galaxies (Cowie et al., 1996; Heavens et al., 2004; Juneau et al., 2005). Did more massive galaxies form earlier than less massive galaxies? To date, no survey has simultaneously reached the sensitivity and the area necessary to fully address the questions of global SFR and "downsizing". The sensitivity of this proposed survey will reach Hα luminosities more than three orders of magnitude below L*(Hα). This will yield unprecedented constraints to the Hα luminosity function at $z = 0.8$, in particular the value of the faint-end slope which is still a matter of debate, and it will give a direct observational evidence as to whether the "downsizing" scenario is true or merely an observational bias.

The ELVIS Legacy.

The legacy that ELVIS will leave behind is the most comprehensive survey ever for emission-line galaxies. The science that will come out of it will make strong constraints on the star formation history of the Universe, and give clues to the very early development of the Universe at very high redshift. This will prepare way for future, amazing instruments and telescopes such as the James Webb Space Telescope (JWST) and the Extremely Large Telescope (ELT).

2.2 Immediate objective:

We propose to obtain narrow-band and J-band imaging in two fields of 1.6 deg^2 for identification of emission-line galaxies at redshifts $z \sim 0.8 - 8.8$ for tracing the star formation density through a significant fraction of the Universe.

As also described above, the sky spectrum in the J band is full of atmospheric OH-lines, only providing a small number of possible wavelengths to place a narrow-band filter. The filter provided by the DARK Cosmology Centre corresponds to $z = 8.78$ (0.80, 1.36, 1.43, 2.17), $\Delta z = 0.10$ (0.02, 0.02, 0.02, 0.03) for Lyα (Hα, [OIII], Hβ, [OII]) (see Fig. 2). For this redshift range, field of view and standard cosmology (H$_0$ = 70 km s^{-1} Mpc^{-1}, $\Omega_{\rm M} = 0.3$ and $\Omega_\Lambda = 0.7$) a comoving volume of ~ 275000 Mpc^3 per pointing at $z = 8.8$ will be surveyed.

How many emitters do we expect will be found?

Lyα

The narrow-band investigation for Lyα-emitters at $z = 8.8$ by Willis & Courbin (2005) find no emitters in a surveyed volume of ~ 900 Mpc^3 with a flux sensitivity of $F = 3.3 \cdot 10^{-18}$ erg s^{-1} cm^{-2}. We use this result to estimate an upper limit of ~ 250 objects in the present survey. If we instead use the shifted luminosity function for Lyα-emitters at redshift $z = 6.5$ summarised by Malhotra & Rhoads (2004) and assume to reach a flux limit of $F = 3.0 \cdot 10^{-18}$ erg s^{-1} cm^{-2}, ~ 200 objects will be found in one pointing. Decreasing the sensitivity to $F = 5.0 \cdot 10^{-18}$ erg s^{-1} cm^{-2}, and still using the same luminosity function, would instead result in ~ 25 objects.

Alternatively, we can use theoretical estimates to find the expected number of emitters. We have used three papers that predict luminosity functions for very high redshift Lyα-emitters: Haiman & Spaans (1999), Thommes & Meisenheimer (2005) and Le Delliou et al. (2006). The prediction by both Thommes & Meisenheimer (2005) and Le Delliou et al. (2006) are in good agreement with observations of Lyα-emitters at $z \sim 6$ by Rhoads et al. (2003), Hu et al., (2004) and Taniguchi et al. (2005). Hence, their predictions are more likely to be correct than the third. Also, their predictions explain why Willis & Courbin (2005) find no objects in their investigation as we do not expect to find any object in such a small comoving volume. To the intended flux limit, Thommes & Meisenheimer (2005) predict that the survey will observe ~ 40 objects, while Le Delliou et al. (2006) predict a lower limit of ~ 25 objects. We thus estimate to identify of the order of a few tens of high-redshift Lyα emitters per pointing and it is extremely unlikely that no sources will be detected. However, if no objects are found, this result will set severe constraints on the star formation rate and/or reionisation at $z = 8.8$.

Other emission lines

To estimate the number of Hα-emitters we may find, we use the Hα luminosity function of Tresse et al. (2002) with $H_0 = 70$, $\Omega_m = 0.3$, $\Omega_\lambda = 0.7$ and without reddening correction (as listed in Table 3 of Doherty et al. (2006). Using this luminosity function in a field of view of 1.6 deg^2, with a line flux limit of $5 \cdot 10^{-18}$ erg cm^{-2} s^{-1} and over a redshift range $z = 0.802 - 0.820$ we calculate that we should expect to detect of the order 6000 Hα-emitters. As mentioned earlier, we expect to detect about one order less of intermediate emitters, hence of the order of 600 intermediate redshift galaxies.

3 Are there ongoing or planned similar surveys? How will the proposed survey differ from those?

Narrow-band surveys in the near-IR, targeting roughly the same redshifts as proposed here, with the purpose of finding very high redshift Lyα-emitters are underway at several telescopes, including UKIRT, CFHT and VLT/DAzLE. However, the VISTA field of view is much larger (three, six and 73 times respectively for a single exposure). Also the surveys at these telescopes are proprietary, i.e. the data will not become public. Compared to these surveys, ELVIS will be outstanding in the combination of field size and depth, and the data will be public, the raw data immediately and fully reduced within six months of delivery.

4 Observing strategy:

Observing plan

We plan to cover two pointings in the narrow-band filter provided by the DARK Cosmology Centre and in the J band. In the narrow-band, in order to gather a statistical sample of emission-line galaxies, the necessary flux limit is $5 \cdot 10^{-18}$ erg s^{-1} cm^{-2}. This is also where the limit in efficiency goes between observing deeper in one field, or more shallow in two, in order to find the same number of objects. The complementary J band data has to reach a 5σ limiting magnitude of 25.5 AB, in order to be able to separate out narrow-band excess objects.

The J band imaging is mandatory for selecting the emission line galaxies based on the (NB - J) color indices thereby identifying the narrow-band excess objects. For analysis of in particular lower redshift objects, and in order to select the few very high redshift Lyα emitters among the much more abundant foreground emission line galaxies, more bands are desirable. Therefore we propose to target fields with already existing, very deep

COSMOS					
Observatory	Filter	CWL	Area (deg^2)	Depth	Status
HST/ACS	i	8140 Å	2	27.2 (AB, 10σ)	Completed
Subaru	B	4560 Å	2	27.4 (AB, 5σ)	Completed
Subaru	V	5466 Å	2	27.2 (AB, 5σ)	Completed
Subaru	r'	5976 Å	2	26.9 (AB, 5σ)	Completed
Subaru	i'	7870 Å	2	26.9 (AB, 5σ)	Completed
Subaru	z'	9490 Å	2	25.6 (AB, 5σ)	Completed
VLA	—	1.4 GHz	2	8.0 (μJy, 1σ)	Completed
GALEX	—	—	—	—	In progress
XMM	—	7 keV	2	—	In progress
CFHT	u*g'r'i'z'	—	—	—	In progress
CFHT/WIRCAM	—	—	—	—	Planned
Spitzer	—	—	—	—	Planned
SCUBA-2	—	—	—	—	Planned
Subaru/XMM-Deep Field					
Observatory	Filter	CWL	Area (deg^2)	Depth	Status
XMM	—	7 keV	1.3	400 ksec	Completed
Subaru	B	4560 Å	1.3	28.2 (AB, 5σ)	Completed
Subaru	r'	5976 Å	1.3	27.5 (AB, 5σ)	Completed
Subaru	i'	7870 Å	1.3	27.2 (AB, 5σ)	Completed
Subaru	z'	9490 Å	1.3	26.3 (AB, 5σ)	Completed
UKIRT/WFCAM	J, H, Ks	1.25, 1.65, 2.15 μm	0.8	25.0, 24.0, 23.5 (AB, 5σ)	Completed
Spitzer	IRAC	3.6, 4.5, 5.8, 8.0 μm	9.1	3.7, 5.4, 48, 38 (μJy, 5σ)	Completed
Spitzer	MIPS	24, 70, 160 μm	9.1	0.23, 18, 150 (mJy, 5σ)	Completed
VLA	—	1.4 GHz	1.3	60.0 (μJy, 5σ)	Completed
CFHT	u*g'r'i'z'	—	—	—	In progress
SCUBA-2	—	—	—	—	Planned

Figure 1: Table of available, or planned multi-wavelength data in the fields proposed to be observed.

coverage. The two proposed fields are:

- **COSMOS.** The COSMOS field, 2 deg^2 located at RA $\sim$ 10h, is one of the largest, on-going multi-wavelength surveys covered from UV to radio.
- **SUBARU/XMM-Deep Field.** This is a 1.3 deg^2 field located at RA $\sim$ 02h covered from X-rays to radio.

The multi-wavelength coverage of the fields is detailed in Fig. 1. With the available data both fields are ideally suited for the needs of an emission-line galaxy study. The available multi-wavelength coverage allow very accurate photometric redshifts to be derived, which will greatly help the selection of emission-line object candidates, and in a secure identification of the emission lines. We also expect that other VISTA Public Surveys will be targeting these fields, and hence that more comprehensive IR data will be available in the future.

The planned observations are therefore:

- Period 79: Subaru/XMM with the narrow-band (185 hours).
- Period 80: COSMOS with the narrow-band (185 hours) and J (165 hours) and Subaru/XMM in J (165 hours).

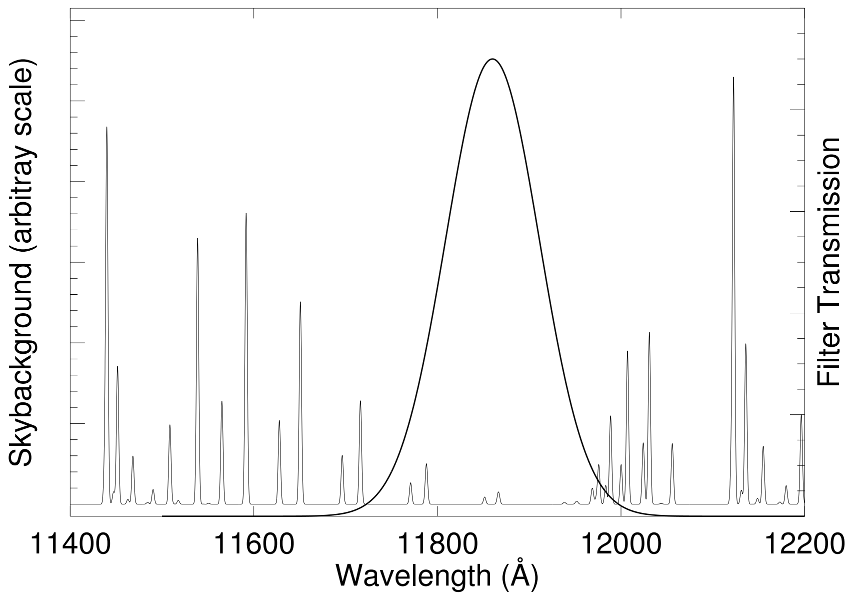

Figure 2: Plot of the narrow-band filter, overlaid on the sky OH-line spectrum.

5 Estimated observing time:

Period	Time (h)	Mean RA	Moon	Seeing	Transparency
P79	180	02h	grey	0.7	clear
P79	5	02h	grey	0.7	photometric
P80	180	10h	grey	0.7	clear
P80	5	10h	grey	0.7	photometric
P80	175	02h	grey	1.0	clear
P80	5	02h	grey	1.0	photometric
P80	175	10h	grey	1.0	clear
P80	5	10h	grey	1.0	photometric

5.1 Time justification:

We have used the Exposure Time Calculator for VISTA, presented on the VISTA homepage. For one paw print, with the narrow-band, DIT= 300, 0.7 arcsec seeing and 2.0 arcsec aperture we reach a sensitivity of $F = 5.0 \cdot 10^{-18}$ erg s^{-1} cm^{-2} (AB magnitude of 25.7) with 5σ in approximately 55 hours. A standard six paw print mosaic will cover 92 % of the full area twice, hence three times this exposure time is needed per mosaic. Overheads are assumed to be approximately 10-15 % for the narrow-band and about 20 % for the J band. Each mosaic will thus take $3 \cdot 55 \cdot 1.15 \approx 185$ hours. We also ask for infrared broad-band imaging for the selection. The J band is most suited for this. Again, the exposure time calculator gives an exposure time of approximately 50 hours to reach magnitude 25.5 (AB, 5σ) in the J band. This magnitude will enable us to single out objects with excess in the narrow-band filter. For a J band mosaic, we hence need $3 \cdot 50 \cdot 1.20 \approx 180$ hours. For each observation block we ask that, at least, five hours have photometric conditions so as to enable the photometric calibration.

6 Data management plan:

6.1 Team members:

Name	Function	Affiliation	Country
J. P. U. Fynbo	PI	DARK Cosmology Centre	DK
K. Nilsson	OB preparation, Data reduction	DARK Cosmology Centre	DK
P. Best	Data reduction	Institute for Astronomy, Edinburgh	UK
A. Bunker	Quality control	University of Exeter	UK
K. Coppin	Data reduction	Inst. for Computational Cosmology, Durham	UK
J.-G. Cuby	Quality control	OAMP, Marseille	F
M. Doherty	Source catalogs	ESO	ESO
W. Freudling	Documentation	ESO	ESO
J. Hjorth	Funding	DARK Cosmology Centre	DK
R. Ivison	Quality control	Institute for Astronomy, Edinburgh	UK
J.-P. Kneib	Quality control	OAMP, Marseille	F
J. Kurk	Source catalogs	Max-Planck-Institut f. Astronomie, Heidelberg	D
P. Møller	Quality control	ESO	ESO
L. F. Olsen	Data reduction	DARK Cosmology Centre	DK
K. Pedersen	Data reduction	DARK Cosmology Centre	DK
P. Rosati	VO, archiving	ESO	ESO
I. Smail	Quality control	Inst. for Computational Cosmology, Durham	UK
W. Sutherland	Technical issues, VDFS	Institute of Astronomy, Cambridge	UK

6.2 Detailed responsibilities of the team:

The Survey will be led from Copenhagen and the DARK Cosmology Centre who will take the overall responsibility for the survey and its management. The DARK Cosmology Centre is a research centre funded with 6MEuro from the Danish National Research Foundation until the end of 2010 with a likely 5-year extension until 2015. We therefore have both the manpower and computing facilities to manage the survey. We foresee the following tasks:

- Observation planning.
- OB creation.
- Software development.
- Homepage creation and maintenance.
- Preliminary quality control of pipelined data.
- Supplementary data reduction; mosaicing, NB specific artifacts removal.
- Image quality control.
- Source catalog creation.
- Catalog quality control.
- Documentation control.
- Release preparation.

The tasks will be roughly divided as marked in the table in section 6.1, but may be subject to change over the running period of the project.

We will use the VISTA Data Flow System (VDFS; Emerson et al. 2004, Irwin et al. 2004, Hambly et al. 2004) for all aspects of data management, including: pipeline processing and management; delivery of agreed data products to the ESO Science Archive; production of a purpose-built IVOA compliant science archive with advanced datamining services; enhanced data products including federation of VISTA survey products with SDSS survey products. Standardised agreed data products produced by VDFS will be delivered to ESO, with copies remaining at the point of origin.

The VDFS is a collaboration between the UK Wide Field Astronomy Units at Edinburgh (WFAU) and Cambridge (CASU) coordinated by the VISTA PI (QMUL) and funded for VISTA by PPARC. The VDFS is a working systems-engineered system that is already being successfully employed for the UKIRT WFCAM surveys as a test bed for the VISTA infrared surveys, and which is sufficiently flexible to be applicable to any imaging survey project requiring an end-to-end (instrument to end-user) data management system. We emphasise the track record over the last decade of both the Cambridge and Edinburgh survey units in processing and delivering large-scale imaging datasets to the community as exemplified by the WFCAM Early Data release (EDR, (*http://surveys.roe.ac.uk/wsa/dboverview.html*) Lawrence et al 2006, Dye et al 2006).

6.3 Data reduction plan:

The data reduction will be using the VDFS, operated by the VDFS team, and augmented by individuals from ELVIS, especially for product definition and product Quality Control. We divide the plan into two distinct but intimately related parts: pipeline processing and science archiving. Much greater detail can be found in the SPIE papers cited previously.

6.3.1 Pipeline processing

The Cambridge Astronomy Survey Unit (CASU) are responsible for the VDFS pipeline processing component which has been designed for VISTA and scientifically verified by processing wide field mosaic imaging data from UKIRT's NIR mosaic camera WFCAM and is now routinely being used to process data from the WFCAM at a rate of up to 250GB/night. It has also been used to process ESO ISAAC data e.g. the FIRES survey data and a wide range of CCD mosaic camera data.

The pipeline is a modular design allowing straightforward addition or removal of processing stages and will have been tested on a range of input VISTA datasets. The standard processing includes: instrumental signature removal – bias, non-linearity, dark, flat, fringe, cross-talk; sky background tracking and homogenisation during image stacking and mosaicing – possible extras may include removal of other 2D systematic effects from imperfect multi-sector operation of detectors; assessing and dealing with image persistence from preceding exposures if necessary; combining frames if part of an observed dither sequence or tile pattern; producing a consistent internal photometric calibration to put observations on an approximately uniform system; standard catalogue generation including astrometric, photometric, shape and Data Quality Control (DQC) information; final astrometric calibration based on the catalogue with an appropriate World Coordinate System (WCS) placed in all FITS headers; photometric calibration for each generated catalogue augmented by monitoring of suitable pre-selected standard areas covering the entire field-of-view to measure and control systematics; frames and catalogue supplied with provisional calibration information and overall morphological classification embedded in FITS files; propagation of error arrays and use of confidence maps; realistic errors on selected derived parameters; nightly extinction measurements in relevant passbands; pipeline software version control – version used recorded in FITS header; processing history including calibration files recorded in FITS headers.

We may need to create task-specific software for the narrow-band data, to compensate for special artifacts, such as a small central wavelength/FWHM shift over the tiles. We have already discussed this with the VDFS team and no serious complications compared to broad band reduction are foreseen.

6.3.2 Science archiving

The concept of the science archive (SA, Hambly et al. 2004 and references therein) is key to the successful exploitation of wide field imaging survey datasets. The SA ingests the products of pipeline processing (instrumentally corrected images, derived source catalogues, and all associated metadata) into a database and then goes on to curate them to produce enhanced database-driven products. In the VDFS science archive, the curation process includes, but is not limited to, the following: individual passband frame association; source association to provide multi-colour, multi-epoch source lists; global photometric calibration; enhanced astrometry including derivation of stellar proper motions; consistent list-driven photometry across sets of frames in the same area; cross-association with external catalogues; and generation of new image products, e.g. stacks, mosaics and difference images etc., all according to prescriptions set up for a given survey program. Archive curation includes quality control procedures, as required and led by the public survey consortium, and supported by archive team members. All these features are available in the context of a continually updating survey dataset from which periodic releases (as required by the community) can be made.

Moreover, end-user interfaces were catered for from the beginning in the VDFS design process, and the philosophy has always been to provide both simple and sophisticated interfaces for the data. The former is achieved via simple point-and-click web forms, while the latter is achieved via exposing the full power of the DBMS back-end to the user. To that end, full access to Structure Query Language and the relational organisation of all data are given to the user.

We have developed a generalised relational model for survey catalogue data in the VDFS. The key features to note are the normalised design with merged multi-waveband catalogue data (the table of most use for scientific queries) being part of a related set of tables that allow the user to track right back to the individual source images if they require to do so; and also that the merged source tables (as derived either from individually analysed images, or consistently across the full passband set available in any one field) are seamless, and present the user with a generally applicable science-ready dataset. Similar relational models describe the organisation of all data in the science archive (image, catalogue, calibration metadata, etc.) - see Hambly et al. (2004) and references therein. The science archive has a high-speed query interface, links to analysis tools such as TopCat, and advanced new VO services such as MySpace. Data products are being successfully ingested into the WFCAM Science Archive (WSA) in Edinburgh, with the EDR in Feb 2006, and the WSA concept was also demonstrated on the SuperCOSMOS Science Archive (SSA). *http://surveys.roe.ac.uk/ssa/*

ELVIS is intrinsically a multi-wavelength project and most science will come from the linking of VISTA data with COSMOS and Subaru/XMM data and the WSA is designed to enable such links.

6.4 Expected data products:

Instrumentally corrected frames (pawprints, tiles etc) along with header descriptors propagated from the instrument and processing steps (science frames and calibration frames)
Statistical confidence maps for each frame
Stacked image data for dithered observations
Derived catalogues (source detections from science frames with standard isophotal parameters, model profile fitted parameters, image classification, etc.)
Data Quality Control database
Database-driven image products (stacks, mosaics, difference images, image cut-outs)
Frame associations yielding a survey field system; seamless, merged, multi-colour, multi-epoch source catalogues with global photometric calibration, proper motions (where appropriate)
Source remeasurement parameters from consistent list-driven photometry across all available bands in any one field

6.5 General schedule of the project:

- Period 79 we observe Subaru/XMM with the narrow-band.
- Period 80 we observe COSMOS with the narrow-band and J and Subaru/XMM in J.
- Expected early data release, with reduced and mosaiced images from the Period 79 run, in March, 2008.
- Expected second data release, with reduced and mosaiced images from the Period 80 run, in October 2008.
- Final data release expected Spring, 2009, with all data reduced and calibrated, also including source catalogs.

7 Envisaged follow-up:

We will be able to make a line identification from the multi-wavelength data available in these fields, and using photometric redshift catalogs from other surveys. For the final confirmation of a smaller sub-sample of candidates, spectroscopic follow-up may be necessary. Obvious choices would be VIMOS-MOS, ISAAC, Subaru/FMOS, Subaru/MOIRCS or after commissioning, X-shooter. X-shooter will cover the entire wavelength range from UV to IR in one exposure. A rough calculation show that a few hours of spectroscopy on X-shooter would be sufficient to detect a $5 \cdot 10^{-18}$ erg s^{-1} cm^{-2} emission line with a 5σ significance. X-shooter is planned to be installed at the VLT during 2007. On a slightly longer time scale an intrument like KMOS will be perfect for further spectroscopic follow-up of the data set resulting from this survey.

Note that we are not planning to include spectroscopy in the Public Survey. Follow-up spectroscopy will be made by individual groups.

8 Other remarks, if any:

We hope to get access to commissioning data for the VISTA narrow-band filter in order to investigate and prepare for the special corrections that may be necessary in the data reduction.

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