1 UKIDSS Large Area and Galactic Clusters Surveys

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1.1 Abstract:

The UKIRT Infrared Deep Sky Survey (UKIDSS, www.ukidss.org) is the next generation near–infrared sky survey, covering the wavelength range $0.8 - 2.4\mu$m ($ZYJHK$), and is an ESO public survey. UKIDSS commences in March 2005, and comprises 5 sub–surveys covering Galactic and extra–Galactic targets with different depth/area combinations. This proposal concerns deep i' imaging for the Large Area Survey (LAS) (over 2000 sq. degs, 53 nights), and for the Galactic Clusters Survey (GCS) (over 1000 sq. degs, 40 nights). The LAS area is contained within the SDSS footprint, and benefits from the SDSS $u'g'r'i'z'$ photometry, as well as the galaxy and quasar redshift surveys. The VST i' imaging, 1.5 mag. deeper than SDSS, will greatly enhance the usefulness of the LAS specifically for finding and studying very red objects, especially $z > 6$ quasars, L, T, and Y brown dwarfs, and $z > 1$ ellipticals. The goal of the GCS is the measurement of the sub–stellar mass function in a range of environments. The VST i' imaging will extend the diagnostic power of the UKIDSS $ZYJHK$ photometry, as i'-J provides a reliable measure of stellar effective temperature, while i'-J versus $J{-}H$ provides excellent reddening determination for very low mass cluster stars.

2 Description of the survey:

2.1 Scientific rationale:

The UKIRT Infared Deep Sky Survey (UKIDSS), and complementary optical data

UKIDSS is a set of 5 near–infrared surveys which will commence in March 2005. Exploiting the large grasp of the Wide Field Camera on UKIRT, over the 7 years of the campaign UKIDSS will collect 100 times as many photons as 2MASS, opening up a vast new parameter space for exploration. The 5 surveys cover complementary combinations of depth and area, and target both Galactic and extra–Galactic science. The surveys have been designed, and will be executed, by the UKIDSS consortium. The data will be pipelined by the Cambridge Astronomical Survey Unit (CASU). The products (catalogues and images) will then be ingested into an archive by the Wide Field Astronomy Unit (WFAU) at Edinburgh. A process of curation of the database leads to the final survey products of seamless images and multi–band merged catalogues across the survey areas, accessed using the WFCAM Science Archive (WSA) query tool. The UKIDSS consortium has no proprietary rights to the data, and the surveys will be released to the ESO community shortly after each observing block, on completion of the verification process. The first release, scheduled for Autumn 2005, will immediately set a new standard in near–infrared sky surveys. ESO astronomers will have 18 months proprietary access to this world–leading resource, for each release. There is no significant competition, until surveys with VISTA commence in some two years time, which will reinforce ESO's advantage. Therefore the combination of UKIDSS, VISTA, and VLT provides a rich resource for ESO astronomers for several years. This proposal is concerned with enhancing two of the five UKIDSS surveys, with VST deep i' imaging.

The layout of the 5 UKIDSS surveys is illustrated in Fig. 1. There are three extra–Galactic surveys, named, in order of increasing depth, the Large Area Survey (LAS, K=18.4, 4000deg^2), the Deep Extragalactic Survey (DXS, K=21.0, 35deg^2), and the Ultra Deep Survey (UDS, K=23.0, 0.77deg^2). Additionally there are two Galactic surveys, named the Galactic Plane Survey (GPS, K=19.0, 1800deg^2), and the Galactic Clusters Survey (GCS, K=18.7, 1400deg^2). All magnitudes quoted in this proposal are on the Vega system, and all detection limits are 5σ in a 2arcsec. aperture.

The extent to which suitable complementary optical imaging is available, or needed, varies between the surveys. The requirements of the UDS are being met by Subaru–SuprimeCam and VLT–VIMOS. The GPS, surveying highly reddened objects, has no requirement for optical imaging. Of the three remaining surveys, all the fields

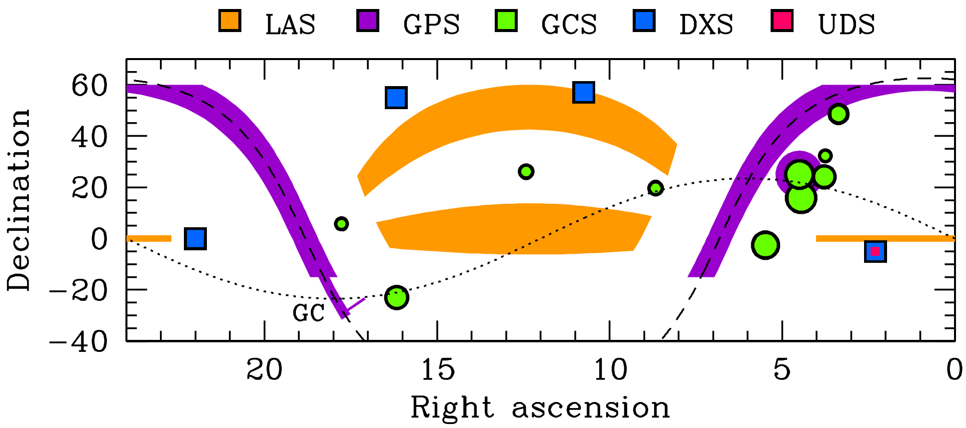

Figure 1: Sky coverage of the 5 elements of UKIDSS. The colour of each survey is given by the key at the top of the figure. The regions covered by the current proposal are the LAS northern equatorial band (9h–16h), the LAS southern equatorial stripe (22h–4h), and the GCS clusters below Dec+25°. GC marks the Galactic Centre, and the dotted line is the ecliptic.

that are visible from Paranal are targeted in this Call for Proposals. VST imaging of the DXS is included in the VST–Census proposal (PI Oliver). The current proposal concerns deep i' imaging of LAS and GCS fields.

VST imaging of the UKIDSS Large Area Survey (LAS)

The LAS was conceived as the near–infrared counterpart to SDSS, and will survey 4000deg^2 within the SDSS footprint over the 7 years. The depth limits (confirmed by commissioning data) in the different bands are Y=20.5, J=20.0 (after two passes), H=18.8, K=18.4, with equal 40s exposure in each band. Note that the Y filter is a new filter at 0.97–1.07μm, between the z' and J bands (Warren and Hewett, 2002). These depths are a good match to the SDSS depths for the SEDs of galaxies in the nearby universe. The extended wavelength coverage provided by the 4 near–infrared LAS bands, for studying SDSS targets, is illustrated in Fig. 2.

Although complementarity with SDSS set the framework of the LAS, we anticipate that much of the most fruitful science will come from the study of very–red objects, i.e. objects bright in UKIDSS, but faint in SDSS — high–redshift objects, cool objects, and dusty objects. Fig. 2 illustrates examples. The signature of these objects is a strong break (e.g. redshifted Lyα or 4000Å break) between the optical and near–infrared domains. Deep imaging in the i' or z' band, much deeper than offered by SDSS, is required to accentuate this break. The UKIDSS Consortium is particularly interested in the study of the highest–redshift $z > 6.4$ quasars, and cool brown dwarfs. In the following we design a VST i' survey to satisfy these goals, and include brief remarks on the general benefits of such a survey.

The LAS was rated by external review as having highest priority amongst the 5 surveys, and accordingly is being accelerated, such that half the area, 2000deg^2, will be completed in the first two years of the surveys. The target regions for this 2–year plan are the two equatorial bands, illustrated in Fig. 1 (coloured orange), deliberately selected as the regions accessible from Paranal with VLT and VST.

Highest–redshift $z > 6.4$ quasars. The new generation of telescopes and instruments have allowed astronomers to explore beyond redshift $z = 6$. Analysis of the spectra of the highest–redshift quasars discovered (Fan et al., 2003), indicate that we may be on the threshold of the epoch at which the intergalactic medium was reionised. The epoch of reionisation is predicted to occur over a relatively short redshift interval (Gnedin, 2000). As such it is seen as a fundamental event in cosmic history, and the study of this epoch is one of the great goals of observational cosmologists. Analysis of the WMAP one–year polarisation cross–power spectra (Kogut et al., 2003) indicates a higher redshift of reionisation than the quasar data, $11 < z_r < 30$. This may point to a more complex history of reionisation than previously predicted. These results motivate searches for quasars beyond the limit reached by SDSS $z = 6.4$. At higher redshifts, because of saturation at the high absorption optical

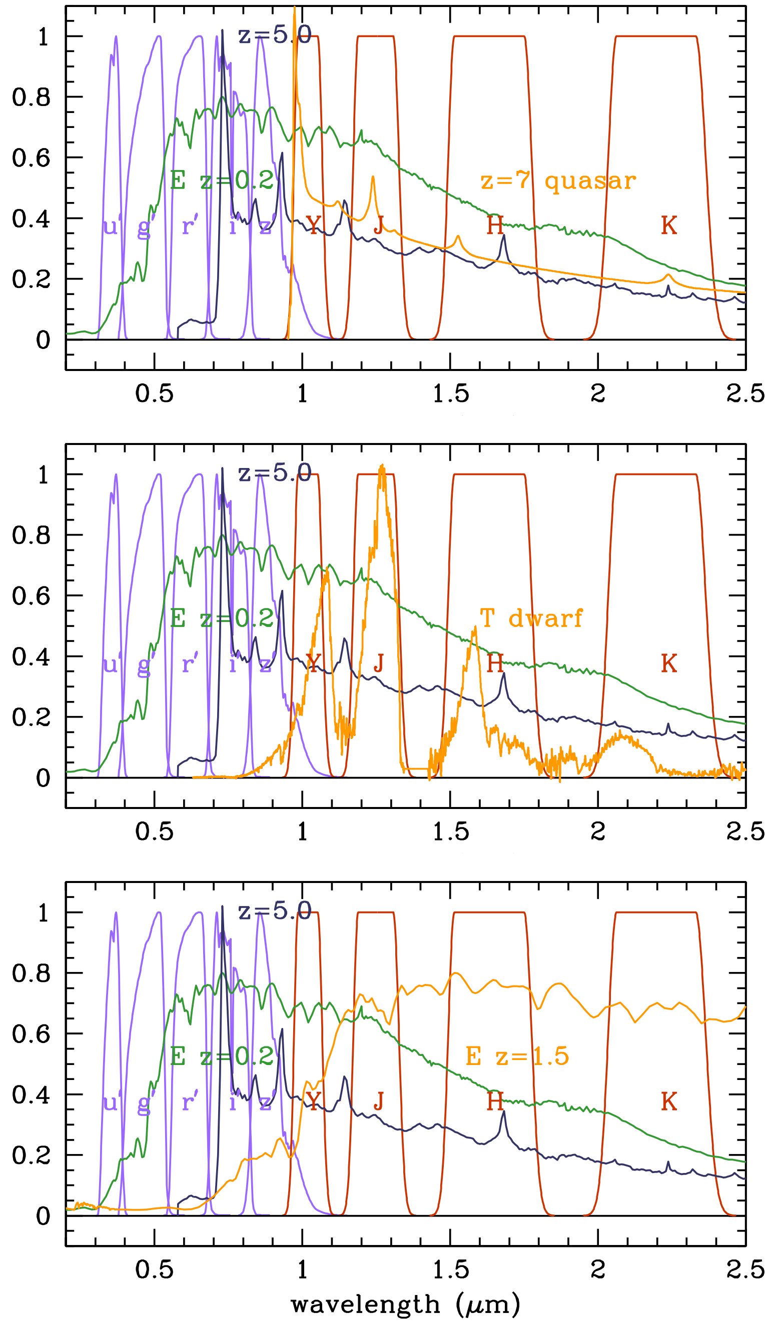

Figure 2: Example spectra of very red objects that will be discovered in the LAS, highlighting the differences between optical and near–infrared surveys. The SDSS filter set is plotted pale blue, and the WFCAM *YJHK* filters are plotted red. The spectra of an elliptical galaxy at $z = 0.2$, plotted green, and a $z = 5$ quasar, dark blue, represent classes of object readily identified in the SDSS database. The study of these classes will be enhanced by the LAS, by greatly extending the wavelength coverage. By contrast the three spectra plotted orange, from top to bottom a hypothetical $z = 7$ quasar, a T brown dwarf, and an elliptical galaxy at $z = 1.5$, represent classes of object that are specifically near–infrared sources, practically invisible in the optical. As detailed in the scientific rationale, the addition of VST deep i' imaging will greatly enhance the exploitation of the UKIDSS LAS for the study of such classes.

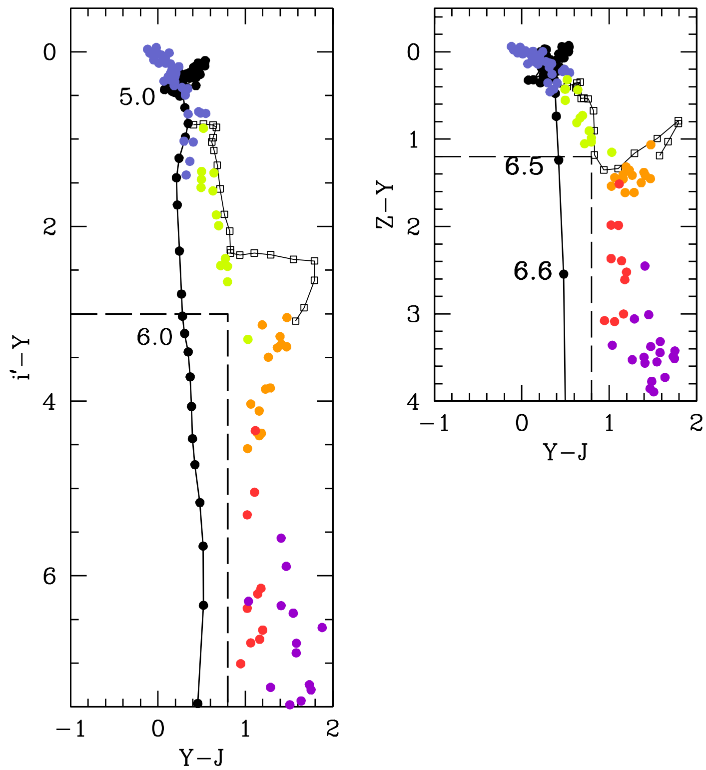

Figure 3: Synthetic colours of stars, brown dwarfs, high–redshift quasars, and redshifted elliptical galaxies. *LHS: i'-Y v Y-J, RHS: Z-Y v Y-J*, where *Z* is the VST bandpass, with a squarer profile than the SDSS z'. These figures illustrate the strengths and weaknesses of using either the i' or the *Z* filter as the shortest wavelength band for the study of very red objects. As detailed in the scientific rationale, the overall preference is for the i' band. Key: blue O-K stars, green M stars, orange L brown dwarfs, red T brown dwarfs, purple model T/Y brown dwarfs, filled black circles redshifted quasars $0 < z < 7$ $\Delta z = 0.1$, open black squares elliptical galaxies $0 < z < 2$ $\Delta z = 0.1$. Dashed lines mark the quasar selection boundaries. Note that the hypothetical Y dwarf sequence turns rapidly redder to $Y{-}J > 2$ at even cooler temperatures < 300K.

depths, analysis of the Lyα, β, γ forests (e.g. White et al., 2003) is no longer useful, but measurement of the red damping wing of the IGM (Miralda–Escudé 1998, Wyithe and Loeb 2004, Meisinger and Haiman, 2004), and possibly weak metal transitions (Oh, 2002), will be pivotal in charting the transition through reionisation.

The detection of quasars at $z > 6.4$ is one of the key goals of the LAS. Selection is illustrated in Fig. 3, and requires deep imaging in either the i' or *Z* bands (here we use *Z* to distinguish the square VST filter from the SDSS z' filter which has a red tail). Quasars are identified as bluer than L and T brown dwarfs in *Y-J*, and very red in $i' - Y$ or *Z-Y*. Selection by $i' - Y > 3.0$ is effective over the redshift range $5.9 < z < 7.2$. Selection by $Z{-}Y > 1.2$ is effective over the redshift range $6.5 < z < 7.2$.

For the purposes of this proposal the key point to note is that *the effective depth of the LAS survey for this science goal is currently set by the depth of the SDSS i' and z' imaging, and so not using the full power of UKIDSS*. With deeper VST imaging we can search fainter, substantially increasing the number of detected quasars. To make this clear, consider the SDSS detection limit i'=22.0. A $z = 7$ quasar fainter than Y=19.0 will appear as an upper limit above the detection boundary, so that Y=19.0 is the current UKIDSS limit, using SDSS for i'. The near–infrared data are deep enough to allow a survey to Y=20.0. A VST survey to $i' > 23.0$ would make this possible. Our proposal is to include a small comfort margin, and to survey to a 5σ detection limit i' =23.5. A similar analysis for the Z filter argues for a depth limit Z= 21.7. The required integration times are therefore similar, but we consider i' to be the preferred solution because the redshift range is greater. In addition, as is evident from inspection of Fig. 3, the danger of contamination of the sample of candidates by compact elliptical galaxies at $z \sim 1.4$, misclassified as stellar, is removed.

The greater i' depth has a very significant effect on the usefulness of the LAS for a survey for high–redshift quasars, *increasing the surface density of detected* $z > 6.4$ *quasars by a factor 4.* Using the luminosity functions of Schneider, Schmidt, and Gunn (1994), and Fan et al. (2001), over the full 4000 sq. degs of the LAS to Y=19.0, we expect to find only 3 to 4 quasars with redshifts $6.4 < z < 7.2$. Reaching Y=20.0, over the 2000 sq. degs of the proposed VST survey we expect to find 7 to 9 quasars in this redshift range.

L, T, and Y brown dwarfs. A second key goal of the LAS is the study of brown dwarfs. This includes the search for objects cooler than T, the hypothesised Y dwarfs, and the measurement of the density distributions of brown dwarfs of different types. Deep i' imaging will greatly benefit these areas by extending the depth to which spectral classification is possible. The colour $i' - J$ is an excellent measure of spectral type / effective temperature, increasing almost linearly with spectral type. The colour $Z - J$ is not so good since there is a plateau over the spectral range L0 to T0. The proposed VST survey will increase the depth to which spectral typing is possible by 1.5mag., compared to using SDSS. Referring to Fig. 3, it can be seen that all M dwarfs could then be spectrally typed down to the survey limit Y=20.5 (previously 19.0), and all L dwarfs down to Y=19.0 (previously 17.5). Now the colours of Y dwarfs are uncertain, but the Burrowes et al. (2003) models, plotted in Fig. 3, indicate they drift slowly redder in Y-J, and then rapidly turn redder in Y-J near 300K. It can be seen that to distinguish the slightly warmer Y dwarfs of 400K, from the earlier L dwarfs, which have similar Y-J, it is essential to detect the L dwarfs in the i' band. Improving the depth to which this discrimination is possible by 1.5mag., increases the volume surveyed by a factor 8. The study of the spatial distribution of brown dwarfs of different spectral types, e.g. measurement of their scale height, enjoys the same gain.

General benefits. Although the survey depth in the i' band has been designed based on specific goals, we anticipate that the VST data will produce wide benefits to the exploitation of the combined LAS+SDSS+VST dataset, and expand the usefulness of the LAS for ESO astronomers. One class of object not discussed so far are luminous red galaxies (Eisenstein et al., 2001), which have been used very successfully for the study of large–scale structure and galaxy clusters at intermediate redshift, $z \sim 0.4$. With the VST imaging proposed here it would be possible to apply the same selection methods at higher redshifts, identifying the brightest ellipticals galaxies at $z > 1$ (Fig. 2). One can anticipate wide interest in such a catalogue. An example science goal is the measurement of the space density of the most massive clusters $1 < z < 1.5$ (pinpointed by their red sequence, Gladders and Yee, 2000), which is sensitive to the details of structure formation. Another is the measurement of the Integrated Sachs-Wolfe (ISW) effect as a function of redshift via cross-correlation with WMAP/Planck, which can provide direct constraints on the equation of state of dark energy as well as its sound speed (Hu and Scranton, 2004).

More generally, because the LAS opens up a large new parameter space, 3 mag. deeper than 2MASS, new science goals will become apparent from exploring the database. We would expect further examples of rare red objects to be of interest. The most extreme objects of a class (i.e. the coolest/reddest/oldest/brightest/highest-redshift) can illuminate the study of the population. For example the coolest halo white dwarf places a limit on the age of the Galaxy halo. The good image quality of the VST data relative to the SDSS data is also an important asset, and the increased depth of the i′ imaging would allow detailed galaxy morphological studies (e.g. Blanton et al. 2003) to be extended to include galaxies of lower luminosity, or of higher redshift (allowing measurement of evolution), or to improve the precision at a given magnitude of previous studies. Finally, the time interval between the SDSS and VST imaging expands the parameter space to include variability and proper motions.

VST imaging of the UKIDSS Galactic Clusters Survey (GCS)

Unlike the other elements of UKIDSS, the GCS was designed to meet a single specific science aim, the measurement of the sub–stellar mass function in a range of environments. The GCS was ranked by external review 2nd of the 5 surveys, and is also being accelerated, such that it will be 41% complete after the first 2 years. As with the LAS, targets visible from Paranal will be prioritised in the 2–year plan.

Broadly speaking, the process of star formation (SF) is now reasonably well understood in terms of hierarchical fragmentation of collapsing molecular clouds (Levy and Lunine 1983; Mannings, Boss and Russell 2001). In detail, however, there is no complete picture of SF (Shu et al. 1987). In particular, the spectrum of masses resulting from the SF process, commonly known as the initial mass function (IMF), cannot be predicted. This is unfortunate, because the IMF is a fundamental tool in studies of galaxy formation, stellar birthrate (Miller and Scalo 1979), the chemical evolution of galaxies (Cameron 1993) and the contribution of substellar objects to the total mass in stellar systems. This last point is particularly interesting, since brown dwarfs (BDs; $m < 0.08M_{\odot}$) have relatively high mass-to-light ratios at large ages and are not easily observed. It is only recently that small-scale, deep infrared studies have begun to tackle the question of the form of the very low mass IMF. The UKIDSS GCS proposal aims to measure the very low mass end of the stellar MF in a number of clusters and associations to masses $m \sim 0.01M_{\odot}$ in order to provide a firm footing for theoretical models and more general Galactic studies. By measuring the MF in a number of Galactic environments and at a range of different ages, the GCS aims to study the evolution of the MF over time, its relation to the IMF, and the universality (or otherwise) of this fundamental tool of stellar astrophysics.

The need for i' imaging: Deep i'–band imaging will enhance greatly the diagnostic power of UKIDSS GCS photometry. The increased baseline of $i'-K$ over pure infrared indices minimises the effects of individual passband measurement errors on the colour index, generally making for better discrimination in observational HR–diagrams. Furthermore, observations of field dwarfs (Dahn et al. 2002) show that $i'-J$ (or equivalently $I-J$) is the most reliable indicator of stellar effective temperature for the cool dwarfs targeted in the GCS (see also Hawley et al. 2002). This is because $i'-J$ increases monotonically with effective temeparture T_e; contrast this with pure infrared colour indices which, in addition to not having a simple monotonic relationship with T_e, are susceptible to differential reddening when this is unknown, and are affected by the presence of circumstellar disks. Estimation of reddening for individual targets is of course best achieved in a 3-colour space (Cardelli et al. 1989) that includes an optical or near–infrared passband, but excludes infrared passbands that can be affected by circumstellar material. For example, Lucas and Roche (2000) found that *I-J* versus *J-H* provides excellent reddening determination for very low mass cluster stars, where that choice of indices avoids uncertainties in the distance modulus when calculating true colours. Additionally, assessing the presence of disks is best done by comparing *H-K*, for example, with the expected value based on a measurement of the intrinsic *I-J*. Once again, *I-J* is more sensitive than *J-H*, the latter being moreover susceptible to modulation by accretion activity (e.g. observations in the Sigma-Ori cluster by Oliveira et al., 2004). Hence, given the interplay between extrinsic effects (reddening, disks etc.) and pure infrared colours, plus the known behaviour of *I-J* as a T_e estimator and the pragmatic trade-off between depth and increasing colour baseline (e.g. R observations having the depth required to match the infrared data would be impractical), we propose VST $i'-$band complementary imaging for the UKIDSS GCS.

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2.2 Immediate objective:

UKIDSS Large Area Survey 2000deg^2

The goal of the LAS part of the proposal is to obtain i' imaging to a homogeneous 5σ limiting magnitude of 23.5, of the area covered by the LAS 2–year plan, i.e. the two equatorial blocks shown in Fig. 1. To improve on the SDSS image quality we require seeing better than 0.9arcsec. The stripe in the southern Galactic hemisphere is a section of the SDSS equatorial stripe no. 82. Each SDSS stripe is 2.5° wide. Stripe no. 82 has been scanned repeatedly, and we have selected the region where the coadded depth and image quality are optimal. This region is defined by $-25° < \alpha < +60°$, $-1.25° < \alpha < +1.25°$ i.e. 212.5deg^2. Our preference is that the northern Galactic block is defined by the sections of stripes 8 to 15, above Galactic latitude 30°, which is the region plotted. Nevertheless there is some scope for compromise against the KIDS plan, if necessary (see below), and in any case our intention is that the final outline must be contained within the SDSS DR4 footprint, details of which will not become available until July 05.

We will calibrate (i.e. zero point, extinction, and colour terms) these data using the SDSS photometry of these fields. Therefore no calibration observations with VST are required for the LAS part of this proposal.

UKIDSS Galactic Clusters Survey 1000deg^2

The goal of the GCS part of the proposal is to obtain calibrated i' imaging to a homogeneous 5σ limiting magnitude of 23.8, of the areas covered by the GCS having Dec$< +25°$ (photometry for the more northerly areas will be sought elsewhere). There is no suitable existing deep optical data in the target fields.

The GCS target list is available at http://www.roe.ac.uk/ nch/gcs/table.gif. The philosophy in the survey is to observe to the same apparent magnitude limit in each cluster (K=18.4, in a single pass, with a second pass for proper motions) rather than trying to tune exposure times to reach the same mass limit in all. This is a pragmatic decision in the face of large uncertainties in ages, model predictions, global and differential reddening and the simple fact that one might as well employ the "natural" depth reached with a given survey instrument (observing overheads dominate if using shorter exposure times; on the other hand, struggling to go significantly deeper merely results in a highly skewed distribution of time per target that would put far too much weight on the most distant and aged systems). We follow the same philosophy here, and take a "natural" survey timescale for VST i'-band imaging of 1000s per pointing that reaches $i' \sim 23.8$. This is well matched to our science requirement of reaching $i' - K \sim 5$ (e.g. Chabrier et al. 2000), from K = 18.4 with good signal-to-noise for the reddest objects that we expect to observe (but we reiterate that this is heavily dependent on assumed ages, models and reddening).

The resulting target list of open clusters and star formation associations is as follows:

Target	RA	Dec	Area^a	Comments
	hh mm	dd am	deg^2	
Pleiades	03 47	+24 07	40	Just over 1/2 cluster accessible
Hyades	04 27	+15 52	290	All accessible
Taurus-Auriga	04 30	+25 00	190	1/2 region accessible
Orion	05 29	-02 36	314	All accessible
Praesepe	08 40	+19 40	28	All accessible
Coma-Ber	12 25	+26 06	38	Just under 1/2 region accessible
Sco	16 10	-23 00	154	All accessible
IC-4665	17 46	+05 43	3	All accessible
			1057	

^{a}The quoted area is the area below Dec=+25°.

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

There are no current or planned surveys that are within a factor of ten of the size of the UKIDSS LAS and GCS at the specified depths. Future surveys with VISTA (that will have a survey speed about 3 times faster than WFCAM) are in the planning stage. No details of plans for surveys using WIRCAM on CFHT are currently available, nor of plans for surveys by University of Hawaii astronomers using WFCAM.

We are of course aware of the KIDS proposal, which will cover a substantial part of the LAS region proposed here (Fig. 1), and to slightly greater depth in the i' filter. As a consequence we would be happy to remove the region of overlap with KIDS from our proposal, in the event of it being covered by KIDS. There are some geometric and airmass constraints on the KIDS region, and they would prefer the centroid of the UKIDSS LAS to move southward very slightly, as would be possible by extending the lower declination stripes to lower Galactic latitude than our proposed limit of $b = 30°$, in the region of $\alpha = 8h$ (KIDS Fig. 1). As noted above there is still some possibility for compromise with KIDS over the detailed outline of UKIDSS LAS, from within the SDSS DR4 footprint.

4 Observing strategy:

The observing strategy is mostly straightforward since all observations are restricted to the i' band, and the two surveys are individually to a uniform depth. We propose that the data be taken in DITHER mode, to ensure contiguous coverage. There might be an opportunity for compromise with other surveys here, i.e. to use JITTER mode to ensure that the psf is well understood for all detected images, resulting in gaps in the coverage. While a nuisance to deal with, in principle this only means a small loss of effective area. Nevertheless we note that KIDS also propose DITHER mode. We anticipate splitting the 600s integration for the LAS into 3 exposures, and the 1000s of the GCS into 4 exposures, subject to modification depending on the recorded on–sky characteristics of the instrument.

We require photometric conditions for the GCS. For the LAS we could tolerate thin cirrus conditions, for some of the survey, provided the integration times are increased by 30% to compensate. We have incorporated this possibility into the plan, below.

5 Estimated observing time:

Calibration observations are not required for the LAS (see above). We assume approx. 1 hour per night total spent on calibration observations for the GCS. On this basis, allowing for overheads, and a typical 9 hour night, we assume overheads of 25% and 30% for the LAS and GCS surveys, translating to survey speeds of 43.2 and 24.8 deg^2 per night. Nevertheless since we could tolerate thin cirrus for the LAS, we allow for the possibility that half the LAS area is executed in these conditions. Therefore the LAS requires 23 nights 'clear' and 30 nights 'thin', while the GCS requires 40 nights 'photometric'. We assume seeing better than 0.9arcsec for all observations, and have based the exposure time on median 0.8arcsec seeing.

The estimated time assumes grey sky or better. We would be prepared to compromise to use bright sky, which would require increased exposure time, and a proportionate larger allocation of time.

The programme could be completed in two years, with a breakdown as follows:

Period	Time (h)	Mean RA	Moon	Seeing	Transparency
P77	27	17h	grey	0.9	photometric GCS
P77	42	15h	grey	0.9	clear LAS
P77	54	15h	grey	0.9	thin LAS
P78	153	4h	grey	0.9	photometric GCS
P78	62	11h	grey	0.9	clear LAS
P78	81	11h	grey	0.9	thin LAS
P79	27	17h	grey	0.9	photometric GCS
P79	42	15h	grey	0.9	clear LAS
P79	54	15h	grey	0.9	thin LAS
P80	153	14h	grey	0.9	photometric GCS
P80	62	11h	grey	0.9	clear LAS
P80	81	11h	grey	0.9	thin LAS
total	838				

5.1 Time justification:

The calculated exposure times are taken from the OmegaCAM webpage, and are translated to 5σ Vega magnitudes in a 2arcsec aperture for 0.8arcsec seeing, in grey time. For the LAS, $i' = 23.5$, the required integration time is 600s, and for the GCS, $i' = 23.8$, the required integrtion time is 1000s.

6 Data management plan:

We shall 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
- database ingestion of pipeline products
- production of enhanced database-driven products, including federation of VST survey products with UKIDSS surey products
- dissemination via a purpose-built science archive with Virtual Observatory services using IVOA standards
- delivery of survey products to the ESO/STECF Science Archive Facility (SAF)

The VDFS is a systems-engineered project that is being employed for the UKIRT WFCAM and VISTA infrared surveys that are complementary to VST public surveys in the optical, and is sufficiently flexible to be applicable to any imaging survey project requiring an end-to-end (instrument to end-user) data management system.

The pipeline processing component of the VDFS has been scientifically verified by processing wide field mosaic imaging data using a range of existing CCD mosaic cameras e.g. ESO WFI, CFHT 12K and MegaCam, CTIO Mosaic, KPNO Mosaic, AAO WFI, INT WFC, and WHT PFC. It has also been used to process ESO ISAAC data e.g. the FIRES survey data, and recent commissioning data from UKIRT WFCAM.

6.1 Team members:

Name	Function	Affiliation	Country
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S. Warren (UKIDSS Survey Scientist)	Coordination	Imperial College, University of London	UK
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M. Read (VDFS team)	User Interface Design	University of Edinburgh	UK
E. Sutorius (VDFS team)	Archive Operations	University of Edinburgh	UK
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6.2 Detailed responsibilities of the team:

see Table above

6.3 Data reduction plan:

Following VDFS, 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, and 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.

6.3.1 Pipeline processing

The VDFS pipeline shall be used for all processing. This includes the following processing steps but is a modular design so that extra steps are easily added. All the steps have been tested on a range of input datasets.

- instrumental signature removal – bias, non-linearity, dark, flat, fringe, cross-talk
- sky background tracking and removal during image stacking – possible need to also remove other 2D background variations from imperfect multi-sector operation of detectors
- define and produce a strategy for dealing with image persistence from preceding exposures
- combine frames if part of an observed dither sequence or tile pattern
- consistent internal photometric calibration to put observations on an approximately uniform system
- basic catalogue generation including astrometric, photometric, shape and Data Quality Control (DQC) information
- final astrometric calibration from the catalogue with an updated World Coordinate System (WCS) in all FITS headers
- basic photometric calibration from catalogue using suitable pre-selected standard areas covering entire field-of-view to monitor and control systematics

- each frame 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 header

6.3.2 Science archiving

The concept of the science archive (Hambly et al. 2004 and references therein) is key to the successful exploitation of wide field imaging survey datasets. The science archive ingests the products of pipeline processing (instrumentally corrected images, derived source catalogues, and all associated metadata) into a database. Furthermore — and this is the critical point — the science archive system 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 programme. 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 relational model is applicable to any imaging survey project, and provides an easy-to-use science-ready data resource for the community scientist in the form of a seamless, merged multi-colour multi-epoch source catalogue.

6.4 Expected data products:

6.4.1 Pipeline products (provided to ESO–SAF)

- Instrumentally corrected frames along with header descriptors propagated from the instrument and processing steps (science frames and calibration frames);
- statistical confidence maps for each frame

- stacked 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

6.4.2 Archive

- 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:

- T0: Start of observations
- T0+4months; Public release of science products from first month of survey observations
- T0+8month; Public release of science products from first 6 months of survey observations
- Thereafter we would hope that science products can be released to the ESO community within 1-2 months of raw data arriving in the UK.
- Optional reprocessing of data based on improved knowledge of instrument would also be considered.

References: **1.** Emerson J.P. et al., 2004, "VISTA data flow system: overview", in Optimizing scientific return for astronomy through information technologies, eds. P.J. Quinn & A. Bridger, Proc. SPIE, vol. 5493, 401 **2.** Irwin M.J. et al., 2004, "VISTA data flow system: pipeline processing from WFCAM and VISTA", in Optimizing scientific return for astronomy through information technologies, eds. P.J. Quinn & A. Bridger, Proc. SPIE, vol. 5493, 411 **2.** Hambly N.C. et al., 2004, "VISTA data flow system: survey access and curation; the WFCAM science archive", in Optimizing scientific return for astronomy through information technologies, eds. P.J. Quinn & A. Bridger, Proc. SPIE, vol. 5493, 423

7 Envisaged follow-up:

We will provide the processed i' imaging requested here in the same manner as the remainder of UKIDSS, without any proprietary period for the UKIDSS consortium. In the same spirit, to allow equal opportunity to all ESO astronomers, we make no request for VLT guaranteed time for exploitation of the data.

8 Other remarks, if any:

We have based our proposal on the sensitivity figures provided by the Omega-CAM consortium, in particular the sensitivity of the i' band relative to the Z band. For the LAS part of the proposal we wish to retain the option to switch from i' to Z should the actual sensitivities achieved in the two bands prove substantially different, and dictate that this is the most efficient filter for achieving our science goals.