1 Title: VISTA VARIABLES IN THE VIA LACTEA

PI: D. Minniti, Univ. Catolica, Chile
CoPI: Phil Lucas, Univ. Hertfordshire, UK

1.1 Abstract - from proposal

We propose a public IR variability survey of the Milky Way bulge and an adjacent section of the mid-plane where star formation activity is high. This would take 1920 hours, covering $\sim 10^9$ point sources within an area of 520 sq deg, including 33 known globular clusters and $\sim$ 350 open clusters. The final products will be a deep IR atlas in 5 passbands and a catalogue of $\sim 10^6$ variable point sources. These will produce a 3-D map of the surveyed region (unlike single-epoch surveys that only give 2-D maps) using well-understood primary distance indicators such as RR Lyrae stars. It will yield important information on the ages of the populations. The observations will be combined with data from MACHO, OGLE, EROS, VST, SPITZER, HST, CHANDRA, INTEGRAL, and ALMA for a complete understanding of the variable sources in the inner Milky Way. Several important implications for the history of the Milky Way, for globular cluster evolution, for the population census of the bulge and center, and for pulsation theory would follow from this survey.

2 Survey Observing Strategy

According to the latest VISTA dimensions of 1.475×1.017 deg available at http://www.vista.ac.uk, 20×11=220 tiles are needed to map the proposed bulge area, and 38×4=152 tiles for the disk. Adding some X and Y overlap (1 arcmin = 0.017 deg) between tiles for a smooth match among them, our unit tile covered twice is 1.458×1.00=1.458 sq deg. The bulge survey area is then covered by 20×11 tiles mapping 20×16 = 320.8 sq deg with tiles of Δl×Δb= 1.0deg×1.458 deg. Similarly, the plane region is now covered by 38×4 tiles mapping 55.4×4 =221.6 sq deg in the plane with tiles of Δl×Δb=1.458deg×1.0 deg.

Figure 1 (created using the development version of the SADT) shows the idea of the tiling. The detail of this figure should be ignored however as although the tiles cover the right area their number is wrong. This is because it was not made with the currently favoured tile spacing or orientation. A revised version of the plot will be generated when a released version of SADT is available.

Figure 2 shows the coverage map of the Galactic Centre.

2.1 Scheduling Requirements

The total estimated observing time per Period is shown in Table 1 which also shows the requirements on Moon, seeing and transparency conditions.

Table 1: Estimated observing time

Period	Time (h)	Mean RA	Moon	Seeing	Transparency
P81	292	12:00–19:00 h	any	0.8	clear
P83	292	12:00–19:00 h	any	0.8	clear
P85	652	12:00–19:00 h	any	any	thin
P87	525	12:00–19:00 h	any	any	thin
P89	168	12:00–19:00 h	any	0.8	clear
Total	1929				

The times in Table 1 include overheads (both for readout and for changing to a new tile) and time spent on standard stars for the Z, Y observations.

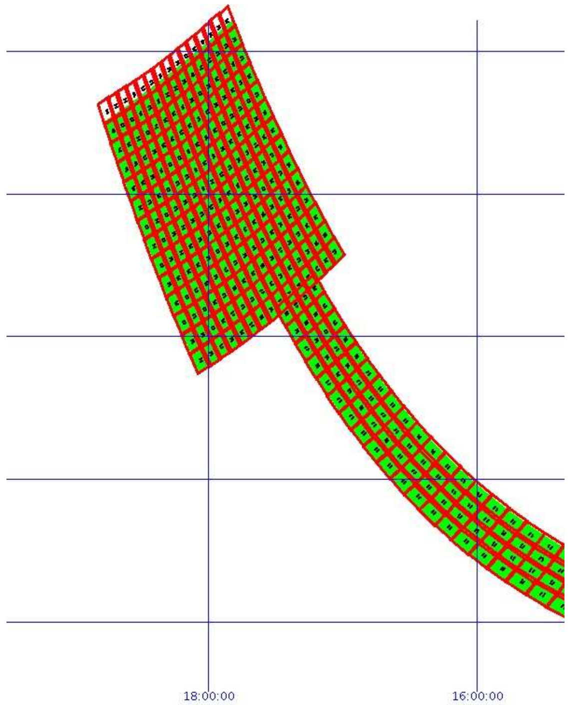


Figure 1: Map of the inner Via Lactea/Milky Way showing the VVV survey area covered by the VISTA tiles: the VVV bulge survey area between $-10° < l < 10°$ and $-10° < b < 5°$, and the VVV plane survey area between $-10° < l < -65°$ and $-2° < b < 2°$. The detail of this figure should be ignored as although the tiles cover the right area their number is wrong, because it was not made with the currently favoured tile spacing or orientation.

During the **first year (P81 - 2008)** the whole 220 tile bulge area will be observed for 6 consecutive epochs. Since the 220 tiles can be covered on 10.86 hours (Fig. 3) this will take 65 hours in total. If the observations are carried on in June, this will correspond approximately to 6.5 nights, otherwise it can take slightly longer.

The following 86 hours will be devoted to complete imaging of each bulge tile through the $ZYJHK_s$ filters in turn (i.e. quasi-simultaneously in the same OB), before moving to the next tile. This will provide reliable near-simultaneous fluxes and colours for each tile area. The observing parameters for the quasi-simultaneous multi colour bulge survey are given in Fig. 4. The estimated 86 hours include 1.5 hours per night (i.e., $8 \times 1.5 = 12$ hours) to adquire standard stars in Z, Y at the beginning, middle and end of each night.

The identical strategy will be repeated for the 152 tiles covering the disk area with the observing parameters given in Fig. 4 for the single epoch (thus 6 epochs require $6 \times 7.5 = 45$ hours) and Fig. 5 for the quasi-simultaneous multi colour disk survey (adding 1.5 hours per night for standard stars this makes 96 hours). The total time spent on the disk for the first year is thus 141 hours. Summed to the 151 (65+86) hours for the bulge, we require 292 hours in total during the first year.

Note that the individual single epoch OBs in K_s all have the same limiting depth (in the same conditions), whether forming part of the Bulge or Disk components of VVV. Figs. 5 (Bulge) and 6 (Disk) differ only in the number and phasing epochs.

Being fully aware of the confusion and background limits, the observing plan would circle alternatively through fields of varying density for optimal sky subtraction. The filter order in the OBs will be optimized to minimize the overheads.

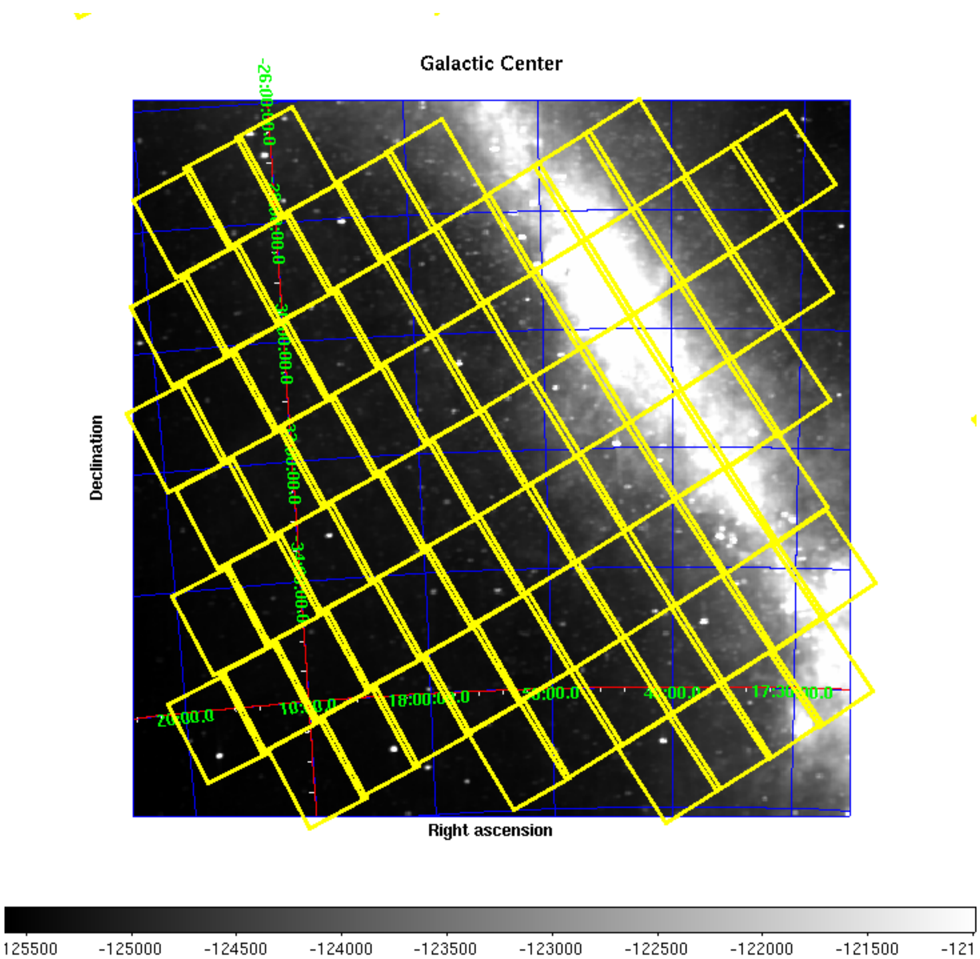


Figure 2: Coverage of the Galactic center region overlayed on the mid-IR all-sky map.

During the **second year (P83 - 2009)** we will acquire another 20 epochs in K_s for the whole bulge ($20 \times 10.86 = 217$ hours) and 10 for the plane ($10 \times 7.5 = 75$ hours), for a total of 292 hours. These extra epochs will improve our ability to detect variable sources (but will not permit finding the phase). These data will also allow the creation of deeper master maps in K_s, in order to fine tune the strategy for the main campaign of the following year.

During the **third year (P85 - 2010)** the main bulge variability campaign of 60 epochs is carried out during $60 \times 10.86 = 652$ hours. According to the PSP requirement, only 40 nights can be consecutive, while the others will be spread over the bulge season. We will use the K_s band to map the whole bulge and inner plane.

During the **fourth year (P87 - 2011)** the main Galactic plane variability campaign is carried out over 70 epochs using $70 \times 7.5 = 525$ hours in K_s, following a similar strategy as in the case of the bulge in the previous year. According to the PSP requirement, only part of these observations can be carried on over 27 consecutive nights.

Finally, during the **fifth year (P89 - 2012)** we will acquire 12 more epochs for the bulge and 5 more for the disk, with observations spread over the season taking a total of $12 \times 10.86 = 130$ and $5 \times 7.5 = 38$ nights, respectively. This allows the measurement of longer-timescale variables, and the search for high-proper motion objects.

At the first submission of the VVV project, when the telescope overheads were not known and thus not accounted

Table 2: 1st-2nd-3rd-4th-5th Yr Variability VVV Fields

Depth, DIT and NDIT etc. will be as in the 1st year. Only the observing time needed for the K_s tiles is listed below.					
Year	Region	Elapsed time/tile (s)	Tiles	Epochs	Total (hr)
1st	bulge	161.7	220	6	151
1st	plane	161.7	152	6	141
2nd	bulge	161.7	220	20	217
2nd	plane	161.7	152	10	75
3nd	bulge	161.7	220	60	652
4nd	plane	161.7	152	70	525
5th	bulge	161.7	220	12	130
5th	plane	161.7	152	5	38

for in our estimations, we had included repeated observations of a few selected fields (open clusters, globular clusters, Baade-like windows, Galactic centre, etc.) over a short timescale (i.e., 10-40 times per night) during the fifth year. These observations would allow us to find short period variables, planetary transits (free floating planets) and microlensing events. Thus, the originally estimated 1920 hours needed to complete the present survey included these observations. Now that overheads have been added, to stay in the approved 1920 hours we had to drop these observations thus exclude this scientific goal from our list. Even if with lower priority with respect to the RR Lyrae, we still consider the search for planets and microlensing events to be scientifically valuable, and relatively cheap to include in the present survey. It would only require to increas by ~ 10 nights the approved time, and these fast repeated observations could be carried on during the fifth year. Obviously, the PSP and ESO will decide whether such observations are scientifically worthwhile.

We also envisage starting the survey with a period of VVV Science Verification during which we will verify the observing strategy, OBs, data reduction, and if necessary refine these to optimize the data and the efficiency of acquiring it. We have not included this time here.

2.2 Observing Requirements

Figs. 5 and 6 show the spreadsheet used to generate the total observing times needed for years 1-5, for bulge and disk, respectively. We have already included readout and acquisition overhead, thus the worst case scenario should not be much different than the present estimation. In any case, slight change in the observing efficiency will result in a slight increase/decrese of the number of epochs taken during the 3rd, 4th and 5th year.

3 Survey Data Calibration Needs

3.1 Detector characteristics

Standard sequences of dark/bias frames, twilight and dome flatfields, and also linearity, bad pixel maps, cross-talk and gain calibrations will be needed in order to remove the instrumental signatures. Twilight skyflats will be used in preference to dark-sky flats which can be influenced by thermal emission and fringing (probably at very low levels). The preliminary detailed observatory calibration plan appears to cover the majority of the requirements of this survey.

3.2 Photometry

3.2.1 External photometric calibration

For external photometric calibration, the VVV Survey in principle does not need to be supported by standard field observations outside the survey, except during the ZYJHK_s campaign in year 1 for which standard stars will be observed at the beginning, middle and end of the nights. According to the VVV observing strategy only one filter (K_s) per single night will be used during the variability campaigns.

During the first period of the survey (P81) we applied for clear time and good seeing. During this period we will make the external calibrations and transformations to the standard system using 2MASS and UKIDSS as described in the draft VISTA Calibration Plan.

In the case of exposures only in one filter during the whole night, the calibration scheme for a single star in every particular filter is:

$$m_{\rm cal} = m_{\rm inst} + ZP - k(X-1) = m_{\rm std} + clr_{\rm std}$$

where $m_{\rm cal}$ is the calibrated magnitude, $m_{\rm inst}$ is the measured instrumental magnitude, ZP is zero point, k is the extinction coefficient, X is the airmass of the object. From the right side of this equation $m_{\rm std}$ and $clr_{\rm std}$ are the corresponding standard magnitude and color. This assumes that the second-order extinction term and color dependency of X are both negligible. An overall zeropoint for a given frame will be obtained by averaging the zeropoints for every standard star.

The photometric calibration and quality control is done using 2MASS stars in the frames themselves, applying color equations to convert 2MASS photometry to the VISTA photometric system. There will be hundreds of unsaturated 2MASS stars in J, H, K_s with photometric errors < 0.1 mag and quality flags of "AAA" in every chip of VISTA. A large fraction of these can be sufficiently isolated even in the crowded fields. One possible source of errors is the difference between transmission curves of J filter in both systems, but the latest results of UKIRT WFCAM shows that the RMS scatter of 600 measurements of 46 standard stars, measured in 19 nights is less than 2%. For the Z, Y filters we recommend that some of the VISTA standard fields overlap with those of UKIRT WFCAM, and we will complement these data with observations at other telescopes if necessary.

3.2.2 Internal photometric accuracy

The internal gain-correction in all detectors applied by the flatfield should place them on a common zeropoint system. After deriving this ZP in each tile, a double check using the overlap regions will be made to estimate the internal photometric accuracy. The median offset of stellar-like objects will be computed for each overlap region and if there is some visible trend all measurements will be put on the same system. Because we can compare the measurements only at the edges of each detector, this probably will overestimate the internal errors of the final photometry. This cross-calibration using overlaps between tiles will be used to improve our photometric solution and bring all survey data onto a common survey-wide flux scale.

3.3 Astrometry

Astrometric calibration will be achieved using the numerous unsaturated 2MASS point sources available in each field. Usually, astrometric calibration incorporates a cubic radial distortion term, but higher order terms can be used if needed, i.e. where the relation between $r_{\rm true}$, the true on-sky angular distance from the optical axis, and r, the distance measured in a VISTA image, takes the form:

$$r_{\rm true} = k_1 r + k_3 r^3 + k_5 r^5 + \ldots$$

where k_1 is the scale at the center of the field. The solution of this equation together with a linear "plate" constant solution of each chip

$$x' = ax + by + c; \quad y' = dx + ey + f$$

gives astrometric residuals over the whole field better than 100 mas comparable with the global systematic residual in the 2MASS point source catalog.

The first results of UKIRT Infrared Deep Sky Survey and WFCAM show that the constant k_3 has a small wavelength dependence and that the higher order distortion terms are insignificant, compared to absolute systematic accuracy of 100 mas. For VISTA the wavelength dependence and higher order terms are expected to be negligible.

4 Data Reduction Process

We will use an enhanced VISTA Data Flow System (VDFS; Emerson et al. 2004, Proc SPIE, 5493, 401; Irwin et al 2004, Proc SPIE, 5493, 411; Hambly et al 2004, Proc SPIE, 5493, 423). It will meet all basic data processing and management requirements of our survey once extraction of variables from difference images has been implemented:

(i) removing instrumental signature, merging pawprints into tiles and calibrating photometrically and astrometrically;

(ii) extracting source catalogs on a tile by tile basis;

(iii) constructing survey level products - stacked pixel mosaics, difference images and merged catalogs;

(iv) providing the team with both data access and methods for querying and analyzing the data;

(v) producing VO compliant data products for delivery to the ESO archive

Next, we discuss the individual data processing/reduction steps, to the extent to which the properties of VISTA are currently known.

Figure 7 shows a flow chart of the Data Processing.

4.1 Removing the instrument signature, quality control and calibration (Pipeline)

The Cambridge Astronomy Survey Unit (CASU) component of the VDFS will be responsible for the basic pipeline processing and first pass calibration, all done on daily basis. The VISTA pipeline is a modular design allowing straightforward addition or removal of processing stages and has been tested on various datasets. The basic correction includes:

(i) linearity correction: the WFCAM non-linearity is better than 1% and therefore there is no correction for non-linearity. A correction will be implemented for VISTA although our science goals are related to faint targets so the linearity is not critical.

(ii) dark/bias will be taken daily for all exposure times and readout modes

(iii) electronic effects such as odd-even column effect, quasi periodic structures, etc. Their presence will be studied in detail in the future and if necessary, appropriate corrections will be included in the pipeline.

(iv) cross-talk between individual array readout channels is present in almost all infrared instruments. Unfortunately, jittering can not remove the artifacts because they are always separated from the source that produced them by a constant offset. If possible VDFS will remove any cross talk effects (which will be possible if the detector behaviour is sufficiently stable), and in any case these will be flagged using the detector properties.

(v) persistence is a detector "memory" preserving the knowledge that a bright star was present on a certain array location over a few subsequent images. Unfortunately, bright stars are common in our fields. Fortunately, it is possible to predict where persistence may occur from previous images, and any remnant persistence after jitters mimics an extended source while our project is aimed at point sources. Persistence can still affect our photometric accuracy, therefore we will vary the order in which tiles are observed during the variability campaign, where possible. The importance of persistence in VISTA data will not be known until the instrument is on sky, but VDFS has a method to remove persistence, subject to its characteristics being sufficiently reproducible (stable), and can also flag possible persistence events. (WFCAM's persistence is not sufficiently stable that it can be compleltely removed, but it is hoped that the situation with VISTA will be better).

(vi) flat fielding: the WFCAM experience shows that weekly twilight sky flats taken in 9-point jitter sequence are sufficient to provide 1% level correction. Ideally, the sky flats will be taken alternating filters every day as necessary to obtain flats for all bands during each week.

(vii) sky subtraction: perhaps this is the most important of the basic corrections steps because of the large (and variable on time scale of minutes!) sky background, in comparison with the targets. We will use the data itself to create a sky frame and then we will subtract it from the individual frames after rescaling to the sky level of the frame. The WFCAM experience shows that the residual gradients are below 1%. Some of our fields will be very crowded and to improve the sky subtraction will use priorities and/or concatenation to try to ensure that each night also contains some uncrowded fields for creating skies. We hope to avoid having to observe offset skies, but will keep the possibility under review when we see the real data.

(viii) Last but not least, the pipeline produces instrument corrected astrometrically and photometrically calibrated tiles (with calibration information included in the image headers), extracts object catalogues from these, and updates a database which facilitates monitoring of selected quality control parameters (i.e. seeing, ellipticity of stellar images, sky brightness and noise, zero point and extinction trends e.g. http://casu.ast.cam.ac.uk/survey-progress/wfcam). The WFCAM experience shows that the external astrometric accuracy is of order 100 mas, and the internal one is about 50 mas. The typical photometric accuracy is at the 2% level. VISTA should be at least as good.

The pipeline products are: corrected astrometrically and photometrically calibrated tiles in each filter used, confidence maps and homogeneous object catalogs (merged for all filters if observed in same OB (each covering just one tile area). The pipeline records the processing history and calibration information of each file in the FITS header, including calibration files and quality control parameters.

The contact person responsible for the interaction with the pipeline team is V.D. Ivanov (ESO).

4.2 Combination/image subtraction (archive)

The "second" order data processing requires higher access to larger sets of data to produce survey products. It is carried in the Wide Field Astronomy Unit's (WFAU) VISTA Science Archive (VSA) in Edinburgh. The Science Archive contains only calibrated data and catalogs, it does not contain any raw data.

The Science Archive is responsible for:

(i) image stacking to produce stacked and differenced tiles, and source merging: obviously, in the case of the VVV the same field will be observed more then once. This implies a capability to merge both tiles and catalogs derived from different tiles in the same area. Naturally, these procedures can not be implemented by the pipeline which at any time operates only on data from a given night. Therefore both coadding and differencing combination is performed at the Science Archive where the combining tools have access to all multi-epoch data. The VDFS stacking and merging are described in Irwin et al. (2007, in prep) and Hambly et al. (2007, in prep). This "post-processing" allows to facilitate complex requirements such as measuring upper limits for an object detected in some bands for all other bands in which this object was not detected or selection of objects from multi-color criteria, in cases where the imaging in the different filters was carried out at different times.

(ii) Quality Control (QC): assessment of the data quality and filtering of the data that do not meet the established criteria for photometric and astrometric accuracy. The multiple epochs of our VVV Survey naturally allows quality control by internal comparison. External comparisons (e.g. 2MASS) will also be used for quality control and calibration in the appropriate filters.

(iii) Identification of Variables

Very importantly, the Archive can carry out the image subtraction analysis that will allow us to create the catalog of variable sources and to derive their light curves. The image subtraction part of the analysis will be also be implemented at Hertfordshire UK and at PUC in Chile. If everything works fine at the Archive, these facilities will only be used to perform a more detailed analysis of a few specific fields (e.g., star clusters, the galactic centre, etc). However, they will serve as backup plan to run the analysis of the full area should the Archive have difficulties to cope with the huge data load.

The variability detection via image subtraction will be carried out only after a sufficient data is acquired and the timing is described in Sec. 2. The basic principle of the differential image subtraction is simple: given a set of images of the same field, the best seeing image is degraded to the quality of each of the other images and subtracted from them (Alard 2000, A&ASuppl., 144, 363; Alard & Lupton 1998, ApJ, 503, 325). Ideally, all constant sources cancel out and the variable sources appear as quasi-stellar positive or negative images. This method provides excellent results for crowded fields in which the traditional aperture or PSF-fitting photometry fails because of the contamination from the nearby sources. Our survey will benefit tremendously from the differential image analysis, in comparison with the direct source photometry. VDFS already has already implemented the differencing, which is being tested on WFCAM data. Further VDFS development to extract variables from the difference images is underway and should be completed (and tested on WFCAM data) before the VVV survey begins.

Direct point source photometry will also be performed for the first years data in all filters to be used as reference.

Our project will tap into both the VDFS team experience handling the WFCAM/UKIRT and VISTA data, and the experience of the VVV team members who are leading participants in other surveys such as OGLE and in the routine data processing and delivery to ESO.

Our experts on the variability detection are D. Minniti, M. Catelan (Univ. de Catolica, Santiago) J. Borissova (Univ. de Valparaiso) and M. Rejkuba (ESO). They will interact with the Archive unit for the implementation of the procedure.

Note that there will be no real-time alerts for microlensing, these would be detected in the post-processing data.

4.3 Variability and Other Analysis

4.3.1 Variability

The members of the team in Chile will carry out the final analysis: variability studies, including light curves fitting, period determination, source identification/classification. etc.

The steps here are:

(i) Variable selection according to robust criteria.

(ii) Preliminary variable classification (using peak to peak amplitudes, color-magnitude diagrams, color-color diagrams, etc.).

(iii) Period determination for periodic objects (roughly half of the variable objects are expected to be periodic according the experience of the microlensing databases, the rest are not periodic or transients or fluctuations in the data).

(iv) Light curve fitting where appropriate.

4.3.2 Other

Members of the team in Europe will take the lead in cross checking and combining the data with other large datasets. The datasets are UKIDSS GPS (near IR), VST/VPHAS+ (optical) and GLIMPSE and GLIMPSE-II (mid-IR). This will lead to:

(i) improved extinction maps for the survey region.

(ii) determination of most likely spectral type and luminosity class for all stars detected in multiple wavebands.

(iii) identification and classification of Young Stellar Objects.

5 Manpower and hardware capabilities devoted to data reduction and quality assessment

5.1 VDFS manpower and hardware

As already described we will use the VISTA Data Flow System (VDFS) for all aspects of data management, including: pipeline processing and management; delivery of agreed data products to the ESO Science Archive by internet transfer.

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 team at CASU (pipeline) consists of Irwin, Lewis, Hodgkin, Evans, Bunclark, Gonzales-Solares, Riello, and at WFAU (archive) of Hambly, Bryant, Collins, Cross, Read, Sutorius, Williams, with overall VDFS coordination by Emerson. The VDFS is a working 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 as to be applicable to any imaging survey project requiring an end-to-end (instrument to end-user) data management system. We emphasize 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*; Dye et al 2006, MNRAS 372, 1227) and Data Release 1 (DR1 Warren et al 2007 MNRAS 375, 213).

The VDFS pipeline and archive teams each have, by design, appropriate hardware to handle VISTA data and products, as verified by success in handling the (similar type) WFCAM data. The VDFS Science Archive uses a commercial relational database management system for creating imaging and catalog products on-demand via web interface applications that provide access to the database through Structured Query Language (SQL) queries.

The two VDFS Units (CASU & WFAU) are funded by long term 'rolling' grants and were built up specially to handle VISTA data, using WFCAM data as a real test bed.

5.2 Other manpower and hardware

The VVV survey team involves astronomers of Chilean institutions, of the European Southern Observatory, and of many of its member nations, in addition to the UK VDFS. Our Chilean team includes experienced members from the microlensing surveys (OGLE, MACHO, EROS), as well as staff ESO members experienced in all aspects of IR imaging and instrumentation. Since we submitted the VVV Survey proposal to the PSP our Chilean FONDAP project was renewed - FONDAP is a national Chilean project with substantial funding -. The VVV Survey proposal was one of the big components for the next 5 years of funding request. We requested funding for hardware (computers, database, infrastructure), and for manpower (postdocs and students). The funding was approved, and we have already hired a postdoc (Dr. P. Pietrukowicz) who wil be 100% dedicated to the VVV. Another independent national funding project (BASAL) has just been approved for 5 years, renewable for longer. Finally, we have applied for a third one (*Nucleo Milenio*) entirely dedicated to the VVV.

With these new means that became available to us after the VVV was approved, we will count on the following, fully dedicated, people:

- (at least) 6 postdocs: 2 at PUC (Dr. Pietrukowicz + another one from the new BASAL funding); 1 at UV; 1 at UdeC; 1 at Hertfordshire hired by PL and another one at the IAC hired by E. Martin.
- 8 dedicated PhD students: 2 at PUC, 2 at UV, 1 at UdeC and another one at La Serena.

This makes already 6+8=14 FTE per year, i.e., 70 FTE for 5 years. Obviously, each postdoc contract will not last as long, but the funding we have are long term ones, thus we will be able to hire new people in 2-3 years. In addition to these 70 FTEs, one has to add the contribution to the all the people listed in Table 3 and its continuation Table 4. It is true that most of them will dedicate to the VVV only a small fraction of their time, but they are key persons in their institutions, and will be crucial to apply for funding and hire manpower (see also Section 5.3).

Our European team members also have extensive experience of large surveys (IPHAS, UKIDSS, SuperCosmos). At Hertfordshire there is a concentration of VISTA and UKIDSS PIs and co-PIs (VIDEO, VMC, VVV, UKIDSS GPS), so we plan to submit joint proposals to the UK funding body (PPARC) for postdoc funding to assist with quality control as well as science analysis. At Hertfordshire there is already a UKIDSS postdoc (Burningham) who will devote part of his time to VISTA support in future. We have capable people in charge of the data reduction, pipeline, photometry, astrometry, database, light curves, and simulations.

5.3 Detailed responsibilities of the team:

We have created a web page that will be regularly updated with information on the VVV survey progress. In the same page (http://www2.astro.puc.cl/VVV) we have included a committment statement about each Team memeber. We report here just a summary of the main responsibilities.

DM and PL will manage and be involved in all aspects of the project, as will JE for the VDFS. They will hold regular telecons, or meetings, including other key team members as appropriate, to review VVV progress and to negotiate the assignment of tasks to team members as necessary and generally manage the survey in response to actual performance, rate of progress and events.

As described in the next section there will a 5-10 member Quality Control Team from which, at any one time, there will always be (at least) one 'duty' member monitoring the VDFS products and processing. This is in the steady state - naturally early in the survey there will be an even more intense level of effort required from the team.

VI, MZ and MC will help deciding the data taking strategy and scientific priorities. VI and RB will lead the OBs preparations efforts, aided by RG, JB, IS, LM, RK, GC & JE.

All members of the collaboration will be involved in the photometry led by GP and DG (including DIA photometry), and will support MR, AS, MM in making the Monte-Carlo simulations to compute detailed photometric and sampling efficiencies. The astrometry will be carried out by GC, LM and MTR. RM and WG will decide on variability and phasing criteria, along with AA, JJC, BB, FM. LM and EB will take charge of creating the variability catalogue, including LK, GC, CT, AS, CP, GB.

6 Data quality assessment process

The team realizes the importance of the timely quality control process, especially considering how important any long-term trends will be for our variability analysis. Therefore, we will form a QC team, that will include 5-10 VVV team members that will exercise routine QC. The QC duty will be distributed among the QC team on a weekly basis - the "QC duty officer" will:

(i) check master frames used

(ii) check random reduced tiles logging in the VDFS VISTA Science Archive. The exact number of tiles will be determined by the frequency with which problems occur during the first year of the survey and the verification rate will be adjusted during the following years. We select a pipeline reduced tile to be the a basic QC element for our Survey because the raw data contain strong instrument signatures (i.e. gradients and patterns before

[1] Designated contact overall with VDFS Management
[2] Designated contact with VDFS pipeline (Cambridge)
[3] Designated contact with VDFS archive (Edinburgh)

Table 3: VVV Team members

Name	Function	Affiliation	Country
Dante Minniti[1]	PI, photometry, light curves, bulge	Univ Catolica	RCH
Phil Lucas	Co-PI, photometry, plane	Univ Hertfordshire	UK
Manuela Zoccali	Photometry, analysis, bulge	Univ Católica (PUC)	RCH
Marcio Catelan[2]	Theory, light curves, bulge	Univ Católica (PUC)	RCH
Lorenzo Morelli	Astrometry, light curves, bulge	Univ Católica (PUC)	RCH
Claus Tappert	Photometry, light curves, bulge	Univ Católica (PUC)	RCH
Giuliano Pignata	Pipeline, astrometry, bulge	Univ Católica (PUC)	RCH
Ignacio Toledo	Pipeline, astrometry, bulge	Univ Católica (PUC)	RCH
Maria Teresa Ruiz	Astrometry, photometry, bulge	Univ de Chile (UCh)	RCH
Giovanni Carraro	Astrometry, photometry, bulge	Univ de Chile (UCh)	RCH
Simon Casassus	Astrometry, photometry, bulge	Univ de Chile (UCh)	RCH
Leonardo Bronfman	Astrometry, photometry, bulge	Univ de Chile (UCh)	RCH
Rodolfo Barba	Reductions, Pipeline, bulge	Univ La Serena (LS)	RCH
Roberto Gamen	Reductions, Pipeline, bulge	Univ La Serena (LS)	RCH
Wolfgang Gieren	Photometry, light curves, bulge	Univ Concepción (UdeC)	RCH
Douglas Geisler	Photometry, analysis, bulge	Univ Concepción (UdeC)	RCH
Grzegorz Pietrzynski	Photometry, astrometry, light curves	Univ Concepción (UdeC)	RCH
Ronald Mennickent	Photometry, astrometry, light curves	Univ Concepción (UdeC)	RCH
Radostin Kurtev	Reductions, pipeline, bulge	Univ Valparaiso (UV)	RCH
Jordanka Borissova	OB Prep, photometry, light curves	Univ Valparaiso (UV)	RCH
Valentin Ivanov[3]	OB Prep, Data Quality Control III	ESO	ESO
Felix Mirabel	Photometry, analysis, bulge	ESO	ESO
Ivo Saviane	OB Prep, Pipeline, bulge	ESO	ESO
Leonardo Vanzi	OB Prep, Pipeline, bulge	ESO	ESO
Lorenzo Monaco	OB Prep, Reductions, bulge	ESO	ESO
Marina Rejkuba	Simulations, light curves, bulge	ESO	ESO
Maria Messineo	Simulations, light curves, bulge	ESO	ESO
Luigi Bedin	Astrometry, simulations, bulge	ESO	ESO
Andrew Stephens	Simulations, photometry, bulge	Hawaii	USA
Beatriz Barbuy	Photometry, analysis, bulge	Univ Sao Paulo	Other
Eduardo Bica	Photometry, analysis, bulge	Univ Porto Alegre	Other
Juan Jose Claria	Photometry, analysis, bulge	Univ Cordoba	Other
Andrea Ahumada	Pipeline, photometry, bulge	Univ Cordoba	Other
CASU (VDFS) team	Pipeline Processing	Cambridge Univ	UK
CASU (VDFS) team	Data Quality Control I	Cambridge Univ	UK
WFAU (VDFS) team	Science archive	Edinburgh Univ	UK
WFAU (VDFS) team	Data Quality Control II	Edinburgh Univ	UK
Jim Emerson	OB prep, VDFS Coordinator Bulge & Plane	Queen Mary Univ London	UK
Janet Drew	VPHAS/VVV joint analysis	Imperial College London	UK
Martin Lopez-Correidora	Galactic structure analysis	IAC	Spain
Eduardo Martin	Variability analysis, plane	IAC	Spain
Bertrand Goldman	Cluster analysis, plane	MPIA Heidelberg	Germany
Teresa Giannini	Cluster analysis, plane	Rome Observatory	Italy
Jochem Eisloeffel	VPHAS/VVV joint analysis	Thueringer Landessternwarte	Germany
Paul Groot	VPHAS/VVV joint analysis	Nijmegen Univ	Netherlands
Juan Fabregat	VPHAS/VVV joint analysis	Univ de Valencia	Spain

Table 4: VVV Team members (continued

Name	Function	Affiliation	Country
Ben Burningham	QC and star formation science	Univ Hertfordshire	UK
Andy Longmore	VVV/UKIDSS GPS overlap	Royal Observatory Edinburgh	UK
Nic Walton	VPHAS/VVV combination	Cambridge Univ	UK
Richard de Grijs	Cluster analysis	Sheffield	UK
Melvin Hoare	VVV/mid-IR/radio analysis	Leeds Univ	UK
Anja Schroeder	Galactic structure	Leicester Univ	UK
Tim Naylor	stellar populations	Exeter Univ	UK
Mike Barlow	Evolved stars	Univ College London	UK
Albert Zijlstra	Evolved stars	Manchester Univ	UK
Glenn White	planetary science	Open Univ	UK
Andrew Gosling	VVV/X-ray analysis	Oxford Univ	UK
Katherine McGowan	VVV/γ ray analysis	Southampton Univ	UK
Andy Adamson	VVV/UKIDSS GPS overlap	Joint Astronomy Center	USA
Reba Bendyopadhyay	VVV/X-ray analysis	Univ Florida	USA
Mark Thompson	Galactic structure	Univ Hertfordshire	UK
Mark Cropper	Galactic structure	Mullard Space Science Lab.	UK
John Lucey	Local group structure	Durham Univ	UK
Eammon Kerins	Microlensing science	Liverpool John Moores Univ	UK
Simon Hodgkin	Planetary transits	IoA Cambridge	UK
David Pinfield	Planetary transits	Univ Hertfordshire	UK

the flat fielding) that might mask real artifacts. Our examination aims to discover unusable data due to for example to artifacts and strange patterns produced by the detector, moon ghosts, trailed frames, etc. Some of these have highly irregular pattern and are hard to be detected by the automated tools. Some calibration frames will be also checked. The raw data will be inspected only to trace problems.

(iii) check the behavior of the pipeline and archive calculated QC parameters by generating and inspecting the QC plots from each night. We will pull from the database a number of critical QC parameters such as:

- Our defined constraints on a tile by tile basis - seeing and transparency. For the period P81, P83 and P89 we require on detector seeing ≤ 0.8 and clear conditions, while the P85 and P87 the seeing is not specified.
- Quality of the pipeline reduction - to detect for example frames where the sky subtraction is not satisfactory, frames suffering from extreme bias offsets, etc.
- The ellipticity for all stellar objects will be calculated as a quality control parameter in the pipeline. The measured values should be around or less than 0.1. It is possible to have elongated images, especially at high airmass, these will be removed.
- The limiting magnitude or the depth of the tiles. The expected single epoch limiting magnitude and σ in the Ks band are the same for Bulge and Disk (Figs. 3 and 4). We will not apply any specific depth cuts to the observations, since all frames can contribute the depth in the stack images. But, we are expecting to eliminate a number of frames that are taken in conditions of very bright sky (usually a few percent) in order to keep the quality.
- Photometric zero point. Since we are asking for “clear” and “thin” conditions we will use the computed zero point for each frame, relative to the mean value for the corresponding filter as an indicator of how much cloud extinction is there. Since the goal is to search for variable stars using the image-subtraction method the variation of the photometric zero point should lie within 0.2 mag of the mean value.

- and others as appropriate and necessary

(iv) Report regularly to the rest of the QC team and to the Management team.

7 Data products and VO compliance

The standardised VO compliant data products produced by the VDFS science archive for VVV in Edinburgh will be delivered to ESO by internet transfer, with a copy remaining at the Science Archive in Edinburgh. These are the calibrated tiles and with their associated source catalogues and the higher level merged science products detailed below.

8 Timeline for delivery of data products to the ESO archive

The VVV survey will operate for five years and will finally cover 520 square degree of Milky Way giving new and interesting data to the community.

All the final objectives of the project will be obtained by merging or differencing different modular blocks of observations achieved during each years of the survey. For this reason the schedule of the data products release is mainly defined by the survey observing strategy.

The VDFS team will release the data to the PIs within two months of the raw data arriving in UK. After further work by the survey team, including QC checking, the annual public releases of VVV data products to the ESO Science Archive are expected to occur six months after the end of the VVV observing season.

In detail data products are expected to appear in the ESO science archive with a yearly release as follow:

- **Year 1 + 6 months -** Release of complete tiles of the whole 300 sq deg in the bulge and 220 sq deg in the plane in $ZYJHJK_s$ bands at first survey epoch together with associated merged and unmerged catalogues.
- **Year 2 + 6 months -** Release of complete tiles of the whole 300 sq deg in the bulge and 220 in the plane in K_s band (five epochs : 1 in year 1 and 4 in year 2) together with associated catalogues.
- **Year 3 + 6 months -** Release of the data products of the year 3 variability campaign in the whole 300 sq deg in the bulge. This will comprise K_s band tiles, a merged catalogue with fluxes from all epochs and a list of likely variables.
- **Year 4 + 6 months -** Release of the data products of the P87 variability campaign in the whole 220 sq deg in the main plane. This will comprise K_s band tiles, a merged catalogue with fluxes from all epochs and a list of likely variables.
- **Year 5 + 6 months -** Release of the data products for long timescale (months) and very short (hours) variability. Release of proper motion catalogue, and an updated merged catalogue of fluxes. Release of stacked K_s tiles using the multiple epochs over 5 years, and single band source catalogues.
- **Year 5 + 18 months -** Release of final variability catalogue with identification of periodic variables and phasing.

The completeness of the coverage in the whole planned observing area is key for meeting the finals aim of the variability survey. If after the planned five years survey the coverage is incomplete due to scheduling or weather we would propose to extend the survey for an additional year in order to complete the observations and meet all the proposed objectives.

VVV-Bulge	**Ks**	**Ks**	**Ks**	**Ks**	**Ks**
Time & depth on sky in coadded Tiles	**yr1**	**yr2**	**yr3**	**yr4**	**yr5**
Vega or AB mags?	Vega	Vega	Vega	Vega	Vega
Depth (mag) required	18.0	18.0	18.0	18.0	18.0
Sigma required	3.0	3.0	3.0	3.0	3.0
Assumptions					
SED assumed in using ETC	BB5000K	BB5000K	BB5000K	BB5000K	BB5000K
Aperture assumed in ETC - arcsec	2.4	2.4	2.4	2.4	2.4
In band sky brightness assumed - Vega mag/arcsec	13.0	13.0	13.0	13.0	13.0
Airmass assumed in ETC	1.2	1.2	1.2	1.2	1.2
In band on-chip image size assumed in ETC - arcsec	0.8	0.8	0.8	0.8	0.8
Extra extinction assumed in ETC	0.08	0.08	0.08	0.08	0.08
Detector Integration Time (DIT) sec used in ETC	4	4	4	4	4
N.B. the DIT assumed will affect the number of seconds to reach a specified depth, because it affects the amount of read noise.					
Time (sec) required per object assuming above values	16	16	16	16	16
Area required sq. deg	300	300	300	300	300
Tiles required to cover area(s)	220	220	220	220	220
effective useful sq deg/tile	1.36	1.36	1.36	1.36	1.36
Assign priorities to different areas?	None	None	None	None	None
Single Tile Strategy					
Parameters set					
DIT already assumed above	4	4	4	4	4
Ndit - # of Exposure coadds	1	1	1	1	1
Nexp # of Exposure loops	1	1	1	1	1
Nmicro- # of microstep positions (steps <3 arcsec)	1	1	1	1	1
Njitter - # of Jitter positions (steps odd # of 0.5 pixels < 30 arcsec)	2	2	2	2	2
Npaw - # of Pawprints in tile	6	6	6	6	6
Observe tile in same OB how many times?	1	1	1	1	1
Number of filters in same OB? If >1 which other?	1	1	1	1	1
Number of tile positions in same OB?	1	1	1	1	1
Resulting values					
Total Exposure sec/tile	48	48	48	48	48
Total Elapsed sec/tile	161.7	161.7	161.7	161.7	161.7
Total Elapsed mins/tile	2.7	2.7	2.7	2.7	2.7
Observing efficiency %/tile	29.7	29.7	29.7	29.7	29.7
Time per object for s-to-n -single OB	16	16	16	16	16
Signal to noise (at depth required in row 3) - single OB	2.9	2.9	2.9	2.9	2.9
Depth (to sigma in row 4) - single OB	18.0	18.0	18.0	18.0	18.0
Multiple Tile Strategy					
# of Tiles per filter for S/N	1	1	1	1	1
Time links between OBs in same filter on a Tile?	no	no	no	no	no
Priorities between OBs in same filter on a Tile?	no	no	no	no	no
Time links between OBs on a Tile in different filters?	no	no	no	no	no
Priorities between OBs on a Tile in different filters?	no	no	no	no	no
Time links between Tiles by position?	no	no	no	no	no
Priorities between Tiles by position?	no	no	no	no	no
Total Elapsed Hours per filter	**9.9**	**9.9**	**9.9**	**9.9**	**9.9**
Telescope overhead time	0.96	0.96	0.96	0.96	0.96
Total time, with telescope overhead time	**10.86**	**10.86**	**10.86**	**10.86**	**10.86**

Figure 3: Years 1-5 Bulge single epochs

1st year Bulge ZYJHKs	Z	Y	J	H	Ks
Time & depth on sky in coadded Tiles					
Vega or AB mags?	Vega	Vega	Vega	Vega	Vega
Depth (mag) required	21.6	20.9	20.6	19.0	18.0
Sigma required	3.0	3.0	3.0	3.0	3.0
Assumptions					
SED assumed in using ETC	BB5000K	BB5000K	BB5000K	BB5000K	BB5000K
Aperture assumed in ETC - arcsec	2.4	2.4	2.4	2.4	2.4
In band sky brightness assumed - Vega mag/arcsec	18.2	17.2	16.0	14.1	13.0
Airmass assumed in ETC	1.2	1.2	1.2	1.2	1.2
In band on-chip image size assumed in ETC - arcsec	0.8	0.8	0.8	0.8	0.8
Extra extinction assumed in ETC	0.00	0.00	0.00	0.00	0.08
Detector Integration Time (DIT) sec used in ETC	10	10	6	4	4
N.B. the DIT assumed will affect the number of seconds to reach a specified depth, because it affects the amount of read noise.					
Time (sec) required per object assuming above values	40	40	48	16	16
Area required sq. deg	300	300	300	300	300
Tiles required to cover area(s)	220	220	220	220	220
effective useful sq deg/tile	1.36	1.36	1.36	1.36	1.36
Assign priorities to different areas?	None	None	None	None	None
Single Tile Strategy					
Parameters set					
DIT already assumed above	10	10	6	4	4
Ndit - # of Exposure coadds	1	1	2	1	1
Nexp # of Exposure loops	1	1	1	1	1
Nmicro- # of microstep positions (steps <3 arcsec)	1	1	1	1	1
Njitter - # of Jitter positions (steps odd # of 0.5 pixels < 30 arcsec)	2	2	2	2	2
Npaw - # of Pawprints in tile	6	6	6	6	6
Observe tile in same OB how many times?	5	5	5	5	5
Number of filters in same OB? If >1 which other?	ZYJHKs	ZYJHKs	ZYJHKs	ZYJHKs	ZYJHKs
Number of tile positions in same OB?	1	1	1	1	1
Resulting values					
Total Exposure sec/tile	120	120	144	48	48
Total Elapsed sec/tile	233.7	258.7	294.7	186.7	186.7
Total Elapsed mins/tile	3.9	4.3	4.9	3.1	3.1
Observing efficiency %/tile	51.3	46.4	48.9	25.7	25.7
Time per object for s-to-n -single OB	40	40	48	16	16
Signal to noise (at depth required in row 3) - single OB	3.0	2.9	2.9	3.0	2.9
Depth (to sigma in row 4) - single OB	21.6	20.9	20.6	19.0	18.0
Multiple Tile Strategy					
# of Tiles per filter for S/N	1	1	1	1	1
Time links between OBs in same filter on a Tile?	no	no	no	no	no
Priorities between OBs in same filter on a Tile?	no	no	no	no	no
Time links between OBs on a Tile in different filters?	no	no	no	no	no
Priorities between OBs on a Tile in different filters?	no	no	no	no	no
Time links between Tiles by position?	no	no	no	no	no
Priorities between Tiles by position?	no	no	no	no	no
Total Elapsed Hours per filter	**14.3**	**15.8**	**18.0**	**11.4**	**11.4**
Telescope overhead time and filter change	3.0				
Total time, with telescope overhead time, 5 filters 1 OB.	**73.9**				

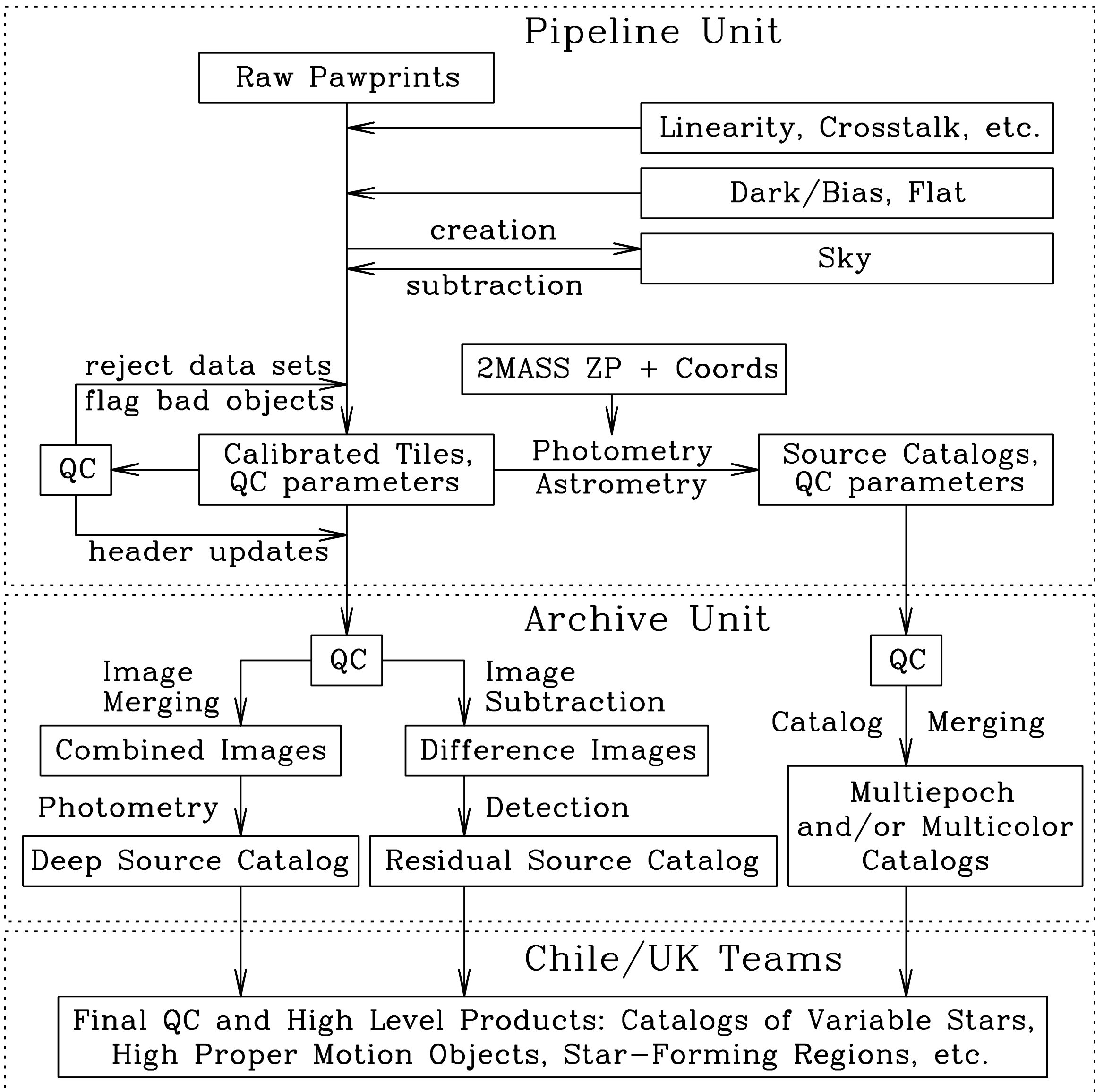
Figure 4: Year 1 Bulge multicolour observations.

VVV-Plane	Ks	Ks	Ks	Ks	Ks
Time & depth on sky in coadded Tiles	**yr1**	**yr2**	**yr3**	**yr4**	**yr5**
Vega or AB mags?	Vega	Vega	Vega	Vega	Vega
Depth (mag) required	18.0	18.0	18.0	18.0	18.0
Sigma required	3.0	3.0	3.0	3.0	3.0
Assumptions					
SED assumed in using ETC	BB5000K	BB5000K	BB5000K	BB5000K	BB5000K
Aperture assumed in ETC - arcsec	2.4	2.4	2.4	2.4	2.4
In band sky brightness assumed - Vega mag/arcsec	13.0	13.0	13.0	13.0	13.0
Airmass assumed in ETC	1.2	1.2	1.2	1.2	1.2
In band on-chip image size assumed in ETC - arcsec	0.8	0.8	0.8	0.8	0.8
Extra extinction assumed in ETC	0.08	0.08	0.08	0.08	0.08
Detector Integration Time (DIT) sec used in ETC	4	4	4	4	4
N.B. the DIT assumed will affect the number of seconds to reach a specified depth, because it affects the amount of read noise.					
Time (sec) required per object assuming above values	16	16	16	16	16
Area required sq. deg	220	220	220	220	220
Tiles required to cover area(s)	152	152	152	152	152
effective useful sq deg/tile	1.45	1.45	1.45	1.45	1.45
Assign priorities to different areas?	None	None	None	None	None
Single Tile Strategy					
Parameters set					
DIT already assumed above	4	4	4	4	4
Ndit - # of Exposure coadds	1	1	1	1	1
Nexp # of Exposure loops	1	1	1	1	1
Nmicro- # of microstep positions (steps <3 arcsec)	1	1	1	1	1
Njitter - # of Jitter positions (steps odd # of 0.5 pixels < 30 arcsec)	2	2	2	2	2
Npaw - # of Pawprints in tile	6	6	6	6	6
Observe tile in same OB how many times?	1	1	1	1	1
Number of filters in same OB? If >1 which other?	1	1	1	1	1
Number of tile positions in same OB?	1	1	1	1	1
Resulting values					
Total Exposure sec/tile	48	48	48	48	48
Total Elapsed sec/tile	161.7	161.7	161.7	161.7	161.7
Total Elapsed mins/tile	2.7	2.7	2.7	2.7	2.7
Observing efficiency %/tile	29.7	29.7	29.7	29.7	29.7
Time per object for s-to-n -single OB	16	16	16	16	16
Signal to noise (at depth required in row 3) - single OB	2.9	2.9	2.9	2.9	2.9
Depth (to sigma in row 4) - single OB	18.0	18.0	18.0	18.0	18.0
Multiple Tile Strategy					
# of Tiles per filter for S/N	1	1	1	1	1
Time links between OBs in same filter on a Tile?	no	no	no	no	no
Priorities between OBs in same filter on a Tile?	no	no	no	no	no
Time links between OBs on a Tile in different filters?	no	no	no	no	no
Priorities between OBs on a Tile in different filters?	no	no	no	no	no
Time links between Tiles by position?	no	no	no	no	no
Priorities between Tiles by position?	no	no	no	no	no
Total Elapsed Hours per filter	**6.8**	**6.8**	**6.8**	**6.8**	**6.8**
Telescope overhead time	0.66	0.66	0.66	0.66	0.66
Total time, with telescope overhead time	**7.46**	**7.46**	**7.46**	**7.46**	**7.46**

Figure 5: Years 1-5 Disk single epochs

1st VVV-Plane ZYJHKs	Z	Y	J	H	Ks
Time & depth on sky in coadded Tiles					
Vega or AB mags?	Vega	Vega	Vega	Vega	Vega
Depth (mag) required	21.5	20.7	20.2	19.3	18.3
Sigma required	5.0	5.0	5.0	5.0	5.0
Assumptions					
SED assumed in using ETC	BB5000K	BB5000K	BB5000K	BB5000K	BB5000K
Aperture assumed in ETC - arcsec	2.4	2.4	2.4	2.4	2.4
In band sky brightness assumed - Vega mag/arcsec	18.2	17.2	16.0	14.1	13.0
Airmass assumed in ETC	1.2	1.2	1.2	1.2	1.2
In band on-chip image size assumed in ETC - arcsec	0.8	0.8	0.8	0.8	0.8
Extra extinction assumed in ETC	0.00	0.00	0.00	0.00	0.08
Detector Integration Time (DIT) sec used in ETC	20	20	10	10	10
N.B. the DIT assumed will affect the number of seconds to reach a specified depth, because it affects the amount of read noise.					
Time (sec) required per object assuming above values	80	80	80	80	80
Area required sq. deg	220	220	220	220	220
Tiles required to cover area(s)	152	152	152	152	152
effective useful sq deg/tile	1.45	1.45	1.45	1.45	1.45
Assign priorities to different areas?	None	None	None	None	None
Single Tile Strategy					
Parameters set					
DIT already assumed above	20	20	10	10	10
Ndit - # of Exposure coadds	1	1	2	2	2
Nexp # of Exposure loops	1	1	1	1	1
Nmicro- # of microstep positions (steps <3 arcsec)	1	1	1	1	1
Njitter - # of Jitter positions (steps odd # of 0.5 pixels < 30 arcsec)	2	2	2	2	2
Npaw - # of Pawprints in tile	6	6	6	6	6
Observe tile in same OB how many times?	5	5	5	5	5
Number of filters in same OB? If >1 which other?	ZYJHKs	ZYJHKs	ZYJHKs	ZYJHKs	ZYJHKs
Number of tile positions in same OB?	1	1	1	1	1
Resulting values					
Total Exposure sec/tile	240	240	240	240	240
Total Elapsed sec/tile	353.7	378.1	390.7	390.7	390.7
Total Elapsed mins/tile	5.9	6.3	6.5	6.5	6.5
Observing efficiency %/tile	67.9	63.5	61.4	61.4	61.4
Time per object for s-to-n -single OB	80	80	80	80	80
Signal to noise (at depth required in row 3) - single OB	4.9	5.1	5.5	5.2	5.0
Depth (to sigma in row 4) - single OB	21.5	20.7	20.2	19.3	18.3
Multiple Tile Strategy					
# of Tiles per filter for S/N	1	1	1	1	1
Time links between OBs in same filter on a Tile?	no	no	no	no	no
Priorities between OBs in same filter on a Tile?	no	no	no	no	no
Time links between OBs on a Tile in different filters?	no	no	no	no	no
Priorities between OBs on a Tile in different filters?	no	no	no	no	no
Time links between Tiles by position?	no	no	no	no	no
Priorities between Tiles by position?	no	no	no	no	no
Total Elapsed Hours per filter	**14.9**	**16.0**	**16.5**	**16.5**	**16.5**
Telescope overhead time and filter change	3.1				
Total time, with telescope overhead time, 5 filters 1 OB.	**83.51**				

Figure 6: Year 1 Disk multicolour observations


Pipeline Unit
Raw Pawprints
Linearity, Crosstalk, etc.
Dark/Bias, Flat
creation
Sky
subtraction
reject data sets
flag bad objects
2MASS ZP + Coords
QC
Calibrated Tiles, QC parameters
Photometry
Astrometry
Source Catalogs, QC parameters
header updates
Archive Unit
QC
Image Merging
Image Subtraction
QC
Catalog
Merging
Combined Images
Difference Images
Photometry
Detection
Multiepoch and/or Multicolor Catalogs
Deep Source Catalog
Residual Source Catalog
Chile/UK Teams
Final QC and High Level Products: Catalogs of Variable Stars, High Proper Motion Objects, Star−Forming Regions, etc.