1 Title: The VISTA near-infrared YJK_s survey of the Magellanic System (LMC, SMC, Bridge & Stream) – VMC

PI: M.-R.L. Cioni, Institute for Astronomy, Edinburgh, UK

1.1 Abstract

The Magellanic Cloud system represents the nearest template for the study of stellar populations and galaxy interactions. Its low metallicity and nearby distance are key issues to exploit the unique VMC data. This survey aims to obtain YJK_s-band photometry across the system down to $K_s = 20.3$ at S/N= 10. This sensitivity corresponds to the bottom of the red giant branch field stellar population and allows us to determine the global spatially resolved star formation history with unprecedented quality ($\sim 20\%$ errors at a resolution of 0.2 dex in age) and to construct a three-dimensional map of the system. A wide-area (184 deg^2) encompassing the D_{25} as well as major features delineated by the distribution of stars and HI gas, will both trace the structure of the galaxies and signatures of past and present interactions. Contemporary optical and kinematic observations of comparable sensitivity (e.g. VST) will provide the community with a superior database for future studies of the system and will give us an excellent insight as to what has happened elsewhere in the Universe.

2 Survey Observing Strategy

2.1 Scheduling requirements

2.1.1 Area

The VMC survey aims to put serious constraints on the SFH and 3D structure of the Magellanic system (LMC, SMC, Bridge & Stream). The necessary spatial resolution across the entire system is only possible using deep wide-field data such as those that will be obtained using VISTA. We propose to cover an area that includes the classical D_{25} (Bothun & Thompson 1988, AJ 96, 877) limit for both galaxies as well as major features traced by the distribution of stars (Irwin 1991, IAU 148, 453, Bica et al. 1995, ApJS 101, 41 & 1999, AJ 117, 238) and HI gas (Staveley-Smith et al. 2003, MNRAS 339, 87, Hatzidimitriou et al. 2005, MNRAS 360, 117, Muller et al. 2003, MNRAS 339, 105). Therefore, we need 184 deg^2 distributed as follows:

116 deg^2 in the LMC (68 tiles),

45 deg^2 in the SMC (27 tiles),

20 deg^2 in the Bridge (13 tiles) and

3 deg^2 in the Stream (2 tiles).

Such a homogeneous wide-area survey will allow us to relate, for the first time, spatial variations in the SFH to the interaction between the LMC and the SMC and between the Magellanic Clouds (MCs) and the MW. We will fully sample stars along the entire RGB with a sufficient S/N that will allow us to use theoretical models to constrain both age and metallicity to an unprecedented accuracy across the whole system (Olsen et al. 2003, AJ 126, 452).

2.1.2 Filters & Seeing

Regions of high source density like the centre of the bar of the LMC may be problematic. To estimate the confusion limit we extracted 2MASS sources in the centre of the LMC and extrapolated the cumulative distribution (i.e. luminosity function). A source density of 1 per 50 detection elements represents this limit (IRAS explanatory supplement, vol. 1, VIII-2). In the best seeing conditions, a detection element ($\sim \sigma^2$) is limited by the instrumental PSF ($\sigma = 0.51''$) and otherwise is given by the seeing itself ($\sigma = 0.8''$). In bluer bands confusion is approached at brighter magnitudes than in redder bandwidths. Confusion limit is not a problem during the best seeing conditions, however if the seeing is $0.8''$ Z-band observations down to 23.5 will be confusion-limited, while Y-band observations will be just about 1 mag brighter than the limit. Therefore, we prefer Y-band over Z-band observations. Because of the airmass observability of the MCs the seeing will be worse and the most crowded regions will already approach confusion at $Y = 20.0$ and $J = 21.5$ (DIMM seeing = $0.8''$), thus it is necessary to observe these regions (about a dozen tiles) during the best possible sky conditions. K_s-band observations will not be limited by confusion for a seeing $\leq 0.9''$. Seeing requirements are discussed in Sect. 2.2.1 as well as in the ESO form, submitted with the scientific proposal, where they are specified separately for crowded and un-crowded regions. Note that these calculations are rather conservative (Hogg 2001, AJ 121, 1207) and are consistent with a large dataset that is also constrained by the processing time. For example, accurate PSF photometry, to disentangle faint stars in crowded fields, requires several iterations (see Sect. 5.2).

2.1.3 Strategy

The survey observing strategy outlined is to complete the observation of three Observing Blocks (OBs), one per filter, on a given tile as close as possible in time (same night). This procedure minimises variability effects on colours, which are more important for brighter objects, and at the same time guarantees more or less homogeneous observing conditions among different bands for a given epoch.

On the other hand, following the recommendation by the PSP, we will observe the remaining K_s OBs *with more-or-less random observations within a given semester*. This will allow us to obtain average K_s magnitudes for RR Lyrae and Cepheid stars with the required accuracy (a few hundredths of magnitude) to unveil the 3D structure features of the Magellanic System. In fact, as average K_s magnitudes will be determined by fitting template light-curves and precise ephemerides to each variable, to constraint the templates we need all epochs not to be taken one after the other on the same night, since if observations for the variables were reduced to just one phase point, then the uncertainty of the K_s values would dominate preventing us from achieving one of the proposed goals of the VMC survey.

A single VMC-OB will observe one tile at one filter. Observations of a given tile will be accumulated until the nominal survey depth is obtained at each wave band as follows:

(a) – $1 \times YJK_s$ (same night)

(b) – $2 \times Y$, $2 \times J$, $11 \times K_s$ independent observations. These YJ OBs can be obtained in the same night when a K_s OB is also observed, but this is not a requirement. K_s OBs will be obtained during the same semester.

When tiles covering the most crowded fields will be observed (under the best sky conditions) we require the observation of also one outer field which will provide a sufficient number of frames to perform the sky subtraction on both the crowded and un-crowded tiles obtained during the same night (Sect. 3.2).

2.1.4 Mid-term goal

The mi-term goal (P81-P84) has been designed to provide the highest legacy value and to support VLT observations. It consists of **(i)** covering the whole Magellanic system by observing three OBs per tile (one per band); this requires $\sim 300^h$ (Sect. 2.2.2) and will provide the community with follow-up targets across the entire system, especially in the halo of each galaxy because of the limitations of previous surveys. The selection of targets is maximised by the three-band photometry made available while the depth obtained with one OB per band reaches sources as faint as the red clump which is comparable with the current limit of high resolution spectrographs. Then **(ii)**, additional K_s-band epochs will be obtained for tiles covering any of the Magellanic system's components according to those that best suit ESO scheduling (Sect. 2.2). These data will be immediately available for matching with existing optical data covering the LMC and the SMC, and analysis of the 3D geometry. Note that VST observations are foreseen to begin in 2009 (P81), therefore the optical counterpart for stars of the Bridge will be available only after this date.

Period	Time (h)	Mean RA	Moon	Seeing	Transparency
P81	37	$0^h - 3^h$	bright	$\leq 1.0''$	thin
P82	300	$0^h - 7^h$	bright	$0.6'' - 1.0''$	thin
P83	75	$0^h - 3^h$	bright	$\leq 1.0''$	thin
P84	300	$0^h - 7^h$	bright	$0.6'' - 1.0''$	thin
Mid-term goal					
P85	75	$0^h - 3^h$	bright	$\leq 1.0''$	thin
P86	300	$0^h - 7^h$	bright	$0.6'' - 1.0''$	thin
P87	75	$0^h - 3^h$	bright	$\leq 1.0''$	thin
P88	300	$0^h - 7^h$	bright	$0.6'' - 1.0''$	thin
P89	75	$0^h - 3^h$	bright	$\leq 1.0''$	thin
P90	300	$0^h - 7^h$	bright	$0.6'' - 1.0''$	thin

2.2 Observing requirements

The observing time (1837^h including the most up-to-date instrument overheads – Sect. 2.2.2) has been distributed in the table above throughout each season to account for the observability of the MCs above airmass 1.6 for about 3^h of consecutive time. This time is required only once (Sect. 2.1.3) because for the other OBs $\sim 1^h$ per night ($\sim 2^h$ if one of the crowdest fields is observed) will be sufficient. The latter can be obtained a month prior or after the following main periods:

SMC – from August to November included

LMC – from October to January included

Bridge – from October to December included

Stream – from August to September included, but observations can be equally well performed in July, October and November. The number of hours requested for each observing period (see first table) assumes only the first two months in order to distribute the observations of the Magellanic System in a way that, according to us, will not occupy a too large a fraction of time on each night.

Note that the Magellanic system's declination means it will probably be observable in periods of mild wind since, judging from Paranal statistics, the wind is preferentially from the North, while its right ascension makes it a primary Chilean summer target.

2.2.1 Exposure time

The estimated exposure time needed to complete the VMC survey has been calculated using the VISTA ETC v1.2 assuming a blackbody (T= 5000 K) flux distribution, an aperture diameter of $1.6''$ and $0.8''$ seeing at airmass 1.5 in K_s-band ($0.9''$ in J and $1.0''$ in Y) which corresponds to a DIMM seeing of also $0.8''$ (this occurs about 45% of the time at Paranal). Standard seeing theory (e.g. Roddier 1981, Progress in Optics XIX, 281) shows that the seeing FWHM varies as:

$$FWHM \sim airmass^{3/5}/\lambda^{1/5}$$

With airmass= 1.0 and $\lambda = 0.55$ for V, and airmass= 1.5 and $\lambda = 2.15$ for K_s, then

$$FWHM(K_s)/FWHM(V) = 1.5^{3/5} \times (0.55/2.15)^{1/5} = 0.97 \sim 1.$$

We have chosen $0.8''$ to be the average seeing for our survey to guarantee homogeneity of the data sensitivity and good point-source separation. In the most crowded regions (e.g. the centre of the LMC bar) in these conditions we will approach the confusion limit. Observations with thin cirrus add an extra extinction of about 0.08 mag in K_s (much lower in J and Y) which decreases by 10% the S/N of the data, although remaining of acceptable quality to achieve the scientific results of the survey. A similar extinction is caused by observing down to

Observing Strategy	Z	Y	J	H	K$_s$
Time (s) & depth on sky in co-added Tiles					
Depth (Vega) required	-	21.9	21.4	-	20.3
Sigma required	-	10	10	-	10
Assumptions					
SED	-	BB5000K	BB5000K	-	BB5000K
Aperture - arcsec	-	1.6	1.6	-	1.6
In band sky brightness - Vega mag/arcsec	-	17.2	16.0	-	13.0
Airmass	-	1.5	1.5	-	1.5
In band on-chip image size - arcsec	-	1.0	0.9	-	0.8
Extra extinction	-	0.0	0.04	-	0.08
Deterctor Integration Time (DIT) sec	-	20	10	-	6
Time per object sec	-	3102.4	2263	-	10688.6
Area sq. deg	-	184	184	-	184
Tiles required to cover area(s)	-	110	110	-	110
Effective useful sq deg/tile	-	1.67	1.67	-	1.67
Priorities of different areas?	-	Y	Y	-	Y
Single Tile Strategy					
Parameters set					
DIT already assumed above	-	20	10	-	6
Exposure co-adds (Ndit)	-	5	8	-	15
Exposure loops (Nexp)	-	1	1	-	1
Microsteps (Nmicro)	-	1	1	-	1
Jitters (Njitter)	-	5	5	-	5
Pawprints in tile (Npaw)	-	6	6	-	6
Repeat tile in same OB how many times?	-	1	1	-	1
Number of filters in same OB? If> 1 which other?	-	1	1	-	1
Number of tile positions in same OB	-	1	1	-	1
Resulting Values					
Total Exposure sec/tile	-	3000	2400	-	2700
Total Elapsed sec/tile	-	3378	2868	-	3378
Total Elapsed min/tile	-	56.3	47.8	-	56.3
Observing efficiency %/tile	-	88.8	83.7	-	79.9
Time per object for S/N - single OB	-	1000	800	-	900
Signal to noise (at depth required) - single OB	-	5.7	5.9	-	2.9
Depth (10σ) Vega - single OB	-	21.3	20.8	-	18.9
Saturation & linearity	-	12.9	12.7	-	11.4
Multiple Tile Strategy					
Number of tiles per filter for S/N	-	3	3	-	12
Time links between OBs in same filter on a Tile?	-	Y	Y	-	Y
Priorities between OBs in same filter on a Tile?	-	N	N	-	N
Time links between OBs in a Tile in different filters?	-	Y	Y	-	Y
Priorities between OBs on a Tile in different filters?	-	Y	Y	-	Y
Time links between Tiles by position?	-	N	N	-	N
Priorities between Tiles by position?	-	Y	Y	-	Y
Total Elapsed Hours per filter	-	309.7	262.9	-	1238.6

airmass 2 or with a DIMM seeing of 0.9″, however, this is acceptable only in the outer (un-crowded) regions or for K_s-band observations which are not limited by confusion. The moon brightness is never a problem because it is always at least 80° away from the MCs.

To reach S/N= 10 at Vega magnitudes of $K_s = 20.3$, $J = 21.4$ and $Y = 21.9$, we need to spend on-source about 3^h, 40^m and 50^m in each band respectively. These integration times will also allow us to reach 1 magnitude deeper sources at S/N= 4 which is well below the turn-off of the oldest stellar population in the LMC. Details of the observing strategy are given in the Table above. Upper magnitude limits have been estimated assuming linearity until about 10^5 e^- which corresponds to a DIT time factor to peak saturation of about 1.5.

The total area covered by the survey (184 deg^2; Sect. 2.1.1) has been calculated taking the 1.5 deg^2 covered by the inner part of each tile and adding the Y overlap (0.135 deg^2) between adjacent tiles. Tiles are 1.5×1.18 deg^2 in size and they overlap by 0.1° in Y and 0.016° in X. The latter is the same as between adjacent paw-prints re-constructing a tile. Although Detector #16 has a 200 bad pixel area we will keep a homogeneous and systematic pattern. The lack of sources due to this region is much smaller than the lack of sources in the line of sight of bright Galactic stars. Moreover associated to each tile there will be a confidence map carrying the information on the affected pixels (Sect. 4.1).

The number of tiles needed to cover any of the Magellanic System components (Sect. 2.1.1) has been derived using a list of pointings, accounting for the overlap mentioned above. Using the SADT we will define RA and DEC boundaries to cover most of the area of the LMC and the SMC, but for the Bridge, the two tiles on the Stream and some tiles in the outer parts of the LMC and SMC it will still be necessary to specify directly the tile centre in oder to optimise the overlap with future VST observations.

2.2.2 Overheads

By observing adjacent tiles in the same filter the tile-change overheads are considerably reduced, from a few tens of seconds to at most 10^s per tile. A slew/preset from the LMC centre to the SMC centre requires $\sim 25^s$. However, if the observation of a VMC OB follows the observation of an OB from another survey at a distant sky position the presetting overheads can be of the order of 2^m or larger. Note that because of the distribution of tiles covering the Magellanic System sequential preference can be given to those tiles which do require the telescope to move by a small amount only in altitude, which keeps tile-change overheads small. Assuming that 75% of the time presetting overheads will be small (15^s) and 25% large (120^s) we attribute to each OB an average of $\sim 41^s$ for presetting.

The observing strategy detailed in the Table above envisages a jitter move after $80^s - 100^s$, depending on filter, which is well above the minimum of 30^s for the LOWFS to work in basic mode. Therefore, there are no extra overheads due to active optics.

No other filter-change overheads are needed if OBs in the same filter precede or follow the remaining VMC OBs. However, it will happen that VMC OBs are interleaved with the observation of OBs from other surveys at other filters. It takes 25^s to change between adjacent filters and 60^s to change between the most distant filters. Adopting the same criterium as above that assumes 75% of the changes to be short and 25% long we obtain an average of $\sim 34^s$ for filter change per OB.

Summarising, the gross time to observe a single tile in three filters (3 consecutive OBs) is $2^h 42^m$, including 50^s to move twice to adjacent filters, 41^s for presetting and 1^s for acquisition, while individual OBs will require on average a gross time of 56^m which includes 34^s for filter change, 41^s for presetting and 1^s for acquisition.

The total survey time results in 1837^h (1811^h for exposure time and 26^h of overheads as discussed above). Because VISTA will effectively observe 10^h and it is envisaged to spend about 1^h per night calibrating the broad band filters the completion of the VMC survey requires ~ 205 nights which correspond to $\sim 17\%$ of the total time available for VISTA Public Surveys (i.e. ~ 236 nights per year). *There is only a moderate number of nights that can be dedicated entirely to VMC observations (i.e. when the Magellanic system's components satisfy the airmass constraint throughout the entire night and this is purely a statistical estimate).*

3 Survey data calibration needs

The calibration, including sky subtraction, of VMC data will be performed in a similar way as it is currently done for the UKIDSS survey. Both the photometric and astrometric calibration are linked to the homogeneous 2MASS PSC which has an astrometry as accurate as $0.1''$ and is consistent to a global photometry of 1% in any wave band. Therefore, assuming that the performance of VIRCAM@VISTA will be similar to that of WFCAM@UKIRT no special calibration procedure, other than the one provided by ESO, is required for the VMC survey and we do not need to observe in photometric conditions.

Note that to estimate the contribution of the MW we plan to use observations from other VISTA Public surveys. For example, the VIDEO survey for faint sources and the VHS survey for bright sources.

3.1 Photometry and astrometry

The VMC data will be calibrated to magnitudes in the Vega system. Calibration on the sky is achieved using observations of 2MASS stars within each field (there are plenty unsaturated ones in every exposure of the Magellanic System), which does allow to derived photometric calibration even during non-photometric conditions, including colour equations for transformation from the 2MASS system to the VISTA system. The latter also corrects for a small (in YJK_s) dependence on Galactic extinction (Warren et al. 2007, astro-ph/0703037).

The procedure (Lawrence et al. 2006, astro-ph/0604426) is to cross-match objects detected by the pipeline with 2MASS unsaturated sources that have $\sigma_{JK}(2MASS) < 0.1$, and to transform the photometry of these stars into the VISTA YJK_s system using empirically derived colour terms. After correcting counts for the known radial variation in pixel scale, the average of these stars gives a global per-frame zero-point. Tests against observations of UKIRT faint standards (Hawarden et al. 2001, MNRAS 325, 563) indicates that this procedure gives a JK_s photometric system accurate to 2%, this accuracy becomes $2-4\%$ in Y. However, VDFS is developing a way to reduce the latter to also 2%; it also aims to achieve a goal of 1% in any wave band. These numbers refer to to data obtained in one night and in one paw-print.

In particular, the calibration of the Y filter obtained using 2MASS will be complemented with the observations performed regularly by ESO. The calibration plan lists 1^h per night to be spent on the observation of standard star fields in any filter as well as a quarterly monitoring (over the first 2 years) around the primary standards to establish the photometric pedigree and accuracy of secondary standards with a goal of 0.005 mag *rms*.

The use of 2MASS for the many non-variable objects detected by VMC assures a homogeneous calibration at each data release, which will include stack of observations at a given filter for a given tile as well as individual catalogues for each epoch (Sect. 7.1). It is also envisaged to combine adjacent tiles at the moment of a given data release, the catalogue extracted from the resulting image will include the Y overlap of tiles down to the same depth as the centre and will be homogeneously calibrated using 2MASS as above. This task is being implemented by the VDFS team. Afterwards the VMC team will check and refine the calibration among tiles using both the X & Y overlap as defined in the observing strategy (see Sect. 2.2.1).

Similarly, the astrometry is as good as $0.1''$ which is sufficient for VMC purposes.

3.2 Sky subtraction

Sky subtraction will be performed using all observations obtained during the same night, in the same filter, building a series of sky subtraction frames as is currently being done for UKIDSS. This procedure works well also for crowded fields provided that some observations of un-crowded fields are obtained during the same night. In fact, the VMC strategy (Sect. 2.1.3) requires the observation of a sparsely populated VMC field any time a highly populated field (like the LMC bar) is observed to provide suitable sky frames.

4 Data reduction process

The data reduction will be using the VISTA Data Flow System (VDFS), operated by the VDFS team, and augmented by individuals from the VMC team, especially for Product Definition (PD) and Quality Control (QC). 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 STFC (former PPARC).

4.1 CASU: pipeline processing

CASU is responsible for the VDFS pipeline processing component which has been designed for VISTA. It has been scientifically verified by processing wide-field mosaic imaging data from WFCAM@UKIRT and is now routinely used to process up to 250GB/night of 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 is on a night-by-night basis with data products defined by the overall OB structure. Those important for the VMC survey are: – non-linearity, dark, flat, fringe, cross-talk and systemic noise correction; – sky subtraction (tracking and homogenisation during image stacking and mosaicing, the latter to remove unexpected 2D systematic effects from imperfect multi-sector operation of detectors; – assess and delay with image persistence from preceding exposures if necessary; – combination of dithered images and of tile pattern; – point source extraction; – astrometric and photometric calibration (the latter put in an internally uniform system as well as in an optimised system obtained by monitoring suitable pre-selected standard areas covering the specific VMC survey area); – shape and data quality information; – bad pixel handling, propagation of error arrays and effective exposure times by use of confidence maps; – realistic errors on selected derived parameters for images and catalogues; – nightly extinction measurements in relevant pass bands; – pipeline software version control. The processing history just described is recorded directly in FITS headers. **Figure 1** shows the flow chart of pipeline operations.

4.2 WFAU: science archiving

The Science Archive (SA) ingests the products of the pipeline processing into a database and then curates them to produce standardised data products. The most important processes for the VMC survey are: – individual passband frame association and source association to provide multi-colour, multi-epoch source lists; – global photometric calibration (using 2MASS); – cross-association with external catalogues (list driven matched photometry); – automatic stacking and source extracting for overlapping tiles in areas of reduced exposure (to be implemented); – deeper stacking in specified fields; – quality control procedures, as required by the public survey consortium, and supported by the archive team members. 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. A point-and-click web form as well as full access to Structure Query Language constitute the dual (simple and sophisticated) end-user interfaces for the data. A generalised relational model for survey catalogue data has been developed in the VDFS. The key features to note are the normalised design with multi-wave band catalogue data that allow the user to track right back to the individual source images and merged-source tables that present the user with a generally applicable science-ready dataset. The SA 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-SA in Edinburgh, with the first data release in July 2006. **Figure 2** shows the flow chart of archive operations.

VMC is intrinsically a multi-wavelength project and most science will come from the linking of VISTA data with other survey data; the SA is designed to enable such links.

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

5.1 Data processing and archiving

We will use the VDFS (Emerson et al. 2004, SPIE 5493, 401; Irwin et al. 2004, SPIE 5493, 411; Hambly et al. 2004, SPIE 5493, 423) for various aspects of data management, including: pipeline processing and management; delivery of agreed data products to the ESO-SA; production of a purpose-built IVOA compliant science archive with advanced data-mining 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. Based on two years of experience at running the WFCAM processing pipeline, CASU have estimated the manpower requirements to 3.0 FTE. This includes normal processing, reprocessing after major bug fixes and/or enhancements, system maintenance and upgrades, and liaison with major users. Hardware CPU requirements for the Cambridge processing pipeline are specified to have an over-capacity of a factor of at least 3 (to allow for the inevitable variations of data flow rates and reprocessing requirements). Data storage will be purchased as required and all raw and processed files will be stored using lossless Rice tile compression to save a factor of about 4 in hardware requirements. Manpower provision at the VDFS Edinburgh science archive centre currently stands at 2.0 FTE dedicated operations staff and around 1.0 FTE of astronomer-scientist management, oversight and systems support. Hardware provision for storage of pipeline-processed science product files, database server catalogue storage and associated web servers and other infrastructure is currently funded, via a rolling grant, to 2010 and is renewed every two to three years.

It is expected that to handle VISTA images, those of individual tiles, a 64 bit workstation, running Linux, with a few Tby of disk-space and at least 4 Gby of physical memory will be necessary.

5.2 Survey team

The VMC survey team includes 20 members (see Table) who will be among the first scientists to exploit the survey data. Our expertise covers a broad range of astrophysical topics from stellar astronomy to galactic dynamics and each member has a well-established position in his/her field of research. The team will be in place until about a year after the completion of the survey and it has already expanded seeking postdocs and/or students to work in association with the VMC survey as follows.

The FTE fraction that each existing or planned member will spend on VMC is listed in the Table and some of the major tasks of each member are described below. Note that for a maximum exploitation of the VMC survey we will need postdoc and PhD support. However, in the worst-case scenario that this will not be available (which is highly unlikely) the completion of the survey is guaranteed within the existing FTE commitments of core members. Moreover, the FTEs will be re-distributed on a yearly basis according to the people involved with the survey aspects at any given time.

The PI, **Cioni**, has submitted an application for an Early Research Grant within the FP7 programme to create and support for 5 years a group comprising of two postdoctoral researchers and two Ph.D. students working specifically on the VMC survey. She is also preparing an application for a standard STFC grant to support one additional postdoc for the QC, PSF photometry, calibration and analysis of the VMC data. By the beginning of VISTA operations the PI will be working at the University of Hertfordshire (UK) as a senior lecturer. This post will allow her to spend 0.6 FTE on the VMC survey and to yearly recruit Ph.D. students, via the usual University routes, for the data analysis and exploitation tasks. In fact, starting this fall, a Ph.D. student will begin modelling the galactic foreground component and mapping the extinction (using initially UKIDSS data). This study will be applied to VMC data and will allow us to disentangle the foreground contribution as well as to evaluate the extinction along the line of sight. These are fundamental tasks to correctly interpret the SFH of the Magellanic System. The PI will also apply for funding that will partially release her from teaching duties increasing the FTE percentage that can be spent on the VMC survey.

The OBs will be prepared by Cioni, or her postdoc, in collaboration with Emerson, Ripepi and de Grijs.

Many team members will be involved in the definition of the data products, quality control and early-science assessment (i.e. QC focused on science aims). The hardware and software capabilities listed below, currently or planned to be available to team members, also include those required to exploit the data.

The most relevant areas will be coordinated by: **Clementini** (RR Lyrae & Cepheid stars), **Girardi** (Star formation history – SFH) and **de Grijs** (Clusters). The analysis of variable stars requires hardware which is already in place or that can easily be upgraded to meet the requirements of the large VISTA images. The software is also already available and has been used on infrared images for similar studies. For the analysis of clusters, to interpret their stellar population but also to find new candidates (by **Ivanov**), hardware and software do also already exist and are accessible to team members.

A fundamental step in the extraction of the SFH from field stars and in the analysis of the cluster stellar population is to perform Artificial Star Tests (ASTs). This operation is not supported by VDFS. Therefore, we have to perform independent PSF photometry on the calibrated images with and without adding artificial stars (and this has to be done many times, for each individual image). Of course, this would be better done using the same PSF algorithm and parameters as already tweaked by VDFS. The software to perform the PSF photometry is being developed at CASU and will be offered at WFAU to run on the calibrated images in the archive. Girardi, Kerber (postdoc) and a new Ph.D. student will test and refine the AST strategy working on a couple of tiles, in a workstation in Padova. However, AST and PSF photometry on all images will be performed in Hertfordshire where machine(s) dedicated to these tasks will be acquired by the PI, and at the SGI Altix 3700 (28-node, 64-bit) cluster in UCLan chaired by Gibson.

Another fundamental issue to be solved will be how to compare the photometry, which will be in the natural photometric system of the telescope, with the models which are in effective temperature, or perhaps presented as theoretical spectra. This involves folding models through the band-passes, comparing the results with the data, and updating the band-passes. This is a general problem which will have to be solved over all the surveys, but is of particular interest to the VMC group. Furthermore as **Naylor**'s τ^2 technique (2006, MNRAS 373, 1251) allows objective comparison between data and the models, we are ideally placed to do this work.

People involved in dynamical simulations of the system to constrain models of evolutionary interaction between the MCs and the MW as well as between the LMC and the SMC, **Bekki**, **Mastropietro** and **Moore**, already have sufficiently capable hardware, disk space and software to perform these simulations for both the preparation and exploitation of the VMC survey data. In particular, Mastropietro uses the GASOLINE code (N-body + gas dynamics) and can easily project FITS images onto her simulations. At a later stage, **Wilkinson** will contribute to the modelling of the correlations between kinematics and chemistry as well as actively pursuing spectroscopic follow-up. **Gibson** and **van Loon** will also contribute to the exploitation of the combined kinematic and photometric data. In particular, Gibson will convolve the SFH with his Galactic Chemical Evolution code.

The identification of special objects like PN in the VISTA images using existing catalogues to evaluate the quality and depth of the detections as well as the finding and follow-up of new candidates will be done by **Leisy**. He will analyse the data (both images and catalogues) to identify extended sources as well as complementing the VMC data with high-resolution Hα and [OIII] observations which will allow him to develop a method to increase the census of PNe within the system. He already uses a computer meeting VISTA requirements and has developed the software to perform this investigation. Follow-up observations are also the main interest of **de Blok** because of his involvement in SALT operations.

Oliveira and **Evans** will concentrate on the process of star formation and on young stars while **Groenewegen** and **Wood** will concentrate on evolved stars (both these studies will combine VMC data with mid-IR data from Spitzer, that will be publically available and eventually from Akari, depending on data availability). The software to cross-correlate different catalogues exists and has been tested for similar tasks.

Public outreach initiatives within the VMC survey comprise setting-up a dedicated web page, that will also be used by team members to post results of their investigations, producing posters and teaching packs. Several team members are already involved in similar activities and there are no limitations imposed by available hardware and software.

Name	Function	FTE	Affiliation, Country
M.-R.L. Cioni	**PI**, OB, QC-III, PD	0.6	University of Edinburgh/Hertfordshire, UK
2× *Postdoc (ERC)*	QC, SFH, VAR, 3D	1.6	University of Hertfordshire, UK
2× *PhD (ERC)*	AST, SFH, VAR, 3D	2.0	University of Hertfordshire, UK
Postdoc (STFC)	OB, QC, PSF, PHO	0.8	University of Hertfordshire, UK
PhD (from 09.07)	GAL, EXT	1.0	University of Hertfordshire, UK
L. Girardi	AST, PHO , PD, SFH	0.2	INAF, Padova Observatory, I
PhD (from 11.07)	AST, PHO, SFH	1.0	INAF, Padova Observatory, I
Postdoc: L. Kerber (from 09.07)	AST, PHO, SFH	>0.5	INAF, Padova Observatory, I
T. Naylor	PHO, PD	0.1	University of Exeter, UK
PhD	PHO	0.2	University of Exeter, UK
B.K. Gibson	SFH	0.1	University of Central Lancshire, UK
Postdoc: A. Marcolini	SFH	0.1	University of Central Lancshire, UK
Postdoc	SFH	0.1	University of Central Lancshire, UK
G. Clementini	VAR-3D, PD	0.2	INAF, Bologna Observatory, I
M. Marconi	VAR-3D	0.2	INAF, Naples Observatory, I
V. Ripepi	VAR-3D	0.2	INAF, Naples Observatory, I
Postdoc: M. Dall'Ora	VAR-3D	0.4	INAF, Naples Observatory, I
PhD or Postdoc	VAR-3D	0.5	TBD, I
R. de Grijs	CL-3D, PD	0.2	University of Sheffield, UK
PhD	CL-3D	>0.5	University of Sheffield, UK
J.M. Oliveira	SF, FU	0.2	Univerisity of Keele, UK
C.J. Evans	QC-III, SF	0.1	ATC, Edinburgh, UK
V.D. Ivanov	CL, SF, FU	0.1	ESO, Santiago, ESO
K. Bekki	SIM-3D, PD	0.2	University of New South Wales, AUS
C. Mastropietro	SIM-3D	0.2-0.25	University of Munich, D
B. Moore	SIM-3D	0.15	University of Zürich, CH
Postdoc	SIM-3D	0.2	University of Zürich, CH
PhD	SIM-3D	1.0	University of Zürich, CH
J.Th. van Loon	GIA, KIN-3D	0.2	Univerisity of Keele, UK
PhD	GIA, KIN-3D	0.5	Univerisity of Keele, UK
M.I. Wilkinson	SIM, CL, KIN-3D	0.1-0.2	University of Leicester, UK
Postdoc	SIM, CL, KIN-3D	0.1-0.2	University of Leicester, UK
P. Leisy	PN, SFH, FU	0.15	ING, La Palma, E
M.A.T. Groenewegen	GIA, VAR	0.1	University of Leuven, B
PhD	GIA, VAR	0.8	University of Leuven, B
W.J.G. de Blok	FU	0.1	MSO/University of Cape Town, AUS/ZA
P.R. Wood	GIA, VAR	0.1	Mount Stromlo Observatory, AUS
J. Emerson	VDFS Coordinator, QC, OB	0.1	Queen Mary University of London, UK
CASU (VDFS) team	Pipeline processing, QC-I	0.5	University of Cambridge, UK
WFAU (VDFS) team	Science Archive, QC-II	0.5	University of Edinburgh, UK

Note 1: List of acronyms: AST – Artificial Star Tests; CL – Clusters; EXT – Extinction map; FU – Follow-up; GAL – Galactic foreground; GIA – Giant stars; KIN – Kinematics match; OB – Observing block; PD – Product definition; PHO – Photometric accuracy; PN – Planetary Nebulae; QC – Quality Control; SF – Star Formation; SFH – Star Formation History; SIM – Simulations of system; TBD – To Be Determined; VAR – Variable stars.

Note 2: Fields in italics indicate persons planned to be involved in the VMC analysis.

Note 3: The CASU (VDFS) team consists of Irwin, Lewis, Hodgkin, Evans, Bunclark, Gonzales-Solares and Riello. The WFAU (VDFS) team consists of Hambly, Bryant, Collins, Cross, Read, Sutorius and Williams.

6 Data quality assessment process

The PI will supervise the data analysis and work on the product definition and quality assessment of the data products as well as coordinating the science exploitation on behalf of the team and contributing to various aspects of it. She will take care of the QC-III with a partial support by Evans located at Edinburgh. This aspect, estimated on the basis of about a year of UKIDSS experience, is going to take 0.25 FTE. This number may scale with image size (VISTA images are four times larger than WFCAM images) and is likely to be higher at the beginning of VISTA operations then after a year. The effort currently listed in the Table above refers to the average effort the team plans to provide, however, this may vary if necessary.

QC-0 (the most basic version) occurs on Paranal, while more sophisticated versions will be run in Garching and later in Cambridge. QC-I and QC-II are performed by VDFS people at different moments throughout the data reduction process generating automatically QC parameters (see the Data Reduction Library Design v1.6 at http://www.vista.ac.uk/vdfs/esoqc1/). These parameters will be available via a QC database in Cambridge (http://casu.ast.cam.ac.uk/surveys-projects/wfcam/data-processing/) and are also recorded in the data product FITS headers. The QC-III involves checking either remotely or from Edinburgh the pipeline processed data using available scripts to accept or flag the data. Scripts associated to each checking step will evolve accordingly with the experience on VISTA data. In addition a JPG image is created for each tile which is inspected by eye to look for obvious artifacts that might have escaped the scripts. The team will have two persons for a day-to-day point of contact each with one of the main VDFS components: CASU and WFAU. Currently these are postdocs planned for the PI's group.

The overall quality control will identify datasets that obviously were not processed in some clear manner. This information will be fed back to the CASU or WFAU group to allow them to investigate what went wrong, if a clear fault is found then the data will be reprocessed with modified processing components. Datasets that were incorrectly observed will also be identified, i.e. appropriate calibration files not available, or in bad conditions. These datasets cannot be fixed by altering the pipeline processing and will need to be re-observed with appropriate changes to the observing strategy.

Data that will become available after commissioning and science verification will be promptly and thoroughly analysed by team members to assess the performance of the camera: efficiency of sky subtraction, source extraction, sensitivity and accuracy. Overheads and survey strategy will be revised accordingly.

7 Data product and VO compliance:

7.1 Main data products

The main data products of the VMC survey that will be delivered by VDFS to the ESO-SA facility are:

– instrumentally calibrated single-band images of tiles (i.e. survey QC pipeline processed products)

– statistical confidence map for each tile;

– derived single-band single-epoch tile-object catalogue based on a standard VDFS-CASU set of object descriptors (agreed with the PI) including astrometric and photometric (aperture) measures, morphological classification, and source extraction flags;

– individual multi-wave band and multi-epoch aperture matched catalogues per tile obtained as a result of linking individual single-band single-epoch catalogues;

– homogeneous epoch-merged and band-merged master catalogues per tile. Such a catalogue will be created at each major survey data release (e.g. mid-survey) from stacked images obtained up to a given date or when all the OBs corresponding to a given tile will be completed.

The set of astrometry and photometry parameters extracted from single-band images by CASU (in agreement with the PI) are optimal for point sources in the detection sense but otherwise are tuned to give the best overall performance, which in the case of VMC will be essentially tuned for objects that are point-source like (i.e. Irwin 1985, MN 214, 575; 1997; 1997, 7^{th} *Canary Islands Winter School*; Irwin et al. 2007, MNRAS 375, 1449).

The parameters to be extracted from stacked images will be set by the VMC survey team, these can be either the same as those set during pipeline processing at CASU or tunable from SExtractor.

All available metadata will be included in the FITS headers.

The data will (under presently budgeted plans) be delivered from VDFS directly to the ESO archive servers in Garching using transfer protocols (to be determined) via the Internet.

While most of these specifics are being implemented in VDFS, source extraction flags and matching of tiles prior to the extraction of point sources, in order to cover the Y tile-overlap down to the same sensitivity as that in the centre of each tile, should be in place by the beginning of VISTA operations or soon after that.

The format of the data product produced by the VDFS should be according to VO and ESO standards. The VMC PI will take care of extracting the information listed above prior to each data release.

7.2 Other data products

These include:

– result of the PSF photometry;

– result of AST experiments: images of the completeness and photometric errors (these will be independent measures, complementing those derived from PSF photometry) as a function of position in colour-magnitude diagrams;

– result of a refined global photometry and astrometry either than the one obtained using 2MASS; this will use the overlap information among tiles in the X and Y directions;

– cross-correlation with VST observations, subject to GTO policy release;

– cross-correlation with kinematic and abundance data from the AAOmegallan or other programs, subject to acceptance, scheduling and policy release;

– catalogues of known variables (i.e. RR Lyrae stars, Cepheids, late-type giants and eclipsing binaries) containing multi-epoch and mean magnitudes.

These additional data products will be delivered by the VMC PI to ESO either directly or via VDFS.

8 Timeline delivery of data products to the ESO archive:

It is expected that Public Survey observations will begin in Q2-2008 (P81). By then commissioning and science verification data will allow us to evaluate the efficiency of our observing technique as well as to revise the observing time requested accounting for the instrument efficiency and real overheads.

Before observations begin we will hold a team meeting to distribute the detailed workload of the project, in order to meet our mid-term goal after the first two years of observations (P81-P84). If necessary, the FTE commitment will be revised and the tasks will be re-distributed among team and newly acquired associate members, respectively. Team members have applied and obtained, or are in the process of applying, for funding to employ postdocs and Ph.D. students who will promptly contribute to the preparation, quality assessment, analysis and exploitation of the data.

The time-scale for availability of survey products depends on ESO for the receipt of raw images at VDFS (currently this is estimated to be about 17 days after observations are taken) and on VDFS for the release of individual point-source catalogues (per tile, per band and per epoch). The latter aim is to achieve the extraction and verification of the newly arrived data within 7 days of their receipt at CASU. Then, these data will be made available to the PI who, or the team person in charge, will perform the final quality control operations.

Survey data products, on a tile by tile and epoch by epoch basis (Sect. 7.1), will be delivered to the ESO archive within the semester following the one in which the raw data arrived. This means that data collected in any given Period (e.g. P81) will reach ESO by the end of the following Period (e.g. P82). This procedure strictly follows the ESO progress review which will take place every 6 months.

Stacked images will be created by VDFS-WFAU at each public data release (e.g. the *mid-term* goal) or when all the OBs corresponding to a given tile will be completed. They will be made available to the PI who, or the team person in charge, will set the extraction parameters (Sect. 7.1). Then, VDFS-WFAU will produce homogeneous aperture matched, band-merged and epoch-merged master catalogues (Sect. 7.1) per tile. These, will reach ESO by the end of the semester following the one in which the observations were completed or the one after the *mid-term* goal (end of P85). The ESO observing plan review will coincide with project *mid-term*.

The observation of the Magellanic System will be mostly obtained from August to January, inclusive, of each year. Therefore, before the next 6-months observing season begins we will have analysed the data of the previous observing season and we will have delivered the data to the ESO archive. These will be discussed in a yearly meeting where we will assess the progress of the survey as well as define the writing and publication of early-survey results. According to this time-scale we plan to also release the result of PSF photometry and ASTs 6 months after each public data release while, further data products (including a refined global astrometry and photometry) will be available within a year after the completion of the survey.

During the following years much will be learned from the combination between VMC data and those from other surveys (e.g. optical and kinematics). As soon as the first data (images and catalogues) will be available sub-groups, as defined in the original proposal, will begin testing and upgrading analysis routines (i.e. cross-correlation algorithms, artificial star tests, light-curve analysis, cluster analysis, nebulae characterisation, etc...) to perform efficiently and up to expectations with the VMC data.

Note that a IAU Symposium on the Magellanic Clouds has been approved in Keele (UK) for the European summer of 2008; this will be an ideal place to present early science results from VMC.

Finally, the collection of VMC data on the southern ecliptic pole (near the LMC) will considerably increase the science outcome of early GAIA observations in this region ($\sim$2011) which might be released as early as 2012.

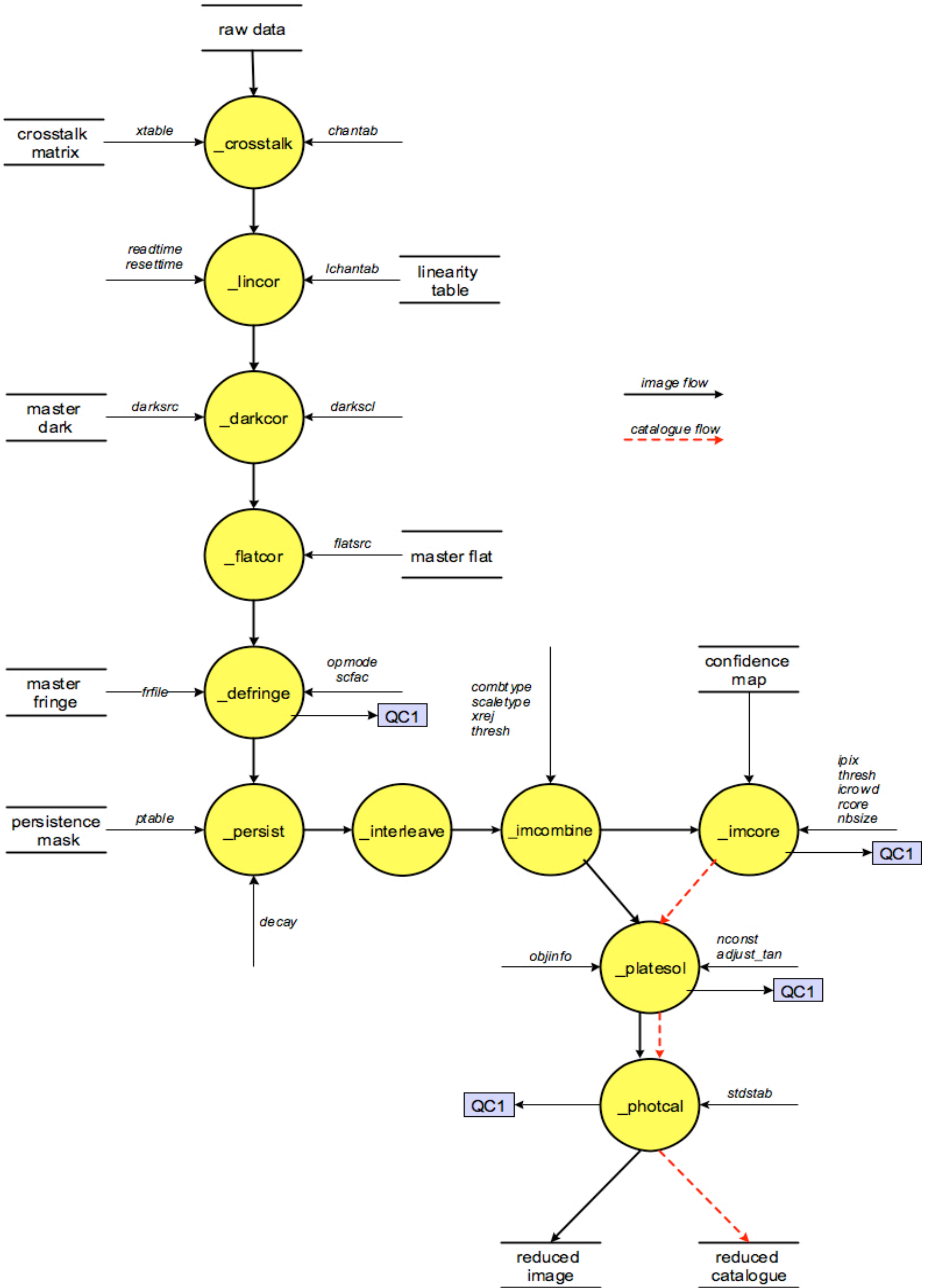

Figure 1: A block diagram synthesising each pipeline step from raw data to the calibrated product.

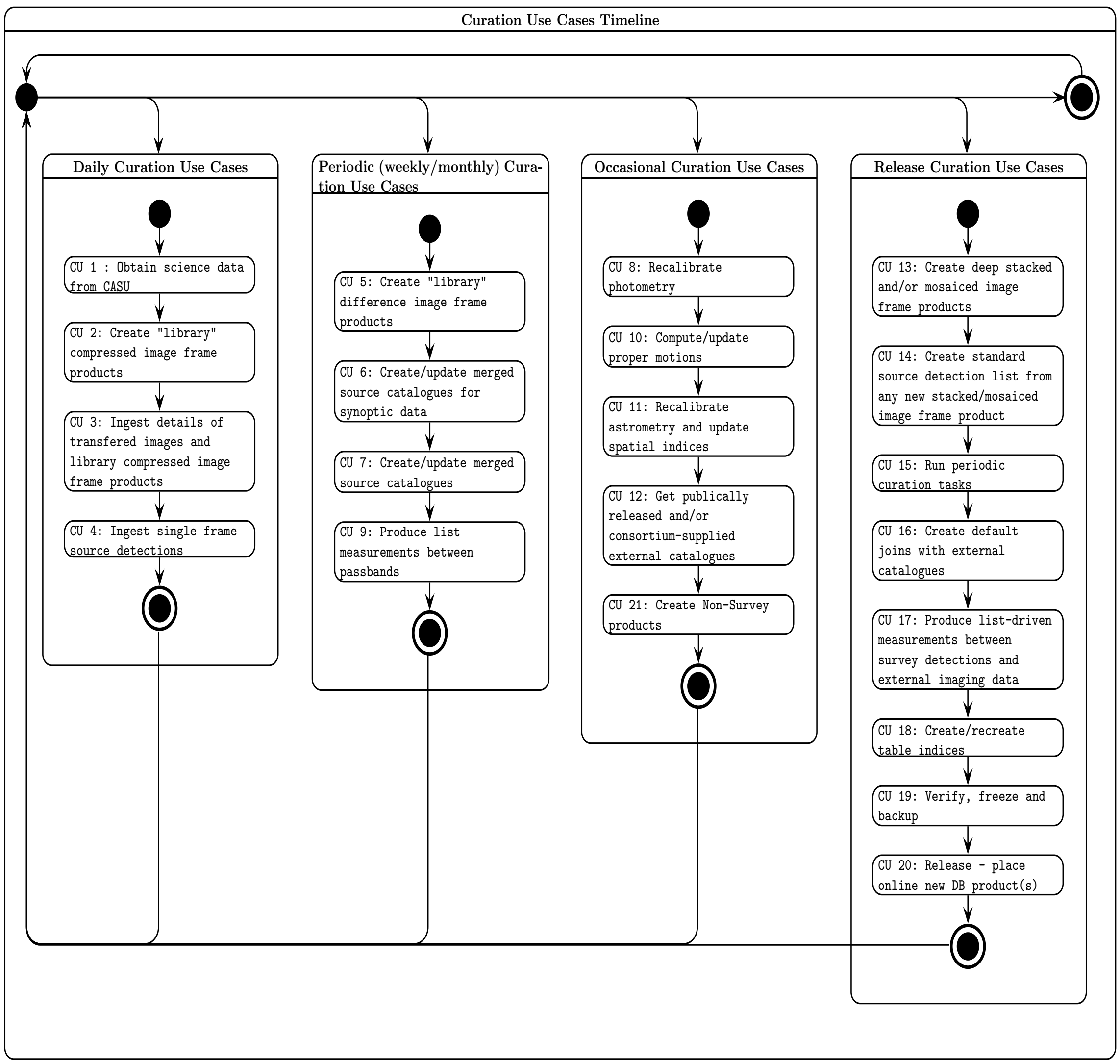

Figure 2: A block diagram synthesising each archive curation step. QC-II is between CU4 and CU5.