PUBLIC SURVEY PANEL REVIEW 2011:
VISTA PUBLIC SURVEY STATUS REPORT

This report must be returned to the Observing Programmes Office of the European Southern Observatory (opo@eso.org) before **October 14, 2011**.

ESO PROPOSAL No.: 179.B-2003
TITLE: The near-infrared YJKs survey of the Magellanic Clouds system (VMC)
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1. Scientific Aims (brief description)

The aims of the VMC survey are the determination of the spatially resolved star formation history (SFH) and the three-dimensional (3D) geometry of the Magellanic system. The Magellanic system comprises the Large Magellanic Cloud (LMC), the Small Magellanic Cloud (SMC), the Magellanic Bridge and Stream. The main VMC science goals drive the observing strategy with respect to depth and multi-epochs.

The SFH requires data as deep as the oldest main sequence turn-off point of the stellar population and multi-filters to sample variations in age and metallicity. The SFH is recovered from the analysis of colour-magnitude diagrams (CMDs) and simulations of the observed stellar population, accounting for Milky Way foreground stars and reddening. The 3D geometry is derived using different density and distance indicators like the Cepheid and RR Lyrae period-luminosity relation, period-luminosity Wesenheit relations and the luminosity of red clump stars. The different indicators are going to probe the structure of the system as a function of time.
The VMC survey science addresses many other issues in the field of star and galaxy formation and evolution, such as: stellar clusters and streams, extended sources, proper motion, star formation, distance scale, models of Magellanic system evolution, and extinction mapping.

2. Detailed progress report with respect to initial estimate from the Survey Management Plan (including preliminary results, whether published or not).

2.1. Progress report

The observations for the VMC survey, started in P84 (instead of P81 from the SMP), have progressed slower than expected. Several fields have been initiated, two fields in the LMC were completed in P86 and 8 fields may be completed in P88 of which 6 in the LMC and 2 in the SMC. Therefore, only fractions of the allocated time have been used to acquire data, significantly undermining the completion of the survey within five years. It should be noted that this might be due to the observing conditions, technical time and the interweaving of VMC observations with other VISTA surveys.

The quality of the data with respect to the expected sensitivity and crowding as well as requested observing conditions has proved successful. Contrary to the SMP an integration time of 5 sec was adopted in the Ks band following the revision of the Exposure Time Calculator prior the start of the survey. Further tests confirming this

choice were done during the science verification period. The seeing constrained was relaxed to vary from 0.8 arcsec in Ks in crowded fields, like the LMC bar, to 1.2 arcsec in Y for outer and less dense parts of the galaxies, like the Magellanic Bridge. Despite the increase in the VISTA overheads, compared to those estimated in the SMP, the total number of hours of the VMC survey has increased only marginally, from 1837 h estimated to 1889 h actual.

Following the recommendation of the PSP, the Mid-term goal was abandoned. The current VMC strategy aims to complete a given field within one year. This means that the Magellanic system is progressively covered field by field year by year. The distribution of the fields to cover in a given year optimizes the available survey time with respect to RA and DEC with the result that fields observed in a given year are not necessarily adjacent to previous fields, at least at the beginning of the survey. Priority is also given to specific fields of particular interest for the astronomical community, e.g. the 30 Doradus field and the South Ecliptic Pole (SEP) field.

In addition, the SMP strategy requested one epoch per band to be observed in the same night. The "same night" requirement was revised to accommodate a length of 1.5 h per OB in P84. This length was then limited to 1 h from P85. Therefore, only fractions of a VMC epoch (~ 1 h) per band fit in one OB. The present strategy is more flexible in the sense that pairs of bands are observed one after each other as part of the same OB and three such structures are observed as close as possible in time.

The table in Section 6 shows the progress of the VMC survey.

The quality of the VMC data has remained consistently good over the different observing periods guaranteeing homogeneity in the data.
The VMC data have been cross-correlated with the optical Magellanic Cloud Photometric Survery (MCPS) catalogue, mid infrared Spitzer catalogues, micro-lensing and the 2MASS catalogues. These catalogues have been implemented at Wide Field Astronomy Unit (WFAU) and can be queried together with the VMC catalogue.

Observations with the VLT Survey Telescope (VST) are required, as specified in the SMP, to obtain the periodicity information for stars in the Bridge. These, combined with the mean Ks band magnitudes from VMC, will allow the investigation of the 3D structure of the Magellanic Bridge for the first time. The collection of this data is about to commence, 40 h have been allocated to the STEP GTO programme in P88. This time will focus on 10 fields, of which 2 in the SMC and 8 in the Bridge. Among these fields 7 have already been initiated by the VMC survey.

2.2. Publications

The first VMC paper (Paper I – Cioni et al. 2011, A&A 527, 116) describes the survey strategy and first data. It informs the community about the survey, provides the coordinates of the observed fields, and the details of how the observations are performed and analyzed. The data quality is presented and science topics are addressed to show that the data meet expectations and bear a great potential for different studies.
An ESO Messenger article, based on the VMC Paper I, appeared in No. 144, p. 25.
An image press release appeared in http://www.eso.org/public/news/eso1033/.

The main image is also the front cover of the ESO Messenger No. 141.

The second VMC paper (Paper II – Miszalski et al. 2011, A&A 521, 157) is based on Planetary Nebulae (PNe). It analyses the VMC data for a sample of ~100 known PNe revealing some nebulae morphologies for the first time and aiding, together with data at other wavelengths, in the identification of contaminant non-PNe. Implications for the PNe luminosity function are also discussed.
Pre-empting the above paper, Miszalski, Napiwotzki, Cioni & Nie (2011, A&A 529, 77) show a serendipitous discovery of a PNe in the VMC survey data in the tile including 30 Doradus. This result demonstrates the potential of the VMC survey to detect PNe without traditional narrow-band imaging surveys.

The third VMC paper (Paper III – Gullieuszik et al. 2011), resubmitted recently after adjusting for the referee comments, is focused on the mass-loss rates and luminosities in LMC AGB stars. Dust radiative transfer models are presented and fitted to the stars spectral energy distribution obtained by combining VMC data with exiting data at other wavelengths. Despite the limited area covered this study shows that mass-loss rates, luminosities and chemical classification for AGB stars are reliable and offer already strong constraints to AGB evolutionary models.

The fourth VMC paper (Paper IV – Rubele et al. 2011) has also been resubmitted to the referee recently after addressing the referee comments. This paper demonstrates that the VMC data, due to the combination of depth and little sensitivity to differential reddening, allows the derivation of the space-resolved SFH of the LMC with unprecedented quality compared to previous wide-area surveys. The method uses simultaneously two CMDs, the code STARFISH and a database of models for the LMC population at various ages and metallicities as well as a model for the Milky Way. The fields studied so far are fit extremely well by a single disk model which once implemented into the SFH calculation shows that systematic errors in the star formation rate and the age-metallicity relation are reduced by a factor of two.

Other VMC papers currently in preparation are:

- RR Lyrae stars in the LMC (Moretti et al.):
  In this paper we show Ks light curves and the period-luminosity metallicity relation for RR Lyrae stars in the SEP field. We give an estimate of the distance using this relation and of the metallicity from the Fourier analysis of cross-correlated micro-lensing survey data.

- The Cepheid distance to the LMC (Ripepi et al.):
  We use our much improved Ks-band period-luminosity and Wesenheit relations to estimate the distance of the LMC. Using the galactic Cepheids with known trigonometric parallaxes as reference for the zero point, we get a preliminary distance modulus of 18.46 (0.06) mag.

- Stellar clusters in the SEP field (Guandalini et al.):
  In this paper we present the analysis of VMC data for known stellar clusters in the SEP field. We have examined 21 clusters (2 of them are multiple clusters) and for every cluster we have estimated their morphology, age and metallicity.

- Reddening map in 30 Doradus (Tatton et al.):
  The red clump data are proved to be useful in constructing reddening maps of high angular resolution. The region of highest reddening is the region surrounding R136. Reddened stars are more dominant in regions directly South, East and West of this.

- Near-infrared variables from the VLT-FLAMES survey (Evans et al.):
  This study analyses the multi-epoch Ks-band VMC data for the massive star population of the 30 Doradus region. Many stars, which were discovered as massive binaries in the FLAMES observations, show a variability that is greater than three times the expected dispersion at their magnitudes.

- Proper motion (Cioni et al.):
  The comparison between VMC and 2MASS sources suggests that stellar populations of a different type have a different proper motion within the LMC, with Galactic stars clearly recognizable from their motion. Systematic errors in the astrometry of VMC data at the level of a few mas have been quantified.

In preparation for the arrival of VMC data in the Bridge region, Bagheri, Cioni & Napiwotzki have submitted a paper to A&A this month presenting the analysis of unexplored observations from the 2MASS, DENIS and SuperCOSMOS surveys. This study finds that the Bridge is more extended than assumed previously and that there is a differing density of stars with a north-south division as well as an old stellar population in addition to the younger population already known.

3. Quality Control and Phase3. The Phase3 submission plan should be described here. In addition the PI should comment on Quality Control of the acquired data.

3.1 The PI should comment on the quality control and the science validation of the acquired data.

The Cambridge Astronomy Survey Unit (CASU) is making available tiles and their catalogues, as well as paw-print stacks, on a monthly basis, and these data are ingested at WFAU where they are linked by epoch and used to create deep stacks of paw-prints and tiles. While the work of CASU has reached a steady regime, the work at WFAU has only recently approached this status.

The first v1.0 data release made by WFAU to the VMC team via the VISTA Science Archive (VSA) dates 30th September 2010 for observations obtained up to P84 included. In this data release single-epoch tiles and their catalogues are available together with deep stacks of paw-prints, i.e. without the benefit of depth due to the reconstruction of deep tiles, organized into the variability tables, i.e. linked by epoch. Deep tile images, on two tiles only (those released to the community), were created on 18th February 2011. Deep tiles on partially completed fields and their link into the variability tables were made available on 9th September 2011 for all observations obtained up to P86 included and reduced with v1.1 of the software.

Data from CASU are quality checked by the VMC team as follows:

- Images of tiles are inspected by eye to recognize obvious artifacts;
- Average parameters, e.g. seeing, are inspected to confirm the ESO classification of the observations (within or out specifications) for both completed tiles and individual paw-print images for tiles that did not reach completion. Those paw-print images meeting VMC specifications are included into the deep tiles. They also contribute to multi-epoch observations organized by paw-prints instead of by tiles. Parameters are also confronted with QC CASU values across many nights.
- All paw-print images are inspected at Padova prior to the creation of tiles from which to extract magnitudes with the PSF method and derive the SFH. CMDs are created and the sensitivity in each band is verified.
- The QC resulting from the three steps above is fed back to CASU, in case a re-processing of the data might be needed, and to WFAU to flag data that should be excluded from deep tiles.

Data from WFAU are quality checked by the VMC team as follows:

- Deep tile images are inspected by eye to look for obvious artifacts and for the counterparts of known PNe, stellar clusters and young stellar objects.
- Multi-epoch data for known variable stars, i.e. Cepheids, RR Lyrae stars and long period variables, are arranged by phase and their light-curve is inspected. Here all tile data points and/or paw-print data points are used, also those corresponding to observations out of specifications.
- CMDs and magnitude distributions of single and deep tile catalogues are created to assess the sensitivity of the data. Source detection is inspected as a function of coordinates in the sky.
- Cross-correlations between the VMC data and data at other wavelengths as well

as the use of VMC data within user-made programs to address a specific scientific question also provide a means of QC of the VMC data.

From a VMC point of view, the main difference between v1.0 and v1.1 data is the link of epochs by tile with the implementation of the correct Julian day value.
While in v1.0 data the Julian day refers to the beginning of the set of exposures included in one OB, i.e. one tile epoch, in v1.1 data each star carries a mean value from all exposures where this stars is present. Note that the time it takes to observe a sequence of 6 paw-prints as part of a VMC OB is 1 h during which stars like RR Lyrae variables experience a significant variation in brightness.

3.2 The PI should describe the current status of the Phase 3 submission. Any feedback or requested modifications of data products or timeline for survey releases should be described here. PIs should also include any relevant information for the scientific validation of the data products.

The first VMC data corresponding to two completely observed tiles (the 30 Doradus and SEP tiles in the LMC) were submitted as part of Phase 3 to ESO in April 2011. This data release comprises: deep tiles in Y, J and Ks bands, confidence maps, source lists and band-merged catalogues as well as preview images.
The data were reduced at CASU with software v1.0 (see 3.1 for quality issues), further processed and prepared at WFAU, adjusted following ESO validation procedures and released worldwide in September 2011.

The released data comprise observations obtained from November 2009 until November 2010 and may present the following issues: a variable depth due to bad pixels in detectors #1, #4 and #16 as well as some bad rows, point-like objects residuals of flat fielding, variable vignetting and spurious detections around bright stars. Observations obtained prior to 20th November 2009 had an intermittently bad channel in detector #6 also causing spurious objects. The issue with detector #16 affects the magnitude of stars in its upper stripe and this may cause a shift in the distribution of stars in CMDs. This effect is more pronounced in those diagrams involving the Y band. Future data releases will allow isolating the affected sources from the information in the catalogues.
Catalogues were created from images that were filtered for nebulosity with size of the order of 30 arcsec, but the filtering process was not applied to the images.
The Julian day, whilst being incorrect in the released data (see 3.1), has no direct influence on them, since only deep tiles are released and not individual epochs, but the general user is warned about it in the data release description. It is the intention of the VMC team to replace these v1.0 data with v1.1 data, at the next data release together with individual epochs. Deep tiles were produced only from data that met the observing criteria for the VMC survey.

The feedback from ESO on the original data referred to: unpacking of compressed data, missing header parameters, links among submitted files and zero-point values. An inconsistency between the validation software at ESO and at WFAU was also found. These issues were resolved and new data were prepared and accepted.

In the near future, v1.1 data will also be made available to the astronomical community via the VSA.

As written in the SMP, the VMC team is preparing other data products, such as the results of artificial star tests experiments, completeness and photometric error estimates for the fields that have been analyzed for the SFH recovery. The VMC PI will contact ESO shortly to explore the best way for making these data products available to the worldwide astronomical community.

4. Are any changes proposed with respect to the Survey Management Plan in P89 (e.g., in strategy, field coordinates, exposure time and/or other

Based on what follows the VMC team requests 100 h of allocation in P89.

In line with the SMP, odd periods are better suited to observe the Magellanic Bridge, SMC and Magellanic Stream parts of the VMC survey and a time allocation of 100 h is well suited to the visibility of the targets at the VMC observing conditions. This is just 25 h longer than stated in the SMP. It takes into account the observational experience showing that the observing rate of VMC was higher in odd periods (e.g. P85) than it was in even periods (e.g. P86).

During P89 we propose to spend 20 h completing Ks observations of SMC fields already in the queue and partially observed as well as 11 h for similar observations of Bridge fields. In addition we plan to begin the observation of 6 new VMC fields of which 3 in the SMC and 2 in the Bridge, this takes ~62 h. The remaining 7 h to reach a grand total of 100 h will be used to re-submit OBs that have in the meantime expired, because of their time validity, in order to reach completion of the affected fields. The requested time and the distribution of the fields accounts for the visibility of VMC fields within the range of airmass specified for the homogeneity of the survey and the time distribution of Ks epochs.

No other change is foreseen for strategy, exposure time and other settings.

5. Observing Plan.
Please include the specific request for P89 observing time in the table below.

Period	Field name/ mean RA	Filter	Time (h)	Seeing	Moon	Transparency	Comments / strategy (e.g., no. of epochs)
89	5 SMC	Ks	20	0.8-1.0	all	thin	TK7-TK11
89	5 Bridge	Ks	11	1.0	all	thin	TK8-TK11
89	3 SMC	YJKs	37	0.8-1.2	all	thin	YJ all + 6Ks
89	2 Bridge	YJKs	25	1.0-1.2	all	thin	YJ all + 6Ks
89	SMC & Bridge	Ks	7	0.8-1.0	all	thin	Expired TKn

6. Overall survey completion

Specify the overall survey completion after the first 1.5yr of operations. What has been achieved? Please provide total estimate of the time necessary to complete the survey using the current survey observation overheads. In case this differs from the request in the approved SMP, please provide a short rationale for the difference.

The table below shows the completion of the VMC survey as of 15th October 2011. This amounts to ~16% overall with a greater completion rate in the Y and J bands than in the Ks band. This is expected due to the different number of OBs in each wave band. The completion rate is higher for the Bridge and Stream regions that are covered by a smaller number of tiles compared to the LMC and SMC.

Description	VMC	LMC	SMC	Bridge	Stream
No. of tiles	110	68	27	13	2
No. of epochs	1980	1224	486	234	36
No. of Y epochs	330	204	81	39	6
No. of J epochs	330	204	81	39	6
No. of K_s epochs	1320	816	324	156	24
Observed Y epochs	82	38.5	23	14.5	6
Observed J epochs	82.5	36.5	23	17	6
Observed K_s epochs	150.5	85	29.5	21	15
Observed epochs	315	160	75.5	52.5	27
Completion in Y	24.8%	18.9%	28.4%	37.2%	100%
Completion in J	25%	17.9%	28.4%	43.6%	100%
Completion in K_s	11.4%	10.4%	9.1%	13.5%	62.5%
Total completion	15.9%	13.1%	15.5%	22.4%	75%

The total length of the VMC survey, ~ 1900 h, is marginally more than what was requested in the SMP, ~1850 h. This is due to a combination of different factors, such as a shortening of the DIT time in the Ks band, a reduced seeing that allows to meet sooner the requested sensitivity and the nesting of OBs within the revised p2pp structures, against the increase in VISTA overheads.

The estimated time to complete the VMC survey depends strongly on the percentage of executed observations versus the allocated time. If all the time allocated to the VMC survey so far were used to successfully observe VMC tiles the present completion of the survey would be ~25%, even considering that 10% of the time was used for repeating observations.

While in P84 and P85 the percentage of successfully completed VMC observations was at least 80% (out of 130 h allocated) in P86 this percentage dropped to ~30% (out of 300 h allocated). P86 OBs have been carried over to the subsequent periods and at present their completion is about 50%. See the table below for details as of 15th October 2011. Note that repeated observations occurred either because the observing conditions were not met throughout the

entire duration of a given OB (beyond the 10% tolerance applied by ESO on the OB quality), or because of other reasons, such as a high stellar ellipticity.

Period (run)	Allocated (h)	Observed (h)	Observed (%)	Repeated (h - %)
P84 (B)	100	79	79	11 - 11
P85 (C)	30	29	96.5	5 - 17
P86 (D)	300	152	50.7	38.5 - 12.8
P87 (E)	82	43	52.4	5 - 6
P88 (F)	4	0	0	0 - 0
Total	516	303	58.7	11.5

With on average 400 h to be allocated in each of the few coming years, 100 h in odd periods and 300 h in even periods, the VMC survey may reach completion by end of P96 (within 6 years from start), but this estimate assumes a rate of observation of 100%. At a reduced rate of 75% the total survey length will be of 8 years.

This input will be reviewed by the Public Survey Panel and will be taken together with the section on the survey progress report (Sect. 2) and Phase 3 submission report (Sect. 3) into account to assess your survey together with the other VISTA surveys and to make recommendations regarding the time allocation for Period 89 and beyond.