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

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1.1 Abstract: (10 lines max)

The Magellanic Clouds represent the nearest templates for the study of stellar populations and galaxy interactions. This survey aims to collect YJK_s-band photometry across the entire system (LMC, SMC & Bridge) 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 (0.2 dex in age) and to construct a three-dimensional map of the system. A wide-area coverage (285 deg^2, 90 deg^2 and 45 deg^2 on the LMC, SMC and the Bridge) encompassing the D_{25} as well as covering major features delineated by the distribution of stars and HI gas, will both trace the structure of the galaxies and signatures of past interactions. Contemporary kinematic and optical observations of comparable sensitivity (e.g. AAOmegallan@AAT and STEP@VST) will provide the community with a unique database for future studies of the system and will allow us to predict much better what has happened in other places in the Universe.

2 Description of the survey: (Text: 3 pages, Figures: 2 pages)

2.1 Scientific rationale:

To understand the history of formation and evolution of galaxies we need to study the distribution of age, chemical abundance and kinematics of the stellar as well as the gaseous component. Moreover, we need to obtain a global picture of the star formation history (SFH) that accounts for both the intrinsic evolution as well as the effects of interaction with neighbouring systems.

Why the Magellanic Clouds?

The Magellanic Clouds (MCs) represent an ideal laboratory for these studies because they span a broad range of stellar populations and are actively forming stars at present. Furthermore, the ongoing interaction between the Clouds themselves and with the Milky Way (MW) is representative of the environmental effects that galaxies experience in groups similar to our own (i.e. the Local Group). The MCs are close enough to resolve in detail their stellar content which provides additional sampling of metallicity space compared to the MW as well as a much more extended age range of the massive cluster systems (younger, but more massive than the MW's open clusters). The MCs lie in a region of low Galactic extinction and we know their distances quite accurately, which is essential for precise absolute photometric studies. The irregular appearance of these galaxies in the sky is dominated by the distribution of young stars, while evolved stars trace a more regular elliptical structure of also greater extent. Their thickness along the line of sight is rather small (it is higher for the Small Cloud) but a three-dimensional (3D) map has never been obtained. Embedded in each galaxy is a bar, which is the result of galaxy evolution and/or interaction. At present the Clouds constitute a binary system, although it is possible that it formed only ≈ 4 Gyr ago while the birth place of each galaxy was different. They are connected by an HI-dominated gaseous stream (the Bridge), that may also result from their interaction with the MW.

Relation to previous studies

Observations of the MCs to disentangle their structure and stellar population were performed using small telescopes: deep but spatially limited HST observations and wide-area but shallow optical (i.e. MCPS, MACHO & OGLE) and near-infrared (i.e. 2MASS & DENIS) surveys. Instead, follow-up observations using large telescopes (i.e. VLT and Keck) have provided detailed chemical abundances of limited samples of stars. Even though these projects had a successful impact on our understanding of the system, a global picture is still lacking. Analysing deep and homogeneous multi-band data obtained from the proposed VMC survey will remedy this important issue. Furthermore, combining VMC data with the results of on-going or planned wide-area spectroscopic surveys

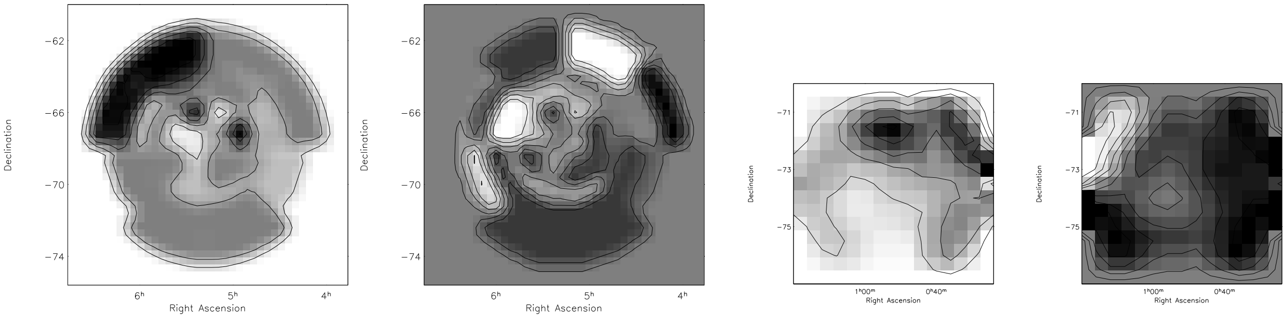


Figure 1: (from left to right) Distribution of metallicity (contours: $Z = 0.003 - 0.015$ in steps of 0.003) and of mean age (contours: $3 - 9$ Gyr in steps of 1 Gyr) of the stellar population across the LMC and across the SMC (same contours except that the highest age is 10 Gyr). Darker regions correspond to higher numbers.

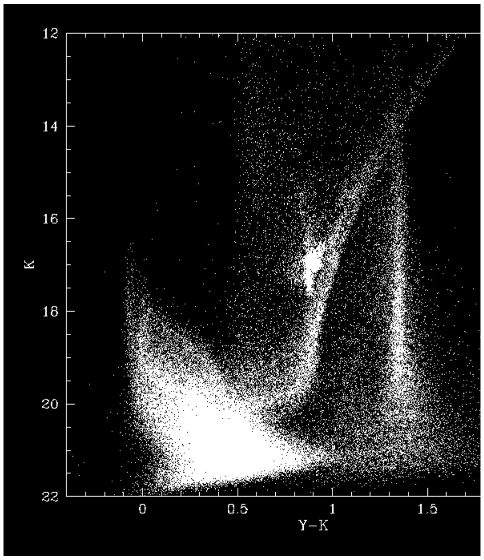
(that allow us to disentangle different generations of stars from their chemistry) and complementary wide-area optical photometric surveys will provide us with the ultimate understanding of the SFH across the Magellanic System.

Information about the SFH of the Large Magellanic Cloud (LMC) has been derived from the study of many relatively small regions located in the outer and inner disk as well as along the bar. In the Small Magellanic Cloud (SMC), apart from the quite comprehensive study by Harris & Zaritsky (2004, ApJ 127, 1531), which does not probe the outer structure, there have been considerably fewer (and less detailed) observations of the field and cluster stellar populations than in the LMC. Cioni et al. (2006, A&A 448, 1; 2006, A&A *accepted*) compared the K_s magnitude distribution of asymptotic giant branch (AGB) stars with theoretical distributions to provide surface maps showing the inhomogeneous distribution of metallicity and mean age within each galaxy (**Fig. 1**). It remains unclear whether this is due to tidal interaction and how long this inhomogeneity can be seen after its formation. Using VMC data the distribution of field stars in different phases of evolution, i.e., upper main-sequence (MS) stars, sub-giant stars, upper and lower red giant branch (RGB) stars, red clump stars, RR Lyrae, Cepheids, AGB stars and nebulae will be traced out to distances never yet explored. In particular we aim to sample the population of RGB stars because their behaviour is better understood and, because they are likely more metal poor and significantly less centrally concentrated, they trace the tidally stripped parts of galaxies and the extended halo component. Densities of different stellar objects are strongly correlated with the SFH. RGB and red clump densities, for instance, are affected by the cumulative SFH between 1 and 12 Gyr. A peak of SFR of equal intensity will generate 10 red clump stars in 1 Gyr and just 1 at 10 Gyr (the dependence on metallicity is much smaller and not an issue). Therefore, measuring the SFH, at least roughly via sub-giant stars, is important for the analysis of density maps.

We have performed several simple tests of the SFH-recovery efficiency, based on simulations of VMC data like the one shown in **Fig. 3**, after cleaning for Galactic foreground stars. The SFH was then recovered using the Harris & Zaritsky StarFISH code using both YK and JK colour-magnitude diagrams, bins 0.2 dex wide in log(age), and default values for main StarFISH parameters. A typical result is shown in **Fig. 2**, which plots the ratio simulated/recovered SFH as a function of stellar age. Discrepancies are less than 50 percent, and are systematic because a similar pattern appears for different input SFHs. These experiments give us confidence that it will be possible to recover the spacially resolved SFH with ~ 25 percent accuracy and with a 0.2 dex resolution in age, for each one of the VMC pointings.

Outstanding problems

Despite numerous previous studies, it has not yet been established conclusively whether the field stellar population has experienced the same SFH as the cluster stellar population system. While it is relatively well established that the LMC contains a large excess of clusters likely induced by the last close passage between the Clouds, little is known about SMC's cluster population. By combining integrated properties with resolved stellar population studies, the MC cluster system offers a unique chance to independently check the accuracy of age (and corresponding mass) determinations based on broad-band spectral energy distributions. Anders et



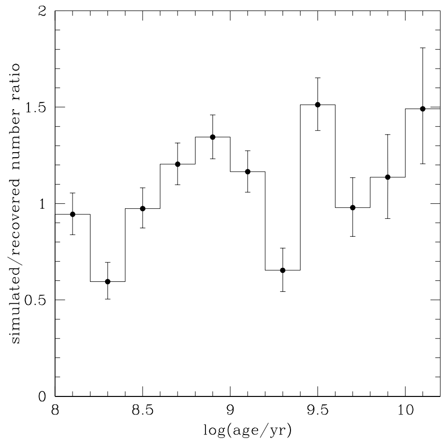


Figure 2: Simulated/recovered SFH ratio as a function of stellar age. Bins are 0.2 dex wide in log(age).

Figure 3: Simulated colour-magnitude diagrams for a 0.6 deg^2 LMC area close to Hodge 10, whose SFH is known from HST data (Holtzman et al. 1999, AJ 118, 2262). The simulation uses UKIDSS filter curves, a uniform extinction of $A_V = 0.18$ mag, and the photometric errors expected from our targeted S/N. Clearly shown are: the MS with turn-offs between 10^8 to 10^{10} yr, at $-0.1 < (Y-K) < 0.7$ and $16.5 < K < 20.5$; the complete RGB, plus early-AGB and red clump phases; the Galactic foreground stars, mostly comprised in the almost-vertical sequences at $0.5 < (Y-K) < 1.5$.

al. (2004, MNRAS 347, 196) and de Grijs et al. (2006, MNRAS 366, 295) developed a method that employs multiple passband observations to simultaneously obtain cluster ages, masses, metallicities and extinction values. Absolute ages were derived with a precision of 35% and relative ages to within a few percent, i.e. an order of magnitude better (**Fig. 5**). This is the precision we expect to reach from the analysis of the homogeneous VMC data set. Moreover, by including near-infrared passbands we can constrain any metallicity and extinction variations much more precisely than using optical data alone, as has been done so far. The slope and the colour of the RGB in the (K_s, $J-K_s$) diagram is also a reliable metallicity indicator (Ivanov & Borissova 2002, A&A 390, 937; Valenti et al. 2004, MNRAS 354, 815). Wide-field homogeneous VMC data will produce a complete (except for inter detector gaps) census of the cluster population. For comparison, OGLE found 72 new clusters in the central 2.4 deg^2 of the SMC and 126 in the central 5.8 deg^2 of the LMC. A search for clusters in the MW based on the 2MASS database using a robust method based on the stellar surface density has also been carried out (Ivanov et al. 2002, A&A 394, L1; Borissova et al 2003, A&A 411, 83). This technique will work better in the Clouds than in the MW because of the much lower confusion along the line of sight.

The Bridge regions holds important clues about the most recent ($\approx 10^8$ yr ago) interaction between the Clouds, and indeed about its own formation history and possible origin; what is the age difference between the western and eastern parts of the Bridge? Our multi-passband survey will answer this question and will also test the formation scenario predicted by simulations of a Magellanic collision. Galaxy interactions play a major role in controlling the SFH of field stars and clusters but also in transforming galactic morphologies. The SFH of the MCs depends strongly on the interaction history of the triple system (LMC-SMC-MW), thus on the orbits and masses of the MCs. Constraints on these fundamental parameters can be set by comparison with chemodynamical simulations (Bekki & Chiba 2005, MNRAS 356, 680; Mastropietro et al. 2005, MNRAS 363, 509; Connors, Kawata & Gibson, astro-ph/0508390) while the self-consistency of the predicted orbits will be assessed using precise proper motion data provided in the future by GAIA astrometry. Although current models explain reasonably well the formation of the bar, the disk and the halo of the LMC as well as the gap in the age distribution of clusters, there are still significant uncertainties. For example, because the formation histories of field stars and globular clusters as well as the structural and kinematic properties in the LMC are different from those in the SMC, it is not yet clear wether these two galaxies were born as a pair. Moreover, did the stellar halo form via a different mechanism for Magellanic-type dwarf galaxies than for large spirals? (i.e. by

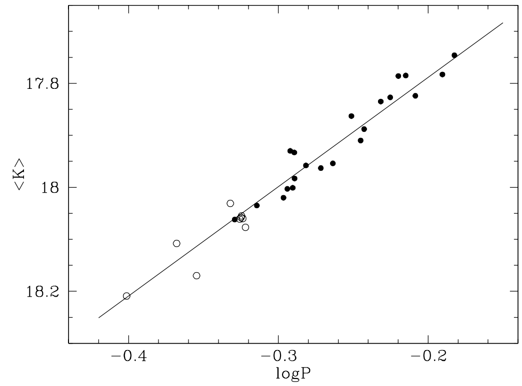


Figure 4: Log$P-<K>$ relation for Reticulum RR Lyrae stars. Open symbols are RR*c* stars after their periods have been fundamentalized by adding 0.127 to log$P$. Filled symbols are RR*ab* stars. The line is the theoretical prediction for the derived distance.

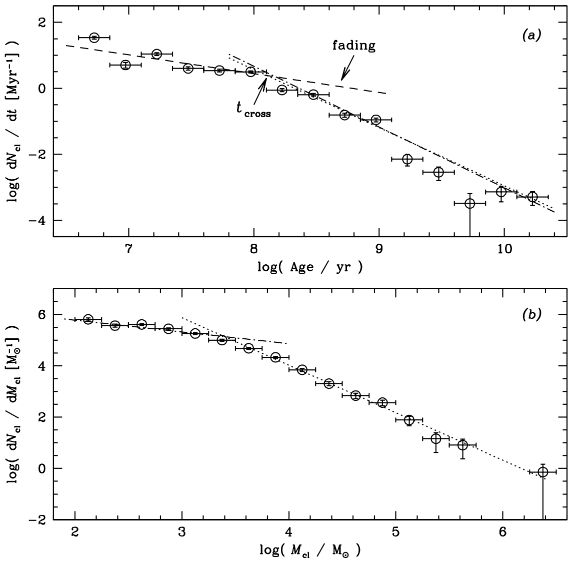


Figure 5: *(a)* – The LMC cluster formation rate (in number of clusters per Myr) as a function of age. The dashed line is the least-squares power-law fit to the fading, non-disrupted clusters, for a constant ongoing cluster formation rate. The dotted and dash-dotted lines are the disruption lines for the most likely age ranges where disruption may dominate evolutionary fading. *(b)* – Mass spectrum of the LMC clusters; the dotted line represents a power-law fit to the cluster-mass-function (CMF) that is as yet unaffected by disruption; the slope of the dash-dotted line is entirely determined by the initial CMF slope derived from the dotted line, and stellar population synthesis.

tidal galaxy interaction rather than by merging/accretion of subgalactic clumps?). Stars are expected to be stripped by gravitational forces along with the gas (although stellar debris may have a different distribution with respect to the gas); can we re-trace their path?

One of the key points of this survey is to provide a 3D picture of the Magellanic system. For this we plan to use different density and distance indicators: (i) the red clump's apparent magnitude, (ii) the period-magnitude relation for RR Lyrae stars which sample the old stellar population ($t > 10$ Gyr), (iii) the period-magnitude relation for Cepheids which sample the young stellar population (about 100 Myr). None of them is free of *problems*, however, their combination will ultimately constrain the structure of the system. In particular the red clump's magnitude related to any other quantity depends on the SFH (Girardi & Salaris 2001, MNRAS 323, 109). Recovering the SFH with a resolution of 0.2 dex in the age (**Fig. 2**) will provide us with an accuracy of 0.05 mag on the determination of distance moduli, which is necessary for our study. The period-magnitude relation for RR Lyrae stars exists only in the near-infrared bands and is especially useful in the K_s band (Longmore et al. 1986, MNRAS 220, 279; Bono et al. 2001, MNRAS 326, 1183). Although it is weakly affected by evolutionary effects, spreads in stellar mass inside the instability strip, and uncertainties in the reddening correction, it does depend on metallicity. Dall'Ora et al. (2004, ApJ 610, 269) show the application of this relation to refine the distance to the Reticulum cluster in the LMC (**Fig. 4**). The theoretical calibration of this relation relies strongly on the $(V-K)$ colour. RR Lyrae stars in the MCs have $K_s \approx 18.0-19.0$ mag and optical data of comparable sensitivity covering most of the LMC and the SMC from which to derive the period of the variation, are available from the OGLE II, III and SuperMACHO surveys while similar data covering the Bridge will be obtained from STEP (Sect. 3). Thus, it is of prime importance to measure the mean K_s-band magnitude of RR Lyrae stars with the VMC survey. Our strategy is optimized to do so. The instrinsic accuracy of the period-magnitude-metallicity relation (i.e. ≈ 0.05 mag; Dall'Ora et al. 2004, ApJ 610, 269) can also be used as a tool to map the 3D distribution of the stellar populations in the MCs. As for Cepheids, it is well known that the period-luminosity relation in the near-infrared bands is much narrower than the corresponding optical relations and less affected by systematic uncertainties related to our knowledge of the reddening and the metal content (e.g. Caputo, Marconi, Musella 2000, A&A, 354, 610).

Due to the reduced dependence on the intrinsic width of the instability strip these relations can be used to

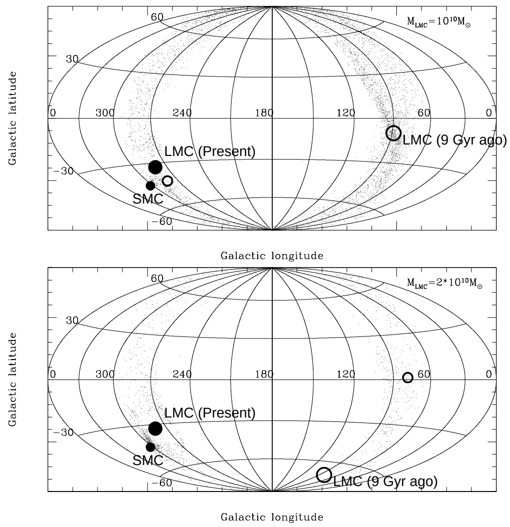


Figure 6: Distribution of old stars stripped from the LMC disc for two models produced, assuming a different LMC total mass. The present locations of the LMC and the SMC are indicated by large and small filled circles, whereas their locations ≈ 9 Gyr ago are indicated by large and small open circles.

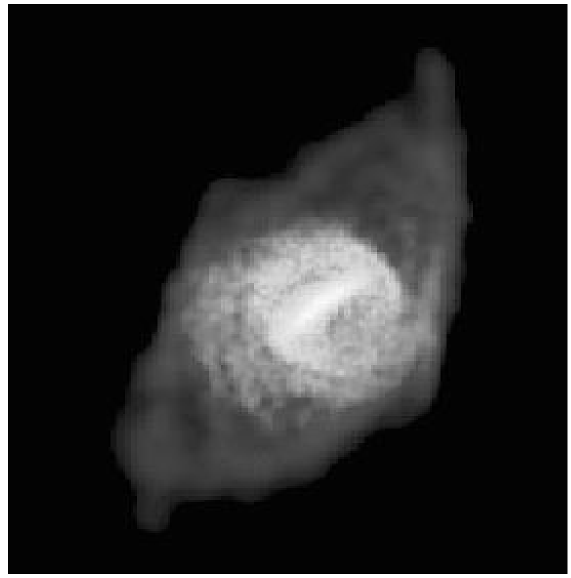


Figure 7: Simulated LMC stellar surface density (face-on projection). Greyscale is a logarithmic scale, where white corresponds to a density of 10^2 $M_\odot$ pc^{-2} and dark grey to 10^{-2} $M_\odot$ pc^{-2}. The bar and the strong warp are visible.

constrain the MC geometry. The observed properties of RR Lyrae and Classical Cepheids will be compared with an updated theoretical scenario based on nonlinear convective models of pulsating stars (e.g. Bono et al. 2005 ApJ 621 966; Marconi et al. 2003, ApJ, 596, 299). For RR Lyrae stars accurate metal dependent period-luminosity relations in the K band have been derived on the basis of an extensive model set both for the fundamental and the first overtone mode. As for Classical Cepheids, the application of theoretical period-luminosity and period-luminosity-colour relations to both near-infrared and optical data will allow us to infer self consistent evaluations of distances, reddenings and metal abundances (Caputo et al. 1999, ApJ, 525, 784; 2001, A&A, 372, 544) as well as sound contraint on the 3D structures. Moreover, further information on the star formation history of the SMC could be inferred from the application of theoretical period-age and period-age-color relations to observed Classical Cepheids. These tight relations have been already applied to both field and cluster Cepheids in the Milky Way and in the Magellanic Clouds (Bono et al. 2005, ApJ, 621, 966; Marconi et al. 2005; MemSait, *in press*).

Ancillary science

Previous shallow near-infrared surveys (i.e. 2MASS & DENIS) have been unable to probe to such K_s magnitudes as to readily reveal obscured, reddened massive stars as well as faint (old) PNe. With the benefit of the K_s-band VMC observations we will no doubt discover a wealth of embedded and obscured massive stars in their nascent clouds, which will reveal whether our view of present-day star-formation in the Clouds is representative of the true situation, i.e. are we 'missing' large numbers of the most massive stars that are still in obscured clusters? The fusion of the wide-field VMC & STEP photometry with AAOmegallan spectroscopy (Sect. 3) will identify both high- and low-mass emission line stars, in particular determining the incidence of circumstellar disks via their infra-red excesses.

The density of PNe in the Clouds is low (< 5 deg^{-2}) and it is therefore important that VMC observations cover a wide area. PNe will be bright in K_s because of Brackett Gamma emission and much fainter, if detected, in YJ (continuum) compared to other emission-line objects, unless they belong to a binary system. According to the evolution scenario, the number of presently known PNe corresponds to just 10% of the predicted number. Thus, we are missing the majority of the population which are fainter and more extended. VMC data combined with broad-band optical data and in particular with Hα and [OIII] images (Jacoby et al. 2002, AJ 123, 269; Reid & Parker 2006, MNRAS 365, 401; Leisy *private comm.*) will allow us to design a method to uncover many of the missing PNe in the Clouds and in the Bridge (if any). The study of both PNe and HII regions will complement the information from the oldest stellar population (e.g. RGB and horizontal branch stars) and will allow us to constrain the evolution scenarios as well as the age-metallicity degeneracy.

2.2 Immediate objective:

The main goal of the VMC Public survey is to obtain deep and homogeneous YJK_s-band photometry across the LMC, the SMC and the Bridge to a sensitivity limit corresponding to $K_s = 20.3$ at $S/N = 10$. This survey reaches sources 6 magnitudes fainter than those detected by 2MASS ($S/N = 10$ at $K_s = 14.3$) across a wide-area, yet never explored at this sensitivity, and with a spatial resolution which, considering the average seeing, is a factor of 3 better than that of 2MASS. These specifics translate into a tremendous improvement on the study of the overall stellar population: all RGB stars, red clump stars, RR Lyrae, Cepheids, turn-off and upper main-sequence stars will be detected and used to infer the properties (structure and history) of the system. Moreover, observations in the near-infrared domain provide a higher source-to-celestial background contrast than in the optical domain. The seeing is better and the interstellar absorption is lower, making images sharper and thus overcoming crowding effects within the galaxies.

From the systematic analysis of these data we aim to derive the global and spatially resolved SFH, using both field stars (**Fig. 2 & 3**) and star clusters (**Fig. 5**), that accounts for both the intrinsic evolution within each galaxy and the dynamical evolution of the interaction between the LMC and the SMC and between the MCs and the MW. By tracing in detail the extent of different kinds of stars and deriving, using up-to-date stellar evolutionary models, age and metallicity, we will constrain the epoch of formation of each galactic component. In particular, because of the wide area covered, we will constrain the halo formation scenario. On the basis of these new data, simulations of this fascinating three-body system will be tested and improved to account for the effect of each stellar component and for the inhomogeneous distribution of age and metallicity across the system (**Fig. 6 & 7**).

The observing strategy (Sect. 4) designed to reach the required sensitivity allows us also to obtain the mean K_s mag of RR Lyrae and Cepheid stars by combining 5 independent observations. The amplitude of the near-infrared lightcurve variation of these variables is low (about $0.2 - 0.4$ mag). Thus, only a few points are necessary to calculate their mean magnitude. This information together with the period of variation obtained from optical surveys will constrain the slope of the zero-point of the period-magnitude relations (e.g. **Fig. 4**) as well as improving the current empirical constraints on the metallicity dependence. Both period-magnitude relations will be used to derive the 3D structure of the MCs.

We plan to sample through regions spatially limited by the size of individual VISTA detectors (i.e. pawprints and not tiles) beyond the D_{25} radius to reveal the history of the extented structure of the Magellanic system. This technique is an ideal compromise between integration time and surface area needed to meet the goals of the survey.

3 Are there ongoing or planned similar surveys? How will the proposed survey differ from those? (1 page max)

The VMC survey proposed here is strongly linked and complementary to other spectroscopic and "photometric visual surveys" of the LMC-Bridge-SMC system, which will strongly benefit from each other, providing a new, complete and absolutely unique view of this system. A list of these contemporary surveys is given below.

- AAOmegallan (Oct. 2006–Dec. 2008) is a large spectroscopic survey program proposed by several members of our team (PI: van Loon, co-I's include Cioni), using AAOmega on the AAT, with the goal of observing $\approx 150,000$ stars sampling all structural, kinematical, chronological and chemical stellar populations encompassing both the MCs and the Bridge. This survey will reach red clump stars at about $K_s = 17$. Pilot study observations were successfully obtained in February 2006.

- STEP (Oct. 2007 – 2008) is a Guaranteed Time Observation (GTO) program to survey the SMC and the Bridge proposed by some members of our team (PI: Ripepi, co-I's include Cioni), using OmegaCAM on the VST, with the aim of addressing various issues concerning the SFH, the structure and the stellar components of the SMC. These data will provide the period of the light variation of RR Lyrae stars and Cepheids that, combined with the mean K_s-band mag from VMC, constitute powerful distance indicators.

- The SIRIUS camera on the 1.4-m telescope in South Africa has monitored a region of about 3 deg^2 along the LMC bar since 2000 and a region of about 1 deg^2 centred on the SMC since 2001. Both monitoring projects were completed in 2005. This Japanese-led survey has a S/N$\approx$ 20 at $K_s = 16.0$ (i.e. about half a magnitude fainter than the 2MASS limit), although the data products, subject to a collaborative agreement, have not yet been finalised (to be expected by mid-2006). Major questions related to the evolution of Long Period Variables and Cepheids will be answered by this program.

- Two Spitzer Space Telescope survey programs to map the LMC (SAGE; Meixner et al.) and the SMC (S3MC; Bollato et al.), with as key goal the production of a mid-infrared point source catalogue. The scientific issues focused on by the survey teams (including van Loon for S3MC) are all related to the interstellar medium. The link with the proposed VMC survey is that many of the mid-infrared point sources will be dusty giants, and so by combining this survey with the Spitzer mid-IR survey, we might be able to relate the dust production sites to age and metallicity, on statistical grounds. Both Spitzer data products will be publically available in about a year from now.

- Akari (formerly Astro-F, successfully launched on 21.02.06) will carry out a shallow 7-band all sky survey plus targeting about 2 deg^2 of the LMC in the mid-infrared and far-infrared domain. These observations will take place during phase II (Sept. 2006–June 2007) and a catalogue of sources should be released after about 1 year (proprietary period). Although the pixel size is rather large, these data will allow us to study dusty sources with respect to age and metallicity.

- MOSAIC observations from the Blanco 4m-telescope at NOAO of the outer regions of the MCs (from about 7° to 20° away from the galaxy centers) are being proposed by a team lead by A. Saha. The aim of this deep (about 2 mag below the faintest turn-off) Washington broad-band ($CRIM$ filters) and narrow-band survey is to probe the extent and properties of the halo of the MCs. Both RGB stars, disentangled from nearby dwarf stars, and MS stars will be used for this purpose. We are in contact with the PI to coordinate fields overlap that will eventually benefit the science goals of both surveys.

- Additional 2MASS observations covering the MCs, but not the Bridge, have been performed throughout the nominal survey time. These deep data ($6 \times t$) which will be released at the end of 2006 should reach about 1 mag fainter sources ($K_s \approx 15$ at S/N= 10). Although including the red giant bump they will not reach red clump stars. They will provide an up-to-date bright complement to VMC data.

4 Observing strategy: (1 page max)

This proposal aims to put serious constraints on the SFH across the Magellanic system (LMC+Bridge+SMC) to an unprecedented level of spatial resolution, which is only possible using deep wide-field data. To derive the global properties of the system we propose to cover a large enough 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 Symp. 148, 453) and HI gas (see Staveley-Smith et al. 2003, MNRAS 339, 87 for the LMC, Hatzidimitriou et al. 2005, MNRAS 360, 117 for the SMC and Muller et al. 2003, MNRAS 339, 105 for both the high HI column density portion of the Bridge and the lower-column density portion to the north). Therefore, we need to cover an 285 deg^2 across the LMC. These comprise $17° \times 15° = 255$ deg^2 centred on ($\alpha = 5.5^h$, $\delta = -60.5°$) and 30° deg^2 south towards NGC1841 cluster to trace the transition between regular and irregular isophlets (Irwin 1991, IAU Symp. 148, 453). Similarly, we will cover an area of $9° \times 10° = 90$ deg^2 centred on the SMC ($\alpha = 1^h$, $\delta = -72.5°$) and an area of $5° \times 9° = 45$ deg^2 along the Bridge region ($\alpha = 3^h$,

$\delta = -73^{\circ}$), These areas sum up to 420 $\deg^2$ and provide the best coverage to obtain a detailed star formation history of the Magellanic sytem.

Compromising between area covered and observing time in order to maximises the scientific output of the survey we propose to pawprint–sample the entire system. The size of each detector ($11.6' \times 11.6'$) includes statistically enough sources down to $K_s = 20.5$ (on average across the whole area surveyed) to determine the SFH with sufficient spatial resolution, yet much better than anything currently available. Simultaneously, 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 MCs and the MW. The Magellanic Stream, which also resulted from this interaction, has been excluded from this survey because of its large extent on the sky. Substructures originating from galaxy-to-galaxy interactions will be traced mainly by MS and RGB stars. Thus, we need to 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. 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) in each bandwidth. 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 is limited by the instrumental PSF ($0.51''$; $50 \times 0.51'' \times 0.51'' = 13$ arcsec^2) and otherwise is given by the seeing itself ($0.8''$; $50 \times 0.8'' \times 0.8'' = 32$ arcsec^2). In bluer bandwidths confusion is approached at brighter magnitudes than in redder bandwidths. This confusion limit is never approached 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. However, because of the airmass observability of the MCs the seeing will be worse (Sect. 5) and the most crowded regions will approach confusion at $Y = 20.2$, $J = 21.0$ and $K_s = 22.3$ (DIMM seeing $= 0.8''$).

Our strategy is to observe one pawprint in each filter (once) as close as possible in time. This procedure minimises variability effects on colours, which are more important for brigther objects, and at the same time guarantees more or less homogeneous observing conditions among different bands. On the other hand, to obtain average K_s magnitudes for RR Lyrae and Cepheid stars we need to observe individual K_s-band observing blocks (OBs) in separate nights. Observations in YJ that require each a single OB should be taken during the same night when also a K_s band OB is observed. Our mid-survey goal (P80+P82) consists of covering those parts of the galaxies and the Bridge that will be already observed by VST and AAOmega. These parts preferentially cover the main body of each galaxy, therefore, we will also observe some fields in their outer halo to provide targets for 2008 AAOmega observations (the Harris & Zaritsky survey currently used for target selection is more or less limited to the main body of the Clouds). During the following three years we will complete the survey by observing the remaining fields.

For the purpose of photometrically calibrating the survey data, we plan to link them to the much brighter 2MASS data (one-to-one for JK_s observations and using colours for Y-band observations), therefore we do not require a special calibration procedure other than the one provided by ESO. Moreover, we do not need to observe in photometric conditions.

5 Estimated observing time:

Period	Time (h)	Mean RA	Moon	Seeing	Transparency
P79	40	$0^h - 3^h$	bright	$0.8''$	thin
P80	300	$0^h - 7^h$	bright	$0.8''$	thin
P81	40	$0^h - 3^h$	bright	$0.8''$	thin
P82	300	$0^h - 7^h$	bright	$0.8''$	thin
P83	40	$0^h - 3^h$	bright	$0.8''$	thin
P84	300	$0^h - 7^h$	bright	$0.8''$	thin
P85	40	$0^h - 3^h$	bright	$0.8''$	thin
P86	300	$0^h - 7^h$	bright	$0.8''$	thin
P87	40	$0^h - 3^h$	bright	$0.8''$	thin
P88	300	$0^h - 7^h$	bright	$0.8''$	thin

5.1 Time justification: (1 page max)

The estimated exposure time needed to complete the VMC survey has been calculated using the VISTA ETCv1.1 assuming $0.8''$ 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 (http://www.eso.org/gen-fac/pubs/astclim/paranal/seeing/seewind/). We have chosen this to be the seeing limit for our survey to guarantee homogeneity of the data and good point-source separation. In the crowdest regions (e.g. the centre of the LMC bar) these conditions approach the confusion limit (Sec. 4). 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 airmass 2, however, this is acceptable only in the outer (uncrowded) regions which are not limited by confusion at this low airmass. The moon brigthness is never a problem because it is always $80° - 100°$ away from the MCs.

To reach S/N= 10 at Vega magnitudes of $K_s = 20.3$, $J = 21.3$ and $Y = 21.8$, we need to spend on-source 3.5h, 50m and 1h 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.

Our strategy relies on pawprint-sampling the Magellanic Cloud system, thus without covering the gaps among the detectors to reconstruct a tile. To cover a pawprint in the K_s band, reaching the above sensitivity, we need five individual OBs of about 53m each set up as follows: DIT= 6s, NDIT= 12, Nexp= 7, Jitter= 5, Npaw= 1, making up a total on-source integration of 2520s and 654s overheads (79% efficiency). In the J band a single OB of about 58m is enough to meet the sensitivity of the survey, its set up will be: DIT= 10s, NDIT= 12, Nexp= 5, Jitter= 5, Npaw= 1, making up a total on-source integration of 3000s and 474s overheads (86% efficiency). In the Y band the set up of a single OB will be slightly different: DIT= $20s$, NDIT= 12, Nexp= 3, Jitter= 5, Npaw= 1, making up a total on-source integration of 3600s and 294s overheads (92% efficiency). The length of a Y-band OB will be about 65m and a single OB will be sufficient to reach the required sensitivity. Note that because of scheduling requirements observations can be split into OBs of approximately 30m in each wave band without affecting the survey output. Accounting for detector saturation and linearity we expect to well detect sources fainter than $K_s = 11.2$, $J = 12.5$ and $Y = 13.0$ mag, respectively. This level is approximately equal for similar sources.

The global time (including overheads) necessary to cover a single pawprint in 3 bands is about 6h30m, including 50s overheads to move twice to adjacent filters because our strategy is to observe each pawprint in 3 bands before changing pointing. However, only 3h are needed as close as possible in time to complete three OBs (one per band), while the remaining OBs to reach the requested sensitivity in K_s can be obtained at any other time throughout the season, provided the separation from the first observed K_s-band OB is greater than one day.

The entire Magellanic System (LMC+Bridge+SMC) spans an area of 420 deg^2 ($285+90+45$ deg^2 respectively) which requires 260 pawprints. One pawprint covers 1.62 deg^2. Thus, a total (integration+overheads) time of 1690h or 211 nights is necessary to complete the survey. Note that accounting for detector gaps the total effective area covered will be about 37% (i.e. ≈ 155 deg^2) of the whole area surveyed.

The observing time has been distributed in the Table above to account mainly for the observability of the Magellanic Clouds above airmass 1.5 for at least 3^h of consecutive time but also for the observing time of the VST-GTO program, for the planned AAOmegallan program and for other observations that will be undertaken during the same period (Sect. 3). Note that the Magellanic system's declination is of a highly probable observability in case of mild northerly wind that prevents pointing to northern targets. Judging from Paranal statistics if such a wind is blowing, it is preferentially coming from the North.

6 Data management plan: (3 pages max)

6.1 Team members:

Name	Function	Affiliation	Country
M.-R.L. Cioni	**PI**; Data Quality Control-III	University of Edinburgh	UK
K. Bekki	Exploitation (B)	University of New South Wales	AU
G. Clementini	Exploitation (D,B)	INAF, Bologna Observatory	I
W.J.G. de Blok	Exploitation (A,B)	Mount Stromlo Observatory	AU
C.J. Evans	Exploitation (C,F)	ATC, Edinburgh	UK
R. de Grijs	Exploitation (A,C)	University of Sheffield	UK
B.K. Gibson	Exploitation (A,B)	University of Central Lancshire	UK
L. Girardi	Exploitation (A)	INAF, Padova Observatory	I
M.A.T. Groenewegen	Exploitation (E)	University of Leuven	B
V.D. Ivanov	Exploitation (C,F)	ESO, Santiago	CL
P. Leisy	Exploitation (E)	ING, La Palma	E
M. Marconi	Exploitation (D,B)	INAF, Naples Observatory	I
C. Mastropietro	Exploitation (B)	University of Zürich	CH
B. Moore	Exploitation (B)	University of Zürich	CH
T. Naylor	Exploitation (B)	University of Exeter	UK
J.M. Oliveira	Exploitation (F)	Univerisity of Keele	UK
V. Ripepi	Exploitation (D,B)	INAF, Naples Observatory	I
J.Th. van Loon	Exploitation (B,E)	Univerisity of Keele	UK
M.I. Wilkinson	Exploitation (B,C)	University of Cambridge	UK
P.R. Wood	Exploitation (C,E)	Mount Stromlo Observatory	AU
CASU (VDFS) team	Pipeline processing	University of Cambridge	UK
CASU (VDFS) team	Data Quality Control-I	University of Cambridge	UK
J. Emerson	VDFS Coordinator	Queen Mary University of London	UK
WFAU (VDFS) team	Science Archive	University of Edinburgh	UK
WFAU (VDFS) team	Data Quality Control-II	University of Edinburgh	UK

Note 1: Areas of scientific interest are coded as follows: A - star formation history; B - galaxy structure, substructures and interaction; C - clusters; D - pulsating stars (RR Lyrae, Cepheids); E - AGB, post-AGB stars, planetary nebulae; F: star formation, obscured massive stars.

Note 2: The CASU (VDFS) team consists of Irwin, Lewis, Hodgkin, Evans, Bunclark, Gonzales-Solares, Riello. The WFAU (VDFS) team consists of Hambly, Bryant, Collins, Cross, Read, Sutorius, Williams.

6.2 Detailed responsibilities of the team:

We will use the VISTA Data Flow System (VDFS; Emerson et al. 2004, Irwin et al. 2004, Hambly et al. 2004) for all aspects of data management, including: pipeline processing and management; delivery of agreed data products to the ESO Science Archive; production of a purpose-built IVOA compliant science archive with advanced datamining services; enhanced data products including federation of VISTA survey products with SDSS survey products. Standardised agreed data products produced by VDFS will be delivered to ESO, with copies remaining at the point of origin. The VDFS is a collaboration between the UK Wide Field Astronomy Units at Edinburgh (WFAU) and Cambridge (CASU) coordinated by the VISTA PI (QMUL) and funded for VISTA by PPARC. The VDFS is a working systems-engineered system that is already being successfully employed for the UKIRT WFCAM surveys as a test bed for the VISTA infrared surveys, and which is sufficiently flexible as to be applicable to any imaging survey project requiring an end-to-end (instrument to end-user) data management system. We emphasise the track record over the last decade of both the Cambridge and Edinburgh survey units in processing and delivering large-scale imaging datasets to the community as exemplified by the WFCAM Early Data release.

The VMC science survey team includes 20 members (see Table above) 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 is likely to expand seeking postdocs and/or students to work in association with the VMC survey.

The PI, Cioni, comes to this having compiled and exploited the DENIS catalogue towards the MCs to study in particular the evolved stellar population and its relation to the spatially resolved chemical and formation history of both Clouds. She will supervise the data analysis and work on the product definition and quality assessment of the data [roducts as well as coordinating the science exploitation on behalf of the team and contributing to various aspects of it. The OBs will be prepared by Cioni, van Loon, Ripepi and de Grijs accounting for overlap with AAOmega, VST and cluster field distribution.

Different scientific topics will be tackled by sub-groups within the team: – De Grijs and Ivanov will focus on the cluster properties and the system's interaction history; – Girardi will analyse the field population, first subtracting the Galactic foreground component and then deriving the spatially resolved SFH, with the aid of synthetic data and available SFH-recovery algorithms; – artificial star tests will be performed, using the VDFS code or standard routines, by Girardi and Ivanov; – Clementini, Marconi and Ripepi will coordinate the light curve analysis of the RR Lyrae and Cepheid star population addressing issues related to the structure of the Magellanic System (3D map) using variable stars as population tracers as well as combining these observations with those from optical studies; – Oliveira and Evans will concentrate on the process of star formation and on young stars while Groenewegen, van Loon and Wood will concentrate on evolved stars (both these studies will combine VMC data with mid-infrared data from Spitzer, that will be publically available and eventually from Akari, depending on data availability); – Leisy will analyze 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; – Gibson and Wilkinson, as well as other members of the AAOmegallan collaboration, will trace the distribution of different populations of stars combined with the kinematic and abundance data obtained from AAOmega (in particular van Loon will use red-clump stars to constrain the 3D structure of the system); – Naylor has been developing data mining techniques based on his τ^2 fitting work (2005, *Protostars and Planets*, Proc. p8502) which can be applied to search colour-magnitude-position spaces for structures that have the colour-magnitude dependencies expected of stellar groups; – Bekki, Mastropietro and Moore will use the data to constrain models of the evolutionary interaction between the MCs and the MW as well as between the LMC and the SMC; – de Blok will relate the SFH and any feature traced by stars with the structures (holes and arms) seen in the HI, to check if consistent conditions/rules for star formation can be derived. 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.

6.3 Data reduction plan:

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

The Cambridge Astronomy Survey Unit (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 includes: – non-linearity, dark, flat, fringe and cross-talk correction; – sky subtraction (tracking and homogenisation during image stacking and mosaicing); – combination of dithered images; – point source extraction; – astrometric and photometric calibration (the latter put in an internally uniform system as well as in an optimized system obtained by monitoring suitable pre-selected standard areas covering the specific VMC survey area); – shape and data quality information. The processing history including calibration files is recorded directly in FITS headers.

The Science Archive (SA) ingests the products of the pipeline processing into a database and then curates them to produce enhanced database-driven products. This process includes: – individual passband frame association and source association to provide multi-colour, multi-epoch source lists; – global photometric calibration; – cross-association with external catalogues and generation of new image products (e.g. stacks, mosaics and difference images); – quality control procedures, as required by the public survey cosortium, 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-waveband 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 early-data-release in February 2006.

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

6.4 Expected data products:

The data products will be made available a few months after the observation of a given pawprint is performed. The main data products are: – instrumentally calibrated frames (pawprints) along with header descriptors propagated from the instrument and processing steps (science and calibration frames); – statistical confidence map for each frame; – stacked data for dithered observations of single targets; – derived object catalogues based on a standard VDFS set of object descriptors including astrometric and photometric measures, and morphological classification; – homogeneous band-merged catalogues (Y, J and K_s).

Further data products will be released within about a year after the completion of the survey. A partial release will be made about a year after the mid-survey goal. These include: (i) cross-correlation with VST observations – subject to GTO policy release; (ii) cross-correlation with kinematic and abundance data from the AAOmegallan program – subject to policy release (the AAOmegallan data archive will be also kept in Edinburgh); (iii) catalogues of known variables (i.e. RR Lyrae and Cepheids) containing multi-epoch and mean K_s-band magnitudes.

6.5 General schedule of the project:

If this proposal is awarded time observations will begin in August 2007. By then commissioning 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 define the strategy of the project and the workload, in order to meet our mid-term goal after the first two years of observations (2007 – 2009). As an immediate consequence team members will apply for funding to employ postdocs and students who will promptly contribute to the exploitation of the data.

The time-scale for availability of survey products depends on ESO for the release of raw images and on VDFS for the release of band-marged catalogues. The ESO policy in this respect is generally to have data products delivered to the ESO archive within the semester following the one in which the raw data was sent out. By default, it is likely that the same will apply for VISTA.

Project mid-term approximately corresponds to the expected completion of the AAOmegallan and STEP observations. Therefore it is essential that we maximize the scientific output from all three surveys. During the following years much will be learned from their unique combination.

As soon as the first data (images and catalogues) will be available sub-groups, as defined in the previous section, 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.

The observation of the Magellanic System as proposed in this survey (defined as airmass above 1.5 for 3 consecutive hours to execute once an OB in each filter; see Sect. 5) will be mostly obtained from August to January, inclusive, of each year. Therefore, before the next 6-months observing season begins we will have analyzed the data of the previous observing season. These will be discussed in a yearly meeting where we will access the progress of the survey as well as define the writing and publication of early-survey results.

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

7 Envisaged follow-up: (1 page max)

The global, wide and homogeneous coverage of the Magellanic System in YJK_s bands down to a sensitivity that directly matches recently or newly obtained optical observations is going to provide a unique database for a variety of astrophysical topics, from the investigation of the properties of individual/rare stars to the parametrisation of the galaxies as a whole and their dynamical history.

We expect that a number of follow-up studies will originate from the public release of the VMC survey data. These will span the range from stellar via galactic to extra-galactic topics. For example, such a deep survey in the outer regions of the MCs will provide information on the distant Universe. The sensitivity of the VMC survey ($Ks = 21.5$ and $J = 23.5$ at S/N=4) corresponds to the current UKIDSS Deep Extra-galactic Survey limit which aims to detect obscured objects (starburst galaxies and obscured AGN) as well as normal galaxies defined in the rest-frame optical spectral energy distribution at $z > 1$. These newly detected objects will be suitable targets for multi-object spectroscopic studies to confirm their redshift as well as observations at mm, far-infrared and X-rays wavelengths to characterize their properties.

Although the VISTA data combined with STEP data and the abundance and kinematics results from AAOmegallan will close the picture on the global chemical and dynamical evolution of the Magellanic Cloud system, follow-up spectroscopic studies are envisaged using large-scale telescopes (i.e. VLT) able to access sources much fainter than the RGB clump. These will be mostly devoted to the determination of the chemical abundance of peculiar stars and or the kinematics of newly discovered substructures, that are not yet targeted by other surveys. The availability of VMC data will provide a wealth of suitable targets for new VLT instruments such as the echelle near-infrared spectrograph CRIRES and the multi-object near-infrared spectrometer KMOS.

Concerning dust enshrouded star formation and obscured evolved stars VMC data are sensitive enough to provide counterparts to Spitzer detections. The availability of near-infrared sources will immediately allow us to fully exploit the Spitzer database across the MCs. For example stellar clusters in star forming regions will be spatially resolved by VISTA but not by Spitzer. The combination of both datasets will certainly contribute to highlight targets for subsequent follow-up studies.

The measurement of the mean K_s magnitude of variable stars (i.e. RR Lyrae and Cepheids) is essential to use these stars as distance indicators, assuming that their period is known from optical studies. However, the latter do not extend at present to such large distances from the MCs centers but this is perhaps just a matter of time. To our knowledge, at least one proposal (see Sect. 3) aims to characterize the MC halos by observing a region $7^\circ - 20^\circ$ from the galaxy centers. The VST could undertake a similar study as well as a follow-up monitoring study that will provide the period of variables at these large, and not yet explored, distances around the MCs.

8 Other remarks, if any: (1 page max)