Spectroscopic follow-up of the VMC survey

The VISTA survey of the Magellanic Clouds system
VMC survey

- Filters: Y, J, K$_s$
- Camera: 16 Raytheon detectors
- Sampling: 0.34”/pix
- FOV: 1.65 deg$^2$
- Area: 218 deg$^2$
- Sensitivity: YJK$_s$~22 (5σ Vega)
- Saturation: K$_s$~10
- Epochs: 3 (YJ) + 12 (K$_s$)
- Time-scale: 2009+


http://star.herts.ac.uk/~mcioni/vmc/

~30% complete
VMC primary science

VMC is the most sensitive survey of the Magellanic system in the near-IR and with the best spatial resolution.

- **Spatially resolved star formation history**
  - By reaching stars below the old main-sequence turnoff
  - By interpreting colour-magnitude diagrams

- **3D geometry**
  - Using Cepheids and RR Lyrae stars
  - Using red clump giant stars
VMC legacy science

- Milky Way
- Star formation
- Individual stars
- Stellar clusters
- Galaxy dynamics
- Quasars

Average quality of VMC individual epochs

<table>
<thead>
<tr>
<th>Filter</th>
<th>FWHM</th>
<th>Ellipticity</th>
<th>Zero-Point</th>
<th>Mag. Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>0.98 (0.13)</td>
<td>0.06 (0.01)</td>
<td>23.16 (0.22)</td>
<td>20.00 (0.89)</td>
</tr>
<tr>
<td>J</td>
<td>0.96 (0.11)</td>
<td>0.06 (0.01)</td>
<td>23.26 (0.33)</td>
<td>19.85 (0.70)</td>
</tr>
<tr>
<td>Ks</td>
<td>0.93 (0.10)</td>
<td>0.06 (0.01)</td>
<td>23.02 (0.13)</td>
<td>19.28 (0.26)</td>
</tr>
</tbody>
</table>

VISTA field of view
VMC survey progress
Bridge & Stream

Bridge is 50% complete; Stream is 97% complete!
VMC survey progress

LMC & SMC

LMC is 19% complete; SMC is 38% complete!
Science highlights & spectroscopy
VMC: embedded clusters

191 clusters identified by eye from VMC 30 Dor image
83 clusters with CO counterparts;
44.5% overlap with YSOs from Spitzer
69 newly discovered!

Cluster luminosity is related to cluster mass:
LMC clusters are more luminous than MW ones.

Spectra (NIR) to measure the mass of clusters!

Romita et al., in preparation
VMC: RR Lyrae stars

Reddening can be estimated from RR Lyrae stars.

Spectroscopic [Fe/H] are better than those from Fourier decomposition.

PL relation in SEP field.

Being updated with recent OGLE-IV data!

PL relation in 30Dor field.
The spatial resolution of VMC data allows us to identify the post-AGB stars even in crowded regions of the Magellanic Clouds.

Spectra provide gravity that is used in the separation between YSOs and post-AGB stars.

Kasmath et al., in preparation
VMC: PNe

Identify non-PNe to characterize the luminosity function. Multi-λ approach to identify PNe and symbiotic stars.

PNe occupy a specific VMC colour space.

VMC detects some PNe morphologies for the first time.

VMC finds new candidate PNe.

Spectra are needed to confirm PN & symbiotic nature!

Age and [Fe/H] are derived from the best fit theoretical CMDs.

Reddening and distance modulus are also derived.

Systematic errors are reduced if geometry of LMC is taken into account.

Spectroscopic [Fe/H] would remove the degeneracy with age in the RGB!
VMC: reddening map of 30 Dor

Extinction values for > 150,000 red clump stars. Key regions:
• R136 (Tarantula Nebula)
• SN 1987A
• HII regions (along a molecular ridge)

Highlights:
• Probes higher extinctions than optical can,
• A more detailed map than with OGLE-III,
• VMC is the only near-IR survey that resolves stars down to the red clump.

De-reddening RC stars is necessary before using them for tracing 3D geometry.

Spectroscopic [Fe/H] to correct the red clump magnitude for 3D study!

Tatton et al., to be submitted
Different stars show a different proper motion in tile LMC 8_8 (outer-disk SEP) over a time range of 10 years.

With the radial velocity sub-structures can be studied in space motion.

Cioni et al. in prep.

* adapted from Nikolay & Weinberg (2000)
VMC: quasars

Quasars are mostly confined in region A and B of the colour space.

Quasars have a $K_s$ light-curve with a slope $> 10^{-4}$ mag/day.

Spectra can: (1) measure the nature and z of candidates; (2) study the ISM.

VMC: high PM MW objects

Search for stars with a positional offset > 1” between 2MASS and VMC (>0.1”/year):

119 objects found of which 73 new!

Search for faint co-moving objects:

11 were found of which 1 brown dwarf; follow-up spectroscopy on-going.

Spectra provide the source types.

Ivanov et al., in preparation
Spectroscopic needs & outcome

- Target confirmation (PNe, Quasars, YSOs).
- Metal abundance (Cepheids, RR Lyrae and Red clump stars).
- Radial velocity (all stars as faint as the red clump).
- Area (LMC, SMC, Bridge and Stream)
- No. of targets ~ 300,000 (~1/3 of available population)

Present day studies are field limited. GAIA will not help in MCs.

- Characterization of MC sub-structures in space motion.
- Link sub-structures with merging history
- Study the chemical history of the MCs.
- Relate the SFH to the chemical evolution.
## Sensitivity and resolution

<table>
<thead>
<tr>
<th>Stars Type</th>
<th>Range of $V$</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young stars</td>
<td>$V &gt; 12$</td>
<td>Super-giant stars</td>
</tr>
<tr>
<td>Intermediate-age stars</td>
<td>$V &gt; 16$-17</td>
<td>AGB and RGB stars</td>
</tr>
<tr>
<td>Old stars</td>
<td>$V &gt; 16$</td>
<td>RGB stars and</td>
</tr>
<tr>
<td></td>
<td>$V &gt; 19$</td>
<td>RR Lyrae stars</td>
</tr>
</tbody>
</table>

In the Magellanic Clouds

R~7,000, velocity to ~ a few km/s, S/N > 20

The largest study has ~6,000 giants (RV) and ~1,000 (CaT); 30 were found to trace a distinct population (Olsen+ 2011)

There is 1 EMP star each 100 stars with [Fe/H]<-2 (Cole)