Maria-Rosa Cioni

University of Hertfordshire

Alexander von Humboldt Stiftung/Foundation

From DENIS to VMC

a near-infrared perspective of the Magellanic Clouds

A historic view

- "Some of the most interesting objects of research can be reached only from the southern hemisphere: the central parts of the galaxy and the nearest extragalactic systems" (A. Blaauw 1991).
- Two micron sky survey (TMSS) limited to sources with K=3 (Neugebauer & Leighton 1969).
- 1970s: ESO plan for a "Chili-map" (details?)
- 1989: DENIS (PI Epchtein) and 2MASS (PI Kleinmann) to survey the sky in the near-IR on a joint effort in the northern and southern hemispheres respectively to K~14.
- 1991: DENIS and 2MASS took separate routes and would differ in: observing strategy, spatial resolution, filters and sensitivity.
- 1997: I joined the DENIS team to work on the Magellanic Clouds.

DENIS: Deep Near-Infrared Survey of the southern sky (PI N. Epchtein)

ESO 1mT
La Silla

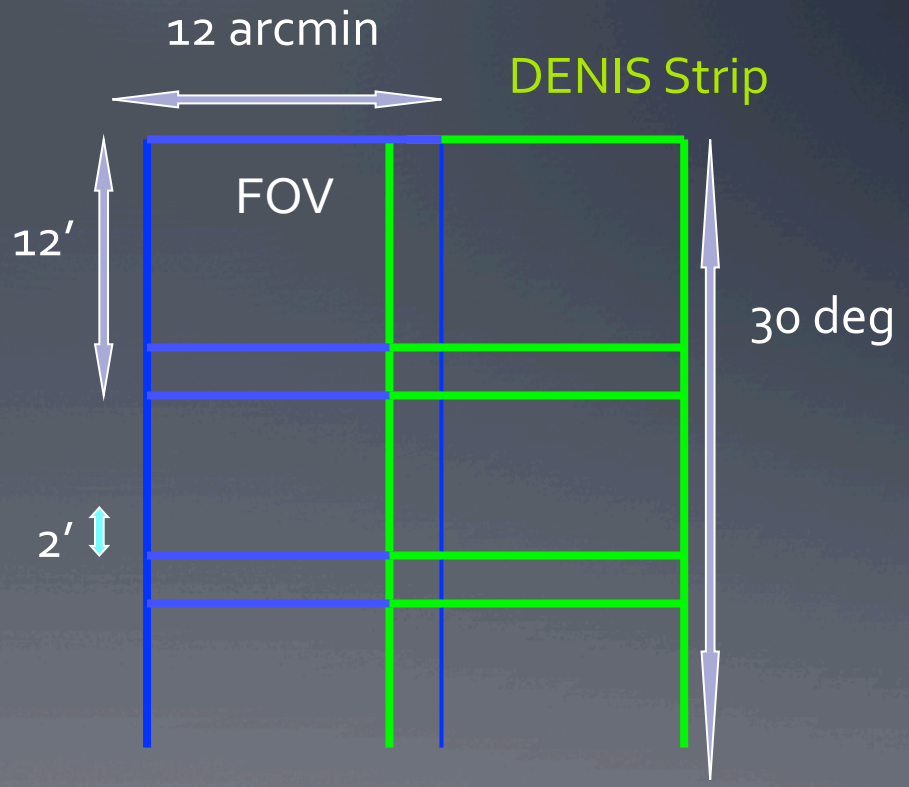
Filters: I,J, Ks (simultaneously)

Camera: NICMOS3 256x256 arrays for J and Ks and Tektronix 1024x1024 CCD for I

Sampling: 1 arcsec

Sensitivity: I=18, J=16 and Ks=14 at 3σ (Vega)

Time: 1995 – 2001



Consortium of several EU institutes.
Data centers: IAP and Leiden.

DCMC: DENIS Catalogue towards the Magellanic Clouds (Cioni et al. 2000)

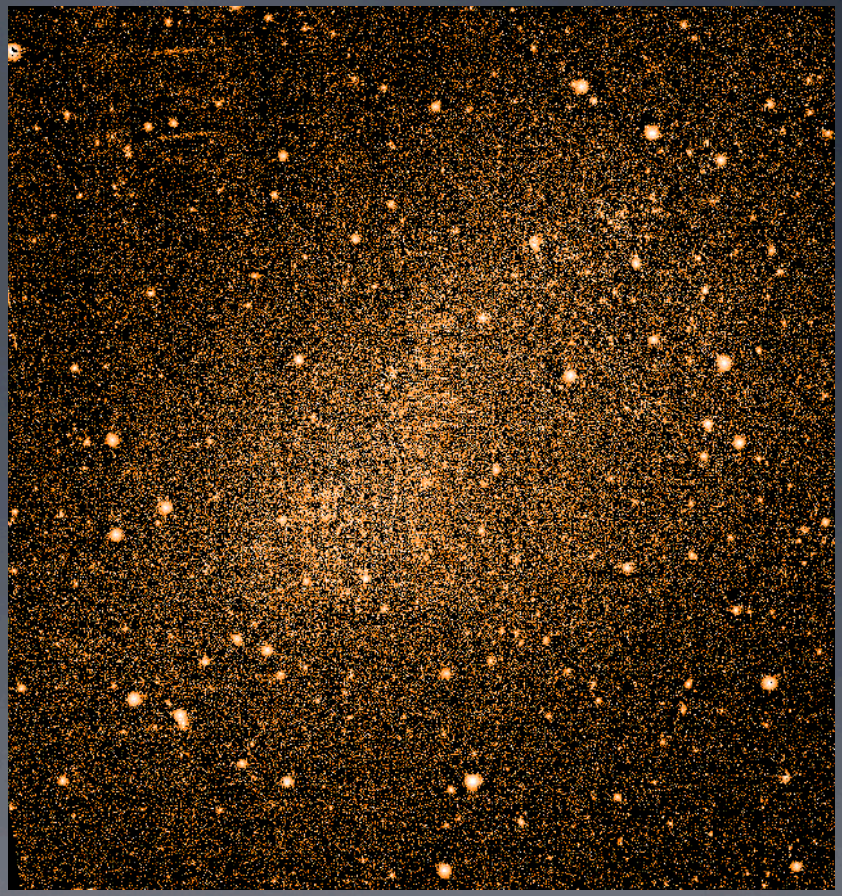
Coverage: 20x20 deg^2 (LMC) and 15x10 deg^2 (SMC)

Sources: 1.4 million (LMC) and 0.3 millions (SMC)

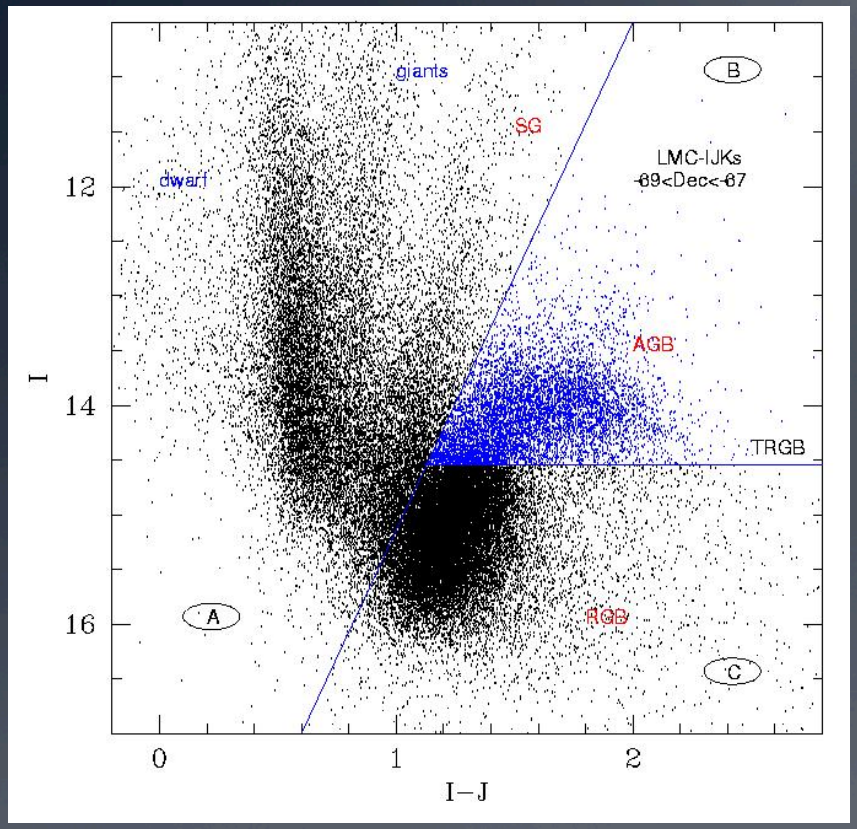
Astrometry: 0.001 – 1.32 arcsec

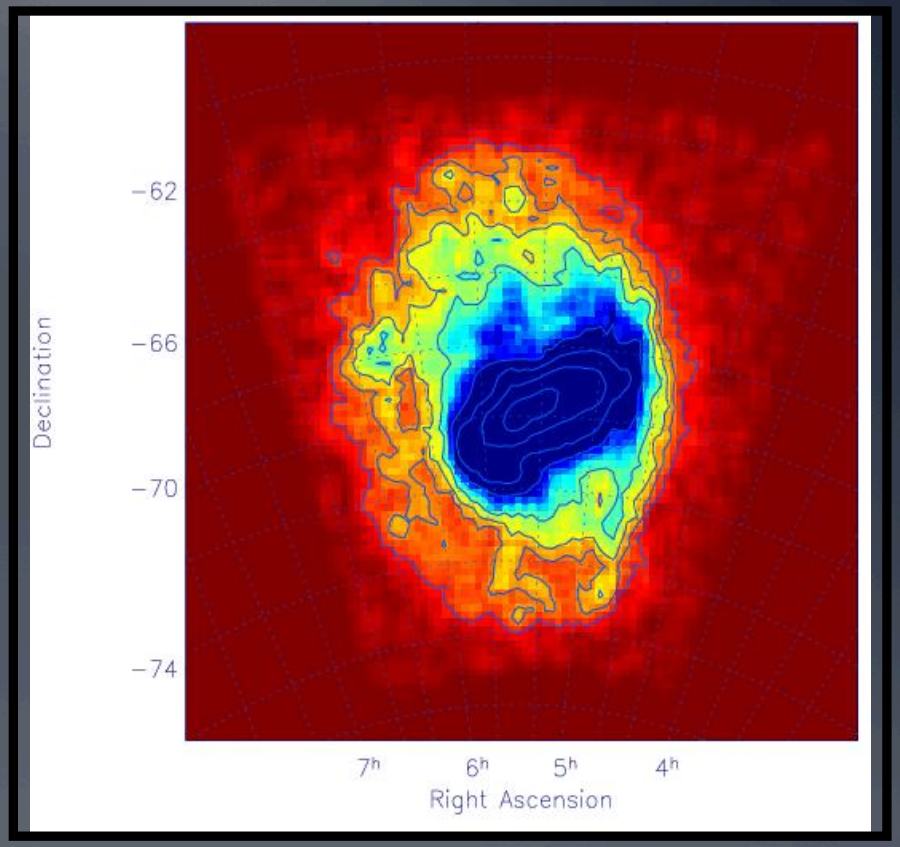
Photometry: 0.01-0.2 mag

Objects: 70% of them belong to the Magellanic Clouds and most of them are red and asymptotic giant branch stars



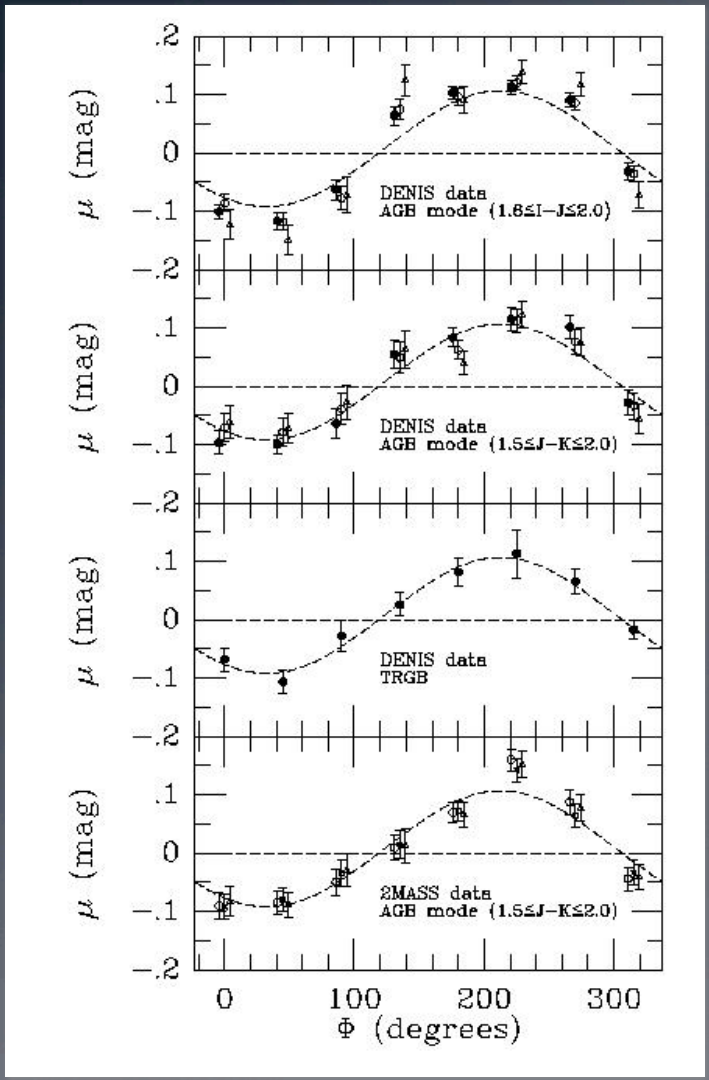
DENIS I-band image of the SMC





LMC morphology from the distribution of AGB stars (Cioni, Habing & Israel 2000)

AGB stars are smoothly distributed. AGB stars trace a disc, a thick bar with a clear nucleus as well as possible spiral arms.



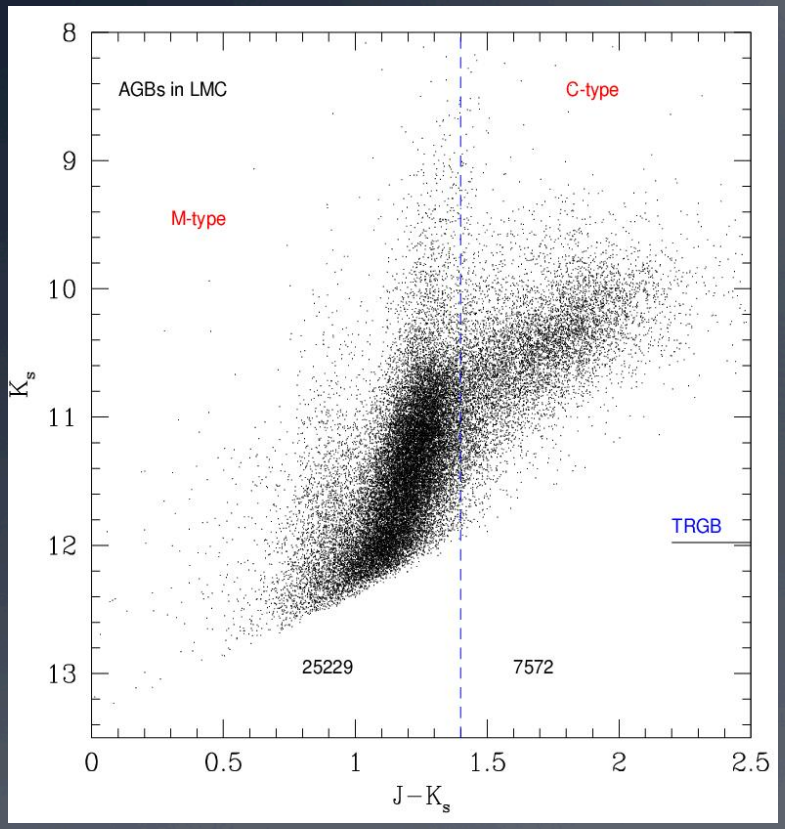
Geometry of LMC disc (van der Marel & Cioni 2001)

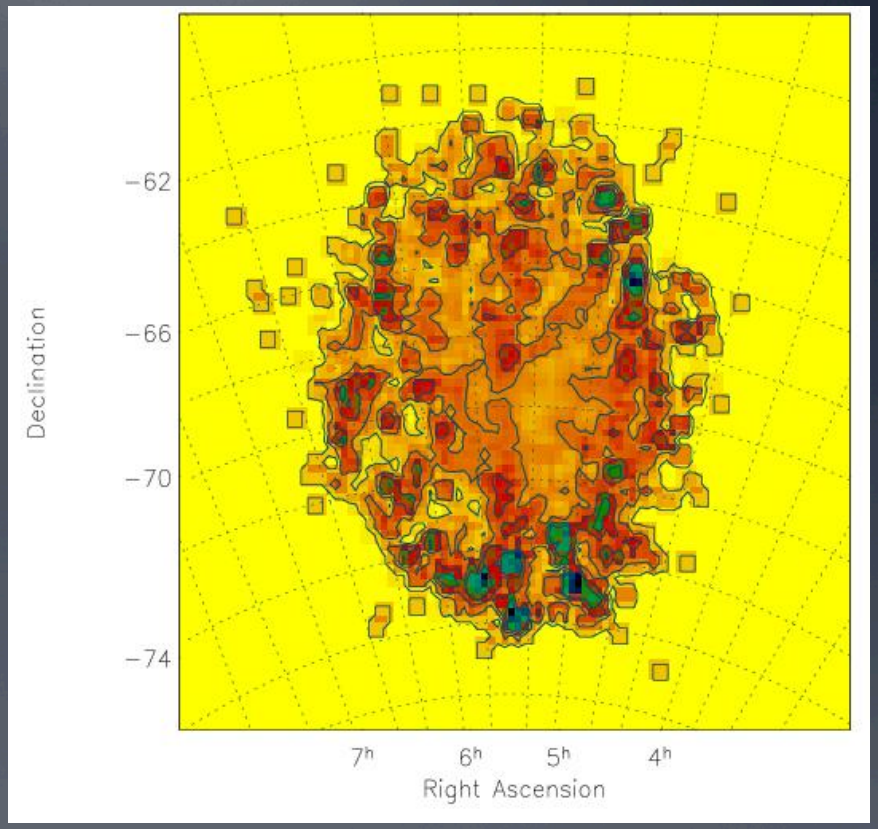
Inclination = 30-40 deg

Line of nodes position angle = 120-150 deg

The LMC disc is elliptical with ellipticity ε=0.2-0.3.

Variations of the parameters depend on: type of tracer, warps and twists of the disc, spatial sampling and systematic errors.





The C/M ratio across the LMC (Cioni & Habing 2003; Cioni 2009; Feast et al. 2010)

The C/M ratio shows a positive gradient in the LMC and no bar. This corresponds to Δ[Fe/H]=0.3 dex.

Other imaging observations of the Magellanic Clouds

Near-IR: 2MASS (1997-2001), IRSF (2001-2006)
- provided population boxes in (J-Ks) vs. Ks, morphology

Optical: MCPS (1995-2001), HST (2005), NOAO outer limits (on-going)
- provided SFH, morphology, proper motion, disk extent

Microlensing: MACHO (1992-1999), EROS (1990-2003) , OGLE (1992-)
- provided frequently sampled light-curves
- provided, in combination with DENIS and 2MASS, multiple period luminosity relations for evolved stars

Mid-IR: mini-ISO (1995-1998), MSX (1996-1997), Spitzer (2005)
- provided data for obscured giant stars

: VISTA survey of the Magellanic Clouds system (PI M. Cioni)

VISTA 4mT
Paranal

Filters: Y,J, Ks

Camera: 16 Rayethon detectors over a FOV=1.65 deg^2

Sampling: 0.34 arcsec/pix

Area: 218 deg^2

Sensitivity: Y=21.9, J=22 and Ks=21.5 at 5σ (Vega) – Saturation: Ks=10

Epochs: 3 (Y) and 12 (Ks)

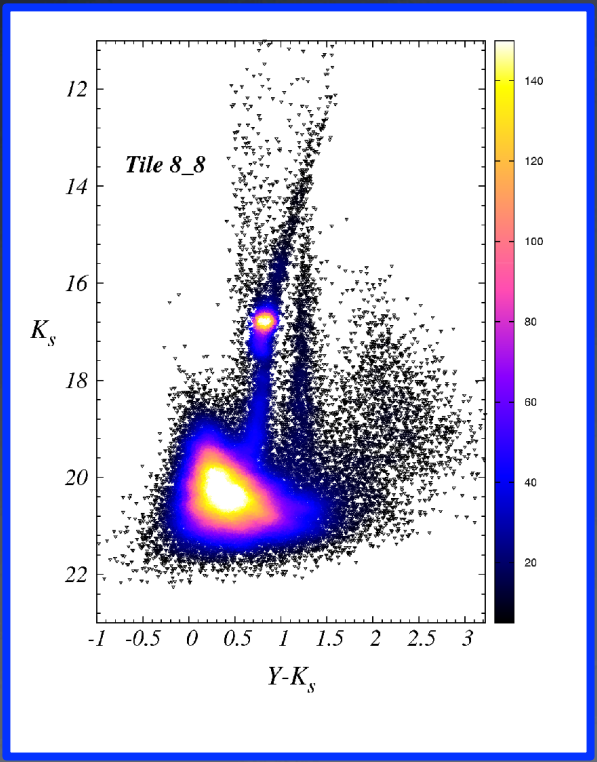
Time: 2009 – (~25% complete)

SMC clusters

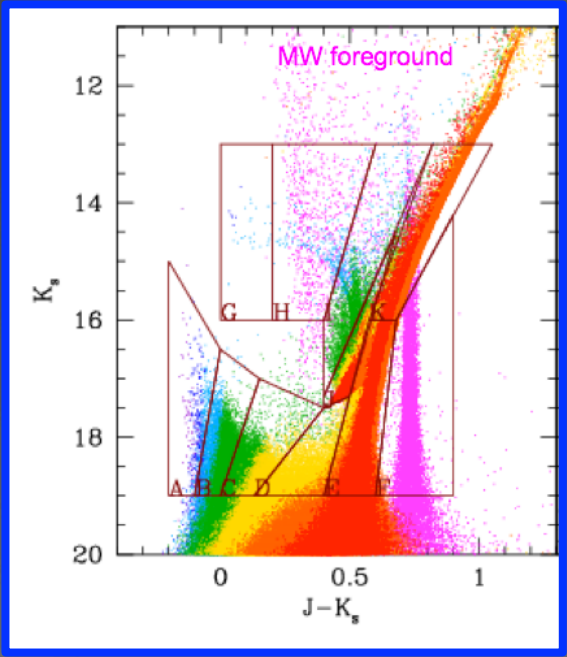
Team of several Institutes worldwide.
Data centers: Cambridge and Edinburgh.

Star formation history

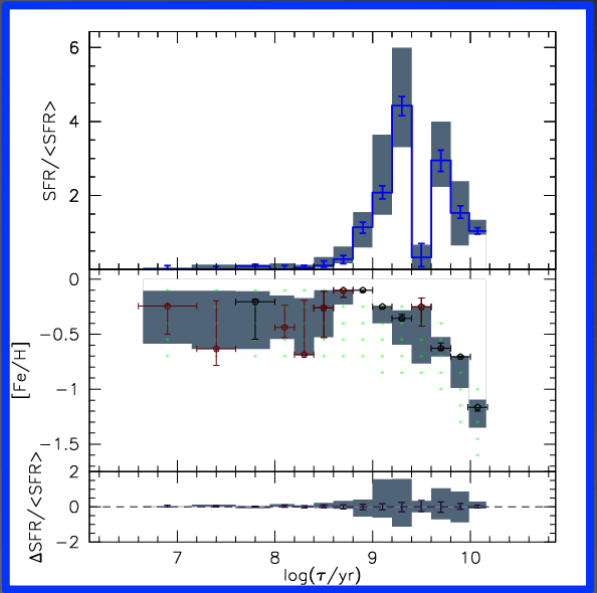
Rubele et al. 2012 (VMC Paper IV)



CMD of tile LMC 8_8 (1.65 deg²).



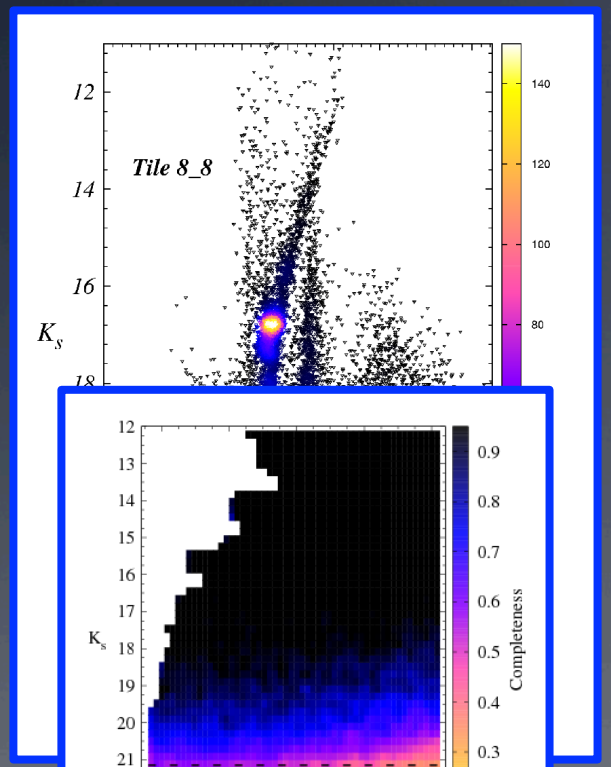
Stellar population models.



Derived SFR(t) and [Fe/H](t) for sub-regions of 0.12 deg².

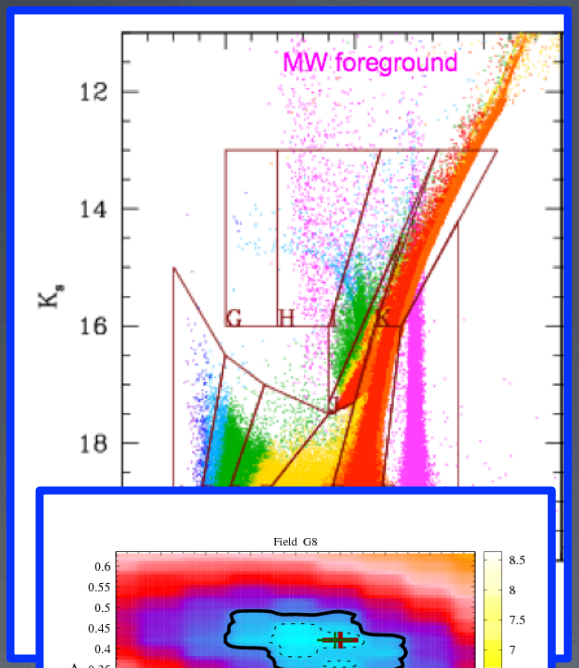
Star formation history

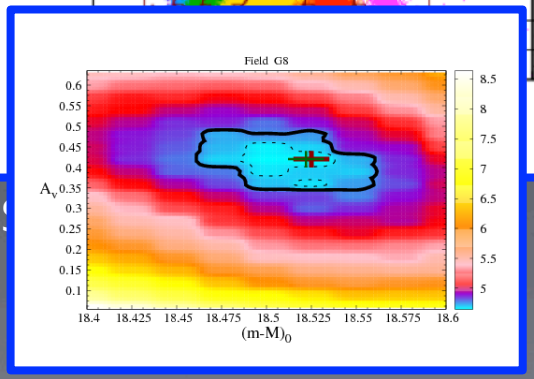
Rubele et al. 2012 (VMC Paper IV)



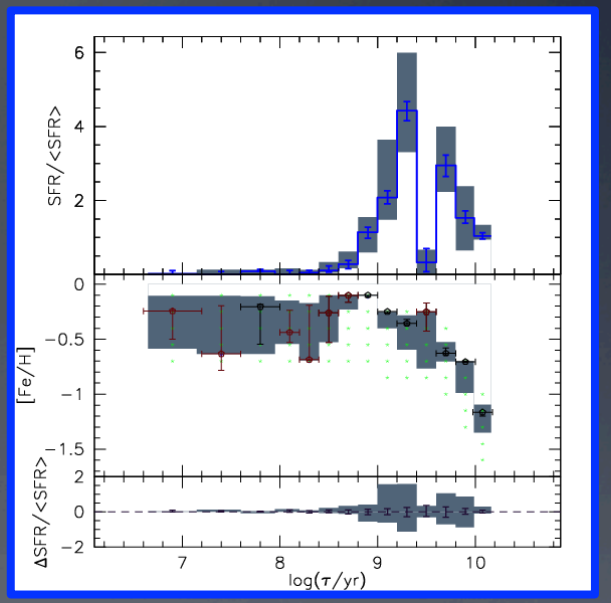
CM … deg^2).

Completeness via ASTs.





X^2 resulting from STARFISH code



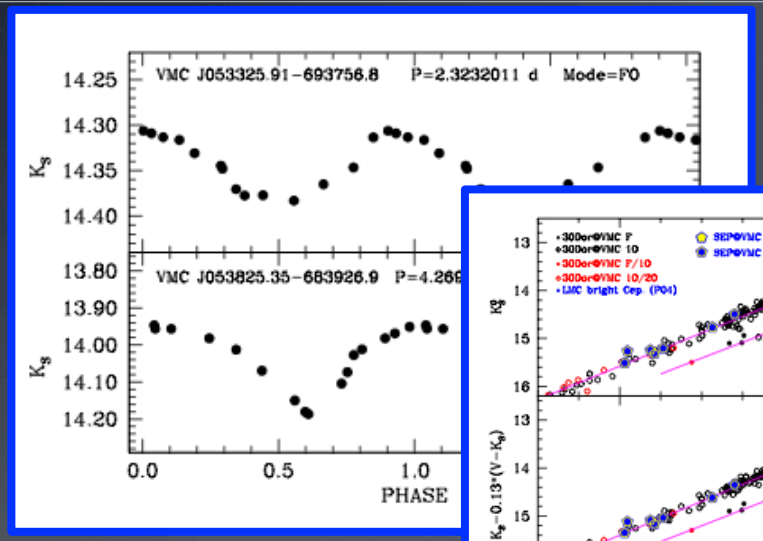
Derived SFR(t) and [Fe/H](t) for sub-regions of 0.12 deg^2.

Results:

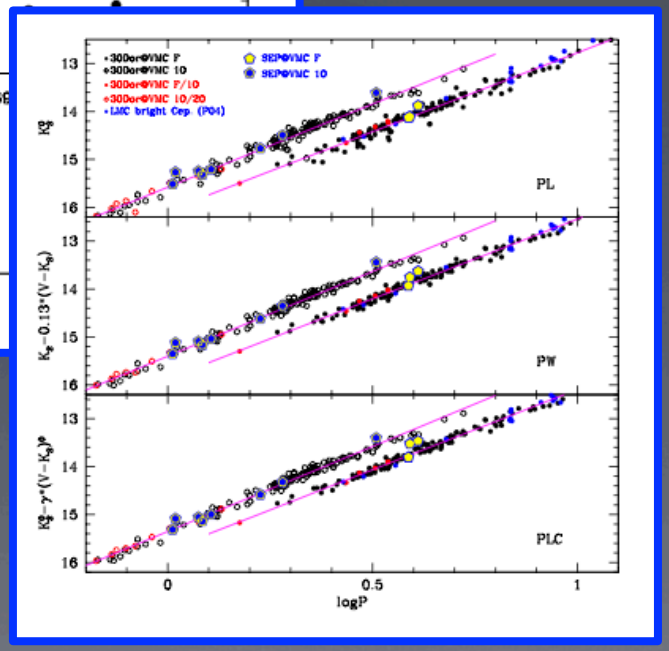
1) Near-Infrared SFH works!
2) Disk geometry with 4 tiles
3) Further reduction of systematic errors.

Variable stars - Cepheids

Ripepi et al. 2012 (VMC Paper V)



Cepheid light-curve where σ ≈ 0.01 mag.



Period-luminosity, period-wasenheit, period-luminosity-colour relations where period is from OGLE or EROS-2.

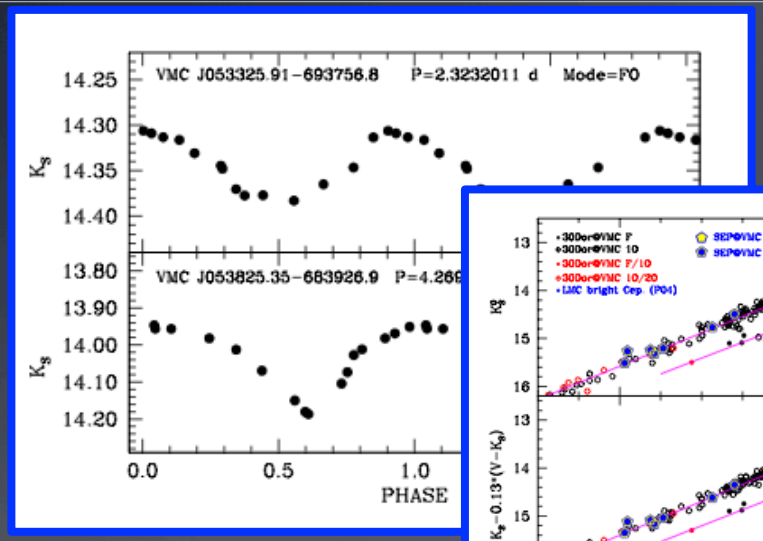
Points include both 30 Dor area and SEP area in LMC.

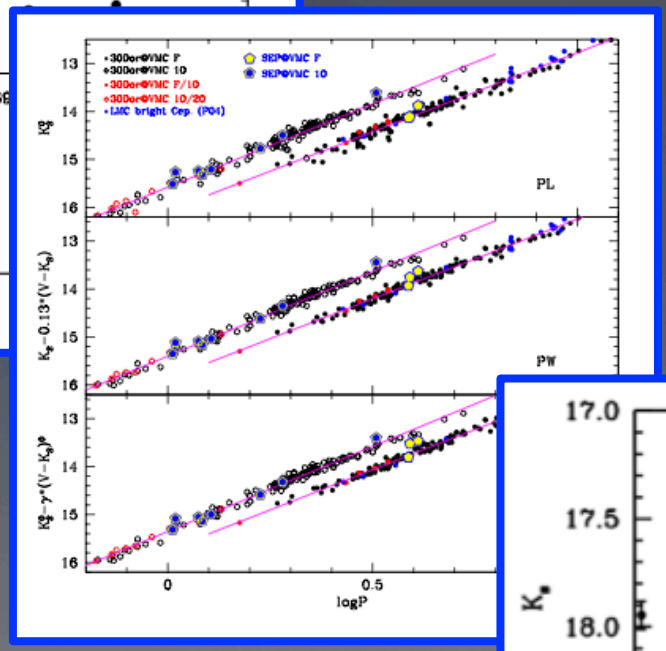
Short period Cepheids are included for the first time! The ($V-K_s$) colour is used for the first time!

rms ~ 0.07 mag.
$(m-M)_0$=18.46+/-0.03 mag

Variable stars - Cepheids

Ripepi et al. 2012 (VMC Paper V)

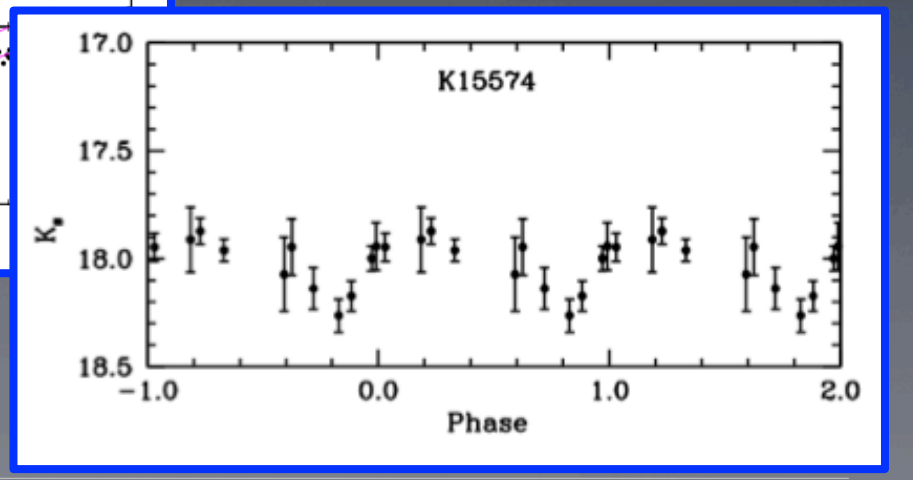




Period-luminosity, period-wasenheit, period-luminosity-colour relations where period is from OGLE or EROS-2.

Points include both 30 Dor area and SEP area in LMC.

Cepheid light-curve where σ ≈ 0.01 mag.

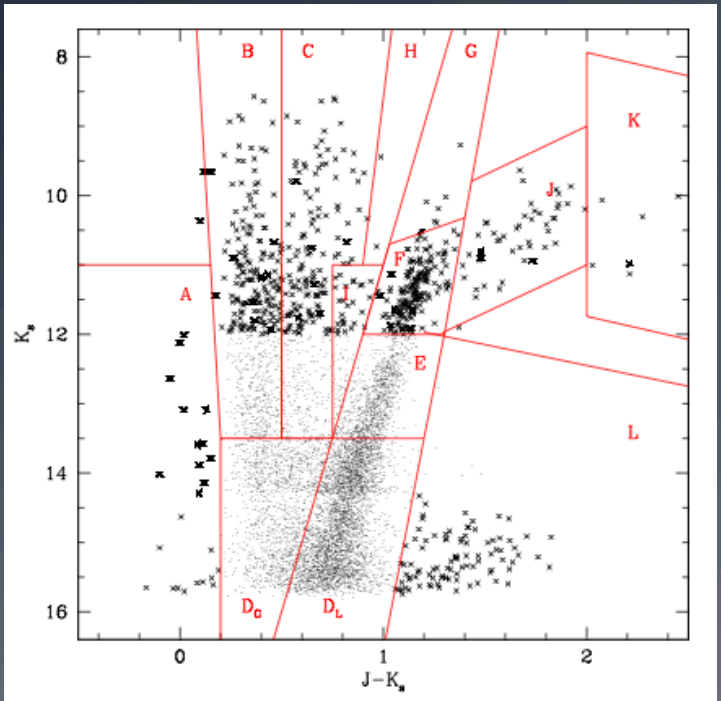


Similar work on RR Lyrae stars is in final stages of preparation (Moretti et al.)

Proper Motion: 2MASS-VMC

Cioni et al. in prep.

2MASS all sky + 6x and VMC



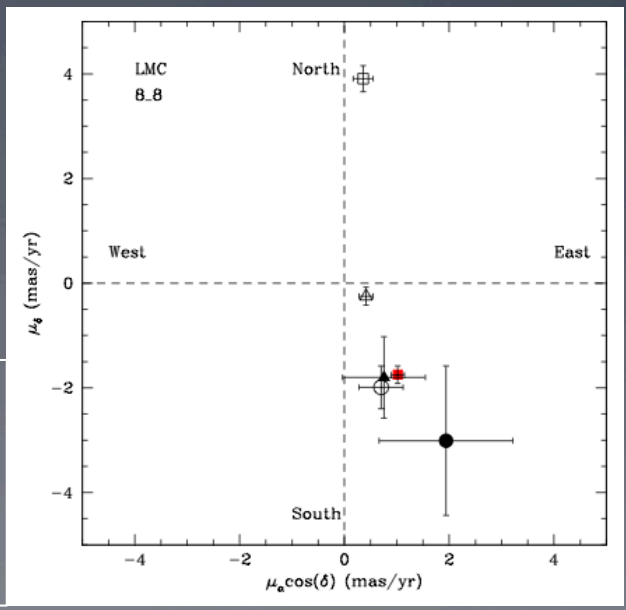
BCD_{MW}	2338
JK	59
$D_{LMC}E$	5140
AGH	32
FJK	228

= MW foreground (empty square)
= LMC carbon stars (filled triangle)
= LMC RGB stars (empty triangle)
= LMC young stars (filled circle)
= LMC AGB stars (empty circle)

Preliminary results:

Time range ~ 10 years,
Tile LMC 8_8 (outer disk - SEP),
Population boxes adapted from Nikolay & Weinberg (2000).

Different types of stars show a different proper motion.



VMC and future studies

VMC main goals:

- spatially resolved SFH
- 3-dimensional geometry

Other teams are aiming at measuring the 3-D geometry using other data, e.g. OGLE-IV, Spitzer.

VMC has no real competitor and the Ks band is going to remain unique also in the E-ELT era.

Planned facilities, GAIA, Euclid and LSST will provide data for studies of the proper motion and source variability across the Magellanic system.

Follow-up observations with instruments under study, 4MOST and MOONs, will provide the radial velocity and chemical information for many Magellanic objects.