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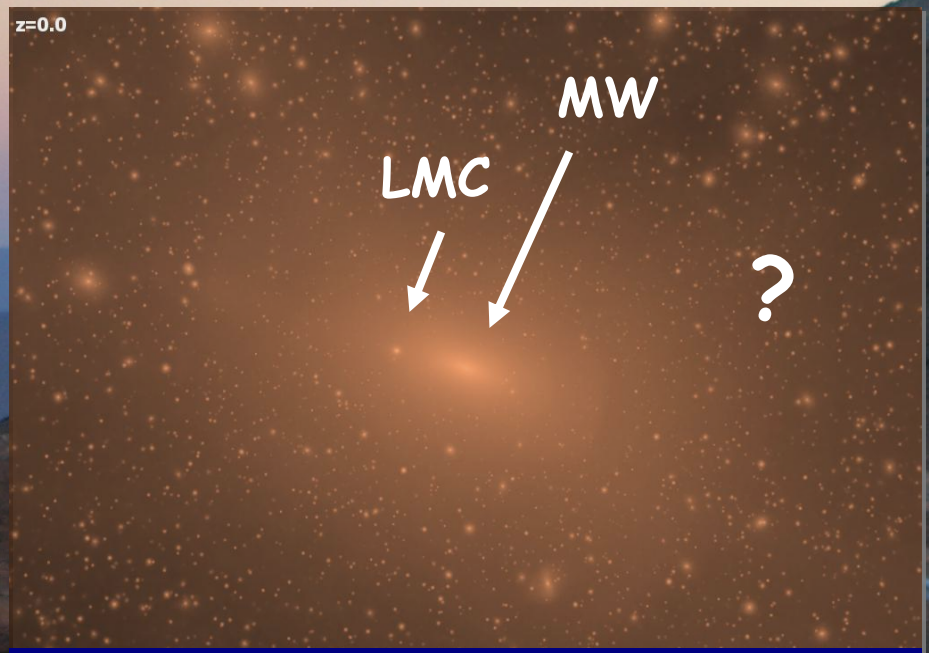
The Magellanic Clouds as a template for the study of stellar populations and galaxy interactions

CSIRO (Australia), 16-17 July 2007

Introduction



Substructure formation: dark matter halos

(Diemand et al. 2006)

- Galaxies are embedded in dark matter halos
- Galaxies are made of luminous matter (stars & gas)
- Different generation of stars change galaxy chemistry
- Galaxies, stars and gas move

Questions & answers ?

- Do we understand the full picture?
- The full picture is complex!

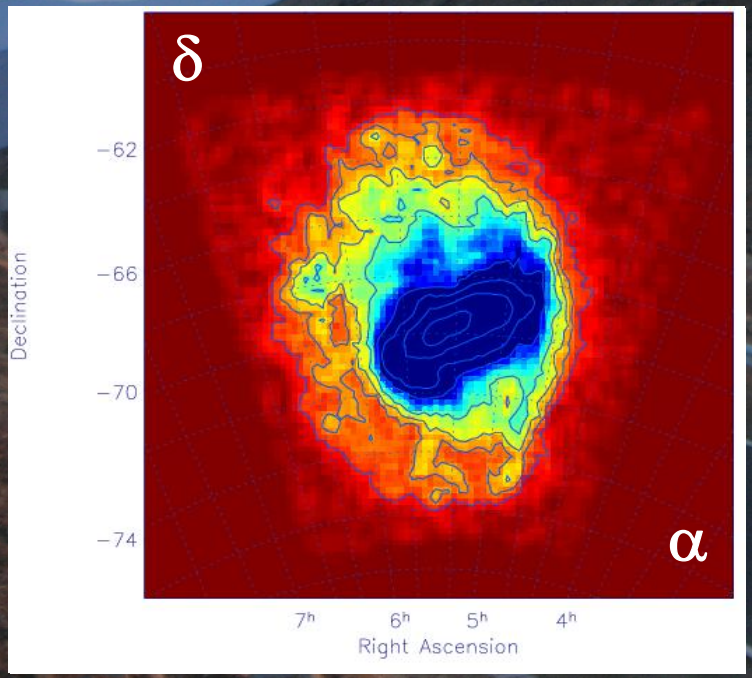
- Can the Magellanic Clouds help?
- Metal poor - early Universe
- known distance - high details
- less reddening - sharp & deep
- Interacting irregular galaxies - many
- the largest MW satellites - neighbours
- extended history!

A "biased" view of the MCs (highlights)

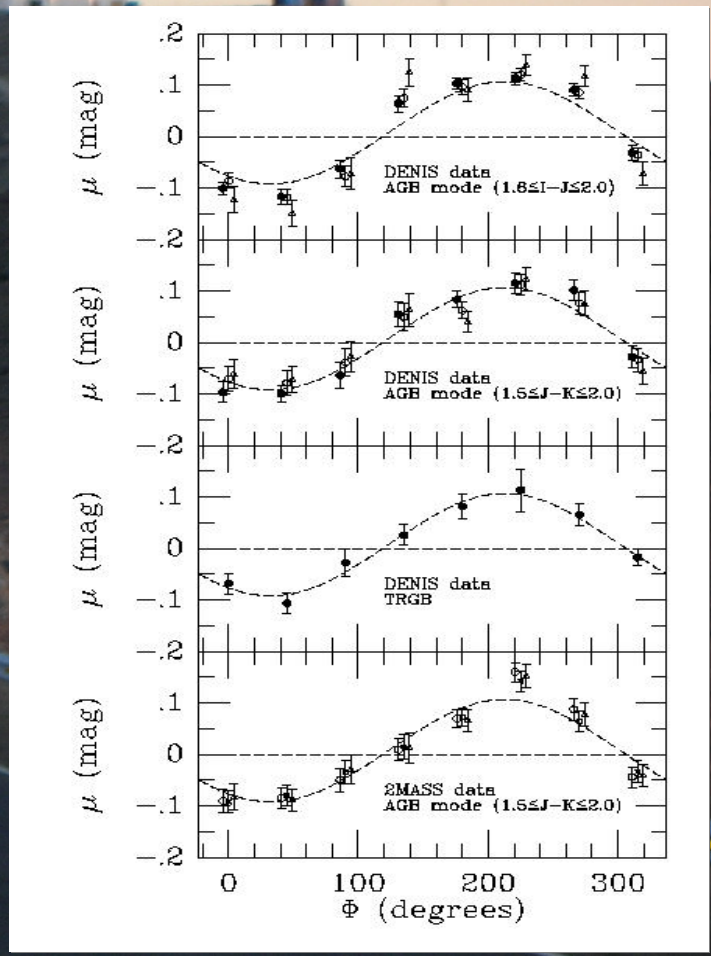
- Near-IR
- Upper RGB & AGB stars
  - Number density - morphology & structure
  - C/M ratio - metallicity (Fe/H]
  - Ks mag - variation of mean age & metallicity
- Opt. Spectra - dynamics & chemistry

The structure of the LMC

AGB stars are smoothly distributed and trace the orientation of the galaxy in the sky



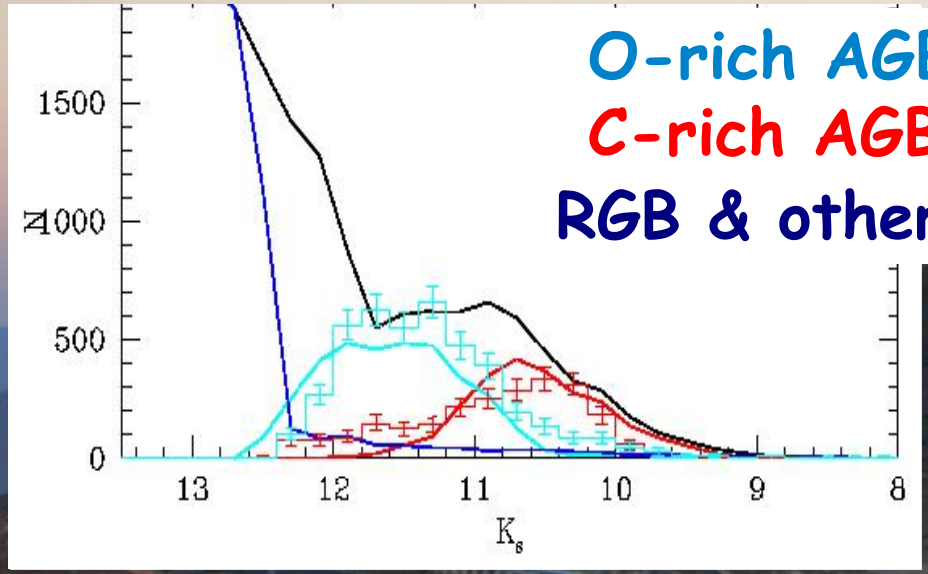
Cioni, Habing & Israel 2000



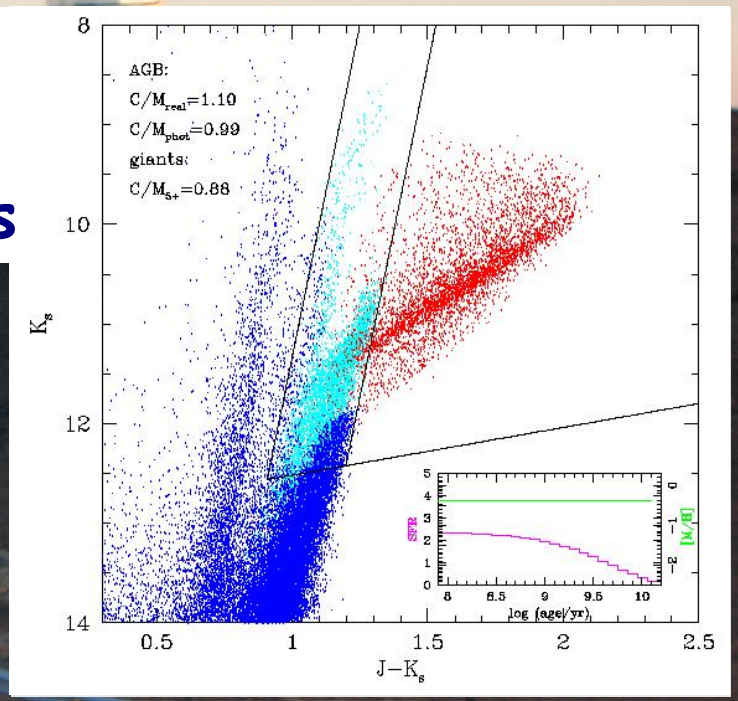
van der Marel & Cioni 2001

Ks-method

- The SFR derived from localized regions does not produce a good fit across the whole galaxy!



Cioni et al. 2006



- The magnitude distribution of C-rich and O-rich AGB stars as a function of position in the galaxy is interpreted using stellar evolutionary models spanning a range of SFRs and metallicities

- The best fit model to each histogram corresponds to the best mean metallicity and age of the entire stellar population at that location
- The absolute value of age and metallicity is model dependent
- The range of SFRs and Zs chosen shows spatially relative differences but is not exhaustive

Theoretical Ks distribution

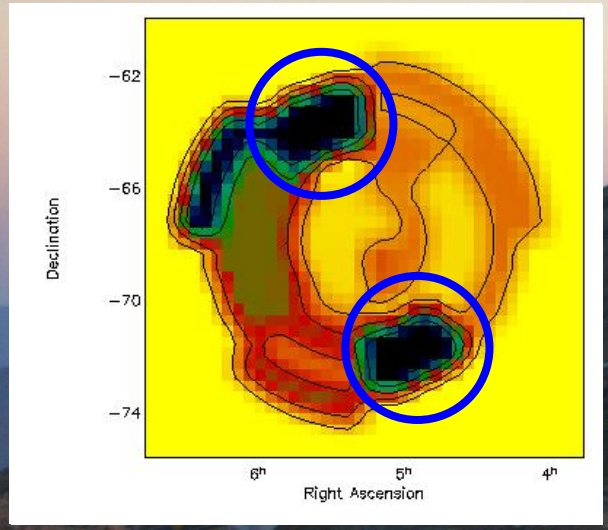
- TRILEGAL code: simulates stars according to a SFR, AMR and IMF

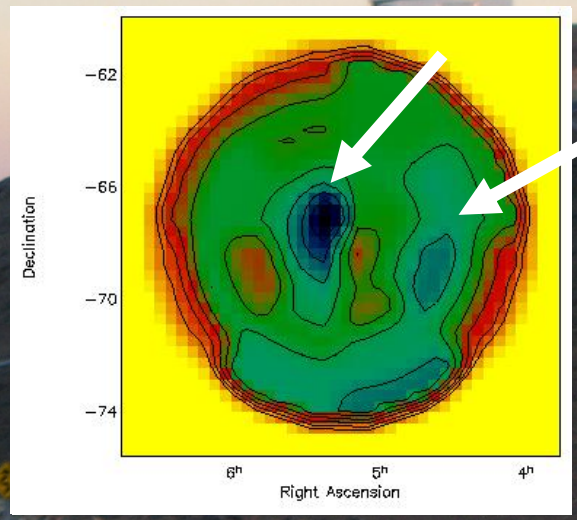
- L, Teff, g are interpolated among stellar evolutionary tracks from:
  - Bertelli et al. (1994) - massive stars
  - Girardi et al. (2000) - low & intermediate mass stars
  - Marigo et al. (1999) - thermal pulsing AGB stars

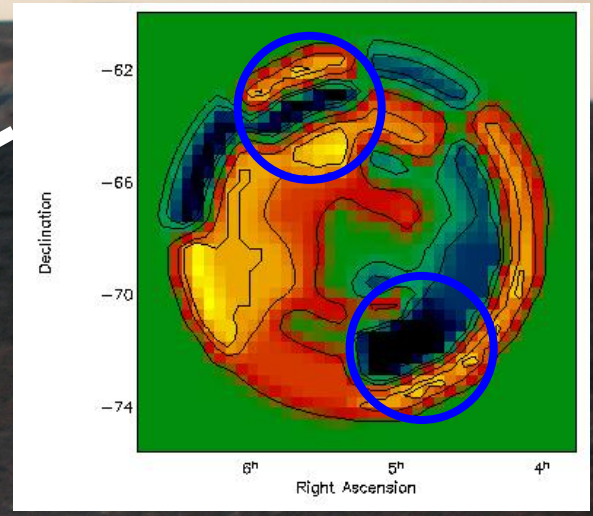
- Using bolometric tables to derive magnitudes and include photometric errors

Large Magellanic Cloud

mean metallicity, C/M & mean age







The population is younger in the E than in the W

The bar has a composition stellar population

The C/M ratio is a robust indicator of metallicity

Maps are corrected for the LMC orientation

Regions poorly constrained:

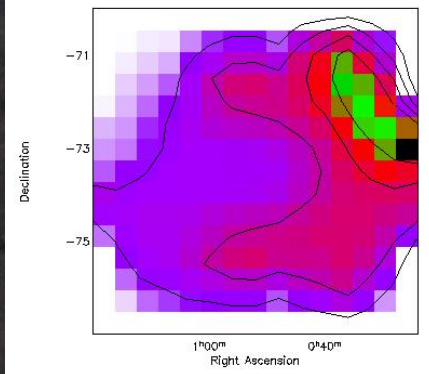
(Cioni et al. 2006)

Small Magellanic Cloud

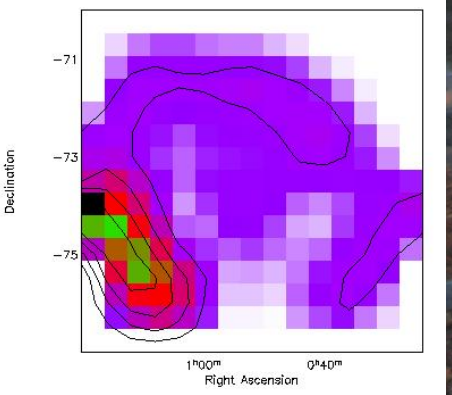
Snap shots of the average metallicity (iron) across the galaxy

The highest concentration moves with age

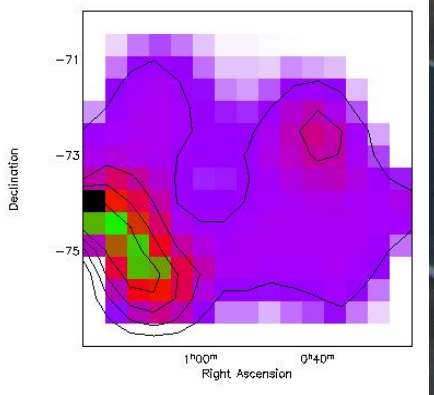
10.6 Gyr



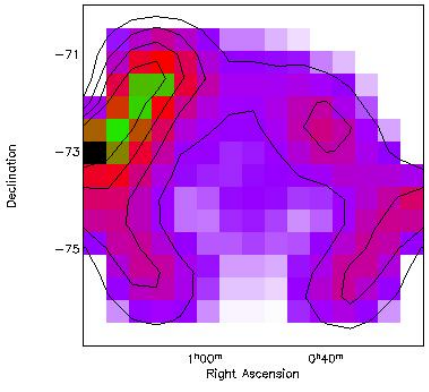
2 Gyr



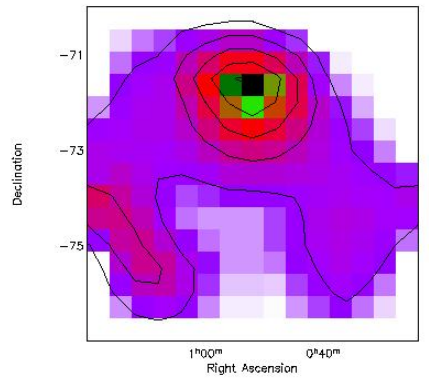
3.9 Gyr



6.3 Gyr



8.7 Gyr



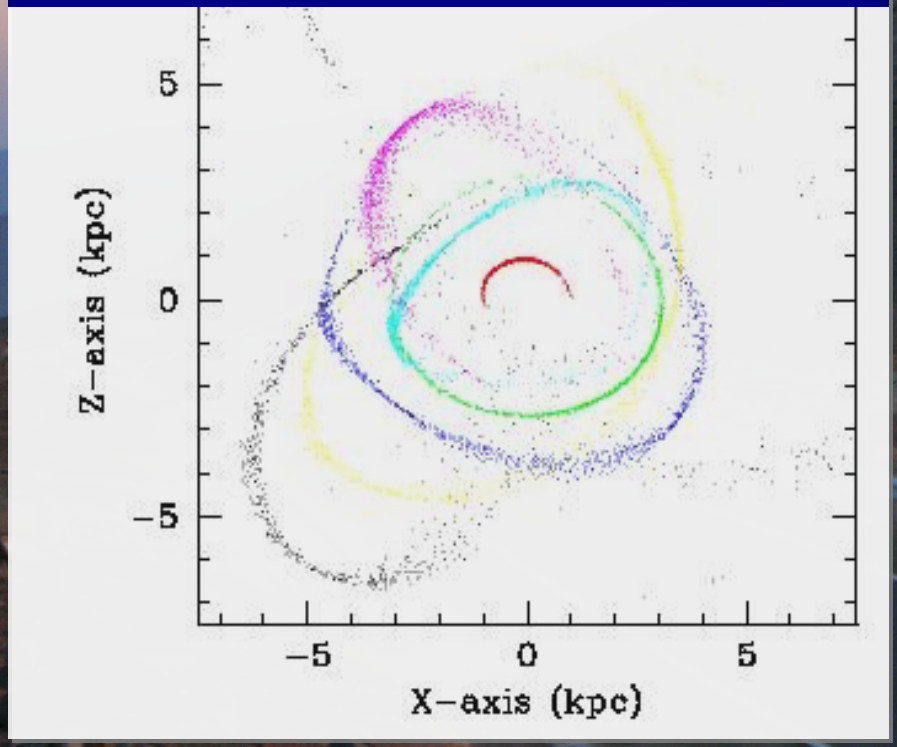
A ring-like feature?

Colours equal different metallicity:
Z = 0.008 (red), 0.004 (green) and 0.001 (blue)

- Harris & Zaritsky 2004:
  - inward propagation of star formation
  - remnant of a gas rich merger

In-homogeneities as fossil records of a clumpy past

Dynamical simulations



(Bekki & Cioni, 2007)

- Distribution of stars originating from different stellar clumps
- Each clump has an age and a metallicity
- Clumps of $<10^7$ M_{sun} dissolve to form field stars

What is missing?

- Absolute values of age and metallicity
- Kinematics and detailed chemistry
- Effects of interactions (intrinsic versus extrinsic star formation)
- 3D picture
- Link between gas & stars

- New instruments & models should allow us to "complete" / "complicate" the picture of the Magellanic system

The VISTA Public Survey of the Magellanic Clouds (LMC+SMC+Bridge+Stream)

PI = M. Cioni

Co-Is = K. Bekki, G. Clementini, W. de Blok, C. Evans, R. de Grijs, B. Gibson, L. Girardi, M. Groenewegen, V. Ivanov, P. Leisy, M. Marconi, C. Mastropietro, B. Moore, T. Naylor, J. Oliveira, V. Ripepi, J. van Loon, M. Wilkinson, P. Wood

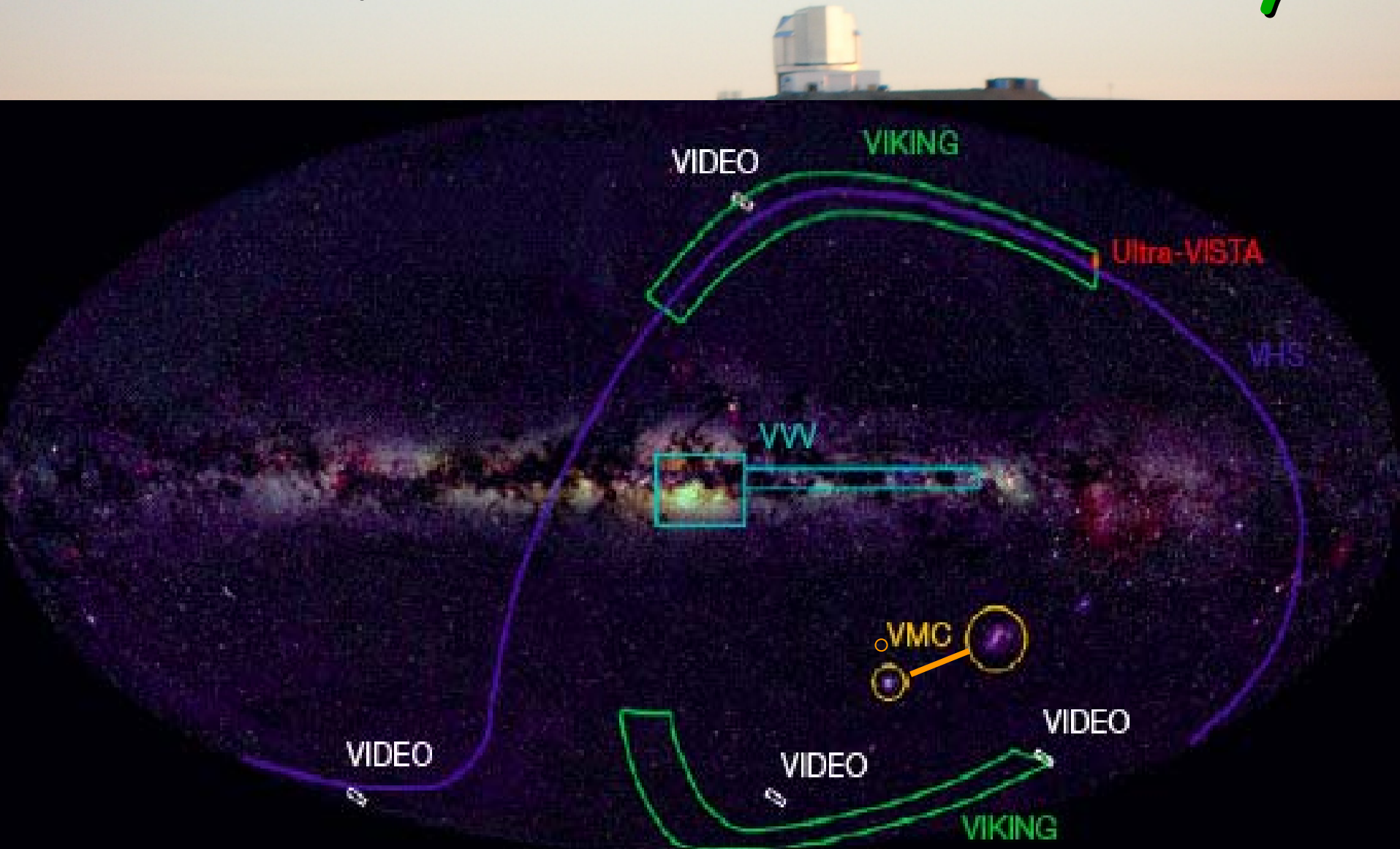
VISTA is a new and the best IR telescope of this time!

Arnaboldi et al. 2007, The Messenger 127

VISTA Public Surveys

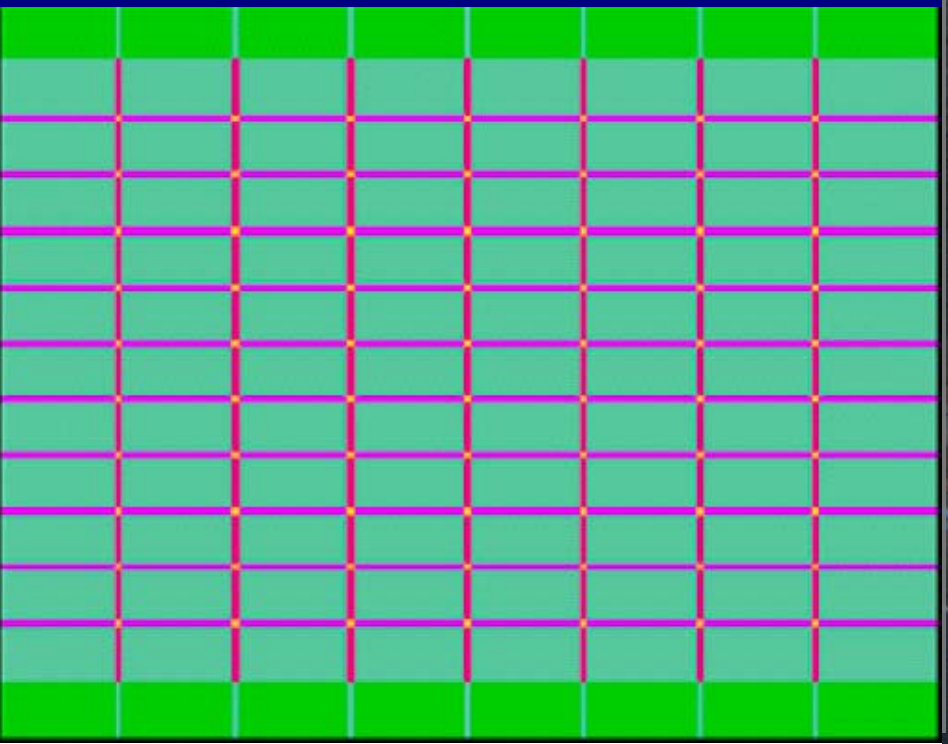
- Ultra- ; Dunlop, Frax, Fynbo, Le Fevre
- Hemisphere Survey (VHS): McMahon
- Deep Extragalactic Observations Survey (VIDEO): Jarvis
- Variables in the Via Lactea (VVV): Minniti
- Kilo Degree Galaxy Survey (VIKING): Sutherland
- Near infrared survey of the Magellanic System (VMC): Cioni

Area of VISTA Public Surveys



VISTA telescope & camera

VISTA tile



Detectors distance 95% in X and 47.5% in Y; 6 pointings fill a tile

- 4m telescope @ Paranal
- 16 IR detectors
- 0.84-2.5 micron
- ZYJHKs & 1.18 NB
- 0.339"/pix resolution
- 0.51" instrument PSF
- 75% time for Public Surveys

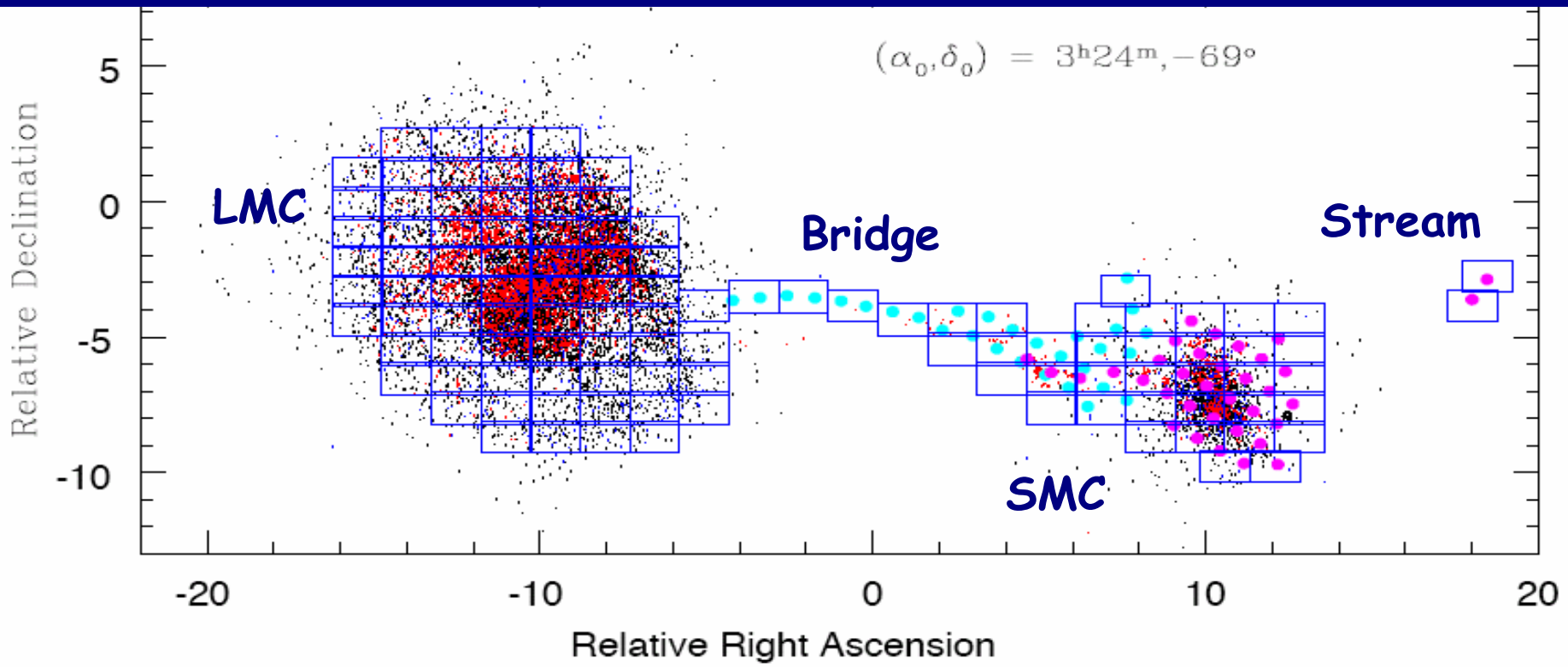
- A tile covers 1.65 deg^2
- Each pixel is covered at least twice

VMC area

VST- optical fields

VISTA tile ~ 1.6 sq.deg.

Filters = Y, J, Ks Time = 180 nights £ 1,500,000



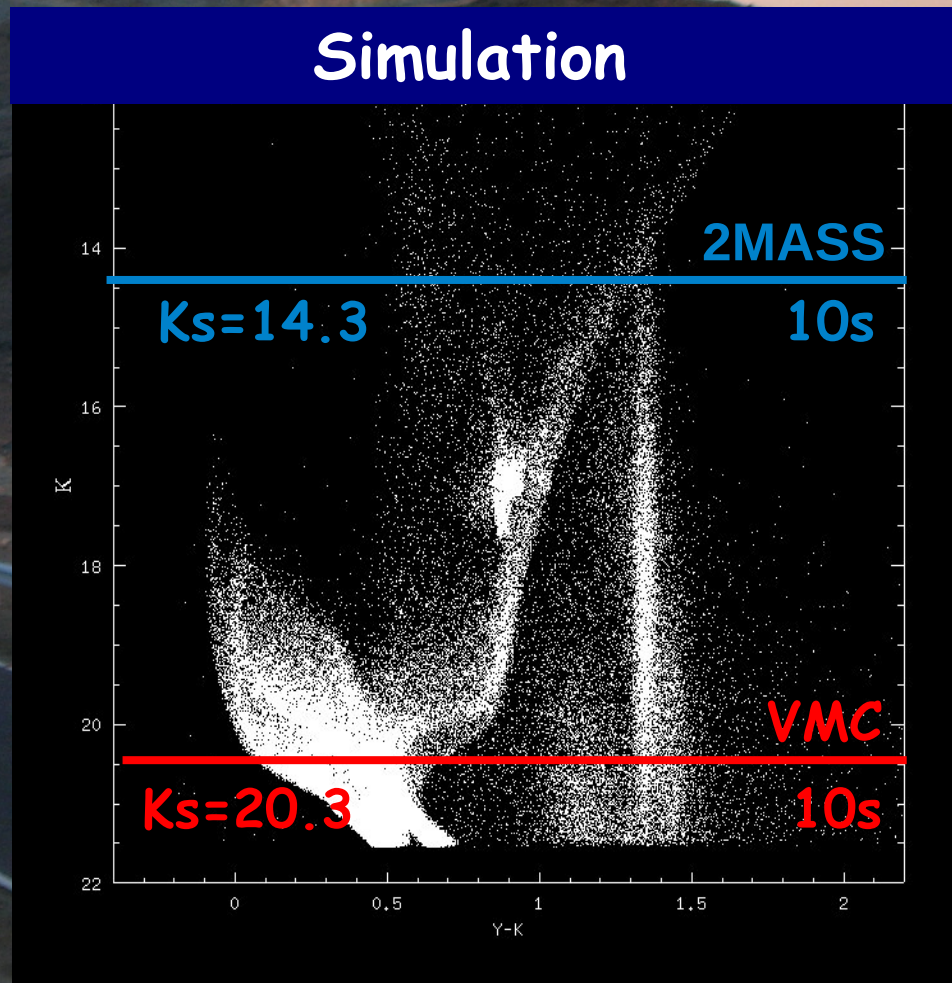
VMC (2008-2013) will produce a unique infrared data base to fully comprehend the Magellanic System

VMC observing strategy

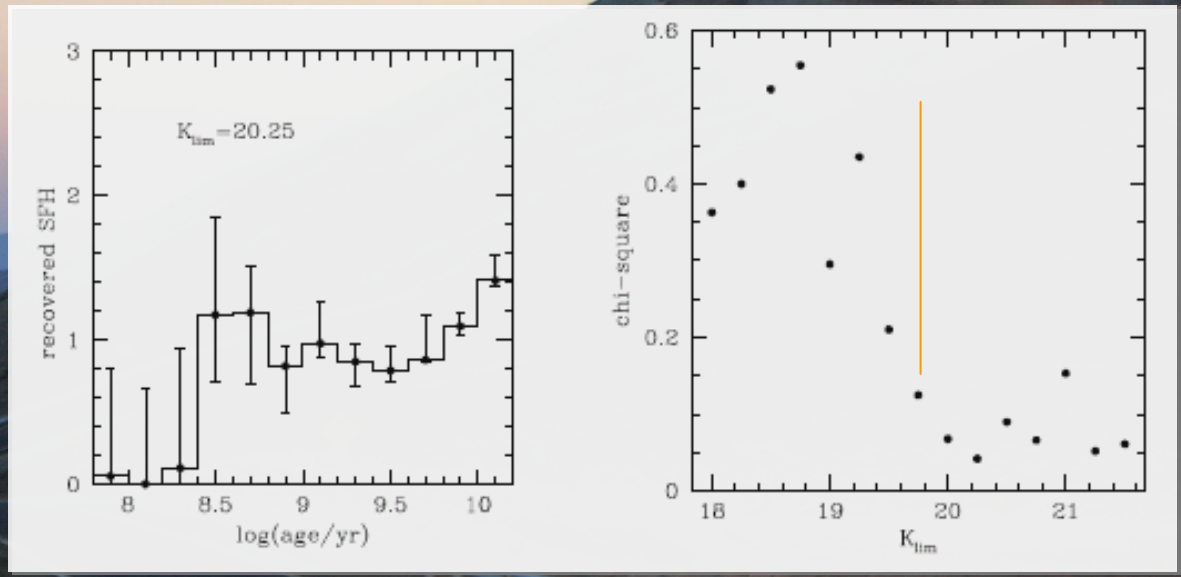
- Total area = 184 deg2
  - 116-LMC, 45-SMC, 20-Bridge, 3-Stream
- Seeing = 0.6", 0.8", 1.0"
- Sensitivity @ S/N = 10
  - Y = 21.9, J = 21.4, Ks = 20.3
- Integration ~80% efficient:
  - 1 x YJKs - same night
  - 2 x YJ and 11 x Ks - same semester
- Mid-term goal:
  - One epoch @ 3 filters for each tile
  - More epochs on a given Magellanic component

VMC science goals

- Spatially resolved SFH & metallicity evolution
- 3D geometry of the system & age dependency (empirical and theoretical)
- Substructures: new clusters and streams



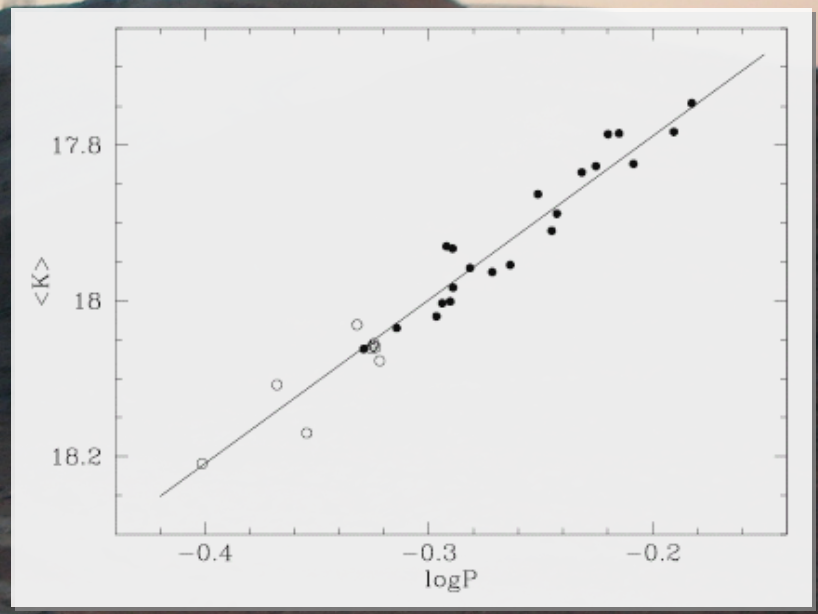
Star formation history



- Recovered SFH for 0.1-12 Gyr constant SFR; errors similar to expectations
- Chi^2 of recovered minus observed SFH for different tests vs survey depth

Geometry indicators

- The red clump luminosity
- The period-luminosity relation for RR Lyrae and Cepheids
- Standard candles in clusters



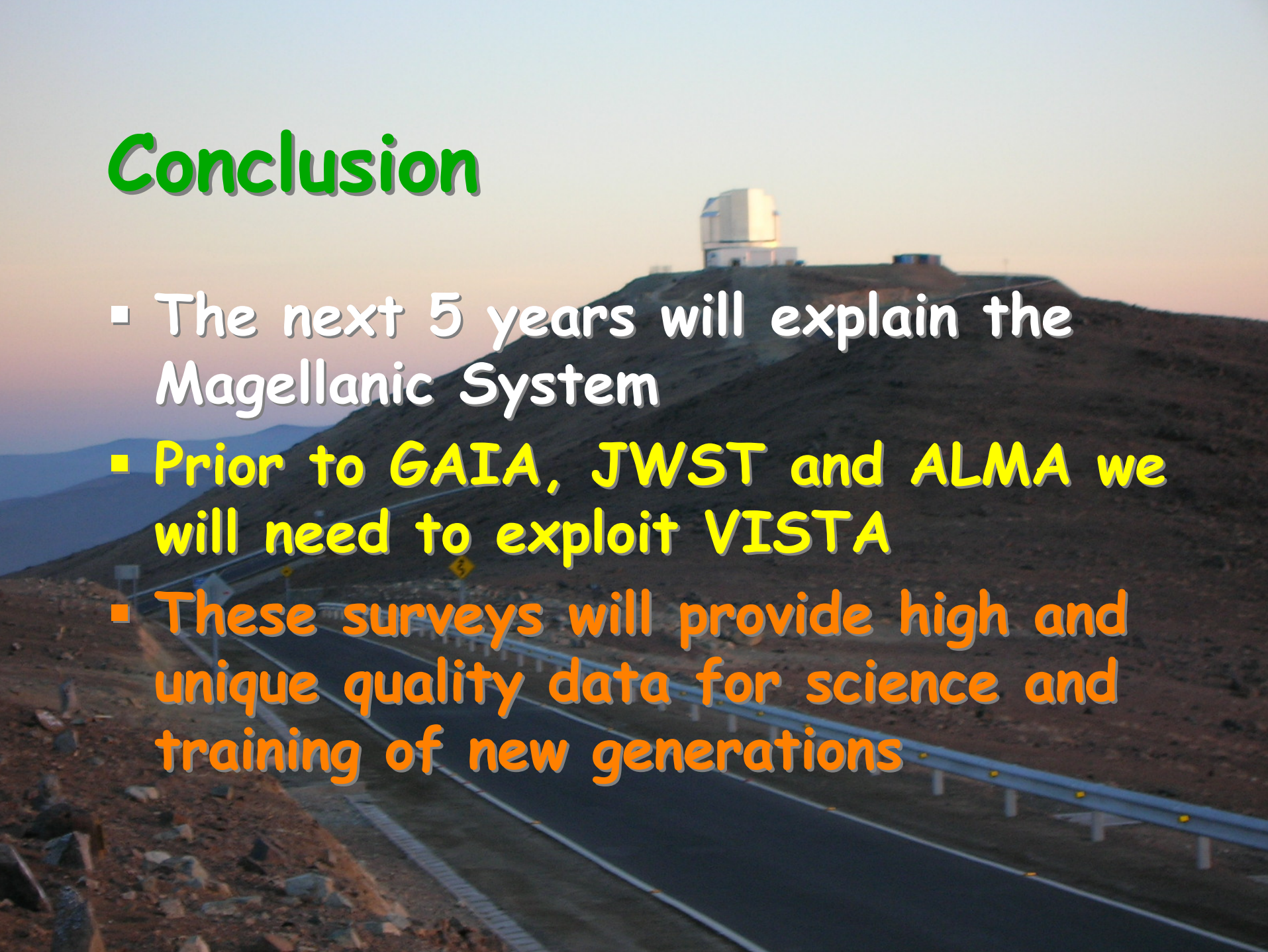
Log(P) vs Ks relation for RR Lyrae stars in the Reticulum

Ancillary science

- Distance to the LMC - reduce the uncertainty via IR tracers
- Obscured massive stars; pre-MS 1.5 Msun unreddened;
- PNe & HII regions w/spectra
- Proper motion w/2MASS (~15 years)
- Follow-up!

Complementary surveys

- EROS-II (MCs, wide coverage) recent
- SIRIUS & deep 2MASS (Ks~16) recent
- SAGE & S3MC ongoing
- MOSAIC (Deep outer MCs) ongoing
- Akari (all sky + LMC) ongoing
- STEP @ VST (Bridge var. & SMC) planned
- GAIA planned



Conclusion

- The next 5 years will explain the Magellanic System
- Prior to GAIA, JWST and ALMA we will need to exploit VISTA
- These surveys will provide high and unique quality data for science and training of new generations