The near-infrared YJKs VISTA ESO Public survey of the Magellanic Clouds system

Core: Cioni (PI), Bekki, Clementini, Emerson, Evans, de Grijs, Gibson, Girardi, Groenewegen, Ivanov, Marconi, Miszalski, Napiwotzki, Oliveira, Piatti, Ripepi, van Loon, Wilkinson

+ CASU and WFAU

Associates: many

Postdocs: For, Kim, Moretti, Muraveva, Rubele

Students: Romita, Sun, Tatton, Zivkov

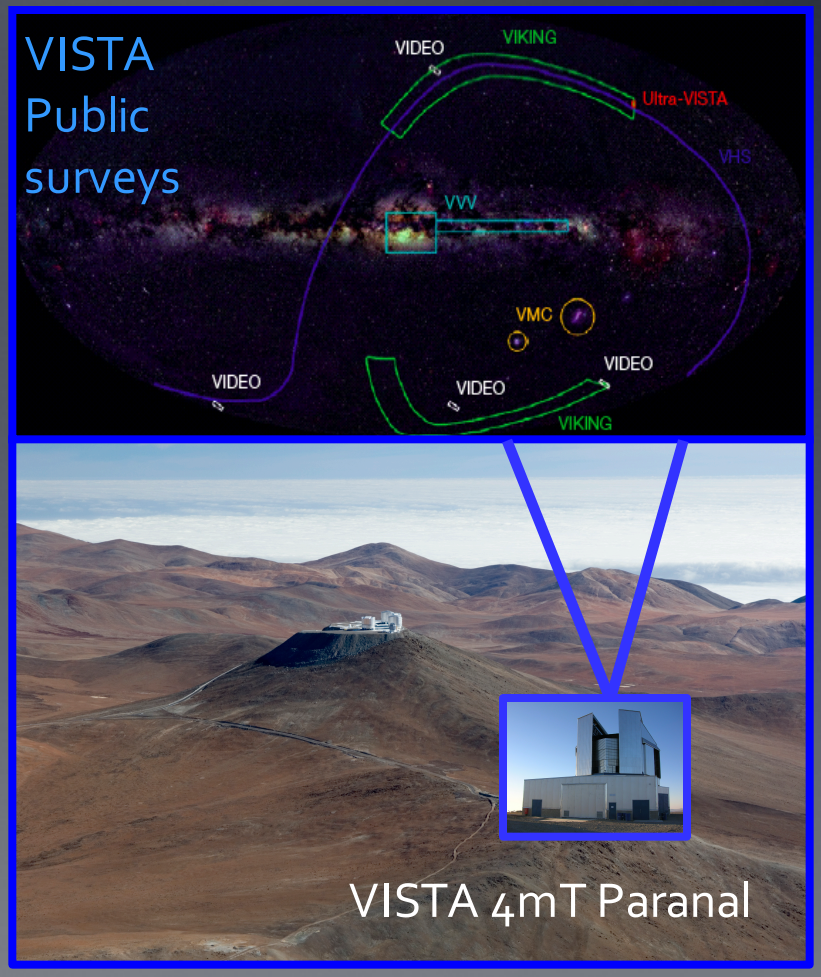
7th October 2015 – ESO Garching: Rainbows in the Southern Sky

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

VMC survey

~70% complete

- Filters: Y, J, K_s
- Camera: 16 Rayethon detectors
- Sampling: 0.34"/pix
- FOV: 1.65 deg^2
- Area: 170 deg^2
- Sensitivity: YJK_s~22 (5σ Vega)
- Saturation: K_s~10
- Epochs: 3 (YJ) + 12 (K_s)
- Time-scale: 2009-2018

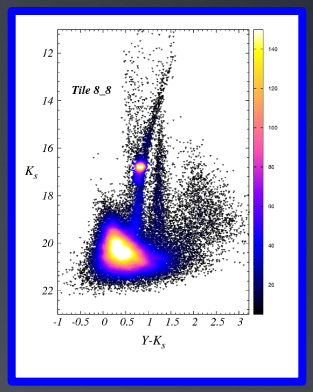


Cioni +2011; Paper I

VMC main science

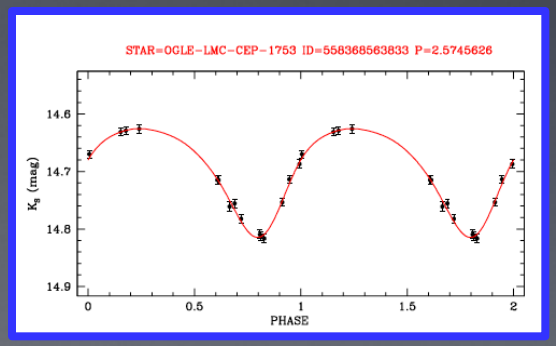
- Spatially resolved star formation history
  - By reaching stars below the old main-sequence turnoff
  - By interpreting CMDs with models

  (defines survey depth)



- 3D geometry
  - Using Cepheids and RR Lyrae stars
  - Using red clump giant stars

  (defines survey monitoring)



- Legacy science
  - Milky Way, Star formation, individual stars, stellar clusters, system dynamics, quasars, etc.

VMC observing strategy

VISTA field-of-view = Pawprint = 1.65 deg²
16 detectors, large gaps

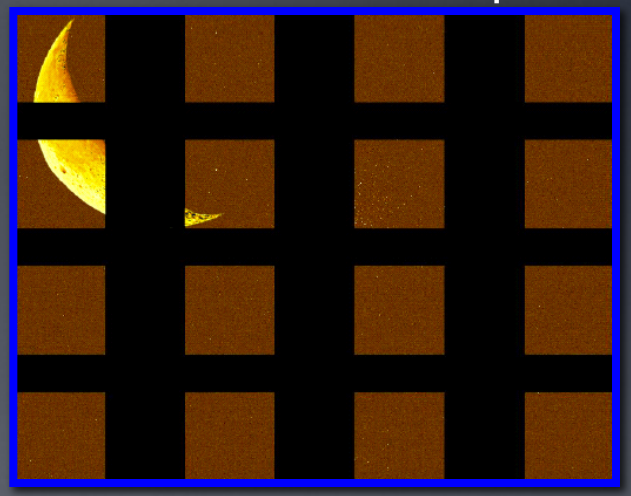
6-point mosaic
Filled gaps = Tile
2-6 observations per central field = 1.5 deg²
1 observation in the wings

VMC has 110 tiles
12 epochs of each tile in Ks within 2 years
(cadence:: 0-1-3-5-7-17 days for the rest)
3 epochs of each tile in Y and J
(no requirement, could be same night)

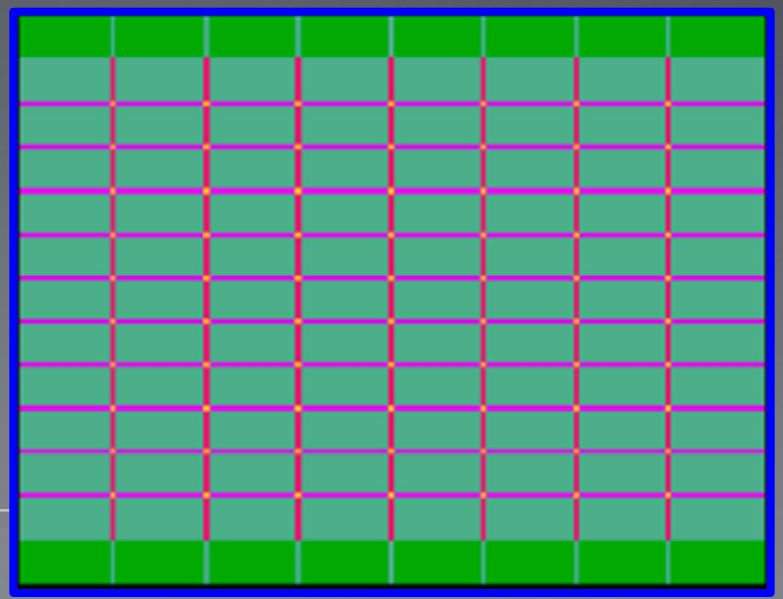
Individual tile observations take 1^{h}.
The VMC survey takes ~2000 h or ~250 nights.

Service mode, sky quality (thin, airmass, seeing).

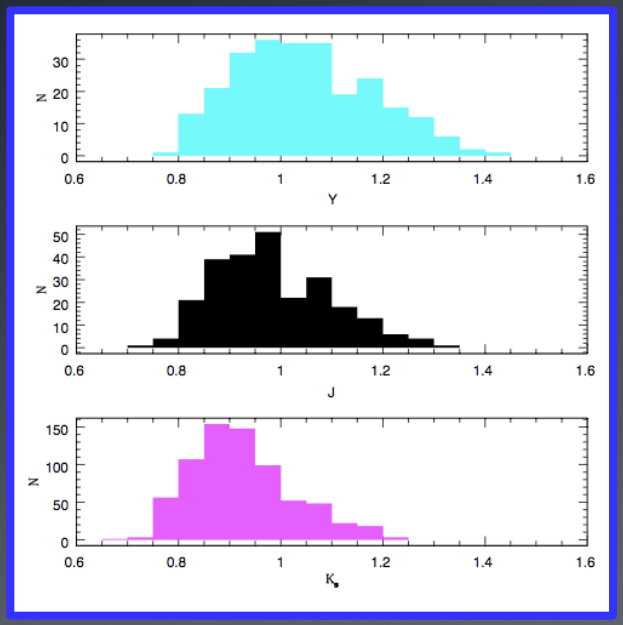
Pawprint



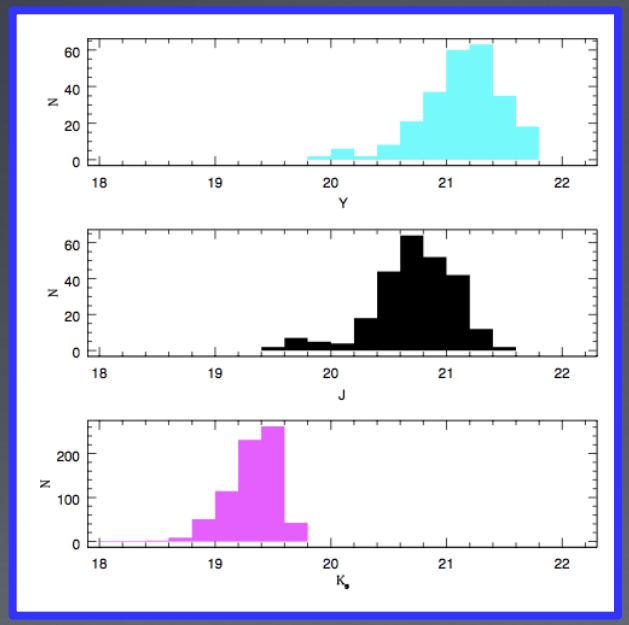
Tile



Data progress and quality

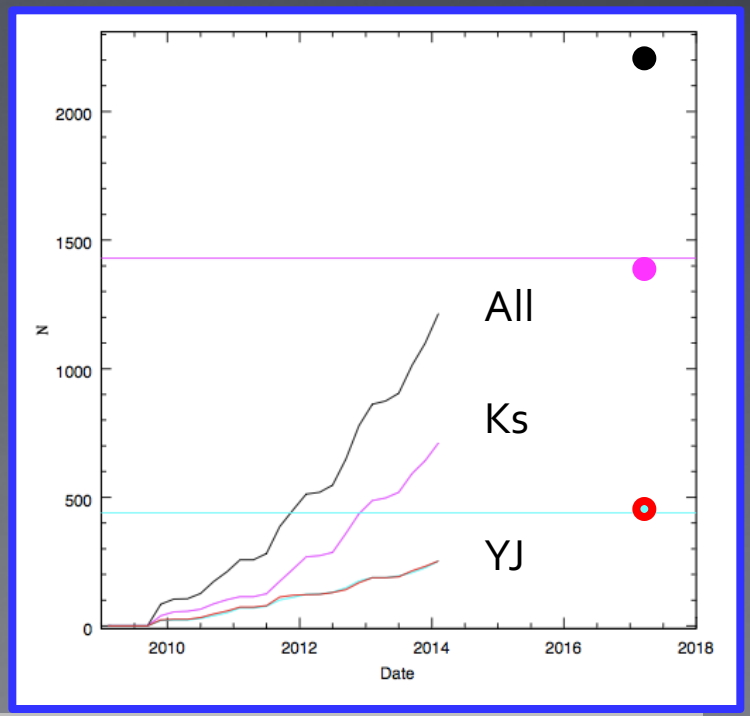


FWHM
(two peaks for crowded and un-crowded fields)



Sensitivity of Individual epochs
(~1^h observation, Vega mag)

Expected completion 2009-2018



VMC data path

Pawprint and tile images. Catalogues per filter and epoch.

VDFS pipeline

Deep stacked images and catalogues. Link epochs and filters.

Data release.

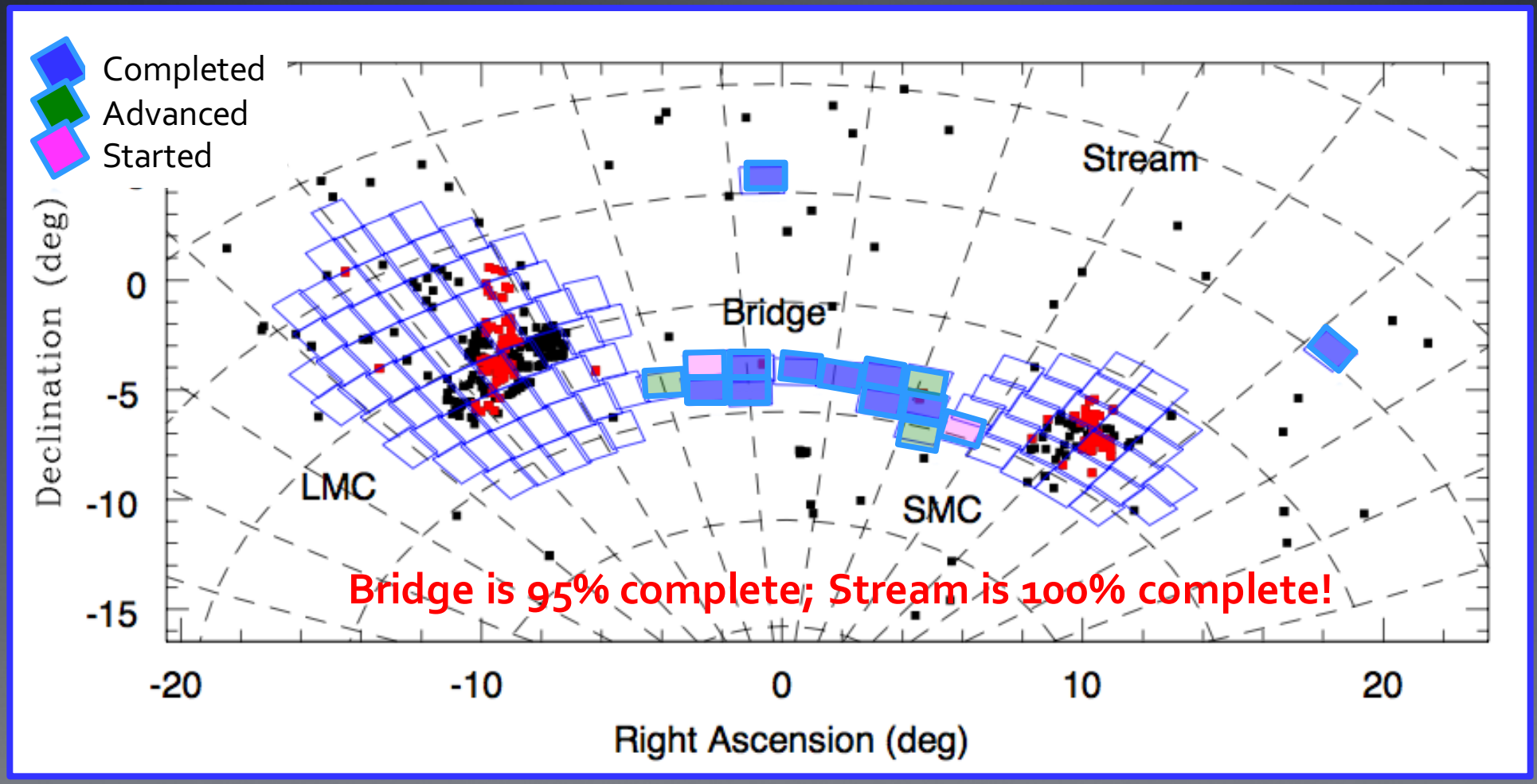
Observations

INAF, Padova
INAF, Bologna
INAF, Naples

PSF and completeness. Variability.

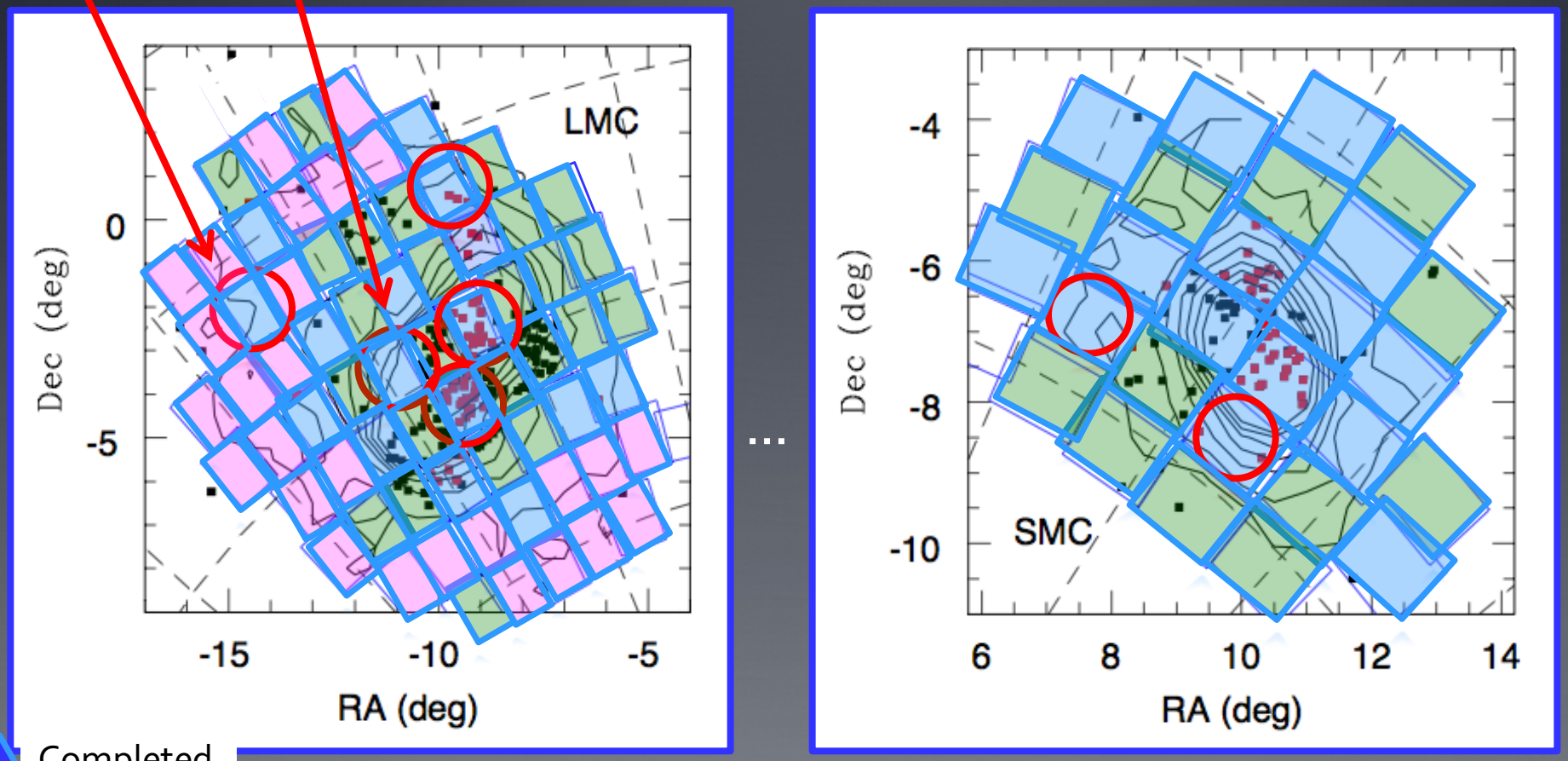
Data release.

VMC survey progress
Bridge & Stream



Advanced = all YJ and at least 6 K_s epochs have been observed.

VMC survey progress
LMC & SMC



Completed
Advanced
Started

Public

LMC is 55% complete; SMC is 95% complete!

Advanced = all YJ and at least 6 K_s epochs have been observed.

VMC images

In the LMC bar

Spiral galaxy

Stellar clusters

Galaxy cluster

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

VMC papers

- The VMC survey - I. Strategy and first data (Cioni et al. 2011)
- The VMC survey – II. Planetary Nebulae (Miszalski et al. 2011)

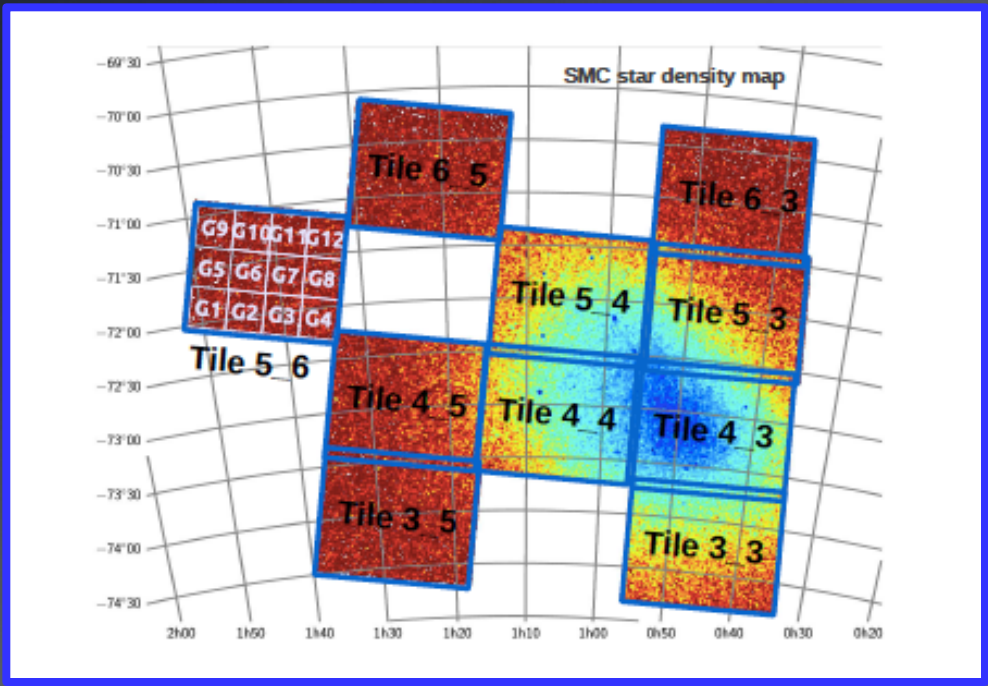
>270 citations

- The VMC survey – III. The SED of AGB stars (Gullieuszik et al. 2012)
- The VMC survey - IV. The SFH of the GAIA field (Rubele et al. 2012)
- The VMC survey – V. Classical Cepheids (Ripepi et al. 2012)
- The VMC survey – VI. Quasars behind the Magellanic system (Cioni et al. 2013)
- The VMC survey – VII. Reddening in 30 Dor tile (Tatton et al. 2013)
- The VMC survey – VIII. Anomalous Cepheids (Ripepi et al., 2014)
- The VMC survey – IX. Variable stars (Moretti et al. 2014)
- The VMC survey – X. Proper Motion (Cioni et al. 2014)
- The VMC survey – XI. 47 Tuc stellar populations (Li et al. 2014)
- The VMC survey – XII. Star clusters in LMC (Piatti et al. 2014)
- The VMC survey – XIII. Type II Cepheids (Ripepi et al. 2014)
- The VMC survey – XIV. SFH in SMC (Rubele et al. 2015)
- The VMC survey – XV. SMC-Bridge clusters (Piatti et al. 2015)

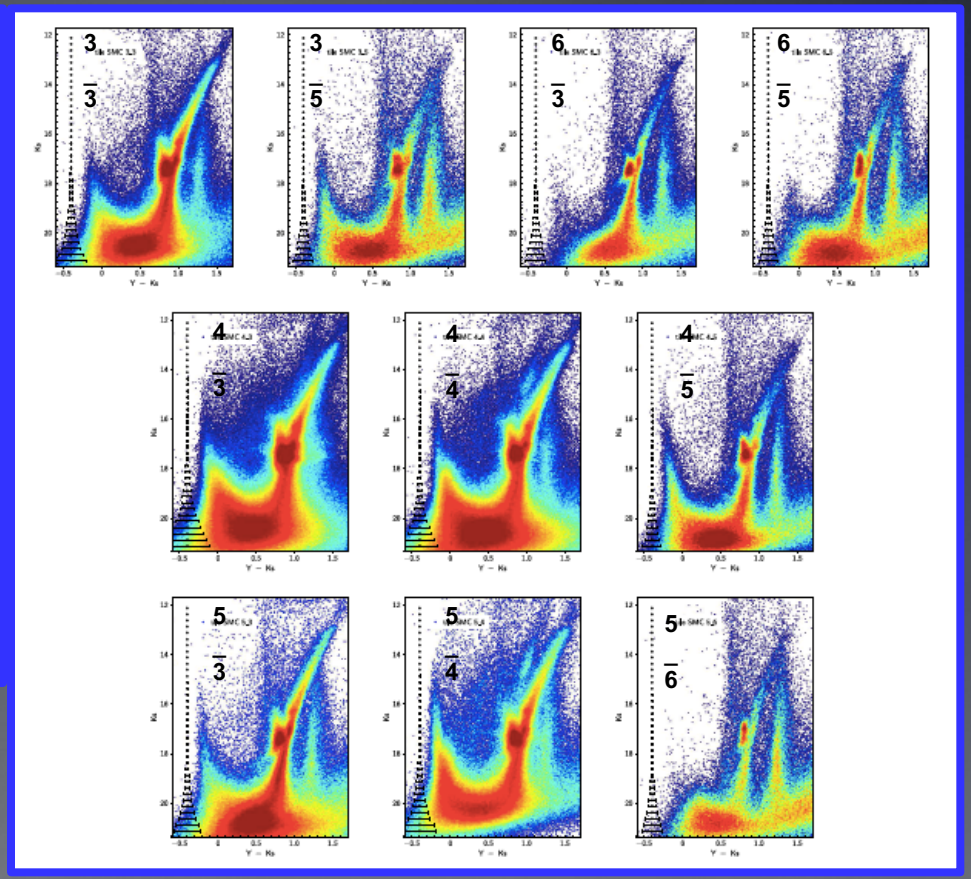
Two Messenger articles (2011, 2013); 3 Preparatory articles; 2 Related articles; 2 Submitted articles

2015
Science highlights

SMC Star Formation History



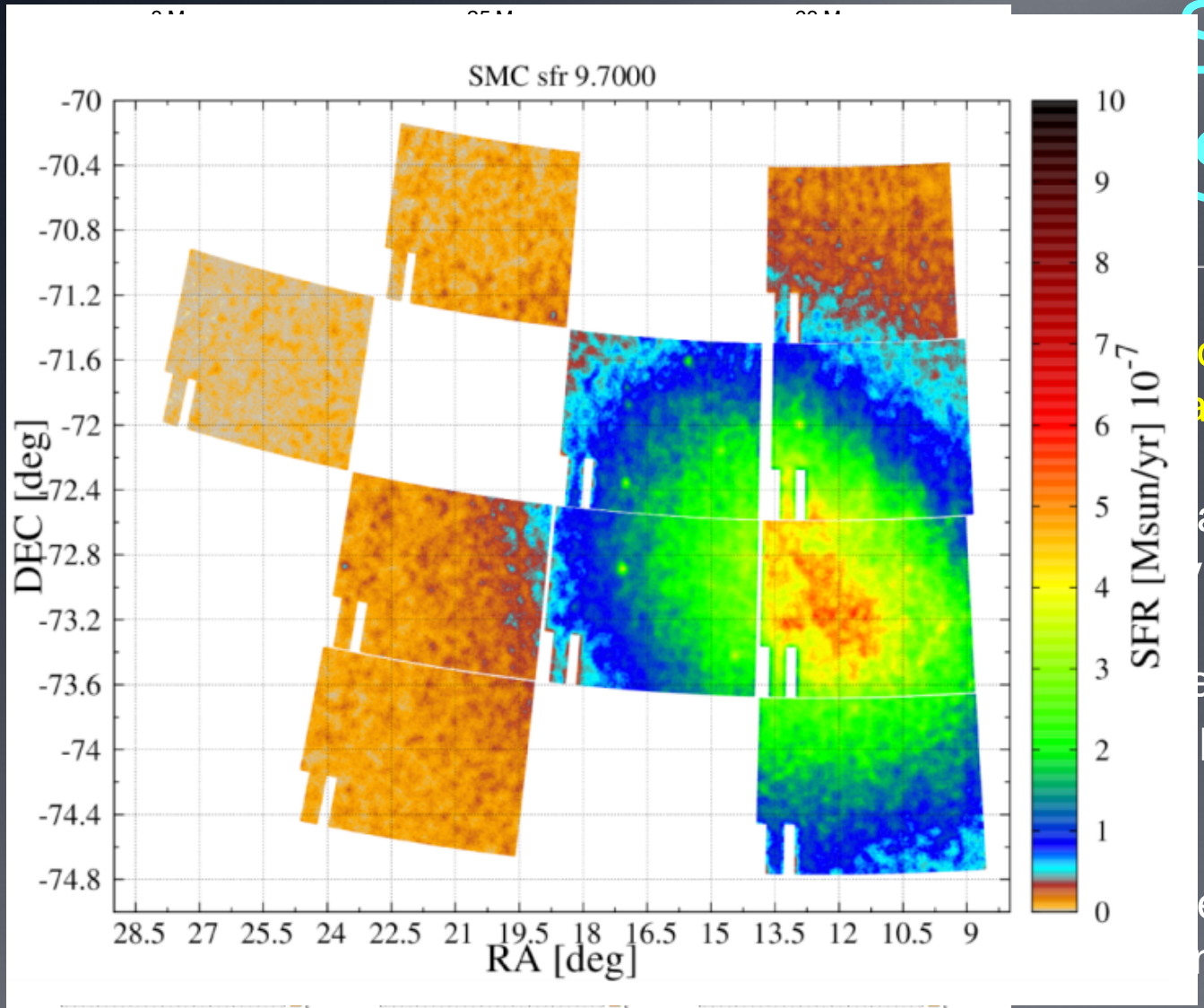
The best combination of partial models that describe the composite stellar population is obtained using STARFISH.

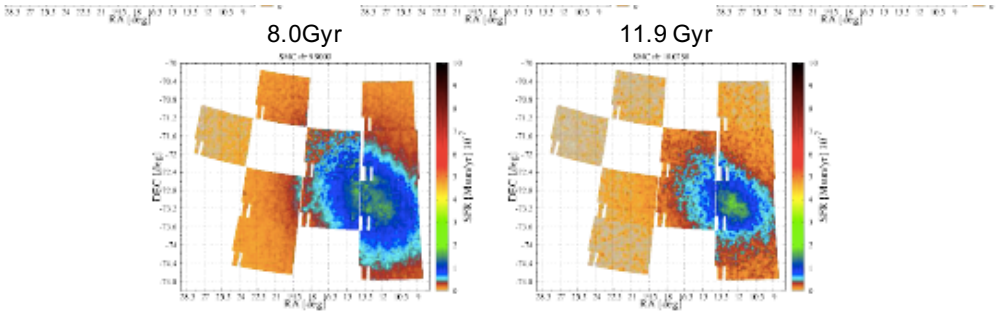


The CMDs contain a range of stellar populations that sample the whole history of the SMC.

(Rubele+2015, Paper XIV)

SMC SFH





ost detailed SFR map to
area and resolution)!

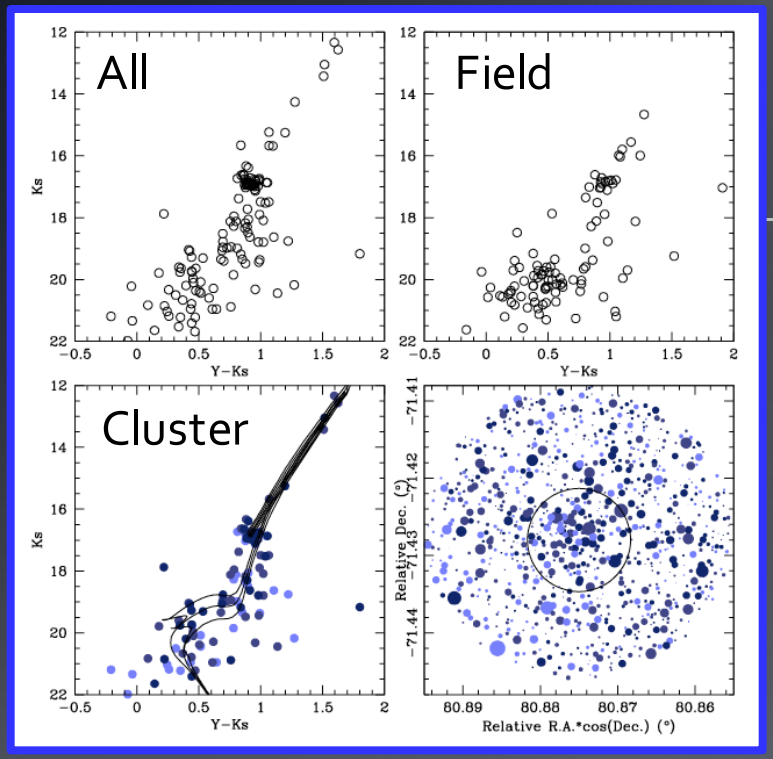
as been modest at ages
r (0.15 $M_\odot$ yr^{-1}).

er peak at 1.5 Gyr agrees
peak in star cluster and
istory.

er SF is happening in
ntre and to the East.

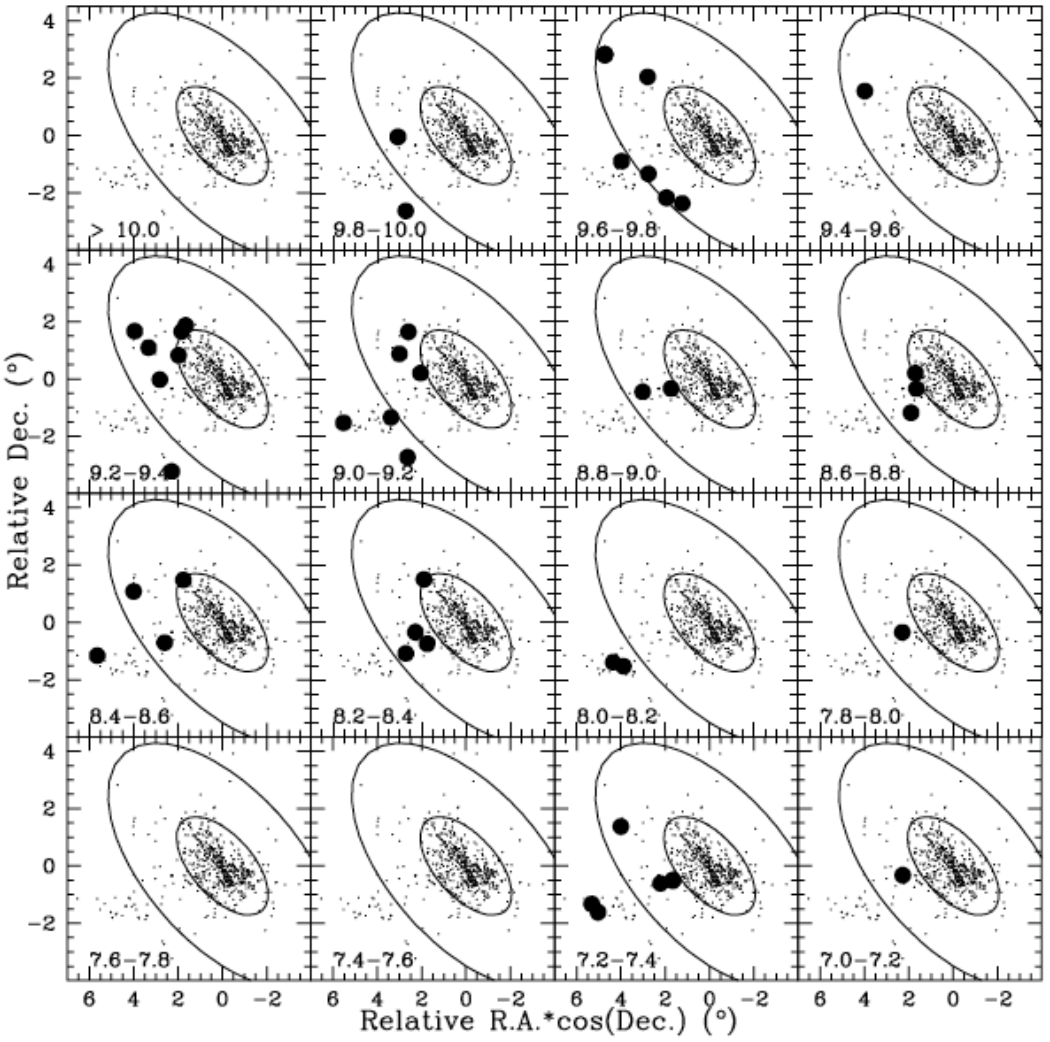
(Rubele+2015, Paper XIV)

Bridge-SMC star clusters



We derive age and metallicity of star clusters after cleaning CMDs for Milky Way stars.

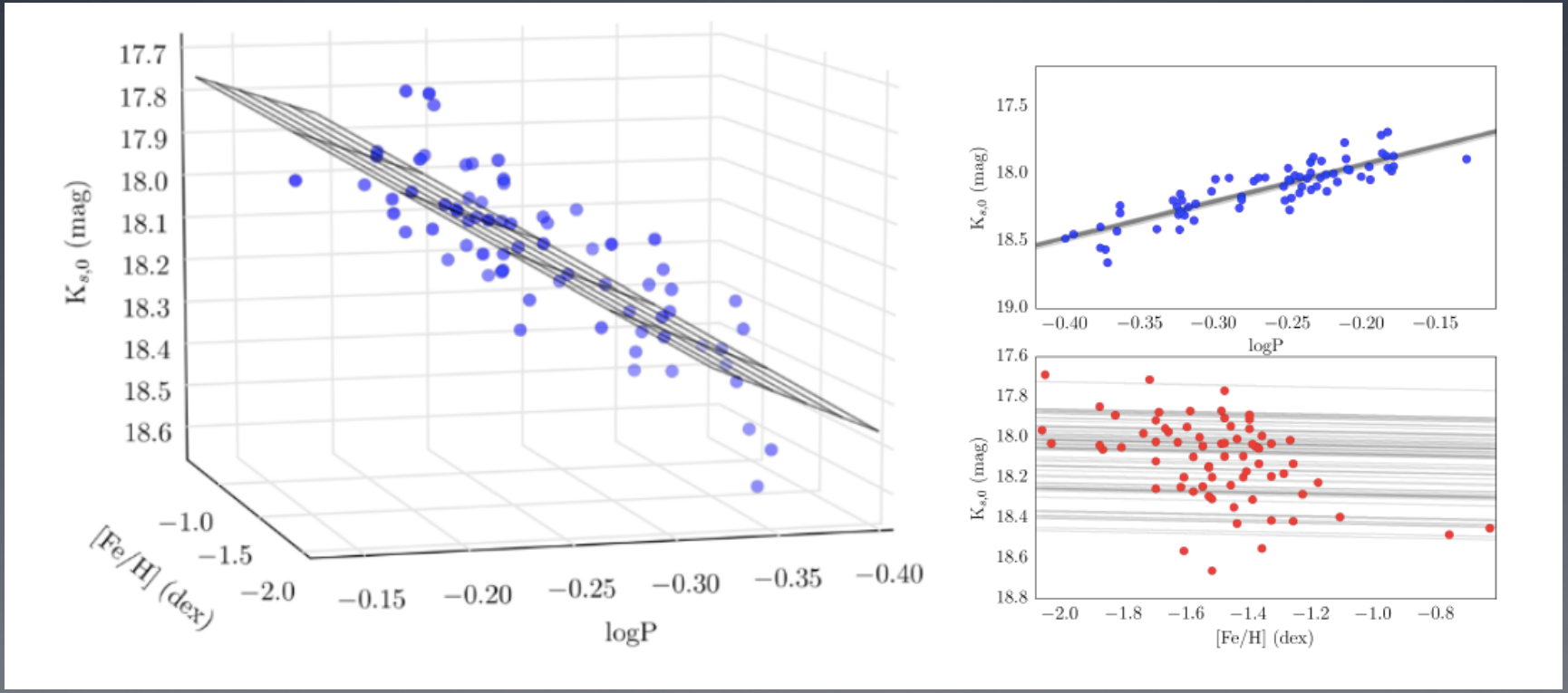
There is an excess of star clusters at log(t yr^{-1})<9 that may be due to the interaction with the LMC.



Piatti+2015; Paper XV

$PL_{Ks}Z$ relation for RR Lyrae stars

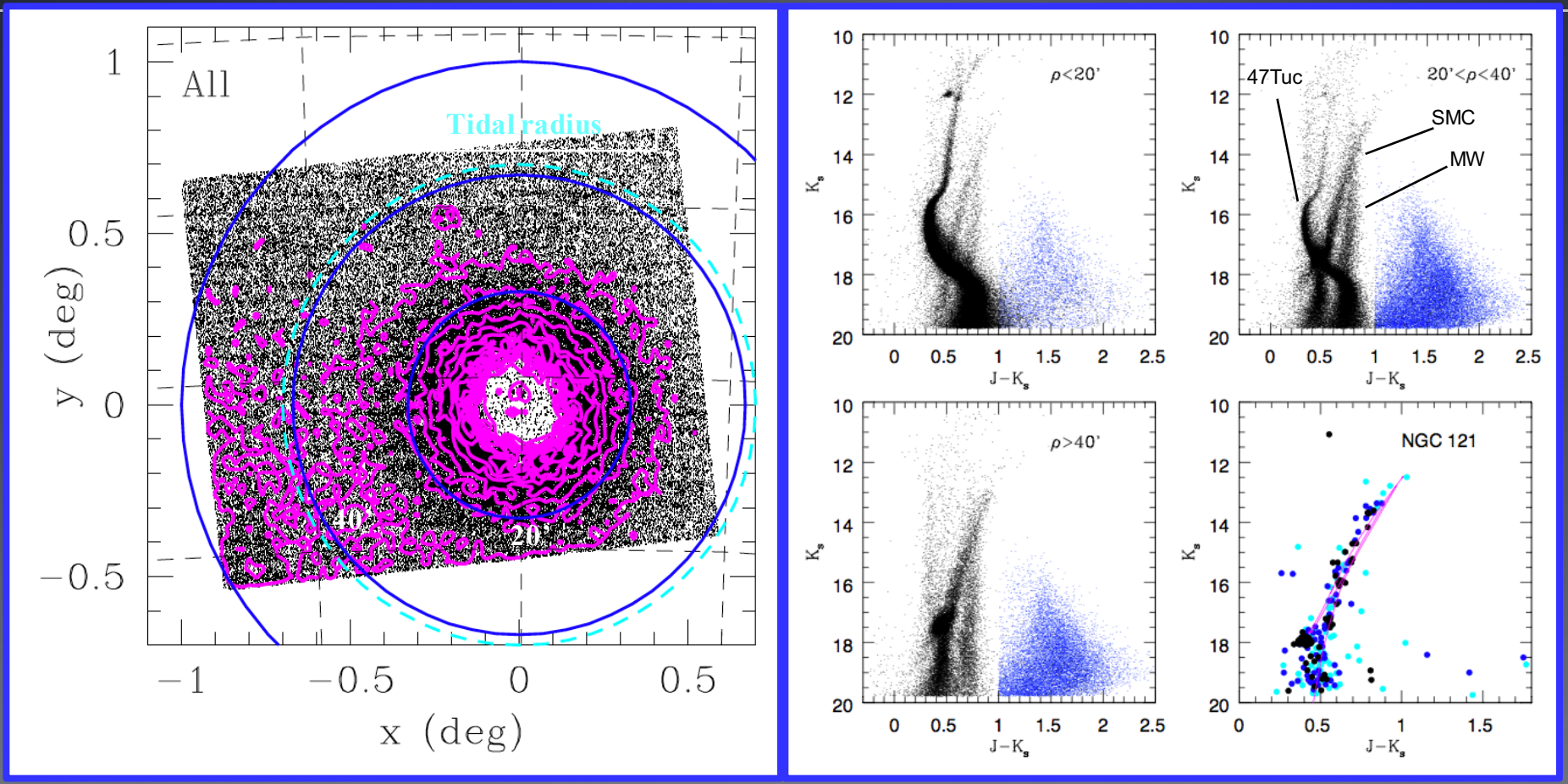
70 RR Lyrae stars with spectroscopic metallicities, accurate mean Ks mag from VMC and OGLE periods.



$M_{Ks} = (-2.73 \pm 0.25)\log P + (0.03 \pm 0.07)[Fe=H] - (1.06 \pm 0.01)$

Muraveva+2015

SMC, 47 Tuc, MW, and galaxies

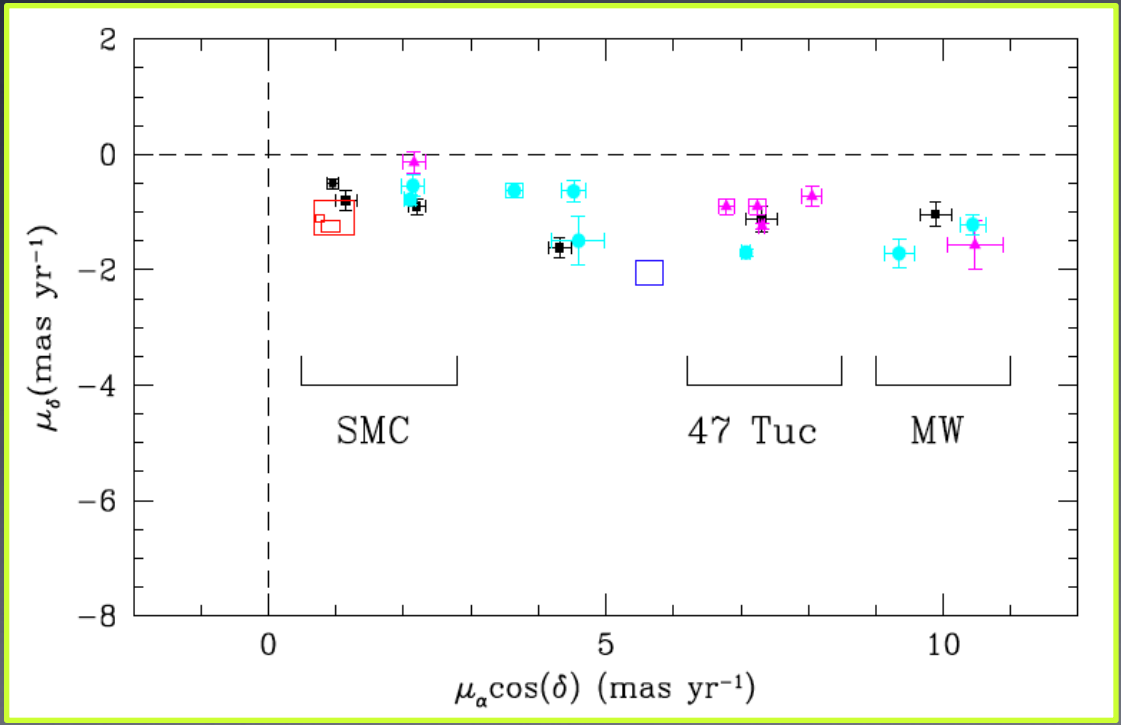


Different stellar populations dominate the CMD at different distances from the centre of the Milky Way star cluster 47 Tuc.

Cioni et al., submitted, Paper XVI

Proper motions of stellar pops.
(i.e. pushing VISTA to astrometry limit)

10 Epochs in 1 yr in Ks (most tile on 2 yr on average)



Squares are HST values.
Systematic errors ~ 20%.
Scatter = influencing populations

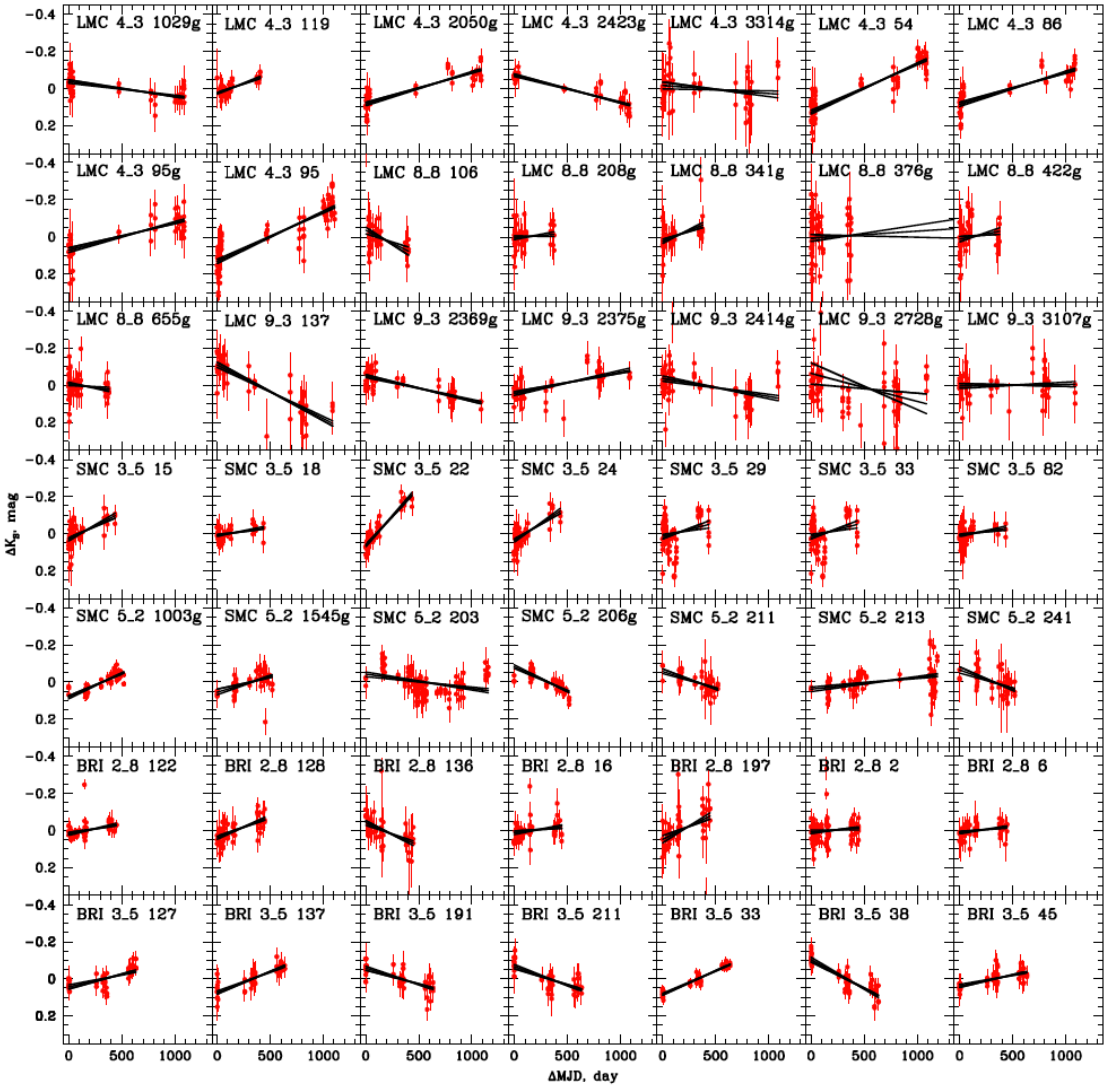
SMC (~10000 sources):
$\mu_\alpha \cos(\delta)$=+1.79(0.05)
μ_δ=-0.69 (0.05)

47 Tuc (~35000 sources):
$\mu_\alpha \cos(\delta)$=+7.26(0.03)
μ_δ=-1.25 (0.03)

MW (~4000 sources):
$\mu_\alpha \cos(\delta)$=+10.22(0.14)
μ_δ=-1.27 (0.12)

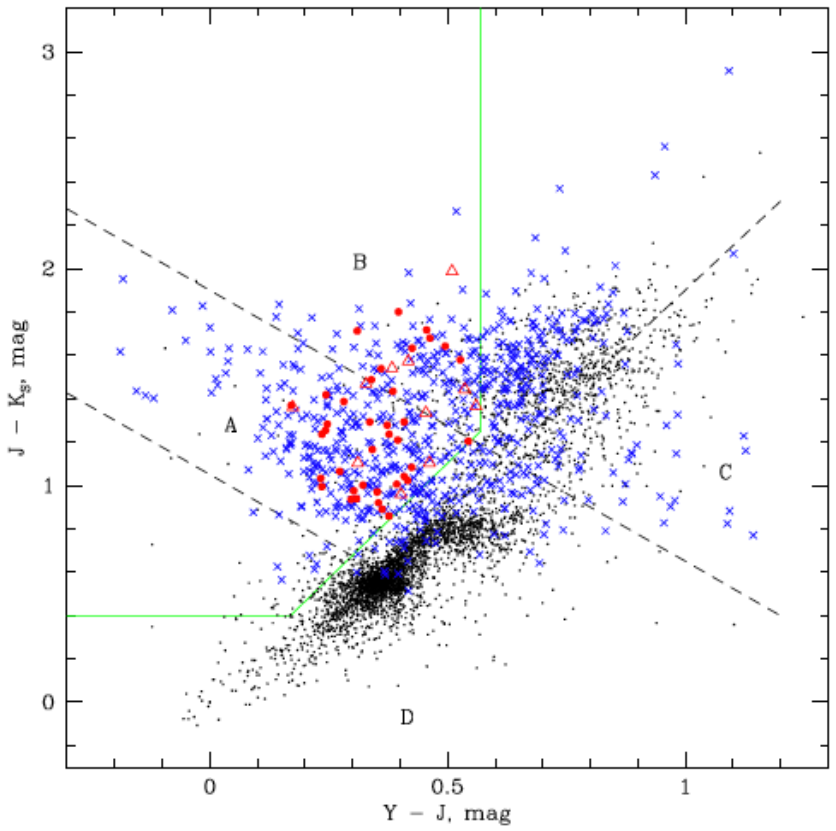
Calibrated with respect to 22500 background galaxies.

Cioni et al., submitted, Paper XVI



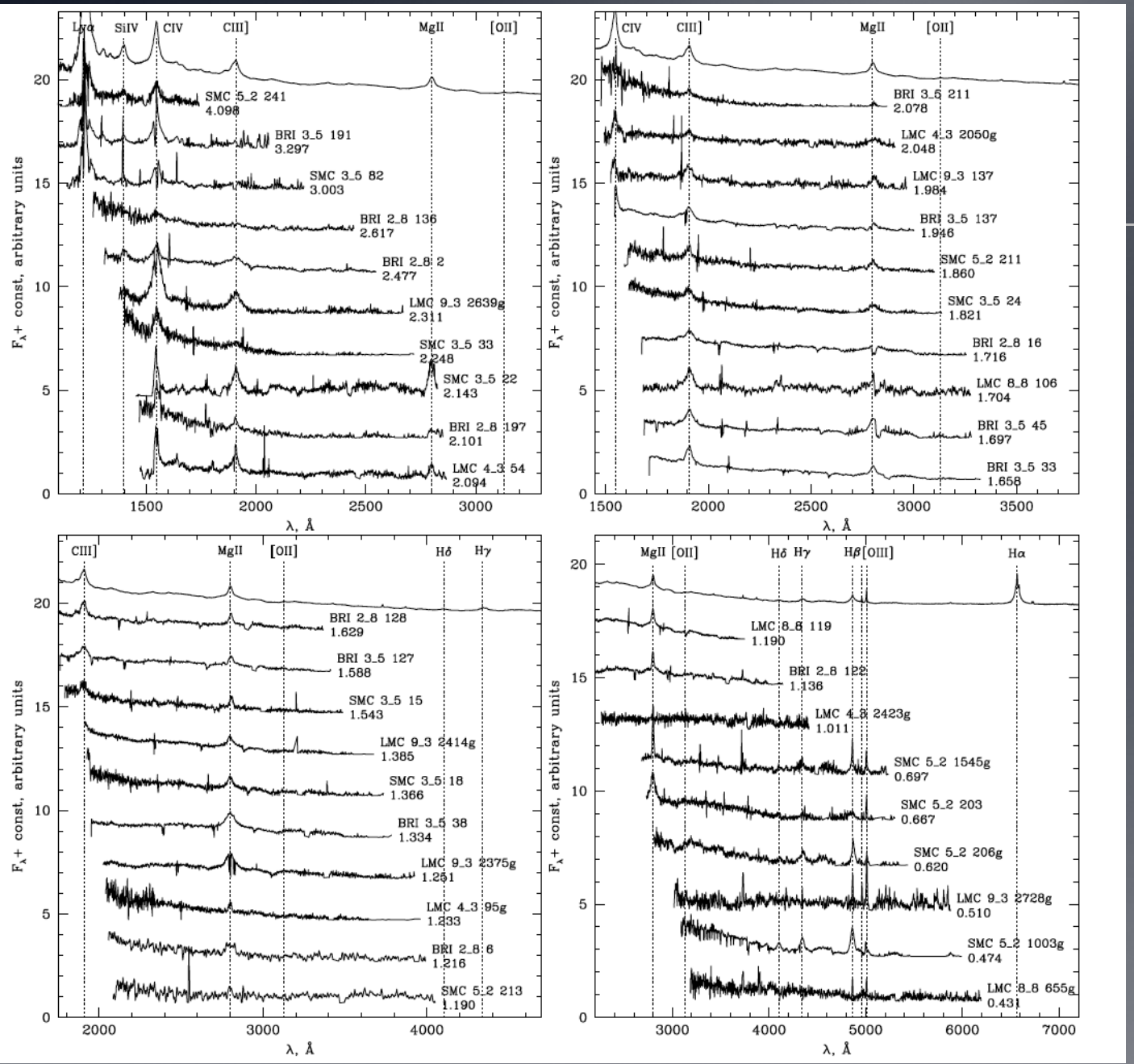
Quasars

Red = spectroscopically confirmed
Blue = Kozłowski et al. 2013
Black = stars



Quasars occupy mostly regions A and B of the colour-colour diagram and are variable in Ks.

Ivanov et al., submitted



Quasars

We confirmed 37 mostly new quasars of which:

10 behind the LMC
13 behind the SMC
14 behind the Bridge

z = from 0.5 to 4.1

Our method provides a 76% success rate.

Quasars are located in the outer regions of the system.

Ivanov et al., submitted

Classical Cepheids in the SMC

See tomorrow talk

Present and future surveys

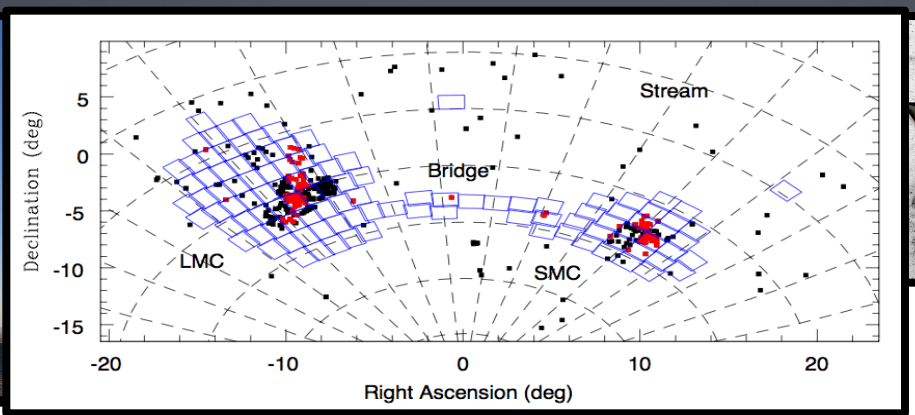
Survey	Time scale	Area (deg^2)	Repeats	Scale (“/pix)	FWHM (“)	Filters	Sensitivity (AB)	S/N
STEP	2011+	74	30 (8)	0.21	0.9-1.2	girHα	24	5
OGLE-IV	2010-2014	540	~400 (I)	0.26	1.0	VI	21, 20 (Vega)	10
SMASH	2013-2016	480	1	0.27	1.0	uz + gri	24	10, 20
Skymapper	2010+	All South	6	0.34	1.5	uvgriz	22-20	5
VMC	2009-2018	170	12 (K_s)	0.34	0.9	YJK_s	22.5-23.4	5
LSST	2021-2031	δ<+34	56-184	0.2	0.8	ugrizy	22-27.5	5
Gaia	2013-2018	All	70	<<0.2	-	G band	20.7 (Vega)	>10
Euclid	2020-2026	|b|<30	1	0.1, 0.3	-	Vis, YJH	24	5

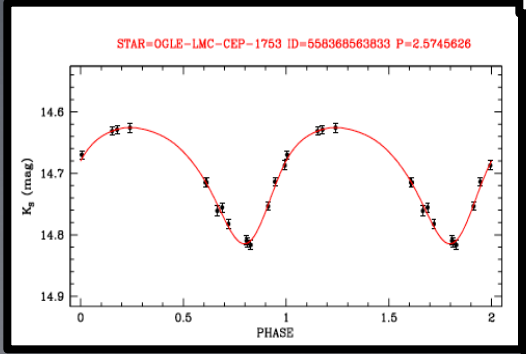
All of these surveys provide targets for spectroscopic follow-up studies with e.g. new ESO instruments MOONs and 4MOST.

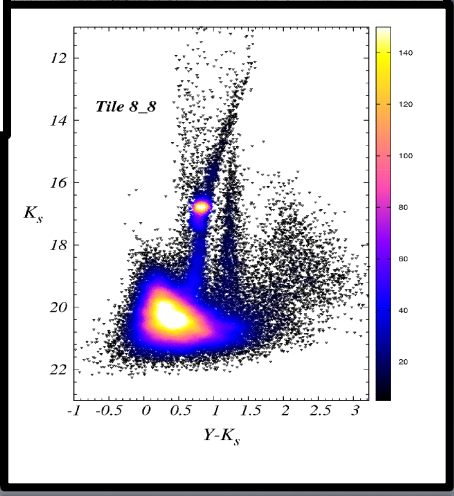
Conclusions

The Magellanic Clouds are the closest example of interacting galaxies.
In view of the latest discoveries (DES dwarf galaxies associated with MCs),
MCs likely the biggest members of a group at its first infall into the MW.

The VMC survey provides high quality data to study stellar populations.
The VMC survey is 70% complete.







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

Additional Material

Other papers

Preparatory:

- Recovery of the SFH (Kerber et al. 2009)
- Detection of Planetary Nebulae (Miszalski et al. 2011)
- Multi-wavelength study of the Bridge (Bagheri et al. 2013)

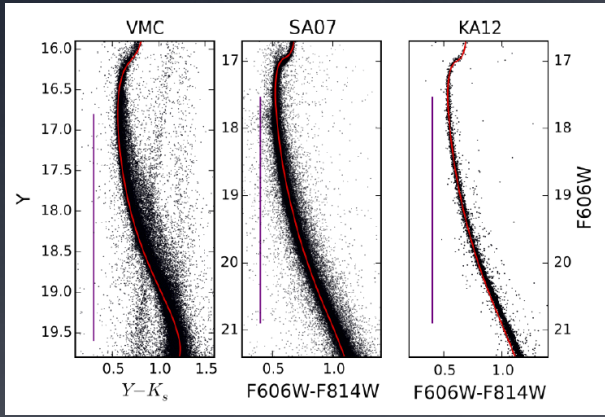
Related:

- RR Lyrae PLZ relation (Muraveva et al. 2015)
- Embedded star clusters (Romita et al. 2015, submitted)

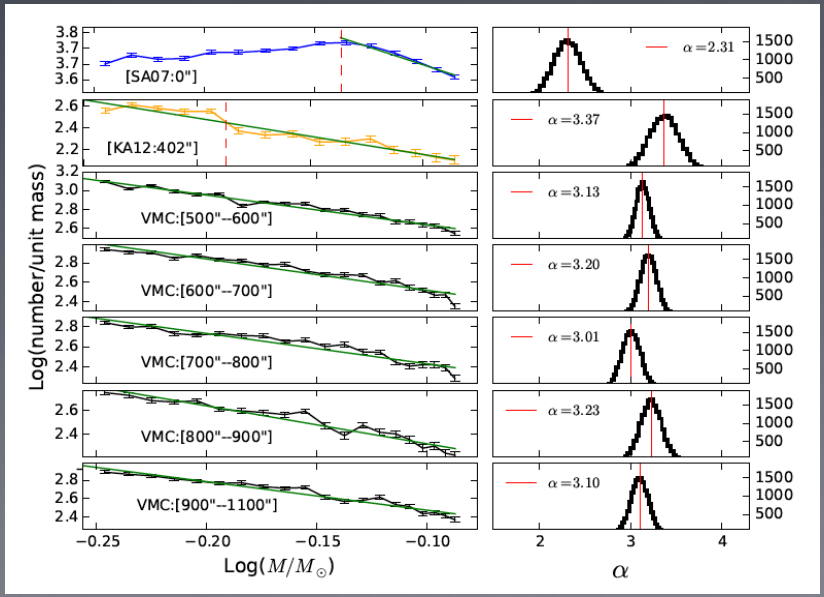
Submitted:

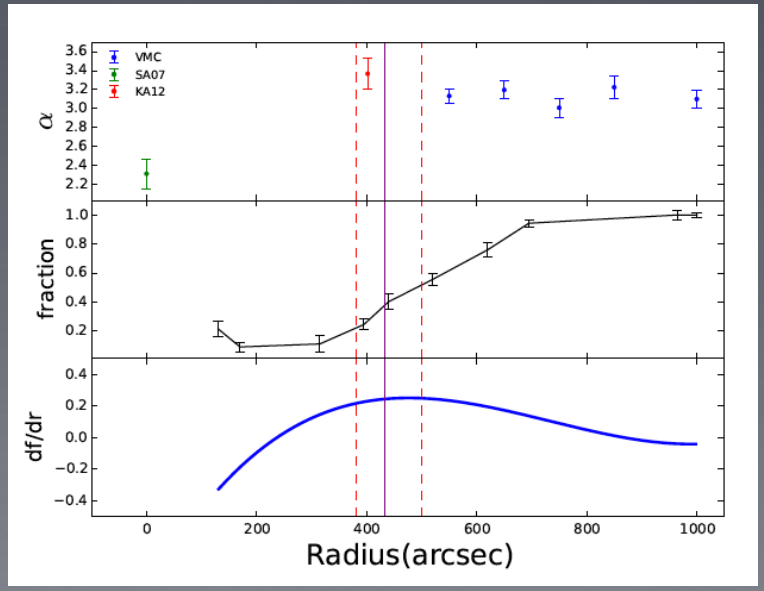
- The VMC survey – XVI. 47 Tuc mass function (Zhang et al.)
- The VMC survey – XVII. SMC and 47 Tuc PMs (Cioni et al.)

Radial dependence of the low-mass MF in 47 Tuc



The radial distribution of power-law slopes α show the importance of both mass segregation and tidal stripping for both FG and SG stars in 47 Tuc





Zhang et al., submitted