THE MAGELLANIC CLOUDS

Carme Gallart

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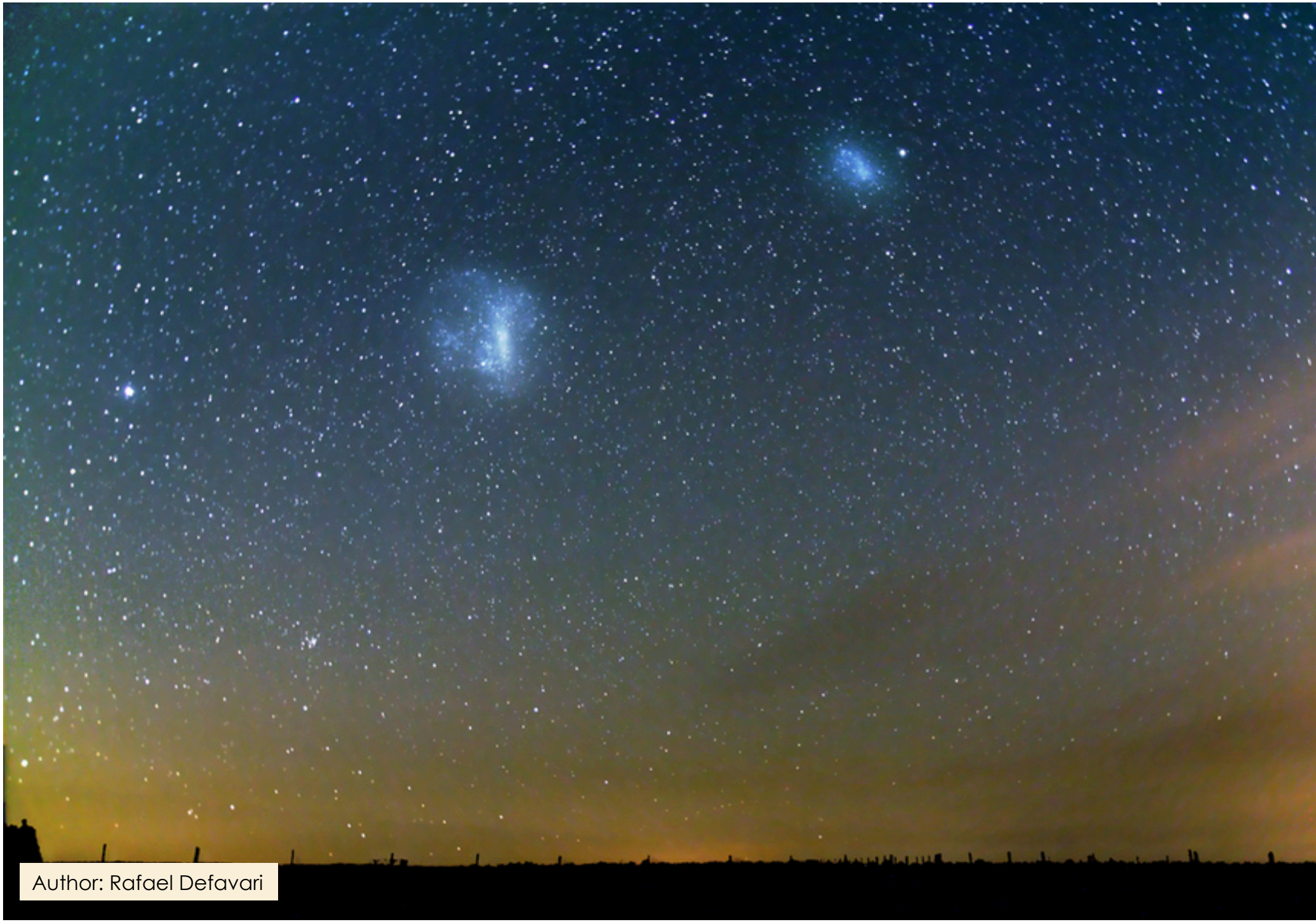
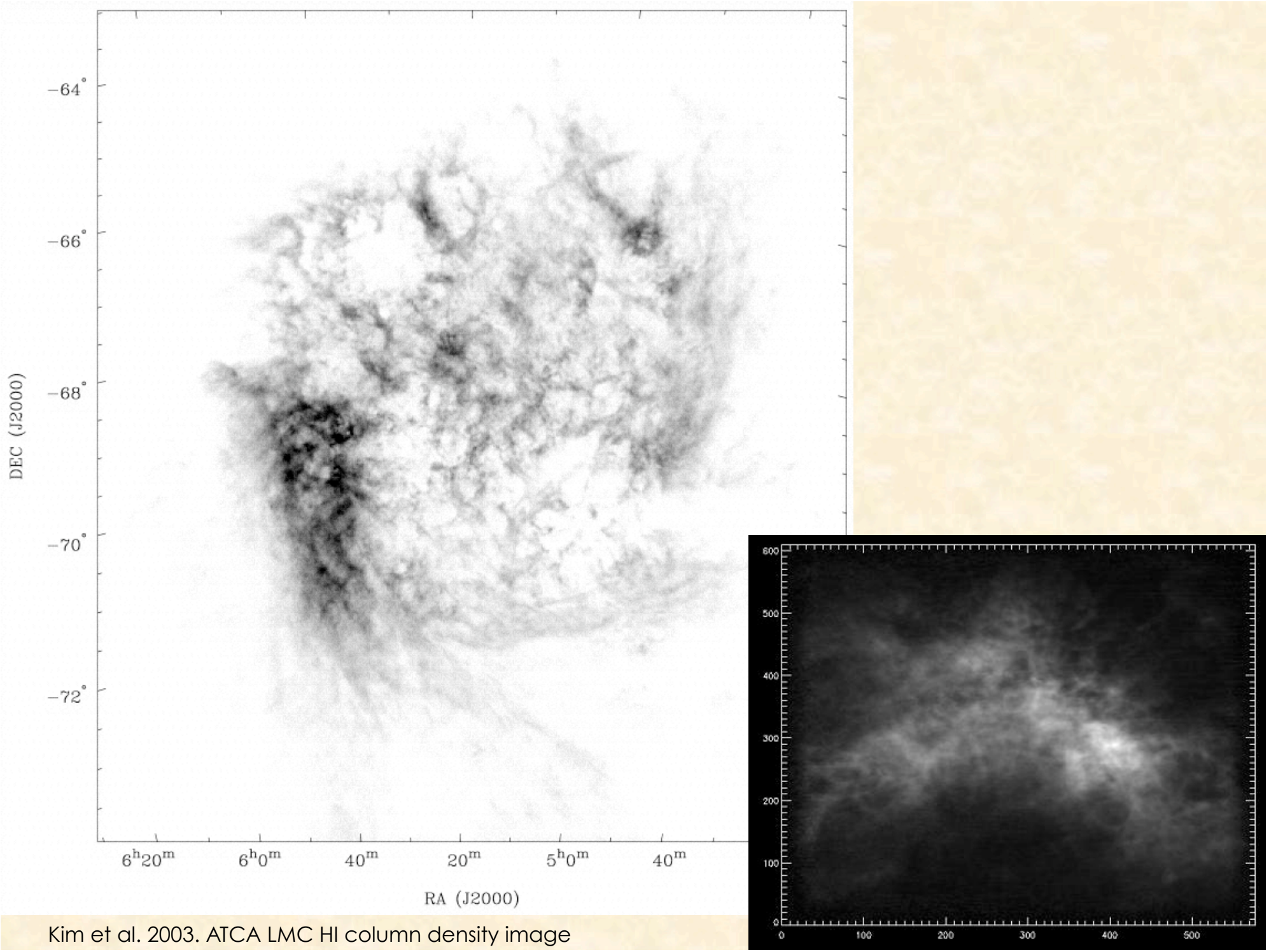
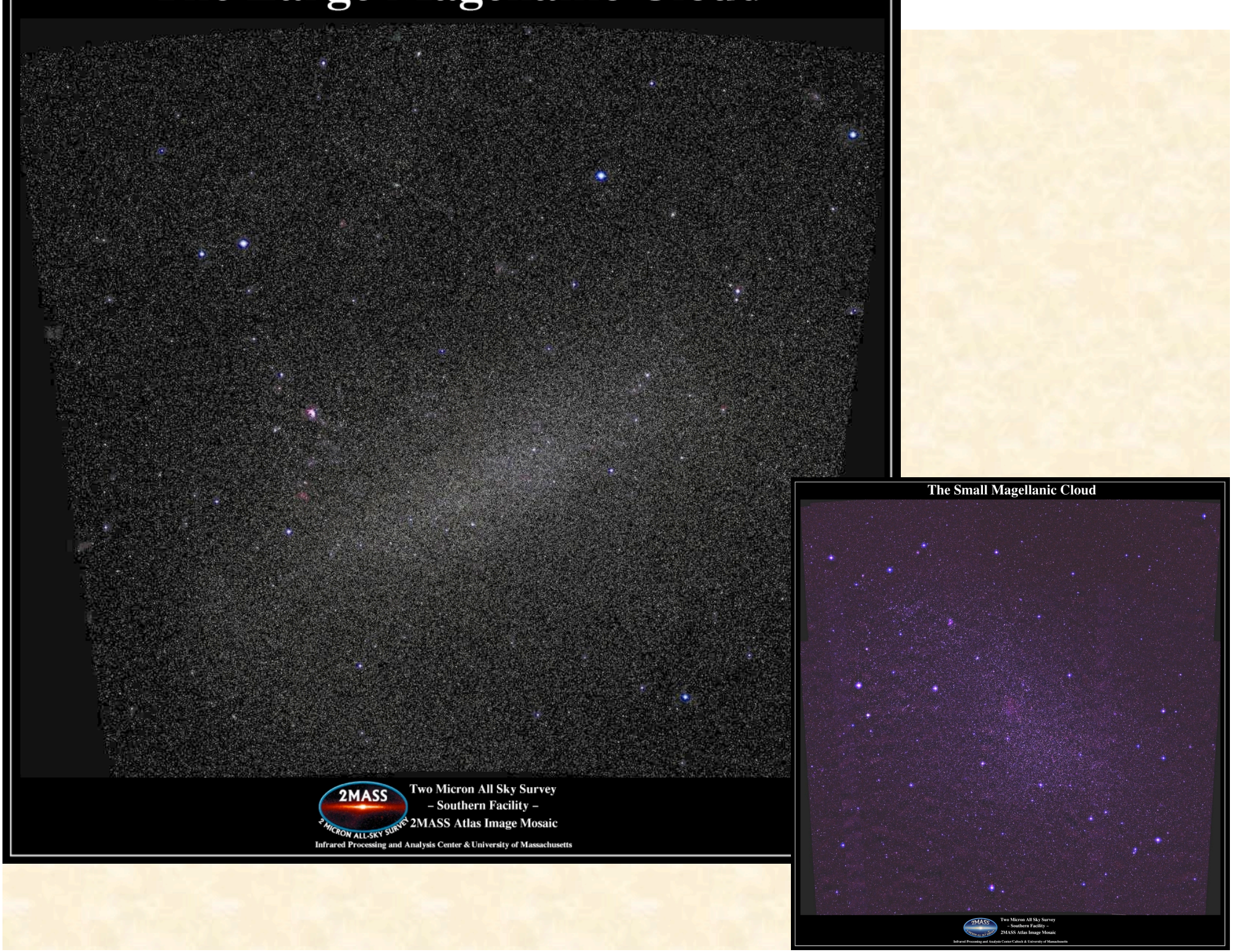
1.- OVERVIEW OF THE MAGELLANIC SYSTEM


Author: Rafael Defavari

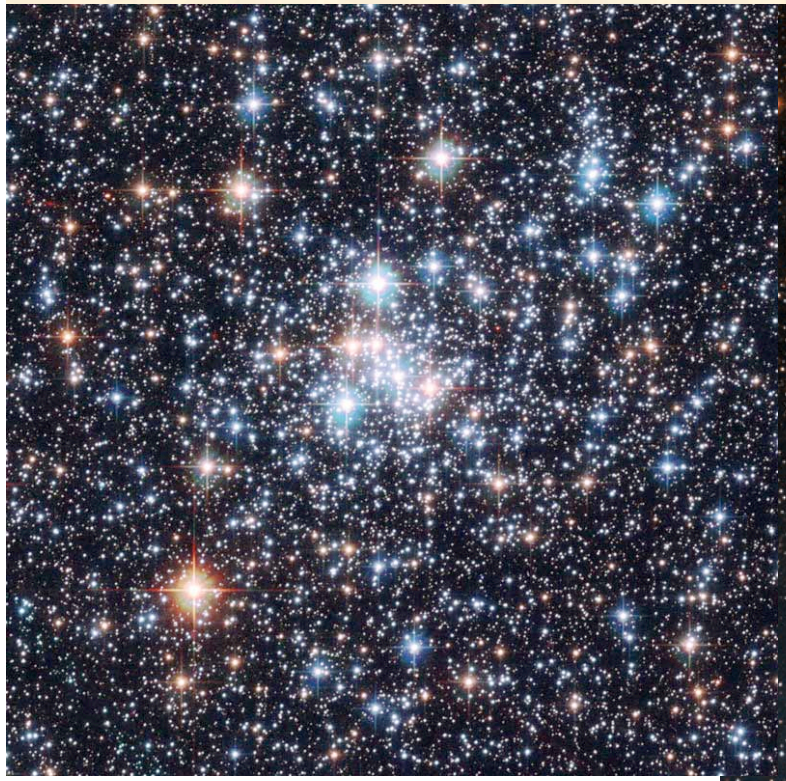


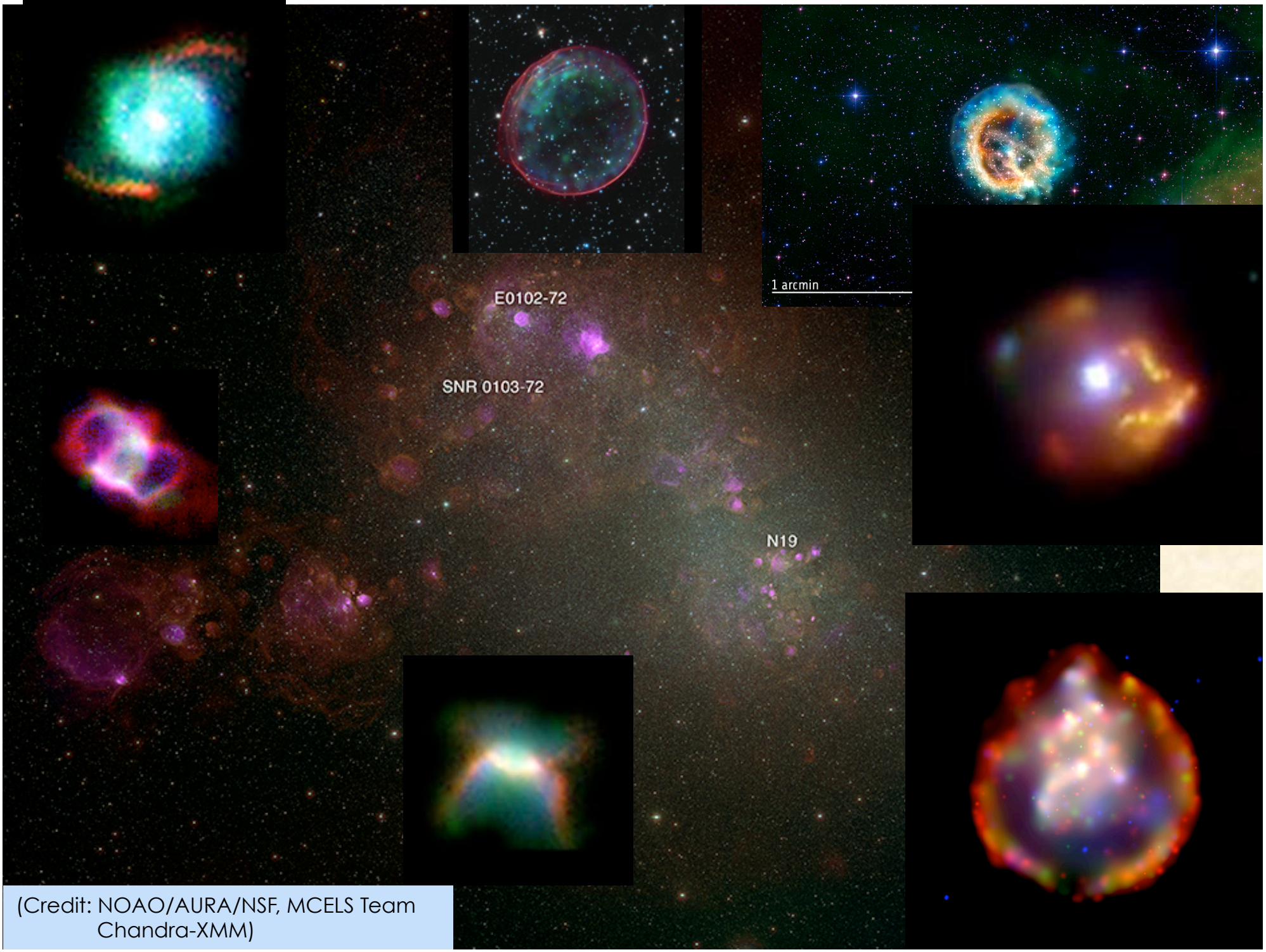
Kim et al. 2003. ATCA LMC HI column density image

Photo: Esa, Eckhard Slawik


2MASS
2 MICRON ALL-SKY SURVEY
Two Micron All Sky Survey
– Southern Facility –
2MASS Atlas Image Mosaic
Infrared Processing and Analysis Center & University of Massachusetts

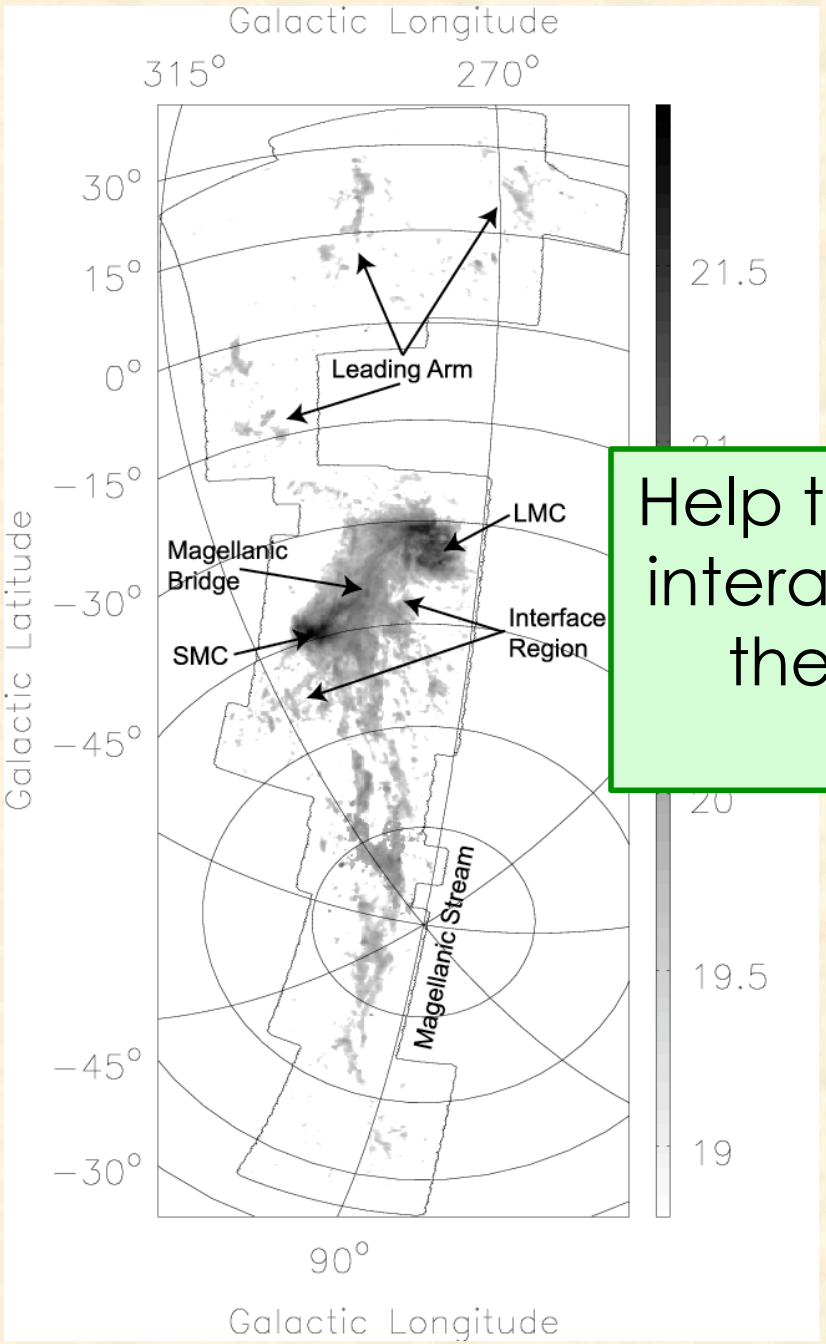
The Small Magellanic Cloud
Two Micron All Sky Survey
– Southern Facility –
2MASS Atlas Image Mosaic
Infrared Processing and Analysis Center/Caltech & University of Massachusetts

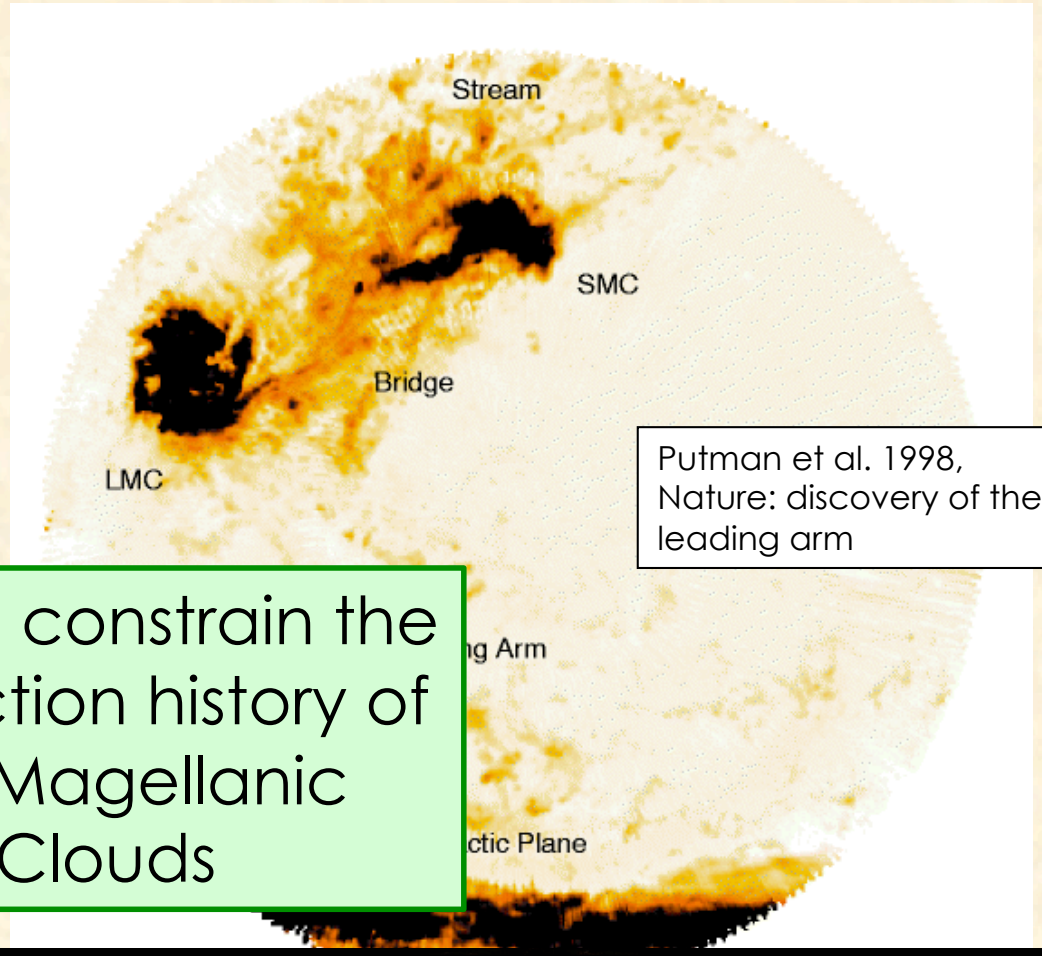




(Credit: NOAO/AURA/NSF, MCELS Team
Chandra-XMM)

Brüns et al. 2005
The Parkes H I Survey of the Magellanic System

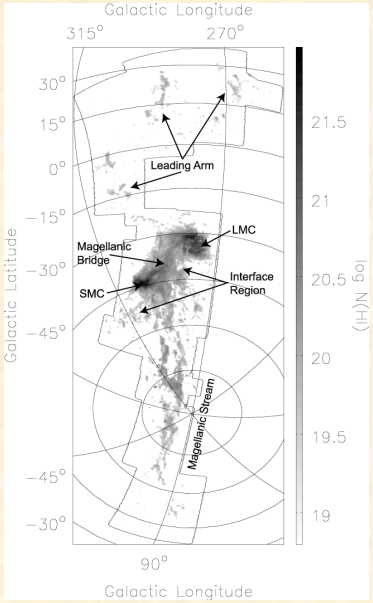


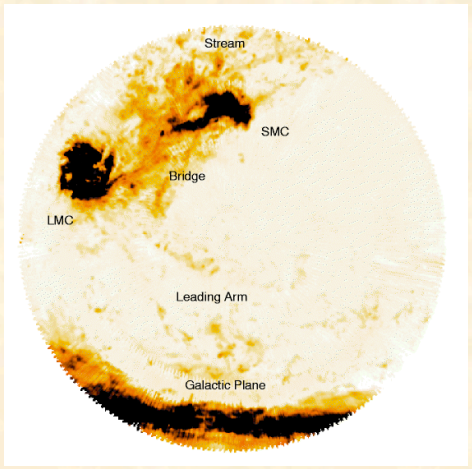


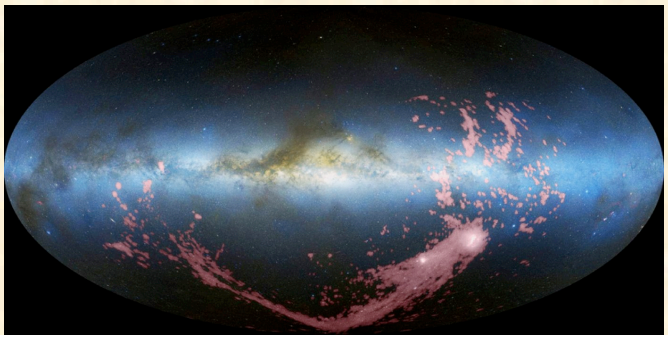
Putman et al. 1998,
Nature: discovery of the leading arm

Help to constrain the interaction history of the Magellanic Clouds

Nidever et al. 2010: The 200° long Magellanic Strean





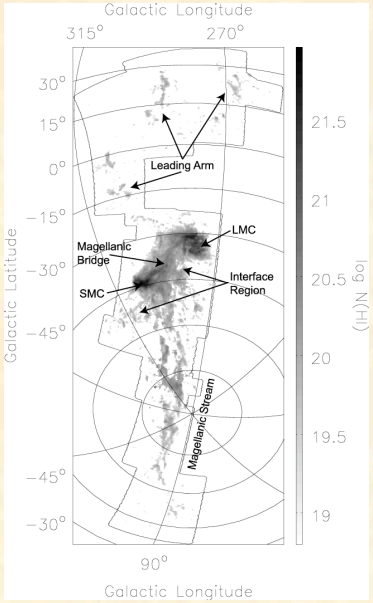


Traditionally, two main mechanisms for the formation of the Magellanic Stream:

-Tidal interaction of the MCs with the MW (Murai & Fujimoto 1980, Gardiner & Noguchi 1996, Lin et al. 1995, Davies & Wright 1977, Lin & Lynden-Bell 1977

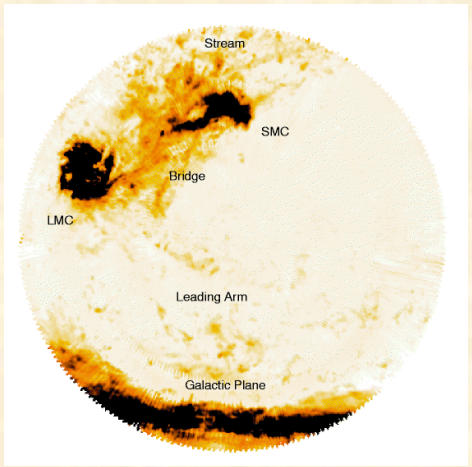
-Ram pressure stripping from the MCs during passage through Galactic Halo/disk (Matewson et al. 1987, Barnes 1996, ASP, Sofue 1994, Moore & Davis 1994, Mastropietro et al, 2005)

Implied multiple interactions between the MCs and the MW.



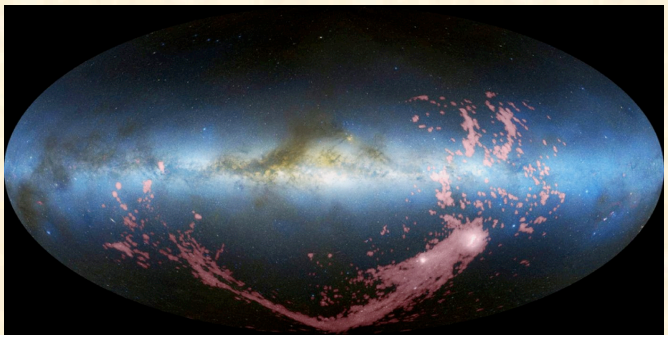
Very precise HST proper motions of LMC & SMC imply very large galactocentric velocities close to scape velocity:
(Kallivayalil et al. 2006a,b, Piatek et al. 2008)

➔First passage scenario proposed
(Besla et al. 2007)



New generation of models demonstrating that repeated MCs-MW interactions are not mandatory. MS may originate in LMC-SMC interactions
(Besla et al. 2010, Ružička et al, 2010, 2011; Diaz & Bekki 2011, 2012)
[or blow-out from LMC hypothesis: Nidever et al. 2008]

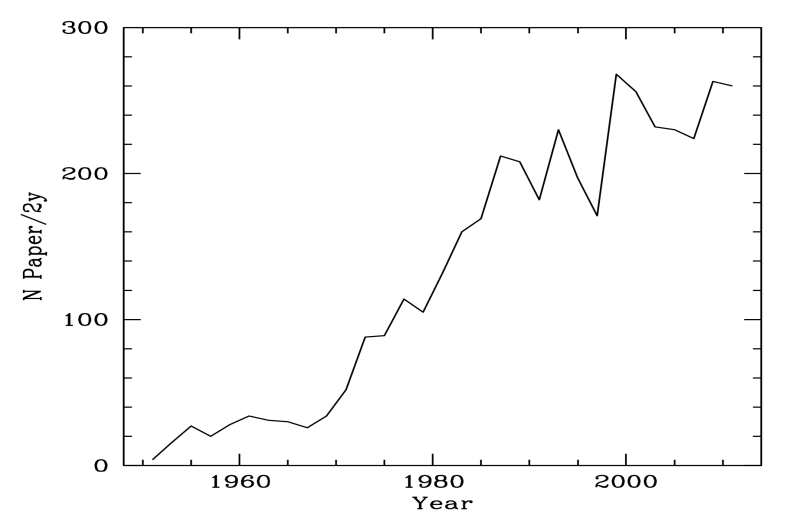
However, difficulty in reproducing some details of the MS unless some interaction with MW happens.



Possibilities opened by
-modified values of LSR circular velocity
(Shattow & Loeb 2009, Ružička et al, 2010, Diaz & Bekki 2011)
-lower proper motions measured for MCs
(Vieira et al. 2010: less precise but possibly more accurate)

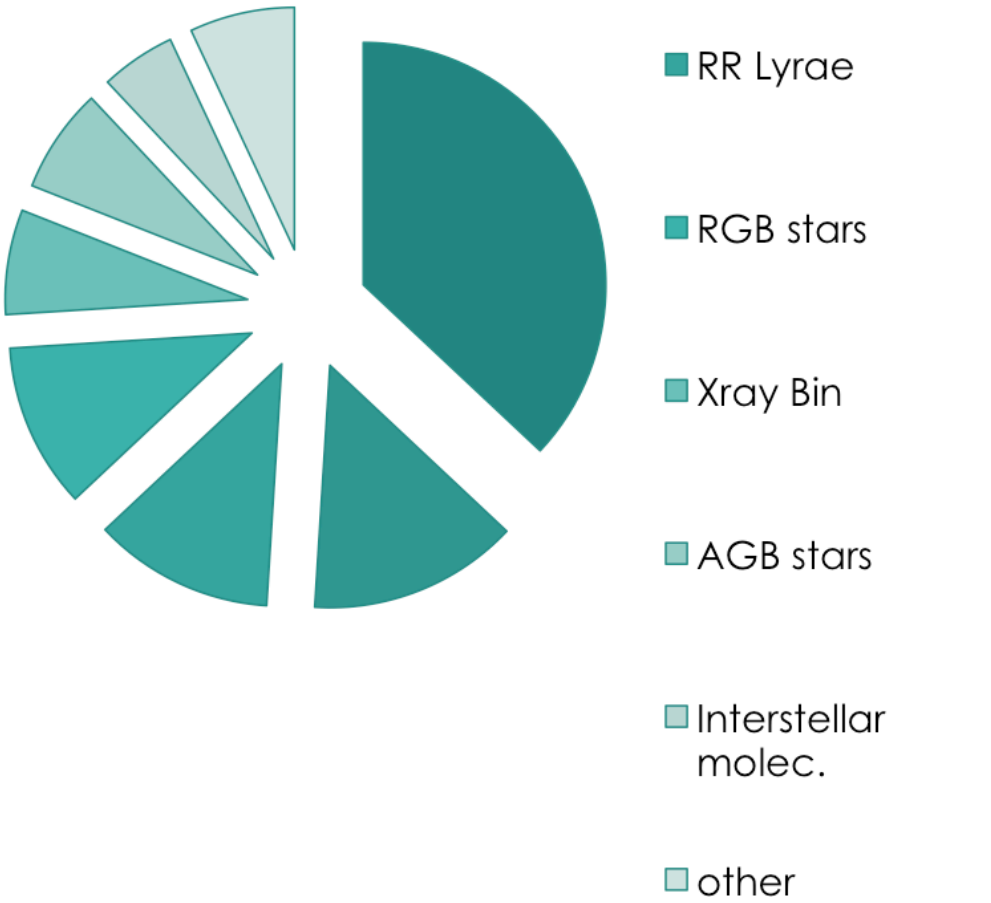
2.- LITERATURE ON THE MAGELLANIC CLOUDS

Literature on the Magellanic Clouds

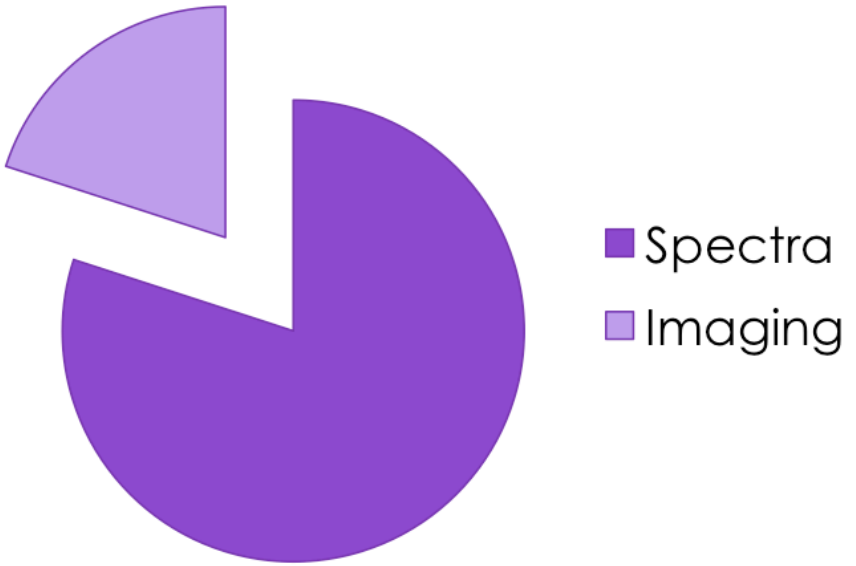


FACILITY	PAPERS (2002-2012)	CITATIONS (2002-2012)	AVERAGE CIT/paper
HST	144	3992	27.7
Spitzer	135	2749	20.4
ESO	109	3271	30.0
NOAO	68	1513	22.3
Magellan	23	442	19.0
XMM+Chandra	21	228	10.9
TOTAL	1058	21518	20.3

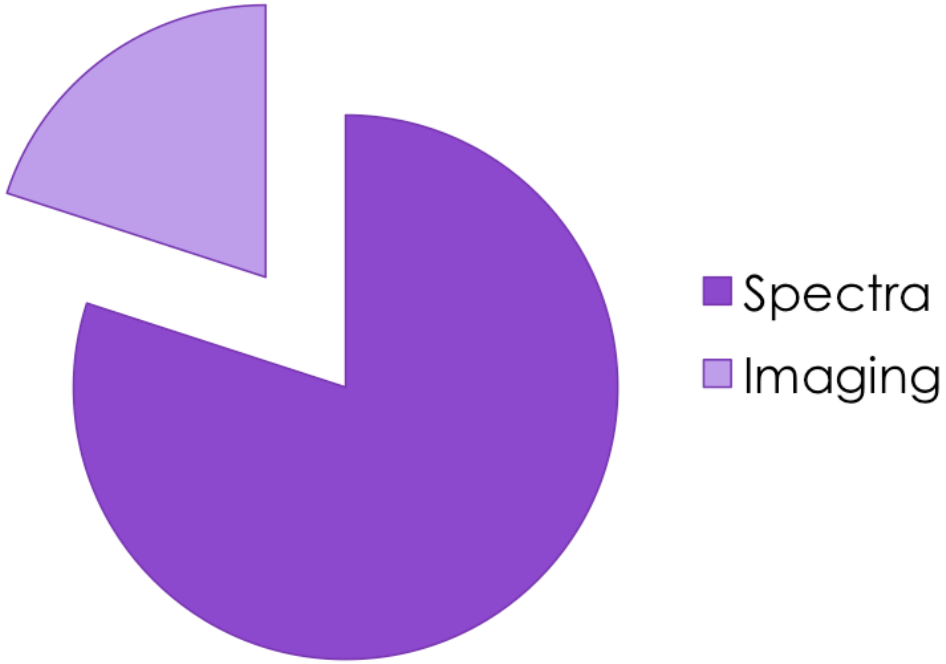
ESO CONTRIBUTIONS BY SUBJECT (2002-2012)



ESO CONTRIBUTIONS BY OBSERVING TECHNIQUE (2002-2012)



ESO CONTRIBUTIONS BY OBSERVING TECHNIQUE (2002-2012)



NOAO CONTRIBUTION BY OBSERVING TECHNIQUE

ESO CONTRIBUTIONS BY SUBJECT (2002-2012)

- Massive stars & Recent Star Formation
- Cluster & Field stars imaging
- RR Lyrae
- RGB stars
- Xray Bin
- AGB stars
- Interstellar molec.
- other

NOAO CONTRIBUTIONS BY SUBJECT (2002-2012)

- Sne & Pne
- Massive stars & Recent Star Formation
- Star clusters
- Variable stars
- RGB & RSG spectra
- Overall structure & Evolution
- other

3.- THE MAGELLANIC CLOUDS AS ASTROPHYSICAL LABORATORIES

The Magellanic Clouds and the calibration of the extragalactic distance scale

PERIODS OF 25 VARIABLE STARS IN THE SMALL MAGELLANIC CLOUD.

The following statement regarding the periods of 25 variable stars in the Small Magellanic Cloud has been prepared by Miss Leavitt.

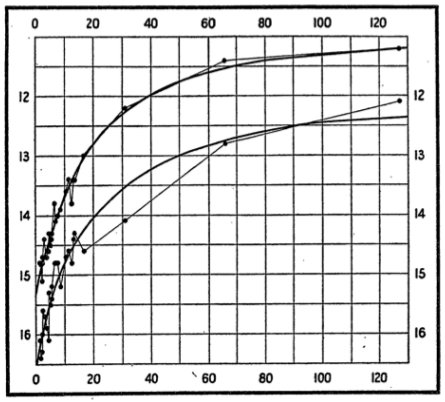


FIG. 1.

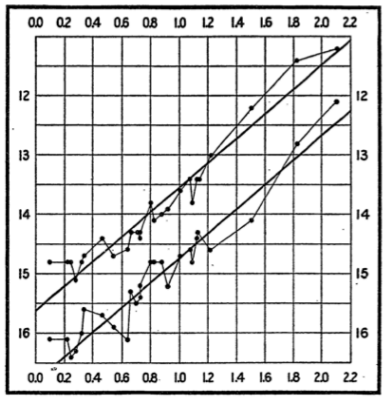
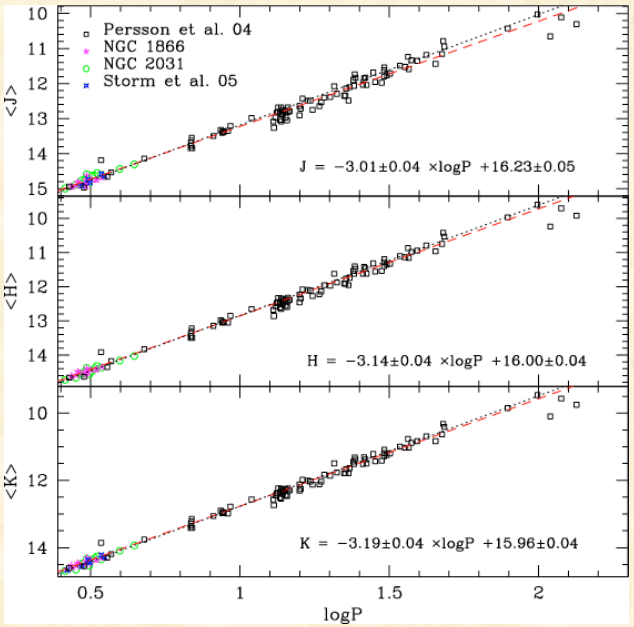
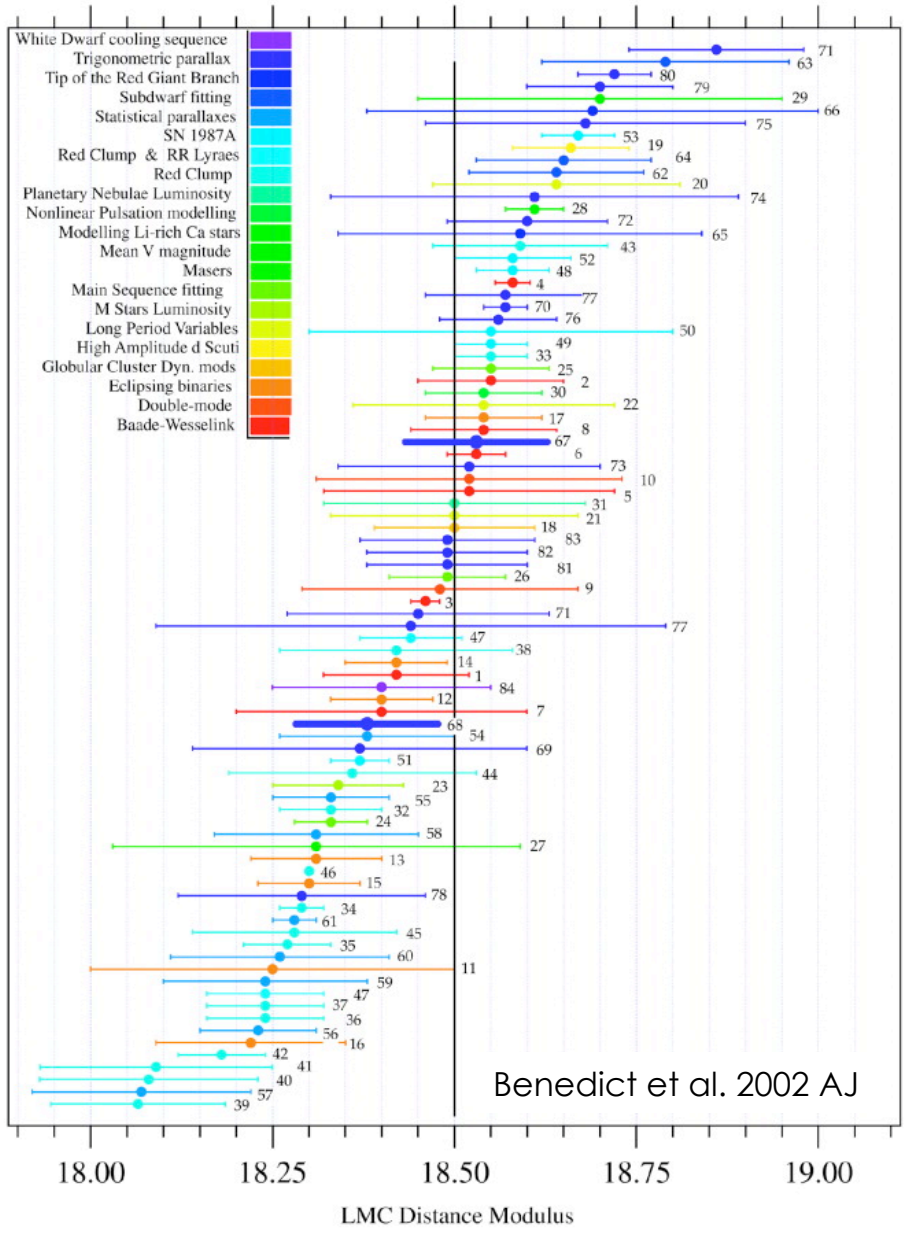


FIG. 2.



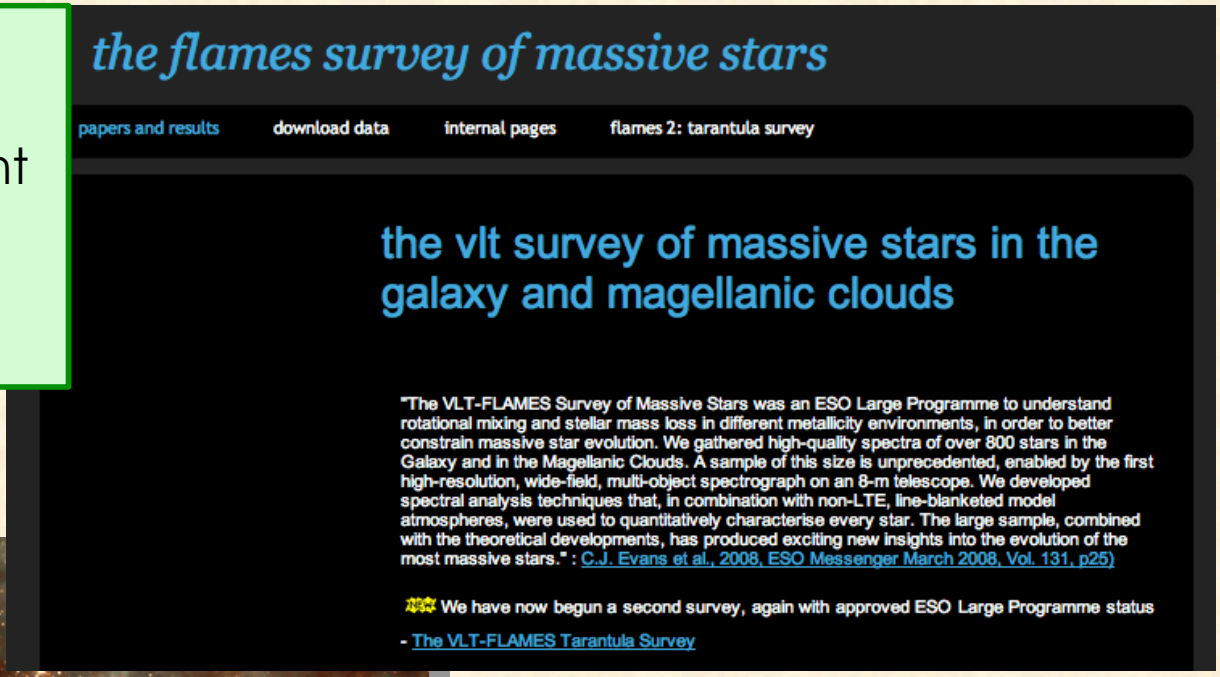
Infrared photometry of Cepheids in the LMC clusters NGC 1866 and NGC 2031 Testa et al. 2007

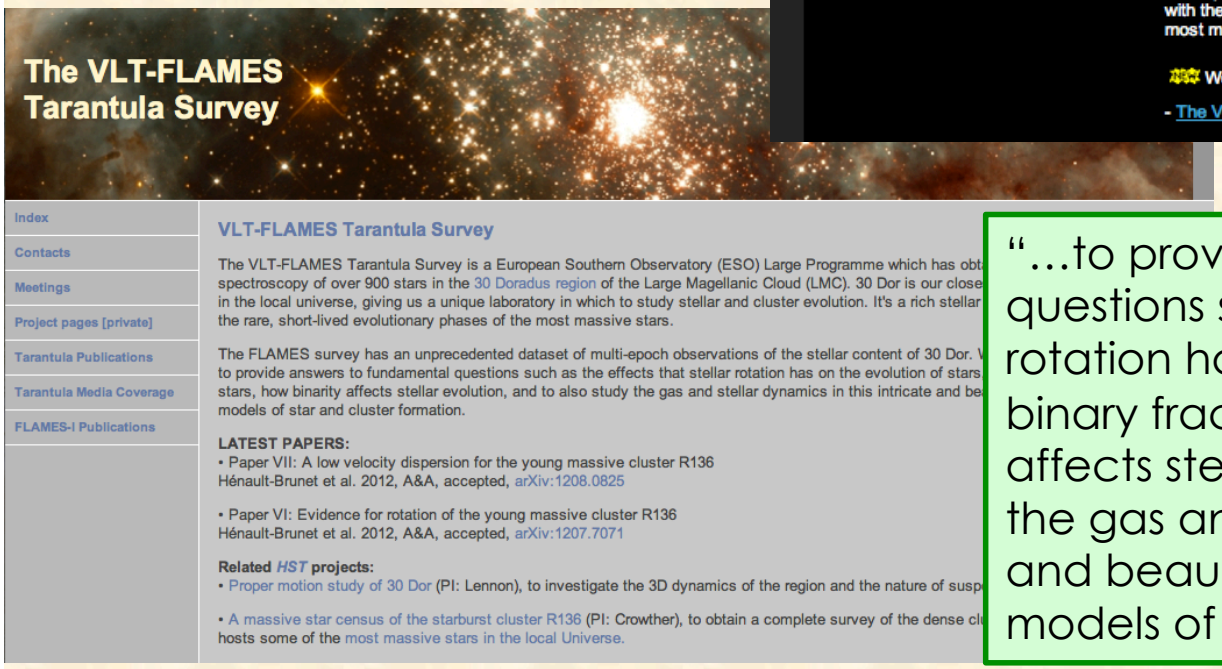


Benedict et al. 2002 AJ

The Magellanic Clouds and the study of massive stars and star formation

"ESO Large Programme to understand rotational mixing and stellar mass loss in different metallicity environments, in order to better constrain massive star evolution."





"…to provide answers to fundamental questions such as the effects that stellar rotation has on the evolution of stars, the binary fraction of massive stars, how binarity affects stellar evolution, and to also study the gas and stellar dynamics in this intricate and beautiful cluster, to provide input for models of star and cluster formation."

The Magellanic Clouds and the testing of stellar evolution theory

The Astrophysical Journal Letters, 728:L43 (4pp), 2011 February 20 doi:10.1088/2041-8205/728/2/L43

A CLASSICAL CEPHEID IN A LARGE MAGELLANIC CLOUD ECLIPSING BINARY: EVIDENCE OF SHORTCOMINGS IN CURRENT STELLAR EVOLUTIONARY MODELS?

S. Cassisi[1] and M. Salaris[2]

The Astrophysical Journal, 728:93 (16pp), 2011 February 20 doi:10.1088/0004-637X/728/2/93

THE MASS-LOSS RETURN FROM EVOLVED STARS TO THE LARGE MAGELLANIC CLOUD. IV. CONSTRUCTION AND VALIDATION OF A GRID OF MODELS FOR OXYGEN-RICH AGB STARS, RED SUPERGIANTS, AND EXTREME AGB STARS

Benjamin A. Sargent[1], S. Srinivasan[2], and M. Meixner[1]

The Astrophysical Journal, 728:93 (16pp), 2011 February 20 doi:10.1088/0004-637X/728/2/93
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THE MASS-LOSS RETURN FROM EVOLVED STARS TO THE LARGE MAGELLANIC CLOUD. IV. CONSTRUCTION AND VALIDATION OF A GRID OF MODELS FOR OXYGEN-RICH AGB STARS, RED SUPERGIANTS, AND EXTREME AGB STARS
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The Astronomical Journal, 125:742–753, 2003 February

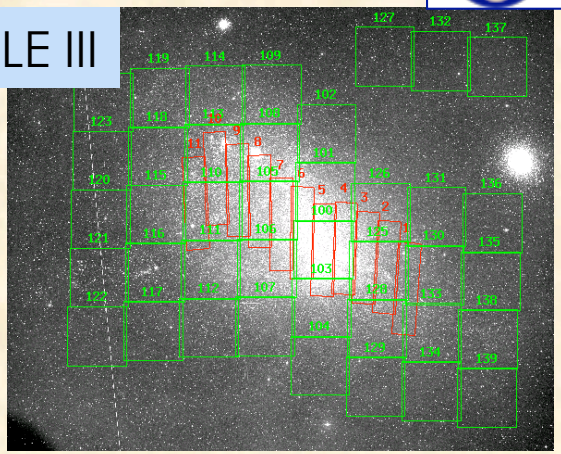
TESTING INTERMEDIATE-AGE STELLAR EVOLUTION MODELS WITH VLT PHOTOMETRY OF LARGE MAGELLANIC CLOUD CLUSTERS. I. THE DATA[1]

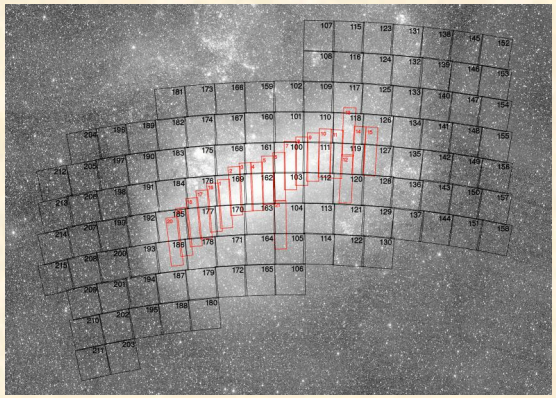
Carme Gallart,[2,3] Manuela Zoccali,[4] Gianpaolo Bertelli,[5,6] Cesare Chiosi,[7] Pierre Demarque,[8] Leo Girardi,[9] Emma Nasi,[6] Jong-Hak Woo,[8] and Sukyoung Yi[10]

The Magellanic Clouds and the microlensing experiements

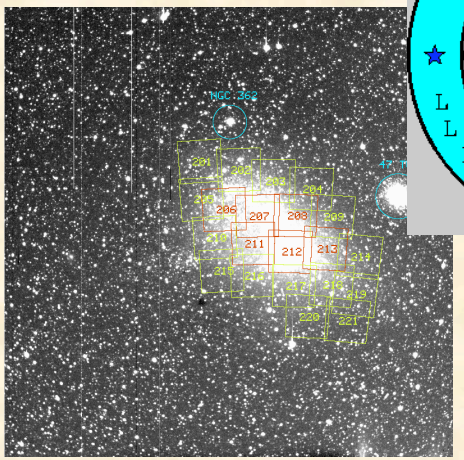
OGLE

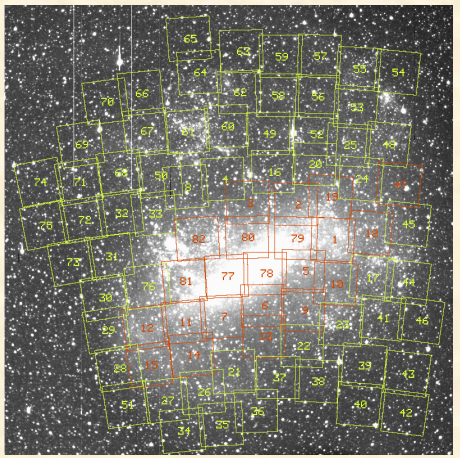
OGLE III





MACHO





The Magellanic Clouds and the life-cycle of observable matter.

- Main
- Project
- Team
- Observations
- Product
- Publications
- Links
- Employment
- News
- Logon

The key transition phases of matter are traced via dust emission in the interstellar medium, the newly forming stars and the evolved dying stars.

SAGE-LMC, SAGE-SMC and SAGE-Spec are legacy projects using the Spitzer Space Telescope. 30 Doradus is an open time program. SMC-Spec is a guaranteed time program. HERITAGE is an open time key programme using the Herschel Space Observatory.

Magellanic Bridge (SAGE-SMC) in addition to Spitzer spectroscopy of the dust

KINGFISH) and a stepping stone to the deep surveys (e.g., GOODS & SWIRE).

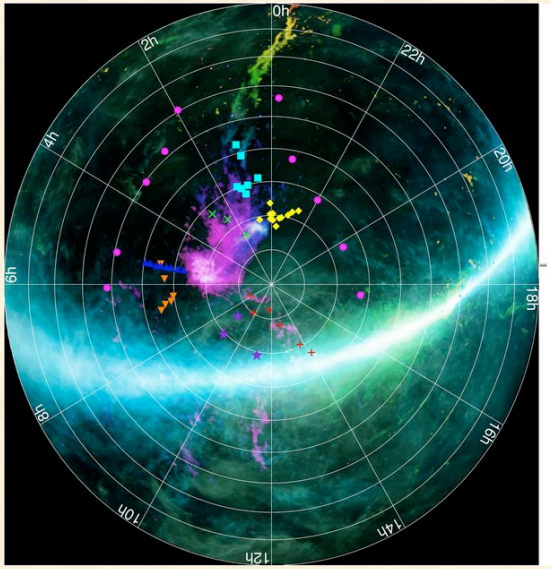
SAGE-LMC, SAGE-SMC and SAGE-Spec are legacy projects using the Spitzer Space Telescope. 30 Doradus is an open time program. SMC-Spec is a guaranteed time program. HERITAGE is an open time key programme using the Herschel Space Observatory.

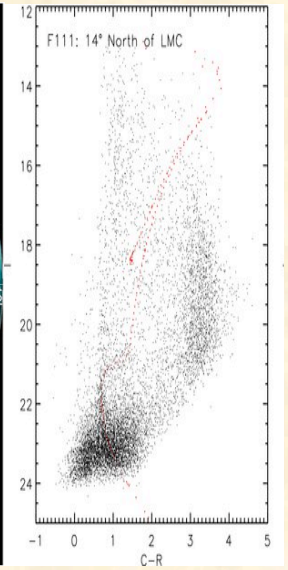
4.- STRUCTURE AND EVOLUTION OF THE MAGELLANIC CLOUDS

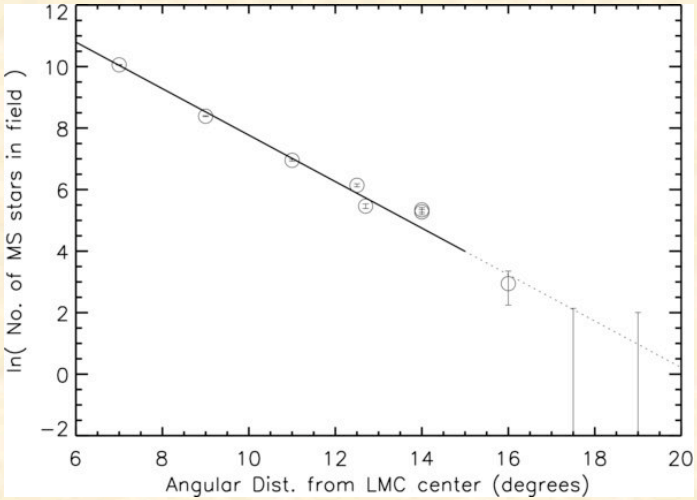
-

Spatial extent of the Large Magellanic Cloud

traced by dwarfs below the oMSTO

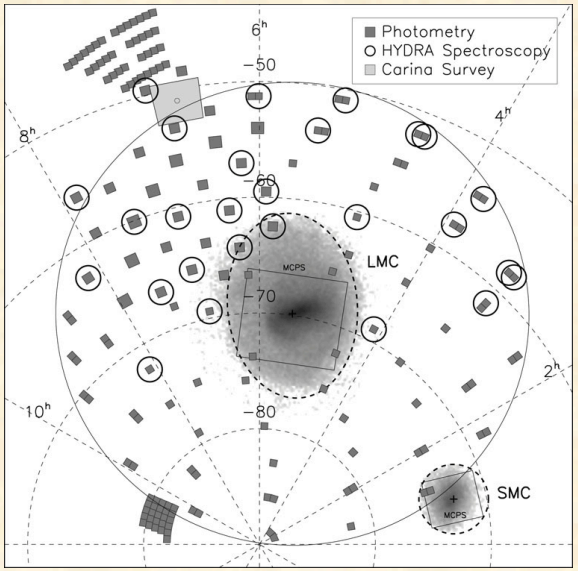


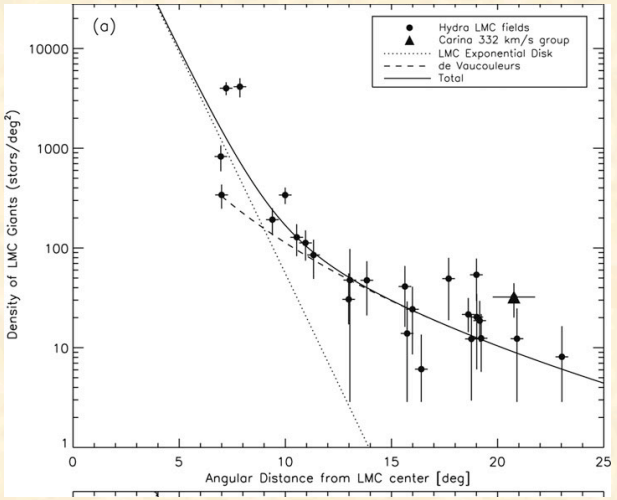




Saha et al. 2010, AJ: The NOAO outer limits project

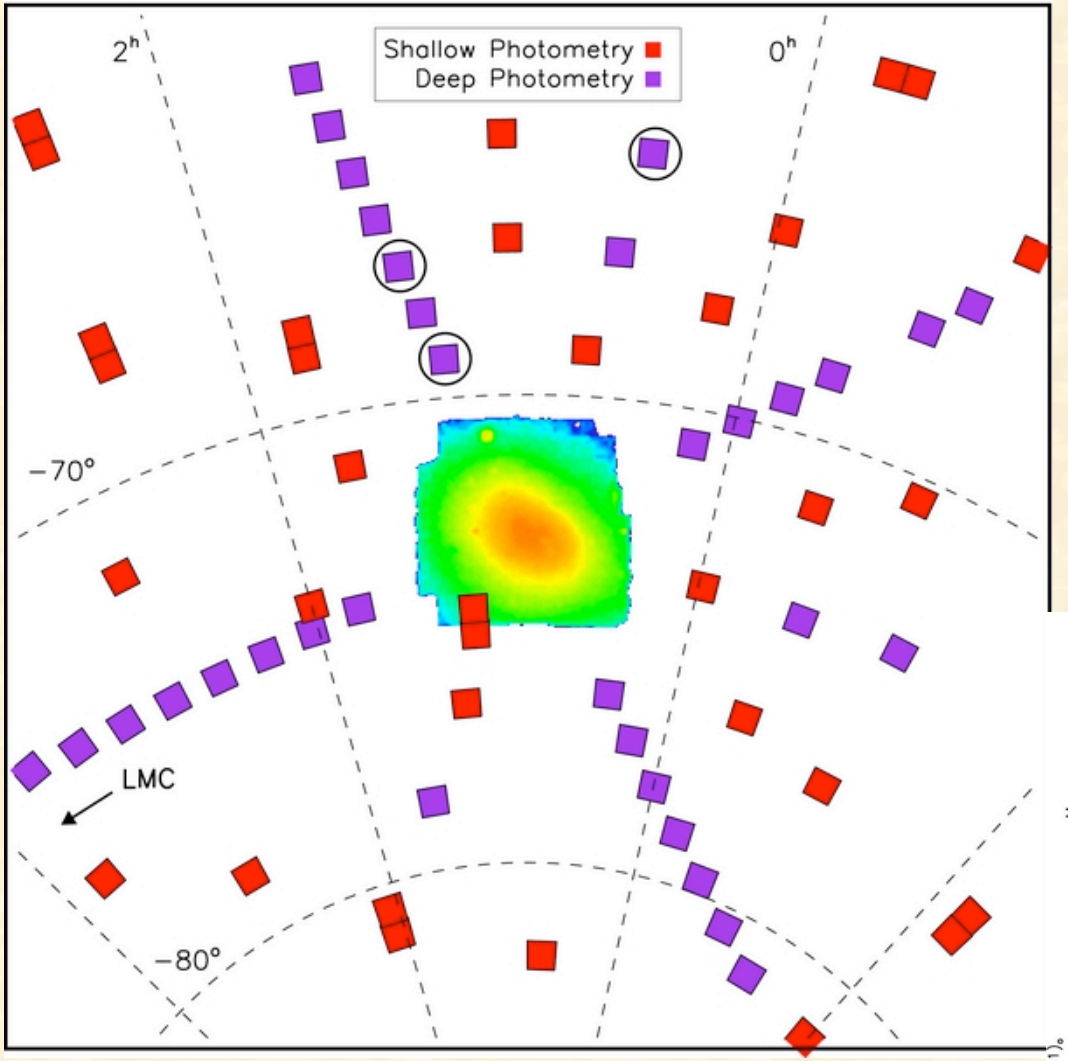
traced by spec. confirmed RGB stars

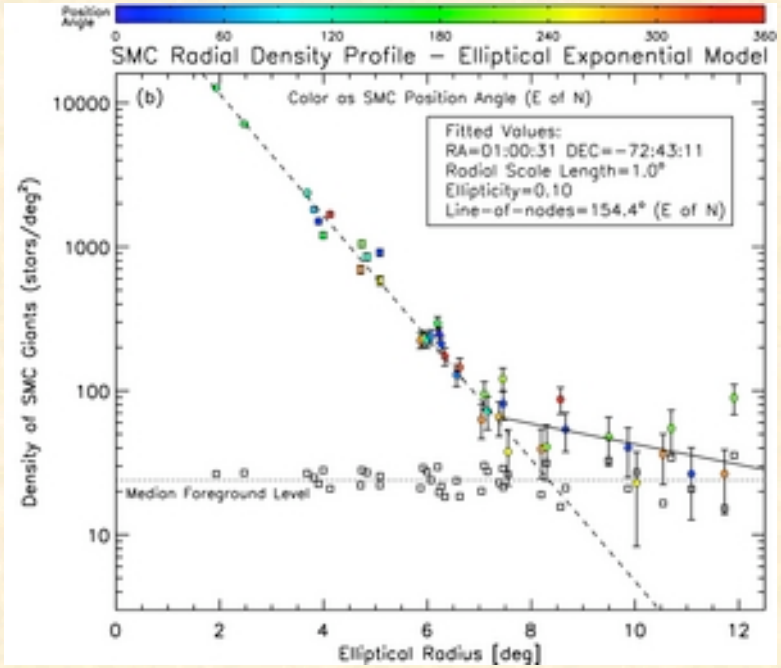


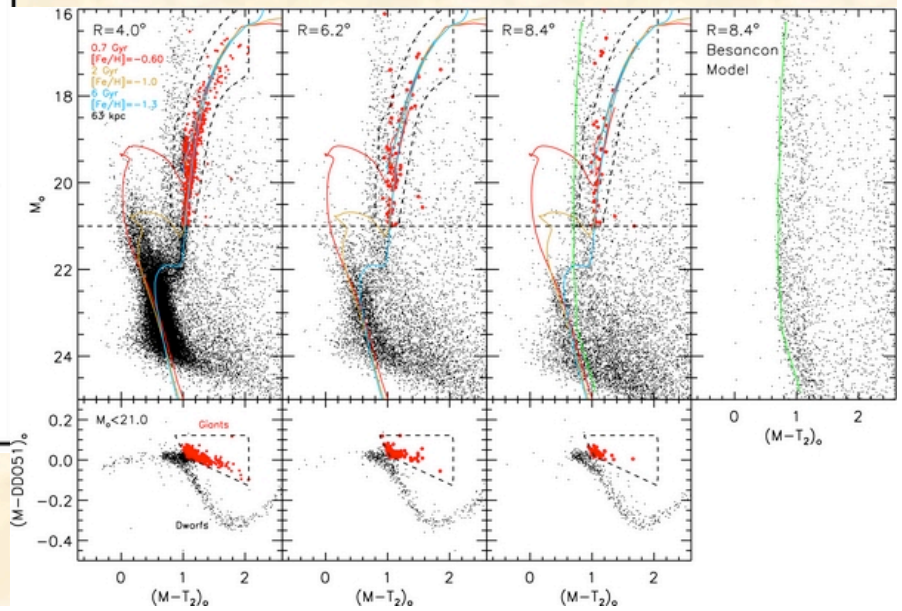


Majewski et al. 2009, IAUS 256

Spatial extent of the Small Magellanic Cloud



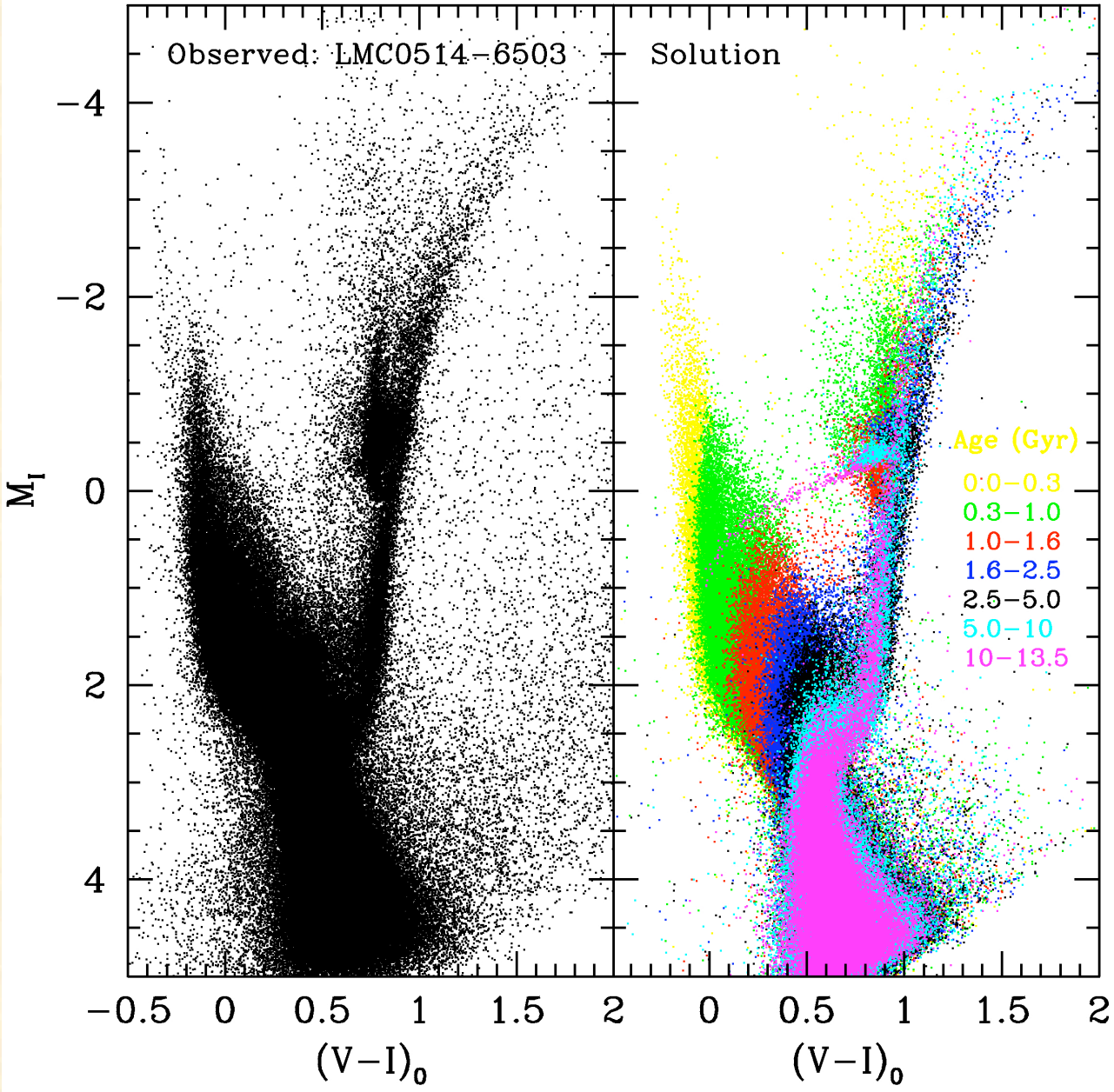




Nidever et al. 2011, ApJLett

The star formation history of the Magellanic Clouds

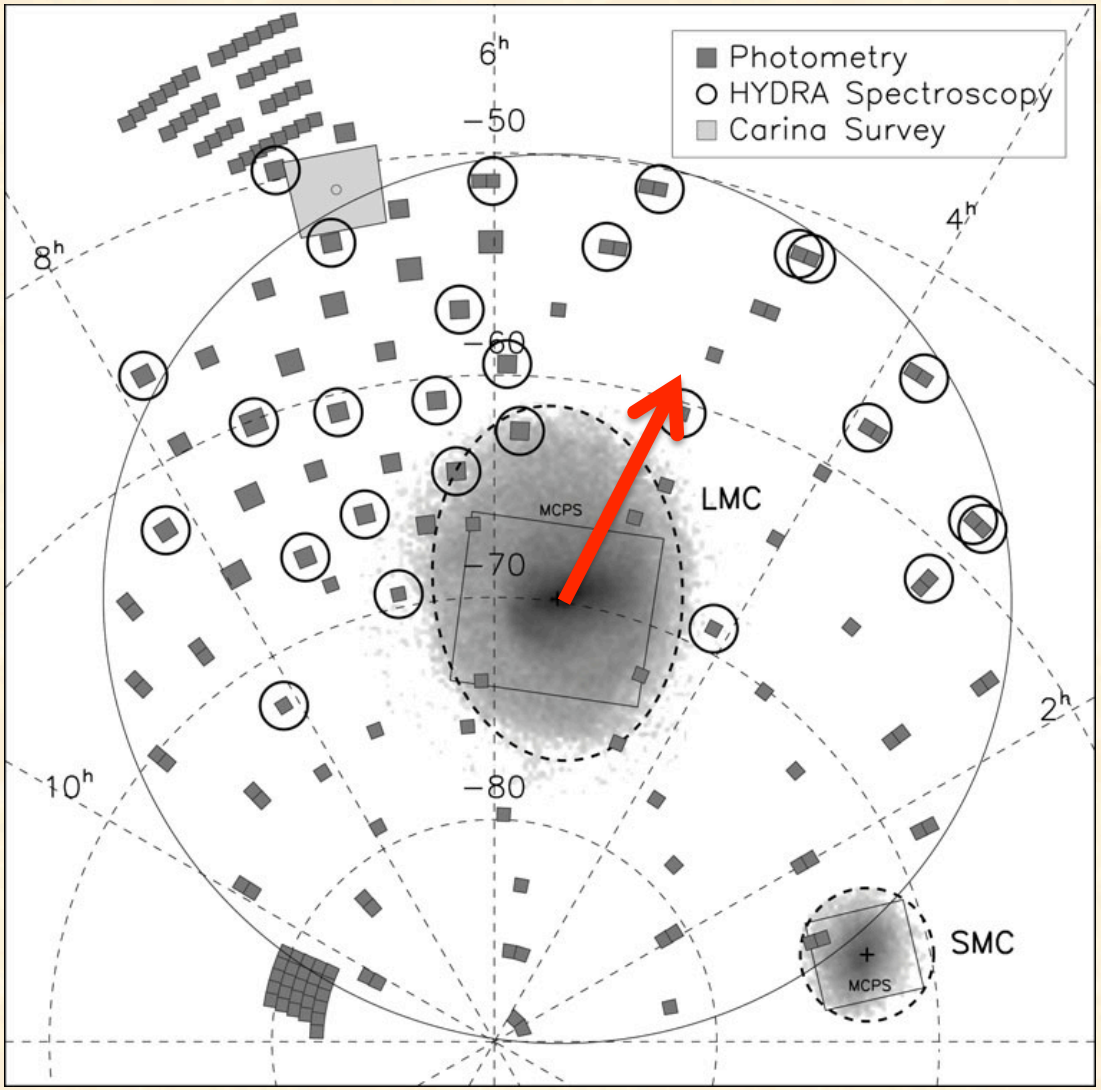
Thanks to their proximity, the Magellanic Clouds are ideal systems to obtain their SFHs in detail.



Color-magnitude diagram obtained with CTIO 4m, 4° from the center, and model CMD obtained from the best fitting SFH

The star formation history of the Magellanic Clouds

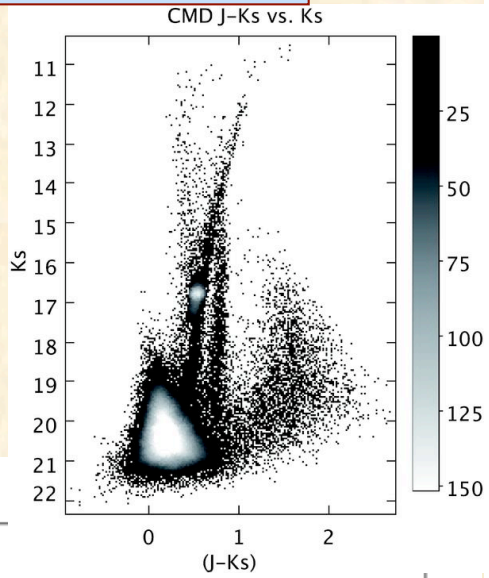
However, the MCs are huge on the sky, and a complete coverage is challenging.



To cover a (conservative) area of radius=12 degrees in the LMC, ≈1300 images with a typical 35'x35' wide field imager are necessary (1h/image)=≈160 nights

The star formation history of the Magellanic Clouds: the challenge of a complete coverage

& STEP@VST



VMC:

-184 sq. deg. to Y=21.9, J=21.4, Ks=20.3
-1837h, 200 night survey over 5 yr

Aims:

(1) quantitative SFH

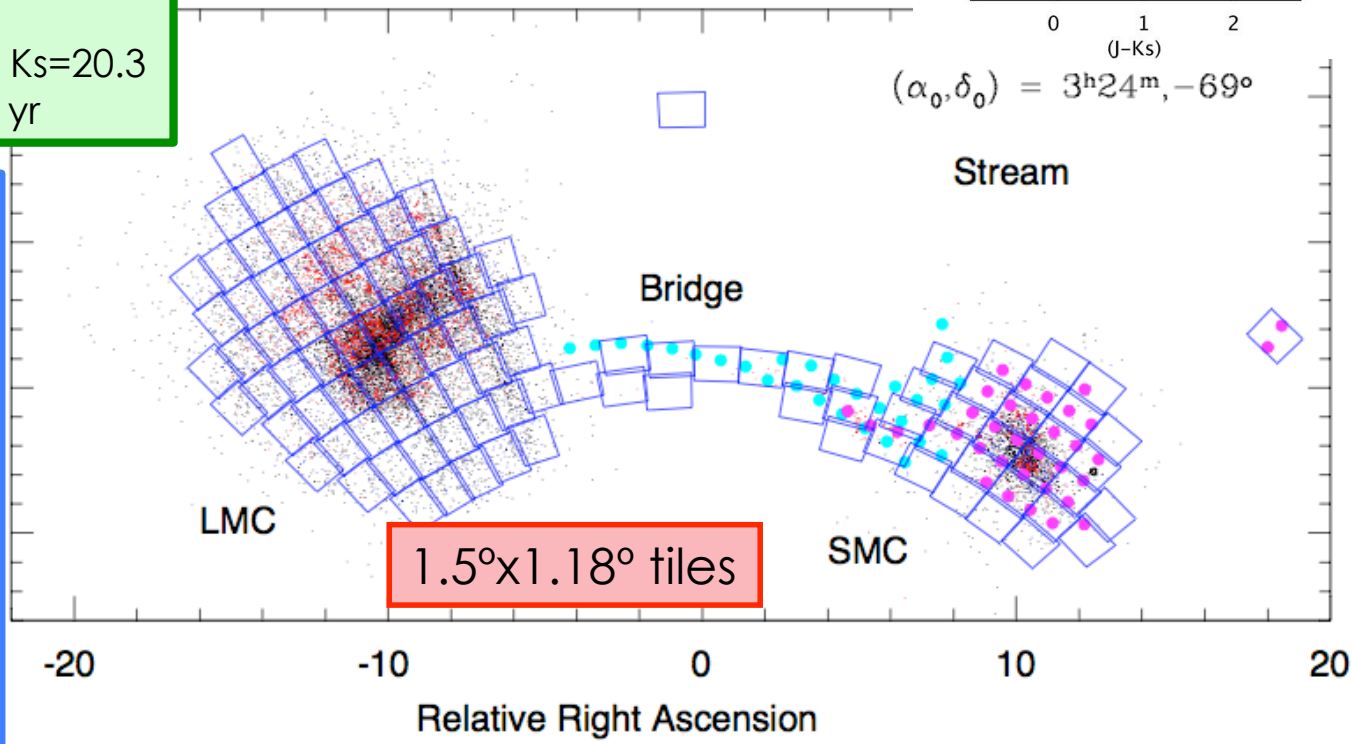
(2) 3-D structure

(3) stellar clusters

(4) planetary nebulae

(5) proper motion

(6) star formation



The star formation history of the Magellanic Clouds: the challenge of a complete coverage

MCs extension of DES

-Few hundred sq. deg.
-30-50 night survey over 3-5 yr
-Pilot project approved

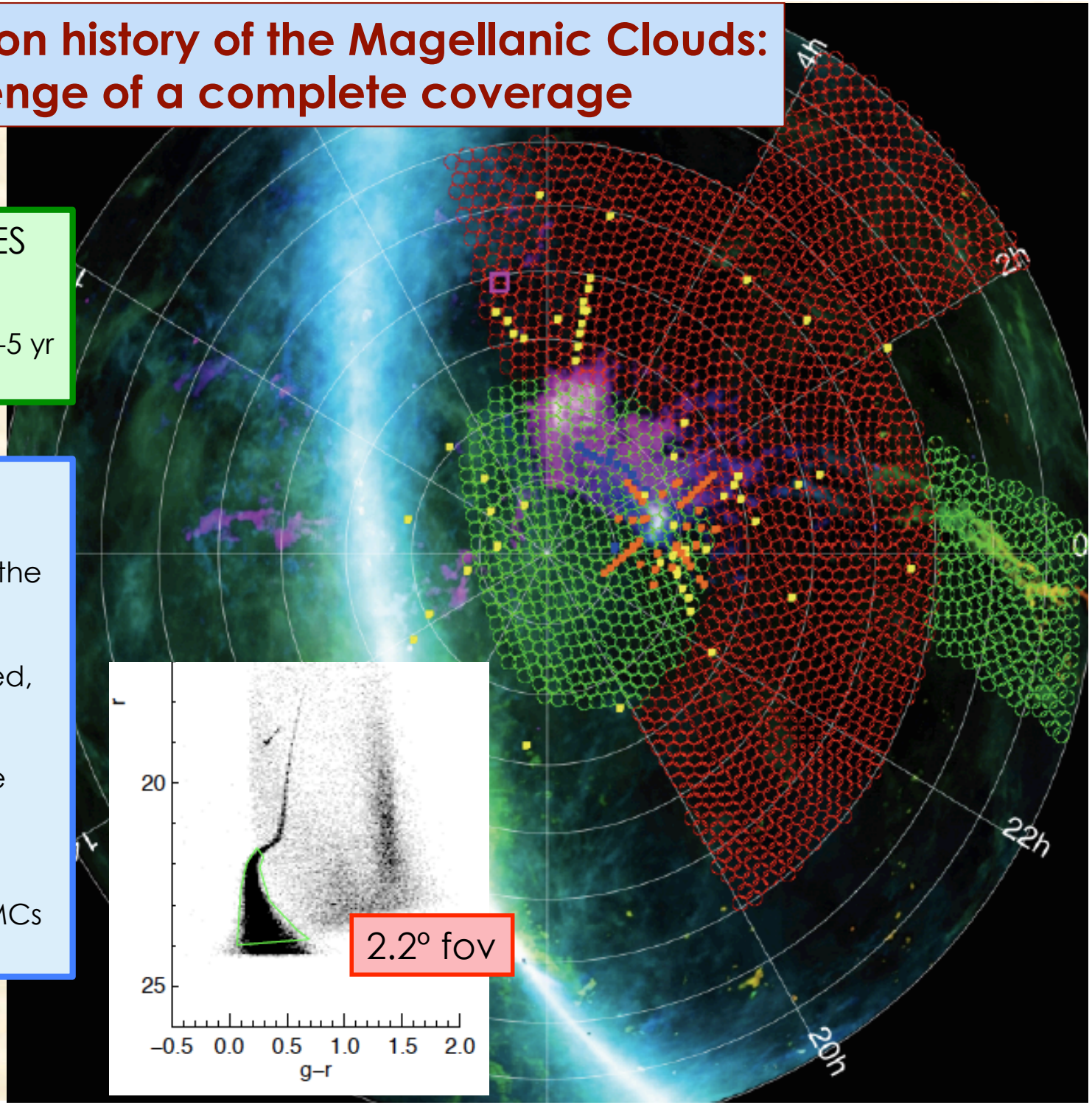
Aims:

(1) map the periphery of the MCs with oMSTO stars

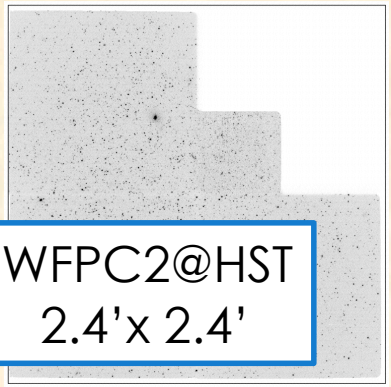
(2) derive spatially resolved, precise SFHs

(3) create 3D maps of the MCs using RR Lyrae;

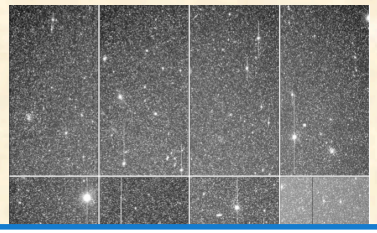
(4) relate the large-scale stellar distribution of the MCs with their H I gas.



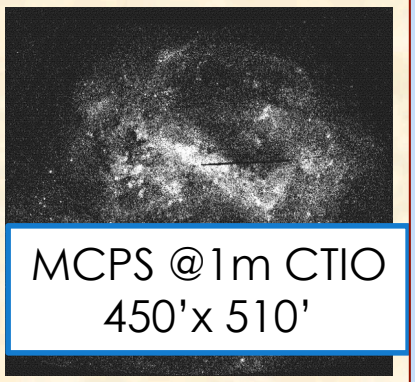
The star formation history of the Magellanic Clouds: steps of different size



WFPC2@HST
2.4'x 2.4'

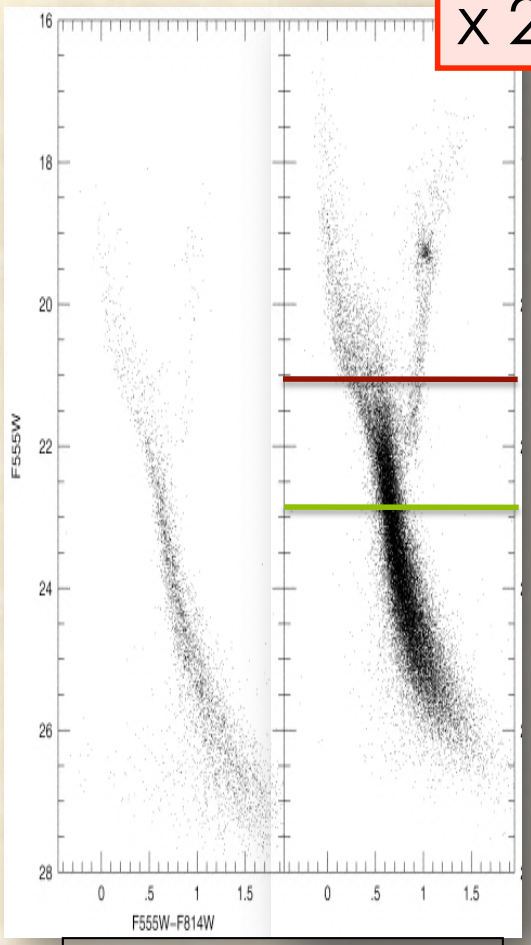


WFI@2.2mESO
MOSAIC@4mCTIO
35'x 35'



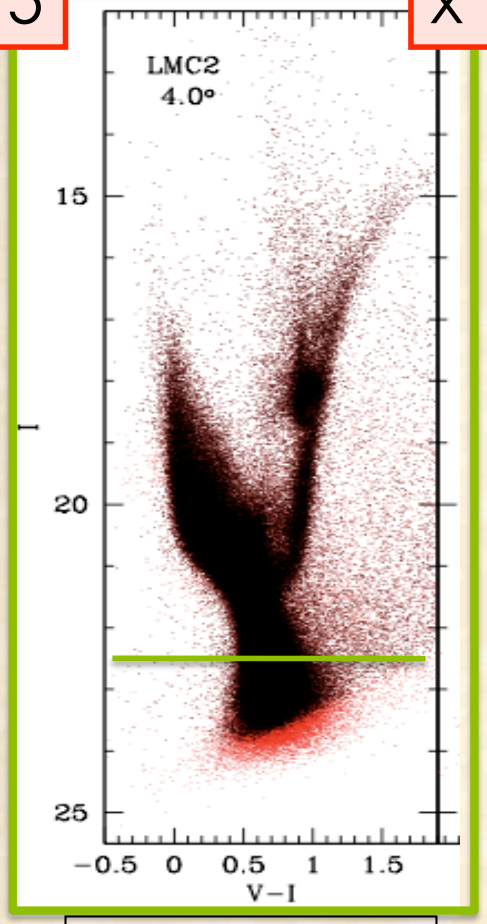
MCPS @1m CTIO
450'x 510'

x 215

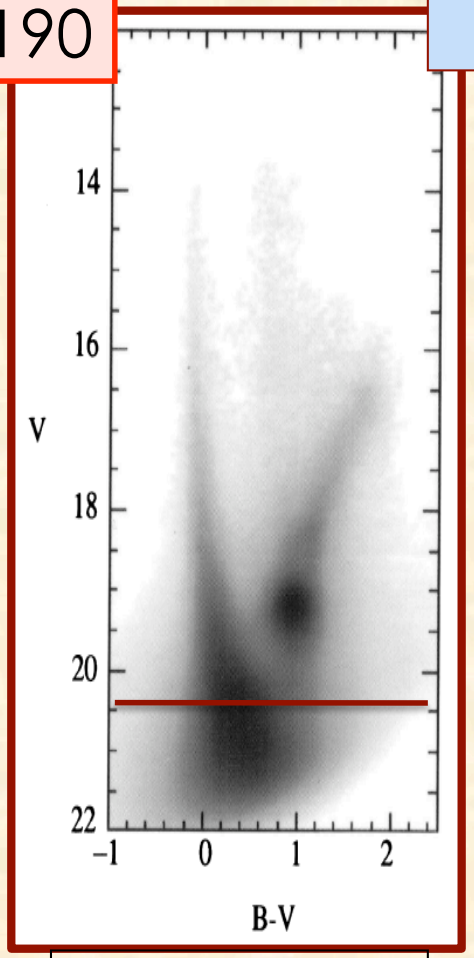


Holtzman et al. 1999

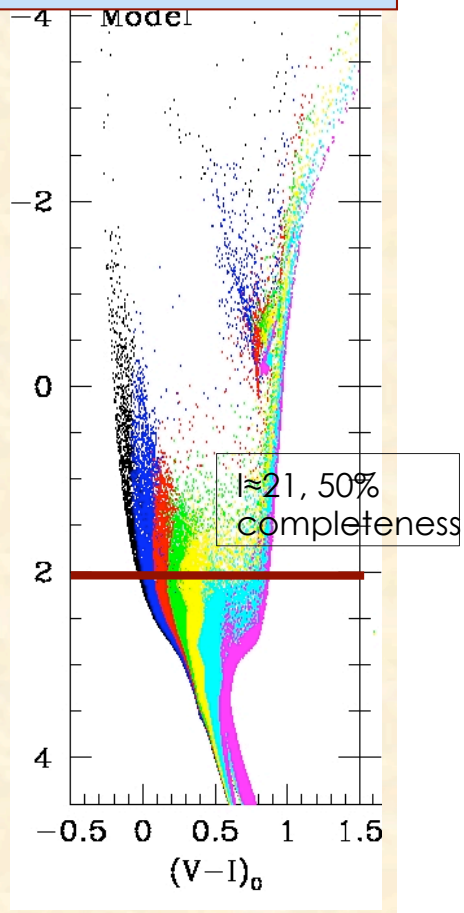
x 190



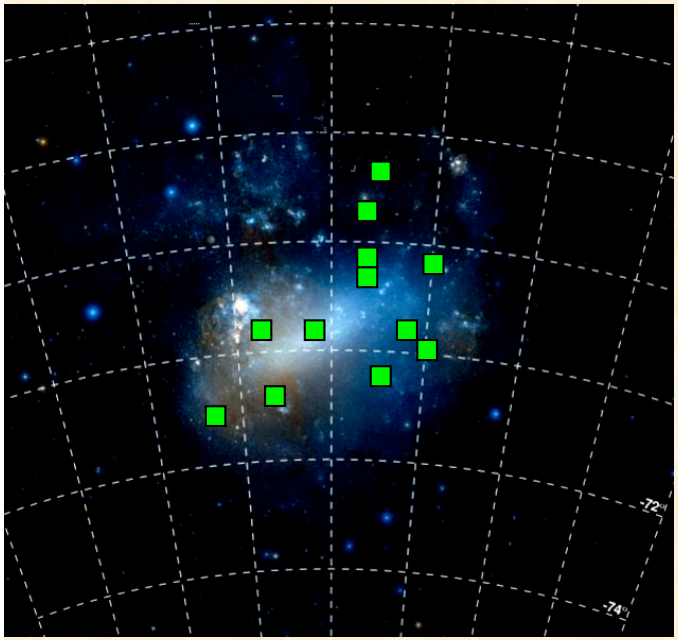
Gallart et al. 2008



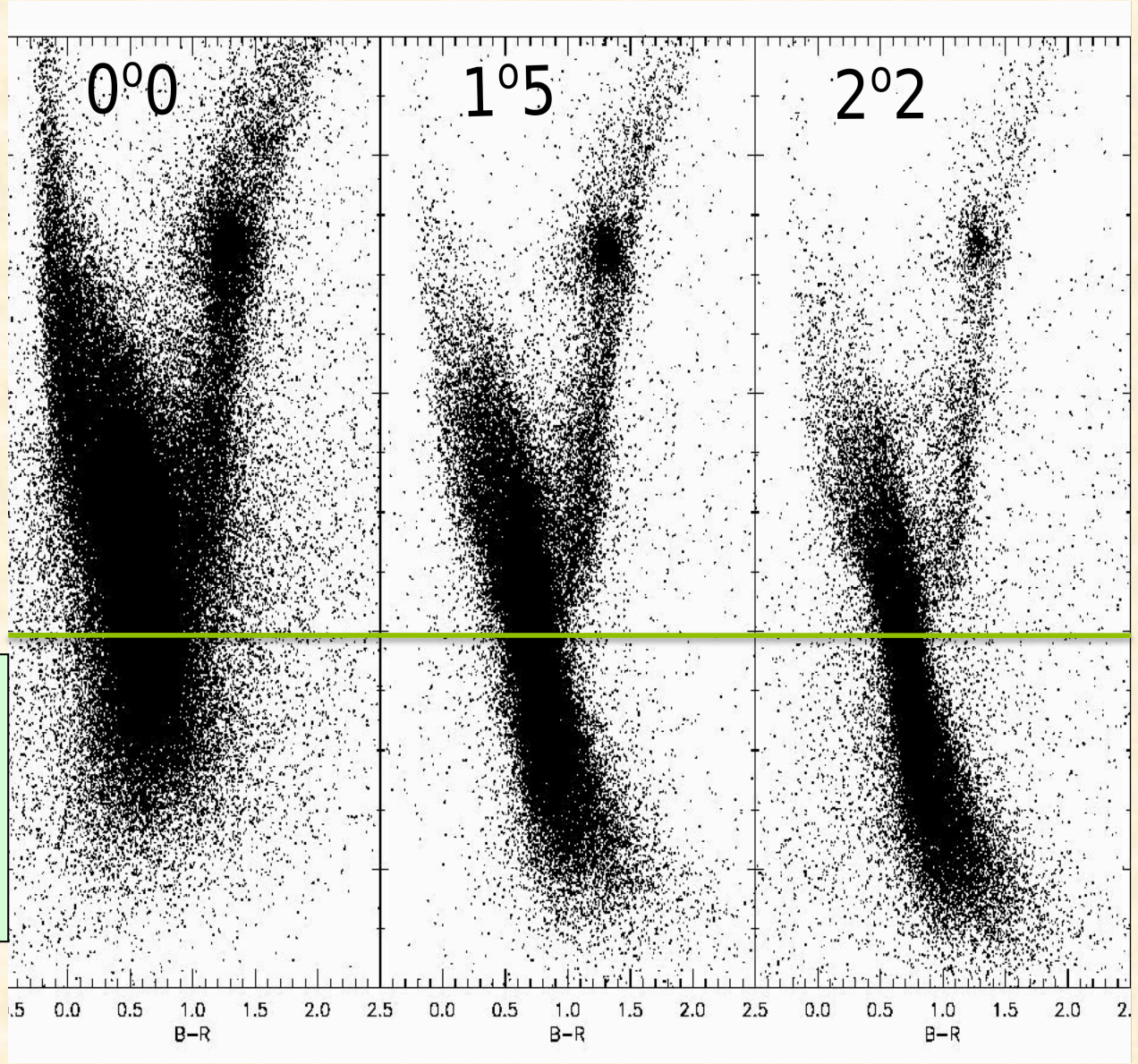
Zaritsky et al. 1997

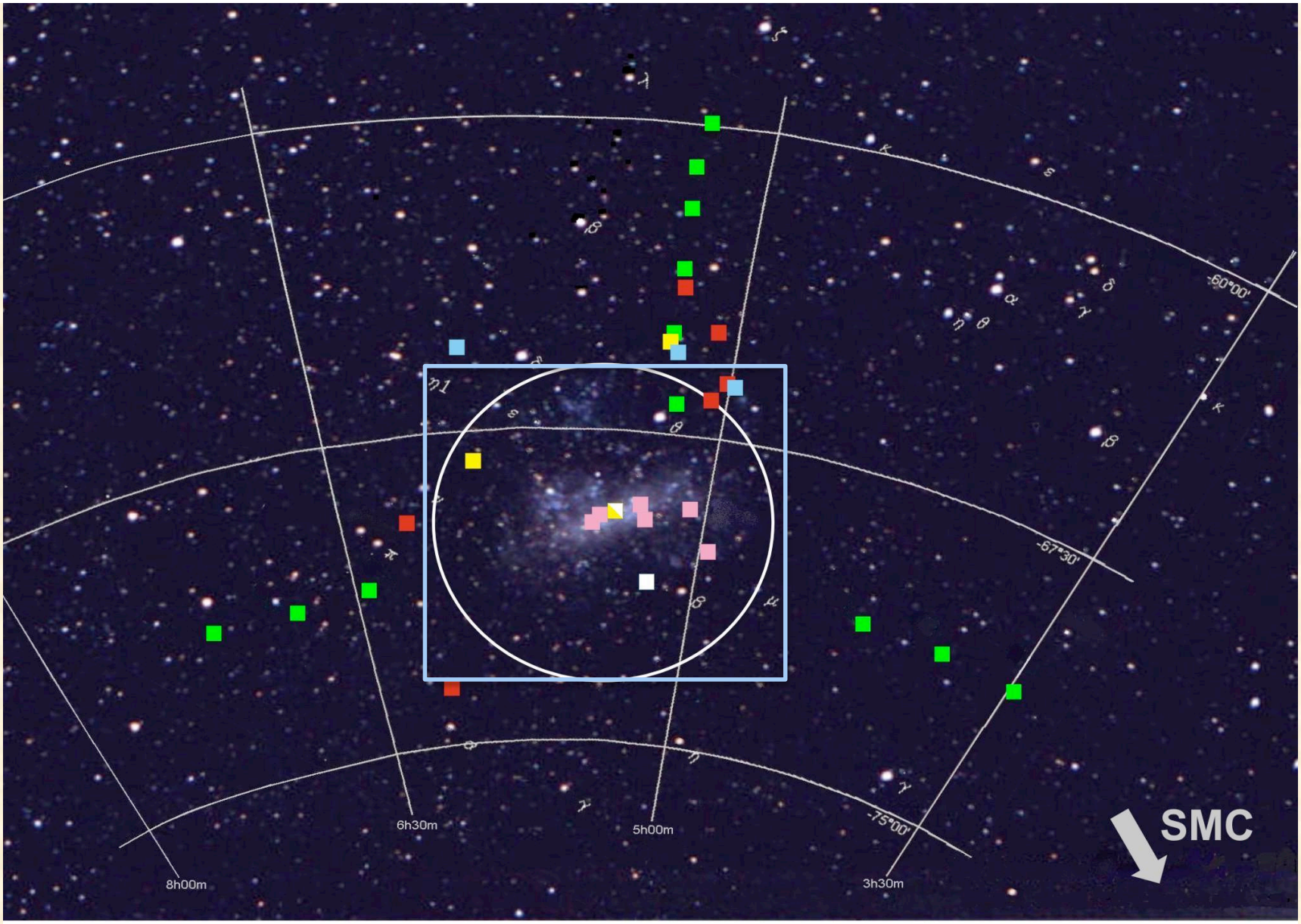


The star formation history of the Magellanic Clouds: oMSTO in the bar from the ground?



VIMOS imaging using short (e.g. 10 min) intervals of excellent seeing.
Monelli et al., 2012 in prep.



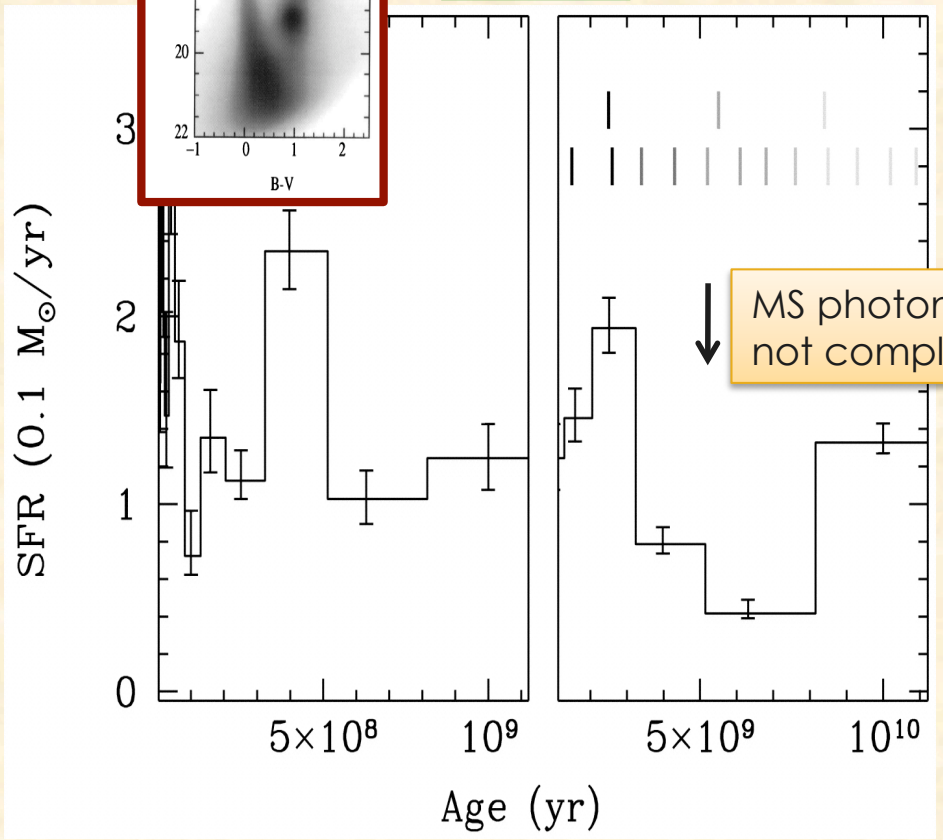


- Bertelli et al. (1992)
- Holtzman et al. (1999)
- Olsen (1999)
- Smecker-Hane et al. (2002)
- Javiel et al. (2005)
- Nuestros campos

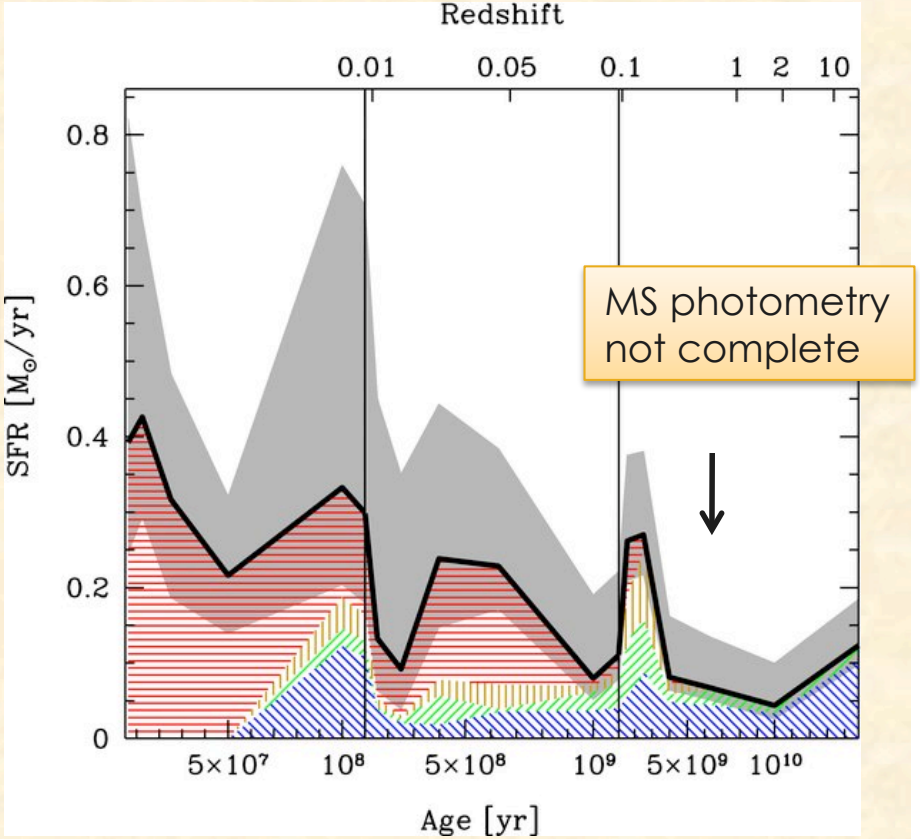
The (recent) star formation history of the Magellanic Clouds

Harris & Zaritszy 2004, 2009
-Magellanic Clouds Photometric Survey (1m LCO)
-Global SFH derived using star-fish

SMC



LMC



The (recent) star formation history of the Magellanic Clouds

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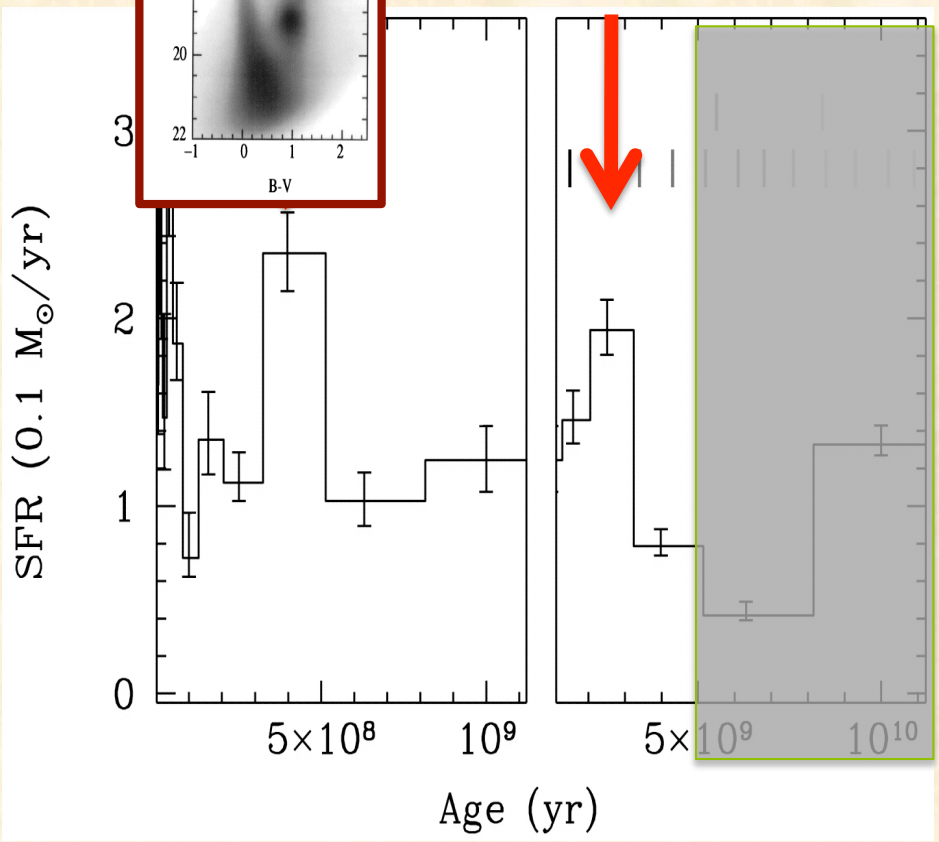
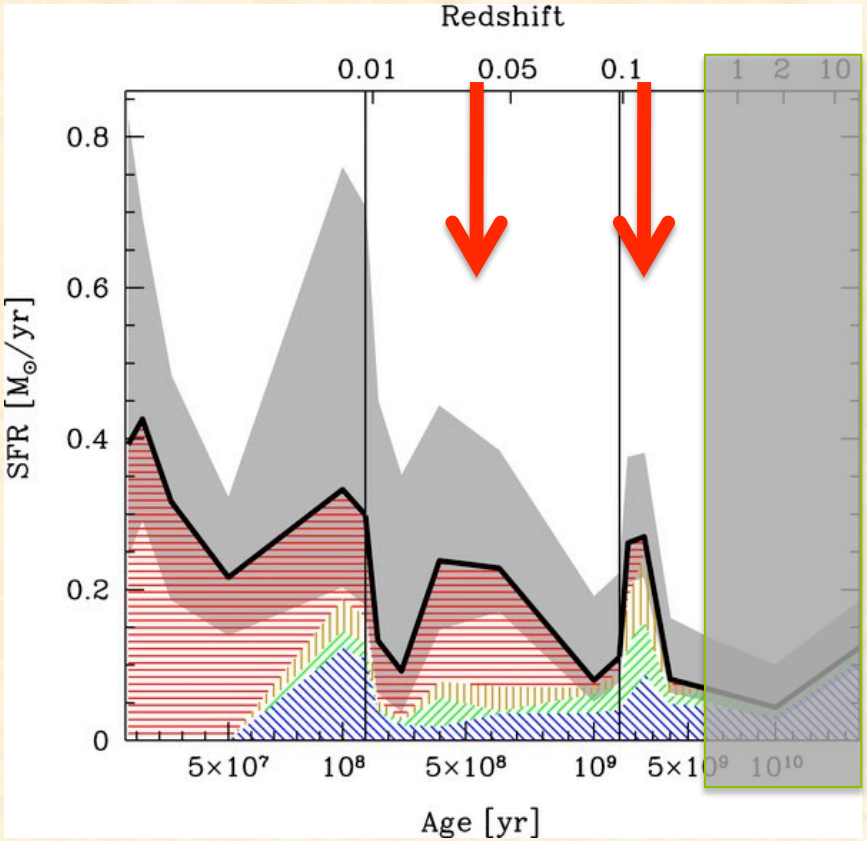
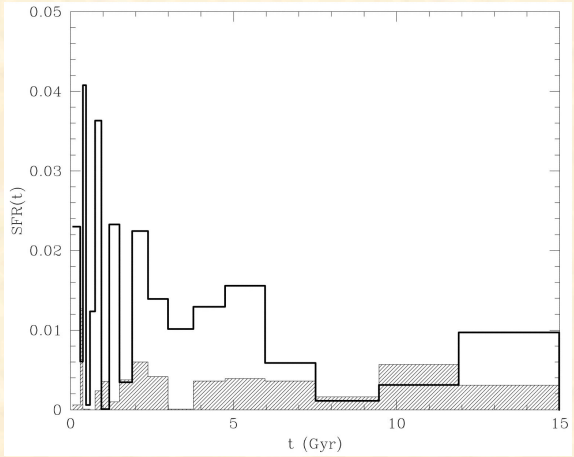


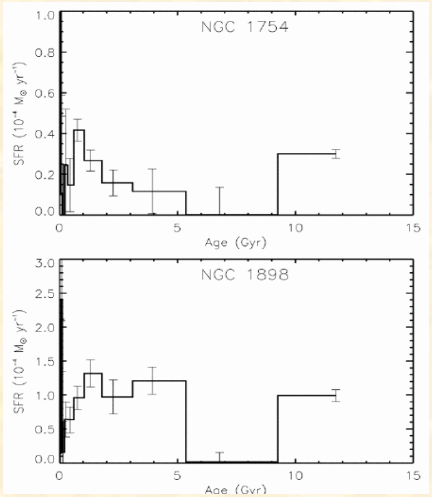


Apparently correlated SF bursts ≈2.5 &≈0.5 Gyr ago

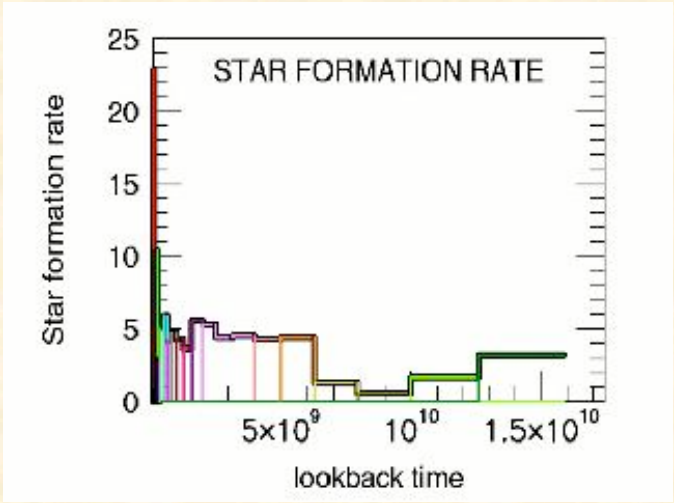
The (complete) star formation history of the Magellanic Clouds from (tiny) WFPC2 fields. I The bar



Smecker-Hane et al. 2002



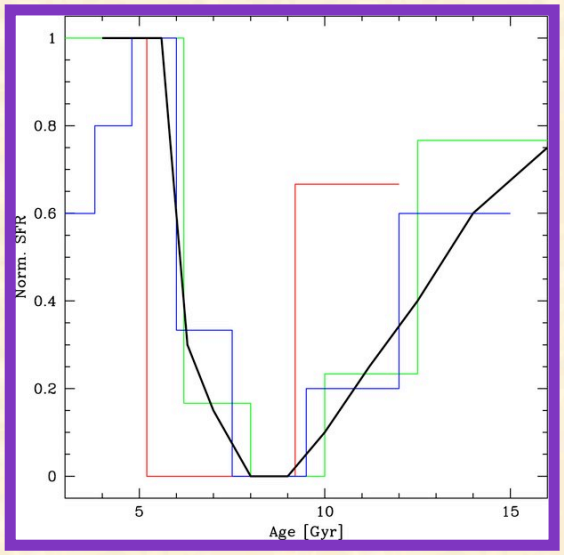
Olsen 1999

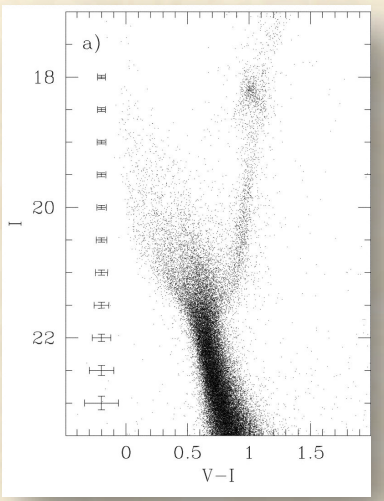


Holtzman et al. 1999

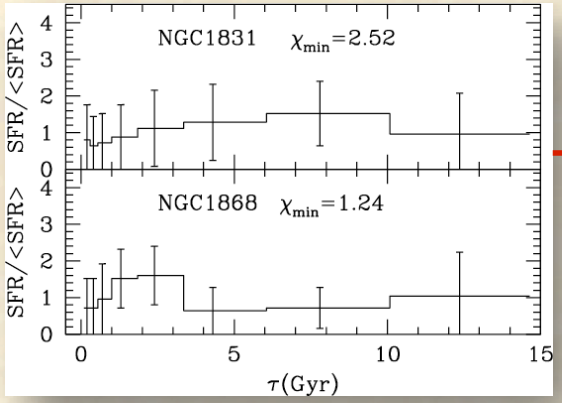
LMC Bar Fields

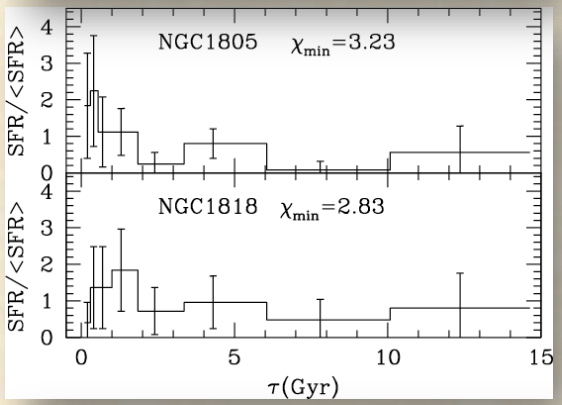
Different studies agree on an epoch of depressed SFR between ≈6-10 Gyr ago

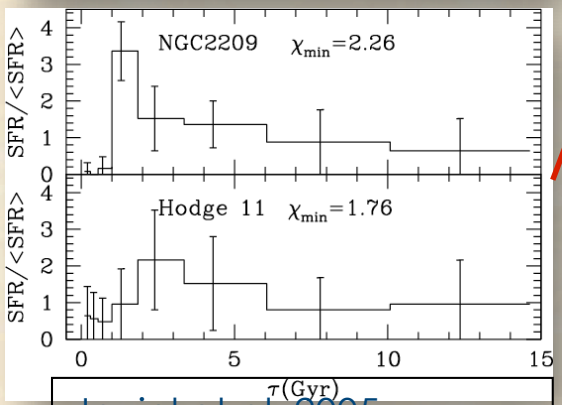




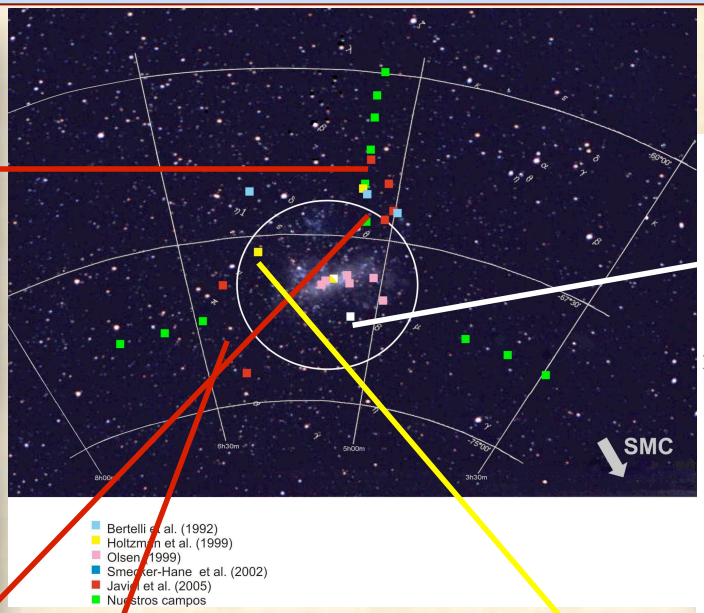
The (complete) star formation history of the Magellanic Clouds from (tiny) WFPC2 fields

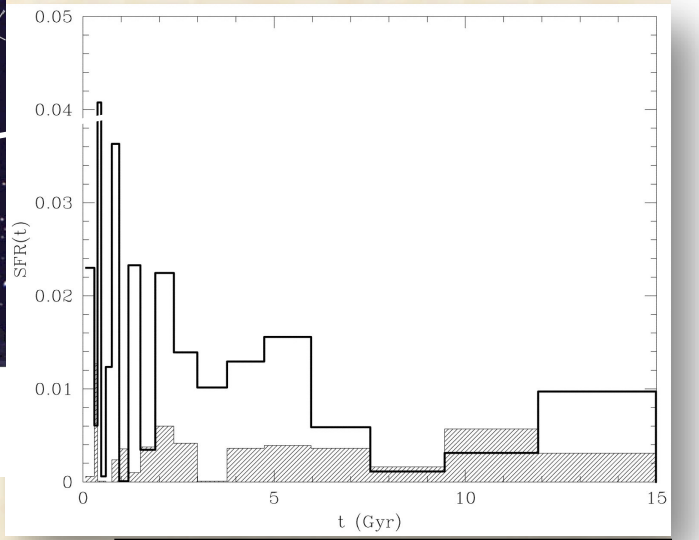






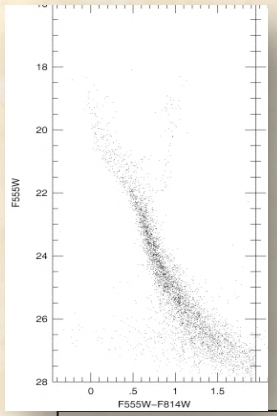
Javiel et al. 2005



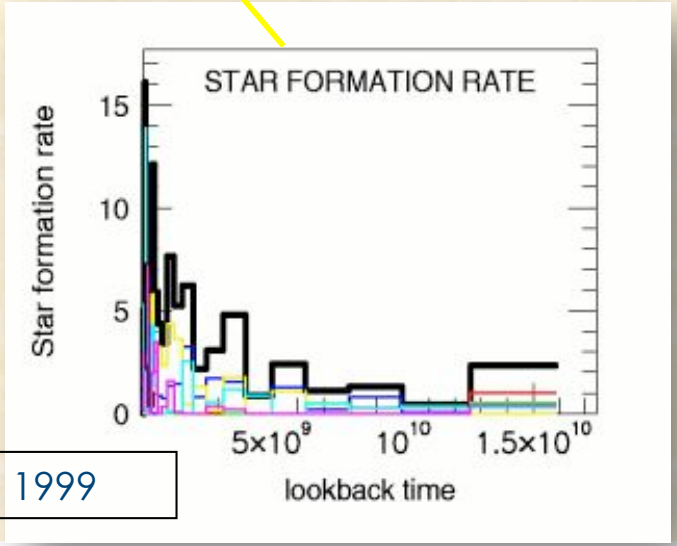


Smecker-Hane et al 2002

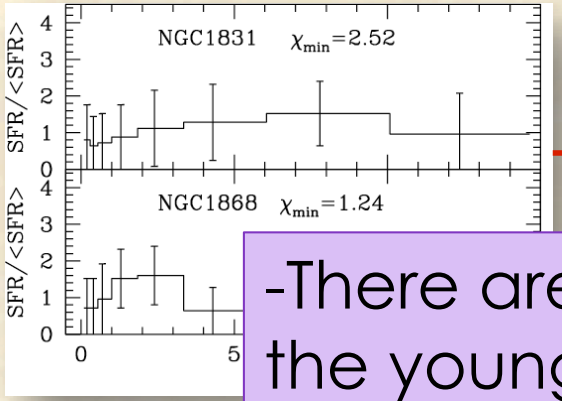
SFH: Disk Fields

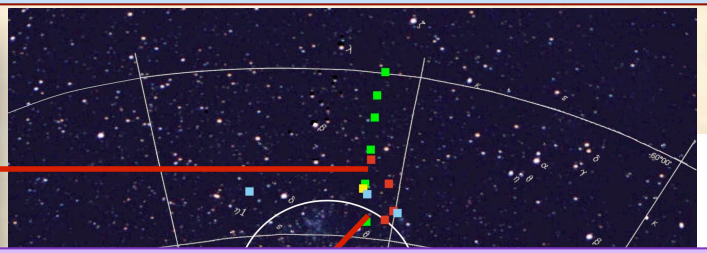


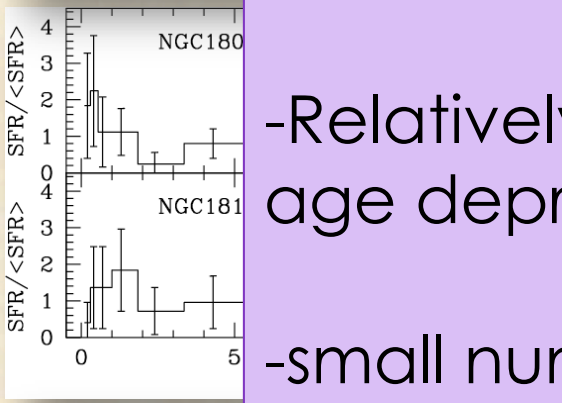
Holtzman et al. 1999

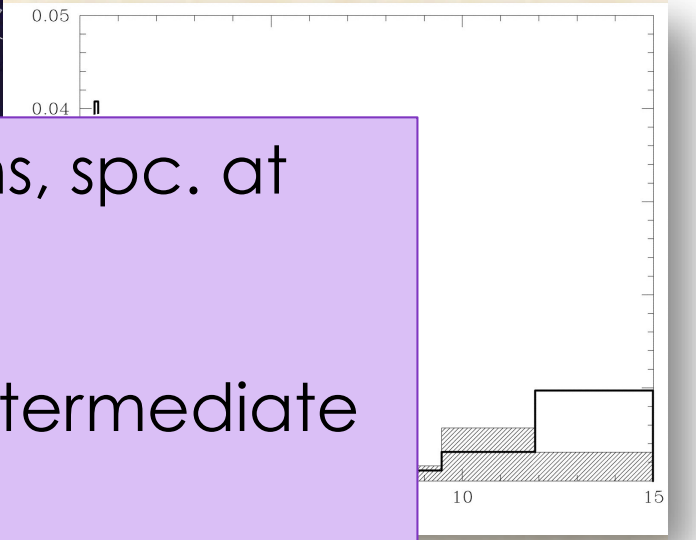


The (complete) star formation history of the Magellanic Clouds from (tiny) WFPC2 fields







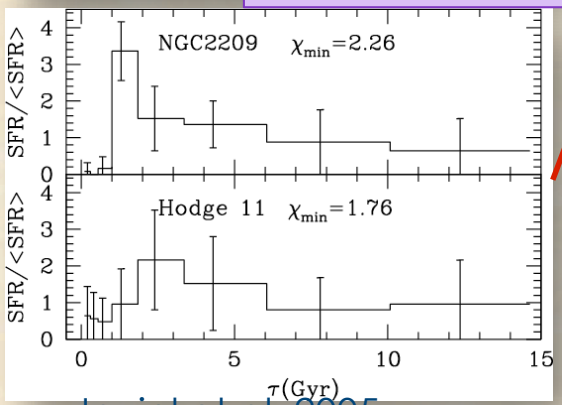


et al.

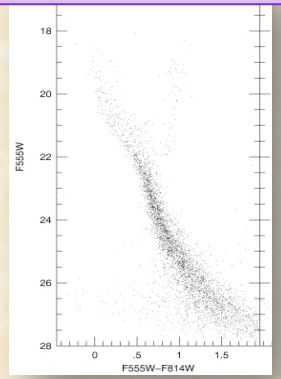
-There are field to field variations, spc. at the young side

-Relatively flat SFR(t), with no intermediate age depression

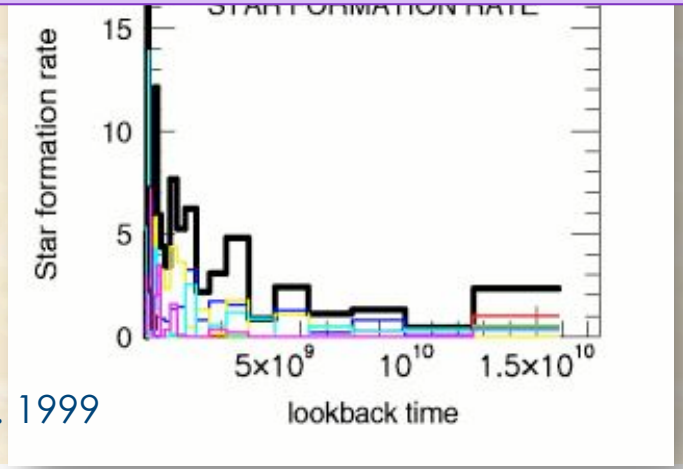
-small number stats, spc at young ages?



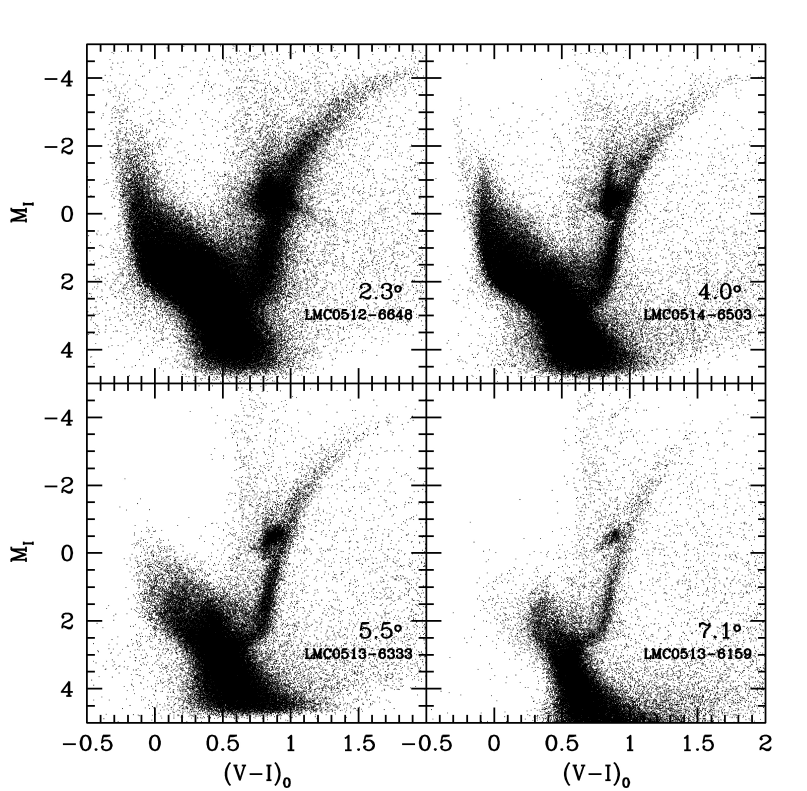
Javiel et al. 2005

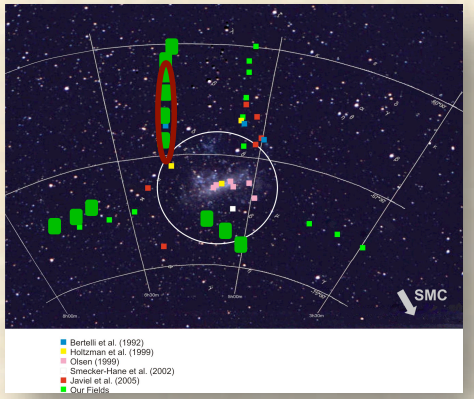


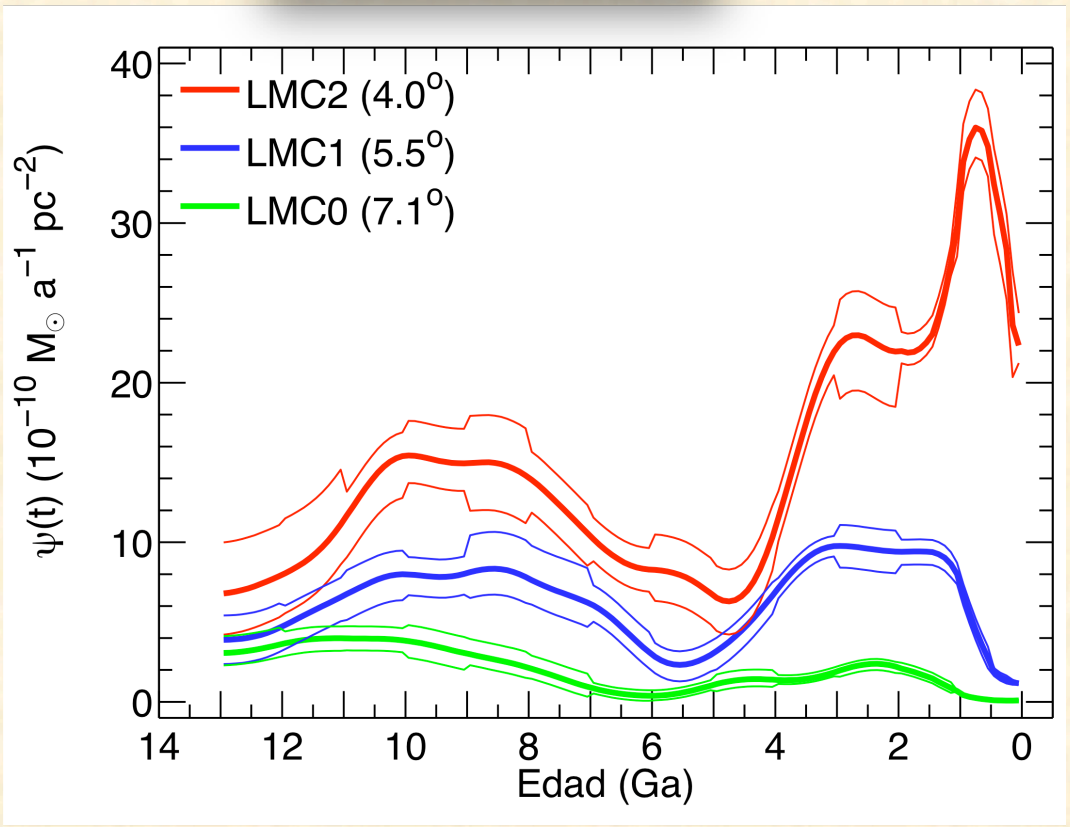
Holtzman et al. 1999



The (complete) star formation history of the Large Magellanic Cloud from (35'x35') fields

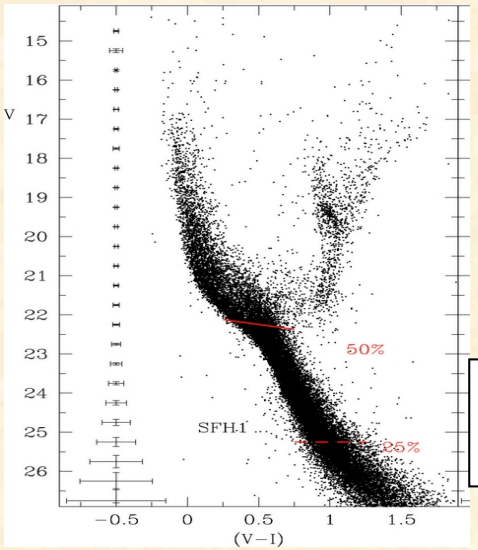






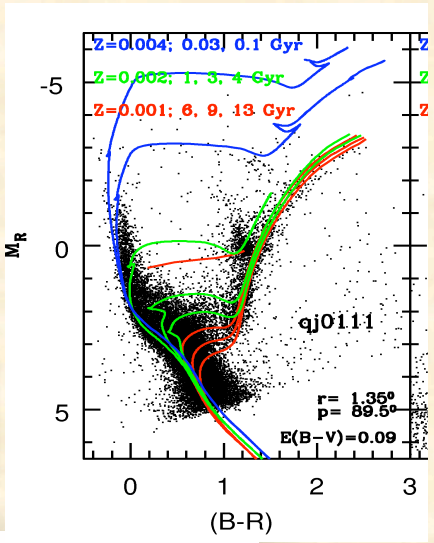
Gallart et al. 2008
Carrera et al. 2011
Meschin et al. 2012
-4m CTIO+MOSA
-(2.2 ESO+WFI)

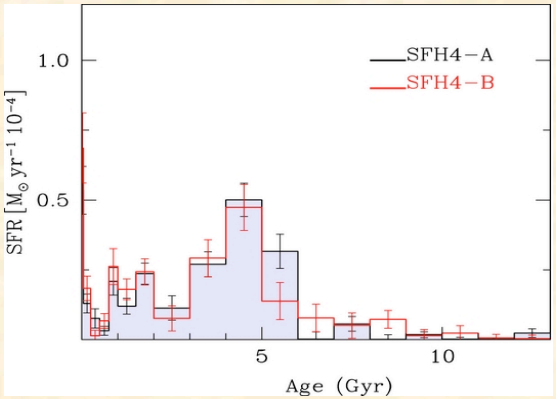
The (complete) star formation history of the Small Magellanic Cloud from (small) ACS fields

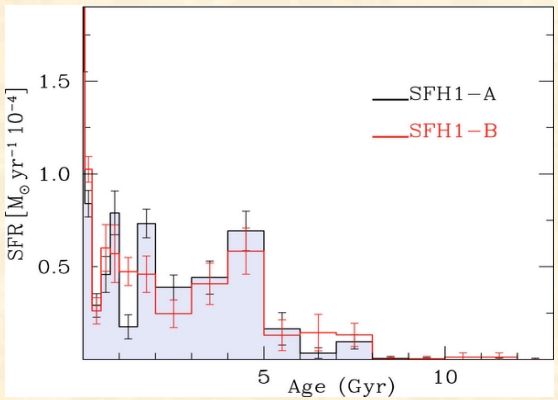


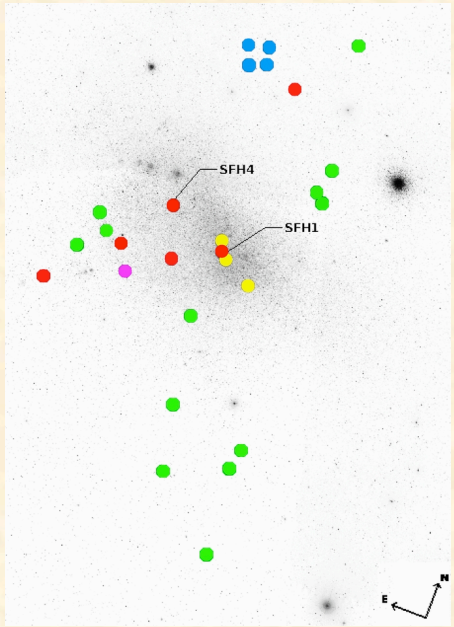
Cignoni et al. 2012
2 out of 6 ACS fields

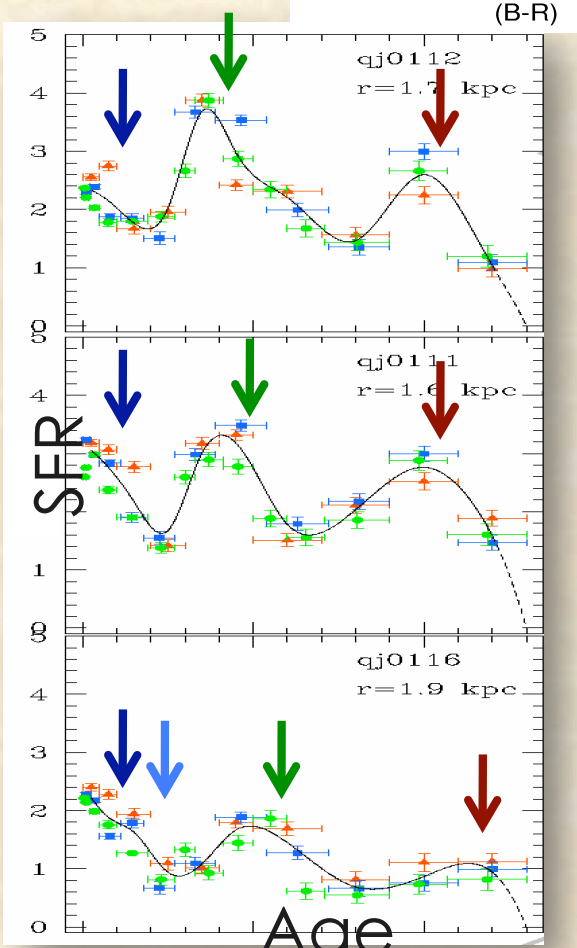
Noël et al. 2007
-12 LCO 100“ fields



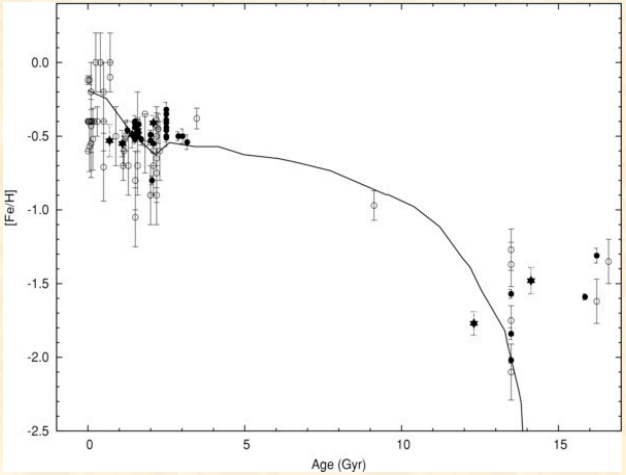




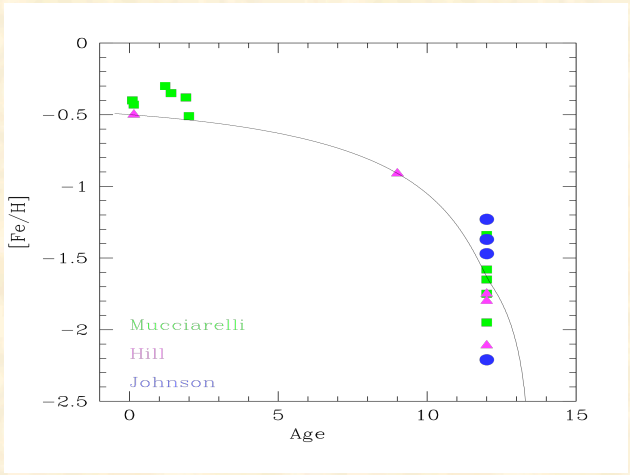




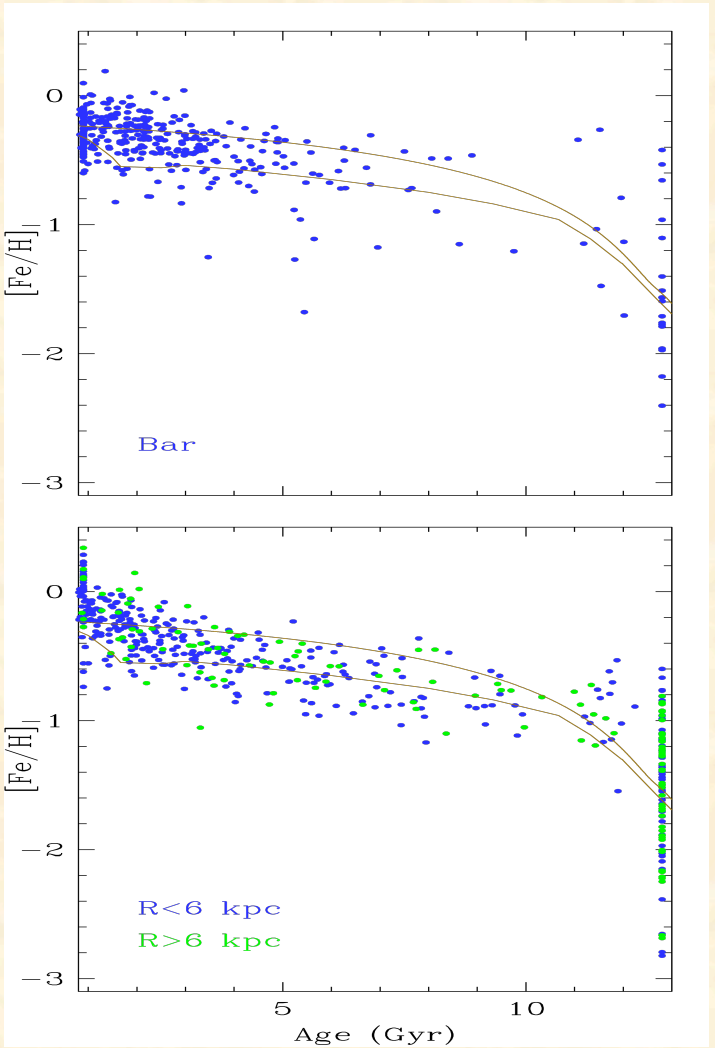
The chemical enrichment history of the Magellanic Clouds . I. LMC.



Sharma et al 2010 CaT, FORS2@VLT



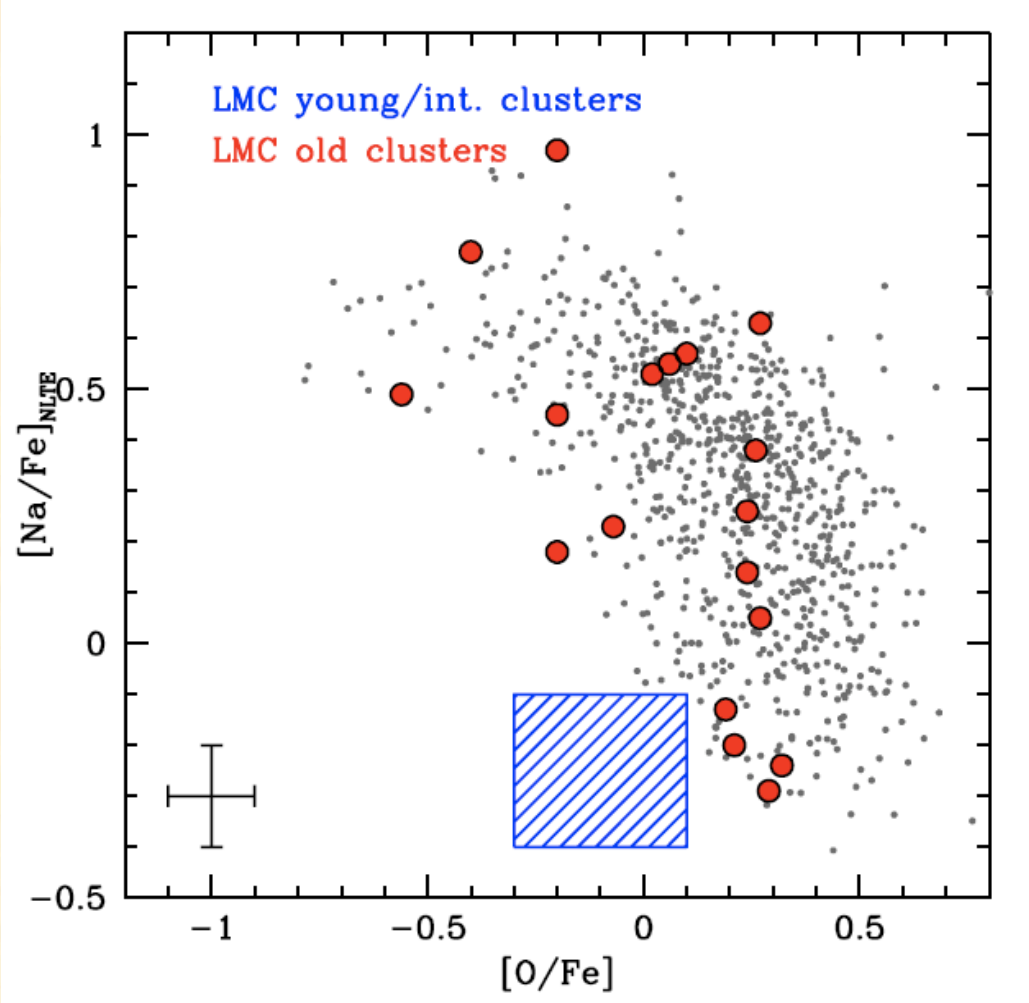
Hill et al. 2000 (HR, FLAMES@VLT, SV)
Mucciarelli et al 2007-2011 (FLAMES@VLT)
Johnson et al. 2006 (MIKE@Magellan)



Data from Carrera et al. 2009, 2001, Cole et al. 2005, CaT

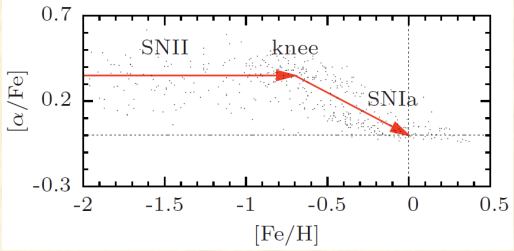
The chemical enrichment history of the Magellanic Clouds . I. LMC Clusters, HR

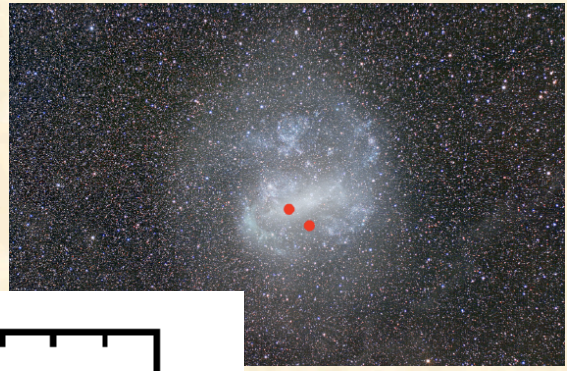
Chemical anomalies in old LMC globulars, but not in intermediate-age and young ones

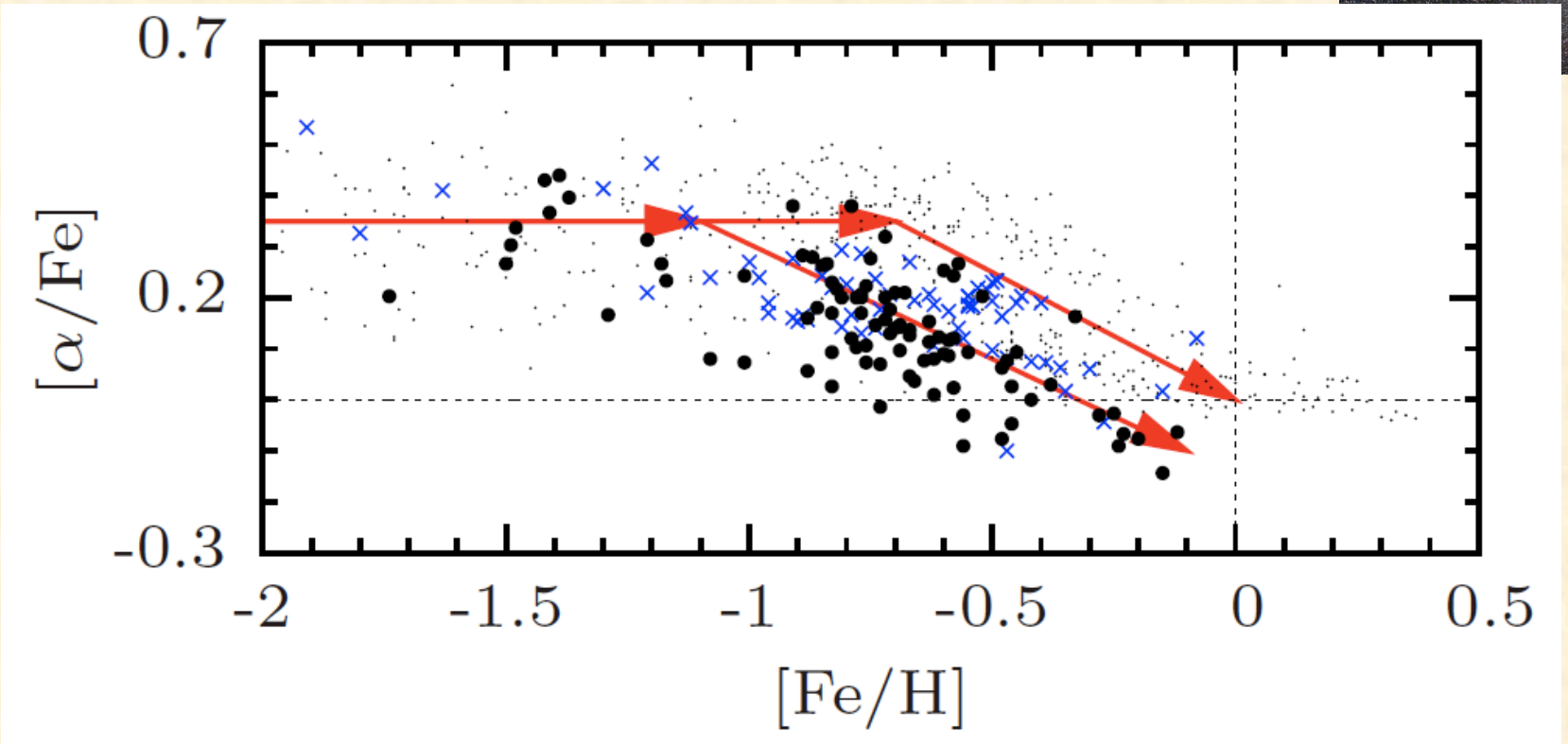


Mucciarelli et al. 2012, (2011, 2010, 2009, 2008, 2007)
FLAMES@VLT

The chemical enrichment history of the Magellanic Clouds. II. LMC field, HR.

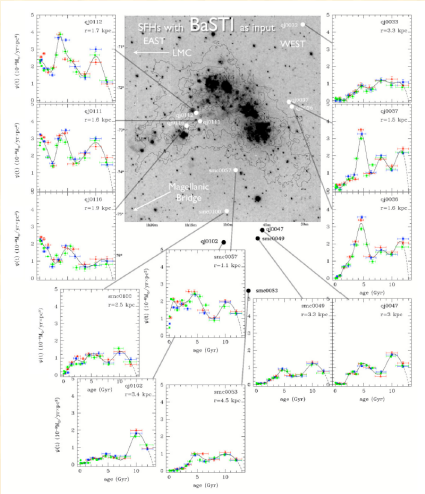






Van der Swaelmen, Hill & Primas, 2012 in prep

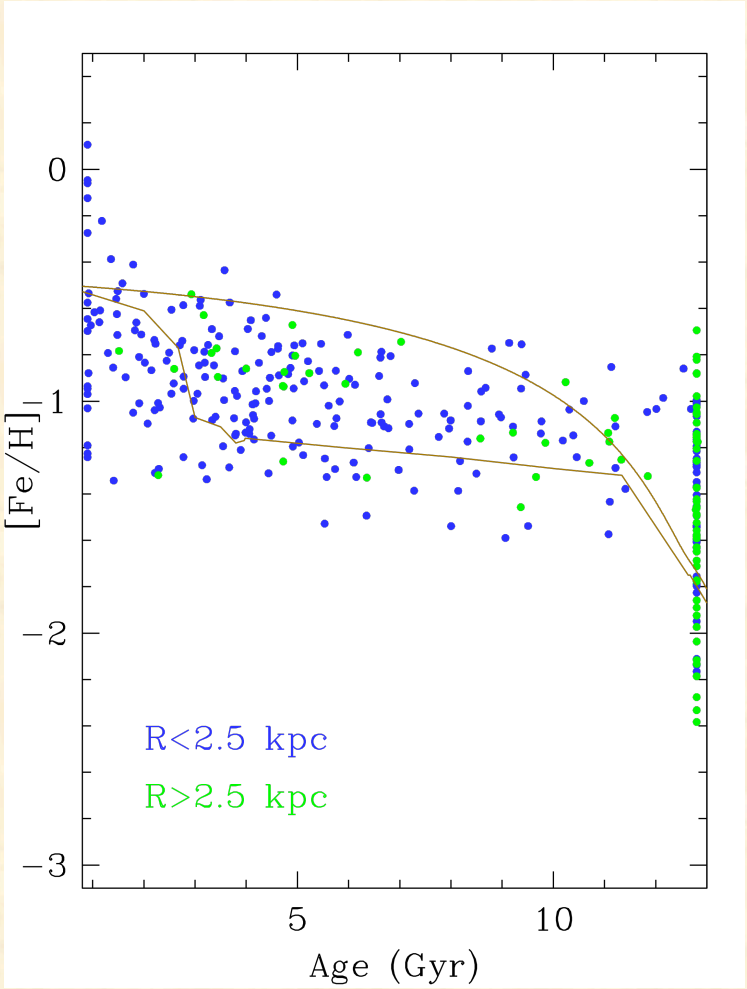
The chemical enrichment history of the Magellanic Clouds . II. Field stars, CaT

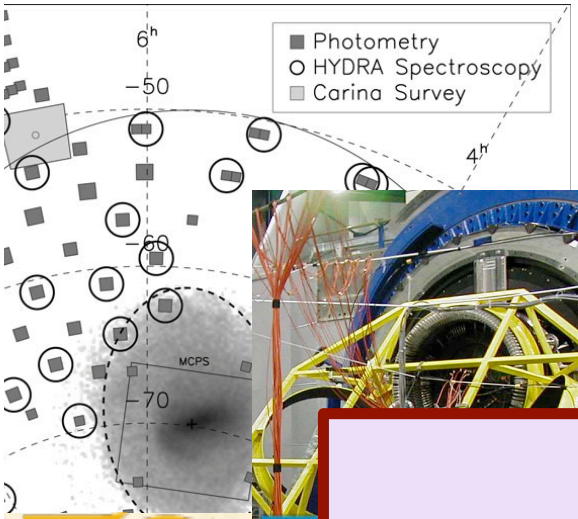


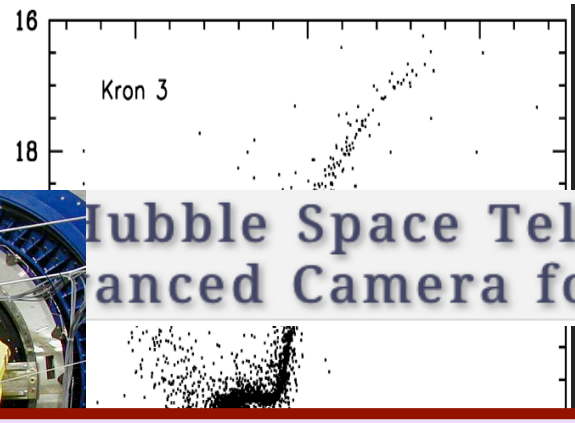
Carrera et al. 2008, FORS2 data

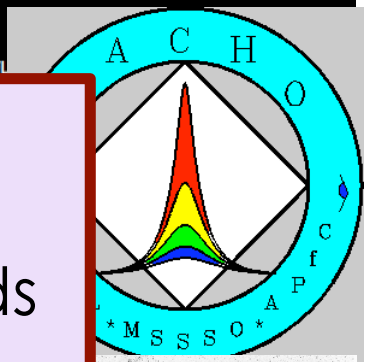
Other CaT studies, with consistent results by:

Parisi et al. 2010, 2009, FORS2
de Propris et al. 2010 4mCTIO









ESO Niche and likely more successful future contribution to Magellanic Clouds science (aimed at the study of MCs formation and evolution):
a large
FLAMES@VLT spectroscopic survey
of stars of all ages, cluster & field