

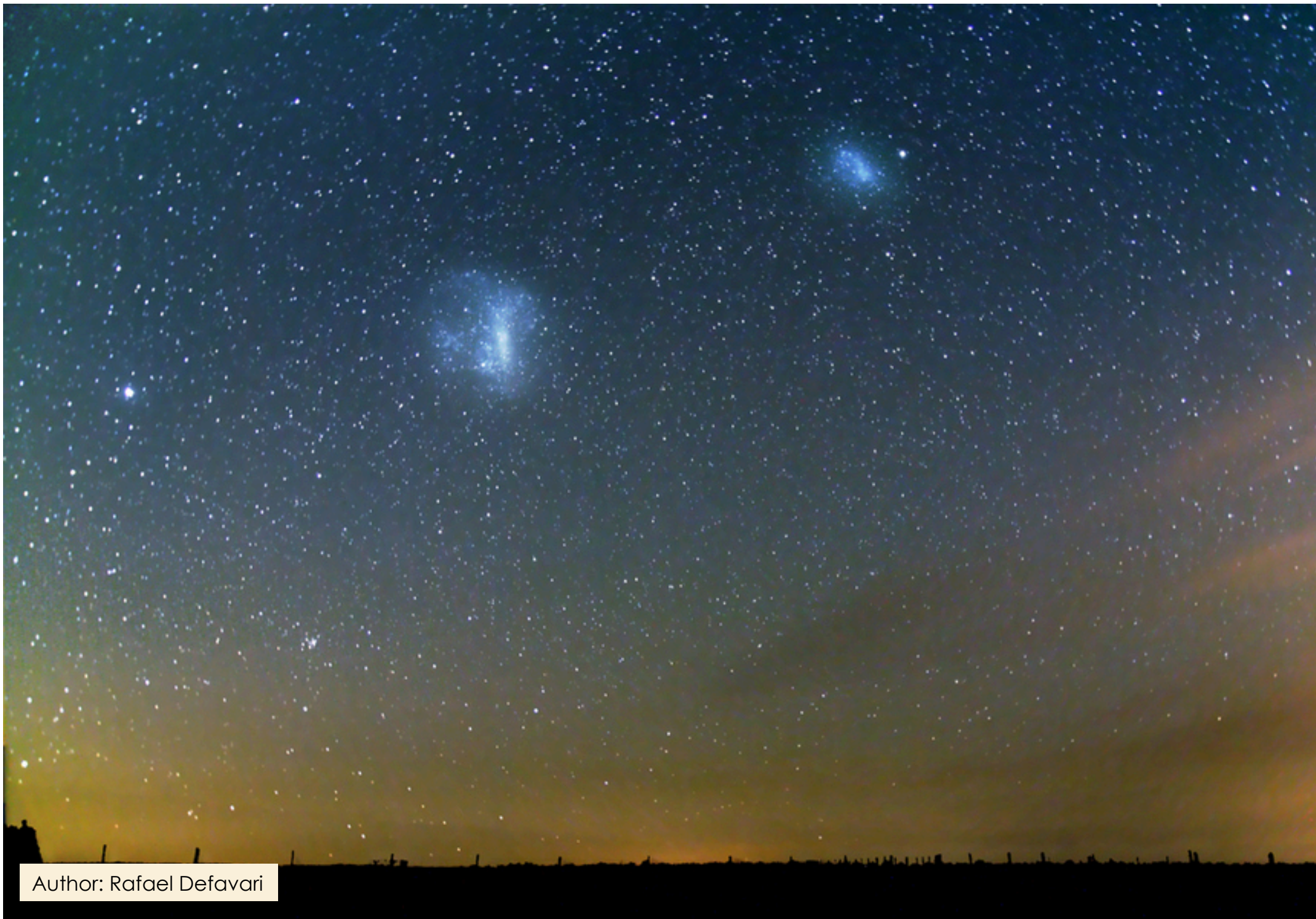
THE MAGELLANIC CLOUDS

Carme Gallart

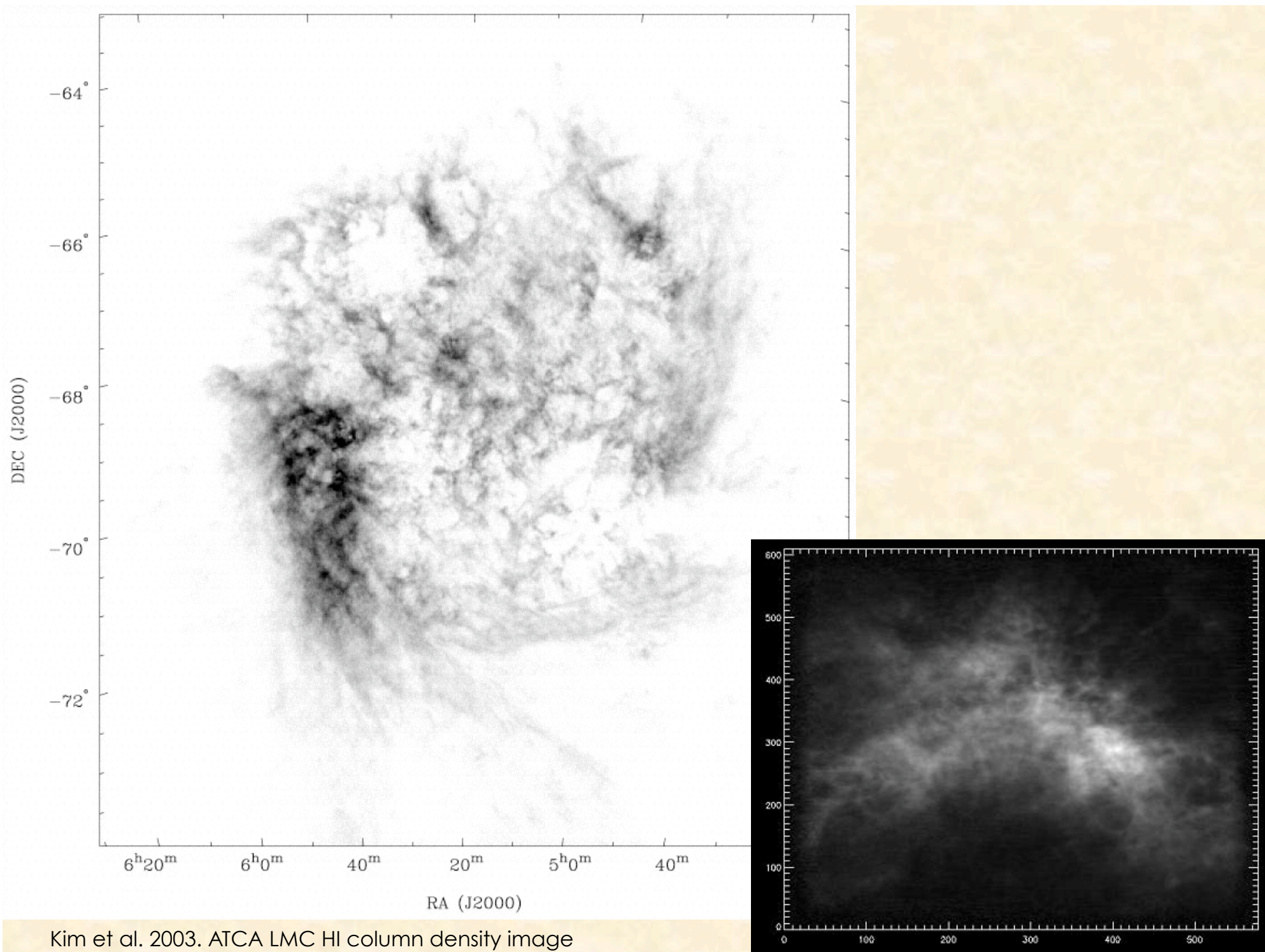
Instituto de Astrofísica de Canarias, Spain



1.- OVERVIEW OF THE MAGELLANIC SYSTEM



Author: Rafael Defavari



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

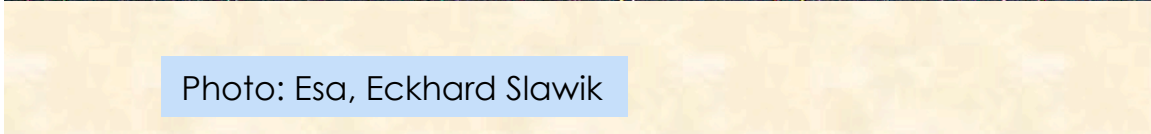
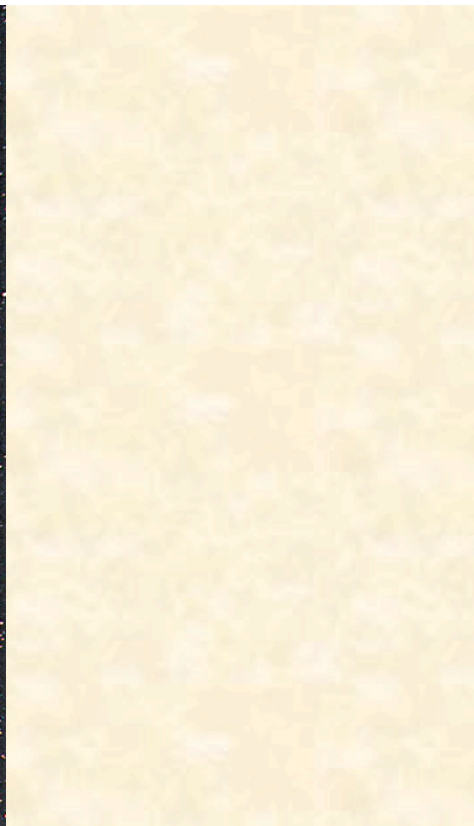
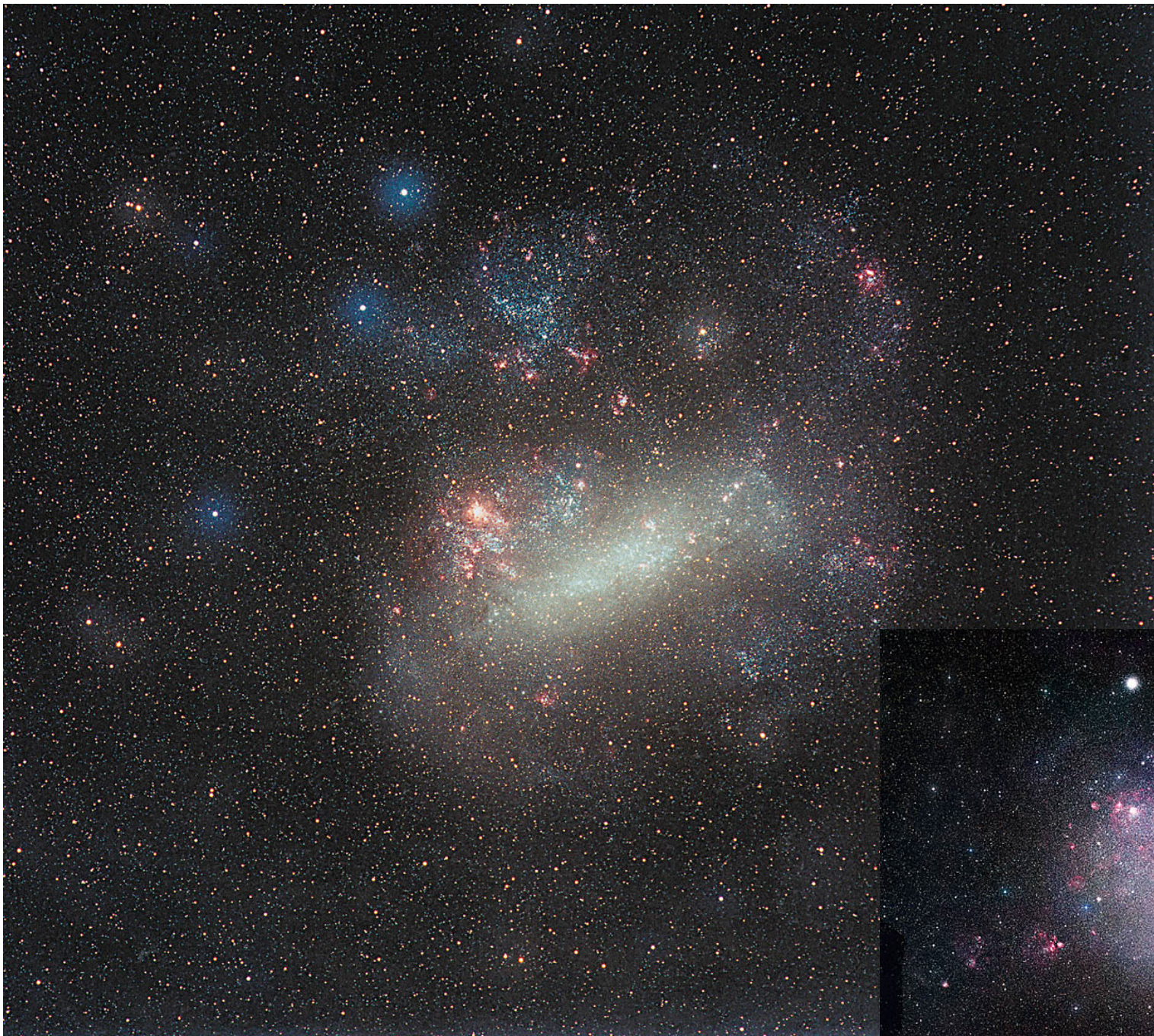
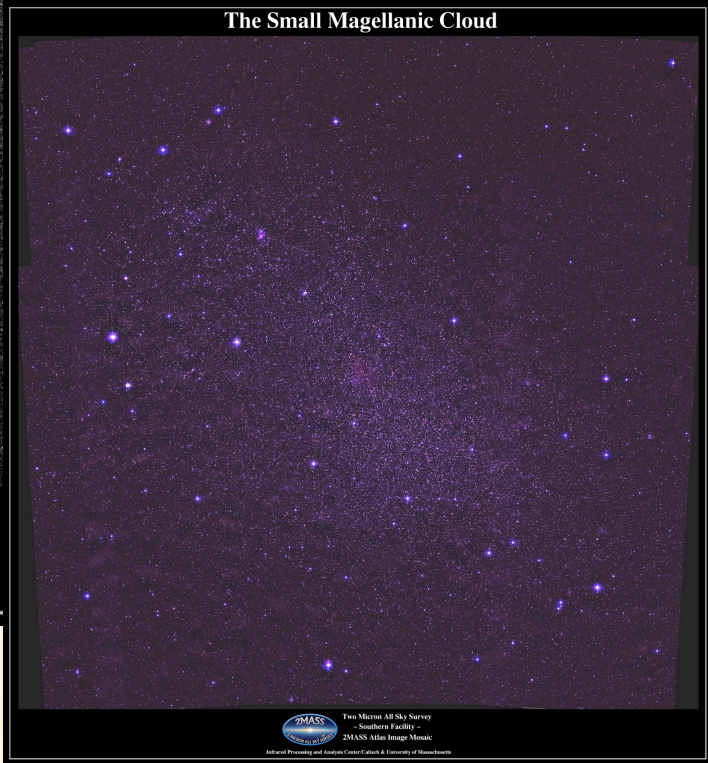
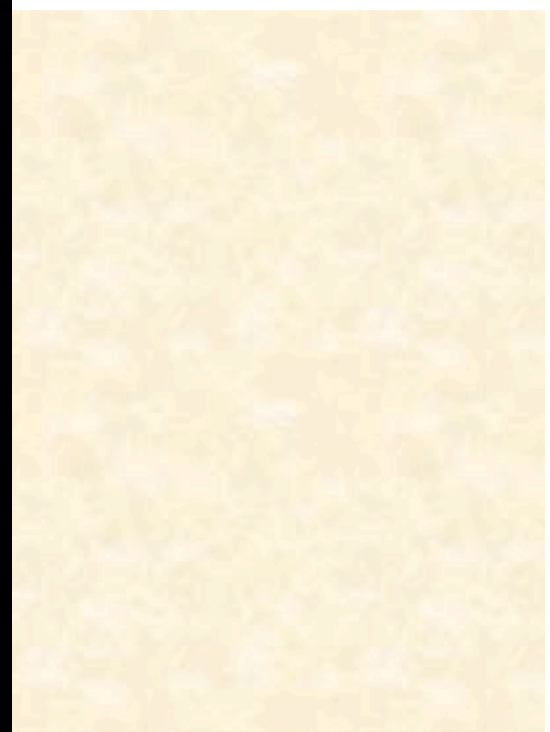
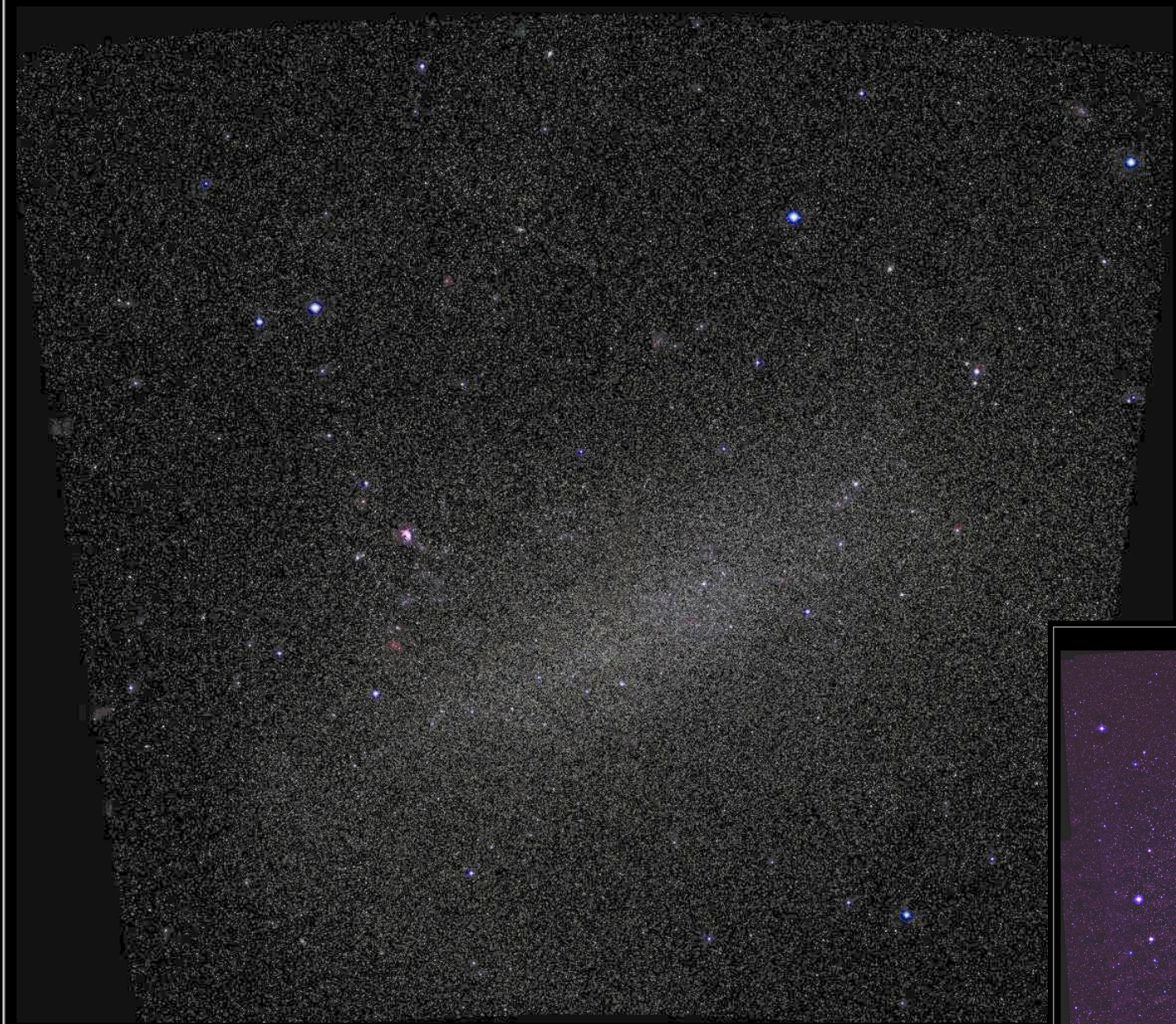


Photo: Esa, Eckhard Slawik



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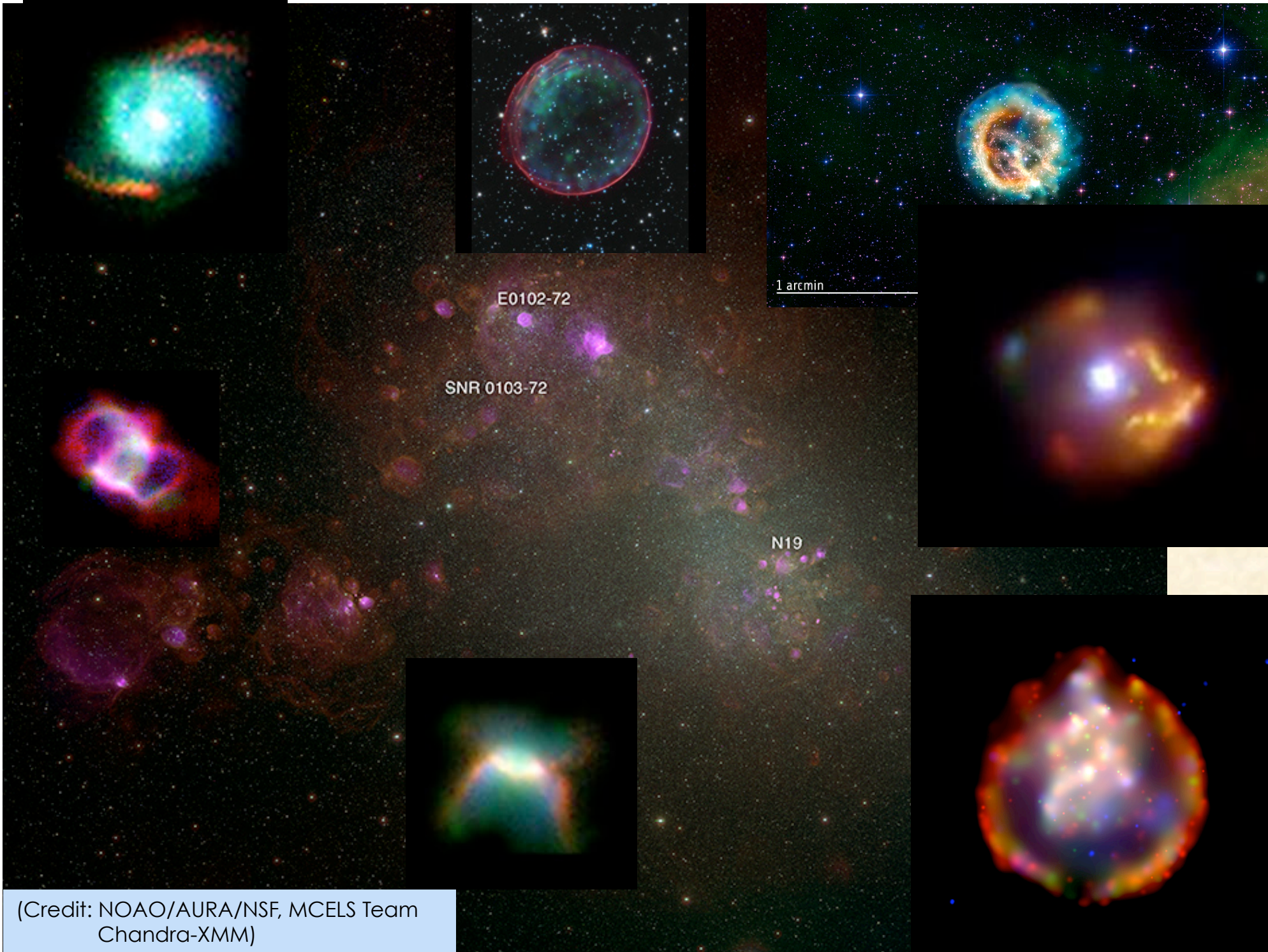


2MASS Two Micron All Sky Survey
- Southern Facility -
2MASS Atlas Image Mosaic
Infrared Processing and Analysis Center & University of Massachusetts

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

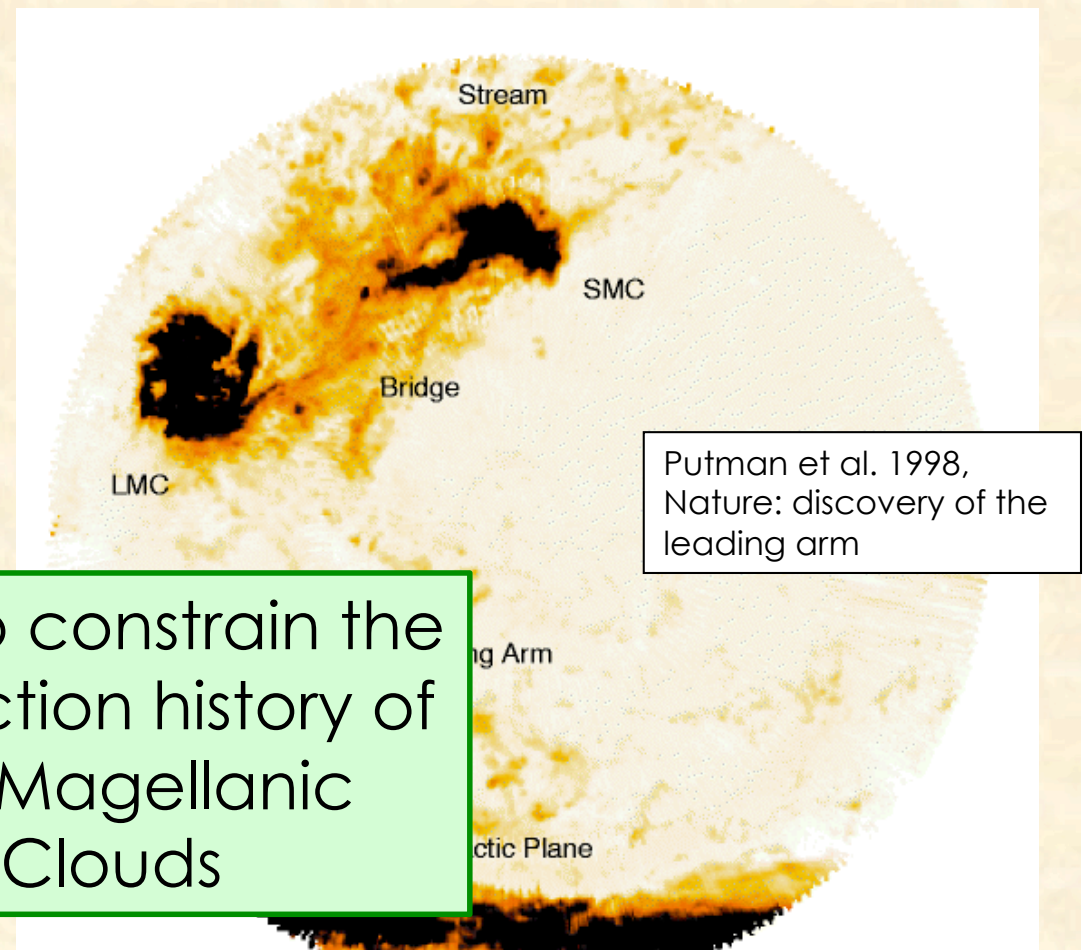
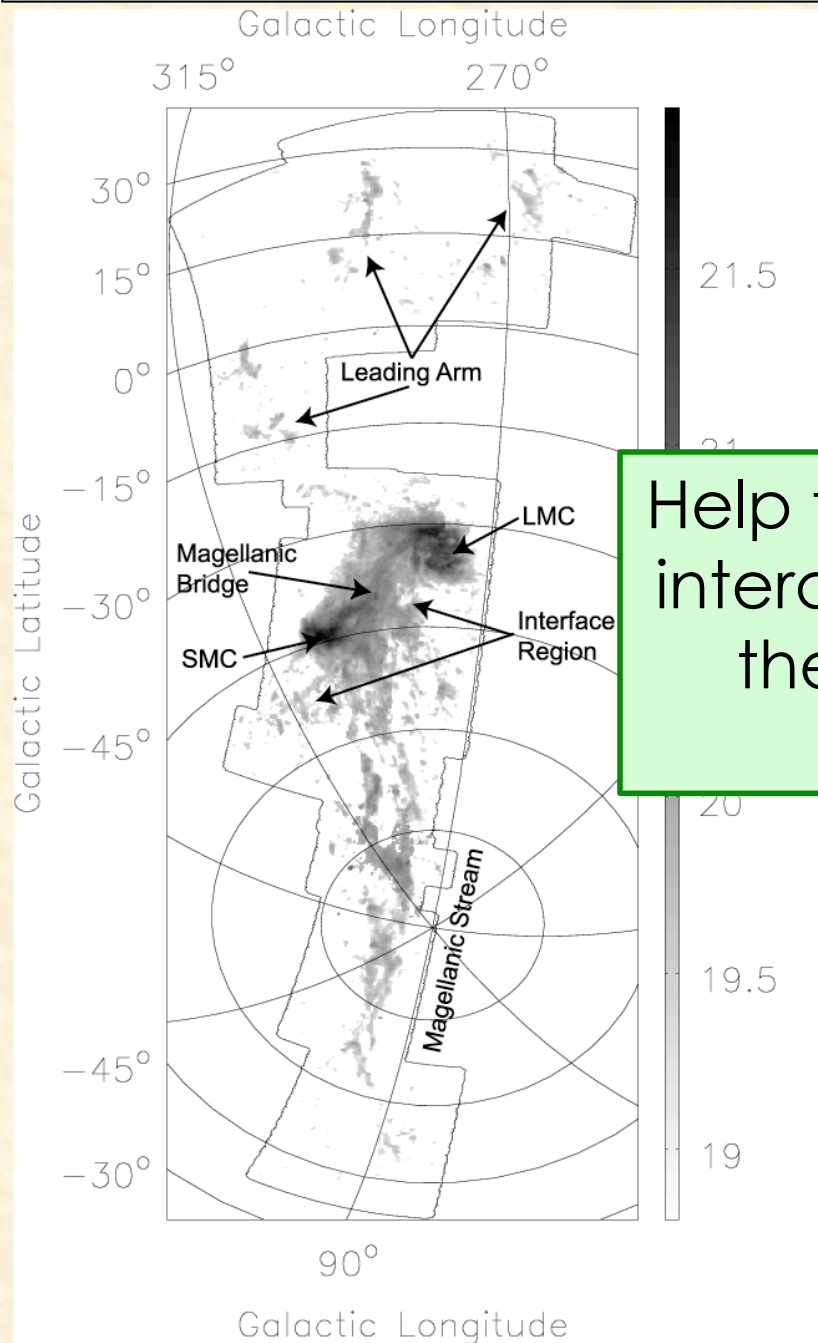






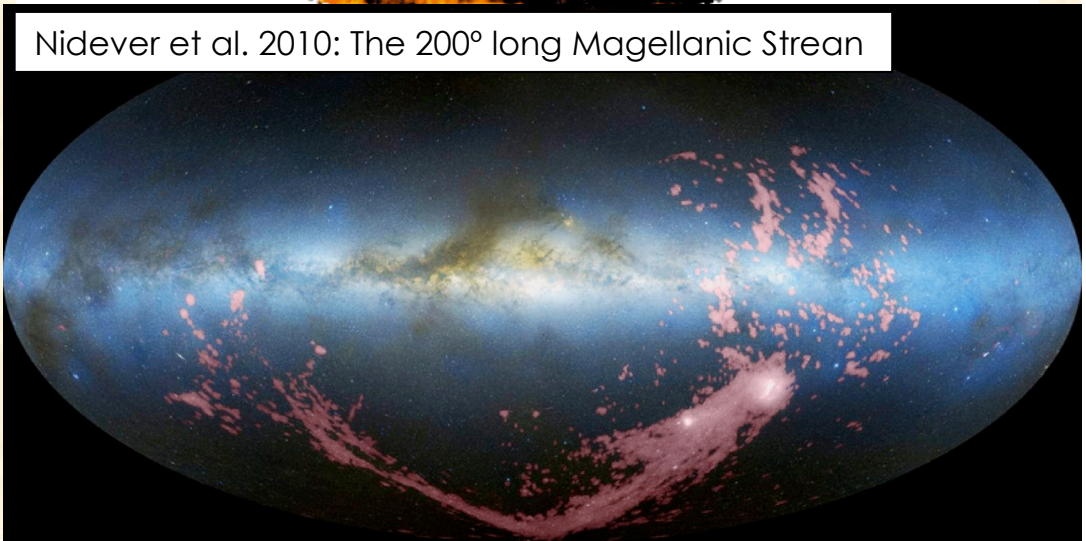
(Credit: NOAO/AURA/NSF, MCELS Team
Chandra-XMM)

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

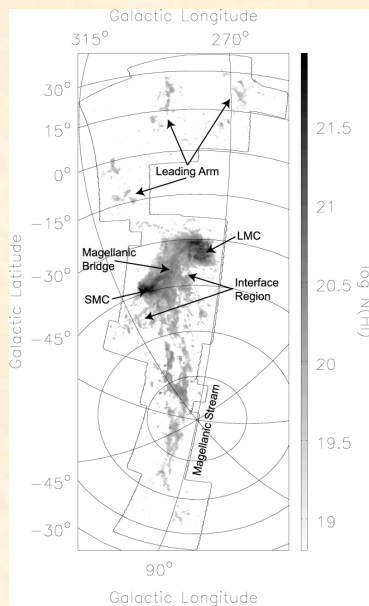


Putman et al. 1998,
Nature: discovery of the
leading arm

Help to constrain the
interaction history of
the Magellanic
Clouds



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



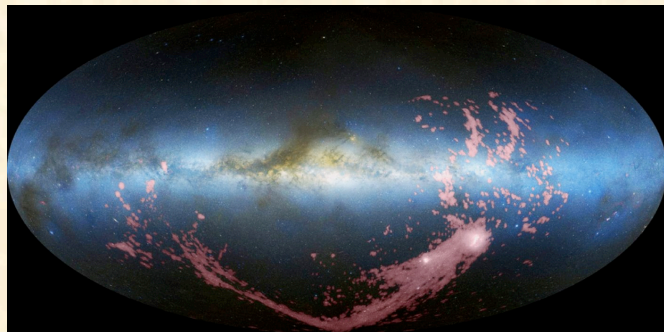
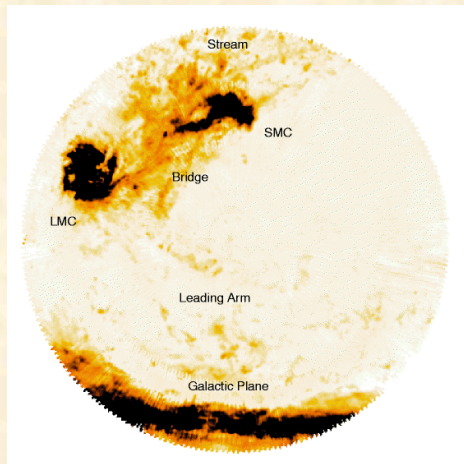
Traditionally, two main mechanisms for the formation of the Magellanic Stream:

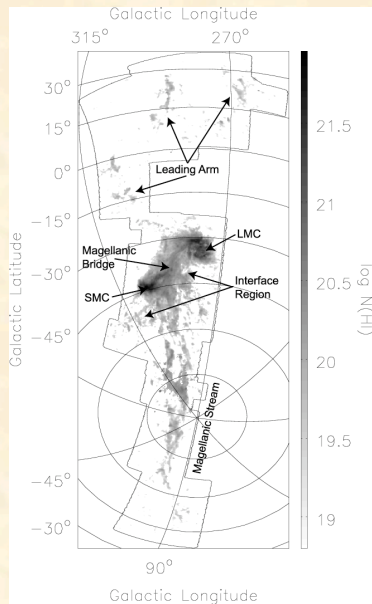
-Tidal interaction of the MCs with the MW (Murai & Fujimoto 1980, Gardiner & Noguchi 1996, Lin et al. 1995, Davies & Wright 1977, Lin & Lynden-Bell 1977)

-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.





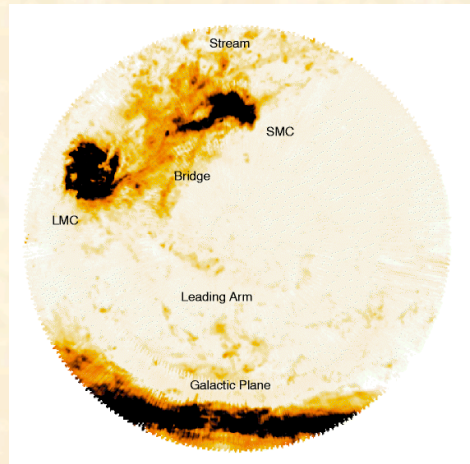
Very precise HST proper motions of LMC & SMC imply very large galactocentric velocities close to scape velocity:
 (Kallivayalil et al. 2006a,b, Piatek et al. 2008)

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



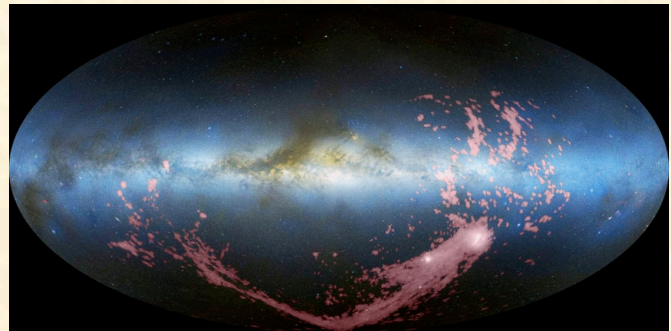
New generation of models demonstrating that repeated MCs-MW interactions are not mandatory.
 MS may originate in LMC-SMC interactions
 (Besla et al. 2010, Ružička et al, 2010, 2011; Diaz & Bekki 2011, 2012)
 [or blow-out from LMC hypothesis: Nidever et al. 2008]

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



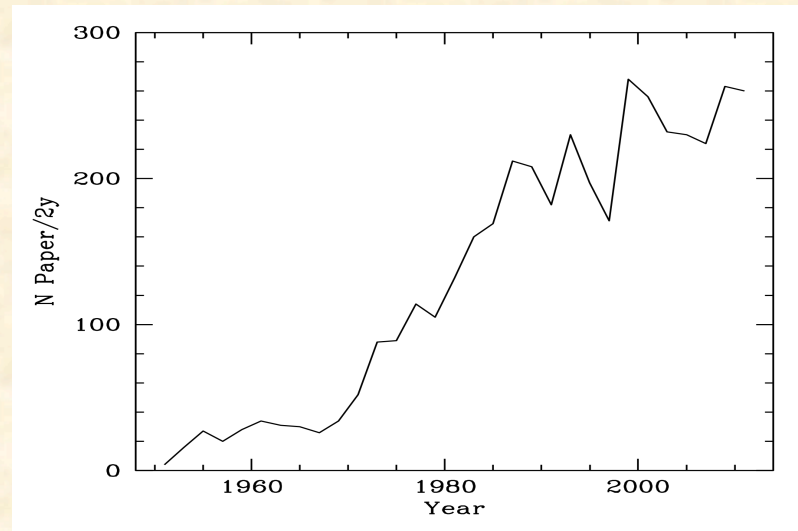
Possibilities opened by

- 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)



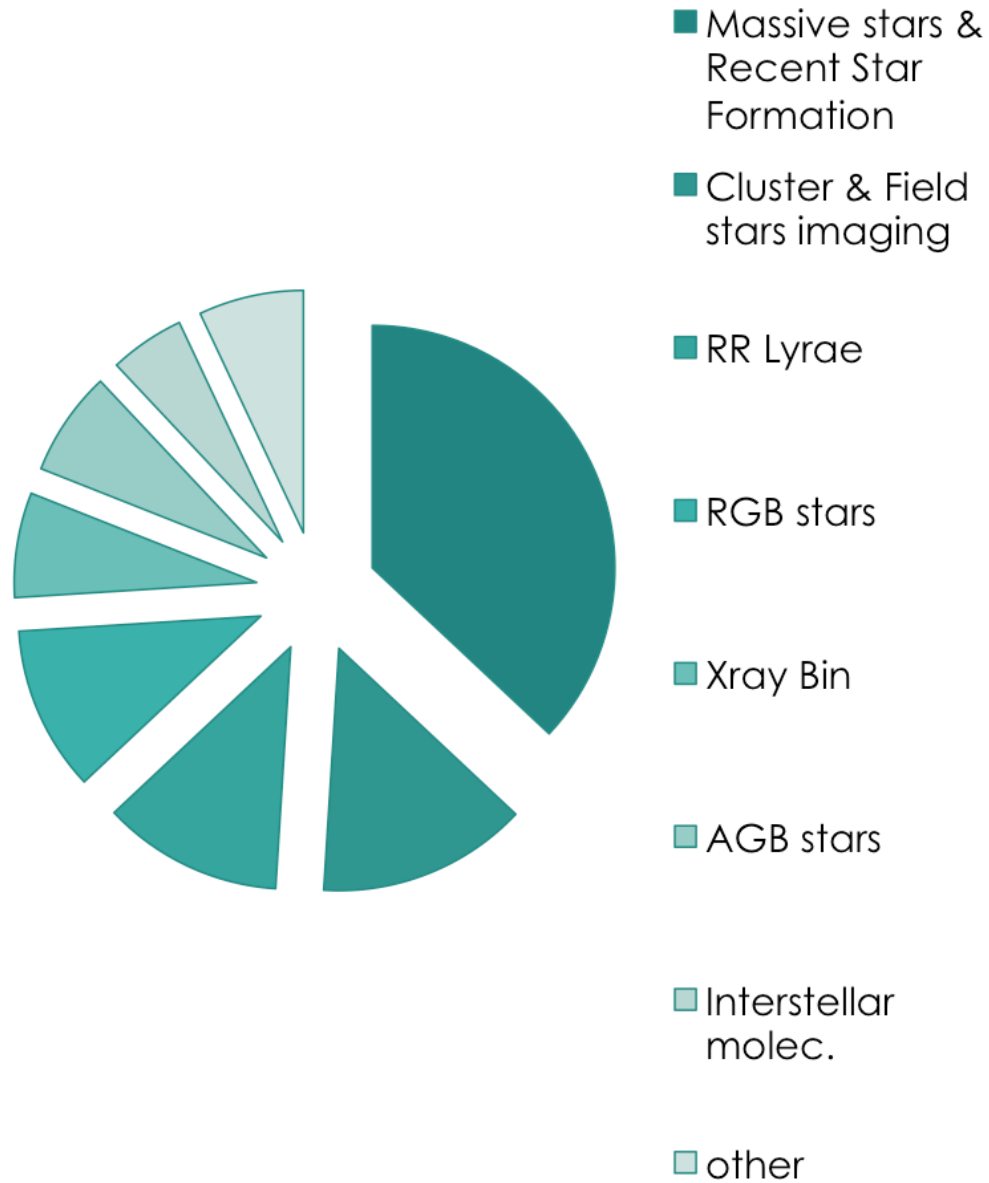
2.- LITERATURE ON THE MAGELLANIC CLOUDS

Literature on the Magellanic Clouds

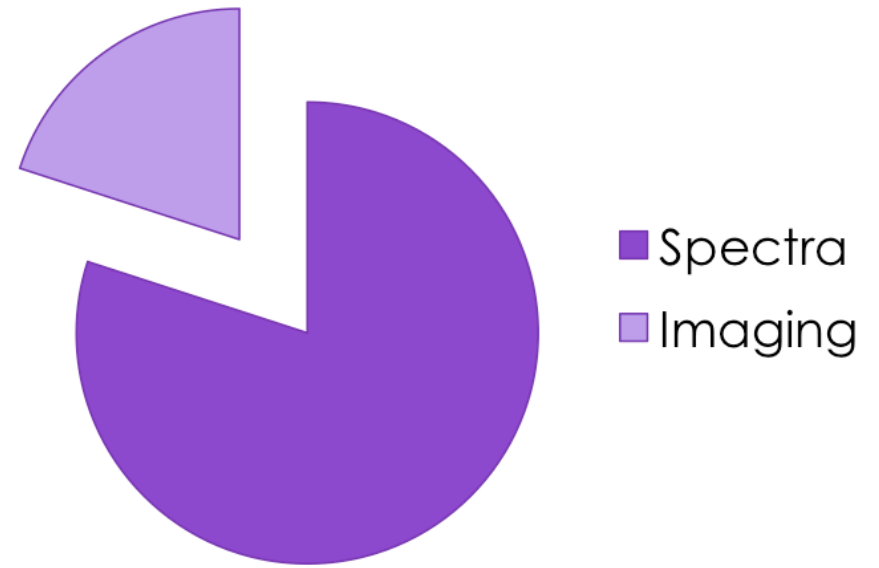


FACILITY	PAPERS (2002-2012)	CITATIONS (2002-2012)	AVERAGE CIT/paper
HST	144	3992	27.7
Spitzer	135	2749	20.4
ESO	109	3271	30.0
NOAO	68	1513	22.3
Magellan	23	442	19.0
XMM+Chandra	21	228	10.9
TOTAL	1058	21518	20.3

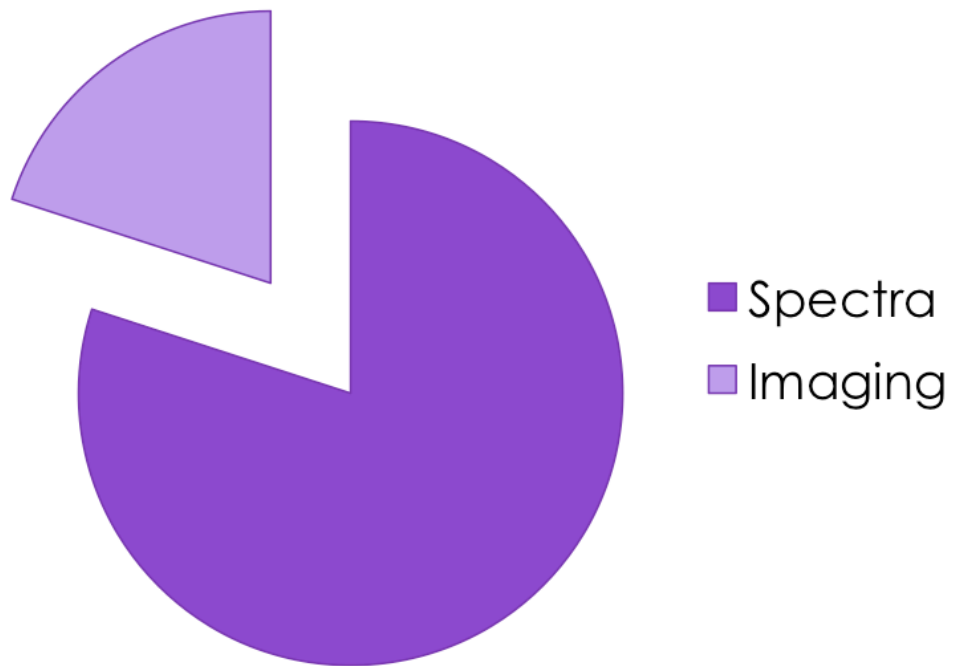
ESO CONTRIBUTIONS BY SUBJECT (2002-2012)



ESO CONTRIBUTIONS BY OBSERVING TECHNIQUE (2002-2012)



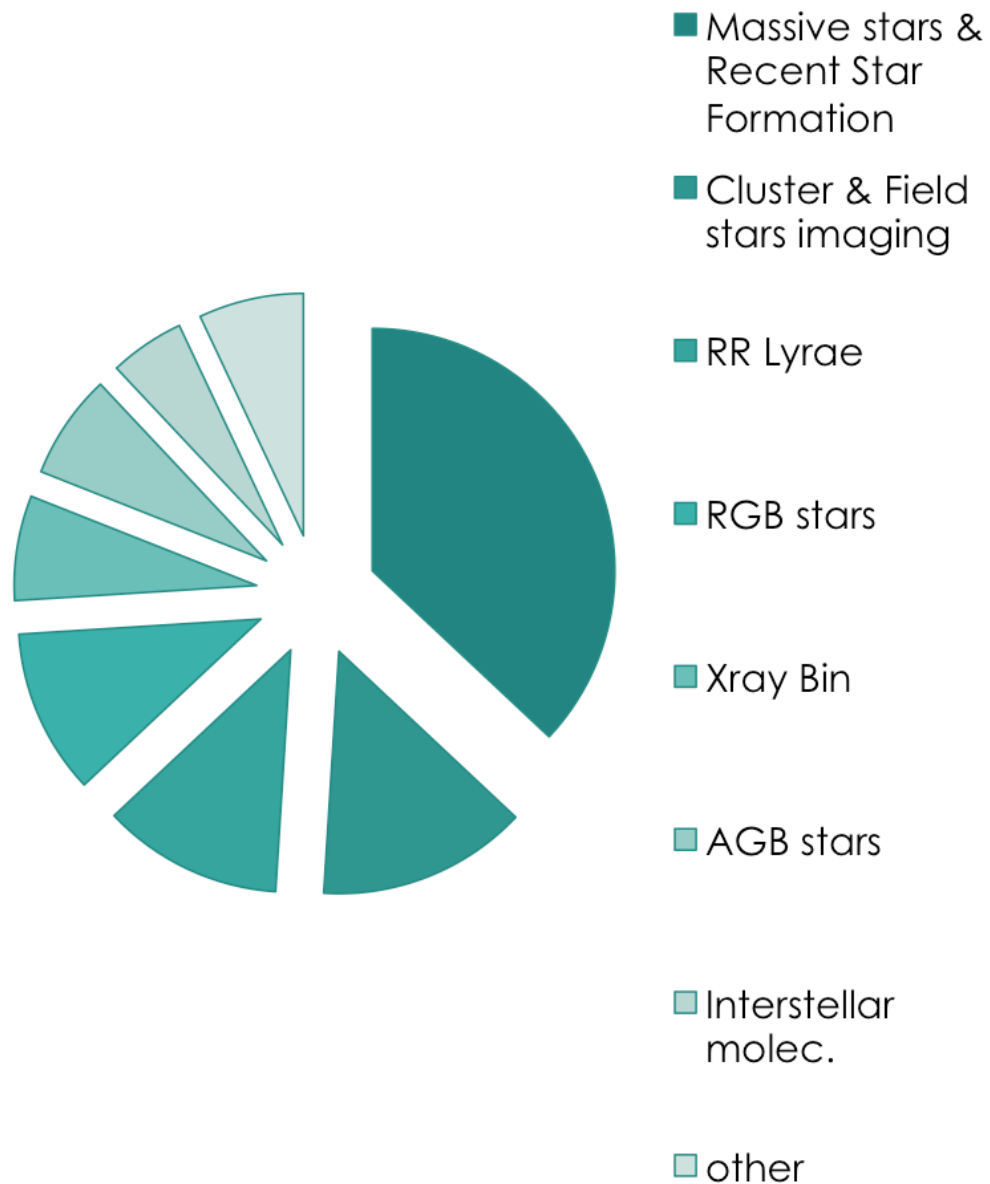
ESO CONTRIBUTIONS BY OBSERVING TECHNIQUE (2002-2012)



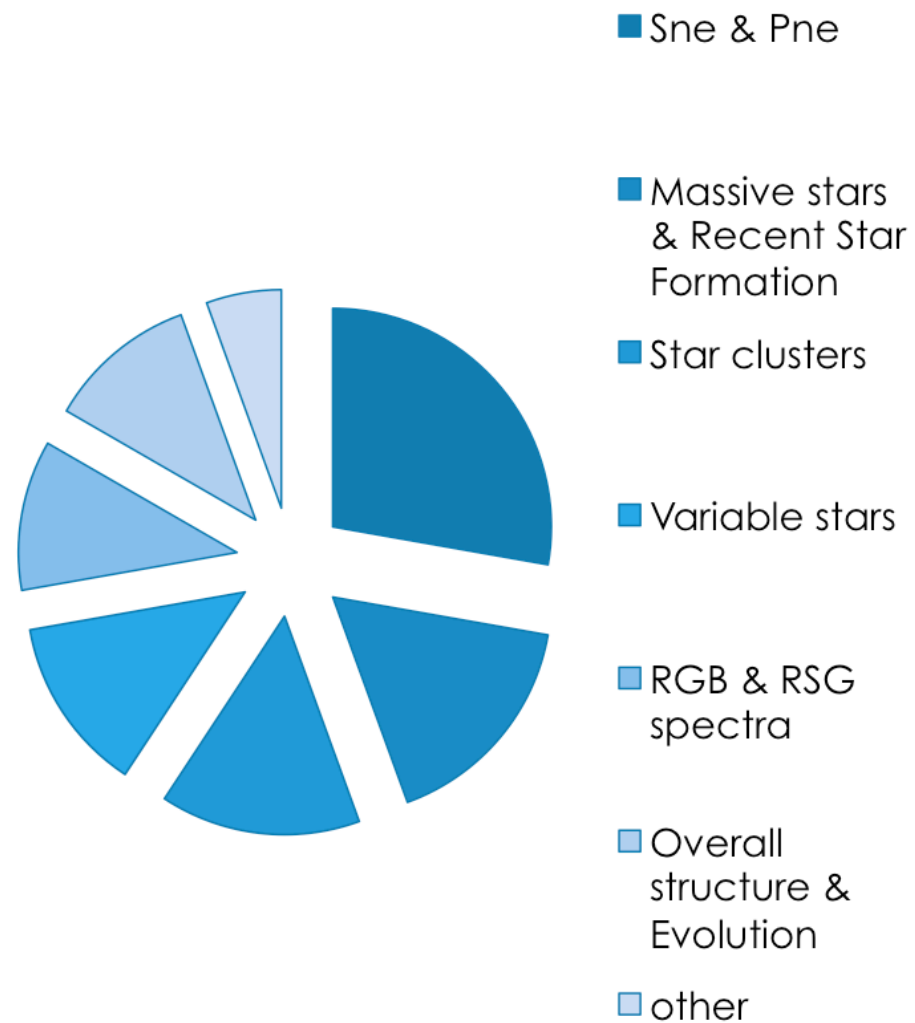
NOAO CONTRIBUTION BY OBSERVING TECHNIQUE



ESO CONTRIBUTIONS BY SUBJECT (2002-2012)



NOAO CONTRIBUTIONS BY SUBJECT (2002-2012)



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.

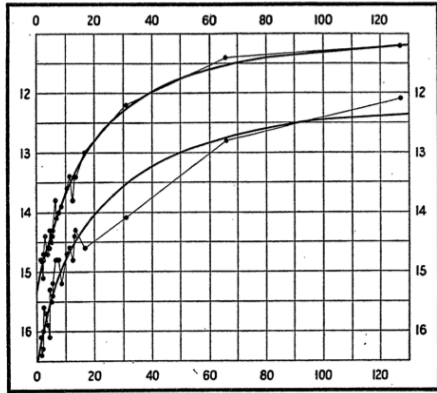


FIG. 1.

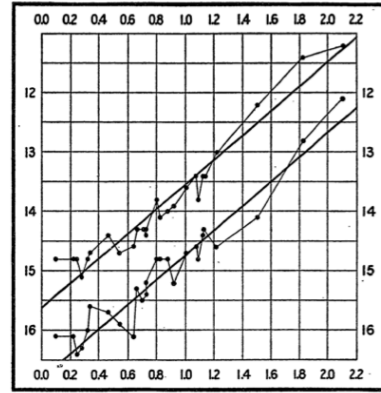
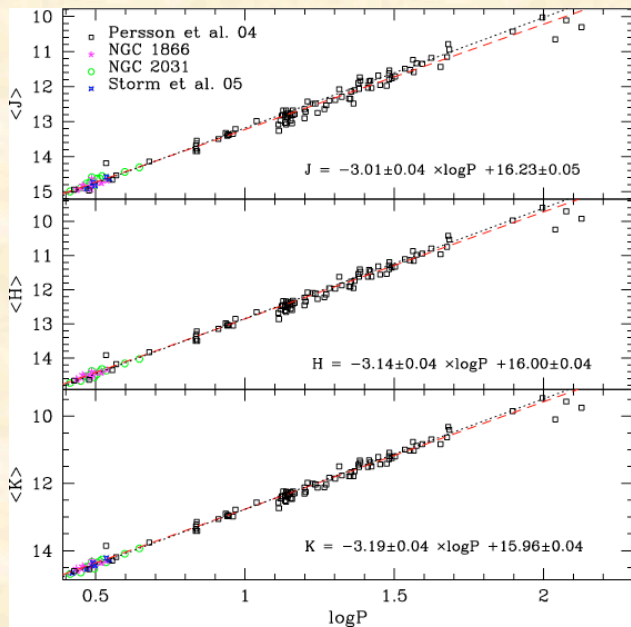
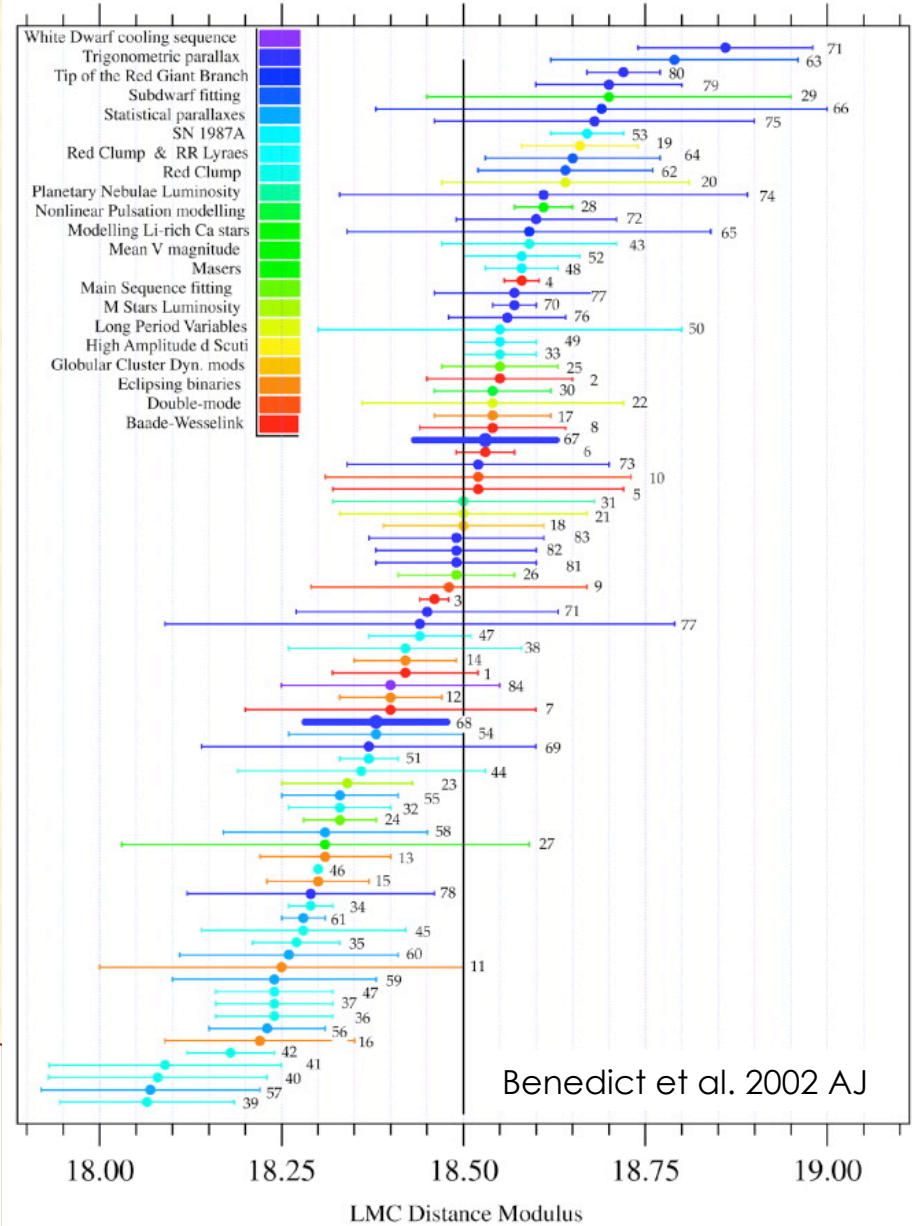


FIG. 2.



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.”

the flames survey of massive stars

[papers and results](#)

[download data](#)

[internal pages](#)

[flames 2: tarantula survey](#)

the vlt survey of massive stars in the galaxy and magellanic clouds

“The VLT-FLAMES Survey of Massive Stars was an ESO Large Programme to understand rotational mixing and stellar mass loss in different metallicity environments, in order to better constrain massive star evolution. We gathered high-quality spectra of over 800 stars in the Galaxy and in the Magellanic Clouds. A sample of this size is unprecedented, enabled by the first high-resolution, wide-field, multi-object spectrograph on an 8-m telescope. We developed spectral analysis techniques that, in combination with non-LTE, line-blanketed model atmospheres, were used to quantitatively characterise every star. The large sample, combined with the theoretical developments, has produced exciting new insights into the evolution of the most massive stars.” : [C.J. Evans et al., 2008, ESO Messenger March 2008, Vol. 131, p25](#)

🌟 We have now begun a second survey, again with approved ESO Large Programme status

- [The VLT-FLAMES Tarantula Survey](#)

The VLT-FLAMES Tarantula Survey

Index	VLT-FLAMES Tarantula Survey
Contacts	The VLT-FLAMES Tarantula Survey is a European Southern Observatory (ESO) Large Programme which has obtained spectroscopy of over 900 stars in the 30 Doradus region of the Large Magellanic Cloud (LMC). 30 Dor is our closest in the local universe, giving us a unique laboratory in which to study stellar and cluster evolution. It's a rich stellar population, containing the rare, short-lived evolutionary phases of the most massive stars.
Meetings	
Project pages [private]	
Tarantula Publications	The FLAMES survey has an unprecedented dataset of multi-epoch observations of the stellar content of 30 Dor. We aim to provide answers to fundamental questions such as the effects that stellar rotation has on the evolution of stars, how binarity affects stellar evolution, and to also study the gas and stellar dynamics in this intricate and beautiful cluster.
Tarantula Media Coverage	
FLAMES-I Publications	LATEST PAPERS: <ul style="list-style-type: none">• Paper VII: A low velocity dispersion for the young massive cluster R136 Hénault-Brunet et al. 2012, A&A, accepted, arXiv:1208.0825• Paper VI: Evidence for rotation of the young massive cluster R136 Hénault-Brunet et al. 2012, A&A, accepted, arXiv:1207.7071 Related HST projects: <ul style="list-style-type: none">• Proper motion study of 30 Dor (PI: Lennon), to investigate the 3D dynamics of the region and the nature of suspected massive stars.• A massive star census of the starburst cluster R136 (PI: Crowther), to obtain a complete survey of the dense cluster and to identify the hosts of some of the most massive stars in the local Universe.

“...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](https://doi.org/10.1088/2041-8205/728/2/L43)

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

S. CASSISI¹ AND M. SALARIS²

THE ASTROPHYSICAL JOURNAL, 728:93 (16pp), 2011 February 20

doi:[10.1088/0004-637X/728/2/93](https://doi.org/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

BENJAMIN A. SARGENT¹, S. SRINIVASAN², AND M. MEIXNER¹

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doi:[10.1088/0004-637X/728/2/93](https://doi.org/10.1088/0004-637X/728/2/93)

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BENJAMIN A. SARGENT¹, S. SRINIVASAN², AND M. MEIXNER¹

THE ASTRONOMICAL JOURNAL, 125:742–753, 2003 February

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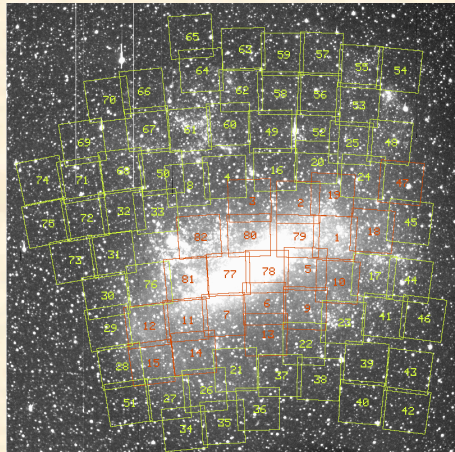
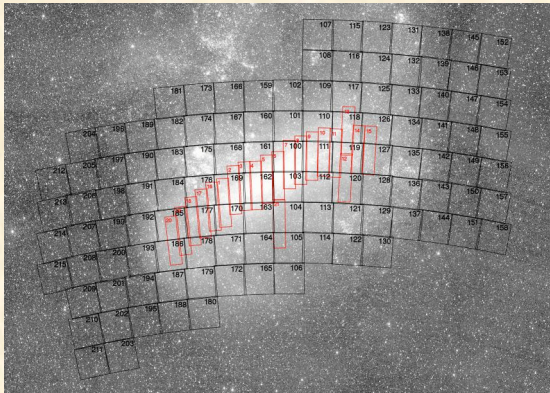
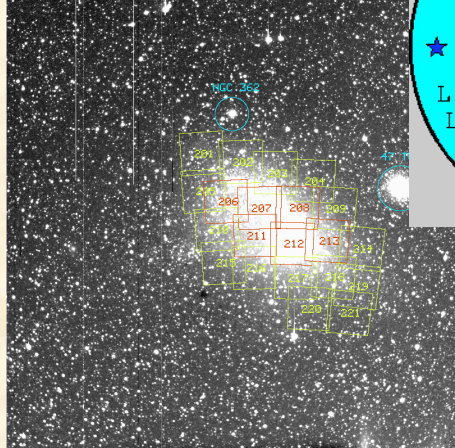
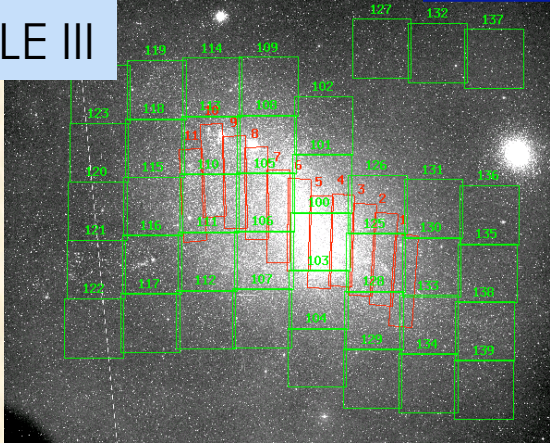
TESTING INTERMEDIATE-AGE STELLAR EVOLUTION MODELS WITH VLT PHOTOMETRY OF LARGE MAGELLANIC CLOUD CLUSTERS. I. THE DATA¹

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 YI¹⁰

The Magellanic Clouds and the microlensing experiments

OGLE

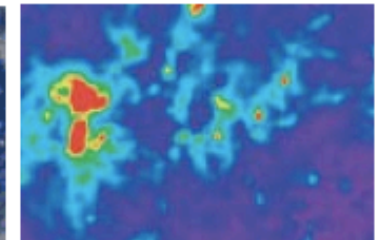
OGLE III



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



Surveying the Agents of Galaxy Evolution (SAGE)



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

Surveying the life-cycle of observable matter in the Magellanic Clouds and the Magellanic Bridge (SAGE-SMC) in addition to Spitzer spectroscopy of the dust composition in the Large Magellanic Cloud (SAGE-Spec 30 Doradus) and Small Magellanic Cloud (SAGE-Spec 30 Doradus) and the Herchel Space Observatory (SAGE-HERITAGE) of Galaxy Evolution. This is a fundamental project for the understanding of the relation between star formation and the evolution of galaxies. SAGE is a source of information for the community (e.g., KINGFISH) and a stepping stone to the deep surveys (e.g., GOODS & SWIRE).

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.

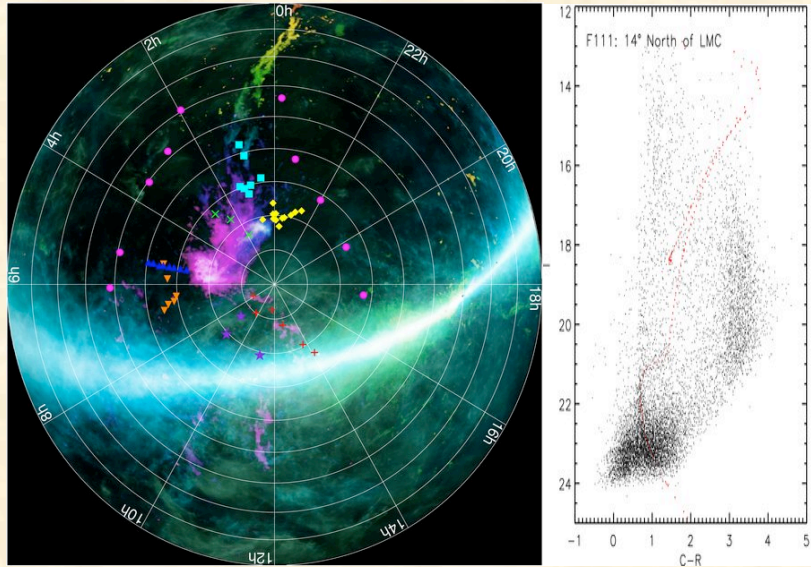
SAGE-LMC, SAGE-SMC and SAGE-Spec are legacy projects using the Spitzer Space Telescope. 30 Doradus is an open time program. SMC-Spec is a guaranteed time program. HERITAGE is an open time key programme using the Herschel Space Observatory.

4.- STRUCTURE AND EVOLUTION OF THE MAGELLANIC CLOUDS

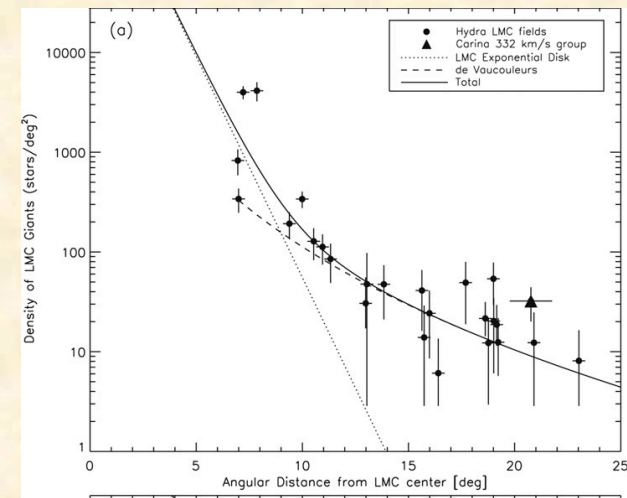
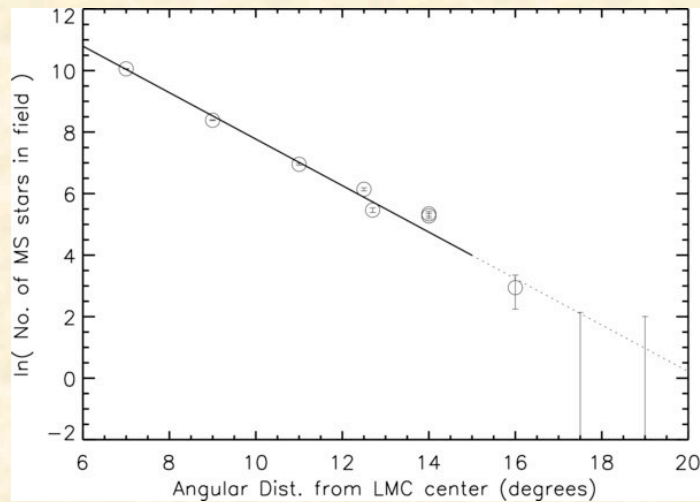
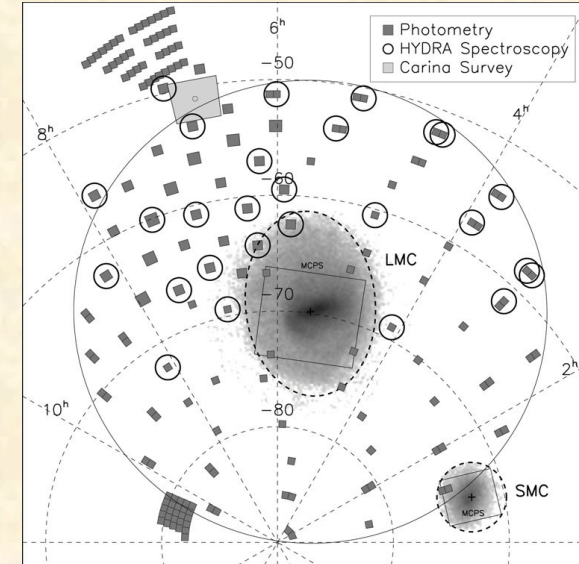
-

Spatial extent of the Large Magellanic Cloud

traced by dwarfs below the α MSTO



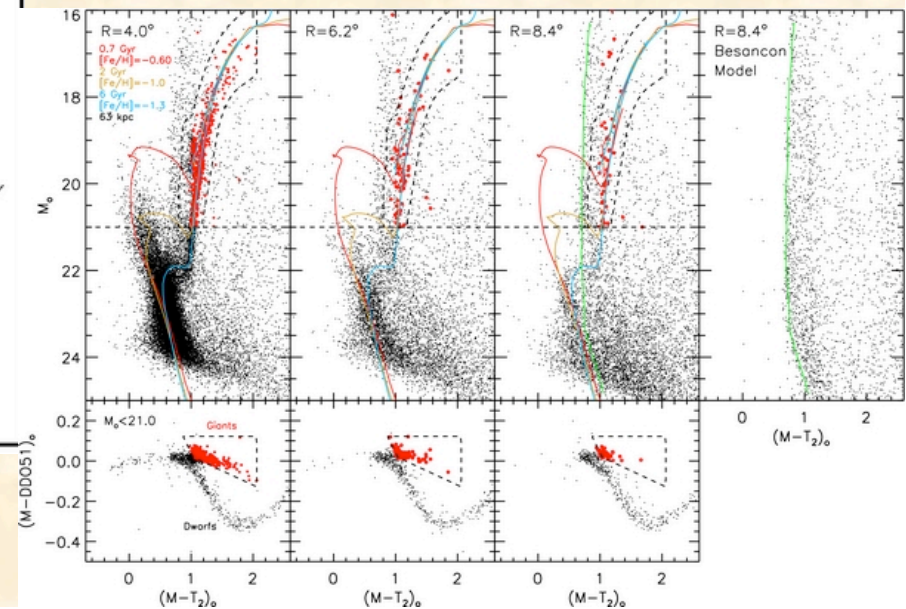
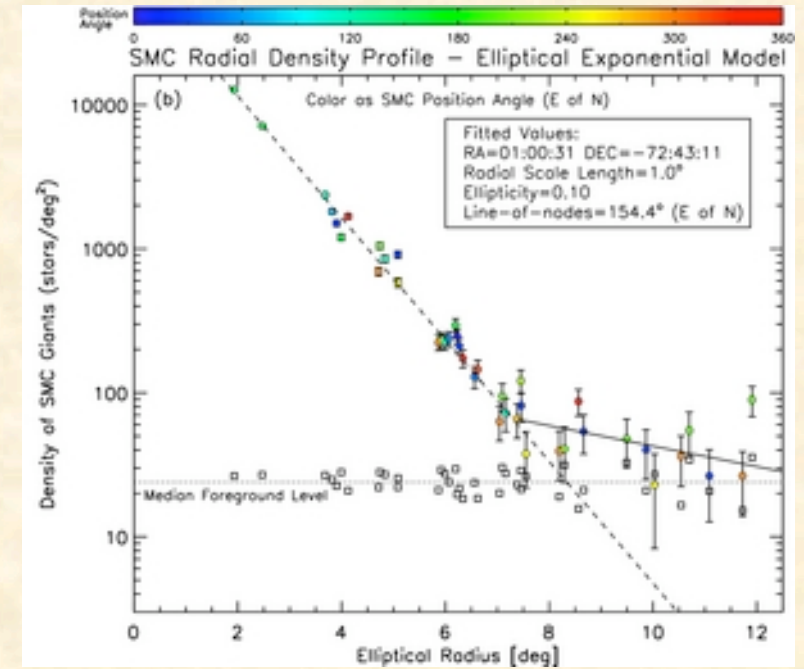
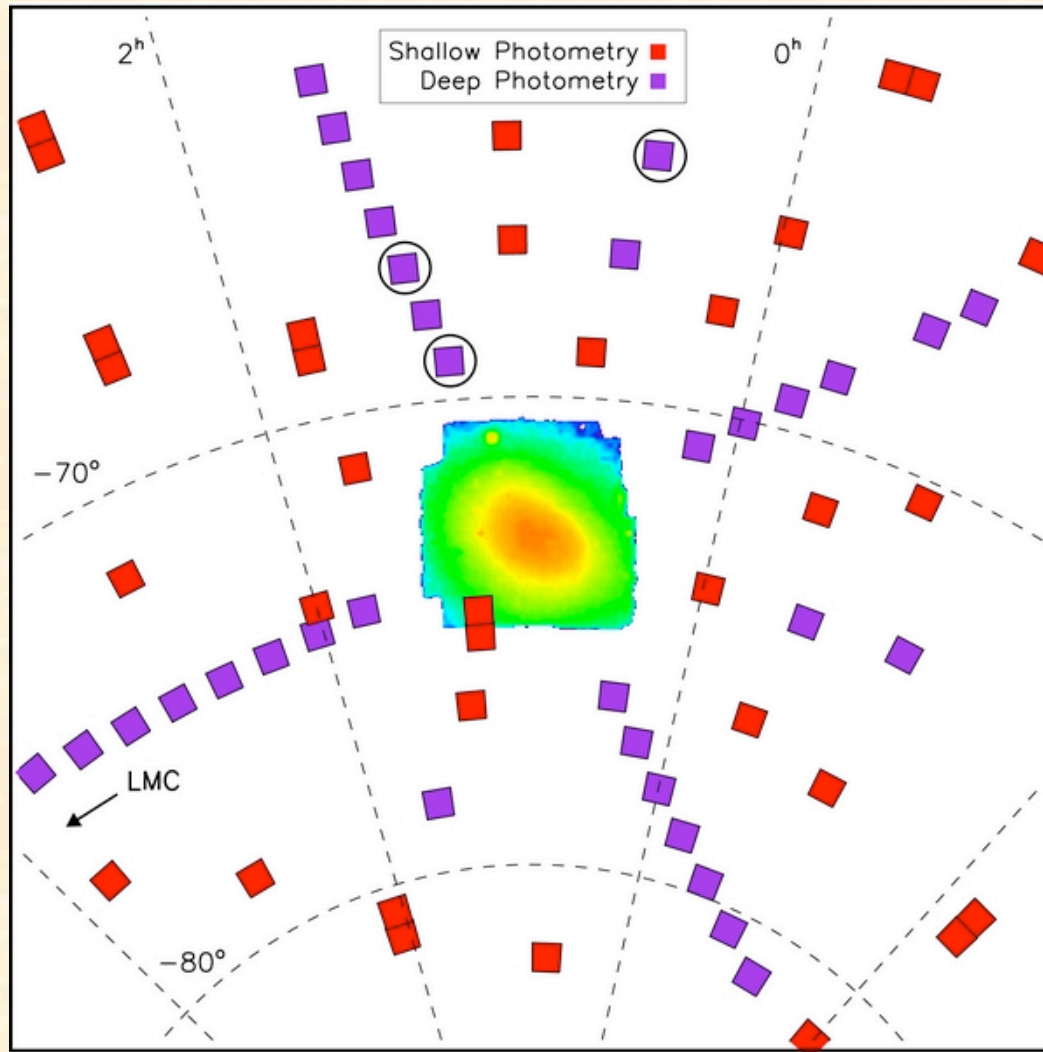
traced by spec. confirmed RGB stars



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

Majewski et al. 2009, IAUS 256

Spatial extent of the Small Magellanic Cloud

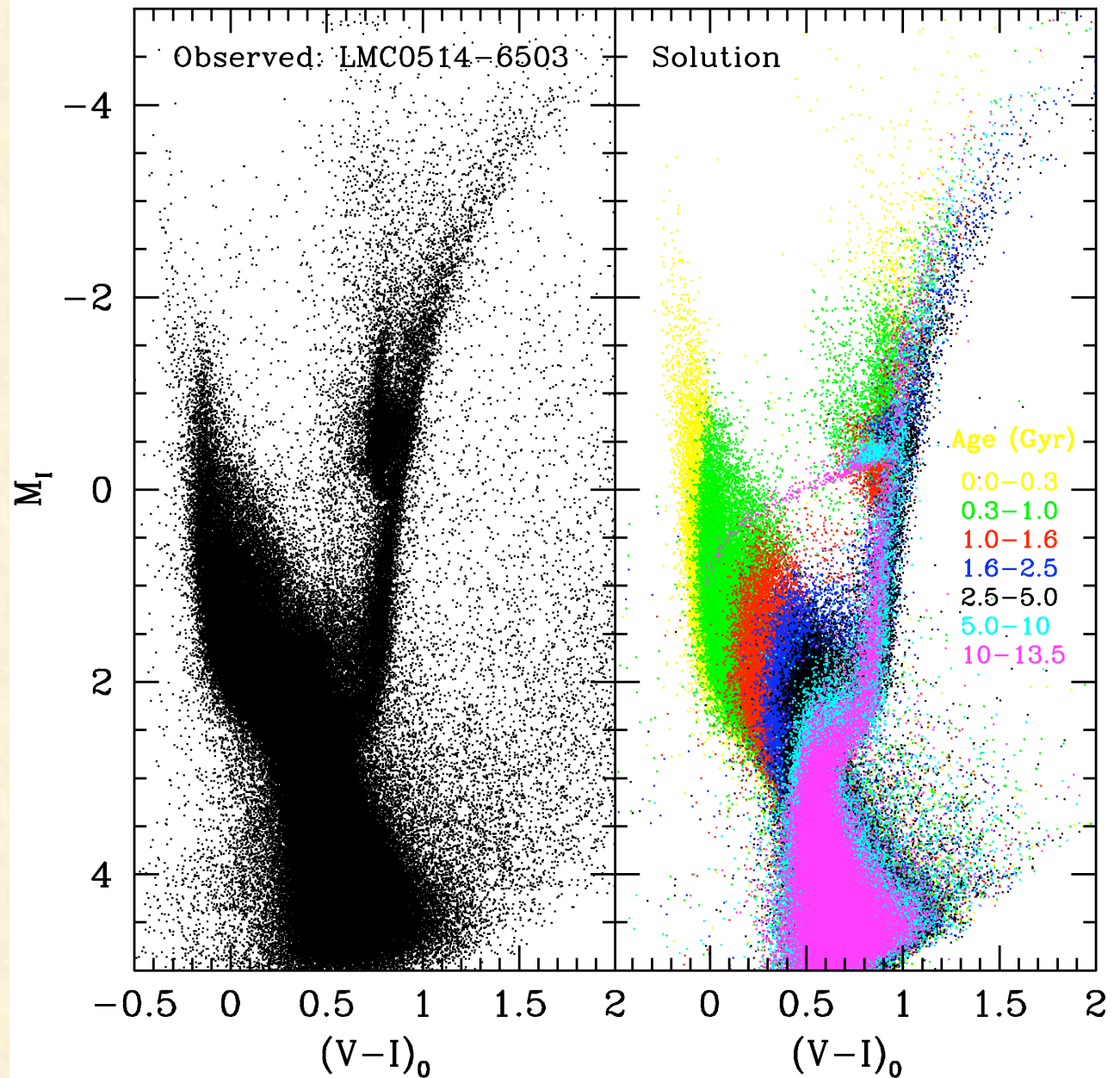


Nidever et al. 2011, ApJLett

The star formation history of the Magellanic Clouds

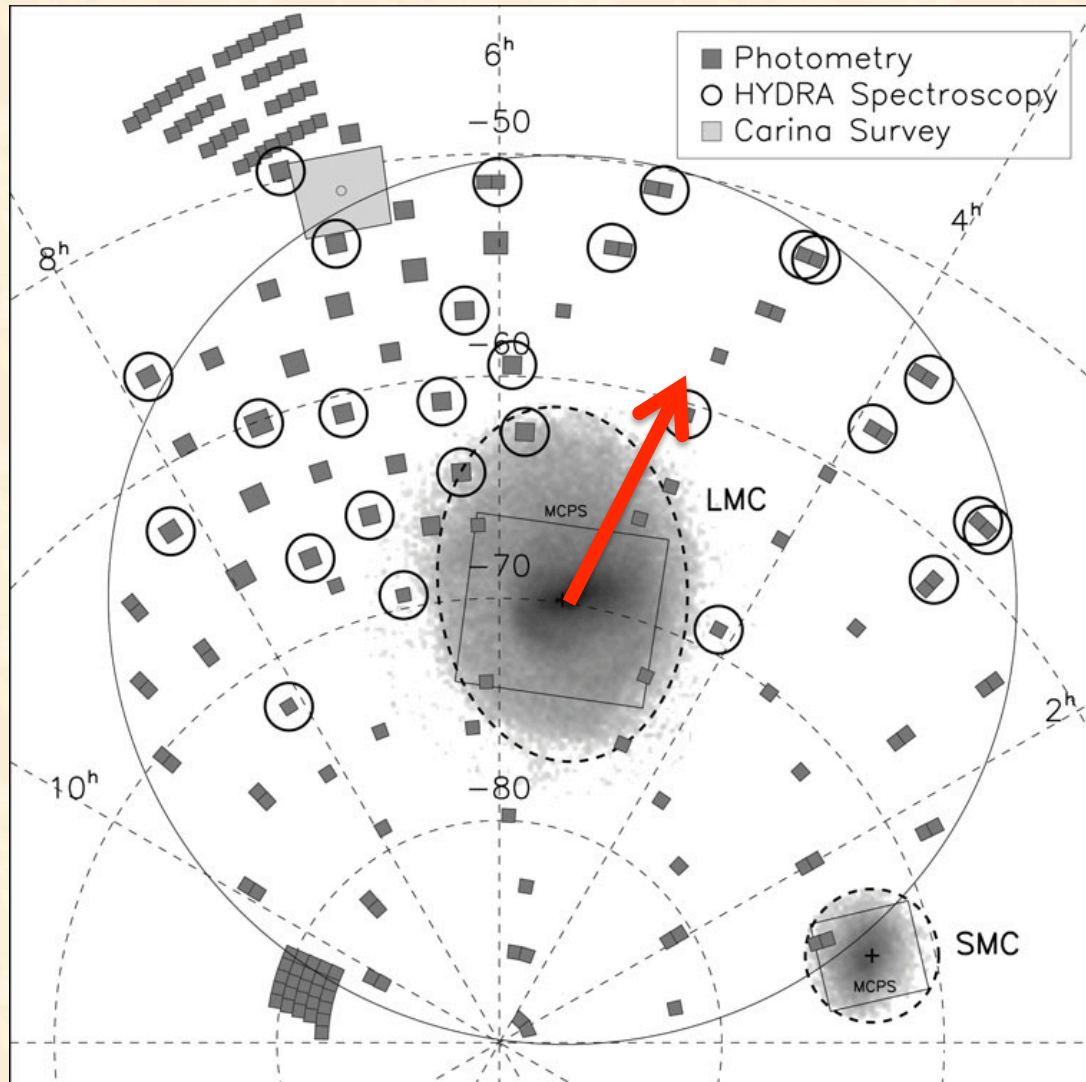
Thanks to their proximity, the Magellanic Clouds are ideal systems to obtain their SFHs in detail.

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.

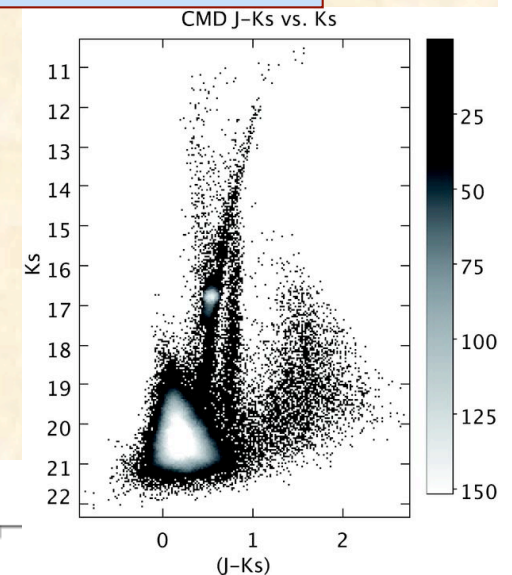


To cover a (conservative) area of radius=12 degrees in the LMC, ≈ 1300 images with a typical 35'x35' wide field imager are necessary (1h/image) ≈ 160 nights

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



& STEP@VST

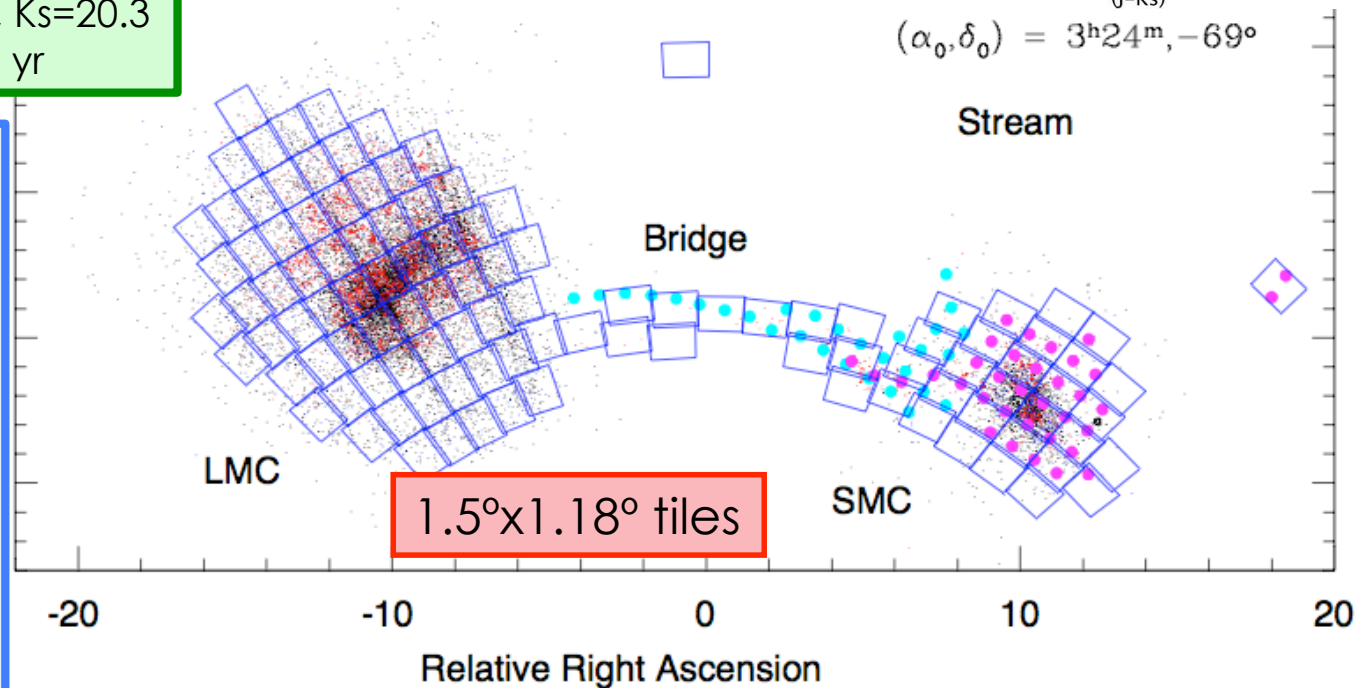


VMC:

-184 sq. deg. to $Y=21.9$, $J=21.4$, $K_s=20.3$
-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



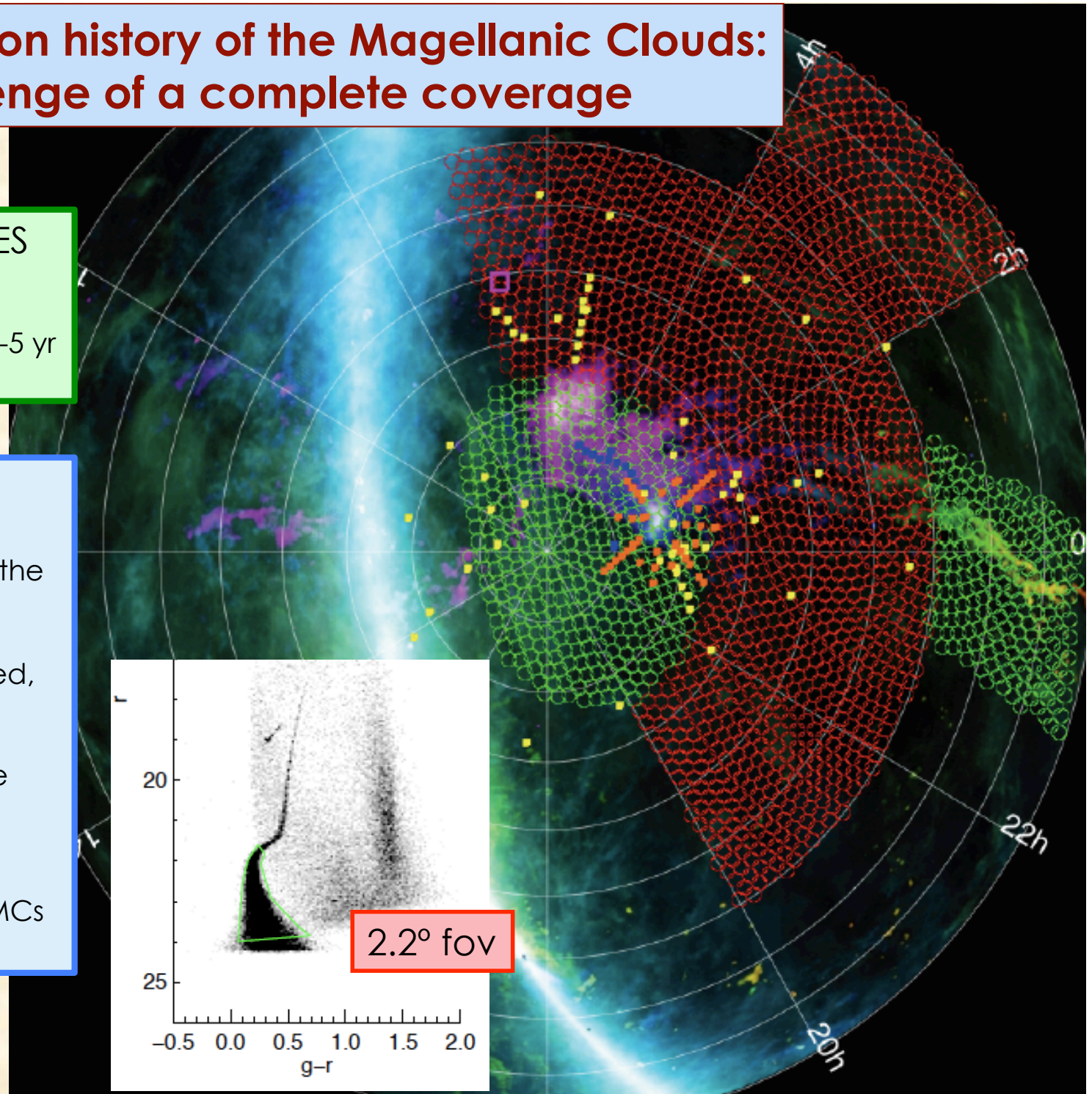
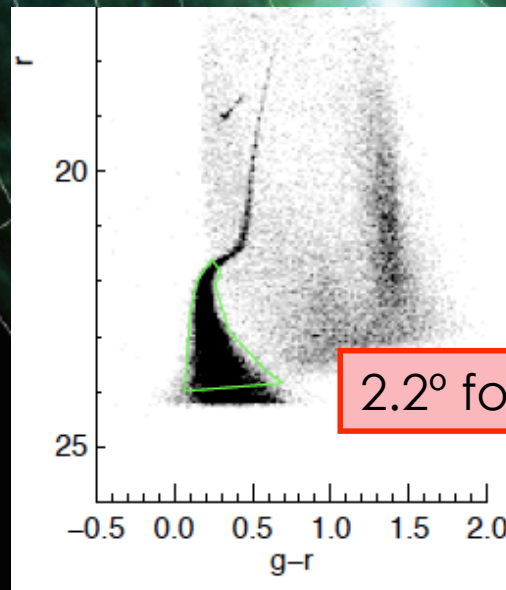
The star formation history of the Magellanic Clouds: the challenge of a complete coverage

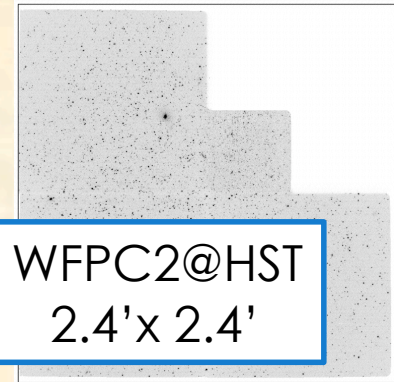
MCs extension of DES

- 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.

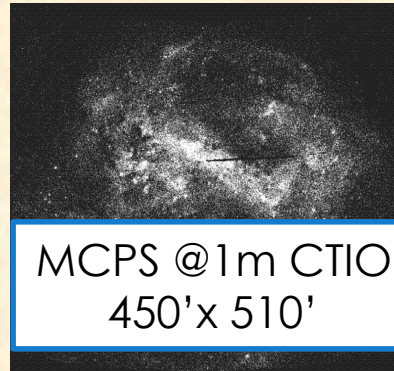




WFPC2@HST
2.4' x 2.4'

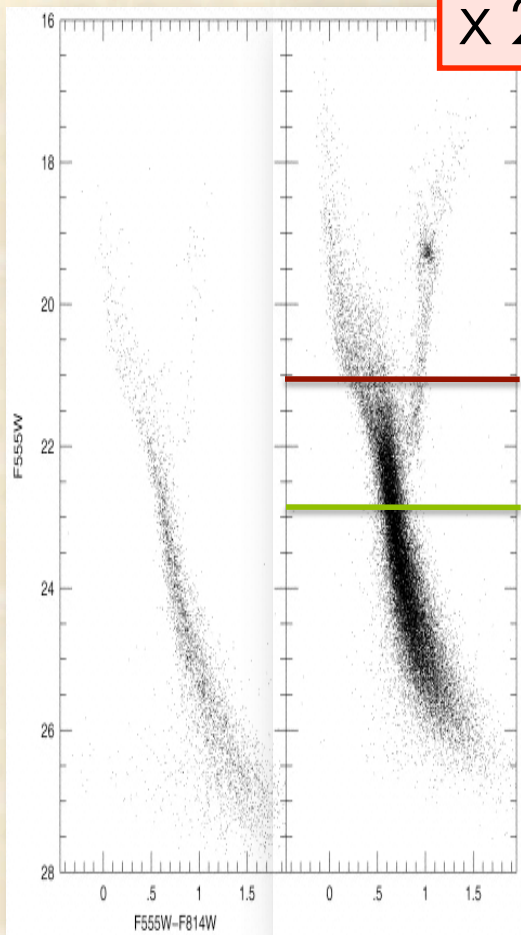


WFI@2.2mESO
MOSAIC@4mCTIO
35' x 35'

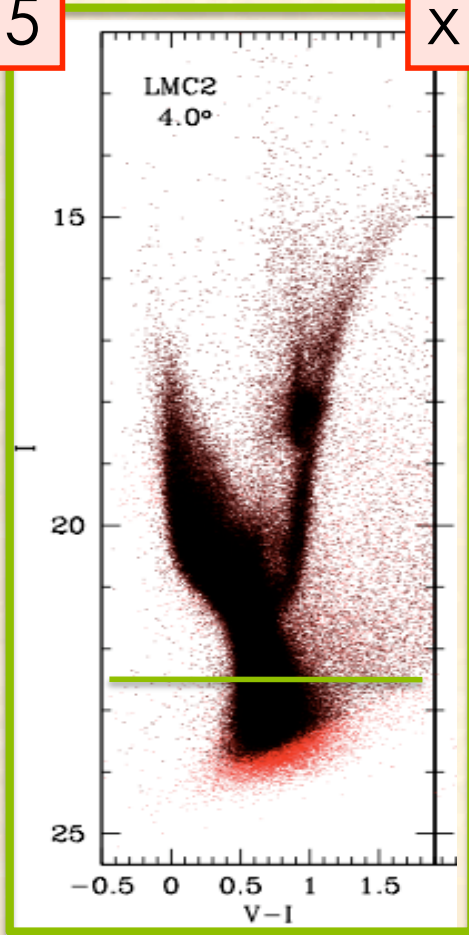


MCPS @1m CTIO
450' x 510'

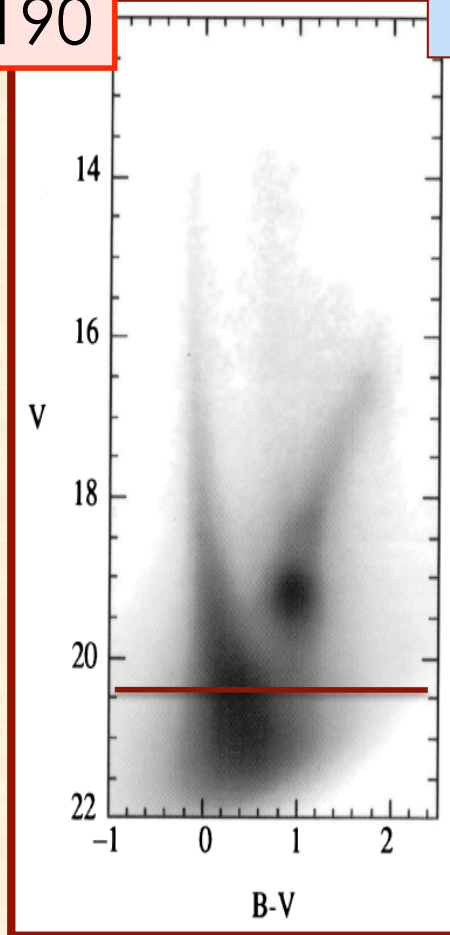
The star formation history of the Magellanic Clouds: steps of different size



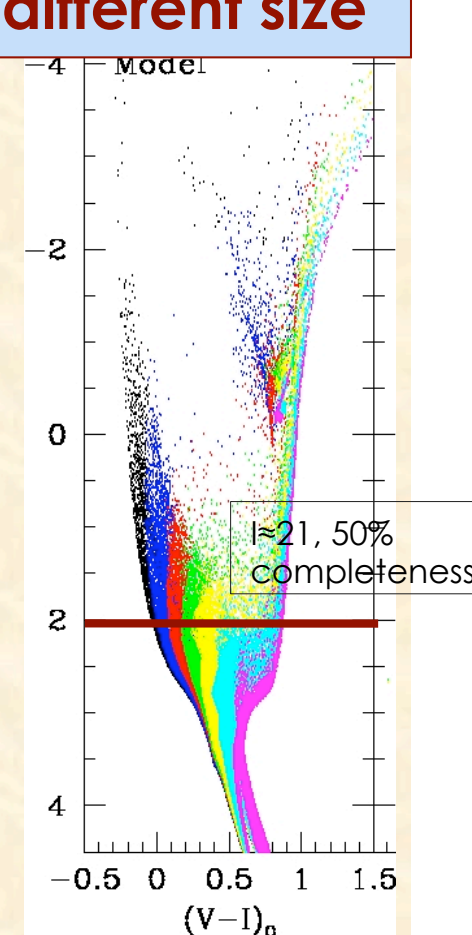
Holtzman et al. 1999



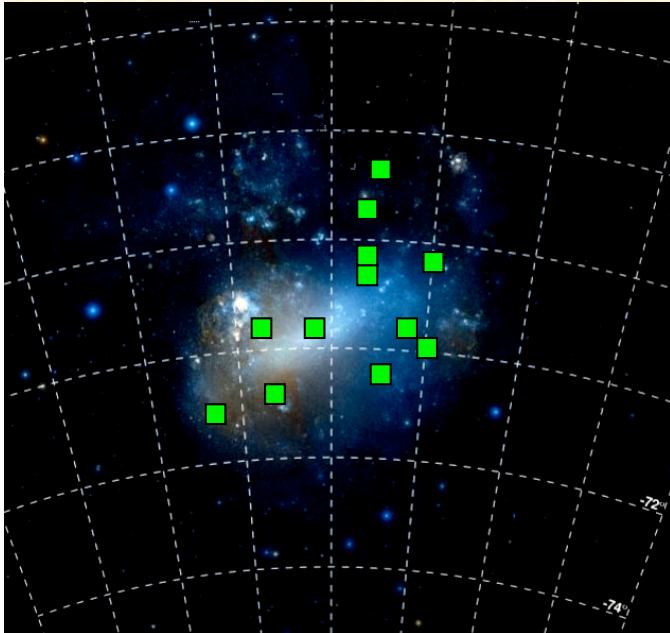
Gallart et al. 2008



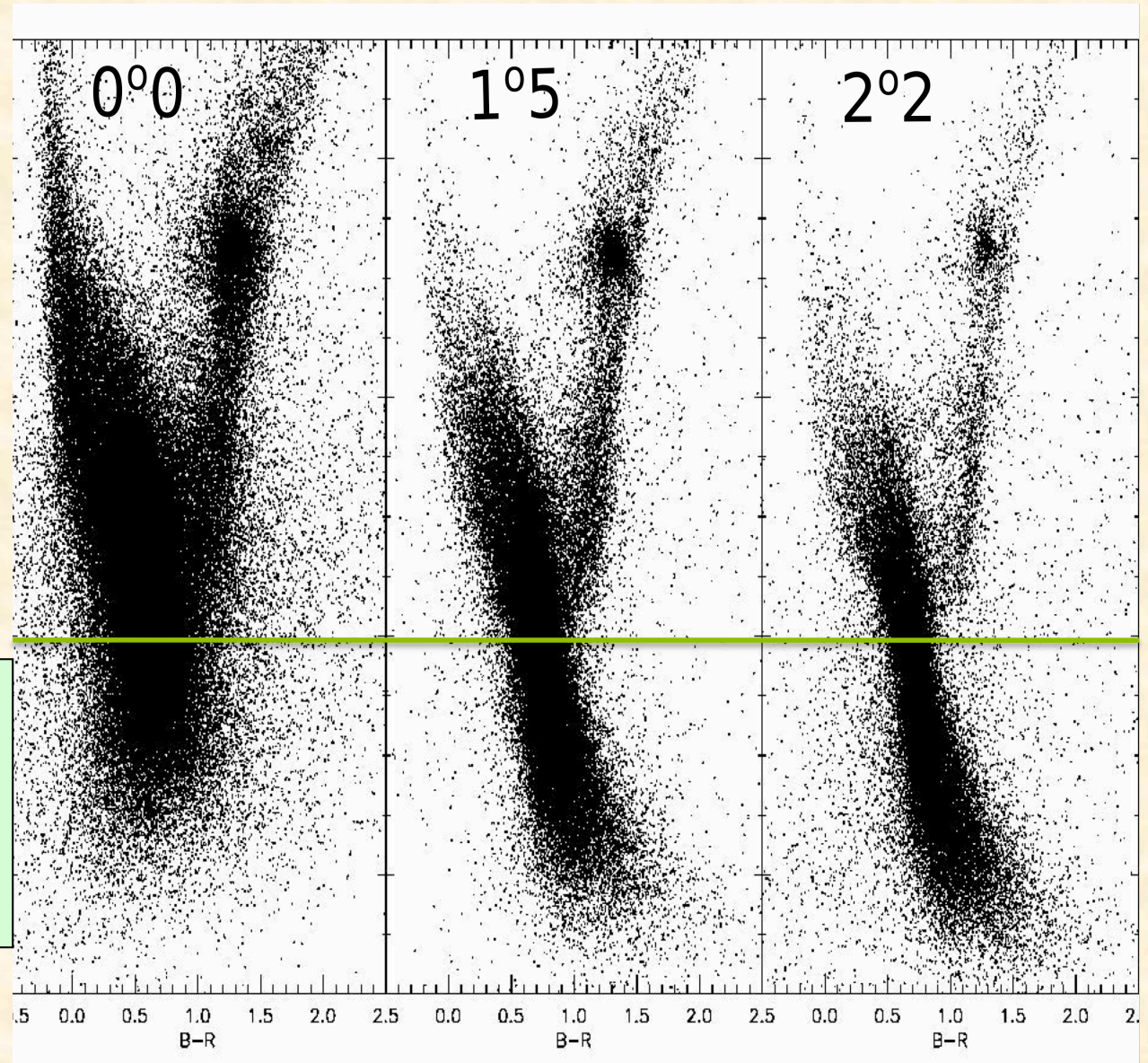
Zaritsky et al. 1997

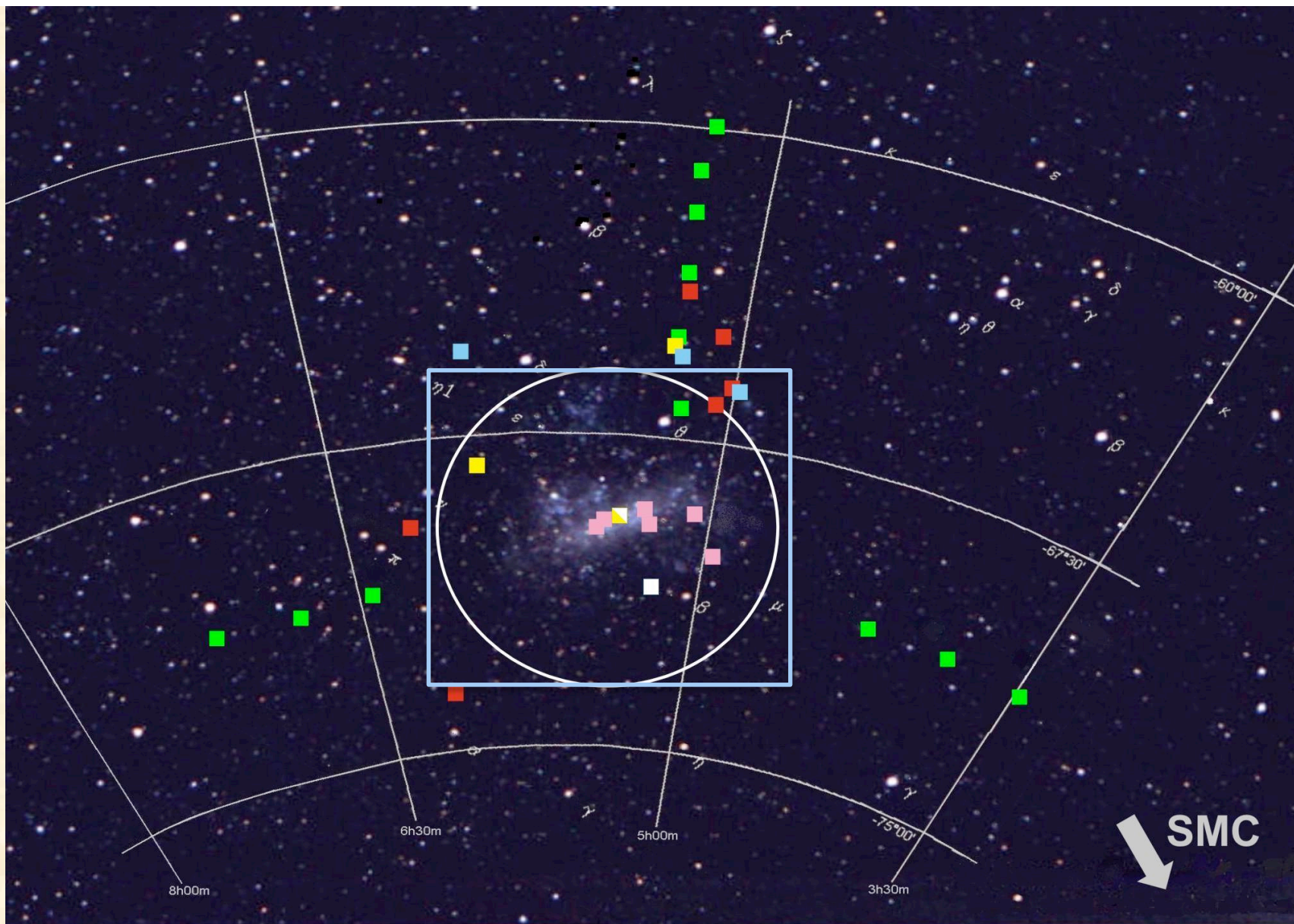


The star formation history of the Magellanic Clouds: oMSTO in the bar from the ground?



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

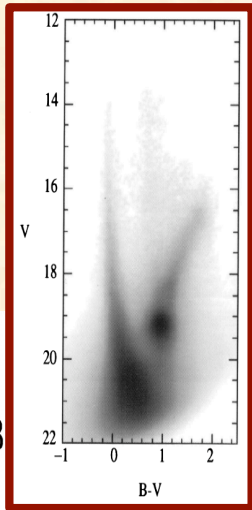




- Bertelli et al. (1992)
- Holtzman et al. (1999)
- Olsen (1999)
- Smecker-Hane et al. (2002)
- Javiel et al. (2005)
- Nuestros campos

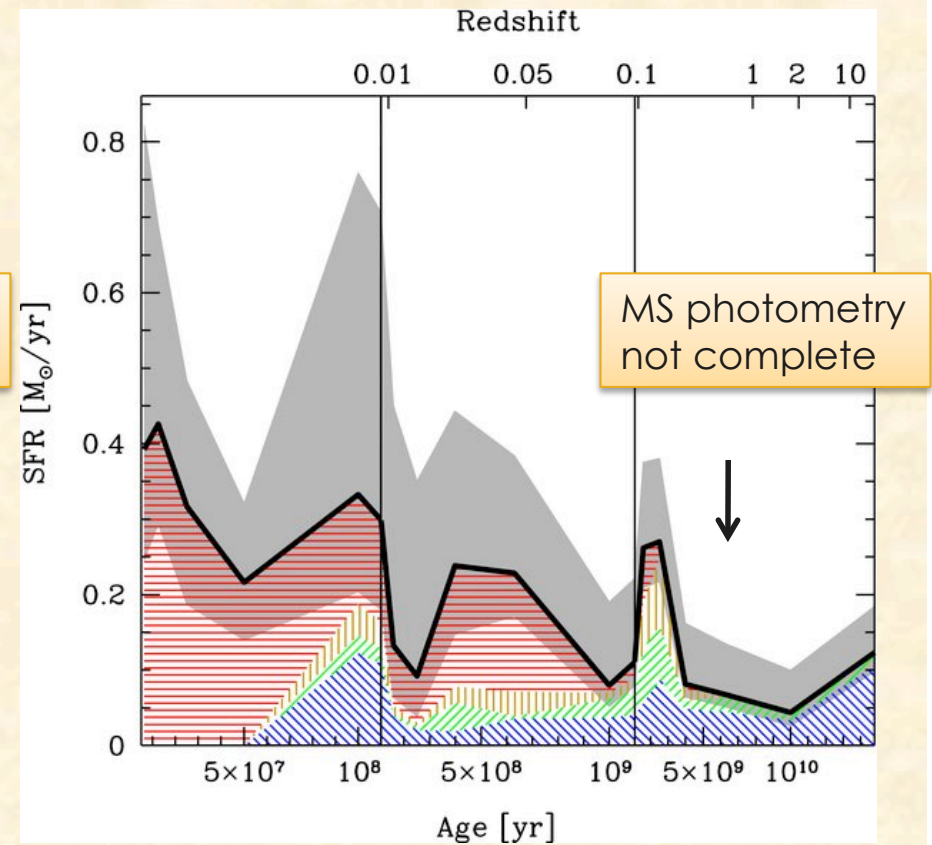
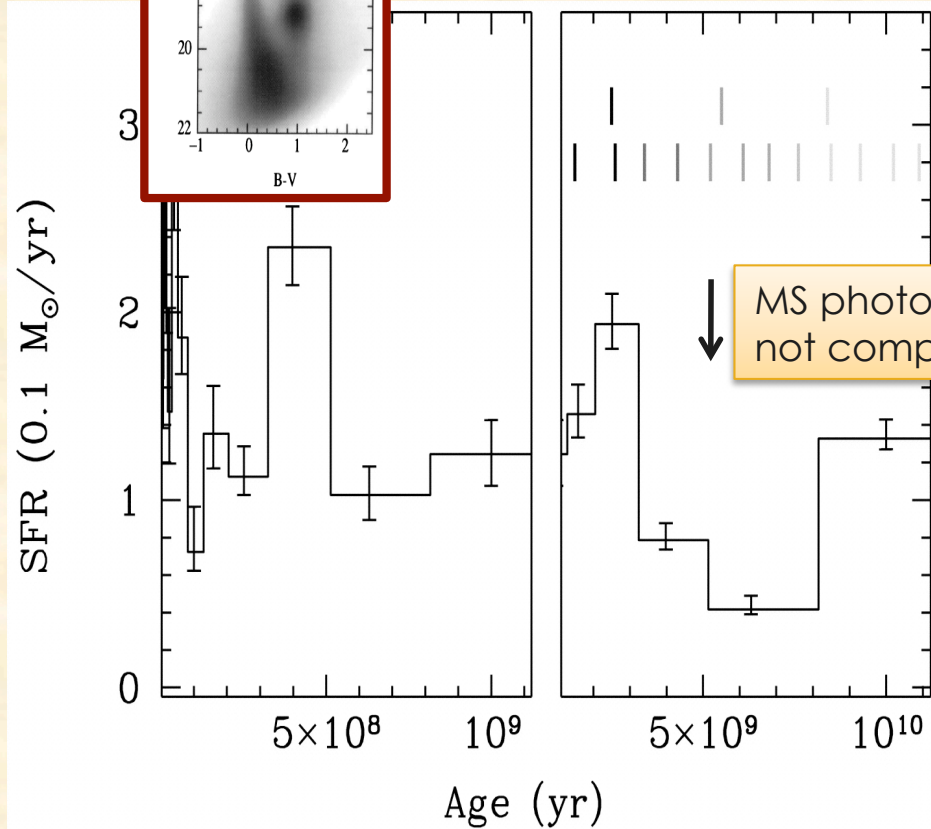
The (recent) star formation history of the Magellanic Clouds

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



SMC

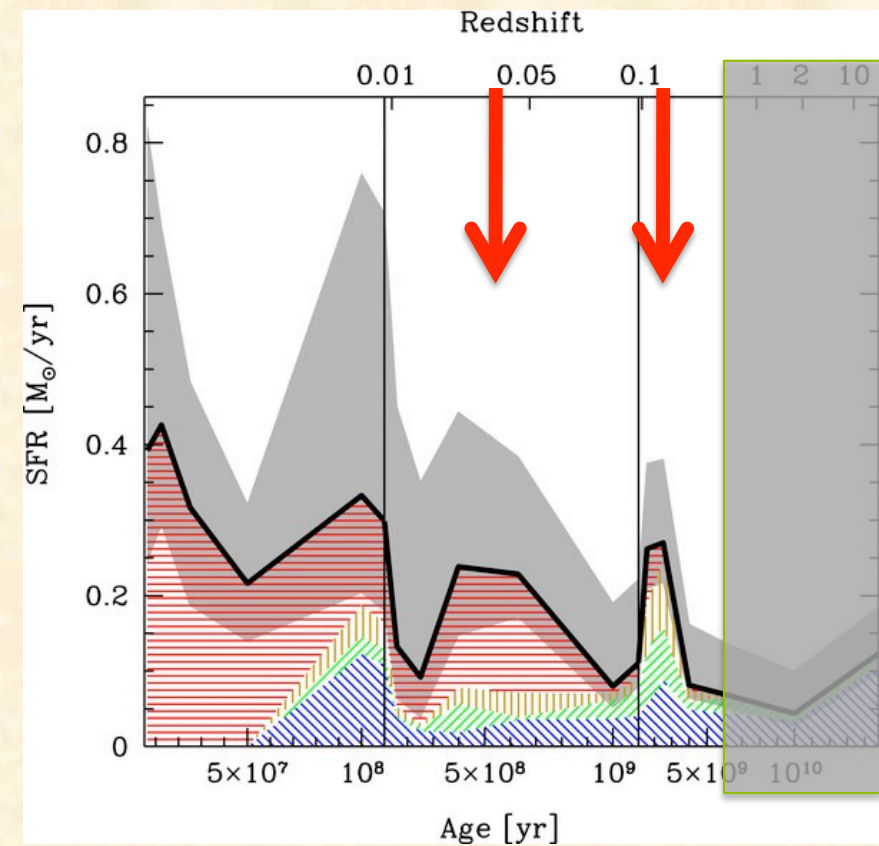
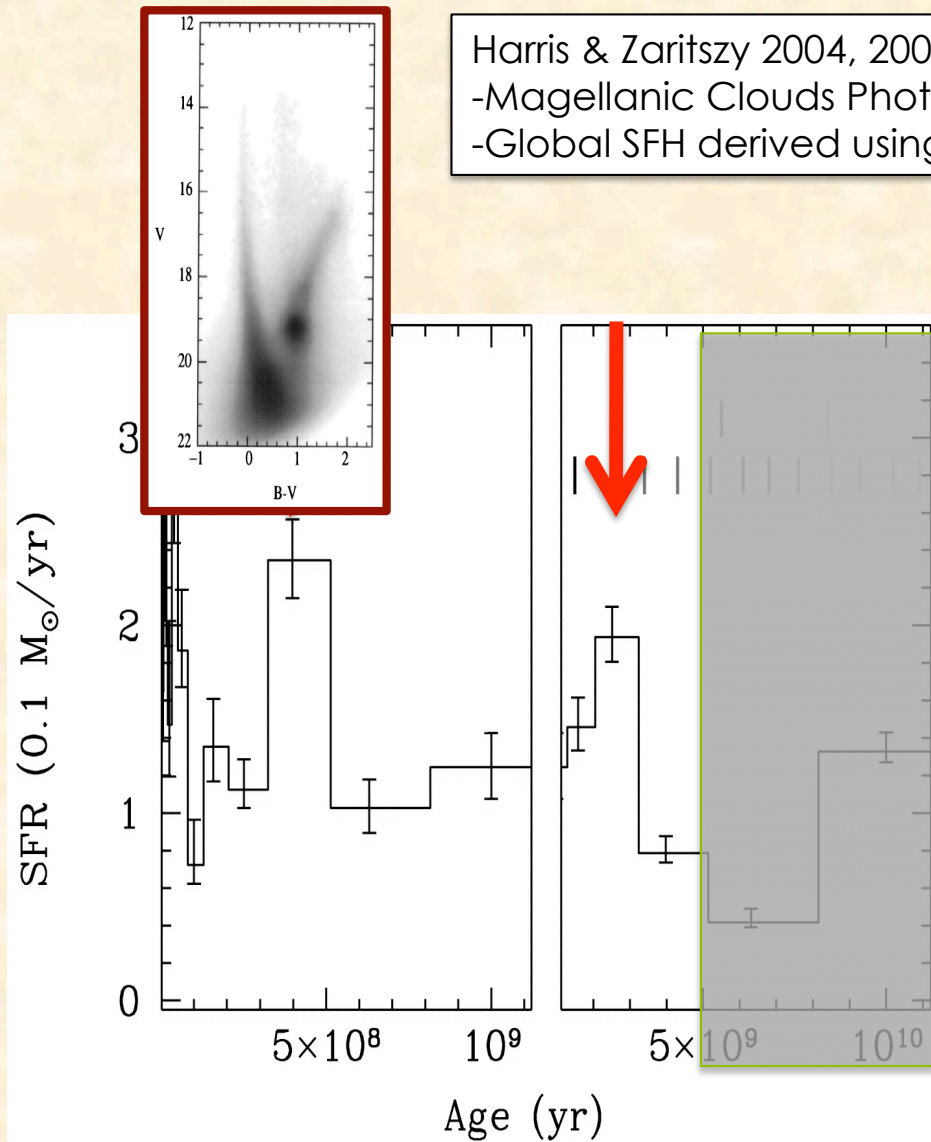
LMC



The (recent) star formation history of the Magellanic Clouds

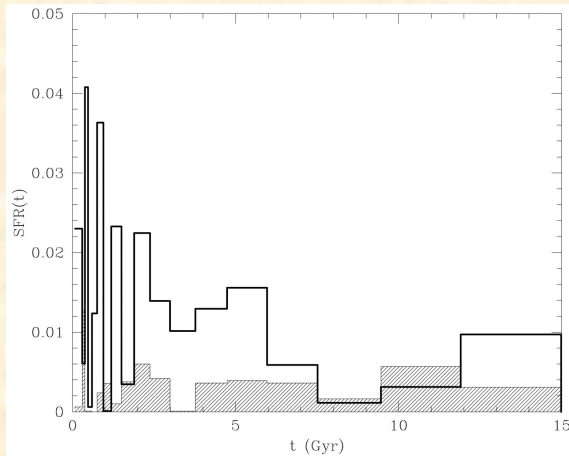
Harris & Zaritsky 2004, 2009

-Magellanic Clouds Photometric Survey (1m LCO)
-Global SFH derived using star-fish

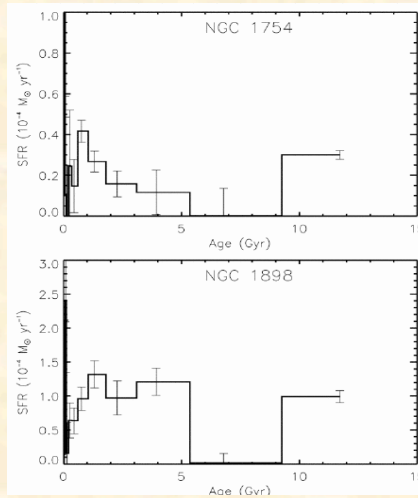


Apparently correlated SF bursts ≈ 2.5 & ≈ 0.5 Gyr ago

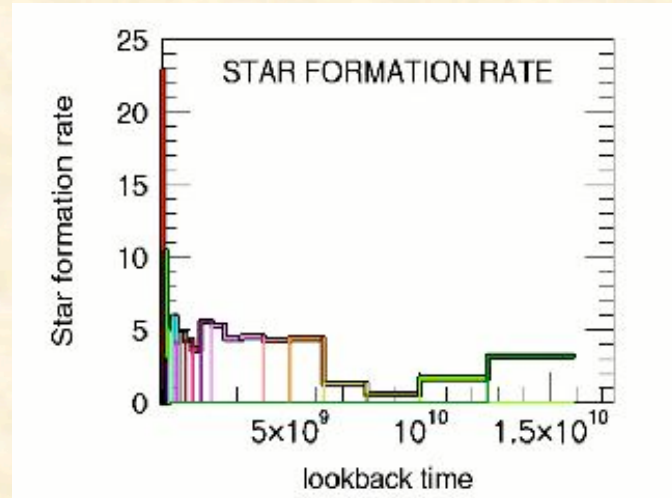
The (complete) star formation history of the Magellanic Clouds from (tiny) WFPC2 fields. I The bar



Smecker-Hane et al. 2002



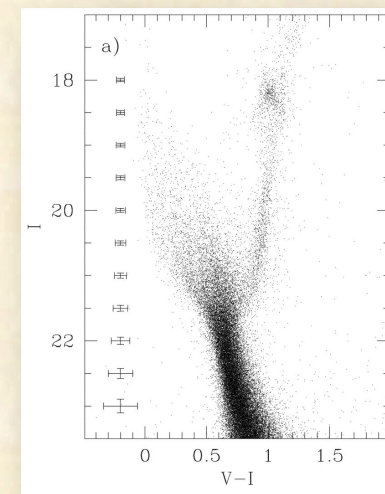
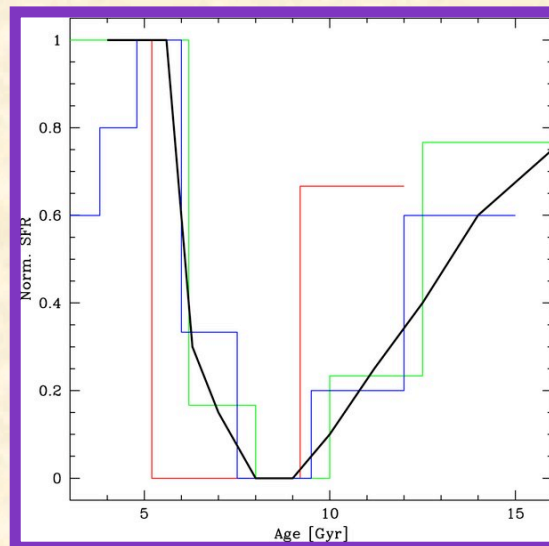
Olsen 1999



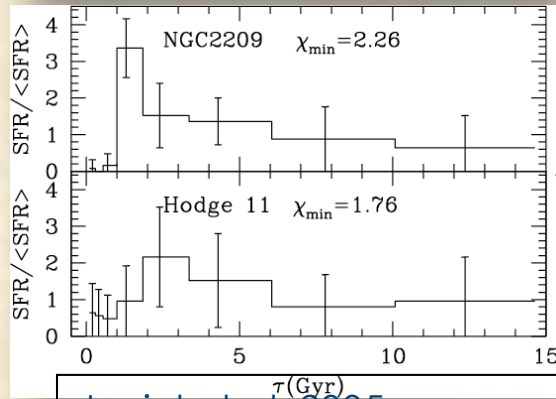
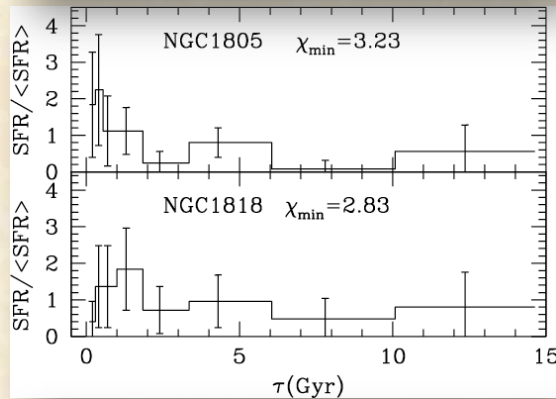
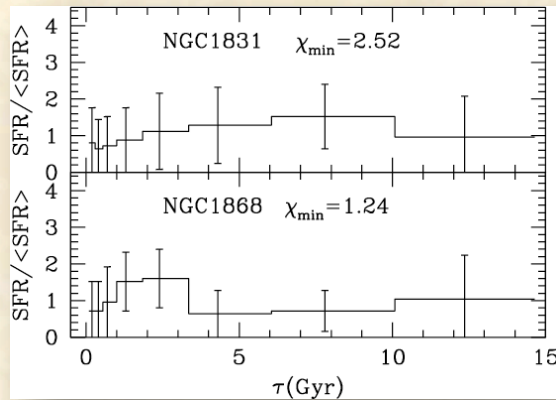
Holtzman et al. 1999

LMC Bar Fields

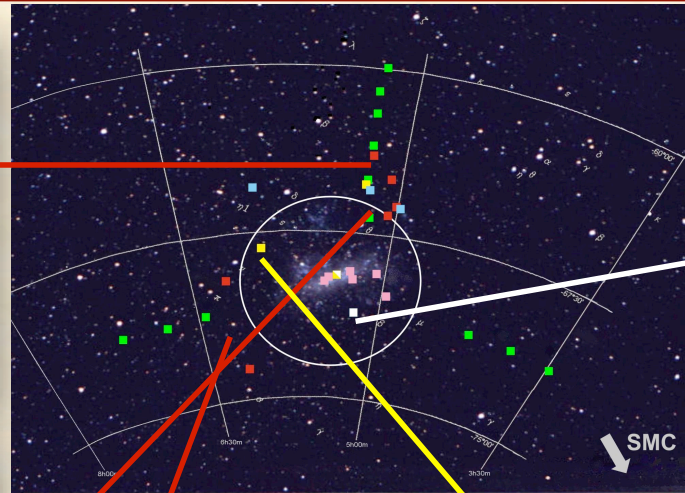
Different studies agree on an epoch of depressed SFR between $\approx 6-10$ Gyr ago



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

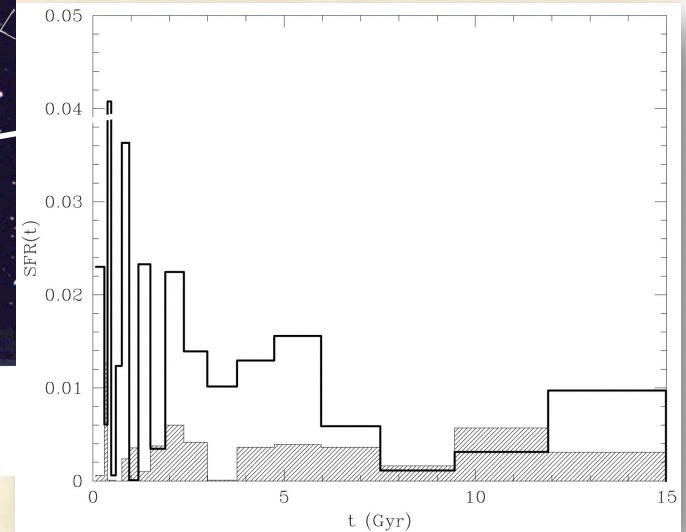


Javiel et al. 2005

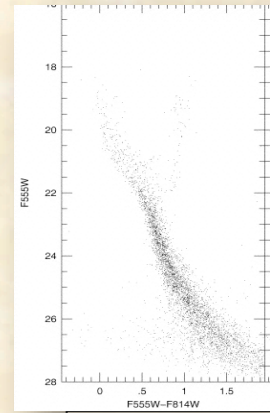


- Bertelli et al. (1992)
- Holtzman et al. (1999)
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- Smecker-Hane et al. (2002)
- Javiel et al. (2005)
- Nuestros campos

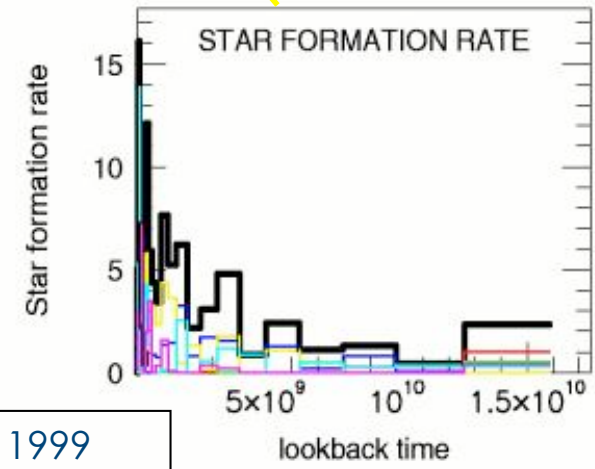
SFH: Disk Fields



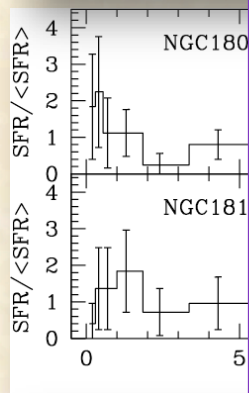
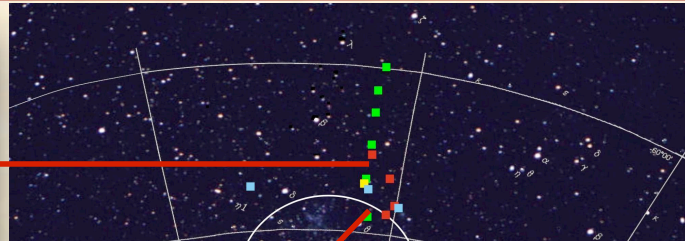
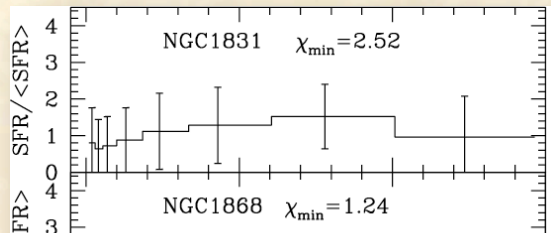
Smecker-Hane et al 2002



Holtzman et al. 1999



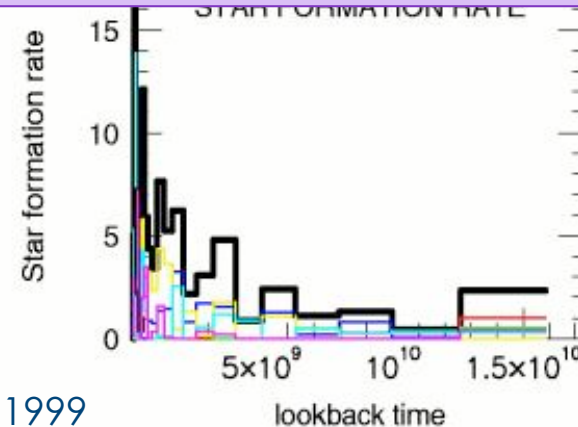
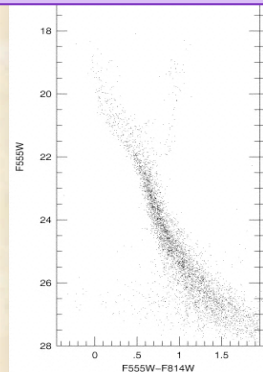
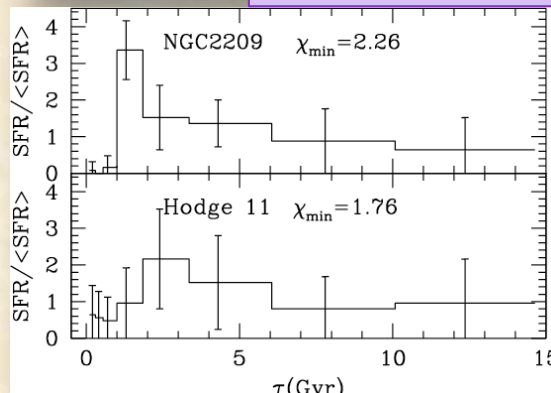
The (complete) star formation history of the Magellanic Clouds from (tiny) WFPC2 fields



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

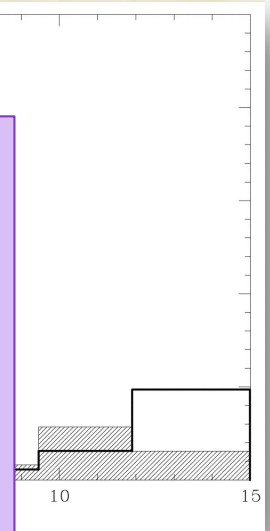
-Relatively flat SFR(t), with no intermediate age depression

-small number stats, spc at young ages?



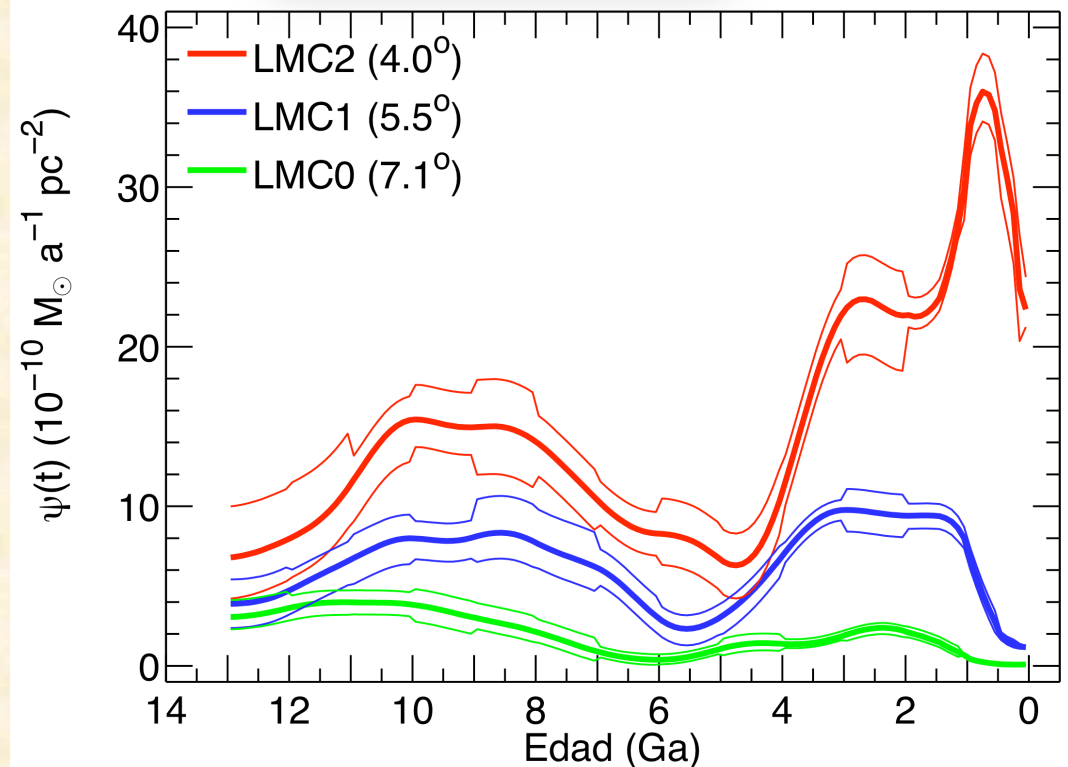
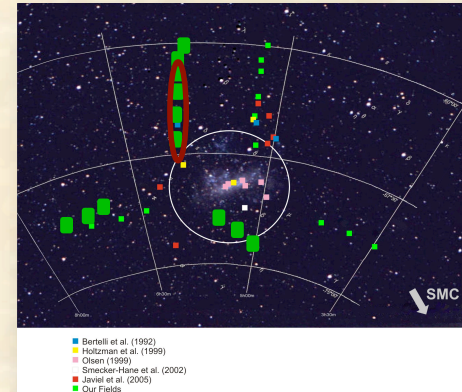
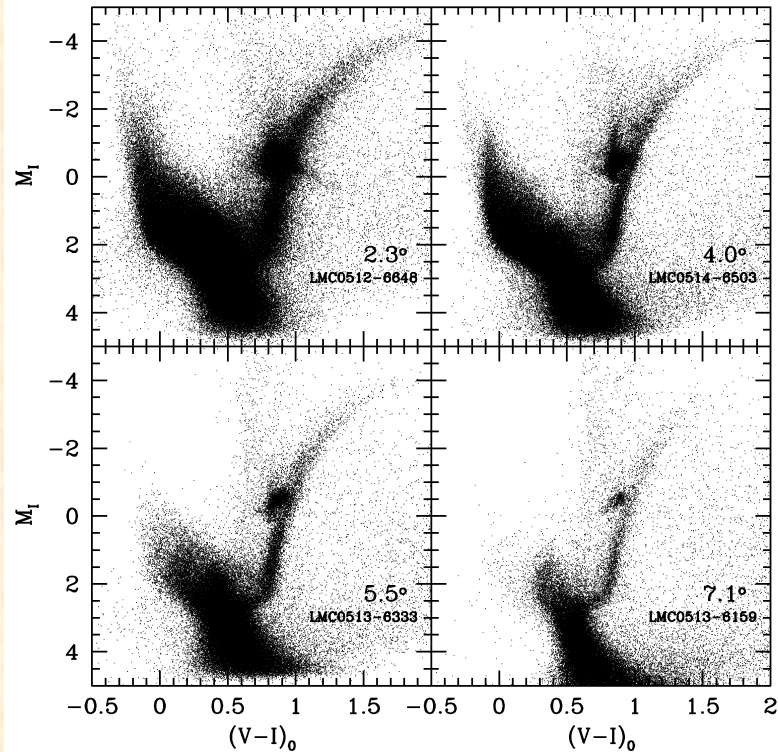
Javiel et al. 2005

Holtzman et al. 1999



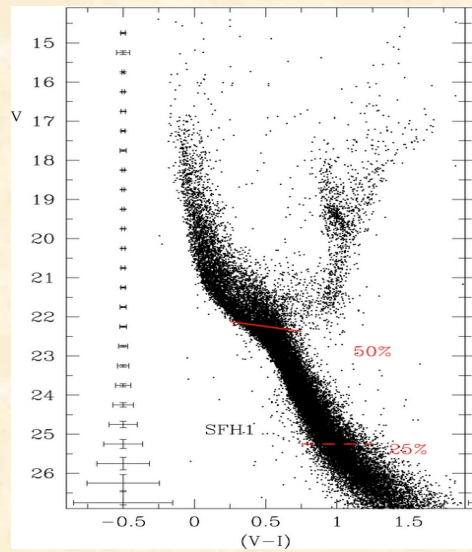
et al.

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



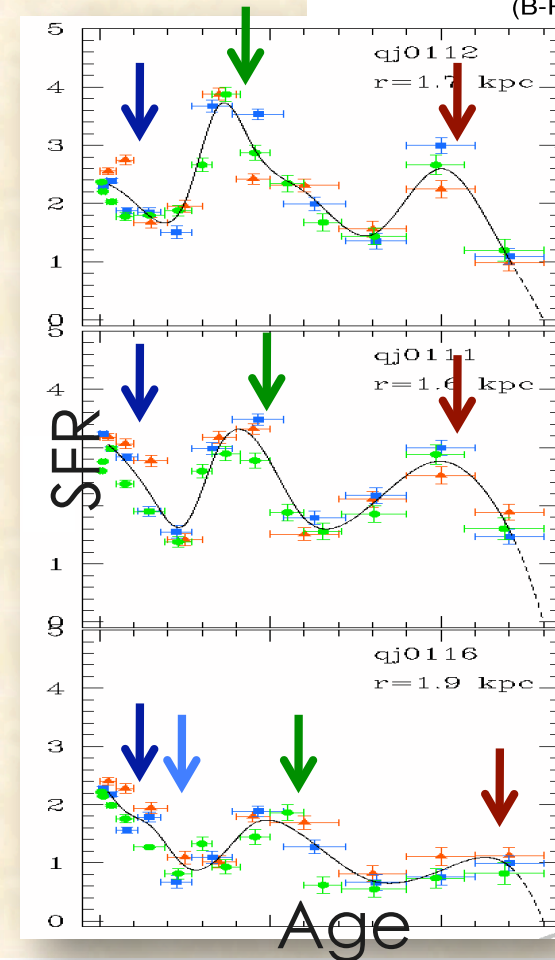
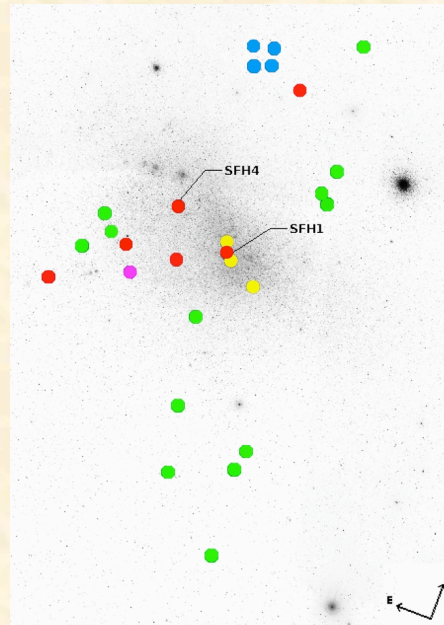
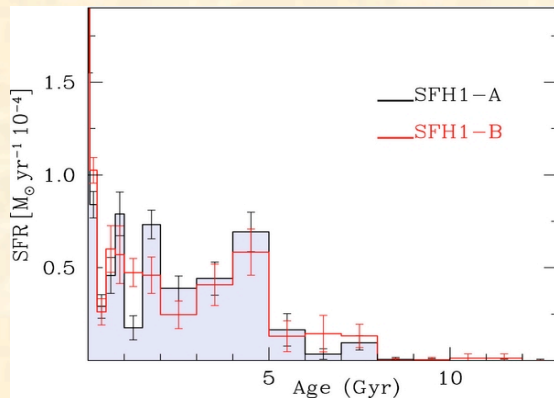
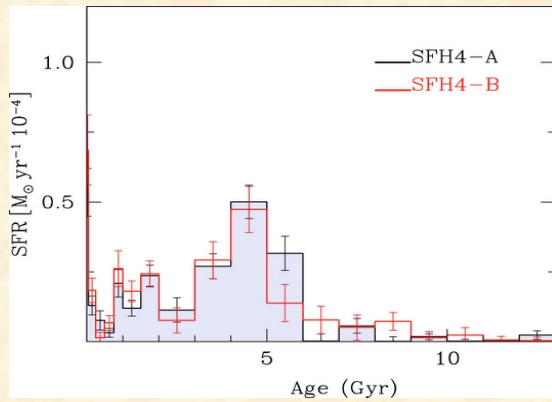
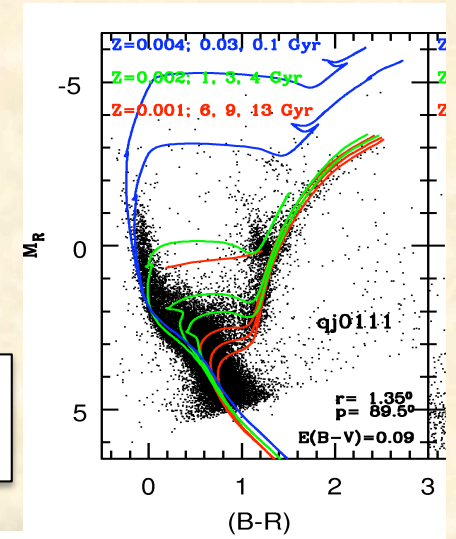
Gallart et al. 2008
 Carrera et al. 2011
 Meschin et al. 2012
 -4m CTIO+MOSA
 -(2.2 ESO+WFI)

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

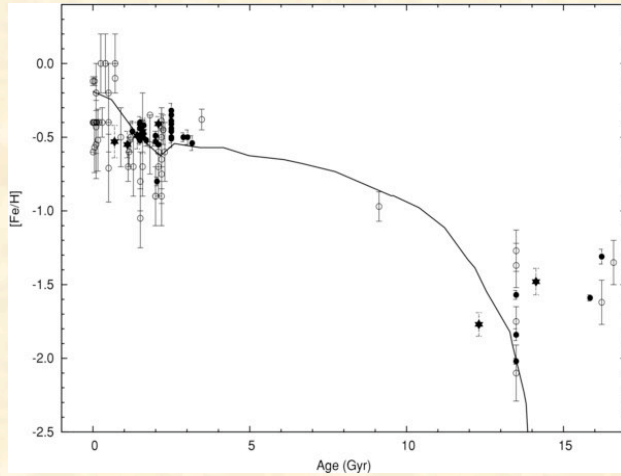


Cignoni et al. 2012
2 out of 6 ACS fields

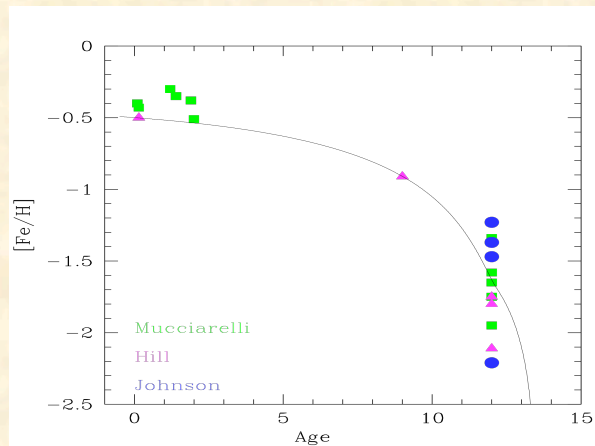
Noël et al. 2007
-12 LCO 100" fields



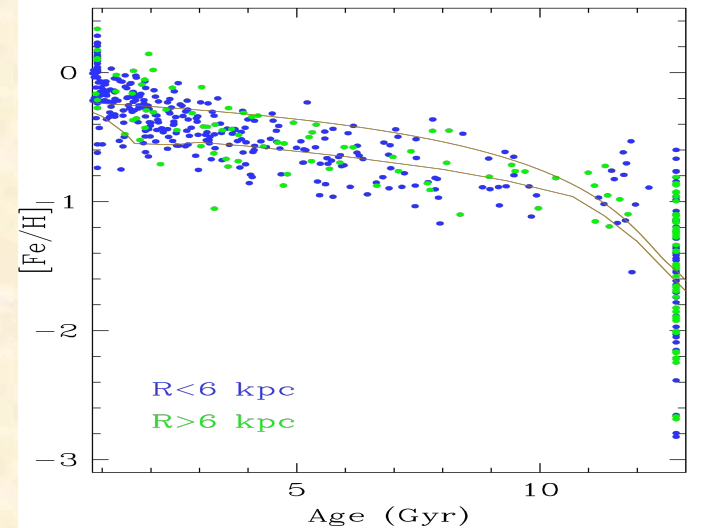
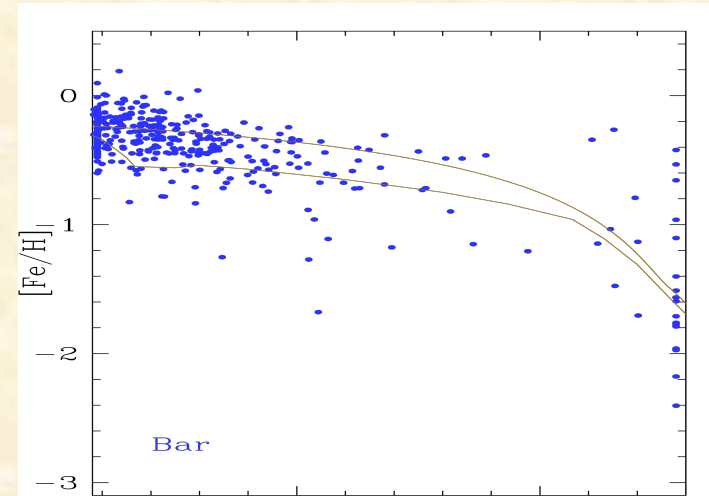
The chemical enrichment history of the Magellanic Clouds . I. LMC.



Sharma et al 2010 CaT, FORS2@VLT



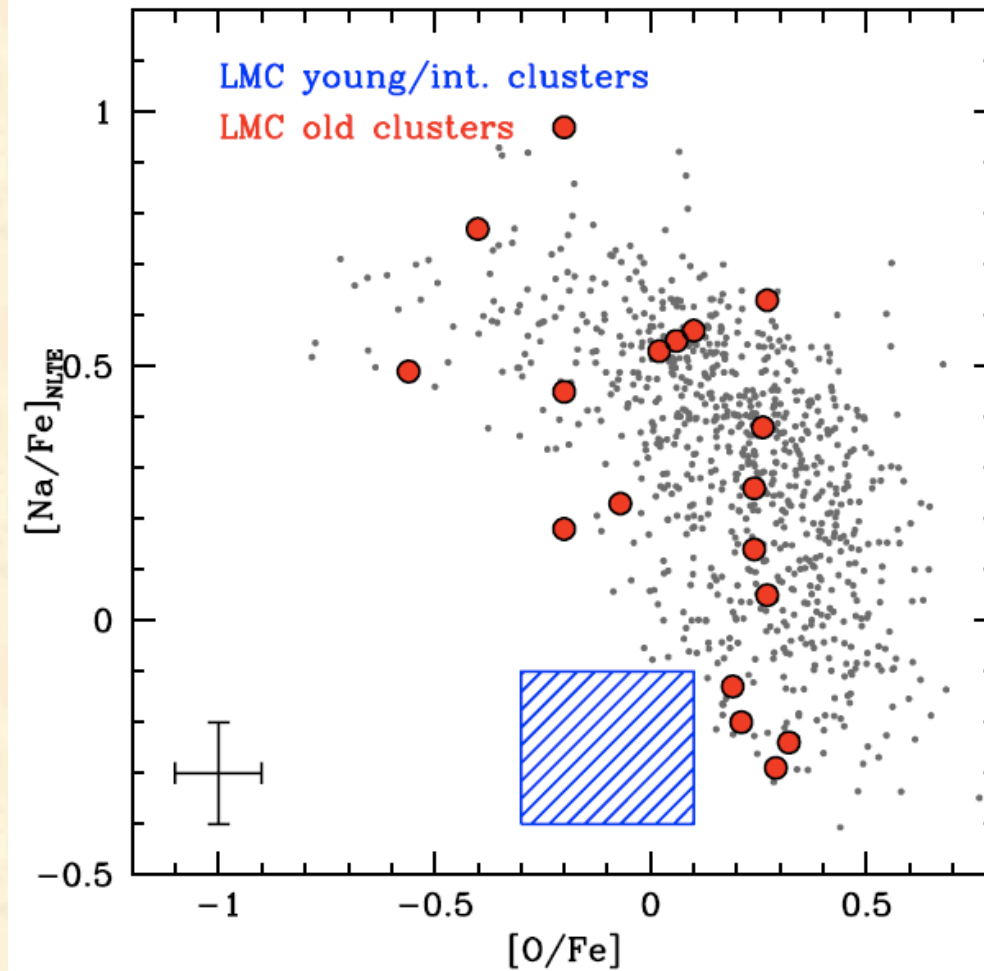
Hill et al. 2000 (HR, FLAMES@VLT, SV)
Mucciarelli et al 2007-2011 (FLAMES@VLT)
Johnson et al. 2006 (MIKE@Magellan)



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

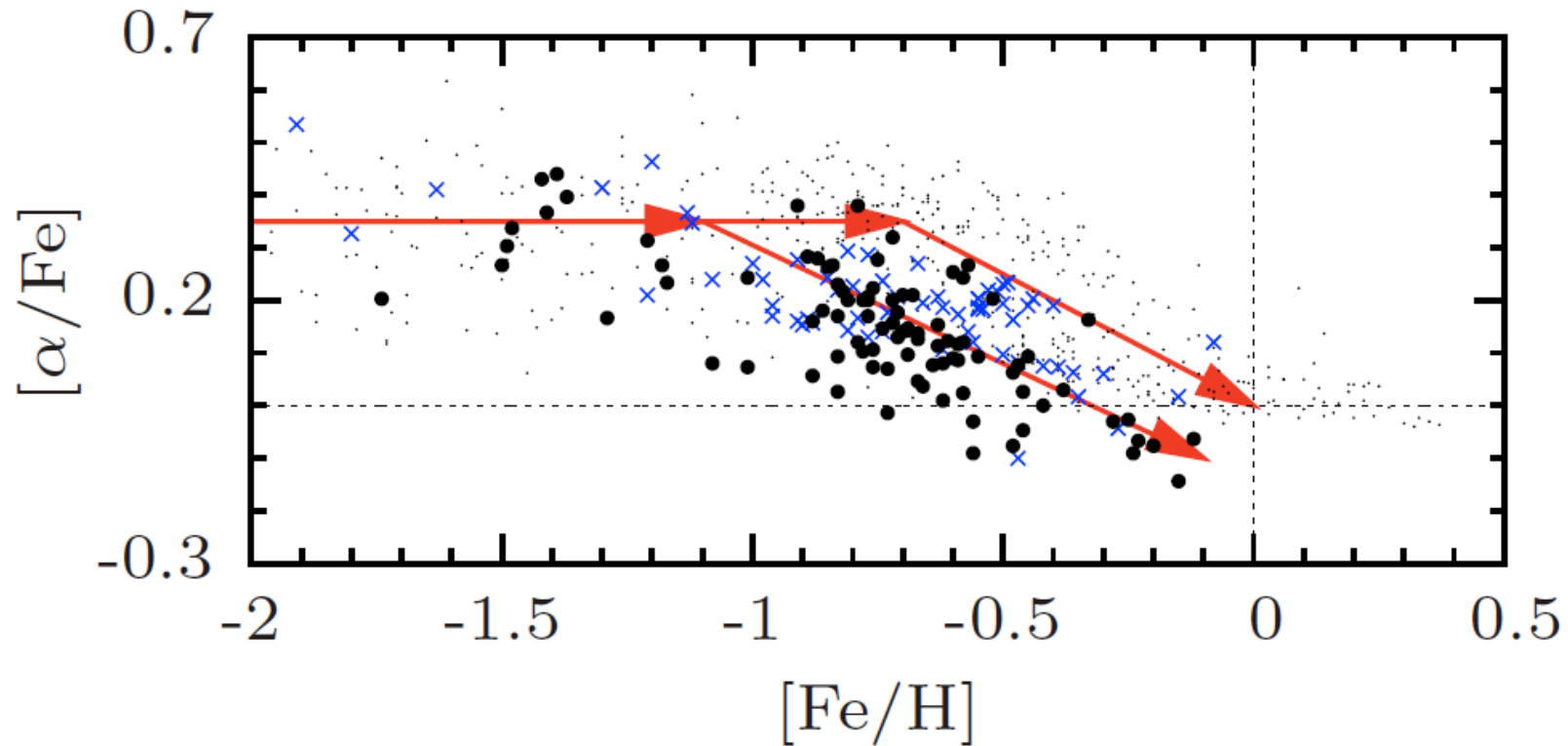
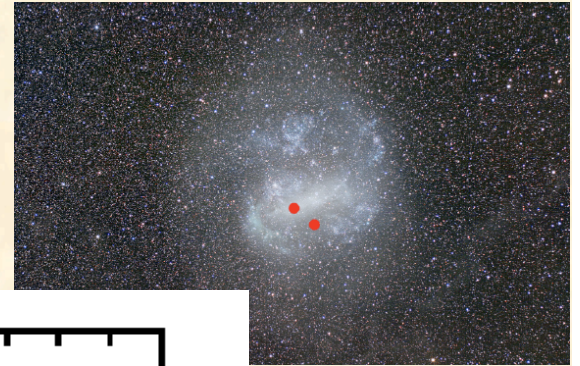
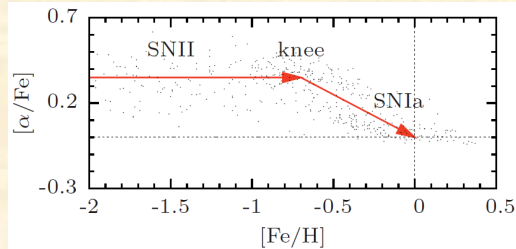
The chemical enrichment history of the Magellanic Clouds . I. LMC Clusters, HR

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



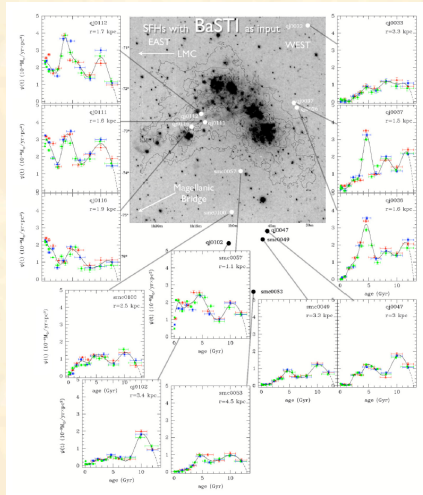
Mucciarelli et al. 2012, (2011, 2010, 2009, 2008, 2007)
FLAMES@VLT

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



Van der Swaelmen, Hill & Primas, 2012 in prep

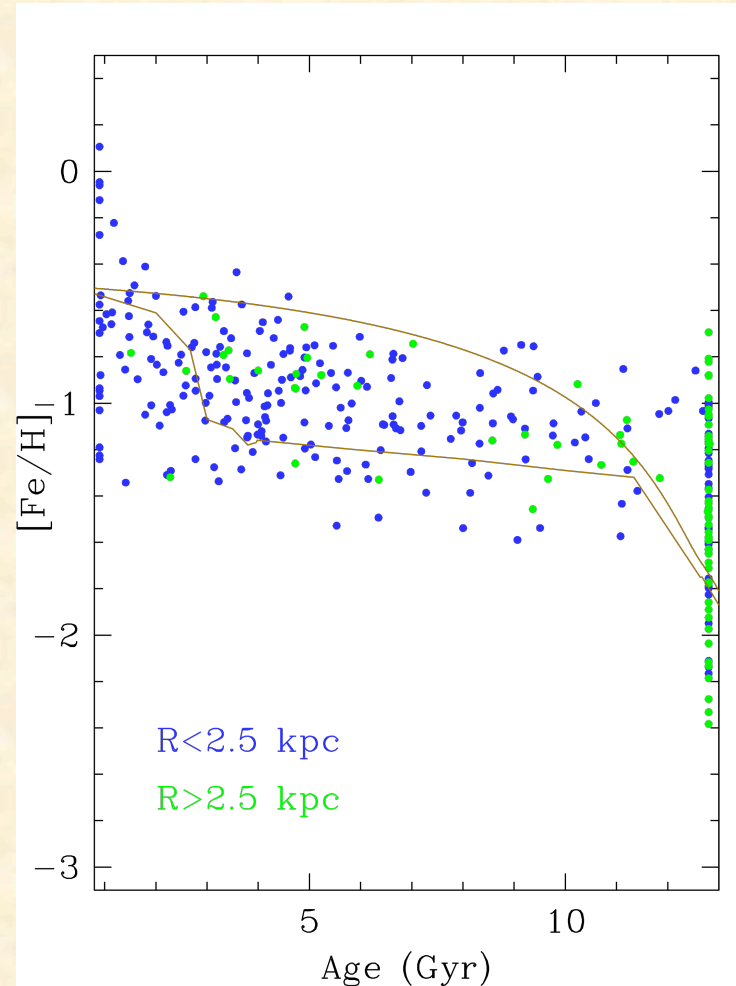
The chemical enrichment history of the Magellanic Clouds . II. Field stars, CaT

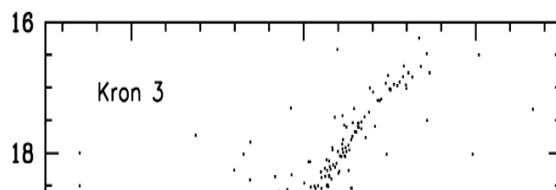
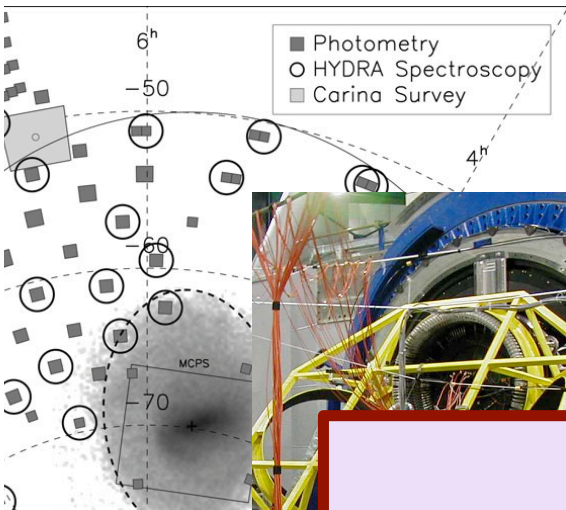


Carrera et al. 2008,
FORS2 data

Other CaT studies, with
consistent results by:

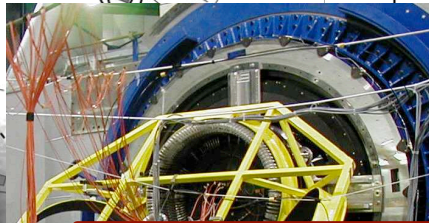
Parisi et al. 2010, 2009, FORS2
de Propris et al. 2010 4mCTIO





the flames survey of massive stars

[papers and results](#) [download data](#) [internal pages](#) [flames 2: tarantula survey](#)

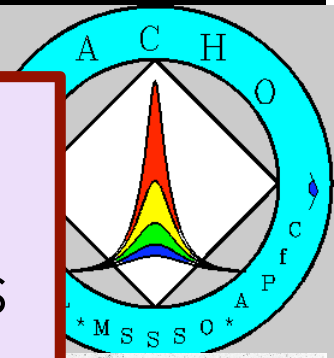


Hubble Space Telescope
Advanced Camera for Surveys

the vlt survey of massive
galaxy and magellanic c



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



SAGE
Agents of
Galaxy Evolution (SAGE)

- [Main](#)
- [Project](#)
- [Team](#)
- [Observations](#)
- [Products](#)

Surveying the Agents of Galaxy Evolution (SAGE) will trace the life cycle of matter that drives the evolution of a galaxy's appearance. The key tracers are traced via dust emission in the interstellar medium, the newborn stars and the evolved dying stars. Our study consists of Spitzer Space Telescope observations of the Large Magellanic Cloud (SAGE-LMC) and the Small Magellanic Cloud (SAGE-SMC) in addition to Spitzer spectroscopy of star formation and composition in the Large Magellanic Cloud (SAGE-Spec, 30 Doradus) and the Small Magellanic Cloud (SMC-Spec). The emission from the coldest dust will

