The interaction history of the Magellanic Clouds as told by their stellar populations

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I A T E

First-passage model (Unbound)

Kalivayalil et al. 2006, Besla et al 2007;2012

- SMC-LMC formed an interacting system 5-6 Gyrs ago

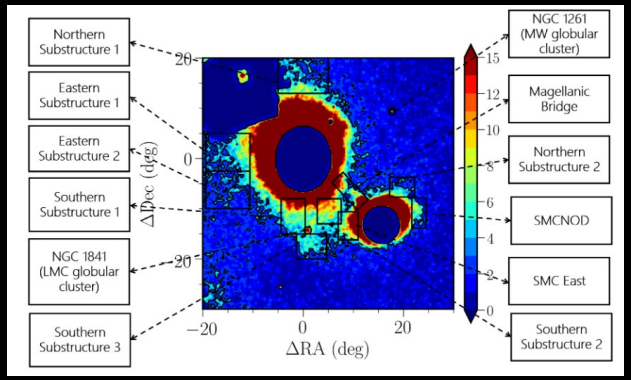
- The MCs are likely on their first infall into the Milky Way, entering its virial radius ~2 Gyr ago

- The LMC and SMC may have been interacting each-other for a long time

- A recent (~200 Myr ago), near-direct collision Zivick et al. 2018; Choi et al. 2022

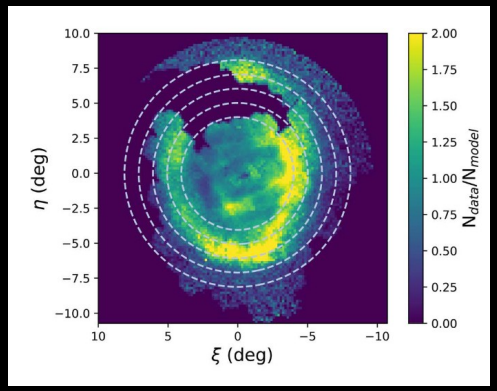
See Vasiliev 2023, Galaxies, 11, 59 for a review about the future and past orbits of the MCs

Several substructures in the periphery of the MCs



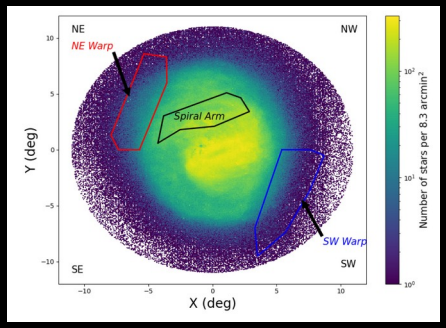
EL Youssoufi et al. 2021

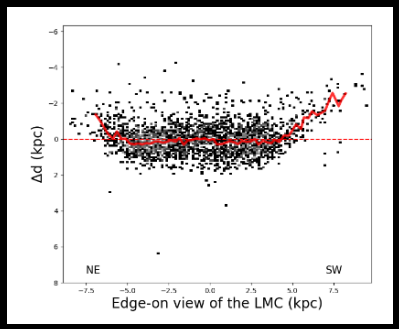
Ring-like overdensity



Choi et al. 2018b

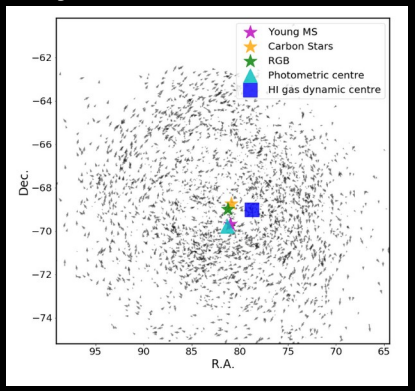
Single spiral loop and warp





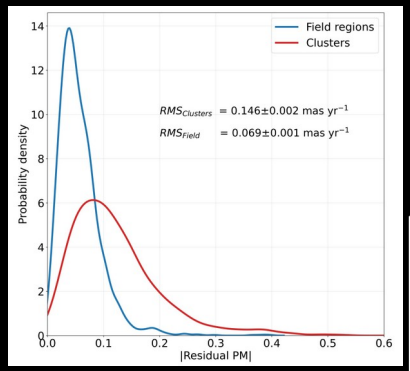
Saroon & Subramanian 2022

Offsets of the Dynamical centres



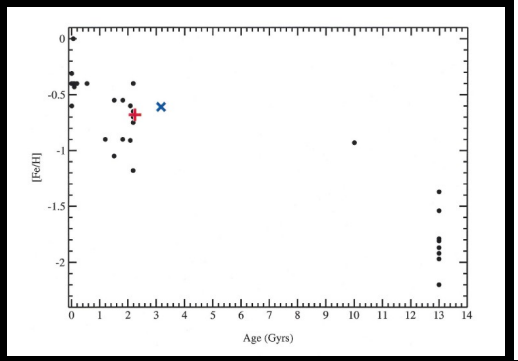
Wan et al. 2022

Different kinematics for clusters and field stars

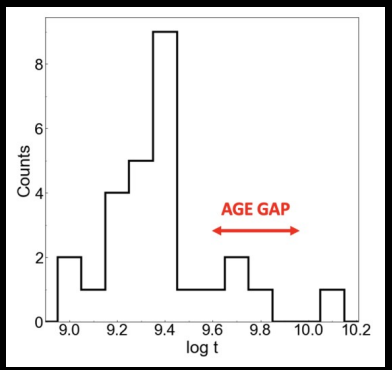


Dhanush et al 2024

Age-gap



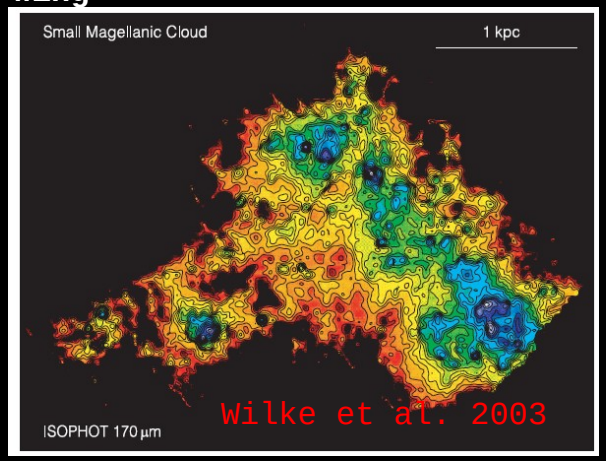
Rich et al 2001



Gatto et al. 2024

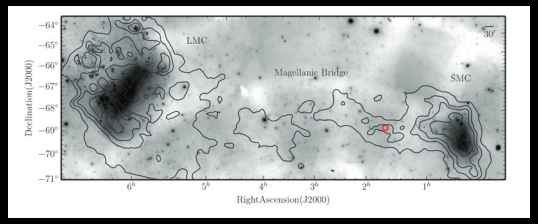
SOME MUTUAL INTERACTION SIGNATURES IN THE LMC

Wing

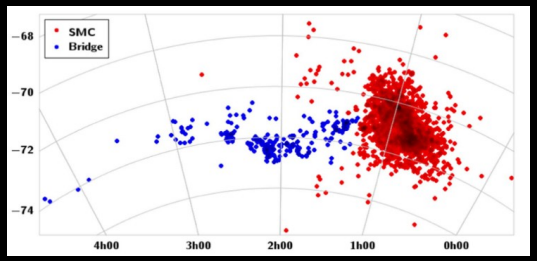


Wilke et al. 2003

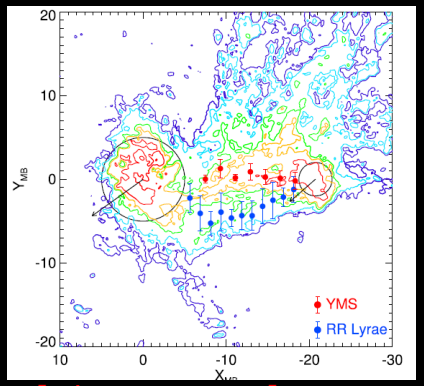
Bridge



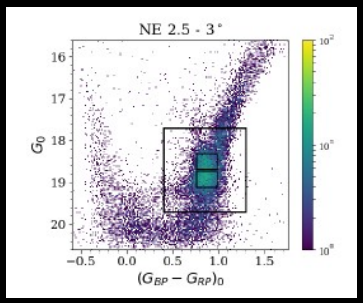
Kalari et al. 2020



Bica et al. 2020



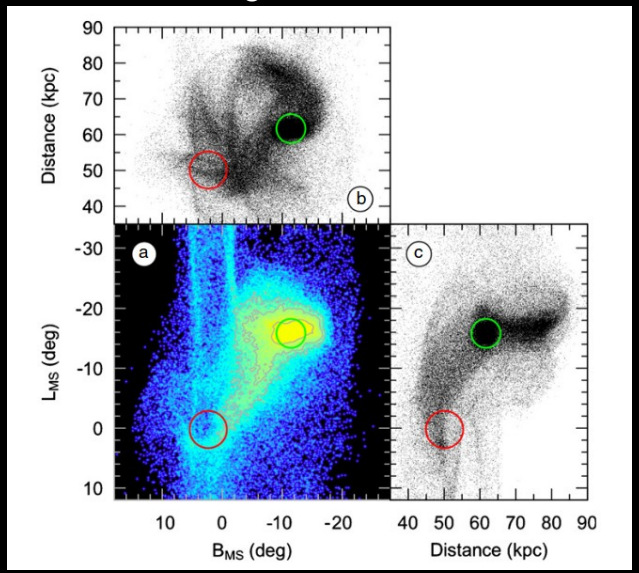
Belokurov et al.



Omkumar et al. 2021

At least three branches

Counter-Bridge



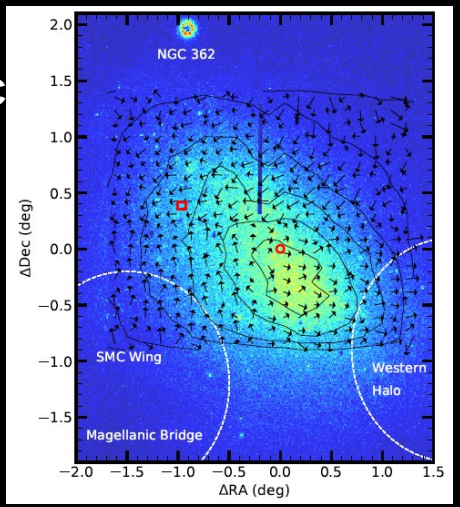
Diaz & Bekki 2012

First Counter-Bridge cluster found by Dias et al. (2021)

West Halo

Form a ring arround the SMC inner regions

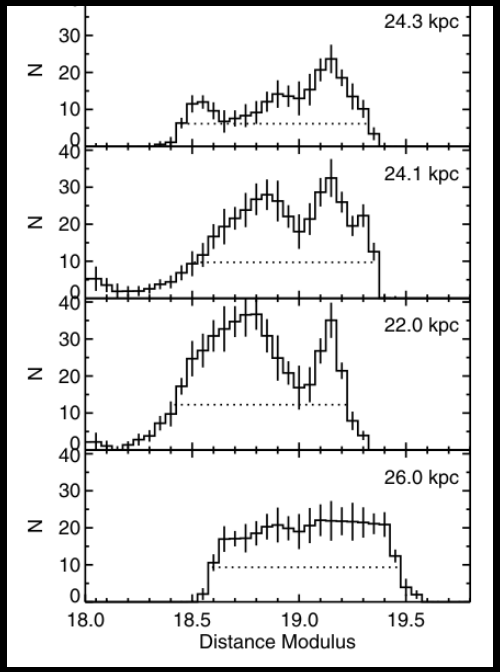
(Dias et al. 2016,2022)



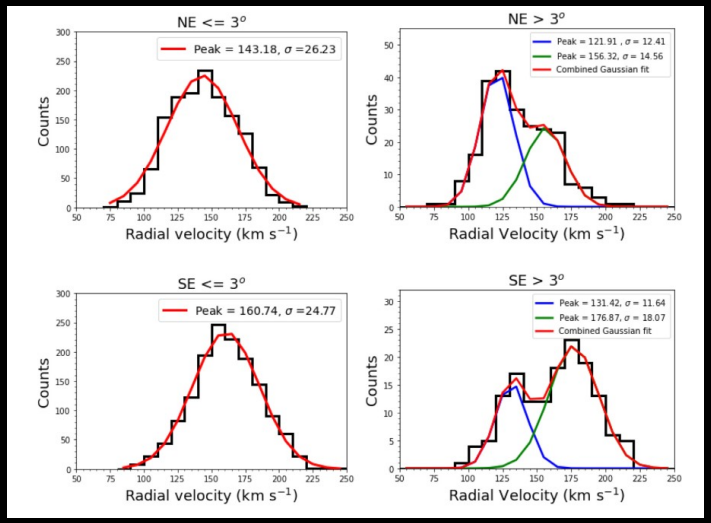
Niederhofer et al. 2018

SEE NEXT TALK

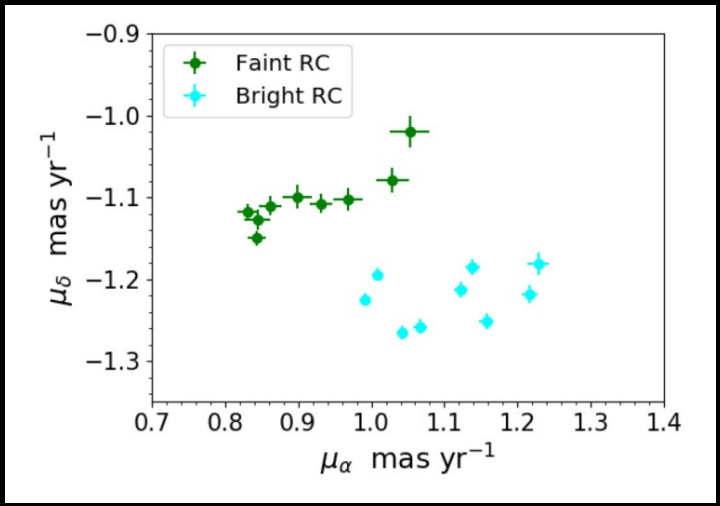
Regions with bimodal distribution of distances, proper motions, and radial velocities



Nidever et al. 2021



James et al. 2021



Omkumar et al. 2021

See also:

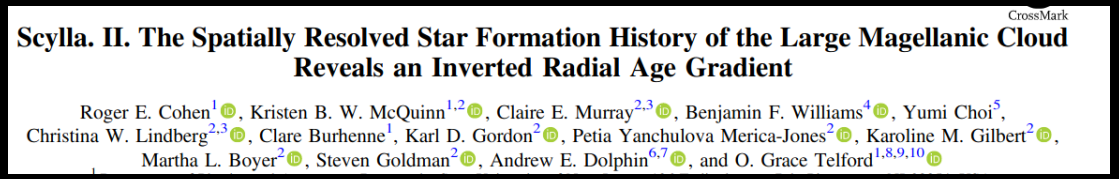
Mucciarelli et al. 2023b

Almeida et al. 2024

Dynamical model must reproduce:

Kinematics → SEE NEXT TALK

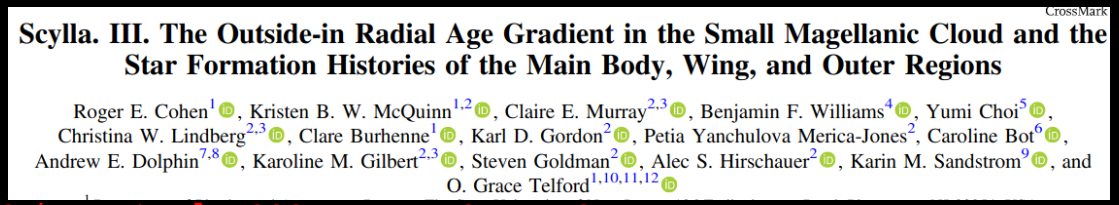
Star Formation History



Scylla. II. The Spatially Resolved Star Formation History of the Large Magellanic Cloud Reveals an Inverted Radial Age Gradient

Roger E. Cohen[1], Kristen B. W. McQuinn[1,2], Claire E. Murray[2,3], Benjamin F. Williams[4], Yumi Choi[5], Christina W. Lindberg[2,3], Clare Burhenne[1], Karl D. Gordon[2], Petia Yanchulova Merica-Jones[2], Karoline M. Gilbert[2], Martha L. Boyer[2], Steven Goldman[2], Andrew E. Dolphin[6,7], and O. Grace Telford[1,8,9,10]

Cohen et al. 2024, ApJ, 975, 42



Scylla. III. The Outside-in Radial Age Gradient in the Small Magellanic Cloud and the Star Formation Histories of the Main Body, Wing, and Outer Regions

Roger E. Cohen[1], Kristen B. W. McQuinn[1,2], Claire E. Murray[2,3], Benjamin F. Williams[4], Yumi Choi[5], Christina W. Lindberg[2,3], Clare Burhenne[1], Karl D. Gordon[2], Petia Yanchulova Merica-Jones[2], Caroline Bot[6], Andrew E. Dolphin[7,8], Karoline M. Gilbert[2,3], Steven Goldman[2], Alec S. Hirschauer[2], Karin M. Sandstrom[9], and O. Grace Telford[1,10,11,12]

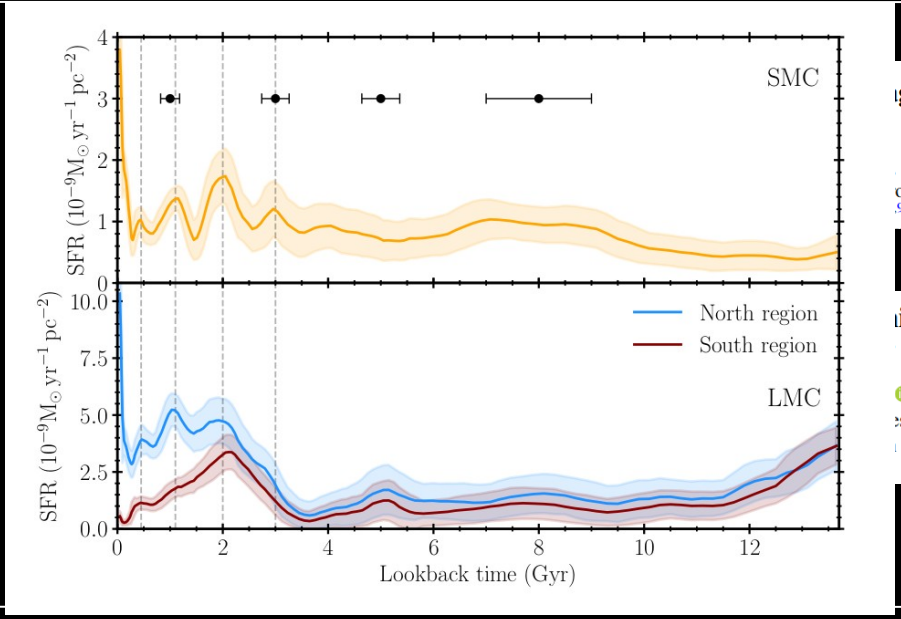
Cohen et al. 2024, ApJ, 975, 43

Chemical Properties →

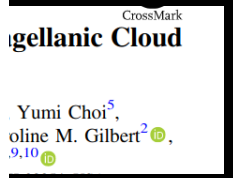
Dynamical model must reproduce:

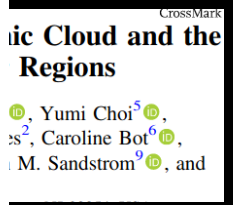
Kinematics → SEE NEXT TALK

Star Formation History

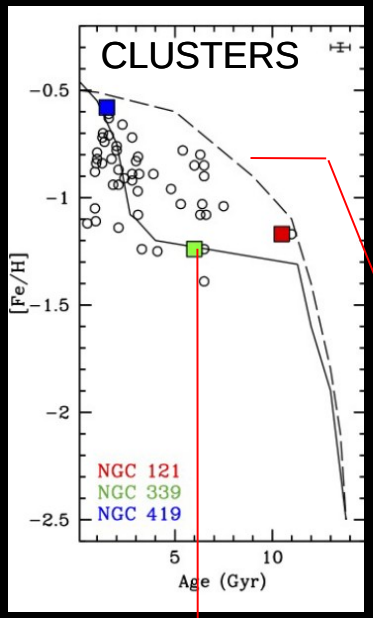


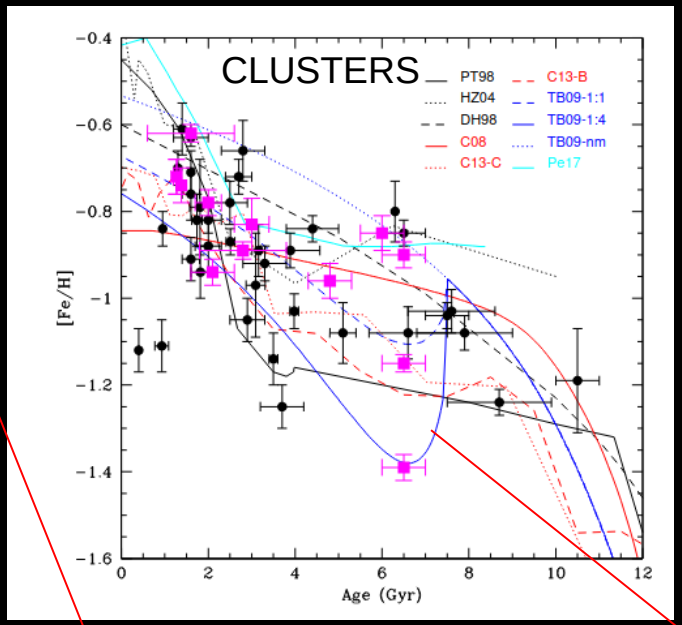
Massana et al. 2024

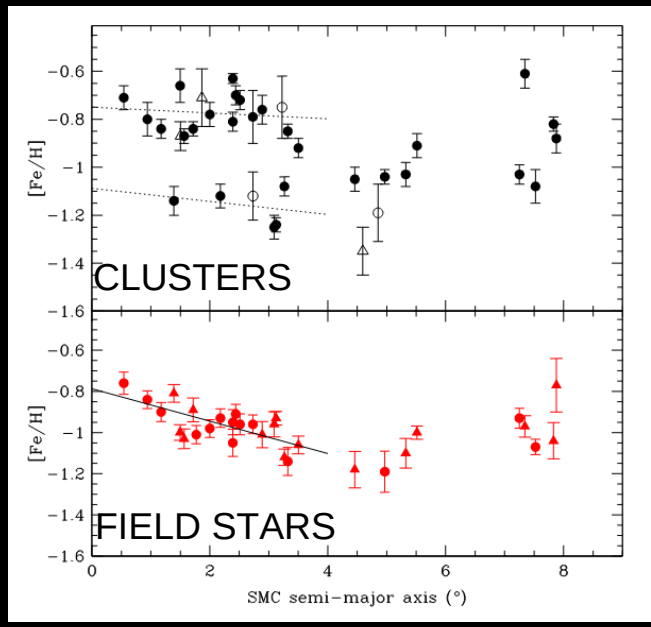




Chemical Properties →







Mucciarelli et al. 2023

Parisi, Geisler et al. 2009, 2010, 2015, 2016
Geisler, Parisi et al. 2022

Bursting model
(Pagel & Tauvaisiene 1998)

Closed box model
(Da Costa & Hatzidimitriu 1998)

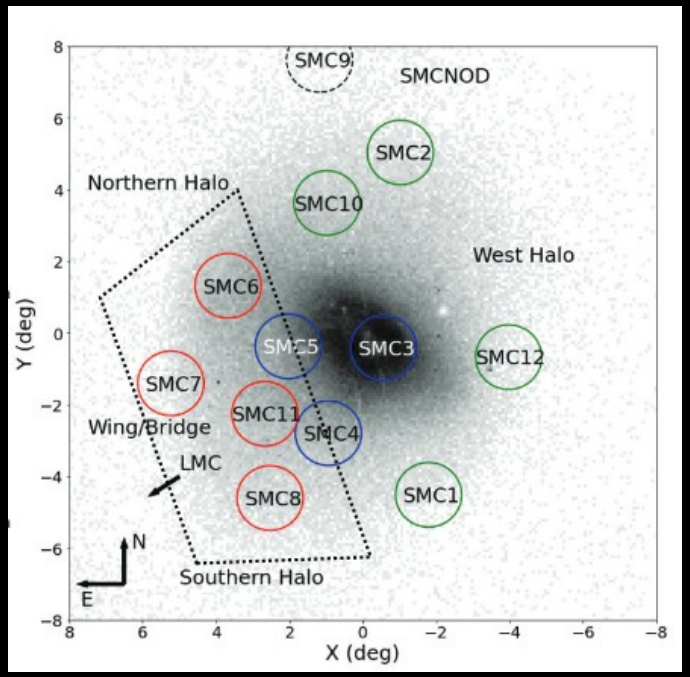
Merger model
(Tsujimoto & Bekki 2009)

Metallicity dispersion not observed in field stars

Cignoni et al. 2013
Carrera 2008
Carrera et al. 2009
Rubele et al. 2018

Not a single AMR for SMC clusters

FIELD STARS



“all regions explored by APOGEE seem to show a single chemical enrichment history”

APOGEE + GAIA
HR spectroscopy
RGB stars

Almeida et al. 2024

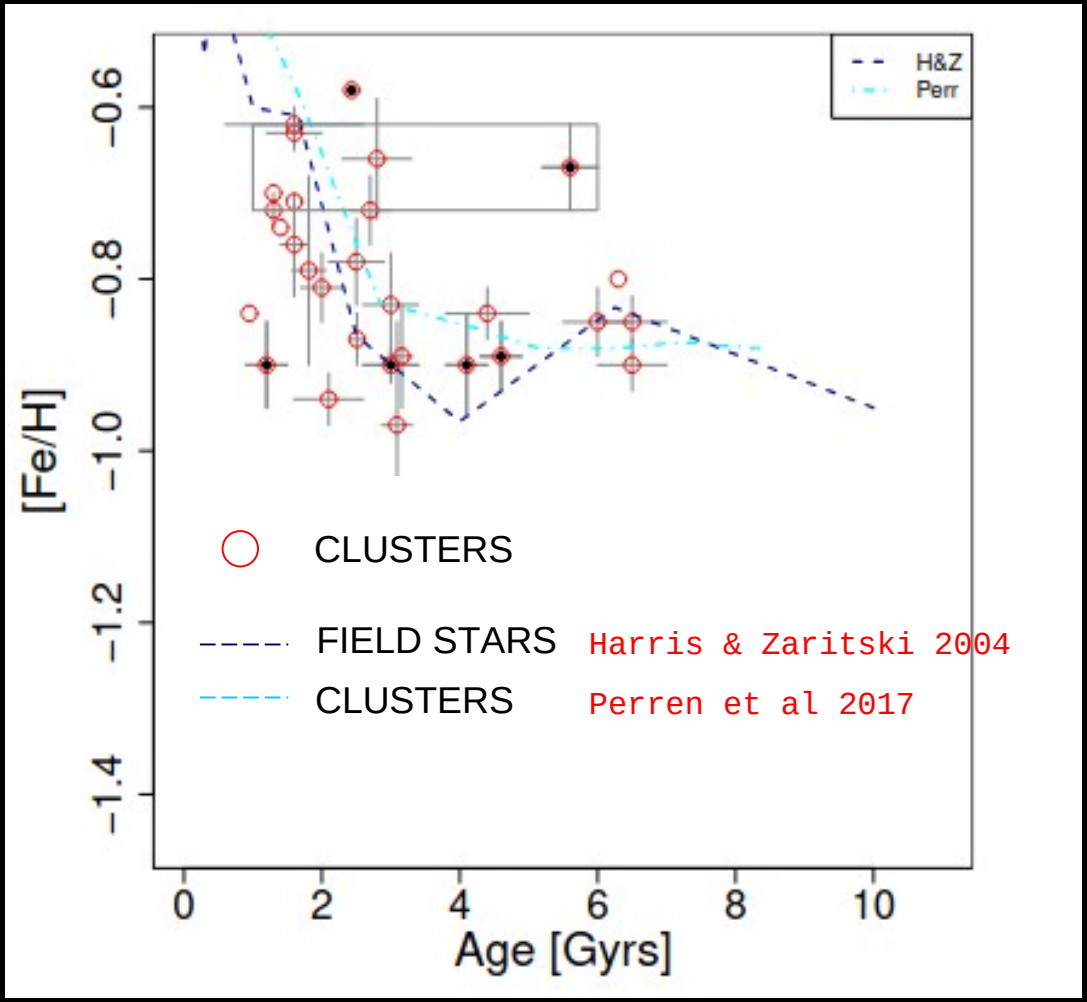
See for a different point of view:

Mucciarelli et al. 2023b

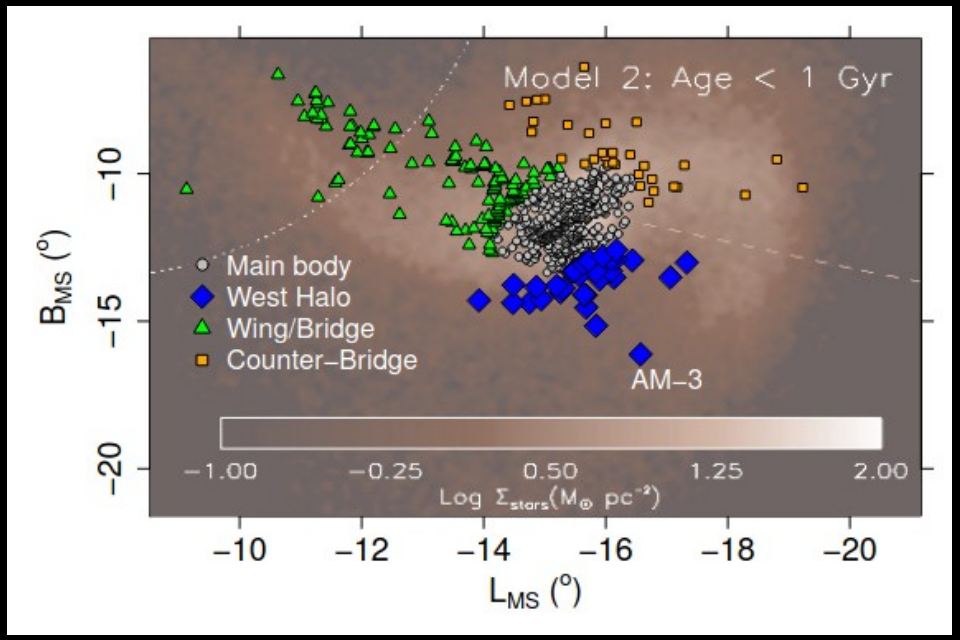
FLAMES-GIRAFFE
+ GAIA
HR spectroscopy
RGB stars

MAIN BODY

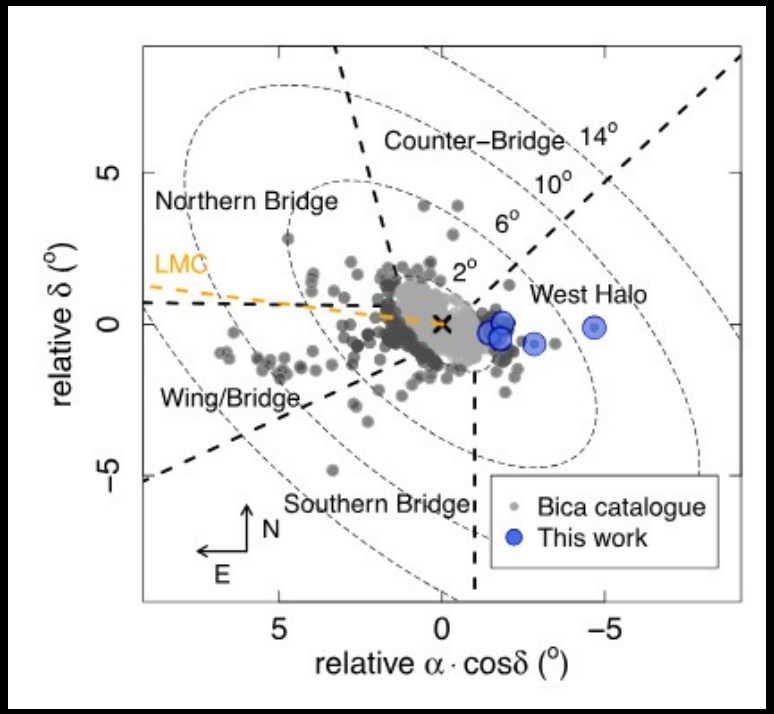
Same AMR for clusters and field stars



De Bortoli, Parisi et al. 2022



Dias, Kerber, Barbuy et al. 2016



Dias, Parisi et al. 2022

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VISCACHA

VISCACHA Survey

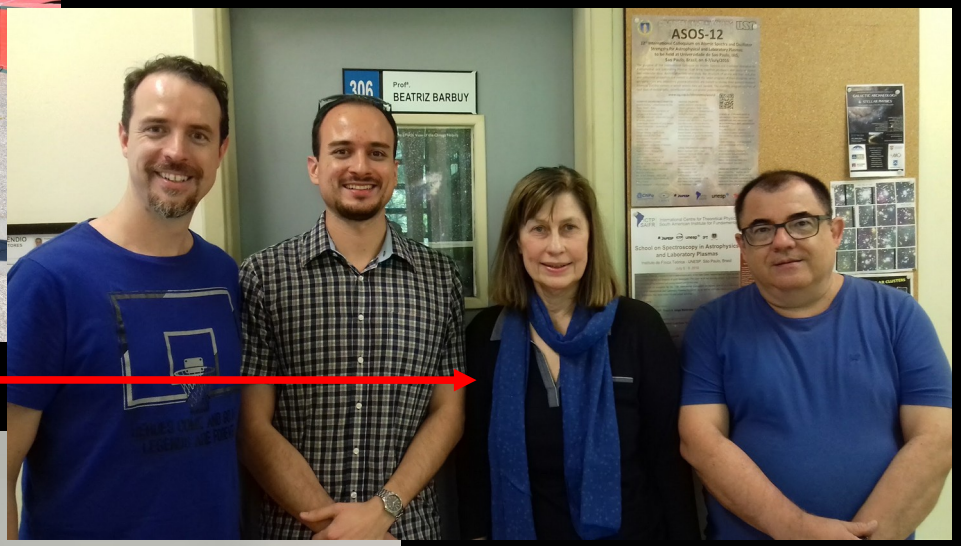
http://www.astro.iag.usp.br/~viscacha/

SOAR/SAMI + GEMINI/GMOS

CHEMICAL EVOLUTION

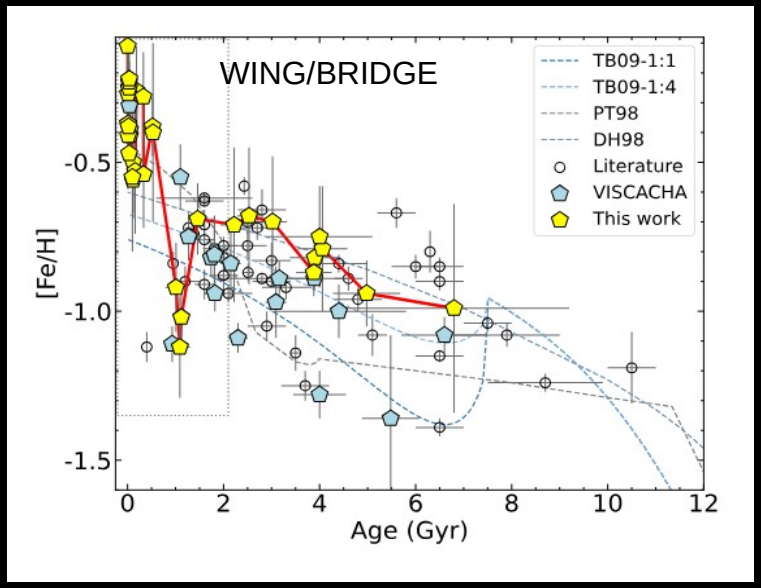
IN EACH EXTERNAL REGION

VISCACHA Survey

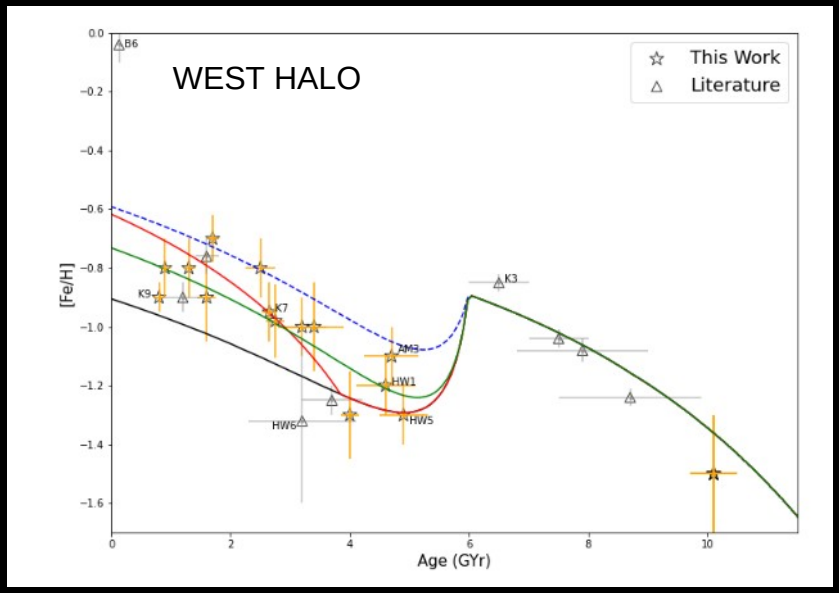


BEATRIZ BARBUY

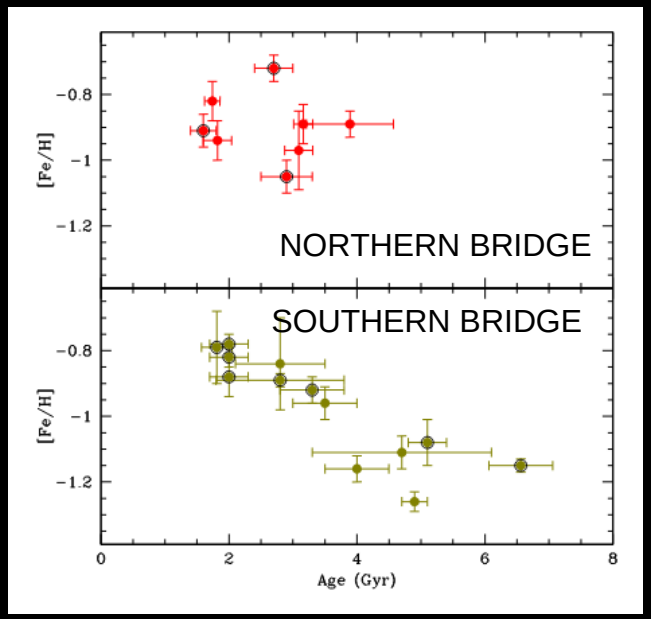
VISCACHA



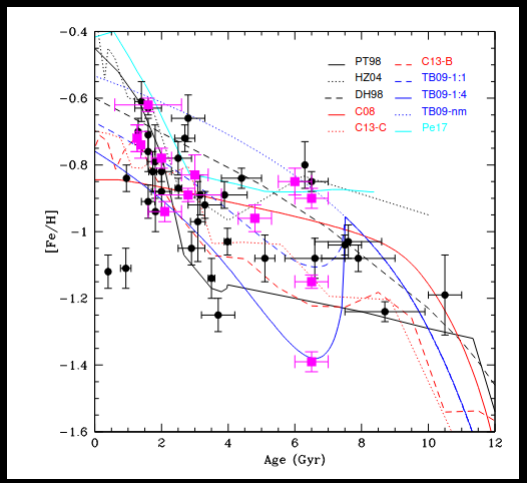
Oliveira et al. 2023



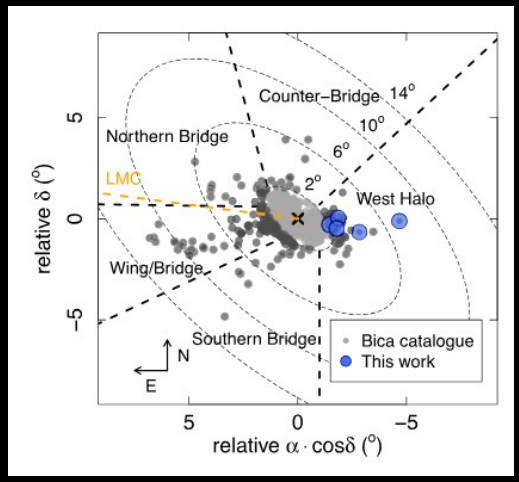
Saroon et al. 2023



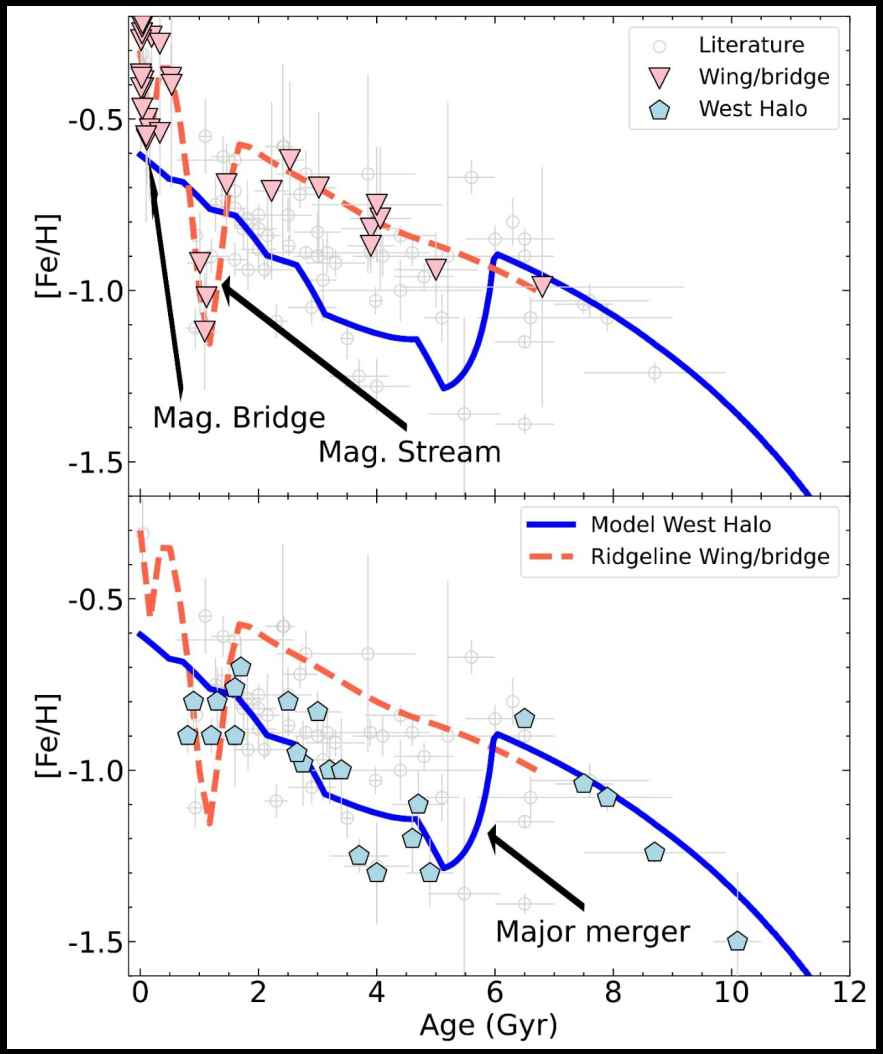
Parisi et al. 2024



Parisi et al. 2023

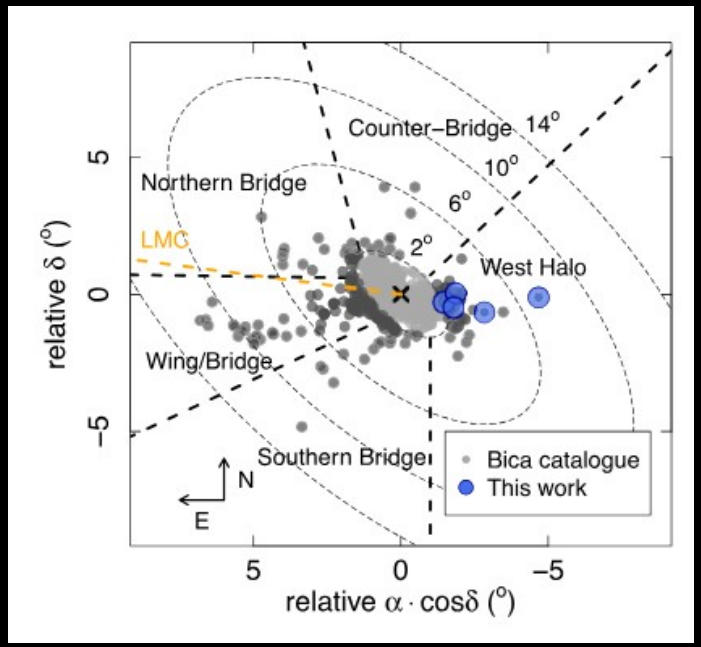


Dias, Parisi et al. 2022

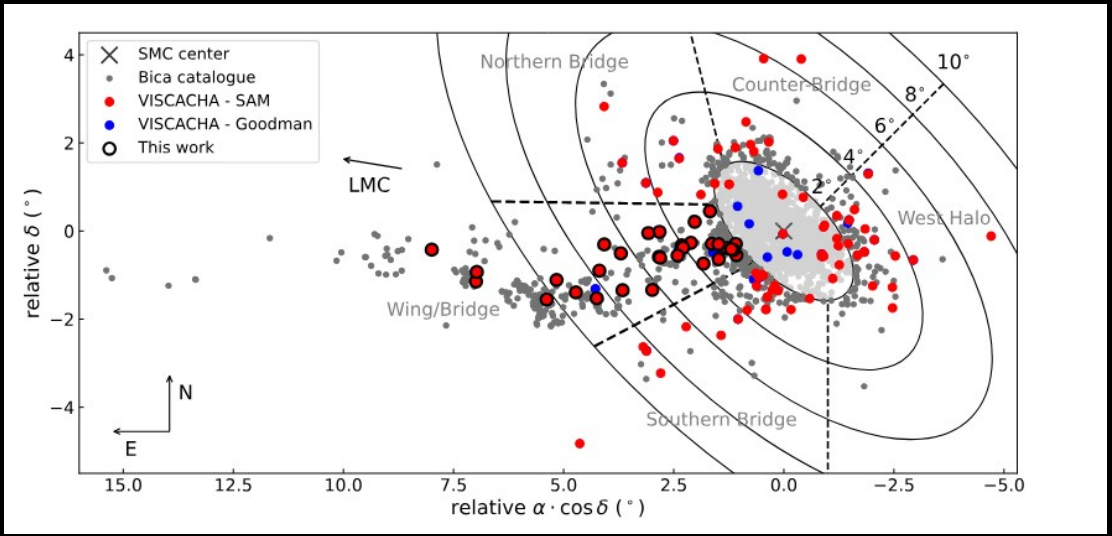


Oliveira et al. 2023

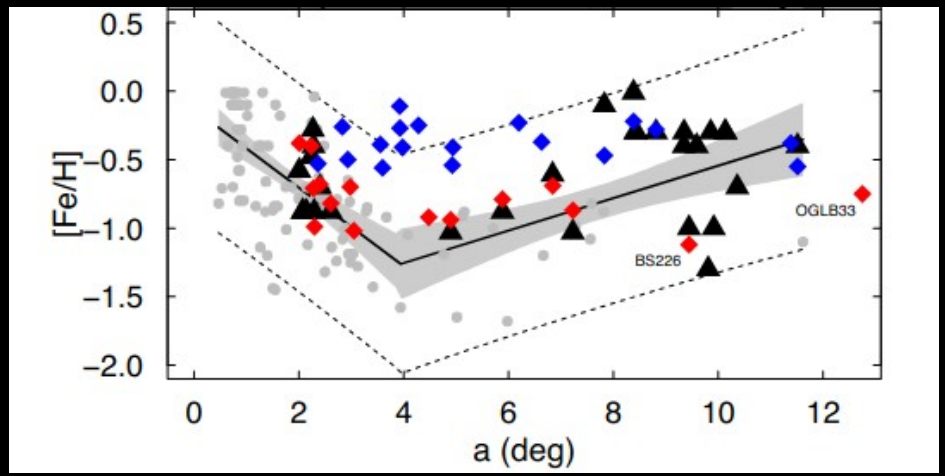
Saroon et al. 2023



Dias, Parisi et al. 2022



Two groups of Clusters in the Wing/Bridge



Metal-poor group

older than de Bridge

[Fe/H] < −0.6 dex

Metal-rich group

younger than de Bridge

[Fe/H] > −0.5 dex

Oliveira et al. 2023

Take these messages home

- Star clusters are excellent tracers of the chemical evolution and dynamical history

- Age-Metallicity relation is a powerful tool to disentangling the complexity of the SMC

- Metallicity dispersion is real so it is mandatory to analyze clusters in different SMC regions and not as a whole

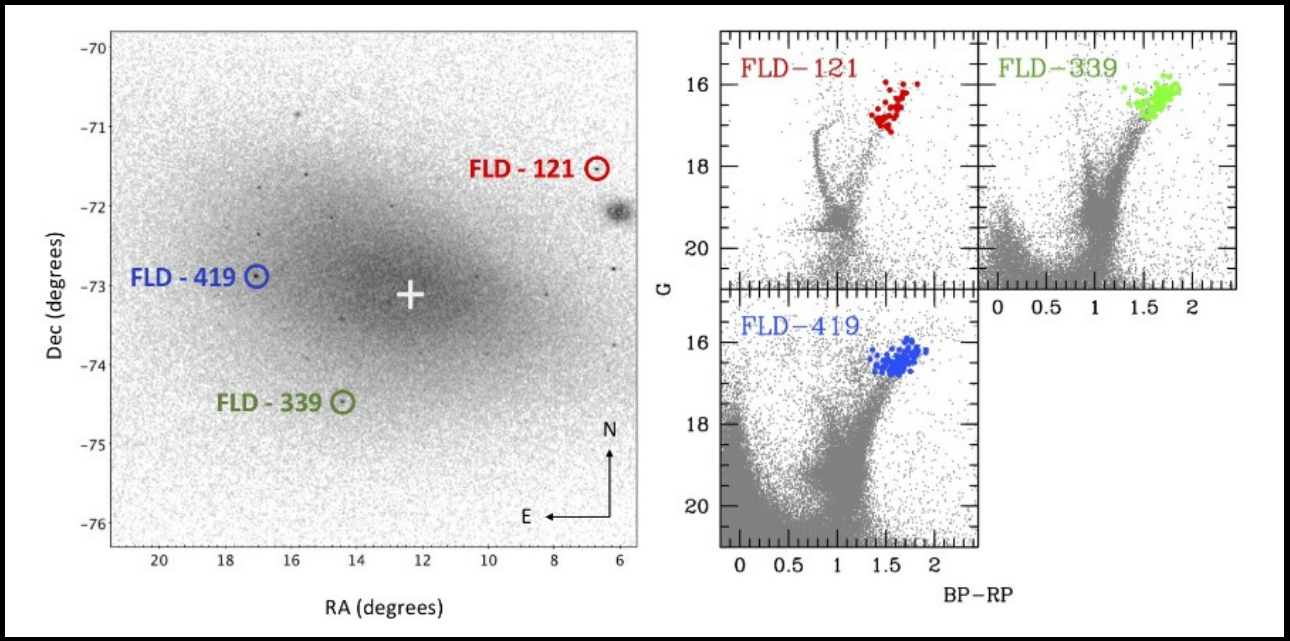
- Do field stars and clusters have the same chemical evolution or not? If they don't… Could that difference be due to dynamic effects?

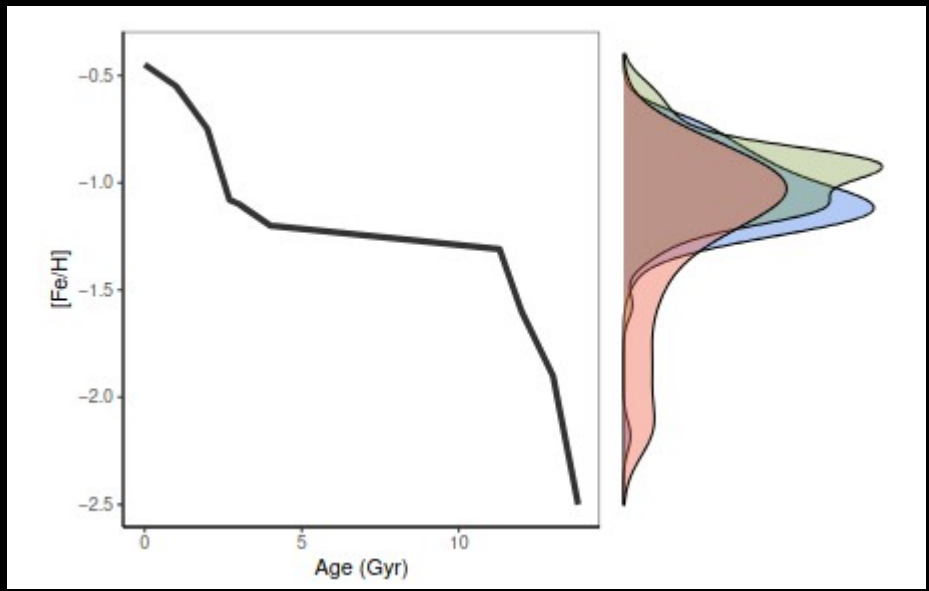
- Dynamics and kinematics are also necessary (see next talk!)

Credit: B. C. Quint/SOAR/CTIO/NOIRLab/NSF/AURA

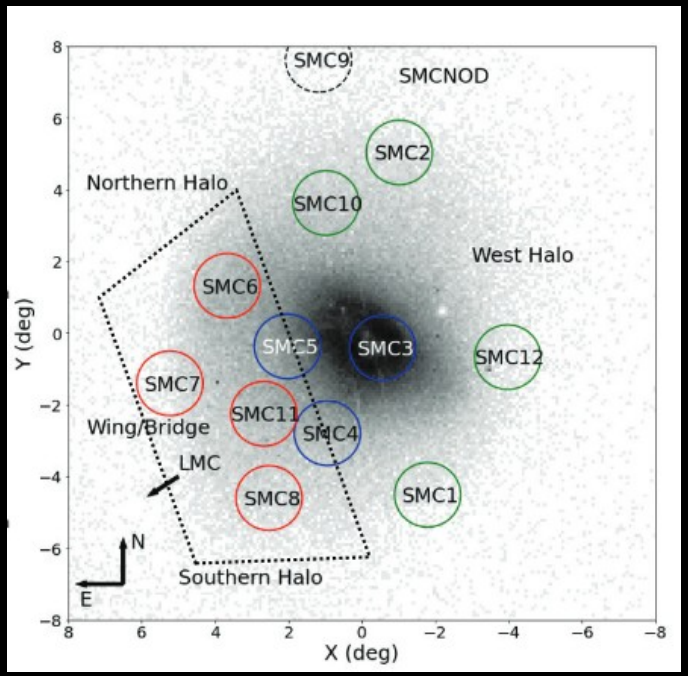
VISCACHA

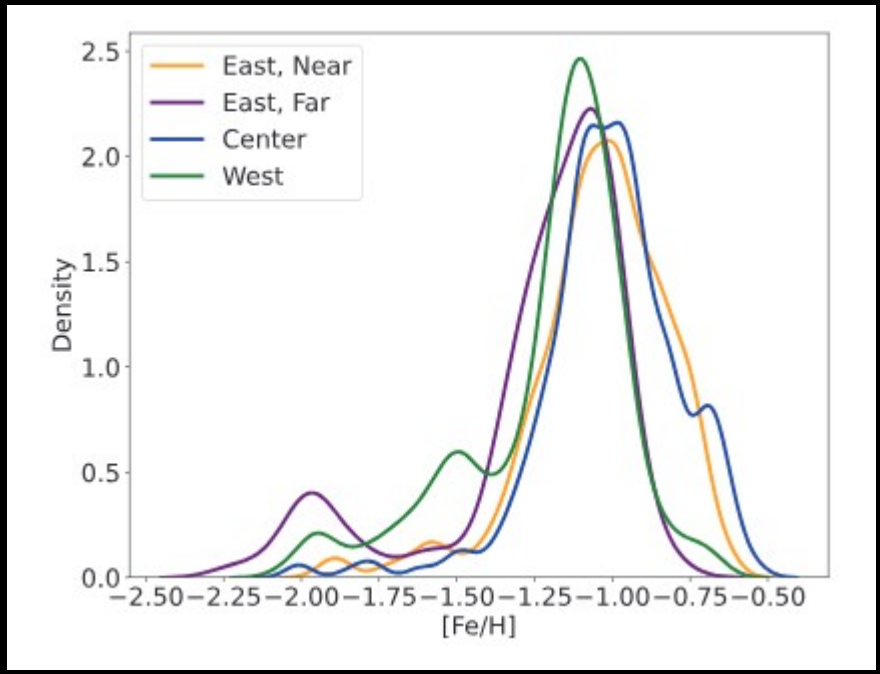
ADDITIONAL SLIDES



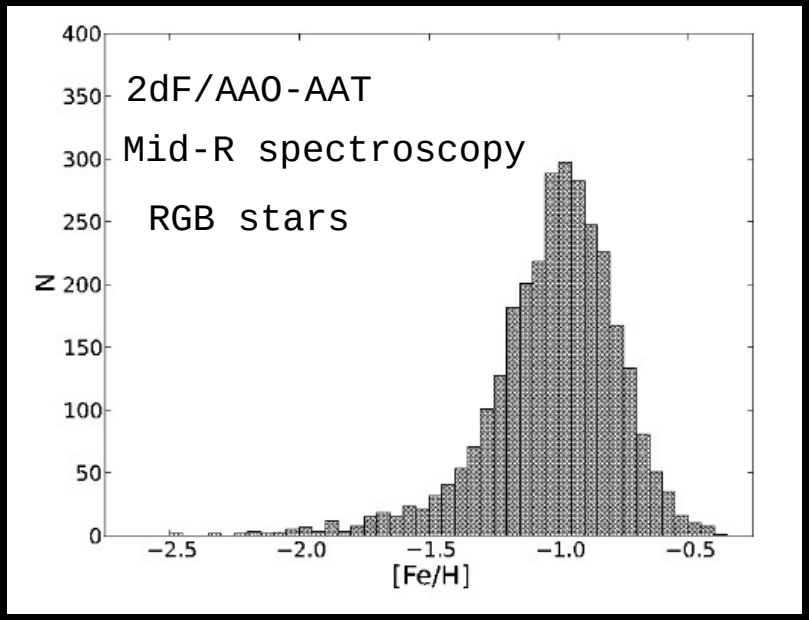


Mucciarelli et al. 2023b

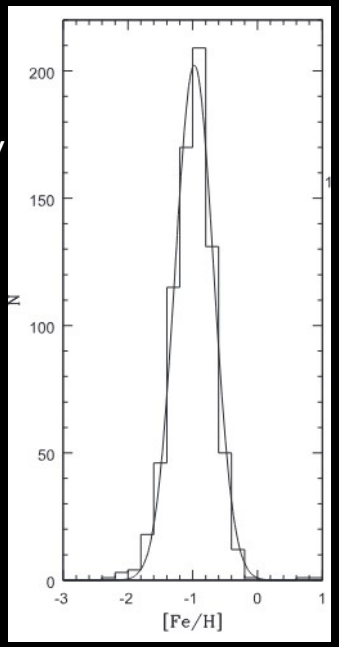


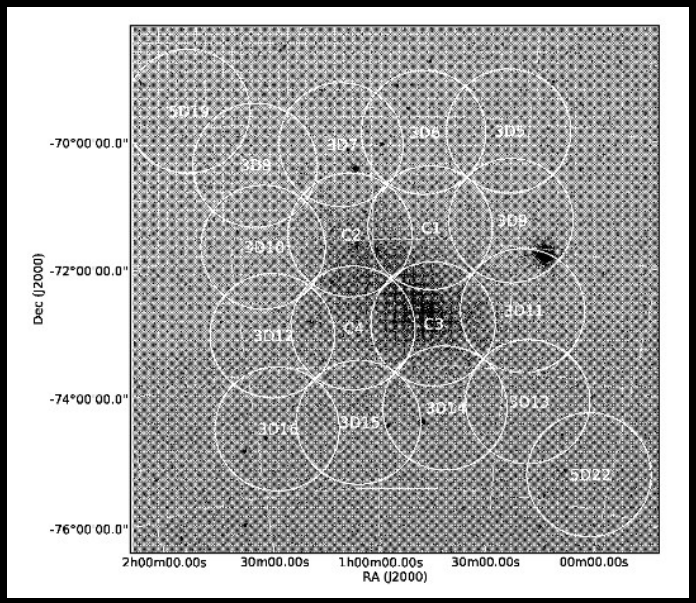


Almeida et al. 2024

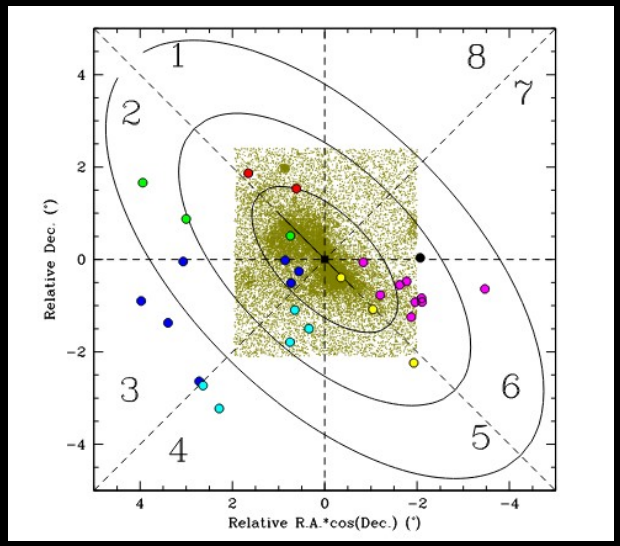


Fors2/VLT
Mid-R spectroscopy
RGB stars





Dobbie et al. 2014



Parisi et al. 2016

The Magellanic Clouds is one of the nearest interacting systems of dwarf galaxies

Putman+ 1998; Diaz & Bekki 2012; Hammer+ 2015

Large Magellanic Cloud

Distance: 49.6 ± 0.5 kpc
(Pietrzyński et al. 2019)

Flat disc morphology with a single spiral arm and an asymmetric stellar bar
(e.g. van der Marel 2001 ; Ruiz-Lara et al. 2020)

Warped outer stellar disc
(e.g. Choi et al. 2018; Saroon & Subramanian 2022)

Small Magellanic Cloud

Distance: 62.4 ± 0.8 kpc
(Graczyk et al. 2020)

Elongated, triaxial structure with a line-of-sight depth of ~14kpc (inner regions), ~23 kpc (in the eastern part)
(Subramanian & Subramaniam 2012, Nidever et al. 2013)