


VISCACHA

THE MAGELLANIC CLOUDS HISTORY TOLD BY THEIR STAR CLUSTERS

Bruno Dias, IAI/UTA, CHILE

Jul 27, 2022

Gemini Science Meeting

Affiliation:

UNIVERSIDAD DE TARAPACÁ
Universidad del Estado

Support:

Agencia Nacional de Investigación y Desarrollo
Ministerio de Ciencia, Tecnología, Conocimiento e Innovación
Gobierno de Chile

Fondecyt
Fondo Nacional de Desarrollo Científico y Tecnológico

VISCACHA survey observations:

SOAR TELESCOPE

NOIR Lab

GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders

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2nd GSM 2007, FOZ DO IGUAÇU, BRAZIL

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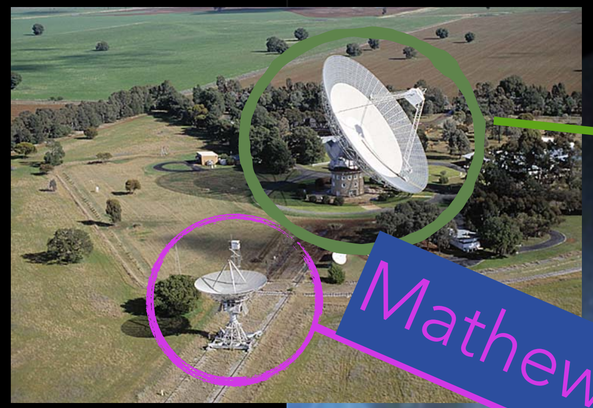
200° MAGELLANIC STREAM (TRAILING) + LEADING ARM: RAM PRESSURE VS. TIDAL ORIGIN

VISCACHA

Parkes, 18m, 64m



Putman+98

Mathewson+74

RAM PRESSURE:

ONLY GAS LEFT BEHIND

Gunn & Gott (1972)
Moore & Davies (1994)

TIDAL STRIPPING:

GAS+STARS PRESENT LEADING AND TRAILING STRUCTURES

Broeils & van Woerden (1994)
Gardiner & Noguchi (1996)

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TIDAL MODELS

BOUND

Diaz & Bekki (2012)

- LMC and SMC have been bound to the Milky Way
- Only recently (~2 Gyr ago) LMC+SMC became a pair
- Orbital period 1.5-2 Gyr

1ST INFALL

Besla et al. (2007)

- LMC and SMC have been a pair, but far away from the Milky Way
- Only recently (~2 Gyr ago) LMC+SMC arrived to the MW vicinity
- Hyperbolic orbit (1st infall) or 2nd passage (orbital period ~6 Gyr)

DO THE MODELS REPRODUCE THE OBSERVATIONAL EVIDENCE?

BOUND

1ST INFALL

DO THE MODELS REPRODUCE THE OBSERVATIONAL EVIDENCE?

	BOUND	1ST INFALL

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Position*, morphology, kinematics Mag. Stream (Gardiner & Noguchi 1996; Diaz & Bekki 2012; Besla et al. 2010, 2012)		

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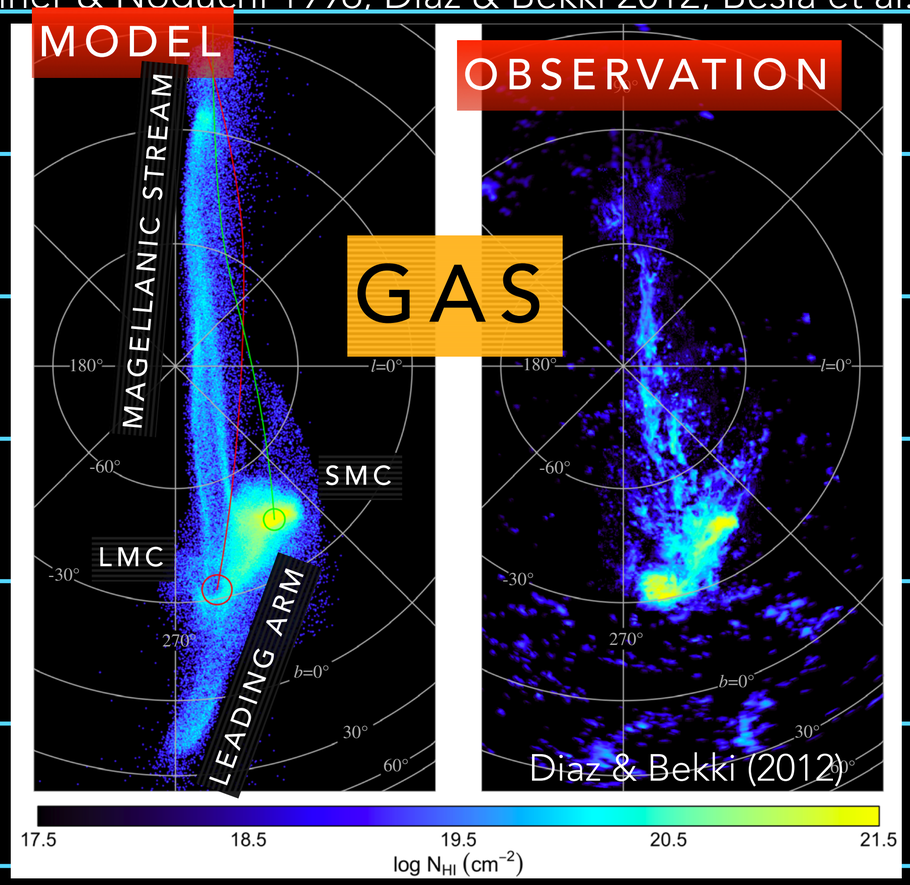

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1ST INFALL

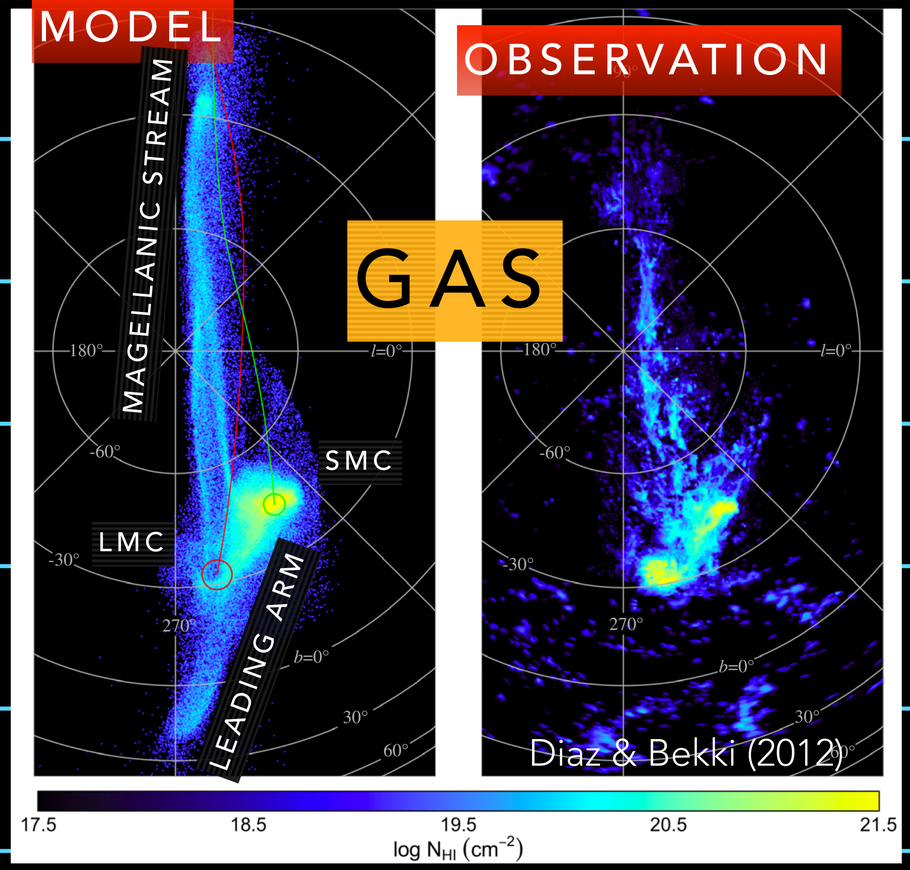
Position*, morphology, kinematics Mag. Stream

(Gardiner & Noguchi 1996; Diaz & Bekki 2012; Besla et al. 2010, 2012)

MODEL

OBSERVATION

GAS

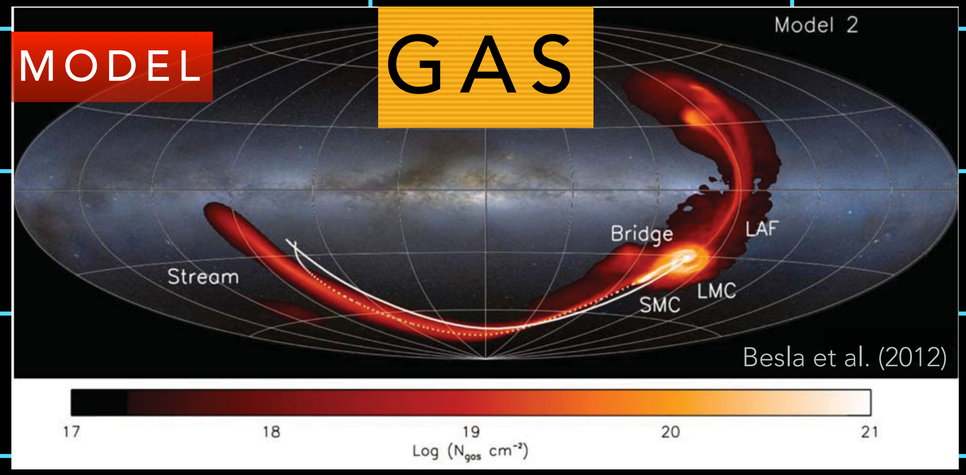


OBSERVATION

Nidever et al. (2010)

MODEL

GAS



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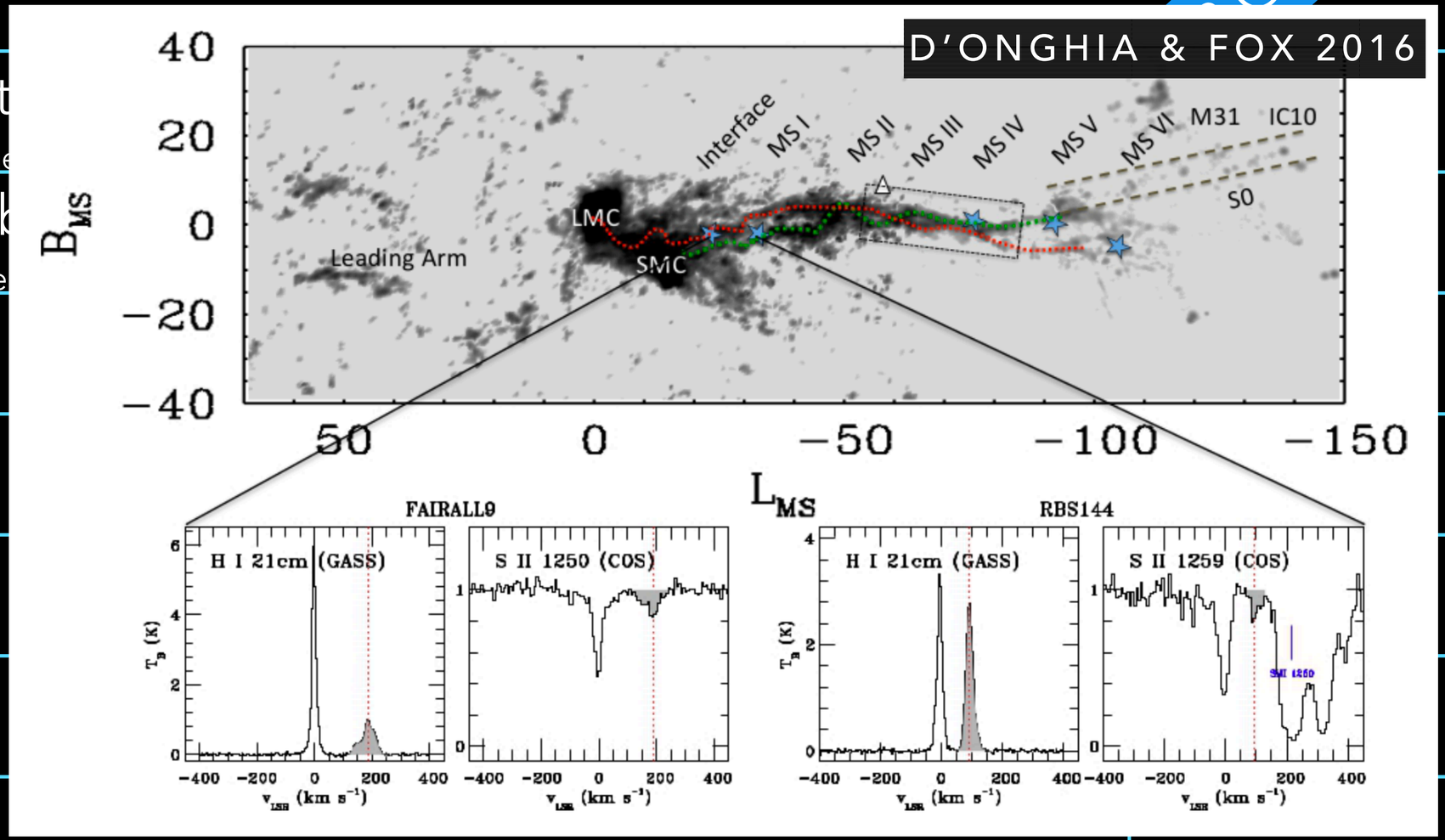
1ST INFALL

Posit (Gardine	
Doub (Nideve	
	YES



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LMC local wake and Northern overdensity (Conroy et al. 2021)		

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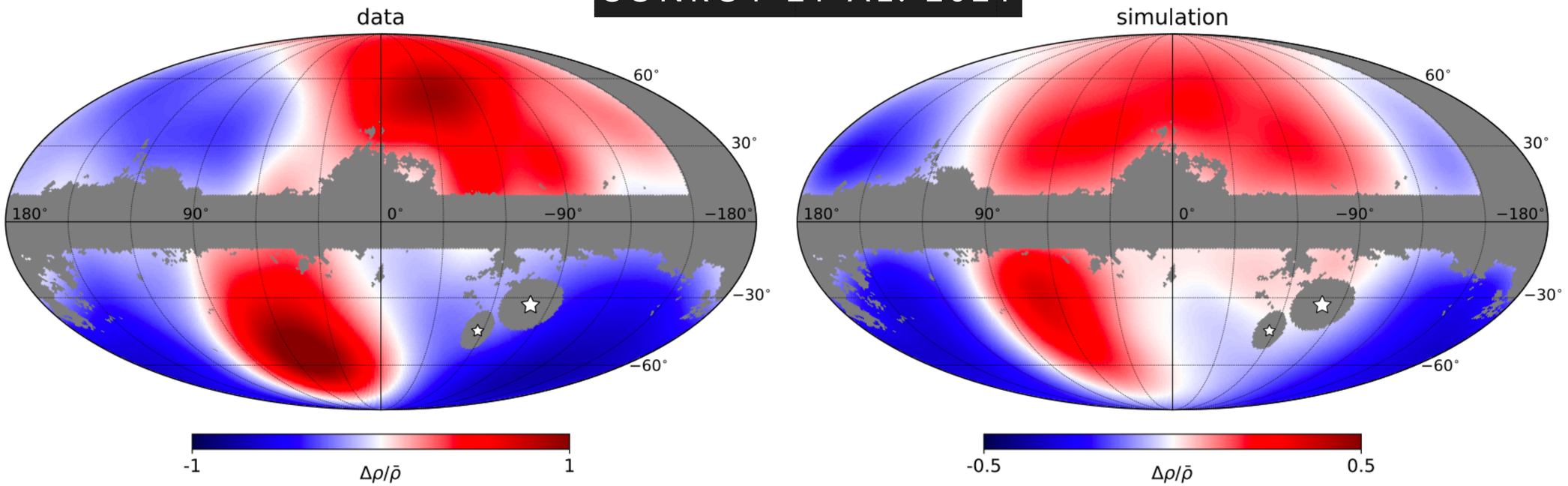
CONROY ET AL. 2021



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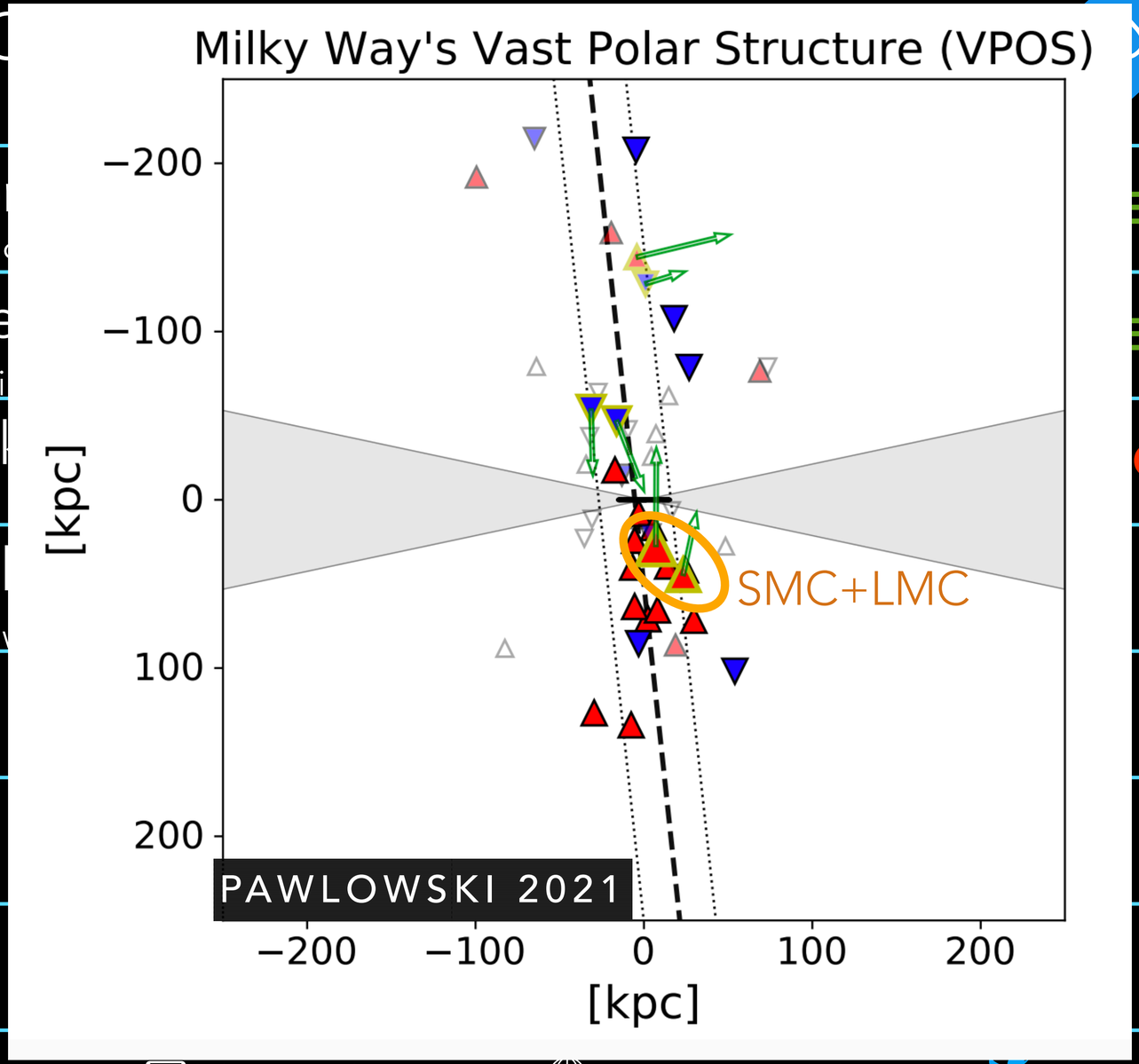
Plane of satellites: origin of VPOS = LMC? (Nichols et al. 2011; Pawlowski 2018, 2021; Li et al. 2021; Hammer et al. 2021)		

DO THE MODELS REPRODUCE THE OBSERVATIC

Position*, mo (Gardiner & Noguchi 19		YES
Double filame (Nidever et al. 2008; Di		NO?
LMC local wa (Conroy et al. 2021)		YES
Plane of satell (Nichols et al. 2011; Pa		



ND

1ST INFALL

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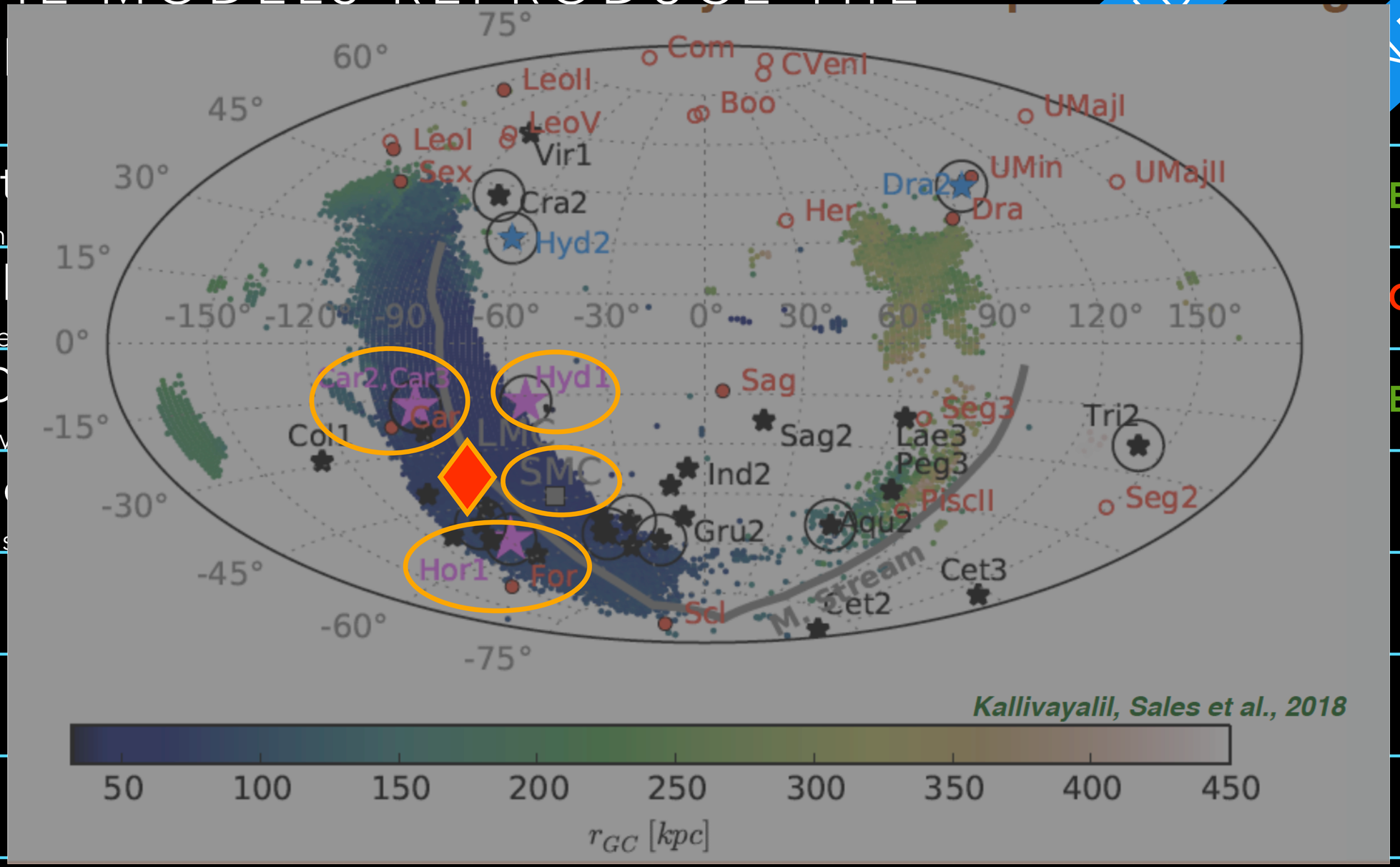

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Plane of satellites: origin of VPOS = LMC? (Nichols et al. 2011; Pawlowski 2018, 2021; Li et al. 2021; Hammer et al. 2021)	YES??	YES??
What is the LMC mass? (Kallivayalil et al. 2013; Guglielmo et al. 2014; Erkal et al. 2019, 2020)		

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What is the LMC mass? (Kallivayalil et al. 2013; Guglielmo et al. 2014; Erkal et al. 2019, 2020)	LIGHT ($\sim 10^{10} M_\odot$)	

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How is the MW potential? (Besla 2007; Nidever et al. 2008; Diaz & Bekki 2012)	SIMPLE (ISOTHERMAL SPHERE)	

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How is the MW potential? (Besla 2007; Nidever et al. 2008; Diaz & Bekki 2012)	SIMPLE (ISOTHERMAL SPHERE)	REALISTIC (NFW)

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How is the MW potential? (Besla 2007; Nidever et al. 2008; Diaz & Bekki 2012)	SIMPLE (ISOTHERMAL SPHERE)	REALISTIC (NFW)
What is the source and precision of the PMs (Kallivayalil et al. 2006, Vieira et al. 2010, Niederhofer et al. 2018, Helmi et al. 2018)		

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Plane of satellites: origin of VPOS = LMC? (Nichols et al. 2011; Pawlowski 2018, 2021; Li et al. 2021; Hammer et al. 2021)	YES??	YES??
What is the LMC mass? (Kallivayalil et al. 2013; Guglielmo et al. 2014; Erkal et al. 2019, 2020)	LIGHT ($\sim 10^{10} M_\odot$)	HEAVY ($\sim 10^{11} M_\odot$)
How is the MW potential? (Besla 2007; Nidever et al. 2008; Diaz & Bekki 2012)	SIMPLE (ISOTHERMAL SPHERE)	REALISTIC (NFW)
What is the source and precision of the PMs (Kallivayalil et al. 2006, Vieira et al. 2010, Niederhofer et al. 2018, Helmi et al. 2018)	GROUND <0.3 mas/yr	

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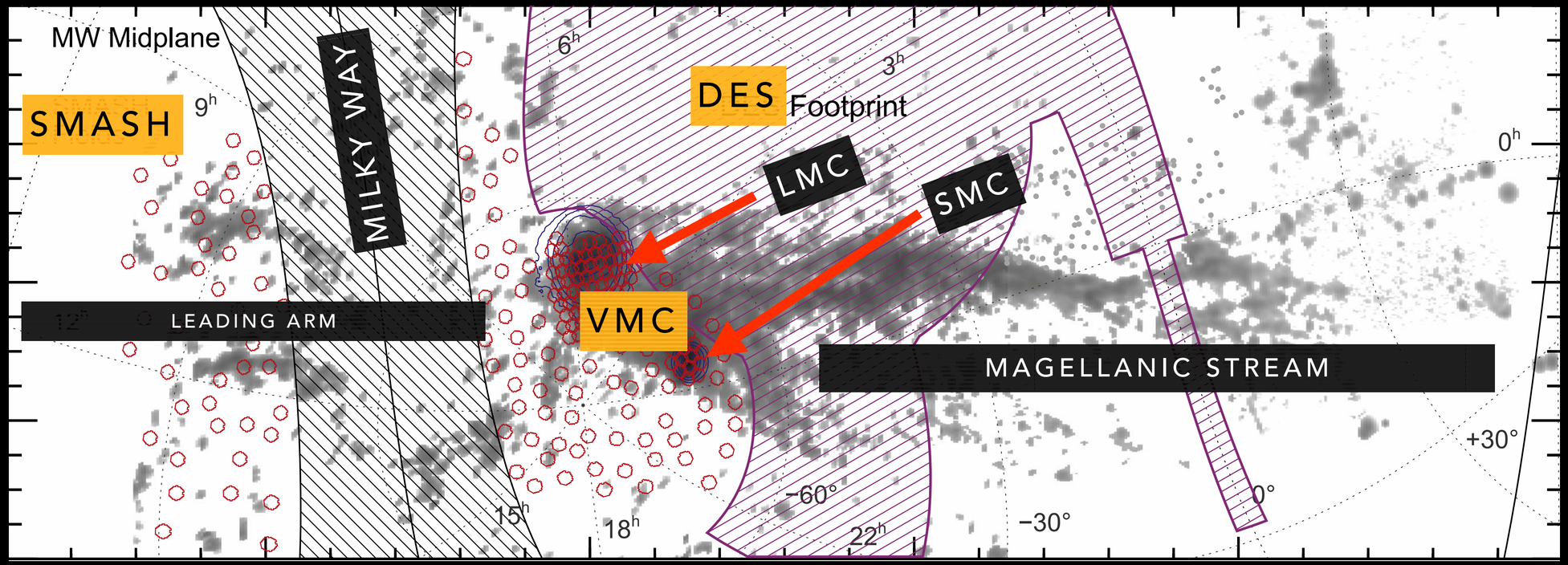
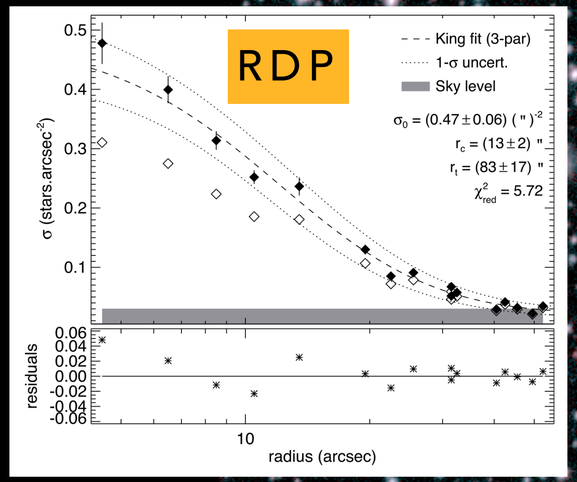
How is the MW potential? (Besla 2007; Nidever et al. 2008; Diaz & Bekki 2012)	SIMPLE (ISOTHERMAL SPHERE)	REALISTIC (NFW)
What is the source and precision of the PMs (Kallivayalil et al. 2006, Vieira et al. 2010, Niederhofer et al. 2018, Helmi et al. 2018)	GROUND <0.3 mas/yr	SPACE <0.06mas/yr

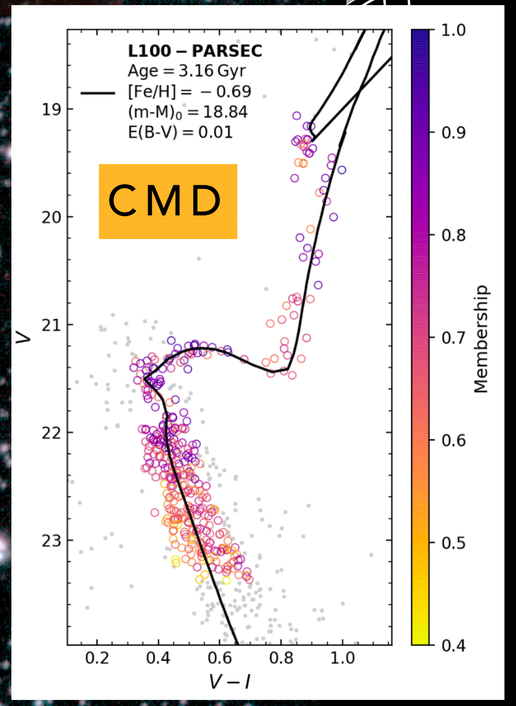
MANY SURVEYS HAVE BEEN LOOKING FOR THE STELLAR COUNTERPART OF THE TIDAL EFFECTS CAUSED BY THE ORBITS OF THE SMC/LMC

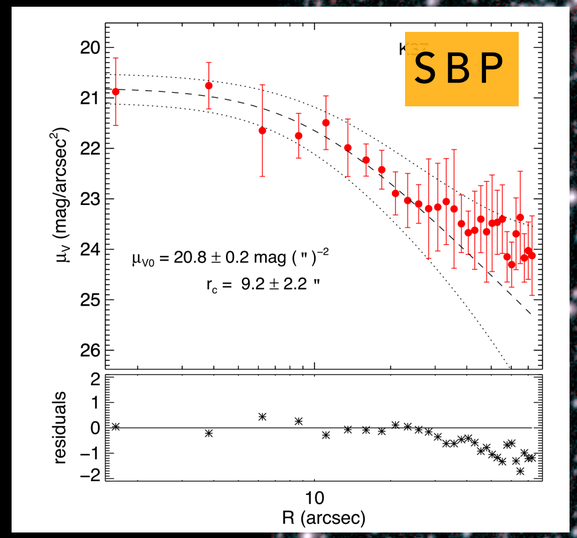


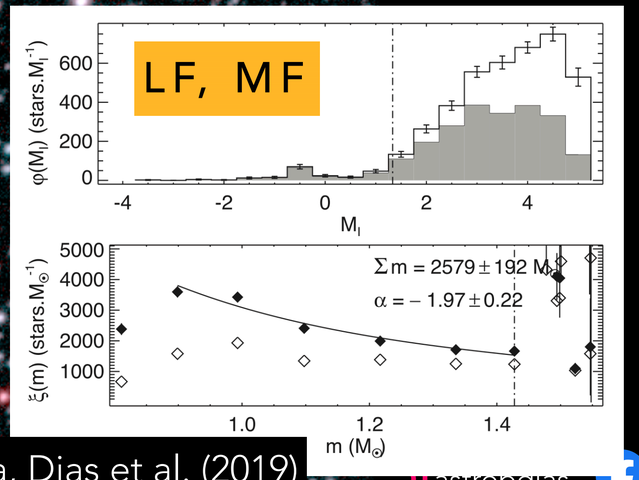
Background image: Nidever et al. (2017)

WHY STAR CLUSTERS?





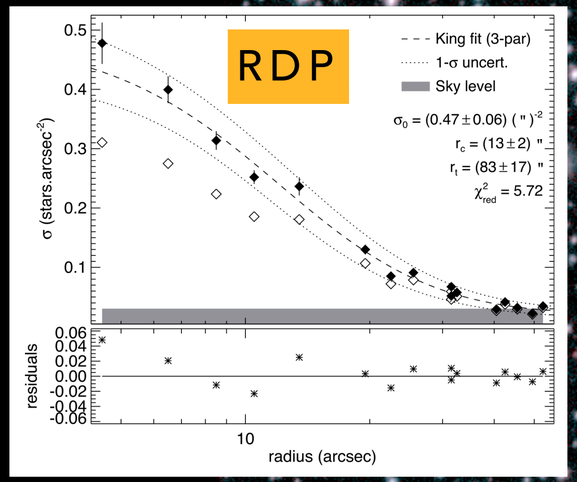


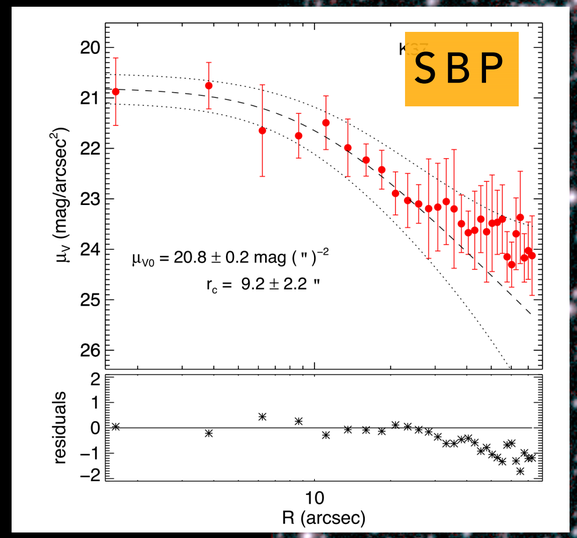


30″

Maia, Dias et al. (2019)

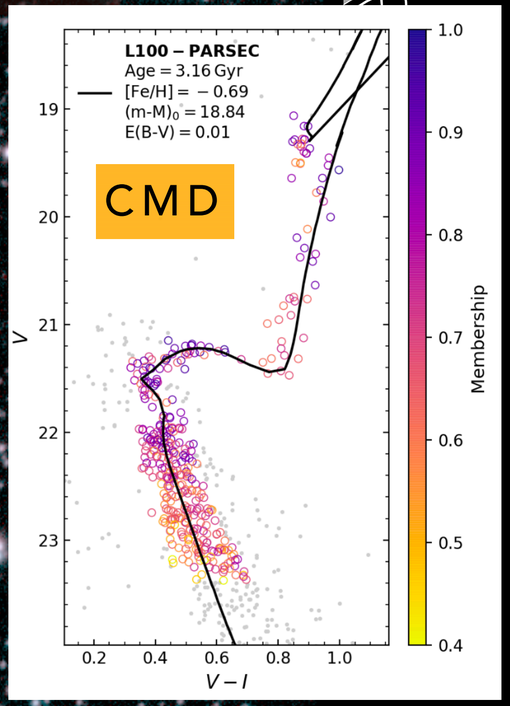
WHY STAR CLUSTERS?

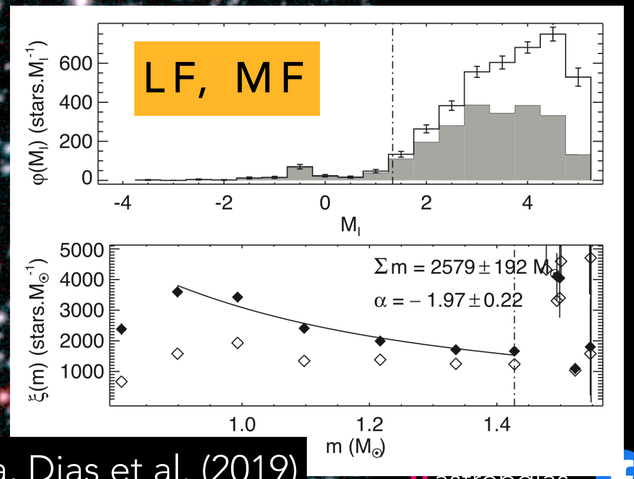




- 3D MAP OF SMC, LMC, AND BRIDGE WITH:
- AGE
- METALLICITY
- REDDENING
- CORE RADIUS
- TIDAL RADIUS
- ELLIPTICITY
- TOTAL MASS
- MASS FUNCTION
- DISSOLUTION
- eMSTO
- ...

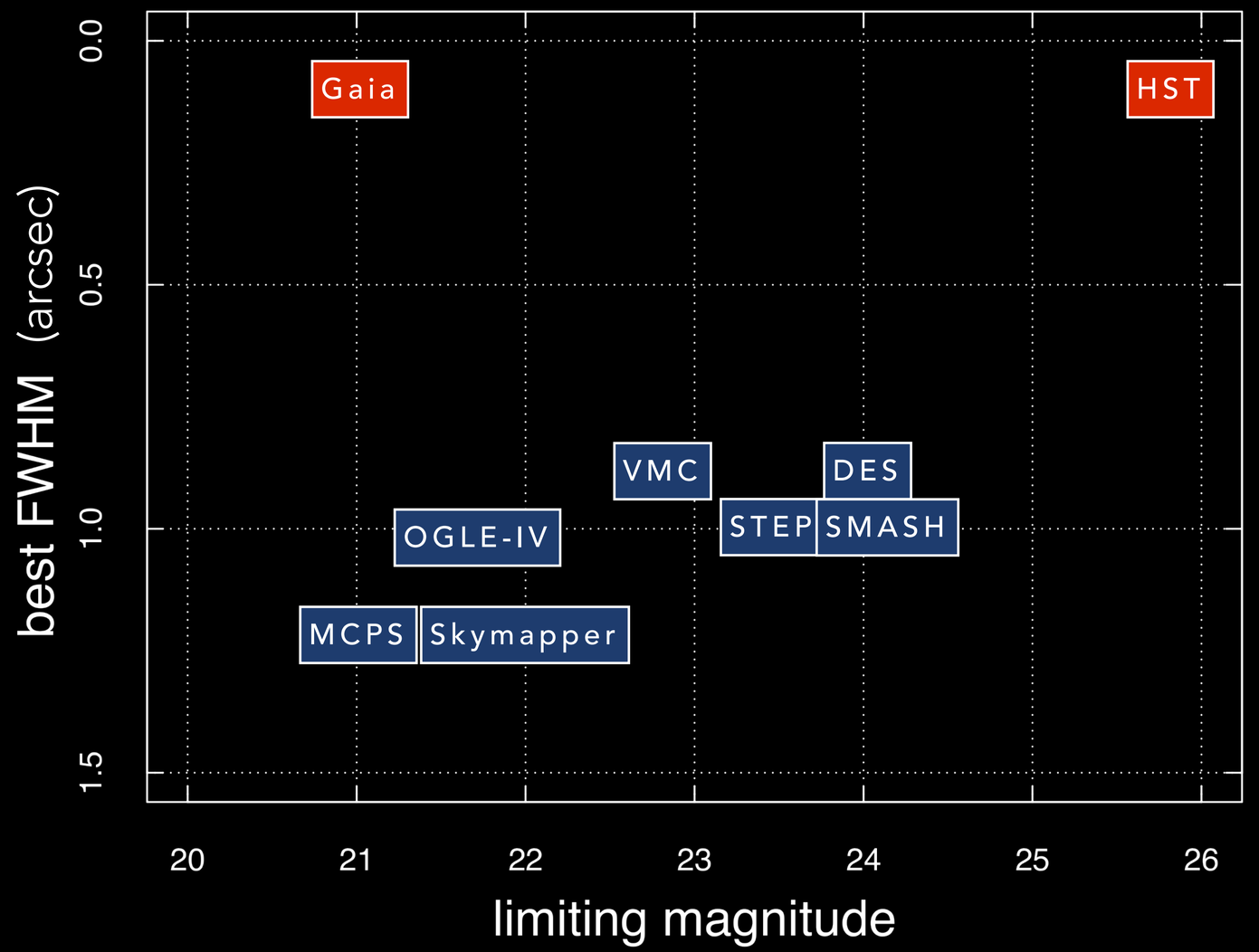
30”





Maia, Dias et al. (2019)

WHY ANOTHER SURVEY?

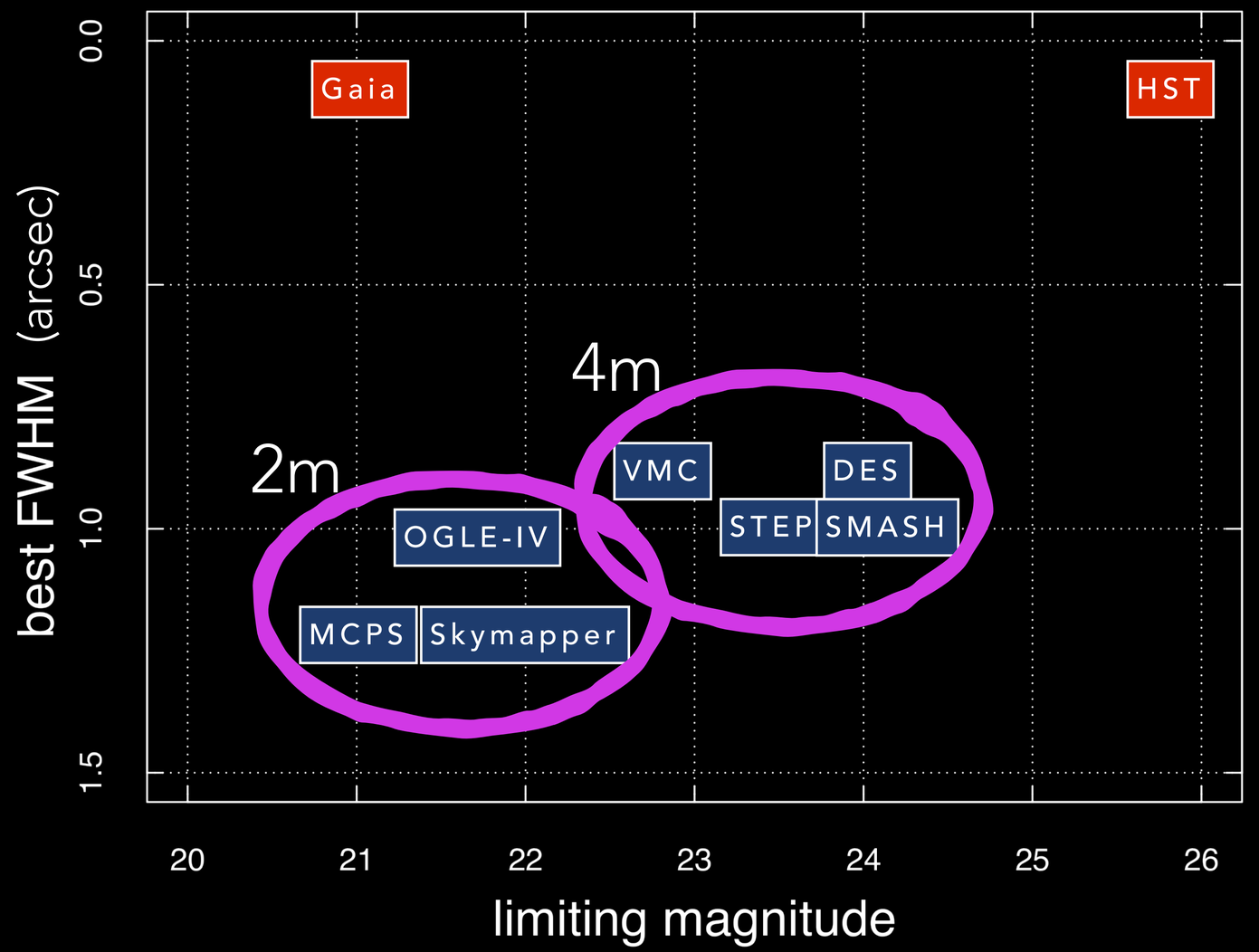


VISCACHA

Space

Ground

WHY ANOTHER SURVEY?

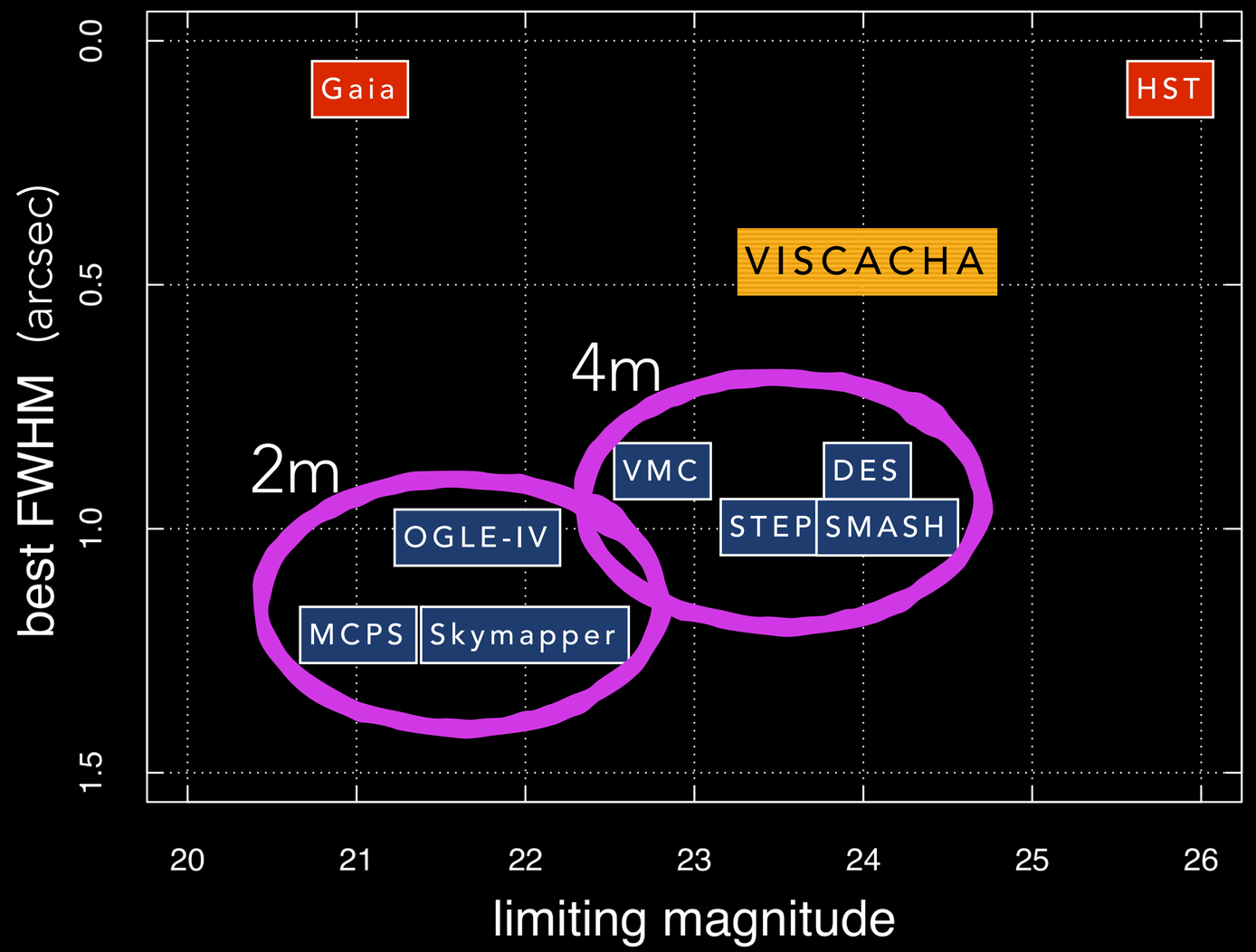


VISCACHA

Space

Ground

WHY ANOTHER SURVEY?



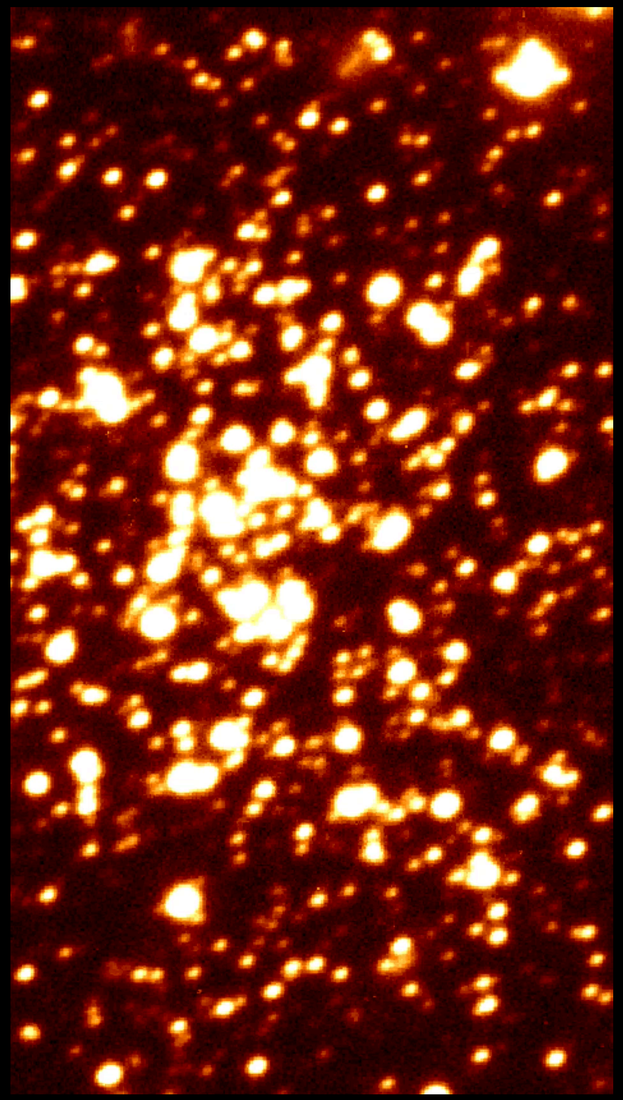
VISCACHA

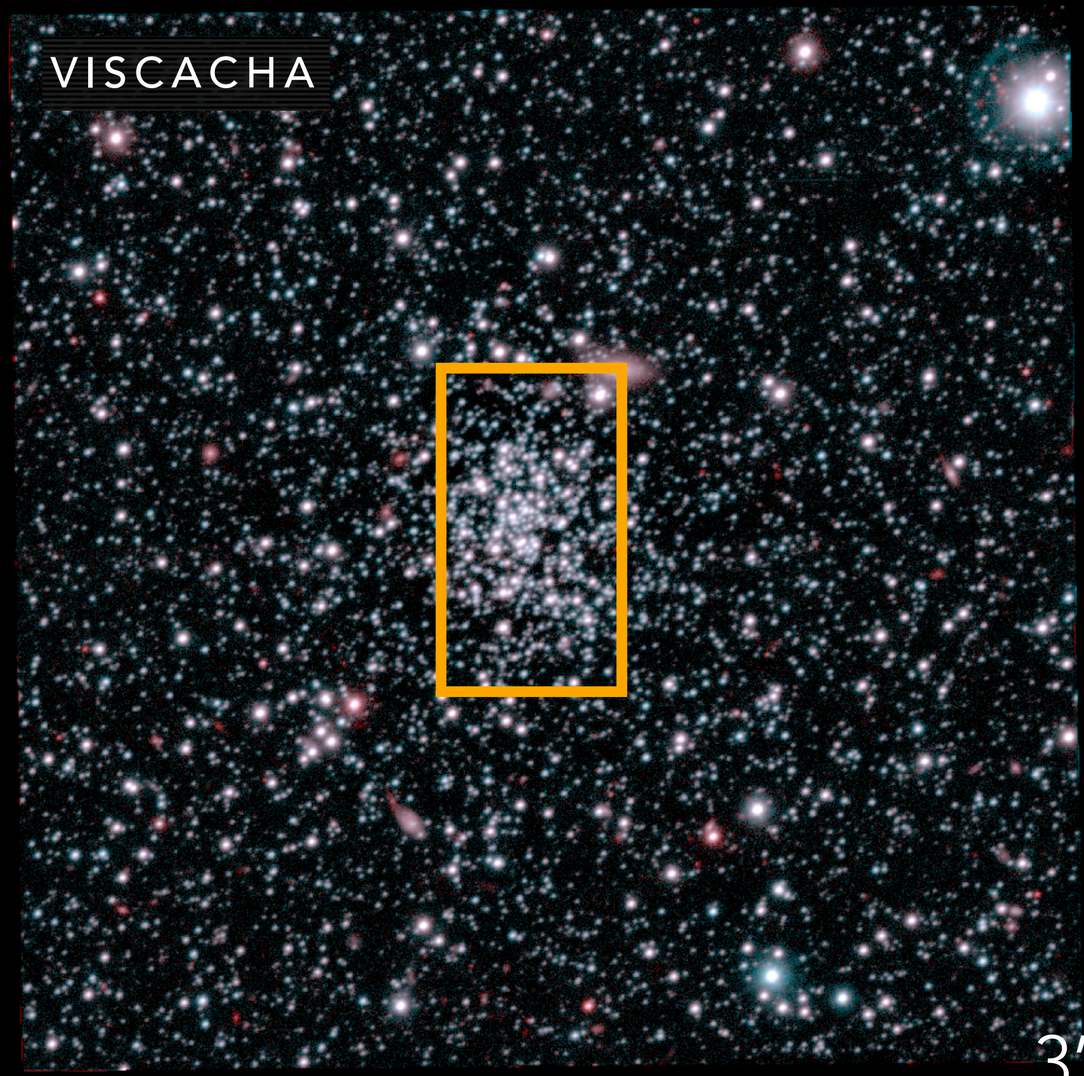
Space

Ground +AO

Ground

VISCACHA AND SMASH





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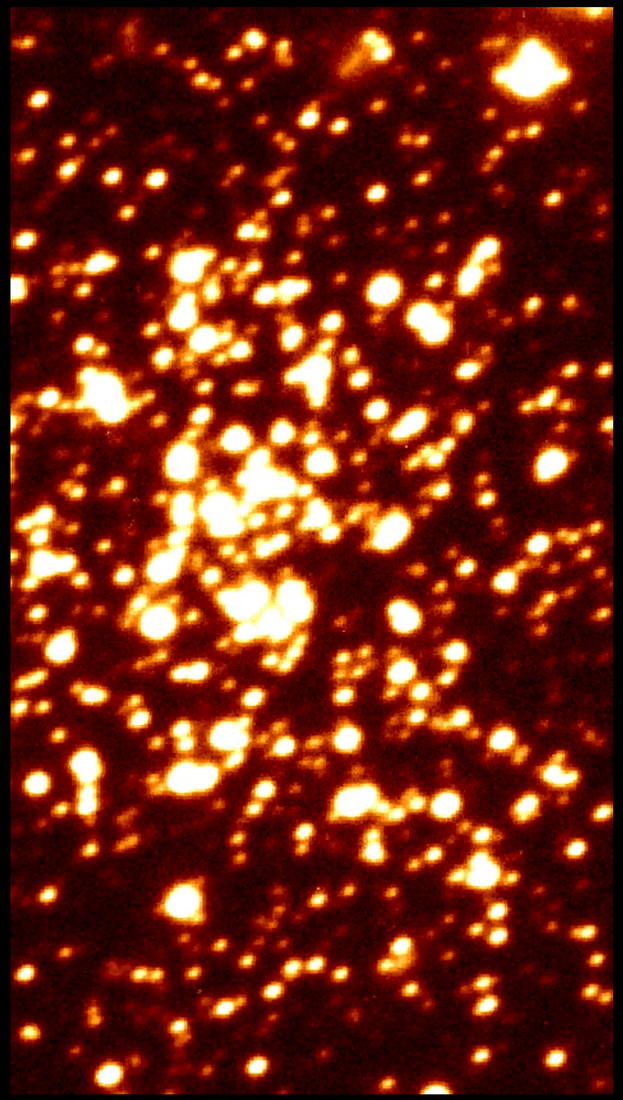
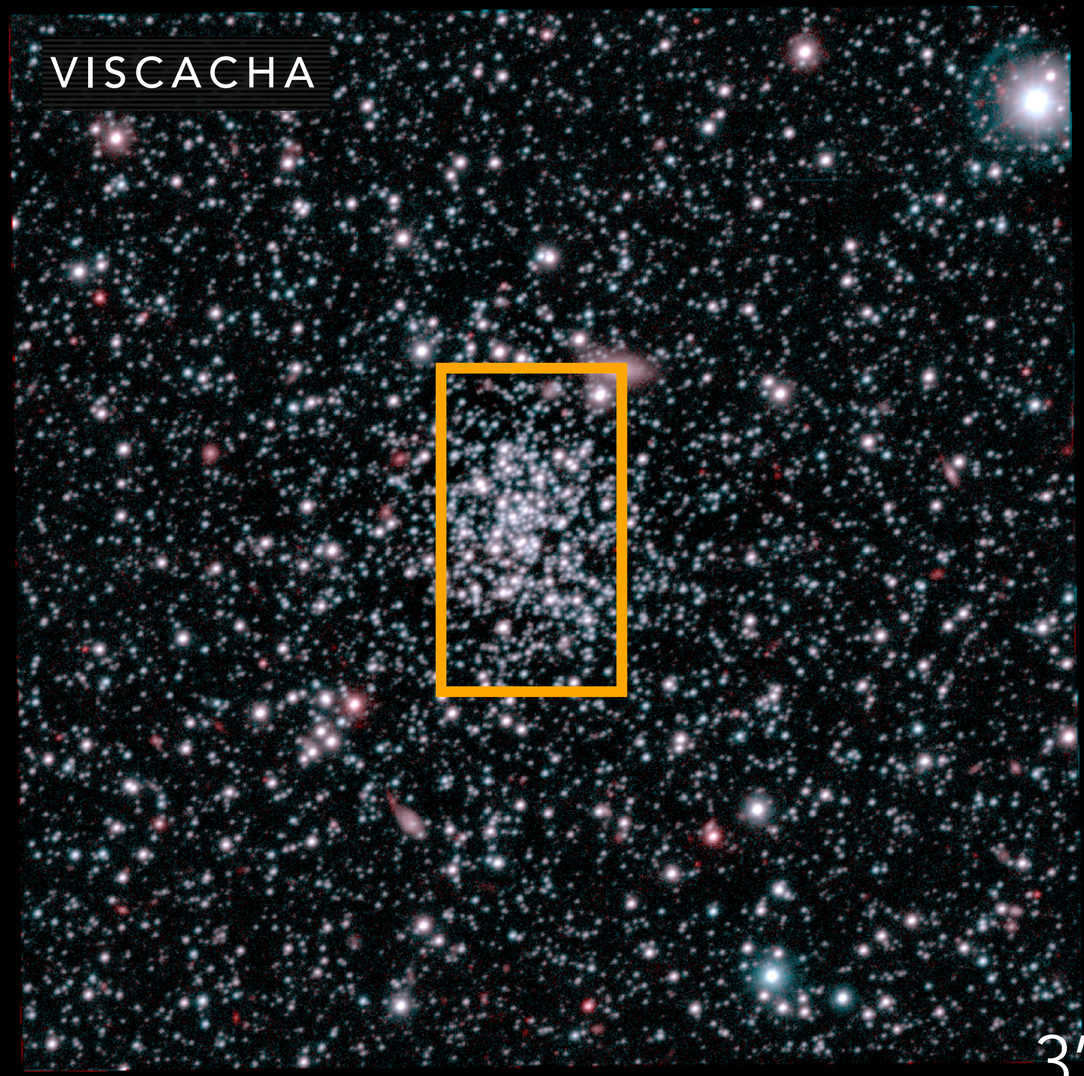
VISCACHA AND SMASH





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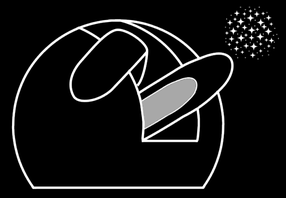
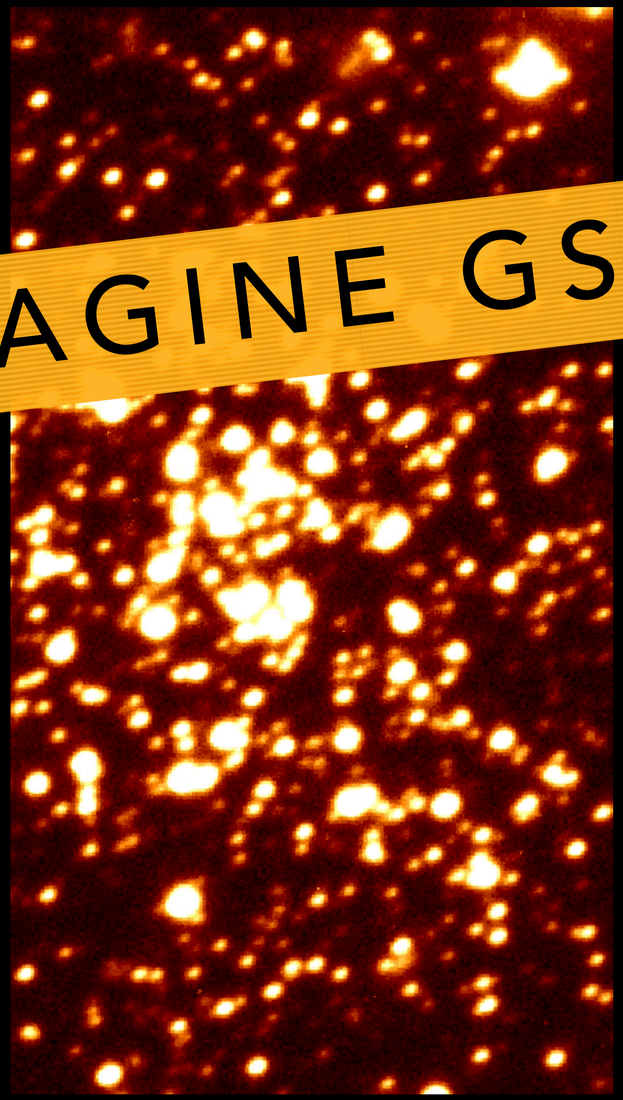
VISCACHA AND SMASH





VISCACHA

IMAGINE GSAOI+GEMS HERE ...

3′

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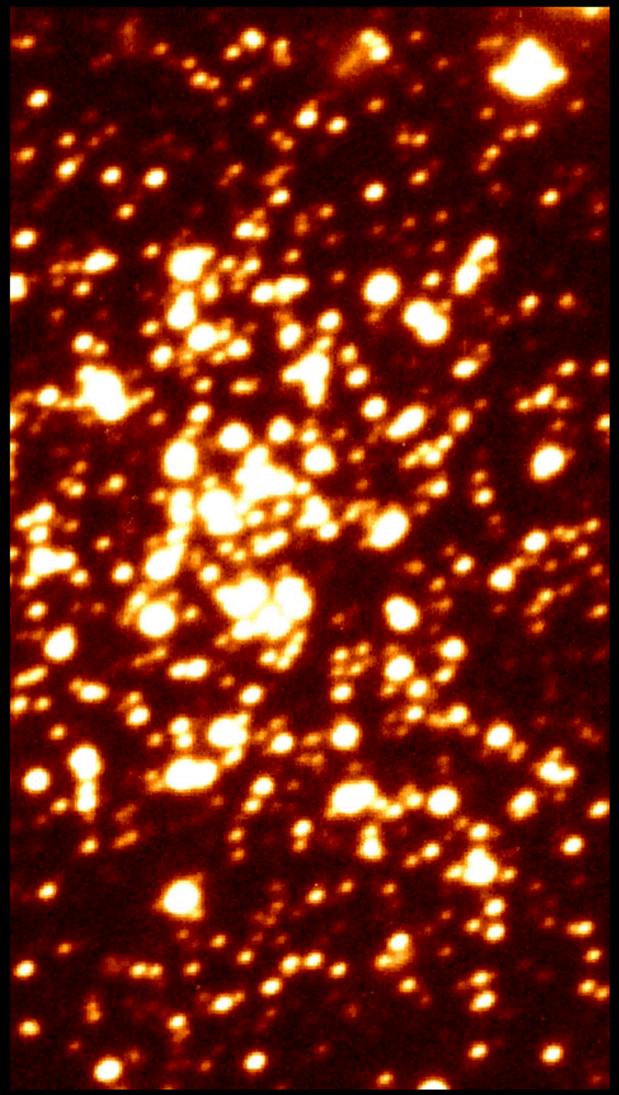
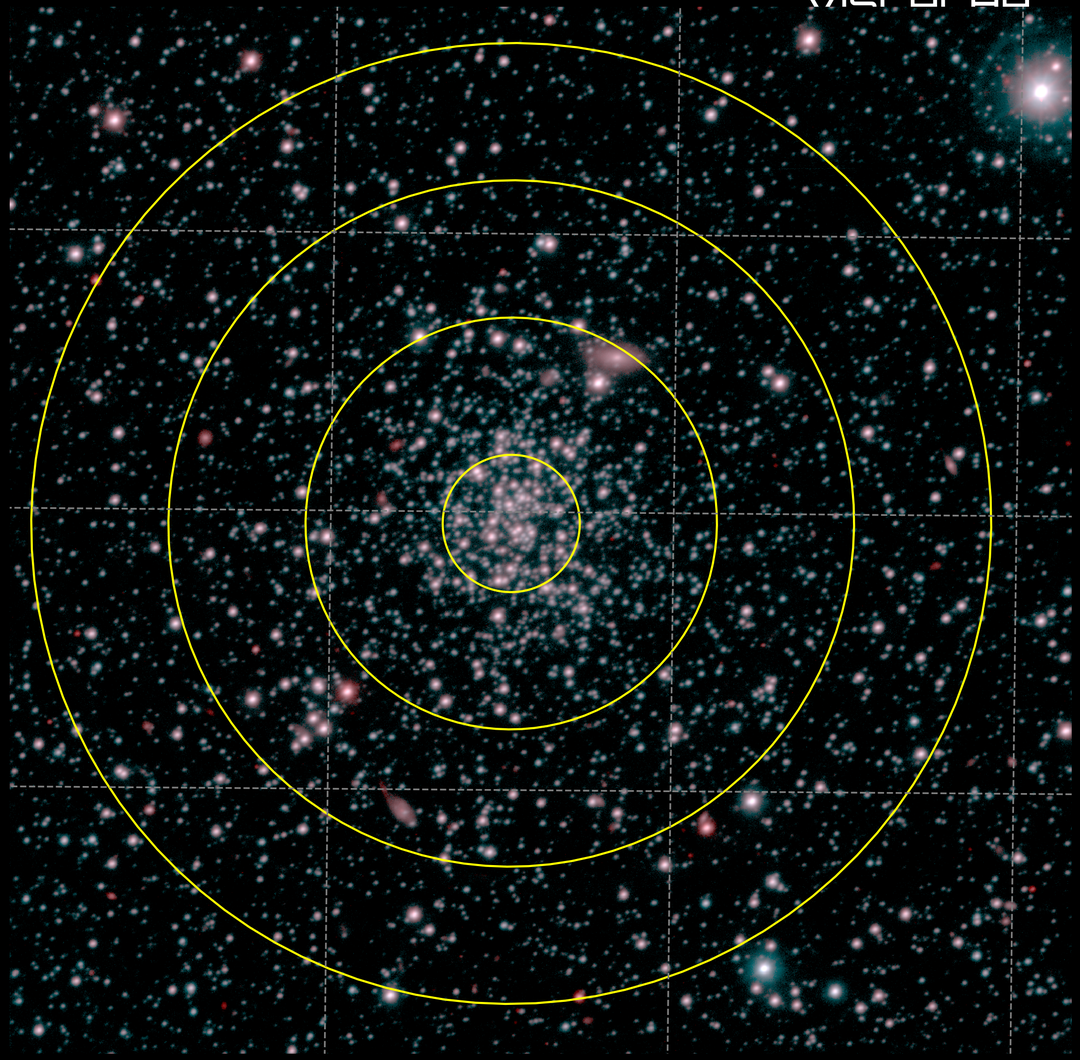
VISCACHA AND SMASH





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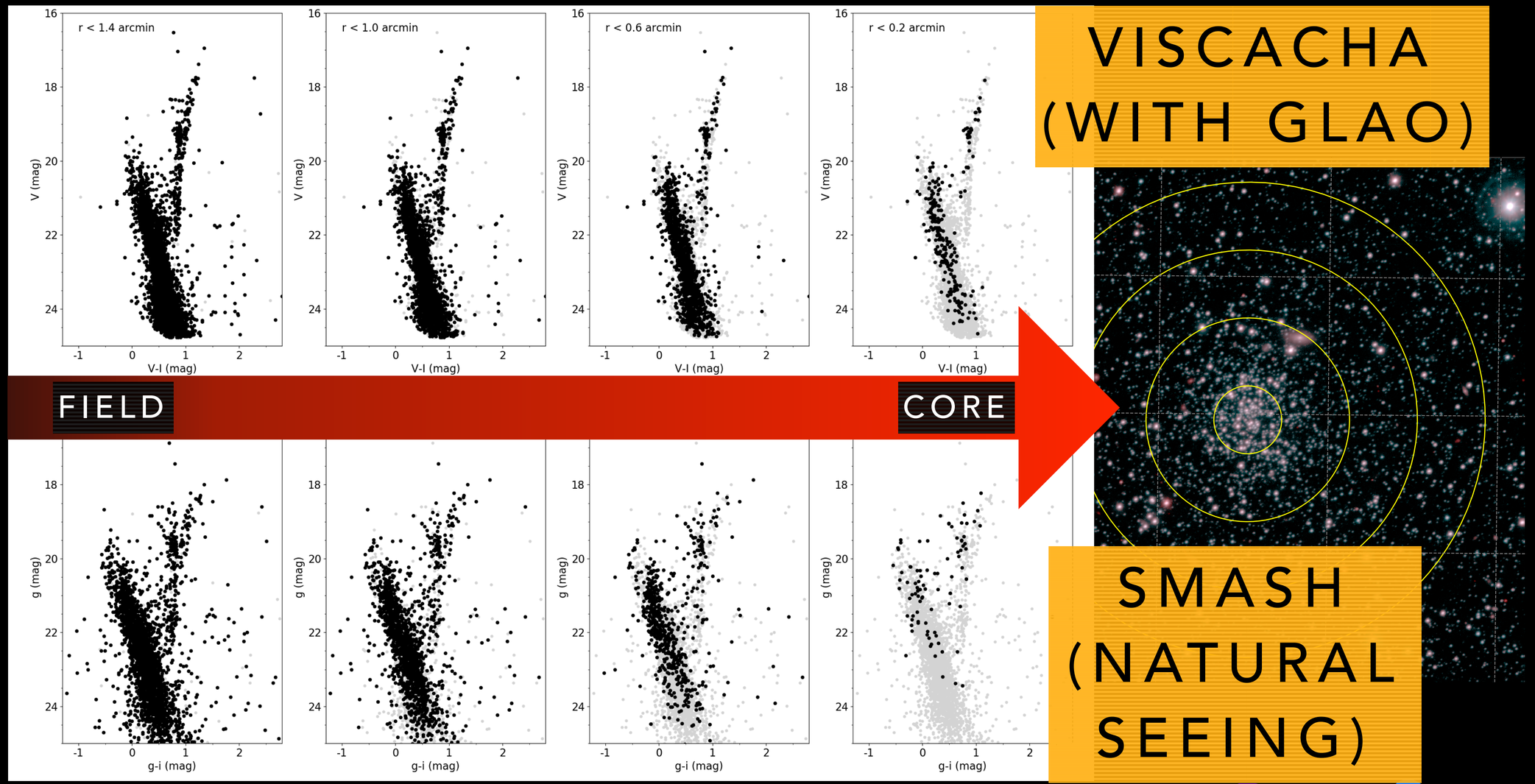
VISCACHA AND SMASH



VISCACHA (WITH GLAO)

SMASH (NATURAL SEEING)

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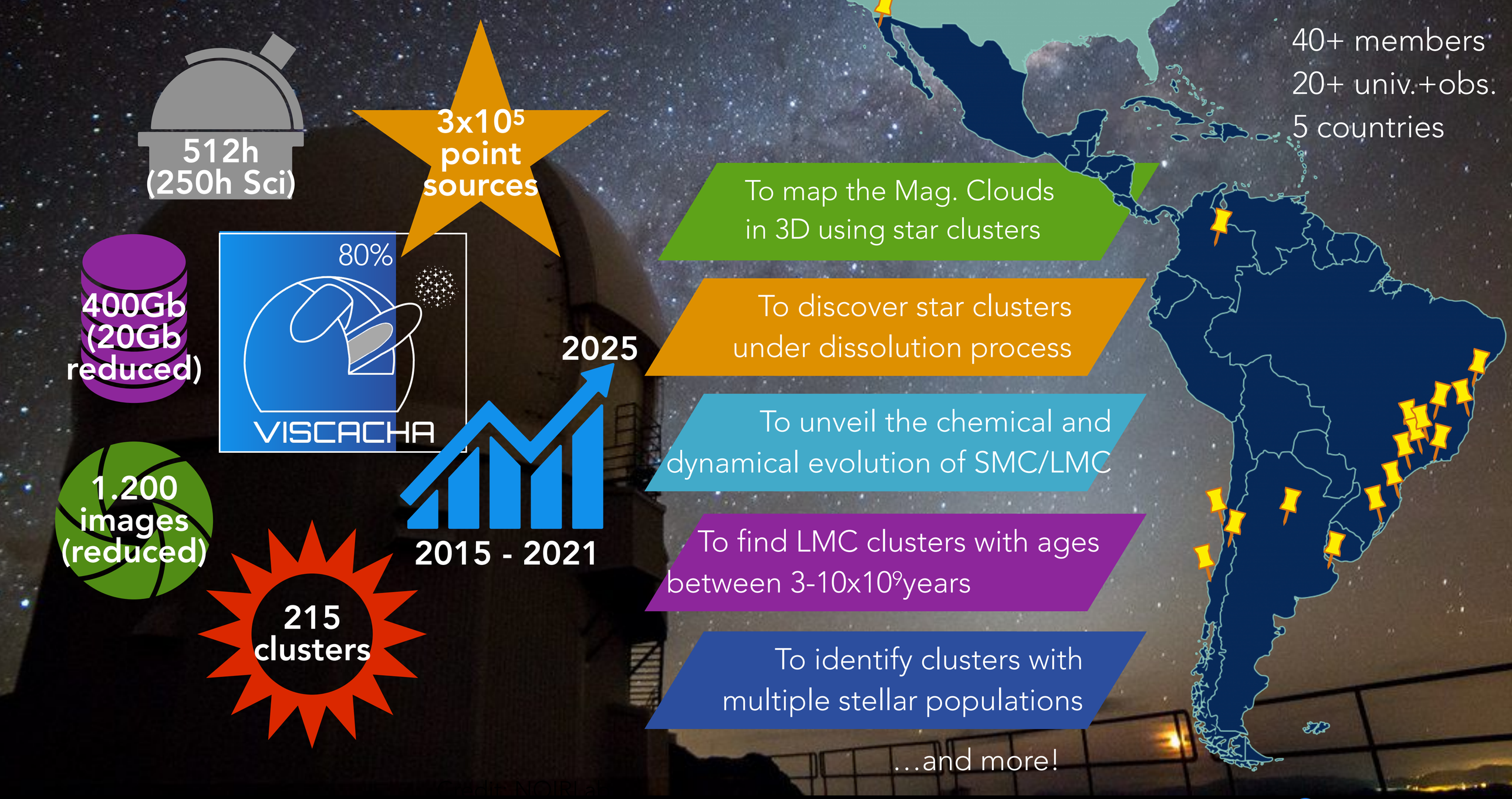

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512h
(250h Sci)

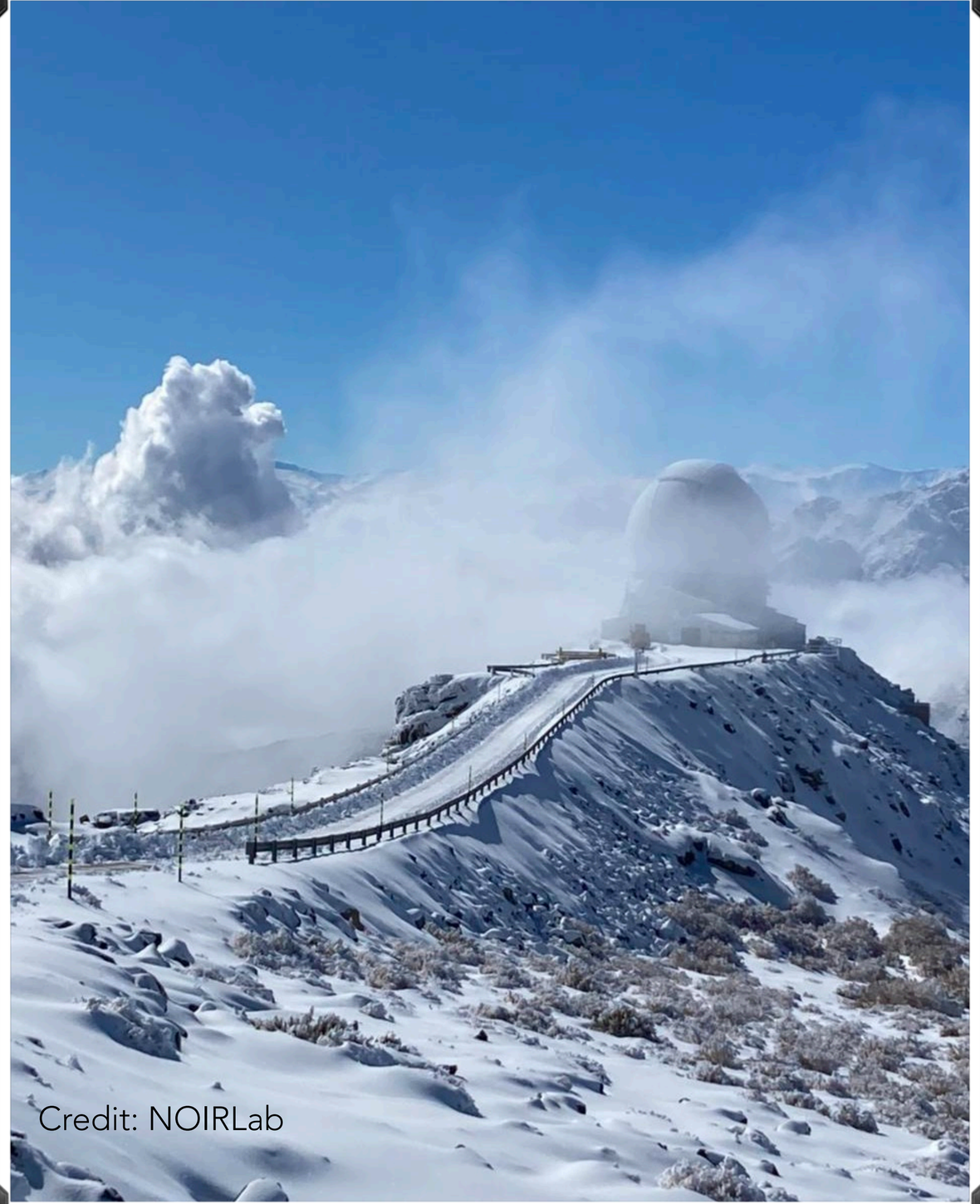
80%

VISCACH

400Gb
(20Gb
reduced)

1.200
images
(reduced)

215
clusters



Credit: NOIRLab

40+ members
20+ univ.+obs.
5 countries

VISCACHA SPECTROSCOPIC FOLLOW-UP + GAIA PROPER MOTIONS

GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders

Chile (PI: Dias et al.) +
Brazil (Kerber et al.) +
Argentina (Parisi et al.)

Joint project: 2018,2019,2020,2021

Credit: NOIRLab

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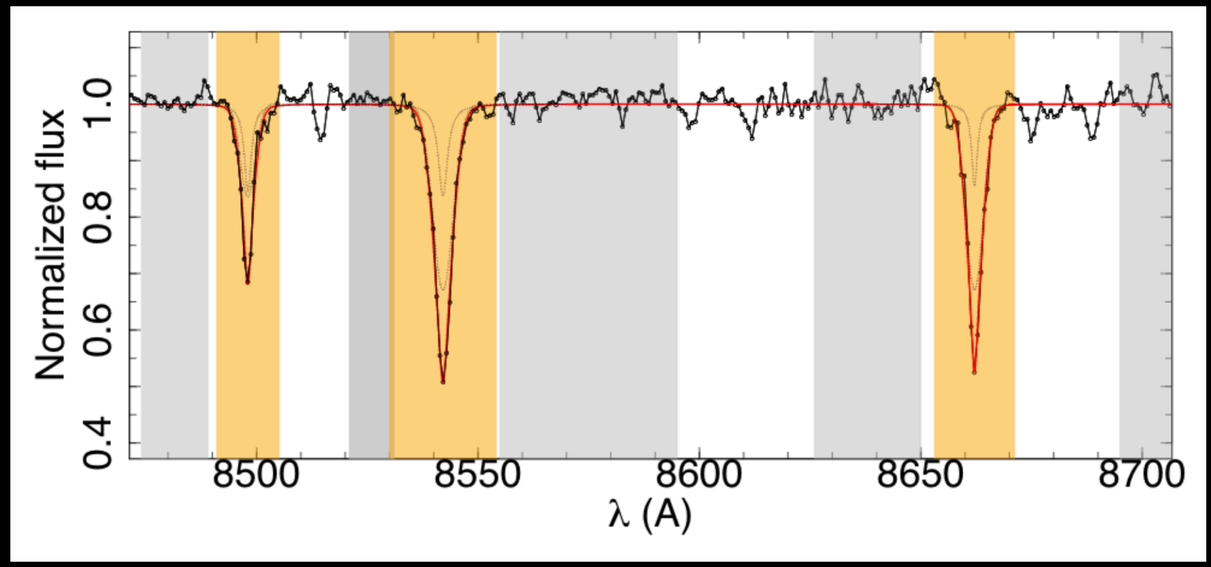
VISCACHA SPECTROSCOPIC FOLLOW-UP + GAIA PROPER MOTIONS

SEE POSTER DIAS & PARISI

SEE POSTER DE BORTOLI ET AL.

GMOS

- Call triplet spectroscopy:
  - Metallicities
  - Radial velocities



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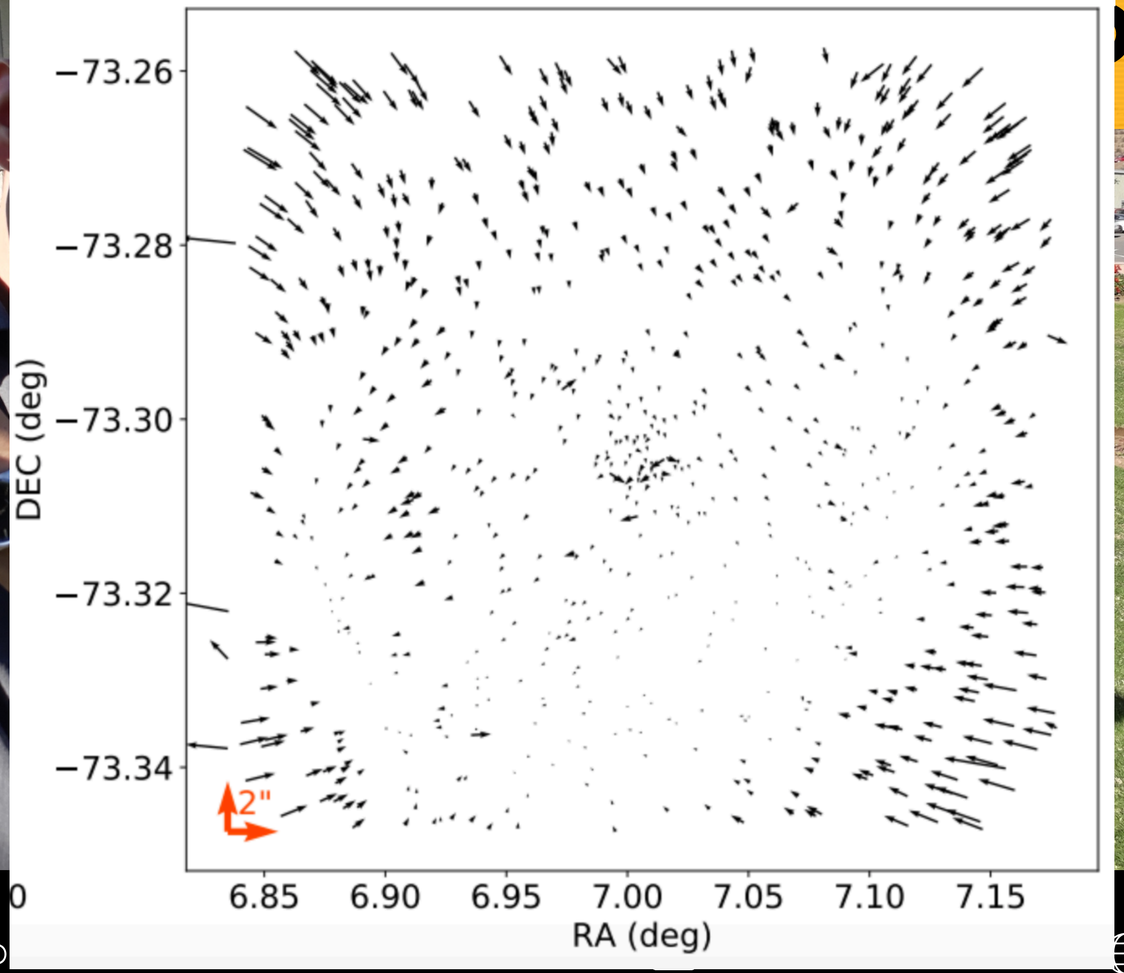
VISCACHA SPECTROSCOPIC FOLLOW-UP + GAIA PROPER MOTIONS

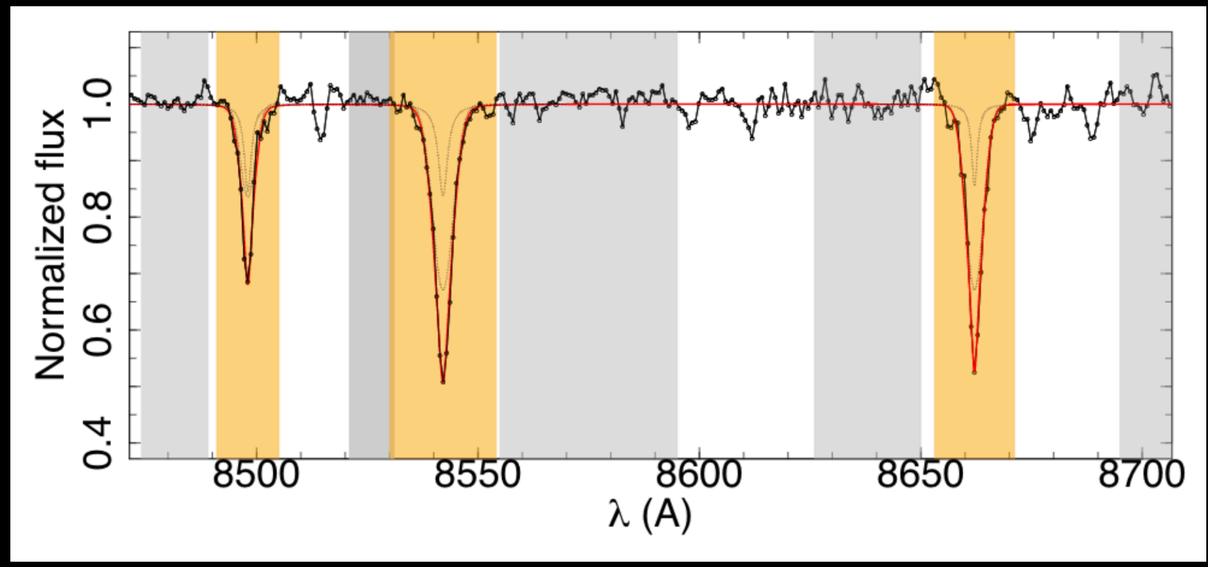
Distortion map of GMOS-S field



SEE POSTER DIAS & PARISI

SEE POSTER DE BORTOLI ET AL.

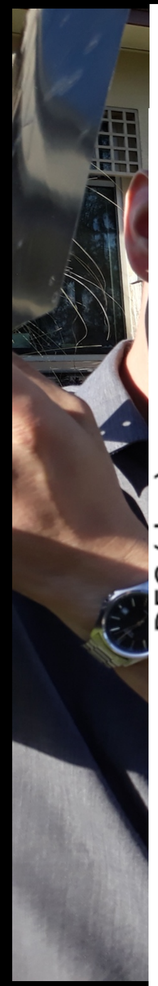
- Call triplet spectroscopy:
  - Metallicities
  - Radial velocities



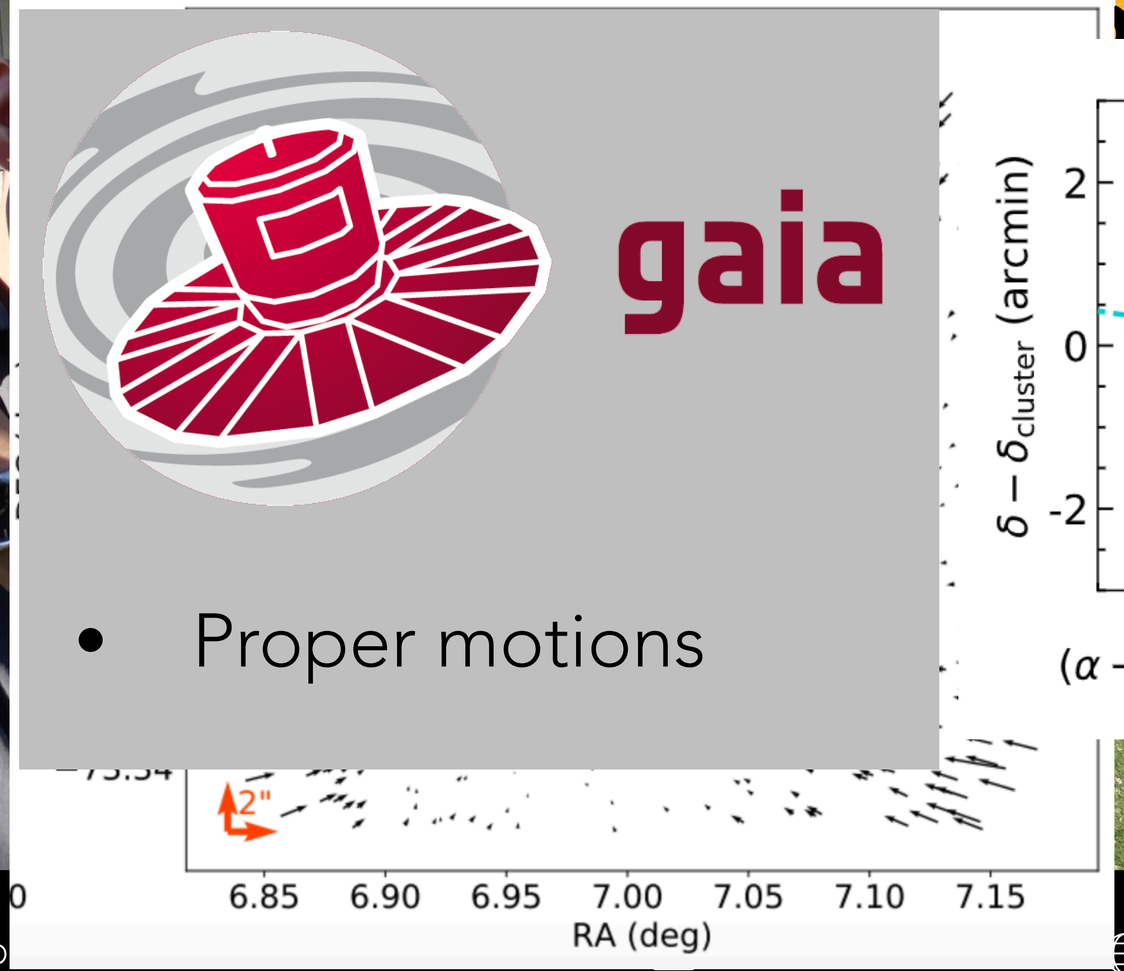
VISCACHA SPECTROSCOPIC FOLLOW-UP + GAIA PROPER MOTIONS

SEE POSTER DIAS & PARISI

SEE POSTER DE BORTOLI ET AL.

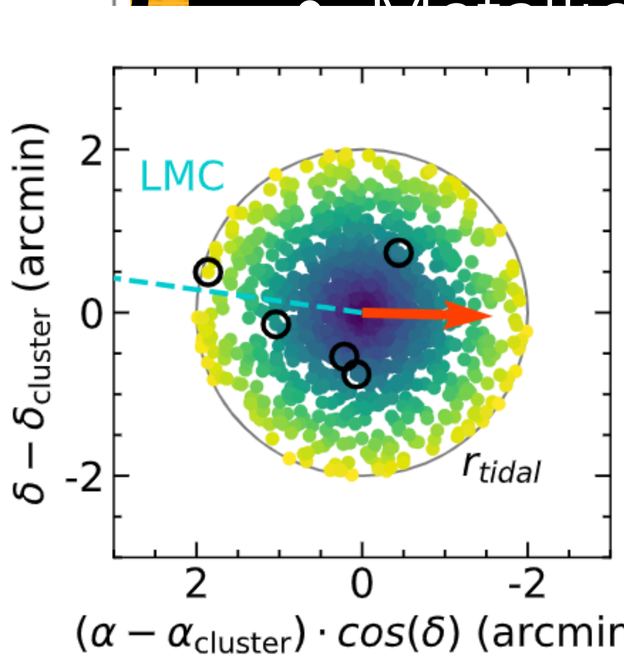


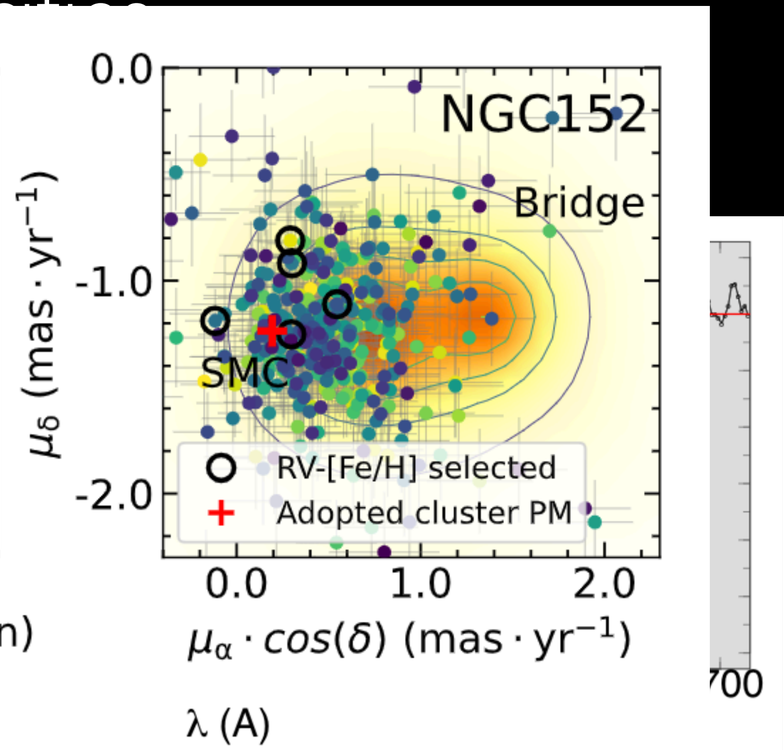
Distortion map of GMOS-S field



- Proper motions

- Call triplet spectroscopy:





FURTHER EVIDENCE TO BE CONSTRAINED BY OBSERVATIONS

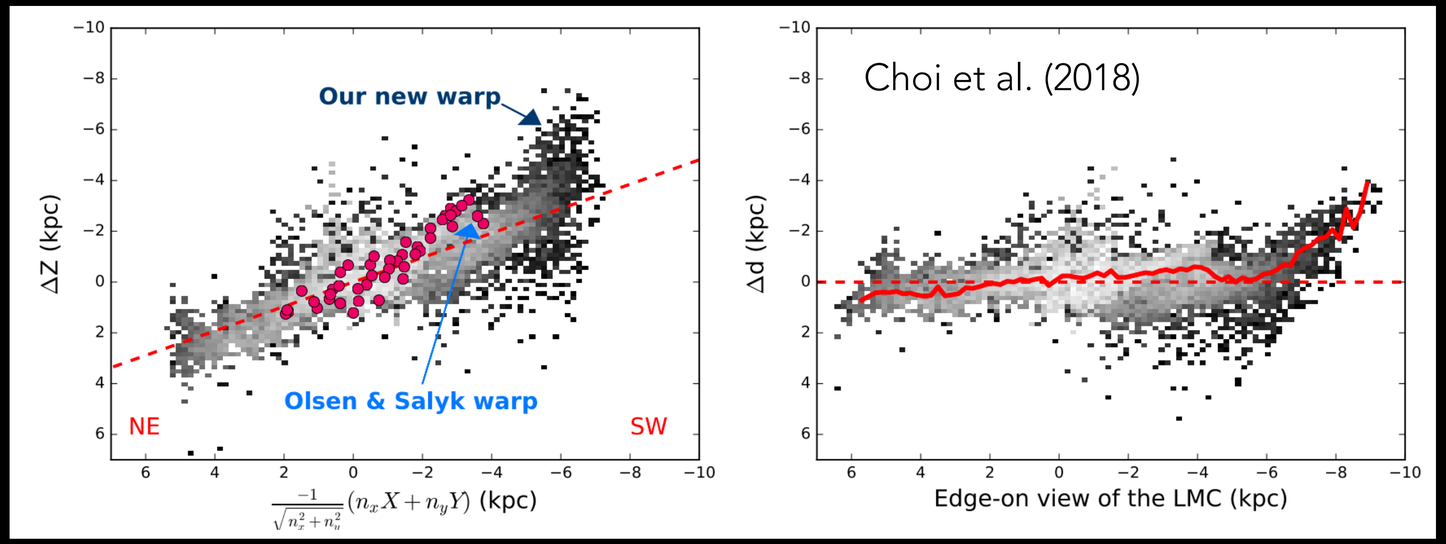
- Besla et al. (2012) analysed the case of a direct collision SMC-LMC
  - Model 1 has no collision and it does not affect much the SMC morphology
  - Model 2 has collision and it produces the Bridge and Counter-Bridge from the SMC stars (and gas) and it also produces a warp in the LMC

How do the star clusters see the SMC and LMC morphology?

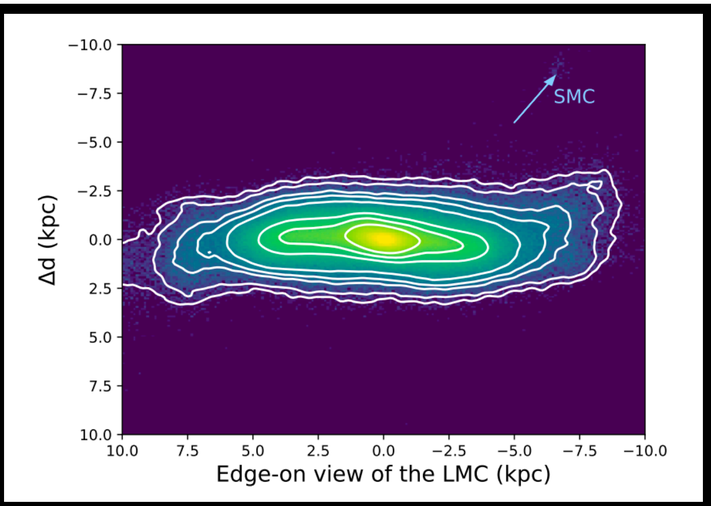
SMC-LMC DIRECT COLLISION PRODUCES A WARP IN THE LMC

Photo by Juan Carlos Muñoz (ESO)

Line of nodes = intersection between LMC and sky plane



Besla et al. (2012)



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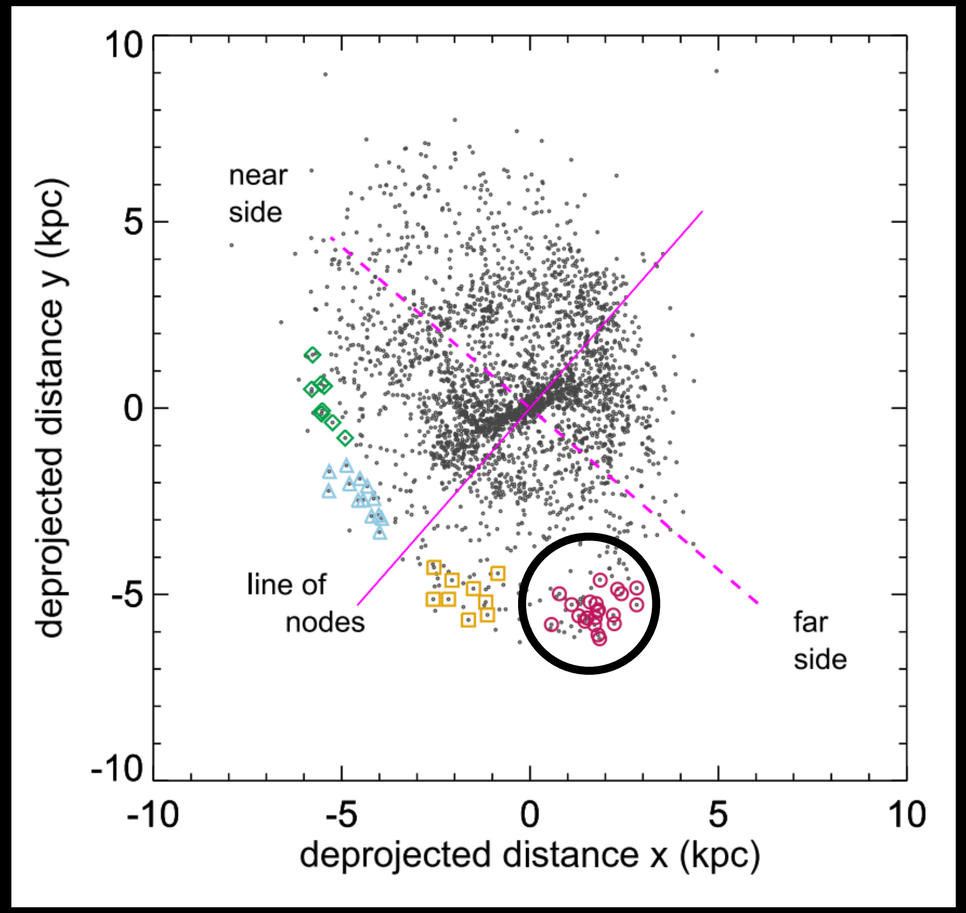
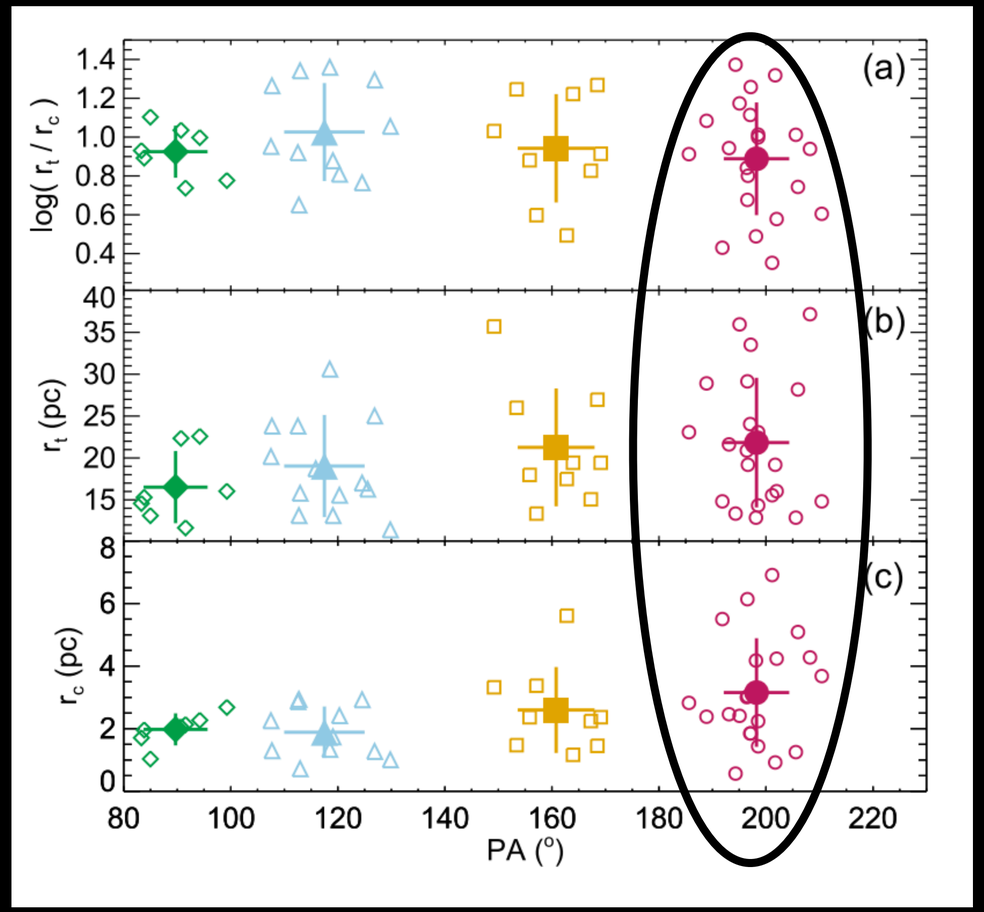
STAR CLUSTERS IN THE WARP REGION SHOWS A LARGE SPREAD IN STRUCTURAL PARAMETERS: COINCIDENCE? NO REASONABLE EXPLANATION OR RELATION FOUND SO FAR...





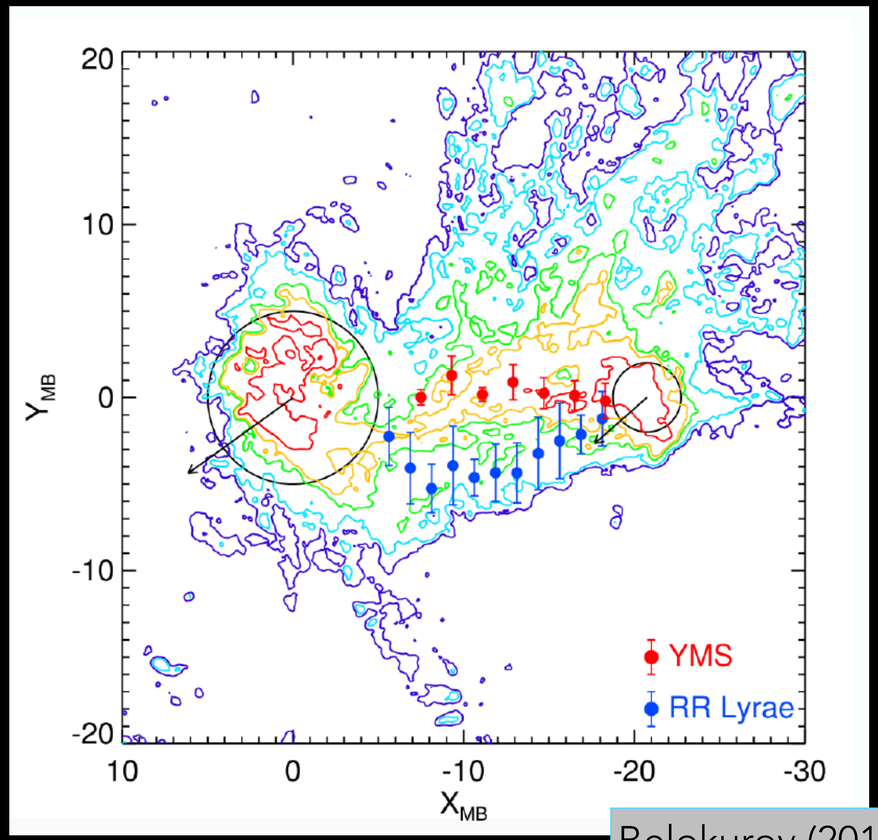
Santos Jr. et al. (2020)

PAPER II

WHY??

MAGELLANIC BRIDGE: AGE, LOCATION

FIELD STARS



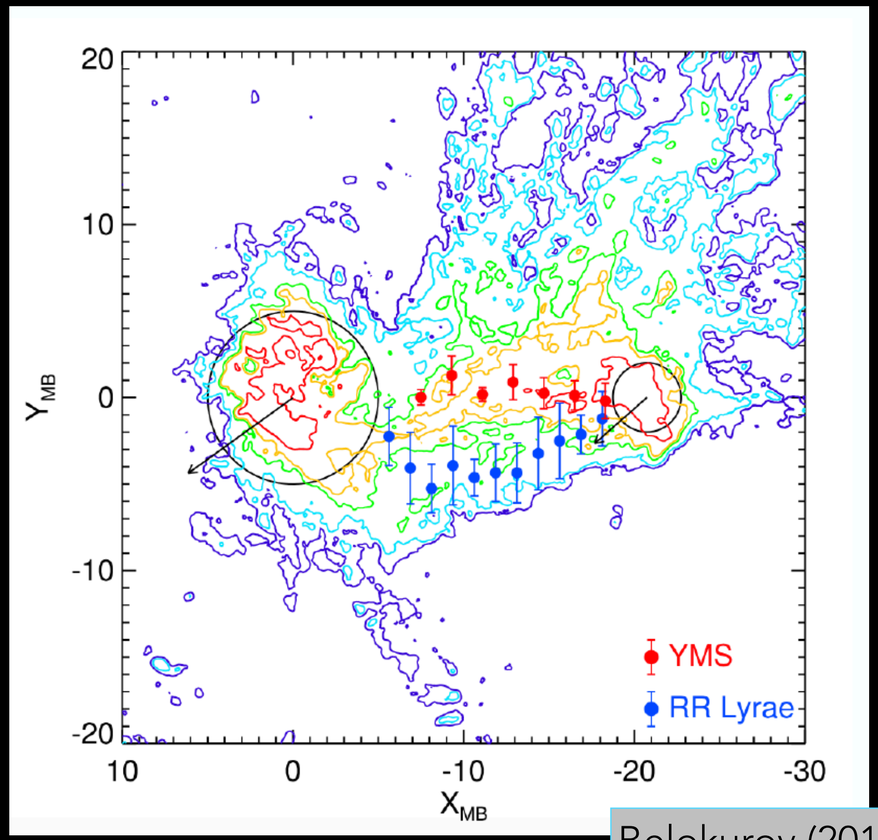
Belokurov (2019)

STAR CLUSTERS

MAGELLANIC BRIDGE: AGE, LOCATION

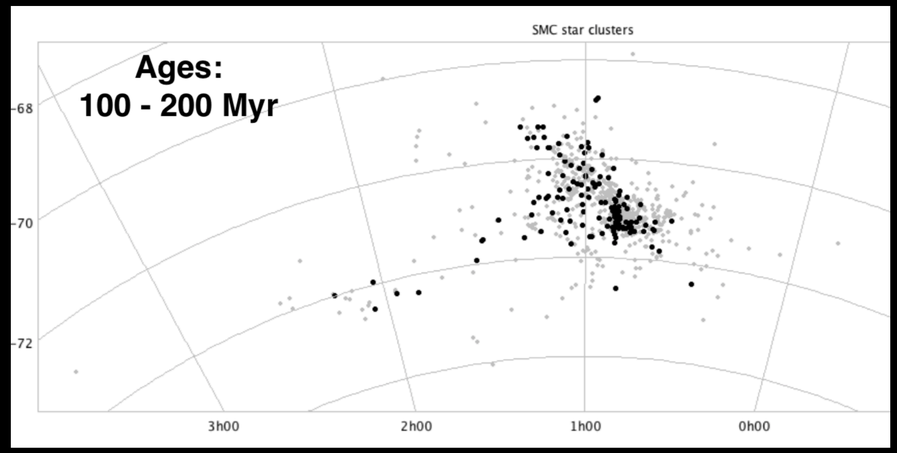
VISCACHA

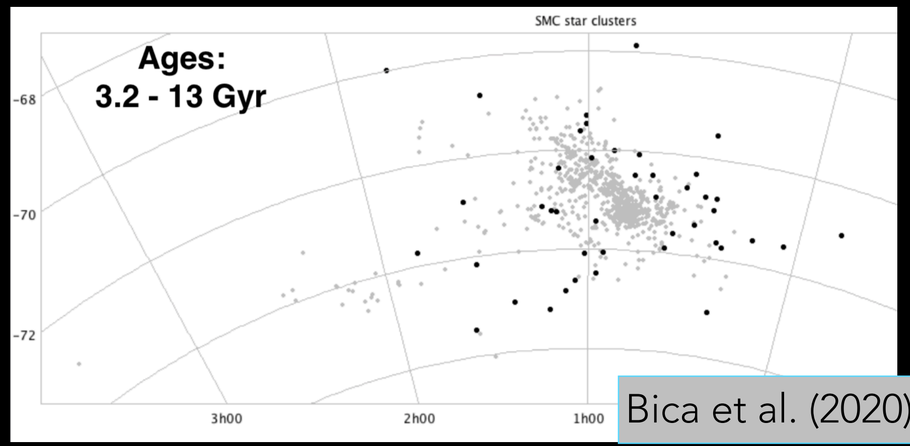
FIELD STARS



Belokurov (2019)

STAR CLUSTERS



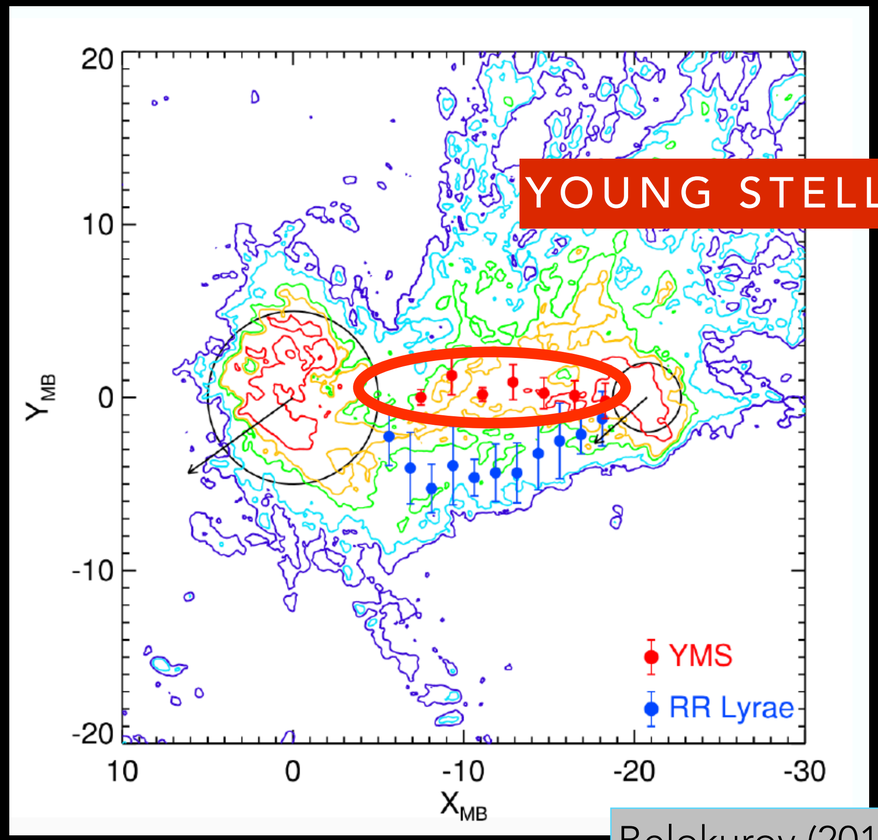


Bica et al. (2020)

MAGELLANIC BRIDGE: AGE, LOCATION

VISCACHA

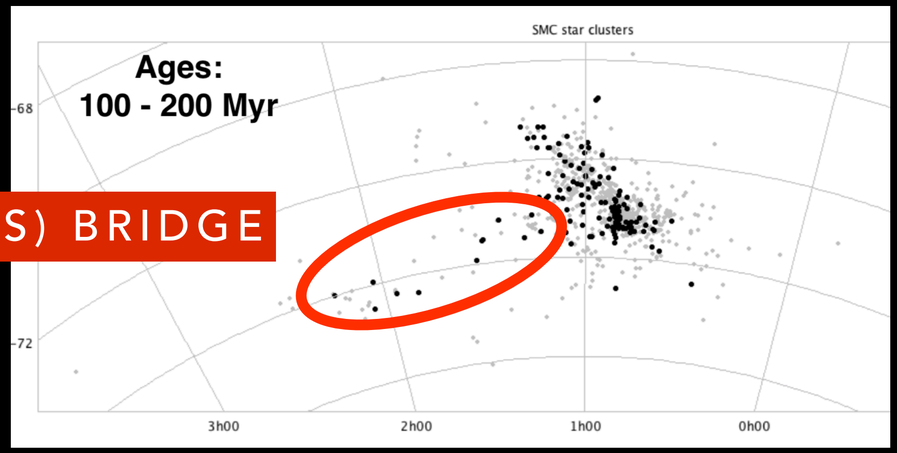
FIELD STARS

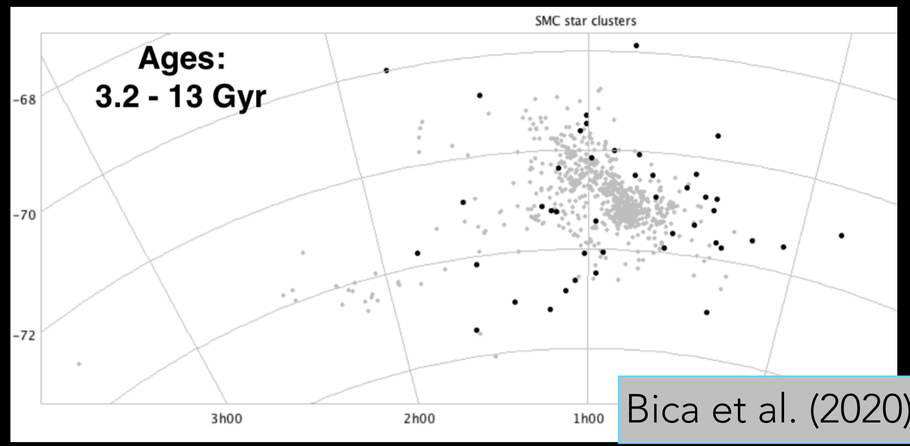


Belokurov (2019)

STAR CLUSTERS

YOUNG STELLAR (+ GAS) BRIDGE



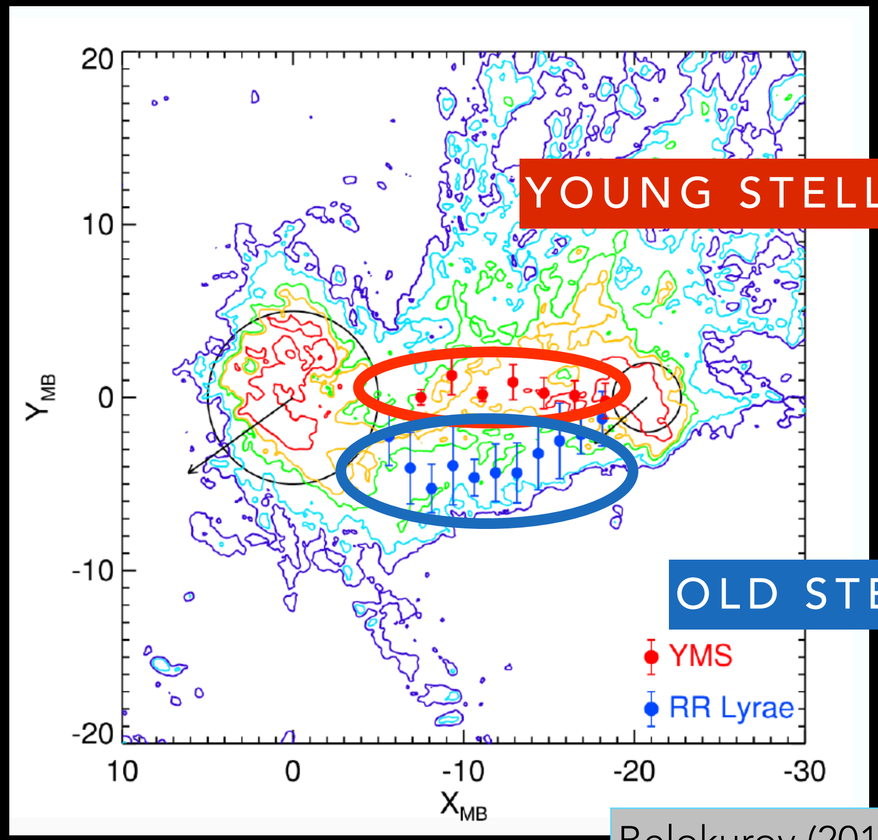


Bica et al. (2020)

MAGELLANIC BRIDGE: AGE, LOCATION

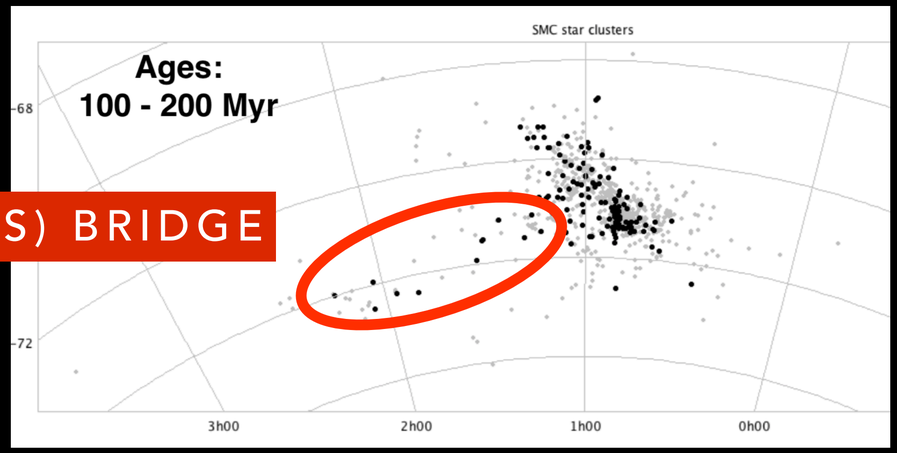
VISCACHA

FIELD STARS

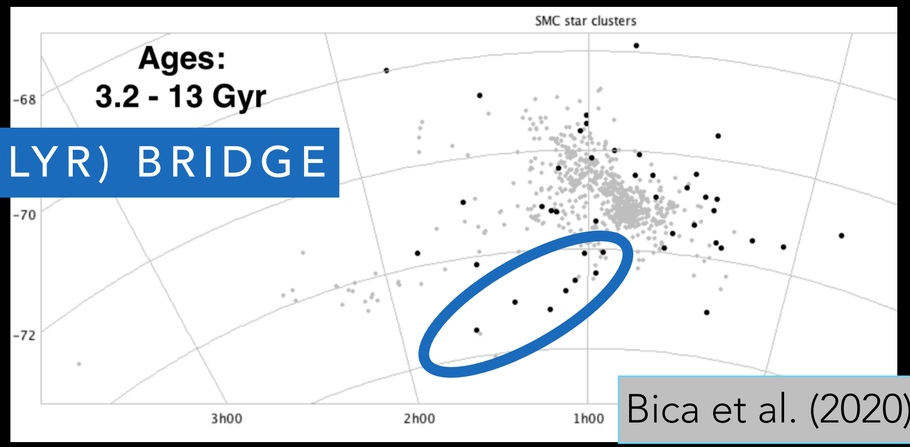


Belokurov (2019)

STAR CLUSTERS



YOUNG STELLAR (+ GAS) BRIDGE

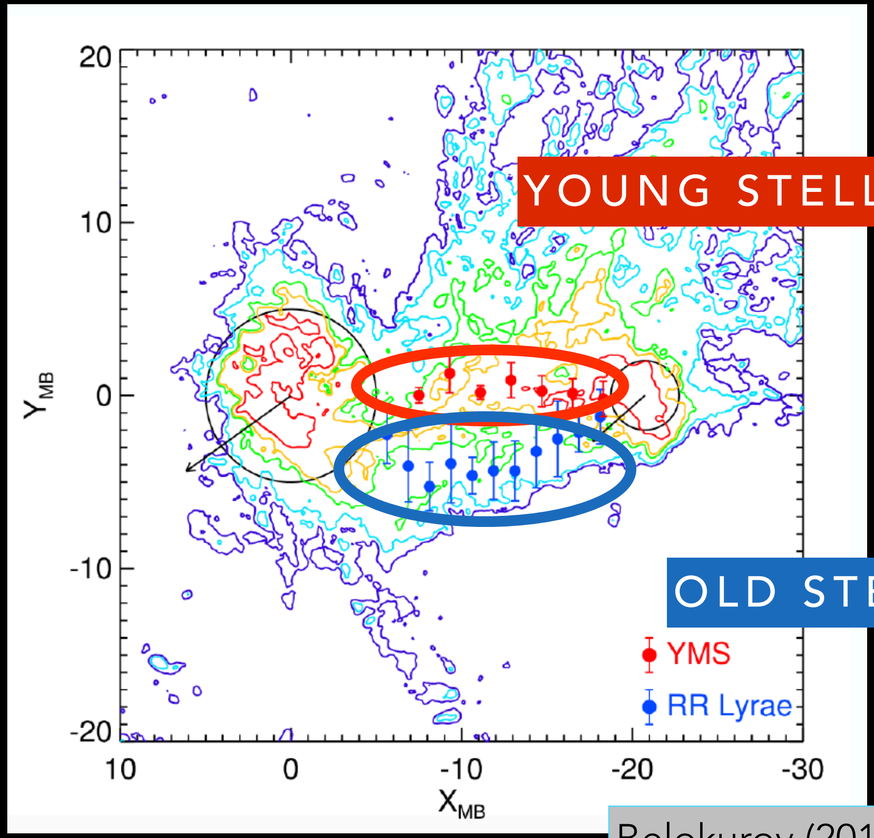


OLD STELLAR (RRLYR) BRIDGE

Bica et al. (2020)

MAGELLANIC BRIDGE: AGE, LOCATION

FIELD STARS

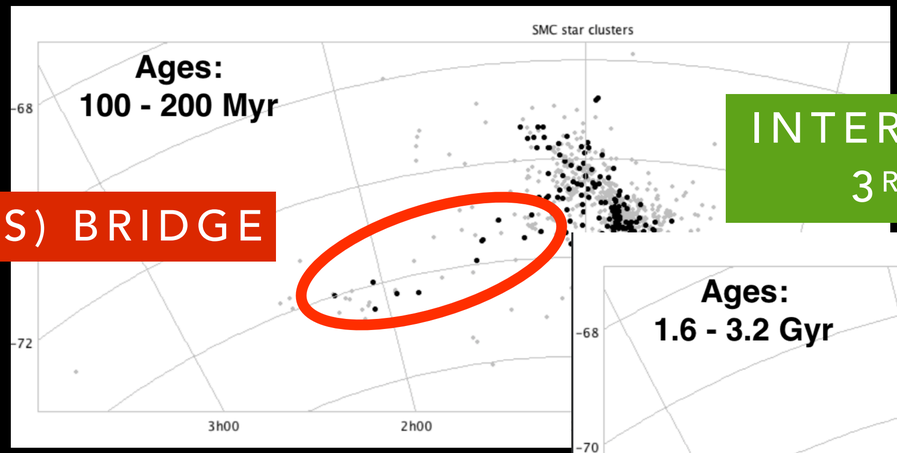


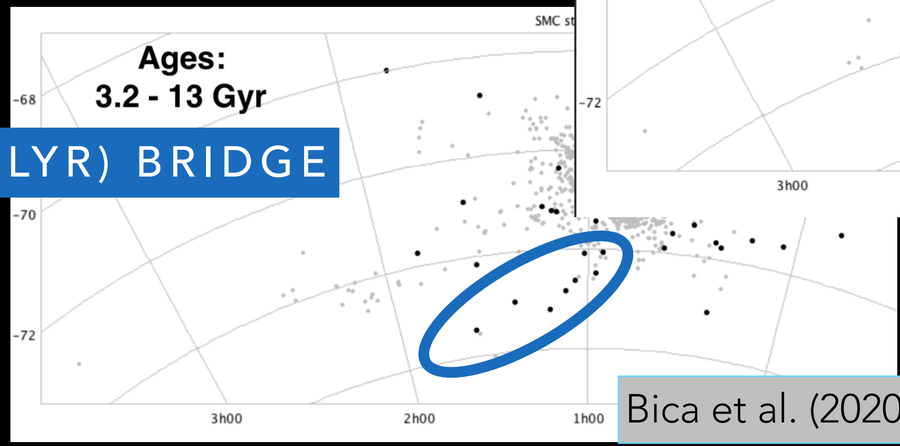
Belokurov (2019)

YOUNG STELLAR (+ GAS) BRIDGE

OLD STELLAR (RRLYR) BRIDGE

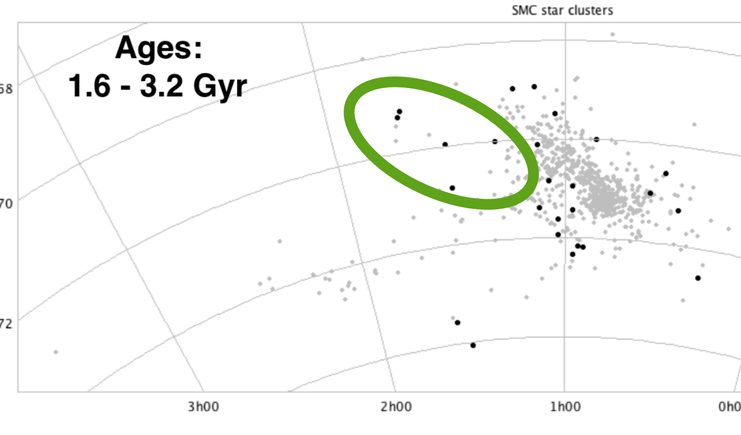
STAR CLUSTERS



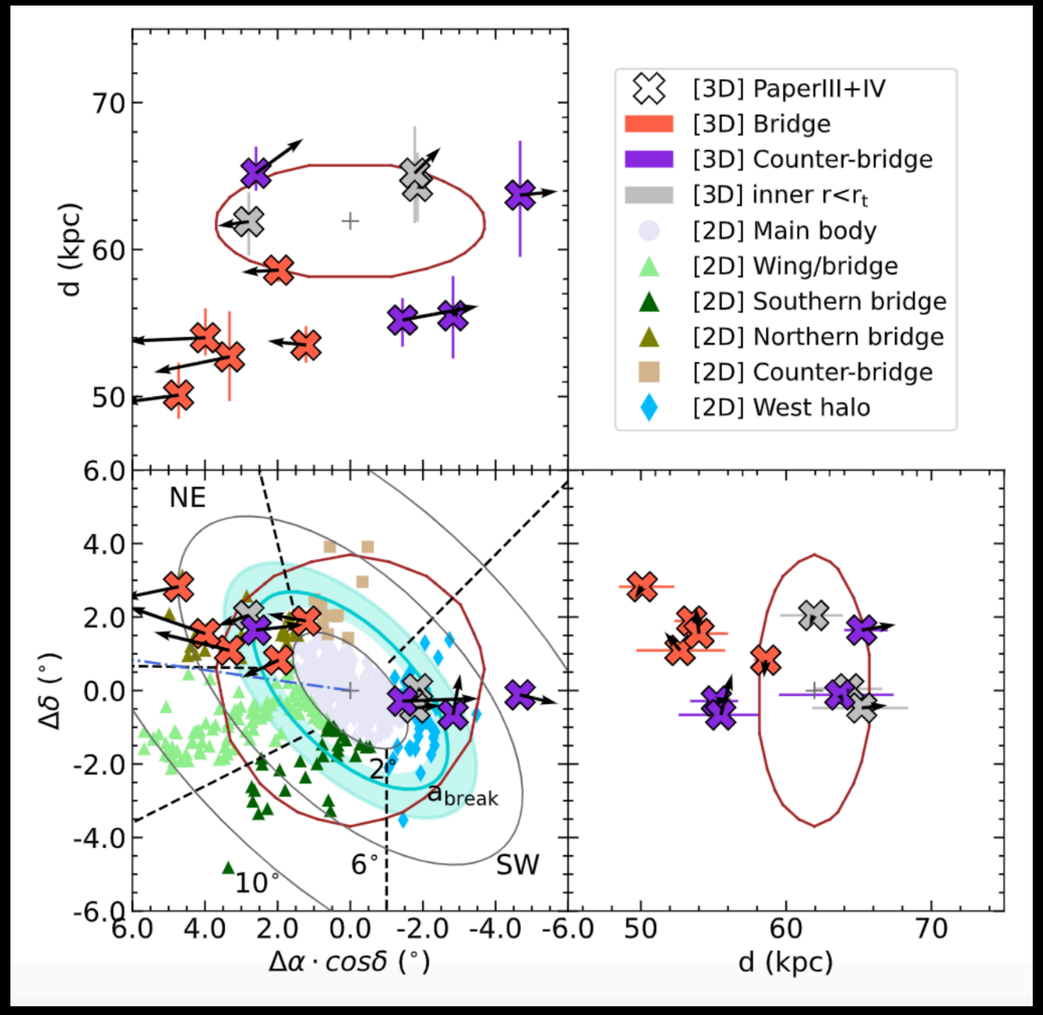


Bica et al. (2020)

INTERMEDIATE-AGE 3RD BRIDGE?

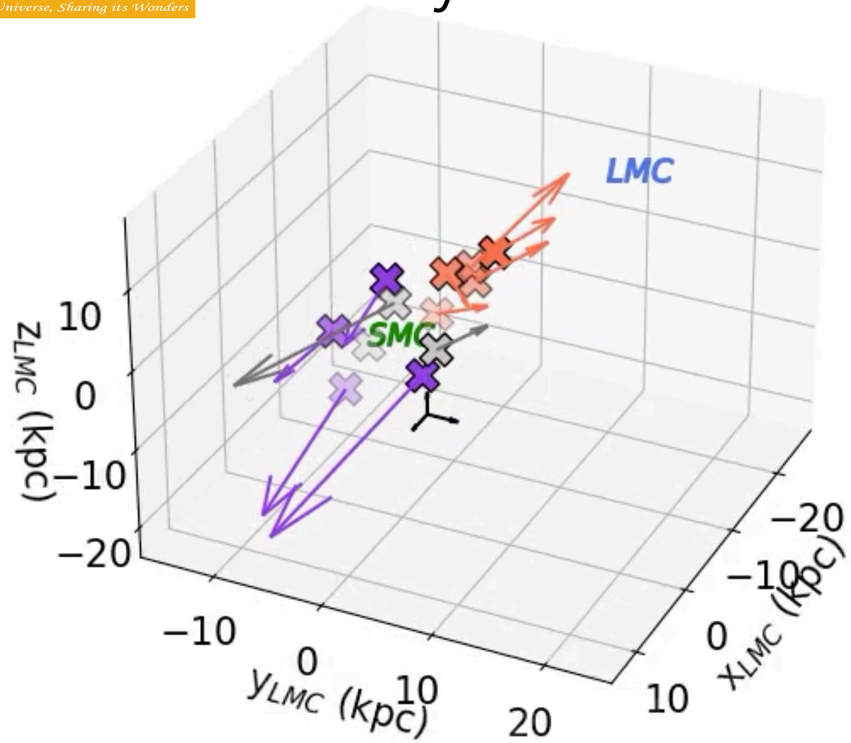


A THIRD BRIDGE BRANCH DETECTED: IT IS ALSO OLD...



GEMINI OBSERVATORY
Exploring the Universe, Sharing its Wonders

was key to find these results



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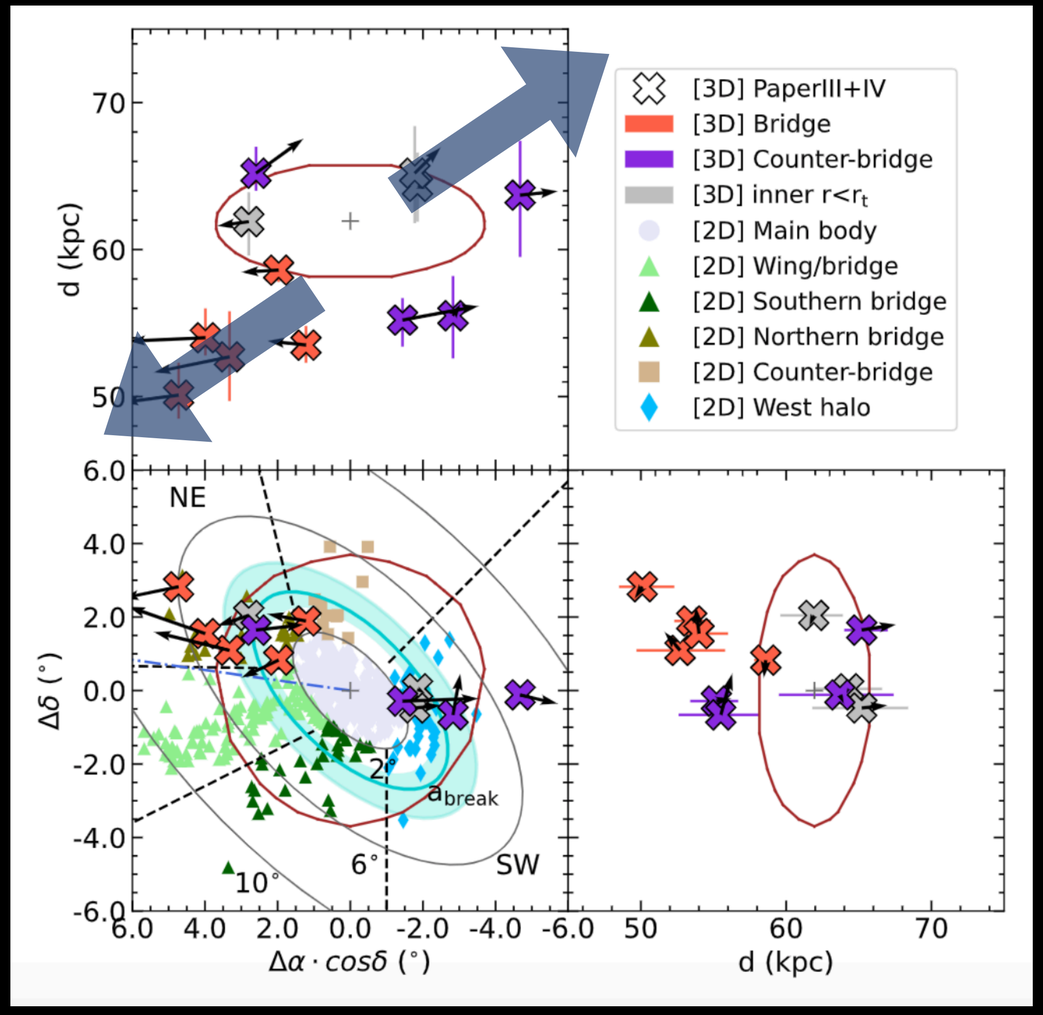
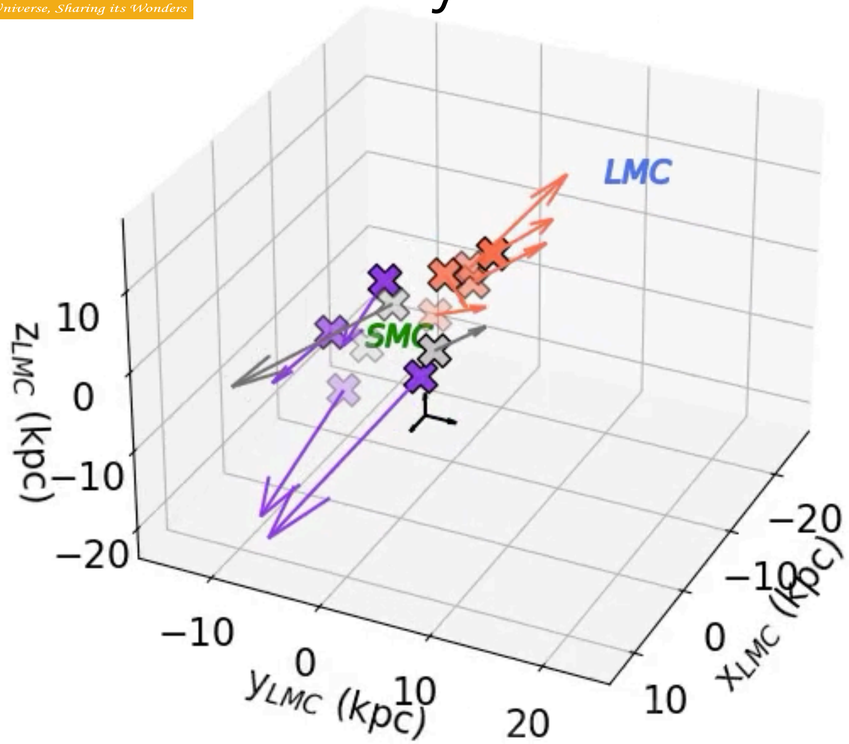
A THIRD BRIDGE BRANCH DETECTED: IT IS ALSO OLD...



GEMINI OBSERVATORY *Exploring the Universe, Sharing its Wonders* was key to find these results



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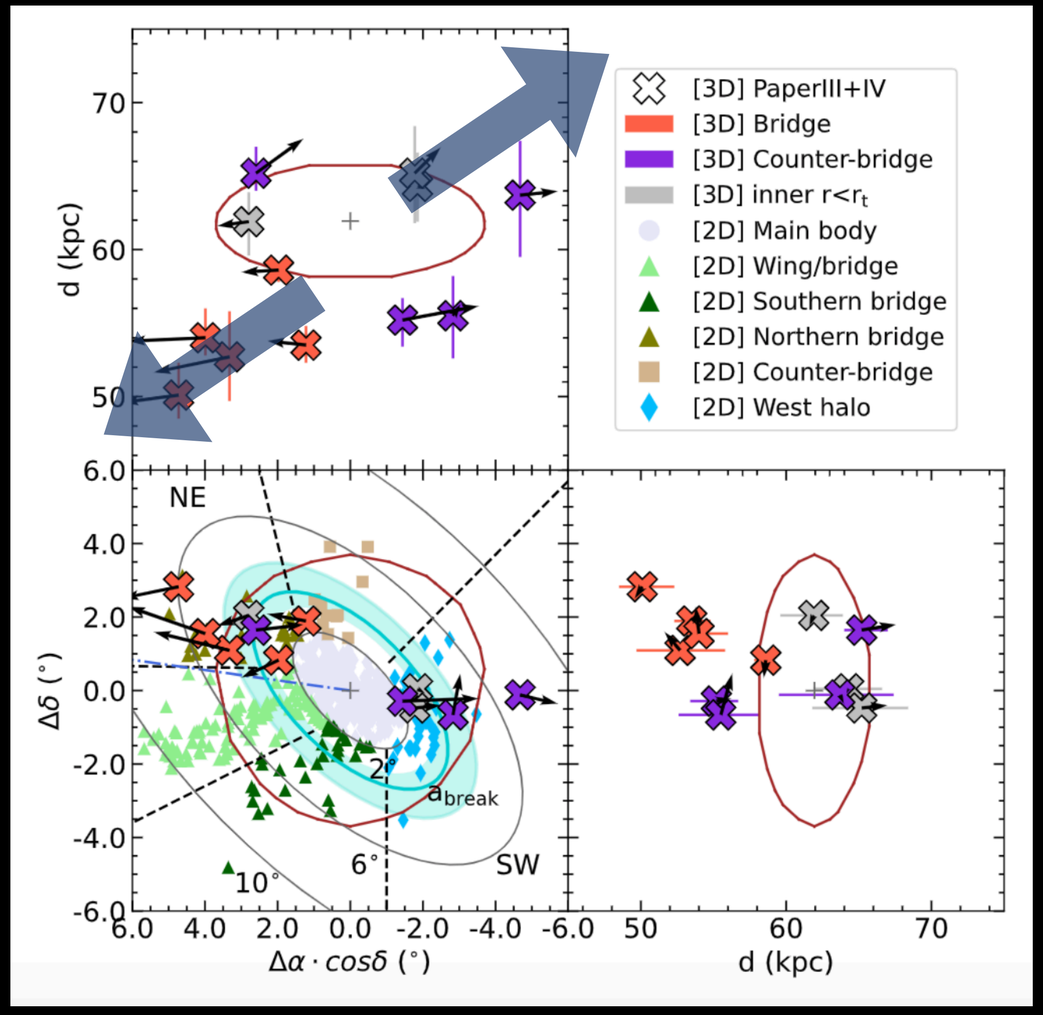

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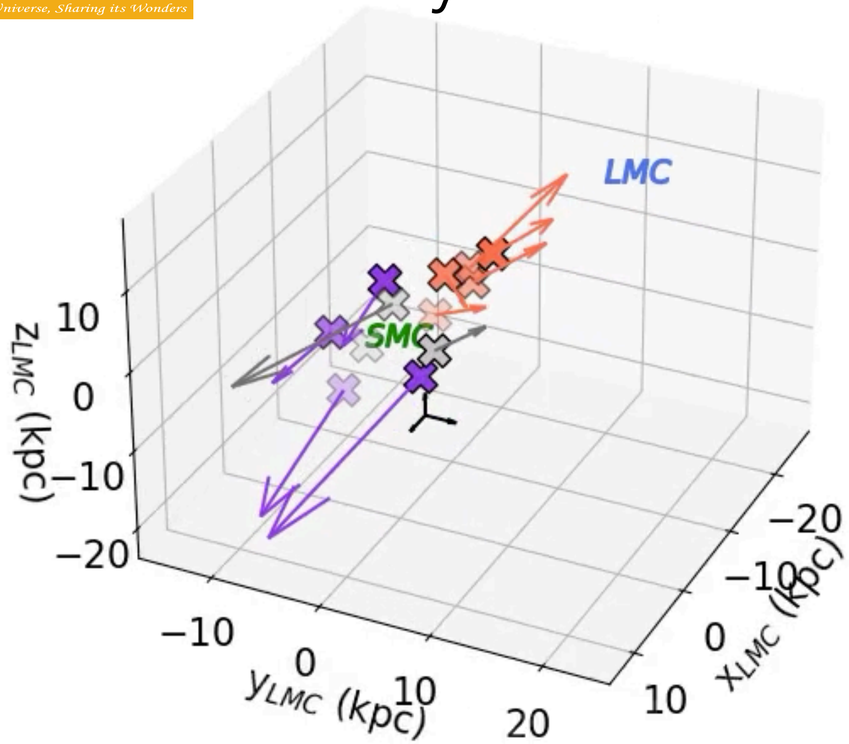

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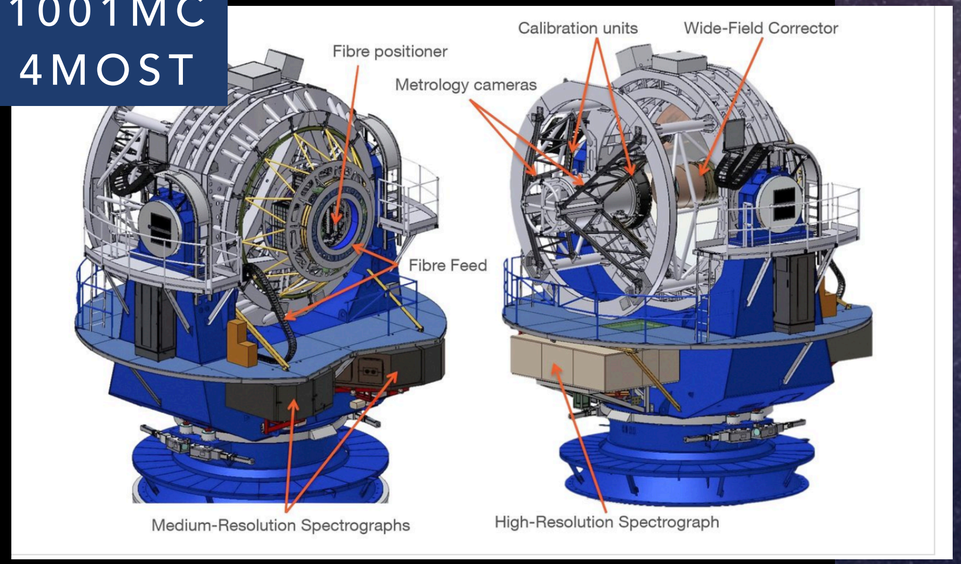
THE FUTURE FOR THE MAGELLANIC CLOUDS

3D KINEMATICS, CHEMICAL EVOLUTION, STARS, ISM...

VISCACHA

1001MC
4MOST



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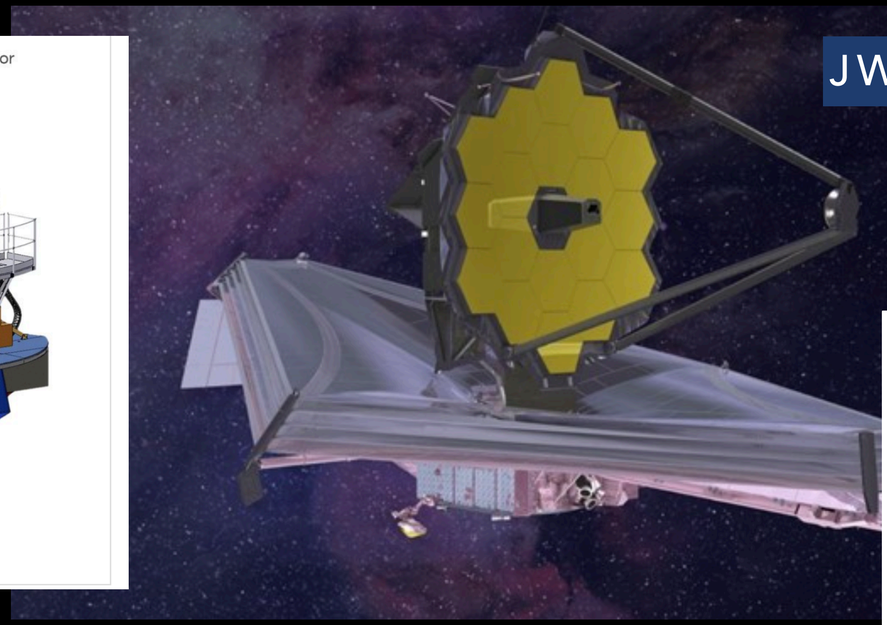
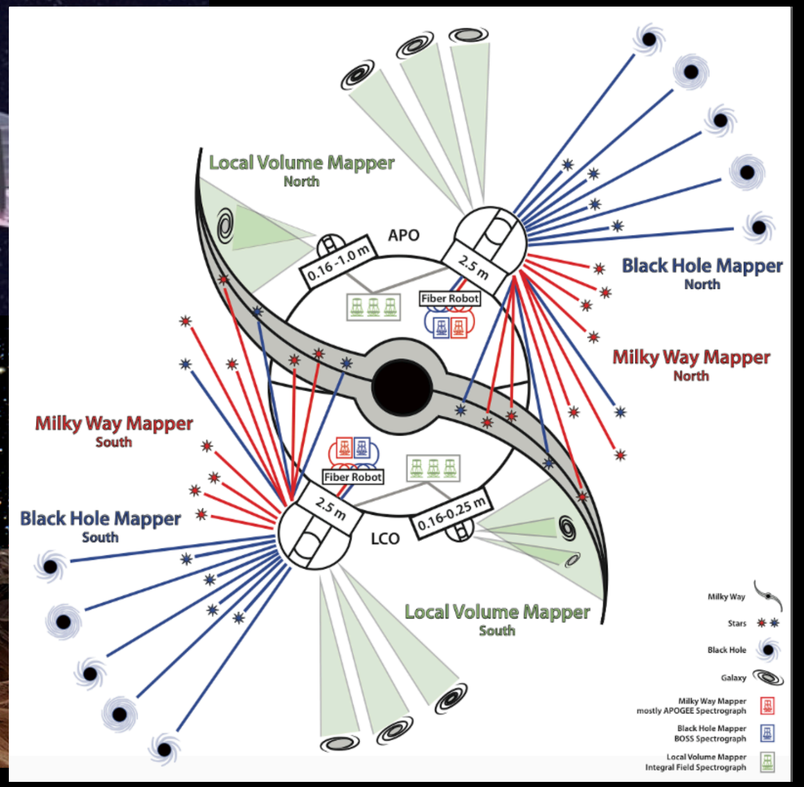
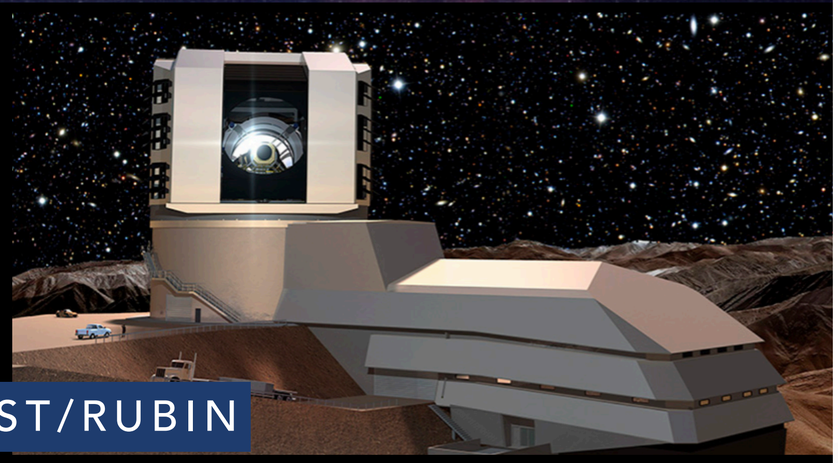


LVM
SDSS-V



gaia



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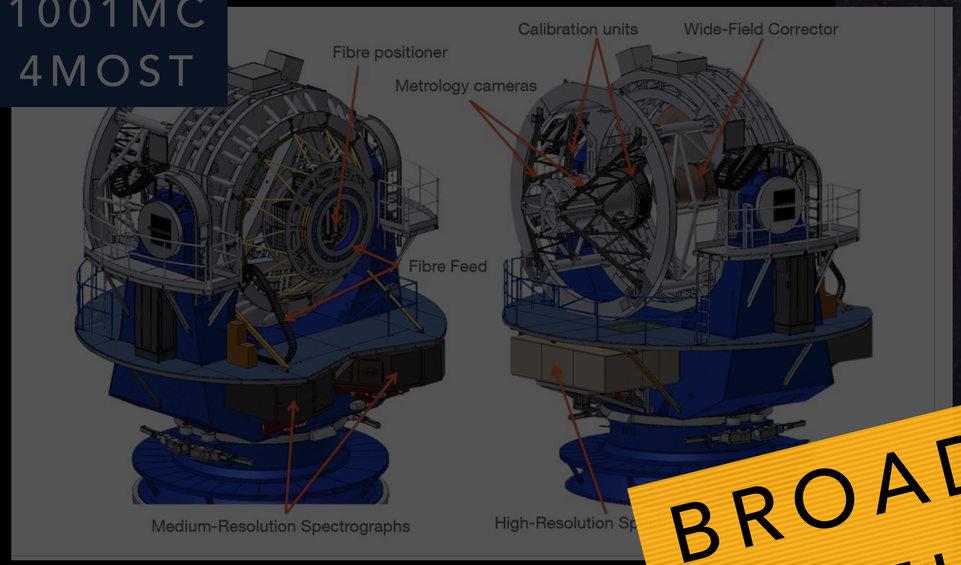

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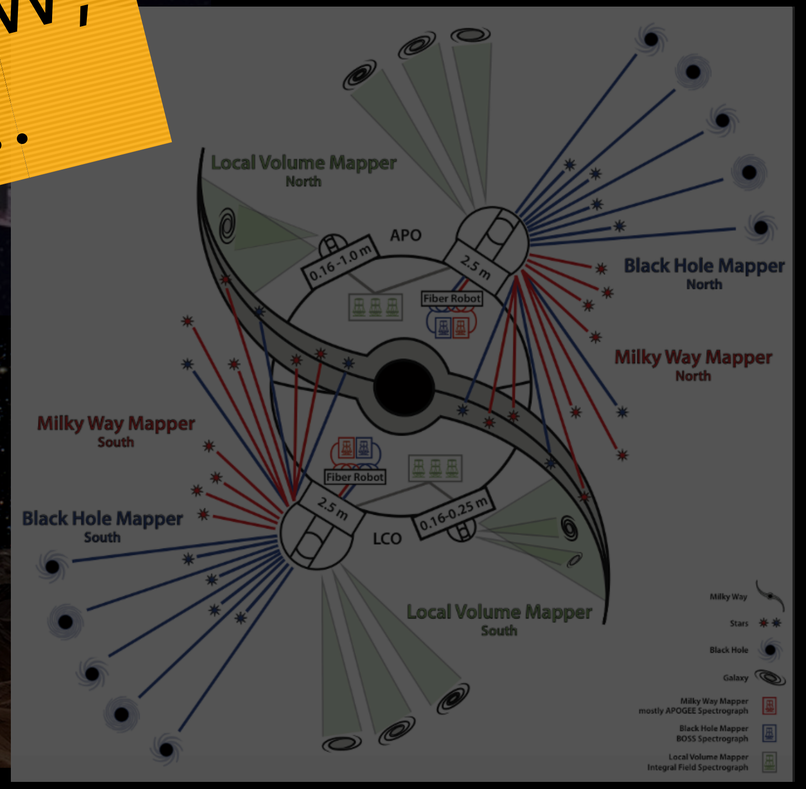

BROAD GENERAL VIEW, FIELD STARS, GAS...

gaia

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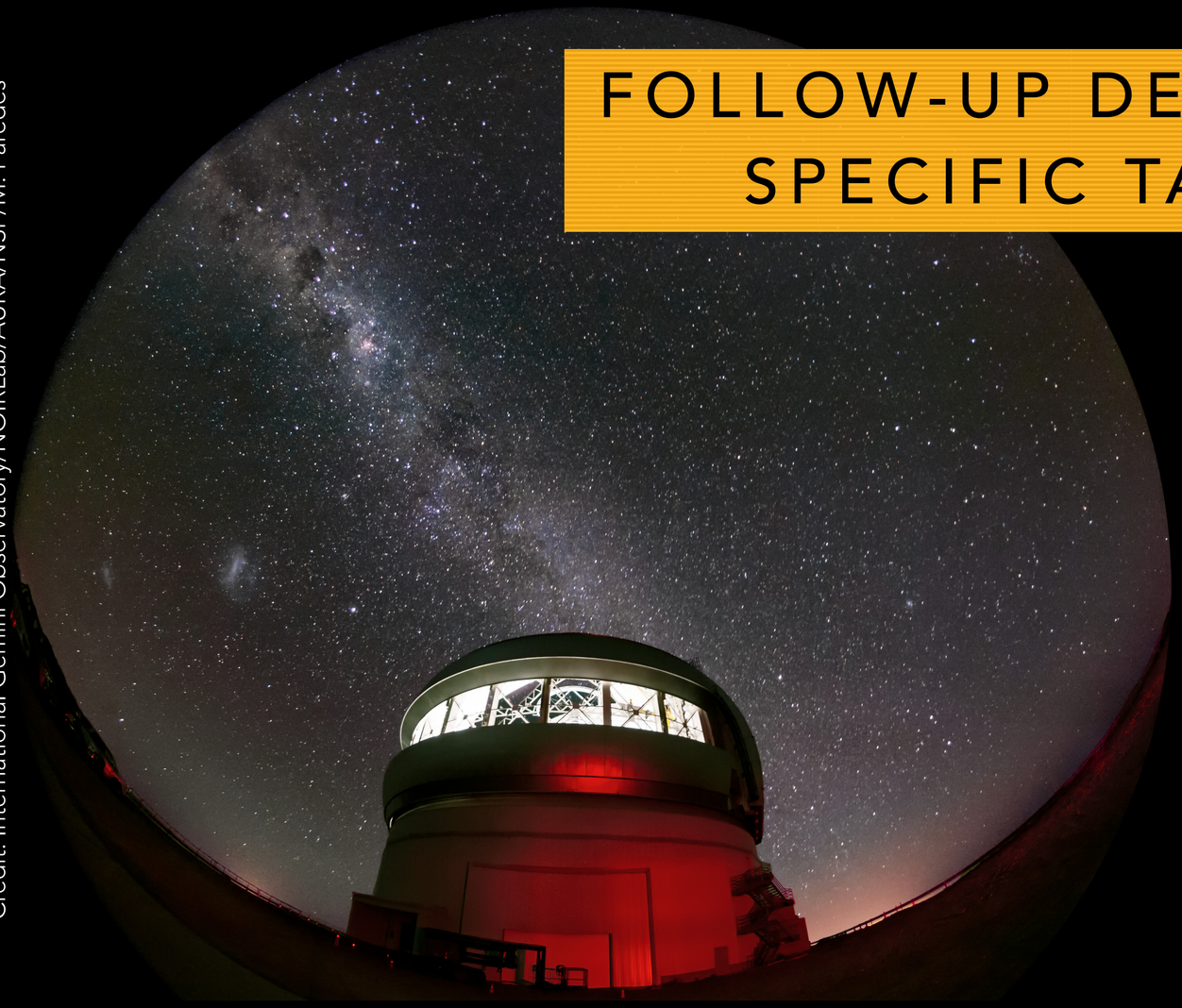

Credit: International Gemini Observatory/NOIRLab/AURA/NSF/M. Paredes

FOLLOW-UP DETAILED OBSERVATIONS FOR SPECIFIC TARGETS: STAR CLUSTERS

- GMOS-S: continue our program on RV and [Fe/H] with CaT spectroscopy
- GMOS-S: variability at cluster core (see poster by Martinez-Vasquez)
- GSAOI+Gems: deeper CMDs for the star cluster cores

Bruno Dias, UFMG, Brazil 8/Jul/2022.

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TAKE HOME MESSAGES

- The **Magellanic Clouds** have gained a lot of attention of large surveys and still too many discoveries to be done and to follow-up
- **VISCACHA** survey plays a key role wrt star clusters in the Magellanic Clouds
- The complex structure of the SMC and LMC are being enlightened by **VISCACHA** clusters
- **Gemini** is crucial to get cluster kinematics, metallicities, and even deeper CMDs in the cluster cores

Bruno Dias, GSM2022, Seoul, South Korea. 27/Jul2022
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Photo by Juan Carlos Muñoz (ESO)