

## THE VISCACHA SURVEY REVEALS THE SMC IN 8D





#### Bruno Dias, UNAB, Chile

Nov 21, 2024

IAUS395 - Stellar populations i the Milky Way and beyond In honour of Beatriz Barbuy



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#### 12/11/2016: FLÁVIA & BRUNO WEDDING



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Beatriz + Bruno 2005-2007: Undergraduate 2008-2010: Master 2010-2014: PhD 2015+2016: PhD prize 2010-2024: 31 papers (~2/yr)

Beatriz beyond the stars: Respect, teamwork, ethics, organisation, communication, work-life balance...





#### 2 KEY PAPERS FROM PHD WITH BEATRIZ THAT MADE MY EARLY CAREER

A&A 590, A9 (2016) DOI: 10.1051/0004-6361/201526765 © ESO 2016

Astronomy **A**strophysics

#### FORS2/VLT survey of Milky Way globular clusters

II. Fe and Mg abundances of 51 Milky Way globular clusters on a homogeneous scale\*,\*\*

B. Dias<sup>1, 2, 3</sup>, B. Barbuy<sup>2</sup>, I. Saviane<sup>1</sup>, E. V. Held<sup>4</sup>, G. S. Da Costa<sup>5</sup>, S. Ortolani<sup>4, 6</sup>, M. Gullieuszik<sup>4</sup>, and S. Vásquez<sup>7, 8, 9</sup>

#### Metallicity scale for MW globular clusters Dias+16 (full range, incl. metal-rich in the bulge) Carretta+09 (obsolete, no metal-rich)

Details, catalogue, references here:



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#### 2 KEY PAPERS FROM PHD WITH BEATRIZ THAT MADE MY EARLY CAREER

A&A 591, A11 (2016) DOI: 10.1051/0004-6361/201527558 © ESO 2016



SMC west halo: a slice of the galaxy that is being tidally stripped?

Star clusters trace age and metallicity gradients\*,\*\*

B. Dias<sup>1,2</sup>, L. Kerber<sup>3</sup>, B. Barbuy<sup>2</sup>, E. Bica<sup>4</sup>, and S. Ortolani<sup>5,6</sup>

#### The VISCACHA survey Maia, Dias, Santos Jr., Kerber+19 and 10+ other papers so far (>40 team members)

Details, codes, data products, references here:



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NGC362 (8.6kpc)

#### 47Tuc (4.5kpc)

SMC (62kpc)

VMC survey: IR image of the SMC

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#### Z~20kpc

### Y~4kpc

X~4kpc

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#### Subramanian et al. (2012): RRLyrae

#### Z~20kpc











Rosell A Carnero in Kind M Carrasco in Carretero J in Cunha C E D'Andrea C B

d.	The Proper Motion Field of the Small Magellanic Cloud: Kinem Evidence for Its Tidal Disruption 20   Show affiliations 20   Zivick, Paul (D); Kallivayalil, Nitya (D); van der Marel, Roeland P. (D); Besla, Gurtina; Linden, Sean Kozłowski, Szymon (D); Fritz, Tobias K. (D); Kochanek, C. S.; Anderson, J. (D); Sohn, Sangmo Ton Geha, Marla C. (D); Alcock, Charles R.
	The VMC Survey - XL. Three-dimensional structure of the Small Magellanic Cloud as derived from red clump starsShow affiliations2021Show affiliationsTatton, B. L. ; van Loon, J. Th ; Cioni, MR. L. D ; Bekki, K. ; Bell, C. P. M. D ; Choudhury, S. ; de Grijs, R. ; Groenewegen, M. A. T. ; Ivanov, V. D. D ; Marconi, M. D ; Oliveira, J. M. D ; Ripepi, V. D ; Rubele, S. ; Subramanian, S. D ; Sun, NC.
oed?.	Gaia view of a stellar sub-structure in front of the Small Magell Cloud   Show affiliations   Omkumar, Abinaya O. ; Subramanian, Smitha D ; Niederhofer, Florian D ; Diaz, Jonathan ; Cioni, Maria-Rosa L. D ; El Youssoufi, Dalal D ; Bekki, Kenji ; de Grijs, Richard ; van Loon, Jacco T
ud )17	A Galactic Eclipse: The Small Magellanic Cloud Is Forming Stars nwo Superimposed Systems Show affiliations Hide authors Murray, Claire E. D ; Hasselquist, Sten D ; Peek, Joshua E. G. D ; Lindberg, Christina Willecke D ; Almeida, Andres D ; Choi, Yumi D ; Craig, Jessica E. M. D ; Dénes, Helga D ; Dickey, John M. D ; D Teodoro, Enrico M. D ; Federrath, Christoph D ; Gerrard, Isabella. A. D ; Gibson, Steven J. D ; Leahy, Denis D ; Lee, Min-Young D ; Lynn, Callum D ; Ma, Yik Ki D ; Marchal, Antoine D ; McClure-Griffiths, N. M. D ; Nidever, David D ; Nguyen, Hiep D ; Pingel, Nickolas M. D ; Tarantino, Elizabeth D ; Uscanga, Lucero D ; van Loon, Jacco Th. D
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# THE VISCACHA SURVEY





# STAR





100

1.1

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CLUSTERS?

30″



#### VISCACHA paper I





# WHY STAR CLUSTERS?



10 R (arcsec)

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

30"



VISCACHA paper I















![](_page_13_Picture_3.jpeg)

#### VISCACHA AND SMASH With AO No AO

![](_page_14_Picture_1.jpeg)

![](_page_14_Picture_2.jpeg)

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![](_page_14_Figure_4.jpeg)

![](_page_14_Picture_6.jpeg)

![](_page_14_Picture_7.jpeg)

![](_page_14_Picture_8.jpeg)

### VISCACHA AND SMASH

![](_page_15_Picture_1.jpeg)

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![](_page_15_Figure_3.jpeg)

![](_page_15_Picture_5.jpeg)

![](_page_15_Picture_6.jpeg)

### VISCACHA AND SMASH

![](_page_16_Figure_1.jpeg)

![](_page_17_Picture_0.jpeg)

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40+ members 20+ univ.+obs. 6 countries

![](_page_17_Picture_3.jpeg)

![](_page_17_Picture_5.jpeg)

![](_page_17_Picture_6.jpeg)

![](_page_17_Picture_7.jpeg)

![](_page_17_Picture_8.jpeg)

![](_page_18_Picture_0.jpeg)

I VISCACHA meeting. IAG-USP, São Paulo, Brazil. 13-14/July/2018

# JULY 2018

![](_page_18_Picture_4.jpeg)

![](_page_19_Picture_0.jpeg)

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![](_page_19_Picture_2.jpeg)

![](_page_19_Picture_5.jpeg)

![](_page_19_Picture_6.jpeg)

![](_page_19_Picture_7.jpeg)

### WHICH 8 DIMENSIONS?

- 2D: RA, DEC (Bica catalogue + fine tune density profile VISCACHA photometry)
- 3D: Distance (CMD, VISCACHA photometry)
- 4D: Radial velocity (CaT spectra, VISCACHA spec. follow-up)
- 6D: PMRA, PMDEC (average Gaia astrometry)
- 7D: Age (CMD, VISCACHA photometry)
- up)

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![](_page_20_Picture_9.jpeg)

8D: Metallicity (CMD, VISCACHA photometry + CaT spectra VISCACHA follow-

![](_page_20_Picture_11.jpeg)

![](_page_20_Picture_13.jpeg)

![](_page_20_Picture_14.jpeg)

![](_page_20_Picture_15.jpeg)

- Dias et al. (2014,2016) framework: split the SMC outer regions azimuthally
- Possibly shaped by interactions with the LMC

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![](_page_21_Picture_4.jpeg)

![](_page_21_Figure_5.jpeg)

- Dias et al. (2014,2016) framework: split the SMC outer regions azimuthally
- Possibly shaped by interactions with the LMC

VISCACHA: Full phase-space vector

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![](_page_22_Picture_5.jpeg)

![](_page_22_Figure_6.jpeg)

- Dias et al. (2014,2016) framework: split the SMC outer regions azimuthally
- Possibly shaped by interactions with the LMC

VISCACHA: Full phase-space vector

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![](_page_23_Picture_5.jpeg)

![](_page_23_Figure_6.jpeg)

- Dias et al. (2014,2016) framework: split the SMC outer regions azimuthally
- Possibly shaped by interactions with the LMC

VISCACHA: Full phase-space vector

![](_page_24_Figure_5.jpeg)

# BRIDGE AND COUNTER-BRIDGE

![](_page_25_Figure_1.jpeg)

![](_page_25_Figure_2.jpeg)

![](_page_25_Figure_3.jpeg)

#### Dias et al. (2021, 2022) VISCACHA papers III, IV, IX

![](_page_25_Picture_6.jpeg)

![](_page_25_Figure_7.jpeg)

### 2D: AGE-METALLICITY ALONE IS NOT OBVIOUS AT ALL

![](_page_26_Figure_1.jpeg)

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![](_page_26_Picture_3.jpeg)

See: Dias et al. 2016 Parisi et al. 2022 De Bórtoli et al. 2022 Oliveira et al. 2023 Saroon et al. 2023 Parisi et al. 2024 Dias et al. 2025 Etc etc

![](_page_26_Picture_5.jpeg)

![](_page_26_Picture_8.jpeg)

![](_page_26_Picture_9.jpeg)

![](_page_26_Picture_10.jpeg)

8D: AGE-METALLICITY + PHASE-SPACE VECTOR + DIAS16 FRAMEWORK

![](_page_27_Figure_1.jpeg)

![](_page_27_Figure_3.jpeg)

8D: AGE-METALLICITY + PHASE-SPACE VECTOR + DIAS16 FRAMEWORK

![](_page_28_Figure_1.jpeg)

![](_page_28_Figure_3.jpeg)

8D: AGE-METALLICITY + PHASE-SPACE VECTOR + DIAS16 FRAMEWORK

![](_page_29_Figure_1.jpeg)

![](_page_29_Figure_3.jpeg)

![](_page_30_Picture_0.jpeg)

# INTERPRETATION OF THE 8D DATA

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![](_page_30_Picture_3.jpeg)

![](_page_30_Picture_5.jpeg)

![](_page_30_Picture_6.jpeg)

### DIFFERENT SMC SUBSTRUCTURES SHOW DIFFERENT HISTORIES SEE PARISI BY PARISI

![](_page_31_Figure_1.jpeg)

![](_page_31_Figure_3.jpeg)

![](_page_32_Picture_0.jpeg)

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![](_page_32_Picture_2.jpeg)

![](_page_32_Picture_3.jpeg)

Bridge ~200Myr ago

![](_page_32_Figure_6.jpeg)

![](_page_32_Figure_7.jpeg)

### DIFFERENT SMC SUBSTRUCTURES SHOW DIFFERENT HISTORIES SEE PARISI BY PARISI

![](_page_33_Figure_1.jpeg)

![](_page_33_Figure_3.jpeg)

![](_page_34_Picture_0.jpeg)

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![](_page_34_Picture_2.jpeg)

![](_page_34_Picture_3.jpeg)

#### West Halo Merger ~6Gyr ago

#### Nidever et al. 2010

![](_page_34_Figure_6.jpeg)

![](_page_35_Picture_0.jpeg)

# TAKE HOME MESSAGES

- The SMC has a complex structure, kinematics, evolution history
- Solution to analyse observations: phase-space vector + age + [Fe/H]
- Star clusters are more suitable than field stars (ages, distances...)
- VISCACHA = stellar and galaxy evolution people working together
- The SMC is breaking apart (we can finally see it in detail)
- Full chemo-dynamical simulations are required

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![](_page_35_Picture_10.jpeg)

#### PARABÉNS E MUITO OBRIGADO PROF. BEATRIZ!

![](_page_36_Picture_1.jpeg)

![](_page_36_Picture_3.jpeg)

R

![](_page_36_Picture_4.jpeg)