Leibniz-Institut für Astrophysik Potsdam

Proper motion of the outer LMC and the impact of the SMC interaction

Thomas Schmidt*, Maria-Rosa Cioni, Florian Niederhofer

***tschmidt@aip.de**

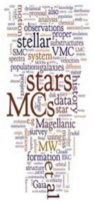
Introduction

Proper motion studies help us to understand key aspects of galaxy formation in the Local Group. One of these aspects is identifying past merger events. The Large and Small Magellanic Clouds (LMC and SMC) are the closest interacting pair of dwarf galaxies, where we can study resolved stellar populations across multiple ages. The high precision of the Gaia mission gave new insights. However, there are still many open questions. It is still unclear if the Clouds are on their first infall into the Milky Way (Besla et al. 2007), and the number of interactions between LMC and SMC in the past is unknown. Simulations suggest two or three interactions in the past. So far, the most obvious fact is that they had at least one interaction, which is most visible in a bridge of gas and stars connecting them. This study presents our newest findings that suggest debris of a stripped SMC influencing the proper motion measurements in the South-East of the LMC, previously only found in radial velocities (Olsen et al. 2016).

Observations

Data presented in this study is a combination of Gaia Data Release 2 (DR2; Gaia Collaboration et al.2018) and data from the VISTA survey of the Magellanic Clouds system (VMC; Cioni et al. 2011). It consists of multi-epoch near-infrared observations in the Y, J, and K_s-band filters of 110 overlapping tiles across the Magellanic system: 68 over the LMC, 27 over the SMC, 13 over the Bridge, and two over the Stream components. Each tile covers 1.77 deg2 in the sky. In this study, we focus on the area of the sky covered by the 53 outer LMC tiles. Since the 15 inner VMC tiles show significant crowding issues and will be discussed separately (Niederhofer et al. In prep).

European Research Council
Established by the European Commission



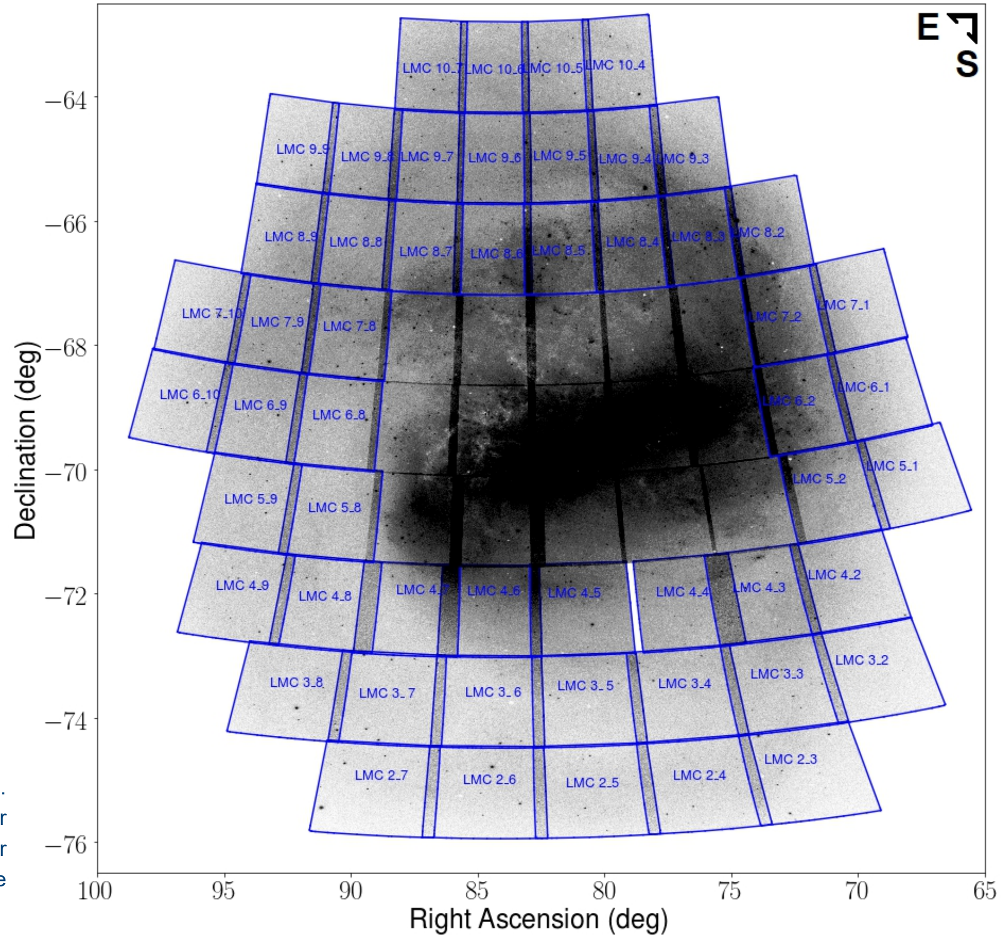


Figure 1: Distribution of VMC tiles across the LMC. The tiles used in this study are those in the outer regions of the galaxy and are indicated by their names. The image in the background shows the distribution of all VMC sources.

SVM membership classification

We used a subset of the Gaia DR2 catalogue (609,525 sources), comprising stars with G<18 mag for which StarHorse distance estimates (Queiroz et al. 2018) were available. This subset was then used as a training sample for a machine learning classification algorithm called support vector machines (SVM) to bypass some of the limitations of the StarHorse sample and transfer its benefits to a larger sample which includes fainter stars. SVMs are binary large-margin classifiers and a supervised learning algorithm. Crossmatching the sample with the VMC data and adding J and K_s magnitudes of the VMD survey further improved the membership classification. The resulting catalogue of LMC population (Fig. 2) provides a large clean sample reaching below the red clump, which would otherwise contain a significant fraction of faint Milky Way foreground sources (Fig. 3), especially influencing proper motion measurements in regions with low stellar density.

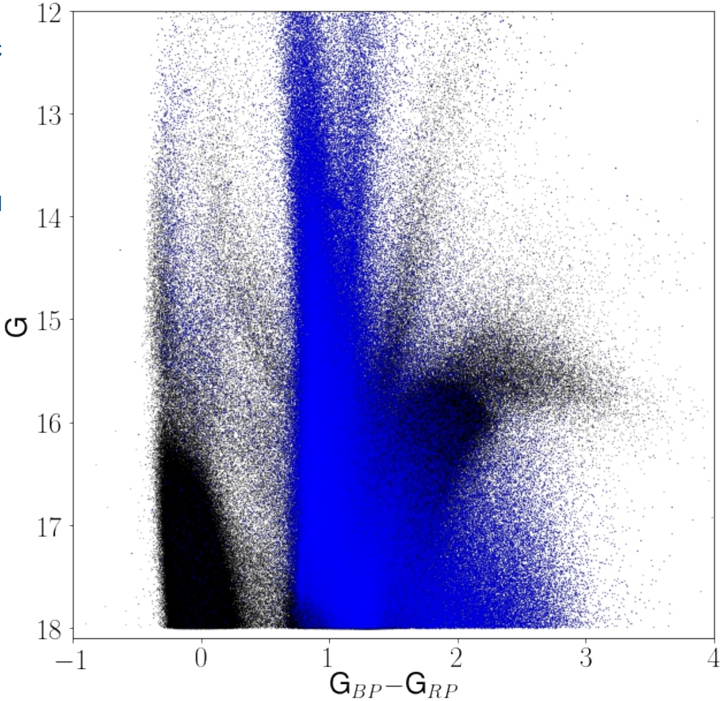


Figure 3: CMD of sources in the LMC outer regions with VMC and Gaia DR2 photometry as well as StarHorse distances (black) and the MW stars from our training sample having StarHorse distance estimates d<10 kpc (blue).

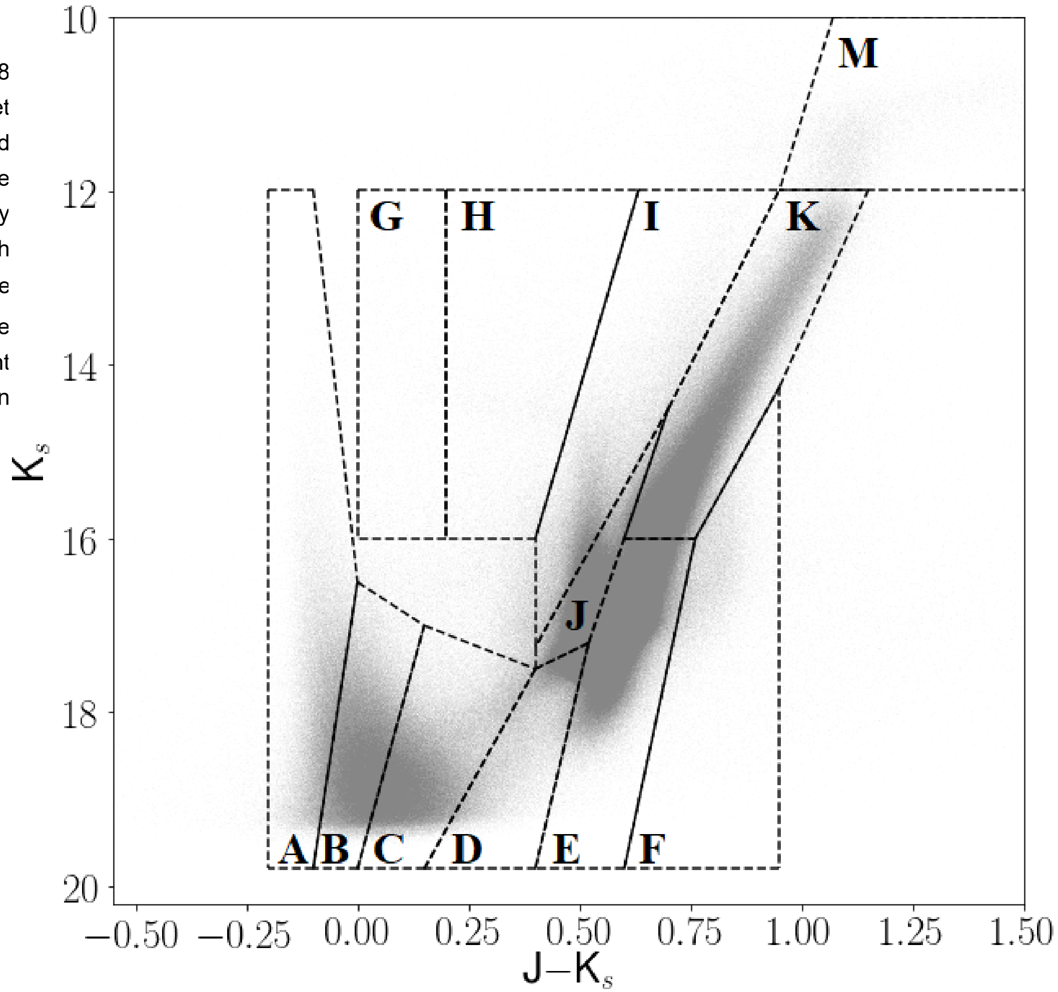


Figure 2: Near-infrared CMD of LMC stars with overlaid boxes to distinguish multiple populations according to El Youssoufi et al. (2019).

Proper motion maps

We divided the catalogue into two age groups: a young population (<1 Gyr old) containing stars in the CMD regions A, B, G, H and I and an older population (>2 Gyr old) which contains stars in the CMD regions D, E, J, K and M, as described in El Youssoufi et al. (2019)., There are 808,515 and 2,738,707 stars in the young and old age group, respectively.

Figures 4 and 5 show the residual proper motion maps of LMC stars from the GaiaDR2 sample divided into young and old, respectively, after subtracting the LMC bulk motion. Both maps show a rotation of the LMC as expected.

The rotation is clearly visible in the northern and western regions of the outer LMC, where the north western and western spiral arms are located. Regions in the east and parts of the south west also show a visible rotation. Only the south eastern region, where the south eastern arm is located, does not show a clear rotation compared to the rest of the galaxy.

A possible explanation is that SMC debris from an interaction between LMC and SMC is influencing the proper motions as the debris is moving in the opposite direction with respect to the expected rotation (Fig. 6). Hints on this population were previously only found in radial velocities (Olsen et al. 2016).

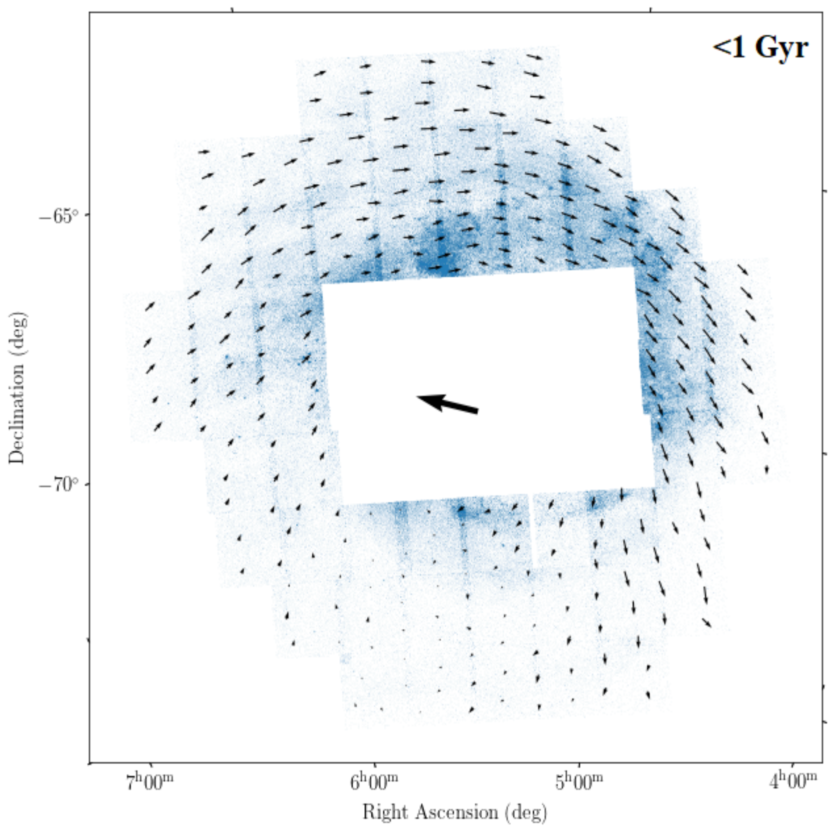
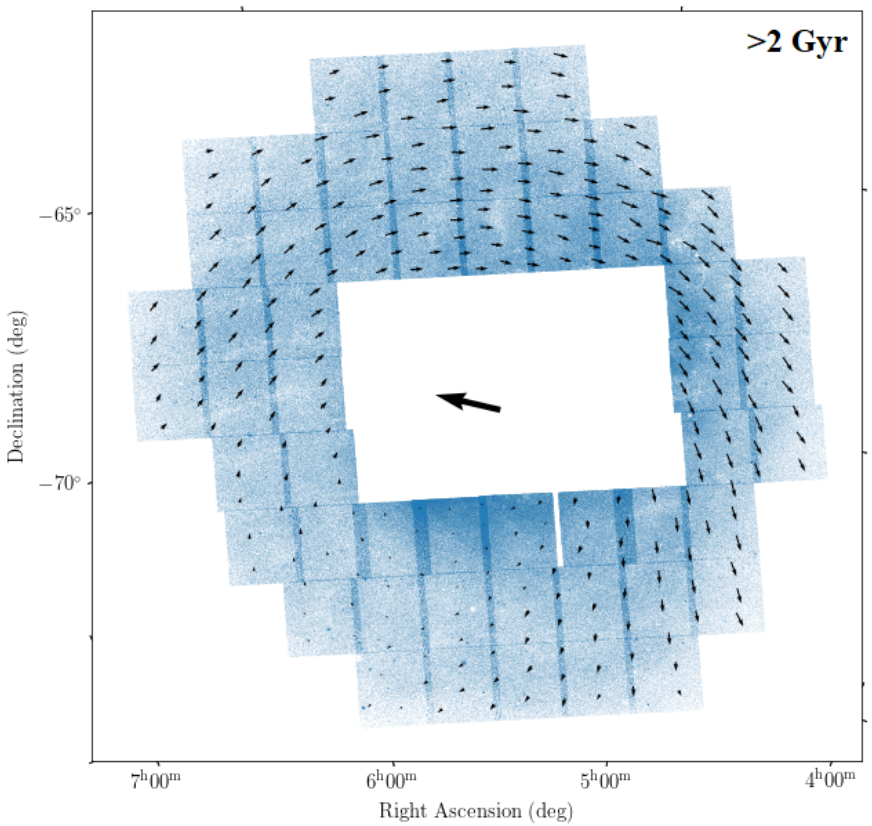


Figure 4+5: Gaia DR2 proper motion maps of the LMC for samples of stars <1 Gyr old (left) and >2 Gyr old (right) selected in a CMD based on VMC data, see text for details. Each vector represents the median proper motion of at least 100 stars for the young population and of at least 2000 stars for the old population. The central vector indicates the bulk motion of the LMC



Summary

We combined the VMC data with data from the Gaia Data Release 2 to study the outer regions of the LMC.

- We introduced a new method to distinguish between Magellanic and Milky Way stars based on a machine learning algorithm trained on StarHorse distance estimates
- We showed residual proper motion maps of two populations (<1 Gyr and >2 Gyr)
- We found hints of stripped SMC debris in the south east of the outer LMC

Future outlook

We plan to improve the method with the next version of the StarHorse catalogue in combination with Gaia EDR3 data. Early tests suggest a significant improvement of the SVM classification with enhances the resolution of the proper motion maps.

References: [1] Besla et al. 2007; ApJ, 668, 949; [2] Gaia Collaboration et al.2018a, A&A, 616, A1; [3] Olsen et al. 2016; Pacific Conference Series, Vol. 491, 257; [4] Cioni et al. 2011; A&A, 527, A116; [5] Queiroz et al. 2018; MNRAS, 476, 2556; [6] El Youssoufi et al. 2019; MNRAS, 490, 1076; [7] Diaz & Bekki 2012 ApJ, 750, 36

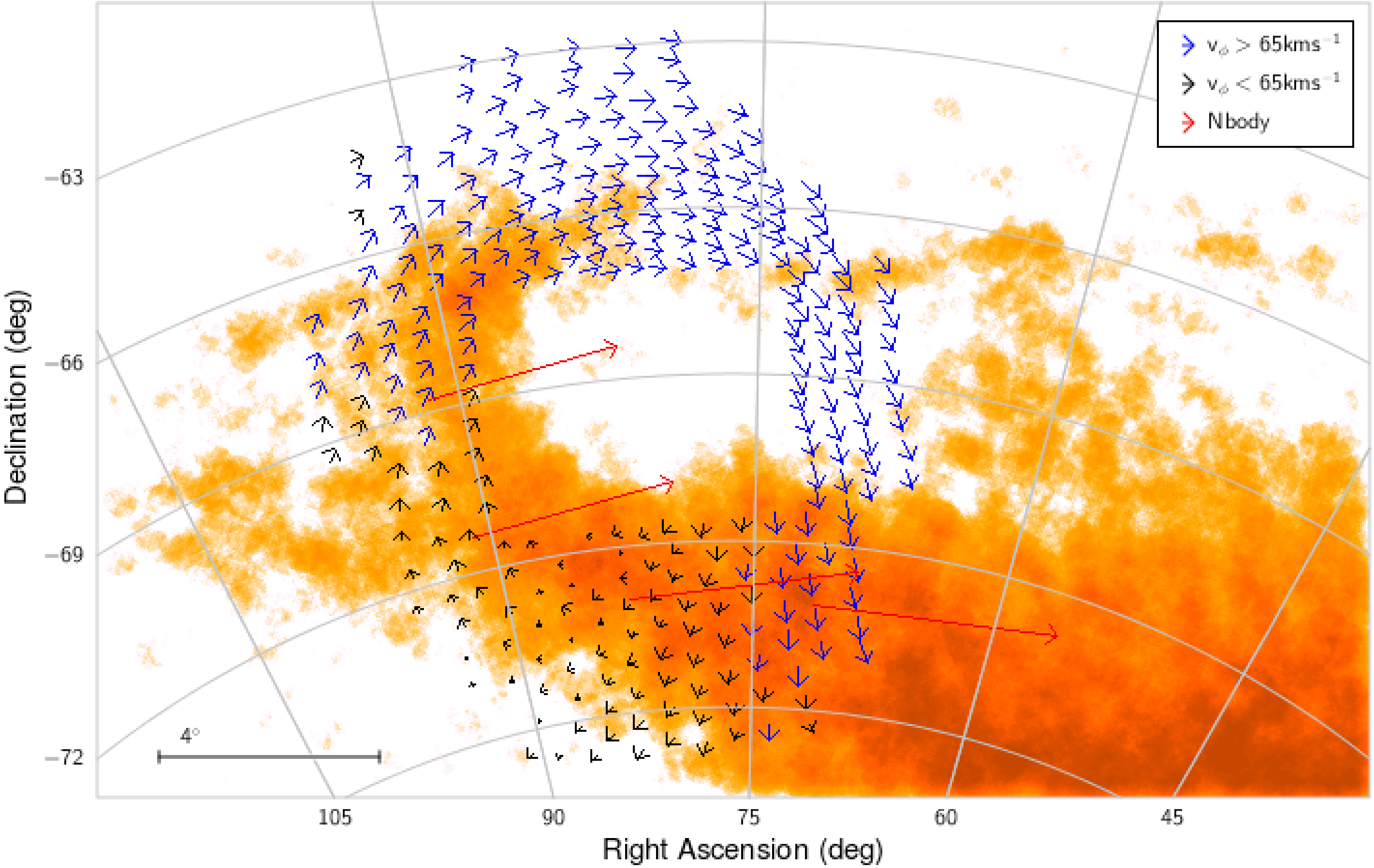


Figure 6: Gaia DR2 proper motion of the full sample of LMC stars, superimposed to the model density distribution of stripped SMC stars (Diaz & Bekki 2012). The proper motion vectors are colour coded by the rotational velocity, with stars rotating slower than average indicated in black and average rotation speed in blue. Each arrow corresponds to the ensemble velocity of at least a few thousand stars. The proper motions of the stripped SMC stars are shown in red.