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Proper motion of the Magellanic Bridge: Removal of foreground stars

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Abstract. The Large and Small Magellanic Cloud (LMC and SMC) are the most luminous dwarf galaxy satellites of the Milky Way. Thanks to their close proximity (50-60 kpc), they provide one of the best opportunities to study in detail the kinematics of resolved stellar populations in an interacting pair of galaxies. Large photometric surveys like the ongoing Gaia mission and the near-infrared VISTA survey of the Magellanic Cloud system (VMC) will have a significant impact on our insight into the Magellanic system. We have combined the individual strengths of VMC and Gaia DR2 data to improve our understanding of the internal kinematics of the galaxies. In this study, we present results from our ongoing project dedicated to measure and analyse the proper motions of large samples of stars across the Magellanic Clouds, efficiently removing Milk Way foreground stars utilising distances derived with the StarHorse code.

Keywords. Magellanic Clouds, stars: kinematics, surveys

1. Introduction

Dwarf galaxies enable us to study early phases of galaxy evolution. They are essential to many open questions in the hierarchical structure of the Universe. The Magellanic Clouds (MCs) belong to the most luminous satellites of the Milky Way (MW) and are currently in an early phase of minor merging with each other and also with the MW. There are still significant uncertainties regarding the origin of the MCs and their interactions with one another and with the MW. For example, it is unclear if the MCs are on their first infall into the MW (Besla *et al.* 2007). Also, the number of interactions between LMC and SMC in the past is unknown. Dynamical simulations suggest two or three interactions in the past. So far, the most obvious sign of, at least, one interaction is a bridge of gas and stars, the so-called Magellanic Bridge, connecting the two galaxies. Proper motion measurements are a crucial step to understand the kinematics of the MCs.

2. Overview

Data presented in this study are a combination of Gaia DR2 data (Gaia Collaboration *et al.* 2018) and data from the VISTA survey of the Magellanic Clouds system (VMC; Cioni *et al.* 2011). We focus on the 13 Bridge tiles covered by the VMC survey.

Accurate proper motion measurements at large distances often rely on combining proper motion measurements of as many individual stars of a given population as possible, while removing others. This is already a challenge for measuring the proper motion of dense populations (e.g. star clusters) at the distance of the MCs (~ 50 kpc). It becomes even more complicated if the population is sparsely distributed. In Schmidt *et al.* (2018),

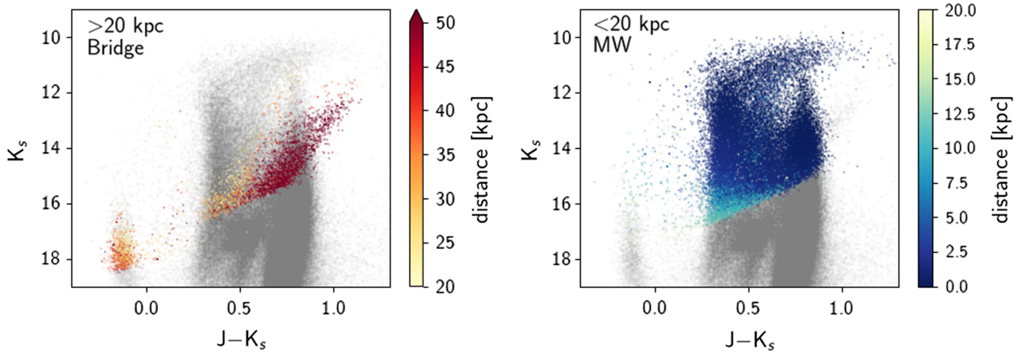

Figure 1. Colour-magnitude diagram of stars towards the Magellanic Bridge (grey). Stars with G $<$ 18 mag are colour coded by StarHorse distances.

we presented the first proper motion maps of the Magellanic Bridge by combining VMC and Gaia DR2. Those maps indicated a flow of stars from the SMC towards the LMC. The results for the central regions of the Bridge, however, seemed to be mainly influenced by the contamination of MW foreground stars. More sophisticated methods are needed to further investigate the motion of these regions.

The focus of this study is to show the removal of MW foreground stars utilising the StarHorse distances. StarHorse is a Bayesian tool for determining stellar masses, ages, distances, and extinctions for field stars (Queiroz *et al.* 2018). The code was applied to Gaia DR2 data to derive distances. The data were provided by the group developing the StarHorse code and is at its current stage limited to sources with G $<$ 18 mag (Anders *et al.* 2019). Due to the limitation in G magnitude this sample covers only the upper Red Giant Branch of the MCs stellar populations, excluding the Red Clump (see Fig. 1).

3. Implications

It should be clearly stated that the purpose of StarHorse is to provide distance estimations for MW stars using priors that reflect the properties of the MW. Therefore stars associated with the MCs generally end up further away. The individual distances of the Bridge stars do not reflect their actual distance, but they indicate that those stars unlikely belong to the MW foreground. We used a distance of more than 20 kpc to select our sample of candidate Bridge stars. This selection provides a "cleaner" sample than achieved with a cut in parallax ($\omega > 0.2$). The resulting proper motion of the central Bridge is 1.79$\pm$0.14 mas/yr in Right Ascension and $-$0.7$\pm$0.07 mas/yr in Declination. This motion is in agreement with the previously found flow of stars from the SMC towards the LMC.

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