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New Proper Motions of the Small Magellanic Cloud Using HST and Implications for Milky Way Mass

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Abstract. As new work on the proper motions (PMs) of the Large Magellanic Cloud (LMC) has come out, our view of the history of the Magellanic Clouds has evolved. We now believe they are on their first infall into the Milky Way (MW), having been tidally bound at the start of infall (though not necessarily now). Combining these observations with initial PMs of the Small Magellanic Cloud (SMC) suggests a new formation mechanism of the Magellanic Stream through the stripping of material from the SMC. However, large uncertainties remain in the exact mass of the LMC. We present a measurement of the systemic proper motions of the SMC from astrometry with the Wide Field Camera 3 (WFC3) on the Hubble Space Telescope (HST), covering a ∼3 year baseline of 30 fields with background QSOs. We find these motions to be $\mu_W = -0.82 \pm 0.06$ mas/yr and $\mu_N = -1.23 \pm 0.07$ mas/yr. Combining these measurements with previous efforts in studying the Clouds will help constrain their interactions with each other and the MW, including the mass of the LMC and the MW, as well as provide new insight into the internal dynamics of the SMC.

Keywords. Galaxies: Kinematics and Dynamics, Galaxies: Magellanic Clouds

1. Introduction

The Large and Small Magellanic Clouds (LMC and SMC, respectively) constitute the closest example of a pair of interacting dwarf galaxies. Between them lies a distinct bridge of HI gas (Putman *et al.* 2003), often referred to as the Magellanic Bridge. From early theoretical models it has been predicted that the Bridge must have formed from recent tidal interactions between the SMC and LMC (eg, Gardiner & Noguchi 1996). Kallivayalil *et al.* (2013) demonstrated with high precision PM measurements of the Clouds that such an encounter must have happened, and Carrera *et al.* (2017) found SMC stars present in the Bridge region due to stripping by the LMC. However, uncertainties remain in the exact history and orbits of the Clouds, due in significant part to the uncertainties in the PM of the SMC that stem from a lack of understanding of the structure and internal kinematics of the SMC.

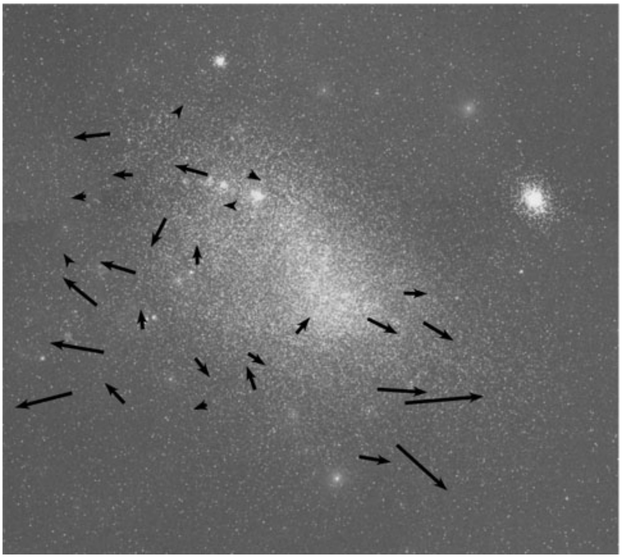

Figure 1. Proper motions for each field observed with the systemic motion of the SMC subtracted from them. The residual vectors are scaled to 65 km/s.

2. Data & Analysis

To provide more insight into the SMC, 30 new fields were selected, centered on background QSOs. These QSOs were spectroscopically confirmed candidates from the Optical Gravitational Lensing Experiment II database, done using the AAOmega instrument on the Anglo-Australian Telescope (Kozłowski *et al.* 2013). Two epochs of observations were conducted using the HST WFC3 instrument with a baseline of ∼3 years.

For the systemic properties of the SMC, we find as an initial analysis a PM of $\mu_W = -0.82 \pm 0.06$ mas/yr and $\mu_N = -1.23 \pm 0.07$ mas/yr for the SMC. This translates to a Galactocentric velocity of $\sim 255 \pm 20$ km/s, and we find an overall velocity dispersion for the SMC of ∼55 km/s. Combined with the LMC PM from Kallivayalil *et al.* (2013), we find a rough relative velocity of the SMC to the LMC of $\sim 105 \pm 27$ km/s, which falls on the order of the escape velocity of the SMC from the LMC (Kallivayalil *et al.* 2006).

As a first step in understanding the internal dynamics of the SMC, we subtracted the average motion from each field to produce a set of residual vectors (seen in Figure 1). In the residual motions, we see apparent outflowing regions of stars. The southeastern section in particular corresponds well with the direction of the Magellanic Bridge. While there has been possible evidence for rotation in the inner stellar portions of the SMC (eg, Evans & Howarth 2008), we do not find noticeable signs of rotation in the outer regions. Further work will be required to fully understand the implications for the SMC kinematics and its dynamical history.

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