The Proper Motion Field along the Magellanic Bridge: a New Probe of the LMC-SMC interaction

Scientific Category: RESOLVED STELLAR POPULATIONS

Scientific Keywords: Astrometry, Dynamics, Interacting And Merging Galaxies, Magellanic Clouds, Resolved Stellar Populations

Instruments: ACS, WFC3

Proprietary Period: 12 Proposal Size: Small

Orbit Request	Prime	Parallel
Cycle 22	17	17
Cycle 24	5	5
Total	22	22

Abstract

Our HST proper motion (PM) measurements of the LMC and SMC have revolutionized our understanding of the Magellanic System, and have spurred new research on its use as a cosmological probe of galaxy formation. The PMs imply that the Magellanic Clouds are likely on their first infall towards the Milky Way (MW). The disturbed nature of the Magellanic System is therefore likely due to the LMC-SMC interaction, and not to the MW influence. This has emphasized the importance of dwarf galaxy interactions for galaxy evolution. The Clouds are connected by a complex of gas and stars called the Magellanic Bridge. We propose to map the stellar PM field of the Bridge, similar to our prior HST mapping of the LMC PM rotation field. Our state-of-the-art N-body simulations show that the PM field will tightly constrain the impact parameter of LMC-SMC orbit at its last pericenter 100-300 Myr ago, which is the main uncertainty in our understanding of the LMC/SMC interaction history. This will test whether the tidal debris between the galaxies is due to a recent direct-hit collision. It will also test models in which the tidal debris is responsible for the observed microlensing events. We will observe once 3 fields for which first-epoch archival data already exists, and observe twice 5 other fields over a 2-cycle time baseline. With the established data reduction techniques of our successful HSTPROMO collaboration, this will yield PM accuracies of 10-25 km/s per field, well below the 130 km/s velocity difference between the Clouds. This will yield the best constraints to date on the LMC/SMC interaction, and will further test the importance of dwarf-dwarf interactions for galaxy evolution.

Assignment:
1) Breakdown Abstract and Section 1 in terms of Abstract Guidelines

2) Read through the remaining sections - what is the goal/point of each section?
Do the remaining sections relate to the abstract/section 1?

■ Scientific Justification

1 Cosmological Importance of the Magellanic System

Most of our understanding of galaxy dynamics is based on studies of line-of-sight velocities. Proper motions (PMs) are required to determine 3D velocities. Our HSTPROMO collaboration (see "Past HST Usage" Section) has been successfully determining PMs throughout the Local Group (e.g., van der Marel et al. 2012). Our 2002–2009 measurements of the Large and Small Magellanic Clouds (LMC/SMC) revealed that they move faster with respect to the Milky Way (MW) than previously believed (Kallivayalil et al. 2006a,b, 2013). This has revolutionized our understanding of the Magellanic System, and spurred much new research on the use of the LMC/SMC as cosmological probes of galaxy formation and evolution.

We showed that the PM measurements imply that, instead of being long term companions, the Magellanic Clouds are likely on their first infall towards the MW (Besla et al. 2007). Such late infall is not unexpected in light of cosmological simulations (Boylan-Kolchin, Besla & Hernquist 2011). This confirms that the hierarchical build-up of galaxies like the MW continues to the present day, and is directly affected by galaxies like the LMC/SMC. The Clouds are connected by the Magellanic Bridge, a complex of gas and stars that connect the Clouds (see Fig. 1), and they lead the Magellanic Stream, a long tail of hydrogen gas that spans 150° across the sky. This gaseous debris will eventually feed the MWs gaseous halo, so the formation mechanism of such structures is an important mode of gas supply to our MW.

Much debate has ensued about the formation of the Stream in light of our PM results (e.g., Diaz & Bekki 2012; Peebles & Tully 2013). Traditional models of the Stream have relied on tidal or ram pressure forces from the MW to create the Stream. But these forces are negligible if the Clouds have spent most of their time at large distances from the MW. In Besla et al. (2010) we showed that instead the Magellanic Stream and Bridge may be due entirely to interactions between LMC and SMC. This has put focus on interactions between dwarf galaxies as an important component of galaxy evolution. Evidence for such interactions has also been found in other Magellanic irregulars, like NGC 4449 (Martinez-Delgado et al. 2012). In Besla et al. (2012) we argued that dwarf-dwarf interactions may be the primary driver for the formation of the entire class of Magellanic Irregulars.

The goal of the present proposal is to use HST to map the PM field over the extent of the Magellanic Bridge to better understand the LMC/SMC interaction history. These first PM measurements for stellar debris associated with the Magellanic System will be compared to our detailed N-body simulations, which will allow us to distinguish between different possible scenarios. Furthermore, stellar debris from the encounter has been proposed as the source of the microlensing events observed towards the LMC by the MACHO and OGLE collaborations (Besla et al. 2013). Such models depend sensitively on the tangential motions of the stellar debris, which we will directly constrain. *Our study has cosmological importance for understanding the formation and evolution of both dwarf and massive galaxies.*

2 The LMC-SMC interaction

The past orbit and interaction history of the LMC and SMC can in principle be determined by backward orbital integration. This requires the 3D velocities of the Clouds and their