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HST PROPER MOTIONS IN LOW FOREGROUND EXTINCTION WINDOWS OF THE GALACTIC BULGE

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RESUMEN

En este trabajo presentamos los avances en un proyecto que estudia la estructura del bulbo Galáctico a través de la cinemática de las poblaciones estelares en varias ventanas de baja extinción. La técnica utilizada para este propósito es la de los movimientos propios, la cual ha sido complementada con velocidades radiales cuando ha sido posible. Los movimientos propios de las estrellas del bulbo en nuestra muestra han sido calculados a partir de imágenes del Telescopio Espacial Hubble (*HST*), alcanzado precisiones $>1(mas\ yr^{-1})$ para $\sim 140{,}000$ estrellas en 10 campos situados estratégicamente en ambos extremos del bulbo/barra Galáctico.

ABSTRACT

We report on the advancements of a project which studies the Galactic bulge throught the kinematics of the stellar population in several low foreground extinction windows. In order to obtain the kinematics of as many stars as possible we have used the technique of proper motions in several fields with Hubble Space Telescope (*HST*) observations available. These proper motions have been complemented with radial velocities whenever possible. Our preliminary results consist of a sample of $\sim 140{,}000$ proper motions with accuracies $>1(mas\ yr^{-1})$ distributed over 10 fields strategically placed at both ends of the Galactic bulge/bar.

Key Words: Galaxy:bulge — Galaxy: kinematics and dynamics — Galaxy: stellar content — methods: data analysis

1. INTRODUCTION

The Galactic bulge is the closest sample of bulge kinematics that we can obtain. However, in spite of its proximity there are still a fair amount of uncertainties related to the main structural parameters that define the bulge. One of the main difficulties to observe stars in the bulge is the strong differential reddening in the Galactic plane. In addition, the disk and bulge population are very difficult to separate based on photometry alone, due to the overlapping of both populations in the color-magnitude diagram (CMD) (Holtzman et al. 1998). Furthermore, blue stragglers extend brighter than the turn-off, overlapping with young main sequence stars.

These problems effectively limit optical work to a few "windows" where we know the extinction is limited. Hence, detailed stellar proper motions and radial velocity studies have customarily been constrained to a few small fields such as the Baade's window (Terndrup et al. 1995; Spaenhauer et al. 1992; Kozłowski et al. 2006; Kuijken & Rich 2002; Soto et al. 2007), Sagittarius-I (Kuijken & Rich 2002), SWEEPS(Clarkson et al. 2008), near NGC 6558 (Kuijken 2004; Soto et al. 2012), Plaut's window (Vieira et al. 2007), and a few other fields.

Our goal with this project is to disentangle the structure of the bulge by constraining the phase-space distribution function with spatial coordinates, proper motions, and radial velocities.

2. PROPER MOTIONS AND RADIAL VELOCITIES TO UNDERSTAND THE GALACTIC BULGE

Proper motions have been obtained using two procedures depending on the data available in each field (see Figure 1). Proper motions for those fields along the Galactic minor axis and at positive longitudes, which have a combination of *Wide Field Planet Camera 2* (WFPC2) and *Advanced Camera for Surveys* (ACS) observations, have been calculated using a modification of the Anderson & King (2000) approach (Kuijken & Rich 2002). These modifications solve the undersampling of the Point Spread Function (PSF) by fitting an analytical model which improves the centroid accuracy in the undithered WFPC2 first epoch observations, obtained from the HST archive. On the other hand, for the proper motion of the fields in the far side of the bar, which have properly dithered observations

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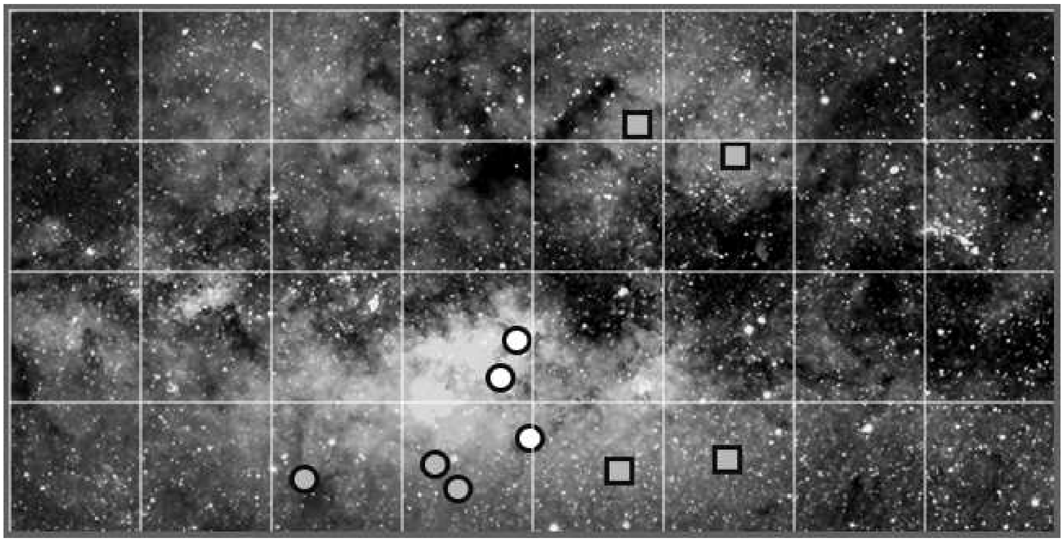

Fig. 1. Fields of our study, projected into an optical map (Mellinger 2008) extending from longitude $+20^\circ$ to -20°, and latitude -10° to $+10^\circ$. The three fields along the Galactic minor-axis (white circles) have only WFPC2 observations, while those in the near-end of the bar (positive longitudes; grey circles) have a combination of WFPC2 and ACS observations for first and second epoch respectively. Those on the far-side of the bar (negative longitudes; grey squares), have ACS observations for first and second epoch. Radial velocities, on the other hand, have been obtained for minor-axis and near-end fields only.

on both epochs, we have used the procedure by Anderson et al. (2006). This second technique takes into account the geometric distortions and the PSF variations across the images in order to improve the accuracy.

Radial velocities have also been included for a subsample of our proper motion stars. The radial velocity data consisted in 82 VIMOS IFU fields (covering each an area of 27"×27") in the same fields along the minor axis and near side of the bar (Soto et al. 2012). These radial velocities were derived using a deconvolution technique that combined the positions and magnitudes from the HST images to extract the contribution of each star to the flux of each fiber of the spectral data cube. Using this deconvolution technique ~3200 radial velocities were obtained, which combined with the proper motions produced 3-D motions for ~ 1400 stars in the fields along the Galactic minor axis.

3. PRELIMINARY RESULTS AND DISCUSSION

The undersampling of the PSF in the WFPC2 images of the first epoch in the minor-axis and near-end bar fields contributed to the systematic errors in our proper motions (see Soto et al. 2014). Hence, the proper motion accuracy for these fields was > 1 $mas\ yr^{-1}$, which at the distance of the bulge (~ 8 kpc) corresponds to $\sim 37\ km\ s^{-1}$. The achieved proper motion precision allowed to combine them with radial velocities for the three fields along the Galactic minor axis for a significant number of turn-off, main sequence (MS), and red-giant branch stars (RGB) stars, as previously mentioned. The derived 3-D kinematics in these fields is consistent with a triaxial bulge population (Soto et. al 2012); where a similar evidence has been found by Babusiaux et al. (2010) for a sample of metal-rich stars with proper motions from Sumi et al. (2004).

On the other hand, the new proper motions, in the fields at the far-side of the bar, with ACS observations for first and second epoch show accuracies well below 0.8 $mas\ yr^{-1}$ for non saturated stars with $m_{F814W} < 23$. Hence, the far-side fields have provided us with a sample of ~100,000 stars with reliable proper motions. These preliminary proper motions in the far side of the bar suggest a bulge population consistent with the kinematic observed in our fields in both ends of the bar. This is also in agreement with recent findings (Valenti et al. 2013) which indicate a significant fraction of metal-rich (i.e. bulge-like) stars in the corners of the boxy bulge, several degrees away from the galactic minor-axis.

This project is still on-going, the current sample is expected to be complemented by a dynamical model of the bulge which will allow us to study in more detail the dynamics and orbit pattern consistent with the kinematics observed.

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