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A Warp in the LMC Bar?

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1. Introduction

LMC, SMC, Milky Way are known to have experienced close encounters. The interaction of the Milky Way with the Magellanic Clouds could result in tidal forces which could alter the structure of the Clouds. We look for evidence of the interaction, like the presence of a warp, by studying the geometrical structure of the LMC bar. We use the brightness of core helium-burning red clump stars in the central regions of the LMC. The difference in the mean magnitudes of the de-reddened red clump stars is used as differential distance indicator. The analysis is similar to that of Olsen & Salyk (2002), but the central region of LMC near the bar, is studied here. The detailed version of this work is submitted to the ApJ letters.

2. Photometric Data, Analysis and Results

OGLE II survey (Udalski et al, 2000) consists of photometric data of 7 million stars in B, V and I pass bands in the central 5.7 degree of LMC. The observed region is divided into 336 sections of size 7.1×7.1 arcmin^2 each. The red clump stars are identified using I vs (V−I) CMD (Figure 1a). The frequency distribution of red clump stars is estimated in both I magnitude and (V−I) colour after correcting for the data incompleteness. The peak of the (V−I) and I distribution for each region is estimated and the reddening to the region is calculated using the relation E(V−I) = $(V-I)_{(obs)} - 0.92$ mag. The interstellar extinction is estimated by $A_I = 1.4\,E(V-I)$. After correcting the mean I mag for interstellar extinction, I_0 for each region is estimated. The center of the LMC is taken to be $05^h19^m38^s.0$ $-69^o27'5''.2$ (2000.0) (de Vaucoulers & Freeman 1973). The mean red clump magnitude of the LMC center is taken as I_0^c and the difference is red clump magnitudes are estimated as $\Delta I = I_0 - I_0^c$. This difference is a measure of the relative distances such that ~ 0.1 mag in ΔI corresponds to 2.5 Kpc in distance.

ΔI as shown in figure 1b is found to vary in the east-west direction such that both the east and the west ends of the bar are closer to us with respect to the center of the bar. Thus the ΔI variation

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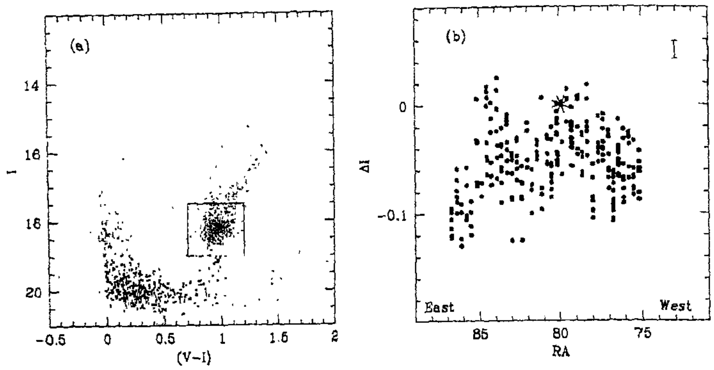

Figure 1. The figure 1(a) shows a typical I vs (V−I) CMD and the region occupied by the red clump stars. A plot of RA vs ΔI is shown in figure (b), typical error in ΔI is also indicated.

points to a c-type warp in the LMC bar. Also, most part of the bar is found to be located above the plane of the disk, if the disk is considered to be at $\Delta I = 0$. The above facts have direct impact on the microlensing optical depth in LMC. The brighter red clump stars could result from either the bar being located closer or due to lower metallicity and/or younger age. The second possibility is ruled out as no significant change in metallicity or age is found in these regions (Subramaniam & Anupama 2002). The ΔI variation thus indicates the geometry of the bar. The bar geometry is defined by three angles, the angle of the line of nodes, Θ and the inclination angles, i and ζ. The values of the angles are estimated to be $\Theta = 139^\circ.2 \pm 2^\circ.8$, $88^\circ.3 \pm 21^\circ.2$ $\zeta = -60^\circ.2 \pm 3^\circ.6$, $\zeta = 39^\circ.0 \pm 16^\circ.7$ $i = 32^\circ.7 \pm 11^\circ.9$, $31^\circ.2 \pm 29^\circ.3$ for east and west side of the bar respectively. The values of i and Θ as estimated by van der Marel & Cioni (2001) are $34^\circ.7 \pm 6^\circ.2$ and $122^\circ.5 \pm 8.3$ and by Olsen & Salyk (2002) are $35^\circ.8 \pm 2^\circ.4$ and $145^\circ \pm 4^\circ$ respectively. Therefore, the value of i, for the bar region is similar to that for the outer region, except that the error is large indicating true variations in the value. The angle ζ has opposite signs on the east and west of the bar and this points to the warp in the bar. The dis-location of the bar with respect to the disk could be due to the galaxy- galaxy interactions. Since the bar is located above the disk, the tidal signatures seen in the bar could be due to the perturbations on the bar due to the disk.

References

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