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The inner Galactic Bulge

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Abstract. 2MASS near infrared data in the direction of the Galactic Center are analyzed in order to derive the position angle of the inner bulge/bar ($|l| < 14$). Using clump stars as distance indicators, we find a position angle of $50^0 \pm 14$. This value is in agreement with the angle derived for the external bar. No evidence is found of an external bulge structure distinct from the inner one.

Key words. CM diagram – clump stars– Galactic Structure

1. Introduction

One of the challenges of the modern astrophysics is to cast light on the complexity of galaxy formation and evolution. To understand our Galaxy is the first step towards achieving a successful theory of galaxy formation. Star counts have been extensively used to derive the Galactic structure and their importance has been increasing with the new large area surveys in the recent past. In particular the advent of NIR arrays has allowed the study of the Galaxy inner part structure where the interstellar extinction becomes relevant. In spite of the efforts made in the recent past, some Galactic parameters remain still controversial or totally unknown. Some of these are linked to the age, age distribution and structure of the bulge, its position angle, shape and axial ratios. Their importance is far from being marginal, since they can give information about the formation process of the bulge itself. At present, it is not clear whether the bulge formed as a result of the dynamical evolution of the disk (Raha et al. 1991; Athanassoula et al. 2002) or by accretion of a dwarf galaxy (Wyse 1997; Walker et al. 1996). The shape of the bulge can cast light on the formation process: in particular boxy bulges are often found in interacting galaxies and can be formed as a result of the interaction (Dettmar et al. 1990).

Concerning the morphological parameters of the bulge, while evidences have been advanced that the bulge is triaxial (Dwek et al. 1998; Binney et al. 1997; Bissantz & Gerhard 2002), the position angle of the inner ($|l| <$ 10) bar/bulge is uncertain. Defining a reference system where the positive x-axis points towards decreasing l, and the y-axis increases away from the observer, then the position angle β is the angle between the bulge major axis and the y-axis. Different studies in literature give values going from:

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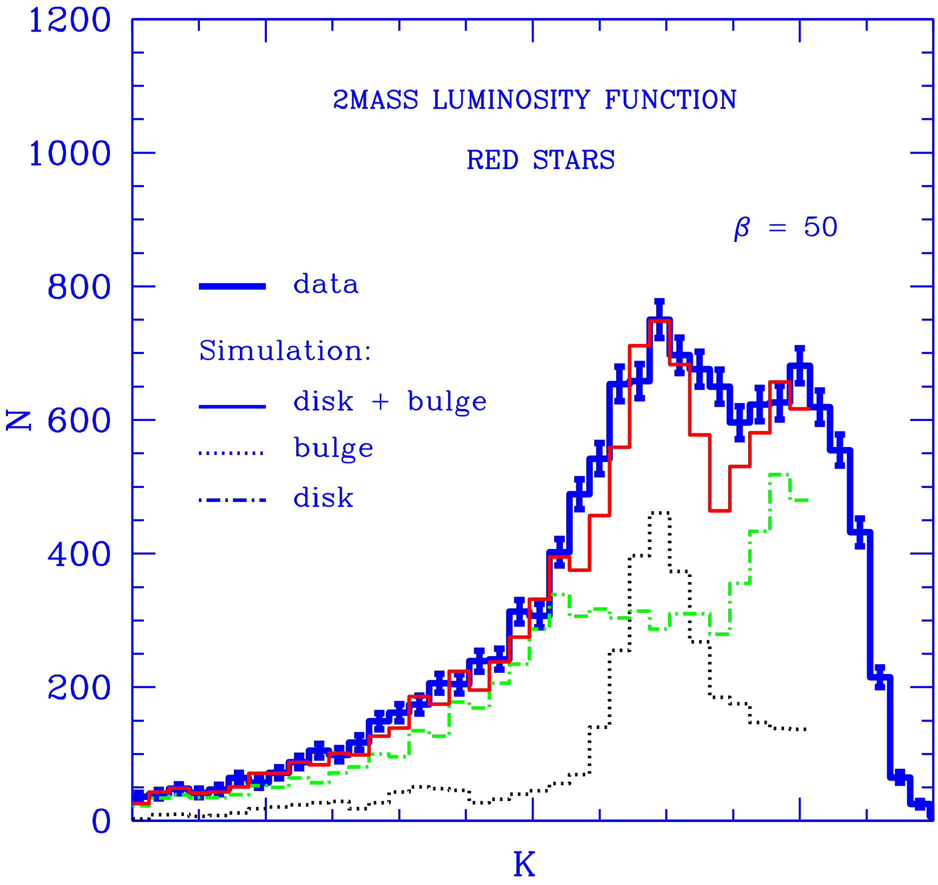

Fig. 1. 2MASS K-band luminosity function of the red evolved stars in a field at (l,b)=(10.48,-3.78) (heavy solid line). The thin solid line represents the best fit obtained using the Padova Galaxy model where disk and bulge are included. The bulge boxy shape G2 reproduces the data when the axis values are (x_0,y_0,z_0)=(1.5,0.4,0.2) Kpc

40^0(Sevenster et al. 1999; van Loon et al. 2003);

25^0 (Model B2,G2) (Dwek et al. 1998);

12^0(Lopez-Corredoira et al. 2000; Robin et al. 2003).

The external bulge has recently been found to extend as far as l=27^0; its position angle of the external bar/bulge is estimated as $45^0 \pm 9$ when l = $(15\text{-}27)^0$ (Picaud et al. 2003; Hammersley et al. 2000).

The question then arises: is there an external structure (bar) extending to l = 27^0, distinct from the inner bulge? (Lopez-Corredoira et al. 2000; Robin et al. 2003). This paper deals with the determination of the bulge/bar position angle in the inner regions using NIR data.

2. The position angle of the Inner Bar

The position angle of the inner bulge is derived using as distance indicator the magnitude of the red clump stars in 2MASS data for 10 fields (26×26 arcmin^2) located in the central regions of the Galaxy between $-140 < l < 140$ and $|b| < 50$. The selected fields are characterized by a low reddening to avoid spurious features due to the absorption along the line of sight. Red clump stars have been proved to be good distance indicators (Girardi & Salaris 2001), since the intrinsic spread in luminosity in the age range 1-10 Gyr is estimated to be at maximum about 0.1 mag. An additional spread of 0.2 mag can be assumed as a metallicity effect in the K passband. The observed clump has a larger width because of the distribution of the stars along the line of sight. One of the critical assumptions is that disk red sources do not influence the location of the clump peak. The contamination by red giants of the disk population is then derived and subtracted using the Padova model already described (Bertelli et al. 1995; Vallenari et al. 2000; Bertelli et al. 2003), where more detail can be found.

The absorption along the line of sight A_K is measured in each field assigning the absolute magnitude M_K = -1.55 and $(J-K)_0$ = 0.70 to the clump (Girardi & Salaris 2001) for metallicities in the range Z=0.008-0.2 (McWilliam & Rich 2004). With these assumptions, the position angle of the inner bar is obtained from simple geometric considerations and turns out to be $\beta = (50^0 \pm 11)$ when the distance Sun-Galactic center, $R_\odot$=8.0 Kpc. Little dependence is found on $R_\odot$.

If different values for M_K and $(J-K)_0$ are adopted the position angle varies as follows: using M_K = -1.65 and (J-K) = 0.75 (Lopez-Corredoira et al. 2002), which imply that K2-III stars dominate, we get $\beta = (54^0 \pm 17)$; using M_K = -1.85 and (J-K) = 0.64 (Robin et al. 2003), for which K1-III stars are the dominant population, we get $\beta = (59^0 \pm 18)$. Even taking these uncertainties into account the position-angle for the inner bar agrees with the value for the external bar. Finally, as a further check, we model the Galactic bulge clump luminosity function using the Padova Galaxy Model, where several bulge mass distribution laws are considered. As a preliminary result, the shape of the Galactic Bulge is best matched by the triaxial boxy model G2 (Dwek et al. 1995) characterized by (x_0,y_0,z_0)=(1.5,0.4,0.2) kpc when a position angle $\beta = 50^0$ is assumed (see Figure 1).

3. Conclusions

The magnitude and luminosity function of the red clump stars are used to derive the position angle of the Inner Galactic Bulge in 10 low reddening windows. We derive a position angle of $\beta = 50^0 \pm 11$. This result shows little or no dependence on the Sun-Galactic center distance, nor on the adopted theoretical values of the mean clump color and magnitude. The estimated β is in agreement with the position angle of the external bulge/bar (Picaud et al. 2003). This gives no further support to the hypothesis that the inner and the external bulge/bar are two distinct structures having different morphologies. However, to reach a firmer conclusion on this point a detailed analysis of the observed fields is needed before discarding the possibility that the other parameters as shape, dimensions of the axis, axial ratios are changing at varying Galactic latitude.

References

Athanassoula, E. 2002, ApJ 569, L83

Bertelli, G., Bressan, A., Chiosi, C., Ng, Y. K., & Ortolani, S. 1995, A&A 301, 381

Bertelli, G.,Vallenari, A., Pasetto, S. & Chiosi, C. 2003 in GAIA Spectroscopy Science and Technology, ed. U. Munari ASP Conf. Ser.,vol. 298, p. 153

Binney, J., Gerhard, O. & Spergel, D. 1997, MNRAS 288, 365

Bissantz, N. & Gerhard, O. 2002, MNRAS 330, 591

Dettmar, R-J. & Barteldrees, A. 1990, bg work 259

Dwek, E., Arendt, R. G., Hauser, M. G., Kelsall, T., Lisse, C. M., Moseley, S. H., Silverberg, R. F., Sodroski, T. J. & Weiland, J. L. 1995, ApJ 445, 716

Dwek, E., Arendt, R. G., Hauser, M. G., Fixsen, D., Kelsall, T., Leisawitz, D., Pei, Y. C., Wright, E. L., Mather, J. C., Moseley, S. H., Odegard, N., Shafer, R., Silverberg, R. F. & Weiland, J. L. 1998, ApJ 508, 106

Girardi, L. & Salaris, M. 2001, MNRAS 323, 109

Hammersley, P. L., Garzn, F., Mahoney, T. J., López-Corredoira, M., & Torres, M. A. P. 2000, MNRAS 317, L45

López-Corredoira, M., Hammersley, P. L., Garzn, F., Simonneau, E. & Mahoney, T. J. 2000, MNRAS 313, 392

López-Corredoira, M., Cabrera-Lavers, A., Garzón, F. & Hammersley, P. L. 2002, A&A 394, 883

McWilliam, A. & Rich, R.M. 2004 in Origin and Evolution of the Elements, eds. A. McWilliam and M. Rauch, in press

Picaud, S., Cabrera-Lavers, A. & Garzn, F. 2003, A&A 408, 141

Raha, N., Sellwood, J. A., James, R. A.& Kahn, F. D. 1991, Nature 352, 411

Robin, A. C., Reyl C., Derrie, S. & Picaud, S. 2003, A&A 409, 523

Sevenster, M. N., Saha, P., Valls-Gabaud, D. & Fux, R. 1999, MNRAS 307, 584

Vallenari, A., Bertelli, G., & Schmidtobreick, L. 2000, A&A 361, 73

van Loon, J. T., Gilmore, G. F., Omont, A., Blommaert, J. A. D. L., Glass, I. S., Messineo, M., Schuller, F., Schultheis, M., Yamamura, I. & Zhao, H. S. 2003, MNRAS 338, 857

Walker, Ian R.; Mihos, J. Christopher & Hernquist, L. 1996, ApJ 460, 121

Wyse, R. F. G., Gilmore, G. & Franx, M. 1997, ARA&A 35, 637