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Estimation of Galactic model parameters in high latitudes with 2MASS

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ABSTRACT

Context. In general, studies focused on the Milky Way's structure show a range of values when deriving different Galactic parameters, such as radial scalelengths, vertical scaleheights, or local space densities. Those values are also dependent on the Galactic coordinates under consideration for the corresponding analysis, as a direct consequence of observing a structure (our Galaxy) that is far from being as smooth and well-behaved as models usually treat.

Aims. In this paper, we try to find any dependence of the Galactic structural parameters on the Galactic longitude for either the thin disc or the thick disc of the Milky Way that would indicate possible inhomogeneities or asymmetries in those Galactic components.

Methods. Galactic model parameters have been estimated for a set of 36 high-latitude fields with Two Micron All Sky Survey (*2MASS*) photometry. Possible variations with the Galactic longitude in either the scaleheight and the local space density of these components are explored.

Results. Galactic model parameters for the different fields show that they are Galactic longitude-dependent. The thick disc scaleheight changes from ~800 pc at $150° < l < 230°$ to ~1050 pc at $|l| < 30°$. A plausible explanation for this finding might be the effect of the flare on this Galactic component, which changes the scaleheight (h_z) with Galactocentric distance (R) following the approximate law: $h_z(R) = (940 \pm 20) \times [1 - (0.12 \pm 0.02)(R - R_\odot)]$. The effect of the flare is more prominent in some lines of sight than in others, producing the observed changes in the parameters with the Galactic coordinates used to derive them.

Key words. Galaxy: general – Galaxy: stellar content – Galaxy: structure – infrared: stars

1. Introduction

Detailed study of star counts in the Milky Way permits us to recover basic structural parameters, such as its disc scalelength and disc scaleheight. Our knowledge of the structure of the Milky Way, as inferred from star count data, is about to enter the next level of precision with the advent of new surveys such as *2MASS*. This will require the refinement of models of Galactic structure to fit the parameters of the basic components of Milky Way.

Researchers have used different methods to determine the Galactic model parameters. In Table 1 of Karaali et al. (2004) we can find an exhaustive list of the different values obtained for the sctructural parameters of the discs and halo of the Milky Way. One can see that there is an evolution in the numerical values of model parameters. The local space density and the scaleheight of the thick disc can be given as an example. The evaluations of the thick disc have steadily moved towards shorter scaleheights, from 1.45 to 0.65 kpc (Gilmore & Reid 1983; Chen et al. 2001), and higher local densities (2–10 per cent). In many studies the range of values for the parameters is large. For example, Chen et al. (2001) and Siegel et al. (2002) give 6.5–13 and 6–10 per cent, respectively, for the local space density of the thick disc.

Different model parameters revealed for the Galactic disc may be due to the warp and flare. The disc of the Milky Way is far from being radially smooth and uniform. On the contrary, its overall shape presents strong asymmetries. While the warp bends the Galactic plane upwards in the first and second Galactic longitude quadrants ($0° \leq l \leq 180°$) and downwards in the third and fourth quadrants ($180° \leq l \leq 360°$), the flare changes the scaleheight as a function of radial distance.

This warp is present in all Galactic components: dust (Drimmel & Spergel 2001; Marshall et al. 2006), gas (Burton 1988; Drimmel & Spergel 2001; Nakanishi & Sofue 2003; Levine et al. 2006; Voskes & Burton 2006), and stars (López-Corredoira et al. 2002b; Momany et al. 2006). All these components have the same node position, and their distributions are asymmetric. However, the amplitude of the warp seems to depend slightly on the component one looks at: the dust warp seems to be less pronounced than the stellar and gaseous warps that share the same approximate amplitude (López-Corredoira et al. 2002b; Momany et al. 2006).

The stellar and gaseous flarings for the Milky Way are also compatible (Momany et al. 2006), showing that the scaleheight increases with the Galactocentric radius for $R > 5$ kpc (Kent et al. 1991; Drimmel & Spergel 2001; Narayan & Jog 2002; López-Corredoira et al. 2002b; Momany et al. 2006). The behaviour of this flare in the central discs of spiral galaxies has not been studied so well due to inherent difficulties in separating the several contributions to the observed counts or flux. López-Corredoira et al. (2004), for example, find that there is a deficit of stars compared to the predictions of a pure exponential law in the inner 4 kpc of the Milky Way, which could be explained as being a flare which displaces the stars to higher heights above the plane as we move to the Galactic centre.

In this scenario, where on the one hand the mean disc ($z = 0$) can be displaced as much as 2 kpc between the location of the maximum and the minimum amplitudes of the warp (Drimmel & Spergel 2001; López-Corredoira et al. 2002b; Momany et al. 2006), and on the other the scaleheight of the stars can show differences up to 50 per cent of the value for $h_z(R_\odot)$ in the range $5 < R < 10$ kpc (Alves 2000; López-Corredoira et al. 2002b; Momany et al. 2006) to fit a global Galactic disc model that accounts for all these inhomogeneities is, at the very least, tricky. Because of this the results in the Galactic model parameters might depend on the sample of Galactic coordinates used, as the combined effect of the warp and flare will be different at different directions in the Galaxy, hence at different lines of sight.

For this paper, we derived the structural parameters of the thin and thick discs of the Milky Way by using data from *2MASS* survey, to observe changes in the parameters with the Galactic longitude. We briefly describe the *2MASS* data, density functions, and the estimation of the Galactic model parameters in Sect. 2. Dependence of the Galactic model parameters on the Galactic longitude is given in Sect. 3. Finally, our main results are discussed and summarised in Sects. 4 and 5, respectively.

2. 2MASS data

The *Two Micron All Sky Survey* (*2MASS*, Skrutskie et al. 2006) provides the most complete database of near infrared (NIR) Galactic point sources available to date. During the development of this survey, two highly-automated 1.3-m telescopes were used, one at Mt. Hopkins (AZ, USA) to observe the Northern Sky and one at Cerro Tololo Observatory (CTIO, Chile) to complete the Southern counterpart of the survey. Observations cover approximately 97 per cent of the sky with simultaneous detections in J (1.25 μm), H (1.65 μm), and K_s (2.17 μm) bands up to limiting magnitudes of 15.8, 15.1, and 14.3, respectively.

In this paper we have used data from the *All Sky Release* of *2MASS*, made available to the public on March 2003. It includes a point source catalogue of ~470 million stars (Cutri et al. 2003). We extracted those areas at Galactic latitudes of $45° \le b \le 55°$ and $60° \le b \le 70°$, where both the differential reliability and completeness of the *2MASS* catalogue are 0.99; thus, the nominal limiting magnitudes of the survey can be easily achieved.

2.1. Stellar density from the red clump population

López-Corredoira et al. (2002b) present a method for deriving stellar densities and the interstellar extinction along a given line of sight, which was developed in a subsequent series of papers (Drimmel et al. 2003; Picaud et al. 2003; López-Corredoira et al. 2004). The method relies on extracting the red clump (RC) population from the colour–magnitude diagrams (CMDs) as they are the dominant giant population (Cohen et al. 2000; Hammersley et al. 2000). These stars can be easily isolated as they form a conspicuous feature in the CMDs. The absolute magnitude and intrinsic colour of this population are well defined: $M(K) = -1.62 \pm 0.03$, $(J-K)_0 = 0.61 \pm 0.01$ with a small dependence on the metallicity and age (Alves 2000; Grocholski & Sarajedini 2002; Salaris & Girardi 2002; Pietrzyński et al. 2003). Of course, there is some dispersion with respect to those values ($\sigma[(J{-}K)_0] \sim 0.1$), but we know that this population is dominant and the dispersion of absolute magnitudes and colours is not very large, so the use of an average value of $M(K)$ and $(J-K)_0$ is a good approximation. Therefore, we can extract spatial information directly from the apparent magnitudes and $(J-K)$ colours of the RC stars in the CMDs.

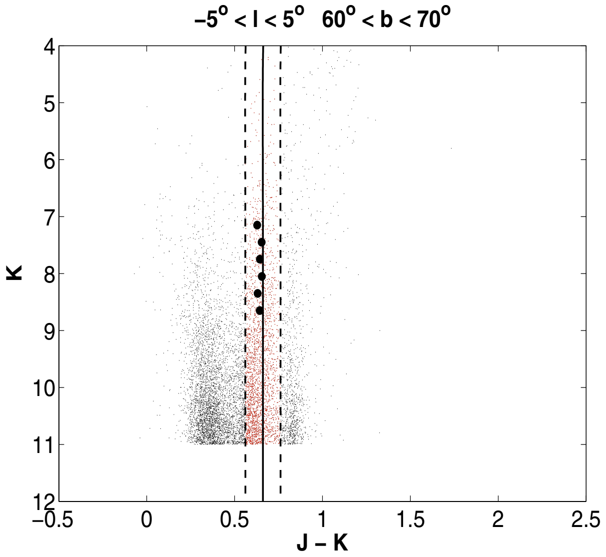

Fig. 1. K vs. $J-K$ *2MASS* colour–magnitude diagram for the field centred at $l = 0°$. The fitted trace that we assign to RC giants population (solid line) and the limits for extraction of the stars (dashed lines) are also shown (see Sect. 2 in Cabrera-Lavers et al. 2005 for details).

This method has been used before in Cabrera-Lavers et al. (2005) to analyse the thick disc of the Milky Way, extracting some results about the structural parameters of this component that were in good agreement with previous estimates for the Galactic thick disc. The full details of the application of the method can be found in that paper and also in López-Corredoira et al. (2002b), so they will not be repeated here. As a brief summary, the RC stars are first isolated in the CMDs by means of theoretical traces predicted using the "SKY" model (Wainscoat et al. 1992), and they define the approximate area in the CMD where the RC population lies. Once these stars are identified, RC stars are extracted around a trace fitted to the maxima of a series of consecutive Gaussian fits to different colour histograms at fixed apparent magnitudes, m_K (see Fig. 1). The distance along the line of sight to those stars can be derived easily from the apparent colour and magnitude. By obtaining the number of RC stars in each interval of apparent magnitude, the stellar density can be derived once the absolute magnitude and intrinsic colour of the RC are known (the main assumption of the method). As we obtain densities along the line of sight, they can be transformed into densities in cylindrical coordinates (R, z).

The possible contamination due to dwarf stars in the extracted counts is the more restrictive issue when applying the method. To minimise this effect, we extracted only stars up to $m_K < 10$ from the CMDs. In this range, contamination is less than 10 per cent of the total number stars, and it is even lower for brighter apparent magnitudes (Cabrera-Lavers et al. 2005). A magnitude $m_K = 10$ corresponds to a distance from the Sun of approximately 2.5 kpc for a RC star, suitable for analysing the disc more than 1 kpc above the Galactic plane but unable to reach the range of distances where the halo dominates the counts. Thus, the following analysis is made ignoring this Galactic component.

Other aspects that affect the method, such as the metallicity dependence of the colour of the RC population, any possible contamination of lower luminosity giants in the counts, or the Malmquist bias (Malmquist 1920) in the absolute magnitude of the RC stars, have been taken into account, and their possible effects on the results were deeply discussed in Sect. 3 of Cabrera-Lavers et al. (2005). In any case, the uncertainties are always lower than the one coming from the contamination of dwarf stars.

We first collected 10 × 10 degree fields in the *2MASS* catalogue centred at fixed Galactic longitudes (in $\Delta l = 10°$ bins), with $60° \leq b \leq 70°$. We have to average several fields to obtain a sufficient number of RC stars to build up a conspicuous feature in the CMD that could be easily identifiable. The densities extracted are fitted by a double exponential following Eq. (1), for both the thin and thick discs, with the additional constraint of producing the same local-disc space density for the thin disc as was obtained previously in Cabrera-Lavers et al. (2005).

Therefore, we assume a distribution for the discs as follows:

$$\rho_i(R,z) = n_i \exp(-|z|/h_{z,i}) \exp(-(R-R_0)/H_i), \qquad (1)$$

where $z = z_\odot + r\sin(b)$, r is the distance to the object from the Sun, b the Galactic latitude, $z_\odot$ the vertical distance of the Sun from the Galactic plane we assume to be 15 pc (Hammersley et al. 1994), R is the projected of the Galactocentric distance on the Galactic plane, R_0 the solar distance from the Galactic centre (Reid 1993, 8 kpc), $h_{z,i}$ and H_i are the scaleheight and scalelength, respectively, and n_i is the normalized density at the solar radius. The suffix i takes the values 1 and 2 as long as the thin and thick discs are considered.

As this study focuses on the dependence of the scaleheight and solar normalization on the Galactic longitude, for the scalelengths of the thin and thick discs we used the values of 2.1 kpc (López-Corredoira et al. 2002b) and 3 kpc (Cabrera-Lavers et al. 2005) respectively, which were also obtained with *2MASS* data. It has to be noted that the range of Galactocentric distances covered along each line of sight is so narrow that the effect of changing the value of the radial scalelengths is negligible (Cabrera-Lavers et al. 2005). The possible implications of a different scalelength for the thick disc will be discussed in Sect. 4.2.

Figure 2 shows stellar densities profiles extracted at four different Galactic longitudes, as an example of the application of the method, while the Galactic model parameters are given in Table 1. Columns (2) and (3) give the scaleheight of the thin and thick discs, respectively, while the local space density of the thick disc (n_2/n_1) is given in Col. (4). Error bars in the scaleheights come from the uncertainty in the double exponential fit, by assuming Poisson noise in the extracted counts and taking the uncertainty in the distance above the plane into account as we have grouped 10 × 10 degree fields.

3. Dependence of the Galactic model parameters with the Galactic longitude

Figure 3 shows the variation in the scaleheight of the thin disc with the Galactic longitude. No obvious global trend is observed in the thin disc scaleheights, with a sample of values very compatible with a constant value of $\langle h_z \rangle = 187$ ($\sigma = 36$) pc, in agreement with the usual estimates for this component (e.g., Bahcall & Soneira 1984; Robin & Crézé 1986; Reid & Majewski 1993; Siegel et al. 2002; López-Corredoira et al. 2002b). As shown in Fig. 3, we have overplotted a sinusoidal fit with no physical meaning to the data. One can say that the scaleheight of the thin disc shows slight variation with the Galactic longitude. However, the scatter and the error bars are large, being compatible with a constant value independent of the Galactic longitude. We can therefore conclude that the thin disc scaleheight is found to be a constant as a function of Galactic longitude.

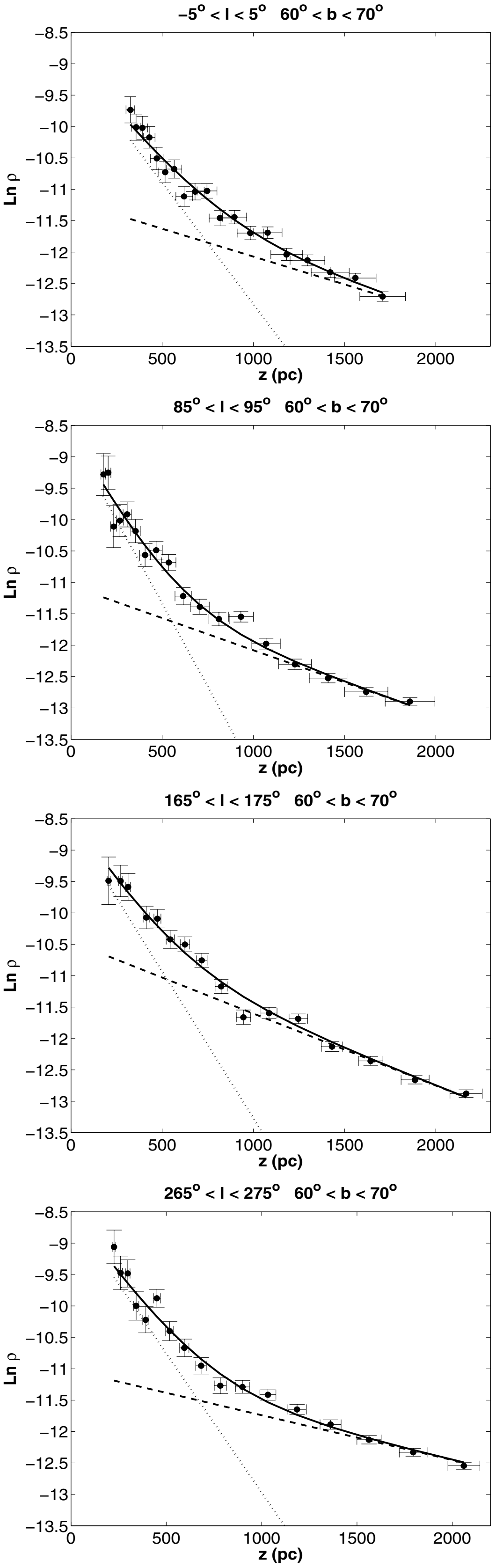

Fig. 2. Density of red clump stars (in stars pc^{-3}) obtained from the CMDs for the Galactic longitudes of 0°, 90°, 170°, 270°. The best fits for a sum of thick disc (dashed line) and thin disc (dotted line) components are also shown as a solid line. Error bars come from the Poisson noise in the extracted counts and from the uncertainty in the distance above the plane.

Table 1. Galactic model parameters for the 36 star fields analysed with *2MASS* data.

	Thin disc	Thick disc	
$\langle l \rangle$ (°)	h_z (pc)	h_z (pc)	n_2/n_1 (%)
0	258 ± 25	1127 ± 142	10.79 ± 2.71
10	209 ± 18	1043 ± 77	13.75 ± 4.17
20	187 ± 13	974 ± 48	14.48 ± 3.62
30	161 ± 26	963 ± 101	11.85 ± 2.95
40	169 ± 11	1074 ± 70	9.63 ± 2.41
50	197 ± 7	909 ± 38	8.08 ± 2.02
60	202 ± 22	943 ± 90	9.21 ± 2.31
70	185 ± 13	904 ± 92	9.69 ± 2.43
80	248 ± 19	914 ± 60	11.83 ± 4.71
90	191 ± 12	994 ± 82	6.19 ± 1.54
100	180 ± 22	754 ± 65	12.97 ± 3.18
110	269 ± 25	922 ± 139	11.03 ± 2.76
120	211 ± 20	933 ± 68	11.61 ± 3.40
130	140 ± 18	807 ± 57	7.79 ± 1.94
140	165 ± 13	949 ± 65	8.34 ± 2.08
150	221 ± 16	827 ± 67	13.97 ± 3.51
160	167 ± 17	848 ± 71	11.26 ± 3.90
170	214 ± 14	872 ± 58	12.52 ± 3.89
180	183 ± 14	839 ± 54	12.24 ± 3.07
190	143 ± 18	815 ± 33	9.99 ± 3.48
200	172 ± 19	807 ± 51	12.81 ± 3.94
210	186 ± 13	956 ± 66	10.31 ± 2.59
220	160 ± 17	959 ± 103	9.32 ± 2.34
230	199 ± 16	1008 ± 68	11.59 ± 2.59
240	201 ± 21	922 ± 58	13.84 ± 3.46
250	176 ± 20	903 ± 80	11.93 ± 4.72
260	210 ± 11	965 ± 89	7.21 ± 1.81
270	225 ± 22	1003 ± 36	8.83 ± 1.52
280	197 ± 20	1002 ± 65	8.07 ± 2.05
290	192 ± 28	1005 ± 120	9.75 ± 3.46
300	198 ± 23	991 ± 129	13.59 ± 3.40
310	209 ± 15	1149 ± 89	12.62 ± 3.16
320	176 ± 17	1155 ± 106	11.09 ± 2.85
330	214 ± 16	1096 ± 71	13.76 ± 4.44
340	149 ± 24	987 ± 57	9.70 ± 3.47
350	174 ± 21	1066 ± 80	10.94 ± 2.74

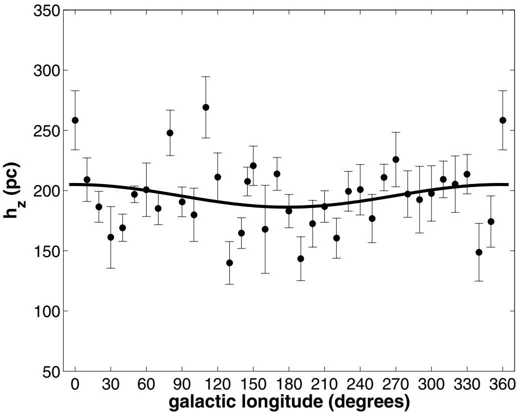

Fig. 3. Variation in the scaleheight of the thin disc with the Galactic longitude.

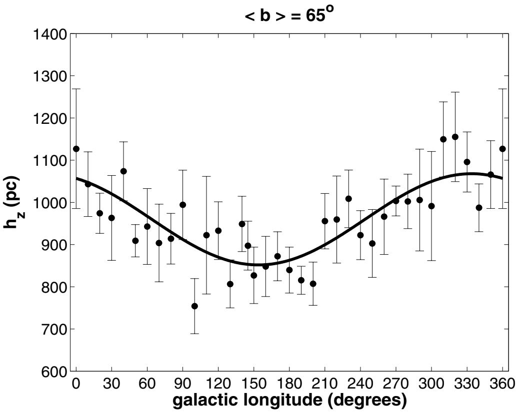

Fig. 4. Variation in the scaleheight of the thick disc with the Galactic longitude.

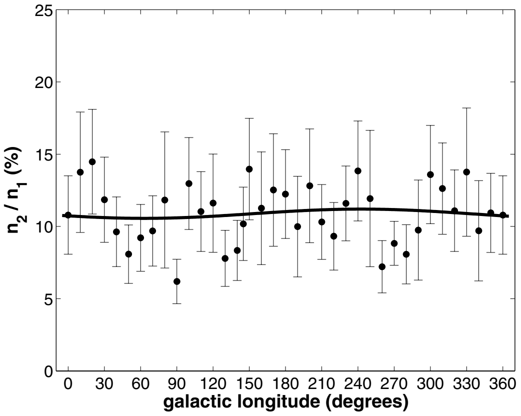

Fig. 5. Variation in the relative space density of the thick disc with the Galactic longitude.

For the thick disc the variation in the scaleheight with the Galactic longitude is more pronounced (Fig. 4). There is a maximum in the inner Galaxy ($|l| < 30°$), whereas there is a local minimum in between $150° < l < 230°$. The mean of the scaleheight for the data, $\langle h_z \rangle = 957$ ($\sigma = 100$) pc is well within the given range found in the literature (Spagna et al. 1996; Ng et al. 1997; Buser et al. 1998, 1999; Siegel et al. 2002; Larsen & Humphreys 2003; Cabrera-Lavers et al. 2005).

The variation in the local space density of the thick disc relative to the local space density of the thin disc (n_2/n_1) with the Galactic longitude is given in Fig. 5. The trend gives a constant local space density, $(n_2/n_1) \sim 10$ per cent, which confirms that the variation in h_z in Fig. 4 is not an artifact of an anticorrelation in the local normalization (assuming, for example, a constant value $(n_2/n_1) = 10\%$, we still get the result in Fig. 4).

We checked the effect of the Galactic latitude on the variation in the scaleheight of the thick disc with the Galactic longitude for the *2MASS* data. Figure 6 shows the variation in the scaleheight with the Galactic longitude for fields at $\langle b \rangle = 50°$. The trends in Figs. 4 and 6 are similar, although the zero points are different. The equations of the sinusoidal fits for the data in the fields with $\langle b \rangle = 50°$ and $\langle b \rangle = 65°$ are as follows:

$$h_z = 918 - 141.45 \sin (l - 84.65°), \qquad (\text{at } \langle b \rangle = 50°), \tag{2}$$

$$h_z = 959 - 108.02 \sin (l - 63.87°), \qquad (\text{at } \langle b \rangle = 65°). \tag{3}$$

The difference between the scaleheights is larger (it amounts to up to ~100 pc) for the longitudes corresponding to different minima in the two figures. No evident differences are found between the overall shape of the distributions; hence, the observed behaviour is associated to a global trend in the thick disc rather than to something exclusive of a restricted range of latitudes.

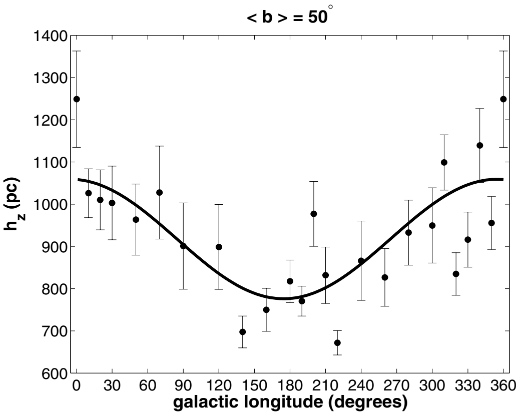

Fig. 6. Variation in the scaleheight of the thick disc with the Galactic longitude, for fields with Galactic latitude $\langle b \rangle = 50°$.

4. Discussion

4.1. Does the flare affect the scaleheight?

It is well known that the Galactic disc shows a flare, which produces an increase in the scaleheight as we move outwards in the Galaxy. In López-Corredoira et al. (2002b), the flare was modelled by an exponential increase in h_z with R, obtaining a law that approximately reproduced the observed counts up to $R < 15$ kpc. On the contrary, a flare with the opposite trend (an increase in h_z as R decreases) was found for the inner Galaxy by López-Corredoira et al. (2004), who then proposed an expression that summarises both regimes with a smooth transition between them:

$$h_z(R) = h_z(R_\odot) \times \left[1 + 0.21(R - R_\odot) + 0.056(R - R_\odot)^2\right]. \quad (4)$$

The variation in the scaleheight of the thin and thick disc with Galactic longitude could be related with the flare itself. When the line of sight is pointing to the inner Galaxy ($|l| < 30°$), the mean Galactocentric distance of the sources is lower than when the line of sight is in the anticentre direction. We can then translate the h_z vs. longitude plot in a h_z vs. R plot by deriving the mean Galactocentric distance to either the thin or thick disc sources, a procedure that is made by binning the data by the Galactocentric distance, R, and determining the mean radii of the red clump stars in each bin to average them. Figure 7 shows the variation in the scaleheight of the thin and thick discs with Galactocentric distance. It has to be noted that the range of Galactocentric distances is very narrow, so a possible derivation of parameters for the flare is far from conclusive. We compared the López-Corredoira et al. law in both cases considering $h_z\ (R_\odot) = 200$ pc and $h_z\ (R_\odot) = 900$ pc for the thin and thick discs, respectively. While the predictions for the thin disc are compatible with the data (although a constant value of h_z can also fit the data), the observed trend for the thick disc is just the opposite with an increase in h_z when moving to lower values of R (represented by means of a linear fit on the lower panel of Fig. 7), a result that complete disagrees with the one obtained for the outer thin disc ($R > 6$ kpc) in López-Corredoira et al. (2002b).

To obtain a more accurate representation of the flare in the thick disc, it would be necessary to increase the range of Galactocentric distances. For this reason, *2MASS* data at $\langle b \rangle = 50°$ are useful. They correspond to lines of sight at lower heights above the plane, thus the mean Galactocentric distance of the thick disc sources increases, improving the fit. In Fig. 8 we show the variation in the scaleheight of the thick disc with respect to the mean Galactocentric distance, combining the results at $\langle b \rangle = 50°$ with those at $\langle b \rangle = 65°$. By means of a linear fit to the data we obtain the following expression:

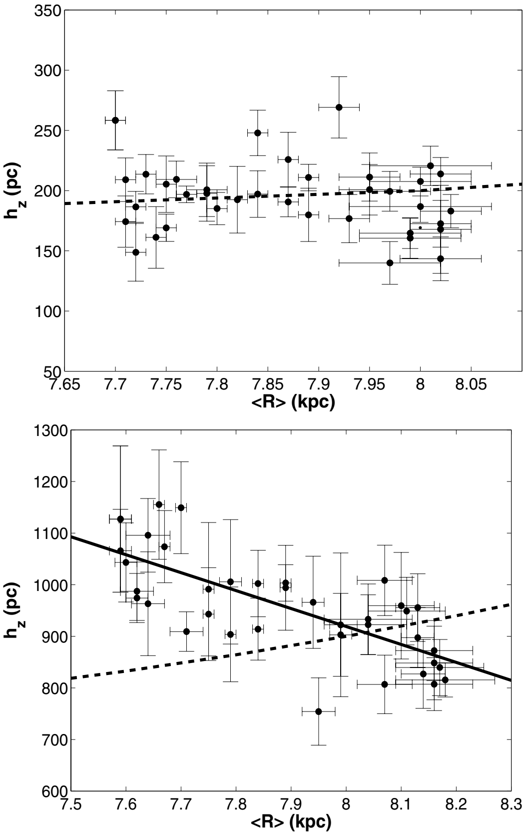

Fig. 7. Variation in the scaleheight of the thin (above) and thick (below) discs with R.

$$h_z(R) = (940 \pm 20) \times [1 - (0.12 \pm 0.02)(R - R_\odot)] \quad \text{(pc)}. \quad (5)$$

It is not very common to observe an increase in the scaleheight as we move to the inner Galaxy. Furthermore, no similar analysis of a possible flare in the thick disc is found in the literature. In a very recent article, Momany et al. (2006) analysed the warp and flare of the disc of the Milky Way but only concentrated on those related to the thin disc. By using red giant branch stars in the range $0.45 < z < 2.25$ kpc, they obtained a slight increase in the scaleheight of the disc with increasing Galactocentric radii, up to $R \sim 15$ kpc (their Fig. 15). They claim that the overall mean scaleheight around 0.65 kpc they obtained was a reflection of a mixture of the thin and thick disc populations. If we put together the known trend in the scaleheight of the thin disc (that is, an increasing h_z as R increases) with the result obtained in this paper for the thick disc (an increase in h_z as R decreases), one must expect that a sort of "cancellation" appears, producing a nearly constant h_z at intermediate heights above the plane.

To check this possibility, we did a simple simulation for a combination of a thin disc with the density laws of López-Corredoira et al. (2004) and a thick disc with an increase in h_z represented by Eq. (5) and a relative space density of 10 per cent respect to the thin disc according to Cabrera-Lavers et al. (2005). The resulting densities are fitted by a single exponential law (as if only one component were present), obtaining in that way the expected variation in scaleheight with the Galactocentric distance.

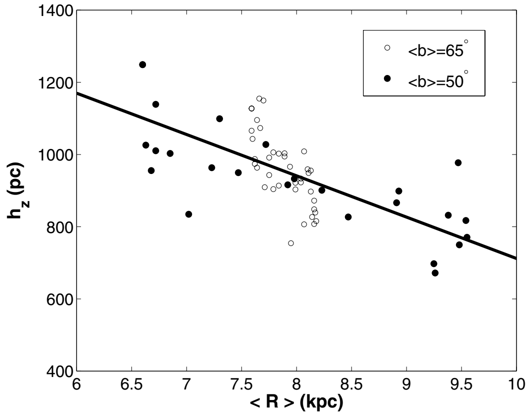

Fig. 8. Variation in the scaleheight of the thick disc with R by using *2MASS* data at $\langle b\rangle = 50°$ and $\langle b\rangle = 65°$. The best linear fit to the observed trend is also shown.

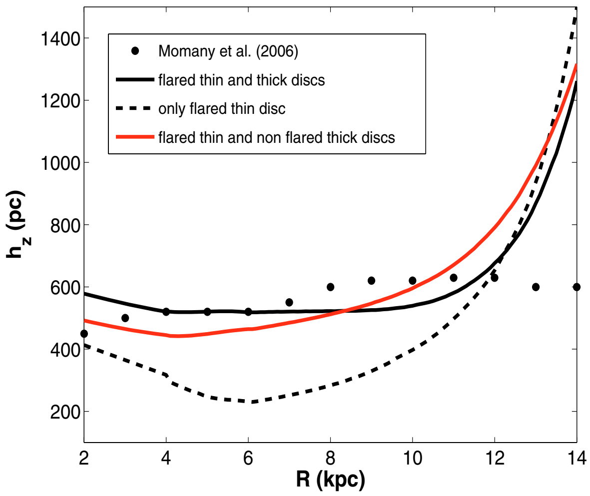

Fig. 9. Variation in the scaleheight with R taken from the work of Momany et al. (2006) compared with the simulations of different possible combinations of thin and thick disc densities, following the results of López-Corredoira et al. (2004) (for the thin disc) and this paper (for the thick disc).

When comparing this simulation with the data taken from Momany et al. (2006, Fig. 9), good agreement is observed. In the range of distances $4 < R < 9$ kpc, a nearly constant scaleheight is expected that is not far from what is observed. Note that we did not perform any kind of fit to the Momany et al. data, so the coincidence in the value for h_z at $4 < R < 7$ kpc is very interesting. Predicted values for $R > 10$ kpc are higher than these, but it was expected due to the excessively high increase in h_z for the thin disc that the López-Corredoira et al. model produces in this range of Galactocentric distances. A more modest increase in h_z with R for the thin disc (as obtained in Alves et al. 2000 or in Momany et al. 2006) would produce better agreement with the data, but this was beyond the scope of this comparison. For $R < 4$ kpc, an excessive increase in h_z is again obtained in the simulation, but again it was known that the validity of the López-Corredoira et al. model for $R < 2.5$ kpc is not clearly demonstrated.

We also introduced some changes into the simulation. By eliminating the contribution of the thick disc (that is, assuming that only the thin disc is observed), we recovered the predictions of the López-Corredoira et al. model, with the scaleheight corresponding to the thin disc (Fig. 9). It is even more remarkable how, when a flaring in the thick disc is neglected (assuming a constant scaleheight of 940 pc for this component), the trend still follows the increase in the scaleheight due the thin disc, but with higher h_z values as corresponds with the mixing of both populations. The result is also less sensitive to other parameters, as the relative space density of the thick disc (no changes were obtained by varying it from 5 to 15 per cent) or the value of $R_\odot$ (assumed as 8 kpc).

A combination of a flared thin disc and a flared thick disc with opposite trends seems, then, to be compatible with the observed scaleheights at intermediate heights above the plane, such as those of Momany et al. (2006). Thus, the observed variation in the scaleheight of the thick disc with the galactic longitude has been obtained here as expected.

4.2. Effect of the scalelength of the thick disc

In Sect. 2.1 we addressed what we considered a fixed scalelength of 3 kpc for the thick disc, as obtained in Cabrera-Lavers et al. (2005). However, a different scalelength would reproduce the observed variation in the scaleheight without the need for a flare in the disc itself. For example, a shorter scalelength of 2 kpc for the thick disc would increase the predicted star counts in the inner disc and reduce them in the outer disc, relative to the assumed 3 kpc scalelength, simulating a higher scaleheight in the inner disc and a lower scaleheight in the outer disc, as was found in Sect. 4.

However, the effect of the scalelength on the derived densities is negligible, as we are moving in a very narrow range of Galactocentric distances. To reproduce the same density as results from a scalelength of 3 kpc and a scaleheight of 1100 pc, like those derived in the inner Galaxy but with a constant scaleheight of 800 pc, the scalelength has to change by a factor ∼1.4 with respect to the assumed value of 3 kpc (that is, around 4.2 kpc), a value that is 11σ above what is derived in Cabrera-Lavers et al. (2005).

In order to check this statement, we repeated the analysis of Sect. 2 in a series of nine test fields but assuming two different scalelengths for the thick disc: $H = 2$ kpc and $H = 2.5$ kpc. The results are shown in Fig. 10, together with sinusoidal fits to the data. The observed trend is nearly coincident with that of Fig. 4 in both amplitude and the positions of the minima. Hence, the effect of a different scalelength from the assumed one of 3 kpc has to be discarded as responsible for the results discussed in this paper.

5. Conclusion

By using NIR data from *2MASS* we have observed significant changes in the structural parameters of the thin and thick discs of the Milky Way, which are more than simple fluctuations caused by model fitting to the data.

A plausible explanation for the observed changes in the scaleheight of the discs arises from the combined effect of the warp and flare in the Galactic thin and thick discs, which displaces both structures from the assumed position expected for a "smooth disc" (that is, a flat, azimuthally homogeneus and constant scaleheight disc). This implies that the effect is more noticeable in some directions than in others, producing variations in the parameters resulting from a fit of a single Galactic model. The observed trend in the change of the scaleheight with galactic longitude is reproducible theoretically by assuming the

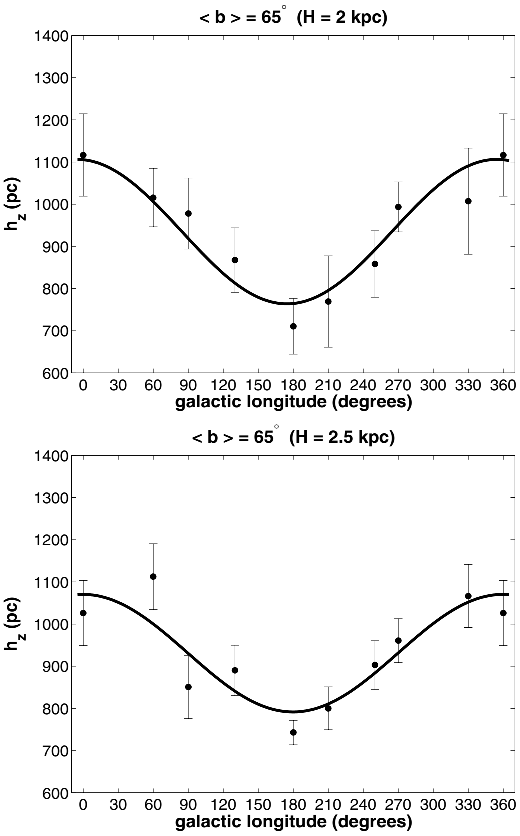

Fig. 10. Variation in the scaleheight of the thick disc with the Galactic longitude obtained by assuming a scalelength of $H = 2$ kpc (above) or $H = 2.5$ kpc for this component (below).

accretion of intergalactic matter onto the Galactic disc, which in general produces a different pressure depending on both the Galactocentric radius and azimuth, the same pressure as would also be responsible for the formation of S-warps and/or U-warps in galaxies (López-Corredoira et al. 2002a). The pressure would be similar to a piston mechanism only from one side of the disc (Sánchez-Salcedo 2006, Sect. 4.6). As a result of this mechanism, the scaleheight of the disc would present a similar shape to that obtained in Fig. 4. However, it is hardly our intention to consider that our result is a demonstration that this speculative hypothesis is the correct one for explaining the uncertain origin for the Milky Way's flare and warp; but it is consistent with the observed data.

The flare obtained in the thick disc from *2MASS* data has an opposite trend to that commonly assumed for the thin disc, with a scaleheight that increases as we move to the innermost Galaxy, being the first time that a possible flare in this Galactic component is observed. It is beyond the scope of this paper to determine a theoretical scenario from the observed results that supports the origin of this possible flare, although some asymmetries in the thick disc have been known for some time now (Parker et al. 2003). We suspect that the different behaviour in the inner Galaxy is related to the interaction of the 4 kpc inner-Galactic bar (López-Corredoira et al. 2007) with its surroundings. However, it is more difficult to explain the possible effect of this component on the thick disc, although some known asymmetries of this component have been suggested as caused by the Galactic bar (Parker et al. 2004). Unfortunately, we do not have enough information to add anything in this regard. Probably, kinematic analyses using radial velocity data like those provided by the *Sloan Extension for Galactic Understanding and Exploration* (SEGUE, Newberg et al. 2003) or the *Radial Velocity Experiment* (RAVE, Steinmetz et al. 2006) will be very valuable for going deeper into this topic.

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