Simulating the sky for GAIA: discussing the Galactic absorption model

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1 Introduction

An important part of the preparation to the GAIA mission is devoted to the simulation of the colour-magnitude diagrams of the Galaxy for any given line-of sight (l,b) to be used to test GAIA performances. In order to properly simulate the Galaxy, a key issue is represented by the absorption model, in particular at low Galactic latitudes. The intrinsic uncertainties in the Galaxy star count prediction due to interstellar extinction can be as large as 26% (Chen et al 1999), far from being marginal. Several models of Galactic absorption are presented in literature. Mendez & van Altena (1998) make use of the large-scale properties of the dust layer in the Galaxy to derive the absorption in the plane of the Galaxy. They claim that it is possible to predict star-counts with a mean accuracy of 15% or better for $|b| < 10$ degrees. The authors suggest that a differential optical absorption of 0.5 mag/kpc is adequate to reproduce the available reddening maps in the distance range $2 \leq r \leq 6$ kpc. The internal uncertainties declared by the authors are of the order of E(B-V)=0.25.

Schlegel et al (1998) using the DIRBE 100 and 240 μm data construct maps of the dust temperature: the 100 μm map may be converted to a map proportional to dust column density and finally to the reddening. In high-latitude regions, the dust map well correlates with maps of H I emission, but deviations are coherent in the sky and are especially conspicuous in regions of saturation of H I emission toward denser clouds and of formation of H2 in molecular clouds. These maps are expected to be not extremely accurate at $|b| < 5$ degrees.

Recently Drimmel & Spergel (2001) present a tridimensional model of the dust distribution based on COBE-DIRBE infrared data. Rescaling factors are included by Drimmel (2002) based on FIR data. At high Galactic latitude the rescaling factors are calculated from the Schlegel et al (1998) maps. This model is meant to be used to derive the absorption along the line of sight even near and in the Galactic plane, since it accounts for the presence of the spiral arm structure. As stated by Drimmel (2002), regions having anomalous emission due to warm dust are not well described by the model, especially the Orion region and the Galactic center at $|l| < 3$ degrees.

In this paper we compare the various models of absorption in three groups of directions, namely at high galactic latitude, in the direction of the Carina arm and towards the Galactic center.

2 The data

We independently derive the absorption along the line of sight from the colour-magnitude diagrams of 15 directions (see Table 1 where the data are presented)following a method described in Bertelli et al (1995), Vallenari et al (2000). Bertelli et al. (1995) proved that the slope of the main sequence in the CMD of the disk population is mainly governed by the extinction along the line of sight. At each magnitude V the bluest stars on the main sequence can be interpreted as the envelope of the main sequence turnoffs of the population having absolute magnitude M_{tur}, shifted towards fainter magnitudes and redder colours by the increasing distance and corresponding extinction. Starting from an initial guess, the amount of extinction at increasing distances is adjusted until a satisfactory agreement between the main sequence blue edge location in the data and in the theoretical simulations is reached. The comparison between data and simulations is made using a χ^2 test. We point out that these determinations of extinction are weakly dependent on the adopted age and metallicity range of the population. To estimate the uncertainty due to the combined effect of different age and metallicity distributions, we derive the extinction separately for all the components. The determination of the extinction along the line of sight A_V turns out to be different from the adopted values at maximum of 0.2 mag, which can be assumed as internal error on our extinction determinations (Vallenari et al 2000).

3 Discussion

Fig.1 present the simulations in the direction of the center. Fig.2 is the analogous for the Carina arm, Fig.3 refers to the extinction at low b, and finally Fig.4 gives the simulation at intermediate Galactic latitude. In the direction of the center, we derive the extinction from large field of view using unpublished ESO 2.2m WFI data. The reddening is found to be almost always highly variable from 0.5 to 1.5 mag inside the fields. Drimmel model reproduces reasonably well the observed reddening, at least when $|b| > 1$ degrees, when rescaling factors are not used. Rescaling factors result in a definitely too large absorption. In fact Drimmel (2002) recommends to not make use of rescaling factors, at least at $|l| < 3$ degrees, but from our simulations possibly at larger $|l|$. Mendez & van Altena model does not completely cover the inner region of the Galaxy. At the observed directions, it predicts an extremely low reddening.

In the direction of the Carina arm, we derive the extinction along the line of sight in 5 fields. As independent check of our determinations we plot as well the estimate obtained independently by Carraro & Patat (2001) and Patat & Carraro (2001) from the study of the clusters located along the line of sight in the proposed directions. The expected reddening from Drimmel model is too high of 4-5 magnitudes in comparison with the data, regardless whether rescaling factors are included or not (Fig.2). Immediately outside the spiral arm (direction of NGC 3411) at $|b| > 3$ degrees, the agreement is quite good. We cannot however exclude that the apparent disagreement is due to small scale fluctuations, since the size of the observed fields is quite small and the fields themselves are choosen to be inside low reddening regions. Mendez & van Altena model gives a more convincing agreement. Schlegel maps produce contradicting results.

At low galactic latitude (Fig.3) outside the spiral arm, or inside it , but at $|b| > 1$ degrees observations and models (both Mendez & van Altena, Drimmel, and Schlegel maps) agree inside 1 magnitude.

At intermediate latitude, we simulate a field of 3.5×3.5 degrees from GSPC2 catalog, deriving a good agreement (inside 0.5 mag) between the observations and the data.

4 Uncertainties on simulations of Galactic Fields for GAIA

In Fig.6 we reproduce the expected distribution of stars in the direction of the Galactic center at varying extinction for V< 20 mag. Decreasing the reddening of 1 mag. increases the number of objects of about 60%. Table 2 translates the expected density of stars at varying reddening into spectral crowding following Katz (2002) using the baseline design when magnitudes brighter than V=17-18 are considered.

In the studied region, due to the high extinction of A_V =7.5 mag, stars can be observed even at high dispersion. Intermediate/low dispersion might be necessary only if A_V is 3 magnitudes lower than expected. We point out, however that in the observed region, due to the high reddening only stars at a distance of about 3-4 Kpc can be observed, depending on the limiting magnitude.

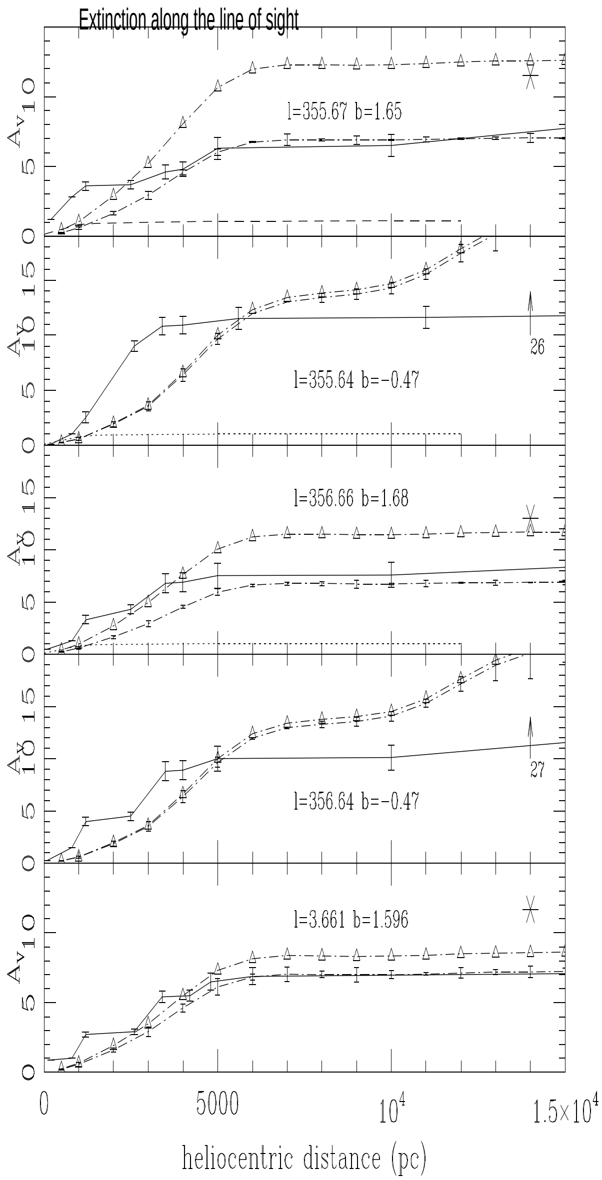

Figure 1: Extinction along the line of sight towards the Galactic center. Our determination is the mean value in a field of 0.5x0.5 degrees. The error bars indicate variable reddening inside the field. Solid line is our determination, dotted line represents Mendez & van Altena model, dotted-dashed line is Drimmel model without rescaling factors,triangles are the analogous with rescaling factors. The star (or the arrow) gives the value from Schlegel et al (1998) maps.

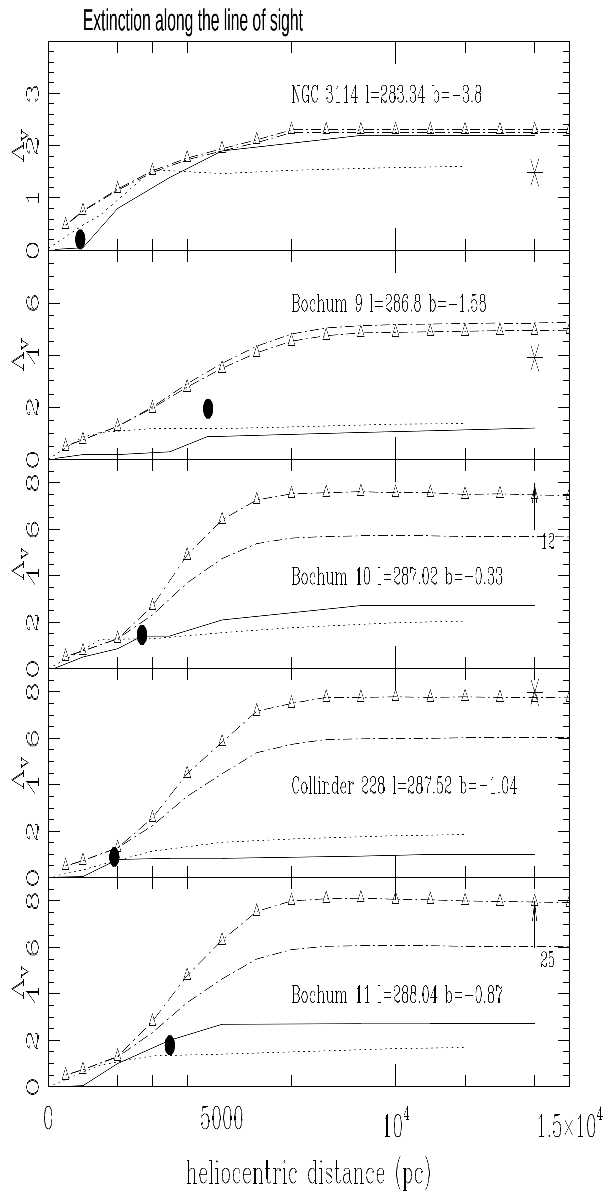

Figure 2: Extinction along the line of sight towards the Carina arm. Solid line is our determination, dotted line represents Mendez & van Altena model, dotted-dashed line is Drimmel model without rescaling factors, triangles are the analogous with rescaling factors . The star (or the arrow) gives the value from Schlegel et al (1998) maps. The solid dot is the extinction derived from Carraro & Patat and Patat & Carraro

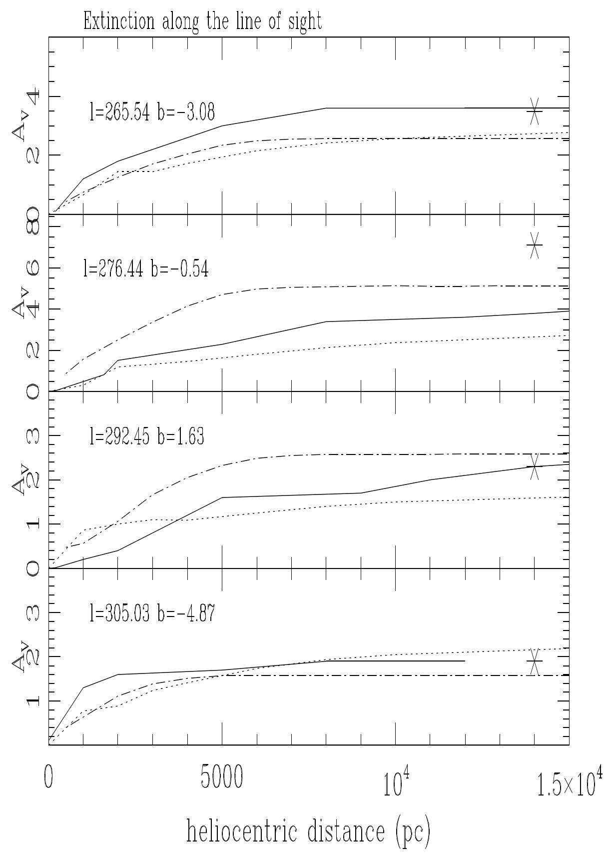

Figure 3: Extinction along the line of sight on the Galactic plane. Solid line is our determination, dotted line represents Mendez & van Altena model, dotted-dashed line is Drimmel model. The star (or the arrow) gives the value from Schlegel et al (1998) maps

Table 1: General information on the fields: central coordinates, dimension of the selected part of the field, total number of stars therein, and references. V2000 stays for Vallenari et al (2000), CP2001 is Carraro & Patat (2001), PC2001 indicates Patat& Carraro (2001).

	l	b	$size$	N_{stars}	References
			Galactic Center Fields		
Field 1	355.67	1.65	$16' \times 24'$	64431	
Field 2	355.64	-0.47	$16' \times 24'$	12000	
Field 3	356.66	1.68	$16' \times 24'$	23100	
Field 4	356.64	-0.47	$16' \times 24'$	18300	
Field 5	3.66	1.59	$16' \times 24'$	21000	
			Carina fields		
NGC 3114	283	-3.8	$3'.3 \times 6'.5$	2060	CP2001
Bochum 9	286.80	-1.58	$9'.6 \times 9'.6$	4312	PC2001
Bochum 10	287.02	-0.33	$9'.6 \times 9'.6$	600	PC2001
Bochum 11	288.04	-0.87	$9'.6 \times 9'.6$	786	PC2001
Collinder 228	287.52	-1.04	$3'.3 \times 6'.5$	1100	CP2001
			Galactic Plane Fields		
Field 6	265.545	-3.089	$6'.4 \times 9'.6$	2787	V2000
Field 7	276.448	-0.546	$12'.0 \times 12'.0$	6580	V2000
Field 8	292.468	1.638	$9'.6 \times 9'.6$	12153	V2000
Field 9	305.029	-4.876	$9'.6 \times 9'.6$	9380	V2000
			Intermediate Latitude Field		
Field 10	123.00	27.00	$210' \times 210'$	11741	GSPC2

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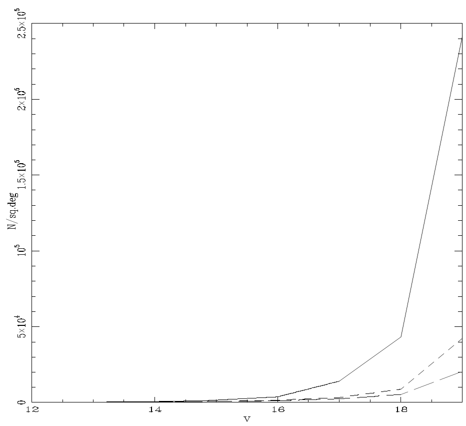

Figure 4: Number of stars per sq degree at (l,b)=(356.6,1.68) at varying reddening for V< 20 mag. Solid line is low reddening A_V=4.5 at d=5 Kpc from us, short-dashed is A_V=6.5 at d=5 Kpc and long-dashed is A_V=7.5 at d=5 Kpc.

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Table 2: Expected crowding of the spectra as a function of the extinction

A_V	Number of stars/sq deg	Crowding factors		
		R=5000	10000	20000
	V< 17			
4.5	1.032e+04	0.98	1.90	3.80
6.5	4061	0.42	0.83	1.65
7.5	3267	0.30	0.71	1.45
	V< 18			
4.5	3.358e+04	3.70	7.38	14.77
6.5	9212	0.95	1.88	3.75
7.5	6609	0.67	1.33	2.66