Baltic Astronomy, vol. 8, 195–202, 1999.

THE SPATIAL RESOLUTION OF THE EXTINCTION STRUCTURE FROM GAIA

B. Chen[1], J.-L. Vergely[2], D. Egret[2], J. Torra[1,3], F. Figueras[1] and C. Jordi[1]

[1] *Departament d'Astronomia i Meteorologia, Universitat de Barcelona, Avda. Diagonal 647, E-08028 Barcelona, Spain*

[2] *CDS, Observatoire de Strasbourg, 11 rue de l'Université, F-67000 Strasbourg, France*

[3] *Institut de Estudis Espacials de Catalunya, Edifici Nexus 104, Gran Capità 2-4, E-08034 Barcelona, Spain*

Received January 25, 1999.

Abstract. The distribution of the interstellar medium is filamentary and patchy, making difficult to obtain the global parameters describing the various components of our Galaxy. By model-model comparison, we found that the intrinsic uncertainty in Galaxy model simulation due to interstellar extinction can be as large as 25 % in star count and 0.2–0.4 mag in $B-V$ color. *Gaia* will make possible to map the extinction structure not only at larger distance but also in unprecedented details. From Galaxy model simulations we compare the spatial resolution of the extinction structure in a radius of 250 pc around the Sun, as detected by *Hipparcos* and *Gaia*. The spatial resolution of the extinction structure detected by *Gaia* as a function of the heliocentric distance is also given.

Key words: ISM: extinction, modeling, cloudy structure – orbital observatories: Gaia

1. INTRODUCTION

Stellar population studies need a good knowledge of the 3-dimensional distribution of galactic extinction. Maps of the interstellar medium column density across the sky, made using emission in the H I line or emission from dust in the diffuse medium (Schlegel et al. 1998), show that the distribution is fairly patchy. On the other hand, our knowledge about the distribution of interstellar extinction is mainly based on observations in the solar neighborhood. For these reasons, some structure and kinematic parameters of our Galaxy are still ambiguous at some level. For example, the discrepant result about the disk density scale length has been found from 2.5 kpc (Robin et al. 1992) to 6.0 kpc (Méndez & van Altena 1998).

Gaia will not only measure 3-dimensional extinction distribution at large distances but also will give much better resolution of the extinction structure than the resolution obtained from *Hipparcos* observations in the solar neighborhood. In Section 2, we compare three existing extinction models in two low extinction regions and show that a new extinction model, which can represent extinction at smaller scales, is needed from *Gaia*. In Section 3, we discuss the spatial resolution of the extinction structure which will be detected by *Gaia*.

2. THREE-DIMENSIONAL EXTINCTION DISTRIBUTION

2.1. *Differences among the extinction models*

The interstellar extinction $A_V(r, l, b)$ as a function of distance, and galactic direction has been discussed by several authors. Arenou et al. (1992) constructed an extinction model from the Hipparcos Input Catalogue, in which the sky was divided into 199 cells. This extinction model works reasonably not farther than 1–2 kpc from the Sun. Another extinction model has been built by Hakkila et al. (1997), who combined previous investigations on extinction distribution and made a statistical correction for distances at which the studies do not provide data. Recently, assuming that the large-scale volume density of the absorbing material follows a decaying exponential away from the galactic plane, Chen et al. (1998) show that a better extinction model can be constructed from the *Cobe/Iras* all sky reddening map (Schlegel et al. 1998).

In Fig. 1 we show the extinction distributions from the three extinction models in two low extinction regions SpA23 (179°, +2.5°) and Baade's Window (1°, -4°). We can see that in Baade's Window all three models provide similar values for the extinction distribution. However, in the SpA23 field both Hakkila et al. (1997) and Arenou et al. (1992) models cannot predict the low extinction value due

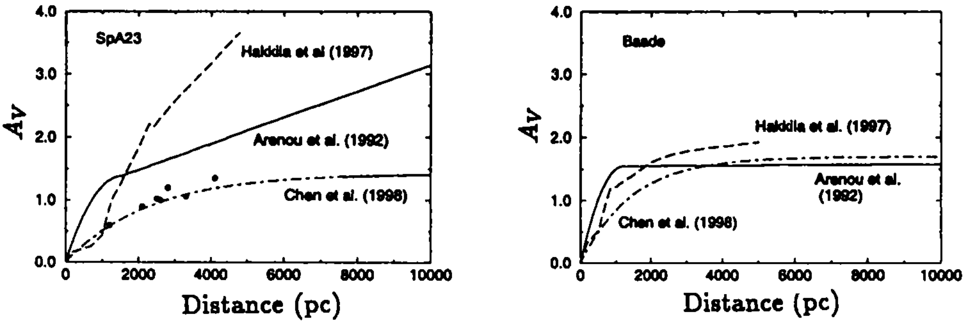

Fig. 1. The extinction in the line of sight in two low extinction fields. The solid circles in the SpA23 field are the observed values derived by Robin et al. (1992).

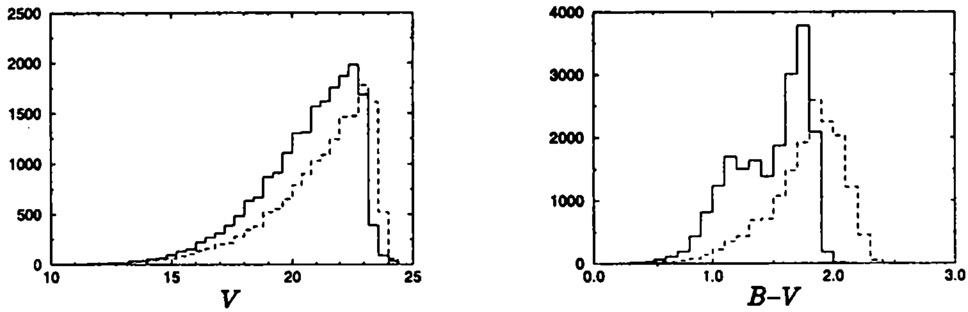

Fig. 2. Model simulations from Chen et al. (1998) extinction model (solid lines) against that from Hakkila et al. (1997) extinction model (dashed lines) for V and $B-V$. The simulated catalogues are generated in a field of 30×30 arcmin^2 in the galactic direction SpA23 (179°, +2.5°).

to much lower angular resolution in their models. The difference in visual extinction between Chen et al. (1998) and Hakkila et al. (1997) is 2.5 mag at a distance of 5 kpc.

2.2. Uncertainty in the star count simulation

Galactic structure studies involve the analysis of star count observations and their comparison with Galaxy model simulations. The simulated catalogues obtained from a Galaxy model should be able to reproduce the real observations as precisely as possible. However, the intrinsic uncertainty due to interstellar extinction can be significant (Torra et al. 1999). As an example, we use our Galaxy model to simulate the *Gaia* observations in a field of 30×30 arcmin^2 in the direction SpA23 (179°, +2.5°). Two simulated catalogues have been generated. The only difference between these two catalogues is the extinction distribution: one is from Hakkila et al. (1997) and the other is from Chen et al. (1998). The "observed" variables (V and $B-V$) in the two simulated catalogues are compared in Fig. 2. Because extinction predicted by Hakkila et al. (1997) model is larger (see Fig. 1) in this direction, the simulated $B-V$ colors with the Hakkila et al. extinction model are shifted toward the red side. We find that the difference is 25 % in star count and 0.2–0.4 mag in $B-V$ color in this field down to $V = 21$ mag.

Gaia will measure trigonometric parallaxes to faint stars. In Fig. 3, we show the histogram of simulated stellar distances in a field of 30×30 arcmin^2 in the direction SpA23 (179°,+2.5°) with the limiting magnitude $V = 21$ mag. The Chen et al. (1998) extinction model is used. We see that *Gaia* will provide stellar distances even for stars several kpc far from the Sun and, as a consequence, a high accuracy of extinction measurement as a function of distance can be achieved.

3. THE SPATIAL RESOLUTION OF THE EXTINCTION STRUCTURE FROM GAIA

Dark clouds of the Galaxy are not uniformly distributed in space. They are fragmented in structures which follow a specific scale law. From the extinction calibration of the *Gaia* multicolor photometry, the parallax estimation of individual star and the star density, it is possible to specify the minimum size of the clouds that could be detected. The structures smaller than this minimum size will be smoothed. Three factors play an important role in the resolution determination:

- the error of color excess estimation from the photometry calibration;
- the distance error;
- the star density.

These factors depend on the distance of the studied area. Thus, the resolution decreases as the heliocentric distance increases. In

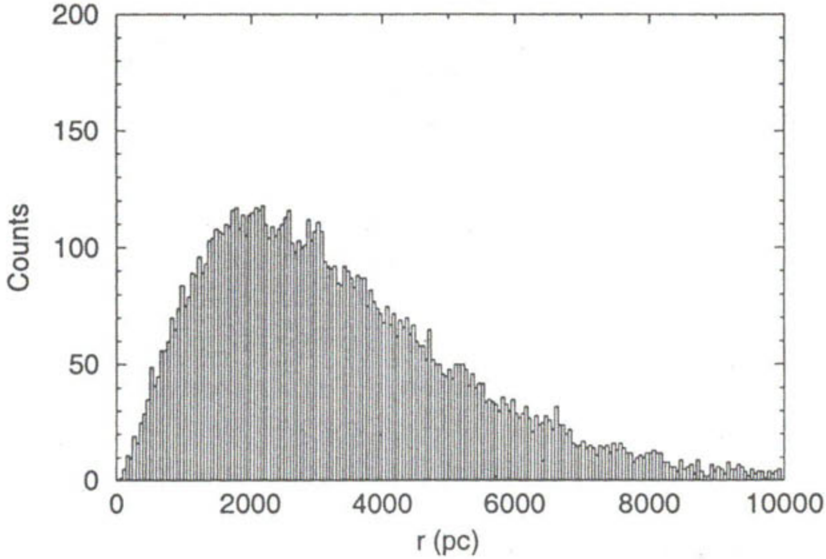

Fig. 3. The histogram of simulated stellar distances in a field of 30×30 arcmin^2 in the direction SpA23 (179°, +2.5°) for the limiting magnitude $V = 21$. The Chen et al. (1998) extinction model is used.

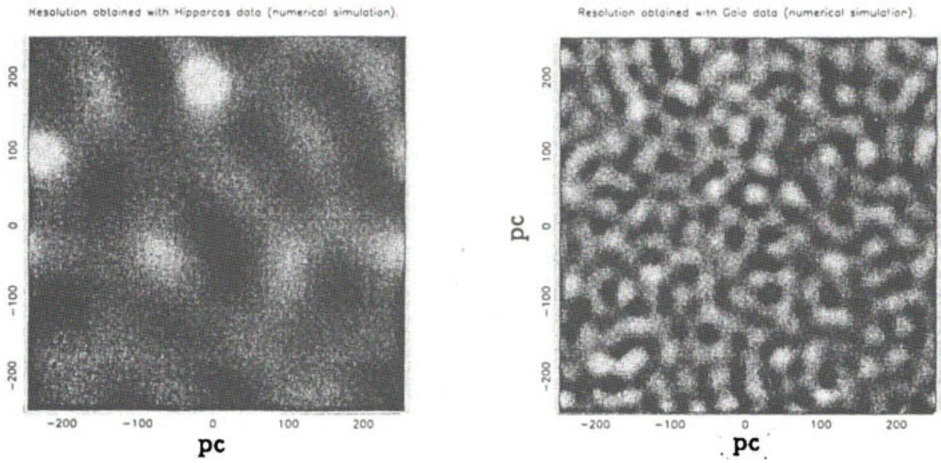

Fig. 4. The spatial resolution of the extinction structure from *Hipparcos* (left) and *Gaia* (right).

order to compute the star density at different distances, simulated catalogues have been created from our Galaxy model software according to the *Hipparcos* and *Gaia* observational criteria ($V \approx 21$ mag). Because the extinction calibration is not available for all types of stars from *Gaia*, we assume that 25 % of all "observed" stars have good extinction calibration. This value has been used to derive the mean distance between two stars and the spatial resolution of the extinction structure.

In Fig. 4, we show the spatial resolution on the extinction structures in a radius of 250 pc around the Sun as detected by *Hipparcos* and *Gaia*, respectively. These maps are obtained from Fourier analysis with a power spectrum cut off corresponding to the resolution (Vergely 1998). The resolution of extinction structures is 2–10 pc for *Gaia* and 20–40 pc for *Hipparcos*. The high accuracy measurement of the interstellar extinction by *Gaia* allows us to detect small molecular clouds and understand the nature and origin of these clouds. In Table 1, we show the spatial resolution of the extinction structure detected by *Gaia* as a function of the heliocentric distance in two directions: (ℓ,b) = (92°, -2.5°) and (ℓ,b) = (166°, -23.5°). We find that the resolution detected by *Gaia* at 1500 pc will be the same as that by *Hipparcos* at 250 pc.

4. CONCLUSION

In this study we show that *Gaia* will improve our knowledge about galactic extinction in two aspects. First, because the individual distances can be derived for remote stars from *Gaia*, we can construct a 3-dimensional extinction model in the Galaxy. We have compared extinction distributions in two low extinction regions from the three existing extinction models. We can see that the difference is in a range of 1–2 mag at a distance of several kpc. This can lead a 25 % difference in star count and 0.2–0.4 mag in B–V according to *Gaia* observational criteria. A new extinction model from *Gaia* will help us to constrain the galactic structure parameters and to study distribution of the extragalactic structures.

The second aspect – high accuracy of interstellar extinction from *Gaia* will allow us to detect and investigate small molecular clouds. From Galaxy model simulation we show that the resolution of the extinction structure within a radius of 250 pc around the Sun is 2–10 pc (in a conservative estimation) for *Gaia* and 20–40 pc for *Hipparcos*.

The spatial resolution of the extinction structure detected by *Gaia* as a function of the heliocentric distance is given.

Table 1. Spatial resolution of the extinction fluctuations detected by *Gaia* as a function of the heliocentric distance in two directions: $(\ell,b) = (92°, -2.5°)$ and $(\ell,b) = (166°, -23.5°)$.

Distance interval in pc	Resolution in pc $(\ell,b)=(92°,-2.5°)$	Resolution in pc $(\ell,b)=(166°,-23.5°)$
0–500	5	6
500–1000	13	15
1000–1500	27	30
1500–2000	45	50
2000–2500	68	76
2500–3000	96	108
3000–3500	129	146
3500–4000	167	191
4000–4500	210	241
4500–5000	258	297
5000–5500	311	358
5500–6000	370	422

ACKNOWLEDGMENT. This work has been supported by CICYT under contract ESP97-1803.

REFERENCES

Arenou F., Grenon M., Gómez A. 1992, A&A, 258, 104
Chen B., Figueras F., Torra J., Jordi C., Luri X., Galadí-Enríquez D. 1998, A&A (submitted)
Hakkila J., Myers J.M., Stidham B.J., Hartmann D.H. 1997, AJ, 114, 2043
Méndez R.A., & van Altena W.F. 1998, A&A, 330, 910
Robin A.C., Crézé M., Mohan V. 1992, A&A, 253, 389
Schlegel D.J., Finkbeiner D.P., Davis M. 1998, ApJ, 500, 525
Torra J., Chen B., Figueras F., Jordi C., Luri X. 1999, Baltic Astronomy, 8, 171 (this volume)
Vergely J.L. 1998, PhD thesis, CDS, Observatoire de Strasbourg