J. Astron. Space Sci., Vol. 4, No. 2. 1987

Distribution of Interstellar Reddening Material in the Galactic Plane

Chulhee KIM
Department of Earth Science Education
Chonbuk National University
(Received November 21, 1987; Accepted December 19, 1987)

Abstract

By using the recently determined color excess and distance data of classical cepheids by Kim (1985), the distribution of interstellar reddening material was studied to see the general picture of the average rate of interstellar absorption out to about 7-8 kpc in the Galactic plane in various directions from the sun.

I. Introduction

To see how the reddening material is distributed along galactic longitude, more accurate color excess and distance data for many celestial objects are necessary. Not much interest has been given to this kind of project due to lack of reliable color excess data for many celestial objects. Recently extensive study had done by Lucke (1978) through the investigation of color excess distribution for OB stars. But his study was limitted to the space near the sun.

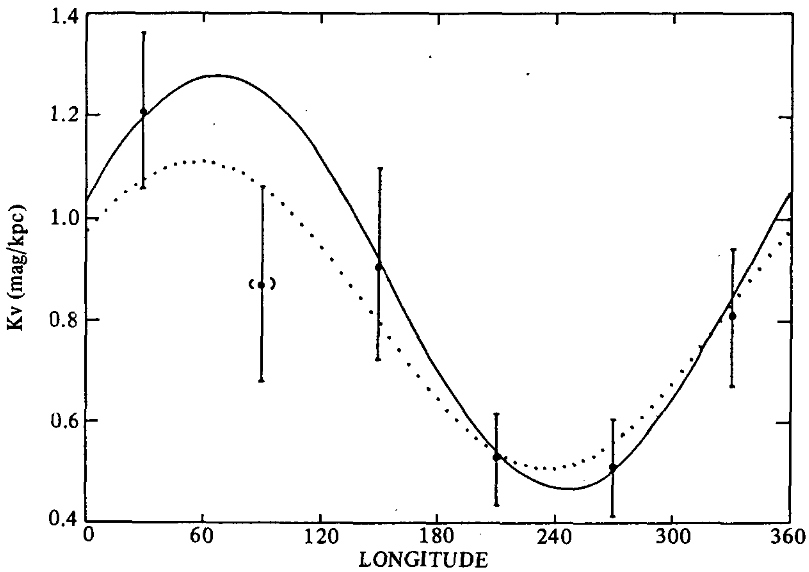
In this sense, classical cepheids are better candidate for the investigation of longer distance from the sun. Recently color excesses of 446 Cepheids have been taken from literature and transformed to a single homogeneous system by KIM(1984, hereafter Paper I). These new color excesses believed to be the most reliable values presently available and recently determined period-Luminosity (PL) relation (Stother, 1983) makes it possible to determine the distance of cepheids from the galactic center more accurately.

The main purpose of this paper is to obtain the general picture of the mean color excesses $\langle E(B-V) \rangle$ out to about 7-8 kpc in the Galactic plane in various directions from the sun by using those new color excess and distance data given by KIM (1985).

II. Discussion

In 1962, Fernie showed that the rate of interstellar absorption within 1 kpc of the sun is a roughly sinusoidal function of Galactic longitude on the basic of OB-star data. A tentative explanation of this result was proposed, in which the sun is supposed embedded in a segment of interstellar dust. This sinusoidal function was later confirmed (Fernie, 1968) with cepheid data. To examine this result in light of the new data, the cepheids in Table 1 of Paper I have been grouped in 60° intervals of Galactic longitude, and the average rate of interstellar absorption (Kv) in visual magnitude per kpc was determined for each group.

The results are shown in Fig. 1. The dotted curve and solid curve correspond to least-squares solutions for a sinusoidal function through all six points, and through the five points which exclude the point marked with parentheses. We note that the southern Milky Way is less heavily obscured by dust than the northern Milky Way and also that the least-squares fitting is good in the case where the second point is excluded. All five points connected with the solid curve are placed almost on the curve in spite of large probable errors noted by the bars. If it is true that Kv is expressed with a sinusoidal function, the value of Kv in the region of ℓ=60° - 120° is noticebly smaller by about 0.4 magnitude than predicted. This will be discussed in a more detailed way below.



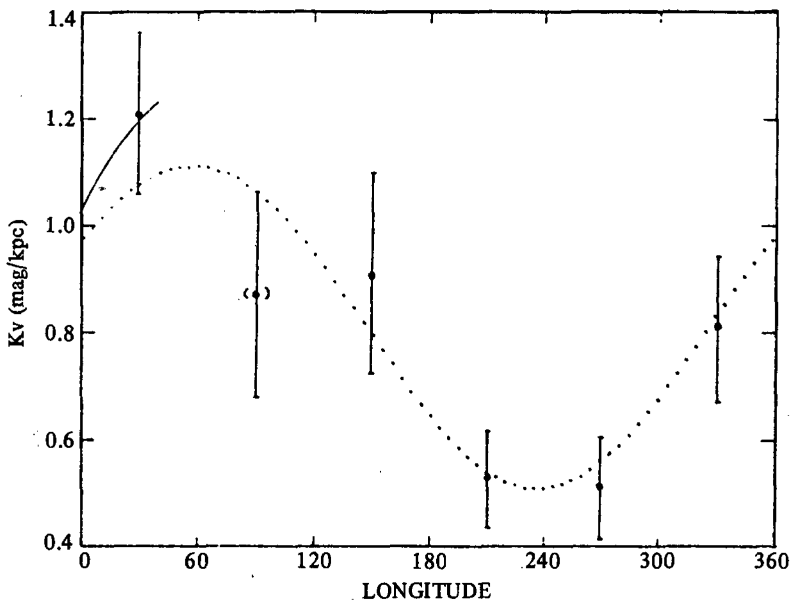


Fig. 1. The everage rate of interstellar absorption with distance as a function of galactic longitude.

An extensive study of the distribution of color excesses and interstellar absorption utilizing color excess data of 4000 OB stars to map the mean color excesses E(B-V) out to about 2 kpc from the sun in various directions has been carried out by Lucke (1978). Efremov, Ivanov, and Nikolov (1981, hereafter EIN) discussed the cepheid distribution in connection with the dust complexes studied by Lucke based on the assumption that the cepheids have been investigated uniformly with direction. Although it is impossible to neglect the influence of directional differences in the probability of discovering cepheids with different distances and periods, the assumption may not be too far from reality. We expect to see fewer cepheids behind the dense clouds of the interstellar matter. We also expect that the distribution of cepheids farther than 2 kpc from the sun is strongly influenced by heterogeneous absorption.

In Fig. 2. we plot the cepheid distribution on the projected Galactic plane (KIM, 1987) together with the dust complexes of Lucke out to 2 kpc and within 200 pc of the plane to-study the correlation between cepheid and dust complex distributions. This correlation holds well toward the constellation Puppis at $\ell=240^{\circ}$ which is by far the most transparent region along the Galactic equator (FitzGerald and Moffet, 1976). This region is characterized by a marked absence of clouds and the distance of cepheids in this direction reachs to nearly 8 kpc. Only a few cepheids can be seen in the direction toward $\ell=90^\circ$ where there are regions of extremely heavy absorption starting at a distance of about 300 pc which blocks out most of the stars behind it. A similar situation holds in the directions $\ell=55^\circ$ and $\ell=270^\circ$. In the direction $\ell=290^\circ$, a strip of cepheids, which appears to be located in the Carina arm, more than 8 kpc length is observed. This direction may be the most transparent along the Galactic equator based on the distribution of cepheids.

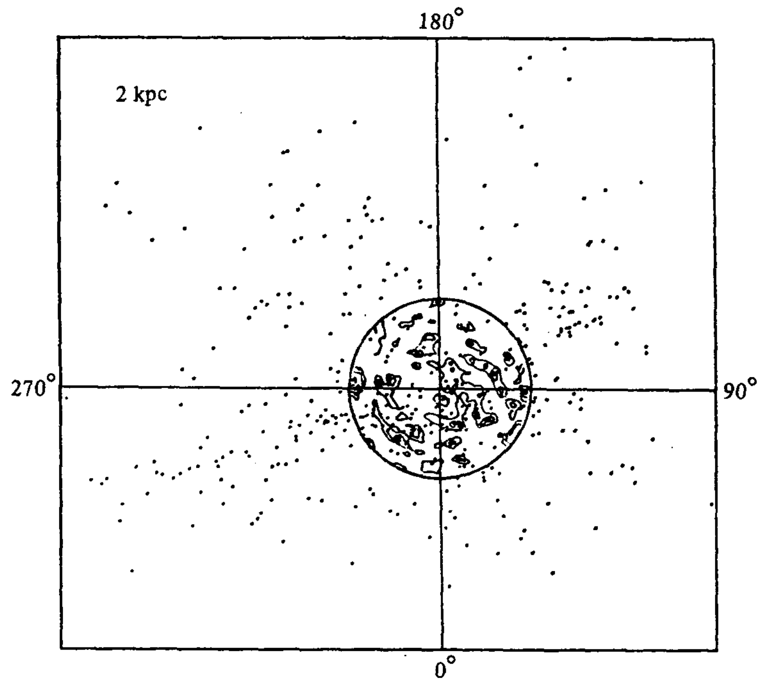


Fig. 2. The distribution of cepheids on the projected galactic plane and dust complexes within 2 kpc from the sun.

However, in some directions the correlation is suspect. Towards $\ell=30^\circ$, $\ell=65^\circ$, and $\ell=120^\circ$ where Lucke marked several heavily absorbing clouds in the region within 2 kpc from the sun, we can see the number of cepheids to be comparable to the number observed in other regions at distances of more than 2 kpc. It is, therefore, difficult to estimate to what extent the observed distribution of cepheids comes from its real heterogeneity and to what extent from the existence of vast obscuring dust complexes as already pointed out by EIN. It seems that the contour maps of color excess within 2 kpc from the sun given by Lucke are not enough to explain the distribution towards all directions beyond 2 kpc.

To investigate the spatial distribution of color excesses qualitatively for large distances from the sun, we plot Kv for six different longitudes at three different distances in Fig. 3. The solid line, dotted line, and broken line correspond to Kv for six longitudes (averaged over 60°) with distances of R< 2 kpc, R<4 kpc, and R< 8 kpc from the sun. At all longitudes except ℓ=300° - 360°, Kv decreases as the distance increases, and this can be explained by the fact that the sun is supposed embedded in a relatively dense reddening material or cloud. In other words, if the reddening material is distributed uniformly, there will be no distinct change of Kv along the distance from the sun.

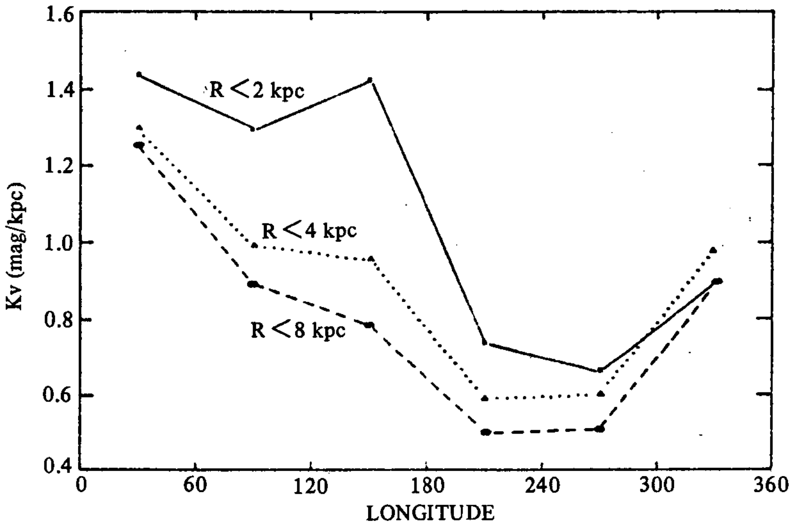


Fig. 3. The average rate of interstellar absorption as a function of Galactic longitude at three different ranges of distance from the sun; R <2 kpc solid lines; R <4 kpc dotted lines; R <8 kpc broken lines.

Also in spite of the fact that the reddening material in R< 2 kpc by Lucke show very heterogeneous distribution in the region of ℓ=30° - 130°, all cepheids except two are distributed within R < 5 kpc and the boundary of distribution lies exactly on the dotted arc surprisingly as marked in Fig. 2. Furthermore, in this region, not much change of Kv can be seen for R<2 kpc, however Kv is decreasing as distance scale increases from R < 4 kpc to R < 8 kpc. These results also show that the sun is supposed embedded in a dense cloud but it seems that the position of the sun is not the center of cloud but the edge of cloud.

In the regions of ℓ=0° - 120°, absorption smoothly decreases without any abrupt changes. However, in the region of ℓ=120° - 180°, absorption inside the 2 kpc region from the sun is markedly higher than outside suggesting a possible boundary where the absorption changes abruptly. This may be related to the Perseus Arm. The situation is different for longitudes in the interval $\ell=300^\circ$ - 360°, where Kv for $R<4$ kpc is higher than Kv for $R<2$ kpc suggesting that a dense cloud is located between 2 kpc and 4 kpc from th sun, possibly associated with the Carina arm. In Fig. 1, we note that Kv is abnormally small towards $\ell=90^\circ$ compared with the model wherein Kv along the galactic equator is expressed as a sinusoidal function. Because there are several heavily obscuring clouds in this direction in Lucke's map, one possible explanation is that the reddening value toward $\ell=90^\circ$ is relatively very small beyond 2 kpc from the sun. Otherwise, the sinusoidal model of Kv may oversimplify the real situation. In reality, Lucke's color excess contour map shows complex structure which deviates far from the simple sinusoidal pattern.

III. Conclusion

We tried to see how reddening material within several kpc from the sun are distributed by utilizing the color excess and distance data of classical cepheids. Although it is not available to map the mean color excesses out to further distance with cepheid data like Lucke had done, rough picture of distribution can be seen. Reddening material is distributed very heterogeneously in the region of $R<8$ kpc and the distribution can't be inferred from the information of Lucke for $R<2$ kpc. We also believe that the sun is embedded by the relatively dense cloud as Fernie suggested but the size and volume of this cloud can't be estimated at this stage. To obtain more reliable result, it is necessary to compile color excess and distance data for all bright objects such as cepheids, RR Lyrae stars, OB stars and clusters, etc.

References

Efremov, Yu. N., Ivanov, G. R., and Nikolov, N. S. 1981, *Astrophys. Space Sci.* **75**, 407.

Fernie, J. D. 1962, *A. J.* **67**, 224.

Fernie, J. D. 1968. *A. J.* **73**, 995.

FitzGerald, M. P. and Moffet, A. F. 1976, *Sky and Telescope,* p. 104.

Kim, C. 1984, *Dissertation,* Brigham Young University.

Kim, C. 1985, *J. Astron. Space Sci.*(KOREA). 2, 131.

Kim, C. 1987, in *Preparation.*

Lucke, P. B. 1978, *Astron. Ap.* **64**, 367.

Stothers, R. B. 1983, *Ap. J.* **274**, 20.