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Distribution of interstellar matter in the direction of LN45

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Abstract. Study of light extinction in the direction of LN45 was carried out using 2MASS data and the behavior of interstellar matter in this direction was unraveled. A case study on a field in the direction $\ell = 315°$ and $b = -0.76$ is presented here. Based on the fitting of "red clump" locus, we find that the extinction per kpc $c_J = 0.16$ mag/kpc makes a good fit up-to the distance of 3 kpc whereas beyond this distance its value increases continuously to a value 0.32 at a distance of 7 kpc. As far as the distribution of material is concerned, this finding indicates that the interstellar (IS) density is higher between 3 to 7 kpc (a region occupied by Scutum-Crux spiral arm) compared to the local region.

Keywords : ISM: dust, extinction – ISM: individual (Milky Way) – Bulge

1. Introduction

The inner region and bulge of the Milky Way Galaxy are highly obscured regions of the Galaxy. The extinction towards the nuclear bulge (NB) is so high that it is almost impossible to observe at visual wavelengths. Recent near IR wavelength surveys of the inner region and bulge of the Galaxy allow access to the inner regions of the Galaxy. Previous studies of the NIR extinction towards the NB (e.g. Schultheis et al. 1999, Dutra et al. 2003) show it to be highly patchy. Until recently, extinction law parameter (α) which indicates the relationship between extinction and wavelength as $A_\lambda \propto \lambda^{-\alpha}$ was thought to be a constant with $\alpha \sim 2$ (Martin and Whitet 1990, Rieke and Lebofsky

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1985, Nishiyama et al. 2006) for the NB. However, recent studies show clear evidence of varying extinction law towards the NB and the other directions in the Galactic plane in the optical, near- and mid-infrared wavelength bands (e.g. Fitzpatrick and Massa 2009, Ganesh et al. 2009, Gosling et al. 2009, Indebetouw et al. 2005, Jiang et al. 2006, Nishiyama et al. 2009). Ganesh et al. (2009), in their recent study, used the infrared colour-colour diagram (CCD) $(J-K_s)$ vs $(K_s-[mid-IR])$ to determine the extinction coefficients $A_{[mid-IR]}/A_V$ for an ISOGAL field in the direction of $\ell = 315°$ and $b = 0°$ which is named as field LN45. In this communication, we discuss the results based on this paper and as an illustration a case study in the direction $\ell = 315°$ and $b = -0.76°$ is made.

2. Interstellar extinction and distance scale

The measurement of IS extinction in the optical range is only possible for the nearby region. Neckel et al. (1980) report IS extinction A_V based on the optical observations of early type stars in the direction of $\ell = 314.0°$ and $b = 0.0°$, which is close to the field reported in this study, to be nearly uniform between 2 and 3 mag up to a distance of ~ 3.5 kpc. IR surveys are helpful in finding the extinction at farther distances. Red giants are the most numerous population that is observed in near- and mid-IR surveys like 2MASS, ISOGAL, GLIMPSE etc. throughout the Galaxy. The reddening of various IR colours may be used to trace the IS extinction(A_V). However, the near-IR colours $J-K_s$ or $H-K_s$ are most useful because of greater sensitivity to the extinction with $A_J - A_{K_s} \sim 0.17A_V$ and $A_H - A_{K_s} \sim 0.06A_V$ (Glass 1999). Such methods were used for systematic studies of the extinction in large areas by Schultheis(1999) using DENIS survey and by Dutra et al. (2003) who used 2MASS survey. The numerous giants of the "red clump", for which the luminosity is assumed to be known, provide opportunity to estimate both the extinction and the distance from the colour-magnitude diagrams (CMDs) such as J vs $J-K_s$. This is by far the best way to make 3D estimate of the extinction (i.e. the 3D distribution of IS material) along the Galactic sight-lines by determining the distance from their well defined intrinsic luminosities and colours. Indebetouw et al. (2005) have exploited the "red clump" stars of 2MASS to explore the extinction along various sight-lines. Ganesh et al. (2009) have carried out the detailed study of IS extinction as a function of distance in the direction of $\ell = 315°$ and $b = 0.0°$ using the J vs $J-K_s$ CMD. As an illustration, a field of $0.2° \times 0.3°$ centered in the direction of $\ell = 315°$ and $b = -0.76°$ is considered here. The CMD is shown in Fig. 1. For the present study 2MASS and SPITZER data sets have been used.

With a good number of "red clump" stars being present, the distance and extinction can be estimated reasonably well by adjusting the parameter c_J and the distance in the equations (1) and (2), given below, to make a good fit in the CMD (Figure 1).

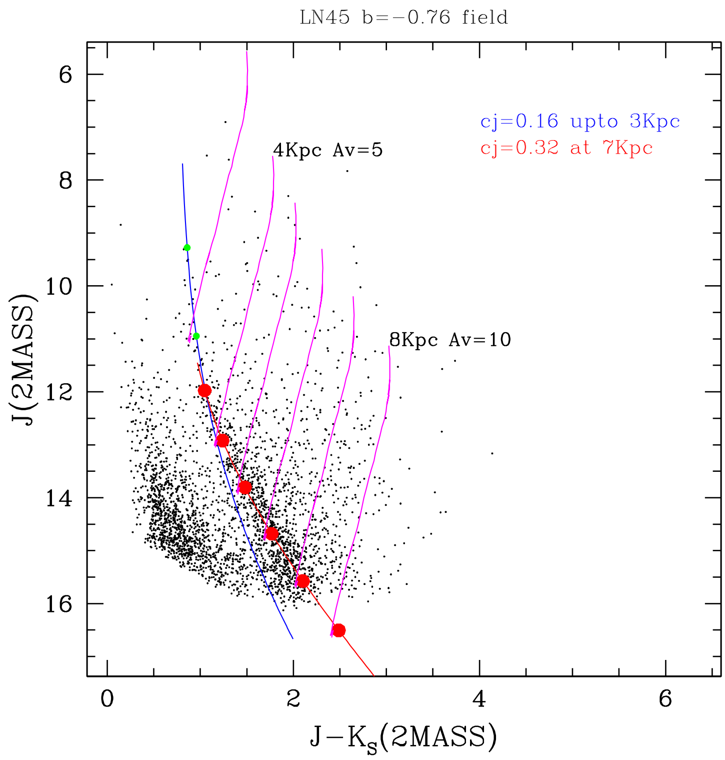

Figure 1. J vs $J - K_s$ CMD. Black dots represent the data. Red clump locus is shown with blue and red solid line for fixed and varying c_J. Red giant isochrones are shown in magenta colour (Bertelli el al. 1994). The large filled red circles are points spaced at 3,4,5,6,7 and 8 kpc while green dots label 1 and 2 kpc (normal extinction).

$$J = M_J + 5log(d/10pc) + c_J(d/1000pc) \quad (1)$$

$$J - K_s = M_J - M_{K_s} + (c_J - c_{K_s})(d/1000pc) \quad (2)$$

where c_J and c_{K_s} define the extinction per unit kpc distance in J and K_s and d is the distance. Mean absolute magnitudes of the "red clump" stars are: $M_J = -0.95$, $M_{K_s} = -1.65$ and $J_0 - K_{s0} = 0.75$, and the extinction ratios: $c_J/c_{K_s} = A_J/A_{K_s} = 2.5$ (cf. Indebetouw et al., 2005; Ganesh et al., 2009). The curve of the red clump locus then depends only on the extinction parameter c_J and d to be fitted.

The two parameters, extinction per unit distance(c_J) and the distance d are adjusted to find the best fit. We find that a single extinction law does not make a good fit, the law changes from location to location, making the situation very complex. To simplify the problem, we first defined the approximate distance scale assuming the average extinction for the field to be proportional to the distance and fit a mean curve for the "red clump" locus (RCL). The details of the methodology are discussed in Ganesh et al. (2009).

3. Results and discussions

Figure 1 shows $J-K_s$ vs J CMD where the blue line represents the RCL with local value of c_J. It is clear from Fig. 1 that a simple curve with single c_J and c_{K_s} does not properly fit the red clump locus. This is not surprising since the variation of the extinction with distance, represented by c_J, is smaller in the local region as compared to that in the spiral arm region where large molecular clouds are located. In the present case the value of c_J is found to be 0.16 for distances < 3 kpc. Beyond 3 kpc, c_J increases continuously to a value of 0.32 at a distance of 7 kpc i.e. c_J depends on the distance. These values provide a reasonably good fit to the RCL. The field discussed here is off the Galactic mid-plane, hence the change in the value of c_J is not as large as in the mid-plane (Ganesh et al., 2009). The values of c_J which fit well are shown in the figure.

4. Conclusions

The extinction law is shown to vary with distance and line of sight. The stars in the "red clump" can be traced along the line of sight using 2MASS data up to the Scutum-Crux arm in the direction of $\ell = 315°$. The locally accepted value of c_J is suitable to fit the RCL only up to a distance of ~ 3 kpc in this direction. Beyond 3 kpc in the direction of $\ell = 315°$ and $b = 0°$, c_J is found to increase with distance.

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