The Interstellar Reddening Law within 3kpc from the Sun

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Abstract. We have investigated the interstellar reddening law of young open clusters within 3kpc from the Sun using optical, near-IR 2MASS, and Spitzer IRAC data. The total-to-selective extinction ratio $R_V$ of 162 young open clusters ($\log t_{age} \lesssim 7.3$) listed in the open cluster database WEBDA is determined from the color excess ratios. The young open clusters in the Sgr-Car arm show a relatively higher $R_V$, those in the Per arm and in the Cygnus region of the local arm show a relatively smaller value, and those in the Mon-CMa region of the local arm show a normal value ($R_V \approx 3.1$).

1. Introduction

To determine the physical parameters of stars and clusters accurately, we should know the correct interstellar reddening. Precise knowledge of $R_V$ is of crucial importance for the determination of distances of reddened stars or clusters. Many investigators determine the total extinction $A_V$ by assuming the total-to-selective extinction ratio $R_V$ to be 3.1. In 1940s, from multicolor photometry of many O and B type stars Stebbins & Whitford (1943) concluded that the law of selective absorption is the same for all directions in the Galaxy. Later Johnson & Borgman (1963) conducted multicolor photometry of O, B stars and showed that there is no unique reddening law. In addition, they showed that there is a minor variation of $R_V$ with galactic longitude. Later Serkowski et al. (1975) confirmed such a variation from the spatial variation of wavelength of maximum polarization. Whittet (1977) presented a functional form of $R_V$ variation against galactic longitude. Recently Fitzpatrick & Massa (2009) showed that the interstellar reddening law $R_V$ is different for different sightlines.

Recently Hur et al. (2012) showed that an abnormal reddening law for the intracluster medium of the young open clusters in the $\eta$ Carina nebula. However they obtained a fairly normal reddening law for the foreground stars. On the other hand, Sung et al. (2013a) found a nearly normal reddening law toward the young open cluster NGC 6231 from the optical to mid-IR photometric data. Now it is possible to study the reddening law toward young open clusters in a homogeneous way because the homogeneous near-IR 2MASS data as well as mid-IR Spitzer IRAC images are available for many young open clusters. In this paper we present a preliminary result from our systematic investigation of the reddening law.
2. Large Scale Variation of \( R_V \)

The reddening law for the young open clusters is determined as the same way as the method described in [Hur et al. (2012); Sung et al. (2013b)]. The intrinsic color relations between \((B - V)_0\) and \((V - \lambda)_0\) for 2MASS \(JHK_s\) bands are presented in [Sung et al. (2013b)], and those for \(Spitzer\) IRAC bands will be published in the forthcoming paper.

We have analyzed the photometric data for 192 young open clusters with \(\log \tau_{age} \lesssim 7.3\). Among them 16 clusters (e.g. Mayer 1, Be 65, Cz 13, Cr 173, etc) are either lack of \(UBV\) photoelectric or CCD data or \((U - B)\) color. And 4 clusters (e.g. Cz 20, NGC 2453, etc) are not young open clusters, 6 clusters (Cr 96, Cr 107, NGC 2448, etc) seem to be not clusters, and 4 clusters (BH 121, BH 205, IC 2948, and Loden 153) are parts of the other young clusters. And therefore we determined the reddening law of 162 young open clusters. We also determined the color excess ratios in the \(Spitzer\) IRAC bands for 38 clusters. The \(R_V\) of the young open clusters is determined the relation between \(R_V\) and color excess ratios by Guetter & Vrba (1989). Figure 1 shows the color excess ratios for the OB stars in the young open cluster Trumpler 16. A few foreground B type stars show a fairly normal reddening law of \(R_{V,fg} = 3.1\), while cluster OB stars behave abnormally and well match to the solid line of \(R_{V,cl} = 4.6\). Although most stars do not show any excess emission in the optical to near-IR, some stars show an evident excess emission in the mid-IR, especially in \(8.0\) \(\mu m\).

In this paper we only describe the reddening law of the general interstellar medium. And therefore we only take the \(R_{V,fg}\) for the young open clusters with an abnormal \(R_{V,cl}\). Figure 2 shows the \(R_V\) with respect to galactic longitude. For some clusters we cannot...)
determine the $R_V$ reliably because of small values of reddening or no early type stars in the foreground. The young open clusters in the Sgr-Car arm show a relatively high value ($R_V \approx 3.2$), those in the Per arm and in the Cygnus region have a smaller value ($R_V \approx 2.9$), and those in the Mon-CMa regions have a nearly normal value ($R_V \approx 3.1$). In addition the fluctuation of $R_V$ is also noticeable ($\sigma_{R_V} \approx 0.15$). However the overall variation of $R_V$ well follows the equation given by Whittet (1977) except for the CMa-Vel direction.

3. Conclusion

From the analysis of photometric data for 162 young open clusters we confirmed the large scale variation of the reddening law in the galactic plane, which implies the real variation of dust size distribution in the galactic plane. We also found a large fluctuation of $R_V$ for a given region. The cause of this fluctuation is still uncertain, and therefore a systematic photometric survey of open clusters to provide homogeneous photometric data, e.g. the Sejong Open cluster Survey (SOS) (Sung et al. 2013b) is required to confirm the real fluctuation.

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