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Intracluster extinction in young open star clusters

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Abstract. An analysis of near-infrared data in combination with optical observations, indicates a normal interstellar extinction law around hot O and B stars at wavelengths ≥ 0.9 μm. At shorter wavelengths, it can be either normal or anomalous depending upon the physical conditions of intracluster material. In some cases, anomaly is found to be due to a small shift in grain-size distribution towards smaller than normal sized particle, while in other regions, exactly opposite grain size distribution seems to be responsible for the anomaly.

Key words : star clusters—near-infrared—star formation

1. Introduction

The regions in and around extremely young (~ 10^6 yrs) open star clusters contain O and B stars embedded in nebulosity produced from their parent molecular clouds. Thus, conditions in these regions provide a unique opportunity for examining the effects of strong radiation field on the surrounding dust grains responsible for extinction. As near-infrared photometry has proved to be a useful tool for such studies, we carried out JHK photometry in the regions of three young star clusters namely NGC 654 (Sagar & Qian 1989); IC 1805 (Sagar & Qian 1990); and NGC 1976 (Qian & Sagar 1993). Similar observations are available in literature for some more young stellar regions/complexes (see table 1). In this article, these observations have been used to examine the interstellar extinction law around hot O and B stars.

2. Interstellar extinction law

In the observational studies of interstellar extinction law, nowadays people use parameters like $E(V-J)$ and $E(V-K)$ instead of $E(B-V)$ (Smith 1987; Tapia *et al.* 1988, 1991) because they do not depend on properties like the chemical composition, shape and structure, degree of alignment of interstellar matter (Voshchinnikov & Il'in 1987; Cardelli *et al.* 1989; Mathis 1990 and references therein). However, the colour excess to be used as a measure of interstellar extinction should be selected carefully in the case of extremely young (~ 1 Myr) open star clusters as they are generally embedded in emission nebulosity and also contain massive young stellar objects. In such circumstances, the blueing effects, ultraviolet excess, circumstellar dust, and gas shell, etc., may be present in and around the cluster members. In the light of our earlier discussions (see Sagar & Qian 1990), we have estimated the colour excess ratios relative to $E(V-J)$ for the study of interstellar extinction around O and B stars. For this, we have combined the JHK observations with the optical data (for details see Sagar & Qian 1989, 1990; Qian & Sagar 1993). In table 1, the results are compared with those in other regions of O and B stars as well as with normal interstellar extinction law given by van de Hulst curve No. 15 (cf. Johnson 1968) and also by Cardelli *et al.* (1989). The extinction law is found to be normal in general for the wavelength $\lambda \geq \lambda_I$, where λ_I (~ 0.9 μm) is the effective wavelength of the I passband, in the case of all clusters. However, at shorter wavelengths, law of extinction is generally not only anomalous but also different for different regions, e.g.,

(a) In the case of NGC 654 and star 211 in IC 1805, the anomaly is in the sense that the value of the total to selective absorption ratio is less than 3.1, a value given for the normal interstellar extinction law. This is similar to that reported by Roth (1988) for Trumpler 37; by Krelowski & Strobel (1987) for Perseus region; and by Tapia *et al.* (1991) for NGC 663, 1502 and 1893. The effects suggest that the matter responsible for the extinction in these regions seems to'be less efficient at longer wavelengths and the distribution of dust grain sizes is smaller biased toward smaller values compared to dust in the diffuse medium.

(b) The anomalous effect observed in regions around star 72 and 143 in IC 1805 and around Group 2 stars in NGC 1976 is exactly opposite to the one discussed above. The anomaly is similar to the one observed in the regions of Carina nebula clusters by Smith (1987) and Tapia *et al.* (1988) and in the Sco-Ori region by Krelowski & Strobel (1987). In these regions, grain size distribution seems to be biased toward larger than normal sized particles.

(c) The extinction law is normal around most of the hot O and B stars in IC 1805 and in the vicinity of Group 1 stars in NGC 1976. This is similar to that found in OB associations by Leitherer & Wolf (1984). These results indicate that strong radiation coming from grains responsible for extinction have not changed the size distribution of intracluster grains responsible for extinction compared to that of normal-sized dust particles.

In the regions discussed in (a) and (b), the anomaly in the law of interstellar extinction is such that it either increases or reduces extinction only in U and B passbands keeping the values generally normal for $E(U-V)/E(U-B)$ and near-infrared colour excess ratios.This makes the extinction in these regions quite different from that in dense molecular clouds like those in Ophiuchus (Chini 1981); where most colour excess ratios differ from the corresponding normal values.

3. Discussions

The interstellar extinction law around hot O and B stars can be understood in terms of Seab & Shull's (1983) model of interstellar dust grain processing due to passage of shock waves. The results of the model are naturally dependent on the physical conditions of the intracluster material. Small inhomogeneities in them would therefore result in large differences in the observed parameters at slightly different positions in the cluster as well as in the sky. Consequently, depending upon the physical conditions of intracluster material, grain size distribution resulting from the interactions of strong radiations of hot O and B stars can be

Table 1. A comparison of normal interstellar extinction law with that in direction of various young star forming regions/complexes

Regions	$\frac{E(U-V)}{E(V-J)}$	$\frac{E(B-V)}{E(V-J)}$	$\frac{E(V-R)}{E(V-J)}$	$\frac{E(V-I)}{E(V-J)}$	$\frac{E(V-H)}{E(V-J)}$	$\frac{E(V-K)}{E(V-J)}$	$\frac{E(V-L)}{E(V-J)}$	Reference
van de Hulst curve No. 15	0.75	0.43	0.35	0.70	1.13	1.21	1.27	1
Mean extinction	0.78	0.45	0.35	0.73	1.15	1.24	1.32	2
Star 143 in IC 1805	0.40 ± 0.02	0.23 ± 0.01	—	—	1.05 ± 0.06	1.07 ± 0.06	—	3
Star 211 in IC 1805	1.13 ± 0.10	0.67 ± 0.07	—	—	1.11 ± 0.12	1.17 ± 0.12	—	3
NGC 1976 Group 1 stars	0.62 ± 0.02	0.41 ± 0.02	0.40 ± 0.02	0.73 ± 0.03	1.24 ± 0.05	1.26 ± 0.05	1.30 ± 0.06	4
NGC 1976 Group 2 stars	0.31 ± 0.01	0.22 ± 0.01	0.25 ± 0.01	0.51 ± 0.02	1.15 ± 0.03	1.22 ± 0.04	1.29 ± 0.05	4
Sco-Ori region	0.52 ± 0.04	0.35 ± 0.03	0.31 ± 0.03	0.67 ± 0.06	1.20 ± 0.09	1.35 ± 0.10	1.45 ± 0.11	5
Perseus region	1.06 ± 0.22	0.48 ± 0.14	0.35 ± 0.10	0.64 ± 0.23	—	1.21 ± 0.25	1.24 ± 0.30	5
Carina nebula	—	0.34 ± 0.08	0.32 ± 0.06	0.68 ± 0.14	1.16 ± 0.07	1.22 ± 0.06	—	6

Note : Number in the reference column denotes following : 1, Johnson (1968); 2, Cardelli *et al* (1989), 3, Sagar & Qian (1990); 4, Qian & Sagar (1993); 5, Krelowski & Strobel (1987); and 6, Tapia *et al.* (1988).

either normal or shifted by a small amount in either direction compared to that of normal sized particles. The anomaly depends on the direction of the shift, which ultimately depends on the grain destruction mechanism. In the case of selective destruction of smaller grains, a shift toward large grains can arise and could be the case for (b) regions discussed above. On the other hand, a small shift in the opposite direction can be found if the large sized grains are destroyed.

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