

NON-UNIFORM EXTINCTION IN TEN YOUNG OPEN CLUSTERS

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INTRODUCTION

It is believed that groups of new stars have their birth places within gravitationally bound molecular clouds. With time ($\approx 10^7$ – 10^8 yr) the gas and dust of the clouds are either used in star formation processes or blown away by radiation pressure of hot stars present in the system. Consequently, a systematic study of non-uniform extinction in young ($\leq 10^8$ yr) open clusters helps in understanding the star formation processes in these clusters. Most of the earlier studies (cf. Blanco & Williams 1959; Reddish 1967; Krelowski & Strobel 1979) on the subject are based either on accurate observational data without reliable cluster members or vice-versa and the importance of the use of both accurate observational data and reliable cluster members in the type of analysis discussed here is shown by Bohannon (1975).

Sagar (1987) has noticed the evidence for the presence of non-uniform extinction in 10 out of the analyzed 15 young open clusters on the basis of reliable proper motion members and use of accurate photometric and spectroscopic data. The possible cause of non-uniform extinction in these 10 objects is discussed here. The details of the observational material used in this study are given elsewhere (cf. Sagar 1987).

WHAT COULD BE THE CAUSE OF NON-UNIFORM EXTINCTION?

To understand the possible cause of non-uniform extinction observed in the clusters under discussion, variations of $E(B-V)$ with spatial position, luminosity and spectral class of members have been studied in detail by Sagar (1987). The main results are listed in Table 1 which indicate that the cluster sample can be divided into the following three groups:

(a) A clear dependence of $E(B-V)$ on spectral type and luminosity

in the sense that colour excess increases with luminosity and effective temperature of the star has been noticed for the clusters namely IC 1805, NGC 6823 and 6913.

(B) Clusters that belong to this group are NGC 654 and 6611. They show weak dependence of colour excess with either spectral type or luminosity or both.

(C) Clusters namely NGC 1976, 2244, 2264, 4755 and 6530 show no dependence of $E(B-V)$ with either spectral type or luminosity, belong to this group.

In addition to above, we noticed that in NGC 2264, generally members brighter than $M_V = 1.0$ mag have low value of $E(B-V)$ in comparison to faint members ($1.0 \text{ mag} < M_V < 3.3 \text{ mag}$). Similarly, a few bright IC 1805 members ($M_V < -4.0 \text{ mag}$) are less reddened than the faint stars ($-4.0 \text{ mag} < M_V < -1.0 \text{ mag}$).

The theoretical models for star formation processes (cf. Larson 1973; Yorke & Krugel 1976; Bhattacharjee & Williams 1980) as well as ultraviolet observations (cf. Krelowski & Strobel 1981 and references therein) suggest that circumstellar material may be present around newly formed massive stars and its mass is positively correlated with the stellar mass. Ages of group A clusters are based on pre-MS stars i.e. relatively low-mass stars and recent studies of clusters indicate that star formation may proceed over a long time, with lower-mass forming first and higher-mass stars only later. It means that massive stars in these clusters should be younger than the cluster age i.e. they may have just arrived on the MS and hence, the observed correlation of $E(B-V)$ with spectral type and luminosity for group A clusters may be due to the presence of circumstellar material around young massive stars. With time this circumstellar material will be blown away by the radiation pressure of the star. It may indicate that in NGC 6823 and 6913, luminous stars might have not found enough time to blow off their relict circumstellar material while stars brighter than $M_V = -4.0$ mag in IC 1805 and $M_V = 1.0$ mag in NGC 2264 have been able to do so. Bright stars in NGC 2264 have been able to blow off the relict circumstellar material of relatively low-mass stars in comparison to the same in IC 1805. It may be because of the fact that the former are relatively older than the latter. However, the physical scenario presented

above could not explain the following observed facts:

- (1) There is no dependence of colour excess either on luminosity or spectral type in NGC 1976, 2264 and 6530 although their ages are comparable to group A clusters and they also contain massive stars.
- (2) Luminous stars in IC 1805, NGC 1976, 2244, 6611 and 6823 have low as well as high values of reddening.

CONCLUSIONS

The following conclusions may be drawn from this analysis:

1. The observed systematic spatial variation of $E(B-V)$ in NGC 6530 and 6611 may be because of the presence of systematically varying amounts of gas and dust either inside the clusters region or in its immediate vicinity.
2. Contrary to Krelowski & Strobel (1979), we observed that the scatter in $E(B-V)$ does not depend upon the spectral class at least in the spectral range of O to K. However, in this regard our conclusions agree with that drawn by Bohannan (1975).
3. Random variation of $E(B-V)$ over the cluster face may be caused by either a patchy distribution of interstellar matter across the cluster region or the presence of a circumstellar shell around young massive stars or a combination of both. Further observations are desired to resolve the situation.
4. Variation of $E(B-V)$ with either luminosity or spectral type is not observed in all the clusters younger than 5×10^6 yr and having massive stars.
5. Variation of reddening across the cluster face, with spectral type and luminosity of members in clusters under study cannot be correlated with its galactocentric distance, R_G (see Table 2 in Sagar 1987).

On the basis of the above, one may conclude that the variation of reddening in one cluster is distinctly different from the others and there is no uniformity in the relationship of extinction spatially, or with spectral type or luminosity or age, among these clusters. All these indicate that the observed variation of reddening in young open clusters may not be explained by a "simple", or even "relatively simple" physical scenario. Actually, it depends upon the

factors like age of cluster members, initial spatial distribution of matter in the molecular cloud, subsequent star formation processes and distribution of massive stars in the cluster and its location in the Galaxy, etc.

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Table 1. Results of Variation of E(B-V) With Spatial Position, Luminosity and Spectral Class of Members of Clusters Under Discussion.

Cluster	Variation of E(B-V) with			Group
	Spatial position (Behavior)	Luminosity (Correlation)	Spectral Type (Correlation)	
NGC 654	Random	Weak	No	B
IC 1805	Systematic	Yes	Yes	A
NGC 1976	Random	No	No	C
NGC 2244	Random	No	No	C
NGC 2264	Random	No	No	C
NGC 4755	Random	No	No	C
NGC 6530	Systematic	No	No	C
NGC 6611	Systematic	No	Weak	B
NGC 6823	Random	Yes	Yes	A
NGC 6913	Random	Yes	Yes	A