Mon. Not. R. astr. Soc. (1989) **240,** 551–561

JHK photometric study of the variable interstellar extinction in the direction of open star cluster NGC 654

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Accepted 1989 March 14. Received 1989 March 7; in original form 1988 July 28.

Summary. *JHK* magnitudes have been determined for 18 stars in the field of NGC 654. Study of the interstellar extinction law in the cluster direction indicates an anomalous distribution of interstellar grains causing more extinction in *U* and *B* pass-bands compared to that obtained from the colour excesses $E(V-J)$, $E(V-H)$ and $E(V-K)$ using a normal reddening law. This implies a small shift in the grain-size distribution towards smaller than normal sized particles. Patchy distribution of interstellar matter seems to be responsible for the non-uniform extinction in the cluster region.

1 Introduction

The young open star cluster NGC 654 (CO140+616) in Cassiopeia, has been classified as Trumpler class II2r by Lyngå (1984). The cluster has been studied a number of times mainly because of the non-uniform extinction across its face. Several *UBV* photometric studies of the cluster, mostly photographic, are available (Müller 1955; Pesch 1960; Hoag *et al.* 1961; McCuskey & Hauk 1964; Moffat 1972; Samson 1975; Stone 1980; Joshi & Sagar 1983). Other investigations of the cluster include spectral classification (Hoag & Applequist 1965; Turner 1976); proper motion (Stone 1977) and polarization (Samson 1976). The distance and age of the cluster, determined by various studies, ranges respectively from 1.6 to 2.9 kpc and 15 to 60 Myr with modal values of 2.4 kpc and 35 Myr (*cf.* Joshi & Sagar 1983; Sagar *et al.* 1986 and references therein).

The presence of non-uniform extinction has been indicated by many investigators (Müller 1955; Pesch 1960; Starikova 1964; Reddish 1967; Samson 1975; Stone 1977, 1980; Joshi & Sagar 1983; Sagar 1987, 1988). The study of non-uniform extinction based on reliable cluster members and precise observational data shows a weak dependence of colour excess $E(B-V)$ with spectra type and luminosity, and a random spatial distribution of $E(B-V)$ (Sagar 1987, 1988). Samson (1975) proposed that the existence of a dust shell of interstellar matter, remaining from the period of cluster star formation, around the cluster seems to be responsible for the

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non-uniform extinction across the cluster region. However, McCuskey & Hauk (1964) and Stone (1977) have held local dust clouds lying in the cluster direction responsible for the observed non-uniform extinction. Stone (1980) indicates that the extinction across the entire cluster region is very patchy, and that there is no indication that it varies with distance from the cluster centre as might be expected for the dust-shell model described by Samson (1975).

Whether the large colour excess $E(B-V)$ observed for some cluster members (*cf.* Joshi & Sagar 1983; Sagar 1987 and references therein) is caused by the presence of hot and ionized dust circumstellar envelopes around the stars as indicated by Reddish (1967), or is due to a patchy distribution of interstellar matter itself across the cluster region, is not clear from the existing observations. The present near-infrared photometric observations are aimed at determining the wide band *JHK* infrared fluxes and then using them to study the interstellar extinction law in the direction of the cluster as well as the possible causes of non-uniform extinction across the cluster region.

2 Observations and reduction

Eighteen stars brighter than $V=13$ mag and having a high proper motion membership probability (generally $\geqslant 80$ per cent) in NGC 654 have been selected for the present observations. Most of them have colour excess $E(B-V)\geqslant 0.9$ mag (*cf.* Joshi & Sagar 1983).

The observations have been carried out by one of us (QZY) between 1987 November and 1988 February on the Cassegrain focus of the 1.26-m infrared telescope of Beijing Astronomical Observatory located at the Xinglong station (*cf.* Hu 1986). The near infrared photometer is built by Infrared Laboratories Inc., Tucson, USA and has InSb as a detector. The effective wavelengths and bandwidths at half maximum (given inside the bracket) of the filters J, H and K in μm are 1.26 (0.25), 1.68 (0.40) and 2.28 (0.48), respectively. The block diagram of the data acquisition system and other details of the instruments are given elsewhere (*cf.* Hu 1986).

The programme stars were measured with respect to the set of well calibrated CTIO near infrared standards taken from Elias *et al.* (1982) and IR photometric manual of the NASA Infrared Telescope Facilities (1986, private communication). The colour equation for the system has been obtained by plotting J_0, H_0 and K_0, the instrumental magnitudes corrected for Earth's atmospheric extinction, against the *JHK* magnitudes and colours of the standards, as shown in Fig. 1. A least squares linear regression yields the following relation between them:

$$J=J_0+0.053\,(\pm 0.014)\,(J\text{-}K)+4.533\,(\pm 0.005);$$

$$H=H_0+0.001\,(\pm 0.022)\,(J\text{-}H)+4.657\,(\pm 0.007)\text{ and}$$

$$K=K_0=0.080\,(\pm 0.021)\,(J\text{-}K)+4.032\,(\pm 0.008).$$

These relations are shown in Fig. 1 and indicate a very small colour dependence of the present system in the range of $(J\text{-}K)=-0.1$ to 1.0 mag.

The error in *JHK* magnitudes for a single observation has been estimated as $[(1.09/SN)^2+E]^{1/2}$; where SN is the signal-to-noise ratio and E is the error in fixing the zero point. Standards BS 696, 1641, 1980 and 4550 have been used to estimate the nightly zero point for the programme stars. Accuracy of the zero points is better than 0.02–0.03 mag in all the filters and is the main source of error in *JHK* magnitudes of stars brighter than 9 mag. For faint stars, a relatively weak signal (i.e. poor signal-to-noise ratio) is the major source of uncertainty in the observations. The programme stars have been observed generally twice on different nights and their weighted averages together with the corresponding observational errors are listed in Table 1.

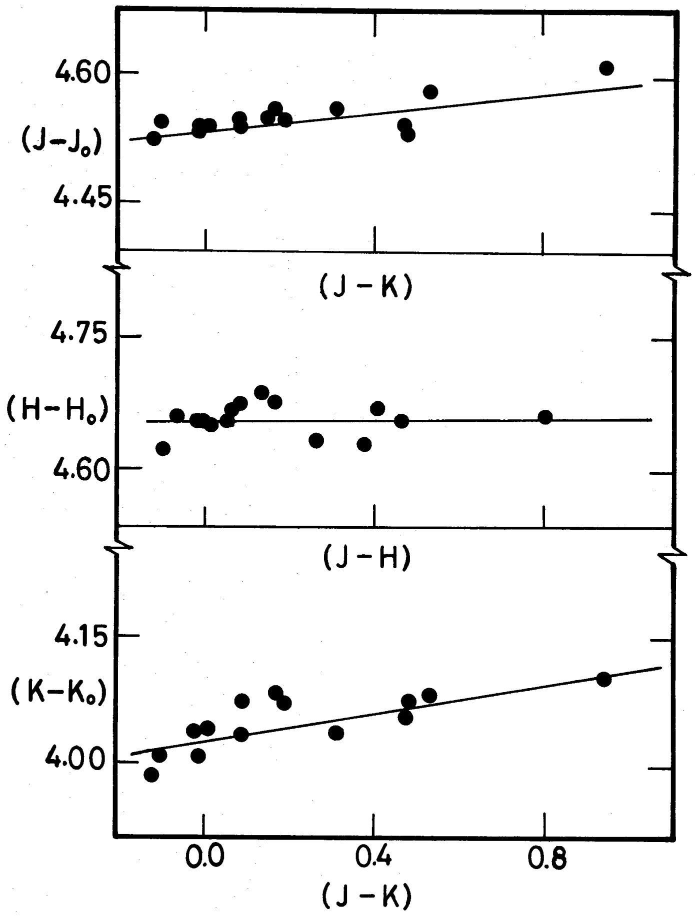

Figure 1. Plot of $(J\text{-}J_0)$ versus $(J\text{-}K)$, $(H\text{-}H_0)$ versus $(J\text{-}H)$ and $(K\text{-}K_0)$ versus $(J\text{-}K)$ diagrams. The least squares straight line fits are shown by solid lines.

3 Cluster membership of stars

Stone (1977) has determined the relative proper motion for 186 stars spread in a 34×31 arcmin^2 region centred on the cluster with an average standard error of ± 0.07 arcsec per century in each coordinate. Using the same data, Zhao *et al.* (1985) have estimated a relatively reliable membership probability (p) for all the stars. Distribution of the stars according to p indicates that most of the investigated stars are either in a low p group ($\leqslant 10$ per cent) or in a high p group ($\geqslant 80$ per cent). This means that proper motion study of this cluster has been able to segregate cluster members from field stars. The values of p for the programme stars are taken from Zhao *et al.* (1985) and are listed in Table 1. Except one star, all have $p \geqslant 80$ per cent. The statistically expected number of field stars, estimated on the basis of median p of the sample, is only one.

4 Interstellar extinction law

The apparent colour–colour diagram $(J\text{-}H)$ versus $(H\text{-}K)$ for the programme stars is plotted in Fig. 2, where the reddening vector for the normal interstellar extinction law appears to fit the data satisfactorily within observational uncertainties, with the exception of stars 88 and 90. Possible reasons for their peculiar location in the $(J\text{-}H)$ versus $(H\text{-}K)$ diagram are discussed in the next section.

Table 1. *JHK* magnitudes of stars in NGC 654. Membership probability (p) in per cent after Zhao *et al.* (1965). V magnitudes are taken from Joshi & Sagar (1983) and spectral types from Hoag & Applequist (1965) and Turner (1976). Photometric spectral types are given in parentheses.

Star	J± σ (mag)	H± σ (mag)	K± σ (mag)	p (per cent)	V (mag)	Sp. type
9	7.69±0.02	7.47±0.02	7.35±0.02	96	9.33	(B3 Ib)
52	10.08±0.04	9.87±0.04	9.76±0.05	80	11.63	(B5 V)
57	9.09±0.02	9.07±0.02	9.12±0.02	94	9.47	(B5 V)
76	10.62±0.06	10.45±0.05	10.30±0.07	95	13.05	(B3 V)
78*	10.21±0.09	9.90±0.05	9.89±0.08	94	11.45	B1.5 IV
88	10.83±0.08	10.51±0.06	10.25±0.06	92	11.71	B1 V
90	11.25±0.11	11.06±0.08	10.62±0.09	94	12.22	B2 IV
94	10.69±0.06	10.53±0.04	10.62±0.08	94	13.03	(B3 V)
100	10.52±0.06	10.37±0.05	10.31±0.07	95	12.56	(B3 V)
108	10.87±0.07	10.62±0.07	10.41±0.08	96	12.76	(B2 V)
109	8.92±0.02	8.75±0.02	8.73±0.02	94	10.62	B2 Ib
111	4.72±0.02	4.32±0.02	4.22±0.02	92	7.32	F5 Ia
114	10.13±0.05	9.96±0.03	9.93±0.06	89	11.39	B5 V
119	11.50±0.13	11.38±0.07	-	95	12.97	(B2 V)
125*	10.73±0.11	10.50±0.07	10.51±0.11	97	11.85	B1.5 V
131	10.30±0.05	10.16±0.04	10.27±0.07	87	11.21	B2 IV
133	10.55±0.05	10.45±0.04	10.34±0.07	85	12.36	(B4 V)
161	9.36±0.02	9.33±0.03	9.37±0.03	63	9.87	(B9 V)

* Values are based on only one set of observations.

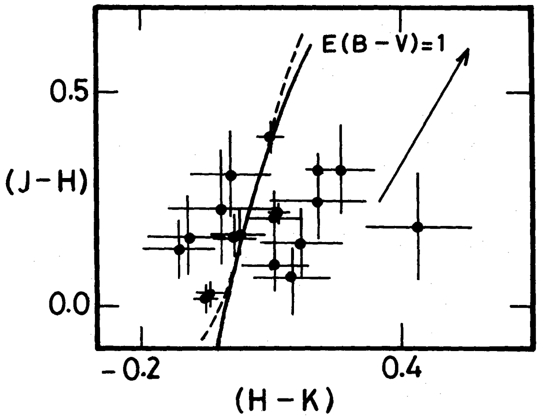

Figure 2. The (J–H) versus (H–K) diagram of stars under discussion. The length of the cross represents the observational error (σ). Continuous and dotted curves are the intrinsic main sequence and supergiant locus, respectively. The standard reddening vector for $E(B-V)=1$ mag is shown by an arrow.

In order to derive intrinsic infrared fluxes from the observed data, a knowledge of the interstellar extinction law in the direction of the cluster is required. Johnson (1968) has given a value of 5.6 to the ratio of total to selective absorption $R = A_v/E(B-V)$ for the cluster NGC 654 and has derived an anomalous interstellar extinction law in the direction of cluster. However, contrary to this, both Turner (1976) and Stone (1980) have derived a normal interstellar extinction law. They used the variable extinction method to estimate the value of R and found it very close to 3.1.

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The approach adopted here for examining the interstellar extinction law is to determine values of the total V-band interstellar extinction A_V as well as reddening vectors from the colour excesses estimated from the combination of near-infrared data with UBV photoelectric photometry given by Joshi & Sagar (1983) and two-dimensional spectral types reported by Hoag & Applequist (1965) and Turner (1976). When spectroscopic spectral types are not available, photometric ones are estimated using Johnson & Morgan's (1953) Q-method and its equivalent method described in detail by Sagar & Joshi (1979); luminosity classes are based on the location in the intrinsic colour–magnitude diagrams of the cluster given by Joshi & Sagar (1983). For the stars with spectroscopic determinations, the photometrically determined spectral types generally differ only by one subtype or less. The spectral types and V magnitudes of programme stars are listed in Table 1. Colour-excesses are calculated using the spectral type-intrinsic colour calibration given by Koornneef (1983) and Schmidt-Kaler (1982) for the different luminosity classes. These values are listed in Table 2. Because UBV magnitudes are determined better than JHK magnitudes, a typical uncertainty of ~0.05 mag is present in $E(U-V)$ and $E(B-V)$ and of ~0.1 mag in $E(V-J)$, $E(V-H)$ and $E(V-K)$.

4.1 ESTIMATES OF TOTAL INTERSTELLAR EXTINCTION IN THE V-BAND

The average values of colour excess and the corresponding values of the total V-band extinction A_V, assuming Koornneef's (1983) normal interstellar extinction law, are also given in Table 2. For the reasons given below, stars 57 and 161 are considered as field stars and were

Table 2. Colour excesses for the individual stars, mean colour excesses for the NGC 654 and A_V derived from them using the normal interstellar extinction law.

Star	E(U-V) (mag)	E(B-V) (mag)	E(V-J) (mag)	E(V-H) (mag)	E(V-K) (mag)
9	1.37	0.75	1.88	2.11	2.26
52	1.54	0.95	1.90	2.17	2.30
57	0.66	0.31	0.73	0.81	0.78
76	1.69	1.00	2.89	3.14	3.32
78	1.71	0.94	1.84	2.23	2.28
88	1.66	0.90	1.51	1.92	2.22
90	1.56	0.91	1.50	1.79	2.27
94	1.95	1.16	2.80	3.04	2.98
100	1.94	1.14	2.50	2.73	2.82
108	1.64	0.98	2.43	2.77	3.02
109	1.83	1.05	2.03	2.24	2.29
111	1.60	0.93	1.94	2.12	2.17
114	1.28	0.78	1.61	1.84	1.89
119	1.53	0.91	2.01	2.22	-
125	1.56	0.82	1.72	2.04	2.07
131	1.47	0.80	1.45	1.68	1.61
133	1.72	1.01	2.21	2.38	2.52
161	0.49	0.28	0.63	0.67	0.64
Mean colour excess	1.63±0.18	0.94±0.12	2.01±0.45	2.28±0.43	2.40±0.46
A_V	2.95±0.09	2.91±0.09	2.73±0.15	2.69±0.13	2.68±0.13

not used in this analysis, as well as being excluded from the subsequent discussions of the non-uniform extinction in the cluster. However, they have been used in the analyses of the reddening law requiring only the ratios of colour excesses.

(i) Their colour excesses in each photometric band are very low compared to the average values of the other cluster stars.

(ii) Both are situated at large distances from the cluster centre (see fig. 1 in Stone 1977).

(iii) In both colour–magnitude and colour–colour diagrams (see figs 1 and 2 in Joshi & Sagar 1983) they are located far from the cluster sequence.

Consequently, we believe that they are foreground field stars having the same proper motion as cluster stars.

The values of A_V derived from the mean values of $E(U-V)$ and $E(B-V)$ in Table 2 are in excellent agreement with each other and yield a mean value of $A_V = 2.93 \pm 0.06$ mag. Similarly, the average values of $E(V-J)$, $E(V-H)$ and $E(V-K)$ also imply almost the same value of A_V with a weighted mean of 2.70 ± 0.08 mag. Thus, the values of A_V derived from $E(U-V)$ and $E(B-V)$ are higher than that derived from $E(V-J)$, $E(V-H)$ and $E(V-K)$, which indicates that the ratios of $E(U-V)$ or $E(B-V)$ to other colour excesses are anomalous. The analyses to follow further strengthen this finding.

4.2 COLOUR EXCESS DIAGRAMS

The colour excess diagrams based on the data of Table 2 are shown in Fig. 3. The ratios of colour excesses relative to $E(B-V)$ listed in Table 3 are determined from Fig. 3 using linear

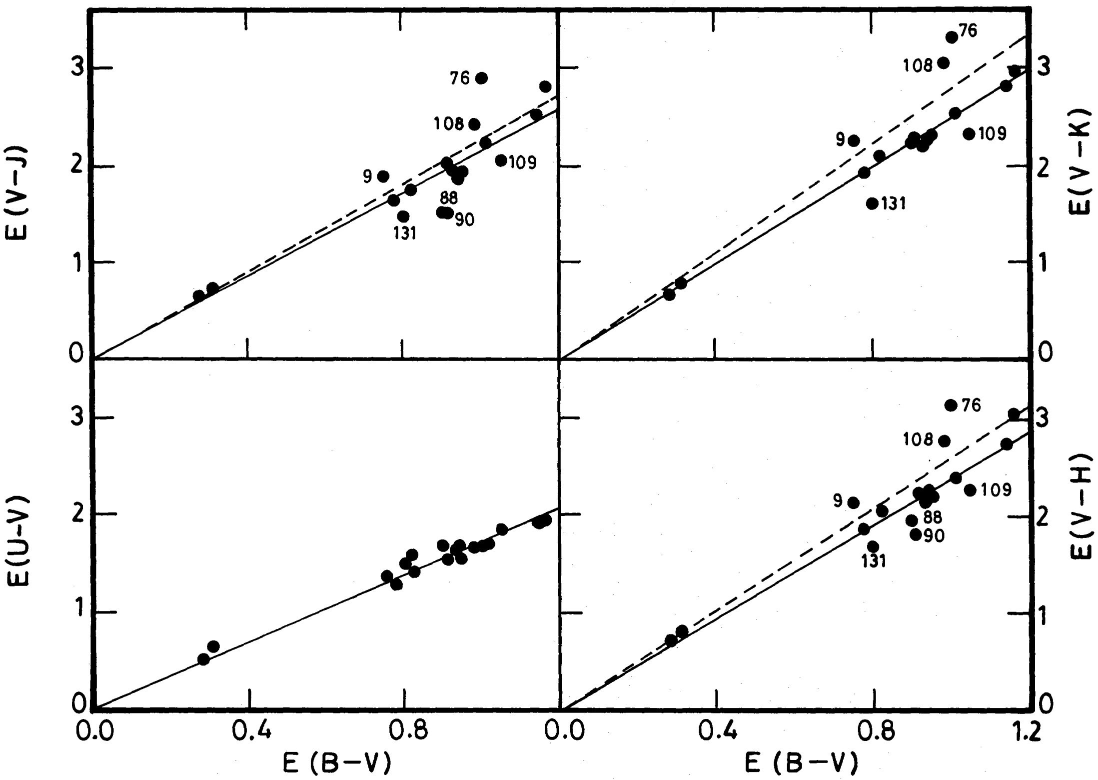

Figure 3. Colour excess diagrams for the NGC 654 stars. The solid line in each diagram shows the least squares linear fit passing through the origin and the dashed lines show the reddening directions characteristic of a normal interstellar extinction law. Stars discussed in the text are marked.

Table 3. Interstellar extinction law in the direction of NGC 654.

	$\frac{E(U-V)}{E(B-V)}$	$\frac{E(V-J)}{E(B-V)}$	$\frac{E(V-H)}{E(B-V)}$	$\frac{E(V-K)}{E(B-V)}$	$\frac{E(U-V)}{E(V-J)}$	$\frac{E(B-V)}{E(V-J)}$	$\frac{E(V-H)}{E(V-J)}$	$\frac{E(V-K)}{E(V-J)}$
Van de Hulst curve No.15	-1.71	2.30	2.58	2.78	-0.74	-0.43	1.12	1.21
Mean law (Koornneef 1983)	-	2.28	2.62	2.82	-	-0.44	1.15	1.24
Colour-excess diagrams	-1.73±0.07	2.14±0.30	2.41±0.28	2.53±0.28	-0.81±0.13	-0.47±0.07	1.13±0.05	1.19±0.13

least squares fits to the data points and forcing the lines to pass through the origin, because both a zero value to $E(B-V)$ or to any other colour excess and non-zero value for the remaining are not permitted by any interstellar extinction law. For comparison, the colour excess ratios derived from curve 15 of van de Hulst (see Johnson 1968) and those for a mean reddening law taken from Koornneef (1983) are also presented in the table. Within observational errors, they agree with those derived from the programme stars. However, it is worth pointing out that, except for $E(U-V)/E(B-V)$, the derived mean values of colour excess ratios are smaller compared with those given for normal interstellar extinction law and the discrepancy increases systematically from J to K colours. In order to see whether the colour excess ratios determined relative to any other colour excess are in better agreement with those of the normal interstellar extinction law or not, they are plotted against $E(V-J)$ in Fig. 4 and the values of colour excess ratios are presented in Table 3. The colour J is chosen because it most closely represents emission from the stellar photosphere and also is least affected by excess emissions arising from emission lines, circumstellar envelopes, etc., if they are present. Comparisons of these ratios with those derived from curve 15 of van de Hulst and the mean reddening law indicate that, except for the ratio with $E(U-V)$, agreement is better than that observed earlier relative to $E(B-V)$.

An inspection of Figs 3 and 4 indicates that:

(i) The value of $E(U-V)/E(B-V)$ given by the normal interstellar extinction law fits all the observed points very well in the plot of $E(U-V)$ versus $E(B-V)$.

(ii) An anomalous interstellar extinction law given by the mean values of the ratios of $E(V-J)$, $E(V-H)$ and $E(V-K)$ to $E(B-V)$ fits all the programme stars except 9, 76, 88, 90, 108, 109 and 131. Compared to the mean values, the individual values of these colour excess ratios are higher for stars 9, 76 and 108 and are smaller for stars 109 and 131. The remaining two stars 88 and 90 also belong to the latter group except in the $E(V-K)$ versus $E(B-V)$ plot where their $E(V-K)/E(B-V)$ values are very close to the mean value.

(iii) All the observed stars in the plots of $E(V-H)$ and $E(V-K)$ versus $E(V-J)$ can be fitted fairly well with the normal interstellar extinction law except for stars 88 and 90.

(iv) All the stars except 76, 88, 90 and 131, follow an anomalous interstellar extinction law in the $E(U-V)$ versus $E(V-J)$ and $E(B-V)$ versus $E(V-J)$ plots.

4.3 NATURE OF INTERSTELLAR EXTINCTION

Analysis of the last two sub-sections indicates that the interstellar extinction law is normal in general for the wavelengths $\lambda \geqslant \lambda_V$, where λ_V (~ 0.55 μm) is the effective wavelength of the V-

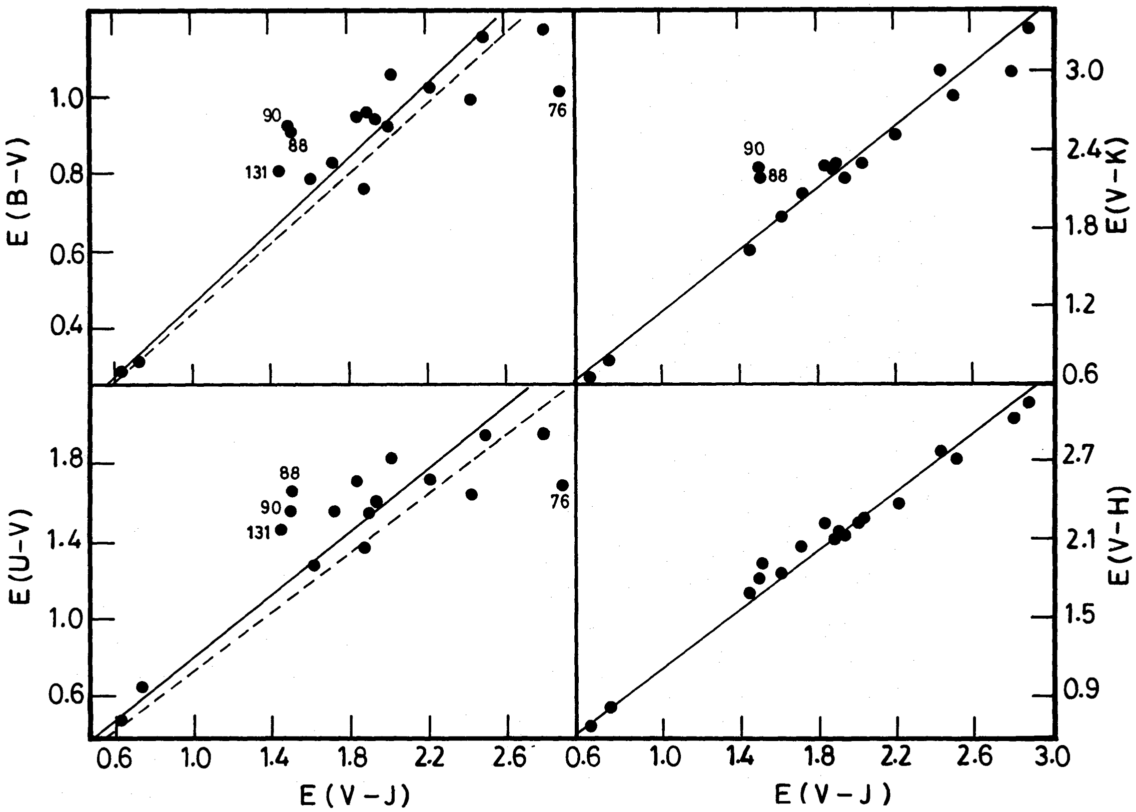

Figure 4. Plot of $E(U-V)$, $E(B-V)$, $E(V-H)$ and $E(V-K)$ against $E(V-J)$. The solid and dashed lines represent the same as in Fig. 3. In the $E(V-H)$ versus $E(V-J)$ and $E(V-K)$ versus $E(V-J)$ diagrams both the lines coincide. Stars discussed in the text are marked.

band, and is anomalous in the wavelength range of λ_U-λ_V, where λ_U (~ 0.35 μm) is the effective wavelength of the U-band. The anomaly is in the sense that the value of the total to selective absorption ratio is less than that given by the normal interstellar extinction law. A similar result has also been reported recently by Roth (1988) in the direction of the open star cluster Trumpler 37. Such results are expected if the interstellar dust present in front of the cluster stars has an anomalous grain-size distribution which increases the extinction preferentially in the U and B bandpasses. Unusually good alignment of interstellar grains in the cluster region has been indicated by Samson (1976) on the basis of polarization observations. But the extinction due to them is still such that a relatively normal value has been found for the ratio $E(U-V)/E(B-V)$.

For some stars (see Section 4.2) individual values of colour excess ratios differ significantly from the mean values. This could be because of the presence of peculiar features like emission lines, circumstellar envelopes, etc., in them, or because of interstellar reddening vectors that are different from the mean in the direction of these stars. To clarify this, high-resolution spectroscopic and polarimetric observations are required.

4.4 DISCUSSION ON THE EXTINCTION LAW

It has been long suspected that in the vicinity of hot OB stars the interstellar extinction law may be modified due to the influence of strong radiation fields on the dust grains responsible for the extinction. The present study in combination with the ones carried out by Smith (1987) and Tapia *et al.* (1988) for Carina Nebulae clusters, and by Roth (1988) for the open cluster Trumpler 37, provides an opportunity for examining this proposition. All these studies clearly indicate, within the errors, that for $\lambda \geqslant \lambda_V$ the interstellar extinction law is very close to normal if the observed colour excesses are normalized with a parameter like $E(V-J)$ that does not depend strongly on the properties of the interstellar matter responsible for the extinction (Voshchinnikov & Il'in 1987). Such normalization leads to the conclusion that the interstellar extinction anomaly affects only the extinction in U and B bandpasses.

The observed extinction anomaly in NGC 654, which is similar to that reported by Roth (1988) for Trumpler 37, implies that the material responsible for extinction seems to be less efficient at longer wavelengths, probably indicating a small shift in the grain-size distribution towards smaller grain-sizes than normal. On the other hand, in the anomalous interstellar extinction observed by Smith (1987) and Tapia *et al.* (1988) in Carina Nebulae clusters, the anomaly is due to reduced extinction in U and B bandpasses. Consequently, that effect is exactly opposite to the one observed here and in Trumpler 37, and implies a grain-size distribution biased towards larger than normal-sized particles.

Both the effects mentioned above can be understood on the basis of Seab & Shull's (1983) model if interstellar dust grain destruction is carried out by the strong radiation fields emitted by hot OB cluster members. The grain-size distributions finally resulting from Seab & Shull's (1983) model depend on the physical parameters of the interstellar material which can vary from one cluster region to other. Such variations can produce a small shift in the grain-size distribution compared to that of normal-sized particles which can reproduce both effects, depending on the direction of shift (*cf.* Roth 1988; Tapia *et al.* 1988 and references therein).

5 Intrinsic *JHK* magnitudes

In the light of the discussions of the last section the interstellar extinctions in $(V-J)$, $(V-H)$ and $(V-K)$ colours are estimated individually for each star from their colour excesses $E(V-J)$, assuming a normal interstellar extinction law. Based on the spectral type and luminosity class listed in Table 1, intrinsic colours are estimated using the calibration given by Koornneef (1983) and Schmidt-Kaler (1982). The differences between the observed intrinsic colours $(V-H)_0$ and $(V-K)_0$ and calibrated ones are listed in Table 4, which indicates that except for stars 88, 90 and 94, all stars including the heavily reddened $[E(B-V) \geqslant 1$ mag$]$ ones have normal H and K colours within the observational uncertainties. Infrared excess is present in stars 88 and 90 in the K-band, while star 94 is flux deficient in the same band. Because of the K-band excesses in stars 88 and 90, they occupy a peculiar (extreme right) position in the apparent $(J-H)$ versus $(H-K)$ diagram (Fig. 2).

The major sources of error in the differences listed in Table 4 are the uncertainty in the *JHK* values, inaccuracy in the estimation of colour excess $E(V-J)$ and its ratio with $E(V-H)$ and $E(V-K)$, errors in spectral type and luminosity classification, and the uncertainty in the calibration because conversion of observed intrinsic magnitudes to monochromatic fluxes requires knowledge of the stellar energy distributions inside the filter bandpasses. Consequently, the small K-band differences observed for stars 88, 90 and 94 cannot be statistically significant.

6 Possible cause of non-uniform extinction

In the last section we observed that the heavily reddened stars have normal colours in H and K. Instead of this, infrared excess radiation is expected if the heavy reddening of cluster members is caused by the presence of hot and ionized gas in the form of circumstellar material around them. It means that cluster stars have been able to blow off their pre-main sequence circumstellar material during their ~35 Myr main sequence lifetime (Joshi & Sagar 1983).

Table 4. Results of infrared excess and deficiency in the members of NGC 654. Δ is the spectral classification calibrated colour minus the observed colour corrected for the normal interstellar extinction law, e.g. $\Delta(V-K)=(V-K)_{\rm sp}-(V-K)_0$.

Star	Δ(V-H) (mag)	Δ(V-K) (mag)
9	0.05	0.07
52	0.02	0.06
76	0.18	0.26
78	-0.11	0.00
88	-0.18	-0.35
90	-0.06	-0.41
94	0.18	0.49
100	0.15	0.28
108	0.02	-0.01
109	0.10	0.23
111	0.11	0.24
114	0.01	0.11
119	0.09	-
125	-0.05	0.07
131	-0.01	0.19
133	0.16	0.22

Therefore, the cause of non-uniform extinction across the cluster region is the patchy distribution of local dust clouds lying in the direction of the cluster, and not the presence of circumstellar shell around the stars. This is in agreement with the findings of McCuskey & Hauk (1964) and Stone (1977, 1980).

7 Conclusions

An analysis of the present *JHK* photometry in combination with the *UBV* photoelectric photometry reported earlier by us (Joshi & Sagar 1983) and the available spectroscopic and polarization information yields the following main conclusions.

(i) At wavelengths greater than 5500 Å, the extinction law is similar to that of the normal interstellar medium. The presence of unusually well aligned interstellar grains indicated by polarization measurements seems to increase the extinction in the *U*- and *B*-bands slightly compared to the extinctions derived from near infrared colour excesses using a normal interstellar extinction law. This implies that the material responsible for extinction seems to be less efficient at longer wavelengths and, probably, its grain-size distribution has been shifted by a small amount towards smaller than normal-sized particles.

(ii) The large colour excess $E(B-V)$ observed for some cluster members is due to the presence of a patchy distribution of interstellar matter in front of them, and not because of the presence of hot and ionized gas circumstellar shells around them, as has been indicated for some young massive stars in other open clusters (see Sagar 1987 and references therein).

Acknowledgments

Useful discussions with Dr H. C. Bhatt and the constructive comments given by Dr M. Tapia as referee are gratefully acknowledged. We also thank Dr P. M. Williams for useful suggestions.

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