1990ApJ...353..174S

THE ASTROPHYSICAL JOURNAL, 353:174–180, 1990 April 10
© 1990. The American Astronomical Society. All rights reserved. Printed in U.S.A.

NEAR-INFRARED PHOTOMETRIC STUDY OF OPEN STAR CLUSTER IC 1805

RAM SAGAR
Indian Institute of Astrophysics
AND
QIAN ZHONG YU
Beijing Astronomical Observatory
Received 1988 December 6; accepted 1989 May 31

ABSTRACT

We have measured the *JHK* magnitudes of 29 stars in the region of open star cluster IC 1805. These, and the existing infrared and optical observations, indicate a normal interstellar extinction law in the direction of the cluster. Further, most of the early-type stars have near-infrared fluxes as expected from their spectral types. Patchy distribution of ionized gas and dust appears to be the cause of nonuniform extinction across the cluster face.

Subject headings: clusters: open — interstellar: matter — photometry

I. INTRODUCTION

The extremely young open star cluster IC 1805 (C0228+612) in Cassiopeia has been classified as Trumpler class II3mN by Lyngå (1984). This cluster has been extensively studied photometrically (see Hoag *et al.* 1961; Ishida 1969; Moffat 1972; Baade 1983; Joshi and Sagar 1983; Kwon and Lee 1983, and references therein) as well as spectroscopically (see Ishida 1970; Mermilliod 1986, and references therein). Relative proper-motion measurements of stars in the cluster region have been carried out by Vasilevskis, Sanders, and van Altena (1965). The recent accurate estimates of the cluster distances indicate a value of 2.4 kpc, though earlier estimates varied from 1.6 to 2.5 kpc (see Kwon and Lee 1983; Joshi and Sagar 1983).

The cluster is widely dispersed and contains one of the largest group of O stars embedded in emission nebulosity (Westerhout 1958; Akabane *et al.* 1967). The stellar radiation from such stars can modify the interstellar material present in their immediate vicinity. Thus, conditions in the cluster provide a unique opportunity for examining the effects of an intense radiation field on grains in the surrounding dust clouds and also to see how this affects the law of interstellar extinction in emmission nebulae.

Radio observations such as 4170 MHz map of Akabane *et al.* (1967) and the Hα picture (see Ishida 1969) of the cluster region show a shell-like filamentary structure with several intensity peaks. Studies at visible wavelengths (Johnson *et al.* 1961; Vasilevskis, Sanders, and van Altena 1965; Ishida 1969, 1970; Moffat 1972; Baade 1983; Joshi and Sagar 1983; Kwon and Lee 1983; Sagar 1987, 1988) indicate the presence of nonuniform extinction across the cluster region, which is not surprising in view of the extremely young age of ~1 Myr of the cluster (Sagar *et al.* 1986). The values of $E(B-V)$ of cluster members show large variation, ranging from 0.5 to 1.3 mag, and seem to be well correlated with the position of stars. It is not clear from the existing observations whether the large $E(B-V)$ observed for some cluster members is caused by the presence of relic circumstellar material around them (Reddish 1967; Sagar 1987, 1988) or by the distribution of absorbing matter in the cluster (Ishida 1969, 1970; Moffat 1972). Infrared excess radiation at wavelengths longward of about 1 μm is expected if hot and ionized gas is present in the form of circumstellar material around the stars.

We have carried out *JHK* photometry of the open cluster IC 1805 to (*a*) understand the possible cause of nonuniform extinction across the cluster region, and (*b*) study the law of interstellar extinction in the direction of the cluster. Near-infrared photometry has proved to be a useful tool for such studies (see Tapia *et al.* 1984; Smith 1987; Roth 1988; Tapia *et al.* 1988; Sagar and Qian 1989), especially when combined with observations at other wavelengths.

II. OBSERVATIONS AND REDUCTION

Twenty-nine stars brighter than $V = 13$ mag and having a high ($\geq 50\%$) probability of cluster proper-motion membership are included in the present analysis. Most of them have $E(B-V) > 0.85$ mag (Joshi and Sagar 1983).

The observations were carried out by one of us (Z. Y. Q.) between 1987 November and 1988 February on the Cassegrain focus of 1.26 m infrared telescope of Beijing Astronomical Observatory located at the Xinglong station. The details of instruments used for the observations are given elsewhere (Hu 1986; Sagar and Qian 1989).

Instrumental magnitudes of the program stars were first corrected for atmospheric extinction and then converted into standard system using the color equation given earlier by Sagar and Qian (1989) for the open star cluster NGC 654 which was also observed during the same period.

The error in *JHK* magnitudes for a single observation has been estimated as $[(1.09/\mathrm{S/N})^2 + E^2]^{1/2}$, where S/N is the signal-to-noise ratio; and E is the error in fixing the zero point of the photometric system, which is better than 0.02–0.03 mag in all three passbands. While this is the main source of error in *JHK* magnitudes of stars brighter than 9.0 mag, poor S/N is the major source of error in the observations of faint stars. The stars have generally been observed twice on different nights, and their weighted average as well as the corresponding observational errors are listed in Table 1.

We find from the infrared catalog of Gezari, Schmitz, and Mead (1987) that three stars in the cluster region have infrared magnitudes. Only one of them, star 160, has been observed by us; present *JHK* magnitudes are in very good agreement with

© American Astronomical Society • Provided by the NASA Astrophysics Data System

1990ApJ...353..174S

TABLE 1

JHK MAGNITUDES OF PROGRAM STARS

Star	$J \pm \sigma$ (mag)	$H \pm \sigma$ (mag)	$K \pm \sigma$ (mag)	P (%)	V (mag)	Spectral Type
18	10.78 ± 0.07	10.41 ± 0.06	10.16 ± 0.07	78	12.61	(B1.5 V)
21	8.93 ± 0.02	8.58 ± 0.02	8.46 ± 0.02	71	11.29	B0 IV
23	9.38 ± 0.02	9.22 ± 0.02	9.06 ± 0.03	83	11.45	B1 V
49	10.36 ± 0.08	10.08 ± 0.05	9.90 ± 0.05	72	12.80	(B0.5 V)
53	10.98 ± 0.09	10.90 ± 0.09	10.79 ± 0.11	70	12.82	(B3 V)
62	10.70 ± 0.09	10.48 ± 0.05	10.49 ± 0.08	87	12.54	(B1 V)
69	10.88 ± 0.07	10.30 ± 0.04	10.50 ± 0.08	82	12.34	(B2 V)
70	6.57 ± 0.02	6.38 ± 0.02	6.21 ± 0.02	85	8.31	B0.5 Ia
72	10.54 ± 0.06	10.38 ± 0.05	10.34 ± 0.03	80	12.38	(B1 V)
74	7.50 ± 0.02	6.74 ± 0.02	6.54 ± 0.02	63	11.40	K0 II
82	10.45 ± 0.06	10.36 ± 0.05	10.12 ± 0.05	84	12.50	(B1.5 V)
103	9.40 ± 0.02	9.37 ± 0.02	9.29 ± 0.03	84	10.56	B0 V
104	7.48 ± 0.02	7.36 ± 0.02	7.32 ± 0.02	79	8.79	O7 V
111	10.59 ± 0.05	10.29 ± 0.05	10.28 ± 0.07	87	11.52	B2 V
112	8.87 ± 0.02	8.80 ± 0.02	8.72 ± 0.02	89	9.92	O9 V
113	8.47 ± 0.02	8.06 ± 0.02	7.67 ± 0.02	85	10.92	O9 VE
118	9.00 ± 0.02	9.00 ± 0.02	8.89 ± 0.02	86	10.30	O9 V
121	10.30 ± 0.06	10.26 ± 0.05	10.06 ± 0.09	74	11.59	(B1.5 V)
136	9.73 ± 0.03	9.65 ± 0.03	9.34 ± 0.05	77	11.04	(B1 V)
138	8.64 ± 0.02	8.66 ± 0.02	8.74 ± 0.03	80	9.58	O6.5 V
143	8.38 ± 0.02	8.33 ± 0.02	8.31 ± 0.02	86	11.40	(O9 V)
149	10.14 ± 0.07	10.14 ± 0.05	10.07 ± 0.08	86	11.24	B3 V
152[a]	11.84 ± 0.21	11.58 ± 0.16	10.99 ± 0.16	77	12.96	(B2.5 V)
160	6.42 ± 0.02	6.29 ± 0.02	6.16 ± 0.02	64	8.11	O5 Ia
169	10.54 ± 0.09	10.37 ± 0.06	10.31 ± 0.09	82	11.73	B2 IV
170[a]	9.14 ± 0.03	9.14 ± 0.03	9.11 ± 0.04	75	10.07	A2 II
183[a]	10.08 ± 0.06	10.07 ± 0.07	9.99 ± 0.09	80	11.15	B1 II
211[a]	10.38 ± 0.08	10.34 ± 0.07	10.32 ± 0.12	85	11.03	B1 V
221[a]	10.45 ± 0.08	10.45 ± 0.13	10.39 ± 0.20	86	11.64	B8 II–III
148[b]	6.76	6.59	6.52	6	7.87	O6
192[b]	7.54	7.38	7.28	67	8.43	O5 V

NOTES.—Stars are numbered according to Vasilevskis, Sanders, and van Altena 1965. *p* is taken from Zhao *et al.* 1985. Photometric spectral types are given in parentheses.

[a] *JHK* values are based on only one set of observations.

[b] *JHK* magnitudes are borrowed from the *IRAS* Catalog.

those listed in the catalog. For the other two stars, 148 and 192, *JHK* magnitudes borrowed from the infrared catalog are listed in Table 1 and have been used in further analyses.

III. CLUSTER MEMBERSHIP OF STARS

Relative proper motions of 354 stars in the cluster region have been determined by Vasilevskis, Sanders, and van Altena (1965) with a mean error of ±0".16 per century. Using these data, Zhao *et al.* (1985) have estimated in a relatively reliable way the probability of cluster membership, *p*. A histogram of *p* of all the investigated stars indicates that most of them have either $p \leq 20\%$ or $p \geq 60\%$. It means that relative proper-motion data have been able to segregate cluster members from field stars. The statistically expected number of field stars, estimated on the basis of median *p* of the sample is five, although only one star, 148, of the sample has a very low value of $p = 6\%$. Ishida (1969, 1970) has considered this star as a cluster member based on its *UBV* data and spectral type. Therefore we have included it in our analyses.

IV. THE OBSERVED $J-H$ VERSUS $H-K$ DIAGRAM

The apparent $J-H$ versus $H-K$ diagram for the program stars is plotted in Figure 1, where reddening vector for normal interstellar extinction law seems to fit the data satisfactorily. In Figure 1, the observational points show a greater spread along the reddening vector than in the perpendicular direction. This cannot be explained by observational errors alone and indicates the presence of nonuniform extinction in the cluster region, in agreement with the findings at visual wavelengths (see § I). The positions of stars 69, 113, and 152 are peculiar in the sense that $H-K$ value is too blue for the corresponding $J-H$ value for star 69, and $H-K$ colors are too red for stars 113 and 152. All the three stars have a high *p* value ($\geq 77\%$) and are also located toward the cluster center (see Fig. 2 in Vasilevskis, Sanders, and van Altena 1965). The possibility that they are cluster members is therefore very high, and their peculiar position in Figure 1 will be discussed in detail later.

V. INTERSTELLAR EXTINCTION LAW

Several authors have estimated the value of total-to-selective absorption $R = A_V/E(B-V)$ in the direction of IC 1805 with a view to studying the nature of interstellar extinction, but their results are at variance with each other. Johnson (1968) obtained $R = 5.7$, indicating anomalous interstellar extinction law. On the other hand, Ishida (1969) and Kwon and Lee (1983) found $R = 3.8$ and 3.44, respectively. These values indicate that interstellar extinction law is not very different from the normal one. Kwon and Lee (1983) also found regional variation in the value of *R*, with the maximum at 3.82 ± 0.15

© American Astronomical Society • Provided by the NASA Astrophysics Data System

1990ApJ...353..174S

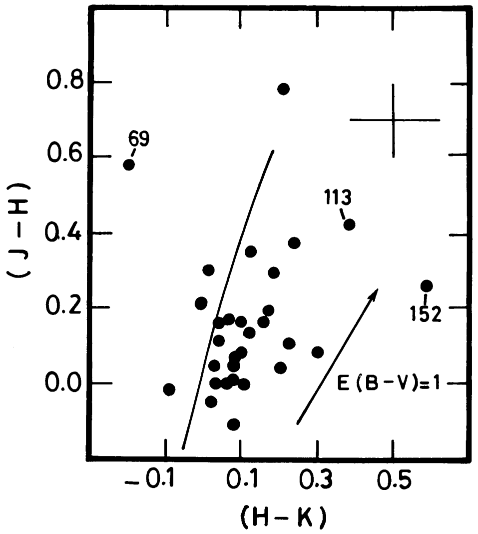

FIG. 1.—$J-H$ vs. $H-K$ diagram of stars under study. Cross represents a typical uncertainty. Continuous curve is the intrinsic main sequence taken from Koornneef (1983). Reddening vector for $E(B-V) = 1$ mag is shown by an arrow.

for stars located in the outer region, and the minimum at 3.06 ± 0.05 for stars located in the central region.

In the light of above discussions, we decided to reexamine the interstellar extinction law in the direction of the cluster. We have calculated the color excesses by pooling the present infrared data with the *UBV* photoelectric data of Joshi and Sagar (1983) and two-dimensional spectral types given by Ishida (1970) and Mermilliod (1986). These color excesses have been used to determine the reddening vectors. In the absence of spectroscopic information for the program stars, photometric spectral types have been estimated using *UBV* photometric *Q*-method described in detail in Sagar and Joshi (1979). Luminosity classes of these stars are based on their location in the intrinsic color-magnitude diagrams of the cluster (Joshi and Sagar 1983). The spectral types and V magnitudes of program stars are listed in Table 1. Color excesses are calculated using the spectral type–intrinsic color calibrations given by Koornneef (1983) and Schmidt-Kaler (1982) for the different luminosity classes. $E(U-V)$ and $E(B-V)$ are generally uncertain by ~0.05 mag, while $E(V-J)$, $E(V-H)$, $E(V-K)$, $E(V-L)$, and $E(V-M)$ have a typical error of ~0.10 mag. This is mainly because *UBV* magnitudes are more accurate than *JHKLM* magnitudes.

As all the color excesses for star 170 are significantly smaller than the corresponding average values of other cluster members, it has been considered as a foreground field star having the same proper motion as cluster members. It has therefore been excluded from the further analyses.

In order to understand the nature of interstellar extinction in the direction of cluster at both optical and near-infrared wavelengths, the following analyses have been carried out.

1. For each star the values of V-band extinction A_V are estimated from $E(U-V)$, $E(B-V)$, $E(V-J)$, $E(V-H)$, and $E(V-K)$ assuming a normal interstellar extinction law. Their mean values and standard deviation are given in Table 2. The values of A_V so obtained for a star generally agree with each

TABLE 2

$E(V-J)$ AND COLOR EXCESS RATIOS

Star	$E(V-J)$ (mag)	A_V (mag)	R	$\frac{E(U-V)}{E(V-J)}$	$\frac{E(B-V)}{E(V-J)}$	$\frac{E(V-H)}{E(V-J)}$	$\frac{E(V-K)}{E(V-J)}$	$\frac{E(V-L)}{E(V-J)}$	$\frac{E(V-M)}{E(V-J)}$
18.......	2.41	3.39 ± 0.07	3.2	0.78	0.45	1.20	1.31		
21.......	3.04	4.09 ± 0.07	3.2	0.75	0.42	1.15	1.21		
23.......	2.69	3.52 ± 0.08	3.1	0.72	0.41	1.10	1.17		
49.......	3.08	4.23 ± 0.14	2.9	0.79	0.45	1.13	1.20		
53.......	2.03	3.02 ± 0.11	2.8	0.73	0.44	1.07	1.13		
62.......	2.46	3.33 ± 0.13	2.8	0.77	0.46	1.13	1.14		
69.......	2.00	2.85 ± 0.16	3.0	0.76	0.46	1.33	1.25		
70.......	2.25	3.08 ± 0.12	3.0	0.81	0.45	1.11	1.20		
72.......	2.46	3.02 ± 0.26	3.5	0.61	0.36	1.11	1.14		
74.......	2.19	2.91 ± 0.21	3.2	0.82	0.39	1.11	1.15		
82.......	2.63	3.38 ± 0.11	3.2	0.69	0.40	1.07	1.18		
103......	1.84	2.48 ± 0.12	2.9	0.80	0.44	1.08	1.16		
104......	2.03	2.73 ± 0.05	3.0	0.75	0.44	1.14	1.18		
111......	1.47	2.13 ± 0.09	2.9	0.78	0.50	1.27	1.30		
112......	1.75	2.45 ± 0.15	2.8	0.84	0.47	1.12	1.19		
113......	3.15	4.16 ± 0.32	3.8	0.68	0.38	1.18	1.31		
118......	2.00	2.62 ± 0.08	3.0	0.74	0.43	1.07	1.15		
121......	1.87	2.56 ± 0.13	2.8	0.79	0.47	1.07	1.20		
136......	1.93	2.65 ± 0.08	3.1	0.77	0.46	1.09	1.27		
138......	1.66	2.24 ± 0.18	2.5	0.81	0.47	1.09	1.07		
143......	3.72	3.38 ± 1.01	5.1	0.40	0.23	1.05	1.07		
148......	1.83	2.46 ± 0.14	3.0	0.66	0.45	1.18	1.25	1.29	1.36
149......	1.56	1.99 ± 0.12	2.8	0.65	0.44	1.05	1.11		
152......	1.63	2.64 ± 0.31	3.0	0.98	0.58	1.21	1.60		
160......	2.38	3.12 ± 0.08	3.1	0.74	0.42	1.09	1.16	1.28	1.41
169......	1.73	2.43 ± 0.12	2.8	0.82	0.48	1.15	1.21		
183......	1.69	2.34 ± 0.22	2.5	0.81	0.51	1.06	1.13		
192......	1.61	2.31 ± 0.09	3.1	0.85	0.47	1.20	1.29	1.34	
211......	1.27	2.05 ± 0.46	1.9	1.13	0.67	1.11	1.17		
221......	1.40	1.79 ± 0.20	3.2	0.84	0.36	1.02	1.07		

1990ApJ...353..174S

other within the standard deviation of 0.25 mag. However, for stars 72, 113, 143, 152, and 211 they differ significantly.

2. Whittet and van Breda (1980) suggest that in the absence of complete data at long wavelengths, the approximation $R = 1.1E(V-K)/E(B-V)$ generally used to deduce R is relatively insensitive to the adopted reddening law. Therefore we have used this relation to evaluate the value of R and have listed them in Table 2. For stars 72, 113, 143, and 211, the values of R differ significantly from its normal value.

3. In the observational studies of interstellar extinction law, it is now customary to use parameters like $E(V-J)$ and $E(V-K)$, instead of $E(B-V)$ (Smith 1987; Roth 1988; Tapia *et al.* 1988; Sagar and Qian 1989), because they do not depend on properties like the chemical composition, shape, and structure, degree of alignment of the interstellar matter (Voschinnikov and Il'in 1987). Also, they are better measure of the total amount of interstellar extinction because of their larger values compared to either near-infrared or optical color excesses. However, the color excess to be used as a measure of interstellar extinction should be selected carefully as the cluster is embedded in emission nebulosity and also contains young stellar objects. In such circumstances, the blueing effects, ultraviolet excess, circumstellar dust, and gas shells, etc., may be present in and around the cluster members. It is therefore preferable to use V passband rather than U or B, because it is least affected in such cases. Similarly, in the near-infrared, J passband is preferred, with a view to minimizing the contributions from the possible presence of circumstellar material, etc., around young stellar objects and also to choose a photometric band which most closely represents the emission from the stellar photosphere. We have therefore estimated the color excess ratios relative to $E(V-J)$. The results are listed in Table 2. For stars 69, 72, 113, 143, 152, and 211, the values of at least two color excess ratios or R significantly differ from the corresponding values given by a normal interstellar extinction law. Also their A_V values estimated from different color excesses generally differ significantly from each other. Consequently they have not been included in the analysis of the reddening law. They either follow different interstellar extinction law or have near-infrared excesses. They are discussed in the next section.

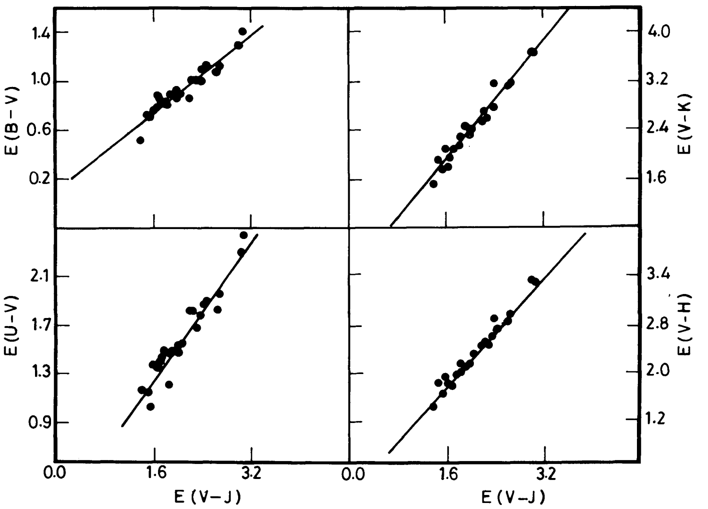

FIG. 2.—Color excess diagrams for IC 1805. Solid line in each diagram represents the least-squares linear fit to the data points.

The color excesses $E(U-V)$, $E(B-V)$, $E(V-H)$, and $E(V-K)$ are plotted against $E(V-J)$ in Figure 2, where solid lines represent the following least squares linear fits.

$$E(U-V) = 0.71(\pm 0.04)E(V-J) + 0.12(\pm 0.09)\,, \quad r = 0.96\,;$$

$$E(B-V) = 0.40(\pm 0.03)E(V-J) + 0.10(\pm 0.06)\,, \quad r = 0.96\,;$$

$$E(V-H) = 1.13(\pm 0.05)E(V-J) - 0.03(\pm 0.10)\,, \quad r = 0.98\,;$$

$$E(V-K) = 1.21(\pm 0.06)E(V-J) - 0.5(\pm 0.12)\,, \quad r = 0.98\,;$$

where r is the regression coefficient of the linear relation. The slopes of these straight lines represent reddening directions in the form of color excess ratios and are given in Table 3 along with the mean reddening directions determined from the ratios of color excesses. For comparison, the color excess ratios derived from curve 15 of van de Hulst (see Johnson 1968) and those given by Koornneef (1983) are also listed in the table. The present reddening directions agree very well with those given for the normal interstellar extinction law.

4. Following Tapia *et al.* (1988), the ratios $E(V-K)/E(B-V)$ and $E(V-K)/E(V-J)$ are plotted against $E(V-K)$ in Figure 3. The horizontal line in the diagram represents the value of the ratio for the normal interstellar extinction law. In the case of anomalous interstellar extinction law, the ratio $E(V-K)/E(B-V)$ varies significantly with the optical depth (Tapia *et al.* 1988), as expressed by the value of $E(V-K)$ here, while the value of $E(V-K)/E(V-J)$ remains the same for all the values of $E(V-K)$. Least-squares linear fits to the data points yield

$$E(V-K)/E(B-V) = 0.14(\pm 0.06)E(V-K) + 2.32(\pm 0.16)\,, \quad r = 0.43\,;$$

$$E(V-K)/E(V-J) = 0.03(\pm 0.02)E(V-K) + 1.11(\pm 0.06)\,, \quad r = 0.29\,.$$

TABLE 3

REDDENING LAW IN THE DIRECTION OF IC 1805

Source	$\frac{E(U-V)}{E(V-J)}$	$\frac{E(B-V)}{E(V-J)}$	$\frac{E(V-H)}{E(V-J)}$	$\frac{E(V-K)}{E(V-J)}$	$\frac{E(V-L)}{E(V-J)}$	$\frac{E(V-M)}{E(V-J)}$
van de Hulst curve 15	0.74	0.43	1.13	1.21	1.27	1.30
Mean law[a]	...	0.44	1.15	1.24	1.30	1.33
Color excess diagrams	0.71 ± 0.04	0.40 ± 0.03	1.13 ± 0.05	1.21 ± 0.06		
Color excess ratios	0.77 ± 0.07	0.44 ± 0.05	1.12 ± 0.07	1.19 ± 0.08	1.30 ± 0.03	1.38 ± 0.04

[a] Values are taken from Koornneef 1983.

© American Astronomical Society • Provided by the NASA Astrophysics Data System

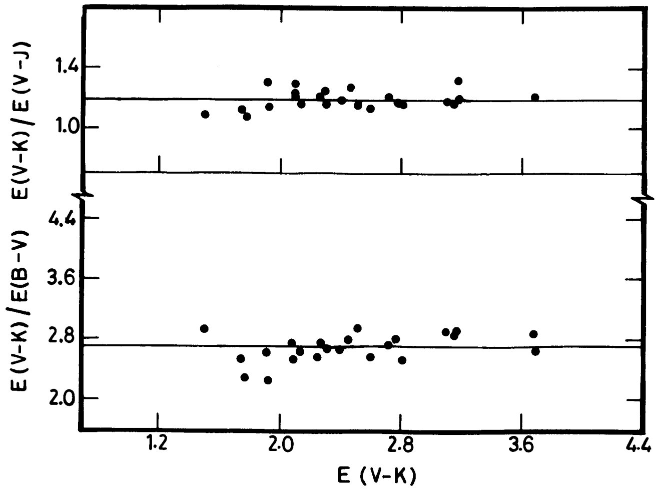

FIG. 3.—Plot of $E(V-K)/E(B-V)$ and $E(V-K)/E(V-J)$ against $E(V-K)$. Values of the ratios for the normal interstellar extinction law have been shown by horizontal lines.

As the values of r are <0.5, linear relations are not statistically significant. This may therefore imply absence of anomalous interstellar extinction law toward the cluster.

5. Hiltner (1956) has given the degree of polarization for seven of our program stars. We first estimated the value of A_V from $E(V-J)$ assuming the normal interstellar extinction law and then calculated the ratio of degree of polarization to A_V for them. The ratio varies from 0.03 to 0.06 with a mean value of 0.05 ± 0.01 which is very close to the normal value of 0.06. The polarization measurements, thus, indicate the presence of normal interstellar extinction law in the direction of IC 1805.

a) Interstellar Extinction Law around Peculiar Stars

We thus conclude that the interstellar extinction law in the direction of most of the cluster member is normal. However, as mentioned earlier, the observed values of color excesses for stars 69, 72, 113, 143, 152, and 211 (see Table 2) merit further discussion. For stars 72, 143, and 211 the values of $E(U-V)/E(B-V)$, $E(V-H)/E(V-J)$, and $E(V-K)/E(V-J)$ are in good agreement with the corresponding values given by the normal interstellar extinction law. But the $E(U-V)/E(V-J)$ and $E(B-V)/E(V-J)$ values are significantly different from the corresponding normal values. This may imply the presence of anomalous extinction in the vicinity of these stars. For stars 72 and 143, the anomaly is due to reduced extinction in *U* and *B* passbands and is similar to the one observed in the direction of Carina nebula clusters by Smith (1987) and Tapia *et al.* (1988). In the case of star 211, however, opposite effect is seen. This is similar to that reported by Roth (1988) and Sagar and Qian (1989) in open star clusters Trumpler 37 and NGC 654, respectively.

For stars 69, 113, and 152, the values of $E(V-H)/E(V-J)$ and $E(V-K)/E(V-J)$ are larger than the corresponding normal values. For star 152, the ratios $E(U-V)/E(V-J)$ and $E(B-V)/E(V-J)$ are also large. The peculiar color excess ratios observed for these stars may be due either to the presence of small infrared excesses (see § VI) or their interstellar reddening vectors being different from the mean. As the reddening law is generally normal at the wavelengths $\lambda \geq \lambda_V$ and star 113 is a known type of emission star (see Table 1), we suspect that the former is responsible for the peculiarities of the ratios of color successes. However, to confirm this, polarimetric and high-resolution spectroscopic observations are required.

b) Interstellar Extinction Law around Hot OB Stars

It has long been suspected that in the vicinity of hot OB stars, the interstellar extinction law may be modified due to the influence of strong radiation field on the dust grains responsible for the extinction. The present study, in combination with the similar ones in Carina nebula clusters (Smith 1987; Tapia *et al.* 1988), NGC 654 (Sagar and Qian 1989), OB associations (Leitherer and Wolf 1984), and Trumpler 37 (Roth 1988), provides an excellent opportunity to examine this proposition as large numbers of OB stars are present in the regions of these objects. The effects observed in these studies can be divided into the following three groups.

1. The results of IC 1805 (except for the regions in the immediate vicinity of stars 72, 143, and 211) and OB associations indicate that strong radiations coming from massive OB stars have not changed the size distribution of grains responsible for extinction compared to that of normal-sized dust particles. The interstellar extinction law is therefore normal and is similar to van de Hulst's theoretical curve 15.

2. The anomalous interstellar extinction observed in the regions of NGC 654, Trumpler 37, and stars 72 and 211 in IC 1805 belongs to this group. The matter responsible for the extinction in these regions seems to be less efficient at longer wavelengths, probably indicating a small shift in the grain size distribution toward smaller sized than normal.

3. The anomalous effect observed in the regions around star 143 in IC 1805 and in Carina nebula clusters is exactly opposite to the one discussed above. In these regions, grain size distribution seems to be biased toward larger than normal sized particles.

In the regions of group 2 and 3 clusters, the anomaly in the law of interstellar extinction is such that it either increases or reduces extinction only in *U* and *B* bandpasses keeping the values normal for $E(U-V)/E(B-V)$ and near-infrared color excess ratios. This makes the extinction in these regions quite different from that in dense molecular clouds, like those in Ophiuchus (Chini 1981) and Orion (Breger, Gehrz, and Hackwell 1981), where most color excess ratios differ from the corresponding normal values. It seems clear that intracluster dust grains in the regions under discussion show quite different extinction properties than the general interstellar material and dense molecular clouds.

The interstellar extinction law around hot OB stars can be understood in terms of Seab and Shull's (1983) model of interstellar dust grain processing due to the 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 OB stars can be 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 larger grains can arise. On the other hand, a small shift in the

TABLE 4

Results of H and K Flux Excess and Deficiency

Star	$\Delta(V-H)$ (mag)	$\Delta(V-K)$ (mag)
18	−0.19	−0.30
21	−0.11	−0.07
23	0.06	0.05
49	−0.03	−0.03
53	0.11	0.14
62	−0.03	0.12
69	−0.43	−0.13
70	0.02	−0.03
72	0.04	0.13
74	0.02	0.09
82	0.12	0.03
103	0.07	0.07
104	−0.04	0.02
111	−0.22	−0.16
112	0.00	−0.01
113	−0.18	−0.39
118	0.10	0.08
121	0.08	0.03
136	0.05	−0.16
138	0.05	0.21
143	0.26	0.45
148	−0.11	−0.10
149	0.11	0.12
152	0.13	−0.65
160	0.08	0.06
169	−0.05	−0.04
183	0.09	0.09
192	−0.13	−0.16
211	0.01	0.04
221	0.14	0.17

Note.—Δ is the spectral type calibrated color minus observed intrinsic color, e.g., $\Delta(V-H) = (V-H)_{\rm SP} - (V-H)_O$.

opposite direction can be found if the large sized grains are destroyed.

VI. NEAR-INFRARED FLUXES

It is well known that the presence of hot and ionized gas in the form of a circumstellar shell around young stars can be indicated by excess radiation at wavelengths longward of about 1 μm. In order to determine the presence of such radiations in the cluster members, the following simple analysis has been performed. Based on the spectral classification of the cluster stars, intrinsic colors are assigned using Koornneef's (1983) calibration. Their differences with the corresponding observed intrinsic colors are listed in Table 4. They indicate that most of the heavily reddened [$E(V-J) > 2.5$ mag] stars have normal near-infrared colors. Only for stars 69, 113, 143, and 152, the differences are ≥0.35 mag in H or K passband. The peculiar location of stars 69, 113, and 152 in the apparent $J-H$ versus $H-K$ diagram (Fig. 1) also supports the above statement.

The major sources of error in the differences listed in Table 4 are (*a*) the observational uncertainties in *JHK* magnitudes, which are more pronounced for star 152 (see Table 1); (*b*) inaccuracies in the estimation of $E(V-J)$ and in its ratio with $E(V-H)$ and $E(V-K)$, which can be the case for star 143 (see § V); (*c*) uncertainty in the calibration of observed *JHK* magnitudes because their conversion to monochromatic fluxes requires knowledge of the energy distributions inside the filter bandpasses to be secure; and (*d*) errors in the spectral and luminosity classifications. Consequently, the small H or K differences observed in the above stars cannot be statistically significant.

VII. CONCLUSIONS

We have carried out *JHK* observations for 29 stars brighter than $V = 13$ mag in the region of open cluster IC 1805. Analysis of the present data in combination with photometric, spectroscopic, *IRAS*, and polarimetric data yields the following results.

1. The interstellar extinction law in the direction of most of the cluster members is normal.

2. In Seab and Shull's (1983) model, the grain size distribution resulting from the interaction of strong radiations of hot OB stars depends upon the physical conditions prevailing in the intracluster material, which in turn therefore decides whether the nature of interstellar extinction in the vicinity of hot OB stars is normal or anomalous. A small shift in the grain size distribution toward either direction compared to normal can produce anomalous interstellar extinction only in U and B passbands.

3. It is the presence of filamentary structure in the ionized gas and dust rather than of circumstellar material around cluster members that appears to be responsible for the large range in the values of their color excesses.

4. Leitherer and Wolf (1984) found that young stars like the present ones generally show infrared excess in L and M. Only three of the O-type stars in our list have L and M magnitudes from the *IRAS* catalog. None of them shows any excess radiation.

We thank Drs. H. C. Bhatt, S. K. Jain, and R. K. Kochhar for useful discussions and also for reading the manuscript, and an anonymous referee for comments.

REFERENCES

Akabane, K., Miyazawa, K., Takahash, T., Ishizawa, Y., and Nakajima, T. 1967, *Tokyo Astr. Bull.*, **177**, 241.
Baade, D. 1983, *Astr. Ap. Suppl.*, **51**, 235.
Breger, M., Gehrz, R. D., and Hackwell, J. A. 1981, *Ap. J.*, **248**, 963.
Chini, R. 1981, *Astr. Ap.*, **99**, 346.
Gezari, D. Y., Schmitz, M., and Mead, J. M. 1987, in *Catalog of Infrared Observations* (2d ed.; NASA Pub. No. 1196).
Hiltner, W. A. 1956, *Ap. J. Suppl.*, **2**, 289.
Hoag, A. A., Johnson, H. L., Iriarte, B., Mitchell, R. I., Hallam, K. L., and Sharpless, S. 1961, *Pub. US Naval Obs.*, **17**, 490.
Hu, J. W. 1986, in *Proc. 2d Japan—China Workshop on Stellar Activities and Observational Techniques*, ed. K. Sadakane and A. Yamasaki (Kyoto: University of Kyoto), p. 185.
Ishida, K. 1969, *M.N.R.A.S.*, **144**, 55.
———. 1970, *Pub. Astr. Soc. Japan*, **22**, 277.
Johnson, H. L. 1968, in *Nebulae and Interstellar Matter*, ed. B. M. Middlehurst and L. M. Aller (Chicago: University of Chicago Press), chap. 5.
Johnson, H. L., Hoag, A. A., Iriarte, B., Mitchell, R. I., and Hallam, K. L. 1961, *Lowell Obs. Bull.*, **5**, 133.
Joshi, U. C., and Sagar, R. 1983, *J.R.A.S. Canada*, **77**, 40.
Koornneef, J. 1983, *Astr. Ap.*, **128**, 84.
Kwon, S. M., and Lee, S. W. 1983, *J. Korean Astr. Soc.*, **16**, 7.
Leitherer, C., and Wolf, B. 1984, *Astr. Ap.*, **132**, 151.
Lyngå, G. 1984, in *Catalogue of Open Star Clusters Data*, 1/1 S7041 (Strasbourg: Centre de Donnees stellaires).
Mermilliod, J.-C. 1986, *Bull. Inf. CDS*, **31**, 175.
Moffat, A. F. J. 1972, *Astr. Ap. Suppl.*, **7**, 355.
Reddish, V. C. 1967, *M.N.R.A.S.*, **135**, 251.
Roth, M. 1988, *M.N.R.A.S.*, **233**, 773.
Sagar, R. 1987, *M.N.R.A.S.*, **228**, 483.

Sagar, R. 1988, *Vistas Astr.*, **31**, 503.
Sagar, R., and Joshi, U. C. 1979, *Ap. Space Sci.*, **66**, 3.
Sagar, R., Piskunov, A. E., Myakutin, V. I., and Joshi, U. C. 1986, *M.N.R.A.S.*, **220**, 383.
Sagar, R., and Qian, Z. Y. 1989, *M.N.R.A.S.*, **240**, 551.
Schmidt-Kaler, Th. 1982, in *Landolt/Bornstein, Numerical Data and Functional Relationships in Science and Technology, New Series*, Group VI, Vol. **2(b)** ed. K. Schaifers and H. H. Voigt (Berlin: Springer), p. 14.
Seab, C. G., and Shull, J. M. 1983, *Ap. J.*, **275**, 652.
Smith, R. G. 1987, *M.N.R.A.S.*, **227**, 943.
Tapia, M., Roth, M., Costero, R., and Navarro, S. 1984, *Rev. Mexicana Astr. Ap.*, **9**, 65.
Tapia, M., Roth, M., Marraco, H., and Ruiz, M. T. 1988, *M.N.R.A.S.*, **232**, 661.
Vashchinnikov, N. N., and Il'in, V. B. 1987, *Soviet Astr. Letters*, **13**, 157.
Vasilevskis, S., Sanders, W. L., and van Altena, W. F. 1965, *A.J.*, **70**, 806.
Westerhout, G. 1958, *Bull. Astr. Inst. Netherlands*, **14**, 215.
Whittet, D. C. B., and van Breda, I. G. 1980, *M.N.R.A.S.*, **192**, 467.
Zhao, J. L., Tian, K. P., Jing, J. Y., and Yin, M. G. 1985, in *Special Issue for Tables of Membership for 42 Open Clusters* (Shanghai: Shanghai Observatory, Akademica Sinica).

Z. Y. QIAN: Beijing Astronomical Observatory, Chinese Academy of Sciences, Beijing, 100080, China

R. SAGAR: Indian Institute of Astrophysics, Bangalore 560034, India