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PHOTOMETRY IN UBVRIJHKL OF THE EARLY MAIN SEQUENCE IN THE PLEIADES DOWN TO GOV

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SUMARIO

Se hizo fotometría fotoeléctrica en UBVRIJHKL para treinta y nueve miembros de las Pléyades, en un intento para determinar la dependencia en longitud de onda de la extinción interestelar en todo el cúmulo. Durante esta investigación, se encontró exceso en el infrarojo en algunas de las estrellas observadas que no podía ser debido totalmente a enrojecimiento interestelar. Este exceso infrarojo fue interpretado en algunas estrellas de tipo espectral B, como emisión infraroja proveniente de una envolvente circunestelar. No solamente se encontraron excesos en el infrarojo, sino que también deficiencias y finalmente se encontró exceso infrarojo en una estrella ráfaga miembro del Cúmulo.

ABSTRACT

Photoelectric photometry in UBVRIJHKL of thirthy-nine members of the Pleiades cluster was obtained in an attempt to determine the dependence of interstellar extinction on wavelength throughout the cluster. In the process of the investigation infrared excess was found in some of the members not totally due to interstellar reddening. For some B stars, the infrared excesses were interpreted as infrared emission from circumstellar shells. It was found that not only excesses are present, but deficiencies as well, and finally, infrared excess was found for a flare star in the Pleiades.

Introduction

As a consequence of the recent developments in infrared detectors long-wavelength observations, otherwise difficult, have become possible. In recent years an extensive amount of work has been done in this part of the spectrum, ranging from bright stars to quasars, from problems of galactic structure to problems of evolution; one of the subjects that has received attention has been the law of interstellar extinction. Several studies have been published on the subject primarily by Johnson and Borgman (1963), Johnson (1965, 1967a, 1968) and Lee (1968), in which they show that the extinction law is not the same throughout the galaxy. Initially, the purpose of this work was to make a detailed study of the interstellar extinction in the Pleiades cluster, but during its development, some particular characteristics in the cluster were disclosed that prevented us from carrying out the original idea; however, these findings may contribute to a better understanding of the Pleiades cluster as a whole.

Observations

The present investigation is based on observations with Johnson's UBVRIJHKL equipment for thirty nine members of the Pleiades, ranging from B6 to GO in spectral type. The observations were made on the photometric system defined by Johnson, Mitchell, Iriarte and Wisniewski (1966a); an additional filter (the H filter) at a wavelength of 1.62 μ was used for all the stars.

The observational data are listed in Table 1. The numbers in the first column are those of Hertzsprung (1947). The number of observations given in columns 11 and 12 refer only to the infrared photometry. The spectral types are from Mendoza (1956). The rotational velocities and the notes are from Anderson, Stoeckly and Kraft (1966). The indication that four of the members have Hα in emission was taken from Merrill's list (1933)

The probable erros of the infrared observations are given in Table 2 as averages for the different magnitude intervals. It should be mentioned that the observations of faint objects were made possible not only as result of improvements in the detectors but also due to the refinements in Johnson's photometers. In reality, the principal source of the errors is inherent in the atmospheric conditions: i. e., the amount of water vapor prevailing during the observations.

Discussion

Table 1 provides us with sufficient multicolor data for the investigation of interstellar extinction in the cluster by the color-difference method described by Johnson (1968); the method consists essentially in the comparison of the observed colors of reddened stars of known spectral type with the appropriate intrinsic colors. This procedure permits us to obtain the variation of interstellar extinction with wavelength. From Table 1 and the intrinsic colors published by Johnson (1966b,

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TABLE 1

H II	*V*	*U–V*	*B–V*	*V–R*	*V–I*	*V–J*	*V–H*	*V–K*	*V–L*	*JHK*	*L*	*Spec.*	*V sin i Km/sec*
468*	3.70	–0.52	–0.12	–0.01	–0.10	–0.18	–0.22	–0.24	–0.33	8	7	B6 III	220
785	3.87	–0.47	–0.07	0.02	–0.03	–0.06	–0.12	–0.13	–0.11	5	4	B7 III	40
1432*	2.87	–0.44	–0.09	0.03	–0.01	–0.08	—	–0.09	–0.03	14	4	B7 III	220
2168*	3.62	–0.45	–0.09	0.01	–0.05	–0.13	–0.21	–0.23	–0.17	7	6	B8 III	215
980*	4.18	–0.48	–0.06	0.07	0.05	0.03	–0.03	0.11	0.23	5	4	B6 IVn	275
447	5.46	–0.37	–0.04	0.04	–0.01	–0.07	–0.09	–0.13	–0.16	5	5	B7 IV	260
563	4.30	–0.57	–0.11	0.00	–0.10	–0.15	–0.28	–0.22	–0.27	5	4	B6 V	135
541	5.65	–0.43	–0.07	0.03	–0.04	–0.12	–0.21	–0.19	–0.18	5	5	B8 V	245
817	5.76	–0.27	–0.04	0.05	0.02	–0.03	–0.04	–0.08	–0.07	4	4	B8 V	220
1823	5.45	–0.39	–0.07	0.03	–0.03	–0.12	–0.22	–0.23	–0.32	4	4	B8 V	270
2181*	5.09	–0.36	–0.08	0.08	0.01	–0.02	–0.06	–0.02	+0.07	9	4	B8 p	340:
859	6.43	–0.17	–0.02	0.02	0.00	0.01	0.00	–0.04	0.00	2	2	B9 V	250
2425	6.17	–0.24	–0.05	0.01	–0.04	–0.08	–0.10	–0.09	–0.18	3	2	B9 V	310
1234	6.83	–0.05	0.02	0.06	0.07	–0.11	–0.17	–0.02	0.04	2	2	B9.5 V	260
2263	6.57	–0.14	–0.02	0.01	–0.03	–0.12	–0.09	–0.13	–0.28	3	2	B9.5 V	90
801	6.85	0.05	0.04	0.07	0.09	0.11	0.16	0.17	0.06	2	2	A0 V	190
1084	8.11	0.65	0.36	0.37	0.64	0.84	0.97	1.00	1.07	13	8	A0 V	—
1375	6.32	0.00	0.02	0.04	0.03	–0.03	0.00	0.02	0.24	2	2	A0 V	160
2500*	6.72	0.00	0.06	0.09	0.16	0.22	0.21	0.25	0.28	2	2	A0 V	15
717/	7.22	0.24	0.16	0.20	0.33	0.48	0.56	0.52	0.54	2	2	A1 V	15
1876*	6.95	0.22	0.13	0.12	0.19	0.29	0.26	0.27	0.35	3	3	A1 V	105
1028*	7.40	0.23	0.11	0.12	0.17	0.26	0.29	0.33	0.40	2	2	A2 V	110
2488	7.55	0.16	0.08	0.08	0.10	0.15	0.13	0.07	0.08	3	2	A2 V	120
1425	7.79	0.28	0.16	0.17	0.26	0.33	0.31	0.32	0.36	2	2	A3 V	185
1384	7.71	0.33	0.21	0.22	0.35	0.46	0.63	0.66	0.67	2	2	A4 V	215
158	8.21	0.40	0.26	0.24	0.38	0.42	0.59	0.58	—	3	–	A7 V	70
2415	8.14	0.34	0.21	0.20	0.30	0.41	0.46	0.53	—	3	–	A7 V	100:
157	7.92	0.45	0.34	0.33	0.54	0.68	0.85	0.89	0.84	3	3	A9 V	100
1284	8.36	0.38	0.30	0.26	0.43	0.61	0.79	0.81	0.70	3	3	A9 V	100
531	8.58	0.50	0.34	0.32	0.52	0.63	0.77	0.78	0.98	2	2	Am ?	75
3031	8.87	0.43	0.38	0.38	0.60	0.75	0.92	0.93	—	2	–	F2 V	230
605	9.00	0.52	0.44	0.42	0.70	0.89	1.04	1.08	1.19	2	2	F3 V	80
1338	8.64	0.49	0.46	0.38	0.67	0.73	1.06	1.18	1.52	3	2	F3 V	110
1122	9.29	0.49	0.46	0.41	0.68	0.92	1.13	1.10	1.14	3	2	F4 V	—
1766	9.13	0.54	0.47	0.43	0.72	0.97	1.20	1.25	1.28	2	2	F4 V	50
745	9.46	0.64	0.53	0.50	0.85	1.12	1.37	1.28	1.69	2	2	F5 V	—
1613	9.87	0.65	0.54	0.47	0.77	0.95	1.30	1.36	—	2	–	F8 V	—
727	9.71	0.61	0.56	0.49	0.83	0.96	1.23	1.29	1.27	2	2	F9 V	—
739	9.48	0.69	0.63	0.53	0.89	1.07	1.31	1.34	1.34	2	2	G0 V	—

*Notes to Table 1

468.–SBi, HD 23302, Hα emission.
1432.–Hα emission.
2168.–VB, SBi, HD 23850.
980.–Hα emission.
2181.–Hα emission.
2500.–SBi, HD 23964.
717.–Vel. Var. ? HD 23387
1876.–Vel. Var. ? HD 23763.
1028.–Vel. Var. ? HD 23489.

1968), the color excesses were computed. The results appeared very intringuing, namely, that some of the stars showed large excesses in the infrared that could be interpreted as infrared emission. The fact that Pleione, a well known shell star, was among them strengthened the idea. Johnson (1967b) from a list of eighty five stars in the Bright Star Catalogue which were observed from the ultraviolet to 3.4 μ in the infrared, with spectral types earlier than A2, concluded that the K-L excesses observed for the stars with emission lines are due to infrared emission from circumstellar shells.

Among these are the well known shell stars ϕ Per, $\varkappa$ Dra and P Cyg. Although he does not mention it specifically, Johnson lists some Pleiades stars that show the above mentioned effect. To compute the value of R for the Pleiades, knowing that the infrared excess for some of the stars is not caused only by interstellar reddening would be meaningless. The next step then, should be to find a way to discriminate the stars that we believe show infrared emission, from those without it.

TABLE 2

Probable errors of a single observation

Mag K	*K*	*J—K*	*K—L*
3-5 th	±0.04	±0.04	±0.06
5-6 th	±0.05	±0.04	±0.05
6-7 th	±0.05	±0.05	±0.08
7-8 th	±0.06	±0.07	±0.12
>8 th	±0.10	±0.09	±0.13

A cursory inspection of Johnson's intrinsic colors for the spectral types listed in Table 1, indicates that there is practically no excess in 3.4 μ (L) radiation when compared with that at 2.2 μ (K). We can take advantage of this fact and proceed to investigate the relationship between the observed K-L and the spectral type for the stars in the Pleiades. Since these stars are reddened, to a certain extent, it is necessary first to correct the data for the effects of interstellar reddening. Following Johnson (1967b), it is assumed that the color-excess in K-L is twenty percent of the color excess in B-V. The values for E(B-V) and $(K\text{-}L)_0$ were computed; the correlation between $(K\text{-}L)_0$ and spectral type is shown in Figure 1. The solid line in the diagram represents the relationship between K-L and spectral type for black bodies of the same temperature as the stars.

Figure 1 shows very interesting features. Following the assumption that stars with emission show K-L excesses, we proceed to identify in our diagram the four B type stars in the Pleiades for which Merrill (1933) found Hα in emission, and indeed among the stars with larger excesses we find three of them: Alcyone, Merope and Pleione. Electra, a spectroscopic binary, does not show any

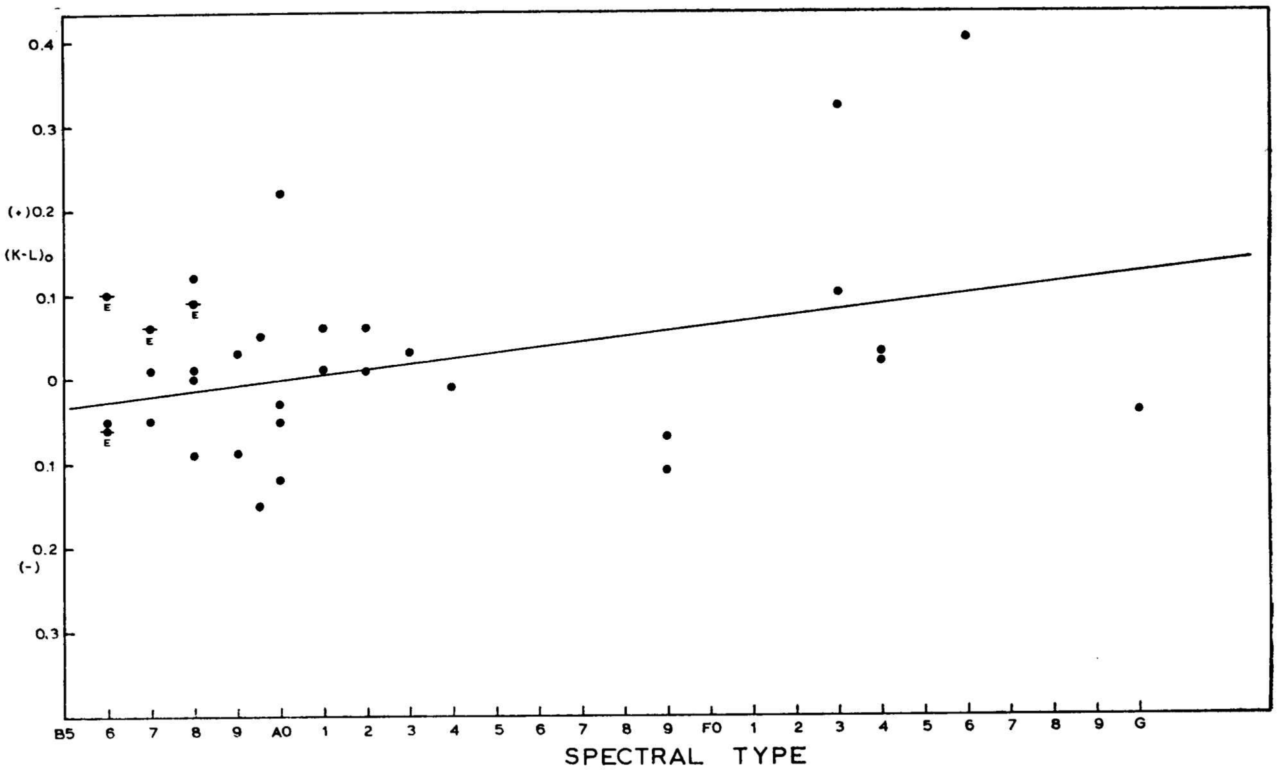

Fig. 1.—*$(K—L)_0$ versus spectral type for the Pleiades stars. The capital E's designate emission stars. The nearly horizontal line represents the relationship between K—L and spectral type por brack bodies of the same temperature as the stars.*

excess; instead four other stars H II 2168, H II 1375, H II 1338 and H II 745 are the ones that show larger excesses. But something else is evident in the diagram: large infrared deficiencies are also present that cannot be explained on the basis of observational errors alone, indicating that, if it is true that some of the stars radiate like black bodies in the relevant wavelengths, others do not. At this point the investigation of the interstellar extinction in the Pleiades has shown us that at least some of the members in the cluster do not fit with our preconceived ideas about them and that it is obvious that a more thorough analysis of the data is needed.

By definition the intrinsic colors of an AOV star are approximately zero in the UBVRIJHKL system. Therefore, if we compare the color indices of any given star with those of an AO star, the results should give the spectral energy distribution of that star. We compare the colors of the stars in Table 1, corrected for interstellar reddening, with their corresponding intrinsic colors using an AO star as a base line. The necessary corrections were derived from the corresponding color excess ratios of the theoretical curve No. 15 of van de Hulst, normalized to $E_{(B-V)} = 1.00$, as given by Johnson (1968). The value of R that he obtained for the curve is $R = 3.05$. A "normal" reddening law is assumed.

In Table 3 the results of these computations are given and in Figures 2-8 the actual energy distribution curves relative to an AO star are plotted. The values of H at 1.62 μ were excluded from

TABLE 3

H II	$(U-V)_0$	$(B-V)_0$	$(V-R)_0$	$(V-I)_0$	$(V-J)_0$	$(V-K)_0$	$(V-L)_0$
468	− .55	− .14	− .03	− .13	− .23	− .30	− .39
785	− .56	− .12	− .02	− .11	− .18	− .26	− .26
1432	− .49	− .12	.01	− .06	− .15	− .15	− .12
2168	− .45	− .09	.01	− .05	− .13	− .23	− .17
980	− .62	− .14	.01	− .08	− .15	− .09	.00
447	− .51	− .12	− .02	− .14	− .25	− .33	− .40
563	− .62	− .14	− .02	− .15	− .22	− .28	− .36
541	− .46	− .09	.01	− .07	− .17	− .25	− .24
817	− .36	− .09	.01	− .06	− .15	− .21	− .22
1823	− .42	− .09	.01	− .06	− .17	− .29	− .38
2181	− .38	− .09	.07	− .01	− .04	− .02	.04
859	− .24	− .06	− .01	− .06	− .08	− .15	− .12
2425	− .26	− .06	.00	− .06	− .10	− .12	− .21
1234	− .14	− .03	.02	− .01	− .23	− .15	− .11
2263	− .16	− .03	.00	− .05	− .14	− .16	− .31
801	− .02	.00	.04	.03	.00	.06	− .06
1084	.04	.00	.08	.06	.01	.00	− .03
1375	− .03	.00	.02	.00	− .08	− .04	.18
2500	− .10	.00	.04	.06	.08	.10	.10
717	.02	.03	.10	.12	.18	.16	.16
1876	.05	.03	.04	.03	.06	− .01	.06
1028	.14	.06	.08	.09	.14	.20	.25
2488	.13	.06	.06	.07	.10	.01	.02
1425	.16	.09	.11	.15	.17	.13	.16
1384	.16	.11	.14	.19	.23	.38	.38
158	.28	.19	.18	.27	.26	.39	—
2415	.31	.19	.18	.27	.36	.47	—
157	.33	.27	.27	.43	.52	.70	.64
1284	.33	.27	.24	.38	.54	.75	.61
3031	.40	.36	.36	.57	.70	.87	—
605	.42	.38	.37	.60	.75	.93	1.11
1338	.35	.38	.32	.54	.55	.98	1.29
1122	.40	.41	.37	.60	.80	.97	.99
1766	.44	.41	.38	.62	.83	1.10	1.10
745	.54	.47	.45	.75	.98	1.13	1.51
1613	.65	.54	.47	.77	.95	1.36	—
727	.61	.56	.49	.83	.96	1.29	1.27
739	.62	.59	.50	.83	.98	1.23	1.22

the Table because intrinsic colors for this wavelength for spectral types earlier than A2 are not available at the present time. It must be emphasized that the diagrams actually show the observed values *corrected* for interstellar reddening and that as a consequence they should show a relatively close relationship with their corresponding intrinsic colors. For the sake of keeping the descriptions of the diagrams in an orderly manner we proceed to discuss them in spectral type sequence.

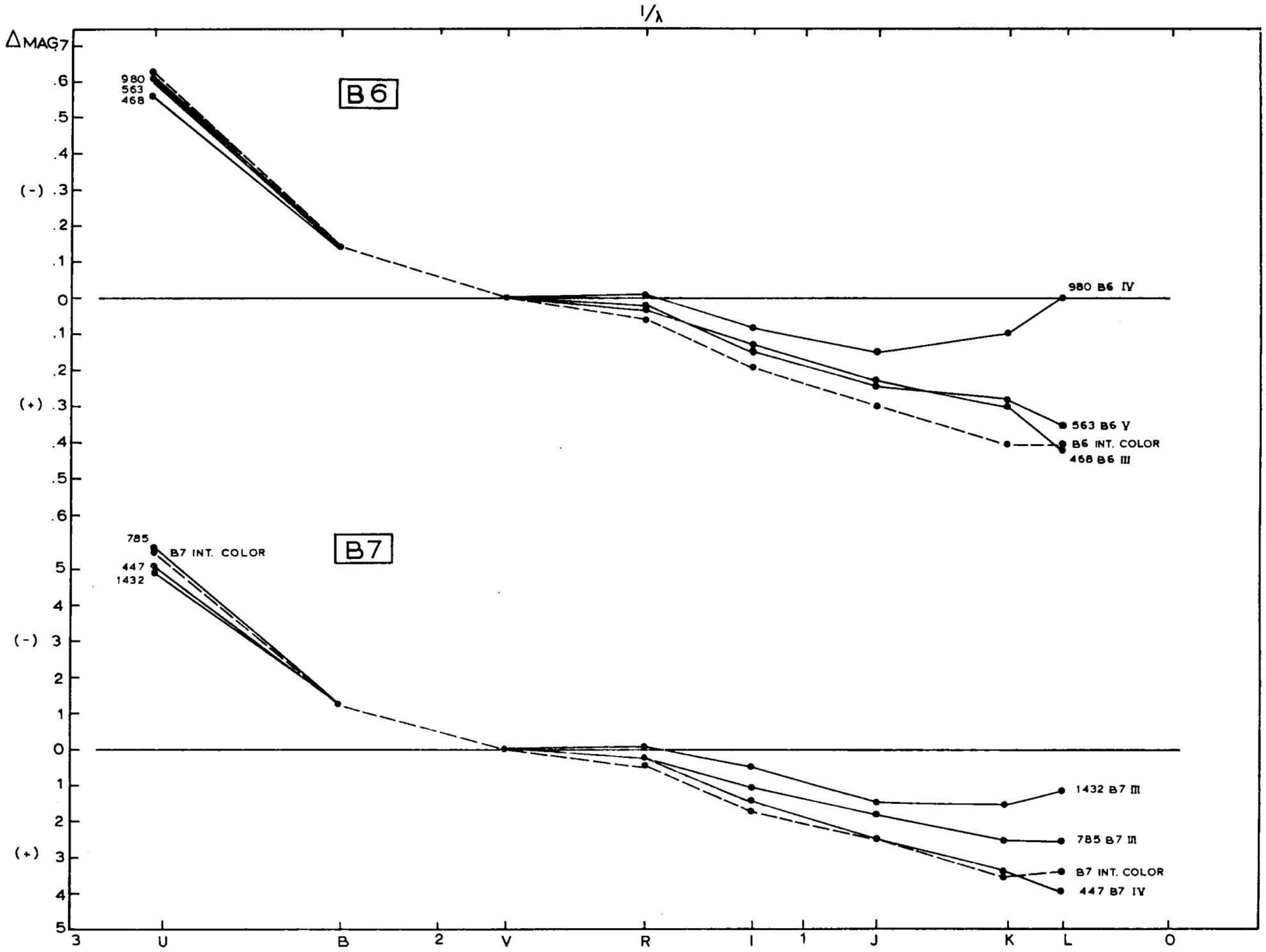

Fig. 2.—*The spectral-energy curves for B6, B7 stars in the Pleiades cluster. The data is relative to an A0 V star. The dotted line represents the intrinsic color for the spectral type.*

B6.—The outstanding feature in this class is Merope, H II 980, one of the Hα emission stars, showing excesses from 0.88 μ (I) to 3.4 μ (L). As a group these stars have one thing in common: they all lie above the curve representing the intrinsic color of a B6 type star and this means that in different degrees, they all show excess. Electra, H II 468, another of the stars with Hα in emission, appears to have an energy distribution almost identical to that of Taygeta, H II 563, which is not known to be in emission; moreover, the drop of its curve from 2.2 μ (K) to 3.4 μ (L) is more pronounced.

B7.—Alcyone, H II 1432, has been identified as being in emission and shows sizable infrared excess.

B8.—Among the stars in this spectral group we find Pleione, H II 2181, classified as B8 peculiar, and indeed it is. Merrill (1933) found Hα in emission in this star; it also appears in Mendoza's (1958) list of Be stars. Struve (1951) called it a prototype shell star. Pleione's curve presents a continuous excess from 0.70 μ (R) to 3.4 μ (L) in the diagram and it is the only star observed that shows relatively large excess in R. The H II 1823 curve is peculiar in the sense that it deviates from the one representing the intrinsic color of this class at 1.25 μ (J), and it shows infrared deficiency. The curves of the remaining stars in the diagram fall between the aforementioned extremes.

B9.—The energy distribution curves of the two representatives of this spectral type fit beautifully with those of the intrinsic colors for this class.

B9.5.—The curves in this diagram are peculiar and they cannot be explained by adducing their observational errors as the main cause of their peculiarities.

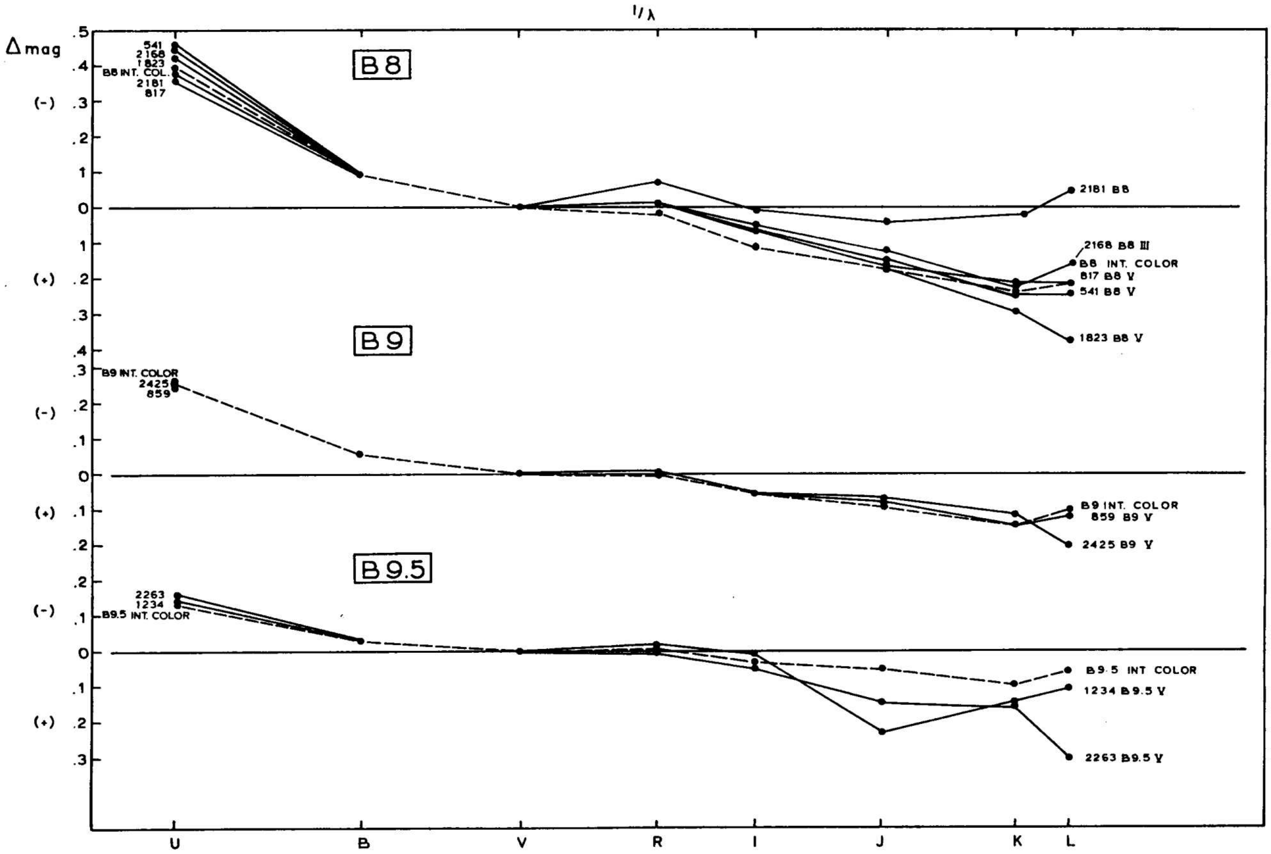

Fig. 3.—*The spectral-energy curves for B8, B9 and B9.5 stars in the Pleiades cluster. The data is relative to an A0 V star. The dotted line represents the intrinsic color for the spectral type.*

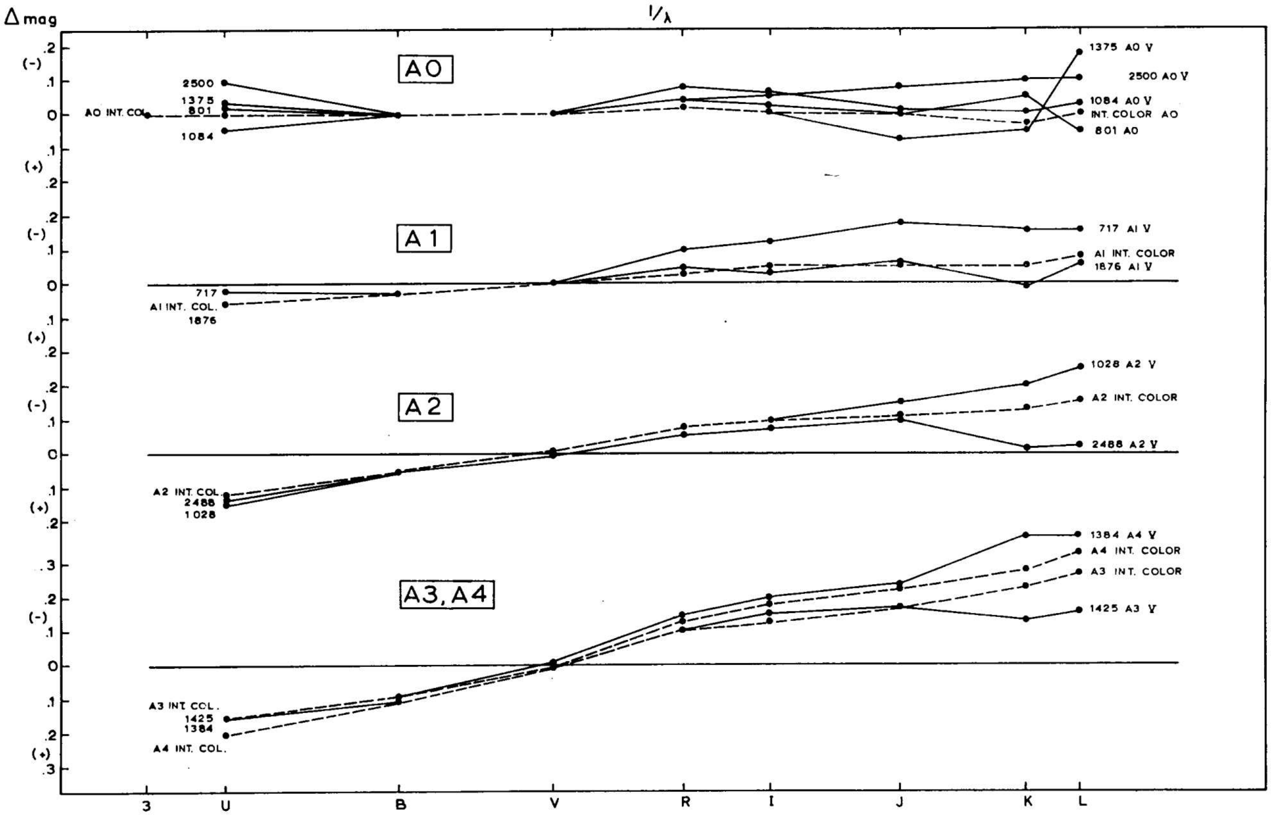

Fig. 4.—*The spectral-energy curves for A0, A1, A2, A3 and A4 stars in the Pleiades cluster. The data is relative to an A0 V star. The dotted line represents the intrinsic color for the spectral type.*

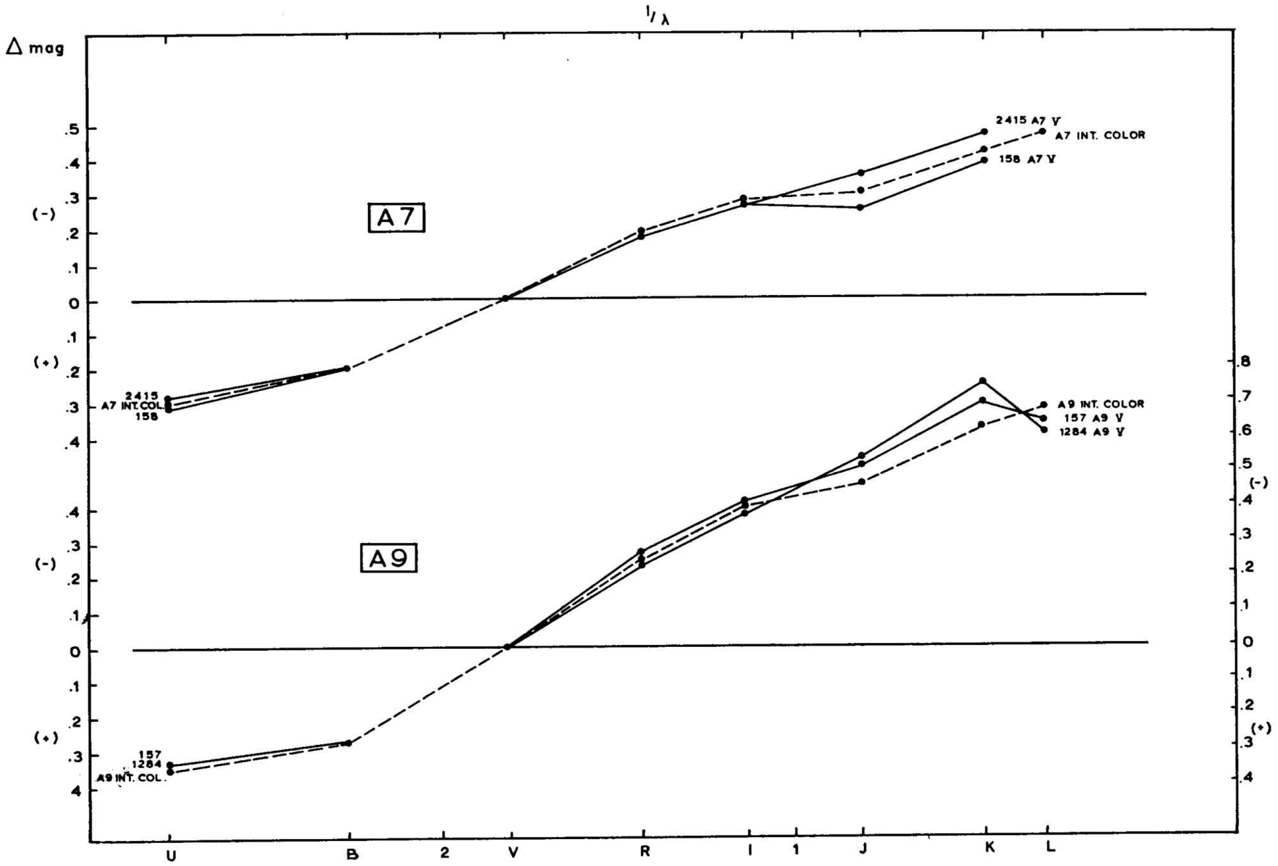

Fig. 5.—*The spectral-energy curves for A7, A9 stars in the Pleiades cluster. The data is relative to an A0 V star. The dotted line represents the intrinsic color for the spectral type.*

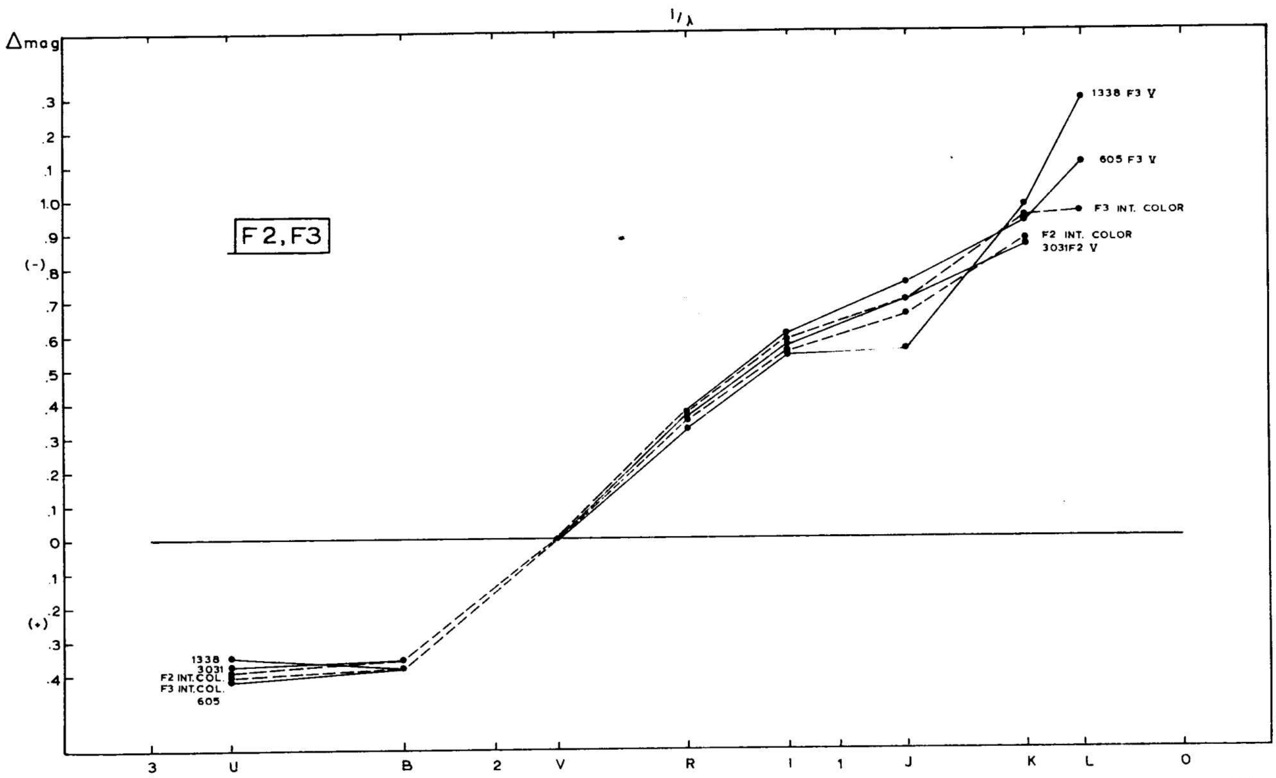

Fig. 6.—*The spectral-energy curves for F2, F3 stars in the Pleiades cluster. The data is relative to an A0 V star. The dotted line represents the intrinsic color for the spectral type.*

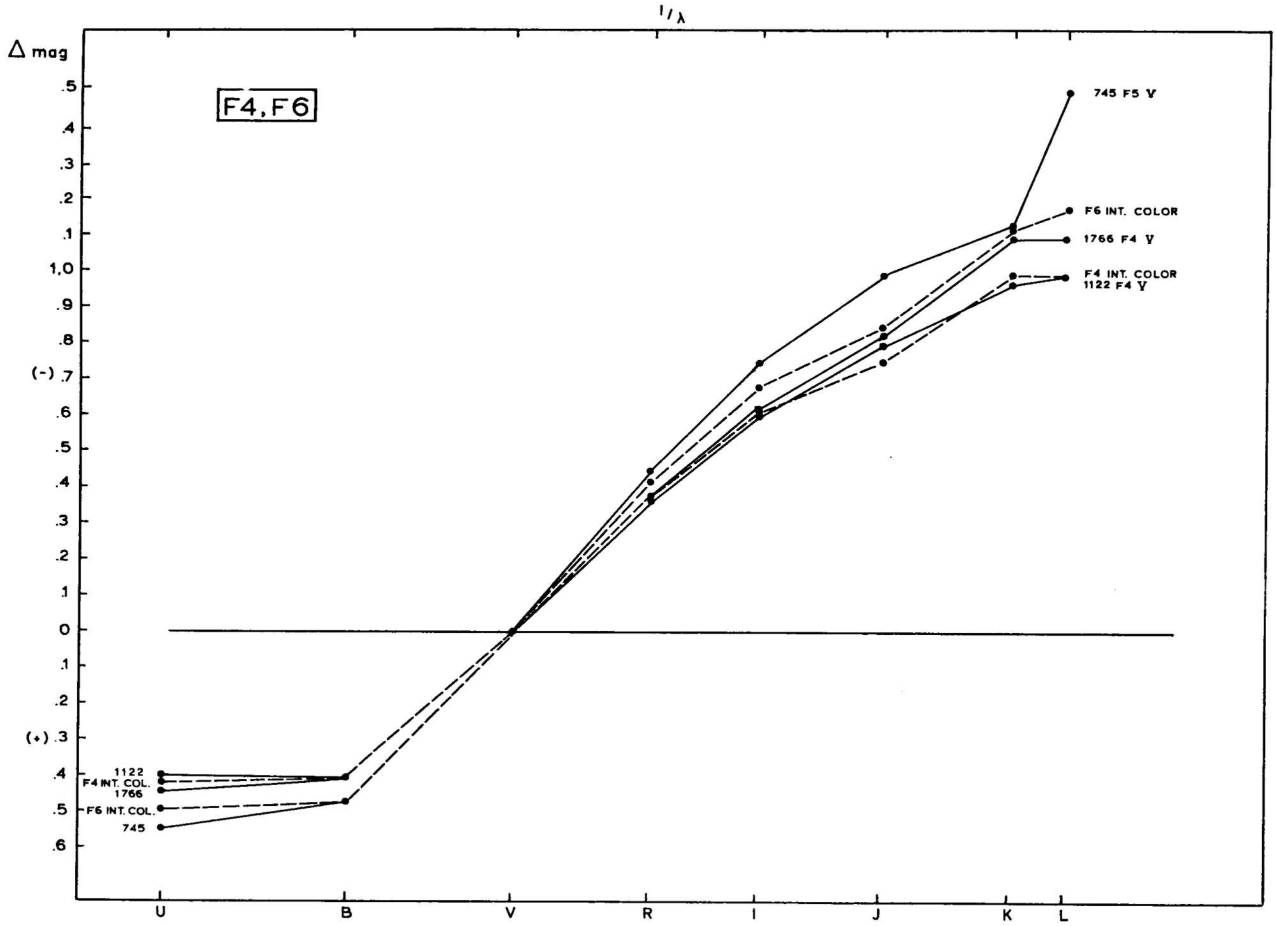

Fig. 7.—*The spectral-energy curves for F4, F6 stars in the Pleiades cluster. The data is relative to an A0 V star. The dotted line represents the intrinsic color for the spectral type.*

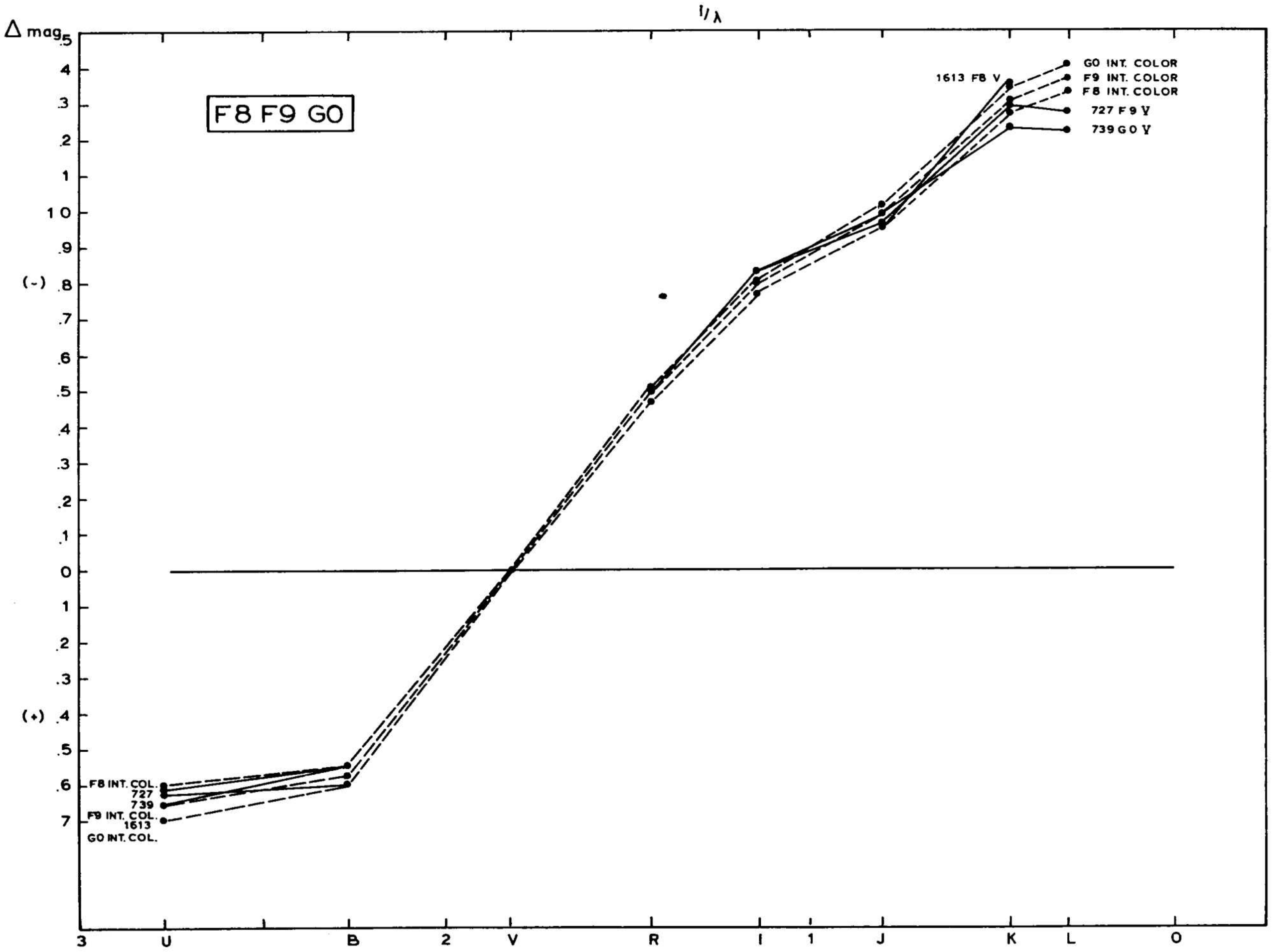

Fig. 8.—*The spectral-energy curves for F8, F9 anl G0 stars in the Pleiades cluster. The data is relative to an A0 V star. The dotted line represents the intrinsic color for the spectral type.*

A0.—Four members in this spectral class were observed, the H II 1375 curve appears to be interesting with a drop between 0.88 μ (I) and 1.25 μ (J) and then a very steep rise from 2.2 μ (K) to 3.4 μ (L); the probable error of the mean of the observations for this particular star is ±0.01 in KL, which supports the idea that the increase in intensity from K to L is real. H II 1084 has a $E_{(B-V)} = 0.36$, the largest among the stars in Table 1. H II 2500 has two companions H II 2507 and H II 2503 which according to Hertzsprung are members of the cluster. They are about four magnitudes fainter and one of them, H II 2503, falls inside the diaphragm (16″ in diameter).

A1, A2, A3, A4.—The samples for each of these spectral types are small and the data are discussed together. H II 717, A1V show excesses at all wavelengths from R to L. The diagrams for A2, A3 and A4 stars show deviations relative to their intrinsic colors resembling the ones we have found for other spectral types. The plots for H II 1876, H II 2488 and H II 1425 have similar configurations.

A7, A9.—It is unfortunate that for the two A7 stars, 3.4 μ (L) values are not available; otherwise, nothing outstanding is apparent in the plots.

F2, F3.—The stars in this group fit well with their corresponding intrinsic colors at all wavelengths, with the exception of 3.4 μ (L) which appears in excess for H II 1338 and H II 605. For these stars, K ∼ 8 mag. (which is faint), but the increase in intensity, at least for H II 1338, seems to be real.

F4, F6.—With the exception of H II 745, F6V, which shows a very large increase in light intensity from 2.2 μ (K) to 3.4 μ (L), the other stars in this spectral class appear to be normal.

F8, F9, G0.—These diagrams show a remarkable consistency between the stars observed and their corresponding intrinsic colors.

Up to now, no attempt has been made to discuss in detail the energy distribution curves. The danger of overinterpreting the data is always present and the amount of minute details in the curves could cause just that. At the same time, in the discussion that follows, an effort has been made to avoid the other extreme, oversimplification.

When we start to treat the diagrams as a whole we find two broad features, namely, that although the observational errors for the brighter stars are in general smaller, the differences from their intrinsic colors are larger. We also notice that excesses or deficiencies of two kinds are present in the plots: the ones that show smooth curves suggesting that the excesses or deficiencies are present at all wavelengths, and the ones that show sudden increments or decrements particularly between K and L. We have already mentioned that one possible reason for the infrared excesses for some of the B stars could be infrared emission from circumstellar shells, and in this connection Johnson's work (1967b) was cited. The fact that a well known shell star, Pleione, is among the stars that show infrared radiation excess supports this conjecture; furthermore, we mentioned that four stars among the brighter ones are known to be Be stars. Now, emission features are believed to occur only in rapidly rotating stars of class B. Finally, the stars of class B in the Pleiades have large velocities of rotation, which reinforces the infrared emission hypothesis and it could account for the various degrees of excesses for the rest of the B stars. However, it should be mentioned, at this point, that in one of the Be stars in the cluster, Electra H II 468, the infrared excess is not of the same order of magnitude as the ones found for the other three. Perhaps this fact can be explained by the assumption that shell spectra are variable in intensity. The seven brightest members in the Pleiades, with the exception of H II 563, are either Be or have been classified as III or IV in luminosity class, or both. According to their position in the two color diagram, they have evolved from the main sequence; five of them show infrared excesses including Maia, the only B type star in the cluster that has fairly sharp lines in the spectrum, meaning that either it does not rotate rapidly —which apparently is true— or its axis of rotation is in the direction of the observer (Struve 1945).

There are three stars, H II 2500, H II 717 and H II 745, with spectral types A0V, A1V and F5V respectively, that show the same deviations from their intrinsic colors as do the stars we discussed earlier; however, the curves for the infrared excesses could possibly be explained in a different way. H II 2500, a spectroscopic binary, has a close companion 3″5 away and four magnitudes fainter; the companion H II 2503, which has been considered to be a member of the cluster by Hertzsprung, was included in the measurements of H II 2500. If H II 2503 is indeed a member of the cluster, then its spectral type should be between G0 to G5 and the infrared radiation of such a star could account for the excesses. H II 717 has been suspected to have variable radial velocity, (Anderson et. al. 1966) and it is known that most shell spectra are variable in intensity and radial velocity, so perhaps it is a shell star. H II 745, an F5V star, appears to be brighter in the infrared than its corresponding intrinsic spectral type; moreover, it shows a very large K-L excess. The general shape of the energy distribution curve for this star, plus the fact that its spectral type is F5 and that the latest spectral type known for a shell star is A5, suggest that some other mechanism needs to be found to explain the excesses. H II 1375, and A0V, and H II 1338, an F3V, show small deficiencies and then, a very steep rise between K and L. We cannot offer any explanation for the infrared deficiencies or for the sudden increase in intensities that are present in some stars.

TABLE 4

Color-Excess ratios for H II 1084

Star	*Spec.*	$\frac{E_{U-V}}{E_{B-V}}$	$\frac{E_{B-V}}{E_{B-V}}$	$\frac{E_{V-R}}{E_{B-V}}$	$\frac{E_{V-I}}{E_{B-V}}$	$\frac{E_{V-J}}{E_{B-V}}$	$\frac{E_{V-K}}{E_{B-V}}$	$\frac{E_{V-L}}{E_{B-V}}$	E_{B-V}
H II 1084	A0 V	1.81	1.00	0.97	1.78	2.36	2.86	2.97	0.36

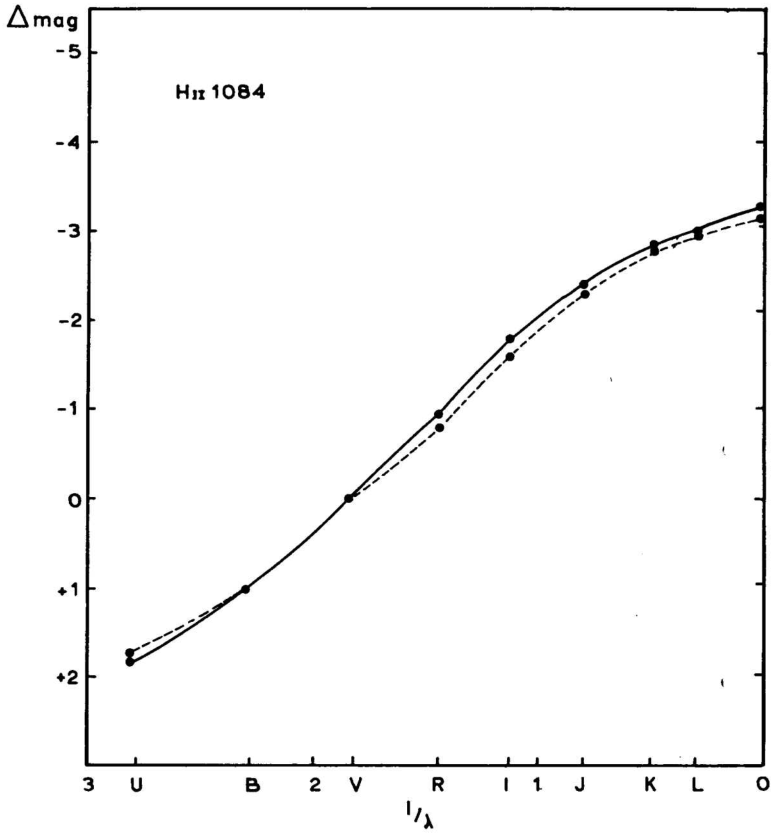

Fig. 9.—*The interstellar-extinction curve for the Pleiades. The dotted line represents van de Hulst's theoretical curve No. 15.*

Now we go back to the original objective of this work, which is the determination of R for the Pleiades cluster by Johnson's color-difference method. Due to the peculiarities shown by some of the stars in the cluster, it seems safer to use for this purpose the reddest star in the group, H II 1084, the same star used by Mendoza (1965) for the determination of the interstellar law in the Pleiades. The results of these computations are listed in Table 4 and the resultant extinction curve is shown in Figure 9, having deduced from it the value of R = 3.2. This values is lower than the one found by Mendoza which is R = 3.6; maybe the reason for this difference is simply that the value obtained here is based on a larger number of observations. Nevertheless, the new value corroborates the idea that the value of R is larger than the value of R = 3.00 that was generally accepted for the cluster not long ago.

In the course of another work to be published later by the author, a faint member of the Pleiades, H II 1306, was observed in JHKL and the results are given in Table 5, together with val-

TABLE 5

Star	*V*	*U−V*	*B−V*	*V−J*	*V−K*	*V−L*
1306	13.36	2.49	1.34	2.51	3.89	4.52

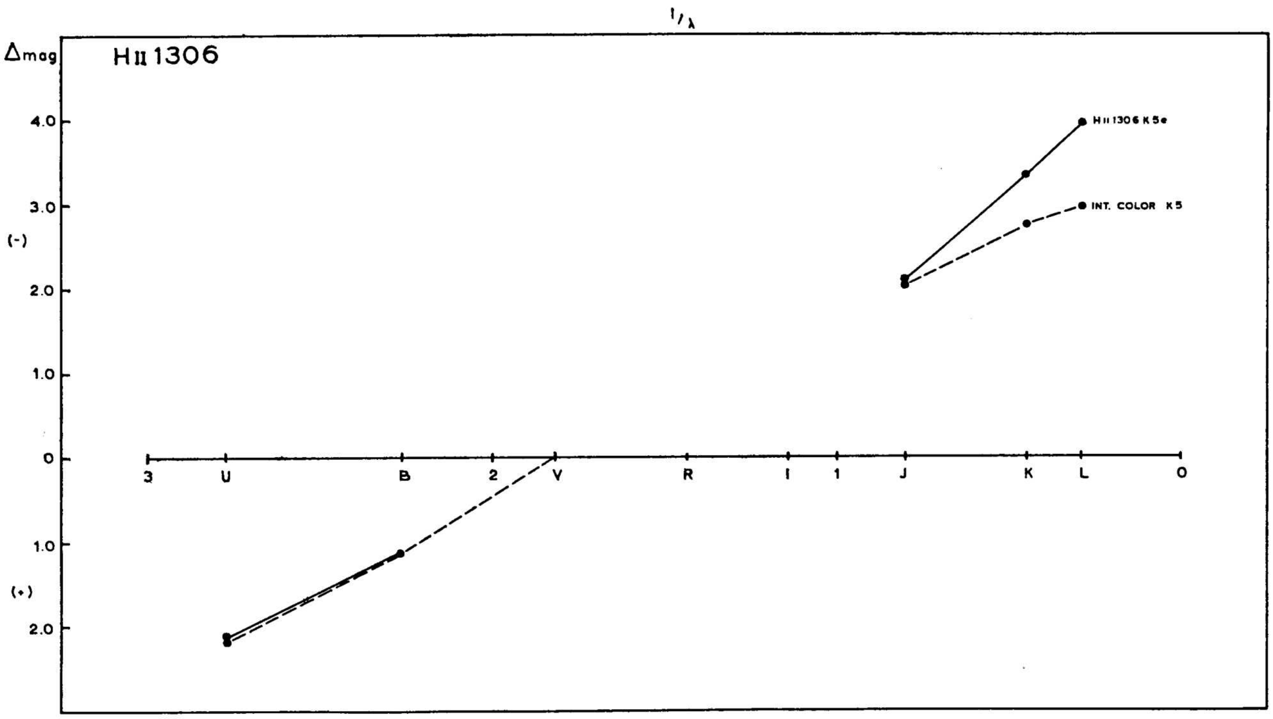

Fig. 10.—*The spectral-energy curve for HII 1306. The data is relative to an A0 V star. The dotted line represents the intrinsic color for the spectral type of the star.*

ues for UBV by Iriarte (1967). The new values of K and V—K corroborate the observations done by Johnson, and his suggestion that H II 1306 has infrared excess (Iriarte 1967). H II 1306 has been classified by Herbig (1962) as a dK5 (e) and was found to be a flare star by Johnson and Mitchell (1957). In order to see how large the infrared excess is for H II 1306, we proceeded to correct the observed colors for interstellar reddening and compared them with the intrinsic colors of the corresponding spectral type; the results are plotted in Figure 10. From the inspection of the plot we notice that H II 1306 does not show excess in the ultraviolet as some flare stars in young associations do (Mendoza 1966) and that when corrected for reddening the UBV colors of the star are indistinguishable from those of a normal main sequence star of the same spectral type. However, H II 1306 shows infrared excess although smaller in magnitude than the ones found by Mendoza (1966) for some flare stars in younger associations, suggesting that the star is reaching the main sequence and that at least in the visual regions of the spectra, the strong T Tauri characteristics are minimized (Haro, 1954, Herbig, 1962).

Conclusions

The main conclusions presented in this paper may be summarized as follows:

1.—The presence of infrared excesses in some of the brightest B type stars in the Pleiades cluster. These infrared excesses were interpreted as infrared emission from circumstellar shells.

2.—Large infrared excesses were found in stars with spectral types later than B, primarily in K—L. The most conspicuous cases are H II 1375, H II 1338 and H II 745, with spectral types A0V, F3V and F5V respectively.

3.—Infrared deficiencies for some of the members of the cluster were also found.

4.—It has been suggested that ultraviolet excess and infrared excess are associated with late type stars that are still approaching the main sequence. H II 1306, a flare star, does not show ultraviolet excess, however, it has infrared excess.

5.—The investigation of the interstellar reddening in the Pleiades cluster has pointed out the danger of using stars with excesses that may not be entirely due to interstellar reddening.

6.—A value of R = 3.2 for the Pleiades was found.

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REFERENCES

Anderson, C. M., Stoeckly, R., and Kraft, R. P., 1966, Ap. J., **143**, 299.
Haro, G., 1954, Bol. Obs. Tonantzintla y Tacubaya **11**, 11.
Hertzsprung, E., 1948, Ann. Leiden Obs., Vol. **19**, No. 1A.
Herbig, G. H., 1962, Ap. J., **135**, 736.
Iriarte, B., 1967, Bol. Obs. Tonantzintla y Tacubaya, **4**, p. 79.
Johnson, H. L., and Mitchell, R. I., 1957 Ap. J., **128**, 31.
Johnson, H. L., and Borgman, J., 1963, B. A. N., **17**, 115.
Johnson, H. L., 1965, Ap. J., **141**, 923.
Johnson, H., L., Mitchell, R. I., Iriarte, B., and Wisniewski, W. Z., 1966a, Comm. Lunar and Planetary Lab., **4**, 99.
————. 1966b, Ann. Rev. Astr. and Ap., Vol. **4** (Palo Alto, Clif.: Annual Reviews, Inc.), 193.
————. 1967a, Ap. J., **147**, 912.
————. 1967b, Ap. J., **150**, L 39.
————. 1968, Nebulae and Interstellar Matter, ed. L. H. Aller and B. M. Middlehurst (Chicago: University Press).
Lee, T. A., 1968, Ap. J., **152**, 913.
Mendoza, E., 1956, Ap. J., **123**, 54.
————. 1958, Ap. J., **128**, 207.
————. 1965, Bol. Obs. Tonantzintla y Tacubaya **4**, 3.
————. 1966, Ap. J., **143**, 1010.
Merrill, P. W., Burwell, C. G., 1933 Ap. J., **78**, 87.
Struve, D., 1945, Pop. Astr., **53**, 259.
————. 1951, Astrophysics, ed. J. A. Hynek (McGraw-Hill Book Company, Inc.).