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UBV PHOTOELECTRIC PHOTOMETRY FOR FAINT STARS IN THE PLEIADES CLUSTER

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The two and three-color photographic and photoelectric photometry of Johnson and Mitchell (1958) in the Pleiades cluster, shows a broadening of the main sequence for stars fainter than V≈12 which corresponds to B-V = +0.85 in their color-magnitude diagram. According to them this is about the point in which stars that are still in the process of gravitational contraction should be expected. But it is at this point, also, that the photographic observations begin to predominate over the photoelectric ones in the color-magnitude diagram of the cluster. As the probable error of their photographic observations is about eight times that of their photoelectric ones, it was thought to be of interest to reobserve some of the stars at the faint end of the color-magnitude diagram of the Pleiades.

Three color photoelectric photometry in the UBV System of Johnson and Morgan (1953) was done for 30 stars in the Pleiades Cluster (HII 2411 included in Table 1 is a member of the Hyades) using the 40″ reflecting telescope of the Tonantzintla Observatory, during the years 1964-66. The photomultiplier employed was a refrigerated RCA 1P21. The amplifier was of the Gardiner and Johnson (1955) type. With a few exceptions, each of the stars was observed at least three times. It should be mentioned that the program stars were always observed near the meridian and that 40% of the observing time was spent on standard stars, to minimize the effects of the relatively poor sky conditions in Tonantzintla. Stars HII 1234 and HII 1084 were used as secondary standards in the cluster.

The observations are listed in Table 1: Column 1 gives the Hertzsprung (1947) number of the star; columns 2, 3 and 4, the V magnitudes and the B-V and U-B colors respectively; column 5, spectral types by Herbig (1962); column 6, the number of observations.

There are 14 stars observed photoelectrically by Johnson and Mitchell (1958) in common with the ones presented here. The agreement of the photoelectric data is good, as shown by the filled circles in Fig. 1. The open circles represent the differences between their photographic observations and the photoelectric data listed here. One star, HII 191, was not plotted because of the large discrepancy. The differences, Iriarte minus Johnson, are shown in Fig. 1 as a function of B-V.

The probable error of a *single observation* for the stars in Table 1 is: V, ± 0.04; B-V, ± 0.04; U-B, ± 0.08. The observations of the faint Pleiades stars are considerably more discordant than the observational errors would explain, suggesting that these stars are all slightly variable.

The color-magnitude diagram plotted in Fig. 2 includes all the photoelectric observations of Johnson and Mitchel (1958) for the stars considered by them as "cluster members" and "probable members"; the weighed mean of the photoelectric observations for the stars we have in common, plus photoelectric observations for stars for which they have photographic values in the aforesaid categories. No corrections were made for interstellar reddening or absorption.

As can be noticed in Fig. 2, the main sequence between B-V≈+0.6 and B-V ≈+0.8 is very narrow, without taking into account the double stars, but from them on a broadening of the main sequence is apparent even if some of it could be due to the larger observational errors at faint magnitudes.

Two stars are of special interest: HII 335 classified as "non member" and HII 793 as "probabre non member" by Johnson and Mitchell. Both stars lay below the main sequence in their diagram. HII 793 was considered to be a member of the cluster by Haro (1966), based upon its proper motion (Hertzsprung 1947) and his discovery that it is a flare star. The new photometry confirms cluster membership. HII 335 is a member on the basis of its proper motion and the new photometry. Both stars were observed photographically by Johnson and Mitchell.

Five other stars, Nos. 81, 83, 105, 257, 2199, lay below the main sequence in the Johnson-Mitchell diagram; they are plotted as open circles in Fig. 2. These stars were considered to be members of the cluster by Hertzsprung, but the photometry of Johnson and Mitchell, according to the criteria adopted by them, and that done by the author, do not corroborate membership. It should also be mentioned that, because of the small proper motion of the cluster, a number of incorrect assignments to cluster membership may be expected; this problem can be ameliorated when radial-velocities become available.

In Fig. 3, the Zero age main sequence (ZAMS; Johnson and Iriarte 1958) was plotted on the faint end of the Pleiades color-magnitude diagram adjusted to a true distance modulus of m-M=

Table 1

HII	*V*	*B-V*	*U-B*	*Spc.*	*N*
81	13.56	+0.88	+0.39		3
83	14.89	+0.99	+0.71		4
105	13.78	+0.95	+0.43		3
133	14.32	+1.38	+1.11		3
134	14.39	+1.55			3
146	14.60	+1.41			2
186	10.49	+0.79	+0.29		3
189*	14.00	+1.36	+1.18		3
191*	14.39	+1.46	+1.12	d K7	3
257	12.60	+0.80	+0.33		3
335*	13.78	+1.25	+1.08		3
357*	13.52	+1.28	+1.15	K5	4
451	13.36	+1.19	+1.04	d K5	3
740	13.45	+1.08	+0.95		3
793*	14.32	+1.33	+1.12		3
799*	13.61	+1.33	+1.20	K3	5
1061*	14.19	+1.30	+1.16	d K5	4
1110	13.41	+1.23	+1.11		2
1306*	13.36	+1.34	+1.15	d K5 (e)	3
1332	12.46	+1.04	+0.79	K5	3
1348	12.64	+1.17	+1.05	K5	3
1454	12.87	+1.12	+0.89	K5	3
1531*	13.41	+1.22	+1.05		3
1653*	13.69	+1.28	+1.05	K7	3
2199	14.38	+1.08			1
2407	12.28	+0.98	+0.68	K3	3
2411*	14.18	+1.59	+1.04		4
2601	15.09	+1.56		M2	3
2908	13.41	+1.15	+0.92	K5	3
3030*	14.02	+1.35	+1.18	d K7	3
3063*	13.44	+1.16	+0.88		3

Notes to Table 1

189.—U variable.

191.—Flare star. G. Haro and E. Chavira, "Vistas inAstronomy" (Ed. A. Beer), Vol. 8, 89, 1965.

335.—U variable.

357.—U variable. Flare Star. G. Haro and E. Chavira "Vistas in Astronomy" (Ed. A. Beer), Vol. 8, 89, 1965.

793.—Flare Star. G. Haro. "Nebula and Interstellar Matter". Vol. VII of Stars and Stellar Systems. Ed. L. H. Aller, B. M. Middlehurst. In Press.

799.—Possible Flare during one of the observations.

1061.—Flare Star. G. Haro, "Nebula and Interstellar Matter". Vol. VII of Stars and Stellar Systems. Eds. L. H. Aller, B. M. Middlehurst. In Press.

1306.—Flare star. H. L. Johnson and R. I. Mitchell, Ap. J., 128, 31.

1531.—Flare star. G. Haro and E. Chavira, "Vistas in Astronomy" (Ed. A. Beer). Vol. 8, 89, 1965.

1653.—Flare star. G. Haro and E Chavira, "Vistas in Astronomy" (Ed. A. Beer). Vol. 8, 89, 1965.

2411.—Hyades Cluster member. Flare star. G. Haro and E. Chavira, "Vistas in Astronomy". (Ed. A. Beer). Vol. 8, 89, 1965.

2601.—Flare star. G. Haro, "Nebula and Interstellar Matter". Vol. VII of Stars and Stellar Systems, Eds. L. H. Aller, B. M. Middlehurst. In Press.

3030.—Flare star. G. Haro and E. Chavira, "Vistas in Astronomy". (Ed. A. Beer). Vol. 8, 89, 1965.

3063.—U variable.

+5.4. As the ZAMS was not tabulated fainter than $M_v = +8.1$, the mean Hyades main sequence was attached to ZAMS to obtain a standard sequence for redder stars. The stars plotted have been corrected for reddening and absorption. A mean reddening, $E_{(B-V)} = +0.04$, and a value of $R = A_v/E_{(B-V)} = 4.0$ (Mendoza, 1965) was adopted.

From Fig. 3 it appears possible to establish that the Pleiades main sequence differs from the Hyades main sequence. There is no sign of systematic turnoff to the upper right; instead, one finds stars both above and below the ZAMS. Circled dots designate the flare stars found by Johnson and Mitchell (1958), Haro and Chavira (1965) and Haro (1966). These stars are all fainter than V=13 (which corresponds to $M_v = 7.5$) and have the same distribution in the diagram as do the other stars.

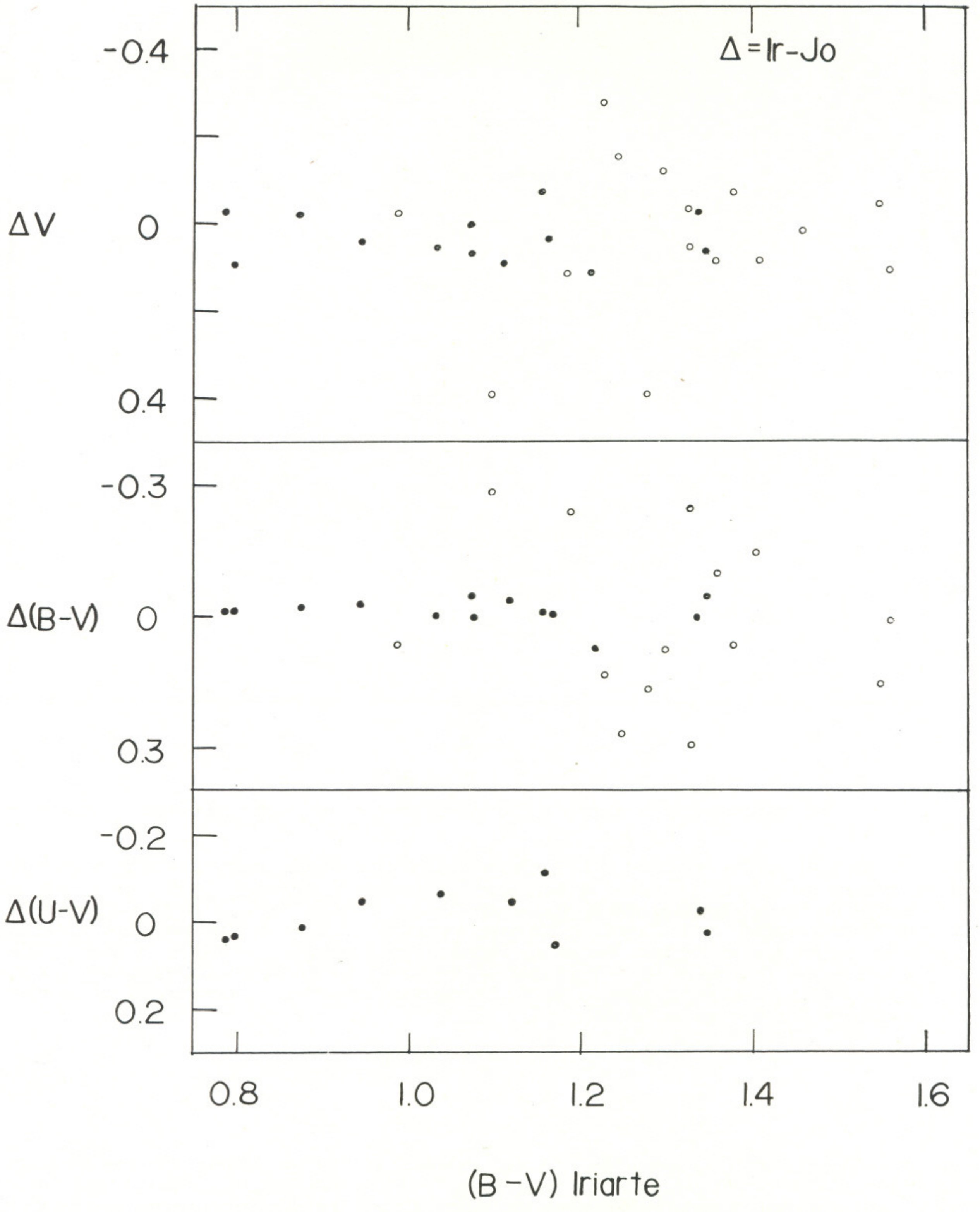

Fig. 1.—*Iriarte's data compared with Johnson and Mitchell data as a function of B-V. See text for explanation.*

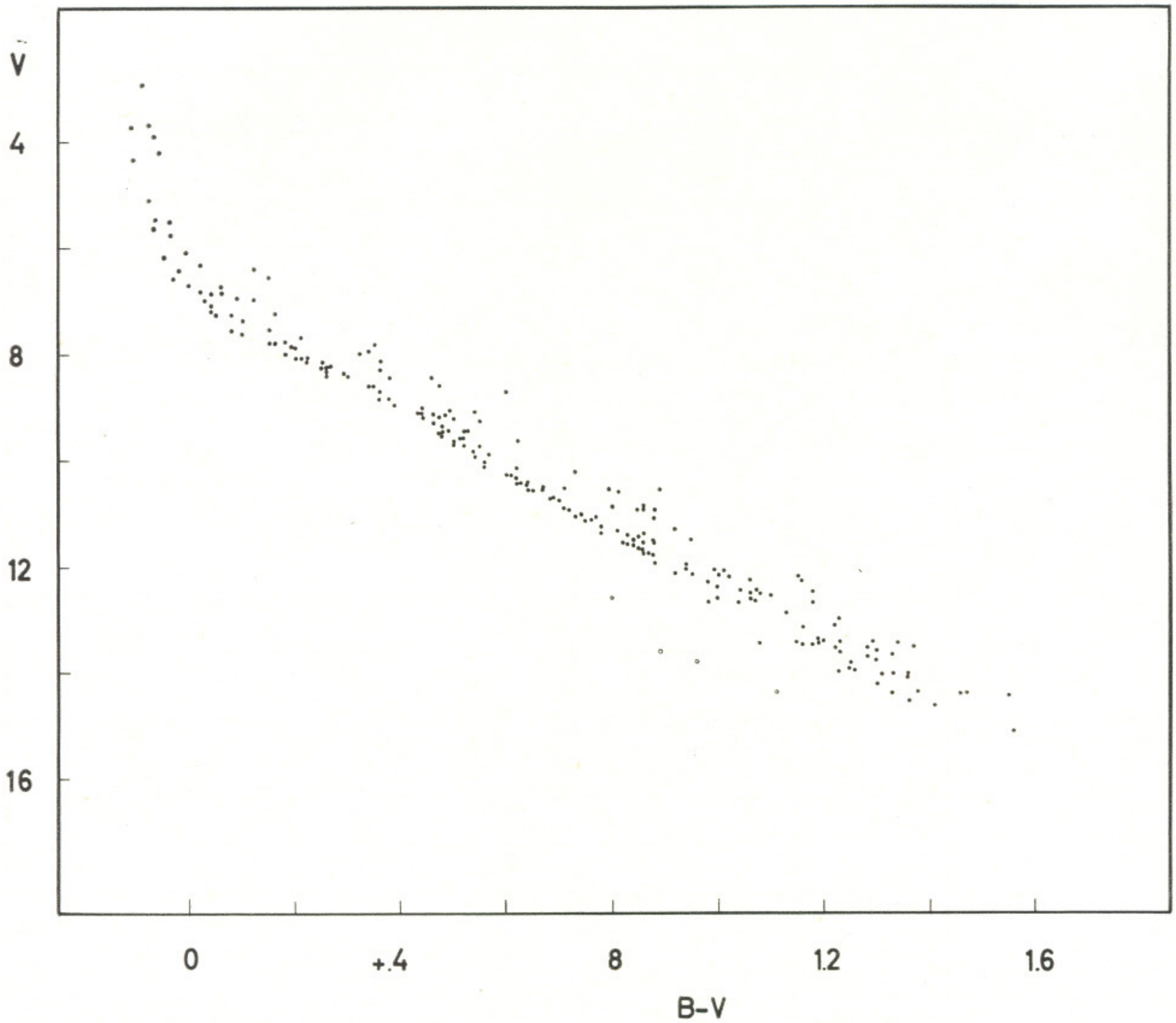

Fig. 2.—*Color-magnitude diagram of the Pleiades Cluster. See text for explanation.*

As the flare stars are expected to be in the process of gravitational contraction (see for example Haro and Chavira, 1965), they should appear, according to theory, above the ZAMS. An attempt to explain this discrepancy between theory and observations is given in the light of the infrared work done by Mendoza (1966) on T Tauri stars. It seems plausible to think that perhaps the bolometric corrections for the stars at the faint end of the Pleiades main sequence are similar to those of the T Tauri stars, and thus much larger than that which the B-V colors suggest. This hypothesis seems justified by the fact that H. L. Johnson (1967) has observed two of the flare stars in the Pleiades in the infrared. The data are as follows.

Star	*K*	*J-K*	*V-K*
HII 1306	9.64		+3.72
HII 2082	9.76	+1.68:	+4.22

The probable error of a K magnitude is ± 0.2 according to him. As Johnson has remarked, the color index V-K is ≈ 4.0 just as for the majority of T Tauri stars Mendoza observed, and this is again about a magnitude redder than would be expected for a normal main sequence star of spectral type K5 (Herbig gives d K5e as the spectral type of HII 1306. The UBV color for HII 2082 obtained by Johnson U-V=2.25, B-V=1.10 indicate a spectral type around K5). It appears then-that these stars —only two observed so far— have infrared excesses like the T Tauri stars, although smaller in magnitude.

The author did not have opportunity to observe a flare of the size of the one observed in HII 1306 by Johnson and Mitchell, but the small variations they found among the faint members of the Pleiades were fully corroborated.

This work was suggested by Dr. G. Haro. I am indebted to Dr. H. L. Johnson for allowing me to use his data and for his friendly criticism, and to Mr. Jorge Ruiz for reducing the observations at the Computing Center of the National University of Mexico.

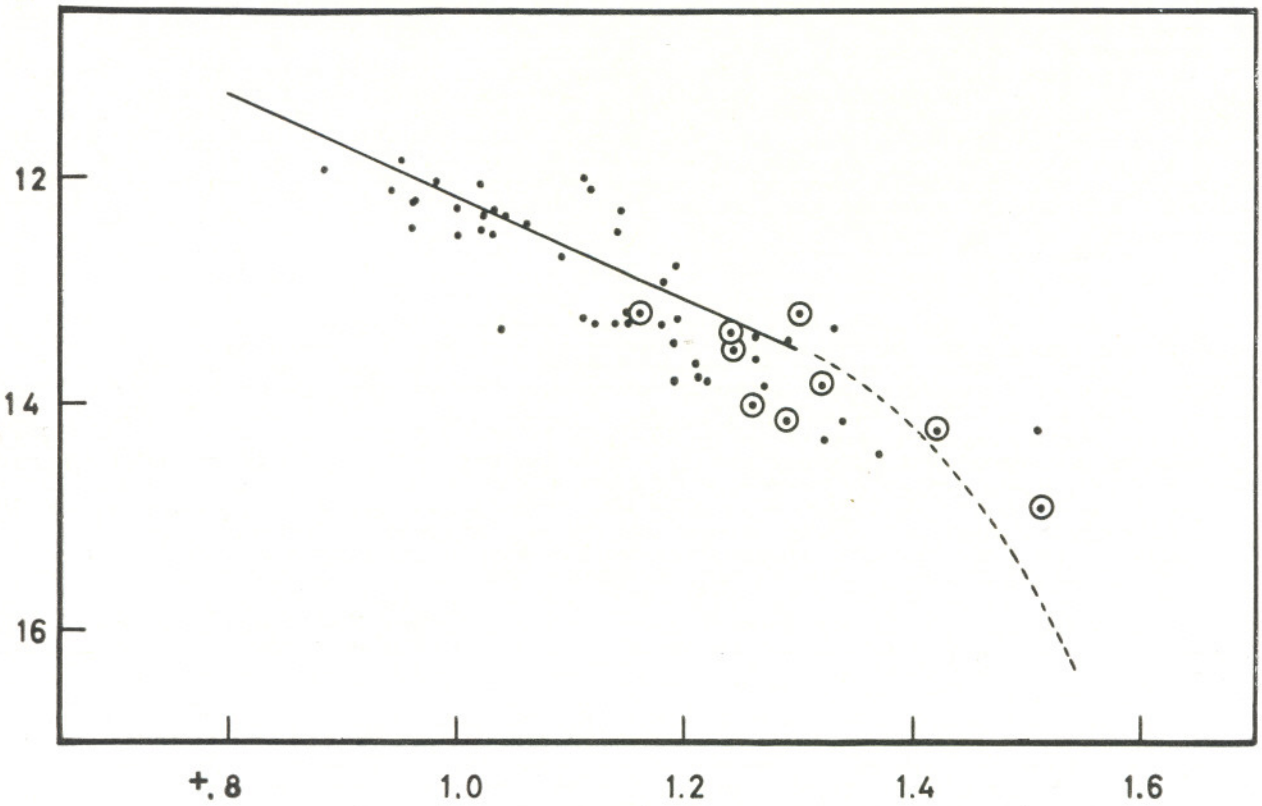

Fig. 3.— *Faint end of the color magnitude-diagram of the Pleiades Cluster. The solid line represents the zero age main sequence (Johnson and Iriarte 1958). The dotted line the mean Hyades main sequence.*

R E F E R E N C E S

Gardiner, A. J. and Johnson, H. L., 1955, *Rev. Sci. Instr.*, **26**, 1145.
Haro, G., and Chavira, E., 1965, *"Vistas in Astronomy"* (Ed. A. Beer) Pergamon Press Vol. 8, **89**.
Haro, G., 1966, *"Nebula and Interstellar Matter"*. Vol. VII of Stars and Stellar Systems. Eds. L. H. Aller, B. M. Middlehurst. In Press.
Herbig, G. H., 1962, *Ap. J.*, **135**, 736.
Hertzsprung, E., 1947, *Ann. Leiden Obs.*, Vol. 19, Nº 1 A.
Johnson, H. L., and Mitchell, R. I., 1958, *Ap. J.*, **126**, 134.
Johnson, H. L., and Morgan, W. W., 1953, *Ap. J.*, **117**, 313.
Johnson, H. L., and Iriarte, B., 1958, *Lowell Observatory Bull. No. 81*, **47**.
Johnson, H. L., 1965, *Interstellar Extinction Preprint*. To be published in Nebula and Interstellar Matter Vol. VII of Stars and Stellar Systems. Eds. L. H. Aller, B. M. Middlehurst.
Johnson, H. L., 1967, *Private communication*.
Mendoza, E., 1965. Bull Ton & Tac N° 26
Mendoza, E., 1966, *Ap. J.*, *143*, 1010.