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COMPARATIVE UBVR PHOTOMETRY OF ORION FLARE STARS AND Hα EMISSION-LINE STARS

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SUMARIO

Se presenta fotometría fotográfica multicolor de 279 estrellas ráfaga y estrellas de emisión en el conglomerado de Orión.

Estos objetos difieren totalmente de las relaciones estandar UBVR de color para estrellas de la secuencia principal. Un estudio colorimétrico comparativo indica que la presencia de eHα es un criterio útil estadísticamente para separar los objetos más anómalos en el diagrama de magnitud color y en el diagrama de color-color. La tendencia hacia el azul de las estrellas de baja luminosidad que se dirigen a la secuencia principal en el diagrama B-V/V, ya manifiesta en V $\sim$ 15^m, toma la forma de una franja que cruza en su totalidad la secuencia principal en V $\sim$ 16^m, B-V $\sim$ 1^m3. Las estrellas ráfaga sin emisión generalmente aparecen con luminosidad constante, dentro de la exactitud fotográfica, en las bandas UBVR.

Un detalle interesante del diagrama V-R/V es la segregación de estrellas ráfaga inactivas y objetos de emisión. Esta segregación posiblemente esté asociada con el origen de las variaciones de color y magnitud de las mismas. Se sugieren interpretaciones evolutivas en términos de la trayectoria hacia la secuencia principal.

ABSTRACT

Multi-colour photographic photometry for 279 flare stars and emission stars in the Orion aggregate is presented. These objects depart entirely from the standard UBVR colour relations for main sequence stars. A comparative colorimetric study indicates that the presence of eHα is a useful criterion on a statistical basis for separating out the more anomalous objects in the colour-magnitude and two-colour arrays. The blueward trend of stars of lower luminosity towards the main sequence in the B-V/V diagram, already evident at V $\sim$ 15^m, takes the form of a band crossing the main sequence entirely at V $\sim$ 16^m, B-V $\sim$ 1^m3. Non-emission flare stars generally appear at constant brightness at photographic accuracies in the UBVR bands.

An interesting feature of the V-R/V diagram is the segregation of quiescent flare stars and emission objects which is possibly associated with the nature of the colour and magnitude variations of these stars. Evolutionary interpretations in terms of pre-main sequence tracks for stars of discrete mass are also suggested.

I. Introduction

Haro and Chavira (1969) have pointed out that flare stars which appear below the main sequence, that is, which depart blueward and appear subluminous as compared with the B-V/V relation for unreddened zero-age main-sequence stars, exhibit emission at Hα with differing intensities and possess conspicuous and more or less permanent ultraviolet excesses. The strong stellar concentration of 255 Hα emission-line stars in the vicinity of the Orion nebula discovered by Haro (1953) consists of many such T Tauri-related variables including a number of flare stars. In view of the general correlation between the strength of Hα emission relative to the continuum and the ultraviolet excess in T Tauris (Kuhi 1970) it is anticipated that separation of non-emission flare stars and emission stars may occur in the UBVR two-colour arrays. Furthermore, a criterion of non-emission may lead to colour-magnitude diagrams of the Orion flare stars largely uncontaminated by anomalous ultraviolet and blue continua.

II. Photometric Data

The present work is an extension of an earlier photometric programme (Andrews 1970) and includes recently discovered flare stars as well as additional emission stars from Haro's list. Mean UBVR magnitudes have been derived for 279 stars, 103 of which are emission objects. A total of 52 plates taken at the 32/36-inch Baker-Schmidt of the Boyden Observatory were measured by means of iris-diaphragm photometry utilizing 109 photoelectric standards in the region of the Orion aggregate. The reduction techniques, plate-filter combinations and standard sequences have been given elsewhere (Andrews 1969, 1970).

The instrumental UBV passbands match fairly closely the standard system of Johnson and Morgan (1953) with effective wavelengths, 3700, 4400, 5800 A, respectively, and the instrumental R passband of half-width 800 A is centred near that of Johnson (1965) with an effective wavelength of

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7200 A. Comparison with the UBV photometry for bright stars in Orion by Sharpless (1952, 1954, 1962), Johnson (1957), Morgan and Loden (1966), and for stars fainter than 12^m5, by Walker (1969), and with the UBVR photometry of bright non-variables by Mendoza (1967) and Lee (1968) shows agreement to within $\pm 0^m1$. See Fig. 1. For the few faint stars in common there is no evidence of larger systematic errors. The diverging lines in Fig. 1 represent the internal mean errors of the present photographic photometry. The colorimetric results rely strongly on the adopted faint magnitude scales, and difficulties in transforming to the standard UBVR system for stars with anomalous spectra are undoubtedly encountered.

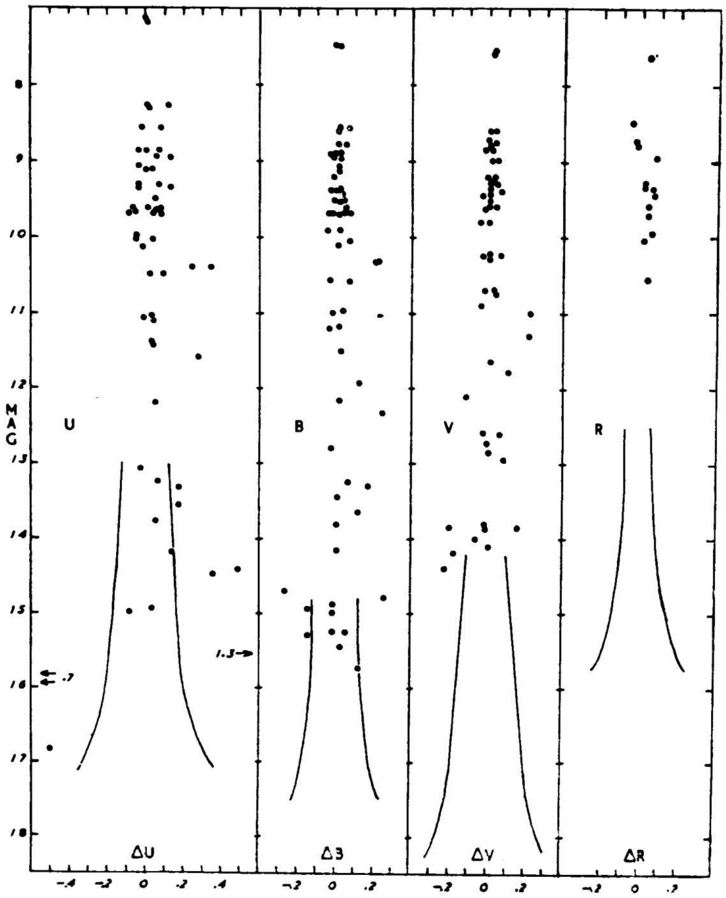

Fig. 1. Comparison with other UBVR Photometry. *Magnitude Residuals (comparison minus present) are shown for photoelectric standards measured in common with other authors (See Text). Below 12^m5 the residuals are Δm(p. e. — p. g). for stars measured by Walker (1969), and the diverging lines represent the internal mean errors of the present photographic photometry.*

Mean UBVR photometric data for flare stars and emission stars are given in Tables 1 and 2, respectively, together with the number of measures and the magnitude dispersions. Programme stars were selected from the outer region of the Orion aggregate to avoid the densest nebulosity. Small variations in background density were taken into account, and a general empirical limit to the background density was applied such that the magnitude dispersions were independent of density. The upper limit to these corrections was 0^m15 in R and 0^m5 in U, B and V and was approached in

TABLE 1

Flare Stars : Mean Magnitudes, Number of Measures and Dispersions

Ton. No.	$\bar{U}$	n_U	σ_U	$\bar{B}$	n_B	σ_B	$\bar{V}$	n_V	σ_V	$\bar{R}$	n_R	σ_R
2				$17^m.95$	(3)	±.21	$17^m.47$	(14)	±.40	$15^m.63$	(1)	
4	$15^m.24$	(2)	±.04	14.94	(4)	.10	13.79	(7)	.10	12.56	(2)	±.01
5				17.10	(6)	.17	15.89	(21)	.15	14.67	(8)	.16
6	17.24	(2)	.16	16.22	(5)	.09	14.77	(15)	.09	13.32	(7)	.09
7				18.43	(1)		18.58	(4)	.36	15.89	(4)	.04
8				17.81	(4)	.04	16.82	(15)	.08	14.68	(7)	.10
10	17.59	(5)	.24	16.82	(9)	.16	15.41	(21)	.16	13.94	(10)	.07
12	17.01	(3)	.46	17.53	(6)	.28	17.26	(12)	.53	15.51	(3)	.21
13				17.78	(4)	.09	16.88	(15)	.13	14.99	(7)	.10
14	16.40	(6)	.35	16.72	(10)	.38	15.40	(20)	.21	13.76	(10)	.15
15				17.28	(4)	.04	16.00	(15)	.13	14.46	(7)	.08
16	17.50	(1)		17.12	(7)	.13	15.76	(18)	.15	14.01	(9)	.12
17				17.06	(5)	.08	15.65	(15)	.09	13.86	(7)	.06
18	17.16	(1)					15.75	(1)		14.29	(1)	
19	17.75	(2)	.42	17.35	(9)	.30	16.23	(10)	.20	14.34	(8)	.11
20				17.20	(10)	.19	16.08	(22)	.15	14.21	(10)	.17
21				17.90	(1)		17.75	(14)	.20	15.14	(10)	.21
22				16.28	(10)	.37	15.01	(22)	.18	13.41	(10)	.21
23	16.87	(6)	.35	16.27	(10)	.29	14.85	(19)	.17	13.30	(8)	.21
24	16.54	(3)	.37	15.68	(5)	.13	14.38	(8)	.09	13.05	(3)	.10
25				15.4	(1)		14.1	(1)		13.0	(1)	
26				17.73	(5)	.13	16.81	(8)	.09	14.85	(3)	.08
28				17.89	(3)	.03	17.04	(15)	.10	15.12	(7)	.09
29				17.47	(4)	.07	16.16	(15)	.13	14.43	(7)	.05
30				17.27	(9)	.24	16.12	(14)	.07	14.44	(7)	.15
31	17.43	(3)	.11	16.76	(5)	.06	15.31	(15)	.09	13.74	(7)	.06
32				17.21	(6)	.11	15.89	(18)	.14	14.17	(9)	.11
33				18.17	(2)	.18	18.09	(10)	.36	15.72	(4)	.14
34	15.56	(5)	.21	15.37	(10)	.18	14.10	(19)	.14	12.72	(7)	.12
35				17.79	(5)	.14	16.96	(6)	.14	15.03	(3)	.07
36				17.61	(7)	.14	16.79	(19)	.17	15.09	(9)	.16
37				17.53	(7)	.23	16.52	(13)	.09	14.36	(5)	.14
38				17.35	(5)	.17	16.14	(8)	.10	14.56	(3)	.10
39	14.94	(4)	.10	16.40	(8)	.34	16.26	(17)	.36	14.64	(9)	.12
40				17.16	(6)	.10	15.82	(18)	.11	14.17	(9)	.10
41				17.15	(6)	.18	16.40	(19)	.24	14.52	(8)	.16
42	15.24	(4)	.36	15.80	(9)	.23	14.68	(22)	.15	13.06	(10)	.09
43	13.20	(7)	.38	13.55	(9)	.19	12.74	(22)	.14	11.69	(10)	.12
45	15.36	(7)	.43	15.76	(6)	.37	14.77	(18)	.17	13.44	(9)	.10
46				17.62	(5)	.17	16.57	(8)	.10	14.94	(3)	.04
48				17.34	(9)	.19	16.31	(19)	.20	14.64	(8)	.12
49				17.52	(4)	.12	16.67	(17)	.17	14.84	(9)	.12
50				17.31	(8)	.09	16.08	(20)	.24	14.41	(9)	.10

TABLE 1 (continued)

Ton. No.	$\bar{U}$	n_U	σ_U	$\bar{B}$	n_B	σ_B	$\bar{V}$	n_V	σ_V	$\bar{R}$	n_R	σ_R
51	$14^{\rm m}.39$	(3)	±.27	$15^{\rm m}.01$	(4)	±.45	$13^{\rm m}.94$	(8)	±.25	$12^{\rm m}.68$	(3)	±.12
52							18.04	(6)	.32	15.76	(4)	.07
53							17.32	(12)	.37	15.57	(5)	.18
55				16.49	(5)	.37	15.69	(14)	.25	14.16	(7)	.16
56				17.03	(5)	.15	15.67	(8)	.14	14.01	(3)	.09
57	17.28	(1)		17.17	(9)	.17	16.11	(19)	.18	14.32	(9)	.10
58	14.32	(6)	.50	14.62	(9)	.18	13.62	(15)	.11	12.34	(7)	.04
60				16.92	(8)	.22	15.91	(18)	.27	14.39	(9)	.17
61				17.95	(3)	.27	17.51	(11)	.28	15.45	(5)	.14
62	17.68	(2)	.18	16.87	(5)	.06	15.43	(14)	.09	14.00	(6)	.05
63	15.14	(7)	.37	15.02	(9)	.21	13.71	(20)	.13	12.34	(9)	.10
65				17.40	(5)	.18	16.89	(20)	.36	15.34	(7)	.28
66	17.12	(4)	.09	16.37	(5)	.07	14.98	(15)	.09	13.52	(7)	.05
67										12.85	(7)	.37
68							15.58	(14)	.43	13.95	(7)	.24
69				17.03	(7)	.28	16.53	(16)	.25	14.89	(7)	.23
70	16.53	(4)	.10	16.18	(5)	.12	14.64	(15)	.09	12.96	(7)	.05
71	15.0	(2)	.15	15.66	(10)	.38	14.73	(22)	.21	13.43	(10)	.18
72	14.22	(7)	.63	14.86	(9)	.42	13.86	(22)	.28	12.51	(10)	.20
73				17.65	(5)	.19	16.55	(8)	.08	14.70	(3)	.01
75				17.18	(9)	.18	16.48	(17)	.20	14.84	(7)	.21
76				16.94	(5)	.18	15.64	(14)	.20	14.22	(7)	.07
77	14.81	(2)	.01	14.43	(9)	.22	13.28	(22)	.11	11.96	(10)	.12
78				17.63	(9)	.26	17.79	(11)	.31	15.91	(3)	.10
79	16.30	(6)	.18	15.84	(9)	.14	14.45	(20)	.06	13.01	(9)	.07
80	15.55	(6)	.15	16.32	(9)	.19	15.40	(16)	.20	14.01	(7)	.10
81				17.82	(4)	.18	16.93	(14)	.27	14.88	(7)	.17
82				17.16	(5)	.12	15.91	(15)	.16	14.24	(7)	.09
83				16.17	(7)	.22	14.87	(13)	.12	13.43	(5)	.14
84				17.42	(9)	.22	16.66	(18)	.16	15.02	(9)	.16
85	16.39	(4)	.38	16.14	(10)	.17	14.99	(19)	.12	13.79	(9)	.15
86	14.68	(7)	.39	14.92	(9)	.27	13.93	(22)	.13	12.61	(10)	.13
87	16.32	(6)	.52	16.95	(10)	.24	16.04	(22)	.20	14.24	(10)	.11
88				17.08	(4)	.17	15.97	(14)	.19	13.90	(7)	.16
89	16.17	(6)	.41	16.13	(10)	.21	14.98	(22)	.19	13.61	(10)	.15
90	16.87	(4)	.15	16.14	(5)	.14	14.73	(15)	.17	13.30	(7)	.06
91				17.88	(4)	.09	17.18	(8)	.10	14.72	(3)	.06
92				17.10	(5)	.12	15.78	(15)	.10	14.24	(7)	.09
93	17.07	(2)	.39	16.78	(5)	.30	15.68	(8)	.15	14.13	(3)	.04
94				17.51	(2)	.09	16.72	(14)	.14	14.84	(7)	.10
96				18.14	(1)		18.03	(5)	.11			
97	16.83	(5)	.23	16.54	(7)	.26	15.13	(18)	.17	13.47	(9)	.14
98				17.96	(2)	.12	17.78	(15)	.17	15.65	(5)	.16
99				17.02	(5)	.51	15.45	(8)	.51	13.76	(3)	.16
100	17.35	(4)	.06	17.39	(5)	.07	16.33	(18)	.21	14.52	(9)	.12
101	16.82	(6)	.25	16.89	(9)	.25	15.74	(20)	.15	14.21	(9)	.16
102	16.65	(4)	.13	15.87	(5)	.12	14.35	(15)	.06	12.41	(7)	.08
103				18.08	(4)	.07	17.78	(6)	.12	15.50	(2)	.01

TABLE 1 (continued)

Ton. No.	$\bar{U}$	n_U	σ_U	$\bar{B}$	n_B	σ_B	$\bar{V}$	n_V	σ_V	$\bar{R}$	n_R	σ_R
104	$15^{m}.72$	(7)	±.18	$15^{m}.92$	(10)	±.14	$14^{m}.74$	(22)	±.14	$13^{m}.21$	(10)	±.11
105				17.50	(8)	.18	16.66	(22)	.19	14.59	(10)	.20
107				17.47	(9)	.13	16.57	(22)	.20	14.49	(10)	.20
109	17.63	(2)	.10	17.04	(5)	.07	15.56	(15)	.14	13.89	(7)	.11
111	17.19	(5)	.26	17.32	(9)	.14	16.51	(19)	.15	14.86	(9)	.17
112				18.22	(2)	.05	17.90	(11)	.27	15.53	(5)	.15
113	17.14	(6)	.22	16.65	(10)	.12	15.39	(19)	.13	13.97	(9)	.12
114	17.52	(1)		17.09	(9)	.22	15.90	(15)	.10	14.46	(6)	.14
115	15.24	(3)	.12	15.99	(5)	.30	15.25	(8)	.34	13.66	(3)	.23
116	17.16	(2)	.05	17.08	(7)	.12	15.78	(16)	.15	14.18	(7)	.13
117				17.92	(7)	.10	17.46	(17)	.16	15.39	(6)	.21
118	17.19	(2)	.13	16.57	(3)	.05	15.20	(9)	.13	13.83	(4)	.05
119				17.95	(5)	.10	17.26	(15)	.20	14.99	(7)	.13
124				17.22	(5)	.33	16.27	(13)	.65	14.62	(5)	.03
125				16.58	(5)	.11	15.02	(13)	.09	13.52	(5)	.10
127	17.51	(4)	.38	16.61	(5)	.26	15.16	(14)	.15	13.64	(7)	.12
128				17.84	(4)	.19	17.02	(7)	.11	15.28	(2)	.01
129	17.83	(2)	.33	17.36	(5)	.13	16.17	(14)	.12	14.27	(7)	.07
130	16.48	(6)	.15	15.94	(10)	.37	14.39	(19)	.07	12.86	(9)	.06
131	17.56	(1)		17.45	(7)	.15	16.21	(22)	.15	14.35	(10)	.08
132				17.18	(3)	.02	15.91	(15)	.10	14.22	(7)	.11
133				17.68	(5)	.35	16.91	(8)	.16	14.89	(3)	.13
134	16.36	(6)	.41	16.09	(10)	.29	14.89	(22)	.11	13.76	(10)	.09
135				17.73	(3)	.19	17.22	(12)	.23	15.46	(6)	.26
136				17.15	(5)	.07	15.65	(15)	.08	14.01	(7)	.09
137				17.88	(6)	.18	17.34	(17)	.24	15.41	(6)	.19
138	16.93	(1)		17.26	(5)	.20	15.92	(2)	.03	14.47	(3)	.15
139	16.81	(6)	.38	16.29	(11)	.20	14.93	(19)	.11	13.25	(9)	.07
140				17.82	(3)	.00	17.03	(15)	.11	14.92	(7)	.11
141	16.77	(6)	.27	16.07	(7)	.13	14.66	(18)	.08	13.14	(9)	.06
142				17.13	(7)	.24	15.87	(13)	.10	14.36	(5)	.08
143	16.67	(3)	.23	15.82	(5)	.07	14.48	(8)	.10	13.19	(3)	.04
144	15.60	(6)	.50	16.19	(10)	.48	15.38	(19)	.47	14.12	(9)	.31
145							17.6	(13)	.19	15.50	(7)	.18
146	12.97	(6)	.34	13.60	(9)	.16	12.61	(22)	.12	11.45	(9)	.10
147				16.14	(9)	.23	14.80	(17)	.17	13.08	(9)	.12
148	17.5	(1)		16.87	(5)	.19	15.40	(7)	.12	13.75	(3)	.04
149				17.76	(3)	.04	16.69	(13)	.16	14.93	(7)	.08
150				17.38	(7)	.23	16.27	(13)	.08	14.62	(5)	.11
151	15.48	(3)	.18	16.66	(9)	.29	15.79	(18)	.20	14.24	(8)	.20
152	15.86	(3)	.17	15.96	(8)	.15	14.81	(11)	.14	13.57	(5)	.05
153				16.82	(8)	.22	15.55	(12)	.17	14.17	(6)	.11
155	16.80	(1)		17.25	(7)	.19	15.99	(18)	.25	14.33	(9)	.10
156	17.88	(1)		16.13	(1)		14.94	(1)		13.35	(1)	
157	15.14	(7)	.71	16.35	(9)	.55	16.30	(17)	.67	14.91	(7)	.38
158				16.46	(5)	.62	15.02	(8)	.11	13.61	(3)	.07
161				17.54	(8)	.16	16.99	(17)	.18	15.21	(7)	.21
162				17.58	(6)	.30	17.33	(20)	.24	15.15	(9)	.18
163	16.79	(1)		16.99	(9)	.18	15.84	(22)	.16	13.95	(10)	.11

TABLE 1 (continued)

Ton. No.	$\overline{U}$	n_U	σ_U	$\overline{B}$	n_B	σ_B	$\overline{V}$	n_V	σ_V	$\overline{R}$	n_R	σ_R
164				$17^m.45$	(9)	±.16	$16^m.47$	(22)	±.15	$14^m.29$	(10)	±.14
165							17.91	(6)	.09			
166	$17^m.10$	(2)	±.06	17.10	(5)	.30	15.85	(8)	.17	14.30	(3)	.07
167	17.81	(1)		17.30	(5)	.10	15.98	(15)	.15	14.41	(7)	.09
168	17.55	(1)		18.10	(4)	.11	17.77	(6)	.12	15.71	(1)	
169	14.92	(8)	.13	14.64	(10)	.12	13.52	(23)	.08	12.41	(10)	.06
170				18.00	(3)	.11	17.34	(14)	.19	15.25	(7)	.17
171	16.63	(1)		16.91	(5)	.10	15.74	(8)	.09	13.90	(3)	.13
172	17.34	(2)	.04	16.65	(3)	.11	15.37	(9)	.17	14.05	(4)	.03
177				18.15	(1)		17.32	(1)		15.45	(1)	
178				17.30	(1)		16.01	(1)		13.89	(1)	
179				16.78	(1)		15.49	(1)		14.00	(1)	
186				17.60	(1)		16.35	(1)		14.64	(1)	
187	17.08	(1)		16.12	(1)		14.68	(1)		12.82	(1)	
188	18.4	(1)		16.44	(1)		15.15	(1)		13.32	(1)	
189				17.67	(1)		16.74	(1)		14.65	(1)	
190	17.40	(1)		17.64	(1)		16.94	(1)		15.15	(1)	
191	16.51	(1)		16.90	(1)		15.72	(1)		14.34	(1)	
192	16.48	(1)		16.05	(1)		14.74	(1)		13.31	(1)	
193	15.61	(1)		15.05	(1)		13.95	(1)		12.70	(1)	
194				15.44	(1)		14.47	(1)		12.95	(1)	
195				17.44	(1)		16.48	(1)		14.80	(1)	
196				16.53	(1)		15.18	(1)		13.22	(1)	
197	15.56	(5)	.14	16.16	(8)	.33	14.91	(12)	.15	13.60	(6)	.12
198	17.14	(1)		16.24	(1)		14.76	(1)		13.19	(1)	
199				16.97	(1)		15.88	(1)		14.51	(1)	
200	17.10	(1)		16.93	(1)		15.51	(1)		13.70	(1)	
201	14.71	(5)	.32	14.78	(7)	.17	13.48	(12)	.11	12.17	(6)	.07
202				14.64	(1)		13.85	(1)		12.74	(1)	
203	16.6	(1)		17.12	(1)		15.78	(1)		14.34	(1)	
204	16.6	(1)		16.49	(1)		15.19	(1)		13.45	(1)	
205				17.38	(1)		16.27	(1)		14.87	(1)	
206	15.05	(7)	.43	14.96	(10)	.20	13.54	(22)	.11	12.05	(10)	.12
207	16.98	(1)		17.33	(1)		16.16	(1)		14.63	(1)	
208	14.35	(1)		14.24	(1)		13.02	(1)		11.97	(1)	
209				15.41	(1)		13.83	(1)		11.94	(1)	
210	15.30	(1)		15.06	(1)		14.10	(1)		12.89	(1)	
211	16.10	(1)		15.62	(1)		14.52	(1)		13.27	(1)	
212							17.06	(1)		14.89	(1)	
213	14.24	(1)		14.03	(1)		13.37	(1)		12.32	(1)	
214	16.06	(1)		16.48	(1)		15.33	(1)		13.78	(1)	
215				17.35	(1)		16.24	(1)		14.31	(1)	
216	15.73	(1)		15.17	(1)		13.98	(1)		12.61	(1)	
217	15.7	(1)		14.83	(9)	.20	13.91	(22)	.14	12.70	(10)	.10
218	17.4	(1)		16.52	(9)	.30	15.46	(18)	.16	13.97	(8)	.12
219	15.5	(1)		15.82	(1)		14.39	(1)		12.86	(1)	
220							18.8	(1)		15.6	(1)	
221				16.67	(1)		15.86	(1)		14.35	(1)	
222				16.55	(1)		15.16	(1)		13.54	(1)	

TABLE 1 (continued)

Ton. No.	$\bar{U}$	n_U	σ_U	$\bar{B}$	n_B	σ_B	$\bar{V}$	n_V	σ_V	$\bar{R}$	n_R	σ_R
223	16^m.12	(5)	±.34	15^m.83	(7)	±.17	14^m.40	(9)	±.10	12^m.90	(9)	±.08
224	14.95	(1)		14.92	(1)		14.05	(1)		12.86	(1)	
225	14.19	(1)		14.25	(1)		13.51	(1)		12.35	(1)	
226				16.08	(7)	.28	15.20	(11)	16	13.73	(5)	.08
227	15.76	(1)		15.30	(1)		14.15	(1)		12.83	(1)	
228	15.07	(1)		15.28	(1)		14.14	(1)		12.90	(1)	
229	16.17	(1)		16.05	(1)		14.77	(1)		13.31	(1)	
230							12.3	(1)		11.5	(1)	
231	15.24	(1)		14.52	(1)		13.22	(1)		11.72	(1)	
232				17.77	(1)		16.74	(1)		15.02	(1)	
233				17.45	(1)		16.33	(1)		14.68	(1)	
234	16.71	(1)		16.33	(1)		15.08	(1)		13.70	(1)	
235				17.3	(1)		15.9	(1)		14.4	(1)	
236							15.93	(1)		14.30	(1)	
237							17.40	(1)		15.59	(1)	
238				17.05	(1)		15.85	(1)		14.11	(1)	
239							18.0	(1)		15.5	(1)	
240				17.63	(1)		16.67	(1)		14.91	(1)	
241	16.26	(1)		15.95	(1)		14.62	(1)		12.92	(1)	
242				18.04	(1)		17.42	(1)		15.59	(1)	
243				17.45	(1)		16.64	(1)		14.77	(1)	
244	14.95	(1)		14.71	(1)		13.73	(1)		12.56	(1)	
245				17.85	(1)		17.37	(1)		15.02	(1)	
246	17.3	(1)		17.7	(1)		17.26	(1)		15.6	(1)	
247	15.58	(1)		15.19	(1)		13.85	(1)		12.43	(1)	
248				16.99	(1)		16.03	(1)		14.36	(1)	
249				17.00	(1)		15.64	(1)		14.50	(1)	

TABLE 2

Hα -Emission Stars in Orion: Mean Magnitudes and Colours,
Number of Measures and Dispersion in Magnitude.
(Haro No. = Designation according to Haro (1953) list)

Haro No.	Other Desig.	V	U-B	B-V	V-R	n(UBVR)	σ(UBVR)
71	VY	$15^{m}.15$	$-1^{m}.29$	$0^{m}.82$	$1^{m}.47$	5- 5-15- 7	13-13-24-11
84	V360	12.40	0.16	1.37	1.31	7- 9-20- 9	34-22-14-13
85	V557	15.61	-0.26	1.25	1.56	1- 7-12- 5	00-21-15-11
91	KN	13.16		0.94	1.03	0- 7-13- 6	00-23-14-05
94	IS	15.76		0.60	1.62	0- 2-13- 9	00-39-30-24
95		14.58	-0.26	1.34	1.61	3- 7-12- 6	21-23-11-07
98		17.08		0.55	1.97	0- 6-12- 6	00-15-14-23
103	V367	15.34	-0.28	1.02	1.77	5- 8-12- 6	34-22-46-20
112		14.37		1.18	1.43	0- 7-12- 6	00-22-16-07
119	BC	14.88	-1.02	0.91	1.51	7-10-22-10	14-11-13-08
121		16.13		0.82	1.47	0- 4- 8- 3	00-38-21-19
135	IM	15.80		0.35	1.35	0- 6-19- 6	00-33-28-28
136		13.57	0.28	1.23	1.06	5- 8-12- 6	19-24-11-05
140		15.24		0.74	1.37	0- 4- 8- 3	00-19-21-17
142		15.14		0.96	1.72	0- 4- 8- 3	00-21-13-09
145		17.09	-0.67	1.07	2.09	1- 5- 8- 3	00-41-19-09
147		16.38		0.76	1.84	0- 7-14- 6	00-19-20-17
151		14.31		1.07	1.49	0- 3- 6- 4	00-36-11-06
153		15.64		1.36	1.70	0- 7-12- 6	00-19-13-06
158		14.13		1.02	1.32	0- 8-22- 9	00-20-12-10
159	HY	14.17	-0.21	1.17	1.29	5- 8-17- 6	16-12-20-17
162		16.39	-0.52	0.96	1.82	2- 7-12- 6	36-16-23-28
164		15.42		0.54	1.36	0- 6-11- 6	00-19-22-11
165		12.50		1.03	1.12	0- 7-12- 6	00-23-14-11
167		15.91	-1.41	1.02	1.64	1- 2- 8- 3	00-01-20-04
169	AB	13.67		1.07	1.37	0- 7-12- 6	00-38-22-14
170		13.87		1.16	1.31	0- 7-12- 6	00-13-10-10
171		16.12		0.96	1.76	0- 4- 9- 4	00-18-29-18

TABLE 2 (continued)

Haro No.	Other Desig.	V	U-B	B-V	V-R	n(UBVR)	σ(UBVR)
175		14.79	-0.46	1.06	1.32	4- 7-12- 5	21-13-15-07
177	XY	16.42	-1.07	0.75	1.67	4- 5-15- 6	31-12-19-14
180	AA	12.81	-0.35	1.16	1.28	4- 7-12- 5	07-18-16-05
189	AU	15.88	-0.45	0.92	1.65	2- 4- 8- 2	06-12-18-07
195		15.68		0.34	1.41	0- 4- 7- 2	00-20-44-06
204		14.49	0.34	1.60	1.92	3- 5- 8- 3	48-13-11-11
206		15.75	-0.66	0.94	1.50	3- 5- 8- 3	18-13-18-02
207		13.62	-0.07	1.28	1.20	3- 5- 8- 3	04-11-11-02
208		13.32	0.32	1.18	1.02	3- 5- 7- 3	02-12-08-06
209	AX	14.49	-0.22	1.25	1.58	3- 5- 8- 3	19-13-14-03
213		$15^{m}.47$	$0^{m}.12$	$0^{m}.97$	$1^{m}.51$	2- 5- 8- 3	22-36-25-05
214	V584	16.04	-0.17	1.22	0.82	1- 4- 8- 3	00-16-56-43
216	V571	14.67	-0.26	1.32	1.72	3- 5- 8- 3	24-14-23-02
218	V582?	16.22	0.22	1.07	1.78	2- 5- 8- 3	23-16-37-28
221		16.42		1.03	1.88	0- 4- 8- 3	00-10-15-05
226	BE	15.31	0.44	1.37	1.61	3- 5- 8- 3	46-44-68-64
227		16.61	-0.49	1.02	1.10	2- 5- 8- 2	34-34-107-06
228	GCVS 608	15.46	-0.55	1.00	1.53	3- 5- 8- 3	40-32-23-22
229	BF	9.75	0.27	0.24	0.28	3- 4- 8- 3	15-08-06-03
230		14.79	0.15	1.03	1.65	3- 4- 8- 3	39-09-26-16
231	V573	15.56	-0.49	0.75	1.47	3- 5- 8- 3	51-27-16-08
232	OY	15.60	-0.42	1.13	1.57	3- 5- 8- 3	34-62-57-60
233	V576	16.83	-0.32	0.76	1.75	2- 5- 8- 3	38-19-13-09
234		16.14		1.19	1.97	0- 5- 8- 3	00-15-18-19
236	AV	14.17	0.27	1.22	1.24	3- 5- 8- 3	66-65-59-74
237	V577	14.10	0.14	1.37	1.44	3- 5- 7- 2	04-14-09-01
239	TW	15.34	-0.52	0.74	1.71	3- 5- 8- 3	39-32-23-14
240		17.05	-0.96	0.42	1.92	3- 5- 8- 2	23-19-42-20
241	NT	14.60	-0.61	0.92	1.19	3- 5- 8- 3	08-12-17-06
242		15.70	-0.37	1.08	1.71	3- 5- 7- 3	55-38-24-05
244	AT	15.82	0.69	0.82	1.59	2- 5- 8- 3	46-51-43-26
245	V594	13.94	-0.22	1.10	1.42	2- 5- 8- 3	01-21-07-10
246	V591	16.14	-0.39	1.16	2.09	1- 5- 8- 3	00-17-20-15
247	V587?	16.24	-0.06	1.07	2.01	3- 5- 8- 3	77-40-68-60
248		15.91	-0.13	1.46	1.81	1- 5- 8- 3	00-10-13-06

Notes to Table 2

Flare stars in which Hα —emission has appeared either permanently or temporarily, and for which mean magnitudes and colours are already listed in Table 1, include the following objects [Haro Nos. (Haro 1953) or variable star designation with Tonantzintla Nos. (Haro 1968, Haro and Chavira 1969) given in parenthesis]:
12 (216), 34 (203), 48 (200), 61 (76), 64 (82), 70 (97), 74 (45), 78 (214), 80 (101), 83 (79), 101 (201), 102 (162), 104 (72), 106 (86), 108 (197), 113 (104), 148 (206), 154 (146), 166 (42), 168 (14), 174 (39), 176 (151), 178 (218), 183 (226), 198 (157), 200 (144), 210 (80), 219 (51), 222 (148), 223 (12).
V394 (16), V726 (21), V408 (54), V654 (78), V833 (92), V839 (93), V588 (111), V593 (115), SW (208), V874 (246).

very few cases. Internal mean errors over the 13 sq. deg. photometric field are summarized in Table 3 in terms of magnitude at which they apply:

TABLE 3

Internal Mean Errors

Mean Errors	*U*	*B*	*V*	*R*
$\pm 0^m10$		14^m8	14^m7	14^m5
0.15	15^m0	16.3	16.7	15.0
0.20	16.0	16.8	17.2	15.5
0.25	16.5	17.8	17.7	15.7
0.30	17.0	18.0	18.0	16.0

The mean error of a colour determination may be estimated by combining the mean errors in magnitude quadratically at each point in the colour-magnitude and two-colour arrays. For example, for a typical point within the diagrams for non-emission flare stars we find:

$$V = 15^m0 \pm 0.11,\ V\text{-}R = 1^m5 \pm 0.14,\ B\text{-}V = 1^m4 \pm 0.19,\ U\text{-}B = 0^m4 \pm 0.31$$

The accuracy is low for colour-magnitude work. The colour excesses reported for some of these stars and the peculiar brightness fluctuations detected by Mendoza (1968) and commented upon by Haro (1969) are, however, several times greater than our mean errors.

III. Discussion

Two-colour diagrams are constructed for all emission stars with a designation according to emission strength.* See Figs. 2 to 4. For comparison with the mean colour distribution of flare stars, excluding those which have exhibited eHα, the colour dispersions in B-V, U-B and U-V at constant V-R are indicated by vertical lines at intervals of 0^m1 in V-R. The use of V-R as abscissa in all the diagrams is particularly instructive since apart from the fact that V-R is probably least affected by line and continuum anomalies (Mendoza 1968) it is also approximately linearly related to apparent brightness. Photometric accuracies then fall off towards the red in the colour diagrams. Kuhi (1970) has found that contamination of continuum colours by emission is present in V-R although the effect is small (0^m03 to 0^m10 over the bandwidth of 1900 A of the standard R filter). However, Kuhi (1966) and Anderson and Kuhi (1969) have shown that small changes in eHα strength in T Tauris are accompanied by either an increase or a decrease in the ultraviolet emission continuum so that a simple correlation is not expected in these T Tauri-related objects. This is especially true since the present work is not made simultaneously with the emission strength estimates of Haro. On a statistical basis, however, the colour diagrams demonstrate that U-B and U-V are strongly affected by the presence of eHα.

The B-V/V diagram (Fig. 5) for emission stars further demonstrates the remarkable differences between this class of stars and the non-emission flare stars (c. f. Andrews 1970 Fig. 3). The number of emission stars below the main sequence in the range $15^m < V < 16^m$ is extremely high, and includes a large number of objects for which the eHα strength is only weak. As in the case of the flare stars there is a complete absence of emission stars with B-V $\gtrsim 1^m6$, and a strong blueward trend towards

* Haro (1953) gives a classification of eHα strength relative to the continuum: 5 = very strong, 4 = strong, 3 = medium, 2 = weak, 1 = doubtful, 0 = absent. Designation in Figs. 2 to 6 follows: *Permanent eHα*, 5-5, 5-4 (large filled circles), 5-3 (triangles), 4-4, 4-3, 3-3 (smaller filled circles); *Temporary eHα*, 5-1, 5-0, etc. or *Weak eHα*, (small open circles).

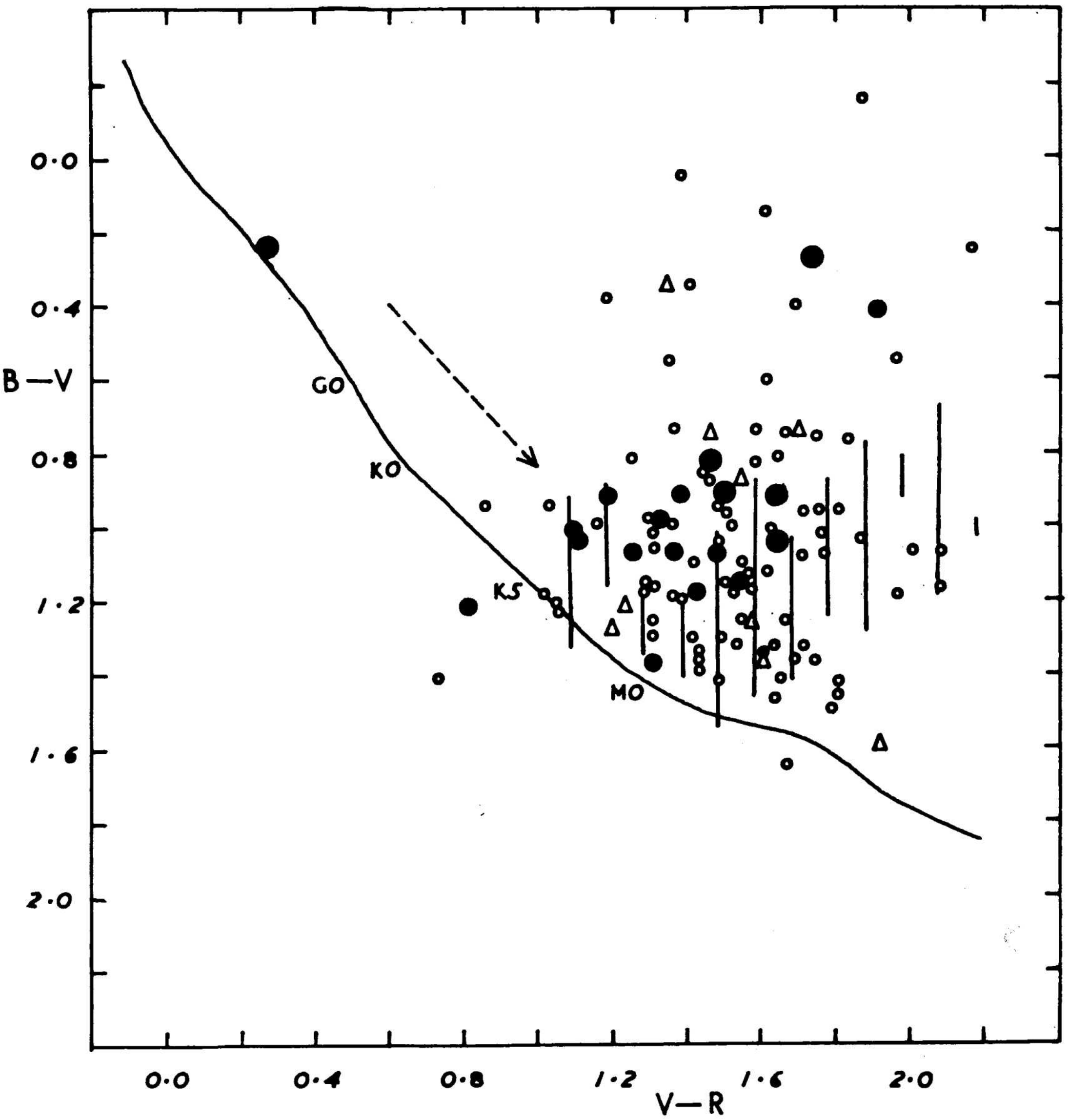

Fig. 2. Hα-Emission Stars: B-V/V-R Diagram. *Stars are desiganted according to eHα strength (See Text). For comparison, the dispersions in B-V of flare stars at constant V-R (in steps of 0m1) are shown as vertical lines. The direction of normal interstellar reddening tracks is indicated by the broken line.*

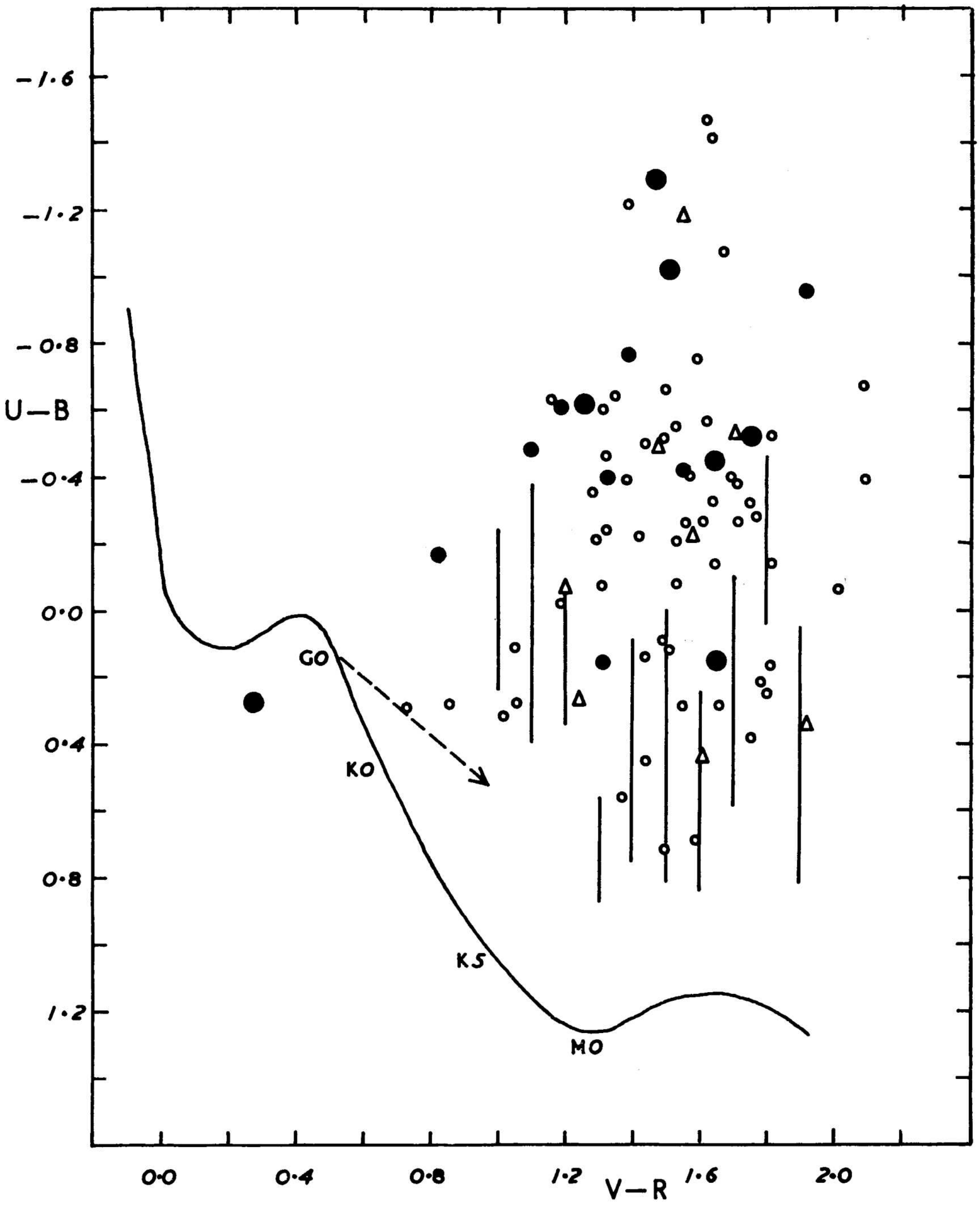

Fig. 3. Hα-Emission Stars: U-B/V-R Diagram. *Designation as in Fig. 2.*

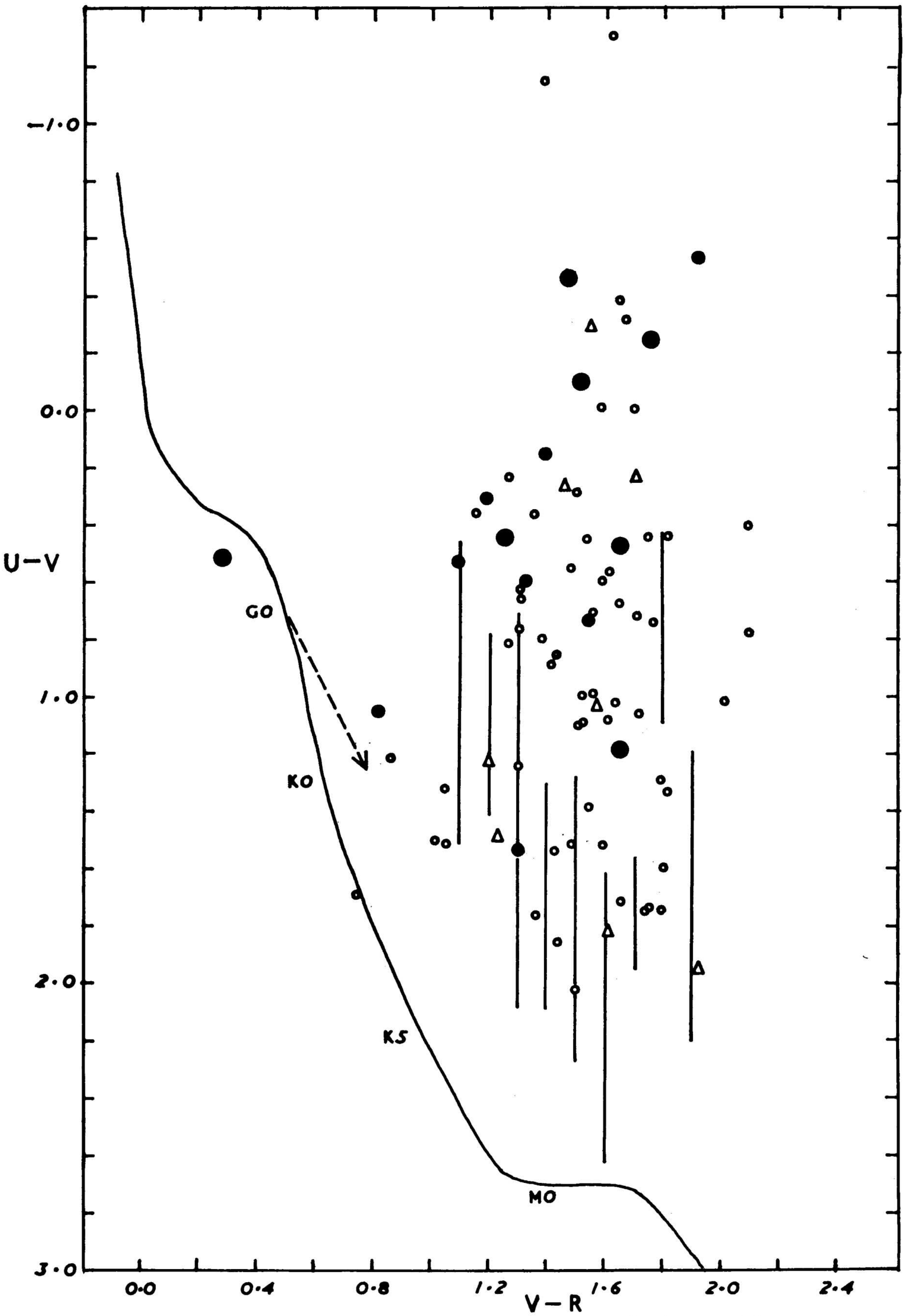

Fig. 4. Hα-Emission Stars: U-V/V-R Diagram. *Designation as in Figs. 2 and 3.*

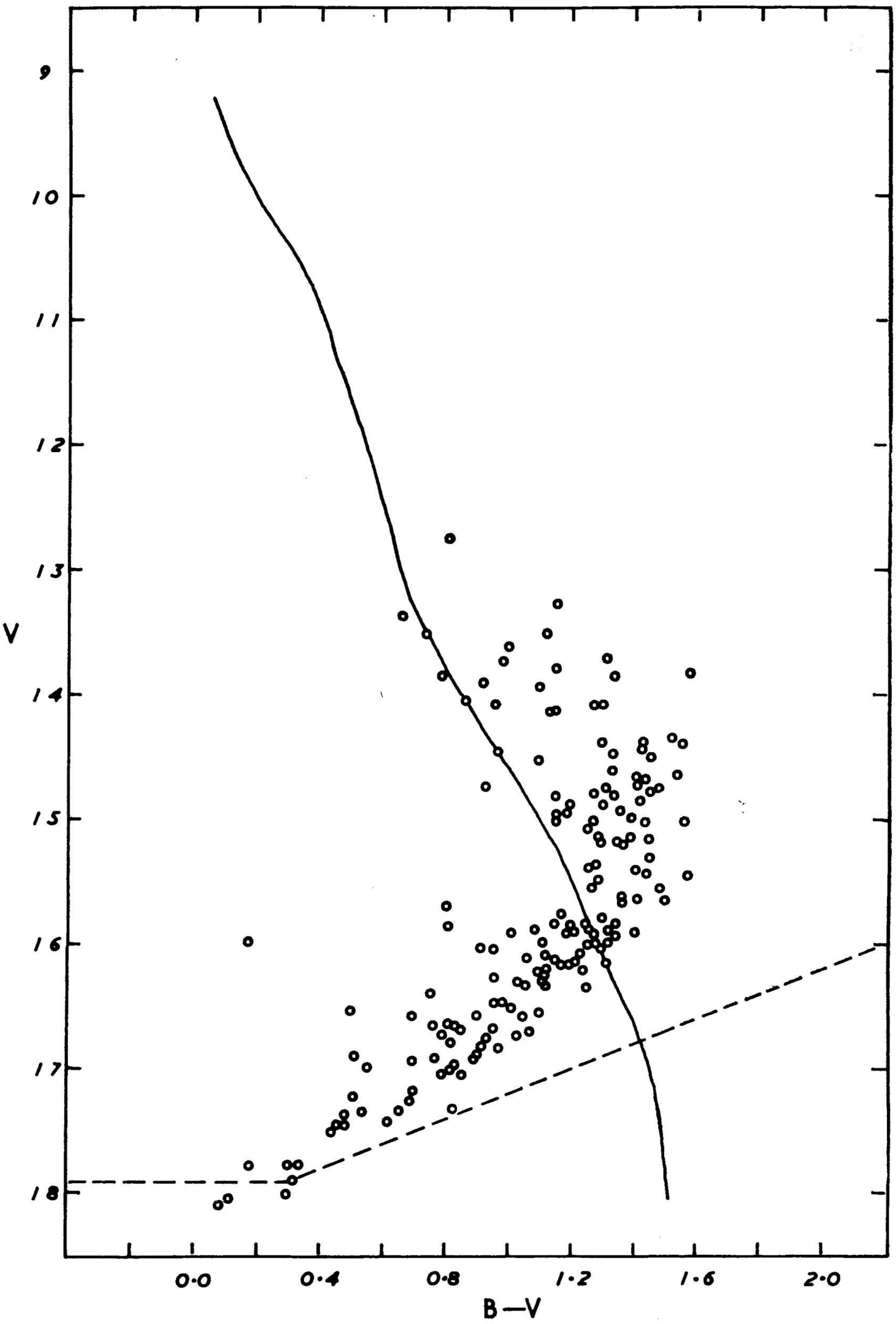

Fig. 5. Hα-Emission Stars: B-V/V Diagram. *Designation as in Figs. 2 to 4. The unreddened zero-age main-sequence (solid line) and the limit imposed by the photometric standards (broken line) are shown.*

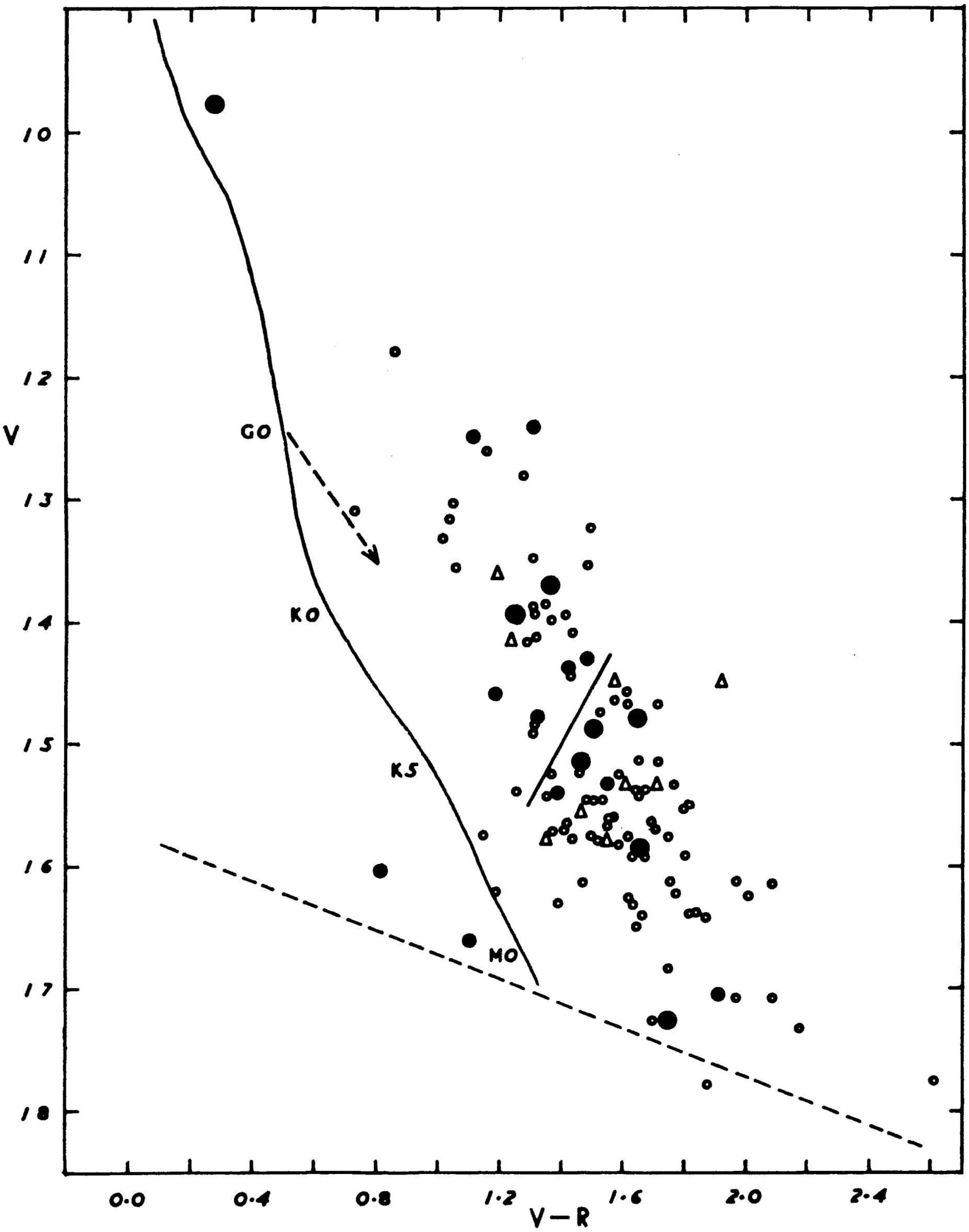

Fig. 6. **Hα-Emission Stars: V-R/V Diagram.** *Designation as in Figs. 2 to 5. The straight line traversing the emission-star distribution indicates one region of high density in the non-emission flare-star distribution (See Text).*

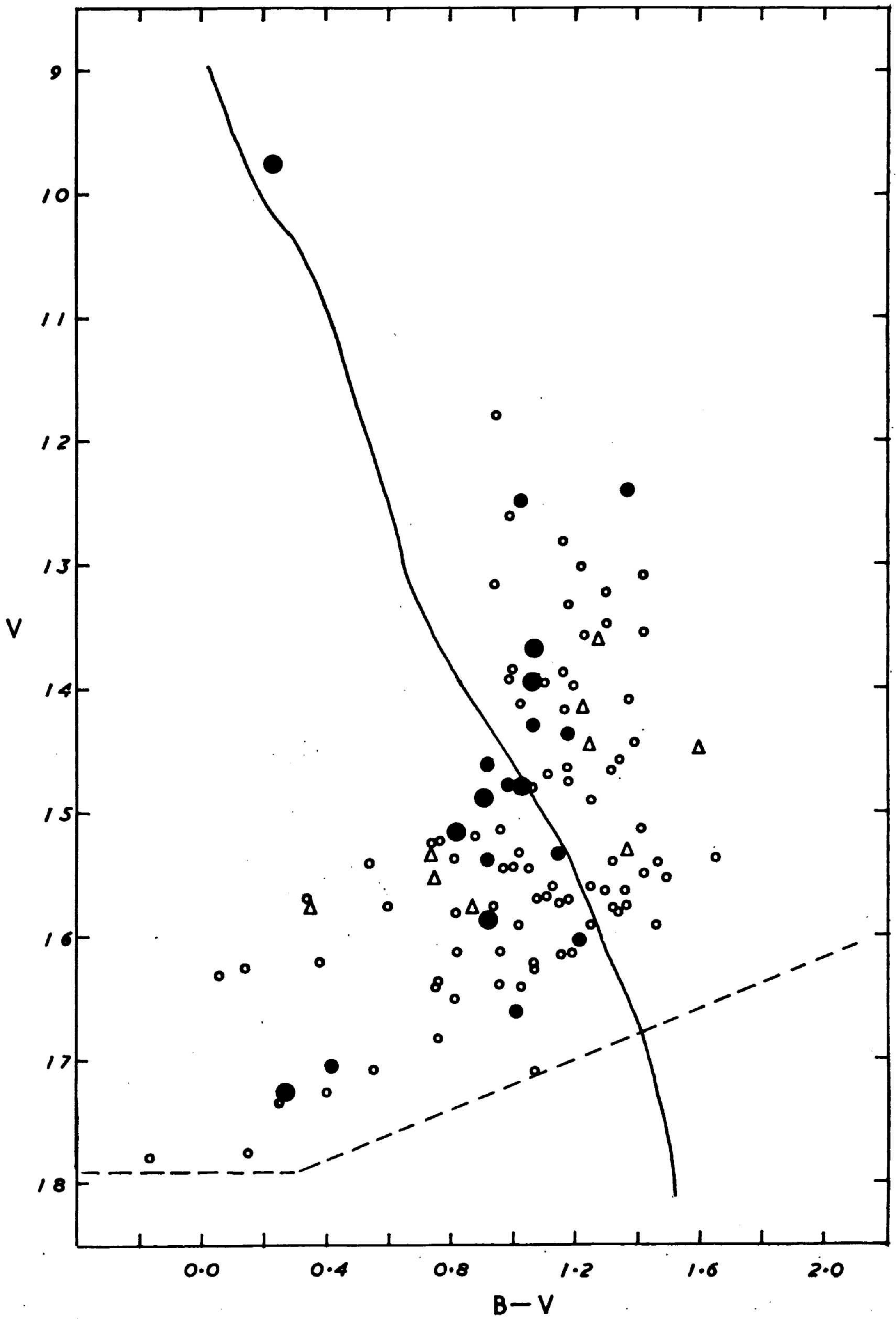

Fig. 7. Non-Emission Flare Stars: B-V/V Diagram. *The systematic departure of the Orion flare stars below the zero-age main-sequence is shown.*

fainter magnitudes. In V-R/V (Fig. 6) the emission stars, at first sight, appear similarly distributed to the non-emission flare stars well elevated above the main sequence. Nevertheless, attention is drawn to the fact that three vacant lanes traverse the V-R/V diagram of the non-emission flare stars (See Andrews 1970 Fig. 4) emerging redward at V = 14^m0, 14^m6 and 15^m2, at V-R 1^m5, 1^m6 and 1^m8, respectively. This feature may perhaps be dismissed were it not for the fact that these vacant lanes avoided by flare stars actually show a preponderance of emission stars. There is further evidence that the converse is also true, that emission stars systematically avoid the regions of the V-R/V diagram occupied by flare stars. The solid line in Fig. 6 passing through V = 14^m3, V-R = 1^m55 and V = 15^m4, V-R = 1^m30 represents the straight-line fitting of photometric data for 16 flare stars (Ton. Nos. 5, 6, 83, 89, 90, 118, 130, 141, 158, 172, 192, 194, 219, 223, 229 and 234) to within $\pm 0^m15$ in V, all non-emission objects. On the other hand, further flare stars do not appear within $\pm 0^m5$ in V as defined by this narrow band, although 16 emission objects lie within the latter range but outside this narrow band (i. e. Ton. Nos. 45, 66, 79, 80, 104, 144 and 197, and Haro Nos. 71, 95, 112, 119, 140, 151, 164, 175 and 209).

In view of the separation of emission and non-emission objects in the two-colour diagrams, it is of interest to examine the colour-magnitude diagram of stars in which the T Tauri characteristics are supposedly absent. In Fig. 7 the B-V/V diagram has been constructed for all flare stars omitting those which have shown eHα and those with large magnitude dispersions indicative of variability. At V = 15^m to 17^m the scatter in B-V is seen to be only $\pm 0^m2$, that is, of the order of the mean photometric errors. Accuracies are insufficient to quantitatively define the colour-magnitude relationship at V = 17^m but the blueward trend which is already evident at V = 15^m is maintained at fainter magnitudes. The point at which the flare star distribution crosses the main sequence is approximately V = $16^m0 \pm 0.14$; B-V = $1^m3 \pm 0.26$ prior to correction for interstellar absorption and reddening. The cut-off imposed by the limits of the photoelectric B and V scales is given in Fig. 7 by the dashed line. A search for red stars fainter than V = 16^m below the turn-off of the flare stars revealed several objects with B-V up to 1^m9, mostly imbedded in regions of dense obscuration. It appears that the faint blue flare stars define a major anomaly of the Orion aggregate.

IV. Concluding Remarks

The results cannot be interpreted with any confidence in terms of pre-main sequence evolutionary tracks although the accuracy is comparable with the photographic measures employed by Walker (1956) in his classical work on NGC 2264 (We note that 64% of Walker's stars fainter than $M_V = +4^m$, supposedly gravitationally-contracting, were measured photographically). Lack of reliable transformations of the observed parameters into M_{bol} and $\log T_e$ for stars exhibiting such anomalous UBVR relationships, combined with scanty information on reddening and total absorption in Orion, allows only a few tentative suggestions. Attempts to utilize the V-R/V diagrams in Orion (Sedyakina 1971) and NGC 2264 (Nandy 1971) on the basis that V-R is less affected than B-V by intrinsic colour excesses are finally thwarted by the same doubts. Certainly, more accurate observations are required to discuss the fitting of isochrones to the faint tail of the colour-magnitude diagram in relation to problems of star formation as attempted by Sedyakina (1971). The result that the blue excesses increase towards lower luminosities is fundamentally difficult to reconcile with existing theories of gravitationally-contracting stars, an effect pointed out by Haro in Orion and NGC 2264 (Haro and Chavira 1964). Recently, renewed interest in circumstellar shells enveloping young objects (See e. g. Strom, Strom and Yost 1971) suggests that the solution may be found in the properties of the remnant gas and dust shells accompanying gravitational collapse in stars of differing mass. At least three possible explanations are available for the vacant lanes in the V-R/V diagram of the Orion flare stars. Firstly, there may exist discontinuities in the mass distribution of these objects related either to an observational selection effect or to star formation itself since the lanes are suggestive of evolutionary tracks in the $M_{bol}/\log T_e$ diagram. This attractive hypothesis might be considered jointly with the second explanation. The appearance of emission stars, many of which are variables, within the vacant lanes may be accounted for by the nature of their excursions in the colour-magnitude diagram. Parenago (1954), in his classification of Orion variables from the frequency function of random observations of magnitude, arrived at the interesting conclusion that stars of different classes (e. g. Class I favouring 'relapses', Class III, 'outbursts' from mean brightness) appear to be quiescent over restricted magnitude ranges. This effect alone, of course, could produce a clumpiness in the colour-magnitude diagram derived from mean photometric data. It is noteworthy that at photographic accuracies the non-emission flare stars appear constant in UBVR, a point which is at variance to the photoelectric work of Mendoza (1968). Lastly, the presence of systematic scale errors in the V and R magnitudes could distort the V-R/V diagram, but the use of mean data scarcely leads one to expect a pronounced effect. That the ultraviolet and blue excesses found in a variety of T Tauri-related objects are a common feature of many stars in the Orion aggregate, even apart from flare and emission stars, is clear from the recent work of Sincheskul (1971) who has published a UBV photographic catalogue for the Orion field to V = 15^m. A comparative UBVR study of other nearby flare star aggregates to faint limits, such as in the Pleiades, and a detailed study of the colour and magnitude tracks of variables associated with them is urgently needed.

REFERENCES

Anderson, L. and Kuhi, L. V., 1969, I. A. U. IVth Colloq. Non-Periodic Phenomena in Var. Stars (ed. Detre, L.) Academic Press Budapest, p. 93.
Andrews, A. D., 1969, Ibid. p. 137.
————, 1970, Bol. Obs. Tonantzintla y Tacubaya **5**, No. 34, p. 195.
Haro, G., 1953, Ap. J., **117**, p. 73.
————, 1968, Stars and Stellar Systems Vol. 7, Nebulae and Interstellar Matter (ed. Middlehurst, B. H. and Aller, L. H.) Chicago Univ. Press, p. 141.
————, 1969, Bol. Obs. Tonantzintla y Tacubaya **5**, No. 32, p. 79.
Haro, G. and Chavira, E., 1964, O. N. R. Symposium, Flagstaff, Arizona.
————, 1969, Bol. Obs. Tonantzintla y Tacubaya **5**, No. 32, p. 59.
Johnson, H. L., 1957, Ap. J. **126**, p. 134.
————, 1965, Ap. J. **141**, p. 923.
Johnson, H. L. and Morgan, W. W., 1953, Ap. J. **117**, p. 313.
Kuhi, L. V., 1966, Pub. Astr. Soc. Pacific **78**, p. 430.
————, 1970, XVIth Liege Intern. Astroph. Colloq. Pre-main Sequence Stellar Evolution, p. 295.
Lee, T. A., 1968, Ap. J. **152**, p. 913.
Mendoza, E. E., 1967, Bol. Obs. Tonantzintla y Tacubaya **4**, No. 29, p. 149.
————, 1968, Ap. J. **151**, p. 977.
Morgan, W. W. and Loden, K., 1966, Vistas in Astronomy **8** (ed. Beer, A. and Strand, K. Aa.) Pergamon Press, p. 83.
Nandy, K., 1971, Pub. Roy. Obs. Edinburgh **7**, No. 4.
Parenago, P., 1954, Pub. Sternberg Astr. Inst. **25**, p. 226.
Sedyakina, A. N., 1971, Var. Stars (Acad. Sci. U. S. S. R.) **18**, No. 2, p. 213.
Sharpless, S., 1952, Ap. J. **116**, p. 251.
————, 1954, Ap. J. **119**, p. 200.
————, 1962, Ap. J. **136**, p. 767.
Sincheskul, V. N., 1971, Catalogue UBV Data in Orion Association, Acad. Sci. Ukranian S. S. R.
Strom, K. M., Strom, S. E. and Yost, J., 1971, Ap. J. 165, p. 479.
Walker, M. F., 1956, Ap. J. Suppl. **2**, p. 365.
————, 1969, Ap. J. **155**, p. 447.