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THE LAW OF INTERSTELLAR REDDENING AND ABSORPTION*

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ABSTRACT

The law of interstellar reddening and the slope of the reddening lines in the plot of $U - B$ versus $B - V$ have been reinvestigated in the light of more extensive data. The data consist of a catalogue of 262 O stars for which we have three-color photometry and slit spectrograms. The anomalous behavior of stars in the Great Rift in Cygnus found by Johnson and Morgan is confirmed. The equation of the mean reddening line is

$$\frac{E_{(U-B)}}{E_{(B-V)}} = 0.72 + 0.05 E_{(B-V)} .$$

A rediscussion of the ratio of total to selective absorption, with additional new data, gives

$$R = \frac{A_V}{E_{(B-V)}} = 3.0 \pm 0.2 \text{ (p.e.)} .$$

I. INTRODUCTION

There have been several suggestions (Baade and Minkowski 1937; Stebbins and Whitford 1945; Sharpless 1952; Johnson and Morgan 1955*a*) that the law of interstellar reddening and absorption is not the same everywhere. We wish here to reinvestigate, on the basis of more extensive data, the suggestion by Johnson and Morgan (1955*a*) that the law of interstellar reddening for the region of the Great Rift in Cygnus ($40° < 1 < 49°$) differs from that elsewhere in the Milky Way.

The ratio of total to selective absorption is also discussed here. Morgan, Harris, and Johnson (1953) and Blanco (1955) have found that the value of this ratio is

$$R = \frac{A_V}{E_{(B-V)}} = 3.0 ,$$

where A_V is the total visual absorption and $E_{(B-V)}$ is the color excess on the $B - V$ system, as determined from Whitford's (1948) interstellar absorption-curve, while Sharpless (1952) has derived a value of $R = 6.0$ for the region of the Orion Nebula.

When one uses the Q method for the determination of interstellar reddening (Johnson and Morgan 1953), he must know the characteristics of the reddening line (Morgan, Harris, and Johnson 1953) in the $U - B$ versus $B - V$ plot. The usual practice has been to assume, because of the relatively small number of data, that the reddening line is linear. Blanco, however, has shown, on the basis of the observed response of the photometer, the observed interstellar absorption-curve, and assumed stellar intensity distributions, that a slightly curved line is to be expected.

II. THE LAW OF INTERSTELLAR REDDENING

The data upon which our investigation of the law of interstellar reddening and the character of the reddening lines in the $U - B$ versus $B - V$ plot is based comes from catalogue of 262 O stars listed in Table 1. This catalogue was compiled from both published and unpublished data obtained by the two authors. The first column numbers

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TABLE 1

CATALOGUE OF O-TYPE STARS

No.	Star	1900 α	1900 δ	l	b	Spectrum	V	B-V	U-B
1...	108	$0^{h}00^{m}.9$	+63°07'	85.6	+ 1.4	O8 fp	7.40	+0.18	-0.79
2...	+63°12	0 08.2	+63°37'	86.5	+ 2.0	O9 Ib	9.76	+0.55	-0.45
3...	1337	0 12.5	+50°53'	85 5	-10.9	O9 III	5 9*	+0.03	-1.01
4...	+60°39	0 16.2	+61°10'	87.1	- 0.7	O9 V	9.46	+0.24	-0.70
5...	+61°74	0 20.4	+62°00'	87.7	+ 0.1	O9 V nn	9.55	+0.32	-0.66
6...	+62°79	0 20.9	+62°53'	87 8	+ 1 0	O9.5 IV	9.22	+0.41	-0.56
7...	+61°105	0 25.6	+61°53'	88.3	- 0.1	O9 V	9.29	+0.27	-0.69
8...	No. 1 ref. 3	0 34.0	+60°25'	89.3	- 1.6	O9 IV	9.99	+0.37	-0.61
9...	No. 110 ref. 4	0 42.2	+62°27'	90.2	+ 0.5	O7	11 40	+0.48	-0.53
10...	5005	0 47.0	+56°05'	91.0	- 5.9	O6	7.76	+0.09	-0.83
11...	5689	0 53.5	+63°05'	91.5	+ 1.1	O6	9.13	+0.34	-0.68
12...	+62°249	1 19.5	+62°31'	94.5	+ 0.9	O9.5 V	10.04	+0.70	-0.34
13...	8768	1 21.4	+62°45'	94.7	+ 1.1	O9.5 IV	8.69	+0.40	-0.60
14...	+60°261	1 25.9	+60°37'	95.6	- 0.9	O7	8.63	+0 31	-0.67
15...	9974	1 32.4	+57°39'	97.0	- 3.6	O6 + W R	10.69	+0.02	-0.86
16...	10125	1 33.9	+63°40'	95.9	+ 2.3	O9.5 Ib	8.22	+0.31	-0.65
17...	E 236894	1 45.4	+57°57'	98.6	- 3.0	O8 V	9.37	+0 19	-0.76
18...	+59°367	1 51.6	+60°02'	98.8	- 0.7	O9.5 Ib	9 77	+0.53	-0.52
19...	12323	1 55.8	+55°08'	100.7	- 5.3	O9 V*	8.90	-0.02	-0.93
20...	+61°370	1 56.4	+61°24'	99.0	+ 0.9	O9 V	10.06	+0.70	-0.37
21...	12993	2 02.1	+57°27'	100.9	- 2.8	O5	8.98	+0.20	-0.80
22...	13268	2 04.6	+55°41'	101.8	- 4.4	O8 V nn	8.18	+0.13	-0.83
23...	No. 7 ref. 2	2 05.4	+59°26'	100.7	- 0.8	O9 V	11.03	+0.97	-0.13
24...	14434	2 14.8	+56°27'	102.8	- 3.2	O6	8.49	+0.16	-0.78
25...	14442	2 14.9	+59°06'	101.9	- 0.7	O5 V	9.22	+0.41	-0.62
26...	+60°470	2 15.8	+60°22'	101.6	+ 0.5	O8 V	9.88	+0.70	-0.36
27...	14633	2 16.7	+41°02'	108.9	-17.5	O8 V	7.44	-0.21	-1.09
28...	+61°411	2 19.0	+61°33'	101.5	+ 1.8	O8:	10.19	+0.99	-0.09
29...	14947	2 19.5	+58°25'	102.7	- 1.1	O6 f	8.01	+0.45	-0.60
30...	+60°497	2 24.2	+61°11'	102.2	+ 1.7	O7	8.80	+0.57	-0.49
31...	+60°498	2 24.5	+61°07'	102.3	+ 1.6	O9 V	9.92	+0.54	-0.46
32...	+60°501	2 25.0	+61°02'	102.4	+ 1.6	O6.5	9.60	+0.46	-0.58
33...	15558	2 25.1	+61°01'	102.4	+ 1.6	O6	7.81	+0.52	-0.56
34...	15570	2 25.2	+60°55'	102.4	+ 1.5	O5 f veiled	8.11	+0.70	-0.41
35...	15629	2 25.7	+61°05'	102 4	+ 1.6	O5	8.42	+0.43	-0.62
36...	+60°512	2 26.4	+60°57'	102.6	+ 1.6	O6	9.41	+0.50	-0.53
37...	+62°424	2 28.4	+62°31'	102.2	+ 3.1	O8	8.83	+0.45	-0.57
38...	16429	2 33.1	+60°51'	103.3	+ 1.8	O9.5 III	7.67	+0.62	-0.38
39...	16691	2 35.5	+56°28'	105.5	- 2.0	O5 f	8.70	+0.48	-0.57
40...	17505	2 43.4	+60°01'	104.8	+ 1.6	O7	7.06	+0.40	-0.64
41...	17520	2 43.5	+59°59'	104.9	+ 1.6	O8 V	8.27	+0.32	-0.68
42...	17603	2 44.4	+56°38'	106.5	- 1.4	O7 f:	8.45	+0.64	-0.42
43...	+59°562	2 45.6	+60°03'	105.1	+ 1.7	O8 V	9.73	+0.47	-0.53
44...	+60°586	2 46.4	+60°14'	105.1	+ 2.0	O7	8.48	+0.30	-0.67
45...	+56°739	2 47.4	+57°02'	106.7	- 0.8	O9.5 Ib	9.96	+1.00	-0.07
46...	+60°594	2 49.1	+61°01'	105.0	+ 2.8	O9 V	9.30	+0.36	-0.64
47...	18326	2 51.6	+60°10'	105.7	+ 2.2	O8	7.82	+0.38	-0.63
48...	18409	2 52.4	+62°19'	104.7	+ 4.1	O9 Ib	8.36	+0.42	-0.59
49...	19820	3 06.2	+59°11'	107.8	+ 2.3	O9 IV	7.1*	+0.50	-0.48
50...	24431	3 48.1	+52°21'	116.6	+ 0.2	O9 IV-V	6.72	+0.38	-0.61

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TABLE 1— Continued

No.	Star	1900 α	1900 δ	l	b	Spectrum	V	B-V	U-B
51. .	24534	3h 49m.1	+30°45′	131.1	-15.9	O pe (var)	6.07	+0.31	-0.82
52. . .	No 7 ref 3	3 51.0	+56°56′	113.9	+ 4.0	O7.5	10.08	+0.27	-0.69
53. . .	+56°864	3 51 1	+56°56′	113.9	+ 4.0	O6 nn	9.68	+0.28	-0.69
54 .	+56°866	3 51 4	+56°49′	114.0	+ 3.9	O9 V	10.28	+0.36	-0.60
55. .	24912	3 52.5	+35°30′	128.3	-11.9	O7	4.02	+0.02	-0.92
56 . .	E 237211	3 55.3	+56°15′	114.8	+ 3.8	O9.5 I? p*	8.98	+0.49	-0.51
57. .	34656	5 14.0	+37°20′	137 7	+ 1 5	O7	6.79	+0 02	-0.90
58. . .	E 242908	5 16.0	+33°25′	141.2	- 0.3	O5	9.04	+0.28	-0.72
59. . .	E 242926	5 16.1	+33°13′	141.4	- 0.4	O6	9.35	+0.34	-0.65
60. . .	E 242935	5 16.2	+33°19′	141 3	- 0.4	O8	9.43	+0.20	-0.73
61. . .	35619	5 21.0	+34°41′	140.7	+ 1.3	O7	8.55	+0.24	-0.71
62 . .	+34°1058	5 22 0	+34°35′	140.9	+ 1.4	O8 nn	8.78	+0.26	-0.73
63 . .	35921	5 23.0	+35°18′	140.4	+ 1 9	O9.5 III	6.81	+0.20	-0.78
64. . .	+39°1328	5 25.2	+39°59′	136.8	+ 4.9	O9 III ?*	9.84	+0.57	-0.46
65. . .	36483	5 26.9	+36°24′	140.0	+ 3.2	O9.5 III	8.18	+0.43	-0.55
66. . .	36619	5 27.9	-23°30′	194.1	-26.0	O7	8.60	+0.23	-0.69
67. . .	36861	5 29.6	+09°52′	162.8	-10.5	O8	3.39	-0.19	-1.03
68 . .	36879	5 29.7	+21°20′	153.0	- 4.4	O6	7.57	+0.20	-0.80
69. . .	37041	5 30.5	-05°29′	176.4	-18.4	O9.5 Vp	5.19	-0.16	-0.95
70. . .	37043	5 30.5	-05°59′	176.8	-18.7	O9 III	2.77	-0.25	-1.08
71. . .	37742-43	5 35.7	-02°00′	174.0	-15.3	O9.5 Ib	1.79	-0.20	-1.06
72. . .	E 248894	5 48.0	+20°51′	155.6	- 1.1	O8: V: nn	9.29	+0.24	-0 73
73. . .	39680(A)	5 49.0	+13°49′	161.8	- 4.4	O6: pe	7.99	+0.02	-0.96
74. . .	41997	6 03.2	+15°44′	161.8	- 0.5	O7	8.40	+0.39	-0.63
75. . .	42088	6 03.7	+20°31′	157.7	+ 2.0	O6	7.54	+0.06	-0.89
76. . .	No. 21 ref. 2	6 04.3	+13°08′	164.2	- 1.5	O9 V	10.23	+0.46	-0.56
77. . .	No. 22 ref. 2	6 05.1	+13°12′	164.3	- 1.3	O9 V	10.57	+0.46	-0.54
78. . .	E 254755	6 12.5	+22°43′	156.8	+ 4.8	O9 V: p?	8.84	+0.60	-0.44
79. . .	E 255055	6 13.6	+23°20′	156.4	+ 5.3	O9 V: p	9.38	+0.26	-0.70
80. . .	44597	6 17.5	+20°27′	159.3	+ 4.8	O9 V	9.02	+0.26	-0.69
81. . .	44811	6 18.8	+19°45′	160.1	+ 4.7	O7.5 V	8.42	+0.14	-0.80
82 . .	45314	6 21.6	+14°57′	164.7	+ 3.0	O9 ? pe	6.64	+0.15	-0.88
83. . .	46056	6 26.0	+04°54′	174.0	- 0.8	O8	8.17	+0.18	-0.75
84. . .	46149	6 26.6	+05°06′	173.8	- 0.6	O8	7.58	+0.18	-0.78
85. . .	46150	6 26.6	+05°00′	174.0	- 0.6	O6	6.74	+0.13	-0.82
86. . .	46202	6 26.9	+05°03′	174.0	- 0.5	O9 V	8.17	+0.17	-0.74
87. . .	46223	6 27.0	+04°53′	174.2	- 0.6	O5	7.26	+0.22	-0.76
88. . .	46485	6 28.6	+04°36′	174.6	- 0.4	O8	8.26	+0.32	-0.68
89. . .	46573	6 29.1	+02°36′	176.4	- 1.2	O7	7.93	+0.34	-0.66
90. . .	46966	6 31.1	+06°10′	173.5	+ 0.9	O8	6.86	-0.04	-0.92
91. . .	47129	6 32 0	+06°13′	173.6	+ 1.2	O8	6.06	+0.05	-0.88
92. . .	-00°1385	6 35.2	-00°16′	179.7	- 1.2	O8	9.87	+0.31	-0.67
93. . .	47839	6 35.5	+09°59′	170.6	+ 3.6	O7	4.65	-0.25	-1.06
94. . .	48099	6 36.6	+06°27′	173.9	+ 2.3	O6	6.37	-0.05	-0.94
95. . .	48279	6 37.5	+01°49′	178.1	+ 0.3	O8	7.90	+0.13	-0.80
96. . .	+00°1576	6 39.7	+00°43′	179.3	+ 0.3	O9 III:	9.26	+0.43	-0.59
97. . .	+01°1560	6 46.7	+01°30′	179.5	+ 2.2	O8:	9.66	+0.28	-0.68
98. . .	52266	6 55.4	-05°40′	186.8	+ 0.7	O9 V	7.23	-0.01	-0.90
99. . .	52533	6 56.5	-02°59′	184.5	+ 2.1	O9 V	7.70	-0.09	-0.95
100. .	53975	7 02.0	-12°14′	193.4	- 1.0	O8	6.47	-0.10	-0.98

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TABLE 1—Continued

No.	Star	1900 α	1900 δ	l	b	Spectrum	V	B-V	U-B
101...	54662	7ʰ04ᵐ6	-10°11'	191.8	+ 0.5	O6	6.21	+0.03	-0.88
102...	54879	7 05.5	-11°39'	193.2	0.0	O9.5 V	7.66	0.00	-0.86
103...	57061	7 14.5	-24°47'	205.8	- 4.4	O9 III	4.39	-0.14	-0.99
104...	57236	7 15.2	-21°49'	203.3	- 2.8	O8	8.75	+0.20	-0.73
105...	57682	7 17.2	-08°48'	192.1	+ 3.9	O9 V	6 44	-0.19	-1.04
106...	61347	7 33.7	-13°38'	198.4	+ 5.1	O9 Ib	8.43	+0.17	-0.76
107...	-29°4849	7 40.0	-29°05'	212.4	- 1.6	O9.5 II:	10.00	+0.22	-0.72
108...	63005	7 41.6	-26°15'	210.2	+ 0.2	O7	9.11	-0.02	-0.95
109...	64315	7 48.2	-26°10'	210.9	+ 1.5	O6: nn (e)	9.21	+0.22	-0.74
110...	65087	7 51.9	-28°16'	213.1	+ 1.0	O7 f	9.97	+0.16	-0.79
111...	66811	8 00.1	-39°43'	223.6	- 3.9	O5 f	2.25	-0.26	-1.11
112...	149757	16 31.7	-10°22'	334.0	+22.3	O9.5 V	2.56	+0.02	-0.86
113...	157857	17 20.7	-10°55'	340.6	+11.8	O7 f	7.78	+0.18	-0.80
114...	-29°13809	17 31.7	-29°03'	326.7	- 0.1	O9 V	9.74	+0.68	-0.34
115...	160730	17 36.4	-24°15'	331.3	+ 1.6	O8	9.68	+0.66	-0.40
116...	316232	17 39.4	-29°11'	327.5	- 1.6	O9 IV	10.30	+0.68	-0.37
117...	162978	17 48.7	-24°52'	332.2	- 1.1	O8	6.20	+0.04	-0.89
118...	163800	17 52.9	-22°30'	334.7	- 0.8	O8	7.04	+0.31	-0.69
119...	163892	17 53.4	-22°27'	334.9	- 0.8	O9 IV	7.44	+0.09	-0.79
120...	164438	17 56.0	-19°06'	338.1	+ 0.3	O9 IV	7.48	+0.34	-0.66
121...	164492	17 56.3	-23°01'	334.7	- 1.7	O7	7.63	0.00	-0.86
122...	166546	18 06.0	-20°27'	338.1	- 2.4	O9.5 III	7.25	+0.05	-0.86
123...	-14°4922	18 06.3	-14°58'	342.9	+ 0.2	O9.5: II:	9.73	+0.85	-0.30
124...	166734	18 06.9	-10°46'	346.6	+ 2.1	O8 f	8.42	+1.09	-0.12
125...	-20°5043	18 08.1	-20°20'	338.4	- 2.8	O6	9.52	+0.85	-0.20
126...	167263	18 09.3	-20°25'	338.4	- 3.0	O9 II	5.98	+0.04	-0.88
127...	167330	18 09.6	-12°34'	345.4	+ 0.7	O9 I-II	8.23	+0.66	-0.45
128...	167633	18 11.0	-16°33'	342.0	- 1.5	O6	8.14	+0.27	-0.72
129...	167659	18 11.1	-19°00'	339.9	- 2.7	O8	7.39	+0.22	-0.74
130...	167771	18 11.6	-18°30'	340.3	- 2.5	O8	6.54	+0.12	-0.84
131...	-12°4964	18 11.8	-12°21'	345.8	+ 0.3	O8	9.82	+0.91	-0.22
132...	-12°4979	18 12.4	-12°17'	345.9	+ 0.2	O7 (f)	10.44	+0.68	-0.32
133...	-11°4586	18 12.5	-11°20'	346.8	+ 0.8	O8 (I?)	9.40	+1.00	-0.14
134...	167971	18 12.5	-12°17'	346.0	+ 0.2	O8 f	7.50	+0.77	-0.32
135...	-12°4984	18 12.7	-12°00'	346.2	+ 0.3	O9 V	9.93	+0.83	-0.26
136...	-13°4927	18 13.0	-13°48'	344.6	- 0.6	O5	10.08	+0.84	-0.32
137...	168112	18 13.1	-12°08'	346.2	+ 0.1	O6	8.52	+0.69	-0.40
138...	-13°4930	18 13.2	-13°52'	344.7	- 0.7	O9.5 V	9.44	+0.30	-0.70
139...	-12°4994	18 13.4	-12°09'	346.2	+ 0.1	O9: V:	9.81	+0.70	-0.39
140...	-13°4941	18 14.4	-13°06'	345.4	- 0.6	O9.5 IV	9.75	+1.08	-0.07
141...	-15°4930	18 14.6	-15°08'	343.6	- 1.5	O6 p	9.42	+0.74	-0.37
142...	-12°5009	18 14.7	-12°13'	346.3	- 0.2	O8	9.54	+0.68	-0.42
143...	-16°4826	18 15.2	-16°05'	342.9	- 2.2	O5	9.89	+0.76	-0.37
144...	168917	18 17.1	-14°25'	344.6	- 1.8	O9 V:	8.44	+0.43	-0.58
145...	-11°4620	18 17.9	-11°58'	346.9	- 0.8	O5	10.17	+0.80	-0.31
146...	-10°4682	18 18.8	-10°52'	347.9	- 0.5	O7	9.63	+0.56	-0.55
147...	169582	18 20.2	-09°49'	349.0	- 0.2	O5 f	8.70	+0.56	-0.49
148...	169727	18 21.0	-13°43'	345.7	- 2.3	O6	9.29	+0.79	-0.37
149...	169755	18 21.1	-14°34'	344.9	- 2.7	O8 V	9.26	+0.53	-0.51
150...	-08°4617	18 23.8	-08°38'	350.5	- 0.5	O8.5 (V)	9.36	+0.91	-0.21

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TABLE 1—Continued

No.	Star	1900 α	1900 δ	l	b	Spectrum	V	B-V	U-B
151...	170452	18h 24m.4	-13°01'	346.7	- 2.6	O9: V	8.75	+0.53	-0.48
152...	-13°5015	18 25.8	-13°38'	346.3	- 3.3	O7	10.02	+0.53	-0.54
153...	171198	18 28.3	-12°20'	347.7	- 3.2	O7:	9.54	+0.57	-0.48
154...	-08°4634	18 28.9	-08°10'	351.5	- 1.4	O9? V? p	9.44	+0.91	-0.18
155...	-04°4503	18 30.2	-04°53'	354.5	- 0.1	O7	10.83	+0.75	-0.31
156...	171589	18 30.6	-14°12'	346.3	- 4.6	O7 f	8.28	+0.32	-0.69
157...	172175	18 33.6	-07°57'	352.2	- 2.3	O6 f	9.44	+0.63	-0.43
158...	172275	18 34.2	-07°27'	352.7	- 2.2	O6	9.35	+0.77	-0.36
159...	173783	18 42.0	-09°25'	351.9	- 4.9	O9 I	9.31	+0.51	-0.52
160...	-06°4903	18 42.5	-06°25'	354.6	- 3.6	O8	9.94	+0.31	-0.72
161...	-05°4769	18 43.2	-05°37'	355.4	- 3.3	O8 (I:)	10.40	+0.75	-0.35
162...	-00°3584	18 48.4	-00°41'	0.4	- 2.2	O8	9.98	+0.62	-0.45
163...	175514	18 50.6	+09°13'	9.4	+ 2.0	O8: V nn	8.59	+0.59	-0.45
164...	175754	18 51.7	-19°17'	344.0	-11.3	O8 f	7.04	-0.07	-0.97
165...	175876	18 52.3	-20°33'	343.0	-12.0	O6	6.95	-0.10	-1.01
166...	+24°3843	19 37.7	+24°06'	27.9	- 0.5	O8 V	10.34	+0.99	-0.01
167...	+22°3782	19 39.0	+23°03'	27.1	- 1.3	O7	9.34	+0.56	-0.52
168...	+25°3952	19 41 5	+25°07'	29.2	- 0.7	O8	10.15	+0.63	-0.42
169...	+24°3866	19 41.5	+24°52'	28.9	- 0.9	O8 f	9.57	+1.18	+0.02
170...	186980	19 42.4	+31°52'	35.0	+ 2.7	O7.5	7.48	+0.08	-0.84
171...	+27°3512	19 42.6	+28°00'	31.8	+ 0.6	O7.5	8.77	+0.20	-0.78
172...	+24°3881	19 42.8	+24°36'	28.9	- 1.3	O6 f	9.12	+0.69	-0.43
173...	+29°3772	19 46.7	+29°09'	33.2	+ 0.4	O7 f	10.10	+0.50	-0.53
174...	188001	19 47.9	+18°25'	24.2	+ 5.4	O8 f	6.22	+0.01	-0.92
175...	188209	19 49.0	+46°47'	48.5	+ 9.2	O9.5 III	5.61	-0.05	-0.96
176...	E 227018	19 56.1	+35°02'	39.2	+ 1.9	O7	8.99	+0.38	-0.62
177...	E 227245	19 58.6	+35°24'	39.8	+ 1.7	O7	9.74	+0.62	-0.44
178...	+33°3717	20 00.6	+33°25'	38.4	+ 0.3	O7:	10.28	+0.47	-0.54
179...	190864	20 01.9	+35°19'	40.1	+ 1.1	O6	7.76	+0.20	-0.78
180...	E 227757	20 03.5	+36°04'	40.9	+ 1.3	O9.5 V	9.20	+0.18	-0.75
181...	191423	20 04.7	+42°19'	46.2	+ 4.6	O9 V:	8.03	+0.16	-0.76
182...	191978	20 07.5	+41°04'	45.5	+ 3.5	O8	8.02	+0.14	-0.78
183...	192001	20 07.6	+41°50'	46.1	+ 3.9	O9.5 IV	8 25	+0.32	-0.60
184...	192281	20 09.0	+39°58'	44.8	+ 2.6	O5 f	7.55	+0.38	-0.61
185...	E 228368	20 09.5	+34°43'	40.5	- 0.5	O7	8.39	+0.49	-0.51
186...	192639	20 10.8	+37°03'	42.6	+ 0.6	O8 f	7.11	+0.35	-0.63
187...	193117	20 13.5	+40°32'	45.7	+ 2.2	O9.5 II	8.70	+0.61	-0.42
188...	E 228766*	20 13.8	+37°00'	42.9	+ 0.1	(O6 f or WR)	9.14	+0.65	-0.37
189...	E 228779	20 14.0	+34°30'	40.9	- 1.4	O9.5 Ib	8.92	+1.31	+0.22
190...	193322	20 14 6	+40°25'	45.7	+ 2.1	O8	5.84	+0.11	-0.77
191...	E 228841	20 14.8	+38°34'	44.3	+ 0.9	O7.5 p	8.94	+0.56	-0.42
192...	E 228854	20 15.0	+36°02'	42.3	- 0.7	O8:	8.93	+0.70	-0.28
193...	193443	20 15.2	+37°57'	43.8	+ 0.5	O9 III	7.24	+0.40	-0.53
194...	193514	20 15.5	+38°57'	44.7	+ 1.0	O7 f	7.40	+0.45	-0.51
195...	193595	20 15.9	+38°44'	44.6	+ 0.8	O7	8.72	+0.36	-0.58
196...	193682	20 16.5	+37°30'	43.6	0.0	O5	8.41	+0.51	-0.48
197...	E 228989	20 16.7	+38°23'	44.4	+ 0.5	O9 V nn	9.72	+0.77	-0.20
198...	+36°4022	20 17.3	+36°29'	42.9	- 0.7	O9.5 II	9.94	+0.83	-0.20
199...	+38°4043	20 18.7	+38°24'	44.6	+ 0.2	O9 III	9.02	+0.59	-0.39
200...	E 229196	20 19.7	+40°34'	46.5	+ 1.3	O5	8.54	+0.90	-0.15

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TABLE 1—Continued

No.	Star	1900 α	1900 δ	l	b	Spectrum	V	B-V	U-B
201...	E 229202	20h 19m.8	+39°50'	45.9	+ 0.8	O8 V:	9.53	+0.87	-0.12
202...	194334	20 20.0	+38°34'	44.9	+ 0.1	O7.5 V	8.77	+0.84	-0.16
203...	E 229232	20 20.3	+38°47'	45.1	+ 0.1	O5 f	9.52	+0.82	-0.17
204...	E 229234	20 20.3	+38°12'	44.6	- 0.2	O9.5 III	8.92	+0.77	-0.19
205...	No. 17 ref. 7	20 20.5	+39°20'	45.6	+ 0.4	O7	9.86	+1.18	+0.11
206...	+39°4168	20 20.7	+39°26'	45.7	+ 0.5	O7	9.99	+1.07	+0.03
207...	+37°3929	20 21.3	+37°09'	43.9	- 1.0	O8 f	10.15	+1.25	+0.23
208...	194649	20 21.7	+39°54'	46.1	+ 0.6	O6.5	9.00	+0.95	-0.09
209...	+36°4063	20 21.9	+37°03'	43.9	- 1.2	O9.5 Ib	9.71	+1.14	+0.08
210...	+40°4179	20 24.1	+40°16'	46.7	+ 0.5	O8 V:	9.65	+0.57	-0.43
211...	195213	20 24.9	+40°28'	47.0	+ 0.4	O7	8.74	+0.84	-0.26
212...	195592	20 27.2	+43°59'	50.0	+ 2.3	O9.5 Ia	7.08	+0.87	-0.19
213...	No. 1 ref. 5	20 27.5	+41°10'	47.8	+ 0.5	O9 V?	11.09	+1.42	+0.31
214...	+40°4212	20 28.0	+40°52'	47.6	+ 0.2	O9 ?	10.29	+1.63	+0.54
215...	+40°4219	20 28.6	+41°06'	47.9	+ 0.3	O8	10.22	+1.18	+0.10
216...	+40°4220	20 28.8	+40°58'	47.8	+ 0.2	O7 f	9.1*	+1.67	+0.55
217...	No. 12 ref. 6	20 29.1	+40°55'	47.8	+ 0.1	O	11.4*	+3.01	+1.69
218...	No. 6 ref. 5	20 29.2	+41°05'	48.0	+ 0.2	O8 (V)	10.67	+1.22	+0.16
219...	No. 9 ref. 5	20 29.6	+40°55'	47.9	0.0	O5 f	10.80	+1.93	+0.65
220...	+40°4227	20 29.6	+40°58'	47.9	+ 0.1	O6 f	9.01	+1.28	+0.15
221...	No. 7 ref. 5	20 29.7	+41°00'	47.9	+ 0.1	O6 f	10.49	+1.44	+0.28
222...	+41°3804	20 30.2	+41°12'	48.2	+ 0.1	O9.5 Ia	9.88	+1.52	+0.40
223...	+45°3216	20 30.5	+45°19'	51.4	+ 2.6	O8	9.07	+0.39	-0.57
224...	+41°3807	20 30.6	+41.16'	48.3	+ 0.1	O6 f	10.04	+1.44	+0.26
225...	+36°4145	20 32.5	+37°04'	45.2	- 2.8	O9 V	8.95	+0.65	-0.37
226...	+42°3835	20 38.6	+42°49'	50.4	- 0.1	O9 p?	9.20	+0.91	-0.19
227...	+45°3260	20 42.2	+45°58'	53.2	+ 1.5	O9 V	9.06	+0.51	-0.50
228...	199579	20 53.1	+44°33'	53.4	- 0.9	O6	5.96	+0.05	-0.85
229...	202124	21 08.8	+44°07'	55.0	- 3.2	O9.5 Ib	7.80	+0.22	-0.69
230...	206267	21 35.9	+57°02'	66.9	+ 3.4	O6	5.62	+0.21	-0.74
231...	+49°3591	21 36.7	+50°03'	62.6	- 2.0	O7.5	9.67	+0.52	-0.48
232...	207198	21 42.2	+61°59'	70.7	+ 6.8	O9 II	5.96	+0.31	-0.64
233...	+28°4211	21 46.7	+28°24'	50.2	-20.0	O pec	10.54	-0.34	-1.26
234...	E 235673	21 54.1	+52°19'	66.1	- 1.9	O7	9.14	+0.21	-0.77
235...	209481	21 58.7	+57°31'	69.6	+ 2.0	O9 V	5.56	+0.07	-0.86
236...	209975	22 02.1	+61°48'	72.4	+ 5.3	O9.5 Ib	5.10	+0.09	-0.84
237...	+53°2790	22 04.3	+54°02'	68.3	- 1.3	O9.5 III? p	9.86	+0.25	-0.71
238...	210809	22 07.9	+51°56'	67.7	- 3.4	O9 Ib	7.54	+0.05	-0.89
239...	210839	22 08.1	+58°56'	71.5	+ 2.5	O6 f	5.04	+0.26	-0.74
240...	+53°2843	22 14.9	+53°46'	69.5	- 2.4	O8	9.50	+0.21	-0.74
241...	No. 21 ref. 1	22 18.5	+55°08'	70.7	- 1.5	O5	10.29	+0.26	-0.73
242...	E 235825	22 19.6	+54°44'	70.6	- 1.9	O9 V	9.28	+0.24	-0.73
243...	+54°2761	22 19.9	+55°11'	70.9	- 1.6	O5 f	9.98	+0.34	-0.68
244...	+62°2078	22 22.2	+62°54'	75.0	+ 4.9	O7	9.72	+1.11	0.00
245...	214680	22 34.8	+38°32'	64.8	-17.3	O9 V	4.88	-0.20	-1.04
246...	215835	22 42.9	+57°33'	74.8	- 1.0	O6 n	8.58	+0.32	-0.66
247...	216532	22 48.6	+61°54'	77.3	+ 2.7	O8	8.00	+0.54	-0.48
248...	+55°2840	22 51.0	+55°51'	75.1	- 3.0	O7.5 p	10.01	+0.45	-0.56
249...	216898	22 51.8	+61°46'	77.6	+ 2.4	O8	8.00	+0.53	-0.48
250...	217086	22 53.0	+62°12'	77.9	+ 2.7	O5	7.64	+0.62	-0.44

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TABLE 1—Concluded

No.	Star	1900 α	1900 δ	l	b	Spectrum	V	B-V	U-B
251...	E 240160	$22^h 57^m.4$	+56°27'	76.2	- 2.8	O9	10.02	+0.48	-0.52
252...	E 240165	22 58.0	+56°39'	76.3	- 2.6	O9.5 V	10.13	+0.47	-0.53
253...	218195	23 01.0	+57°43'	77.1	- 1.8	O8	8.34	+0.27	-0.70
254...	218915	23 06.7	+52°31'	76.0	- 6.9	O9 I	7.20	+0.02	-0.90
255...	+60°2522	23 16.2	+60°38'	79.9	+ 0.3	O7 f	8.67	+0.41	-0.62
256...	No. 7 ref. 1	23 18.4	+61°35'	80.5	+ 1.1	O8 (f)	10.80	+0.75	-0.35
257...	+62°2299	23 43.1	+62°50'	83.6	+ 1.5	O8	9.58	+0.61	-0.47
258...	+61°2559	23 48.6	+61°52'	84.0	+ 0.5	O9 V	9.72	+0.29	-0.66
259...	+66°1661	23 52.4	+67°00'	85.4	+ 5.4	O9 V	8.72	+0.81	-0.20
260...	E 240464	23 53.7	+59°43'	84.2	- 1.8	O9 V	9.59	+0.30	-0.61
261...	+66°1675	23 57.0	+66°51'	85.8	+ 5.2	O7	9.05	+1.09	+0.04
262...	225160	23 58.9	+61°40'	85.1	+ 0.1	O8 f	8.19	+0.27	-0.72

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No. 7... Nassau, J. J. and Harris, Daniel III, 1952, Ap. J., 115, 459 - 474, table 1.

NOTES

No. 3 AO Cas
No. 19 Fainter than 10 Lac
No. 49 CC Cas
No. 56 Ia from N III, C III weak.
No. 64 C III weak
No. 188 Spectroscopic binary
No. 217 Variable
No. 218 Photometric measurements include a fainter and probably bluer companion.
No. 246 CQ Cep. Variable in Magnitude and Spectrum.

The following stars have only one photometric observation: Nos. 3, 69, 147, 148, 149, 151, 153, 156, 159, 164, 165, 175, 183.

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the stars consecutively. The second column gives the *Henry Draper Catalogue* number, the *Bonner Durchmusterung* number when not in the *HD*, or, if the star is in neither catalogue, a number is given followed by a reference. References in this column are listed at the end of the table, and the number of the star in this column is that used in the original publication. The next four columns give the positions in equatorial and galactic co-ordinates. The Lund pole was adopted for computing the galactic co-ordinates. Without exception, slit spectrograms were available for spectral classifications. Most of the spectral types were determined by Morgan (see Morgan, Code, and Whitford 1955) from McDonald, as well as Yerkes, slit spectrograms, and the remaining ones were classified by one of us (Hiltner) on McDonald spectrograms. The photometric observations were obtained either at McDonald or at Lowell Observatory, or both. The same filter and cell

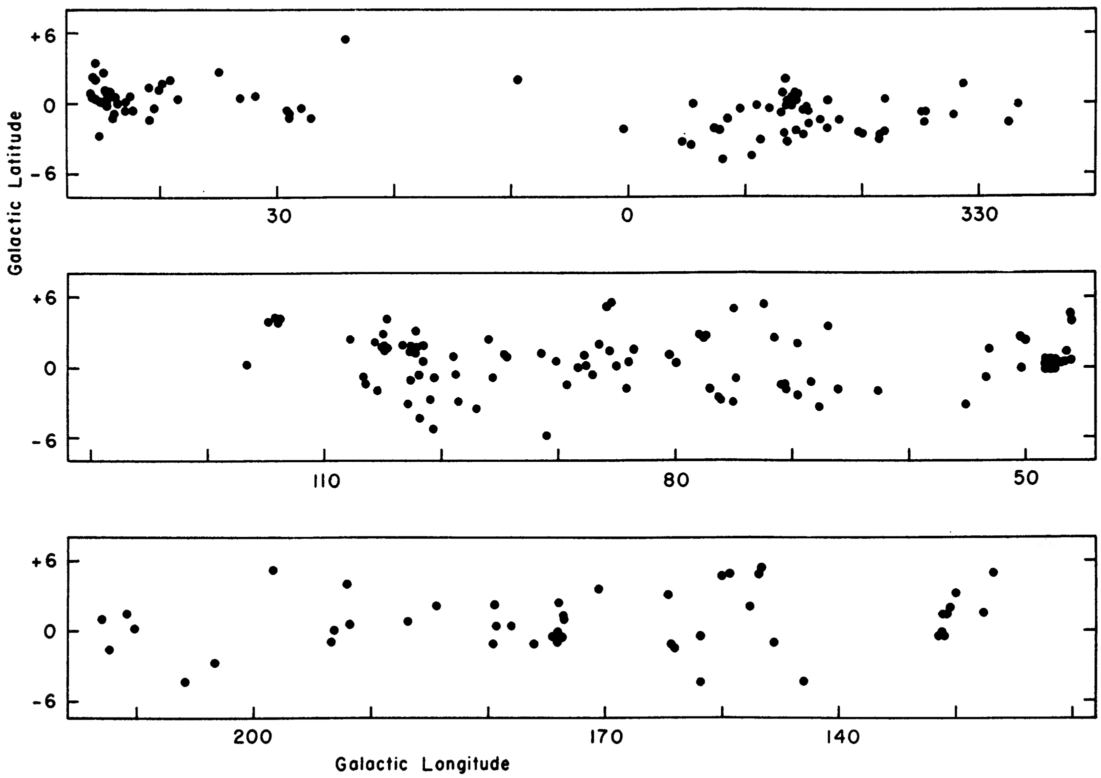

FIG. 1.—Distribution of O-type stars recorded in the catalogue

combinations were used by the two observers. No systematic differences in the two sources of data were detected.

Figure 1 shows the distribution of stars in galactic co-ordinates. Figure 2 gives the two-color plot for the stars in the catalogue except for BD+28°4211 and No. 12, reference 6. The open circles refer to the stars from galactic longitude 40.0 to 48.8 and galactic latitude $-3°$ to $+5°$. The filled circles refer to all other stars. It is apparent from the plot of the filled circles that the reddening line is not linear but curved, as suggested by Blanco (1955). The equation

$$\frac{E_{(U-B)}}{E_{(B-V)}} = 0.72 + 0.05 E_{(B-V)}$$

represents the data satisfactorily.

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It is also apparent from Figure 1 and from Figure 3, where only the Rift stars are plotted, that the stars in the Great Rift are anomalous. The stars in this region clearly give a straight line for the reddening law in contrast to that of those outside this region. In any case, the introduction of a curvature for the Rift stars would not be compatible with the observations. The cause of this discrepancy is obscure but most probably will be found in variations in interstellar absorption. However, intrinsic peculiarities of the Rift stars relative to others cannot be eliminated with the data at hand. For example, the intersection of the most probable line for the Rift stars and those outside intersect at $B - V = -0.1$, not at that color where the color excess is zero. But in our discussion we shall assume that the effect is caused by a variation in the reddening law.

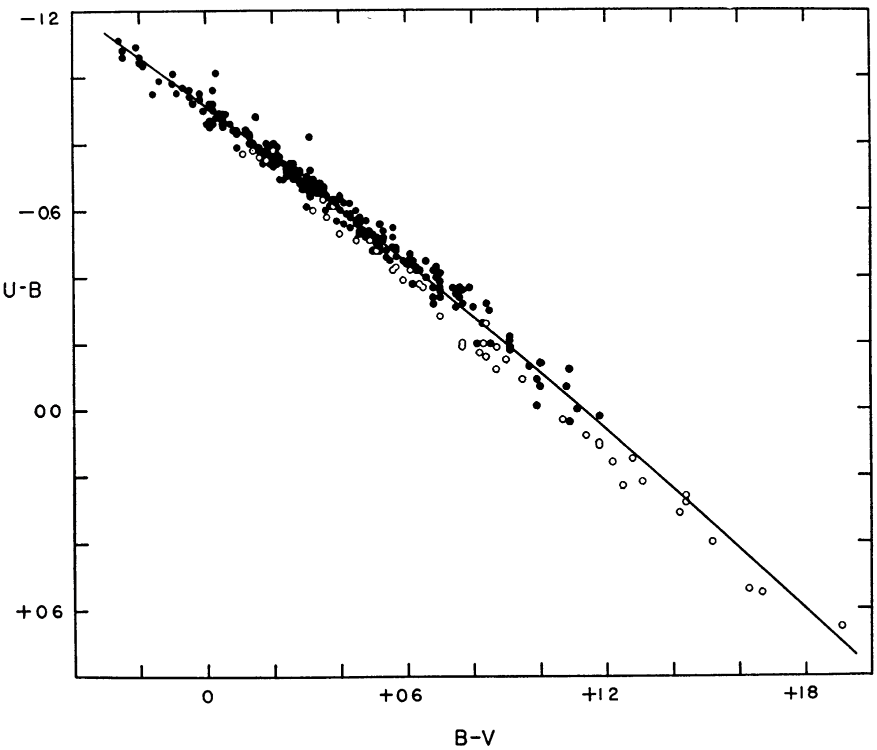

FIG. 2.—$U - B$ versus $B - V$ for the stars of Table 1. The open circles designate stars behind the Great Rift in Cygnus; the filled circles, stars elsewhere in the Milky Way. The line represents the reddening line:

$$\frac{E_{(U-B)}}{E_{(B-V)}} = 0.72 - 0.05\, E_{(B-V)} .$$

It is also apparent from the plot of $B - V$ versus $U - B$, for the stars outside the Great Rift in Cygnus, that the scatter in the diagram increases with reddening. This can be interpreted as evidence for a small general variability in the reddening law

III. THE RATIO OF TOTAL TO SELECTIVE ABSORPTION

Aside from the determinations of

$$R = \frac{A_V}{E_{(B-V)}} = 3.0$$

from Whitford's (1948) interstellar absorption-curve by Blanco (1955), there have been several determinations of this ratio. Oort (1938) discusses several, leading to a value of

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$A_{pg}/E_1 = 9$, where A_{pg} is the total photographic absorption and E_1 is the color excess on the C_1 system of Stebbins, Huffer, and Whitford (1940). Since the scale of C_1 is 0.483 that of $B - V$ (Morgan, Harris, and Johnson 1953, eq. [2]), this value gives $R = 3.3$. Stebbins (1950) mentions a value of

$$\frac{A_{pg}}{C_{int}} = 4.0 \pm 0.2$$

obtained from observations of the colors and brightness of the near and far sides of the Andromeda Nebula, from which we get $R = 3.0$. Sharpless has found $R = 6$ from unreddened and moderately reddened stars in the region of the Orion Nebula.

We can add another direct determination to this list by taking advantage of the fact that the region of the double cluster in Perseus is more heavily reddened on one side of

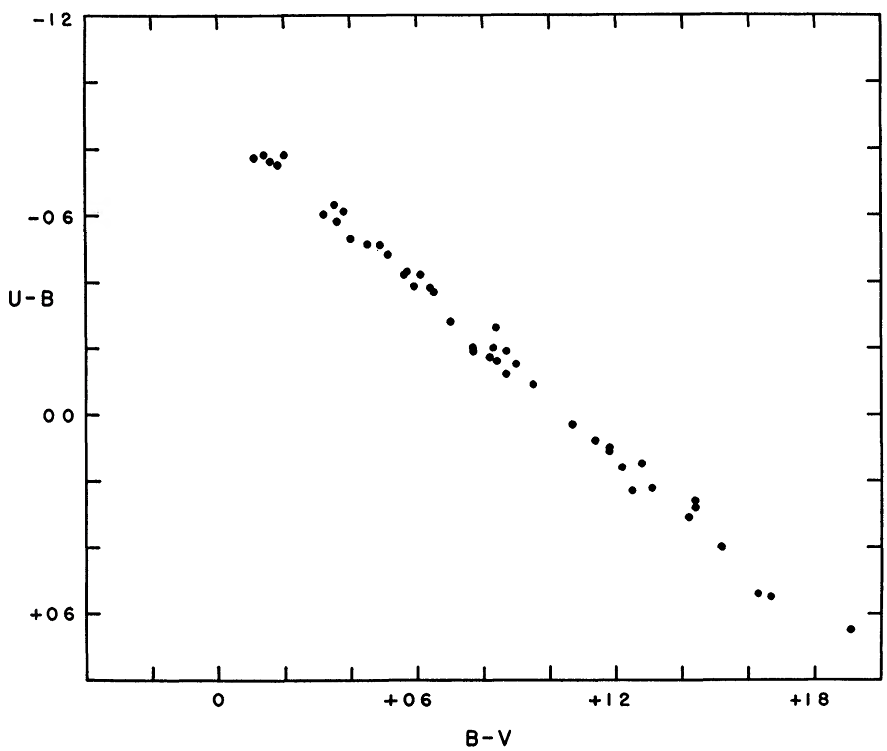

FIG. 3.—$U - B$ versus $B - V$ for stars from galactic longitude 40°0 to 48°8 and galactic latitude $-3°$ to $+5°$.

the clusters than on the other. There are a large number of stars (cluster members) of the same spectral types and luminosity classes situated in both regions. For example, there are 12 B1 V stars (Johnson and Morgan 1955*b;* Johnson and Hiltner 1956) whose observed colors range from $B - V \sim + 0.2$ to $B - V \sim + 0.7$. From all the available stars we find

$$R = 3.0 \pm 0.3 \text{ (p.e.)} .$$

The foregoing evaluations of R suggest the value

$$R = \frac{A_V}{E_{(B-V)}} = 3.0 \pm 0.2 \text{ (p.e.)} ,$$

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if we omit Sharpless' determination of $R = 6$ for the Orion Nebula. The existence, however, of Sharpless' determination raises the question of the value of R that applies to other possibly peculiar regions. We are especially concerned with the region of the Great Rift in Cygnus, where a variation in the law of interstellar reddening (see Sec. II) may be in evidence. If we assume that the Rift stars of Table 1 are all of the same absolute luminosity and at the same distance, we obtain $R = 2.1$. The assumption of equal distance for the stars is certainly not correct, since these stars are distributed along the spiral arm behind the Great Rift.

If we correct the distances of these stars by arbitrarily placing the Rift stars on the spiral arm, according to the model of the Galaxy of Morgan, Sharpless, and Osterbrock (1952) (a correction of about 0.2 mag. per degree of galactic longitude), we obtain $R \simeq 3.0$. While this determination from the Great Rift in Cygnus has low weight because of the uncertainties in the distance corrections, it does argue against an abnormally high value for R in this region. A departure from the normal reddening line does not necessarily reflect a departure from the normal total to selective ratio that we have determined here. This follows, of course, since a third spectral region (ultraviolet) is employed in establishing the reddening line, and peculiarities in the absorption at this region alone may affect the reddening line.

IV. CONCLUSIONS

Additional evidence has been given for the divergence of the reddening in the region of the Great Rift in Cygnus from that generally elsewhere in the Milky Way, in the sense that the Great Rift absorbs more ultraviolet light compared to blue and yellow light than other interstellar clouds do. The curvature of the reddening line suggested by Blanco is also confirmed by our observations, except for the Cygnus stars that give a linear relationship. In this connection we should point out that our new reddening line (eq. [1]) is identical, for small reddening, with that of Johnson and Morgan (1953) and that their derived relationships for spectral type, reddening, etc., apply directly. The only change required at the present time is the making of a second approximation to include the effect of the second term on the right of equation (1).

The effect of the divergence of the reddening line in Cygnus from equation (1) will be small for reddening ranging from zero to moderate, since in the equation

$$Q = (U - B) - \frac{E_{(U-B)}}{E_{(B-V)}} (B - V)$$

the coefficient of

$$\frac{E_{(U-B)}}{E_{(B-V)}},$$

$B - V$, is small. Furthermore, in the Q method of determining color excess, we use the equation $E_{(B-V)} = (B - V) - 0.337Q + 0.009$, and errors in Q appear in $E_{(B-V)}$ reduced by a factor of 3. Tests show that divergences of the reddening lines from equation (1), by the amount found in Cygnus, will not introduce errors in $E_{(B-V)}$ greater than 0.02 or 0.03 mag., for $E_{(B-V)} < -0.7$ or $A_V < 2.1$ mag. These remarks apply only to O and B stars, of course.

The ratio of total to selective absorption has been found to be $R = 3.0$, with the only discordant determination that of Sharpless. More recent and unpublished data analyzed with that published by Sharpless (1952) show that a value near 3 is not necessarily discordant in this region. Blaauw (1956) has also shown that evolutionary effects within the association may vitiate the earlier results. However, the probable error, ± 0.2, should be regarded as a minimum value.

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