

STUDIES IN SPECTRAL CLASSIFICATION. III. THE H-R DIAGRAMS OF NGC 2244 AND NGC 2264

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ABSTRACT

New, more accurate, spectral types on the MK system have been determined for the brighter stars in the clusters NGC 2244 and NGC 2264. The resulting H-R diagrams indicate that the two clusters—and their accompanying complexes of gas and dust—are located at similar distances from the Sun—around 800 pc. The reduction in the measured distance for NGC 2244 is due principally to the use of a high ratio (6) to total of selective absorption, in accordance with a recent determination of H. L. Johnson.

1. The O-type clusters NGC 2244 and NGC 2264 form the nuclei of the two O-associations in Monoceros; the projected distance between them is about $5^{\circ}.5$. Recent determinations of the distance to NGC 2244 are 1660 pc (Johnson 1962) and 2200 pc (Becker and Fenkart 1963); some recent determinations for NGC 2264 are 800 pc (Walker 1956) and 715 pc (Becker and Fenkart 1963). The two clusters are associated with great complexes of gas and dust; the large-scale structure has been described by Morgan, Ström-gren, and Johnson (1955). The emission nebula surrounding NGC 2244 seems to be located on the edge of a gaseous ring about 3° in diameter; the great emission region surrounding NGC 2264 is of approximately the same size, and appears on small-scale plates to overlap the ring (see Fig. 12 of Morgan *et al.* 1955). The color excesses of the two clusters are strikingly different; the values of $E_{(B-V)}$ are $0^m.08$ for NGC 2264 (Walker 1956), and $0^m.46$ for NGC 2244 (Johnson 1962); the distance determination of NGC 2244 is therefore sensitive to the ratio of total to selective absorption.

2. New spectrograms of optimum quality for classification were obtained for the brightest O- and B-type members of each cluster with the 82-inch reflector and Casse-grain spectrograph of the McDonald Observatory. The spectral types resulting from the reclassification are listed in Tables 1 and 2, together with the values of V_0 determined from the photoelectric photometry of Johnson (1962) for NGC 2244 and of Walker (1956) for NGC 2264. The stars are identified on Figure 1 (NGC 2244), and Figures 2 and 3 (NGC 2264), which are from photographs obtained with the 48-inch Schmidt telescope of the Mount Palomar Observatory; the maps of NGC 2264 are from a negative taken by Osterbrock; that of NGC 2244 is from the Yerkes glass negative copy of the National Geographic Society-Palomar Observatory Sky Survey. The values of V_0 in Table 1 were computed on the assumption of a ratio of total to selective absorption of 6 for NGC 2244. The reality of this high ratio has now been established by Johnson (1965); and we are indebted to him for sending a copy of his manuscript before publication. In the case of NGC 2264, the color excesses are so small that there is a difference of only 0.2 mag. in V_0 between the ratios of 3 and 6 for total to selective absorption; Table 2 lists two sets of V_0 , on these two assumptions.

3. The H-R diagrams of the two clusters are illustrated in Figure 4. The values of V_0 for NGC 2264 are those corresponding to a ratio of 3 for total to selective absorption; the points would be moved up systematically 0.2 mag. in V_0 if the ratio is 6 instead of 3. It can be seen that the distances of the two clusters are quite similar; the earlier determinations of the distance of NGC 2244 appear to be too great. Although plotted separately

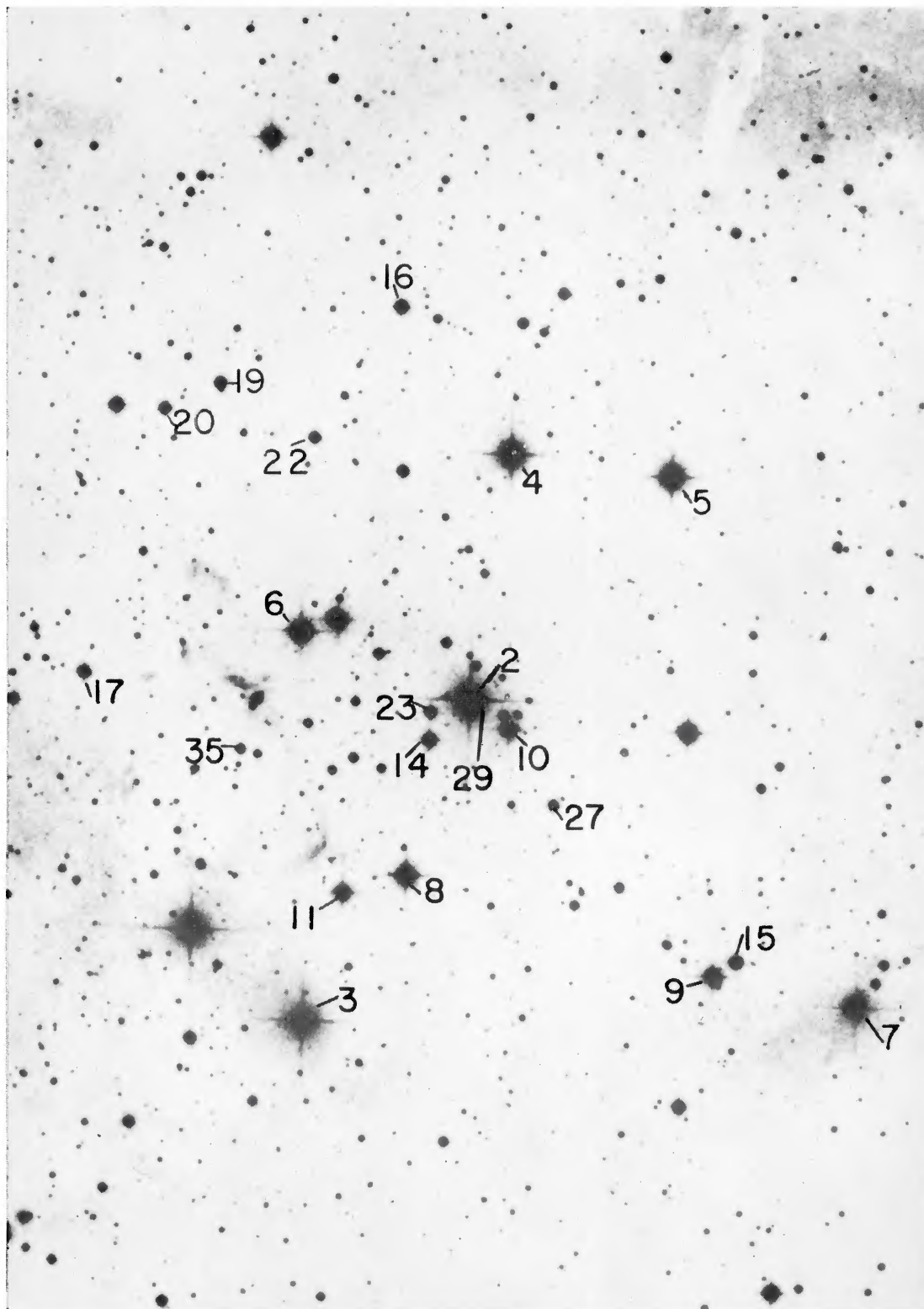


FIG. 1.—Map of NGC 2244. The stars numbered are those listed in Table 1. From negative copy of the National Geographic Society-Palomar Observatory Sky Survey.

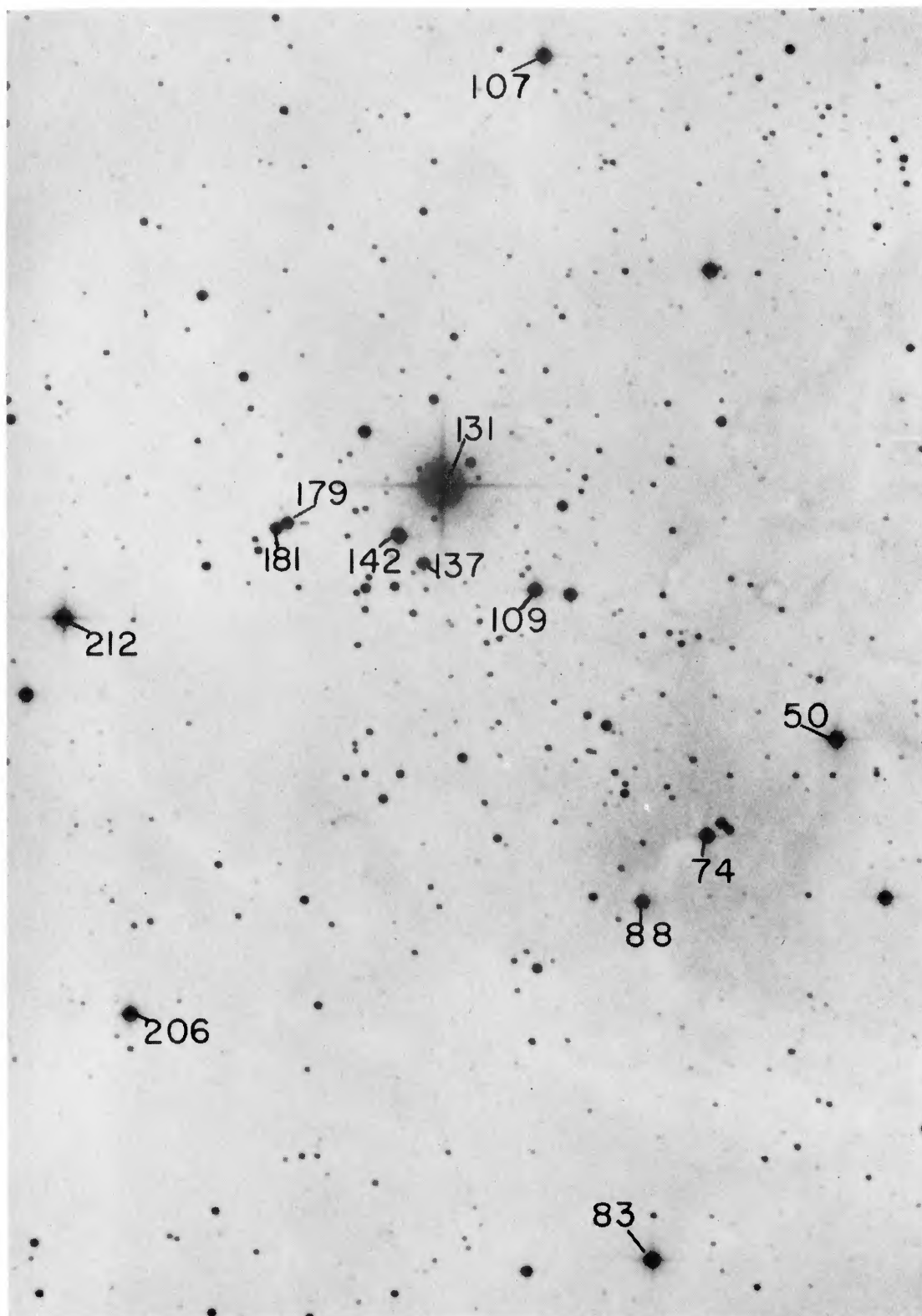


FIG. 2.—Map of northern region of NGC 2264. The stars numbered are those included in Table 2

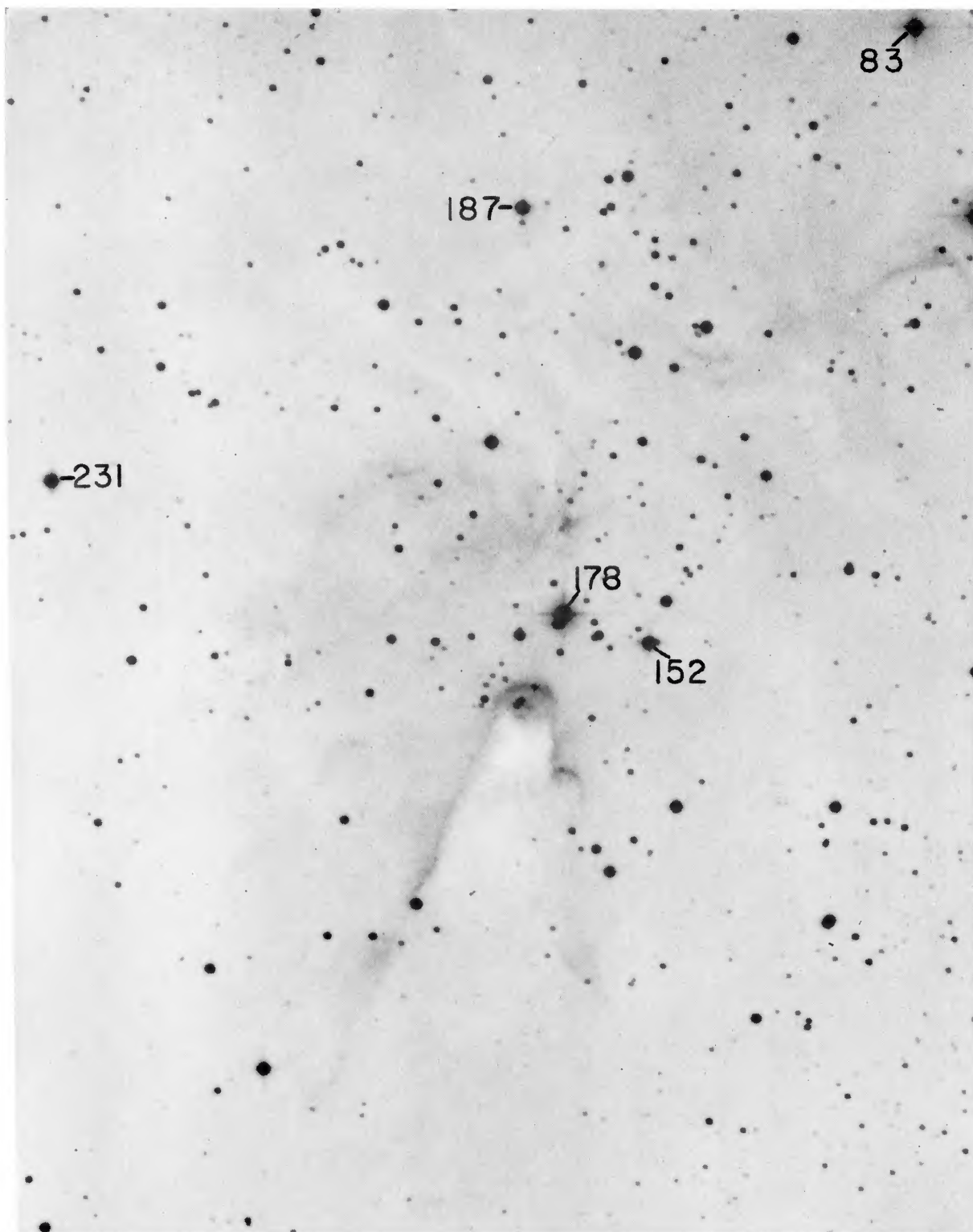


FIG. 3.—Map of southern region of NGC 2264. The stars numbered are those included in Table 2

TABLE 1
NGC 2244

HD	Johnson	MK	E	$V_0 \ 6E$
46223	3	O4	0 55	3 95
46150	2*	O5	46	3 96
46149	4	O8 5	48	4 68
46056	7	O8 Vn	50	5 19
46106	5	B0 V	44	5 26
46202	6	O9 V	.48	5 29
	8†	B0 5 V	45	5 84
	9	B1 Vn	44	6 65
	10*	B1 5 V	44	6 72
	11	B1 V	.44	7 07
	14*	B2 V	.46	7 55
	17‡	B3 Vp	.52	7 60
	16	B2 V	43	8 11
	22	B2 5 V	51	8 12
	15	B2 V	39	8 28
	23*	B2 5 Vn	48	8 33
	27	B2 5 V	49	8 66
	19	B7 V	.40	8 66
	20	B8 V	39	8 73
	29*	B5 V	47	8 85
	33	B6 Vne	0 49	9 01

* See text for explanation

† Two-line binary

‡ H v strong.

TABLE 2
NGC 2264

Walker	MK	E	$V_0 \ 3E$	$V_0 \ 6E$
131*	O7	0 08	4 38	4 14
178	B1 5 V	05	6 99	6 84
212	B2 IV	09	7 20	6 93
83.	B2 IV	09	7 66	7 39
50†	B2 5 V	10	7 81	7 51
74*	B3 Vn	07	8 23	8 02
206	B7 V	04	8 58	8 46
107.	B7 V	07	8 60	8 39
88*	B3 V	10	8 72	8 42
142*	B6 V	07	8 76	8 55
231.	B5 Vn	02	8 90	8 84
109*	B6 V	04	8 96	8 84
152	B8 Vn	04	8 98	8 86
187.	B8 V	05	9 06	8 91
137*	B8 V	05	9 73	9 58
179*	B9 5 V	05	9 80	9 65
181*	B9 Vn	0 03	9 94	9 83

* See text for explanation.

† Two-line binary

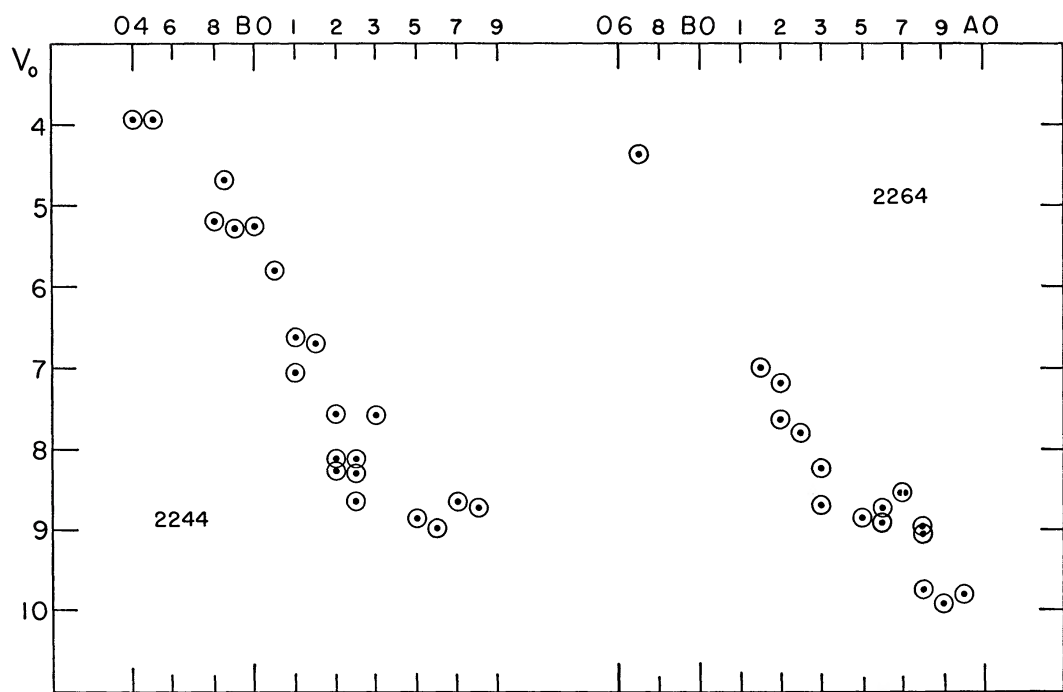


FIG. 4.—H-R diagrams for NGC 2244 and NGC 2264. No corrections have been made for duplicity

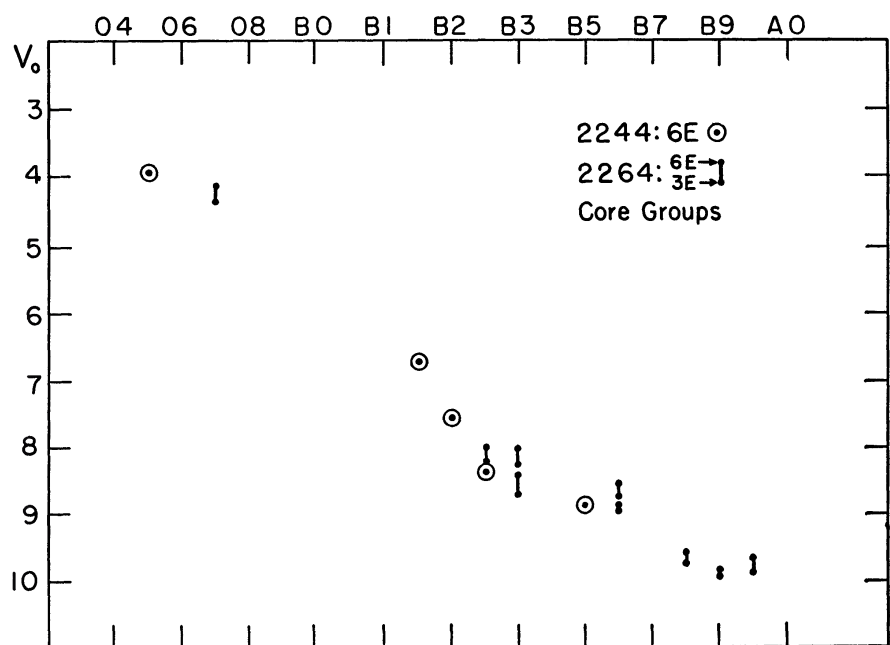


FIG. 5—H-R diagram for central regions of NGC 2244 and NGC 2264. No corrections have been made for duplicity, except for the two-line binary No. 50 in NGC 2264 (see text).

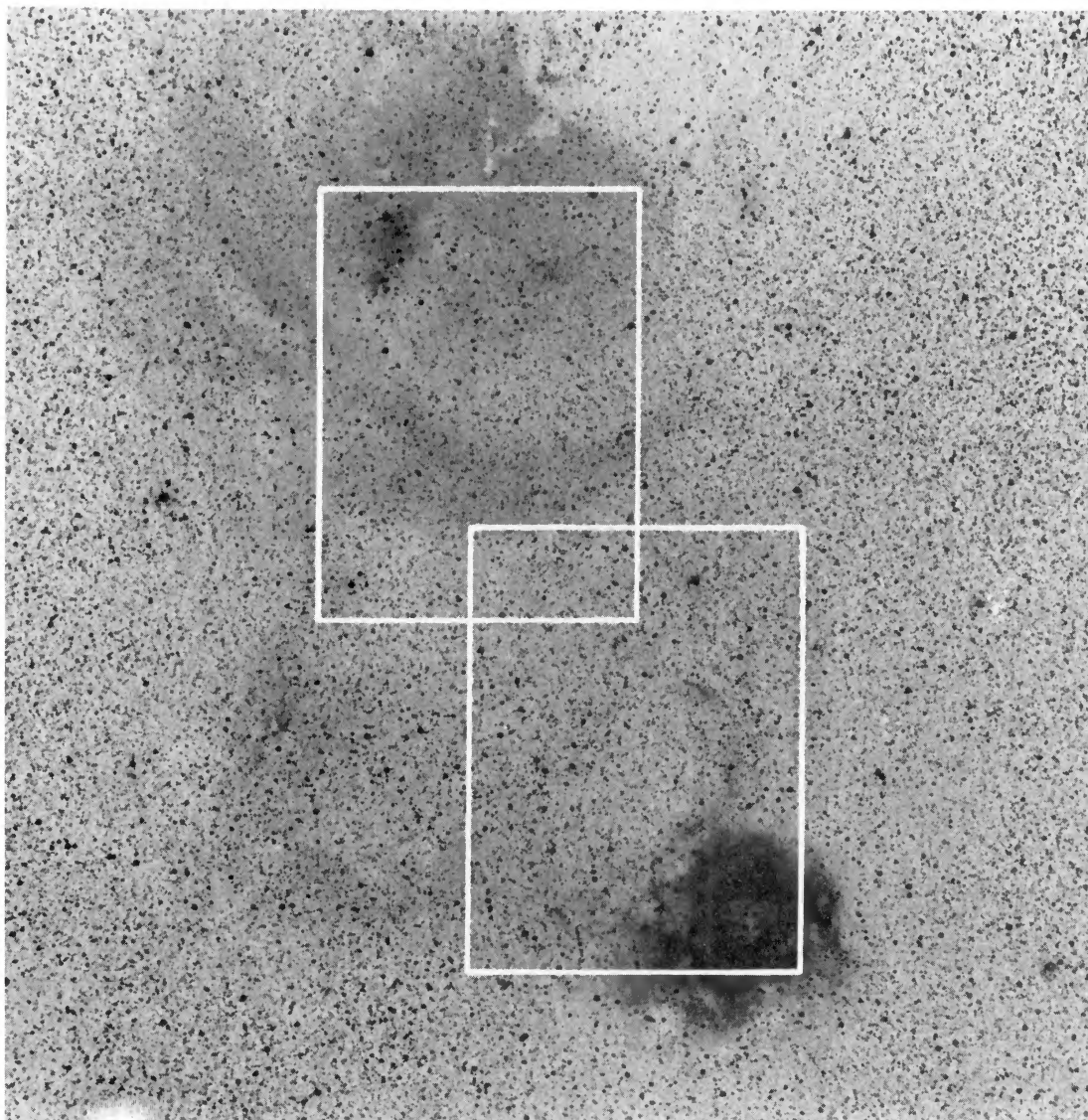


FIG. 6.—Field of NGC 2244 and NGC 2264, from microschmidt plate by H. M. Johnson. The two rectangles show the fields illustrated in Figs. 7 and 8.

for clarity, the two diagrams can be combined into a single one with satisfactorily good agreement for the assumption that both clusters are at the same distance from the Sun.

4. A more selective comparison is given in Figure 5, where the brighter members of the inner part of each cluster (marked by asterisks in Tables 1 and 2) are plotted together. Star 50 in NGC 2264 is a two-lined spectroscopic binary; it was estimated that the brighter member of this binary is about 0.5 mag. fainter than the combined light of the two stars; and the V_0 plotted in Figure 5 has been corrected by this amount. The vertical lines plotted for the stars in NGC 2264 in Figure 5 represent the range in V_0 on the two assumptions for the ratio of total to selective absorption. The combined main sequence is very narrow; and the indication is strong that the two clusters are in fact located at similar distances from Earth. It is likely that NGC 2264 is the nearer of the two by a slight amount. A comparison of Figure 5 with the H-R diagram of the Upper Scorpius region gives a distance modulus of 9.5, in agreement with Walker.

5. The actual spatial relationship of the three principal emission structures is of some interest. With a picture of the Galactic spiral structure similar to that of Morgan, Sharpless, and Osterbrock (1952*a, b*), and discussed in greater detail recently by Becker and Fenkart (1963) and by Becker (1963), we can outline some probabilities: (1) In the longitudes at which the two clusters occur we would expect to be looking along a greatly foreshortened spiral arm. (2) Segments of spiral arms as defined by H II regions in the

TABLE 3
O STARS IN CENTRAL RING

HD	MK	E	V_0 3 <i>E</i>	V_0 6 <i>E</i>
46966	O9 V	0 27	6 07	5 26
47129	O8 V	37	4 97	3 86
48099	O6	0 28	5 54	4 70

nearer giant spirals are extremely narrow, considerably narrower than spiral arms as defined by stars; and we would expect the "diamond-ring" H II region containing NGC 2244 to be somewhat more distant than the H II region surrounding NGC 2264. (3) However, the similar diameters of the two great H II regions indicate that their distances from Earth are not very different.

6. Further evidence on the relationship between the H II regions is given in Figures 6, 7, and 8. Figure 6 is from a plate taken by H. M. Johnson with the Meinel-Pearson microschmidt; the field is approximately 10° in diameter, and the over-all structure of the H II regions is illustrated. The two white rectangles show the field included in Figures 7 and 8, which are from a red plate taken with the Palomar 48-inch Schmidt by Osterbrock. An inspection of Figure 7 shows conclusively that there is an organic relationship between the nebulosity surrounding NGC 2244 and the ring to the north; the Rosette Nebula and the ring are parts of a single complex structure.

7. The relationship between the ring and the great emission complex surrounding NGC 2264 is not so easily determined. The fine filamentary structure of the western and northern parts of the ring is strikingly different from the amorphous nature of the great emission region to the north (Fig. 8). On the other hand, there is a suggestion of some sort of interaction between the two structures in the region where they overlap. The most probable spatial arrangement at present seems to be that NGC 2244 and its associated ring are slightly more distant than the NGC 2264 complex, but they are not likely to be separated in space by more than 100–200 pc.

8. An intriguing problem for the future is the investigation of the association of stars with the great emission ring. There are three O stars that seem to be connected with it; they are listed in Table 3. The photometry is from Hiltner (1956), and the spectral types

are new determinations. The color excesses are less than those for the members of NGC 2244, but they are greater than those listed for NGC 2264 in Table 2.

9. There is one star in NGC 2244 of especial spectroscopic interest; it is No. 17. Its spectral type is B3 V, but the hydrogen absorption lines are far stronger than in standard stars of this class. Its location and color excess establish its cluster membership, and also establish the fact that it is located at the bright edge of the main sequence. There are five cluster members of earlier spectral type that are fainter than this star; and it appears to be an exception to the relationship between Balmer line intensity and luminosity. In the width of $H\gamma$, it resembles the brighter stars in the Orion Nebula cluster.

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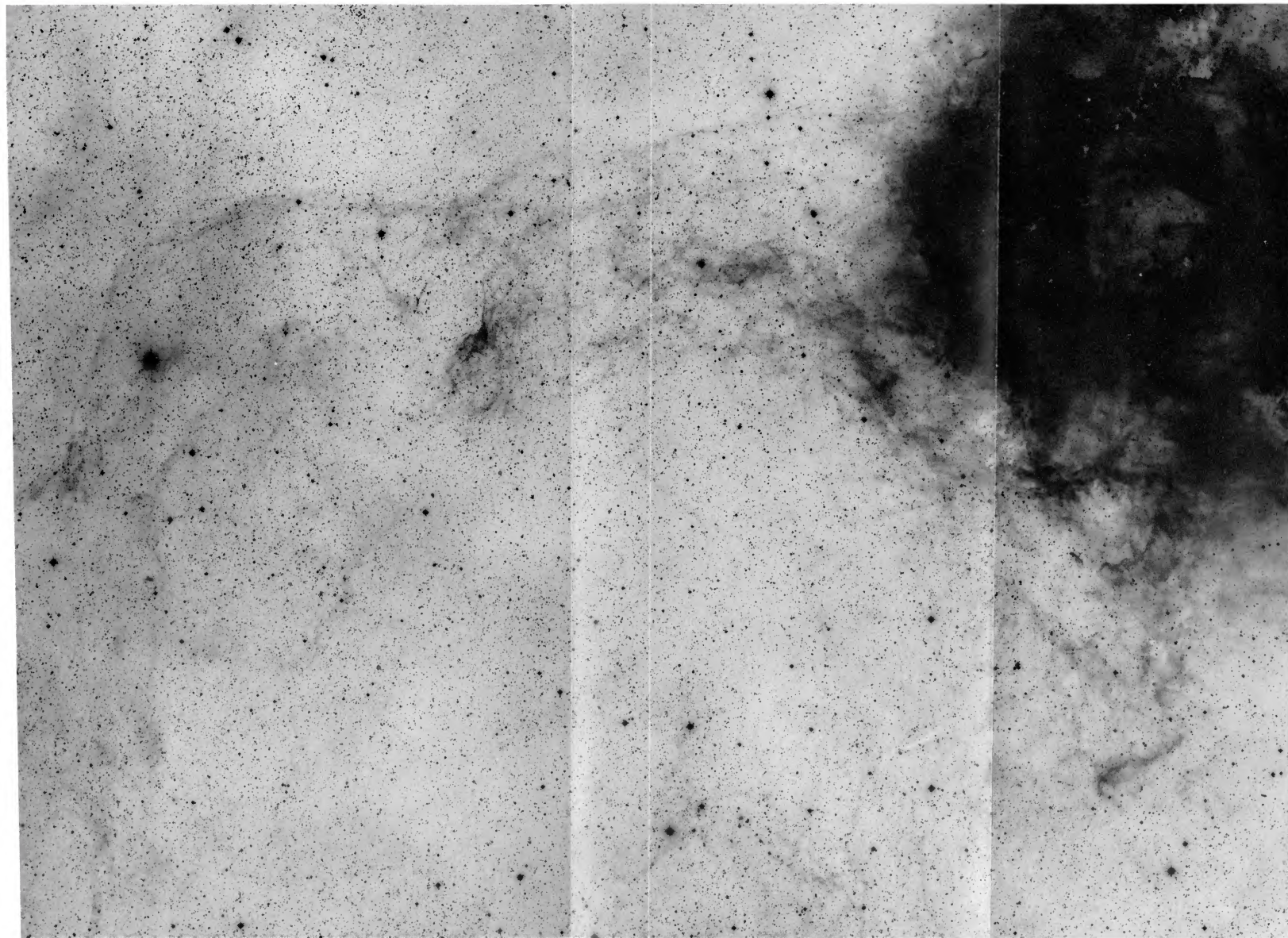
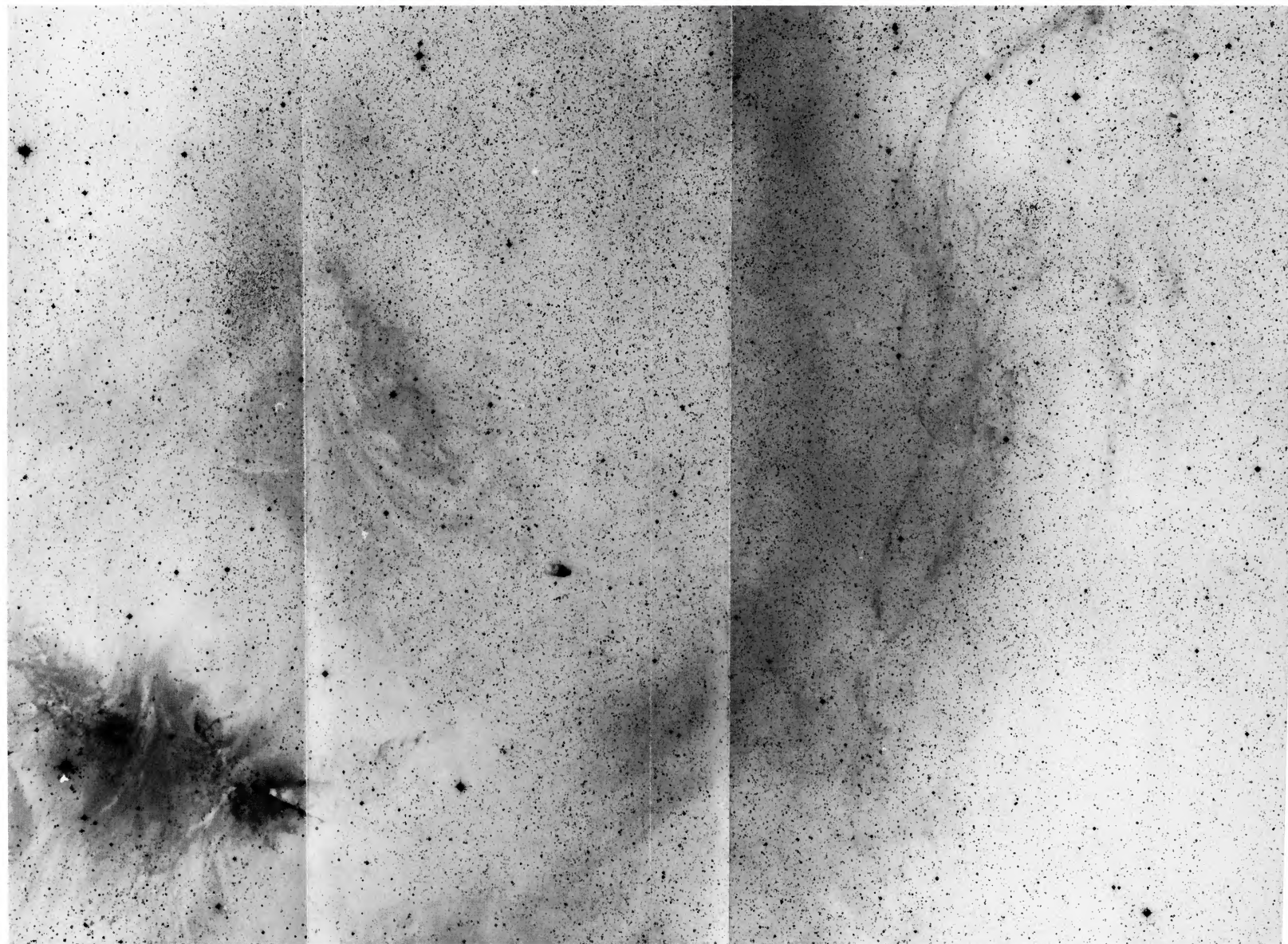


FIG. 7.—Region north of NGC 2244. Red-sensitive plate and red filter. Mount Palomar 48-inch Schmidt. North is at left

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