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The polarization and intensity distribution in the Crab nebula derived from plates taken with the 200-inch telescope by Dr. W. Baade
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TABLE 4

Star	JOHNSON and MORGAN			Haute Provence			
	V	B	B-V	Gr	Bl	Gr-Bl	"Wh"
	m	m	m	m	m	m	m
Pleiades 681	9.24	9.79	0.55	9.24	9.79	0.55	9.59
" 996	7.53	7.61	0.08	7.50	7.59	0.09	7.58
" 993	9.14	9.30	0.16	9.13	9.31	0.18	9.26
" 620	9.86	10.40	0.54	9.85	10.41	0.56	
" 385	10.20	10.92	0.72	10.15	10.86	0.71	
" 597	8.77	9.94	1.17	8.77	9.93	1.16	9.38
" 569	7.68	8.92	1.24	7.71	8.94	1.23	
B D +21° 894				10.19	10.44	0.25	10.40

THE POLARIZATION AND INTENSITY DISTRIBUTION IN THE CRAB NEBULA DERIVED FROM PLATES TAKEN WITH THE 200-INCH TELESCOPE BY DR W. BAADE

BY L. WOLTJER

Polarizations and intensities were determined at a large number of points in the Crab nebula with a nearly circular diaphragm of about 5" diameter on plates taken by Dr BAADE with the 200-inch telescope. The plates were calibrated with the aid of WALRAVEN's photoelectric measures. The accuracy of our results is discussed.

Introduction.

In the autumn of 1955 Dr BAADE took a number of plates of the Crab nebula with the 200-inch telescope. Four of these plates were taken through a polaroid filter. These plates were described by Dr BAADE in *B.A.N.* No. 462. The orientation of the polaroid filter was such that maximum transmission occurred in position angles 0°, 45°, 90° and 135°. Dr BAADE also obtained an interfocal calibration plate of Selected Area 68. The exposure time for all these plates was 20 minutes. Dr BAADE was so kind to send these plates to Leiden together with two plates taken without a polaroid filter and with exposure times of 5 and of 30 minutes and thus enabled us to make a detailed study of the amorphous mass of the nebula. As all plates were taken in the wavelength region 5200 Å to 6400 Å the contribution of light from the filaments must be very small. In this paper we will give the results of our measurements. A full discussion of the results will be given in a following publication.

The measurement of the plates.

All plates were measured in an iris photometer using a fixed diaphragm and a variable wedge. On all plates we made measurements every half millimeter on the plate in both directions with a nearly circular diaphragm of 0.47 mm diameter. The positive *y*-axis in our coordinate system points north,

the positive *x*-axis west. The south west component of the central double star is at the origin. As one mm on the plate corresponds to 0.186 minutes of arc the diaphragm has a diameter of about 5". It was therefore possible to obtain a detailed picture of the nebula.

The calibration.

From a preliminary comparison with WALRAVEN's photoelectric results it appeared that it was not possible to reduce all plates with the same calibration curve. Moreover, the range in brightness of the stars in S.A. 68 was not sufficient to obtain a complete calibration curve. Therefore we decided to use WALRAVEN's photoelectric results for the calibration of all our plates. This implied that we had to assume that the spectrum of the continuum is constant over the nebula. For most photoelectric measurements were made in the photographic region. As the position angles of the maximum of the electric vector are the same for the photoelectric measurements and for the photographic plates, every plate can be calibrated against a corresponding set of photoelectric measurements.

We selected a number of appropriate photoelectric observations which we first corrected for the filamentary light. The filaments are distributed quite unevenly over the nebula, but they are not concentrated so strongly to the centre as the light of the

TABLE I

Polarizations in the Crab nebula. For every point the position angle of the maximum of the electric vector is given in degrees and below it, in italics, the degree of polarization in percent

y	x	-11	-10.5	-10	-9.5	-9	-8.5	-8	-7.5	-7	-6.5	-6	-5.5	-5	-4.5	-4	-3.5	-3	-2.5	-2	-1.5	-1	-0.5	0	x	y'
+10.5																									+1'.95	
+10																									+1'.86	
+9.5																									+1'.77	
+9																									+1'.76	
+8.5																									+1'.58	
+8																									+1'.49	
+7.5																									+1'.40	
+7																									+1'.30	
+6.5																									+1'.21	
+6																									+1'.12	
+5.5																									+1'.02	
+5																									+0'.93	
+4.5																									+0'.84	
+4																									+0'.74	
+3.5																									+0'.65	
+3																									+0'.56	
+2.5																									+0'.47	
+2																									+0'.37	

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TABLE I (continued)

y	x	+0.5	+1	+1.5	+2	+2.5	+3	+3.5	+4	+4.5	+5	+5.5	+6	+6.5	+7	+7.5	+8	+8.5	+9	+9.5	+10	+10.5	+11	x/y
+10.5																								+1'.95
+10							86 21	90 17	76 30	71 25	68 24	71 18	88 11	93 13	101 15		113 6	137 16	136 25					+1'.86
+9.5				128 32	105 17		97 12	69 16	61 26	63 26	69 21	64 16	77 16	83 8	87 10	78 12	94 10	106 12	160 20	145 28	164 31			+1'.77
+9				130 17	125 13		84 4	54 11	54 25	59 24	53 19	55 11	70 7	64 14	59 16	97 13	85 14	99 14	158 11	174 20	159 25			+1'.67
+8.5			77 15	150 10	146 11	157 6	29 18	30 22	35 25	30 18	17 11	40 21	62 7	69 9	59 12	71 8	93 16	88 14	170 8	7 21	160 16	140 20		+1'.58
+8		81 46	56 23	37 17	169 8	25 11		17 17	1 12	17 10	161 4	144 9	90 3	75 7			94 11	96 12	28 1	165 18	170 28	139 18		+1'.49
+7.5		71 38		52 10	56 11	13 9	5 7	179 6	150 17	151 3	21 4	135 10	94 6	96 9	73 15	61 17		135 11	174 14	169 34	159 16			+1'.40
+7		68 23	82 16	88 12	69 14	152 9	147 18	147 19	137 8	104 8	69 7	94 8	101 13	95 13	82 18	73 16	76 15	122 10	11 12	176 19	25 3			+1'.30
+6.5		93 7	107 13	122 15	130 29	137 26	147 25	157 26	150 17	122 10	11	103 9	92 14	89 15	89 18	89 22	88 15	93 11	91 18	0 19	40 26	22 24		+1'.21
+6		169 19	168 14	155 23	149 36	144 34		158 29	152 20	141 22	145 22	131 9	101 12	85 13	94 16	107 16	68 10	60 9	61 23	47 44	39 43	31 32		+1'.12
+5.5		158 29	158 22	160 23	158 32	154 40	156 47		155 32	142 27	146 20	142 8	125 6	69 4	85 6	104 5	110 5	79 11	63 26	57 30	47 28	47 32		+1'.02
+5		157 21	158 21	159 21	164 26	168 31	158 45		143 26	148 9		157 7	159 5	148 5	159 5	111 3	84 11	76 21	73 29	72 12	44 28	40 37	41 41	+0'.93
+4.5		167 15	171 17	163 23	170 25	170 30	161 34	151 38	145 36	150 24		152 11	139 15	125 10	95 5	73 6	71 17	79 21	88 20	95 12	54 18	52 26	27 29	+0'.84
+4		167 13	170 18	173 25	171 27	174 23	169 16	153 18	145 23	154 24		149 27	152 31	151 14	45 12	59 23	64 21	85 15	112 24	115 18	84 9			+0'.74
+3.5		163 17	164 19	176 25	175 27	176 24	6 20	5 12	159 13	147 26	147 31	144 29	143 28	131 16	102 12	70 17	62 19	102 11	123 17	125 25	131 25	143 54	145 83	+0'.65
+3		159 31	163 24	176 28	178 23	179 19	4 18	11 17	168 10	142 18	27	143 29	145 29	136 10	79 8	63 9	5 6	164 2	133 11	127 27	136 40	146 56	155 68	+0'.56
+2.5		157 32	164 28	173 30	177 28	179 21	6 22	12 19	179 10	150 15	138 17	142 16	157 15	169 5	155 3	179 6	162 16	3 8	163 2	127 19	141 43	152 53		+0'.47
+2		155 28	159 30	167 33	170 31	169 21	4 1	8 22	1 14	8 7	70 4	28 2	42 8	32 7	149 13		165 13	165 13	141 5	148 18				+0'.37

+ 1.5	148 149 155: 164 167 27 23 24: 27 23	175 0 4: 30 47 20 17 12: 8 20	59 72 60 105 132 15 12 9 11 8	145 168 3: 164 9 13 10: 33	+0'.28
+ 1	140 139 148 170 163 27 26 19 19 16	165 179 29 45 20 18 7 14	45 44 120 126 137 23 12 4 13 20	162 3 169 164 10 27 50 72	+0'.19
+ 0.5	134 131 147 174 160 28 29 15 11 11	161: 160 52 53 19: 10 8 15	33 12 147 127 124 18 12 11 15 14	127 8	+0'.09
0	133 124 137 142 132 19 20 13 6 8	128: 113 80: 71 55 11: 11 15: 19 21	29 172 137 120 20 19 23 27	114 33	0'
- 0.5	140 131 126 105: 116 18 14 14 5: 13	113 105: 98 86 71 19 22: 27 25 23	43 143 128 19 45 43	124 46	-0'.09
- 1	142 143 132 121: 120 21 18 15 14: 21	105 114 99 95 20 30 35 36	77 144 141 130: 125 15 63 62 66: 54	128 65	-0'.19
- 1.5	146 149 138 131 24 27 20 20	120: 111 107 104 101 23: 27 39 44 45	118 151 146: 140 26 53 48: 71		-0'.28
- 2	151 152 151 150 150 33 36 34 31 21	151: 120: 110 120: 15: 16: 32 49:	138 151 145: 41 51 86:		-0'.37
- 2.5	154 156 158 158 161 43 46 40 39 37	168 168 138 126 132 31 19 15 33 43	147 158 167 136 56 66 40 50		-0'.47
- 3	157 159 160 163 166 44 44 45 48 43	169 168 162 143 138 43 35 28 23 39	147 147 157 139 52 54 37 23		-0'.56
- 3.5	162: 163: 167 167 168 35 37 39 45 46	170 170 159 144: 44 34 32 41:	149: 145: 143: 139 50: 57 32 21		-0'.65
- 4	176 167 168 173 175 27 29 36 41 41	175 174 167 160 151 40 37 37 37 39	145 140 41 39		-0'.74
- 4.5	178 2 176 3 6 27 29 32 38 39	7 6 0 165 157 41 37 36 35 44	149 138: 45 46:		-0'.84
- 5	175 7 12 13 16 24 31 29 31 41	16 7 171 165 160 37 34 42 55 49	145 134 45 44		-0'.93
- 5.5	173: 7 16 18 21 21: 27 24 20 24	34 20 169 162 162 37 35 44 61 51	156 147 133 52 52 40		-1'.02
- 6	165 9 18 54 25 20 18 22	49 0 157 148 153 20 15 31 58 59	148 144 143 56 64 42		-1'.12
- 6.5	16 28 67 23 13 18				-1'.21
- 7	159 3: 17: 45 47 39: 29: 16				-1'.30
- 7.5	154 14 172 51 32 35				-1'.40
y	0'.09 0'.19 0'.28 0'.37 0'.47	0'.56 0'.65 0'.74 0'.84 0'.98	1'.02 1'.12 1'.21 1'.30 1'.40	1'.49 1'.58 1'.67 1'.77 1'.86	y +x'
					1'.95 2'.05

TABLE 2
The intensity distribution in the Crab nebula

$\gamma \backslash x$	-16	-15.5	-15	-14.5	-14	-13.5	-13	-12.5	-12	-11.5	-11	-10.5	-10	-9.5	-9	-8.5	-8	-7.5
+16																		
+15.5																		
+15																		
+14.5																		
+14																		
+13.5																		
+13																		
+12.5																		
+12																		
+11.5																		
+11																		
+10.5																		
+10																		
+9.5																		
+9																		
+8.5																		
+8																	2	4
+7.5																	3	6
+7															1	3	6	7:
+6.5														3	4	9	11	11
+6													1	4	6	9	14	14
+5.5												1	2	6	8	17	18:	23
+5												2	5	7	10	19:	23:	30
+4.5											1	3	4	8	11	20	28	36
+4											2	3	5	7	11	19	33	34
+3.5											1	3	5	10:	10	17	27	40
+3											3	3	5	11	11	13	17	32
+2.5									3	2	4:	5:	5:	8	10:	15	15	22
+2							1	1	2	3	4	6	5	7	10:	10	10	17
+1.5							3	1	3	4	5	7	11	12	13:	14	14	14
+1						1	5	3	3	5	8	11	13	11	11:	11	18	11
+0.5					2	2	5	5	7:	11	12	13:	14:	13:	12	8	7	16
0					3	3:	6	6	10	16	17	17	18	18	14	6	5	7
-0.5					3	3:	5	7	11:	15	24	26	24	25	17	12	8:	4:
-1					2	3	5	7	13	22	30	36	33	32	30	18	23	22:
-1.5					2	2	4	7	21	31	32	49	41	40	44:	32	29	41
-2					2	5	5	11	28	34	43	64	56	49:	59:	61	57	63
-2.5			2		3	4:	8	14	43	49	58	66	66	68:	70	72	74	75
-3			5		7	8	13	25	48	51	53	61	73	74:	75:	77	75	69
-3.5			5		7	9	17	25	43	51	50	61	67	72:	77:	79	89	85
-4			3		7	12	19	25	35	45	52	62	63	68	81	87	96	91
-4.5			3		6	15	23	23	41	53	56	60	60	69	82	86	90	92
-5			3:		7:	16	31	27	45	49	52	50	56	74	83	91	82	85
-5.5			4:		9:	14	19	21	30	36	37:	38	46	54	69	84	84	85
-6			4		10	14	16	19	21	26	34	35	37	38	48	67	71	75
-6.5	1	4	4		9	12	15	15	17	25	30	33:	33:	37	36	46	57	65
-7	2	4	7		9	12	13	13	15	17	22	31	27	31	27	33	49	64
-7.5	2	3:	7		9	10	11	13	13	13	14	15	16	14	20	29	31	48
-8	2	2	4		7	10	9	10	9	11	9	10	10	19	18	20	23	36
-8.5	2	1	4:		5	6	4	3	6	9	7	7	8	12	16	15	13	17
-9		1	4		3	3	4	3	4	4	6	8	7	10	11	8	9	12
-9.5			1		2	2	4	3	4	4	6	7	6	8	7	8	7	8
-10					2	2	2	2:	2	2	5	4	4	5	7	6	5	5
-10.5					1	1	1	3	4	3	4	4	4	4	5	4	4	4
-11								3	4	2	3	2:	2:	4	3	3	4	4
-11.5								2	2	1	1		1	1	2	4	2	3
-12								1	1						2	2	2	3
-12.5																2:	2	3
-13																	1	5
-13.5																	1	3
-14																	1	
-14.5																		
$\gamma \backslash x'$	-2'.98	-2'.88	-2'.79	-2'.70	-2'.60	-2'.51	-2'.42	-2'.33	-2'.23	-2'.14	-2'.05	-1'.95	-1'.86	-1'.77	-1'.67	-1'.58	-1'.49	-1'.40

TABLE 2
The intensity distribution in the Crab nebula

-7 -6.5 -6 -5.5 -5					-4.5 -4 -3.5 -3 -2.5					-2 -1.5 -1 -0.5 0					x y'
									I	I					+2'.98
									2	I	I				+2'.88
									2	I	I	I	I		+2'.79
									I	I	I	2	2	2:	+2'.70
									I	I	2	2	3:		+2'.60
										I	I	3	3	5:	+2'.51
										I	2	3	3	6	+2'.42
										2:	4:	5	5	9	+2'.33
										3	5	6	7	9	+2'.23
										4	5	9	9	12	+2'.14
										6	7	5	10	15	+2'.05
										7	9	8	7	11	+1'.95
										8:	9	6	5	11	+1'.86
										9:	9	8	7	13	+1'.77
										16:	15	10	16	21	+1'.67
										23:	22	20	41	38	+1'.58
										26	21	34	51	42	+1'.49
										32	32	35	49	67	+1'.40
										42	55	73	77	93	+1'.30
										79	101	86	91	124	+1'.21
										86	90	101	141	162	+1'.12
										80	106	146	159	173	+1'.02
										96	126	151:	175	182	+0'.93
										124:	151	185:	207	201	+0'.84
										134	172	203	219	217	+0'.74
										177	221	238	237	222	+0'.65
										231	264	266	251	263	+0'.56
										206	241	266	268	271:	+0'.47
										200:	214	222	286	286:	+0'.37
										189:	209	205:	233	299	+0'.28
										157:	181	204	205	226	+0'.19
										151:	172:	189	213:	220:	+0'.09
										150	171	185	237	208:	+0
										158	180	224	212	202:	-0'.09
										156	187	245	218:	204:	-0'.19
										168	211	269	258	206	-0'.28
										179	206	246	255	234	-0'.37
										187	209	233	227	248	-0'.47
										184	194	196	200	212	-0'.56
										164	165	170	174	172:	-0'.65
										187	178	167	166	181:	-0'.74
										200	191	177	163	171	-0'.84
										173	156	156	131	128	-0'.93
										96	115	117:	101	89	-1'.02
										58	76	76	84	65	-1'.12
										53	50	54	52	57	-1'.21
										49	38	36	39	42	-1'.30
										38	31	25	23:	26	-1'.40
										23	18	17:	13	16	-1'.49
										14	13	11	10	16	-1'.58
										10	10	8	9	13	-1'.67
										10	9	6	8	6	-1'.77
										8	6	5	8	5	-1'.86
										8:	6:	6	6	5	-1'.95
										8	5	4:	3	3	-2'.05
										6	4	2	2	3	-2'.14
										3	2	2	3	3	-2'.23
										2	2	I	3	I	-2'.33
										2	2	I			-2'.42
										2	2				-2'.51
										2	3				-2'.60
										2	2:				-2'.70
-1'.30	-1'.21	-1'.12	-1'.02	-0'.93	-0'.84	-0'.74	-0'.65	-0'.56	-0'.47	-0'.37	-0'.28	-0'.19	-0'.09	0	y' x'

TABLE 2 (continued)

$x \backslash y$	+0.5	+1	+1.5	+2	+2.5	+3	+3.5	+4	+4.5	+5	+5.5	+6	+6.5	+7	+7.5
+16					1							1			2
+15.5					1				3	1		2	2		4
+15		1:			1		1	2	2	3		3	3	4	5:
+14.5	3:	2:	3	2	1	2	2	3	3	3	6	6	6	7	8
+14	4:	2:	3:	2	3	2	3	4	5	7	7	11	11	15	14
+13.5	5	3	2	4:	5	5	6	9	10	11	10	14	15	20	17
+13	4	5:	5	6	7	8	9	12	15	16	14:	16	18	27	25
+12.5	10	8	8	10	9	9	11	13	19	19	18	21	26	33	27
+12	11	12	19	16	14	11	12	13	17	21	21	27	32	32	29
+11.5	11	14	14	14	13	15	16	15:	21	25	26:	32	38	37	35
+11	12	14	13	14	14	17	21	21	29	34	35	37	43	42:	41
+10.5	14:	17	19	20	19	18	30	32	42	46	44	46	55	62	53:
+10	16:	26	29	32	29	35	43	43	51	57	59	64	67	69	68
+ 9.5	20	25	37	49	51	49	59	67	68	73	72	79	78	77	74
+ 9	28	36	52:	71	76	78	84	83	85	77	77	85	83	84	78
+ 8.5	38	46	67	88	95	94	107	106	109	99	94	92	94	91	91
+ 8	54	69	78	101	130	141:	128	115	112	122	127	111	101	103:	114:
+ 7.5	86	85	79	116	153	166:	176	153	149	139	141:	131	119	108	111:
+ 7	105	71	86	136	158	185	204	194	185	160	163	152	135	130	115
+ 6.5	103:	84	108	149	172	198	214	228:	201	185	165	170	153	136	124:
+ 6	147	143	143	178	194:	209:	202	216	212	187	165:	162	150	135	128
+ 5.5	179	184	172	188	218:	222:	198:	182:	172	177:	169	177	165	138	122
+ 5	211	204	197	198	189	187	191:	197:	181	178	163	156:	138	127	113
+ 4.5	222	212	201	194	179	183	181	170	161:	152	120	107	108	107	112
+ 4	248	224	193	194	188	193	174:	165	152:	133	123	110	121	107	103
+ 3.5	242	242	208	216	211	207	199	158	147:	125:	104	96	97	97	96
+ 3	269	254	225	248	221	194	170	153:	136	127	101:	89	100	98	95
+ 2.5	289	278	239	240	222	168	156	123	106	112	113	94	104	109	90
+ 2	288	287	243	229	218	154:	145	120	99	106	107	100	93:	100:	75
+ 1.5	313	294	282:	226	224	175	149	129:	115	102	103	91	85:	87	85
+ 1	311	326	286	237	243	201	158	152	124:	107	96	93	92	95	82
+ 0.5	276	341	274	250	252	212	185	158	132	127	105	91	94	88	79
0	212	275	278	256	213	197:	190	164	146	139	109	74:	78	72	75
- 0.5	192	231	239	231:	197	185	157:	161	156	144	117	42:	58:	62	63
- 1	200	208	199	207:	182	173	160	155	149	128:	67	35	43	53	48
- 1.5	197	183	183:	169	157	163:	162	149	140	111	54	35	38	41	39
- 2	219	185	182	176	176	155:	129:	125	119:	106:	71	35	35:	32	36
- 2.5	242	221	210	187	167	152	131	112	106	93	78	51	37	38	34
- 3	198	187	188	185	174	143	124	105	99	90	72	61	46	44	37
- 3.5	186	192	181	168	152	136	117:	107	92	79	67	57	57	47	30
- 4	160	164	150	144	137	126	103	88	82	68	57	53:	54	45	31
- 4.5	154	127	115	111	101	100	102	89	68	59	48	49	50:	44	31
- 5	131	108	98	94	85	81	83	79	59	49	55:	45	47	44	54
- 5.5	93:	89	77	68	59	70	75	65	58	59	61	50	45	46	47:
- 6	58	65	56	63	59	50	53	49	33	38	46	47	44	42	37
- 6.5	57	46	48	54	49	29	25	30	30	25	37	36	35	37	31
- 7	48	43	42	41	33	19	16	14	29	33	23	25	28	27	27
- 7.5	33	33	32	29	21	19	17	11	11	19	16	20:	22	23	25
- 8	19	23	20	15	17	10	7	9	6	9	13	16:	19	18	20
- 8.5	17	14	14	8	11	9	5	5	5	5	10	12	14	12	14
- 9	17	9	8	9	9	6	5	4	4	3	6:	7	9	8	8
- 9.5	8	5	6	8	10	6	5	4	3	2	3	4	5:	5	5:
- 10	6	5	6:	13	10:	6:	5	3	3:	2	3	2	3	3	3
- 10.5	4	4	5	11	8:	6:	4	3	3:	3	1	2	1		
- 11	6	3	4	4	6	4	4	1	2	2	2	2	1		
- 11.5	3	3	3	4	4	2	1	2	3:	2:	2	2	1		
- 12	3	1	1	2	2	1	1	2:	3	3	3				
- 12.5	1	1	1	2	2	1	1	1	1	1					
- 13			1	1	2	2	4	1	1	1					
- 13.5			1					1							
- 14			1												
- 14.5															
$y \backslash x'$	+0'.09	+0'.19	+0'.28	+0'.37	+0'.47	+0'.56	+0'.65	+0'.74	+0'.84	+0'.93	+1'.02	+1'.12	+1'.21	+1'.30	+1'.40

TABLE 2 (continued)

+8	+8.5	+9	+9.5	+10	+10.5	+11	+11.5	+12	+12.5	+13	+13.5	+14	+14.5	+15	+15.5	+16	x y'
2	2	1	4	3	2	2											+2'.98
3	3	3	4	4	4	2	2										+2'.88
6	7	5	5	5	5	3	2										+2'.79
13	6	6	8	6	5	3	3	1									+2'.70
12	9	9	9	9	7	4	3	1									+2'.60
18	13	10	12	12	7	5	4	2	2								+2'.51
22	15	14	14	10	7	5	3	2	2								+2'.42
26	25	19	13	9:	6	4	4	4	2	1:							+2'.33
33	29	25	17	10	8	5	4	4:	4	2		1					+2'.23
31	31	31:	21	14	11	10	8	5	4	2	1	1					+2'.14
34	31	34	26	21	14	13	10	7	7	5	3	3:	2				+2'.05
45	41	38	35	27	17	16	14	12	9	7	5	4	2				+1'.95
53:	48	47	47	38	25	21	18	15	14	10:	5	4	2				+1'.86
66	58	49	46	39	26	20	22	21	14	12	5	3	2	1			+1'.77
75	64	57	54	46	33	22	22	23	19	14	7	4	2	1			+1'.67
79	58	49	48	54	44	26	23	28	22:	15:	8	5	2:	1	1		+1'.58
89	63	39	43	46	51	33	22	27	24	17	11	5	2	2	2		+1'.49
96	70:	47	37	44	51	36	28	27	29	20	13	9	4	2	2	1:	+1'.40
101	76	57	41:	52	51	33	35	27	28	21	14	12	6	2	2	1:	+1'.30
119	87	67	49	55	37	26	28	31	23	19	13	11	6	5	3	1:	+1'.21
121	90	72	66	49	35	30	28	27	20	19	17	13	9	7	3	1:	+1'.12
108	87	91	76	55	47	43	36	22	25	21:	16	11	8	5	2	1:	+1'.02
99	83	89	80	50	61	50	31	25	24	21	14	10	7	3	1	1:	+0'.93
85	84	90	78	74	66	41	25	20	17	14	12	9	4	2:	1		+0'.84
86	84	92	91	79	59:	36:	20:	16:	15	14	7	5	4	2	1		+0'.74
91	82	94	90	71	52	34	19	15	13	12	7:	5	3	2	1:		+0'.65
90	76	72	73	64	45	37	25	20	16	11	8	4	3	2	1		+0'.56
70	63	59	56	53:	40	30	21	21	18	12	8	4	2	2	1		+0'.47
72	58	47	46	42:	37	31	22	22	18	9	4	4	2	2	1		+0'.37
75	52	46:	42	31	31	31	23	19	15	8	4	4	2	2	1		+0'.28
68	53	44	37	25	23	22	20	15	13	9	4	4	2	2	1		+0'.19
70	33	32	26	23	21	17	13	12	11	7	5	4	2	2	1		+0'.09
61	25	26	21	16	16	11	11	8	8	7	4	4	2	2	1		0
57	28	23:	20	18	11	7	7	4	4	4	3	4	1:	2	1		-0'.09
52	37	22	17	11	10	9	7	6	5	4	3	4	1	2	1		-0'.19
43	32	23	17	15	12	9	7	6	4	4	2	2	2	2	2		-0'.28
38	33	24:	19:	17	15	11	9	6	5	4	2	2	2	2	2		-0'.37
33	30	25	22	17	16	13	9	6	5	4	3	2	2	2	2		-0'.47
29	27	26	23	17	16	12	7	6:	7	5	3	2	2	2	2	1:	-0'.56
28	30	26	20	16	14	10	7	6	6	5	4	3	2	2	2	1:	-0'.65
28	32	24	17	14	12	10	8	7	5	5	4	3	2	2	2	1:	-0'.74
31:	31	23	16	13	13	10	8	6	5	5	3	2	1	2	2	1:	-0'.84
35	31:	23	16	12	13	11	9	6	5	5	3	2	1:	2	2	1:	-0'.93
37	29	22	22	15	11	9	9	8	6:	5:	3	2	1	1	1	1:	-1'.02
32	25	20	18	15	12	9	8	9	7	5:	4	2	2:	1	1	1:	-1'.12
28	26	19	14	13	9	6	9	8	5	5	8	2:	2	1	1	1:	-1'.21
28	20	16	14	12	9	8	9	6:	4	3	7	4:	2	1	1		-1'.30
23	17:	16	13	12	10	10	8	5	4	3	3	4	1		1		-1'.40
29	15	13	13	12	13	9	7	2	2	2:	1	1					-1'.49
16	14	12	13	10	9	7	4	2	1	1	1						-1'.58
9	11:	11	7	9	6	4	3	2	1	2							-1'.67
6:	7	6	4	4	4	3	2	3	1:	4							-1'.77
2	3	2	2	1	2	1	2	2	1:	2							-1'.86
				2	2	1	1	1	2	1							-1'.95
				3	2	1	1	1	2								-2'.05
				2	2	1	2	2	2								-2'.14
				2	2	1:		1	1								-2'.23
				1		1											-2'.33
						3											-2'.42
						1											-2'.51
						1											-2'.6c
						1											-2'.7c
+1'.49	+1'.58	+1'.67	+1'.77	+1'.86	+1'.95	+2'.05	+2'.14	+2'.23	+2'.33	+2'.42	+2'.51	+2'.60	+2'.70	+2'.79	+2'.88	+2'.98	y' x'

amorphous mass. Therefore we applied to all photoelectric values obtained without a filter a correction of 0.9 units on WALRAVEN's white scale, estimated from a comparison of his measurements with and without a filter. Statistically this should give a correction of the right amount. As the construction of the calibration curve is a statistical process this should be sufficient.

At every point where we had selected a photoelectric observation we computed a wedge reading by averaging all our wedge readings in an area equal to the area of WALRAVEN's diaphragm. In this way we obtained a large number of calibration points for every plate. It appeared that, except for low intensities, all calibration curves are straight lines. This is in agreement with the results of HOLMBERG¹⁾ for photographic plates of this kind. For the polarization plates the linear part of the calibration curve begins at an intensity of about 70 in our units. Therefore we fitted by least squares straight lines to the calibration points for intensities above 90. For smaller intensities free-hand curves were drawn through the points, in which also a few points from the calibration plate of S.A. 68 could be included, because all calibration curves were almost identical for low intensities.

The two plates taken without a polaroid filter were treated separately. They were calibrated in the same way as the polarization plates, but in addition a number of WALRAVEN's observations with green filter and large diaphragm were included. This was necessary as the thirty-minute plate reaches to the edge of the nebula, where the photoelectric measurements without filter are not very reliable because of the relatively large contribution by the filaments. In the construction of the calibration curves these points received five times the weight given to the small-diaphragm points.

The plate with the thirty-minute exposure cannot be used for the central part of the nebula, whereas the five-minute plate does not give reliable results for the fainter regions; there is, however, a small region where both can be used. Straight lines were fitted to the calibration points, with the extra condition that the plates should fit together in the region of overlap.

The polarizations.

At every point in the nebula where the intensity is not too small we have measurements for four orientations of the polaroid at our disposal. In principle three are sufficient to determine the intensity, the degree of polarization P and the position angle of the maximum of the electric vector q . The most correct

procedure would be to solve the four equations for the three unknowns by least squares. However, this would involve a considerable amount of work, as polarization measurements were made for nearly a thousand points in the nebula. Therefore we solved the unknowns directly from the four measurements, which is much more convenient. The formulae used are the same as those given by WALRAVEN.

The results for the polarizations are shown in Table 1, where we give for every point the position angle of the electric vector in degrees, and below it, in italics, the degree of polarization in percent. A colon denotes cases where only three measurements were used, or where the result might be influenced by nearby stars or plate defects. In Figure 1 the polarizations are shown graphically against a photograph of the nebula. The length of each line corresponds with the degree of polarization, while its orientation indicates the direction of the electric vector.

The intensity distribution.

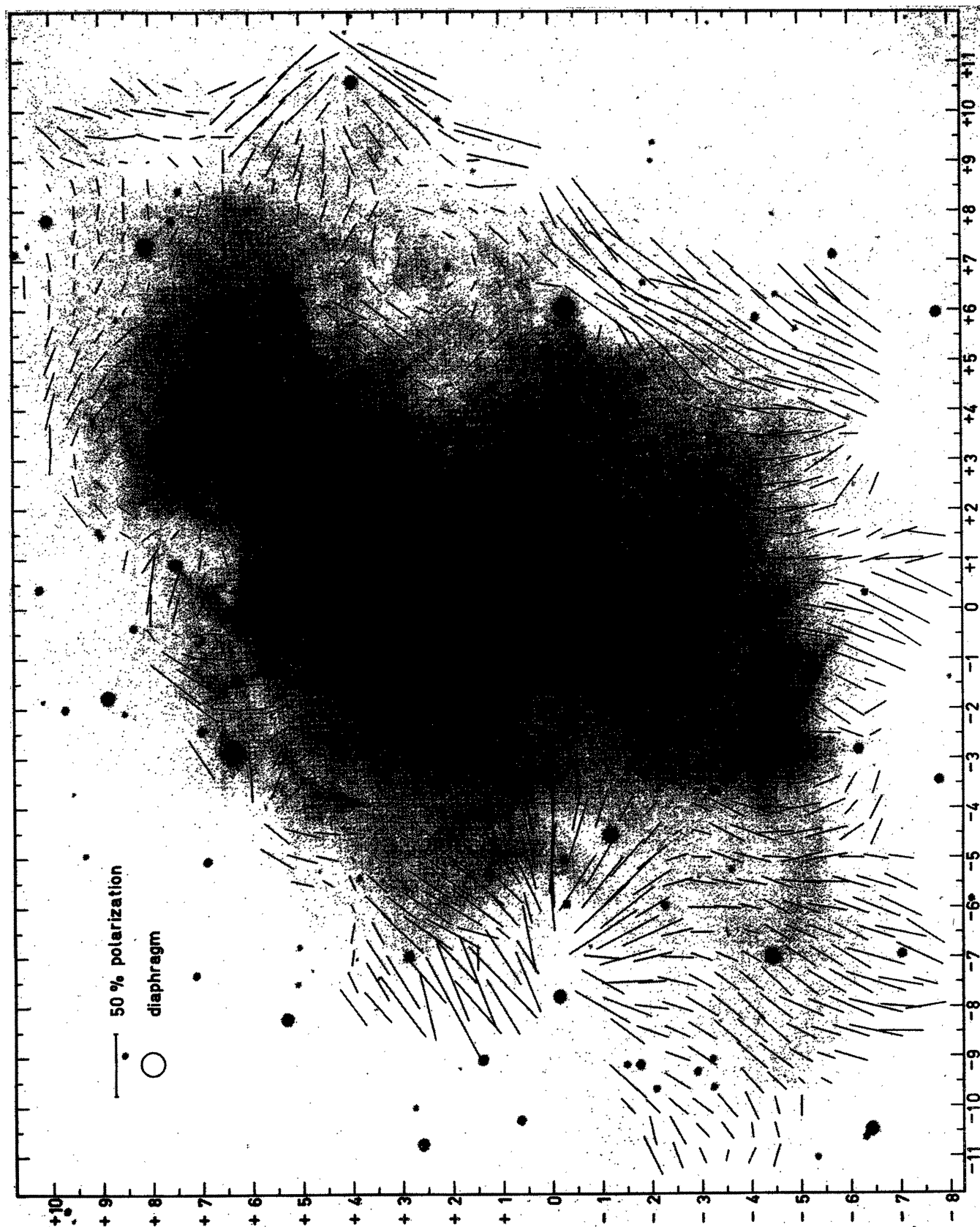
To obtain the best values of the intensities in the nebula the results of all plates were included. After making extensive comparisons of the different plates it appeared that the following combination gives the most reliable results. For intensities smaller than 91 only the thirty-minute plate has been used. For intensities between 91 and 114 the measures on the polarization plates were used. For larger intensities we combined the results from the polarization plates and the five-minute plate, giving double weight to the polarization plates. Combining our results in this way we use only the straight parts of the calibration curves and we have no systematic differences in the overlapping regions. The final intensities are given in Table 2. A map of isophotes projected against the nebula is shown in Figure 2. These isophotes are given for every 25 intensity units, but the isophotes for 1, 5 and 10 units are also shown. Our unit of intensity corresponds to 1.89 of the green filter units used by WALRAVEN.

The accuracy of the results.

For all points used in the calibration we compared the polarizations found photoelectrically by WALRAVEN with the values computed for these points by averaging our results. The systematic difference in position angle for points where the degree of polarization is larger than 10 percent and where the intensity is larger than 68 units on our scale was found to be $q_{pg} - q_{pe} = 1^\circ.1 \pm 1^\circ.0$, and thus can be neglected. The root mean square difference in the individual position angles for these points is $\pm 5^\circ.9$. This gives us a combination of the errors in both results. Large

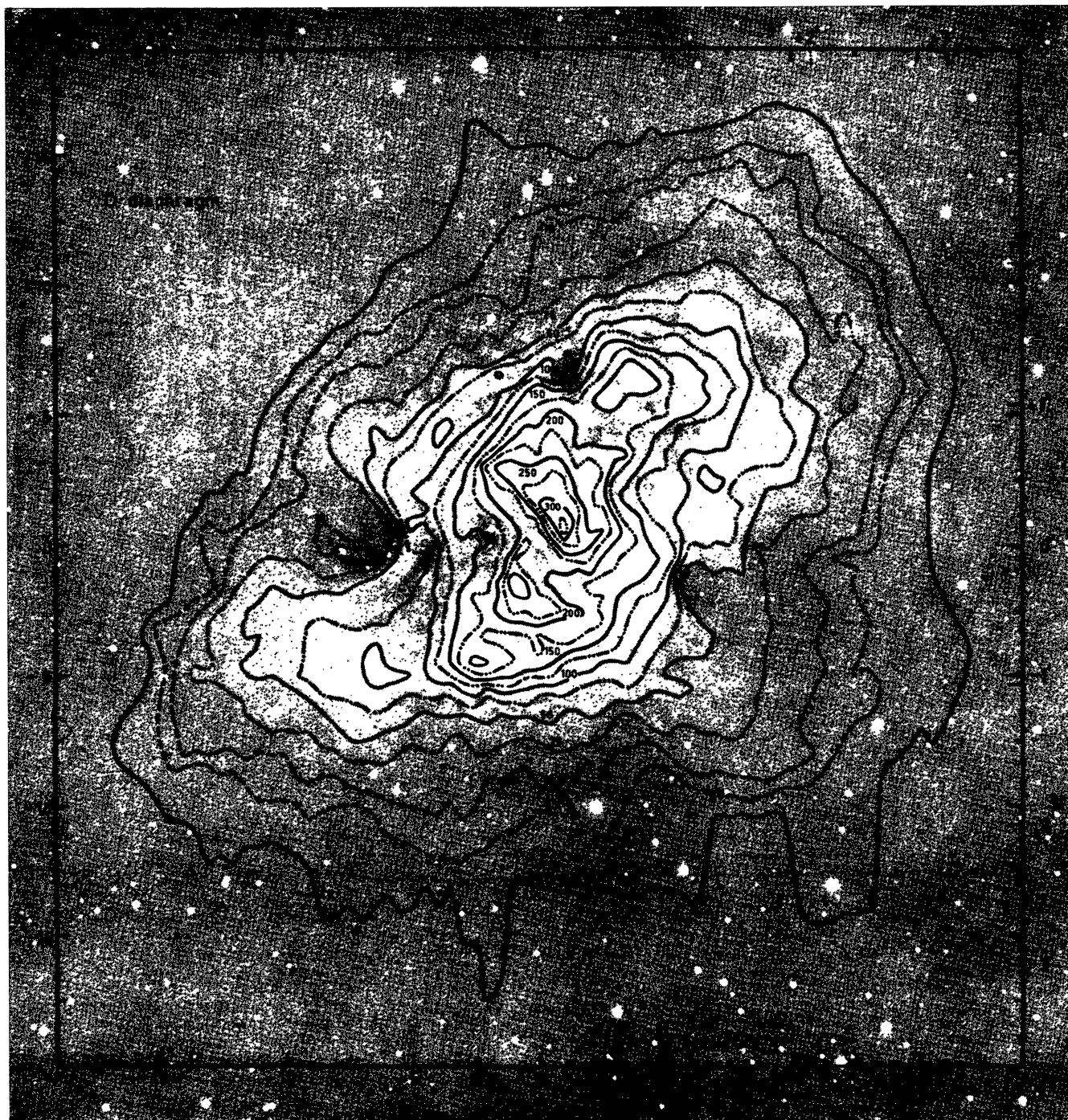
¹⁾ E. HOLMBERG, *Lund Medd Ser. II*, No. 128, 1950.

FIGURE 1



Polarizations in the Crab Nebula, measured photographically

FIGURE 2



Photographic isophotes in the Crab Nebula

systematic errors are not to be expected as the intensities on the polarization plates were calibrated with aid of the photoelectric measures.

Because in our calibration a correction for the influence of the filaments was applied to WALRAVEN's results, our degrees of polarization are somewhat larger than his. After correcting the photoelectric results in the same way there is no systematic difference in the degrees of polarization. The root mean square difference between the photographic and photoelectric results is ± 4.2 percent. As the correction for filamentary light is a statistical one it seems likely that most of the deviations are in the corrected photoelectric results. Up to here the discussion only refers to the comparison of the photoelectric results and an average of our results. It can be shown that, if we assume the mean error in the intensity from every polarization plate to be μ , the mean error in the degree of polarization is approximately $70 \mu/I$ percent and the mean error in the position angle is about $2000 \mu/\rho I$ degree, where I denotes the total intensity. It will be found that μ is about 6 for intensity values larger than 114. Thus for an intensity of 150 we expect for our individual results a mean error of 2.8 percent in the degree of polarization and when the degree of polarization is 20 percent a mean error of 4.0 degrees in the position angle.

The systematic difference of the intensity from the polarization plates minus that from the five-minute plate is +2 units, and thus can be neglected. For individual points the root mean square difference between the two is ± 4 units for intensities larger than 114. This indicates mean errors in the intensities from the individual polarization plates of about 6 units. There is also no systematic difference between the polarization plates and the thirty-minute plate, the root mean square deviation for individual points between 91 and 114 being ± 5 . These results would indicate mean errors of about ± 3 in our final intensities. However, there is some uncertainty caused by a systematic difference between $I_0 + I_{90}$ and $I_{45} + I_{135}$ in the western part of the nebula, where

the values of the first quantity are up to fifteen percent larger than those of the last one. But this difference does not seem to have had much effect on the polarizations or on the average intensities from all four plates as we do not find systematic deviations in this region with the intensities from the other plates or with the photoelectric polarizations. For intensities below 90 units we expect mean errors of about five percent in the intensity, increasing in the fainter parts of the nebula.

The integrated magnitude of the nebula.

One intensity unit in Table 2 is equivalent to 1.89 of the units in WALRAVEN's table for the green intensities and therefore corresponds to 0.775 stars of the 25th magnitude per square second of arc. When we add all numbers in our table we find a sum of 1.442×10^5 units. Observing that there is one number in the table for every $(0.093)^2$ square minutes of arc we find for the integrated visual magnitude of the nebula 8^m.64. As WALRAVEN's green intensities are in the MORGAN-JOHNSON system, our value for the magnitude of the nebula is also in this system. OORT and WALRAVEN¹⁾ found for the photographic magnitude of the nebula 9^m.14 and a colour equivalent to a G2 star. Adopting therefore a colour index of 0^m.64 for the integrated nebula we find a visual magnitude of 8^m.50. The agreement between the two values is reasonable in view of the difficulties caused by the filamentary lines and the peculiar spectral distribution in the continuum.

My most sincere thanks are due to Dr W. BAADE for putting these valuable plates at my disposal and thus making this investigation possible. I wish also to thank Prof. J. H. OORT, who suggested this investigation, and Dr TH. WALRAVEN, who allowed me to use his unpublished data, for valuable discussions.

¹⁾ J. H. OORT and TH. WALRAVEN, *B.A.N.* 12, 285 (No. 462), 1956.