Photo-electric observations of the polarization and surface brightness of the Crab nebula made at the Observations de Haute Provence

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COMMUNICATIONS FROM THE OBSERVATORY AT LEIDEN

PHOTO-ELECTRIC OBSERVATIONS OF THE POLARIZATION AND SURFACE BRIGHTNESS OF THE CRAB NEBULA MADE AT THE OBSERVATOIRE DE HAUTE PROVENCE

BY TH. WALRAVEN

The polarization and surface brightness of the Crab nebula were observed by means of a double-beam photo-electric photometer attached to the 80-cm telescope of the Observatoire de Haute Provence during the moonless period of October 1956. A chart of the polarization is given, covering nearly the entire nebula, as observed with a diaphragm of 0.304 minutes of arc diameter and without colour filter. Observations with colour filters showed that the bright central parts of the nebula have a colour index B − V = 0.82 in JOHNSON and MORGAN's scale.

The photo-electric observations.

The results of the photo-electric observations of the polarization of the light of the Crab nebula made in the winter 1954-1955 at the Leiden Observatory [1]) made it desirable to continue the observations with a larger instrument and in a better climate. At our request the 80-cm reflector of the Observatoire de Haute Provence was kindly put at our disposal during two weeks in October 1956.

For this occasion a photometer was constructed containing a calcite prism which splits the beam of star light passing through the diaphragm into two perpendicularly polarized components. The polarized beams are projected into photomultipliers of type 1P21 by small reflecting prisms. This unit is mounted in a frame carried by the telescope, such that it can be rotated around the optical axis of the telescope and adjusted at a certain desired position angle. During the rotation the diaphragm does not change its position, and also the images formed by the Fabry lens (cemented to the prism) stay in the same place on the photocathodes.

The frame carries a double slide by means of which a guiding eyepiece can be adjusted on a reference star.

The intensities of the polarized beams are measured by means of two independent amplifiers and galvanometers. The light-marks of the galvanometers register the deflections simultaneously, side by side, on a sheet of photographic paper fixed on a rotating drum.

In order to reach a high speed in the observations it was decided to use the method of trailing through the nebula. For this purpose the screw moving the guiding eyepiece in the direction of declination was given a continuous rotation by means of a small motor. During the motion the reference star was kept on the cross wires by means of the slow-motion controls of the telescope. As a consequence the image of the nebula in the focal plane moves slowly over the diaphragm. An electrical contact on the rotating screw provides position marks on the recorded intensity curves. The right-ascension of the trail can be set with the scale of the other screw. By starting and ending the trail well outside the nebula the clear sky was recorded. A trail was made in 8 minutes. In order not to distort the intensity curve the time constant of the amplifiers had to be short; it was 1 second for the largest input resistance, of 1000 Megohm.

With this equipment three sets of trails were made, each covering the entire nebula. Two of these surveys were made with colour filters and a large diaphragm, and one without filter but with a smaller diaphragm.

The following glass filters were used: green, OG 4 combined with BG 14; blue BG 25 plus GG 13. The

[1]) *B.A.N.* **12**, 285 (No. 462), 1956.

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thickness was 2 mm for all filters. The diaphragm used with the filters had a diameter of 3.10 mm, corresponding to 0.856 minutes of arc. The nebula was trailed at seven right-ascensions, separated by the size of the diaphragm. At each right-ascension two trails were made, one with the photometer in position angle 0°, which gives the intensities of the components with the electric vectors in position angles 0° and 90°, and one with the photometer turned to position angle 45°, with electric vectors in 45° and 135°. With the small diaphragm the nebula was trailed at fourteen positions in right-ascension, also separated by about the size of the diaphragm, which in this case had a diameter of 1.10 mm or 0.304 minutes of arc. Unfortunately, no time was available to repeat any of the observations.

Before and after each trail we observed the star BD +21°894, which is situated south-east of the Crab nebula. On a number of nights the brightness of this star was compared with that of some stars in the Pleiades.

The reductions.

In the records a line was drawn through the portions at the beginning and the end, which represented clear sky. Deflections from this zero line were read at the coordinate markings. The readings were multiplied by factors such that the deflections of the comparison star became 1000.

If the intensities of the polarized components with the electric vector in position angles 0° and 90° are designated by I_0 and I_{90}, and those of the other pair by I_{45} and I_{135}, the degree of polarization P may be computed from the formula:

$$P = \left\{ \left(\frac{I_0 - I_{90}}{I_0 + I_{90}} \right)^2 + \left(\frac{I_{45} - I_{135}}{I_{45} + I_{135}} \right)^2 \right\}^{1/2} , \qquad (1)$$

while the position angle q of the maximum electric vector may be found from:

$$\tan 2q = \frac{I_{45} - I_{135}}{I_{45} + I_{135}} \times \frac{I_0 + I_{90}}{I_0 - I_{90}} . \qquad (2)$$

If the observations are correct the condition:

$$I_0 + I_{90} = I_{45} + I_{135} = 2I \qquad (3)$$

must be fulfilled.

Results.

In Table 1 the quantities P, q and I are given for the observations without filter.

If x and y are the coordinates in minutes of arc, counted from the central star of the Crab nebula as origin, we have the following relations with the coordinates A and D of the double slide:

$$x = 0.276\ (15.9 - A) \qquad (4a)$$

$$y = 0.276\ (D - 22.2). \qquad (4b)$$

At the top of each series the coordinates A and x are indicated; the first and second columns of the table give the coordinates D and y respectively.

As no observations have been repeated we abstain from giving estimates of the probable errors. A colon indicates the values which cannot be trusted because clouds were passing during the recording.

A chart of the polarization observed with the small diaphragm is given in Figure 1. In the lower left- and right-hand corners, which have not been observed with the small diaphragm, the polarization derived from observations with the large diaphragm is shown.

In Tables 2 and 3 the intensities are given as observed with the colour filters and the large diaphragm. The relation between D and y as given by equation (4b) has to be changed slightly and becomes for Table 2:

$$y = 0.276\ (D - 21.5), \qquad (4c)$$

and for Table 3:

$$y = 0.276\ (D - 21.9). \qquad (4d)$$

Except for the few special areas mentioned the polarization of the observations with large diaphragm has not been computed.

The values in Tables 1, 2 and 3 have been used to calibrate the zero points and magnitude scales of the photographic photometry of the Crab nebula described in the following article, which gives the polarization and intensity distribution with much finer detail than the photo-electric photometry.

We confine the further discussion to the colour of the nebula. The intensities in the tables are expressed in a thousandth of the comparison star as a unit. Table 4 gives the magnitude of this star, BD + 21°894, as found by comparison with star No. 681 in the Pleiades according to HERTZSPRUNG's catalogue [1]). The colours and magnitudes of some other stars in the Pleiades show that the filters used in our photometer give very nearly the same system of colours as that of JOHNSON and MORGAN [2]). The last column of Table 4 gives the magnitudes of the comparison star and some of the Pleiades as determined without filter. The significance of these magnitudes for the calibration of the observations without filter of the Crab nebula is impaired by the circumstance that the spectrum of the latter is entirely different from that of the stars.

According to the magnitudes of the comparison star given in Table 4 the unit of intensity in Table 1 is equivalent to a surface brightness of 2.7 stars of the 25th magnitude per square second of arc. For the units of Tables 2 and 3 the corresponding numbers of stars are 0.41 and 0.32, respectively.

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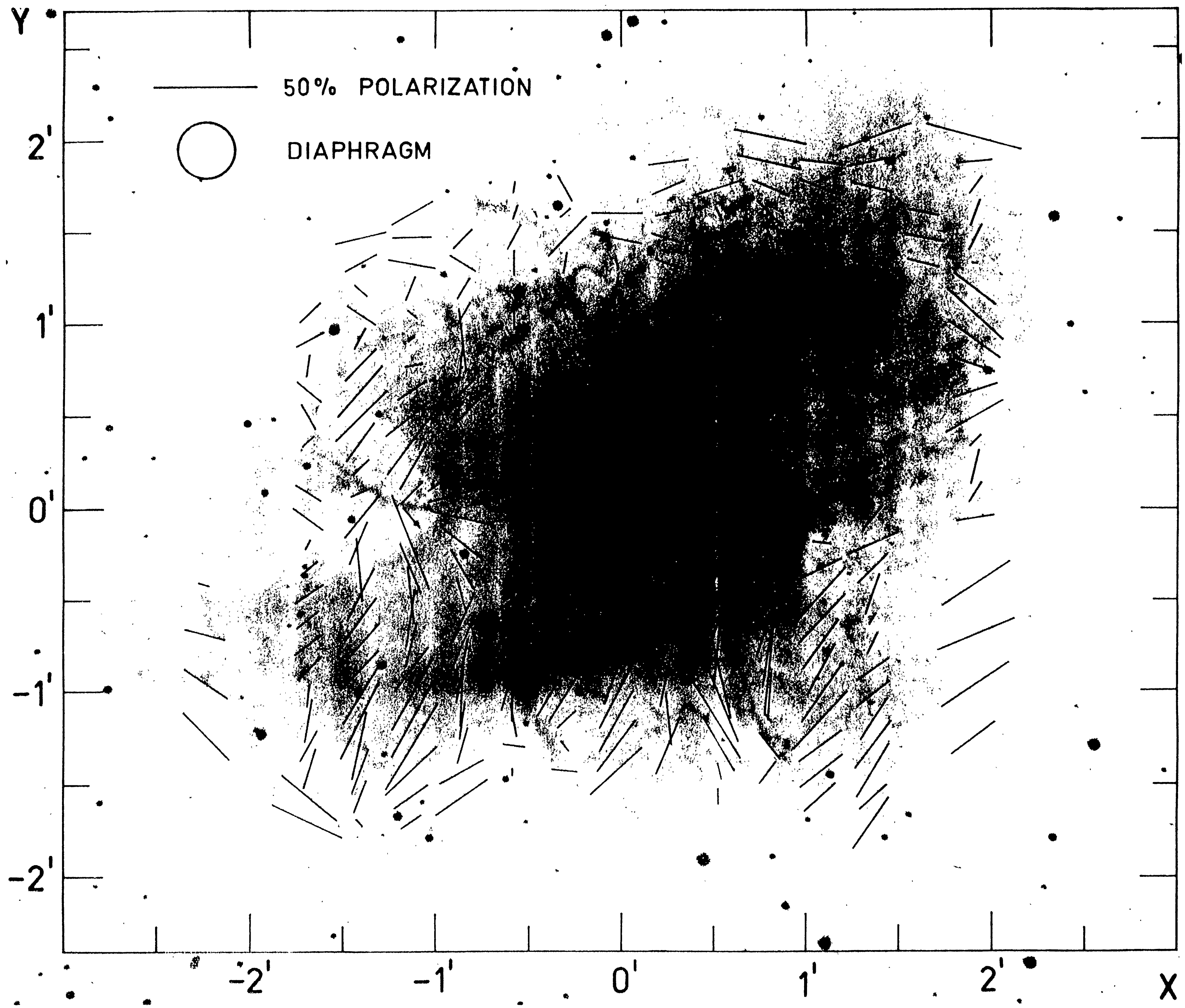
1) *Mém. Ac. R. Danemark*, Sect. Sc., 8ième Série, t. IV, No. 4, 1923.

2) *Ap. J.* **117**, 313, 1953.

FIGURE 1



Polarizations in the Crab Nebula, measured photoelectrically

TABLE I

$A = 9$ $x = +1'.904$

D	y	P	q	I
29.5	+2.015	0.38	71	5.1
29.0	+1.877	0.13	94	6.2
28.5	+1.739	0.07	142	7.7
28.0	+1.601	0.09	161	8.4
27.5	+1.463	0.11	157	8.3
27.0	+1.325	0.02	90	8.3
26.5	+1.187	0.19	54	8.8
26.0	+1.049	0.29	48	9.7
25.5	+0.911	0.24	53	11.3
25.0	+0.773	0.16	69	13.7
24.5	+0.635	0.16	105	12.7
24.0	+0.497	0.24	115	10.5
23.5	+0.359	0.06	138	7.8
23.0	+0.221	0.16	169	6.2
22.5	+0.083	0.07	153	5.2
22.0	−0.055	0.14	96	4.8
21.5	−0.193	—	—	4.2:
21.0	−0.331	—	—	3.6:
20.5	−0.469	—	—	3.2:
20.0	−0.607	—	—	2.7:
19.5	−0.745	—	—	2.0:
19.0	−0.883	—	—	2.0:
18.5	−1.021	—	—	2.3:
18.0	−1.159	—	—	2.1:
17.5	−1.297	—	—	2.0:

$A = 10$ $x = +1'.628$

D	y	P	q	I
30.0	+2.153	—	—	7.9:
29.5	+2.015	—	—	11.2:
29.0	+1.877	—	—	12.7:
28.5	+1.739	—	—	12.8:
28.0	+1.601	0.12	80	16.7
27.5	+1.463	0.14	81	19.2
27.0	+1.325	0.11	78	20.3
26.5	+1.187	—	—	20.8:
26.0	+1.049	—	—	20.5:
25.5	+0.911	—	—	20.2:
25.0	+0.773	—	—	19.4:
24.5	+0.635	—	—	16.8:
24.0	+0.497	—	—	14.3:
23.5	+0.359	—	—	14.3:
23.0	+0.221	—	—	14.0:
22.5	+0.083	—	—	10.7:
22.0	−0.055	—	—	11.0:
21.5	−0.193	—	—	9.1:
21.0	−0.331	—	—	7.4:
20.5	−0.469	—	—	5.2:
20.0	−0.607	—	—	6.1:
19.5	−0.745	—	—	6.6:
19.0	−0.883	—	—	6.1:
18.5	−1.021	—	—	6.0:
18.0	−1.159	—	—	6.0:
17.5	−1.297	—	—	4.8:
17.0	−1.435	—	—	4.1:
16.5	−1.573	—	—	3.8:

$A = 11$ $x = +1'.352$

D	y	P	q	I
29.5	+2.015	0.30	113	9.7
29.0	+1.877	0.20	101	12.5
28.5	+1.739	0.16	79	14.4
28.0	+1.601	—	—	—
27.5	+1.463	—	—	—
27.0	+1.325	0.17	84	23.8
26.5	+1.187	0.12	84	26.8
26.0	+1.049	0.06	81	27.0
25.5	+0.911	0.09	108	23.8
25.0	+0.773	0.10	110	20.8
24.5	+0.635	0.05	108	19.8
24.0	+0.497	0.06	86	18.2
23.5	+0.359	0.08	81	16.8
23.0	+0.221	0.07	105	18.2
22.5	+0.083	0.04	124	18.9
22.0	−0.055	0.13	142	15.7
21.5	−0.193	0.21	115	11.0
21.0	−0.331	0.17	132	8.6
20.5	−0.469	0.17	163	8.6
20.0	−0.607	0.05	151	9.5
19.5	−0.745	0.10	156	8.8
19.0	−0.883	0.15	125	8.0
18.5	−1.021	0.18	128	7.2
18.0	−1.159	0.19	149	6.4
17.5	−1.297	0.22	145	5.0
17.0	−1.435	0.26	149	1.8
16.5	−1.573	0.14	135	3.0
16.0	−1.711	0.29	147	2.2

$A = 12$ $x = +1'.076$

D	y	P	q	I
29.0	+1.877	0.17	83	10.3
28.5	+1.739	0.16	76	10.6
28.0	+1.601	0.08	76	19.4
27.5	+1.463	0.03	76	24.1
27.0	+1.325	0.06	90	30.4
26.5	+1.187	0.06	112	34.2
26.0	+1.049	0.09	143	33.5
25.5	+0.911	0.16	152	29.5
25.0	+0.773	0.18	146	26.2
24.5	+0.635	0.19	140	23.6
24.0	+0.497	0.22	143	22.0
23.5	+0.359	0.02	143	20.8
23.0	+0.221	0.02	39	21.8
22.5	+0.083	0.15	39	28.9
22.0	−0.055	0.09	35	39.2
21.5	−0.193	0.06	81	26.9
21.0	−0.331	0.17	114	18.8
20.5	−0.469	0.28	138	15.2
20.0	−0.607	0.27	138	13.5
19.5	−0.745	0.25	146	11.5
19.0	−0.883	0.22	154	10.0
18.5	−1.021	0.27	148	9.3
18.0	−1.159	0.33	137	8.5
17.5	−1.297	0.20	126	7.5
17.0	−1.435	0.21	128	7.1
16.5	−1.573	0.16	131	5.0

$A = 13$ $x = +0'.800$

D	y	P	q	I
29.5	+2.015	0.26	76	7.4
29.0	+1.877	0.24	75	10.7
28.5	+1.739	0.14	68	14.7
28.0	+1.601	0.13	42	19.2
27.5	+1.463	0.10	12	26.5

TABLE I (*continued*)

D	*y*	*P*	*q*	*I*
A = 13				*x* = + 0′.800
27.0	+1′.325	0.10	157	36.4
26.5	+1.187	0.18	155	40.8
26.0	+1.049	0.31	151	40.0
25.5	+0.911	0.39	144	38.5
25.0	+0.773	0.30	143	38.4
24.5	+0.635	0.15	151	36.7
24.0	+0.497	0.07	157	31.3
23.5	+0.359	0.12	27	29.2
23.0	+0.221	0.08	21	32.8
22.5	+0.083	0.04	82	37.8
22.0	−0.055	0.14	89	40.6
21.5	−0.193	0.20	91	40.3
21.0	−0.331	0.22	104	35.0
20.5	−0.469	0.09	129	26.2
20.0	−0.607	0.28	163	21.5
19.5	−0.745	0.36	172	17.4
19.0	−0.883	0.35	175	13.6
18.5	−1.021	0.21	176	11.8
18.0	−1.159	0.04	25	9.8
17.5	−1.297	0.12	37	7.7
17.0	−1.435	0.10	145	5.8
A = 14				*x* = + 0′.524
29.5	+2′.015	—	—	4.3
29.0	+1.877	—	—	7.2
28.5	+1.739	0.20	110	11.4
28.0	+1.601	0.05	24	19.0
27.5	+1.463	0.04	22	26.2
27.0	+1.325	0.10	144	32.2
26.5	+1.187	0.23	144	38.1
26.0	+1.049	0.34	152	43.8
25.5	+0.911	0.21	170	42.1
25.0	+0.773	0.26	167	41.9
24.5	+0.635	0.23	176	43.8
24.0	+0.497	0.22	178	44.8
23.5	+0.359	0.23	174	43.3
23.0	+0.221	0.24	174	44.2
22.5	+0.083	0.15	170	46.8
22.0	−0.055	0.11	150	46.8
21.5	−0.193	0.14	122	44.9
21.0	−0.331	0.15	117	42.8
20.5	−0.469	0.17	142	39.6
20.0	−0.607	0.33	165	31.8
19.5	−0.745	0.35	176	26.1
19.0	−0.883	0.40	11	20.8
18.5	−1.021	0.40	20	15.5
18.0	−1.159	0.34	29	12.1
17.5	−1.297	0.23	30	9.5
17.0	−1.435	0.06	8	6.8
16.5	−1.573	0.06	0	5.0
A = 15				*x* = + 0′.248
29.0	+1′.877	0.16	94	5.2
28.5	+1.739	0.16	112	7.0
28.0	+1.601	0.11	101	11.5
27.5	+1.463	0.14	77	16.4
27.0	+1.325	0.11	72	19.7
26.5	+1.187	0.11	137	26.4
26.0	+1.049	0.18	150	35.0
25.5	+0.911	0.21	160	41.6
A = 15				*x* = + 0′.248
25.0	+0′.773	0.19	162	46.2
24.5	+0.635	0.25	176	49.1
24.0	+0.497	0.30	164	53.7
23.5	+0.359	0.28	159	58.3
23.0	+0.221	0.22	144	62.6
22.5	+0.083	0.20	136	61.7
22.0	−0.055	0.17	134	55.0
21.5	−0.193	0.19	135	45.2
21.0	−0.331	0.29	147	42.9
20.5	−0.496	0.38	154	44.7
20.0	−0.607	0.37	159	39.8
19.5	−0.745	0.35	165	31.6
19.0	−0.883	0.30	169	25.3
18.5	−1.021	0.22	177	20.5
18.0	−1.159	0.17	5	14.1
17.5	−1.297	0.25	159	9.8
17.0	−1.435	—	—	7.2
16.5	−1.573	—	—	5.2
A = 16				*x* = − 0′.028
29.5	+2′.015	—	—	2.4
29.0	+1.877	—	—	2.4
28.5	+1.739	—	—	3.2
28.0	+1.601	0.20	89	7.5
27.5	+1.463	0.18	83	11.1
27.0	+1.325	0.05	11	15.1
26.5	+1.187	0.11	175	20.9
26.0	+1.049	0.16	6	30.0
25.5	+0.911	0.14	8	36.2
25.0	+0.773	0.18	5	39.5
24.5	+0.635	0.28	171	46.9
24.0	+0.497	0.32	162	51.8
23.5	+0.359	0.34	159	54.6
23.0	+0.221	0.22	154	47.5
22.5	+0.083	0.18	139	49.6
22.0	−0.055	0.20	141	49.9
21.5	−0.193	0.18	138	45.5
21.0	−0.331	0.22	147	47.5
20.5	−0.469	0.29	151	47.0
20.0	−0.607	0.31	156	40.2
19.5	−0.745	0.27	159	33.6
19.0	−0.883	0.30	166	27.3
18.5	−1.021	0.30	155	18.0
18.0	−1.159	0.30	152	11.2
17.5	−1.297	0.25	145	8.6
17.0	−1.435	0.24	131	5.2
A = 17				*x* = − 0′.304
29.5	+2′.015	—	—	2.4
29.0	+1.877	—	—	3.9
28.5	+1.739	0.09	27	12.5
28.0	+1.601	0.05	131	13.8
27.5	+1.463	0.21	133	8.3
27.0	+1.325	0.10	175	13.4
26.5	+1.187	0.08	5	22.8
26.0	+1.049	0.05	15	20.6
25.5	+0.911	0.15	27	24.8
25.0	+0.773	0.15	14	31.4
24.5	+0.635	0.24	0	40.5
24.0	+0.497	0.20	3	43.5
23.5	+0.359	0.15	171	42.2

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TABLE 1 (*continued*)

D	*y*	*P*	*q*	*I*
A = 17				*x* = − 0′.304
23.0	+0′.221	0.08	149	39.4
22.5	+0.083	0.05	146	38.8
22.0	−0.055	0.03	157	38.9
21.5	−0.193	0.08	155	38.4
21.0	−0.331	0.18	161	38.7
20.5	−0.469	0.27	164	37.7
20.0	−0.607	0.31	155	35.4
19.5	−0.745	0.34	153	36.9
19.0	−0.883	0.44	152	36.7
18.5	−1.021	0.24	153	22.0
18.0	−1.159	0.10	137	13.8
17.5	−1.297	0.06	37	11.2
17.0	−1.435	0.12	85	7.9

D	*y*	*P*	*q*	*I*
A = 18				*x* = − 0′.580
28.5	+1′.739	0.05	169	3.4
28.0	+1.601	0.06	164	4.6
27.5	+1.463	0.10	154	6.1
27.0	+1.325	0.10	0	18.7
26.5	+1.187	0.02	97	32.9
26.0	+1.049	0.11	0	31.1
25.5	+0.911	0.12	27	18.9
25.0	+0.773	0.07	14	20.8
24.5	+0.635	0.12	5	23.5
24.0	+0.497	0.02	107	26.9
23.5	+0.359	0.19	104	29.4
23.0	+0.221	0.26	106	30.6
22.5	+0.083	0.22	106	30.5
22.0	−0.055	0.17	96	28.0
21.5	−0.193	0.07	78	25.8
21.0	−0.331	0.02	161	26.6
20.5	−0.469	0.14	156	28.4
20.0	−0.607	0.26	151	28.5
19.5	−0.745	0.38	160	30.1
19.0	−0.883	0.34	165	31.8
18.5	−1.021	0.21	0	23.5
18.0	−1.159	0.15	11	14.8
17.5	−1.297	0.08	82	8.6
17.0	−1.435	0.01	0	6.1
16.5	−1.573	—	—	4.9

D	*y*	*P*	*q*	*I*
A = 19				*x* = − 0′.856
28.5	+1′.739	—	—	3.0
28.0	+1.601	—	—	4.2
27.5	+1.463	0.10	135	4.2
27.0	+1.325	0.12	62	6.7
26.5	+1.187	0.09	148	8.5
26.0	+1.049	0.11	155	9.9
25.5	+0.911	0.25	4	13.9
25.0	+0.773	0.18	176	16.0
24.5	+0.635	0.11	138	18.9
24.0	+0.497	0.21	139	19.9
23.5	+0.359	0.35	132	23.5
23.0	+0.221	0.31	125	24.8
22.5	+0.083	0.27	105	22.9
22.0	−0.055	0.24	79	19.7
21.5	−0.193	0.20	49	21.6
21.0	−0.331	0.17	29	19.4
20.5	−0.469	0.16	13	17.7
20.0	−0.607	0.25	157	18.3
19.5	−0.745	0.25	159	18.3
19.0	−0.883	0.25	172	17.0
18.5	−1′.021	0.26	177	14.2
18.0	−1.159	0.14	174	11.2
17.5	−1.297	0.16	167	7.9
17.0	−1.435	0.21	119	6.0
16.5	−1.573	0.26	127	5.9

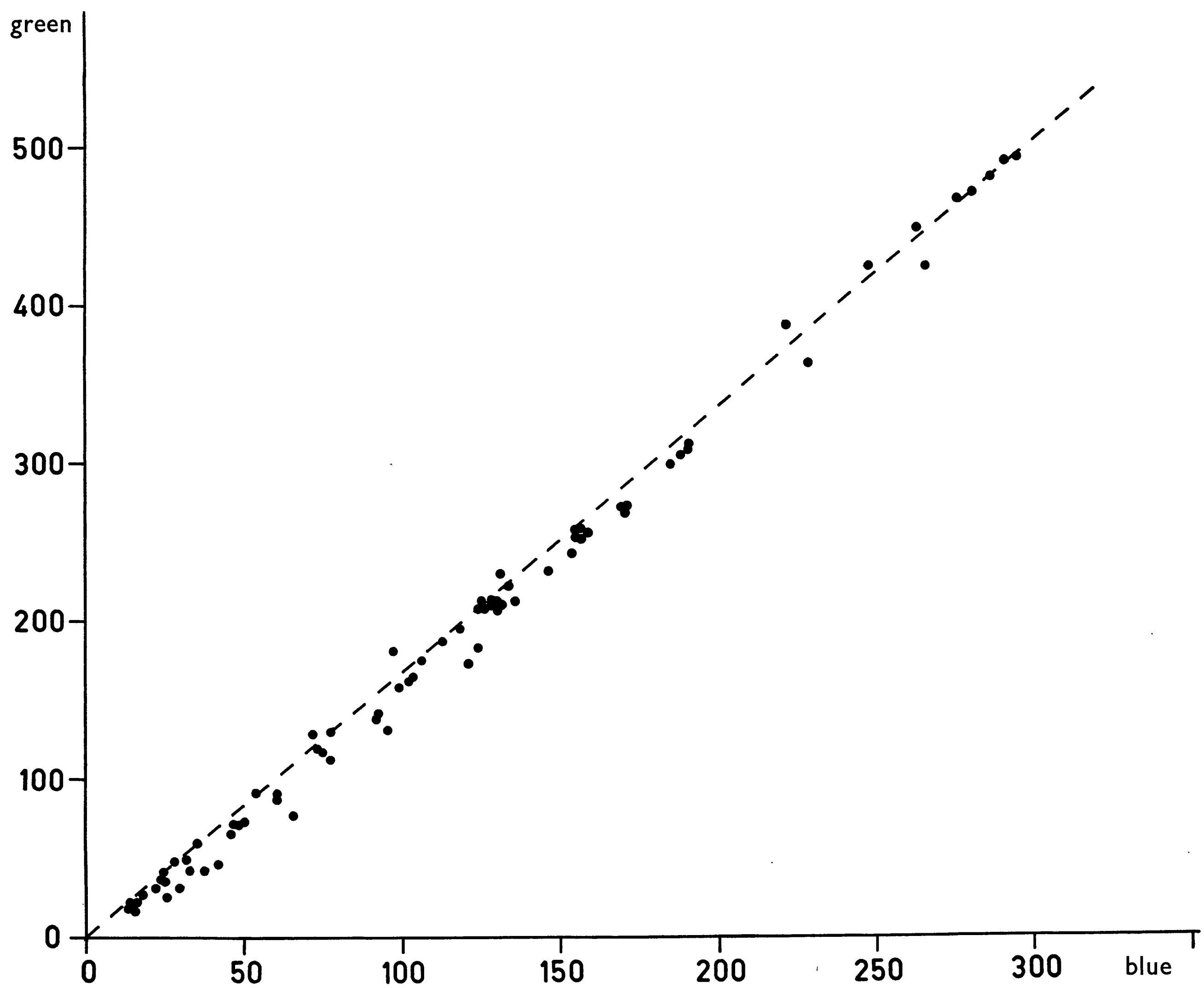
D	*y*	*P*	*q*	*I*
A = 20				*x* = − 1′.132
28.0	+1′.601	0.19	120	2.6
27.5	+1.463	0.16	90	3.4
27.0	+1.325	0.18	82	4.1
26.5	+1.187	0.11	161	5.3
26.0	+1.049	0.03	39	7.2
25.5	+0.911	0.02	122	8.8
25.0	+0.773	0.04	101	10.7
24.5	+0.635	0.12	123	12.4
24.0	+0.497	0.27	130	14.2
23.5	+0.359	0.32	145	12.7
23.0	+0.221	0.21	152	10.7
22.5	+0.083	0.13	138	9.7
22.0	−0.055	0.10	37	8.4
21.5	−0.193	0.38	21	8.5
21.0	−0.331	0.20	22	11.2
20.5	−0.469	0.24	4	13.2
20.0	−0.607	0.21	173	14.5
19.5	−0.745	0.19	168	17.4
19.0	−0.883	0.22	145	22.9
18.5	−1.021	0.32	152	20.5
18.0	−1.159	0.33	154	14.6
17.5	−1.297	0.40	151	10.3
17.0	−1.435	0.24	136	7.5
16.5	−1.573	0.15	126	8.6
16.0	−1.711	0.10	123	10.0

D	*y*	*P*	*q*	*I*
A = 21				*x* = − 1′.408
28.0	+1′.601	—	—	1.7
27.5	+1.463	0.19	101	3.1
27.0	+1.325	0.14	120	4.6
26.5	+1.187	0.04	45	6.0
26.0	+1.049	0.14	59	11.4
25.5	+0.911	0.09	152	14.1
25.0	+0.773	0.15	138	9.2
24.5	+0.635	0.26	141	8.6
24.0	+0.497	0.27	136	8.1
23.5	+0.359	0.20	147	7.3
23.0	+0.221	0.09	137	8.1
22.5	+0.083	0.07	107	8.8
22.0	−0.055	0.19	142	8.1
21.5	−0.193	0.19	158	7.4
21.0	−0.331	0.24	5	8.8
20.5	−0.469	0.24	156	12.6
20.0	−0.607	0.20	147	14.3
19.5	−0.745	0.21	139	16.9
19.0	−0.883	0.21	137	18.0
18.5	−1.021	0.27	149	16.1
18.0	−1.159	0.34	154	13.1
17.5	−1.297	0.27	168	10.3
17.0	−1.435	0.21	162	8.0
16.5	−1.573	0.14	162	5.4
16.0	−1.711	0.01	45	3.3

TABLE 1 (*continued*)

D	*y*	*P*	*q*	*I*	*D*	*y*	*P*	*q*	*I*
A = 22				*x* = − 1′.684	*A* = 22				*x* = − 1′.684
26.0	+1′.049	0.11	135	3.4	20.5	−0′.469	0.11	124	13.7
25.5	+0.911	0.12	117	5.2	20.0	−0.607	0.10	129	15.1
25.0	+0.773	0.10	172	5.7	19.5	−0.745	0.13	126	15.8
24.5	+0.635	0.13	52	5.7	19.0	−0.883	0.15	137	16.7
24.0	+0.497	0.10	27	6.0	18.5	−1.021	0.10	175	13.2
23.5	+0.359	0.07	135	8.6	18.0	−1.159	0.16	174	10.9
23.0	+0.221	0.00	—	9.3	17.5	−1.297	0.12	156	8.0
22.5	+0.083	0.10	58	6.5	17.0	−1.435	0.17	166	4.6
22.0	−0.055	0.15	56	5.4	16.5	−1.573	0.26	49	4.0
21.5	−0.193	0.02	162	6.1	16.0	−1.711	0.30	65	4.4
21.0	−0.331	0.08	135	10.3					

FIGURE 1



Comparison of the intensities observed with blue and green filters

TABLE 2

Intensities observed with green filter

D	y \ A, x	24.5 − 2′.374	21.5 − 1′.546	18.5 − 0′.718	15.5 + 0′.110	12.5 + 0′.938	9.5 + 1′.776	6.5 + 2′.594
34	3′.45	0	0	56	1	0	0	0
	3.31	4	0	47	1	0	0	0
33	3.17	2	0	22	2	0	0	0
	3.03	0	0	12	16	0	0	3
32	2.90	0	0	4	44	0	2	2
	2.76	0	0	2	52	2	4	1
31	2.61	0	0	1	56	5	7	1
	2.47	0	0	1	59	12	10	2
30	2.35	1	0	0	61	23	15	4
	2.21	1	0	1	48	42	23	5
29	2.07	1	0	5	20	63	32	6
	1.93	1	0	10	25	93	41	15
28	1.79	1	0	16	42	130	59	30
	1.66	0	1	27	73	182	80	40
27	1.52	0	8	51	120	231	100	45
	1.38	0	16	71	163	273	113	42
26	1.24	0	23	92	209	—	117	41
	1.10	0	30	117	274	—	120	31
25	0.87	0	40	141	313	—	121	21
	0.73	1	44	162	367	301	122	19
24	0.69	3	46	176	427	273	117	20
	0.55	6	44	196	475	258	104	18
23	0.41	9	41	214	495	255	86	14
	0.28	9	40	213	496	260	66	12
22	0.14	9	38	211	485	—	54	10
	0	10	38	213	470	255	46	7
21	−0.14	17	48	208	451	245	39	3
	−0.28	24	70	207	427	233	33	3
20	−0.41	31	98	212	391	212	30	2
	−0.55	36	119	222	351	173	25	3
19	−0.69	41	136	226	308	139	24	4
	−0.73	42	137	211	259	112	24	6
18	−0.87	40	129	189	185	89	25	19
	−1.10	35	115	158	131	66	25	27
17	−1.24	26	99	130	79	50	22	29
	−1.38	17	71	71	49	39	17	30
16	−1.52	10	49	43	32	23	12	31
	−1.66	5	35	32	36	12	8	24
15	−1.79	1	24	18	47	9	5	8
	−1.93	0	13	14	42	13	3	1
14	−2.07	0	8	14	30	14	2	1
	−2.21	2	6	6	17	30	1	17
13	−2.35	3	5	3	8	30	1	31
	−2.47	4	0	4	1	29	0	41
12	−2.61	5	0	4	0	22	0	0

In Figure 2 the intensity in green light of the Crab nebula is plotted against that in blue. The rather large scatter can be explained as due to the combined effect of guiding errors of about 1″, thin clouds, and the superposition of stars and gaseous filaments with different colours. Nevertheless it is clear that the weak outer parts of the nebula are bluer than the central part. This effect is most probably due to the gaseous filaments surrounding the amorphous nebula. Although the blue filter excludes the strong line λ 3727 and the green nebular lines, it transmits several of the weaker lines of the spectrum of the filaments, whereas the spectral region transmitted by the green filter is practically free from such lines. As can be seen in the direct photographs by BAADE [1]), the filaments are relatively more important in the outer parts of the nebula.

The colour index, relative to the comparison star, of the brightest regions of the nebula, found from the slope of the line shown in Figure 2, is 0.57. According to

[1]) *B.A.N.* **12**, 312 (No. 462), 1956.

TABLE 3
Intensities observed with blue filter

D	y \ A, x	24.5 $-2'.374$	21.5 $-1'.546$	18.5 $-0'.718$	15.5 $+0'.110$	12.5 $+0'.938$	9.5 $+1'.766$	6.5 $+2'.595$
34	3'.34	0	0	0	0	0	2	0
	3.20	0	0	0	1	0	0	0
33	3.06	0	0	0	10	0	0	0
	2.92	0	0	0	22	0	−1	0
32	2.79	0	0	0	25	1	0	0
	2.65	0	0	0	30	4	4	2
31	2.51	0	0	1	33	9	9	3
	2.37	0	0	3	29	16	12	4
30	2.24	0	0	4	17	25	17	5
	2.10	0	0	5	14	36	26	9
29	1.96	0	0	8	26	55	38	16
	1.82	0	1	12	39	78	50	18
28	1.68	0	2	19	50	97	61	18
	1.54	0	6	29	73	131	70	20
27	1.41	0	12	48	102	169	76	23
	1.27	0	20	62	126	192	78	22
26	1.13	0	26	75	170	199	80	17
	0.99	1	31	92	190	196	81	15
25	0.86	2	34	102	228	184	81	14
	0.72	5	36	106	265	170	77	13
24	0.58	6	35	118	280	158	68	12
	0.44	8	31	128	290	154	58	7
23	0.30	9	29	130	294	155	49	5
	0.16	10	28	128	286	156	40	3
22	0.03	12	31	125	275	156	31	3
	−0.11	16	38	124	262	153	27	3
21	−0.25	20	47	130	248	146	25	5
	−0.39	24	57	132	220	136	23	8:
20	−0.52	29	69	134	—	121	23	8:
	−0.66	32	78	133	188	92	23	7:
19	−0.80	34	82	127	154	78	21	8:
	−0.94	31	79	113	124	61	18	15
18	−1.08	24	73	99	95	47	15	18
	−1.21	17	56	72	66	32	14	17
17	−1.35	14	42	49	43	25	13	17
	−1.49	9	26	34	31	15	10	18
16	−1.63	5	16	23	26	7	7	11
	−1.77	2	11	16	27	5	6	6
15	−1.90	1	8	12	28	4	2	0
	−2.04	0	7	9	22	10	1	0
14	−2.18	2	6	6	11	11	1	0
	−2.32	2	3	4	2	11	0	0
13	−2.46	2	1	2	0	11	1	0
	−2.59	2	0	0	0	8	0	0
12	−2.73	2	0	0	0	2	0	0

Table 4 the colour index of the comparison star is 0.25; consequently the colour index of the continuous radiation of the nebula is 0.82, which corresponds in JOHNSON and MORGAN's calibration to a spectral type K0.

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