Citation:

W.H. Julius, The total solar radiation during the annular eclipse on April 17th 1912, in:
KNAW, Proceedings, 15 II, 1912-1913, Amsterdam, 1913, pp. 1451-1463

Astronomy. — *"The total solar radiation during the annular eclipse on April* 17th 1912. By Prof. W. H. JULIUS.

Scheme of the investigation.

The annular eclipse of the sun on April 17th, 1912, offered a rare opportunity for investigating the total amount of radiation due to the entire "solar atmosphere" i.e. to the complex of layers of the sun lying outside the level, generally indicated as surface of the photosphere.

Every part of the solar atmosphere emits some proper radiation and scatters some photospheric light, and it is only natural to suppose that the lowest layers bear the greatest share in that radiation and scattering. Now, at a total eclipse the base of the atmosphere is always wholly or partly screened by the moon; whereas during the annular phase of the eclipse of April 1912 even the lowest strata of the atmosphere all round the disk contributed to the remaining radiation. From the minimum value through which the remaining radiation passes at the instant of centrality one must be able to calculate an upper limit, which the radiation, emitted and scattered by the entire solar atmosphere, certainly does not exceed.

Since a reliable determination of such an upper limit would afford an important criterion for testing fundamental ideas regarding the nature of the photosphere, the principal aim kept in view in devising our actinometric apparatus was, that the minimum of the radiation curve should come out as sharply and definitely as possible.

On former occasions (during the eclipses of 1901 in Karang Sago, Sumatra and of 1905 near Burgos) we measured the march of the total radiation by means of a thermopile directly exposed to the sun's rays, without making use of any lenses or mirrors to concentrate the beam. If circumstances had then allowed us to find the true shape of the radiation curve, if would have been possible to calculate from those data trustworthy values for the radiating power of successive concentric zones of the solar disk. [1]) Unfortunately the weather did not favour the Sumatra and Burgos observations; so we desired to make similar observations again. The apparatus had proved satisfactory, and sensitive enough to give measurable indications of heat even during totality; for at Burgos a break in the clouds had permitted us to state that at mid eclipse the unscreened part of the

[1]) W. H. JULIUS. A new method for determining the rate of decrease of the radiating power from the center toward the limb of the solar disk. Proc. Roy. Acad. Amst. 8, 668, 1905; Astroph. Journal 23, 312, 1906.

corona radiated less than $^1/_{200000}$ of the output of the uneclipsed sun or $^2/_5$ of that of the full moon. [1])

For observing the radiation during the annular eclipse we therefore decided to follow substantially the same plan, though with some alterations in the apparatus. This time the minimum would not be so low. From a close discussion of the Burgos results we presumed it to lie somewhere between $^1/_{10000}$ and $^1/_{1000}$. So the galvanometer could be taken less sensitive, but, on the other hand, the steadiness of the zero could be improved and the period of oscillation shortened.

Quickness of indication was, indeed, a very important condition, which not only the galvanometer but also the recipient of the radiation had to satisfy, if the minimum were to be observed exactly.

At the observing station near Maastricht [2]), selected by the Eclipse Commission of the Royal Academy of Amsterdam, the annular phase of the eclipse was expected to last less than one second. [3]) Our thermopile, used in Sumatra and Burgos, required 10 seconds for reaching a stationary temperature after being suddenly exposed to a constant source of radiation, and therefore would be too slow to catch the minimum, although quick enough to give the greater part of the radiation curve with sufficient accuracy.

Description of apparatus.

We determined on arranging two separate equipments: a rapidly working one, and a slower one, both suited for measuring the intensity of radiation from the first until the fourth contact, but in some respects complementing each other. The slower set of apparatus consisted of a *thermopile* (the same as used before), a moving-coil galvanometer of SIEMENS and HALSKE with accessories, and suitable resistances. The thermopile was very carefully protected against all disturbing influences; it reacted only upon the radiation that passed through a long tube fitted with diaphragms and mounted parallactically, so as to be easily kept pointing towards the sun by means of a finding arrangement [4]). We had ascertained by a special

1) Proc. Roy. Acad. Amst. Vol. **8**, p. 503, 1905.

2) A preliminary account of the observations made by the Netherlands Expedition on April 17th 1912 is to be found in Proc. Roy. Acad. Amst. Vol. **14**, p. 1195 (1912). Cf also: NYLAND, "De eklips van 17 April 1912", Hemel en Dampkring **10**, 1, May 1912.

3) According to J. WEEDER, Proc. Roy. Acad Amst. **14**, 947, 1912.

4) A description of the instrument is given in: Total Eclipse of the Sun, May 18, 1901; Reports on the Dutch Expedition to Karang Sago, Sumatra, N^o^. 4, "Heat Radiation of the Sun during the Eclipse", by W. H. JULIUS (1905).

inquiry, that for temperature differences between the solderings not greater than those produced by full sunshine, the electromotive force of the thermopile could be considered strictly proportional to the intensity of irradiation. The deflections of the SIEMENS and HALSKE galvanometer were observed visually, by examining the positions of a bright index on a transparent scale. With a permanent shunt of 16 Ohms the instrument was just dead-beat; one millimeter deflection then corresponded to 10^{-8} Amp. The deflections were proportional to the current. The observer had the resistance box close at hand, in order to keep the image on the scale, and marked the epoch of each reading by means of a doublehanded chronometer, one hand of which could be stopped and made to catch up again (a "chronographe rattrapante"). Many readings were also made, in the course of the eclipse, with the thermopile screened; the zero proved very satisfactorily constant.

Our second actinometric set was especially intended to answer rapidly and to give a photographic record of the middle part of the radiation curve. It included a *bolometer* and a galvanometer with a moving coil of extremely small moment of inertia. Both instruments have been designed and constructed by Dr. W. J. H. MOLL, who also was in charge of this equipment on eclipse day. The bolometer consisted of many strips of very thin platinum (Wollaston sheet) coated with lampblack, and mounted so as to form two equal gratings, one of which received the radiation. A thick copper frame warranted quick equalization of temperature of all screened parts, while an envelope of non-conducting material protected it against rapid external changes. The whole was fastened to the end of a tube with diaphragms, which was directed toward the sun by an assistant.

As will appear from the photographic records, the galvanometer answered the purpose admirably (time of dead-beat swing less than one second; deflection 4 mm. for 1 microvolt; zero steady within 0.1 millimeter); but the instrument being only a temporary one, adapted to the requirements of this eclipse and not yet to general use, Dr. MOLL, who has since been improving the pattern, desires to publish full particulars at a later date.

In order to obtain reasonable bridge-currents within the very wide range of sensitivity imposed by the phenomenon, the observer varied the resistance of the principal bolometer circuit by steps, as the eclipse proceeded, and each time read the strength of the main current on a milliammeter; the resistance in the bridge being left unaltered. That the zero reading of the sensitive galvanometer was very little influenced thereby, was a proof of the symmetry of the arrangement.

Observations made with the bolometer.

During the greater part of the eclipse the galvanometer deflections were only visually observed, by noticing the motion of the reflected image of a slit on a transparent scale; but from 5 minutes before until 5 minutes after centrality the image was received on a photographic recording drum.

For a reproduction of the photogram we must refer to the *Astrophysical Journal* **37**, p. 229, Plate X, Fig. 1. On the same plate, Fig. 2 shows the central part of the curve on a larger scale [1]), and Fig. 3 gives on the same scale a control of the volt-sensitivity of the galvanometer, effected immediately after the eclipse was over. It shows well the qualities of the instrument.

The vertical lines are time-signals, produced by a small electric lamp flashing up at intervals of ten seconds in front of the slit of the recording apparatus; the first line following the minimum of the curve corresponds to $0^h34^m57^s$ Leiden M. T.

Two of the zero-readings, obtained by screening the bolometer, are visible on the curve (Fig. 1), one at 0^h30^m, another at 0^h37^m. A straight line joining them may quite safely be taken to represent the zero during the interval. The ordinate of the minimum thus comes out to be a quarter of a millimeter. At 11^h30^m (6 minutes after first contact) a deflection of 6.1 mm. [2]) was observed visually, the intensity of the main current at that time being $^1/_{195}$ of its value at the time of recording. Reduced to the latter value of the main current, the deflection corresponding to full sunshine would have been more than $195 \times 6.1 = 1190$ mm., or nearly 5000 times the deflection at minimum.

A few irregularities in the curve, especially at $0^h31^m20^s$ and at $0^h36^m40^s$, require explanation. They are not genuine, but simply due to an excusable negligence of the assistant who had to point the bolometer at the sun. The emotions of the event making him forget to keep the tube continuously in the right direction, he had twice suddenly to make up for the loss. Fortunately the minimum is unaffected.

Discussion of the bolometer results.

If the apparatus had followed the radiation instantaneously, the minimum would have been lower yet. We may therefore certainly

[1]) The striped aspect of the curve is connected with the click of the recording apparatus.

[2]) As a basis for calculation we purposely select this *small* deflection, because the great deflections of the provisory galvanometer were not strictly proportional to the current.

conclude from these observations, that at the central phase of the annular eclipse the solar radiation fell below $^1/_{5000}$ of its ordinary value.

This remainder must in part be due to the unscreened ring of the disk. Assuming the apparent surface of that photospheric ring to be $^1/_{2500}$ of the surface of the disk (which certainly is a low estimate), and its apparent radiating power per unit of disk-surface to be $^1/_4$ of the average intrinsic radiating power of the disk, we may say that at the epoch of centrality the photosphere was still able to furnish us with at least $^1/_{10000}$ of the ordinary amount of radiation.

Consequently, less — and probably *much* less — than $^1/_{10000}$ of the sun's total radiation toward the earth is left as proceeding from the annular part of the *solar atmosphere* visible round the moon's edge.

So far, the inference is pretty sure, because it depends on the outcome of direct observations only.

What we want to deduce next, however, is an estimate of the radiation due to the entire solar atmosphere — or rather to the visible half of it. This we cannot do without making some simplyfying assumptions concerning the absolutely unknown conditions prevailing in the sun.

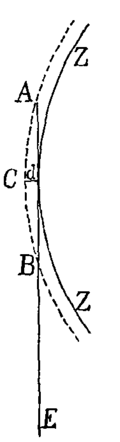

Fig. 1.

Let ZZ (fig. 1) be the photosphere (with radius r), ABE the direction toward the earth. If the radiating and scattering power of the solar atmosphere were distributed homogeneously through its whole depth d, the emission due to the hemispherical shell would bear approximately the same ratio to the atmospheric emission observed at mid-eclipse, that the volume of the hemispherical shell $(2\pi r^2 . d)$ bears to the volume of the ring produced by the rotation of the segment ABC about the sun's diameter, which is parallel to AB, ($2\pi r$-segm. ABC).

That proportion is

$$p = \frac{rd}{\text{segment } ABC}.$$

For small values of d the surface of the segment is nearly $^2/_3\, d . AB$, and the ratio becomes

$$p = {}^3/_2 \frac{r}{AB}.$$

Suppose we may replace the actual heterogeneous atmosphere by an ideal homogeneous one for which $d = 2000$ kilometers ($= {}^1/_{350}$ of the sun's radius). The corresponding value of AB is about $0{,}15\,r$, giving for the ratio

$$p = {}^3/_2 \frac{r}{0\,15 r} \doteq 10.$$

Our conclusion therefore is, that less than $^1/_{1000}$ of the sun's total radiation is emitted or scattered by parts of the celestial body lying outside the photospheric surface.

Even though we are free to admit an uncertainty of several hundreds percent in some of the estimates on which the above calculation is based, our result yet makes it impossible to maintain the current ideas on the nature of the photosphere.

Most solar theories, indeed, consider the photosphere to be a layer of incandescent clouds, whose decrease of luminosity from the centre toward the limb of the solar disk would be caused by absorption and scattering of light in an enveloping atmosphere ("the dusky veil"). According to calculations made by PICKERING, WILSON, SCHUSTER, VOGEL, v. SEELIGER, and others, such an atmosphere should intercept an important fraction ($^3/_4$ to $^1/_3$) of the photospheric radiation. The atmosphere is of course in a stationary condition ; receipts and expenses must balance each other. Now, what would become of that immense quantity of absorbed energy, of which only something of the order of magnitude $^1/_{1000}$ is emitted and scattered ? So long as we have no evidence of any other form of solar output, especially proceeding from the atmospheric layers, and comparable in magnitude with the sun's total radiation, we are forced to reject the cloud-theory of the photosphere.

The radial variation of the brightness of the disk depends on the nature of the photosphere itself, not of its envelope. A new interpretation of the photosphere, agreeing with this result, will be proposed in a subsequent paper.

Observations made with the thermopile.

We now proceed to the discussion of the observations made for finding the shape of the entire radiation curve. In this part of the work our thermopile arrangement had the advantage of the bolometric apparatus in point of proportionality, within wide limits, between radiation and galvanometer deflection.

The total resistance of the thermopile circuit had to be varied in a few steps from 1300 for full sunshine to 100 for the central quarter of an hour, and back again. Table I contains the deflections

TABLE I.

Leiden mean time	Intensity of radiation	Leiden mean time	Intensity of radiation	Leiden mean time	Intensity of radiation
23h12m23s	4960	0h21m23s	849	0h44m54s	612
13 52	(1ste contact)	23 42	680	46 37	733
15 35	4950	25 3	593	47 36	805
23 5	4725	28 1.4	410	48 37	872
25 16	4625	28 34.6	375	49 43	945
28 2	4460	29 10.4	335	50 22	993
29 40	4360	30 50.6	224	50 56	1034
31 28	4280	31 28.4	183	54 2	1222
37 15	3950	31 57.0	153	55 16	1313
38 52	3880	32 27.2	122	55 58	1386
40 27	3765	33 5.8	87	56 53	1453
46 23	3355	33 28.0	66.5	57 50	1550
48 31	3170	33 52.6	46	58 55	1640
50 20	3150	34 23.4	21	59 57	1738
51 43	3075	(minimum)	2.5	1 1 8	1839
0 3 36	2213	35 16.2	20	3 16	1962
5 8	2075	35 52.0	50	4 17	2010
6 41	1954	36 14.6	70	5 38	2095
8 7	1828	36 36.6	89	6 50	2190
9 45	1685	37 9.2	119	7 49	2325
11 38	1551	37 40.8	149	9 9	2382
13 39	1438	38 10.0	178	38 40	4340
14 53	1342	38 29.7	198	40 40	4380
16 52	1203	39 7.2	238	42 10	4425
17 49	1107	39 43.8	277	44 40	4520
18 38	1054	40 16.8	317	46 10	4600
19 28	978	40 50.6	356	52 10	4590
20 8	925	43 56	545	54 10	4660

all reduced to the lowest value of the resistance, and reckoned from zero-positions that were found by interpolation between a series of zero-readings, made in the course of the eclipse with the thermopile shaded. The shift of the zero was small and regular.

Plate XI[1]) Fig. 1, is a reduced copy of the original mapping of the Table I. The deflections observed between $0^h28^m10^s$ and $0^h41^m30^s$, plotted on a ten times larger scale, are shown on Plate XI, Fig. 2. These latter observations give evidence of the exceptionally favourable condition of the sky especially during the middle part of the eclipse. When uniting the observational points by a curve, I was quite surprised to find it so perfectly smooth and symmetrical, for in our country a sky without even invisible haze is a rare occurrence.

The central part of this curve corroborates our conclusion drawn from the photographic curve, viz. that the minimum value of the radiation was $^1/_{5000}$ of the maximum. Indeed, the real minimum value could not be reached by the slow apparatus; but if we prolong the lower parts of the falling and the rising branch of the curve downward as nearly straight lines (beginning at points corresponding to 10 seconds before and 10 seconds after centrality), they meet at *one* millimeter above zero, and according to Plate XI Fig. 1, the maximum was represented by about 5000 millimeters.

The rest of the observations ran somewhat less regularly, both in the falling and in the rising phase of the radiation. From notes on sky-condition, made by other members of the party, we could afterwards state that the depressions in the series of points exactly corresponded to hazy cloudlets passing before the sun. Yet some arbitrariness was left in the process of tracing the radiation-curve so as to answer to an ideally constant degree of transparency of the sky. We simply made the curve pass through the *highest* points (because the observed values could only be too small), and for the rest took care that the curvature should vary as regularly as possible.

Special attention may be drawn to the points B (Plate XI Fig. 1), marked by small circlets. They are deduced from the Burgos observations of 1905[2]) in the following way.

In the course of that eclipse the sun shone sometimes for a few minutes in a beautifully clear patch of sky between heavy clouds, and happened to do so during the phases in which the radiation passed through one-half of its maximum value. The exact epochs at which the intensity was $\frac{1794000}{2} = 897000$ occurred 33^m38^s before second

[1]) Cf. *Astrophysical Journal*, **37**, p. 232, 1913.

[2]) *Astrophysical Journal* Vol. **23** p. 312, 1906.

contact and 33m43s after third contact; so, on the average, $33^2/_8$ minutes were required for the moon to cover the second effective half of the solar disk.

Now, at Burgos the moon's edge took $77^3/_4$ minutes to cross the whole solar disk; at Maastricht, in 1912, it took $80^3/_4$ minutes. If, therefore, the ratio of the radius of the moon's disk to the radius of the sun's disk had been the same in both cases, then the time necessary for covering the second effective half of the solar disk would have been, at Maastricht, $33^2/_8 \times \frac{80^3/_4}{77^3/_4}$ = very nearly 35 minutes.

But at Maastricht the moon's radius was practically equal to the sun's radius, whereas at Burgos the radii were in the proportion 132,8:126,8. This difference between the two cases implies that the interval of 35 minutes, calculated for Maastricht, is a little too great. Indeed, when drawing circles representing the sun and the moon in the right proportion and position, and taking the distribution of brightness on the disk into consideration, one easily concludes that the interval has to be taken about 25 seconds smaller say $34^1/_2$ minutes.

Consequently, the results obtained in 1905 required that in 1912, at the epochs $0^h0^m20^s$ and $1^h9^m20^s$ (i.e. $34^1/_2$ minutes before and after centrality), the radiation should have shown half its maximum intensity, or $\frac{4960}{2} = 2480$ scale divisions. This is indicated by the points *B*. The agreement with the actual observations of 1912 is indeed very satisfactory.

During the middle phase of the Burgos eclipse the conditions were, on the contrary, so unfavourable, that the central part of the radiation curve, there obtained, claims no confidence.

It was worth while, therefore, to found on our present eclipse-curve a renewed application of the method, formerly devised [1]), of determining the rate of decrease of the radiating power from the centre toward the limb of the solar disk.

Discussion of the thermopile results.

On a homogeneous piece of paper a circle of 40 centimeters in diameter, representing the sun, was drawn, and divided in the manner shown by the adjoined figure [2]). There are concentric zones,

1) *Astrophysical Journal* **23**, 312, 1906.

2) The figure is not a copy of the original drawing, as this could not be so much reduced on account of the delicacy of the lines.

indicated by the numbers 1 to 12, and arcs representing the moon's limb in a series of positions. The width of the sickle-shaped strips bounded by these arcs, is $^1/_{20}$ of the sun's radius, excepting the strips *a, b, c, d,* for which it is $^1/_{40}$.

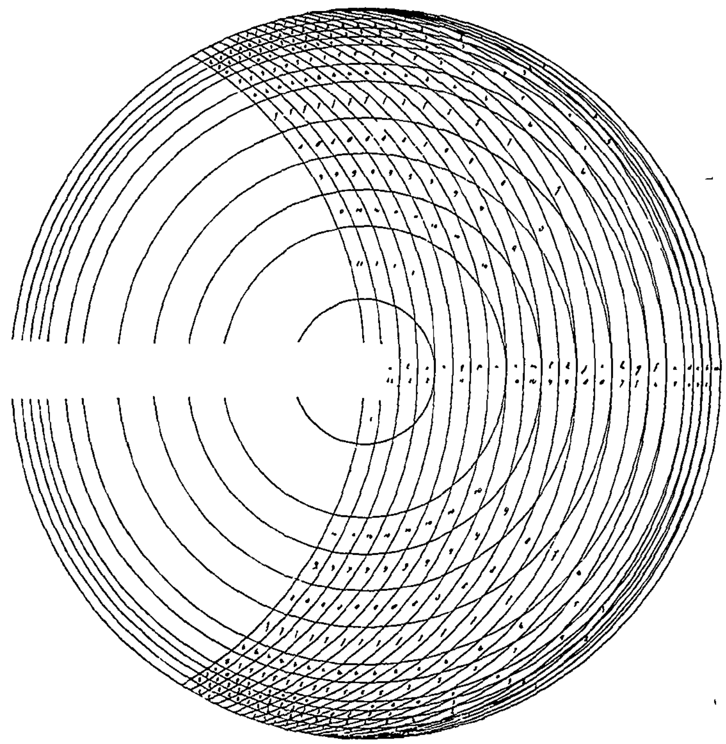

Fig. 2.

In $40^3/_8$ minutes the moon's limb accomplished a distance equal to the sun's apparent radius; so the strips *a, b, c, d,* required $^1/_{40} \times 40^3/_8$ minutes each for reappearing from behind the moon, the strips *e* to *u* took $^1/_{20} \times 40^3/_8$ minutes each. On our curve (Plate XI l. c.) we read the successive increments of the radiation, corresponding to the series of sickle-shaped strips. We shall denote these increments by the same letters as the strips.

The increment *a* is entirely due to radiation from zone 1; the increment *b* to radiation from the zones 1 and 2, etc.

Let us indicate by x_n the average intensity of the radiation with which a unit of disk-surface, belonging to zone *n*, supplies our thermopile. Then the increment *h*, for instance, will be composed as follows:

$$h = \theta_1 x_1 + \theta_2 x_2 + \dots \dots \theta_7 x_7.$$

θ_1, θ_2 etc. being the surfaces of the parts that the corresponding zones contribute to the strip h. Though possible, it is extremely tedious to calculate these surfaces. We therefore determined them by cutting out and weighing the pieces of each strip. So the unit of area, adopted for measuring the surfaces, corresponds to a piece of our drawing-paper weighing 1 milligram. Expressed in that unit, the coëfficients $\theta_1, \theta_2 \ldots \theta_7$ were found to be 8,1, 11,9 . . . . . . 298. Table II contains all the coëfficients of $x_1, x_2, x_3 \ldots \ldots x_{12}$ thus

TABLE II.

Increments.	Coëfficients of:											
	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}
$a=$ 47	251.0											
$b=$ 53.5	83.0	168.4										
$c=$ 58.5	25.5	88.5	137.5									
$d=$ 62	13.8	34.5	78.5	123.0								
$e=$ 130	15.7	37.5	59.6	113.0	264.0							
$f=$ 135	10.9	21.0	31.1	45.0	163 0	217.0						
$g=$ 140	8.5	15.0	19.5	27.0	80.0	146.0	192.0					
$h=$ 144	8.1	11.9	15.8	21.1	55.3	77.0	298.0					
$i=$ 147	7.7	10.3	12.3	15.9	42.0	55.5	198.0	146.5				
$j=$ 150	7.4	9.3	11.0	13.2	33.0	42.0	123.5	247.0				
$k=$ 152	7.1	8.4	9.2	11.9	28.7	34.8	93.5	168.5	120.0			
$l=$ 153	6.9	8.2	8.8	10.2	25 4	30.2	76.6	108.2	204.2			
$m=$ 154	6.9	8.1	8.5	9.8	22.4	27.5	66.0	86.5	142.0	98.2		
$n=$ 154.5	6.8	8.0	8.3	9.5	20.8	24.9	58.0	73.4	96.4	165.3		
$o=$ 154	6.8	7.7	8.1	9.2	19.8	22.6	52.5	63.6	77.8	119.7	77.7	
$p=$ 154	6.8	7.6	8.0	9.0	19.1	21.1	49.1	57.3	66.2	82.2	134.0	
$q=$ 154	6.7	7.5	7.8	8.8	18.3	19.7	44.9	53.0	57.7	68 9	164.7	
$r=$ 153.5	6.7	7.4	7.6	8.6	17.6	19.0	42.4	49 7	53.4	69.0	181.2	
$s=$ 152.5	6.8	7.5	7.6	8.4	17.0	18.2	40.3	45.5	49 2	54.5	143.0	50.3
$t=$ 151.5	6.8	7.5	7.5	8.2	16.7	17.5	39.2	42.9	46.5	51.1	115.3	83.6
$u=$ 149.5	6.8	7.4	7.5	8.1	16.5	17.1	38.0	41.7	45.1	48.3	102.0	97.0

obtained. The first column gives the values of the increments of the radiation as read on the eclipse-curve. Every horizontal row defines an equation. From the first equation we obtain x_1, from the second equation x_2, etc.

TABLE III.

Distance of Zone from Centre of Disk.	Average Radiating Power per Unit of Zone Surface: Found directly from the Equations	Reduced to value 100 at Centre	Found by graphical Interpolation	Distance from Centre of Disk.
0.9875	$x_1 = 0.18725$	48.6	40.0	1.0
0.9625	$x_2 = 0.2254$	58 5		
			61.0	0.95
0.9375	$x_3 = 0.2457$	63.9		
0.9125	$x_4 = 0.2631$	68 4	69.0	0.9
0.875	$x_5 = 0.2813$	73.0		
			74.2	0.85
0.825	$x_6 = 0.2900$	75.4		
			77.8	0.8
0.75	$x_7 = \left\{\begin{matrix}0.3038\\0.3103\end{matrix}\right\} = 0.3071$	79 8		
			80.7	0.75
0.65	$x_8 = \left\{\begin{matrix}0.3221\\9.3305\end{matrix}\right\} = 0.3263$	84 8		
			83 3	0.7
0.55	$x_9 = \left\{\begin{matrix}0.3463\\0.3432\end{matrix}\right\} = 0.3447$	89.5	87.4	0.6
			91 0	0.5
0.45	$x_{10} = \left\{\begin{matrix}0\ 3519\\0.3562\end{matrix}\right\} = 0.3540$	92.0		
			93.8	0.4
			96.5	0.3
0.3	$x_{11} = \left\{\begin{matrix}0.3656\\0.3694\\0.3681\\0.3934\end{matrix}\right\} = 0.3691$	95.9		
			98 3	0.2
			99.5	0.1
0.125	$x_{12} = \left\{\begin{matrix}0.3817\\0\ 3842\\0.3860\end{matrix}\right\} = 0.3840$	99.8		
			100.0	0.0

The results are collected in the second column of Table III. The third column shows the same values converted into percentages of the intensity prevailing in the centre of the disk. After they had been plotted on millimeter paper, a smooth curve was drawn, fitting the points as well as possible. On this "distribution-curve" the numbers of the fourth column were read as ordinates, belonging to the places defined in the fifth column. Our results are thus made more easily comparable with those obtained by other observers.

It is not surprising to find the shape of our distribution-curve sensibly different from the shape of any of the curves that represent VOGEL's spectrophotometric measurements. Indeed, the latter show the distributions characteristic of special groups of rays, each covering a narrow part of the spectrum; they are germane, but yet vary considerably with the wave-length. The combined effect of *all* waves (invisible ones included), that are absorbed by our thermopile, must give a distribution-curve of another type, less simple than that to which VOGEL's curves for nearly monochromatic light belong.

Summary.

During the annular eclipse of the sun on April 17th 1912 the variation of the total radiation has been observed near Maastricht under exceptionally favourable sky-conditions, with two mutually independent sets of apparatus.

One set, comprising a bolometer and a short-period recording galvanometer, served the purpose of finding as accurately as possible the proportion of the minimum to the maximum radiation.

The ratio was found to be nearly $^1/_{5000}$. On this result we based an estimate of the total amount of energy radiated and scattered by the entire solar atmosphere; we thus obtained a very small fraction of the solar output (about $^1/_{1000}$).

It is impossible, therefore, to ascribe the fall of the sun's brightness from the centre toward the limb of the disk to absorption or scattering of the light by an atmosphere, enveloping a body that otherwise would appear uniformly luminous. The cloud-theory of the photosphere is not borne out by the facts.

With the other set of apparatus, consisting of a thermopile and accessories, we obtained a sufficient number of reliable readings for constructing the whole radiation-curve, from the first until the fourth contact, with a fair degree of exactness. Besides confirming the value of the minimum as found with the bolometer, this curve procured the data necessary for once more determining the rate of decrease of the radiating power from the centre to the limb of the solar disk.