88
10-9-74

LA-5590-MS
Informal Report

Dr-983

UC-34b
Reporting Date: August 1974
Issued: August 1974

Near Infrared Photography of the Outer
Corona During the 30 June 1973
Solar Eclipse

by

Leon J. Radziemski, Jr.

los alamos
scientific laboratory
of the University of California
LOS ALAMOS, NEW MEXICO 87544

UNITED STATES
ATOMIC ENERGY COMMISSION
CONTRACT W-7405-ENG. 36

MASTER

DISSEMINATION OF THIS DOCUMENT IS UNLIMITED

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

In the interest of prompt distribution, this LAMS report was not edited by the Technical Information staff.

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151
Price: Printed Copy \$4.00 Microfiche \$1.45

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

NEAR INFRARED PHOTOGRAPHY OF THE OUTER CORONA DURING THE
30 JUNE 1973 SOLAR ECLIPSE

by

Leon J. Radziemski, Jr.

ABSTRACT

Near infrared photographs of the solar corona were made at sea level from a ship, Canberra, positioned about 300 miles west of Nouakchett, Mauritania. We obtained polarimetry by taking exposures through HR plane polarizing filters oriented at three successive 60° intervals. Kodak 2424 Aerographic infrared film was used. The pass band of the filter-film combination was about 90 nm centered around 840 nm. The inner corona was occulted by a disk placed 1.5 m in front of an $f/2.9$, 230-mm-focal-length, Dallmeyer lens. One complete set of frames was obtained which shows changes in streamer structure with changing filter orientation. On the frame with the polaroid's axis of transmission almost parallel to the north solar axis, four outer coronal streamers to the west can be followed out to $11 R_\odot$, and two broad diffuse streamers to the east to $7 R_\odot$ where they merge into a single blur. A broad, diffuse illumination is also visible to $15 R_\odot$ to both east and west. The streamers are extensions of those seen in inner coronal photographs. Photographic photometry shows that the sky background in the wavelength region covered by this experiment was about 1.1×10^{-10} SSB.

I. INTRODUCTION

In 1970, C. Lilliequist of the High Altitude Observatory in Boulder, Colorado, reported¹ on photographs taken during the 7 March 1970 total solar eclipse showing coronal streamers out to beyond $12 R_\odot$, unusual for a ground-based experiment. This success was due in part to apparatus which was different from that normally used on coronal photography experiments. He used infrared film and filters which limited his passband to 35 nm centered about 880 nm, a baffling tube to reduce light scattered into the camera, and an occulting disk one meter in front of the lens to exclude the inner corona and provide a radial vignetting function. Late in 1972, we learned that he was planning to improve the experiment by including photographic polarimetry during the 30 June 1973 eclipse, and we decided to do a complementary

experiment from the ship Canberra which was to sail to a site on the center line of the eclipse. Because of the similarity of the experiments, we were able to work closely with him on the design of the instrument and reduction of the data, and have both benefitted from discussions of the experiment. Ours was dubbed CIRPE (Canberra Infrared Polarization Experiment), and was part of LASL's SEX VI operation. We have reported preliminary results at a meeting of the Solar Physics Division of the American Astronomical Society.² The present report documents the technique used and results as of July 1974.

II. APPARATUS

A. Camera

With Lilliequist's help we designed a camera-baffling tube system which had an unobscured

field of view (FOV) to $14 R_{\odot}$, and a partially vignetted FOV to $20 R_{\odot}$. Vignetting was introduced by the first aperture in the camera body, which was a Hasselblad 500 EL body. A Magazine 70 was used to hold the film. The lens was a Dallmeyer $f/2.9$ with a nominal focal length of 254 mm. From scale measurements on the eclipse photographs we determined the actual focal length to be 229 ± 5 mm. An Ilex #5 Electronic shutter was mounted between the camera body and lens. The timer was an Ilex "Speedcomputer." The longest available exposure on the timer was 4-s, so longer exposures were made up of multiples of 4-s exposures. As far as we could tell, the shutter was entirely free of vibration.

Directly in front of the lens, we placed a 4-position filter wheel. Three positions held 100 mm diameter infrared polarizing filters* custom made for this experiment by Dr. A. Makas of Polaroid Corporation. In the fourth position we had a Wratten 87 filter laminated in glass. Figure 1 shows details of the camera.

The baffling tube shown in Figs. 2 and 3 was 35 cm in diameter. Four baffles were placed within the tube to intercept scattered light. Their positions (in distance from the occulter) were 37.5 mm, 72.5 mm, 110 mm, and 134 mm, and their diameters were, respectively, 28.4 cm, 22.2 cm, 15.5 cm, and 11.3 cm. An occulting disk 112 mm in diameter (Fig. 2) was placed at the end of the barrel, 1.5 m from the lens. Details of the vignetting pattern caused by the occulter are discussed below in Sec. V. B.

B. Film

The fastest film available with extended infrared sensitivity is Kodak 2424 Aerographic Infrared.³ It is a low-resolution film which falls off sharply in sensitivity beyond 900 nm. The 70-mm-wide

Fig. 1. Base, camera, and tracking telescopes.

roll used for the eclipse photographs was kept at refrigerator temperature (10°C) or below except for a period of 24 h around the eclipse and a period of 12 h while disembarking from the ship. In order to obtain an absolute calibration of the film's energy-density characteristic curve, we obtained from J. Eddy of the High Altitude Observatory an

Fig. 2. View of occulting disk and baffles.

* Polarizing filters, design characteristics: Polaroid Corp. Designation HR, HD dichroic filter epoxy laminate to glass
 $k_1 < 20\%$ at 700 nm; $k_1 > 70\%$ at 800 nm
 $k_2 < 2\%$ at 900 nm
 k_1 and k_2 identical for all three filters to 5% over 700-900 nm region.

Fig. 3. Assembled apparatus.

opal diffuser which was calibrated to 800 nm and extrapolated beyond. This was mounted in front of the filter wheel during calibration exposures. This opal only reduces the intensity of the light entering the instrument by about 10^5 , so additional filters were necessary to reduce it to the correct portion of the density-log E curve. Because ND filters tend to break down beyond 700 nm we needed two ND2 and one ND1 filters in series with the opal. For the calibration photographs a step strip was placed into the camera body about 1 mm away from the film. The observing program we planned was identical to that of Lilliequist, 12- and 24-s exposures through the Wratten 87, and 24- and 48-s exposures through each of the three polarizing filters. These times were based on his experience in 1970 and the changes introduced by the polarizing filters and slightly different cameras. No program for sky polarimetry was included; we planned to use the edge of the FOV for that purpose.

C. Tracking

We planned to stabilize the image by photo-tracking, using a modification of the system

commonly used on other eclipse experiments. A table gimballed about two axes was built, and the instrument mounted with the optic axis normal to the table. Narrow and wide angle trackers were mounted with their optic axes parallel to, but displaced from, that of the camera, so that their FOV would not be obscured by the baffling tube. We collimated by centering an image of the sun in both trackers and the camera at the same time. Both trackers are clearly shown in Fig. 1.

Since Kodak 2424 film has low resolution, the tracking requirements were not too stringent. Image motion would be noticeable with translational motion of 5.6 min of arc. By looking at previous polarization plots,⁴ we decided that useful information could be obtained even if the tracking were good only to 5 min of arc although this would blur any fine structure. In observation of the middle to outer corona this degradation was not a severe problem.

During the eclipse, we guided by hand because of a failure of the electronics. The image of the corona was kept between lines ruled on a ground glass screen in the focal plane of the tracking telescope. We estimated from observation at the time, and later from the actual photographs, that our translational tracking was good to $1/3 R_\odot$ on the average (5 min of arc), with no excursions greater than one $R_\odot$. The tracking efforts on eclipse day were aided by the fact that there was very little wind and sea; the ship's roll was no more than $\pm 1^\circ$. The small amount of wind was reduced by portable wind screens made of Wilson Lumite tennis court curtains and an aluminum frame. A photo of the apparatus with windscreen appeared in *Sky & Telescope* 46, 152 (1973).

III. ECLIPSE DAY OPERATIONS

Although we obtained probably the most sheltered spot on the ship, directly behind the bridge, setup for our experiment was difficult because of the wind and occasional showers. Figure 4 shows the apparatus during assembly. We were ably assisted in assembly and observations by R. Ramsey of Bell Laboratories and R. C. Smith of Control Data Corporation.

When it became evident that the photoelectric tracking would not function, we changed our

Fig. 4. Apparatus being assembled aboard ship; R. C. Smith is in the foreground.

observing program, eliminating the 48-s exposures, and adding a number of shorter exposures. This was very fortunate because the 48-s exposures would have been overexposed anyway, as indeed were Lilliequist's. The actual observing program followed was, in sequence (as verified by a tape we made in real time):

Wratten 87 : 1/15, 1/4, 1, 12 s

Polaroid #1 CCW: 1/15, 1/4, 1, 12, 24 s

Polaroid #2 CCW: 1/15, 1/4, 1, 12, 24 s

Polaroid #3 CCW: 1/15, 1/4, 1, 24 s

The 12-s exposure on the Polaroid #3 was accidentally omitted. The length of the eclipse was 5 min 30 sec, with mid-eclipse about 10:30 UT. At 13:35 UT we began the calibration frames. That program was as follows:

Wratten 87 : 1/15, 1/4, 1, 12, 24 s

Polaroid #1 CCW: 1/15, 1/4, 1, 12, 24 s

Polaroid #2 CCW: 1/15, 1/4, 1, 12, 24 s

Polaroid #3 CCW: 1/15, 1/4, 1, 12, 24 s

At 14:00 UT the calibration exposures were complete.

There is some disagreement as to the actual position of the ship during totality. The navigator claims its position to be $18^{\circ}48' N$ and $21^{\circ}12' W$, but local circumstances as timed by Dr. Smiley of Brown University lead to a position (computed by J-15 codes) of $18^{\circ}58' N$ and $21^{\circ}32' W$.

IV. QUALITATIVE RESULTS

Good images were obtained on the 12 and 24-s exposures; photographic densities as measured on a microdensitometer reached 1.85. The shorter exposures were underexposed. Figures 5 and 6 contain, respectively, a schematic and a print of the Polaroid #2, 24-s frame. This frame shows the most detail because the axis of the polaroid was almost parallel to the north solar axis. The principal features, seen in more detail on the original negative, are all close to the sun's equatorial plane. To the west the two sharper streamers are seen to about $11 R_{\odot}$ on the originals, while the diffuse radiation both to east and west extends at least to $15 R_{\odot}$. The star image near the W is the third magnitude M-type star, μ Geminorum, which is $15.6 R_{\odot}$ from the center of the moon's disk. These results alone demonstrate again the usefulness of this experimental technique.

V. DATA REDUCTION

A. Film Calibration

In order to determine the characteristic curve for the film it is necessary to know the transmission of the opal-ND combination and the transmission of the steps on the Kodak step tablet in the wavelength range of the experiment. We determined the passband of the instrument to be about 80 nm (50% width) centered about 840 nm. It was found by multiplying the nominal sensitivity

Fig. 5. Schematic of Polaroid #2, 24-s frame, describing details seen in the original.

Fig. 6. Reproduction of Polaroid #2, 24-s frame with inner corona superimposed. The insert was taken by the team of S. Stone, D. Call, and W. Regan.

curve for 2424 film by the average transmission of the HR filters, or the Wratten filter. The resultant sensitivity curves for the film-filter combination are shown in Fig. 7, along with Lilliequist's curve. Measurements of the steps and ND filters were made on a Cary spectrophotometer (which measures in density units, $D = \log 1/T$) in the wavelength range 600 to 950 nm. The densities of the steps were reasonably constant over the range from 770 to 900 nm, and averages over this range were used for the step densities. The ND filters varied by about 10% in density or 50% in transmission over this interval, but in roughly a linear fashion. The value at the center of the interval was taken as the mean transmission or density. We estimate the accuracy of the ND average transmission to be about $\pm 3\%$, or about $\pm 2\%$ in density. Table I contains the densities of the steps, ND filters, and opal-ND combination. Included also for comparison are measurements made by Lilliequist on a similar step tablet.

Next the photographic densities of the 24-s, 12-s, and 1-s exposures of the step tablet were measured on the M-2 Photometric densitometer. A 100- μ m aperture was used for these as well as the scans of the coronal images. A section of a typical scan is shown in Fig. 8. The ramps are due to leakage around the edges of the steps which were positioned about 1 mm in front of the film. The

Fig. 7. Film-filter sensitivity characteristics.

centers of the ramps were taken as the density values. There was also a variation in intensity along the steps in the other direction; the most nearly constant part of the frame was used. Since there was not enough density range on the 24-s step exposure, a composite $D \log E$ curve was made using the 24-s, 12-s, and 1-s exposures, the latter two normalized to the 24-s exposure in absolute position. We compensated for small reciprocity failure effects by observing the residual shifts in overlapping portions of the different

Fig. 8. Photographic density along steps 1 to 10, Polaroid #3, 24 s.

TABLE I
MEASURED DENSITIES OF THE NEUTRAL DENSITY FILTERS
USED IN COMBINATION WITH HAO OPAL, AND STEPS ON KODAK STEP TABLET,
IN THE WAVELENGTH RANGE 775 TO 900 NM

<u>STEP</u>	<u>DENSITY</u>	<u>DENSITY</u> ^a _{cl}
1	0.08	0.07
2	0.34	0.36
3	0.63	0.60
4	0.82	0.85
5	1.05	1.05
6	1.27	1.29
7	1.48	1.50
8	1.72	1.70
9	1.90	
10	2.16	
11	2.33	
12	2.59	
13	2.80	
ND1	0.63	
ND2	1.24	
ND2+gl	1.26	
opal	5.00 (HAO Measurement)	
opal+ND filter package = 8.13		

^a Densities similarly obtained by Lilliequist by a similar method on his step tablet.

segments and again normalizing to the 24-s exposure. The $D \log E$ curves for exposures made through the three polarizing filters were almost identical and were averaged into one curve. The curve for the Wratten filter was slightly displaced from the others, perhaps because of the different spectral response. This presents no problem as long as the appropriate $D \log E$ curve is used for each exposure. Fig. 9 shows the composite 24-s curve, where it is compared with one obtained by Lilliequist, also for a 24-s exposure. The curve obtained by Lilliequist is made up of two segments from exposures of the same duration but with different amount of ND filter in place. The agreement at the lower densities is good. The difference at the upper end is attributed to different measurement characteristics of the densitometers. From this curve we could see immediately that there would be a disagreement between coronal intensities because the LASL coronal densities only went up to 1.85, while Lilliequist's peaked at 2.2.

B. Vignetting Function (T_v)

The purpose of the occulter placed 1.5 m in front of the objective lens was to exclude the inner corona and to provide a vignetting function (T_v) to keep the exposure within the latitude of the film. The curve was computed analytically by calculating the ratio of the unobscured to total area

Fig. 9. Comparison of $D \log E$ curves; LJR 24 s and 12 s from this work; C L 24 s private communication from Lilliequist.

of the lens for a set of off-axis angles, which corresponded to viewing the corona at varying distances from the center of the eclipse. $T_v=0$ corresponds to total obscuration, $T_v=1$ to no obscuration. As the lens-occultor distance was fixed by practical consideration different T_v curves were obtained using various $k=D_{\text{lens}}/D_{\text{occ}}$ values. Using a measured diameter for the front surface of the lens of 84 mm, an occulting disk diameter of 112 mm ($k=0.75$) gave a T_v curve which went to zero at $2 R_\odot$ and to one at $14 R_\odot$. This design was adopted. The first coronal intensity calculations using this calculated curve indicated that it was not correct, that the real T_v was closer to a $k=0.65$ curve. An experimental T_v curve was then obtained in the following way. Photographs were made of a cloudless sky, in a direction opposite to the rising sun, hoping that the sky would provide a uniform background. Exposures were made with the occulter in place, and absent, and step tablet exposures were also made. The sky proved to be uniform in a direction parallel to the horizon. Using the characteristic curve the intensity of the exposures with and without the occulter in place was computed, and the ratio taken. This gave T_v as a function of position on the film, or equivalently as a function of r . The measured curve and some calculated curves are contained in Fig. 10. The measured curve corresponds approximately with a $k=0.65$ computed curve. The source of the discrepancy between the original design and actual curve was that the limiting aperture was a collar behind the lens with diameter of

Fig. 10. Comparison of theoretical and experimental vignetting functions. k = diameter of the lens/diameter of the occultor.

70 mm. This gives a $k=0.625$. For practical purposes the real vignetting function is as good as the one designed although some information between 2 and $3 R_{\odot}$ was lost.

C. Coronal Intensities

All of the densities of the 12-s and 24-s coronal exposures were measured on a densitometer. Each exposure was measured in a 570×570 matrix, with a $100\text{-}\mu\text{m}$ by $100\text{-}\mu\text{m}$ aperture, and with a stepping distance of $100\text{ }\mu\text{m}$ in each coordinate and a spot size of $0.1 R_{\odot}$ square. Before processing, the raw data were averaged by computer to $0.3 R_{\odot}$ or $0.6 R_{\odot}$ squares. Recall that the tracking resolution corresponded to approximately a $0.3 R_{\odot}$ square.

The photographic densities were transformed to intensities through the $D \log E$ curve and the vignetting function was then applied. At this point it was necessary to consider the registration of the vignetting function and the eclipse image. Although the vignetting function is very likely in the same position on each frame, it is possible that the eclipse image is not due to inaccurate pointing. Fortunately, there is an image of the inner corona on the exposures from a small pin-hole in the center of the occulter normally used for alignment. This image was used to obtain the position of the eclipse on the frame. The position of the vignetting function was found by using the following assumption. At the position in the corona (about $3 R_{\odot}$) where T_v begins to move away from zero, the photographic density is dominated by the T_v curve rather than the variations in coronal intensity, and the densities on opposite sides of the disk should be symmetric about the center of the occulter. Densities were determined and plotted and the centers so calculated. The smaller data point size was very helpful in this task.

The exposure taken through the Wratten 87 filter was used for intensity calculations. Using the $0.3 R_{\odot}$ data point size, I vs r plots were made at azimuthal angles from 0° (solar N) to 315° in 45° intervals. By changing the centering slightly, we determined that the I vs r plots were sensitive to centering changes of about $0.2 R_{\odot}$. To reduce the effects of centering uncertainty, we averaged intensities in directions 180° apart. The sky

brightness was assumed to be that intensity which must be subtracted from the raw intensities to make the I vs r plots most nearly straight lines on log-log plots. The resulting plots for the polar and equatorial regions are contained in Figs. 11 and 12 where they are compared with Keller's 1973 results.⁵ Lilliequist's results are not included because they are too preliminary to report. The plots for the $45\text{--}225^\circ$ and $135\text{--}315^\circ$ directions are very similar to the polar plots and are not given. Although the slopes of our curves agree reasonably well with Keller's, there is a shift of about a factor of two in the absolute positions of the curves. We have considered many possible sources of this discrepancy. The most likely origin is that the sky was considerably less transparent during the eclipse than at the time when the calibration exposures were taken. We have already taken into account the fact that the solar elevation was considerably different at the two times, 48° at eclipse time and 85° at calibration time. A correction was entered into the log E

Fig. 11. Coronal intensity as a function of r , equatorial average, sky background removed, $n_{ck}(\text{slope})=2.00$, $n_{ljr}=2.47$.

Fig. 12. Coronal intensity as a function of r , polar average, sky background removed. $n_{ck} = 2.42$, $n_{ljr} = 2.39$.

part of the $D \log E$ curves to compensate for the 30% greater mass of intervening atmosphere at eclipse time. Errors in the calibration of step densities, opal transmission, and ND transmission have been ruled out by cross-checking these quantities. Neither theory nor previous infrared experiments⁶ predicted such a drastic change in intensity between the 550- to 700-nm range (Keller) and our 840- to 880-nm range. We concluded then that our intensities should approximate his and hence have shifted our curves upwards in absolute value. In our opinion, this necessity for a shift to compensate for an effect of uncertain origin reduces the usefulness of the I vs r curves. However, we can still obtain an important result, namely, an estimate of the sky background.

D. Sky Background

From our raw intensity data, we subtracted 0.5×10^{-10} SSB (standard solar brightness) to obtain the straight lines on Figs. 11 and 12. The correction necessary to bring our intensities to Keller's values is 2.0 in the polar case and 2.3 in the equatorial. This gives a corrected sky intensity of 1 to 1.2×10^{-10} SSB, which is a reasonable value as demonstrated by the following comparisons. We estimate the uncertainty in this value to be $\pm 0.4 \times 10^{-10}$ SSB. Assuming that sky brightness is linearly related to the atmospheric pressure and taking into account the λ^4 variation of a Rayleigh sky, we calculate from Keller's sky brightness of 1.15×10^{-10} SSB measured at 36,000 ft:

At sea level

$$\begin{aligned} B_s &= B_s^{ck} \frac{P}{P^{ck}} \left[\frac{\lambda}{\lambda^{ck}} \right]^4 \\ &= 1.15 \times 10^{-10} \cdot \frac{760}{190} \left[\frac{6500}{8400} \right]^4 \\ &= 1.65 \times 10^{-10} \text{ SSB.} \end{aligned}$$

This is in reasonably good agreement with our experimental number considering the assumptions involved. Also our value, when multiplied by the factor of eight to allow comparison with typical visual range values, compares well with numbers such as 1×10^{-9} SSB as given by Van de Hulst.⁷

The important conclusion is that it is practical and possible to obtain a low sky background by this technique, even from sea level, and even when skies are not perfectly clear visually. This provides a new method for observing the middle and outer corona from the ground.

E. Polarization

The polarization is even more sensitive to the registration and centering of the individual images, and the problem is more complex because there are three images to be compared. To this time, polarization results which are reliable and

reportable have not been obtained.

F. Conclusions and Recommendations

We conclude that the experimental method used in our work is a feasible method for studying the middle and outer corona from the ground. While it does not have the advantages of airborne instrumentation, it is a relatively low-cost experiment. If such an experiment were carried aboard an aircraft during an eclipse, we would have the opportunity to view the corona against lower sky backgrounds than ever before obtained by experiments performed within the earth's atmosphere, and hence to define the corona-solar wind interface with more accuracy than ever before possible. We recommend that an experiment of this type be included in the flight planned for the October 1976 eclipse. Collaboration in this effort with C. Lilliequist is recommended because of his experience with the technique.

ACKNOWLEDGMENTS

We gratefully acknowledge the help of R. C. Smith who helped design and fabricate the instrumentation. His help and that of R. Ramsey aboard ship were necessary to successful completion of the observing program. The encouragement and advice of A. N. Cox and C. F. Keller are appreciated, as well as the support of G. R. Waterbury, R. D. Baker, and C. Browne.

REFERENCES

1. Carl Lilliequist and Edward Schmahl, "The Far Outer Corona in the Near Infrared," *Sky & Tel.* 40, 77 (1970).
2. Leon J. Radziemski, Jr., and Carl Lilliequist, "Near Infrared Photography of the Outer Corona During the 30 June 1973 Solar Eclipse," paper given at the 4th meeting of the Solar Physics Division of the American Astronomical Society, 11 Jan. 1974; *Bull. of A. Astron. Soc.* 6, 293 (1974).
3. Kodak Handbook, "Kodak Data for Aerial Photography," M-29 (1973).
4. Charles F. Keller, "Results of Polarization Observations of the Outer Corona from a Jet Aircraft," *Solar Phys.* 21, 425 (1971).
5. Charles F. Keller and James E. Tabor, "Absolute Intensities of the Outer Corona Obtained from a Jet Aircraft at the 30 June 1973 Total Solar Eclipse," in press.
6. R. Michard, "Observations Aeriennes de la Couronne Externe a l'Eclipsé du 20 Juin 1955," *Ann. Astrophysique* 19, 229 (1956). D. E. Blackwell, "A Study of the Outer Corona from a High Altitude Aircraft at the Eclipse of 1954 June 20," *Month. Not. Roy. Astron. Soc.* 115, 44 (1955).
7. H. C. Van de Hulst, "The Solar Corona," *Bull. Astron. Inst. Neth.* 11, 135 (1950).