VII.—*Report on the Total Solar Eclipse of April* 6, 1875.

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[Plates 9–14.]

I. INTRODUCTORY.

It is never an easy task to make out the plan of operations for the observation of a phenomenon so rare and of such short duration as a total solar eclipse. We must be careful on the one hand not to risk failure by the adoption of new and uncertain methods, and on the other hand we must bear in mind that the mere repetition of what has been done before does not justify any large expenditure of time and money.

In drawing out the instructions for the expedition the Committee of the Royal Society had to consider in how far the old methods could be perfected, and in how far new ones should be tried.

The principal methods hitherto employed successfully in total solar eclipses consist in spectroscopic eye observations and the obtainment of photographs of the corona. As the Royal Society had secured the services of Professor Tacchini, and as Mr. Janssen intended to observe the eclipse for the French Government, it was considered that spectroscopic eye observations were sufficiently provided for. As far as the photographic impressions of the corona itself were concerned, it was arranged that the same instrument with which Colonel Tennant had taken his photographs during the Eclipse of 1871 should be sent to one of the stations with an observer practised in its use.

Considering, therefore, that the attack of the corona was in excellent hands as far as the old methods were concerned, the Committee of the Royal Society decided to adopt new methods which should open fresh fields of research.

We give a short account of what these methods were and what questions they are likely to solve.

The Prismatic Camera.

During the Total Solar Eclipse of 1871 Mr. Respighi and Mr. Lockyer independently made observations with a spectroscope deprived of its collimator. A series of rings was seen by them corresponding to the refrangibilities of the rays sent out by the corona. The chief object of the observers during the last eclipse was to obtain photographs of these rings, and the instrument employed has been termed a *prismatic camera.*

The great advantage of the prismatic camera is that it combines the functions of a telescope with those of a spectroscope, that is to say, it does not present us with the spectroscopic view of one section only of the corona, but of the whole chromosphere and corona. The instrument which was in use in Siam consisted of a camera of 5 feet focal length. The object glass, which belonged to Mr. LOCKYER, had an aperture of $3\frac{3}{4}$ inches. In front of the object glass was placed a prism with a refracting angle of about 8 degrees.

Supposing that the corona and chromosphere only send out the same homogeneous light, one image only will appear on the sensitive plate, the only effect of the prism being to displace the image. As far as protuberances are concerned we know they give a spectrum of bright lines, and we expect therefore to find on the plate each protuberance represented as many times as it contains lines in the photographic region. The different protuberances would be arranged in a circle round the sun, and these circles would overlap or not, according to the dispersive power of the prism and the difference in refrangibility of the lines. Fig. 1, Plate 9, represents a series of protuberances such as we might expect to find if the dispersive power is small. Fig. 2, Plate 9, the same protuberances if the dispersive power is large. The dotted line represents the edge of the sun. As far as the corona is concerned we know very little. If the conclusion which TENNANT and STONE derived from recent eclipse observations is correct, and the higher regions of the corona send out continuous light, we shall find no distinct outline of the corona as we do in ordinary photographs, but we shall find this image drawn out along the line of dispersion.

Thus a corona which would appear in an ordinary photograph as fig. 3 will be drawn out as represented in fig. 4. Such an image would present a striated appearance, each irregularity being drawn out by the prism. If such an irregularity were confined on an ordinary photograph to a mathematical point it would appear in the plates exposed in the prismatic camera as a mathematical line. As a rule, however, the irregularity will cover a surface of measurable extent. The visibility of such a local irregularity depends on the relative brightness of the surrounding objects, which will overlap, and, if bright enough, mask the irregularity. The continuous spectrum will be most easily observed, if, as actually happens, it is confined to the lower part of the corona. The moon in this case will form a sharp edge to the irregularity, and prevent any overlapping from the side on which it is situated. If the corona give a series of bright lines instead of the continuous spectrum we shall find a series of outlines on the photograph similar to that corresponding to the protuberances. We might indeed have the two cases combined, and then we should find a series of images standing out of the continuous band. If we find that part of the corona gives a continuous spectrum that part alone will be drawn out into a band. We thus see that the prismatic camera not only gives us an indication of the spectrum of one part only of the corona, but that it gives us a combined representation of the spectrum of every part of the corona and chromosphere, and that careful examination of the result enables us to analyse it into its constituents.

The Spectroscopic Camera.

The chief drawback of the prismatic camera consists in the difficulty of obtaining a scale by means of which the refrangibility of the different rays can be determined. In order to complete the preparations as much as possible, it was arranged to endeavour to obtain photographs of the spectrum of the prominences by means of a telescope and ordinary spectroscope, the slit of which was provided with shutters, so that the solar spectrum could be photographed and used as a scale either before or after totality. It was hoped that photographic impressions of at least the brightest lines of the chromosphere could be obtained and identified by means of the solar spectrum. These brightest lines could then have been easily recognised on the plates of the prismatic camera, and would have formed a scale for the weaker protuberance lines and other phenomena visible on the plates.

Before discussing in detail the results, we have to give a short account of the journey and the preparations.

II. CHOICE OF STATIONS.

Three stations were available for the observation of the eclipse. The eastern coast of the Malayan Peninsula (Siam), the western coast of the Malayan Peninsula, and the Nicobar Islands. As the weather was rather doubtful during the month of April at all three stations, it was decided to divide the expedition into three parts. Although the journey to Siam was much longer, and much less time was therefore left for preparations on the spot, the liberal invitation and offer of help by the King of Siam, made it certain that all possible preparations would be made before the arrival of the expedition. Circumstances over which the expedition had no control prevented them from carrying out the original plan of sending some of the observers to Mergui, on the western side of the Malayan Peninsula. There were observers therefore at two stations only; Lem Chulie, in the Malayan Peninsula, and Camorta, in the Nicobar Islands.

III. THE EXPEDITION TO SIAM.

Journey to the Observatory.—Preparations for the Eclipse.

The expedition left Southampton on February the 11th, in the Peninsular and Oriental Steamship 'Surat.' It consisted of the following gentlemen:—

Mr. ARTHUR SCHUSTER.
Mr. R. MELDOLA.
Mr. FRANK EDWARD LOTT.
Mr. FREDERICK BEASLEY.
Mr. J. REYNOLDS.

They were joined at Suez by Dr. H. W. VOGEL, of Berlin.

At Galle Messrs. MELDOLA, REYNOLDS, and Dr. VOGEL separated from the rest, and waited for the Government steamer which should carry them to Camorta.

The remainder of the party arrived in Singapore 24 hours late, and at once communicated with the Governor of the Straits Settlement, in order to avoid any possible delays in the journey. Sir ANDREW CLARKE placed H.M.S. 'Lapwing' at the disposal of the expedition, but he could not tell when the steamer would be able to start. As the Siamese merchant steamer 'Kromahtah' left Singapore the same night for Bangkok, the expedition took Sir ANDREW CLARKE'S advice to take a passage in this boat, especially as it was urged that she would complete the passage in less time than the 'Lapwing.'

Dr. SCHUSTER, however, forwarded a request to Sir ANDREW CLARKE to send the 'Lapwing' as soon as she was ready to the spot of observation, so that the expedition might profit by the help of the officers and crew. The expedition has also to acknowledge the assistance they have received by the valuable advice of the Honourable Major MCNAIR, a gentleman who is well acquainted with the country of Siam.

The S.S. 'Kromahtah' arrived in front of the bar which prevents the entrance into the Meinam river at low water at noon, on Sunday, the 28th March. A slight accident to the engine had caused a delay of several hours, in consequence of which the steamer could not enter the river before nightfall. It was late in the night when the expedition at last arrived at Bangkok, after a journey of 45 days. In spite of the inconvenient hour, two boats were, by order of His Majesty the King of Siam, on the look out for the expedition to convey them to the residence of Mr. ALABASTER.

It was past one o'clock in the morning when they arrived there, but several important points were settled during the night in order to secure a speedy journey to the observatory, which, under the superintendence of Captain LOFTUS, had been already built on the spot suggested by the Committee of the Royal Society. It became, however, apparent next morning that it was impossible to leave on that day. Several important points had to be settled with the Siamese authorities, the instruments had to be transhipped, and owing to the state of tide it was useless to leave after eleven o'clock in the morning. Much to their regret the expedition were compelled to defer their departure until Tuesday morning. The day, however, was not lost. The observatory had been built on a lonely spot on the sea coast, and the expedition was, therefore, entirely dependent for any help on the capital. Arrangements were made for regular communications with the capital.

We cannot speak too highly of the assistance which the expedition has derived from the intelligent aid of Mr. ALABASTER. His thorough acquaintance with the objects of the expedition, aided by his knowledge of the language and high position in the country, had enabled him to make many arrangements before their arrival which saved a great deal of time, and, in fact, rendered the completion of the preparations in the short time left before the eclipse possible. The expedition called on His Excellency CHAU PHYA SRI SURAWONGSE WAY WADHN-KALAHOME (the Minister of War), His Excellency CHAU PHYA BHANUWONGSE KROMATAH (the Minister of Foreign Affairs), and His Excellency PHYA BASHAKARAWONGSE (Private Secretary to His Majesty the King). One of the chief reasons which had induced Dr. SCHUSTER to pass the day in Bangkok was to call on the English Consulate, with the request to send on, with as little delay as possible, the much-needed aid from the gunboat, which was hourly expected. The expedition was chiefly in want of intelligent workmen. In case any instrument had been damaged on the journey they were without resources to remedy the fault. The expedition was kindly received by Mr. NEWMAN, the Acting Consul, who promised to do everything in his power to further the objects of the expedition.

In the afternoon the expedition had an audience with the King. His Majesty expressed the great interest which he took in the objects of the expedition. He referred to the well known great knowledge of astronomy which his father possessed. The late King had died in consequence of a fever contracted on a journey made to observe the total solar eclipse which had taken place in 1868 in the southern parts of his kingdom. Finally His Majesty said that he had given orders that every possible help should be given to the expedition.

Early on the next morning the expedition embarked on the Siamese S.S. 'The Northern Siam Enjoying,' which had been placed at their disposal. An unfortunate delay on the journey prevented them from reaching the observatory that night, and they had to anchor near the coast in a very rough sea. On the morning of Wednesday, at 10 o'clock, they at last arrived at the observatory. The ship had to anchor about half a mile from shore. At the observatory Captain LOFTUS had been engaged for some time to prepare for the arrival of the expedition. The spot had been judiciously chosen. A small brook ran into the sea close by. A landing stage had been erected in the brook. A channel had been marked out in the sea through which the boats which were to carry the instruments could enter the brook. The landing of the instruments was, therefore, greatly facilitated; but the strong wind and rough sea prevented any attempt to effect the landing during the first day.

The place of the observatory, as determined by Captain LOFTUS, was latitude 13° 0′ 30″ N., and longitude 100° 2′ 10″ E., being about $1\frac{1}{2}$ miles S.W. of the central line. The longitude had been obtained by means of a magnetic bearing, which could be obtained from the top of a tree on a distant pagoda marked on the Admiralty Chart.

It had taken considerable time and trouble to clear the ground from the jungle by which it was covered. A comfortable house had been built of bamboo sticks and palm leaves for the English observers; a similar house was built for Mr. J. JANSSEN, who had arrived at the observatory about a week before the English expedition.

His Grace the ex-Regent of Siam arrived at the observatory on the following day, and stopped until after the eclipse. He took a great interest in the preparations, and his presence was a guarantee that no trouble should be spared to render the stay of the King's guests as pleasant as possible. The minor arrangements, which were considerable, had been entrusted by the King to the Governor of Pitchaburee, to whose anxious care to carry out all their wishes the expedition is greatly indebted.

It must be borne in mind that everything had to be brought through considerable distance either by water or over bad roads, and the continued wants at short notice of wooden planks, bricks, &c., often severely taxed the energies of the Siamese officials. Even the drinking water had to be brought from a spot many miles distant.

All through Wednesday the wind did not abate, and arrangements were made to land the instruments during the night if possible. At three o'clock in the morning Mr. LOTT went on board, and succeeded after some difficulty, and not without risk, in getting the instruments into the small boats. The boats had to make several journeys, but all went well, and on Thursday, the 1st of April, at noon, all the instruments were at the observatory. The eclipse was to take place on the following Tuesday. This late arrival was due to several unforeseen events. Our delay between Galle and Singapore, and slow passage to Bangkok, and a double considerable delay on both sides of the Meinam bar, all combined to produce a total delay of three or four days. Until the arrival of part of the crew of the 'Lapwing,' on the evening of the 3rd of April, we were without the help of trained workmen. Though the instruments were fairly in order during the eclipse, there is no doubt that the short time of the preparations has considerably damaged the results.

Everything belonging to the photographic department was put under the supervision of Mr. BEASLEY. Captain LOFTUS had prepared several dark rooms, two of which were on wheels and could be shifted to any spot where they were wanted. The walls of the rooms were made of several layers of palm leaves, but these were not found a sufficient protection against sunlight. As the expedition had brought tents, they were put up inside the dark rooms prepared by the Siamese. This arrangement proved to be of very great advantage. While the photographer could work in complete darkness inside his tent, the chemicals were placed within easy reach on shelves in the outer room, to which only very little light had access. The assistants carrying the plates to and from the instruments could enter the room and communicate with the photographer without allowing any light to enter the tent.

The instruments had suffered some damage on the journey which could not be repaired without proper tools. The workmen from the 'Lapwing' were, therefore, somewhat impatiently expected.

On the evening of the 1st of April a steamer was announced to be in sight, but, to the disappointment of the observers, it only brought a letter from Sir WILLIAM WISEMAN, Commander of the 'Lapwing,' announcing that he had arrived at Bangkok, and asking in what way he could assist the expedition. Owing to the great readiness with which the Siamese facilitated communication with the capital, the long-expected help from the 'Lapwing' arrived at last on Saturday night, the 3rd of April. During the two remaining days those of the officers and crew which Sir WILLIAM WISEMAN had sent did everything in their power to assist the expedition, and contributed not a little to the successful completion of the preparations.

The erection of the siderostat gave comparatively little trouble; owing to the excellent packing of Messrs. COOKE, it was lifted out of the case almost ready for use. A brick foundation had been built for it, and the adjustments were made in the usual way. The beam of rays reflected from the mirror were thrown into a telescope lent to the expedition by Mr. LOCKYER. The telescope was placed inside a hut so as to protect it from showers of rain. A movable cover could be placed over the siderostat. The image given by the telescope was focussed on the slit of a spectroscope which was provided with quartz lenses and prisms.

We cannot help mentioning here the great advantages which the siderostat possesses over the equatorial in temporary observatories. It is always comparatively easy to find a sure foundation for the plate on which the siderostat rests, while it is much more difficult firmly to fix the pillar of the equatorial into the ground. The horizontal telescope belonging to the siderostat can be easily levelled and firmly fixed with brick and mortar. In latitudes, moreover, where the sun stands high at noon, solar observations with a refracting equatorial are very inconvenient.

The steamer which had carried the officers of the 'Lapwing' also had brought Mr. ESCHKE, assistant to Mr. VOGEL, who had been on one of the expeditions sent out to observe the transit of Venus, and had come to Bangkok in the hope of finding Professor H. W. VOGEL, who, as we have already mentioned, was attached to that part of the expedition which had proceeded to the Nicobar Islands. As, however, the expedition was greatly in want of another gentleman skilled in photography his arrival proved fortunate. The coating and development of the plates could now be altogether separated and carried on in two separate rooms, which helped to prevent confusion during the eclipse. The spectroscopes were adjusted in the usual way. Photographs of distant objects were taken, and when the camera had been in this way adjusted for almost parallel rays the prisms were set into minimum deviation for the violet rays, and the collimators adjusted so as to send parallel rays through the prisms. One of the collimators was found to be too long for accurate adjustment. As it could not be shortened easily, and as the wooden camera was easily made shorter, the latter plan was preferred to bring out the FRAUNHOFER lines. We confess that this was an unfortunate mistake, as converging rays passed in this way through the prism. It must, however, be remembered that part of the day only preceding the eclipse could be entirely given up to the adjustment of the spectroscopes, and that owing to the many and various considerations which had to be attended to, mistakes were almost inevitable.

His Majesty the King of Siam had offered to send FRANCIS CHIT, a skilled photographer in his service, to assist the members of the expedition. As Mr. BEASLEY had brought with him a small but exceedingly good camera for landscape photographs, Dr. SCHUSTER thought it advisable to try to get photographs of the corona. Although the camera did not follow the sun's motion, it was hoped that in short exposures this motion would not much affect the results. Mr. FRANCIS CHIT was charged with the preparation and development of the plates.

If any of the instrumental adjustments were not made with the accuracy which would have been desirable, it was not through want of care of any member of the expedition.

It was only by working 12 hours a day in the hottest month of the year, and sometimes during additional hours of the night to adjust the clocks, that the instruments were in working order a few hours before the beginning of the eclipse.

After this introduction it will be useful to give a short account of the final arrangements which were made for observation.

IV. ARRANGEMENTS DURING TOTALITY.

The observatory which, as has already been mentioned, was built before our arrival, consisted of two parts, separated from each other by a distance of about 40 yards. The smaller of the observatories was intended for the siderostat. Mr. LOTT was put in charge of it during totality. It was hoped that photographs of the spectrum of the prominences and lower parts of the corona should be obtained by the set of instruments connected with the siderostat.

The larger observatory was bounded on each side by a dark room. In one of these rooms Mr. ESCHKE prepared the plates. In the other Mr. BEASLEY took charge of the development. The sailors of the 'Lapwing' had been trained to carry the photographic plates at the times fixed beforehand to and from the instruments.

Attached to Mr. PENROSE'S equatorial was a spectroscope with a camera which was of shorter focal length than the one connected with the siderostat. The equatorial carried the prismatic camera. Arrangements were made to change the plate one and three minutes after the beginning of totality, so as to obtain three photographs of the different phases of the eclipse.

Mr. and Mrs. LOFTUS took charge of the small camera, by means of which a set of photographs of the corona were obtained. The times of exposure were fixed at the suggestion of Mr. JANSSEN at 2, 4, 8, and 16 seconds. A double set of four photographs was thus obtained. Mr. CHIT in a separate dark room prepared and developed the necessary plates. The Honorable H. N. SHORE, R.N., had undertaken to take a sketch of the corona. Messrs. A. W. MURRAY and PATTISON called out the time remaining for observation.

The following gentlemen also gave their valuable assistance during the eclipse :—

Messrs. W. J. FIRKS, R.N., BIETJE, W. BRAY HENDRICKS, EDWARD LOFTUS ; also Captain A. J. THOMPSON, S.R.N., and Captain CHUNG, S.R.N., and MOM DANG.

V. THE ECLIPSE—GENERAL APPEARANCES.

Description of eclipses by eye-witnesses are generally so discordant that no conclusion can be drawn from them. The following remarks, however, seem worthy of notice :—

A great many of the inhabitants of Bangkok were fortunate enough to witness the total solar eclipse in 1868, and they were unanimous in their opinion about the great difference in the appearance of the corona and in the general aspect of the eclipse. The difference seems to have been so striking that some of the Siamese asserted that this last one was no total eclipse at all. The first point they mentioned was the much greater darkness in 1868. In proof of this we cite the following from an account of the eclipse by Sir HARRY ST. GEORGE ORD, C.B., then Governor of the Straits Settlement, who witnessed the eclipse at the invitation of the late King of Siam.

" At the time of the complete obscuration of the sun, which took place at $11^h\ 30^m$, the darkness was so considerable that at a distance of a few feet a person's features were undiscernible and all sense of distance appeared to be lost, the thermometers could not be read without a light held close to them, and the face of the sky was studded with stars as in deep twilight."

During this last eclipse several persons both at the observatory and in Bangkok were looking out for stars, and more than four could in no case be seen. Though the lamps had been lighted for the benefit of those who had to draw, write, or read, the lamps were blown out by the wind, but no inconvenience whatever was produced by this.

The signal for beginning and end of totality could be seen without difficulty at the small observatory 40 yards off, and Mr. LOTT could read a small watch hung up a distance of $1\frac{1}{2}$ feet from his face inside a shed which did not admit any direct light from the corona. Part of this striking difference between the two eclipses may be due to the peculiar atmospheric conditions. There was, indeed, in 1875 a considerable haze over the country, and the sky, though cloudless, was by no means clear. But eye-witnesses affirm that it is the corona itself which was brighter this time and much better defined. The light in the former eclipse was much softer and pleasant to look at. In the last one it was quite as intense as a bright full moon.

Another difference which those who could compare this eclipse with the one in 1868 noticed related to the corona, which they agreed was much more irregular and less well defined than on the present occasion. The characteristic feature of the eclipse in 1868 was formed by the protuberances, and the corona fell more into the background. This time the protuberances could only be seen with the naked eye by a few, and the corona surrounded the moon like a regular and well-defined star.

Some observers note the particular appearance of one protuberance, which they say was of a white dazzling light, and stood out bright from the background, while the other protuberance appeared red and dark on a bright ground. On referring to our photographs we find that the white protuberance was indeed by far the strongest, and contained a great quantity of the particular ultra-violet light, of which we shall have to speak in discussing the results of the prismatic camera.

VI. RESULTS OF THE PRISMATIC CAMERA.

The plates exposed in the prismatic camera present at first sight a somewhat complicated appearance. Two plates have been exposed during totality. No. 1 (fig. 9, Plate 10) during one minute, and No. 2 (fig. 8, Plate 10) during two minutes. They show only such differences as are to be attributed to a difference in phase of the eclipse.

As the protuberances must form the scale to which we shall have to refer the rest, they are the first object of our investigation.

1. *Protuberances.*

During the first part of the eclipse two strong protuberances close together are noticed*; on the limb towards the end these are partially covered, while a series of protuberances came out at the other edge. The strongest of these protuberances are repeated three times, an effect of course of the prism, and we shall have to decide if possible the wave lengths corresponding to the images. We expect *à priori* to find the hydrogen lines represented. We know three photographic hydrogen lines: F, a line near G, and *h*. F is just at the limit of the photographic part of the spectrum, and we find indeed images of protuberances towards the less refrangible part at the limit of photographic effect. For, as we shall show, a continuous spectrum in the lower parts of the corona has been recorded, and the extent of this continuous spectrum gives us an idea of the part of the spectrum in which each protuberance line is placed. We are justified in assuming, therefore, as a preliminary hypothesis, that the least refrangible line in the protuberance shown on the photograph is due to F, and we shall find support of this view in the other lines. In order to determine the position of the next line the dispersive power of the prism was investigated. The prism was placed on a goniometer table in minimum deviation for F, and the angular distance between F and the hydrogen line near G, *i.e.* $H\gamma$, was found, as a mean of several measurements to be $3'$. The goniometer was graduated to $15''$,

* Figs. 5 and 6 show the protuberances as seen on the photographs at the beginning and end of eclipse.

and owing to the small dispersive power, and therefore relatively great breadth of the slit, the measurement can only be regarded as a first approximation. Turning now again to our photographs, and calculating the angular distance between the first and second ring of protuberances, we find that distance to be $3' \ 15''$. We conclude, therefore, that this second ring is due to hydrogen. We, therefore, naturally looked for the third photographic hydrogen line, which is generally called *h*, but we found no protuberance on our photographs corresponding to that wave length. Although this line is always weaker than $H\gamma$, its absence on the photograph is rather surprising, if it be not due to the fact that the line is one which only comes out at a high temperature. This is rendered likely by the researches of FRANKLAND and LOCKYER (Proc. Roy. Soc., vol. xvii. p. 453).

We now turn to the last and strongest series of protuberances shown on our photographs. The distance between this series and the one we have found reason for identifying with $H\gamma$ is very little greater than that between $H\beta$ and $H\gamma$. Assuming the distances equal, we conclude that the squares of the inverse wave lengths of the three series are in arithmetical progression. This is true as a first approximation. We then calculated the wave length of this unknown line, and found it to be approximately somewhat smaller than 3957 tenth-metres. No great reliance can be placed of course on the number, but it appears that the line must be close to the end of the visible spectrum.

In order to decide if possible what this line is due to, we endeavoured to find out both by photography and fluorescence whether hydrogen possesses a line in that part of the spectrum. We have not at present come to any definite conclusion. In vacuum tubes prepared by GEISSLER containing hydrogen a strong line more refrangible than H is seen, but these same tubes show between $H\gamma$ and $H\delta$ other lines known not to belong to hydrogen, and the origin of the ultra-violet line is therefore difficult to make out. We have taken the spark in hydrogen at atmospheric pressures, as impurities are easier to eliminate, but a continuous spectrum extends over the violet and part of the ultra-violet, and prevents any observation as to lines. We are going on with experiments to settle this point.

Should it turn out that the line is not due to hydrogen, the question will arise what substance it is due to. It is a remarkable fact that the calculated wave length comes very close to H. YOUNG has found that these calcium lines are always reversed in the penumbra and immediate neighbourhood of every important sunspot, and calcium must therefore go up high into the chromosphere. We draw attention to this coincidence, but our photographs do not allow us to draw any certain conclusions.

At any rate it seems made out by our photographs that the photographic light of the protuberances is in great part due to an ultra-violet line which does not certainly belong to hydrogen. The protuberances as photographed by this ultra-violet ray seem to go up higher than the hydrogen protuberances, but this may be due to the relative greater length of the line.

In some of the protuberances the lower edge does not seem to touch the body of the moon, but the gas seems to hang like clouds in the corona.

Figs. 8 and 9, Plate 10, are copies of the photographs obtained by means of the prismatic camera.

2. *The Corona.*

We shall now have to examine the corona as shown on the photographs taken by the prismatic camera. If the spectrum given by the light of the corona is a line spectrum, we expect to find well-defined edges forming the limb of the moon. Only one such edge is seen on the photograph. It corresponds to the second ring of protuberances, and is, therefore, probably due to hydrogen. This was to be expected, as we know by the eye observations of LOCKYER and RESPIGHI that the hydrogen lines are the strongest lines in the photographic part of the corona. The upper part of the corona, as seen on the photographs, is such as would be given by homogeneous light, *i.e.* only one image of the corona is seen. We have tried several ways of finding the wave length of this light. A circle of the size of the image of the moon was cut out of paper and put over the photograph until the corona was symmetrical round this circle, as we know it to have been symmetrical round the moon. When the circle was in this position its edge coincided with the $H\gamma$ lower edge of the corona.

The photograph of the corona was enlarged to the same size as the photograph of the prismatic camera. They were laid over each other so that the outlines of the corona coincided as well as possible. Here, again, it was found that the edge of the moon coincided with the $H\gamma$ ring of protuberances.

We think, therefore, that we are entitled to say that the photographic rays of the corona are chiefly due to the hydrogen line $H\gamma$. Fig. 7, Plate 9, represents the protuberances and image of the corona symmetrical about the second series of protuberance as seen on our photograph.

In addition to this line spectrum of the corona, our photographs show strong marks of a continuous spectrum in its lower regions. This is chiefly shown by the well-defined structure running parallel to the line of dispersion due to irregularities drawn out by the prism into bands. We can easily determine the limits of the continuous spectrum by examining them at the inner side of the photographs. On the one side the structure stops short at the hydrogen line F. On the other edge, however, it extends to a considerable distance beyond the ultra-violet prominence line. Traces of light are distinctly seen to a wave length of 3530 and beyond.

Knowing the limits of the continuous spectrum we can determine approximately the height to which it extends; the distance between the extreme limit of the structure to the protuberance near H is about one and a half times the distance between the protuberance F and H. We know that we have no photographic trace beyond F, hence the angular height of the protuberance must be at least half the angular distance between the two prominences. The angular distance between the two prominences is rather more than 6′, hence the continuous spectrum extends at least to a distance of 3′ from the sun. The continuous spectrum is well shown on the photographs, figs. 8 and 9, taken at the beginning and end of the eclipse respectively. One of the plates in the prismatic camera was exposed during the last part of the eclipse until the signal for the end of totality was given. All the observers agreed in saying that the signal was given rather too late, and the fogginess of the plate indicates the great intensity of the light. Yet the edge of the sun is not drawn out into a continuous band, but rather into three distinct bands, showing that at the time of exposure the lower part of the chromosphere only had appeared. These lower parts gave out light of such intensity that to all observers it appeared as if the body of the sun had come out.

A series of rapid photographs taken at beginning and end of totality would no doubt give most interesting results.

VII. RESULTS OF THE SPECTROSCOPIC CAMERA.

Arrangements were made to photograph the spectrum of the prominences and corona by means of a camera attached to a spectroscope. No results were obtained, and we must, therefore, discuss the reason of this failure, and see whether the instruments can be improved in such a way as to give a fair chance of success in other eclipses. The light of the corona no doubt is very feeble, but considering that the prismatic camera has given good photographs in one minute, and that we have obtained direct photographs of the corona in two seconds, success is not out of question. Even the instruments used during the last eclipse have not had a fair trial. Owing to delays on the journey only one day could be given to the adjustments of the instruments, and as the spectroscopes had never been used before they could not in that time be brought into the best possible state. It was, indeed, found that all the collimators were too long. As they could not be made shorter without considerable delay, the cameras had to be adjusted for the rays which were converging as they passed through the prism. This, of course, damaged much the definition of the image, especially as the prisms were made of quartz. In order to obtain a reference spectrum the cusp of the reappearing sun was thrown on the slit and exposed for about 15 seconds. Yet even this reference spectrum did not appear, showing that the instrument must have been out of order. The focal length of one of the cameras used was too large, yet the other ought to have given results had the image of the corona been bright enough. This camera was attached with its spectroscope to the only equatorial available for use for the purpose; it was kindly lent to the expedition by Mr. PENROSE. The proportion of the aperture to the focal length in this instrument is 1 : 16. This proportion in the reflecting telescope used by Dr. JANSSEN is 1 : 4, it has, therefore, 16 times as much light as that used by the English expedition. The observations to be made during total solar eclipses have arrived at such a point that a successful attack can only be made with instruments constructed for the purpose. We feel sure that if in future expeditions an instrument similar to that used by Mr. Janssen is provided, the spectrum of the corona can be photographed. As far as the higher regions are concerned, it is true we shall not learn anything beyond what is given by the prismatic camera, but as far as the lower regions are concerned important results may be expected.

VIII. PHOTOGRAPHS AND SKETCHES OF THE CORONA.

We must inquire next what information was obtained from the photographs and sketches of the corona itself. Eight photographs were obtained by means of a small camera belonging to Mr. Beasley, the object glass having a focal length of about 13 inches. The camera was not moved by clockwork, but during the short exposure the sun's movement, though visible, does not materially affect the results. The times of exposure were 2, 4, 8, and 16 seconds, and two photographs of each exposure were obtained. As these two sets show exactly the same phenomena we need only consider one set, remembering, however, that the other set excludes the possibility of any of the results being affected by irregularities in the collodion-film. The four photographs are shown in figs. 10, 11, 12, and 13.

Looking over one set we are first struck by the rapid increase in the extent of the corona through an increase in the time of exposure; the last of the photographs, having been exposed 16 seconds, shows an extent exceeding the diameter of the sun.

The next point of interest is the symmetry of the outer corona round the sun's axis. This symmetry was dwelt on by Mr. E. J. Stone, in the eclipse of April, 1874. (Memoirs of Royal Ast. Soc., vol. xlii. p. 31.)

The small size of our photographs does not, indeed, allow us to fix the position of the axis within one or two degrees, but even then, allowing for this uncertainty, the symmetry is very striking. We have marked, as well as could be ascertained, the position of the sun's axis on fig. 7, Plate 9. The similarity in the corona, as observed by us and by Mr. Stone just one year before, is exceedingly curious. The drawings given by Mr. Stone, in so far as they agree amongst themselves, agree with the corona observed at Siam. This similarity does not merely extend to the symmetry about the sun's axis, but also to the irregularities in this symmetry. Thus the nearly straight boundary lines of the corona, which cut the axis at nearly right angles, are not quite parallel but converge in both eclipses towards the east. The west side of the corona seems much more compact, the east side broken up into what the Siamese called fish-tails. The similarity is, perhaps, most striking between Mr. Bright's drawing (L. C., p. 51) of the corona in 1874, and the drawing made by Prince Tong (fig. 14, Plate 13), by order of His Majesty the King of Siam, of the corona in 1875. The two drawings could certainly pass for representations of one and the same eclipse.

At the observatory the Honorable H. N. Shore undertook to sketch the corona.

Fig. 15 is the sketch made by him during totality. Fig. 16 a more detailed copy directly after totality.

The similarity between this sketch and Mr. Wright's of the corona in April, 1874, again is very striking.

One point connected with Mr. Shore's drawing deserves special notice. A remarkable rift in the corona towards the south excited his notice during the eclipse, and he tried to give as correct a representation of it as possible. This rift is shown not only in all our photographs of the corona itself, but also in the prismatic camera. It is, indeed, the rift by means of which the upper part of the corona could be most exactly determined to be due to hydrogen.

This shows that though the substance giving the green line may play an important part in the corona, the structure is in great part due to hydrogen.

This is confirmed by an observation of Captain Herschel's, who, in 1871, found the green line of the corona to cross the field with the slit across the edge of a rift. (Memoirs of Royal Ast. Soc., p. 23.)

A great number of drawings have been made by the Siamese. We especially note the drawings made by the following gentlemen :—

H.R.H. Chau fa Maha Mala (fig. 17, Plate 14).
H.R.H. Prince Devanndaywongse (fig. 18, Plate 14).
H.R.H. Prince Chetochereun (fig. 19, Plate 13).

His Majesty the King has sent a drawing of the prominences as seen by him during the eclipse (fig. 20, Plate 14).

IX. THE CAMORTA EXPEDITION.

It has already been stated that Mr. Meldola and Dr. Vogel separated at Galle in order to join the expedition sent out from India in charge of Captain Waterhouse. They arrived at Camorta on the 22nd of March, and found that considerable preparations had already been made by the Assistant Commissioner, Mr. F. A. De Roepstorff. All the instruments were in excellent working order on the day of the eclipse, but clouds prevented any observation during totality.

Dr. Vogel, assisted by Mr. Good, third officer of H.M.S. 'Enterprise,' had intended to photograph the spectrum of the prominences by means of plates prepared by his method, which had the greatest sensibility in the yellow part of the spectrum.

The prismatic camera was in charge of Mr. R. Wood, chief engineer of H.M.S. 'Enterprise.'

The quartz telespectroscope was attended to by Mr. Meldola.

Arrangements had been made to make polariscopic observations by means of a polariscopic camera, placed at the services of the expedition by Mr. Spottiswoode, F.R.S. The instrument was attended to by Dr. Rud. The dark chamber was in charge of Mr. Reynolds.

Captain WATERHOUSE had intended to photograph the corona by means of the same instrument used by Colonel TENNANT in 1871.

Captain KING and Mr. CHATTERJEE had volunteered to act as timekeepers.

Professor TACCHINI undertook all the observations to fix the latitude and longitude of the spot of observation, and also to determine the local time. Professor TACCHINI had also watched any prominences during the days preceding the eclipse and on the morning of the eclipse. He writes: "On the mornings of the 4th and 6th April the sun was almost entirely free from protuberances, which was in favour of the special object of the expedition to examine the light of the corona. On the morning of the 6th at the angle 107° I saw bright flames which seemed to indicate an eruption, but after having finished the examination of the limb all had disappeared, and with the narrow slit I saw no reversed lines beyond the ordinary ones of hydrogen, and I also obtained the same result in other parts of the limb."

Considering the complete state of preparation, it is a matter of great regret that the observations were prevented by the state of the weather.

X. SUMMARY OF RESULTS.

In conclusion we give a summary of the results which we have obtained :—

1. The light given out by the prominences when analysed by a prism gives in the less refrangible part of the photographic spectrum two lines, which are most likely due to the hydrogen lines $H\beta$ and $H\gamma$.

2. The strongest protuberance line lies in the ultra-violet. The actinic effect of the protuberances must chiefly be due to this line.

3. The upper parts of the corona give a photographic spectrum which is homogeneous and apparently due to the hydrogen line near G.

4. The lower parts of the corona send out a strong continuous spectrum, extending into the ultra-violet to a wave length 3530, that is, beyond N, and reaching to a height of about 3′ from the sun.

5. Photographs of the corona show that the extent of the corona rapidly increases with increasing times of exposure. The corona has, therefore, no definite outline.

6. We have been able to confirm the results obtained by Mr. STONE that the corona is symmetrical round the axis, the greatest extent being in the direction of the sun's equator.

7. The corona presents a striking resemblance to that observed just one year before by Mr. STONE at the Cape of Good Hope.

Fig. 1.

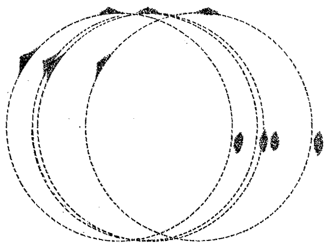


Fig. 2.

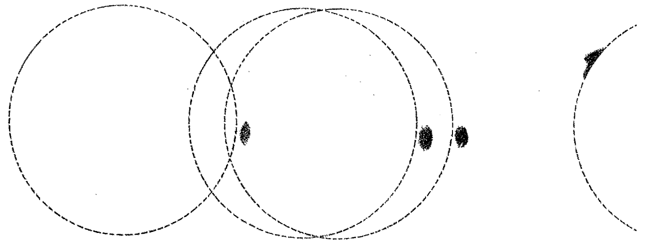
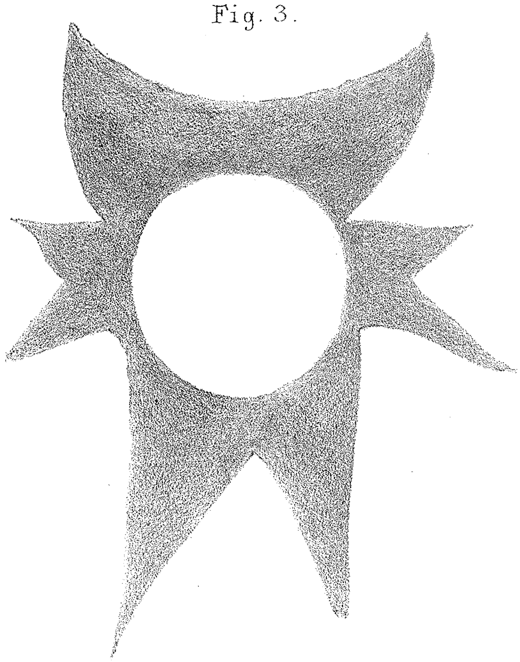


Fig. 3.



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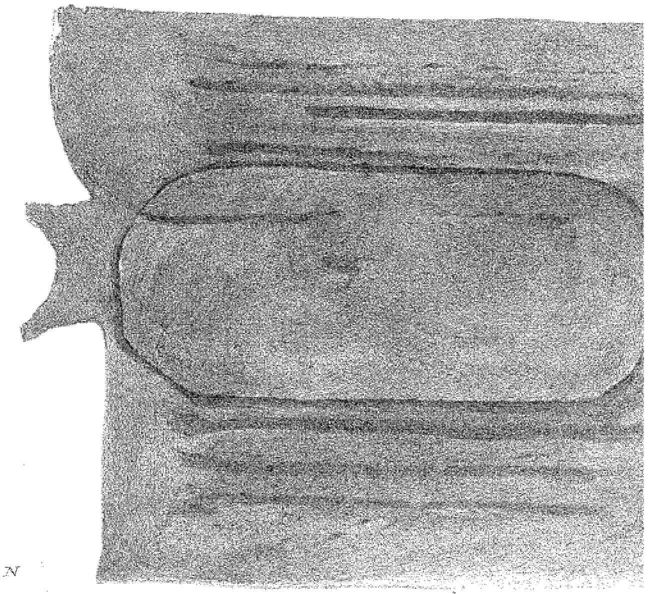


Fig. 7

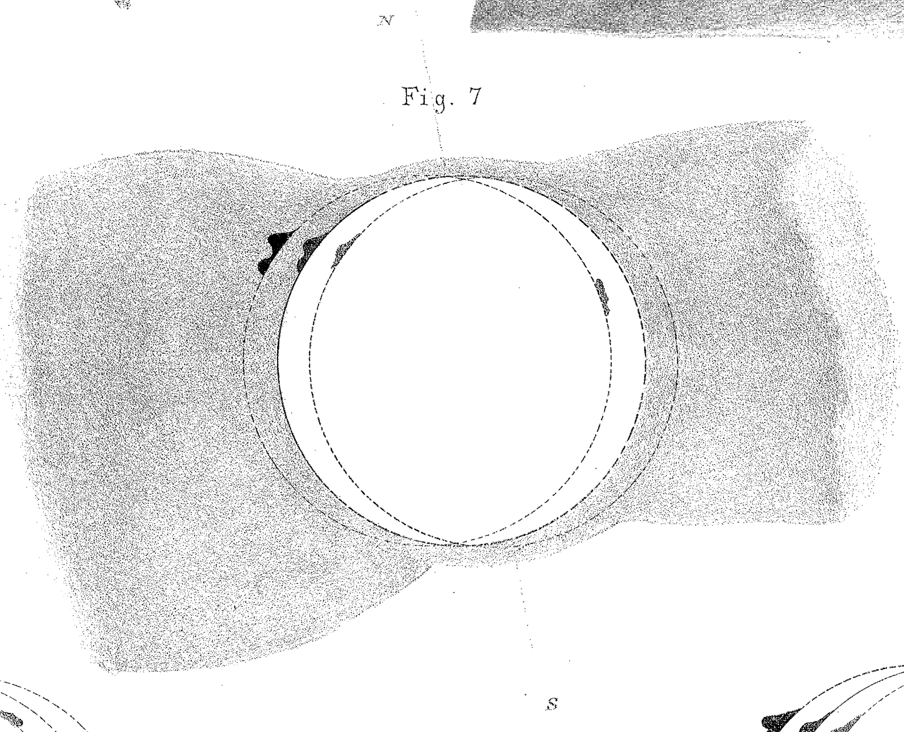
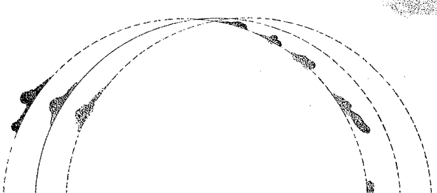


Fig. 5.



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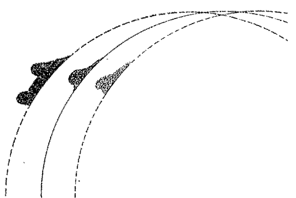

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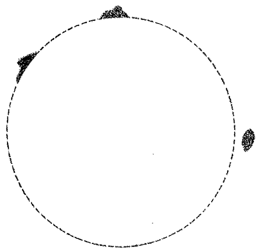

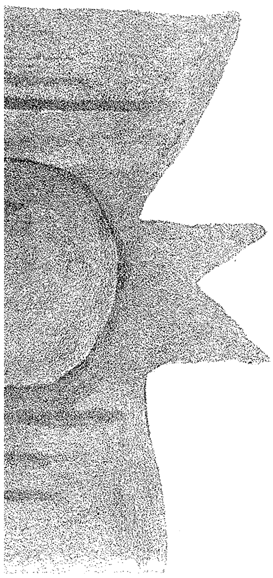

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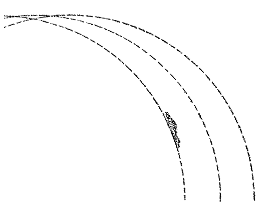
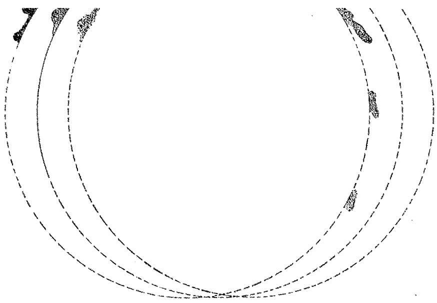
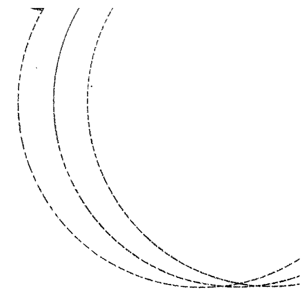
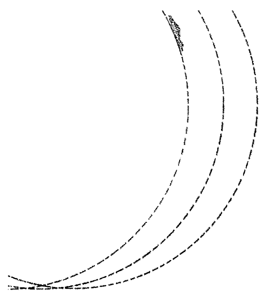








W. West & Co. lith.

Fig 8.

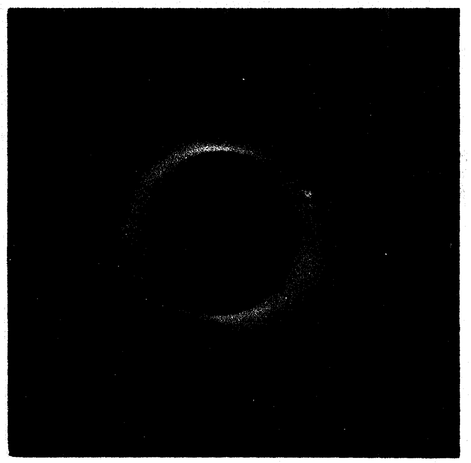


Fig 9.

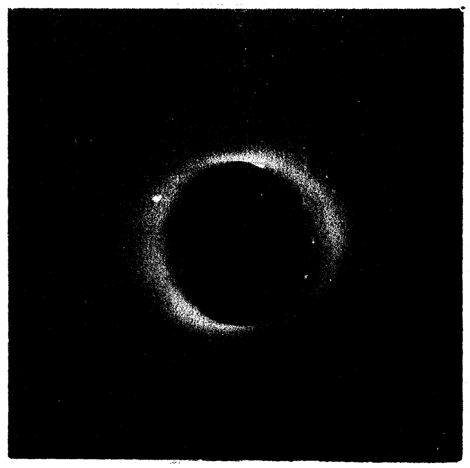


Fig 10.
Exposure 2 Seconds.

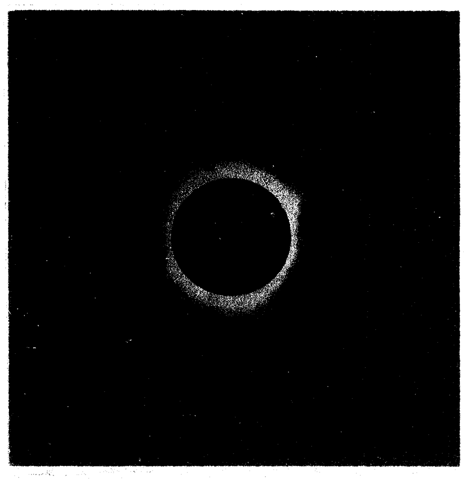


Fig 11.
Exposure 4 Seconds.

Fig 12.
Exposure 8 Seconds.

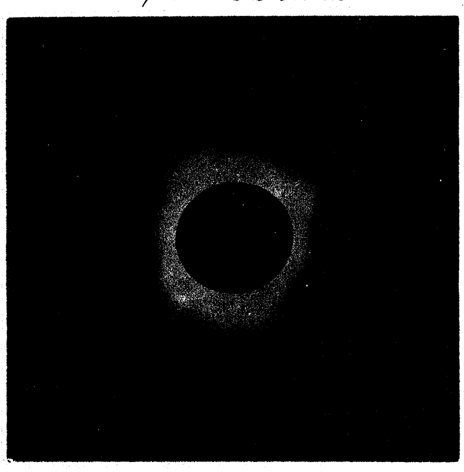


Fig 13.
Exposure 16 Seconds.

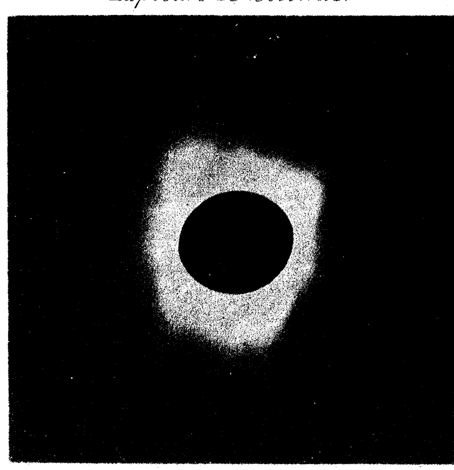
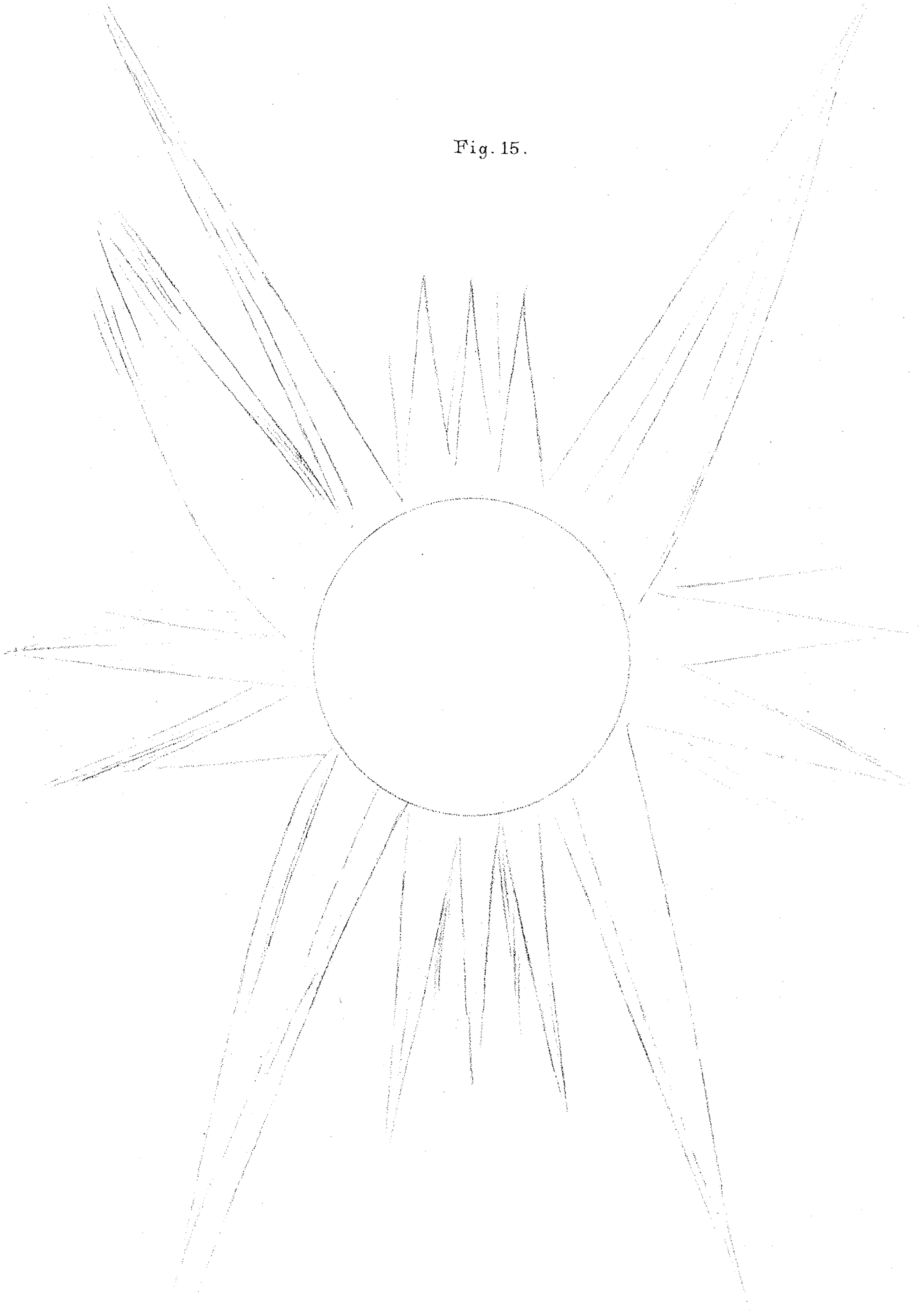
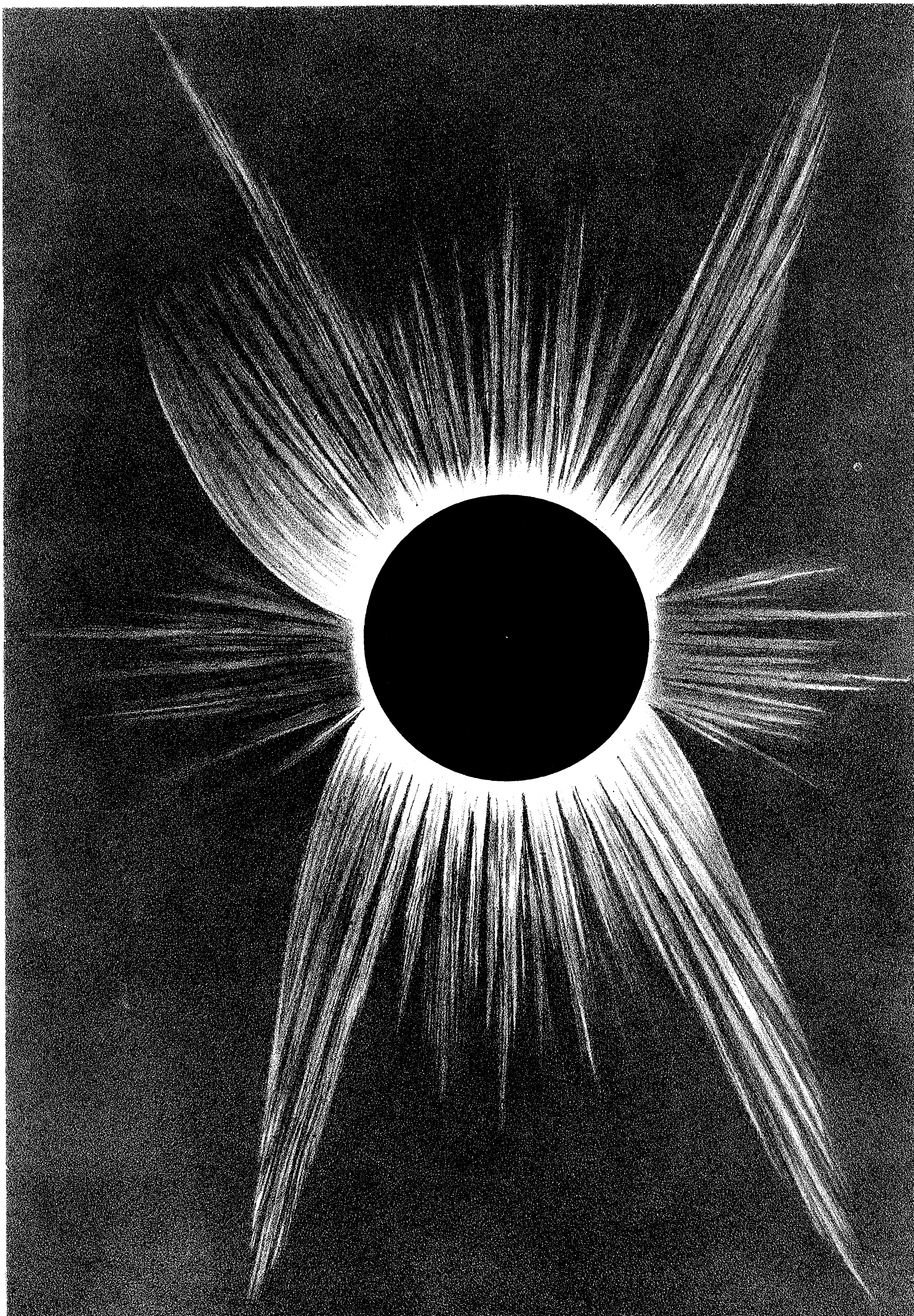


Fig. 15.



W. West & C[o] lith.

Fig. 16



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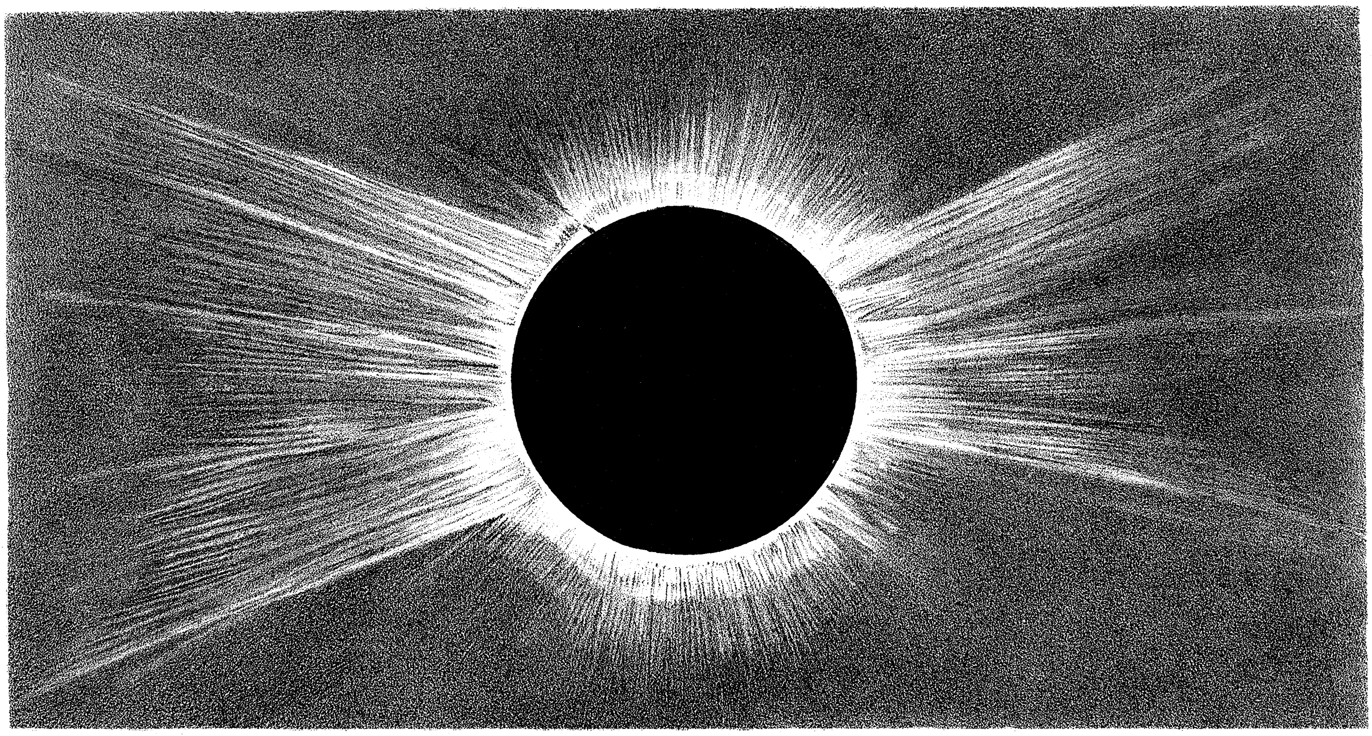

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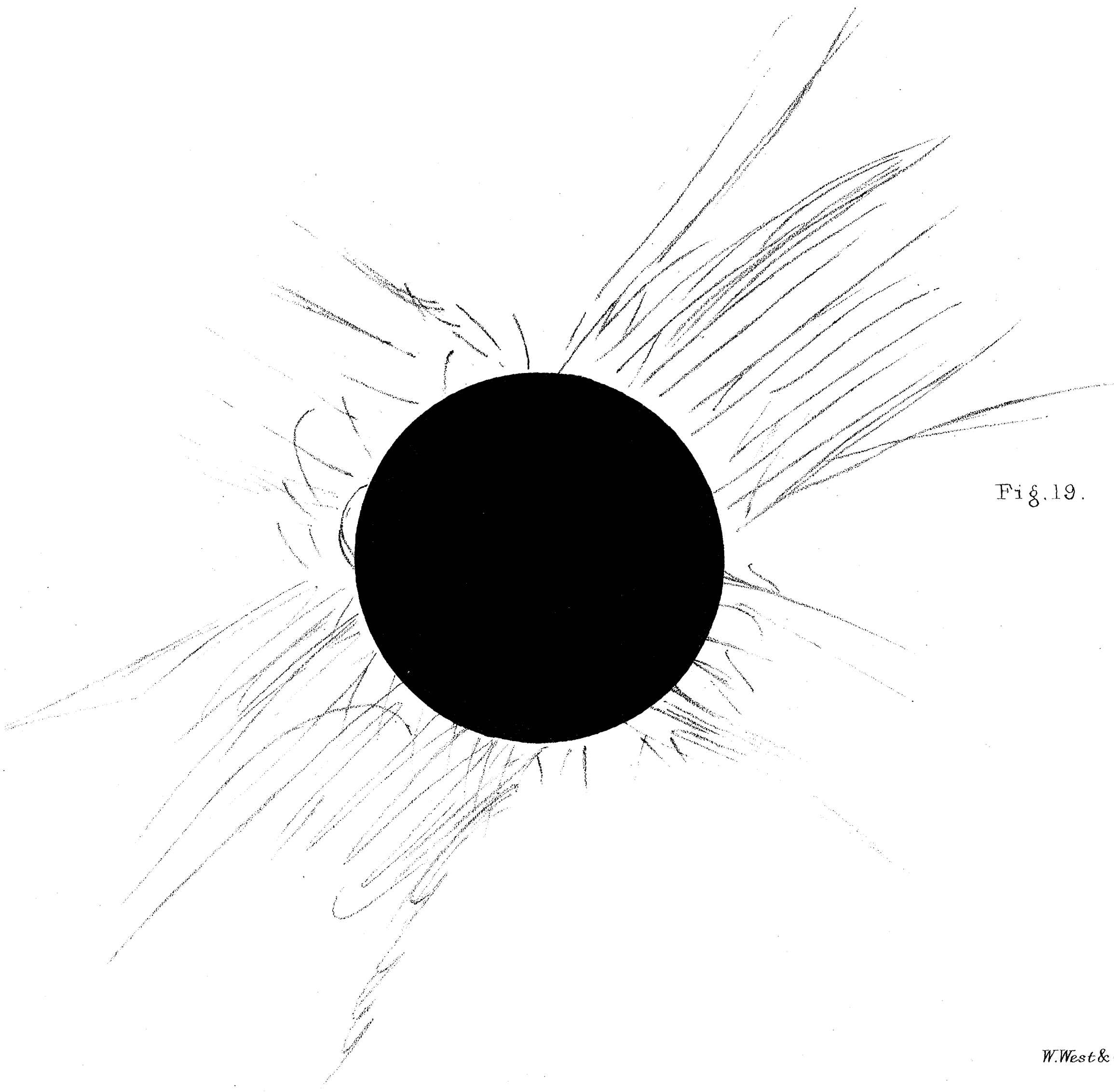
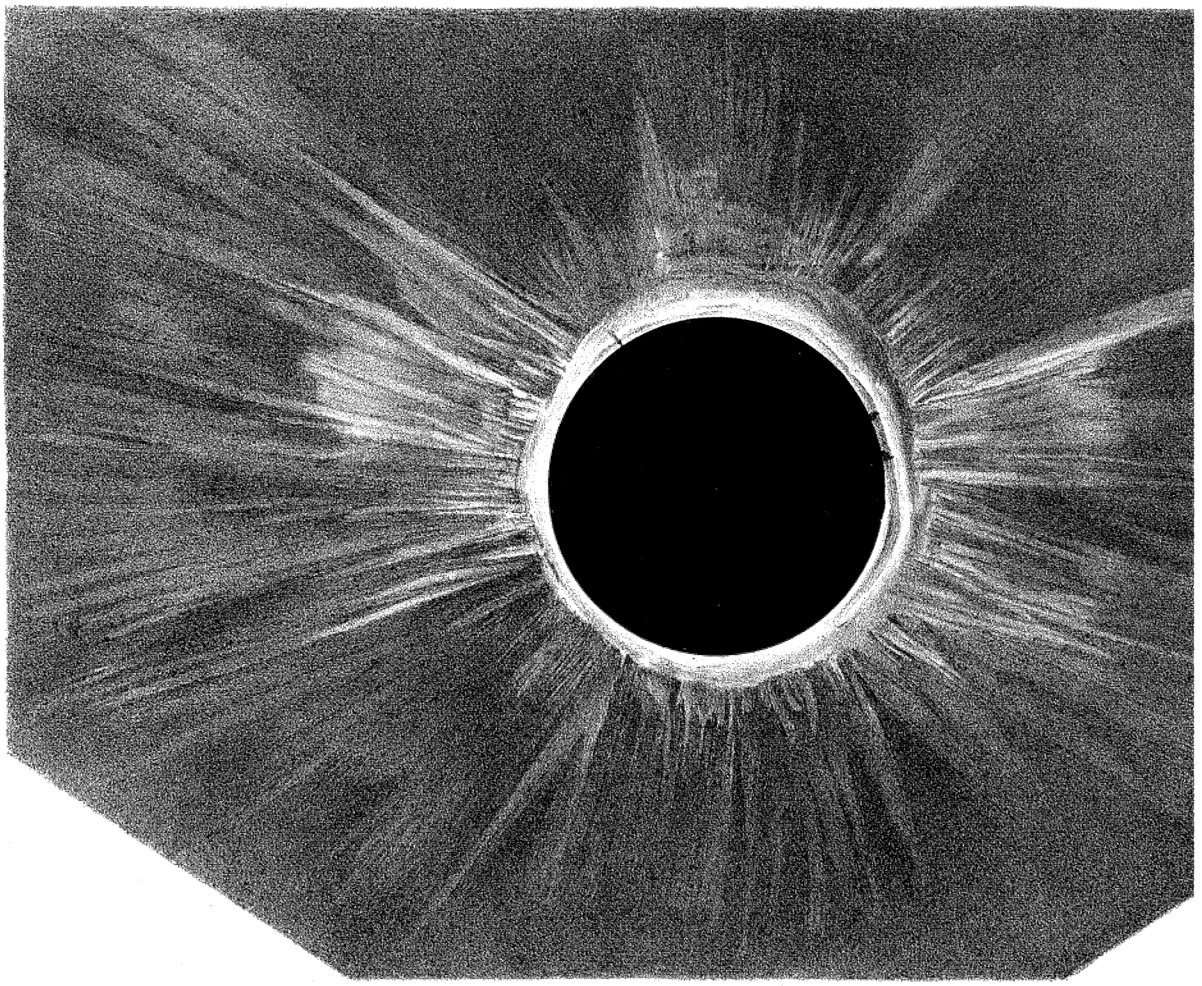


Fig. 19.

W. West & Co. lith.



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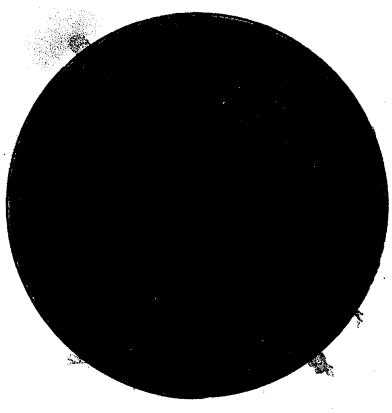

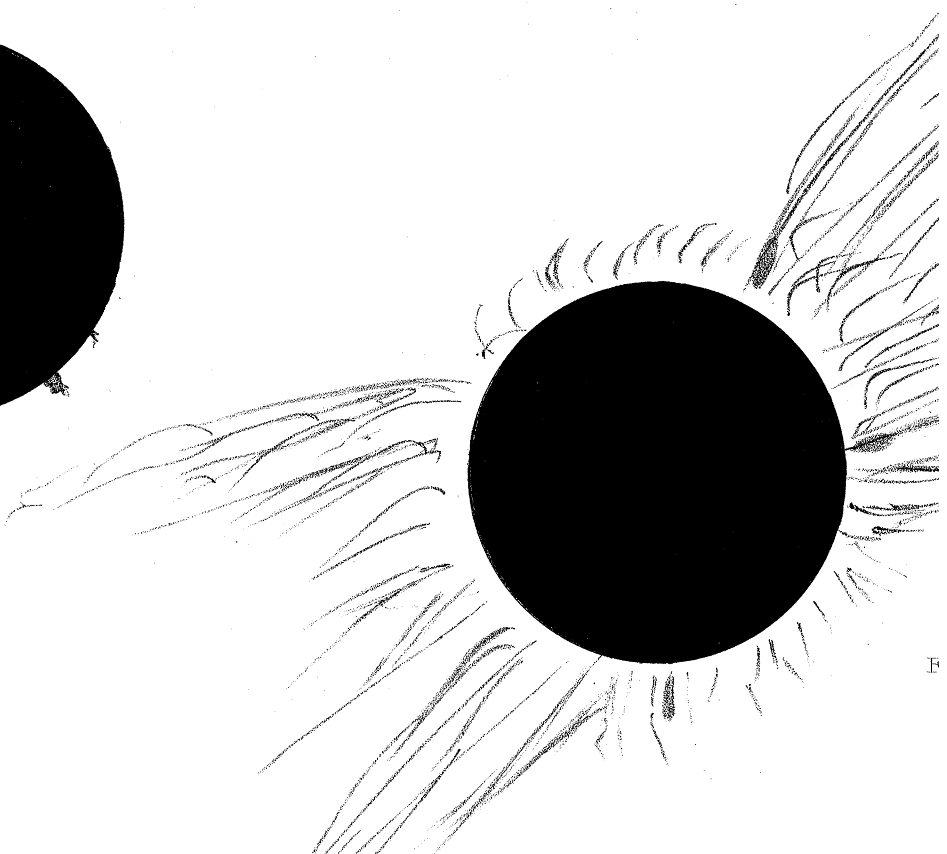

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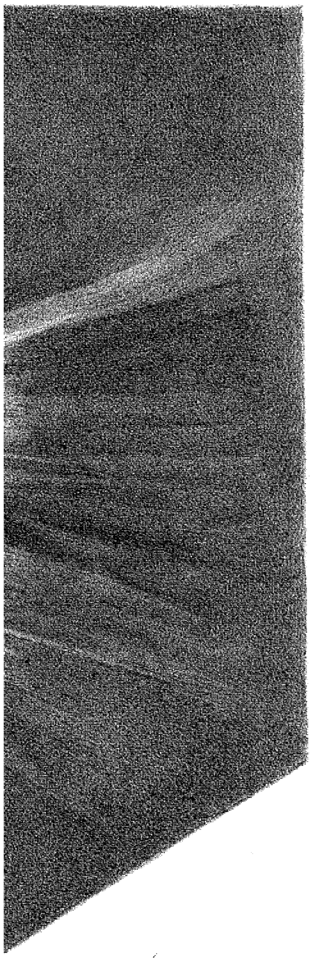

Fig. 17.

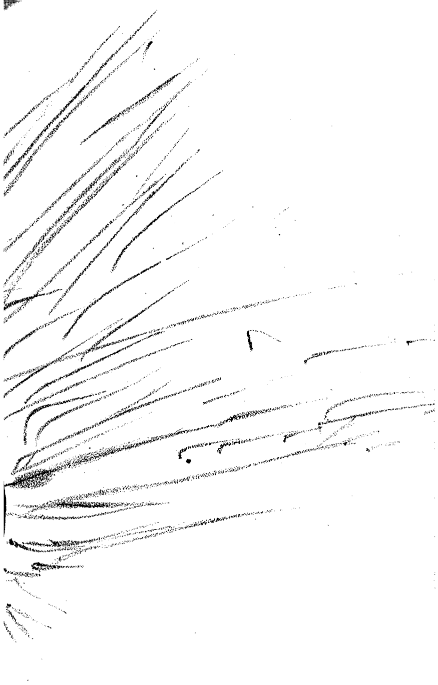

Fig. 18.

W. West & Co. lith.

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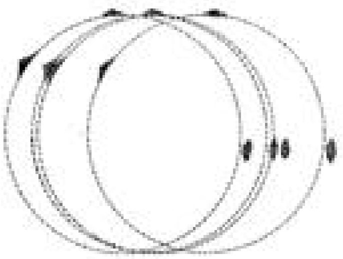

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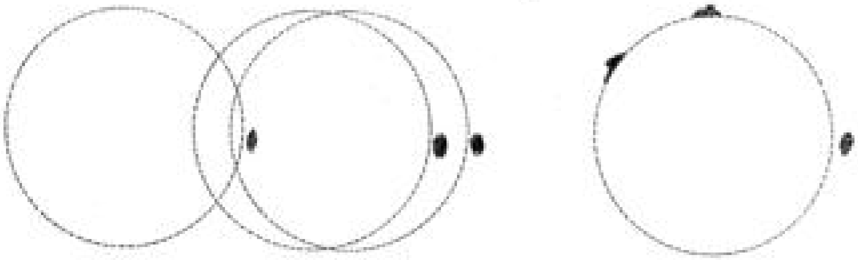
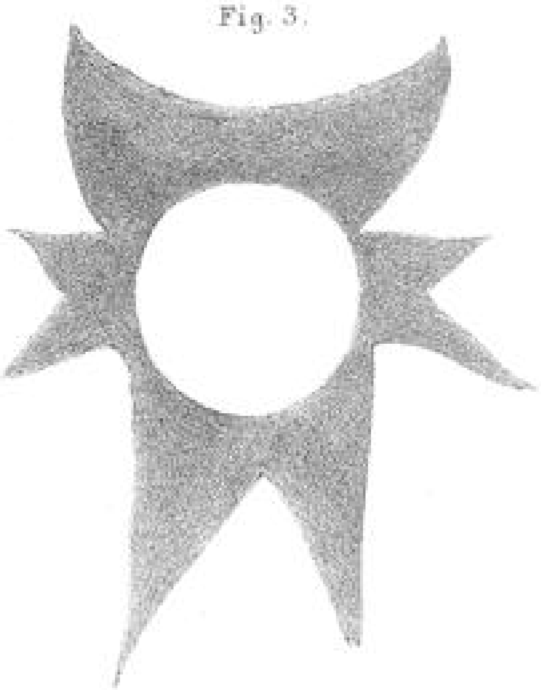


Fig. 3.



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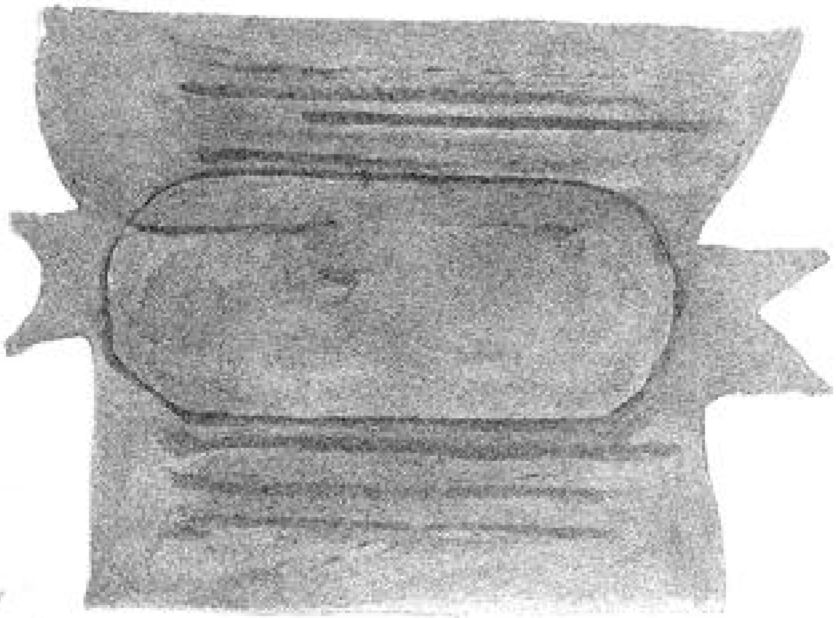
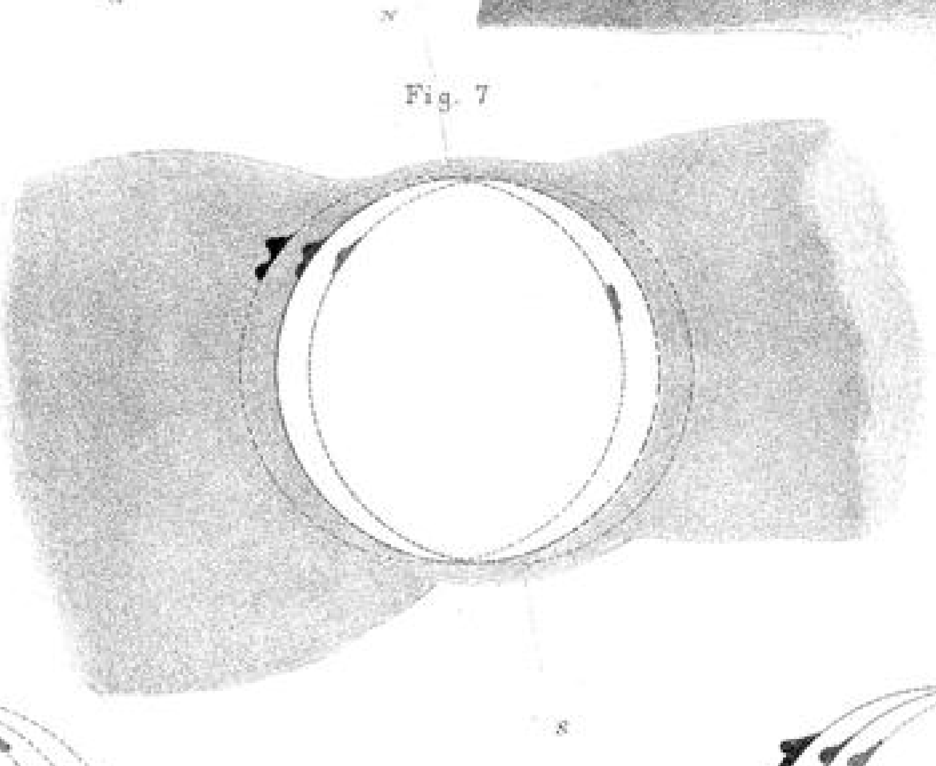


Fig. 7



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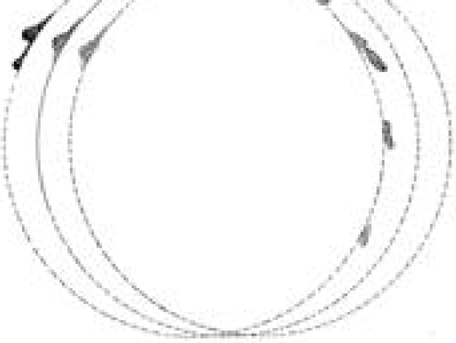
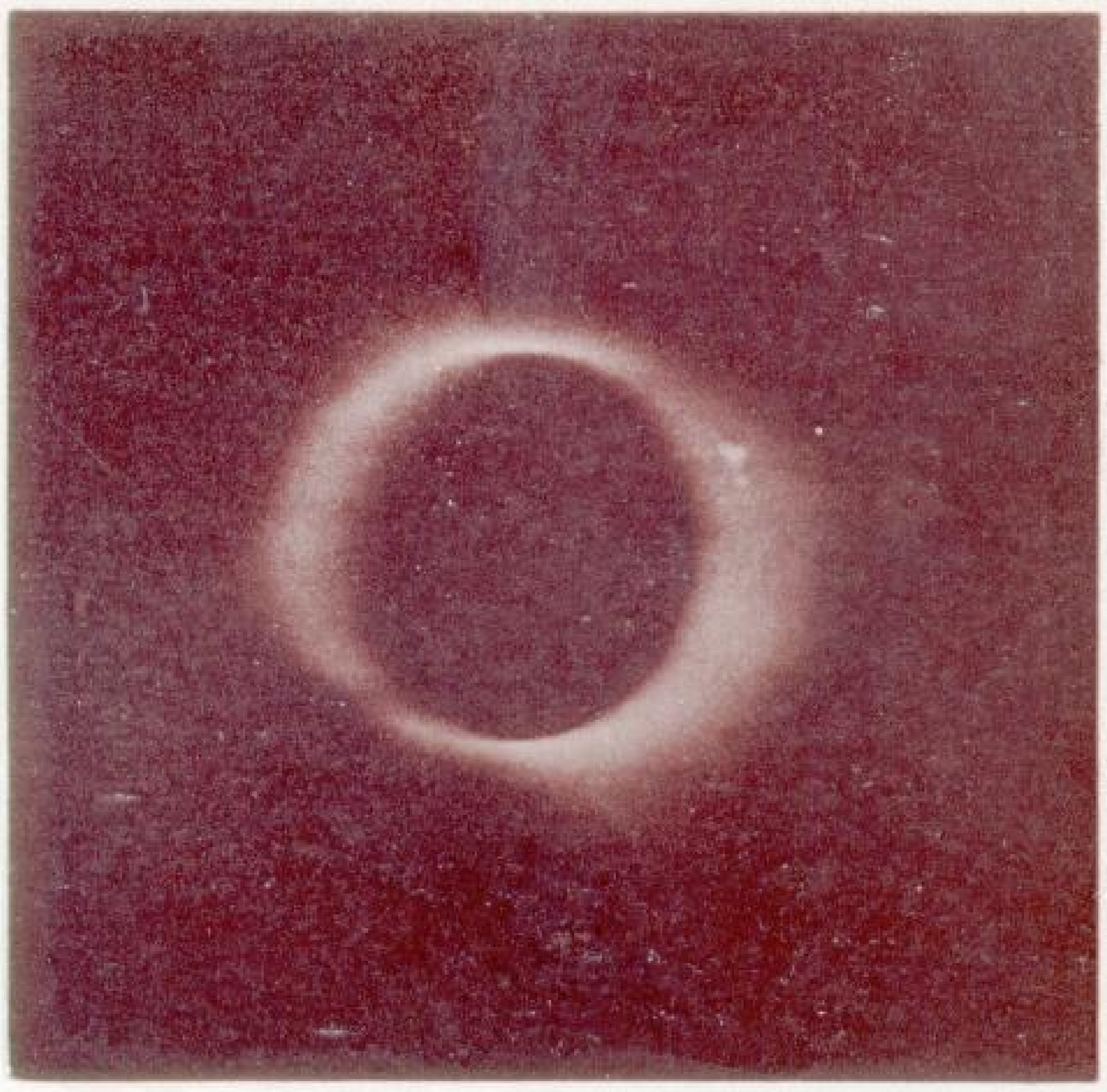


Fig. 6.

W West & C° lith.

Fig 8.



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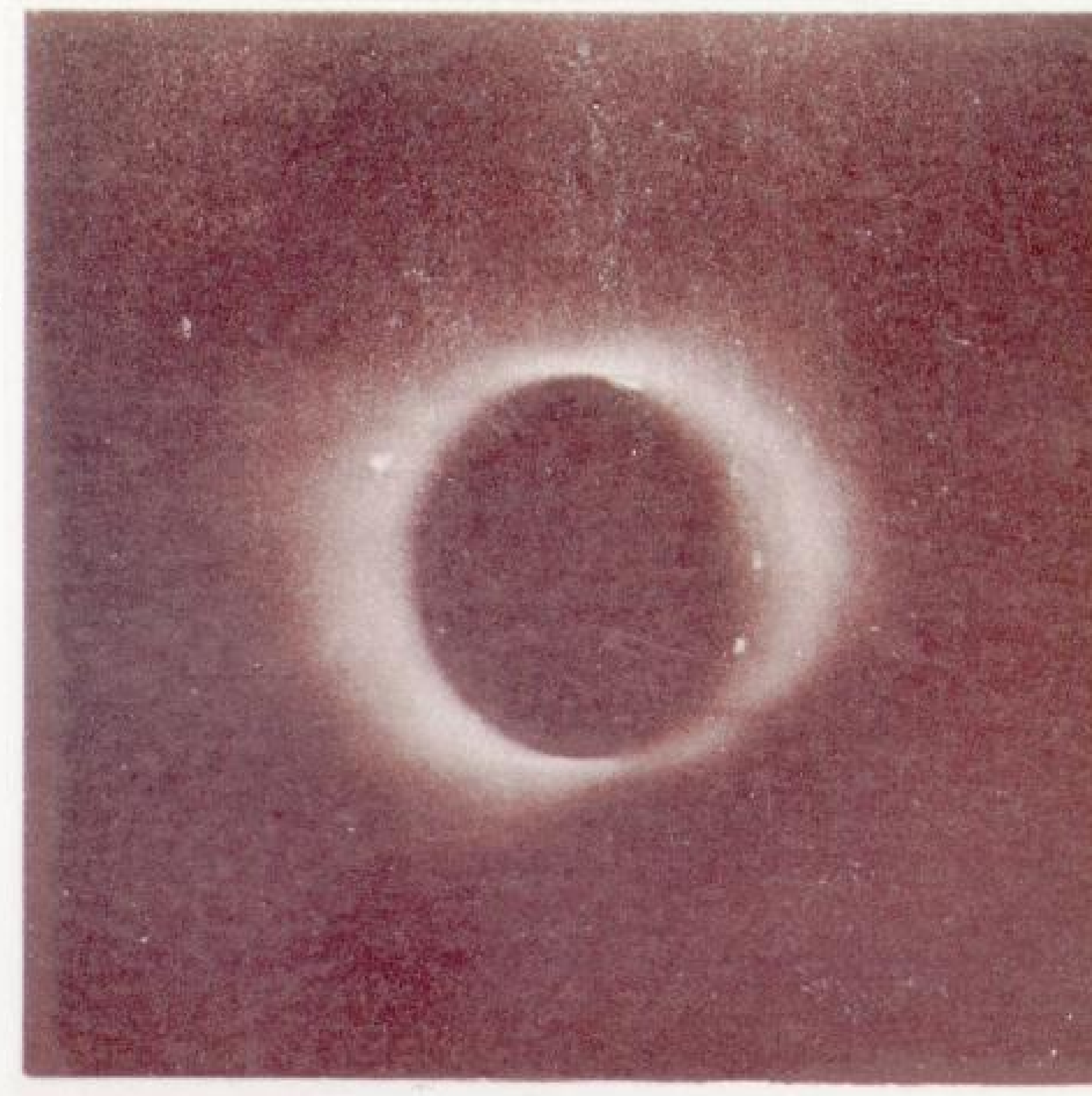
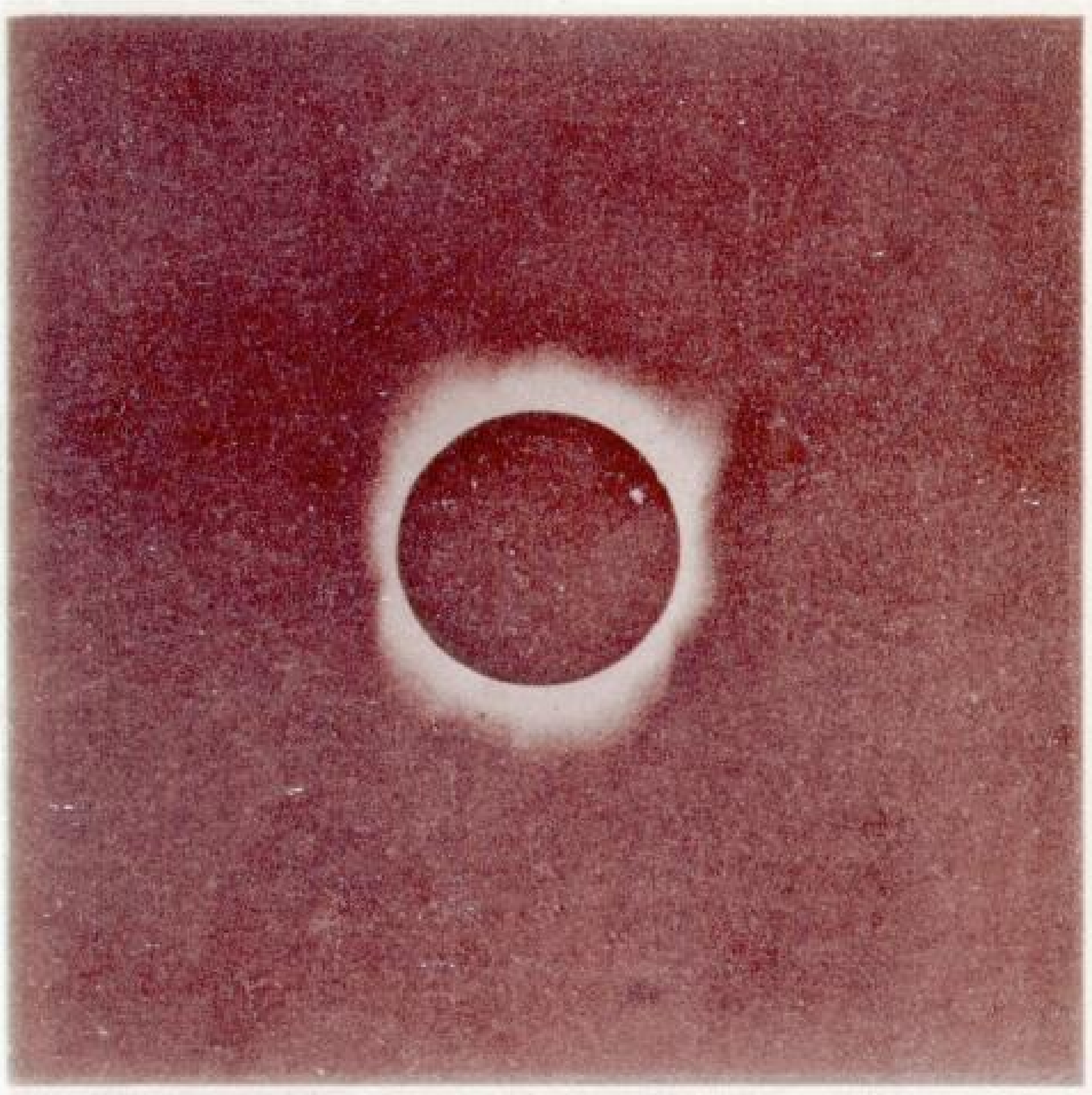


Fig 10.
Exposure 2 Seconds.



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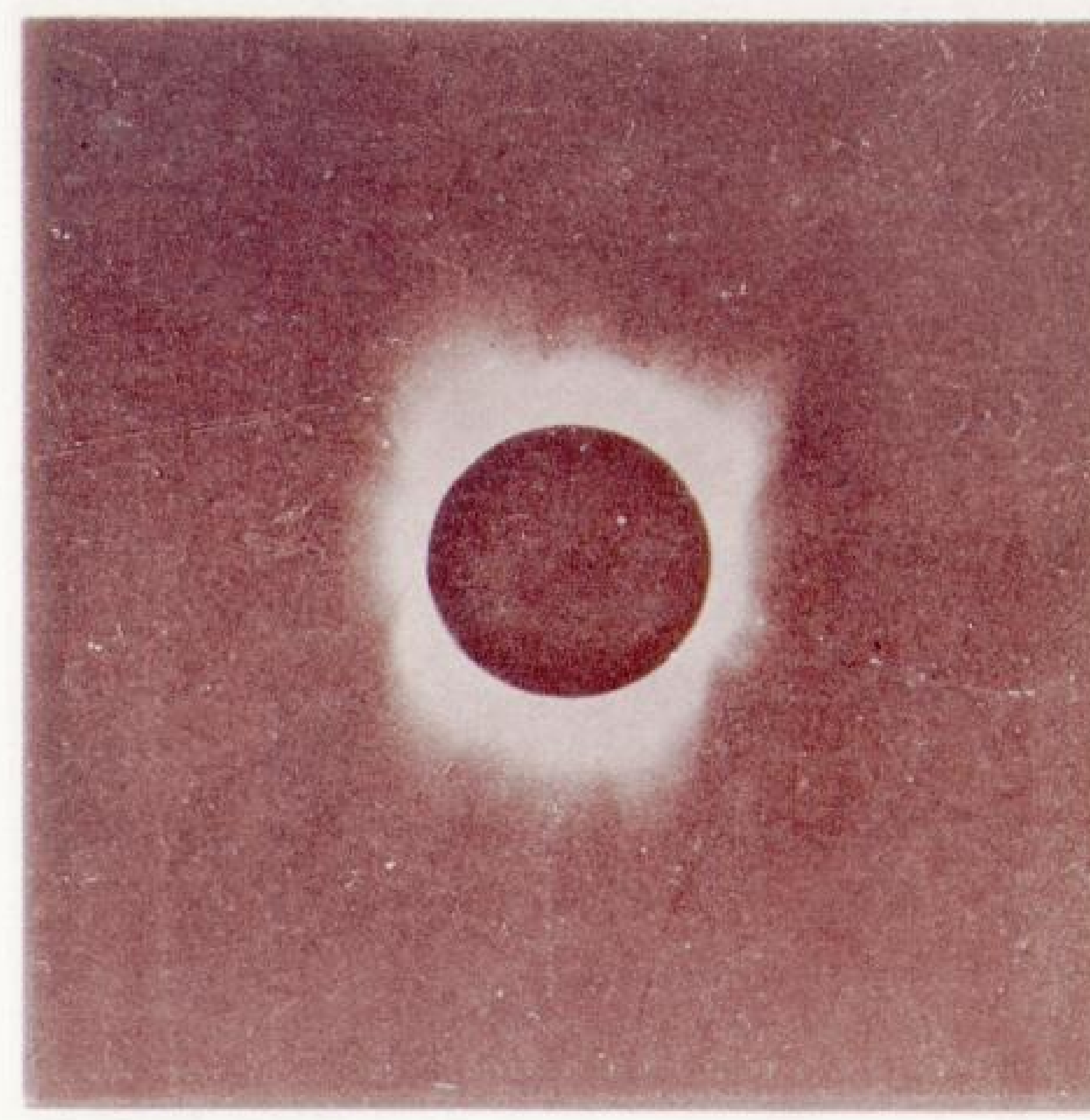

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Exposure 8 Seconds.

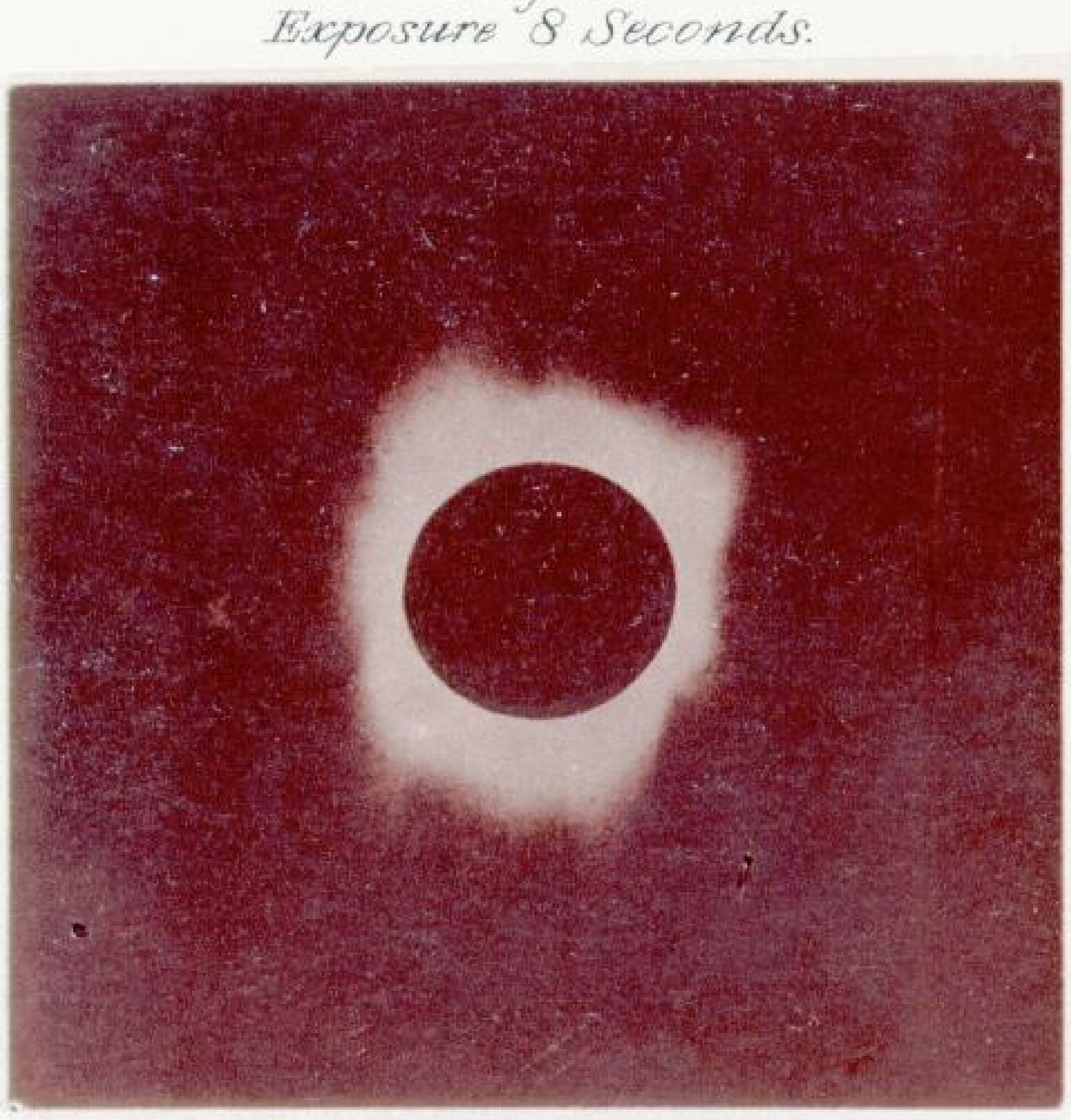
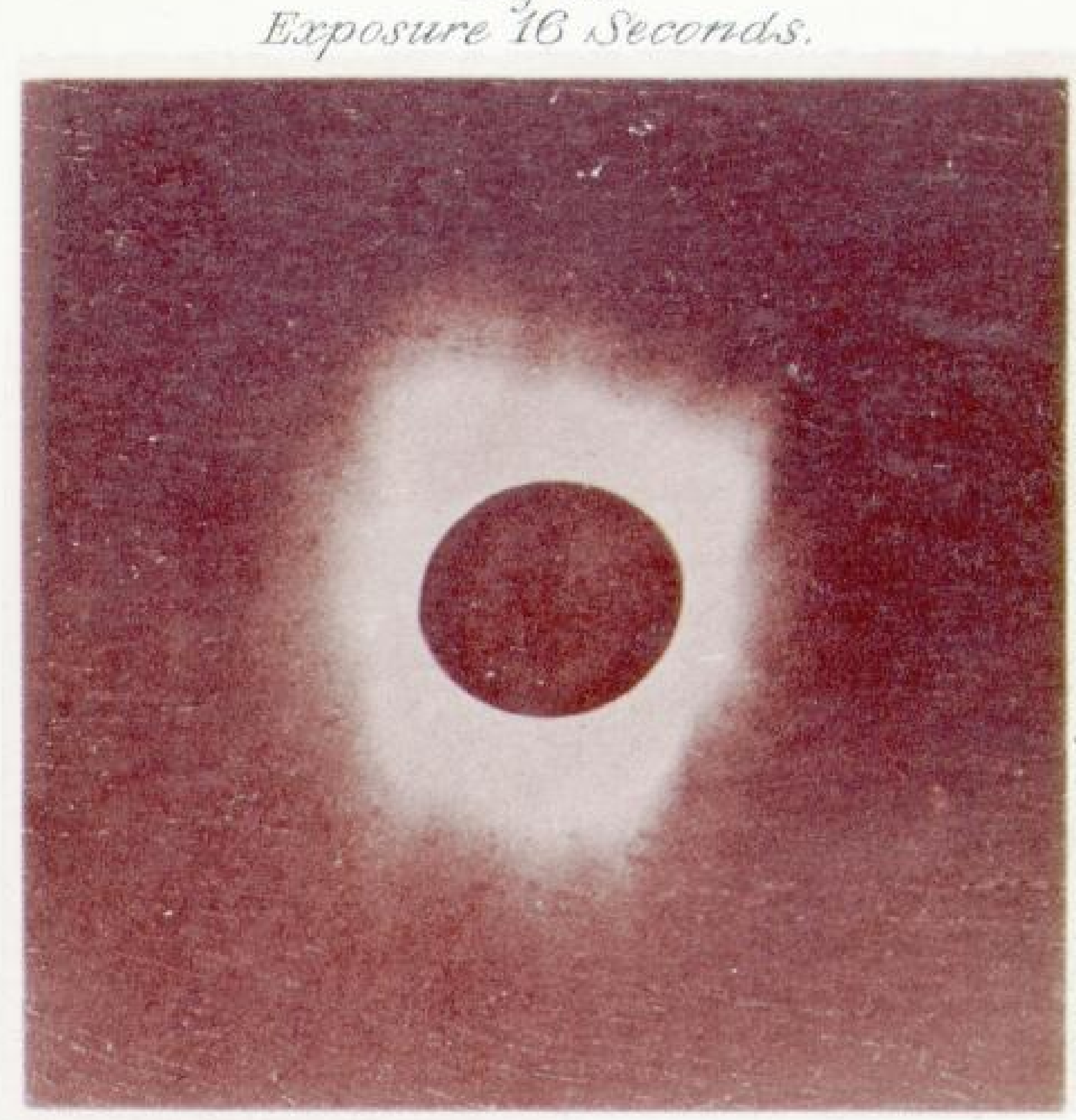


Fig 13.
Exposure 16 Seconds.



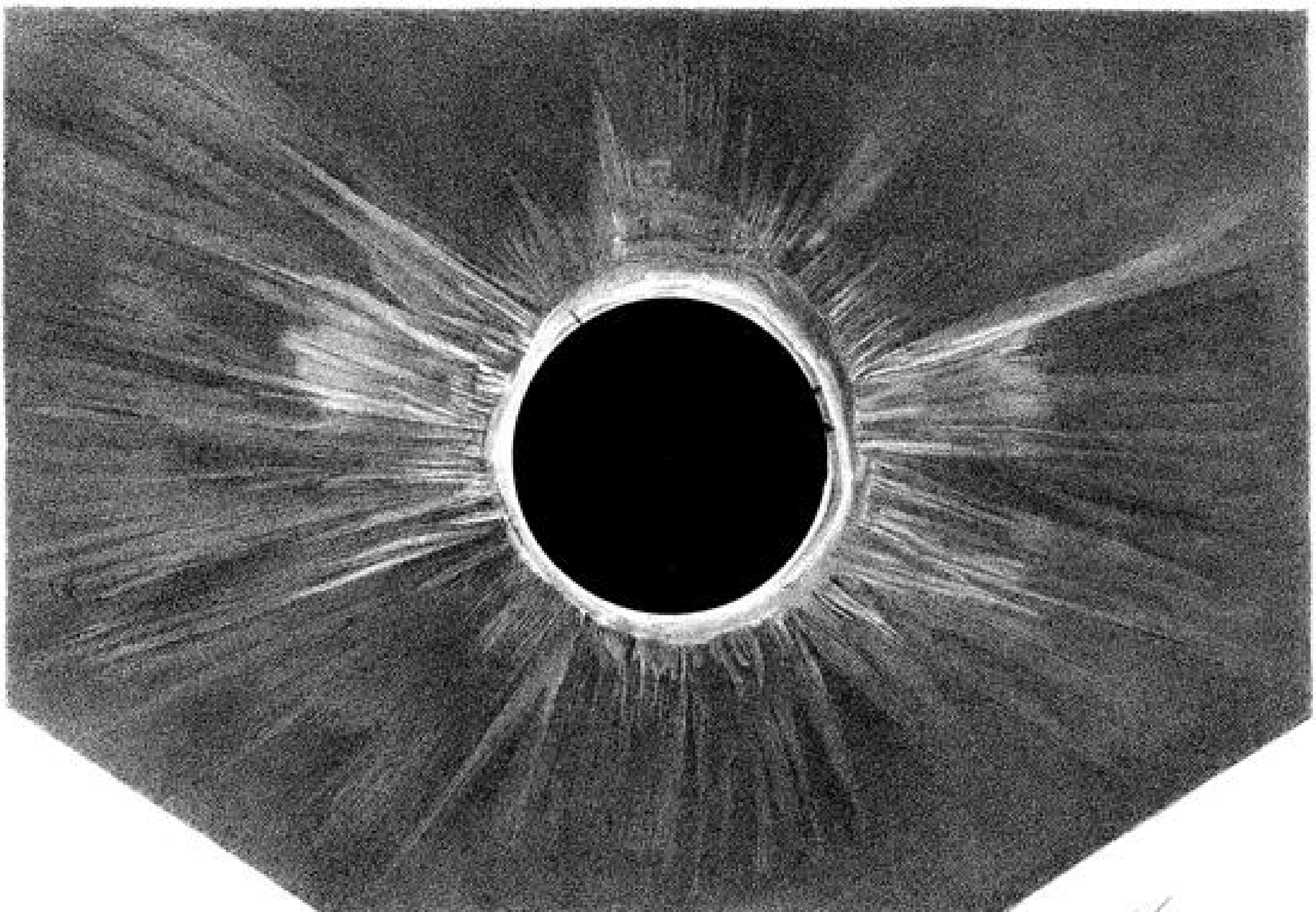
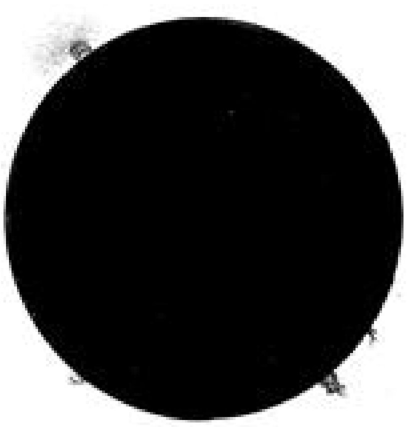


Fig. 17.



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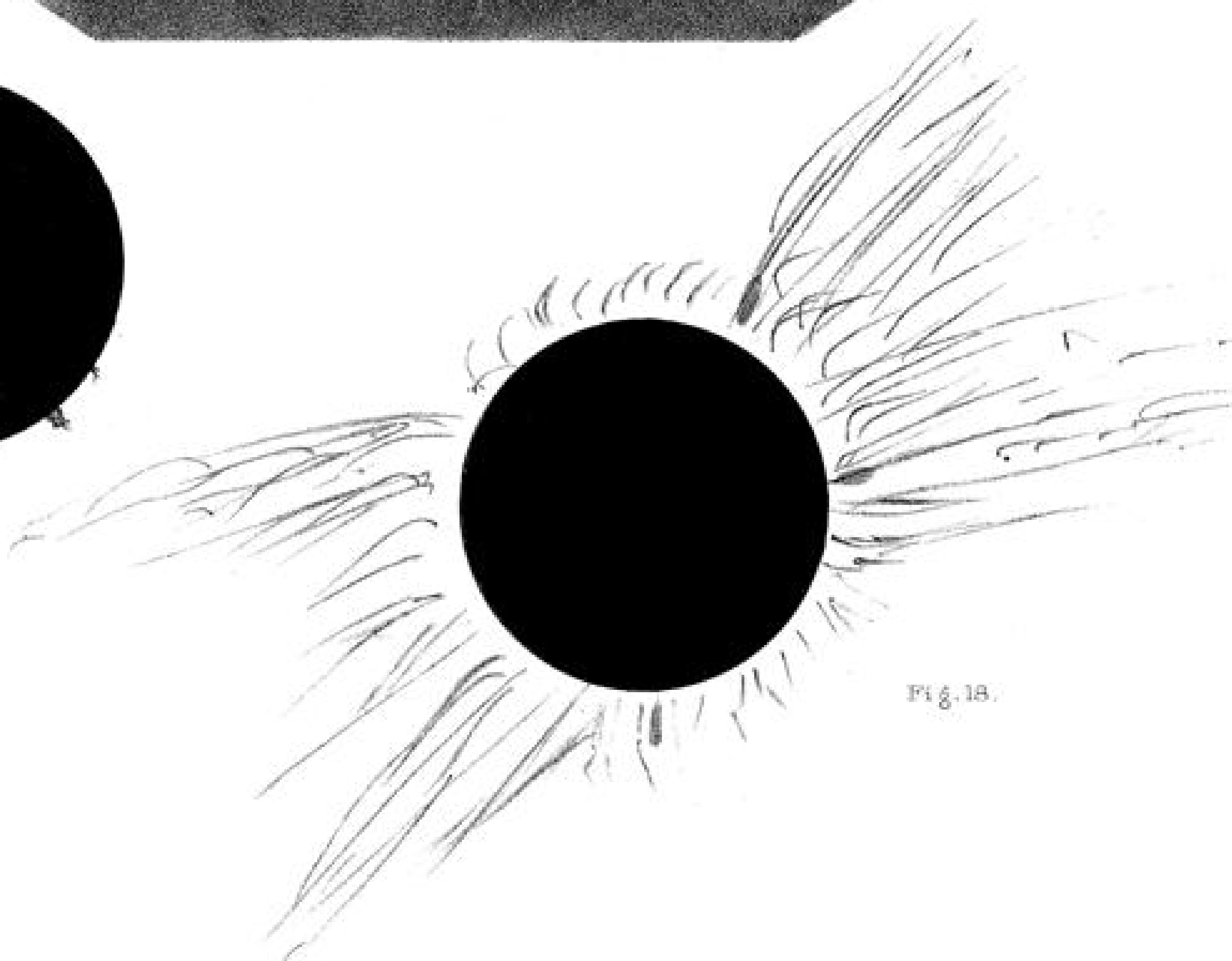

Fig. 18.

W. West & Co. lith.