#SCIENCE

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*THE DEVELOPMENT OF PHOTOGRAPHY IN ASTRONOMY (I.).**

THE American Association for the Advancement of Science has now completed an existence of half a century. It has become one of the leading scientific institutions of this country. Since its organization fifty years ago the world has advanced with wonderful rapidity in all directions, and especially in the various fields of science. It is hardly too much to say that the scientific progress in the last half century far exceeds all that was done in the preceding thousand years. The life of this Association practically covers the development and comparative perfection of many of the sciences. This is especially true of the wonderful art of photography. At the beginning of the work of this Association the great discovery of making pictures by the natural light of the sun had just been made, and while it aroused a widespread interest all over the world at that time there were very few who dreamed of the great future value of photography in the arts and sciences. One of those who saw something of the future of Daguerre's discovery was the celebrated Scottish astronomer Dr. Dick, whose works on popular astronomy are still useful and delightful reading. In his 'Practical Astronomer,' published in 1845, he said:

*Address of the Vice-President before Section A—Mathematics and Astronomy—of the American Association for the Advancement of Science, August 22, 1898.

"It is not improbable, likewise, that this art (still in its infancy) when it approximates to perfection, may enable us to take representations of the sublime objects of the heavens. The sun affords sufficient light for this purpose; and there appears no insurmountable obstacle in taking, in this way, a highly magnified picture of that luminary which shall be capable of being again magnified by a powerful microscope. It is by no means improbable, from experiments that have hitherto been made, that one may obtain an accurate delineation of the lunar world from the moon herself. The plated discs prepared by Daguerre receive impressions from the action of the lunar rays to such an extent as permits the hope that photographic charts of the moon may soon be obtained; and, if so, they will excel in accuracy all the delineations of this orb that have hitherto been obtained; and, if they should bear a microscopic power, objects may be perceived on the lunar surface which have hitherto been invisible. Nor is it impossible that the planets Venus, Mars, Jupiter and Saturn may be delineated in this way, and objects discovered which cannot be descried by means of the telescope. It might, perhaps, be considered as beyond the bounds of probability to expect that very distant nebulæ might thus be fixed, and a delineation of these objects produced which shall be capable of being magnified by microscopes; but we ought to consider that the art is yet in its infancy, that plates of a more delicate nature than those hitherto used may yet be prepared and other properties of light may yet be discovered which shall facilitate such designs."

Had Dr. Dick lived until the present day he would be amazed to see what portions of his prediction have in a measure come true. To him the most improbable of the things he forecast for photography to accomplish was the delineation of the nebulæ, and yet it is in this direction that photographic astronomy has most decidedly excelled. To use highly magnified images for photographing the details of the planets seemed to him to be among the first triumphs that were to fall to astronomical photography; yet to-day they are almost as far from realization as they were in the days when good Dr. Dick charmed his readers with vivid descriptions of the wonders of astronomy. I do not think the most active imagination could have foreseen in Dr. Dick's day the marvellous extent to which astronomy at the close of the nineteenth century would be influenced by that light-picturing process just then being developed by Daguerre and others.

After all, however, it is easy in the case of great discoveries of this kind to predict what they will amount to. This is usually done by immensely exaggerating all their possibilities and thus, by a happy chance, hitting one or more of their realities, for strict account is usually kept only of the hits in such cases, the misses being rejected by a charitable world as a matter of no importance. We are used to wonders in these days of wonders, and have a happy habit—from frequent practice—of correctly guessing the outcome of some of the great discoveries. But when Dr. Dick wrote, these things were not so easily foreseen, for the possibilities of the sciences were not so apparent then as they are now.

So great have become the possibilities of photography in the astronomical investigations of to-day that an account in detail of its accomplishments would far exceed the limits of this paper, and for that reason I shall be forced to a brevity in dealing with this subject that must necessarily pass over many of the interesting things photography has done for astronomy in its comparatively short lifetime.

It does not come within the province of a paper of this kind to deal with the question of priority in the discovery of photography (though something might be said on that point for America), as the process interests us only in so far as its application to astronomy is concerned.

It appears that on the very first announcement of Daguerre's wonderful discovery on the 19th of August, 1839, the celebrated French astronomer Arago, who addressed the Paris Academy on the subject, quickly foresaw the great advantage it must necessarily be to the science of astronomy, especially in the faithful delineation of the surface features of the sun and the moon, for these two objects, at least, were bright enough to register themselves with the sluggish materials then in use. It is specially gratifying to Americans that the first efforts to utilize the new discovery for the benefit of astronomy were made in this country, and that Americans have always been prominently identified with the process from its very earliest conception.

Within less than one year from the announcement of Daguerre's discovery, in March of 1840, Dr. John W. Draper, of New York City, had succeeded in getting pictures of the moon which, though not very good, foreshadowed the possibilities of lunar photography. Five years later the Harvard College Observatory may be said to have commenced its remarkable career of astronomical photography, when Bond, with the aid of Messrs. Whipple and Black, of Boston, succeeded in getting still better pictures of the moon with the 15-inch refractor. These pictures, on daguerreotype plates, seem to have been fairly good, and to have shown much detail, though the telescope was wholly uncorrected for the photographic rays. They attracted a very great interest in the subject, especially in England, but the difficulties encountered led to failures generally, except in the case of De La Rue, Dancer and one or two others. To Dancer is doubtless due the earliest success in lunar photography. Excellent photographs, it is said, were made by him as early as February, 1850. In 1858 De La Rue, using a 13-inch metal speculum, without clockwork, and guiding by following a lunar crater seen through the plate, made the most important of the early efforts at lunar photography. From this time De La Rue made the best pictures of the moon until the subject was taken up again in America in 1860 by Dr. Henry Draper, son of the illustrious John W. Draper. Like De La Rue, Dr. Draper constructed his own telescope, a $15\frac{1}{2}$-inch reflector. With this instrument he secured excellent photographs of the moon, superior to any previously made, and capable of considerable enlargement. These pictures were the best taken until Lewis M. Rutherfurd began his remarkable work about 1865. Rutherfurd's work marked the most important step until then made in astronomical photography. From this time on he produced such admirable photographs of the moon that they have not been excelled until within the past few years. These were made with a refractor of 11-inches aperture which had been constructed under his immediate supervision. It was the first telescope corrected specially for the photographic rays. Some excellent lunar photographs, in the meantime, had been made with the great four-foot reflector of the Melbourne Observatory.

The completion of the Lick Observatory in 1888 marked another decided advance in the photography of the moon. The great focal length of the magnificent instrument gave an unenlarged image of the moon about six inches in diameter, which in itself was a great advantage.

The admirable lunar photographs made by MM. Loewy and Puiseux, with the equatorial coude at Paris, in the past few years have excelled anything yet made in this direction.

But what is shown by the best lunar photographs has not yet approached that which can be seen with a good telescope of very moderate size. The minute details are at present beyond the reach of photography, but its accurate location of the less difficult features is of the highest value. The greatest interest in any observation of the moon would be in any changes that might take place on its surface. It has long ago been shown that no changes on a large scale have occurred in recent times. It is, therefore, to the minuter details, if anywhere, that we must look for change in the moon, and these at present are much beyond the reach of the photographic plate.

The sun, from its abundance of light, offered special inducements to the early workers in photography. It would rather appear, however, that the moon had the most charm for the first photographic astronomers. This was doubtless due to the singular and wonderful wealth of detail its surface continually presented, while the sun, except for a few occasional spots, was at best only a blank surface. When carefully and conscientiously studied, however, it highly rewarded those who took up its study photographically.

The first picture of the sun seems to have been made on a daguerreotype plate by Fizeau and Foucault in 1845. During the total eclipse of the sun on July 28, 1851, a daguerreotype was secured with the Königsburg heliometer (2.4 inches in diameter and 2-feet focus) by Dr. Busch, which appears to have been the first photographic representation of the corona. It showed a considerable number of details quite close to the moon. But in the early eclipses the photographic work seems to have been mainly devoted to representations of the solar prominences, which at that time were as rarely seen as the corona itself. During the eclipse of 1869, however, Professor Himes secured a photograph which showed the brighter structure of the corona; similar pictures were also obtained during the same eclipse by Mr. Whipple, of Boston. The corona was also slightly shown on pictures made as early as 1860 by M. Serrat. None of them, however, showed more than slight traces of the corona, extending only for a few minutes of arc from the moon's limb. Nearly all the pictures seem to have been taken with an enlarging lens, which was doubtless used to get the prominences on a larger scale. Mr. Whipple, however, in 1869, did not use any primary enlargement, and this gave him a decided advantage in point of exposure time. In nearly all of these pictures the exposures, with the slowness of the then-existing plates, were evidently too short to show the corona, except perhaps in the case of Whipple, who gave 40 seconds exposure. The other observers seemed to be content with much shorter exposures.

The first really successful photographs of the corona were obtained at the eclipse of of December 22, 1870, when it was shown on the plate to a distance of about half a degree from the moon's limb. This picture, made by Mr. Brothers at Syracuse, Sicily, showed a considerable amount of rich detail in the coronal structure; and the same can also be said of the photographs of this eclipse taken by Colonel Tennant and Lord Lindsay's party. These seem to have been the first pictures to really show the great value of photography for coronal delineation. The eclipse of 1871 was still more successfully photographed, and an excellent representation of the corona, full of beautiful detail, was secured.

All of these pictures were made with the wet process, for the dry plate was not successfully used until about 1876, and it was five or six years later before it became generally useful or at all reliable. For some years previous to this, photographers had been at work with varied success upon different methods of preparing and sensitizing plates that could be used dry. Indeed, at the eclipse of 1871, at Baikul, India, it appears that Mr. Cherry used a dry plate on which he exposed a number of images of the sun before totality for the orientation of the eclipse plates. It would seem that he had only two of these plates and they were both intended to be used for orientation. The second plate, however, was broken before it could be used. It is probable they were known to be less sensitive than the wet plates, which doubtless prevented their being used for the corona.

Though the pictures of 1870 and 1871 showed the value of the photographic method, it had so far failed to show the greater and fainter extensions of the corona. In speaking of the eclipse of 1871 and the success attained by photography at that time, it is well here to mention the evil influence that the old method of drawing had upon at least one observer. A Mr. Holiday had made observations of the corona from a housetop, and thus describes the result in his report: "As soon as the eclipse was over, I came down from the roof and plunged my head into cold water, for I was violently excited, and before breakfast I had made three drawings from my memoranda." If photography has done nothing more for astronomy than to prevent occurrences of this kind it would at least deserve lasting respect from a humane point of view.

In 1878 extensive preparations were made to observe the eclipse of July 29th of that year. Photography was to play an important part, though astronomers did not rely very strongly upon it, for it appears that all were prepared to make the customary drawings of the corona, and unfortunately each person faithfully carried out that purpose. A most suggestive illustration of the uncertainty of such work is found in the large collection of drawings published in a volume issued by the United States government relating to the eclipse of 1878. An examination of these forty or fifty pictures shows that scarcely any two of them would be supposed to represent the same object, and none of them at all closely resembled the photographs. The method of free-hand drawing of the corona made under the attending conditions of a total eclipse received its death-blow at that time, for it showed the utter inability of the average astronomer to sketch or draw under such circumstances what he really saw.

At this time the dry plate was still in its infancy, and the results with it ranged from failure up to a fair picture of the corona. The greatest extension of the corona obtained, however, seemed to be about half a degree from the moon's limb, while Professors Newcomb and Langley traced it nearly six degrees with the eye alone. The results, nevertheless, were highly important, and they demonstrated the success of photography for this class of work.

One of the cameras at this eclipse was put in charge of a private soldier, with instructions to give an exposure of 65 seconds. The instructions were faithfully carried out, but as no one had told him to draw the dark slide the plate remained unexposed.

The total eclipse of 1882 proved to be of special interest, from the fact that a small unknown comet was then in the immediate neighborhood of the sun, and was seen with the naked eye during the eclipse. The increased sensitiveness of the plates then in use secured a strong impression of this object. The known history of the comet is comprised within the few minutes of totality of that eclipse, for it was never seen afterwards.

In the eclipse of 1886 photography again held an important position. But the extremely humid climate of Granada (one of the observing stations) and the necessity of employing volunteer observers led to numerous disasters, such as the failure to get the sun's image on the sensitive plate in the most important instrument; the breaking of the polar axis just before totality in the next important instrument; the failure of an assistant to make the exposures with another until totality was all but over; the fact that two native policemen stood in front of the photometer during totality; the two weeks' delay of the steamer in getting away from the island; the seizure of the plates by the customs officials on arrival at New York, and, after their rescue, the subsequent delay for want of time to develop the plates, until May of next year, when they had undergone decomposition, so that the results were not as good as might have been expected.

The closing of the year 1888 and the opening of 1889 brought one of the most important eclipses that had yet occurred from a photographic standpoint. Certainly no previous eclipse, nor any since, so far as that is concerned, was photographed by so many different persons, and with such a varied assortment of cameras, telescopes, etc. The path of this eclipse lay across Nevada and California, and every photographer, amateur or professional, near the line of totality took part in the work. The amateur photographers of San Francisco and Oakland banded together under the leadership of Mr. Charles Burckhalter and photographed the eclipse in a systematic manner, the result being a most excellent collection of negatives of the corona. In some of these pictures the coronal streamers were carried to a far greater extent than at any previous eclipse; especially was this so in the photographs made by two of the amateur photographers, Messrs. Lowden and Ireland. At this eclipse the lot fell to the writer to make the photographs for the Lick Observatory. But at this time the Observatory had no instruments suitable for the work. To secure as large an image as possible with the poor equipment at hand, a 3½-inch visual objective by Alvan Clark was selected. This lens, after being reduced to 1¾ inch in diameter and mounted in an oblong box fastened to a polar axis driven by the clockwork belonging to the 12-inch equatorial, was found to give a fairly good photographic image. With this and two small photographic cameras, nine negatives of the corona were secured. The best of these was one made with the Clark visual objective. By extreme care in development, this negative not only showed the exquisite polar systems of streamers and the details of the corona close to the moon, but also carried the coronal extensions a great distance along the ecliptic. This was by far the most successful eclipse photographically of any that had yet been observed, and forever set aside as worthless the crude and wholly unreliable free-hand sketches and drawings previously depended upon.

The eclipse of December 21, 1889, was successfully photographed, among others, by Mr. Burnham and Professor Schaeberle, comprising the Lick Observatory eclipse expedition which was sent to Cayenne. It was at this eclipse that Father Perry lost his life through the trying climatic conditions. With the sickness of death upon him, this brave man, fearless in his duty, stood by his cameras and carefully carried out his program during the eclipse, only to collapse at its close and die a few days later on the vessel that was carrying him away from the fateful spot.

The eclipse of 1893 was successfully photographed in Brazil, Africa and Chile. Professor Schaeberle made arrangements for the photography of the corona on a large scale, and with his apparatus at Mina Bronces, Chile, secured a fine series of photographs with a photo-heliograph of 40-feet focus, which he mounted on a hill sloping towards the sun. The image was formed by a stationary lens five inches in diameter upon a large sensitive plate which was moved by clockwork to counteract the sun's motion during the few minutes of the eclipse. In these pictures the image of the sun was on such a large scale that the coronal details could be very accurately studied. Upon these plates Professor Schaeberle found a hazy ill-defined spot at forty minutes' distance from the sun's center. This he subsequently found also on the African and Brazilian plates, taken by the English and American astronomers. This object was in motion away from the sun, as shown by the photographs, which covered an interval of 2 hours and 36 minutes of absolute time. Professor Schaeberle believes this was a comet. It is not impossible, however, that it was a mass of coronal matter moving out from the sun, such as has been shown by the spectroscope frequently to occur in the case of solar prominences. The fact that the object seemed to be connected with the sun by a coronal streamer would rather favor the explanation. The drawing given in *Astronomy and Astro-Physics*, p. 307, Vol. XIII., seems to further support this idea.

During the solar eclipse of 1896 the sky was cloudy at nearly all the stations, and especially where the most elaborate preparations had been made for photographic work. A few photographs were obtained, however, some of which, with very small lenses, showed the coronal extensions to a great length. Mr. Burckhalter, of Oakland, Cal., had arranged an ingenious device for grading the exposures of the Corona. Clouds unfortunately prevented the trial of this experiment. The most important photographic work at this eclipse was the photographing of the flash spectrum, or the momentary reversal of the Fraunhofer lines which occurs when the edge of the sun disappears behind the moon or reappears from it, and for an instant exposes the reversing layer, which was first seen by Professor Young at the eclipse of 1870. This extremely important picture was made by William Shackleton, a young Englishman, who patiently waited and watched the spectrum at the edge of the sun, and at the instant of the reversal of the lines exposed a plate which caught, for the first time, the fugitive bright lines which are only visible for about a second. This photograph was a triumph for photography, for the record of the phenomenon now does not rest upon the authority of any hasty observations, but remains a permanently visible record.

Our record closes with the eclipse of January 22, 1898, which was photographed in India by American and English astronomers. The photograph of the flash spectrum was successfully repeated by many observers. The coronal extensions were carried to a greater extent than at any previous eclipse, by photographs secured with a very small lens by Mr. and Mrs. Maunder.

In speaking of the photography of the corona it is well to mention the extremely ineresting experiments of Dr. Huggins in an endeavor some years ago to photograph it without an eclipse. By the use of absorbing media, and later with extremely short exposures, he obtained very corona-like appearances, and it is not yet certain that they were not true coronal forms. Such experiments should be tried at very high altitudes in a pure atmosphere, and it is to be hoped that these efforts will be again undertaken under more favorable conditions.

The transit of Venus across the sun's disc in 1882 was very successfully photographed, and the measures of the pictures made by the Americans has given a good redetermination of the solar parallax. A fine series of photographs of this transit with wet plates was obtained by Professor D. P. Todd at the Lick Observatory. This was six years before the completion of the Observatory.

There is no question but that Janssen, of Meudon, succeeded many years ago in making the best photographs of portions of the sun's surface that have yet been made. These pictures show the granulation of the solar surface and the details of the sun spots with admirable clearness. Janssen has always used the old wet-plate process, which seems to give the best results in solar work. The instrument with which his work is done is a very crude affair. The lens, 5 inches in diameter, is placed in a wooden box, which is mounted on an old camera stand on rollers. It is not provided with clock work. When Janssen wishes to make a photograph of the sun he wheels this primitive affair, stained and daubed with nitrate of silver, from a shed on to a platform, elevates it towards the sun, makes an exposure with a rapidly moving slit, and secures a photograph which, so far, but few have approached in excellence. These pictures are enlarged by a secondary lens in the camera box to about twenty inches in diameter. One peculiar feature of these photographs is the frequent presence of blurred regions, in striking contrast to the generally exquisite sharpness of the granular surface. These disturbed regions are believed by Janssen to be due to actual disturbances on the sun's surface, and, therefore, to be true phenomena of the sun. I have always had the impression that these features are simply due to the presence of small areas of bad seeing which are passing at the moment of exposure; that is, they are the effects of small local disturbances in our own air, such as every visual observer is familiar with in night work. I remember having once secured a photograph of the moon with the 12-inch of the Lick Observatory which showed just such a blurred spot on its surface. This question could be easily settled with a few exposures made a minute or so apart, for if the blurred appearance repeats itself at the same point on the sun's disc, then it can not be due to local atmospheric disturbances. Doubtless M. Janssen has long ago decided this question, but, if so, it has escaped my notice.

For the first successful photographs of the sun's surface, however, we must return to America. The first pictures to show this granulation and the details of the sun spots were taken by Lewis M. Rutherfurd in 1870. These pictures were also made with the collodion, or wet process.

From the importance of a more thorough understanding of the effects of the sun upon the climate of the earth, daily photographs of the solar surface are made at a number of observatories, principally at Greenwich, Kew and in India. These have been kept up for a great many years. The Lick Observatory has in recent years also taken up this subject. It is scarcely probable that a single day goes by without photographs of the sun being made at some one of these observatories. Thus a valuable record is kept of the changes taking place on the solar surface. Just what effect these sun storms have upon the earth is not yet definitely understood, but there seems to be an almost certain connection between some of the solar disturbances and terrestrial magnetic storms, so that when the sun is violently agitated a corresponding disturbance of the earth's magnetism occurs. It is not yet seen just how these disturbances may affect the weather; so far the testimony seems inconclusive, and local conditions on the earth may fully compensate for any effect solar storms might have here. In the meantime the work done in this connection at Greenwich and other places will continue to grow in importance. One thing that this repeated and constant photographing of the sun has proved is the non-existence of the so-called intra-mercurial planets, which before the days of photography were so frequently seen transitting the sun, by Lescarbault and many others. No strange thing, aside from an alleged comet, which was afterwards traced to a stain on the photographic film, has been shown on any of these photographs, with the exception, perhaps, of one of the sun photographs made in India which caught a distant bird in its flight and showed clearly its head and outspread wings projected against the sun.

Just as this continuous photographing of the sun's surface has forever disposed of the alleged frequent transits of intra-mercurial planets, so will the photographic plate finally, when it has attained more perfection in dealing with the planets, show that many of the strange features ascribed to the surfaces of some of them do not exist.

As I have said, the early photographs of eclipses seem to have been made with the sole end in view of securing pictures of the solar prominences. This was very important at first, for by the photographs it was proved that they were true solar phenomena. Possibly also in the very first photographs a picture of the corona was considered a hopeless matter on account of the lack of sensitiveness of the plates. The eclipse of 1868 is memorable for having shown Janssen and Lockyer that the visibility of the prominences did not necessarily depend upon a total eclipse of the sun. They found that by the aid of the spectroscope the prominences could be seen and studied at any time. This was an extremely important step, and placed our knowledge of the nature of the prominences upon a firm and lasting footing. The fact that these objects could be made visible with the spectroscope soon suggested to Professor Young the idea that they might also be photographed at any time; and in 1870 he made efforts to secure impressions of them upon the photographic plate, and met with partial success. To photograph successfully these objects, however, required the invention of a special instrument, for the older methods must necessarily result in failure. In observing the prominences visually with the spectroscope it is necessary to examine them through a slit which is very narrow compared with the height of the prominences. Only a small section of the prominence can, therefore, be seen at once, and to see it all the slit must be moved over the prominence. If the slit is widened more of the object is shown, but at the same time such a flood of light is admitted that it is lost in the glare. If an instrument could be devised whereby the slit could be moved in front of a photographic plate, successively exposing to the plate all parts of the prominence, it will readily be seen that the entire image could be photographed. To do this there must be two slits moving in perfect unison—one placed across the sun in front of the grating or prism, the other in front of the photographic plate and adjusted perfectly to the spectral line of the prominence so as to exclude all light save that emitted by the prominence itself, and thus, by the gradual motion of these two slits, the entire object is successively uncovered and an exact photograph secured of it.

The solar prominences consist mainly of incandescent hydrogen and calcium. The best results are secured by calcium alone. It is curious to see photographs of the same prominence made by using the hydrogen or calcium lines independently; these pictures often differ considerably, thereby showing the peculiarity of distribution of the calcium and hydrogen in the same prominence. The two components are differentiated, and it is thus shown just what part each component takes in the composition of the prominence. To make one of these pictures takes several minutes of exposure, during which time the slits slowly travel over the region of the prominence. This extremely ingenious device owes its existence to the inventive genius of Professor Hale, who devised and built the first instrument of this kind, and secured the first actual spectroscopic photograph of the prominences. These first pictures were made in 1891. It is, therefore, now a matter of no great labor to make not only photographs of single prominences at any time, but through a further ingenious extension of the possibilities of the instrument it is made to move across the entire sun's disc, thus securing every prominence at that time visible.

By hiding the sun's image by an occulting disc in the first sweep, and then making a second similar but more rapid sweep with the sun's image uncovered, the sun itself with all its faculæ, spots, etc., is impressed in the blank space left for it, and a complete picture of the sun and all its surroundings, with the exception of the corona, is secured. This is the method employed by Professor Hale. These pictures, however, show only those features of the sun which are due to hydrogen or calcium, and the solar surface thus appears very different from the telescopic view of it. The calcium regions come out with extraordinary distinctness, so much so, indeed, as at times to obliterate completely the sun spots, which at that moment are so distinct to the eye with the same telescope. Admirable work of this kind has also been done by M. Deslandres, of the Paris Observatory, who has devised an instrument similar to that of Professor Hale.

From the first photograph of a star by Bond in 1850 to the present time, stellar photography has gradually risen to a prominence as remarkable as it is important. The real increase of importance in this work, however, has occurred within the past ten or fifteen years, since the successful introduction of the very rapid dry plate. The wet, or collodion process was poorly adapted to the photography of the stars, and of no use whatever for comets and nebulæ. As implied by the term 'wet process,' the plate must remain wet through the entire work from its first coating with collodion until its final washing as a negative. The exposure time must, therefore, be very limited. Not only was the exposure of short duration (from fifteen to twenty minutes), but the plate was very slow in its action compared with the dry plate of today. The combination of these two difficulties made it impossible to photograph anything except the brighter stars. Dr. Gould at Cordoba managed to increase the exposure time by keeping a stream of water playing over the plate. This, however, might cause a deterioration of the film. With the inherent difficulties of the wet plate to contend with, it is little wonder that no faint stars, nebulæ or comets were photographed. Notwithstanding this, the photographs of the star clusters, etc., of the southern skies obtained, under the direction of Gould with an 11-inch photographic refractor by the wet process, were of the highest value, and showed, upon measurement, a striking agreement in accuracy with visual work. The same can be said of Mr. Rutherfurd's photographs of the Pleiades, Præsepe, etc., which were made prior to Dr. Gould's, and which were the first photographs of this kind. These extremely valuable photographs of Rutherfurd are now receiving a most thorough measurement under the careful supervision of Professor J. K. Rees, of Columbia College, where Mr. Rutherfurd's negatives are stored. To this institution Mr. Rutherfurd left his telescope and measuring instruments.

In 1857 Bond had shown, by measurement of a series of photographs of the double star Mizar, that the highest confidence could be placed in measures of star plates. This has been fully verified in late years by Gill, Elkin and others. Dr. Elkin showed, in 1889, that measures of a photograph of the Pleiades taken by Mr. Burnham, with the great telescope at Mt. Hamilton, had equal value with his heliometer measures of the same stars.

From the necessary conditions the collodion process could make no advance in stellar photography. Previous to 1876 experiments had been made to get a workable dry plate, and for the next six years more or less success had been attained in their manufacture. But the photographers themselves took hold of these plates with much caution because of their uncertainty. By 1881 or 1882, however, they were beginning to be used and gave considerable promise of their ultimate value, as was shown by the photographs of the comet of 1881, which were made by Draper and Janssen. These were the first photographs ever made of a comet. Efforts had been made to secure pictures of Donati's comet, in 1858, but without success.

In the fall of 1882 the world was thrilled by the advent of a magnificent comet which suddenly appeared near the sun in September, and for the next four or five months delighted astronomers with the splendor of its display. Attracted by the great brilliancy of the comet, Dr. Gill, at the Cape of Good Hope, with the aid of a local photographer and his photographic lens, secured a fine series of photographs of the comet with dry plates. When these photographs reached the northern hemisphere they attracted a great deal of attention, not only on account of the comet itself, but also from the number of stars that were impressed on the plates. At this period the Henry Brothers were making a chart of the stars along the ecliptic in their search for asteroids. They had at this time reached the region of the Milky Way, and the marvellous wealth of stars they encountered upon entering the boundaries of that vast zone completely discouraged them in their endeavors to carry their charts through the rich region traversed by the ecliptic. While hesitating as to the advisability of continuing their work the photographs of the great comet came to their notice. They were struck with the great number of stars shown on these pictures along with the image of the comet. The idea at once occurred to them that they could use this wonderful process to make their charts. It was to this simple incident that the active application of the stellar photography of to-day is due. They began at once the construction, with their own hands, of a suitable photographic telescope of 13½ inches' diameter for the photography of the stars. This instrument was soon finished, and the astronomical world knows to-day what wonderful results these men produced with it; the exquisite star pictures which were marvels of definition, the photographs of the nebulæ, of Saturn and Jupiter, the moon, etc., were perfect revelations.

In 1859 Tempel, at Florence, Italy, had found a diffused cometary-looking nebula connected with and extending southwesterly from the star Merope, of the Pleiades. From that time on astronomers wrangled over this object, which many of them believed had no existence. One of the first things done by the Henry Brothers was to photograph the Pleiades. These pictures showed nebulous strips near Merope, and though they did not resemble any that had been drawn by the numerous observers of the Merope nebula they rather confirmed the existence of Tempel's object. Upon these plates was shown a new nebula connected with the star Maia where none was previously known. It required the most powerful of existing telescopes to verify this visually. This was finally done, however, and it then began to dawn upon astronomers what great possibilities lay in the photographic plate for the detection and study of the nebulæ. It was soon seen that their light was strongly photographic; that it was really more actinic than visual. A later photograph with a longer exposure showed the Merope nebula just as the best observers had drawn it, and at the same time filled the entire group of stars with an entangling system of nebulous matter which seemed to bind together the different stars of the group with misty wreaths and streams of filmy light, nearly all of which is entirely beyond the keenest vision and the most powerful telescope. This was a revelation. The question had often been asked whether it would ever be possible to photograph as faint a celestial body as could be seen with a powerful telescope. Here was the answer. It was not only possible to photograph some of the faintest objects seen in the telescope, but it was possible also to photograph some others which could never be seen in the sky. In one of his reports Admiral Mouchez called attention to the fact that the only way they could see the satellite of Neptune at the Paris Observatory was on the photographs made by the Henry Brothers, for they had no telescope sufficiently powerful to show it visually.

The Henrys applied themselves assiduously to celestial photography, with the most remarkable success. They led the world in this work. While they were at the height of their activity astronomers elsewhere were but beginning to awaken to the great importance of the subject. And yet there seems to have been essentially no public recognition of the work of these two men, to whom astronomy owes so much. In personal appearance and temperament they are so extremely dissimilar that one would scarcely take them to be brothers. Up to the time they began their photographic work they had between them discovered fourteen asteroids, by the slow and tedious visual process of picking them out by their motion from the countless thousands of small stars. If one examines a list of the asteroids he will be struck with the manner in which these fourteen small planets are recorded. According to this list the first one of these was discovered in 1872 by Prosper Henry, the next one by Paul Henry, and so on alternately throughout the entire fourteen until 1879, when the last one found was attributed to Paul Henry. It is a curious fact, and one which will be readily understood by all who are acquainted with the unselfish affection existing between these two brothers, that the credit for the discovery of these fourteen minor planets is ascribed alternately to Prosper and Paul Henry. It is likely that we shall never know which brother discovered any one of these planets.

Singularly enough, the photographic plate not only did away with the necessity of making these charts by eye and hand to facilitate the discovery of asteroids, but it also did away with the necessity of the charts themselves for that purpose, for the little planet, which is moving among the stars, now registers its own discovery by leaving a short trail—its path during the exposure—on the photographic plate. The first of these photographic discoveries of asteroids was made by Dr. Max Wolf in 1892. They are now found wholesale in this manner by photography.

It was the success of the Henry Brothers' work that led to the International Astro-Photographic Congress which met at Paris in 1886. It was their work that caused this Congress to meet at Paris. The Congress adopted the Henry Brothers' lens as a model for the instruments to be used, and the work of this great undertaking was based on that of the Henry Brothers. It was stated once by Admiral Mouchez that every object glass at the Paris Observatory had either been made by the Henry Brothers or refigured by them.

Perhaps, as Dr. Dick himself thought in the early days of photography, the most unpromising subject for the photographic plate to deal with was the nebulæ. Most of these objects appeared so feeble in their light that but little encouragement in that direction was offered the celestial photographer.

One of the brightest and most promising of the nebulæ is that in the sword of Orion, and this was naturally one of the first of these objects to receive photographic attention. In September, 1880, Dr. Henry Draper began the photography of the nebulæ with this object, and succeeded, with 51 minutes' exposure, using the dry plate, in getting a good picture of the brighter portions of the nebula. This was the first nebular photograph. With 104 minutes' exposure in March, 1881, with an 11-inch refractor, he secured a still better plate, which showed stars down to the 14.7 magnitude, which were visually beyond the reach of the same telescope. But in March, 1882, he obtained the best picture of this wonderful nebula, with an exposure of 137 minutes. These pictures marked a new era in the study of the nebulæ. When these results were communicated to the French Academy by Dr. Draper, Janssen took up the subject with a silver-on-glass mirror of very short focus, having the extraordinary ratio of aperture to focus of $\frac{1}{3}$; the aperture being 20 inches, with a focus of 63 inches. This remarkable instrument was constructed in 1870 for the total solar eclipse of 1871. With this Janssen found it easy to photograph the brightest parts of the nebula with comparatively short exposures. This extremely powerful photographic instrument seems to have been unused for the past fifteen years; but very recently it has been brought into use again, I understand, with the most astonishing results in photographing the nebulæ. Unfortunately for science, the death of Dr. Draper, in 1882, put a stop in America to the work he had inaugurated. But it was at once taken up in England by Common, who, with a three-foot reflector, attained rapid and immediate success. His photographs of the great nebula of Orion are still classic. They were a great advance over the work of Draper, for the reflector was not only a larger telescope, but was also better adapted for photographic purposes, and especially for photographing the nebulæ. In January of 1883, with only 37 minutes' exposure, he secured what was by far the most striking and beautiful picture which had yet been taken of the great nebula. These pictures greatly extended the region of nebulosity, and the delicate details were also better shown.

The writer remembers how much he was impressed a few years later with the beauty of one of Common's photographs. It created in him the first ambition to do work of this kind. Indeed, this picture, and one of a densely crowded region of a part of the constellation of Cygnus, by the Henry Brothers, first called his attention to the great value of the photographic plate for astronomical purposes. It was at this time that the writer conceived the idea of photographing the Milky Way, though the experiments were not then successful for the want of a proper instrument. The great nebula, which has always had such a fascination for astronomers, was subsequently taken up by Isaac Roberts, who, by very prolonged exposures, still further extended the nebulous region and secured very beautiful pictures of it. Among the finest photographs of this object that have been made in recent years is one taken by Dr. H. C. Wilson at Northfield, Minn., with an 8-inch photographic refractor with an exposure of nine hours. The amount and sharpness of detail shown on this beautiful photograph is very striking, and essentially embraces all that has been done on this nebula by photography up to the present time.

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(To be concluded.)

THE INTERNATIONAL CONGRESS OF ZOOLOGY.*

THE Fourth International Congress of Zoology met at Cambridge on Tuesday, August 23d, and the four following days. There were about 300 members present. The attendance from America was scarcely

* Based on reports in the London *Times*.