We have passed on our way down Erith and Greenhithe, famous yachting-places. Beyond them on the Kentish shore, Gravesend, with its narrow streets, its quaint shops and houses, is also a great yachting centre. It is too the home of whitebait fishing, the fish being taken in open boats, in long peak-shaped nets with a very small mesh.

Away on the north shore of the river lies for some distance a tract of low, swampy country. Here is the abode of wildfowl, and here, during a hard winter when fowl are plentiful, there is abundance of sport to be had. It is hard work, and by no means without a spice of danger; but wildfowl-shooting is one of those things that, if a man has once taken up with it, he is never content to abandon. Canvey Island, flat, dismal, lies hereabouts, and is a favourite spot for punt shooters; but the sport has been somewhat overdone of late years, and the birds are now generally wild and difficult to get at. There are marshes, too, on the Kentish shore to the eastward of Thames Haven, but it is not safe to visit them without a guide.

Southend, which shares perhaps with Ramsgate and Margate the proud distinction of being the paradise of Cockaigne; Sheerness, with its dockyard and its forts; these are our halting-places on our road to the Nore, where the striped buoy falls to the rhythm of the short seas, and the waving ball that surmounts the tall pole catches the eye for a long distance, a welcome signal to homeward-bound ships.

We have reached the mouth of "The Royal River," and in bidding it adieu, we may quote once more the words of Mr. C. Austen Leigh:—

> "And if, which God in heaven forefend,
> On us an alien foe descend,
> The ancient stream has many a son
> To fight and win as Alfred won;
> High deeds shall illustrate the shore,
> And freedom shall be saved once more
> On Tamise ripe."

W. T. MAINPRISE.

THE PHOTOGRAPHY OF THE HEAVENS.

BY WILLIAM HUGGINS, D.C.L., F.R.S.

IN TWO PAPERS.—FIRST PAPER.

IT is through light alone that we have any knowledge of the universe which lies outside the small speck-like planet on which we find ourselves. The eye, notwithstanding its great powers, is subject to several limitations in its reception, and in its interpretation of the light which reaches us. At the best, we are purblind, for the eye is sensitive to one octave only of light-waves—a small oasis in the great range of waves which come to us from luminous sources such as the sun and the stars. We may perhaps form some idea of our position in respect of light if we try to imagine what would be our condition musically, if our ears were as limited in range as are our eyes: if we were able to hear one octave of notes only in the middle of the key-board, and were deaf to all sounds above and below that small range of notes.

Another limitation arises from the circumstance that the eye is not able to profit by the cumulative effect of a continued luminous stimulus, which is too feeble to excite vision at the instant of falling upon the retina. We know that looking long does not enable us to perceive what is too faint to be seen at the first glance. Indeed, the eye speedily tires, and it is at the first glance only, and on a small part only of the retina, that we can discern the faint images of stars which are near the limit of our powers of vision.

As we have to use the same pair of eyes over again, the rapidity with which impressions fade out is an essential condition of the uninterrupted use of our eyes. Reading would be wearisome if it were necessary to wait, after turning over a page, for the impression of the former page to pass slowly from our eyes. The great rapidity with which the eye is able to present a *tabula rasa* to every new object is one of the most valuable of its powers.

There is also the limitation of area. It is only when the images on the retina are very minute, and even then only by an unconscious movement of the eye, that we can see (as we suppose at once) a large range of objects.

In all these points the photographic plate contrasts favourably with the eye, and is able to some extent to supplement it. By the choice of suitable substances, we can give to the plate the power of receiving the light which is invisible to the eye, because it lies beyond its range of power.

The action of a feeble light upon the plate accumulates by lengthened exposure, so that a star's image too feeble to produce a sensible photographic effect in one second may be able to impress itself strongly on the plate in one minute, by the cumulative effect of the sixty successive seconds of action. We shall see that for the faintest stars which have been photographed more than one hour's continuous action of the star's light has to be gathered up before a photographic image of sensible strength is obtained.

A plate, unlike the retina, retains the impression of the light which has come upon it, and so may be said to possess a memory which is unfailing. The plate can treasure up for all time the most complex forms, or

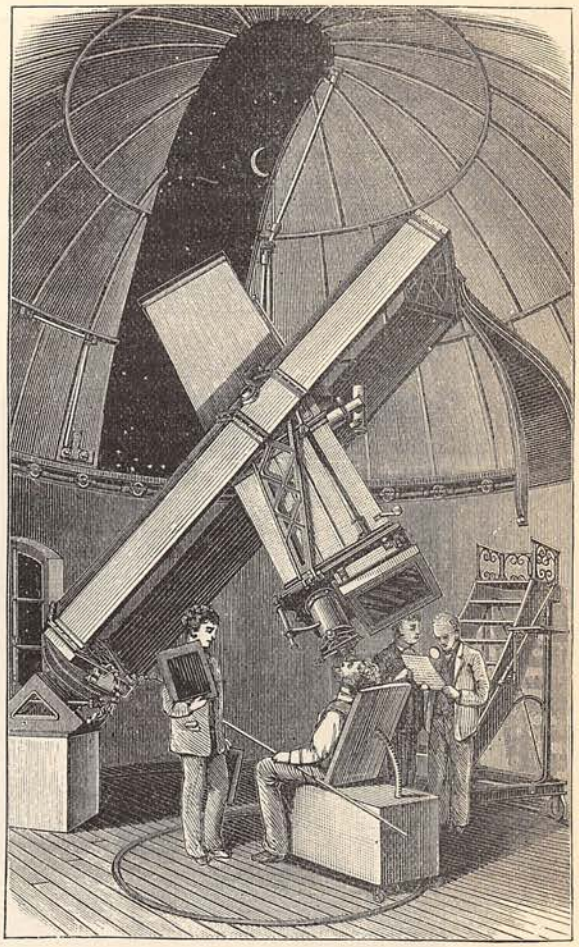
it may be the images of many thousand stars, which have once impressed themselves upon it. Again, by taking successive plates we can obtain a map of the whole heavens traced by the finger of light, on as large a scale as we may desire.

With these great advantages are bound up necessarily certain drawbacks: the plate has "*les défauts de ses bonnes qualités.*" In consequence of the cumulative action, the photographic picture is not true to nature. For example, in the case of the photograph of a nebula, the long exposure necessary to bring out the fainter portions causes the brighter parts to be so much overdone as to be wanting in details, and any bright stars which may be present are no longer, as they should appear, small points, but have grown into large discs, which may overlap each other, and may conceal what is close about them.

We have said already that photographic vision does not correspond with that of the eye. If ordinary gelatine plates are used, the violet light which is near the limit of the eye's power appears the most brilliant light to the plate, and the picture may not correspond with what we see, but represents a sun-spot, for example, as we should see it if our eyes were attuned to a higher octave of light-waves.

These drawbacks, and some other more subtle ones, are well understood, and if taken carefully into consideration, need not detract much from the enormous advantage which photographic plates possess as a help to astronomical research.

An almost limitless field of discovery lies before the astronomical photographer.



PHOTOGRAPHIC APPARATUS AT PARIS OBSERVATORY.

It would be outside the scope of this short paper to trace, even in outline, the history of the use of photography in the astronomical observatory; but it is desirable to point out that the recent remarkable photographs of the heavens which have excited, and most justly, great popular enthusiasm, have not been obtained by any new method, or by apparatus of novel construction, but are due to the much greater suitability of the modern dry plate for astronomical work. Gelatine plates can be made to possess very great sensitiveness, and being dry, can be exposed for any length of time that may be necessary.

Daguerre, shortly after his great discovery, endeavoured to get a picture of the moon on his silver plates, but apparently without success. Shortly afterwards, in 1840, Dr. J. W. Draper succeeded in obtaining a portrait of the moon limned by her own rays on the metal which had been considered peculiarly her own.

At the Great Exhibition of 1851 in London, there were exhibited photographs of the moon taken by Professor Bond at Cambridge, U.S. Towards the end of the succeeding year Mr. De la Rue began the series of photographs of the moon and the planets which are so well known. During the next few years we find the names in England of Hartnup, Crookes, Fry, Huggins, Dancer, Baxendell, Williamson, and others.

We pass over thirty years, and come to speak of some recent successes.

M. Janssen has within a few weeks presented to the Academy of Sciences at Paris a photograph of a solar spot which may be regarded as one of the most perfect of the solar photographs which have been taken by him at the observatory of Meudon. This photograph shows with great beauty and distinctness the minute structure of the spot itself, and also the disturbed solar surface for some distance around it.

M. Janssen says: "We see (in the photograph) that the striated structure of the penumbra is itself composed of granulations arranged in "chapelets." On the edges of the penumbra the granulation is very brilliant and close, but in the penumbra itself the granules are less luminous and are wider apart, leaving dark openings between the rows of grains. The spot presents two very beautiful bridges, and an isolated and very brilliant mass of matter which unites them."

From the sun we pass to the faintest class of celestial

objects, and give an illustration to show what photography can do to record the forms of the nebulæ.

This fine photograph of the great nebula in Orion was taken by our countryman, Mr. Common, F.R.S., at Ealing, in 1883.

The photograph was obtained by causing the image of the nebula, formed by a silvered glass mirror of 3 feet diameter, to fall upon the plate, during an exposure of one hour. Mr. Common found that more details are brought out by every increase in the length of the exposure, and that the extreme limit of useful exposure with his instrument was not reached even at one hour and thirty minutes. With the comparatively short exposure of thirty-seven minutes Mr. Lassell's faint stars in the central parts of the nebula are distinctly shown, while details of the nebula itself, not represented in the best drawings that have occupied so much time and labour, and which indeed the eye can hardly discern and the hand could never properly represent, are clearly present in the photograph.

THE GREAT NEBULA IN ORION.
(*From a Photograph by Mr. Common, F.R.S.*)

We have now to speak of the magnificent results which have been obtained at Paris and elsewhere, in making charts of the stars by photography. Enthusiastic admiration is the only feeling with which we can view a plate a few inches square upon which five thousand stars have, by their own light, and within an hour, fixed a permanent record of their positions and their relative brightness. In this case, also, there is nothing new in the instrument by which the images of the stars are produced upon the plate, but the wonderful success is due to the modern plate being dry and extremely sensitive.

More than twenty years ago Mr. Rutherfurd, of New York, constructed a refracting telescope, in which the corrections for achromatism were made for the kind of light—blue and violet—which acts most strongly upon the sensitive film, instead of for the light towards the yellow end of the spectrum, which is most suitable for vision. This telescope had an aperture of 11¼ inches and a focal length of about 14 feet.

The instrument constructed by MM. Paul and Prosper Henry, and erected at the Paris Observatory, is precisely similar, but has a little larger aperture—about 13 inches.

Mr. Rutherfurd's limited success was caused, as I have stated, by the inferiority of the collodion plates then in use, but he clearly foresaw the great achievements which have now been realised. He said: "The power to obtain images of ninth magnitude stars with so moderate an aperture promises to develop and increase the application of photography to the mapping of the sidereal heavens. There is every probability that the chemistry of photography will be much improved, and more sensitive methods devised."

I should mention that Dr. Gill, Her Majesty's Astronomer at the Cape of Good Hope, was one of the first to call attention to the fact that the time was now come for the fulfilment of Mr. Rutherfurd's prophecy. In 1882, at the Cape of Good Hope, Dr. Gill took very successful photographs of the great comet of that year

with an ordinary photographic portrait lens lashed on to a telescope mounted equatorially, and moving by clockwork. He was surprised to find upon the plate, besides the comet, a complete photographic chart of the part of the heavens where the comet was situated, of all stars down to the eighth magnitude.

The apparatus employed at the Paris Observatory is represented in the accompanying illustration (p. 607).

At the first glance surprise may be felt at seeing an observer intently engaged upon an eye observation. One of the difficulties to be overcome in taking photographs of the heavenly bodies arises from the circumstance that the earth on which the instruments rest is in motion. The well-known consequence is that the stars rise, south, and set. It is obvious, therefore, that a star's image on the plate would be a line, longer or shorter according to the length of exposure, unless the photographic telescope had a corresponding motion in the opposite direction, by which, notwithstanding the earth's rotation, the star's image could be made to remain stationary on the plate. In the illustration the large metal parallelopiped contains two telescopes. In the upper half is placed the specially constructed refractor, about 13¼ inches aperture, which is corrected so as to give sharp images of the stars with the kind of light which is most effective in its action on the plate. At the lower end of this telescope will be seen the "back," carrying the photographic plate. Placed parallel to this telescope, and immediately below it, is a second telescope of about the same focal length and 9½ inches aperture. To the eye-piece of this telescope the observer's eye is directed. These telescopes are so accurately placed that when the observer sees a star exactly in the centre of the field of view of the eye-piece, he knows that the image of the same star formed by the photographic telescope falls precisely on the middle point of the plate. Both telescopes are moved together by an accurately adjusted clock motion, and if this motion could be made as perfect as that of the earth, and further, if there were no shift of the star's apparent position during the exposure, by a variation in the refractive action of our atmosphere, the star's image would remain absolutely at rest upon the plate, and the photographic image of the star would be perfectly round.

Such mechanical perfection is scarcely attainable, and the changes of varying atmospheric refraction exercise a sensible effect during the time of exposure, so that, practically, the telescopes cannot be left to themselves, but it is necessary for an observer to keep with great care the image of the star precisely at the same spot, by small amounts of occasional control by hand of the motion of the instrument. He is aided in knowing that the star's image is stationary, by suitably placed wires across the field of view. So perfectly can this be accomplished that during an exposure of one hour there is no sensible falling off from the perfect roundness of the star-images.

HARLOWE'S HELPMATE.

By FRANK BARRETT, Author of "John Ford," "Hidden Gold," "Honest Davie," &c.

CHAPTER THE TENTH.

MOTLEY AND HARLOWE had stopped payment! It was a terrible shock to all of us; for, little as we knew of financial matters, we understood that the stopping of a bank implies failure in business, with disaster and ruin to all concerned in it.

We were speechless, our eyes fixed on Philip in blank dismay. His hand trembled slightly; there was pity and grave solicitude in his pale face as he looked at his young wife. He was wondering, perhaps, how she would receive this sudden announcement of their downfall. I also was anxious for her; for she, having flown so high, must suffer most by the overthrow. Would she burst into a passion of tears as she realised the humiliation to which she must submit in relinquishing her proud position in society? Would she in sudden anger upbraid Philip for placing her in a fool's paradise, for culpable neglect in a matter where her dignity and happiness were concerned? These were the questions I asked myself.

She was the first to speak. Going to her husband's side, and laying her hand tenderly on his arm, she said:

"Philip, dear, how can I help you?"

Oh, I could have cried out "Bravo!" when I heard the brave woman say that. Philip was moved also. I saw a tear fall down his cheek as he put his arm about her, and looked fondly into her face.

"You don't mean to say it's all up with everything?" said Potter, aghast.

"It is not so bad as that," said Philip, with a short laugh. "I believe Motley will pull through the difficulty, but he does not disguise the fact that he may fail, and you see we cannot accept any invitation with that danger hanging over us."

Madge shook her head.

"A business like that can't collapse in a moment," said Potter, who seemed to feel himself particularly ill-used. "How long has it been going wrong, Phil?"

"I heard nothing until this morning."

"But Motley must have known. Of course you're not to blame. But I should like to know what on earth he's been staying at Brighton for this last ever-so-long with affairs in a shaky condition? Hang it all! I should hold him responsible if I were you. You

and to dim hope, struggling against readier unbelief in the dictum Gilbert Hurst long before, she later, at St. Clair's had learnt of their mutual master, Robert Vaughan.

But even that was fated to more conflict.

Her destination reached, she traversed sleepy little Stillcote guided by landmarks Jacob had pointed out last autumn. Past the lodgings of his clerkly days, where her father went to and fro each morning ; down the quaint irregular High Street, where shop folks stared at her, so evidently a stranger ; by St. Clement's, its rectory shadowed by the buttressed tower ; by Stuarts, where guelder roses peeped at her from the old walled-in garden ; and so towards Jacob's dwelling.

She looked up at his bow window, longing for the old man's smile : the only one in the world she could now count upon. He had not written back to her, but she never doubted his ready welcome. How much she would have to tell him : how much to withhold !

On Miss Ambler's shining knocker she sounded a summons, modest enough, but it set the echoes flying down the old town, and brought in immediate response a small rosy-cheeked handmaid, with very red eyes.

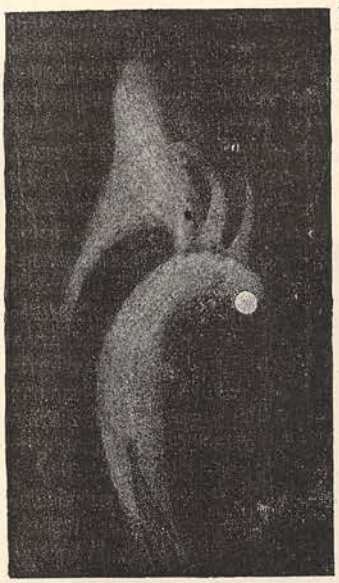
"Mr. Cheene, miss!" ejaculated Nancy, as, too tired to wait for invitation, Sydney entered while asking for him—"oh, didn't you know, miss? Hadn't nobody sent you word of it? Why"—recklessly crumpling a clean apron over her face—"poor Mr. Cheene, he died o' Thursday, miss, an' they've buried him on'y this very mornin' !"

END OF CHAPTER THE THIRTY-THIRD.

THE PHOTOGRAPHY OF THE HEAVENS.

BY WILLIAM HUGGINS, D.C.L., F.R.S.

SECOND PAPER.



NEBULA NEAR MAIA.
(*From a Drawing by MM. Henry.*)

EACH of the plates of the starry heavens taken by MM. Henry, in the way we have described, corresponds to a little more than six square degrees, and in the case of the plate reproduced in the illustration on page 653, there are impressed upon it more than 5,000 stars; the faintest of these stars are beyond those which the eye could see with an instrument of the same aperture.

The length of exposure depends upon the smallness of the stars which it is desired to include, a very great relative extension of time being necessary for the fainter stars. MM. Henry give the following lengths of exposure for stars of different magnitude. These times apply, of course, only to the apparatus and to the plates used by them, on a night of average clearness.

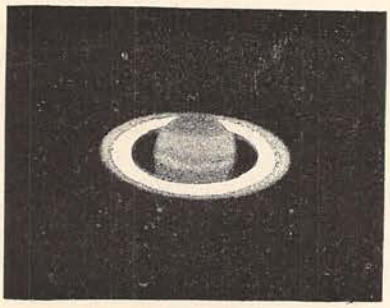
1st magnitude stars require	One two-hundredth of a second.
2nd ,, ,, ,,	One hundredth and a third of a second.
3rd ,, ,, ,,	Three hundredths of a second.
4th ,, ,, ,,	Eight hundredths of a second.
5th ,, ,, ,,	One-fifth of a second.
6th (faintest visible to the naked eye)	Half a second.
7th magnitude stars require	One second and a third of a second.
8th ,, ,, ,,	Three seconds.
9th ,, ,, ,,	Eight seconds.
10th (mean magnitude of the asteroids)	Twenty seconds.
11th (mean magnitude of the asteroids)	Fifty seconds.
12th (mean magnitude of the asteroids)	Two minutes.
13th magnitude stars require	Five minutes.
14th ,, ,, ,,	Thirteen minutes.
15th ,, ,, ,,	Thirty-three minutes.
16th ,, ,, ,,	One hour and twenty-three minutes.

The stars of the sixteenth magnitude are the smallest which have been photographed by the Brothers Henry. The duration of exposure of the brightest stars, as compared with that of the faintest on the plates, is as 1 to 1,000,000. The relative brightness of any two consecutive magnitudes is 2,512.

M. L'Amiral Mouchez, the director of the Paris Observatory, has recently invited astronomers of different nations to unite in making a complete photographic chart of the whole heavens ; and he has shown that such a great work, on the scale which he adopts, could be accomplished within ten years. We should then possess, and be able to hand down as a magnificent legacy to the astronomers of coming centuries, a permanent record of the positions, and the relative brilliancy at this time, of some twenty to thirty millions of stars. This number is too great for the mind adequately to realise, and is indeed overwhelming as compared with the number of stars which have been recorded by the slow process of measurement by eye.

If it were thought desirable to risk a small loss of extreme accuracy of position by taking a much larger piece of the sky on each plate, and not to go below stars of the ninth magnitude, a photographic map of the heavens could be accomplished in a much shorter time. It is on these lines that Dr. Gill has been

working at the Cape of Good Hope, with the assistance of the able photographer, Mr. C. Ray Woods. Each plate is six inches square, and covers an area of about thirty-six degrees, about four times as great as



PHOTOGRAPH OF SATURN.
(*MM. Henry.*)

that of the Paris plates. In this way the whole sky, from dec. 63° to 90°, has been photographed in duplicate. Owing to the generosity of Mr. James Nasmyth, Dr. Gill will be shortly in possession of an instrument similar to that at the Paris Observatory, but rather smaller in aperture. This instrument will be used for photographing special areas, and especially those containing dense clusters.

In our own country similar work has been begun by Mr. Isaac Roberts, near Liverpool. In May last he began the regular work of taking photographs of the stars in the northern hemisphere, commencing at the Pole. He works with a silver-on-glass reflector of twenty inches aperture and 100 inches focal length. In consideration of the frequent atmospheric changes that occur in our climate, Mr. Roberts has decided to limit the time of exposure to fifteen minutes, and therefore not to include the fainter stars. He says :—"The chart upon which I am engaged will be upon a scale twice the size of Argelander's, and will contain a larger number of stars than are shown in his work."

At the beginning of this paper I spoke of the fields of discovery which were before the astronomical photographer. The Brothers Henry, on November 16th, took a photograph of the Pleiades, and were astonished to see a sort of spiral nebulosity apparently issuing from one of the bright stars of the group, known as Maia. This was found to appear in four other plates, and they then realised that the photographic plate had "seen" and recorded an object which had hitherto escaped the most careful scrutiny by eye of many observers with many instruments. It may be that it shines chiefly by blue-violet light, and is therefore much brighter, as considered by its action on the plate, than by its power of exciting vision. Henry's plate is reproduced in the accompanying illustration. In the original negative more detail can be made out than on a print on paper. The illustration on the previous page shows the nebula on a magnified scale, as drawn by MM. Henry.

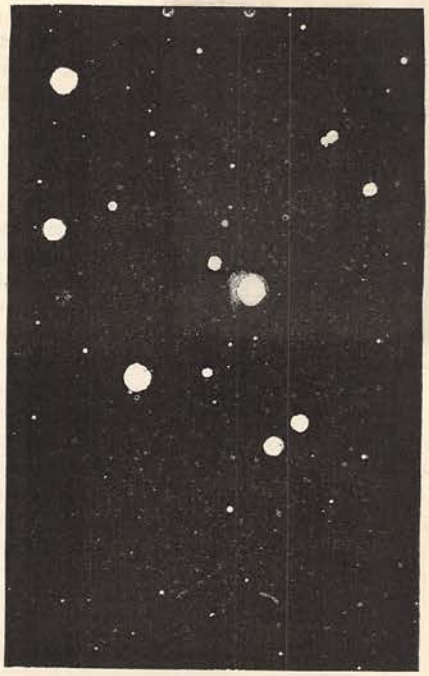
Professor E. C. Pickering, of Harvard College Observatory, states that in a plate taken there on November 3rd, 1885, an irregularity of photographic action about this star was noticed, but was put down to some defect in the plate.

When photography had shown the existence of the nebula, M. Otto Strune succeeded in seeing it with the thirty-inch object glass of the new Pulkowa telescope. He has since been able to glimpse the object with a fifteen-inch telescope. The nebula has also been seen since by MM. Perrotin and Thollon ; but M. Perrotin adds :—"We have seen the nebula because we knew that it existed. We should certainly not have observed it otherwise."

MM. Henry have obtained since traces of two nebulæ in the Pleiades, both of them near bright stars. One, a faint nebulosity near Merope, they consider does not resemble the nebula discovered there by M. Tempel, but is similar to the nebula seen by Mr. Common with his three-foot reflector in 1880. The third nebula appears as a faint nebulosity starting from Electra, and proceeding towards the east ; this object is evidently at the limit of photographic visibility that can be reached with their instrument, and required an exposure of three hours.

Among other results which the Brothers Henry have obtained at the Paris Observatory, the following are of great interest and value :—Good photographs of the principal planets, those of Saturn (of which an illustration is given) being especially fine ; the principal division in the ring, and the belts upon the ball, are very distinct. Their recent photographs of Jupiter show the red spot and the apparent influence of this spot upon the adjoining belt.

The satellite of Neptune has been photographed



NEW NEBULA NEAR MAIA.
(*MM. Henry.*)

in all parts of its orbit, even at the point of nearest approach to the planet. Forty-two plates have been obtained of the Milky Way and other regions of the sky. More than 600 double or multiple stars have been photographed, besides the star-clusters of Hercules, Clypeus Sobieskii, Ophiuchus, and Perseus. Two hours' exposure on the nebula of Orion brought out very faint details with great distinctness.

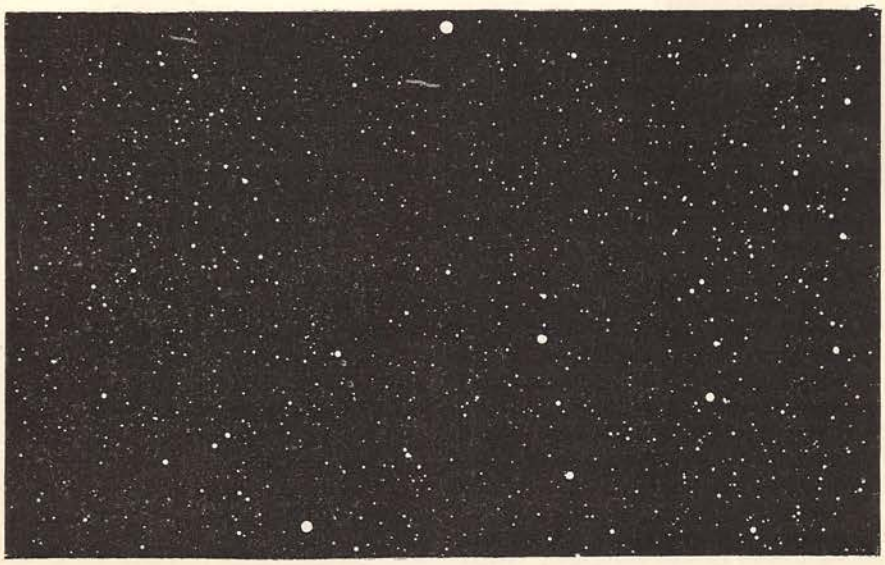
The Emperor of Brazil has already given orders that the Observatory of Rio de Janeiro shall be furnished with a photographic apparatus similar to that at the Paris Observatory, and that it shall take part in the photographic survey of the heavens proposed by Admiral Mouchez.

for determining the motions of satellites, and may even lead to the detection of others, if any such exist.

It is not too much to hope that the study of double and multiple stars will be greatly helped by photography, and it may be that the delicate work of observations for parallax and for proper motions may be, to say the least, confirmed by the photographic plate.

The photographic method is specially applicable to the study of groups of stars such as the Pleiades, for the purpose of determining whether the members of the cluster have a physical connection, and are in movement among themselves.

At present, indeed, photography seems less easily applicable to stellar photometry, and to the study of



PHOTOGRAPH OF A PORTION OF CYGNUS.
(Part only of the Photograph by MM. Henry.)

Another important result is the possibility of discovering asteroids by photography. Small stars appear on the plate as very minute round points, but an asteroid would be distinguished at once in consequence of its proper motion among the stars, for its image on the plate would be a short line. This line, by its length and position, would indicate the asteroid's motion in direction and velocity. The Brothers Henry have already obtained the image of an asteroid of the eleventh magnitude, which showed its motion by a sharply-defined line, all the neighbouring star-images being minute round points.

Professor D. P. Todd, who regards the evidence in favour of the existence of a trans-Neptunian planet to be well founded, has said recently:—"The capacity of the modern dry plate for the registry of the light of very minute stars, makes the application of this method the shortest and surest way of detecting any such object." The success of MM. Henry in photographing the satellite of Neptune shows that photography may take the place of eye observations

the changes in the light of stars which are variable, but the difficulties in this direction of work are certainly not insuperable, and success here also lies probably in the near future.

The writer has not referred to a far more refined application of photography to the heavens, one on which he has specially worked—namely, the photography, not of the simple images of the stars, but of their light after passing through a prism. The writer obtained the spectrum of a star on a collodion plate as far back as 1863. He has since photographed the spectra of many stars, of two comets, and of the nebula in Orion. It is not the place to speak of the increase of our knowledge of the physical conditions of those bodies which these photographs have given to us. Space forbids to speak of the photography of the corona of the sun, and the determination, photographically, of the motions of stars in the line of right.*

* The writer wishes to express his thanks to Mr. Common, Admiral Mouchez, and the Brothers Henry, for the original photographs from which the illustrations have been made.