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PHOTOGRAPHS OF THE MILKY WAY AND OF COMETS

MADE WITH

THE SIX-INCH WILLARD LENS AND CROCKER TELESCOPE

DURING THE YEARS 1892 TO 1895

BY

E. E. BARNARD

ASTRONOMER IN THE LICK OBSERVATORY

UNIVERSITY OF CALIFORNIA

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INTRODUCTION.

ACKNOWLEDGMENTS.

In the later days of my connection with the Lick Observatory it became my desire to see a number of the star and comet photographs that I had made collected into a volume. The expense of reproducing the pictures prohibited this, unless outside financial help could be obtained. It became my duty, therefore, to secure, if possible, the necessary money for this purpose. This was successfully accomplished through correspondence and by personal interviews. No serious difficulty was experienced and I can not help but be grateful for the friendly manner in which all the contributions were made. The total amount thus contributed was $2,225.

I would gratefully acknowledge my indebtedness to the generosity of the following persons whose liberal contributions made possible the reproduction of the photographs for this volume:

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Mingled with the pleasure of finally bringing out this volume is the sad knowledge that since the contributions for the work were made a number of the subscribers have passed on to their final rest.

In conclusion, I wish to express my deep obligations to Professor W. W. Campbell, Director of the Lick Observatory, for many courtesies, and especially for help in the final publication of the volume.

I am also deeply indebted to my niece, Miss Mary R. Calvert, for invaluable help in the preparation of the manuscript and of the negatives, in the checking and identification of the star lists, and in many other ways.

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To Mr. Clarence Hough, president of the Chicago Photogravure Company, I am indebted for many courtesies, and to Mr. A. B. Brunk, superintendent of the above firm, I owe everything in the way of excellence that pertains to the reproductions. With unbounded patience and skill, and with a deep interest in the outcome, he has endeavored in every way to produce the best possible work.

I also owe many obligations to Professor E. B. Frost, Director of the Yerkes Observatory, and to Professor George E. Hale, Director of the Solar Observatory of the Carnegie Institution, for courtesies extended to me at various times during the progress of the work.

THE REPRODUCTIONS.

The very great delay in the appearance of this volume of photographs can only be attributed to the writer's anxiety to secure the best possible reproductions of the original pictures. Various methods of reproduction were tried, only to meet with disappointment and failure. The process, finally adopted, is known as the "collotype," which consists of a printing surface on a ground glass plate, that can be used for ink printing in the ordinary press. This process is capable of giving excellent results in the hands of an expert, but under ordinary conditions it is undesirable from the various difficulties that beset it, apparently, on all sides.

The work was begun in 1895–6, and thirty-six plates were then completely printed. The reproductions becoming unsatisfactory, it was abruptly stopped. These thirty-six plates were paid for by the writer, personally. Eleven complete sets were finally rejected, so that only twenty-five of those first printed are used in the volume. After some fifteen years' delay the work was again resumed. In the mean time trials had been made of other processes in various cities. The collotype seemed, after all, to be the most satisfactory. Fortunately, the same man was able to take up the work again, and his previous experience with the pictures was of the greatest importance. Hence, to the skill and intelligent interest, and especially to the enthusiasm of Mr. A. B. Brunk, of the Chicago Photogravure Company, belong whatever excellence these reproductions may possess.

The collotype is an old but interesting process, and one not well known to the average person in these days of half-tones. It has some advantage over the half-tone. Lantern slides and enlargements may be made from the pictures, and in the close examination of small stars it avoids the confusion produced by the screen of the half-tone. I have prevailed upon Mr. Brunk to give me an account of the process as worked by him. The work is very delicate, and no written description can present all the little niceties in the actual working, and the difficulties that must be overcome before the result is a success.

THE COLLOTYPE PROCESS.

The illustrations in this volume were printed on cylinder presses from plates prepared by the photo-gelatin process, also known as "collotype," a brief description of which is given in the following: Gelatin solution, sensitised with bichromate of ammonia, is poured over a heavy glass plate, forming thereon a very thin coating which, after having been baked in an oven at a moderate temperature, represents the picture carrier proper, now firmly adhering to the (printing) plate. The image of any given subject is obtained on the plate by slowly exposing its sensitive surface under a negative to (preferably) artificial light. This manipulation is similar to that of the printing of a photograph except that for this process a reversed negative is required. During the exposure, the chromatic gelatin undergoes a change to the effect that wherever the light is permitted to pass through the negative it will harden the gelatin surface and the various degrees of hardening will correspond minutely to the various values of the negative. When the exposure is closed, the plate is bathed in running water for the purpose of fixing the picture and washing the bichromatic salts out of those parts of the gelatin that were not affected by the light.

The changes taking place on the gelatin surface during the exposure, were observed accidentally, at about the middle of the last century, and through another accidental observation, a few years later, it was found that chromatic gelatin, when properly moistened with water, will accept printer's ink in its exposed (*i. e.* hardened) parts in exact proportion to the various degrees of hardening; while the same ink will be rejected by the gelatin in all those parts of the plate not affected by the light, for instance, among others, in the very dense or opaque parts of the negative. The gelatin not having been hardened in these places, holds enough moisture to repulse the greasy ink. Thus the highest lights will appear alongside of heavy shadows together with all the intermediate values as they are shown in a good picture, provided due care has been exercised during the various stages of operation. For best results, it is also quite essential that faultless negatives be used, since the means of eliminating defects in negatives are rather limited with this process, because of its extraordinary faithfulness of reproduction. Negatives afflicted with fogginess should not be used.

In quite a few instances these photo-gelatin prints have been pronounced as being superior to photographs, because the weaker parts of a negative, which often are lost in a photograph, can be well preserved on the process plate through additional local exposures and with the aid of carefully handled burning-lenses.

These process pictures are of great durability and they are not subject to changes like fading photographs.

A. B. BRUNK,
Chicago Photogravure Company.

August 15, 1912.

THE "WILLARD" PHOTOGRAPHIC LENS.

The so-called "Willard" lens is of more than passing interest, and a brief account of what is known of it may be of historical value.

Willard, from all I can learn, was not a maker of lenses, but simply a photographic stock dealer. I have been informed that the lenses bearing his name were made by Charles F. Usner in New York City, who, in the early days of photography, made portrait lenses for such stock dealers as Willard & Co. and Holmes, Booth & Hayden. These large lenses were used for making portraits during the wet-plate period of photography. Their great size was necessary to collect as much light as possible and thus to shorten the exposure for portrait sittings. Upon the introduction of the extremely sensitive dry plates they were no longer needed, and much smaller and less expensive lenses were substituted.

The advent of the Willard lens into astronomical work was due to the total eclipse of the Sun, which was visible in northern California on January 1, 1889. Through the influence of Professor Holden, a large number of amateur photographers, especially those in San Francisco and neighboring cities, became greatly interested in this eclipse. Under the general supervision of Mr. Charles Burckhalter of the Chabot Observatory, Oakland, California, these amateur photographers, many of whom were very skillful, were assigned positions on the line of totality to secure, with crude appliances, the best results obtainable in the representation of the corona. Some of the photographs were excellent, especially those taken by Messrs. Wm. Lowden, F. R. Ziel, and Wm. Ireland.

Mr. Ireland was especially fortunate in being able to secure the use of a large portrait lens of some 6 inches aperture and 31 inches focus, which he borrowed for the occasion from Wm. Shew, a photographer on Montgomery Street, San Francisco, who had used the lens, which had originally cost several hundred dollars, for making fashionable portraits (especially in the later sixties). Though Mr. Ireland had no equatorial mounting for the lens, his photographs were very successful, particularly in showing the great extent of the coronal streamers.

Impressed by the excellent results from this lens, Director Holden purchased it from Mr. Shew for the Lick Observatory with funds provided for the purpose by Hon. C. F. Crocker.

I had been endeavoring to photograph the star clouds of the Milky Way with a small Voigtländer rectilinear lens attached to the 6-inch equatorial, but because of the slowness of the lens, had secured but feeble impressions of these clouds. The great light ratio of the old 6-inch lens, suggested that it would perhaps serve my purpose. The results of some experiments which I made with it in photographing the Milky Way were very beautiful and intensely interesting. When the importance of the lens for such astronomical work became apparent, Professor Holden placed it in the hands of Brashear, who refigured it and greatly improved the definition of the star images.

DIMENSIONS OF THE LENS.

The following measures of the lens were made by the writer soon after its purchase by the Lick Observatory:

Diameter of the front lens, 5.85 inches = 148.6 mm.
Solar focus, 42.59 inches = 108.2 cm.
Diameter of the back lens, 6.73 inches = 171.0 mm.
Solar focus, 70.2 inches = 178.3 cm.

The distance from the rear surface of the front lens to the surface of the back lens was 12.8 inches. A diaphragm of 3.83 inches aperture was placed between the two sets of lenses at a distance of 5.54 inches from the front lens.

A recent determination from negatives made in 1895 gave

Focus: 30.66 inches = 778.9 mm.
Scale: 1 inch = $1^\circ.81$; $\therefore$ 1 cm. = $0^\circ.71$.

A small lantern lens was also frequently used. Indeed, it was with the lantern lens that the remarkable nebula of ν **Scorpii** was discovered.

THE WORK WITH THE LENS.

The early Milky Way and comet photographs were made with the "Willard" lens in a wooden camera box strapped onto the 6½-inch equatorial as a guiding telescope. The photographs of Swift's comet were thus made. Afterwards the lens, in its wooden box, was transferred to an ordinary equatorial mounting made by Brashear, and fastened to a flat iron plate which was attached to the upper end of the declination axis (see frontispiece). This mounting, as well as the lens, was the gift of Hon. C. F. Crocker, and the telescope, therefore, bears his name.* This usual form of equatorial mounting did not permit exposures to be carried through the meridian, which, except in south declinations, was a great drawback to the work. The only available means of guiding was a small telescope, of 2.4-inch aperture, belonging to the writer. This was fastened to the wooden camera box.

There was no means of illuminating any spider threads. Fine iron wires were, therefore, inserted between the lenses of a negative eyepiece. These were coarse enough to be just visible, in black relief, on the dark sky. A star in focus would be hidden behind these wires. To render it visible, therefore, the image of the guiding star was thrown slightly out of focus. The intersection of the wires

*Hon. C. F. Crocker has authorized the construction of an equatorial stand to take the Willard photographic telescope bought by him for the observation of the eclipse of December, 1889. The mounting will be made by Mr. Brashear, and will be provided with a driving clock, controlled in the manner invented by Mr. Keeler. The Willard lens, together with a 5½-inch Dallmeyer camera (lent to us by Mr. Pierson), will be mounted side by side, for the present, and will be employed by Mr. Barnard in making photographs of the Milky Way.—*E. S. H. Publ. A. S. P.* **2**, *128, 1890.*

placed over this small luminous disc for guiding, produced four small segments of light. During the exposure the illuminated quadrants were kept perfectly equal—the slightest deviation from equality could be detected. This method permits great accuracy in guiding, even with a small telescope, but it requires a brighter star to guide on than usual. For a comet without a bright nucleus, however, the guiding became a serious question, subject to considerable uncertainty, especially if the comet was faint. This will account for the ragged condition of the trails in the case of Brooks's comet. These dark guiding wires were used with the 6½-inch, as well as with the smaller telescope.

For housing the instrument in this form a small observatory building, with a dome and a very wide shutter, was erected near the water tank "Huyghens," where it still stands. (See frontispiece.)

ELECTRICAL PHENOMENA.

To judge from the almost entire absence of electrical storms on Mount Hamilton, one would get the impression that very little electricity was present in any form. While guiding, in making these photographs with the Willard lens, however, the writer frequently met with a singular experience which, while it may not be a new one, was at least an unknown feature to me at the time. Perhaps I may be permitted to describe it in connection with the present work.

On chilly or cold nights I wore an Esquimaux coat made of reindeer skin, and heavy rubber overshoes. Frequently, on bringing the eye to the telescope on such nights a spark would discharge with a slight shock between the eye and the eyepiece. This was extremely annoying, and finally became so disagreeable that it was found convenient frequently to touch the metal of the instrument, which would produce a discharge from the finger instead of from the eye. The probable explanation of this phenomenon is that it was due to the fur coat and the insulation of the rubber overshoes, the body becoming electrically charged like a Leyden jar. The approach of the eye to the eyepiece would discharge this electricity into the telescope from the eye. This phenomenon, under similar circumstances, sometimes occurred in observing with the 36-inch refractor. Neither telescope, at that time, had any electrical appliances.

On one occasion, when going to bed in the early morning, the conditions were such that rubbing the hands over the sheets produced a perfect shower of sparks, apparently threatening to set the sheets on fire.

There were also other similar manifestations of an electrical nature at different times.

THE CONDITION OF THE ORIGINAL NEGATIVES.

A few of the very early negatives have badly deteriorated from a want of complete fixation. These plates are brownish yellow in large areas and can not be copied now (except perhaps with an isochromatic plate and a yellow screen), but fortunately, before this deterioration began, I had made glass positives of these from which duplicate negatives were made. In fact, duplicate negatives have been made of all the originals used in this volume. These are permanent. No serious loss, therefore, has occurred or can occur.

Perhaps in extenuation of this oversight in the fixing it would be as well to say that a worker in the wet plate process (as I had been), was more apt to sin in this respect than a beginner in photography, because, with the collodion process, only a comparatively short fixation was necessary. The same held true for the washing of the negatives—a very little washing serving for a wet plate. My previous experience in wet plate work misled me, so that some of the first negatives (dry plates) were not thoroughly fixed. The effect of this mistake did not show at once, but after some years the negatives became brownish, and will ultimately be destroyed. At present there seems to be no remedy for a negative in this condition. Insufficient washing is not necessarily so fatal to permanency, for if signs of a defect in this direction are detected soon enough, little or no injury will have occurred and the plate can then be thoroughly washed. The effects of incomplete fixation, however, can not be remedied so far as I know, even when the deterioration is detected in its earliest stages.

Some of these early plates were varnished and they seem to have suffered very little. I have noticed some of these carefully, and where certain portions of the film near the edges of the plate failed to be covered with the varnish, the film has gone bad. It is extremely important that the negative should be varnished as a further preventive of deterioration, as it protects the film, the gelatin being very much affected by atmospheric conditions. Above all things, however, the plate must be thoroughly fixed. It is not safe to assume that the negative is fixed as soon as it is cleared in the hypo. To remove a plate from the fixing bath under such conditions is almost certain to insure its ultimate destruction. It should remain in the hypo at least fifteen minutes after it is apparently fixed. A thorough washing is also necessary to remove the hypo from the gelatin.

EASILY REMEDIED DEFECTS IN NEGATIVES.

There is one class of defects, however, that sometimes comes on a negative or positive in the drying, or later by accident, about which I have not seen anything written. If a negative is wet again after it is dry, "tears" will almost certainly form in the drying. Sometimes they occur in the original drying of the negative. These often leave semi-transparent markings. If examined closely, it will be seen that the film is thinner at these points or they will appear as slight indentations. By accident, in the early days at the Lick Observatory, I found the remedy for these. Thoroughly wet the negative again. The markings will quickly disappear. To prevent a repetition of the trouble, remove all the water from the film carefully with absorbent cotton before putting to dry. If drops of water get on a plate when dry they will cause these peculiar markings. Of course the remedy is the same as before. If a negative happens to be near a window and fine snow is blown in on it, wherever a speck of snow touches the plate a minute transparent spot will appear, so that the picture will be full of pinholes. Examined with a glass, these usually appear like small craters with raised walls. They are removed almost instantly by immersing in water as in the other cases. If the surface of the negative has been injured by being rubbed or slightly scratched, the abrasions will show on a print. The "water cure," however, will effectually remove these from the negative if the film has not been cut too heavily. The remedy in all the above cases is almost sure to be perfect; if not, there will at least be a very great improvement in the condition of the negative. In very stubborn cases a prolonged soaking helps. I make mention of these facts because the simple remedy does not seem to be generally known even among those who have had great experience in photographic work.

The above is a slightly modified extract from a paper by the writer (Suggestions in Respect to Photographing Comets with Special Reference to Halley's Comet) in *Pop. Astron.*, **17**, 608–9, 1909.

PHOTOGRAPHS OF THE EARTH-LIT MOON, ETC.

Experiments were made at various times in photographing the earth-lit portion of the new and the old Moon. It was found that an exposure of about 30 seconds, with the quickest plate, was necessary to show this phenomenon well. With the small lantern lens, however, a photograph of this appearance could be secured with one second's exposure.

Photographs were also made of the total lunar eclipses of 1895, March 10 and September 3, for two purposes: First, to see how well the lunar surface could be shown by photography, with such a lens, in a total eclipse, at which time the Moon is usually of a strong red color; second, to see if any small body revolving about the Moon, such as a lunar satellite (which would usually be lost in the glare of the Moon, and which during totality might be outside the shadow and hence fully illuminated) could be found.

For illustration of this non-stellar work, I have selected four photographs of the Moon made with the Willard lens under different conditions of illumination, etc. These are shown in Plate 1. The first two pictures show the night surface of the Moon illuminated by sunlight reflected from the Earth. The first photograph represents the new Moon in the evening sky of 1895, February 26. The second is the old Moon in the morning sky of 1895, August 17.

This phenomenon of the bright crescent embracing the ashy-hued globe of the Moon is sometimes popularly known as the "Old Moon in the young Moon's arms," especially when seen in the evening sky.

One of the lunar photographs which was made in 1895, August, $19^d\ 0^h\ 30^m$ G. M. T., shows the crescent as a mere thread of light. The entire dark part is also shown, but faintly. According to the *American Ephemeris*, new Moon occurred at that time on August $20^d\ 0^h\ 55^m.7$ G. M. T. The photograph was therefore made when the Moon lacked but $24^h\ 26^m$ of new. The thin crescent was a beautiful object to the naked eye. In recent years discussions have arisen over the question as to how near the time of new Moon the crescent can be seen. The photograph will, at least in part, answer this question.

The photograph of the total lunar eclipse of 1895, September 3, shows the Moon's surface illuminated by sunlight refracted by the Earth's atmosphere.

It is not necessary here to add (and want of space prevents it) a third example of illumination of the Moon's surface, *i. e.*, by direct sunlight; the three kinds of lunar illumination being

First—Reflected sunlight.
Second—Refracted sunlight.
Third—Direct sunlight.

A fourth picture of the earth-lit Moon (1895, June 25) with the planet **Venus** near the horn of the lunar crescent, is given as a matter of interest, but is without scientific value.

THE PHOTOGRAPHS OF THE MILKY WAY.

It has been thought best to give on the page facing the picture, where the peculiarities could be readily pointed out, a brief description of the principal features of each photograph, especially in the case of the Milky Way. In general this has been done, but certain regions are worthy of a more detailed account which, for brevity, should be placed in the main text. For this reason a description of the singular regions of **Scorpio** and **Ophiuchus** is printed here.

THE GREAT NEBULOUS REGIONS OF SCORPIO AND OPHIUCHUS.

The main features of the wonderful nebulous regions of **Scorpio** and **Ophiuchus** were discovered by the writer with the Willard lens. It is perfectly proper, therefore, that an account of his further investigations of the same regions with a more powerful photographic telescope should be incorporated here, especially as the regions in question have not been investigated by any other writer.

Through the courtesy and deep interest of Professor George E. Hale, Director of the Solar Observatory of the Carnegie Institution, the 10-inch Bruce photographic telescope of the Yerkes Observatory, was transported in 1905 to Mount Wilson at an altitude of 6,000 feet, where the writer went for the special purpose of further investigating these and other regions of the Milky Way. The following information, therefore, is that gained from the present photographs, supplemented by the additional information from those taken at Mount Wilson.

THE NEBULA OF ν SCORPII.

This object, remarkable as it is in appearance, is of far greater interest in the direct evidence it gives of the obscuration of light in space. This obscuration is manifest at a number of points in connection with the nebula; it runs all the way from a slight cutting off of the stars behind to perhaps a total extinction of their light. The boundaries of the nebula may roughly be taken thus, for 1855.0:

α	15^h	59^m	δ $-18°$	$20'$
	16	4	-18	0
and				
	16	10	-21	0
	16	16	-18	50

To the southeast its fainter portions involve the stars BD $-19°$ 4357, $-19°$ 4359 and $-19°$ 4361. The last two are in a dense nebulous mass in which, on the north side, are a thin dark lane and a narrow strip of brighter nebulosity. The two stars are connected with $-19°$ 4357, which is also nebulous, by a thin thread of nebulosity. North and following are dark regions with apparently very few stars.

The evidence for this obscuration is based upon the following considerations: The sky outside of the nebulosity gives the impression of a uniform distribution of the stars over this part of the heavens, and I think there is no question but that this is actually the case. The edges of the western end of the nebula, near the stars BD $-17°$ 4511, $-17°$ 4502 and $-18°$ 4240 are definitely defined. It will be seen that within the limits of the nebula in this region occurs an abrupt thinning out and dimming of the stars, the line of demarcation being the outlines of the nebula. In the northern and diffused side of the nebulosity, and also in the eastern portion near BD $-19°$ 4359 and 19° 4361, this thinning out of the stars is remarkable.

One of the strongest facts in this argument is, that at a point 40′ north and west of BD $-19°$ 4359, or, in 1855.0 α 16^h 10^m, δ $-19°$ $15'$, a patch of the partially hidden background, about one square degree in area, is seen through an opening in the nebulous matter. The nebulosity can readily be traced all around this opening, perceptibly dimming the light of the stars wherever it falls, but the small space in question is free from it. In reality, these stars are but a part of the rather uniform stellar background which is seen through a hole in the nebulosity from ν **Scorpii**, that partly obscures the stars in this region. On the face of it, this seems a strange statement, but if one examines the evidence it will be seen to be true. In a photograph made with the 10-inch Bruce telescope of the Yerkes Observatory which appears in the *Astrophysical Journal* (Vol. 31, January, 1910, Plate I), this spot of stars is 1.4 inches from the left side of the plate and 2.3 inches from the bottom. It will be seen, further, in that photograph, that this patch resembles exactly, in its clearness and in the number of stars, the background of the sky farther to the north, where manifestly there is no nebulous matter; or, in other words, it is simply the regular sky shining through a hole in the nebulosity. Perhaps the most remarkable thing, however, is that the brighter parts of the nebula seem nearly, if not quite, transparent, the darker portions apparently being the denser and more opaque.

THE GREAT NEBULA OF ρ OPHIUCHI.

One can not look upon a photograph of this extraordinary region without wondering what is really meant by its strange phenomena. I think there is no question that strong indications of light obscuration are shown, though for various reasons the evidence is not so clear as in the case of the nebula about ν **Scorpii.**

First of all, the picture gives the impression that the sky here (as in the case of the ν **Scorpii** region, which is really a part of the present one) shows a uniform distribution of the small stars. Suddenly in this background occurs, apparently, a hole almost free of stars, in which, fitting closely, is the great nebula of ρ **Ophiuchi**. From this hole and nebula several sharply defined lanes run eastward. From the west side of the bright part of the nebula about ρ **Ophiuchi** is a bordering of feeble nebulosity about 45 minutes wide and abruptly terminated at its edges. This feebler nebulosity seems to blot out the stars almost completely. Indeed, all around the nebula, except to the northeast, this obscuring matter is evident. To all appearances the nebula lies in a hole in a rich portion of the Milky Way, with vacant lanes extending from it to the east. Besides the two main masses, σ **Scorpii** is involved in a very strong and irregular condensation with much detail. This condensation is directly connected with the large nebula and spreads out in a faint diffusion for several degrees to the south. The main mass of the great nebula is at ρ **Ophiuchi**. It consists of two condensations whose centers are about 30 minutes apart—the eastern and brighter one surrounding ρ. The northern portion of this part of the nebula is beautifully ribbed. Another condensation, equally remarkable, lies 1 degree south of ρ at the eighth magnitude star CD $-24°$ 12684. This latter object is very remarkable; from the star as a center, issue four bright whorls of nebulosity which are about 20 minutes to 30 minutes long, the north and south ones being the longest. Some 14 minutes north and slightly east of this star is a singular U-shaped dark marking very sharply defined. Immediately following the star CD $-24°$ 12684 is apparently a dark whirlpool which is formed at the beginning of the vacant lanes running to the east from the region of ρ **Ophiuchi**. The lower or southern of these lanes, which is one half degree broad, is the strongest marked. Its edges are very clearly defined for about 7 degrees, after which it becomes broken and shattered and ends 10 degrees to the east in an irregular group of small holes or black spots. The northern and shorter of the two most conspicuous lanes is marked for about 2 degrees with very black, irregular and sharply defined rifts and perforations, which unfortunately are lost in the reproduction.

One would hesitate in passing on the character of these dark lanes. Near the great nebula there is every evidence that they are mixed up with the nebulosity and I think obscuration is strongly indicated. The larger and more extended of the lanes is so blank and so definite on its edges that one would almost believe that a long strip of obscuring matter lies between us and the stars here. If we accept this as obscuration due to some peculiar condition of a band of dim nebulosity, such an object would be unique among the brighter nebulosities. At the same time these dark lanes are not infrequently connected with a brighter nebulosity, as in the present case. We have excellent examples of this in the wonderful region in **Taurus** near the feeble nebulosity in α 4^h 10^m $\delta + 27° 55'$ (see "On a Nebulous Groundwork in the Constellation Taurus," *Ap. J.* **25**, 218, 1907), and in the case of the nebula Dreyer *Second Index Catalogue* 5146 (see Plate 81) which is placed at the east end of a dark lane over 1 degree long. At the same time we must admit the presence of feeble extensions of nebulosity near bright nebulæ that apparently do not cut off the light of the stars. A good example of this is the extended nebulosities about the **Pleiades**, which, from their connection with the cluster, are evidently on this side of the small stars. Though these nebulosities are feebly shown in streaks and masses over a region perhaps 10 degrees square, the background of small stars is uniform, and if these small stars are beyond the nebulosities they shine through with undimmed light. Other similar cases might be cited, such as the extension of faint nebulosities eastward from M8 and the great curved nebula in **Orion**, etc. It would appear, therefore, that some nebulæ and nebulosities do not produce this obscuring effect, while it is very marked in others. The **Orion** nebula is a good example of the absence of the general background of faint stars close to a nebula. There is a scattering of small bright stars about the nebula itself, but it is noticeable that the fainter ones are missing close to it. Another striking case of obscuration is the region immediately about M 78 = Dreyer 2068 (also in **Orion**) where the brighter part of the nebula is apparently surrounded for some distance by an obscuring medium which cuts out the light of the stars near it.

Two bright nebulæ, one below and the other above 22 **Ophiuchi**, make with that star an "eye," which is very striking in appearance.

Perhaps it will be well to state here that the remarkable nature of the region about ρ **Ophiuchi** was first shown in my early photographs with the Willard lens. But the presence of nebulosity here had been found by me earlier, in my comet sweeping at Nashville, Tennessee, and it was this knowledge, and the desire to investigate the supposed nebulosity, that led me to make the photographs with the Willard lens which resulted in the discovery of one of the most remarkable nebulous regions in the entire heavens.

While on the subject of this probable obscuration of the stars, it may be well to mention some recent visual observations which would seem to confirm the idea that the light of the stars may be interrupted by interposing nebulous or other matter in space.

In the *Astrophysical Journal* for December, 1913, the present writer has shown by visual observations with the 40-inch refractor of the Yerkes Observatory of the small black spot in a dense star cloud in the Milky Way (Plates 54–55), and of the black "notch" in the nebulous stream running south from ζ Orionis (Plate 20) that they are not true vacant sky, but apparently consist of dense, feebly luminous matter which is more or less opaque. In the article referred to, the following statements are made with respect to these two bodies:

> *The Small Black Spot in [1855.0] α 18^h 7^m δ $-18°$ $15'$:* On the night of July 27 of the present year [1913], the conditions were very favorable, both for transparency and for steadiness. Under these conditions the "hole" or spot was examined very carefully with the 40-inch telescope. With the following edge of the spot cutting across the middle of the field, which is some three times smaller than the spot, it was quite distinctly seen that the preceding half of the field, in which there were no stars, was very feebly luminous, while the following side showed a rich, dark sky with the few small stars on it. From the view, one would not question for a moment that a real object—dusky looking, but very feebly brighter than the sky—occupies the place of the spot. It would appear, therefore, that the object may not be a vacancy among the stars, but a more or less opaque body.

> *The Small, Black Notch in the Nebulosity South of ζ Orionis. [1855.0] α 5^h $33^m.6$ δ $-2°$ $35'$:* On the night of November 4 [1913], with good conditions of seeing and fair transparency, I examined this object with the 40-inch telescope and a power of 460. The position was carefully located with the aid of the photograph. The outlines of the spot—so sharp and clear in photographs of this region—could not be made out with any definiteness. The view showed that the spot is certainly not clear sky, for the field was dull, apparently indicating the presence of some material substance at this point. To me the observation would confirm the supposition of an obscuring medium.

THE PHOTOGRAPHS OF COMETS.

The great comet of 1882 was successfully photographed at the Cape of Good Hope by Dr. Gill, with the aid of a local photographer and his portrait lens. Several naked eye comets appeared later, but nothing of consequence seems to have been done in the effort to photograph them with portrait lenses until the appearance of Swift's comet of 1892. This object, from its brightness, promised much for photography. The photographs obtained of it with portrait lenses showed their very great value for such investigations and fixed the position of this form of instrument as one of the most important in any observatory.

COMET I 1892 (SWIFT).

VISUAL OBSERVATIONS.

This comet was discovered by Dr. Lewis Swift at Rochester, New York, 1892, March 6. Perihelion occurred April 6. (Berberich *A. N.* **130**, 215, 1892.) It was a large comet visible to the naked eye at the time of discovery and subsequently. Its greatest theoretical brilliancy occurred in the first half of April. During the period covered by the photographs, it was receding from the Earth and diminishing in brightness. Following are notes on its visual appearance:

1892, March 7^d $16\frac{1}{2}^h$.* Easily visible to the naked eye; as noticeable as a sixth magnitude star. The finder of the 12-inch telescope showed a tail about 15 minutes long. In the 12-inch, the comet was large and round and 7 or 8 minutes in diameter, with an almost stellar nucleus, of the eleventh magnitude, in the middle of the nebulosity. Though no tail was seen, its presence was indicated by the haziness of the sky near the head.

March 8^d 17^h. With the eye the comet was at least fifth magnitude. It was a little brighter than Davidson's comet of 1889.

March 9^d 17^h. Moonlight. The comet was very noticeable to the naked eye. The head was somewhat brighter than M8. It was like a hazy star and about as large as the **Orion** nebula appears to the naked eye, but brighter, and could not have been missed in a casual glance at the sky even in moonlight. The nucleus was not stellar in the 12-inch.

March 15^d 17^h. It was quite visible to the naked eye, like a star of the fifth magnitude. Nearly full moon. In the 12-inch the nucleus was eleventh magnitude, but no tail could be seen.

March 21^d 17^h. Through breaks in clouds. To the naked eye it was a large, hazy spot of the third or fourth magnitude.

*The time given in all of these observations is Pacific Standard Time, which is 8^h 0^m slow of Greenwich Mean Time.

April 3^d 16^h 20^m. The comet was bright to the naked eye with a faint, slender tail which reached faintly to the star BD $-8°$ 5150 ($5^m.8$) but not beyond it, a length of about 18°. This star was touching the south edge of the tail, which also passed close to the north of BD $-5°$ 5378 ($4^m.2$)—just free of the star.

April 4^d 16^h. Sky very thick. The head was slightly inferior to a third magnitude star. The tail was about as long as on the 3d.

April 5. In clouds.

April 6^d 16^h. The comet was conspicuous to the naked eye. The tail was visible for about 25 degrees and not quite 1 degree wide. The star BD $-3°$ 4961 ($5^m.4$) was in the north edge of the tail, while BD $-3°$ 4906 ($6^m.4$) and BD $-3°$ 4918 ($5^m.5$) were in the axis of the tail. The nucleus was suspected to be double with the 12-inch [perhaps this had something to do with the mass shown in the tail on the 7th].

April 7^d 16^h 15^m. The star BD $-3°$ 4961 was in the axis of the tail (which extended several degrees beyond the star). The head was equal in brightness to BD $-10°$ 5506 ($4^m.2$).

April 18. First clear night for a long time.

April 22^d $15\frac{1}{2}^h$. To the naked eye the comet was as bright as BD $+9°$ 4732 of the 4.0 magnitude, with a tail 8 degrees long. A starlike nucleus was visible in the 6-inch guiding telescope. The driving clock refused to work and the guiding throughout on this date was done by hand.

April 24^d 15^h 30^m. The tail passed over BD $+14°$ 4668 ($6^m.5$) and extended 5° beyond M 15. To the eye the nucleus was brighter than BD $+11°$ 4784 ($5^m.5$).

April 26. Sky veiled with haze. To the naked eye the comet's head was brighter than BD $+11°$ 4784.

May 22^d 14^h. No tail was visible to the naked eye, but the head was of the fifth magnitude.

May 23. Head alone visible to the naked eye, like a star of five and one half magnitude.

May 29^d $14\frac{1}{2}^h$. The comet was still faintly seen with the naked eye.

May 30^d 14^h. About sixth magnitude, but with no tail.

DESCRIPTION OF THE PHOTOGRAPHS.

1892, April 4. The tail consists of three widely diverging streams of matter. The two outer ones do not meet in the center of the head when prolonged, but seem to proceed more from the sides as if they were branches of a parabola that curved around the central brightness of the head. The main central streamer is double and fragmentary, part of the way. The north side of it is concave and at a distance of 2°.5 from the head suddenly becomes straight and nearly parallel with the south side of the streamer. There are a number of faint diverging streamers on both sides of the head—mainly on the north.

April 5. The tail gradually widens, the edges being stronger. Near the head the south portion is separated from the main tail and is connected with the head by a narrow, faint streamer.

April 6. The tail consists of two broad branches, the north one of which is the broadest and heaviest. This north branch has an abrupt bend in it toward the south at 39 minutes from the head. At this point there are a number of condensations. At 2°.8 from the head, the south edge of the north branch is strongly curved toward the south. Between the condensations and the head, the tail seems to be made up of a great number of separate strands more or less diffused, many of which do not seem to originate in the center of the head. The south branch is rather faint and broad.

April 7. The tail is separated into four or five slender diverging threads near the head, three of which are strongly marked. The two north ones are very long and slender and the south one—apparently the main one—is more or less convex to the north near the head, and at a distance of 1°.9 widens out into a great mass from which, apparently, a new system of streamers originates. The nucleus is visible in the center of the head and the two outer streamers would form a parabolic curve around it.

April 18. The head is small. The tail is formed of a bundle of widely diverging, slender streamers, some of which are bent and curved near the head.

April 22. The tail consists of three main broad diverging streamers, with several short and diffused ones from the sides of the head, which itself is small. It very much resembles the photograph of April 4. The north side of the middle streamer is concave and well defined and makes a rather abrupt change of direction. Farther out, at a distance of 1°.9 from the head, this separates into several streamers. At 5°.6 from the head is a long, diffused condensation.

April 24. The head is small and the tail consists of a number of diffused, broadening streamers, the central one of which is very strongly defined and irregular. About 1°.9 from the head a large portion is missing from the north side of the tail.

April 26. A large defect occurred in development which covers a portion of the tail. Through this defect the tail can be freely traced. The head is small. The tail, near the head, is made up of a bundle of six or eight diverging streamers, but the main tail consists of three strong streams the central one of which is double, two narrow strong streamers forming a border to it.

May 22. The tail consists of a slender, long streamer with some slight curvature on the north side at 28 minutes from the head. Farther out, it separates into several feeble strands, while near the head, especially on the north side, are a number of very thin, faint, short streamers.

May 23. The tail consists of one rather long, straight streamer. On each side of this is a widely diverging streamer giving the impression that if a longer exposure could have been made the tail would have consisted of three diverging main branches, very much like those of April 4.

May 30. The tail is short and apparently consists of a longer streamer on the south side and a short one on the north at a considerably different angle, the one on the south being more or less disconnected from the head.

POSITION ANGLES AND LENGTH OF THE TAIL.

The following position angles of the main axis of the tail were taken off from the BD charts with the aid of a large protractor:

	Position Angle.	Length of Tail.	
1892 April 4	261°	7°	to edge of plate
5	257	7	to edge of plate
6	257	7	to edge of plate
7	257	7	
18	260	8	
22	263	11	
24	261	6	
26	262	5	
May 22	262	6½	
23	263	10	
30	255	2	

DISCOVERY OF COMET V 1892.

On the night of 1892, October 12, in my regular work of photographing the Milky Way, I gave an exposure of $4^h\ 20^m$ with the Willard lens on a region a few degrees west of **Altair** (Plates 71 and 101). When the plate was developed and examined, a short hazy streak was found on it in the position (1855.0) $19^h\ 30^m$, $+12° 50'$. A comparison with another plate, which I had taken of the same region on September 26 of that year, and on which the object did not appear, showed that it was probably a new comet. On the night of October 13, this object was located with the 12-inch telescope and found to be a faint comet moving toward the southeast. With the 12-inch it was faint and round with a slight central brightening, but with no nucleus. The comet was estimated to be twelve and one half or thirteenth magnitude. (See *A. J.* **12**, 102, 277, 1892–3.) The trail, 9 or 10 minutes long and very diffused, is a little brighter along the axis. It is a conspicuous object near the middle of the plate.

This comet has been shown by M. J. Coniel (*Bull. Astron.* **12**, 245, 1895) to have a period of about six and one half years. It was due to return in 1899 and 1905–6 and also in 1911, but it has not been seen since 1892.

Perhaps it may be well to state here that this was the first comet discovered by the aid of photography.

COMET III 1892 (HOLMES).

This comet was discovered by Mr. Edwin Holmes in London on November 6, 1892. According to Prof. Lewis Boss, perihelion occurred 1892, June 13.

From several points of view, it was one of the most remarkable comets that has been observed. At the time of discovery it was distinctly visible to the naked eye as a star of the sixth magnitude or brighter, which, in the telescope, resembled a sharply defined planetary nebula. There is every evidence that, from a rather faint object, the comet must have rapidly attained to naked eye visibility by a sudden outburst of light somewhat similar to that of the **Novæ**. On January 16, 1893, after having gradually faded away for a couple of months, until it was excessively faint and diffused in the telescope, it once more suddenly became a bright star-like object—as bright as the seventh or eighth magnitude. Then, through a process of diffusion and fading exactly similar to that which took place immediately following its discovery, the comet again became faint, and finally faded from view.

Though this object has been observed at several returns since 1892, it has presented no peculiarities different from that of the ordinary faint telescopic comet, as will be seen from the following brief history:

The comet was discovered at its first predicted return by Perrine at the Lick Observatory on 1899, June 10. It was observed by Aitken with the 36-inch in August and September (*A. N.* **151**, 29, 1900). He described it as being very faint—not as bright as the fourteenth magnitude star. At this return, it was also observed by the writer at the Yerkes Observatory on eight dates from August 15 to November 7, and was described as ranging from thirteen and one half to sixteenth magnitude, with a very faint nucleus part of the time, and feebly brighter in the middle. At this time there was nothing to distinguish it from the ordinary faint telescopic comet. During this apparition (1899) it seems to have been observed only at the Lick and Yerkes observatories.

At the return of 1906 the comet must have been very faint. No visual observations seem to have been made. A number of photographs were secured of it, however, by Dr. Max Wolf at Heidelberg, so that the return was fully verified. (*A. N.* **172**, **173**, *passim*, 1906, 1907.)

From the faintness at the returns of 1899 and 1906, one would rather infer that previous to 1892 it had been an ordinary periodic comet, whose faintness had prevented its earlier discovery, and that the outbursts of light and attendant phenomena of 1892 were caused by some accident which happened to it at that time—due, possibly, to the peculiarity of its orbit and its relation to the asteroid zone.

So great is the interest attached to the extraordinary phenomena presented by the comet in 1892 and the possible connection they may have with the life history of these bodies, that it would seem that as full an account as possible of the various peculiarities of the apparition of that year should be preserved. As no adequate description of the comet, as seen at that time with a powerful telescope, seems to have been printed by other observers, I have prepared the following condensed notes from my observations of that return.

I would call special attention to the large, irregular mass shown on the photograph of 1892, November 10, about 1 degree southeast of the comet (center in 1855.0 α 0^h $45^m.2$ $\delta + 37^\circ 35'$) covering an area of one or two square degrees, and connected with the comet by a narrow, short strip or tail. I do not question but that this object (which is well shown in Plate 103) had something to do with the outburst of light in the early part of November, 1892. It is a pity that no photographs were taken of the region of the comet on 1893, January 16.

VISUAL OBSERVATIONS.

The announcement of the discovery of this comet was received at the Lick Observatory on November 8, 1892. The comet was observed that night with the 12-inch refractor. Its appearance was absolutely different from that of any comet I had ever seen—a perfectly circular and clean cut disk of dense light, almost planetary in outline with a faint, hazy nucleus and a slight condensation some 5 seconds south following the nucleus. With the naked eye it was just as bright, exactly, as the brightest part of the Great Nebula of **Andromeda**, near which it was visible.

At 8^h 0^m a careful estimate made the diameter 260 seconds. At 9^h 40^m micrometer measures made the north and south diameter 286 seconds.

November 9^d 6^h 5^m. To the eye, it appeared brighter than on the 8th, and was certainly brighter than the brightest part of the nebula and resembled a small star. It was equal in brightness and almost in appearance to the star 32 **Andromedæ** (BD $+ 38^\circ$ 90). It seemed brighter at 8^h 30^m. It was then brighter than 32, and almost equal to ν **Andromedæ** (BD $+ 40^\circ$ 171, of $4^m.7$). It was estimated to be nine-tenths the brightness from 32 to ν. This would make it 4.8 magnitude. It was certainly brighter than on the 8th, and with the eye alone would readily be mistaken for a star. At 8^h 30^m it was examined with the 4-inch comet seeker, with which the diffused haze surrounding the comet could be seen, also faint traces of a tail. With the 12-inch telescope there was a very diffused, faint envelope $12' \pm$ in diameter surrounding the comet with a faint diffusion following. At the center was a slight condensation, which followed the nucleus by $\frac{1}{2}' \pm$. The north preceding edge of the cometary disc was best defined.

November 11. With the 12-inch, the north preceding edge of the comet was very well defined, while south following it was very hazy and diffused. The nucleus, though faint, was almost stellar. Several small stars were shining through the nebulosity, one of which was 20 seconds from the nucleus. The comet more than filled the field of view.

November $12^d\ 9^h$. The comet was certainly a little less bright to the naked eye, and was about the mean brightness of 32 and ν **Andromedæ**, or 5.1 magnitude. It was more hazy to the naked eye than on the few previous nights.

November $13^d\ 9^h\ 0^m$. The comet was certainly fading. It was about three-tenths or four-tenths the brightness from 32 to ν, or 5.2 magnitude. At $11^h\ 45^m$ with the 12-inch telescope, it was considerably larger and less bright and not quite so definite. The measured diameter was 582 seconds.

November $14^d\ 7^h\ 40^m$. In the 12-inch, it was larger and fainter and more diffused. The measured diameter was 546 seconds. At 9^h, the comet was fainter to the naked eye. It was but little brighter than the star 32 **Andromedæ**.

November 16. In the 12-inch, the comet was not dense—a remarkable change from its previous well defined appearance. It was much larger, some 10 minutes in diameter, and fainter—through diffusion, apparently—and the edges were not so well defined. There was nothing about it different from other comets, except its size. The north preceding edge was best defined while the south following was diffused. Preceding the center was an ill defined nucleus from which a diffused brightening extended south following. At $7^h\ 20^m$, to the naked eye, it was a little less bright than the mean between 32 and ν **Andromedæ** and was star-like. It was considerably brighter than BD $+ 36^\circ$ 148 ($6^m.5$), about $1^\circ \pm$ south-east of it.

November 21. The comet was 15 minutes in diameter, very diffused south following, with a feeble brightening near the middle. The north preceding edge, though not diffused, was very dim and hazy. It was very much fainter than 32 **Andromedæ** and was just fairly visible to the naked eye.

December 5. The comet was extremely diffused, especially south following, but was very easy with the 12-inch. It was about twelve and one half magnitude. The more diffused part was 20 minutes in diameter. By sweeping rapidly, the comet seemed to diffuse over a very large area—greater than the field of 42 minutes. A faint condensation was visible in the preceding part with a feeble brightening south following. The preceding edge was a little more definite than the rest, but it was all very vague. In the finder it was very large, diffused and dim.

December 7. The comet was brightest and least diffused when seen in the comet-seeker.

1893, January 4. In the 12-inch telescope it was excessively faint and very large—indefinitely large. With 150 diameters there was only the feeblest trace of it.

January $6^d\ 16^h\ 30^m$. In the 12-inch the comet was very faint.

January 16. On this date, the sky cleared after dark, which was the end of a cloudy spell of several days duration. Between 6^h and 7^h I set for Holmes's comet with the 12-inch telescope, with little expectation of seeing it again on account of its faintness. A small, bright hazy star presented itself in the field. When examined with a magnifying power of 150, the object appeared small, bright and strongly condensed. Thinking this could not be the comet, a second setting was made with the same result. Still uncertain, a series of measures was made to see if the object was in motion. The results finally showed that it was really the comet. In the finder it looked like an eighth magnitude star. As soon as the measures proved that it was Holmes's comet a telegram was prepared announcing the remarkable change that had taken place in it. Either just before the message was sent by Professor Holden or just afterwards, a telegram from Palisa, at Vienna, came announcing the change. At $9^h\ 55^m$ in the 12-inch the nucleus was tenth magnitude and star-like, but it had only been showing for a few minutes. The comet was certainly brightening. By comparison with the stars BD + 33° 232 ($7^m.8$) and + 33° 236 ($8^m.2$) in the finder of the 12-inch telescope, it was 7.9 magnitude, and appeared like a small, bright star—wholly undistinguishable from a star. At $10^h\ 10^m$ it was certainly increasing in brightness. The nucleus could then be easily made out and was distinct, though at first it was only suggested. "With 150 it looks exactly like **Nova Aurigæ** with 700 on the 36-inch." At $10^h\ 20^m$ there was no question but that the nucleus was brightening; it had become very easy and seemed to have formed during the observations.

With the 36-inch telescope the appearance of the comet was the same as that on November 8 with the 12-inch. Its outline was quite definite and the nucleus was pretty bright, central, hazy and yellow, while the nebulosity was bluish. At $10^h\ 55^m$, with 360 diameters, there was a feeble glow surrounding the comet about 1 minute in diameter. At $11^h\ 0^m$ with the 12-inch telescope it was certainly brighter and the nucleus better seen. In the finder it was fully equal to BD + 33° 246 ($8^m.1$).

The following measures of the diameter were made on this date:

h	m	″	
8	15	29.4	(1) with 12-inch telescope
9	50	32.4	(2) with 12-inch telescope
10	30	44.0	(3) with 36-inch telescope
10	43	47.2	(3) with 36-inch telescope
11	14	46.7	(2) with 36-inch telescope

January 17. At $6^h\ 20^m$, with the 12-inch telescope, the comet had a beautiful star-like nucleus, which was surrounded by a disk of fainter nebulosity. At $7^h\ 9^m$ the nebulosity was 46″.0 in diameter. The north edge of the comet was too indefinite to permit more than a rough guess at the setting for the diameter. At $8^h\ 0^m$ the nucleus was the most conspicuous object. It was yellowish and just as bright as, but more conspicuous than, the star BD + 33° 247 of the 9.4 magnitude. The nucleus, which at the first observation on January 16 was scarcely visible, was now strikingly conspicuous. In the finder the comet was almost stellar,

though a little hazy—like a small, hazy star, and was of the same brightness as BD + 33° 232 of the 7.8 magnitude. At 8^h 45^m the nucleus was probably somewhat brighter. At 9^h 20^m and 10^h 35^m there was no change in the appearance of the comet or nucleus.

January 18. At 6^h 55^m the diameter was roughly 90 seconds. In the finder it was of perceptible size, and hazy, compared with the comparison star. With the 12-inch there were only the feeblest traces of a nucleus. The comet was pretty strongly condensed and perhaps not any brighter than on the 17th. At 7^h 35^m the nucleus was very hard to see, not brighter than the thirteenth magnitude, and placed, possibly, a little preceding the center. The comet was round and much brighter in the middle, but ill defined at the edges. At 9^h 45^m the nucleus was very difficult and faint, about thirteenth magnitude. It was almost lost in the small brightening that surrounded it. The comet itself was very noticeable and hazy in the finder.

January 19. At 6^h 50^m a rough measure made the diameter of the comet north and south 121 seconds. There was no limit to the edges of the nebulosity. The nucleus was bright. At 9^h 50^m the nucleus was twelfth magnitude, but was not distinct.

January 20. At 6^h 45^m, with the 36-inch telescope, the measured diameter was 136 seconds. It was much brighter in the middle, and the edges were not definite. It looked like a great nebulous sphere with a conspicuous nucleus of the tenth magnitude in its center.

January 22^d 7^h 30^m. With the 36-inch the comet was very diffused and about 3 or 3½ minutes in diameter. The nucleus, which was hazy and indistinct and of the twelfth magnitude, was difficult from the dense glow about it.

January 23^d 8^h 0^m. In the 12-inch the comet was about as before, except that the nucleus was very indistinct and hard to see.

January 24. Moonlit sky. In the 12-inch the comet was brightish and cometary looking—quite large and conspicuous as a considerable nebula. It was whitish and dense and somewhat brighter in the middle.

DESCRIPTION OF THE PHOTOGRAPHS.

1892, November 10. The comet consists of a sharply defined, dense, circular disc 8 minutes in diameter, somewhat diffused on the north following edge. This is surrounded by a fainter, diffused, circular nebulosity 19 minutes in diameter. Straggling from this towards the southeast is a faint nebulous strip which widens out into an irregular mass whose center is 48 minutes from the center of the comet and which is 39 minutes in diameter.

November 16. The comet is a rather sharply defined, dense, circular disc 16 minutes in diameter, the south following edge of which is more or less diffused.

Through this disc several star trails are visible. The exterior and fainter nebulosity has disappeared and there is no trace of the diffused mass south following the comet.

November 18. The comet consists of a circular, rather sharply defined disc of unequal density 15 minutes in diameter through which star trails are visible. The south following edge is diffused as if brushing out to form a tail. There are slight traces of a diffused glow about this disc, which may be 28 minutes in diameter. Nothing is shown of the mass of November 10 south following.

November 21. The comet consists of a circular disc 19 minutes in diameter, very diffused on the following side, but fairly sharply defined preceding. A great many stars are seen through this, one of which, just within the preceding edge, is bright. There are no evidences of exterior nebulosity.

December 8. The comet is large, about 25 minutes in diameter, and rather faint with a great number of stars shining through it. The preceding edge is definite, but the following side is diffused. Preceding the center is a definite nucleus from which a slender brightening runs to the following edge of the comet.

In connection with these observations it is important to refer to the visual observations of the spectrum of the comet which were made by Professor Campbell at the Lick Observatory. (See *A. N.* **131**, 211, 1892.)

> The spectrum of the very interesting comet discovered by Holmes is of an extreme type and probably unique. Visual observations made November 8 and 9 showed a continuous spectrum for all parts of the comet. It extended from near *D* to above *G* for the nucleus, for the very condensed and nearly circular coma (about 5′.5 in diameter), and for the very condensed tail seen within this coma. Outside the coma, in the direction of the tail, a very faint glow was just visible in the high power finder of the spectroscope (which would probably be seen to better advantage under low power). This, also, gave a continuous spectrum, though very short, in the yellow and green. The position of maximum brightness in the spectrum was near λ 515, which doubtless was due to the presence of a slight trace of the usual green band. But, except for the fact that the maximum brightness was higher than is generally the case in continuous spectra, it would have escaped detection. The increased brightness was more noticeable in the spectrum of the very faint parts of the comet than in that of the bright parts. There was possibly a trace of the yellow band; but, if so, it was exceedingly faint.
>
> Photographs of the spectrum extending from $H\beta$ to $H\delta$ show it as continuous, but the wide slit required leaves it in doubt whether the Fraunhofer lines were present or not.

COMET IV 1893 (BROOKS).

This comet was discovered by Mr. W. R. Brooks at Geneva, New York, 1893, October 16. It had passed perihelion on September 19. During the period covered by the photographs, the comet, though approaching the Earth, was theoretically diminishing in brightness. It was just faintly visible to the naked eye for about one day—October 21. This increased brightness was only temporary and was undoubtedly due to the disturbed condition of the tail on that date. The comet had been carefully looked for with the naked eye under the best conditions previous to this, but the records do not show that it was so visible on any other date.

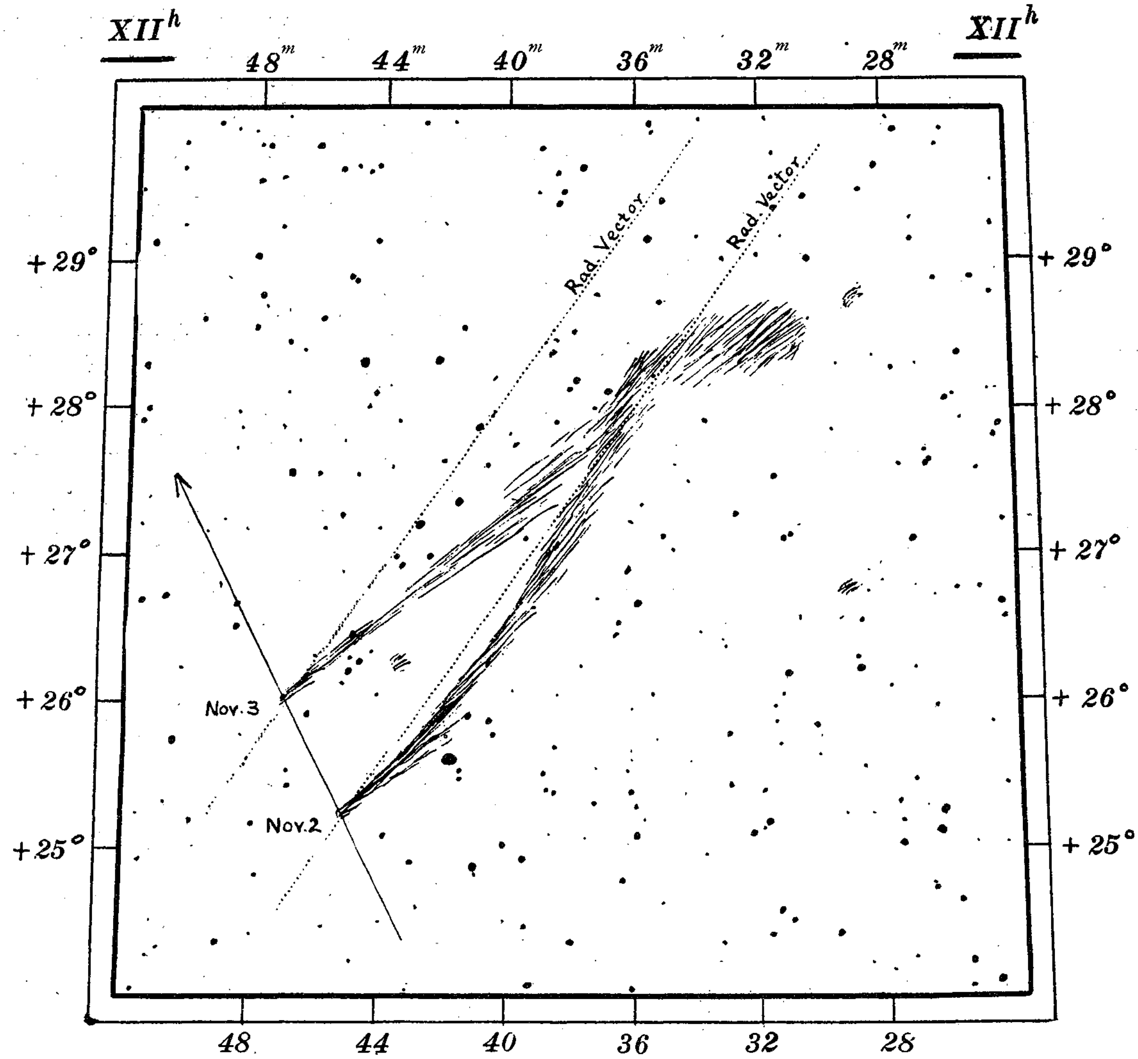

Diagram showing the relative positions of the tail of Brooks's comet and the radius vector on 1893, November 2 and 3.

Brooks's comet should hold an important position in cometary photography for it was the first to show the abnormal phenomena which have so complicated the problems presented by these strange bodies and which, in later years, have added so marked an interest to their study. Another fact also brought out first by this comet was the remarkable photographic activity of its light. Though only feebly visible to the naked eye for one day, and never specially bright as a telescopic object, the fainter features of its tail were well shown with relatively very short exposures—relatively short in comparison with the time required by some of the comets of later years which have been far brighter visually than this one.

Some of the phenomena shown in the photographs of it were unique at the time and they mark an important epoch in the study of comets. There were several periods of great disturbance in the tail, the one that covered the dates October 21, 22 and 23 being the most extraordinary. Though not so striking, the deflections of the tail on November 3 and November 7 are fully as important, because, probably, the same cause was responsible for all these peculiarities. This comet was the first to show these extraordinary "freak" changes, which one would call abnormal. It would seem that these two features—abnormal phenomena and quick photographic action—are, for some reason, closely related. The comets (whether bright or faint) that show the most remarkable and abnormal features seem to be the quickest in photographic action. Under the word "abnormal" I would not include such a phenomenon as the great mass shown to be receding from the head of Swift's comet on 1892, April 7, because this could be easily explained on the assumption that it was a mass of matter expelled from the head which was moving outwards in the direction of the tail. As "abnormal" features, I would include a shattering of the tail such as occurred in the case of Brooks's comet on October 23, etc., which had the appearance of being due to some external force; also, I would include double curvature of the streamers or parts of the tail, and sudden changes in the direction of the tail not accounted for by the motion of the comet such as occurred in Brooks's comet on November 2–3 and 6–7.

VISUAL OBSERVATIONS.

There are but few visual notes on this comet and those, with the exception of October 21, are telescopic.

1893, October 17^d 16^h 40^m. With the 12-inch a nucleus and tail were visible.

October 20. Tried to see it with the naked eye but could not.

October 21^d 16^h 40^m. It was faintly visible to the naked eye as a dim streak about one degree in length.

October 26^d 16^h 30^m. With the 12-inch there was a short tail visible, but the comet was not bright.

October 27^d 16^h 40^m. It was pretty bright, but the tail was dim.

November 2^d 15^h 20^m. The head was pretty bright, but there were only faint traces of tail.

November 6. With a low power on the 12-inch the tail could be traced for less than 1 degree.

DESCRIPTION OF THE PHOTOGRAPHS.

1893, October 18. The head is small. The tail is narrow for 8 minutes and then widens out into a fan-shaped form consisting of the main branch and a smaller branch on the south side. There seem to be some irregular condensations near the head.

October 20. The tail consists of a main branch which is strong, but irregular and gradually widens, and a shorter streamer on the north side at an angle of 25 degrees to the other.

October 21. This is a very beautiful and unique picture. The tail near the head is slender. At about 11 minutes from the head it becomes fainter. It then becomes stronger and curves northward to a point 18 minutes distant. It then irregularly widens and is convex to the north, to a projection on the north side at a distance of 45 minutes from the head. There is another saw tooth projection on the north side at a distance of 54 minutes. From this point on, the tail consists of irregular short diffused strips, and is gently convex to the north. The whole picture strongly reminds one of the ancient descriptions of a comet as a "torch in the heavens." The reproduction is a faithful copy of the original.

October 22. This is a very remarkable picture. The tail near the head for a distance of 11 minutes is diffused with a very short, narrow streamer on the north side at an angle of 15 to 20 degrees. Then begins the main streamer which apparently is disconnected from the head, and which has a sharp definite point in the end towards the head. This streamer is narrow and somewhat irregular and extends to a point about 56 minutes from the head, where it is rather suddenly deflected to the north and continues a short distance further, parallel with its original direction. There are some irregularities in it near the following end. At 50 minutes from the head begins a long irregular mass at a distance of 11 minutes south of the main branch. This runs parallel with the main branch for 17 minutes. Then it is suddenly deflected to the north at a sharp angle and continues parallel with its original direction in an irregular manner to a distance of $2^\circ.7$ from the head, where it suddenly turns south and apparently terminates. Beyond this at a distance of $3^\circ.7$ from the head is an irregular strip of nebulosity 34 minutes long at nearly right angles to the main direction of the tail and 56 minutes south of its axis. This seems to be disconnected, or at least is connected with the main tail by a very feeble nebulosity. Then in the axis of the main tail, continued, at a distance of $3^\circ.7$, completely separated from the other part of the tail, is a larger mass 39 minutes in diameter, slightly elongated in the direction of the main tail. The whole tail in this region has the appearance of being disrupted and shattered by some force moving through it towards the south. The reproduction fairly represents the original.

November 2. The tail is rather slender and very strongly and irregularly concave to the north. It is very irregular, both in form and density, but of nearly uniform brightness to the end. A slender streamer runs tangent to the curvature of the tail for a distance of $1^\circ.1$ on the south side. At a point $2^\circ.9$ from the head is an abrupt gap in the tail for a distance of 34 minutes which is almost, if not quite, devoid of nebulosity. At $3^\circ.6$ from the head, the tail is suddenly bent at an angle of nearly 90 degrees toward the south. This latter portion, which extends for 59 minutes, consists of several cloud-like masses. The north side of the tail is somewhat more definite, the south side being diffused. The general impression given by this picture is that the tail, which was moving toward the northwest, was beating against a heavy current of resistance, like a strong wind, which, near the end of the tail, suddenly became so strong as to bend it abruptly backwards at nearly right angles.

November 3. The tail is somewhat concave and better defined on the south side for a distance of 2°.8 from the head, where it begins to bend slightly to the north and continues to a distance of 3°.7, where there is a large, round mass on its south side, the center of which is 4°.4 from the head. A slender, short streamer running from the head on the north side makes an angle of about 10 to 15 degrees with the main tail. There is a sudden dent in the tail 2°.2 from the head on the south side.

November 6. The head is small and the tail is sharply defined and nearly straight on the north side for a distance of 1°.9, while the south side is more diffused and seems to consist of a great number of short streamers making an angle of about 20 degrees with it. On the north side is a short streamer at a slight angle to the tail. At a distance of 1°.5 from the head is a small, elongated nebulous mass detached from the tail but nearly parallel with it, whose length is 11 minutes and width 3 minutes. At 1°.9 from the head, the tail is suddenly bent to the north and then continues in its original direction in irregular and disconnected masses to a distance of 6°.5, where a larger and more distinct mass is situated, slightly to the north and west of the elongated nebula, Dreyer 4631. This strip is 39 minutes long and less than 11 minutes in width. Its axis runs nearly north and south. Unfortunately this mass, whose center is (1855.0) $12^h\ 33^m.7 + 33^\circ\ 25'$, has been cut out by the mask in the reproduction. Its position would be 0.3 inch to the right of the upper right corner of Plate 112. Part of the nebula (Dreyer 4631) is shown at the right side, 0.25 of an inch from the top, like a "nick" in the edge of the plate.

November 7. The tail, which is long and slender, widens slightly towards the end, and for one half its length is best defined on the south side, and for the rest of the way on the north. It is irregular in brightness, especially at points 1°.0 and 3°.6 from the head. At its end, it diffuses to the elongated nebula (Dreyer 4631) of November 6. A slender, faint streamer runs at a very slight angle to the tail on the south side. The general appearance of the tail, especially near the middle, is that of a slightly wavy streamer.

November 10. This is a beautiful picture. The head is exceedingly small. The tail consists of a main branch which is irregular and widens slightly towards the end and is very narrow towards the head. Two very diffused side streamers appear and extend for 1°.1—one on each side of the main tail. The south one of these is very diffused and wide, the north one less so. At 4°.5 from the head is a brighter condensation.

November 11. The tail is long and slender and wavy. There are several slender streamers on the north side, one of which has its origin at a distance of 1°.5 from the head and extends to a distance of 4°.2. There is a short streamer on the south side of the head, making a slight angle with the tail. At a distance of 4°.2 from the head is a brighter condensation in the tail.

November 12. The tail is long and slender and irregular. There is a short streamer on the south side which is apparently slightly convex to the south. A very slender, long streamer on the north side begins 1°.0 from the head and runs to a distance of 1°.8. The tail apparently terminates at a distance of 5°.0, but there is a continuation of this which has apparently drifted toward the south and is especially strong in the form of an elongated mass at a distance of 7°.5 from the head in the position (1855.0) $12^h\ 37^m.5 + 39°.0$.

November 13. The head is very small. The tail is slender for 22 minutes and then widens slightly and separates into two parts, the south one of which becomes strong and wider and seems to be separated by a narrow, dark strip 1°.9 from the head. After this the tail extends in a fragmentary manner to and beyond the star *α* **Canum Venaticorum.** An elongated portion near that star, at a distance of 5 degrees from the head, is especially noticeable.

November 14. The head is very small. The tail is slender and of uniform brightness for a distance of 2°.8, after which it becomes very faint and diffused. It is very narrow near the head and at a point 22 minutes distant a part of the tail curves slightly to the north, but a slender thread continues for 54 minutes or so in the original direction. The tail can be traced to the north of and beyond *α* **Canum** very faintly.

November 15. No. 1. The tail is long, slender and diffused. There is a dark streak running from the head on the south side of the tail for about 54 minutes. The head is very small.

November 15. No. 2. The tail is a little stronger in this plate. The dark streak on the south side is still visible. A diffused streamer from the head runs along the south side of the tail for 34 minutes. This diffuses toward the main tail and the dark streak is seen to be due to a vacancy where the diffusion from the streamer has not yet reached the south edge of the main tail. At a distance of 2°.3 from the head the tail continues in an irregular straggling condition to its end.

November 19. The tail is long, slender and diffused and rather irregular; it seems to be somewhat brighter at a distance of 3°.0 from the head.

REMARKABLE PECULIARITIES OF THE TAIL.

The tail of this comet frequently exhibited very remarkable and unique phenomena. So strange and unaccounted for are some of these that they have suggested the presence of some outside influence, coming neither directly from the Sun nor from the comet itself, as being responsible for them. These peculiarities consisted of disruptions, distortions and deflections of the tail. For a few days the tail would be parallel to itself, and agree with the direction of the radius vector. It would then be thrown forward, and in one case, November 2, the end of it was in *advance* of the radius vector. On two occasions, November 2–3 and November 6–7, the end of the tail remained stationary for a whole day, apparently retarded, while the rest of it, with the head, moved forward in the direction of the original motion. (See Plate 114 and diagram.) In each case the tail resumed its former parallelism as if it had finally been released from restraint. These changes of direction of the tail are not so evident in the individual plates and even in the tabulations they do not forcibly impress one. I, therefore, sought a method that would bring out the peculiarity in a more striking manner. As the comet remained in the same region of the sky, the plates on successive nights would, of course, show the same stars, with the comet in a different position. If, therefore, two negatives on successive dates are carefully superposed, star for star, and copied in a camera, the effect will essentially be the same as if the comet had been photographed on one plate on two successive dates. If no change has occurred in the direction of the tail in the mean time the two tails will be parallel in the composite picture. This method, which does not seem to have been used before (except by the writer), is far more effective in showing changes in the tail than any mere tabulation of position angles could be. Separating the original negatives into pairs, on successive dates, I superposed them thus, for examination. It was found that with two striking exceptions the tails were essentially parallel.

Following are the notes of this examination:

October 18 / October 20	Considerably divergent	November 10 / November 11	Slightly inclined (converging)
October 20 / October 21	Essentially parallel	November 11 / November 12	Somewhat inclined (diverging)
October 21 / October 22	Parallel	November 12 / November 13	Parallel
November 2 / November 3	Great deflection of the tail on November 2	November 13 / November 14	Parallel
November 6 / November 7	Great deflection of the tail on November 6	November 14 / November 15	Parallel

To exhibit these peculiarities on the dates of November 2 and 6 I have prepared the two pictures of Plate 114 which show that a strong deflection of the end of the tail occurred on these dates. It is hardly necessary to attempt any explanation concerning these two photographs. They speak for themselves far more forcibly than any description can do. After the changes in direction on November 2 and 6 the tail had again swung back to its normal position on November 3 and 7. A lesser change of this kind took place, also, between November 10 and 11.

In later years a similar, but much more violent case of acceleration of the tail occurred in the case of comet *c* 1908 (Morehouse), on 1908, September 16, when the tail was thrown ahead of the radius vector at a very great angle (*Ap. J.* **28**, 295, 1908).

POSITION ANGLES AND LENGTH OF THE TAIL.

To show the deviation of the tail from the radius vector the following table has been prepared where:

P = position angle of the tail taken from the BD charts.
P' = computed position angle of the radius vector.

		P	P'	$P-P'$	Length of Tail.
1893, October	18	324.0	322.6	+ 1°.4	3°
	20	318.0	322.5	− 4 .5	3½
	21	320.5	322.6	− 2 .1	5
	22	322.6	322.8	− 0 .2	4
November	2	321.7	323.8	− 2 .1	5
	3	305.7	323.8	− 18 .1	5
	6	322.6	323.9	− 1 .3	7
	7	312.7	324.0	− 11 .3	6
	10	320.7	324.2	− 3 .5	7
	11	312.7	324.2	− 11 .5	7
	12	321.0	324.2	− 3 .2	9
	13	319.5	324.2	− 4 .7	6
	14	317.0	324.4	− 7 .4	6½
	15	318.6	324.2	− 5 .6	8
	19	322.2	324.2	− 2 .0	6

The minus sign indicates that the tail lagged behind the radius vector.

On account of the curvature and irregularity of the tail, as shown on the photographs, the measured position angle must necessarily be uncertain, depending, as it does, upon the part of the tail used.

POSSIBLE CAUSE OF THE PECULIARITIES OF THE TAIL.

For a great many years I have called attention to the fact that some of the phenomena of comets' tails have indicated the presence of some kind of disturbing medium which they encounter in space. In the *Astrophysical Journal* for January, 1909, pages 70–71, I have given a brief outline of a theory to account for these changes.

If we accept it as a fact, and I think it is a fact, that the tail of a comet is sometimes broken or changed by some force or influence not directly due to light pressure or to the forces present in the comet itself, it becomes a very important problem to determine what this unknown cause may be. That it is actual matter in the planetary spaces which the tail encounters, does not seem probable. Swarms of meteors (such as we know do exist) might have some such influence, but it would probably be slight so far as attraction or collision is concerned, and could have no effect in producing an acceleration of the tail perpendicular to the radius vector, as is shown to have occurred in the case of this comet in the first part of November, 1893, where the effect was apparently in defiance of the laws of gravitation. No ordinary matter thus encountered and obeying only the laws of gravitation could produce the effect. It has occurred to me (*Ap. J.* **29**, 70, 1909), that a possible explanation of this peculiarity in comets' tails might be found in a similar cause to that which makes the aurora. The latter has been attributed to solar disturbances which produce magnetic storms on the Earth. These disturbing influences—which we will call them for want of a better name—must be going out from the Sun in various directions at more or less frequent intervals. The effect of these upon the attenuated matter of a comet's tail would likely be great, especially in view of the electrical conditions which may exist in the particles forming the tail. We know that the speed of such an influence must be vastly greater than that which could possibly be produced by gravitation. It would not appear that the effect of this disturbing influence should necessarily be radial with respect to the Sun's center. Possibly its action may sometimes be in a curved or orbital direction, such as might produce the acceleration shown in the tail on November 2 and 6. It would not prove that this idea is wrong if we should fail to find a coincidence of auroral display with disturbances in the tail of a comet. These disturbing influences are doubtless more or less local in their direction, and that which would produce a magnetic storm on the Earth might have no effect in the direction of the comet, and of course the reverse of this might be true. The frequent presence of the aurora would only show that the conditions were favorable for disturbances elsewhere in the solar system.

If it is thus true that the influence of a disturbance on the Sun is not widespread in direction in the solar system, it would account for the want of coincidence, sometimes, of an outburst on the Sun with an auroral display, the Earth having been missed, as it were, by the outgoing disturbance.

It may be that these ideas do not appear to be in accord with the known facts so recently established with respect to radiant energy. But this, after all, may not seriously affect them, because we do not yet know all the facts relating to the Sun and space. It is indeed possible that the comet's tail, with its far-reaching sweep across space, may act as a sensitive indicator of the presence of otherwise unknown forces at work in the region of our Sun.

COMET II, 1894 (GALE).

This comet was discovered by Mr. Walter F. Gale at Sydney, N. S. W., 1894, April 1. It passed perihelion 1894, April 13. At discovery the comet was 55½ degrees south of the equator, but it finally became visible above our southern horizon. The nearest approach to the Earth occurred about May 1.

Though the comet was visible to the naked eye, the tail, which was faint, could not be seen without a telescope.

Following are notes which were made during the brighter period of the comet:

VISUAL OBSERVATIONS.

1894, April 28. With the 12-inch telescope it was a conspicuous object, bright, large and round. It was visible to the naked eye, like a hazy star of the fifth or sixth magnitude and appeared somewhat less in size than the cluster Dreyer 2422. The cluster was about one fourth brighter than the comet.

April 29. The comet was noticeable to the naked eye as a bright hazy spot of about the fifth magnitude. In the 12-inch it was brightly condensed and round—about 6 or 8 minutes in diameter—but with no tail or nucleus.

April 30. It was conspicuous to the naked eye, and brighter than BD—18° 2190 of the 4.5 magnitude. It was large and round in the 12-inch and 6 to 8 minutes in diameter with no trace of tail. The 36-inch telescope showed a very small nucleus of the thirteenth magnitude.

May 2. It was conspicuous to the naked eye as a large hazy star of the fourth magnitude, brighter than the star BD—12° 2385 of the 5.0 magnitude. It was nearly as bright as BD—2° 2450, 4.8 magnitude.

May 3. The sky was thick during the exposure. To the naked eye the comet was a large spot of hazy light, approximately round. Though not so bright intrinsically as the star BD—3° 2339 ($3^m.7$) it was more conspicuous.

May 4. The sky was so thick that it was doubtful if the photographic plate would show anything of the comet. To the naked eye it was easily and conspicuously visible, but not so noticeable as the star BD—3° 2359, 3.7 magnitude.

May 5. Sky good and clear.

May 10. Faintly visible in moonlight with the naked eye.

May 22. Very faintly visible to the naked eye. It was round in the 12-inch with no trace of tail.

DESCRIPTION OF THE PHOTOGRAPHS.

1894, April 29. The head is large, round and diffused. The tail is a mere thread, perhaps double after 34 minutes from the head.

May 2. The head is large, round and diffused. The tail is rather slender and widens slightly. At its connection with the head it is a mere thread.

May 3. The head is large, round and diffused. The tail is long, straight and slender. Very narrow where it joins the head.

May 4. The main tail is very long and slender and slightly widening. This tail does not reach the head but is apparently disconnected at a distance of 45 minutes from it. There are two slender streamers, one north and one south of the main tail, whose intersection would not be at the center of the head. Between these there is considerable nebulosity. In this case it is evident that the supply of matter for the main streamer of the tail had ceased some time before the photograph was made and that the tail was drifting bodily outward into space—a similar case to that of Borrelly's comet, 1903, July 24 (*Ap J.* **18**, 210, 1903).

May 5. The head is large, round and diffused. There is a very feeble streamer from it on the north side of the tail at an angle of about 20 degrees. The tail at first is long and slender—almost thread-like near the head. At a distance of 1°.9 from the head it widens out somewhat on the north side. The south side of the tail continues to the end as a long slender line. The north branch is broader and less definite but well defined. At 1°.3 from the head a fine thread-like line makes its appearance and runs out free of the north side of the tail to a distance of 3°.7 from the head.

May 8. The head is large, round and diffused. The tail consists of one or more faint threads.

POSITION ANGLES AND LENGTH OF THE TAIL.

The following position angles of the main axis of the tail were taken from the BD charts with a large protractor. They are very approximate:

	Pos. Ang.	Length of Tail.
1894, April 29	114°	2°
May 2	113	6
3	105	10
4	112	8
5	115	9
8	108	4

It may not be entirely out of place to insert at this point some further remarks concerning portrait lenses, as the information may be of service to others using this class of instrument.

One of the most important advantages of the portrait lens over other forms of photographic telescopes is its wide field of view, which makes it invaluable for photographing the tails of comets and the great structures of the Milky Way. The same lens can be made to give a perceptibly larger or smaller field, using a flat plate in both cases. This is due to the fact that in such a lens there is a small allowance (which I will call the focal limit) in the determination of the focus, so that a very slight change toward or from the lens will not materially affect the size and sharpness of the images in the center, while at the same time it will affect the field. If advantage is taken of this and the plate kept close to the inside limit, the field of good definition will be slightly increased, while the reverse of this occurs if the plate is at the outside limit. It is, therefore, an advantage to keep close to the inside limit. If the plate is brought nearer the object glass a focal zone (in which the stars are small and sharp) will be produced away from the center of the plate, while at the center all the stars will be perceptibly increased in size. Such a picture is misleading, as it gives the impression that the stars near the middle are brighter and that there are fewer faint stars, when in reality the stars of different brightness may be uniformly distributed over the entire region. This may lead, therefore, to an erroneous idea of the distribution of stars of different magnitudes. This peculiarity has been avoided as much as possible in the present work and this notice is given only as a caution. Plate 31 perhaps shows this peculiarity, where the plate was possibly just inside the focal limit.

To those just beginning work with a portrait lens, a good index of the position of the plate with respect to the focus is as follows:

Larger images in the middle with smaller and sharper images in a zone away from the middle	Plate inside true focus.
Sharpest images at the middle but not small enough	Plate outside true focus.

Fortunately, for portrait lens work, very few plates of glass such as are used for making dry plates are really flat. It seems to be the custom (which is the correct way) to put the emulsion on the concave side of the plate. This materially improves the field of a star plate. Once in a while, but very seldom, however, the emulsion has been put on the convex side. Such a plate will give a bad negative, as the convex surface at the middle will then fall inside the focus, and instead of curving with the focal plane will curve against it.

It is well to mention here that in long exposure work the lens should be protected by a "dew cap" (not long enough to cut down the field of view) to cut out light from parts of the sky other than that being photographed, otherwise a decided fogging effect may be produced by light striking the lens from larger portions of the sky than necessary. This is especially valuable when photographing a comet in a dawnlit or twilit sky.

PERSONAL BIBLIOGRAPHY.

A short personal bibliographical list of papers more or less intimately connected with the subjects of this volume may be of interest. This list, brought up to date, is given here. The following explains the abbreviations used:

A. and Ap. = Astronomy and Astrophysics.
A. J. = Astronomical Journal.
Ap J. = Astrophysical Journal.
A. N. = Astronomische Nachrichten.
M. N. = Monthly Notices of the Royal Astronomical Society.
S. M. = Sidereal Messenger.

MILKY WAY, NEBULOSITIES, ETC.

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IDENTIFICATION OF STARS, NEBULÆ, ETC.

Much time is often wasted in identifying the individual stars on long exposure photographs made with portrait lenses. To facilitate the use of the present plates, it was deemed important to identify a few of the known stars for use in finding the places of others. As it would disfigure the pictures to mark such stars upon them, it was decided to refer their positions to the sides and top or bottom of the plates. These identifications are collected at the end of the text descriptive of each photograph under the heading "Identification of Stars," etc., where, in the last column:

R means right side
L means left side
T means top
B means bottom

Where a star is not bright or well known, the number in the Bonn or Cordoba Durchmusterung is assigned it, and the position given for 1855.0 or 1875.0. Some of the nebulæ are also thus identified, the number assigned to the object having been taken from Dreyer's *New General Catalogue of Nebulæ and Clusters of Stars* or from his *Index Catalogues*.

In like manner the smaller defects that have occurred in the reproduction are (when necessary to avoid mistakes) located in a similar way.

It has been thought unnecessary to thus identify the stars in the comet photographs, for, having fewer stars to deal with, the difficulty of their identification is not so marked. From the position of the head and the approximate position angle of the tail, the location of the comet on the charts is very easily determined.

In the present work, the stand has been taken that there exist in space masses of more or less opaque matter, nearer to us in general than the stars, whose presence, in the form of partially luminous "nebulosity," is shown by the scarcity or entire absence of stars which seem to be blotted out by it in certain parts of the sky. These probable obscuring masses are apparently more frequent in the Milky Way, where, perhaps, the great number of stars more readily indicates their presence. The belief in the existence of this obscuring matter is not based alone on the photographs contained in this volume, though they gave rise to it. It has been strengthened and, to me made a fact, by the study of the later and more perfect photographs (more perfect because of the larger scale) which were made by me with the Bruce telescope of the Yerkes Observatory in the past eight or ten years, and especially of those made by me with the same telescope on Mount Wilson, California, in the summer of 1905. A photographic search has been made in recent years with this instrument for these apparently vacant or nebulous regions, with the hope of accumulating as much information as possible as to their extent and distribution. The most remarkable of these singular features seem to be in the southern region of the Milky Way in **Ophiuchus** and **Scorpio**, though some striking cases are found in **Taurus** and **Cepheus**.

It is possible that later discoveries made on some of the photographs of the Milky Way included in this volume may render it desirable to know the exact times when the plates were taken. All of the exposure times are, therefore, printed here. In the case of the comet photographs, the exposure times will be found in the descriptions accompanying the plates.

LIST OF EXPOSURE TIMES OF STAR PLATES

Plate No.	P. S. T.	Duration of Exposure.	Plate No.	P. S. T.	Duration of Exposure.	Plate No.	P. S. T.	Duration of Exposure.	Plate No.	P. S. T.	Duration of Exposure.
	h m	h m		h m	h m		h m	h m		h m	h m
2	8 30	1 47	24	14 35	4 10	46	10 38	3 5	68	11 34	2 13
3	9 52	1 30	25	16 2	1 25	47	10 38	3 5	69	11 50	5 10
4	10 5	2 50	26	9 25	3 16	48	13 22	2 15	70	9 14	4 43
5	16 25	2 0	27	9 25	3 16	49	9 38	3 0	71	8 50	4 20
6	15 48	3 15	28	9 10	3 0	50	9 38	3 0	72	8 58	2 35
7	8 40	3 0	29	8 6	2 28	51	12 40	3 30	73	11 10	3 0
8	10 45	4 10	30	14 45	0 30	52	12 40	3 30	74	9 17	5 0
9	8 50	5 0	31	15 47	2 0	53	9 40	1 20	75	10 0	4 0
10	14 34	2 0	32	9 29	2 0	54	11 0	4 10	76	13 4	4 17
11	14 8	3 15	33	12 30	1 0	55	11 40	4 30	77	10 44	3 15
12	10 47	3 0	34	10 48	4 0	56	12 55	3 0	78	11 2	6 5
13	8 35	4 0	35	10 40	3 20	57	11 48	4 25	79	10 45	5 20
14	14 44	0 20	36	{ 11 12	4 0	58	11 48	4 25	80	10 45	5 20
15	{ 8 30	5 0		{ 10 50	3 30	59	8 46	3 5	81	13 38	4 15
	{ 8 28	5 15	37	10 32	1 55	60	10 42	4 30	82	11 50	7 0
16	11 50	6 0	38	11 18	3 35	61	14 30	2 21	83	11 54	5 0
17	11 50	6 0	39	11 55	4 0	62	. . . .	4 30	84	11 52	6 21
18	10 42	2 0	40	11 18	3 35	63	. . . .	4 30	85	13 55	6 0
19	12 50	4 20	41	11 0	3 0	64	11 0	5 10	86	11 10	4 20
20	14 0	2 0	42	12 12	4 5	65	13 25	3 20	87	14 55	4 0
21	13 0	3 0	43	12 12	4 5	66	11 5	5 30	88	15 25	3 0
22	11 55	2 10	44	11 20	4 0	67	11 18	4 5	89	14 12	3 5
23	11 55	2 10	45	10 30	2 51						

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E. E. BARNARD.

Yerkes Observatory,
Williams Bay, Wisconsin,
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