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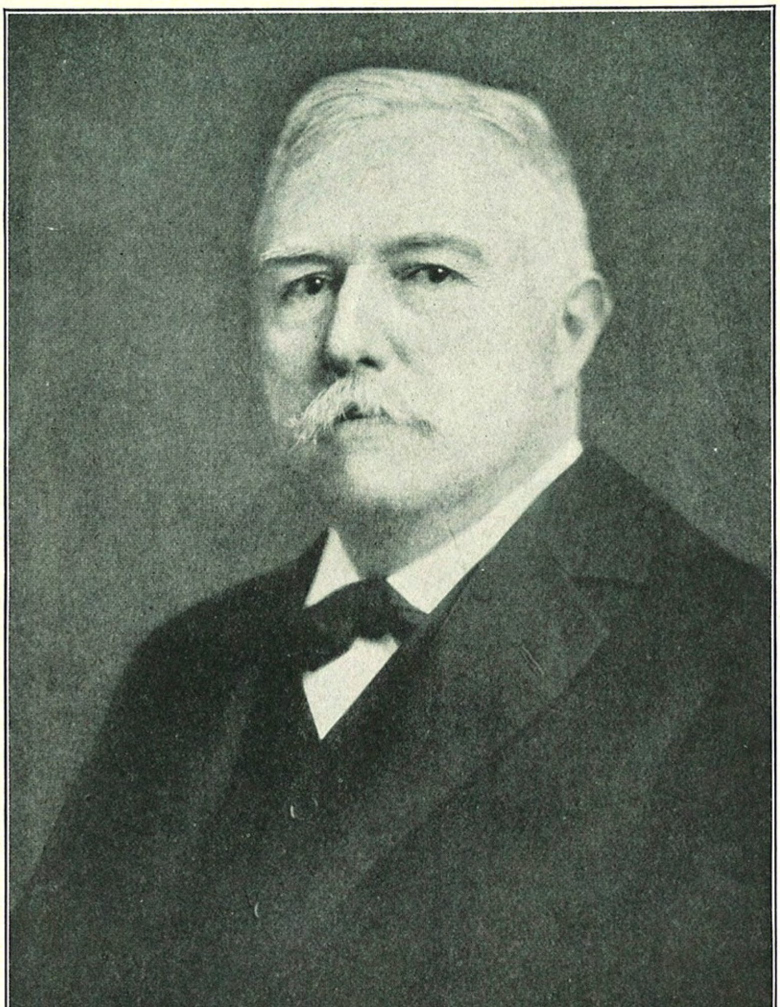

E. E. Barnard.

EDWARD EMERSON BARNARD

1857–1923

By Edwin B. Frost

By the death on February 6, 1923, of Edward Emerson Barnard, professor of practical astronomy in the University of Chicago, and astronomer at the Yerkes Observatory, the world has lost one of its foremost searchers of the skies, and the National Academy of Sciences one of its most distinguished investigators in the field of physical science.

He was born at Nashville, Tenn., on December 16, 1857, the son of Reuben and Elizabeth Jane (Haywood) Barnard. The death of his father before his birth threw a heavy burden upon his mother, who was obliged to support herself and her two young sons. Those were hard times for poor people in that section of our country, and they were still harder after the Civil War came on, a few years later, bringing tragedy to all on the scene of conflict. The Battle of Nashville made an impression upon the lad that never left him. Later in his youth he survived an attack of cholera, when that plague raged beyond its usual bounds.

His mother's firmness of character was such that she did not lose her taste for culture in the struggle with poverty. The name Emerson, given to the young son in honor of our American philosopher, was an evidence of this. She inspired the lad with a desire to know good literature, although his opportunities for any regular education in school were most meager; in fact, Edward Barnard attended the common school only two months in his life. His mother had a taste for art, also, and partially supported herself by modeling wax flowers. That she had impressed upon her son character and self-reliance was indicated by her statement that the lad, when less than 9 years old, could be depended upon to do a task in which many other boys had failed. A photographer in Nashville had on the roof of his studio a ponderous enlarging camera which had to be kept pointed at the sun. Most of the lads had lacked the patience necessary in the human substitute for a driving clock, and went to sleep at the task. Edward Barnard justified his mother's confidence; he worked in that studio, in various capacities, for 17 years. His duties, doubtless often monotonous, were fitting him to be a pioneer in the photography of the heavens.

As a boy, he had watched with wondering eyes the starry skies above him, as he lay upon an old wagon box in the yard; and he had, indeed, learned to know the stars, but not their names or their constellations. A man employed in the studio, who had mechanical skill, one day picked up in the street the small objective of a broken spyglass, and, making for it a paper tube, constructed a telescope for the young apprentice. With this, Edward Barnard studied the stars further, but still without the means of identifying them, until chance brought into his hands, somewhat later, a volume of the works of Thomas Dick, who enjoyed a considerable reputation as a writer on astronomy, as well as on theology. It seems that Barnard found his first star map here, and was delighted to learn the conventional names of the objects with which he was already so familiar. Later, he put together a better instrument for which he purchased lenses of 2¼ inches aperture.

The young man was now supporting himself and his mother by his daily work in the studio, but a passion for astronomical observation had already developed. Through rigid economy he gratified this passion by the purchase, in 1876, of a 5-inch telescope, equatorially mounted, from John Byrne, of New York, the price of which, $400, represented some two-thirds of a whole year's earnings. This gives sufficient evidence of his determination to acquaint himself with the science of astronomy. In 1877 the American Association for the Advancement of Science held its annual session at Nashville, and the youth of 20, who was becoming locally well known for his zeal as a stargazer, joined the association. His friends persuaded him to bring his telescope and meet the president, Simon Newcomb. This distinguished astronomer,

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already eminent at the age of 42, whose researches were in the domain of theory rather than of observation, advised young Barnard that to accomplish anything important in astronomical research he must first be well grounded in mathematics. This advice might have discouraged a less ardent seeker for knowledge of the stars, but it inspired Barnard to do just what was advised. He applied himself diligently to elementary mathematics and other common items of education which he had been obliged to neglect in his youth, and from his own slender earnings hired a tutor for some branches of his study.

In January, 1881, while still an employee at the studio, he married Miss Rhoda Calvert. She had come from Yorkshire, England, to Tennessee a few years earlier with her brothers, who were artists and who also had work in connection with the studio. His marriage greatly influenced his subsequent career, as his wife most unselfishly encouraged and helped him in his efforts to obtain a better education and to overcome some cultural deficiencies of which he was conscious. She proved a true helpmeet in every way, caring for the household in a most prudent manner and taking over all responsibility for his now invalid mother. This made it possible for him to improve every opportunity that presented itself for his advancement.

On May 12, 1881, Barnard discovered his first comet in the morning sky near Alpha Pegasi. He found it again on the next night, but could not afterwards locate it, and inasmuch as he did not send out any announcement to the astronomical world, and it was not seen by any other astronomer, this comet was never assigned a place in the formal records of astronomy—no number was given it, and it was not counted by Mr. Barnard himself. Of course, from what was later known of his reliability and skill as an observer, there could be no question as to the certainty of his observation, but at that time he was unknown among astronomers.

This accidental discovery, however, developed his interest in the search for comets, and he began systematically to sweep the sky for them. His diligence was rewarded on the night of September 17 of the same year, when he found a comet in the constellation Virgo. He announced the discovery to Dr. Lewis Swift, so that it was observed by other astronomers and received the name "Comet 1881 VI." Mr. H. H. Warner, who had established at Rochester, N. Y., the private astronomical observatory of which Doctor Swift was the director, had taken much interest in astronomy and offered a prize of $200 for each unexpected comet discovered by an American observer. The award was made to Mr. Barnard for the discovery of this comet, and it happened opportunely, for at that time the young man was building a little house for his bride and his mother, and the burden of paying notes on borrowed money as they came due was a serious one. Five times in all Barnard received this award for the discovery of a comet, and it meant to his family the possibility of owning their modest home. That dwelling is still known in Nashville as the "Comet House." Few, indeed, are the astronomers whose keen eyesight and extraordinary diligence in the quest for celestial discovery have literally provided them with a roof to sleep under. It was very little, however, that he slept under that roof when the sky was clear.

I am describing these circumstances in this detail because they may seem almost incredible to some of our contemporary European astronomers who have reached positions in our science in university or governmental observatories after passing through a very definite and uniform course of study and training. That inborn genius can find a way of achieving its ideal in America, we may call to witness our lately departed friends, Burnham and Brashear, as well as Barnard.

A year later, on September 13, 1882, the second recorded comet (1882 III) was discovered with the 5-inch telescope. A rather dramatic incident occurred a month later, October 14, of which we have a printed record in Barnard's own words. He had been searching for comets through the early part of the night and had set his alarm clock for a later hour in order to get some much-needed rest. He says that when the alarm clock sounded he had been dreaming of discovering a wonderful field of comets, big and little, with long and short tails, in his field of view. After he awoke he began sweeping in the neighborhood of the great comet of 1882, and to his astonishment saw 12 or 15 small comets of varied appearance in the vicinity. He had obtained positions for 7 or 8 of these when the dawn came. He announced his discoveries to Doctor Swift, but this astronomer did not distribute the information. Speaking of this omission Mr. Barnard has said: "Whether he thought that I was trying to form a comet trust or had suddenly gone demented has never been clear to me." These comets were undoubtedly real, and fragments of the great comet. Schmidt, of Athens, reported one such object which he observed on October 8, another was observed by E. Hartwig on October 9, and still another by Brooks, of Phelps, N. Y., on October 21. They were never separately announced in the list of comets.

During this time young Barnard was working in the studio by day for a livelihood and studying, by himself or with a tutor, on cloudy and moonlit nights. In 1880 he planned to write a booklet on Mars, and solicited subscriptions from friends in Nashville to cover the cost of printing. We have been unable to find a copy of this, which was planned to be a duodecimo; and it is doubtful whether it was ever actually printed. Three years later we find the young amateur conducting an astronomical column in a journal known as the Artisan, which was published twice every month at Nashville. In the same year friends who had perceived the genius of the young man offered him a fellowship in Vanderbilt University at Nashville, giving him an opportunity to devote his time exclusively to his studies and to make use of the 6-inch equatorial of the small observatory of the university. The stipend was only about $300, together with a house on the university campus near the observatory, and it was a venturesome step for a young man with a wife and a mother dependent upon him to give up his work at the studio and endeavor to live on the sum provided. But his wife bravely counseled acceptance of the offer, and said, "We will get along somehow"; and they did. Barnard became enrolled as a special student in the school of mathematics, at the same time having the care of the observatory. Later he received an appointment as instructor in practical astronomy, continuing his studies in mathematics, physics, and chemistry and some of the modern languages.

The young astronomer's first trip into the outer world was made in 1884, when he attended the meeting of the American Association for the Advancement of Science at Philadelphia, visiting en route the observatories at Cincinnati, Allegheny, Washington, Cambridge (Harvard), Albany, and Princeton, and seeing for the first time those cities, together with New York and Boston. Every economy had to be practiced, and he was accustomed to avoid unnecessary hotel bills by traveling in day coaches at night. His record of this trip, in daily postal cards and letters to his wife and his mother, is very humorous and interesting. He had formed in advance, mental pictures of the prominent contemporary astronomers, and many of them turned out to be quite different from his anticipations. Thus, he had expected that Prof. E. C. Pickering would be a formal and distant dignitary, as might befit a native of Boston and the director of the Harvard College Observatory. To his surprise, he found that "Professor Pickering is comparatively a young man, and strongly resembles a simple countryman. Had anyone shown him to me on the street and told me that was the famous director of the Harvard College observatory, I should not have taken his word on oath. I should have been positive there was a mistake. However, he is the most unassuming man that you can imagine, and I admired him very much, indeed."

At this meeting in Philadelphia, he received a most friendly welcome and recognition from the astronomers whom he had at last met in person, and could henceforth feel that he was one of the fraternity.

In 1887, at the age of 30, he graduated from the school of mathematics at Vanderbilt. Meanwhile, he had discovered seven more comets—the last on May 12, 1887—namely, 1884 II, 1885 II, 1886 II, 1886 IX, 1886 VIII, 1887 III, 1887 IV. Of these comets, 1884 II was periodic, with a return expected every 5.4 years, but it escaped detection in subsequent years. In 1887 he published in the Astronomische Nachrichten a parabolic orbit for Comet 1887 III.

In 1883 he had independently discovered the Gegenschein, while sweeping the skies, and had become extraordinarily familiar with the objects in the sky which could be seen with a small telescope. He had given special attention to the planet Jupiter and was an independent discoverer of the great red spot, as he was unaware that its presence had been announced some months previously, in July, 1878, by C. W. Pritchett, of Glasgow, Mo. Barnard was a careful delineator of what he saw, and many of his early sketches of Jupiter were published in the first volumes issued by the Astronomical Society of the Pacific.

In 1887 the Lick Observatory was nearing completion, and Prof. E. S. Holden had been chosen director, functioning ad interim as the president of the University of California. He corresponded with Barnard, and in that summer offered him a position on the staff then in process of formation. Barnard accepted the opportunity to join this finely equipped institution, and in September he and his wife started on their interesting journey to California. They found temporary lodgings in San Francisco, until they should be able to make their home on Mount Hamilton. There were delays in the completion of the observatory, and the regents of the university were unable to make provision for the astronomers until the trustees of the Lick estate had formally turned over to them the completed observatory. Mr. Barnard, again finding himself in need of the salary which was not forthcoming, obtained work in copying legal papers in the office of a lawyer. Early in the next spring the Lick trustees invited him to come to the mountain and make an inventory of the observatory's equipment. Finally, on June 1, 1888, Director Holden was able to write, with evident relief after the trying delay: "The observatory begins its active existence to-night." S. W. Burnham and J. M. Schaeberle were senior astronomers, J. E. Keeler and E. E. Barnard, juniors; and work began enthusiastically. Mr. Barnard became very warmly attached to these members of the staff. This was his first opportunity to be regularly associated with astronomers of considerable experience, and it was of great importance to him. In turn, his associates highly appreciated Barnard's ability as an observer and his tremendous capacity for work.

The 12-inch telescope was assigned to Barnard, together with the comet-seeker, and his technical knowledge of photography was very soon utilized by Director Holden. On September 2, Barnard discovered Comet 1889 I, and in October, Comet 1888 V. He also observed their positions assiduously with the excellent equatorial and filar micrometer. He further observed nebulae and planets, and in 1889 made a notable observation of the eclipse of Japetus by the ring system of Saturn. He could see that the sunlight illuminated the satellite through the crape ring, thus indicating that the ring was quite transparent, and supporting the view that it was made up of small particles. During that year he discovered Comet 1889 II, as well as 1889 III, which has a computed period of 128 years. His most important work, however, was the beginning he made during that summer in photographing the Milky Way with the Willard lens, which became a famous instrument in his hands. This was a portrait lens of 31 inches focal length, which had been used by some photographer and had received its name from the dealer in such lenses in New York. This camera was strapped to the 6½-inch equatorial, which served as a guiding telescope. Barnard's long exposures with this instrument brought out the wonderful richness of the star clouds and other features of the Milky Way as they had never before been revealed. They thrilled him and his associates with their significance and beauty, and later the entire scientific world shared in this appreciation of them.

Barnard was the first to observe the return of d'Arrest's comet in 1890, and, in the following year, of comets Encke and Tempel-Swift, and he discovered Comets 1891 I and 1891 IV. In 1892 he made the first discovery of a comet by photography, finding on his plate taken on October 12, Comet 1892 V, for which a period of 6.5 years was computed, but which has never been observed at a subsequent return.

As a junior member of the staff of the Lick Observatory, Mr. Barnard did not receive a regular assignment at the 36-inch telescope, but his friend Burnham was always glad to check any important observation for him or give him opportunity of examining the object with the great refractor. Mr. Burnham resigned his position in June, 1892, and resumed work as clerk of the Federal Court in Chicago. Mr. Barnard had naturally been eager for an opportunity to make regular use of the great refractor, but he was unable to secure this privilege until the first of July, 1892, when he received the coveted assignment for one night each week. On the eleventh night of his use of it (September 9, 1892) he made his brilliant discovery of the fifth satellite of Jupiter. We quote from his own account of his observations in Astronomy and Astrophysics, 11: 749, 1892:

Friday being my night with the 36-inch telescope, after observing Mars and measuring the positions of his satellites, I began an examination of the region immediately about the planet Jupiter. At 12 o'clock as near as may be, to within a few minutes, I detected a tiny point of light closely following the planet near the 3rd satellite which was approaching transit. I immediately suspected it was an unknown satellite and at once began measuring its position angle and distance from the 3rd satellite. On the spur of the moment, this seemed to be the only method of securing a position of the new object, for upon bringing the slightest trace of the planet in the field the little point of light was instantly lost.

I got two sets of distances and one set of position angles, and then attempted to refer it to Jupiter, but found that one of the wires of the micrometer was broken out and the other loose. Before anything could be done the object rapidly disappeared in the glare of Jupiter. From the fact that it was not left behind by the planet in its motion, I was convinced that the object was a satellite. A careful watch was kept at the preceding limb of the planet for the reappearance of the satellite, but up to daylight it could not be seen.

Though positive that a new satellite had been found, extreme caution suggested that it would be better to wait for a careful verification before making any announcement.

The following night with the 36-inch belonging to Professor Schaeberle, he kindly gave it up to me, and shortly before midnight the satellite was again detected rapidly leaving the planet on the following side. That morning I had put new wires in the micrometer, and now began a series of careful measures for position. As I have said, the satellite was so small that no trace of Jupiter could be admitted into the field for reference in the measures. It was necessary, therefore, to bisect the satellite, with the planet out of the field, and then by sliding the eyepiece bring the limb of Jupiter into view and bisect it. This method did not permit any measures from the polar limbs of Jupiter. Following the satellite thus, it was seen to recede from the planet to a distance of some 36″ from the limb, when it gradually became stationary. Remaining so for a while, it began once more to approach the planet and rapidly disappeared in the glow near the limb. The measures, repeated as rapidly as possible, thoroughly covered the elongation and gave the means of approximating to its period.

The following morning a telegram was sent out announcing the discovery. Subsequent observations have thoroughly confirmed the discovery.

On account of its extreme closeness to the planet it is difficult to say just what its magnitude is. Taking everything into account, I have provisionally assigned it as thirteenth magnitude. I hope to be able to settle definitely this question by observing some little star near Jupiter, and then afterwards determining its magnitude when the planet has left it. Until this is settled, any estimate of the actual size of the satellite must be the merest guess, but it will probably be found to not exceed 100 miles in diameter, and perhaps less than that.

After the first few observations I inserted a piece of smoked mica in the eyepiece, and using this as an occulting bar, the measures were made with ease and accuracy. Careful measures thus made from the polar limbs for the Jovicentric latitude of the satellite show that its orbit lies sensibly in the plane of Jupiter's equator and that consequently the satellite is not a new addition to the Jovian family, since it would doubtless require ages for the orbit to be so adjusted if the object were a capture.

The reader will note from this extract the element of independence which was a characteristic of Barnard's discoveries. He perceived with a sort of intuition that this was probably a new satellite; in fact, he was convinced of it by his brief observations on the first night. His exercise of great care in making no premature announcement was also characteristic. He, furthermore, was quick to realize that it would be a matter of general interest whether the satellite had been newly acquired by Jupiter, and his measurements to decide this point were made a few evenings later. We also see an illustration of his readiness to adapt his observing methods to difficult circumstances in providing a piece of smoked mica for occulting the brilliant planet. His scientific caution and ingenuity are illustrated by his proposal that the magnitude of the object should be determined by comparison with some star of about the same magnitude which some night would lie near the planet's position and thus afford a reliable basis for an estimate of brightness.

This first addition to the family of Jupiter, which had received careful telescopic observation for nearly three centuries, brought to Mr. Barnard instant recognition as an observer of the first class. The Lalande gold medal of the French Academy of Sciences was awarded to him a few months later for this notable astronomical feat. Professor Barnard followed this satellite with very careful micrometric measurements for many years after its discovery, seeking to improve our knowledge of its orbit, and he published 14 papers covering his observations of elongations, nearly all of them in the Astronomical Journal. The difficulty of observing the object was not because it was so faint, but because of the brightness of the planet. Quite good conditions of seeing were always necessary for observing it, even with the large telescope. So far as is known to the writer, the fifth satellite has never been photographed, and the smallest aperture with which it has been observed is that of the 18½-inch equatorial of the Dearborn Observatory at Evanston, with which Prof. G. W. Hough observed it on October 15 and November 11, 1892. The discovery of this satellite doubtless renewed interest in the search for others by the use of photography, resulting in the discovery of three further, remote satellites at the Lick Observatory, VI and VII by C. D. Perrine and IX by S. B. Nicholson, while VIII was discovered by P. J. Melotte, at Greenwich.

During his later years at the Lick Observatory Mr. Barnard gave much attention to careful measurements of the diameters of the planets, including the four largest asteroids. He made a comprehensive study of the dimensions in the Saturnian system and measured the ellipticity of Uranus. He gave particular attention to the diameters and the appearance of the brighter satellites of Jupiter. These extensive researches were published in a series of papers in various astronomical journals, several of them appearing after he had left the Lick Observatory.

It was not only to the study of the Milky Way that Barnard was applying photography with distinguished success. He studied the comets, and took a great interest in the remarkable behavior of their tails as revealed on his negatives. Swift's comet (1892 I) was the first to show on Barnard's photographs the extraordinary changes which the tails of comets may undergo. His subsequent photographs of many comets show that these mutations are characteristic of the tails of some comets, but not of others. Cloudy weather had interfered with observations of this comet during March, but the photographs taken on April 4 and 5 displayed extraordinary transformations in the short interval between them. The significance and value of the photographic records of these capricious changes were instantly appreciated by Barnard, as will be seen from the following quotation from his article written some years later and appearing in the Monthly Notices of the Royal Astronomical Society, 59: 355, 1899:

> This [Swift's comet of 1892] was the first comet to show to the photographic plate the extraordinary changes to which these bodies are subject. Indeed, if it had not been for the photographic plate we should have known nothing of the extraordinary changes that occurred in this comet and several that have since appeared. . . .
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> For the study of the phenomena of the tails of comets, the portrait lens has shown itself most admirably suited. It has added an interest to the physical study of these bodies that did not exist previously; for the most interesting of the phenomena shown by comets must always escape the visual observer and pass unknown, without the aid of the portrait lens and the photographic plate. Unlike the planets, the comets often traverse the entire solar system. They are, therefore, our only means of exploring the regions between the planetary orbits. Instead of ponderous bodies like the planets, they are but flimsy creations of enormous dimensions. They are thus likely to be easily subject to disturbances in their forms that would produce no perceptible effect on their motions. What these influences may be we do not know; probably swarms or streams of meteors, which we know do exist in space, or possibly some other cosmical matter yet unknown. Such objects might be (and possibly have been) revealed to us by their effect upon the form of the comet's tail as it sweeps through space.

The comet discovered by Holmes in the autumn of the same year (1892 III) was also photographed by Barnard when this round, tailless object, whose motion was almost entirely in the line of sight, was situated very near the great nebula in Andromeda. The motion of the comet among the stars was, in fact, so slight that Barnard, with an exposure of 75 minutes, obtained, on the night of November 21, 1892, a sharp picture of the Andromeda nebula, together with the comet! a circumstance which is not likely to be duplicated. Brooks's comet of the next year (1893 IV) excited Barnard's interest in a high degree by its behavior, which was quite exceptional in those early days of cometary photography. He speaks of his plates of October 21 and 22 as follows (ibid., p. 358):

> There is an utter transformation of the comet in this picture. The tail is larger and brighter and very much distorted, as if it had encountered some resistance in its sweep through space. This disturbance seems to have disrupted the northeast edge of the tail. The small side tail has apparently been swept away, while the more distant portion of the main tail is streaming in a very irregular manner. The entire picture is highly suggestive of an encounter with some sort of resistance. Is it possible the tail passed through a stream of meteors such as we know exist in space? Whatever the cause may have been, the appearance of the tail utterly excludes the idea of the phenomenon being due to irregular emission of the matter from the nucleus—an explanation quite satisfactory in the case of Swift's comet.
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> In passing, this particular photograph seems to explain at least one of the ancient descriptions of a comet, viz., "a torch appeared in the heavens." The comet as shown in the photograph, is sufficiently suggestive of a torch streaming irregularly in the wind.

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[On the next day the tail of the comet] appears a total wreck in this photograph, and is still more suggestive of a disaster. It is very badly broken, and on the southwest side hangs in irregular cloudlike masses. Near the extremity a large gap exists in the tail, as if something had gone through it from the northeast, and a large mass is torn off beyond this break and seems to be drifting independent of the comet.

For nearly 30 years these unexplained caprices of the tails of comets fascinated Professor Barnard, and whenever a new comet appeared in the sky he was filled with suppressed excitement as to its behavior on the photographic plate. Comet Morehouse (1908 IV) was thoroughly satisfying in this respect, and he obtained no less than 350 photographs of it. He would sometimes take successive photographs of it as long as it could be followed above the horizon, before the interference of the moon or dawn.

The results of Barnard's assiduous campaign at the Lick Observatory, from 1892 to 1895, in the study of the Milky Way and comets by photography, are preserved in Volume XI of the Publications of the Lick Observatory. This volume did not appear until 1913—nearly 20 years after the photographs were taken—because of the difficulties which Professor Barnard found in securing satisfactory reproductions of his pictures. His studies of these photographs had been so minute that he recognized details which would have escaped anyone else, so that his standard of excellence of their reproduction became very exacting, indeed, beyond the possibility of the processes of photogravure and heliogravure. The publication of the volume had been made possible by subscriptions for the purpose which Mr. Barnard had secured from California friends of the Lick Observatory and of himself. The collotype process was employed, and the reproductions are as satisfactory as could be expected by any such process. But for a number of years the responsibility of issuing this volume was a heavy one for Mr. Barnard. He became discouraged with what he regarded as the impossibility of securing adequate reproductions, and the work lapsed. He even attempted to return to the Lick Observatory, for distribution among the subscribing friends, the money already expended. He was, however, persuaded to resume his efforts, and, fortunately, was able again to secure the services of the expert in collotype who had begun the work. The volume contains 129 plates, from 92 photographs of the Milky Way and 42 of comets; and it will stand as a monument to the great skill and the untiring zeal of the pioneer in his beginning in this important field of investigation.

A leave of absence was granted Mr. Barnard in the summer of 1893 to make his first trip to Europe. Mrs. Barnard accompanied him, and thus had an opportunity to visit her old home and her relatives in England. The very cordial welcome given to Barnard by his English colleagues also made this a most pleasant visit. He then went over to the Continent and made the personal acquaintance of some astronomers in France and Germany.

Mr. Barnard's residence of nearly eight years in California was full of romantic interest for him. The conditions for his work were very fine, and a clear sky was assured in advance during many months of the year. His residence on the mountain was novel to one who had always lived in a city, and the views of mountain and canyon made a strong appeal to the artistic element in his nature. The life was isolated in winter; but this was broken by visits on Saturday evenings of the winter tourists in California, and acquaintances were established—many of them lasting—with interesting people from different parts of the world. The association with his fellow observers and their families in the little colony was congenial, and particularly close was his friendship with Professor Burnham, who, like himself, was an ardent and expert user of the camera. This phase of their life on the mountain was well brought out in Mr. Barnard's biographical sketch of Mr. Burnham, published in Popular Astronomy, 29: 309, 1921. There was an element of the wild in the howl of the coyotes in the canyons and in the occasional deer seen around the mountain. In the gray dusk, one morning, as Mr. Barnard was nearing the door of his cottage, he saw before him the great form of a panther, or mountain lion, standing a few yards away. Each was returning from his night's work, and each silently respected the rights of the other. After a moment, the panther quietly walked on over the mountain.

The free and hearty cordiality of the Californians, and their appreciation and respect for the men of science on Mount Hamilton, was keenly felt; and Mr. Barnard occasionally participated in the meetings and activities of the Camera Club and of the Bohemian Club of San Francisco, as well as with the colleagues at Berkeley. Conditions of life on the mountain were comparatively simple and at the start Mr. Barnard's salary was small; but these circumstances were much improved toward the end of his stay, and his opportunities for the use of the great telescope were increased so that he often worked with it on two and sometimes even three nights a week. However, circumstances into which we need not enter finally led him to desire a change, and in 1895 he accepted an invitation to become a member of the staff of the Yerkes Observatory, then in process of construction as a department of the new University of Chicago. His official title was to be professor of practical astronomy and astronomer at the Yerkes Observatory, but no duties of giving instruction were involved for him, beyond an occasional popular lecture in the summer courses at the university. His official connection with the university began on October 1, 1895. As had happened at the Lick, there were unexpected delays in the completion of the Yerkes Observatory, so that for the greater part of a year Professor Barnard lived in Chicago near the Kenwood Observatory, the equipment of which had been presented to the university by Prof. George E. Hale and his father, William E. Hale. This period constituted something of a gap in Mr. Barnard's observational activity, but the time was usefully employed in preparing for publication some of the results of his observations at Mount Hamilton, including his attempts at securing reproductions of the photographs of the Milky Way and comets made there.

In the summer of 1896, Professor and Mrs. Barnard occupied a cottage on the shore of Lake Geneva, and began the construction of the house which was to be their home for the next quarter of a century, on land which they had purchased adjacent to the grounds of the observatory. In February, 1897, Mr. Barnard went to England to receive the gold medal of the Royal Astronomical Society, but, owing to delay of the steamer by bad weather, he unfortunately did not arrive until the day after the annual meeting of the society. A special meeting was held on March 2, at which Professor Barnard exhibited and explained some of his most notable photographs, taken at the Lick Observatory, and a dinner was given like the one prepared on the evening which he missed. As Mr. Barnard was very keen to begin work with the 40-inch, which was then expected to be ready in the spring, as well as to complete the equipment of his new home, in which he took a great interest, he sailed for home after a stay in England of less than three weeks, and was back at Williams Bay by the middle of March.

A few weeks later the 40-inch objective was brought from Cambridge by Alvan G. Clark, and was adjusted by him in its cell on the great instrument. It was first used on the night of May 21, and the tests of its performance were highly satisfactory. There were occasional opportunities during the next week, when the sky was clear, for further tests, and on the night of May 28 Professor Barnard had a narrow escape. He was observing during the latter part of that night, until daylight, and left the dome at dawn. Just before 7 o'clock, as the result of faulty connection of the supporting cables, the moving floor fell, involving its almost complete destruction, but fortunately without injuring the telescope itself. Had this happened a few hours earlier, the observer could hardly have escaped a serious injury or death.

This delayed the formal opening of the observatory until October 21, 1897, and Mr. Barnard had to exercise his patience in waiting for further use of the great refractor. As soon as it was ready for regular work, Professor Barnard again plunged into observing, having the great telescope at his disposal regularly for two and often for three or four nights each week. He was, of course, interested in making some tests of the quality of the 40-inch as compared with the 36-inch telescope which he had previously used. He, therefore, observed some of the difficult double stars, such as Schaeberle's companion to Procyon, and Kappa Pegasi, and secured some elongations of the fifth satellite of Jupiter. He studied some of the variable stars in Messier 5 which had recently been discovered by Prof. S. I. Bailey, finding a couple of additional variables in that cluster. He also measured in the daytime the diameters of Venus and Mercury, sometimes under especially fine conditions of seeing.

He began at this time a micrometric triangulation of some of the globular star clusters, measuring in this first year the positions of 95 stars in Messier 5 and a smaller number in Messier

13, comparing the positions of the latter with measures obtained by Scheiner at Potsdam on photographs taken in 1891. The views of astronomers as to the size of the clusters were quite different then from those entertained at present, and Mr. Barnard had hoped that precise measures with the large telescope would reveal internal motions within a few years. He extended his triangulations to many other globular clusters until he had finally included in his program 20 clusters. In spite of his ardor and his experience as a photographer, Mr. Barnard still found it difficult to recognize the superior advantages of the measurement of star clusters on photographs with the use of rectangular coordinates. He put his trust in the filar micrometer more than in the measuring machine, particularly because he could recognize certain of the cluster stars as triple, which were confused in a single image on the photograph then at hand, taken with an instrument of one-fifth the focal length of the great refractor. A very few years later, when remarkably fine photographs had been secured by G. W. Ritchey with the 40-inch telescope, through a yellow filter and with the double-slide plate holder, Mr. Barnard measured some photographs of the clusters, and in subsequent years took some equally good ones himself. The excellent accordance between his measures on the negatives and those he made visually with the micrometer was to him an evidence that astrometric investigations could be satisfactorily made by photography; to his colleagues this accordance was a demonstration of Barnard's extraordinary skill at the telescope with the micrometer. Similarly, when his visual determination of the parallax of Krueger 60 was very closely confirmed by Schlesinger's measures on plates taken with the 40-inch telescope, it convinced Barnard that good parallaxes could be obtained by the new photographic method; while for us it was again a demonstration of Barnard's great skill as an observer.

It was probably no small disappointment to Mr. Barnard that his measures in the clusters, continued for nearly 25 years, yielded so little in the way of proper motions—in fact, it could hardly be asserted that a single one of the cluster stars showed an appreciable motion with respect to its fellows. From what we know now, it would have been better to omit much of this labor by visual methods, and to trust to photographic records made from time to time for the establishment of the motions which certainly must exist, but which will evidently require a long lapse of time for accurate determination. Progress is being made in the considerable task of evaluating these micrometric measures which were expressed in position angles and distances, and referred to selected stars in the clusters. In Messier 5, 239 stars were included; in Messier 13, 247; and in several other clusters the numbers run over 100. The measures certainly represent accurately the positions of the selected stars during the score of years that they were under Barnard's observation. Plans were begun some 15 years ago for the publication of these measures; but they were delayed in the natural hope that with a longer time some evidences of motion would be established. Considerable attention was given during this work to following changes in brightness of some of the variables, and a few new variables were discovered by Professor Barnard in the clusters. He observed, in particular, Bailey's No. 33 in Messier 5, and determined its period with great precision, contributing half a dozen papers to the discussion of this star alone during the score of years that he observed it. At first he thought that the period was constant, but later the continued observations showed that it first lengthened, then shortened.

Although Mr. Barnard would naturally not be regarded as a regular observer of variable stars, he nevertheless discovered some 10 of these objects, most of them visually, and he followed particular ones for many years; thus, he published three papers on the period and variation of RS Aquarii, which he discovered visually in 1898. He also followed rather closely several especially interesting stars of this sort, discovered by others, which required large optical power when they were near minimum.

The novae were of especial interest to him. He determined their positions micrometrically with great precision with respect to neighboring stars; he estimated carefully their fluctuations in light, and noted the change in focus which resulted from their change in spectrum when the stars were too faint to be observed spectroscopically; he examined them minutely with the great telescope to detect the presence about them of nebulous shells or phenomena of that nature. He, in fact, discovered visually, in the summer of 1892, the nebulous ring about Nova Aurigae. He included in his studies most of the historical novae for which the positions could be determined—all of this with the 30-or 40-inch telescopes. He was an independent discoverer of Nova Aquilae on the night of June 8, 1918, the date of the American eclipse. After his return to the observatory, he found that he had photographed the star on 54 dates during the preceding 25 years, the Willard lens having been used on 4 dates and the Bruce telescope on the remainder. He then determined the star's brightness on these plates. His observations of this character were very numerous: he contributed no less than 14 papers or notes to cover Nova Persei of 1901 and 8 such papers on Nova Aquilae of 1918.

In view of the great range of temperature through which micrometric measurements are made with the 40-inch refractor, extending from $-25°$ F. ($-32°$ C.) to $+100°$ F. ($+38°$ C.), he began, in 1897, a series of control measures of the difference in declination between Atlas and Pleione. These observations were made on 506 nights during the past 25 years, and thus constitute a great mass of valuable unpublished material bearing both on the constancy of the telescope and micrometer and on that of the stars themselves.

At the Yerkes Observatory he kept up his micrometric observations of the fainter satellites of the planets, which he had begun at the Lick Observatory, and contributed to the Astronomical Journal 10 papers of observations of Saturn and several of Phœbe, the ninth satellite, which he caught as a very faint object in the opposition of 1904, when the planet was 17° south of the Equator. At the oppositions of 1906 and 1912–13, when he had a good ephemeris of the satellite, he observed it several times, and estimated it to be of the fourteenth magnitude. We believe that Professor Barnard's measures with the 40-inch telescope are the only visual determinations of the position that have yet been made of this difficult satellite. He observed visually Perrine's sixth satellite of Jupiter and published his measures in three papers.

Professor Barnard took part in the campaign for observation of the asteroid Eros, during the opposition of 1900 and 1901, for the determination of the solar parallax.

In 1897 Miss Catherine W. Bruce, of New York, at the solicitation of Professor Barnard, gave to the University of Chicago the sum of $7,000 for a photographic telescope of the highest type of excellence with which he could continue his photographic investigation of the Milky Way and comets. Experiments were at once begun with various types of portrait lens, some of them furnished by Mr. Brashear, in order to find which was the most suitable objective for the purpose. At this time the cameras were strapped to a small equatorial, which was later installed for instruction at the university. This search for a suitable objective was continued for several years, and in December, 1899, the quest led Mr. Barnard to Europe, for he was determined to secure an objective which would represent the highest quality attainable in optical construction. Several of the leading European firms made small objectives for the test, but choice was made of the 10-inch doublet produced by John A. Brashear, of Allegheny.

The small wooden observatory for the Bruce telescope, having a dome 15 feet in diameter, was erected, in 1904, at a point 350 feet from the great dome and a less distance from Mr. Barnard's own home. The interest accumulated on the Bruce fund was sufficient to pay for the building. Warner & Swasey had provided for the telescope the excellent mounting, of a new pattern particularly well adapted for the purpose. Besides the 10-inch doublet, the mounting carried a Voigtländer portrait lens of 6¼ inches aperture, which had been refigured by Brashear, and a 5-inch guiding telescope.

Professor Barnard was now provided with equipment which he had awaited for some years. When the sky was clear and not rendered useless by the obnoxious presence of the moon, Mr. Barnard was generally to be found there making a long exposure on some part of the Milky Way or on a comet, unless he had an assignment with the 40-inch telescope.

He was unhampered by any administrative or editorial duties, and free from any engagements in the classroom, so that he was able to gratify to the full his passion for observing. To him, a night at the great telescope was almost a sacred rite—an opportunity for a search for truth in celestial places. Rarely has a priest gone up into the temple with a deeper feeling of responsibility and of service than did this untiring astronomer go up into the great dome. He was usually ready before the sun had set, and impatiently waiting until the darkness should be sufficient for him to "get the parallel" for the thread of the micrometer before he could observe faint objects. During the day preceding one of his nights, his associates in the observatory were generally conscious of his keen anxiety for a clear sky, as evidenced by a frequently repeated nervous cough, which was always worse if the prospects for the night were unfavorable.

It was a marvel to all of us that his bodily strength was equal to the tasks which he put upon himself. He was accustomed to get on with very little sleep, and if the night was cloudy he could never trust himself to relax, but was constantly on the lookout for a possible clearing of the sky. Nevertheless, he often appeared in his office by 7 o'clock in the morning, and began work on the reduction of his observations of the night before. He was a very painstaking and accurate computer, and it was seldom that the positions of any celestial objects measured by him required correction for any numerical errors after they were published. From about 1906 he had the valuable assistance of Mrs. Barnard's niece, Miss Mary R. Calvert, who helped in his computations and in his correspondence, and in filing and cataloguing the great number of photographs and reduction sheets which he accumulated. The bibliography at the end of this paper is based upon a card catalogue which she had prepared and kept up to date.

The nebulous regions of the Milky Way were always of much interest to Mr. Barnard, and he early discovered on his photographs great nebulous areas which had not been previously suspected. He investigated many cases of nebulous stars, or of stars which seemed to be involved in "nebulosity," a word which he commonly used to describe vague and indefinite nebulous matter, generally of great extent. In some cases the term may represent a real distinction between a gaseous nebula and one which yields a continuous spectrum; in other cases it may denote finely divided matter reflecting light from a stellar source. The following quotation is from one of his early papers, entitled "The great nebula of Rho Ophiuchi and the smallness of the stars forming the groundwork of the Milky Way."[1]

> For many years this part of the sky troubled me every time I swept over it in my comet seeking; though there seemed to be scarcely any stars here, there yet appeared a dullness of the field as if the sky were covered with a thin veiling of dust, that took away the rich blackness peculiar to many vacant regions of the heavens. This was fully fifteen years ago, at Nashville, Tennessee, when I searched for comets with a five-inch refractor.
>
> After going to the Lick Observatory, I still noticed this peculiarity of that part of the sky, and finally found that two small stars north of Antares were involved in nebulosity and that the whole region seemed to be covered with a very weak diluted nebulosity. . . .
>
> This part of the sky coming within the sphere of my work in photographing the Milky Way, on March 23, 1895, I made a photograph of it with $2^h\ 20^m$ exposure. The resulting negative showed a vast and magnificent nebula, intricate in form and apparently connected with many of the bright stars of that region, including Antares and Sigma Scorpii.

Professor Barnard had early formed a plan for securing a photographic chart of the Milky Way, and he was quick to accept an invitation from Professor Hale to bring the Bruce telescope to Mount Wilson for photographing particularly the southern portions of the Galaxy, in so far as they could be reached from that latitude. The telescope was, accordingly, transported to Mount Wilson, under the auspices of the Carnegie Institution of Washington, in January, 1905, and Professor Barnard spent about nine months on the mountain, engaged in this work. The telescope was back in its own dome at Williams Bay before the end of the year, and for the next 17 years was always available for Mr. Barnard's use, being seldom employed by any other observer.

In 1907 the Carnegie Institution undertook to publish the Atlas of the Milky Way when it should be ready, and during several years search was made for the best mode of reproduction of the pictures. Careful experiments were undertaken by experts in photogravure, and with the heliotype process, but the degree of perfection desired could not quite be attained. Finally, Mr. Barnard accepted the suggestion that photographic prints would most faithfully reproduce the wonderful details of the original negatives. Accordingly, with infinite pains, he made positives from the original negatives and then second negatives from which the prints could be prepared. In this way, the contrast in faint regions was increased and details were brought out

[1] Popular Astronomy, 5: 227, 1897.

which might otherwise have been lost. A firm of commercial photographers in Chicago, A. Copelin & Son, personally well known to Mr. Barnard, undertook the task of making the necessary number of 700 prints from each of the 50 negatives selected to represent the Galaxy. For two years, beginning in May, 1915, Mr. Barnard made frequent trips to the city, and personally inspected each of the 35,000 prints, rejecting hundreds and even thousands of those which seemed to him to be lacking, in some detail, the high quality of excellence which he desired.

It was very difficult for Mr. Barnard to take time from the reduction and discussion of current observations in order to devote himself to the descriptions which were to accompany the photographs. He was also constantly finding new points of interest, as he studied each photograph in detail, which led him to desire new photographs centering on special regions, or having longer exposures than he had previously given. The publication of this Atlas was accordingly delayed, but, fortunately, Mr. Barnard had been prevailed upon to give more time to the completion of the text, and it had been finished, so far as the 50 regions illustrated were concerned. It is to be regretted that he had not written the introduction, which would have summed up his views on the structure of the Milky Way, based upon a personal knowledge more intimate than that possessed by any other person. His notes on the introduction are fragmentary, but they can be used, and it is hoped that the Atlas can be published during 1926, in essentially the manner in which Mr. Barnard would have desired it, and accompanied by charts from drawings giving the coordinates of the region of each photograph, with a designation of the important features.

During the last decade, Mr. Barnard had taken a special interest in the dark markings in the Milky Way. At first he called them vacancies, and it was only gradually that he was led to the view that they were, after all, in many instances, dark objects projected against the Milky Way and absorbing its light. The titles of some of his papers show this gradual transition in the interpretation of these extraordinary structures.

In his paper entitled "Some of the dark markings of the sky and what they suggest," Astrophysical Journal, 43: 1–8, 1916, he says:

> An important fact that may come from our knowledge of the existence of dark nebulae is that their masses must be much greater than would be assumed for the ordinary nebulae, because they are perfectly opaque and must be relatively dense, and hence comparatively massive. If this is so, then we must take into account these great masses in a study of the motions of the stars as a whole.

In that paper he placed side by side a luminous gaseous nebula and a dark object of very nearly the same shape: the resemblance is striking.

One of his most notable papers, "On the dark markings of the sky, with a catalogue of 182 such objects," published in the Astrophysical Journal in 1919, summed up his studies of these objects, which will doubtless be designated in the future by the numbers which he assigned to them in the catalogue.

A very important question in recent years has been the proper location in our stellar system of the globular star clusters. From his studies of their appearance on his photographs of the Milky Way, Professor Barnard was led to the opinion that the clusters are in some instances obviously projected against the background of the Milky Way. To show his ideas as to the relative distances of some clusters and the Milky Way, we may quote from a short note published in the Astronomical Journal in 1920:

> Just as the great star clouds of the Milky Way act as a background against which non-luminous masses may be seen in dark relief, they must act also as a screen and thus hide any object that is behind them. This gives us a means of inferring the relative distances, etc., of many of the great globular clusters. The rich regions of Sagittarius and Aquila, in which some of the finest globular clusters occur, are specially remarkable for their density. That these clusters are nearer than the great star clouds is evident, for they would not be seen through the star clouds if beyond them.

He cites as particular examples, N. G. C. Nos. 6266 (M 62), 6273 (M 19), 6293, 6304, 6333 (M 9), 6528, 6656 (M 22), and 6712.

Although Professor Barnard had given great attention to the surface markings of the planets, it was not until 1905 that he began experiments in photographing the planets with the large refractor, employing a secondary magnifying lens. It will be understood that the direct images of the planets are so small, even in an instrument of long focus, that the grain of the plates makes it impossible to secure a satisfactory photographic enlargement. This work required great skill and patience, because, as Professor Barnard said:[2]

Better conditions are required for successful work in this direction than for visual observations. One can do much visually under conditions where the best definition is only momentary, but for these enlarged photographs any break in the definition for even a single second during the exposure means injury or total ruin to the image. In all the exposures, though of only a few seconds' duration, it was necessary to guide the telescope to keep the image stationary. This was done by bisecting the polar cap by cross-wires (spider threads) in the focus of the long guiding finder (61½ feet focus) of the 40-inch telescope.

It was intended that a full description of this photographic work on planets should be published in the Astrophysical Journal, but Professor Barnard never found time to do this. He obtained also pictures of Jupiter and of Saturn, but instants of the finest seeing when such work was in progress were too rare to yield entirely satisfactory pictures. When visiting Mount Wilson in 1911, Mr. Barnard obtained fine photographs of Saturn with the 60-inch reflector.

We have mentioned before that Mr. Barnard's early interest in the photography of comets and their tails did not abate after the Bruce telescope was put into operation at the Yerkes Observatory. He secured fine series of photographs of all that appeared in our sky, of which may be particularly named: Giacobini's of 1905–6, Daniel's of 1907, Morehouse's of 1908, Halley's of 1909–10, Brooks's of 1911, Delavan's of 1914. Of these, Comet Morehouse of 1908 and Brooks of 1911 exhibited the most remarkable activity in their caudal demonstrations, and their eccentricities kept Mr. Barnard almost constantly at the telescope while it was possible to photograph them.

The return of Halley's comet was awaited with the keenest anticipation by Mr. Barnard. He took many photographs of the region where it might be expected in 1909, and followed it persistently after it was revealed on Prof. Max Wolf's plate of September 11 of that year. The records of previous appearances of Halley's comet had been most carefully studied by Mr. Barnard, but there were many points on which the history was silent or incomplete. He determined to provide against this deficiency at the return of 1910. He kept very full notes on all his observations during the 20 months through which he was able to follow the comet, and embodied these in a long paper appearing in the Astrophysical Journal for June, 1914, entitled "Visual observations of Halley's comet in 1910" (39: 373–404). In this paper he says:

Halley's comet at its return in 1910, though a brilliant and interesting object to the naked eye—especially in the month of May—was, nevertheless, a disappointment when considered from a photographic standpoint. It is safe to say that it did not give us any new information concerning these strange bodies.

The expected passage of the tail of the comet so close to the earth as to envelop it on May 18-19, 1910, kept Mr. Barnard on the qui vive, and the sky was watched throughout the day as well as the night with the greatest care. Mr. Barnard felt amply rewarded for his pains by the spectacle of the tail in the early morning of the 19th, when he could map it visually for a length of 120°; even on the preceding morning he had been able to record its length as 107°. He last saw the comet a year later, on May 23, 1911, when he secured a position of it with the 40-inch telescope, with some difficulty on account of its faintness.

In order to have observations of this comet made in longitudes otherwise unoccupied, the Committee on Comets of the American Astronomical Society, of which Professor Barnard was an active member, secured a grant from the Bache fund of the National Academy of Sciences, which made it possible to send Mr. Ferdinand Ellerman, of the Mount Wilson Observatory, to photograph it at Diamond Head, Hawaii. Mr. Barnard spent considerable time in preparing his part of the report of the committee, which was printed in the Publications of the Society in 1915.

It will be understood that in addition to his photographic observations of comets, Professor Barnard was always obtaining their positions with the filar micrometer of the 40-inch telescope, whenever such positions were necessary, upon the first appearance of a comet or after it became

[2] Monthly Notices of the Royal Astronomical Society, 71: 471, 1911.

too faint for moderate instruments. It may seem a little singular that the large number of long exposures made by Mr. Barnard on the Milky Way did not lead to the discovery of other new comets; but such was the case, and we may well believe that this possibility was not overlooked by one to whom comets had meant so much in his earlier career. In addition to those already mentioned, he was the first to observe, at their predicted return, Encke's comet in 1914 and Pons-Winnecke in 1921. On a plate taken while he was at Mount Wilson in 1905, he found, some months later, the impression of a comet, which received the name 1905 f, but was not observed elsewhere.

In spite of Professor Barnard's passion for exact measurement, he still regarded his splendid pictures rather from the point of view of a photographer than from that of an expert in measurement; of course, whenever it was necessary he obtained the positions of comets or other objects on the negatives, but in a general way he had these two distinct attitudes of mind in his work. He was somewhat reluctant to feel that the photographic procedure in astronomy could in many cases supersede the older visual methods for which, in some respects, a much higher degree of expert skill was necessary. His collection of some 1,400 negatives of comets contains material on which a vast amount of measurement could be made, and we trust that this will soon be done in the study of the peculiar internal motions of comets and their tails. The negatives of the Milky Way and of fields of the sky taken by Professor Barnard at Yerkes Observatory number about 3,500, in addition to about 500 taken by him at Mount Wilson. These constitute a rich field for investigation of stellar motions, for discovery of variable stars, and for statistical studies of the structure of the universe. It is hoped that these plates, which extend over nearly a score of years, may soon be investigated under the "blink" comparator for motions and variables, and it is certain that the full study of this splendid series of photographs will bring to light many important facts.

Occasionally Mr. Barnard had time to investigate pairs of plates under the "blink" comparator; thus, on confronting a plate taken in May, 1916, with one of the same field he had obtained with the Willard lens in August, 1894, he discovered the star in Ophiuchus having a proper motion of 10″.3 per year, the greatest proper motion thus far detected. This motion was, in fact, so unexpectedly large as to make the discovery very difficult, but the plates were numerous enough to confirm its reality. The position of the object, familiarly known by our staff as Gilpin, was carefully measured by Mr. Barnard with the filar micrometer. Its parallax was investigated here and at other observatories and was found to be 0″.53, corresponding to a distance of 6.1 light years, thus making this dwarf the nearest star, after the system of Alpha Centauri. With the large scale of the 40-inch telescope, photographs taken a week apart make the proper motion evident and measurable!

Professor Barnard was deeply interested in eclipses of the sun, and he secured with a visual lens some excellent photographs of the corona at the total eclipse of January 1, 1889, at The Willows, a point in California not far from Mount Hamilton.

In 1900, at the station of the Yerkes Observatory, at Wadesboro, N. C., he was again favored with a clear sky and secured excellent photographs with the horizontal telescope of 61½ feet focus, but here he denied himself the privilege of a direct view of the corona, remaining inside the spacious camera with Mr. Ritchey to assure the accuracy of the exposures and the perfection of the result. They saw the corona only as it was projected on the photographic film.

Mr. Barnard was invited to join the large expedition to Sumatra organized by the United States Naval Observatory for the total eclipse of May 18, 1901. His station was at Solok, and he planned every detail with the greatest of care for photographs of the corona on a very large scale. The duration of totality was very long, nearly a maximum of six minutes. It was tragic that a thick blanket of clouds prevented him from making any observations at that time. He was absent from the observatory for about six months, and this further deprived him of the opportunity of observing Nova Persei when it was bright.

He was greatly interested in the eclipse of June 8, 1918, and made a trip of inspection with the writer in September, 1917, to select suitable stations in Wyoming and Colorado. He went on with the advance guard of our party to our principal station at Green River, Wyo., six weeks before the date of the eclipse. He took infinite pains in the adjustment of the horizontal telescope used with our coelostat, and could be content with nothing but perfection in the focusing of all the cameras for which he had any responsibility. Unfortunately, a great cloud drifted across an otherwise perfect sky on that afternoon, covering the sun until two or three minutes after totality was over. Mr. Barnard had been again interested in studying the conditions for the eclipse of September 10, 1923, and up to within a fortnight of his death we had still hoped that he might be a member of our party.

Lunar eclipses were not neglected by Professor Barnard. He had photographed successfully, at the Lick Observatory, the eclipses of 1894 and 1895, and it was his custom to make with the Bruce telescope many photographs of the different phases of each lunar eclipse which occurred in favorable weather. With that instrument he also kept a photographic record of all interesting conjunctions of the planets and similar occurrences.

The displays of the aurora, which are frequently visible in Wisconsin, were a delight to Professor Barnard, and he recorded fully their details and published two extended papers regarding them. His notes covering the aurora for almost another solar cycle are still unpublished. He also gave attention to the self-luminous night haze, which his long vigils had given him unusual opportunities to observe, and he presented two papers on the subject to the American Philosophical Society, one in 1911 and the other in 1919.

We thus find him a keen observer of nature in most of its visible phases. The meteors did not escape him or his photographic plate, nor did the 17-year locusts at their regular recurrence. In the growth of the trees which he had planted about his home he had great satisfaction, and he had much pleasure in following the development and planting of the grounds of the observatory, when that became possible a few years ago.

In his will Professor Barnard bequeathed to the University of Chicago his home, as a memorial to his wife, whose death occurred on May 25, 1921. To the Yerkes Observatory, he left also his scientific books and the medals and awards he had received in recognition of his notable services to science.

Professor Barnard's home had been a center of generous hospitality for a quarter of a century, and nowhere was he more entertaining that as host in his own home. He was full of humor and could tell most amusingly of his experiences in early life and of his travels. It has been the writer's good fortune to make many railroad trips with him, and he was always a most agreeable companion. He was shy and restive in larger companies where he was not well acquainted with the other guests, and was often quite nervous before giving a lecture on a subject with which he was perfectly familiar. After he was well started in an address he quite lost this shyness and would describe the intimate details of his pictures in a charming way. He never spoke more interestingly than in one of his last lectures which he gave one evening, on the subject of comets, at the meeting of the American Astronomical Society, at the Yerkes Observatory, in September, 1922.

Mr. Barnard's delicious vein of humor was very familiar to his intimate friends. He could tell of some of his varied experiences in a distinctly original manner. Conformity to the latest fashion was of no special concern to him. He was accustomed to wear a black tie of a type perhaps more familiar in the seventies, though evidently somehow procurable even at the present time. This variety is mounted on a pasteboard frame, and is attached, rather precariously, to the collar button by a small elastic cord. Accidental detachment was, therefore, of frequent occurrence; in fact, the presence or absence of the tie was sometimes used by a friend as a test of vision; but to the suggestion that a more modern type of tie, the kind that passes around the neck of the wearer, might save the inconvenience of perpetual uncertainty as to whether or not the tie was attached, the reply was made by Mr. Barnard: "Why, this kind of tie once saved my life!" To the surprised inquirer he added: "You see, I was at the Grand Canyon, and looking down into that vast chasm, suddenly the tie fell off and floated down half a mile into the depths below. What if it had been around my neck!"

Always mindful of the difficulties that he had to overcome in his early beginnings as an astronomer, Professor Barnard was most generous in giving advice and assistance to all sincere aspirants for knowledge of astronomy who approached him with questions, by letter or in person, and he gave his time freely to such, in exhibiting and explaining his most significant photographs. He willingly took his turn in speaking to the large number of visitors admitted to the Yerkes Observatory on Saturday afternoons, and often stayed long after the closing hour in explaining details to those who had evinced a real interest. He was most kind to other workers in astronomy, and tolerant in expressing opinions of them, even though their views might differ very greatly from his, and though he might regard them as radically wrong. He avoided controversy, and seldom took his pen to oppose the views of others.

Professor Barnard was not a teacher. He had missed the inspiration and opportunity of studying astronomy under some gifted enthusiast. He had, of course, profited by taking part in the work at an institution so well planned and organized as was the Lick Observatory by Director Holden, and had received much benefit from the sane counsel of his seniors there, particularly from Mr. Burnham; but he did not realize from experience the mutual importance of the relation of teacher and pupil, or know the satisfaction of the teacher in having an apt follower in his research to whom he may pass on the acquisitions of his years of study. Mr. Barnard could not bring himself to lose time at the telescope in having a pupil take part in measurements, which he could himself make so much better, and he begrudged the possible loss in quality of a photograph if some one less skilled than himself took some part in the guiding. Accordingly, he trained no one to be his successor; he left no disciple who could take up his work after receiving the benefit of his unequaled experience as an observer and of his exceptional knowledge of the heavenly bodies.

Mr. Barnard was stricken with diabetes early in the year 1914, and had to undergo the severe privation, by the doctor's orders, of giving up observations with the large telescope for a year. As a result of his obedience, his health was greatly improved, and for seven years longer he kept up his observing most industriously and really beyond the measure of his bodily strength. It was regarded by the director of the observatory as no small part of his duties to see that such a man should be induced to spare himself as much as possible and to restrict his night work both to save him from exhaustion and to gain time for the reduction and discussion of his great accumulation of observations. But it was almost impossible for Mr. Barnard to keep away from the Bruce photographic telescope when the sky was clear and the moon did not interfere.

He was greatly affected by the death of his wife after a brief illness and after 40 years of married life in which she had devoted herself completely to his comfort. They had no children, and thus Mr. Barnard missed the joys and responsibilities of parenthood, even as he had himself missed the experience of the relation of son to father.

His final illness was of only six weeks' duration, and began rather acutely. The best of medical skill was given him, and up to a short time before his death the specialist was hopeful of his recovery. He died at 8 o'clock on the evening of February 6, and simple funeral services were held on the following day in the rotunda of the observatory, which seemed to us the appropriate place. The interment was at Nashville, after services attended by many friends in his native city and from his alma mater. He had always been highly appreciated at Nashville, and one of the interesting evidences of this was the erection, not long ago, by the Nashville Automobile Club, in cooperation with the Nashville Historical Committee, of a tablet at the place in the city where the young enthusiast discovered his first comet in 1881.

Measured by the calendar, his life was but little more than 65 years, but, by the number of hours he had spent under the nocturnal sky or in the domes, his period of activity was more than that of many who had passed four score years.

His services to science were recognized by the learned societies. He was vice president of the American Association for the Advancement of Science in 1898, and delivered an address upon the "The development of photography in astronomy." In the same year he was elected a foreign associate of the Royal Astronomical Society. He became a member of the American Academy of Arts and Sciences in 1892, of the American Philosophical Society in 1903, and of the National Academy of Sciences in 1911. He was made a director of the B. A. Gould fund, under the auspices of the National Academy, in 1914, and at the same time an associate editor of the Astronomical Journal. He had been for three years (1892–1894) associate editor of the journal Astronomy and Astrophysics. In addition to the medals mentioned heretofore in this article, he received from the French Academy of Sciences in 1893 the Arago gold medal, and in 1900 the Janssen gold medal; he was the recipient of the Janssen prize of the Astronomical Society of France in 1906, and was awarded the Bruce gold medal of the Astronomical Society of the Pacific in 1917. The last-named society had three times awarded him the Donohoe comet medal. He was given the honorary degree of doctor of science by Vanderbilt University in 1893, and that of doctor of laws by Queen's University, of Kingston, Ontario, in 1909.

The voluminous character of his contributions to astronomical literature has already been indicated, but we may add that a card catalogue of his writings includes no less than 900 items, without being complete. A bibliography of his articles which appeared since his connection began with the University of Chicago in 1895 has been published in the list of publications of the faculties issued annually by the University of Chicago and also collected in two special volumes of this character covering the first 25 years of the work of the university. These contain the titles of 377 articles and 6 book reviews by Professor Barnard, to which number will be added, as time permits their preparation, numerous posthumous papers covering his unpublished observations.

His last measurements with the 40-inch telescope were made on the night of December 16, 1922, when he secured the position of Baade's comet; his last visual observations with that instrument were on December 21, when he made 19 estimates of the brightness of Nova Persei, referred to 13 comparison stars; and his last use of that instrument was later on that night when he made a photograph of the cluster Messier 36 with an exposure of two hours. A photograph of the region of Gamma Leonis, made on the following night with the Bruce telescope, closed his long and untiring work with that instrument. His last visual observation was of the occultation of Venus on the morning of January 13, 1923, which he observed from the window of his sick room. Thus closes the record of the astronomical activity of one of the greatest observers of our time, of whom may be truly said, "Aperuit caelos."

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We are indebted to Miss Mary R. Calvert for the preparation of the following bibliography, which has been arranged topically, and without giving the exact title of each paper. We believe that it will be of more convenience to the user to have the articles on a given subject grouped in this manner. A strict chronological order has not been followed in the arrangement under each topic, but it seemed wiser to collect together the papers which appeared in the same journal, and a regular order has been followed where a series of journals contained the papers. Titles have not been given in full except for papers which were of a special importance or were of a general character and summed up Professor Barnard's studies in that particular field, but many minor contributions and notes have not been included in this list.

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