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The Barnard Objects: Then and Now

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This book is dedicated to all those who have looked at the stars and wondered what they were. Keep looking up and keep wondering.

Foreword

Tim Hunter, Gerald Dobek, and James McGaha are among the greatest observers of the night sky of our time. Tim, who clearly has a visual mind, was for some years the Head of the Department of Medical Imaging at the University of Arizona, but his first love was astronomy, and not only has he set up two magnificent amateur observatories, the 3towers Observatory and Grasslands Observatory both in southern Arizona, but has contributed immensely to the protection of one of our most valuable natural and cultural resources, the dark sky, as co-founder with David Crawford of the International Dark-Sky Association. Jerry, Head of Science and Departmental Head of astronomy at Northwestern Michigan College who makes professional observations of small-amplitude variable stars from his home observatory published (in 2011) an annotated and updated edition of E.E. Barnard's legendary *A Photographic Atlas of Selected Regions of the Milky Way* (Cambridge University Press), thereby making a reasonable facsimile of it available to all those who have ever seen it and despaired of ever owning a copy of the original. James McGaha, a retired Air Force pilot, is Director of the Grasslands Observatory and is a leading practitioner of asteroid and comet astrometry and photometry as well as a contributing author to *Skeptical Inquirer* magazine.

All three of these outstanding observers share a love for the life and work of Edward Emerson Barnard, one of the greatest observational astronomers of all time (his only rivals are the likes of Galileo and William Herschel) whose name is recalled in the eponymous "Barnard's Star," "Barnard's Loop" (in Orion), and the 370 "Barnard Objects" whose visible darkness

make them among the most beautiful and photogenic objects in the night sky. In this magnificent book, they have shared their long fascination with Barnard and especially the dark nebulae cataloged under their name—most of which they have reimaged using more modern techniques than those available to him, while compiling a staggering amount of information about them. Like Barnard's *Atlas*, this is a book for the ages; it will be savored by anyone with an interest in the structure and evolution of the Milky Way who has been intrigued by these impressive and mysterious objects. It is exactly the kind of book that E.E. Barnard, as a young man working at a Photograph Gallery in Nashville whose interest in the night sky was perennial even before he learned the names of the stars and planets, would have given his eye teeth for. In his case, a few rude star charts in a book given to him by a thief as a surety of a loan first introduced himself to the formal knowledge of the heavens. This book, on the other hand, comes as close as anything in text or digital form to comprehending the beauty and variety and sheer ravishment of the heavens themselves. Anyone who opens the book will find it impossible to put down. I enjoyed it immensely. As with all great books, it compels the reader to go beyond its pages to experience directly that which it describes—and in this case, one could no better honor the authors than to go out to some inky-black spot (not so easy to come by these days as for Barnard who, from downtown Nashville, could see the Milky Way and even the gegenschein with the naked eye) and "look up in perfect silence at the stars."

If I may be permitted a personal reflection. Like the authors, I have always had the greatest admiration for Barnard, whose achievements could only be explained, as Tim Hunter points out, as the works of genius. If we did not know of him as much as is known about the lad of Stratford who went to London to seek his fortune on the stage, we might well be inclined to introduce the equivalents of Baconian or Oxfordian or other theories to explain how such rudimentary circumstances could produce the Swan of Avon. In Barnard's case, the documentation is remarkably complete, with an enormous number of documents—including even diaries kept in his early life, and abundant portraits showing him progress through the stages of hardship, success, and setback—kept at Vanderbilt, University of California-Santa Cruz, and the University of Chicago. Instead of seeming like a case of abracadabra or creation ex nihilo, one can track how one step led to the next—and ultimately mountains were climbed. For all that, it is still almost unbelievable.

So if not magic, what? Nothing other than genius could ever have seen him from the impoverished circumstances of his early life as an urchin on the streets of the part of Nashville known as "Varmint Town" to the dizzying

heights of astronomical discovery he achieved. The odds against were long beyond belief. Despite having only two months of formal schooling—and not even having a book about astronomy to pore over until he was nineteen—he was an omnivorous learner, who picked things up wherever he went. It was his good fortune that, in order to support his poor mother and feeble-minded brother (his father died before he was born), he was placed at age nine by sheer chance as a very lowly assistant in a Photograph Gallery, and there learned to refine his innate talent for art (apparently inherited from his mother who made flowers in wax to support herself and her family) and the remarkable technical skills needed to carry out the darkroom magic which led to some of the remarkable discoveries described here.

I first became intrigued by Barnard when, at about ten, I became seriously captivated by the wonders of the night sky and those who studied them best. He, with Galileo, William Herschel, and Percival Lowell, was my great hero, and as I learned more about him, my admiration only grew. In my late twenties (at about the time I began preparing for a professional career in psychiatry), I became interested in the way that different observers saw things in the telescope, especially on the surfaces of planets, and made the surprising discovery that Barnard's long-lost (and possibly even destroyed) drawings of Mars, made with the 36-inch Clark refractor at Lick Observatory in 1892 and 1894 and searched for in vain by the likes of Carl Sagan in the post-Mariner 4 era, had in fact survived. I found that out in 1987, and appreciated fully for the first time just how much remained to be discovered in the history of astronomy. It was the careful study of Barnard's (and other) Mars drawings I embarked on then that led me to write a book, *Planets and Perception* (University of Arizona Press, 1988). Before I had finished that, I had begun to ponder the idea of writing a proper biography of Barnard himself.

It seemed rather daunting, simply because of Barnard's extraordinary range—he observed everything that shone or obscured (with the possible exception of the Moon, to which he gave little attention), and though he was one of the keenest-eyed visual observers who ever lived, he was one of—perhaps the greatest—astronomical photographers during the age of its first flowering (the late-nineteenth and early twentieth century). He was to comets and the Milky Way what Matthew Brady was to Abraham Lincoln or the battlefields of the Civil War, or Ansel Adams to Half-dome or El Capitan. In addition, his life took place against a stirring background of events. He was born in Nashville in 1857, the year of the infamous Dred Scott decision that sent the country hurtling inexorably toward civil war. (The Nashville slave market, still a going concern in his early childhood, was at the corner

of 4th and Charlotte, a close walk from 4th and Cherry where the Photograph Gallery he worked from the age of nine was located.) On his seventh birthday, he heard the cannons during the Battle of Nashville, in which the Confederate army began and the city was placed under Union occupation. As his reputation for astronomy grew (largely owing to his prolific discovery of comets), his career played out against the backdrop of just-founded institutions—Vanderbilt University, Lick Observatory, Yerkes Observatory, Mt. Wilson. Thus writing his life would entail also learning about the leading figures, institutions, astronomical techniques, and discoveries of the whole remarkable period which included the emergence of astrophysics. The vast scope required of Barnard's biography made the whole thing daunting; but it also made it—ultimately—irresistible.

In addition, one of Barnard's achievements was one of the most highly coveted books by anyone who owns a small astronomical library. That book is *A Photographic Atlas of Selected Regions of the Milky Way* (1927), based on the photographs he obtained with the Bruce astrograph of the Yerkes Observatory mostly during a sabbatical at Mount Wilson in 1905. Unfinished at the time of his death, it represented the fruits of 20 years of hard work by one of the most driven and hard-working astronomers of any era—though in the end, like the apples of Tantalus, its completion remained out of reach of Barnard himself. To some extent, it was finished by his niece and assistant Mary Calvert and his boss, the Yerkes director Edwin B. Frost. However, it is distinctively Barnard's in vision and style of thought. What Barnard has achieved here remains *sui generis*, *sub specie aeternitatis*, a monument for all time. His plates express not only their celestial subject matter—the grandest subjects any artist can attempt to remember—but the unique living force of the artist's personality, the distinctive design, pattern, or "inscape" (to use a term coined by Gerard Manley Hopkins, our friend David Levy's favorite poet) of his vision. The texts are worth pondering, and Barnard was capable of a poetic turn of phrase as when (in his earlier *Milky Way and Comet Photographs*) he described the Great Star Clouds in Sagittarius as "like the billowy clouds of a summer afternoon; strong on the side towards the Sun, and melting away into a thin atmosphere on the other side. Forming abruptly at their western edge against a thinly stars strewn space, these star clouds roll backwards toward the east in a broadening mass to fade away into the general sky, beyond the limits of the present picture."[1]

[1] E.E. Barnard, "Photographs of the Milky Way and of Comets made with the six-inch Willard lens and Crocker telescope during the years 1892 to 1895." *Publications of the University of California*, vol. XI (Sacramento, 1913), p. Plate 49.

But above all Barnard's was a strongly visual imagination, and the pictures speak for themselves.

When the authors of the present work asked me to contribute a foreword to the present work, I was honored to do so. The job done—the stage set—I could take this opportunity to pull down my sails and seek safe harbor again. However, as I have begun to write and caught a favoring wind as it were, I have once more become inveigled by the wonderful story—all the difficulties overcome, dramatic incidents, charm and perseverance of Barnard's life. All of that comes back to me as I recall the 3 years or so in which I spent a substantial part of my own life following Barnard's footsteps and sometimes even getting close to what must have been my thoughts. Writing Barnard's biography has been one of the intellectually most challenging and satisfying things I have done in my life, and the book that emerged from it, *The Immortal Fire Within: The Life and Work of Edward Emerson Barnard* (Cambridge University Press, 1995), remains I think the best thing I have ever done in (and for) astronomy.

Though the *Atlas* is the major focus in the present book, and in some ways was the fulfilment of Barnard's richly creative life, it exists in the context of the entire sweep of Barnard's career. Messrs. Hunter, Dobek, and McGaha have covered Barnard's life, techniques, and achievements with great completeness and mastery. But perhaps I will be allowed, briefly, as his biographer to summarize a few of the highlights that led from his first moments of transport under the night sky, when he looked at the stars and wondered what they were, to the last days of his life when—even when clearly dying—he watched an occultation of Venus by the moon through the window of his sickroom.

I might begin still earlier, but let me begin when Barnard was a young man in his early twenties sweeping the sky for comets from the still-dark skies of his native Nashville. Though the comets were then the prizes he sought, inevitably he was brought into contact with many of the wonders of the background sky across which they moved, and the Milky Way was for him the wonder of wonders. In an 1883 article for the Nashville *Artisan*, he wrote of his experiences comet sweeping and of being often close companion to awe:

> Sweep on through glittering star fields and long for endless night! More nebulae, more stars. Here a bright and beautiful star overpowering in its brilliancy, and there close to it a tiny point of light seen with the greatest difficulty, a large star and its companion. How plentiful the stars now appear. Each sweep increases their number. The field is sprinkled with them, and now we suddenly sweep into myriads and swarms of glittering, sparkling points of brilliancy—we have entered the milky way. We are in the midst of millions on

> millions of suns—we are in the jewel house of the Maker, and our soul mounts up, up to that wonderful Creator, and we adore the hand that scattered the jewels of heaven so lavishly in this one vast region. No pen can describe the wonderful scene that the swinging tube reveals as it sweeps among that vast array of suns.[2]

In his sweeps, Barnard encountered many nebulae. Their nature was one of the great unsolved problems of astronomy of the day. Most were readily distinguished by their fantastic forms, but some were like those famously marked by comet-seeker Charles Messier that, as Barnard put it, appeared as "roundish patches of foggy matter, extremely like comets in appearance." Occasionally he also came across a singularly baffling object, unlike any of these, as on July 17, 1883. While sweeping for comets southwest of the Trifid Nebula (M20) in Sagittarius, he noted a "small triangular hole in the Milky Way, as black as midnight," which he later described as "a most remarkable small inky black hole in a crowded part of the Milky Way … with a bright orange star on its n[orth] p[receding] border and a beautiful little cluster [NGC 6520] following."[3]

This, evidently, was one of the mysterious voids discovered by William Herschel while making the "star gauges" by which he had attempted to plumb the depths of the sidereal universe a century before. Herschel had indeed thought them true voids, and the novelist Thomas Hardy, writing a year before Barnard penned the article just quoted, described them as "impersonal monsters, namely, Immensities… the voids and waste spaces of the sky." Darkness visible, they evoked both beauty and fear, and held the mind with the same kind of irresistible fascination that black holes do for us today—and were, as Hardy put it, places where "our sight plunges quite beyond any twinkle we have yet visited. Those are deep wells for the human mind to let itself into."

Through his long apprenticeship in the Photograph Gallery in Nashville, where he began as a nine-year-old human clock drive, cranking a set of wheels to keep a giant camera, "Jupiter," aimed on the Sun to help shorten the exposure times of portraits, and lasted until he left the Gallery for a position as a Special Fellow and director of the small observatory at Vanderbilt University, Barnard became one of the greatest experts in photography and photographic processes as applied to astronomy in his time. (In addition to learning the techniques of photography, he also found a wife through his place of employment—Rhoda Calvert, 13 years his senior; she was the

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[2] William Sheehan, *The Immortal Fire Within: the life and work of Edward Emerson Barnard*. (Cambridge: Cambridge University Press, 1995), p. 50.

[3] Ibid., p. 68.

older sister of the Calvert brothers originally from Morley, Yorkshire, England, who after emigrating to the United States acquired the Photograph Gallery from Van Stavoren. They were married in 1881.)

On the strength of his work with small telescopes and his many comet discoveries, in 1889 Barnard began work as a member of the original small staff of astronomers at Lick Observatory in California. However, as its most junior member, he not given regular time on the Observatory's most coveted instrument—the 36-inch refractor, then the largest in the world—Barnard made sweet uses of adversity. Adapting to long-exposure photography of the night sky a cheap and rather ancient six-inch portrait lens (the "Willard lens") that had been picked up the Lick Director Edward S. Holden for photographing the total eclipse of the Sun of January 1, 1889, Barnard began a remarkable program of wide-field photography of comets and the Milky Way. The first Milky Way photograph was exposed for three hours on stars of Sagittarius on August 1, 1889, and centered on the small triangular hole he had noticed during his comet sweeping years before. The inscrutable details in this and other plates presented at once a revelation and a conundrum. In 1894, he described a particularly striking one to the English barrister and astronomer Arthur Cowper Ranyard as "essentially a region of vacancies. There is a great chasm here in the Milky Way." Another showed the peculiar region centered on Rho Ophiuchi, where a century before William Herschel had exclaimed to his sister Caroline, "Here surely is a hole in the heavens." At the time Barnard—who was cautious and did not allow himself to get swept away—agreed with the Herschels, but Ranyard thought otherwise: "The dark vacant areas or channels … seem to me to be undoubtedly dark structures, or absorbing masses in space, which cut out the light from a nebulous or stellar region beyond them."[4] Ranyard, who died of cancer that same year, proved to be right, but Barnard hesitated. The question nagged at him, however, and solving it became the great intellectual adventure of his life.

Despite Barnard's enormous productivity at Lick (his most famous result, which vaulted him to international fame, was the discovery of the fifth satellite of Jupiter in 1892), he clashed with Director Holden. Recognizing Barnard's unhappiness, the dynamic George Ellery Hale recruited him to Yerkes Observatory in the village of Williams Bay in southern Wisconsin, and Barnard arrived in 1895—even before its new telescope, a 40-inch refractor that "licked the lick"—was available. The change of scene was not an entirely happy one for him. A native of the South, and a lover of sunny California where he and Rhoda had hoped on retirement to

[4] Ibid., p. 274.

repair to a small plot of land they acquired in San Jose where they could build a house and plant oranges, he despaired of the harsh winters, and yet as an obsessive "observaholic," he refused on even the coldest winter nights to sacrifice even a scrap of clear skies. In later years, visitors to the Yerkes Observatory were amazed that he continued to work even when the temperature in the dome was ten or fifteen degrees below zero Fahrenheit, and when they asked him how he kept warm, he replied: "We don't!" One profoundly miserable winter night, when the temperature plunged to -26° Fahrenheit, Barnard was observing with the 40-inch Yerkes refractor; S.A. Mitchell, who was at that time an assistant at the observatory, was working at the 12-inch refractor. At 2 a.m., a haze came over the sky. "We each left [our respective] dome to go down stairs to thaw out," Mitchell later recalled. "Inwardly, I must confess that I hoped it had clouded for good. If he felt the same he did not say so. The haze was only the last traces of moisture being frozen out of the atmosphere for it cleared off an we both went back to work until seven o'clock… [O]h! the torture of working so long at a stretch at such temperature with one's vitality at so low an ebb!"[5] On another equally bitter night, Barnard did stop work and close the dome, even though the stars were still shining brightly. The next morning, he explained that he had done so from worry that the telescope might break or be injured in the extreme cold. Edwin Brant Frost, who succeeded Hale as Observatory director after the latter left for Mount Wilson, knew that Barnard would never abandon work solely with a thought to his own comfort, agreed that this precaution was prudent, and posted a sign that henceforth whenever the temperature in the dome dropped below −25° Fahrenheit work should stop—for the sake of the telescope!"

Though Barnard was an avid user of the 40-inch refractor, his first priority at Yerkes was his Milky Way photography, which he hoped to carry forward with a more suitable instrument than the primitive "Willard lens." He managed to secure a grant from reclusive New York City heiress and astronomy patron Catherine Wolfe Bruce to purchase an astrograph centered on a 10-inch doublet lens by Pittsburgh telescope-maker John Brashear. It was to be mounted with two other telescopes, a 6 ¼-inch doublet and a 5-inch guide scope, on the same bent pier mounting. (Perhaps somewhat to Barnard's chagrin, Miss Bruce provided the money for an even larger astrograph to Max Wolf, Barnard's friend and rival, at the Heidelberg Observatory.) At first, Barnard hoped to employ the telescope at Yerkes, but through hard experience realized that the seeing conditions, especially in

[5] S.A. Mitchell, "With Barnard at Yerkes Observatory and at the Sumatra Eclipse," *Journal of the Tennessee Academy of Science*, 3:1 (1925), p. 25.

winter, would never allow him to get the best results with it. Meanwhile, the ever-restless Hale, endowed by the Carnegie Institution with a 10,000,000 gift and appointed to a committee to help decide the best uses for the money for the promotion of astronomy, was spending most of his time in California, planning to set up a high-altitude solar observatory and a large reflecting telescope on "Wilson's Peak" (elevation 5886 feet) near Pasadena. Hale's reports of conditions there were tantalizing, but at the moment no money could be found to bring Barnard and the Bruce out there, and so Barnard reluctantly went ahead with having the Bruce telescope set up on the grounds at Yerkes (between the 40-inch dome and his home on the shore of Lake Geneva). Though the telescope had not yet been delivered, work on the dome proceeded. Just after Christmas 1903, Barnard wrote to Hale:

> It is very cold and disagreeable here. It has been as low as 20 degrees below zero. It remains cold all the time with tremendous winds…. We got the tinner to come and finish the shutters…. But he has yet to come and do all the soldering…. It is too cold now.[6]

Meanwhile, it became apparent that Hale was not going to return to Williams Bay but instead would remain in California (though still as director of Yerkes) to establish the Mount Wilson solar observatory. Dartmouth-trained spectroscopist Edwin B. Frost would in Hale's absence serve as acting director at Yerkes.

Barnard began intensively lobbying Hale to find a way for him to bring the Bruce telescope there as well. Hale was willing, and at the beginning of February 1904 managed to secure a grant of $1000 from hardware- and steel-pipe millionaire Joseph D. Hooker for a grant of $1000 for the "Hooker expedition" to bring Barnard and the Bruce telescope out west. Two weeks later, the Bruce telescope arrived at Yerkes from the Cleveland telescope-making firm of Warner and Swasey, and since Barnard was now expecting to be off to California as soon as possible, temporarily set it up in the corridor of the Yerkes main building. Continuing the correspondence with Hale, the latter noted that there was at the time only a rugged trail to Mount Wilson, and that therefore Barnard would be better off setting up on nearby Mount Lowe (named after Civil War balloonist, Dry Ice manufacturer, and real-estate speculator, who had established an observatory upon yet another nearby peak, Echo Mountain) which could be reached by railway.

Barnard hoped to ship the telescope out to Mt. Lowe and arrive himself by early May, but now Hale began to hang fire—there were doubts about

[6] Sheehan, *The Immortal Fire Within*, p. 333.

the spring-time seeing conditions, and money problems, as Hale found himself in the uncomfortable position of finding that he did not have money to pay the astronomers' salaries. When he informed Barnard of the situation in March, Barnard was in bed with a bad case of bronchitis, as he always was by the end of a harsh winter of observing in Williams Bay. He did his best to commiserate with Hale's financial struggles, and assured him that he ought not to let his own wishes for the Bruce telescope to interfere in any way. But he promptly added:

> It is needless to say that I am extremely anxious to get a chance at the southern part of the Milky Way from Mt. Lowe…. I looked out the other morning about 3 o'clock … at the Milky Way and that glorious region in Scorpio and Sagittarius was coming up in the low south next, and it made me feel that it would be a great thing….
>
> I am satisfied that you will do all in your power to get the Bruce out there and I hope you will succeed, but as I say if it interferes with your plans for your other work, why let it go.[7]

With the prospects for the Mount Lowe expedition now dimming, Barnard decided to go ahead and mount the Bruce telescope on its brick pier at Yerkes, and begin work there. He encountered various difficulties adjusting the telescope, while the situation in California also disappointed; dust was coming up from the desert and covering the sky with whitish haze, making it seem pointless to take the Bruce telescope out there. However, then conditions improved again, and by fall the trip was on again. Hale was having better luck with the seeing at Mount Wilson, and the financial situation had improved. Hoping to avoid another Midwestern winter, Barnard was more than eager to come out. In early November he informed Hale of trying to get an eight-hour exposure on the Pleiades and a nine-hour exposure on the Milky Way in Cassiopeia. But the results were little better than he had obtained with the Willard lens on Mt. Hamilton. "The night was not transparent," he explained. "We have had very little clear weather this fall until the end of last week which has kept up till now and it is singularly perfect—it is Indian summer in appearance—but the sky is thickish at night and on faint nebulosities it is very poor."[8] A few days later, the weather turned "cold and raw and cloudy, with a miserable north wind." After another unsuccessful attempt at the Pleiades, he decided there was no point to continuing; instead, he hoped to set out for Mount Wilson, noting "I may be on time to get at [the Pleiades]" there. The telescope (except the 10-inch lenses which would travel with Barnard as hand luggage) set out in early December. After seeing Rhoda (suffering from heart problems) off to New York from where she would set sail to England to spend the time Barnard was away with relatives there, Barnard himself set out—to San

[7] Ibid., p. 334.

[8] Ibid., p. 336.

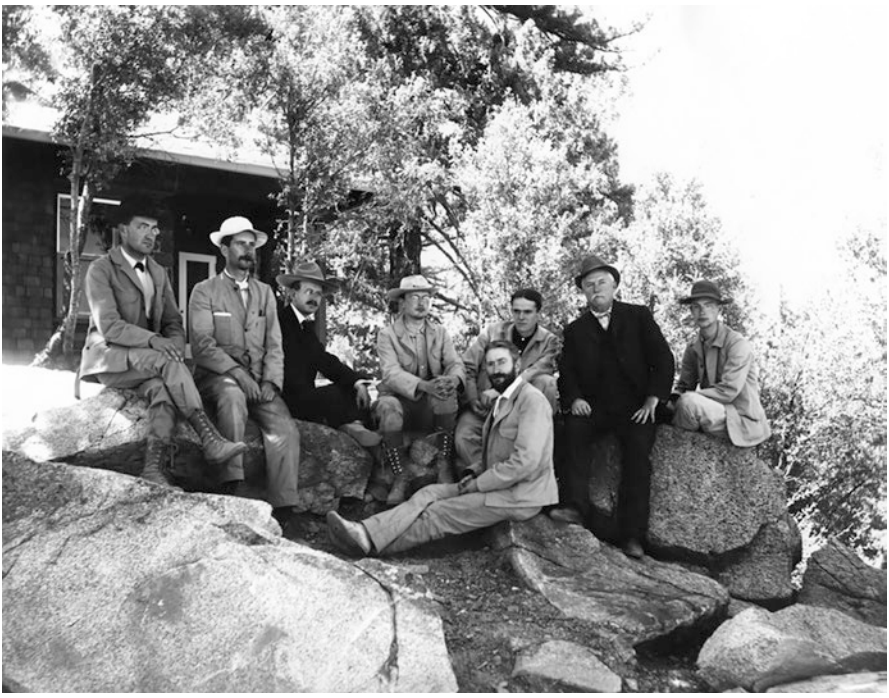
Francisco—Lick—Pasadena—and on January 10, 1905, after a climb of five hours most of it on foot and with the 10-inch lenses fastened on one side of a mule and balanced on the other side, arrived at the summit (the males-only "Monastery," like those in the Levant Hale had read about) safe and sound. The last part of the journey was in fog and rain.

On Mount Wilson with the Bruce

By this time, Hale had already drawn after him several members of the Yerkes staff—Walter S. Adams, Ferdinand Ellerman, and George Willis Ritchey—as well as another transplant from Yerkes, the Snow solar telescope, a horizontal telescope of coelostat design that Hale and Ritchey built at Yerkes in the autumn of 1903 and since shipped to Mt Wilson. Others who came out to Mt. Wilson on a temporary basis while Barnard was there included Charles Greeley Abbot of the Smithsonian Institution, his assistant, Leonard Ross Ingersoll, and Henry Gale, a former football player who was now a University of Chicago physicist interested in sunspot spectra. Adams would later recall fondly those early days at the Monastery:

> Hale had introduced Abbot to the Oriental stories … on the monasteries of the Levant, and our evenings usually started off with a dramatic rendering by Abbot of the tale of the Jew of Constantinople and Solomon's seal which he knew by heart. Occasionally the Smithsonian challenged all comers to a game of duplicate whist, but more often the group would gather around the fireplace for discussions of plans of work or of the state of the world in general. Hale's amazing breadth of interests, his great personal charm, and his stories of important figures in science and international affairs make these evenings stand out in memory.[9]

[9] W,S, Adams, "Early Days at Mt. Wilson—II, *Publications of the Astronomical Society of the Pacific*, 59 (1947), pp. 97–115:pp. 99–100.



Mt. Wilson group 1905. Seated in front is F. Ellerman; from left to right are Construction Superintendent H.L. Miller, C.G. Abbot, G.E. Hale, L.R. Ingersoll, W.S. Adams, E.E. Barnard, and C. Backus. Credit: Henry E. Huntington Library and Art Gallery.

Now in his glory, with the Pleiades that the struggled to capture from Yerkes still accessible and the Galaxy to explore, Barnard wasted no time, and had soon erected the Bruce telescope in a small wooden structure on a small hillock on the trail midway between the Monastery and the Mt. Wilson Solar Observatory and the Observatory workshop. Within this improvised structure he had mounted together on the cement pier four telescopes—the 10-inch Bruce, a 6 ¼-inch photographic telescope, a 3 ½-inch doublet, and a lantern lens. The very first plates were exposed on the night of January 27.

At first, Barnard was prone to experience night terrors of the kind he had sometimes experienced years earlier when observing Jupiter with his small telescope all alone in Nashville. The Mt. Wilson Solar Observatory was still in the early construction stage, and sometimes, while working in the small Bruce Observatory, he was the only person on the mountain. Moreover, since the small observatory was separated by some distance from the Monastery, which was hidden from view by heavy foliaged spruce trees,

even when others were about he found himself, "essentially isolated from the rest of the mountain," as he later recalled:

> I must confess that at times, especially in the winter months, the loneliness of the night became oppressive, and the dead silence, broken only by the ghastly cry of some stray owl winging its way over the canon, produced an uncanny terror in me, and I could not avoid the dread feeling that I might be prey any moment to a roving mountain lion. The sides of the [Bruce] observatory were about five feet high, so that it would have been an easy thing for a hungry mountain lion to jump over it and feed upon the astronomer. So lonely was I at first that when I entered the Bruce house and shoved the roof back I locked the door and did not open it again until I was forced to go out.[10]

Fortunately, with the coming of spring (and the increasing accessibility of the southern Milky Way), the loneliness and oppression that he had experienced during the winter began to lift. A good part of this had to do with the reawakening of insect life, which "began its notes in the chaparral":

> The dread of the night soon passed away and the door was left open and it became a pleasure to sit and listen to the songs of nature while guiding the telescopes in long exposures, heedless of all beasts of prey. No one knows what a soothing effect these "noises of the night" have on one's nerves in a lonely position like that on Mount Wilson.[11]

Generally, Barnard found the skies at Mt. Wilson much better than at Yerkes—after the drenching rains early in the season, the dust which had been a matter of concern completely settled out, and Barnard began to obtain magnificently deep plates of the southern Milky Way. In all, he would expose some five hundred plates with his three telescope and his lantern lens—from which he later quarried most of the material used in the *Atlas of Selected Regions of the Milky Way*. As usual he worked like a fiend. For many years he had been used to getting by on a few hours of sleep a night, but on Mt. Wilson he often gave up sleep altogether. Adams later recalled:

> Barnard's hours of work would have horrified any medical man. Sleep he considered a sheer waste of time, and for long intervals would forget it altogether. After observing until midnight, he would drink a large quantity of coffee, work the remainder of the night, develop his photographs, and then join the solar observers at breakfast. The morning he would spend in washing his plates, which was done by successive changes of water, since running

[10] E.E. Barnard, unpublished manuscript; Yerkes Observatory Archives.

[11] Ibid.

> water was not yet available. On rare occasions he would take a nap in the afternoon, but usually he would spend the time around his telescope. He liked to sing, although far from gifted in the art, but reserved his singing for times when he was feeling particularly cheerful. Accordingly, when we at the Monastery heard various doleful sounds coming down the slope from the direction of the Bruce telescope, we knew that everything was going well and that the seeing was good.[12]

From Yerkes, Frost, on hearing from Barnard of the excellent conditions he was enjoying, wrote, "It is a pleasure to know that you are having such fine weather for work, but I hope you will not overdo, and you will give up some clear nights when you need sleep."[13] Barnard could always be counted upon to ignore such advice. He knew, moreover, that he might never again have such a grand opportunity to explore the star clouds, diffuse nebulae and strange dark regions which he had first recorded with the Willard lens and regarded as vacant spaces but would eventually conclude, after years of study, were clouds of obscuring matter (and, as we know now, interstellar dust). Doubtless Barnard would have loved to stay on Mt. Wilson with Hale, Adams, Ellerman and Ritchey, and escape the unhealthy winters of southern Wisconsin. But as Barnard was the Yerkes Observatory's most celebrated astronomer, Frost would never have agreed to give him up. Moreover, except in photography where he broke new ground, he was a skilled practitioner of the classical methods of astronomy (much of his work at the Yerkes 40-inch involved wielding a micrometer to make precise measures of double stars and the stars of globular clusters in which he hoped to detect proper motions) rather than a pioneer of the astrophysics of the Sun and stars on which Hale had staked the future of the new observatory. So in mid-September 1905, after a stay of eight months, Barnard packed the lenses of the Bruce telescope and his precious plates in the saddlebags of his mule and, escorted down the mountain early one morning by Adams, retraced the journey by train in reverse order to the one that had brought him here.

Publishing the best of these photographs—and analyzing the markings shown on them—henceforth became one of the great goals of Barnard's life, spread over much of the last two decades of it. The funding for what was to be tentatively called *An Atlas of the Milky Way* was provided by a grant of the Carnegie institution of Washington, D.C. in 1907. When he began, Barnard clearly intended to include a large part of the Milky Way accessible from Mount Wilson—hence the title. However, as time passed, the scope of the project was scaled back; the final selection of areas to be

[12] Ibid., pp. 97–98.

[13] E.B. Frost to E.E. Barnard, July 27, 1905; Vanderbilt University Archives.

included was made much later, and it proved that inclusion of only a third or a quarter of the plates needed to compass the original project could be accommodated. Thus, instead of an atlas of the Milky Way, Barnard endeavored to include only the most interesting or representative sections—and the title was modified, by Frost after Barnard's death, to the more precise *A Photographic Atlas of Selected Regions of the Milky Way*. However, even thus scaled back, the work proved to be daunting. Barnard toiled at it in desultory fashion for 16 years until his death—and even then it was still unfinished.

This was perhaps an inevitable result for someone pursuing as many lines of work as Barnard did while at the same time attempting to uphold almost unachievable standards of perfection. And no sooner did he begin planning the *Atlas* than he began to run into difficulties. The first and most serious was trying to honor a binding commitment to previous work. In 1895, he had agreed (quite enthusiastically) to produce a collection of Milky Way and Comet photographs taken with the Willard lens at Lick. These were pioneering work, highly significant and in the case of comets, at least, full of time-dependent phenomena such as tail-detachment events which represented the only record of them available. Barnard knew their importance, and so did his colleagues and supporters, who raised a substantial sum in subscriptions and grants in order to reproduce them, in his words, in a first class manner. But at that moment Barnard was "fallen on evil days." Barnard and much of the rest of the staff had been engaged for some time in what can only be described as internecine warfare with the Director Edward S. Holden. From this distance, it is apparent that the strife owed at least as much to Barnard's rather neurotic personality—seeded in the insecurity and hardship of his early life of deprivation—as to Holden's rather stiff and autocratic West Point manner. In any case, at almost the very moment that Barnard promised to put the Milky Way and Comet photographs in order, he departed Lick for Yerkes, and needless to say was soon absorbed in the researches favored at the new institution. The Milky Way and Comet photographs were cast aside for several years—possibly Barnard himself had managed to put them out of mind. But they represented an obligation he could not evade. Finally, in 1902, with Barnard just returned from a long (and unsuccessful) eclipse expedition to Sumatra, a new Lick Director, W.W. Campbell, reminded him of the project and offered to provide whatever support he could (including financial) toward its completion. The project briefly (if feebly) was stirred again, but once more faltered. The main problem was Barnard's perfectionism. He was simply unable to satisfy himself with the quality and uniformity of any of the methods of reproduction available. Collotype, photogravure, halftone all were tried. All failed.

There was another hiatus until 1907, when Campbell began to press again. Barnard committed to finish by the end of the year, or else "every cent of the money, dollar for dollar … will be returned to California, and I shall once more be free from worry in that direction." He added, "To me the whole thing has been a most bitter disappointment. It has caused many an illness from worry on it."[14]

The worry continued, and was only compounded with the Carnegie grant for publication of the Bruce photographs. Clearly the commitment to the old project had now become a millstone around his neck. At Christmas 1907, fighting off bronchitis in order to finish a remarkable series of observations with the 40-inch of the edgewise rings of Saturn, he confided to his old Lick colleague John M. Schaeberle his near-despair over the Milky Way and Comet Photographs. "It has been a heart rending affair, and I have finally given it up," he wrote. "The pictures already made are many of them full of errors and I don't propose to do anything with them. Life is short and uncertain, and I can't stand the strain any longer… I would rather die than to have a faulty work go out. I have therefore decided to give up any more efforts, and to put the money out of my hands, as I do not want to die with anything in my possession that does not belong to me."[15]

Barnard was as good as his word. He wrote a check to Lick Observatory for the entire amount he had collected in 1895, together with the printed sheets of the Milky Way reproductions he had already finished in his abortive attempts to produce something satisfactory, and explained to Campbell from the sickbed to which the Saturn observations had reduced him:

> My sole desire in the matter has been to put in the hands of astronomers a trustworthy set of reproductions of these Milky Way and comet photographs. I have no desire to get out a volume simply for the sake of the volume. Recognizing at last the hopelessness of bringing out these pictures to my satisfaction, and feeling of late the uncertainty of life, I have finally decided, while it is within my power (but not without much pain and disappointment) to close up the matter and to abandon the work to its fate.[16]

Campbell, however, refused to let the matter drop, and with extraordinary patience and tact eventually managed to see it through. In the end, Barnard was (briefly) able to satisfy himself with the quality of reproductions by the (previously rejected) Chicago Photogravure Company, and finally, ending a struggle of almost two decades, the *Milky Way and Comet Photographs* appeared in an edition of 1000 copies. It appeared as volume 11 of the *Publications of the Lick Observatory* (University of California Press, 1913)

[14] Sheehan, *The Immortal Fire Within*, p. 352.

[15] Ibid.

[16] Ibid., p. 353.

(Though the publication date is given as 1913, Barnard did not actually finish the Introduction until December 16, 1913, and the actual printed copies did not appear until the following September.)

The long and often bitter struggle was over, with Campbell, who had had to exercise extraordinary patience and restraint in nurturing it along, having previously accounted for the unprecedented delays to the Comptroller of the University of California:

> Astronomical subjects are extremely difficult to reproduce satisfactorily, and Barnard's temperament is such that discouragements led him to put the subject entirely aside for two or three years at a time. Shortly after I became Director [in 1901] I insisted that he go on with the work, partly because the photographs were the first great successes in their lines, and partly to show our good faith with private contributors. Barnard's entire freedom from business ability has made the administrative questions difficult, but the scientific merits of the subject have been sufficient to preserve my patience.[17]

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At last Barnard could begin to turn his attention to the *Atlas*, though it had to compete for his attention with work still in hand—of which the most significant strain was the work on the dark markings of the Milky Way. In 1907, he had still clung to the idea that they were vacancies. However, "one beautiful transparent moonless night" in the summer of 1913, he was photographing the southern Milky Way with the Bruce telescope (now at Yerkes) when he experienced an epiphany as to their nature:

> I was star struck with the presence of a group of tiny cumulous clouds scattered over the rich star-clouds of Sagittarius. They were remarkable for their smallness and definite outlines—some not being larger than the moon [i.e., half a degree across]. Against the bright background they appeared as conspicuous and black as drops of ink. They were in every way like the black spots shown on photographs of the Milky Way, some of which I was at that moment photographing. The phenomenon was impressive and full of suggestion. One could not resist the impression that many of the small spots in the Milky Way are due to a cause similar to that of the small black clouds mentioned above—that is, to more or less opaque masses between us and the Milky Way. I have never seen this peculiarity so strongly marked from clouds at night, because the clouds have always been too large to produce the effect.[18]

Those might not have been the good old days in many respects. However, in one respect they were enviable: there were no city lights in Williams Bay,

[17] Ibid., p. 354.

[18] E.E. Barnard, "Some of the Dark Markings on the Sky and What They Suggest," *Astrophysical Journal*, 43 (1916), 1–8:4.

and the Chicago light dome that has made sensitive observations at the site impossible did not yet exist. Under these conditions, the clouds appeared perfectly black and darker than the star- and Milky Way-lit sky. (Nowadays, they would of course appear brighter, due to reflection of artificial lights, and the effect that made such a strong impression on Barnard would have been lost.)

Around this time Barnard began somewhat haphazardly to jot down in his atrociously bad handwriting various scattered notes and comments which later served as the basis of what became the Introduction to the *Atlas*. Meanwhile, Frost—who though not the demon researcher that Hale had been and that, later, Otto Struve would be—was a genuinely humane and understanding person, had been thinking about how to spare Barnard the frustration he had experienced with the *Milky Way and Comet Photographs*. He persuaded Barnard that direct photographic prints would most faithfully reproduce the details of the original negatives. And so Barnard selected fifty of his best negatives, and then painstakingly made a second negative from each from which the prints could be made by a commercial photography firm (Copelin & Son in Chicago). During 1915, 1916, and 1917, Barnard traveled often to Chicago to inspect the prints—35,700 in all, making up a limited edition of 700 copies. The descriptions were written after Barnard had made a careful study of the prints and negatives, but progress was uneven—mainly, as Frost noted, "of Professor Barnard's well-known eagerness to observe the heavens whenever the sky was clear," which "left him little time for the remainder of the preparation of the work for publication."[19]

In addition, Barnard suffered a serious crisis of health. In February 1914, he noticed that he was tiring more easily, thirsty much of the time, and passing copious amounts of urine (which made life extremely difficult for someone who was often required to guide a telescope while exposing a photographic plate for several hours without a break). He tried to push through, but on March 8, 1914, took to his bed; when, three nights later, he observed the nearly total eclipse of the Moon, it was from his bedroom window. The physicians were called in, and at once diagnosed diabetes mellitus. The diagnosis was easy, but in those days before insulin, the treatment was obscure, and outlook for the diabetic patient bleak. Barnard's physicians agreed with the prescription by Sir William Osler in his influential textbook of medicine. "Sources of worry should be avoided," Osler had directed, "and the patient should lead an even, quiet life, if possible in an equable climate." On medical advice, Barnard's doctors ordered him to

[19] E.B. Frost, Introduction to E.E. Barnard, *A Photographic Atlas of Selected Regions of the Milky Way*, E.B. Frost and M.R. Calvert, eds. (Washington, D.C.: Carnegie Institution, 1927), p. xi.

forego observations with the 40-inch telescope, and, as Frost noted, bore his banishment from the great telescope "manfully." However, he added, 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 spent from December 1914 to March 1915 in California, and on his return had recovered his health to the point where he was once more able to resume work at the great telescope—though for the rest of his life he would continue in the grips of a desperate struggle with the vitality-sapping, wasting disease.

Despite his struggles, those years were productive ones, with the *Atlas* was only occasionally his principal concern since as Frost noted, "the reduction and publication of current observations had, with him, the right of way."[20] Clearing the vast backlog of work, and the publication of the Milky Way plates, simply had to wait.

In May 1916, he discovered the star informally referred to by the Yerkes staff as "Gilpin" (after a character whose horse runs away with him in a poem by William Cowper) and now known as "Barnard's Star"—a red dwarf star that was then (and is still) that with the greatest proper motion of any known and, because of its relative proximity to us (6.0 light years away), a regular staple of science fiction stories ever since. (It provides a way station for interstellar travelers in Douglas Adams' *Hitchhiker's Guide to the Galaxy* series and Arthur C. Clarke's *The Garden of Rama*, and is a setting of Kim Stanley Robinson's *Icehenge*, among others.)

During a brief rebound of his health in the fall of 1917, Barnard traveled with Frost to scout three potential observing sites along the path of totality of the forthcoming eclipse of June 8, 1918, and observed from the site chosen as the most promising—Green River, Wyoming—for the eclipse. A poignant moment came the night after the eclipse, when Barnard savored the childlike joy of standing in awe beneath the sky upon independently discovering Nova Aquilae, the brightest nova of the twentieth century. On attaining to its maximum brightness two days later, Barnard caught it on its rising above Castle Rock, and described it as "very white and very much brighter than Vega. It twinkles very much—low altitude. It must be as bright as Sirius."

His most important work concerned the dark markings of the Milky Way, and his still-evolving ideas about them were carefully documented in a series of crucial papers published in the *Astrophysical Journal* in 1913, 1915, 1916, and 1919—the last including his famous catalog of 182 dark objects.

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[20] Ibid.

Another highlight of these twilit years was the visit to Yerkes on May 6, 1921, of the Berlin professor Albert Einstein. In a group photograph taken in the Yerkes dome, Barnard appears a few places to Einstein's right; a gaunt and unsmiling figure with sunken eyes and hollow cheeks, a grizzled mariner steering off a coast of stormy seas. Just ten days later tragedy struck: Rhoda, long in poor health, suffered a stroke. Five days later she was dead. They had married forty years earlier, during Barnard's years of struggle as a young man employed at the Photograph Gallery in Nashville and searching (successfully) for comets with a small telescope at night. Now, he wrote to astronomer Frederick Slocum of the Van Vleck Observatory, "I am sad beyond measure. She loved me and cared for me more than I knew or could appreciate, but it all comes back to me now and I am heartbroken." To W.H. Wright at Lick he wrote, "I have felt so unhappy and broken in spirit, that it seemed impossible to write… I am thinking of Mrs. Barnard all the time."[21] Even the dream of growing oranges in California had to be given up; it was simply unthinkable without Rhoda.

After Rhoda's death, Barnard soldiered on, only too keenly aware that his own days were numbered. Finally, toward the end of 1922, he finished the first draft of the descriptions of the photographs for the *Atlas*. He hoped soon to turn to the rest, but he was now running out of time. On December 16, 1922—his sixty-fifth birthday—he traveled to Chicago for a meeting of a local astronomical club. The next night he tried to examine Nova Persei of 1901 with the 40-inch, but was unable to get any kind of image; the object glass was completely coated with frost. The next night he was assigned to the instrument was December 23; the sky was overcast. On Christmas morning he was at Frost's house with the rest of the staff for about an hour, but excused himself early, due to distress from an acute inflammation of the bladder. The next day Frost drove to Milwaukee to consult his oculist. By the time he returned he found that Barnard was laid up in bed. A physician, Dr. McDonald, was called out, and succeeded in relieving Barnard's distress by means of a catheter, but recognized that the real problem was an enlargement of the prostate, for which the remedy was surgery. In Barnard's case, because of the diabetes, this was ruled out. Nevertheless, the catheter had cleared up the bladder inflammation within a week, and Barnard improved to the point where he was, Frost noted, "getting sleep and rest and [dressing up] to go down to breakfast, and [doing quite a little writing for his Atlas]."[22]

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[21] Sheehan, *The Immortal Fire Within*, p. 413.

22 Ibid., p. 415.

Barnard never again returned to the great telescope. His last astronomical observation, of an occultation of Venus by the Moon, was made through his bedroom window on the morning of January 13, 1923. He and Mary Calvert worked a few hours every afternoon on the Atlas, and he tried to keep up his correspondence. On the day after the occultation, he wrote to the Lick Observatory Director W.W. Campbell, "I am sick in bed… My greatest unhappiness [is] that I can do no observing at all." A week later he told Wright, "I am sitting up this morning… My strength is returning but my main trouble is unchanged…. In the meantime I am subject to the catheter with the forlorn hope that things will come all right again… It is distressing to be away from my observations."[23]

At the beginning of February, a Chicago specialist in metabolic diseases, Dr. Rollin Turner Woodyatt, was called out to Williams Bay, and after examining Barnard expressed the hope that he could be taken to Presbyterian Hospital in Chicago, placed on a strict diet and given the new treatment for diabetes—insulin. In this way, he hoped, it might be possible to bring things to the point where an operation could by attempted. But it was too late. Barnard was by then suffering from other complications, including congestive heart failure. The end was near. He told Mary Calvert that "he didn't mind dying, but was sorry not to finish his work."[24] Almost to the very end, the *Atlas* nagged at him.

After about noon on Monday, February 5, his consciousness began to cloud up, and he was no longer coherent. He was attended through the night by Calvert, Oliver J. Lee of the Yerkes staff and Lee's wife. Drs. Woodyatt and McDonald were also at his bedside, and the following day Barnard received the new insulin treatment—but it was too late. His vital functions were now rapidly failing, and at 4 p.m. the doctors decided that nothing more could be done and gave him a hypodermic injection of morphine. His pulse ceased at 8 p.m. Frost, recording the time, added: "*ad astra*"—to the stars.

To which he might well have added—as the light of Barnard's life went out—to the dark nebulae.

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23 Ibid., p. 416.

24 Ibid.

But enough from me. Now, dear reader, it is time to turn the page and commence reading—and studying—and enjoying this remarkable book, in which "the immortal fire" of Barnard's spirit truly lives again.

Flagstaff, AZ, USA
January 11, 2023

William Sheehan

Preface

The Barnard Objects have fascinated professional and amateur astronomers for over 100 years. Edward Emerson Barnard (more commonly known as EE Barnard) was a leading pioneer in the development of astrophotography. He recognized that guided long exposures (up to 15 + hours) produced revolutionary astronomical photographs and data not otherwise attainable. While Barnard was one of the most experienced, hard-working, and productive visual observers in history, his seminal work with photography contributed to the eventual demise of visual professional astronomy.

Barnard was particularly fascinated by regions of nebulosity both bright and dark (areas where there was absence or diminution of the number of stars). Nebulae are common throughout the Milky Way. Barnard was not the first person to recognize dark nebulae or even to photograph them, but he along with his friend and colleague Max Wolf (1863-1932) of Heidelberg University were among the first to understand dark areas were not holes in the Milky Way but were areas where material obscured background stars. Barnard's extensive photography of the Milky Way coupled with his intense study of dark nebulae finally convinced him they were not holes in the sky as believed by William Herschel but areas of obscuring material.

Barnard noted that long exposures revealed some stars in dark regions, and the longer the exposure the more stars were revealed. He also felt small dark nebular bodies which look like tiny black ink dots were silhouetted against brighter background starry regions like the visual effect of small earth clouds being silhouetted against the bright Milky Way observed from an exceptionally dark sky site. He observed that some dark nebular areas

had sharp margins along a part of their periphery while other portions imperceptibly blended with the starry background. This suggested some type of obscuring material in front of and partially or totally obscured bright background material.

Barnard and Wolf finally concluded dark nebulae are obscuring clouds of gas and dust, though uncertain as to the exact composition of such clouds. Today, our understanding of both bright and dark nebulae is considerably advanced over that of a century ago during Barnard's time. We remain quite far from fully characterizing these complex regions which consist of varying mixtures of molecular gas (mainly hydrogen), ionized gas (mainly hydrogen), dust (simple carbon and silicate compounds), ices (frozen water and gases), and complex organic compounds.

Nebulae of all types are fascinating objects. They range in size from mere arc seconds to many degrees. Some are bright from the effects of light from nearby luminous stars reflected off dust, gas, and ice particles. Others are regions of energized gas emitting radiation in portions of the electromagnetic spectrum, and others are dark from the obscuring effects of gas and dust. Many have a mixture of bright and dark regions. Most of the bright nebulae are gorgeous visual objects and many more of them also are photographic gems either in black and white or in color.

Barnard observed and photographed objects throughout the sky visible from the northern hemisphere. In the later part of his career, his attention was most focused on examining the Milky Way. He produced a personal list of selected dark nebulae now known as Barnard Objects which were collected and codified in a 1927 posthumous publication *A Photographic Atlas of Selected Regions of the Milky Way* edited by Edwin B Frost, Director of Yerkes Observatory, and Mary R Calvert, Barnard's niece and assistant. This publication was based on Barnard's work and followed upon his initial list of 182 dark nebulae published in 1919 (*Astrophysical Journal*, January 1919; 49:1-23). Earlier he had published "Photographs of the Milky Way and Comets," Volume 11 of the *Publications of the Lick Observatory* (1913). This was based on his photography of the Milky Way from 1892 to 1895 using Lick Observatory's Crocker Astrograph.

Barnard's images were obtained with black and white photographic plates. Successful professional color astrophotography did not take place until 1959 when Super Anscochrome film was introduced. The first amateur color astrophotographs were published in *Sky & Telescope* in 1963 and 1964. Nowadays, film is no longer used for most everyday photography and rarely used for astronomical imaging. In astronomy film has been replaced by digital imaging with CCD and CMOS chips. Amateur astronomers produce thousands of stunning color astrophotographs daily, many of which are the same objects Barnard first imaged more than 100 years ago.

The classic Barnard Objects numbering 1-370 are favorite objects for amateurs to optically observe as well as photograph. In 2014, I started a project to image all the Barnard Objects in color using a variety of instruments at the Grasslands Observatory (http://www.3towers.com) in Southeastern Arizona. This project continues with most of the objects having been imaged, mainly with wide-field techniques but some with more detailed imaging due to their unique features or small size. The goals for this project were to present all the Barnard Objects on the Grasslands Observatory website and to write a book illustrating all the objects.

The more I contemplated the book project and researched Barnard and his legacy, I realized a picture book with hundreds of images was not practical or particularly useful. After much thought, the present book has evolved with the important work from co-authors Jerry Dobek and James McGaha. Chapter 1 is a general introduction to Barnard and his work. Chapter 2 defines nebulae and looks at them from multiple points of view. That dovetails into Chapter 3 which lists and discusses many of the most important astronomical catalogs in common use. Chapter 4 is an in-depth discussion of EE Barnard's work with dark nebulae.

Visual observations of the larger and brighter Barnard Objects are discussed in Chapter 5 which leads to Chapter 6 that gives a detailed discussion of our color imaging techniques for the Barnard Objects. In Chapter 7, selected plates from *A Photographic Atlas of Selected Regions of the Milky Way* are presented with selected modern color images of the objects Barnard noted on those plates. Jerry Dobek has extensive experience with Barnard's work and photography which was demonstrated by Jerry's 2011 republication of the *Photographic Atlas* (Cambridge University Press, Cambridge, UK). The original 1927 *Atlas* did not contain Barnard Objects having numbers from 176 to 200. Barnard had preliminarily marked nebular locations for such "missing" objects which Jerry has "found" and listed in Chapter 8 along with our color images of these missing objects.

Chapter 9 provides an overview of the Barnard Objects as they are found today. We have also provided a glossary of common terms, a general bibliography for Barnard Objects and nebulae as well as a current table of all the Barnard Objects.

I hope you find the book interesting and informative if not scholarly. If it fails in this regard, the blame is mine. No matter what, I hope you appreciate EE Barnard for the astronomical giant he was, and I hope you realize how much fun I had collating all this material. Please give credit for the highlights of the book to my co-authors and reserve its shortcomings to me.

Tucson, AZ, USA Tim B. Hunter

Acknowledgements

The authors were helped with this project by too many persons to name individually if we were to be fair to everyone. We can mention a few persons who have gone way beyond the ordinary to assist us, hoping we have not forgotten someone important.

Dean Salman was invaluable in setting up the Grasslands Observatory for remote operation. His friendship and expertise are much appreciated. Dr. Peter Mack of Astronomical Consultants & Equipment, Inc. has provided us many years of support for our operation often driving to the observatory in the middle of the night to assist with a repair at no small inconvenience to himself. That is greatly appreciated.

Frank Lopez of Stellar Vision and Dean Koenig of Starizona have provided us with endless advice on equipment and building setup. Frank has also made some middle of the night trips to help us in need. Dr. Richard Buchroeder helped us with optical questions and supplied the proper references for the lenses used in Barnard's time.

A book is only successful if behind the scenes there are skilled copy editors and indexers who actually put a book together. These persons usually remain unidentified but are much needed and valued.

Tim B. Hunter
James E. McGaha

In addition to those previously mentioned, Gerald Dobek wishes to thank Dr. Tim Hunter. Tim has been a very good friend for many years, and he is the one who took the initiative and lead on this book. I would also like to thank my mother, Winifred May Dobek (Née Johnson), who was my inspiration and drive to becoming an astrophysicist. And lastly, to my Kim.

Gerald O. Dobek

Contents

About the Authors

Tim B. Hunter obtained a BA from DePauw University in 1966, an MD from Northwestern University in 1968, a BS from the University of Arizona in 1980, and an MSc degree from Swinburne University (Melbourne) in 2006. Currently, Dr. Hunter is Professor Emeritus in the Department of Medical Imaging in the College of Medicine at the University of Arizona and was Head of the department from 2008 to 2011. He was on the Arizona Medical Board (AMB) from 1997 to 2006.

Dr. Hunter has been an amateur astronomer since 1950, and he is the owner of two observatories, the 3towers Observatory and the Grasslands Observatory (http://www.3towers.com). He is also a prime example of someone whose hobby has run amok, spending more time and money on it than common sense would dictate. He has been the President of the Tucson Amateur Astronomy Association, Inc. (TAAA) and a member of the TAAA since 1975. He is a past Chair of the Board of Trustees of the Planetary Science Institute (PSI). Since 1986, Dr. Hunter has been interested in the growing problem of light pollution. In 1987, he and Dr. David Crawford founded the International Dark-Sky Association, Inc. (IDA). IDA is a nonprofit corporation devoted to promoting quality outdoor lighting and combatting the effects of light pollution. Since 2007, Dr. Hunter has written a weekly "Sky Spy" column for the *Caliente* Section of the *Arizona Daily Star*.

Gerald O. Dobek obtained two BS degrees in Mathematics from Trinity College and Ferris State University, an MSc Honours in Astronomy from the University of Western Sydney, and a DSc in Astronmy/Astrophysics from James Cook University. Jerry is currently the Head of Sciences and Department Head of Astronomy at Northwestern Michigan College, Traverse City, Michigan, where he teaches Astronomy. As a professional astronomer, he researches small amplitude variable stars using his private observatory at his home in Traverse City, Michigan. Jerry also continues to research dark nebulous material in the Milky Way. In 2011, he republished Edward Emerson Barnard's A Photographic Atlas of Selected Regions of the Milky Way (Cambridge University Press) adding update information and a mosaic of the fifty plates contained within the Atlas. Jerry holds membership in numerous astronomy and science organisations: Royal Astronomical Society (RAS), American Astronomical Society (AAS), American Association for the Advancement of Science (AAAS), the American Association of Variable Star Observers (AAVSO), The Astronomical Society of the Pacific (ASP), and is a founding member of the IDA. Along with being an advid observational astronomer, Jerry also enjoys writiing and playing music on his twelve and six string guitars.

James E. McGaha obtained a BS in Management and Physics from Georgia Tech University, an MA in Management and Psychology from Webster University, and a MS in Astronomy and Astrophysics from the University of Arizona. He is currently a retired Air Force pilot and is a skeptic lecturer. He is the Director of the Grasslands Observatory (www.3towers.com) and specializes in asteroid and comet astrometry and photometry. He has made over 2900 Minor Planet Electronic Circulars (MPEC) publications and discovered 63 comets. He is a contributing author for *Skeptical Inquirer* magazine. He is a Fellow of the Royal Astronomical Society (FRAS).