Pioneering Astronomy at Lick Observatory

In 1888 the world's largest telescope and a band of dedicated observers stood on an isolated California mountaintop ready to push back the frontiers of astronomy.

by John R. Gustafson

The bleary-eyed astronomer put away his dinner dishes, doused the fire, and prepared for the night's work. Sherburne Wesley Burnham, tired from camping in the wilderness fifty miles from San Francisco, was nearly ready to leave the isolated mountain peak where he had spent the last sixty days. As he looked down from the lofty summit, any signs of civilization in the valley below were lost beneath a summer fog that spilled through the Golden Gate and spread across the San Francisco Bay.

It was midsummer 1879, and Burnham had been sent to assess the qualities of the sky from Mount Hamilton, soon to be the home of the world's first mountaintop observatory. The observatory, founded by James Lick, a wealthy and eccentric San Franciscan, would open in the summer of 1888 with the world's largest telescope — a 36-inch refractor. The world's best telescopes at the time were located in Washington, Cambridge, Paris, and...
Top left: The world’s first mountaintop observatory, Lick Observatory would have been an unusual sight for travelers in nineteenth-century California.

Above: The observatory’s large dome, here an unfinished superstructure, housed the world’s largest telescope when completed in 1888.

Left: Winters could be harsh on Mount Hamilton, as this photograph of the astronomers’ quarters shows.

Bottom: Lick’s three-foot-diameter objective lens was the heart of the observatory’s main instrument. Lick trustee Richard S. Floyd poses beside the lens.

Opposite page: On December 27, 1886, the 36-inch lens arrived on a horse-drawn stagecoach.

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Greenwich, and the largest was 26 inches. Lick’s extraordinary telescope and the clear, steady skies of Mount Hamilton would put Lick Observatory at the forefront of astronomy.

Three men — Sherburne Burnham, Edward E. Barnard, and James E. Keeler — used Lick’s resources to do trailblazing research during the observatory’s early years. These astronomers would discover a new moon of Jupiter, study the nature of the planets better than ever before, classify thousands of stars, and probe the chemical properties of mysterious gaseous clouds in the sky.

The story of Lick Observatory begins with the California gold rush. James Lick arrived in San Francisco on the eve of the gold rush and through shrewd real estate ventures amassed a fortune during California’s population boom before the Civil War. By 1873, when Lick suffered a stroke, he was worth over $3 million.

Without a family to leave his fortune to, Lick began to consider seriously how he would dispose of his wealth. Contacts Lick had made with several prominent scientists, including Joseph Henry, the secretary of the Smithsonian Institution, and Louis Agassiz, the famous Swiss-born naturalist, convinced Lick that he should build a lasting
scientific institution as a monument to his name.

Lick established a trust that provided for many projects. The largest chunk of money, $700,000, would go toward the construction of an observatory. Lick specified that the observatory would hold a telescope “superior to and more powerful” than any other. Lick’s scientific advisors convinced him to build his observatory on a mountaintop, not in downtown San Francisco, as he had originally wanted. This was an unprecedented idea. Few astronomers then understood the advantages of mountaintop observing. For the sake of convenience, big telescopes had always been erected near a university or town in the lowlands.

In 1876, shortly after selecting Mount Hamilton as the observatory site, Lick died. He never saw his dream fulfilled. The work of building the observatory fell to Richard S. Floyd and Thomas Fraser, and the task facing the two men was immense. “The possibility that a complete astronomical establishment might one day be planted on [Mount Hamilton] seemed more like a fairy tale than a fact,” wrote Floyd. “It was at that time a wilderness. A few cattle ranches occupied the valleys around it. Its slopes were covered with chaparral or thickets or scrub oak. Not even a trail led over it.”

**Building a Road to the Summit**

In February 1876 Floyd and Fraser watched as a work crew built “Lick Avenue,” a twenty-six-mile road to the mountain’s summit. Six hundred men raced to finish the road before the next winter — blasting, grading, and spreading gravel. By December the road was finished.

But the road up the mountain brought an unexpected problem: squatters. In a letter to Floyd, Fraser described his effort to reclaim the observatory site in what he called the “Battle for Mount Hamilton.”

“I took possession of Mount Hamilton . . . and built a house on the summit 8 x 12 with door and lock all complete. I had a very hard time getting the lumber up as the men had to carry it in a great many places. I have got 3 men in the house to defend it. There was a cabin built on the top [by the squatters] but I tore it down and set fire to it. I will have to keep three men till those that was squatters gives the thing up for a bad job. The squatters are over on the other side of the mountain and they might try to come back but they will soon leave I think as they will get starved out.”

The next task was a thorough investigation of Mount Hamilton’s sky conditions. Everyone suspected the sky would be clearer and darker on Mount Hamilton than in the lowlands, but the astronomers wanted to know how much better. To find out, Floyd hired Burnham, who was working in Chicago as a court reporter. Burnham, who had served with the Union Army as a shorthand reporter, had also developed a skill for which he gained international recognition. His keen eye and tireless energy, coupled with a 6-inch refractor purchased from the Alvan Clark firm, made him one of the best double star observers in the world.

In 1879 Burnham camped on Mount Hamilton for two months and tested the sky conditions with his 6-inch refractor. Burnham observed hundreds of double stars during his stay and discovered forty-two double stars. “If the proof is in the eating, these discoveries ought to be eloquent on the subject of Mount Hamilton for the site of an Observatory,” Burnham wrote to Floyd.

Satisfied with the unique conditions on Mount Hamilton, Floyd and Fraser’s next task was to blow the top off the mountain so they could create a flat platform to hold the main observatory building, domes for the 12-inch and 36-inch telescopes, and several small buildings to serve as housing for a transit telescope, the observatory staff, and storage facilities. With a ton of black powder, Fraser and his work crew blasted free the topmost 70,000 tons of mountain and removed the rubble by hand. Then they raised a small building for a 4-inch transit telescope and began laying the foundation for a dome to house a 12-inch refractor.

**Lenses Travel Cross-Country**

The 12-inch telescope was made by the Alvan Clark company, the premier telescope-making firm in America. The Clark firm would also painstakingly craft the objective lens for the 36-inch telescope in a process that lasted several years. By the autumn of 1886 the Clarks had completed the 36-inch lens in their Massachusetts workshop. Even though wintertime travel was risky, Fraser left on a journey to bring back the lens. Fraser and the Clarks packed the lens elements with meticulous care in steel boxes containing wooden boxes stuffed with curled hair to protect the valuable glass throughout the bumpy train ride.

Fraser and the lens traveled on a private car that was given special priority by the railroads. Other trains moved onto side tracks until the Lick Observatory car passed. After arriving in San Jose, Fraser hauled the lens by wagon to Mount Hamilton, and then Fraser and Floyd installed the lens in the metal cell that would attach to the telescope. They were assisted by a young, inventive astronomer named James E. Keeler.

Keeler had been hired by the Lick Trust specifically to provide scientific expertise as the observatory neared completion. The only university-trained scientist among the staff astronomers, Keeler was also a mechanical whiz. While in his teens, Keeler ordered a pair of lenses from an advertisement in *Scientific American* and with these
— water had worked into the track and frozen solid — but with the shutter open the astronomers could see stars. They tried to observe the bright star Aldebaran, but they couldn’t focus the telescope. The eyepiece drawtube was too long, which prevented an image from focusing on the eyepiece. After the astronomers cut off a piece of the drawtube, they focused on Aldebaran. Floyd called it “a blazing red sun.”

Snow fell for several days, but the sky finally cleared on January 7. The dome was still frozen in one position. “We are all waiting in this office for Saturn to come by our shutter, which should be in about 2 hours,” Floyd wrote in his logbook. When Saturn drifted into view, everyone wanted a look. Keeler described Saturn’s image in the world’s largest telescope as “the greatest telescope spectacle ever beheld by man. The giant planet, with its wonderful rings, its belt, its satellites, shone with a splendor never before equalled.”

On June 1, 1888, Lick Observatory was turned over to the University of California to officially begin operations. Burnham joined the staff of Lick Observatory that year. His presence brought immediate prestige to the organization, just as the observatory’s 36-inch refractor and unprecedented location brought instant fame to the mountain.

Also joining the staff was Edward Emerson Barnard. Barnard was so eager to work at Lick that he left his position at Vanderbilt University a year before the observatory opened. As a result, Barnard and his wife spent a year in San Francisco waiting for his position to start.

Barnard brought with him experience in a technique new to astronomy: photography. Barnard was a self-taught astronomer driven by a love of telescopes and of observing the sky. As a boy Barnard was forced to drop out of school to help support his family, but he found work in a photographic studio and rapidly learned the techniques of photography, which he later used in pioneering photography of the Milky Way Galaxy.

As soon as he could, Barnard bought a telescope for $380, two thirds of his annual salary. In 1881 he discovered a comet, the first of twenty he found in his career. Barnard’s observing abilities also won him a fellowship at Vanderbilt University. Using Vanderbilt’s 6-inch refractor, Barnard demonstrated his keen eyesight one night as he watched the Moon occult the star Beta Capricorni. Because the Moon has no atmosphere, he reckoned, the star should “blink off” instantaneously as it passed behind the Moon’s limb. But Barnard thought it took seven tenths of a second to flicker out. He had discovered that Beta Capricorni is a double star, the seven tenths-second delay was caused by the companion star’s occultation. The discovery was confirmed by Burnham, who was then at Dearborn Observatory in Chicago.

**Life on the Mountain**

This collection of astronomers from the East didn’t have an easy time during the early years at Lick. Living conditions on Mount Hamilton were primitive and cramped, and there was little to do for recreation. At fifty years of age, Burnham was an informal, folksy man with a reputation for his keen eye and clear mind. He came to Mount Hamilton with his wife and children, who received inadequate housing and no schooling. Keeler, very different from Burnham, was a serious thirty-one-year-old bachelor with an impressive education. Barnard, also thirty-one, was hard-driving and highly neurotic.

Lick Observatory’s initial research program, as out-

Above: Sherburne Wesley Burnham, a fifty-year old double star observer and court reporter from Chicago, was one of the original Lick staff astronomers. This engraving of Burnham was published in 1889.

Opposite page: Burnham used the 36-inch refractor to discover and catalog hundreds of double stars, a popular area of research at the time.
lined by its first director Edward S. Holden, included four major areas. Double star research, Burnham’s specialty, was of long-standing interest in the nineteenth century. Discovering and cataloging pairs so future astronomers could study the orbits of these pairs were prerequisites for an observatory at the time. Astrometry — measuring star positions — was valuable for studying the overall distribution of stars across the sky. Holden also wanted to make an accurate photographic atlas of the Moon.

But the innovative technological research lay in the fields of spectroscopy and photography. Spectroscopy allows astronomers to study the component colors in a star’s light and determine certain properties about the star. Although Isaac Newton had discovered that a prism disperses light into a rainbow of colors in the 1700s, work on classifying stars by spectra was crude throughout most of the 1800s.

Photography was invented in the 1830s, but the emulsions that were used remained far too insensitive for astronomy until the 1880s. Several astronomers had made long-exposure photographs of the Sun and Moon, but even most of the brightest stars were out of the range of this technique. Observations had to be written or sketched in notebooks. However, more sensitive emulsions made photography a certain tool for the future of astronomy in the 1880s. Barnard had extensive photographic experience and would undertake influential experiments with photography.

Probing the Stars

Spectroscopy was pioneered at Lick Observatory, and Holden had recruited Keeler primarily for his expertise in this field. With the world’s largest telescope and a specially designed spectroscope at his disposal, Keeler became the leading spectroscopist in the world. The spectroscope created a spectrum that Keeler could examine visually. Keeler began the work of recording the spectra of stars and cataloging this information, which was the most important contribution to science in the observatory’s early history and would lay the groundwork for understanding the types of stars in the Galaxy.

Stars were not understood well in 1888. Twenty years before, Italian astronomer Angelo Secchi divided stars into four classes, based on early, crude inspections of spectra. Astronomers knew stars had different brightnesses and temperatures. They also had a rough conception of the disk of stars that is the Milky Way. However, a great deal of basic research on the spectra of stars and stellar motions relative to Earth had to be done to produce a picture of what stars and the Galaxy are like.

One primary field of spectroscopic research was
measuring radial velocities of stars. Holden gave Keeler two nights per week on the 36-inch telescope for this work, because the director considered measuring radial velocities of stars “the principal spectroscopic work for which the great telescope was designed.” Keeler’s measurements would enable astronomers to determine the solar system’s motion with respect to nearby stars and would prove the first step in a march to map out the motions of stars in the Milky Way. This in turn led to a better understanding of our Galaxy’s contents, size, and dynamics.

As the work progressed, Keeler observed several stars bright enough for him to measure the Doppler shift created by their radial motion in their spectra. He shined an iron arc lamp into the spectroscope and used the micrometer to measure the positions of the star’s spectral marks relative to the known wavelengths produced by the arc lamp. But Keeler was also intrigued by nebulae and turned his spectroscope on these objects to help settle a long-festering argument. At the time a debate raged among astronomers regarding the widths and wavelengths of the strongest lines visible in the spectra of nebulae. Keeler, aided by the powerful Lick telescope, the quality of his spectroscope, and the sharp images on Mount Hamilton, helped resolve this debate by showing distinct spectral lines. Because of Keeler’s work astronomers soon had better understanding of the chemical properties of nebulae.

While Keeler produced more and more of the world’s finest spectra, Barnard pioneered celestial photography. “There is no doubt but that [photography] is the Astronomy of the future,” he wrote. The ease with which Barnard accepted photography’s growing role in astronomy undoubtedly resulted from his twenty years of experience in photography. Holden relied on Barnard to develop the series of photographic plates he was taking to create an atlas of the Moon, the director’s major research undertaking.

The Beginning of Astrophotography
Barnard first made a camera from a wooden box that held a 6-inch wide-field lens and a photographic plate. The box was strapped onto the side of a 6-inch refractor he used for guiding the photographs. “[W]ith only the rudest equipment,” Barnard began photographing comets. He was amazed at the results and later wrote: “It appears that there is now some hope of tracing [a comet] from day to day by photographic means, and of obtaining in this way some clue to the energy of the forces which produce [the] observed changes.”

The power of a wide-field lens coupled with a photographic plate was fully demonstrated when Barnard turned his celestial camera toward the Milky Way. Barnard’s photos, “the only photographs ever made, here or elsewhere, that show at all the true Milky Way,” as he characterized them, revealed “vast and wonderful cloud forms, with all their remarkable structure of lanes, holes, and black gaps and sprays of stars.”

Barnard’s photographs showed structures along the Milky Way never before seen and sent a wave of excitement through the world of astronomy. They also showed known structures and nebulae in better detail than ever before. Although the photographs weren’t instantly used as data, they pointed the way toward an increasingly important role for photography in the future of astronomical research.

Burnham continued discovering and cataloging double stars, including 198 new pairs discovered with the 36-inch telescope and 56 more with the 12-inch refractor. The information Burnham gathered about these stars — magnitudes, positions, position angles, and colors of the members in double star systems — would be used by astronomers after Burnham’s time to determine how double stars orbit each other and how they are distributed throughout the Galaxy.

John Schaeberle was assigned the task of measuring star positions. A quiet bachelor, Schaeberle was well suited to Mount Hamilton’s isolation and working alone with the 4-inch transit instrument. To determine stellar positions, Schaeberle watched the stars passing through the view of the transit telescope and timed their passage with a clock. This gave him the exact time the star passed directly overhead and by calculation the star’s position relative to other stars.

Can You See the Martian Canals?
Although the staff members had their own areas of research, some subjects attracted all of them. Mars in particular was a hot topic at the end of the nineteenth century. The popular press, fueled by news from Italian astronomer Giovanni Schiaparelli, reported signs of intelligent life on the Red Planet. This was largely based on Schiaparelli’s observations of “canals,” or straight, fine
markings on the planet’s surface. The Lick astronomers were eager to see if the 36-inch scope would reveal these markings.

On one evening Schaeberle claimed to see Martian canals and described them as twin, parallel tracks. Keeler, however, observed the planet along with Schaeberle and saw only faint markings, not thin lines. Barnard, who had exceptional eyesight, also reported seeing only faint splotchy markings without significant patterns.

Barnard and Keeler, those with the most experience, were extremely skeptical. The problem in resolving this debate was that the detail on the planet’s surface was so subtle it was impossible to see distinctly, which left the nature of this detail open for interpretation. The debate would only be resolved years later, when much larger telescopes provided a clearer view of Martian surface details.

In 1888 astronomers were also trying to understand the outer planets. Astronomers knew a great deal about the orbits and masses of these planets but not much about their atmospheres and compositions. Uranus and Neptune were faint enough to make studying them very difficult. Jupiter and Saturn were relatively bright, but spectroscopy was primitive and no one had the expertise to use it to its full advantage until Keeler began using the 36-inch telescope.

With his spectroscope Keeler extensively studied Saturn, Jupiter, Uranus, and Neptune. In all these planets he saw broad absorption bands now known to be caused by methane. At the time some astronomers believed the outer planets were self-luminous, but Keeler’s research supported the notion that they shine by reflected sunlight.

Another question that fascinated astronomers of the time was the nature of Saturn’s rings. Using the 12-inch refractor, Barnard observed an eclipse of one of Saturn’s moons, Iapetus. When Iapetus passed behind the planet’s rings, Barnard could see the moon shining faintly through the outer ring. This proved the ring was partially transparent and offered an important clue to the nature of the rings.

A Fifth Moon for Jupiter

Soon after Barnard gained access to the 36-inch telescope, he made a major discovery. One night while observing Jupiter, Barnard noticed an extremely faint dot of light in the same field of view as Jupiter. He followed the faint light for several hours and on the next night saw it again. On September 9, 1892, Barnard realized he had discovered a fifth moon of Jupiter, which was later called Amalthea.

This discovery made Barnard a national celebrity: he was described in newspapers as “the greatest astronomer of all time.” In subsequent years several more Jovian moons were discovered by Lick astronomers, but none caused the excitement generated by Barnard’s discovery of Amalthea.
This discovery marked the high point of the early days at Lick Observatory. By that time the first group of pioneer astronomers had begun to move on to other observatories and fields. In 1890 Keeler left to get married and start a family. He returned to Allegheny Observatory in Pittsburgh, where he replaced Langley as director. There he continued to advance spectroscopy and proved that Saturn’s rings are composed of countless small particles. In 1898 Keeler came back to California as Lick’s second director. As director Keeler photographed hundreds of nebulae unknown before his time and established the existence of the spiral structure in some nebulae that would later be called galaxies.

After four years at Lick, Burnham returned to a courtroom job in Chicago. In Illinois Burnham kept up with astronomy and later joined the staff of Yerkes Observatory in Wisconsin. Barnard stayed at Lick until 1895 when he joined Burnham at Yerkes. Barnard continued experiments with photography and produced a series of extraordinary Milky Way photographs that showed astronomers the complex arrangement of the Galaxy for the first time.

Although the early astronomers at Lick Observatory left and went on to great careers elsewhere, great things continued to happen at Lick. Heber D. Curtis extended Keeler’s work by pushing forth the understanding that spiral nebulae are galaxies. Robert Grant Aitken followed in Burnham’s tracks — discovering, cataloging, and studying thousands of double stars. William W. Campbell organized many solar eclipse expeditions that led to associate Robert J. Trumpler’s confirmation of the general theory of relativity. Trumpler’s studies of stars in clusters led to the discovery that dark matter absorbs light in space, one of the most important new ideas of twentieth century astronomy.

Lick Observatory has left a major imprint on modern astronomy. When it was founded in 1888, it was the world’s first mountaintop observatory and housed the world’s largest telescope. And fortunately for astronomical knowledge, three of the era’s greatest astronomers, Barnard, Burnham, and Keeler, spent busy, productive years at Lick. The discoveries they made and the work they did there serve as a powerful reminder of the American pioneer spirit.

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