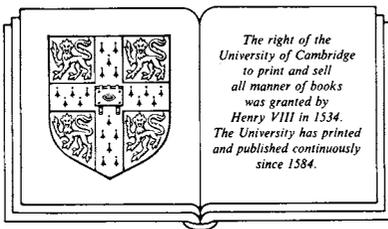


James E. Keeler

PIONEER AMERICAN ASTROPHYSICIST
AND THE EARLY DEVELOPMENT OF
AMERICAN ASTROPHYSICS

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To Irene

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1

A raw country boy from Florida

On August 12, 1900, James E. Keeler lay dying in a San Francisco hospital. An outstanding scientist, he had been felled by a stroke at the age of forty-two. The director of the Lick Observatory of the University of California, in two short years he had photographed with its reflecting telescope hundreds of spiral “nebulae” and had recognized them as important constituents of the universe. His work was the beginning of the scientific study of the galaxies.

Keeler was a pioneer astrophysicist, whose work and scientific techniques underlie much of our modern view of the universe. He was among the first American scientists to apply the methods of physics to investigate the physical nature of planets, stars, nebulae, and the objects that we today call galaxies. In Keeler’s day, the new word “astrophysics” meant the use of spectroscopes and spectrographs on telescopes to analyze the light from celestial objects that reaches the surface of the earth. In our day it has grown to include measurements of X-ray, ultraviolet, far infrared and radio radiation as well, many of them made from rockets or artificial satellites. The principles have not changed one iota.

Keeler was born just before the American Civil War, in the same decade as Theodore Roosevelt and Emperor William II of Germany, Max Planck, Pierre Curie and Henry Ford. He was trained at the first American research university, Johns Hopkins in Baltimore. He worked as an assistant, the equivalent of a modern “postdoc”, for Samuel P. Langley, one of the first astrophysicists in America and indeed in the world. Keeler had one year of postgraduate study in Germany, then the acknowledged world center of physics. Like many of the leading American scientists of his time, he attended the lectures of Hermann von Helmholtz, Robert Bunsen and Heinrich Kayser, learning from the men

who were laying the groundwork of electrodynamics, optics and spectroscopy.

In 1886 Keeler was the first professional astronomer hired at Lick Observatory, then still in the building stage. The mechanical and technological developments of post-Civil War America were being applied to scientific research, especially in astronomy, the study of the whole universe. The country's tradition had been tinkering and invention, but the astronomer Simon Newcomb, and the physicist Henry A. Rowland were two of the first and most influential voices to speak up for pure research. A very few wealthy men and women, like James Lick, William Thaw, Charles T. Yerkes and Catherine W. Bruce, personally financed the building of successive monster telescopes and auxiliary spectroscopes and spectrographs to unlock the secrets of the universe. American money and technology, applied at fine observing sites in the favorable climate of California, enabled the United States to overtake Germany and Great Britain, and become the world leader in observational astronomy. American physics emphasized increasingly accurate quantitative measurements, and the physical conclusions that could be drawn from them.

Keeler was intimately involved in every stage of this development. Lick Observatory was the first large mountain-top astronomical observatory, and the first large research institution in California. There with the 36-inch refracting telescope, the largest in the world, Keeler studied the spectra of the planets, stars, and nebulae. Most of his work was based on extremely accurate wavelength measurements, for which he set new standards of astronomical precision. At Lick and later at Allegheny Observatory near Pittsburgh, Keeler made many fundamental new discoveries on the nature of the objects that make up the universe.

Especially during his years in the East, Keeler's career was very closely associated with that of his younger friend George Ellery Hale, the founder of Yerkes Observatory and later of Mount Wilson as well. Keeler was intimately involved in the beginnings of Yerkes Observatory, the second high-technology, big astronomy research institution that started its life at the end of the last century. Hale and Keeler founded the *Astrophysical Journal*, the first and for many years the only research journal of its field.

By his contemporaries, Keeler was considered the outstanding American astrophysicist of his time. He was admired and respected by astronomers all over the world, as much for his personality as for his research attainments. His contemporaries gave him nearly every award and honor to which an astronomer could aspire. They expected even greater things of him, but like Adonis, the darling of the gods, he was struck down before his time.

Through Keeler's life we can see not only his scientific discoveries, but the whole little world of American astronomy and spectroscopy at the end of the last century. His career was intimately linked not only with Hale's but with those of Edward S. Holden, W. W. Campbell and E. E. Barnard. Three future directors of Lick Observatory worked under Keeler in the years 1898-1900. He knew practically every important American astronomer, corresponded with many of them, helped scores of them in their research. He started the first serious graduate program in observational astronomy at Lick Observatory in 1898, a program that over the years turned out many of America's research pioneers. Every person who works in astrophysics today is, in some sense or other, one of James E. Keeler's scientific heirs.

James E. Keeler's wife always considered him a Connecticut Yankee,¹ and at least one of his fellow students at Johns Hopkins thought of him as "a raw country boy from Florida,"² but he was born in La Salle, Illinois on September 10, 1857. La Salle is on the Illinois River, in the rich and fertile northern part of that state, settled by New England pioneers in the first half of the nineteenth century. Both Keeler's parents could trace their ancestry through Revolutionary War soldiers back to the Pilgrim settlers.³ His father, William F. Keeler, was descended from Ralph Keeler, who was born in England and emigrated to Hartford, Connecticut in 1637. Ralph Keeler's great great grandson, Samuel Keeler, was an officer in the Continental army during the Revolution. Samuel Keeler's grandson Roswell married Mary Plant, daughter of a wealthy family in upstate New York, and their son William was born in Utica on June 21, 1821. He in turn married Anna Dutton, daughter of Henry Dutton, of Bridgeport, Connecticut, on October 5, 1846.

Henry Dutton was an honor graduate of Yale, a lawyer who served several terms in the Connecticut legislature and Senate. In 1847 he was appointed a professor of law at Yale and moved to New Haven, where he continued to practice until he became a county judge in 1852. In 1854 he was elected governor of Connecticut and served one full term; a few years later he was appointed a judge of the Supreme Court of Connecticut, a post he held until he retired in 1866 at the age of seventy. During all this time he had continued to teach at the Yale Law School, and after his retirement he devoted his main efforts to it until his death in 1869. As a judge he was not considered particularly learned, but practical, with a good knowledge of precedents, quick to grasp a legal point, and advanced in his ideas.

Henry Dutton's elder brother Matthew was another Yale product, who

had graduated with highest honors, and stayed at New Haven as a tutor until he was ordained as a minister in 1814. He served a congregation at Stratford, Connecticut for seven years, but then returned to Yale as professor of mathematics and natural philosophy, as science was then called. He was considered a remarkable mathematician, and was a very popular teacher, but he died at the age of 42, "from general debility brought on by intense application to his work."⁴ James E. Keeler combined in his career many of the characteristics of these two brothers. Henry Dutton's father and grandfather had both served in the Revolution, and through them Keeler was descended from John Punderson, one of the founders of the first church in New Haven.

William and Anna Keeler's first son, Henry Dutton Keeler, was born on November 3, 1847. A few years later William, with his brothers James and Edward, sailed from New York around Cape Horn to San Francisco during the California Gold Rush, to seek their fortunes. James died on the voyage, and Edward in California. William did not make his fortune, but he certainly did see the gold fields, and probably worked in them for a time.⁵ From California he took passage on another ship for China, and then continued around the world via the Cape of Good Hope and then home again. By 1853 he was in business as a watchmaker in La Salle. The Keelers' first daughter Minnie was born there in 1854, but she died at the age of three, the same year James Edward, named for his two dead uncles, was born. By this time his father had become a senior partner in the La Salle Iron Works, which did all kinds of foundry and machine work, steam engines, casting and general machinery.⁶

The Keelers' last child, Elizabeth Eliot, was born in 1860. A few months later Abraham Lincoln was elected president, on a platform of stopping the expansion of slavery. The Civil War soon broke out, and by the end of 1861 William Keeler obtained, with the aid of his congressman, Owen Lovejoy, a commission as acting assistant paymaster in the United States Navy. In January 1862 he was assigned to the crew of U.S.S. *Monitor*, the famous Union ironclad steamship. During her voyage from New York to Hampton Roads the *Monitor's* engine-room ventilating system failed and the engineers were overcome; Paymaster Keeler was able to draw on his La Salle Iron Works experience and operate the engines until the engineers were revived and returned to duty. During the *Monitor's* battle with the Confederate ironclad *Merrimack*, he was in the pilot house and when Captain John L. Worden was blinded by a shell that smashed into the armor, Keeler gave him first aid and notified the executive officer to take over command. As the "saviors of the North," the crew of the *Monitor* were instant celebrities, and in the months

following the battle their ship was visited by President Lincoln, Vice President Hannibal Hamlin, several cabinet officers and senators, and, by Keeler's count, at least 19 generals.⁶

That summer, while the *Monitor* was supporting the Union army on the James River, south of Richmond, Anna's brother Henry M. Dutton, a lieutenant in the 5th Connecticut Volunteers, was killed in the fighting at Cedar Mountain.⁷ The carnage was fearful as the Confederate and Union Armies blasted away at each other in the dark woods, and after the battle over half the company officers in the 5th Connecticut were reported killed or missing in action, the latter meaning that their corpses were so mutilated by gunfire or grapeshot as to be unidentifiable. Judge Dutton hurried to the battlefield, but was unable to find the body of his namesake and only son.

Keeler was able to go home on leave for a month when the *Monitor* was sent to the Washington Navy Yard for repairs in October. He continued to serve on her until she went down at sea in a gale off Cape Hatteras at the end of December 1862. Keeler tried to save the ship's money, but the safe in his cabin was underwater by the time he got to it, and he had to go over the side on a rope. The only possessions he had when he was picked up by a boat from the U.S.S. *Rhode Island* were the clothes on his back.⁶

Keeler was then transferred to the U.S.S. *Florida*, assigned to blockade duty off Southern ports until the end of the war. He was wounded twice, and received a pension of \$10 a month for the rest of his life. In March 1865, Keeler was able to bring his teen-age son Henry aboard the *Florida*, where he helped his father buy stores and deliver payrolls, and lived in the cabin with him. They saw many Florida and Gulf Coast ports together, and after General Robert E. Lee's surrender and the defeat of the Confederacy, they enjoyed a cruise to Panama, when the *Florida* carried men and money destined for the Pacific Squadron to the Isthmus. Keeler was finally allowed to go home in November 1865, and was released from the Navy a few months later.⁸

Meanwhile, young Eddie, who throughout his life was always known by his middle name to his family and close friends,⁹ was growing up back in Illinois. During and after the Civil War he attended school at an institution he later described as La Salle High School,¹⁰ perhaps with some exaggeration, for the family moved to Florida in November 1869, when he was only 12 years old. Just a few months before they left, Keeler had seen the solar eclipse which swept across the United States in 1869, a vivid sight that he never forgot.¹¹

William Keeler had not much liked Key West or the other Florida ports he saw or visited from his ship during the War, but perhaps a few winters

back on the snowy prairies of northern Illinois convinced him of the advantages of living in a more moderate climate. His sister and brother-in-law, David and Frances Brown, had moved from Chicago to Lake Worth, in southern Florida near Palm Beach, and their reports probably helped convert him. Anna's father, Henry Dutton, died in New Haven in April 1869, and no doubt whatever inheritance she received from his estate helped the Keelers buy land and build a house near Mayport, at the mouth of the St. John's River, eighteen miles downstream from Jacksonville.

Mayport was a very small town. The Keelers' house, which they named Thalassa, was a large mansion, surrounded by a palmetto forest that opened out to a fine view of the sea.¹² William Keeler promoted himself and was known as "Major Keeler" to the locals; under this name he operated a general repair business with his own small shop and forge, and planted and cultivated orange, pecan, and date-palm trees, as well as beans, corn, potatoes, and other garden vegetables.¹³ He wrote a weekly Mayport letter for the Florida Times-Union, signed with the pseudonym "Silex", or later, "Monitor", in which he chronicled the comings and goings of ships from the sea and vacationers from Jacksonville and points north. He often wrote of the healthful effects of an outdoor Florida life, as when he described a physician who "worn down by the cares and anxieties of his professional business, has for a few days laid aside pills, powder and physic, and has prescribed for himself the sea air and salt water of our Mayport beach. His prescription is a wise one, and if followed will result in his complete restoration to health."¹⁴ Although the Major welcomed visitors from Jacksonville and urged them to enjoy their holidays and vacations in Mayport, he felt it his duty to warn them not to bathe in the nude in front of the summer cottages, but rather to go further away up the beach for the sake of modesty.¹⁵

There was no school remotely matching Eddie Keeler's interests or abilities in tiny Mayport, and all his further education after the family left Illinois was at home with his parents. He helped out with work on the house and in the shop, and had plenty of time for tramps on the beach with his brother Henry, and games and visits with his friends in and around the little community of Mayport.¹⁶ He liked boats and sailing.¹⁷ But he studied too, with his father, who subscribed to the *Scientific American*, and his mother, who subscribed to *Harper's Magazine*, and somehow, between them, they managed not only to give the boy a solid grounding in reading, writing and arithmetic, but also to help him make himself an expert sketch artist, and a master of tact who got along well with people all his life.⁹

Ed Keeler developed his interest in astronomy from the practical side of surveying,³ which he learned from his father. He ordered a two-inch achromatic lens from Queens, an optical dealer in Philadelphia who advertised in *Scientific American*, and two smaller lenses for an eyepiece. Within a week after he got them, he had assembled his first telescope, and although the cloudy winter weather prevented him from observing stars, he tested it on distant ships and the Mayport lighthouse. Soon he was observing the moon, double stars, Saturn, Jupiter, the Orion nebula, and the Ring nebula in Lyra.¹⁶ He kept a careful record of the objects he observed, and drew sketches of lunar craters and planets. Astronomers who saw these drawings in later years pronounced them excellent.¹⁸ In 1877 Keeler built a meridian circle from the telescope, using a pasted-on protractor scale and a small kitchen clock which “kept execrable time” to convert it into an instrument of at least semiprecision.¹⁹

At last near the end of 1877 he got his chance to go north for an education. Earlier that same year his brother, Henry, who had been working as a clerk in a trust company in New York, died unexpectedly at the age of 29, while on vacation at Branford Point, Connecticut.²⁰ Probably he had contracted some kind of fever, for the cause of death was given as “colic.”⁶ His father thought of Henry as a “young and promising botanist,”¹² but there is no indication that he had ever entered college. Ed’s chance came through his sister Lizzie, who was attending a private school in Tarrytown, New York. She was taken with her class to visit the private observatory of Charles H. Rockwell, a wealthy amateur astronomer. When they looked at Saturn through the telescope, she said she had often seen it in her brother’s telescope down home in Florida. Her remark attracted Rockwell’s attention, who wanted to learn more about this unusual brother, and ended up bringing him north and helping finance his education.⁹

Rockwell, five years younger than Keeler’s father, had been born to a wealthy family in Norwich, Connecticut, and studied chemistry at Yale. In 1850 he sailed around Cape Horn to California, and may conceivably have met William Keeler at that time, although no record of such a meeting survives. During the Civil War he served as a captain in the Quartermaster Corps at Port Hudson, Vicksburg and St. Louis, purchasing ammunition and stores for the Army and forwarding them to New Orleans. At the end of the War he was on General Phil Sheridan’s staff and distinguished himself at Cedar Creek, the battle from which Sheridan was absent in Winchester, twenty miles away.²¹ Rockwell lived in Chicago for a few years after the War, and then in 1869 moved to Tarrytown, in

Westchester County, New York, the millionaire colony where he counted among his neighbors John D. Rockefeller, William Rockefeller, and Jay Gould. Here at his "Italian Villa" Rockwell built his own observatory, and devoted himself to astronomy for the last thirty-five years of his life.²²

Somewhere along the line Rockwell and Keeler's father had met and become friends.²³ Both their families go back to the early days of Connecticut, and were heavily involved in the New England migration to northern Illinois.³ At any rate, Rockwell, impressed by what he could learn of young Keeler, arranged for him to come north and visit Yale, Harvard, and Johns Hopkins. In writing to these universities, Rockwell described Keeler's knowledge of mathematics and science, emphasizing that he was brilliant and hard working but relatively untrained. He wrote of Keeler's practical skill and ability, demonstrated by the instruments he had constructed himself "with only the resources of a poverty stricken plantation."²⁴ Another by no means negligible qualification of Keeler's was that, as the grandson of the late Governor Dutton, he had "good stuff in him."²⁵ When Rockwell met Keeler on December 5, 1877, he liked the "lankey green country boy" who had worked his passage north from Mayport to New London, helping the captain navigate the schooner by the sun and stars.²⁶ No doubt he did; yet Keeler's free trip was probably not completely independent of the fact that his father was a deputy collector of customs at Mayport and a close personal friend of all the captains who visited that port frequently. George J. Brush, the professor of physics who interviewed Keeler at Yale, was William Keeler's cousin.³ Keeler's own idea was to become a scientific workman in Alvan Clark's optical establishment in Cambridgeport, Massachusetts, well known to him from the pages of the *Scientific American*, but luckily for astronomy there were no job openings there at the time.²⁷ All the professors who met Keeler agreed that he should become a scientist, and that although his level of training would not qualify him to enter Yale or Harvard, Johns Hopkins was just the place for him.²⁸

Johns Hopkins University was very young when Keeler arrived in Baltimore late in December 1877; it had admitted its first students in the fall of the previous year, and Keeler's class was the second in the history of the institution. It had been founded by the will of Johns Hopkins, a wealthy Baltimore financier who left half his seven-million-dollar estate, consisting largely of Baltimore and Ohio railroad stock, to build a university. The trustees lured Daniel Coit Gilman away from the University of California to be Hopkins' first president, and he built it as America's first research university. Gilman had been trained at Yale, and had been deeply involved in the founding of its Sheffield Scientific School, where

he was librarian, professor of geography and secretary of the governing board for many years before he left for California. At Johns Hopkins, with a large endowment and complete freedom from church or state control, he was determined to promote scholarship of the highest order. He modelled Johns Hopkins on the German universities which then dominated so much of world science. It was primarily a university for advanced work by graduate students, but also had an undergraduate department where students were supposed to receive the kind of instruction that other universities gave only in their post-graduate courses. Gilman wanted to leave the kind of work usually done by undergraduates to other institutions. During Keeler's years at Johns Hopkins it was a growing institution, with on the average about eighty graduate students and only thirty undergraduates in the whole university.²⁹

The faculty numbered twelve, all personally selected by Gilman. The first professor appointed had been young Henry A. Rowland, the outstanding physicist, whose laboratory was the first in the country with an instrument shop in which the apparatus needed for physical research could actually be produced. He rarely lectured, and never taught a systematic course. On one occasion, when asked what he would do with the undergraduates, Rowland replied, "Do with them? Do with them? *I shall ignore them!*" In fact, he stimulated them by his example, rather than by lecturing to them. With his vigorous personality, keen pursuit of science, and incisive intelligence, Rowland provided an inspiring model for the budding young physicists. A few years later he was to deliver a stirring "Plea for Pure Science".³⁰ Keeler took most of his physics courses from Charles S. Hastings, a young Yale Ph.D. who had studied abroad at Berlin, Heidelberg and the Sorbonne. He specialized in optics and had a keen interest in astronomy.³¹ The star of the faculty was J.J. Sylvester, the English mathematician, who, like Rowland, did not teach undergraduates. Another outstanding scientist was Ira Remsen, the professor of chemistry, who had received his Ph.D. at Göttingen, and followed the German scheme of involving his graduate students fully in his research. There was no astronomy professor at Hopkins, but Simon Newcomb, the outstanding astronomer of the day, came over twice a week from the Nautical Almanac Office in nearby Washington to teach a course in the winter of 1877, and frequently thereafter.³² Samuel P. Langley, the pioneer astrophysicist from Allegheny Observatory, near Pittsburgh, gave a series of lectures on the sun and radiant energy a few years later.²⁹

When Keeler entered Johns Hopkins he was twenty years old. He was nearly six feet tall, with light hair, blue-gray eyes and a fair complexion.³³ The father of one of his classmates described him as a backwoods charac-

ter straight from a Mark Twain novel, speaking with a pronounced “Cracker drawl.”³⁴ Yet his air of quiet competence impressed everyone with whom he came in contact, and he made many close friends among his classmates and the graduate students at Johns Hopkins. Gilman had introduced an undergraduate group system in place of the traditional college schedule in which all the students took essentially the same courses. Instead, students at Hopkins could push forward as rapidly as they chose, or stretch out their course of studies over a longer period if they preferred. No fixed time was required to complete any of the seven possible groups of courses; usually it took three years, rarely four, and students who came with better preparation than required for matriculation could finish in as little as two years. Keeler, who did not complete his matriculation requirements until shortly before he graduated, took a little less than four years to complete his program in Group 3, “for one who prefers Mathematical studies, with reference to Engineering, Astronomy, Teaching, etc.” He majored in physics and German, and took minors in mathematics, chemistry and astronomy. In addition, he worked as a part-time laboratory assistant and did some numerical computing for the *Baltimore Sun Almanac* to help pay his expenses.³⁵

It was hard work, but Keeler enjoyed it. One fellow student testified to the spirit of those early times at Johns Hopkins, calling them “a dawn wherein ’twas bliss to be alive”.²⁹ In later years, Keeler always felt extremely positive about his alma mater and the education that he and his classmates had received there.³⁶

At the end of his first year at Hopkins, Keeler had an unusual summer opportunity. Through his patron Rockwell, he got the chance to join a scientific expedition to Colorado to observe the total solar eclipse of July 29, 1878. Solar eclipses provide the only conditions under which the faint solar corona and the regions of space immediately surrounding the sun can be observed. They happen only infrequently, and the path of totality is a narrow corridor that may be located in any part of the world. Rockwell, a skilled amateur astronomer, was going with the party sent out by the Naval Observatory, under the leadership of Professor Edward S. Holden, to make scientific measurements of the eclipse. Holden’s group included Hastings, Keeler’s teacher at Johns Hopkins, Lieutenant Samuel W. Very, a scientifically trained Navy officer, and Edgar W. Bass, a mathematics professor from West Point. Rockwell and Keeler accompanied them, as volunteers, at Rockwell’s expense.³⁷ Keeler had already met Holden soon after his arrival at Hopkins. He had, at the Naval Observatory astronomer’s request, made a drawing of the Orion

Nebula, based on his observations with a small telescope, for comparison with an earlier drawing by Sir William Herschel.³⁸

The West was still wild in 1878. Holden, on the basis of available climatological data, originally planned to go to Virginia City, a mining camp located on the eclipse path in the Montana Territory. However, knowledgeable Army officers warned the superintendent of the Naval Observatory that the Indian hostiles might be out on the warpath that summer, and Holden was ordered to stay a little closer to civilization. The site he picked, Central City, Colorado, is less than 450 miles from the spot on the Little Big Horn where Crazy Horse, Gall and their Sioux and Cheyenne warriors had annihilated Custer and five troops of the Seventh Cavalry just two summers before.

Keeler traveled alone from Baltimore to Denver, getting up at 3 a.m. on a hot July morning to catch the 6:55 train to Harrisburg. Two of his closest friends at Hopkins, David T. and William C. Day, got him to the station with two minutes to spare. En route to Denver he had to change trains five times, at Harrisburg, Pittsburgh, Indianapolis, St. Louis, and Kansas City. An avid sightseer, Keeler admired the iron and steel works he saw in Harrisburg and in Pittsburgh, but he admired a pretty waitress in the station restaurant at Topeka even more. The rest of the passengers behaved like hogs, according to Keeler's account, eating with their hats on, drinking whiskey, and otherwise acting in ungentlemanly fashion, so when Keeler "smashed" (flirted with) the waitress, she ignored the other customers and devoted all her efforts to him. But the train soon left Topeka, and he was again bored by the dry flat prairies of Kansas and eastern Colorado. Finally he reached Denver, more than three days after his departure from Baltimore. He took the horse-drawn bus to the American House, as instructed, but found that Rockwell, who had arrived there two or three days previously, had gone off on a trip. Keeler decided to take advantage of the situation to improve his education and "went down 16th street . . . into a sort of rum shop theatre, more to see what kind of rowdies Colorado furnished than to see the play." But it was pretty tame stuff by Eastern standards, "nothing compared to the New Central in Baltimore, and the girls even wore high-necked dresses, but they were bold and cheeky." Disappointed, he left after the first act and went back to the hotel.

The next day he made a sightseeing trip around the city, and was entranced by the sight of the Rocky Mountains, rising abruptly out of the plain just west of Denver. Back at the hotel he met Very and Rockwell, who had returned from his trip, and the three of them drove out to visit the Princeton eclipse party, which was under the direction of Charles A.

Young, the pioneer astronomical spectroscopist. He and his group, which totaled thirteen observers, including Princeton physicist Cyrus F. Brackett and seven graduating seniors, were preparing to observe the eclipse from a site near Denver. Arthur C. Ranyard, an English spectroscopist who was Secretary of the Royal Astronomical Society, was with them.³⁹ Keeler was introduced to Young and was impressed by the fine instruments the Princeton astronomers had brought to Colorado, particularly the first astronomical spectroscope he had ever seen. That day, with Rockwell in town, Keeler confined his theatrical activities to watching a performance by an educated pig, which could count and do simple arithmetic, and, in the evening, seeing the famous actor Joseph Jefferson star as Rip Van Winkle at the Opera House.

The next day Hastings and Holden arrived in Denver, discussed their plans for observing the eclipse with Rockwell, Very and Keeler, and then went on to Central City.⁴⁰ The other three followed the next day, and Keeler was greatly impressed by the mountain scenery, and by the little narrow-gauge railroad that zigzagged up the mountain from Golden to Central City, 8,400 feet above sea level. They settled in the Teller House, a three-story, 150-room hotel, and Holden arranged with the manager for his party to observe the eclipse from its flat roof. While waiting, they all went sightseeing in Central City's Bob-tail Gold and Silver Mine, at that time one of the largest and richest mines in Colorado.⁴¹ The weather was perfect, cool and comfortable, with clear skies every day.

On July 29, the date of the eclipse, a few light clouds appeared before noon, but soon dissipated. As the moon covered the sun, the sky darkened, and Keeler heard roosters crowing and dogs howling, and saw nighthawks wheeling around the hotel. One local wag reported that a few well-known citizens went into their favorite bar for a nightcap,⁴² but Keeler does not mention this episode. Just before totality he saw the shadow bands, an alternating dark and light eclipse phenomenon, sweep across the landscape. At totality he rapidly sketched the corona, observing with a two-inch aperture telescope which had a large field of view. He took one hasty glance with his naked eye and saw the grandest sight he ever expected to see.⁴¹ As soon as the eclipse was over he made a crayon drawing on black board of his sketch, from his memory, which he had trained by observing scenes for one or two minutes and then drawing them without looking at them again. Keeler's drawing, published in his first scientific paper as part of the Naval Observatory report on the eclipse, shows coronal streamers and the flattened, equatorial shape of the corona characteristic of times of sunspot minimum.³⁷

Holden, using a larger telescope, searched the darkened sky near the

sun during the eclipse, looking for a planet inside the orbit of Mercury, which the French astronomer Urbain LeVerrier thought he had observed at an earlier eclipse. Holden found no such object, and from his observations was able to rule out the existence of any intramercurial planet as bright as a third-magnitude star. Hastings measured the polarization of the light from various places in the corona quantitatively, but found to his consternation that it was tangential, rather than radial as all previous reliable observers had found, and as he expected it to be. He suspected something was wrong with his instrument. Nevertheless, when he checked it he found everything in order, so he published the results, but neither he nor anyone else afterward ever really believed the polarization was tangential.⁴³

The eclipse over, that evening the astronomers invited the people of Central City up to the roof of the Teller House and showed them the planet Jupiter, double stars and clusters through their telescopes. Keeler exhibited his drawing of the corona, and received congratulations on it. Everyone in the group felt satisfied with their results as they headed back to the East. Keeler stopped in Illinois for his first visit with friends and relatives in La Salle since his departure with his family nine years before.⁴⁴ A few weeks later, on his twenty-first birthday, he was back in Baltimore, beginning his second year at Johns Hopkins.

Along with physics and mathematics, Keeler took one or more courses in German nearly every term.⁴⁵ Many of the Johns Hopkins fellows had studied in German universities, and they founded an informal “Kneipe” or club, at which they drank beer and discussed the problems of the world in German.²⁹ Keeler must have taken a lively part in these proceedings. Yet all was not peaches and cream; at least one unreconstructed rebel, the Virginian Walter Hines Page, was unhappy with the “Germanism” of Johns Hopkins, which he considered “at least unnatural” in a Southern city like Baltimore. He described one fellow graduate student whom he did not like as a horrible example of a grind: “He can make dictionaries but can no more appreciate the soul beauties of literature than a piano manufacturer can appreciate Wagner. He is a native of Connecticut, and Connecticut, I suppose, is capable of producing any phenomenon”.²⁹

During Keeler’s sophomore year his 18-year-old sister Lizzie came up from Florida by schooner for a month-long visit with him in Baltimore in May 1879. There she first met his friend and classmate David Day, her future husband. A year later, in the summer of 1880, Day accompanied Keeler on his first trip back home to Florida since he had entered Johns Hopkins. The two of them spent most of July and August at Mayport, dividing their time among picnics, trips, visits, and helping Keeler’s father