Denver's Great Telescope

This guidebook will introduce you to the University of Denver's historic Chamberlin Observatory in south Denver, which houses a 20-in. aperture Clark-Saegmuller Refractor type telescope. This telescope, one of the largest of its era, saw first light in July 1894 and is still functional. Regular classes and public viewing sessions still occur. Astronomy at the University of Denver has remained continuously active since 1880, in the pursuit of research, teaching and community outreach. Please visit the Internet home pages of the University of Denver observatories for more information (http://www.du.edu).

Photo by George Beam, 1898
University of Denver Penrose Archives

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DENVER'S GREAT TELESCOPE By Claire M. Stencel & Robert E. Stencel

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Denver's Great Telescope

Your Guidebook to the University of Denver's Historic Chamberlin Observatory

By Claire M. Stencel & Robert E. Stencel
Glenn E. Montgomery, Editor

first edition, 2006

Notice: Cover may have additional 5.875" panels on both left and right sides that will be folded into the spine, and glued. So as to achieve double thick front & back covers.

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Denver's Great Telescope

Acknowledgements

History is made by many, many people. With apologies to those who played significant roles in bringing this booklet forth but have not been properly credited, we especially thank: Herbert J. and Beverly Howe, Stephen Fisher, Yelena McElwain, Glenn Montgomery, Russ Mellon, Tom Melscheimer, Herschel Neumann, Fran Ohmer, Alyssa Phillips, Hank Rael, Bob Raynolds, Aaron Reid, Hal and Dolly Secrist, Susan Conat Stencel, Barbara and Tom Stephen, David Trott, Barry Winter, William Herschel Womble, Astronomy students at the University of Denver, staff of the University of Denver Physical Plant, Ed Kline, Larry Brooks, Public Night volunteers and officers of the Denver Astronomical Society, the geniuses at Software Bisque, our friends at S&S Optika, the staff at the Denver Museum of Nature & Science Gates Planetarium, Don Asquin, clockmakers Al Baumbach and Bill Dillon, University Park Neighbors, reporters John Ensslin, Ann Schrader, Warren Smith and Joseph Verrengia, and many other individuals who have contributed in one way or another over the many years to the survival of the University of Denver's historic Chamberlin Observatory.

Kindly bring concerns for any errors of fact or omission in this text to the attention of the authors for correction in a subsequent edition. Photos are largely from the DU Penrose Archives, the Howe family or newly imaged by the authors unless credited differently, insofar as is possible.

This book is dedicated to Mr. Glenn E. Montgomery, whose sustained interest in astronomy at the University of Denver is cause for cheers. We appreciate his financial underwriting and publication of this book and the proceeds of its sale for the observatory. To him and all involved in sustaining Denver's grand telescope, our thanks and a heartfelt "Hipp, Hipp, Hoorah!"

Denvers's Great Telesope

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For information about this book, see page 96

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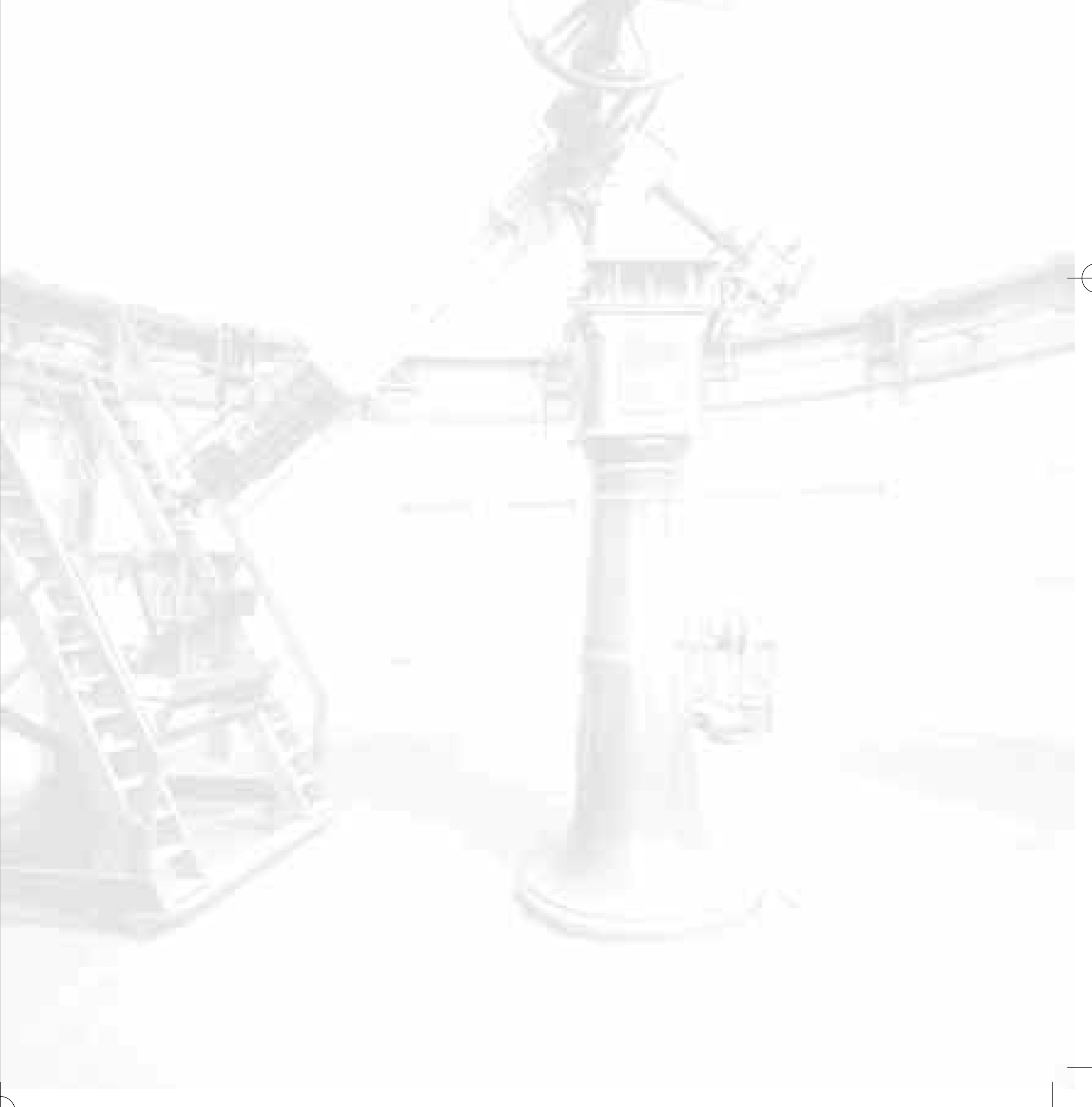
"Astronomy serves the following needs: to encourage the habit of accurate observation; to strengthen reasoning by the application of mathematics to astronomical phenomena, and its pure disciplinary value of lifting the mind from daily cares, to the contemplation of awe-inspiring grandeur and majestic laws that bind countless worlds into one harmonious whole, providing order and beauty out of apparent chaos."

—Professor Howe,
First Director, Chamberlin Observatory

Introduction



Opposite Page
The Chamberlin Observatory telescope, a 20-inch Clark Saegmuller refractor, was among the largest of its kind at time of construction. The telescope - aimed north and seen from the west side of the dome room - saw first light in 1894, and is still used today by students, teachers and visitors. Shown in the similar cover photo is the telescope and Professor Herbert Howe, the man responsible for the design of and instrument installation at the observatory.
© Courtesy of University of Denver Penrose Archives

The Telescope - Introduced and Illustrated

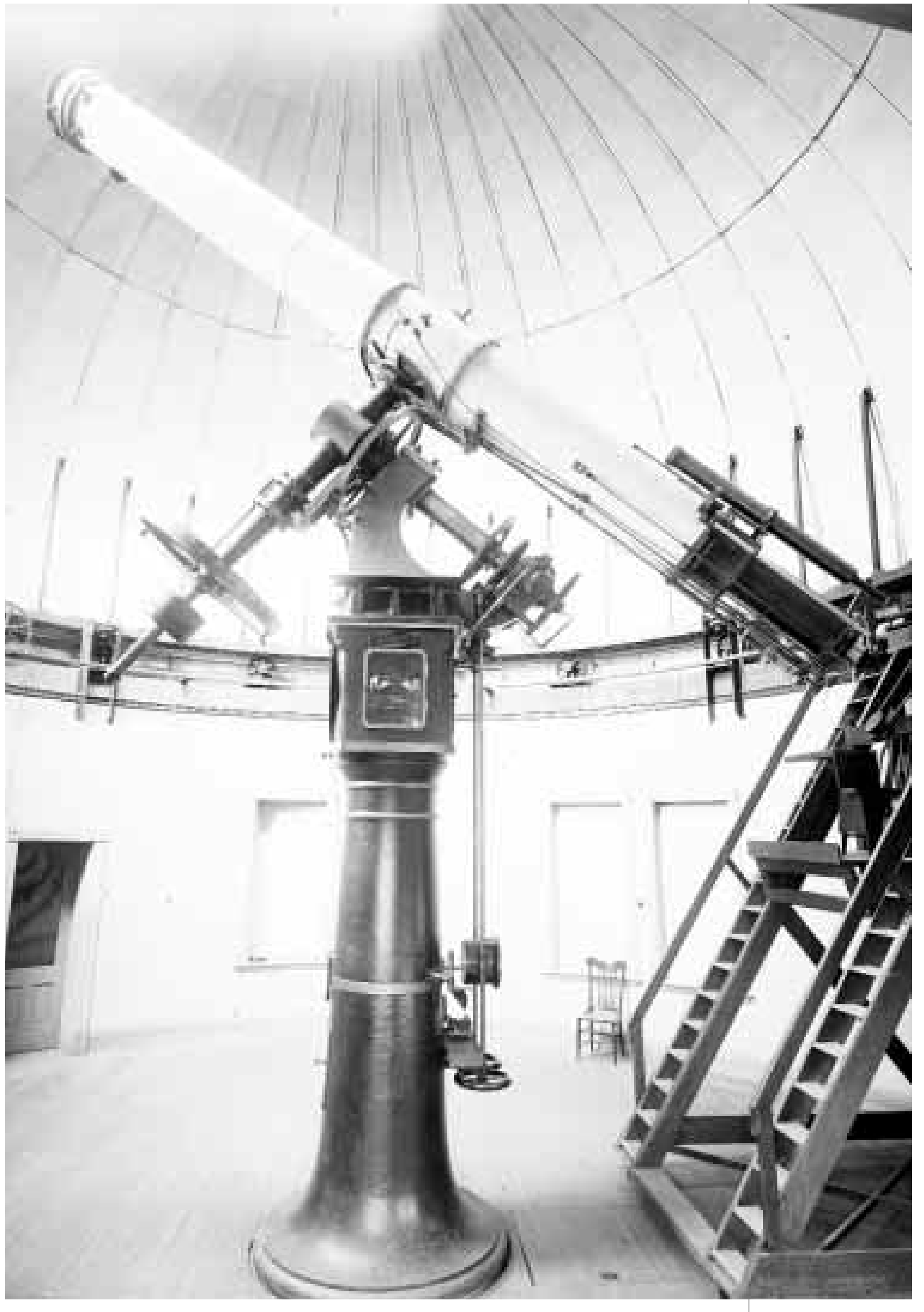
At the heart of the University of Denver's historic Chamberlin Observatory lies the telescope, a 20-in. aperture Clark-Saegmuller Refractor. The telescope first saw light in July of 1894, and is still used by scientists, students and visitors today. It is among the largest of its kind still in use in the United States. In this guidebook, we will explore some of the facets of this great Refractor telescope, tell stories about some of the people behind it, and explore the past and future of the University of Denver's historic Chamberlin Observatory.

The observatory is named after its patron, Humphrey B. Chamberlin, who pledged $50,000 in 1888 to see it built and equipped. Professor Herbert A. Howe, the astronomer at the University of Denver at that time, was responsible for overall design, instrument specification and installation. Alvan Clark & Sons of Cambridge, Mass., the foremost opticians of the day, crafted the lenses for the telescope. When it was made, the primary lens was priced at $1,000. Today, it is considered priceless. The mechanical mounting for the telescope was built by George N. Saegmuller, who owned and operated Fauth and Company instrument makers in Washington DC.

Humphrey Chamberlin was active in the Denver real estate business at the time, so Saegmuller and Clark both accepted land holdings as part of their payment. However, when the great Silver Panic of 1893 caused the bottom to drop out of the landowning business, Mr. Chamberlin went bankrupt and the properties offered to Saegmuller and Clark rapidly declined in value. Professor Howe paid Clark with his own cash and compensated Saegmuller by delaying delivery of his finished telescope for a time, personally assisting with its display at the Chicago Columbian Exposition of 1893. The telescope components and lenses were finally shipped to Denver by 1894. Howe was concerned for the safety of the 150-lb. lenses, so he personally transported it from Cambridge to Denver in a private train car.

Howe performed final assembly of the telescope at Chamberlin Observatory, in addition to his duties as Dean and professor at DU. The University assisted as much as it could in paying Clark and Saegmuller, but Howe had to pay some of the fees out of his own pocket.

Trial observations began on July 14, 1894, with "first light." This initial use of the telescope by Howe included observations of stars in the famed cluster M13 in Hercules and Earth's moon. The first public use of the telescope occurred on August 1 of the same year, when Howe entertained the Swedish Methodist Christian Endeavor Society with a look at Saturn. The telescope began its professional use in late fall. Observations of Mercury's passage across the face of the Sun (called a transit) were recorded on November 10 and 11. These observations were the first published results from the Chamberlin Observatory, printed in the Astronomical Journal in the spring of 1895.



Opposite Page Top
The University of Denver's historic Chamberlin Observatory, which houses Denver's great telescope under its 40 foot diameter dome, as it appeared in 1898 in a photo attributed to George Beam. Note that there were very few buildings in the surrounding area.
© Courtesy of University of Denver Penrose Archives

Opposite Page Left
The telescope and interior of the dome room as they appeared in the 1890's. The telescope is aimed southeast. [Howe, 1897]

Opposite Page Right
The south face of the University of Denver's historic Chamberlin Observatory, featuring the donor's name carved in stone. The dome and its slit mechanism, and a red sandstone archway above the double door main entrance to the observatory, can also be seen.

If the opportunity to visit Denver's great telescope arises, enjoy the view, and be sure to look for the following points of interest throughout the building:

MAIN FLOOR:
Portraits of Chamberlin, Howe, Recht and Everhart; Fauth pendulum clocks designed to keep civil and Sidereal time; the Bruce Micrometer; Transit telescope and library.

TELESCOPE ROOM:
The Clark-Saegmuller Refractor; photo displays; slit ropes and dome drive wheels; Saegmuller's Finder Circles; Observing ladder.

BASEMENT (access limited):
Main pier room; Transit pier room.

The Telescope's Journey to Denver

By March of 1888, soon after Mr. Chamberlin made his offer to build and equip an observatory for the University of Denver, Professor Howe began a search for the most important part of any observatory - the telescope.

Very quickly, Howe began receiving descriptions of equipment and price listings from various suppliers eager for the work. Howe came to the conclusion that the telescope best suited to the new observatory and budget would be one with a 20-in. lens, huge by the standards of the day. In the meantime, Chamberlin had visited lens manufacturers, including Alvan Clark & Sons. He considered this company too expensive, but it eventually got the work.

In July of 1888, Howe embarked on a train trip to visit observatories around the country. After stopping at a dozen major observatories and talking with a number of potential suppliers, Howe returned to Denver, having been gone for nearly six weeks.

Howe and Chamberlin continued negotiations with various sources until December, when it was decided that Saegmuller's company would build the mounting for the telescope, their price being best. Chamberlin bargained with Clark to lower their price. A contract was finally made with Clark in March for a 20-in. lens to place in the Saegmuller mounting, but it was not signed until April. Construction of the observatory building began soon after.

The 5,600-lb. tripod for the support of the telescope pillar arrived by train on May 1 of 1890. Howe picked it up at the station, where he was faced with a bill of $326, much more than he had been expecting. The tripod had been shipped in separate cases, causing the price to go up (it was eventually argued down to $88). Teamsters hauled the tripod to the observatory,

arriving on May 9. On May 12, the tripod was hoisted onto the pier and adjusted by Howe, assisted by Roeschlaub, for the next few days. It was finally bolted down on May 30.

In August 1891, Howe learned from Saegmuller that the supporting column of the telescope could be cast in Denver (avoiding shipping costs), and the contract was given to F.M. Davis. The pillar was installed in October 1891.

The final costs of the telescope came to $4,185: $3,000 for the telescope, $1,000 for the lens, and $185 for transportation costs. Howe and Chamberlin had to borrow money to cover these costs and were in debt for the mortgage on the observatory. Despite the challenges, the telescope saw its first light in July of 1894, when it was used to view stars in the great cluster in Hercules and Earth's moon.

Opposite Page
A view from the eyepiece end of the main telescope, showing the 5- and 6-inch diameter finder telescopes astride the main tube. The main telescope tube is 26 feet long and when in horizontal parking position, sits 19 feet above the floor.

Denver's great telescope is located at 2430 East Warren Avenue, Observatory Park in south Denver, at GPS coordinates Longitude 104˚ 57'10.8" W, Latitude 39˚ 40'33.8" N, Elevation 5417 ft. above sea level

Overall Length, Width, Height and Other Interesting Facts

Standing nearly 19 ft. tall, even with the main telescope tube parked horizontally, in a domed room that peaks at 32 ft. above floor level, it is easy to understand how the first sight of Denver's great telescope captures the imagination of most visitors, young and old. The major setting circle wheels range up to 4 ft. in diameter, the main polar shaft is close to 7 ft. long, and even the 6 ft. and 8 ft. finder telescopes look miniature next to the nearly 26 ft. long white main tube supporting the exquisite 20-in. aperture doublet lens. At the time of its completion, the great telescope was among the largest in the world.

To appreciate the times within which Denver's Great Refractor was being built, here are the existing great Refractor telescopes at the commencement of the project in 1888:

- Lick Observatory 36-in., Mt. Hamilton, California (1888)
- Cote d'Azur Observatory 30-in., Nice, France (1887)
- Pulkova Observatory 30-in., St. Petersburg, Russia (1885)
- Vienna Observatory 28-in., Vienna, Austria (1878)
- US Naval Observatory 26-in., Washington, D.C. (1873)

The following great Refractors were being completed during the six years (1888-1894) that Chamberlin Observatory and its telescope were under construction:

- Paris Observatory 33-in., Meudon, France (1891)
- Chamberlin Observatory 20-in., Denver, Colorado (1894)

This list of cities and institutions certainly placed Denver among world-class sites. Sadly, the Silver Crash of 1893 eclipsed the potential for Denver's great telescope by eliminating Mr. Chamberlin's plans to fully support its staffing and operation, and causing Professor Howe to struggle financially to keep the doors of the college open.

During the remaining years of the 19th century, Chamberlin Observatory was joined by the following giants:

- Yerkes Observatory 40-in., Williams Bay, Wisconsin (1897)
- Potsdam Observatory 32-in., Potsdam, Germany (1899)
- Archenhold Observatory 27-in., Berlin, Germany (1896)

Throughout the first two decades of the 20th century, great Refractor telescopes were completed at Lowell, Allegheny and Johannesburg observatories, among others. However, these were quickly superceded by the mammoth 60 and 100-in. Reflectors built at Mt. Wilson, California in the early years of the 20th century.

Opposite Page Top Left
Professor Howe at the lens of the telescope, circa 1895. The lens is 20 inches across, and the telescope was among the largest in the world at the time of its completion.
© Courtesy of University of Denver Penrose Archives

Opposite Page Bottom
This view of Denver's great telescope shows it aimed due south, with the counterweights and large Declination circle seen prominently in the foreground.
© Courtesy of University of Denver Penrose Archives

Telescope Vitals

Aperture and Focal Length

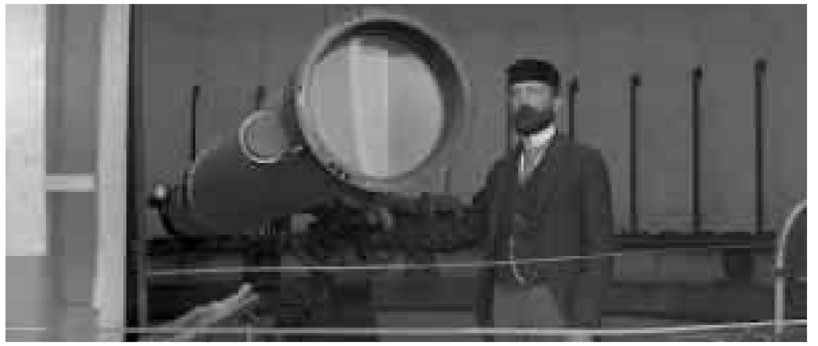
Telescopes are characterized by two key parameters: aperture and focal length. Aperture refers to the diameter of the main optical component. In the case of the Great Refractor at the University of Denver's historic Chamberlin Observatory, this is the 20-in. (50 cm) diameter lens that sits in the top of the tube. Focal length is much like it sounds - focus length: how far from the lens will an image focus? In the case of the Chamberlin Refractor, this is 300-in., which explains the length of the tube between lens and viewing eyepiece: 28 ft. or nearly 7.5 meters. The ratio of focal length to aperture is called an f-number, 300-in./20-in., or f/15 in this case.

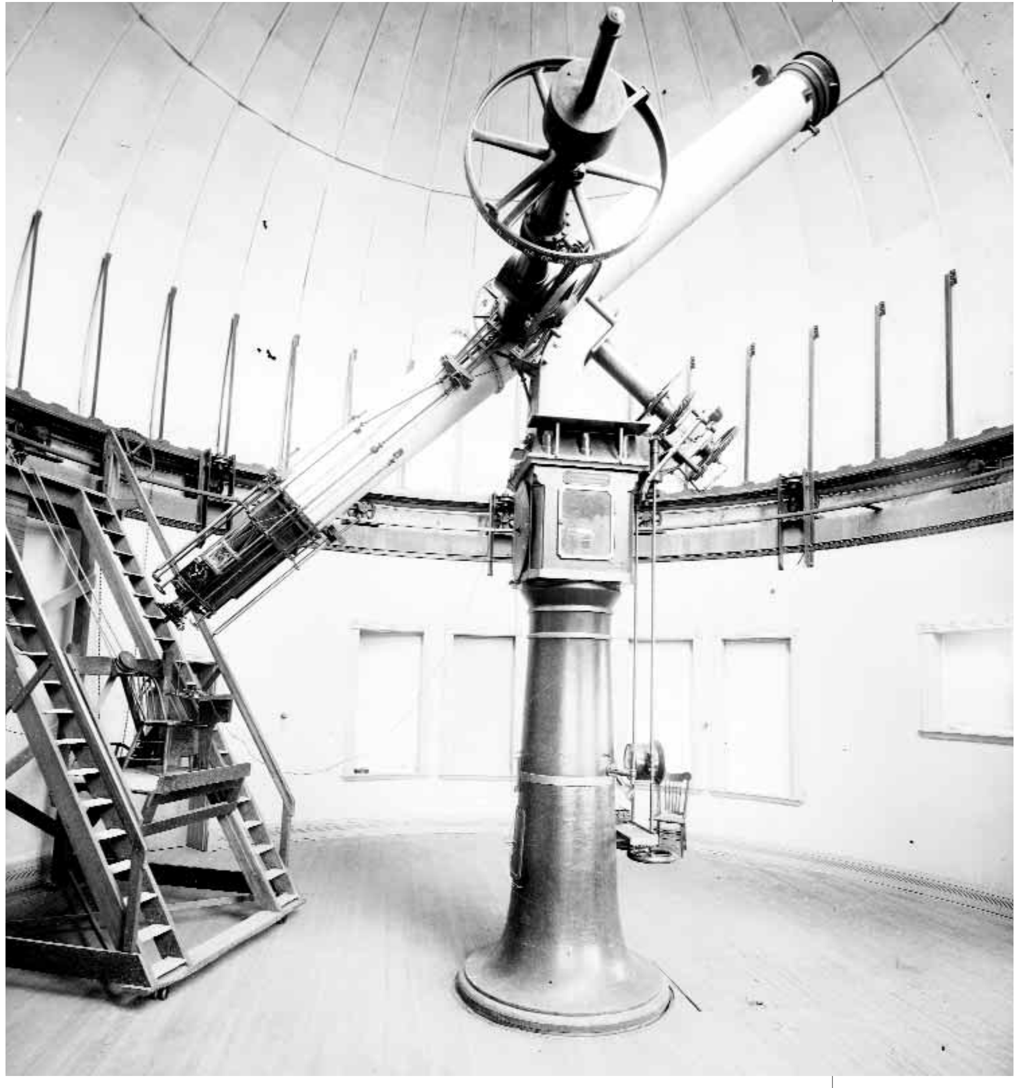
Astronomical lenses of the times were typically doublets. The advantage of a double lens - two pieces of finely shaped glass made of slightly differing types of glass - is that the pair compensates for the slightly color-dependent focus for each lens. A single lens, such as a glass prism, tends to spread out the light out into component colors (Red, Orange, Yellow, Green, Blue, Violet). This differential behavior in glass, water and even in air, is called refraction. In single lenses, such as a magnifying glass, this prismatic spread is called chromatic aberration. In a doublet, correction for chromatic aberration is achieved over most of the rainbow, except the blue and red ends. This results in a purplish halo seen in the eyepiece around the brightest objects, such as planets. Superior color correction can be achieved with triplet lenses and the like, as is found in modern refractors, but the cost quickly escalates.

One frequently asked question concerns magnification with telescopes. Marketing telescopes on magnification alone can be misleading. One rule of thumb is, no more than about 50x per in. of aperture. For a 20-in. aperture, that's about 1000x at maximum. For a more common 8 or 10-in. telescope, less than 500x is enough. Why? Over-magnification exaggerates both atmospheric turbulence as well as optical imperfections, decreasing the quality of the view. Magnification is actually another ratio: the focal length of the main optic divided by the focal length of the eyepiece. Typical eyepieces have focal lengths around 1-in. (25 mm). In the case of the great Denver telescope, a 1-in. focal length eyepiece delivers 300x magnification (300 in. focal length of the doublet lens divided by 1-in. focal length of the eyepiece). This is a basic explanation of the parameters of common optical devices, such as binoculars: e.g. 7 x 50 refers to 7x and 50mm apertures. For more information, see the References and Suggested Readings at the end of this book, or contact your local astronomer.

Types of Telescopes

The telescope is an invention only four centuries old. Galileo's improvement of the simple lens-type telescope enabled him to discover the rings of Saturn, craters on the moon, sunspots and most important, the major satellites of Jupiter - still called the Galilean satellites in his honor. This provided





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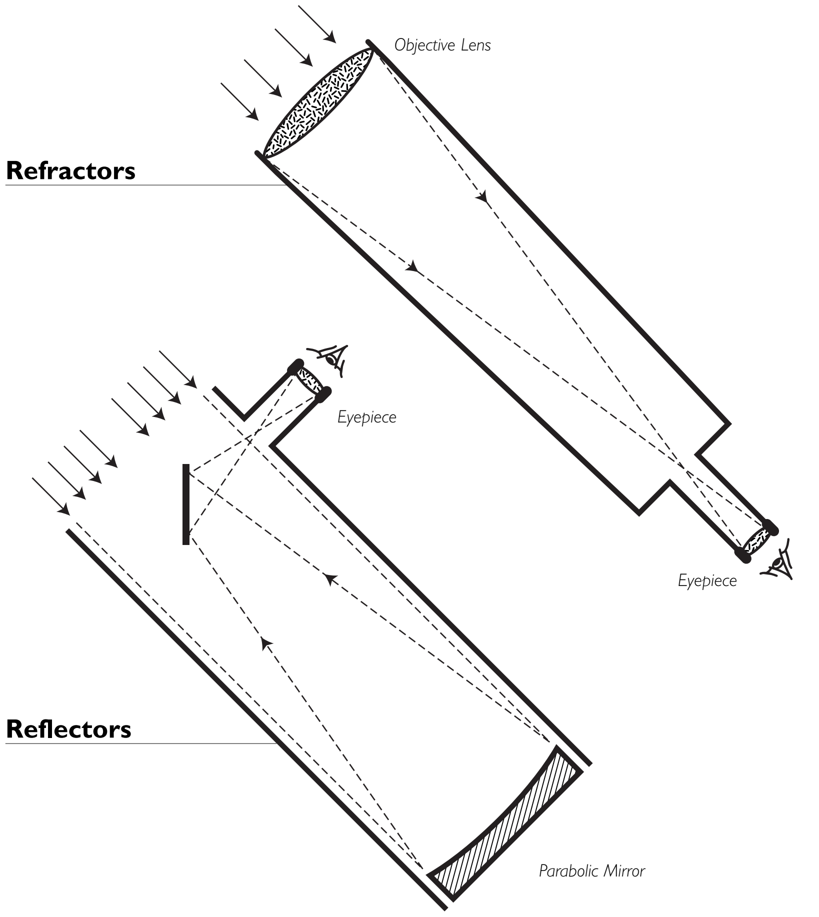
Facing Page
The two main types of telescopes are reflectors and refractors. Reflectors use mirrors to bounce the image into the eyepiece lens. Refractors, like the Chamberlin telescope, use multiple lenses to bend light and magnify.

Opposite Page
An interesting mid-century view of the refractor looking through the dome slit, with photographic guide telescope attached. © Courtesy of University of Denver Penrose Archives



evidence that the Earth orbits the sun, just as the Galilean satellites orbit more massive Jupiter. Galileo's early telescope was made using a pair of simple lenses separated by a few feet, and it achieved only 3 power magnification (3x). Lens-type telescopes are called Refractors because they bend light in lenses to magnify. In the great Refractors, the same principle applies: the large doublet lens in front refracts and bends the light down the tube to a point where the eyepiece lenses can image the view. Eyepiece lenses can be simple or compound sets of glass.

Later in the same century as Galileo, Isaac Newton described and built the first reflector telescope using a curved mirror rather than just lenses. A curved mirror, much like a cosmetic or shaving mirror, collects and magnifies light by changing the path of incoming light along its surface and bouncing it back to an eyepiece lens. The same aperture and focal length parameters mentioned earlier apply, giving similar magnification ratios. Mirror type telescopes are called reflectors because they bounce light off

curved surfaces to achieve magnification. The Newtonian is only one of several telescope designs that use mirrors.

An endless argument continues about which type is better. Reflectors often have a central obscuration that reduces contrast and crispness of view compared with refractors, but reflectors can be made much larger than any refractor because the main optic can be supported from underneath. The latest reflectors are up to 11 meters in diameter, while the biggest Refractor ever made was the Yerkes 40-in. (1 meter) built in 1897.

A great deal of human ingenuity has gone into improving optical designs of both types of telescopes, although no telescope is completely free of defects (called optical aberrations). People with corrective lenses know some of these: astigmatism, distortions, chromatic aberration, coma, the list goes on. Compound lenses and lens plus mirror combinations can achieve excellent images, but sometimes at an astronomical expense.

Opposite Page
People interested in purchasing telescopes for private use can start small. Binoculars are a good starting point, and small, portable telescopes, such as the 10 inch reflector and 80 mm refractor pictured, can offer excellent observing in bright and dark locations.

Notes on Purchasing a Telescope

For those interested in telescopes, here's some general advice:

First, small is beautiful - binoculars are an affordable and versatile "starter telescope" that will deliver excellent views in a dark sky location. Plus, they resolve lunar features and moons around Jupiter, and they are useful for daytime views as well. With a tripod and bracket, one can set these up and share a stable view of day and night vistas.

Second, get to know local astronomers - professional and/or amateur - and learn from them about telescopes. Colleges, observatories and planetarium facilities often have personnel who can provide free information, and sometimes classes, on what counts in telescope selection. Astronomy clubs often host viewing sessions open to the public where visitors can see and look through a variety of small, portable telescopes, plus talk with the owners about what they like and dislike.

Third, a rule of thumb: US$100 or more per in. of aperture for smaller telescopes with quality optics. Equally important is a sturdy mount. Less important are the bells and whistles, such as computer control.

Buyers should work with a reputable dealer or become familiar with a variety of telescopes before making an investment that will meet their needs and not end up collecting dust in a closet or storage area.

Ideally, one will learn what's in the sky and not be dependent on computer pointing (programs that show the locations of stars). Also, one will learn that light pollution can be defeated, by spreading the word about energy efficiency and smarter lighting. For more information, see the Suggested Readings at the end of this book.

"It is always a delight to have an idea grow into a fact, so I shall take great pleasure in the building and equipment of the observatory... It is my ardent hope that much pleasure and profit may come to the students of the University of Denver, and to our Colorado citizens generally, from the sight which will here be possible of the great universe..."

- Humphrey B. Chamberlin

Origins

Opposite Page Top
The south face of Chamberlin Observatory, in Observatory Park in south Denver. Humphrey Barker Chamberlin offered to build this observatory for the University of Denver in 1888. The building was largely complete by 1892 and the telescope has been operational since 1894.

Opposite Page Bottom
Alvan Clark, Sr., owner of the lensmaking firm Alvan Clark and Sons of Cambridge, Mass. Clark's company, later led by Alvan G. Clark, provided the lens for Chamberlin Observatory a few years after the elder Alvan Clark's death. [Howe, 1897].

Chamberlin Offers to Build an Observatory

After the University of Denver's Chapel Hour ended on February 7, 1888, Professor Herbert Alonzo Howe was called into the Chancellor's office, where an anonymous letter had arrived. The mysterious letter contained an offer to build and equip a new observatory for the university. The author of the letter asked that plans for the building and instruments be prepared. Professor Howe, being the only university employee with astronomical expertise, was chosen to design the observatory.

Howe worked in his spare time to produce a plan in four days. Within this time, the local newspaper caught wind of the news and reported that an anonymous gentleman would be funding the first building built in the newly designated University Park. Within 10 days of the newspaper story, it came to light that the "anonymous gentleman" was in fact Humphrey Barker Chamberlin, a local land developer, businessman and amateur scientist. Plans and specifications were sent to Chamberlin, who became the project manager for the planned observatory.

Chamberlin was often away on business, attempting to interest Easterners in buying Colorado land. While on these trips, he also visited observatories in the East to gain ideas and figure out costs. In March of 1888, Chamberlin wrote to Howe, asking him what size telescope he desired for the new observatory. He also suggested that Howe should personally visit some of the observatories, to inspect the design and instrumentation.

One of the few sources of Mr. Chamberlin's own words is the account at groundbreaking published in the Denver Daily News, June 4, 1888, which reads in part: "It is always a delight to have an idea grow into a fact, and so I shall take great pleasure in the building and the equipment of the observatory. The site is fully one thousand feet higher than that occupied by any large telescope yet mounted. From this fact and the favorable atmospheric conditions, I look for important contributions to astronomical science."

Making the Lens: Alvan Clark's Story

The firm, Alvan Clark & Sons, was famous for high-quality object glasses, having created a 36-in. lens for California's Lick Observatory and later a 40-in. lens for the University of Chicago's Yerkes Observatory, located at Lake Geneva, Wisconsin. Despite their work with observatories and production of high-quality products, the company was fairly small and did not have the extensive history of other machine shops of the time.

Alvan Clark, born in Ashfield, Massachusetts in 1804, initially worked as a wagon maker. He eventually became interested in drawing and engraving, in addition to painting portraits, for which he received an income. He ultimately got a job engraving printing cylinders. He married Maria Pease in

Opposite Page
The massive German Equatorial mount for the telescope, built by George N. Saegmuller of Fauth and Company of Washington, D.C.

1826, and became the manager of a branch of the engraving business in Providence, Rhode Island the following year. The family moved twice more, once to New York City, and then to Fall River, Massachusetts in 1832. Clark continued his interest in portraits and the study of art while working as an engraver and manager of an engraving shop. His study of art gave him an exceptional awareness for detail and allowed him to eventually make a living solely by painting portraits.

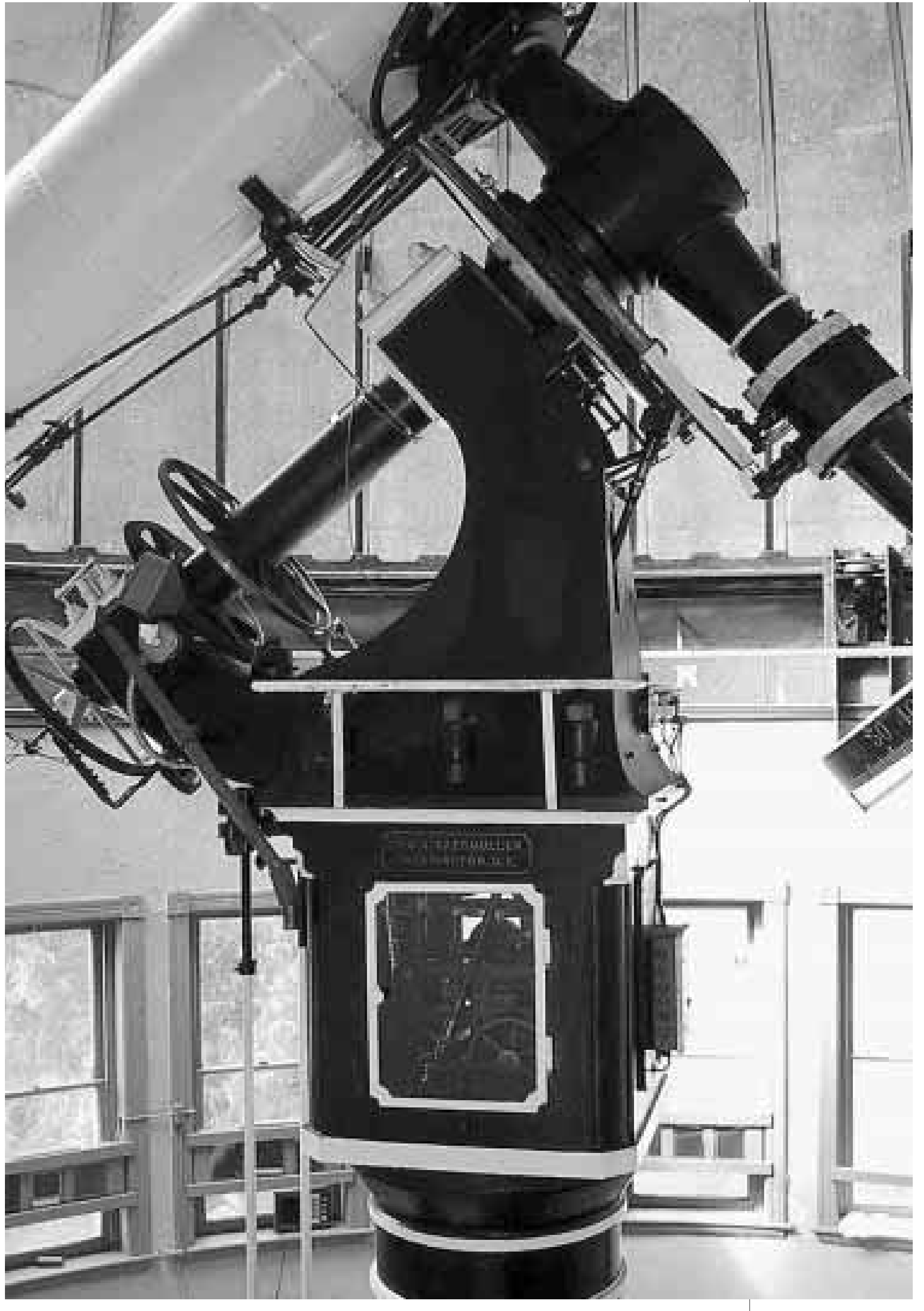
The family moved again in 1836, this time to Cambridgeport, Massachusetts. He opened a studio in Boston, where he painted portraits of the local residents, as well as the celebrities of the day. By the 1850s, photography became a rival for Clark's realistic portrait style, but he kept his studio open until 1860. At this point, Clark began the Alvan Clark & Sons telescope business, and worked with his sons to create better telescope optics. Clark visited the Harvard Observatory and pointed out slight errors in the European-made lens. He sold his first telescope, a 5-in. refractor, to a teacher of English and Science in 1848. He was awarded an honorary Master of Arts degree in 1854 by Amherst College for his lens making, observing and reporting.

Alvan Clark & Sons broke size records with their larger lenses, but they also produced smaller instruments for personal use by telescope enthusiasts. Alvan Clark passed away at the age of 83 in 1887, a few years before Chamberlin would request a lens from the company. At this point, the firm began to sub-contract much of the mount making work to two companies, Fauth and Warner Swasey. The latter built the mount for the 40-in. Yerkes telescope, in which Alvan Graham Clark installed the lens in 1897. As of this time, the 40-in. Yerkes lens remains the largest object glass in use in the world.

The Telescope Mounting: George Saegmuller's Story

The mechanical portion of Denver's great Refractor was designed and built by George Nicholas Saegmuller in Washington DC. He was born in 1847 in Nürnberg, Germany. During his youth, he learned the trades of instrument maker and machinist, in addition to instrument design. When he moved to the United States in 1870 at age 23, he gained employment in New York City where he made models used for obtaining patents. Soon after, he moved to Washington, D.C., where he began work for the Wurdemann Instrument Shop. At the shop, he became acquainted with the US Coast and Geodetic Survey (USCGS) organization, at which he eventually went to work as chief of the instrument shop.

While working with the USCGS, Saegmuller joined with Camill Fauth and Henry Lockwood to form a company that produced instrument design and manufacturing. The company was called Fauth, and Saegmuller was in charge of the design and sales effort. Saegmuller eventually left USCGS to devote



Opposite Page Top
The stone pier, which supports the telescope mounting. The pier is made of red sandstone suppied by the Kimball stone company, and stands 25 feet tall. The quarry drill marks and tuckpoint beadwork are still easily seen up close.

Opposite Page Bottom
A rare photo taken June 23, 1890 by Professor Howe, of the construction of the basement walls and central pier. Looking southeast. The ladder rests against the short cast iron "tripod" which would eventually support the telescope assembly. © Courtesy of University of Denver Penrose Archives

himself full time to Fauth, which was a very successful business. Saegmuller created larger and better telescopes and instruments, using the Fauth name.

Saegmuller won the contract for the Chamberlin telescope mounting by allowing Mr. Chamberlin to pay in Denver real estate, rather than in money. This caused a problem when real estate values plummeted during the Silver Panic of 1893. Despite the money problems, Saegmuller worked closely with Howe in future years, fixing malfunctions personally and furnishing other instruments for the observatory.

By 1894, Saegmuller informed Howe that he would need $3,000 to complete the telescope mount. Howe did not have the money to pay the fee, but Saegmuller provided him with some free advice and assistance in how to illuminate parts of the telescope, because electric lighting had not been part of the original design. Howe finished the work himself.

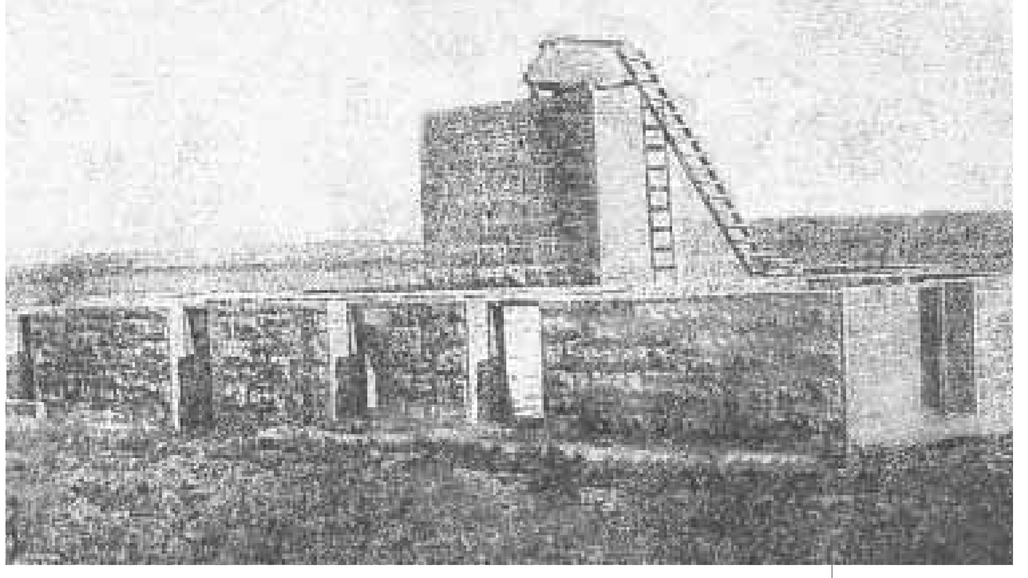
After the completion of the Chamberlin telescope, Saegmuller continued to do business in Washington, D.C., both under the Fauth name and his own. He created an extensive line of telescopes and other instruments, and worked with universities and government agencies, particularly the Navy. He moved to Rochester, N.Y., in 1905 to join with Bausch and Lomb. While working in Rochester, Saegmuller kept in touch with Howe and personally repaired parts and instruments that he had created for the Chamberlin observatory.

TELESCOPE MACHINERY - STATIC PARTS

The Pier

The massive stone base, also called the pier, occupies much of the central volume of the observatory. It supports the telescope and was built along with but isolated from the foundations of the observatory building. The base is built from the same red sandstone as the rest of the observatory, strengthened by concrete. It begins 12 ft. below grade and is 25 ft. tall, with 16 ft. sides at its base and 12 ft. sides at its top just below the observing room floor. The core was backfilled, and it is topped with large stones. Professor Howe estimated the total weight at 320 tons.

The capstones were built atop the stone pier, made of the same type of stone as the outside walls of the observatory. The stone came from the Kimball stone company, a local quarry. The stones were delivered by rail, being too large to carry in a carriage or cart. In 1889, when the work on the stone pier was beginning, there was a misunderstanding regarding the building materials. Five large stones were delivered to University Park to build the pier, but were mistakenly taken to the University Hall building where they were cut into lintels. Replacing the large stones would take two weeks, between mining and shipping. Instead of waiting, and further delaying the con-



Opposite Page Top
Schematic of the telescope and its support system, identifying key elements.

Opposite Page Bottom
View of the underfloor "tripod" that supports the telescope. The structure features three adjustable footpads. The writing is the original shipping address, handling information and the name of the railroad that handled the parts.

struction of the observatory, Howe allowed the builders to use three large stones and six smaller stones as capstones for the pier, rather than the two large ones that they had lost.

The Tripod

Atop the stone pier but below the observing room floor is a massive iron three-legged stand that support the telescope, surrounded by a galvanized iron "apron" for extra support. The overall weight of the tripod, its feet and rock anchors is over 5,600 lbs.

This "tripod" arrived by freight in Denver on May 1, 1890. Professor Howe was surprised at the high shipping bill ($326), but it was eventually reduced to $88.

Teamsters hauled the tripod into place, finally arriving at the observatory on May 9. The following day, Professor Howe surveyed and marked the proper positions for the base, which would sit atop the pier. The base was hoisted onto the pier on May 12. Howe spent the following day adjusting it, assisted by Mr. Roeschlaub, the architect. The two of them used a large wrench (almost 5 ft. tall) to turn the large nuts of the base, and to position and tighten the iron plates. By May 14, the cement was poured into the boltholes, and the tripod was finally fastened down with Howe's assistance on May 30, 1890, but it would still be years before the telescope itself arrived. Howe notes obtaining a photograph of the observatory when, on June 23, 1890, he "took a couple of photographs of the tripod and pier."

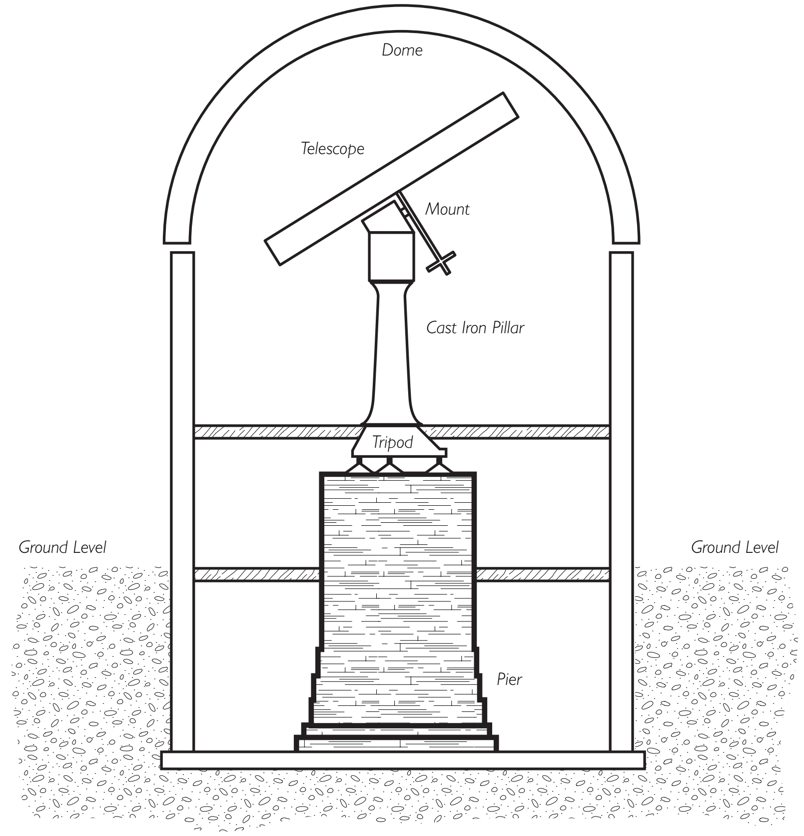
The Cast Iron Pillar

The tall black main pillar supports the equatorial headstock upon which the moving portions of the telescope sit. The pier is made of two iron castings, each weighing over 4,500 lbs., or 9,000 lbs. together.

The pillar was cast in 1891 in Denver by local firm F.M. Davis, which had made the lowest bid. It was cast in about two weeks and was inspected on August 31 by Howe and Roeschlaub, who found it quite acceptable. The lower casting was delivered to the observatory by rail on October 12th. At this point, the dome of the observatory had been attached, and the only way to get the pillar pieces into the dome room was to lower them through the shutter of the dome. There were no mechanical cranes that could be used to lift the heavy pillar, so it was all done with muscle power, winching it up through a hole in the floor over the south entrance.

The following day, it was set into place, but not before breaking one of the supporting ropes and swinging into a scaffold. It was soon discovered that the top and bottom parts of the pier did not fit together exactly. By Howe's calculation, the pieces were 1/32nd of an inch apart. This was overcome, in Howe's words, "by the use of a sledge and bolts." After the pillar was in place, Howe spent hours cleaning off the lime dust that coated it.

Telescope Support System



Opposite Page
The tall, black cast-iron pillar on the left supports the tube of the telescope. The pillar weighs 9,000 lbs. In this image, which appeared in the 1939 DU yearbook, two observers stand at the instruments around the pillar, and two on the observing ladder.
© Courtesy of University of Denver Penrose Archives

TELESCOPE MACHINERY - MOVING PARTS

The Equatorial Head

The equatorial head sits at the top of the pier, holding the "tube" part of the telescope in place. The head allows the telescope to swivel on its base and position itself on any section of the sky.

This type of mounting is called a German Equatorial mount. It enables the telescope to move in longitude- and latitude-like motions called Right Ascension and Declination.

Objects in the sky are assigned individual Right Ascension (R.A.) and Declination (Dec.) coordinates. For example, Betelgeuse sits at 5 hours 55 minutes by +7 degrees 24 minutes. The coordinate system has its origin at the point above the equator of Earth where the sun crosses north annually at the spring equinox. Right Ascension is reckoned in hours from 0 to 23 hours, 59 minutes, 59 seconds toward the east. Declination is reckoned in degrees north or south of the equator, from 0 to 90 degrees in each direction. From Denver, everything above 50 degrees north Declination is circumpolar and visible all night long. Everything south of 50 degrees south Declination can never be seen from Denver. In between, we see the stars rise and set.

Facing the telescope control dials, the right-left, east-west motions of the telescope tube follow lines of Right Ascension across the sky in circles around the North Pole direction. These movements are initiated with the right hand wheel under the dials and tracked by the indicators on the Star Wheel (see below). The perpendicular, north-south Declination motions of the tube are initiated with the left hand wheel under the dials and similarly tracked by indicators. "Digital protractors" called encoders are also used to provide a signal from the rotating shafts that support tube motion, to provide input to a computer sky map to augment pointing.

A special kind of time called Sidereal helps observers keep track of what stars are available for viewing. Sidereal time refers to the Right Ascension of stars on the Meridian line at a given moment. The Meridian line is a great circle from the south point on the horizon up through the top of the sky and over to the north horizon point, dividing the sky into east and west hemispheres. Though the Meridian may not sound familiar, it is used when telling time: a.m. and p.m. refer to whether the sun is antemeridiam or postmeridiam. Noon in civil time refers to the average moment the sun crosses the Meridian. In spring, Sidereal time is approximately 12 hours different from civil clock time, so that Orion near six hours R.A. can be seen due south about 6 p.m. In early fall, Sidereal time is approximately the civil clock time, so that Sagittarius near 18 hours R.A. can be seen toward the southwest after sunset (6 p.m. = 1800).

Facing Page Left
The equatorial mount detail, which indicates how the telescope can swivel in celestial longitude and latitude movements. These movements are called, respectively, Right Ascension [east-west] and Declination [north-south].

Facing Page Right
The clock drive, which compensates for the rotation of the Earth, allowing the telescope to correctly follow the movements of stars. The clock drive, originally weight driven, was upgraded with an electrical motor in 1977.

Opposite Page
Another rare photo taken June 6, 1891 by Professor Howe, of the construction of the forty foot diameter dome. Looking northeast. Note the extensive scaffolding. © Courtesy of University of Denver Penrose Archives

The Clock Drive

Many visitors inquire about the spinning wheels in the glass case near the center of the telescope support. Those moving parts are the "governor weights" of the clock drive mechanism. They are key to the telescope's useful operation because they move the telescope forward to follow stars by compensating for the rotation of the Earth itself. Just as the sun and moon rise and set daily, so do the fixed stars because the Earth spins, changing our view direction in the cosmos on a regular 24-hour cycle.

As originally built, the clock drive motor was weight-driven, much like windup "grandfather" clocks. As Professor Howe described it, a Young's double conical pendulum (centripetal regulator) was used, with the addition of electrical contacts for synchronization with the Sidereal time clock and chronometer recording (see below). The pendulum makes two revolutions per Sidereal second. An electric motor for winding the clock was originally contemplated as well (installed in 1910), and in winter, warm air from the rooms below can be admitted up inside the cast iron pillar to warm the clock mechanical parts.

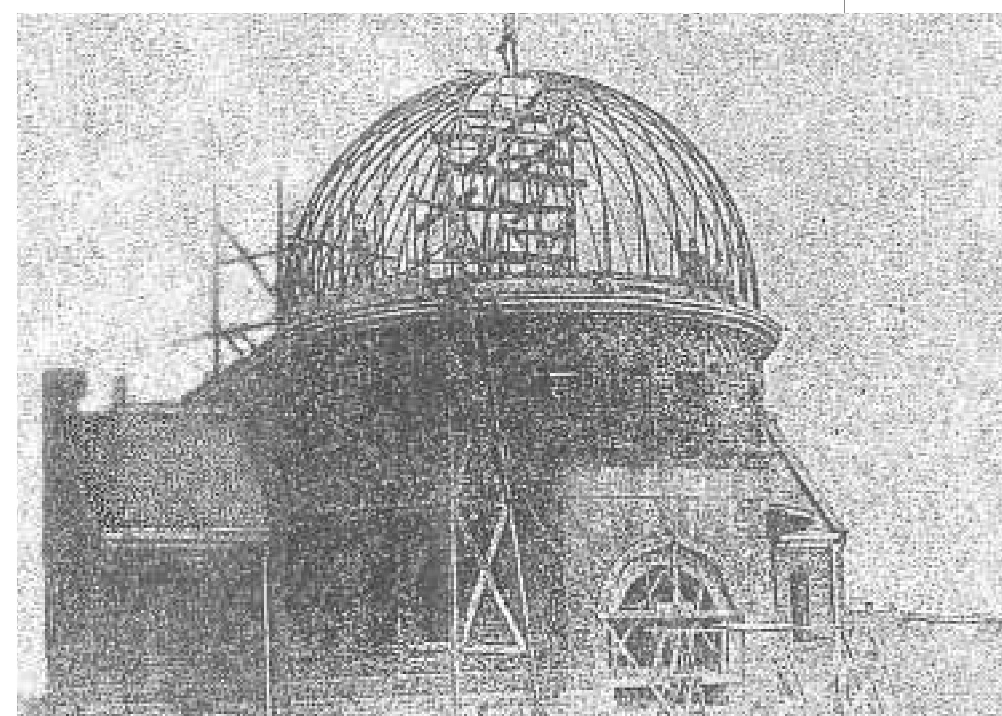
During Professor Everhart's tenure as Director, the fully mechanical clock was upgraded with a synchronized electrical motor in 1977.

The Dome

To ensure quality in the dome for the observatory, Howe visited other observatories and investigated the construction of their domes. Howe had a difficult time deciding on the material that should be used. Some of the possibilities included wood, metal and even paper. He spent many hours calculating weight, cost and durability of different materials, eventually deciding that metal was the way to go.

By Thanksgiving of 1889, excavation for the circle for the dome was begun. In early December, Howe utilized his surveying skills to locate the center of the dome so that the workers could begin building the surrounding walls. On January 22, 1890 he received a letter from a Mr. Scherzer, saying that Chamberlin had awarded his company the contract for the dome. Howe received blueprints from Scherzer by the end of the month. The blueprints were given to the architect and construction on the base began.

The dome for the large observatory was delivered to University Park in August 1890 and the skeleton for the small dome was begun. Unfortunately, the iron parts of the large dome were left on the construction site with no protection. By October 1890, Howe was fed up with this, and he spent more than eight hours moving the three tons of iron into a shed. He covered the dome parts with canvas for extra protection, but the canvas was soon stolen.



Howe and a number of workers laid out the dome base and boltholes on May 8, 1891. The tracks were installed on May 13, and the radial adjustment of the wheels completed on May 16. The ribs of the dome were all in place by May 27, despite a few days of snow and rain. Unfortunately, the shutter did not quite fit straight when it was first built, but shortening one of the dome's ribs rectified the problem. On June 6, 1891 Howe reports that he "took short exposure photographs of the dome." The galvanized iron was put into place by June 18. The dome was nearly completed.

Opposite Page Left
The Star Dial, which sets the ascension and declination of the telescope. The central instrument serves as an analog computer in aiming the telescope and was designed by George Saegmuller. Electric clocks above the StarDial keep track of Local, Greenwich and Sidereal times. In recent years, a laptop computer with Sky software provides computer assistance and extensive data for the observers as well.

Opposite Page Right
The Declination circle, one of important tools used to set the north-south angle of the telescope to properly view stars. This axis also carries large counterweights that balance the 26 foot long telescope tube and finders, so that motions in the Right Ascension axis are smooth.

Opposite Page Bottom
The analog "Finding Circles" computer designed in 1888 by George Saegmuller, installed on Denver's great telescope at the University of Denver's historic Chamberlin Observatory. These wheels and pointers help aim the telescope.

After the iron was placed on the dome, it had to be adjusted to work out all the wrinkles in the metal. Once this was finished, it was discovered that the rotation of the dome did not work as smoothly as it should. This problem was difficult to correct and took until September to do so. After the mechanical kinks were worked out, it was time to paint the dome. It was decided that the dome should be white, and painting was finished over a few days.

Howe spent Thanksgiving of 1891 checking the driving mechanism of the dome. He discovered that a complete rotation of the dome took 50 seconds. The dome was refurbished with new lead seals and paint in 1997, among other building repairs, partially funded with a grant from the Colorado Historical Society.

Clocks and Dials

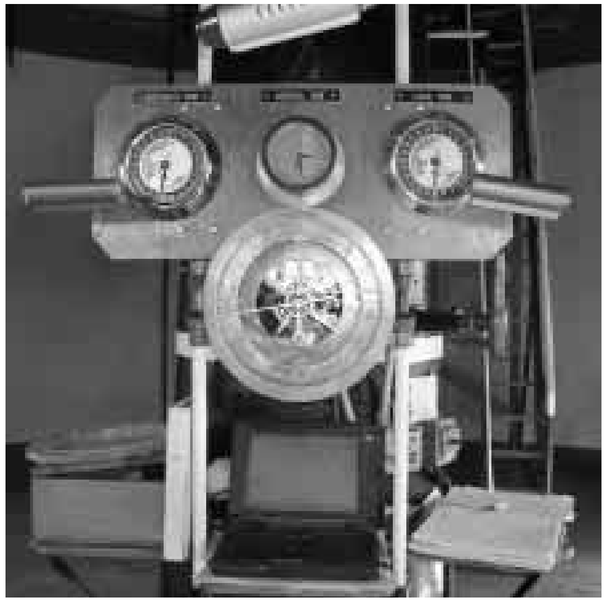
The clocks and dials of the observatory were the subject of a great deal of deliberation on Howe's part. Even before deciding on the architect of the observatory, Howe visited and investigated many companies. He eventually decided to get clocks from Saegmuller and Fauth.

One of the most important clocks in the observatory sat inside the telescope mount. The weight-driven clock mechanism kept the telescope focused on a particular point in the sky, making adjustments against the rotation of the Earth. The clock-driven mechanism has been replaced by an electrical one.

The time-keeping clocks of Chamberlin consist of a Sidereal clock attached to the pedestal of the telescope, and two four-legged astronomical regulators located on the main floor. One displays civil or solar time, the time that is used on a regular basis. The other displays Sidereal time, which measures the rotation of the Earth in relation to the stars. The clocks' designer is designated by a small manufacturer's seal on their faces, which reads "FAUTH & CO. WASHN D.C."

The clock that sits on the telescope's pedestal is printed with 24-hour Roman numerals and graduated with 5-minute marks. Two hands are pointers, one for setting the Right Ascension of the telescope, the other to set the Declination on the fixed outer chapter graduated in degrees. Saegmuller, the designer of this Star Dial clock with its eight-day windup mechanism, battled with Simon Newcombe, Director of the US Naval Observatory, over patent rights to its design. Saegmuller also designed two weight-driven drum chronographs that also sit in the observatory. Unfortunately, these chronographs have missing pieces, and no longer work, but they can be restored.

The two grandfather-style clocks on the main floor, plus the telescope clock, all manufactured by Saegmuller (Fauth) circa 1890, have recently become functional again, thanks to local members of the National Association of Watch and Clock Collectors — Al Baumbach and Bill



Dillon. The classroom clocks are anchored into the main pier for stability, and track civil and Sidereal time, respectively. The telescope clock tracks Sidereal time as part of the Star Wheel feature of the Saegmueller designed mount. All three clocks have 7-day windup weights or springs, which means it takes regular activity to keep them running. They all were subjected to well-meaning but inept amateur maintenance and repair over the past one to two decades, resulting in a sludge of dirty oil and mangled gear wheel repair attempts. The clock experts needed to take the innards to their clock shops and carefully clean and repair the mess, and in one case make from scratch a replacement piece. With a clean bill of health and a set of maintenance pointers, there is hope that these clocks will tick well into the new century.

Facing Page
The Bruce Micrometer, named for Catherine Bruce of New York, who donated funds for the instrument to the observatory in 1899. The micrometer is used to accurately measure the positions of asteroids, comets, double stars and even faint nebulae.

Opposite Page
The photometer is used to specifically measure the brightness of stars using electronic measurements rather than visual ones. Here, a student in the 1950's uses the photometer to locate and record brightness from a celestial object.
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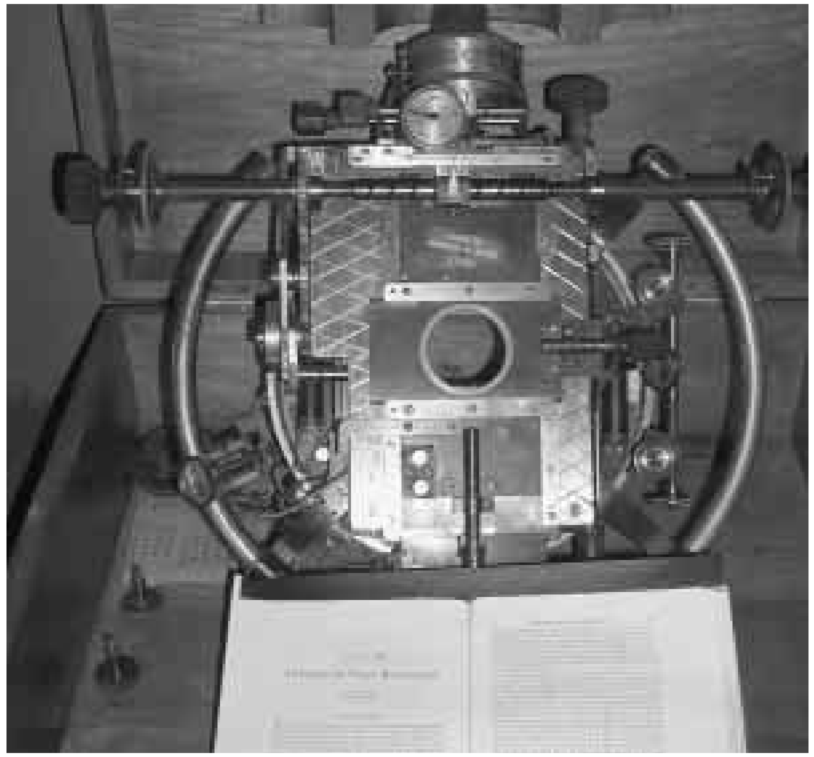

Focal Plane Instruments

A focal plane instrument is simply the sensor that sits at the eyepiece end of the telescope. The human eye is the most basic and universal of all astronomical sensors. Used for "visual astronomy" for centuries, many important discoveries have been made by the unassisted human eye. The well-known magnitude system for star brightness is based on our visual response to light. Professor Howe himself used visual astronomy to track the asteroid Eros in 1899, along with reporting numerous positions of nebulae.

Astrometry, the measurement of star positions based on a celestial coordinate system, has been in use since the days of visual astronomy, though it is a more precise science with the use of the telescope. The observatory's Bruce Micrometer, an instrument meant to assist in the position measuring of faint nebulae, was built in 1899. It was a surprising and generous donation from Miss Catherine Bruce of New York, an acquaintance of Chamberlin's. The micrometer allows the observers to measure positions for the stars or nebulae of interest by comparing previous observations of catalogued stars, and measuring the small x, y offsets to the location of the object being measured.

Photography was primitive in the 1880s and few people knew anything about it, but astronomers were beginning to realize that photographic skills

Opposite Page Top
The 5-inch finder telescope, one of two, is attached to the side of the main telescope. The telescope was used by Howe before Chamberlin observatory was built, in a makeshift observatory constructed on the roof of the University's Preparatory Building (then located in downtown Denver).

Opposite Page Bottom
A close up of the reverse side of the 5-inch refractor shows the balance of the engraved words "Alvan Clark & Sons 1882, Cambridgeport, Mass."

would be valuable to them. At that time, Howe designed photographic capability into the new telescope, and the end of December 1888 found Professor Howe on an eclipse-viewing trip to Winnemucca, Nevada, paid for by H.B. Chamberlin. The eclipse of the sun, which about 20 astronomers had traveled to Nevada to observe, came off in the early afternoon on Tuesday, January 1, 1889, and some good photographic observations were obtained. The first clear photographs of the moon were taken with the 20-in. instrument on January 16, 1902. Over the decade, comets, planets and starfields were photographed, with a few surviving glass plates in evidence. The most noteworthy attempt at photography came in 1918. In March, Dr. Schlesinger, Director of Allegheny Observatory, contacted Howe. Schlessinger wanted to attach a 60-lb. camera for star photography to the observatory's 20-in. Refractor to photograph the June 1918 solar eclipse predicted over Denver. Small displacements in stellar positions around the sun had been predicted by Einstein's new theory of relativity, and this was a chance to test the theory. Unfortunately, clouds prevented the effort. Later, Professor Recht would publish photos of the March 1932 lunar eclipse.

The practice of photometry replaced visual estimates of star positions and magnitudes by the middle of the 20th century, with specific repeatable electronic measurements. Both digital and film photography are used in the practice of photometry. Photometers began appearing at Chamberlin Observatory as early as the 1950s. The Charge Coupled Device, or CCD camera, is a modern digital camera used for astronomical imaging, astrometry and photometry, and these have seen some use at Chamberlin since the late 1990s.

The Finder Telescopes

The story of the main telescope's two "finder telescopes," telescopes smaller than the 20-in., began with Professor Howe's acquisition of the 5-in. telescope. The little telescope was purchased from a man in Milwaukee for $850 in 1883. This lead to the construction of a small, temporary observatory on the roof of the Junior Preparatory Building, which was one of the university buildings. It was located in downtown Denver, and today is the Denver Center for Performing Arts site. Professor Howe raised the funds with pledges, starting the long tradition of DU observatory sponsorship by individuals. This brass 5-in. aperture Refractor is engraved with the words, "Alvan Clark & Sons 1882, Cambridgeport, Mass." First light occurred on December 8, 1883, three years after his first astronomy lectures in Denver. Sponsors were treated to views on the first-ever public viewing night, on March 1, 1884. Thereafter, all manner of celestial phenomena brought visitors to Professor Howe and his telescope.

The observatory's other finder telescope, a 6-in., belonged to Howe before plans to build an observatory had begun. The telescope, made by the Grubb Company, was precious to Howe, and it was difficult to get him to part with it, though other scientists attempted to borrow the telescope. It was eventually used as the main telescope in the smaller Student Observatory, which sits next to the larger

Opposite Page
The observing ladder was designed by Howe, who had originally wished to have a hanging platform. The original ladder is still in use today, and remains sturdy and workable.

Chamberlin. The telescope was moved for safekeeping onto the 20-in. as a finder in the 1970s after vandalism in the smaller building. Records indicate that a 6-in. Saegmuller-Braeshear refractor had been used initially at the Student Observatory, but that it was sold off and replaced with the 6-in. Grubb.

Howe's diaries allude to challenges he faced after arriving in Denver in 1880 in terms of any kind of telescope. Since there was no observatory and nothing in the way of a telescope in Denver then, Howe arranged for the US Coastal Survey to loan him a surveyor's transit. The instrument arrived on February 26, 1881. It had an aperture of 1.5 inches and was manufactured by Jones of Liverpool. The University people were very interested in it. Within a few days he had set up a transit post somewhere on campus and had begun observing with this small instrument. Governor John Evans also had a 3-in. telescope, which Professor Howe used to show people the moon and planets. He also adjusted the instrument better than it had been before. To protect his transit post, he built a fence around it. The University's location at 14th and Arapaho was rather isolated, so observing was not impeded by buildings.

Later that year, in the early morning of October 1, an extremely bright and beautiful comet was visible. The comet was named Comet Couls, after its discoverer. Howe borrowed Governor Evans' telescope to view it and began computing an ephemeris (a timetable for moving objects). The comet was spectacular. Through an opera glass the tail was 20 degrees long. John Hipp, having returned from school teaching, was the only student in Astronomy. He found the Comet interesting but was more interested in eclipses. His Professor found the Comet more interesting, particularly since he could use his mathematical skills to calculate its orbit. Governor Evans' 3-in refractor and tripod still can be seen on display at the Byers-Evans historical house in central Denver.

The Observing Ladder

Most visitors distinctly remember the observing ladder used to reach the telescope eyepiece. The observer's platform, which lifted the observer up to the level of the telescope's eyepiece, was a bit of a nuisance to Howe. He had wished to have the platform hanging from the dome track, a bit like a moveable balcony. However, stability issues prevented the hanging platform from working. If the dome was rotated while the platform was occupied, the observer might fall off and become injured, or the platform might swing and hit the observatory wall.

It was decided that the platform would sit on the floor. The final design was of a platform sitting between two ladders. The platform itself could be raised and lowered using a rope, and the entire structure could be moved around the dome by wheels. The platform is still in use today.

Early in 1890, despite the fact that work on the observatory had been halted, Professor Howe continued work on the design of an observer's platform. He originally wished to have it hanging from the dome track and not touching

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Opposite Page
The Transit Telescope (also known as the Meridian Circle) was put in place in 1892, and is shown in use during the 1950s. The eyepiece view contains lines made of wire as fine as spider webbing, the middle one representing the celestial meridian. This allows measurement of exact times of passage of known stars, from whence local time can be derived.
© Courtesy of University of Denver Penrose Archives

the floor, but eventually decided that it would be necessary for its stability to rest on the floor, at least on the legs nearest the telescope. Later, he would describe the observing ladder as follows: "This is 13 ft. high, 6 1/2 ft. wide and 9 ft. deep. The 4 ft. x 3 ft. platform slides up and down on 4 heavy trunk rollers, supported by a 3/4-in. Manila rope which takes a turn and a half around a 6-in. oak drum; it is counterbalanced as to require the pressure of only one finger to raise it. If two or three heavy persons are on the platform at once, an extra turn of the rope around the drum gives extra security against sliding downwards. The chair is mounted on four truck castors, which are equipped with anti-friction wheels so that they rotate about their vertical spindles easily. A ring of iron concentric with the top of the wall of the observing room, and 3 ft. less in diameter keeps the chair from running against the lights on the wall." Its triangular shape allows the telescope tube to swing past the platform without collision. The basic design adapted by Professor Howe was developed earlier for similar use at Paris and Lick observatories.

From the observing ladder, one can also access a very clever optical arrangement that brings a magnified view of the Declination setting circle to the eyepiece end of the telescope. A parallel magnified view of the Right Ascension setting circle is accessed near the observer's hand wheels and star dial station on the south side of the pillar.

Transit Telescope

The Transit telescope was set into place in September 1891, in the room that would eventually become the library. The telescope itself sits atop a small pillar to keep from being affected by the vibrations of passing traffic. Originally, the roof of the library would slide open, acting as a small observatory. The portion of the roof that opened has since been sealed, and no longer opens.

Transit telescopes were used in many 19th century observatories to keep time. By knowing your geographic longitude relative to the prime meridian at Greenwich, England, and by observing the passage of a catalogued star directly south of the Transit telescope, the time relative to Greenwich could be determined. In the days before radio, TV and Internet, railroads and banks would pay local observatories for the time signal via telegraph.

The Transit telescope itself is perpendicular to a horizontal axis that points east and west. On the axis are two metal circles with graduations carved into them (representing 360 degrees in all). These circles measure the angle at which the telescope is pointing at any given time. The telescope also contains a level, which sits on the horizontal axis, ensuring that the telescope sits on a flat base. The inside of the telescope is filled with black lines, both horizontal and vertical. These appear to be wires, but are actually delicate spider web. The middle line, which crosses the lens horizontally, represents the celestial meridian.

Opposite Page
The library, the room in which the Transit Telescope sits, houses a collection of astronomical books, including some owned by Howe. A large part of the library is made of books donated to DU by the widow of Terry Schmidt, an amateur astronomer and publisher of astronomical 35mm slide sets, along with a collection of books from the Denver Astronomical Society. Note the unique slate globe which can be used to explain celestial coordinates.

Library

The University of Denver received a great number of astronomical books from Professor Howe, who began a collection in the 1880s. Most of Howe's books are housed in the on-campus Penrose Library. The observatory's library, which complements the Penrose collection, is now part of the Transit room, which was created in the early 1990s. A library had been planned into the original design of the observatory, placed in the east side of the ground floor circular room. Later remodeling turned this area into an open classroom.

The estate of Mr. Terry Schmidt, an amateur astronomer and publisher of astronomical slides, donated the majority of the books in the Chamberlin Library. Schmidt's "Tersch" company provided sets of astronomical slides to universities and astronomy groups. Additionally, Schmidt was the owner of a small "telescope farm" with video and spectroscopic capabilities near Eleven-Mile Reservoir in South Park, where he studied meteor showers. Schmidt also collected a number of astronomy books, which his wife donated to Chamberlin after Schmidt passed away. The books were placed in the former Transit room, where bookshelves were built in the style of the rest of the observatory. The observatory serves as a reference room for interested astronomers, and the collection is varied and eclectic in its contents.

Additional Construction and Maintenance Notes

Custodians:

Howe often traveled around the country, and had a family of his own to take care of. This made it necessary for the university to provide a maintenance man for the observatory. For the first 10 years, the university normally had one or two male students occupy the caretaker's room. The students would take care of both maintenance and janitorial work, and would get a discount on their tuition. The university provided painting and grounds keeping, but Howe himself was in charge of the care of the telescope and instruments.

The first student janitor, Mr. Law, did not live up to his responsibilities. He did not keep the observatory clean and was found to have done several things that were "of a hazardous nature." One of these involved stuffing papers into a burning stove, then leaving the building and locking the door behind him. Howe returned to the observatory shortly after Mr. Law departed, and was forced to take the door off the hinges to extinguish the fire.

Mr. Sprague, another student janitor, was living in the observatory when the telescope was installed. He provided assistance in installing the telescope and was allowed the responsibility of escorting observatory visitors on occasion. Other janitors at the observatory included Mr. Smith, Mr. Green, Mr. Gullette, Mr. Buckley, Mr. Gipe, Mr. Whitehead, Mr. Miller and Mr. Painter. However, there are no details about these men in observatory notes or Howe's diaries.

Facing Page
The East wing of the observatory, looking northwest, housing the Transit Telescope and Schmidt Memorial Library. Note the stonework detail near the roof peak, and the narrow window slot centered below the gutter on the south face. That window was part of a set of openings that originally allowed the transit telescope to see the sky to the south, north and overhead. The openings have been roofed over, but these could be restored to their original function.

Opposite Page Top
The dedication stone at the entrance to the observatory, indicating Mr. Chamberlin's donation to the University of Denver in 1890, and the modern landmark plaque. The observatory became Denver Landmark #220 in 1994, one hundred years after Denver's great telescope became operational.

Opposite Page Bottom
View of the west wing of the University of Denver's historic Chamberlin Observatory, looking generally northeast. In addition to interesting stonework near the roof peak, a chimney for the fireplace in the first floor Director's office is prominent, along with two small windows of a second floor room.

In the early 1950s, a student custodian named Hal Secrist lived in the observatory during college at DU. He eventually wrote his memoirs, "With Eyes on the Stars," which provides our best insight into midcentury life in and around Denver's great telescope.

Stonework:

The stone of the observatory is dark red sandstone from the Kimball stone company. Roeschlaub, the architect of the observatory, had initially wanted to build with brownstone, but there was altogether too much difficulty in obtaining it. In early September, 1890, the Kimball stone began arriving at the University Park railroad site. The construction of the observatory was briefly halted in December, when the stone supply was exhausted, and the stone company had to find another quarry. Another source of hard sandstone was acquired from the Archalow quarry in Lyons, Colorado, and construction eventually completed.

Woodwork:

The wooden skeleton of the observatory is made up of wood from Oregon. There was a slight problem with getting the railroad to ship in the Oregonian wood, but it was eventually resolved, and the construction began. The joists for the first floor of the observatory were completely finished by

Opposite Page
Doorknobs, a drawer pull and a cupboard latch are among the detailed architectural features of the observatory. The doorknob with the flower surrounded by feathers is similar to the "Daisy" design of Pennsylvania designers in the early 1880's.

November 13, 1890, and work was begun on the window frames. It was discovered that the big joists in the round rooms of the observatory were too weak to hold the dome, causing the wood to crack. The wood remains cracked, but stable, today. In June 1891, the plastering was begun on the interior of the observatory. Thin strips of wood were nailed over the studs, forming a base on which the plaster could be applied. No insulation was placed between the walls of the dome.

Electrical service:

Electricity had not been part of the initial plan of the observatory, having not yet come to a small prairie town such as Denver. In May 1891, Howe began integrating electrical wiring into the design of the observatory. He spent hours drilling holes in the walls of the building to place wires, and made diagrams of where he wanted the wires placed. The wiring did not begin until June 1892, when Chamberlin gave Howe a formal approval of installation. The cost of installing wires all around the observatory was $42. In July, electric fixtures were installed, but the wiring was not finished until August. The 50-volt DC wiring was eventually changed over to modern 110-volt AC.

ARCHITECTURAL NOTES AND POINTS OF INTEREST

Design Story

Professor Howe created the original conceptual design of Chamberlin Observatory after having visited other observatories around the country. He drew the most strongly from the Goodsell Observatory in Northfield, Minnesota, on the campus of Carleton College. Howe's designs were well-thought-out, but it would take an architect to make the design a reality.

Mr. Robert S. Roeschlaub, who would also oversee the construction, would create the final design of the observatory. Howe worked closely with Roeschlaub, bringing him sketches, photographs and books that he felt were applicable to the design. They did not have much trouble with the base rooms of the observatory, but the dome took longer to decide on. Howe had a difficult time deciding what the dome should be made of. The decision was finally made to use metal, and the design of the observatory finalized in the summer of 1899.

Form and Function

Though the observatory is a mainly functional building, it has its artistic points as well. Small details in the construction and features of the building may not catch attention, but they deserve a second look.

Chamberlin's architect added architectural accents to the design of the observatory, which add to the overall charm of the old building. The doorknobs, for instance, are carved with floral designs and other patterns, which

Opposite Page
Robert S. Roeschlaub, the architect for Chamberlin Observatory, drew this architectural section design, one of many pages of originals in the DU archives. Some of the features include the proportions of telescope support structure, interior woodwork details, and detail of an exterior "wrot" iron balcony that was removed decades ago due to rust-induced failure.
© Courtesy of University of Denver Penrose Archives

might be overlooked by the majority of visitors. One doorknob, carved with a flower surrounded by petal or featherlike shapes, has been identified as a daisy pattern, likely produced in Pennsylvania after 1885. Another, a flower surrounded by concentric circles, has been identified as a Nashua style, created by the Peters Lock Company after 1875. These designs were identified by the antique experts at Grandpa Snazzy's Hardware at 1832 S. Broadway in Denver.

Other points of interest include door hinges, drawer pulls, cabinet hardware and latches. Though many of the hinges have been painted over, their carved designs still show through the paint. Even the keyholes have designs carved into them, though some have been painted over as well. Restoration is planned.

Some of the door and window frames are also carved with designs, as is the post at the base of the staircase. Even the radiator is carved with floral and ivy designs. The radiators have been painted over as well, but the designs still show through to those who know to look.

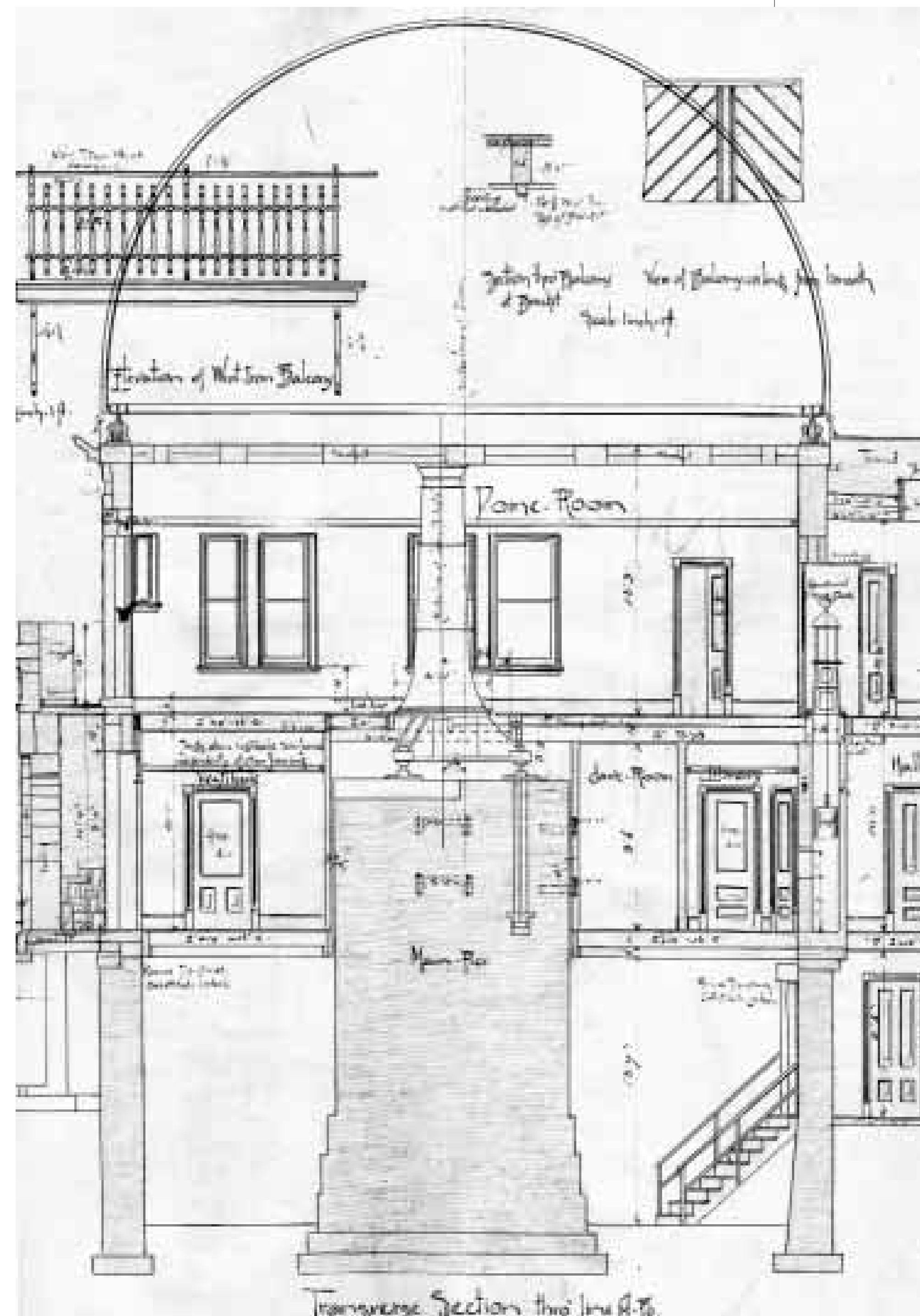
Roeschlaub

Architect Robert Sawyers Roeschlaub was born in 1843 in Bavaria. His family moved to the United States when he was a small child, settling in Quincy, Illinois. Quincy was a departure point for many gold seekers headed to the Rocky Mountains. Roeschlaub's father joined the search for gold, and returned with stories of Denver and the mining camps there.

Roeschlaub joined the Illinois Volunteer Infantry at age 18 and fought in the Civil War. He eventually worked his way up to first lieutenant and leader of his company, after being wounded at Chickamauga. In 1865, he left the service as a captain, returned to Quincy, and worked in a stationery store. He was soon employed by a local architect, Robert Bunce, from whom he received on-the-job training in architecture until 1872.

When Roeschlaub decided to begin his own business, he remembered his father's stories about Denver, and chose to set up shop there. He arrived in Denver in early 1873, when the local population was around 5,000 and the economy was booming. Roeschlaub's business quickly became a success, causing him to hire temporary assistance for some jobs. His early jobs were mainly schools and churches, allowing him to forge a permanent connection with the Denver school boards, ensuring future work.

To support his business more steadily, Roeschlaub took on projects outside of Denver. One of his better-known designs is the Central City Opera House, built in 1878. In 1888, Roeschlaub worked with the trustees of the University of Denver to build the Trinity Methodist Episcopal Church and the Haish Manual Training School, both near downtown Denver.



Facing Page
Oblique aerial view of Observatory Park and surroundings, taken in 1964 showing complete urbanization in the years since 1894 when Denver's great telescope saw first light. Urbanization has brought problems of spilled light, glare and excessive skyglow that impact astronomical conditions.
© Roach Photo, Denver, used with permission.

Opposite Page
The Observatory and Student Observatory as they appeared in September 1917, with relatively few buildings in the surrounding area.
© Courtesy of University of Denver Penrose Archives

In 1891, a large chimney collapsed on the Elbert School, which Roeschlaub designed. There were no injuries, but local newspapers blamed the architect in reports. He was later proved not to be at fault, but the damage was done. Roeschlaub's business began to lose customers after this unfortunate incident. However, shortly before this destructive event, the DU trustees had asked Roeschlaub to design and manage the construction of University Hall. Soon after, the company received a contract to design and build an observatory building and later, a private home for Professor Howe. University Hall was completed first, having been given the highest priority.

The observatory was an odd case for Roeschlaub, because he did not have to design the building (the plans were provided by Howe). The bids from construction firms were delivered to Roeschlaub and then shown to Chamberlin and Howe for final decisions. Roeschlaub corrected any design problems.

Roeschlaub's firm continued in Denver until 1912 with a low number of projects. Roeschlaub himself became more and more personally involved with each job, because of the loss of employees over the years. Despite the lack of business, Roeschlaub's reputation as an excellent architect was increasing. When the Colorado chapter of the American Institute of Architects was formed, Roeschlaub became its president and remained so until his retirement in 1912. The Isis Theatre was his last project in Denver, and he considered it to be ornate and flashy. As a result of poor health, Roeschlaub moved to San Diego with his wife. He passed away in California at the age of 80 in 1923.

The Land Around the Observatory

Early in the University of Denver's history, Rufus Clark donated large tracts of land in south Denver to help establish the new campus. The observatory occupied part of the land, but in June 1952, Colorado Seminary (the official name of the University of Denver) officially sold the land surrounding the observatory to the City of Denver for $10, to create Observatory Park. The contract, Denver City Deed #110597, officially ensured that nothing would be built that would obscure the telescope view, despite the fact that the city owned the land. The contract stated that the land must be used as "an observatory site," rather than a real-estate site where new homes could be built.

The land that was purchased stretched from Warren and Iliff to South Milwaukee Street and South Fillmore Street, and it included both of the observatory buildings. The contract also stated that if the land was used for any purpose other than observing, the land and buildings would be returned

Facing Page
The student observatory, which was built at the same time as the large observatory, but completed in May 1891, three years before the main telescope was ready. The little observatory was used while the larger was being completed, and was equipped with a 6-inch refractor and small transit telescope.

Opposite Page
A news article from The Sun newspaper, November 29, 1892. The complete article discusses the observing of comet Swift by Professor Howe making use of the Student Observatory for his research.

to the university. This contract saved the university money, because it transferred all maintenance and care of the land to the city. It also ensured that the light pollution was kept to a minimum, stating, "said real estate will not be lighted in such manner ... as to seriously interfere with the use of said real estate ... for an observatory site."

The Student Observatory

Along with the building of the larger Chamberlin observatory, Howe and Chamberlin planned a smaller observatory, to be used by students and to act as a stand-in until the larger was completed. On March 17, 1890, Chamberlin gave Howe full authorization to begin the designing and equipment pricing for the small observatory. Architects completed the plans for both observatories in April of the same year.

In May, when traveling to pick up the tripod for the big telescope, Howe signed a contract for a dome for the small observatory with Scherzer, a company in Chicago. Later that month, the center of the little observatory was plotted out to be 150 ft. west and 125 ft. south of the southwest corner of the large observatory. It was not until July that bids began on the building of the small observatory. Bids came in quickly, however, and the one-worker excavation began in August.

Excavation and construction went quickly, and by August 29, work on the wall of the little observatory was just at the ground level. The sheeting for the little dome was soon being placed. The dome was assembled on the

ground and was to be hoisted up when the little observatory was completed. By September 5, the equatorial pier in the little observatory was almost finished and the Transit pier had been started. There were a dozen men working on the small observatory by September 10, allowing work to progress even more rapidly. The walls were up to the floor line by September 13, and the stonework was almost complete by the 20th. However, the builders had deviated slightly from the line laid for them, and the dome's Transit slit for the 2-in. Transit telescope was not framed correctly. The small Transit instrument reportedly was stolen about 1965.

By the 21st of October, the track of the little dome was in place, the ribs were up and the carpenters were beginning to apply wooden sheathing. The sheathing was completed and the tin exterior of the dome was being applied by October 29. The tracks for the dome were completed, and the telescope pillar fastened to its pier on Friday, October 31. By the end of November, the little observatory was nearly completed, with the exception of the 6-in. telescope, which was not installed until May of the next year. However, the contrast between the two observatories was great. The small observatory was completed in a matter of months, while the larger took years.


HANGS ABOVE THE CITY

The keys to the little observatory were handed over to Professor Howe on May 4, 1891. That evening, he used the 6-in. telescope to observe Saturn and some double stars. On May 9, Howe spent the afternoon preparing to observe the transit of Mercury from the small observatory. Sadly, clouds prevented Howe from seeing the event. Howe entertained more than 50 university students from the Evans Literary Club on June 3, and observed a partial eclipse of the sun on June 16.

Over the years, a variety of small telescopes were used in the Student Observatory, from Schmidt cameras to small reflectors, to robotic and custom instruments. Mechanical problems, tall trees, lights, sprinkler systems and safety issues now limit the actual use of the building.

"When one first experiences a truly magical place, the resulting impression is indelible. So it is with Chamberlin Observatory. Kids, especially, will never forget their first view of the grand telescope and their own, personal peek through it. Over the last twenty years. I have heard countless wide-eyed children say, "Wow!"

—David Trott, long time DU Astronomy Instructor

Significant Others

Mr. Chamberlin's Story
Dr. Howe's Story
Donald Menzel
Albert Recht
The Denver Astronomical Society
Edgar Everhart
Robert Stencel

Opposite Page Left
Humphrey Barker Chamberlin (1847-1897), the wealthy entrepreneur who paid for the construction of the observatory bearing his name. This portrait of him is displayed in the main room of the observatory.

Opposite Page Right
An article from a local newspaper, The Daily News, at groundbreaking for the new observatory, June 4, 1988, reporting in Chamberlin's own words, his gift to the University of Denver. © Courtesy of University of Denver Penrose Archives

Mr. Chamberlin's Story

Humphrey Barker Chamberlin was born on February 7, 1847 in Manchester, England to Robert Chamberlin and Eliza Barker. The Chamberlin family migrated to the United States in 1852, initially living in New York City, but eventually moving to Oswego, N.Y. Humphrey attended grammar school and the State Normal School at Oswego in central New York state. His father made a decent living for the family by working as a carpenter.

In the early 1860s, Chamberlin worked for a telegraph company, developing skills as a telegraph operator. He would use these skills at age 16, working in the military telegraph corps for the Union during the Civil War of 1863. He remained with the corps until 1866, when he returned home to Oswego, attained a job as a clerk in a drugstore and eventually opened his own store in Fulton, N.Y.

In 1871, after having moved to the larger city of Syracuse, N.Y., Chamberlin met and married Miss Alice Packard. At age 24, Chamberlin was already an established businessman, but he had an incurable wanderlust. Despite his success in Syracuse, he traveled to Brooklyn to work at the headquarters of the Young Men's Christian Association (YMCA). Chamberlin worked hard but was forced by poor health to return home to Oswego, where he stayed at his parents' home. He was diagnosed with nervous prostration, and was advised to go to Colorado, where the mountain air was believed to have curative properties.

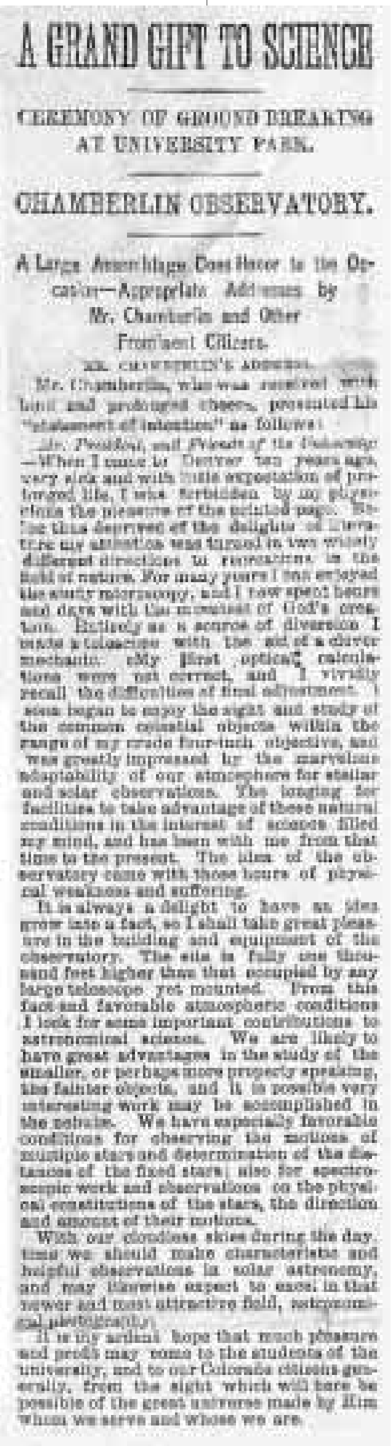
Chamberlin fell in love with Colorado, where he was able to hunt, fish and study various wild animals and plants. He made many friends within the Denver YMCA, as well as the Methodist community and their project, the University of Denver. Chamberlin became friends with another English immigrant, Henry Tuggy, the first president of the Denver chapter of the YMCA. The two formed a partnership and created a successful shoe company in the fall of 1881. Through this friendship, Chamberlin became a director of the Denver YMCA.

Chamberlin's brother-in-law, Durand C. Packard, moved from New York state to Denver, and they worked together in mining investments, insurance and real estate. Chamberlin resigned from the Tuggy Boot and Shoe Company and opened his own real estate firm. He later formed Chamberlin, Mills and Packard with his brother-in-law and Edmund S. Mills, dealing in real estate, insurance and loans. In the mid-1880s, the company was divided, Packard taking the insurance business, and Chamberlin continuing in real estate. In addition to Denver, he engaged in land speculation and investments in Pueblo, Colorado, San Antonio, and Fort Worth, Texas.

Chamberlin's focus was on property rather than money, so his charitable donations to the Methodist Church and University of Denver were most

often land and promises rather than cash. He did not donate and walk away; he managed his charitable donations to get maximum return. He was involved in a great number of community programs, including the YMCA, the Lawrence Street Methodist Church and the Rocky Mountain Chautauqua. He also purchased and operated the Kibler Stove Co. of Irondale, the Iron Springs Company located at Manitou and various local utility companies.

The Sherman Silver Purchase Act of 1890 mainly contributed to the boom in Colorado. The act required the government to annually purchase and coin an amount of silver equal to the estimated production, which kept the price of silver up. Colorado was the largest silver producing state, so millions were contributed annually to the state's economy. The Silver Panic in May 1893 was caused by the deterioration of the economy, and the repeal of the Free Coinage Act sunk Colorado deeper into the depression. Chamberlin's business, The Chamberlin Investment Company was one of the businesses destroyed by the depression. He had borrowed



A GRAND GIFT TO SCIENCE

CEREMONY OF GROUND BREAKING AT UNIVERSITY PARK.

CHAMBERLIN OBSERVATORY.

A Large Assemblage Does Honor to the Occasion—Appropriate Addresses by Mr. Chamberlin and Other Prominent Citizens.

MR. CHAMBERLIN'S ADDRESS.

Mr. Chamberlin, who was received with loud and prolonged cheers, presented his "statement of intention" as follows:

Mr. President, and Friends of the University—When I came to Denver ten years ago, very sick and with little expectation of prolonged life, I was forbidden by my physicians the pleasure of the printed page. Being thus deprived of the delights of literature my attention was turned in two widely different directions to recreations in the field of nature. For many years I had enjoyed the study microscopy, and I now spent hours and days with the minutest of God's creation. Entirely as a source of diversion I made a telescope with the aid of a clever mechanic. My first optical calculations were not correct, and I vividly recall the difficulties of final adjustment. I soon began to enjoy the sight and study of the common celestial objects within the range of my crude four-inch objective, and was greatly impressed by the marvelous adaptability of our atmosphere for stellar and solar observations. The longing for facilities to take advantage of these natural conditions in the interest of science filled my mind, and has been with me from that time to the present. The idea of the observatory came with those hours of physical weakness and suffering.

It is always a delight to have an idea grow into a fact, so I shall take great pleasure in the building and equipment of the observatory. The site is fully one thousand feet higher than that occupied by any large telescope yet mounted. From this fact and favorable atmospheric conditions I look for some important contributions to astronomical science. We are likely to have great advantages in the study of the smaller, or perhaps more properly speaking, the fainter objects, and it is possible very interesting work may be accomplished in the nebulae. We have especially favorable conditions for observing the motions of multiple stars and determination of the distances of the fixed stars; also for spectroscopic work and observations on the physical constitutions of the stars, the direction and amount of their motions.

With our cloudless skies during the day time we should make characteristic and helpful observations in solar astronomy, and may likewise expect to excel in that newer and most attractive field, astronomical photography.

It is my ardent hope that much pleasure and profit may come to the students of the university, and to our Colorado citizens generally, from the sight which will here be possible of the great universe made by Him whom we serve and whose we are.

Opposite Page Top
A portrait of Professor Herbert A. Howe, 1882. © Courtesy of University of Denver Penrose Archives

Howe's complete biography, " Denver's Pioneer Astronomer" by H. J. Howe & R. E. Stencel is available in print. See the information on page 96.

Opposite Page Bottom
Professor Howe at the telescope in 1895. While teacher, Dean and Registrar at DU, Howe still managed to spend much of his precious free time scanning the skies, and taking care of the observatory. © Courtesy of University of Denver Penrose Archives

money to buy land and other assets that were suddenly worthless and could not be sold to gain equity. Chamberlin fell into bankruptcy.

Sadly, Chamberlin never regained his fortune. He worked for a time at the New York Life Insurance Company. Then he moved back to England, where he continued to work in life insurance. On May 17, 1897, he suffered a heart attack and passed away at age 50.

Before the economic crash in 1893, Chamberlin had contributed to many organizations and causes in Denver. One of these was the University of Denver's Chamberlin Observatory building, for which he paid construction costs for the project. By 1893, Chamberlin had paid $56,000 for the observatory, but it was not yet completed. The building itself was finished, and instruments had been ordered and fabrication had started, but they had not been delivered or paid for. Payment for the instruments would be left to Professor Herbert A. Howe, the University's astronomer who had conceptualized the project and managed it along with Chamberlin.

Professor Howe's Story

Herbert Howe was born to Alonzo and Julia Howe in 1858 in the city of Brockport, N.Y. Howe was one of three children, having two sisters, Carrie and Sarah. In 1861, the family moved to Chicago, where Howe's father worked as the Professor of Mathematics at the University of Chicago.

At the age of 8, Howe lost his mother, Julia. Not wishing his children to be motherless, Howe's father married Julia's sister, Sarah. As the child of a university employee, Herbert was introduced to college life at a young age. At the age of 9, he was admitted into the grammar school level of the University of Chicago. He quickly rose through the ranks. He was accepted into the high school level at only age 10 and into the university itself at age 13. He graduated from the university with distinction at the young age of 16.

In 1875, Howe traveled to the University of Cincinnati to study for an M.A. degree. He supported himself by working as an assistant in astronomy in the Cincinnati Observatory, where he received room and board from the director. He received his degree in 1877, and continued as an astronomy student for the next three years, specializing in double stars. While working at the observatory, Howe printed a catalogue of double stars that he had discovered. The catalogue was mailed to universities in foreign countries (115 were sent in all).

Howe's sister, Carrie, passed away in October, 1879. This caused him to worry about his own health problems, which could not be correctly diagnosed by doctors of the day. Despite his health worries, he enjoyed his

astronomy work and his life at the University of Cincinnati. In March of 1880, Howe was offered a position in a new college that would be re-opened in Denver, Colorado. The pay would not be high (about $50 a month), but the position sounded promising. Howe took a one-year leave of absence, discussing the matter with his father after he returned. He eventually accepted the offer and began studying to prepare for his teaching position.

On September 30, 1880, Howe left

Opposite Page
The original floor plan for the ground floor of the observatory, including a library in the main room. This represents the facility in Howe's day. Several interior walls have been removed to make the main room suitable for classes and lectures. [Howe, 1896].

Chicago for Denver, a trip that would take 53 hours by train. Colorado, still being called "The Great American Desert" at this point, had only had railroads for 10 years, and the area appeared very strange to the big-city professor. The train finally arrived in Denver on October 2. Howe explored Denver, which he did not find very impressive compared with Chicago. He did, however, appreciate the open and natural landscape.

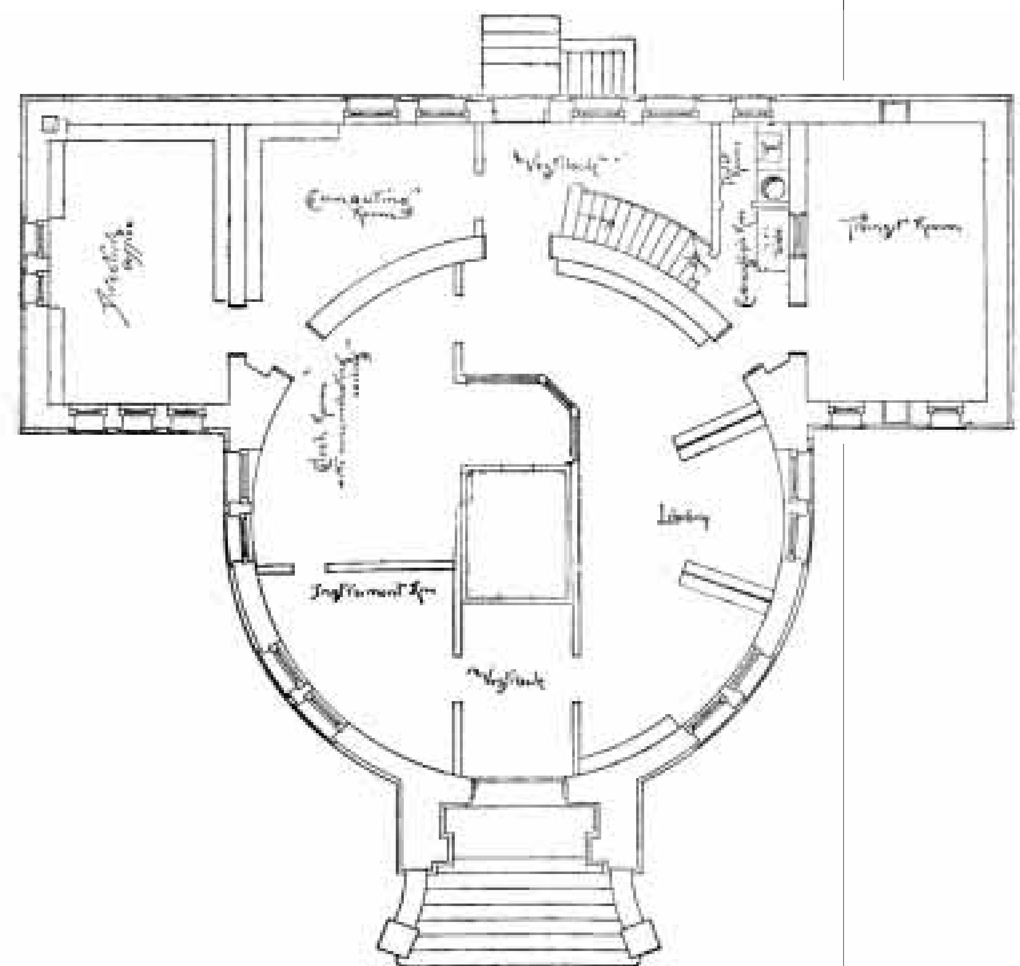
School began on October 4, with a faculty of seven including Howe. One of the classes that Howe was assigned to teach, a geometry class, had only two students. Although the school was small, it was as regimented as a military school. The faculty set rules and schedules, and chapel meetings were compulsory. A devoutly religious man, Howe attended church in the morning and evening on Sundays, and was quickly drafted by the Baptist church into teaching Sunday school classes.

In January, Professor Howe met Joseph C. Shattuck, a member of the University of Denver's Board of Trustees. Shattuck had a daughter, Fannie, who was to be hired as an assistant primary teacher at the university. She arrived at the school in February and made a favorable impression, both on the university and on Professor Howe. Fannie Shattuck and Herbert Howe were married in 1884.

During his time at Cincinnati, Howe had become interested in determining the orbits of heavenly bodies, and his calculations were long and difficult. He referred to the calculations as Kepler's Problem, and attempted to both simplify and improve the accuracy of his calculations. After settling in at DU, he began writing out his latest equation for publication. While he was enjoying himself at the new university, a problem soon became evident. The university had no astronomical equipment. Howe arranged to borrow a transit telescope from the US Coastal Survey. When the telescope arrived in late February, Howe set it up on campus and began using it to observe the night sky.

In April 1881, when spring quarter began, Howe's teaching duties included the university's first astronomy class. In addition to the class, Howe began writing astronomical articles for local newspapers, including subjects such as using sun angles to determine time of day. The telescope was returned to its owners in the summer, creating a total lack of observational equipment on campus.

In October of 1882, a comet became visible, and Howe was able to borrow Governor Evans' 3-in. telescope to observe the comet. He took notes on the orbit of the comet, and wrote a series of articles for the Rocky Mountain News and The Sidereal Messenger. A transit of Venus across the sun occurred in December, and Howe had written articles predicting it. Following this, he was besieged by requests for information, and wrote an article for the Tribune and Republican newspapers. Howe had to borrow a



telescope to view the transit, because the university still had no equipment. In February of 1883, Chancellor Moore informed Howe that he would like to get an observatory for the university, but a new preparatory building was a higher priority.

Howe began working on his doctorate, as well as continuing his work on Kepler's Problem and a study of the Great Comet of 1882. Boston University sponsored Howe's doctoral degree. In October of 1883, Howe received a letter from a man in Milwaukee, who was willing to sell a 5-in. telescope and dome for $850.

In November, a decision was made to put an observatory on the roof of the Junior Preparatory Building in downtown Denver. On Thanksgiving, Howe finished his thesis on Kepler's Problem. The dome had arrived on November 27, before the holiday, and work began on the observatory on

Opposite Page Top
Howe's elementary algebra class at the University of Denver, 1889.
© Courtesy of University of Denver Penrose Archives

Opposite Page Bottom
Howe and his son on Howe's tricycle. In addition to spending time at the observatory, Howe enjoyed riding around town on his "high-wheeled bicycle."
© Courtesy of University of Denver Penrose Archives

November 30. The little observatory was completed by December 8, when Howe used the little telescope to observe the moon.

Howe finished off the year working on a study of the orbital path of the Great Comet of 1882 as a part of his doctoral thesis, in addition to Kepler's Problem. He worked continuously on his thesis through May 1884, putting in six or seven hours every day. On June 8, Howe received a letter from Boston University saying that it had granted him a Doctorate of Science. In the meantime, many visitors had been interested in visiting the university's new observatory, and Howe was happy to accommodate them.

In addition to his teaching and observing duties, Howe took on a side job as a book reviewer for a math and astronomy publication called "The Sidereal Messenger." He also wrote occasional articles on astronomical events for the local newspapers and tutored privately. For exercise, Professor Howe liked to ride on his high-wheeled Star bicycle. He could often be seen speeding around the roads surrounding the university.

On March 16, 1885, there was a partial eclipse of the sun, which Howe and 200 visitors observed through the 5-in. university telescope. In June, Howe was informed that he had been elected Professor of Mathematics and Astronomy for the ensuing year. Additionally, he was put in charge of the boys' dormitory, which led to some interesting and frustrating times for Howe. In December, however, a joyous event occurred; Fannie gave birth to the couple's first son.

In January 1886, the university's Board of Trustees picked a site for the new campus. Rufus Clark was offering the new site, later called University Park. Clark had previously used the land as a potato farm and agreed to sell it only if the land was used as a combined educational and residential area. These terms were agreed to, and the land was purchased for $19,400.

In January of 1887, Howe was forced to begin wearing prescription glasses. There were no electric lights at the university, and the long hours of work with poor lighting had taken a toll on his vision. This did not, however, deter him from the study of astronomy. During the winter quarter at the university, he began scheduling evening sessions for students at the little observatory, which the students seemed to enjoy.

Early in October of 1887, Howe received an offer to use a jeweler's transit with the university's telescope from a citizen named A.M. Wood. A mounting post was erected in the backyard of the university, and Howe viewed Venus. On December 27, the State Teachers Association began meeting in the high school building at the university. Howe was elected president of the association on December 28, adding to his workload.

The next year held many exciting events for Howe. On January 28, 1888,

an eclipse of the moon occurred. The eclipse was not visible from the small observatory, because the girls' dormitory was in the way. Howe was not disheartened, however, and took a 2-in. telescope to the roof of the Haish building (along with a number of students and his 2-year-old son). Reporters from the Republican and Rocky Mountain News newspapers visited to interview Howe about the eclipse.

Howe was frustrated at his lack of a well-equipped observatory, and was surprised and delighted when Chancellor Moore called him in to read an anonymous letter offering to fund an observatory for the university.

Opposite Page Top
Donald H. Menzel, DU graduate, 1922 and eventually Director of Harvard College Observatory. While an undergraduate in Denver, he helped Howe with Denver's great telescope and was featured in an article in the University of Denver student newspaper, The Clarion, November 1920. The article discussed Menzel's prediction of the appearance of a comet. © Courtesy of University of Denver Penrose Archives

Opposite Page Bottom
Professor Albert W. Recht, Chamberlin Observatory's second Director, following Howe's death in 1926. Dr. Recht also was Chairman of the DU Mathemetics Department during his tenure, and his sons played an important role in the Denver Research Institute. © Courtesy of University of Denver Penrose Archives

Significant Others

Donald H. Menzel

Donald Menzel, a native of Colorado, was arguably one of Dr. Howe's best students. Menzel grew up in Leadville, the son of a railroad technician. He developed an interest in engineering and chemical technology at a young age. Menzel attended high school in Denver as a transfer student, graduating in 1916. After high school, Menzel continued on to the University of Denver, where the excitement about the 1918 solar eclipse was building.

He became a helper at Chamberlin observing sessions and he was mentioned numerous times in Howe's diaries. Howe and Menzel met often to work on the observatory, and enjoy discussions of astronomy. Menzel earned his Masters in Chemistry in 1923, and was recommended by Howe for doctoral work at Princeton University. There, Henry Norris Russell - a key player in the fields of quantum physics and astronomical spectroscopy - took him on as a Ph.D. student. Under Russell's guidance, Menzel began research that led him to create thermodynamic and chemical composition diagnostic methods that are used in astrophysical analysis today.

Menzel's distinguished career is documented in the archives of both the University of Denver and Harvard College Observatory, of which he was director in the 1950s. His accomplishments also include founding the High Altitude Observatory in Climax, Colorado. The High Altitude Observatory is now a part of The National Center for Atmospheric Research (NCAR), which was founded by one of Menzel's students. In addition to working at observatories, Menzel took multiple solar eclipse expeditions, wrote books and created films on astronomy, and served during World War II, during which he conducted experiments on solar flare activity and radio propagation.

Professor Albert W. Recht

Albert Recht was born in 1898 in Cleveland, Ohio. He attended school in Arvada, Colorado, and graduated from high school in 1915. From 1915 to 1920, Recht attended the University of Denver. In 1926, after Dr. Howe's death, Recht was named the second Director of Chamberlin Observatory. Recht was a recent graduate of the University of Denver, having completed school in 1920 with an undergraduate degree in mathematics. Recht is mentioned in Howe's diaries as a helper at the observatory, beginning with an entry from April 15, 1920, in which Howe describes Recht "as one of my computers." Howe was complimenting Recht's skill with numbers.

Most of what is known about Recht centers on his career at the observatory, including publishing reports and entertaining observers. In 1937, Recht published the 1937 Chamberlin Observatory Report, which includes a bibliography of Howe's publications, and cites publications by Recht and his

colleagues. In 1939, Recht was awarded his Ph.D. in astronomy from the University of Chicago for cometary orbit studies.

In the same year, Harold Secrist began living at Chamberlin as the latest of a long line of student custodians. He wrote a memoir in 1999 titled, "With Eyes on the Stars," which included vignettes of Dr. Recht, campus life and the new astronomy club.

In 1954, Recht authored a textbook titled "A Space Trip for the Joneses." The book was later revised in 1959 and used by classes in mimeo form, but was never published. The next year, Recht wrote another Chamberlin Observatory Report, which was published in Volume 65, Issue 9 of the Astronomical Journal. Recht's report contained commentary, staffing, the Moonwatch program (the beginning of the Space Race), public interest

Facing Page
In this image, Prof. Recht and helper, Mr. Parks, work on cleaning the lens of the Denver's great telescope. Recht has a lunar far-side crater named after him, located at longitude 124 degrees and latitude +9.8.
© Courtesy of University of Denver Penrose Archives

Opposite Page
Students and visitors to the observatory enjoy scheduled DU astronomy classes and Denver Astronomical Society public nights, where they can look through Denver's great telescope, ask questions and investigate the observatory. Outreach is one of the important missions of the University of Denver's historic Chamberlin Observatory, as illustrated by the "blue card" announcing the ongoing public night program founded by Dr. Recht and staffed by the D.A.S.

in a close approach of Mars, and a national amateur astronomy convention in Denver that same year.

After Recht's death, it was several years before another astronomer was hired. Care of the observatory was largely left to DU staffer Mr. Francis Ohmer, before Professor Everhart's arrival in the late 1960s.

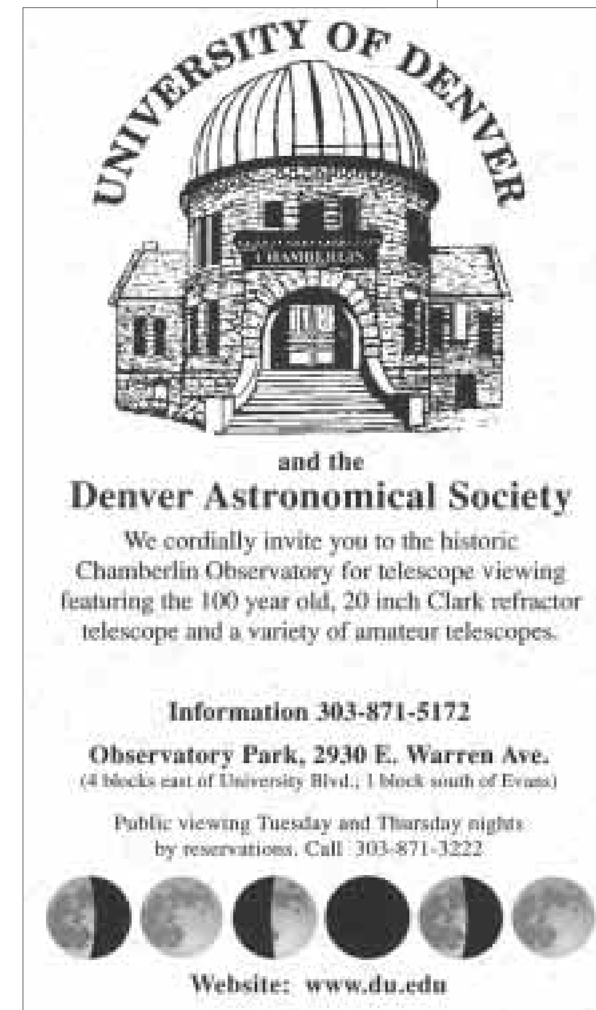
The Denver Astronomical Society

The Denver Astronomical Society, or DAS, was begun in 1949 by an active group of amateur telescope makers. The organization was formed with the goal of providing for its members a place to discuss and increase their knowledge of astronomy, as well as to promote astronomy and astronomical education to the public. Members range from the "armchair" or casual astronomer to serious amateur scientists. The club generally had around 150 members per given year. In the 1950s, the DAS was instrumental in constructing and operating the first public planetarium in Denver at the Natural History Museum (now the Museum of Nature and Science). The DAS has also received recognition from groups like the Smithsonian Astrophysical Observatory, which named the society one of the top 10 "Moon Watch" organizations.

Additionally, the DAS has played a vital role in the rejuvenation of Chamberlin Observatory, where many of their meetings are held. In 1988,

David Tondreau, a member of the DAS, decided that the observatory needed to be saved from deterioration. A "rescue committee" was formed of volunteers. They solicited external sponsorship and approached the DU administration to transfer the title of the observatory to his group. Although the committee members were unable to get what they wanted, they did bring Chamberlin's state into the public eye.

The DAS has worked with observatory directors Recht, Everhart and Stencel to keep the building in shape, and have helped raise funds to update technology and displays. Most importantly, DAS volunteers have provided thousands of hours for public-access observing nights, to keep the public interested in astronomy, observing and the observatory's future. Their partnership has been key to extending outreach to the community beyond what DU staff can cover with limited time and resources.



Professor Edgar Everhart

Professor Edgar Everhart arrived at the University of Denver in 1967 from Connecticut. He is best known for his research in atoms and molecules, but had a passion for observational astronomy. In 1964, during an observing session, he discovered a comet, which was later named Ikeya-Everhart. Everhart is remembered for his discovery of the comet Everhart and his computations of the effects of planets on the changes in comet orbits.

The University of Denver has several memos written by Everhart that describe the state of the astronomy program in 1976, the nomination of Chamberlin for the National Register of Historic Places in 1980, and several annual reports. One report, from 1977, describes the modernization of the telescope by the addition of an electric motor drive, a new eyepiece mount, a photoelectric photometer and a setup that would allow for astronomical photography.

Opposite Page
Professor Edgar Everhart, the third director of Chamberlin Observatory, is known in the astronomical world for his calculation of orbits, construction of special telescopes and for the discovery of the comets Everhart and Ikeya-Everhart.
© Courtesy of University of Denver Penrose Archives

In 1984, Everhart retired from teaching at the University of Denver, but he remained the Director of Chamberlin Observatory. At this time, the university was undergoing a serious financial crisis, and thus was unable to hire a replacement director. Due to financial troubles at DU, a replacement was not found until after Everhart's death.

Below are the elements for comets discovered by Everhart.

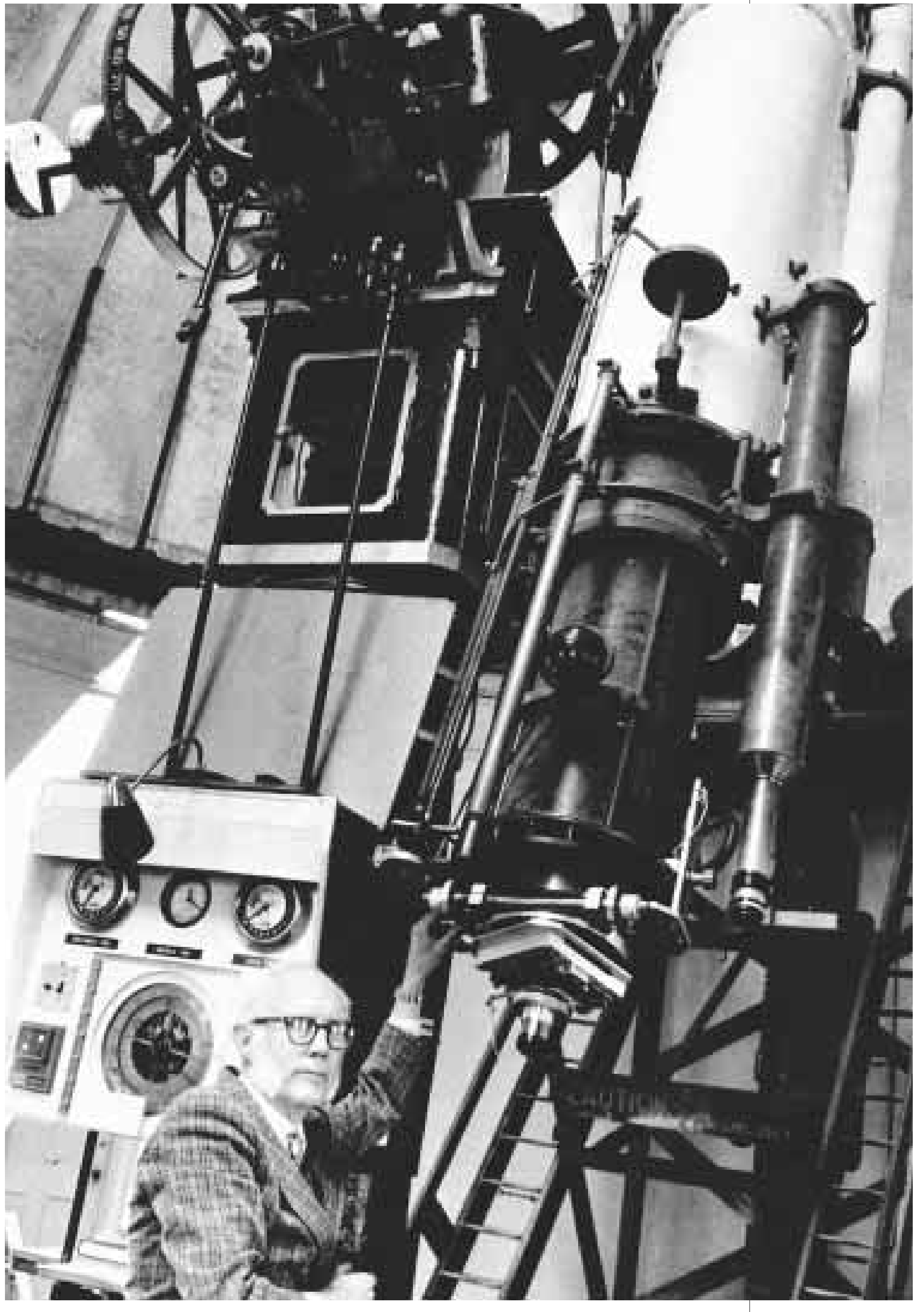
1964 h (Everhart)	1966 d (IkeyaEverhart)
perihel. = 1964/08/23.19	perihel. = 1966/08/05.32
peri dist, q = 1.2592750 AU	peri dist, q = 0.8818800 AU
ecc, e = 0.9965130	ecc, e = 1.0000000
incl, i = 67.96890 degrees	incl, i = 48.27900 deg.
long. asc. node = 280.44510 deg.	long. asc. node = 107.66000 deg.
arg. perihel. = 20.68560 deg.	arg. perihel. = 50.04700 deg.
equinox 1950.0	equinox 1950.0

Professor Robert E. Stencel

Robert Stencel, the fourth Director of Chamberlin Observatory, and the William Herschel Womble Professor of Astronomy, first visited the observatory in 1988 as a speaker for the DAS. He observed the facility's poor condition, which was due both to the building's age (nearly 100 years) and the lack of funding from the financially stricken university during the oil bust of the 1980s. At this point, Everhart, the third director, was retired and unable to make frequent visits because of poor health.

In 1990, William Herschel Womble, a 1932 graduate of DU, left a bequest to the university of funds to endow an astronomy program "to promote educational research in astronomy and astrophysics ... and to construct, operate and equip a mountaintop observatory." The Chairman of the Department of Physics and Astronomy, Professor Herschel Neumann, arranged that this bequest allow for the hiring of a new astronomer. On July 1, 1993, Professor Stencel joined the faculty as DU's first endowed chair Womble Professor of Astronomy, to continue his work on stellar atmospheres and infrared astronomy, and to build the new observatory at Mt. Evans (1997) and the Student Astronomy Lab on campus (2004), among other projects.

Stencel took an interest in the decrepit observatory, organizing a Chamberlin Centennial Re-Dedication in October of 1993. The event was meant to bring in new life and interest, in addition to setting off recovery efforts. The university was still plagued with financial problems from the 1980s and was unable to offer extra funding, but volunteers were eager to assist. Certain necessary repairs, such as the dangerously failing balcony and restroom flooring were contracted to a local carpenter. James Parnell, a restoration engineer, advised the proper methods to re-pointing mortar in



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Professor Robert Stencel is the current, 4th Director of the observatory, beginning in 1993. In addition to being Director of the observatory, Stencel also holds the University of Denver's William Herschel Womble Chair in Astronomy.

Opposite Page Top
A modern view of Denver's great telescope as seen from the North service porch.

Opposite Page Bottom
These "digital protractor" devices, called encoders, have been added to measure turning of the moving telescope shaft, and report the angular position to a laptop. Sky software [http://www.bisque.com/] tracks the motion of the telescope on a detailed skymap. This upgrade has enhanced the ability to find faint objects lost in Denver's excessive skyglow, and represents the marriage of old and new technologies.

the basement, which was done largely by volunteers. Money from neighborhood fundraising and grants from the 1772 Foundation totaled around $25,000 to rejuvenate the observatory and repair flooring and the roofing on the north service porch.

On August 1, 1994, close to the centennial anniversary of the telescope's first light, the Denver City Council approved the resolution to name Chamberlin as a Denver Landmark, protecting it from being demolished. The entirety of the writing and assembly of the Landmark application was completed by Stencel's wife, Susan Conat Stencel. A successful application was made to the Colorado Historical Society (CHS) for a $100,000 grant for emergency repairs in 1997, along with the matching $50,000 from the university, which dealt primarily with the leaking dome and failing basement walls.

Much more remains to be done to recover the observatory's original condition yet foster modern teaching and outreach, in an ideal marriage of the historical and modern. By augmenting manual star-finding methods with encoders and computers, observers have regained three to 10 times the efficiency in finding stars and nebulae in Denver's light-polluted skies.

At the beginning of the 21st century, the University of Denver's historic Chamberlin Observatory is used almost every night, mainly for DU astronomy classes, and for public observatory nights conducted by volunteers from the DAS. The latter public events enable members of the community to view stars and planets through the observatory's big telescope or with portable telescopes set up in the surrounding park land.

The legacy of Howe's love of the stars lives on at the University of Denver, not only within the walls of Chamberlin Observatory, but also in the new programs and tools provided for students and the public.

“The University of Denver’s historic Chamberlin Observatory is many things: architectural marvel unique in Denver, center of the University Park community, and it codifies the past, present and future of astronomical arts and sciences.”

-Professor Stencel, Fourth Director, Chamberlin Observatory

Activities and Programs

Opposite Page Top
A glass-plate image of Comet Morehouse obtained by Prof. Howe as it appeared over Denver on Oct. 1, 1908. At the time of observation, the comet was in constellation Cepheus and approximately 1.15 AU distant [107 million miles; http://ssd.jpl.nasa.gov]. © Courtesy of University of Denver Penrose Archives

Opposite Page Middle
A glass-plate image of Halley's Comet, as it appeared in the Denver skies on May 24, 1910. At the time of observation, the comet was in constellation Cancer and approximately 0.2 AU distant [18 million miles; http://ssd.jpl.nasa.gov]. © Courtesy of University of Denver Penrose Archives

Opposite Page Bottom
A glass plate image of Brooks Comet as it appeared over Denver on Feb. 23, 1911. At the time of observation, the comet was in constellation Aquarius and approximately 4.75 AU distant [440 million miles; http://ssd.jpl.nasa.gov]. © Courtesy of University of Denver Penrose Archives

Observatory Programs in Howe's Time

Howe's Solution to Kepler's Problem

In addition to observing celestial bodies, Howe was interested in calculating and predicting their orbital movements. He began orbit calculations during his time at Cincinnati, referring to these calculations as Kepler's Problem, in honor of the 17th century astronomer Johannes Kepler. Eventually, when Howe decided to work on a doctorate, he refined solutions to Kepler's Problem as part of his doctoral thesis. He used his calculations to determine the orbit of the Great Comet of 1882. His calculations were finished in November 1883, and he was granted a Doctorate of Science degree from Boston University, and international recognition for his solutions.

It was effectively the middle of the 19th century before the mathematics of gravity were on a sound enough footing to enable their application to finding planet Neptune, based on its perturbations of the other planets. Indeed, only 300 or so large asteroids had been discovered before Howe's time, since the first one found in 1801. Between these and rogue comets, the world's relatively few astronomers and telescopes were kept busy full-time measuring positions by eye and calculating orbits with longhand arithmetic. At Denver's Chamberlin Observatory, Howe was poised to make contributions along these lines. Comets were still somewhat unexplained in detailed terms at this time as well. The distinction between long and short period comets was only beginning to be recognized, and in turn the implication for structure and evolution of the solar system hardly imagined, awaiting the insights of Gerald Kuiper in the mid-20th century. Recall that Edmond Halley only forecast the regular 76-year return of his famous comet as recently as 1758, hence the necessity for Howe to diligently solve the orbit for the Great Comet of 1882, among others, while anxiously awaiting the return of Halley's comet in 1910.

Howe's Study of Asteroids and Comets

Howe had an interest in asteroids and comets, in addition to planets and stars, and could make good use of Denver's great telescope for research thereof. In 1898, asteroid Eros, originally believed to be a small planet, was discovered, and it captured Howe's attention. The asteroid was small and difficult to see, but Howe searched for it in May 1899. One day, he was able to spot it visually, which was quite impressive considering how difficult the asteroid was to see. His observation of the asteroid was later reported in the Astronomical Journal.

One of the first, if not the first, astronomy students to use the observatory to observe comets was Mr. Dickerman, who was a graduate student working on his doctorate. Starting in late 1895, Mr. Dickerman observed comet Perrine and comet Swift. He found reduction of the data on comet Swift to be very difficult and received much assistance from his mentor, Professor Howe. Dickerman succeeded in getting his Ph.D. He also somehow suc-

ceeded in breaking the large cast iron gear wheel on the Delta axis, causing the telescope to be out of commission for eight long months. It was finally made operational again with a new Saegmuller gear wheel in December 1896, long after Mr. Dickerman had departed. In the fall of 1896, Professor Howe was observing Brooks' comet, which was plainly visible, and Spitaler's comet, which was hard to find. His book "A Study of the Sky," which then had just been published, contained a chapter on comets and meteors. He described comets as being "rather loose aggregations of small bodies which fly along together like so many grape-shot."

Other comets and asteroids appeared as well, such as the asteroid Alkinene, which was observed along with the comet Coddington in 1898. Temple's

Opposite Page Top
The Drum Chronometer was a recording device primarily used in association with the Transit Telescope, to record the moment an observer noted a specified star transiting. From the combination of several stars, an exact local time could be derived. For astrometry, moving objects could similarly have their precise position and time correlated. [Howe, 1896].

Opposite Page Bottom
A glass-plate image of the solar eclipse that occurred January 1, 1889 as observed by Howe and others from Winnemucca, Nevada on a scientific expedition organized by Mr. Chamberlin. Totality occurred close to 2 p.m. that day.
© Courtesy of University of Denver Penrose Archives

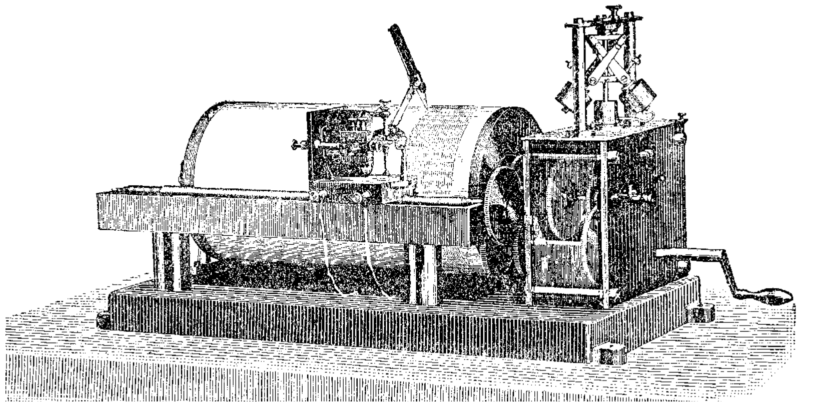
comet appeared the same year as Eros, and comets Giacobini and Borrelli appeared in 1903. Howe computed a package of comet observations, which he mailed to Germany. His findings were printed in the German astronomical journal Nachrichten and mailed to subscribers all over the world.

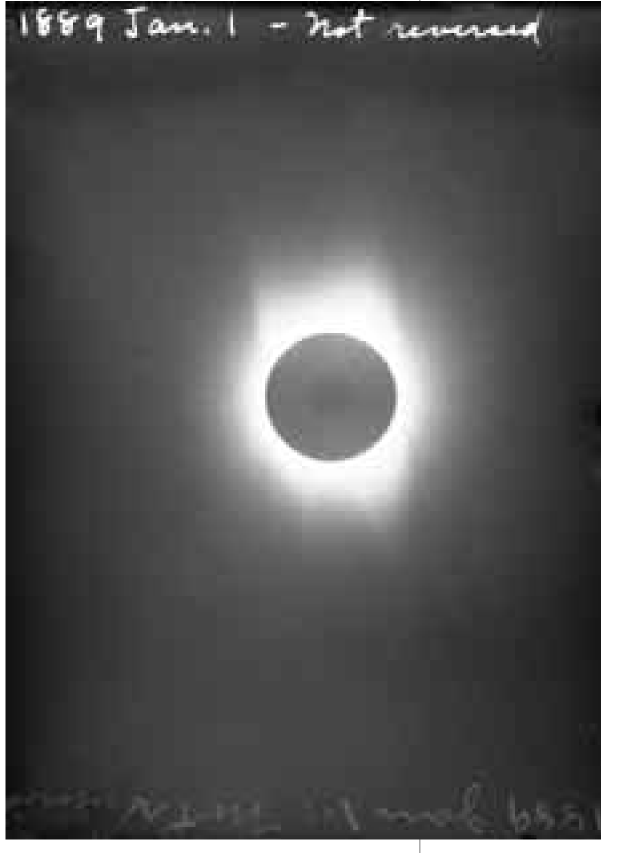
1905 was an exciting year for observing quite a number of comets. Comets Temple, Bourrelli, Brooks, Schaer and Giacobini were all observed at this time. The following year also produced a grand display of such comets as Kopff, Finlay and Holmes, followed in 1907 by comet Daniel and asteroid Eros, and in 1908 by comet Morehouse. All of these received as much attention as Howe's busy schedule would allow. But it was the comet that appeared in late 1909 that excited the world's attention. Halley's comet is a large periodic comet in an elliptical orbit, which brings it back to circle the sun every 76 years, with an appearance in 1986 and predicted return in 2062. In its 1909/1910 apparition, it passed perihelion, or closest approach to the sun, on the same side as the Earth, then occupied in its orbit. This brought the comet much closer to Earth than it later was at its passage in 1986/1987. Comet Halley in 1910 was a spectacular sight in the night sky for many months and was something that viewers all over the world would never forget. Professor Howe got his first sighting of comet Halley at 3:45 a.m. on the morning of October 12, 1909. Early in 1910, Professor Howe was observing comet Halley at every chance he got. In addition to observing, he was writing articles and preparing lectures on Halley.

In the very early morning on Thursday, May 19, 1910, came the long-awaited event, which led to an often repeated - and somewhat ironic - story about Dr. Herbert Alonzo Howe, and what happens to a soul who works long hours with a lack of sleep. The story has the dedicated astronomer sitting patiently by his telescope awaiting a spectacular celestial event, yet becoming so tired that just at the critical moment that the vision is to be observed, his eyes closed in a so-needed sleep, only to awaken later bitterly disappointed and full of guilty self-reproach at having missed this once-in-a-lifetime opportunity. Passing through the tail of the comet had obviously done the Earth no harm, and although Professor Howe was disappointed to have missed two hours of what may have been a spectacular meteor shower, he certainly did not miss very much of what was to be seen during the 1910 close approach of the Halley's comet.

The Great Fireball of 1900

In December, 1900, a meteor was spotted and named the Great Fireball of that year. In January, Howe received a letter from two men claiming to have fragments of the meteor. The men claimed that they would make the fragments available for study if they could be paid for their troubles. A man later wrote that he believed that the meteor had fallen near Pearl, Colorado, which was near the state's northern border.





Howe received another letter from a Mr. Shippey of Walden, Colorado in February 1901. Mr. Shippey offered Howe a percentage of the money for the sale of the meteor fragments. The professor wrote a long reply to the man, giving a negative response to the offer. It is unknown whether the man actually had fragments of the meteor in his possession or not.

This story of bright meteor sightings has been repeated over the years many times, in large part because of the clear skies of Colorado and a tendency for people to enjoy looking at the evening sky. For years, geologist Jack Murphy, while at the Denver Museum of Natural History (now the Museum of Nature and Science), coordinated numerous bright meteor sighting reports and attempted to triangulate the best of these. In a few cases, where sufficiently good data existed, field searches for fresh meteorite material were organized. In recent years, the Internet has facilitated tracking of bright meteor reports. A network of wide-angle cameras was established to improve data collection and triangulation. Reports could be submitted on Web pages affiliated with Cloudbait Observatory (www.cloudbait.com). While improved meteor trajectories could be defined, most burn up miles overhead and little reaches

Opposite Page Top
A glass-plate image of the waning crescent moon obtained August 24, 1919 at 15h29m. © Courtesy of University of Denver Penrose Archives

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The double cluster h & chi in constellation Perseus, as it appeared on the 15th of September, 1904, despite the presence of a bright gibbous moon. © Courtesy of University of Denver Penrose Archives

the ground. Identification of actual meteorites involves isotopic analysis, because appearances alone are not enough to prove extraterrestrial origin - unless the fall itself is witnessed.

Surveying - One of Howe's Many Talents

In addition to astronomy, math and language classes, Howe taught surveying at the University of Denver. In 1909, his class was faced with the daunting tasks of calculating where the 105th meridian crossed the city in Denver, and finding the mile-high level on the Capitol grounds. The class was enthusiastic about the project, and Howe repaid them by becoming engrossed in it as well. Howe visited the State Engineer at the time, a Mr. Jaycne, and borrowed his notes on the elevations of benchmarks. Unfortunately, the notes were somewhat inadequate, and Howe wrote a letter to the Coast Survey to fill in the gaps. Howe visited the City Engineers Office many times, having difficulty finding a particular benchmark at 19th and Wynkoop. Howe also received information from the U.S. Geological Survey, and spent much of his time drawing diagrams on a chart that showed the location of buildings of consequence, such as City Hall.

In April, Howe was taking measurements from the sun, and discovered that the street was slightly off from the plans that the city had given him. This made it necessary to alter all the computations that had been made so far. It was also discovered that the elusive Wynkoop monument had been partially destroyed in 1878, but not marked as such on the plans.

June 12, 1909 was an exciting day for the class, because it was discovered that the top of the second step above the landing on the main entrance to the Capitol was one mile above sea level. Howe got permission from Governor Shafroth to put a brass tablet on the step stating that it was exactly one mile above sea level. The plaque was fastened to the step at the State Capitol building on July 6, 1909, and is still there today. Howe would later report on all this in the publication: "The l05th Meridian in Denver and Its Mile High Level" Proceedings of the Colorado Scientific Society, X, 75.

Observatory Programs After Howe

Attendance Figures Over Time

The popularity of the observatory among the general public has varied over time, generally going up, but declining in recent years. Professor Howe's diaries show a great public interest in the new observatory, including groups upwards of 800 during the second half of 1894. According to an article by Thomas Bartlett in 1950, between the years of 1894 and 1929, the estimated number of guests was around 50,000. Professor Recht, one of the observatory Directors, began accurately tallying visitor numbers and reported 50,000 guests between 1929 and 1949

Facing Page
Portion of a star chart for the winter sky as it appears in the textbook written by Professor Howe. [Howe, 1897].

Opposite Page Top
Glass-plate images of Jupiter as it appeared June 15, 1909 near opposition [Virgo]. © Courtesy of University of Denver Penrose Archives.

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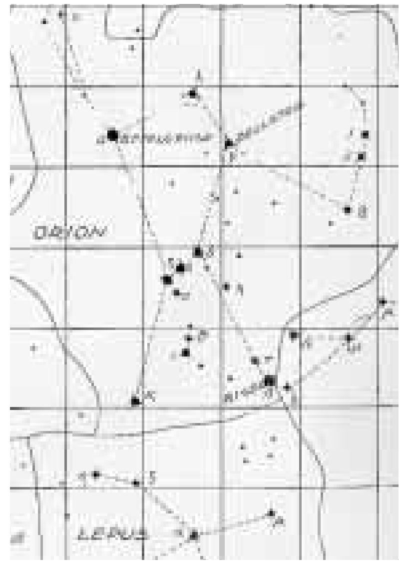
The Fauth Sidereal time clock, which sits in the main room of Chamberlin Observatory. It is anchored to the telescope pier to minimize vibration and keep accurate time. Spring-wound, 7 day movement.

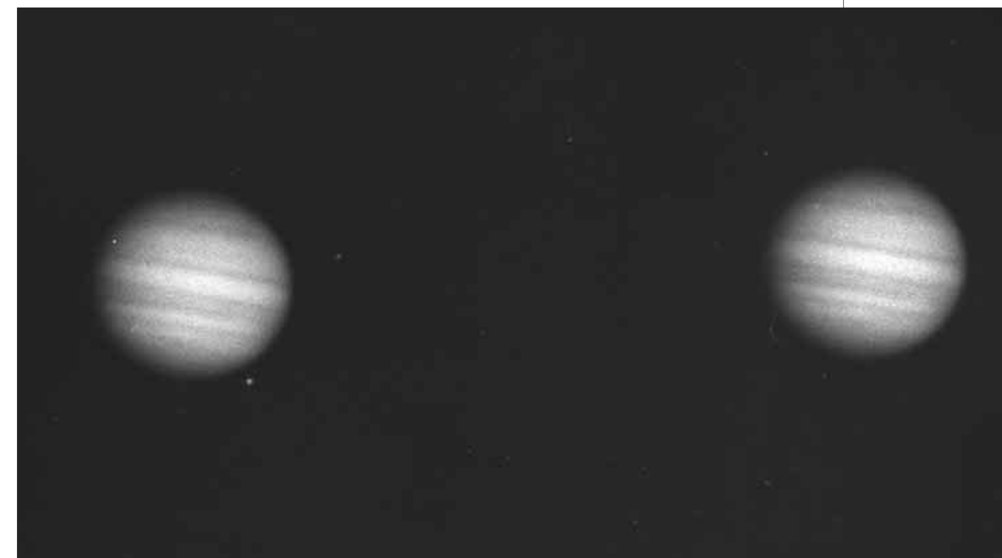


(that's 2,500 annually, on average). Bartlett notes that on November 16, 1949, the 50,000th visitor since Recht began careful tally in 1929 was nine-year-old Susan Wyman of Park Hill Elementary School in Denver. She was awarded a 3.5-in. Reflector telescope as a prize. Recht's 1960 Observatory Report notes an estimated 130,000 visitors during his 31-year tenure as Director through 1960 (or 4,000+ annually, perhaps increased with the postwar population growth and space race excitement). Physically, it takes a minute or more per person to climb up to the telescope, look through it, and climb down again. Given a two-hour program on half the nights of the year, one can calculate that about 21,000 visitors per year would represent capacity.

According to Professor Everhart from the text of a speech in 1980, Francis Ohmer, Recht's replacement, reported 213,142 guests between 1926 and 1980, though the precise source for these figures is unknown (averaging 3,947 annually). Telescope-use logbooks maintained by Professor Stencel since 1994 indicate an average of 4,500 students and guests annually during that recent decade, with relatively little promotion of these evenings. At that rate, with upwards of 2,500 to 4,500 guests per year, the 11 decades since opening would have enabled approximately one-quarter to one-half million telescopic views by Denver students, residents and visitors. This makes astronomy outreach at DU second in numbers only to hockey game attendance!

The Struggle With Lighting Pollution

As electric lights became more affordable and housing density grew around the observatory, issues of glare, light trespass and sky glow have become a problem for observing. Poorly aimed lights and excessive lighting, such as found around commercially zoned districts, cumulatively create light pollution. The lights create a sky glow, which makes it difficult to see fainter stars in the night sky. The lights also represent a substantial amount of energy waste, going upward into the sky - illuminating clouds and birds. Visibility of the Milky Way vanished from Denver a couple of decades ago, and the ability to see all but the brightest stars confounds most observatory visitors and students. This is a widespread problem for observers, because there are fewer and fewer places where there are no electric lights. The area around Chamberlin was once a perfect spot to observe the night sky, free



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Images of Mars obtained by Professor Howe with Denver's great telescope during times of close approach. Top row: 1909 Sept. 28, 37 million miles distant, in Pisces. Middle row: 1911 Nov. 19, 46 million miles distant, in Taurus. Bottom row: 1911 Dec. 2, 47 million miles distant, in Taurus. © Courtesy of University of Denver Penrose Archives

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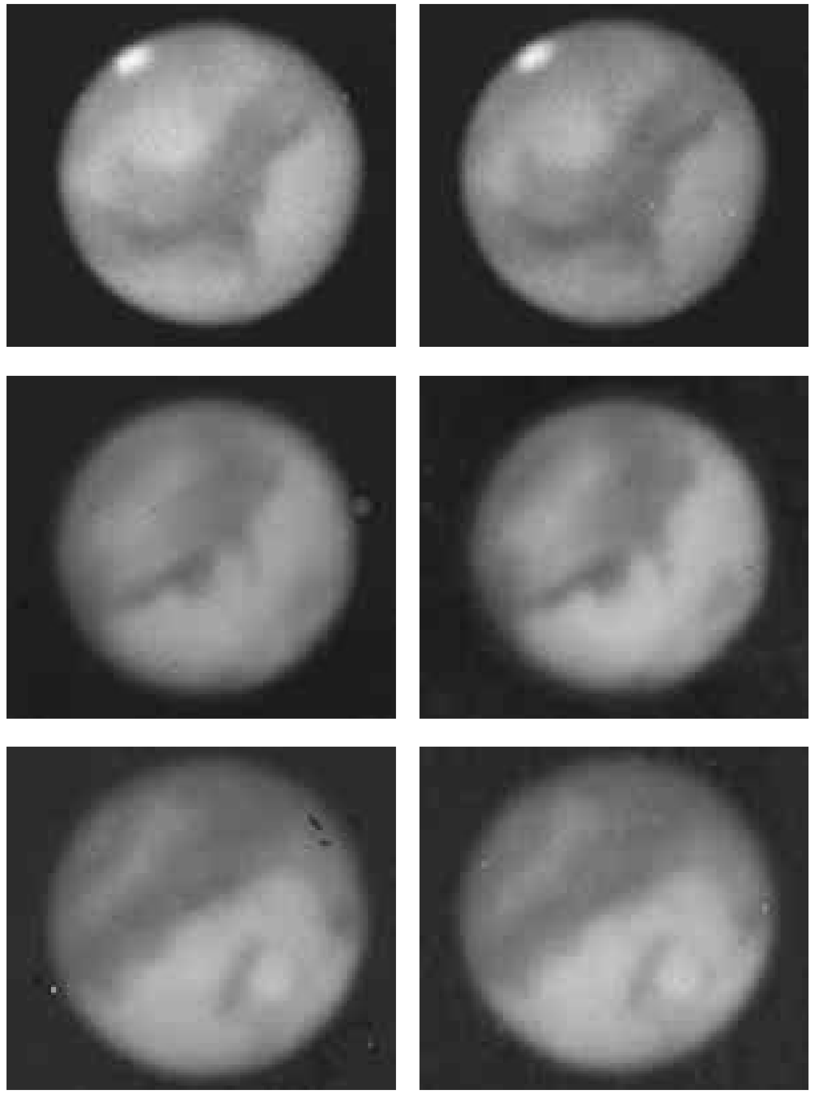
The observatory in 1898. Buildings were beginning to spring up around the observatory, as evident in this image. © Courtesy of University of Denver Penrose Archives.



from the glow of electric lights. Over the years, Observatory Park has been under assault by more and more lighting, making observing increasingly difficult.

Astronomers recognized the growing problem as early as 1980 and formed the International Dark Sky Association (www.darksky.org). In Colorado, campaigns to modify building codes to deal with glare, light trespass and sky-glow problems have been underway for several years at local, county and statewide levels. Artificial light is a form of radiation that we must learn to use wisely, not only because of the energy and environmental costs, but for human health reasons. Increasingly, the link between disruption of nocturnal melatonin production (a brain hormone) and stress, eyesight problems and cancer is being recognized. For those with problem lights from a neighbor, talk with the person about adding some shielding to shade your direction, or replacing the light with one of many energy efficient, directable lamps now available in hardware stores. Colorado members of the Dark Sky Association are also available to help with your questions.

The Future of the Observatory

A student recently asked how the study of astronomy helps the nation. Astronomy inspires and challenges. Since ancient times, people have learned to use the stars for time and calendar keeping. Movements of the planets inspired theories of gravitation, which helped promote physics and engineering, and continue to offer extreme tests for both - relativity/cosmology and spaceflight. Finally, astronomy gives us "the biggest picture" of the universe and our place in it, and it provides lessons about why we should take better care of this special planet we depend on - starting with keeping an eye out for hazardous asteroids and finding cures for energy-wasting light pollution.

What does this suggest about the outlook for the old observatory? Denver's great telescope may currently be valued as a million dollar antique, but for comparison, the NASA Hubble Space Telescope was a several-billion dollar enterprise. This is representative of the scope and scale of early 21st century big science in space. The major categories of exploratory vehicles include in-situ probes to planets, and large, multi-wavelength telescopes in orbit. The nature of the prioritization and funding process presses the community to achieve order of magnitude technical and scientific improvements within a constrained budget pool. The incredible expense in space yields incredible returns, but it also motivates the ground-based astronomy community to apply clever new methods such as adaptive optics to cancel the blurring effects of Earth's atmosphere.

Concurrent with the creation of the largest refractor telescopes, such as the Chamberlin (20-in. aperture), Lick (36-in.) and Yerkes (40-in.), the competing technology of reflector (curved mirror) telescopes was rapidly advancing. The Mt. Wilson 100-in. aperture telescope was operational during Howe's career, the giant Palomar 200-in. (5 meter) followed when Chamberlin Observatory was barely 50 years old. Today, several 8- and 10-meter aperture

Opposite Page Top
Goodsell Observatory, Carleton College, Northfield, Minnesota, the model adopted by Howe for the design of DU's historic Chamberlin Observatory [Howe, 1896].

Opposite Page Bottom
Prof. Recht with Denver's great telescope, with a photographic guide scope tube mounted on the side. © Courtesy of University of Denver Penrose Archives.

telescopes rule the ground, with serious discussion of building 30- to 100-meter ground-based telescopes - nearly the size of a football field!

In light of the foregoing, what now are the possible roles and futures for the University of Denver's historic Chamberlin Observatory and its antique telescope? Three overlapping roles include research, teaching and outreach - the trinity for university faculty and academic facilities most everywhere. In light of this, in October 1993, Professor Stencel organized a Chamberlin Centennial Re-dedication event to officially breathe new life into the old observatory and to set the stage for renewed recovery efforts. In those days, the University of Denver was busy with larger issues of financial recovery from a recent recession. Thus he began to organize funds, volunteers and contracts for work at Chamberlin's Observatory.

The high point in this period was reached on Aug. 1, 1994 - close to the 100th anniversary day of the telescope's first light, when the Denver City Council unanimously approved the resolution naming Chamberlin Observatory as a Denver landmark, giving it real legal protections from demolition. Susan Conat Stencel deserves the full credit for writing and assembling the landmark application and guiding it through the review processes.

As of this writing, in addition to programmatic needs, there are many infrastructure needs to attend to as well. Approximately $150,000 (in 1997 dollars) in grant and matching money provided key repairs for Chamberlin Observatory under the Colorado State Historical Society grants program, which also mandated creation of a preservation master plan. Items identified include problems with electrical wiring, plumbing, the heating system, floor damage related to the heating system, serious wood rot on nearly all the exterior window frames, plaster failures, an inadequate fire and security alarm system, to name a few, as well as strategies for Americans with Disabilities Act (ADA) accommodations. Therefore, it remains a priority to complete the key points of the preservation master plan to improve the building's condition. Beyond the preservation master plan, there is the desire to expand the building for the purposes of ADA, an improved meeting space (e.g., "digital classroom" space) to provide decent restrooms and storage, as well as other amenities should such an opportunity arise and be fundable.

Thanks to the perseverance of those directly associated with the drive to sustain the astronomical tradition Chamberlin Observatory represents, there exist several proposed goals for the coming years regarding its survival: (1) restore the Clark-Saegmuller refractor to its historically accurate condition, and continue public outreach programs with staff and volunteer collaboration; (2) address code and ADA problems with the building, per the preservation master plan - developed as part of a building preservation grant from State Historical Society; (3) recapture the research and training component for which Chamberlin was intended, but has lost due to antiquated equipment and infrastructure.

The most important facet of the Chamberlin Observatory is that it continues to be a magnet that enables students and the public to view astronomical objects, and not be merely an architectural mausoleum. Although it appears that Chamberlin Observatory has survived with volunteer help and occasional emergency repairs, it awaits the interest and energy of an organization willing to invest in a level of staffing and budget never before provided. Ever since Mr. Chamberlin became unable to provide the University of Denver with the operational endowment he intended, his observatory has survived on whatever spare time people could afford to devote to it. In 1952, DU gave away the land surrounding the observatory to become a public city park, perhaps prophetically. Because modern teaching and research demand newer facilities, which the University of Denver has acquired, the ideal observatory co-management organization should be closely aligned with the curatorial needs of the old observatory. Additionally, there should be continued collaboration with volunteer telescope operators for outreach, especially to sustain the frequent public viewing nights, all while continuing the long, unbroken tradition of hosting DU astronomy classes on-site. Sustaining Chamberlin Observatory will inspire new students and fulfill Howe's vision "to encourage the habit of accurate observation; to strengthen reasoning by the application of mathematics to astronomical phenomena, and its pure disciplinary value - lifting the mind from daily cares, to the contemplation of awe-inspiring grandeur."

Opposite Page
The grave of Professor Herbert Howe, and his wife Fannie, sits in Denver's Fairmont Cemetery, block 80.

Endowment

In October 1890, a penniless prospector named Bob Womack discovered gold in Colorado in an ancient crater west of Pikes Peak, where only a handful of people lived. The place was Cripple Creek, and during the next few years, it would become a boomtown, producing millions of dollars in gold. Most of Cripple Creek's ore was shipped to smelters in Denver and Colorado Springs, Colorado. The foothill communities shared not only in refining the gold, but also in furnishing the necessities of life for those who mined the gold, as well as the luxuries demanded by newly rich mine owners.

The mineral boom led to prosperity throughout Colorado, including Denver. Real estate was in demand, and Humphrey Chamberlin began to make a good living in land speculation, especially in south Denver. After the University of Denver planned to relocate there, Mr. Chamberlin began to think about how he could help the school and sell properties near its new campus. With his interest in astronomy, sponsoring an observatory came to mind, as he proposed in 1888. But an observatory, like a school, is more than just a place - it needs paid staff. An endowment fund can provide annual interest dollars from capital to do just that, and more.

In early 1891, Chamberlin, spoke privately to Professor Howe at a reception, indicating that he desired to provide an endowment for the observatory. He asked the Professor to write out and give him a plan of work for the ensuing year in case he made arrangements for him to devote all of his time to the observatory. This, of course, was never destined to happen. When Professor Howe furnished a response on January 7, Chamberlin suggested to him that he obtain a personal loan of $3,000 for 90 days to give to Mr. Kempf so that the latter could get back to work on the construction. Although making great plans, it would appear that Mr. Chamberlin had cash-flow problems in the short term.

In 1890, Congress had passed the Sherman Silver Purchase Act, requiring the federal government to purchase silver equal to the total U.S. production annually. This was a great boon to Colorado with its booming mining industry and was reflected in foothill communities such as Denver which benefited greatly from this legislation. However, this amounted to a government subsidy of the mining industry. By 1892, it had become a political issue in the presidential election. That November, Grover Cleveland, a Democrat, defeated the incumbent Republican president Benjamin Harrison.

The spring of 1893 was a time of recession that turned into an economic crisis of "panic" proportions. One of the things blamed for the panic was the Sherman Silver Purchase Act of 1890. The act was repealed in October 1893. In silver producing regions, already affected by the general business depression, the effect of the repeal was to make the economic crisis immeasurably worse. In Colorado, the booming prosperity of the late 1880s was

about to turn into a grinding depression. At University Park in the fall of 1892, these looming problems had not yet had any effect.

Still lacking an endowment for the observatory in the first years of the 21st century, the present Director has been seeking ways to secure the future of the facility and its astronomy educational programs. As history shows, private donations always have, and always will play a role in furthering of observatory facilities and programs. Contact the University of Denver for more information about these charitable opportunities.

Ultimately, we, the friends of the University of Denver's historic Chamberlin Observatory, should proceed in a way that makes people look back decades from now at what we accomplished and say, "Those folks did things right!"

Appendices

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Sky & Telescope magazine;
Astronomy magazine

Telescopes:
Antique Telescopes:
Antique Telescope Society
Historical Astronomy Division of the American Astronomical Society

Web Sites:
http://www.du.edu/~rstencel/Chamberlin
http://www.darksky.org

Deed Creating Observatory Park, 1952

Clerk and Recorder office, City and County of Denver
Recorded in Book 7152, Page 57, 1952 July 23, No.110597

DEED: Know all men by these presents that Colorado Seminary, a corporation organized and existing under and by virtue of the laws of the State of Colorado, of the City and County of Denver, State of Colorado, for the consideration of Ten Dollars [$10.00] and other valuable considerations in hand paid, receipt of which is hereby acknowledged, has granted, bargained, sold and conveyed by these presents does grant, bargain, sell, convey and confirm to the City and County of Denver, a municipal corporation organized and existing under and by virtue of the Constitution of the State of Colorado, the following described real property situate in the City and County of Denver, State of Colorado, to-wit:

That portion of Observatory Park, situated between Warren Avenue and Iliff Avenue, and between South Milwaukee Street and South Fillmore Street, University Park Amended Map;

Excepting and reserving, however, unto said grantor, its successors and assigns, all structures situated on said real estate or at any time constructed on said real estate by the grantor, together with the right to remove same, and also excepting and reserving unto said grantor, the right to use said real estate as an observatory site, including the right to use the observatory buildings now situated on the premises; provided, however, that no such enlargement and no such replacement shall be of such size or location as to seriously interfere with the use of the remainder of said real estate for park purposes. The rights herein reserved shall obtain in respect of each such observatory building so long as the grantor uses such building solely for observatory purposes, and no longer. Should any such building be used for any other purpose at any time, the grantor shall within thirty [30] days thereafter serve written notice upon the grantee of such change in use, and that all rights herein reserved in respect of that building [except the right to remove the building within a reasonable time] may be terminated at any time thereafter upon the grantee giving the grantor thirty [30] days written notice of such termination.

While in exercise of the rights herein reserved, the grantor, its successors and assigns, shall be responsible for the care and maintenance of all such observatory buildings and all such buildings shall be under the sole control and supervision of the grantor.

The grantee, as part of the consideration hereof, covenants with the grantor that it will comply with, and the conveyance is made subject to, the restriction that said real estate shall not be lighted in such manner as to seriously interfere with the use of said real estate by the grantor, its successors and assigns, for an observatory site. This covenant and restriction shall run with the land, for the benefit of the grantor, its successors and assigns, so long as the grantor, its successors and assigns, uses some portion of said real estate as an observatory site.

With all its appurtenances and warrant this title to the same, signed and delivered this 16th day of June A.D. 1952. Colorado Seminary, by Robert W. Selig, President; Attest: S. Arthur Henry, Secretary, State of Colorado, City and County of Denver, ss. Notarized.

Publications of Dr. Herbert Alonzo Howe

Reprinted from "Denver's Pioneer Astronomer: Herbert A. Howe"

Monthly Notices of the Royal Astronomical Society

Vo1:Pg.	Title
58:356.	Observations of Nebulae at Chamberlin Observatory
58:515.	part 2
58:523.	Lists of Nebulae Discovered at Chamberlin Observatory
60:129.	part 2
60:611.	part 3
60:130.	Nebula Observations
60:140.	The Bruce Micrometer of Chamberlin Obs.

Publications of the Astronomical Society of the Pacific

Vol: Pg.	Title
09:94.	Review of Howe's Descriptive Astronomy by Edward S. Holden (1897)
15:250.	Review of Lick Observatory Publications, Volume VI
15:97.	Annual Reports from the Chamberlin Obs., 1902-09
16:107.	ditto; 18:146. ditto; 19:90. ditto; 20:98. ditto; 21:145. ditto; 22:191. ditto.

The Sidereal Messenger

Vol: Pg.	Title
02:45.	Logarithmic Computations
02:228.	Two Book Reviews
03:97.	The Great Comet of September, 1882
04:64.	Book Review
04:205.	Eclipses for Students
07:95.	Book Review
07:262.	New Observatory at Denver, June, 1888
07:306.	Visit to Carleton College Observatory
08:375.	Note concerning 20-in. Chamberlin objective exhibited in France
08:448.	Earth Tremors
09:34.	Denver Students' Observatory
10:376.	Progress at Chamberlin Observatory, 1890

The Astronomical Journal

Vol: Pg.	Title
09:142.	An Error in Chauvenet's Astronomy
10:102.	Corrections to Chauvenet's Astronomy
14:164.	Observations of Transit of Mercury
14:167, 174.	Comet 1894e (Swift)
15:23.	Comet 1894e (Swift)
15:61.	Comparison Stars for Comet lS9Je
16:80.	Comet 1895a (1895 II)
17:13.	Comet 1894 IV
18:17.	Comet 1896 VI
19:78.	Comet 1898c (Coddington)
20:49,103.	Observations of asteroid Eros (1893) (302 observations)
20:145.	Comets 1898 VIII and 1899 I
20:161.	Comet 1899c (Tempel II)
21:30.	Observations of Eros (1900)
23:190.	Notes on Wolf's new star of Sept. 21, 1903
26:78.	Elements of comet 1910a
26:92.	Comet 1908c (Morehouse)
27:160.	A new traveling wire micrometer for an equatorial
31:25.	Comets 1911 V (Brooks), 1912a (Gale), 1913b (Metcalf)
31:41.	Observations of Eros (1912, 1914-15) (252 observations)
37:21.	Comets 1924c (Finsler), 1925b (Reid), 1925a (Shajn) and Ganymede (1036)

Astronomische Nachrichten

Vol: Pg.	Title
159:307.	Rediscovery of Eros, 1901 Aug. 2
163:342.	Comets 1902 III and 1903 I
171:161.	Comets 1905 I (Encke), 1904 I, 1905 II (Borrelly), 1904 III (Tempel II), 1904 II, 1905 III
180:345.	Eros (1907), Comets 1907d (Daniel), 1907e (Mellish)
186:289.	Comets 1905 V (Shaer), 1906 I (Giacobini), 1905 VI (Brooks), 1905 IV (Kopff), 1906 IV (Kopff), 1906 V (Finlay)
188:415.	Comet 1910b (Metcalf) and Eros (1910)
192:55.	Comets 1910a, 1910e (Faye), 1911f (Quenisset), 1911g (Beljawsky), 1911b (Kiess)
200:121.	Comet 1910 II (Halley). (209 observations)

Astronomy and Astrophysics

Vol: Pg.	Title
11:745.	Occultation of Mars, September 3, 1892
12:88.	Solar Eclipse of October 20, 1892
12:89.	Occultation of o Piscium, November 30, 1892
12:505.	Experiments in Electric Lighting
13:709,826.	The 20-in. Equatorial of Chamberlin Observatory Popular Astronomy

Vol: Pg.	Title
03:131, 193.	Adjustment of a Small Equatorial
04:166.	A Study of the Sky, by H.A. Howe, book notice
04:225, 363.	The Teaching of Descriptive Astronomy
05:112.	Pronunciation of Star Names
05:444.	Observations of Meteors
06:369.	The Place and Function of Astronomy in Education
07:447.	A Brilliant Fireball
08:21.	Leonids Observed at University Park
08:107.	Occultations During the Eclipse of December, 1899
08:346.	Observations of Eclipse of May 28, 1900
08:347.	Rediscovery of Eros (1900)
08:399.	Occultation of Saturn, co-authored with J.O. Howe
09:29,69, 169,225.	Astronomical Books for the Use of Students
09:286.	Book Review
10:107.	The Great Fireball
10:548.	Lunar Eclipse of October 16, 1902
10:553.	Total Eclipse of Moon
11:166.	A Texas Meteor
12:80.	Book Review: A New Life of Galileo
13:108.	Occultation of Aldebaran, December 20, 1904
26:290.	Eclipse Plans of Chamberlin Observatory (Yerkes and Allegheny Observatories co-operate)
27:569.	A Desideratum in Solving Kepler's Problem. (Abstract)
30:161.	Kepler's Problem for High Planetary Eccentricities
30:615.	A Table of (x-sinx). (Abstract)
33:419.	The Cleaning of an Object Glass

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Chamberlin Observatory Construction Chronology

Reprinted from "Denver's Pioneer Astronomer: Herbert A. Howe"

1888	June 13	Initial ceremonial groundbreaking at Simpson's Grove site
1889	Nov. 28	Foundation digging begins at Observatory Park site
	Dec. 17	Load of bad foundation stone returned to shipper
	Dec. 26	Concrete (base of) perimeter wall poured
1890	Feb. 5	Pier stone laying begun using wooden derrick
	Feb. 17	Mr. Chamberlin authorizes construction of Student Observatory
	March 20	Top course, Transit pier stonework scrapped and redone
	March 28	Main pier stonework essentially complete
	May 1	Telescope support tripod arrives by rail in Denver (5,600 lbs.)
	May 12	Telescope tripod installed (fastened down by May 30)
	May 17	Location for Student Observatory selected (bids opened July 28)
	Aug. 7	Dome components arrive by rail in Denver, on site by Aug. 15
	Aug. 13	Student Observatory excavation begun
	Sept. 5	Large floor joists arrive from Oregon, on site by Nov. 15
	Sep. 20	Student Observatory stone walls complete
	Oct. 11	Howe spends hours moving dome iron into protective shed
	Oct. 21	Student Observatory dome track in place
	Nov. 13	First floor decking and window framing underway, main building
	Dec. 5	Stone shortage halts work
	Dec. 13	Second floor joists in place
	Dec. 15	Work halted over payment dispute among subcontractors, and winter
	Dec. 25	Howe designs observing ladder; Mr. Chamberlin expresses desire to provide endowment for observatory
1891	Jan. 19	Work resumes
	Feb. 17	Balcony door framed
	April 13	Cornice built (main building) and plastering at Student Observatory
	April 24	Top course of stone laid, ready for dome installation
	April 29	Howe named Dean of Liberal Arts
	May 4	Student Observatory completed, 6-in. telescope mounted May 2
	May 9	Dome installers at work, Mercury transit observed
	May 27	Dome ribs erected
	June 18	Galvanized covering of dome completed, exterior of observatory finished; plastering and Transit pier underway, steam fitters for main floor
	July 2	Student Observatory Transit pier
	July 8	Stone lettering over south entrance, main building, completed
	July 11	University Park stop on electric tram line opened
	July 25	Fireplace mantle installed, Director's office
	Aug. 5	Contract let for local casting of telescope support column
	Aug. 28	Mr. Law, first live-in student and janitor, arrives
	Sep. 12	Main dome leveling finished
	Oct. 7	Main dome painting completed
	Oct. 12	Support column casting delivered (4,500 lbs.)
1892	Jan. 11	Howe asked to write textbook by Silver, Burdett & Co.
	March 1	Installing electric wires around building, awaiting telescope
	April 9	Meridian circle, chronograph and Transit telescope arrived
	July 11	Electric lights on at observatory
	Oct. 20	Solar eclipse observed
1893	Jan. 1	General business downturn leading to Silver Panic of 1893, on June 27
	May 12	Mr. Chamberlin refuses to pay Saegmuller for telescope work in progress
	May 29	Hale requests loan of 6-in. finder telescope for Pikes Peak site survey
	June 17	The Howes arrive in Chicago for Columbian Exposition showing of telescope
	July 10	Chamberlin Investment Co. bankrupt
	Nov. 28	"One of the 6-in. telescopes" shipped out to a school in Fort Worth, Texas
	Dec. 2	Howe offers Pickering at Harvard, one year rental on the 20-in. for an Arizona site
	Dec. 6	Howe proposes charging visitors 50 cents per person to defray expenses
1894	May 10	Optics arrive by rail from Alvan Clark & Sons, escorted by Professor Howe
	July 14	First light with 20-in. refractor
	Aug. 1	First visitor group views through Denver's Great Telescope

Additional Information

For more information about Denver's Great Telescope, the University of Denver's historic Chamberlin Observatory and/or to obtain copies of this and other books from the Sources & Citations list, please use the following addresses:

Director, Chamberlin Observatory
Department of Physics & Astronomy
University of Denver
Denver, CO 80208 USA
303-871-2238
http://www.du.edu/physastron
http://www.du.edu/~rstencel
email: rstencel@du.edu

Befriend the Observatory

Interested in a closer connection to things astronomical? Join the Friends of the Observatory, and heaven's blessings will be showered upon you. Membership benefits include private observing sessions, an annual special event star-party at Chamberlin, electronic or printed newsletters, notifications about special astronomical events and lectures, and much more!

Program and infrastructure at the University of Denver's historic Chamberlin Observatory is largely supported by private donations, fund-raising events, limited University funds and publication projects such as this book. Gifts are encouraged and welcomed.

Tax-deductible donations may be made to:
UNIVERSITY OF DENVER, CHAMBERLIN FUND
and mailed to the address given above – thank you! All contributions will receive written acknowledgement. If you are interested in helping with named gifts, or the observatory endowment fund, contact the University of Denver Advancement Office at 303-871-2739.