



MENU

[Contents](#)

[Acknowledgements](#)

[Introduction](#)

[Summary](#)

[Nominations](#)

[Other Sites](#)

[Existing National
Historic Landmarks](#)

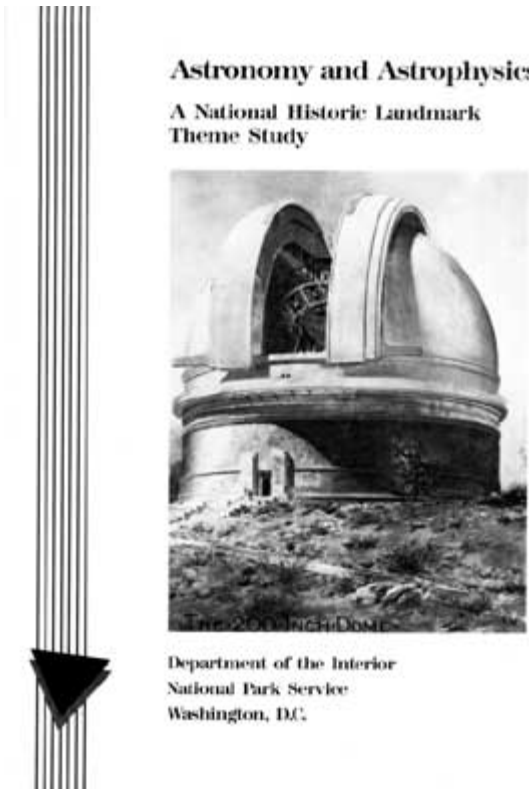
[Glossary](#)

National Park Service



ASTRONOMY and
ASTROPHYSICS

Excerpts from a
National Historic Landmark Theme Study



200-inch Hale Telescope and Dome

(Photo Credit: Russell W. Porter drawing, Palomar Observatory)

Dr. Harry A. Butowsky
National Park Service
Department of the Interior
May 1989



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Cover Page

MENU

Contents

[Acknowledgements](#)

[Introduction](#)

[Summary](#)

[Nominations](#)

[Other Sites](#)

[Existing National
Historic Landmarks](#)

[Glossary](#)

Astronomy and Astrophysics

Table of Contents



TABLE OF CONTENTS

[Acknowledgements](#)

[Introduction](#)

[Summary of Nominations](#)

[Nominations](#) (see below)

[National Register Sites Considered But Not Recommended for National
Historic Landmark Designation](#)

[Other Sites Considered But Not Recommended for National Historic
Landmark Designation](#)

[Sites Less Than 50 Years Old](#)

[Sites That Are No Longer Extant](#)

[Existing National Historic Landmarks in Astronomy](#)

[Existing National Historic Landmarks in Other Themes](#)

[Glossary of Astronomical Terms](#)

Appendix (omitted from on-line edition)

- Regulations of the National Historic Landmarks Program
- National Historic Landmarks Program Information Sheet
- National Historic Landmarks Assistance Brochure
- National Register of Historic Places Information Sheet
- National Register of Historic Places Information Brochure

Nominations

- [Hale Solar Laboratory](#), Pasadena, California
- [Lick Observatory Building](#), Mount Hamilton, California

- [Lick Crossley 36-inch Reflector](#), Mount Hamilton, California
- [Mount Wilson Observatory](#), Pasadena, California
- [Palomar Observatory 200-inch Reflector](#), San Diego County, California
- [Palomar 48-inch Oschin \(Schmidt\) Telescope](#), San Diego County, California
- [United States Naval Observatory](#), Washington, DC
- [University of Illinois Observatory](#), Urbana, Illinois
- [Gaithersburg Latitude Observatory](#), Gaithersburg, Maryland
- [Blue Hill Meteorological Observatory](#), East Milton, Massachusetts
- [Horn Antenna](#), Holmdel, New Jersey
- [Cincinnati Observatory](#), Cincinnati, Ohio
- [Allegheny Observatory](#), Pittsburgh, Pennsylvania
- [Stellafane Observatory](#), Springfield, Vermont
- [Reber Radio Telescope](#), Greenbank, West Virginia
- [Yerkes Observatory](#), Williams Bay, Wisconsin

TO THE MEMORY OF
EDWARD BUTOWSKY
1903-1988

[History](#) | [Links to the Past](#) | [National Park Service](#) | [Search](#) | [Contact](#)

 [Top](#)

Last Modified: Mon, Nov 5 2001 8:00:00 pm PDT

http://www.cr.nps.gov/history/online_books/butowsky5/astro0.htm





Cover Page

MENU

[Contents](#)

[Acknowledgements](#)

[Introduction](#)

[Summary](#)

[Nominations](#)

[Other Sites](#)

[Existing National
Historic Landmarks](#)

[Glossary](#)

Astronomy and Astrophysics

Acknowledgements



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May 1989

 [Top](#)

[History](#) | [Links to the Past](#) | [National Park Service](#) | [Search](#) | [Contact](#)

Last Modified: Mon, Nov 5 2001 8:00:00 pm PDT
http://www.cr.nps.gov/history/online_books/butowsky5/astro1.htm





Cover Page

MENU

[Contents](#)

[Acknowledgements](#)

[Introduction](#)

[Summary](#)

[Nominations](#)

[Other Sites](#)

[Existing National
Historic Landmarks](#)

[Glossary](#)

Astronomy and Astrophysics

Introduction



INTRODUCTION

The Astronomy and Astrophysics National Historic Landmark Theme Study was prepared by the National Park Service for the National Park System Advisory Board as part of the National Historic Landmarks Program. The purpose of the study is to identify the sites, structures, buildings and objects significant in the history of the sciences of astronomy and astrophysics in the United States. Those properties nominated for National Historic Landmark designation in this study will be evaluated by the National Park System Advisory Board, a committee of scholars and other citizens. The Board will then recommend to the Secretary of the Interior the properties, which in its opinion, should be designated as National Historic Landmarks. The decision to designate or not designate a recommended property rests with the Secretary. A complete explanation of the purpose of the National Historic Landmarks Program and regulations of the program can be found in the appendix to this study.

The subject of astronomy was first covered by the National Park Service as part of Volume XX of the National Survey of Historic Sites and Buildings report, The Arts and Sciences: Scientific Discoveries and Inventions, 1964. The sites related to the history of the science of astronomy that were examined for designation under this theme were:

1. Lowell Observatory, Arizona
2. Meteor Crater, Arizona
3. California Institute of Technology, California
4. International Latitude Observatory, Ukiah, California
5. Lick Observatory, California
6. Mount Wilson Observatory, California
7. Old Naval Observatory, District of Columbia
8. Harvard College Observatory, Massachusetts
9. Maria Mitchell Observatory, Nantucket, Massachusetts

10. Nathaniel Bowditch House, Massachusetts
11. David Rittenhouse Birthplace, Pennsylvania
12. Matthew Fontaine Maury House, Virginia

At the 51st meeting of the Advisory Board on National Parks, Historic Sites, Buildings and Monuments in 1964, the following sites were recommended for designation as National Historic Landmarks.

1. Old Naval Observatory, District of Columbia (to recognize Matthew Fontaine Maury)
2. Nathaniel Bowditch House, Massachusetts (Navigation)

The board recommended that all action on the following observatories and on other sites related to the development of astronomy be deferred until a thorough study of the subject was made.

1. Lowell Observatory, Arizona
2. Lick Observatory, California
3. Mount Wilson Observatory, California
4. Harvard College Observatory, Massachusetts
5. Maria Mitchell Observatory, Massachusetts

Consideration of all the other sites discussed in the theme study was also deferred.

At the 53rd meeting of the Advisory Board on National Parks, Historic Sites, Buildings and Monuments in 1965, the Lowell Observatory was reconsidered and recommended for designation as a National Historic Landmark.

In 1975 the National Park Service, as part of a revision of the Science and Invention Theme Study, recommended the designation of the Edwin Hubble House in California as a National Historic Landmark. The Hubble House was designated in 1976.

In 1987 the National Park Service began a comprehensive study of observatories and other sites significant in the development of the history of astronomy in the United States. This study was soon expanded to include the related science of astrophysics. At that time only two properties, the Lowell Observatory and the Edwin P. Hubble House, were listed in the National Park Service publication, [History and Prehistory in the National Park System and the National Historic Landmarks Program](#) as landmarks significant in the science of astronomy.

In reviewing for this theme study I consulted Vol. XX of the National Survey of Historic Sites and Buildings Survey report, [The Arts and Sciences: Scientific Discoveries and Inventions](#), 1964, and the general

files and records of the National Historic Landmarks program. In addition, I reviewed properties listed in the National Register of Historic Places. These sources yielded the following properties for consideration under this theme.

1. Old Observatory, Alabama
2. Harquahala Peak Observatory, Arizona
3. Hale Solar Laboratory, California
4. Chamberlain Observatory, Colorado
5. Georgetown University Astronomical Observatory, District of Columbia
6. Old Naval Observatory, District of Columbia
7. University of Illinois Astronomical Observatory, Illinois
8. Earlham College Observatory, Indiana
9. McKim Observatory, Indiana
10. Portland Observatory, Maine
11. Gaithersburg Latitude Observatory, Maryland
12. Blue Hill Meteorological Observatory, Massachusetts
13. Harvard College Observatory, Massachusetts
14. Detroit Observatory, Michigan
15. Goodsell Observatory (New Observatory), Minnesota
16. Barnard Observatory, Mississippi
17. Weston Observatory, New Hampshire
18. Cincinnati Observatory, Ohio
19. Ohio Wesleyan University Student Observatory, Ohio
20. Allegheny Observatory, Pennsylvania
21. Stellafane Observatory, Vermont
22. Reber Radio Telescope, West Virginia
23. Buckstaff Observatory, Wisconsin
24. Washburn Observatory, Wisconsin

Additional sites, including the new Naval Observatory in Washington, DC, the Palomar Observatory in California, Yerkes Observatory in

Wisconsin, the Dearborn Observatory in Illinois, and the Horn Antenna in New Jersey, were suggested by historians of astronomy and included on my initial study list. Further reading in the field of astronomy resulted in the inclusion of many additional sites, such as the Leander McCormick Observatory in Virginia, the McDonald Observatory in Texas, Sacramento Peak Observatory in California and the Kitt Peak Observatory in Arizona. In all, more than 100 sites, including laboratories, workshops, homes and sites associated with the lives and achievements of famous American astronomers, were included on my additional study list.

The subject of Prehistoric American Indian Astronomy (Archaeoastronomy) was not included within the framework of this theme study. The sites and issues involved in this discipline require the skills of a trained archeologist/anthropologist with a knowledge of astronomy and should be studied as a separate theme study.

In order to be recommended for designation as a National Historic Landmark a potential site must possess national significance in the history of the development of the sciences of astronomy or astrophysics in the United States. This significance can be demonstrated by the association of the property with some important event in the history of astronomy or through its association with the life of an important individual who has made a significant contribution to the science of astronomy. A full listing of these criteria can be found in the regulations of the National Historic Landmarks Program (36 CFR 65) in the appendix to this report.

From the initial study list of more than 100 properties, a total of 25 were actually visited. Of this total, 16 properties are recommended for designation as National Historic Landmarks. One site, the Blue Hill Meteorological Observatory, was included to represent the science of meteorology. No other sites representing the science of meteorology were studied.

Many of the properties not recommended for landmark designation are now listed in the National Register of Historic Places or are believed to be eligible for listing in the National Register of Historic Places. Other sites were not recommended for designation for a variety of reasons that are discussed in the sections at the end of this theme study. A short summary of those sites recommended for designation under this theme follows on the next page. A complete listing of all other properties examined but not recommended for designation can be found at the end of this study.

[History](#) | [Links to the Past](#) | [National Park Service](#) | [Search](#) | [Contact](#)

 [Top](#)

Last Modified: Mon, Nov 5 2001 8:00:00 pm PDT

http://www.cr.nps.gov/history/online_books/butowsky5/astro2.htm







Cover Page

MENU

[Contents](#)

[Acknowledgements](#)

[Introduction](#)

[Summary](#)

[Nominations](#)

[Other Sites](#)

[Existing National
Historic Landmarks](#)

[Glossary](#)

Astronomy and Astrophysics

Summary of Nominations



SUMMARY OF NOMINATIONS

CALIFORNIA

HALE SOLAR LABORATORY PASADENA

The Hale Solar Laboratory is important because of its association with its owner-builder, George Ellery Hale. Hale was an internationally famous scientist, a trustee behind the endowment of the Huntington Library and Art Gallery in San Marino, California, and a trustee and organizer of the California Institute of Technology.

The Hale Solar Laboratory was Hale's office and workshop for the later years of his life. Hale's scientific contributions were many, especially in the area of astronomy. Hale was one of the first scientists to compare observations in physics laboratories here on earth to what is seen in the heavens. He, more than anyone else, was the person most responsible for the rise of the science of modern astrophysics in the United States.

The Hale Solar Laboratory was also the site of many scientific discoveries, the most famous being Hale's refinement of the spectrohelioscope, a device that made it possible to observe the hydrogen-rich prominences of the sun.

LICK OBSERVATORY BUILDING MOUNT HAMILTON

The 36-inch Clark refractor housed in the Lick Observatory building was the first large telescope erected on a site chosen for its astronomical advantages, rather than for convenience in the builder's backyard, or on a university campus. The location of the telescope on Mount Hamilton proved to be an excellent choice and provided an example that has been followed from 1888 until the present day. The discoveries of early Lick astronomers began a tradition of excellence at Lick that has had a profound impact in shaping the history of American astronomy in the twentieth century. By combining excellent equipment, a favorable location, and the proximity to the resources of the University of California, Lick established the pattern for large modern observatories that has continued to this day and has left a major imprint on modern

astronomy.

LICK CROSSLEY 36-INCH REFLECTOR **MOUNT HAMILTON**

The Crossley 36-inch reflector at the Lick Observatory was the first of a long line of metal-film-on-glass modern reflecting telescopes that have dominated major astronomical advances for the past century. In addition, the Crossley has produced more scientific results than any other telescope of its size including several historically important studies in stellar evolution, the structure and spectra of planetary nebulae, and the discovery and spectral analysis of faint variable stars in young clusters. The Crossley also contributed to studies that confirmed the expansion of the universe.

MOUNT WILSON OBSERVATORY **PASADENA**

The establishment of Mount Wilson Observatory in 1904, by American astronomer George Ellery Hale, brought a new era to the science of astronomy. The Snow horizontal telescope and the two solar tower telescopes were the first major instruments placed on Mount Wilson. Completion of the 60-inch reflector in 1908 and the 100-inch Hooker reflector in 1917 made Mount Wilson the home of the two largest telescopes in existence and the center of the astronomical world. These telescopes represented a quantum leap in mechanical and optical engineering capability. They laid the technological foundation for all large modern telescopes. Many of the major advances and greatest names in 20th-century astronomy are associated with the Mount Wilson Observatory, including Edwin P. Hubble, who in 1929 used the 100-inch Hooker reflector to gather data that showed the universe to be in a regular state of expansion, thereby providing the first clues to the origin of the universe.

PALOMAR OBSERVATORY 200-INCH REFLECTOR **SAN DIEGO COUNTY**

The construction and delivery of the Pyrex glass disk for the Palomar 200-inch reflector in 1936 marked a watershed in the history of astronomy. With the successful casting of this large mirror, the Palomar project, conceived by George Ellery Hale (1868-1938), and funded with a grant of \$6 million by the Rockefeller Foundation, moved toward the completion of the largest reflecting telescope in the world by 1948. In the 40 years since the completion of the Palomar project, the 200-inch reflector remains at the leading edge of research in the sciences of astronomy and astrophysics and stands today as a monument to George Ellery Hale and his efforts to produce the finest instruments in the world to answer the fundamental questions concerning the origin and nature of the universe.

PALOMAR 48-INCH OSCHIN (SCHMIDT) TELESCOPE **SAN DIEGO COUNTY**

Although not as well known as the 200-inch Hale reflector, the 48-inch Oschin (Schmidt) telescope at the Palomar Observatory has performed

invaluable scientific research and has prepared the way for many of the important discoveries made by the 200-inch. This instrument was first used in 1950 to carry out two surveys of the Northern Hemisphere, one through a red filter and one through a blue, so that a comparison of the two black and white prints would reveal how cool (red) or how hot (blue) a star was. The surveys involved taking 1758 plates of the northern sky and recorded stars never seen before. The Palomar sky survey is the standard reference atlas for deep sky observation and provides a base line with which to measure changes in deep sky observation targets in future surveys. It is used as a standard reference tool for all modern observatories doing deep sky observation.

DISTRICT OF COLUMBIA

UNITED STATES NAVAL OBSERVATORY WASHINGTON, DC

The United States Naval Observatory is the oldest scientific institution in the Navy, being first established in 1830 as the Depot of Charts and Instruments. The observatory is most noted for its work in study of positional astronomy and timekeeping. The Naval Observatory, along with the Royal Observatory in Greenwich, England, and the Pulkovo Observatory in the Soviet Union, is one of the few places in the world that continually observes and redefines the positions of the sun, moon, planets, and stars. The United States Naval Observatory is the only place in the United States where precise instruments measure celestial motions to provide accurate time and other astronomical data which are essential for safe navigation at sea, in the air, and in space.

ILLINOIS

UNIVERSITY OF ILLINOIS OBSERVATORY URBANA

The University of Illinois Observatory is significant because of its association with the development of the selenium photoelectric cell which revolutionized the science of astronomical photoelectric photometry--the measurement of celestial magnitudes. The research was conducted on the 12-inch Warner and Swasey refractor telescope located in the second-story equatorial room of the 1896 brick observatory. The development of the selenium cell was done by Joel Stebbins (1878-1966), in the years from 1907 to 1922, while he was the director of the University of Illinois Observatory. As a result of Stebbins work at Illinois with the photoelectric cell, photoelectric photometry became the standard technique in determining stellar magnitudes. The determination of stellar magnitudes is one of the most fundamental measurements in the field of astronomy.

MASSACHUSETTS

BLUE HILL METEOROLOGICAL OBSERVATORY EAST MILTON

The Blue Hill Meteorological Observatory is the foremost structure

associated with the history of weather observations in the United States. Founded by Abbott Lawrence Rotch on February 1, 1885, the observatory took a leading role in the newly emerging science of meteorology and was the scene of many of the first scientific measurements of upper atmosphere weather conditions using kites to carry weather instruments aloft. Knowledge of wind velocities, air temperature and relative humidity at various levels came into use as vital elements in weather prediction due to techniques developed at this site. By 1895 the observatory was the source of weather forecasts of remarkable accuracy. The observatory remains active to this day, continuing to add to the data base of weather observations now over 100 years old, and stands as a monument to the science of meteorology in the United States.

MARYLAND

GAITHERSBURG LATITUDE OBSERVATORY GAITHERSBURG

The Gaithersburg Latitude Observatory is significant for its association with the study of polar motion, and for its symbolic value in representing an important and long-lived program of international scientific cooperation. Established in 1899 by the International Geodetic Association, the International Polar Motion Service was a cooperative effort among scientists worldwide to study the Earth's wobble on its rotational axis. The Gaithersburg Latitude Observatory was one of six observatories around the world (in the United States, Russia, Japan, and Italy) commissioned under this program.

Between 1900 and 1960 these observatories were the best source of information on polar motion available to scientists. Data supplied by the six latitude observatories have been used in hundreds of scientific papers and studies investigating the geophysics of the earth. The observatories have enabled geodesists to better understand the size and shape of the earth and astronomers to adjust their observations for the effects of polar motion. In more practical terms, the work done by the observatories contributed to studies attempting to determine earthquake mechanisms and the elasticity of the earth, and to predict climate variations. The space program has also benefited from this work; polar motion study is necessary to determine orbit patterns of spacecraft and satellites, and aids tracking techniques used in deep space navigation.

The latitude observatories made a major contribution to science on an international scale. The research undertaken in these small, simple structures fueled work done in earth motion studies for decades. From its construction in 1899 until the obsolescence of man-operated telescopic observation forced its closing in 1982, the Gaithersburg Latitude Observatory played an integral role in this important scientific endeavor.

NEW JERSEY

HORN ANTENNA HOLMDEL

The Horn Antenna, at the Bell Telephone Laboratories in Holmdel, New Jersey, is significant because of its association with the research work of two radio astronomers, Dr. Arno A. Penzias and Dr. Robert A. Wilson. In 1965 while using the Horn Antenna, Penzias and Wilson stumbled on the microwave background radiation that permeates the universe. Cosmologists quickly realized that Penzias and Wilson had made the most important discovery in modern astronomy since Edwin Hubble demonstrated in the 1920s that the universe was expanding. This discovery provided the evidence that confirmed George Gamow's and Abbe Georges Lemaitre's "Big Bang" theory of the creation of the universe and forever changed the science of cosmology--the study of the history of the universe--from a field for unlimited theoretical speculation into a subject disciplined by direct observation. In 1978 Penzias and Wilson received the Nobel Prize for Physics for their momentous discovery.

OHIO

CINCINNATI OBSERVATORY
CINCINNATI

The Cincinnati Observatory is one of the oldest functioning observatories in the United States. Founded in 1843, it was located on Mount Adams until 1873, when it was moved to its present site on Mount Lookout, just off Observatory Avenue, in Cincinnati. The present observatory building dates from 1873.

The Cincinnati Observatory was the first fully equipped observatory in the midwest and is associated with the productive careers of such famous American astronomers as Ormsby MacKnight Mitchel (1809-1862), who published the Sidereal Messenger, the first attempt to bring astronomy to the masses in the United States, and Paul Herget (1908-1981), who was the world's foremost authority on the computation of planetary orbits. In addition, the Cincinnati Observatory is associated with Cleveland Abbe (1838-1916), a meteorologist who began to issue daily weather bulletins in 1869. Abbe's work proved so popular with the American public that steps were taken to establish a permanent government institution to continue this service--the United States Weather Bureau.

PENNSYLVANIA

ALLEGHENY OBSERVATORY
PITTSBURGH

The Allegheny Observatory at the University of Pittsburgh is significant because of its association with the careers of astronomers Samuel Pierpont Langley (1834-1906), James Edward Keeler (1857-1900), and telescope maker John Alfred Brashear (1840-1920).

Langley was professor of astronomy and physics at the University from 1867 to 1887 and director of the Allegheny Observatory. During that time he invented the bolometer and used it in 1878 to make spectral

observations of solar and lunar radiation. His paper on The Bolometer and Radiant Energy (1881) became a scientific classic. While Langley was the director, the Allegheny Observatory was the leading American observatory on matters relating to the study of solar physics.

James Edward Keeler succeeded Langley as director of the Allegheny Observatory and used the 13-inch Fitz-Clark refractor with a spectroscope to show, in 1895, that the rings of Saturn were rotating as a unit but that the inner boundary had a considerably shorter period than the outer. This was the first observational evidence that the rings were not solid but consisted of discrete particles circling the planet at different speeds.

John Alfred Brashear was named acting director of the Allegheny Observatory after Keeler's departure for the Lick Observatory in 1898. Brashear was a self-taught optician whose service to astronomy began in 1876 when he began to make astronomical telescopes. Over the years of his active career Brashear not only made both of the larger telescopes used at the Allegheny Observatory, but came to be recognized as one of the best telescope makers of his day. In the years since Brashear's death in 1920, the Allegheny Observatory has used his telescope (the Thaw refractor) to do fundamental work in the field of astrometry, including the search for stars whose oscillations betray the presence of invisible companions.

VERMONT

STELLAFANE OBSERVATORY SPRINGFIELD

The Stellafane Observatory in Springfield, Vermont, possesses national significance for its pioneering role in the development of amateur telescope making and popular astronomy in the United States. The Stellafane complex contains both the original clubhouse of the first organized group of amateur telescope makers in the country, the Springfield Telescope Makers, Inc., and the first large optical telescope built and owned by that kind of amateur society. Since their construction in 1924 and 1930, respectively, the clubhouse and observatory have remained in continuous use by the Springfield Telescope Makers, and have been preserved essentially in original condition. Stellafane now holds an international reputation which attracts thousands of amateur telescope makers and astronomers to annual conventions held on the site.

WEST VIRGINIA

REBER RADIO TELESCOPE GREENBANK

The Reber Radio Telescope was the first parabolic antenna specifically designed and built to do research in the newly emerging field of radio astronomy. The telescope was designed and built by Grote Reber, an amateur astronomer and electronics expert from Wheaton, Illinois, who from 1937 until after World War II, was the world's only active radio

astronomer. The telescope design is the forerunner of the majority of present day radio telescopes.

WISCONSIN

YERKES OBSERVATORY
WILLIAMS BAY

Yerkes Observatory was founded by American astronomer George Ellery Hale in 1897 and represents his revolutionary concept for an observatory that would also be a physical laboratory. To the majority of astronomers at the time an observatory was simply a place for a telescope and observer. For example, when the new United States Naval Observatory in Washington, DC, was completed in 1893, there was no provision for a darkroom or for a spectroscopic laboratory. In contrast, Yerkes Observatory was provided with laboratories and a variety of mechanical and electronical workshops. Yerkes represented the wave of the future and established the modern observatory as a research institution where the astronomer, using the disciplines of chemistry and physics, supported by engineering and optics workshops, could apply his talents to the understanding of the wonders of the universe. In the years since its founding by George Ellery Hale, Yerkes has attracted the most famous astronomers in the world, and contributed significantly to the sciences of astronomy and astrophysics.

[History](#) | [Links to the Past](#) | [National Park Service](#) | [Search](#) | [Contact](#)

 [Top](#)

Last Modified: Mon, Nov 5 2001 8:00:00 pm PDT
http://www.cr.nps.gov/history/online_books/butowsky5/astro3.htm





Cover Page

MENU

[Contents](#)

[Acknowledgements](#)

[Introduction](#)

[Summary](#)

[Nominations](#)

[Other Sites](#)

[Existing National
Historic Landmarks](#)

[Glossary](#)

[▲ Top](#)

Astronomy and Astrophysics

Nominations



NOMINATIONS

- [Hale Solar Laboratory](#), Pasadena, California
- [Lick Observatory Building](#), Mount Hamilton, California
- [Lick Crossley 36-inch Reflector](#), Mount Hamilton, California
- [Mount Wilson Observatory](#), Pasadena, California
- [Palomar Observatory 200-inch Reflector](#), San Diego County, California
- [Palomar 48-inch Oschin \(Schmidt\) Telescope](#), San Diego County, California
- [United States Naval Observatory](#), Washington, DC
- [University of Illinois Observatory](#), Urbana, Illinois
- [Gaithersburg Latitude Observatory](#), Gaithersburg, Maryland
- [Blue Hill Meteorological Observatory](#), East Milton, Massachusetts
- [Horn Antenna](#), Holmdel, New Jersey
- [Cincinnati Observatory](#), Cincinnati, Ohio
- [Allegheny Observatory](#), Pittsburgh, Pennsylvania
- [Stellafane Observatory](#), Springfield, Vermont
- [Reber Radio Telescope](#), Greenbank, West Virginia
- [Yerkes Observatory](#), Williams Bay, Wisconsin

[History](#) | [Links to the Past](#) | [National Park Service](#) | [Search](#) | [Contact](#)

http://www.cr.nps.gov/history/online_books/butowsky5/astro4.htm





Cover Page

MENU

[Contents](#)

[Acknowledgements](#)

[Introduction](#)

[Summary](#)

[Nominations](#)

[Other Sites](#)

[Existing National
Historic Landmarks](#)

[Glossary](#)

[▲ Top](#)

Astronomy and Astrophysics

Other Sites



OTHER SITES

[National Register Sites Considered But Not Recommended for National Historic Landmark Designation](#)

[Other Sites Considered But Not Recommended for National Historic Landmark Designation](#)

[Sites Less Than 50 Years Old](#)

[Sites That Are No Longer Extant](#)

[History](#) | [Links to the Past](#) | [National Park Service](#) | [Search](#) | [Contact](#)

Last Modified: Mon, Nov 5 2001 8:00:00 pm PDT
http://www.cr.nps.gov/history/online_books/butowsky5/astro5.htm





Cover Page

MENU

[Contents](#)

[Acknowledgements](#)

[Introduction](#)

[Summary](#)

[Nominations](#)

[Other Sites](#)

**Existing National
Historic Landmarks**

[Glossary](#)

Astronomy and Astrophysics

Existing National Historic Landmarks



EXISTING NATIONAL HISTORIC LANDMARKS FOR ASTRONOMY

The 1987 edition of [History and Prehistory in the National Park System and the National Historic Landmarks Program](#) lists only two sites as National Historic Landmarks because of their significance in the history of astronomy--the Edwin P. Hubble House and the Lowell Observatory.

ARIZONA

Lowell Observatory
1 mile west of Flagstaff, Arizona

Astronomical research here has contributed greatly to the knowledge of the universe. First evidence of expansion of the universe was obtained at Lowell in 1912. In 1930 astronomer Clyde Tombaugh used a special wide-angle 13-inch astrographic telescope to discover the planet Pluto. NHL designated December 21, 1965.

CALIFORNIA

Hubble (Edwin) House
1340 Woodstock Road
San Marino, Los Angeles County
California

Home of one of America's greatest 20th century astronomers who, among other accomplishments, discovered extragalactic nebulae and their recession from each other. NHL designated December 8, 1976.

EXISTING NATIONAL HISTORIC LANDMARKS IN OTHER THEMES

The National Historic Landmarks listed below were all identified as significant in other themes. These sites should also be listed for

astronomy in addition to their primary themes.

DISTRICT OF COLUMBIA

Administration Building, Carnegie Institution of Washington
1530 P Street, NW
Washington, DC

Built with funds donated by Andrew Carnegie, the Institution operates the Mount Wilson Observatory and conducts research in the physical and biological sciences. NHL designated June 23, 1965.

Old Naval Observatory
23rd and E Streets, NW
Washington, DC

The Old Naval Observatory originally housed a 26-inch refracting telescope built by Alvan Clark and Sons in 1870. Astronomer Asaph Hall used this telescope to discover the two Martian satellites, Deimos and Phobos, in 1877. This discovery greatly enhanced Clark's reputation as a master telescope builder. The Old Naval Observatory is also associated with the work of Simon Newcomb (1835-1909), Canadian-born American astronomer, who was one of the foremost of all mathematical astronomers. Starting in 1875 Newcomb began a series of observations to prepare more accurate tables of observations of lunar and planetary motions. The results, published in the Nautical Almanac, were used through the first half of the 20th century. In 1893 the U.S. Naval Observatory moved from this location to Massachusetts Avenue at 34th St., NW. NHL designated January 12, 1965.

ILLINOIS

Millikan (Robert A.) House
5605 Woodlawn Avenue
Chicago, Cook County
Illinois

One of America's best known 20th-century scientists, Millikan received the 1923 Nobel Prize in physics for his work in demonstrating the existence of electrons. In Millikan's later years he investigated the origin and nature of cosmic rays. NHL designated May 11, 1976.

MASSACHUSETTS

Bowditch (Nathaniel) Home
North Street
Salem, Essex County
Massachusetts

Bowditch effected great advances in navigation and helped bring European mathematics to America. (Bowditch was also an important early American astronomer who was elected to the Royal Astronomical Society in 1829, the first American to be so honored.) NHL designated January 12, 1965.

NEW YORK

Draper (John W.) House
Draper Park
407 Broadway
Hastings-on-Hudson
Westchester County, New York

Home of the well-known mid-19th-century scientist who, in addition to significant contributions to physics and chemistry, also wrote important works in intellectual history. Draper was the first person to succeed in photographing a stellar spectrum. NHL designated May 15, 1975.

VIRGINIA

Banneker (Benjamin) SW-9 Intermediate Boundary Stone
18th and Van Buren Streets
Arlington County, Virginia

This boundary stone commemorates the accomplishments of Benjamin Banneker, a gifted mathematician, (and astronomer), who helped survey the District of Columbia and who was at that time the most famous Black man in America. NHL designated May 11, 1976.

WYOMING

Medicine Wheel
15 miles northeast of Kane
Big Horn County
Wyoming

Made of loose, irregularly shaped, whitish flat stones placed in a circle. Twenty-eight linear spokes, 70-75 feet in length, radiate from the hub. The National Historic Landmark form states that its intended purpose is unknown. (This site is often referred to as the "Stonehenge of the West." It has been found to be aligned to the rising and setting positions of the summer solstice sun, and the rising of three bright stars of the summer sky on that longest day of the year. Significant in Archeoastronomy.) NHL designated August 29, 1970.

[History](#) | [Links to the Past](#) | [National Park Service](#) | [Search](#) | [Contact](#)

 [Top](#)

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http://www.cr.nps.gov/history/online_books/butowsky5/astro6.htm





[Cover Page](#)

[MENU](#)

[Contents](#)

[Acknowledgements](#)

[Introduction](#)

[Summary](#)

[Nominations](#)

[Other Sites](#)

[Existing National
Historic Landmarks](#)

[Glossary](#)

Astronomy and Astrophysics

Glossary



GLOSSARY

absorption spectrum - Dark lines superimposed on a continuous spectrum.

achromatic - Free of chromatic aberration.

almanac - A book or table listing astronomical events.

altazimuth mounting - a mounting with two axes, to allow movement in both horizontal and vertical planes, used with telescopes, antennas and precise surveying instruments.

astrometry - That branch of astronomy that deals with the determination of precise positions and motions of celestial bodies.

astronomical unit (AU) - a unit of length equal to the mean radius of the earth's orbit around the sun (93 million miles).

astronomy - The branch of science that treats of the physics and morphology of that part of the universe that lies beyond the earth's atmosphere.

astrophysics - The part of astronomy that deals principally with the physics of stars, stellar systems, and interstellar material. Astrophysics also deals with the structures and atmospheres of the sun and planets.

atmospheric refraction - The bending or refraction of light rays from celestial objects by the earth's atmosphere.

azimuth - The angle along the celestial horizon, measured eastward from the north point, to the intersection of the horizon with the vertical circle passing through an object.

bands (in spectra) - Emission or absorption lines, usually in the spectra of chemical compounds or radicals, so numerous and closely spaced that they coalesce into broad emission or absorption bands.

"big bang" theory - A theory of cosmology in which the expansion of the universe is presumed to have begun with a primeval explosion.

bolometric magnitude - A measure of the flux of radiation from a star or other object received just outside the earth's atmosphere, as it would be detected by a device sensitive to all forms of electromagnetic energy.

calculus - A branch of mathematics that permits computations involving rates of change (differential calculus) or of the contribution of an infinite number of infinitesimal quantities (integral calculus).

cassegrain focus - An optical arrangement in a reflecting telescope in which light is reflected by a second mirror to a point behind the objective mirror.

celestial equator - A great circle on the celestial sphere 90° from the celestial poles; the circle of intersection of the celestial sphere with the plane of the earth's equator.

celestial poles - Points about which the celestial sphere appears to rotate, intersections of the celestial sphere with the earth's polar axis.

cepheid variable - A star that belongs to one of two classes (type I and type II) of yellow supergiant pulsating stars.

charged-coupled device (CCD) - An array of electronic detectors of electromagnetic radiation, used at the focus of a telescope (or camera lens). A CCD acts like a photographic plate of very high sensitivity.

chromatic aberration - A defect of optical systems whereby light of different colors is focused at different places.

constellation - A configuration of stars named for a particular object, person, or animal; or the area of the sky assigned to a particular configuration.

continuous spectrum - A spectrum of light comprised of radiation of a continuous range of wavelengths or colors rather than only certain discrete wavelengths.

corona - Outer atmosphere of the sun.

coronagraph - An instrument for photographing the chromosphere and corona of the sun outside of eclipse.

cosmic background radiation - The microwave radiation coming from all directions that is believed to be the redshifted glow of the big bang.

cosmic rays - Atomic nuclei (mostly protons) that are observed to strike the earth's atmosphere with exceedingly high energies.

cosmology - The study of the organization and evolution of the universe.

coude focus - An optical arrangement in a reflecting telescope whereby light is reflected by two or more secondary mirrors down the polar axis of the telescope to a focus at a place separate from the moving parts of the telescope.

diffraction - The spreading out of light in passing the edge of an opaque body.

diffraction grating - A system of closely spaced equidistant slits or reflecting strips which, by diffraction and interference, produce a spectrum.

dispersion - Separation, from white light, of different wavelengths being refracted by different amounts.

doppler shift - Apparent change in wavelength of the radiation from source due to its relative motion in the line of sight.

eclipsing binary star - A binary star in which the plane of revolution of the two stars is nearly edge on to our line of sight, so that the light of one star is periodically diminished by the other passing in front of it.

electromagnetic radiation - Radiation consisting of waves propagated through the building up and breaking down of electric and magnetic fields; these include radio, infrared, light, ultraviolet, X rays, and gamma rays.

emission line - A discrete bright spectral line.

ephemeris - A table that gives the position of a celestial body at various times, or other astronomical data.

equatorial mount - A mounting for a telescope, one axis of which is parallel to the earth's axis, so that a motion of the telescope about the axis can compensate for the earth's rotation.

faculus (pl. faculae) - Bright region near the limb of the sun.

flash spectrum - The spectrum of the very limb of the sun obtained in the instant before or after totality in a solar eclipse.

flocculus (pl. flocculi) - A bright region of the solar surface observed in the monochromatic light of some spectral line.

fluorescence - The absorption of light of one wavelength and reemission of it at another wavelength; especially the conversion of ultraviolet into visible light.

focal length - The distance from a lens or mirror to the point where light converged by it comes to a focus.

focal ratio (speed) - Ratio of the focal length of a lens or mirror to its aperture.

focus - Point where the rays of light converged by a mirror or lens meet.

Fraunhofer line - An absorption line in the spectrum of the sun or a star.

Fraunhofer spectrum - The array of absorption lines in the spectrum of the sun or of a star.

galaxy - A large assemblage of stars; a typical galaxy contains millions to hundreds of million of stars.

globular cluster - One of about 120 large star clusters that form a system of clusters centered on the center of the Galaxy.

Greenwich meridian - The meridian of longitude passing through the site of the old Royal Greenwich Observatory, near London; origin point from which longitude is measured on the earth.

Hertzsprung-Russell (H-R) diagram - A plot of absolute magnitude against temperature (or spectral class or color index) for a group of stars.

hypothesis - A tentative theory or supposition, advanced to explain certain or phenomena, which is subject to further tests and verification.

interferometer (stellar) - An optical device, making use of the principle of interference of light waves, with which small angles can be measured.

latitude - A north-south coordinate on the surface of the earth; the angular distance north or south of the equator measured along a meridian passing through a place.

light - Electromagnetic radiation that is visible to the eye.

light year - The distance light travels in a vacuum in one year; one light year equals approximately 6,000,000,000,000 miles.

longitude - An east-west coordinate on the earth's surface; the angular distance, measured east or west along the equator from the Greenwich meridian, to the meridian passing through a place.

luminosity - The rate of radiation of electromagnetic energy into space by a star or other object.

magnitude - A measure of the amount of light flux received from a star or other luminous object.

maser - An radiation; particular acronym for microwave amplification of stimulated emission a device for amplifying a microwave (radio) signal at a wavelength into a coherent beam.

microwave - Short-wave radio wavelengths.

Milky Way - The band of light encircling the night sky, which is due to the many stars and diffuse nebulae lying near the plane of our Galaxy.

monochromatic - Of one wavelength or color.

Newtonian focus - An optical arrangement in a reflecting telescope, in which a flat mirror intercepts the light from the primary mirror before it reaches the focus and reflects it to a focus at the side of the telescope tube.

Newton's laws - The laws of mechanics and gravitation formulated by Isaac Newton.

nova - A star that experiences a sudden outburst of radiant energy, temporarily increasing its luminosity by hundreds to thousands of times.

objective - The main lens or mirror of a telescope. The larger it is, the brighter the image is and the sharper it is (i.e., its resolution is better).

opacity - Absorbing power; capacity to impede the passage of light.

optics - The branch of physics that deals with light and its properties.

parallax - An apparent displacement of an object due to a motion of the observer.

parallax (stellar) - An apparent displacement of a nearby star that results from the motion of the earth around the sun; numerically, the angle subtended by 1 AU at the distance of a particular star.

photocell (photoelectric cell) - An electron tube in which electrons are dislodged from a cathode when it is exposed to light and are accelerated to an anode, thus producing a current in the tube, whose strength serves as a measure of the intensity of the light striking the cathode.

photographic magnitude - The magnitude of an object, as measured on the traditional, blue-violet-sensitive photographic emulsions.

photometry - The measurement of light intensities.

photomultiplier - A photoelectric cell in which the electric current generated is amplified at several stages within the tube.

prime focus - The point in a telescope where the objective focuses the light.

prism - A wedge-shaped piece of glass that is used to disperse white into a spectrum.

radio astronomy - The technique of making astronomical observations in radio wavelengths.

radio telescope - A telescope designed to make observations in radio wavelengths.

reflecting telescope - A telescope in which the principal optical component (objective) is a concave mirror.

refracting telescope - A telescope in which the principal optical component (objective) is a lens or system of lenses.

resolution - The degree to which fine details in an image are separated or resolved.

resolving power - A measure of the ability of an optical system to to

resolve or separate fine details in the image it produces; in astronomy, the angle in the sky that can be resolved by a telescope.

Schmidt telescope - A type of reflecting telescope invented by Bernhard Schmidt, in which certain aberrations produced by a spherical concave mirror are compensated for by a thin objective correcting lens.

science - The attempt to find order in nature or to find laws that describe natural phenomena.

spectral sequence - The sequence of spectral classes of stars arranged in order of decreasing temperatures of stars of those classes.

spectrograph - An instrument for photographing a spectrum; usually attached to a telescope to photograph the spectrum of a star.

spectroheliogram - A photograph of the sun obtained with a spectroheliograph.

spectrophotometry - The measurement of the intensity of light from a star or other sources at different wavelengths.

spectroscope - An instrument for directly viewing the spectrum of light source.

spectroscopy - The study of spectra.

spectrum - The array of colors or wavelengths obtained when light from a source is dispersed, as in passing it through a prism or grating.

steady state (theory of cosmology) - A theory of cosmology which proposes that the universe has existed and will exist forever in its current form. The observed expansion of the universe being caused by the continuous creation of new matter so that the average density and appearance of the universe remains the same at all times.

theory - A set of hypotheses and laws that have been well demonstrated as applying to a wide range of phenomena associated with a particular subject.

thermal energy - Energy associated with the motions of the molecules in a substance.

thermal radiation - The radiation emitted by any body or gas that is not at absolute zero.

transit - An instrument for timing the exact instant a star or other objects crosses the local meridian. Also, the passage of a celestial body across the meridian; or the passage of a small body across the disk of a large one.

21-cm line - A spectral line of neutral hydrogen at the radio wavelength of 21 cm.

ultraviolet radiation - Electromagnetic radiation of wavelengths shorter

than the shortest (violet) wavelengths to which the eye is sensitive; radiation of wavelengths in the approximate range 100 to 4000 angstroms.

universe - The totality of all matter and radiation and the space occupied by the same.

variable star - A star that varies in luminosity.

[History](#) | [Links to the Past](#) | [National Park Service](#) | [Search](#) | [Contact](#)

 [Top](#)

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