DOI: https://doi.org/10.24215/26840162e012

Cultural Heritage of Observatories – Changing Structures over Time

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Wolfschmidt, G.; 2024 “Cultural Heritage of Observatories – Changing Structures overTime”. Cosmovisiones/Cosmovisões 5 (1): 147-157.
DOI: https://doi.org/10.24215/26840162e012
Recibido: 31/03/2023, aceptado: 21/06/2024.

Resumen

El patrimonio astronómico representa el patrimonio científico en su contexto cultural. La astronomía como parte integral y destacada de la vida cotidiana en diferentes sociedades es visible en la estructura de los observatorios astronómicos. Pero los edificios astronómicos, los instrumentos y la investigación y el conocimiento astronómico cambian con el tiempo y están permanentemente en un proceso de construcción. Debido a estos cambios, los observatorios no necesariamente demuestran el *Valor Universal Excepcional* potencial que sería necesario para la inscripción en la Lista del *Patrimonio Mundial*. Pero estos observatorios pueden incluirse en la lista acreditada por la IAU (independiente de la Unesco) de *Patrimonio Astronómico Excepcional*, cuando sean destacados en la historia de la astronomía debido a sus logros científicos.

En esta contribución, me gustaría presentar el desarrollo de la arquitectura y los instrumentos de observatorios desde la Edad Moderna hasta nuestros días. Primero se mostrarán ejemplos de observatorios barrocos o neoclásicos. En la época barroca, la astronomía se vincula muy a menudo con otras ciencias, no solo celestes, sino también terrestres (topografía) y se realizaron observaciones meteorológicas, especialmente, la *Torre Matemática* de Kremsmünster debe mencionarse en este contexto. Luego se hablará de lo que se ha logrado en los observatorios modernos alrededor de 1900, como La Plata y Hamburgo, donde la transición de la astronomía clásica a la astrofísica moderna pudiera presentarse como una candidatura seriada transnacional a la Unesco; esta transición es visible en la arquitectura, la elección de los instrumentos, y la disposición de los edificios del observatorio en un "Parque de la Astronomía".

Los observatorios recientes, alrededor del año 2000 (por ejemplo, el Very Large Telescope de ESO), los observatorios radioastronómicos como Jodrell Bank, Effelsberg u observatorios subterráneos de neutrinos (Gran Sasso, Italia) cambiaron su apariencia por completo; estos son impresionantes estructuras metálicas que ya no recuerdan la forma típica de los observatorios con cúpulas.

La iniciativa de la Unesco *Astronomy & World Heritage* (AWH) se puede ampliar para incluir el patrimonio de la ciencia y la tecnología en general –ejemplos de esto son se podrían incluir el edificio principal o el campus principal de una universidad además de su observatorio, o que se incluyan laboratorios físicos, meteorológicos, sismológicos o geomagnéticos.

El patrimonio cultural de la astronomía, la ciencia y la tecnología juega no sólo un papel importante en las instituciones científicas, sino también en las primeras instituciones dedicadas a la educación y la divulgación de la ciencia para el público en general y especialmente para gente joven. En este sentido, la astronomía fue la ciencia líder en la divulgación – ejemplos importantes son el Gottorf Globe, el Eise Eisinga Planetarium en Franeker, y el planetario de proyección, inventado por Carl Zeiss de Jena.

Palabras clave: Patrimonio, Cultura Astronómica, Observatorios, Unesco, Valor Universal Excepcional

Abstract

Astronomical heritage represents scientific heritage in its cultural context. Astronomy as an integral and outstanding part of daily life in different societies is visible in the architectural structure of astronomical observatories. But astronomical buildings, instruments and astronomical research and knowledge change over time and are permanently in a process of construction. Due to these changes, observatories do not necessarily demonstrate potential *Outstanding Universal Value* which would be needed for inscription on the World Heritage List.

But these observatories can be included in the IAU-accredited list (independent of Unesco) of "*Outstanding Astronomical Heritage*", when they are outstanding in the history of astronomy due to their scientific achievements. In this contribution, I would like to present the development of architecture and instruments of observatories from the Early Modern Time until today.

First, I will show examples like Baroque or neo-classical observatories. In the baroque time astronomy is linked very often to other sciences, not only celestial, but also terrestrial (surveying) and meteorological observations were made, especially, the *Mathematical Tower* of Kremsmünster should be mentioned in this sense. Then I will discuss what has been achieved for modern observatories around 1900 like La Plata and Hamburg where the transition from classical astronomy to modern astrophysics should be presented in a serial transnational Unesco application; this transition is visible in the architecture, the choice of instruments, and the arrangement of the observatory buildings in an "Astronomy Park".

The recent observatories around 2000 (e.g.ESO Very Large Telescope), radioastronomy observatories like Jodrell Bank, Effelsbergor underground neutrino observatories (Gran Sasso,Italy) changed their appearance completely; these are impressive metallic structures which no longer remind of the typical shape of observatories with domes.

The Unesco initiative *Astronomy & World Heritage* (AWH) could be broadened in order to include the heritage of astronomy, science and technology in general –examples are e. g. including the main building or the main campus of the university in addition to the observatory or including physical, meteorological, seismological or geomagnetic laboratories.

Cultural heritage of astronomy, science and technology plays not only an important role in scientific institutions, but also in the first sites devoted to education and popularization of science for the general public and especially for young people. In this respect, astronomy was the leading science for popularization – important examples are the Gottorf Globe, the Eise Eisinga Planetarium in Franeker, and the projection planetarium, invented by Carl Zeiss of Jena.

Keywords: Heritage, Astronomical Culture, Observatories, Unesco, Outstanding Universal Value

Introduction — Outstanding Astronomical Heritage

Astronomical heritage represents scientific heritage in its cultural context – Unesco:

> "Properties relating to astronomy stand as a tribute to the complexity and diversity of ways in which people rationalised the cosmos and framed their actions in accordance with that understanding. This includes [. . .] the development of modern scientific astronomy. This close and perpetual interaction between astronomical knowledge and its role within human culture is a vital element of the outstanding universal value of these properties." (https://whc.unesco.org/en/astronomy/, consulted: 08.03.2023).

Astronomy as an integral and outstanding part of daily life in different societies is visible in the structure of astronomical observatories – in respect to architecture, instruments, scientific, cultural and historic value. But astronomical buildings and instruments change over time and are permanently in a process of construction (also research and practices are not static). This is the reason, that the IAU list of *Outstanding Astronomical Heritage* (OAH) was created and compiled[1]. This list includes observatories, that are "outstanding", of evident importance in the history of astronomy due to their scientific achievements, but they do not necessarily demonstrate potential *Outstanding Universal Value* (OAH), (Ruggles & Cotte 2010, Ruggles 2016), which would be needed for inscription on the *World Heritage List*. There are different reasons, why observatory buildings were abandoned (e.g. due to a missing patron) or were destroyed. The astronomer had no successor or moved to another place, like Tycho Brahe (he moved from Island Hven/Denmark, to Prague). Hevelius' famous Observatory in Gdańsk (Danzig), Poland, was destroyed by fire, or Leipzig Observatory during WWII. But also the permanent modernization of observatories was a significant threat. This is the cause, that buildings were changed considerably. On the other hand, this change is also important for the progress of science / astronomy but as a consequence the buildings can lose their *Outstanding Universal Value*. Another possibility at the end of 20th century is that astronomers left the historical observatory building in the city center completely, and moved to a University campus, e.g. Leiden, Utrecht, Göttingen, and Dorpat/Tartu, Estonia. But also instruments have disappeared, were renewed according to the scientific development, or instruments were moved to a museum; e.g., the instruments of Mannheim Observatory are in the *Technoseum*, of Gotha Observatory are in the *Deutsches Museum* in Munich. The famous observatories with open air telescopes of Nuremberg Castle Observatory (1678–1757), Herschel in Slough or Schroeter in Lilienthal (Figure 1) disappeared completely.

In this sense, the development of architecture and instruments of observatories from

[1] Observatories in OAH list, check here (https://web.astronomicalheritage.net/heritage/outstanding-astronomical-heritage): More detailed contributions can be found: Wolfschmidt 2022 and Wolfschmidt 2021.

Early Modern Time until today is presented, cf. Wolfschmidt (2021 and 2022), especially modern observatories around 1900 like La Plata and Hamburg with the transition from classical astronomy to modern astrophysics (Wolfschmidt 2009).

The recent observatories around 2000 (e.g., ESO), radio astronomy observatories or underground neutrino observatories changed the appearance of an observatory completely. The Unesco initiative Astronomy & World Heritage (AWH) could be broadened to include the heritage of science & technology in general. This expanded idea of cultural heritage plays also an important role in the first institutions devoted to education and popularization of science for the general public – and astronomy was the leading science (Wolfschmidt 2017).

Tower and Bastion Observatories in the Early Modern Time

Renaissance also referred to as "the birth of modern science", and the starting point of observatories in the Western culture. Examples are observatories with platforms on buildings, bastions, towers, e.g., Hevelius in Danzig (1641–1679), Nuremberg Castle Observatory (1678–1757), Paris, Greenwich. Tower Observatories can be found in e.g., Copenhagen Round Tower (1642), Prague, Bologna (1725), Vilnius (Figure 2), and Berlin Academy Observatory. In the Baroque time astronomy is linked very often to other sciences, not only celestial, but also terrestrial, and meteorological observations were made. Especially the "*Mathematical Tower*" Kremsmünster, Austria (1749), offers a lot of cultural implications like paintings and sculptures but also a Baroque museum of science; this collection of *naturalia* and *artificialia* intends to present the large variety of the world, a microscopic image of the macrocosm. In summary, one can see very well the relevance of Baroque observatories to the cultural heritage of mankind.

Observatories around 1800 — Innovative Architecture and Instruments

In the neo-classical time, important inventions were made like the introduction of the dome before 1800, e.g., Kew/UK(1769), Dublin/Ireland (1785), Gotha/Germany (1788), Armagh/UK (1790) (Figure 4). Previously, instead of the dome, cylindrical or conical structures were used. Strong fundaments with a pillar leading to the ground[2], the equatorial mounting with the introduction of the first clock drive are essential for precise observations, made by Fraunhofer of Munich for the Tartu Refractor (1824), and made by Grubb of Dublin for the 15-inch-

[2] But you can also get a strong fundament by observing on the ground floor through windows like in Greenwich, Stockholm or Gotha.

Armagh Reflector (1835). Around 1800, new telescopes were invented, the achromatic refractor, first by the Dollonds of London, then by Fraunhofer with impressive apertures of 24-cm. Also the reflector was improved from speculum (Lord Rosse's Leviathan (1845), Birr Castle) to silver coated, invented independently by Justus von Liebig (1835) with Steinheil (1856), and by Foucault (Paris 1860, Marseille 1864).

Also the architecture of observatories changed remarkably around 1800 (cf. Müller 1992); it was the beginning of a standardisation of observatory architecture: the Octagon or the shape of the Greek Cross. The origin of an octagonal shape is the Tower of the Winds in Athens from Antiquity. Then, the Tower of the Winds in Vatican Observatory "Specola Vaticana" (1789), Lwiw/Ukraine (1771), Radcliffe Observatory Oxford (1773), Halle/Saale, Germany (1788), Bogotá/Columbia (1803), Vassar College/USA (1865), and Barcelona (1904). Examples for observatories in Neo-Classicism style with the shape of the Greek cross are e.g., Oslo/Norway (1831), Athens/Greece (1846) (Figure 5), Bonn/Germany (1844), Quito/Ecuador (1873), or with the Latin cross: Royal Observatory Berlin (1835).

Observatories with Three Domes – Pulkovo as Prototype, 19th Century

The architecture of observatories changed again in the 19th century with the introduction of the "three dome façade". The famous early examples are Helsingborg/Helsinki Observatory, Finland (1834), Kazan Old University Observatory, Russia (1837), and Pulkovo Observatory, St. Petersburg, Russia (1839). Pulkovo was the prototype for many observatories throughout the 19th century like Astrophysical Observatory Potsdam (1874/79).

Modern Observatories 1900: From Classical Astronomy to Modern Astrophysics

An impressive example for changing structures over time offer the modern observatories around 1900. There are three important alterations (Wolfschmidt 2009):

• The change of the research field: The transition from classical astronomy (positional astronomy, astrometry) to modern astrophysics (spectroscopy, astro-photography, photometry, and solar physics).

• The change of the instrumentation: From the classical astronomical instruments like transit instrument, meridian circle, refractor, heliometer to the astrophysical instruments like astrograph, reflecting telescope, Schmidt telescope with several smaller astrophysical instruments like cameras, spectrographs, photometers, and special solar physics instrumentation.

• Instead of one observatory building with the domes on the top of the roof, an ensemble of buildings in an *astronomy park*

was introduced[3]. There is a clear separation between the observatory domes on one side and the main building with an impressive architecture with library, administration, offices, and residential buildings for the astronomers –always ready to observe.

It was already discussed in detail what has been achieved for modern observatories around 1900 like La Plata, Argentina (1883), and Hamburg, Germany (1906/12), (Figure 6&7), where the transition *From Classical Astronomy to Modern Astrophysics* (Wolfschmidt 2009) will be hopefully presented in a serial transnational Unesco application. This change is visible in the architecture, the new choice of instruments, the arrangement of the observatory buildings in an "astronomy park", and the international scientific cooperation. This corresponds to the main categories according to which the Unesco "*Outstanding Universal Value*" has been evaluated (Ruggles & Cotte 2010). This proposal is based on the criteria of a comparability of the observatories in terms of the urbanistic complex and the architecture, the scientific orientation, the equipment of instruments, authenticity and integrity of the preserved state, as well as in terms of historic scientific relations and scientific contributions.

Heritage of Astronomy, Science & Technology

This change from astronomy to science and technology is connected to the move of observatories to a University Campus. In the 18th and 19th century, the main building or the campus of the university was sometimes connected with an observatory like in Vilnius/Lithuania (1753), Kazan/Russia (1837), or women colleges like Vassar College, Poughkeepsie, USA. Astronomy was the leading topic in the context of the development of science with their early chemical (e.g., Wetzlar, Lisbon), physical, meteorological, seismological or geomagnetic laboratories (Göttingen University at the time of Carl Friedrich Gauß), and many colonial observatories like the Jesuit Observatory Havana/Cuba (1857) have this combination.

The Unesco initiative "*Astronomy & World Heritage*" could be widened to include also heritage of science and technology in general, when it is merged with astronomy[4]: Examples of the late 19th and 20th century are the Astro- and Geophysical Observatory Potsdam- Telegraphenberg, founded in 1874 (today Campus Potsdam, Albert Einstein Science Park with astronomy, solar physics, geoscience, AWI, meteorology and climate research), La Plata Observatory (with meteorology and geophysics).

[3] Another development of landscape design was the move out of the cities, and if available, in order to improve the observing conditions, to a hill or mountain like Nice Observatory or Pic du Midi, France, or Lick, Mt. Wilson, and Palomar observatories, USA.

[4] The Unesco initiative "*Heritage of Astronomy, Science and Technology*" (HAST, 2018) was abandoned in the meanwhile.

Public Observatories, Planetaria, Museums – Popularization of Science

The *Portal to the Heritage of Astronomy* has also a section *Places connected to the Sky*, promoted also during IAU's *100 Years Under One Sky*. In this context, some early public observatories, globes and planetariums, astronomical museums, and stargazing locations for the general public should be presented. Cultural heritage of astronomy, science and technology plays an important role in the first institutions devoted to education and popularization of science for the general public and especially for young people – and astronomy was the leading science, cf. detailed examples in Wolfschmidt (2017):

• Large walkable globes like the Gottorf Globe in Schleswig (1664) and in St. Petersburg Academy (Wolfschmidt 2007).

• Popular observatories for star gazing like the "Urania" in Berlin (1888), Zürich (1907), Vienna (1910), starting point for the public understanding of science (Author 2008), in addition with a physical cabinet for hands-on experiments, and a scientific theatre for popular lectures in an understandable, inspiring form as well as in an entertaining manner, that promoted a Humboldtian view of the "*Cosmos*".

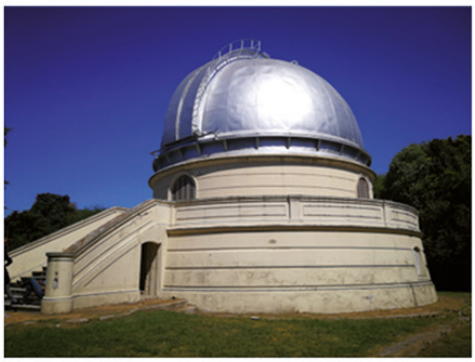
• Planetariums are impressive tools for popularization like the Eise Eisinga Planetarium (Figure 3) in Franeker (1781) of the Enlightenment Era. This shows in real time the motions of the planets around the Sun – located in a private house (scale 1 millimetre: 1 million kilometres). An improved version of this idea, a more sophisticated device, was the projection planetarium, the "*wonder of Jena*", invented by Carl Zeiss of Jena, and inaugurated in 1925 in the "Deutsches Museum" in Munich as the first planetarium in the world. An earlier presentation – not for the general public–took place in Jenain 1923.

• "*Physikalischer Verein*" (Physics Association– Society for Education and Science) in Frankfurt am Main (1824) with physics, chemistry, astronomy, meteorology, technology, and an observatory (1907), cf. Kitmeridis (2018), connected to the natural history "*Senckenberg Museum*" (1821).

• Astronomical museums in former observatories like Sydney or Rio de Janeiro.

• Science and technology museums with observatories and a planetarium like the "Deutsches Museum" in Munich (1903/1925), cf. Wolfschmidt (2017).

Figure 1: 20-inch-Reflector Lilienthal (1782) – Figure 2: Vilnius Observatory, Lithuania (1753) – Figure 3: Eise Eisinga Planetarium in Franeker (1781); Figure 4: Dome of Armagh (1790) – Figure 5: Athens Observatory (1846), Greek Cross; Figure 6+7: La Plata (1885) and Hamburg (1912) observatories with astronomy park – Figure 8: 76-m-Lovell Radio Telescope, Jodrell Bank (1957). (photos: Wolfschmidt).



Recent Astronomical Observatories – Cutting Edge Research

The recent optical, radio and neutrino observatory buildings around 2000 – super size telescopes like ESO's 8-m-Very Large Telescope (VLT), Thirty-Meter-Telescope (TMT), ESO's 39-m-Extremely Large Telescope (ELT) or radio astronomy observatories like 76-m-Jodrell Bank (Figure 8), 100-m-Effelsberg, LOFAR, SKA, or "underground" neutrino observatories like Gran Sasso, Italy, and Kamiokande, Japan –changed the architectural appearance completely; these are impressive metallic or concrete structures which no longer remind of the typical shape of observatories with domes.

Conclusion: Observatories as "scientific monuments"

In this contribution, have discussed the link between science and culture, the interaction between astronomical knowledge, and the history of mankind, our view of the world –visible in observatories worldwide. The emphasis is especially on the changing innovative architecture of the buildings (tower, introduction of the dome, octagon, Greek cross, three dome façade, astronomy park), profound change in observation technology and development of instruments (including mountings and clock drives), and scientific scope of observatories during the last four centuries. In this context, the IAU list of *Outstanding Astronomical Heritage* (2018) is introduced for promoting and safeguarding the tangible fixed and moveable heritage (material culture, books, archives, photographic plates) and intangible astronomical heritage (scientific practices and traditions, discoveries, architectural, historical, social and aesthetic value). This OAH survey also provides information on preparing WHL nomination dossiers, particularly sites for comparison. In addition, examples were given for heritage of astronomy merged with science and technology. Finally, early institutions devoted to popularization of astronomy, science and technology were presented as an integral part of daily life.

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