Russian Astronomical Sites on the World Heritage List

O.B. Dluzhneskaya*[1] and I.V. Kuznetsova†[2]

[1]Institute of Astronomy of the Russian Academy of Sciences, Moscow, Russia
[2]Sternber Astronomical Institute of Moscow State University, Moscow, Russia

Abstract

The UNESCO World Heritage List includes natural or human-made sites that have cultural, historical, or ecological significance, as determined by UNESCO experts. This article focuses on three sites from the Russian UNESCO List that have scientific significance and are related to astronomy and astronomical heritage.

Keywords: *Astronomical Heritage, Pulkovo Astronomical Observatory, Struve Geodetic Arc, Observatories of Kazan State University*

1. Introduction

There are 33 UNESCO World Heritage sites in the Russian Federation, which is 2.6% of the total number. It is important for Russia to take measures to expand the geography and diversity of the nominated sites, focusing not only on popular landscape and mixed natural and cultural sites but also on technological and scientific-cultural nominations.

To develop and refine the criteria for selecting objects for the UNESCO World Heritage List, scientific and practical conferences and other events are regularly held in countries participating in the Convention on the Protection of the World Cultural Heritage. For example, at the international conference "Astronomy and World Heritage: Across Time and Continents" as part of the "AstroKazan-2009" congress (Kazan, August 20-23, 2009), the conference resolution included a proposal to create a new category, "Space Heritage", as part of the UNESCO Thematic Initiative "Astronomy and World Heritage" (Dluzhnevskaya (2021). It was also proposed to include Space Technology as an important segment of the Astronomy World Heritage (Marov (2016).)

Currently, three objects on the Russian UNESCO list of scientific importance are related to astronomy and astronomical heritage: the Pulkovo Observatory, the Struve Geodetic Arc, and the Observatories of Kazan Federal University (the Kazan City Astronomical Observatory and the V. P. Engelhardt Astronomical Observatory).

2. The Pulkovo Observatory

The Pulkovo Observatory is an astronomical observatory of the Russian Academy of Sciences that conducts research in the fields of astronomy and geophysics. The Pulkovo Observatory was founded on August 7 (19), 1839, by decree of Emperor Nicholas I. The observatory is located in Saint Petersburg, 19 kilometers south of the city center, on the Pulkovo Heights.

The observatory's scientific activities cover almost all priority areas of fundamental research in modern astronomy: astrometry, celestial mechanics, astrophysics, stellar astronomy, the Sun and solar-terrestrial connections, extragalactic astronomy, instruments and methods of astronomical observations, and more. The observatory offers regular guided tours.

The Astronomical Museum of the Pulkovo Observatory is located in the Round Hall of the main building. The large Ertel–Struve vertical circle, which was used to determine the declinations of stars and planets using

*olgad@inasan.ru, Corresponding author
†irinakuznetsova-64@mail.ru

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Figure 1. D. Gobert. Observatory on Pulkovskaya Hill near St. Petersburg. 1840s. (Engraving)

the absolute method (now part of the collection of the Astronomical Museum of the Pulkovo Observatory), is also on display. The museum houses over 20,000 exhibits related to science, technology, and local history. It also features historical astronomical instruments.

The center of the Round Hall of the Pulkovo Observatory is the initial zero point of Russia's triangulation. The Pulkovo meridian, which passes through this center at $30°19'34''$ east of Greenwich,was the reference point on all old geographical maps of Russia.

Since 1990, the observatory has been part of the UNESCO-protected site "Historical Center of Saint Petersburg and related monument complexes" [Historic Center of Saint Petersburg and Related Groups of Monuments — UNESCO World Heritage Center], although geographically it is located outside the city. By Decree of the President of the Russian Federation № 275 dated April 2, 1997, the Pulkovo Observatory was included in the State Register of Especially Valuable Cultural Heritage Sites of the Peoples of the Russian Federation [New Law of the Russian Federation, (1997), The Collection of Laws of the Russian Federation, (1997)]. The object of cultural heritage of Russia of federal significance is registered as reg. № 781520299100006 (EGRON), object № 7810327000.

From the history of the Pulkovo Observatory: The first director of the Pulkovo Observatory was the outstanding scientist and astronomer-academician Vasily Yakovlevich (Friedrich Georg Wilhelm) Struve.

Vasily Yakovlevich (Friedrich Georg Wilhelm) Struve was born on April 15 (New Style), 1793, in the city of Altona, near Hamburg, in the large family of a gymnasium director.

At the age of 15, he entered the University of Dorpat (Tartu) to study philology under the influence of his father and older brother. Even then, the young man felt that his true calling was in another field, and he began attending lectures on astronomy and physics. After graduating from the university, he declined a position as a teacher of literature to pursue his passion for astronomy at the university's observatory. In 1818, he became the director of the Dorpat Observatory. It was here that Struve began his research on binary stars. In total, during his lifetime, he studied 12,000 stars and established binarity of 2,500 of them. Before Struve, no more than 500 such stars were known! His star catalogues have won worldwide recognition and have been awarded medals by the Royal Society of London. In addition, he was able to determine the distance to the Vega using the trigonometric parallax method, he proved that the density of stars increases towards the main plane of the Milky Way; he presented arguments the presence about interstellar extinction.

Since 1833, V.J.Struve has been an active participant in the construction of the Pulkovo Observatory,

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Figure 2. Portrait of V.Ya. Struve. On the background is the Pulkovo Observatory.

which was built under the supervision of architect Alexander Pavlovich Bryullov, brother of the famous artist. While engaged in scientific work, Struve also paid much attention to the technical equipment of the observatory. Thanks to his efforts, the Pulkovo Observatory was equipped with advanced instruments (including, at that time, the world's largest refractor with a 38-centimeter lens; (Litvinova & Pavlenkov (1893).

In 1857, when Vasily Yakovlevich's health began to fail, his eldest son Otto assisted him in his work, and later became the head of the observatory. In the autumn of 1863, V. I. Struve celebrated the 50th anniversary of his scientific career, and in August 1864, he celebrated the 25th anniversary of his beloved creation, the Pulkovo Observatory. These were the last significant events in his life. On November 23, 1864, the great scientist passed away. For almost a quarter of a century, Struve was director of the Pulkovo Observatory, and under his leadership it became, in the words of American astronomer Benjamin Gould, "the astronomical capital of the world". And the French physicist Biot, talking about the Pulkovo Observatory, said that "Russia has a scientific monument, which is the highest in the world". Outstanding scientists worked here, the most accurate observations were carried out, and star catalogs were compiled. In 1941-1944, the observatory was located on the front line and was almost completely destroyed. Many valuable instruments were destroyed, and a unique library with rare astronomy books was burned down. After the war, the Pulkovo Observatory was rebuilt from scratch, and a new complex of buildings was constructed in 1954.

The architectural ensemble of the Pulkovo Observatory is a complex of scientific and administrative buildings united by a common design. The main building is located exactly along the Pulkovo meridian and is oriented according to the cardinal directions.

By Decree of the President of the Russian Federation No. 275 dated April 2, 1997, the Pulkovo Observatory was included in the State Register of Particularly Valuable Cultural Heritage Sites of the Russian Federation.

2.1. Pulkovo meridian

The Pulkovo Observatory was originally conceived not only as a scientific center, but also as the main geodetic reference point of the Russian Empire. A conventional meridian was drawn through its central pavilion, which became the starting point for longitude on all Russian maps, topographic surveys, and even for marking railway tracks. The Pulkovo Meridian is an imaginary line that extends from the North Pole to the South Pole, with coordinates of $30°19'34''$ East longitude from Greenwich. Visually, the meridian "begins" in the center of the round hall of the Pulkovo Astronomical Observatory and "continues" on the

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Meridian Path of Pulkovo Hill. The spire of the Peter and Paul Cathedral rises very close to the meridian line.

Figure 3. The Round Hall of the observatory's astronomical museum, through the middle of which runs the Pulkovo meridian.

Unlike Greenwich, which was already gaining international weight at the time, the Pulkovo Meridian was focused on the internal needs of a giant country, representing an attempt to create its own sovereign coordinate system. The scientific significance of the meridian was immense. It served as the foundation for the Russian system of absolute longitudes and was used as a reference point for the famous "arc measurement of the meridian" from the Danube to the Arctic Ocean, as part of Struve's ambitious project to refine the shape of the Earth. Pulkovo astronomers determined coordinates of stars and time with incredible precision for their time, and they also conducted geodetic measurements that allowed them to create the world's best military topographic maps.

After the 1884 international conference that established Greenwich as the world's zero longitude, Russia, although it did not immediately sign the agreement, began a slow process of adopting the unified standard. However, in practical geodesy and cartography, the Pulkovo meridian continued to dominate till the 1920s. In 1919, Soviet Russia, in an effort to internationalize, officially adopted the Greenwich system and world time zones.

3. The Struve Geodetic Arc: 2,820 km from Norway to the Black Sea

In 1816, Struve was asked to make a topographic map of the Livonia province. This applied work gave rise to the idea of grandiose research in him. For many years, he supervised the measurement of the meridian arc over a vast area from the Danube to the Arctic Ocean, with a total length of more than 2,800 km. The measurement results provided valuable knowledge about the parameters of the Earth, its shape and size, as well as materials for making accurate maps of Russia. **Today, this arc is named after the astronomer Struve.**

In 1617, the Dutch astronomer Willebrord Snellius developed a triangulation method that remained the standard for over 300 years. If you take three clearly visible points that form a triangle on the ground and measure one side and two angles (although in practice, all three angles are always checked), you can calculate the lengths of the other sides. And if you form a chain of triangles, each of which shares one side with the previous one, the task reduces to measuring the angles sequentially and accurately measuring the base of one reference side, which can be relatively small for ease of accurate measurements.

Snellius built a quadrant to measure angles between vertices. The device was a quarter of a circle with

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two rotating tubes aimed at two high objects. A scale with degree divisions was located between the tubes.

In 1669-1670, Jean Picard used the triangulation method for the first high-precision measurement of the Paris meridian. To achieve this, he modified the quadrant by adding a telescopic sight with an eyepiece equipped with two mutually perpendicular threads, a micrometric screw, and a gradation with a quarter-minute step. As a result, Picard achieved a relative measurement error of approximately 0.44%. It turned out that the length of a meridian arc of 1° is 110.6 km at the equator, 111.3 km near Paris, and 111.9 km near the **Arctic Circle**.

A single, long-range, and continuous measurement system based on a common methodology was required to radically improve accuracy. This opportunity existed in the Russian Empire, which stretched thousands of kilometers from north to south and allowed to construct a long chain of triangulation points within a single state and under a unified scientific leadership.

3.1. The northern part of the arc

Interest in the degree measurements of the meridian was supported not only by academic science, but also by the military department. This factor played an important role in the further development of the project, although its influence was not immediately noticeable.

By the early 1810s, Vasily Yakovlevich Struve (real name Friedrich Georg Wilhelm), an astronomer and director of the Dorpat Observatory, was already actively engaged in the task of measuring the meridian's degrees. Analyzing the geography of the Russian Empire and the accumulated data, he arrived at several key conclusions. Firstly, the meridian passing through the Dorpat Observatory extended over 20° in latitude across the western provinces of the empire. Later, the actual length of the measured arc was $25°20'$, which is approximately one-fourteenth of the Earth's circumference. Moreover, the route did not cross major maritime areas, allowing for a continuous chain of triangulation points with minimal restrictions.

Some of the triangulation points were metal signal rods securely fixed on the roofs of buildings. Others were marked by stone pyramids, individual protruding boulders, or light wooden towers made of logs.

Each point was selected based on a variety of factors, including good mutual visibility of several landmarks, ease of observation, stability of the base, and minimal deviation from the meridian line.

In 1822-1823, Vasily Yakovlevich Struve and his colleagues conducted dozens of measurements. The most advanced universal geodetic instruments designed by Reichenbach were used for angular observations. These instruments allowed not only to measure horizontal angles, but also to determine declinations of celestial bodies and calculate the latitude at each observation point with high accuracy.

After receiving unsatisfactory results over and over again, Vasily Yakovlevich came up with a method of repeated measurements to identify systematic errors.

To measure the base distances, he designed an original device: two measuring rods, each two fathoms long, with bubble levels. These rods were placed on sawhorses in a very precise manner to measure the distance between two triangulation points. It is worth noting that the entire Struve line consists of 10 bases, each approximately 10-12 kilometers long

The project to extend the arc through Finland was approved personally by Nicholas I, who ordered that three thousand silver rubles be allocated for the work each year. By 1844, this stage had been completed, and Struve traveled to Stockholm to negotiate with King Oscar I about continuing the measurements in Sweden and Norway.

The original plan was to connect the new arc to the existing triangulation chain laid out by Jöns Swahnberg in 1801-1803. However, a detailed reconnaissance of the area conducted jointly by Swedish surveyors and specialists from the Pulkovo Observatory revealed that the old points did not meet the required accuracy standards.

As a result, it was decided to build a new triangulation network from scratch, with only the general direction of the route remaining unchanged. The Swedish side agreed to finance a significant portion of the work. Over the next ten years, the measurements were conducted in extremely challenging conditions, with strong winds, rough terrain, significant elevation changes, and harsh weather making the expeditions difficult. Despite these obstacles, the Scandinavian section of the arc was successfully completed by 1855.

After the work was completed in the north in 1855, the entire Struve arc was a single system with the following characteristics:

- 265 triangulation points;
- 258 triangles with a common side;

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- 13 main points equipped with astronomical stations for accurate determination of latitude.

The total length of the arc was about 2820 km, or 25.2° of the meridian arc, making it the longest triangulation chain in the history of geodesy.

In the following years, Vasily Yakovlevich Struve and Osip Khodzko conducted repeated control measurements using the most advanced instruments available at the time. These checks confirmed the high accuracy of the initial calculations and solidified the scientific value of the project.

Figure 4. A map showing the entire length of the Struve Arc.

3.2. How the Struve Arc influenced science

Triangulation measurements allowed:

- To create the most detailed topographic maps of the western part of the Russian Empire with an error of only 3.5 cm per kilometer (as later revealed by modern measurements).
- Correlate these data with those obtained during the "Great Trigonometric Study". Thanks to this, it was possible to confirm that our Earth has a more complex geoid shape and to estimate its parameters even more accurately.

Of the 265 triangulation points, only 34 have survived to the present day. Of these, only two are located in Russia: "Myakipiallus" and "Point Z". The remaining points are located in ten other modern countries: Norway, Sweden, Finland, Estonia, Latvia, Lithuania, Belarus, Moldova, and Ukraine. It is worth noting that eight of these points were previously part of the Russian Empire.

In 1993, at the initiative of Finland, the remaining sites were designated as UNESCO World Heritage Sites. Two sites have been preserved in Russia.

The Struve Geodetic Arc was inscribed on the UNESCO World Heritage List in 14–15 July 2005 at the 29th session of the World Heritage Committee in **Durban**, South Africa.

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4. Observatories of Kazan Federal University (KFU)

Two astronomical observatories of Kazan Federal University (KFU) were included in the UNESCO World Heritage List in Russia in 2023. The decision was made on September 18 at the 45th session of the UNESCO World Heritage Committee.

4.1. Observatories of Kazan University

Astronomical Observatory of Kazan University is a Russian astronomical observatory located in the city of Kazan at an altitude of 75 meters above sea level. It is affiliated with the Department of Astronomy of Kazan University. The Department of Astronomy of the Imperial Kazan University was founded in 1810 by Joseph Johann Litrow. On November 11, 1814, observations began at a small observatory (temporary construction) above a stone gatehouse in the university botanical garden. At the time, it was the easternmost observatory in Europe.

In 1822 the observatory was temporarily placed in a wooden gallery (part of I. M. Simonov's apartment). In 1827 the university yard was chosen as the permanent place of the observatory, and in 1833 the construction of the observatory building began. In 1835 a 23-cm (9-inch) refractor was ordered from Fraunhofer's workshop.

In 1837 the permanent observatory building was completed, and in June of that year the first observations were made in it. In 1838, a 9-inch refractor was installed in the main movable dome. The official date of birth of the University Astronomical Observatory was April 13, 1838, when permanent observations (on the Vienna Meridian Circle) began in the new observatory building

On February 23, 1885, a time service was established: a clock showing the exact Kazan mean time was exhibited in the window of the department

4.2. V.P. Engelhardt Astronomical Observatory

The V.P. Engelhardt Astronomical Observatory of Kazan State University (AOE) is a Russian astronomical observatory located 20 km west of Kazan in the village of Oktyabrsky in the Zelenodolsky District of Tatarstan, at an altitude of 92 meters above sea level. The reason for establishing the observatory was the inconvenience of observation in the city center due to strong light pollution.

The observatory arose from the friendship of two astronomers. It's worth telling more about these remarkable men. The first of them was Dmitry Ivanovich Dubyago (1849–1918), who founded the observatory and became its first director. D.I. Dubyago was a professor of astronomy at Kazan University. He was born in the Mogilev province. After receiving his initial education at the Gatchina Institute, he entered the Physics and Mathematics Department of St. Petersburg University.

After graduating with a PhD, he was retained at the university to prepare for a professorship. In 1873, Dubyago was appointed to the Pulkovo Observatory, where he initially worked as a out of staff astronomer before becoming an adjunct-astronomer. From 1881 to 1884, he lectured at Saint Petersburg University as a private lecturer. In 1884, he was appointed a professor. Dubyago was appointed a full professor and director of the observatory in Kazan. His dissertations are "A Study of the Orbit of Neptune's Satellite" (1878) and "The Theory of the Motion of the Planet Diana" (1880). For his work, he was awarded the title of Doctor of Astronomy and Geodesy by the St. Petersburg Academy of Sciences (Department of Astronomy & Kazan State University (2026).

The second is Vasily Pavlovich Engelhardt (1828–1915). A member of the well-known Engelhardt noble family, Vasily Pavlovich is the grand-nephew of Prince Grigory Potemkin-Tavrichesky. The illustrious prince bequeathed his fortune to his nephew, Engelhardt's grandfather.

After graduating from the St. Petersburg School of Jurisprudence in 1847, V.P. Engelhardt served in the 1st and 5th Departments of the Governing Senate. In 1853, he retired and devoted himself to astronomy.

In 1875, he settled in Dresden, where he built the Great Observatory with his own funds in 1879, where he worked alone without assistants until 1897. Engelhardt's main research focused on comets, asteroids, nebulae, and star clusters. From 1879 to 1894, he observed 50 comets and 70 asteroids. From 1883, he studied nebulae and star clusters, compiling a catalog of more than 400 nebulae. Starting in 1886, he observed 829 stars from the Bradley catalog to detect their companion stars.

D.I. Dubyago and V.P. Engelgardt met and became friends by correspondence — they both studied the asteroid Diana.

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In 1897, due to his advanced age and illness, V.P. Engelhardt ceased his practical observations and, in his will, donated all his unique astronomical equipment from his private observatory in Dresden to Kazan University, as well as funds for the development of the observatory. Among the treasures were a 12-inch Grubb refractor, a meridian circle, a heliometer, comet finders, precise clocks, and a rich library. A capital of 50 thousand rubles in securities was also bequeathed.

On July 21, 1899, Dmitry Ivanovich Dubyago was appointed Rector of the Imperial Kazan University, which contributed to the positive decision to build a second observatory near Kazan. Emperor Nicholas II issued a decree allocating funds and land for the construction. The construction of the observatory began on March 7, 1899. On September 21, 1901, the suburban astronomical observatory of Kazan University was inaugurated.

In 1903, the Observatory was officially named the Engelhardt Observatory, and it still bears this name today.

Figure 5. The V.P. Engelhardt Observatory at the beginning of the 20th century.

Until the end of his life, Engelhardt was actively involved in both the construction and the operation of the new observatory.

On September 21, 2014, another significant event took place. With the support of the Russian and Tatar authorities, the Kazan Federal University, with the active participation of KFU employees and with the help of colleagues from Germany, the ceremony of reburial of the ashes of V.P. Engelhardt in the crypt under the Southern Meridian Mark — the tomb of the Astronomical Observatory of KFU, where Vasily Pavlovich's friend and associate, Professor Dmitry Ivanovich Dubyago, was previously buried.

The Engelhardt Astronomical Observatory houses a variety of modern telescopes from different eras, including the zenith telescope, the Heide astrograph, the Maxetov meniscus telescope, the AFR astrograph, the AZT-14 telescope with a modified CPOM detector, and others.

The observatory took part in the creation of a fundamental coordinate system, providing 14 high-precision star catalogs; solar monitoring of solar-terrestrial interactions; optical and radio observations of meteors; research on comets, the Moon, and asteroids. Relativistic astrophysics is being developed here; optical observations of Earth's satellites are being conducted.

Currently, the Observatory is a complex of buildings: a two-storey building in the classical style is adjacent to the main building with an astronomical tower and a meridian circle pavilion. In the early 20th century, it housed apartments for employees.

By the time the observatory was included in the World Heritage List, it had not only retained its architectural integrity, but also its original research and educational function. The observatory is home to a planetarium. The planetarium was opened on June 23, 2013. In 2016, the planetarium was named after Alexei Leonov, a two-time Hero of the Soviet Union who made the first spacewalk in history. The idea came up during Leonov's participation in the International School of Space Science, which was held at KFU in August 2016.

The V.P. Engelhardt Astronomical Observatory is a territory, buildings, and scientific site that is organically connected to the surrounding landscape and forms a single ensemble. Seven of the Astronomical

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Observatory's facilities have been included in the State Register of Immovable Urban Planning and Architectural Monuments

Conclusion

The article focuses on the history of three astronomical sites that have been included in the UNESCO World Heritage List. Each site has its own unique history, beauty, and scientific significance. As part of the UNESCO Astronomy and World Heritage Thematic Initiative, which was established in 2004, criteria were developed for the inclusion of "Astronomical and Archaeoastronomical Sites" in the World Heritage List. It was proposed to create a new category "Space Heritage", which should include "Space Technology Heritage" (Marov (2016). It is very important for Russia to continue working on the inclusion of various objects related to astronomy, archaeoastronomy, or the history of space exploration in the list of World Heritage candidates. to preserve the historical, cultural, and scientific-technological values of humanity.

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References

Department of Astronomy Kazan State University 2026, The role of D.I. Dubyago in the history of the Kazan Observatory, https://kpfu.ru/physics/struktura/kafedry/otdelenie-astrofiziki-i-kosmicheskoj-geodezii/httpskpfurumain-pagep-sub5769p-view1/200-let-kazanskoj-astronomii-5

Dluzhnevskaya O. B., 2021, Heritage and Modern Times, 4, 177

Litvinova E. F., Pavlenkov F. F., 1893, V. Ya. Struve, his life and scientific work : a biographical essay. Printing house of Yu. N. Erlich, Sankt-Peterburg

Marov M. Y., 2016, Space Technology World Heritage: Basic Concept. Kazan Federal University, Kazan, pp 253–263

New Law of the Russian Federation, 1997, Rossijskaya gazeta, April 7

The Collection of Laws of the Russian Federation, 1997, April 7, 1997, № 14, Article 1606

doi: https://doi.org/10.52526/25792776-26.73.1-151