Astronomy and World Heritage: across time and continents

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ASTRONOMY AND WORLD HERITAGE: ACROSS TIME AND CONTINENTS

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This collective monograph contains results of the study carried out by the European, Asian and American scientists – specialists in archaeoastronomy and basic astronomy, made in the framework of the UNESCO Thematic Initiative "Astronomy and World Heritage" (Coordinator Mrs. Anna Sidorenko-Dulom, UNESCO HQ). The book examines the major milestones in astronomical research and discoveries involving historival monuments of interest to archeoastronomy and of international value. The monograph will be useful to professional researchers in the field of archeology and the history of astronomy, as well as to students of relevant scientific disciplines and to laymen of a broad interest.

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From the Scientific Editor

This collective monograph aims to highlight the results of scientific research in the field of archeoastronomy integrating archeology and the history of astronomy. It is composed of the set of papers submitted to the UNESCO International Conference "Astronomy and World Heritage: Across time and continents" which was held in Kazan (Russia) in August 2009. The baseline of the Conference was the UNESCO Thematic initiative "Astronomy and World Heritage" launched in 2004. Distinguished delegates from 15 countries attended the meeting including specialists in the fields of astronomy and archaeology, UNESCO and IAU representatives, as well as directors of astronomical observatories and coordinators of international projects. The Conference under auspice of President of Tartar Republic Mintimer Shaymiev became one of the most remarkable events of the International Year of Astronomy, as it was proclaimed at the 62-th General Assembly of the United Nations.

The monograph contains a comprehensive review of the main results of the study made until recently by European, Asian and American scientists and represents a synergism of astronomy and archaeoastronomy/archeology. It examines the major milestones in astronomical research and presents the actual discoveries "across time and continents", from the megalith monuments of past civilizations through medieval and optical astronomy, and ultimately to the modern time culminating with the beginning of space exploration. The topics reflect the role of astronomy in the life of nations of various continents, ranging from the most ancient witnesses of the conducted astronomical observations to the modern international astronomical projects. The contents expands our views of space environment tremendously, and in particular, allows us to survey the long period of human beings' history, involving the first primitive astronomical instruments of the ancient times through the new exciting opportunities to penetrate deep in our space environment and to have close up views of other worlds. Basically, the book represents an excellent illustration of the great progress which the mankind achieved for a few millennia of its evolution, specifically in such advanced science like astronomy, in attempts to understand its own position in the boundless Universe.

Unfortunately, because of some reasons including financial constraints, the organizers could not accommodate obvious needs to publish the Conference Proceedings soon after the event has ended. Nonetheless, interest of the participants has not been lost, and an original idea eventually was modified to publishing the collective monograph. The results discussed in Kazan were only slightly updated, and the papers kept current importance and represent state of art in this area of fundamental science. We are aware that not all papers are written in good English because no native English-speaking editor was available, and apologize for this disadvantage.

The drafters and associate scientific editors paid the great efforts to compile the monograph contents as coherently as possible. I am pleased to thank them and all the authors submitted their papers for publication for contribution and cooperation. I acknowledge an invitation of the Kazan Federal University and Engelhardt Astronomical observatory to be Scientific Editor of the monograph.

Mikhail Ya. Marov, Academician, Russian Academy of Sciences
February, 2016

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PREFACE

Since the time when ancient man recognized himself as a thinking creature and directed his eyes to the sky, he awared the greatness of the Universe and asked questions about relationship of celestial events with natural phenomena and their influence onto life on Earth. Addressing such possible connections, ancient people have started regular observations of the sky luminaries, attempting to explain and to predict future events and their development. Thus, the astronomy was one of the first and most important sciences in the ancient world. Investigations in the field and application of the gained knowledge had both practical and sacral meaning. That is why the majority of archaeoastronomical monuments are rooted in observatories and sanctuaries, with burials and altars. Study of these monuments brought evidence of the high level of astronomical knowledge in the ancient world.

The level of understanding and accuracy of scientific predictions was certainly determined by the level of perfection of the observational instruments. The principle of work and level of their development influenced not only the accuracy of results but also the types of objects available for observation, and possible depth of penetration into outer space. Evidently, stone instruments allowed people to perform only astrometric observations determining positions of the Sun, the Moon, planets and some stars. When 400 years ago Galileo Galilei invented the first telescope, the possibility to investigate the nature of celestial objects raised significantly giving rise to the first astrophysical studies. Improvement of optical and then radio telescopes allowed us not only to extend the scope of problems under consideration but, based on gathering significant data storage, to reveal actual and statistical relations between various objects.

With the beginning of space era which opened opportunities to launch space vehicles for astronomical observations and space probes for *in situ* measurements on the Moon and planets, the humankind received the new powerful instruments for direct investigations of our space environment including high-quality images of planetary surfaces, atmospheres, and even extraterrestrial matter return back to Earth for detail studies in terrestrial laboratories. In the recent decades, our knowledge about structure and evolution of stars and of interstellar matter, as well as understanding of processes in the Universe, life origin, and the fundamentals of cosmology has dramatically increased.

Astronomy is not confined any more by the traditional constraints. The relevant branches involving Astrobiology, Cosmochemistry and Archaeoastronomy have appeared and rapidly progressed. An interest to examination of ancient monuments that have been instrumental for astronomical observations has grown significantly during the recent decades. Since the 1981, the so called Oxford conferences were held every 3 years (named after the first conference that took place at the Oxford University in the 1981), with the International Steering Committee in charge.

European scientists dealing with the problems of archaeoastronomy has united in the European Society for Astronomy in Culture – SEAC, and organize scientific conferences yearly. Another society joining archaeologists and astronomers is the International Society for Archaeoastronomy and Astronomy in Culture – ISAAC which was founded in 1995 in the USA.

There are two professional journals dealing with the problems of archaeoastronomy: "Archaeoastronomy" (Center for Archaeoastronomy) published in USA and "Archaeoastronomy" (Supplement to Journal for the History of Astronomy) published in Great Britain. The first conference on the archaeoastronomy in Russia took place on the 15-18 of October, 1996 in Moscow, in the Institute of Archaeology of the Russian Academy of Sciences (RAS). Scientists of Russia, FSU countries, and several countries of Europe and America had an opportunity to meet at the International

SEAC conference “Astronomy of ancient civilizations” in the framework of astronomical meeting JENAM in Moscow, in Sternberg State Astronomical Institute of Moscow University, held from 23 to 27 of May, 2000. Besides, there was the round table discussion during the International symposium “Astronomy 2005 – Modern State and Prospects” that took place from May 30 to June 6, 2005 in the Moscow State University

More details about international collaboration of archaeologists and astronomers can be found in the book “Astronomy of Ancient Societies”, NAUKA PH., Moscow, 2002, pp. 10 – 42.

UNESCO program “Astronomy and World Heritage”

Throughout the years, UNESCO worked hard to preserve the humankind culture as the World Heritage. Thanks to these efforts, most valuable monuments of various nations were preserved for descendants. In particular, they witness diverse forms of acquiring astronomical knowledge in ancient time. Objects of pride for tenths of countries recognized as World Heritage objects are the breathtaking monuments of ancients civilizations, such as Decorated Grottoes Of The Vézère Valley (France), Stonehenge (Great Britain), Lines of Nasca (Peru), Pyramids in Giza (Egypt), Temple Of Heaven (China), Ulug Beg Observatory in Samarqand (Uzbekistan). Currently, having preservation status of UNESCO they are not only subjects to regular scientific investigations but also bear invaluable public education mission. Great number of visitors had a chance to be acquainted with the history of ancient nations of all continents, their ways of life, notions, and high level of scientific and practical knowledge.

At the end of 2003, the UNESCO Centre of World Heritage (United Nations Educational, Scientific and Cultural Organization) has announced the beginning of new project directed to reveal and preserve the objects of archaeoastronomical and astronomical nature of historical and cultural value all over the world and the strategy of thematic program "Astronomy and World Heritage". General criteria of selection of arhaeoastronomical objects and observatories were discussed. It was decided to consider:

• Objects situated or organized in connection with celestial objects or astronomical events;
• Images of the sky and/or of celestial objects and astronomical events;
• Observatories and instruments;
• Objects closely connected with the history of astronomy.

In the follow up process, this program progressively developed covering the new categories of astronomical objects of fundamental interest for the humankind which are deserved to be preserved for the future generations. As it was mentioned, this was accounted for the level of astronomical knowledge determined by technical capacities of the society in different epochs of its existence, technological progress and, respectively, the perfection of astronomical instruments.

Presently, the great numbers of photographic plates collected in the archives of observatories are almost out of use and inaccessible for scientific investigations. However, being often obtained in the framework of international programs, they "kept the sky" as it was in the time of observation which will never happen again. In the course of time, the value of these collections may be only increased. Since the end of previous century, the worldwide process of transfer of the information contained at the photographic plates to digital carriers has been started, along with the creation of "glass libraries" aimed to unify into virtual archive all observatories of the world. This data set is regarded as everlasting value for the world astronomy.

In the end of twentieth and in the beginning of twenty first centuries, the enormous data set on outer space was derived by means of ground-based telescopes and especially by spacecraft placed outside the Earth atmosphere. Obviously, alongside with the ground-based instruments including the ancient (stone) ones which we value as Astronomical

Heritage, the new powerful tools such as space vehicles equipped with the unique instruments should be complemented to this entity because they returned information of the great importance and broadened up tremendously our horizons about astronomical objects and the Universe as a whole. They should be addressed as a new category of Space Technology/Science Heritage involving both tangible and intangible (virtual) objects, such as respective space facilities and vehicles, and onboard instruments. Basicaly, this category is to be commemorated and preserved as historical objects or a part of operational infrastructure, mock-ups, drawings, or other documentation.

Certainly, tangible objects that provided brake through into space and made possible space research are of special importance. These are the launch pads and space facilities where the space vehicles and/or orbital stations have been manufactured, as well as some space probes that safely returned back to Earth. As examples, one may refer to some entities of historical mission such as Vostok space ship and space suite of the first Earth cosmonaut Yu. Gagarin; Apollo space vehicle delivered the first man to the Moon and Neil Armctrong space suite; Luna, Mars and Venus landers; Hubble, Chandra, Planck, Kepler telescopes, etc.

Indeed, space explorations not only ensured unprecedented knowledge about surrounding space and deeps of the Universe, but also opened the new frontiers in the robust engineering and challenging technologies development. Space technologies made possible to land on planets and small bodies - comets and asteroids, return to the Earth's labs extraterrestrial matter which complemented meteorites' collections in many countries and hence, paved the road to answering fundamental questions about the Solar system origin and evolution. Discovery of multitude of extrasolar planets around other stars allowed us to put the problem of the Solar system origin on the new ground. Comparative planetology approach expanded our knowledge about the nature and trends of the home planet evolution. Astronomy and space technologies are regarded as cornerstones in understanding of our place in the Universe and the fate of our civilization. All “valuables” of astronomical heritage involving the tangible objects (either “put to a safe box” or the protective buildings), and intangible space objects that tremendously expanded our knowledge about outer space, are undoubtedly deserved to be value among the most outstanding historical achievements of the human culture.

One of the main events of the UNESCO was International conference “Astronomy and World Heritage: across time and continents” that took place in Kazan, from August 20 to 23, 2009 under the auspice of President of Tatarstan Respublic Mintimer Shaymiev. The Academy of Sciences of Tatarstan and Kazan State University were the hosting institutions. The Conference was organized in one of most ancient and beautiful cities of Russia where the architectural complex of the downtown, Kazan Kremlin, is already recognized by UNESCO as an object of the World Heritage.

At the opening session, the coordinator of the UNESCO Thematic Initiative “Astronomy and World Heritage”, Dr. Anna Sidorenko-Dulom, shares her views concerning the significance of the results of scientific research in the field. In the Introductory part, Prof. Clive Ruggles (Emeritus Professor of Archaeoastronomy at the University of Leicester, UK, UNESCO/IAU) dealt with the history of objects study in the framework of UNESCO initiative “Astronomy and World Heritage”. Dr. C. Martin (Spain) discussed the key points of the international project “Star light” that he is heading. Acad. of Respublic Tatarstan N. Sakhibullin touched upon the topic of astronomical heritage in Kazan, including the most interesting historical episodes. Professor of Moscow State University B. Shevchenko dealt with the 50th anniversary of the launch of the USSR “Luna-3” which flied by the Moon and transmitted the first images of its far side.

The Conference participated coordinators of the UNESCO Thematic Initiative from 15 countries, distingushed scientists – astronomers and archaeologists, and the directors of astronomical observatories from Russia and other countries. The topics of the Conference reflected the role of astronomy in the life of nations of various continents, evident from the most ancient astronomical observations to the modern most ambitious international astronomical projects.

Historical Monuments

The humankind history left behind the amazing buildings since the very beginning, the process of their creation still remaining a puzzle. In particular, there is yet no answer how our ancient ancestors with their primitive tools could excavate 50-tons stone plates and to move them for hundreds of kilometers, to build monuments of a not clear enough purpose that are still a subject of discussion in the scientific community.

The megalith monuments like dolmens or menhirs may serve as an example. Menhirs are the lonely installed large stones used since ancient times (usually together with the other menhirs or chains of menhirs, as well as in complex with the remote reference points like mountains or rocks) to fix basic astronomical directions having applied practical or sacral meaning. One of the examples of using menhirs for astronomical observation with calendar creation purpose might be set by granite massive megaliths of Iset river headstream in Ural, Khakasia, Russia. Another example are megalith monuments are ancient cult rock sanctuaries that were used for astronomical observations and calendar purposes in Kabila, Buzovgrad, Tatul and Tangardyk in Bulgaria.

Greatest monuments of the past epoch that are widely presented in the steppe regions of Russia and other Eurasia countries are the barrows, burials of the nomadic tribes populated this area since the I-st millennium B.C. Of them, the Great Salbyk barrow in Siberia, Russia and Novokondurovsky- I barrow "with moustaches" are to be mentioned as the most prominent from archaeoastronomical point of view.

The petrogliphs are widely presented all over the world as images on the rocks in the mountains, caves, on stone banks of rivers and lakes. Their meaning was basically sacral. As an example, many petrogliphs on the rocks of Onega Lake fix directions toward cardinal points, azimuths of rise and set of the Sun and the Moon, and other astronomical reference points, representing kind of astrolabes in the Stone Age.

Basic and most popular “astronomical device” of the ancient men was the gnomon. Any object can be the gnomon (stone, stick, ledge of the rock, etc.) if it provides a shadow and its position can be marked onto the surface of the ground, rock or on the wall of grotto. Not only direction of the shadow (azimuth) has been marked but also its length in various time of year. With the help of such an “instrument” the sun-dial and even the calendars were marked: points of agricultural work (for the settled people), terms of seasonal migration and other important periods (for the nomadic people). For example, there are many rock images discovered in the grottos and on the walls of the rocks with benches or under ledges that have served as a gnomon in the Dagestan Mountains. The position of shadow of these gnomons on certain images informed inhabitants of surrounding settlements about the beginning of a certain agricultural work or about coming of dates of some special meaning. There are also a number of “portable” ancient stone calendars. These are smaller shallow stones with the hollow for the gnomon in the center and with hollows on circumference with respect of the position of the end of gnomon’s shadow at various times of a day, and also important dates for the inhabitants of Dagestan.

Ancient people have especially honored the Sun, and the complexes of solar observatories investigated by the archaeologists bring evidence how accurate were the observations for this luminary, which was most important for the people.

The past civilizations on all the continents of our planet have left behind the proofs of high level of their culture and achievements in various sciences including astronomy. Witnesses of high level of astronomical knowledge are represented by the objects that seem to be plainly suited for everyday use: ceramic vessels, various furniture, bracelets and other accessories. Many of them bear astronomical symbols that may be interpreted as representation of the sky luminaries or as relevant to calendar purpose. Subjects of this kind related to various epochs from paleolith and to the beginning of new era have been excavated at the end of previous century in Ukraine near the villages Gonzy and Mezin, and also in Kiev.

Quite new type of archaeological monuments having also astronomical meaning was discovered and investigated in the 1980s of the last century on the territory of steppe beyond Ural. There were more then twenty fortified cities discovered of the Syntash-Arkaim type dated by the Bronze Age (the so called "Country of Cities"). From the archaeoastronomical viewpoint the Arkaim and Sarym-Sakly complexes are among the best studied. The "Country of Towns" (dated from the end of III-th millennium B.C. to the first quarter of the II-th millennium B.C.) represents the unique form of ancient organization of socio-cultural medium. The discovery of this complex proved existence of many remarkable monuments of the ancient people inhabited areas at the immense spaces of Russia, which fortunally had not been yet disturbed by illeagal invasion and are still waiting their investigators. In this regard it is worth to mention about the campaign launched in the Institute of Archeology RAS involving compilation of maps which integrates various data available on astronomical objects of archeological value and heritage at the territory of Russia.

The medieval astronomy that have replaced the ancient one in the course of time used more perfect giant astronomical instruments (measured by tenths of meter in high and of length) especially purposed for exact determination of stellar coordinates and for watching the planet movements. The preserved remainders of Samarquand observatory, the complexes of astrometric instruments in five cities of India that were still preserved in a good condition are the witnesses of great importance and value of astronomy in Eastern states of that time.

With the start of era of optical astronomy, the observatories received specialization on observation of certain types of objects and used different methods of observations. Among them, special attention was paid to solar observatories whose mode of construction undergone improvements until the twentieth century. Numerous high mountain observatories were set up including those purposed to observe cosmic rays and high energy particles that are partially absorbed and create showers of secondary origin particles in the Earth's atmosphere. In the period of 17th to 19th century there were a large number of more or less similar observatories that were built mainly in European countries. That fact allowed us to implement several important joint projects, "Carte du Ciel" serving as a good example.

With the beginning of space era, the astronomy met new unprecedented possibilities to investigate and resolve many challenging problems. Nonetheless, the actual question remains - how to preserve for the future generations all important valuables gathered during millennia?

The Contents: An Overview

In the present monograph, an international collaboration of astronomers and archaeologists from 15 countries of Europe, Asia and America attempted to reflect the most important stages of the development of human awareness and gaining knowledge on the structure of the world around us based on the results of astronomical observations since the very beginning, from the study of ancient monuments, through the epochs of optical and radar astronomy towards space exploration.

The monograph consists of tree parts:

A. Archaeo-astronomical objects;

B. Astronomical observatories of XVII–XX centuries;

C. Space World Heritage.

A. Archaeo-astronomical objects

Dr. M. Rappengluck (Germany) presents fundamental review of the investigated monuments of Paleolitic epoch as the core of astronomical observations at that pre-historic time.

Dr. J. Halbrook (USA) deals with the subject of World Heritage left by the America natives. The Astronomy and World Heritage Initiative has to goal of increasing the number of World Heritage Sites related to the sciences. In this article, indigenous astronomy sites that can be considered for new UNESCO initiative are presented and discussed.

In the paper by T. Potyomkina (Institute of Archaeology of the RAS, Moscow) named “A Stone Age Astrolabes: Lunar and Solar Signs of Onega Lake Petroglyphs”, the original symbolic figures in the shape of circles, crescent- and half-moon with 1-2 “beam” lines directed to the same side. The author concludes that there are reasons to consider lunar and solar signs of this kind as the most ancient astrolabes. The petroglyphs are dated by the end of the Vth to middle of the IIIth millenia B.C.

In the paper by V.D. Victorova and N.P. Anisimov (Institute of History and Archaeology, Urals Branch of RAS, Ekaterinburg) the granite megaliths of the Ural at the Iset` river headstream are discussed. The priority directions of orientation of entrances into the dolmen chambers were found in the recently discovered megalith monuments of the Eneolith Age, West and North-West. There is a lunar sign onto the side of covering construction of “Moon’s” (“Lunny”) tunnel.

The many years of collaboration of V. Larichev (Institute of Archaeology and Ethnography SB RAS, Novosibirsk) and Ye. Gienko, S. Parshikov, S. Prokopyeva (Siberian State Geodesic Academy, Novosibirsk) resulted in investigations of several archaeological complexes on the north of Hakasia (pre-mountains of Kuznetsky Alatau, mountain ridge “Sunduky”). The results presented reaviled the high level of observational astronomy and calendar-making of the priests of paleometal culture in the middle of the IIth millennium B.C.

The knowledge of the moments of equinoxes and of the solstices, watched the moments of disappearance and appearance of stars in the dome of the sky formed the main source for astral religion and proto-scientific ideas about the Nature at nomadic peoples of the mountain and steppe zone of the south of Siberia.

Archaeoastronomical aspects of the great burial barrow are investigated in the paper by L. Marsadolov (The State Hermitage Museum, Saint Petersburg). The Great Salbyk Barrow (situated in 60 km from the Abakan city, Khakasia) is the most know Siberian megalithic monument. The barrow height exceeds 20 m, and originally it was pyramid-shaped. There was a square “fence” made of huge stone slabs weighting several tonnes each. The size of largest slabs was up to 5 meters. Inside the fence, a square pit-grave had been dug, and there were seven persons buried in timber on its bottom. It seems probable that the chief of an alliance of tribes and his favourites were buried in the grave. The construction of big barrows in Salbyk probably was based on the astronomical knowledge of that time. Signs in the form of circles, crescents and other figures were discovered on the barrow's slabs. On the basis of the new analyses, the barrow is dated to the 5th century BC.

A. Kirillov (Institute for Physics of Mining Processes NAS of Ukraine, Donetsk, Ukraine) and N. Kirillova (Institute of Physics and Engineering of the NAS of Ukraine, Donetsk, Ukraine) have considered special features of the architecture of the barrow complex “Novokondurovsky-I” situated toward South-West direction on the left bank of the Big Karaganka river (Chelyabinsk region). It is the complex architectural composition consisting of central embankment of 12 m in diameter and two “moustache”- curved ranges of colored stones. According to archeological data, the central stone embankment was in form of hexagon. Northern and southern moustaches are 236 and 216 m long. It can be assumed that the Novokondurovsky-1 barrow “with moustaches” was founded in the days after solar eclipse of June in 503 BC.

N. Dmitrieva (The International Centre of the Roerichs, Moscow) and V. Romeiko (The Moscow City Palace of Children's Creativity) has collected species of folklore of Evenki, the inhabitants of Tunguska taiga, and made an analysis of modern scientific hypothesis attempting to explain the phenomenon of Tunguska. It was the first natural cataclysm of extraterrestrial origin of such range, registered by the naked eye witnesses. The rich ethnographic material of the Evenki preserved myths, tales and puzzles about Tunguska phenomenon.

In the short note M. Ozel (Qag University, Office of Astronomy and Space Studies Tarsus, Mersin, Turkey) argues that the complete solar eclipse of the year 585 on the territory of Turkey described by Herodotes was predicted in advance, the fact being proved by the whole set of historical facts based on the investigation of ancient manuscripts. In this regard it is interesting to note that the strip of the complete solar eclipse of March 29, 2006 covered exactly the same territory.

A. Rustamov (Shamakhy observatory of the Academy of Sciences of Azerbajan) describes in “Ancient solar observatory of Gobustan” the site rock carvings of boats that may have served a calendar function. There is a “sun dial” where a gnomon could have been hung with clear demarcations for the solstice. The Gobustan site is an example of human early symbolic representation of solar and lunar timekeeping.

M. Israpilov (Institute for Geothermal Problems Dagestan Scientific Center Russian Academy of Sciences) presents his investigation of 210 ancient lunar-solar calendars in Dagestan. They mainly represent images of animals, circles, crosses, fylfots, lines etc. performed with ochre and by carving in stone onto horizontal and vertical surfaces of the rocks, in the caves and grottos. Many of the calendars compile the gnomon and instrument to calculate lunar eclipses.

The Bulgarian archaieologists A. Stoev and M. Stoeva (respectively Yuri Gagarin Public Astronomical Observatory, and Institute of Philosophical Research, BAS, Sofia), and P. Stoeva (Solar – Terrestrial

Influences Institute, BAS, Stara Zagora, Bulgaria) investigate megalithic monuments near two of the largest ancient settlements of the Early Bronze Age in Central Trakia, Bulgaria, the ancient cult rock sanctuary Buzovgrad (1800 – 1600 BC) and sanctuaries in Eastern Rodopy, Tatul and Tangardyk Kaya. The rock-cut megalithic monument Cabyle is located at the acropolis of the ancient city. Mutually perpendicular trenches and relief image of the Great Goddess – Mother Cybela have been hewn in the rocks. Another megalithic monument is the ancient cult rock sanctuary Buzovgrad used for sunset observations during the summer solstice and used for astronomical observations and calendar maintenance purpose. It is supposed that this rock sanctuary served a solar cult. Two impressing sanctuaries in the East Rhodopes, Tatul and Tangarduk Kaya, were investigated and they are described as sites for observations of sunrises and meridian culminations of the Sun in days of equinoxes and of solstices. Near the sanctuaries, one may observe a lot of carvings in stone circles of various sizes interpreted as solar symbols and other signs. It might have been connected with the cult to the Great Goddess-Mother.

The Ukrainian archaeologists I. Vavilova and T. Artemenko (Main Astronomical Observatory of the NAS of Ukraine) give a short description of the most famous archaeological discoveries on the territory of modern Ukraine witnessing ancient astronomical culture of the ascendants of Ukrainians from the Paleolithic era to the beginning of new era. Those discoveries are dated by the epoch of Upper to Middle Paleolith and Eneolith era, when the territories were first populated by the Slavic tribes.

Indian archaeologist Shikha Jain (Development and Research Organisation for Nature, Arts and Heritage, Gurgaon, India) in the paper «The Jantar Mantar: 18th Century Pre-Telescopic Masonry Observatories in India» tells us about the complex of monumental astronomical instruments, most significant set of observational instruments of the pre-telescopic era. The instruments called yantras, ranging in height from a few centimeters to 22.6 meters, were designed and built to measure astronomical quantities such as declinations, altitudes, eclipses and times of the Sun, Moon and other planets at different times of the year. Presently, the observatories at Jaipur, Varanasi, Delhi, and Ujjain are the only existing historic pre-telescopic masonry type of observatories in India.

The most famous medieval observatory is described in the paper "Ulugh Beg Observatory in Samarquand" by S. Ehgamberdiev (Ulugh Beg Astronomical Institute of the Uzbek Academy of Sciences, Uzbekistan). In 1420 Ulugh Beg built the giant observatory in Samarquand. This construction was cylindrical in shape, being approximately 48 meters in diameter and 35 meters high. Its main instrument consisted of two meridian arcs, with a radius of 40 meters. The arcs were sunk 11 meters into the rock at the lowest point while their top rose 30 meters above the ground. The main result of observation is the catalog of 1,018 stars.

Kh. Ibadinov told us about the birth of astronomical knowledge and modern astronomy in Tajikistan, and about the prospects of the future astronomical observations.

The fundamental study was made by C. Benoist and F. Le Guet Tully (Université de Nice Sophia Antipolis, CNRS, Observatoire de la Côte d'Azur, Nice, France), and J. Davoigneau (DAPA, Ministère de la Culture, Paris, France). In the paper "Survey of large meridian instruments across continents & time" the ongoing project aiming at listing and comparing large and fixed meridian instruments through time and across continent are presented. Here the authors focus on Asia, Middle-East and Europe and cover roughly the last millennium. They also discuss an international collaborative effort with the "Carte du Ciel" project initiated in 1887 by Paris Observatory.

B. Astronomical observatories of XVII–XIX centuries.

This part dedicated to the optical astronomical observatories is started with the extensive review named “Astronomical Heritage – Solar observatories and instruments, 17th to 19th centuries” by G. Wolfschmidt (Institute for History of Science, Hamburg University). Christoph Scheiner (1575–1650) observed the sunspots in the Jesuit College in Ingolstadt since 1611. The sunspots were recorded in the important observatories like Greenwich, Paris or Danzig (Gdansk). In the middle of the 19th century a significant upturn in solar research started with the discovery of the 11 years solar cycle and the beginning of astrophysics, especially with photography and spectroscopy of the Sun. The most important observatory was the ETH observatory, built in 1861–1864 by Gottfried Semper (1803–1879). Further observatories to be mentioned are Kew Observatory, Potsdam Astrophysical Observatory, Collegio Romano in Rome, Kalocsa Observatory, Hungary, Meudon and Pic du Midi, France.

Another paper by the same author is titled «Astronomical Heritage – development of modern Solar tower observatories, 20th century». George Ellery Hale (1868–1938) deals with the idea of a tower telescope. In 1904 the 60 foot tower in Mt. Wilson was ready; in 1908 the 150 foot tower was built. Two coelostat mirrors reflect the light into the tower; the spectrograph is located in a place of constant temperature far below the surface. In order to test Einstein's general theory of relativity an interesting expressionistic architecture, the Einstein Tower Potsdam, was designed by Erich Mendelsohn (1887–1953) in 1920 to 1922. The optical design, made by Carl Zeiss of Jena, surpassed the Mt. Wilson solar observatory in respect to light intensity. More solar tower observatories were built in the 1920s and 1930s. New observational possibilities were created by Bernard Lyot (1897–1952) in Pic du Midi. An interesting new feature, the vacuum tower telescope, was introduced in the 1960s. This resulted in taking images without distortions.

Acquaintance with the historical European observatories continues the paper “History of the first Astronomical Observatory in Bulgaria”, presented by V. Golev (Department of Astronomy with University’s Observatory at St Kliment Ohridski University of Sofia, Bulgaria), A. Stoev (Yuri Gagarin Public Astronomical Observatory, Stara Zagora, Bulgaria), and P. Stoeva (Solar – Terrestrial Influences Institute, BAS, Stara Zagora, Bulgaria). Astronomical Observatory of the St Kliment Ohridski University of Sofia, founded in 1894, is the oldest astronomical institution in Bulgaria and all new astronomical institutions like the Institute of Astronomy of the Bulgarian Academy of Sciences. The first observational device of the new observatory was the telescope of Peter Beron (magnification 500 times). It is the first astronomical instrument used for teaching astronomy in the university education. Today this telescope, together with other astronomical instruments relating to the initial stage of the University Observatory, is the item of the permanent exposition.

Alba Zanini (Istituto Nazionale di Fisica Nucleare, Torino, Italy) and Marisa Storini (Instituto di Fisica dello Spazio Interplanetario, Roma, Italy) presented the paper “The High Mountain Research Stations: the first laboratories for the study of cosmic rays, elementary particles and high energy physics”. The high mountain observatories played a crucial role in cosmic ray physics, astrophysics, high energy and particle physics. Before the construction of the particle accelerators, the observation of cosmic rays in high altitude was the only way to study the high energy interaction mechanisms and preserves its importance in the high energy astrophysics. The first High Mountain Observatories (HMO), built all around the world in the first half of 1900’s, manifested an extraordinary period in which the most important physicists, many of them being awarded with Nobel Prize, created new detection techniques and performed discovery of new elementary particles, setting up the basis of the modern astrophysics and cosmology. Until recently, the activity at HMO's gives a substantial contribution to the fundamental research in space science.

In the paper "Astronomical Observatories of Ukraine in the UNESCO's Astronomy and World Heritage Initiative" by the team of Ukrainian astronomers: G. Pinigin, Zh. Pozhalova (Research Institute "Nikolaev Astronomical Observatory", Mykolaiv), L. Kazantseva, (Astronomical Observatory of Taras Shevchenko National University of Kyiv), S. Andrievsky, V. Karetnikov (Research Institute "Astronomical Observatory" of I.I. Mechnikov Odessa National University), the astronomical observatories of Ukraine are described. In the team of astronomers, A.Rostopchina-Shakhovskaya and N. Bondar (Research Institute "Crimean Astrophysical Observatory", Crimea) describe the Crimea observatory which is after 2014 is under jurisdiction of Russia. All these organizations compiles with criteria of the project "Thematic studies". Astronomical observatories in Kyiv, Nikolaev and Odessa are presented as objects for the subject "Astronomy from Renaissance to mid-XX century", and Crimea Astrophysical Observatory – for the "Modern Astronomy" subject. In the middle of 2009 the respective materials were submitted to the Working Group of the IAU/UNESCO.

Yu. L. Mentsin and I. K. Lapina review the history of Astronomical Observatory of the Moscow University which played an important role in the development of the Russian and world science.

In the paper "Central (Pulkovo) Astronomical Observatory of the RAS - The World's Cultural Wealth of the Mankind" the authors, main officers of the Observatory, A. Stepanov, V. Abalakin and S. Tolbin tell about the creation of the Observatory, its main instruments, directions of investigations. The Pulkovo observatory was completely destroyed in the years of World War II, and then repaired and rebuilt in the 1947. The complex of Pulkovo observatory was submitted to the List of UNESCO World Heritage.

J. Davoigneau and F. Le Guet Tully discuss how and why the Pulkovo model was introduced in most observatories of the 19th and 20th centuries.

Detailed history and world importance of the Enghelgardt Astronomical observatory was done by the director of EAO Yu. Nefedyev. The observatory has been founded on the basis of the Department of astronomy of Kazan University and it is the oldest one in Russia. Many professional astronomers were educated there since 1810. Nowadays a new observatory of the Kazan University was founded where the modern equipment (9-inch refractor, meridian circle, heliometer and others) were supplied.

C. Space World Heritage Vision

In the paper "Astronomical World Heritage for future" B.Shustov (Institute of Astronomy of the RAS, Moscow) share his views about the past and future of the astronomical heritage in Russia and all over the world. The most important activity at the beginning of space era was organization of observational stations which became a basis for the first global geodesy program named The Large Chord. The project allowed us to make a number of fundamental discoveries that became of universal significance. In 2000 IAU General Assembly supported the initiative of Commission 5 and adopted the project of International Virtual Observatory. An accumulated observational material is considered as valuable source of information to solve many astronomical problems.

The problems of systematization and statistics of names of the objects on the Moon are considered by S. Pugacheva and V. Shevchenko (Sternberg State Astronomical Institute of Moscow State University, Moscow) in their paper. The names on the selenographic maps not only allow us to get right orientation on the map but also have a morphological meaning. The International Astronomical Union has established the standard form of nomenclature for designation of relief details (2008).

M. Marov (Russian Academy of Sciences) in the paper ”Space Technology World Heritage: Basic Concept” analyses space exploration which manifested the new great milestone of the human civilization. It made possible observations in the whole wavelength and also, direct *in situ* measurements in other worlds. Space astronomy ensured the most significant progress in astrophysics gaining invaluable knowledge about space objects and the Universe as a whole. These breakthroughs became possible owing to the great technology developments, specifically those aimed towards space exploration. The author argued that it is therefore prerequisite to include Space Technology as an important segment of the Astronomy World Heritage.

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I am pleased to express my gratitude to all authors submitted their papers and the Scientific Editors A.Boyarchuk, V. Abalakin, J. Halbrook , Yu. Nefedyev and T. Potyomkina for the great efforts they paid in due course of preparation of the manuscripts for publication in this collective monograph. I am especially thankful to Academcian M. Marov who agreed on the editorial board request to serve as the Chief Editor of the monograph and paid great efforts to improve its quality within the available time constraints. I acknowledge the generous support of Tatarstan Ministry of Science and Kazan University for the financial support of the project.

O.B. Dluzhnevskaya

A. ARCHAEO-ASTRONOMICAL OBJECTS

A1. STONE AGE TIME-RECKONINGS AND COSMOVISION:

The Heritage of the Skywatchers from Earlier Prehistory

Michael A. Rappenglück, Secretary of SEAC,
Germany

A1.1. General Overview

Since the beginning and especially during the last decades of the 20^{th} c. scientific research has strengthened the evidence that during Earlier Prehistory (35,000-9,000 BP) man observed certain celestial phenomena and reflected about the spatiotemporal structure of his lifeworld (An overview is given in Marshack 1991, Frolov 1977-1979; Laritchev 1998, 1999; Rappenglück 1999, 2001, 2002, 2003, 2004a, b, 2007, 2008). Remnants of his time-reckonings and cosmovisions can be found depicted on transportable and fixed objects (mobile/parietal art) within and outside of caves or related to certain natural or artificial monuments. During Earlier Prehistory simple natural calendars, complicated "palaeo-almanacs", the knowledge of some asterisms and certain cosmographies already seem to have been components of an archaic astronomy. An excellent ability of imagination and abstraction, but also of technical knowledge was required to transform the knowledge into suitable systems of time-reckoning and cosmographic models. Practical requirements (e.g., orientation, calendar) and the need for cosmovisions, which offered people a meaning of life, motivated Earlier Prehistory man to watch the sky. After one century of palaeoastronomical research it is obvious that astronomy is one of the oldest sciences and an important part of the first stages in the development of man.

A1.1.1 Chronology and Geographical Limits

A very brief chronology of Earlier Prehstory from Lower Paleolithic to the Epipalaeolithic is given in table 1. In general the geographical area is set globally. With respect to the archaeological records and the hitherto known evidence of palaeoastronomical findings it is at present however restricted to Africa, Australia, and Eurasia. Concerning the most complex, elaborated and best proven examples, the following four case studies are taken from the European Upper Paleolithic and Epipaleolithic data.

A.1.1.2 The Archaeological Record of Earlier Prehistory – Classification

The archaeological record of Earlier Prehistory in general can be divided into fixed and mobile artefacts. There exists rock art - paintings, engravings, sculptures - within deep caves and outdoors at special places, along rivers or at rock shelters. The characteristics of caves and rock shelters were very important in archaic life and worldview, too (Rappenglück 1999, 2007). There are evidences for an experience of landscape features, as proven by the existence of thematic maps on bones and in caves. The construction of dwellings, the structure of open air campsites, tools and mobile artwork set up further categories. Concerning the graphical records there exist two kinds of representations on parietal or mobile artwork: abstract signs and naturalistic depictions.

A.1.1.3 The Data of Palaeoastronomy

At least since the Aurignacien (ca 35,000-23,000 BP) hunter-gatherer cultures denoted periodical annual phenomena of flora and fauna (phenology) on various parietal and mobile objects (Frolov 1977-1979; Marshack 1991; Rappenglück 2008). The biological rhythms of animals, e.g., the activity during day or night, the mating season, the duration of their pregnancy, the time of birth and incubation, the change of fur, the formation and dropping of the antlers, the annual migration, in particular the migration of birds, the promotion of spawn etc. were well known to the hunters. As gatherers they didn’t fail to discover the periodic system in the development of plants. This is proved by many examples of phenological representations of animals (mammals, birds, reptiles and even insects) as well as, even if rare, of plants in Earlier Prehistoric art. The seasonal change of summer and winter camps can be read out of the remains of the consumed and otherwise used fauna and flora. Local cave-sanctuaries had been visited time-factored, too. Creation and Renewal of graphic parietal and mobile art followed special time periods. In addition there exist evidences that the illumination of certain cave entry areas and rock shelters during the year with respect to the equinoxes or solstices were important for people of those days (Esteban and Emili Aura Tortosa 2001).

Scientific research affirmed that in Earlier Prehistory parietal and mobile art different phenological designed astronomical natural calendars, which use a system of images and signs to denote certain periods, did exist. Especially the observation of the moon, concerning time periods, the moon’s phases and his local change about the horizon had been known up to a period of several lunar years (Frolov 1977-79; Marshack 1991; Rappenglück 2008). Apart from the lunar time reckoning people used solar and lunisolar time-factored notations, too (Frolov 1977-79; Marshack 1991; Rappenglück 2008). Among mobile objects, from the Aurignacian to the Azilian, several tally sticks and tally pebbles (Azilian) illustrate different kinds of time-reckoning (Frolov 1977-79; Bahn and Couraud 1984; Couraud 1985; Marshack 1991; Rappenglück 1999, 2003). Often combinations of the astronomical periods with biological rhythms of certain animals or / and the human wife (menstruation, pregnancy) exist. This kind of representation could be designated best of all with the term of an "almanac" which combines calendar dates, calendar and important information of different fields (Rappenglück 2008). Furthermore, in some very complicated cases, especially if longer periods are noted, a clearly structured counting – a so-called "arithmetic" notation – of astronomically significant time units has been used.

There are evidences for the knowledge of certain asterisms (Northern Crown, Pleiades, Hyades, and others) during the Upper Paleolithic (Rappenglück 2008), which were important for time reckoning or well-suited for orientation purposes.

Finally it is necessary to draw attention on the use of simple measuring instruments for astronomical purposes (Rappenglück 1999). The archaeological record yields examples for protractors, rods and ropes for measurement, plumb bobs and gnomons. These auxiliaries however fall into the heritage of metrology, surveying, and mathematics.

A1.1.4 Astronomical Heritage of Earlier Prehistory – A General Remark

To identify, to substantiate and to evaluate the astronomical heritage of Earlier Prehistory, a multifaceted and broad-minded objective is necessary (Rappenglück 1999). A rigorous scientific approach should observe phenomenological methodology, iconographical strictness, recognition of multiple levels of meaning, dates and diversity of methods from human disciplines, natural sciences and experimental archaeology, the concurrence of syntactic, semantic and pragmatic aspects, and the primacy of archaeological dating to any astronomical dating. Research should not be based on suggested reconstructions. So far only in some museums specific indications of astronomical objects exist. There is not one signification on the spot. The Palaeolithic astronomical heritage is not explicitly protected. Often it is implicitly listed within an existing general preservation of historic buildings and monuments. Up to now there are only some first beginnings to promote Palaeolithic astronomical heritage. Since some years the media coverage (printed matter, audio-visual material, electronic media, planetarium programs) raise awareness of proto-astronomy, proto-mathematics and other proto-sciences during Palaeolithic times. There is no special database to collect objects and scientific studies dealing with Palaeolithic astronomical heritage, which is accessible by interested people, e.g. scientists, monumental conservators, politicians, artists. To take care of the Astronomical Heritage of Earlier Prehistory it would be important to have specific indications of monuments and of objects in museums, replicas of important astronomical objects, a scientific promotion of the media coverage, the installation of travelling exhibits, the presentation within formal and higher education, including special majors, databases collecting all available information, peculiar research programs to examine nearly forgotten archaeological depots and finally the preservation of parietal and mobile objects having palaeoastronomical significance.

The respect of additional possible astronomical explanations offers mankind an exceptional chance to get deeper insights into the evolution of human scientific thinking and thereby the development of human worldviews. Thus the signification and protection of the palaeoastronomical heritage of Earlier Prehistory is an important desideratum.

A1.2 Case Studies

A1.2.1 The Decorated Plate of the Geißenklösterle (Fig. A.1.1)

I(***A1.2.1***) PRESENTATION AND ANALYSIS OF THE OBJECT

a) Geographic position: The cave ruin of Geißenklösterle is situated near the village of Weiler in the Ach valley, close to the town of Blaubeuren in the Blau valley, region of Alb-Danube, Baden-Württemberg, Germany.
b) Location: φ: 48° 24' 0” N | λ: 9° 46’ 0” E, alt.: 580.0 m a. s. l. / map: TK 25 7624, L 7724.
c) General description: The cave ruin of Geißenklösterle is situated at the Bruckfels rocks, ca 60 m above the present valley floor of the Ach valley, belonging to the widespread drainage basin of the Proto-Danube river system, which is a pronounced karst area. The Geißenklösterle represents a few remnants of a once much more widely ramified cave system, which had collapsed long before humans stayed there during Middle Palaeolithic

(Mousterian) epochs. Today a circus of pinnacles and a rock arch still exist. The Upper Palaeolithic archaeological strata (Horizon II a, b), of the Geißenklösterle yield several figured art work: half reliefs of a bison and an anthropoid, full reliefs of a mammoth and a bear, all made of mammoth ivory, two fragment of unknown sculptures (animals?) and a painted piece of limestone (Hahn 1979; Holdermann, Müller-Beck and Simon 2001: 103, 109).

d) Inventory of the remains: In the Horizon II b of the archaeological layers a very small rectangular mammoth ivory plate was excavated in the year 1979 (Hahn 1979: 117-120). It measures only 38 mm x 14.1 mm x 4.5 mm. The artist cut, smoothed and carved side A and notched side B and the edges finely. On one side of the small, right-angled cut panel the half-relief of an anthropoid figure, composed partially of a human figure and a pouncing feline, is shown in the style of an adorant. Between its legs there is to be seen a long, artificial extension of the body axis which runs down on the height of the right heel. On the other side (B) of the panel and on all four edges a series of intentionally and periodically set notches can be recognized. In the edges a total of 39 cuts in groups of 6, 13, 7 and 13 are to be count. On the side B the notches are arranged in four vertical series: 13, 10, 12 and 13 = 48, with one notch more or less in the vertical series v_2 or v_3,so that the total number of the notches could amount to48±1.

e) Dating: With respect to the stratigraphy the small plate has to be put into the Aurignacian I/II14 between 34,000-30,000 BP (Rappenglück 2001). Up to now there exist five uncalibrated 14C dates for the lower level II b: 33,700 ± 825 BP (H 4751-4404), 32,680 ± 470 BP (Pta-2116), 31,870 ± 1,000 BP (Pta-2270) and 31,070 ± 750 BP (Pta-2361). A cautious calibration applied the plate has an age of 32,500-38,000 cal BP (including the confidence limits). There is some evidence, that the small plate is to be dated at the start of the oscillation of Arcy/Denekamp, a temperate climatic epoch between 31,500 and 30,000 BP (35,000-32,000 cal BP).

f) History of the site and the object: The cave was excavated from 1973 to 1991 and again since 2001 (Hahn 1979; Holdermann, Müller-Beck and Simon 2001: 103). The archaeological layers, containing industries from Mesolithic (Horizon I n, Beuronian A) to Upper Palaeolithic (Magdalenian, Gravettian, Aurignacian) epoch, have been preserved very well till the archaeological intrusion. The artefacts of Middle Palaeolithic epoch had been damaged by soil liquefaction before Upper Palaeolithic time. The object was deposited at Tübingen, LDA Baden-Württemberg (accession number G 58.264).

g) Cultural and symbolic dimension: Scientific research (Rappenglück 2001) makes evident that the anthropoid presents an asterism equivalent to the today's constellation of Orion at the spring equinox about 33,000 BP, related to a lunar and a pregnancy time reckoning, the basis of which is given by the heliacal rising and setting of the star Betelgeuse (α Ori, 0.43v mag). This star was quite suitable as a celestial time signal to announce spring and summer. He set heliacal about 14 days before the spring equinox and rose heliacal approximately 19 days before the summer solstice (height 3°). Depending on the form of the natural horizon and atmospheric conditions Betelgeuse remained invisible for 86 ± some days (that are about 3 lunation / 88.5 days). This numerical value reminds of the sum of all notches on the panel from the Geißenklösterle: 87 ± 1. The star phases of Orion indicated the time of the pregnancy and the date of according to an archaic version of the today well-known formula of Naegele: If the last menstruation had begun before the fathering and just when Orion, the "human being“, rose heliacal, 19 days before the summer solstice, then the birth was to be expected 14 days before the spring equinox, when the constellation declined heliacal. Thus it could also be made sure that the birth took place after the severe winter half-year, in the spring and that there was remaining enough time for a sufficient nutrition of the baby, before the beginning of the next winter. The women of the Australian aborigines used rods with menstrual calendars noted on it to determinate the date of the birth. Still today the lunar year, the solar year and the duration of pregnancy are referred on each other with the help of an analogous arithmetic help, the Gravidarium. Ethnoastronomical comparisons suggest that the Geißenklösterle culture related their asterism of the sky anthropoid to the cycles of cosmic power and fertility.

h) Authenticity and integrity: In the year 1979 the plate has been excavated *in situ* during an archaeological campaign (Hahn 1979). It was discovered in Horizon II b (square 58), at an original dwelling layer, beneath a 5 cm thick bone ash strata. It was found unburnt and close to a concentration of tools and other artwork, probably nearby a fireplace. The layer was deformed and at the same time sealed by a collapse of the ceiling. The object was shifted a little bit (some cm) from the originally position by movement of the soil. The surface of the figure, with a few exceptions, shows an originally weathering. Due to the digging a very small piece (1mm) of the left upper corner has broken apart. The uppermost thin ivory lamination of the front side was slightly injured by the modern excavator. At the back side a part was chipped, but later restored. Nevertheless the sculpture is complete. Because all edges are carrying artificially made notches it is obvious, that the small plate is complete and not a part of a larger object. The back side shows tiniest spots of manganese and ochre, which had been intentional put on.

i) Justification for Outstanding Universal Value: The object is an exceptional and outstandingly artwork of humankind, illustrating the highly developed cognitive and aesthetic abilities of early Upper Paleolithic cultures. It is the hitherto oldest identifiable visualization of an asterism combined with a denoted practice of time-reckoning according to the lunar and the pregnancy period. Moreover the object illustrates the reference of a certain kind of mythic concept to time-reckoning and an idea of asterism.

II (*A1.2.1*) PRESENT OBJECT MANAGEMENT

a) Present use: The original object is accessible only for scientific examinations. There are replicas available for public displays and private ownership.

b) Protection: The plate is at depository at Tübingen, LDA Baden-Württemberg (accession number G 58.264).

c) State of conservation: The object is well preserved. Apart from a little repair of a tiny part of the back side that had chipped away, there was no further restoration done.

d) Context and environment: Traces of use indicate that the piece perhaps was carried in a bag. The embedding of the object in a layer spotted with ochre, a mineral often used during rituals in Palaeolithic time, also show the importance of the bas-relief for the archaic owner (Hahn 1979: 117-120).

e) Archaeological/historical/heritage research: Several times the object was carefully described and examined. For an overview, including the astronomical interpretation, see Rappenglück 2001.

f) Main threats or potential threats to the object: It is well preserved at the depository at the LDA, Tübingen.

g) Management: Though the original object in very rare cases is shown the public, replicas of the object are displayed at several museums all over the world.

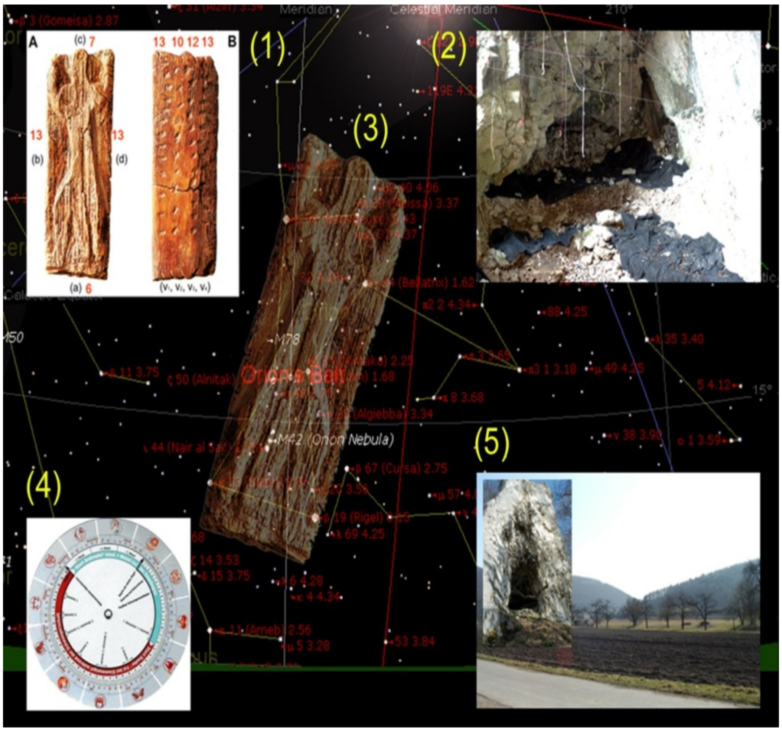

Fig. A1.1 One of the oldest representations of a human figure worldwide comes from the Geißenklösterle cave (Germany), Aurignacian I/II(35,000-

32,000BP)

It can be made evident that the anthropoid present the constellation of Orion at the spring equinox about 33,000 BP, related to a lunar and a pregnancy calendar, following the Naegele rule, and the heliacal rising and setting of Betelgeuse (α Ori). (1) Face and back of the mammoth ivory plate, showing the bas-relief of an anthropoid and intentional cut marks on the edges and back, denoting the astronomical time-reckoning. (2) The excavation area. (3) The plate and the sky area of today's constellation Orion. (4) Just like in the Aurignacian still today the lunar year, the solar year and the duration of pregnancy are referred on each other with the help of an analogous arithmetic help, the Gravidarium. (5) View from the rock arch of the Geißenklösterle cave ruin to the v-shaped end of the valley, which denotes just the south point. From 32,000-33,500 BP Orion was culminating above this prominent landmark at autumnal equinox. Graphic: Michael Rappenglück.

A1.2.2 The That(s) Bone (Fig. A1.2)

I (***A1.2.2***) PRESENTATION AND ANALYSIS OF THE OBJECT

a) Geographic position: Grotte du Thaï/Thaïs, Saint-Nazaire-en-Royans, Dép. Drôme, France at the confluence of the rivers Bourne and Isèrethe. The cave is situated at the foot of the Vercors limestone mountainous massive.

b) Location: φ: 45° 3' 52.52" N | λ: 5° 16' 23.69 "E, map: IGN 1:25.000 (Série Bleue TOP 25).

c) General description: The cave consists of two dry sections (Thaï 1/Thaï 2) and continues into a very large system of water filled galleries.

d) Inventory of the remains: A piece of a bovine rib (87 mm x 27 mm) is engraved on both faces (Marshack 1991a). Seven long incised lines composed of distinct sets (1-2 cm) of smaller marks, perpendicular carved to the principal lines, are running in boustrophedon style more or less parallel to the longer edges of the bone fragment. The sequence is characterized by clustering, variation, and periodicity. The microscopic analysis shows the diversity of the sets, made by various tools and at different times over a longer period. It is evident that the notation was not meant aesthetically. A denotation of hunting marks can be ruled out.

e) Dating: Four 14C dates of bone found in the layers of the second hall (Thaï 2) give data (Brochier and Livache 1997) between 11,980 and 11,270 BP uncalibrated, falling into the Older Dryas (13,540-13,350 BP cal) and Allerød (13,350-12,680 BP cal).

f) History of the site and object: The cave of Thaïs was well known since a long time. 1878 a little exploration of the cave was done. From that time some graffiti had been left by the speleologists. 1968-1969 an excavation campaign was realized (Brochier, and Brochier 1973). In the 70' the cave was prepared for touristic visits. 1957 the first siphon, which opened the access to a very large and deep labyrinth of water filled galleries, was discovered. The object itself is now deposited at C.A.P. de Valence.

g) Cultural and symbolic dimension: The engraving is a non-decorative notational system, which on both sides of the bone plate illustrates a combination of an observational lunar time reckoning of 3 ½ years together with watching the solstices (Marshack 1991). The continuity and periodicity of the Boustrophedon way of marking visualizes the movement of the moon especially during a time period between the winter and the summer solstice. The notational sequence is a positional and topographic model of the moon's course within a certain interval of days related to the solar year, in particular the winter and the summer point. The object shows that Palaeolithic man at least in the Late Magdalenian or in the Azilian epoch had a concept of synchronizing the lunar with the solar movement and time reckoning.

h) Authenticity and integrity: The bone piece # 450 was discovered in situ during an excavation campaign 1968-1969 (Brochier and Brochier 1973). It was located in the layer C"1. Though the bone itself is a fragment of rib, which had been picked up and used by Azilian man for engraving, the intentional cut sequence of marks is completely executed.

i) Justification for Outstanding Universal Value: The object represents the hitherto most elaborated and complex time factored sequence within the corpus of Paleolithic mobile art (Marshack 1991; Laritchev 1998, 1999; Frolov 1977-1979; Rappenglück 2001). It illustrates the existence of a non-arithmetical observational lunar time-reckoning with the inclusion of a solar time factor given by the observation of solstices in Upper Palaeolithic culture (Azilian), ca 12,000 years ago.

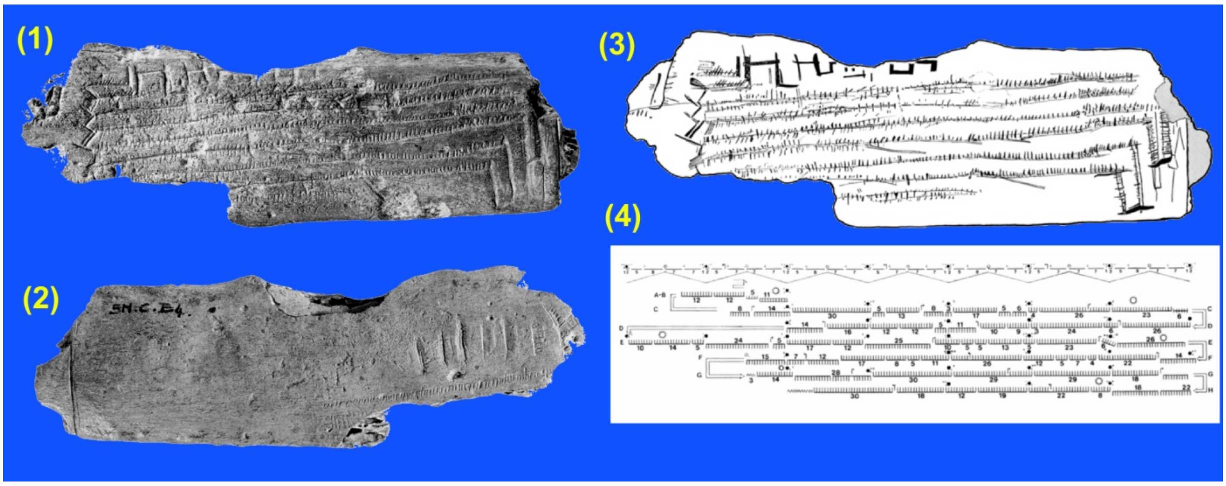

Fig. A1.2 Front (1) and back (2) of the bone # 450 discovered in the cave of Thaïs, showing the elaborated and very complex astronomical notation. (3) Line rendition of the boustrophedon sequence and subsets on the front. (4) The lunisolar time-reckoning model. Graphic: Michael Rappenglück, Photos and drawings after Marshack 1991: 26, Figure A.1.1, 31, Fig A1.5.

II *(A1.2.2)* PRESENT OBJECT MANAGEMENT

a) Present use: It is displayed at the Musée de Valence, Valence, France (Brochier and Soleil 1991).

b) Protection: The object (# 450) is at depository at C.A.P. de Valence, 1990, Inventory # 792-33.

c) State of conservation: The normal procedures of conservation are applied.

d) Context and environment of the site and object: Close to the cave of Thais the rock shelter (Abri) of Campalou contained a rich archaeological layer (C"2), dating to the Late Magdalenian (12,800 ± 300 BP [LY-436]) and Epipalaeolithic/Azilian (Brochier and Brochier 1973). There engravings on bone had been found. The object ranks among a special class of Palaeolithic mobile art, denoting time-factored sequences.

e) Archaeological/historical/heritage research: Based on earlier archaeological studies (Brochier and Brochier 1973) and on own research aided by a microscope Marshack (1973, 1991a) has done detailed scientific examination of the object.

f) Main threats or potential threats to the object: There are no potential threats to the object within the scope of usual storage, except damages due to force majeure.

g) Management: There is no special management related to the object.

A1.2.3 The "Ishango" Bone (Fig. A1.3)

I (*A1.2.3*) Fig. A1.3 PRESENTATION AND ANALYSIS OF THE OBJECT

a) Geographical position: The object was found in an open air site on a terrace (12 m) named Isango [Isanga]-Isoro, localized at the northwest shore of Lake Rutanzige (Lake Edward) close to the outflow of the Semliki River, Virunga National Park (near the town of Goma, Democratic Republic of the Congo). Since 1979 the Virunga National Park is classified on the list of World Heritage (http://whc.unesco.org/en/list/63) and in 1994 it was set on the World Heritage List in Danger. The landscape of the Virunga National Park (ca 300 km x 150 km) is characterized by the Lake Kiwu and Lake Edward, the Volcanoes of Virunga, the Ruwenzori Range with the peak of Mt. Stanley (5,109 m), and the Great Rift Valley. Flora and fauna are exceptional, too. The Virunga National Park for example is well known because of the mountain gorillas living there.

b) Location: φ: 0° 07' 37.09" S | λ: 29° 36' 1.45" E, UTM: 35M 789459 9985951; alt.: 912 m a. s. l. / map: Democratic Republic of the Congo, Series 1501, Joint Operations Graphic (Air) 1:250,000 U.**S.** Defence Intelligence Agency, SA 35-4 Lubero, Congo (Kinshasa).

c) General description: During Upper Palaeolithic (LSA: Lower Stone Age) epoch the open air site of Ishango (11) situated at Semliki Plains close to the Semliki River and at the shores of Lake Rutanzige was the home of early fisherman and gatherers, who settled there. The excavation of the site revealed small points made of ivory, barbed bones, fishbones, bones of different species of mammals, quartzite tools, a decorated haft made of a baboon bone, and several humane relicts (Brooks et al. 1995: 548-549).

d) Inventory of the remains: The artefact is a slightly curved fibula of a baboon (length: ca 10 cm), showing a dark brown colour (De Heinzelin 1962; Huylebrouck 2008: 141-163). A short piece of quartz is fixed to one head of the bone and served as a blade. It protrudes only 2 mm above the bone. The tool was used for engraving purposes. The artefact shows groups of notches arranged into three columns running the length of the bone. The first column (G) consists of four sets of 11, 13, 17, and 19 cuts (in sum 60). In a modern terminology these counts signify all prime numbers between 10 and 20. The second column (M) is made of eight sets having 3, 6, 4, 8, 10 (9+1), 5 (1+4), 5, and 7 scores (in sum 48). The third column (D) consists of four groups with 11, 21, 19, and 9 cuts (in sum 60). The notches on row G and D are each 60.

e) Dating: A first approach to date the object, done by de Heinzelin (1957, 1962), was based upon the lithic industry: 11,000-8,500 BP (Mesolithic / Old Magosian). But later a 14C dating of the cultural layer, using shells, which had been overlaid by volcanic tuffs (W-283 Ishango, Kivu, Zaire) gave an age of 19050 ± 500 BP (Meyer and Suess 1956: 448; De Maret, Van Noten, and Cahen 1977: 505). A new dating of the archaeological layers Ishango 11 [LSA] (Brooks et al. 1995: 549, table 1; Yellen 1998: 191-193; Mercader and Brooks 2001: 202-203) gives sufficient evidence that the object has an age of between 16,500 ± 480 (Beta 22050) and 25,290 ± 65 (Beta331 88/ETH 5872) cal BP (samples: mollusc shell / ostrich eggshell).

f) History of the site and object: Starting with the 1930s geological surveys were done by V. E. Fuchs, W. Adam, J. Lepersonne, J. de Heinzelin, and J. Verniers (Brooks et al. 1995: 552, fn. 4) in the area of the Semliki River, which incidentally resulted in the discovery of archaeological remains from the Middle Stone Age (MSA)/ Late Stone Age (LSA) and the establishment of a basic Upper Semliki stratigraphy (Brooks et al. 1995: 548-549, 552, fn. 4, 6, 7). A re-evaluation of the Ishango site with respect to dating and cultural status was done by Brooks and Smith (1987) and Brooks et al. (1995).

g) Cultural and symbolic dimension: The selection of certain numbers of notches on the artefact is not casual (De Heinzelin 1962; Huylebrouck 1996; Pletser and Huylebrouck 1999, Huylebrouck 2008: 141-163). The bone is not a simple tally stick, but a kind of calculator based on special number systems. The counts on the left and right columns (G, D) signify odd numbers (9, 11, 13, 17, 19, and 21). According to a modern terminology the notches of the first column (G), 11, 13, 17, and 19 are prime numbers between 10 and 20. They represent also a prime quadruplet. The numbers of the third column (D) are understandable as 10+1, 20+1, 20-1, and 10-1. It is supposed that a counting by digits was the standard for this reckoning. Moreover the set of all numbers show a multiplication and division by 2. The sum of numbers in the central column (M) is 48. Both other columns add up to 60 notches each. Thus it is very probable that a mixed base of 10 and 12 was used. Moreover the bone could have been used for a time-reckoning following the observable course of the moon over a period of ca 5 ½ (synodical) months, based on a period of a double lunation of 59/60 days (Marshack 1991: 27-32; Zaslavsky 1979, 1992).

h) Authenticity and integrity: Already discovered in 1950 the bone was described by de Heinzelin 1962. The object comes from the level S.X. Ishango 11 and is well-preserved. Originally it was designed for making incisions upon an unknown substrate. Even a tiny fragment of quartz, which served as a blade, is attached to the head of the bone handle. The Ishango bone was brought to the L'Institut Royal Belge des Sciences Naturelles (IRBSN), Brussels. The artefact is fossilized and shows only minor changes of the surface due to water and chemical influences of the ambient soil.

i) Justification for Outstanding Universal Value: The Ishango bone illustrates that man during Earlier Prehistory had reached a very complex proto-mathematical knowledge beyond simple counting. This includes the selection of certain numeral bases (10, 12), specific kinds of numbers (odd, even, prime numbers), rules of multiplication and division by two. Moreover such a kind of Paleolithic slider rule could have been used for time-reckoning, for special games or other purposes.

II (*A1.2.3*) PRESENT OBJECT MANAGEMENT

a) Present use: The object is on permanent display in the L'Institut Royal Belge des Sciences Naturelles, Brussels, Belge.

b) Protection: The object is well protected according to the usual standards of deposition and exposition of a modern museum.

c) State of conservation: The normal procedures of conservation following international standards are applied.

d) Context and environment of the site and object: In the environment of Ishango there exist several open air sites at the banks of the Upper Semliki River and along the northern shore of Lake Rutanzige: Kabale, Katanda, and Kasaka for instance (Brooks et al. 1995). They reveal artefacts dating to the Early Stone Age (ESA: 2.5 Ma-300 ka BP), Middle Stone Age (MSA: 300-50 ka BP), Late Stone Age (LSA: 50-8 ka BP), and to the Neolithic Epoch (8-1.3 ka BP). During the excavations of the team led by de Heinzelin a co-worker, Marcel Spinglaer, discovered in 1957 another intentionally decorated bone handle, coming from the same level as the first one and dated to a comparable epoch (Semal 2009). The notes concerning this artefact were assembled by de Heinzelin in 1998. This object shows also intentional cuts, which are arranged in six sets of cuts, partially subdivided into series of longer and shorter grooves ([14 long, 6 short], 6 [long], 18 [long], 6 [long], 20 [long], [6 long, 2 short]). This sequence is interpreted as a kind of reckoning using a mixed base of 6 and 10 in a number system.

e) Archaeological/historical/heritage research: The archaeological research is documented in de Heinzelin (1962), Brooks et al. (1995: 548-549), and Huylebrouck (2008: 141-163). The decorated bone of Ishango was first presented and interpreted as an example of proto-mathematics by J. de Heinzelin (1962). Huylebrouck (1996, 2008), Pletser and Huylebrouck (1999), and others also argued for a palaeo-mathematical meaning. A palaeo-astronomical interpretation of the object was introduced by Marshack (1972[1991: 21-32]) and still discussed by Zaslavsky (1979, 1992).

f) Main threats or potential threats to the object: There are no potential threats to the object within the scope of usual storage, except damages due to force majeure.

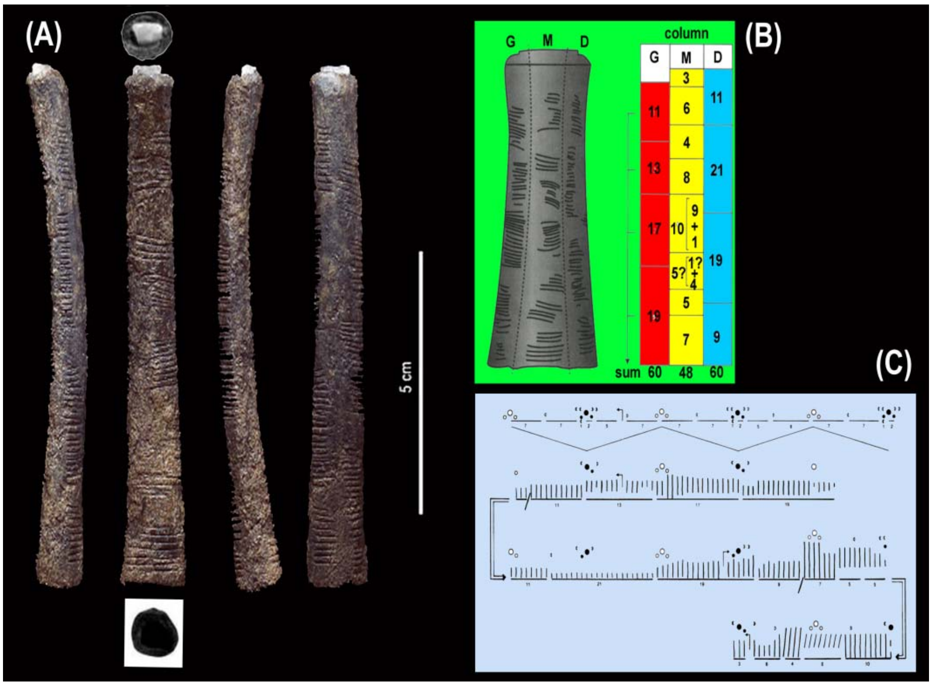

Fig. A1.3 (A) The intentional decorated bone of Ishango; (B) Sets of countable notches arranged on the stick. (C) The system of cuts parallelized to a model of lunar time-reckoning according to A. Marshack (1972/1991). Collage: Michael Rappenglück based upon an image from the Royal Institute for Natural Sciences of Belgium in Brussels, Huylebrouck 2006, and Marshack 1991: 30, Fig. 3.

g) Management: The Ishango bone is displayed for the public at the L'Institut Royal Belge des Sciences Naturelles, Brussels, Belge. Some international scientific conferences, for example in 2007 (http://etopia.sintlucas.be/3.14/Ishango_meeting/Ishango_meeting.htm) had been dedicated to the interpretation of this unique artefact and its significance for the history of the cognitive evolution of the human mind.

A1.2.4 The Astronomical Rock Panels in the Cave of Lascaux (Fig. A1.4/5)

I (*A1.2.4*) PRESENTATION AND ANALYSIS OF THE SITE

a) Geographical position: The cave of Lascaux is situated in the valley of the river Vézère, 1200 m southeast of Montignac (Com. Montignac, Dép. Dordogne, Rég. Aquitaine, France). About 800 m to the northwest of the hamlet Régourdou the entrance of Lascaux I is located just below the top of the Lascaux hill, ca 90 m over the valley floor of the Vézère. From top of the hill, ca 30 m above the original cave, one has a quite good panoramic view across the landscape (Rappenglück 2004). The slightly inclined hills shape a natural horizon of only 1-2° altitude. Even today the height still is a very good place to watch thoroughly the sky, in particular the starry sky, although woods are covering some of the area and new buildings prevent one from having a complete panorama. But at the time of the Lascaux there was a much better view, because of the half-high vegetation, no artificial constructions and of course no artificial lighting.

b) Location: φ: 45° 03' 17" N | λ: 1° 10' 44" E, alt.: 185 m a. s. l. / map: IGN 3615 (Série Bleu 2035 O), Montignac, Grotte de Lascaux, 1 :25000

c) General description: The cave (Rappenglück 1999) is embedded in the Santon limestone massif, which formed in the Upper Cretaceous period (100-64 million years ago). Once in time Lascaux I was a passage cave and part of a gigantic karst system, which was supplied by the Palaeo-Vézère. The subterranean rooms consist of three long and narrow rooms, which form galleries shaped analogue to the letter "k" and measure almost 250 m in extension. In comparison with some other Lascaux I is a cave of middle depth, which to some extent is simply accessible.

d) Inventory of the remains: All over the cave, with the exception of the Mondmilch Gallery and the Silted-up Chamber, 1.963 figures can be count (Aujoulat 2005). Monochrome and polychrome paintings and engravings are registered. The corpus includes animals (horse, aurochs, bison, bovine, stags, ibex, feline, woolly rhino, bird, bear), an anthropoid, a chimera, perhaps some abstract representations of plants, and signs (geometric figures, series and sets of dots etc).

e) Dating: The artists used charcoal only very sparingly for painting. Thus up to now there isn't any 14C-age available directly from the rock pictures. Nonetheless pieces of charcoal were found in archaeological relevant layers at the entrance and in some parts of the cave („Axial Diverticle", „Passage", „Well"). Nine 14C-dating have been made up to now (Rappenglück 2004): 18,600 ± 160 (Gif A 95582), 17,190 ± 140 BP (GrN-1632), 16,100 ± 500 BP (Sa-102), 15,516 ± 900 BP (C-406), 9,070 ± 90 BP (GrN 3184), 8,660 ± 360 BP (Ly-1197), 8,510 ± 100 BP (GrN-1182), 8,060 ± 75 BP (GrN-1514), 7,510 ± 650 BP (Ly-1196). With respect to a

99.7% probability (3 σ) the results can be arranged into an older group, from 21.380 calBC to 12.865 calBC (Badegoulian/Magdalenian), and a younger one, from 8.646 calBC (78,5 %) to 4.204 calBC (Mesolithic). Based upon the known archaeological industry, pollen analysis, and stylistic evaluations, it is thought that the majority of the rock pictures are to be associated with the final Badegoulian and mostly the Lower Magdalenian, 17,000-15,000 years ago. But at present it can't be quite excluded that a few following a different style may belong to later Mesolithic epochs up to about 5,000 BC. There is however evidence that Mesolithic man only occupied the entrance or camped nearby, without leaving cultural remains within the cave. In addition some of the younger ages are regarded as unreliable, because of mixed up archaeological layers.

f) History of the site: In the course of the epochs the entrance of the cave was difficult to access and sometimes even sealed (Aujoulat 2005: 26-29, 56-61). It can be proven that visits by man of the Solutrean and Magdalenian (18,790-14,616 BP) had been very limited and were restricted to short time spans. It is possible that during the Mesolithic period (weighted mean of the five recent dates: 8,380 ± 60 BP) people attempted to go into the cave, but remained at an occupation site close to the entrance. They left no traces of cultural layers within the cave. Thus the cave stayed undisturbed until it was discovered anew at 12/09/1940.

g) Cultural and symbolic dimension: This is a subject of the continuous study.

A1.2.5 Phenological and astronomical natural calendars:

There are clear indications for the existence of a natural calendar (Rappenglück 2008): The majority of depicted animals show seasonal characteristic features: The deer indicate their rutting season at the start of autumn. The horses illustrate mainly the period from the end of the winter to the beginning of the spring, i.e. the time of the mating and the foaling. There are also single animals in the summer fur. Most of the bovine testify the season of the midsummer at the end of which, in August / September their rutting season takes place. The behavior of the ibexes indicates the summer / autumn when they meet in same-sexual herds. The notation of certain seasons is enhanced by addition of stylized plants as abstract signs to the animal pictures: In the "Axial Diverticle" one “Chinese Horse“ is shown in its summer fur, highly pregnant and surrounded by stylized branches, illustrating the time of foaling around summer solstice. To make particularly evident a change of the seasons, occasionally a pair of identical animals is depicted, from whom one still indicates the old season and the other one already the new one in its appearance and behavior. In the cave of Lascaux the painting of the two "crossed" bison shows the transition of the late autumn/winter to the summer, because one animal (on the right) still is depicted with the dark winter fur, while the other one (on the left) is getting already its thinner and brighter summer fur. In another part of the cave a pair of attacking ibexes (Capra ibex) is depicted. The left clearly shows the darker winter fur. Hence the violent fights of the male animals during the rutting season from December to January (around the winter solstice) are shown.

Several rock pictures show deer in their appearance and behaviours at the start of autumn. A belling old stag in the “Axial Diverticle” indicates the rutting season. On its left an ancient wild horse in its winter fur and before foaling, signals the transition from winter to spring. Below the animals a series of 39 points divided in 2 sets (13 [= 6 + 1 + 6] and 26 [= 7 + 5 + 14]), makes evident a counting with the value 13. Further analysis shows that the row of points, each spot counting 7 days, illustrates a sequence of 13 weeks (91 days) from summer solstice (21.6.) to autumn equinox (23.9.) and 26 more weeks (182 days) to the time of the spring equinox (21.3). Thus the time between the rutting season of the deer, around the autumn equinox and the foaling of the ancient wild horse from March to June is denoted. In sum there are 39 weeks (273 days: ca 10 sidereal / 9 synodical months) depicted. This is similar to the Komi calendar, in which the Elk signifies the autumnal equinox and the year was divided in the hunting season of the elk and the bear, separated by nine months, the pregnancy time of the elk cow.

A1.2.6 Asterism of the Pleiades and Hyades:

Above the back of the aurochs (#18) in the "Hall of Bulls" a strange heap of six spots resembles the open star clusters of the Pleiades (M 45; 1.5 mag) (Rappenglück 1996, 2001, 2004, 2008). The animal's eye, a big spot about which is depicted a half arc, surrounded by a group of 12 dots signify Aldebaran (α Tau) and the Hyades. The aurochs himself is a forerunner of the later Taurus constellation. Within the scope of the archaeological dates and supported by astronomical considerations about the proper motion of Aldebaran, the star representing the eye of the bull, the Pleiades were close to the autumn equinox ca 15,300 BC / 17,250 BP. Similar to traditions of some North American people a natural calendar could have followed the rhythm in the life of the bison: The year started with the rutting season and the mating of the aurochs between August and October parallel to the heliacal setting of the Pleiades about the 26th August. 28 days later (a sidereal month) the autumn equinox took place. It ended around the heliacal rising of the open star cluster about the 11th of October (some day's ±). About 319 days passed from first up to the last visibility. The beginning of spring divided almost exactly this period (161/158 days).

A1.2.7 An archaic cosmography in the cave of Lascaux

In the shaft of the "Dead Man" of the Lascaux cave two panels with pictographs illustrate an archaic cosmovision of Magdalenian time (Rappenglück 1999, 2004 a/b, 2008). Multiple viewpoints and levels of imagination are combined into a map of the cardinal parts of the sky and slightly enhanced to a panorama of the heavens. The display is based on the functionality of a gnomon and certain shamanistic-totemistic concepts, including ideas about a cave of creation and a primeval hunting sacrifice. The northern wall points in a sequence from the east to the west: a bison with a remarkable object hanging below the hindquarters of his belly - two shapes which look like a spear and an arrow - a “bird person” and a “bird stick - a wooly rhinoceros - and six spots, with two faded lines under it. Almost exactly on the opposite side on the northern rock one can recognize a wild horse.

A detailed case-study of this rock panel, based on the geometry of the scene and on ethnoastronomical records handed down by people worldwide, reveals the following astronomical results: It is a depiction of a sky panorama recognized by Magdalenian people from top of the Lascaux hill, around midnight, summer-solstice time, ca 14,500 BC / 16,450 BP. The date fits well to the uncalibrated archaeological dating of matter from the shaft with a scope of ca 18,800 to 15,400 BP (Badegoulian/Magdalenian). The “bird-man” is a gigantic asterism positioned in the Milky Way, partially presented by the dark clouds, located there. It consists of stars of the today constellations Cygnus, Vulpecula, Aquila and Serpent. The “bird-man”-asterism is in its lower culmination. In the east the bison-asterism is shaped by stars of the today's constellations Lyre, Hercules, Ophiuchus and Libra.

In the west the wooly rhino-asterism consists of stars in Pegasus, Pisces, Andromeda, Pegasus and Aries. The little bird who sits on the stick is given by stars of the dolphin and eagle. About 10° east of the southern point the wild horse asterism corresponds to culminating Leo, close to the point of the winter solstice in those days. Seen from the bottom of the shaft the bird-man is oblique and the bird-stick indicates the centre, the direction to the zenith, the plumb line and the meridian (azimuth 0°). Viewed from the top of the shaft the bird-stick appears to be inclined (45.3°) to a fictive baseline drawn from the tip of the bird-stick to the feet of the bird-man, who then stands upright (90.7°). Astronomically evaluated the bird-stick points to the pole of the northern sky at Lascaux (φ: 45.1° N), while the bird-man indicates a line from the nadir to the zenith. Both birdlike figures symbolize the sky and signify the zenith and the northern celestial pole. Ca 14,500 BC, δ Cygni (2.84 mag), was less than 3° away from the northern celestial pole, which in those days was situated in the Milky Way. The bird-stick is pointing to this polestar, which is indicated by the right wrist of the bird-man.

By his appearance - head and claws of a bird, wing-like stretched arms and bony shape - the bird-man can be typified as a shaman in ecstasy, who transformed himself in a migrating bird for being able to travel through the different realms of the cosmos and to reach the realm of the celestial pole flying across the Milky Way. The bird-man is ithyphallic, because he ejaculates the life-giving substance of the Milky Way, thus helping to renew, restore and conserve the cosmic fertility. He stands close to the bird-stick, which acts for him as his spirit-helper, embodies the world-axis, and serves the shaman as a handy symbol of cosmic power. Rotating around the cosmic axis the bird-man-shaman makes the starry sky revolve. According to ancient traditions summer solstice was one important time for the shaman's activity. In another view the bird nesting on the top of the stick symbolises the sun, culminating at summer solstice.

At that time it was ritually shot by an arrow, according to ancient traditions worldwide. That practice indicates the starting descend of the sun on the ecliptic accompanied by the declining daylight. The angle of 68.6° between the arrow and the bird-stick corresponds to the culmination of the sun at 69.3° at the place of Lascaux and at summer-solstice, ca 14,500 BC. The bird-stick served as a gnomon, which at night with the help of the circumpolar constellations is aligned to the pole of the sky to ensure an exact working during the day. The arrow signifies the gnomon's shadow at the summer solstice. Shadow sticks, which carry figures on their top, quite similar to the "bird-stick", are known from ethnoastronomical records. At the place and epoch of Lascaux the azimuth between the rising and the setting of the sun at summer solstice is ca 111°. This angle is given by intersecting the arrow and the baseline on which the bird-stick and the bird-man are standing. The vertical and the horizontal angle which determine both together the points of rising, culmination and setting of the sun at the summer solstice are complementary to each other – a peculiarity for location at the latitude of Lascaux plus/minus some degrees. Finally the six dots and additional two lines below the set positioned beneath the tail of the wooly rhino indicate the bisecting of the year in two periods of six months at summer solstice.

a) Authenticity and integrity: The authenticity of the art work as dated to the Upper Palaeolithic time is ensured by radiometric dating of archaeological layers, pollen analysis, stylistic analysis, and the archaeological industry (Rappenglück 1999; Aujoulat 2005). At the time of its new discovery (12/09/1940) the cave was in a status of geological and climatically integrity, with only the minor usual modifications of the soil and the walls (A. Leroi-Gourhan 1979). From 1952 to 1963, the year the cave was closed, several research campaigns took place. In the course of the excavations and for touristic development some serious intrusions have been made. To make the underground environment safer and more comfortable for tourists, the owners enlarged the cave entrance, lowered its floor, drained off standing pools of water, and installed electric lights and air conditioning. Thus the integrity of the whole ensemble was disturbed and further archaeological research, e.g. of the cave floors, had been made hardly possible.

Justification for Outstanding Universal Value: The cave of Lascaux contains the hitherto most elaborated and complex astronomical notations in the Earlier Prehistory. These are phenological and astronomical natural calendars, the display of certain star clusters like the Pleiades and the Hyades, and the illustration of some selected asterisms of the night sky at summer solstice midnight. Finally Lascaux I present the so far only known cosmovision of Upper Palaeolithic hunter-gatherers combined with an archaic totemistic-shamanistic worldview.

(b) PRESENT OBJECT MANAGEMENT

b1) Present use: At present the cave is closed for non-essential visitors.

b2) Protection: At 27/12/1943 the cave was classified as a historic monument of France (A. Leroi-Gourhan 1984: 180). Since 1979 the cave of Lascaux is on the World Heritage List of UNESCO (Prehistoric Sites and Decorated Caves of the Vézère Valley, Serial ID-Number 85-011). Because of serious contamination by the perspiration of the crowds of visitors, the use of high-powered lights which caused a beset of the walls by microorganisms and fungi the cave was closed for the public in 1963. An air condition system was installed to improve the cave climate. After a time of recovery till 2001 the conservation status declined rapidly, because of new biological attacks. Though a new air conditioning system that was installed, in January 2008 it was necessary to strictly close the cave for three months for everyone, except one conservator once a week, who was permitted to enter the cave for 20 minutes.

b3) State of conservation: The actual state of conservation (2009) is very bad and needs quick and permanent improvement. More than 50% of the caves art is rapidly disappearing, caused by the attack of biological contamination. In July 2008 the UNESCO world heritage committee has challenged the French government to report on the success of its efforts to save the Lascaux within six months. In February 2009 the officials reported that the biological contamination was stopped, but not removed.

b4) Context and environment: The cave of Lascaux is situated within an area rich of caves, rock shelters, and settlements along the valleys of the Beune, Vézère, and Dordogne and at the surrounding hills dating to Earlier Prehistory. Many of these sites handed down parietal and mobile art, which date from all Upper Palaeolithic epochs. Some of the prehistoric sites and decorated caves of the Vézère are already listed as UNESCO World Heritage.

b5) Archaeological/historical/heritage research: There exist numerous scientific archaeological, historical and heritage studies about the cave and artwork of Lascaux (A. Leroi-Gourhan 1979, 1984: 200; Rappenglück 1999; Aujoulat 2005). Also a lot of speculative work and some serious research have been done concerning an astronomical interpretation of some parts of the decorated rock panels. A certain overview is given in Rappenglück 1999

b6) Main threats or potential threats to the object: In 1940 Lascaux, a closed cave with an own air conditioning, came suddenly abruptly in contact with the outside air. Soon after the discovery of the cave the number of visitors climbed each day, reaching 300 by the end of September 1940. In October the tourism operation at Lascaux was taken over by the Rochefoucauld family, who owned the land. The French Ministry of Culture, closed the cave to the public until the end of World War II, when resources would be available to develop the site most responsibly. On the 14th of July, 1948 the cave was given access to the public, after stone stairs, bronze doors, input sluices and lighting were installed by the owner. Up to 125,000 people visited the site each year.

Unfortunately, the changes made to accommodate tourism upset the cave's fragile ecological balance. Carbon dioxide and water vapor exhaled by the constant human traffic formed carbonic acid, which attacked and corroded the rock and the calcite deposits lining the walls. When first recognized in 1955, officials responded by developing a system to monitor and regulate carbon dioxide to mitigate the deterioration. Since July 1958 the ventilation system was installed and seemed to work, but the cave's excess humidity promoted the growth of microorganisms. The large number of guests and the change of the climatologic conditions endangered the cave very quickly in spite of all precautionary efforts. In 1960 patches of green algae (the “green disease”) appeared on the walls and were found at an increasing rate and there was the risk that the artwork would be lost in just a few years.

Examinations of some biological cultures of numerous species of algae (Cyanophyta, Chlorophyta and particularly Xantophyta), amoebas, bacteria and fungi, which had been taken from the walls showed an extensive biological population on the walls of the cave. The electric light causes the growth of these the micro organism (fungus, lichen, alga), which partly get their nutrients (minerals) directly from the walls and from the atmosphere, without any necessary relation to the sol. In the case of Lascaux the water and the air carried the spores. The algae lived on the surface of the rocks, but also in the calcite crystals, which make a thin film on the walls. There are also bacteria present and spawn. The micro organisms were brought in by the visitors and during the preparation of the corridors for the visit of the guests. The biological contamination of the sol, the rock walls and the atmosphere in the cave caused a series of lasting destructions, which consists of pulverisation and liquid biological substances. Thus the chemical neutrality of the walls and the pigments was changed and became instable.

The increase of the temperature, the humidity and of carbon dioxide formed calcite crystals, which in addition threatened to cover the paintings completely in the course of time. The destruction of the pigments happens twice: By unsaturated calcium carbonate water, which penetrates the cave and by acids, produced by the breath and transpiration of the visitors and at the same time by calcite of different forms: micro-concretions and others, caused by saturated calcium carbonate water, which also is a consequence of the guests breath. In 1963 the French Ministry of Culture permanently closed the cave to the general public, allowing access only to five visitors, mainly researchers, with special permission and for a limited time (35 min). The purpose was to isolate the cave against exterior effects. But it was not sufficient to only lock the underground galleries, to switch out the lightning, to install an artificial ventilation, to cool the cave by a cold point in the entrance which urges the condensation here instead of the walls, to establish a constant level of temperature, air humidity and CO_2, and to evacuate the carbon dioxide and the infiltrated water. In addition a shock treatment was carried out to clean of the air by spraying different antibiotic aerosols (penicillin, streptomycin, kanamycin), which destroyed the bacteria, while the disinfection of the walls and the ground took place by means of pulverized algaecides and bactericides which are considered as harmless to the paintings. The algae colonies died in the course of some months, and the paintings. In 2001 after modernization of the air conditioning system a white mould (fusarium solani) started spreading quickly all over the cave. It turned out that the fungus, which was already in the cave was probably triggered by the perspiration of people working in the cave, but other causes are discussed, too. The cave was closed strictly and scientists started to treat the new biological attack by biocides (benzalkonium chloride, streptomycin, and polymyxins) and chemically by hydrated lime spread on the floor. During January 2008 walls in a part of the cave, which were serious affected, were treated with a new fungicide. But this turned out to be unsuccessful. Since February 2009 black stains of fungus (Ulocladium) have finished spreading, but they still are there (Bastian et al. 2009).

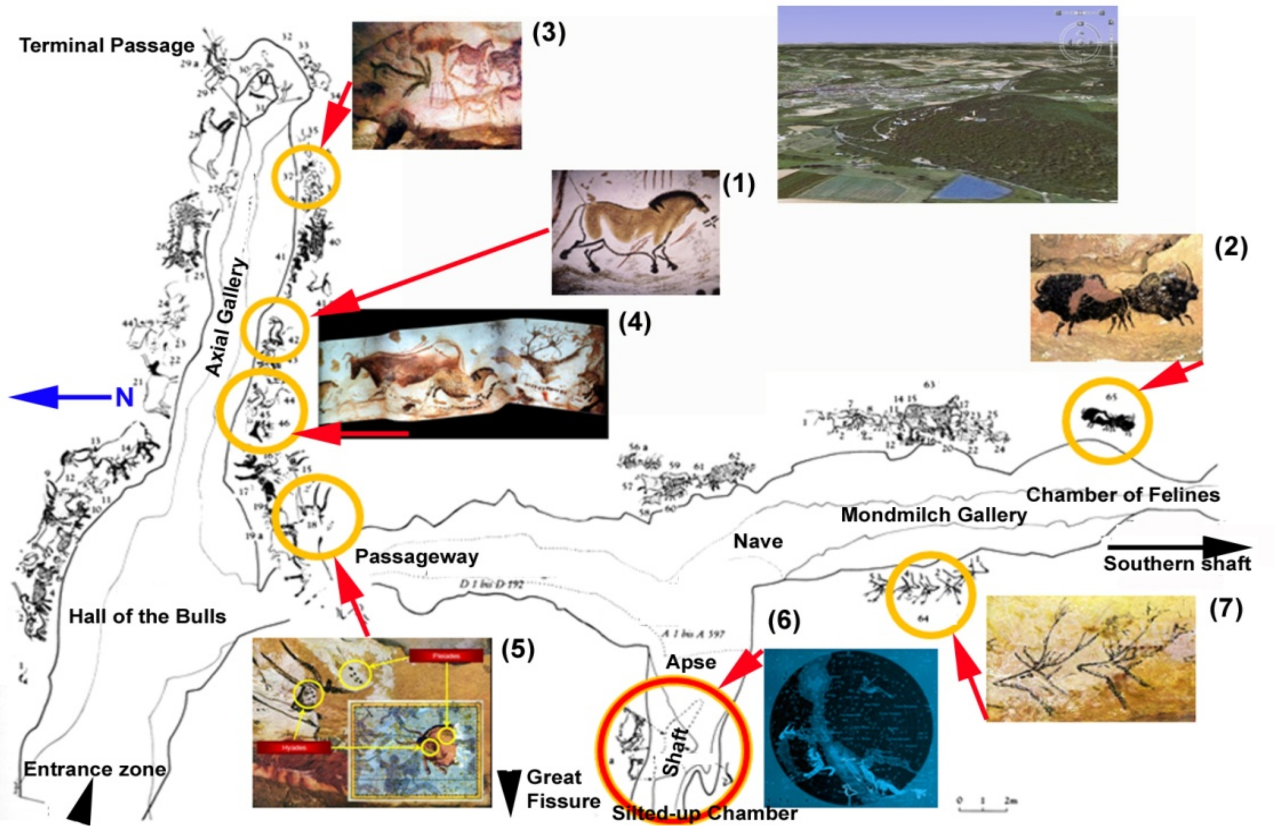

Fig. A1.4 The hitherto known rock panels with astronomical implications in the cave of Lascaux: Phenological natural calendar: (1) the "Chinese Horse" (Axial Gallery) (2) the "Crossed Bison" (3) the "Fronting Ibex" (Axial Gallery). Palaeoastronomical almanac: (4) the "Roaring Stag and Pregnant Horse Motif" (Axial Gallery) (7) the "Five Swimming Stags" (). Asterisms: (5) the Pleiades and Hyades above the Aurochs #18 (Hall of Bulls). (6) Totemistic-shamanistic

Cosmovision and representation of the starry sky at summer solstice, around midnight, ca 14,500 BC (Shaft). Graphic: Michael Rappenglück.

b7) Management: At present the cave of Lascaux is closed to the public. In the 1980s a detailed 3D-replica of the cave's most representative galleries of Lascaux had been reproduced, the Painted Gallery and the Great Hall of the Bulls, just 200 meters from the real thing. One third of the corpus is copied. Lascaux II has been open since 18/07/1983. More than 250,000 tourists each year visit the replica. Some of the other important Lascaux frescoes, including the Scene of the Dead Man, were duplicated in detail and the copies placed on display at the Musée d'art préhistorique du Thot (Tonac, Dordogne, France) and the Musée d'Aquitaine (Bordeaux, France). Since 2009 a virtual display of the Lascaux cave is presented on the Internet at the following address: http://archaeology.about.com/gi/o.htm?zi=1/XJ&zTi=1&sdn=archaeology&cdn=education&tm=61&f=00&su=p897.6.336.ip_&tt=2&bt=1&bts=1&zu=http%3A//www.lascaux.culture.fr/%23/en/00.xml.

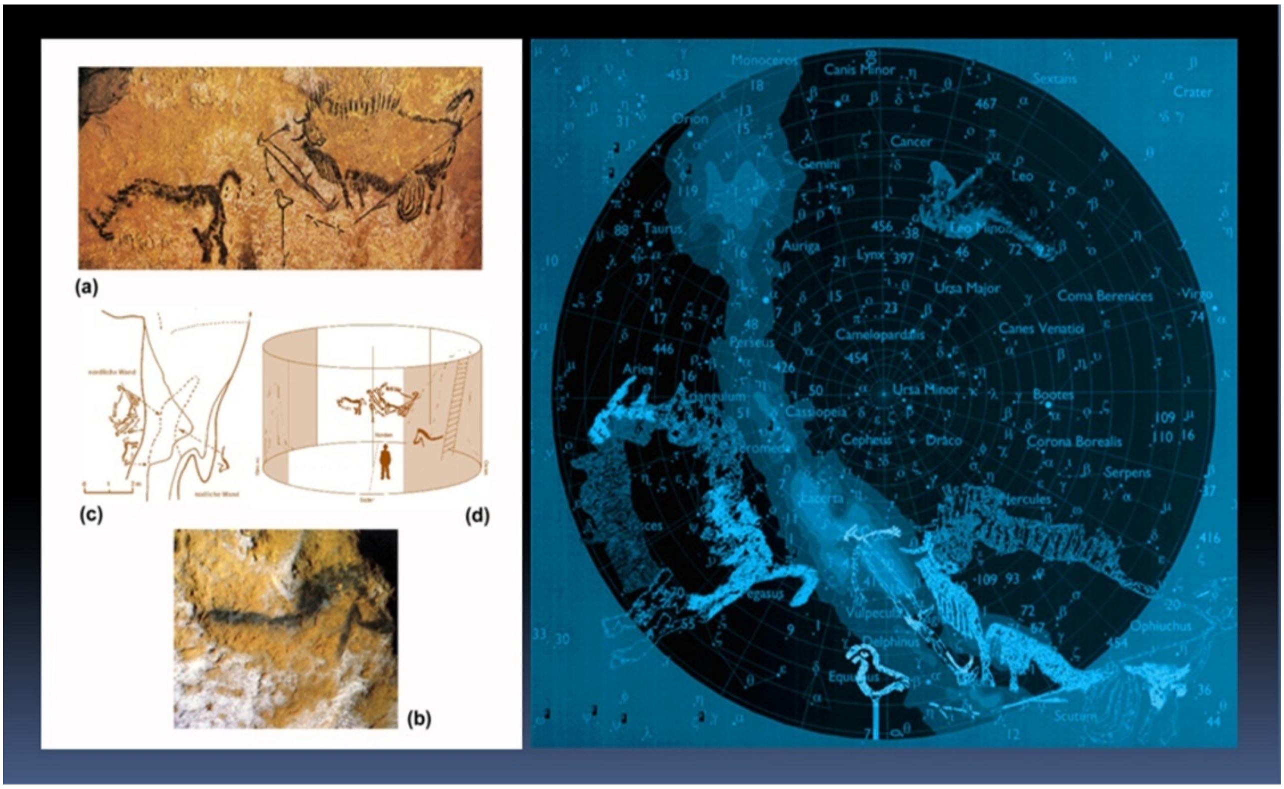

Fig. A1.5 The archaic cosmography in the cave of Lascaux: A Panoramic View of the Sky in the „Shaft of the Dead Man", around midnight, summer solstice, ca 14,500 BC. (a) Depictions on the *northern (b) and southern rock panel (c) Plan of the arrangement of depictions in the shaft. (d) 3D presentation of the composition. Graphic: Michael Rappenglück.*

Table 1

Palaeolithic Periods	
Lower Palaeolithic (ca2.6 Ma 100 ka)	Olduwan (2.6–1.8 Ma)
	Acheulean (1.7–0.1 Ma)
	Clactonian (0.3–0.2 Ma)
Middle Palaeolithic (300–30 ka)	Mousterian (300–30 ka)
	Aterian (82 ka)
Upper Palaeolithic (50–10 ka)	Baradostian (36 ka)
	Châtelperronian (35–29 ka)
	Aurignacian (32–26 ka)
	Gravettian (28–22 ka)
	Solutrean (21–17 ka)
	Magdalenian (18–10 ka)
	Hamburgian (14 ka)
	Ahrensbergian (13 ka)
Epipaleolithic	Swiderian (10 ka), Azilian (10 ka)

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A2. INDIGENOUS ASTRONOMY AND ITS HERITAGE:
Africa, Pacific, Asia, and Beyond.

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Fig. A.2.1: Stonehenge, UK. Photograph by Jarita Holbrook.

Fig. A2.2: The Batamarriba houses aligned to the winter solstice sunset. Togo.

Fig. A2.3: Chichen Itza, Mexico. Site of the light and shadow effects that are controversial because there is no record that such an effect was intentional. Photograph by Troy Cline.

Abstract: The Astronomy and World Heritage Initiative has to goal of increasing the number of World Heritage Sites related to the sciences. Astronomy was chosen to be the focus of the first of these initiatives. Sites associated with telescopes, sky observations, and astronomy discoveries are obvious to included under this initiative, however, sites of indigenous astronomy should also be included. In this article, indigenous astronomy sites that can be considered for this new UNESCO initiative are presented and discussed.

Introduction

The UNESCO Astronomy and World Heritage Initiative is a calculated effort on the part of the UNESCO Office of World Heritage to include sites with a connection to science. They have chosen astronomy to be the science of focus because of the belief that every culture has some relationship to the night sky and therefore has some connection to astronomy. The four criteria proposed at one of the initial UNESCO organized meetings in 2005 focus specifically on astronomy. One of these

criteria must be met in addition to the long-standing criteria of natural or cultural designation applicable to all World Heritage Sites.
The four criteria are:

- History of Modern Astronomy
- Ancient Observatories and Instruments
- Properties whose design and/or landscape setting have significance in relation to celestial objects and events
- Representations of the Sky and/or Celestial Bodies.

The people active in this initiative think it is important to include the heritage of Indigenous Astronomy, but where does it fit within these four criteria?

Indigenous astronomy in the broadest terms is the activities, artwork, and measurements related to the sky executed by people who would not be considered astronomers, where astronomers are defined as individuals with doctorate or master's degrees in astronomy, physics, or astrophysics. Wonderful examples of Indigenous Astronomy are Stonehenge, the Mayan and Aztec calendars, the ancient Pacific navigation techniques, and the sky legends of the indigenous Australians. Examples of Indigenous Astronomy can be found on every continent, however, Indigenous Astronomy is a challenge for the Astronomy & World Heritage Initiative because there is often no material remains or tangible heritage associated with it. The material remains and tangible heritage associated with Indigenous Astronomy is oftentimes not obvious and several steps removed from the act of observing the sky itself. However, these steps and connections leading back to Indigenous Astronomy must be illuminated and understood to ensure the presence of Indigenous Astronomy in this initiative.

Through a dozen years studying the many forms of Indigenous Astronomy and carefully considering the criteria of the initiative, three divisions within Indigenous Astronomy have been identified that can yield potential sites that align with the criteria of the Astronomy & World

Heritage Initiative. They are a) Indigenous Astronomy that is connected to a physical site, b) practices and activities such as navigation that are connected to Indigenous Astronomy, and c) Indigenous Astronomy concepts found in oral forms and other intangible forms such as origin stories, songs, dances, and rituals. Each of these divisions is explored in the following paragraphs demonstrating the clear connections to Indigenous Astronomy.

Physical Sites Connected to Indigenous Astronomy

Physical sites that are connected to Indigenous Astronomy are the easiest to consider first. Consider a place where people made regular observations of the night sky for timekeeping or time-marking purposes. In contrast to scientific astronomy observatories, the observation locations considered here are for observing celestial bodies for societal purposes and reflect Indigenous Astronomy: timekeeping, setting the local calendar, or for religious purposes as examples.

The Ngas people of Nigeria follow a calendar based on regular observations of the moon. They look for the first crescent moon to appear on the western horizon every month. They note the location of the moon relative to horizon features and they note the angle of the tilt of the crescent. Their monthly activities and agricultural activities are based on this lunar calendar. The moon is important to the Ngas and their largest festival is based on observing the first crescent moon of their New Year. The weeklong festival activities include ritually cleaning their homes and their village, gift giving, and drinking “the moon’s beer.” A ceremony with the “sons of the moon”, young boys whose faces are decorated with the full moon, involves the boys shooting arrows into the sky to kill the old moon in order for the new crescent moon to be born (LaPin 1984). The timing of their shooting the moon is precise; the first crescent moon must be sighted the next evening. If the timing is off, the villagers will fall ill. The priest who determines the calendar has an exact location where he stands to do the moon observations, thus there is a physical site connected to his moon watching.

There are a group of sites associated with Native Americans that are a combination of petroglyphs or rock art and physical obstructions that together create light and shadow events that mark certain days of the year. An example is the Sundagger of Fajada Butte, New Mexico, USA (Sofaer and Ihde 1983). The snake descending the temple found at Chitchen Itza in Mexico is another site where a shadow does something unusual on a particular day, in this case the equinox (Forshaw 1984). Chimney rock, also in New Mexico, has associations with observing the lunar standstill with the sun temple used as the observing location looking towards Chimney Rock (Malville, Eddy et al. 1991; Malville 1993; Malville 1999; Malville 2004). Unfortunately, though there has been a lot of research on these sites, there is still debate and controversy as to whether these light and shadow events were intentionally designed by the people who constructed each site, or simply coincidence (Carlson 1987) and see articles by Schaefer and Aveni in (Bostwick and Bates 2006)). Little is known about similar light and shadow sites in the rest of the world (Zedda and Belmonte 2007).

Less controversial is the Indigenous Astronomy found within the indigenous cities of the Americas, such as Teotihuacan in Mexico which has a pyramid of the sun, a pyramid of the moon, and many glyphs connected to celestial deities and thus to celestial bodies. This brings up another important feature of Indigenous Astronomy: often astronomy and religion are combined through the acknowledgement and worship of celestial bodies as deities (Holbrook 2006). Another example of religion, Indigenous Astronomy, and timekeeping is presented for the Batamarriba people of Togo in the concepts section below (Blier 1987). The buildings in an Indigenous Astronomy site might also be aligned to the rising and setting positions of celestial bodies: this is also found in the grand cities of the Americas. These cities have alignments that are connected to both religious purposes and elitism (Aveni and Hartung 1986) in that the celestial events observed served the purpose of reinforcing the divine right of the kings to rule. The celestial event showed the direct connections between controlling the sky and controlling people (Aveni 1989).

Practices and Activities that are Connected to Indigenous Astronomy

There are many practices and activities that are connected to Indigenous Astronomy, such as watching celestial bodies to establish a local calendar as mention already. The local calendar can then be connected to the timing of planting, irrigating, harvesting and other agricultural activities on the one hand (Turton and Ruggles 1978; Snedegar 1998), or tied to determining the religious or ceremonial calendar on the other hand (Niangoran-Bouah 1964; Aveni and Hartung 1986; King 1993).

Navigation by the stars is another example of a practice that has connections to Indigenous Astronomy. The navigators must have some knowledge of the night sky and its daily and seasonal motions in order to employ navigation by the stars effectively. Several ethnic groups in the Pacific have had their navigation knowledge recorded including people in Micronesia, Melanesia, and Polynesia (Goodenough 1953; Gladwin 1970; Lewis 1972; Lewis 1978; Ammarell 1995; Goodenough 1996; Ammarell 1999). Some archaeological sites seem to be specifically associated with navigation, “navigation temples” and voyaging stones with directional markers (Lewis 1972; Finney 1979; Kirch 2004). These are very good examples of practices connected to Indigenous Astronomy that are then connected to a physical site.

Indigenous Astronomy Concepts found in Intangible Forms

Indigenous Astronomy concepts include ideas, beliefs, and understandings connected to the sky that may not be attached to a physical site: such as weather prediction focused on in this section. In fact, much of Indigenous Astronomy is found in these concepts. Other concepts include celestial deities such as solar, lunar, and stellar gods and goddesses (Blier 1987; Holbrook 2006), sun kings as an example of rulers who attribute the right to rule to a direct connection to a celestial body (Jeffreys 1951;

Breutz 1969), and cosmological concepts that are made real in physical structures such as the planning of cities and tombs (Renshaw and Ihara 1999). Weather prediction is often connected to Indigenous Astronomy concepts. There are very few studies of weather prediction show that people watch for the rising and setting of certain stars to know when the rainy or dry season will commence: the Pleiades in the case of the Dogon of Mali (Rogers 2002), and Ursa Major in the case of the Somali of Somalia (Galaal 1968).

Returning to the example of the Ngas of Nigeria, in addition to focusing on the moon to establish their calendar, they look at the tilt of the first crescent moon each month to determine the strength of the seasonal rains. Though there is no underlying physics to explain it, there is an apparent correlation between the local rainfall pattern for the Ngas and the tilt of the moon (Lla Pin ; Lapin 1984; Aveni 1993). Looking again at the Ngas of Nigeria and the importance of the moon in their society; drawn and painted images of the moon that are found throughout Ngas society including those painted annually on the face of young boys during their new year ceremony forming another level of intangible heritage (LAPIN 1984).

The Question of "Universal Value"

To be considered for World Heritage status the case has to be made that a site must be of "universal value". When examining the latest map of the locations of world heritage sites, the majority of the sites are found in Europe, showing a clear bias of unknown cause. When considering Indigenous Astronomy, most of the sites are located outside of Europe which does not bode well for gaining World Heritage status given the overwhelming history of inscripting sites in Europe. However, sites that are already on the World Heritage List have already been proven to have "universal value". Since 2004, members of the Astronomy & World Heritage working group have been studying the current World Heritage list searching for sites that are connected to astronomy, including those connected to Indigenous Astronomy. Their list is found in Table 1. What is important about this list is that most do not have a connection to modern astronomy or history of astronomy, in fact most are connected to Indigenous Astronomy! It is these sites that can be considered for reclassification to include a science designation under the Astronomy & World Heritage Initiative.

Table 1: Sites on the World Heritage List identified by the Astronomy & World Heritage Working Group as having a connection to Astronomy or Indigenous Astronomy.

Country	Established World Heritage Site With Possible Astronomy Connections
Argentina	Cueva De Las Manos, Río Pinturas
Australia	Uluru-Kata Tjuta National Park
Bolivia	Tiwanaku: Spiritual And Political Centre Of The Tiwanaku Culture
Bolivia	Fuerte De Samaipata
Botswana	Tsodilo
Chile	Rapa Nui National Park
China	Temple Of Heaven:An Imperial Sacrificial Altar In Beijing
China	Mausoleum Of The First Qin Emperor
China	Longmen Grottoes
China	Imperial Palaces Of The Ming And Qing Dynasties In Beijing And Shenyang
China	Historic Ensemble Of The Potala Palace, Lhasa
Columbia	San Agustín Archeological Park
Columbia	National Archeological Park Of Tierradentro
Egypt	Nubian Monuments From Abu Simbel To Philae
Egypt	Memphis And Its Necropolis - The Pyramid Fields From Giza To Dahshur
Egypt	Ancient Thebes With Its Necropolis

Ethiopia	Tiya
Ethiopia	Aksum
France	Palace And Park Of Versailles
France	Decorated Grottoes Of The Vézère Valley
Great Britain	Stonehenge, Avebury And Associated Sites
Great Britain	Maritime Greenwich
Great Britain	Heart Of Neolithic Orkney
Greece	Temple Of Apollo Epicurius At Bassae
Greece	Pythagoreion And Heraion Of Samos
Greece	Delos
Greece	Archaeological Sites Of Mycenae And Tiryns
Greece	Archaeological Site Of Olympia
Greece	Archaeological Site Of Epidaurus
Greece	Archaeological Site Of Delphi
Greece	Acropolis, Athens
Guatemala	Tikal National Park
Guatemala	Archaeological Park And Ruins Of Quirigua
Honduras	Maya Site Of Copan
Indonesia	Borobudur Temple Compounds
Ireland	Archaeological Ensemble Of The Bend Of The Boyne
India	Sun Temple, Konarak
India	Ellora Caves
India	Elephanta Caves
Iran	Persepolis
Italy	The Trulli Of Alberobello
Italy	Rock Drawings In Valcamonica
Italy	Archaeological Areas Of Pompei, Herculaneum And Torre Annunziata
Italy	Archaeological Area Of Agrigento
Kenya	Lake Turkana National Parks
Cambodia	Angkor

Korea	Gochang, Hwasun, And Ganghwa Dolmen Sites
Lebanon	Baalbek
Mali	Timbuktu
Mali	Cliff Of Bandiagara (Land Of The Dogons)
Malta	Megalithic Temples Of Malta
Mexico	Rock Paintings Of The Sierra De San Francisco
Mexico	Pre-Hispanic Town Of Uxmal
Mexico	Pre-Hispanic City Of Teotihuacan
Mexico	Pre-Hispanic City Of Chichen-Itza
Mexico	Pre-Hispanic City And National Park Of Palenque
Mexico	Historic Centre Of Mexico City And Xochimilco
Mexico	El Tajin, Pre-Hispanic City
Mexico	Archaeological Monuments Zone Of Xochicalco
Mexico	Ancient Maya City Of Calakmul, Campeche
Norway	Rock Drawings Of Alta
Peru	Rio Abiseo National Park
Peru	Lines And Geoglyphs Of Nasca And Pampas De Jumana
Peru	Historic Sanctuary Of Machu Picchu
Peru	City Of Cuzco
Peru	Chavin (Archaeological Site)
Sudan	Gebel Barkal And The Sites Of The Napatan Region
Sweden	Rock Carvings In Tanum
Syria	Site Of Palmyra
Togo	Koutammakou, The Land Of The Batammariba
Turkey	Nemrut Dag
USA	Mesa Verde
USA	Chaco Culture National Historical Park
USA	Cahokia Mounds State Historic Site
Uzbekistan	Samarkand - Crossroads Of Cultures
South Africa	Ukhahlamba / Drakensberg Park

Zimbabwe	Matobo Hills
Zimbabwe	Great Zimbabwe National Monument

Conclusions

Indigenous astronomy heritage through cultural concepts and practices can be connected to physical sites, however, oftentimes the connections are overlooked or unconsidered. My goal is stimulate nation states to include Indigenous Astronomy heritage sites by thinking about tombs, the layout of urban centers, places of worship, celestial observation sites, and sites of repeated celestial celebrations. The question of the “universal value” remains, however, properties that are already established as a World Heritage Site should be reexamined for possible connections to Indigenous Astronomy. These properties have the best chance of becoming part of the Astronomy & World Heritage Initiative through reclassification to include the astronomy designation.

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A3. A STONE AGE ASTROLABES:
Lunar and Solar Signs of Onega Lake Petrogliphs

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The petroglyphs of Onega Lake were discovered 160 years ago. At present, 1300 preserved images are known at this site. Administratively, the Onega Lake rock carving territory belongs to the Karelian Republic of the Russian Federation. The geographic coordinates of the site are 61,4º Northern latitude and 36º Eastern longitude. The petroglyphs are located in exclusive *topographical conditions*: on the capes rock tips of the eastern coast of the Onega Lake, deeply jutting out into water and directed by extremity of the capes almost exactly to the West (fig. 1, *1, 2, 5)*.

Together with depictions of waterfowls, elks, ships, men, ets., the original symbolic images of disc-, crescent- and half-moon-shaped figures with one-two ray-like lines, directed to one aside are hacked on the rocks (fig.A3, 1*, 3, 6*;A3, 2, *A, B*). The figures were done extremity of the capes and the coastal small islands near the very water, where rocks are almost horizontal with the straight slopes and the smooth surface. The images have been made by hacking the rock surface with stone tools. The pictures belonged to the population of Pit-Comb Ceramic Culture of the Neolithic-Eneolithic Epoch dated by period from the end of V-th millennium to the middle of III-rd millennium BC (Савватеев, 1970, p. 132; Ошибкина, 1996, p. 215, 218).

During 160 years of the Onega Lake rock carvings study, different versions of the purpose and sense of those unusual shaped figures were proposed. The basic discussion was developed between two researchers and their supporters, which occured during more than 70 years. A.M. Linevskiy determined these figures as traps, similarly to the snares of the Permian hunters. V.I. Ravdonikas considered the signs as cosmic solar and lunar symbols. Similarly to the Egyptian hieroglyphs, he regarded those pair lines as Sun and Moon rays (Равдоникас В.И., 1936, p. 28; 1937, p. 12, fig. 2). Let us note that only one researcher - Ф.В. Равдоникас – has considered the Onega symbolic figures in the context of their astronomical orientation. He concluded that the figures fixed a complete Lunar 18.6-year's cycle and that the complex of figures with rays was a lunar calendar (Равдоникас, 1978, p. 129, 130).

Fig. A3.1. The Onega Lake' sanctuary

1 –view on Peri Nose V, VI capes from northwest; 2 – sunset on Besov Nos cape;
3 – petroglyphs of Peri Nos VI cape; 4 – Moon path on the lake surface; 5 – extremity of the Besov Nos cape; 6 – petroglyphs of Peri Nos III cape, the Hermitage' exposition.
1, 4, 5 – Vologodskaya obl - Karelia 2007.
http://lh3.ggpht.com/_A6h_kNdgKGc/R13JRee4gwI/AAAAAAAAASs/adzD_AAJTDg/29.JPG); 2 - Таганова Е., Хапаева С. Бесов Нос, Онежское озеро, июль-август 2003 года. http://www.skitalets.ru/photogallery/besovnos_tagan2003/index.htm; 3, 6 – Жульников, 2006, fig. 18; cover sheet.

In recent years, the majority of investigators interpreted them as signs symbolizing the Sun and the Moon (Савватеев, 1983, p. 94, 95; Poikalainen, 2004, p. 18, 19, 43, 44, fig. 18; Жульников, 2006, p. 62, 64). However, there is no yet clear evidence of these assertions. Also, there is no certainty about the meaning of lines starting at one side of these images.

In this paper we analyze the above figures in a complex manner using the archaeo-astronomical methods. All the graphical, cultural, chronological, natural, geographic, topographic and astronomical features of the symbolic figures of the Onega Sanctuary were taken into account. The main focus of the article is placed on the interrelation between orientation function of the figures, peculiarities of their forms, as well as on azimuthal meanings, calculated on the basis of the directions of rays-like parts of the signs. The symbolical figures with beam lines were selected only from the publications well supplied with the documents which allow us to define quite precisely the form of figures, their possible orientation and topographical binding towards North (Равдоникас, 1936; Савватеев , 1970, 1970; 1983). The total amount of the analyzed symbolic figures is 62.

Astronomical peculiarities of the Onega Lake are caused by the low vertical rate of sunrises/sunsets and moonrises/moonsets. Therefore, the Sun and the Moon set and rise at the horizon occur much slower as compared to the Southern latitudes. In the respective timeframes, light of these luminaries is reflected from water surface of the giant lake with its faultlessly equal horizon (fig.A3,1,*2,4*). Most part of the lake is finely seen from the capes of the sanctuary jutting out into water area(for up to750 m).

The Sun and the Moon rising and setting azimuths for the monument location (61º40′ Northern latitude and 36º Eastern longitude) in the astronomically special days of year in the time of the Onega Sanctuary functioning (3500 yrs. B.C.) were calculated by means of the Red Shift computer program. The obtained results are presented in the Tables 1, 2). According to these data based on the calculated azimuths, a solar day on the Onega Lake site at the summer solstice was lasted about 20 hours. Because nights in these days were light, the rises and settings of the Sun and the Moon were difficult to observe and on the firmament. Only the brightest planets and no stars could be seen in the sky during these days. In turn, in the days of winter solstice the solar day length was approximately 4 hours (see Tab. 1).

The height of the high full Moon in the summer solstice days rose above the horizon for only a half-degree and actually was "rolling" on the horizon during a short time - within an hour. The low full Moon at this time was in the sky for approximately 6 hours (see Tab. 2).

In the winter solstice days, when the high full Moon is in extreme northern position, it moved practically without the moonset. The low full Moon also rose in these days above the horizon low and was shined up to 17-18 hours.

Here we advance the hypothesis that the Sun- and Moon-paths on the lake surface could serve as peculiar “astronomical instruments” and at the same time, as an exact natural marks of the points of sunrises (sunsets) and moonrises (moonsets) on the horizon for an observer at the lake coast, taking into consideration specific conditions of the Sanctuary location on the Onega Lake and peculiarities of the symbolic figures. One or two radial lines located on the solar and lunar signs, could signify the above mentioned paths and indirectly, the Sun and the Moon rising and setting azimuths. In such a case, they should be directed towards the side of the horizon opposite to the luminary, i.e. to an observer place on a coast of the lake. The main part of the figures represents the peculiar forms of the observed celestial bodies.

The rays of the rising (setting) Sun or Moon reflected not only on the water smooth surface, but also on a surface of smooth and humid coastal stones(fig.A3,1,*2,3,6*). The rays of luminaries marked to ancient observer’s different astronomical phenomenon. They hurried up to image the celestial luminary as they saw it and simultaneously, leaving behind its reference point. This may serve as a possible explanation of the fact noticed by researchers, namely that the petroglyphs were best visible in the early morning time during sunrise or in the late evening time during sunset.

Table 1

Azimuths of Sunrises and Sunsets in the Northern Hemisphere for the Geographic Latitude of the Onega Lake sanctuary Latitude 61º North in 3500 year B.C.

Season	Summer solstice		Winter solstice		Equinox	
Phenomenon	Rise	Set	Rise	Set	Rise	Set
Azimuth (expressed in round numbers)	33°	326°	148°	212°	90°	270°

Table 2

Azimuths of High and Low Moonsets and Moonrises in its North and South Positions for the Geographic Latitude 61° North in 3500 year B.P.

Outermost positions	High Moon				Low Moon					
Season	The Summer solstice (declination -29,22°)	The Winter solstice (declination +29,22°)	Spring and autumnal equinox (declination +5,15°)		The Summer solstice (declination -18,92°)		The Winter solstice (declination +18,92°)		Spring and autumnal equinox (declination 5,15°)	
Phenomenon	Rice and Set	No setting	Rise	Set	Rise	Set	Rise	Set	Rise	Set
Azimuth (expressed in round numbers)	Near the South point of horizon from≈172° to ≈188°	Touch upon the horizon at the North point from ≈352° to ≈8°	80°	280°	132°	227°	49°	311°	102°	258°

As far the low rate of rising (setting) of the Sun or the Moon concerned, their disks were not only slowly appeared or disappeared at the horizon but simultaneously also moved gradually along a line of the horizon towards one or other side. Respectively, a luminary glade reflecting of on the water surface moved simultaneously to an observer sitting on the coast. This is why the orientation toward rising (setting) of the observed celestial body was marked with the two lines corresponding to the directions of the light paths in either at the moment of the first rays of light and upper limb of the disk appearance, or at the moment of the observed full disk appearance at rising and vice versa, at setting (fig.A3, 2, *C*). This allows us to suppose that the figures with rays were drawn in order to fix the observed limits of the light path reflecting circumstantial direction and time of rises (settings) of the luminaries at the horizon.

borders of the light path reflecting conditional direction and time of luminaries setting (rising) at the horizon (Потемкина, 2008, p. 68; 2009, p. 240-242, fig. 8). There is a probability that the use of lunar and solar glades to determine azimuths of rises and sets of the main luminaries has led the mankind to the invention of a lighthouse. Nowadays there is such alighthouse on the Besov Nos Cape (fig.A3, 1, *5*).

The stated above opinion led the author to an idea to consider the single, pair and double ray-like lines on symbolical marks of Onega petroglyphs as conditional azimuths of the sunrises (sets) and the moonrises (sets) (Потемкина, 2008, p. 66; 2009, p. 236-241). However, the rays mark reference points of rising (setting) of the main celestial bodies at the horizon not as clearly as the segment points at the horizon, within the limits of appearance or disappearance of a visually observed star above the horizon line. Actual azimuth could be deduced from the intermediate position between two rays represented in figure (fig.A3,2, *C*).

To check the adduced hypothesis and to bring the results in its support, the correlation tables and diagrams of the various types of the study were composed. All marks under consideration were distributed on a conditional horizon according to their basic form and orientation. The data of the correlation tables generally confirm the author's basic hypothesis and prove the possibility to fix the azimuths of rise and set of the Moon and the Sun on horizon by lunar and solar paths with the help of unary and pair lines. Thus, the distribution of figures in respect to the North and of coastal line on the schemes of their arrangement on separate capes show that at 52 of 62 figures (84 %) the ray lines are directed towards the coast and follow its outlines (Потемкина, 2009, fig. 9; 10).

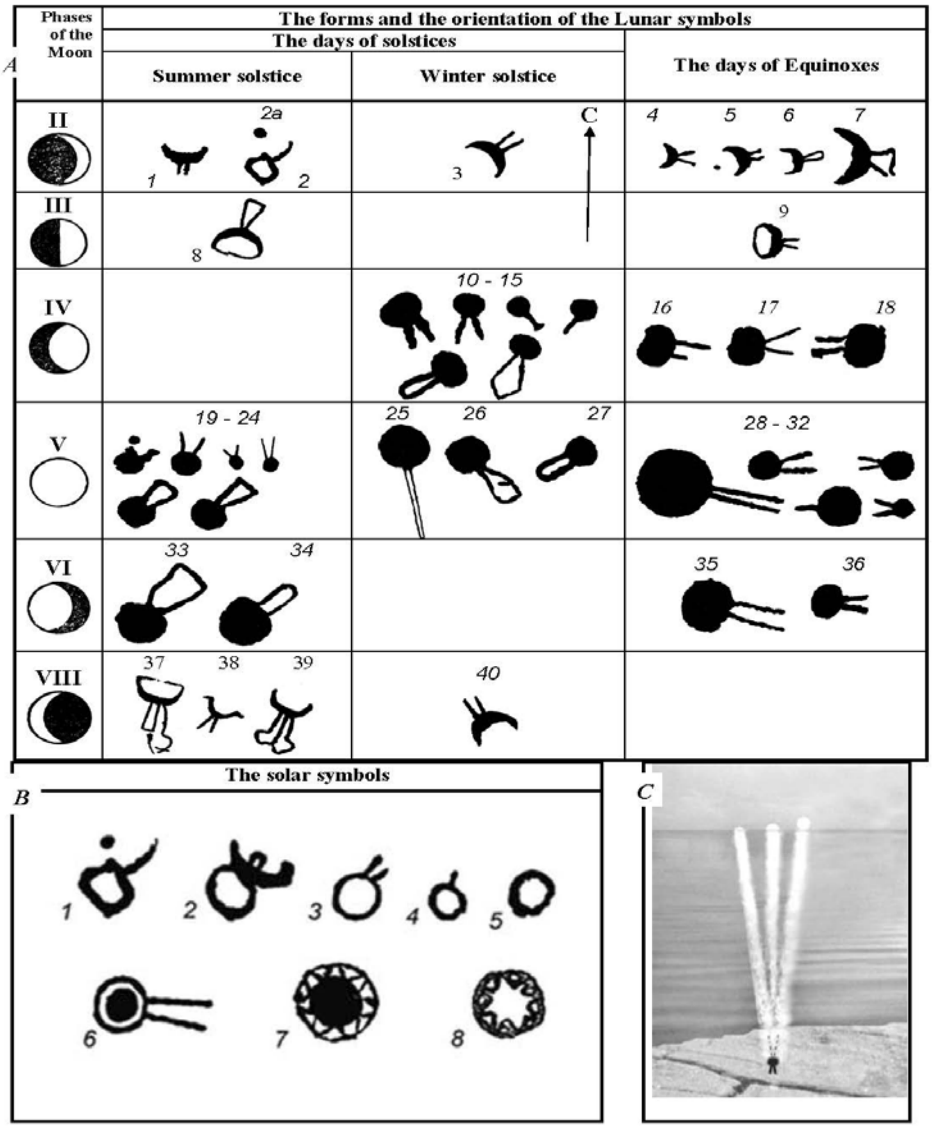

Fig.A3.2. Lunar and Solar symbols at Onega Lake' petroglyphs
A –Lunar symbols: 1, 26, 29, 30, 32, 40 – Peri Nos III; 2, 2a, 8, 15 17, 31, 33, 34, 36, 37, 39 – Karetsky Nos; 4-6, 7, 9, 10, 12 – 14, 18, 19, 20, 23, 24, 27, 28, 35 –Peri Nos VI; 3 – Gury Island; 11 – Besov Nos, northern cape; 21, 22, 25, 38 – Peri Nos III, the Hermitage' exposition. 1-40 – Равдоникас В.И., 1936, tables 1; 2; 4; 7; 8; 12; 16; 20; 21; 23; 37; Савватеев, 1970, fig. 106; 108; 1983, p. 101. Moon phases – Климишин, 1985, p. 34.
B – Solar symbols: 1, 2, 4 - Karetsky Nos ; 3, 7, 8 – Peri Nos III; 5, 6 - Peri Nos VI.
1, 3, 5, 6 – Равдоникас В.И., 1936, table 2, 16, 20; 2, 4, 7, 8 – Савватеев, 1983, p. 83, 101.
C – Scheme of the sunrise/sunset or full moonrise/moonset with reflection of illuminated glade on the water surface of lake and probable reproduction them in rock art images.

Besides, one may suppose that the figures with rays has fixed the

The diagram with the location of all the examined signs on the nominal horizon in accordance with their orientation shows that the azimuths values determined by the rays-like lines, in the most cases correspond or are close to the high and low full Moon azimuths in extreme northern and southern positions. The correspondence to notional solar azimuths is observed in isolated cases only (Потемкина, 2008,p.66,fig.1).

The correlation of the forms and orientation of the symbolic figures with the orientation of different Moon phases in various seasons demonstrates the connection of the examined carvings with the azimuths of the moonrises and moonsets in all visible phases in the days of equinoxes and solstices (fig.A3, 2, *A*).

Table 3

The correlation of figures representing the Moon in the various phases and seasons on the Onega Lake sanctuary

Phases of the Moon Season		Yang Moon, Set	Crescent	Full Moon		Old Moon Rise	Total	
				Rise	Set		Quantity	%
The summer solstice		1	-	2	9	3	15	24
The equinoxes		12	2	5	11	-	30	50
The winter Solstice		-	-	6	9	1	16	26
Total	Quantity	13	2	13	29	4	61	100
	%	21	3	21	49	6	100	100

The derived data prove that at the Onega sanctuary, the azimuths of the moonrises/moonsets in all visible phases and in all seasons of year are fixed (table 3). Among the symbolical figures taken in the sample, the images of the young Moon, half moon, full and old Moon are clearly distinguished. Almost all of them correspond to basic and intermediate Moon phases (fig.A3, 2, *A*). Most of the lunar signs (23 figures, i.e. 38%

of the investigated set) have reference points corresponding to the azimuths of young and full Moon settings at the days of equinoxes (table 3). Taking into consideration the weather conditions on Onega Lake that is covered with ice and thick snow since the middle or end of October through the middle or end of April, these should be days of autumn equinox and days close to it at the end of September - early October. Special contoured manner of performance of some of the 8 total depictions involving their orientation in particular collocation with the lunar signs allows us to assign them solar symbols (fig.A3, 2, *B*). Note that all the Moon signs are cut in the rocks as silhouettes. This hypothesis may be confirmed by peculiarities of the three images, fixing the rise of the old Moon and set of the new one during the summer solstice when the Moon is well seen near the Sun (fig.A3, 2, *B, 1, moon 2*).

At the depictions, crescent-like figures of young and old Moon carved like solid silhouette are adjacent to the circles shown with the contour. It is known that on the 28^{th}-29^{th} day of the cycle, just before its disappearance, the old Moon rises on East closely with the Sun, few hours or even several minutes before the sunrise. This is why the old half Moon is well seen on the sunrise. The elder and thinner the Moon, the closer to the Sun it rises and sets. (fig.A3, 2, *B, 2*).

In a single case, the circle depicted with the contour is adjacent to the young-Moon-setting-related crescent-like figure carved by the solid silhouette. Next to it, the small silhouette circle is placed (fig.A3, 2, *B, 1*). The figure most probably represents the situation of the young Moon being well seen on the 3^{rd} day at West close by the Sun just before and short time after the sunset. The small circle may be referred to the bright planet Venus that is well seen close to the young setting Moon and the setting Sun.

Figures with twin rays on the tips are of special interest (fig.A3, 1, *6*; 2, *A, 7, 8, 15, 25-27, 33, 34*). There are only 18 of such lunar signs (29% of all the signs under consideration). Orientation of these figures is equal or close to the azimuths of the high and low moonrise and moonset in extreme Northern and Southern positions (Потемкина, 2008, p. 66, fig. 1; 2009, p. 255-258, fig. 11). All the above mentioned testifies that the Neolithic Epoch population of the Onega Lake had the certain sign system where among significant set of symbols there were also astronomical reference points, based on the cosmogony notions.

There are also reasons to think that lunar and solar signs of a similar type have been the most ancient astrolabes. The majority of them pointed to the directions of rising and setting the luminaries at the horizon. Some figures marked relative position of the Sun and the Moon at the time of rising and setting in the astronomically significant days of year. The lunar symbols, compiling the overwhelming majority of the images of the luminaries on Onega Lake speaks in favor of an existing opinion that the change of phases of the Moon was the first astronomical phenomenon attracted the human beings attention (Климишин, 1985, with. 33, 34). One of the important reasons to observe the Moon phases during the Neolithic age might be connected to the existence of the lunar calendar, which is considered to be the earliest one.

Lunar calendar was very significant for the ancient people who inhabited shores of big water reservoirs. Such important natural phenomenon as tides and ebbs depend on the mutual position of the Moon, Earth and the Sun. They were especially important for ancient fishermen of Onega Lake. On the Earth surface the tides are caused mainly by Moon. They are also responsible for the floods of various strength occurring daily and every lunar month with 29.5 day interval. The highest event occurs when the Sun and Moon are located along one line and the Moon is full or new.

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A4. ARCHAEOASTRONOMCAL DATA OF THE SITES OF THE ISET` RIVER HEADSTREAM (URAL)

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The search for archaeoastronomical data in the source of Iset River can be reasonably started with reconstruction of the paleo-landscapes during the time of upper and middle Holocene.

1. The peculiarities of the ancient regional landscape.

Two basic factors of ancient landscape cab be assumed in order to determine the lifestyle and mythological (including cosmological) views of the ancient population in the region under investigation.

One factor might be associated with Iset River (Fig. A4.1, 1). After retreat of glacier border which was just in 300 km northward of the Iset headstream underwater channel formed within the system of overflowed lakes: Shitovskoje, Isetskoje, and paleolakes Romanovskoje and Verh-Isetskoje. Underwater channel were easily influenced by climatic changes and defined cycles of regressions and trans-regressions of the water line. Multiple augmentations (from 300 to 500%) of water surface of the overfilled lakes allow us to assume, based on cartographic reconstruction, that ancient tribes had followed water behaviour. Unlike inhabitants of the forest areas, people inhabited numerous islands and peninsulas had an opportunity to observe cycles of motions the celestial bodies within the scope of visible horizon.

Another factor is location of the lake system within Verh-Isetsky granite massif, which is one of the biggest in the northern part of Tagil-Magnitogorsky downfold. This massif extends in the meridional direction for about 100 km. Its tops run along the lake region from east to west. According to archaeological data, western flange has a number of sacral sites visible from the lake islands and peninsulas where astronomical observations have been possibly carried out.

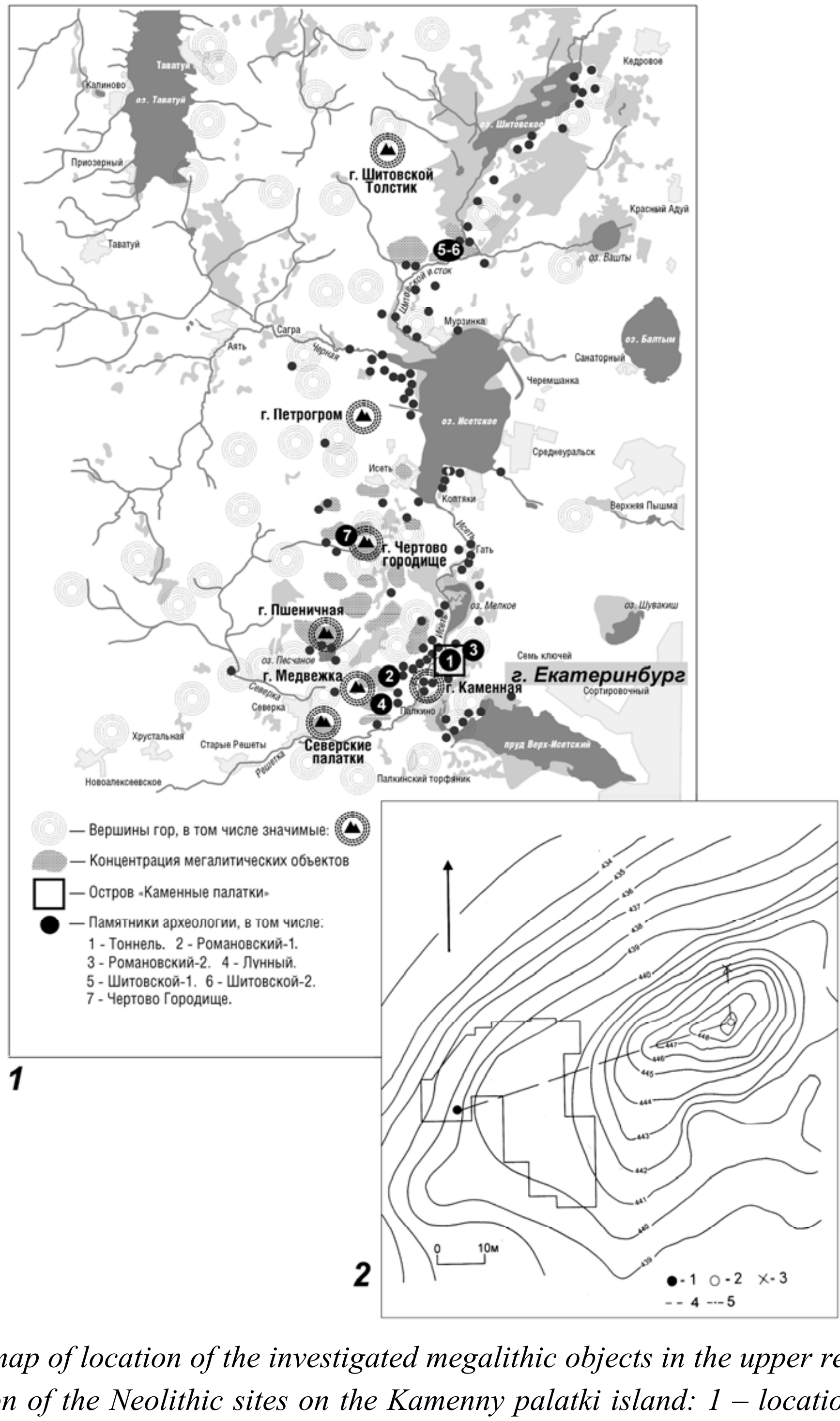

Fig. A4.11 – The map of location of the investigated megalithic objects in the upper reaches of Iset' river. 2 – Location of the Neolithic sites on the Kamenny palatki island: 1 – location of the altar stone in the sanctuary Palatki I; 2 – the bowl on the top of the ridge; 3 – the boulder with the sign, faceted as a ring crossed with diagonal; 4, 5 – lines joining the objects 1 to 3.

Certain experience of determining the visibility regions allow us to suppose the connection of these points with the following sites: Sem` Bratiev mountain top– Ayatskoje Lake; Shitovsky Tolstik mountain top – Shitovskoje Lake; Chertovo Gorodische and Petrogrom mountain tops – Isetskoje and Melkoje Lakes (the latter one joint with Romanovskoje paleolake); Pshenichnaja VI – Peschanoje Lake (Fig. A4.1, 1).

2. The characteristics of the ancient archaeastronomical objects of the region.

Since the XIX-th century, the Iset` headstream is well known as the region of high concentration of the numerous multi-phased archaeological sites. The thousands-years old empirical knowledge about the stellar sky, about the cycles of celestial motion of the Sun and the Moon was of great importance for set up of calendar cycles encompassing economy, household, and routine life. However, all presently known artifacts are regarded as bearing evidence of their relevance to the ancient consumption of astronomical phenomenae.

Kamennye palatki (Rocky tents) island located within the area of Ekaterinburg sity, and southern island of Romanovskoje paleolake, serve as examples. Recently, the north-western part of the island was thouroughly examined based on archaeological excavations during the last 32 years. The relics of various epochs have been discovered. The most important findings are discussed below.

Neolithic Age. There are some evidence that the passage through south-eastern and eastern coast of Caspian Sea via steppe and forest-steppe of the Urals to forest zone of the Trans-Urals and western Siberia was one of the possible direction of the ancient peasants migrations from Near east in the V-th millennium BC (Victorova, 2002, p. 84). The three objects of sacral complex found at the island were identified with Indo-European migrants.

One of the objects, the remains of sacral place, was found at the North-Western edge of the island (Fig. A4.1, 2). The excavation revealed the postholes near fire place, which formed a rectangular figure. Its long diagonal extended in the North-South direction, while the short one – in the West-East direction, with a small Northward declination.

The next object is the polished figure representing the bull horns of 1 m long. It was found at 60 m eastward of sacral place on a slightly slanting surface of western ridge (Fig. A4.2, 1). It is worth to note that this sign is well visible only at early sunrise hours.

Fig.4.2 The sanctuary meaning objects in the upper reaches of Iset river. 1 – horns' sign on the western ridge of the island; 2 – sign of a ring crossed with North-South diagonal; 3 – Western entrance into Romanovsky 2 dolmen; 4 – entrance to Northern portal of the tunnel near the base of Kamennye Palatki island; 5 – Eastern entrance into the Lunny ("Moon's") tunnel; 6 – menhir on the mountain slope of the Medvezhka pick.

The third objects of interest are the bowl found on the top of a ridge and a sign faceted as a ring crossed with diagonal. A sign is located on the horizontal surface of the boulder, 5 m below its top and close to water line (Fig. A4.2, 2). It is worth to stress the point that boulder with a sign was found in 16 m Northwards from bowl in the South-North direction, and diagonal of the sign coincides with the line pointing to South-North as well.

Eneolithic Age. The sacral complex of Eneolithic Ayatskaja culture was discovered in the Eastern and South-Eastern part at the North-Western edge of the island. It consists of two objects. The first one is the megalithic elk's head-shaped figure which was found at the western ridge. This figure is separated from a gibber and is turned for 45 degrees, so that its "eye" is oriented South to the sacral buildings located 22 m from the sculpture.

The two signs situated on each side of the rock with a bowl atop may be identified as relevant to lunar observations. The sign on the North-Eastern side of a rock is made with splits as a bow-looking image and looks like a sickle Moon. The sign recorded near the South-Western side of the rock looks as a half disk of a decrescent Moon. These objects have not been yet dated.

Most recently the Iset headstreams megalithic monuments dated back to the Eneolithic epoch and addressed as archaeoastronomical objects were found and partially studied. Until the beginning of XXI-th century, the megaliths of V-III millennia BC were known only in the three areas of Eurasia: Western Europe, Northern Caucasus and Southern Korea. Nowadays about few tens of the megaliths invoving dolmens, tunnels and menhirs were discovered over the forest-mountain zone of the Trans-Urals. They are of natural-anthropogenic and anthropogenic origin, and appreciably different from Western European, Northern Caucasian and Southern Korean megaliths.

Dolmens. The dolmens represent massive granite structure made of gibbers and stone plates. In the upper reaches of Iset` river, the 5 boulder dolmens were found, two of them were excavated.

Their general features are as follows. They are located at the slopes of rocks, the entrance into a chamber is of 1.2-1.5 m height, West- or North-North-West-oriented. Chambers are rectangular- or triangular-shaped, having length of 1.5-2 m. In front of dolmens, there were recorded deliberately mounded grounds of 9 to 12 square meters long. Their horizontal surface was supported with massive boulders. Inside chambers and within grounds traces of continual sacrifices were recorded: fire place evidence, pieces of ochre, Neolithic (Romanovsky I dolmen) and Eneolithic (Shitovsky 6 dolmen) pottery shards, tools, assemblages of granite artifacts made in form of birds' and/or animals' heads and figures.

Romanovsky 2 dolmen is extremely remarkable (Fig. A4.2,3). Megalithic figure of elk's head was found on the Northern side from its entrance. From occipital side it is supported by menhir, which was deeply dug into the ground. Another menhir was recorded in front of the small (0.5 m) destroyed stone chamber (tunnel?), which was located downwards of the deliberately mounded ground. Chamber is of 1 m depth, though further part was destroyed. All mentioned objects contained assemblages of granite figurines.

Radiocarbon analyses of the charcoals sampled from fire places and grounds provide us with the following datings: Shitovsky 6 dolmen – 4200±210 (SO RAN – 7629), Romanovsky 2 dolmen – 4200±85 (SO RAN – 7443). When incorporating these records with the discovered Neolithic and Eneolithic ceramics, one may conclude that those dolmens are dated in the range of IV-III millennia BC.

Tunnels. There are five known tunnels over the region under consideration, two sites of them being studied with excavations.

One of the investigated tunnels is that of natural-anthropogenic origin located near the Western slope of the island Kamennye Palatki having length of 10 m (Fig. A4.2, 4). It is North-South-oriented, with a small North-Westward declination. Its Northern portal is well-preserved. In the Eastern side of the portal, there is a megalithic figurine of bear's head fixed up on 5 stones. In the center of tunnel there is a second Westward-oriented entrance. Utilization of the Northern and Western directions are most probably not occasional. Inside the tunnel, there is a fissure, perhaps of tectonic origin. According to mythology of Eurasian population, fissure means passage to the Down space. It is worth to notice that at the Western edge of the island, exactly above the tunnel, there is Eneolithic cemetery of the Lipchinskaja culture of the IV-III millennia BC. It might be possible, that triple sacrifices near a bear's head are associated with that cemetery. There are fragments of three ceramic vessels of Lipchinskaja culture found there, and the remains of forest bird is in support of this hypothesis. Close to Western entrance to the tunnel, there are traces of another population of Ayatskaja culture which have performed rituals. The discovered collection consists of pottery shards, pieces of ochre, stone tools.

The second tunnel, named "Lunny" ("Moon's") tunnel, also of natural-anthropogenic origin, is oriented in the West-East direction. Its covering construction is 1.8-2 m in size, Eastern side of which being elk`s head-shaped. There is the sign of decrescent Moon with no less than ten cuts over its diameter (Fig. A4.2, 5). V.N. Chernetsov (Chernetsov, 1964, p. 31) suggested that very similar cuts made on Uralian rock painting sites could be associated with a number of performed rituals. However, together with the picture looking like the decrescent Moon sign, those cuts could imply the number of days of a certain time interval connected with certain lunar phases observed visually on the tunnel's ground.

Mounds of the recorded grounds along both entrances are bordered by massive boulders. Remains of ritual performances were traced as burnt sand, charcoals, and assemblages of granite images of animals' and birds' heads. Radiocarbon age of the relic is 3975±80 (SO RAN-7444).

Menhirs are the upstanding rocks with parallel facets and constricted round-shaped top having various height (from 0.7 to 2 m). They also differ in chronology, function and direction of narrow facets.

The earliest menhirs are the three monuments from Romanovsky dolmen. One of them has preserved in the upstanding position because it was deeply dug into the ground. Its narrow facets are oriented in the East-West direction. It could be possible to date it as Eneolithic menhir, the monument found on slope of the pick of Medvezhka mountain, where rock-painting and tunnel were observed. Near the menhir base (Fig. A4. 2, 6), granite figurines near the roots of a fallen tree have been recovered, analogous those recorded on the dolmen ground.

Two menhir rocks were found at the Kamenny Palatki island, close to North-West and South-East sides of Bronze Age stone quarry. The direction of narrow facets of the stones is East-West. One may assume that some fire rituall s were performed nearby menhirs.

The last group of menhirs is a part of the necropolis of nomadic population, which is dated back to the edge of that era. Two menhirs were recorded near the base of stone boxes, the direction of narrow facets of those stones being different. Menhirs found in the kurgans of Sem` Bratiev (Seven Brothers) mountains and at the extrems of the Shitovsky Lake peninsula are possibly belonged to the same time.

In conclusion, we may argue that population of the upper streams of Iset river in the Neolithic period, the migrants from the Near East, knew how to choose directions on Earth and properly oriented themselves. In mythology of that population the two sides directed South and East had special meaning. One can suppose that Southern direction was of special importance because the South was the place of the migrants` exodus. The Eastern direction might be associated with following ritual: During sunrise the sign of the heavens (Upper space), the bull/male goat horns, were well-visible (Antonova, 1984, pp. 84-85), and during the performed ceremony on the sacral ground there were joy fire and sacrifices dedicated to the rising orb.

During the Eneolithic period the population of Ayatskaja culture kept priority of the Southern orientation on the sacral complexes. It is necessary to add that such a tradition was a very typical for majority of the Urals rock painting sites – the images were drawn on Southward cliffs (Chernetsov, 1971, p. 83). Northern and Western orientation of the tunnel entrances might be most likely interpreted as caused by mythological views of the underground (Down space) where there is no Sun and where their deceased tribesmen had gone.

In the examined area, the beginning of the exploitation of the natural objects for ritual performances, possibly scheduled to match significant astronomical events, started as long ago as the period of Neolithic Age. The population used small tunnels and dolmen-looking rocky hollows. On the turn of the IV-III-th millennia BC – in the Eneolithic period – the natural anthropogenic dolmens and tunnels appeared, with follow up construction of artificial objects. As it was noticed, the most often were Western and Northern orientations of entrances of the main two groups of megalithic monuments. Probably, likewise Western European and Northern Caucasian megaliths, they had grave or memorial functions.

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A5. TO THE ESTABLISHMENT OF ASTRONOMY AND CALENDARISTICS IN ANCIENT CULTURES OF NORTH ASIA (Western Siberia, Khakasia)

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Untill recently, people thoughts about the history of astronomy was rooted in the time when the first gleams of man's interest to the sky, celestial bodies, and the course of time appeared in the ancient cultures. It was mostly related to those places of the Old World where such a curiosity came earlier than somewhere else. Apparently, the events which happened in the heavens first attracted attention of the population living in the IV-th - III-d millennia B.C. in the littoral Mediterranean regions, the cradle of urban agricultural civilizations of Northern Africa, Southern Europe and the Near East, as well as on the territory of Southern and Eastern boundary areas – India and China (Idelson, 1975). However, such ideas are now questioned because of deciphering the calendar-astronomical texts, particularly those dated from the paleolithic time, the most ancient calendar documents in the cultures of early homo sapiens of Eurasia being traced to the 30-th – 35-th millennia from now (Marshack, 1970; 1991; Larichev, 1993; 2009). Also, some objects connected with observations of rises and settings of the celestial bodies (the Sun, the Moon, and planets) Northward of the zones of protocivilizations formation were discovered (Ларичев, 2009). It seems that contribution of the so-called «noncivilized peoples» of Northern Europe, Central and Northern Asia into mastering of the natural and scientific knowledge was erroneously underestimated when considering them as episodical and highly delayed adoptions from the «civilized peoples».

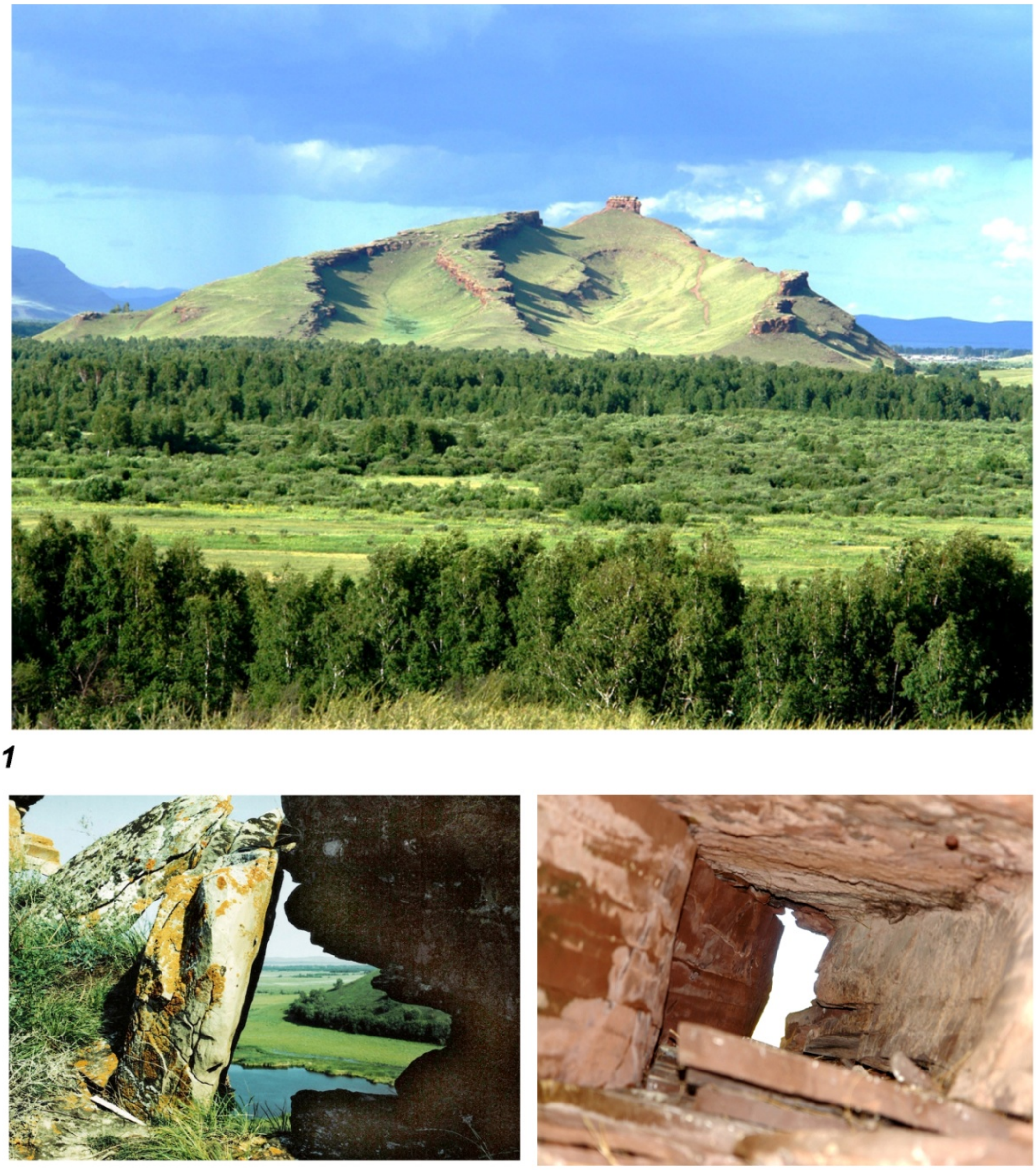

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Fig.A 5.1 The mountain "Sunduk" and "windows" for observations of the Sun and stars.
1 - The First Sunduk, western slope of the mountain with canyons and crests. Astronomical «observatories» and astrosanctuaries are connected with them. The view from West to East.
2 - Astrocomplex «equinoctial» «Window». The sunrise in the day of vernal equinox was observed via this Window. 3 - The «Window» of observation of Arcturus.

The error of the historians of astronomy of the middle of last century using arithmetic and geometry is evident because when dealing with solution of historiographic problems they enlisted only written testimonies, whereas other sources, including astronomical constants of archaeological objects, were not included into account through incomprehensible reasons (Neugebauer, 1968; Van der Waerden 1991). Meanwhile, the positive (in the natural and scientific sense) views of the Nature inherent to ancient inhabitants of Northern Eurasia, as well as the results of their spiritual and intellectual strivings, turned out to be concealed. This concerns the information contexts both of separate specimens of material culture, mobile art objects and various complexes of complicated structures connected with tribal life, production and economical, cult and ritual customs, as well as religious activities, including sanctuaries with rock-drawings, sepulchral fields with vertical gravestones placed above tombs, monumental funeral constructions of tribal chiefs, and so on (Potemkina, 2009; Marsadolov, 2009; Larichev Gienko, Parshikov, Prokopiev, Serkin, 2009).

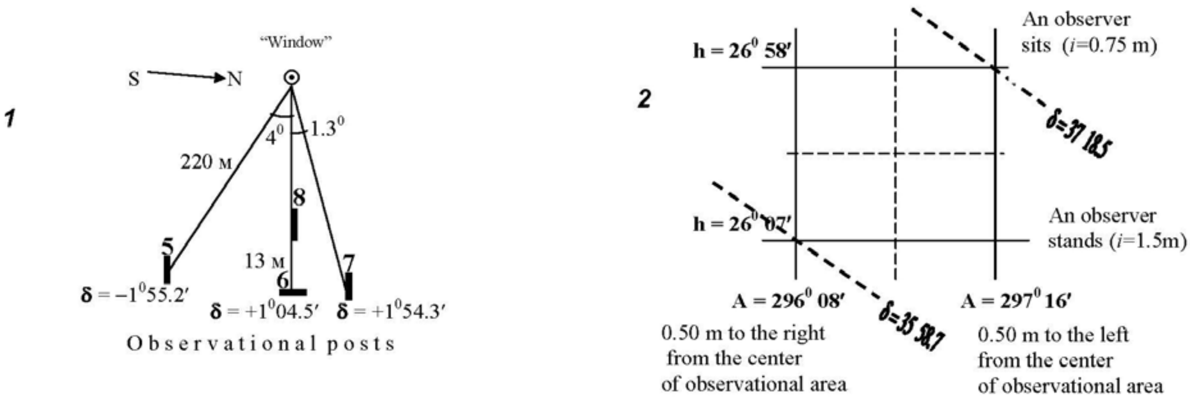

Fig. A5.2 Schemes obtained from geodetic measures and astronomical computations. 1 - a scheme of disposition of grounds (№№ 5-8) of the astrocomplex of observations of sunrises in the days of equinoxes; 2 - a scheme of the utmost values of horizontal coordinates and declinations depending on observer's disposition.

A great number of the enumerated objects have been discovered in Siberia (in particular, in the Altai region), as well as in the North part of Khakasia, in the Belyy Iyus Valley (the White Iyus River) of the Kuznetsk Alatau (mountain ridge «Sunduki»). Relics of the past of the region south of North Asia became the objects of the long-term study for a number of astroarchaeological field trips of the Institute of Archaeology and Ethnography of the Siberian Branch of the Russian Academy of Sciences

(Novosibirsk). Permanent members of the team headed by archaeologist of the Institute, were the researchers of the Siberian State Geodesic Academy.

Astrocomplexes related to the Sun observations, which were constructed in the Southern canyon of the First Sunduk in the Bronze Epoch in the II-nd millennium B.C. are represented in Fig. A5, 1. The astrocomplex of sunrise observations are connected with the days of vernal and autumnal equinoxes. This is why the constructed observatory consisted of two structures:

1) the «Window» restricted by two slabs which were set vertically and obliquely; in space of the «Window» the morning Sun at the beginning of astronomical spring and autumn appeared (Fig. A5, 2); the slabs were placed in an opening of the rocky crest which outlined canyon from the South;

2) four observation grounds distinctly designated by 5-8 slabs placed opposite the «Window» on a slope of the rocky crest which outlined canyon from the North (Fig. A5.2,1). The angular dimensions of the «Window» when observed from the different grounds, varied from 10' to 35', the grounds being placed at 220 m apart from the «Window».

The angle measurements carried out from the grounds allowed ancient people to calculate declinations of the daily parallels passing through the «Window». When observations were carried out from the grounds №№ 5 and 7, the declinations of the daily parallels passing through the «Window» were practically symmetrical relative to zero position (Fig. A5.2,1). Hence it follows that these grounds restricted the «equinoctial period» – the time when the Sun crossed the celestial equator. Taking into consideration the values of declinations, we can calculate that observations of the Sun's passing through the «Window» from two grounds were separated by approximately 10 days (Fig. A5.2,1). During this deliberately time stretched «equinoctial period» one could observe the sunrise in the «Window», being between the grounds №№ 5 and 7. That was especially important with the account for weather factors.

The grounds №№ 6 and 8 were placed on a straight line, in range, with the «Window» (Fig. A5.2,1). Therefore, we can suppose that ground № 8 fixed the direction onto the object of observation from the ground № 6 – onto the equinoctial «Window» (this ground is placed asymmetrically relative to the other two). From the astronomical point of view, asymmetrical disposition of the ground № 6 can be explained as follows: the moments of observation of the Sun passing through the «Window» could correspond to the midpoint date between the winter and summer solstices. As it is well known, because of uneven Earth's orbital motion, the duration of astronomical seasons' turns out to be unequal: the vernal equinox comes approximately two days earlier than the midpoint between two solstices and the autumnal one occurs roughly two days later than the midpoint. It must be equal to nearly 48' at the day corresponding to the midpoint between solstices taking into account the rate of change of the Sun's declination at the period of equinox,. Declination of daily parallel passing through the «Window» when observing from the ground № 6, had an angle of measurements equal to 64'. Therefore, an accuracy of determining the middle of seasons during the year has been accomplished by priests of the Bronze Age within 1 day!

As we see, observation of equinoxes involves considerable difficulties. Priests got over them not only by the use of compound system of observation grounds placed opposite the «Window» in opening in the southern crest. The problem was solved by means of creation of another two posts within the borders of the same canyon, in order to carry out observations not only rises but also settings of the celestial bodies. These posts are briefly discussed below.

The astrocomplex conducted observation of morning rise of the Arcturus Star, «the Northern Sirius» (the Constellation Boötes). For this purpose the complex was composed of two structures:

1) the observation ground placed on a slope of the foot in the Northern crest of the canyon;

2) the «Window» which represented an opening in the upper part of the rocky crest deliberately put into shape of subrectangular (Fig. A5.1,3). This «Window» was limited by restricted territory from which neither the Sun nor the Moon could be observed. The angular dimensions of the «Window» were smaller than diameters of these two celestial bodies, thus the basic idea was to adjust the construction applicable to observations of certain especially bright star came into being. In search for the most suitable star, the utmost values of declinations of daily parallels, taking into account inexact knowledge of observer's position, were calculated. In Fig. A5.2,2, the utmost values of heights h and azimuths A of directions onto the «Window» are shown, as well as the daily parallels restricting the possible values of declinations δ: $35°58.7' \leq \delta \leq 37°18.5'$.

With the use of astronomical program REDSHIFT 3.0, positions of several bright stars of the northern sky in different epochs were modeled. The brightest of them is Arcturus of the Boötes Constellation, which turned out to be the most suitable. The date of the first passage of Arcturus onto the «Window» before the sunrise in the day of the vernal equinox, was determined. The results came to the conclusion that in the year 1500 B.C. the vernal equinox was observed from the 3-d to the 4-th April. In that day, Arcturus was observed in the «Window» 15 minutes before the sunrise.

The information stated above allows us to trace the sequence of priests' actions in the days of expectation of the vernal equinox: in the first morning of Arcturus appearance in the «Window», after such event had been fixed, they came down the slope in haste to occupy the place on the grounds of observation of the sunrise in the equinoctial «Window» of the Southern crest. In the latter, in 15 minutes after the appearance of Arcturus in the morning sky, the Sun's disk appeared, signifying the approach of the vernal astronomical season.

1 2

Fig.A 5.3 Fotos of the sunrise and sunset in the day of summer solstice. 1 - zone of the sunset in the days of summer solstice (the Sun sets under the base of the inclined slab placed above a sanctuary - a part of the astrocomplex «Oval);.2 - atrocomplex «Aperture» where sunrise was observed in the days of summer solstice in the rocky «window opening».

The astrocomplexes were well fitted to observation of sunrises in the days of winter and summer solstices and sunsets in the days of equinoxes. Observations of sunrises in equinoxes were compared and corrected by observation of the moments of sunrises in the days of summer and winter solstices in the same canyon, as well as sunsets in the days of summer solstice and equinoxes. For these purposes astrocomplexes were settled within the limits of the Northern crest (Fig. A5.3, 1, 2). These objects support an idea that priests knew the medium date between the winter and summer solstices caused by variations of the Earth’s movement in its orbit (Ларичев, Гиенко, Шептунов, Комиссаров, Серкин, 2006; Ларичев, Гиенко, Прокопьева, 2007). As it was already mentioned, this circumstance determines unequal duration of the astronomical seasons.

Astrocomplexes of the First Sunduk indicate the high level of observational astronomy and calendaristics of the priesthood of the Paleometal Epoch (the middle of the II-nd millennium B.C.). Its representatives could have fixed precisely the moments of equinoxes and solstices, they knew unequalness of periods from vernal equinox to the autumnal one and from autumnal equinox to the vernal one, as well as the length of cycles from winter to summer solstice, and vice versa. Moreover, they watched the moments of disappearance and appearance of stars in the dome of the sky. The knowledge of circles of rotation of celestial bodies formed the main source for astral religion and protoscientific ideas about the Nature that nomadic peoples of the mountain and steppe zone of the South of Siberia have pursued.

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A6. ARCHAEOASTRONOMICAL ASPECTS OF THE GREAT SALBYK BARROW IN SIBERIA

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Introduction

The Great Salbyk barrow is the best known of the megalithic monuments in Siberia. The barrow is situated 65 km northward of the town of Abakan in Khakasia (Russia). Co-ordinates of the monument are as follows: 53º53'4" of Northern latitude and 90º45'1" Eastern longitude, and the height above the sea level is 540 m. There are more than 50 big and middle-sized barrows, as well as many small ones. Archaeologist S.V. Kiselev excavated the Salbyk barrow in 1954-56 (Kiselev, 1956).

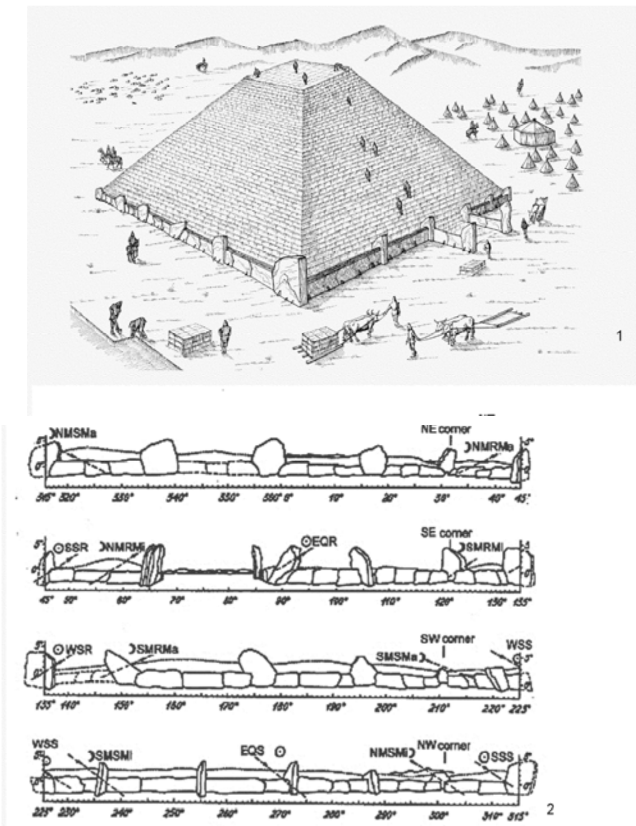

Fig. A6.1. The Great Salbyk barrow

Expedition of the State Hermitage Museum investigated the Salbyk valley in 1992, 1994, 1996, 1998 and 2008 (Marsadolov, 1993; 2007). The expedition re-composed plan of the fence of stone slabs, took samples for the tree-ring and radiocarbon analysis, conducted the astronomical and topographical analyses, and traced connection of the barrow with the surrounding landscape.

The barrow height is more than 20 m, and originally it was pyramid-shaped (Fig. A6.1, 1). Under the mound, a square “fence” (71 x 71 metres) made of huge stone slabs placed vertically and horizontally and weighting several tonnes each was discovered. The size of largest slabs was up to 5 meters.

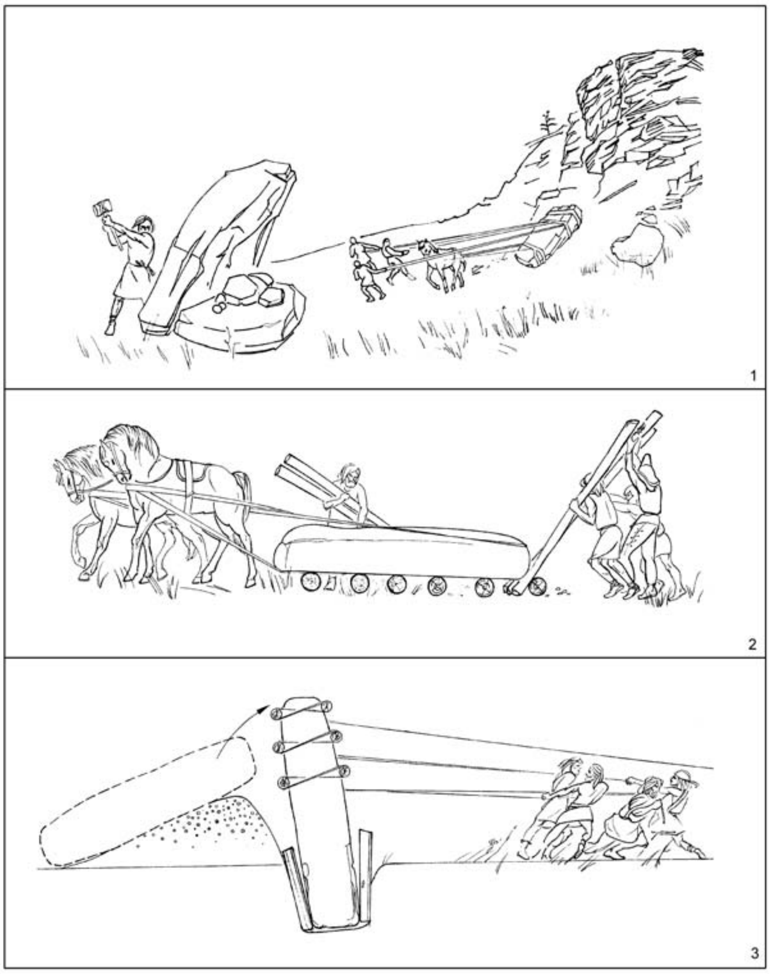

Fig A6.2 Salbyk

Inside the fence, a square pit-grave had been dug, and seven persons buried in timber on its bottom were found. It seems probable that the chief of an alliance of tribes and his favourites were buried in the grave. The construction of big barrows in Salbyk probably was based on the astronomical knowledge of that time. The installation of the fence slabs was connected with the main positions of the Moon and the Sun rising and setting in the astronomically significant days. On the basis of the new analyses, the barrow is dated to the 5-th century BC.

Construction of the barrow

The process of building the great barrow in Salbyk, which is very complex due to its construction and the burial ritual, can be reconstructed in the following way. Probably the construction of this monument took more than one year. Hundreds people participated in building of the burial monument temple.

In the mountain valley, a point for the barrow centre was chosen very carefully. The point had to satisfy certain requirements:

1) It had to be on the highest place between mountains;

2) It had to be surrounded by mountains lower to the West and East than to the North and South;

3) It had to be conveniently situated for astronomical observations.

It should be mentioned that such a place had probably been found in an earlier period, and its significance maintained in later epochs. Near the Great Salbyk barrow, there is the Bronze Age ritual centre with stone sculpture of the Okunevskaya (XVIII-th – XVII-th centuries B.C.) culture, sites of the Early Tagar period (VII-th – VI-th centuries B.C.), etc. After construction of the Salbyk barrow, the cemetery of the Tashtyk (III-th –V-th centuries A.C.) culture located near by continued to function for a long time.

The burial construction consisted of three parts: a corridor (dromos), an extension near a door, and a burial chamber. In the central part of the barrow, but closer to the western wall of the fence, a structure consisting of earth and logs of larch was found. It looked like a reduced pyramid; its height was about 2 m and its upper platform was 8 x 8 m (Kiselev, 1956;

Devlet, 1976). The pyramid was at the first sight snow white because its slopes were covered with a thick layer of birch bark (sometimes up to 15 layers). In addition, the upper logs of larch were rolled up in birch bark. Thus, a larch seemed to be a birch.

Under the pyramid, there was a square pit of 5 x 5 m width and 1.8 m depth. Its walls were lined up with vertical logs. In the bottom of the pit there was a wooden framework with 4 rows of larch logs cut like bars. The chamber was 4 x 4 m; its height was about 2 m. It was covered by six rows of massive logs with a thick layer of birch bark. The bottom of the framework and the space between its walls and the logs covering the pit's walls were full of solid red, water-resistant clay. S.V. Kiselev established that the bottom was covered with birch bark under the clay. Six layers of crossed logs formed a roof under the framework, but they could not withstand the great pressure of the earth and had fallen into the chamber.

In the chamber, the remnants of seven persons were found, men and women. An old warrior was buried in the centre, some of whose bones were broken. A large clay vessel was found in fragments. Near the middle part of the western wall of the framework, on the bottom, a miniature bronze knife was also found.

The dromos began with an entrance near the middle stele of the western wall of the fence and went close to the western slope of the pyramid. There was a narrow hole into the chamber, which appeared to be filled with pieces of wood. The walls of the corridor (its width up to 2-3 m) were covered with logs, and the upper parts of these were covered with a thin ceiling made of hewn planks. Both walls and the corridor's ceiling were decorated with a layer of birch bark.

The fence was made of massive blocks of sandstone placed in a standing position; the largest of those weigh about 30 tonnes. The fence's blocks were put in narrow deep trenches, their width being less than 0.6 m. The depth of the trenches varied from 0.8 to 2 m, depending on the height of the blocks, which were placed in such way that they were on about the same level above ground, with heights of 1.8 to 2 m. The entrance from the barrow’s eastern side was rather complex. From the two middle steles, the long slabs were perpendicular to the line of the wall, resting on two steles placed towards to the east of 5 m. From the eastern side, “the entrance” between the steles was covered with a roof of small slabs placed very carefully, with a small deviation inside the barrow.

During clearing of the western wall, the remnants of the mainly destroyed burials of two persons were found in the SW and NE angles. In the process of studying the fence, near the large stele in south-eastern angle, the destroyed burial of a child was found. In the angle formed by the Southern and Western fence walls, the burial of an adult man with tied, bent legs was discovered. These were probably sacrifices that had been made in the most significant places of the barrow.

The transportation of blocks for the fence must have been very hard work. The barrow was erected in the steppe valley and the nearest deposits of Devonian sandstone are situated on the Kyzyl-Khaya Mountain, 16 km South-Westward from it (Fig. A6.2). The remnants of ancient quarries were found there. The blocks were quarried from the rock, probably with the assistance of wooden wedges, and were transported to the place of the barrow construction, perhaps in winter on wooden rollers (Fig. A6.2). During the clearing of the barrow’s lower part, many larch logs, often dry from forest fires, were discovered. The logs had been moved by ropes, judging from marks on their ends.

Astronomical aspects

Preliminary results of astronomical researches are submitted below by the author and the astronomers V.L. Gorshkov and V.B. Kaptsjug of the Pulkovo Observatory, St. Petersburg.

Astronomical observations had been probably carried out there before the construction of the stone fence. The installation of the fence slabs is connected with the main positions of the rising and setting of the

Moon and Sun on astronomically significant days (Fig. A6.1, 2). Signs in the form of circles, crescents and other figures were discovered on the barrow's slabs. The investigation revealed that the solar directions were connected with vertical stone slabs, the moon directions – with corners of a barrow, but the entrance was oriented on sunrise in the days of equinox.

On one of the slabs from the barrow, a complicated composition is drawn. In the higher part of the slab the sky is represented: a bird, the Sun, stars, a person with vizier in his hand. In the middle part of the slab, a male warrior stands with a foot on the head of a fallen person, nearby is a Moon-woman and also a man. In the lower part of the slab, there are unclear figures of perhaps a horse and a beast. It is possible that on this slab the sequence of the funeral ritual is represented, which corresponds to the archaeological material from the excavations.

In Salbyk valley, some of great barrows have “chains” of vertically standing slabs as well as horizontally placed “slab-altars” near the mound. Outside the barrow, vertical stones of intermediate size were found, aligned to astronomically significant directions. A sculptural representation of a lying tiger was also found. The detailed study of the stone slabs of the fence of Great Barrow revealed the significance of a colour spectrum to the builders — it changes gradually from light to dark tones and conversely.

The “chain” of barrows in the Salbyk burial valley is oriented on a line Northwest to Southeast, the line of the extreme positions for moonrise and moonset. The location of barrows in Salbyk is principally distinguished from the orientation of barrows behind the Saian range. Near the Arzhan settlement in Tuva, the great barrows (6th-5th centuries BC) were erected on a line north-east to south-west and oriented to the Sun — to the high point of sunrise on the day of the summer solstice and the low point of sunset on the day of the winter solstice. Thereby, the orientation of the barrow's chains serves the important additional (religious) criterion for two earlier-chosen large areas of the archaeological sites.

Conclusions

The construction of big barrows in Salbyk having multiple functions (funeral, socio-political, religious, astronomical, architectural, and others) probably was based on the astronomical knowledge of that time. The Great Salbyk barrow, by its monumental construction, can be put in the same group as the famous Stonehenge in England, but by the volume of consumed labour, it probably even significantly exceeds Stonehenge.

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A7. NOVOKONDUROVSKY – 1 KURGAN 'WITH MOUSTACHES' AS THE KEEPER OF TIME AND RITUAL

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Novokondurovsky-I kurgan complex is located on the left bank of the river Big Karaganka, 4 kms to the NE of the Northern outskirt of village Novokondurovka, Kizil district of Chelyabinsk region and 0.5-1.25 km to the SE-ESE of the characteristic threefold bend of the river (φ = 52º37' N, λ = 59º28' E) in the central part of the valley stretching along the left bank to the SW. To the East of the kurgan complex at a distance of 1 km these are two barrows on the peak of a hill (386.2 m). One of them dates from the epoch of the early Iron Age, the other destroyed one is to be expediently dated from the epoch of late nomads of the Middle Ages.

Archaeological excavations headed by I. Lyubchansky were done in field seasons of 2002-2003 (Liubchanski, 2007). The Novokondurovsky-I kurgan with stone ranges - "moustaches" is a complex architectural composition consisting of the central embankment 12 m in diameter, and two "moustaches" - curved stone ranges (fig. A7.1). The site stretches to the East, however the principal axis of the "moustaches" is 14 deg declined from the Eastern direction to the South. According to archaeological data, the central stone embankment was in the form of a hexagon. Northern and southern moustaches are 236 and 216 m long (fig. A7.2). The both "moustaches" end in stone grounds. These are no distinctive grounds at the begining of ranges.

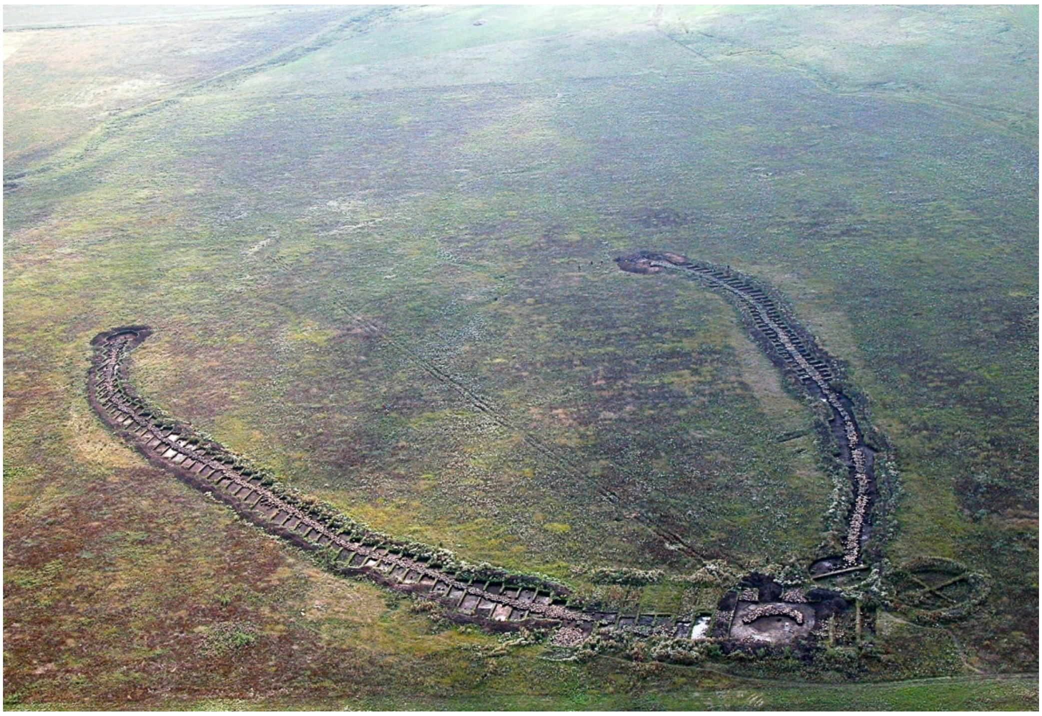

Fig A7.1 The Novokondurovsky-I kurgan

Stone ranges of the kurgan complex are coloured. They consist of red granite and dark-green basaltic tuff sectors. In granite sectors there are granite menhirs 0.8 m high or special-purpose deepenings between stones. The Southern range ends in a ground made of dark-grey limestone.

In Kadyrbaev's classification this is a type IV complex of a kurgan «with moustaches». According to Bejsenov this is a 1-st type kurgan with stone "moustaches" stretching from the primary lonely barrow.

The Novokondurovsky-I kurgan complex is typical of an abject poverty of artefacts. The only finding, based on analogies, which helped to determine the time of creation of the central embankment, i.e. from V-th to the beginning of VII-th century AD, are fragments of the red-clay badly fierd jug-like vessel. They were found in the North-Eastern sector of the central embankment under the second layer of stones, 3 m from the center.

The time estimation (V-th century AD) for the creation of Novokondurovsky – 1 is doubtful. In contrast to other kurgans «with moustaches» investigated in South Trans-Urals, there have neither burial places, nor details of horse harness, ornaments or traces of sacrified animals being attributes of the Middle Ages (except for the vessel) been found. Undoubtedly, the kurgans functions were different. Note that the kurgan is situated on a low streamside terrace, not on an open elevated locality that was typical of steppe people of IV-th - VIII-th centures AD. This distinction was also noted from the comparison of the kurgans «with moustaches» of Central Kazakhstan belonging to the Tasmola culture with the objects of South Trans-Urals. Another feature of kurgans in Kazakhstan dated VII-th – VI-th centures BC is the absence of burial places. The funeral functions began effective only at the second stage of the Tasmola culture development (Botalov, 2006). Extensive enough findings in Solonchanka-I, Solonchanka-IX kurgans and other complexes of kurgans «with moustaches» in South Trans-Urals convincingly show them to belong to the epoch of early Middle Ages. The presence of the grounds along moustaches (Olenina Otnoga) is also typical of kurgans of early Middle Ages. Details of Novokondurovsky-1 kurgan and those in Central Kazakhstan have much in common. In the first place, they have menhirs located at selected points of "moustaches" and utilized as sights to observe Sun and Moon rises and to fix some dates of a calendar cycle. The example is the Kara-Bie complex № 1 referred by Kadyrbayev to the second stage of the Tasmola culture. Scale of the structure is amazing, at the Novokondurovsky-1 complex the length of "moustaches" exceeds 200 m. Remind that according to S. Botalov (Botalov, 2006) the evolution of the kurgan complexes with "moustaches" had tendency of moustaches length reduction followed from kurgan traditions in South Trans-Urals and construction of barrows of the Selentash type. We believe that the occurrence of kurgan «with moustaches» in South Trans-Urals in V-th – VIII-th centuries AD was the second wave connected to resettlement of Turkic population of the mongoloid-Altay community to the west (Botalov, 2006, p. 173), (Tairov, 2003). This may explain the origination of hexagonal (Solonchanka-1, Novokondurovsky-1) and pentagonal (Sarbulat-1) kurgan embankments of main barrow of the complex. For this reason, later dating by an epoch of Middle Ages is possible by single artefacts such as clay vessels. The examined by us monument can be an example of such version.

The Novokondurovsky-I complex is a unique object where astronomic and geodetic measurements were made both before and after archaeological excavations. At the first stage, the reference points of the complex were revealed on the surface by indirect signs of vegetation and outputs of stone ranges. Thus, the Eastern ends of the moustaches have been determined precisely, they were in the as-conserved stage even after excavations. Complex measurements by means of theodolite and professional GPS systems were done in June of 2006 during the field seminar on archaeoastronomy. Results of the first stage of researches (Zdanovich, 2003) have shown a good agreement of archaeological and astronomical datings. As assumed, the end of a south moustache was the basic "workplace" of an ancient observer, where he did rituals on the sunset at summer solstice. The epoch of its construction and utilization for making a calendar (460 AD) has been determined by observations of the Polar star. The moment when the solar disk touches the horizon with its lower edge was the sunset.

Fig. A7.2 The Novokondurovsky-I "moustaches"

After archaeological excavations and reconstruction of the kurgan “with moustaches” it became clear that another decisions are needed to relate the as-recieved azimuths of principal elements of the structure to the events of Sun and Moon rises and sets. Thus a new detail of the structure, i.e. a ground near the Northern range on an azimuth a = -46º34' as measured from the center of ground at the end of the Southern moustache appeared. The azimuth of a direction to the beginning of Northern moustache is a = -50º41' corresponding to summer solstice sunset with height of horizon h = 1º03'. The epoch of construction and functioning of the complex as an instrument for fixing the main dates of solar calendar (V-th century BC) was specified with the help of computer planetaria REDSHIFT-4 and Cartes du Ciel. The idea of a later construction of the main barrow of the complex allows us to explain the fact of the attachment of observer's location in the centre of the barrow with the azimuth of sending to east hill located at a distance of 1 km. The occurrence of the second barrow on a hill 20 m apart from the barrow of the early Iron Age seems natural. Really, nearly a millennium has passed from the moment of construction of the ranges. As a result, it was necessary to specify points of sunrises above the hill during a period close to equinoxes. The spring equinox was always the main date for nomads as it defined the beginning of a new annual cycle.

Since the kurgan complex was built with difference in time, the role of the grounds located North-East from the main embankment close to the northern moustache becomes clear. During the simulation of the astronomic situation close to 500 BC it has been shown that the above-mentioned sunset and rise full Moon are the key for explaning the algorithm of forecasting solar and lunar eclipses. Among the solar eclipses of that epoch the solar eclipse of June 503 BC eight days distant from the summer solstice meets all the requirements the best. That's why it can be assumed that the Novokondurovsky-1 kurgan «with moustaches» was founded in the days after solar eclipse when the two sites, i.e. the ground in the vicinity of Northern range beginning and the end of South "moustache" with full Moonrise direction along the "moustache" were fixed as the closest day to the eclipse. The direction of sunset and the corresponding point at the beginning of northern moustache have been fixed from the ground in summer solstice. An additional verification of the epoch of the complex building was assumption of the direction to the Northern "moustache" end as sighted from the center of the ground located at the Southern "moustache" end. The azimuth of this direction coincides with that of rising of the brightest star Arcturus in the Northern sky. In the first millennium BC it ascended close enough to the point of North. Thus, Arcturus rising was observed in 585-480 BC for horizon height h = 15' above the Northern "moustache" end provided that the azimuth of it’s rising a = 26º47'±30'.

So, there are at least three arguments that show the affiliation of kurgan’s complex Novokondurovsky-1 to the epoch before BC. One of them based on the general evolution of cultures of ancient peoples and their outlook in the Southern Trans-Urals and Central Kazakhstan. The two other are based on the simulation of astronomical picture of the celestial sphere and it’s linkage to the architecture features of the kurgan "with moustache".

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A8. THE TUNGUSKA PHENOMENON AND ITS REFLECTION IN THE WORLD OUTLOOK REPRESENTATIONS OF THE EVENKIS AND IN SCIENTIFIC HYPOTHESES

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On June, 30th, 1908 the Earth planet has been collided by space body weighing more than one million tons. The explosion of an extreme force which occurred over the territory of Central Siberia (co-ordinates of epicenter of the explosion was 60°53'10" North latitude, 101°53'45" East longitude). It caused a huge destructive consequences and is known as the Tunguska phenomenon. Witnesses of the explosion were aboriginals of the Tunguska taiga – the Evenkis.

The Evenkis are indigenous people in Central and Eastern Siberia. They speak Evenki language of Tungus-Manchu group which belongs to the Altai family of languages. Their population is only thirty thousand people but they have explored the territory from the Yenisei to Kamchatka, and from the Arctic Ocean to the border with China. It turns out that on the average the population density amounts only one Evenki per twenty-five square kilometers (Tugolukov, 1988, p. 525).

The Evenkis are children of their intrinsic nature. They do not separate themselves from natural environment, knowing its secrets. In the XV-th – XVI-th centuries the Evenkis learned reindeer herding, becoming the northern most herders in the world. For the Evenk a deer was not only a breadwinner and vehicle, but even a guard. The life cycle of the deer, which was deeply understood by the Evenkis, not only determined the Evenks existence, but their world outlook, which includes the original mythology — a combination of terrestrial and cosmic principles.

The well-known folklorist and investigator of the North, Ivan Ivanovich Suvorov (1914-1972) made the most creative work on the collection of ethnographic material and Evenki folklore. Suvorov studied mode of life, traditions and customs of the Evenk people. Among the myths and sagas he found many legends, stories and tales about how the spirit of the sky – Agdy - was offended by people and unleashed on them his fiery arrow – Pektrume (Suvorov, 1976, p. 35-38).

Agdy (Thunder) is the master of thunder and lightning. The Evenkis represent Agdy in the form of a celestial old man who wakes up in the spring and carves fire with steel. That is why we can hear thunder on the Earth's surface and sparks of lightning strike evil spirits. According to other versions Agdy looks like a little dancing creature with a bear head, human body and wings of an eagle or like a bird with fiery eyes, the flight of which produces thunder, and sparkling of its eyes produces lightning. Agdy was considered as one of the shamanistic spirit-helpers. It was believed that shamans could launch Agdy on alien clan.

The Evenkis perceived the cosmic catastrophe that occurred on June 30, 1908 over the Siberian taiga as a manifestation of God Agdy angriness. Stories about the fall of the meteorite the Evenkis supplemented with fantastic speculations and superstitious additions, but the event itself was represented by them fairly accurately and correctly.

What really happened on June 30, 1908? Around 7 a.m. local time, the big fireball — bolide appeared against the Sun. It was almost hundred meters wide. Leaving a light trail of smoke behind itself, it flew almost 770 km for a few minutes through the Earth's atmosphere. Nearly a thousand miles around the thunder could have been heard. The flight of the cosmic stranger over a deserted taiga at an altitude of 5-10 km has finished with a grand explosion (Wojciechowski, Romeyko, 2008, p. 8-19).

Alive witnesses of the space disaster were the residents of a small trading post Vanavara and those few Evenk nomads, who were in the taiga at that time. In seconds the blast knocked down forests, killed animals, and maimed people in a radius of 30-40 km.

80 million trees fell on the ground making a strange figure, vaguely reminiscent of butterfly wings, covering the area of more than 2150 sq. km (Fig.A8.1, 2). According to various estimations, the energy of the explosion ranged from 10 to 40 megatons of TNT (Romeyko, 2006, p. 65). At the same time due to light radiati dozens of kilometers of taiga flushed up. The forest fire has begun that destroyed what left behind after the explosion. Within the radius of about 30 km there was a partial reversal of the soil. And only in the epicenter of a blast wave, running from the top, charred trunks of trees were left standing straight, devoid of their lush crowns. After that this place was called “telegraph forest”. After the explosion a mutation of plants and insects occurred in the taiga, the growth of trees accelerated, the chemical composition and physical properties of soils changed (Wojciechowski, Romeyko, 2008, p. 144-155).

Earthquakes caused by the explosion were observed in Irkutsk, Tashkent, Tbilisi, and in the German city of Jena. Seismometers of Irkutsk Meteorological Observatory recorded tremors caused by a meteorite for the first time in the history of science. Earthquake started at 00 hours 17 min 11 sec UT. Arrival of the air wave to the observatory was 2.5 minutes later. Explosive air wave, which propagated over the globe, was recorded by many meteorological observatories in the world (Fig.A8.2, 1). Acoustic phenomena spread over more than one million square km with the radius of about 800 km. Such an event is equivalent to a local environmental disaster

Tunguska fireball also caused significant changes in the Earth’s magnetic field. Strange magnetic storm was observed in Irkutsk, which lasted for about 3.5 hours and in many respects resembled the disturbance that occurs after a nuclear explosion (Fig.A8.2, 2).

On the night of June 30/July 1, as well as on the following nights, there was a significant glow of the Earth's atmosphere and night-shining clouds (noctilucent clouds) from the western shores of the Atlantic Ocean to Central Siberia from West to East and from Tashkent to Saint

Petersburg from South to North in the area of more than 12 million square km. The brightness of the sky, according to experts, exceeded usual values by hundreds times, in some places up to thousand times.

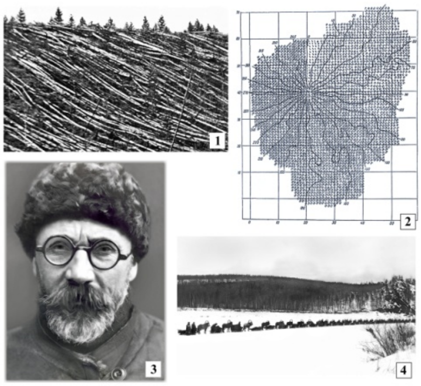

Fig.A8.1 1- Wood inrush (L.Kulik's photo); 2 - physical parameters of the Tunguska accident; 3 – photo of Leonid Kulik; 4 - a transport of Kulik's expeditions on the river Stony Tunguska in the end of winter of 1929 (L.Kulik's photo).

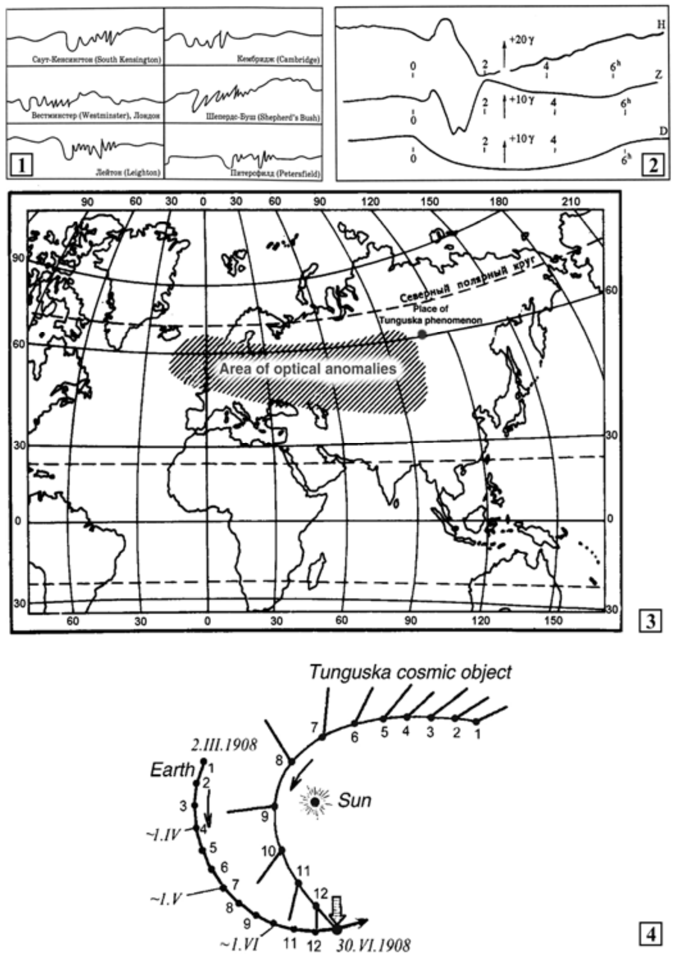

Fig.A8.2 Geophysical parameters of the Tunguska explosion.
1 - The barograms which have been written down in England; 2 - The geomagnetic storm registered in Irkutsk; 3 - Area of anomalies of the Tunguska accident; 4 - The probable scheme of collision of the Tungus body with the Earth

The glow in the sky did not begin immediately after the explosion, but only after 13-15 hours after the collision of Earth with the space alien. Until now, this fact hasn't got any conceivable explanation.

In 1927, the Secretary of the Committee on Meteorites of the USSR Academy of Sciences L.A. Kulik undertook expedition to Central Siberia in search of the site where this unusual meteorite had crashed (Fig.A8.1, 3). During the next two expeditions, their members were conducting tiring work on finding the meteorite substance (Fig.A8.1, 4). Later the aerial survey was carried out, but no pieces of the meteorite have been found (Romeyko, 2006, p. 18).

According to the hypothesis that was initially put forward, the Tunguska space body was an ordinary very large iron or stony meteorite. However in the process of research it became clear that the meteorite hypothesis could not explain several phenomena observed neither in the time of the disaster nor after it:

- Why did the meteor explode like the most powerful explosives, and where, in fact, is its substance gone because so far not a single gram of meteorite matter has been found?
- How could the optical anomalies emerge thousands of miles away from the site where the meteorite fell? How are they related to the meteorite?
- Why did the growth of plants accelerate in the epicenter?
- How can the effect of the magnetic storm, which broke out in the ionosphere immediately after the explosion, be explained?

Later on comet hypothesis was suggested which fully explained the absence of cosmic substance, both in the epicenter of the explosion and around. With some reservations, the nature of optical anomalies was also explained. It was assumed that the comet substance dispersed in the upper atmosphere, causing the glow of the night sky. Modern researchers have found traces of the comet in the peat deposits in the disaster area. They are enriched with elements such as nickel, cobalt, lead and silver. Sodium, zinc, iron, calcium and potassium prevail in the mineral part of the peat, which resembles the chemical composition of the comets spectra (Wojciechowski, Romeyko, 2008, p. 10).

Russian Academician S.S. Grigoryan is the author of the bold theoretical hypothesis, which shows that the icy nucleus of the comet, with its vast reserves of energy (in mass and speed), can freely penetrate in the atmosphere and collapse.

But why wasn't the comet, the mass of which amounted about 1 million tons, discovered in advance, before approaching the Earth? Theoretical calculations of the trajectory of a comet's orbit gave the answer to this question: Tunguska space body approached the Earth from the side of the Sun and therefore couldn't be seen from the Earth (Fig.A8.2, 4). The genetic relationship between the Tunguska body and the orbit of Encke comet was indicated by Soviet astronomer Igor T. Zotkin and Czechoslovakian astronomer L. Kresak (Romeyko, 2006, p. 60-61). The first results of the field works in the late 1950-th were the fused silica and magnetite microbeads of cosmic origin found in the soil. This was the argument in favor of the comet hypothesis, because, in addition to ice cosmic dust is included in the composition of nucleus of a comet.

Historically, a popular hypothesis of nuclear origin of the Tunguska explosion was discussed as well and met a public response though it is poorly scientifically supported. It refers to alien advanced technogenic ideas, acknowledging a blast and destruction of some artificial spacecraft using nuclear fuel related to space missiles, ships, UFOs, etc. The explosion of the nuclear fuel used in engines, could explain not only the destruction and lack of the meteorite substance, but also the mysterious phenomena, which the local peoples witnessed such as "water fight", "face grilling water," "glowing stones", "sickness of local people ", etc. In 1958 the first Integrated Amateur Expedition (IAE) headed to taiga in search of the remains of a spacecraft. But on-ground and aerial inspection of the area could not reveal any material traces of a technogenic disaster. Also no signs of radioactive contamination which could be attributed to the accident of the spacecraft were revealed (Romeyko, Chichmar, 2004, p. 63-71).

It is worth to mention also that American researchers, Nobel Prize Winner C. Cowen and B. Libby, developed the theory of L. La Paz on antimatter nature of the Tunguska meteorite. They put forward their own hypothesis about the collision of the Earth with a mass of antimatter, resulting in the annihilation and the release of large quantities of nuclear energy (Wojciechowski, Romeyko, 2008, p. 192-193).

Recently Russian and foreign enthusiastic researches of the Tunguska problems discover new details of the catastrophe. The only impounded body, which appeared probably in the epicenter of the explosion is the Churgim Waterfalls. According to Italian investigators, the site where the Tunguska meteorite most probably fell is the Lake Cheko.

We can summarize that over the years there have been dozens of theories giving various reasons for the Tunguska catastrophe. The main ideas are: comet theory (30,5%), meteorite theory (28.3%), nuclear theory (8.5%). (Source of information: www.tunguska.ru). Various opinions about the nature of the Tunguska phenomenon, given below, can be assessed not only from the academic viewpoint on the 1908-th event but through the entire spectrum of human imagination, involving sometimes even the sense of humor. They can be reviewed as follows:

- the cause of the disaster was the descent of the awesome god Agdy on Earth; he sent the fiery dart Pektrume, which destroyed the taiga and killed many animals;
- on June 30, 1908 the Earth came through a cloud of cosmic dust;
- the explosion occurred due to the detonation of natural gas, fired by a meteorite which entered the atmosphere;
- the explosion is connected with the outcome of powerful electromagnetic ball lightning of 'vortex' type (underground storm) from depths of Earth;
- the explosion is explained by the breakthrough of solar plasma clot, that triggered the formation, and then the explosion of several thousands of lightning balls with the volume of a quarter of a cubic kilometer;
- the event was caused by the collision of the Earth with a "black hole";

- a comet beaten down by an alien spacecraft exploded over the Tunguska;
- the explosion of the Tunguska body was caused by factors similar to those which initiated the destruction of the Phaeton planet;
- Tunguska meteorite had earthly origin, and emerged due to the ground impact of small cosmic bodies quite long ago, and in 1908 it "came back". In this case, it may have already been found by D. F. Afinogenov in tearly 1970-ies on Stojkovic Mountain, located in epicenter of the explosion.

Evidently, these fantastic ideas have no scientific support and natural explanation of asteroid/comet collision with Earth remains justified. In 1995 the site of the Tunguska catastrophe was declared the State Biosphere Reserve, comprising the area of Kulikovsky in rush, the historic complex of buildings of the first explorers. Scientific research is conducted in the "Tunguska" reserve: in the field of soil science, botany, zoology, ecology; besides an extensive work on development and recovery of the Siberian taiga after natural cosmic and terrestrial catastrophes is performed there. During recent years the epicenter of the Tunguska explosion has been visited by Japanese, American, Polish, Italian, Czech, German, Bulgarian researchers and tourists.

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A9. ECLIPSE OF MAY 28 -584 LOCATION AS WORLD HERITAGE SITE CANDIDATE

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A reliably recorded solar eclipse event during a day-time war of 28 May 585 BC is the famous one because of several reasons: (1) It has a credible written record (mentioned by the ancient historian Heredotus); (2) The record ('The History' of Heredotus) also note that 'the eclipse was 'predicted' by Thales of Miletos (the Ionian capital city at Western Anatolia); (3) The location of this war between Lydians and Medes is now located as the plain by the city of ancient Pteria, also considered as the Anatolian capital of Medes. 'The History' continues to inform us that (4) 'The war has stopped and a peace accord was sealed, with the wedding of prince and princesses of rival kings'. That is, all the elements for a teatrical super-performance is complete, only waiting courageous authors or producers to put this junction of celestial and terrestrial events into a show, including a film or acts of opera or balet performance! All these make the event and place an excellent candidate for a 'world astronomical heritage' site to be preserved and announced. The 'world year of astronomy-2009' would be a good time in this regard!

Pteria is now a modern archaeological excavation site by Sorgun of Yozgat province of central Turkey. The recent March 29 2006 solar eclipse event covering almost the same area of this ancient war after 2590 years was observed by the author and his colleagues with a crowd (mostly unaware of this background). This can also be considered the first (unofficial) 'celebrations' of the notable event. The roles of such coincedences of cosmic events with human affairs in establishing reliable historical chronologies and some further details mentined by Heredotus (i.e., 'prediction' by Thales) will be evaluated.

A10. ANCIENT SOLAR OBSERVATORY OF GOBUSTAN

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Early man was ingenious in practical natural sciences, especially those which could be useful in struggles for survival. He had sufficient motivation for continuous experimentation and observations. An apt example is the invention processes of making artificial fire. Unlike other sciences, the employment of astronomy was instrumental to increase spiritual awareness of ancient people. Study of heaven bodies was required to communicate with the Gods lived at the heavens. Ancient people's knowledge was specifically augmented through the more precise study of the visible movement of the Sun which occupied a central position in their life and thinking. The Sun produced natural heat, allowed to determine orientation and helped in tracking time. Ancient human beings learned to determine the onset of seasons by the Sun's position. For this purpose they used landscape reference points on the horizon, the cracks of caves and rocks or, sometimes even built astronomically aligned structures and devices, some of which are now referred to as ancient solar observatories. Remarkable examples of such ancient observatories were found within Chankillo of the costal Peru (Ghezzi et al, 2007, p. 1239), in the Western Altai on the Mt. "Ocharavatelnaia" (Marsadolov, 2005, p. 57), and at Fajada Butte of Chaco canyon of Mexico (Sofaer, 2008).

Identification of the ancient solar observatories is a considerable contribution to prehistoric investigations. Here, we describe the early structure in Gobustan of the Azerbaijan Republic that seems have been built in order to facilitate observations of sunrises throughout an year. The Gobustan Stone Carving Reserve is located on the southern outcrop of the Caucasus Mountain near the Caspian Sea, some 60 km south of the capital Baku. There are three main concentrations of rock art on the slopes of mesa-like hills Beyukdash, Kichikdash and Jinghirdash.

They are composed of more than 6000 figures found on about 750 rocks (Jafarzade, 1973).

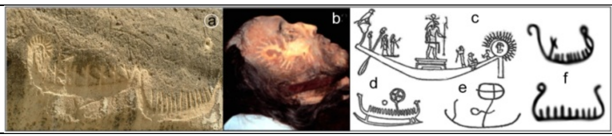

Fig.A10.1 a–"sun boats" on stone № 8, b– fire mane tattoo of Chinese mummy of Cherchen man,
c-f – sun boats from Egypt, Karelia (Russia), Ural (Russia) and Scandinavia

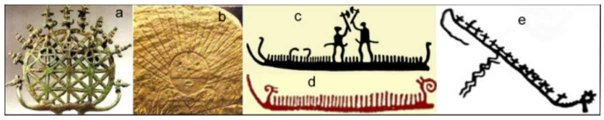

Fig.A10.2 a–Hettian's Sun (E.Akurgal, 2001), b– Saymalitash's Sun (Kergizia), c,d– Scandinavian season boats, e – full moon's "sun boat" on stone No. 1.

Fig.A10.3 Stone № 29.

Fig.A10.4 Ancient Solar Observatory of Gobustan.

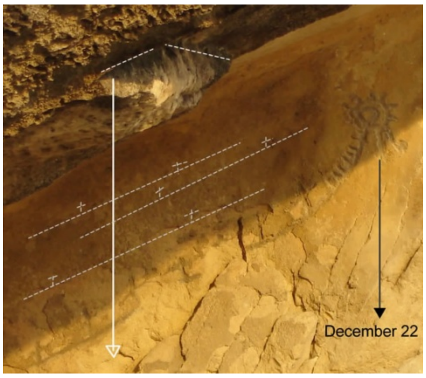

Fig.A10.6 The plummet–gnomon sundial calendar of niche I.

Fig.A10.7 Prehistoric repair of the Ancient Solar Observatory of Gobustan

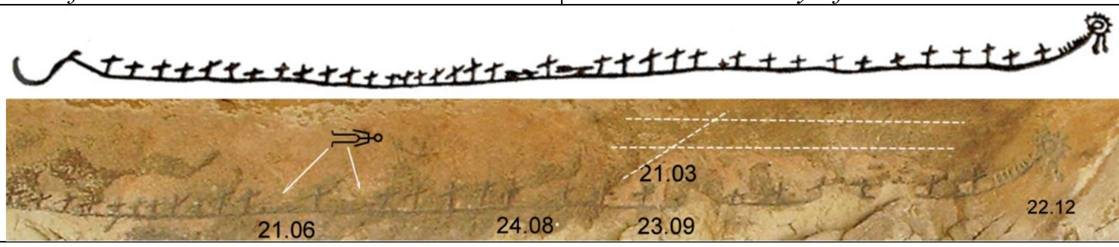

Fig.A10.5 "Sun boat" picture on stone No. 1 with season's positions of sun dial

`Quite a number of the Gobustan rock-carvings represents drawings of boats with lines or crosses along their lengths. Other Gobustan boat carvings carry images of radiant suns on their prows (Fig. A10.1). Researchers interpreted the meaning of the Gobustan boats images differently. Some scholars think that the images of boats were connected with the advanced navigation (Rustamov, 2003) while others regard them as utilized for the carrying souls of dead people to an other world (Rzayev, 1994, p. 65, Formozov, 1980, p. 38). An absence of any other natural maritime features such as fishes, punt-poles, oars or sails in the images is a powerful counter-evidence for the theory that these images emphasized navigation. The mythological theory focusing on the Sun boat carvings is supported by the images, in addition to the superficial analogy with ancient Egypt Sun boats.

The images of boats could be notations of a certain quantity of days. Primitive man and primitive societies are thought to have had no formal writing system, and thus they might have kept track of things by a method of carving notches. Time and timekeeping was always required, and hence there was a need to make such marks. A simple next step would be to unite the lines by underlining. The symbolical boat in terms of final writing version should appear naturally as a symbol of time, which might be perceived as flowing water in a river.

However, any logic theory needs a proof. Archaeoastronomical analysis can decipher symbolic meanings of some of the well known Gobustan boat carvings. The first samples of time boats are the “Sun boats” images with seven crosses and thirteen poles on Stone No. 8 (Fig.A10.1, a). Seven day, thirteen (or fourteen) day is a sequence of the Moon’s paths. These boat images symbolized a quarter and full paths of the Moon.

One can take also as a “full Moon boat” the small “Sun boat” image on the eastern apron of Stone No. 1 with fourteen crosses on board and some not resolvable much shorter lines on the neck (Fig. A10.2, e). The sinuous-like brook from below can be a symbol of the Moon path. Here, in the western coast of the Caspian Sea, the full Moon rises over the sea.

The boat carving on Stone No. 29 at the upper terrace of Beyukdash has 22 lines along its side, and 8 shorter lines nearer the bow (Fig. A10.3), probably meaning that eight months of twenty-two days each make 176 days. Many days of the morning Sun light is taken to cover this slightly oval stone wall, the tangential plane of which lies on an E-W plane facing South. Consequently, the “sun boat” from Stone 29 is a “winter boat” or a “semi-annual boat” which indicates that part of the year between of autumn and spring equinoxes. It is necessary to note about a possible existence of 9-th line hidden by the retouched tuft of the Sun bird, Rooster. In this case, nine months of twenty-two days each, 198 days in total, will be a time from the beginning of illumination till the end of illumination of this oval wall with east edge slightly bent to the North, approximately from September 14-th to March 28-th. Other properties of Stone No. 29 are the E-W line carved on the big stone lying in front and the E–W edge of the stone lying to the right.

The following quote from Ruggles supports the idea of a twenty-two day week: “In Bronze Age Britain a calendar was in use whereby the year was divided into four two and then into two again, giving in all sixteen ‘months’ of from twenty-two to twenty-four days each; and it may be vestiges of an eight-fold division of the year survived into Celtic times and hence into the Middle Ages, where they were represented by the feasts…in addition the four Christianized solstices and equinoxes...” (Ruggles et al., 1999, p. 18).

One can come across other such “season boats” in the boat carvings at Dalbergsa, Evenstorp, Gerdhem and Vastergotland of Scandinavia (Bengt, 2005). Interestingly, figures with 22 lines or oars can be seen on vase paintings from Naqada/Gerzeh Egypt (Bengt, 2005) and stone carving from Saymalitash plateau of Kergizia (Fig. A10.2, b).

Other well-known boat carvings are that found on Stone No. 1, located at the Beyukdash's lower terrace. Stone No. 1 is a huge rock with roughly 7x3x3 m overall dimensions, suggestive of a ship lying on its starboard side pointing approximately Northward (Fig. A10.4). A niche is carved on the Eastern (I) and Northern (II) sides of Stone No. 1. A 240 cm long boat figure is carved on the smooth wall of the East side niche which has a small deviation from the central meridian.

There is a row of 36 crosses with two onboard man figures at horizontal positions from the right and from the left of 17th cross, followed by a sequence of nine much shorter lines along the neck, and the Sun image on the prow (Fig. A10.4). A cornice was cut out on ceiling of the East niche opposite of the 3rd cross (Fig. A10.4, 6).

The northern niche (II) has an oval shape. It starts from the plane with an azimuth of approximately 60 degrees and ends on the equinoctial E-W plane. There is a row of crosses on the lower part of the northern niche (probably depicting a boat), a horizontal apron excavated round a hole (Fig. A10.4).

The cornice (Fig. A10.4, c) could be used to hang plummet–gnomon (Fig. A10.4, g), and it is a good reason to believe that niche (I) served as a horizontal sundial calendar based on changing positions of rising Sun along the horizon (Fig. A10.6). Such an assumption is confirmed by the observed and calculated positions of plummet's shadow for some dates (Fig. A10.5). Calculated position of the shadow on the 22-nd of December stands directly in centre of the Sun image on Stone No. 1. The man figure from the left of 17-th cross marks the summer solstice day.

Some researchers consider the two onboard man figures to be captives. But on our "sun boat" calendar they can symbolize some ceremony celebrated at the midsummer time. Within ancient Stonehenge this was ancestor's day (Pearson, 2005, p. 63-67). While such a version would suit us as well, this question needs additional investigations.

The northern niche (II) could also function as a solar horizon calendar. No shadow appears in niche (II) at the Midsummer Day (Fig. A10.4). The niche (II) is completely illuminated by morning sunlight. However, in the morning time after the solstice shadow begins to appear on the western edge of niche (II) which slowly grows in an Easterly direction until the day of equinox when the Sun rises on the Eastern horizon and finally, it covers the entire northern niche (Fig. A10.4, e). The plane of the front side (WS) has an azimuth of approximately 130 degrees and it could be used to watch the winter solstice with an azimuth of the rising Sun of 122 degrees.

Additional archaeoastronomical evidence could be found by deciphering “sun boat” on Stone No. 1, which was appearently a year boat. 36 passengers resided the main boat of this Stone and seasonal boats from Fossum and Backa Bohuslaen (Fig. A10.5 b & c) could be interpreted as the number of days of an year (36 x 10 = 360 days, thus each cross would indicate 10 days). However, it is necessary to take into consideration that the given designation of a cross was used for reduction of unimaginably long line of crosses of the “year boat”. Other small boats have only day crosses or lines rather than multiples of 10 days.

The nine short lines on the neck could mean nine-fold division of the year getting back into a pre-Christian epoch in some Euro-Asian countries. Such a year with nine months of forty days each had three seasons comprising three months: spring, autumn and winter. Periods of forty days were common time units in the ancient world. The big "chill"- forty days long and small "chill"- twenty days long are used in Azerbaijan as a winter period even today.

Stones No. 1 and No. 29 are located at different levels of Mt. Beyukdash, at a distance of 500 m one between them. However, the times of their creation could be thousands years apart. Therefore, it is possible to have different versions of calendar boats reflecting different ways of reckoning the year during different eras.

Numerous drawings in part of the east apron have been altered over the centuries. Drawings of a bull, a ram, a goat and those similar to the symbol of Twins were engraved on the old boat drawings sailing over the sea. Additional figures of bull and ram can be explained in terms of further development in the rich mythology of the ancient Gobustanians. The other most appreciable change is the fact of prehistoric repair of the solar observatory at Stone No. 1. Some split of the stone resulted from perhaps an earthquake or a sag of the base after a flood were found. There was a danger of Stone No. 1 falling on the East side and shattering. Instead of cutting a new observatory or putting a small prop from East side, another difficult engineering decision was undertaken: strengthening Stone No. 1 with the megalithic balance weight–imprisonment, established on the Western wing.

Another interesting property of Stone No. 1 is an inclination of the East niche or a “sun boat” direction that is close to the ecliptic inclination. Though this seems fantastic, ancient men could measure, nonetheless, an angle (of course, in a natural form) as a difference of midday’s altitudes of the Sun at the spring and summer. This ecliptic direction aligns with the brightest star of Northern sky Vega. Over precession approximately 11,500 years ago Vega described a circle with 15 degrees declination round an empty pole. It is possible that the “sun boat” at Stone No. 1 aimed at the point of the low culmination of Vega during that period.

Conclusions

The example of stone wall No. 29 shows that some astronomical parameters of illumination can be used to decipher calendar inscriptions. They also witness that ancient engravings of boats could be a calculation system. Oval stone walls and niches with boat carvings or with other marks could be used as a gnomonical calendar. Stone No. 1 equipped with two models of original gnomon contains also numerous poorly discernable drawings of long boats. Such stone carvings cover all ancient stone sites of coastal Azerbaijan. Research on such stone carvings with the application of modern methods of image processing can give valuable information not only on archaeoastronomy, but on archaeoarithmetic as well.

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A11. ANCIENT LUNAR-SOLAR CALENDARS OF DAGHESTAN.

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By now 210 most ancient Lunar-Solar calendars was revealed in Dagestan. The major part is presented by drawings of animals, circles, crosses, swastikas, lines etc., executed paint ocher and engraving on horizontal and vertical surfaces of rocks, in caves and grottoes. Separate calendars are presented by numbers, circles and single high standing stones. Many calendars combine sundial and are adapted for calculation of eclipses of the Moon, their age amounting to 12 - 14 thousand years. In some of them ancient co-ordinates of poles and angle of the Earth's axis inclination were preserved. Calendars brought evidence that global catastrophes ocured on Earth in Holocene with periodicity of 4 thousand years.

A12. EARLY BRONZE AGE MEGALITHIC MONUMENTS SITUATED NEAR LARGE ANCIENT SETTLEMENTS in Central Thrace, Bulgaria

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Cabyle and Seuthopolis are two of the largest ancient settlements of the Early Bronze Age. Megalithic monuments have been discovered in the region of every one of these famous capitals. The rock-cut megalithic monument Cabyle is located at the acropolis of the ancient city of Cabyle. Mutually perpendicular trenches and relief image of the Great Goddess – Mother Cybela have been hewn in the rocks. Trenches are oriented East – West and North - South. Archaeoastronomical investigations show that observers standing in the North-South trench can determine moments of culmination of bright objects in the sky, and also that the image of the Cybela Goddess is illuminated in the period between vernal and autumnal equinox (the time of vegetation). Thus, people of that time could measure time in units larger or smaller than a day. Another megalithic monument is the ancient cult rock sanctuary Buzovgrad used for sunset observations during the summer solstice (21 June). Archaeoastronomical investigations show that it is built in the period 1800 – 1600 BCE and used for astronomical observations and calendar maintenance. It is supposed that this rock sanctuary served a solar cult, which confirms the connection Man – Cosmos. At the foot of the sanctuary, in the “Valley of the Thracian Kings” is situated the Odrysian capital Seuthopolis and numerous temples and tombs in tumuli, archeologically dated to the period of 600 BCE – 200 BCE.

1. Introduction

Cabyle and Buzovgrad are the two representatives of Early Bronze Age megalithic monuments around two famous Thracian capitals on Bulgarian lands: Cabyle and Seuthopolis. At the end of the 4-th, and the beginning of the 3-rd BCE, Cabyle was the capital of the Odrysian dynasty of Spartok, according to an inscription discovered in the city of Seuthopolis, the capital of the Odrysian ruler Seuthes III (Fig. A12,1).

Rock sanctuaries in the Bulgarian lands have been dated to the period between the Late Bronze Age (in some places from the Chalcolithic Age) and the end of the Roman period. These sites were always located in places at a relatively higher altitude and with a broad view: on mountain peaks and heights. Their location in itself reveals flat areas that are convenient for astronomical observations. Archaeoastronomical research over many years has shown that most rock sanctuaries localised in the mountainous regions were solar observatories (Muglova et al., 2007, p. 408-410).

The primary dating is based on ceramic finds collected from the surface. Studies have revealed traces of their earliest use back as far as in the Late Eneolithic Age (Venedikov and Fol, 1976). According to archaeological evidence, sanctuaries can be dated to the end of the Bronze Age and even later (Naydenova, 1986). The problem connected with dating of this type of rock sanctuaries that are solar observatories is important because it is not yet known whether all their functional elements connected with the measuring of time can be dated to the first period of their construction.

The other solar observatories in the region are defined as megaliths, because their elements are natural rock formations adapted to the needs of people's observations. These were usually menhirs, cromlechs, triliths or dolmens situated in an appropriate order for securing observations on important points on the line of the horizon or on the celestial sphere. Components of these solar observatories have a number of landscape features nearby and far way such as on the horizon, which fit the general structure of the observation ensemble (Muglova, Stoev, 1996, p. 34, 35).

Fig.A12.1 Map of the territory of the Odrysian Kingdom

Fig.A12.2 The Cabyle rock-cut sanctuary at "Zajchi vruh" peak, which is in the frames of the acropolis of the ancient city of Cabyle

Fig.A12.3 Mutually perpendicular trenches with a variable depth have been hewn out in the rocks and oriented East – West and North – South

Fig.A12.4 Relief image of the Great Goddess – Mother Cybela

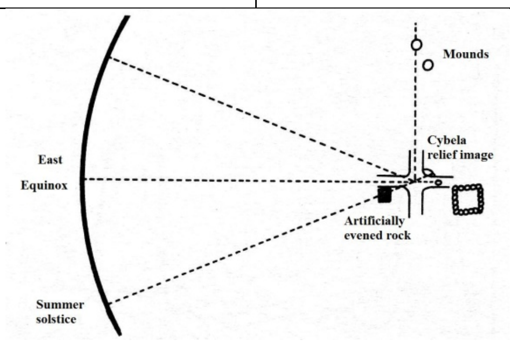

Fig.A12.5 Orientation of the structural elements of the sanctuary

Solar observatories from the Late Eneolithic until the Late Bronze Age have functional elements tracing astronomically significant directions from the points of sunrises and sunsets during the vernal and autumnal equinox and during the winter and summer solstice. They were used to measure time with units longer that the 24-hour period, and they satisfied the calendar needs for economic and public life (Stoev, Varbanova, 1996, p. 94, 95, Potyomkina et al., 2006, p. 189, 190).

Central Thrace, Odrysian Kingdom

The Odrysian Kingdom was the largest one in Europe in the period between the second half of the 5-th century and the first half of the 4-th century BC when it reached the peak of its military, political and economic power. The Mycenaean structure of society, as well as the beliefs, are preserved and developed. Some of the most enchanting myths and legends of the Thracians came from the Odrysian Kingdom. For example, one of them is the eternal story of Orpheus, the sage, singer and teacher of the mystical Thracian cults that the sons of the Sun and the Earth will continue their lives in the eternity (Fol, 1994, p. 53, 54). This belief was shared predominantly by the aristocracy, which employed local and invited Greek masters to create the best works of Thracian architecture, sculpture and painting. Their Orphean beliefs in immortality are found reflected in the images in tombs and sanctuaries, as well as in weapons and decorations of warriors and horses. Thracian spirituality is a contribution to ancient European culture. Traces of it may be found at the deepest layers of Bulgarian and Balkan folklore.

2. Rock sanctuary of the Early Bronze Age settlement of Cabyle

The rock-cut megalithic monument Cabyle is located on the east side of the two-peaked hill "Zajchi vruh" (Taushan tepe in Turkish), which is in the sights of the acropolis of the ancient city of Cabyle (Velkov, 1982, p. 15), (Fig. A12.2). It is the only hill dominating over the Yambol field. The rocks are evened and worked at the top. Mutually perpendicular trenches with a variable depth have been hewn out in the rocks and oriented East – West and North – South (Fig.A12, 3.). Thus, the massif has adopted a specific cross-like shape. $\lambda = 26° 28′ 44.2″$, $\beta = 42° 32′ 52.7″$, altitude h = 239.2 m.

There is a relief image of the Great Goddess – Mother Cybela (Fig. A12.4) on the South – West corner of the “cross”, with South – East exposure. The trench situated at the East – West axis is 12 m long and that one situated North – South is 15 m long. The view revealed from the central part of the cross shows that the local horizon is particularly even following the direction Northeast – Southeast.

The geometry of the spatial organization of the rock-cut monument indicates an exact coincidence of the straight line towards the points of sunrise during vernal and autumnal equinox and the line of the East – West trench (Fig. A12.5.). Projection of the main meridian at the place of observation coincides with the North – South trench (Stoev, Varbanova, 1994, p. 426-428).

The rock, located diagonally following Cybela's image, has been artificially evened out so the first solar rays could illuminate Cybela's image each morning in the period between vernal and autumnal equinox (i.e. during the time of vegetation – half year). In the "autumn-winter" period, the image of the Goddess was practically not illuminated.

Investigations of the North-South trench show that an observer standing in its maximal depth could see the line of the main meridian at the place of observation. Consequently, he or she could practically establish the culmination moments of such bright luminaries in the sky as the Sun, the Moon, planets and bright stars (Muglova et al., 2007, p. 407-409). Using this relatively precise instrument at Cabyle, the ancient observers could have measured time in units larger than a day – a year, half a year, or the duration of the seasons. At the same time, observing the daily solar culmination and some of the brighter stars, they could measure time in units smaller than a day.

3. Buzovgrad – megalithic monument from ancient Central Thrace

The rock sanctuary is near the village of Buzovgrad, on a rocky hill that local people call Buba Kaya (Father's Stone) and there is an excellent vista from it to the South, North, and West. Geographic coordinates of the site are: j = 42° 34' 15". 3 and l = 25° 22' 36".6, and its elevation is 554 m. The total area of the sanctuary is about 800 m^2. The main rock group is in the top part of the hill. Two separately shaped rock blocks placed one on top of the other, close to the upper part of the aperture, thus forming a trilith. The supporting columns are part of the main rock of the massif (Stoev, Stoeva, 2006, pp. 25, 26). Part of the main rock had been additionally shaped to form something like a "throne" at a distance of about 6 m Southeast of the trilith. Its observational point is turned mainly to the West-Northwest. Several grooves resembling "sacrificial altars" have been hewn next to it, continuing to the East. Traces of the fires lit on them are still discernible. The Triglav mountain peak (2,276 m) in the Balkan Range is clearly seen from the observational point, falling into the centre of the light aperture of the trilith. Its slopes are the water-catchment area of the Tundja River (the sacred ancient river Tonzos of the people inhabiting the Kazanluk Valley). Snow cover was until late summer on the mountain ridge, and the contour of its relief is well visible through the aperture of the megalith.

The main axis of the site is determined via observations of the Sun. The most clearly discernible rock forms were tachymetrically photographed. This makes it possible to calculate the declinations of the Sun in the moments when it is on the horizon and the light passing through the visual aperture of the trilith falls on the characteristic grooves of the rock of the "throne". It is supposed that observations of the solar disc during sunset on the day of summer solstice were made when the solar disc touches the visible horizon. Archaeoastronomical investigations show that the object was created and could have been used in this way in the period between 1,800 and 1,600 BCE.

The summer solstice probably marked the “ritual beginning” of the culmination of the agricultural season, which corresponds to the approximate date of the most important feast of the Eneolithic community. It is supposed that rituals practiced on the territory of this megalithic sanctuary are expression of honour to the Sun-God. These rituals completely conform to the cult of the Thracians towards the Great Goddess-Mother and her Son-Sun-God, named Thracian Orphysm. Nowadays, a lot of people gather on June 22 every year and celebrate summer solstice, waiting to see the sunset through the aperture of the megalith (Stoev et al., 2008, p. 128-130).

4. Conclusion and perspectives

- Cabyle and Buzovgrad megalithic monuments are parts of archaeological reserves - the Antiquitic town of Cabyle and the Valley of the Thracian rulers.
- The alignments and other evidence presented show that they are examples of locations/observatories for the observation of solar extreme sunrises, sunsets and meridian culminations.
- Archaeological finds prove their continuous use.
- These Megalithic monuments already are included in many tours of the Yambol and Kazanluk Archaeological museums and tourist firms.

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A13. ANCIENT ASTRONOMY IN UKRAINE:
from the Paleolithic Era to the Beginning of the New Era

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Abstract. We describe briefly the famous archaeological findings at the territory of the modern Ukraine, which are evidence of the ancient astronomical culture of our ancestors. They are dated to the upper-middle Paleolithic times (Gontsy, Mezin, and Kiev-Kirilovskaya settlements), the Eneolithic era (Tripolye Culture), and the beginning of our era (Chernyahiv and Zarubintsy Cultures) in the times when the first Slavic tribes lived in these territories.

Introduction. During the 140-year history of the archaeological excavations and research at the territory of the modern Ukraine, remarkable finds were revealed from the ancient settlements that testify to a deep astronomical culture of our ancestors. These archaeological finds are dated back to the upper-middle Paleolithic times (Gontsy, Mezin, and Kiev-Kirilovskaya settlements), Copper-Bronze-Iron Ages of the Eneolithic era (Tripolye Culture), as well as to the beginning of our era (Chernyahiv and Zarubintsy Cultures) in the times when the first Slavic tribes lived in these territories. The term "finds" hereafter means the various things made from mammoth bones and tusks; birds bones; stone; hand-made ceramic and wood utensils, etc., as well as ornaments on these things.

Paleolithic era. The most speculative interpretation is connected with the finds dated to the upper-middle Paleolithic times (35 - 8 Millennium BCE). It is difficult to explain correctly the knowledge of primitive troglodyte people about heaven and celestial bodies in terms of our contemporary views. Nevertheless, the first scientific methodological approach to establish some interrelation between lunar cycles and systematic grooves/pits on various finds from the Paleolithic settlements at the Eurasian territory were proposed by the Russian, Ukrainian, and French researchers in 1960-s – 1970-s (Rybakov and Abramova (1962), Marshak (1964, 1972), Shovkoplyas (1965), Okladnikov (1967), and Frolov (1977)).

One of the most ancient settlements dated to the 15-th Millennium BCE was discovered in 1871 on the right bank of Uday River near Gontsy village in the Poltava region by F.L. Kaminsky, a teacher and amateur archaeologist. In 1873, 1914-1915, and 1935 this settlement was studied in detail. Among them a well-preserved mammoth's tusk fragment covered by a finely detailed pattern was found (Abramova, 1962, table XXXIX). Later on it was interpreted as a table of lunar phase's observations where V-vivid line is the axis of time and the strokes of different lengths marked phases of the Moon. The same example allows us to discuss tentatively Paleolithic cultural astronomical knowledge that was unearthed in Kiev, at the Kirilovskaya Street (Kiev-Kirilovskaya settlement) by the famous scientist V. Khvoiko (1850-1914) in 1893. A mammoth tusk piece of 30 cm in length (Fig.A13.1), the same as the find from Gontsy, has primitive indentations, V-vivid line and strokes ornamentations bein likely the grooved ancient calendar of lunar phases (see, for example, explanations in Frolov (1977); Zosimovich (1992), p. 13; Vavilova (2010)). This tentative interpretation allows us to conclude that we met a unique example of the primitive humans' skill not only to mark the changes of the Moon phases but also to keep an account of time.

The rest of another upper Paleolithic settlement on the right bank of Desna River near Mezin village, Chernihiv region, was found accidentally in 1908. Because the archaeological expeditions were undertaken in 1930, 1932, 1954-1956 years and now, the Mezin Paleolithic settlement is placed among the most studied sites in Ukraine. Among the finds, there were two preciously ornamented bracelets engraved out of mammoth ivory. These

Paleolithic bracelets (Fig.A13.2) dated back to about 20,000 BCE, and according to Okladnikov (1967): "... are the authentic masterpieces of bone-carver art, causing a surprise due to that they are executed by the stone instruments, without a lathe, drills, and chisels. A bone material for these decorations had an exceptional aesthetic value". The detailed descriptions of these finds as well as other unique Mezin's examples of utensils and primitive art were presented in Shovkoplyas' monograph (1965). It appears that an explanation of the bracelets' patterns is related to lunar calendars based exactly on the period of 10 lunar months or 280 days (see Abramova (1962), table XXXIV; Shovkoplyas (1965), Frolov (1977), Pidoplichko (1998), and Vavilova (2010) for more detail). It coincides with the period of pregnancy for women, and could be chosen by the primitive people as an obvious unit of measurements for all observational events related to the Moon.

A region of interest to compare with is the Crimean peninsula where some Paleolithic settlements of the Mustier epoch (100 - 40 Millenniums B.C.E.) are widely represented. Among them are the well-known Neanderthal Shaitan-Coba, Staroselie, and Ak-Kaya settlements as well as Volchy (Wolf) and Chokurcha Grottos that are decorated by primitive wonderful art works.

Fig.A13.1 (upper) Fig.A13.2 (down). 1) The pattern on the *mammoth tusk fragment* from the Paleolithic Kiev-Kirilovskaya settlement, which is interpreted as the ancient calendar of lunar phases;
2) The Paleolithic *Mezin wide bracelet* engraved out of mammoth ivory: the ornament was interpreted as an ancient lunar-solar calendar.
National Museum of History of Ukraine. Photos by T. Artemenko

Fig.A13.3 (right). The different utensils with a cosmic symbolism belonging to the *Tripolye Culture*.
a, b, c, g) *Tables of Moon' symbols, Moon' sacral metaphor, "Solar boat", and Pryasla* (Burdo (2004)); d) *Vessel with a snake-like ornament*; e) *Binocular-shaped object* (reearthed in Vinnitsa region); f) Typical *vessel with a life-plant ornament*; h) *Sculptures* made by Tripolye' people (Videjko (2004)).
National Museum of History of Ukraine. Institute of Archeology of the NAS of Ukraine.

Eneolithic era. The so-called Tripolye Culture belongs to the period between the second part of the VI-th Millennium and the beginning of the III-rd Millennium BCE. The first finds of this culture were revealed in Cucuteni in Romania and later in the East Galychyna in Ukraine and other areas. The latter is because of the hard work of V. Khvoiko, who discovered this culture at Tripolye village (near by Kiev city) in 1896, and this culture took the name of Cucuteni-Tripolye Culture in the English-language sources.

At the beginning of the XX-th century, the Tripolye Culture was studied by V. Dymitrykevich, K. Gadachek, E. Schtern, A. Spitsyn, M. Bilashivsky, Hv. Vovk, and later on by V. Kozlowska, T. Passek (1935), S. Bibikov, E. Chernysh, V. Markevich, T. Movsha, M. Shmaglij, V. Kruts, M. Videjko (2004) and others. The Tripolye Culture in Ukraine spread out across the forest-steppe region from Carpathians to Dnipro River. From nearly 4400 settlements belonging to this culture found in Romania, Moldova, and Ukraine, 2040 were revealed in the territory of Ukraine.

The Trypillya people worshipped the Sky and the Sun, observed the movements of celestial bodies, and there is some evidence suggesting that such observations played significant role in their life, as it was supported by the discovery of remains of astronomical observatory (Passek (1935), Burdo (2004)). Among examples of the Tripolye Culture art, the unique ornaments on the various ceramic utensils with their mythological astronomical symbols are of great interest (Fig.A13.3). The utensils have been made without a potter circle from potter clay with admixtures of quartz sand and shells of freshwater shellfishes. They can be classified by the used paint color (mainly in black or brown), bichrome (black paint was outlined white or red), and polychrome ones. As far as ornaments is concerned, the spiral (similar to the ornamentation kamares techniques of the Minoan Crete) and cannelure ornaments dominated in early stages of the Tripolye Culture.

The potteries belonging to the middle Tripolye Culture are characterized by the more detailed ornamentation and painting, and the same is true for the late Tripolye period (Bronze Age) when the rope and die patterns appeared. While the technique of making ornamentation was different in different regions among the Tripolye human beings, the design was more or less universal: stylized curvilinear representations of snakes, rain, the Sun, lunar phases, and female breasts. “There are two basic types of pottery that have been discovered: crude pottery with little or no ornamentation, evidently for use as kitchen utensils; and richly decorated pottery of fancy shapes which was hardly used in everyday life. Perhaps, the pear-shaped pots with wide shoulders and narrow opening; helmet-shaped bowls or covers; bowls with openings in the bottom; small saucers with four tiny legs and with heads of horned animals for handles; binocular-shaped objects” (Mykhaylova, 1999), which served as the ritual objects and had an exclusive role in the life of Tripolye people.

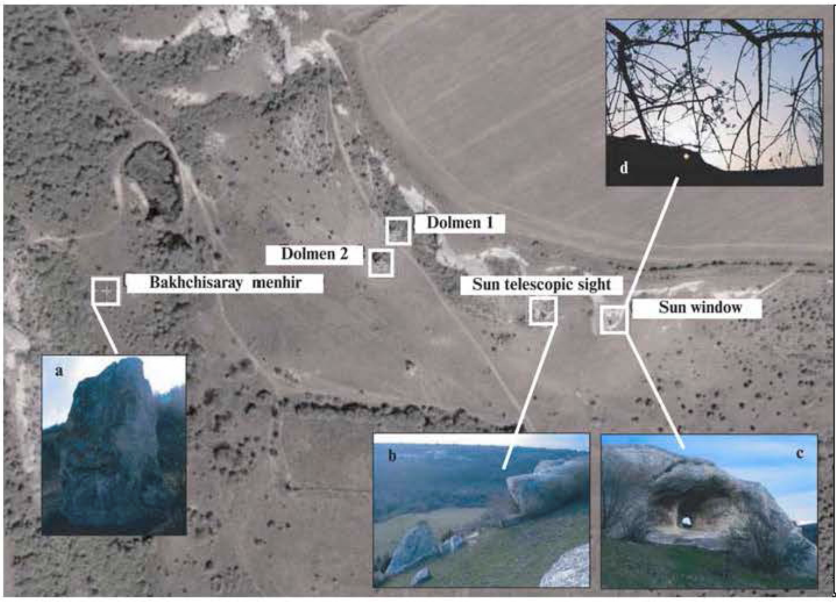

Fig.A13.4 The *Bakhchisaray menhir* (II Millenium B.C.E.) at the Google Earth map: huge ancient astronomical instrument allowing to observe an ascending and descending Sun exactly in the days near the equinoxes (photos 4a-c from http://www.starlion70.narod.ru/page4.htm, photo 4d by A. Terebizh).

Researchers classify the Tripolye ornaments in several types depending on the concepts of these ancient people about the Universe and Space phenomena: vessel-Sun, vessel-Moon, vessel-Heaven, vessel-Earth, and vessel-Universe (see, for example, Passek (1935); Rybakov (1981), chapter 4; Chmyhov et al. (1989)). A lot of ornaments contain the “running spirals” and “snake-like images” as the symbols of infinity and time.

Symbols of the Moon, as well as “solar boats”, which are the most numerous in Tripolye finds, reflects a synchronous rhythm of life of ancient people with events in the foreground. The images of animals belongs to the Moon and just as in case of the Moon disappears and appears, an example are the images of bears in hibernation, disappearing and then appearing again. The patterns of a “solar boat” are depicted often with the wavy lines and symbolize the God of the Sun which is “floating on the heavens” (Burdo, 2004). Other finds are the spindles and “pryasla” (spindle whorls) with solar and zodiac signs as a special kind of cosmic wheel which has been interpreted as symbolizing a string of destiny, time, and life creation. For example, seven constellations of spring-summer zodiac cycle are represented on the pryasla revealed in Tatsenky village, Kiev region, and they are widely exposed in Ukrainian museums. As a whole, the design of the paintings on Tripolye pottery is a carefully thought out complex system having three-tier structure: a) an upper tier with the wavy lines, symbolizing water; b) a middle tier containing solar symbols, often as a circle with a cross in the centre (the four cardinal points) or vertical bars (raining); c) a lower tier having the Earth symbols (shoots, roots, grain fields, animals etc.). Such a “Water-Sun-Earth” vertical cut which is presented on the vessels and bowls demonstrates the cosmogony concept of these ancient people.

Fig.A13.5 a) The *vessel with the agricultural calendar* (IV century. AD) reearthed in Kiev region
b) Interpretation of this calendar by B. Rybakov (1962).
National Museum of History of Ukraine. Photo by T. Artemenko

In 1900, Pablo Picasso who visited an exhibition of Tripolye ceramics held in Paris, expressed his admiration and decided to start creating his own ceramics. He said: "These works of art are excellent examples for modern artists to follow — look at these fantastic shapes of earthenware, look at these elegant ornaments!" (http://www.wumag.kiev.ua/index2.php?param=pgs20052/92).

The Tripolye pantheon, similarly to other cultures of this kind, had Mother-Earth as the head deity. The image of the Woman-Primogenitor is closely connected with the image of the Earth-Bread-Giver. The Tripolye representations of the supreme deity usually took the form of figurines covered with ornaments. With the passage of time, this image went through several changes. At early stages the image of Mother-Goddess emphasized her childbearing function with hypertrophically represented features of her female gender. To clear up the point, a symbol of grain-sown field was carved over her lap. Later the goddess was represented as a slender woman with expressive facial features and carefully arranged hair - some researches claim that the face have even had a sort of make-up. Some representations show the goddess as a pregnant woman with a grain symbolizing the yet-unborn child. The Tripolye Mother-Goddess had companions: the Bull which was the symbol of impregnating male power known to many early cultures and being a prototype of Zeus-Jupiter$ and the Serpent, the intermediary between Earth and the Sky, patron of life-giving rain - it could be possibly linked to the later interpretation of Serpent, similar to the one found in the Biblical story (Mykhaylova, 1999).

Among the most interesting Eneolithic astronomical sites pointing out to an existence of the ancient observatories, the Crimean menhirs near Bakhchisaray city (megalithic stone stelae, II-nd Millenium BCE old) is to be mentioned. Not as large as Stonehenge, it is a real astronomical cult place (Fig.A13.4). In 2000-s the Bakhchisaray menhir (44° 46' 06.5" N, 33° 54' 57.2" E) was studied in detail by A.F. Lagutin from the Crimean astrophysical observatory. He discovered that if to get up near the menhir and look Eastward, it is possible to see a window in a rock on the opposite side of beam (in the distance approximately 300 m), through which the sky is observable. This window (60cm x 120 cm) with the 1-m walls is of handmade origin and cut down in the back wall of grotto of about 3 m deep. If you step back from the menhir a few meters in any direction, then visibility of road clearance though this alignment is not evident. A.F. Lagutin supposed that menhir (Fig.A13.4a, b) and distant window (Fig.A13.4c) were dioptrical sights of a huge optical instrument, fixing the East-West direction in which only during the days of vernal and autumn equinoxes' one could evidently observe the ascending and descending Sun. Lagutin took a few seasons (because of morning fogs and clouds) in order to collect data in support of this hypothesis, and success was enchanting: the rays of an ascending Sun through this window in a rock went straight into the eye of an observer standing at the menhir (Fig.A13.4d).

New era. Territory of the modern Ukraine has been populated by Slavic tribes in the I-st century BCE. The archeological finds of Zarubintsy Culture of the early Eastern Slavs belong to this epoch. Besides, the Chernyakhiv Culture which replaced it in the middle of III-rd century AD was widely represented until IV-th - middle of V-th century AD. Chernyakhiv, as well as Zarubintsy Cultures, were revealed by V. Khvoiko in the Kiev region. At present, more than 2000 settlements and burial grounds of Chernyahiv culture in Ukraine and Moldova have been discovered. The most remarkable astronomy calendar images representing the Zarubintsy Culture were discovered on the utensils from Lepesovka, Chernyahiv, and Romashky settlements in Ukraine. As an example, the image of vessel-calendar from Romashky village, Kiev region, discovered by V. Khvoiko in 1899 and dated IV-th century of our era, is shown in Fig.A13.5. This pattern was investigated in details by B. Rybakov (1962) and identified as the agriculture calendar from the period of May 2 to August 7 (terms from the young shoots to the harvesting holidays, exactly in coincidence with the terms of wheat maturing in the Kiev region.

Conclusion. Ancient astronomy as the mirror of national cultures reflects the knowledge of our ancestors about the Sun, the Moon, and stellar constellations. It likely demonstrates also their deep reverence and worship of the heavens through a cosmological pantheon. They used these symbols like books and passed on their knowledge to the new generations. This unique culture should be collected, described and preserved in all countries. In this context, launch of the UNESCO project purposed to save the world astronomical heritage is highly appreciated in Ukraine.

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A14. ANCIENT SOLAR OBSERVATIONS FROM ROCK SANCTUARIES at East Rhodopes, Bulgaria

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Abstract. Two very impressive sanctuaries from the East Rhodopes are analyzed and shown as examples of observations of solar extreme rises and meridian culminations – Tatul and Tangarduk Kaya. The Tatul rock sanctuary is situated at a rock hill near the village of Tatul, Momchilgrad Municipality. There are a lot of rock cuttings. Some of them are oriented towards sunrise at winter solstice and others towards the sunrise during vernal or autumnal equinox. These orientations show that regular observations of the Sun had been conducted and used for cult purposes and as an agricultural calendar. Large amounts of circles of different sizes carved in the rock interpreted as solar symbols have been found in the region of the sanctuary. Tangarduk Kaya cave sanctuary is situated near the village of Ilinitsa, Kardgali district. The different parts of the cave are formed by the natural processes of the Karst formation and by human activity. At the level of the cave gallery floor the entrance aperture is widened and its vertical section is in a special form as if they are seeing from the inside outwards. The end of the gallery is obviously formed as an altar. The archaeoastronomical investigations show that Tangarduk Kaya cave sanctuary could be connected with the cult of the Great Goddess-mother. In the period between 1000 and 2000 BCE the projection of the entrance aperture during the winter solstice reached 0.4 m from the base of the altar. Besides, this cave sanctuary could be used for determining the year's duration and its beginning, with enough accuracy.

The Eastern part of Rhodopes is one of the places in Ancient Thrace where a great number of rock-cut monuments can be seen. Archaeoastronomical investigations reveal that many of them are oriented in such a way that they could be used for astronomical observations. Tatul and Tangarduk Kaya are two very impressive sanctuaries (Fol, 1990. 52-54p., Fol et al., 2000, 171-173p.) from East Rhodopes bein considered as examples of sites used for observations of solar extreme rises and meridian culminations (Stoev et al. 2007, pp. 63-70.), (Fig. A14.1).

The Tatul rock sanctuary

The Tatul rock sanctuary is situated at an elevation h = 401.4 m with the coordinates: $\lambda = 25° 32' 44.1''$ $\varphi = 41° 32' 30.2''$, near the village of Tatul, Momchilgrad Municipality (Nikolov et al., 1988, pp 28-31), (Fig.A14.2). The highest part of the rock is cut in the form of a truncated pyramid. There is a complex at the top of the sanctuary – a sarcophagus, trap-door, and outfall, connecting the "sarcophagus" (Fig.A14.3) with a vaulted niche beneath it, which contain a second "sarcophagus" with the same orientation and the possibility of closing the trap-door (Fig.A14.4). The long axis of the "sarcophagus" is oriented towards the sunrise at winter solstice.

There is a man-made, East-West oriented trench about 2.5 m in length and 0.8 m wide at the ends, at the south part of the main rock. It is narrowed in the middle and resembles the letter "X" if we watch in the horizontal plane. In the middle of the "X" one can see a vertical aperture with 8-10 cm width and 50 cm depth. The line of sight through this aperture is directed to the Sunrise during vernal or autumnal equinox. There are also different "thrones", which could be considered as places for observation of natural or artificial marks on the horizon.

Many solar symbols – circles of different size hewn out in the rock – have been discovered in the region of the Tatul sanctuary. We can suppose that observation of the Sun during vernal and autumnal equinox had been used for determining the active agricultural period. Orientation of the sarcophagus's main axis towards the sunrise during the winter solstice is probably connected with a cult festival (Muglova et al., 2007, pp 409-411). The "sarcophagus" is oriented towards winter solstice sunrise in the epoch 1500 – 1200 B.C.E. It is supposed that it is connected with a solar cult – it dies and come into the world again. This marks the end of the old year and the beginning of the new one.

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<td>Fig.A14.1 Displacement of the Tatul and Tangarduk Kaya rock sanctuaries in the East Rhodopes</td>
<td>Fig.A14.2 . Tatul rock sanctuary</td>
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<td>Fig.A14.3 The highest part of the sanctuary and the "sarcophagus" with an axis oriented towards the sunrise during a winter solstice</td>
<td>Fig.A14.4 Voulted niche beneath the top of the sanctuary, which contains a second "sarcophagus" with the same orientation and a possibility of closing with a trap-door.</td>
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<td>Fig.A14.5 Tatul rock sanctuary after the archaeological excavations in 2008</td>
<td>Fig.A14.6 The separate Karst rock massif of the Tangarduk Kaya cave sanctuary</td>
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During archaeological excavations, cult figurines of Orpheus and stairs hewn out of the rock have been found within the territory of the sanctuary (Fig.A14.2). They are probably connected with the Orphic mystical rites.

	
Fig.A14.7 Entrance of the Tangarduk Kaya cave sanctuary	*Fig.A14.8 . Altar of the Tangarduk Kaya cave sanctuary*
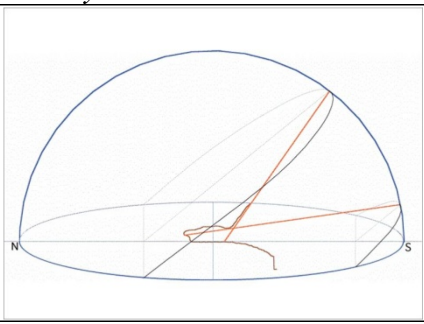	
Fig.A14.9 Vertical plan of the Tangarduk Kaya cave in the meridional plane. Solar beams at culminaton of the sun, at summer and winter solstices and the maximal projections of the entrance are evident	*Fig.A14.10 Vertical projection of the cave entrance*
	
Fig.A14.11 Projection of the Takgarduk Kaya cave entrance on the floor, at noon	

After the excavations in 2006, a monumental temple from the Early Antiquity was revealed. This is evidence of the continuous use of the rock sanctuary – from the Late Eneolithic Age to the Late Antiquity. There are also a lot of sacrificial altars and a huge sacred well for gift keeping, coated with red.

After the archaeological excavations in 2008, the Tatul rock sanctuary has been preserved with shelter constructions, restorations, and conservation activities (Fig. A14.5). There is also a visitors centre in the village of Tatul (1km from the sanctuary).

Tangarduk Kaya cave sanctuary

Tangarduk Kaya cave sanctuary is located near the village of Ilinitsa, Kardgali district. The Tangardak Kaya cave is formed in a separate Karst rock outcrop, close to the ridge of the Ilinitza, elevation h = 618.3 m, $\lambda = 25° \ 15' \ 03.4''$ $\varphi = 41° \ 42' \ 48.6$ (Fig.A14.6). The rocks are Triassic limestone. They have been subject to the strong influence of the endogenous forces (tectonic movements). The processes of physical and chemical weathering have led to the formation of an entrance leading to a widened tectonic fissure, in the base of which there are several small terraces (Stoev et al., 2001, pp 226-235) (Fig. A14.7).

There are two niches on the left wall before the entrance of the cave and other two niches on the wall to the right. An artificial gallery was created following the main tectonic fissure. The gallery is 22 m long and has an average width of 1.5 m. In the foundation, following the fissure, a very sloped corridor was been created. This corridor leads to the entrance of the cave.

At the ground level of the cave the entrance opening of the gallery is widened to its foundation. The vertical section looked at from the inside, has the form of an ellipse with a large eccentricity. The cave's bottom was shaped especially to fulfil the role of an altar (Fig.A14.8). A small terrace is hewn out of the rock underneath the altar. Also, there are two neighbour zones with a nearly elliptical section in the middle of the gallery (Fig.A14.9). The gallery's ceiling has a clearly expressed vault form. One registers sound increase as well as significant reverberation (a loud noise repeated as an echo) and very long echo in the focuses of the vaults. Maximal increase of the sound intensity and reverberation time are in the region of lower sound frequencies.

The astronomical azimuth of the cave's main axis is A=15°08'12". Analysis of the cave's horizontal plan shows that the main axis follows the development of the tectonic fissures in the Karst outcrop. The clearly expressed orientation of the cave's main axis, which is near the main meridian (North-South), as well as the quality of the entry opening (Fig.A14,10), which projects itself maximally along the gallery one hour after noon, gives a reason to seek astronomical meaning in the geometric sizes, orientation and morphology of the cave.

The equation $h_{max} = 90 - \varphi + \varepsilon$ is executed in the point of the summer solstice (where the solar declination δ is at its maximum, and equals the slope of the ecliptic ε). For the contemporary epoch, for which $\varepsilon = 23° 26' 24''$, the distance between the peak of the entrance projection and the altar's foundation is 10.60 m. In the point of the winter solstice the solar declination δ is negative and at its maximum, and equals to $-\varepsilon$. The equation $h_{min} = 90 - \varphi - \varepsilon$ is executed and the distance between the peak of the entrance projection and the altar's foundation is 1.10 m.

Considering that the astronomical azimuth A of the cave's main axis is approximately 15°, the height of the Sun will decrease with one more degree (1°). Consequently, the projection will come 0.25 m closer to the altar's foundation. The Sun culminates high above the horizon during the summer and the higher outer contour of the entrance opening is projected on the floor of the gallery. During the winter, when the Sun culminates at lower heights, the lower inner contour of the entrance opening is projected (Stoeva et al., 2004, pp 99-108) (Fig.A14.11).

The slope of the ecliptic decreases with time. This means that in the past the solar height at noon during the winter solstice, it would have become smaller and smaller; meaning the light from the entrance's projection would have crept closer and closer to the altar. For example, between 2000 BCE and 1500 BCE the projection of the entrance opening did reach up to 0.4 m from the altar's foundation. That is why we can suppose that the Tangarduk Kay cave sanctuary was created during the period of Late Eneolithic and Early Bronze Age.

The results of this research demonstrate that this cave-sanctuary can be related to the cult to the Great Goddess-Mother. Once per year solar rays penetrate into the altar, embodying the sacred marriage between the Goddess-mother and the God-Sun.

In addition, the sanctuary Tangardak Kaya could serve as an instrument for determining the length of the year and its beginning with sufficient accuracy. Systematic observations of the positions of the entrance projections during the daily solar culminations allows one to count the days between the winter and the summer solstice. This procedure would greatly facilitate the creation and usage of a primitive calendar and time reckoning with units larger than a day. This usage is intrinsically related to the economic, religious and daily requirements of the socium of that epoch.

Conclusion.

These two sanctuaries from the East Rhodopes – Tatul and Tangarduk Kaya – are in the frames of temple complexes. They are examples of observations of solar extreme rises and meridian culminations. Summarizing, Tatul and Tangarduk Kaya have solsticial alignments, Tatul also has an East-West equinox alignment and circular figures that are interpreted as solar symbols. Cult ceramics and solar symbols are evidence of their continuous use. These sanctuaries are included in many tours of the Kurdjali Archaeological museum and other tourist firms.

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ASTRONOMICAL HERITAGE: PRE-TELESCOPIC OBSERVATORIES

A15. THE JANTAR MANTAR: 18th Century Pre-telescopic Masonry Observatories in India

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The Jantar Mantars are a group of pre-telescopic masonry observatories established by the ruler Sawai Jai Singh II at five locations in the country, namely Jaipur, Mathura, Ujjain, Delhi and Varanasi in the 18th century, to facilitate measurement of celestial position and movement. The instruments called yantras were designed and built to measure astronomical quantities such as declinations, altitudes, eclipses and times of the sun, moon and other planets at different times of the year.

While the observatory at Mathura is now lost, the four existing Jantar Mantar Observatories in India are historico-cultural monuments that continue to serve as a knowledge base for astronomical studies. In contrast to the observatories at Jaipur, Delhi and Varanasi that have now become surrounded by tall buildings, the Ujjain observatory is still in an isolated place and no man-made structures seriously obstruct the view of the sky from its instruments. While all of the five observatories were constructed during the lifetime of Sawai Jai Singh II, in his prime period between 1718 and 1738, the exact order of construction of each of the observatories has not been clearly established.

In India, before the time of Sawai Jai Singh II, there was no precedent of observatories in the country. Though a number of instruments are described in the Hindu school of astronomy, there is no trace of any early Hindu observatory. Also, though there is reference in history to an observatory constructed by Humayun near Delhi, it is not corroborated by any physical evidence to date. Hence, the observatories at Jaipur, Varanasi, Delhi and Ujjain are the only existing pre-telescopic masonry type historic observatories in the country, of which the Jaipur one is the largest, with the maximum number of instruments, and in the best state of conservation.

These observatories are the only pre-telescopic masonry type observatories in India. Later significant observatories were the Madras Observatory set up in 1786 CE and the Kodaikanal Observatory that boasts of one of the world's oldest extant telescopes, established in 1899 CE. Both are telescopic observatories that are a different group entirely, not directly comparable with the pre-telescopic ones. Hence, the group of Jantar Mantar observatories in India is the first and last example of pre-telescopic astronomical establishments in India, the later ones being post-telescopic observatories.

A number of translated Islamic and European texts were consulted by Sawai Jai Singh II along with information about the instruments used at Maragheh and Ulugh Beg's Observatory at Samarkand through emissaries sent for explorations. The British at Surat sent globes and maps of the universe to help Sawai Jai Singh II in his studies, at the ruler's request.

Jesuit priests came to Jaipur in 1728 and 1734 to visit the astronomical observatory. Sawai Jai Singh II wrote to the King of Portugal for an advisor on astronomy, as a result of which Padre Manuel Padre was sent to Jaipur from Goa. After seven years of observations had been taken from the Delhi Observatory, the Jaipur ruler sent Padre Manuel Padre to Europe, to get the latest tables in around 1728 or 1729. By this time, the Uraniborg (1576), Leiden (1632), Paris (1667), Greenwich (1675), Berlin (1705), St Petersburg (1725) and Upsala (1730) Observatories were known to have been built (Kaye, 1918).

Sawai Jai Singh II built the observatories with the intention to provide more precise readings of the positions and movements of the known planets, the fixed stars, the sun and the moon, so as to construct almanacs in the service of astronomy and the state. He simultaneously recognised the religious significance of astrological considerations in India where these aspects were central to all important activities and events from marriages to military maneuvers. Secondly, Sawai Jai Singh II built large masonry instruments as he thought experiments with small ones had produced inaccurate readings. His keen interest in astronomy, mathematics, and accurate instruments had already found expression, well before the 18th century, in personal observations of the skies using instruments of brass constructed according to the Persian-Arabic school of astronomy. When he found that the axes of these brass instruments rapidly wore down, displacing the centre and shifting the planes of reference, he took to personally designing model instruments of stone and masonry.

Sawai Jai Singh II constructed at least 13 different types of astronomical instruments, ranging in height from a few centimetres to 22.6 metres. These were used for his calculations, particularly at the observatories that were built by him at Delhi, Jaipur, Varanasi, Ujjain and Mathura among which the one at Jaipur is the most significant, as previously stated, comprising of the largest number of instruments in a good state of conservation, but also having Brihat Samrat Yantra, the largest sundial in the world.

The Yantra Mandir, commonly known as Jantar Mantar is an equinoctial dial, consisting of a gigantic triangular gnomon with the hypotenuse parallel to the earth's axis. On either side of the gnomon is a quadrant of a circle, parallel to the plane of the equator.

While the accuracy of the masonry instruments at Jantar Mantar Jaipur may be argued by several scholars in context of the contemporary western developments in astronomy, there is no doubt that it stands as a monumental testimony to the pre telescopic astronomical knowledge and discourses thus contributing to the overall development of astronomy, science and architecture across the world. The Jantar Mantar sites of Sawai Jai Singh II were instrumental in the preparation of the mathematical tables Zij-i-Muhammad Shahi, the basis of which was the Zij of Ulugh Beg completed in 1436 that held sway for close to three centuries, before it was supplanted by telescopic data (Kaye, 1918). The intense academic and cultural exchange among Central and West Asian countries, India and Europe that took place with the Jantar Mantar observatories as the focal points of the same, influenced the development of science in India.

The Jantar Mantar sites are monumental architectural ensembles of varying scale and, amalgamate science and religion of 18th century. These reflect the culmination of principles of medieval observational astronomy that stressed on the use of large scale instruments for better accuracy, as interpreted and expressed by the ruler. True to the belief in accuracy being achieved by increasing the scale of instruments, the Brihat Samrat Yantra at the Jantar Mantar, Jaipur is the largest equinoctial sun-dial in the world. While the use of monumental scale goes back to prehistoric times, when megalithic structures imbibed with astronomical associations were erected as landmarks, the precedents of the observatories of Sawai Jai Singh II are Maragheh and Samarkand observatories from the 13th and 15th centuries.

The theoretical foundation for European, Indian and Arabic astronomy is from Ptolemy and Hipparchus. The Greeks used a sun-dial adopted from the Babylonians. A modified version of the same is the Jai Prakash Yantra at the Jantar Mantar Jaipur. The Romans used only the northern part of the hemisphere – Berossos sundial- for observations, known as Chamilah by Arabian astronomers. Ptolemy was the first person to use small movable quadrants. These were improved by medieval astronomers, and became the focal point of many observatories in the east.

A quadrant with radius 20 metres was used at Ray Observatory in 994 CE. According to Al Battani, the Arabs made the quadrant larger to increase its accuracy and, the same principle was used by Sawai Jai Singh II. Al Biruni constructed an enlarged fixed Ptolemic quadrant with radius of about 7.5 metres. A stone quadrant was used first at Maragheh Observatory along with an Indian teak quadrant (Volwahsen, 2001, pp. 22-23). The instruments of the Samarkand observatory and astronomical tables of Ulugh Beg formed the base for the tables and the observatories developed by Sawai Jai Singh II. The formal vocabulary of Jantar Mantar Jaipur and the other four Jantar Mantar sites in India, were inspired from this 15th century Ulugh Beg's observatory at Samarkand, Uzbekistan. Sawai Jai Singh II used his vast reading and knowledge about astronomical instruments from other lands, to modify, innovate and create his own instruments and observatories. He was influenced by the idea of making large scale masonry instruments of his Arab and Turk predecessors. He first constructed brass instruments as per the Islamic books, found Arabic and Persian astrolabes from the time of Mughal Emperor Shah Jahan and used the astrolabe called Yantra Raj for observations.

While in the international context today, the Royal Greenwich Observatory, UK, founded in 1675, is the most well known and most significant observatory in the world, this observatory is a post-telescopic one with metal instruments and for the same reason deviates from the other observatories comparable with Jantar Mantar. The significant pre-telescopic observatories to which the Jantar Mantar, Jaipur can be compared are those at Maragheh, Dengfeng, Samarkand, Istanbul, Uraniborg and Stjerneborg.

A16. ULUGH BEG OBSERVATORY IN SAMARQAND

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Ulugh Beg (1394 – 1449) was born in Sultaniya during a campaign of his grandfather Amir Temur, founder of a huge empire. At the age of seventeen Ulugh Beg became the ruler of Maverannakhr (Transoxiana), a part of his grandfather's state between the rivers Syrdarya and Amudarya with capital Samarqand, which is now Uzbekistan (Fig.A16.1)

Some scholars believe that Ulugh Beg was just a benefactor and that ideas and methods attributed to him actually originated by other people. Yet many facts substantiate his stature as a scientific genius. In a letter to his father who lived in Kashan (Iran) a well-known associate of Ulugh Beg Giyasiddin Kashi wrote: "He (Ulugh Beg) had great skill in mathematics. For instance, once when he was out hunting while riding horseback, he wanted to determine when an event which was known to have taken place on Monday between the 10th and 15th of Rajab 819, had occurred in summer or winter. Although the day in Rajab was uncertain, he determined by a mental calculation in which degree and minute and zodiacal sign the Sun had been. I could not determine the minutes accurately, because it was difficult by mental calculations and the fraction escaped my memory. However, it is certain that none of [the] astronomer[s] whom I have met can carry out that mental calculation without [using] a zij" (Bagheri, 1997). Another story concerns a scribe who lost a notebook containing a list of every bird killed by Ulugh Beg on hunting expeditions, including the date, species and number of arrows used. The scribe, who expected a heavy punishment, was happy to take Ulugh Beg's dictation from memory to reconstruct the list. Not long afterward the notebook was found. To the astonishment of many, there were only a few mistakes in the dictated list, and then only in dates.

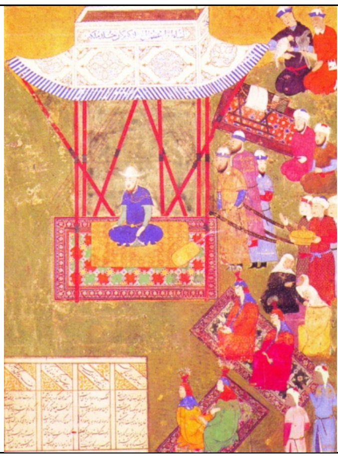

Fig.A16.1 Ulugh Beg on hunting. A XV century miniature. Freer Gallery of Art. Washington

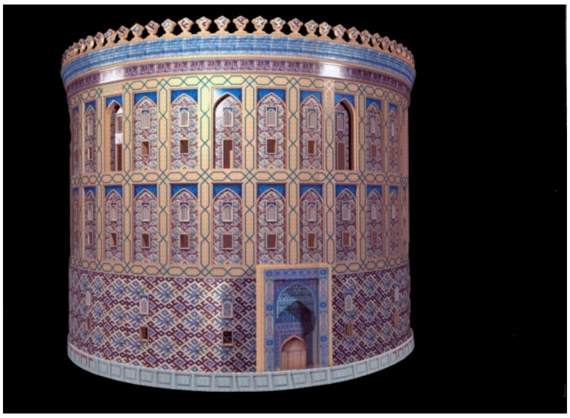

Fig.A16.2 . Ulugh Beg's observatory. A project of reconstruction

Fig.A16.3 The remaining part of the Ulugh Beg's meridian quadrant with a 40m radius

Fig.A16.4 The degrees of arc engraved on the preserved marble plates lined the meridian arc

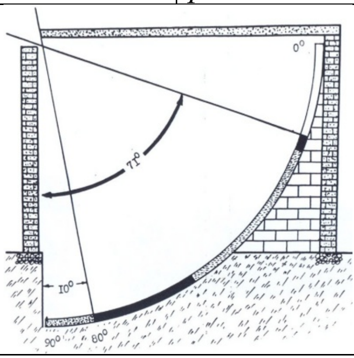

Fig.A16.5 Scheme of the main instrument of the Ulugh Beg's observatory – the meridian quadrant. Preserved marble plates are shown in black

Ulugh Beg used his princely wealth more for education and scientific development than for military and political gain. In 1420 he built a gigantic observatory in Samarqand. This construction was cylindrical in shape, being approximately 48 m in diameter and 35 m high (Fig.A16, 2). Its main instrument consisted of two meridian arcs, with a radius of 40 meters. The arcs were sunk 11 m into the rock at the lowest point while their top rose 30 m above the ground. The remaining underground part of the meridian arcs is shown in Fig.A16.3. It is important to note that the use of two arcs contributed to high accuracy observations. Each measurement was made using both of them, thus canceling out errors due to deviation of the arcs directions from meridian. The arcs were made of fired bricks lined with polished marble plates. The plates were engraved with regularly spaced holes 70 centimeters apart, each corresponding to 1^0. Embedded copper plates contained finer graduations Fig.A16.4.

This instrument probably was used to observe the Sun and the Moon, to determine basic astronomical constants such as the inclination of the ecliptic which is the apparent path that the Sun traces out in the sky during the year to the celestial equator. For instance, the duration of the tropical year – a period between two similar equinoxes (occur around March 21 or September 23) when the Sun passes the point where the celestial equator and ecliptic are intersected was measured to an accuracy of about one minute (Fig.A16.5).

Many years of activity of the Samarqand's observatory resulted in the Zij Ulugh Beg. The main part of the Zij is a catalog of 1,018 stars, which was not known in Europe until 200 years after its original compilations. However, according to the dates of its compilation, 1437, and the number of stars included, it was the first observational catalogue to have been compiled since the second century when Ptolemy reproduced the Hipparchos catalogue in his Almagest (E.B.Knobel, 1917).

To perform these measurements, Samarqand's astronomers had to use instruments other than the meridian arc. However, no description exists of the tools or methods implemented, so we can only speculate and hypothesize. Undoubtedly the Samarqand's observatory was unique and an original construction erected by genius scientists such as Ulugh Beg and his co-workers. Since its excavation in 1908 by archaeologist V.L.Vyatkin, more then ten versions of its constructions were proposed (V.F.Shishkin, 1953). All these versions proposed different approach to explain the shape of the buildings from a closed cylindrical building with astronomical instruments on its roof and using an outer wall as an azimuth instrument, to a hollow construction without roof. We need more information from historical manuscripts of that time to get a more realistic insight into problem of how the observatory looked and operated.

Unlike the instruments, the mathematical methods used in Ulugh Beg's observatory are much better described and discussed in the literature. In the middle ages stellar catalogs gave the latitudes and longitudes of stars using the ecliptic as a fundamental plane. It was thus necessary to transform the measured horizon-based coordinates to the ecliptic system using precise trigonometric tables. The sines of a few angles (60^0, 45^0, 30^0, and so on) were already known exactly from geometrical methods. But the others had to be calculated using multiple-angle formulas and interpolation, and Ulugh Beg used $\sin(1^0)$ as the starting point. Ulugh Beg calculated $\sin(1^0)$ by an original iterative method using base-60 arithmetic. He derived $\sin(1^0)$ as the following row:

$$1/60+2/60^2+49/60^3+43/60^4+11/60^5+14/60^6+44/60^7+16/60^8+26/60^9.$$

This result differs from the value given by modern computers by only $3x10^{-17}$! His trigonometric tables are generally accurate to 8 or 9 decimal places and list the sines and tangents for every arcminute (one-sixtieth of degree) from 0^0 to 45^0. Many other mathematical methods were developed at Samarkand, including the use of decimals well before their use has been standardized in Europe by Simon Stevin in the 16-th century.

Although Ulugh Beg's destiny ended tragically, as a scientist he had been very fortunate. His main achievement - "Zij of Ulugh Beg" had become one of the scientific masterpieces of the Muslim world in 15-th century, followed by its wide dissemination in Europe in the 17-th century. Since then, Zij had been widely commented on, as well as being translated into many languages and had been re-printed (Shcheglov, 1978).

The astronomical observatory in Samarqand epitomizes a brilliant age of astronomical development, and Ulugh Beg himself was undoubtedly one of the key players in its success. However, the most outstanding issue that requires much more robust and systematic research lies in the area of reconstruction of the building of the Ulugh Beg observatory. Unfortunately, there is less known about the main instrument of the observatory - the meridian arcs. Its remaining part is shown in Fig.A16.3. We still lack consensus about specific applications of the arcs as well as many other supplementary tools and instruments that Ulugh Beg and his successors used in their observations. We do not have a list of tools and instruments used; nor do we know about specific methods of observation. Regrettably, most answers to these questions are gone with Ulugh Beg and his successors.

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A17. ASTRONOMY IN TAJIKISTAN: Past, Presenт and Future

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Astronomy has deep historical roots in Tajikistan and other countries of Central Asia. Almost 3000 years from times Reigning Jamshed, people celebrate NAVRUZ as the Day of vernal equinox. Astronomical information is presented in the book of Avesto. Recently astronomical building of 2500 years old were found on East Pamir. Achievements of astronomers of the State of Samanids, as well as the Samarkand’s astronomical school is well known. All these constitute an important segment of the Tajik people culture. Modern astronomy in Tajikistan is rooted in astronomic observatory founded in 1932. In l958 the obsen.atory was transformed in the Institute of Astrophysics of Academy of Sciences of Tajikistan. This is now the centre of astronomy in the country. The Institute significantly contributes in astronomical education and continuous training of astronomical personal. The program of scientific research which the Institute is focused involves the following objects: Small Bodies of Solar system (comets, asteroids, meteoroids), Variable stars, Star formation and evoution, Galaxy dynamic and structure, Earth’s Artificial satellites observations. The advancement of techniques and technology of astrophysical observation is in progress.

Educational programs reforming continues as well. There are special branch of astronomy in the Tajik National University and branch of physics and astronomy in the Tajik State Pedagogical University. Besides, the Section of Astrophysics in the lnstitute of Astrophysics itself has been established. On the base of Hisar Astronomical observatory Training-Methodical Centre “Tajastro" was organized. There are agreements on cooperation with astronomical observatories of Russia, France, and Ukraine, as well as with astronomical societies.

A18. A SURVEY OF LARGE MERIDIAN INSTRUMENTS ACROSS CONTINENTS & TIME

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Abstract: We present an ongoing project aiming at listing and comparing large and fixed meridian instruments through time and across continents. We focus here on Asia, Middle-East and Europe and cover roughly the last millennium. Large meridian instruments not only tell us a lot about basics of the motion of heavenly bodies, but because of their size and proximity to different types of powers, they are also deeply connected to their cultural and historical context. They reflect the multiple scientific, technical and cultural exchanges that occurred between different civilisations at different periods. For all these reasons they represent an interesting vector for addressing astronomical sites into a broad perspective and thinking them as a precious common world heritage.

The concept of meridian in astronomy is at least as old as the use of gnomons for following the motion of the Sun, measuring time, determining the length of the solar year or the day of the solstices. Such observations and measurements were probably discovered independently many times in different cultures. They are, for instance, clearly attested in Greece in the 5th century B.C. [1] or in China in the 7th century B.C. [2]. Concerning heavenly bodies in general, systematic observations of their altitude in a meridian plane were already common at the time of Ptolemy. These were likely performed using relatively small size and portable instruments such as those described in the Almagest. It is unclear when and where larger fixed instruments were built, but these were probably meridian instruments such as quadrants that were used in particular for determining precisely the date of solstices or improving the determination of the obliquity of the ecliptic. Having a fixed instrument opened the way to the possibility of increasing its size. Al-Battani (855-923) had already expressed in his Zij al-Sabi that quadrants should be at least one metre in radius and that any increase in the radius would enhance the precision of the instrument [3].

The present work is an ongoing project aiming at listing and comparing large and fixed meridian instruments through time and across continents. We focus here on Asia, Middle-East and Europe. Putting side by side these instruments offers several interests in the framework of a general reflexion on astronomical world heritage. A first essential point is that these fixed instruments, outstanding by their size, required by nature a permanent establishment and were therefore intimately related to the development of astronomical observatories. Until the beginning of optical astronomy it can even be stated that the building itself is a part of the instrument (e.g. large sextant of Samarkand observatory). A general consequence of the need for large and complex architectural pieces is that large meridian instruments could rarely exist without the financial support of a state. In return, the state would benefit from the dedicated large masonry works that acted as strong symbols of power. As a matter of fact, observatories not only were centres of knowledge but they also provided astrological predictions for the important decisions of the state (Chinese Astronomical Bureau, Maragha observatory for the Ilkhan Mongols, etc.). In addition, they played an essential role in their administration or in religious affairs by setting up calendars. Meridian observations were also crucial for determining latitudes and more generally for mapping the Earth. With the advent of telescope combined to instruments measuring angles, programmes of meridian measurements spread from the 18th century onwards in all the important observatories in Europe. The ambitious long term programmes that were set cannot be understood without stressing the symbolic importance of the official observatory, a token of stability, integrity, order and permanence. For all these reasons, large meridian lines or arcs and the more recent telescopic meridian instruments at the centre of state observatories not only were essential for determining the positions of heavenly bodies. They also were the main device to anchor space and time for most human societies until the development of astronomy in space maintaining a deep connection to their cultural and historical context over a very broad period.

In the following we shortly review some of the main steps in the development of large meridian instruments that covers about one millennium. This review does not pretend to be exhaustive but aims at setting some landmarks for a general history of these fascinating instruments and their related sites (or rather "histories" as all these instruments are not necessarily interconnected).

Middle East, Central Asia and India

It is unclear when the first large fixed quadrants or sextants were built. They were probably associated to the development of the first observatories, important institutions of Islamic astronomy that appeared under the caliphate of al-Ma'mun (813-833) in Baghdad and that lasted until the 18th century [3]. During the eighth and ninth centuries, old Indian and Greek books were translated into Arabic, such as Ptolemy's Almagest translated into Arabic for the caliph al-Ma'mun in the late 820's. Many of Ptolemy's results were tested, improved and discussed thanks to the developments of both theoretical works and intense observational programmes. The latter led to better measurements of the length of the year, and to questioning the invariability of the obliquity of the ecliptic or the constant character of the precession of the equinoxes. They also led to the elaboration of new tables of the sun and the moon as well as new stellar catalogues.

Although it is possible that some of the first observatories already used large instruments, the first clear mention is the large meridian sextant (radius of 20m) built by the Persian astronomer al-Khujandi (940-1000) in Rayy. Then, the two most emblematic large sextants of this tradition (still partly visible today) are those constructed in Maragha (1259) by Nasir al-Din al-Tusi (1201-1274) under the rule of the Ilkhan Mongols and in Samarkand (1420) by the Timourid prince Ulugh Beg. These two institutions had an enormous influence over a large geographical area even if the importance of this influence is still debated in some cases (as for Europe for instance). A clear filiation is however established in the case of the Istanbul observatory (1577) where large meridian quadrants were built, as well as in West central India where the maharajah Jay Singh built between 1724 and 1734 five observatories including large meridian instruments in the cities of Jaipur, Delhi, Benares, Mathura, and Ujjain [4].

China.The use of gnomons to determine the dates of solstices in China is ascertained in 654 B.C. in a passage of the Tso Chuan [2]. As noted by Needham in his monumental Science and civilisation in China, Chinese made extensive use of gnomons in their practice of astronomical observation. It is precisely based on that instrument that Chinese astronomers built in 1276 the Tower of Chou Kung, a pyramidal 12m high gnomon for accurate measurements of the sun's shadow lengths at the solstices at Kao-chheng. Although independent in character, it was erected in the presence of astronomers from Maragha observatory in Persia, both observatories being under Mongol rule at that time.

Europe. The first emblematic mural quadrant in Europe is the famous two metre radius quadrant of Tycho Brahe (1582) installed in Uraniborg, his observatory on the island of Hven. This instrument has been a constant reference for three hundred years. It was followed during the 17th century by several others with added improvements as for instance the 10-foot mural quadrant from Robert Hooke made for the Royal Observatory and later the 7-foot mural arc made by Abraham Sharp in 1689 and used by John Flamsteed who pioneered the use of telescopic quadrants leading to the construction of the largest star catalogue at that time (~3000 stars).

This instrument is intimately related to the early years of the Royal Observatory of Greenwich whose first director, in 1675, was Flamsteed.
The Royal Observatory of Paris, first institutional observatory in Europe founded in 1667, has been organized around the meridian direction. Its main mission was the establishment of precise maps, both terrestrial and for navigation. However, it is interesting to note the absence of any large meridian instrument at the construction of this new building, a consequence of the views of the architect Perrault which were not shared by astronomers. Such a lack has been stressed many times by French astronomers all along the 18th century. This missing large mural quadrant was eventually installed at Ecole Militaire in 1779. It was originally built by Bird in London and was finally transferred to Paris Observatory in 1800.

The 18-th century in Europe has been the witness of major changes both in the institutionalization of astronomy and in its practice. New standards of practical astronomy were set up in parallel to the creation of many new professional observatories. Aiming at improving significantly the accuracy of stellar positions led to searching for higher stability of the instruments. With such a constraint, programmes of meridian measurements became central to all important observatories. Additionally, building large astronomical instruments became a specialized activity, in particular after George Graham who initiated a school of instrument making in England and defined a full suite of observatory instruments. His mural quadrants, with the adjunction of optics and thanks to major improvements in the design of very accurate graduations, gained importance along the century [5]. Following the 8-foot model he built for Edmund Halley in 1725 at Greenwich, large-scale fixed quadrants gradually spread across the observatories of Europe [6]. In parallel, the development of precise clocks associated to meridian instruments played an increasing role in the determination of right ascensions. In this method, the observer records the time at which the object crosses the observer's meridian. This concept, which can be attributed to Jean Picard in the 17th century, started to be intensively used by Ole Roemer with the precision pendulum clock developed by Dutch physicist Christiaan Huygens, but found its full development only in the 19-th century.

In parallel to the development of large meridian instruments in private or professional observatories, another type of meridian observations spread across Europe in the same period: the meridian lines of churches or cathedrals. These are worth mentioning in the present context even if they are not performed within a building dedicated to astronomy. Meant to help the calendar reform by predicting precisely the day of the equinox long in advance [7], they were also, in several cases, made under the initiative of professional astronomers and designed to answer questions such as the variation of the obliquity of the ecliptic. San Petronio cathedral in Bologna is an interesting example as in addition to a first line designed by Ignazio Danti in 1575, the famous astronomer Jean-Dominique Cassini repeated the exercise in 1653-1655 and performed measurements until the end of the 17-th century leading to original astronomical results [8]. Influenced by San Petronio, J.D. Cassini, who became the first director of the Royal Observatory of Paris, is also at the origin of the meridian room of this observatory. Other interesting examples are the meridian lines of 1727 and 1743 in Saint-Sulpice church that were used by astronomer Pierre Charles Le Monnier to asses the variability of the inclination of the Earth's axis. Such measurements based on meridian lines in religious buildings were superseded by much smaller and more precise instruments and abandoned after mid-eighteenth century. There are still several hundred churches in Europe hosting meridian lines.

At the beginning of the 19th century, a new category of meridian instruments, meridian circles, superseded large mural quadrants for providing the most precise measurements of stellar altitudes [9]. The concept of meridian circles goes back to the 1694 Rota meridiana of Ole Roemer [10] that became the model of transit instruments thanks to the minimization of mechanical constraints. The further improvements of the design eventually made this instrument the most adequate not only to measure the precise moment a star would cross the meridian plane but also simultaneously its altitude. Associated to precise clocks, meridian circles were therefore able to provide simultaneously right ascension and declination. The prototype for such instruments was installed in Pulkovo observatory in 1839 and became the dominant model for all 19th century observatories (see e.g. [11]).

After 1890, star mapping activity changed in depth with the use of photography. It also started to be organized in an international collaborative effort with the Carte du Ciel project initiated in 1887 by Paris Observatory director Amédée Mouchez. If meridian observations were still essential to anchor the positions of the brightest stars until the 1990's, the situation changed with the astrometry space mission Hipparcos launched by ESA in 1989, and with the definition in 1998 of the International Celestial Reference Frame based on the radio positions of 212 extragalactic sources distributed over the entire sky. However, it is interesting to note that the Hipparcos mission did not put an end to meridian observations that are still being performed for instance in La Palma with the Carlsberg Meridian Telescope. This telescope, first fully automatic telescope (1984), continues to measure positions of stars fainter than those accessible by Hipparcos.

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A19. THE « CARTE DU CIEL » OR THE «GREAT STAR MAP» HERITAGE ACROSS CONTINENTS

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In April 1887, the French Academy of Sciences invited astronomers from all over the world to attend an International Congress of Astronomical Photography in Paris. As a result a scheme was approved to launch the photographic mapping of the sky by the concerted action of eighteeen observatories in both hemispheres. This very early scientific international cooperation required that each observatory was equipped with a 13-inch astrographic refractor having the same specificity as the one developed and perfected by the Henry Brothers (optics) and Paul Gautier (high precision mechanics) in Paris.

We shall first evoke the survey of the astronomical sites and instruments involved in the « Carte du ciel » which has been undertaken recently in France and in Algeria. Then we shall discuss the interest in terms of international astronomical heritage of launching a survey of all the astronomical sites involved - two of which being Pulkovo and Tashkent.

B. ASTRONOMICAL OBSERVATORIES OF XVII–XIX CENTURIES

B1. ASTRONOMICAL HERITAGE – Solar Observatories and Instruments, 17th to 19th century

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Abstract. Christoph Scheiner (1575–1650) observed the sunspots in the Jesuit college in Ingolstadt since 1611. The sunspots were recorded in the important observatories like Greenwich, Paris or Danzig (Gdansk). In the middle of the 19th century a significant upturn in solar research started with the discovery of the 11 years cycle and the beginning of astrophysics, especially with photography and spectroscopy of the Sun. The most important observatory was the ETH observatory, built in 1861–1864 by Gottfried Semper (1803–1879). Further observatories should be mentioned: Kew Observatory, Potsdam Astrophysical Observatory, Collegio Romano in Rome, Kalocsa Observatory, Hungary, Meudon and Pic du Midi, France.

1 Introductory Remarks

In this article the solar observatories from the 17-th until the 19-th century are presented with the emphasis on the observation of sunspots in private and professional observatories. These are mainly no observatories in the classical sense but only observing posts for the analysis of sunspots. Then the introduction of solar physics is discussed (see also Wittmann et al. 2005), the analysis of the three layers of the Sun (the photosphere, chromosphere and corona), with the help of spectroscopy, photometry and photography, which started in the middle of the 19-th century.

2 Scheiner's Solar Observatory in Ingolstadt, 17-th Century

Around 1608 the most important new instrument was invented – the telescope, but there were not yet special observatories; most observations were carried out from towers, balconies or roofs. Astronomical observations of the Sun started in 1609 by different astronomers like Galileo Galilei (1564–1642), Thomas Harriot (1560–1621), Johann Fabricius (1587–1617) and Simon Marius (1573–1624). The most accurate observations were made by Christoph Scheiner (1575–1650), 1610 to 1616 professor in the Jesuit College Ingolstadt (Scheuerer, 2005). Almost since the establishment of the Society of Jesus in 1534 by St. Ignatius of Loyola, Jesuits have founded colleges, often combined with observatories. Scheiner began to observe sunspots in 1611, together with his assistant Johann Baptist Cysat (1587–1657), with an astronomical telescope (Kepler type) on a special parallactic mounting (projection method). Two observing posts were available: a plattform of the Jesuit College and the tower of Kreuzkirche (the church of the College). By carefully observing the apparent paths of sunspots across the solar disk, Scheiner correctly concluded that the Sun's rotation time is 27 days and the inclination of the rotation axis is 7°. Finally Scheiner published his results in Rosa Ursina sive Sol (1630). The Orbansaal of the former Jesuit College was established in 1725 as a museum, to accommodate the extensive collection of Father Ferdinand Orban. The stucco and the planned but not executed ceiling frescoes should also document together with Orban's exhibits in the museum a synthesis of the arts. Four wall paintings of famous Jesuit astronomers in the shape of a contrabass (so-called "Bassgeigenbilder") are shown in the corners: Christoph Scheiner and Johann Baptist Cysat of Ingolstadt, Athanasius Kircher (1602–1680) and Christoph Clavius (1537–1612) of Rome, painted in 1725 by Christoph Thomas Scheffler (1699–1756).

Observations of sunspots were also made for example in Greenwich Observatory, founded in 1675. The leading architect Sir Christopher Wren

(1632–1723) erected the Royal Greenwich Observatory for the first Royal Astronomer John Flamsteed (1646–1719). But only very few sunspots coud be observed from about 1645 to 1715, due to the so-called Maunder minimum (Meadows, 1970). Walter Maunder (1851–1928) and his wife Annie Maunder (1868–1947) observed in Greenwich observatory. He created the graphical representation of the result, the butterfly diagramme.

3 Solar Observatories in the 19-th Century – Sunspot Observations and Solar Physics

In the 19-th century the Sun was observed in several private observatories besides the professional observatories (Hufbauer, 1991), for example in Carrington's Observatory Redhill (1852, no longer existing). Samuel Heinrich Schwabe (1789–1875), pharmacist, botanist and astronomer, started in 1825 with solar observations using a Fraunhofer telescope. He built an observatory on the top of his pharmacy in Dessau in 1829, which is well renovated. In 1838, Alexander von Humboldt (1769–1859), and also Richard C. Carrington (1826–1875), visited Schwabe's Observatory. Schwabe's sunspot observations continued for 42 years. In 1843 Schwabe had discovered a 10-year periodicity in the number of sunspots visible on the solar disk. Curiously, Schwabe's astronomical researches initially won him greater recognition in England than in Germany; in 1857 Schwabe was awarded with the gold medal of the Royal Astronomical Society.

From 1807 to 1819 the optical workshop was established by Utzschneider, Reichenbach & Liebherr in the former Monastery Benediktbeuern – after monasteries were closed in 1803. Joseph von Fraunhofer (1787–1826) was head of the glass melting laboratory. He observed and examined the solar spectrum in Benediktbeuern, discovered more than 500 dark lines and accurately measured their position. He labeled the most prominent spectral lines with letters, establishing a nomenclature that survives until today. His aim was to improve the achromatic telescope by exact measurement of the refractive index. Fraunhofer's workshop in Benediktbeuern with the glass melting laboratory (melting furnaces and stirring device) is still preserved and presented as an astronomical museum; it could be regarded as a remarkable starting point for solar physics.

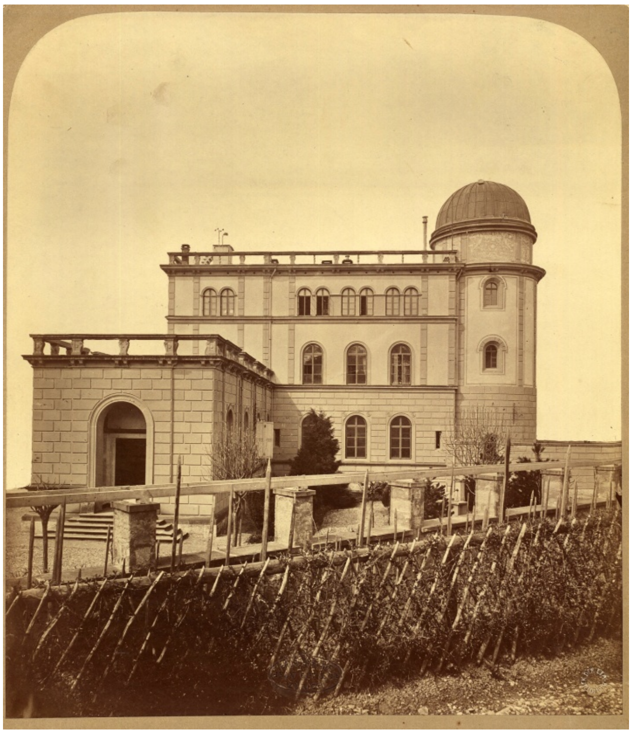

Fig.B1.1 ETH Observatory Zürich, Gottfried Semper, 1861-1864 (Museum für Gestaltung, Zürich)

The most important solar observatory in the 19-th century was the ETH Observatory (Fig.B1.1) of the Eidgenössisches Polytechnikum (Confederate Polytechnical School, today "Swiss Federal Institute of Technology") in Zürich, Switzerland. The Observatory and the Polytechnikum were designed and built in 1861–1864 by the famous architect Gottfried Semper (1803–1879); the dome was erected according to the ideas and specifications of the astronomer Rudolf Wolf (1816–1893) and the well-known engineer Franz Reuleaux (1829–1905). The second floor was used by the meteorological central institute. Semper was appointed as first professor for architecture in 1854 in the just founded Eidgenössisches Polytechnikum. Semper was admired already by his contemporaries as "Michelangelo of the 19th century" (Friedli et al. 1998). Semper is famous besides his buildings – like the Semper Opera in Dresden und Frankfurt, buildings in London and Winterthur as well as monumental buildings like the Kaiserforum in Vienna – for his theoretical and reformatoric work in architecture. The main instrument of the ETH observatory was a refractor in the dome. By analyzing sunspot observations carried out by many different astronomers using various instruments and observing techniques, Rudolf Wolf defined the relative sunspot number. Already since 1928 new buildings like the university hospital and the district heating plant were added near the observatory and disturbed the observations. The ETH Observatory in Zürich (Schmelzbergstrasse 25) was used until 1980, put under monument protection in 1981 and restored in 1995–1997, then the Collegium Helveticum, an interdisciplinary research institute of the ETH, took over the building (1997).

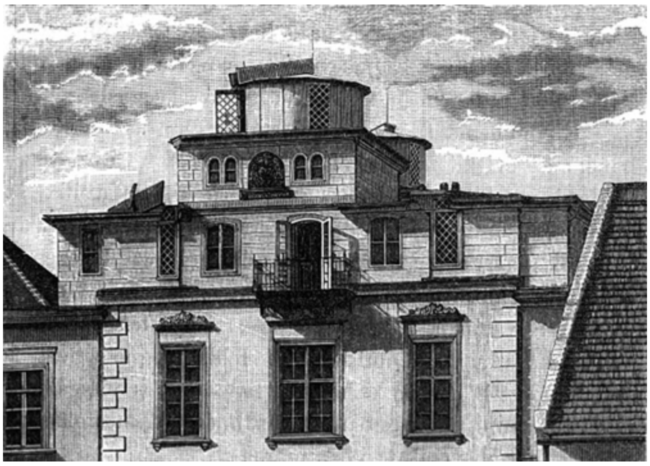

Fig.B1.2 Haynald Observatory, Kalocsa, Hungary, 1878-1919

In the middle of the 19-th century a significant upturn in solar research started with the discovery of the 11 years cycle as mentioned before and the beginning of astrophysics, especially with photography and spectroscopy of the Sun. Examples are the following first solar physics observatories (in brackets the director or leading astronomer and the date of foundation is given): Kew Observatory (1769) with photoheliograph (Warren De la Rue, 1858–1873), Potsdam Astrophysical Observatory

(Gustav Spörer, 1879), Solar Physics Observatory in South Kensington (Joseph Norman Lockyer, 1885, cf. Meadows, 1972), Meudon (Jules Janssen, 1876), Collegio Romano in Rome (Angelo Secchi, 1852) and Haynald Observatory, (Fig. B1.2), Kalocsa, Hungary, 1878–1919 (Gyula Fényi (1845-1927), Károly Braun (1831-1907), cf. Fényi 1889, Wolfschmidt, 2008, p. 92).

Conclusion

I have shown in this overview the development of early solar observatories. In the beginning, in the 17-th and 18-th century, there was no special observing place used, then step by step special architecture and instrumentation was created for solar physics. The best example for a private observatory is Schwabe's Observatory in Dessau with the typical small turret on the top of the roof. The most famous, well preserved solar observatory of the 19th century is the ETH Observatory in Zürich, built by Gottfried Semper, a remarkable astronomical heritage.

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B2. ASTRONOMICAL HERITAGE –

Development of Modern Solar Tower Observatories, 20-th century

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Abstract. George Ellery Hale (1868–1938) had the idea of a tower telescope. In 1904 the 60 foot tower in Mt. Wilson was ready; in 1908 the 150 foot tower was built. Two coelostat mirrors reflect the light into the tower; the spectrograph is located in a place of constant temperature far below the surface. In order to test Einstein's general theory of relativity an interesting expressionistic architecture, the Einstein Tower Potsdam, was designed by Erich Mendelsohn (1887–1953) in 1920 to 1922. The optical design, made by Carl Zeiss of Jena, surpassed the Mt. Wilson solar observatory in respect to light intensity. More solar tower observatories were built in the 1920s and 1930s. New observational possibilities were created by Bernard Lyot (1897–1952) in Pic du Midi. An interesting new feature was introduced in the 1960s, the vacuum tower telescope. The result of the evacuation is images without distortions.

1 The Invention of the Tower Telescope – Mt. Wilson Solar Towers

This article is devoted to the invention of the solar tower, a special new architecture for analyzing the Sun and its magnetic field. George Ellery Hale (1868–1938), director in Yerkes Observatory in Williams Bay, Wisconsin, from 1895 until 1905, used the large 1-m-refractor for solar observations. But it gave a too small image of the Sun and a too low dispersion. Inspired by horizontal telescopes, which were used in the 1890-s, especially by the Lick Observatory, in connection with a heliostat for observing and photographing solar eclipses, Hale started to build the "Snow Telescope". This horizontal telescope was erected in 1903 by George W. Ritchey (1864–1945). It consisted of two plane mirrors (coelostats) which reflected the Sun's light on a concave mirror of 61cm aperture (later mostly a lens was used). The focal length of the instrument was 18m; the solar image at the focus had a diameter of about 17 cm. In 1904 the Snow Telescope was moved to Mt. Wilson Observatory (Fig.B2.1). But it was not extremely successful, because a horizontal solar telescope was affected by air-current from the warmed-up soil; Hale had the idea of a tower telescope. In 1904 the 60 foot tower in Mt. Wilson was ready (the dome was not installed until 1914), in 1908 the 150 foot tower was built with the help of the Carnegie foundation (Fig.B2.2a, b); the steel was manufactured by the Morava Construction Company Chicago. The aperture of the lens was 30 cm. Two coelostat mirrors reflect the light into the tower; the spectrograph is located in a place of constant temperature, far below the surface. But also a spectroheliograph or a magnetograph could be used in combination with the tower telescope. Mt. Wilson as a first modern solar observatory was a model for many others in the world in the 20-th century. Site mangement: Mount Wilson is operated on behalf of the Carnegie Institution of Washington (CIW) by the non-profit Mount Wilson Institute (MWI). In 1984, the Carnegie Institution wanted to close the Mt. Wilson Observatory. But in 1985 the desire of the University of California at Los Angeles (Division of Astronomy and Astrophysics at UCLA) for using the tower for research in solar seismology, was accepted and supported by the Mount Wilson Observatory Association (MWOA). The Friends of Mount Wilson Observatory offer visits to the public.

2 The Einstein Tower Potsdam – Expressionistic Architecture

The US gained an increasing influence in the development of science in the beginning 20-th century. After World War I Germany made heavy efforts to regain its former strong position in the field of science (Wolfschmidt 2008). The last impulse for financing a German solar observatory arose from the spectacular result of the English eclipse expedition in October 1919 – confirming Einstein's theory. The first aim was to test Einstein's general theory of relativity. Already Einstein had proposed three tests: 1. Perihelion motion (shift) of planet Mercury, 2. Light deflection at the Sun's limb and 3. Gravitational redshift of the Sun. Karl Schwarzschild (1873–1916), director of the Astrophysical Observatory Potsdam, made experiments for measuring the gravitational redshift on the top of the library building. This was not successful; John Evershed (1864–1956), Kodaikanal Observatory, India, and Charles E. St. John (1857–1935), Mt. Wilson Observatory, had also problems. Already in December 1919, Erwin Finlay-Freundlich (1885–1964) had started a successful fund rising among German industrialists in order to build a German solar tower observatory. The interesting expressionistic architecture was designed by the Berlin architect Erich Mendelsohn (1887–1953), in close cooperation with his friend Freundlich, astronomer and architect, who gave advice for the instrumentation. Mendelsohn produced the first sketches in 1918, he completed the plans for the design in 1920. Although the internal organization of the structure was fairly established by astronomical needs, but for the outside he retained complete freedom (Achenbach 1937, S. 60–64). Freundlich succeeded to fascinate Mendelsohn for Einstein's world of thought and to inspire him for outstanding architectural ideas. Mendelsohn was looking for new architectural forms of expression which he wanted to achieve with modern materials of steel and reinforced concrete. About these materials, he wrote that "if they are perceived in its elastic potential, this necessarily leads to an architecture that is completely different from anything we knew before". Thus this building is regarded as a perfect synthesis between dynamics and functionality with its gently curved shapes and is known as the best example for expressionistic architecture in art history (Fig.B2.3a, b), Einstein called it organic architecture (Pehnt 1981, p. 117–126). The 20m solar tower was constructed in 1920 to 1922; but due to lack of modern construction material after the war, the tower had to be built with bricks instead of armored concrete. As a protection against the wind and heating, inside of the tower a wooden structure was added, this carries the objective lens. The instrumentation was installed in 1924, made by Zeiss of Jena. The dome of 4,5 m diameter contained the two 85 cm-coelostat mirrors. The lens of 60cm aperture and of 14.50 m focal length produced a solar image of 14 cm diameter. In the cellar in a room of constant temperature two high resolution spectrographs produced solar spectra from red to violet with a length of 12 m. Furthermore, in 1925, a modern physical-spectrographical laboratory was constructed. This test of Einstein's theory of general relativity failed, however, because the measured line shifts are influenced by many other stronger effects, present on the Sun. As a consequence in studying all these effects, the Einstein Tower became the most important solar observatory in the world in the twenties. Freundlich characterized the building as follows: "The design of the telescope as a tower telescope gave the Einstein Tower its special character and allowed the architect to allocate the building the character of a monument due to the epochal significance of the theory of relativity in the development of physics." (Finlay-Freundlich (1969), here p. 541). The optical equipment of the tower telescope surpassed in intensity all similar facilities for more than a decade. In the case of the solar observatory in Mt. Wilson the lens diameter is 30cm compared to the twice as large value for the Einstein Tower. In the 1920-s the Einstein Observatory became not only the leading institute for solar physics in Europe, but even in the world. Only the hope for a proof of the theory of relativity has not been fulfilled, especially because other effects interfere with the measurement. The Einstein Tower was renamed in 1933 in the context of the political development of the Nazi era in Institute for Solar Physics, and affiliated with the Astrophysical Observatory Potsdam. The Einstein Tower, located today in the Wissenschaftspark Albert Einstein on the Telegrafenberg in Potsdam, is still active as a solar observatory and belongs to the Astrophysical Institute, now located in Potsdam-Babelsberg. The Einstein Tower is under monument protection. Remarkably in addition is

Mendelsohn's design of the office furniture and fixtures (still preserved). The tower was restored many times during the past decades; the last very careful restoration (three Million Euro) was carried out in 1997 to 1999, financed by a private grant (2/3 of the costs) and by the Astrophysical Institute Potsdam (1/3) (Huse, 2000).

The Solar Tower Telescope, Solar Observatory, NAOJ Mitaka Campus in Tokyo, Japan (1928) took the Einstein Tower of Potsdam Astrophysical Observatory as a model. The building, decorated with brown brick, was erected in 1930.

Fig. B2.1 Mt. Wilson Observatory: horizontal Snow solar telescope (1903) (copyright Mt. Wilson Observatory, MWO)

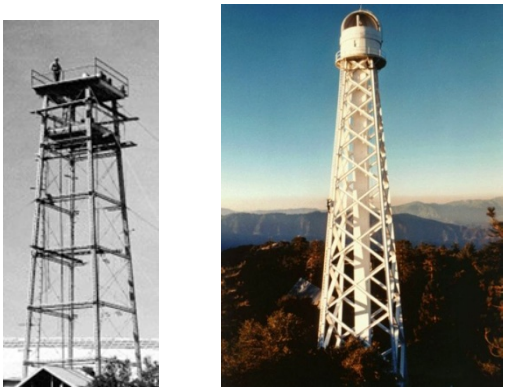

Fig. B2.2a,b Mt. Wilson Observatory: 60-foot tower (1904) and 150-foot solar tower telescope (1908) (copyright Mt. Wilson Observatory, MWO)

Fig. B2.3a,b Einstein Tower in Potsdam, section with the light path (Photo: Gudrun Wolfschmidt)

	
Fig. B2.4 Pic du Midi (1878-1882)	*Fig. B2.5 Left: Kitt Peak Observatory, McMath-Pierce Telescope 1960 and Kitt Peak Vacuum Tower (KPVT) 1973 Right: Sacramento Peak Observatory, Richard B. Dunn Solar Telescope (DST), 1969 (copyright National Solar Observatory (NSO)*

The Solar Tower Telescope was purchased from Zeiss of Jena, Germany, in 1928. The instrumentation is similar to the Einstein Tower of Potsdam, but the objective lens is 45 cm instead of 60 cm, but still larger than most other solar telescopes (30 cm). The Tokyo Tower Telescope, also known as Einstein Tower, belongs to the Tangible Cultural Properties of Japan. The Tower is no longer used for research recently, but its historical value and unique architecture is recognized and designated as National Cultural Monument in 1998.

3 Solar Tower Observatories in the 1920s and Solar Physics in the1930s.

In the 1920-s further solar towers were built after the Einstein Tower Potsdam (1922) in Utrecht, Netherlands (1922), Canberra, Australia (1924), Arcetri, Italy (1926), Solar Laboratory in Pasadena, USA (1926) and in Tokyo, Japan (1928). These solar tower telescopes had mostly 30 cm aperture (Utrecht 25 cm). The optical design of the Einstein Tower in Potsdam in respect to light intensity (60 cm) surpassed all other observatories of the 1920s and even the Mt. Wilson solar observatory. As was shown before, the leading nations in solar physics were Germany, France (Meudon) and the US; there the innovations in solar physics were made: the invention of the spectroheliograph by Hale in Mt. Wilson and independently by Henry Deslandres in Meudon. In addition in 1924, Hale introduced the spectrohelioscope in Mt. Wilson for observing flares; this instrument can be used in any wavelength of the visible spectrum in contrast to the spectroheliograph (only in one wavelength). In the thirties, solar physics became important because of the solar maximum in 1938. An impressive invention was made by Bernard Lyot (1897–1952) in 1931; he designed the coronagraph, producing an artificial eclipse, in order to observe the corona at any time. It needed accurate optical alignment and mechanical stability, but the most important thing was to observe on a mountain observatory in order to avoid stray light for viewing of the very faint corona. Pic du Midi (Fig.B2.4), already built from 1878 to 1882 was extremely good in this respect; here Lyot managed to get the first full daylight photographs of the corona. Besides the coronagraph a 50cm refractor with a spectroheliograph for observing the granulation is used here. Pic du Midi, connected to Université Paul Sabatier, is still an active observatory for astronomy, solar physics and meteorology. In 1994 the observatory was nearly closed; but in 1998 Syndicat mixte Midi-Pyrénées, Département and others invested 39 Million Euro and annual additions. Lyot's success motivated Max Waldmeier (1912–2000) at the ETH Zürich to build another successful coronagraph. He founded the Astrophysical Observatory Arosa, Switzerland, in 1939, a mountain station where he could carry out his observations of the Sun's corona. The third coronagraph in the world, was made by Donald H. Menzel (1901–1976), since 1932 at Harvard College Observatory, in cooperation with Walter Orr Roberts and Hobart P. French on "Fremont Pass Station of the Harvard College Observatory" at Climax, Colorado, in 1940. Walter Orr Roberts discovered the link between solar flares and radio interference and during World War II there was cooperation with the Air Force. In the thirties astronomers recognized the connection between solar cycle of sunspots and magnetic fields, but also the interaction between corpuscular radiation (solar wind) and the Earth's magnetic field. The Sun's activity caused magnetic storms, polar lights (aurora) and radio interferences on Earth and succeeded in catching the military's interest in solar and ionospheric research. At the end of the 1930s Karl-Otto Kiepenheuer (1910–1975), related to Rechlin and astronomer in Göttingen, proposed to establish a solar observatory on Wendelstein in order to improve the predictions of radio interference by observing sunspots. Was this solar research for science or war? (For more information see: Wolfschmidt 1993). Since 1941 a network for the advice for radar ("Funkberatung") existed all over Europe: from east to west: Simeis, Crimea, USSR – Paris-Meudon, France, from North to South: Tromsö, Norway, – Syracuse, Sicily, Italy. By stressing the importance of this research for war efforts Otto Heckmann (1901–1983) in cooperation with Kiepenheuer succeeded in winning the Reichsluftfahrtministerium (RLM, Air Force Ministry) in 1940 to finance finally six solar observatories between 1940 to 1942: Wendelstein / Upper Bavaria, Hainberg-Observatory Göttingen, Zugspitze / Upper Bavaria, Kanzelhöhe (today Austrian Alps), Schauinsland / Freiburg and Syracuse / Sicily / Italy. The instruments were solar tower telescopes with spectrographs and spectroheliographs; at the mountain observatories in addition coronagraphs existed. The solar astronomy had profited by the foundation of the six observatories – four of them existed still after the war. Until today Potsdam, Göttingen and Freiburg are centers of German solar physics. More solar tower telescopes were erected abroad: Oxford (1935, opening 32cm), Griffith Observatory (1935, opening 20 cm), Pasadena CAT (1935, opening 66cm) and the McMath-Hulbert solar towers (1936, 1940), 16 m and 23 m, University of Michigan; the spectroheliograph was further refined in 1932 by Robert R. McMath to take motion pictures. The Pasadena CAT was used by Hale erected in order to study magnetic fields of the Sun in detail.

4. Modern Solar Tower Observatories since the 1960-s.

Two solar towers were erected in the 1950-s, in Meudon and in Russia - Simeis Observatory at the Crimea peninsula with a solar tower telescope (1954), reconstructed in 1974. The Big Bear Solar Observatory (BBSO), California Institute of Technology, founded in 1969, is located in a Lake, where is nearly no turbulence and thus offers excellent climatic conditions to study the Sun. An interesting new feature was introduced in the 2-nd half of the 20-th century, the vacuum tower telescope (Wittmann, Wolfschmidt and Duerbeck 2005). The result of the evacuation is images without distortions. Some modern solar tower telescopes should only be mentioned: National Solar Observatory (NSO) – Kitt Peak's Solar Telescopes (McMath-Pierce Telescope 1960, KPVT 1973, SOLIS 2004) (Fig.B2.5a) and Sacramento Peak, New Mexico (Richard B. Dunn Solar Telescope, DST, 1969, Fig.B2.5b), High Altitude Observatory (HAO) Boulder – Mauna Loa Solar Observatory, Hawaii (1965), and the European solar observatories (1979) – the Observatorio de Teïde, on Tenerife, and the Observatorio del Roque de los Muchachos, on La Palma. The next generation of solar telescopes for the 21-st century (1.5 m GREGOR, Tenerife, Germany, 2006 and Advanced Technology Solar Telescope (ATST), Haleakala, Hawaii, USA National Science Foundation, 2011) is designed as compact Gregory-type reflector, similar to other astronomical telescopes.

Conclusion. There was a remarkable development in the design of solar tower telescopes from the time of George Ellery Hale in Mt. Wilson, then the Einstein Tower until the modern vacuum tower telescope. Long-focus instruments are used for observing the Sun in order to get a large image of the Sun. This enables the astronomers to study the Sun's surface in detail. The Sun heats the atmosphere during daytime; thermal currents distort the image. The first solution of this problem was the construction of double towers, the outer acting as a windshield, the inner carries the optics. The modern tower telescopes are evacuated to improve the images considerably. To summarize, the highlights in respect to UNESCO World Heritage are surely the three solar observatories of the 20-th century which are well preserved in respect to architecture and instruments: Mt. Wilson, California, (first tower telescope), Einstein Tower Potsdam, Germany, (solar tower telescope in expressionistic style) and Pic du Midi, France, (mountain observatory with the first coronagraph). We should also consider in the future some of the modern solar telescopes, also because they need excellent observing conditions, linked very well to the starlight initiative.

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B3. HISTORY OF THE FIRST ASTRONOMICAL OBSERVATORY IN BULGARIA

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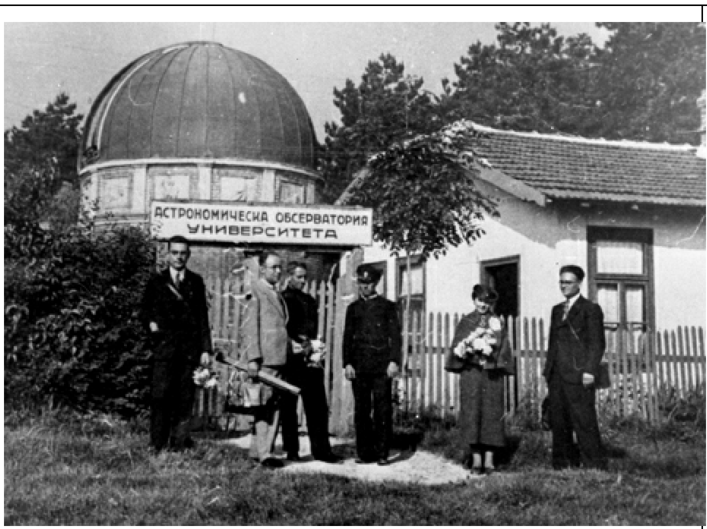
Abstract. Founded in 1894, the Astronomical Observatory and Department of Astronomy of the St Kliment Ohridski University of Sofia (www.phys.uni-sofia.bg/~astro/) is the oldest astronomical institution in Bulgaria, and all the new astronomical institutions like the Institute of Astronomy of the Bulgarian Academy of Sciences came from it. Up to now, the Department is the only structure responsible for the higher education of all three levels (BS, MS and PhD) in the field of astronomy and astrophysics in Bulgaria.

Historical Highlights. Here the history of the Sofia University Astronomical Observatory is presented. It was created on the initiative of Professor Bachevarov – the first lecturer in astronomy in the High School (as initially the University has been called). In1892 – 1894, the old building and the large vault of the Astronomical Observatory (outside of the city of Sofia at that time) had been built. The first observational device of the new observatory was the telescope of Peter Beron – the famous scientist of the Bulgarian national revival. This telescope was manufactured in Munich in the second half of XIX-th century by the G. Merz & Sohn firm and its magnification was about 500 times. It is the first astronomical instrument used for teaching astronomy in the university education program. Today, this telescope, together with other astronomical instruments relating to the initial stage of the University Observatory, are the items of the permanent exposition held at the National Polytechnical

Museum in Sofia. Later on more astronomical instruments were handed over to the Museum, the most important being the 6 inch (15.2 cm) refracting telescope.

	
B3.1 Prof. Bachevarov – initiator of the first astronomical observatory in Bulgaria, started working in 1892 and the first professor in Astronomy at the University.	*B3.2 Astronomical Observatory of the St Kliment Ohridski University of Sofia in 1899.*
	
B3.3 Observations with a "Merz" ocular tube, 1921.	*B3.4 The first telescope in permanent mounting in Bulgaria supplied in 1897 - 6" (15.2 cm) telescope with equatorial mounting produced by "Grubb".*

	
B3.5 The University Astronomical observatory in 1931.	*B3.6 Siegmund Riefler's clock used as a standard for precise time.*

Astronomical Observatory of the Sofia University is one of the first observatories on the Balkans and has actively participated in observations of the first Earth's artificial satellite.

Astronomical Observatory of the Sofia University named after St. Kliment Ohridski is one of the first observatories on the Balkans. The Sofia University is the first higher education institution in Bulgaria. Its history is an embodiment and a continuation of centuries of cultural and educational tradition (Arnaudov, 1939). The Sofia University was founded in late 80s of the XIX century, while the old European universities had been established between XII-th and XIX-th century.

However, the University was established upon strong scholar and educational traditions of the Medieval Bulgaria, dating back as far as to the time of the eminent Bulgarian rulers Knyaz Boris I and Tsar Simeon (Symeon the Great).

The University was opened on October 1, 1888 with only one Department of History and Philology. In 1889/1890 academic year the Department of Physics and Mathematics was founded (Petrov, Kamisheva, 2007).

The Astronomical Observatory of St. Kliment Ohridski University of Sofia marks the beginning of the culture, science and education Renaissance in Bulgaria after the Liberation in 1878. It is founded in 1894, and together with the Department of Astronomy is the oldest astronomical institution in Bulgaria. This was significant advancement for the Sofia University and for the Bulgarian science in the beginning of the 20-th century as a whole (Filipova, 2008).

The construction of the Astronomical Observatory was initiated by Professor Bachevarov (Fig.B3.1), the first professor of Astronomy at the University, and it started to work in 1892. The Observatory site was chosen to be outside of Sofia. At that time, Knyaz Boris Garden was a pasture of the Slatina village, located as far as the Eagle Bridge. The old building and the big dome of the Observatory were finished in 1894 (Fig. B3.2). Construction of of the Rectorate building of Sofia University was completed 30 years later.

The location site of the Sofia University Astronomical Observatory has the following geographic coordinates: longitude 1 h 33 min 23 s E; latitude 42° 42’ 02’’ N; altitude 550 m a. s. l.

As it was mentioned above, the first observational instrument in the newly built observatory was the telescope of the famous Bulgarian scientist, Dr. Peter Beron. In 1886 Peter Beron's nephew, Stefan Beron, gave this telescope to the Bulgarian Literary Society, which in turn donated it to the University in 1892. The telescope was the first instrument used for education of the students in the practical Astronomy (Fig. B3.3).

A few years later Professor Bachevarov had acquired many astronomical instruments including the 6 inch (15.2 cm) telescope with the equatorial mounting produced by the Grubb & Parsons firm (Fig. B3.4). This was the first telescope permanently mounted in Bulgaria. Since 1897 the telescope was used for education in astronomy The telescope was restored in 2004 and is presently in use.

In 1910 Professor Bachevarov carried out observations of the Halley's comet, and his student A. Kunchev calculated the ephemerides of the comet. At that time, the young assistant-professor Kiril Popov published his observations of the Halley's comet in the Comptes Rendus of the French Academy (Sretenova, 2000). Professor Bachevarov's observations and calculations of the circumstances of solar and lunar eclipses are still preserved, as well as the calculations of lunar occultations of stars.

The next head of the Department, Academician Nikola Bonev (between 1928 and 1965), has modernized the Observatory (Fig. B3.5). The courtyard was enlarged, a new building with lecture rooms, as well as a new observational terrace and a new smaller dome, were built. In 1942 the Observatory became the Precise time Service and performed this function up to 1986. Clemens Riefler's clock with a nearly-free pendulum, which attained an accuracy of a hundredth of second a day was used as a time standard (Fig. B3.6). It was also included in the program of the first artificial satellite observation. Nowadays all other old astronomical instruments are exposed in the National Polytechnic Museum in Sofia.

Today, the Observatory disposes modern instrumentation - optical and radio telescopes, CCD-camera, a spectrograph, etc., which are used in the undergraduate and graduate educational programs in Astronomy. All the new astronomical institutions like the Institute of Astronomy of the Bulgarian Academy of Sciences have come from it. Now, the Department of Astronomy is the only structure responsible for the higher education of all three levels (BS, MS and PhD) in the field of astronomy and astrophysics in Bulgaria.

Conclusion.

Astronomical observatories and instruments are among the categories associated with Astronomical Heritage. Astronomical Observatory of the Sofia University named after St. Kliment Ohridski is commemorated by the following properties:

- it is one of the first observatories on the Balkans;
- it has collection of astronomical instruments including the historical telescope of Dr. Peter Beron, the famous scientist of the Bulgarian national revival;
- it possesses astronomical instruments which are authentically associated with the history of Observatory, teaching astronomy and the universitarian education in Bulgaria;
- it participated in the program of the first artificial satellite observation;
- it keeps the archives of the first scientific activities of Professor Bachevarov, involving observations of the Halley comet, calculations of ephemerides, solar and lunar eclipses and occultations of stars by the Moon;
- it disposes modern astronomical instruments;
- it pursues activity with the close relation of programs for higher education and outreach.

All these points represent the heritage value of the Sofia University Astronomical Observatory. Its long history and contemporary continuous activities are crucial for the recognition of its astronomical achievements by the present generation and of their influence on culture and scientific knowledge of the world community.

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B4. THE HIGH MOUNTAIN RESEARCH STATIONS: The First Laboratories for the Study of Cosmic Rays, Elementary Particles and High Energy Physics

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Abstract. The high mountain observatories played a crucial role in cosmic ray physics, astrophysics, high energy and particle physics. Before the construction of the particle accelerators, the observation of cosmic rays in high altitude was the only way to study the high energy interaction mechanisms. The first High Mountain Observatories (HMO), built all around the world in the first half of 1900-s, were witnesses of an extraordinary period in which the most important physicists, many of them awarded with Nobel Prize, created new detection techniques and performed discovery of new particles, setting up the bases of the modern astrophysics and cosmology. Still today the activity at HMO's gives a substantial contribution to the fundamental research in space science. The worldwide distribution of HMO's provides a unique possibility to perform contemporary observations at different geomagnetic conditions, to collect data on long periods and to integrate and validate satellite data.

1. Introduction. The mountains are sites for sport activities, are source of inspiration for painting and literature, but it is still almost unknown their contribution to the modern physics development.

The scientific observation at high altitude sites has a long history: in the ancient times, the mysterious astronomical observatories in South America, as Cuzco in Peru or Tihuanaku in Bolivia, witness the effort of human beings to realize on the top of the mountains extraordinary buildings devoted both to holy ceremonies and to scientific knowledge. More recently; at the first High Mountain Observatories built around the world at the beginning of 1900's, started the cosmic rays observation , that represented the base of the modern astrophysics, cosmoòogy and space science.

Pic du Midi (France, 2887 m asl, built in1873) (Lattes et al., 1947), Tien-Shan (Kazakhstan 3340 m asl, built in 1912) (Dobrotin et al., 1965), Jungfraujoch (Switzerland, 3454 m asl, built in 1926) (Auger et al., 1939), Echo Lake (U.S.A. 3200 m asl, built in 1930) (Kraushaar, 1949), Chacaltaya (5230 m asl, Bolivia, built in 1942) (Lattes et al., 1947), Testa Grigia (Italy 3480 m asl, built in 1947) (Cortini et al., 1948) are the sites where the most important discoveries in this field were obtained.

2. The cosmic ray research at High Mountain Observatories

At the beginning of the 20-th century scientists became very interested in a puzzling phenomenon. There seemed to be rather more radiation in the environment than they could account for by the known sources of natural background radioactivity.

The first scientist to investigate this subject was the Jesuit priest T. Wulf measuring on the top of the Tour Eiffel in Paris the air ionization with an electrometer of his invention and he discovered that the ionization increase in respect to the ground.

After much debate, the puzzle was partly solved by a daring Austrian scientist, Victor Hess. In 1912 he took a radiation counter (he used a gold leaf electroscope) on a balloon flight taking off from the Vienna aeroclub. He risked his life, by traveling to 17,500 feet without oxygen, but managed to observe that the amount of radiation increased as his balloon climbed. This demonstrated that the radiation was from outer space and eventually it was dubbed "Cosmic Radiation" (Hess, 1912).

In the following years, the research on cosmic rays take place mainly at the high mountain research stations. In fact in high altitude over 3000 m asl, the reduced atmosphere layer and the minor contribution of ground radiation allow the evaluation of the different components of the secondary radiation produced from the primary cosmic rays (mainly protons) interaction with atmospheric nuclei.

The epic of research in high-altitude start in the first half of 1900, when physicists from around the world were involved in an extraordinary scientific challenge, that took place in small laboratories on the peaks of the Alps, on the Andes, on the Rocky Mountains, on the Caucasus, and in a few decades led to an entirely new vision of nuclear physics, and opened the way to astrophysics, to physics of elementary particles and to cosmology.

Before the construction and use of particle accelerators (1950 approximately) the laboratories of high altitude were the only places where it was possible to study high energy nuclear interactions, studying the reactions of cosmic rays with air nuclei; in the same years many elementary particles have been discovered in this context, and also the "strange particles"- unstable particles, with special properties with regard to the mechanisms both of production and decay - have been revealed in experiments at high altitude.

At Mont Blanc at 4300 m, Louis Leprince-Ringuet first observed in 1944 several strange tracks in a nuclear emulsion; from 1948 to 1950 evidence of this phenomenon was obtained at Pic du Midi with the cloud chamber invented by P. M. S. Blackett and G. Occhialini in 1933 and used by the Manchester group (C. C. Butler, R. Armenteros e K. Barker).

In the same period, in the USA, C.D.Anderson observed the same tracks with nuclear emulsions on the top of White Mountain, 3200 m asl and at MIT Bruno Rossi carried out a study of these particles analyzing the nuclear interactions produced in a cloud chamber at Echo Lake on Mount Evans at 3200 m in Colorado: the existence of the V particle, with the typical double track, was confirmed.

Also the K-particle, with the typical three charged particle decay, was discovered at Jungfraujoch by C. Powell and one year later by J. Brian Hardin.

Fig. B4.1 Testa Grigia Laboratory at Plateau Rosa (Italy. 3480 m asl founded in 1948)

Fig. B4.2 Pic du Midi laboratory (France, 2887 m asl, founded in 1873)

Fig. B4.3 Jungfraujoch laborator (Switzerland, 3454m asl, founded in 1926)

Fig. B4.4 Chacaltaya laboratory (Bolivia, 5230 m asl, founded in 1942)

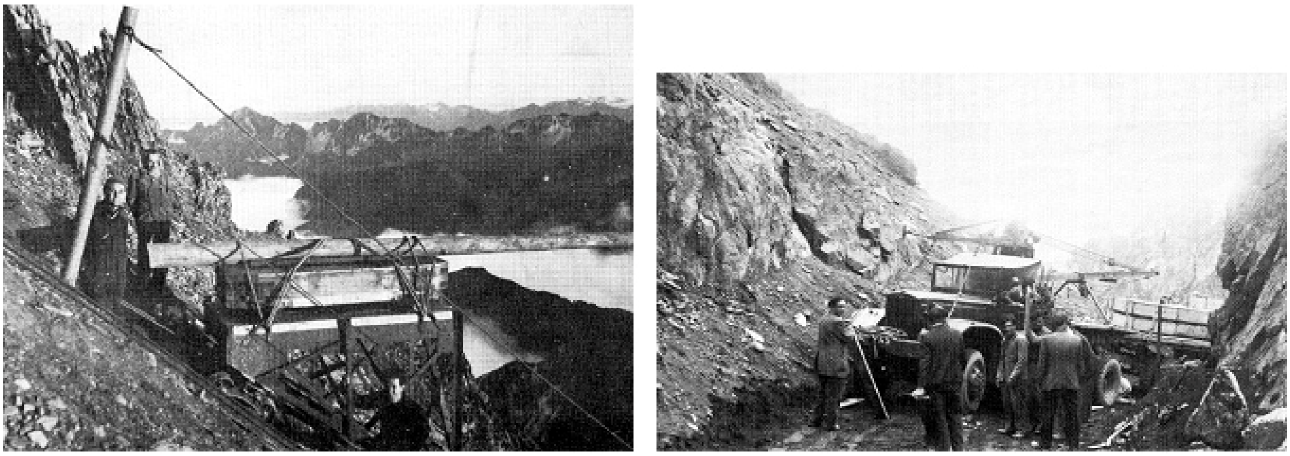
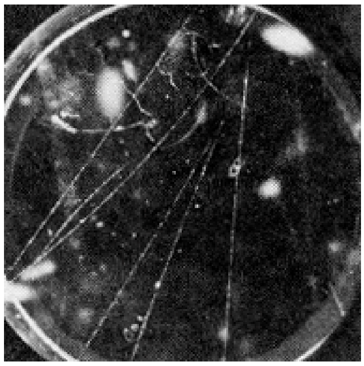


Fig. B4.5 Transport of the electromagnet from Manchester at Pic du Midi (1950)

	
Fig. B4.6 Cesare Lattes at Chacaltaya (1950)	*Fig. B4.7 Rosch, Butler, Blackett, Barneoud, at Pic du Midi (1950)*
	
Fig. B4.8 The monument of Hyperon at Bagnères de Bigorre	*Fig. B4.9 Hyper Λ^0 decay in proton p and pion π*

The discovery of π meson with nuclear emulsion at Chacaltaya (Bolivia, 5230 m asl) allowed C. F. Powell to be awarded by the Nobel Prize in 1950.

The life in the high mountain laboratories required more than just a passion for scientific research, a good dose of adventurous spirit and willingness to work in hard conditions. “The HMO… became in these years the meeting points for young physicists from many countries. The common life in the mountain huts … open the way to wide and ambitious scientific collaborations … “ (Battimelli, Paoloni, 1998).

In Tab. 1 the list of new particles is reported, to point out the high number of particles discovered in HMO in cosmic ray observation.

It is to be stressed the point that many of the young physicists which worked together in high mountain stations were awarded with the Nobel

Prize R.Millikan (1923), A.H. Compton (1927), C.D. Anderson (1936), E.Fermi (1938), P.Blackett (1948), C.F. Powell (1950), other ones were among the founders and leaders of the research at CERN (Centre Europeen de Reserche Nucleaire (R.Armenteros, A.Lagarrigue, L.Leprince-Riguet)

3. The first laboratories

R. Millikan and A.H. Compton start in 1928 a campaigne of experiments in Peru' at Huancayo laboratori (3350 m, founded in 1919) to analize the caractheristics of the unknown "outside" radiation that at the beginning was supposed to be of electromagnetic nature. In the following years the cosmic rays research involved scientists from all over the world. From Rome (Italy), E.Fermi and E.Amaldi work on Monte Bianco and at Testa Grigia laboratory (Fig. B4.1) on the italian side of Matterhorn (3480 m, founded in 1947), from Manchester (UK), G. Rochester and P.Blackett work at Pic du Midi (Fig. B4.2) on Pirenei (France) (2887 m, founded in 1873) and at Jungfraujoch (Switzerland) (Fig. B4.3) (3454 m, founded in 1926), the american school with B.Rossi and C.Anderson work at Echo Lake on Mount Evans (USA) (3200 m, founded 1930) e a White Mountain (3300 m, founded in 1951), C.Powel, C.Lattes and G.Occhialini on Ande at Chacaltaya laboratory (Fig. B4.4) (5230 m, founded in 1942), P.Auger, L.Leprice-Riguet, R.Armenteros from Paris work at Pic du Midi and on the Alps.

3.1 The instruments. The techniques used in experiments at high altitude are mainly nuclear emulsions (in a version optimized for these experiments produced by Ilford in the '40s with a high concentration of grains of silver bromide in order to detect even particles with low ionization) Geiger Muller counters, the coincidence counters invented by B. Rossi, the cloud chamber in the new configuration of P.Blackett. In some cases, transport of equipment at high altitudes was complex and difficult, as shown by the pictures of the time. For exemple, it is to recall that to install the Pic du Midi the electromagnet for the Blakett cloud chamber, (only the base weighs 4 tons!), an inclined plane of 220 meters with a gradient of 42 ° is constructed on the side of the mountain, along which the tool is dragged by teams of eight men who work changes during the seven hours required for climbing. (Fig. B4.5)

3.2 Discoveries at HMO's. Numerous discoveries were made at the high altitude laboratories.

In 1938, P. Auger, placing its detectors in Alps, note that instruments distant from each other simultaneously signal an event : it is the evidence of the formation of the cascade of secondary particles (extensive air shower) produced by primary protons of high energy (up to 1015 eV)

In 1947 at Chacaltaya in Bolivia, C. Lattes (Fig. B4.6), G. Occhialini and C. Powell discover with the nuclear emulsion technique a double nuclear decay interpreted as the experimental evidence of the existence of the pion, the new particle predicted by Yukawa theory (Nobel Prize in 1949).

In 1950, at Pic du Midi, P. Blackett (Fig. B4.7) and R. Armenteros, using the cloud chamber invented in coincidence by Blackett and Occhialini in 1933 and placed in an intense magnetic field, show typical traces looking as inverted V. Simultaneously the same tracks were highlighted by C.D.Anderson in the laboratory at White Mountain in the USA at 3200 m.

This new family of particles was indicated initially as V particles (neutral or charged) and later on the term L hyperons was introduced. In Bagneres de Bigorre a monument commemorates the discovery (Fig. B4.8).

In 1950 at Jungfraujoch laboratory C.Powell discovered with photographic plates the decay into three particles of the K-meson. This first discovery was confirmed a year later by J.B. Hardin.

In 1953, the historical conference on cosmic rays was held in Bagneres de Bigorre, at the foot of Pic du Midi, that gathered all the protagonists of this exciting period, with the aim to systematize new knowledge acquired during those years. This was the beginning of particle physics , and therefore, of the study of symmetry, strangeness and parity conservation.

Tab.1 The most important high mountain laboratories in Europe and around the World.

Pic du Midi	*2887 m slm*	*France*
Testa Grigia	*3480 m slm*	*Italy*
Regina Margherita	*4559 m slm*	*Italy*
Angelo Mosso	*2901 m slm*	*Italy*
Ottavio Vittori	*2165 m slm*	*Italy*
LNGS Gran Sasso	*2150 m slm*	*Italy*
Jungfraujoch Sphinx	*3454 m slm*	*Switzerland*
Gornergrat	*3012 m slm*	*Switzerland*
Schneefernerhaus	*2650 m slm*	*Germany*
Sonnblick	*3106m slm*	*Austria*
Lomnicky Stit	*2634 m slm*	*Slovakia*
BEO Moussala	*2925 m slm*	*Bulgaria*
ASEC Aragats	*3200 m slm*	*Armenia*
Nor Amberd	*2000 m slm*	*Armenia*
Terskol Peak	*3100m slm*	*Russia*
Chacaltaya	*5.400 m slm*	*Bolivia*
Yangbajing	*4.300 m slm*	*Tibet*
Tian-Shan	*3.340 m slm*	*Kazakhistan*
Dome Concordia	*3.200 m slm*	*Antarctic*
Mauna Kea	*3.058 m slm*	*Hawaii*
Norikura	*2.770 m slm*	*Japan*
Mount Hermon	*2.025 m slm*	*Israel*
INCA	*5.400 m slm*	*Chile*
Huanacayo	*4.300 m slm*	*Peru*
White Mountain	*3.340 m slm*	*U.S.A*
Everest Pyramid	*5050 m slm*	*Nepal*

4. The high altitude laboratories today

Even today, in the era of big particle accelerators and space exploration, high-altitude laboratories are sites of excellence for scientific research, for calibration of instruments and for validation of data obtained from artificial Earth's satellites. Very high energy particles (energies much higher as those produced at the Large Hadron Collider (LHC) at CERN) are detectable only in cosmic ray experiments at high altitude; also gamma ray bursts (high energy gamma-rays of unknown origin) are detected at Yangbajjin in Tibet at 4300 m asl. At Chacaltaya laboratory, in Bolivia (5240 m asl) the search for magnetic monopoles and strange particles, relics from the early Universe is carried out. At high altitude large Cherenkov detectors (Magic, Hess) for the study of cosmic microwave background radiation are installed, the "muon telescopes" for the space weather forecast, and the network of neutron monitors for the monitoring of variation in intensity of cosmic rays linked to the solar activity.

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B5. ASTRONOMICAL OBSERVATORIES IN UKRAINE: RELEVANCE TO THE UNESCO ASTRONOMY WORLD HERITAGE INITIATIVE

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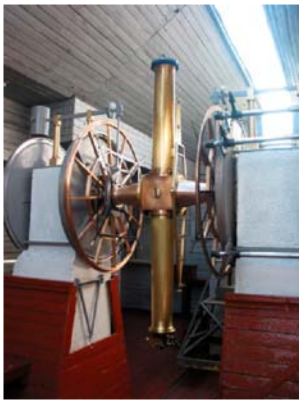
In 2004, the UNESCO World Heritage Center has announced a new Initiative "Astronomy & World Heritage". Its purpose is to find and preserve the historical and cultural sites and buildings related to astronomy. In Ukraine, the astronomical expert group (AEG) to take part in the program called «Initiative» was set up. As a result of its activity, the set "Astronomical Observatories in Ukraine" was suggested to be inscribed in the tentative list of the UNESCO World Heritage (#5267) in 2008. The set originally involved three Ukrainean observatories from Kyiv, Mykolaiv, Odessa, and also Crimean observatory. They were distinguished by the high level of scientific research and integrity.

In 2008-2009, a new project «Thematic Study» as a succession of the «Initiative» has begun under supervision of IAU and UNESCO. The respective working groups were organized to compile a database of most important astronomy sites from prehistory to space astronomy (14 themes in total). In this paper, the description of astronomical observatories of Ukraine is given aiming to accomodate the criteria of the project «Thematic Study». Three observatories (in Kyiv, Mykolaiv and Odessa) are suggested as the objects in the theme "Astronomy from the Renaissance to the mid-twentieth century". Originally the Crimean Astrophysical Observatory was incorporated in the theme "Contemporary Astronomy" as organization being in 2008 under Ukrainean jurisdiction.

Nikolaev Astronomical Observatory Research Institute (NAO). NAO is historical and astronomical complex with the reserved territory of total area of 7.1 hectares in the central part of Mykolaiv city (Ukraine). As for the history of the observatory, NAO was the oldest Naval Observatory in the South-Eastern Europe, founded in 1821 for providing the needs of the Russian Black Sea Navy (Пинигин et al, 2005). Nowadays the names of cities are given in Ukrainian, as it was officially adopted after the Ukraine independence proclaimed in 1990.

The beginning of scientific research at the Observatory is connected with its first director K. Knorre. From 1912 through 1991, NAO was one of the Southern departments of Pulkovo Observatory and since 1992 it has become an independent leading institution of Ukraine in the field of positional astronomy involving dynamics of Solar system bodies, research of the near-Earth space, astronomical instrumentation, etc. In 2007 it was inscribed in the Ukranian Tentative List of the UNESCO WH (#5116). The most significant part of the complex includes the Main building which was built in 1821-1829 in the style of Classicism (Fig. B5.1). This is a classic example of architecture for astronomical observatories of XVIII-XIX-th centuries. It has been used simultaneously for various needs, such as working rooms, spaces for telescopes and appartments for personnel. The astronomical pavilions (1875, 1913, 1955, etc.) with instruments Repsold meridian circle (MCR), Repsold vertical circle (VCR), Carl Zeiss Jena zonal astrograph (ZA) have been preserved since then. MCR (1834) was one of the first telescopes of the Pulkovo Observatory, which has been used in NAO after restoration and modernization for 40 years (Fig. B5.2), since 1955; VCR (1897) has been used for more than 70 years, since 1913; and ZA has been used since 1961, while historically it has been designed by Carl Zeiss firm in Jena (1925) for observations adapting the Astronomische Gesellschaft Catalogs (AGK). About 20 stands demonstrating astronomical, geodetical and navigational instruments and devices, as well as the collection of astronomical clocks of XVIII-XX-th centuries, are exposed in the Observatory museum.

	
Fig. B5.1 Main building of NAO, photo 1913	*Fig. B5.2 Repsold meridian circle, 1834*
	
Fig. B5.3 General view of Crimean astrophysical observatory. It was founded in June 30, 1945	*Fig. B5.4 Reflector named after academician G.A. Shajn - the largest telescope*

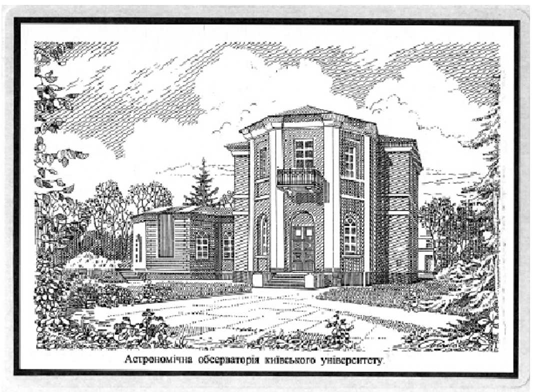
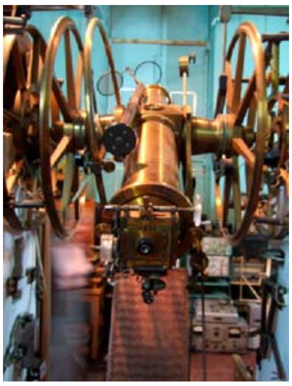

	

Fig. B5.5 Main building of Astronomical observatory of Kyiv University	*Fig. B5.6 Repsold meridian circle, 1871*

The high level of authenticity and integrity of the site is certified by the documents. The documentation is kept in the Observatory archives since the time of foundation in 1821 and includes astrophotographic plates, digital databases of NAO, astrometric catalogs of observations, the library collection of rare books and periodical scientific literature.

The territory of NAO, as one of the oldest European scientific institutions, is protected officially by the Statute for keeping historical and cultural reserved territory named “The Observatory”. In particular, the Main building is regarded as monument of architecture in the State Registry #535. The jurisdiction involves renewal and restoration of the Main building, restoration of telescope pavilions and preservation of the territory of NAO as a scientific and cultural center for popularization of the Observatory history and dissemination of the astronomical knowledge to the general public.

Astronomical Observatory of the National Taras Shevchenko University, Kyiv (*AO KNU*)

AO KNU occupies the area of 2.6 hectares in a historical part of Kyiv. By the Decree of the Expert Committee of the State Service of the National Cultural Heritage in 2007, it was recognized as a historic-cultural monument on the national protection level.

AO KNU has been officially inaugurated on February 7, 1845 (Богородский et al, 1979). The Main Building was designed by V. Beretty and built in 1841-1845, but later on rebuild in the simplified style of Classicism. It has the tower of octahedral shape (Fig. B5.5). There is a meridian room on the West side with an exit to the open terrace, where portable astronomic instruments can be installed. The four forge-iron columns with the relief ornament, a hand rail of stairs made of cast iron, a tiled stove with stucco moulding are preserved in the central hall. The architectural complex had been partially rebuilt in 1860-1890. The Main building is registered as the architecture monument #442 (1979) on the national protection level. The set of laboratories, housing buildings, pavilions for new telescopes was built in 1946-1960. Nowadays, the Main building, the meridian circle pavilion, the astrograph pavilion, the horizontal solar telescope pavilion, three metal pavilions, three brick pavilions, laboratories, housing buildings are situated on the territory of Observatory. The Repsold meridian circle (1871) has the objective lens of 122 mm in diameter D with the focal length F=1480 mm (Fig. B5.6). The Observatory took an active part in the establishing fundamental coordinate system (the frame of reference) by compiling 14 star position catalogues with a high accuracy. In 1996, RMC was trasferred to the AO KNU museum . Another instrument is the double refractor-astrograph (DRA) (D = 200 (240) mm, F = 4500 mm) which was manufactured by Merz and Repsold in 1895. The DRA with dome (1860) is the historical monument of science & technique registered as #433/5-Kv.

Nowadays the Astronomical Observatory is a part of the structure of T.G. Shevchenko National University of Kyiv, which is subordinated to the Ministry of Education and Science of Ukraine. Its main research fields are as folows: the compilation of stellar catalogues, solar service & the solar-terrestrial interactions; optical and radio observations of meteors; investigations of the Moon, comets and asteroids; the relativistic astrophysics; optical observations of the Earth's satellites. As it was mentioned above, the Observatory participated in the creation of the fundamental reference coordinate system and contributed to 14 high accuracy stellar catalogues.

The museum of AO KNU has more than 20 thousands of items, related to science and technology and the regional memorabilia as well. There are also ancient astronomical instruments, such as the passage telescope made by Ertel in 1838, the meridian circle made by Repsold in 1870. And the astrograph made by Repsold in 1895.

"Astronomical Observatory of the Odessa National University" Research Institute (*AO OdNU*)

The Odessa Astronomical Observatory is situated in the park zone of Odessa near the Black Sea beach. It occupies the total area of 1.4 hectares.

It was founded as the branch (observatory) of the Imperial Novorussia University in 1871 (Karetnikov, 2007). The main one-storied building of AO OdNU was designed by A. Bernardazzi and built in 1871. It has a rectangular shape in the East-West direction (Fig. B5.7). In 1886, the round two-storied dome for the Cooke telescope was attached to this building .The main building is a monument of architecture and history under National protection (Resolutions of the Odessa Regional Executive Committee #652, 1984, and #392, 1987).

Fig. B5.7 Main building of Astronomical observatory of the Odessa University

To the East of the Main building, a special meridian pavilion was erected for the Repsold meridian circle (D=135 mm, F=1980 mm), that was installed in 1862; it has a sliding slit in walls and roof along the meridian for observations. About 150,000 observations were made with this RMC, all of them having constituted the basis for compiling about 30 catalogues. At present the RMC is also used for the educational and training purposes, as well as for demonstrations during general public group visits.

Two-storied round tower with the rotating dome was built in 1886 to the East of the main building for installing the Cooke telescope-refractor (CTR). The Cooke & Sons Co. telescope-refractor (1866) is equipped with the objective lens of D=165 mm and F=2850 mm. The CTR was the largest telescope in the Observatory up to 1954. Visual and photographic observations of variable stars, transit of planets through the solar disc, eclipses of the Sun and the Moon. Nowadays the CTR is widely used for the educational and training ends, and for demonstrations during general public group visits as well. In 1915, the round tower and the meridian room were rebuilt in accordance with the design of architect A. Bernardazzi, having taken their present architectural appearance, including the main entrance, the round hall, premises, marble stairs to the first floor, the balcony around the tower, and the platform for observations.

At present, the Research Institute “Astronomical Observatory” is a structural part of Odessa National University named after I.I. Mechnikov. It is subordinated to Ministry of Education and Science of Ukraine. The main scientific fields of the Observatory activities are as follows: determination of star positions, research of the Sun, variable stars, meteors, spectroscopy of stars, and compilation of high accuracy star catalogues. It should be noted that long before the 1917 Bolshevik coup d’état the famous scientist A. P. Hanski who had worked at the Observatory had been awarded with the Légion d’honneur Order of France and received the Janssen Award of the French Academy of Sciences for the prominent research of the Sun done by himself and his colleagues. The archive of photographic observations contains more than 107000 astroplates taken in the XIX – XX-th centuries, the Odessa astroplate collection occupying the third place in the world for the number of astroplates after the Harvard and Sonneberg collections. About 40 telescopes with mirrors up to 1 m in diameter were manufactured in the Observatory optical and mechanical shop in 1968 through 1999, such as the Schmidt telescope, two telescopes for meteor observations, the telescope for Earth's satellite observations, two laser ranging telescopes and many others.

The “Crimean Astrophysical Observatory” Research Institute (*CrAO*)

Historically, in the tentative list of the UNESCO World Heritage was also included CrAO, which is now under jurisdiction of Russian Federation. Since the time of Former Soviet Union it was jointly exploited by Russian and Ukrainean astronomers and benefited to both nations. The main features of this observatory are described below.

The Crimean Astrophysical Observatory is one of the largest observatories in Europe (Dobronravin P.P. et al, 1965, Fig. B5.3). Its instrumentation base allows to perform a wide scope of research in the solar and stellar physics, to study galaxies and ultra-high energy sources, to investigate the dynamical and physical properties of minor bodies in the Solar system, to solve problems of the asteroid hazard and ecology of the near-Earth space. The Night sky brightness at the Nauchny site where CrAO is located, is about 21mag/sec^2 in the visible range. About 20 telescopes of different power are operated at the Observatory. The largest of them is the 2.6 m reflector named after Academician Gregory Shain (Fig. B5.4). There are also the 1.2 m automated reflector, the solar tower telescope with the 1.22 m main mirror, the unique optical gamma-telescope with the total mirror area of 54 m^2, the 22 m radio telescope RT-22. The Observatory cooperates with many institutes of Russia, Ukraine, USA, and the countries of Europe and Asia. The telescope RT-22 is incorporated into the European Very Long Base Interferometry (VLBI) network.

The CrAO is known as the centre of design and manufacturing telescopes and astronomical instruments for the ground-based and space research. The scientific archive of the CrAO contains multi-year observations of the Sun, stars, galaxies and individual objects, different surveys and catalogues. The library contains about 165 thousand items in astronomy and other scientific fields, some of them dating back as far as to the XVII-th century, atlases and celestial charts, different catalogues. Since 1947 CrAO publishes the magazine “Izvestiya Krym. Astrofiz. Obs.” journal (Bull. Crimean Astrophys. Obs.).

The history of CrAO extends over several periods of time: the private observatory of N.S. Mal’tsov at Simeiz in 1900-1908, a branch of the Pulkovo Observatory in 1908-1944, CrAO of the USSR Academy of

Science in 1945-1991, Scientific Research Institute of the Ministry of Education and Science of Ukraine (1991-2014), CrAO of the Russian Academy of Sciences since 2014. The Observatory is located in three picturesque places of the Crimea. The basic departments and administration are in the Nauchny village in Bakhchisaraj region, the Radio Astronomy Laboratory and its subdivision, the Simeiz Observatory, are situated on the Black Sea coast in the Katsiveli and Goluboy Zaliv villages. The five major telescopes and the Satellite Laser Ranging station "Simeiz-1873" have a national heritage status. The Main building at the Simeiz Observatory where Acad. G.A. Shajn lived and worked for years, has a status of architectural value and is under state protection. The same status has a house where Dr. A.P. Hanski lived. Memorial plaques in honour of N.S. Mal'tsov, the founder of the Simeiz Observatory, and a few of the first Simeiz astronomers is fixed on the pavilion where the Observatory's first telescope was installed. The memorial plaque commemorating Acad. A.B. Severny, the former director of CrAO, is mounted at Nauchny.

CrAO preserves traditions and remarkable stages of the development of astrophysics in the XX-th century. It remains a modern world-recognized observatory and represents significant object at the World Heritage level.

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B6. ASTRONOMICAL OBSERVATORY OF THE MOSCOW UNIVERSITY:
Monument of History of Science and Architecture

Yu. L. Mentsin and I. K. Lapina
Sternberg State Astronomical Institute, Moscow University, *Russia*

In the central part of modern Moscow the campus of the ancient Astronomical Observatory of the Moscow University is located. Now this Observatory represents a part of the Sternberg Astronomical Institute of the Lomonosov Moscow State University (SAI MSU), and its present-day name is Krasnopresnenskaya Observatory of SAI. Together with the first observatory of St.-Petersburg Academy of Sciences, it is the oldest one of the now existing Russian astronomical observatories.

The University Observatory was built in 1831 under the supervision of Dmitry Matveyevich Perevoshchikov (1788-1880), well-known Russian scientist and educator, professor of astronomy and later on Rector of the Moscow University and a member of the St.-Petersburg Academy of Sciences. Previously a small astronomical observatory was built at the Moscow University in 1804 by the order of the first trustee of the Moscow Education District Mikhail Nikitich Muravyov (1757-1807). It located in a wooden tower on the roof of the main University building in Mokhovaya Street. It perished in the fire of Moscow in 1812.

Building a new University observatory was postponed for a long time, mainly because of absence of a suitable place. The situation changed in 1827, when a merchant and patron of arts Zoi Pavlovich Zosima donated to the Moscow University his summer residence on a high bank of the Moskva River near the Presnenskaya Gate (at that time it was at the outskirts of Moscow). This site was ideally suited for building an observatory. It was decided to construct it in stone, not only for educational, but also for research purposes. A solid foundation, much deeper than the base of the walls, was built under the observatory tower. This structure, which had been used in building observatories since the beginning of XIX century, protected the tower against vibration and made possible mounting high-precision astronomical instruments. Architect D. G. Grigor'ev, one of the leading architects supervising the restoration of Moscow after the fire in 1812, was the designer of the Observatory building. In addition to the main building of the Observatory, a two-stored wooden house designed by Grigor'ev was built; in it, University astronomers and their families lived for more than hundred years.

Fig. B6.1 D. M. Perevoshchikov, the founder and the first director (1831-1851) of the Astronomical Observatory of the Moscow University

Fig. B6.2 The Astronomical Observatory in 1864. A photo taken by the Observatory Director B. J. Schweizer

Fig. B6.3 The Astronomical Observatory at the beginning of the XX century

Fig. B6.4 The Astronomical Observatory, present view

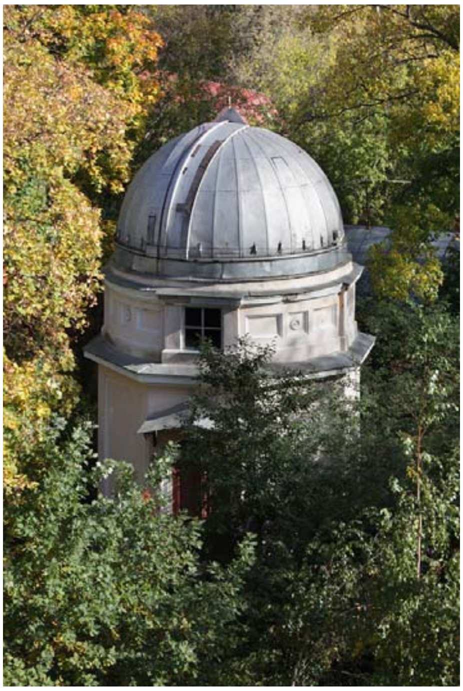

Fig. B6.5 The Nazarovskaya Tower built at the end of the XIX century

Fig. B6.6 The 15-inch telescope-astrograph installed in 1900; regular observations began in 1902

— STAATSPRÄMIE. —

GUSTAV HEYDE

Mathem.-mech. Institut
und
Werkstätten für Präcisions-Optik

Fernsprecher 1798, Amt I. Dresden, den 11. December 1898.
Ammonstrasse 32.

Specialitäten:
Instrumente für Himmelsphotographie
Refraktoren
Passage-Instrumente
Astronom. Uhren und Triebwerke
Drehkuppeln
Universal-Instrumente
Theodolithe
Nivellir-Instrumente
etc. etc.
NEU! Patentirte Reise-Theodolithe
Theodolithe ohne Kreise u. Nonien.
Fernrohrobjektive und Okulare
Prismen, Lupen etc.
H Rapid-Aplanate
Lichtstärkste Momentaplanate

Hochwohlgeboren
Herrn Prof. Dr. W. Ceraski
Direktor der kai. russ. Universitäts Sternwarte
Moskau

Den Empfang Ihres geehrten Schreibens vom 25. Nov. / 7. Dec. a. c. bestens dankend bestätigend theile Ihnen hierdurch ganz ergebenst mit, daß ich mit Ihren Bedingungen vollkommen einverstanden bin.
Die gewünschten neuen Einrichtungen werden Ihren Wünsche gemäß ausgeführt: also die Treppe vom Rand bis zum Gipfel, die feuervergoldete Strahlen-Kugel und die Einrichtung zur Abdeckung der Spalte. Auch sollen die äusseren Rollen von Bronze gemacht werden. Alles auf das Sämtlichste ausgeführt.
Die Aufstellung der Kuppel geschieht unter meiner Leitung im September nächsten Jahres und bin ich gern bereit Ihnen zur Sicherstellung des Lieferungs-Termines jede gewünschte Garantie zu bieten.
Ich werde dem Bewegungsmechanismus und den Rollen ganz besondere Sorgfalt widmen, damit die Kuppel auf das leichteste funktionirt.
Was nun das Cassageschäft anbelangt so bin ich gern bereit eine bedeutende

Fig. B6.7 The Certificate of recognition of the telescope-astrograph as a 1st category monument of science and technology

Fig. B6.8 Elements of the interior of the Museum of history of the University Observatory and SAI: Round hall of the first floor of Astronomical observatory (AO) main building. Photo by M.P.Fedina.

Fig. B6.9 Elements of the interior: The cast-iron staircase in the tower of AO main building. Photo by M.P.Fedina.

Fig. B6.10 Element of the interior tower of AO main building. Photo by M.P.Fedina.

Scientific research carried out at the University Observatory required its regular modernization, which began in 1840-s and included installation of new equipment, building additional rooms, auxiliary towers, etc. The most important and large-scale reconstruction was performed at the turn of XIX century under supervision of the Observatory director, professor of astronomy V. K. Tserasky (1849-1925). A lecture room was attached to the tower of the Observatory main building. A rotating dome and a 15-inch telescope-astrograph were mounted on the tower. This telescope was for a long time one of the biggest astronomical instruments in Russia. The telescope was manufactured by Repsold and Sons (Hamburg); its objective lenses were made by Henri Brothers (Paris), and the dome by Heyde (Dresden). Using funds donated by A. A. Nazarov, who was a graduate from the Moscow University and V. K. Tserasky's schoolmate, four auxiliary towers were built in the Observatory courtyard and equipped with instruments during the reconstruction; the biggest one was named Nazarovskaya.

The reconstruction of the Observatory had a good influence on the adjacent territory. V. K. Tserasky urged the city authorities to pave the nearby street and to plant poplars preserved until now, which protected the Observatory from the city noise and dust. Furthermore, V. K. Tserasky persuaded the University administration to complete an agreement with local builders not to erect nearby houses that would hinder astronomical observations. This agreement referred to a strip of land 10 sazhens (21 meters) wide from the Observatory to the Moskva River going southward parallel to the meridian. Following V. K. Tserasky's proposal, the University has also purchased a ground area adjoining the Observatory to create a meteorological station. Now Russian Federal Hydrometeocenter is located at this site.

It is important to emphasize that almost all buildings in the Observatory campus have been preserved. Moreover, in 1979 the building complex of the Krasnopresnenskaya Observatory was placed under state protection as an architectural monument. In the late 1980-s - early 1990-s this enabled the SAI Directorate, with an active support from the University Administration, to implement a science-based restoration of this object. Now the Krasnopresnenskaya Observatory hosts several SAI laboratories and the Museum of History of the University Observatory and SAI. This museum collected original documents, observation logs, personal belongings, devices and instruments used by the Observatory staff at various times. Visitors of the Krasnopresnenskaya Observatory Museum are as though transferred to Moscow of the XIX-th - early XX-th century. They can see how scientists lived and worked more than a hundred years ago. A special interest of visitors is attracted by the main instrument, the 15-inch telescope-astrograph, which has been conserved and yet works. Visitors' attention is drawn to the Observatory interior-spiral stairs in cast iron, special semicircular furniture made in the XIX-th century, walls decorated with ornaments, ancient instruments and tools, workplaces of renowned scientists, and many other things. Therefore, it is no wonder that the Observatory territory and internal rooms have been used many times for filming features and educational movies.

The Astronomical Observatory of the Moscow University played an important role in the development of the Russian and world science. Many outstanding scientists, such as B. Ya. Schweizer, F. A. Bredikhin, V. K. Tserasky, A.A. Belopolsky, S. N. Blazhko, S. V. Orlov and others, worked here in the XIX-th - early XX-th century. One of the most important scientific achievements of the Observatory researchers was creation by F. A. Bredikhin of the first full mechanical theory of comets' forms and the first in Russia spectral observations of celestial objects he carried out; this founded the Moscow science school of astrophysics. Thanks to close connections with the Moscow University, the Observatory became at the turn of XIX-th – XX-th centuries undisputable leader in the application of astrophysical research methods in Russia.

In 1885 V. K. Tserasky discovered noctilucent clouds and, jointly with A. A. Belopolsky, determined their height. In 1895 V. K. Tserasky measured for the first time in the world the lower limit of the Sun's surface temperature, and ten years later, also for the first time, determined the apparent magnitude of the Sun. In addition, V. K. Tserasky, jointly with S. N. Blazhko, L. P. Tseraskaya, and P. K. Sternberg, laid the foundation of Russian astrophotometry and began regular photographing the sky with the purpose of discovery and study of variable stars.

The Astronomical Observatory of the Moscow University became one of the pioneers in gravimetry studies in Russia. The Moscow Gravity Anomaly was comprehensively studied by B.Ya. Schweizer and P.K. Sternberg; dozens of gravimetrical expeditions to various regions of the European part of Russia have been undertaken. Recognition of scientific merits of the Astronomical Observatory was the election of its researchers and alumni (A. A. Belopolsky, F. A. Bredikhin, S. K. Kostinsky, D. M. Perevoshchikov, M. F.Khandrikov, V.K.Tserasky) to the St.-Petersburg Academy of Sciences. F.A.Bredikhin and A.A. Belopolsky were appointed to the position of the Director of the Pulkovo Observatory of the Academy of Sciences in 1890 and 1916, respectively.

In 1931 on the basis of Astronomical Observatory of the Moscow University, Sternberg Astronomical Institute was created. SAI became the leading centre of astronomical researches in the USSR and modern Russia. The pleiad of outstanding scientists, who worked in the Observatory from 1931 to 1954, before relocating SAI to the new building on Lenin Hills, significantly contributed into development of the majority of astronomy branches. In 1930-1940-s the major science schools of astrophysics

(V.G.Fesenkov, B.A.Vorontsov-Vel'yaminov, G.F.Sitnik, I. S. Shklovsky), astrometry (S. N. Blazhko, M. S. Zverev, E. Ya.Bugoslavskaya), stellar astronomy (K. F. Ogorodnikov, P. P. Parenago, B. V. Kukarkin), celestial mechanics (N. D. Moiseev, G. N. Duboshin), marine gravimetry (L. V. Sorokin) were formed in SAI. Among representatives of these schools there are authors of fundamental discoveries, winners of the highest governmental and scientific awards, Academicians and Corresponding Members of the Academy of Sciences. The works of SAI researchers are internationally recognized. One of illustrations of this recognition was the decision taken in 1946 by the Executive Committee of the International Astronomical Union (IAU) based on B. V. Kukarkin's initiative, to set up the group of variable star researchers from SAI and of the Astronomical Council of the USSR Academy of Science to compile the General Catalog of Variable Stars. The X-th jubilee General Assembly of the IAU was held in 1958 in the Moscow State University and it became an undisputable evidence of the international recognition of scientific achievements of SAI.

The history of Astronomical Observatory of the Moscow University is closely associated not only with the history of our science, but also with the history of sociopolitical and cultural life the USSR and Russia. Among D. M. Perevoshchikov's students there were A. I. Herzen and Mikhail Vasnetsov - the son of well-known artist V. M. Vasnetsov - who became later an outstanding figure of the Russian Orthodox Church abroad. In 1847 D. M. Perevoshchikov was awarded by the Imperial Decree of Czar Nikolay I with a diamond ring for the supervision of installation of lightning rods in the Big Kremlin Palace. The Director of the Observatory P. K. Sternberg was a major political figure in the Russian Social-Democratic Labour Party and later on in the Soviet Union. In the days of World War II many SAI researchers and students of the Astronomy Division of the Moscow State University joined the Red Army, ten of them heroically perished defending the country. E. M. Rudneva, the student of the Astronomy Division, in wartime a navigator in a female night bomber regiment, was awarded the title of a Hero of the Soviet Union posthumously.

Many interesting stories are related to the Observatory Time Service. In the prerevolutionary years P.K.Sternberg hid Bolsheviks' arms in the hour cellar of the Observatory. In the first third of the XX-th century watch-makers and representatives of public services came on Mondays to Presnya to check their chronometers, and on September the 1-st, 1931 radio transmission of exact time signals began from SAI over all USSR territory. The work of the Exact Time Service, which was vital for needs of the defense industry and frontlines, did not stop even in the difficult months of the Second World War, when astronomical observations had to be conducted under German bombs. Soon after the end of the war SAI employees A. S. Mirolyubova and M.A.Smirnova, who provided uninterrupted functioning of the Exact Time Service in the days of the war, were awarded with Lenin Orders.

An important role in the preservation of Astronomical Observatory of the Moscow University as a unique monument of history, science, and architecture is played by the Museum of History of the University Observatory and SAI. This museum which was founded in late 1950-s by the noted astronomer and historian of science P. G. Kulikovsky, originally was in one of the rooms of SAI building on the Lenin Hills, and since 1981 it is located in the main building of the Observatory. Excursions for schoolchildren and amateur astronomers are regularly provided in the museum. A solemn initiation of the first-year students of the Astronomical Division - Physics Faculty of the Moscow State University - takes part here as well as lectures in history of astronomy for the senior students.

The Museum of history and of the University Observatory and SAI actively cooperates with a number of other museums. In particular, some materials from the museum funds were presented in 2005 in the State Historical Museum and Museum of History of the Moscow State University at the exhibitions devoted to the 250-th anniversary of the Moscow University. In the last years employees of the museum regularly take part in meetings of the Advisory Council of the program on monuments of science and technology at the Polytechnical Museum of Moscow. Some exponats of the Museum of history of the University

Observatory and SAI were presented for consideration of the Advisory Council. After an appropriate examination these exponats were recognized as the 1-st category monuments of science and technology, and the information on them was included in the Registry of Russia's Monuments of Science and Technology.

B7. THE CENTRAL ASTRONOMICAL OBSERVATORY AT PULKOVO OF RAS AS THE OBJECT OF WORLD HERITAGE

A.V. Stepanov, V.K. Abalakin, S.V. Tolbin
The Pulkovo Astronomical Observatory, Saint Petersburg, Russia

The Pulkovo Astronomical Observatory situated in the vicinity of Saint Petersburg had been erected in the end of 1830-s following the Edict of the All-Russian Emperor Nicholas the First. It had been constructed after the project of the famous Russian architect Alexander P. Brüllow by the direct participation of its first Director, the outstanding astronomer, Academician Friedrich Georg Wilhelm (Vasily Yakovlevich) Struve. The Observatory was inaugurated on August 19, 1839 and named the Nicholas Central Astronomical Observatory at Pulkovo.

From the very beginning it was conceived to be a principal astronomical institution of Russia, being intended, as it was formulated in the Observatory Statutes, for making "permanent and as well as possible most perfect observations aimed at the great advantage of Astronomy" the Russian Empire needed for its geographic enterprises and for practical astronomy ends as well. By 1839, the unique astronomical instruments were mounted at the Pulkovo Observatory which had been manufactured by well-known German telescope-makers Ertel and Repsolds family by participation of Wilhelm Struve himself. It was the famous Pulkovo transit instruments and the 15-inch (38 cm) refractor, being the world greatest one at that time. Later on, in 1870-s Otto (Otto Vasil'evich) Struve, a son of Wilhelm Struve, having received a generous financing of the Russian Government and the Academy of Sciences, had enriched the instrumental basis of the Observatory by acquiring the 30-inch refractor manufactured in 1885 by the world-known telescope-makers Alvan Clark and Sons in the USA (the objective lens) and the Repsolds in Germany (the mounting).

Wilhelm Struve had developed a new techniques of astrometrical determinations of precise stellar positions which enabled him to increase the accuracy of position observations at Pulkovo Observatory by the factor of 3 through 5 as compared to the accuracy attained at that time by leading world observatories, i. e. the Royal Greenwich Astronomical Observatory and l'Observatoire astronomique de Paris. Having made use of these observations, Wilhelm Struve and his collaborators had determined the fundamental astronomical constants – those of the precession, nutation, aberration, and refraction – and compiled the famous Pulkovo absolute catalogues of stellar positions; these catalogues have brought the world glory to the Pulkovo Observatory which had been reflected in the title "the Astronomical metropole of the world" given to the Observatory as far back as in XIX-th century by an American astronomer Benjamin Gould. These catalogues and the following ones had constituted the basis of all fundamental astrometric coordinate systems which were created in the XIX-th and XX-th centuries.

Fig. B6.1 Pulkovo Observatory in 1855

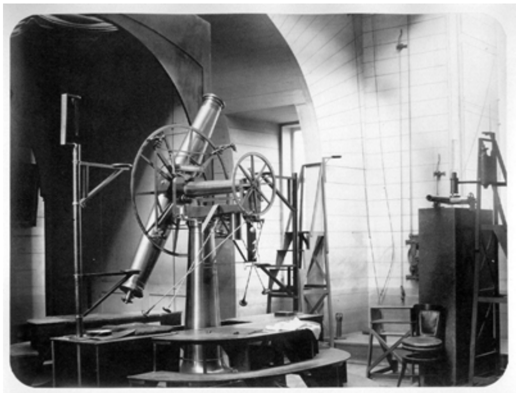

Fig. B6.2 Meridian circle

Fig. B6.3 The main building of the observatory

Fig. B6.4 Big Pulkovo Radio Telescope

The astronomers and geodesists of the Pulkovo Observatory had actively taken part together with scientists from Sweden and Norway in the great international undertaking aiming at the measurement of the meridian arc from the Danube estuary (the village of Staraya-Nekrasovka near Izmail) to the town of Fuglenes in Norway situated on the coast of the Northern Ice Ocean. This unprecedented work was completed in 1851. In the years 1899 through 1901 the Pulkovo astronomers had performed the triangulation operations of the island of Spitsbergen.

It should be noted that on July 15, 2005, the “Struve Geodetic Arc” has been included into the UNESCO List of the World heritage as a transnational monument.

The initial zero-point of the Russia’s triangulation coincides with the center of the Round Hall of the main building of the Pulkovo Observatory. The Pulkovo meridian passing through this center and being located at 30°19,7' East of Greenwich was the initial one on all old geographical maps of Russia.

Otto Struve had written: “So, Pulkovo has gradually become a scientific focus of all work related to the mathematical geography of the Russian Empire, and we are glad to be able to provide herewith a direct practical benefit to the state”.

The Observatory had become a center for providing the exact time to the Russian astronomical and civil institutions. For the first time, in 1914 the determination of the length difference between Paris and Pulkovo had been accomplished using the time of radio signals propogation. The Pulkovo Services of Time and Latitude had performed long-time mutual investigations with such domestic and international institutions as the Gosstandart, the United States Naval Observatory, Le Bureau International de l’Heure and others, engaged in the study of a complex Earth rotation process and in the formation of the Universal and Atomic time scales.

There appeared and developed new directions of astronomical researches at the Pulkovo Observatory in the decades following its inauguration, i.e. the Astrophysics, Astrospectroscopy, Photographic Astrometry. The Solar Service uniting all solar observatories in the world had been created under aegis of the Commission for research of the Sun

(КИСО) which was organized at the Pulkovo Observatory in 1905 and directed by Academician Aristarchos A. Belopolsky. After the WWII in 1948 the High Altitude (Mountain) Station of the Pulkovo Observatory, as initiated by Mstislav N. Gnevyshev, has been built near the town of Kislovodsk and has become one of the centers of the International Sun's Service. Here, for the first time in the USSR, the observations of the solar corona without having to wait for total solar eclipses had been started by the use of the Lyot coronagraph manufactured by the firm "Carl-Zeiss-Jena", Germany; these observations are continuing up to the present time.

The Pulkovo Observatory had been completely destroyed in 1941 – 1944 by shelling and bombardments during the WWII. Its many astronomers and workers had died of starvation during the siege of Leningrad or were killed in action if having been drafted to the Red Army. All large instruments of the Observatory, including the Great 30-inch refractor (the most valuable instrument of the Observatory, according to the words of a great American celestial mechanician Simon Newcomb), as well as the major part of its Library and the Museum collection of ancient astronomical instruments and clocks had been perished. It was the second deadly blow for the Observatory after the bestial Stalinist purges in 1937.

The restoration of the ruined Observatory began already in 1945 under the directorship of Professor Gregory N. Neujmin who died in 1946 due to overstrain of his moral and physical forces. The restoration project has been composed by Academician Alexej V. Shchusev; it was made a reality under the directorship of Academician Alexander A. Mikhailov. The second inauguration of the Pulkovo Observatory after its rising from ruins as the Central (Pulkovo) Astronomical Observatory of the USSR Academy of Sciences has taken place in May 1954 in presence of the representatives of the worldwide astronomical community.

In the post-war years a new research field has appeared at the Pulkovo Observatory – the Radioastronomy which was introduced by Professor Semyon E. Khaikin. Under his leadership the Big Pulkovo

Radiotelescope (BPR) had been built on the precincts of the Observatory, and in village of Zelenchukskaya (the Northern Caucasus) the world greatest radiotelescope RATAN-600 with the circular antenna of diameter of 600 m, formed by adjustable rectangular shields. It should be noted that Professor Khaikin, being in the Physical Faculty of the Moscow State University, had published the manual “The Mechanics” in 1947 for which he was accused by the Soviet ideologists of the “Machistic idealism deviations” and was fired from the University. He could not find a position in Moscow for months but then he was invited by Director Mikhailov to the Pulkovo Observatory to establish the Radioastronomical Division at the Observatory. At the same time Professor Dmitry D. Maksutov worked at the Pulkovo Observatory on the project of a giant reflector with 6 meter mirror. This telescope was built in 1977 by the optical-mechanical workshop LOMO with the most active participation of Drs. Bagrat K. Ioannisiani and Ivan M. Kopylov. It was installed in the foothills of the Northern Caucasus Mountains at the Special Astrophysical Observatory of the USSR Academy of Sciences (SAO).

After the launch of the first artificial Earth satellite in the USSR on October 4, 1957, the first visual and photographic observations of this new man-made celestial object were performed by astronomers of the Pulkovo Observatory.

The scientific activities of the Pulkovo Observatory at the present time embrace practically all priority directions of basic research in the modern Astronomy. Pulkovo astronomers take active part in observations and scientific studies together with astronomers from institutions in the Great Britain, Spain, USA, Denmark, Italy, Belgium, Germany, Japan, Finland, Greece, Bolivia and in many other countries. International conferences, symposia, seminars are regularly convened at the Observatory. In the last two decades Pulkovo astronomers developed several ambitious space projects, such as “Stereoscope”, “Solar Astrometry”, and others.

Nowadays the Astronomical Museum of the Pulkovo Observatory re-created in 1967 is situated in the Round Hall of the Main Building and demonstrates various astronomical devices and old telescopes, the unique optics including the 30 inch objective lens manufactured by the Clarks, astronomical clocks, the gallery of portraits of outstanding astronomers of XVIII-th through XX-th centuries.

One of the basic and traditional tasks of the Observatory consists in its guided tours and lectures aiming at general astronomical enlightenment of laic audience. The Observatory is visited in average by nearly 15 thousand persons per year.

The role of the Pulkovo Observatory as of one of the country's centers of culture and scientific enlightenment has increased after inclusion of the Observatory into the code-list of particularly valuable monuments of the national cultural heritage of the Russian Federation (vid. the Decree of the President of the Russian Federation, Art. 1606, No. 275, April 2, 1997). The Observatory is recognized by enrollment of the "Struve Geodetic Arc" into the UNESCO List of the World heritage as a transnational monument.

There is the Memorial astronomical cemetery on the northern slope of the Pulkovo Hill where Wilhelm Struve and several directors of the Obsevatory as well as outstanding astronomers of XIX-th – XXI-th centuries have been buried. Two memorial military cemeteries with common graves are situated in the close vicinity thereof.

The architectural ensemble of the Pulkovo Observatory created by the genius of Alexander P. Brüllow, Alexey V. Shchusev, Daud H. Enikeyev and others is inserted like a beautiful pearl into the invaluable necklace of palaces and parks in the suburbs of Saint-Petersburg. As it has been mentioned above, the Pulkovo Observatory ensemble was included since 1990 by the UNESCO into the List of the World Heritage together with the historical downtown of Saint-Petersburg and its suburbs.

B8. THE PULKOVO HERITAGE IN WESTERN 19TH AND 20TH CENTURY OBSERVATORIES

J. Davoigneau[1], *F. Le Guet Tully*[2]

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The inventory of the French astronomical heritage which we undertook in the mid-1990s under the auspices of the Ministry of Culture and the Ministry of Research has led us to study in depth the sites, the architecture, the spatial organisation and the instrumentation of the observatories founded in France in the 19th and 20th century. This study allowed us then to undertake comparisons with observatories built during the same period in other countries.

We discuss how and why the Pulkovo model was introduced in most of these observatories and try to establish a typology of the 19-th and 20-th centuries astronomical sites that were examined.

B9. KAZAN OBSERVATORY AS ASTRONOMICAL HERITAGE

Nefedyev Y.A., Andreev A.O., Demina N.Y.
Engelhardt astronomical observatory of Kazan Federal University, Kazan, Russia

There is hardly in doubt that there was a period in the development of science in the middle ages, which is referred to as "dark era". Probably this is true when addressing to Latin Europe. However, many facts argue that at the same time numerous scientists from Islamic countries achieved very high level of scientific study. As examples, one may mention such inventions and finding as large mechanical clocks, pendulum, lenses and prisms, compass, trigonometry, decimal fractions, negative numbers, cubic equations, binomial theorem, logarithms. It should be noted that great Tatar poet Saif Sarai (1321-1396) in his poem "Sukhayl and Gul'dursun" (1394) wrote about the Earth rotation around the Sun – 150 years before Copernicus. All this testify that the modern Kazan astronomy has very deep historical roots.

The Department of astronomy of Kazan University is the oldest one in Russia: education of professional astronomers has begun in 1810 - at the first time in Russia. Among the first students in the Department there were the great mathematician N. Lobachevsky and I. Simonov - a member of round-the-world expedition headed by F. Bellinsgauzen and M Lazarev which discovered Antarctics. Later they both founded a new observatory at Kazan University and supplied it by the modern equipment (9-inch refractor, meridian circle, heliometer and some others).

Astronomical and Cosmic Geodesy Department of Kazan State University was founded in 1930-th for teaching students in geodesy who would participate in the future geodetic and gravimetrical expeditions in different regions of Russia. The new astronomical direction was founded in 1960-s with the main goal to determine fundamental stellar parameters based on modeling stellar spectra formation. For these purposes, space observation were used (TD-1A, BUSS, Copernicus, IUE). Nowadays Kazan astronomers conduct observations in the two astronomical stations

- one located in Ciscaucasian mountains at the height 2500 m, and the second one nearby Antalya (Turkey) equipped with with 1.5 m telescope of Kazan University.

Presently, the department’s personnel includes 4 professors and 12 PhD scientists deling with problems of astrophysics, astrometry, selenodesy, celestial mechanics. Of them, 4 are IAU and 5 EAS members.

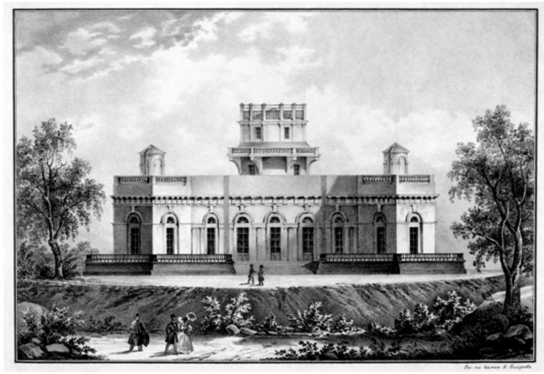
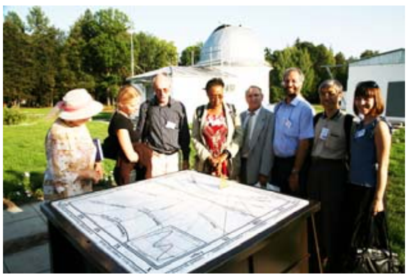
	
Fig. B7.1 The main building of the EAO (1901)	*Fig. B7.2 The department of astronomy and geodesy (1810)*
	
Fig. B7.3 Building of library EAO (A photo of 2007)	*Fig. B7.4 Pavilion of Heliometer EAO (A photo of 2007)*
	
Fig. B7.5 The main administration building of the EAO (1901)	*Fig. B7.6 Sundial EAO*

Fig. B7.7 Planetarium

Fig. B7.8 Telescop Refractor EAO

Fig. B7.9 Perspective schem of EAO

Fig. B7.10 Azimuth mark - burial vault in EAO

Fig. B7.11 Astronomical museum EAO

Fig. B7.12 The observation platform EAO

Fig. B7.13 Night on the ground

Fig. B7.14 Exposition “Steps on the Moon”

Kazan astronomical school maintains scientific collaboration with many Russian and international astronomical units: Special Astrophysical Observatory (Zelenchuk), Institute of Astronomy (Moscow),, Space Research Institute (Moscow), Institute of Applied astronomy (St. Petersburg), Moscow University, Astrophysical observatory, Main Astronomical Observatory (Pulkovo), Odessa Observatory (Ukraine), and Astronomical departments at Latvia, Estonia, the Netherlands, USA, Spain, Great Britain, Germany.

Engelhard Astronomical Observatory (EAO) was founded in 1901. It is situated 24 km from the Kazan city (longitude = 3h 15m 15.74 s, latitude = 55050 ' 20 " 6, H = 94m).

The following researchs are carried out in EAO: coordinate-time problems of astronomy and geodesy, determination of exact positions of stars and compiling star positions catalogues, study and specification of figures and orbits of Solar system bodies, definition of galactic parameters, astronomical instruments, and history of astronomy.

The history of foundation of Engelhard Astronomical Observatory is rooted in the donation to the Kazan University in 1897 of the unique astronomical equipment, made by the known astronomer Vasily Pavlovich Engelhardt from his private observatory in Dresden. He terminated his own astronomical activity because of being advanced in years and desiese and decided to offer all astronomical observatory's instruments and library to the Kazan University. Engelhardt conditioned his donation that instruments must have been established as soon as possible and supervised the process. In 1898, the decree of Emperor had been issued and the ground for the Astronomical observatory building was allocated.

The main instrument, the 12-inch refractor with the 31-cm objective diameter and the length of about 4 m has been installed by English master Grub in 1875. The dome was 6.5 m in height, its internal diameter being about 6 m. It was surrounded by a small balcony with graceful pig-iron lattice. The column for the refractor was laid out separately from walls of the dome and situated under the ground by 3 m.

Meridian circle of EAO has been constructed in 1845 in Hamburg by the known designer of astronomical tools - Repsold. Columns of the tool tower are 2 m higher than floor of the hall and are isolated from other part. Distance between them is 1.1 m. For protection against heating the meridian circle is covered by a wooden sliding small house. At the meridian circle there are two azimuth marks, everyone distant from the center of mercury horizon by 130 m. Southern to the azimuth mark, owing to downturn of district, it was necessary to lift in the way of fillings a special barrow on 5.5 m in height. At the North of territory there is an iron pavilion along the meridian direction.

The azimuth mark in the pavilion with Meridian circle is not only astronomical point, but also a burial vault. It is a unique architectural construction too. It is shaped as a small chapel in the Byzantine style, decorated on perimeter by stars and signs of zodiac. There is a crypt in the pavilion's basis for two persons who intended to be V.P. Engelhardt and past Director D.I. Dubjago. V.P.Engelgardt's died in Dresden in 1915 and because of the Firstst World War involving Germany followed by revolution it was impossible to transfer the body to the Observatory. Nonetheless, astronomers of Engelhardt Observatory did not lose their hopes to fulfill the last will of the founder and to bury his ash under Southern chrism - a tomb next to his friend Dubiago who dyed in 1918.

Of the other telescopes of EAO, the unique in the world heliometer should be mentioned, which is still operational. It is one of the first heliometers produced in the Repsold workshops, which has been made in 1874 and established in EAO in 1908 in the specially constructed round pavilion of 3.6 m in diameter. There are also Zenith telescopes, Geid telescope, the Meniscal telescope of Maksutov system, AFR, the modified AZT-14 telescope equipped with CCD matrix, etc. EAO possesses the big library amounting to about 100000 units in the storage, including the rare copies of books with autographs of the well-known astronomers.

The scientific equipment and several generations of EAO personnel allowed us to carry out important astronomical researches and continue them at the advanced level contributing to the world astronomical science. The fundamental system of coordinates, catalogues of weak stars (CSZ), AGC, FCSZ, etc. have been implemented with the use of Meridian circle. The longest series of lunar observations has been taken with the EAO heliometer, the unique supervision of the Moon with stars is continuing to carry out, catalogues of lunar craters were derived. Coordinates of of the Solar system bodies were definid with the EAO refractor. The structure of interstellar environment and the whole Galaxy were studied in the Department of astrophysics. Catalogues of spectral sizes and parameters of color for more than 30000 stars were compiled. In 1932, EAO was selected as the Center for studying variable stars. Works of the international level are carried out in the Department of meteors. The glass library of the Observatory totals about 50000 photographic plates.

The site of Engelhard Observatory represents the park area with rare trees involving centenary unique cedars and oaks, camomile glades and buildings organically entered in its landscape and pavilions. Thousand pupils from elementary and secondary schools, university students and general public visit EAO yearly. The Astronomical Observatory bears the purpose of keeping of and acquainting with the Astronomical Heritage, in which cultural, scientific and educational components are closely bound. Directors of EAO were: D.I.Dubjago (1901 - 1918); M.A. Grachev (1918 - 1925); A.A. Yakovkin (1925 - 1931); D.Ya. Martunov (1931 - 1956); A.D. Dubjago (1956 - 1958); A.A.Nefed'ev (1958 - 1976); O.I. Belkovich (1976 - 1991); N.G. Rizvanov (02.1991 - 11.1991); N.A. Sakhibullin (1991 - 2008); Yu.A. Nefed'ev (since 2008).

Museum of a history of astronomy was organized in EAO. It contains a set of unique exhibits of historical, scientific, technical and art contents.

Many International and Russian scientific conferences were held with the EAO leadership. The Observatory is the unique scientific - educational and cultural - cognitive astronomical center located on the great Russian territory East of Moscow.

Astronomical objects named after Kazan astronomers

Names of the Lunar craters:

T.A.Banahevich (master);
I.V.Belkovich (professor);
D.I.Dubjago (professor);
V.P.Engelhardt (professor);
M.A.Kovalsky (professor);
A.V.Krasnov (professor);
I.A.Littrov (professor);
N.I.Lobachevsky (professor);
A.A.Yakovkin (professor);
A.A. Nefed'ev (professor).

Names of the comets:

A.D.Dubjago (professor) - 1921 I Dubyago;
A.D.Dubjago (professor) - 1923 III Bernard – Dubyago.

Names of the minor planets:

E.O.Dibay (professor);
A.D. Dubiago (professor);
N.I. Lobachevsky (professor);
D.Ya. Martinov (professor);
O.I. Belkovich (professor);

Other minor planets:

Kazan University;
Siyubeki.

Name of the Martian crater:

D.Ya. Martunov (professor)

C. SPACE WORLD HERITAGE

C1. ON ASTRONOMICAL HERITAGE FOR THE FUTURE: Two Examples

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The development of the technological component of human civilization as a whole is the driving factor for change of civilization. Change of key technologies defines the transition to a new era. In astronomy one can mark out some of such epochs as antique, telescope and space ones. Changing epochs is defined by events (some "beginnings") that cause great changes not only in the actual technology, but also in the world view of people. Each of the "beginnings" has brought to significant changes in basic scientific foundations and leap in the increment of accumulation of information (in astronomy this is the knowledge on the Universe). It may be recalled that basic meaning of the Greek word ἀρχη is "beginning". Specialists in the field of "archaeosciences" usually study the history of science in the "old enough" times that are mainly related to the "commencement" of era. In this sense, the beginning of the space age, though far of our time in half a century only, is also an important object of study by the experts in the history of science. Moreover, now we can say that the breakthrough of humankind into space was the greatest (including astronomy), the legacy of the 20-th century, and its value in the coming centuries will only increase. Of course, this will not happen, if the experts on the history of exploring space will not actively pursue their important work.

It is generally accepted that the humankind should know its history in the broadest scope. But it is very difficult to ensure. On the one hand, the human ability to perceive and remember information evolves (if at all) much more slowly than technology, and rapidly growing bulk of knowledge in any, even a very specified field is no longer covered even by most brilliant single mind. On the other hand, the history (including science) gets a lot of alluvial, and the truth is being gradually lost under these «sedimentary» layers. Many prominent historical events, even some recent ones, have been forgotten or distorted in the mass concept. The responsibilities of "archaeo" scientists is not only to obtain, preserve and make accessible the accumulated scientific information on the past, but also to avoid distorted picture of the most important events in the history of science.

In this paper two topical examples are considered:

1. Astronomers «embrace» the Earth at the beginning of the space age.

The historical materials on astronomical input the dawn period of space era (sixties and seventies of the past centuries) include interesting information on developing organization and technology of astronomical observations of the artificial satellites of the Earth. This information was produced by to few world centers of that period. My particular attention is paid to the work of Astronomical Council of the USSR Academy of Sciences (now the Institute of Astronomy, Russian Academy of Sciences). The most important activity of the Council at the beginning of space era was organization of observations of artificial satellites of the Earth. Preparations for the observations had started before the first “Sputnik” was launched. Staff members of the Council led by A.G. Massevitch have trained future observers from Soviet Union and other countries. A number of special stations for visual observations of satellites were organized. By October 1, 1957 a big network (66 stations) had been built in the USSR under direction of the Council. In 1966 the Astronomical Council started to create an international network for observations of satellites [1].

Under agreements with foreign scientific organizations many stations were built over Europe, Asia, Africa and South America - by 1975 28 observational stations in total. For this network the special instrumentation was developed and a great amount of visual, photographic and, later, laser observations of satellites was obtained. Most of them were equipped with photographic camera AFU-75 (Fig.C1.1). Results of the observations were used in the fields of geodesy, geodynamics, and geophysics.

Fig.C1.1. Sattellite tracking station of the Astronomical Council in French Guiana(Courou). Observations were performed with the photographic camera AFU-75.

In 1961 the Council in collaboration with the Pulkovo Observatory organized the first experiment in the field of space geodesy. The network of observational stations created by the Council became a basis for the first global geodesy program named The Large Chord [2].

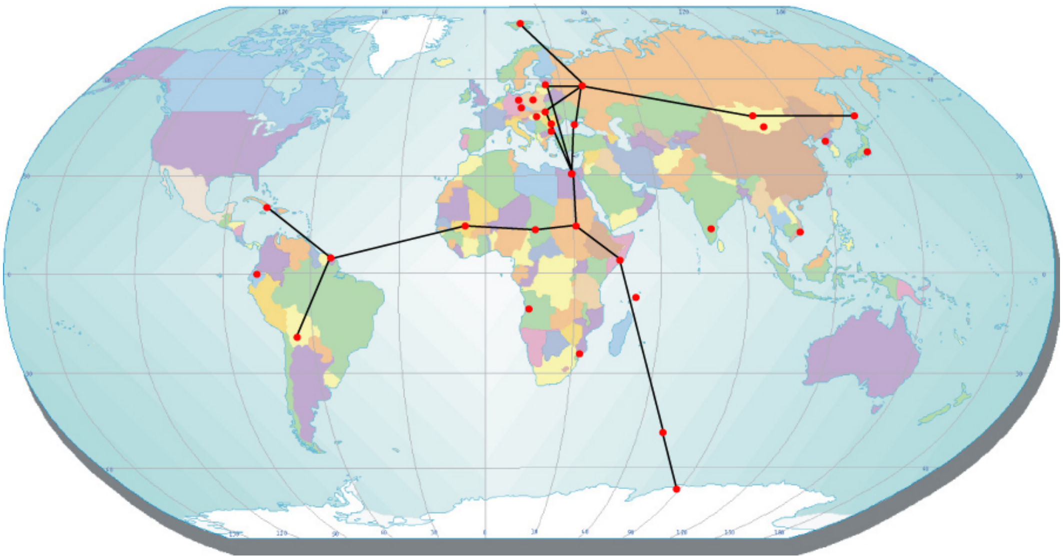

Fig.C1.2. On the basis of the network of artificial satellites observations developed by the Astronomical Council the first global geodetic program The Large Chord has been deployed.

Project Large Chord was carried out by USSR scientists in broad cooperation with foreign colleagues. It was first established a large-scale network, embracing the entire globe. The project allowed making a number of fundamental discoveries that have universal significance and first of all, to clarify the parameters of the Earth's shape. Besides the geodetic research, the observations of satellites were used to study properties and life cycle of the Earth atmosphere.

By the end of eighties most of the stations had completed their work and had been closed. Their instrumentation was transferred to universities and other educational institutions. But these first steps to recognize the Earth as a planet by means of use the man-made space objects seems to be very important contribution to the culture (history of science) of the humankind. Of course, modern technologies greatly exceed by efficiency (accuracy, speed etc.) the observational technologies of the sixties but this “beginning” was bright and as important for future progress as Galileo’s observation with the first telescope for commencement of modern science.

2. Virtual Observatory – to preserve the past for the future.

The rapid progress of modern observational and computational techniques leads to an avalanche growth of the volume of astronomical data. Moore's Law (doubling the elemental density of chips every two years) is applicable to a large extent to astronomy.

This is illustrated in Fig.C1.3 (credit: www.virtualobservatory.org section VAO History).

First of all let me to remind what is the Virtual Observatory (VO). Virtual Observatory (VO) is a collection of integrated astronomical data archives and software tools that utilize computer networks to create an environment in which research can be conducted. At the turn of the century several countries initiated national virtual observatory programs that are aimed to combine existing databases from ground-based and orbiting observatories and make them easily accessible to researchers.

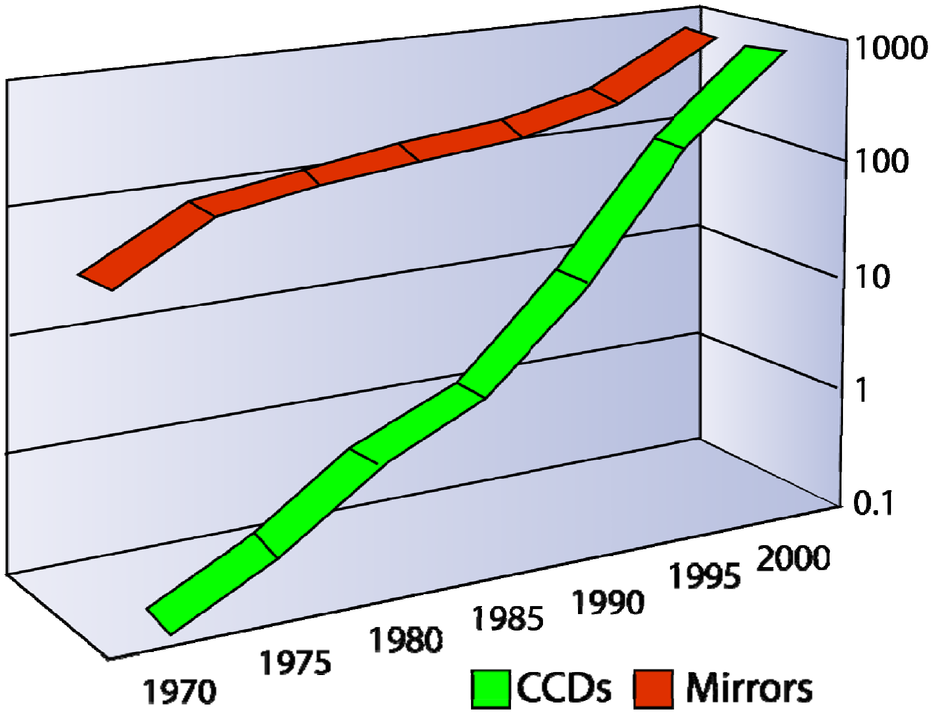

Fig.C1.3. Moore's Law holds true in astronomy: red curve is total area of astronomical telescopes (primary mirrors), in square meters. Green curve is growth of CCDs, in billions of pixels. The amount of data being collected (green line) is following the Moore's Law (www.virtualobservatory.org).

Very soon the idea to integrate the observatories in a world wide network was suggested. In 2000 IAU General Assembly supported the initiative of Commission 5 (Comission's President Dr. O. Dluzhnevskaya) and adopted the project of International Virtual Observatory.

As a result, data from all the world's major observatories became available to all users and to the public. This is significant not only because of the immense volume of astronomical data but also because the data on stars and galaxies have been compiled from observations in a variety of wavelengths: optical, radio, infrared, gamma ray, X-ray and more. Each wavelength can provide different information about a celestial event or object, but also requires a special expertise to interpret. In a virtual observatory environment, all of this data is integrated so that it can be synthesized and used in a given study. The International Virtual Observatory Alliance (IVOA) represents 19 national and international projects working in coordination to realize the essential technologies and interoperability standards necessary to create a new research infrastructure.

In December 2001, the Scientific Council on Astronomy of the Russian Academy of Sciences strongly endorsed the Russian Virtual Observatory (RVO) initiative with Centre for Astronomical Data (INASAN) and SAO RAS as coordinators [3]. The RVO is one of the founders and important members of the IVOA. Principal RVO goals are stated as follows:

- to provide Russian astronomical community (over 30 astronomical institutes and organizations) with a convenient access to the world astronomical resources, and
- to unite Russian and FSU data, to provide them to the rest of the world and to integrate them into the International Virtual Observatory.

The rapid growth of the volume of new astronomical data does not in any way diminish the value of the data previously obtained. The main feature of the world around us is the variability over time, and the main task of the fundamental space science is not only the study of the current properties of celestial bodies and processes occurring in space, but the construction of an evolutionary picture of the Universe. That is why an accumulated observational material is considered as valuable source of information to solve many astronomical problems related to the evolutionary aspects.

New information technologies that appeared at the turn of the XX-th century are efficient to transform conventional photo plate's images into digital form. The digitized plates (images) become eternal records that are easily processed and simply distributed among scientists.

The problem of keeping of the astronomical data that were obtained in the photographic era (particularly scanning glass libraries) as one of the most important tasks of virtual observatories is briefly discussed below. Again, I will keep mostly along my knowledge of the history the Astronomical Council (The Institute of Astronomy, RAS).

The Institute of Astronomy deals with creation of catalogues and digitization of collections of astronomical photographic plates made in the XX-th century. The work was done (and still is being performed) in collaboration with the Sternberg Astronomical Institute of Moscow University and Special Astrophysical Observatory of RAS, as well as with research institutes of Bulgaria, France and Germany.

Typical view of major components of any glass library: astronomical plates and observation log is presented at Fig.C1.4. Various kinds of photo plates (obtained at Zvenigorod observatory of Astronomical Council of RAS [4] is presented at Fig.C1.5.

Fig.C1.4. Glass library (part of) at Zvenigorod observatory of Astronomical Council of the RAS (now Institute of Astronomy, RAS).

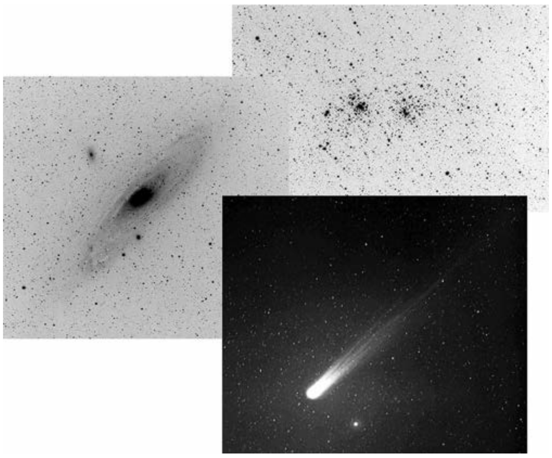

Fig.C1.5.Astrograph plate fragments of astronegatives: the Andromeda (M31), χ and h Persei open cluster, Hiakutake comet (the tail length is five degrees, narrow strings are ionic tail).

The major instrument for digitizing photos is a powerful scanner (Fig.C1.6). This instruments together with the very thorough and time consuming work of skilled astronomers save the scientifically important information for future generations of scientists. Moreover, it is the last chance to save last centuries old information because of natural process of ageing the photo emulsion.

Fig.6. Scanners used to digitize the Moscow plate stacks. Joint project of Sternberg Institute (Moscow University) and Institute of Astronomy (RAS).

It is worthy to remind that glass libraries of the world astronomical observatories were proposed to be included in the list of UNESCO World Heritage.

Conclusion.

In this short note I briefly remind two important contributions that seem to be distinct items of astronomical heritage. The items are not ancient by nature, but they are the foundation stones of the building of a new scientific and cultural age.

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C2. STATISTICS AND SYSTEMATIZATION OF THE NAMES OF THE LUNAR NOMENCLATURE

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Further advance in space explorations makes it necessary to develop a series of maps for provision of space flights, execution of surface and circumlunar applied works, as well as for solving problems of geomorphology, origin and evolution of lunar rocks. Lunar surface maps show mainly the relief topography, which is characterized by exceptional monotony and uniformity in reflectivity as well as in general view. One of the ways to enrich the maps contents and to increase their informativity is to name the mapped objects. Because of this a system of terms for lunar objects and their quantity acquires great importance. Names on lunar selenographical maps not only help to find bearings but carry morphological information as well. The International Astronomical Union (IAU) decided upon a uniform system of conventional symbols for designation of relief details.

The basic principles and traditions of designation of the lunar relief

The modern nomenclature system of lunar names has a centuries-old history. Scientists of selenography laid down the basic principles and traditions of the Moon toponymy. The founders of this science were Riccioli (1598-1671), Hevelius (1611-1687), Schroter (1745-1816). Many names of lunar surface objects used on maps of XVII-th - XVIII-th centuries are lost, but a few remained. We know 201 names given by Riccioli, 5 by Hevelius, 63 by Schroter. They had worked out a system of lunar names, which became a model for the modern one. First and foremost it is designation of lunar craters in aquatic terms, or by terrestrial geographical names and names of scientists (Table A9.1). Now the International Astronomical Union (IAU) and Working Group for Planetary System Nomenclature (IAU/WGPSN) have established uniform of nomenclature for designation of relief details [Shevchenko V.V., 2009].

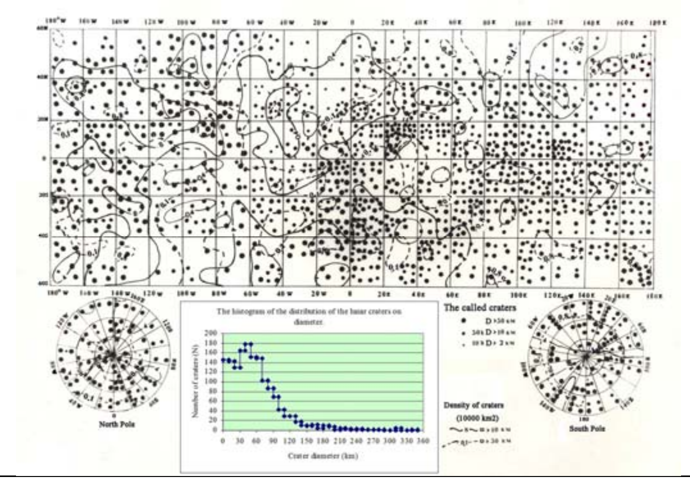

Fig.C2.1 The map presents of the distribution of the naming lunar craters. The histogram shows of the distribution of the called lunar craters from diameter

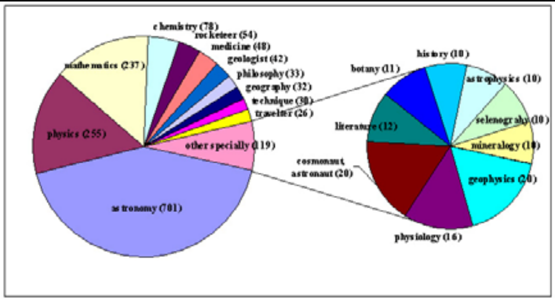

Fig.C2.2 The diagrams show professional activities of persons, whose surnames are given lunar craters

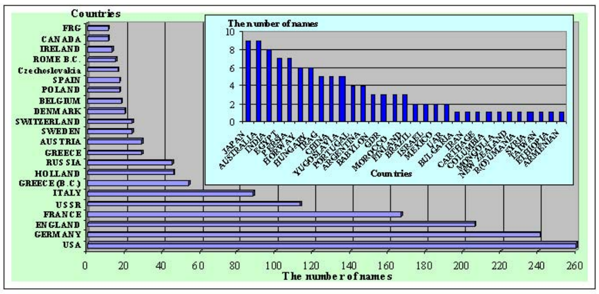

Fig.C2.3 Names of the countries in which the years of active work of the prominent scientists his passed

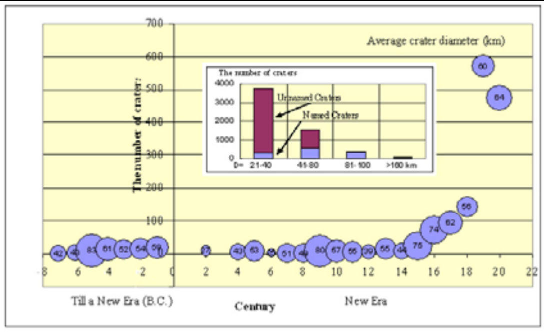

Fig.C2.4 The diagram shows the century and number of the immortalized names of the scientists in years ago. The second diagram presents status of nomenclature for lunar craters

Nowadays IAU approved about 9000 names for the Moon, including names for 1546 craters and 7056 names for small satellite craters, 56 of the lunar names relate to the first Apollo program manned expeditions to the Moon and 26 are connected with the names of space vehicles, scientific research Institutions and geographical locations.

Lunar place-names characterize 18 relief lunar types. The list of types of a lunar relief on system MAS is resulted in Table A9.2. The quantity of names and specified semantics value of names are given in this Table. In the column "Other name" were included the names of the laboratories, institutes, space vehicles are resulted.

Table A9.1. The Founders of the Lunar Toponymy.

Authors of lunar names, dates of life, profession, country.	Categories of lunar relief				
	Craters	Maria	Montes / **Promontoria**	Oceanus / Lacus	Sinus/ Paludes
Riccioli, 1598-1671, astronomer, Italy	182	10	0 / 1	1 / 2	3 / 2
Hevelius, 1611-1687, astronomer, German			3 / 2		
Hell, 1720-1792, astronomer, Hungary	1				
Schroter, 1745-1816, astronomer, German	56		7 / 0		
Lee, 1783-1966, selenographer, England	5	1	1 / 0		
Madler, 1794-1840, astronomer, German	133	3	8 / 1		1 / 0
Lohrmann, 1796-1840, selenographer, German	6				
Birt, 1804-1881, astronomer, England	55		3 / 1		
Gaudibert, 1823-1901, astronomer, France	6				
Scmidt Johann, 1825-1884, astronomer, German	49		1 / 2		0 / 1
Debes, 1840-1923, cartographer, German			1 / 0		
Franz, 1847-1918, astronomer, German		3	1 / 0		3 / 0
Neison, 1851-…, astronomer, England	17				
Blegg, 1858-1944, astronomer, England			1 / 0		
Krieger, 1865-1902, astronomer, German	39		0 / 1		
Konig, 1865-1927, mathematician, Austria	1				
Muller, 1866-1942, astronomer, Czechoslovakia	7				
Fauth, 1867-1941, selenographer, German	5				
Wilkins, 1886-1960, astronomer, England	2				
Lamech, 1894-1962, astronomer, France	9				

Lunar objects names officially approved by IAU are presented on the Gazetteer of Planetary Nomenclature and US Geological Service site [Gazetteer of Planetary Nomenclature, 2010]. The naming rules of the lunar objects and conventions are given on site IAU /Working Group for

Planetary System Nomenclature [Annual Gazetteer of Planetary System Nomenclature, 1986].

The automated database of the lunar names: was created in the Sternberg State Astronomical Institute of the Moscow State University under the leadership of V.V.Shevchenko, the Chairman of the IAU Working Group for naming the lunar relief details [Pugacheva S.G., Shevchenko V.V., 1991; Pugacheva S.G., Shevchenko V.V., et al., 2009].

Table A9.2. Categories of the Lunar Relief.

Categories of the lunar relief	**Quantity of names**		Semantics of names						
	Near Site	**Far Site**	**Own name**	**Symbo-lical**	**Mytholo-gical / Antique**	**Terrestrial**	**Surnames of scientists**	**Recurrence of the name of a crater**	**Other names**
Albedo Feature		1					1		
Catena	11	9	3					14	3
Crater	883	663	69		2 / 73		1401		1
Dorsum	38	1	1				38		
Lacūs	17	3		20					
Landing site name	79			79					
Mare	20	2		19			2		1
Mons	43	5	7			14	12	15	
Oceanus	1			1					
Palus	3			3					
Planitia	1								1
Promontorium	9					3	6		
Rima	108	3	10					101	
Rupēs	8					2		6	
Satellite Feature	7056								
Sinūs	11			11					
Valles	12	2	2			1	2	9	
SUM*	1244	689	92	133	2/73	20	1462	145	6
The quantity of all called objects makes 1933 formations. * Satellite Features of the craters are not taken into account.									

The data base includes all the names of the lunar relief elements approved by IAU with the 5-th best significance level according to the estimation of IAU nomenclature system. Lunar relief names are given in Latin with Russian transliteration. Relief morphological characteristics, selenographical coordinates, reference and bibliographic data are given for every object. The data base structure permits to automatically systemize, choose and select lunar relief elements by any of the above-mentioned characteristics. The database was used for classification of extensive objects by different the morphological type, the year of naming, location and size. If a crater is named by surname of the person, bibliographical data, his field of activities, nationality, dates of life are given. The data of the Lunar Nomenclature were systematized in the next order: type of lunar relief, a surname and a name in Latin language, a surname in Russian, the country, a specialty, years of life; coordinates (latitude, longitude); the size of formation, year of assignment of the name; who has offered the name.

Statistics of the lunar craters names

Here the results of automatic selection of the lunar craters names are presented. The map of distribution of the called craters of the Moon and distribution of craters on their diameter are shown in Fig. C2.1. The statistical analysis has shown that diameters of the lunar craters vary within the limits of 10 m - 600 km. The maximal number of craters corresponds tothose with diameter of 30-70 km. The small satellites craters were not taken into account at map and diagrams. Two big craters having diameters more than 400 km were called in honor memory of the Ejnar Hertzsprung and Sergei Pavlovich Korolev. The craters are placed on the far side of the Moon. Selenographer coordinates of the crater Hertzsprung are 0.71^{o}N, 129.22^{o}W (diameter 587.44 km), coordinates of the crater Korolev are 4.14^{o}S, 157.22^{o}W (diameter 423.41 km)

Ejnar Hertzsprung was born on October 8, 1873 in Copenhagen. He was an active researcher in astronomy and astrophysics. He died in 1967 in Roskilde, Denmark. The date of the statement of the name of the crater is 1970.

Sergey Pavlovich Korolev (1907-1966), the Soviet Scientist and designer in the field of space-rocketry and astronautics. The date of the statement of the name to the crater is 1970.

Location of the called craters in diameter more than 2 km on lunar surface, density of distribution of craters, and also the histogram of distribution of craters depending on their diameters are presented in Fig. C2.1.

According to the IAU rules, the names of satellites' craters are given using the nearest crater's name with addition of Latin letter. The fossae have the name of a nearby crater with addition of capital Latin letter, while for naming rimae the Roman figure in combination with letter r is used.

The activities in naming lunar craters to immortalize scientists are various. In most cases, distinguish scientist who significantly contributed to the different fields of science are selected and proposed to be commemorated. The surnames of people of 65 scientific professions were included in the catalogue of lunar nomenclature. People of various professional areas, whose names have been attributed to lunar craters are summarized in the diagram of Fig. C2.2. The number of names is shown in brackets. Currently, the modern nomenclature system includes 1891 prominent professional individuals, including 47 names of Nobel Prize winners.

In the lunar nomenclature names of scientists from 53 countries over the world are listed, the quantity of names of the countries making 1570. The country of person's residence is given in the diagram of Fig. C2.3. The century of active life of persons immortalized in the names of craters, are shown in the diagram of Fig. C2.4.

Places of landing Apollo spacecraft on the lunar surface are allocated in selected type of lunar relief. American astronauts gave 79 names to lunar craters in landing sites on the Moon. Significant part of these craters have diameter less than 1 km. The names «Planitia Descensus» (7.18N, 64.45W, diameter ~ 1 km) and «Sinus Lunicus» (32.33N, 2.08W, diameter 119.18 km) were taken in honour of the Soviet Space Vehicles "Moon-9" and "Moon-2".

The unique formation located at the near side of the Moon "Reiner Gamma" wass resulted in the USGS catalog (the type of relief – albedo). "Reiner Gamma" is the diffuse area on the lunar surface exhibiting albedo anomalies, which looks like swirls (Shevchenko V.V, 2001). Its area is 3.3 x 103 km^2. M. A. Blagg, K. Müller; P. Lund have offered the name "Reiner Gamma" in memory of the Italian astronomer and mathematics of XVII-th century, Reinieri Vincento. The name has been authorized by IAU in 1935. The coordinates of the "Reiner Gamma" are 7.39^{o}N, 58.96^{o}W, and diameter of the crater is 77.44 km.

A new name of the lunar crater

The International Astronomical Union has made the decision to immortalize the memory of Franz Ulrich Theodor Aepinus and to name a lunar crater in his honour on occasion of his 285-th birthday anniversary. IAU has highly estimated scientific activity Aepinus, who was astronomer and geophysicist. He has predicted the existence of Antarctica (1761), and also put forward idea of investigation of evolutionary processes in space by means of the morphological attributes. The crater "Aepinus" is located in the area of the Moon's North Pole, its coordinates are 87.98^{o}N, 108.55^{o}W, and diameter is 17.4 km.

Conclusion

As the statistical selection confirms, naming lunar craters is international endeavor in origin and cover different periods of the history of human society's development. The lunar nomenclature represents essentially cultures of all countries on the Earth.

As it was said above, diameters of the lunar named craters vary within 10-600 km (Fig. C2.1). A shortage of craters with diameters over 100 km is evident. The diagram (Fig. C2.4) which is constructed according to statistical data (Shevchenko V.V., 2009) testifies to deficiency of the large called craters in the lunar nomenclature.

For a large-scale mapping of the Moon surface it will be necessary to name smaller relief elements. To meet the requirements of the large-scale mapping process it is required to create auxiliary systems for condensation of the number of the named objects. As an example, we can take the system of object naming after Schroter (Levin B.U., 1975) or use the experience of American astronauts who invented a naming system while working on the Moon surface (Annual Gazetteer of Planetary Nomenclature, 1986; Pugacheva et al., 2007; Pugacheva et al., 2009). New systems of lunar names will differ from the personal memorial system of naming the lunar objects, but the basic traditions of lunar toponymy are to be kept, since lunar names is not only a tribute to memory to the great scientists, but also reflection of a history of development of a human civilization.

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C3. SPACE TECHNOLOGY WORLD HERITAGE: Basic Concept

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Abstract. Space exploration manifested the new great milestone of the human civilization. It made possible observations in the whole wavelength and also, direct *in situ* measurements in other worlds. Basically, great breakthroughs of the modern astronomy were achieved due to space born instruments and planetary space missions. Space astronomy ensured the most significant progress in astrophysics gaining invaluable knowledge about space objects and the Universe as a whole, thus broadening up tremendously the human horizons. These breakthroughs became possible owing to the great technology developments, specifically those aimed towards space exploration. It is therefore prerequisite to include Space Technology as an important segment of the Astronomy World Heritage. The idea was put forward at the Astronomy World Heritage meeting held in Kazan, Russia in August, 2009 (ASTROKAZAN'2009) to become a subject of further discussions and clarifications. The next step towards the goal has been undertaken in the authors paper "Space Achievements as World Heritage" published in the Heritage Sites of Astronomy and Archaeoastronomy in the context of the UNESCO World Heritage Convention: A Thematic Study (C. Ruggles and M. Cotte authors/editors), ICOMOS-IAU, Feb. 2011, Ch. 15.

Intoduction: Historical Highlights

XX-th century manifested the great milestone in the advancement of human civilization: the beginning of space exploration. This breakthrough dramatically expanded the human knowledge about space environment, opened the new horizons in space utilization for different applications, and fertilized philosophical concepts of the mankind existence and its place in the Universe. Space exploration impacted the whole spheres of human life and specifically, put astronomy on the completely new ground. These fantastic achievements have been ensured by the great advancement in the technology development, while space technology provided numerous spin-offs which benefited various branches of the human beings' activities.

The idea to address space technology as an important segment of the human cultural heritage is rooted in some preliminary discussions. As early as in 2005 there was round-table discussion of Russian specialists aiming to define a role of the Russian State institutions in the development of the Thematic Initiative on heritage of science and technology. In 2007, on the occasion of 50th anniversary of the Sputnik the meeting *«Fenêtres sur le Cosmos: Spoutnik et l'Aube de l'Age Spatial»* has been organized at the French Senate by ESA/CNES, Paris, France. At this forum, thematic research proposal «Odyssey of human creative genius: towards protection of space technological heritage connected with space exploration» was adopted.

The next important step was undertaken during the 2009: International Conference on "Astronomy and World Heritage: Across Time and Continents" which was held in Kazan, Republic of Tatarstan, Russian Federation. In the Kazan resolution preliminary definition of types of technological sites and facilities connected with space exploration was empasized, in particular, the clearly defined landscape designed and created intentionally by man and intrinsically associated with the Launch Pad and the related structures development. Special focus was given to the most prominent parts of space networks specially designed and built for manned flights, as well as to the historical sites where the concepts of space flight were pioneered and original space vehicle designs were tested.

Another important milestone along the track were ICOMOS/IAU Thematic Study on Heritage of Astronomy held in 2010 in Cairo, Egipt where ‘Space heritage’ preliminary definition was adopted involving i. heritage related to the process of carrying out science in space; ii. heritage related to manned space flight/exploration; and iii. human cultural heritage that remains off the surface of ‘planet Earth’.

Meaningful clarification of space heritage and related technologies was discussed at the International Seminar on Heritage of Astronomy in the Institute of Astrophysics, Paris, France in 2011. Of special importance and interest was the Discussion on tentative proposal of fixed sites and facilities pertaining specifically to space astronomy and/or generally to space science including first of all, “Ground Space Facilities and Launch Pads (Cosmodromes)”.

Preliminary endorsement of Space Astronomy as a segment of Astronomy Heritage and basically, as a segment of Space Technology Heritage was made by the *UNESCO World Heritage Center* (WHC) during the meeting held in St.-Petersburg, Russia on July 4, 2012. There was recommended to set up “International Working Group under UNESCO umbrella in order to discuss the main issue and develop proposals how to progress with Space Technology Initiative of the Committee at its 38th session in 2014”. It was stated that “The World Heritage Committee also welcomes financial and technical support provided by State Parties and the International Astronomical Union for Thematic Initiative “Astronomy and World Heritage”, since 2003 and also encourages cooperation between the UNESCO World Heritage Centre, specialized agencies and relevant interdisciplinary scientific initiatives towards the elaboration of a Global Thematic Study on Heritage of Science and Technology, including studies and research on technological heritage connected with space exploration. Further encourages States Parties, international organizations and other donors to continue to the thematic programmes and initiatives and also requests an updated report on Thematic Programmes to the World Heritage and to accommodate Convention on the World Heritage Resolution quoted (Extract of the

Decision 36 COM5D adopted at the 36th Session of the World Heritage Committee (RF, 2012). In the light of this decision, all main actors concerned were identified "in order to enhance international cooperation and to define new partnership". In the letter of Director of WHC Mr. Kishore Rao to Permanent Delegations of States Parties to the World Heritage Convention, National Commissions for UNESCO, and Advisory Bodies of World Heritage Committee dated July 30, 2012 was, in particular, said: "The working groups were already created in the framework of this initiative – an International Working Group on Astronomy and World Heritage chaired by Prof. Clive Ruggles (http://www2.astronomicalheritage.org/) and a first expert Working Group on technological heritage connected with space exploration chaired by Prof. Mikhail Marov, Academician of the Russian Academy of Science".

Responding this decision, 28th IAU General Assembly held in Beijing, China in August, 2012 accepted MOU where it "expresses its continuing support to the UNESCO Thematic Initiative "Astronomy and the World Heritage" and in response to the UNESCO promotion, is willing to further extend this Initiative over Space Science and Technology with main focus placed on Space Astronomy and relevant facilities".

More detail discussion of the UNESCO World Heritage Committee Initiative concerning Global Thematic Study on Heritage of Science and Technology (including studies and research on technological heritage connected with space exploration addressing Space Astronomy) was undertaken by the author in his paper published in the *Heritage Sites of Astronomy and Archaeoastronomy in the context of the UNESCO World Heritage Convention: A Thematic Study* (C. Ruggles and M. Cotte authors/editors), ICOMOS-IAU, Feb. 2011, Ch. 15. A general understanding is that the proposed segment of Space Astronomy/Technology World Heritage should have an international significance in terms of the human beings tight relationships with sky.

Basic Concept

For the millennia, astronomy developed from primitive naked eye observations to excellent ground based facilities equipped with powerful instruments in optical and radio wavelength. Space exploration manifested the new great milestone of the human civilization. It made possible observations in the whole wavelength and also, direct *in situ* measurements in other worlds. Basically, great breakthroughs of the modern astronomy were achieved due to space born instruments and planetary space missions. Hence, space astronomy ensured the most significant progress in astrophysics gaining invaluable knowledge about space objects and the Universe as a whole, thus broadening up tremendously the human horizons.

Basically, astronomy integrates all contemporary sciences, first of all, mathematics, mechanics, physics, chemistry. Astrophysics stands at potential threshold for the new physics and refined physical laws to be emerged in the modern cosmology. Marriage of astronomy and biology gave birth to the new field – astrobiology attempting to explain life origin and evolution on Earth, other solar system bodies, and extrasolar planets. Astronomy is the unique science closest to philosophy because it is appealed to explain the world around us. We therefore address astronomy at the crossroads of the natural (precise) and human (cultural) sciences driven by technology development and jointly manifesting advancement of civilization. Undoubtedly, there is a synergy between Space Astronomy and Space Technology, the latter serving a driver to progress with astronomy and eventually human beings expansion in space.

The key question is how to utilize and/or commemorate material artifacts in space being after launch rather virtual than tangible objects. The bottom line is that, alongside with the valuable sites, monuments, observatories and instruments, outstanding objects operated in space are to be listed as significant material artifacts among historically important astronomical facilities. Our task is therefore to find out a consistent approach of the legacy of various human artifacts and activities in this particular field of Astronomy which is intimately related with Space Technology development to be recognized as the World Heritage. Obviously, besides virtual world recognized space objects selected and accepted by international bodies (COSPAR, IAU, ICOMOS, etc.) mock ups of astronomical and planetary spacecraft preserved in the ground space facilities and/or museums could be commemorated and assigned as UNESCO Space World Heritage.

Obviously, ground space facilities where recognized spacecraft were designed and manufactured and Launch pads (Cosmodromes) are considered as an important part of the overall space infrastructure. They ensured development and launch of spacecraft and thus are to be regarded historical cornerstones of space exploration. Examples are: OKB-1 (RSC "Energiya"), NPO-Lavochkin, Jet Propulsion Laboratory (JPL), Johnson Space Flight Center (JSFC), Bayconour Space Center, Cape Canaveral Space Center, Koru Launch Pad. One should bear in mind however, existed formal restriction to announce space ventures/cosmodromes' buildings/objects as UNESCO World Heritage, subject to further negotiations. To start with, a part of these facilities and/or cosmodromes infrastructure of exceptional historical value could be suggested to start with selection of relevant entities/objects and hence, the problems solution concerning national jurisdiction and international domain. As an example, some facilities of Bayconour Space Center infrastructure could be recognized as UNESCO Heritage sites; they are shown in Fig. C3.1.

As another example, one may address several astronomical space vehicles equipped with excellent on board instruments of an outstanding value to astronomy. These are, e.g. Hubble Space Telescope, Quant, Chandra, WMAP, Spitzer, Planck, Kepler, etc., to mention a few (see Fig. C3.2). Many spacecraft of historical value (both orbiters and landers) provided close up views of other worlds. They greatly contributed to the planetary exploration and opened up the new Solar system - our closest space environment. Examples are: Luna 9, the first soft landing on the Moon surface; Eagle capsule of first manned landing on the Moon with astronauts N. Armstrong and B. Oldrin as a part of APOLLO program (Fig. C3.3); the first lander Luna 16 made automatic lunar soil return, and the first Moon rover Lunokhod 1 (Fig. C3.4); the first landers on Mars with Mars 6 and Vikings 1 & 2; the first space vehicles for Venus exploration with Veneras 4 & 8; the first detailed study of outer planets, their satellites and rings with space vehicles Voyager 1 & 2; the first entry in the Jupiter atmosphere with Galileo probe; the first landing on Titan with Huygens lander as a part of Cassini-Huygens mission, Rosetta space vehicle with Philae lander to study comet properties, etc. More details on robotic space missions can be found elsewhere (see, e.g., the book shown in Fig. C3.5).

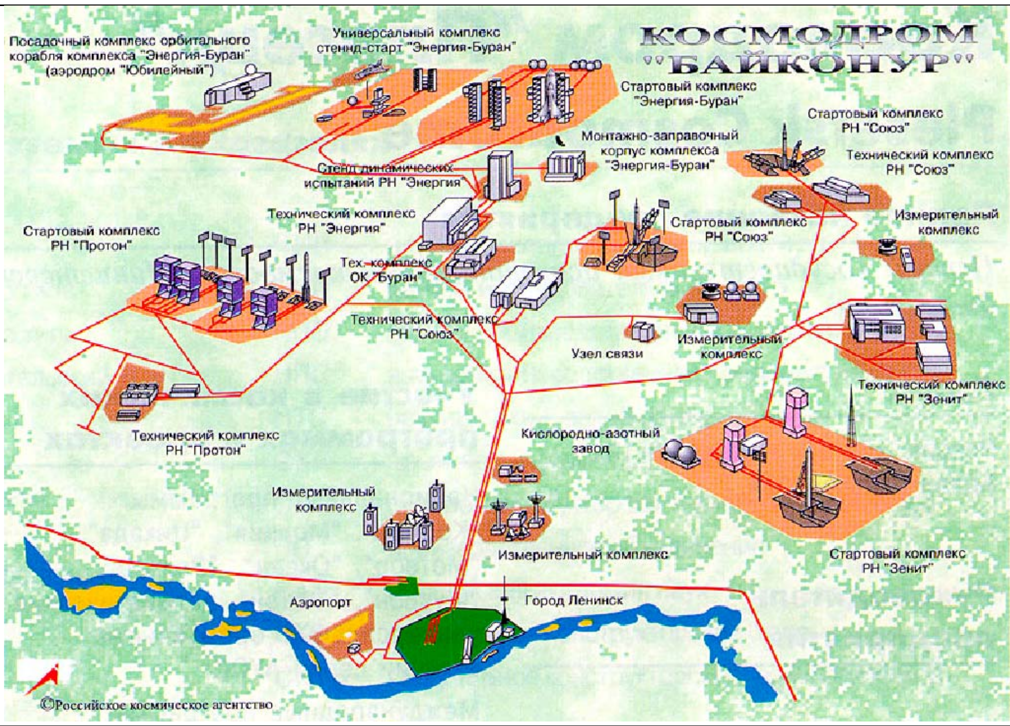
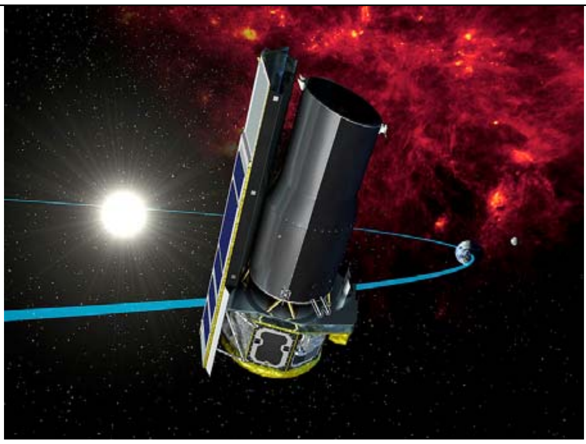


Fig. C3.1 Bayconour Space Pad Center


a


b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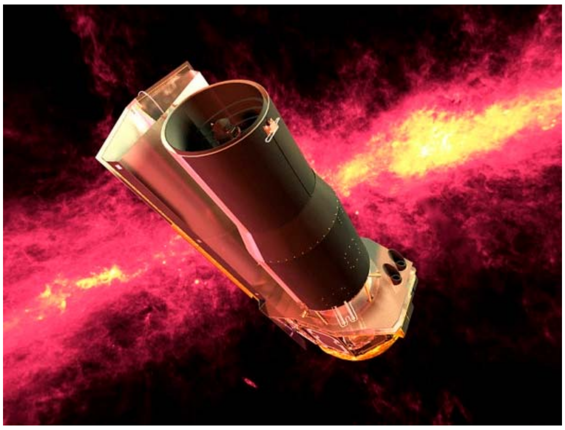
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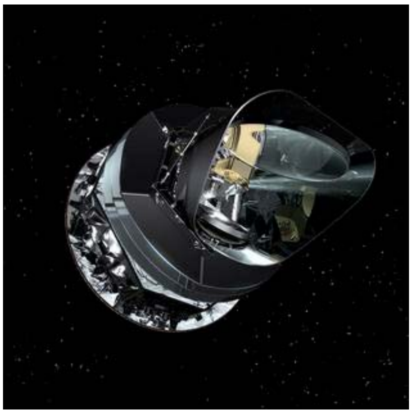
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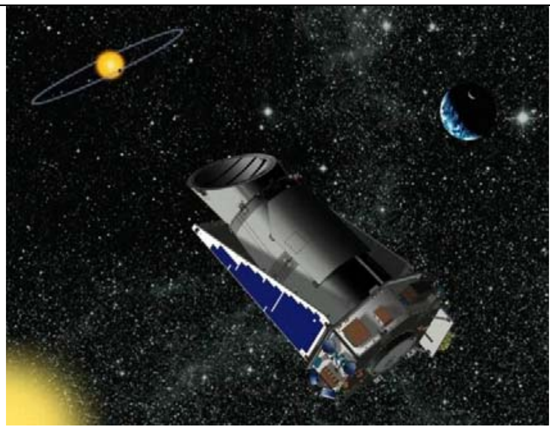
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Fig. C3.2. Examples of astronomical space vehicles of an outstanding value to astronomy: a. Hubble Space Telescope; b. Quant; c. Chandra; d. Spitzer; e. Planck, f. Kepler.

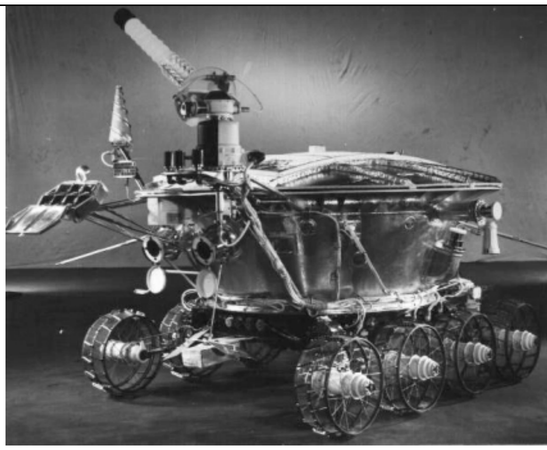

Fig. C3.3. The first Moon rover on the Moon with astronauts N. Armstrong

Fig. C3.4. The first Moon rover on the Moon manned Lunokhod-1.

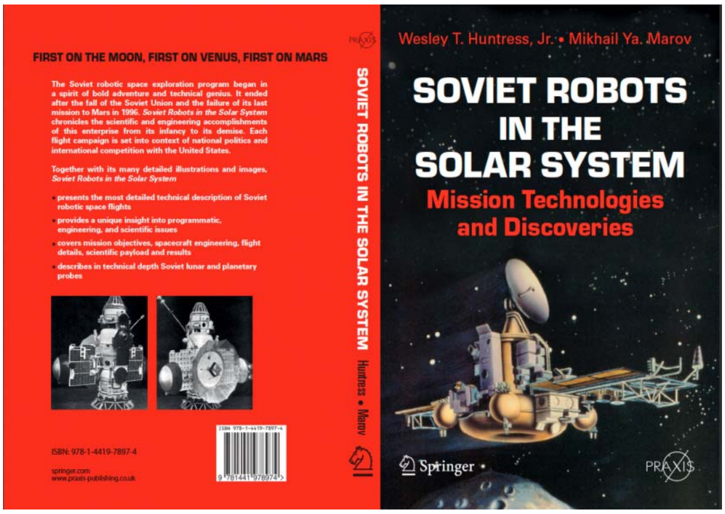

Fig. C3.5. Cover of the book on the Soviet robotic space missions

Reconstruction of solar system origin and evolution is intrinsically related with the detailed study of matter of extraterrestrial origin. This is a challenging goal to deliver extraterrestrial matter for in-depth study in the ground labs, the first step along the track being lunar soil returned by APOLLO and LUNA missions. These samples gave us unique information about the Earth-Moon system and early history of Earth. The main bulk of samples is preserved in Johnson Space Flight Center, Houston, USA, and in Vernadsky Institute, Moscow, Russia. These samples represent the real accomplishments of the human beings' culture and they should be announced as UNESCO Space World Heritage.

In the venue of important topics selected as space legacy Proceedings and/or Manuscripts of space pioneers could be considered. This particular aspect of the Astronomy/Space World Heritage is addressed with a caveat to meet the criteria of the World Heritage Convention. One may suggest to list Konstantin Tsiolkovsky, Hermann Oberth, Robert Goddard, Yuri Kondratyuk, Sergey Korolev, and Verner von Braun among space pioneers. The respective archives are pertinent to select out necessary documents, publications, etc. in an appropriate format. There should be a rather strict approach when soliciting UNESCO patronage over these documents.

Space Heritage Initiative can be further extended to many historically important achievements in space science, technology and spin offs. Besides astronomical/planetary missions hardware one may suggest, e.g., Yu. Gagarin first orbital flight capsule VOSTOK and Gagarin space suite, Apollo 11 lander EAGLE and N. Armstrong space suite, as well as mock ups available of the first orbital stations (Salyut, Skylab), MIR which paved the road to the International Space Station (ISS), and several generations of launchers including Space Shuttle and Buran. This is to be subject to further study and discussions to find out ultimately a consistent approach.

Conclusions

Space exploration manifested the new great milestone in the development of human civilization. It made possible to observe in the whole wavelength what is inaccessible to the ground based facilities and also, to carry out direct *in situ* measurements in other worlds. Basically, great breakthroughs of the modern astronomy were accomplished due to astronomical and planetary space missions. In other words, Space Astronomy and Space Planetary Exploration ensured the most significant progress in gaining knowledge about solar system, our Galaxy, and the Universe as a whole thus broadening up tremendously the human horizons.

A coherent approach is that the proposed segment should have an international significance in terms of the human beings tight relationships with sky. It is therefore prerequisite to consider Space Astronomy represented by space born instruments/space carriers and planetary space probes as an important part of the Astronomy World Heritage.

The outstanding ground space facilities and launch pads (cosmodromes) are to be addressed as very important segments of the overall space infrastructure which ensured the all space achievements. In turn, virtual objects operated in space are addressed as significant material artifacts, generally represented by their material analogs (fully identical mock ups) preserved in the ground space facilities and/or museums. An excellent manifestation of the power of our civilization and the real heritage are the first probes of extraterrestrial matter - lunar rock samples returned by APOLLO and LUNA missions. They occupy an important part of meteorite collections. Space pioneers' manuscripts which advanced civilization towards the beginning of space exploration must not be missed as well. Basically, there is a synergy between Space Astronomy and Space Technology, the latter serving a driver to progress with astronomy and eventually, towards the mankind expansion in space. A consistent approach to the legacy of various human artifacts and activities deserves to be recognized as the UNESCO Space World Heritage. This initiative could be further extended to other historically important achievements in space science and technology.

The idea having some historical roots was put forward at the Astronomy World Heritage meeting held in Kazan, Russia in August, 2009 (ASTROKAZAN'2009) to become a subject of further discussions and clarifications. At its 36th Session (St. Petersburg, 2012), the World Heritage Committee welcomed financial and technical support provided by States Parties and the International Astronomical Union for Thematic Initiative "Astronomy and World Heritage", since 2003 and also encouraged cooperation between the UNESCO World Heritage Centre, specialized agencies and relevant interdisciplinary scientific initiatives towards the elaboration of a Global Thematic Study on Heritage of Science and Technology, including studies and research on technological heritage connected with space exploration. As the first step towards implementation of the idea, the most important parts of the overall space infrastructure involving space facilities where recognized spacecraft were designed and manufactured and launch pads (like Bayconour cosmodrome) were addressed. They ensured development and launch of spacecraft and thus are to be regarded historical cornerstones of space exploration.

References:

De Vorkin, D. The Heritage of Space Science and Space Astronomy. In: Heritage Sites of Astronomy and Archaeoastronomy in the context of the UNESCO World Heritage Convention: A Thematic Study (C. Ruggles and M. Cotte authors/editors), ICOMOS-IAU, Feb. 2011, Ch. 15, pp. 229-233.

Dluzhnevskaya, O.B., and Marov, M.Ya. Odyssey of Human Creative Genius: From Astronomical Heritage to Space Technology Heritage. Astronomy in Focus, Volume 1, XXIX-th IAU General Assembly, August 2015 (*Piero Benvenuti, ed.*), *International Astronomical Union, 2015 (DOI: 00.0000/X000000000000000X)*

Huntress, W., and Marov, M.Ya., 2011. Soviet Robots in the Solar System. Mission Technologies and Discoveries. Springer-Praxis Publishing, Chichester, 453 pp.

Marov, M.Ya. Space Achievements as World Heritage. In: Heritage Sites of Astronomy and Archaeoastronomy in the context of the UNESCO World Heritage Convention: A Thematic Study (C. Ruggles and M. Cotte authors/editors), ICOMOS-IAU, Feb. 2011, Ch. 15, pp. 234-238

Operational Guidelines for the Implementation of the UNESCO WORLD HERITAGE CENTRE.

Conclusions and Perspective

Since the ancient times human beings directed their eyes to the skies with an eager desire to understand mysteries of the Universe. About 400 years ago one of the most remarkable breakthroughs in the humankind history occurred: the great Italian scientist Galileo Galilei invented the first telescope and made with this instrument a few outstanding astronomical discoveries, which opened the era of optical astronomy. In order to honor the 400-th anniversary of the Galileo's telescope invention, the 62-th General Assembly of the United Nations proclaimed 2009 as the International Year of Astronomy.

A half a century ago the new epochal event - the launch of the first Earth's artificial satellite in the USSR occurred which manifested the beginning of space exploration and all-wavelength astronomical observations. It was followed only two years later on by the launch of automatic interplanetary station "Luna-3" that took first ever in the history images of invisible from the Earth ground far side of the Moon. Since then, study of the outer space has started with the numerous vehicles of progressively growing capabilities – orbiters and landers to probe the Solar System bodies involving images transfer, in situ detailed measurements on their surface and in the atmospheres, and even sample return from Moon culminating by the Apollo missions.

Basically, the UNESCO International Conference "Astronomy and World Heritage: across time and continents" has been dedicated to the two remarkable events: 400 years of the first use of telescope for astronomical observations and 50 years since the beginning of close up space bodies exploration with human-made devices. The Conference which was held in Kazan (Russia) in August 2009 under the auspice of President of Tartar Republic Mintimer Shaymiev became one of the most remarkable events of the International Year of Astronomy. The Conference has been attended by the coordinators of the UNESCO Thematic Initiative "Astronomy and World Heritage" from 15 countries, IAU representatives, and many distinguish scientists in the field of astronomy and archaeology, as well as directors of astronomical observatories from Russia and other countries.

Introduction of the new category of astronomical and space objects was in the Conference Agenda, and this problem was thoroughly discussed. The discussion resulted in the inclusion of special paragraph in the Conference Resolution that proposed to include the "Space Heritage" in the register of objects of the UNESCO World Astronomical Heritage.

The success of the Conference and its importance in the promotion of astronomical knowledge was mentioned in the letter of thanks to the organizers of the Conference signed by General Director of the UNESCO K. Matsuura.

Basically, the collective monograph represents a synergism of astronomy and archaeoastronomy/archeology. It contents the main results of the study made until recently by European, Asian and American scientists – specialists in this field participated in the Conference.

The book includes the papers dealing with the study of ancient objects of astronomical importance, description of methods of archaeology related to astronomy, and also astronomical observatories that are valuable from the historic or architectural viewpoints and satisfying the criteria to be included in the topical list of objects of the World Heritage.

The topics reflect the role of astronomy in the life of nations of various continents, ranging from the most ancient witnesses of the conducted astronomical observations to the modern international astronomical projects. The contents expands our views of space environment tremendously, and in particular, allows us to survey the long period of human beings' history, involving the first primitive astronomical instruments of the ancient times through the new exciting opportunities to penetrate deep in our space environment and to have close up views of other worlds. Mastering outer space implies the new stage in the development of our civilization with inevitable prospects of further broadening up of the human scientific horizons and space utilization for practical needs, and eventually expansion over the whole Solar system.

The book examines the major milestones in astronomical research and presents the actual discoveries “across time and continents”, from the megalith monuments of past civilizations through medieval and optical astronomy, and ultimately to the modern time culminating with the beginning of space exploration. It represents an excellent illustration of the great progress which the mankind achieved for a few millennia of its evolution, specifically in such advanced science like astronomy, in attempts to understand its own position in the boundless Universe. The collective monograph comprises important results of the study integrating our knowledge in both astronomy and archaeoastronomy/archeology over the world and paves the road towards more in-depth research in this challenging field. The UNESCO Thematic Initiative “Astronomy and World Heritage” inspiring these studies is higly appreciated.

Appendix 1.

FINAL REPORT

International Conference
“Astronomy and World Heritage: Across Time and Continents”
Kazan, Republic of Tatarstan, Russian Federation,
19 - 23 August 2009

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Acknowledgements

The participants sincerely commended Mr Mintimer Shaymiev, President of the Republic of Tatarstan, and the Government of the Republic of Tatarstan for the hosting and exceptional organization, under UNESCO patronage, of the International Conference “Astronomy and World Heritage: Across Time and Continents” held in Kazan from 19 to 23 August 2009.

The participants expressed their special thanks to Mr Farid Mukhametshin, Chairperson of the State Council of the Republic of Tatarstan, Prof Myakzyum Salakhov, Rector of Kazan State University, Prof. Nail Sakhibullin, Head of the Department of Astronomy at Kazan State University and Prof. Yuri Nefedev, Director of the Engelhard Astronomical Observatory (EAO).
Resolution on astronomical heritage, including space technological heritage

This resolution has been prepared and adopted by internationally recognised experts in astronomy and astrophysics, cosmic exploration, the history of astronomy, archaeoastronomy, cultural *astronomy, history, archaeology, and architecture, at the closing ceremony of the International Conference on Astronomy and World Heritage: Between Time and Continents, held in Kazan, Tatarstan, Russian Federation, 19–23 August 2009.*

Definitions

Tangible astronomical heritage is the material evidence relating to astronomy and representations of astronomy.

Astronomy is characterised by the observation and coherent interpretation of celestial objects and events from the earliest stages of human evolution through to the modern world, including but not confined to the history of contemporary science. It forms part of the efforts by all human beings to comprehend the observable world or universe - the cosmos - within which they dwell and to understand their place within it.

The following are the principal categories of tangible astronomical heritage:

- Observatories as "scientific monuments".
- Material representations of the results of astronomical observations and contextual understanding: constructions, architecture and urbanism related to applied astronomy and/or bearing astronomical information.
- Properties whose design and/or landscape setting have significance in relation to celestial objects or events.
- Monuments, sites and cultural landscapes related to the history of astronomy and/or human cultural practices related to astronomy.
- Sites related to space exploration[1]

Recommendations

In order to help the expert community to apply the resolution, this meeting recommends:

1. In conformity with Article 3 of the *Convention 1972*, that it is for each State Party to the World Heritage Convention who wish to submit nominations of cultural and natural sites relating to astronomical heritage for inscription on the World Heritage List, to identify and delineate properties situated on its territory and that the existing World Heritage criteria, as indicated in the *Operational Guidelines*, can be used for the assessment of outstanding universal value of the cultural and natural properties.

2. That the activities achieved since the creation of the UNESCO Thematic Initiative "Astronomy and World Heritage", as well as the resolution presented above (hereinafter the "Kazan resolution") and related documents should be examined by the World Heritage Committee during its 34th session in 2010.

3. That a special meeting be arranged as soon as possible between the IAU Working Group and ICOMOS so as:

[1] A special expert working group was established by the participants during the Conference. This Working group chaired by Academician Marov, with participation of Academician Boyartchuk and Cosmonaut Gretchko, submitted a proposal to include in the Thematic Study on astronomical heritage a new study on **Space Technological Sites** as technological heritage connected with space exploration (see Annex IV).

a. to discuss the application of the Kazan resolution within the World Heritage Convention;
b. to discuss the possibility of the eventual revision of the Operational Guidelines Annex III; and
c. to discuss the potential for serial nominations relating to astronomy.*

4. To revise of the Operational Guidelines Annex III in order to add new items on the inscription of specific properties connected with astronomy, as well as the definition and categories of tangible astronomical heritage presented in this Kazan resolution. [2]

5. That a unified website be set up for the Astronomy and World Heritage Initiative, integrating its cultural and natural aspects.**

6. To promote the creation of networks between directors of observatories to consider astronomical heritage issues.

7. To promote inter-convention recognition so that both the tangible and intangible nature of astronomical heritage can be recognised and managed at astronomical heritage sites.†

8. To promote the recognition of the ability to see natural starlight in a truly dark night sky as an additional input in protected area management.

Additional proposals

The following should be taken into account during the process of judging applications:

- We recommend additionally that suitable case studies be identified for serial nomination. These would include:

• A group of ancient monuments, whose relationship to astronomy is established by recognising common characteristics among the group,

• A thematically linked group of properties relating to the heritage of modern scientific astronomy, such as the observatories involved in the *Carte du Ciel* project, observatories representing the transition to astrophysics, solar observatories, or meridian lines in churches,

• “Space horizons”: serial cultural sites connected with space exploration,

• “Windows to the universe”: the world’s largest contemporary observatories including the natural components.

- This website would be developed with the support of the Starlight Initiative, within the framework of the existing UNESCO-IAU Memorandum of Understanding and any project agreement yet to be developed on this issue.

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[2] In this regard, the participants took into account the recommendations of the Science meeting held in January 2008, and in particular the paragraph 25 mentioning that specific guidance for sites of scientific and/or technological heritage should be incorporated into Annex 3 of the Operational Guidelines.

It is therefore important to recognise the importance of the protection of natural and cultural sites which contribute by their exceptional night landscape to the astronomical research worldwide; as well as that light pollution can be considered as an imminent threat to the environment, including impacts on animal and plant life. It is necessary to join efforts in promotion of adapted lighting and that a common approach for the safeguarding of natural and landscape sites which can contribute by their exceptional night landscape to the astronomical research worldwide could be developed. Co-ordination and information-sharing could be enhanced, in coordination with the "Starlight" Initiative, between the UNESCO World Heritage Convention, UNESCO Man and the Biosphere Programme (MAB), Ramsar Convention, Organization of the World Heritage Cities (OWHC), World Commission on Protected Areas (WCPA) and other Conventions, programmes and international organizations related to the conservation of cultural and natural heritage.

The participants encourage the "Starlight" Initiative to further develop, in coordination with IUCN and all concerned Programmes and organizations, inputs for the effective management of existing protected areas and sites.

Annex I. List of Members of the International Astronomical Union's Working Group on Astronomy and World Heritage

Abalakin, Viktor (Russia)
Badolati, Ennio (Italy)
Batten, Alan (Canada)
Belmonte, Juan (Spain)
Bhathal, Ragbir (Australia)
Brosche, Peter (Germany)
Davoigneau, Jean (France)
Débarbat, Suzanne (France)
DeVorkin, David (USA)
Dluzhnevskaya, Olga (Russia)
Dürbeck, Hilmar W. (Germany)
Ehgamberdiev, Shuhrat (Uzbekistan)
Engels, Dieter (Germany)
Epifania, Priscilla (Indonesia)
Ferlet, Roger (France)
Fujiwara, Tomoko (Japan)
Funes, José (Vatican)
Glass, Ian S. (South Africa)
Griffin, Elizabeth (Canada)
Gurshtein, Alexander (Russia/USA)
Hearnshaw, John (New Zealand)
Helou, George (USA)
Hidayat, Bambang (Indonesia)
Kak, Subhash (India/USA)
Kepler, S.O. (Brazil)
Kochhar, Rajesh (India)
Krupp, Edwin C. (USA)
Locher, Kurt (Switzerland)
Maglova-Stoeva, Penka (Bulgaria)
Mason, Brian (USA)
Mickaelian, Areg (Armenia)
Nha Il-Seong (Korea)
Osório, José (Portugal)
Pettersen, Bjorn R. (Norway)
Pineda de Carías, María Cristina (Honduras)
Pinigin, Gennadiy (Ukraine)
Pompeia, Luciana (Brazil)
Pozhalova, Zhanna (Ukraine)
Rappenglück, Michael (Germany)
Ruggles, Clive (UK) [Chair]
Shi Yun-li (China)
Simonia, Irakli (Georgia)
Smith, Malcolm (Chile)
Steele, John (UK/USA)
Szabados, Laszlo (Hungary)
Tully, Francoise Le Guet (France)

Hockey, Thomas (USA) [Secretary]
Holbrook, Jarita (USA)
Incerti, Manuela (Italy)
Iwaniszewski, Stanisław (Poland/Mexico)
Wainscoat, Richard (USA)
Wolfschmidt, Gudrun (Germany) [Vice-Chair]
Yang Hong-Jin (Korea).

Annex II. List of Members a special expert working group on Space Technological Heritage established during the Conference:

Academician Marov, Chair of a special expert working group (Russian Federation)

Academician Boyartchuk (Russian Federation)

Cosmonaut Gretchko (Russian Federation)

Annex III. Space Technological Heritage

Groups of Space Technological Sites fall into the following categories:

1. Launch Pads, such as the human-engineered Gagarin Launch Pad in Bayconur Space Centre, together with related auxiliary facilities and roads.

2. Clearly defined landscapes designed and created intentionally by man and intrinsically associated with a given Launch Pad and the development of related structures, e.g. the Bayconur area.

3. The most prominent parts of space networks specially designed and constructed to support manned flights, such as Gagarin Star City in the Moscow region with its facilities for cosmonauts' pre-flight training, education, and the verification of space operations using spacecraft mock-ups.

4. Historical sites where the pioneering concepts of space flight and the design of original space vehicles were tested, such as Kaluga town and the K.E. Tsiolkovsky Museum of Cosmonautics, with their intrinsically related natural landscapes.

Appendix 2.

United Nations
Educational, Scientific and
Cultural Organization

Organisation
des Nations Unies
pour l'éducation,
la science et la culture

Organización
de las Naciones Unidas
para la Educación,
la Ciencia y la Cultura

Организация
Объединенных Наций по
вопросам образования,
науки и культуры

منظمة الأمم المتحدة
للتربية والعلم والثقافة

联合国教育、
科学及文化组织

The Assistant Director-General for External Relations and Cooperation

H.E. Mrs Eleonora Mitrofanova
Ambassador Extraordinary and Plenipotentiary
Permanent Delegate of the Russian
Federation to UNESCO
UNESCO House

Ref.: DG/4.1/09/1879

29 SEP 2009

Dear Ambassador,

Please find enclosed the letter which the Director-General is sending to Mr Rustam Minnikhanov, Prime Minister of the Republic of Tatarstan.

I would be pleased if you would kindly transmit this letter to the addressee. A copy of the letter is enclosed for your information.

Yours sincerely,

Ahmed Sayyad

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