

## MILUTIN MILANKOVIĆ DIGITAL LEGACY

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**Abstract.** The aim of this paper is to present the Digital legacy of Milutin Milanković, the great Serbian astronomer and geoscientist. The Legacy contains various items related to Milanković's life and work: scientific papers, books, manuscripts, photos, letters, diplomas, patents, etc. For this occasion we give more detailed survey of digitized Milanković's books deposited in the Legacy.

### 1. INTRODUCTION

There are important collections of books, scientific papers, photos and other documents in printed form related to people from the past who had important contributions to science. These documents at present are an important part not only of the scientific but of the cultural heritage as well. However, these documents are not easily accessible, particularly not to the wider audience. For this reason, we decided to present in digital form the legacies of the most important Serbian scientists from the past who had significant contributions to different areas of mathematical sciences: pure mathematics, mechanics, astronomy, theoretical physics and geosciences. Digitized items are deposited in several digital repositories with open access of the Faculty of Mathematics in Belgrade:

Digital legacy of Serbian mathematicians, <http://legati.matf.bg.ac.rs>,

Digital archive, <http://digitalnilegati.matf.bg.ac.rs> and

Virtual library, <http://elibrary.matf.bg.ac.rs>.

On this occasion, the aim of this paper is to present Digital legacy of scientific works of famous Serbian astronomer, mechanic, climatologist, civil engineer, professor of the Belgrade University and academician Milutin Milanković (1879-1958). The particular value of this collection is that it is the most complete as it contains all published Milanković's books and scientific papers. His curiosity in natural sciences was very broad and this is reflected in his works. However, Milanković's most important contributions were characterization of climate of the planets of the Solar system and the explanation of the Earth's long-term climate changes caused by astronomical phenomena. Besides papers on these topics, the collection contains some his less known papers, such as on the theory of relativity and cosmology and should be of an interest even today. We classified his books and papers thematically and gave short descriptions of the content of each group. We believe that retro-digitization of Milanković's works and free access to them through Internet, will give the opportunity to the wide audience, scientists, students, but to the general public as well, to read and study directly Milanković's scientific works. In the rest of the paper we shall give a short Milanković's biography and an overview of his most representative books.

## 2. MILANKOVIĆ'S BIOGRAPHY



Milutin Milanković

Milutin Milanković was born on May 28, 1879 in Dalj (Slavonia, nowadays part of Republic of Croatia). The real gymnasium he finished in Osijek, to become a student of civil engineering at the Technische Hochschule in Vienna. There he took the first degree in 1903 and the PhD one in 1904. He was the first Serb who acquired the PhD title in engineering.

Following an invitation Milutin Milanković came from Vienna in 1909, after the University of Belgrade had been founded in 1905, to teach applied mathematics at the Faculty of Philosophy of this University. His coming was a merit of Bogdan Gavrilović and Mihailo Petrović Alas who both taught at the University of Belgrade. As a staff member Milanković was at the Belgrade University till his retirement in 1955. He taught applied mathematics (theoretical physics, mechanics

and astronomy). He was the first in starting lectures in celestial mechanics. Among other subjects he taught history of astronomy and theory of relativity.

Milanković was a full member, and near the end of his life also Vice President of the Serbian Academy of Sciences, member of Deutsche Akademie der Naturforscher Leopoldina in Halle and corresponding member of a number of other academies and scientific societies in the world. Milanković died on December 12, 1958 in Belgrade. His scientific activity resulted in about ten books and more than hundred papers in mathematics, celestial mechanics, astronomy and geophysics.

Milutin Milanković gave to the world science community his well known theory of glacial ages. The results achieved by him taking into account the complex secular computation of perturbations in planet motions were published in *Théorie mathématique des phénomènes thermiques produits par la radiation solaire* in 1922; the publishers were Yugoslav Academy of Sciences and Arts in Zagreb and publishing house Gauthier Villars, Paris. Due to these results he became well known in the world scientific community, so that great German climatologist W. Köppen invited him to cooperate in building a great work *Handbuch der Klimatologie*. For this purpose a part, which was published in 1930, entitled *Mathematische Klimalehre und Astronomische Theorie der Klimaschwankungen* was written by Milanković. Here his theory of planet heating based on insulation was extended with a special reference to the Earth. By applying this theory to the run of glacial ages it was shown that Milanković had given a very good model of Earth, i. e. that he had created a good and mathematically exact theory of terrestrial climate. This work was translated into Russian in 1939.

Already as a well known scientist he started the cooperation on creation of work *Handbuch der Geophysik* prepared by B. Gutenberg. For this work Milanković wrote four sections where he returned to an old and very difficult problem: that of motion of the terrestrial poles. In these contributions Milanković created a theory of motion of terrestrial poles and succession of glacial ages.

His main work is *Kanon der Erdbestrahlung und seine Anwendung auf das Eiszeitenproblem* the printing of which was finished shortly before the beginning of the Second World War. It should be mentioned that the printed sheets were damaged by a bomb which hit the printing office on April 6, 1941 during the Nazi air raid of Belgrade. Fortunately the original typography of the book was preserved. By using it the book was reprinted during the war on a sufficiently low-quality paper.

During the four war years Milanković could send abroad just a few copies. So this important scientific work was printed at the most unfavorable moment, in war time. Due to this the scientific world community learned about Milanković's theory too late. As a consequence the world recognition arrived only after that. This work appears as a synthesis of his many earlier works which concern his research activity within boundary fields between many natural sciences and mathematics.

Milanković was successful in the field of calendar reform, too. During a Congress devoted to the calendar question organized by the Orthodox Churches in

Constantinople in 1923 he proposed an improvement of the Gregorian time reckoning. The proposal contained in Milanković's calendar-reform project was accepted by the Orthodox Christian Community, but some Churches present at the Congress (for instance, the Serbian one) have not started its application.



Milutin Milanković's Medal

Milanković's contribution to world science is honored in many ways. After Milutin Milanković a minor planet, a lunar crater and a Mars crater have been named. In Belgrade one street and one gymnasium have been named after him. On the banknote of two thousands of Serbian dinars the image of Milutin Milanković is depicted. European Geosciences Union - Division on climate established in 1993 Milutin Milanković's Medal for outstanding research in long term climatic changes and modeling.

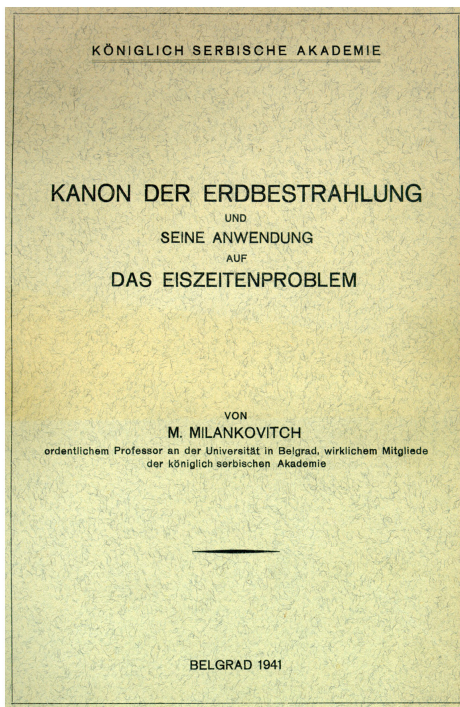
Milanković's student and later the academician, Tatomir Anđelić wrote (1979) very detailed biography of Milutin Milanković.

### 3. MILANKOVIĆ'S BOOKS IN THE LEGACY

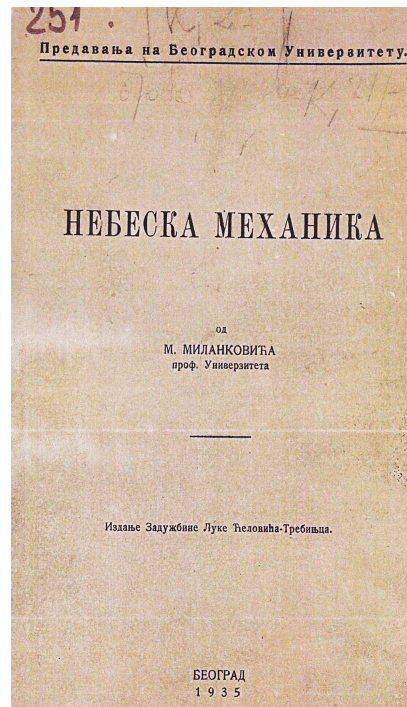
All Milanković's books are digitized and deposited in the Virtual Library and Digital Archive of the Faculty of Mathematics in Belgrade. The list of these books together with active links can be found in the supplement of this article. His most important books are commented and presented in more details in the Digital Legacy of the same institution. Therefore, we shall comment here only briefly some of the Milanković's books.

The book "Kanon der Erdbestrahlung" (*The Canon of Insulation*) is by no means Milanković's the most important book and scientific work. This book presents his astronomical theory of climatic changes. Even if the book is published in Serbia by Serbian Academy of Science, it is written in German that was then the main language of science. However, it took almost two decades that his theory was recognized, widely accepted and experimentally proved. But thereafter Milanković's theory was celebrated as the great achievement in geosciences and particularly in the theory of climate changes. Mainly due to this work, NASA experts said that Milanković was one of the world's "fifteen most important geoscientists". Many Serbian and foreign scientists wrote many scholar and good explanatory articles on Milanković's theory of climate changes and so we do not want to enter into explanation of this theory here. However we would like to note the following facts. Milanković was an excellent mathematician and mechanist even if his basic education was in civil engineering. *Canon* reflects this fact, as it presents very well mathematically founded theory of insulation of planets of Solar system. The mathematical apparatus is based on vector calculus and partial

gradients of perturbation functions appearing in descriptions of planetary orbits. The book is in fact the synthesis of his work in this area which he started immediately upon his arrival in Belgrade. For example he published the book *Phenomenes thermiques* in French already in 1920. Astronomy also advanced very rapidly at this time. Solar constant was determined in 1913 and allowed him to develop mathematically founded theory of thermal phenomena. All these led him to the development of planetary climates. He succeeded determine the average annual temperature on Mars surface,  $-17^{\circ}$  C and this attracted the worldwide attention. He also found a function which represents secular variations of Earth insulation and using them explained the formation of ice ages. This theory made him later famous. For detailed explanation of Milanković's theory of ace ages the reader may consult for example Grubić's articiel (2006).



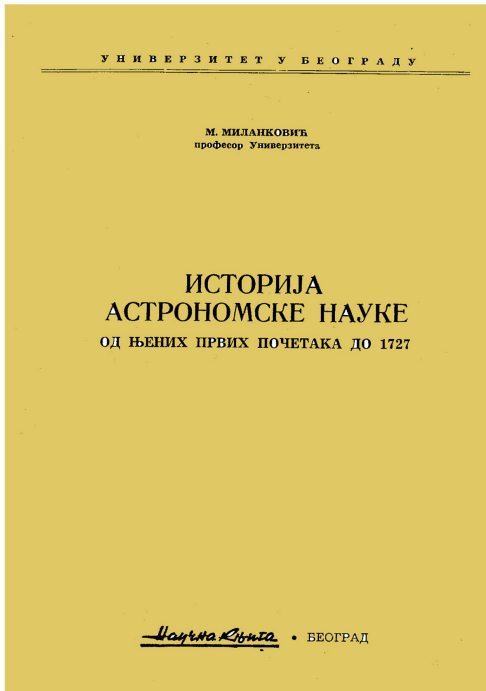
The Canon of Insulation



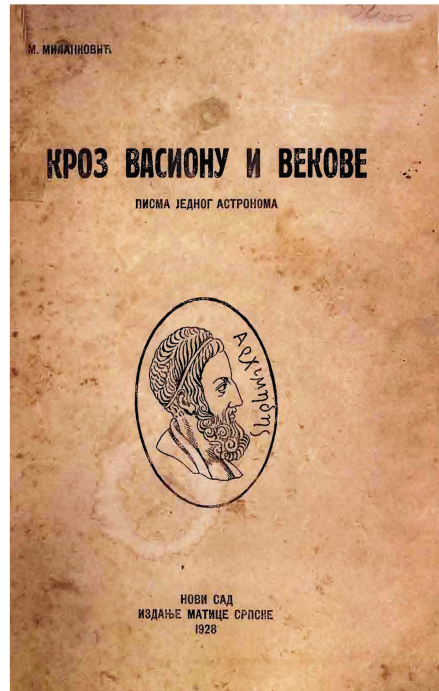
Celestial Mechanics

Milanković wrote two versions of his university textbook "Небеска механика" (*Celestial Mechanics*). The book was published thanks to the sponsorship of "Luka Čelović-Trebinjac" endowment in Belgrade in 1935. The book was based on the lectures on Celestial Mechanics delivered by Milanković at the Belgrade University. At that time already existed several books in Serbian in the field of theoretical mechanics. The main novelty that this book introduced in the Serbian scientific literature is the consistent and systematic use of vector calculus for solving problems of celestial mechanics. Milanković used there the vector-scalar

system of elements of planetary orbits. For this reason connecting his name with this system is fully justified. *Небеска механика* was written on 333 pages with 22 figures in its text. The book is divided into two parts and consist of 15 chapters. The first part *Транслаторно кретање небеских тела (Translatory Motion of Celestial Bodies)* contains nine chapters; the second one *Ротационо кретање небеских тела (Rotational Motion of Celestial Bodies)* is written on 130 pages containing six chapters. At the end of both parts there is a list of references in foreign languages. The book is presented in details by N. Pejović (2011).



History of Astronomy



Through Space and Centuries

Milanković wrote books not only in science but on science as well. The book that is still used in university courses on history of science is his "Istorija astronomske nauke od njenih prvih početaka do 1727" (*History of astronomy since the very beginning untill 1727*). Even if this book is printed after the Second World War, in 1948, Milanković started lecturing history of astronomy immediately upon his arrival in Belgrade, in 1909. We may take that Milanković is the real founder of this course at the Belgrade University. The book arose from his lectures and written notes and so the book, in a sense, is used over a century at the Belgrade University for teaching history of astronomy. The book was not available in bookstores for long time so that for students digital copies from the Virtual Library of the Faculty of Mathematics are very useful. The Milanković's

stand point was that if a student wants to understand the achievements of the contemporary astronomical sciences, he should know the development and evolutions of ideas in astronomy through centuries. So, the first chapters of the book are devoted to astronomy of ancient Greeks and astronomers of this time: Apollonius of Perga, Aristarchus of Samos, Hipparchus, Claudius Ptolemy and some others. However, Milanković considered that Aristarchus had the main role in the foundation of Astronomy as science mainly because he had enough courage to advocate the heliocentric World system in spite of then widespread geocentric perception of the Universe. In the second part of the new astronomy that brought the Renaissance and astronomers of that time: Galileo Galilei, Nicolaus Copernicus, Johannes Kepler, Isaac Newton. Mains achievements, such as Kepler laws of planetary motion and Newton law of universal gravitation.

Milanković highly cherished the written word. After reading his books that popularize science, or on the history of the science, the reader would certainly conclude that Milanković would be a great writer if he did not devoted himself to science. His celebrated book *Through Space and Centuries* without doubt witnesses this opinion. This book fictionalized the development of astronomy through centuries. The novel explains the scientific history of astronomy written as a travelogue prose. It consists of a collection of letters sent by Milanković to the loved one describing the long imaginative journey through the past of millions of years and travel through the deep Universe. Letters represent a treasury of scientific explanations and portraits of famous scientist: Eratosthenes, Ptolemy, Pythagoras, Copernicus, Kepler, Newton, Einstein and Tesla. The book is a collection of records about the cradle of wisdom, scientific knowledge and philosophical views of ancient people of Babylon, China, India, old Greece and Rome up to the modern times. This book of stories about the ancient beauties and thoughts written in the splendid language has become his brand name. Five editions of the book were published in Serbian, one in Slovenian, and two editions in German.

### Acknowledgments

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**SUPPLEMENT: BOOKS AND MONOGRAPHS OF MILUTIN  
MILANKOVIĆ IN VIRTUAL LIBRARY  
(with active links in electronic version of this paper)**

- O primjeni matematičke teorije sprovođenja toplote na probleme kosmičke fizike, Zagreb, 1913.
- O pitanju astronomskih teorija ledenih doba, Dionička Tiskara, Zagreb , 1914.
- Phenomenes thermiques, Paris , 1920.
- Reforma julijanskog kalendara, Belgrade , 1923.



- Nebeska mehanika , Belgrade , 1935.  
Kanon der Erdbestrahlung, Serbian Royal Academy, Belgrade , 1941.  
Kroz vasionu i vekove - jedna astronomija za svakoga, Belgrade , 1943.  
Osnivači prirodnih nauka - Pitagora - Demokritos - Aristoteles - Arhimedes, Belgrade , 1947.  
Astronomska teorija klimatskih promena i njena primena u geofizici, Naučna Knjiga, Beograd , 1948.  
Kroz carstvo nauka, Naučna Knjiga, Beograd , 1950.  
Uspomene doživljaji i saznanja iz godina 1909 do 1944, Naučna Knjiga, Beograd, 1952.  
Uspomene doživljaji i saznanja posle 1944 godine, Naučno delo, Beograd, 1957.  
Astronomische Theorie der Klimaschwankungen, Belgrade, 1957.  
Istorija astronomske nauke - od njenih prvih početaka do 1727, Belgrade , 1979.  
Glas SKA CIX - Kalorična godišnja doba, SKA, Belgrade, 1923.  
Glas SKA CXVII - Kalendar Zemljine prošlosti, SKA, Belgrade, 1926.  
Glas SKA CXX - Ispitivanja o termičkoj konstituciji planetskih atmosfera, SKA, Belgrade, 1926.  
Glas SKA CLXXV - Novi rezultati astronomske teorije klimatskih promena, SKA, Belgrade, 1937.

#### **INTERNET LINKS**

**(All internet sites belong to the Faculty of Mathematics in Belgrade)**

Digitalni legati (Digital legacies): <http://legati.matf.bg.ac.rs>

Digitalna arhiva (Digital Archives): <http://digitalnilegati.matf.bg.ac.rs>

Virtuelna biblioteka (Virtual Library): <http://elibrary.matf.bg.ac.rs>