SPECIAL ARTICLE

Great Scientists From a Small Country in War and Peace

ABSTRAKT

Great scientific discoveries rarely originate from small and poor countries. The Balkan region, an area with frequent wars and numerous invasions, is not considered an appropriate base for scientific research. Despite such opinions, a number of well educated, curious, wise, and brave minds from Serbia and the former Yugoslavia have been able to make significant scientific contributions. As an example, we briefly outline the lives and achievements of two scientists: Milutin Milankovic (1879-1958) and Ivan Djaja (1884-1957). Nikola Tesla (1856-1943), and two Nobel laureates of Yugoslav origin, Leopold Ružička (1887-1976) and Vladimir Prelog (1906-1998), are not included here because their scientific contributions were mainly conducted in the USA or Switzerland. Milankovic and Djaja overcame many obstacles, including wars, to contribute significantly to science. Unfortunately, each generation in Serbia and in the former Yugoslavia has been severely disturbed by at least one war. However, some researchers, despite wars and limited resources were able to complete their great scientific projects. Notably, such scientists stayed in the country or returned home as soon as peace returned. However, following the recent civil war that split Yugoslavia, many capable scientists did not return to their prewar homes.

KEY WORDS

Yugoslavia, Serbia, great scientists, Milankovich Cycles, Djaja, Gjaja, US von Euler, thermoregulation

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Great scientific discoveries rarely originate from small and poor countries, especially if they are frequently engulfed in wars, like it was the case with Serbia, and other parts of the former Yugoslavia. Despite the odds, quite a few well educated, curious, wise, and brave minds have made significant contributions under such circumstances. For example, the achievements of Laza K. Lazarević (1851-1891), Milutin Milankovic (1879-1958), Ivan Djaja (1884-1957), Pavao Stern (1913-1976), and several other Yugoslav researchers clearly show that some scientists are able to make great discoveries under limited resources. ¹ Nikola Tesla (1856-1943), and two Nobel laureates of Yugoslav origin, Leopold Ruzicka (1887-1976) and Vladimir Prelog (1906-1998), are only mentioned here because their major scientific contributions had been mostly conducted in the USA and Switzerland.

Presented here a brief history depicting the life and achievements of M. Milankovic and I. Djaja with commentary on the influence of recent war and NATO military interventions during the disintegration of the former Yugo-

slavia and on scientific output as measured by changes in numbers of articles published in peer-reviewed journals.

Milutin Milanković

Milutin Milanković (also known as Milutin Milankovitch or Milankovich) was a geophysicist, who became well known for his discoveries related to climate change. His theory on climate change is based on the variations of three orbital parameters. The climate changes on very long time-scales are known as 'Milankovich Cycles'. These cycles are primarily responsible for the global climate changes for at least 1.6 million years.

Milutin was born in Dalj in 1879 (Austria-Hungary, now Croatia) to Serbian parents. He died in Belgrade in 1958. He graduated in 1901 from the *Technische Hochschule* in Vienna (Civil Engineering) and two years later earned a doctorate in technical sciences. For five years after graduation, he was a practicing civil engineer in Vienna. In 1909, he accepted the position of chair of applied mathematics in Belgrade.

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Figure 1. Title page of Milankovic's major book, *Kanon der Erdbestrahlung*, that was published in 1941. When Milankovic was fully aware that his theory of solar radiation had been completed, he prepared a manuscript for a book to be published in Belgrade, just before Germany occupied Yugoslavia. The Germans heavily bombed Belgrade on the Easter Sunday in 1941, just a few days after the book was printed, but not bound. The printer's building was totally destroyed. Fortunately, after the wreckage was cleaned, majority of intact pages were found in the cellar storage. The rest of pages were printed after the war and the book was mailed to the libraries all over the world. The authors of this paper have borrowed a copy of the *Kanon* from the Math Library, University of Illinois at Urbana Champaign, Illinois, USA. One can see that the color of paper of the additionally printed pages is slightly different. The book was translated in English and published in 1969 by the U.S. Department of Commerce and the National Science Foundation under the title *Canon of insolation of the Ice Ages problem*.

Two short Balkan wars and World War (WW) I interrupted Milankovic's work. At the beginning of WWI, during his visit to his home in Dalj, Austro-Hungarian soldiers captured him and he was imprisoned in Hungary. Due to his friendship with some influential people, he spent most of his prison years in Budapest. When Milankovic was in his early sixties, another great obstacle for his and other Yugoslav scientists' work appeared: WWII and the German occupation.

Scientific Activity. Milankovic's position at the University of Belgrade was a great challenge for his basic scientific research, and he became deeply involved in the problems of solar climates and temperatures on the planet but unfortunately the wars soon disturbed his work. However, while he was an intern in Budapest, he was allowed to visit a library where he continued to work on his mathematical theory of thermal phenomena caused by solar radiation. Soon after the war, in 1920, these findings were published. Later on, he completed his theory of solar radiation.²

Like other planets, the Earth travels in an orbit around the Sun. One revolution lasts a little over 365 days (a period of one year). At the same time, the Earth spins around from west to east, and the Sun seems to travel across the sky in the opposite direction, from east to west.

The value of the solar constant - total amount of radiation incident on the earth in one year is not perfectly constant. It is variable for less than 1% of the average value. Milankovic advanced the theory that the periodic changes of climate between glacial and interglacial periods are related to the orbital changes of the Earth. Long-term variations of three Milankovic orbital parameters are eccentricity (the shape of the orbit around the sun), precession (changes in the average distance Earth-Sun), and tilt of the Earth.

The eccentricity varies regularly during a cycle that averages about 100,000 years, and it is associated with change in solar constant of about 0.1%. When eccentricity is relatively high, the Earth receives more radiation causing warmer summers and colder winters. Thus, the seasons on one Hemisphere are strengthened, while weakened on the other. Another orbital parameter that influences seasonal and latitudinal changes presents the angle of tilt of the Earth's axis of rotation (varies from 22° to 24.5° with a periodicity of about 40,000 years). Also, a large tilt causes extreme seasons in each Hemisphere, and the duration of the winter-darkness near a pole is determined by the tilt only. Precession presents the change of direction in space of the Earth's rotational axis that occurs with a periodicity of about 22,000 years. The precession affects the seasonality in each Hemisphere; the variations of these three orbital parameters are important for climate changes on very long-term scale, and the periods of these orbital motions are known as Milankovich Cycles.

Citations of Milankovic's publications. Milankovic's publications, according to the *Science Citation Index* and *Web of Science* were quoted 780 times in the period from 1945 to 2005³. His mayor work that deals with the origin of Ice Age, *Kanon der Erdbestrahlung und seine Anwendung auf das Eiszeitenproblem* [Canon of insolation of the Earth and its application to the problem of the Ice Age] (Figure 1), published in 1941, was most often cited during this period.

As a rule, the number of citations for most publications de-

creases over time, but citation distribution of Milankovic's works shows the opposite pattern. In the period from 1945 to 1960, the number of citations of his papers was modest (2,6 per year on average), but later on it steadily increased⁴. For about 50 years, Milankovic's theory was largely unnoticed, until a study of Hayes et al⁵ on examination of deep-sea sediment showed that Milankovic's theory did correspond to periods of climate change. Since this study, the scientists have embraced the Milankovitch Cycle model, and contemporary scientists became interested in his publications from 1920 to 1941 (Figure 2). Thus, his publications belong to a rare category that is known as "Sleeping Beauty".⁶

Figure 2. Citations of Milankovic's publications according to the Science Citation Index and Web of Science (from 1928 to March 2011). Milankovic's publications belong to a rare category of "Sleeping Beauty." Famous example of this type is the Mendel's work on plant hybridization. Mendel's findings were for long distrusted because "mathematics has not legitimate application to biological science." Also, not many of the Milankovic's contemporaries believed in possibility that the calculus may explain climate changes.

Bulletin "Kontakt" recorded appreciation of his work. The "Kontakt", an official journal of the Yugoslav Society of Biomedical Journals and Bulletins, has published the article *Ledena doba i teorija Milutina Milankovica* [The Ice Ages and the Theory of Milutin Milankovic] in 1994.⁷ In addition to a brief introduction, several segments from the paper entitled "The Ice Ages"⁸ were printed and distributed locally in order to spread the awareness of chemical record found in the ocean sediments in 1984, which supported Milankovic's theory. The paper also presents the Devil's Hole findings suggesting that the changes of the Ice Ages are not always cyclical, indicating that the other factors

have an impact on the climate changes, as well. Regardless of this finding, Milankovic's theory has explained to climatologists the single factor that is primarily responsible for the global climate changes for at least 1.6 million years.

Additional interests and recognition. In addition to scientific papers, Milankovic also published a textbook on the history of astronomy, two books for laypersons (*Through space and centuries* and *Through the realm of science*), and three volumes of autobiography (*Recollections, Experiences, and Vision*). In May 1923, he participated at the Congress of Orthodox churches (Constantinople) to present some corrections of the Julian calendar. This calendar was introduced by Julius Caesar in 45 BC upon the advice of the Greek astronomer Sosigens. Although the Julian calendar is considered inferior to the Gregorian calendar, the former calendar is used by many Orthodox Churches (including Serbia and Russia).

Milankovic was a member of the Serbian Academy of Sciences and Arts (Belgrade), the Yugoslav Academy of Sciences and Arts (Zagreb), the German Academy of Naturalists "Leopoldina" (Halle), and a member of many other scientific societies and organizations in Yugoslavia and abroad. Thus, he significantly influenced scientific and cultural development in many countries. The following cosmic objects were named after him: Milankovic—a lunar crater on the far side of the Moon (77,2° N, 168,8° E); Milankovic—a 118 km crater on Mars (at 54,4° N, 213,3° E); and 1605 Milankovich—a miniature planet.

Ivan Djaja

Ivan Djaja (also known as Jean Giaja) had a remarkable scientific career in Belgrade. He was a physiologist internationally known for his research on thermoregulation and deep hypothermia.

Djaja was born in 1884 in France to a Serbian father and French mother. He declared himself as a Serb of Catholic religion. When he was six, his family moved to Belgrade where Djaja attended school. In 1909, he got his doctoral degree in Physiology at Sorbonne University, Paris. He was invited in Belgrade, in 1910, by the Kingdom of Serbia. Djaja was a chairman and founder of the department of physiology at the University of Belgrade. He lived in Belgrade up to his death in 1957. His research work was interrupted by two short Balkan wars, and by the WWI and WWII. The worst period for him was the period of German occupation, 1941-1945 as he suffered like many Serbian intellectuals and was even imprisoned for some time in the Banjica Concentration Camp. Djaja published about 200 papers in various biomedical journals in French, Serbian, German, English, and Italian. His two books "L'Homeothermie" and "La Thermoregulation" (Figure 3)⁹ are well known among physiologists. He also published several fiction books, and three philosophical books, including *L'homme et la vie inventive*.¹⁰

Figure 3. Two books published by Ivan Gjaja in 1938.

Major discoveries. Djaja's main scientific contributions are in the field of thermoregulation and thermal adaptation, and his department soon became internationally known as the "Belgrade School of Physiology."

Djaja's Ph.D. student, Radoslav K. Andjus (1926-2003), was the first to reanimate a rat that was in deep hypothermia.¹¹ Previous attempts to re-warm deeply cooled rats

were unsuccessful and it was concluded by the German physiologists that below 15 °C, the rat couldn't be successfully revived. The closed vessel method of cooling animals, in which hypoxia and hypercapnia are combined, initiated an anecdotal publication on this method.¹¹

Enthusiasm for experimental work is a characteristic feature of all Claude Bernard pupils and their followers. Thus, Djaja proclaimed a motto *Nulla dies sine experimento* - a paraphrase of *Nulla dies sine linea* by Leonardo Da Vinci. Such enthusiastic research that lasted until his death resulted in his acceptance to the French academy of Science, where he was elected on May 23, 1956 as a replacement for Sir Alexander Fleming (Figure 5).

Djaja died in Belgrade in 1957 during second day of the 'International Symposium on Hibernation' that was organized in his honor. Thus, he lived and worked in Belgrade for 47 years where he established a great school of physiology.

Epilogue

The Balkan region, so frequently devastated by wars, is generally not considered a fertile ground for scientific research. However, there have been researchers and intellectuals, such as Lazarevic, Milankovic, Djaja, Andric, Stern, who despite wars and limited resources in Yugoslavia, were able to realize their projects. Thus, in each generation some brilliant men enriched certain areas of science and arts. Of note, these individuals stayed in the country or returned home, as soon as freedom came. However, after the recent civil war that split the former Yugoslavia, many capable scientists were not allowed to return to their homes, especially if they belonged to a different nationality. Consequently, this war in Yugoslavia has been most damaging to scientific endeavors in Serbia, and B & H.¹² (Figure 5).

When Lazarevic, Milankovic, Djaja and other young scientists who were trained in developed countries returned home, they received appropriate support and were given freedom to initiate independent research programs. Such an approach appeared to stimulate their creativity and adherence to their universities. There is a consensus that when young scientists are given such freedom, despite often losing time seeking adequate methods and deciding what they really want to study, acquire an independent and critical way of thinking earlier than researchers who work in a research group with a fixed research program and methods. However, poor countries, cannot afford to finance many scientists, and the selection of the most promising, well trained, researchers is the main challenge for those who make the decisions regarding scientific research.

Another aspect for facilitating science in a small country is international cooperation and this process should be bidirectional. Scientists from small country should be able to

Figure 4. In 1956, Djaja was elected in the French Academy of Science as substitute to Sir Alexander Fleming.

visit international laboratories in prestigious institutions. However, it is also important to invite established foreign scientists to a small country to visit, so as to stimulate local researchers. This is a way to create cooperative international scientific projects that may facilitate scientific research worldwide. First International Symposium on Substance P organized by professor Pavel Stern in Sarajevo (1968)¹³ is an example of such cooperation, as many of the participants continued collaborating with the scientists in Yugoslavia long after the symposium had ended. One of these participants, U.S. von Euler, assisted the Yugoslav pharmacologists in various ways, and he visited Yugoslavia again in 1976 (University of Belgrade) in and in 1982 (University of Tuzla).

IGIC: The influence of the civil war on publishing

Figure 2. Publications from the former Yugoslav republics indexed in the SCI

Figure 5. Publications from six former Yugoslav republics. The papers published from 1988 to 2000 in the journals covered with Science Citation Index from Bosnia & Herzegovina, Croatia, Macedonia, Montenegro, Slovenia, and Serbia are presented.

During the recent war in Yugoslavia and NATO bombings of B&H and Serbia many well educated people have left these states, with a number of them having received training and research experience. It is now time for newly formed states to invite them to return home. The government needs to create a program to turn around this

'brain-drain'. The return of these scientists with valuable experience gained in other more prominent countries, will significantly help the educational, scientific and cultural recovery in these war torn countries. In addition, international scientific, technical, and cultural cooperation should involve local interstate collaboration, so these states that recently were fighting for independence or territorial gains could improve their relationships.

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Veliki naučnici iz male zemlje u ratu i miru

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APSTRAKT

Značajna naučna otkrića retko potiču iz malih i siromašnih zemalja. Međutim, dostignuća nekolicine jugoslovenskih naučnika pokazuju da su oni prevazilazili niz teškoća, uključujući ratove i teške posleratne periode i značajno doprineli nauci. Nažalost, svaka generacija u Jugoslaviji bila je ometena barem jednim ratom i takvi uslovi značajno štete naučnu produkciju. Zato nema mnogo stvaralaca poput Milutina Milankovića (1879-1958) i Ivana Đaje (1884-

1957) i još nekolicine drugih naučnika, koji su unatoč ratova i ograničenih sredstava prevazilazili teške uslove da bi završili svoje naučne projekte. Uočljivo je da su ti naučnici vreme rata provodili u svojoj zemlji ili su se vraćali kući, odmah posle rata. Ovde samo pominjemo u svetu poznatog inovatora i istarživače jugoslovenskog porekla, Nikolu Teslu (1856-1943) i dva Nobelovca, Leopolda Ružičku (1887-1976) i Vladimira Preloga (1906-1998) koji su većinu svojih dela stvorili u Americi, odnosno u Švajcarskoj. Kao primer uspešnih stvaralaca u našim uslovima, u ovom članku su dati podaci o životu i radu M. Milankovića i I. Đaje. U komentaru se navodi da su nakon nedavnog rata, koji je pocepao Jugoslaviju, mnogi stručnjaci otišli u inostranstvo i da ih se većina nije vratila u svoju zemlju.