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On Life and Scientific Activity of Ruđer Bošković

Slobodan Ninković [1)]
Miodrag Lisov [2)]

The paper presents the new insights to origin and family of our great scientist, philosopher, artist and diplomat Ruđer Bošković (1711-1787). His rich career is related to his hometown Dubrovnik, where he was born in 1711. After the initial education at the Jesuit College he went to live and work in Rome, Vienna, Paris and London. He became a member of many scientific associations and academies, published over seventy scientific papers. He founded the astronomy observatory in Brera and then he went to Paris to hold a position of the Director of Naval Optics in Paris. Eventually, devastated by his illness, he went back to Milan where he died in 1787, thus ending the life path of this remarkable person.

Key words: **observatory in Brera, astronomy, theory of natural philosophy, spherical trigonometry, eclipse of the Sun and the Moon, unique force law.**

(1711 – 1787)

Introduction

THIS year, on October 13th and 14th, the 10th jubilee international conference in the area of defense technologies OTEH 2022 was held in the Military Technical Institute.

The best-known regional scientific gathering in the area of defense technologies gathered the representatives from the faculties, institutes and business entities from the Republic of Serbia and 13 foreign countries. During a two-day work, over 100 scientific and technical papers were presented at the international conference.

The tradition of all the held OTEH conferences up to now was for the first lecture to be dedicated to some of the giants of the Serbian science. This year, not without a reason, the choice fell on Ruđer Bošković, a famous scientist of the Serbian origin, whose versatility and devotion to science inspire us nowadays. Bošković gained significant success in the area of: mathematics, physics, astronomy, diplomacy and art. These successes are still impressive today, especially because they should be observed in relation to the time when they were created.

Professor Slobodan Ninković from the Astronomical Society Ruđer Bošković spoke enthusiastically about the significance and role of Ruđer Bošković. This noted lecture, entitled "Life and Scientific Activity of Ruđer Bošković", introduced the participants of the international conference to life and work of brilliant and versatile scientist of our origin, the one that has been listed among 100 of the most famous Serbs.

[1)] Astronomsko društvo „Ruđer Bošković", Kalemegdan, Gornji grad 16, 11000 Beograd
[2)] Military Technical Institute (VTI), Ratka Resanovića 1, 11132 Belgrade, SERBIA
Correspondence to: Slobodan Ninković, e-mail: sninkovic@aob.rs

Figure 1. Title page of the OTEH 2022 Proceedings

Short biography

Being the eighth child in the Bošković family, from parents Nikola and Paola, our great scientist Ruđer Bošković was born on May 18th, 1711 in Dubrovnik.

Ruđer's father, Nikola Bošković, was born in the village Orahov do (Orahovo), on the slopes of Popovo polje in Herzegovina. He came to Dubrovnik in the first half of the 17th century, where he started to work in trade for the notable Dubrovnik's trader Rade Gleđević. Even as a young person, he got certain significant assignments and started trading with the surrounding countries. He went to Novi Pazar very often for trading. Trading enabled him to gain wealth and properties, so he came back to Dubrovnik as a very prominent trader.

His father Boško, according to whom they got the family name Bošković, also came to Dubrovnik. Nikola married Paola there, a daughter of a well-known trader Baro Bettera, who came to Dubrovnik from Bergamo in Italy.

Ruđer's father Nikola was very capable trader and showed a lot of interest for his own people from which he originated. During his travels he was going to Raška, where he showed special interest for orthodox churches. Even though he was going to Dubrovnik where he received the catholic religion, he was aware of his origin and a fact that his father Boško was an orthodox Serb.

Travelling in these regions, Nikola described his own memories and historical events that refer to this period and published them in his precious travelogue ''Relazione dei Monasteri della Provicia di Rassia fatoci dai Signore Nikolo Boscovich in Ragusa''. Together with other descriptions, there he has also described how the Turks burnt down and devastated the Mileševa monastery in 1688 and took away the significant church relics and treasure.

Being aware of the value of these relics he redeemed some of them from the Turks. Thus, it has been mentioned that he bought a silver box in which a part of the Saint Cross was kept, which was presented to the monastery earlier by Marija, a daughter of despot Đurađ.

Figure 2. Orahov Do (Orahovo)

These charities of Nikola Bošković originated out of respect and love toward the nursing garden to the Serbian culture and tradition, the medieval Serbian state of Raška.

Ruđer's mother Paola was from Dubrovnik and she instilled in him a love towards Roman culture and art to a great extent. Since his young age Ruđer was raised in the spirit of Slavism and Mediterranean cultures, with a great impact of Dinara tradition of his Herzegovina ancestors and Roman culture. Ruđer's mother Paola was a very religious person, she found her inner peace in religion and she experienced a deep old age and lived for 103 years.

Ruđer's parents, Nikola and Paola, had nine children: Mara, Marija, Božo, Bartu, Ivan, Antun, Petar, Ruđer and Anica. His brother Petar was into poetry and mathematics, but he got ill and died very young. Other brothers and sisters (siblings) were well-known people of Dubrovnik. His oldest sister Mara was married to a trader Drago. The other sister Marija went to the monastery of St Kata. His oldest brother Božo was a clerk in the Republic of Ragusa. Brother Barua was in the Society of Jesus, he was a professor in Perugia and Rome, and he was also known as a poet and an excellent mathematician. Ivan was in Dominican Order, and Antun died at the age of seven. His youngest sister Anica was very close to Ruđer and very devoted to him, she also wrote poems. We can see that all brothers and sisters of Ruđer, together with being religious, shared their obvious inclination toward art and science.

Ruđer started his education in Dubrovnik, in Jesuit College. Mother Paola wanted him to be in God's service, but his interests were directed toward science, philosophy and art, so with his mother's blessing he left to Rome in 1726. There he underwent all the phases of Jesuit education, and even though he was a non-graduated theology man they showed him a great honor and he became the professor at the college.

During his education his talent and extraordinary capabilities were recognized and at the time he published a poetry work "Eclipse of the Sun and the Moon". He published his first scientific paper *On sunspots*, in 1736, and then many other followed: *On geometry construction of the sphere geometry*, *On the transit of the Mercury across the Sun*, *On the new use of telescope*, and many other. Almost each year Ruđer published one or two publications in the area of:

astronomy, meteorology, physics, mathematics and philosophy, where he exposed new ideas worthy of a genius. Besides, he solved the problems of the construction area at the dome of Saint Peter in Rome, as well as he solved the problem of swamps and regulations of the river Tiber.

Figure 3. Dubrovnik

After spending 26 years in Italy, he moved to Austria, where he exposed himself in a diplomatic activity mediating the dispute between Tuscany and Lucca. By solving the dispute, he met many remarkable persons of the Vienna court. After solving this problem, he was disappointed with numerous intrigues that happened during this dispute. In the end, representing Lucca's interests, he reached the emperor and empress Maria Theresia, with whom he established a very close relationship. In the end, he succeeded in solving the diplomatic dispute in favor of Lucca. As a sign of great respect and gratitude this little country awarded him a noble title, which he renounced, because of his modesty and belonging to the Jesuit Order.

Figure 4. Monument to Ruđer Bošković in Milan

His popularity in scientific and diplomatic circles, as well as in the court, was remarkable. Upon the invitation of the empress Maria Theresia, Ruđer gave his opinion on how to restore the imperial library. After leaving Vienna, he returned to Rome for a short period of time, and then he went to Paris in 1759. In Paris, he was a frequent guest in scientific, diplomatic and noble circles, he visited the court and met the royal family. Already in 1760 he went to London, where he became a member of the English royal scientific society. There he also published significant papers in the area of astronomy. After the unsuccessful departure to Constantinople, Bošković spent some time in Warsaw and Krakow, and then in 1763 he went to Italy again. In Pavia they entitled him a professor of mathematics. His material provisions provided him stability and opportunity to deal with the scientific work. Unfortunately, at the time, he was seriously ill, and due to legs illness, he traveled to France and then to Brussels. He came back to Milan where he was entitled the professor of mathematics and astronomy. After that, he accepted the idea to form the observatory in Brera. With his own resources, he helped in building of the observatory which, according to all its characteristics, was one of the state-of-the-art at the time. Unfortunately, due to certain disagreements, he left the observatory and in 1773 he went to France.

Figure 5. Moon – Ruđer Bošković Crater

At the time, the Jesuit Order to which he belonged was terminated and he accepted the vacancy of the Director of Naval Optics in Paris. Bošković remained at this position until his death. In France he was chosen a member of the Academy of Sciences in Paris, Metz and Marseille.

Very ill, he went back to Italy where he died in Milan in 1787. This was the end of an extremely successful and fruitful life path of a great scientist and creator.

Creative Activity

Bošković's area of interest in science was rather broad. It covers almost all fields of science developed until his time, such as mathematics, mechanics, optics, astronomy, geodesy and civil engineering. He wrote about 70 scientific papers. Besides, Bošković also preceded some later research. His work on basic forces in nature is very well known. It can be added that he was also a philosopher, archaeologist, diplomat, even a poet.

In mathematics, Bošković is well known, especially due to his results in geometry. Since he was active in astronomy, it is not unusual that his interest in geometry primarily concerned spherical trigonometry. There exists a set of formulae derived by him. The title of the work, published in 1737, is *Trigonometriae Sphaericae Constructio*. Bošković's observational work in astronomy, most likely, instigated him to develop an original theory of error analysis, [4]. This theory well preceded the analogous one developed by Gauss.

In mechanics, Bošković was among the first who accepted the Newton's theory of gravitation. It is well known that Bošković started to study the famous *Principia* in 1735.

Somewhere at the time (1735), Bošković was eager in comprehending another famous work of Newton – *Optics*. The acquired knowledge, certainly, helped him later, when he was director of Brera Observatory (Milan, Italy), for the purpose of improving the optical devices there. He made important advances in achromatic lenses.

Bošković has often been said to be an astronomer. Indeed, spherical trigonometry, mechanics and optics, all find a broad application in astronomy. As for observations, Bošković observed the transit of Mercury on November 11th, 1736, about which he published a paper entitled *De Mercurii Novissimo infra Solem Transitu* in 1737. Although he was very active in organizing and preparing expeditions aimed at observing the transits of Venus in 1761 and 1769, he was prevented to observe them personally. The first time he had intended to carry out his observation in Istanbul, but, unfortunately, he arrived too late. The second time Bošković was invited by the Royal Society from Great Britain to lead an expedition to California, but was hampered to travel for some political reasons. He is also known because of his studies of aurora borealis. In theoretical astronomy, Bošković was active in calculating orbits of the solar system bodies. The objective of such calculations is to obtain the orbit using the observational data, in particular, the positions on the sky where the minimum number is three. He was the first to propose a proper procedure, he also gave another procedure for determining the equator of a planet from three observations of its surface. In 1752 Bošković submitted a memoir for the Grand Prix of the French Academy of Sciences which concerned his study of the two giant planets Jupiter and Saturn. The prize was given to Euler, Bošković received an honorable mention only.

In geodesy, Bošković participated in measuring the meridian arc between Rome and Rimini in 1739.

In 1742 Bošković was consulted in the matter of some cracks which had been evident in the dome of St Peter Basilica in Rome for many years. He recommended the use of iron rings which were placed around the dome. This was based on static calculations.

In the field of philosophy, Bošković's methodology is of interest. He defined three sources of knowledge: divine revelation, sensual experience (observation in a broad sense of the term) and reasoning (thought), [5]. Bošković indicated that the sensual experience can be illusory as far as it touches the things superficially, but never completely false. In case of the thought, there is a kind of an intimate sense producing the feeling of truth. According to Bošković, the induction principle is regarded as the only means by use of which it is possible to study nature hoping of being successful. In his opinion for the purpose of validity establishing evidence discordant with an accepted general law is more important compared to searching and listing the facts in favor of that law.

Bošković took the idea of action at a distance from Newton and the continuity principle from Leibniz. He made a distinction between complete and incomplete induction.

Generally, a very copious work entitled *Theoria philosophiae naturalis redacta ad unicam legem virium in natura existentium* has been ragarded as Bošković's most important achievement. Its first edition appeared in 1759 and was printed in Vienna. According to Bošković, the basic scientific and philosophical concepts dealt with : continuity and discontinuity of matter, space, time and motion; questions of partibility and composability of material particles; interactions between the particles; nature and use of infinitely large and infinitely small particles. Altough Bošković devoted special papers to all these questions, the copious work mentioned above appears as a synthesis (Stoiljković and the references therein, especially Ž. Dadić, Ž. Marković and E. Stipanić). There, Bošković considered the fundamental questions of the matter structure, from elementary points towards atoms, molecules, macromolecules, up to the celestial bodies. He pointed out a unique force law of interaction. At high distances we have attraction (gravitation), the repulsive force arises at smaller distances, then the attraction again and so on. Finally, at very small distances, there should exist a strong repulsive force which prevents the contact between particles (bodies). This unique force law is presented as a plot, force intensity versus distance. What is obtained is an oscillating curve with alternate arcs of attraction and repulsion, referred to as Bošković's curve.

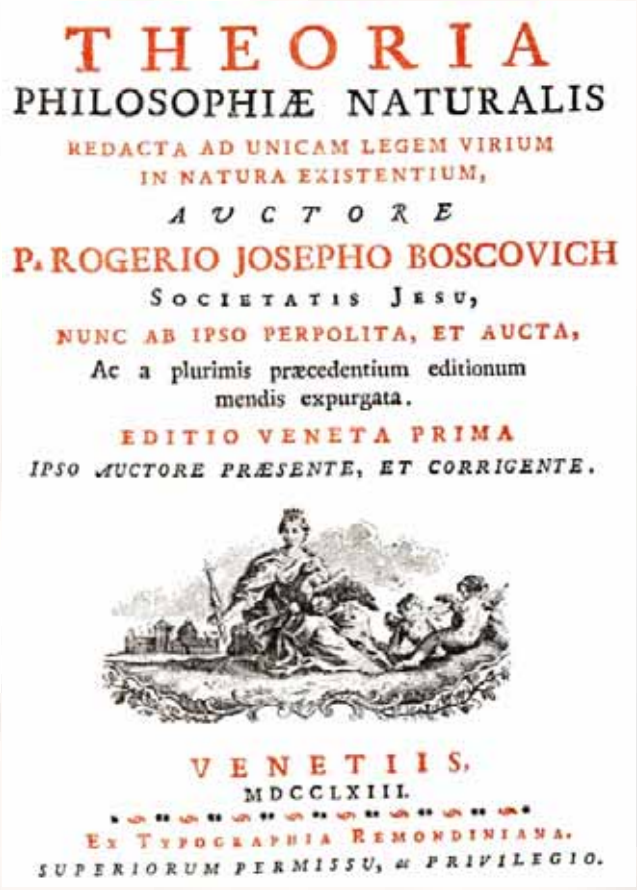
THEORIA
PHILOSOPHIÆ NATURALIS
REDACTA AD UNICAM LEGEM VIRIUM
IN NATURA EXISTENTIUM,
AUCTORE
P. ROGERIO JOSEPHO BOSCOVICH
SOCIETATIS JESU,
NUNC AB IPSO PERPOLITA, ET AUCTA,
Ac a plurimis præcedentium editionum
mendis expurgata.
EDITIO VENETA PRIMA
IPSO AUCTORE PRÆSENTE, ET CORRIGENTE.
VENETIIS,
MDCCLXIII.
EX TYPOGRAPHIA REMONDINIANA.
SUPERIORUM PERMISSU, ac PRIVILEGIO.

Figure 5. Theory of Natural Philosophy (most important work)

It would be intriguing to compare Bošković's ideas to the modern concepts of interaction. According to these concepts at the lowest, subatomic, level the strong interaction is the dominating one. At a higher level of atoms, molecules, due to the very short range of the strong interaction (strongest in nature), there is electroweak interaction. In its special form of electromagnetism, the starting point of which is the Coulomb's law the interaction appears both as attraction and repulsion depending on the interacting particles, more precisely the sign of their charges. Finally, at high distances, like those between the celestial bodies there is gravitational attraction. However, recently it has been established that the expansion of the Universe is not decelerated, but, on the contrary, it occurs with increasing speed! As a consequence, a new concept was developed known as dark energy, which could mean the dominance of repulsion at extremely high distances characteristic for the Universe. Another comment (Stoiljković) may be added. In 1958 Werner Heisenberg wrote "In his main work *Theoria philosophiae naturalis* there is a variety of ideas which found their full meaning only in

modern physics and which show to what extent the philosophical views directing Bošković in natural science were correct".

The contribution of Ruđer Bošković to science (studying nature) and philosophy is undoubtful. His name is present in the names of many organizations. A lunar crater was named after him. The crater Bošković is an impact crater located on the near side of the Moon. Its diameter is 46 km, and its depth is 1.8 km.

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O životu i naučnoj delatnosti Ruđera Boškovića

Ovo je rad koji nam daje osnovna saznanja o poreklu i porodici našeg velikog naučnika, filozofa, umetnika i diplomate Ruđera Boškovića (1711-1787). Njegova bogata karijera vezana je za rodni Dubrovnik, gde je rođen 1711. godine. Nakon početnog školovanja u Jezuitskom koledžu on se dalje školuje i živi i radi u Rimu, Beču, Parizu i Londonu. Postaje član mnogih naučnih udruženja i akademija, objavljuje preko sedamdeset naučnih radova. Osniva astronomsku opservatoriju u Breri, a zatim odlazi u Pariz na mesto direktora optičkog pomorskog instituta. Na kraju, savladan teškom bolešću, vraća se u Milano gde umire 1787. godine, čime se završava životni put ove izuzetne ličnosti.

Ključne reči: **Ruđer Bošković, opservatorija u Breri, astronomija, teorija prirodne filozofije, sferna trigonometrija, pomračenje Sunca i Meseca, jedinstveni zakon sile**