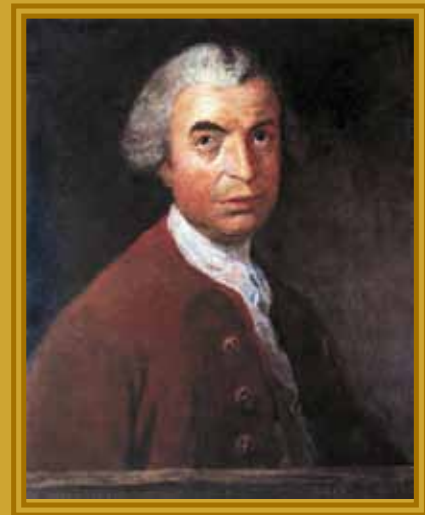

RUĐER BOŠKOVIĆ

*Dubrovnik, 18 May 1711 – Milan,
13 February 1787*





ROGER JOSEPH BOSCOVICH

Croatian scientist and philosopher, astronomer, mathematician, physicist, surveyor, writer, archaeologist, and a diplomat.

Introduction

Ruder Bošković was a prominent Croatian scientist and philosopher, astronomer, mathematician, physicist, surveyor, writer, archaeologist, and a diplomat. He spent his youth in Dubrovnik, where he attended Collegium Ragusinum until the age of 14, by 1725. After that, he joined the Society of Jesus in Rome's novitiate of Sant' Andrea delle Fratte, on the Quirinal Hill, graduating in 1727. From 1727 and 1729, he studied rhetoric at the central school of his order, the Collegium Romanum, where he also took a three-year study of philosophy from 1729 to 1732, and a study of theology from 1738 to 1741. In the period between the two studies, he worked as a master grammaticae et humanitatis at the collegia in Rome and Fermo. As a third-year student of theology, he began lecturing mathematics at the Collegium Romanum study of philosophy. He was ordained to the priesthood and took a vow of obedience to the Pope in 1744.

Bošković changed four professions during his lifetime. He was a public professor of mathematics at the Collegium Romanum study of philosophy from 1740 to 1760, including times away from Rome for research and diplomatic reasons; a professor of mathematics at the Pavia university, re-established under Austrian rule, from 1764 to 1769; a professor of applied mathematics with optics and astronomy at court schools in

Milan from 1770 to 1773; and a director of optics in the French navy from 1774 to 1782.

He undertook four voyages, including a visit to Dubrovnik in 1747, a geodetic and cartographic expedition from Rome to Rimini 1750–52, a journey to Lucca and Vienna due to a hydro-technical dispute between Lucca and Tuscany 1756–58, and a study tour of European capitals 1759–63, when he visited Newton's Cambridge. In 1766, he attempted to make a journey to California to do astronomical measurements, but was forced to give up due to the Spanish court's intolerance of the Jesuits.

Even after the Pope's decree on the suppression of the Society of Jesus in 1773, he remained a priest and accepted a friend's invitation to continue his scientific work in Paris. In order to become a high-ranking official in the French navy, he took French citizenship in 1773. Requesting a leave, he left Paris in 1782 and went to Bassano for three years to supervise the preparation of his five-volume *Opera pertinentia ad opticam et astronomiam* for publishing.

Bošković stands out among Croatian scientists for his unique work which not only advanced science, but also changed the scientific view of the world.

Ruđer Bošković's Geodetic Work

Ruđer Bošković was versatile and left his mark in many scientific fields, one of them being geodesy. Ideas related to geodesy stoked true passion for research in Bošković, from his original plan to travel to South America to measure the length of degree of the meridian arc near the Equator to the research journey along the Rome-Rimini meridian arc.

The first incentive for Bošković's geodetic measurements came from the Portuguese king Joao V in 1750, when he was granted a permission by the Jesuit supreme head (general) and applied for a voyage to Brazil in order to take part in the delineation between the kingdoms of Spain and Portugal, under the condition to be allowed to measure one degree of the meridian arc.

Bošković spent two years on the voyage, together with Christopher Maire (1 October 1750 - 7 November 1752). Its results were published in 1755 (Figure 1a), in a scientific report of the Papal State research which included *Nuova carta geografica dello Stato Ecclesiastico*, the first accurate map of the Papal State created, using jointly collected data, by Christopher Maire.

The main effects of this geodetic measurement were published three more times by Bošković:



Figure 1. Report front pages: a) Report in Latin, 1755 (NSK - National and University Library in Zagreb), b) Summary report for the Bologna Academy journal (*Separatum ex Commentariis academiae Bononiensis*) from the State Archives in Dubrovnik, 1757, and c) Report in French, 1770, Bošković on the Voyage, *Astronomic and Geodetic measurements*

- In 1757, in a summary report for the Bologna Academy journal (Figure 1b),
- In 1760, enclosed to an epic by Benedikt Stay (*Philosophiae recentioris versibus traditae libri X Cum adnotationibus Rogerii Boscovich*),
- In 1770, in French translation, *Voyage astronomique et géographique, dans l'État de l'Église* (Figure 1c)

One of the important problems in the scientific world of the time was the definition of the Earth's figure. Becoming interested in the problem himself, Bošković got involved in theoretical debates, and then in actual measurements with assumptions to be confirmed or rejected. During a survey to measure the length of the meridian arc, Bošković and Maire insisted on maximum achievable accuracy in not only the geodetic measuring of lengths and angles, but in astronomical determination of zenith path lengths of stars. All earlier measurements of the meridian arc length had considerable shortcomings, primarily in terms of low accuracy, and particularly in determining lengths between very distant, end points of the meridian arc. Bošković's innovations in the design of measuring devices saw an increase in the accuracy of base lengths, which improved the accuracy of calculating the whole triangulation network.

In 1741, Bošković presented the idea of geoid being the shape of the Earth in his work *De inaequalitate gravitatis in diversis terrae locis* (Rome, 1741), while in „*De litteraria expeditione per pontificiam ditionem ad dimentiendos meridiani gradus et corrigendam mappam geographicam, iussu et auspiciis Benedicti XIV*“ (Rome, 1755), he became the first to draw attention to the vertical deflection, resulting, in his opinion, from an unequal distribution of the Earth's mass.

Bošković's theory of mass compensation starts from Bouguer's measurements in Peru, which Pierre Bouguer visited as a member of a French expedition sent to define the meridian arc length. Bošković apparently was the first to suspect that the vertical deflection is caused by an unequal distribution of mass of the continents and seas, rather than mountains, which gives it a systematic character.

By applying triangulation, earlier trigonometric chain length measurements ($1^\circ \approx 110$ km) were replaced with measurements of lengths of bases of trigonometric chains (up to several km). Although the survey of the Rome-Rimini meridian arc had started before reports and results of the Lapland and Peru measurements were published, Bošković and Maire, aware of the shortcomings of previous measurements by French scientists (Cassini and others), paid particular attention to the precision of measuring base lengths. Bošković therefore had

to improve the existing or design new devices for measuring lengths before starting his measurement. Due of uneven terrain, the contemporary methods did not allow accurate measurement of lengths shorter than a few kilometres, let alone those up to a hundred kilometres. Bošković came to an idea to raise measuring rods above the ground, putting them in horizontal position, in the direction of the base, on specially designed tripods (Figure 2). The tripods were designed to allow easy change of the height of the plate with measuring rods, by lifting or lowering the central part of the tripod only. The tripods Bošković made for this purpose were a novelty, to be introduced in general surveying practice at a later date, when they were used by Carl Friedrich Gauss. They came to be called Gauss tripods, while they should really be called Bošković's.

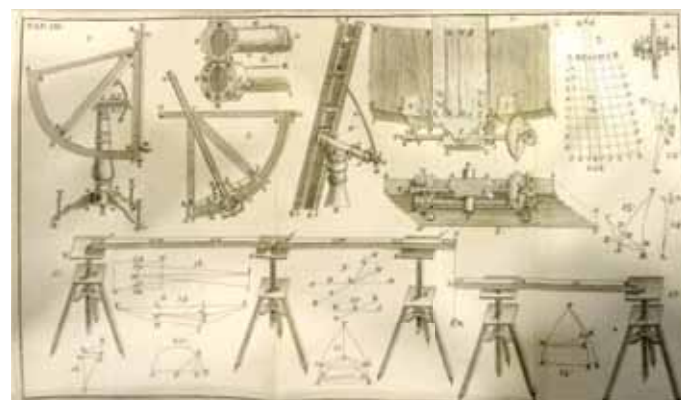


Figure 2. Measuring rods on tripods
(NSK, sig. RIIF-4^a-324 a).

Ruđer Bošković's Cartographic Work

Among the most important of Bošković's works is *De litteraria expeditione per pontificiam ditione ad dimentiendos meridiani gradus et corrigendam mappam geographicam, iussu et auspiciis Benedicti XIV*, divided into five volumes with a total of around 500 pages. Volumes 1, 4 and 5 were written by Bošković himself, while Volumes 2 and 3 (59 pages in



Figure 3. „Nuova Carta Geografica dello Stato Ecclesiastico Delinta dal P. Cristofro Maire, da. Ca. di Gesù sulle comuni Osservazioni sue e del P. Ruggiero Giuse Boscovich...”

total) were written by his associate Christopher Maire. Volume 3 includes a map of the Papal State with a description of how it was produced. The map was created on the basis of exact astronomical and geodetic measurements, according to methodology developed by Bošković. The title of the map is *Nuova Carta Geografica dello Stato Ecclesiastico Delinta dal P. Cristofro Maire, da. Ca. di Gesù sulle comuni Osservazioni sue e del P. Ruggiero Giuse Boscovich...* (Figure 3) and it was published 1750-1759. The map includes an area from the mouth of the Po to the river Tronto, with borders of the Ecclesiastical State in the west, and the coast of the Tyrrhenian Sea including T-Porto in the south. A copy of this map is kept in the cartographic department of the French National Library (BNF – *Bibliothèque nationale de France*) as part of the *d'Anville* collection. The approximate scale is 1:358,000, and the size of each page 50 × 66.5 cm.

Bošković and Maire used existing maps of the Papal State and updated them using their own data managed by Bošković, while Maire provided descriptions and made the calculations. The content of Volume 3 of „*Voyage astronomique et géographique, dans l'État de l'Église*“ entitled „*Détail des opérations concernant la réformation de la Géographie de l'Etat de l'Église*“ (*Extensive Elaboration of the Works Related to Geographic Corrections of the Map of the Ecclesiastical State*) needs to be clarified. The volume contains 25 chapters, with a list of „Geographic Latitudes and Longitudes of all Cities of the

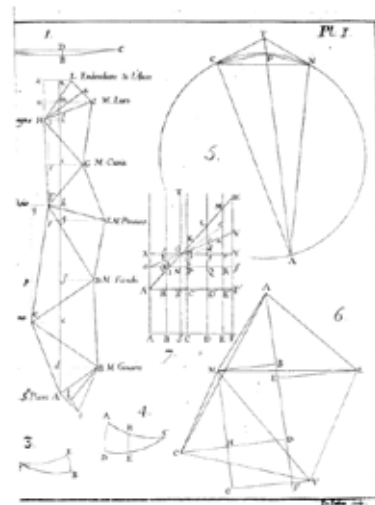


Figure 4. Triangular network around the measured part of meridian



Figure 6: Carte de l'État de l'Église, probably produced 1750-1759, kept in BNF



Figure 7. Carte de l'État de l'Église, 1770, size 39.7 cm × 21,8 cm a).

Ecclesiastical State“. The first chapter states the reasons behind map corrections, explaining the idea to use the observations gained in determining the distance between Rome and Rimini (e.g. developing a triangular network) (Figure 4).

Bošković and Maire used survey results to make corrections on older, existing maps of the area. The authors realised they could not survey the courses of all the rivers and streams, setting the main goal of creating a „general map, and determining the geographic latitude and longitude of towns and villages” that could be seen from the points used to determine the length of the meridian arc. However, the old maps had too many errors and were not much help in determining the position of locations (towns) they had not seen from the surrounding points of visited themselves. They sent letters to all the towns they were not able to visit, providing instructions on how their positions and the positions of the neighbouring towns could be determined. More recent maps of some parts of the Papal State proved very helpful.

There are two maps entitled *Carte de l'État de l'Église*. One was created in the 1750-1759 period and is kept in BNF. According to BNF data, Bošković and Maire are presumed to be its authors. The map is in French, size 53 cm × 35 cm.

The other map bearing the same name is the unsigned *Carte de l'État de l'Église* (Map of the Ecclesiastical State) published

in 1770 as part of Bošković's work *Voyage astronomique et géographique, dans l'État de l'Église* .

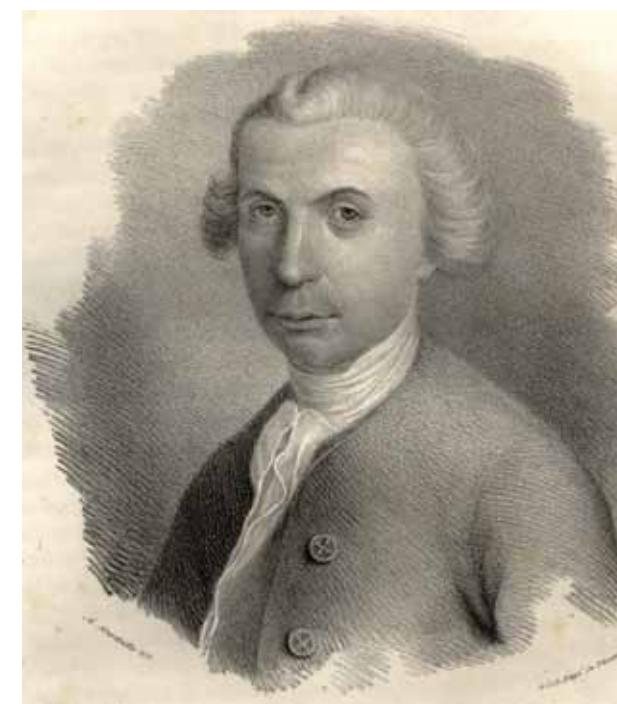
Memberships and Honours

Ruder Bošković was a regular member of *Scientiarum et Artium Institutum atque Academia* in Bologna, corresponding member of *Académie des Sciences* in Paris, honorary member of the *Imperial Academy of Arts* in St. Petersburg, and a regular member of the *Royal Society*. During his lifetime, he received numerous recognitions. On 16 September 1757, he was awarded a noble title by the Senate of the Republic of Lucca for his merits in resolving Lucca's hydro-technical dispute with Tuscany. He also served as poetic inspiration in Rome's circle of Croatian Latinists: in the 10th volume of his epic *Philosophiae recentioris versibus traditae* Benedikt Stay dedicated 1600 hexameters to Bošković's natural philosophy, while Rajmund Kunić wrote an elegy and epigrams in his honour. One of the Moon's craters was named after Bošković, as well as renowned Croatian journals *Kalendar Bošković* and *Almanah Bošković*, along with the most important Croatian scientific institute, “Ruder Bošković”, and the most renowned natural science award, “Ruder Bošković”.

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Hrvatska komora
ovlaštenih
inženjera geodezije

*Croatian chamber of
chartered geodetic
engineers*



Republika Hrvatska Državna
geodetska uprava

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