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Boscovich: his geodetic and cartographic studies

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Abstract. The name of Ruggero Giuseppe Boscovich has many spellings: the Croatian Boscovič, linked to his Dalmatian origin, becomes Boscowich in German. Ruggero Giuseppe Boscovich lived and worked in many cities: Rome, Pavia, Venice, Paris, London, Warsaw, Saint Petersburg and Constantinople, where he carried out diplomatic missions. He was a Jesuit and studied mathematics, physics, astronomy, geodesy, and cartography. His studies in geodesy and cartography were developed in Italy: he measured the meridian between Rome and Rimini, he worked on the new map of the Papal State and he designed the Brera Observatory. In the first part of the present work, we present Boscovich's activities from a chronological point of view. In the second part, we focus on two specific arguments, related to geodesy and cartography: the new map of the Papal State and an attempt to rebuild the associated triangulation.

Key words. Boscovich, Brera Observatory, geodetic activities

1. Introduction

An authoritative biography by an eminent scholar

The biography in the following paragraph is quoted from the *"Enciclopedia Italiana Treccani"* and its on-line sources. These documents were written by the astronomer Luigi Gabba, who directed the Brera Observatory between 1917 and 1922.

Ruggero Giuseppe Boscovich was born on May 18, 1711 in Ragusa, Dalmazia and he died on February 13, 1787 in Milan.

He studied at the "Collegium Ragusinum" and next at the "Collegium Romanum". Boscovich entered the Jesuit company in 1726 and he started teaching grammar and mathematics at the "Collegium Ragusinum" before he became a priest.

His authoritativeness and his knowledge let him to get many commissions. Some of them concerned bridges, streets and canal systems, the stability of the dome of the Papal Basilica of Saint Peter, the library in Vienna, the spire of the Milan Cathedral and the drainage of the "Paludi Pontine".

Boscovich was delegated to claim the rights of the Republic of Lucca in 1757 in Vienna against the government of Tuscany. The controversy was about the draining of the lake Bientina.

Pope Benedictus XIV asked Boscovich and Cristoforo Maire to measure the arc of merid-

Fig. 1. Starting point of the geodetic baseline along "Via Appia" from "Capo di Bove" to "Frattocchie", near Rome

ian between Rome and Rimini. The aims of this work were two:

- the determination of the shape of the Earth and
- the adjustment of the map of the Papal State.

No information is available about the instruments used by Boscovich. Anyway, a few years later, Canivet built a movable sextant in Paris. Boscovich used it to measure azimuthal angles. Boscovich published the *"De literaria expedition per pontificiam ditionem ad dimetiendos duos meridian gradus et corrigendam mappam geographicam"* in 1755.

Boscovich promoted the work of Liesganig in Hungary and the work of Beccaria in Piedmont, where the first meridian measurements were carried on by P. Giovanni Battista, who measured a meridian arc between Mondovì and Biandrate.

Boscovich traveled around Europe: he stayed in Vienna (1758), in Paris (1759), in London (1760), in Warsaw, in St. Petersburg and in Constantinople (1761). In this last city he observed the transit of Venus across the Sun. He published the essay *"Theoria Philosophiae Naturalis redacta ad unicum legem virium in natura existentium"* in 1758 in Vienna. This work relates to the atomistic theory of the universe and it relates with the synthesis of the Leibnizian dynamics and Newtonian mechanism. The interaction between the points is governed by the distances:

- for long distances, the law of universal gravitation governs the interactions,
- for short distances, the interactions are alternately attractive and repulsive, and
- for even shorter distances, the interactions are repulsive and they grow indefinitely with decreasing distance between two elements (this fact implies that contacts are impossible).

He published in Latin the poem *"De Solis ac Lunae Defectibus"* in 1769 in London.

Boscovich taught at the University of Pavia from 1764 to 1768 and at the "Scuole Palatine di Milano" since 1768. During these years his activities concern the school and the Brera Observatory. The Observatory was founded on the initiative the Jesuits, but Boscovich played a major role in its development and equipment with the best instruments of the time.

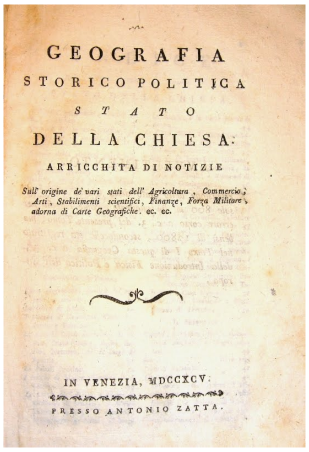
Boscovich carried on some measurements and observations to detect the instrumental errors. Boscovich combined different observations to solve this problem and he wrote many memories about the solution. Schiaparelli said that Boscovich tried to avoid the mechanics observations to detect errors and he preferred to use the astronomical observations. This tool is used nowadays. For this reason Boscovich is considered a precursor of this technique.

Boscovich designed a water-filled telescope with the aim of using it to compare the corpuscular to the wave theory. A similar instrument was used only in 1871 at the Greenwich Observatory by G. B. Airy.

Boscovich had an argument with La Grange (the director of the Observatory) and with the rector of the college of Brera. For this reason Boscovich stopped working at the Brera Observatory. He decided not to stay there as honorary director and he stopped teaching at the "Scuole Palatine". In 1773, the Jesuit company was suppressed and Boscovich moved from Venice to Paris where he became the director of the optical division of the French Marine. He stayed in Paris for ten years; dur-

Fig. 2. The new map of the Papal State

Fig. 3. Detail of the map in Figure 2



GEOGRAFIA
STORICO POLITICA
STATO
DELLA CHIESA:
ARRICCHITA DI NOTIZIE
Sull' origine de' vari stati dell' Agricoltura, Commercio, Arti, Stabilimenti scientifici, Finanze, Forza Militare, adorna di Carte Geografiche. ec. ec.

IN VENEZIA, MDCCXCV.
PRESSO ANTONIO ZATTA.

Fig. 4. Front of the book *"Geografia storico politica Stato della Chiesa: arricchita di notizie"* published in Venice in 1795.

ing this period he published the solution of the following problems:

- how to determine the comet orbit starting from three observations,
- the micrometer
- achromatic telescope.

In 1783 Boscovich went to Bassano, Italy and he published *"Opera pertinentia ad Opticam et Astronomiam"* in 1785. This work is focused on optics and astronomy.

In 1785 he stayed in Tuscany for some months and then he moved back to Milan thanks to his friends Reggio and Cesaris.

To summarize the Boscovich's studies, they are related with:

- optics:
  - the elimination of the chromatic aberration,
  - the detection of the spherical aberration, and

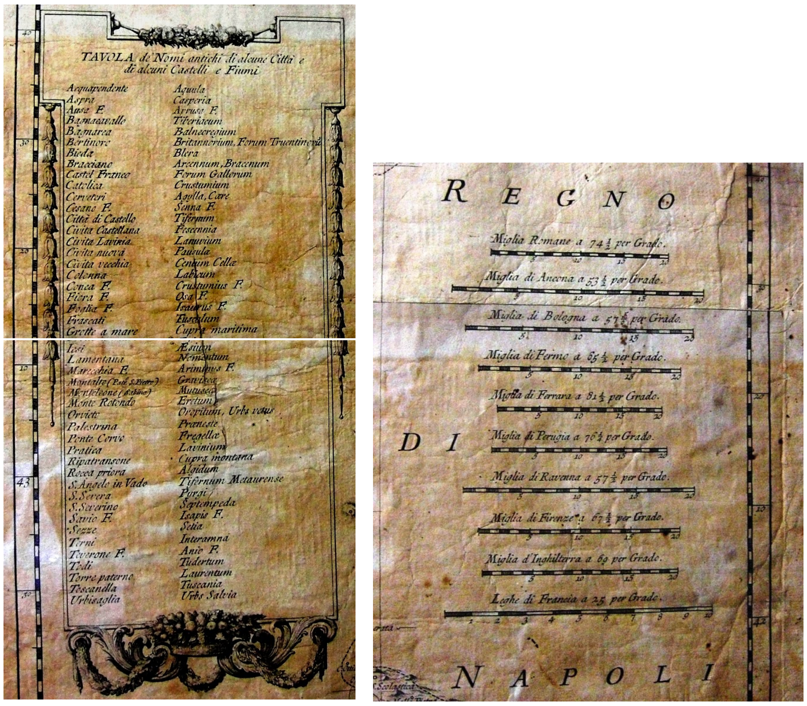


Fig. 5. Table of names and Table of conversion between different units

- the construction of the optic micrometer.
- geodesy,
- astronomy:
  - how to determine the comet orbit,
  - how to determine the Uranus orbit, and
  - the detection of the perturbation of the Jupiter and Saturn orbits.
- mathematics:
  - he developed a graphic solution to solve the spherical triangles,
  - he developed four differential formulas about spherical geometry, and
  - he studied possible non-euclidean geometry.

2. The Observatory of Brera after Boscovich

The history of science, technology, thoughts, arts and literature is not the history of isolated men, but it that of the desires, the research and expectations. Big discoveries and inventions sometimes occur after determined trials, others succeed by chance, however in a fertile climate.

Similarly, the school of the Brera Observatory that started with Boscovich continues today and consolidates the expectations of the scientific community and the technical needs of its contemporary society.

Some important contributions from the direct successors of Boscovich continue until the early 19th century. This is documented in the *"Acta excerpta"*, compiled by the archivist Giovanni Antonio Luraschi starting from 1833. To comply with a request from the Austrian government, he collected there the copies of the records from the Brera Observatories, from 1772 to 1860, when Francesco Carlini was director, *"Acta excerpta"* is part of the historical archive of the Brera Observatory.

A chronological index gives precise information about the material of the archive, as

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Triang.		Anguli obſervati reducti ad cent. °	′	″	Anguli iidem correcti. °	′	″	Hinc latus
Apruſa	L	78	48	22	78	48	18	LH 23862.3
Alt.extr.	a	82	3	10	82	3	6	
Carpegna	H	19	8	36	19	8	36	
		180	0	8	180	0	0	
Apruſa	L	77	19	44	77	19	56	IH 25367.7
Lurus	I	66	35	52	66	36	2	
Carpegna	H	36	3	56	36	4	2	
		179	59	32	180	0	0	
Lurus	I	64	58	37	64	58	31	HG 32465.2
Carpegna	H	69	57	6	69	56	59	
Catria	G	45	4	34	45	4	30	
		180	0	17	180	0	0	
Carpegna	H	37	12	15	37	12	11	GF 27429.8
Catria	G	97	6	12	97	6	1	
Teſius	F	45	41	53	45	41	48	
		180	0	20	180	0	0	
Catria	G	64	51	52	64	51	54	FE 30104.3
Teſius	F	59	33	25	59	33	30	
Penninus	E	55	34	34	55	34	36	
		179	54	54	180	0	0	

SECUNDUM. 141

Triang.		Ang. obſervati reducti ad cen. °	′	″	Anguli iidem correcti °	′	″	Hinc latus
Teſius	F	45	46	33	45	46	33	FD 45316.4
Penninus	E	92	38	54	92	38	56	
Fionchus	D	41	34	31	41	34	31	
		179	59	58	180	0	0	
Teſius	F	30	36	2	38	35	57	DC 37200.7
Fionchus	D	91	56	32	91	56	21	
Sorianus	C	49	27	48	49	27	42	
		180	0	22	180	0	0	
Fionchus	D	60	5	30	60	5	30	CB 42258.3
Sorianus	C	70	10	21	70	10	19	
Januarius	B	44	44	12	44	44	11	
		180	0	3	180	0	0	
Sorianus	C	32	13	6	32	13	10	BA 22954.3
Januarius	B	68	48	20	68	48	30	
Th.D.Petri	A	78	58	18	78	58	20	
		179	59	44	180	0	0	
Januarius	B	32	38	10	32	38	7	Bc 24244.8
Th.D.Petri	A	79	1	10	79	1	3	
Ext.ul.Baſ.	C	68	20	56	68	20	50	
		180	0	16	180	0	0	
Januarius	B	19	17	27	19	17	27	bc 8[illegible]234
Extre. cit.	b	94	24	33	94	24	30	
Extre. ult.	c	66	18	6	66	18	3	
		180	0	6	180	0	0	

Fig. 6. Measurements and their corrections between Rome and Rimini.

completion of the *"Acta"*. Here are cited only Angelo De Cesaris and Francesco Reggio as direct students, Barnaba Oriani and Francesco Carlini as direct successors. The structure of the school of Brera Observatory was more complex and with many more successors.

3. The new map of Papal State

The web-side of the Istituto Geografico Militare (IGM) contains a complete and exhaustive description of the Papal State, written by fathers Cristoforo Maire and Ruggero Boscovich. This web-site also contains the first sheet of this map shown in figure 1.

Ruggero Boscovich measured also a geodetic base along the "Via Appia" from "Capo di Bove" to "Frattocchie" near Rome. This work relates to the measure of the meridian arc between Rome and Rimini.

The map shown in figure 2 was generated by Ruggero Boscovich and Cristoforo Maire. Pope Benedictus XIV asked them to measure an arc of meridian between Rome and Rimini. This work also relates with the problem of the irregular shape of the Earth. The astronomical observations were used with the geodetic ones to correct the map of Papal State. This fact implies that this map was the first map based on scientific operations. This map was engraved on copper and published in three sheets in 1755 at the *"Calcografia Pontificia"*.

The copy of the Collezione Bianconi (no. 233, file B0012901-3) is mounted on canvas on a single sheet; the copy of the general inventory is on three sheets with colored topography. This map extends from the mouth of the river Po to the river Tronto, on the Adriatic sea; to the West it stops at the border of the Papal State; on the side of the Tyrrhenian sea it includes the coastal line Porto Ercole-T. d.a. Cerva. The topography is displayed with hatch lines.

The main cities are represented, distinguishing archbishoprics, bishoprics, cities and lands. The road network is visible. On the top right-hand side, there is a note from the authors with some explanations about the gene-

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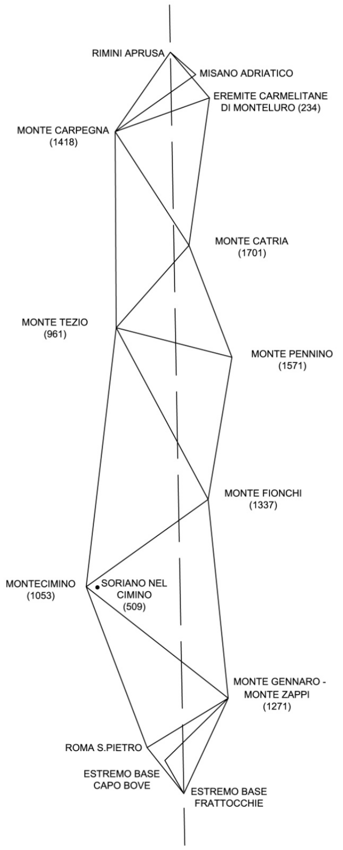

Fig. 7. The hypothetical scheme of the triangulated network between Rome and Rimini

Fig. 8. The new map of the Papal State, extracted from the book shown in Fig 9

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sis of the map. On the left. there is a list with the main cities, their Latin names, castles and rivers. Under the title there is the dedication to Pope Benedictus XIV (detail shown in Fig 3).

Ten different scales are shown, some from ancient Italian cities, others used in the French system, others in the English one.

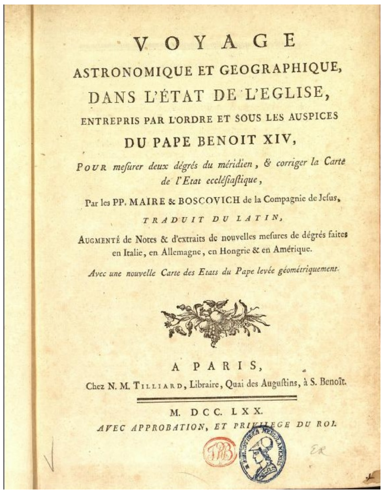
As mentioned before, Boscovich dedicated the map to Pope Benedictus XIV. The Pope real name was Prospero Lorenzo Lambertini; he became a cardinal in Bologna and he was able to compromise with Jansenism.

Figure 4 shows the cover of the book *"Geografia storico politica Stato della Chiesa: arricchita di notizie"* published in Venice in 1795. This books deals with the historical - political geography of the Papal State, the economy, military power and agriculture and it contains many maps.

In this book, a description of the map of the Papal State is included. This map was published in 1755 and it generated a better knowledge of the lands. It is also important because of its scientific and technological merits.

4. An Attempt to rebuild the triangulation

The Papal State was displayed in many maps. One of these was generated by Tobia Maier in 1748 with the support of the heirs of Homann. Another one was generated by the Jesuit Cristoforo Maire and it was corrected by the Jesuit Ruggero Boscovich using astronomical observations. They both wanted to compare the measurements with the ones elabo-



VOYAGE
ASTRONOMIQUE ET GEOGRAPHIQUE,
DANS L'ÉTAT DE L'EGLISE,
ENTREPRIS PAR L'ORDRE ET SOUS LES AUSPICES
DU PAPE BENOIT XIV,
Pour mesurer deux dégrés du méridien, & corriger la Carte de l'Etat ecclésiastique,
Par les PP. MAIRE & BOSCOVICH de la Compagnie de Jesus,
TRADUIT DU LATIN,
Augmenté de Notes & d'extraits de nouvelles mesures de dégrés faites en Italie, en Allemagne, en Hongrie & en Amérique.
Avec une nouvelle Carte des Etats du Pape levée géométriquement.
A PARIS,
Chez N. M. Tilliard, Libraire, Quai des Augustins, à S. Benoît.
M. DCC. LXX.
AVEC APPROBATION, ET PRIVILEGE DU ROI.

Fig. 9. Cover of the book *"Voyage Astronomique"*

rated by the Academics of the Royal Academy of France and to compare the obtained shape of the Earth. Across this map, there are the features measured with its precision.

Figure 5 shows the names of the streets with the Latin names, castles and rivers. The same picture shows a table used to convert different measure units and it is contained in the new Papal State map. The existence of different measure units was a complex problem in the 1700s. Only in 1850 the metric system was adopted in Italy. For this reason the table in figure 5-right is really important.

Tables of logarithms were used to multiply and to subdivide. Calculations were performed in astronomy, in geodesy and in cartography. Boscovich and his school were able to join mathematical and statistical methods with practice.

Between 1750 and 1753, Boscovich, together with Cristoforo Marie, measured the length of the meridian from Rome to Rimini. Marie was a Jesuit brother of the "Collegium Romanum". They generated a triangulation network, composed of eleven concatenated triangles. The network was dimensioned by a geodetic baseline along the "Via Appia antica", from "Capo di Bove", not far from the mausoleum of Cecilia Metella, to Frattocchie, near Rome. This information was contained in one of their reports, entitled *"De Litteraria Expeditione per Pontificiam Ditionem ad Dimentiendos Duos Meridiani Gradus et Corrigendam Mappam Geographicam - Iussu, et Auspiciis Pont. Max. Benedicti XIV - Suscepta a Patribus Societ. Jesu Christophoro Marie et Rogerio Josepho Boscovich XIV. Roma MDCCLV"*.

Today we can confirm the excellent measurements, with an average error of 1.2" and r.m.s. of 8.9". The closures do not take into account the spherical effects, also because the closures by defect prevailed over the straight angles of the 2D triangles. The tables in Figure 6 and Figure 7 show the eleven triangles, their vertices, the measured angles and the adjusted ones thanks to the closures and the length of one of the three sides of each triangle. The modern reiteration with 24 independent layers generates a r.m.s. equals to 1.8". This reiteration was not done by Boscovich, but this result confirms that nowadays the gain is on time, not on quality. The identification of the trigonometric vertices is more difficult, possibly because changes may have occurred to names with time.

For example, a vertex may be located in "Misano Adriatico" near Rimini, because the sea is mentioned. Another vertex in Rome may be the Saint Peter cathedral, mentioned only as "Th. D. Petri". The final vertex of this baseline is at "Le Frattocchie", but the monument is no longer visible.

It is more probable that the vertex called "Soriano" is located on "Monte Cimino" (1053 m a.s.l.) and not at "Soriano del Cimino" (509 m a.s.l.). This fact is also supported by the vertices located on the mountains Carpegna, Catria, Pennino, Fionchi and Gennaro. They are located respectively at 1418, 1701, 1571, 1337 and 1271 m a.s.l.. Figure 7 shows the locations of these points.

To complete this topic, the new map of the Papal State is shown in figure 8. This figure was extracted from *"Voyage Astronomique et Géographique, dans l'État ecclésiastique, par les PP. Maire & Boscovich de la Compagnie de Jesus, Traduit du Latin, Augmenté de Notes d'extraits de degrés faites en Italie, en Allemagne, en Hongrie en Amérique.*

Avec une nouvelle Cartes des États du Pape levée géométriquement. A Paris MDCCLXX". Figure 9 shows the cover of the book.

This book was published fifteen years after the first Latin edition and it certifies the presence of Boscovich in Paris at the time astronomers studied Uranus.

This planet was first confused with a star, then it was classified as a new comet and in the end as a new planet. Boscovich contributed to this European debate and he helped to confirm the Copernican theory and to support the Galilean and Newtonian mechanics.

Acknowledgements. A sincere thanks to the astronomer Pietro Broglia and to the librarian and archivist Agnese Mandrino; they both have enlivened the history of the Brera Observatory. A sincere thanks to the philosopher Luca Guzzardi, who is a scholar of science philosophy and history of science and technique.