God only knows Ruggiero Boscovich, the Temptation of Forces and Their Rejection

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GOD ONLY KNOWS

Boscovich *who*?

Boscovich, Ruggiero Giuseppe
(Ragusa/Dubrovnik 1711 – Milan 1787)
Sometimes also spelled Ruđer Josip Bošković

Chelsea's
Bošković (Branko)

Lebensstationen

- Born in Ragusa (Dubrovnik), Dalmatia, in 1711
- 1720-25: Early student years at the Ragusinum
- 1725: Prosecution at the Collegium Romanum (CR) in Rome
- 1740-41: First course at professor of Mathematics at the CR
- 40s-50s: Architecture expertises in Rome, meridian mesurement in the Papal State, hydraulic expertise in Lucca
- 1763-1772: Professor of Mathematics in Pavia, then Milan (foundation of an Astronomical Observatory in Milan, Brera)
- 1773: Order suppression; Boscovich in Paris, as the Director of Naval Optics
- 1782: In Italy again, for attending the publication of his astronomical and optical works.
- 1785: Back to Milan, man considers him for a post; but he's ill and…
- 1787: dies in Milan, where he's buried (but location not exactly known)

Most important works

- *Theoria philosophiae naturalis redacta ad unicam legem virium in natura existentium* (Vienna 1758, Venice 1763)
- *Elementa universae matheseos* (and many many works in pure and applied math), 1750s
- *De cometis* (1746) and works in determining (geometrically) orbits of comets and planets (Uranus affaire, 1781-82: *Teoria del nuovo astro*)
- *De Solis ac Lunae defectibus* (didactic poem: London 1760, Paris 1779)
- *Opera pertinentia ad opticam et asronomiam* (5 volumes, Bassano 1785)

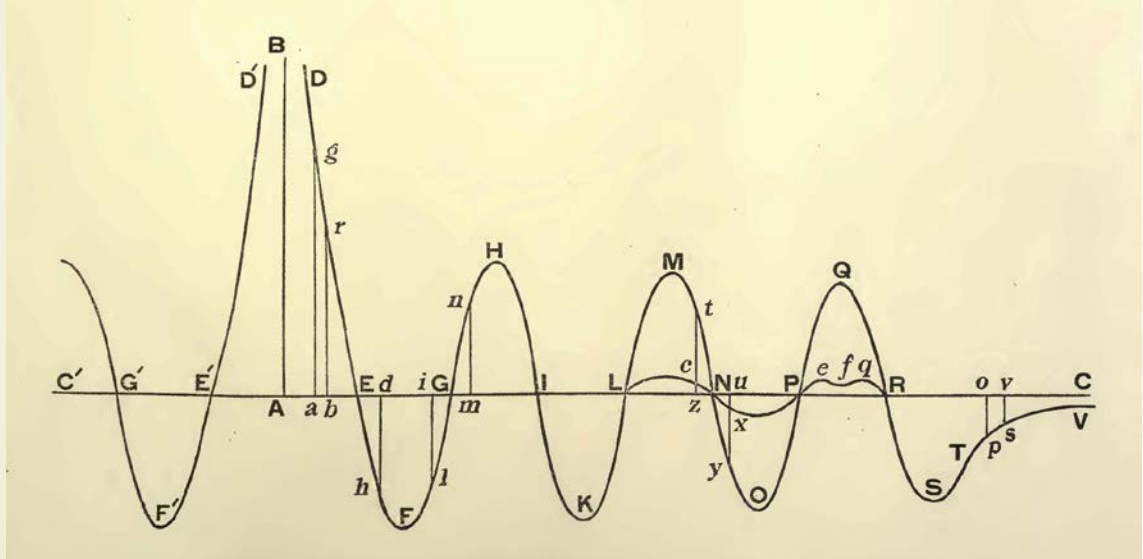
- The subject of my ongoing research
  - …traces back to my engagement with the «National Boscovich Edition» - Boscovich's complete works
  - I am particularly interested in Boscovich's natural philosophy, seen in the broader context of the scientific culture (encompassing epistemology)
  - And the title also conveys my increasing discontent with Boscovich's studies so far
    - But the title also has a more profound reason, that I hope will be clear at the end of the talk…

My discontent with Boscovich's studies

- Four main «chapters» of the literature on Boscovich's natural philosophy:
  - Excellent works analyzing the text of Boscovich natural-philosophical masterpiece in itself, *Theoria philosophiae naturalis redacta ad unicam legem virium in natura existentium* (1758, 1763)
  - Papers emphasizing the debits with the Jesuit philosophical tradition (Paolo Casini, Ugo Baldini)
  - Studies on the Newtonian tradition (John Heilbron)
  - Others wrote about the relationship with Leibniz's philosophy and the history of effects (Boscovich in the 19th or 20th century)

- Of course there are exceptions, like Talanga's edition of *De continuitatis lege* (1754)
- But the studies so far have mainly this in common:
  - They are committed to study the *theory* expounded by Boscovich, its history & development, its meaning, its consequences, its intimate or implicit philosophy… **in itself, or starting from or compared with other theories**.
  - There is no one attempt to consider things in terms of **practices**.
- To be clearer, let me give just one example.

- Why did Boscovich think of a *unique* force which is repulsive and grows asymptotically when two material points come too close, at infinitely small distances; it is attractive and diminishes approximating Newton's inverse-square law, when the distances are big enough (say on Solar System-scale); and it is alternatively repulsive and attractive on medium scale-distances?



Boscovich's idea:

- Infinitesimal distances: repulsion
- Very large distances: attraction
- Intermediate renge: both, alternatively

Theoria philosophiae naturalis redacta ad unicam legem virium in natura existentium (Vienna 1758, Venice 1763)

- Heilbron's answer in his classical *Electricity in the 17th and 18th Centuries*: Newton in the *Opticks* (Query 31) said that "as in Algebra, where affirmative Quantities vanish and cease, there negative ones begin; so in Mechanicks, where Attraction ceases, there a repulsive Virtue ought to succeed". Then early Newtonians came (Desaguliers, 'sGravesande, then Hales and others), who developed similar views on forces.
  - All this is attached to Heilbron's conviction of a growing instrumentalism about the concept of force during the 18th century based on a commitment to the measurements.
- ...Good idea. But it does not function, because in Boscovich's theory there are no assumptions on matter and forces.
  - Forces are «mathematical hypotheses» in the same sense of Newton's *Principia*.
  - Forces are only determined in terms of geometrical properties of the curve which describes the motion of one point in presence of another. So they are epiphenomena of the fact that points at different distances behave differently.
- Note that there are lots of places where he discards «positive theories» on forces, following (or assuming that he follows) Newton in the *Principia.*
- ... And note that all modern rhetoric on Boscovich's influence on later physics (e.g. field conception) is generated by the conviction that his theory is a theory on forces because of surface analogies.

- Reconstructions like Heilbron's are committed to find out analogies with other theories.
  - In itslef, it makes sense. There is a «common root» (Newton), there is a physical question (how to explain that there are both attractions *and* repulsions in nature), and there are early theoretical answers (Desaguliers, 'sGravesande) which result in experiments and measurements (Hales the «good guy», for Heilbron) or not (Boscovich the «bad guy»).
  - What Heilbron oversees is that Boscovich moves from totally different premises.
  - This is not a question of theories but of practices. Boscovich's practice is not a practice of experiments and measurements, but a mathematical practice.

- **I try to turn things upside down: to see things not in terms of analogies among theories but in terms of differences among practices.**

Epistemological sketch

- For practice I mean anything an actor actually *does* – irrespective of its content, which can be practical (measurements, experiments, technological applications…) or theoretical or of other type (e.g. mathematics, physical theory, observational astronomy…)
  - Example: Heisenberg was famously good in *theoretical* physics and mathematics, but he was incapable in doing experiments. For cases like this, I would say that he was grown in the practice of theoretical physics.
- Practice in this sense is a cognate category of:
  - Epistemic culture (Knorr Cetina, 1999)
  - Epistemic virtues (Daston & Galison 2007)
  - Style of thought (Fleck 1935)
  - Style of reasoning (Hacking 1992)

- Notion of practice… in search for refinement
  - But I prefer this to the other cognate formulations, because it is more focused on the active side…
  - …and is more objective (intimate beliefs of the individual actors are unimportant)
- In general, all these concepts are a symptom of the search for **epistemic constraints** of the scientific discourses
  - That is constraints, rooted in historical development, which tell us what is to be known (and what is not: so they entail both a positive and a negative heuristic) and how is to be known what is to be known (so they entail norms)
    - Note that this discourse about «historically-given epistemic constraints» has emerged in the last decades of the 19th century and reached some level of ripeness in the 1930s with key figures as diverse as Gaston Bachelard in France, Ludwik Fleck in the German-speaking area, or P.W. Bridgman in the Anglosaxon world.
- This philosophical stuff obviously needs refinements, clarifications, details…
  - But not now!

- What I am interested in now is Boscovich's practice…
- Which was above of all things a mathematical practice

- To make clear this point, 3 examples:
  1. Boscovich's discourse on the concept of force in itself
  2. His opposition to the living forces
  3. Application of a "mathematical style" to different issues (without examples)
     - Mathematical style will be also my answer to the question why Boscovich rejected forces.

- Of course they are interrelated issues; here I treat them as separate both for the sake of clarity and shortness

1) The concept of force in itself (1740)

- Boscovich's early claims about forces:
  - Dissertation in mechanics on the trajectory of projectiles in non-resistant space (1740)
  - In order to make clear his discontent with any physical notion of force, Boscovich quotes in his own text the Definition VIII from Newton's *Principia*: « 'I use interchangeably and indiscriminately words signifying attraction, impulse, or any sort of **determination** toward a center, considering these **forces not from a physical but only from a mathematical point of view**. Therefore, let the reader beware of thinking that by words of this kind I am anywhere defining **a species or mode of action or a physical cause or reason**'. And Newton had said little above: 'This concept is purely mathematical, for I am not now considering the physical causes and sites of forces.' »
  - As far as inertia is concerned, it is a force only in the sense that «in the very idea of body transmitted by mechanics [*mechanice tradita*]» a «determination to preserve its state of rest or uniform rectilinear motion» is assumed. Other forces are forces insofar as «every cause changing that state is called extrinsic force [*vis extrinseca*], that is not pertaining to its concept [i.e. the concept of body]. »

- It is Boscovich's acquaintance with mechanics (that is, a *mathesis mixta*) which guides his discontent of the notion of force as a physical entity.
- Note that this discontent remains practically unchanged in the *Theoria*.
  - He repeats his arguments about *vis inertiae*, adding that «whether this depends on an arbitrary law of the Creator or on the nature of points itself or on some attribute of them, whatever it may be, **I do not seek to know**; even if I wished, **I see no hope to find it**.» (§8)
  - Plus, for any couple of points a distance-dependent determination to approach or recede from one another exists. «This **determination** I call ***force*** [...]; this term **does not denote the mode of action, but the determination itself**, whatever its origin, whose magnitude changes as the distances change» (§ 9) — a qualification reminiscent of Newton's caveat closing Definition VIII of the *Principia*. Therefore, there is nothing special in forces, the term force being nothing but a description of a change of a kinematic state.

2) Against living forces (1745)

- In 1745 Boscovich defends a dissertation *De viribus vivis* (where he first announces his typical curve)
- By plotting a diagram, he shows that both mv and mv^2 are legitimate, depending on what you measure: the effect in time (mv) or the effect in space (mv^2).
- Boscovich states that even Leibniz would agree that mv is *a* measure of force; that is, in Leibniz's terms, the measure of *dead force*, which is a force that stops acting. However, Boscovich argues further that Leibnizians as well as their opponents allow for a *living* force — a *vis viva* — that is a remnant of powers' actions within the body on which they have acted (see Boscovich, 1745, § 20). According to Leibniz, it is this force, and not momentum, that preserves its quantum as mv^2. On the contrary, Boscovich contends, this force does not exist. It depends only on the quantities one chooses to deal with.

Boscovich's graphical representation of momentum *and* living force as generated by instantaneously acting "pressures" (Boscovich, 1745, Fig. 3).

An instantaneous pressure *EF* increases over a time *AC* and causes instantaneous changes of velocity.

Time is divided into infinitesimals, so the area *FEef* is a rectangle.

Therefore, since pressure ∝ acceleration, we have $v = at$, or in geometrical terms the area *BAEF* is a velocity.

So over time forces are measured through simple velocities: momentum is easily thought in modern terms as the integral of (or the area covered by) instantaneous velocity changes: $\int mdv = \int pdt$.

Now *AC* represents the space traversed and *EF* forces continuously acting over time.

EF generates a velocity ∝ to *EF* and the time in which it acts; so $dv = EF \cdot dt$.

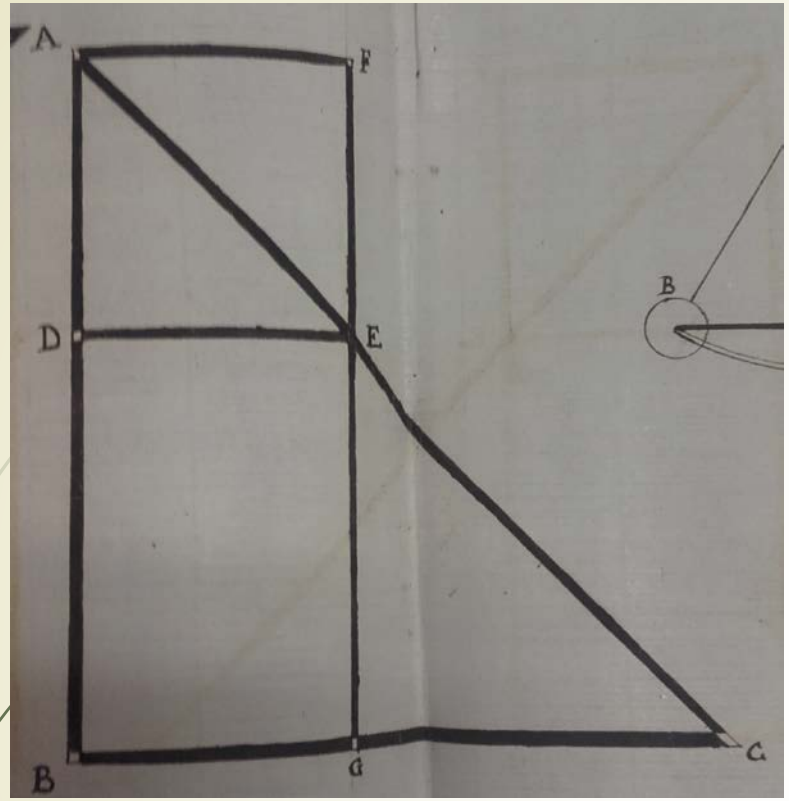
But if *Ee* is infinitesimal, a point moves uniformly linearly; then the time corresponding to *Ee* is ∝ to the space traversed and inversely proportional to the velocity: $dt = \frac{Ee}{v}$.

Let us substitute: $dv = EF \cdot \frac{Ee}{v}$, $v \cdot dv = EFEe$.

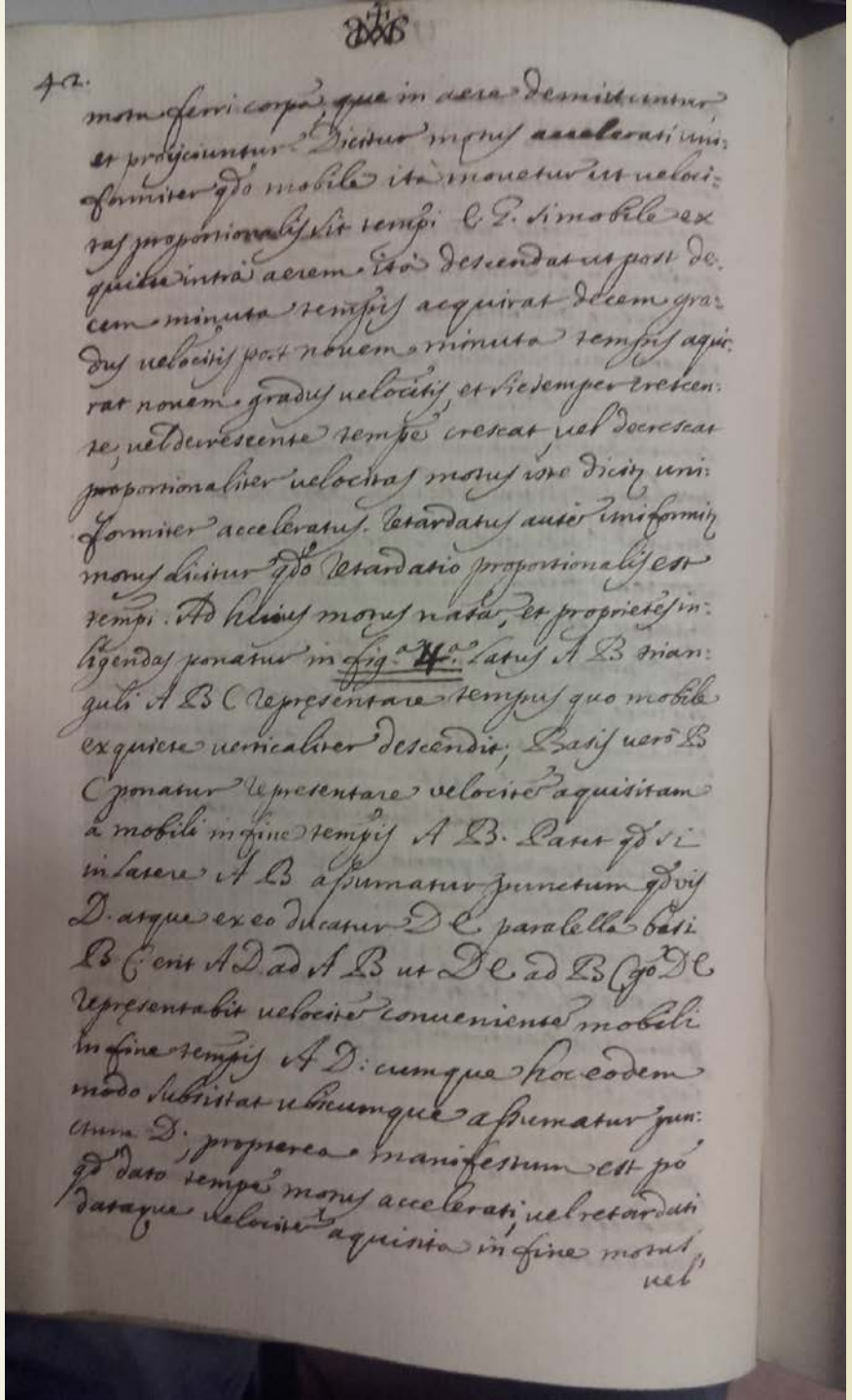
So as a function of space, forces are measured through velocities squared!

Boscovich's models

- In Boscovich's descriptions of the diagram, the concepts adopted and the language are clearly Newtonian.
- But the diagram itself is not. Costabel (1961) maintained that it was reminiscent of Oresme's diagrams…
- …and it is; but a direct influence seems excluded.
- Though, Boscovich's antecessor at the Collegium Romanum, Orazio Borgondio, did something similar.
  - Biblioteca Casanatense (Rome) and Viganò (Brescia) preserve a manuscript by Orazio Borgondio under the title *Mecchanicae Elementa* (Biblioteca Casanatense, Ms. 552). The second chapter deals with "De motu aequabili, accelerato, et retardato" (uniform, accelerated and decelerated motion) in a typical geometrical fashion which is very similar to Boscovich's approach of his 1745 paper on the living forces. A diagram with area explicitly representing velocity is exposed.



- AB is time during a free fall
- DE, BC are increasing velocities
- Then, the area ABC represents the space traversed (BC/2 is the term to be considered, because it is *velocitas media*: «Merton Theorem» of uniform acceleration)



3) Boscovich's mathematical style

- Such kinds of demonstrations are not original in themselves (Borgondio's ms does not contain more than Galilei's «Giornata Seconda» of the *Dialogo* and his *Le mecaniche*, both well known at the Collegium in the 18th century)
- What Boscovich learned at the Collegium Romanum was not only demonstrations of theorems, which were curricular to all mathematical classes
- He learned an entire «mathematical style», which he applied to issues as diverse as it might be:
  - Metaphysics (continuity principle, defended in a work specially devoted to it in 1754)
  - Mechanics
  - Natural philosophy
  - Theology…

Boscovich's mathematical razor

- Now, Carolyn Iltis (1970) remarks that Boscovich explains neither why, in the second interpretation of the diagram, time is substituted with space, corresponding to the same segment *AC*, nor why he now introduces forces, causing his schema to appear arbitrary.
- But the reason is that both the introduction of forces and the substitution with space *are* indeed arbitrary, because mathematics fits both pictures.
- The diagram is independent from its two interpretations, but it can be tailored to both. This has more to do with Boscovich's mathematical approach than with any physical meaning of the geometrical construction itself.

- To me, matter is nothing but indivisible points, that are non-extended, endowed with a force of inertia, and also **mutual forces represented** by a simple continuous curve having those definite **properties** which I stated [...]; these **can also be defined by an algebraic equation**. **Whether this law of forces is an intrinsic property of indivisible points; whether it is something substantial or accidental superadded to them, like the substantial or accidental shapes of the Peripatetics; whether it is an arbitrary law of the Author of Nature, who directs those motions by a law made according to His Will; this I do not seek to find, nor indeed can it be found from the phenomena**, which are the same in all these theories.

R.G. Boscovich, *Theoria*, § 516.

Boscovich's agnosticism about causes

- Remember what Boscovich says about inertia: «Whether this depends on an arbitrary law of the Creator or on the nature of points itself or on some attribute of them, whatever it may be, I do not seek to know; even if I wished, I see no hope to find it.» (*Theoria*, §8)
- Though, this is not a statement against causes. Rather, it is **agnosticism**.

- **Philosophical speculation.** This reminds me of Wittgenstein's *Tractatus* (T6.41): «The sense of the world must lie outside of the world».
  - Boscovich is no «anticipation» at all, but the attitude is very similar – because the interest of both is similar. Both Boscovich and Wittgenstein are interested in *structures*: logic and mathematics provide *structures* not *reasons* (sense, causes…). Even if their reasons and backgrounds are different (relevant for Boscovich is the Jesuit background).

- For Boscovich, all this has a definite meaning: mathematics does not provide the foundation of the world, but it does **illustrate, describe** the world – if one is careful enough in using it.
- So forces, e.g., might be really out there — or maybe not. **God only knows.** But after all, since **we human have mathematics in order to overcome difficulties and divergences – because mathematics fits with more theories –** who does it care?

God's in his Heaven –

All right's with the world

THANK YOU FOR YOUR ATTENTION!

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Cautionary note on «pure» and «mixed» mathematics

H.J.M. Bos, "Mathematics and rational mechanics". In The Ferment of Knowledge. Studies in the Historiography of Eighteenth-Century Science, Cambridge: Cambridge UP, 2008, p. 329:

- "The object of mathematics [in J.E. Montucla's Histoire des mathematiques, 1799-1802] is the mutual relations of magnitude and number of any objects which are capable of increase or decrease. This explains the terminology 'pure' and 'mixed'. Pure mathematics treats the relations between (variable or constant) quantities irrespective of the objects they measure or count; mixed mathematics deals with quantities, and their relations, as they occur in natural objects which can be counted or measured. The terminology is indeed an appropriate one, better than the division into 'pure' and 'applied' now in use, which overlooks the dialectical nature of the use of mathematics and suggests that one either practices pure mathematics or takes a ready parcel of mathematics and applies it elsewhere."