Epistemology of Newtonian Gravity

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In certain research programs, such as the mechanistic theory of the universe according to which the universe is a huge clock (and a system of vortices) with the push as the sole cause of movement, the particular Cartesian metaphysics functioned as a powerful heuristic principle: it discouraged scientific theories, such as the "essentialist" version of Newton's action at a distance, which were incompatible with it (*negative heuristics*). And it encouraged the auxiliary hypotheses that could have saved it from apparent contradictions, such as the Keplerian ellipses (*positive heuristics*).

The first edition of Newton's *Principia* contains only two additional comments on the methodology: the notification that the purpose of the paper is to explain "how to determine the true motions from their causes, effects, and apparent differences, and, conversely, how to determine from motions, whether true or apparent, their causes and effects"[1]; and, in the Scholium at the end of Book 1, Section 11, Newton asserts that his distinctive approach makes possible a safer argumentation in natural philosophy.

In the second edition (1713) Newton introduces separate sections for the phenomena and rules involved in determining the universal gravity[2], and at the end of the General Scholastic of the third edition, 1726, includes the most famous methodological statement:

> "I have not as yet been able to deduce from phenomena[3] the reason for these properties of gravity, and I do not feign hypotheses. For whatever is not deduced from the phenomena must be called a hypothesis; and hypotheses, whether metaphysical or physical, or based on occult qualities, or mechanical, have no place in experimental philosophy. In this experimental philosophy, propositions are deduced from the phenomena and are made general by induction. The impenetrability, mobility, and the impetus of bodies, and the laws of motion and the law of gravity have been found by this method. And it is enough that gravity really exists and acts according to the laws that we have set forth and is sufficient to explain all the motions of the heavenly bodies and of our sea." [4]

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[1] Isaac Newton, „Philosophiæ Naturalis Principia Mathematica, I Ed.", The British Library, 1687, par. XIV, https://www.bl.uk/collection-items/newtons-principia-mathematica.

[2] Isaac Newton, *Philosophiae Naturalis Principia Mathematica, II Ed.*, 1713, https://www.e-rara.ch/zut/338618.

[3] În filosofia contemporană "deducerea din fenomene" este cunoscută sub denumirea de "inducție eliminatorie" și "inducție demonstrativă".

[4] Isaac Newton, „Philosophiae Naturalis Principia Mathematica, III Ed.", *Science* 177, nr. 4046 (1726): 943, https://doi.org/10.1126/science.177.4046.340.

adding later, "unless as conjectures or questions proposed to be examined by experiments." [5]

Newton warns in the *Principia* that he uses mathematical theory in a new way, with the forces treated abstractly, independently of the mechanism, only mathematically. Clarke and Berkeley in the 18th century assert that these passages express strict causal agnosticism. Newton writes that, using terms such as "attraction," he does not intend to define a "species or mode of action or a physical cause or reason." [6]

Referring to Newton's claim to "deduce" the law of universal gravity from the phenomena of orbital motion, Lakatos claimed that this statement is at least misleading and, at worst, a subterfuge. Only a hypothetical-deductive construct of its demonstration of universal gravity makes sense.

According to Andrew Janiak, the anti-metaphysical reading of the mathematical treatment of Newton's force is a reasonable one. Anti-metaphysical interpretation can be supported by the famous methodological statement of the *Principia*, "*hypotheses non fingo*", "I feign no hypotheses." [7] As the mathematical treatment of force can be interpreted as expressing strict causal agnosticism, focusing exclusively on empirical descriptions of the movements in the solar system, "Newton's methodology can be interpreted as expressing a more general metaphysical agnosticism." [8]

For Newton, science, "experimental philosophy," involves explanatory sentences that can be "deduced from phenomena." What cannot be deduced in this way is merely a hypothesis. But Newton does not circumvent hypotheses, he only does not include them into science, considering them purely speculative. Their place is reserved in *Opticks* Queries[9], and in explicit annotations in the *Principia*. The hypotheses are developed by Newton when he does not have independent

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[5] Isaac Newton, *An Account of the Book Entitled Commercium Epistolicum Collinii & Aliorum, de Analysi Promota*, 1715, 312.

[6] Andrew Janiak, *Newton as Philosopher* (Cambridge University Press, 2010), 16.

[7] Lakatos afirmă că cea mai bună reconstrucție rațională a faimoasei expresii "*hypotheses non fingo*" a lui Newton este probabil; "Eu resping degenerarea comutărilor de probleme care sunt concepute pentru a păstra unele teorii care sunt sintactic metafizice, cf. Imre Lakatos, „Criticism and the Methodology of Scientific Research Programmes", *Proceedings of the Aristotelian Society* 69, nr. 1 (1968): 180.

[8] Janiak, *Newton as Philosopher*, 17.

[9] Isaac Newton, *Opticks : Or, A Treatise of the Reflections, Refractions, Inflections and Colours of Light* (London : Printed for William Innys at the West-End of St. Paul's, 1730), http://archive.org/details/opticksortreatis1730newt.

empirical support for those assertions. In the General Scholium, he states: ""For whatever is not deduced from the phenomena must be called a hypothesis; and hypotheses, whether metaphysical or physical, or based on occult qualities, or mechanical, have no place in experimental philosophy" [10]

From Newton's point of view, gravity is not mechanistic; but he also admits that he does not know the "reason" for the properties of gravity expressed in the law of universal gravity, namely that he does not have a physical explanation of this force, refusing to make assumptions on this subject. Unlike Leibnitz, he explicitly states that a certain causality in nature is non-mechanical, thus challenging the prevailing mechanistic philosophy at that time. In this regard, Stein and DiSalle assert that Newton was a radical empiricist in metaphysical debates: he not only rejects the mechanistic philosophy of Descartes, Leibniz, and Huygens, but transforms the metaphysical questions considered by them as purely *a priori* into empirical issues, whose answers depend on the development of physics. [11]

Newton is willing to hold metaphysical positions, such as in the structure of space and time or causality, but he rejects Cartesian *a priori* approaches, putting physics ahead of metaphysics, which makes him, according to Stein and DiSalle, not an antimetaphysician, but an empirical metaphysician, with a principial empirical attitude towards metaphysical questions.

In order to understand movement in a manner consistent with its laws, Newton postulates absolute space[12], thus allowing it to conceive the movement as a change in absolute space. This idea allows Newton to save the perceptible effects of acceleration of bodies as real movements in absolute space[13].

Newton's natural philosophy can only be understood if we consider his conception of God:

> "Newton invoked God in the action at a distance for a specific reason, to support gravity in the universe, warning against a vision of the universe as a mere machine. He thus tried to develop a concept about God that would provide a stable, organized and predictable model of the natural world, a God who

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[10] Newton, „Philosophiae Naturalis Principia Mathematica, III Ed.", 943.

[11] Janiak, *Newton as Philosopher*.

[12] În Scholium, declară explicit că spațiul absolut nu este perceptibil (Newton, „Philosophiæ Naturalis Principia Mathematica, I Ed.", 414.) fiind conștient că mișcarea adevărată este dificil de detectat dacă este mișcare absolută.

[13] Newton, „Philosophiae Naturalis Principia Mathematica, III Ed.", 423.

> projects on rational and universal principles, accessible to all people ... he appeals to God to explain the mechanisms he cannot explain otherwise, including the action at a distance." [14]

Newton's theory of gravity was fundamentally rejected by his contemporaries for violating the norms of mechanistic philosophy. According to Andrew Janiak, Newton was forced to defend his mathematical treatment of force and movement on a fundamental metaphysical basis[15]. After the revolution in physics in the 17th century, from the neo-Aristotelian ("scholastic") philosophy to Cartesianism, Newton caused a new paradigm shift by replacing the mechanistic philosophy with the natural philosophy. This second schism occurred in the absence of a conceptual continuity. Although without a metaphysical system of his own, Newton defended himself by articulating a compelling relationship between mathematical and metaphysical physics in disputes about space and time, matter, laws of motion, the nature of forces, and the relationship of God with the world.

Principia has triggered a broad discussion among Newton's contemporaries about the methodology to be adopted when studying the natural world.

As Andrew Janiak states, for Newton force was the main concept that explained the movement and its causes in nature. He conceived forces as ephemeral actions, like quantities, through the connection between mass and acceleration, providing a means of measuring forces. In Book III of *Principia*, Newton identifies the centripetal force that maintains planetary orbits with the force of gravity, which causes the free fall of objects on earth. Hence the conclusion, in Book III, that all bodies are attracted to each other in proportion to their amount of matter (universal gravity). He acknowledges, however, that he does not know the cause of gravity: "I have not as yet been able to discover the reason for these properties of gravity from phenomena, and I do not feign hypotheses." [16]

By the seventh sentence of Book III of Principles, Newton came to the following conclusion: "Gravity acts on all bodies universally and is proportional to the quantity of matter in each." [17]

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[14] Nicolae Sfetcu, *Isaac Newton despre acțiunea la distanță în gravitație - Cu sau fără Dumnezeu?* (MultiMedia Publishing, 2018), http://doi.org/10.13140/RG.2.2.24577.97122.

[15] Janiak, *Newton as Philosopher*.

[16] Alexandre Koyre, *From the Closed World to the Infinite Universe* (Johns Hopkins University Press, 1957), 229.

[17] Newton, „Philosophiae Naturalis Principia Mathematica, III Ed.", 810.

The methodology of *Principia* of discovering the forces present in nature was controversial, including for the action at a distance. In the second edition of 1713, he added other methodological observations, called by him "*regulae philosophandi*", or the rules of philosophy. The first two rules refer to causal reasoning, and the third rule, much debated by contemporaries, referred to an induction problem: we have perceptions and experiments for knowledge, but on what basis can we generalize? Newton gives a partial answer in proposition seven of the Third Book of Principle, in Rule 3:

> "Those qualities of bodies that cannot be intended and remitted [i.e., increased and diminished] and that belong to all bodies on which experiments can be made should be taken as qualities of all bodies universally." [18]

Newton links this third rule to his laws of motion:

> "That all bodies are movable and persevere in motion or in rest by means of certain forces (which we call forces of inertia) we infer from finding these properties in the bodies that we have seen. The extension, hardness, impenetrability, mobility, and force of inertia [This is a potentially confusing way to refer to the specific mass, which we would call the inertial mass of a body. See the third definition in the *Principia*[19].] of the whole arise from the extension, hardness, impenetrability, mobility and force of inertia of each of the parts; and thus we conclude that every one of the least parts of all bodies is extended, hard, impenetrable, movable, and endowed with a force of inertia. And this is the foundation of all natural philosophy." [20]

Leibniz asserted that Newton's three-dimensional Euclidean space allows distinct states, but indistinguishable if the absolute positions of all material bodies are changed, while retaining their relative positions[21]. The same laws of motion are valid in all inertial frames, so it would be impossible, by applying Newton's laws, to determine what the inertial framework is. Leibniz concludes that we should use the principle of parsimony to reject such "metaphysical" entities.

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[18] Newton, *Philosophiae Naturalis Principia Mathematica, II Ed.*

[19] Newton, „Philosophiae Naturalis Principia Mathematica, III Ed.", 404–5.

[20] Newton, 95–96.

[21] Michael Friedman, *Foundations of Space-Time Theories: Relativistic Physics and Philosophy of Science* (Princeton University Press, 1983).

But Newtonian mechanics does not satisfy the principle of relativity for absolute acceleration and absolute rotation, only for inertial frames. In accelerated or rotated systems, Newtonian laws are no longer valid. It would result that absolute acceleration and rotation have physical significance, resulting in a dilemma, as discussed by Michael Friedman. Basically, the combined theory of Newtonian space and time and Maxwell's electrodynamics prove to be false[22]. Einstein resolved this paradox in 1905, keeping Maxwell's laws intact but changing the transformations that link inertial frames.

Newton introduced the term "experimental philosophy" in 1712, in a passage at the General Scholium of *Principia* where he set out his methodology against hypotheses. His purpose was to defend his theory of gravity against critics, especially Leibniz's:

> "Experimental Philosophy reduces Phaenomena to general Rules & looks upon the Rules to be general when they hold generally in Phaenomena.... Hypothetical Philosophy consists in imaginary explications of things & im- aginary arguments for or against such explications, or against the arguments of Experimental Philosophers founded upon Induction. The first sort of Philosophy is followed by me, the latter too much by Cartes, Leibnitz & some others." [23]

As Alan E. Shapiro states, the term rather refers to empirical science. It was also added to the second edition of the *Principia* in 1713, where he stated that he demonstrated the existence of gravity even though he could not find its cause, listing the different properties of gravity. Newton also exposes his methodology in Query 31 of *Opticks*, where he is concerned with force and natural philosophy. Newton's experimental philosophy is considered to have two essential elements: the exclusion of hypotheses from natural philosophy; and the requirement that sentences in experimental philosophy be "duced from the phenomena and are made general by induction." Newton thus rejects the hypothesis without experimental support. Those with experimental support, but insufficient to help demonstrate scientific principles, are allowed but distinct from established principles, like the queries in Optics. This type of hypothesis can suggest new experiments and help explain the properties and principles already discovered.

In the second English edition of *Principia*, 1717, Newton detailed the term "experimental philosophy" and introduced the induction method:

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[22] Friedman.

[23] Newton, „Philosophiæ Naturalis Principia Mathematica, I Ed."

> "This Analysis consists in making Experiments and Observations, and in drawing general Conclusions from them by Induction, and admitting of no Objections against the Conclusions, but such as are taken from Experiments, or other certain Truths. For Hypotheses are not to be regarded in experi- mental Philosophy. And although the arguing from Experiments and Obser- vations by Induction be no Demonstration of general Conclusions; yet it is the best way of arguing which the Nature of Things admits of, and may be looked upon as so much the stronger, by how much the Induction is more general. And if no Exception occur from Phaenomena, the Conclusion may be pronounced generally. But if at any time afterwards any Exception shall occur from Experiments, it may then begin to be pronounced with such Exceptions as occur." [24]

Thus, the existence of gravity "has been proved mathematical demonstrations grounded upon experiments phaenomena of nature: & Mr Leibnitz himself cannot deny they have been proved."

Confirmation is, according to Newton, first by mathematical demonstration and secondly by experiment. He was convinced that a deductive mathematical approach leads to certainty and the experiment may provide some foundations needed for a science, but until the 18th century he did not assign to the experiment the leading place in his methodology.

According to Laudan[25], Newton considered that one of the central purposes of natural philosophy is to show the Creator's hand in the details of his creation, because "to discourse of [God] from the appearances of things, does certainly belong to Natural Philosophy." [26] The theories, according to Newton, can be certain or very probable. Between two rival theories, Newton would probably have chosen what would have promoted his cognitive goals, as in the case of mechanistic philosophy. But it must to take into account that some of Newton's cognitive purposes differ from those of today. Therefore, according to Laudan we can evaluate their rationality by determining whether their actions have promoted some goals, and their actions can be determined as rational only with reference to the corresponding weighted product of their cognitive utilities.

According to Robert Disalle, Newton offers inductive arguments for a metaphysical conclusion, while Einstein uses epistemological analyzes to decompose metaphysical notions. But Newton's arguments have the same basic form and purpose as Einstein's. Newton's thought

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[24] Newton, *Philosophiae Naturalis Principia Mathematica, II Ed.*, 404.

[25] L. Laudan, *Progress and its Problems: Toward a Theory of Scientific Growth* (University of California Press, 1977).

[26] Newton, „Philosophiae Naturalis Principia Mathematica, III Ed."

experiments on the bucket of water are, in essence, arguments for a way to connect physical processes with the structures of space and time. [27]

Until at least the second half of the century, Locke and Newton's systems were perceived as being based on very similar principles and methods, composed of natural and moral philosophy. Locke and Newton share a similar conception of the scientific method, based on rational and regular experiments and observations and the use of generalization and deduction. Thus G. A. Rogers writes:

> "What Locke found in the *Principia* was the exemplification of a method to which he himself already subscribed. He already believed that a combination of observation, generalization or induction, and deduction was the only route to knowledge of nature and that the *Principia* exhibited just that method in its most fruitful manner... It confirmed for him all his own methodological conclusions... The *Principia* was for Locke the vindication of a general methodological approach to which he had subscribed for perhaps twenty years." [28]

Hume also explicitly associates his work with the Newton's method, although there is a clear distinction between Hume's inductivism and Locke's conception of the methodology of natural science. [29]

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[27] Robert Disalle, „Spacetime Theory as Physical Geometry”, *Erkenntnis* 42, nr. 3 (1995): 317–337.

[28] G. A. J. Rogers, „Locke’s Essay and Newton’s Principia”, *Journal of the History of Ideas* 39, nr. 2 (1978): 217–32, 229.

[29] Graciela de Pierris, „Hume and Locke on Scientific Methodology: The Newtonian Legacy”, *Hume Studies* 32, nr. 2 (2006): 277–329.

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