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# Commentary on Boulos

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**In Response to:** Pierre Boulos's *The Newtonian Revolution as a revolution in scientific reasoning*


My basic understanding of Boulos' claims starts with his title, i.e., that Newton was responsible for a "revolution in scientific reasoning." The concept at the center of the discussion is "empirical success" which for "a theory" he characterizes as "not limited to prediction, but also generates reliable measurements of the parameters of the phenomena." According to Boulos this results in a "method of answering important theoretical questions empirically by measurement from phenomena" made possible via "systematic dependencies that make the phenomena into measurements of theoretical parameters." This is illustrated (argued for) by considering the case of the argument for the moon's gravitation towards the earth which appears in Propositions III and IV, Book III of the *Principia*. Two attendant claims are also made: (i) that this "model of evidential reasoning exploits these agreements in a way that the stakes are raised for rival theories" and (ii) that in contrast to those who claim later developments are to be seen as confirmation of Newton's position "we claim that the developments by Newton's successors on perturbation theory helped realise Newton's ideal of empirical success."

I lay no claim to being a Newtonian scholar. The last time I looked at the history of seventeenth century physical science with any degree of seriousness was more than thirty years ago. Consequently, portions of my remarks are merely raising questions instead of making comments on Boulos' claims.

There is a voluminous literature on the issue of Newton's scientific methodology. As a sampling over an extended period of time which represents a variety of points of view consider: Snow (1927); Burt (1932); Blake (1933); Burke (1936); Strong (1951) and (1957); Crombie (1957); Kargon (1965); McGuire (1967) and (1970); Palter (1967); Shapere (1967); Achinstein (1990); and Stein (1990). Making an assessment of Newton's contributions to scientific methodology is difficult for a variety of reasons. First, we have writings over a roughly sixty year period to assess. Moreover, these writings range from multiple edition publications to private correspondence and personal notes. Second, we have Newton's well-known antipathy to criticism and its impact on his public positions. Third, we have the fact that we are dealing with a seventeenth century author and his context. Extreme care must be given to not unintentionally provide an anachronistic interpretation. Where does the Boulos claim fit in the landscape represented by the extant Newtonian literature? What is new or different about the Boulos claim? Is there some problem of Newtonian interpretation for which Boulos proposes a resolution? I am unsure about the answer to any of these questions. I believe that all of the authors listed above would acknowledge that Newtonian science is mathematical in at least two ways -- that the ideal of scientific knowledge is demonstrative, i.e., it should be laid out in the Euclidean manner and that those aspects of nature which admit of mathematical representation are fundamental. Consequently, both systematic dependencies and measurement *per se* are standardly assumed aspects of Newtonian science. Exactly, what beyond this is Boulos claiming?

Boulos' claims rest on Newton's "Rules of Reasoning in Philosophy" and their utilization in the argument for the moon gravitating towards the earth. Before coming to my set of questions I wish to set out both these aspects of the Newtonian position and an additional one. The Rules as they appear in the 3rd edition (without their commentaries) are as follows:

> RULE I: We are to admit no more causes of natural things than such as are both true and sufficient to explain their appearances.
>
> RULE II: Therefore to the same natural effects we must, as far as possible, assign the same causes.
>
> RULE III: The qualities of bodies, which admit neither intension nor remission of degrees, and which are found to belong to all bodies within the reach of our experiments, are to be esteemed the universal qualities of all bodies whatsoever.
>
> RULE IV: In experimental philosophy we are to look upon propositions collected by general induction from phænomena as accurately or very nearly true, notwithstanding any contrary hypotheses that may be imagined, till such time as other phænomena occur, by which they may either be made more accurate, or liable to exceptions.

The first two rules concern the parsimony of causal relationships while the second two concern conditions connected with induction. The set of four rules did not exist in all three editions of the *Principia.* In the first edition a set of nine hypotheses introduced Book III. In the second edition they were broken up into three groups–Rules of Reasoning in Philosophy, one Hypothesis which was no longer placed at the beginning, and Phenomena. To the first two former hypotheses, now relabeled as rules, a third was added. The extended discussion of this third rule is addressed to Cartesians, to mechanists in general, and to Leibniz in particular. In the third edition a the fourth was added and a fifth existed in draft form. The fifth is an anti-Cartesian polemic which was never published. Koyre (1960). These changes over time complicate determining the role the Rules actually played in Newton's reasoning. Correspondence further complicates the task by making it appear as if the latter Rules were constructed to deal with critics rather than guide reasoning.

A paraphrasing of the essence of the Newtonian argument for the moon gravitating towards the earth is as follows:

- (Proposition III): The force by which the moon is retained in its orbit tends to the earth (from Phen VI and Prop II or III Book I) and is inversely as the square of its distance of its place from the earth's center.
- (Proposition III Cor.): This force in descending to the earth's surface will continually increase as the square of the inverse of its height.
- (Proposition IV a): Let us assume the mean distance of 60 diameters.
- (Proposition IV b): If we imagine the moon, deprived of all motion, to be let go, so as to descend towards the earth with the impulse of all the force by which it is retained in its orb, it will in the space of one minute of time, describe in its fall 15 Paris feet, 1 inch, and 1 line 4/9. (From Prop XXXVI, Book I or Cor IX, Prop IV Book I)
- (Proposition IV c): At the surface of the earth in the space of one second of time it will describe 15 Paris feet, 1 inch, and 1 line 4/9.
- (Proposition IV d): A pendulum oscillating seconds in the latitude at Paris will be 3 Paris feet 8 lines ½ in length. The space which a heavy body describes by falling in one second of time is to half the length of this pendulum as the square of the ratio of the circumference of a circle to its diameter, and is therefore 15 Paris feet, 1 inch, and 1 line 7/9.

- (Proposition IV e): Therefore, the force by which the moon is retained in its orbit becomes, at the very surface of the earth, equal to the force of gravity which we observe in heavy bodies there.
- (Proposition IV f): Therefore, the force by which the moon is retained in its orbit is the very same force which we commonly call gravity; (Rules I and II)
- (Proposition IV g): for, were gravity another force different from that, then bodies descending to the earth with joint impulse of both forces would fall with a double velocity.

This rendition overlooks the moves made in Proposition III in order to achieve the inverse square law for the moon. The other crucial presupposition is that the mean distance is 60 diameters. Neither was obviously the case.

Propositions V, VI, and VII then generalize this result. There is the explicit invocation of Rules I, II, and IV in the *Scholium* to Proposition V and the explicit invocation of Rule III in Corollary II of Proposition VI.

One of my concerns is that considering only this argument utilizes a very small portion of the Newtonian corpus–a few pages at the start of Book III in the 3rd edition of the *Principia*. There is only a single and rather extraordinary case contained here -- the case for the moon gravitating towards the earth. There are both other sources of methodological pronouncements in Newton than the four rules in Book III and quite different studies than those undertaken in the *Principia.* How complete and generalizable a view do we have on the basis of this portion of the Newtonian corpus. Consider the following from the *Opticks*:

> "As in Mathematiks, so in Natural Philosophy, the Investigation of difficult Things by the Method of Analysis ought ever to precede the Method of Composition. This Analysis consists in making Experiments and Observations, and in drawing general Conclusions from them by Induction, and admitting no Objections against the Conclusions, but such as are taken from Experiments, or other certain Truths. For Hypotheses are not to be regarded in experimental Philosophy. And although the arguing from Experiments and observations 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 much stronger, by how much the induction is more general. And if no Exception occur from the 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. By way of this Analysis we may proceed from Compounds to Ingredients, and from motions to the Forces producing them; and in general from Effects to their Causes, and from particular Causes to more general ones, till the Argument end in the most general. This is the Method of Analysis: And the Synthesis consists in assuming the Causes discover'd, and establish'd as Principles, and by them explaining the Phenomena proceeding from them, and proving the Explanations. " *(Opticks* 4 ed., 404-405).

This quotation reveals what I believe to be a key aspect of the Newtonian methodology–that it is at least a two step process involving both analysis and synthesis. Of these two components it is analysis which receives the lengthy discussion in the above quotation. Synthesis is taken as better understood than analysis as the standard presentation of geometry is an illustration of synthesis. Synthesis in natural philosophy, as well as in geometry, functions to demonstrate interrelationships. Both aspects are involved in doing science-- simply analysis or simply synthesis will not do.

The argument for the moon gravitating towards the earth is part of which aspect of science? The propositions up to Proposition X in Book III are arguing for it and after Hypothesis I its consequences are being explored. In other words the first ten propositions involve the method of analysis and those following Hypothesis I are components of the method of synthesis. This is supported by the Preface to the first edition where Newton says: " In the third book I give an example of this in the explication of the System of the World; for by the propositions mathematically demonstrated in the former Books, in the third I derive from the celestial phenomena the forces of gravity with which bodies tend to the sun and the several planets. Then from these forces, by other propositions which are themselves mathematical, I deduce the motions of the planets, the comets, the moon, and the sea." *(Principia*, xviii)

Now I am ready to raise my set of questions beyond the one already raised about the location of the Boulos position in the Newton literature.

If the argument we have considered is reasoning to principles rather than from principles, in what sense are we answering "theoretical" questions? In what sense are we dealing with "empirical success" of "a theory" when reasoning to principles? For that matter, in what sense is it appropriate to use "theory" when discussing Newton?

1) Are other examples from the Newtonian corpus illustrating this mode of reasoning? If so, what are they and in what ways are they similar and in what ways different? If not, then how can this case be considered representative of scientific reasoning?

2) What would be required to consider something a revolution? Revolution requires change. How is the Newtonian reasoning a change? What is it a change from? What were its contemporary competitors? Moreover, not all changes are revolutionary. What about a change makes it a revolutionary change? A setting out of both the background and contemporary alternative positions would be needed in order to assess whether there was a revolution. In addition the scientific revolution is multi-dimensional involving a switch from a geocentric to a heliocentric astronomy, the conversion from Aristotelian to Newtonian dynamics, adherence to and the development of a mechanical philosophy and a change in the view about the status of first principles. Singling out a particular component for special consideration seems likely to neglect complex interrelationships.

3) In what way were further developments not simply confirmation? Perhaps Boulos' position provides and alternative way of viewing the relationship of data and theory other than confirming data, but that remains unclear to me. With no specific references given it is hard to assess the basis on which the other claim was made. Moreover, in the *Principia* itself lunar theory was not taken as a confirming instance as it was part of the method of analysis not part of the method of synthesis.

4) How does this purported Newtonian methodology up-the-ante for competing theories? What is presupposed in this claim? Why does a competitor have to agree that identical measure results are disadvantageous to their position? How are two effects determined to be the same? Isn't such a determination theory dependent? Is there an illustration of how this impacted a competing theory?

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