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Isaac Newton, Interdisciplinarian: Newton's Cross-Domain Evidential Reasoning

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Abstract

This paper argues that Newton employed a non-hypothetical method of evidential reasoning called demonstrative induction in his chronological studies. In demonstrative induction, inductive risk is confined to the premises, and the secureness of the conclusion depends on the secureness of those premises. I show that Newton's approach to chronology exemplifies two key restrictions on demonstrative induction: (i) premises must be supported by inductive generalizations (or by stronger forms of demonstration, such as mathematical or geometrical reasoning), and (ii) inductive risk should be confined to premises drawn from domains of inquiry whose claims are better established, thereby "exporting" inductive risk to more certain domains. Drawing on Newton's use of sources from history, biology, social science, and astronomy, I analyze how he transformed data from these fields into evidence for his chronological scheme. The strategy of exporting inductive risk, I argue, reveals a common evidential pattern across his natural philosophical, historical, and theological work, and sheds light on the deeper methodological unity that underlies his otherwise disparate intellectual pursuits.

Key Words: Newton, demonstrative induction, hypothetical induction, evidence, chronology

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1. Introduction

In this paper, I examine how Newton marshals evidence for his conclusions in his chronological investigations. I build on a literature that seeks to clarify how Newton's methodology differs from the "method of hypotheses."[1] This literature has focused on showing how Newton avoided conjecture and instead sought to deduce his theoretical conclusions from observable phenomena in what are called "demonstrative inductions," especially in the *Principia*. In such inferences, the reasoning is deductive in form but necessarily depends on fallible auxiliary assumptions, which bear all the inductive risk. The conclusion is only as secure as the premises on which it rests. Understanding what kinds of propositions can serve as premises is therefore necessary for explaining how Newton can be said to avoid conjecture.

The contribution of this paper is twofold. First, I show that Newton relies on demonstrative induction to draw conclusions in his chronological studies. Second, and more

[1] E.g., Glymour, 1980; Worrall, 2000; Smith, 2002; Harper, 2011; Ducheyne, 2012; Harper, 2016; Walsh, 2019; Belkind, 2022.

significantly, I argue that he implicitly imposes two restrictions on the auxiliary assumptions that enter into his deductions: (1) these assumptions are drawn from domains outside of chronology (e.g., astronomy)—a strategy I refer to as the exporting of inductive risk—and (2) they are themselves supported either by demonstrative induction or by inductive generalization. In other words, he uses more secure principles from other domains to deductively infer conclusions in chronology. My analysis helps to explain how, and in what sense, Newton avoids conjecture in his chronological works and sheds light, more generally, on the unity of his methods across disciplinary contexts.

In Section 2, I discuss Newton's claims about his empirical methodology—namely, his insistence on avoiding the method of hypotheses and instead employing the methods of geometers. I then explicate the pattern of induction I attribute to him. In Section 3, I contextualize Newton's interest in chronology. In the following sections, I examine the different domains Newton used to develop evidence for his chronological scheme and show how his reasoning fits my evidential model. Section 4, for example, concerns Newton's framework for interpreting texts; Section 5 discusses the biological and social scientific models he constructed to reason about chronology; and Section 6 analyzes his use of astronomy to date historical events. In each of these sections, I show that, as much as possible, Newton does not conjecture specific historical hypotheses and then seek evidence to support them (as I am, ironically, attempting to do). Instead, he adopts more general principles from other domains to eliminate chronological hypotheses and arrive more securely at specific chronological conclusions.

2. Newton's Method: Avoiding Conjecture and Seeking Certainty

Across his disciplinary pursuits, from his early optical papers to his revisions of the *Principia* decades later, Newton claims to be avoiding hypotheses. Hypotheses, for Newton, are such not in virtue of their propositional content, but of their evidential status. Newton uses the term hypothesis to signify whatever is *not deduced from the phenomena*—or, as he puts it in some places, "founded on experience" or "deduced from experiment."[2] In the General Scholium appended to the second edition of the *Principia*, Newton most famously declared his *non fingo* methodology:

> 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 philosophy, propositions are deduced from the phenomena and are made general by induction.[3]

In avoiding hypotheses, Newton takes himself to be opposing the "method of hypotheses" championed by, among others, Huygens, Descartes, and Hooke. As Huygens writes, this method,

> ...differs distinctly from the method employed by geometers in that they prove their propositions by well-established and incontrovertible principles, while here principles are tested by the inferences which are derivable from them. The nature of the subject permits of no other treatment.[4]

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[2] Newton, 1672, pp. 5004-5005.

[3] Newton, 1999, p. 943. I follow Shapiro's change of "experimental philosophy" to "philosophy" for the reasons he gives; Shapiro, 2004. See Newton, 2004 and CUL Add. Ms. 3970, fol. 621v. for further examples of Newton explaining what he means by "hypothesis."

[4] Newton possessed a copy of Huygens, 1690 (Harrison, 1978); Translation is from Huygens, 1900, p. 4.

In the method of hypotheses, one conjectures hidden structures of the world. Evidence comes when such conjectures lead to accurate predictions—"especially when these verifications are numerous; but above all when one employs the hypothesis to predict new phenomena and finds his expectations realized."[5]

Newton did not approve of this method, and, contra Huygens, explicitly stated that he modeled his empirical investigations on the method of geometers. In a letter to the secretary of the Royal Society concerning his optical theories, Newton writes,

> I drew up a series of such Experiments on designe to reduce the Theory of colours to Propositions & prove each Proposition from one or more of those Experiments by the assistance of common notions set down in the form of Definitions & Axioms in imitation of the Method by which Mathematitians are wont to prove their doctrines.[6]

Philosophers of science since Newton have been skeptical about Newton's claims to have deduced his theories from phenomena.[7] Logically weaker claims cannot deductively support logically stronger claims, and Newton's phenomena are logically weaker than the theoretical propositions he purports to have deduced.[8] In order to achieve deductive inferences, Newton must therefore be employing auxiliary hypotheses to strengthen his premises. This sort of inference has been referred to as a demonstrative induction.[9] Such inferences are non-ampliative (and hence deductive); the premises deductively entail the conclusion. But they are inductive because they reason from more specific cases (e.g., data) to more general cases (e.g., theory). Typically, they achieve such deductive status by pairing premises of lesser generality (the data) with premises of greater generality to conclude premises of intermediate generality.[10] For example, Newton's argument for an inverse-square attractive force can be roughly schematized as two subproofs, each of which is a demonstrative induction of this nature:

Proof of Book 3, Proposition 1:[11]

(Proof of a Centripetal Force)

1.	Kepler's area rule obtains for the circumjovial planets	*Book 3, Phenomena 1*
2.	Kepler's area rule obtains iff there is a centripetal force	*Book 1, Proposition 2 or 3*
3.	The force maintaining the orbit of each circumjovial planet is centripetal toward Jupiter	*Conclusion 1*

(Proof of an Inverse-Square Attractive Force)

4.	Kepler's period rule obtains for the circumjovial planets	*Book 3, Phenomena 1*
5.	Kepler's period rule obtains iff (if centripetal force, then inverse-square attractive force)	*Book 1, Prop. 4, Corol. 6*
6.	The force maintaining the orbit of each circumjovial planet is centripetal toward Jupiter	*Conclusion 1*
7.	The force maintaining the orbit of each circumjovial planet is an inverse-square attractive force toward Jupiter	*Conclusion 2*

[5] Ibid., p. 4.
[6] CUL Ms. Add. 9597/2/18, fol. 27r.
[7] See Worrall, 2000, pp. 46-47.
[8] Ibid.
[9] See Norton, 2010, section 8.
[10] Ibid.
[11] Newton, 1999, p. 802. My schematization. See Harper, 2016 for Newton's deduction of universal gravitation.

The phenomena from Book 3 are premises of lesser generality: they concern the motion of particular orbiting bodies. The propositions from Book 1 are of greater generality: they are generic claims relating forces and motions of any bodies whatsoever.[12] Together they deductively conclude facts about the presence of forces in our solar system.

Since demonstrative inductions typically depend on fallible premises, their conclusions are likewise fallible. But because the inference is deductive, the inductive risk—the risk of error one takes on in making an inductive leap—is confined to the premises. This confinement is advantageous: by employing auxiliary assumptions, such as the mathematical propositions of Book 1, one can deductively derive substantive theoretical conclusions from observable data while locating the risk of error solely in those assumptions. By contrast, conjecturing a hypothesis and supporting it through predictive success disperses inductive risk among the hypothesis and all auxiliaries. In demonstrative induction, testing shifts from achieving numerous and novel accurate predictions to accumulating warranted premises that can support substantive conclusions. Often these premises serve to eliminate alternatives until only one remains, thereby rendering the inference deductive—a strategy sometimes called *eliminative induction*.[13]

While Newton's inferences in the *Principia* and *Opticks* have been analyzed as demonstrative inductions, I argue that Newton also employs demonstrative inductions in his chronological investigations.[14] This view is compatible with the latest treatments of Newton's work on chronology. Schilt has performed an invaluable analysis of the development of Newton's reading and writing on chronology.[15] By establishing a fairly detailed meta-chronology—a chronology of Newton's chronological work—through careful examinations of draft manuscripts, Schilt has provided the necessary timeline to understand the trajectory of Newton's study. Schilt uses this trajectory to reveal how, and more importantly for Schilt, why Newton worked on this subject matter (something to which I will turn toward the end of this paper). A decade earlier than Schilt's book, Buchwald and Feingold's work was the most extensive examination of Newton's chronological work. Their focus was on Newton's view of different sources of data—for example, Newton's skepticism about the testimony of authors from the past.[16] They also argue for the novelty of his use of data; for example, that Newton uses averaging techniques in a historically novel way. They also argue that Newton employs the "Newtonian Style" that Bernard Cohen, George Smith, and Bill Harper have discussed, in which Newton develops an initial idealized model that he subsequently de-idealizes in a data-driven manner.[17] Finally, Feingold also has briefly discussed Newton's reasoning as a form of the "composite method of analysis and synthesis" by pointing out that Newton tries to reason from more certain claims to less certain claims (e.g., by reasoning from the more recent past to the more distant past).[18]

My analysis does not conflict with these views but supplements them by focusing on a different aspect of Newton's evidential reasoning. For example, the Newtonian Style (or "closing the loop," as Smith calls it) is a large-scale, diachronic methodology of iterative de-idealization

[12] Smith, 2002, pp. 194-198.
[13] See Norton, 2010, section 8.
[14] See footnote 1, although not all of these authors use the specific term demonstrative induction.
[15] Schilt, 2021.
[16] Buchwald and Feingold, 2013.
[17] Cohen, 1983, chapter 3; Harper and Smith, 1995, pp. 143-144; Smith, 2002, pp. 206-2012.
[18] Feingold, 2016, p. 534.

and also serves as a strategy for avoiding conjecture. However, it is distinct from demonstrative induction, which is a static relation of inductive support.[19] While demonstrative induction is conceptually separate from the Newtonian Style, it can serve as a building block of the latter by, for example, generating the initial idealized model that is later de-idealized. The Newtonian Style has been identified in Newton's chronological work, and my contribution is to analyze the static relations of inductive support that are used as part of this broader methodological process, particularly by identifying his reliance on demonstrative induction in his chronological investigations.

However, my analysis of Newton's evidential reasoning goes beyond simply showing that he employed demonstrative inductions. Since, in demonstrative induction, the secureness of the conclusion is dependent on the secureness of the premises, establishing norms for permissible premises is important for making more secure conclusions. I identify two restrictions on premises that are implicit in Newton's demonstrative inductions in chronology.

First and most familiarly, as much as possible, Newton supports his premises with inductive generalization. Whereas in the method of hypotheses, one reasons from the unknown (hidden causes) to the known (the observations), in inductive generalization, one reasons from the known (the established instances) to the unknown (the cases where one does not yet know whether some claim obtains). Thus, inductive generalization reasons from the certain to the less certain in the more traditional manner as prescribed by Aristotle's *Posterior Analytics*, in contrast to the method of hypotheses employed by many of the "new sciences" of the 17th century.[20]

Newton endorses inductive generalization in several places throughout his work, most noticeably in the third and fourth rules of reasoning in philosophy in the third edition of the *Principia*. In Book 3 of the *Principia*, Newton inductively generalizes the conclusions of his deductions from phenomena. E.g., he generalizes the inverse-square attractive force established to hold between Jupiter and the sun, as well as between Saturn and the sun, to hold for the other planets as well: "for no one doubts that Venus, Mercury, and the rest...are bodies of the same kind as Jupiter and Saturn."[21] Many other steps in his empirical reasoning throughout the complicated argument of Book 3 and throughout the *Principia* rely on extending claims to hold beyond established cases. Applying the third law of motion to gravity is a case of inductive generalization; as is ultimately extending the inverse-square attractive force to hold between all bodies across all distances.[22]

Nearly all recent Newton scholarship that interprets him as employing demonstrative induction also recognizes that it is used in tandem with inductive generalization—the conclusions of the latter serving either as premises of a demonstrative induction, as generalizations of the conclusions of a demonstrative induction, or both. In identifying

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[19] See Genin, 2018, chapter 1, on the diachronic-static distinction in induction.

[20] See McMullin, 2001 on inductive inferences in the 17th century.

[21] Newton, 1999, p. 806.

[22] One can further categorize inductive generalization into subtypes. For example, Belkind, 2017, distinguishes between Baconian Induction and Universal Induction in Newton's reasoning. Baconian Induction involves generalizing from observed phenomena and experimental results (e.g., light dispersion in prisms), while Universal Induction extends established laws beyond observed cases (e.g., universal gravitation). Belkind argues that Newton did not follow a single model of induction but instead employed a multi-layered approach, incorporating these two forms of induction with demonstrative induction. My account is, therefore, in harmony with Belkind's view and further extends it to Newton's work in chronology. However, due to space constraints, I place less emphasis on differentiating between these subtypes of inductive generalization.

demonstrative induction alongside inductive generalization in Newton's chronological work, I follow this scholarly tradition, such as Walsh's analysis of Newton's evidential reasoning in his optical studies.[23] My analysis, therefore, contributes to the ongoing effort to carefully demonstrate the extent to which Newton's evidential reasoning is consistent across different domains.

Why license inductive generalization, but prohibit the method of hypotheses? Smith has argued that confining inductive risk to inductive generalization affords particular advantages.[24] Generalizing only from secure cases ensures that such generalizations will survive, in a potentially modified form, any future theory change that retains the secure cases in at least a modified form. The generalization may need to be revised in scope and precision, but will not need to be discarded entirely. The same cannot be said for hypotheses supported through the method of hypotheses; these may very well need to be discarded entirely. Newton's fourth rule of reasoning allows for revision to an inductively generalized conclusion in the face of counterexamples or the limits of precision; inductively generalized conclusions can be made "more exact or liable to exceptions" in the future.[25] As we will see in Newton's chronological investigations, Newton likewise confines inductive risk to inductive generalization, and allows that such generalization may need to be made more exact or liable to exceptions.

The second restriction Newton uses to purchase greater certainty in the construction of his chronology is what I call the "exporting" of inductive risk to other empirical domains. The spirit of avoiding the method of hypotheses means—not avoiding fallible assumptions altogether—but not conjecturing about the system under investigation. Newton's premises that he uses to assist his deductive inferences come from areas outside of chronology. Since demonstrative inductions confine the inductive risk to the premises, requiring that premises come from outside of the current domain of interest exports the inductive risk to a different discipline. This strategy can be effective if one's current domain of inquiry is difficult to access (e.g., the deep past). One can, in this manner, exploit the success of a different discipline that has accumulated many well-established claims. This can be seen clearly in the case of Newton using astronomical arguments to derive chronological datings.

Newton states in several places that he appeals to different domains of inquiry as part of his investigative strategy. Consider the following scholium in the *Principia* that Smith argues is essential for understanding Newton's method and underappreciated:[26]

> Mathematics requires investigation of those quantities of forces and their proportions that follow from any conditions that may be supposed. Then, coming down to physics, these proportions must be compared with the phenomena, so that it may be found out which conditions [or laws] of forces apply to each kind of attracting bodies. And then, finally, it will be possible to argue more securely concerning the physical species, physical causes, and physical proportions of these forces.[27]

We see here an endorsement of the idea that it is advantageous to exploit the certainty afforded by a particular discipline in order to arrive at more certain results in another. Newton wanted as much as possible to use mathematics (specifically geometry) to draw conclusions in

[23] Ducheyne, 2012; Walsh, 2019; Belkind, 2017.
[24] Smith, 2002, pp. 213-221; Smith, 2014, pp. 273-280.
[25] Newton, 1999, p. 796.
[26] Smith, 2002, p. 198.
[27] Newton, 1999, p. 588.

natural philosophy.[28] As he matured, he came to recognize this ideal as implausible for most empirical contexts, and consequently shifted to talking about the use of experiment to draw conclusions.[29] What I will show is that, even when Newton is not able to rely on mathematics for doing natural philosophy, he still exploits a more general strategy of exporting inductive risk to more certain areas of inquiry.

Newton exports the inductive risk in chronology to principles of textual interpretation, biology and social science, and astronomy. For example, in his earliest manuscripts on chronology, Newton writes that "the surest arguments for determining times past are those taken from Astronomy,"[30] and a little later in the same manuscript, "And because arguments drawn from Astronomy are accounted the surest, we shall now confirm our recconing by an argument of that sort."[31] We see here Newton stating—in near as possible terms—that in chronology, it is preferable to isolate the inductive risk to the domain of astronomy.[32] As Newton's theory and method in chronology developed over his life, he came to rely more and more on these types of arguments. Newton's posthumously published *Chronologies of Ancient Kingdoms Amended*, representing his latest work on the subject, holds that "I have drawn up the following Chronological Table, so as to make Chronology suit with the Course of Nature, with Astronomy, with Sacred History, and with *Herodotus* the Father of History, and with it self...I do not pretend to be exact to a year: there may be Errors of five or ten years, and sometimes twenty, and not much above."[33] This paper will explain what Newton means by this declaration.

3. The Context of Newton's Chronology

Chronology concerns the dating and ordering of historical events. Newton wrote at great length on the subject, but was reticent to publish any works on the subject.[34] When his *Chronologies* was leaked to the public, he defended his manuscript as follows: "When I lived at *Cambridge*, I us'd sometimes to refresh myself with History and Chronology for a While, when I was weary with other Studies."[35] Chronology in 17th century England had long been appreciated for its importance for the study of history.[36] Geography and chronology were viewed as the "right and left eyes"[37] of historical understanding, and were a standard (if brief) component in the university curriculum.[38] Yet, chronology also had by Newton's time attained a bad reputation due to multiple large personalities in past generations engaging in petty and pedantic feuds with one

[28] Shapiro, 2004. Note also that Newton denied the existence of mathematics entirely detached from nature. Geometry derives from measurement of physical space; it is "abstracted" from experience but not speculative. Mathematical reasoning offered precision and certainty within natural philosophy, not because it was a priori, but because it was a disciplined generalization of experience. See Garrison, 1987.
[29] Ibid.
[30] New College Ms. 361(3), fol. 166r.
[31] New College Ms. 361(3), fol. 168r.
[32] Thus, in the terminology of Worrall, 2000, Newton's interdisciplinary assumptions are often explicit as opposed to imiplicit premises in his deductions from phenomena.
[33] Newton, 1728a, fol. 8.
[34] Newton's reticence regarding publication was not unique to chronology: the traumatizing reception to Newton's early published optical works began a lifelong distaste for publishing. See Guicciardini, 2016. Schilt, 2016, argues that Newton's distaste for publishing also reflected more principled views on scholarship.
[35] Newton, 1724, p. 320.
[36] Buchwald and Feingold, 2013, p. 111; Grafton, 1975.
[37] Baker, 1700, p. 124
[38] Buchwald and Feingold, 2013, p. 111.

another.[39] The abrasive nature of the personalities involved, such as Scaliger and Petavius, combined with the fact that there were many alternative systems and little room for breakthroughs.[40] The saturation of the field and the fact that secular history was of little concern to divines (which made up the majority of the faculty and students) meant that chronology was not viewed as a prestigious area of research.[41]

Newton's claim to only engage in chronology when he was exhausted by other intellectual pursuits—while possibly literally true—conveys a false sense of the importance of chronology to Newton's worldview.[42] Schilt, for instance, argues that Newton's chronological works were not simply instances of "universal histories": a common genre of scholarship focused more on secular history for its own sake.[43] Schilt argues that Newton's interest in chronology, as evidenced by the development over time of his manuscripts, is to a large extent in providing an accurate timeline to interpret prophecies; knowing what parts of Biblical prophecies have come to pass and when helps one to understand what is to come and when. Take Newton's early work on chronology, such as the 'Theologiæ Gentilis Origines Philosophicæ' (the 'Origines'). Schilt's careful examination of draft manuscripts shows that the motivations behind this early work carried through to all of Newton's subsequent chronological works, up to the posthumously published and incomplete *Chronology of Ancient Kingdoms Amended*.[44]

Whereas the *Principia* gave a sweeping theory of space, time, and motion, his chronological investigations, paired with his prophetic interpretations, cover a sweeping complete picture of the entire history of the world from its beginning to the apocalypse.

Beyond the prophetic concerns that Schilt emphasizes, I emphasize the importance to Newton of recovering lost natural philosophical knowledge. Newton's 'Origines' was propelled by his interest not only in prophetic interpretation but also in tracing the origins and corruption of both religion and natural philosophy.[45] For Newton, the knowledge of the true "frame of the world"[46] was, historically, deeply intertwined with the first and true religion: Noah was the inheritor of this original true knowledge of religion and natural philosophy, and it was distorted over time as it was passed down to Noah's descendants who populated the Earth.[47] Chronology was, for Newton, the key to understanding the origination, dissemination, and ultimate corruption and loss of this knowledge.[48] It therefore had immediate importance for understanding both theology and natural philosophy. Newton, like many other early moderns, saw himself as recovering lost knowledge as opposed to discovering new ideas.[49] In the opening to his posthumously published *System of the World*, Newton contextualized the claims he was about to make by informing the reader that "It was the ancient opinion of not a few, in the earliest ages of philosophy...that the earth...described an annual course about the sun."[50] In an unpublished

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[39] Buchwald and Feingold, 2013, p. 112; Grafton, 1975, p. 157.
[40] Buchwald and Feingold, 2013, pp. 112-113.
[41] Buchwald and Feingold, 2013, p. 111.
[42] Schilt, 2020, argues that theology, chronology, and prophetic studies were more important to Newton than physics and mathematics.
[43] Schilt, 2021, p. 20. Schilt is arguing here against Buchwald and Feingold, 2013 and others.
[44] Schilt, 2021.
[45] Yahuda Ms. 16.2. See Feingold, 2016; Iliffe, 2017; Schilt, 2021. Newton's interest in the past also had to do with his anti-Cartesianism and his looking to Euclid, see Guicciardini, 2002.
[46] New College Ms. 361(3), fol. 25r.
[47] Ibid.
[48] Ibid.
[49] Iliffe, 2017, chapter 6; Haycock, 2002, chapter 6.
[50] Newton, 1728b, p. 1.

preface to the *Principia*, Newton wrote "...it was also known to the ancients that the moon is heavy toward the earth, and that the stars are heavy toward one another, and that all bodies in a vacuum fall to the earth with equal velocity and thus are heavy in proportion to the quantity of matter in each of them."[51] In these passages, Newton states that heliocentrism and universal gravitation were known to the ancients.[52] Chronology and natural philosophy are importantly connected—at the end of the paper, I will say more about the exact nature of this connection.

The time Newton spent on chronology increased with age, and his theory and method evolved.[53] Newton eventually adopted a novel scheme for chronology, in which he greatly collapsed the duration of events before the Assyrian empire. This scheme posited that before the Assyrian empire, the population sizes of cities and kingdoms were significantly smaller than typically imagined.[54] The low population model was a consequence of the fact that after the Noachian deluge, the human race would not have been able to repopulate to an "empire" size until the time of the Assyrian empire. He also developed new methods for arriving at chronological conclusions—in particular, the use of biological, social scientific, and astronomic generalizations to arrive at chronological facts, as opposed to textual hermeneutics alone.

The following sections will show that Newton approached chronology in his characteristic manner of seeking certainty, and frequently criticized "the Historians" for adopting particular claims based on conjecture. Indeed, his standard way of rejecting an alternative view was to point out the way in which it was based on conjecture:

> But while the Historians allow no more time then the reign of one king between the rapture of Europa & the voyage of Menalaus it seems to me that they found only the rapture of Europa in the Annals of the Phenicians, & by conjecture subjoyned the voyage of Menalaus as a thing wch happend soon after.[55]

Similar statements can be found throughout his works and will be discussed below, such as his dismissal of received timelines and quantitative population estimates. While it is not clear that conjectural history is the same as the method of hypotheses in natural philosophy, what matters is that Newton saw all these approaches as involving unacceptable speculation and as running counter to his own more secure method of reasoning. "For whatever is not deduced from the phenomena must be called a hypothesis."[56] Whereas his contemporaries would often speculate a historical claim, whose evidence was based on the fact that the claim accorded with other data, Newton sought to provide a more principled foundation of knowledge on which to build history—deduction from phenomena.

4 Textual Interpretation

4.1 Newton's Approach to Textual Interpretation

At the heart of the enterprise of chronology for Newton was the interpretation of texts. In the following subsections, I will describe how Newton's distinctive method of interpretation of

[51] Newton, 1999, p. 53.
[52] See also the Classical Scholia, where Newton suggests the ancients were aware of the inverse-square law; Newton, 2001.
[53] Buchwald and Feingold, 2013, chapter 4; Schilt, 2021.
[54] Buchwald and Feingold argue that Newton adopted this new timeline in the 1690's, as they date Keynes Ms. 146, in which the low population model appears, to 1702.
[55] Keynes Ms. 146, fol. 18r.
[56] Newton, 1999, p. 943.

texts is similar across his studies of prophecy, alchemy, and chronology. This method involves cross-referencing many texts to arrive at the identification of the reference of figurative, symbolic, or otherwise encoded language. I argue that this method of textual interpretation follows the demonstrative inductive pattern discussed above. Instead of conjecturing interpretive meanings and testing them by how well they make sense of the texts, Newton instead adopts more general interpretative rules in order to constrain the interpretation of texts and arrive at a more conclusive identification of the meaning of names and phrases.

Ideally, interpretative rules can be specified so clearly that there is one available rendering of a chronological scheme, given a particular set of texts. To attain such an ideal is to achieve a demonstrative induction. In doing so, Newton could isolate the inductive risk away from chronology, and export it to the area of textual hermeneutics. The past provides no observational access, other than through theory-mediated analysis of data. In the case of history, data analysis is mediated primarily through theories of textual interpretation. In Newton's view, the place to start in an inquiry into history is therefore a careful construction of a theory of interpretation of texts. Contrast such an approach to one in which various historical hypotheses are proposed, tested, and incorporated into a growing body of chronological theory. Newton did not work this way. Newton instead identified clear cases of textual referents and inductively generalized hermeneutic principles to be applied to less certain cases. The goal was to constrain interpretation more and more in this manner so as to be able to arrive as certainly as possible at a single chronological scheme.

4.2 Textual Interpretation in Prophetic and Chymical Studies

By the time Newton turned to serious study of chronology, he had already developed his approach to the interpretation of texts in the context of prophetic translation. The eminent Cambridge exegete, scholar of Judaism, and Puritan Mede—served as Newton's foundational role model for the interpretation of prophecy: "As M^{r} Mede layed the foundation & I have built upon it."[57] Newton approved of Mede because the latter laid out explicit rules for interpretation and applied them consistently.[58] Newton criticized others (not by name) for being inconsistent and unsystematic in their textual interpretations.[59]

In several unpublished manuscripts, Newton wrote down his own rules of interpretation for prophecy. In an untitled treatise on revelation, Newton criticizes other prophetic interpreters for the speculative nature of the meanings they assign to prophecy. Newton's first rule is:

> To observe diligently the consent of Scriptures & analogy of the prophetique stile, and to reject those interpretations where this is not duely observed...Thus if any man interpret a Beast to signify some great vice, this is to be rejected as his private imagination becaus according to the stile and tenour of the Apocalyps & of all other Prophetique scriptures a Beast signifies a body politique & sometimes a single person which heads that body, & there is no ground in scripture for any other interpretation.[60]

This rule should be understood as an endorsement of inductive generalization in textual interpretation. That is, if there are clear examples of a symbol's meaning, then that meaning should be applied universally; one should not conjecture a meaning for which there is no support other than that it provides a sensible reading.

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[57] Yahuda Ms. 1.1, fol. 15r
[58] Ibid.; Mede, 1672.
[59] Yahuda Ms. 1.1, fol. 1r
[60] Yahuda Ms. 1.1, fol. 12r.

Newton's second rule is "To assigne but one meaning to one place of scripture."[61] These two rules bear similarity to Newton's first two rules of reasoning in philosophy as laid out in the *Principia*.[62] Newton's rules for interpretation illustrate that Newton's desire to avoid speculative hypotheses was present not just in the arena of dealing with the cause of gravity, or in challenging Huygens, Descartes, and Hooke's approach to investigating natural philosophy. Newton's epistemic prescriptions carry over into textual interpretation as well. He writes:

> This language so far as I can find, was as certain & definite in its signification as is the vulgar language of any nation whatsoever: so that it is only for want of skill therein that Interpreters so frequently turn the prophetic types & phrases to signify what ever their ffansies & Hypotheses lead them to.[63]

In textual analysis, Newton wanted to rely as much as possible on clear cut cases, inductively generalize interpretative rules, and apply these interpretative rules to less certain cases. The way to do this was the extensive cross-comparison of many passages, finding cases where the meaning of a symbol is clear, and applying it to a case where the meaning is left unspecified.

Newton employed a similar approach in his chymical studies. In the alchemical tradition, chymical procedures were standardly coded into images, symbols, figurative language, and *decknamen*.[64] Newton's alchemical investigations involved time-intensive analysis of many different texts in order to reveal their intentionally secretive meanings.[65] Greenham argues that Newton's approach to textual interpretation of alchemical manuscripts shared with prophetic interpretation what he calls a descriptive-translational approach: symbols were to be approached not as metaphors or allegories, but as coded language that needed to be converted into a literal, plain descriptive meaning.[66] Just as Newton used cross-comparison of texts in prophecy, Newton cross-compared alchemical manuscripts in much the same way to identify the referents of figurative and symbolic alchemical language with specific chymical products or intermediary results of a given procedure.[67] The difference between prophecy and alchemical studies, Greenham notes, is that prophecy can only be done with textual cross-comparison, whereas in alchemy, Newton was able to go back and forth between the library and the laboratory in order to iteratively and interactively refine an interpretative scheme for alchemical symbolism. The observationally accessible material facts of how metals and minerals behaved on the workbench allowed for inferences about the referents of *decknamen* and figurative processes. The textual hermeneutics in Newton's alchemy is somewhat complicated by the fact that Newton believed that the "authentic adepts" of alchemy "would not use the common *Decknamen* of the day in a

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[61] Yahuda Ms. 1.1, fol. 12r.
[62] Snobelen, 2001; Ducheyne, 2012, pp. 264-269.
[63] Keynes Ms. 5, fol. Ir.
[64] Principe, 2012, p. 215.
[65] Greenham, 2015, chapter 1; Newman, 2019, pp. 24-36.
[66] Newton scholarship in the past has tended to think of Newton as a scientist who brought scientific-mindedness to humanistic study. This picture is in part evidenced by the apparent lack of interest Newton displayed in the humanities in his early notebooks. Greenham, however, argues that Newton adeptly followed in a tradition of humanist scholarship: Newton's notebooks and dog-earing of books are best understood as an informed, Newtonian development of "commonplacing" and indexing techniques, as well as other humanist methods developed in the 17th century academy. See Greenham chapter 3, section 3. Greenham also suggests that the Protestant tendency for looking for a literal translation of scripture from the original language and Newton's descriptive-translational approach share common origins in this humanist tradition of textual hermeneutics. C.f. Peter Harrison (2001), who sees Newton's textual hermeneutics as a result of his Protestantism.
[67] Greenham, 2015, p. 193.

rigid, standardized way"[68]; attention to subtle features of the text fixed the multiple potential meanings of a term. Regardless, the decoding of texts was not to be done by hypothesizing meanings, but by the cross-referencing of facts derived from the library and the laboratory.

4.3. Textual Interpretation in Chronological Studies

Virtually all of the points just made about Newton's textual methods apply to his use of texts in the context of chronology. The vast majority of Newton's writings on chronology—from his earliest notes and draft materials to his *Ancient Kingdoms Amended*—is spent showing how to relate different king lists, genealogies, writings by historians, myths, poems, and other historical records with one another. In various drafts and notes to the 'Origines' for example, Newton discusses figures from mythology spanning from Electra, Medusa, Bacchus, to Egyptian gods such as Isis and Amun.[69] He weaves these figures into profane history by identifying them with one and another, and explaining how they were real individuals, who were deified by different cultures. Newton adopted a Euhemeristic stance, treating mythological stories as a preserved memory of real historical persons and events.[70] Much time is spent on identifying heroes and Gods from Greek and Egyptian myths with Noah and his descendants. Newton, following the Biblical exegete Bochart, identifies Saturn with Noah.[71] He also relates different generations of Noah's descendants to Hesiod's four ages of man. He strives to find ways to map familial relations onto one another in a self-consistent manner, sometimes appealing to etymological arguments:

> The word Chanaan just like the word Hamon is supplied with a grammatical termination. The basic word is Chana humble...and in contracted form Chna. Therefore Osiris is the brother of Chanaan and therefore son of Cham.[72]

In addition to identifying persons with one another, Newton also looks to more figurative myths and attempts to translate this figurative language into literal descriptions of historical events. Thus, Newton in chronology also employs Greenham's descriptive-translational approach.

In Newton's effort to translate figurative language, Buchwald and Feingold argue that Newton employs the "Newtonian Style" in his development of an interpretive scheme.[73] The Newtonian style involves 1) idealizing the system being explored, 2) idealizing in a way that allows for discrepancies between the idealized system and the observed system to reflect details that make a difference in the target system being studied, and 3) using these discrepancies to guide iterative de-idealizations of the model.[74] Newton seems to utilize this type of reasoning in his interpretation of historical records by first crafting general associations between figurative symbols and meanings. Though Buchwald and Feingold do not note it, Newton establishes these general associations by inductive generalization; that is, by finding clear-cut cases of associations and generalizing to interpretative principles. He then applies these principles to particular cases, refining the exact meaning by paying careful attention to multiple texts. For example, first,

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[68] Newman, 2019, pp. 181-182.
[69] E.g., New College Ms. 361(3).
[70] Euhemerism is the position that myths are retellings of profane history, in which humans are deified. Euhemerism was prevalent in Newton's milieu, and Newton himself was an avid Euhemerist. See Manuel, 1963, p. 106; Buchwald and Feingold, 2013, p. 156.
[71] Yahuda Ms. 17.2, fol. 10r.
[72] Yahuda Ms. 17.2 fol. 2v.
[73] Buchwald and Feingold, 2013, p. 4.
[74] See Smith, 2014 for an in-dept exposition of this iterative process.

Newton looks at ancient Greek and Egyptian myths and identifies cases where mythic floods are explicitly used to figuratively represent invasions by another country. He then generalizes to the principle that floods refer to invasions. He then looks at historical passages to see how to identify particular historical invasions with particular flood language: "...Deucalion's flood for the invasion of Greece by the armies of Sesostris in the reign of Deucalion."[75] Rulers, invaders, and other actors involved in these particular events can then be identified across different accounts from different cultures. Different timelines can then be aligned and mutually corrected.

While the above analysis is correct, Buchwald and Feingold argue that the evidence for Newton's textual interpretative scheme comes from the "synchronization" of many different texts.[76] What Buchwald and Feingold mean by synchronization as a source of evidence is not entirely clear, although it would seem they have in mind both a form of coherence and consilience testing.[77] While this type of evidential reasoning may well have been persuasive for Newton as he constructed his interpretive scheme, I argue that he actively pursued a higher epistemic standard: namely, that of supporting particular textual interpretations via demonstrative induction. In particular, he pursued the kind of demonstrative induction that I have already outlined: demonstrative induction that only employs premises able to receive, at a minimum, inductively generalized support, and premises that were not conjectures about history itself. That is, Newton was not solely looking for an interpretative scheme that could make sense of many different texts. He was looking for clear enough cases that could inductively support textual interpretative principles—hoping to attain enough interpretative principles to arrive at definitive, singular, and deductively derived interpretations of particular texts that then entail chronological facts. The development of Newton's chronological writings over time show Newton adopting increasingly more principles in pursuit of this goal. These principles serve to constrain the interpretation of historical texts more and more so as to arrive at a more conclusive chronological timeline. In each case, the principles are supported by inductive generalization and concern first and foremost the interpretation of texts, not chronological posits themselves. I now review several examples of the kinds of general interpretative principles Newton adopted.

First, as we have already seen, Newton adopted a Euhemerist assumption.[78] This assumption licensed him to look for the real-world historical basis of mythological texts. This position was fairly common among scholars of the day. But Newton offered inductive support: he cites Galileo's naming Jupiter's moons after the Medici as an example of a deification of a political figure: "The worship of Gods seems to have begun in this way. The ancients gave the names of their ancestors to the Planets and Elements in the same way as Men have been depicted in the Constellations, & Galileo named the stars that circle Jupiter Medicean in honour and memory of his benefactors, and others have recently transferred to the Moon the names of very famous men."[79] Newton argued it was therefore likely also common in the past that political figures were elevated, and in time, mythologized.

We also see in Newton's earliest writings an effort to assess the trustworthiness of authors, to accept or dismiss their records: "The names of the Assyrian kings were frequently compounded of Assar, Adon, Pul, & such other words as occurr not in the names of the kings

[75] New College Ms. 361(3), fol. 163r.
[76] Buchwald and Feingold, 2013, p. 156.
[77] See Bokulich, 2020, for a discussion of the differences between calibration, coherence, and consilience testing in the measurement of geological timescales. Bokulich explicitly connects her ideas to Smith, 2014, and his analysis of "closing the loop" testing and so is particularly relevant here.
[78] Buchwald and Feingold, 2013, p. 156.
[79] Yahuda Ms. 17.2, fol. 14r.

which Ctesias hath set down in his list, & therefore that list can scarce be genuine."[80] Newton is here inductively generalizing typical names of the Assyrian kings, and dismissing Ctesias' list on the basis of its incompatibility with this generalization.

In later writings, such as *Ancient Kingdoms Amended*, we see Newton adopting much stricter principles that license him to dismiss greater amounts of textual reports. For example, Newton's chronologies trace the "introduction of letters" to different cultures. These datings allow for the application of the following principle:

> ...and yet before the use of letters, the names and actions of men could scarce be remembred above eighty or an hundred years after their deaths: and therefore I admit no Chronology of things done in *Europe*, above eighty years before *Cadmus* brought letters into *Europe*.[81]

Unlike in his earlier writings, Newton at this point is no longer making claims about the earliest ages, as he believed his epistemic access to such times was too limited. Newton pointed to Greek authors stating that their own knowledge of the earliest times of their own culture was mainly speculation. Newton concluded, "for the Europeans had no Chronology ancienter then the Persian Monarchy. And whatever Chronology we have now of ancienter times has been framed since by reasoning & conjecture."[82]

Newton also appealed to the common tendency of cultures to inflate their own antiquity as evidence for his principled dismissal of speculations on early times. Newton writes, "Now all nations before they began to keep exact accompts of time have been prone to raise their antiquities & make the lives of their first fathers longer than they really were."[83] And elsewhere writes, "By putting Reigns and Successions equipollent to Generations, and three Generations to an hundred or an hundred and twenty years (as appears by their Chronology) they have made the Antiquities of *Greece* three of four hundred years older than the truth."[84] This interpretive assumption allowed him, for example, to disregard the claim by the Egyptian priests made to Solon (as reported by Plato in the *Timaeus*), that the story of Atlantis occurred 9,000 years prior.[85] Without a principled way to dismiss Plato's second-hand dating of the Atlantis story, Newton would have had trouble synchronizing this account into his general historical timeline. Along this same vein, Newton also adopted the principle that it was common for chronologers to "double" the same historical personage in different ages, licensing Newton to contract historical timelines and identify different individuals from different ages as one and the same.

Newton also came to the belief that prose writing was to be considered more trustworthy than non-prose writing. "The *Greek* Antiquities are full of Poetical Fictions, because the *Greeks* wrote nothing in Prose, before the Conquest of Asia by *Cyrus* the *Persian*."[86] The justification of this principle is possibly that Newton viewed prose writing as more recent and therefore more reliable. Newton frequently noted that knowledge of the past diminishes the further back one goes.[87] This inductively generalized observation seems to justify many interpretive principles.

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[80] Yahuda Ms. 7.3i, fol. 2r.
[81] Newton, 1728a, p. 7.
[82] Keynes Ms. 146, fol. 14r.
[83] Keynes Ms. 146, fol. 14r.
[84] Newton, 1728a, p. 3.
[85] Ibid.
[86] Ibid.
[87] Keep in mind that, for Newton, *access* to the more distant past was more limited, but the knowledge itself that was possessed by peoples of the more distant past was less corrupted.

These principles are then in turn applied to establishing cases as more or less reliable regardless of their recency—e.g., dismissing relatively more recent poetic writings.

The idea with these textual interpretative principles is always to eliminate alternative hypotheses, ideally so that Newton is left with a single chronological conclusion. In this way, Newton can turn what would otherwise be an inductive inference into a deductive inference. By doing so, the inductive risk is confined as much as possible to systematic principles of textual interpretation, which stand themselves on inductively generalized support. In this sense, Newton is attempting to avoid hypotheses in chronology.

The final result of this lofty methodological goal may appear to us less than satisfying. The textual interpretative principles seem too crudely supported, and fail to really eliminate enough alternative readings so as to provide a deductive inference to singular chronological conclusions. Additionally, one might object that the distinction between making textual interpretative hypotheses and chronological hypotheses is not particularly meaningful. Is identifying the Egyptian king Sestros with the Biblical pharaoh Sesac an interpretative hypothesis and not a chronological hypothesis? Evidently, Newton was not satisfied with this approach either, as the developments of his research show an undeniable attempt to find more sure methods of arriving at chronological conclusions than those afforded by textual interpretation approaches alone.

Despite qualms the contemporary reader may have with Newton's use of texts, we see Newton refraining from specifying many details of early history that his contemporaries speculated on.[88] Faced with the lack of records of the ancient past, Newton responded that "the best way to come to any certainty therein, is to begin with the later times where history & chronology is certain, & reccon upwards as high as we can proceed by any good arguments."[89] Even in his seemingly speculative use of texts, Newton's aim was to avoid, as much as possible, conjecturing any chronological hypotheses.

5. Biology and Social Scientific Assumptions

Recall Newton's claim to "make Chronology suit with the Course of Nature."[90] Newton developed two models that played an important role in the transformation of his chronology to an abbreviated timeline: a model of average reignal length, and a qualitative model of the stages of development of human societies. This latter model is the main concern of a 1702 manuscript entitled *The Original of Monarchies*.[91]

Newton looked at the lengths of monarchical rules for cases where he had reliable information, such as the monarchs of England:

> The thirty Kings of *England*; *William* the Conqueror, *William Rufus*, &c. Reigned 648 years, which is $21\frac{1}{2}$ years a-piece. The first twenty four Kings of *France*; *Pharamundus*, &c. Reigned 458 years, which is 19 years a-piece.[92]

He drew from this data upper and lower bounds for *average* reignal lengths—that is, bounds for the ratio of the total reign of multiple monarchs over the number of monarchs.[93] Establishing upper and lower bounds for such a number allowed him to take king lists from more

[88] Buchwald and Feingold, 2013, p. 146, 409.
[89] Yahuda Ms. 8.1, fol. 6r.
[90] Newton, 1728a, p. 5.
[91] Keynes Ms. 146. Date of Ms. calculated by Buchwald and Feingold, 2013.
[92] Newton, 1728a, p. 52.
[93] Buchwald and Feingold, 2013, pp. 300-305.

distantly past times and revise the total length of time that a set of rulers could have reasonably ruled:

> Thus the *Greek* Chronologers...have made the Kings of their several Cities, who lived before the times of the *Persian* Empire, to Reign about 35 or 40 years a-piece, one with another; which is a length so much beyond the course of nature, as is not to be credited. For by the ordinary course of nature Kings Reign, one with another, about eighteen or twenty years a-piece: and if in some instances they Reign, one with another, five or six years longer, in others they Reign as much shorter: eighteen or twenty years is a medium.[94]

Subsequent revision in turn allowed for a conclusion about the approximate length of various Kingdoms and Empires. Newton is here deriving his model from observable and reliable data, inductively generalizing, and applying it to less certain cases. The generalization is licensed by facts about biology and sociology—the same biological and sociological facts that made it unreasonable for a series of monarchs in early middle age England to have ruled for longer than a given period of time apply everywhere throughout time, including during the time of the rulers of ancient Assyria and Egypt (e.g., human life span has an upper bound). These inferences are fallible. Nevertheless, by using this kind of argument, Newton is exporting the inductive risk away from specific and speculative claims about the past, and to the domain of bio-social regularities. Newton is not positing a historical timeline and supplying supportive evidence. He is instead adopting more general claims about "the course of nature" in order to deductively entail specific chronological facts (in this case, a range of dates).[95] The former are generic facts about societies, just as Book 1 of the *Principia* concerns generic relationships between forces and motions.

Next, Newton also developed a model of the "origin of civilization." A central debate within chronology during Newton's day concerned population growth, and in particular, how to square the account of scripture with reasonable models of population growth.[96] While some scholars opted for extending the length of history to allow for the apparent population growth that occurred seemingly so soon after Noah,[97] Newton arrived at an *abbreviated* historical timeline, and instead argued that societies early on were significantly smaller in population than typically imagined.[98] For example, Egypt at the time of Jacob and his family's emigration could only have been a few hundred people. And Nineveh at the time of Nimrod and the construction of the Tower of Babel likewise could not have been a large metropolis. As evidence of Egypt's low population at the time of Jacob, Newton noted that Jacob's entourage of about 70 people grew to rival the Egyptian population by the time of Moses, only a few generations later, and that this would only be possible if Egypt's initial population was in the hundreds, not thousands. While other scholars employed mathematical models of population growth to reason about chronology, however, Newton avoided making overly specific quantitative assumptions about population growth.[99] He instead developed a qualitative model of the stages of civilization growth. Buchwald and Feingold schematize this model as follows: growth in population leads to towns, growing towns result in assemblies of 'fathers' that produce 'laws,' which results in the need for judges, then towns with courts and judges evolve into cities, villages emerge

[94] Newton, 1728a, p. 52.
[95] E.g., Keynes Ms. 146, fol. 5v.
[96] Ibid.
[97] Ibid.
[98] Newton, 1728a, pp. 3-6.
[99] Buchwald and Feingold, 2013, pp. 188-194.

surrounding cities, then city judges enlarge their authority, the office of judge transforms into that of a king, kingdoms enlarge by conquest or merger.[100]

Buchwald and Feingold again emphasize the use of the Newtonian Style: Newton crafts an idealized model and then fine-tunes it in light of observation. I argue that this model is also a non-chronological model that allows for deductive inferences about chronology. Further, it meets my two restrictions: 1) this model is a general model of the stages of transition of social groups from towns into cities into expansionist empires, and not a claim about the dating or ordering of specific events, and 2) the evidence for this model is inductive generalization. Newton based this model on better-known historical occurrences, such as the development of the Roman empire, and in some ways most apparently, on ancient Israel.[101]

Applying this model to other civilizations deductively entailed a variety of results: most importantly, that each civilization would need to pass through each stage in order. Since each stage was associated with various defining properties, identifying the presence of one of these properties could determine what stage a particular civilization was in at a particular time. From this information follows more: such as bounds on population size and the civilization's prior duration. For example, in reference to the city of Nineveh at the time of Nimrod, Newton notes that "before the days of Jonah, the Bible never referred to the rulers of the city as 'kings of Assyria; only as 'kings of Nineveh.'"[102] Newton also notes that after the fall of the later Assyrian empire (the one that harassed the Kingdom of Israel), the cities under its rule quickly reverted back to autonomous city-states, suggesting that before this late coming empire, Assyrian rule never progressed past the stage of city-states.

This evidential reasoning might appear to be the method of hypotheses; the "hypothesis" of a low population in Assyrian territory before a certain date makes certain predictions that seem to be confirmed by Biblical passages. But in fact what we are seeing is a deductive inference facilitated by the assumption of Newton's qualitative model of civilization stages.

Harper analyzes Newton's deduction from the phenomenon of universal gravitation in terms of establishing systematic dependencies (if and only if relations) that allow for measurements to set parameters. For example, in Book 1 of the *Principia*, Newton establishes that the rate at which areas are swept out by a radii to a center increases iff the direction of centripetal force is off-center in the direction of motion, decreases iff the direction is off-center in the opposite direction, and constant iff the direction is to the center. Thus, observing the rate of sweeping *measures* the direction of force. Harper refers to this as a "general methodology in which phenomena constrain theory to approximations established by measuring parameters."[103]

With the above examples, I argue that we see a similar effort in chronology: sociological conditions, such as the presence of rulers over individual cities, measure which particular stage a civilization is in, and these in turn entail approximate population sizes, the ability to maintain armies of certain approximate sizes, and other facts.[104] Thus, a model of social change, based on inductive generalization, allowed Newton to use historical data to deductively entail chronological facts.

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[100] Buchwald and Feingold, 2013, p. 196.
[101] Keynes Ms. 146, fols. 1r-4r and 12r-14r.
[102] Buchwald and Feingold, 2013, p. 198 draw attention to this passage; Keynes Ms. 146, fols. 5v-6v.
[103] Harper, 2016, p. 230.
[104] Additionally, Newton seems to permit hypothetical inductive evidence (i.e., observing the above entailments witnessed in texts) if it adds further confirmation to a proposition already deduced from the phenomenon—that is, if it serves as supplemental rather than primary evidence for a proposition. Smith, 2014, makes the same point about Newton's evidential reasoning in gravity research.

The fact that Newton avoided precise quantitative assumptions about laws of population growth—unlike his contemporaries—and instead opted for a qualitative model of stages of civilization is telling. There was little reliable data concerning rates of population growth in the past.[105] Further, Newton may have believed that there was little reason to think that population growth rates are uniform across time enough to license inductive generalizations. Alternatively, the successive transition through qualitative stages was documented in several cases in similar ways. Thus, the latter provided a more reliable model to facilitate a determination of the nature of different societies at different times.

6. Astronomical Assumptions

Lastly, Newton ultimately comes to anchor his chronology on the basis of inferences facilitated by astronomy. In particular, Newton leveraged the precession of the equinoxes to turn astronomical reports from antiquity into evidence for chronological claims. Newton examined historical descriptions of the position of asterisms (notable patterns of stars) relative to the equinoctial colure: "Hipparchus tells us, that Eudoxus...drew the Equinoctial Colure, through the left hand of Arctophylax, and along the middle of his Body, and cross the middle of Chela, and through the right hand and fore-knee of the Centaur, and..." (this goes on for a while).[106] The relation of stars to the celestial colures changes over time due to precession, and so Newton was able to calculate backwards when the night sky would have appeared as such, given a precession rate of around one degree per 72 years. Newton did the same for astronomical references in Hesiod and in remarks by Pliny the Elder about Thales.[107] Ultimately, these datings provided a way to calibrate his timeline by anchoring events to approximate dates derived from astronomical computation. Newton also pointed to the fact that his astronomical arguments from different historical records from different time periods resulted in datings that agreed with one and another.[108]

Nevertheless, using the precession of the equinox to date past events is a demonstrative induction. There are only a handful of parameter values needed for such a dating: the placement of the equinoctial colures relative to the fixed stars at the time being dated, the current placement of the colures, and a rate of precession. Given the truth of the premises, the conclusion about dating follows deductively. The last two of these were known from observation. The first value required textual interpretative assumptions.[109] Compare Newton's use of astronomy to that of the influential chronologer Scaliger. Scaliger predated Newton in using the precession of the equinox to try to date historical events.[110] Newton, however, used descriptions of the equinoctial colures, which are latitude-independent, whereas Scaliger used latitude-dependent celestial

[105] Buchwald and Feingold, 2013, pp. 176-194.
[106] Newton, 1728a, p. 83.
[107] Ibid.
[108] Ibid.
[109] Buchwald and Feingold, 2013, chapter 8, stress that the process of extracting astronomical information from ancient records required hefty interpretative choices. Namely, Hesiod, the remarks by Pliny, and Aratus' poem do not give astronomical information in the form of mathematized coordinates, but in the main form of constellation positions in the sky. For example, a passage from Aratus might describe the equinoctial colure passing through the hand and foot of a particular constellation. Newton had to make assumptions about how to map such points within a constellation onto particular stars—which, as Buchwald and Feingold note, requires an assumption that such areas of the described constellations do in fact map onto particular stars, and not just areas of the sky. Buchwald and Feingold also once again stress the historical novelty of Newton's mathematical-scientific use of data—e.g., using averages in order to cancel out observational error.
[110] Grafton, 1975, p. 163.

markers.[111] Newton's astronomical dating therefore did not require any historical assumptions about the latitude of the astronomical observations being dated. From any perspective on evidence, Newton's dating strategy is advantageous compared to Scaliger's as it requires less auxiliary hypotheses and hence less risk. But once again, Newton is specifically avoiding conjectures about history, and instead confining inductive risk as much as possible to the more secure arena of astronomy. Newton evidently found his astronomical arguments to provide a more firm foundation for his chronology. His final works on chronology are built around a timeline anchored by fundamentally astronomical results.

7. Religious Assumptions?

It is illustrative to now look at an example of a domain that Newton did *not* use to derive his chronological scheme. Although Newton was devoutly religious, believed in God, and held to the idea of a Prisca Sapientia—a lost knowledge that existed before it was corrupted by history—these beliefs do not appear to enter into the premises of Newton's inductive inferences in his chronological investigations. They are, if anything, conclusions established by these inferences.[112]

Feingold writes that for Newton, the authority of scripture was due mainly to its antiquity, rather than its inspiration.[113] Scripture—whether the Masoretic texts, Septuagint, or otherwise—was not assumed to be infallible—quite the opposite, it was already the result of corrupted knowledge.[114]

The evidence for the Prisca is complicated. For the early modern thinker, there was no shortage of inductive evidence for the nonmonotonicity of Western knowledge. The vast majority of writings from antiquity had been, and were still, lost to the Latin West, even after the reintroduction of important works brought back from the Byzantine and Islamic worlds.[115] The sliver of extant material indicated impressive learning. Pre-Socratic atomist and heliocentric beliefs provided particularly salient examples for Boyle, More, and Newton: before lapsing into Aristotelianism, ancient thinkers were in possession of truths only now being rediscovered.[116]

Additionally, Newton found in his historical research evidence for the diffusion of both religious and natural philosophic knowledge through various cultures. Newton pointed to myths, cultic practices such as widespread Vestal worship, as well as the use of (in his mind, superior) lunar-solar calendars before the adoption of solar or lunar calendars.[117] Tracing this diffusion, Newton concluded that this knowledge was inherited by both ancient Egypt and ancient Israel from a common origin, which he identified as coming from Noah and his descendants. From Egypt and Israel, this (degenerating) knowledge passed to Greece, Persia, and other cultures. The

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[111] Buchwald and Feingold, 2013, p. 249.

[112] This is obviously not to say that Newton drew conclusions about religion only from chronology. Newton, for example, believed that God's necessary existence was evident from the order of nature (e.g., celestial phenomena) and the principles of natural philosophy; Iliffe, 2017, pp. 77-103.

[113] Feingold, 2013, p. 531. Not that inspiration was absent from Newton's epistemology: "search the scriptures thy self & that by frequent reading & constant meditation upon what thou readest, & earnest prayer to God to enlighten thine understanding if thou desirest to find the truth," Yahuda MS 1.1 fol. 2.

[114] Feingold, 2013, p. 526. Schilt, 2021 (e.g., p. 228) emphasizes that Newton viewed prophetic writings as the more reliable among scripture, as opposed to scriptural documentation of secular history. See also Manuel, 1974, pp. 84-88.

[115] Grant, 2007, chapter 6.

[116] See Iliffe, 2017, chapter 6; Haycock, 2002, chapter 6.

[117] Newton, 1728a, pp. 71-79.

point here is simply that Newton's chronology did not assume a Prisca, but rather argued for it, using the same evidential reasoning that we have been discussing.

8. Conclusion

I have argued that Newton avoids, as much as possible, conjecturing chronological claims. He does so by adopting premises from different domains, supported by inductive generalization, in order to eliminate alternative chronological hypotheses. Throughout his work, he attempts to develop powerful methods of deductively concluding historical claims. The advantage of this approach is that it either depends on secure results, or else confines inductive risk to claims that can be supported through a restricted form of induction.

While I have argued that Newton appeals to the results of particular disciplines in order to arrive at more certain results in others, I do not mean to suggest that for Newton there is a clear hierarchy of disciplines. Rather, all disciplines—even mathematics—have more certain subdomains and less certain ones.[118] Careful analyses, I believe, will show Newton to be exploiting the certain parts of various domains to infer more securely into the less certain parts of another domain. This can be seen particularly well with Newton's theology. Greenham, building on Janiak's analysis of Newton's divine metaphysics, contrasts it with what he, following Harrison's framework, describes as physico-theology.[119] In the former, a priori theology—e.g., necessary aspects of the nature of God and God's relationship to the world—entails results about metaphysics, such as the nature of forces and motions. In the latter, contingent empirical facts established from natural philosophy are then used to draw conclusions in theology—e.g., Newton's "God of the gaps" style design arguments. This situation is a clear illustration of Newton's criss-crossing interdisciplinary inferences.

Ever since the Sotheby sale of Newton's papers, the relationship of Newton's different disciplinary interests—particularly his "naturalistically acceptable" interests and his religious and esoteric interests—has been a hotly contested issue. I take it that the interesting question here is not about Newton's psychology—whether Newton believed his religious and scientific pursuits to be related—but is instead about the inferential links between these domains.

The current state of play concerning the different disciplinary interests of Newton is that there is prima facie no grand unified connection between *all* of Newton's activities, in terms of content or method.[120] The recent trend has been to emphasize the differences in his methodologies between disciplines, noting that Newton showed characteristic adeptness in "wearing the hat" of whatever field he did work in.[121] The general received view at this point grants that the common denominator of Newton's work is his at least stated desire for attaining

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[118] Guicciardini, 2016, pp. 405-408, makes this point about mathematics for Newton.

[119] Janiak, 2008; Harrison, 2005; Greenham, 2015, p. 236.

[120] "Prima facie there are far more dissimilarities than similarities between Newton's style of argument and use of evidence in, say, mathematics and in Church history. As things stand, it is impossible to see how such radical differences can be subsumed under the same general approach. The fact that Newton deployed distinct modes of proof and rhetorical strategies in these fields of enquiry is hardly surprising, since each field or discipline had its own practices and styles of argument. Indeed, it was surely a mark of his greatness that he was able to very quickly attain technical expertise in a variety of intellectual traditions that had very different requirements in terms of argument, use of evidence, and style of demonstration. It is worth adding that Newton himself recognized a strict compartmentalization in his approach to distinct disciplines, and frequently cautioned against mixing approaches and demonstrations that were appropriate in one domain with those that were appropriate in another." Iliffe and Smith, 2016, pp. 28-29.

[121] Ibid.

as much certainty as permitted in his studies.[122] Detailed work must be done showing a specific connection between some area of Newton's work and another, as opposed to a Grand Unified Theory of Newton. As already reviewed, there has been excellent work in this vein by Greenham showing the connection between Newton's theology and chymistry, by Guiccardini on musical harmonies in Newton's reasoning about physics, and Janiak on the connection between Newton's theology, metaphysics, and natural philosophy.[123]

My examination of Newton's strategy of "exporting" inductive risk in chronology points to a pattern of inductive inference that has applicability across many of Newton's disciplinary pursuits. My analysis helps explicate the way in which Newton can be said to be avoiding conjecture, in a way that is not specific to a particular discipline. Further, it is itself a claim about Newton's belief in a need to cross-fertilize between different domains.[124]As such, my examination sets the stage for future analyses of the relationships between Newton's different disciplinary interests. I believe future analyses will continue to show "complicated, non-hierarchical, entangled relations of inductive support"[125] between Newton's different epistemic activities. Just as Newton extensively cross-referenced and synchronized texts, his inductive strategies suggest that he similarly synchronized the results of different disciplines. Additionally, the picture painted here reinforces the point that Newton did not merely apply scientific-mindedness to his humanistic studies but used the methods most appropriate to each situation to weave together as complete a theory as possible from the book of Nature.

Newton scholarship has come a long way from viewing Newton as the "last of the magicians."[126] This characterization came in part out of a view of alchemy as entangled with religion and magic.[127] Today, Newton's alchemy has been shown to be, in fact, nearly devoid of any religious or "magical" content.[128] His investigations of metals and minerals turn out to be yet further examples of Newton's characteristically rigorous method of empirical investigation.[129] No longer a magician, Newton might appear to be merely an early modern chymist who happened to hold heterodox Christian beliefs.

Yet we should not be too quick to lose sight of the fact that Newton did participate in an esoteric tradition. Newton's connection to this tradition is not so much through his interest in chymistry, however, or even primarily through his theology—but through his view of history. History involves the corruption of a true philosophy and religion disseminated through Noah's descendants. It involves the transmission and preservation of a Prisca Sapientia, for those who are able to find it and uncover it.[130] This view of history is not Newton succumbing to "irrationality" or "superstition," but is instead supported, as I have argued, by the same kind of principled investigative strategy that Newton employs in his most celebrated sciences.

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[122] Ibid.

[123] Greenham, 2015; Guiccardini, 2013; Janiak, 2008.

[124] This conclusion dovetails nicely with Ducheyne, 2005, who argues for the centrality of what he terms Unification_2 in Newton's methodology. Unification_2 involves extending a principle from one domain to another based on the assumption of uniformity in nature—such as applying laws governing celestial bodies to terrestrial objects. I am grateful to an anonymous reviewer for highlighting this connection.

[125] Norton, 2024, p. 206.

[126] Keynes, 1978, pp. 363-364.

[127] See Principe, 2012, chapter 4 for a discussion of alchemy's 19th and 20th century reinterpretation as a practice that was first and foremost about the religious transformation of the alchemical practitioner. See also Copenhaver, 2015, for a discussion of James George Frazer's distorting influence on the conception of magic in the 20th century.

[128] Newman, 2019.

[129] Ibid.

[130] See Hanegraaff, 2012, for a contemporary scholarly account of esoteric currents throughout history.

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