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**INTERPRETING ARISTOTLE'S
METEOROLOGICA I 7.344a5-8 IN RENAISSANCE
AND EARLY MODERN PHILOSOPHY**

Abstract

This paper focuses on Renaissance and early modern readings of Aristotle's *Meteorologica* I 7.344a5-8, showing how the various interpretations of this passage were foundational for the establishment of an epistemology based on hypotheses and conjectures, and how this passage informed major philosophical and scientific elaborations of the time, extending its influence beyond the original field of application. The paper considers authors such as Alexander of Aphrodisias, Philoponus, Nifo, Pomponazzi, Wurstisen, Descartes, Galileo, Charleton and Boyle.

Keywords

Aristotle, Meteorology, Hypotheses, Conjectures, Epistemology

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1. An Ambiguous Passage

This paper¹ focuses on Renaissance and early modern readings of Aristotle's *Meteorologica* I 7.344a5-8, showing how the various interpretations of this passage were foundational for the establishment of an epistemology based on hypotheses and conjectures, and how this passage informed major philosophical and scientific elaborations of the time, extending its influence beyond the original field of application. Since a great deal has been written on the topic of hypotheses and hypothetical knowledge in early modern philosophy, it is important to narrow the boundaries of the present research.²

First of all, and in general, this paper does not deal with the use of scientific hypotheses in itself, but rather with how Renaissance and early modern thinkers hark back to Aristotle's exact statement to legitimise their epistemologies.³ The kind of hypothetical and conjectural knowledge under investigation should not be confused with other forms of knowledge based on hypotheses understood as presuppositions or principles, like mathematics. It characterises, more specifically, a form of provisional knowledge, which could be considered reliable in the explanation of natural phenomena.

For this very same reason, the paper does not focus on the debate about how "to save the phenomena" (σώζειν τὰ φαινόμενα), which concerns an applied branch of mathematics, that is, astronomy. This issue marks a sharp distinction between astronomy and natural philosophy at least until the Renaissance. Astronomers' hypotheses were considered to be mathematical fictions useful in three regards: for the purpose of making the celestial motions accessible to calculations; for computing the entries in astronomical almanacs; and for saving what is manifest to sensation in the heavenly bodies. While hypothetical, the provisional and conjectural knowledge considered in this paper deals with real, physical causes of nature, for which an effect

¹ A shorter version of this paper was presented at the workshop "Proof in Natural Philosophy. Between Antiquity and the Early Modern Period", Prague, 19-21 May 2022. All translations are mine unless otherwise stated. I would like to thank the two reviewers for their comments and suggestions to the text.

² In his seminal study, Craig Martin has emphasised how Aristotle's words shaped the definition of meteorology as a science in the Renaissance, and how it was relevant for the making of an "epistemology of meteorology". See Martin (2009); Martin (2011).

³ For the method of hypothesis in science, see Laudan (1981).

should in theory be the product of a single cause or a specific group of causes, and with something that is not manifest to sensation. The problem is about the certainty of such causes as causes of effects.⁴ For any set of sensory experiences, there might be an infinite number of hypotheses and conjectures consistent with that experience. Some would call this the problem of under-determination.

In the English translation prepared by E. W. Webster in 1931 for W. D. Ross's edition of Aristotle's works, *Meteorologica* I 7.344a5-8 (Fobes) reads as follows:

We consider a satisfactory explanation of phenomena inaccessible to observation to have been given when our account of them is free from impossibilities. The phenomenon available suggests the following account of the matters in question.⁵

Jonathan Barnes's canonical edition maintained the same translation without changing a word. The English version, however, is somewhat poor and misleading since it does not give a full account of Aristotle's thought, especially in comparison to the original passages in Greek, which runs:

ἐπεὶ δὲ περὶ τῶν ἀφανῶν τῇ αἰσθήσει νομιζομένῃ ἰκανῶς ἀποδεδείχθαι κατὰ τὸν λόγον, ἐὰν εἰς τὸ δυνατὸν ἀναγάγωμεν, ἕκ τε τῶν νῦν φαινομένων ὑπολάβοι τις ἂν ὧδε περὶ τούτων μάλιστα συμβαίνειν.

William of Moerbeke's medieval translation renders the passage in Latin:

Quoniam autem de immanifestis sensui putamus sufficienter demonstrasse secundum rationem, si ad possibile reduxerimus, ex hiis que nunc apparent, existimabit utique aliquis sic de hiis maxime accidere.⁶

This formulation became popular during the Renaissance with the Giuntine edition of Aristotle's works. Following the Latin version, we may attempt a more convincing English translation:

⁴ There were attempts in Arabic science and philosophy to make the astronomical hypotheses real, that is, to conflate mere conjectures to save the phenomena with physical causes, thus transgressing the boundaries between astronomy (mathematics) and natural philosophy. However, the distinction remained sharp up to Galileo and even beyond.

⁵ Barnes (1984) p. 562.

⁶ Minio-Paluello and Verbeke (1951) p. 22.

Since we consider that we have given a sufficient demonstration in accordance with reason about things that are not manifest to sensation if we have arrived at what is possible, then from the evidence available one could suppose that the following is largely the case with these things.

The passage seems reasonably clear, yet Greek commentators provide two different and competing interpretations. Alexander of Aphrodisias (II-III A.D.) finds Aristotle's sentence quite natural and somewhat irrelevant from an epistemological standpoint, and comments:

Now Aristotle himself undertakes to assign the causes of comets and similar things, and he says that those things which are not manifest to sensation we think that they are sufficiently demonstrated by reason when they are explained and nothing impossible follows [from them]. It is also not clear to sensation how comets and other similar things are generated.⁷

At first sight, Alexander's comment is unclear in its implications because in the first sentence what is not manifest to sensation seems to be phenomena like comets and similar, and not the causes of their generation, while in the second sentence what is obscure to sensation seems to be the causes of generation. However, Alexander uses two different terms to characterise the property of not being manifest. In the case of the phenomena, Alexander employs the expression τῇ αἰσθήσει ἀφανῶν, just like Aristotle, while for causes his phrasing is ἀδηλον δὲ τῇ αἰσθήσει. In the first case, phenomena are not observable or accessible to sensation, while in the second case only the causes remain obscure. It is likely here that Alexander is appealing to common sense by stating that for phenomena in the sky it is not possible to see with the same certainty what sensation perceives with sublunar things. Since these phenomena are not manifest, knowledge of their causes by means of

⁷ *Commentaria in Aristotelem Graeca* III 2, p. 33 (Hayduck): Ἐπὶ τὸ τὴν αἰτίαν αὐτὸς ἀποδιδόναι τῆς τῶν κομητῶν γενέσεως καὶ τῶν τούτοις ὁμοίων μέτεσι, καὶ φησὶν ὅτι ἐπεὶ περὶ τῶν τῇ αἰσθήσει ἀφανῶν τότε νομιζομένων ἰκανῶς ἀποδεικνύναι τῷ λόγῳ, ἐπειδὴν τοῖς δειχθεῖσι μηδὲν ἀδύνατον ἔπεται, ἀδηλον δὲ τῇ αἰσθήσει καὶ τὸ πῶς οἷ τε κομήται γίνονται καὶ τῶν ἄλλων ἕκαστον τῶν τοιούτων, ἐκ τῶν νῦν δοκούντων τε καὶ φαινομένων ἡμῖν οὕτως ἂν ὑπολάβοι τις ἔχειν τὰ κατ' αὐτὰ, ἢ ἐκ τῶν φαινομένων τε καὶ ὁρωμένων περὶ αὐτὰ οὕτως ἂν ὑπολάβοι τις γίνεσθαι τὰ κατ' αὐτὰ. Alessandro Piccolomini's translation of Alexander of Aphrodisias's commentary states: "Aggreditur nunc ipsemet assignare causas cometarum & his similibus, & inquit quod quoniam de his quae sensui immanifesta sunt, tunc arbitramur sufficienter demonstrari ratione, quando ad ea quae ostensa sunt, nullum sequitur impossibile. Immanifestum autem est sensui quomodo cometae & alia his generantur," see Piccolomini (1540) 7v.

sensation is thus also obscure. Because of their distance from the Earth, it is not possible to provide a reliable account of this kind of knowledge.

According to John Philoponus (V-VI A.D.) what is not manifest are causes, rather than effects. Phenomena in themselves are perfectly perceivable. Thus, about the explanation of comet formation, Philoponus writes that

since the cause of their coming to be is hidden from our senses, Aristotle says, those who are producing an account of them and all such matters, and are willing to investigate their natural causes, must give such accounts of them that will not entail anything impossible or contradictory to evidence. What he says is the following. If we bring our accounts of the comets to what is possible as far as the evidence is concerned, so that nothing impossible follows from them (as it does from the theories of comets stated by our predecessors), but on the contrary, our accounts are in accord and agreement with the facts – if this is the case – then we shall be stating the explanation as far as the evidence is concerned.⁸

Philoponus's exegesis is complex and pivotal for understanding the subsequent interpretations. According to him, causes of comets and of similar phenomena cannot be known through sensation. This sentence – as mentioned above in connection with Alexander – could mean either that from experience it is impossible to deduce the cause, or that sensation does not grasp the cause. The latter is a quite implausible reading since according to Aristotle causes are known only through the intellect and never by virtue of sensation. The sentence would mean, therefore, that no experience or observation can be the yardstick or grounds for scientific knowledge of causes. Since it is impossible to provide causal knowledge of phenomena from effects – of which Philoponus does not say whether they are manifest or not – then the only way to provide a reliable, even if not scientific, account in this respect is to produce an explanatory theory in such a way that it is not in contradiction with all the other data and evidence gathered by means of experience. This “not contradictory explanation” of the phenomenon works

⁸ *Commentaria in Aristotelem Graeca* XIV 1, pp. 89.32-90.9 (Hayduck): Λοιπὸν μέτεισιν ἐπὶ τὴν αὐτῶ δοκοῦσαν τῆς γενέσεως τῶν κομητῶν αἰτίαν, καὶ τίνα τρόπον μετιτέον τὴν περὶ αὐτῶν διδασκαλίαν, ἀπαγγέλλει. ἐπειδὴ γὰρ ἀδηλὸς ἐστὶ τῇ αἰσθήσει ἡμῶν ἢ περὶ τῆς γενέσεως αὐτῶν αἰτία, δεῖ, φησί, καὶ περὶ αὐτῶν καὶ περὶ πάντων ποιουμένους λόγον τῶν τοιούτων καὶ φυσιολογεῖν αὐτὰ βουλομένους τοιούτους ἀποδιδόναι λόγους περὶ αὐτῶν, ὡς μηδὲν αὐτοῖς ἀδύνατον ἔπεσθαι μηδὲ τοῖς φαινομένοις μαχόμενον. τοῦτο δὲ ὁ φησὶν ἐστίν· ἐὰν εἰς τὸ δυνατὸν ἀναγάγωμεν ὅσον ἐκ τῶν φαινομένων τοὺς περὶ αὐτῶν λόγους, καὶ μηδὲν αὐτοῖς ἀδύνατον ἔποιτο, οἷα συνέβη τοῖς ὑπὸ τῶν πρὸ ἡμῶν περὶ τῶν κομητῶν εἰρημένοις, τούναντίον δὲ συμφώνους ἀποδώσομεν καὶ ὁμολογούντας τοῖς πράγμασιν, εἰ οὖν τοῦτο γένοιτο, συμβαίνοντα τοῖς φαινομένοις λέξομεν. Translation from Kupreeva (2012) p. 73.

as a hypothesis, and it is valid until evidence, or a fact, refutes it. The impossibility of converting the hypothesis into causal cognition leads to the exclusion of natural investigations like meteorology from the realm of science, which, for Aristotle, always involves knowledge of causes.

Philoponus's epistemological remarks failed to catch the attention of medieval philosophers. Neither in Averroes nor in Thomas Aquinas or any other commentators is there discussion of this passage in any detail. Philoponus's commentary was published only in 1551 from the manuscript in the Biblioteca Nazionale Centrale di Firenze, Laur. 85.1, surnamed 'Oceanus'. It had marginal impact until the second half of the sixteenth century, and no relevant traces are evident before. Alexander's interpretation remained dominant, reinforced also by Moerbeke's translation which stated that effects are not manifest. This was the opinion of Pierre d'Auvergne (XIII-XIV A.D.) in his commentary on the *Meteorologica*. He believes that what is not manifest are natural effects and introduces an interesting epistemological touch of sophistication. According to d'Auvergne, in this passage Aristotle establishes that knowledge of things that are not manifest to sensation cannot reach the same certainty as mathematical demonstration, or the scientific and necessary character of the demonstration *propter quid*. Knowledge of things not manifest to sensation contents itself with finding a possible explanation that does not lead to impossible conclusions. Ultimately, it is a conjectural kind of knowledge.⁹

2. Renaissance Commentators

In the Renaissance a position similar to Philoponus's was developed by Agostino Nifo (ca. 1470-1538) in his *In libris Meteorologicis commentaria*, written around 1523 but only published in 1531. Commenting on the passage, Nifo refers to the opinions of Alexander and Pierre d'Auvergne. He writes that both philosophers maintained the idea that "immanifestis"/"manifestis" should have been referred to natural effects. Natural effects must be understood in two ways: (1) as something that is evident to sensation (*alii sunt sensibus nostris satis manifesti*), like the salting of the sea; whereas (2) others,

⁹ D'Auvergne (1497) f. biiiiiva.

like comets, are barely manifest (*alii sunt vix manifesti*) because they are distant from the senses. The certainty of evident natural effects is absolute, while that of things barely manifest is a mere hypothesis, which is credible only if it explains the phenomenon and does not lead to impossible things (*de vix manifestis certitudo non omnino quaerendam est, sed talis, qua concessa nullum sequatur impossibile*). The barely manifest natural effects are simply possible.¹⁰

This explanation according to Nifo is unacceptable: even if it is true that some natural effects are more or less evident (*licet aliqui naturales effectus sint manifestiores, et aliqui minus manifesti*), they are certain at least for their existence (*omnes tamen sunt certissimi saltem quo quia est*). Nifo does not deny that some natural effects are known by one or many senses, or some by the proper sense, while others to the proximate sense, but for the very fact that they exist they are very manifest (*omnes quo ad quia sunt, manifestissimi videntur*) and their knowledge is thus very certain (*omnium certissimam notiam essent tradendum*). Alexander's interpretation is therefore incorrect.¹¹

According to Nifo, in the Latin translation of Moerbeke the phrase “de immanifestis sensui” refers to the causes of natural effects, just as Philoponus argued with respect to the Greek text. The causes of natural effects are unknown and not immediately manifest to us. For this reason, in natural investigations we should follow a twofold process: one investigation that finds the cause (*quo causae inveniuntur*) and another that explains the reason for the natural effects through the cause (*quo effectus hic propter quod est ex causis inventis*). These are the two traditional steps of *regressus*: analysis and synthesis. The first stage of the process, that proceeding from effects to causes, is conjectural and probable, while the second is demonstrative.¹² However, the latter is not a demonstration *simpliciter*, but rather “ex suppositione” – that is, from the conjecture of the discovered causes it explains the reason for the effects. Nifo, as in many other works and like many other authors of his time, explains *regressus* theory using the example of the lunar eclipse. What is interesting is that the example of lunar eclipse in the Aristotelian tradition

¹⁰ Nifo (1531) f. 26va.

¹¹ *Ibid.*

¹² On the problem of *regressus* see Sgarbi (2023).

refers to demonstrative *regressus*, that is, to a logical procedure that leads to science. The same procedure used for the lunar eclipse must be employed for comets and other things, and therefore it is possible to have scientific knowledge of meteorological effects. Nifo is suggesting that Aristotle in this passage of the *Meteorologica* is not advancing an alternative way of discovering causes or of finding knowledge, less certain and more conjectural. The logical process is the same; the result is equally scientific.¹³

In his edition and translation of Aristotle, *Physicarum acroasum hoc est naturalium auscultationum liber*, Nifo explains the twofold process of *regressus* in relation to the *Meteorologica*. In the first step, the mind merely identifies the cause of the effect, while in the second step it grasps the actual connection between the cause and that particular effect from which the process of establishing knowledge started. The second kind of knowledge does not provide a better understanding of the cause in itself, but only of its connection with the effect and, for this reason, even the demonstration *propter quid*, especially in the field of natural philosophy, retains a hypothetical character because the knowledge of the cause comes from sensation and experience. However, if the cause, taken as a hypothesis, is capable of explaining phenomena other than the effect with which the investigation starts, then it must be admitted as true. Nifo explicitly states that:

it seems to me that in the *regressus* made in physical demonstrations, the first process, by which the discovery of the cause is put into syllogistic form, is a merely conjectural syllogism, since the discovery of the cause by its means is syllogized in a merely conjectural fashion. But the second process, by which the reason why the effect is so is syllogized through the discovered cause, is demonstration *propter quid* – not that it makes us know absolutely (*simpliciter*), but conditionally (*ex conditione*), provided that this really is the cause, or provided that the propositions which represent it to be the cause are true, and that nothing else can be the cause. [...] But you object that in that case the science of nature is not a science at all. We must say that the science of nature is not a science absolutely (*simpliciter*), like mathematics. Yet it is a science *propter quid*, because the discovery of the cause, gained through a conjectural syllogism, is the reason why the effect is so. [...] That something is a cause can never be so certain as that an effect exists; for the existence of an effect is known to the senses. That it is the cause remains conjectural, even if that conjectural existence is better known than the effect itself in the order of knowledge *propter quid*. For if the discovery of the cause is assumed, the reason why the effect is so is always known. Hence, in the *Meteorologica* Aristotle grants that he is not setting

¹³ Nifo (1531) f. 26va-b.

forth the true causes of natural effects, but only insofar as was possible for him, and in conjectural fashion.¹⁴

Interpreting the theory advanced by Aristotle in this passage within the epistemology of *regressus*, Nifo makes meteorology a true science. Of course, in doing this he is also changing the very idea of Aristotelian science. At the very beginning of his commentary on the *Meteorologica*, while Nifo denies that meteorology can be a science in itself (*in se*), he explicitly supports the idea that it could be a science of “that is” (*quia est*).¹⁵

Nifo makes another important observation that distinguishes this kind of conjectural knowledge – which is construed as a science of “that is” – from astronomical hypotheses and conjectures. In his commentary on *De caelo* he writes:

[...] a good demonstration proves that the cause necessitates the effect, and conversely. Now it is true that, the eccentrics and epicycles being conceded, the observed phenomena follow and that they can, therefore, be saved in this way. But the converse does not hold. Starting with appearances, the existence of eccentrics and epicycles does not follow with necessity; only provisionally, until such time as a better cause be discovered [...] Those therefore err who, starting out from a proposition whose truth may be the outcome of various causes, decide definitively in favour of one other cause. The appearances can be saved by the sort of hypotheses we have been talking about, but they may also be saved by other suppositions not yet invented. [...] From the apparent motions one can easily move to the eccentrics and epicycles. But it is impossible to go in the reverse direction, since one would then be moving

¹⁴ Nifo (1549b) f. 6rb: “videtur mihi in regressu, qui fit in naturalibus demonstrationibus, primum processum, quo syllogizatur causae inventio; secundum vero quo syllogizatur per inventionem causae propter quid effectus esse, demonstrationem propter quid, non quia faciat scire simpliciter, sed ex conditione, dato quod illa causa sit, vel dato quod propositiones verae sint, quae repraesentant causam et nulla alia causa esse possit. [...] Sed occurris, quia tunc scientia de natura non esset scientia. Dicendum scientiam de natura non esse scientiam simpliciter, qualis est scientia mathematica; est tamen scientia propter quid, quia inventio causae, quae habetur per syllogismum coniecturalem est propter quid effectus [...] Nunquam enim causa potest esse ita certa quia est, sicut effectus, cuius esse est ad sensum notum. Ipsum vero quia est causae, est coniecturale, utrum tale esse coniecturale est notius ipso effectum in genere notitiae propter quid. Nam posita inventionem causae, semper scitur propter quid effectus, unde et Aristoteles in libro Meteororum concedit se non tradidisse veras causas effectuum naturalium, sed quod erat sibi possibile coniecturabiliter.” Translation by Randall (1961) pp. 44-5, slightly modified.

¹⁵ *Ibid.*, f. 8rb.

from the unknown to the known, the appearances being what is known to us, the eccentrics and epicycles unknown.¹⁶

According to Nifo, Aristotle's *Meteorologica* I 7.344a5-8, has nothing to do with astronomical hypothesis because in the field of meteorology the conversion of effects and causes in the demonstration, through *regressus*, is possible, while this is not the case with eccentrics and epicycles. The epistemology of meteorology concerns natural philosophy, while the epistemology of astronomy concerns mathematics. The two realms are duly distinct and need to be kept separate.

There is at least one Renaissance author who tends to conflate the two epistemological perspectives, or at least uses the passage from Aristotle in the discussion of hypotheses in astronomy. In his *Quaestiones novae in theoricis novas planetarum* (1568), Christian Wurstisen (1544-1588) advances a kind of scepticism about the nature of astronomical hypotheses which anticipates what Robert Boyle elaborated a century later, as we shall see. Asking whether celestial spheres have as many orbits as astronomers assign, Wurstisen answers that:

No one has ever been able to decide, for the human mind merely conjectures that a given arrangement agrees with the natural effects and with observation. God alone knows the true causes, the order and arrangement of his noble and marvellous work. He offers us this work for contemplation, but he has sent us only a few rays of the knowledge he has of it. The heavens are spread out over the humble abode the earth furnishes to mortals. We do not dwell in the heavens. We can neither see them face to face nor touch them without hands, and no one has come down to us from there to tell us what he has seen. [...] It is excellent, according to my opinion, on this and similar things what Aristotle said in the first book, chapter seven, of the *Meteorologica*, by stating ἐπεὶ δὲ περὶ τῶν ἀφανῶν τῇ αἰσθήσει νομιζομένῃ ἰκανῶς ἀποδείχθαι κατὰ τὸν λόγον, ἐὰν εἰς τὸ δυνατόν ἀναγγώμεν. That is, concerning these objects, then, which do not fall under our senses, we shall hold that we have pushed our

¹⁶ Nifo (1549a) p. 82: "[...] demonstratio bona est, in qua causa convertitur cum effectu, modo licet positus eccentricis & epicyclis, possint salvari & sequantur apparentiae, non e converso, apparentij positus, illi sint, nisi pro nunc, donec invenitur alia causa melior, quae convertitur cum illis. Peccant igitur, quia arguunt a propositione habente plures causas veritatis ad alteram illarum: hae enim appaarentiae possunt per eiusmodi salvari, & per alia quae nondum sunt inventa. [...] licet igitur ab apparentiis ad epicyclos fit processus, quae contra nullus est, quia proceditur ab ignotis ad nota, sunt enim appararentiae notae, eccentrici & epicycli ignoti." Translation by E. Dolan and Ch. Maschler in Duhem (1969) pp. 48-9.

demonstrations far enough when we have reduced them to possible causes, that is to say, to causes from which nothing absurd follows.¹⁷

Wurstisen is unable to decide whether astronomical hypotheses are something physical and real since it is not possible to have experience of them. Because of this impossibility, Wurstisen refers to Aristotle's statement in the *Meteorologica* to justify at least their plausibility also in relation to the limitations of the human mind in knowing the causes of things in general; moreover, the difficulty of knowing the causes of effects is even more considerable for the human mind when the effects are remote from experience.

Nifo's fiercest opponent, Pietro Pomponazzi (1462-1525), does not deal with the passage in question in any great detail in his exposition of the first book of the *Meteorologica* (1524).¹⁸ However, in two other places in his works Pomponazzi does seem to tackle it, albeit indirectly. In his book *De nutritione et augmentatione* (1521), discussing the limits of the human mind and of natural philosophy as a science, he writes that:

Providing a firm and certain judgement in the study of nature is typical of a reckless and ignorant man who does not know where the difficulty lies [...] I believe that in the study of nature we deal with conjectures rather than with certain science.¹⁹

Natural investigations are most of the time conjectures rather than firm, universal and necessary conclusions. By conceiving the study of nature in this way, in his *De incantationibus* (1556 in Basel) Pomponazzi is able to explain

¹⁷ Wurstisen (1568) pp. 10-2: "[...] nemo unquam nisi quatenus naturalibus effectibus & observationibus congruere humana mens colligit, asseverare potuit. Novit solus Deus nobilis & admirandi sui opificij causas exactas, ordinem, dispositionem, in nos autem quibus illud spectandum proposuit, quosdam tantium cognitionis radios emisit. Non enim in coelis super mortale hoc terrae habitaculum expansis versamur, ut hae coram cernere, vel manibus contrectare possimus, nec quisquam e coelis delapsus, nobis illic quae viderit retulit [...] Praeclare (ut mea fert sententia) de his & similibus rebus Aristoteles primo Meteorologicorum cap. 7 pronuntiavit, dicens ἐπεὶ δὲ περὶ τῶν ἀφανῶν τῇ αἰσθήσει νομιζομεν ἰκανῶς ἀποδεδειχθαι κατὰ τὸν λόγον, ἐὰν εἰς τὸ δυνατόν ἀναγάγωμεν. Hoc est, satis arbitramur de ijs quae sensui conspicua non sunt iuxta rationem demonstratum esse, si ad possibile reduxerimus, id est, ut absurdi nihil consequatur." Translation by E. Dolan and Ch. Maschler in Duhem (1969) p. 80.

¹⁸ Paris, Bibliothèque Nationale de France, Lat. 6535, f. 58v.

¹⁹ Pomponazzi (1525) f. 130vb: "in naturalibus firmum et certum iudicium dare est hominis temerarii et ignorantis, qui nescit ubi stat rei difficultas [...] Quare magis in naturalibus, ut opinor, sunt coniecturae quam certa scientia."

why miracles are not only a matter of faith but can also be the subject of natural investigations and have rational explanations. According to experience, for instance, many miracles attributed to demons are not miracles at all. This is the case for miraculous healings:

we can give reasons for these experiences (*experimenta*) through natural causes; neither is there any rational argument that proves conclusively that they are caused by demons; therefore, demons are admitted without reason. Indeed, it is ridiculous and foolish to abandon evident causes and explanations that could be demonstrated by means of natural reasons to look for non-evident causes, which cannot be sustained with any probable argument.²⁰

Here Pomponazzi seems to employ *Meteorologica* I 7.344a5-8, denying the validity of resorting to demons to explain what can easily be explained through reason. He maintains the epistemological principle according to which “in complex and unknown problems, one should accept the solutions that involve fewer contradictions and which chime with sensible experiences and the inferences of reason rather than contrary arguments.”²¹ The reference to conclusions that do not involve contradictions and that accord with experience and reason is an explicit allusion to the passage from Aristotle and the basis for the construction of a conjectural science of nature.

Ludovico Boccadiferro (1482-1585) elaborates a more developed theory in his *Lectiones super Ilibrum Meteorologicorum*, based on Olympiodorus and especially Philoponus.²² According to Olympiodorus, Boccadiferro writes, Aristotle in this passage establishes an epistemological law which every natural philosopher should follow in investigating the occult causes of effects. It states that when the causes of the effects are unknown to us, we must take as true a supposition or a principle from which nothing impossible, non-sensical or against the phenomenon could follow. For Boccadiferro,

²⁰ Perrone Compagni (2011) p. 13: “[...] per causas naturales nos possumus huiusmodi experimenta salvare; neque est aliqua ratio cogens haec per daemones operari: ergo in vanum daemones ponuntur. Ridiculum enim et omnino fatuum est relinque manifest et quae naturali ratione probari possunt et quaerere immanifesta, quae nulla verisimilitudine possunt persuaderi.”

²¹ *Ibid.*, p. 77: “Ultimo supponitur quod in rebus difficilibus et occultis responsiones magis remotae ab inconvenientibus et magis sensatis et rationibus consonae sunt magis recipiendae quam oppositae rationes.”

²² Boccadiferro (1590) p. 68.

therefore, causes are what is not manifest: in summarising Philoponus' interpretation of the Aristotelian passage, Boccadiferro points out that in the phrase "quoniam autem de immanifestis sensui" what is not manifest to sensation are not the effects, but the principles or causes of their generation. Then, with "putamus sufficienter demonstrasse secundum rationem" Aristotle means that we can sufficiently discover causes that can be used by the intellect in a demonstration, where "secundum rationem" means that the demonstration is made by the intellect and not by sensation. However, the expression "si ad possibile reduxerimus" refers to a twofold way of understanding the notion of the possible. On the one hand, "possible" means something that pertains to a thing and that does not actually occur, just as walking pertains to a human being even if he or she is not in actual fact walking at that very moment. In this sense, the "possible" is therefore something inherent to the being of the thing. On the other hand, "possible" can be understood as something added to the nature of the being, and this is the kind of possible being considered here by Aristotle. In this case, nothing impossible or absurd or contradictory should follow in the explanation of the phenomenon adding this element. The explanation is for this reason possible. Finally, "ex ijs" is referred to the supposition, and thus, "quae nunc dicuntur, existimabit utique aliquis, sic de his maxime accidere" means that nothing absurd follows, and that this is the way by which we discover the cause in most instances.²³

Jacopo Zabarella (1533-1589) further develops this conception in his lectures on the first book of *Meteorologica* (1590). First of all, what is not manifest to sensation (*de immanifestis sensui*) is the cause – in this case, the cause of the comets. He points out that it is wrong to say that the effects are not manifest, because the existence of comets is well known. What remains obscure and remote to our knowledge are their cause and reason why (*causa et propter quid*). Indeed, through sensation it is impossible to discover the nature of things. He makes explicit that in giving reasons for comets, we should content ourselves with possible explanations, that is, to provide a possible cause from which nothing contradictory can follow. Through the senses no explanation for why a comet burns or why it lasts over a certain

²³ *Ibid.*

period of time can be provided. Like Nifo, Zabarella frames the Aristotelian epistemology within the theory of demonstration. What is lacking in knowledge of comets is the major premise, which is usually a well-known axiom or a proposition immediately grasped by demonstrative induction. But this major premise cannot be known through sensation in the case of comets, and it is therefore not possible to demonstrate that the discovered cause is the proximate cause of the effect. For this reason, only conjectural knowledge is possible.²⁴

These reflections lead Zabarella to diverge from Boccadiferro's twofold interpretation of the notion of "possible". If the knowledge we are looking for is that of the efficient cause (*causa effectiva*), it cannot be a form of knowledge which does not pertain to or inhere in the effect. Indeed, it would be contrary to the purpose of scientific knowledge, which is necessary and universal, to look for a cause that sometimes is, and at other times is not,

²⁴ Milan, Biblioteca Ambrosiana, D 364 inf, f. 126r: "[...] ideo in reddendis causis cometae debemus esse contenti reduxerimus rem ad id quod possibile sit, in causam possibilem adducamus ad cuius positionem nullum sequitur inconveniens; non enim debemus intelligere quod effectus ipse sit immanifestus sensui, est enim cometa notae existentiae, sed causa, et propter quid, est enim ita a nobis remotus a cometa ut nullo possimus uti auxilio sensum ad cognoscendum quae nam et qualis sit ea natura, quae sive ardens sive aliquo modo cometam facit esse cur tanta sit eius permanentia et duratio debi autem hoc evenit difficile est demonstrare. Est autem ignota maior proposition quae semper solet esse axioma notum, vel proposition per se nota per inductionem ex sensibus, ut Aristoteles primo Posteriorum ex 3o demonstrat, quod enim causa talis sit eius effectus si est causa proxima non potest demonstrari, sed per se notum esse debet via sensuum, cum igitur sensus ad cognoscendas cometae causas, nobis parum auxilietur, dicit Aristoteles sufficienter nos esse demonstraturos si rem ad possibile reduxerimus, intellectu et ratione philosophantes quin sensu uti non possumus an si talem causam inveniamus ipsius cometae, quia possibile sit esse cometae causam, ita ut ea constituta nullum sequatur incommodum id enim est possibile, quo posito nullum sequitur inconveniens. Videtur autem [...] Buccaferreus errorem committere, qui dividens possibile in illud quod complectitur etiam in existens et necessarium et in id quod proprie accipitur pro eo quod potest esse et non esse dicit Aristotelem accipere, hic possibile secundo modo proprie non communiter, sed mihi videtur rem contrario potius modo se habere quaerere enim causa effectiva possibilem in quae possit esse et non esse causa illius effectus est directe contrarium intentioni scientifici quia ex ea causa non fit scientia vera effectus sed quaeritur causa possibilis id quam sit possibile esse necessariam eam illius effectus in qua posita causa ex qua ille effectus consequatur necessario nullum inconveniens ex hac pone sequatur et manifestum est quod illud possibile quo posito non debet aliquid sequi inconveniens non idem est possibile ad verum libet, sed est possibile alterum quod complectitur tam possibile quia in existens et necessarium et hoc Aristoteles hic intelligit".

pertinent to or inherent in the effect. It would be contingent or accidental knowledge. The cause must pertain to or inhere in the effect. At this point, Zabarella makes an interesting conceptual leap from what Aristotle writes to contemporaneous astronomical debates:

It must be noted, however, that what is said here by Aristotle concerning the immanifest causes of comets is the same as that which is said by astronomers about the causes of appearances posited by them in order to save all appearances that occur in the celestial movements, and he does not hesitate to introduce eccentrics and epicycles and to greatly multiply orbs that describe the movements of one planet. This matter is such that they cannot use the testimony of sensation, but they are satisfied if they say that it is possible that it is such, or the cause of the appearance is such, that the appearance is explained in a way that we fall into nothing that is disagreeable, as if they would not reject accepting a better cause if someone would find it.²⁵

Indeed in writing this passage Zabarella had in mind the astronomy of his times and the controversial nature of its knowledge, which has nothing to do either with Aristotle's text or with comets or other meteorological effects. However, Zabarella clearly associates this kind of knowledge with that of astronomy, a form of knowledge mainly based on conjectures.

3. *Early Modern Interpreters*

In early modern philosophy the passage from Aristotle becomes pivotal for the elaboration of an epistemology based on hypotheses, an epistemology that leads to scientific knowledge. The emphasis on causes rather than on effects in relation to what is not manifest to sensation became especially

²⁵ Milan, Biblioteca Ambrosiana, D 364 inf, f. 126r: "Advertendum autem quod id, quod hic ab Aristotele dicitur de caussis cometae immanifestis idem est quod et ab astronomis dicitur de caussis apparentium positum ab eis ut enim omnes apparentias salvent, quae in caelestibus motibus contingunt, non dubitat ponere eccentricos et epicyclos, et ad magnum numerum multiplicare orbem qui unius planetae motibus inserviunt, quod enim ita res se habeat, nullo uti possunt testimonio sensum sed satis habent, si dicant, possibile esse, ut ea sit talis, vel talis apparentiae causa, in qua ita solvetur illa apparentia, ut in nullum incidamus incommodum quasi non recusarent potius eam accipere si quis eam inveniret." I wish to thank Stefano Gulizia for his help with this manuscript, and Craig Martin for the interpretation of this passage.

important with the new astronomical observations made by means of the telescope. Effects that were not manifest to sensation became available via the telescope, and therefore what remained hidden were their causes.

Galileo Galilei (1564-1642) was the first to unveil the hidden effects of the celestial phenomena. Although we find no direct reference to the Aristotelian passage in his works, its conceptuality is heavily present, and not by chance, in the *Discorso delle comete* (1619), written with Mario Guiducci (1585-1646). Galileo and Guiducci's use of Aristotle's *Meteorologica* is evident when they deal with Aristotle's conception of comets and with three other viewpoints "reported by him". This would indicate that they were using Aristotle's work as a textbook for exploring various ideas about comets. Here the two authors are referring to *Meteorologica* I 7.344a5-8: in relation to comets, Guiducci states: "I will explain not affirmatively, but only probably, what dubitatively I judge about such obscure and doubtful matter, as it is called [...] I will advance conjectures."²⁶ The conjectural nature of meteorological and astronomical knowledge is central to Galileo's *Treatise on the Sphere* (c. 1602), written before pointing the telescope up into the sky. Here the Pisan scientist outlines a particular epistemology based on hypothesis:

the first [...] contains appearances, otherwise called phenomena: and these are none other than sensed observations, which every day we see, as for instance the rising and setting of the stars [...] In the second stage there are hypotheses: and these are none other than suppositions concerning the structure of the celestial orbs, and such that they correspond to appearances [...] Then, in the third place, geometrical demonstrations follow, with which through the properties of the circle and of straight lines are demonstrated the particular accidents that follow from hypotheses. [...] And finally, what has been demonstrated through lines, calculating by arithmetical operations, is reduced and arranged in tables [...].²⁷

²⁶ *OG*, VI, p. 188.

²⁷ *OG*, II, pp. 211-2: "il primo [...] contiene l'apparenze, dette altrimenti fenomeni: e queste altro non sono che l'osservazioni sensate, le quali tutto 'l giorno vediamo, come, per esempio, nascere e tramontare le stelle [...] Sono nel secondo loco l'ipotesi: e queste altro non sono che alcune supposizioni appartenenti alla struttura de gli orbi celesti, e tali che rispondino all'apparenze. [...] Seguono poi, nel terzo luogo, le dimostrazioni geometriche; con le quali, per le proprietà de' cerchi e delle linee rette si dimostrano I particolari accidenti, che all'ipotesi conseguiscono. [...] E finalmente, quello che per le linee s'è dimostrato, con operazioni aritmetiche calculando, si riduce e distribuisce in tavole."

The first two methodological precepts are of special interest in order to understand the development of the Aristotelian passage. At the end of the first stage, the cause of the knowable phenomenon is conjectured in the form of a hypothesis, to the extent that Galileo stresses that “we will deal only with hypotheses, striving to confirm and prove them with appearances”.²⁸

Galileo provides an application of this epistemology with the example of the moon’s illumination and of its various shades. His objective, like Aristotle in the *Meteorologica* for comets, is to assign a cause to the effect, but this assignment is rather a hypothesis to be confirmed with a view to recording appearances rather than discovering the real cause. Galileo emphasises that since “we want to assign the cause to an effect, it is necessary that we suppose some things, and we have to reduce to memory others.”²⁹ How this supposition works becomes clear in the *Discourse on Bodies in Water* (*Discorso intorno alle cose che stanno in sull’acqua*, 1612). Again, his main aim is to explain “the true, intrinsic, and total cause” of a specific phenomenon, that “of the ascending of some solid bodies in the water and therein floating”.³⁰ Galileo is manifestly facing a meteorological problem. To do this, he believes that it is necessary to start observing effects and then

reducing the causes of such effects to more intrinsic and immediate principles, in which also are discovered the causes of some accidents [...] and because the demonstrative progression so requires, I shall define certain terms and afterwards explain some propositions, of which, as of true and known things, I make use of to my present purpose.³¹

“True and known things” are hypotheses. Galileo’s main idea is to start with a hypothesis admitted as a cause and, working through its effects, to reduce it to an intrinsic principle, which is either something more primary than the

²⁸ *Ibid.*: “ci occuperemo solamente circa l’ipotesi, ingegnandoci di confermarle e stabilirle con le apparenze.”

²⁹ *OG*, II, p. 251: “Del qual effetto volendo noi assegnare la causa, bisogna che supponghiamo alcune cose, ed altre ce le riduciamo a memoria.”

³⁰ *OG*, IV, p. 67.

³¹ *Ibid.*: “riducendo le cagioni di tali effetti a’ principii più intrinsechi e immediati, ne’ quali anco si scorgano le cause di qualche accidente [...] e perchè così richiede la progressione dimostrativa, io definirò alcuni termini, e poi esplicherò alcune proposizioni, delle quali, come di cose vere e note, io possa servirmi a’ miei propositi.” Galileo works with hypotheses in the framework of Greek mathematics; however, what is important here is their conjectural nature.

hypothesis, or the hypothesis itself but established now as a principle. This epistemology discovers that “the excess or defect of gravity of the solid, unto the gravity of the water, is the true and proper cause of floating or submerision”.³² It is worth noting that for Galileo the gravity is the cause, but he does not explain what gravity is, and thus we remain in the dark as to its nature. In other words, he assigns a causality to gravity without saying what this cause actually is. What is important is that this gravity explains the effects. Galileo develops a kind of scepticism about knowledge of causes. This is evident in the *History and Demonstrations concerning Sunspots and their Phenomena* (*Storia e dimostrazioni intorno alle macchie solari e loro accidenti*, written in 1612, but published in 1613). In the third letter to Mark Welser, Galileo writes that

in our speculating we either seek to penetrate the true and internal essence of natural substances or content ourselves with a knowledge of some of their properties. The former I hold to be as impossible an undertaking with regard to the closest elemental substances as with more remote celestial things. [...] Hence I should infer that although it may be vain to seek to determine the true substance of the sunspots, still it does not follow that we cannot know some properties of them, such as their location, motion, shape, size, opacity, mutability, generation and dissolution. These in turn may become the means by which we shall be able to philosophise better about other more controversial qualities of natural substances.³³

Knowledge of formal causes, substances and essences seem unachievable to Galileo for both elementary and celestial bodies. However, through knowledge of shape, motion, location, etc., and without discovering the essence of the cause, it is possible to provide an explanation for the phenomenon, which remains hypothetical but is nonetheless functional for its purpose.

³² *OG*, IV, p. 108.

³³ *OG*, V, pp. 187-8: “Perchè, o noi vogliamo specolando tentar di penetrar l’essenza vera ed intrinseca delle sustanze naturali; o noi vogliamo contentarci di venir in notizia d’alcune loro affezioni. Il tentar l’essenza, l’ho per impresa non meno impossibile e per fatca non men vana nelle prossime sustanze elementari che nelle remotissime celesti [...] Voglio per tanto inferire, che se bene indarno si tenterebbe l’investigazione della sustanza delle macchie solari, non resta però che alcune loro affezioni, come il luogo, il moto, la figura, la grandezza, l’opacità, la mutabilità, la produzione ed il dissolvimento, non possino da noi esse apprese, ed esserci poi mezi a poter meglio filosofare intorno ad altre più controverse condizioni delle sustanze naturali.” Translation by Drake (1978) p. 199.

The appeal to *Meteorologica* I 7.344a5-8, became important not only for the explanation of meteorological or celestial phenomena placed at a distance from the human eye, but also in developing explanatory strategies and abductive arguments for microscopic effects, also invisible to the naked eye. One of the most striking interpretations of the passage is provided by René Descartes (1596–1650) in his *Principles of Philosophy* (*Principia philosophiae*, 1644). In § 204 of the fourth part, Descartes points out that what cannot be perceived by the senses can be established through hypothesis, bearing in mind that the actual nature may be very different from that supposed. Descartes gives the famous example of the two clock mechanisms:

Although this method may enable us to understand how all the things in nature could have arisen, it should not therefore be inferred that they were in fact made in this way. Just as the same craftsman could make two clocks which tell the time equally well and look completely alike from the outside but have completely different assemblies of wheels inside, so the supreme craftsman of the real world could have produced all that we see in several different ways. I am happy to admit this; and I shall think I have achieved enough provided only that what I have written is such as to correspond accurately with all the phenomena of nature. This will indeed be sufficient for application in ordinary life, since medicine and mechanics, and all the other arts which can be fully developed with the help of physics, are directed only towards items that can be perceived by the senses and are therefore to be counted among the phenomena of nature. And in case anyone happens to be convinced that Aristotle achieved – or wanted to achieve – any more than this, he himself expressly asserts in the first book of the *Meteorologica*, at the beginning of Chapter Seven, that when dealing with things not manifest to the senses, he reckons he has provided adequate reasons and demonstrations if he can simply show that such things are capable of occurring in accordance with his explanations.³⁴

³⁴ *AT*, VIII A, p. 327: “At quamvis forte hoc pacto intelligatur, quomodo res omnes naturales fieri potuerint, non tamen ideo concludi debet, ipsas revera sic factas esse. Nam quemadmodum ab eodem artifice duo horologia fieri possunt, quae, quamvis horas aequae bene indicent, & extrinsecus omnino similia sint, intus tamen ex calce dissimili rotularum compage constant: ita non dubium est, quin summus rerum opifex omnia illa, quae videmus, pluribus diversis modis potuerit efficere. Quod equidem verum esse libentissime concedo, satisque a me praestitum esse putabo, si tantum ea quae scripsi talia sint, ut omnibus naturae phaenomenis accurate respondeant. Hocque etiam ad usum vitae sufficiet, quia & Medicina, & Mechanica, & caeterae artes omnes, quae ope Physicae perfici possunt, ea tantum quae sensilia sunt, ac proinde inter naturae phaenomena numeranda, pro fine habent. Et ne quis forte sibi persuadeat, Aristotelem aliquid amplius praestitisse, aut praestare voluisse, ipsemet in primo Meteorologicorum, initio capituli septimi, expresse testatur, de iis quae sensui non sunt manifesta, se putare sufficientes rationes & demonstrationes afferre, si tantum ostendat ea ita fieri posse, ut a se explicantur.” Translation by Cottingham, Murdoch and Stoothoff (1984) vol. 1, p. 289.

Like Nifo, in this passage Descartes seems to deal with causes rather than effects as things not manifest to the senses. This is clear in his example of two effects, the clockworks, which are identical in their appearance but which, in truth, can be moved by different causes. The real causes are hidden within the clockwork; and even if they are not perceived by the senses, it is possible to argue and suppose a plausible explanation for them. Descartes's emphasis on explaining effects in such a way that all the phenomena may correspond to the hypothesis without referring to the real nature or the cause of the effects themselves could be associated with what Galileo argues in the *History and Demonstrations concerning Sunspots and their Phenomena*. But Descartes takes it a step further. While Galileo did not conceive of hypotheses where there is no starting-point in phenomena or effects, Descartes refers this passage to objects that cannot be perceived. In this sense, what is not manifest are both effects and causes. It is true that in § 204 he mentions only the hidden causes, but the epistemological theory is developed after the exposition of how to acquire knowledge of insensible things, that is, objects that are not perceivable (*insensilium*). These non-perceivable objects are insensible particles of which sensible bodies are constituted: they are invisible corpuscles. Of these corpuscles it is possible to know, not their essences, but some of their properties such as magnitudes, figures and motions using abductive reasoning starting from sensible bodies. What Galileo attributed to celestial bodies, Descartes referred to invisible particles, extending thus Aristotle's original passage to corpuscular and atomistic theories.

The validity of this argument is developed in Part Three of the *Principles*, especially §§ 42-44, in which Descartes deals with problems traditionally associated with meteorology. The effectiveness of this epistemological approach lies in the fact that the causes considered as hypotheses can explain other phenomena than the one initially considered, exactly as in Nifo's theory of *regressus*.

In order to know the true nature of this visible world, it is not sufficient to find some causes by which one can explain what appears in the heaven very far from us; it is necessary also to be able to deduce from the things we see very close to us and which affect us more noticeably. But, even so, I think it is unnecessary for us to consider them all immediately, and deem it preferable for us to attempt first to discover the causes of these more general things, which I have enumerated, so that we may see subsequently whether we can also deduce from these

same causes all the more specific things which we shall have ignored while searching for the causes. And we shall know that we have correctly determined the causes when we observe that we can explain, by their means, not only those phenomena which we have considered up to now, but also everything else about which we have not previously thought. And certainly, if the principles which I use are very obvious, if I deduce nothing from them except by means of a Mathematical sequence, and if what I thus deduce is in exact agreement with all natural phenomena; it seems to me that it would be an injustice to God to believe that the causes of the effects which are in nature and which we have thus discovered are false [...] in order that each reader may be free to form his opinion, I wish what I shall write later to be taken only as an hypothesis which is perhaps very far from the truth. But, even though these things may be thought to be false, I shall consider that I have achieved a great deal if all the things which are deduced from them are entirely in conformity with the phenomena [...] because we will be able to use it in the same way to dispose natural causes to produce the effects which we desire.³⁵

Descartes had already dealt with this argument in the *Discourse on the Method* (*Discours de la méthode*, 1637) within the theory of *regressus*. For Descartes, *regressus* is based on a twofold process: one of proving causes from effects, and the other explaining effects from causes. There is a great difference between proving and explaining. He points out that “the causes from which I deduce effects serve not so much to prove them as to explain them.”³⁶

³⁵ *AT*, VIII A, pp. 98-101: “Ut enim ueram huius mundi aspectabilis naturam agnoscamus, non satis est aliquas causas inuenire, per quas ea quae in coelo eminus aspiciuntur explicentur; sed ex iisdem etiam, illa omnia quae in Terra cominus intuemur, deduci debent. Atqui non opus est, ut illa omnia consideremus ad rerum generaliorum causas determinandas; sed tum demum ipsas postea recte a nobis determinatas fuisse cognoscemus, cum ex iisdem non ea dumtaxat ad quae respeximus, sed alia etiam omnia, de quibus antea non cogitauimus, explicari aduertemus. Vix fieri posse quin causae, ex quibus omnia phaenomena clare deducuntur, sint uerae. Et certe, si nullis principiis utamur nisi euidentissime perspectis, si nihil nisi per Mathematicas consequentias ex iis deducamus, et interim illa quae sic ex ipsis deducemus, cum omnibus naturae phaenomenis accurate consentiant, iniuriam Deo facere uidebimur, si causas rerum, hoc pacto a nobis inuentas, falsas esse suspicaremur, tanquam si nos tam imperfectos genuisset, ut ratione nostra recte utendo fallamur. Me tamen eas, quas hic exponam, pro hypothesis tantum haberi uelle. Verumtamen, ne etiam nimis arrogantes esse uideamur, si de tantis rebus philosophando, genuinam earum ueritatem a nobis inuentam esse affirmemus, malim hoc in medio relinquere, atque omnia quae deinceps sum scripturus tanquam hypothesis proponere. Quae quamuis falsa esse existimetur, satis magnum operae pretium me fecisse arbitrabor, si omnia quae ex ipsa deducuntur cum experimentis consentiant: ita enim ex ea tantundem utilitatis ad uitam, atque ex ipsius ueritatis cognitione, percipiemus.” Translation by Rodger Miller and Miller (2012) p. 104.

³⁶ *AT*, VI, p. 77: “les causes don’t ie deduits ne seruent pas tant a les prouuer qu’a les expliquer.” Translation by Cottingham, Murdoch and Stoothoff (1984) vol. 1, p. 106.

The discovery of the causes rests on experience and it is conjectural, while the following stage from causes to effects serves to explain the effects from these causes scientifically. “To explain effects by a cause, and then prove the cause by the effects,”³⁷ is not a circular argument, as he wrote in the letter of 13 July 1638 to Jean-Baptist Morin. While proving is associated with discovery and with an argument from effects to cause, explaining is related to an argument that moves from causes to effects. Descartes states that it is not so easy to fit a cause to effects, “unless it is the true cause which produces them”.³⁸ Indeed, diverse effects can be generated by diverse causes. But through experience one may discover that a particular cause refers to a particular effect, to the extent that it is possible to say that the effects “have no other causes than those from which I have deduced them.”³⁹ In this way, even if the initial stage of knowledge is conjectural, then the result is a solid scientific conclusion. Like Nifo, albeit in a different manner, Descartes uses his version of *regressus* in order to make sense of the epistemology developed in *Meteorologica* I 7.344a5-8, and to transform mere hypotheses into science. This procedure is not valid only for visible objects, but, by means of the very same epistemological process of testing causes, it can be extended to the invisible world.

Walter Charleton (1619-1707) immediately exploits the new Cartesian interpretation of the passage from Aristotle in his *Physiologia Epicuro-Gassendo-Charltoniana, or a Fabrick of Science Natural, upon the Hypothesis of Atoms* (1654). In the third book, Chapter 1, entitled “The Origine of Qualities”, Charleton refers directly to Galileo and Descartes, showing how contemporary philosophers found a strict relation of analogy between the two epistemological approaches. Charleton explains that the human mind has difficulty in understanding even what is clear and familiar to the senses. What appears is known through the senses, but the cause of the appearances is not always as evident as it seems. He provides some examples of this conflict between what appears to the senses and its causal explanation. For instance, nothing is more evident to the senses than the continuity of a body;

³⁷ *AT*, II, p. 199.

³⁸ *Ibid.*

³⁹ *AT*, II, p. 200.

however, nothing is more abstruse than the composition of the continuum. Equally, nothing is more knowable to sensation than qualities; but again, nothing is so problematic as the knowledge of their origin. Finally, nothing is so manifest and beyond doubt than the reality of motion, “and yet we dare demand of Galileo himself, what doth yet remain more impervestigable, or beyond apodictical decision, then the *Nature* and *Conditions* thereof”.⁴⁰

On the possibility of giving answers to these questions, Charleton states we can provide only a “conjectural opinion,” which can be “candidly accepted in the latitude of *Probability* only”. Charleton’s focus is on how something “*may* be, rather than how *it is*, or *must* be; i.e. that it is, though most *possible* and *verisimilous* [...] yet not absolutely *necessary*”. The purpose of his investigation is not to provide an exact account of nature as God, who first conceived it, has, but rather to describe nature “as may appear most plausibly, satisfactory to the solution of all her Phaenomena”.⁴¹ This would have been, according to Charleton, the doctrine of Aristotle in the *Meteorologica* I 7.344a5-8, which is quoted both in Greek and Latin from the edition of Adrien Turnèbe and Isaac Casaubon.⁴² Aristotle’s epistemological approach would have been endorsed by Descartes himself in § 204 of his *Principles of Philosophy*, quoted by Charleton though omitting the example of the clockworks.

In *An Essay containing a Requisite Digression, concerning those that would exclude the Deity from intermeddling with Matter* (1663), Robert Boyle (1627-1691) considers Aristotelian, Cartesian and atomist epistemology critically. His main aim is to explain why they are all wrong in pretending to explain the origin of things and the world’s phenomena without acknowledging any divine author. He is critical of those philosophers “who scorn to ascribe anything to God” and holds that they are satisfied with providing the most immediate causes of effects, which are sometimes mere abstruse affections unable to explain the nature of the phenomena.⁴³ As, for example, when

⁴⁰ Charleton (1654) p. 128.

⁴¹ *Ibid.*

⁴² Duval (1629) vol. 2, p. 536: “Cum autem de hisce quae sensui pervia non sunt, satis esse iuxta rationem demonstratum putemus, si ad id quod fieri possit, ea reduxerimus, ex hisce quae in praesentia dicuntur, existimaverit quispiam de hisce maxime ad hunc modum usum venire.”

⁴³ Stewart (1991) p. 156.

An account is demanded of that strange supposed sympathy betwixt quicksilver and gold, in that we find that, whereas all other bodies swim upon quicksilver, it will readily swallow up gold and hide it in its bosom. This pretended sympathy the naturalist may explicate by saying that, gold being the only body heavier than quicksilver of the same bulk, the known laws of hydrostatics make it necessary that gold should sink in it and all lighter bodies swim on it; but though the cause of this effect be thus plausibly assigned, by deducing it from so known and obvious an affection of bodies as gravity, which every man is apt to think he sufficiently understands, yet will not this put a satisfactory period to a sever enquirer's curiosity, who will perchance be apt to allege that, though the effects of gravity indeed be very obvious, yet the cause and nature of it are as obscure as those of almost any phenomenon it can be brought to explicate [...].⁴⁴

Curiously enough, but perhaps not by chance, Boyle focuses on the property of gravity that according to Galileo explained the floating and submersion of things in water and seems manifestly to contest the Galilean epistemological tenet that in this kind of investigation one should reduce the causes of effects to more intrinsic and immediate principles. Boyle, instead, makes a case for not desisting “from ascending in the scale of causes till we are arrived at the top of it”. This ascent would lead to the primary causes of things, which can be either “certain primitive, general, and fixed laws of nature” or “shape, size, motion, and other primary affections”. These primary affections, however, were exactly those that Galileo was satisfied to find out, setting aside the search for essences and substances. Boyle disagrees with Galileo not on the importance of knowing primary affections, but rather on the fact that both the laws of nature and the primary affections are inexplicable “without acknowledging an intelligent Author or Disposer of things”.⁴⁵ The problem with Galileo's epistemology is the absence of God in his natural philosophy.

This renunciation of an investigation of primitive causes is typical of “many atomists and other naturalists” – Boyle seems here to be thinking of Charleton and Descartes. Boyle therefore conflates two very different philosophies on the grounds that both philosophers seem to have been (mis)guided epistemologically by the Aristotelian principle set out in *Meteorologica* I 7.344a5-8. Against the atomists, and probably with Charleton in mind, he writes that they “presume to know the true and genuine causes of the things they attempt to explicate, yet very often the utmost they can attain to in their

⁴⁴ *Ibid.*

⁴⁵ *Ibid.*, p. 157.

explications is that the explicated phenomena *may* be produced after such a manner as they deliver, but not that they really *are* so”.⁴⁶ In stressing the conjectural nature of knowledge one can make terrible mistakes in identifying causes. According to Boyle, the same effects can be produced by different causes. For instance, a projectile can be moved by gunpowder or by compressed air or by a spring. For Renaissance mathematicians, who were not looking for causes but rather for a description of effects, the cause was essentially a matter of indifference because the only thing that mattered were the trajectories and, therefore, to explain how and not why something had happened.

Boyle is arguing here like a natural philosopher rather than a mathematician and emphasises the importance of establishing true causes. Hypothetical epistemology is not sufficient. He defines the contours of his position by employing Descartes’s example of the clockworks. In a watchmaker’s shop, many clocks run with different mechanisms that only the artisan knows. An ordinary man, who has seen in his life only the interior of one clock, would presume erroneously that all clocks run in the same way. In spite of the many errors of this epistemological approach, Boyle states, modern philosophers are very much in favour of this doctrine and claim “to assign not precisely the true, but possible causes of the phenomenon they endeavour to explain”. This is, according to Boyle, what “Aristotle himself does in his first Book of *Meteors*,” in which he confesses “that concerning many of nature’s phenomena, he thinks it sufficient that they may be so performed as he explicates them”.⁴⁷

From this epistemological principle, Boyle derives a kind of scepticism about knowing the ultimate causes of effects. There is no certainty that “phenomena of nature must proceed from the magnitudes, figures, motions, and thence-resulting qualities, of atoms.” What is possible, rather, is to seek “particular causes of this or that particular effect or event.” For there is a sharp distinction between showing that it is possible that such an effect proceeds from the various magnitudes, shapes and motions of atoms, and in establishing “what precise and determinate figures, sizes, and motions, of atoms will

⁴⁶ According to Boyle, he wrote this passage before reading the *Physiologia*, yet the reference and the emphasis on “may” and “are” recalls Charleton’s conception almost verbatim.

⁴⁷ Stewart (1991) p. 169.

suffice to make out the proposed phenomena, without incongruity to any others to be met with in nature”. This distinction in knowledge is by no means different from that of the ordinary man, who can argue that the clocks works through springs, and that of the skilful artisan, who knows the precise magnitude, figures and motions of the whole contrivance.⁴⁸

Boyle’s reflections are intended to emphasise the fragility of some kinds of investigations based on hypotheses and the necessity of admitting God as the ultimate cause of things. In no way does Boyle discard the use of hypothesis or hypothetical knowledge for science. Looking at the manuscript entitled *Notes on a Good and Excellent Hypothesis*, Boyle synthesises the Aristotelian and Cartesian perspective on *Meteorologica* I 7.344a5-8. A good hypothesis should be intelligible, containing nothing impossible or absurd or false. It must be sufficient to explicate the main phenomena and be consistent, that is, not in contradiction with other events in nature. An excellent hypothesis, however, should be the simplest and should have sufficient grounds through other proofs. In particular, an excellent hypothesis can on its own explicate phenomena, as well as allowing for the prediction of other effects. Hypothetical knowledge, therefore, can be applied and is sometimes necessary, but its boundaries with true science remain distinct.⁴⁹

4. From Hypothesis to Science

The pathway from Aristotle’s *Meteorologica* I 7.344a5-8, to early modern philosophy was circuitous and roundabout – studded with many misunderstandings, different interpretations and multiple appropriations. As far as we know, Aristotle’s real intention in this passage was to develop a methodology capable of taking into account the variability and instability of empirical investigations and of producing reliable knowledge. Aristotle’s objective of finding a different way of acquiring knowledge was very clear from the beginning of the *Meteorologica*, where he makes it explicit that the objects under investigation are all phenomena that occur by nature’s laws, but not with

⁴⁸ *Ibid.*, p. 170.

⁴⁹ *Ibid.*, p. 119.

the same regularity and necessity as heavenly bodies. This kind of investigation does not lead to science: Aristotle openly confesses that in some cases it will be impossible to achieve a firm conclusion, while in others it will be possible to venture only a partial explanation or an understanding of a few characteristics. This kind of knowledge is not science, and it is conceptually very distant from that acquired through demonstrations and a perfect cognition of causes.

Nifo's move to include these kinds of natural investigations under science – that is, to unify under a unique methodological and epistemological umbrella, that of *regressus*, what Aristotle viewed as distinct – represented a decisive change in the Aristotelian tradition. Hypothetical, provisional and probable knowledge became a part – the preliminary step – in the Aristotelian model of demonstrative science. With early modern philosophers, however, the epistemology of demonstrative science was progressively, albeit not suddenly, abandoned, and hypothetical, provisional and probable knowledge took over to become identified with science in its totality.

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