Experimental versus Speculative Natural Philosophy: The Case of Galileo

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Philosophers looking for historical precedent for some interpretation or reform of science which they themselves are advocating, have all, however much they have differed from one another, been able to find in Galileo their heart's desire. (A. C. Crombie)

1 Introduction

It is a commonplace to suggest that Galileo Galilei was a key figure in the development of modern science. Maurice Clavelin, for instance, writes that not only did Galileo create a new science of motion, but his work marks "the advent of a different conceptual universe" (Clavelin 1974: xi). Stillman Drake claims that the key features of modern science – "its method of inquiry and its criterion of truth" – were "first made clear in the writings of Galileo" (Drake 1957: 3). And Peter Machamer has written of Galileo that "when he was there was no such thing as science,' yet by the time he died science was well on its way to becoming a discipline" (Machamer 2010). But what we call "modern science" is a complex affair, embracing a wide range of attitudes and forms of enquiry. Indeed the question of whether these have anything in common is a hotly contested one. So even if we accept the general claim that Galileo was a pioneer of modern science, it seems reasonable to ask just which features of modern science he pioneered.

In asking this question, my primary interest is not in the content of Galileo's natural philosophy. His substantive contributions to the content of modern science are well known. Best known, of course, are Galileo's telescopic observations, which he claimed to lend support to the Copernican hypothesis. But of greater significance are his contributions to the development of modern physics. One thinks here of his anticipations of the principle of inertia, which Alexander Koyré has described as the "fundamental law" of modern physics (Koyré 1968: 2). Of importance, too, were Galileo's law of falling bodies (the idea that a freely falling body will travel a distance that is proportional to the square of the elapsed time) and his principle of the superposition of motions (the idea, roughly speaking, that two different tendencies can combine to determine the trajectory of a body) (Galileo 1914: 174, 249; 1998: 146–51). But my question is not about the content of Galileo's natural philosophy, but its form. In what ways did the form of Galileo's natural philosophy – the logical structure of its theories and arguments – anticipate the natural sciences of a later age?

This is so broad a question that it runs the risk of being unmanageable; any answer I give can only be partial and selective. There are two ways in which one might try to address the issue. One way would be to look back and to compare Galileo's natural philosophy with that of the late medieval period. We could ask, for instance, to what extent (if at all) Galileo broke with the traditional Aristotelian conception of *scientia*. That conception was marked by two ideals. The first was that of demonstrative argument. The second was that this demonstrative reasoning should lead us back to insights regarding essential properties (Biener 2004: 281–82). A widely held view is that Galileo held on to the first of these Aristotelian ideals, while abandoning the second. He retained the traditional ideal of demonstrative argument, insisting that his conclusions require "necessary demonstrations from their primary and indubitable foundations."[1] If he differed from other natural philosophers in this respect, it was in his insistence (against the traditional Aristotelian disdain for mathematical reasoning in natural philosophy) that his arithmetical and geometrical proofs consituted the kind of demonstrative reasoning that any science required (Fehér 1982: 95). But he did not ground his demonstrative reasoning in "facts about the inner natures or real essences of things" (Osler 1973: 504), at least as Aristotelians conceived them.

I shall make extensive use of such insights. (If there is any novelty in the present paper, it lies in its composition rather than its parts.) But rather

[1] The phrase is used by Salviati on the first day of the *Discorsi*, where he speaks of Galileo having proven his conclusions *da ... indubitati fondamenti con necessarie dimostrazioni provate*.

than looking back, to examine Galileo's relationship to the natural philosophy that preceded him, I shall look forward, to examine just one way in which Galileo's natural philosophy anticipated that of his successors. In doing so, I shall make use of the distinction between experimental and speculative natural philosophy highlighted by Peter Anstey and Stephen Gaukroger. Anstey shows how this distinction was used by natural philosophers themselves, particularly those who defended the experimental approach (Anstey 2005: 14). And Gaukroger's work suggests this was no mere apologetic ploy: there really was a distinction in the late seventeenth century between these two ways of studying the natural world (Gaukroger 2006: 355). Drawing above all on Gaukroger's analysis of Galileo's physics, I shall argue that Galileo anticipates some of the attitudes that would later be associated with experimental natural philosophy. Firstly, his natural philosophy not only uses experiment to test the applicability of its mathematical models (Fehér 1982: 106–7), but is formulated from the very outset in ways that depend on experiments, both real and imagined (Gaukroger 1978: 210). Secondly, while Galileo is prepared to speculate about the underlying mechanisms that give rise to phenomena, his *nuova scienza* is not dependent on the positing of such mechanisms. In this respect, too, his natural philosophy resembles the experimental natural philosophy of a later age.

But first a note of caution. I am using this distinction in a way that anthropologists would describe as "etic" rather than "emic." In other words, I am wielding it as an analytical tool; I am not suggesting that Galileo was aware of it or that he employed it. Peter Anstey argues that natural philosophers within the English tradition begin using this distinction in the late 1650s (Anstey 2005: 217). Stephen Gaukroger traces the distinction to the dispute between Robert Boyle and Thomas Hobbes in 1661 (Gaukroger 2006: 368). While a similar distinction was found among Galileo's Italian successors (Middleton 1971: 92), I am not suggesting that Galileo himself made it. The making of such distinctions does seem to belong a (slightly) later period. What I shall argue is that Galileo's natural philosopher displays at least some of the characteristics of what would later be called "experimental natural philosophy." In doing so, it does anticipate later developments.

2 Experimental and Speculative

So what is the distinction highlighted by Anstey and Gaukroger? Peter Anstey's initial definition is a useful starting point. He writes that

> speculative natural philosophy is the development of explanations of natural phenomena without prior recourse to systematic obser-

vation and experiment. By contrast, experimental natural philosophy involves the collection and ordering of observations and experimental reports with a view to the development of explanations of natural phenomena based on these observations and experiments (Anstey 2005: 15).

What seems decisive here is the question of priority. In the case of speculative natural philosophy, it seems, principled argumentation has priority, and this is merely tested against experience. But in the case of experimental philosophy, it is observation and experimentation that forms the basis of whatever explanatory theorizing might be offered.

In a similar but not identical manner, Stephen Gaukroger argues that what is distinctive of speculative natural philosophy is that it seeks a system of explanation, based on fundamental principles about corporeal entities, that is capable of explaining all the phenomena within the relevant domain. In this sense it could perhaps be better described as "foundationalist" (Gaukroger 2006: 451). In doing so, Gaukroger argues, it "necessarily involved tailoring the *explanandum*" (the phenomena to be explained) "to fit the *explanans*" (the account of underlying causal mechanisms). Experimental natural philosophy, by way of contrast, tailored the *explanans* to the *explanandum* (Gaukroger 2006: 355). Experimental philosophers marked out and explored their domain of enquiry by means of the experimental apparatus that they developed, such as Boyle's air-pump or Newton's prism (Gaukroger 2006: 398). And they believed that the results they obtained were of significance even in the absence of any picture of underlying causal mechanisms.

As examples of the experimental view, Gaukroger offers, first of all, the work of William Gilbert (1540–1603) on magnetism.[2] Gilbert's use of the terrella, a small spherical magnet, enables him to offer experimental evidence of the magnetic properties of the earth, in ways that are not dependent on "fundamental natural-philosophical principles" (Gaukroger 2006: 367). Gaukroger's second example has to do with the dispute between Boyle and Hobbes. What Hobbes found offensive, he argues, is the fact that Boyle was offering explanations that were less than systematic and took no account of "fundamental natural-philosophical questions" (Gaukroger 2006: 372). While Hobbes was prepared to abandon experimental results, assuming that these stemmed from error, rather than abandon his system, Boyle held on to the experimental results, even in the absence of a satisfactory system to back it up. Gaukroger's third example has to be with the dispute between René

[2]The example is particularly interesting, since Gilbert resembles Galileo insofar as his work precedes any *explicit* use of an experimental/speculative distinction.

Descartes and Isaac Newton on the nature of colour. Descartes, he argues, began with a geometrical optics, but his explanation of colour referred to the behavour of the invisible particles that made up the light ray. Newton, by way of contrast, did not move beyond the phenomenal level. He "remained in the realm of geometrical optics and explored causal relations between the phenomena themselves" (Gaukroger 2006: 379).

It seems, from both Anstey and Gaukroger's descriptions, that advocates of experimental natural philosophy were not opposed to offering accounts of causal mechanisms. After all, Newton's account of the ways in which a prism produced colours was a causal account, even if it remained on the level of phenomena. It suggested that the sunlight contained components that behaved differently when transmitted through the prism, "being refracted at slightly different angles along a continuous gradation from red to violet" (Gaukroger 2006: 393). Nor were experimental philosophers opposed to speculations about causal mechanisms that went beyond the phenomena. Indeed they could regard knowledge of such hidden causal mechanisms as an explanatory ideal (Gaukroger 2006: 372). Robert Boyle, for instance, was a leading exponent and defender of experimental philosophy. Yet he was also deeply committed to a mechanist account of underlying mechanism – appealing to nothing more than the shape, size, and motions of impenetrable particles – even if he rarely succeeded in offering explanations of this kind.

Nonetheless, what Boyle and other experimental philosophers insisted on was that any speculation about underlying mechanisms should emerge from, and be firmly grounded in, experimental results. More importantly, they believed that the experimental philosophy did not depend on such an account being available. Scientific progress was possible even in the absence of a metaphysical account – however desirable this may be – of the underlying structure of the material world. Newton, for instance, as he freely admitted in his *Philosophical Transactions* (8: 6109), had no theory of the underlying structure of matter that would explain the optical phenomena he was studying (Gaukroger 2006: 398). As is well known, his theory of universal gravitation would have a similar character. It, too, would provide a quantifiable explanation of wide range of phenomena, without claiming to offer any account of the underlying mechanism.

3 Galileo's Natural Philosophy

In asking whether this distinction sheds light on the work of Galileo, I shall focus on two issues. The first has to do with the role of experimentation in Galileo's natural philosophy. The second has to do with the degree to which his natural philosophy requires an account of the causal mechanisms underlying phenomena.

3.1 The Role of Experimentation

Much ink has been spilt on the question of whether Galileo actually conducted the experiments he describes. There have been those, beginning with Galileo's contemporary Marin Mersenne (1588–1648), who have doubted that Galileo id so, considering his experiments to be only "thought experiments." In more recent times, Alexander Koyré claimed that Galileo would have lacked the ability to perform the experiments required to establish, for instance, his law of free fall, with the required degree of precision (Koyré 1968: 94, 114). More recently, however, there have been successful attempts to replicate Galileo's reported experiments, using equipment that would have been available to him (Settle 1961: 34). And Stillman Drake has produced documentary evidence suggesting that Galileo did, in fact, perform experiments and take careful measurements (Drake 1978: 88–89 *et passim*).

This discussion, however, is of biographical rather than philosophical importance. The key question here is not whether Galileo actually performed the experiments attributed to him; it is what role experimentation plays in his natural philosophy. There are passages in the *Dialogo* in which Galileo, through his spokesman Salviati, appears to make light of the need for experimental proof. In one passage, for instance, Salviati has just spoken about the need for experiment, as opposed to accepting claims on authority. He is then asked by the Aristotelian Simplicio whether he has actually performed the experiment about which he speaks. He replies: "Without experiment, I am sure that the effect will happen as I tell you, because it must happen that way" (Galileo 1967: 145). Koyré concludes from this that Galileo's physics, like all good physics, is "done *a priori*" (Koyré 1978: 166).

There is surely some truth in this view, as we shall see. But if it were taken at face value, it would place Galileo among the speculative rather than the experimental natural philosophers. In fact, however, the situation is more complex. Galileo continues to seek a demonstrative natural philosophy – one in which the conclusions follow with certainly from the premises – but one which (unlike the Aristotelian) relies on mathematical (and above all, geometrical) proofs. Like any mathematical proofs, these can be elaborated in an a priori fashion, without any reference to experience. But whether a particular proof applies to the world of experience – or, better still, whether it accurately describes the structure of the world (Fehér 1982: 104–5) – can only be ascertained experimentally (Machamer 1978: 176). It is experiment which tells us which geometrical proof is to be used, even if the geometrical proof itself can be developed independently of experience.[3]

In any case, even if Galileo was often content to reason his way to a conclusion, the mere fact that he described possible experiments shows that he recognized their importance. When discussing the theory of the tides in the Dialogo, Salviati actually anticipates the *vera causa* (true cause) doctrine later enunciated by Isaac Newton: the idea that we should posit only those causes of whose effectiveness we have independent evidence.[4] Simplicio has just declared his willingness to attribute the tides to a supernatural cause, if all proposed natural explanations have failed. Salviati responds:

> You argue very prudently, and also in agreement with Aristotle's doctrine; at the beginning of his Mechanics, as you know, he ascribes to miracles all things whose causes are hidden. But I believe you do not have any stronger inclination that the true cause of the tides is one of those incomprehensibles than the mere fact that among all things so far adduced as *verae causae* [*vere cagioni*] there is not one which we can duplicate for ourselves by means of appropriate artificial devices [*nessuna ve ne con la quale, per qualunque artifizio si adoperi, si possa rappresentar da noi un simile effetto*] (Galileo 1967: 421).

The "artificial device" (*artifizio*) that Salviati adduces in support of his theory is nothing more elaborate than the movement of water in a vessel. But his point is that something should not be considered a candidate for an explanation unless it can find some experimental support.

Similarly, on the third day of the *Discorsi*, Salviati is pressed by Simplicio for evidence that the world really does conform to the pattern of his geometrical demonstrations. Salviati responds that this is a "very reasonable" request and goes on to describe the relevant experiments (Galileo 1914: 178). Simplicio responds that he is ready to take Salviati's account on trust and to accept his reported results. Whether or not we should do the same, taking on trust Galileo's reports of his experiments, the discussion shows that Galileo recognizes the importance of experimentation. Steffen Ducheyne has recently argued that Galileo's conception of causality was bound up with the idea of experimental interventions. "In order to know nature, we have to

[3]The nearest I have found to a description of this procedure in Galileo's works is in his remarks "On Naturally Accelerated Motion" at the beginning of the third day of the *Discorsi*. See also his letter to Pierre Calcavy on 5 June 1637, cited in Wallace 1974: 93.

[4]See *Regula I* of Newton's *Regulae philosophandi* in book 3 of his *Principia*: *Causas rerum naturalium non plures admitti debere, quam quae et verae sint et earum phaenomenis explicandis sufficiant* (more causes of natural things should not be admitted than are true and sufficient to explain the phenomena).

intervene in nature" (Ducheyne 2006: 444). He cites in support Galileo's definition of a cause, "a cause is that which when put in place, the effect follows; and when removed, the effect is removed" (Ducheyne 2006: 450).[5] While this resembles what would today be called a counterfactual definition of causation, in its context it is associated with experimental interventions.

Stephen Gaukroger goes further and argues that experimentation shapes Galileo's very conception of natural philosophy. Experimentation is not merely the way in which his theories are to be tested; it shapes the very way in which his physical theories are framed and formulated. It has often been claimed that "the laws of Galilean physics are abstract' laws" which refer to "an ideal and abstract reality" (Koyré 1978: 183). It is true, of course, that in setting aside "impediments" (*impedimenti*), such as the resistance of the air, Galileo's proofs do not refer to the world of everyday experience (Galileo 1914: 253). But it is unhelpful, Gaukroger argues, to think of them as an idealisations of, or abstractions from, experienced reality (Gaukroger 1978: 218–19; 2006: 418). There *is* an experienced reality to which they conform. It may not be that of everyday experience, but it is that of "carefully controlled physical experiments" (Gaukroger 1978: 221). It follows that in Galileo's work, the task of natural philosophy is being rethought. It is no longer the study of reality as revealed to everyday observation; it is the study of that reality revealed in experimental situations.

3.2 The Search for Underlying Causes

What about the search for underlying causes? It would be misleading to say, as Gaukroger says about Gilbert, that Galileo draws "systematic connections" at a "purely phenomenal level, instead of being grounded in underlying causes" (Gaukroger 2006: 367). Gilbert, too, was interested in underlying causes, as Gaukroger himself points out, arguing (for instance) that the attractive power of magnets differs from that of electrically charged bodies because of differing underlying mechanisms (Gaukroger 2006: 365). And Galileo does, at times speculate about underlying mechanisms. When he does so, he favours a corpuscularian and atomic theory.

There are a number of places in which Galileo puts forward such views. The first is in his Discourse on Floating Bodies of 1612, where he claims that water is composed of "discrete particles or atoms" that can part in order to

[5] *causa è quella, la qual posta, seguita l'effetto; e rimossa, si rimuove l'effetto.* This particular definition is found in Galileo's notes on the dispute regarding floating bodies (Drake 1981: 217). A similar definition is found in the work on floating bodies itself: a cause is that which, "being present, the effect is there, and being removed, the effect is taken away" (*la qual posta, si pon l'effetto, e tolta, si toglie*)(Galileo 1981: 130).

allow the passage of bodies and accepts a modified form of the Democritean belief in "fire atoms" (*atomi ignei*) (Shea 1970: 13–14; Galileo 1981: 117–18, 176). The second is in his controversy with Orazio Grassi in 1618 regarding the nature of comets. On this occasion, he rejects (in the person of his disciple Mario Guiducci) the idea that motion as such produces heat, arguing that heat is produced by the impact on us of small particles that are released by friction from certain kinds of bodies (Shea 1970: 17; Guiducci 1960: 31–32). This is particularly interesting, since in disputing this idea it is Grassi who can "cast himself in the role of the hard-headed experimentalist" and Galileo who blithely dismisses the experimental evidence (Shea 1970: 17; Galileo 1960: 292–93).

It is, however, in a third and more mature work that Galileo's attitude to such speculations is most clearly revealed. On the first day of the Discorsi, Salviati, Sagredo, and Simplicio are engaged in a discussion on the strength of materials or (more precisely) their "resistance to breakage" (*resistenza dello strapparsi*) (Galileo 1914: 18). Salviati suggests that one of the causes of this resistance is nature's repugnance of a void (*vacuo*). As the discussion continues, he suggests that this repugnance may exist even at the level of the "very smallest particles" (*le minime ultime*) of the material in question (Galileo 1914: 18). The suggestion here is that there may be "extremely minute vacua" (*minutissimi vacui*) – "microvoids," if you like – that affect these smallest particles of matter, binding them together.

The discussion that follows this suggestion is particularly interesting, although much of it is irrelevant here. Salviati argues that since materials can, it seems, be continually divided, they must be made up of an infinity of indivisible parts. For if a continuum were made up of an odd number of indivisible parts, then its division into two equal parts would result in the division of the central indivisible particle, which is absurd (Galileo 1914: 31). But this in turn implies that those parts must be unquantifiable, since an infinity of quantifiable parts would make up an infinite quantity (Galileo 1914: 34). As Thomas Holden has recently shown, Galileo is here taking sides on a long-running metaphysical dispute, insisting that bodies could be composed of an infinity of actual parts (Holden 2004: 59). To make this even slightly plausible, he must treat these parts as equivalent to mathematical points, resulting in a kind of mathematical atomism (Le Grand 1978: 202).

All of this is fascinating, but my question is: What role do such speculations play in Galileo's natural philosophy? My answer is that they play a very minor role. Indeed Salviati introduces the topic with the following remarks.

> Let me tell you something that has just occurred to me and which

> I do not offer as an absolute fact (*verità risoluta*), but rather as a passing thought (*una qual si sia fantasia*), still immature and calling for more careful consideration. You may take of it as you like; and judge the rest as you see fit (Galileo 1914: 19).

Now Galileo is not customarily so modest in the claims he makes, but it seems that he recognizes that such reflections cannot, as they stand, enjoy the kind of demonstrative force that scientific arguments ought to offer (Machamer 1978: 176–77). And indeed the second day of the *Discorsi* begins by effectively sidelining the speculative matter theory of the first day. Those speculations are described by Sagredo as "digressions" (*digressioni*) which have led them aside from the principle question. Salviati apparently agrees. "Whatever the nature of this resistance," he says, "which solids offer to large tractive forces there can at least be no doubt of its existence" (Galileo 1914: 109). So while Galileo does not reject the idea of seeking an account of underlying physical mechanisms – he is no positivist in our modern sense – he does regard such speculations, when they fall short of the demonstrative force that he seeks, as of secondary importance. More importantly, his "new sciences" can make do without them.

A further indication of the secondary role played by such speculation is that Galileo's work on motion is almost exclusively a kinematics. He made little or no progress explaining the causes of motion (Gaukroger 1978: 224; 2006: 419). But he does not regard his work as a failure on this account; on the contrary. At one point in the *Discorsi* Salviati freely admits that while we can explain the speed of freely falling bodies, the cause of their acceleration remains a mystery. But he simply sets this question aside, noting that this is not

> the proper time to investigate the cause of the acceleration of natural motion concerning which various opinions have been expressed by various philosophers, some explaining it by attraction to the center, others to repulsion between the very small parts of the body, while others still attribute it to a certain stress in the surrounding medium which closes in behind the falling body and drives it from one of its positions to another. Now, all these fantasies [*le quale fantasie*], and others too, ought to be examined; but it is not really worthwhile. At present it is the purpose of our Author to investigate and to demonstrate some of the properties of accelerated motion (whatever the cause of this acceleration may be) (Galileo 1914: 166).

One can, it seems, have a perfectly useful "new science" of motion without any account of the causes of motion. This is one of the features that marks his anticipation of what was later called "experimental philosophy."

There is, however, another dimension to this discussion. If Galileo is prepared to speculate about underlying mechanisms, then one cannot simply say (as Stillman Drake does) that Galileo rejected causal enquiries (Drake (1989: 159 n.12). If he is at times apparently indifferent to them, this may reflect nothing more than a recognition of the limits of what we can currently know. As Salviati remarks on the third day of the *Discorsi*, such an enquiry would bear little fruit (Galileo 1914: 166). But there may be more to Galileo's apparent indifference than this. Galileo apparently regards his geometrical demostrations as scientific. But to be scientific, in the traditional sense, it is not enough that they shold offer a mere statement of the facts (*quia*); they must explain why (*propter quid*) the facts are as they are. But if those explanations do not invoke underlying mechanisms, in what sense are they scientific explanations at all? The answer seems to be that they are explanations on the level of formal rather than efficient causality (Machamer 1978: 174–75; Wallace 1974: 96–97). Galileo regards a mathematical formalism that is tested against the reality in question to be itself explanatory.

The distinction between efficient and formal causality is, of course, traditional and Aristotelian. Indeed the very idea of a formal cause might seem strange to us: we are inclined to identify "cause" with "efficient cause." It is, perhaps, this identification that leads modern authors to suppose that Galileo has abandoned causal enquiry. It is, however, more accurate to say that the causal properties Galileo seeks are different from those sought by his predecessors. His formal causes are the mathematically describable properties of the objects whose behaviour is being explained, properties that no Aristotelian would regard as essential (Gaukroger 2006: 401–3). This seems to be the point of Galileo's famous remark about the book of nature: that it is written in the language of mathematics (Galileo 1960: 183–84). It is, once again, experimentation that allows us to pick up which of those mathematically describable properties are generally operative and are therefore the proper subject of a science.

It is this move that allows Galileo, as it would later allow Newton, to be content with a causal account that remains on the level of phenomena, rather than speculating about a realm that is inaccessible to observation. A mechanistic account – one that appealed to underlying mechanisms, such as Galileo's *fantasia* of the microvoids – would be an explanation on the level of efficient causality. But an explanation in terms of the mathematically-describable properties of objects is a different kind of explanation. It is true that the behaviour of the minuscule impenetrable particles that feature in the mechanical philosophy could also be described mathematically (at least in principle). Indeed this was what Descartes had intended to do (Gaukroger 2006: 410). But Galileo's geometrical proofs are not applied to the behaviour of such particles; they are applied to the behaviour of macroscopic objects, in situations of carefully controlled experimentation.

4 Conclusion

At what conclusion, then, have I arrived? Despite the fact that it continues to hold to the traditional, Aristotelian ideal of a demonstrative science, the natural philosophy of Galileo does anticipate the experimental philosophy of the later seventeenth century. It does so in two respects. The first is its emphasis on experimentation. Whatever experiments Galileo himself performed, his geometrically-oriented rethinking of physical problems relies on carefully controlled experimentation. The reality against which his mathematical models are to be tested is not that of everyday observation, but that of experimentation. Like the experimental philosophers of a (slightly) later age, Galileo uses his experimental setups – actual or imagined – to demarcate his realm of enquiry and to determine the kinds of questions that can be asked. The second respect in which Galileo anticipates the experimental philosophy is in his apparent indifference to accounts of underlying mechanisms. It is not merely that he believes that progress can be made even in the absence of any causal account. This is surely true, as his own treatment of motion shows. But more significantly, Galileo's account of causality is more formal than efficient, relying on mathematically-describable relations between experimental phenomena, rather than a metaphysical account of the underlying nature of the world.

Perhaps the best place to end, therefore, is with the pseudonymous *Dialogue Concerning the New Star* of 1605, which most commentators take to be written by Galileo. This engaging dialogue takes place between two rustics (*contadini*) discussing the appearance of the "new star" of 1604, known today as "Kepler's supernova." One of them, Natale, refers to a book written by an Aristotelian philosopher which suggests that this so-called "new star" is closer to us than the moon. His companion, Matteo, replies, "What is this fellow that wrote the book? Is he a land-surveyor?"

> Natale: No, he is a Philosopher.
> Matteo: A Philosopher, is he? What has philosophy got to do with measuring? ... It's the Mathematicians you've got to believe. They are surveyors of empty air, just like I survey fields and can rightly tell you how long they are and how wide. Just so can they.

Natale: He said there in that book that the Mathematicians put it way too high, because they don't understand.

Matteo: How don't they understand? ...

Natale: He says they imagine that sky can be destroyed or created a bit at a time, though not all at once. How should I know?

Matteo: Now, where do Mathematicians talk that kind of reasons? If they just stick to measuring, what do they care whether or not something can be created? If it were made of polenta, couldn't they still see it all right? That wouldn't make it any bigger, or smaller, would it?[6]

If the sky were made of polenta, it wouldn't matter to the new-style natural philosopher, for he could still measure it successfully. This is surely something new in the history of natural philosophy.

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