The Renaissance Mathematicus

JULY 13, 2010 · 4:24 PM

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The Book of Nature is written in the language of mathematics.

The title of this post is probably the most well known genuine quote from the Tuscan polymath Galileo Galilei; he never actually said, “but it moves”! This quote turned up recently in my posts on the paper from Jay Kennedy concerning his discovery of possibly Pythagorean harmonies in the text structure of the writings of Plato. In a comment to my second post on the subject Mike from Ottawa, as well as pointing out a substantial typo in my text, wrote the following:

I wonder what Kennedy thought the Ptolemaic model of the universe was based in if not the idea the universe ran by predictable laws expressible in the language of mathematics.

Mike's comment as well as several of those from Kennedy display an ignorance of what exactly Galileo's quote is supposed to express and so I have decided to write a short exposition on mathematics and its use in the sciences and how that use was categorised from a philosophical standpoint. This is however very much a simplification of a very tricky subject so I would request the professional philosophers and historians of science such as Jim Harrison, John Lynch and the Albino Aussie Anthropoid™ to go gently on their criticism, though if they or anybody else has anything informative and or constructive to add then I would be more than happy should they choose to do so.

Kennedy starts with the Pythagoreans and so shall I. The Pythagoreans, who were a religious cult living in a commune in Southern Italy, believed that the natural numbers are the building blocks (the atoms) that constitute the universe, they also believed that everything could be expressed in terms of ratios between natural numbers some of these ratios being harmonious and others discordant. In fact the word harmony has its roots in arithmetic and it is through the Pythagorean philosophy that it became a fundamental concept in music theory. Naturally the discovery of irrational numbers completely blew this idea out of the water. If something as simple as the diagonal of a square cannot be expressed as the ratio of two natural numbers then the whole foundations of the Pythagorean philosophy are undermined. I'm not going to expand on Pythagorean harmony theory except to say that it permeates the history of Western science and philosophy all the way up to Newton, with many scholars such as Newton himself, Tycho and Kepler being big fans. Now what is important here is that the arithmetic of the natural numbers is a long way from being mathematics, even in the 6th century BCE, both Egyptian and Babylonian mathematics went way beyond this so to claim, as Kennedy does, that the Pythagoreans are fulfilling Galileo's quote is to say the least stretching things somewhat.

Plato, who certainly had a lot of sympathy for the Pythagoreans, goes a lot further. His concept of mathematics is not the arithmetic of the natural numbers but geometry; he famously had the saying, "let nobody ignorant of geometry enter here" erected over the entrance to his school. It is not known for certain why the Greeks abandoned the highly developed algebra of the Babylonians for geometry but it is assumed that the discovery of irrational numbers played a significant role in this decision. The presence of Eudoxus' extraordinary theory of proportions in Book V of Euclid's Elements, in which he defines irrational numbers using geometrical ratios (almost equivalent to the Dedekind cuts we use ourselves), seems to support this assumption. Plato's use of mathematics is however very different from that of the Pythagoreans'. Plato challenges the mathematicians to provide a geometrical description of the movement of the heavens burdening them at the same time with the so called Platonic Axiom; the heavenly bodies move in perfect, uniform, circular motion. This belief goes back to Empedocles who thought that circular motion is the only natural motion because only when things move in circle can a vacuum or void be avoided. Planetary motion is natural motion, so it is circular. Now the Greek astronomers following Plato's injunction developed very ingenious geometrical models to generate uniform circular motion for the planets whose apparent movements are anything but circular or uniform. Here of course we are much closer to a model of the real world written in the language of mathematics but we have a problem it is just a model. Following Duhem, a 19th century French historian and philosopher of science, it is thought that nobody actually believed that the deferents and epicycles of Ptolemaic astronomy were real, they are just a mathematical model to "save the phenomena". This leads to a split in the description of the heavens into cosmology that describes what is really there and mathematical astronomy that is just a useful fiction for calculating the position of planets to do things such as astrology. Enter Aristotle!

Aristotle was famously a pupil of Plato who ended up rejecting the philosophy of his teacher and replacing it with his own. Now Aristotle undertook a massive reorganisation of the theory of knowledge, or epistemology as the philosophers call it. According to Aristotle (and please remember this is a very simplified version of events!) knowledge or scientia (I find it amusing that most of the terminology of Aristotelian philosophy is Latin whereas Aristotle was Greek!) is based on first principles or axioms that are known to be true without the necessity of proof from which further

knowledge is deduced using syllogistic logic. The main purpose of knowledge is the determination of the four causa (causes) of natural phenomena, material, formal, efficient and final. It would take too long to explain this here and it's not particularly relevant to my theme so I wont. Knowledge is thus a priori, descriptive and teleological (the final cause) and mathematics is definitely not scientia.

In Metaphysics II, Aristotle explicitly undermines the possibility of an epistêmê, in the strict sense, with respect to nature. At the end of Book II, Aristotle makes a distinction between the accuracy to be found in mathematics and that in other disciplines. Mathematical accuracy, he says, cannot be expected in all things but only in those which do not contain matter. In particular, then, one cannot expect mathematical accuracy in the study of nature since it is concerned with matter (995a15-20). (Borrowed from the Stanford Encyclopaedia of Philosophy)

What about the mathematical sciences, astronomy and geometrical optics a la Euclid, for Aristotle these are mixed sciences and have a different and lower status to real knowledge delivering scientia. Physics is the name that Aristotle gave to the study of nature and Aristotle's physics is scientia and it is qualitative, descriptive and definitively not mathematical.

If I were doing a description of Greek science I would now need to cover Stoic philosophy however although Stoic philosophy played an important role in Renaissance science it is not relevant to the topic here so I shall skip over it and move into the Middle Ages. Greek science went into steep decline in the 2nd century CE and by the beginning of the Middle Ages science whether mathematical or non-mathematical had almost totally disappeared in Europe. In the 12th century a literate academic culture was re-established in Europe with the establishment of the universities. These institutions where dominated by the Catholic Church and at the beginning science played no role in their curricula however through the first Arabic- Greek Renaissance, in the 12th century, the works of Aristotle became known in Europe and were made compatible to Catholic theology by the work of Albertus Magnus and Thomas Aquinas. The knowledge hierarchy on the mediaeval university was first theological knowledge then Aristotelian philosophy, mathematics played no role and the mathematical sciences were only fictive in the sense of Plato.

This was the situation that ruled as Galileo started to use the book of nature topos.* In his argument with the Aristotelians and the theologians Galileo was operating on an uneven playing field. Theology based on the Bible and the works of the Church Fathers was certain knowledge. Aristotelian physics was knowledge but mathematical astronomy was not knowledge and mathematical physics was a contradiction in terms. The knowledge hierarchy was a pyramid with theology at the top and Aristotelian physics at the bottom the mathematical sciences were not knowledge delivery systems. Galileo tried to challenge the system with what was, in essence, a theological and not a scientific argument. He proposed that God had written two books the Bible and the Book of Nature. The Bible was the word of God and so had to be interpreted by theologians whereas the Book of Nature, and here comes our title quote, is written in the language of mathematics and therefore must be interpreted by mathematicians. Galileo wanted his opponents to consider the two books as being of equal importance and equal significance. He went even further along what could only prove to be a hopeless path, under the circumstances, he claimed that the Bible, that is the word of God, was open to interpretation and therefore variable whereas the Book of Nature was unambiguous and therefore when read would deliver an indisputable truth. This of course is in terms of modern philosophy of science a disaster but Galileo was not really interested in philosophy of science he was interested in proving himself right and his critics wrong. His argument which he never published, he was almost certainly aware of its weaknesses, was that his telescopic observations had refuted the Ptolemaic astronomy therefore as the Book of Nature was unambiguous the Copernican astronomy must be true! Unfortunately there was a least one other model, the Tychonic, that had not been refuted and so Galileo's conclusion was not logical. In reality there were several models competing for acceptance, a situation that I will deal with in a later post. Biagioli thinks that this gap in Galileo's argument in the reason that he ignored the Tychonic system in his Dialogo.

I want to close with three observations on the above. Firstly some might, and in fact do, argue that even if Galileo's arguments were to say the least dubious and more than a little strange he at least should be credited with having introduced mathematical physics. This would be correct if it were true but it isn't. Various areas of the study of nature had been being mathematised since a least the middle of the 14th century and this tendency had already reached a highpoint in the works of Kepler and Simon Stevin before Galileo had published a single word on the subject. I will even go so far as to claim that the replacement of the Aristotelian descriptive and qualitative physics with the quantitative mathematical physics would have continued at the same rate in the 17th century if Galileo had never existed. An indication of this can be found in the work of Christoph Clavius, one of Galileo's friends, supporters and teachers, who already in the last quarter of the 16th century had started to translate Euclid's Elements into Aristotelian syllogisms in order to demonstrate that mathematics is as truth transporting as syllogistic physics in order to achieve the same acknowledgement of the mathematical sciences as Galileo had aimed for with his Book of Nature gambit. Although it was a long fight in the end Clavius and his students were probably more successful in this direction than Galileo who only antagonised with his pseudo theological arguments.

Secondly it is extremely ironical that the Galileo quote was published in his Assayer. This pamphlet was part of a bitter dispute that Galileo carried out with the Jesuit mathematician Orazio Grassi on the nature of comets. It is ironical because Grassi argued based on empirical observations and mathematics that comets are supralunar astronomical object; Galileo however argued in true Aristotelian fashion that comets are sublunar meteorological phenomena, completely rejecting the mathematical arguments, a fact that is quietly swept under the carpet by Galileo fans.

Thirdly the ultimate mathematical book of nature written in the 17th century, Newton's Mathematical Principles of Natural Philosophy, was cast in the form it has, propositions deduced logically from axioms, in order to give it the status of an Aristotelian scientia. As usual in the history of science under the surface things are much more complex than they first appear.

* This section is a condensed version of my understanding of the arguments presented in the final chapter of Mario Biagioli's excellent "Galileo's Instruments of Credit: Telescopes, Images, Secrecy", University of Chicago Press, Chicago, 2006.

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Newton Lied! →

66 responses to "*The Book of Nature is written in the language of mathematics.*"

1.  **Jim Harrison**

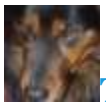
   July 13, 2010 at 9:28 pm

   I'm looking forward to your next publication, the rather large Freshman casebook, All Previous Thought.

   It occurs to me that there are two different debates going on here: one about the centrality of mathematics and one about the proper ambitions of science. As you point out, Aristotle had a limited view of the relevance of mathematics to physics. He was on Galileo's side of things in another way, however, since he did insist that a true cosmology was about how the universe actually was and wasn't just a matter of saving the phenomena, which seems to have been what it had been in Mesopotamia and would sometimes retreat into later to avoid theological complications as in Osiander's infamous preface to Copernicus. To judge by the Timaeus, if I remember it correctly, Plato seems to have inclined to the view that a geometrical explanation of reality was desirable but hedged his bet a different way by talking about likely stories. On this interpretation, Galileo wanted to have it all asserting that it was possible to have a mathematical account of the cosmos that was neither merely a set of accounting tricks or a plausible fable.

   Despite your plea for mercy, I do have to scold you for making one gross error, namely mistaking me for a professional philosopher or historian of science. I'm just a guy who reads a lot. Either that or the last great medieval thinker.

   Reply

   -  **Thony C.**

     July 15, 2010 at 7:13 am

     I'm looking forward to your next publication, the rather large Freshman casebook, All Previous Thought.

     One of my activities as a historian of science is to hold semi-popular public lectures on the subject.
     I have a secret ambition to do a "History of Western Science from 30 000 BCE to 1900 CE" in two 90 minute lectures!

Reply

-  **Michael Weiss**

  March 23, 2014 at 4:33 am

  I'm looking forward to your next publication, the rather large Freshman casebook, All Previous Thought.

  A quote, more or less, from *The Pooh Perplex*.

  Reply

  -  **Jim Harrison**

    March 24, 2014 at 2:38 am

    It took four years for somebody to notice…

2. Pingback: The Return of the Linking Dead « Evolving Thoughts
3. Pingback: Tweets that mention The Book of Nature is written in the language of mathematics. « The Renaissance Mathematicus -- Topsy.com

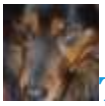
4.  **Brian**

   July 14, 2010 at 11:34 am

   Thirdly the ultimate mathematical book of nature written in the 17th century, Newton's Mathematical Principles of Natural Philosophy, …. As usual in the history of science under the surface things are much more complex than they first appear.

   Now, be gentle with me here (I'm but a Whiggish twat), but wasn't that because Newton didn't want to expose himself to withering attack on two fronts? If he'd unleashed his fluxions (differential calculus or thereabouts) as well as his cosmology then he'd be in a right pickle. From what I understand, he didn't like being pickled by critics.

   Reply

   -  **Thony C.**

July 15, 2010 at 7:15 am

A somewhat longer reply to your inquiry will be posted on RM within the next 36 hours!

Reply

5. Pingback: The Giant's Shoulders #25: 2nd Anniversary Edition! « The Dispersal of Darwin

6. Will Thomas

July 16, 2010 at 3:06 pm

Thony, I've been wondering for a while about "save the phenomenon" and its relationship to astronomy. Since epicycles and such have been made into stand-ins for the futility of a paradigm, the term "save" has come (for me, at least) to have a sort of air of desperation to it. Given possible older connotations of the word "save" not so close to "rescue", might it be better to start using a word like "recover" to indicate the success of mathematics in replicating the original observed behavior? Or would this do injustice to the original connotation as well? What is the original Latin phrase?

Also, if mathematics is understood to recover the phenomenon, then would this indicate a gap between the task of the mathematician and the behavior of nature, thus indicating that even mathematicians (at least prior to Galileo and his quote) understood the language of nature itself to not be mathematical? Actually, perhaps that is your point with this post here....

Reply

- **Jim Harrison**

July 16, 2010 at 4:40 pm

The expression " to save the phenomena" is Greek, not Latin: sozein ta phainomena. Sozein means to save or spare: Sotor (Savior), the epithet of Christ and various Greek gods and several Hellenistic monarchs, is derived from this verb.

Phainomena is the title of a number of ancient books on astronomy so the word was associated with what you can observe in the sky very early on. My books claim that the expression "saving the phenomena," was first used by the 6th Century neoplatonist Simplicius in a commentary on Aristotle's De Caelo (on the Heavens) to explain Plato's understanding of what astronomy should be about.

Of course for a Platonist, if there's a gap between what we see and the mathematics that explain it, so much the worse for the appearances!

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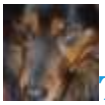
-  **Thony C.**

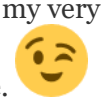
  July 19, 2010 at 3:55 pm

  Oh my god, I have highly intelligent, well-read and well-educated readers (Will) who ask difficult and awkward question.

  Thank god I have highly intelligent, well-read and well-educated readers (Jim) who can answer difficult and awkward question.

  Actually Will I hesitated before including the Duhem thesis in my account because I'm not really convinced that it as universally valid as it is often presented. However there is very little doubt that at least the Aristotelians who were Galileo's opponents only granted mathematical astronomy an instrumentalist status and not an epistemic one and therefore my decision to include it.

  To your question, I actually believe that many mathematical astronomers considered their mathematical models to have an epistemic status. On my reading Ptolemaeus believes that he is presenting a real picture of the heavens in his Syntaxis Mathematiké. I also believe that Peuerbach believed that he was presenting reality when he produced his synthesis of the Aristotelian homocentric cosmology and the Ptolemaic epicycle astronomy in his New Planetary Theory (Nürnberg, 1472). If this were not the case then the synthesis would not be necessary. I'm fairly convinced that other astronomers also believed in the reality of their models.

  I think the doubts that you express are valid and it's one of those themes that is on my very long list of things to investigate more deeply when I have time. 

-  **Mark Thomas**

  March 22, 2014 at 9:16 am

  I believe C S Lewis in his 1964 work "The Discarded Image" indeed refers to Simplicius as the original source of the expression "saving the pheonomena".

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18. Pingback: Theological cosmology | The Renaissance Mathematicus

19.  Abbas Majeed

October 17, 2011 at 6:10 pm

i don't agree with you.For Scientists it is possible to give similar comments on Knowledge.

Reply

20. Pingback: Monday Blast from the Past #2 | The Renaissance Mathematicus

21.  Ron Van Wegen

October 26, 2011 at 2:03 am

You wrote,"...in order to demonstrate that mathematics is as truth transporting as syllogistic physics in order to achieve the same acknowledgement of the mathematical sciences as Galileo had aimed for with his Book of Nature gambit."
I'm not sure what you mean by... "mathematics is as truth transporting as syllogistic physics" this?
Do you mean something like... "mathematics is truth masquerading as syllogistic physics"? or am I missing something simple?
Please forgive me!

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29. Pingback: Open Lab Update | Child's Play

30. Koos

March 25, 2015 at 8:11 am

I am but a mere bystander in this entire conversation in that I simply do not have the depth of reading to partake much ad in that I am not a mathematician. I am a language engineeer, though: we are the types to make computers handle language. Machine translation and speech recognition are two of our kinds of efforts. From my personal experience, limited in the way I decribe above, my phrasing of the connection between mathematics and nature would be that mathematics does not only describe nature, but the reality of every day life.

Researcher and mathematician Claude E Shannon of Bell Labs worked on a project to increase the channel capacity of telephone lines. He and his aids designed a system they called 'information theory' roughly inspired by the physics of entropy. Other researchers took information theory and found it can be applied to medical decision making or document classification or language identification, where a computer decides the language it is fed is French, for instance. The system of formulas developed for one bit of reality, that Bell company thought increasing profits would be nice, could be applied to other pieces of reality – the precarious business of medical decisio making. I am consciously avoiding the word 'nature' here. Language identification is not 'nature'.

I consider myself a hard-nosed diehard atheist, but if there were on argument for a superior mind having designed the human brain this is it. Mathematics is a product of the human mind. It is generally agreed that the brain and the mind have evolved. But why would evolution produce a mind that busies itself with mathematics as a separate activity that then turns out to have several sophisticated applications THAT THIS BRANCH OF MATHEMATICS WAS NOT DESIGNED TO SOLVE?

I can see how an animal smart enough to poke a tree with a stick and thus elecit insects to eat from that tree has the survival edge. I can see how axes, hammers etc. evolved from that as mental concepts. But what is the survival value of the human ability to design a math to increase channel capacity for Bell telephone? And what a weird concept that one formula from this branch of math should be applicable to software seeking to automatically classify documents.

Reply

31. Pingback: The Book of Nature is written in the language of mathematics. | My BlogThe Philosopher's blog.

32. Pingback: Are Science's Preferred Languages Limiting How Smart Folk Think? – Latest Ethiopian and World News

33.  **iamvistinginstructoreric**

July 24, 2019 at 7:51 pm

Reblogged this on Project ENGAGE.

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59. Pingback: We now have more evidence that Galileo probably never said, "And yet it moves." - rebablog

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The Renaissance Mathematicus

The Facts of Life

If your philosophy of [scientific] history claims that the sequence should have been A→B→C, and it is C→A→B, then your philosophy of history is wrong. You have to take the data of history seriously.

John S. Wilkins 30th August 2009

Culture is part of the unholy trinity—culture, chaos, and cock-up—which roam through our versions of history, substituting for traditional theories of causation. – Filipe Fernández–Armesto "Pathfinders: A Global History of Exploration"

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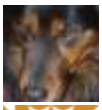

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