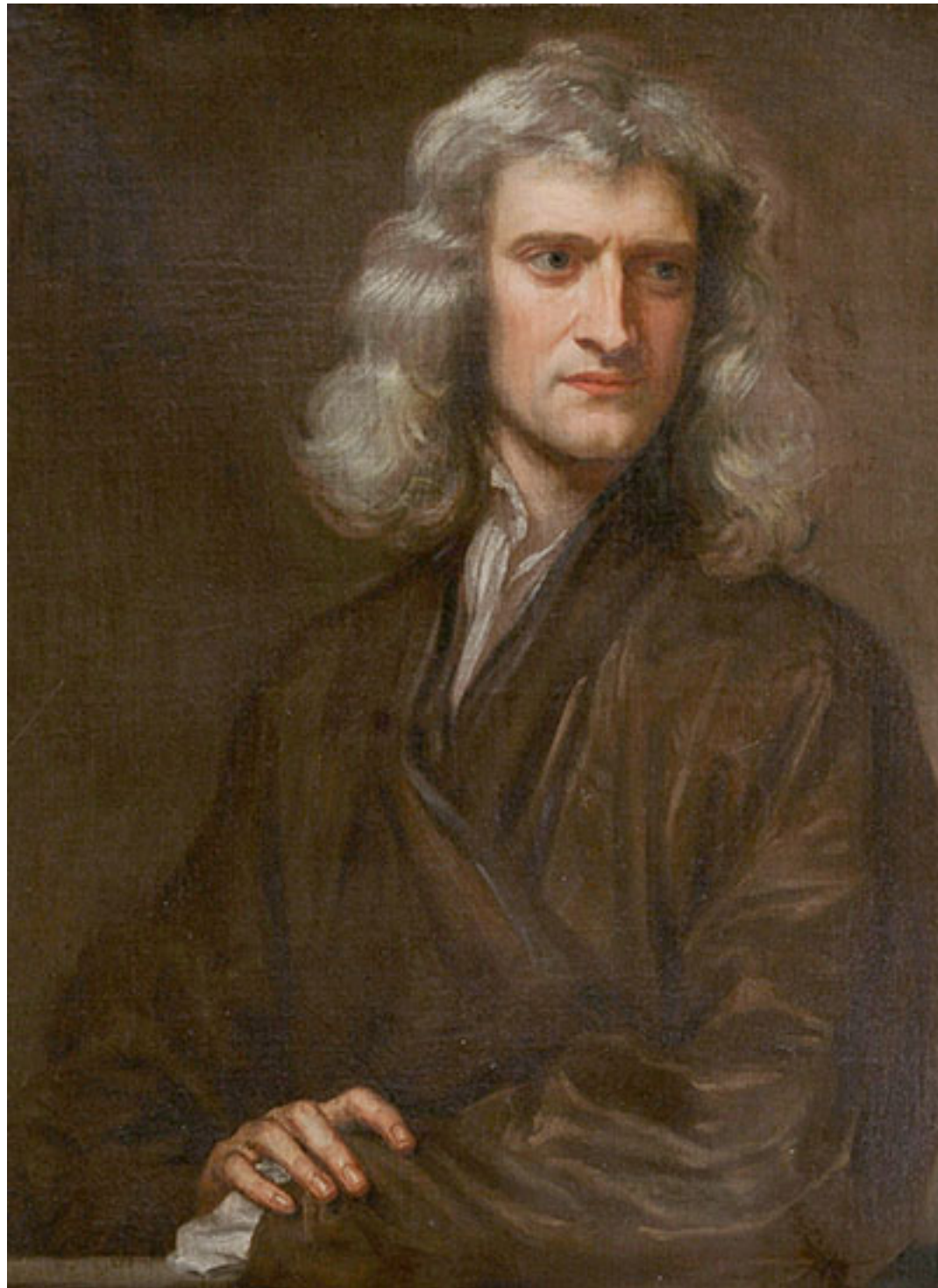


The past is a foreign country:  
they do things differently there.

*L. P. Hartley, “The Go-Between”*



Isaac Newton in 1689

# Newton's Critique of the Law of Universal Gravitation

Hans Mühlen

2022

Hans' interests:

- **gravitation** (classical or quantum)
- **history of physics and mathematics**
- **foundational questions**



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Today's combo feature —

an attempt to answer the question  
*how did Newton think about gravity*



Some time ago I started to read about Newton, just out of curiosity.

I noticed that many Newton scholars kept pointing to **the same quote from Newton.**

They all emphasised **how important this quote was to really understand Newton...**



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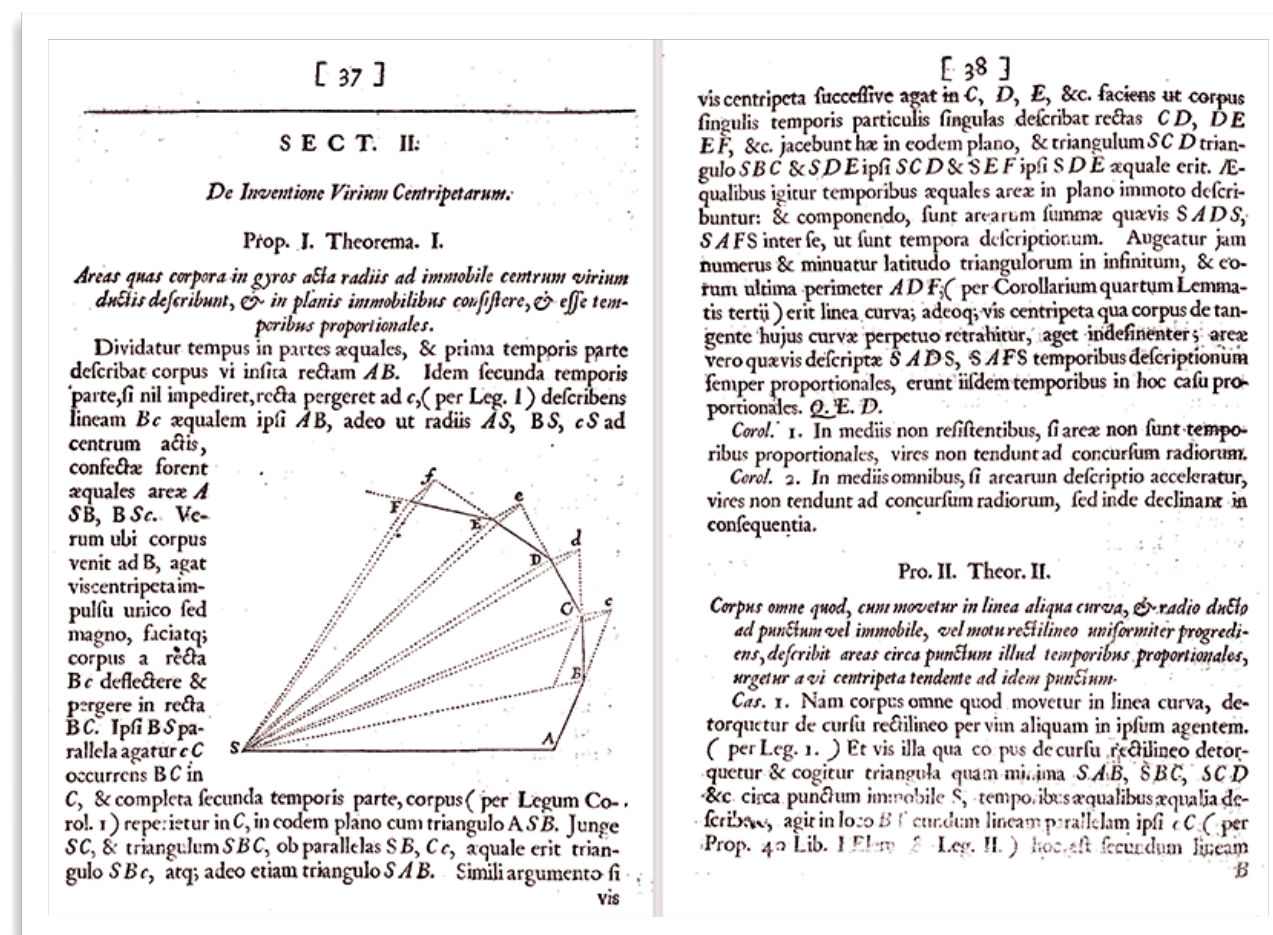
They all emphasised **how important this quote was to really understand Newton...**

**...and yet — they all seemed to disagree on how to interpret the quote.**





Now, here was a **historiographical** puzzle that I felt was just as **challenging** to make sense of as any of my attempts to understand Newton's **mathematics** and **physics**.



With apologies to all physicists in the audience — **in this talk I will analyse that famous quote**, and try to sketch some of the various attempts to interpret it.





With apologies to all physicists in the audience — **in this talk I will analyse that famous quote**, and try to sketch some of the various attempts to interpret it.

...but don't worry, we will learn a lot about Newton and his views on gravity in the process.



# 1. The Historical Context



---

Newton's critique of the law of universal gravitation



But first a few **timelines!**

I refuse to give a talk unless it contains at least one timeline.

They are the lens through which I interpret everything I read in physics as well as in history.



The setting of this tale is **the period we usually call “the Scientific Revolution”** in the 16<sup>th</sup> and 17<sup>th</sup> centuries.

# The Scientific Revolution



Newton's critique of the law of universal gravitation

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Newton's critique of the law of universal gravitation

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**“On the Revolution of  
the Heavenly Spheres”**

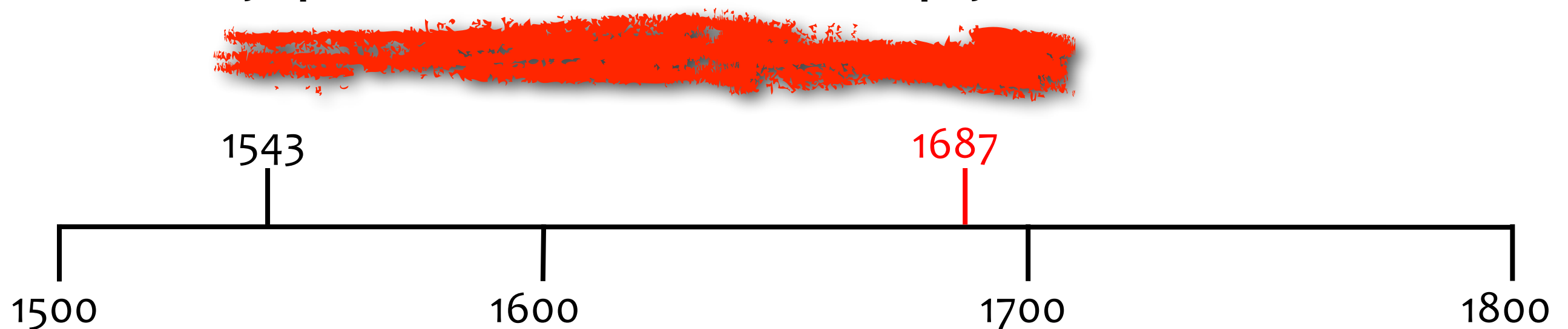


Newton's critique of the law of universal gravitation

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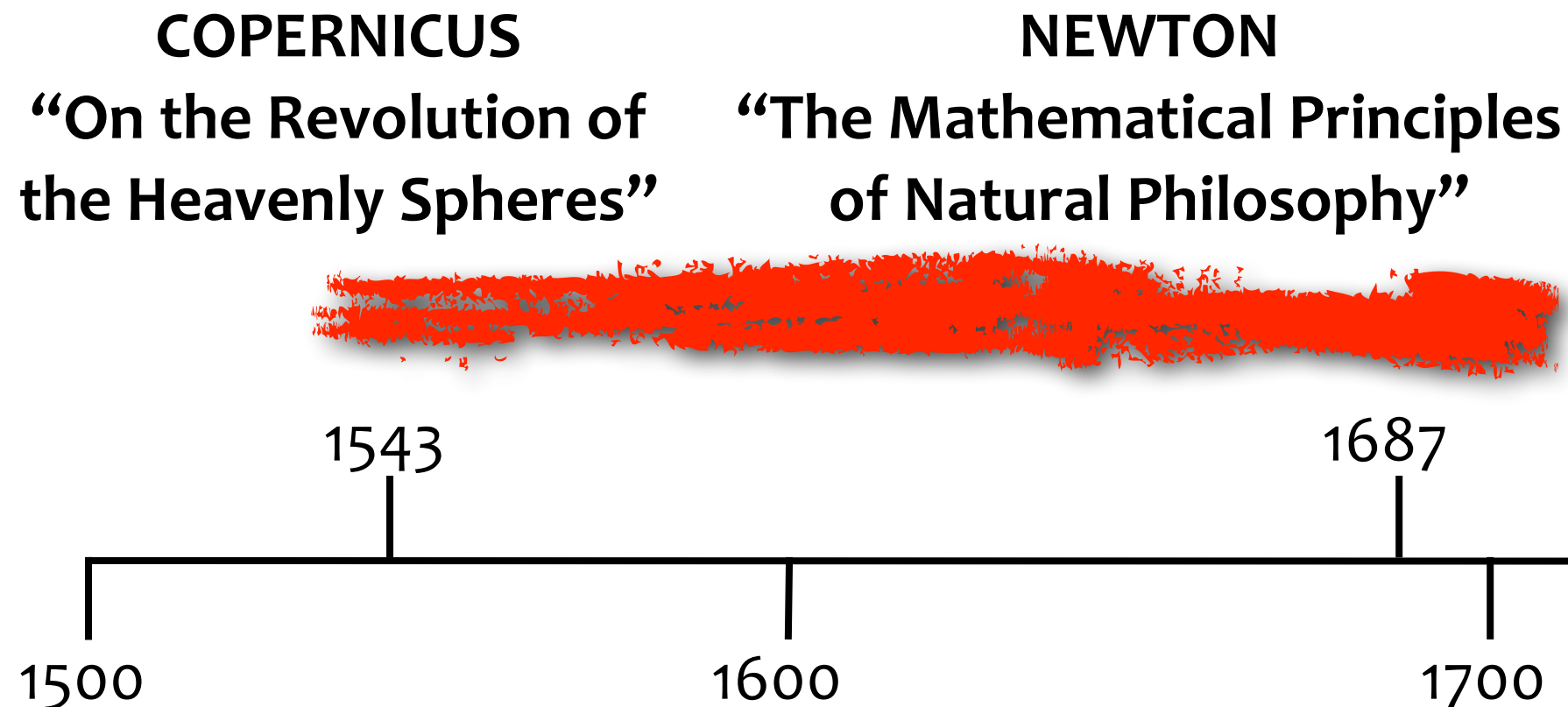
COPERNICUS	NEWTON
“On the Revolution of the Heavenly Spheres”	“The Mathematical Principles of Natural Philosophy”



Newton's critique of the law of universal gravitation

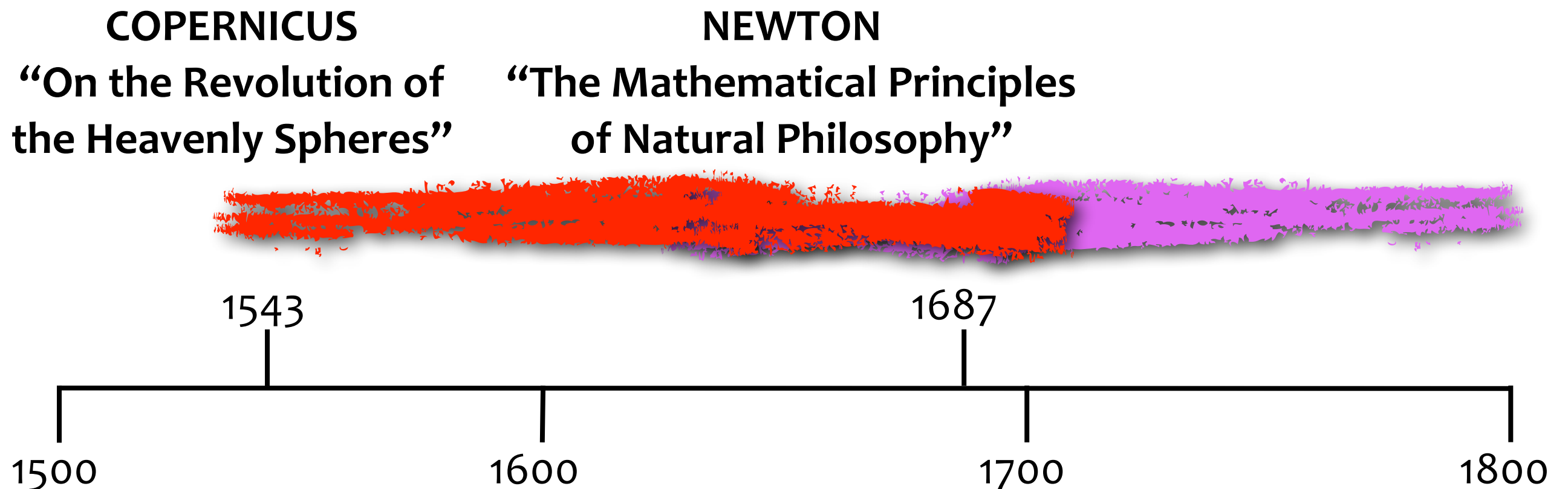


A “revolution” that took 144 years...



Newton’s critique of the law of universal gravitation

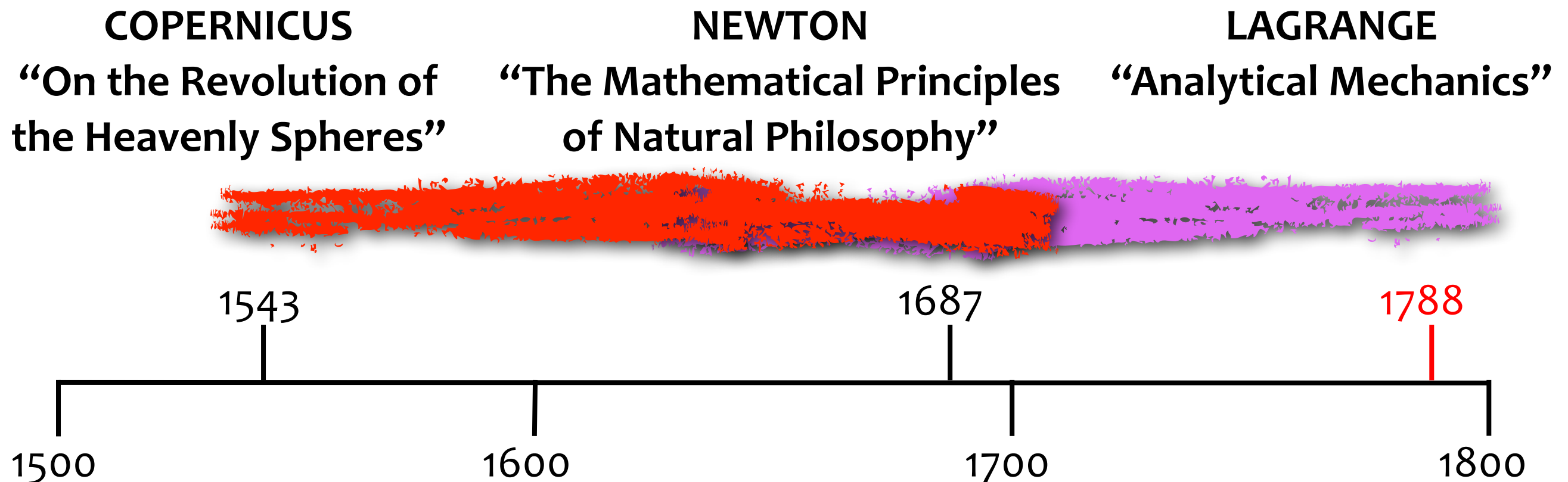
It actually took yet another century to rework the “*Principles*” from Newton’s arcane geometrical formulation to the language of the newly developed calculus.



Newton’s critique of the law of universal gravitation

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An arbitrary (but useful) end point for this process could be:

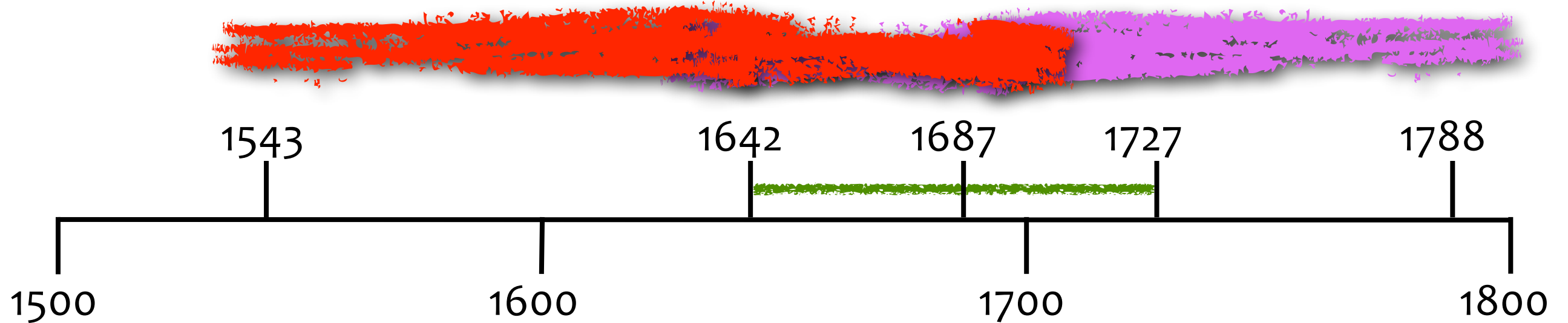


Newton’s critique of the law of universal gravitation

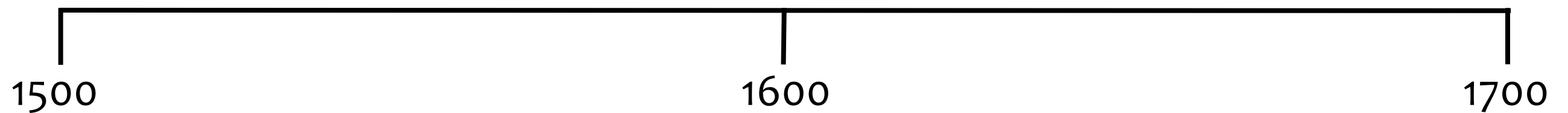
...and our hero

# Isaac Newton

lived right in the middle of this  
*loooong* revolution!



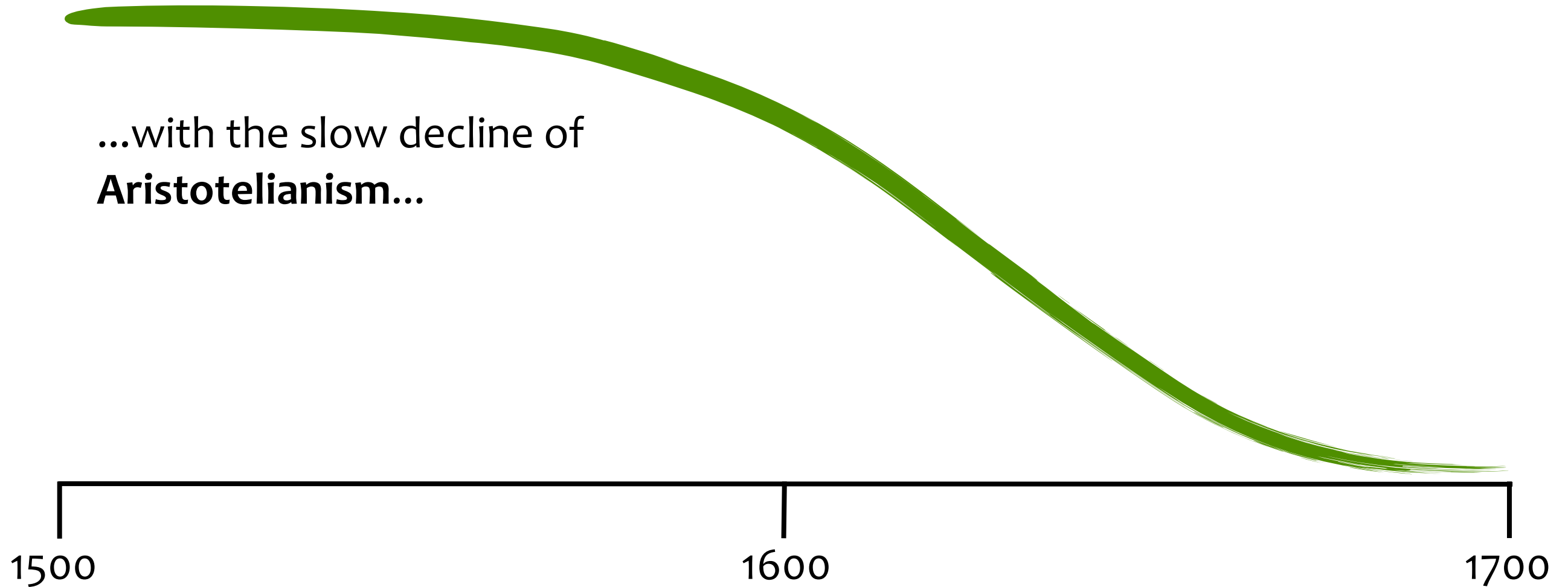
Why call it a “revolution”?  
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Newton's critique of the law of universal gravitation

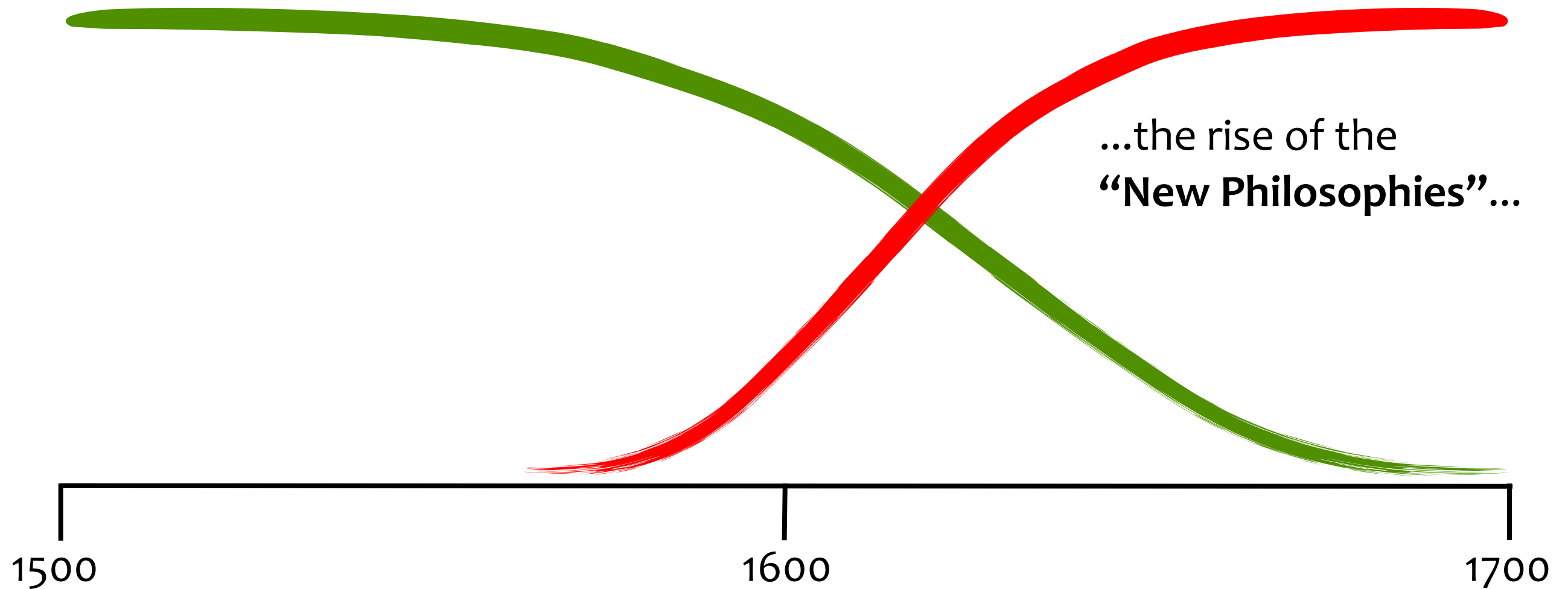
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**Aristotelianism**...



Newton's critique of the law of universal gravitation

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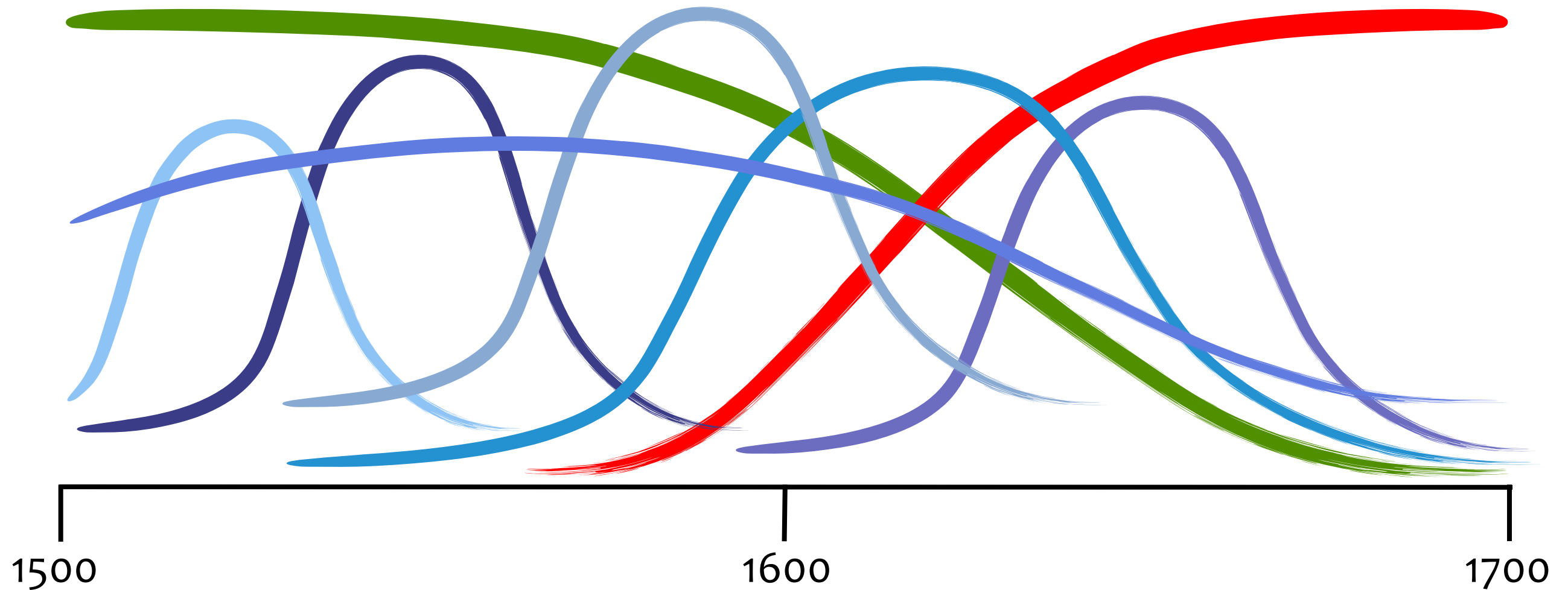


Newton's critique of the law of universal gravitation



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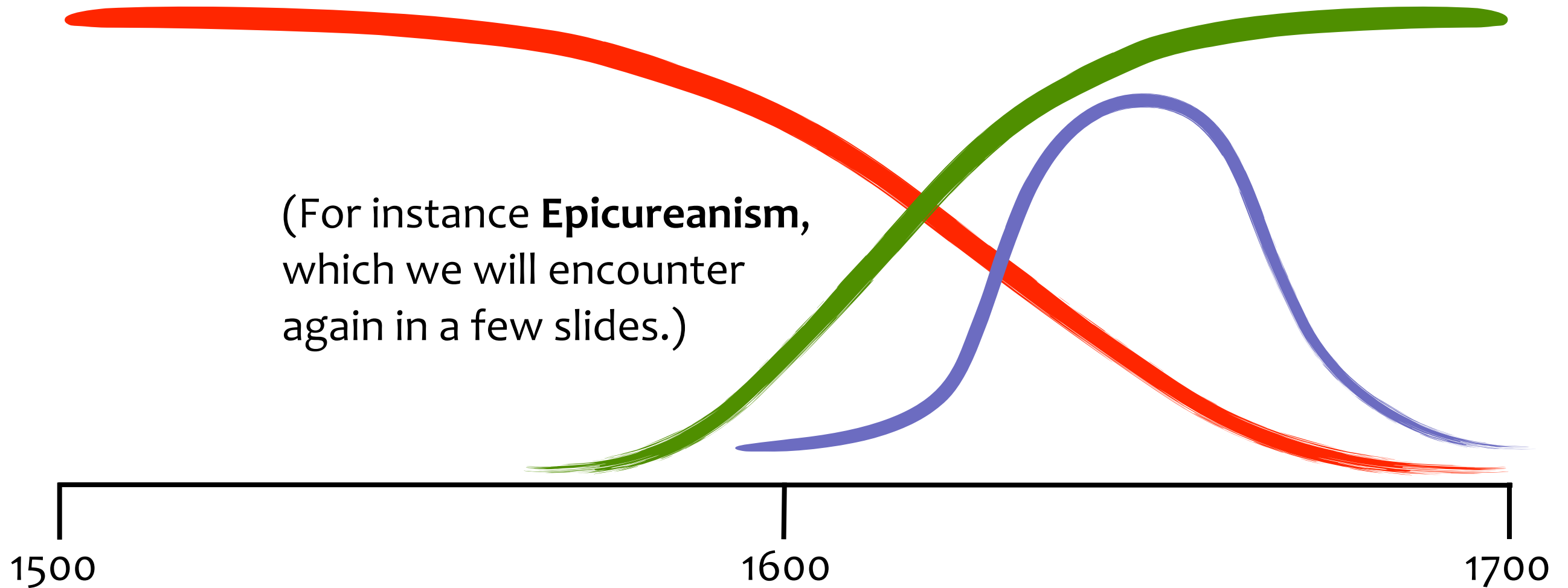


Newton's critique of the law of universal gravitation

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the preceding 15<sup>th</sup> and 16<sup>th</sup> centuries.

(For instance **Epicureanism**,  
which we will encounter  
again in a few slides.)

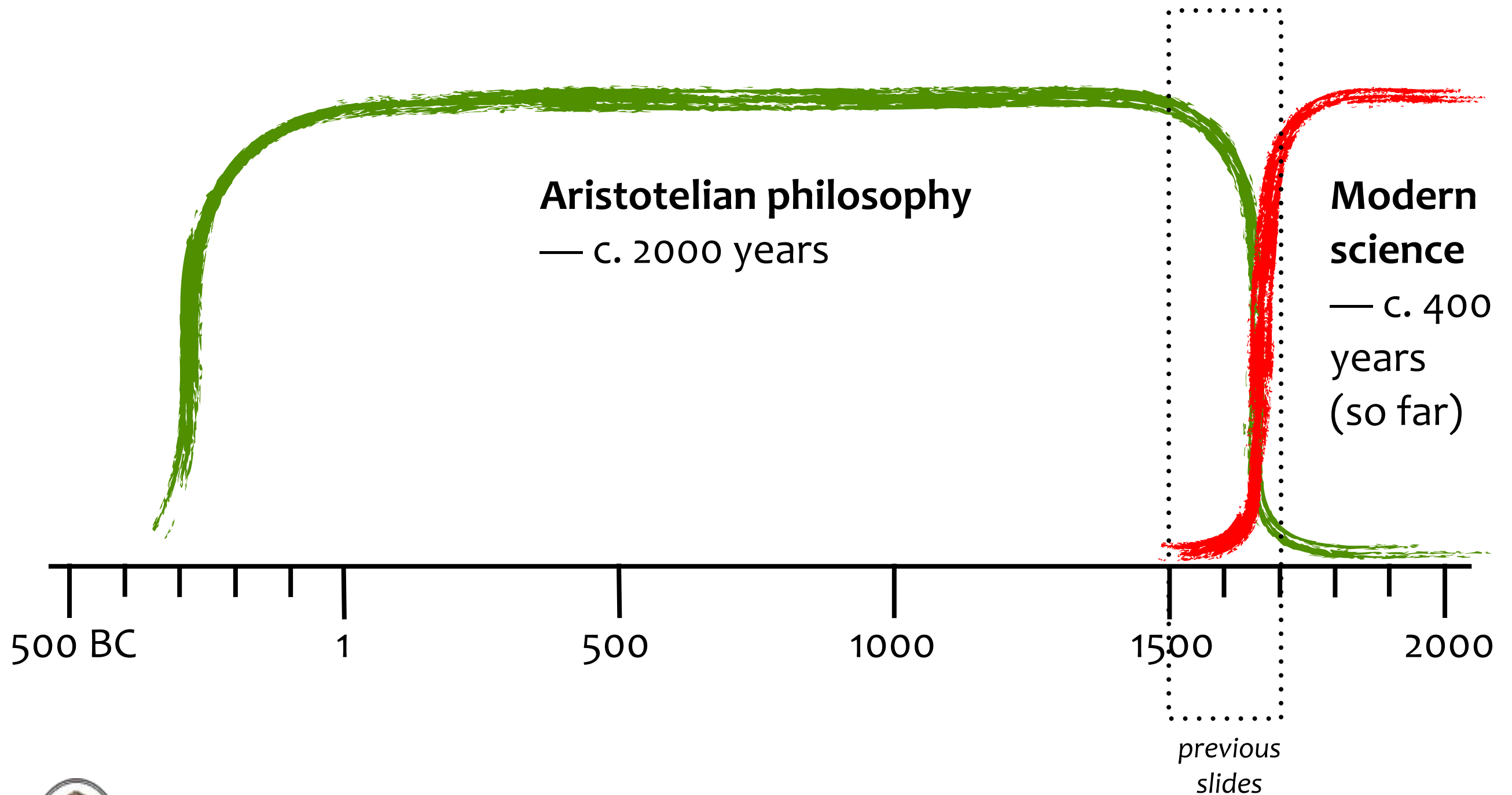


Newton's critique of the law of universal gravitation

No wonder it took 144 years to sort out this mess!



Taking a step back from our timeline we see that **modern science** is really something of an upstart...



Anyhow...

## Back to Newton and his Law of Universal Gravity!



## 2. The Law



Newton's critique of the law of universal gravitation



# A modern representation of Newton's Law of Universal Gravity:

$$F = G \frac{m_1 m_2}{r_{12}^2}$$

- An **attractive** force acting between pairs of massive bodies
- The force acts the same way for any massive bodies (**universal** gravity)
- The *strength* of the force is proportional to the **two masses**, and inversely proportional to the **square of the distance** between their centers of gravity
- The *direction* of the force is along the line joining their centers of gravity (**central force**)
- The force acts **instantaneously** and **at a distance**





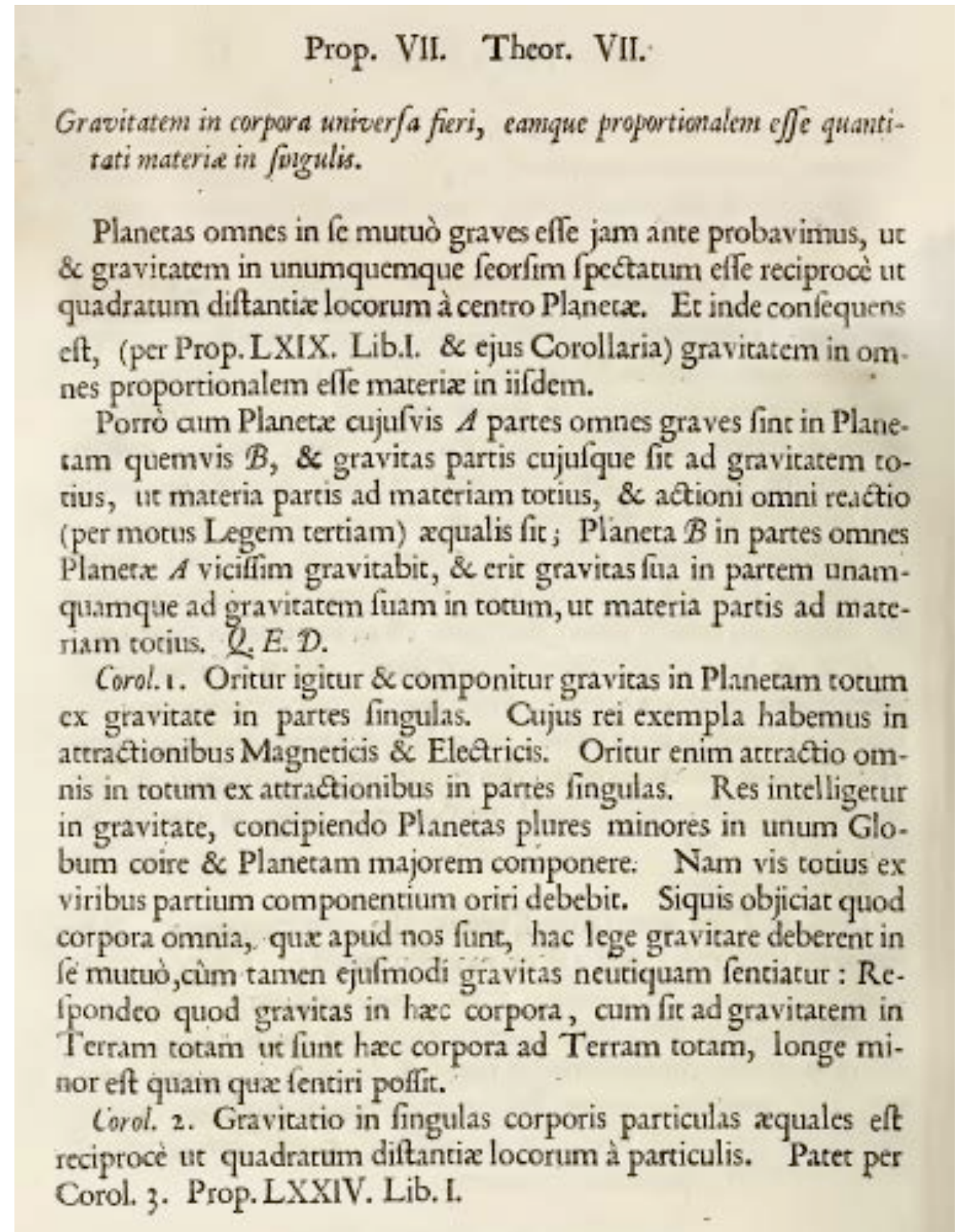
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Proposition 7 from Book 3 of the  
*Philosophiæ Naturalis Principia Mathematica*,  
first published in 1687



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**PROPOSITION VII.**

*That there is a power of gravity tending  
to all bodies, proportional to the several  
quantities of matter which they contain.*

[...]

**COR. 1.** *Therefore the force of gravity  
towards any whole planet arises from,  
and is compounded of, the forces of  
gravity towards all its parts. [...]*

**COR. 2.** *The force of gravity towards  
the several equal particles of any body is  
reciprocally as the square of the distance  
of places from the particles; [...]*



Trying to understand Newton's difficult geometrical and (calculus-)notation-free presentation of mechanics and gravity is a challenge!



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I will have to leave that to another talk...





Trying to understand Newton's difficult geometrical and (calculus) notation-free presentation of mechanics and gravity is a challenge!

I will have to leave that to another talk...

...or you could read Chandrasekhar's beautiful book:

**“Newton's Principia for the Common Reader” (1996)**



# 3. The Quote



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Newton's critique of the law of universal gravitation





The source of the quote is one paragraph in a **letter from Isaac Newton to the Rev. Richard Bentley.**

The letter is dated February 25, 1692|3, some 5½ years after the publication of the *Principles*.



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The letter is dated February 25, 1692|3, some 5½ years after the publication of the *Principles*.

...and most authors only quote the following **out-of-context extract** from the full paragraph:



*[...] That gravity should be innate inherent & essential to matter so y<sup>t</sup> one body may act upon another at a distance through a vacuum w<sup>th</sup>out the mediation of any thing else [...] is to me such an absurdity that I beleive no man who has in philosophical matters any competent faculty of thinking can ever fall into it.*

Letter from Isaac Newton to Richard Bentley, February 25, 1692|3



***What do you think?***

*What is Newton trying to say here?*



*[...] That gravity should be innate inherent & essential to matter so y<sup>t</sup> one body may act upon another at a distance through a vacuum w<sup>th</sup>out the mediation of any thing else [...] is to me such an absurdity that I beleive no man who has in philosophical matters any competent faculty of thinking can ever fall into it.*



The most common interpretation is this:

**Newton rejects action at a distance —  
and in no uncertain terms.**



[...] *That gravity should be innate inherent & essential to matter so **y<sup>t</sup> one body may act upon another at a distance** through a vacuum w<sup>th</sup>out the mediation of any thing else [...] **is to me** such **an absurdity** that I beleive no man who has in philosophical matters any competent faculty of thinking can ever fall into it.*



***But surely***, Newton's gravitational force ***must*** be understood as ***acting at a distance***.

Remember: the expression for the force contains only quantities referring to the properties of the two gravitating bodies (their mass) and to their relative distance.

**There is no place for gravity being “*mediated by anything else*” in this theory!**





So there we are...

— on the one hand we read that Newton **rejects** that gravity acts at a distance.

— on the other, we know that his own theory of gravity **is based on** precisely that.



# 4. What is “Action at a Distance” Anyway?



# ***Action at a distance***

**...any action (like impressing a force)  
between spatially separated bodies.**



When I speak to you, or you look at the slides, we have examples of “**action at a distance**”: *light and sound activate your sensory organs some distance away from the source.*

But we know there is a *mechanism* for continually *mediating* the action (an electromagnetic field, a pressure wave in the air).



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The problem to be discussed here is with ***unmediated action at a distance.***



So we need to distinguish between two kinds of “action at a distance”:

UNMEDIATED  
action at a  
distance

MEDIATED  
action at a  
distance

Let's start looking at the *unmediated* type...



The rejection of unmediated action at a distance has a long history.

Already **Aristotle** (4<sup>th</sup> century B.C.) had emphatically stated that a body can only act on another body by *hitting it, sticking to it, combining with it*, or some other kind of ***contact action***.



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Already **Aristotle** (4<sup>th</sup> century B.C.) had emphatically stated that a body can only act on another body by *hitting it, sticking to it, combining with it*, or some other kind of **contact action**.

Thomas Aquinas (13<sup>th</sup> century) summarised this dogma as:

**“a body cannot act where it is not”.**





Then, in the beginning of the 17<sup>th</sup> century, **Descartes** developed his ***mechanical philosophy*** in opposition to the old Aristotelian ideas.

But also he only accepted ***direct contact action between bodies***.

All causal explanations had to be given in terms of a concrete **mechanical** model of bodies in direct contact.



Descartes' **rational philosophy** only accepted concepts that were **clear and concise**, i.e. made sense to the rational mind (since experience cannot be trusted).

So the Cartesians declared any other mode of explanation than the mechanical to be **unimaginable**.

*And what cannot be imagined, cannot exist.*



***What do you think?***

*Do we have to reject entities  
or modes of explanation  
that we **cannot imagine?***



***What do you think?***

***Is unmediated action at a distance  
an acceptable mode of causal explanation  
in modern physics?***



Next let's take a look at *mediated action at a distance*:

Which causal mediums did natural philosophers during the Scientific Revolution propose, in those cases where the mediation was not obvious (connecting ropes, levers, air, etc)?

Like for the explanation of *electric, magnetic or gravitational* phenomena.



In his rational analysis Descartes had concluded that **there cannot be any vacuum.**

Instead **the world is a plenum** of matter in direct contact. The only possible motion is particles rotating around themselves, or many particles rotating around a common axis in **vortices.**

In this way **there could be no action at a distance**, neither mediated nor unmediated.



Other natural philosophers had no problem with the vacuum.

To them **the world consisted of atoms** (or bodies made of atoms) **moving through the void.**

When they needed a medium to explain apparent action at a distance, they simply ***invented an “aether”, “vapour”, “effluvium”, “emanation”, “atmosphere”, or “spirit”*** to do the trick.



Much like the Cartesian vortices, these invisible and insensible ethers were ***material*** and ***mechanical*** in nature.

They were like very low-density gases of particles **interacting according to the laws of motion and collision** with each other or with bulk matter.





If necessary, the rather *ad hoc* invention of insensible ethers could be rationalised.

Here is a quote from Maxwell, who had to defend a “luminiferous ether” a bit later:

*[...] it is asked, by the advocates of **mediate action**, whether, in those cases in which we cannot perceive the intermediate agency, **it is not more philosophical to admit the existence of a medium** which we cannot at present perceive, than to assert that a body can act at a place where it is not.*

J. C. Maxwell, “On Action at a Distance”, 1876



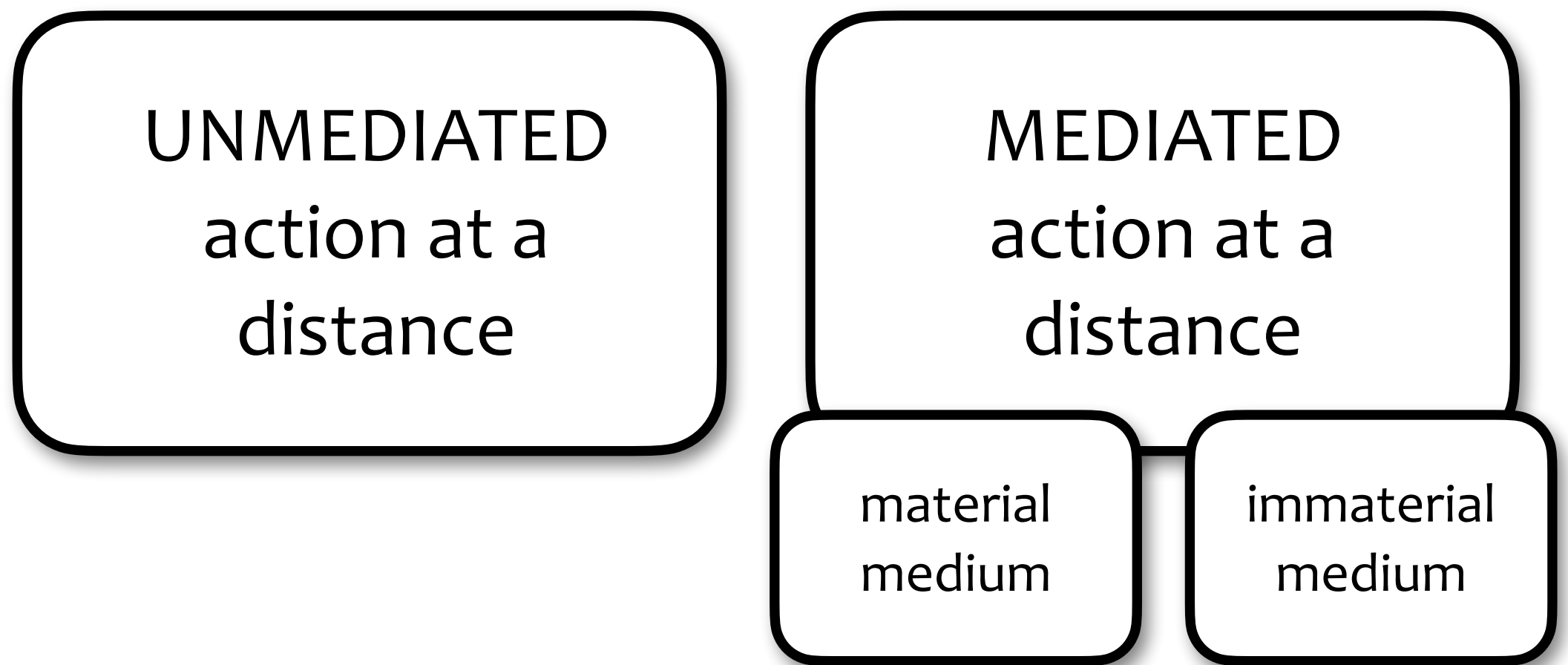
But Newton and his contemporaries also considered *immaterial mediators* of action at a distance.

These are more difficult to grasp for us today.

**God** could be such an immaterial cause (like for miracles). Or **angels**. Or **souls**. Or **insensible “principles”** that did not obey the laws of mechanics.



So we need to revise our classification of  
“actions at a distance”:



# 5. Making Sense of the Newton Quote



---

Newton's critique of the law of universal gravitation



Now let's go back to our paradoxical quote.

It appears that Newton is rejecting action at a distance, an important component of his own theory.

Now that we know a little more about action at a distance — **can we resolve this apparent paradox?**



RESOLUTION ATTEMPT 1:  
**Newton meant something else with  
the term “action at a distance” than  
we do today.**



For us **historical amateurs** it is sooo easy to fall into **traps**. Like this one:

*...just reading one snippet of historical text, taken out of context, without any other understanding of the subject matter than what modern knowledge would suggest.*



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*The past is a foreign country:  
they do things differently there.*

L. P. Hartley, “The Go-Between”





Perhaps the term “action at a distance”  
**meant something different** to people in  
the 17<sup>th</sup> century.



Perhaps the term “action at a distance”  
**meant something different** to people in  
the 17<sup>th</sup> century.

*There are indeed words or concepts that  
have a very different meaning now than  
they did in the past.*



One example of a word that means something very different today than in the 17<sup>th</sup> century is the word “**occult**”.

(For instance: Leibniz, one of his fiercest critics, claimed Newton’s gravity was an “occult quality”.

Yet he did not think that Newton meant that demons were responsible for gravity.

But let’s not get distracted...)



How can we avoid the “historical tourist trap”?

Necessary (but not sufficient) is to first **find out as much as possible about the period in question**, and to try to understand the people and their ideas — as well as one can — **as they were understood back then.**



So, let's pretend we have already spent a couple of years reading all there is to know about the science of the 17<sup>th</sup> century.

Now we can go back to the Newton quote, and see if the apparent self-contradiction dissolves.



RESOLUTION ATTEMPT 1:

**Newton meant something else with the term “action at a distance” than we do today.**

***Nope.***

Newton (by and large) thought of “action at a distance” in the same way as we do today.



RESOLUTION ATTEMPT 2:

**Newton's views on gravity had changed from when he wrote the *Principles* to when he wrote the letter to Bentley.**



Another easy mistake for **historical amateurs** to do is this:

*...cherrypicking quotes from the entire career of a scientist, disregarding the possibility that their opinions may have developed over time.*





Did Newton change his views on how gravity (and other phenomena) worked in the course of his scientific career?

Perhaps he even changed his mind in the new editions of the *Principles* (1713 and 1726)!



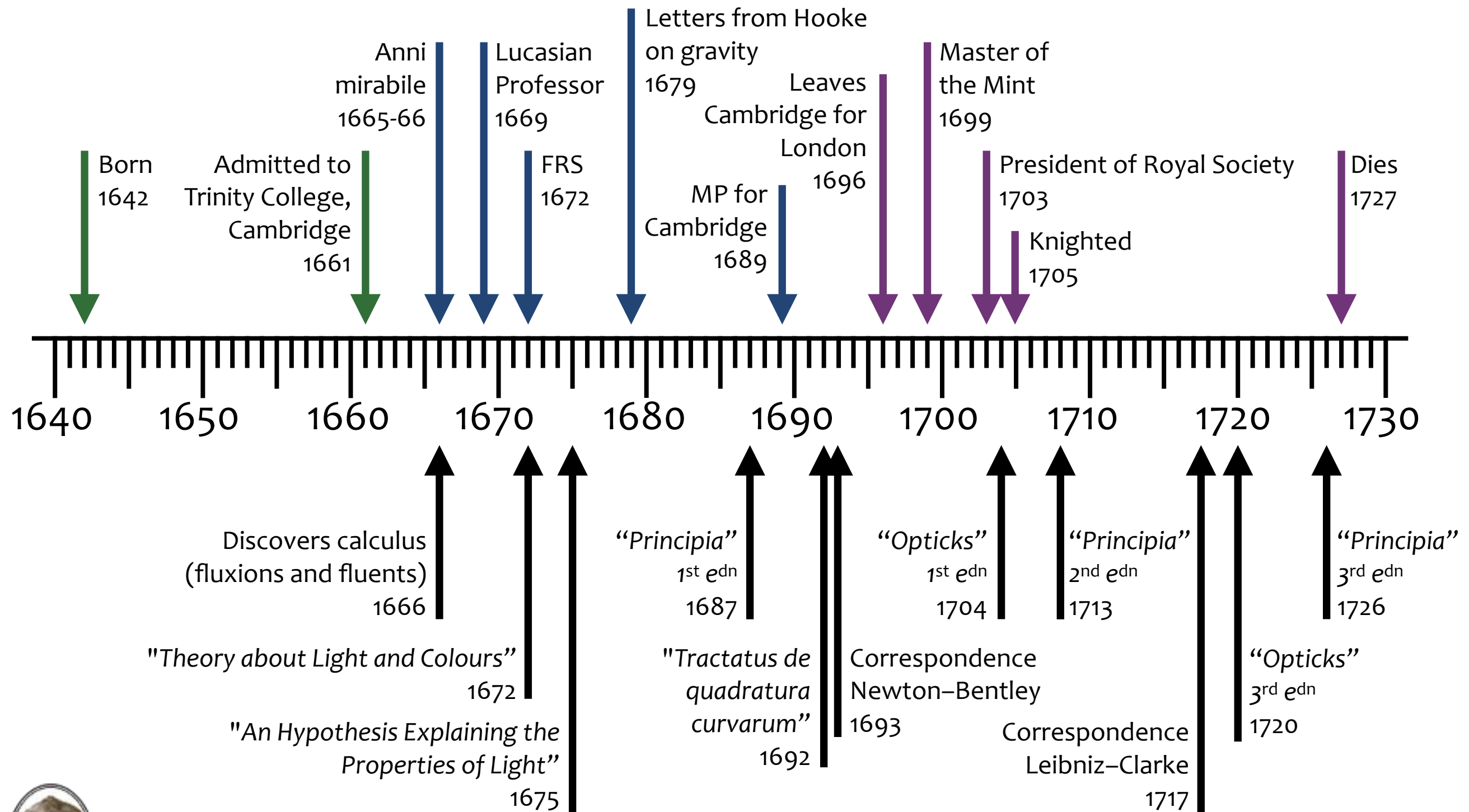
RESOLUTION ATTEMPT 2:  
**Newton's views on gravity had  
changed from when he wrote the  
*Principles* to when he wrote the  
letter to Bentley.**

***No, not really...***

There are important changes to later editions of the *Principles*, but they do not seem to be relevant to the quote..

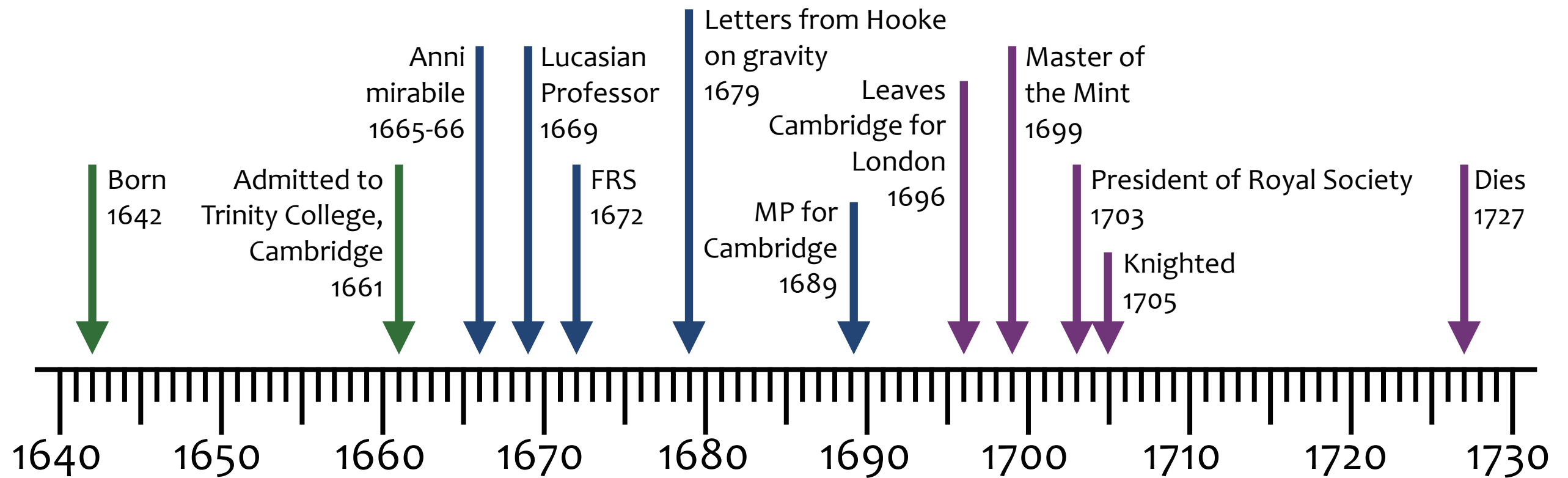


# Newton's life



Newton's critique of the law of universal gravitation

# Newton's life — English politics



Newton's critique of the law of universal gravitation

RESOLUTION ATTEMPT 3:  
**Newton actually *did not* believe in  
action at a distance.**



***Wait, this question is far too imprecise...***

Are we asking about Newton's views on  
***unmediated, materially mediated*** or  
***immaterially mediated*** action at a distance?

...and what was Newton's view on this **in the quote**, and **in the *Principles***, respectively?



[...] *That gravity should be innate inherent & essential to matter so y<sup>t</sup> one body may **act upon another at a distance through a vacuum w<sup>th</sup>out the mediation of any thing else** [...] is to me such an absurdity that I beleive no man who has in philosophical matters any competent faculty of thinking can ever fall into it.*



It seems clear that in the letter to Bentley (1693) it is *unmediated* action at a distance which Newton rejects.





And what about the *Principles*?

There is actually no explicit mention of “action at a distance” in the first edition of the *Principles* (1987).

Partly in response to criticisms of the first edition of the *Principles*, Newton added a few hints in later editions, but he never seems to have endorsed ***unmediated*** action at a distance.



But everyone else — both sympathetic readers as well as critics — interpreted the *Principles* as stating **that the force of gravity does act at a distance** between bodies *without mediation*.



**Critics of the *Principles* noted that Newton did not provide any mechanism of transmission of the gravitational action.**

And this was — in the eyes of many — Newton's real crime: proposing inconceivable *unmediated* gravitational action at a distance.

...but the critics soon died out (literally).



Meanwhile, sympathetic readers could point to the *Principles*, and **refer to the authority of Newton** to conclude that *unmediated* action at a distance was a **perfectly valid mode of causal explanation**.

A clear early statement of this unashamedly anti-Cartesian belief can be found in the preface to the 1713 second edition of the *Principles*, written by the editor Roger Cotes.



The Newton-Bentley correspondence, with Newtons rejection of *unmediated* action at a distance, **wasn't published until 1756.**

So there was nothing to prevent *unmediated* action at a distance from becoming **the new paradigm** for describing fundamental interactions, in “the age of Newton”.

Early theories of electricity and magnetism, for instance, were modelled on Newton's law of gravitation (Coulomb, Ampère).

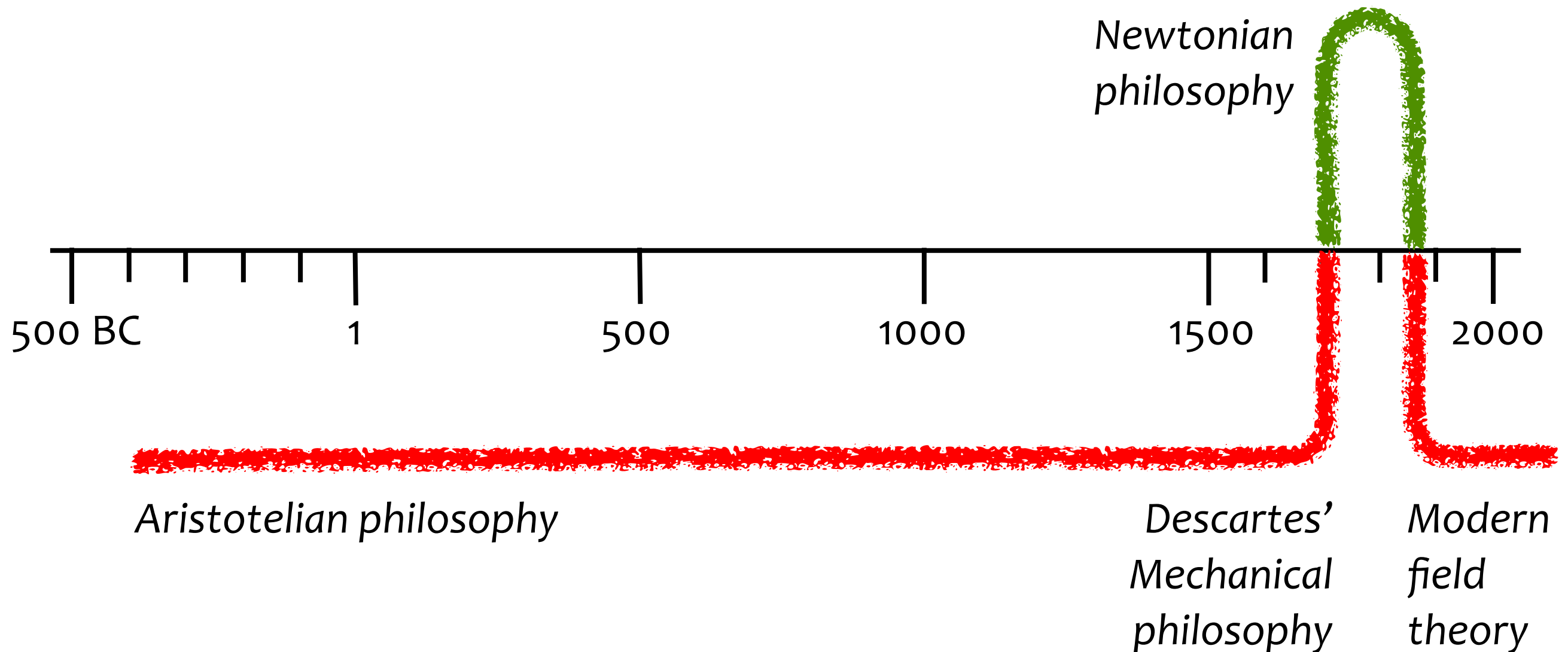


But then, later in the 19<sup>th</sup> century, with new developments in the theory of electrodynamics, *unmediated* action at a distance **fell out of favour** again.

Now proponents of *field theory* could point to the (recently published) Newton quote, and **refer to the authority of Newton** to conclude that unmediated action at a distance was **inconceivable as a mode of causal explanation**.



Q. Is “unmediated action at a distance” an acceptable cause in fundamental theories?  
(majority view)



RESOLUTION ATTEMPT 3:  
**Newton actually *did not* believe in  
action at a distance.**

***Newton did presumably not believe in  
unmediated action at a distance.***

So what about the various forms of  
***mediated*** action?





RESOLUTION ATTEMPT 4:  
**Newton rejected *unmediated* action  
at a distance, but had no opinion  
about a *medium*.**



We are now left with discussing the possibility of *mediated action at a distance*.

If I reveal the end of the full quote, we see that Newton here does not state whether any such mediated action at a distance is of the *material* or *immaterial* kind:



*[...] by and through which their Action and Force may be conveyed from one to another, is to me so great an Absurdity [...] Gravity must be caused by an Agent acting constantly according to certain Laws; but whether this Agent be material or immaterial, I have left to the Consideration of my Readers.*



It is indeed clear also from other texts  
that **Newton didn't pretend to know the  
(mediated) cause of gravity.**



Possibly in response to criticism, Newton added a new discussion section, the “**General Scholium**”, at the end of the second edition of the Principles (1713).

Here he freely admits that he has not presented any mechanism for the transmission of gravitational action.

But he also states that this is not necessary:



*Hitherto we have explained the phenomena of the heavens and of our sea by the power of gravity, **but have not yet assigned the cause of this power.** [...]*

***And to us it is enough that gravity does really exist,** and act according to the laws which we have explained, and abundantly serves to account for all the motions of the celestial bodies, and of our sea.*

I. Newton, “Principia”, 3rd edition 1626,  
General Scholium (translation by A. Motte)



Newton has found the laws of motion, and has shown with mathematical rigour that planets, moons and comets move according to Kepler's three laws if and only if they are acted upon at a distance by an inverse-square force.

Finding a concrete mechanism for this action will not add anything new to the analysis.



And furthermore, **speculating** about such a mechanism without any observational support **is quite unacceptable**.

(This is a wholesale rejection of Descartes' rationalistic philosophy.)

In a passage perhaps even more famous than “our quote”, Newton states his empiricist methodological credo:





*But hitherto I have not been able to discover the cause of those properties of gravity from phænomena, and **I feign no hypotheses**; for whatever is **not deduced from the phænomena** is to be called an hypothesis; **and hypotheses**, whether metaphysical or physical, whether of occult qualities or mechanical, **have no place in experimental philosophy.***

I. Newton, “Principia”, 3rd edition 1626,  
General Scholium (translation by A. Motte)



Here we have stumbled on one of the components of **Newton's inductive-deductive methodology**:

*Knowledge can only be obtained from an **analysis of the phenomena** (experiment, observation); through **induction** we arrive at **general laws**; from these laws predictions about new phenomena can then be obtained (mathematically) through **deduction**; hypotheses (a priori speculation) must be banned from science.*



*In this philosophy particular propositions are **inferred** from the phenomena, and afterwards **rendered general** by induction.*

I. Newton, “Principia”, 3rd edition 1626,  
General Scholium (translation by A. Motte)

*[...] for all the difficulty of philosophy seems to consist in this — **from the phænomena** of motions to investigate the forces of nature, and then **from these forces** to demonstrate the other phænomena;*

I. Newton, “Principia”, 3rd edition 1626,  
Preface (translation by A. Motte)



Sounds very much like the modern  
“scientific method”...

Yes, dear historical tourist, but remember  
that in Newton’s days this was new and  
quite controversial...



RESOLUTION ATTEMPT 4:

**Newton rejected *unmediated* action at a distance, but had no opinion about a *medium*.**

***Yes, and nothing else is really necessary...***



(Incidentally, this is very similar to the present status of our currently best theory of gravity, ***General Relativity***.

It is today often seen as an “effective theory”, awaiting its ultimate causal explanation by a quantum micro-theory.

The only difference is, perhaps, that today no-one has any qualms about “feigning hypotheses” about that quantum micro-theory.)



RESOLUTION ATTEMPT 5:  
**Newton was a *positivist*, so no  
mechanism for action at a distance  
was required.**



So the law only describes the **how** of gravity, not the **why**.

To a modern reader, this sounds very much like **positivism**.

A positivist would only trust the evidence of the senses, and reject any form of metaphysical speculation about hidden underlying causes.





*Was Newton an early positivist?*

**No:** he left open the possibility of a **causal explanation** of the gravitational force by some mechanical medium, like an ether.

*He just hadn't been able to find any such explanation yet, supported by evidence.*



*But if, meanwhile, someone explains gravity along with all its laws **by the action of some subtle matter**, and shows that the motion of planets and comets will not be disturbed by that matter, **I shall be far from objecting.***

Letter from I. Newton to G. W. Leibniz, October 16, 1693



RESOLUTION ATTEMPT 5:  
**Newton was a *positivist*, so no  
mechanism for action at a distance  
was required.**

***No! That is not why he avoided discussing  
material mediators.***

And positivism wasn't introduced until 150  
years later, anyway.



## RESOLUTION ATTEMPT 6:

**Newton rejected *unmediated* action at a distance, but believed that gravity was *mediated* by a *material* ether.**



So, the official version of Newton's **theory** was a purely phenomenological account of gravity.

But in private, Newton tried to find the **elusive underlying cause** of gravity.

And over the years, he came up with several possible **mechanical models for gravity**, all of them rather weird (from a modern point of view).



At the end of **Newton's second most important book, the *Opticks*** from 1704, he added a number of “***Queries***”.

In these he felt free to **speculate**, in the form of open-ended questions, about ideas for which he was able to provide **neither empirical support nor a mathematically rigorous treatment.**



Let's look at Query 21...

Newton assumes **there might exist an “aether”**, a medium consisting of **very small particles**, which pervades both matter and void throughout the universe.

He then uses this aether to explain gravity, like this:



The aether is assumed to get more dense further away from massive bodies.

**So there is a pressure gradient in the aether** surrounding bodies.

What we perceive as gravity is just the action of this pressure gradient, pushing smaller bodies towards larger ones.





*QUERY 21. Is not this [Aethereal ] Medium much rarer within the dense Bodies of the Sun, Stars, Planets and Comets, than in the empty celestial Spaces between them? And in passing from them to great distances, doth it not grow denser and denser perpetually, and thereby cause the gravity of those great Bodies towards one another, and of their parts towards the Bodies; every Body endeavouring to go from the denser parts of the Medium towards the rarer?*

Opticks, 2<sup>nd</sup> English ed<sup>n</sup>, 1717, Queries



(Again I can't help thinking about similarities with modern ideas about gravity.

Every time I read about the Newtonian mechanical gravitational aether-particle models, or the competing Cartesian aether vortices, I get reminded of current models involving *quantum* mechanical particles — the ***gravitons*** — that supposedly explain the ultimate cause of gravity.)



Actually, Newton grew quite fond of the idea of using forces acting at a distance not only for **gravity**, but also as a mechanism to **explain many other phenomena** in nature.

...always being careful not to speculate about the origin of these forces.

Here is a quote from the famous Query 31:



*Query 31. [...] Have not the small Particles of Bodies certain Powers, Virtues, or Forces, by which they **act at a distance** [...] upon one another for producing a great Part of the Phenomena of Nature? For it's well known, that **Bodies act one upon another by the Attractions of Gravity, Magnetism and Electricity**; and these Instances shew the Tenor and Course of Nature, and make it not improbable but that **there may be more attractive Powers than these.***

Opticks, 2<sup>nd</sup> English ed<sup>n</sup>, 1717, Queries



In the preface to the *Principles*, Newton proudly advertises how his inductive-deductive methodology has unlocked the secrets of gravity.

*Oh, if only he had been able to crack all the other mysteries of nature in the same way!*

... perhaps in terms of (still unknown) attractive or repulsive forces between particles?



***I wish we could derive the rest of the phænomena of nature by the same kind of reasoning from mechanical principles;** for I am induced by many reasons to suspect that they may all depend upon certain forces by which the particles of bodies, by some causes hitherto unknown, are either mutually impelled towards each other, and cohere in regular figures, or are repelled and recede from each other; which forces being unknown, philosophers have hitherto attempted the search of nature in vain;*

I. Newton, “Principia”, 3rd edition 1626, Preface





But in the end Newton realised that the whole idea of a mechanical gravitational ether might spoil Newton's beautiful and mathematically rigorous and exact description of planetary motion.

A material ether would introduce friction, and that might make planetary orbits unstable.



[...] *since all phenomena of the heavens and of the sea follow precisely, so far as I am aware, from nothing but gravity acting in accordance with the laws described by me; and since nature is very simple, **I have myself concluded that all other causes are to be rejected and that the heavens are to be stripped as far as may be of all matter**, lest the motions of planets and comets be hindered or rendered irregular.*

Letter from I. Newton to G. W. Leibniz, October 16, 1693





## RESOLUTION ATTEMPT 6:

**Newton rejected *unmediated* action at a distance, but believed that gravity was *mediated* by a *material* ether.**

***Perhaps, but we really don't know for sure...***

It was fun while it lasted, to speculate about various material gravitational ethers, but in the end...



Which options are left for understanding action at a distance?

We haven't talked about *immaterial mediums* yet...



## RESOLUTION ATTEMPT 7:

**Newton believed that matter was not “active”, and therefore could not act on its own.**



There are **keywords in the text** that support this reading of the quote.



There are **keywords in the text** that support this reading of the quote.

To a **modern reader** these would just look like common English words.

It's only thanks to our deeper knowledge about the 17<sup>th</sup> century that we (perhaps) can identify them as **technical terms** with **special meaning to contemporary readers**.



***Tis inconceivable, that inanimate brute Matter, should** (without  $y^e$  mediation of something else  $w^{ch}$  is not material), **operate upon & affect other matter**  $w^{th}$ out mutual contact; as it must if gravitation [...] be essential & inherent in it.*

“...inanimate brute matter”



Other texts by Newton confirm that he distinguished between “**inanimate brute matter**” and “**immaterial substances**” (like *God*, or *angels* or the *human mind*).

Ordinary matter is *passive* and therefore **cannot act directly** on other matter, not without external intervention (like a direct contact force).



Other texts by Newton confirm that he distinguished between “**inanimate brute matter**” and “**immaterial substances**” (like *God*, or *angels* or the *human mind*).

Ordinary matter is ***passive*** and therefore ***cannot act directly*** on other matter, not without external intervention (like a direct contact force).

Immaterial substances, on the other hand, are ***active*** and can act on matter on their own.





It appears then that in the quote Newton is simply saying that:

*“**matter is passive** and therefore incapable of acting in any way whatsoever, let alone act on other matter at a distance”!*



***So the quote we have been looking at is all about Newton telling Bentley that no, he does not believe in active matter.***

And while he is at it, Newton rejects unmediated action at a distance, too.



There remain two strange words in our quote — *inherent* and *essential* — that turn out to mean much the same as “active” matter...



***That gravity should be innate inherent & essential to matter so y<sup>t</sup> one body may act upon another at a distance through a vacuum w<sup>th</sup>out the mediation of any thing else [...] is to me such an absurdity [...]***

“...gravity is inherent and essential to matter”



This goes back to the *natural philosophy* of the ***Epicureans***:

They believed that **gravity** — the ability of matter to attract other matter — **is a property of matter itself**.

Just like *extension*, *mobility* or *impenetrability* — these are ***inherent*** or ***essential*** properties of matter.

Matter without extension *doesn't make sense*.



So to say that

**“gravity is inherent and essential to matter”**

is a special case of saying that

**“matter is active”.**

And Newton didn't approve of either idea.  
To him matter was strictly *passive*.



Inserting another often deleted passage in the quote we see clearly that Newton is referencing the ***Epicureans*** and their view that matter is active:




[...] *Tis inconceivable, that **inanimate brute Matter**, should [...] operate upon & affect other matter w<sup>th</sup>out mutual contact; **as it must if gravitation in the sense of Epicurus, be essential & inherent** in it. [...] That gravity should be innate inherent & essential to matter so y<sup>t</sup> one body may act upon another at a distance through a vacuum w<sup>th</sup>out the mediation of any thing else [...] is to me such an absurdity [...]*






Some important contributors to **Epicurean philosophy** (who took their ideas on space and matter from the **Atomists**)

 **Leucippos** (early 5<sup>th</sup> C.BC)

 **Democritos** (c.460–c.370 BC)

 **Epicuros** (341–270 BC)

 **Lucretius** (c.99–c.55 BC)

**Pierre Gassendi** (1592–1655) 

**Walter Charleton** (1619–1707) 

*The Scientific Revolution:* 



## RESOLUTION ATTEMPT 7:

**Newton believed that matter was not “active”, and therefore could not act on its own.**

*Yes, he rejected the Epicurean view that matter is “active”...*

... even if it is still unclear why Newton hates the idea of active matter so much.



To understand why Newton did not want to be associated with the idea of “active” matter we have to understand the society that Newton lived in.



To understand why Newton did not want to be associated with the idea of “active” matter we have to understand the society that Newton lived in.

Epicureanism was originally mainly an ethical philosophy (on how to live a good life)...

...but in the 17<sup>th</sup> century, **“Epicurean” had become synonymous with “atheist”,** on account of its atomism:



According to Epicurean natural philosophy, there only exist **atoms** moving through a **void**, according to fixed **laws**. And all natural phenomena can ultimately be explained using this model.

*... but if there is nothing but atoms moving through a void according to fixed laws, **there is neither any place nor any need for God.***



According to Epicurean natural philosophy, there only exist **atoms** moving through a **void**, according to fixed **laws**. And all natural phenomena can ultimately be explained using this model.

*... but if there is nothing but atoms moving through a void according to fixed laws, **there is neither any place nor any need for God.***

No wonder that Newton did not want to be accused of holding Epicurean views!



*No wonder that Newton did not want to be accused of holding Epicurean views!*

Being accused of, or even suspected of, having atheist views was not good for your career in 17<sup>th</sup> century England...



*[A footnote — can be skipped]*





**Richard Bentley** wasn't just anybody.

He was up and coming in the Church of England, and a close associate of **Edward Stillingfleet**, the Bishop of Worcester...

...and Stillingfleet and Bentley had just used their influence to prevent the astronomer **Edmond Halley** from getting a Professorship at Cambridge, apparently on account of Halley's "materialist tendencies"...



...and everyone knew that Halley was close to Newton.

Halley had even paid for the printing of Newton's *Principles* out of *his own pocket* (since the Royal Society had spent all their publishing funds for the year on a book on fish).



...and everyone knew that Halley was close to Newton.

Halley had even paid for the printing of Newton's *Principles* out of *his own pocket* (since the Royal Society had spent all their publishing funds for the year on a book on fish).

So first they went for Halley — and now Bentley writes a letter to Newton charging him with Epicurean views...



Now, this is all true, but **Newton had nothing to fear from Bentley.**

In fact, Bentley was *very much* on Newton's side.

The context of the exchange of letters between Newton and Bentley in 1692-93 was this:



The English experimental virtuoso Robert Boyle died in 1691, and in his will he set aside money for a lecture series, “for proving the Christian Religion against notorious Infidels”.

Bentley was appointed to give the **Boyle lectures** in 1692, and for some reason he decided to **use Newton’s recent discoveries in physics to prove the existence of God by design.**



Before his eight sermons were published, Bentley contacted Newton **to make sure he had gotten all the facts straight** (Bentley had no education in mathematics or astronomy).



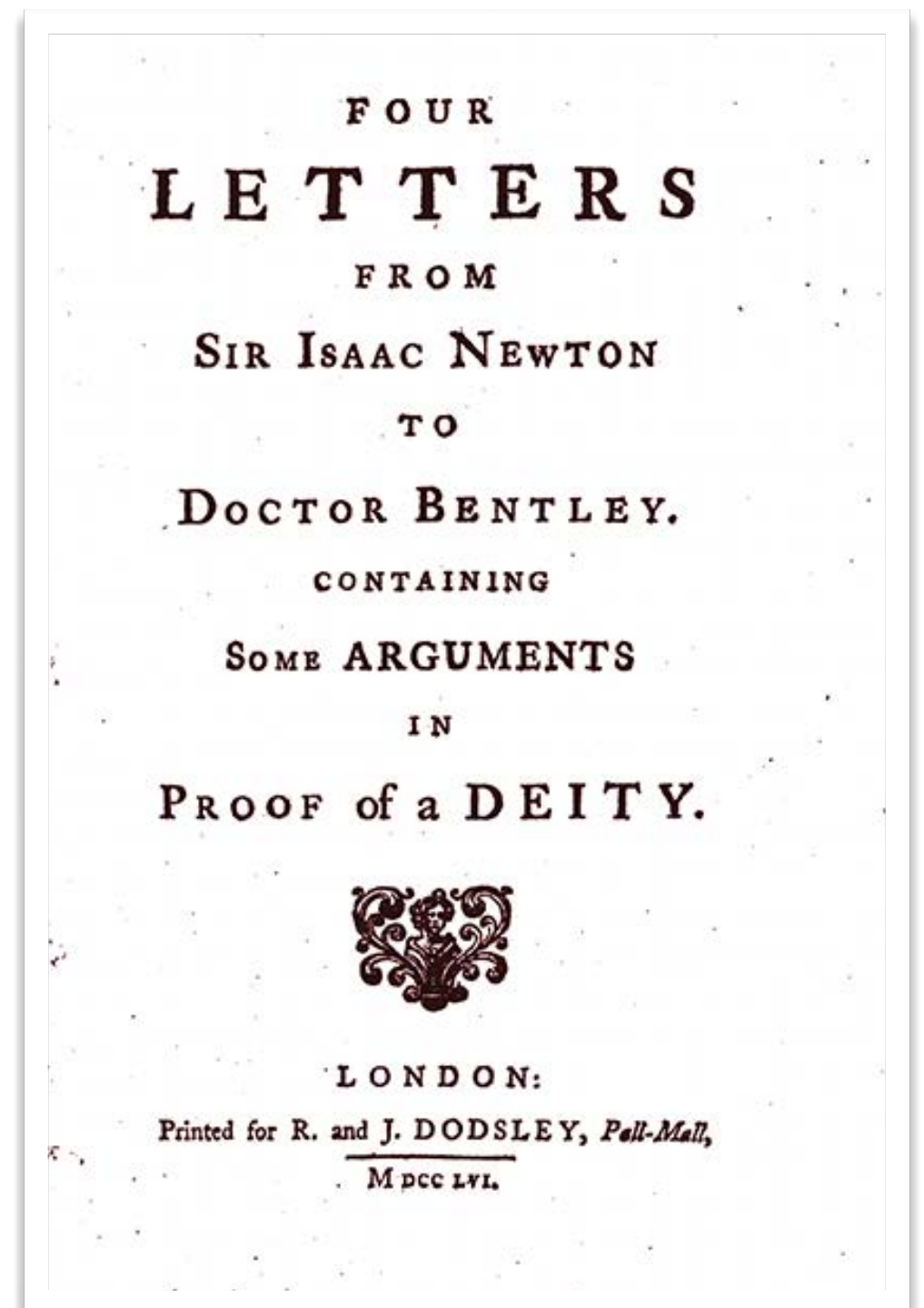
Newton was delighted: he had had similar ideas about the use of the *Principles* to further religion:

*When I wrote my treatise about our Systeme I had an eye upon such Principles as might work with considering men for the beleife of a Deity & nothing can rejoice me more then to find it usefull for that purpose.*

Isaac Newton to Richard Bentley, December 10, 1692



And when in 1756 the letters from Newton to Bentley were made public, it was under the title  
**“... Some Arguments in Proof of a Deity”.**





## RESOLUTION ATTEMPT 8:

**Newton thought gravity was a secondary cause, superadded by God onto matter.**



***Let me summarise what we have learnt so far:***

- Unlike his 18<sup>th</sup> century followers, Newton seems ***not*** to have endorsed ***unmediated action at a distance...***
- He also made a point of ***not*** endorsing any model for ***materially mediated action at a distance*** that is not supported by phenomena; that would be “feigning hypotheses”...



***Let me summarise what we have learnt so far:***

— True, in speculative moments Newton did propose several models for gravity being ***mediated by a material ether...***

...but he was also very well aware of that such ethers would probably ruin his beautiful clockwork universe.



***Let me summarise what we have learnt so far:***

— Newton hoped, but could not show himself, that in the future **other phenomena**, like ***electricity*** and ***magnetism***, would be **explained in the same mathematically rigorous way** as he had explained gravity...

...and most likely this, too, would be done with **attractive or repulsive forces acting at a distance between particles.**



*Let me summarise what we have learnt so far:*

— In the quote in the letter to Bentley, Newton emphasises that he **does not believe that matter is “active”** (i.e. capable of acting at a distance on other bodies on its own)...

...since that would leave **no room for God**  
— an atheist’s position...



We have **one last remaining question** to answer: *why was Newton so afraid of active matter?*

Here the text of the quote won't help us. We need to take a step back to see the bigger picture.



The quote we have been dissecting is from what we could call a “**physico-theological**” discussion between Newton and Bentley:

They were both convinced that **the recent discoveries in physics** (in Newton’s book *Principles*) **had a profound significance for religion.**



And at this time, both felt that **religion had been seriously degraded** in England.

Christianity needed to be vigorously defended against ***atheism, materialism, mechanism, deism, neo-Epicureanism, Hobbeism, ...***

... the Church of England was indeed surrounded by countless serious threats!





But this **erosion and corruption of religion** had happened many times before — since the days of the *original True Religion*, practiced by Noah and his sons.

When this corruption happened, God would intervene, and set things right!

But **God**, the Primary Cause of all things, **would not act directly**, but instead **send some Secondary Agent**, invested with the necessary powers.



But who would fit the bill? **Who could possibly become God's secondary agent in these troubled times?**



But who would fit the bill? **Who could possibly become God's secondary agent** in these troubled times?

It would have to be someone of true genius. Someone who could see through the random phenomena to discover the laws of nature. Someone who could grasp the powers that guide the planets in their immutable paths. And someone who could turn murky alchemy into a powerful tool to unlock the mysteries of matter — and perhaps of life itself.



Yes, who could that possibly be...

Discuss amongst yourselves.



In this grand scheme, how could one  
**understand how gravity can act at a distance**

— without invoking any **material medium** to  
transmit the action

— without assigning the power of acting on  
other matter to matter itself (**active matter**)

— while making sure that **God is necessary** to  
keep the whole system together?



The solution is as simple as it is ingenious!



The solution is as simple as it is ingenious!

God, the Prime Cause of all things, through his own free will, chose to **impress an “active principle” onto all (passive) matter** in the beginning of times.

This “active principle” is the **secondary cause** or **agent** that endows matter with the ability to act at a distance on other matter.



**So without God there would be no gravity,**  
**since matter in itself is passive.** It cannot  
act on its own accord, only through this  
superadded “active principle”.

...so every time you see gravity in action,  
you experience the effects of God’s  
*providence* and *dominion* over the world.

*providence* — God’s guidance or care  
*dominion* — God’s supreme authority





We are now at the end of our quest for finding the answer to the question of *how did Newton think about gravity*.

It has left us quite far away from the modern textbook treatment of Newtonian gravity.



But hey — what did you expect?

*The past is a foreign country:  
they do things differently there.*



# Coda



---

Newton's critique of the law of universal gravitation



**We started with a rather technical historical question** of making sense of one quote from Newton, which paradoxically seemed to have Newton contradict an important feature of his own theory of gravity — action at a distance.



To our big surprise, our investigations lead us to discover that Newton thought of his Law of Universal Gravity as an integral part of his **theological program to prove God's existence, providence and dominion.**



We are used to think of Newton in hagiographic terms, as the **conclusion of the Scientific Revolution**, and the **first of modern scientists...**

*"Nature and Nature's laws  
Lay hid in night:  
God said, Let Newton be!  
and all was light."*

Alexander Pope



William Blake, "Newton"



...and yet closer inspection reveals a Newton who sees his **science as merely a tool for theology.**

And then I have just only hinted at Newtons decades long intense pursuit of **alchemy** and **biblical prophecy!**





The economist John Maynard Keynes summarised his view of Newton:



Newton's critique of the law of universal gravitation



## The economist John Maynard Keynes summarised his view of Newton:

*In the eighteenth century and since, Newton came to be thought of as the first and greatest of the modern age of scientists, a rationalist, one who thought us to think on the lines of cold and untinctured reason. I do not see him in this light. [...] **Newton was not the first of the age of reason. He was the last of the magicians**, the last of the Babylonians and Sumerians, the last great mind which looked out on the visible and intellectual world with the same eyes as those who began to build our intellectual inheritance rather less than 10,000 years ago.*

John Maynard Keynes, “Newton, the Man”, 1946



And I will close with this quote from  
Newton-as-alchemist scholar Betty Jo Dobbs:

*If he, Newton, could but demonstrate the laws of divine activity in nature [...] then he could demonstrate in irrefutable fashion the existence and providential care of the Deity — a grand goal, though hardly a modern one. Newton indeed hoped to restore the original true religion — to effect a “revolution,” a return to a former state, in the earlier meaning of the word revolution....*



And I will close with this quote from  
Newton-as-chemist scholar Betty Jo Dobbs:

*... He was well instructed in the dangers of [mechanism, materialism, deism, and atheism] and he fought a valiant holding against them, but he could not win. **His system was very quickly coopted by the very -isms he fought, and adjusted to suit them.** He came down to us coopted, an Enlightenment figure without parallel who could not possibly have been concerned with alchemy or with establishing the existence and activity of a providential God...*



And I will close with this quote from  
Newton-as-alchemist scholar Betty Jo Dobbs:

*... In conclusion, I would like to suggest that there may be some historical value in evaluating Newton in a different way: **not as one of history's all-time winners**, not as the First Mover of modern science, not as Final Cause of the Scientific Revolution, **but as one of history's great losers**, a loser in a titanic battle between the forces of religion and the forces of irreligion.*

B. J. Dobbs,  
“Newton as Final Cause and First Mover”, 1994



*Thank you for your attention!*



# SECONDARY LITERATURE

- B. J. T. Dobbs, “Newton as Final Cause and First Mover” (1994)  
—, “Newton’s alchemy and his ‘active principle’ of gravitation” (1988)
- S. Ducheyne, “Newton on action at a distance and the cause of gravity” (2011)  
— “Newton on action at a distance” (2014)
- H. Guerlac, M. C. Jacob, “Bentley, Newton, and providence” (1969)
- J. Henry, “Could Isaac Newton have believed in action at a distance?”, [youtu.be/NqvZ9uo61NQ](https://youtu.be/NqvZ9uo61NQ)  
— “‘Pray do not ascribe that notion to me’: God and Newton’s gravity” (1994)  
— “Gravity and De Gravitatione: the development of Newton’s ideas on action at a distance” (2011)
- K. Hutchison, “What happened to occult qualities in the Scientific Revolution?” (1982)
- A. Janiak, “Three concepts of causation in Newton” (2013)
- P. E. B. Jourdain, “Newton’s hypotheses of ether and of gravitation” (1915)
- J. M. Keynes, “Newton, the Man” (1946)
- H. Kochiras, “Gravity and Newton’s substance counting problem” (2009)
- L. Rosenfeld, “Newton’s views on aether and gravitation” (1969)
- E. Schliesser, “Without God: Gravity as a relational property of Newton’s Treatise” (2008)
- P. Suppes, “Descartes and the program of action at a distance” (1954)





*The last clause of your second Position I like very well. Tis inconceivable, that inanimate brute Matter, should (without y<sup>e</sup> mediation of something else wh<sup>ch</sup> is not material), operate upon & affect other matter w<sup>th</sup>out mutual contact; as it must if gravitation in the sense of Epicurus, be essential & inherent in it. And this is one reason why I desired you not to ascribe innate gravity to me. That gravity should be innate inherent & essential to matter so y<sup>t</sup> one body may act upon another at a distance through a vacuum w<sup>th</sup>out the mediation of any thing else & by & through wh<sup>ch</sup> their action and force may be conveyed from one to another is to me such an absurdity that I beleive no man who has in philosophical matters any competent faculty of thinking can ever fall into it. Gravity must be caused by an agent acting constantly according to certain laws, but whether this agent be material or immaterial is a question I left to y<sup>e</sup> consideration of my readers.*

I. Newton, Fourth letter to R. Bentley, February 25, 1692|3



The past is a foreign country:  
they do things differently there.

*L. P. Hartley, “The Go-Between”*