What was Kepler's theory of gravity?

Hans Mühlen
Nordita Day, 8 June 2018

Can we give an answer to the question

What was Kepler's theory of gravity?

without falling into any historiographical traps?

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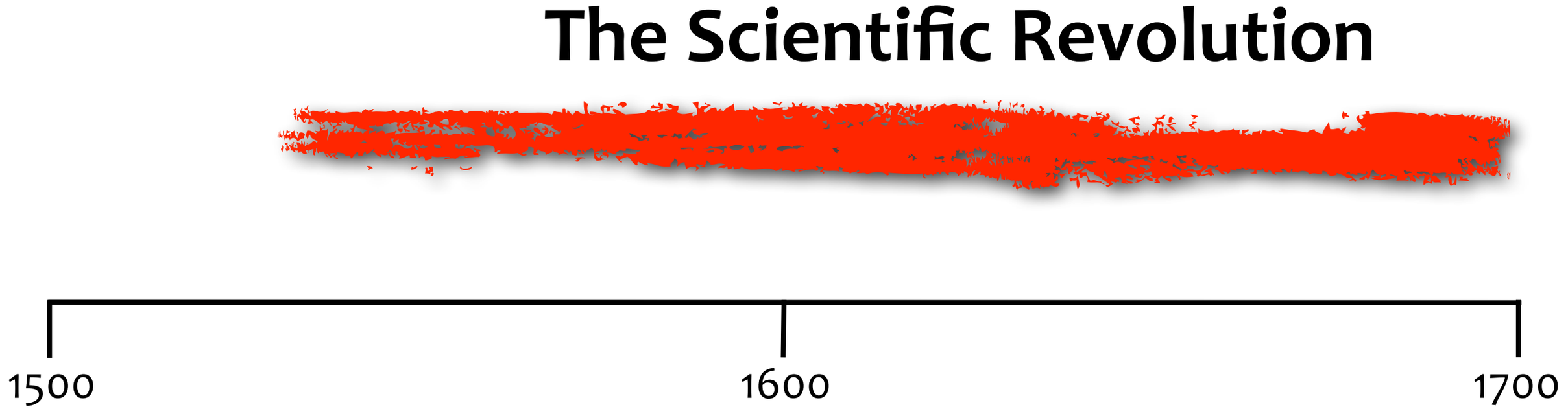
The setting of this tale is the period we usually call “the Scientific Revolution” in the 16th and 17th centuries.

The Scientific Revolution



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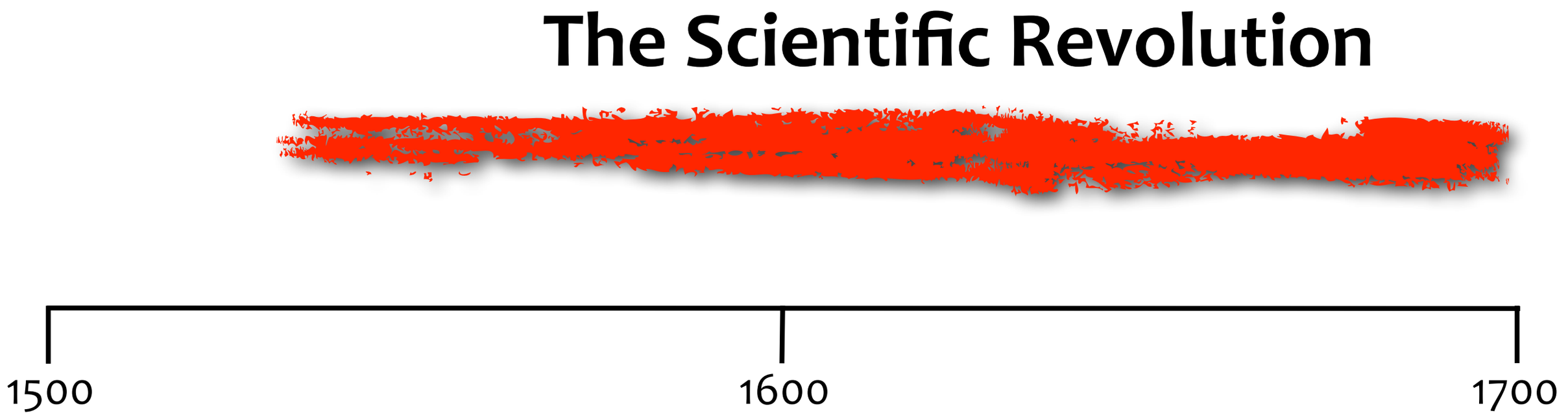

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“On the Revolution of the Heavenly Spheres”

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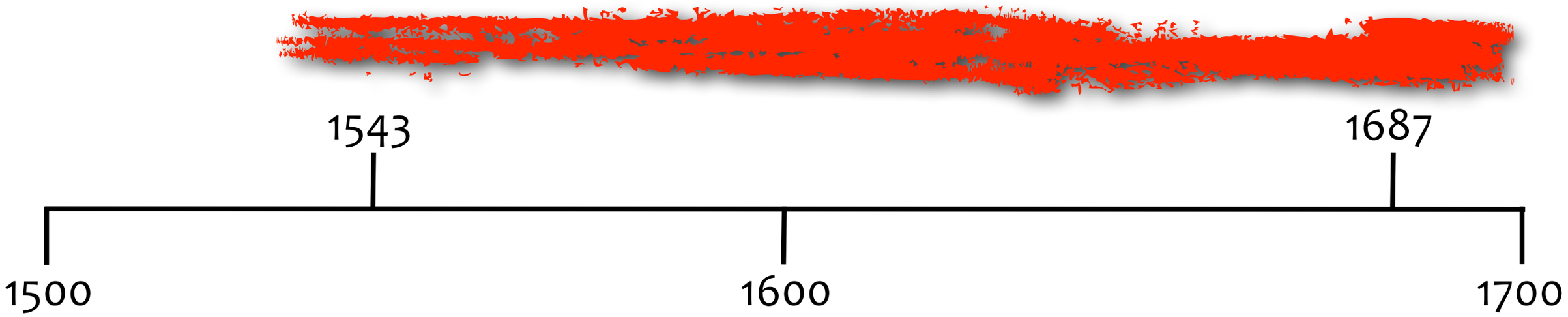

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A "revolution" that took 144 years...

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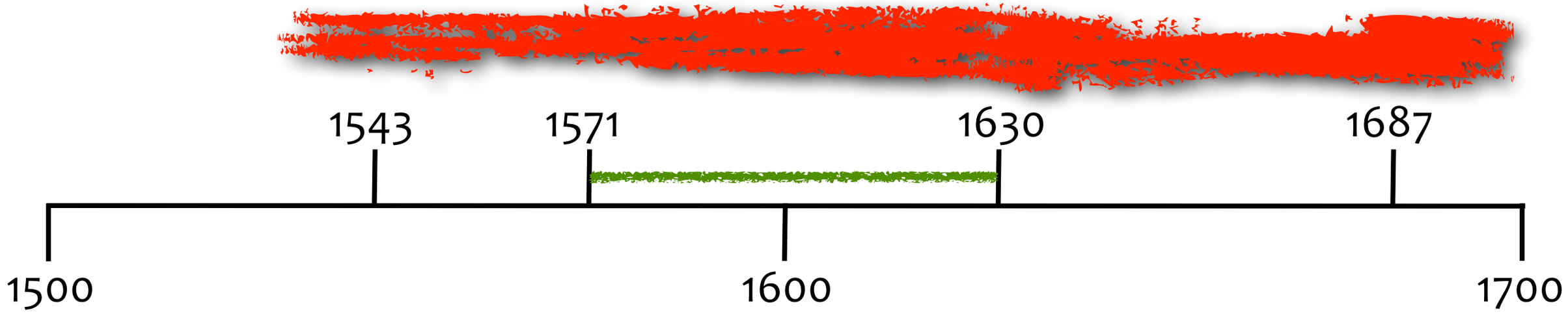
A "revolution" that took 144 years...

...and our hero, the German astronomer

***Johannes Kepler**,*

was right in the middle of the action!



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The 16th and 17th centuries
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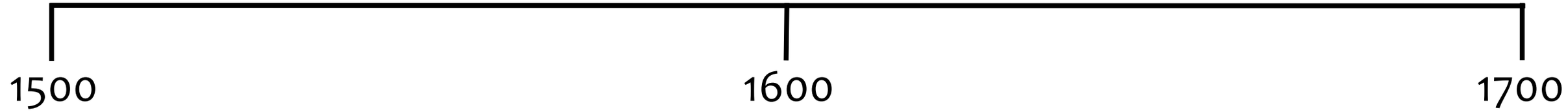

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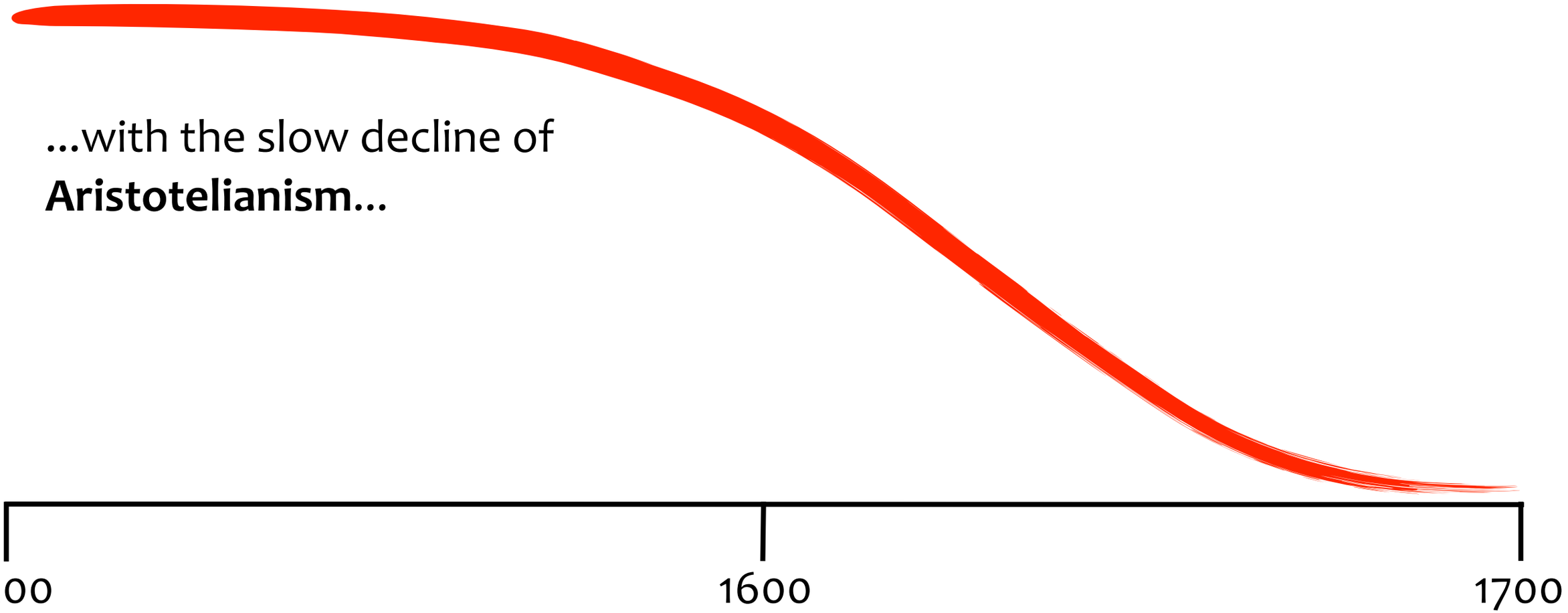
The 16th and 17th centuries
were **a transitional period**
in the history of science...

...with the slow decline of
Aristotelianism...



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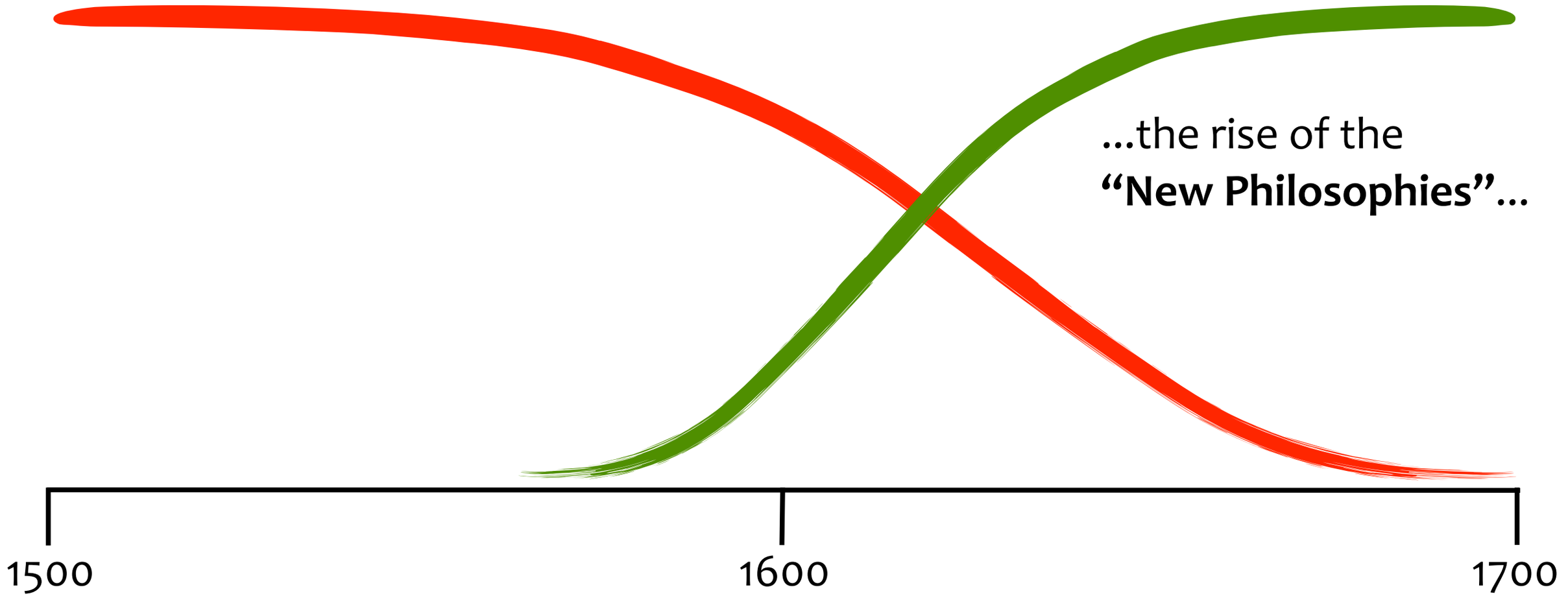

What was Kepler's theory of gravity?

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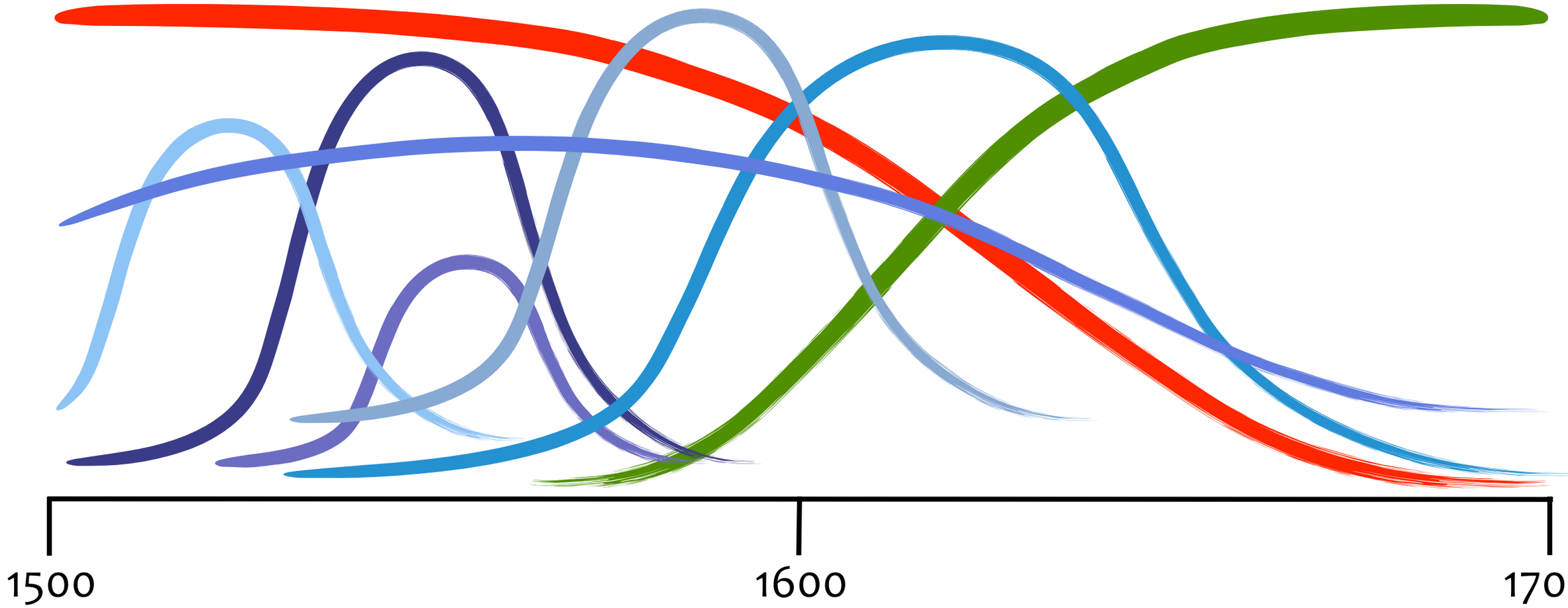
The 16th and 17th centuries were **a transitional period** in the history of science...

...as well as a host of **philosophies from Antiquity,** revived during the Humanist Renaissance.



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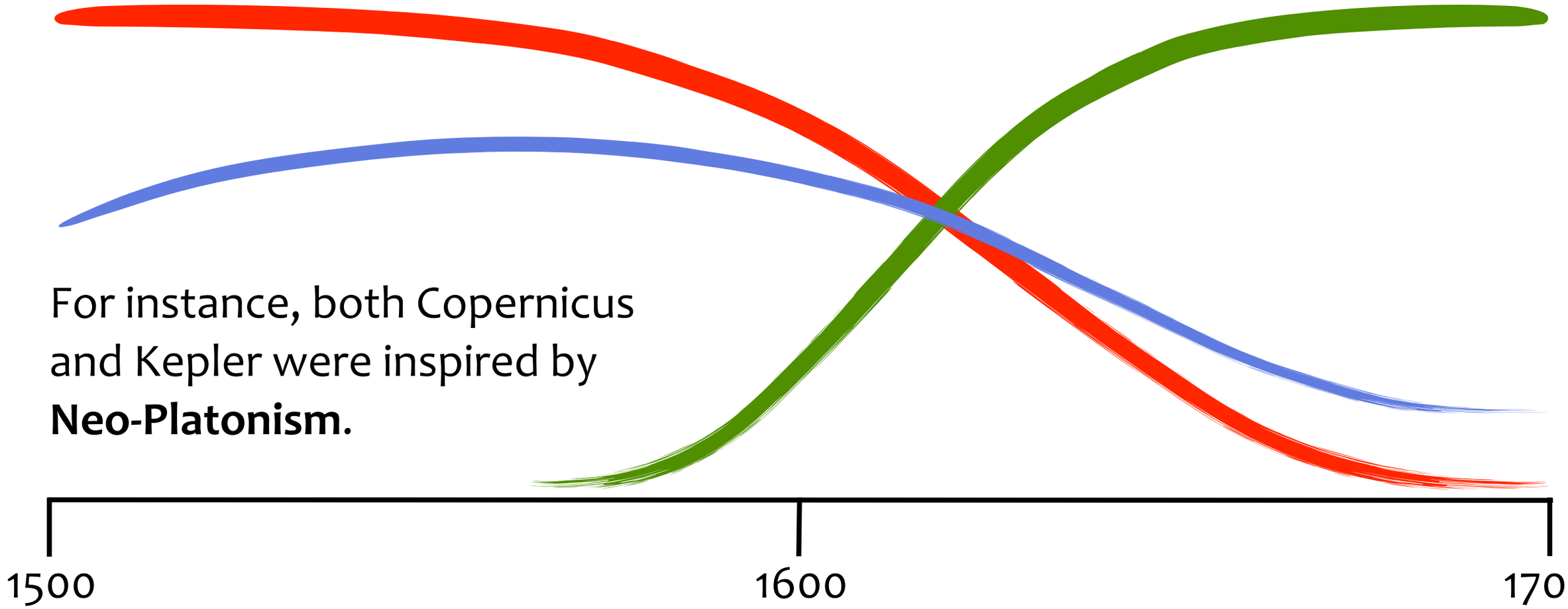

For instance, both Copernicus and Kepler were inspired by **Neo-Platonism.**

What was Kepler's theory of gravity?

No wonder it took 144 years to get it right!

What was Kepler's theory of gravity?

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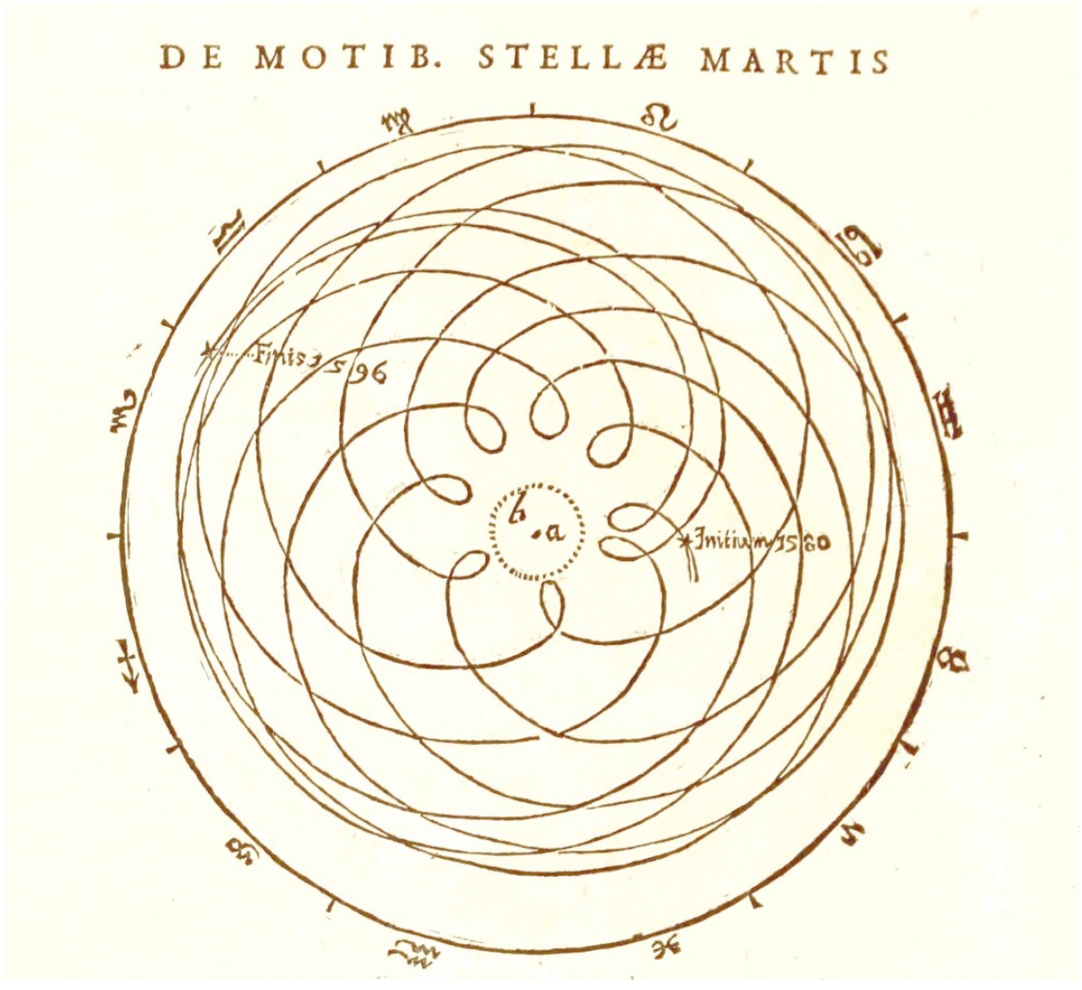
But now let's focus on
Kepler,
the motion of planets,
and **gravity.**



What was Kepler's theory of gravity?

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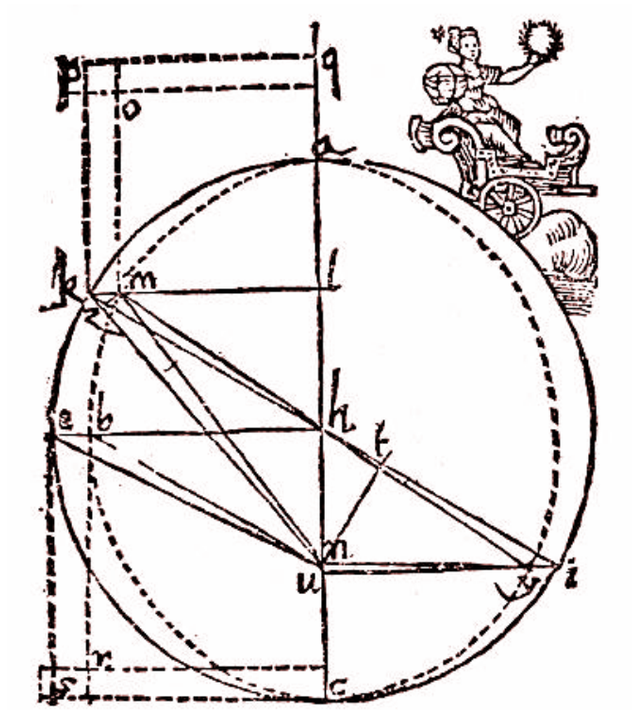
We all know **Kepler's three laws** of planetary motion:

1. *Elliptic orbits*
2. *Area law*
3. *Harmonic law*



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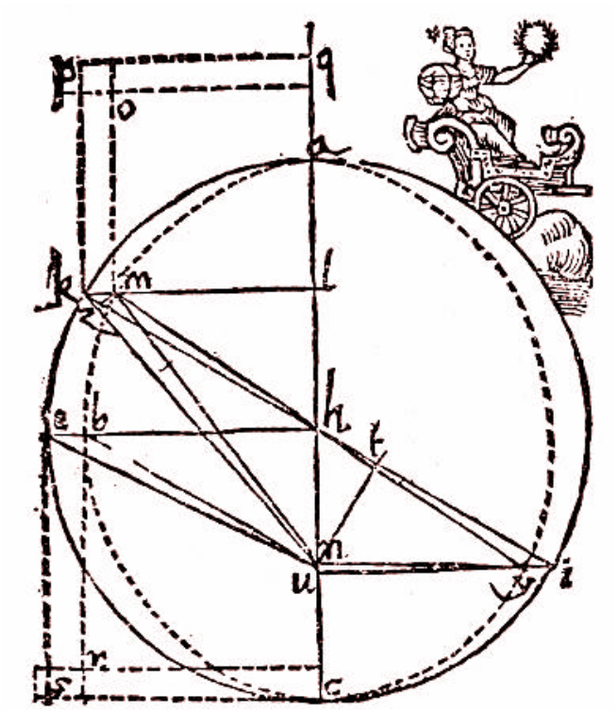

...but here I want to focus on another aspect of Kepler's pioneering work.

Since antiquity the task of the astronomer had been to

“save the phenomena”

What was Kepler’s theory of gravity?

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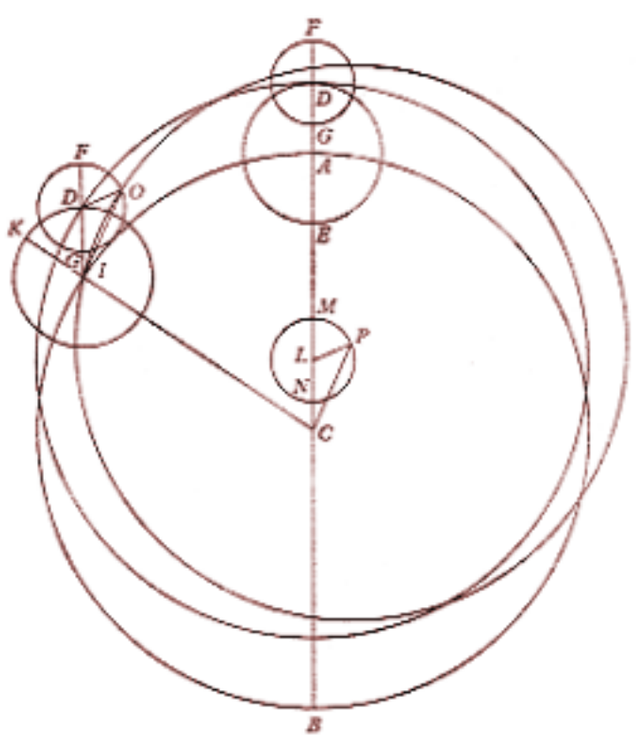
Since antiquity the task of the astronomer had been to

“save the phenomena”

i.e, to develop a mathematical (geometrical) system that *did not need to have any relation to real physics*, as long as it *accurately reproduced observations*.



Kepler instead wanted to find

the true physical causes

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the true physical causes

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His ambition was to fuse all three sciences

- **astronomy**
- **mathematics** (geometry)
- **physics** (mechanics)

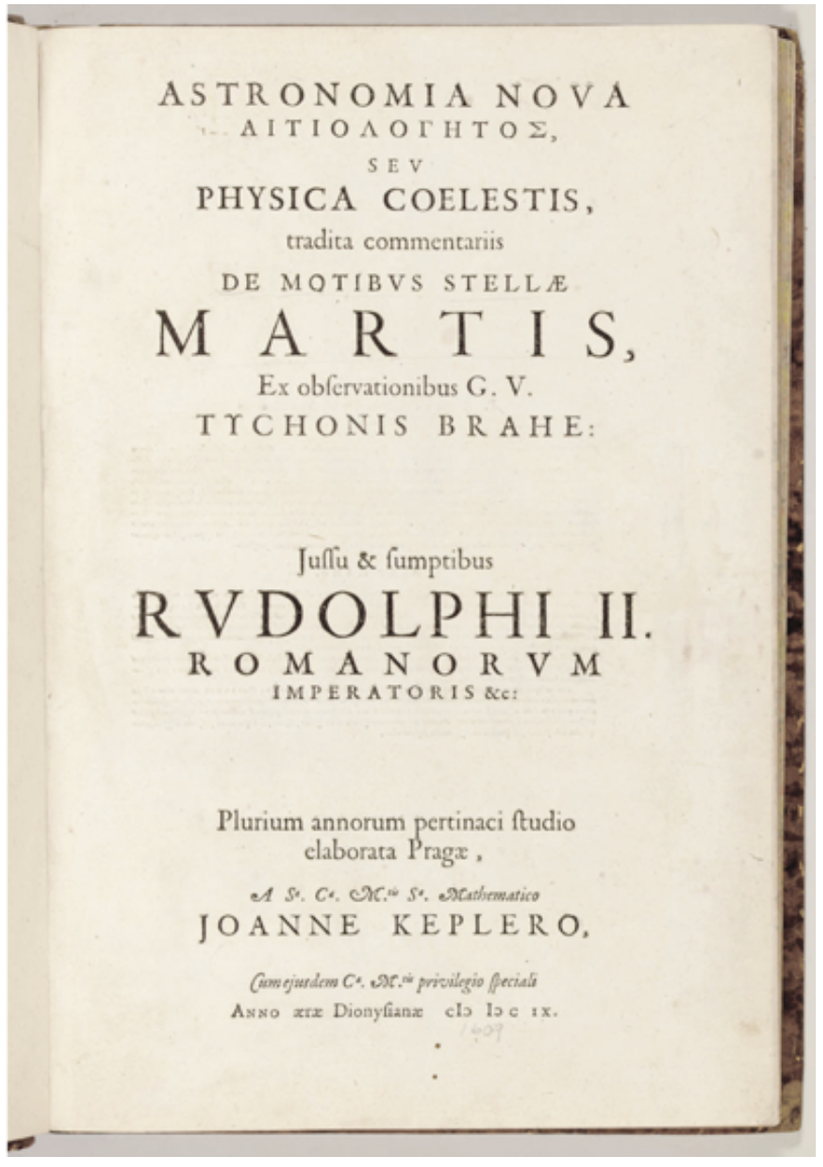
into one integrated system:

a mathematical theory of Celestial Physics

This is beautifully illustrated by the title of one of Kepler's most important books:

A New Astronomy, Causally Oriented, or Celestial Physics

(1609)


ASTRONOMIA NOVA
ΑΙΤΙΟΛΟΓΗΤΟΣ,
SEV
PHYSICA COELESTIS,
tradita commentariis
DE MOTIBVS STELLÆ
MARTIS,
Ex obſervationibus G. V.
TYCHONIS BRAHE:

Juſſu & ſumptibus
RVDOLPHI II.
ROMANORVM
IMPERATORIS &c:

Plurium annorum pertinaci ſtudio
elaborata Pragæ,

A S. C. M.to S. Mathematico
JOANNE KEPLERO,

Cum ejuſdem C. M.to privilegio ſpeciali
ANNO XIX Dionyſianæ CIↃ IↃ C IX.

Since **Kepler broke with ancient traditions** he had little guidance in where to find such physical causes.

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But Kepler's ambitious project to found astronomy on physical causes would remain **unsuccessful**…

…until Newton completed the task some 70 years later.

Let me give you a quick taste of the kind of **physical forces** that Kepler suggested would explain the **motion of the planets.**

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PROBLEM 1

The mean circular orbit around the Sun

What was Kepler's theory of gravity?

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- Surely, if the Earth rotates (Copernicus), the Sun must also rotate.
- There are “emanations” from the Sun, grabbing hold of the planets so that they follow in the rotation of the Sun.

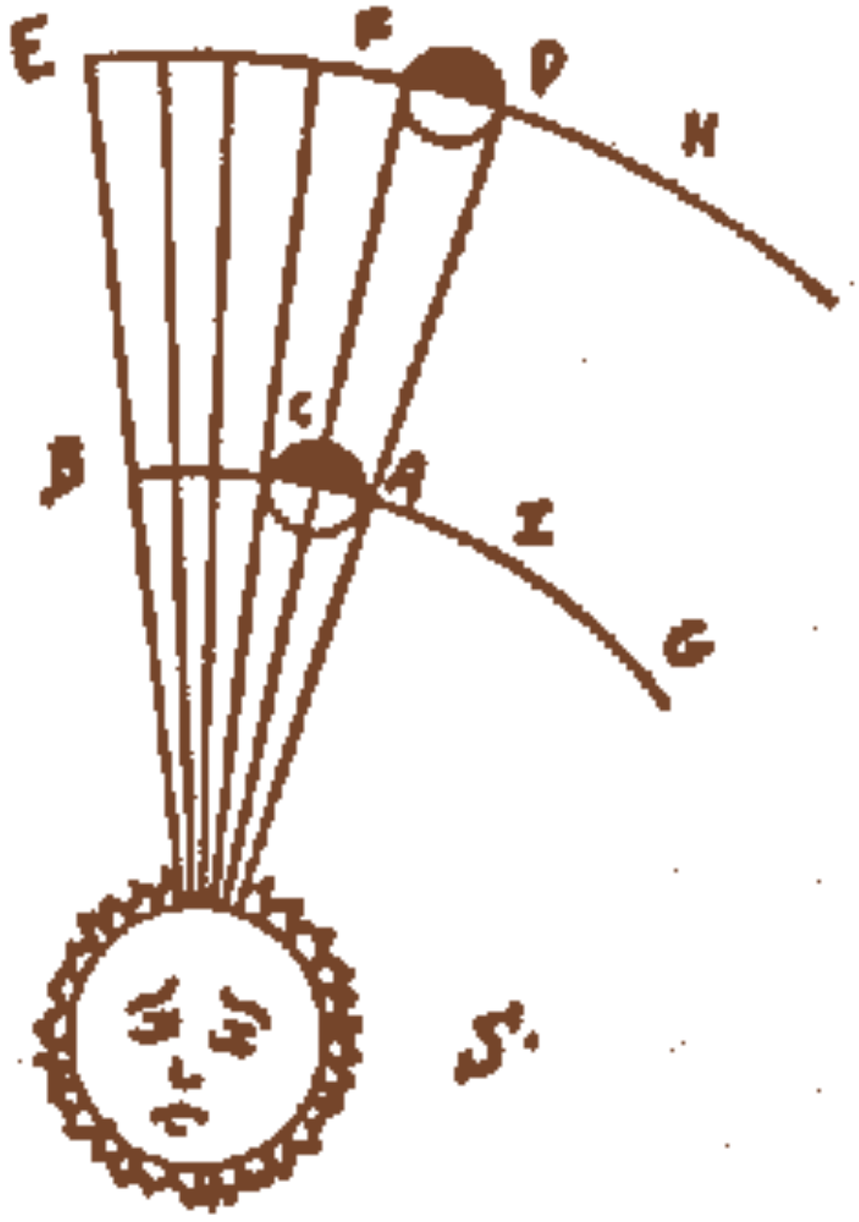
… a rotational force

Kepler kept revising his ideas on what the nature of these "emanations" were:

- perhaps communicating **souls** in the Sun and in the planets? (anima motrix)
- perhaps something like (the Medieval concept of) **light**?
- perhaps **magnetic fibers**? (cf. William Gilbert's book "On the magnet" from 1600)

The moving force would **decrease with the distance** from the Sun.

$$f \sim \frac{1}{r}$$



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Kepler's Inverse Distance Law:

$$v \sim \frac{1}{r}$$

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PROBLEM 2

Orbits are elliptical

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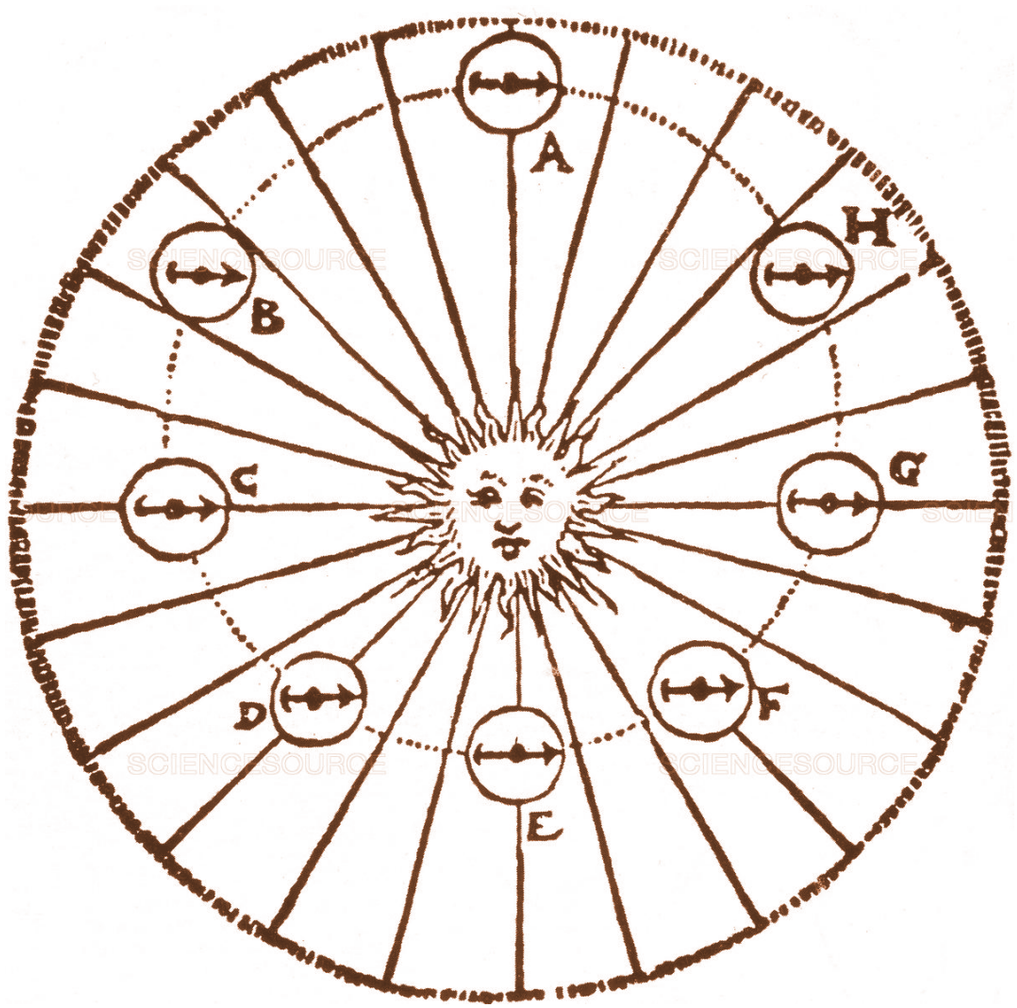
- Again in analogy with magnetism: if the Earth is a **magnet** (Gilbert) then surely so are the other planets.
- The Sun, however, is a magnet with one pole in its center and one on its surface.

- As a result, a planet will be attracted to the Sun for half its orbit, and repelled for the other half (a motion Kepler called “libration”).



… an alternating radial force

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Kepler never managed to prove that the physical forces he suggested would actually reproduce the observed motions of the planets.

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This is in part because:

- he didn't have the correct *laws of physics*
- he didn't have the necessary *mathematical tools*

Let’s come back to the question

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Is the answer the combination of the two quasi-magnetic forces I just have sketched?

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NO!

When we today speak of

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In Kepler’s time, and since antiquity,

“gravity”

meant only one thing:

- heaviness.

Kepler actually did have a “theory of gravity”:

- “Gravity [heaviness] is a mutual corporeal disposition among kindred bodies to unite or join together.”
- This attractive power is proportional to the volume of each body, so that “the earth attracts a stone much more than the stone seeks the earth.”
- “The orb of the attractive power in the moon is extended all the way to the earth” and this is the cause of tides.

(*Astronomia Nova, introduction*)

Exercise (discuss amongst yourselves):

*Show that a **purely attractive radial force** (like gravity) cannot be the cause of elliptical planetary orbits, given the laws of physics that Kepler had at his disposal.*

The moral of this story is simple:

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If you want to understand a historical process on its own terms, **don't make the mistake of projecting modern ideas and concepts into the past…**

…or into the future.

KEPLER SOURCES

- "Mysterium cosmographicum"
  (The Sacred Mystery of the Cosmos) (1596)

- "Astronomia nova"
  (New Astronomy) (1609)

- "Epitome astronomiae Copernicanae"
  (Epitome of Copernican Astronomy) (1618–1621)

- "Harmonices mundi"
  (Harmony of the Worlds) (1619)

- "Tabulae Rudolphinae"
  (Rudolphine Tables) (1627)