Philosophy of Science Survey

Week 12

PHIL 2160. Ohio University. Spring 2021.

Chapter 18: Problems for the Aristotelian Worldview

Scientific Beliefs in the mid-1600s

1. The evidence from the telescope challenges the traditional Aristotelian universe and Ptolemaic system.
2. The Tychonic earth-centered system can be modified to accommodate the evidence from the telescope.
   - This system can also accommodate elliptical orbits.
3. But Kepler's sun-centered system of planetary motion is vastly simpler than other available systems.
   - In Kepler's system, the earth and other planets move around the sun in elliptical orbits at varying speeds, and the earth revolves on its axis.

Scientific Beliefs in the mid-1600s

- The first section of DeWitt's chapter is called "Problems for the Aristotelian Worldview," and we'll review some of these problems.
- But despite the title, these problems are ***not*** problems for Aristotelians themselves.
- Rather, these problems arise primarily *for scientists who accept the Keplerian sun-centered system*.
- So we should understand these problems as ***open problems for a new science***.
  - The emergence of open problems like this stimulates the development of a radically new science.

Open Problems for a New Science

1. If the Earth is in motion, what keeps us on the Earth, and why do heavy objects fall downward?

- Notice "if the Earth is in motion" – this is a problem for those who reject the core Aristotelian beliefs.
- The Aristotelian explanation worked only if the earth is at the center of the universe.
- So for those who rejected the Aristotelian beliefs in the early 1600s, there was no solution to this problem.

Open Problems for a New Science

2. If the Earth is in motion, what keeps the Earth in motion?

- Notice "if the Earth is in motion" – this is a problem for those who reject the core Aristotelian beliefs.
- The pre-1600s principle of motion (review Chapter 12) says that an object in motion will come to a halt, unless something keeps it moving.
- This principle cannot explain why the Earth stays in motion.
- So for those who rejected the Aristotelian beliefs in the early 1600s, there was no solution to this problem.

Open Problems for a New Science

3. If the Earth is in motion, why do we not feel it?

- Notice "if the Earth is in motion" – this is a problem for those who reject the core Aristotelian beliefs.
- For those who rejected the Aristotelian beliefs in the early 1600s, there was no solution to this problem.

Open Problems for a New Science

4. If the Earth is in motion, why do we not observe stellar parallax?

- Notice "if the Earth is in motion" – this is a problem for those who reject the core Aristotelian beliefs.
- To solve this problem, those who rejected the Aristotelian beliefs in the early 1600s had to believe that the stars are incredibly far away and that the universe itself is incredibly, potentially infinitely, vast.
    - Notice how one new core belief (the Earth's motion) requires other beliefs (the location of the stars, the size of the universe).
    - This solution also suggests that we *should* be able to observe stellar parallax; it's just very difficult. And as we noted before, the first observation of stellar parallax was made in the 19th century.

Open Problems for a New Science

- If you were a scientist in the early 1600s and believed the Keplerian sun-centered system, then ***as a scientist, you had to solve the problems*** we just looked at.
- And since these problems ***do not arise*** for the Aristotelian earth-centered worldview, ***you cannot use the Aristotelian worldview to solve these problems***.
  - This is a subtle but important point: Imagine asking an Aristotelian, "what keeps the Earth in motion?" – She would think your question is totally wrong-headed!

Open Problems for a New Science

- So, as DeWitt emphasizes, in the early 1600s, if you rejected the Aristotelian worldview, there was no science to replace the old one.
- That is, "there was no explanation of something as simple as why rocks fall. There likewise was no explanation for how the Earth could be moving at immense speeds in its orbit around the sun, and yet it feels as if we are stationary. . . . Nor is there any explanation for Kepler's elliptical orbits, or for that matter, what keeps planets moving in the first place." (DeWitt).

Chapter 19: Philosophical/Conceptual Changes and the New Science

Science and Culture

- By “culture,” we include broader philosophical, religious, social, and political views and situations.
- This chapter is about the mutual influence between science and culture.
  - DeWitt touched on this topic in the last chapter, which we’ll cover here.
- Before we start, let’s clarify our topic and note why it’s important even today.

Science and Culture

- We should distinguish two questions:

1. How do (or did) science and culture influence each other?
2. Should science and culture influence each other?

- The first question is *descriptive*, and the second is *normative*.
- The descriptive question is asking **how** science and culture **do (or did)** in fact influence each other.
- The normative question is asking whether science and culture **should** influence each other.

Science and Culture

- Our distinction is important, because as some of you pointed out in the annotations, one common view today is that science should be independent from culture (specifically, religion and politics).
- This view is one answer to the *normative* question.
- The normative question is important, because:

a. Science and culture have in fact been influencing each other.

b. And many people think that the mutual influence was sometimes good (or productive, necessary, etc) and sometimes bad (or unproductive, unnecessary, etc).

Science and Culture

- In this chapter, our concern is a version of the *descriptive* question: How did science and culture influence each other in the 17th century?
- And we'll look at two aspects of this mutual influence:

1. Science and religion
2. Science and (speculative) philosophy

Science and Religion

- In Chapter 18, DeWitt described how the need for a new science was also felt as the need for new religious views.
- This makes sense because the Aristotelian worldview has become Christianized over many centuries.
- We'll look at some *open problems for Christian theology* that emerged in the 17th century.

Science and Religion

1. Why would God have created a potentially infinite universe, with so much seemingly wasted space?

- Notice how this problem arises only after accepting the new, non-Aristotelian idea that the universe is vast.
- In the Christianized Aristotelian worldview, the universe is large but neatly organized (e.g., each major celestial body has its own sphere, and the spheres are nested). It reflected God's design.
- But in the new view of the universe, celestial bodies seem randomly scattered with a lot of empty space.

Science and Religion

2. What is the role of humans in a universe where the Earth is like a speck of dust moving in an empty space?

- Notice how this problem arises only after accepting the new, non-Aristotelian idea that the universe is vast.
- In the Christianized Aristotelian worldview, the Earth was at the center of the universe, and this location indicated the importance of humans to God (i.e., God put humans at the most important point in the universe).
- This understanding of humans was obscured by the new view of the universe.

Science and Religion

3. What is the role of God in the universe?

- In the Christianized Aristotelian worldview, God played a role in a teleological explanation of planetary motion.
  - The ether element in the superlunar region has a desire to emulate God's perfection, and a uniform circular motion is one type of perfection.
- In short, God's role in the working of the universe was integrated into the scientific view of the universe.
- But this understanding of God's place in the universe was challenged by Galileo's rejection of the distinction between the superlunar and sublunar regions and the Kepler's view of planetary motion.

Science and Religion

- These problems are all *theological* problems raised by the new scientific views.
- These problems stimulated the exploration of new theological views.
  - "New" doesn't have to mean *never-before-thought-about*. "New" can just mean reconsideration of previously dismissed views.

Science and Religion

- In Chapter 19, DeWitt mentions theological views of Nicholas de Cusa (1401–1464) and Giordano Bruno (1548–1600).
- Both were theologians, and they developed a theological view that is compatible with an infinite universe.
- Their view was that an infinite universe is a reflection of God's infinity.

Science and Religion

- Recall one of the open theological problems: *Why would God have created a potentially infinite universe, with so much seemingly wasted space?*
- De Cusa's and Bruno's view helps answer this question: Because God is infinite, and an infinite universe reflects his infinity.
- As DeWitt says, this view is a "conceptual Band-Aid"—it patches the theological hole created by the new scientific views.
- But this view made the new scientific views more palatable.

Science and (Speculative) Philosophy

- By "speculative philosophy," we mean views about the physical world that are not based on empirical facts ("facts" in our technical sense).
  - Another word for this branch of philosophy is metaphysics.
- The Aristotelian core beliefs were ***not*** speculative in this sense.
  - E.g. there were many empirical arguments for the core beliefs about the Earth.
- Atomism, which DeWitt talks about, is an ancient Greek school of speculative philosophy.

Science and (Speculative) Philosophy

Ancient Greek Atomism

- Key figures: Leucippus (fl. 440 BCE), Democritus (fl. 410 BCE), Epicurus (341–270 BCE), and Lucretius (99–55 BCE)
- The basic view:
  - The world consists of atoms moving randomly in an infinite void.
  - A void is completely empty space.
  - Atoms are solid corpuscles too small to be seen.
  - Atoms come in many shapes, and their motions and collisions explain the diversity of substances and phenomena we observe.
  - The world is mechanical, not teleological.
- Greek atomism was transmitted through the Islamic science and revived in Europe in the early 15th century.

Science and (Speculative) Philosophy

- Greek atomism was a purely speculative philosophy.
- In fact, the theory itself says that atoms and void are unobservable.
  - Atoms are too small to be seen; a void is completely empty.
- Aristotelianism had empirical support, so atomism didn’t become popular in the ancient and medieval science.
- But in the 17th century, scientists needed a replacement for Aristotelianism, and they adopted and developed atomism.
  - This revived atomism was called a “corpuscular” view.

Science and (Speculative) Philosophy

- Notice that this turn to atomism was not empirically supported—atoms and void are unobservable by definition.
- Rather, the turn was supported conceptually or philosophically.
  - This is another example of why a commonsense understanding of science as changing in response to empirical findings is inadequate. Science often changes in response to philosophical ideas.

Science and (Speculative) Philosophy

- For the 17th century scientists, atomism had two promising features:
    1. Mechanical view of the world
    2. Fruitful for theorizing about motion
- DeWitt talks about (2) in the text.

Science and (Speculative) Philosophy

1. Mechanical view of the world

- Review our discussion of Aristotelian teleology (Week 6).
- Aristotelian teleology has two parts:

1. The universe is teleological.
   - Everything in the universe has a purpose, goal, or function.
2. Scientific inquiry aims at understanding why something exists or behaves as it does, and this understanding requires knowing the purpose of a thing.
   - Understanding why is explanation in a deeper sense as opposed to the minimal sense we talked about last week.

Science and (Speculative) Philosophy

- The mechanical view of the world rejects teleology. So (in a simple version):

1. The universe is fundamentally mechanical.
    - Nothing in the universe ultimately has a purpose, goal, or function.
2. Scientific inquiry aims at understanding how a physical (mechanical) process leads to an object or behavior of interest.

- Note that on the mechanical view, there is no deep answer to *why* a rock falls other than what triggers the initial motion and how it falls the rest of its way.
    - Aristotelian physics has a deep answer.

Science and (Speculative) Philosophy

- Greek atomism was mechanical.
  - The world is fundamentally made of motion of atoms in a void, and atoms' motion has no purpose.
- In the 17th century, this *mechanical* view looked promising as scientists were looking for a replacement for the Aristotelian *teleological* view.

Science and (Speculative) Philosophy

2. *Fruitful for thinking about motion*

- We'll talk more about the 17th century theory of motion in the next chapter, but we already know that scientists needed a new theory of motion that coheres with the belief that the universe is vast and that celestial bodies keep moving at varying speeds (without something that is pushing them).
- How do we go about coming up with a new theory?
- Here atomism provided a fruitful conceptual resource.

Science and (Speculative) Philosophy

- In Aristotelian physics, scientists thought about observable motion of objects as the basic motion.
- In atomism, the basic motion is that of atoms in a void, which is unobservable.
- But since the Aristotelian physics needed to be replaced, scientists in the 17th century explored a theory of unobservable, basic motion of atoms in a void.

Science and (Speculative) Philosophy

- In other words, instead of thinking about how a heavy object moves on the Earth (like Aristotelians did), scientists in the 17th century thought about a tiny, invisible corpuscle moving in an empty space.
  - Notice how counterintuitive this new way of thinking is. You are studying motion by thinking about the kind of motion no objects you know exhibit!
- This corpuscular way of thinking about motion helped develop the principle of inertia.

A Word of Caution

- At the end of Chapter 18, DeWitt gives a word of caution.
  - The historical development described in his book and in this course is a broad-brushstroke picture, which is meant to encourage further study.
  - A more complete picture would be very complex, and the rise of a new science would look less sudden than it appears in this book.
- Another important thing to do is to resist *whiggish* interpretations (review Week 2).
  - A whiggish interpretation is anachronistic; it reads the past by focusing on what is similar to our own views.

A Word of Caution

- It is true that atomism and the principle of inertia (and other laws of motion) have survived today.
- But it is important to remember that scientists in the 17th century were ***not*** trying to anticipate views that would be accepted by us.
  - And they did produce many beliefs we no longer accept.
- To better understand their thinking, it’s more helpful to remember that they were trying to solve open problems for a new science and that these problems emerged because they rejected the core beliefs of the Aristotelian worldview.

Chapter 20: The Newtonian Worldview

“Newtonian”

- “Newtonian” does not necessarily mean “Newton’s own work.”
- Newton (1643–1727) himself built on the previous and contemporaneous work by other scientists.
- Moreover, Newton’s own physical theory was modified and extended in the 18th century, and today when we say “Newtonian physics,” we are actually referring to the achievement made after Newton’s death.
- So when we say “Newtonian worldview,” we are using “Newtonian” as an honorific, just as we used “Aristotelian” as an honorific.

The New Science

- Newton's *Principia* (1687) was and is widely regarded as a culmination of the decades of work by a number of scientists.
  - Newton definitely didn't come up with the new science singlehandedly!
- Recall some of the open problems for a new science that scientists in the early 1600s faced.

1. If the Earth is in motion, what keeps us on the Earth, and why do heavy objects fall downward?
2. If the Earth is in motion, what keeps the Earth in motion?

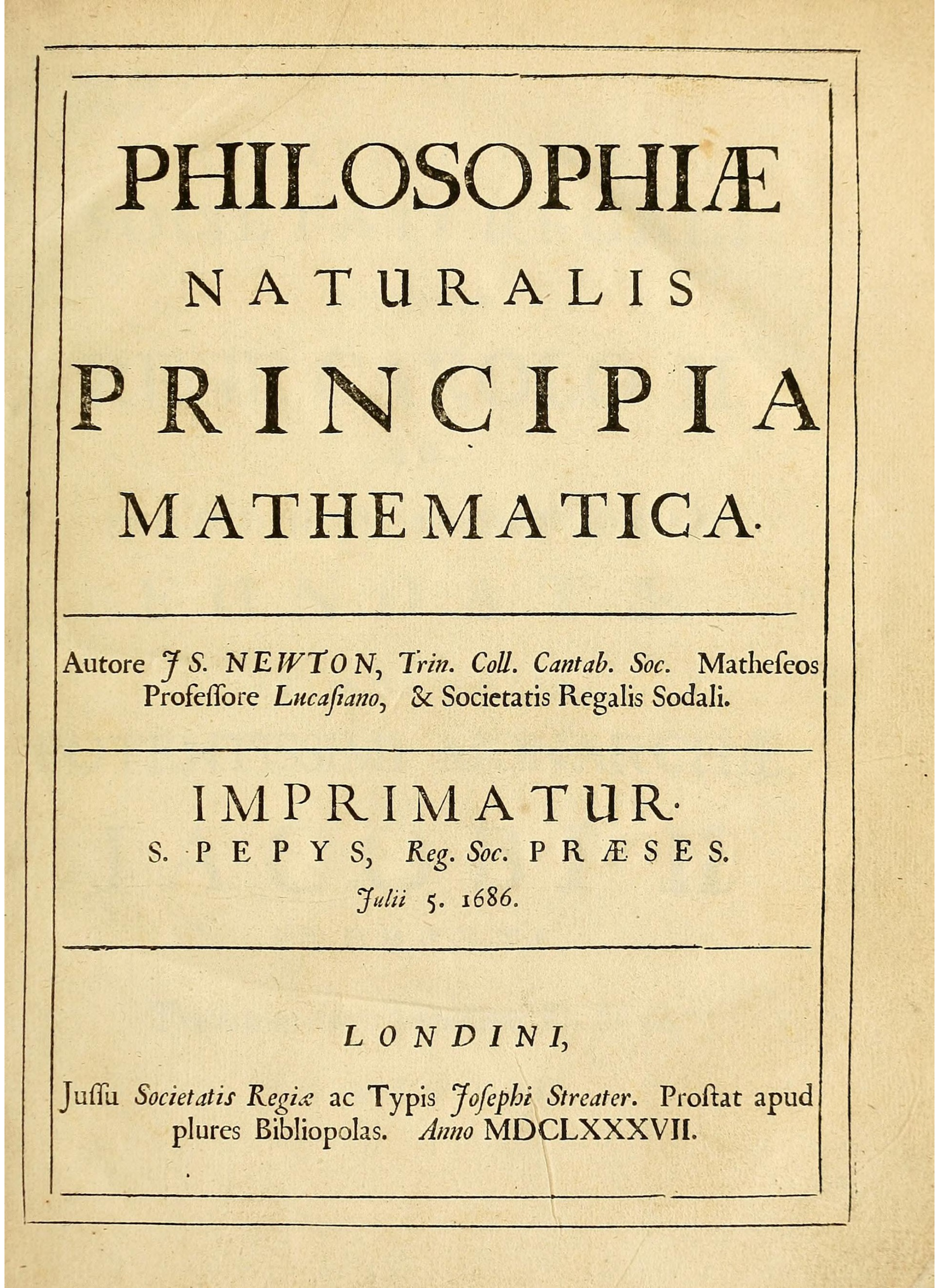
- These problems called for ***a new theory of motion***.

The New Science

- Scientists in the 17th century tried to develop this new theory of motion as a ***mechanical*** theory of motion.
  - Recall the idea of mechanical view of the world we talked about last time.
- In such a theory, only *action by contact* was acceptable.
  - That is, **no action at a distance.**

The New Science

- Many scientists contributed to the new theory of motion, and Newton's *Principia* articulated the theory in a systematic form.
- This system is famously presented as three laws of motion plus the law of universal gravitation.
- We'll look at Newton's own formulations of these laws and the modern versions.



PHILOSOPHIÆ

NATURALIS

PRINCIPIA

MATHEMATICA.

Autore *J S.* NEWTON, *Trin. Coll. Cantab. Soc.* Mathefeos Profeffore *Lucafiano*, & Societatis Regalis Sodali.

IMPRIMATUR.

S. PEPYS, *Reg. Soc.* PRÆSES.

Julii 5. 1686.

LONDINI,

Juffu *Societatis Regiæ* ac Typis *Jofephi Streater*. Proftat apud plures Bibliopolas. *Anno* MDCLXXXVII.

Newton’s *Principia* (*Mathematical Principles of Natural Philosophy*), published in 1687

Newton’s Laws of Motion

First Law

“Every body perseveres in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed thereon.”

Second Law

“The alteration of motion is ever proportional to the motive force impressed; and is made in the direction of the right line in which that force is impressed.”

Third Law

“To every action there is always opposed an equal reaction: or the mutual actions of two bodies upon each other are always equal, and directed to contrary parts.”

Newton’s Laws of Motion

- What we just saw are English translations of Newton’s formulations in the *Principia.*
- We’ll briefly comment on the second law here (and ignore the third) and then discuss the first law.

Newton’s Laws of Motion

Second Law

“The alteration of motion is ever proportional to the motive force impressed; and is made in the direction of the right line in which that force is impressed.”

- The modern statement of this law is $\boldsymbol{F} = \boldsymbol{ma}$.
  - F = force; m = mass; a = acceleration
- The modern statement never occurs in the *Principia*.

Newton’s Laws of Motion

First Law

“Every body perseveres in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed thereon.”

- This is called the law (or principle) of inertia (we read about this in Chapter 12).
- You should know Newton’s version of this law or DeWitt’s restatement in Chapter 12.

Newton’s Laws of Motion

- Referring to the first and second laws of motion, Newton said that they are already “accepted by mathematicians and confirmed by experiments of many kinds.”
- In fact, the law of inertia had been around at least since the 1640s (see next).
  - But Newton didn’t give much credit to his predecessors.
- As you read, pay attention to the two key ideas of inertia:

1. Uniform motion
2. Rectilinear motion (straight line motion).

Newton’s Laws of Motion

- **Pierre Gassendi** (1592–1655), French philosopher, priest, astronomer.
- In *De motu impresso a motore translato* (1642), Gassendi formulated the law of inertia (see quote next).

Newton's Laws of Motion

- "*All motion once impressed, is of itself Indelible*, and cannot be Dimished, or Determined, but by some External Cause, that is of power to repress it. [. . .] Let us suppose, that the space, through which a stone should be Projected, were absolute Inane, or such as the Imaginary spaces; and then we must acknowledge, that it would be carried in a direct and invariate line, through the same space, and with an Uniforme and Perpetual motion, until it should meet with some other space, full of magnetique rayes, Aer, or some other resisting substance." (Gassendi)

Newton’s Laws of Motion

- **Rene Descartes** (1596–1650), French philosopher, mathematician.
- In *Principia philosophiae (Principles of Philosophy)* (1644), Descartes formulated the law of inertia (see quote next).

Newton’s Laws of Motion

- “The first law of nature: each and every thing, in so far as it can, always continues in the same state; and thus what is once in motion always continues to move.” (Descartes)
- “The second law of nature: all motion is in itself rectilinear; and hence any body moving in a circle always tends to move away from the center the circle which it describes.” (Descartes)
- Descartes’s two laws together contain the law of inertia.

Newton’s Laws of Motion

- **Christiaan Huygens** (1629–1695), Dutch physicist
- In *Horologium Oscillatorium (The Pendulum Clock)* (1673), Huygens formulated the law of inertia in one of his hypotheses on the motion of colliding bodies (see quote next).
  - This book was a scientific study of time, called horology.

Newton’s Laws of Motion

- “Hypothesis I: Any body already in motion will continue to move perpetually with the same speed and in a straight line unless it is impeded.” (Huygens)

Newton’s Laws of Motion

- **Gassendi (1642):** An object “would be carried in a direct and invariate line . . . and with an Uniforme and Perpetual motion, until it should meet with . . . some other resisting substance.”
- **Descartes (1644):** “Each and every thing, in so far as it can, always continues in the same state; and thus what is once in motion always continues to move. [. . .] all motion is in itself rectilinear.”
- **Huygens (1673):** “Any body already in motion will continue to move perpetually with the same speed and in a straight line unless it is impeded.” (Huygens)

Newton’s Laws of Motion

- **Newton (1687):** “Every body perseveres in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed thereon.”

Newton's Law of Universal Gravitation

Law of Universal Gravitation

- "There is a power of gravity tending to all bodies, proportional to the several quantities of matter which they contain." (Book III, Proposition VII)
- In the modern version, for two objects with the masses m_1 and m_2, the law is:

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

- F = force acting between two objects; r = distance between the centers of their masses; and G = gravitational constant.

The Newtonian Worldview

- We can note some important contrasts between the Christianized Aristotelian worldview and the Newtonian worldview.
  - The Newtonian worldview in the 17th century was Christianized by default.

1. Ultimate cause of motion
2. Nature of the world
3. Role of God

Ultimate Cause of Motion

- In the Aristotelian worldview, the ultimate cause of motion was an object's *telos* (purpose, internal tendency, unconscious desire).
  - That is, the ultimate cause is ***internal*** to the object itself.
- In the Newtonian worldview, the ultimate cause of motion is a force that acts on an object.
  - That is, the ultimate cause is ***external*** to the object.
  - E.g., Newton's law of inertia says ". . . unless it is compelled to change that state *by forces impressed thereon.*"—these forces are external to the moving object.

Nature of the World

- In the Aristotelian worldview, the world is ***teleological***.
  - Everything has a purpose or function; every motion has a purpose.
  - The world is like an organic system whose various parts perform special functions and are fitted together into a whole.
- In the Newtonian worldview, the world is ***mechanical***.
  - Motion has no ultimate purpose; forces are purposeless.
  - The world is like a mechanical watch whose parts move according to laws of motion but have no ultimate purpose.

Role of God

- In the Christianized Aristotelian worldview, God involved in the day-to-day workings of the universe.
  - God’s perfection is the source of motion in the superlunar region.
  - Things have purposes (internal principles) as designed by God.
- In the Newtonian worldview, God is seen as a watchmaker, who initially created the world and set it in motion but has no further involvement since then.

Gravity as an Occult Force

- Leibniz (1646–1716), German polymath, criticized Newton’s gravity as an “occult” force.
- “Occult” in this context meant something hidden among objects.
  - For example, Aristotelian purposes were occult in this sense.
- In a sense, Leibniz was arguing that Newton’s gravity was like Aristotle’s telos, which the 17th century sciences were trying to do away with.
- Let’s try to understand why Leibniz’s criticism made sense (and hence was quite influential in the development of physics).

Gravity as an Occult Force

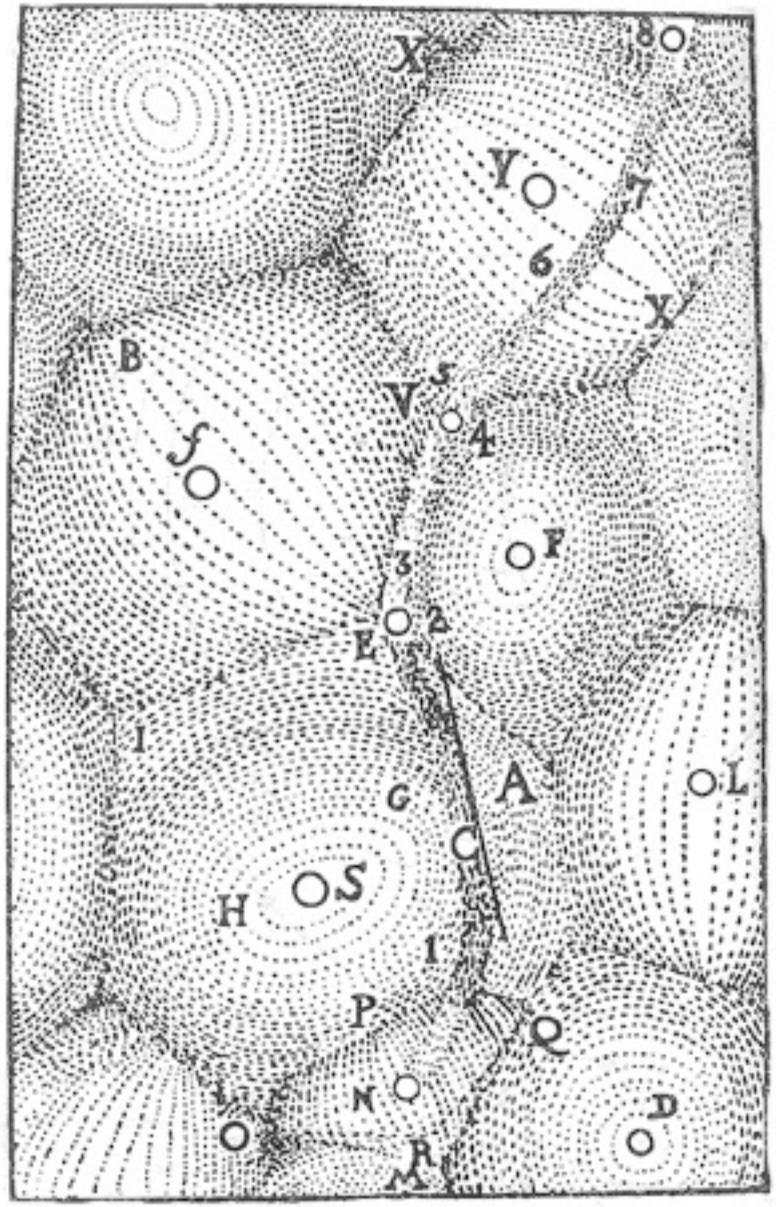
- Recall that the new science was supposed to be mechanical and avoid any action at a distance.
- Newton says, “there is a power of gravity tending to ***all bodies***.”
- And this power is understood to be a force of mutual attraction.
- So even a dust particle in the remote part of the universe is attracting every one of us on the Earth (and everything else in the universe).
- Similarly, the moon, the sun, and other planets are attracting us (and we are attracting them!) and everything else.

Gravity as an Occult Force

- But there are no visible connections between all these things in the universe.
- So gravitational attraction seems to be action at a distance.
  - Review DeWitt's dropped pen example (apparent action at a distance) and compare it to his rubber band example (no action at a distance).
- DeWitt points out that one way to respond to Leibniz's criticism is to adopt an instrumentalist attitude toward gravity.
- The instrumentalist about gravity claims that Newtonian physics with gravity (like the gravitational constant G) is a useful instrument to make predictions but does not believe that it explains *why* objects move the way they do.

Gravity as an Occult Force

- Another response might be to ask whether Leibniz's criticism is fair: Could there be a physics *without* action at a distance?
- If action at a distance is necessary, then of course Newton is justified in introducing what seems like action at a distance.
- But on this point, Leibniz's criticism seems fair, because other scientists in the 17th century were working on a purely mechanical model of the universe, where even planetary motion is explained by contact action.
  - See, e.g., Descartes' vortex theory of planetary motion (next)



In Descartes's vortex theory, the universe is full of material particles (remember he is a corpuscular theorist). A vortex is a circling band of those particles. Descartes tried to explain planetary motion by situating planets in the system of vortexes.

By analogy, imagine you drop a ball into a large whirlpool (which is a vortex of water). The ball will be carried by water and traces certain paths.

Similarly, in Descartes's theory, planets move because of vortexes of material particles in the universe.

From Descartes's *Principles of Philosophy* (1644)

Gravity as an Occult Force

- Especially among the scientists on the continental Europe, Descartes's vortex theory was considered superior to Newton's theory of universal gravitation, because Descartes's theory avoided an occult force.
- Descartes's theory remained influential until the mid-18th century, but it was abandoned because scientists could not develop a mathematical treatment of the theory.
- And by then the mathematical apparatus of Newton's theory (i.e., Newtonian physics) was very successful at prediction and explanation of the data.