

Chapter 8

Tycho, Kepler, Galileo: What it takes the change a worldview

8.1 Homework

Readings – DW 15-17

Study questions – Give a short answer to the following questions:

1. What are the main motivations that lead Kepler to find out about the elliptic orbits?
2. Which new evidence did the telescope give to scientists?
3. Explain how this new evidence conflicts with the Aristotelian worldview.

8.2 Introduction

In this chapter, our goal is to consider what could cause the complete renewal of our worldview, the so-called Scientific Revolution, over the two centuries separating Copernicus' publication of *On the Revolutions of the Heavenly Spheres* and Sir Isaac Newton's publication of the *Principles of Natural Philosophy*.

We will see what it takes to change a worldview:

1. On the scientific side
2. From the point of view of the historical and intellectual background

8.3 Towards the Scientific Revolution: the Scientific Side

8.3.1 Tycho and Kepler

Accurate Data – Tycho Brahe (1546-1601)

- Invented an earth-centered system which is equivalent to Copernicus' system
- Most importantly, gathered *an enormous amount of extremely accurate data*
- Gave Kepler the task to make sense of Mars' trajectory

The Princess and the Pea – Johannes Kepler (1571-1630)

Major works :

- *Mystery of the Universe,*
- *New Astronomy (Commentary on Mars),*
- *Epitome of Copernican Astronomy*
- *The Harmony of the World*

The end of the uniform circular motion – The princess and the pea

Working on Tycho's data on Mars, he figured that it would be *impossible* to construct a mathematical model with circular uniform model which would give a *perfect* account of the data.

Discussion Question: do we ask for perfect empirical adequacy in the natural sciences? No. Most often, scientists deal with approximations. So, in this sense, Kepler *was not* a modern scientist, but rather belongs to the tradition of mathematician-astronomers.

Kepler's system – The laws we know... and some more surprising stuff...

- Sun centered
- Elliptical orbits
- Varying speed: Law of equal area (see Figure 8.2)
- Magnetism of the Sun – Gilbert (1544-1603) – *De Magnete* for the first time equates the magnetism of the lodestone with the magnetism of the Earth. This gave Kepler and others the idea that *there are some unobservable forces*. Kepler thought that the Sun exerts a quasi-magnetic force on the planet
- The universe and the five perfect solids – See Figure 8.3
- Harmonies of the universe

Obviously, the laws were integrated by Newton in his own system. But this is not the only feature of Kepler's thought which had some influence on the future science. Indeed: the idea that the book of nature is written in mathematical language.

Kepler's philosophy – As you already know, the idea that the universe is written in mathematical language comes from the neo-platonists.

- Strong influence of Neo-platonism : Sun, Mathematics
- Human's reason is a gift that God gave us to discover the beauty of the world

8.4 Galileo and the evidence of the Telescope

Galileo – Mathematician and astronomer – 1564-1642

- The first to use the telescope (invented just before 1600)
- Devout Catholic
- Devout Realist Attitude towards science

The evidence – with the telescope

Observation	Consequence
Mountains on the Moon – see Fig. 8.4	The Moon is a Big Rock + Rocks can fly
Many more stars than we thought	Size of the Universe
Moons of Jupiter	The fact the the Earth has a Moon is not an isolated fact
Rings of Saturn	Saturn is not a perfect ethereal sphere – and is in the superlunar area
Sunspots	The Sun is not a perfect ethereal sphere either
Phases of venus – see Fig. 8.5	Counts as empirical disconfirmation for Ptolemy, while Sun-centered systems can make sense of it

Is the Evidence Compelling – This is an important question for philosophy of science

- The evidence is *not* definitive
- That said: serious cracks in Aristotle's worldview, in particular serious problem for the idea that the heavenly bodies are perfect spheres made of the fifth element.
- That said again: no way to save the system with small amendment. *Taking the evidence seriously calls for a complete renewal of the worldview.*

New terrestrial physics – Thought experiment and quantitative laws

Principle of Equivalence – between rest and uniform motion

CAREFUL: Galileo: only circular inertia

The boat and the principle of inertia – the importance of thought experiments in science. Imagine that you are on a boat, confined in a cabin with no window. Take with you some butterflies, a gold fish in a bowl, a bottle of water and a recipient. The point is: whatever the experiment you conduct with these “instruments” and within the cabin, *you won't be able to decide whether the boat is moving or not*. Indeed, nothing changes in the ordinary physics when the boat is in a uniform motion.

—→ *This undermines all the arguments that there should be obvious observable effects of the movement of the Earth.*

Discussion Question : the role of thought experiment in sciences

Quantitative laws of motion –

- real experiments in the modern sense
- use of mathematics: quantitative laws and vector decomposition

8.5 Historical and Intellectual Background

The Scientific Revolution is not the sole effect of discussion among scientists or philosophers. It took place during highly agitated times, which featured the downfall of Christendom as a unified political entity, of absolute kingdoms, and ultimately of feudal systems. There is no way we could give an exhaustive historical account of this complex period, but here are some key ideas.

The revival of Hermetic Philosophy – The Hermeticus Corpus was rediscovered in the 15th century. As you have seen, the neo-platonist, magical tradition has had an important influence on the serious consideration of the Sun-centered systems.

The European Renaissance and the Protestant Reformation – 14th-16th centuries

Printing Press – Gutenberg 1439 – books are much accessible, and not only to a few religious scholars

Travels and Discoveries – New world, new men (who incidentally never heard of our God) – The world is not a small, cosy, Christians-centered cosmos, but is much larger and greatly diverse.

Universal Reason – All human beings share some qualities, in particular rationality. *Rationality is what gives human beings their autonomy*, i.e. their ability to decide for themselves. Humans means to discover the truth are surely limited (our senses and our reason are not superpowers), but there are the best they have.

—→ *We ought to use our reason, by contrast to appeal to authority and blind faith in our search for the truth in all domains, including science, morality and even religion.*

Humanism – Humanism is complex intellectual movement. A central idea is that *human beings possess a special value for being both rational and free agent*. This is in some sense the beginning of the idea of human rights. Whatever the color, religion, etc. human beings are to be valued. As a consequence, torture, murder etc. are banned.

The Protestant Reformation – 16th century, Martin Luther

The Protestant Reformation is complex, but an important aspect is that Luther borrowed from the humanists the idea that each person can have a personal relation to the Bible. Luther claimed that everyone, being provided by the same ability to reason, has also the ability to think for him- or herself about religion, thus putting into doubt the authority of the institutional Catholic Church.

One important factor: the Church corruption and the abuse of indulgences

Modern Philosophy against Aristotle – The two centuries during which the Scientific Revolution occurred are also century of deep philosophical revolution

Philosophy and Science – No distinction at that time. All the best philosophers are also important scientists, and vice versa.

- Descartes: invention of analytical geometry (guess who invented the the Cartesian system and Cartesian coordinates)
- Pascal: Fluid Mechanics
- Leibniz: co-inventor of the infinitesimal calculus

SO: We have to keep in mind that ultimately, philosophy and science are not separated, and that all the systems of philosophy have modern science in their horizon

NOTE: Newton's book is: *The Principles of Natural Philosophy* – “Natural Philosophy” is what we call physics – philosophy of nature if you wish

Against Aristotle 1 – virtus dormitiva

From Moliere, *The Imaginary Invalid* (1673)

Moliere invites us to laugh about the doctor's explanation of the fact that taking opium puts you to sleep:

...Learnidissimo bacheliere
Quem estimo and honoro,
Domandabo causum and rationem, quare
Opium facit dormire.
A quoi respondeo,
Quia est in eo
Virtus dormitiva,
Cujus est natura
Sensus stupifire.

Why does opium put you to sleep? “Because there is in opium a sleeping faculty the nature of which is to stupefy the senses” — Thanks !

The idea among the modern philosophers was that Aristotle’s natures were just not explaining anything.

Against Aristotle 2 – Bacon and Inductivism

- Bacon advocated a new method in science:
 - gather the data
 - infer the law by *induction*
 - Many recognize that this method is unpracticable:
 - no science is made this way
 - no science can be made this way
- Necessity of hypotheses to inform the observation

That said, this was important as an attack against the Aristotelian Way of explaining the world: privilege to experience instead of to deduction

Against Aristotle 3 – Descartes and the Re-foundation of knowledge

- Logic and Mathematics are the model: the only domains where we have reached some certainty
- Renounce all previous beliefs, accepted without rational justification
- Reconstruct on true foundations our entire body of knowledge
- Material Bodies reduced to matter, and matter reduced to extension – NO QUALITIES, ONLY QUANTITY
- The only scientifically acceptable explanations are in terms of *mechanistic interaction by contact* – the world should be explained solely in terms of billiards balls.
- Use of experiment at the end of the process, in order to choose between two possible hypotheses

→ *The teleological and essentialist worldview is replaced by a mechanistic and mathematical worldview*

A concentration of Great Minds who spent their lives discussing with each other Europe as a center of amazing intellectual life. Refutations, letters. objections and answer.

Note on the Church and the scientific Revolution – It is not the case that there is a simple conflict between the Church and Modern Science

- The Copernican system is used for a long time before Galileo
- The problems that Galileo encountered are partly due to his character, along with his realist attitude towards science, and finally to the Protestant Reformation and the Counter-Reformation. We are talking of war times, nothing less.

- All the philosophers and physicists in this story are strong believers, and religious considerations are direct part of their scientific research : example: Leibniz and Newton on the existence of absolute space

8.6 Conclusion

We have seen that the Scientific Revolution is part of a more general historical revolution in worldview, which includes technological (the telescope), political (the downfall of absolute regimes), religious (the difficulties of the Catholic Church), philosophical (The Enlightenment), and broadly intellectual (the renaissance and the rise of humanism).

One may say: here is what it takes to change a worldview...

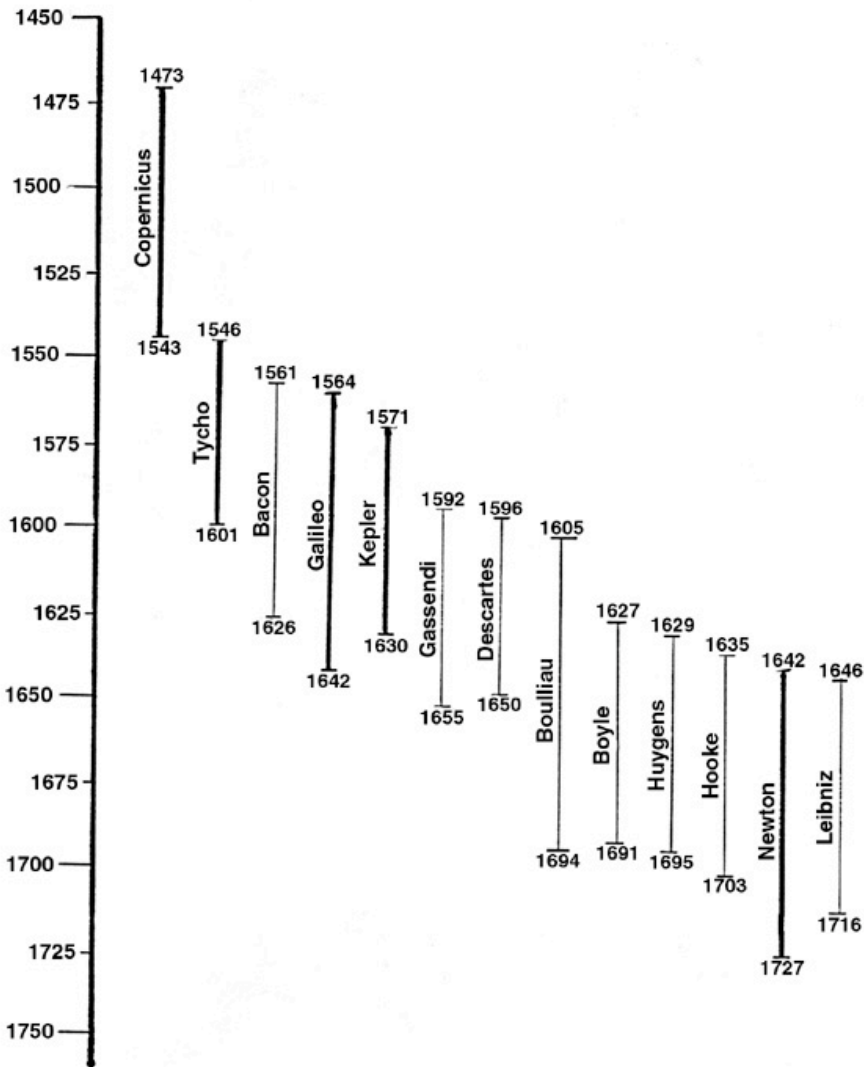


Figure 8.1: The Scientific Revolution Timeline (From Robert Hatch's website)

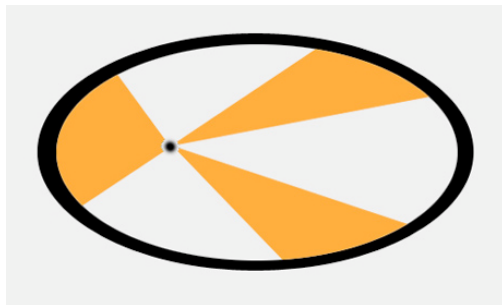


Figure 8.2: Kepler: second law (from www.uk.atronomy.com)

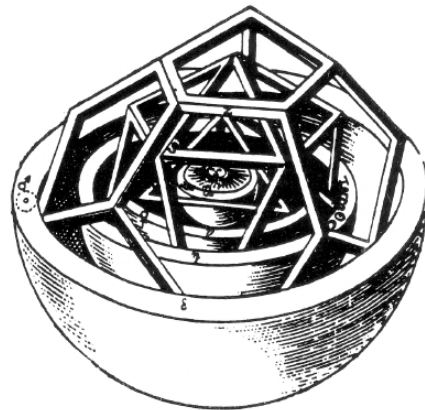


Figure 8.3: Kepler's solids (From *The mystery of the universe*)

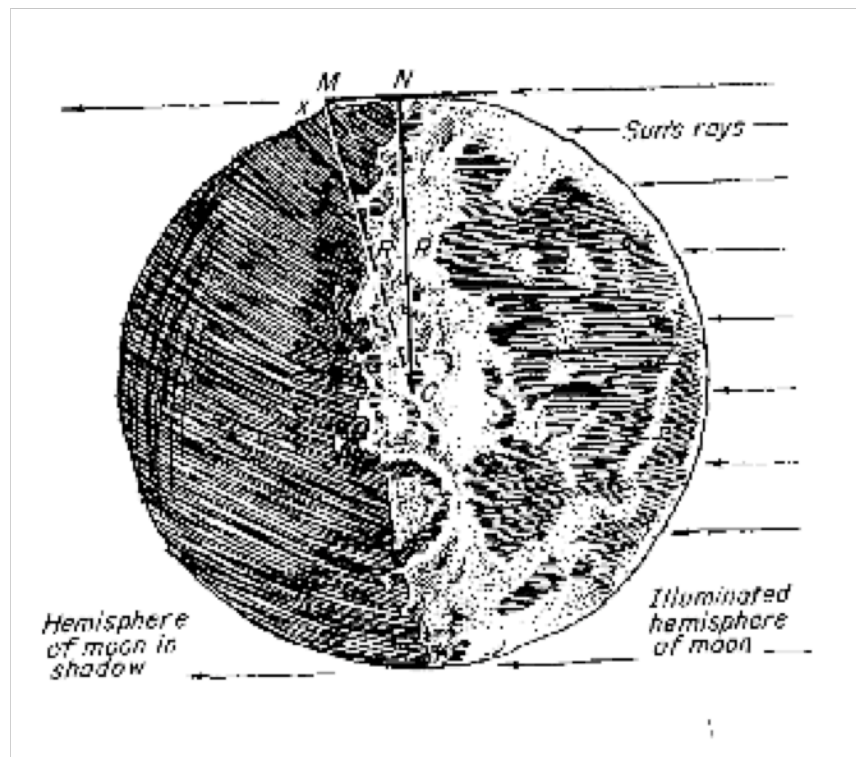


Figure 8.4: Mountains on the Moon

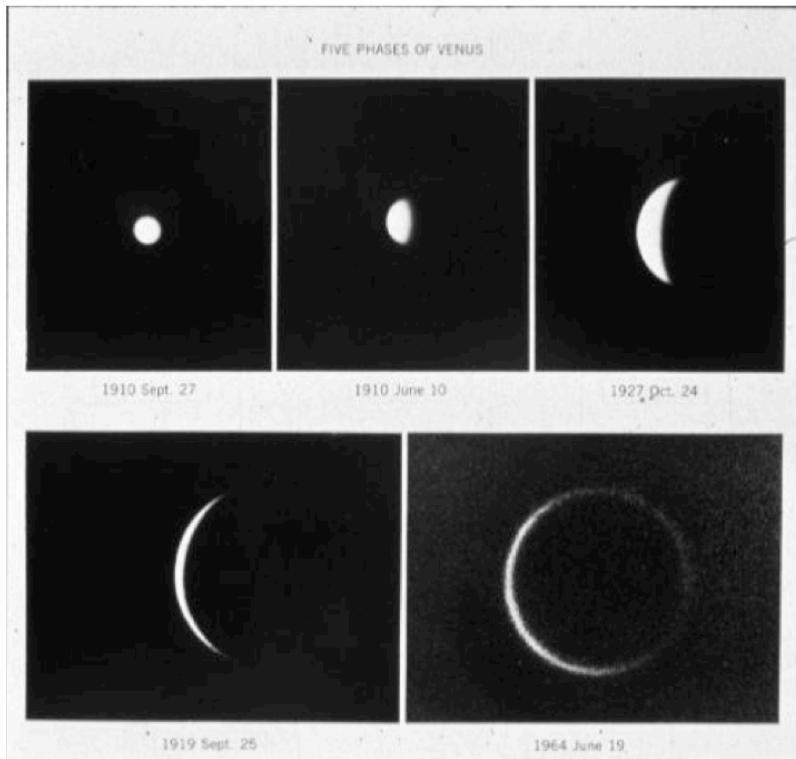


Figure 8.5: Phases of Venus