

HoS 323/623: The Scientific Revolution

Monday/Wednesday; 2:30–3:45p
2120 Chamberlin Hall

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Office Hours—drop by 1p–3p Wednesdays and 10a–11:30a Thursdays. Also by appointment!

Introduction

This course is about the development of a particular branch of “science” or, as most of our authors would have called it, “natural philosophy” from antiquity through the early 20th century. Natural philosophy may have been born from the desire to know more—and with a higher degree of certainty—about the mundane world around us. But by the 20th century, an increasing number of prominent intellectuals regarded science (now just called “science”) as the univocally *best* way of knowing most things. How did this transition happen? Why did this notion that science provided the best kind of knowledge become so pervasive in Western cultures (including our own)?

In philosophy, “epistemology” refers to the nature, methods, and limits of human knowledge. As you will see many intellectuals in Western Europe perceived a growing epistemological crisis in the years between 1300 and 1600. In other words, intellectuals sensed increasing discord over the nature and proper methods for divining (T)truth. A variety of elements contributed to this crisis, including controversies about the balance between empirical observation and deduction, debates about what constitutes a valid and sufficient explanation for a phenomenon, and arguments over the proper relationship between theology and philosophy. Some of these questions may be familiar to you; many are part of ongoing debates today. In the eyes of many historians, though, the solutions to these dilemmas that were developed during the 17th century marked a critical turning point, providing a powerful intellectual legacy that continues to hold great sway in our present.

Natural philosophy served as the major intellectual arena for attempts to resolve the epistemological crisis. Paradoxically, this arrangement occurred because natural philosophers had helped to create the crisis (for instance, through the transition to a Copernican system). Natural philosophy was thus interwoven into the intellectual life of the early modern era. Our main content for this course is the transformation of natural philosophy during the 17th century—commonly referred to as the “Scientific Revolution”—as a means to examine the epistemological issues discussed above. Despite what you may have heard, we cannot be sure that one, coherent “scientific method” emerged from these debates, nor that the 17th century truly was a time of radical intellectual transformation. Part of your task this term will be to decide whether something novel and crucial did occur during the 17th century, and if so, what was it? This is not merely an idle, historical question. Through a close examination of the time period often considered to mark the birth of modern science, we hope to gain a fresh perspective on science in our own era: its unarticulated assumptions, tensions, and relations to other domains of knowledge.

Texts (in the order you’ll need them)

1. Thomas Kuhn, *The Copernican Revolution*
 2. Maurice Finocchiaro, *The Essential Galileo*
 3. °Francis Bacon, *Selected Philosophical Works*, ed. Sargent—> °there are online alternatives
 4. Dana Densmore, *Selections from Newton’s ‘Principia’*
 5. Albert Einstein, *Relativity: The Special and General Theory*
- Many texts can be found on Learn @ UW. These are marked with an “R->” in the schedule. You *must* print out and bring these readings with you to class.

My Objectives

1. To familiarize you with the transition from “natural philosophy” to “science” over roughly two thousand years.
2. To help you develop an ability to read and analyze difficult texts.
3. To help you learn how to interact with primary scientific sources, and interpret broad intellectual developments.

My expectations

The best kinds of courses are conversations between professor and student about something that matters to both. As much as possible, we will attempt to emulate this in our classroom and in assignments. Given this “conversation” metaphor, there are some very basic ground rules for a good conversation:

1. Be present in mind and body.
2. Be on time.
3. Demonstrate respect for each other and for the course material.
4. Take responsibility for your own learning and for the learning of others.

What does this mean in a practical sense? First, it means that attendance is mandatory. You must inform me of any event that might constitute a legitimate excused absence (e.g., interview, athletic event, etc.) *well in advance* of the event (not the night before). More than one unexcused absence (except, of course, for circumstances such as illness, athletic competition, etc.) will *significantly* affect your grade.

Secondly, it means that *there won't be any extensions* (except in rare cases of grave illness, family crisis, etc.). If you have several papers or exams on the same day or during the same week, create a work schedule and complete some assignments beforehand. **Late work just won't be accepted.** That goes for reading quizzes as well. Please communicate with me. Please. Really. Don't simply elect to not show up.

Finally, it means that you should learn your classmates' names and use them in discussion, referring to each others' points. If you are not speaking up in class, *I will likely call on you*. I know this is a horrible feeling if you are a shy person (I am one of those, so I empathize). Still, this is a skill that we in the university should be teaching you—the art of sharing your intellectual insights in public with your peers. So speaking is not punishment, it's practice (now drop and give me 20 push-ups).

Academic Honesty

Plagiarism of internet-based resources is widespread. If and when you use them for this class, please keep in mind that (1) websites are often unreliable sources of information, and (2) it is plagiarism to use information and/or language from websites without adequate citation and/or properly presented quotations. This is important to recall. Rephrasing the ideas contained on the site but retaining the structure of what is presented *does not* constitute putting it into your own words. When in *any doubt whatsoever*, provide the proper citation. If you have any questions or concerns about what constitutes plagiarism or cheating, please do not hesitate to ask.

Evaluation

- 50% Wednesday reading quizzes—5 pts. each, 10 total (out of 13 Wednesday meetings).
- 10% Galileo Trial preparation
- 10% 750 to 1,000 word “Common Knowledge survey.
- 20% 2,500 to 5,000 word research paper/project on a selected topic.
- 10% Class participation (includes attendance, discussion, 5-min papers, and evaluation responses.)

Winter/Spring 2012— Schedule

THE FIRST REVOLUTION: COPERNICUS IN LIGHT OF PHILOSOPHY, MATHEMATICS, THEOLOGY

M	Jan 23	Intro	
W	Jan 25	Ancient Astronomy & the Two-Sphere Universe	Kuhn, <i>The Copernican Revolution</i> , pp. 1-44
M	Jan 30	The Ptolemaic System	R-> Ptolemy, <i>Almagest</i> , Book I: chs. 1, 4, 6-7 Kuhn, 45-77 [skip subsection: "The Theory of Homocentric Spheres," pp. 55-59]
*W	Feb 01	Aristotelian and Medieval Cosmologies	Kuhn, 78-99 MEET AT PLANETARIUM!
M	Feb 06	Mathematics & Natural Philosophy in <i>De Revolutionibus</i>	R-> Prefatory materials to <i>De Rev.</i> Kuhn, 123-44 [skip the excerpts from <i>De Rev.</i>]
*W	Feb 08	Copernicus's Innovation	Kuhn, 144-65, 169-71, 181-84 [includes text of Book I of <i>De Revolutionibus</i>]
M	Feb 13	Tycho Brahe, Kepler, and observations	R-> Donahue, <i>Selections from Kepler's Astronomia Nova</i> , 1-5, 11-28
OPTIONAL [Extra credit]: FIELDTRIP TO SPACE PLACE at 2300 S. Park Street in the Villager Mall; 5pm-8pm. (http://spaceplace.wisc.edu/location.shtml) Build Galilean telescopes. \$20 cost for telescope kits.			
*W	Feb 15	Galileo, Astronomical Observation, and Courtly Life	Kuhn, 219-25 Galileo, <i>Sidereus Nuncius</i> (Finocchiaro, <i>Essential Galileo</i>): Read 45-58, skim 59-82, read 83-84 [handout] Reactions to Galileo's Telescope
M	Feb 20	First Inquisition of Galileo (1616) R-> indicates reader [page numbers] indicate pages from <i>The Essential Galileo</i>	R-> Benedetto Castelli to Galileo (14 Dec. 1613) [103-109] Galileo to Castelli (21 Dec. 1613) [146-48] Robert Cardinal Bellarmine to Foscarini (12 April 1615) [163-67] Galileo on the Copernican Opinion, Part III (1615) [168-70] Lorini's Complaint (1615) R-> Consultant's Report on Letter to Castelli (1615) R-> Consultants' Report on Copernicanism (24 Feb. 1616) R-> Inquisition Minutes (25 Feb. 1616) [175-76] Special Injunction (26 Feb. 1616) [176-78] Decree of the Index (5 March 1616) R-> Galileo's Letters to Tuscan Secretary of State (March 6 & 12, 1616) R-> Cardinal Bellarmine's certificate (26 May 1616) R-> Correction of Copernicus's <i>De Rev</i> (1620)
*W	Feb 22	<i>Dialogues on the Two Chief World Systems</i> (DTCWS)	DTCWS (in Finocchiaro, <i>Essential Galileo</i>), 190-92, 218-21, 227-33, 267-71 Report of the Special Commission (1632), 272-76

R-> indicates reading in course reader; *indicates quiz that day (usually Wednesday)

M	Feb 27	Second Inquisition of Galileo (1633) R-> indicates reading in the collection, "The Later Inquisition Proceedings" [page numbers] indicate pages from Finocchiaro, <i>Essential Galileo</i>	[276–282] Galileo's First Deposition (12 April 1633) R-> Orregi's Report on the <i>Dialogue</i> (17 April 1633) R-> Inchofer's Report on the <i>Dialogue</i> (17 April 1633) R-> Commissary General to Cardinal Barberini (28 April 1633) [282–294] Galileo's Second Deposition and subsequent documents R-> John Paul II, "Lessons of the Galileo Case" R-> Cardinal Poupard, "Galileo: Report on Papal Commission Findings" Optional: R-> Biagioli, <i>Galileo, Courtier</i> , 313–52
TBD	TBD	TBD	EVENING DEBATE ON GALILEO

The Cartesian Revolution in Physics

W	Feb 29	Aristotelian Physics	R-> Aristotle, <i>Physics</i> , Bk I, ch. 1; Bk. II, chs. 1-3.195a27 (McKeon, pp. 218, 236–41)
M	Mar 05	Aristotelian Physics & Renaissance Naturalism	R-> Aristotle, <i>Physics</i> , Bk. II, chs. 7-8 (McKeon, pp. 247–51) R-> Westfall, <i>Construction of Modern Science</i> , 25-30
*W	Mar 07	Galileo on Falling Bodies	R-> Aristotle, <i>Physics</i> , Bk. III, ch. 1: 200b.12-25; 201a, 10-14 (253–254); Bk. IV, ch. 8: 214b.15–216a.20 (283–85) Galileo, <i>Two New Sciences</i> , in Finocchiaro, <i>Essential Galileo</i> , 300–12, 342–56).
Mon. through Wed. in Late Feb., early Mar. -- POSSIBLE NIGHT SKY OBSERVATION			
M	Mar 12	Cartesian Metaphysics & Physics	R-> Descartes, prefatory letter to <i>Principles of Philosophy</i> R-> Descartes, <i>Treatise on Light</i> , Chapters 6 & 7
*W	Mar 14	Cartesian Physiology & Perception	R-> Descartes, <i>Treatise on Man</i> (excerpts) R-> Descartes, <i>Principles of Philosophy</i> , Part II, 1-4, 23, 64 ◊ R-> Descartes, <i>Optics</i> 1, 4-6

EMPIRICISM & NATURAL PHILOSOPHY

M	Mar 19	Natural Philosophy and Empirical Research	Bacon, <i>New Organon</i> (excerpt TBA). Find it online at: http://www.constitution.org/bacon/nov_org.htm
*W	Mar 21	Empirical Natural Philosophy to "Science"	Bacon, <i>New Atlantis</i> . Find it online @ http://www.gutenberg.org/ebooks/2434 . Download or read in HTML R-> Vannevar Bush, <i>Science The Endless Frontier</i> (excerpt) ---Due: "Common Knowledge" survey (750–1000 words)---

M	Mar 26	Newton and the "crucial experiment"	[email] Newton, letter to Oldenburg (1672) R-> Sepper, <i>Newton's Optical Writings</i> (excerpt)
W	Mar 28	Modern debates	R-> Collins & Pinch, <i>The Golem</i> , ch. 5 (wrong chapters uploaded) --Due: mid semester evaluation--

SPRING BREAK

THE NEWTONIAN WORLDVIEW (OUR MODERN WORLDVIEW?)

M	Apr 09	<i>Principia</i> I	Densmore, <i>Selections from Newton's Principia</i> , pp. 1-21
W	Apr 11	<i>Principia</i> II	Densmore, pp. 23-31
M	Apr 16	<i>Principia</i> III	Densmore, pp. 31-46
W	Apr 18	<i>Principia</i> IV	Densmore, pp. 47-91 [excerpts]
*M	Apr 23	Thinking about God & Nature through Newton's eyes	"General Scholium", <i>Principia</i> R-> Newton, <i>Opticks</i> , Query 31 (excerpt) Keynes, "Newton, the Man". Find online:

FOR AND AGAINST THE NEWTONIAN (MODERN?) WORLDVIEW

W	Apr 25	Goethe on Color	[handout] Goethe's optical experiments R-> Goethe, "Polarity" and extracts from <i>Theory of Color</i> R-> Helmholtz, "On Goethe's Scientific Researches" R-> Ribe & Steinle "Exploratory Experimentation"
M	Apr 30	Romanticism pro- and anti-Newton	R-> Halley, "Ode" to Newton (from Newton's <i>Principia</i>) R-> Extracts from English poets: Thompson, <i>To the Memory of Sir Isaac Newton</i> Blake, <i>Milton</i> and <i>Jerusalem</i> Coleridge, <i>Frost at Midnight</i> Haydon, "The Immortal Dinner" Keats, <i>Lamia</i> Wordsworth, <i>Prelude</i>
*W	May 02	Another revolution? Special Relativity	Einstein, <i>Relativity</i> , Preface and Part 1 (pp. 3-50).
M	May 07	General Relativity	Einstein, <i>Relativity</i> , Part 2 (pp. 77-110).
*W	May 09	An "Einsteinian" Worldview: What does it all mean?	Einstein, <i>Relativity</i> , Parts 2 & 3 (pp. 127-145). --Due: end-of-course evaluation--

Due: Final paper project—Before you leave campus for break

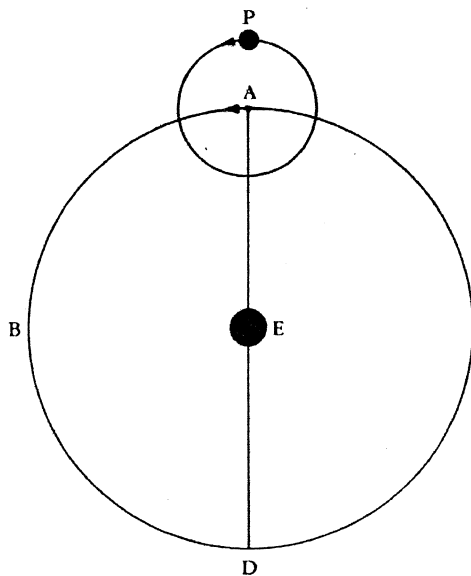
Ptolemaic Astronomy Terms

EPICYCLE¹

In the diagram below, **E** is the Earth and **P** is a planet. The circle **B** is the deferent, and the center of the epicycle, **A** moves around the Earth (along the deferent) in a counterclockwise motion.

Types of Epicycles: In Kuhn's terminology, there are two kinds of epicycles. In "major epicycles," (like the one shown below) the epicycle rotates in the same direction as the deferent. In "minor epicycles," the epicycle rotates in the opposite direction from the deferent (imagine **P** rotating clockwise, rather than counterclockwise).

Function of the Epicycle: "Major epicycles" produce the looped patterns that (from the Earth) appear as retrograde motion. "Minor Epicycles" don't produce retrograde motion; rather they shift or otherwise deform the path that the planet would follow if attached rigidly to the deferent alone. For instance, a minor epicycle can squish the deferent's circular path into an oval shape. (See Figure 22 on p. 67 of Kuhn for two examples of minor epicycles in action)



¹ The initial diagrams for the epicycle, eccentric, and equant are from Mike Crowe, *Theories of the World from Antiquity to the Copernican Revolution*.

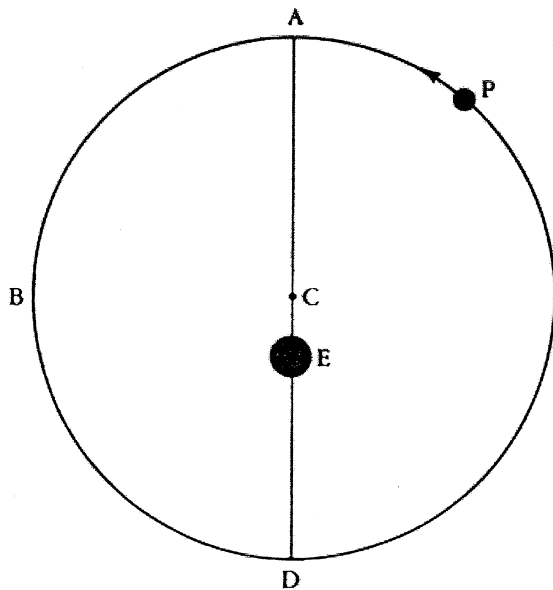
Ptolemaic Astronomy Terms

ECCENTRIC

In this diagram, **E** is once again the Earth, and **P** is a planet traveling around deferent **B**. However, the Earth is no longer the center of the deferent (the center is at point **C**). The distance between the Earth, **E**, and the center of the deferent, **C**, is the “eccentricity” of the orbit. If we were to move the Earth further from the center, we would say that the orbit of planet **P** has become more eccentric.

Function of the Eccentric: An eccentric orbit changes the *apparent* speed of the planet (viewed from Earth) as it travels around the deferent. Note that the *actual* speed of the planet remains constant. (If we were watching **P** from above, as in this diagram, it would seem to be moving at a constant, uniform speed along the deferent).

This optical effect occurs because we can only locate a planet visually from Earth by watching it against the background of the fixed stars. Turn to the next page to see how this works.



Ptolemaic Astronomy Terms

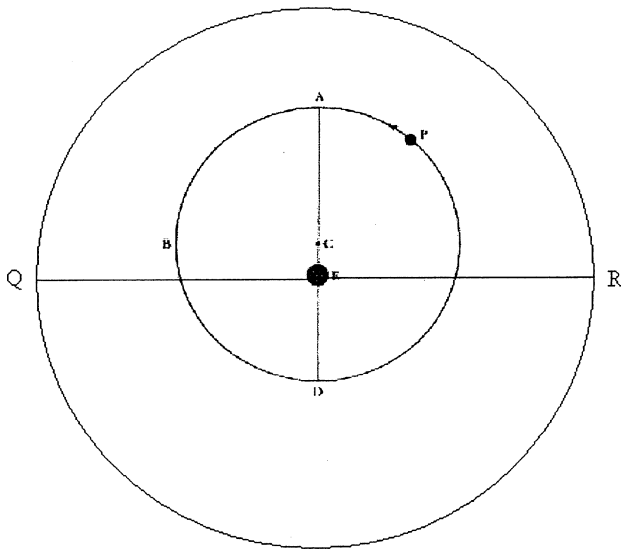
EGCENTRIC (CONT'D)

Let's take this eccentric orbit and place it inside the celestial sphere (not drawn to scale), remembering that Earth is always at the absolute center of the celestial sphere (my drawing shows it slightly offset, but that's my fault).

In this diagram, the larger, outer circle represents a slice through the sphere of the fixed stars. The entire diagram shows one two-dimensional plane cut from the three dimensional celestial sphere. We are looking at the plane from the sphere that contains the orbit of planet **P**. The line **QR** bisects this slice of the celestial sphere (so the area of the circle above **QR** is equal to the area below **QR**).

Now from Earth, we will see the planet **P** moving against the background of the fixed stars. When **P** is on the line connecting **E** and **R**, we will see the planet **P** amidst the stars that surround point **R**. Similarly, when the planet is on the line between **E** and **Q**, we will see planet **P** amidst the stars that surround point **Q**.

Now recall that **QR** bisects the celestial sphere. But from the diagram, it should be clear that the line **QR** does not bisect the orbit followed by **P** (since **P** is traveling on an eccentric orbit, i.e., the smaller circle). So when **P** travels counterclockwise on its eccentric deferent between the point where we observe it at **R** and when we can observe it at **Q**, it must travel a much greater distance than when it goes from **Q** to **R**. The net result is that, from a viewpoint on Earth, **P** moves more quickly from **Q** to **R** than vice-versa. So when **P** is closer to the Earth (based on its eccentric orbit), it seems to be traveling faster.



Ptolemaic Astronomy Terms

EQUANT

In this figure, **E** is once again the Earth. Note that it is no longer at the center of the deferent (point **C**). What we see here is an equant added to an eccentric orbit. In principle, there's no connection between the two: one could use an equant without an eccentric. In practice, Ptolemy only used equants when he had also utilized an eccentric. Hence the two are shown together above.

Point **Q** is the equant point. Planet **P** will always maintain a constant angular velocity about point **Q**. Imagine the planet beginning at point **A**. Now imagine a line connection **P** to **Q**. Obviously, as **P** moves along its deferent, this line will rotate about point **Q** (and its length will change, as the distance between **P** and **Q** changes). At any time, we can measure the angle between the imaginary line **PQ** and the line **AQ** (which isn't moving). (So when the planet reaches point **F**, angle **PQA** will be 90 degrees; at point **B**, it will be 180 degrees, etc.)

To say that **P** maintains a constant angular velocity about **Q** means that the angle **PQA** changes at a constant rate (say, 2 degrees per day).

Example: When **P** starts at **A** and moves to **F**, it will have swept out an angle of 90 degrees (relative to point **Q**). If it takes five months to complete this path, it will also take five months to move from **F** to **B**.

Function of the Equant: The equant changes the *actual* speed of the planet in its orbit. (Recall that the eccentric changed the *apparent* speed, the speed as viewed from Earth). As shown in the diagram above, both the eccentric orbit and the equant serve to make the planet move faster when it is closer to Earth.

