Philosophy of Science Survey

Week 11

PHIL 2160. Ohio University. Spring 2021.

Chapter 17: Galileo and the Evidence from the Telescope

Galileo Galilei (1564–1642)

- Italian astronomer, physicist, and engineer
- Studied medicine at the University of Pisa
  - Studied mathematics privately
  - Left without a degree in 1585
- Professor of mathematics at the University of Pisa (1589–1592)
- Professor of mathematics at the University of Padua (1592–1610)
- Publishes *Sidereal Messenger* in 1610 and moves to Florence.
- *Dialogue Concerning the Two Chief World Systems* (1632)

SIDEREVS NVNCIVS

MAGNA, LONGEQVE ADMIRABILIA
Spectacula pandens, ſuſpiciendaque proponens
vnicuique, præſertim verò
PHILOSOPHIS, atq; ASTRONOMIS, quæ à

GALILEO GALILEO

PATRITIO FLORENTINO
Patauini Gymnaſij Publico Mathematico

PERSPICILLI

Nuper à ſe reperti beneficio ſunt obſeruata in LVNÆ FACIE, FIXIS IN-NVMERIS, LACTEO CIRCVLO, STELLIS NEBVLOSIS,
Apprime verò in

QVATVOR PLANETIS
Circa IOVIS Stellam diſparibus interuallis, atque periodis, celeritate mirabili circumuolutis; quos, nemini in hanc vſque diem cognitos, nouiſſimè Author deprehendit primus; atque

MEDICEA SIDERA

NVNCVPANDOS DECREVIT.

VENETIIS, Apud Thomam Baglionum. M DC X.
Superiorum Permiſſu, & Priuilegio.

Sidereal Messenger (1610)


museo
galileo

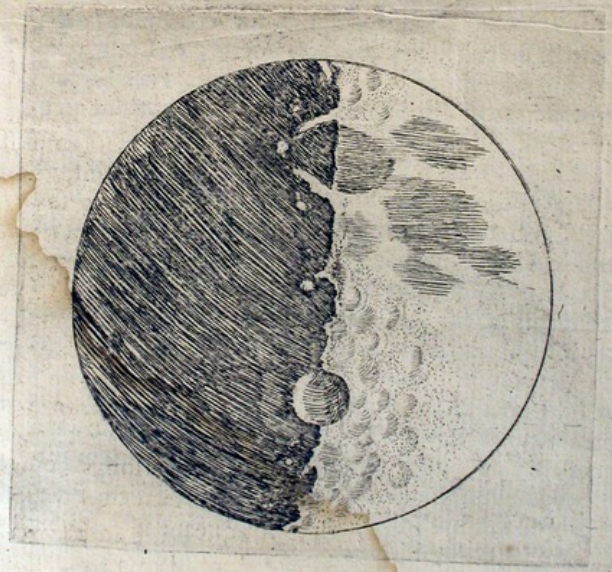

museo
galileo

Galileo's Observations and the Aristotelian Worldview

- DeWitt discusses many of Galileo's observations, so here we'll just focus on two and how they relate to the Aristotelian worldview.

1. Mountains of the moon
2. The phases of Venus

ctum daturam. Depreſſiores inſuper in Luna cernuntur magnæ maculæ, quàm clariores plagæ; in illa enim tam creſcente, quam decreſcente ſemper in lucis tenebrarumque confinio, prominente hincindè circa ipſas magnas maculas contermini partis lucidioris; veluti in deſcribendis figuris obſeruauimus; neque depreſſiores tantummodo ſunt dictarum macularum termini, ſed æquabiliores, nec rugis, aut aſperitatibus interrupti. Lucidior verò pars maximè propè maculas eminet; adeò vt, & ante quadraturam primam, & in ipſa fermè ſecunda circa maculam quandam, ſuperiorem, borealem nempè Lunę plagam occupantem valdè attollantur tam ſupra illam, quàm infra ingentes quæda eminentiæ, veluti appoſitæ præſeferunt delineationes.



Hæc

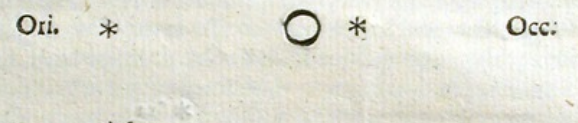
Sidereal Messenger (1610)

min. 2. sec. 30. ab hac occidentalior distabat min. 1. Vici-

* fixa

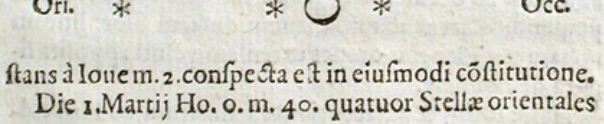
niores Ioui exiguæ apparebant, præsertim Orientalis, extremæ verò erant admodum conspicuæ in primis verò occidua, rectamque lineam secundum Eclypticæ ductum designabant ad vnguem. Horum Planetarum progressus versus ortum ex collatione ad prædictam fixam manifestè cernebatur, ipsi enim Iuppiter cum adstantib. Planetis vicinior erat, vt in apposita figura videre licet. Sed Ho. 5. Stella orientalis Ioui proxima aberat ab eo min. 1.

Die 28. Ho. 1. duæ tantum Stellæ videbantur, orientalis distans à Ioue min. 9. Occidentalis verò m. 2. Erant



* fixa

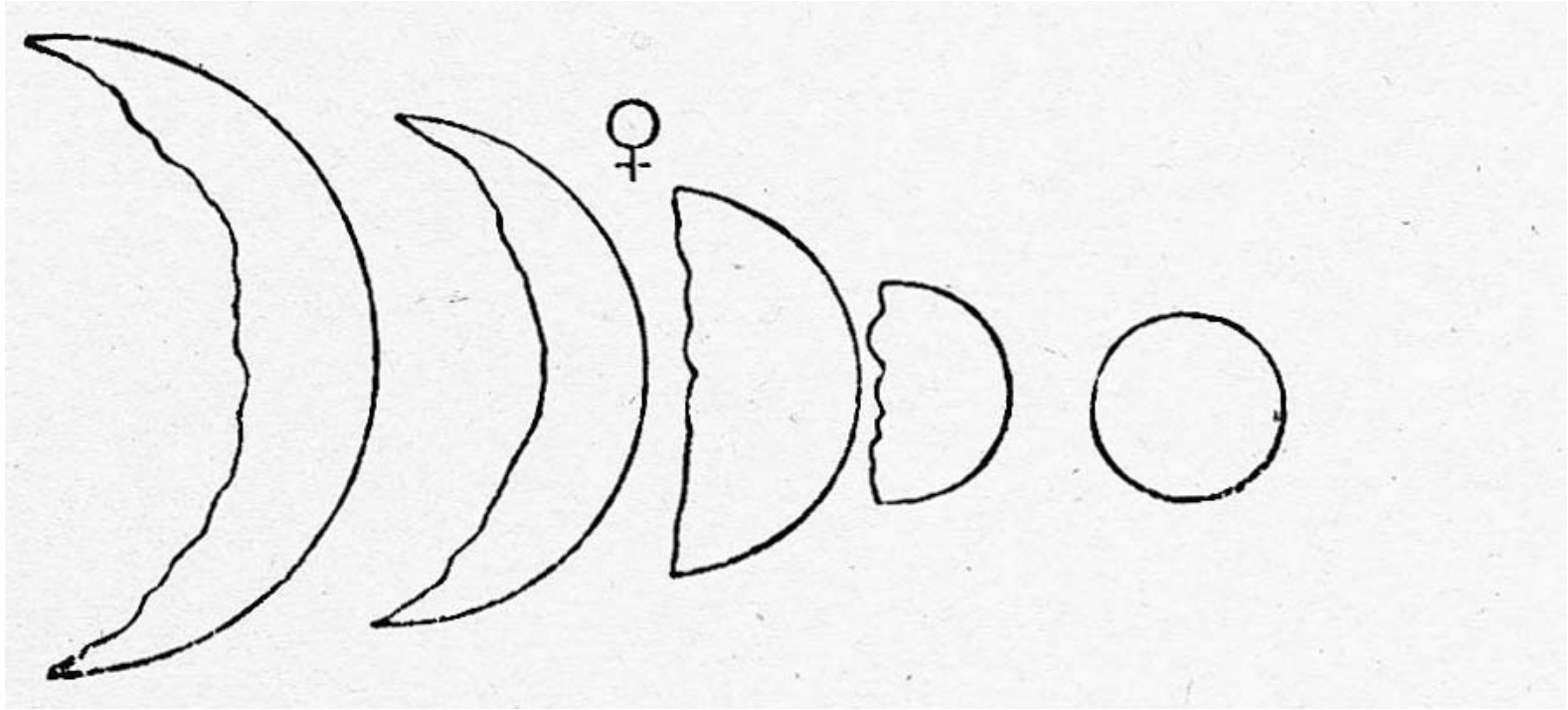
satis conspicuæ, & in eadem recta: ad quam lineam fixa perpendiculariter incidebat in Planetam orientalē, veluti in figura. Sed hora 5. tertia Stellula ex oriente di-



stans à Ioue m. 2. conspecta est in eiusmodi cōstitutione.

Die 1. Martij Ho. 0. m. 40. quatuor Stellæ orientales omnes

Sidereal Messenger (1610)



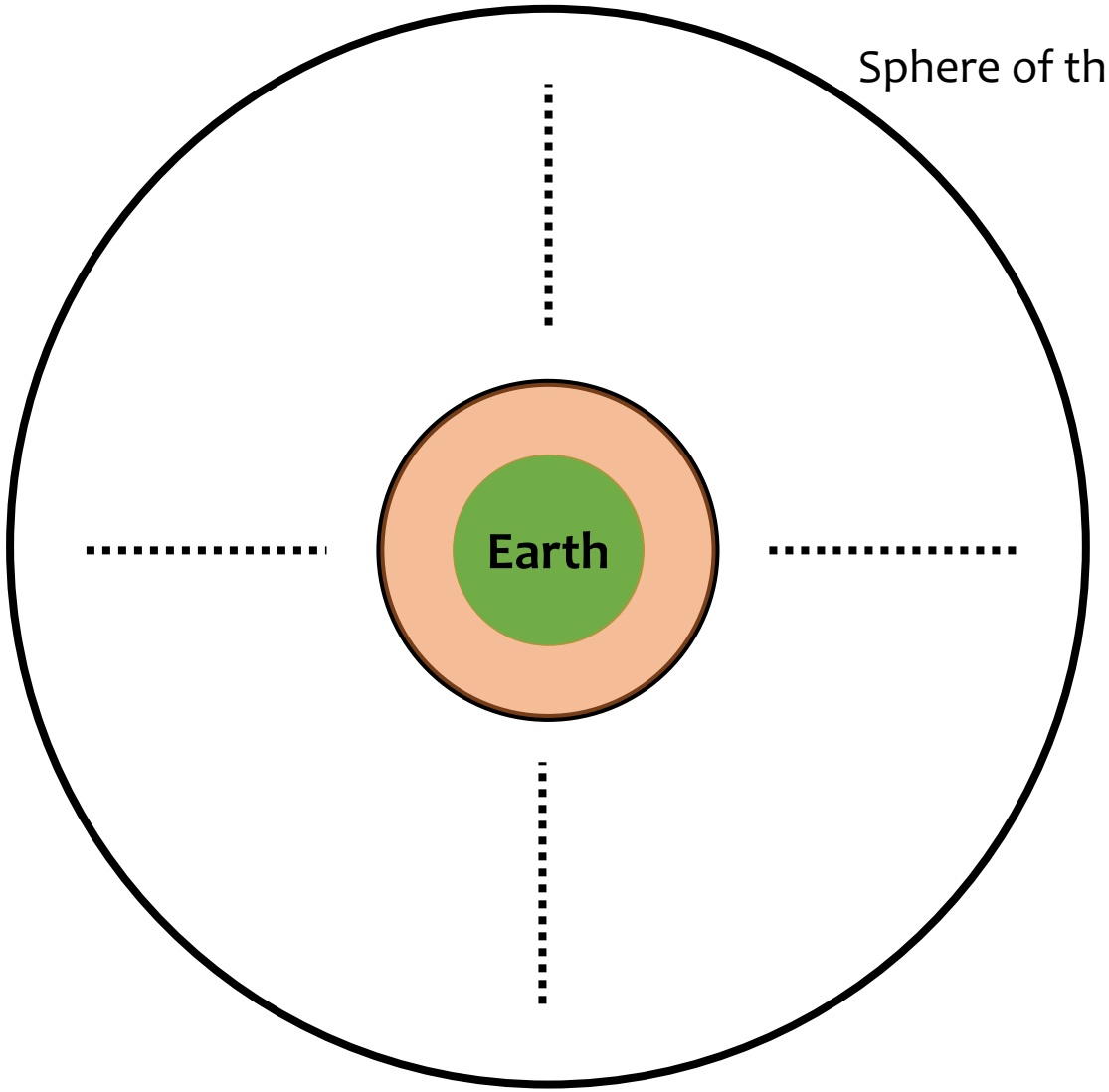
Galileo’s drawing of Venus’s phases (1610)

Phases of Venus

Galileo's Observations and the Aristotelian Worldview

- The mountains of the moon challenged the Aristotelian belief that the universe divides into two regions. (see next)

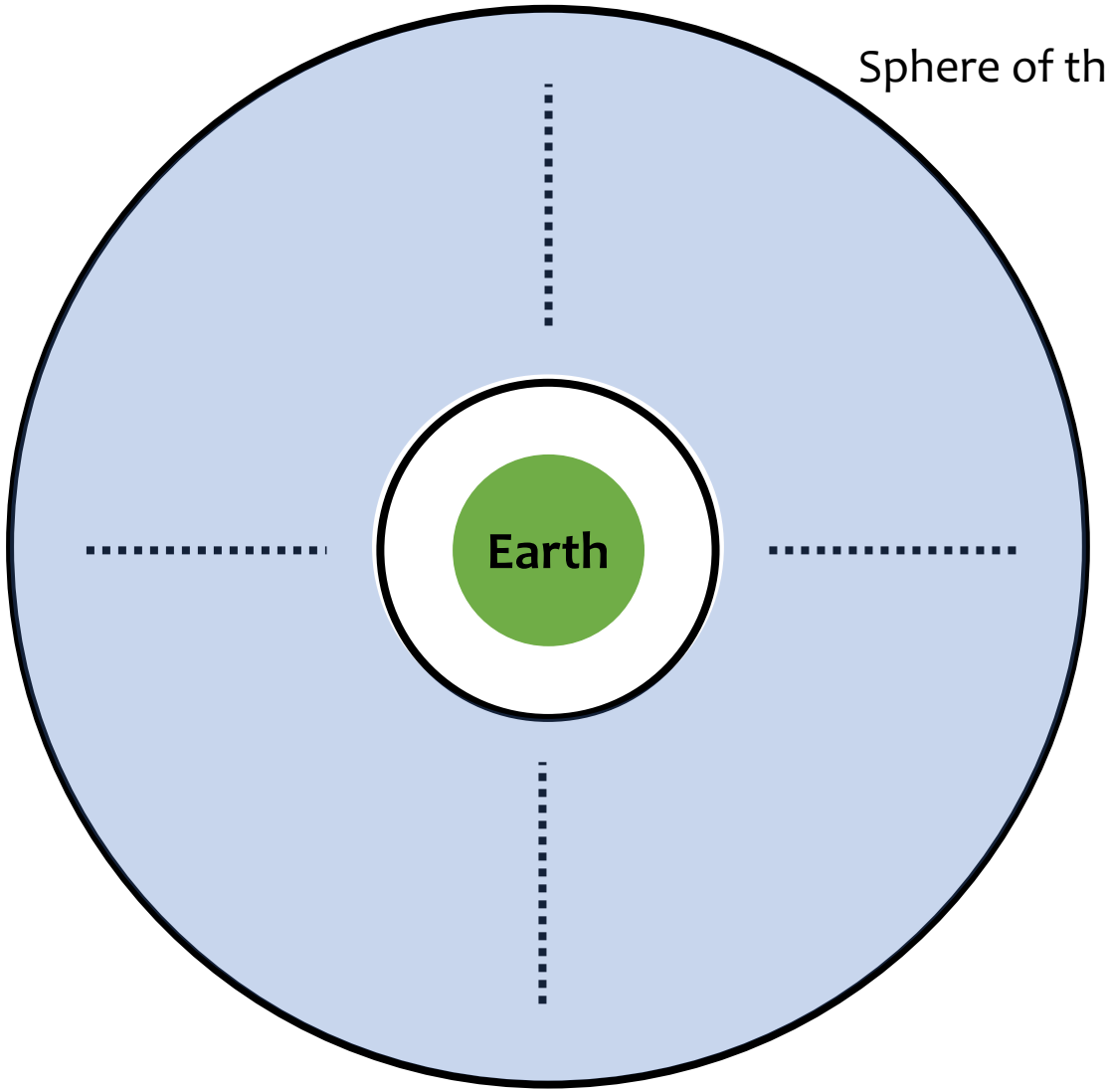
Aristotelian Universe (Review)



Sublunar Region
The region below the sphere of the moon (excluding the moon itself), including the earth.

Composed of four elements: earth, water, air, fire

Aristotelian Universe (Review)



Superlunar Region
The region above the sphere of the moon (including the moon itself).

Composed of the fifth element, ether.

Galileo's Observations and the Aristotelian Worldview

- Galileo's observations suggested that the objects in the superlunar region are similar to the Earth.

Galileo's Observations and the Aristotelian Worldview

- The phases of Venus challenged the Ptolemaic system.
- We can unpack this challenge as disconfirmation reasoning.

1. If the Ptolemaic system is true, then we will not observe a complete set of phases of Venus.
2. But we do observe a complete set of phases.
3. So the Ptolemaic system is not true.

Galileo's Observations and the Aristotelian Worldview

- But Galileo's observations didn't settle a debate between the earth-centered views and the sun-centered views, because the observations were compatible with many views.
- For example, both the Copernican (sun-centered) and the Tychonic (earth-centered) systems predict a complete set of phases of Venus.
- What we are seeing here is a very common pattern of scientific inquiry: observations alone rarely settle a debate in science, despite a popular perception of how science works. Let's look at this detail more.

The Nature of the Evidence from the Telescope

- “With respect to the debate between advocates of Earth-centered and sun-centered systems, it is important to keep in mind that there is no data available from naked-eye observations that can settle the debate.” (DeWitt)
- This is an example of **underdetermination** of theories by evidence (review Week 4).

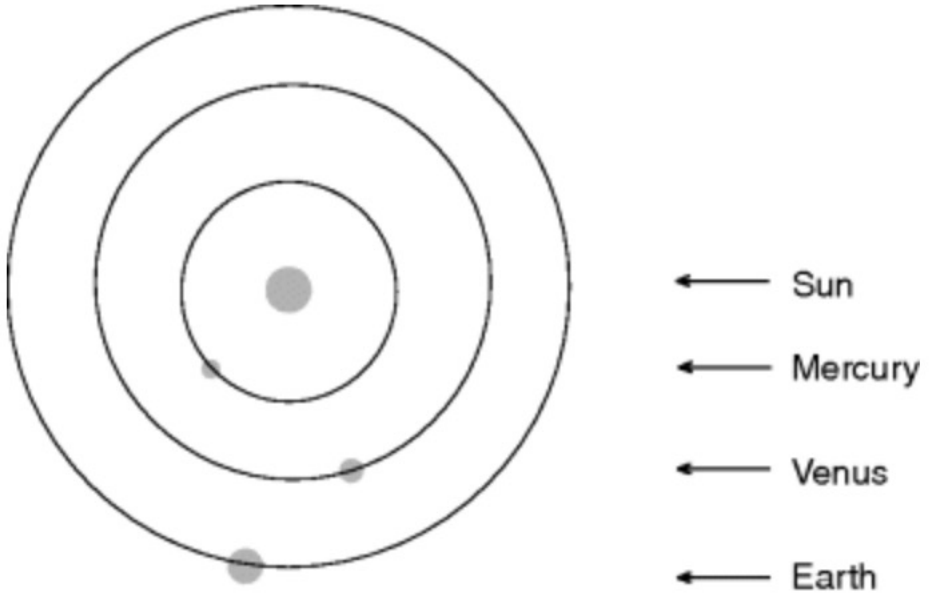
The Nature of the Evidence from the Telescope

- "Even with the telescope there is no way to tell **directly** whether an Earth-centered or sun-centered view is correct." (DeWitt)
- "Even today, we still have no technology that **directly** shows whether the Earth moves around the sun, or whether the sun moves around the Earth." (DeWitt)
- **Direct evidence** (review Weeks 2–3)
  - Straightforward, sensory experience
- Direct evidence for a sun-centered view would be to simply see with our eyes the sun sitting at the center of the universe (or today, the center of the solar system).

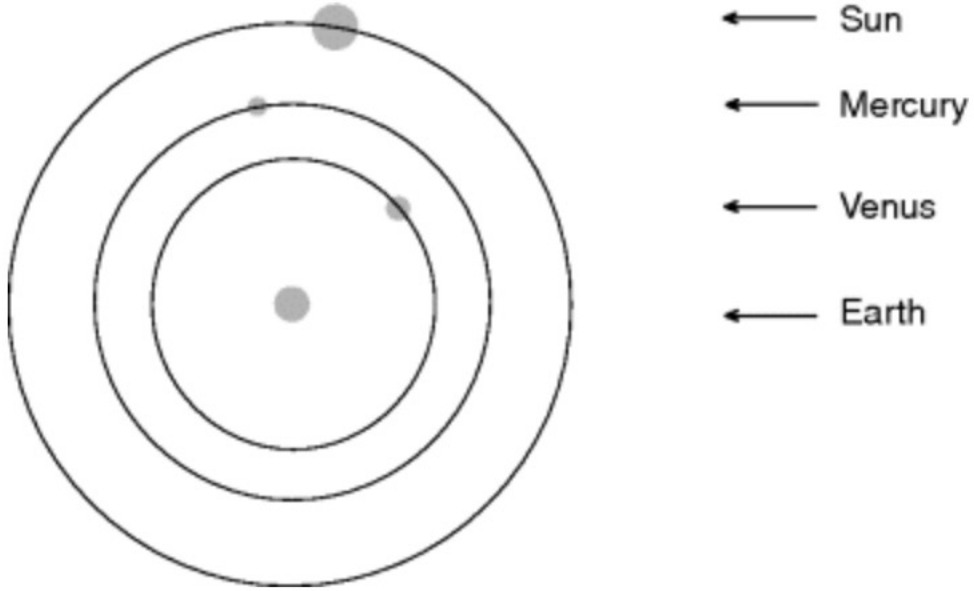
The Nature of the Evidence from the Telescope

- But the direct evidence of this kind is unavailable, even when we could observe the Earth and the sun from space.
  - See DeWitt's Figures 17.1–3 (reproduced next).

Our observation would look like this.



But our observation is compatible with both the Earth-centered (bottom) and the sun-centered systems (top).



So our observation underdetermines the two systems.

The Nature of the Evidence from the Telescope

- Does the lack of direct evidence for the sun-centered view mean that we have no good reasons to hold the sun-centered view?
- No! We do have very good reasons for the sun-centered view.
- Recall our discussion of confirmation reasoning and the reason why science relies on induction (Week 3).

Confirmation and Disconfirmation Reasoning (Review)

Confirmation (Inductive)	Disconfirmation (Deductive)
If T, then O	If T, then O
O	Not O
So, probably T	So, not T

The Nature of the Evidence from the Telescope

- Direct observation provides *one type* of reasons (evidence) for a belief about what the world is like.
  - E.g., I believe that daffodils in my garden are yellow because I see them.
- But science also relies on other types of reasons.
  - Indirect evidence (coherence of beliefs)
  - Confirmation/disconfirmation reasoning
- These other types of reasons are not inferior to direct observation.
  - "direct" does NOT necessarily mean good or definitive, and "indirect" does NOT necessarily mean bad, provisional, or inconclusive.

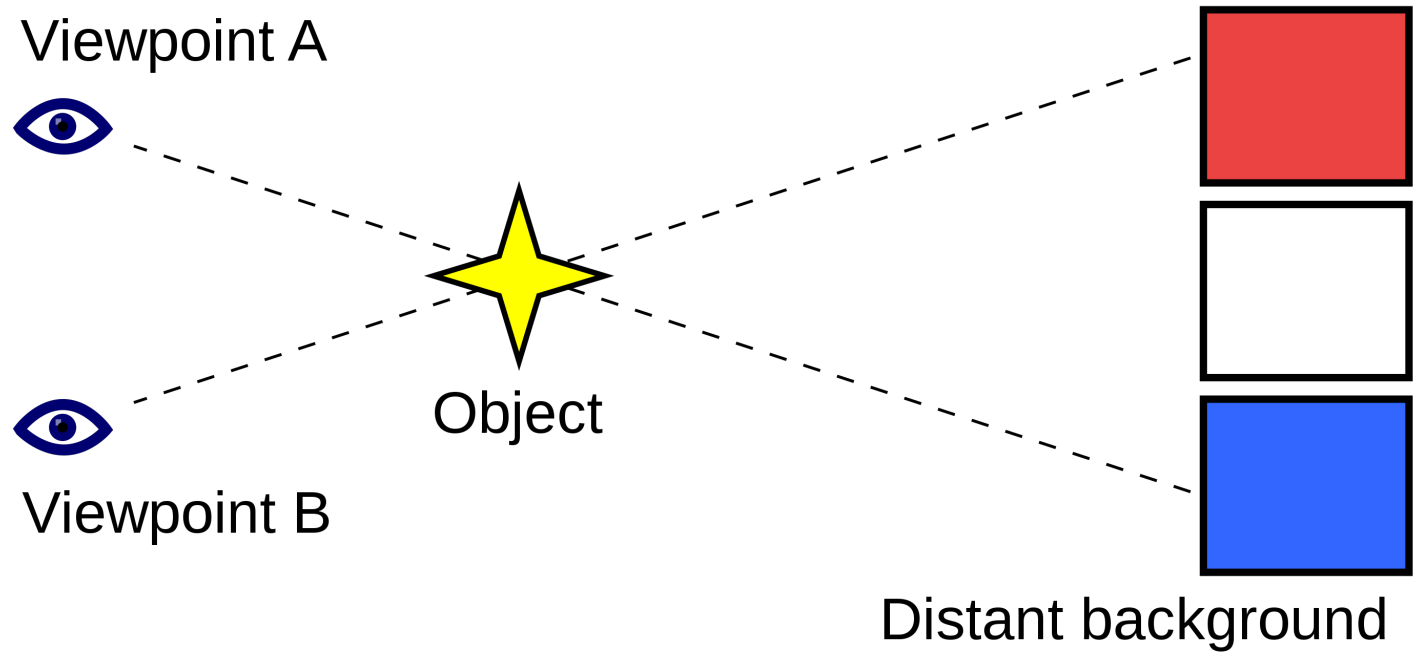
The Nature of the Evidence from the Telescope

- Today, one strong reason for the sun-centered view is confirmation reasoning based on stellar parallax.
- Recall (the lack of) stellar parallax was used in Ptolemy's argument for the Earth-centered view.
- Let's review the argument (from Week 6).

The Earth as Stationary (Review)

Argument from stellar parallax (a simpler version)

1. If the Earth is in motion (say in orbit), we should detect stellar parallax.
2. But we do not detect stellar parallax.
3. So the Earth is not in motion.



(Ordinary) Parallax

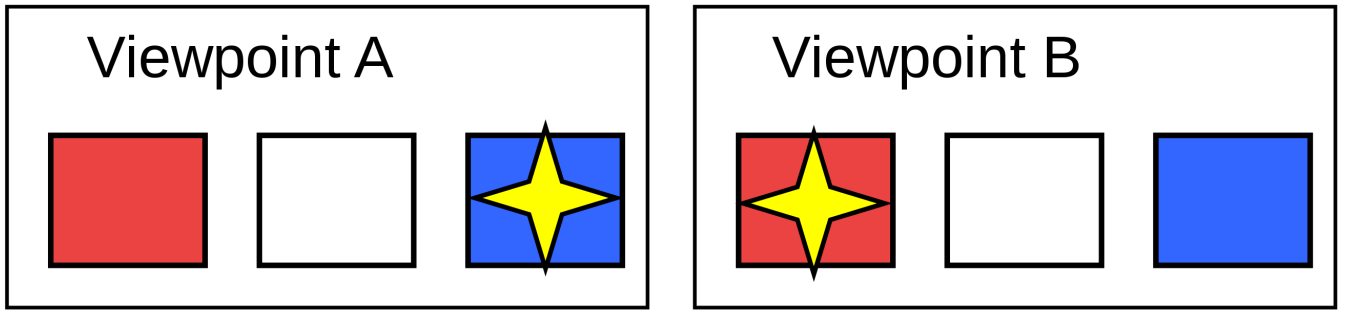


Diagram is from Wikipedia
(https://commons.wikimedia.org/wiki/File:Parallax_Example_en.svg)

Stellar Parallax

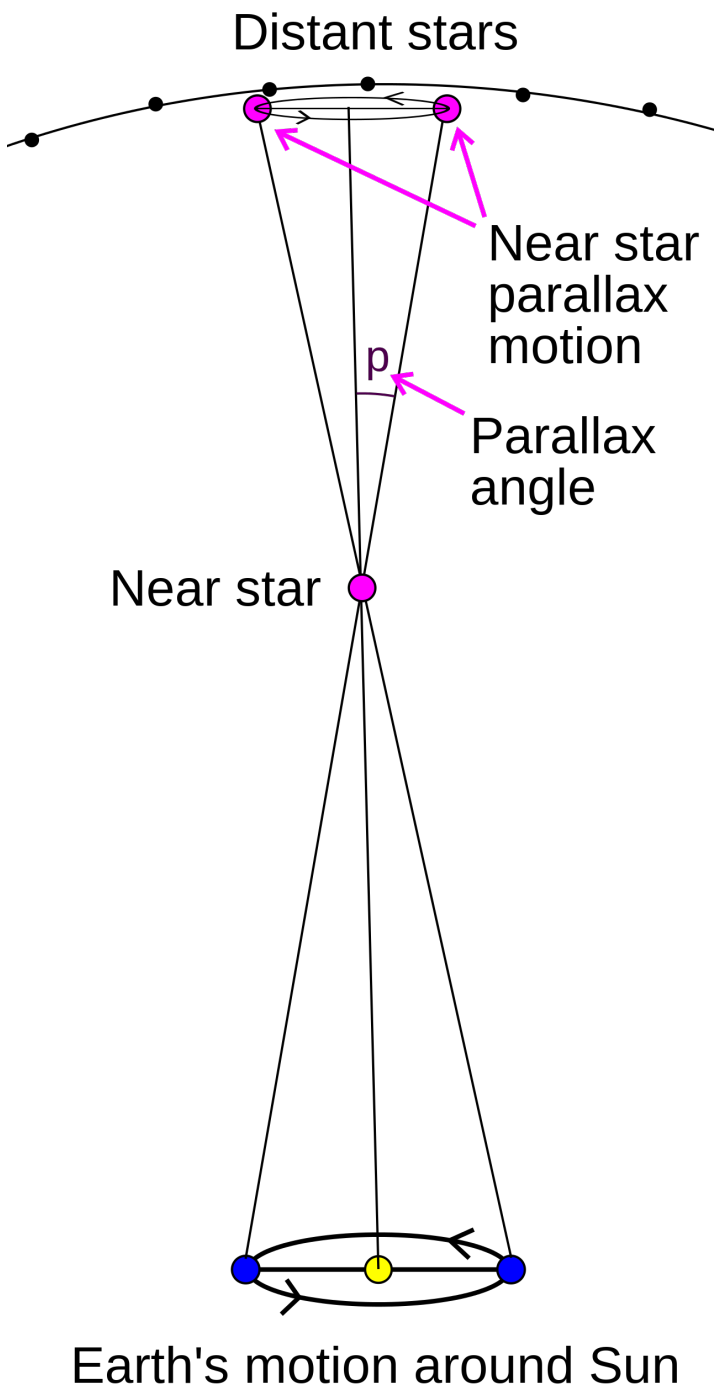


Diagram is from Wikipedia
(https://commons.wikimedia.org/wiki/File:Stellarparallax2.svg)

The Earth as Stationary (Review)

- We can easily detect ordinary parallax. Changing the viewpoint by an inch (or even less) would cause detectable parallax.
- If the Earth is moving around the sun, in 6 months, we will be almost 200 million miles away from where we are now.
- But Ptolemy points out that we don’t detect stellar parallax.

The Earth as Stationary (Review)

Argument from stellar parallax (a simpler version)

1. If the Earth is in motion (say in orbit), we should detect stellar parallax.
2. But we do not detect stellar parallax.
3. So the Earth is not in motion.

- This version doesn't account for a key auxiliary assumption.

The Earth as Stationary (Review)

Argument from stellar parallax (full version)

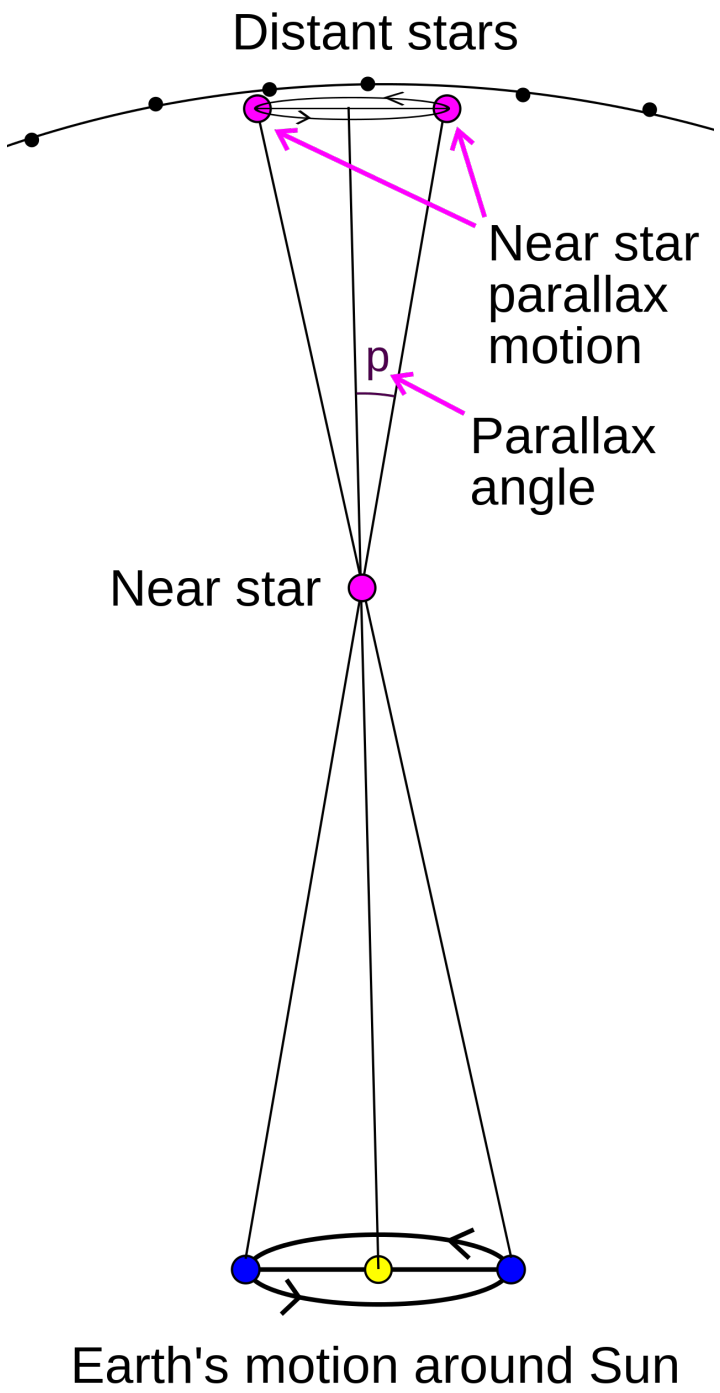
1. If the Earth is in motion (say in orbit), and ***if the stars are not incredibly far away,*** then we should detect stellar parallax.
2. But we do not detect stellar parallax.
3. So the Earth is not in motion.

- But this auxiliary hypothesis turns out to be false, and if the stars are incredibly far away, stellar parallax can be so small that we don't detect it.
- In fact, it's very difficult to detect stellar parallax. It was only in 1838 that the first accurate detection was made.

The Nature of the Evidence from the Telescope

- Today, our reasoning goes like this:

1. If the Earth is moving around the sun, then we should detect stellar parallax. (see diagram next)
2. We do detect stellar parallax.
3. So probably, the Earth is moving around the sun.



Stellar Parallax

This is a prediction of the sun-centered view.

Diagram is from Wikipedia (https://commons.wikimedia.org/wiki/File:Stellarparallax2.svg)

The Nature of the Evidence from the Telescope

- As we said before, stellar parallax is very difficult to measure, because the stars are so far away that a parallax angle will be extremely small.
- The first successful measurement was made by Friedrich Bessel in 1838.
  - Almost 300 years after the publication of Copernicus's *De revolutionibus*.
- Bessel measured the parallax angle of a particular star (61 Cygni) to be 0.314 arcsecond.
  - 1 arcminute = 1/60 of a degree
  - 1 arcsecond = 1/60 of arcminute = 1/3600 of a degree

The Nature of the Evidence from the Telescope

- The evidence from the telescope, either in the 16th century or today, is not as definitive as it is often assumed.
- What is underappreciated is the fact that evidence often underdetermines multiple theories and that, as we discuss next, when new evidence is reported, scientists often have to debate over their **standards of evidence** (review Week 5 on falsifiability).
  - What counts as admissible or credible evidence
  - How much evidence is sufficient
- Galileo participated in a debate over standards of evidence.

The Galileo Affair

- DeWitt summarizes Galileo's relationship with the Church, and both Galileo's and Cardinal Bellarmine's views about evidence.
- This episode is sometimes called the Galileo affair. If interested, here is a very good introduction with primary sources:
- Maurice A. Finocchiaro. *The Trial of Galileo*. Hackett, 2014.

The Galileo Affair

Historical background

- As DeWitt mentions earlier in the chapter, the Catholic Church was often tolerant of scientific investigations and new ideas.
- But in the 16th and 17th centuries, the Catholic Church actively combated heresy.
  - This was a response to the Protestant Reformation, which started in 1517. (The response is called the Counter Reformation.)
- Thirty Years' War (1618–1648), a violent war between Protestants and Catholics. The Galileo affair occurred in the middle of this war.

The Galileo Affair

Historical background

- Galileo was a Catholic living in a Catholic country, so his intellectual activities were subject to the jurisdiction of the Congregation of the Index and the Congregation of the Holy Office (the Inquisition).
- In the Catholic Church, a congregation is a committee of cardinals.
- The Congregation of the Index was founded by Pope Pius V in 1571. Its purpose was to compile a list of forbidden books.
- The Congregation of the Holy Office was founded by Pope Paul III in 1542. Its purpose was to defend Catholic faith, and its specific duty was to suppress heresies.

The Galileo Affair: First Judgment (1610–1616)

- *Sidereal Messenger* (1610)
- Galileo becomes Philosopher and Chief Mathematician to the Grand Duke of Tuscany.
- Ulisse Albergotti's *Dialogue* (1613) presents biblical criticism Galileo's Copernican views.
- The Grand Duchess Christina presents the biblical objection to Benedetto Castelli, who was Galileo's friend and follower.
- Galileo replies in letters to Castelli (1613) and Christina (1615).

The Galileo Affair: First Judgment (1610–1616)

- In 1615, Dominican friar Lorini files a written complaint against Galileo to the Congregations of the Index and of the Holy Office.
- In 1616, the Inquisition rejects the heresy charge against Galileo.
- But in the process, the Inquisition judges that the Copernican sun-centered view, including the Earth's motion, is scientifically false and theologically heretical or erroneous.
- Cardinal Robert Bellarmine of the Inquisition gives a private warning to Galileo.

The Galileo Affair: First Judgment (1610–1616)

Bellarmine's Certificate (May 26, 1616)

"... [Galileo] has only been notified of the declaration made by the Holy Father and published by the Sacred Congregation of the Index, whose content is that the doctrine attributed to Copernicus (that the earth moves around the sun and the sun stands at the center of the world without moving from east to west) is contrary to Holy Scripture and therefore ***cannot be defended or held***."

- This allows Galileo to ***discuss*** the Copernican views.

The Galileo Affair: Trial and Second Judgment (1616–1633)

- In 1623, Cardinal Maffeo Barberini is elected Pope Urban VIII
  - In 1616, Cardinal Barberini was instrumental in preventing the direct condemnation of Galileo and the Copernican views.
  - Urban was an admirer of Galileo.
- In 1624, Galileo goes to Rome to pay respects to Urban.
  - He stayed in Rome for 6 weeks and had weekly meetings with Urban.
  - The details of their conversations are unknown, but see next.

The Galileo Affair: Trial and Second Judgment (1616–1633)

- "There is evidence . . . that Urban VIII did not think Copernicanism to be a heresy . . . [Urban had a] liberal inclination that, as long as one exercised the proper care, there was nothing wrong with the **hypothetical discussion** of Copernicanism; that is, with treating the earth's motion as a **'hypothesis':** studying its consequences, its value for understanding and explaining physical reality, and its utility for making astronomical calculations and predictions." (Finocchiaro, *The Trial of Galileo*, p. 21)

The Galileo Affair: Trial and Second Judgment (1616–1633)

- After returning from Rome, Galileo begins his work on a book on Copernicanism.
- In February 1632, Galileo publishes *Dialogue on the Two Chief World Systems, Ptolemaic and Copernican*.

DIALOGO
DI
GALILEO GALILEI LINCEO
MATEMATICO SOPRAORDINARIO
DELLO STVDIO DI PISA.
E Filoſofo, e Matematico primario del
SERENISSIMO
GR. DVCA DI TOSCANA.

Doue ne i congreſſi di quattro giornate ſi diſcorre ſopra i due

MASSIMI SISTEMI DEL MONDO
TOLEMAICO, E COPERNICANO;

Proponendo indeterminatamente le ragioni Filoſofiche, e Naturali tanto per l'vna, quanto per l'altra parte.

CON PRI VILEGI.

IN FIORENZA, Per Gio: Batiſta Landini MDCXXXII.

CON LICENZA DE' SVPERIORI.

Galileo's *Dialogue* (1632)

The Galileo Affair: Trial and Second Judgment (1616–1633)

- To avoid trouble, Galileo did many things in the *Dialogue*.
- For example, he wrote the book as a dialogue among three characters:

1. Simplicio, defending geocentrism
2. Salviati, defending Copernicanism
3. Sagredo, an uncommitted observer

- In this way, Galileo could claim that his characters *discuss* Copernican ideas as a hypothesis but that no one is defending them.

The Galileo Affair: Trial and Second Judgment (1616–1633)

- But in the book, the geocentric side gets criticized, and the Copernican side gets defended.
  - Simplicio often presented traditional arguments (including those favored by the Church), and Salviati gave clever counterarguments, which made Simplicio confused.
  - "Simplicio" is similar to "semplice" (Italian for simpleton).
- Many complaints on Galileo's *Dialogue* emerge in Rome.
- In the summer of 1632, Urban appoints a special commission to investigate, eventually sending the case to the Inquisition.

The Galileo Affair: Trial and Second Judgment (1616–1633)

- In 1633, the Inquisition finds that Galileo's *Dialogue* taught, defended, or held the Copernican views.
  - This was a lesser charge than what Galileo could have gotten, and the Inquisition tried to make a plea bargain with Galileo.
- Galileo agrees to plead guilty to the lesser charge by saying that he inadvertently made a transgression and was ready to make amends: he had no malicious intent.
- Urban decides that Galileo should be interrogated under the verbal threat of torture, in order to determine his true intent.

The Galileo Affair: Trial and Second Judgment (1616–1633)

- In the interrogation (June 21, 1633), Galileo again denied any malicious intent.
- Next day Galileo receives the sentence of "vehemently suspected of heresy."
  - This is the second most serious offence handled by the Inquistion.
- Galileo's *Dialogue* was banned, and he received the prison sentence, which was immediately commuted to house arrest, and Galileo resumes work.

Robert-Fleury, *Galileo before the Holy Office* (19th century)

The Galileo Affair: Final Years (1633–1642)

- In 1638, Galileo publishes *Discourses and Mathematical Demonstrations Relating to Two New Sciences*.
  - Two sciences were mechanics and the physics of materials
- Galileo dies on January 8, 1642.

Quiz 8

Understanding the Galileo Affair

- The Galileo affair is commonly misunderstood.
- "The most common view of the trial of Galileo is that it epitomizes the conflict between enlightened science and obscurantist religion. One version of this view is found inscribed in a public monument in Rome near Villa Medici, the palace where Galileo resides on some of his visits to Rome, and where he was held under house arrest for about a week after the 1633 sentence. The inscription reads: 'it was here that Galileo was kept prisoner by the Holy Office, being guilty of having seen that the earth moves around the sun'."
  (Finocchiaro, *The Trial of Galileo*, p. 1.)

Understanding the Galileo Affair

- “The historical and cultural importance of this minor tourist attraction is that it expresses one of the most common myths widely held about the trial of Galileo, including several elements: that he ‘saw’ the earth’s motion (an observation still impossible to make even in the twenty-first century); that he was ‘imprisoned’ by the Inquisition (whereas he was actually held under house arrest); and that his crime was to have discovered the truth.” (Finocchiaro, *The Trial of Galileo*, p. 1.)

Understanding the Galileo Affair

- “And since to condemn someone for this reason can result only from ignorance, prejudice, and narrow-mindedness, this is also the myth that alleges the incompatibility between science and religion.” (Finocchiaro, *The Trial of Galileo*, p. 1–2.)

Understanding the Galileo Affair

- Finocchiaro listed three misunderstandings:

1. Galileo "saw" the earth's motion.
2. Galileo was imprisoned by the Inquisition.
3. Galileo's crime was to have discovered the truth.

- We saw (2) and (3) are not correct, and we have also discussed that we do not have direct observation (i.e., we don't directly see) the earth's motion.

Understanding the Galileo Affair

- We can better understand the Galileo affair by seeing it as a disagreement over **standards of evidence** (review Week 5 on falsifiability).
- That is, it was a disagreement over:
  - What counts as admissible or credible evidence
  - How much evidence is sufficient
- DeWitt discusses these points in his section on "Falsifiability issues."
- We'll look at some original texts.

Understanding the Galileo Affair

- Joshua 10: 12–13 was the most common passage cited in the biblical objection to Copernican ideas.

“. . . Joshua said to the LORD in the presence of Israel: “Sun, stand still over Gibeon, and you, moon, over the Valley of Aijalon.” So the sun stood still, and the moon stopped . . . The sun stopped in the middle of the sky and delayed going down about a full day. . . .” (NIV)

- Let’s now look at Galileo’s response

Galileo's Letter to Castelli (1613)

- "In regard to the first general point of the Most Serene Ladyship [the Grand Duchess Christina], it seems to me very prudent of her to propose and of you to concede and to agree that the Holy Scripture can never lie or err, and that its declarations are absolutely and inviolably true. I should have added only that, though Scripture cannot err, nevertheless some of its interpreters and expositors can sometimes err in various ways." (Finocchiaro trans.)

Galileo's Letter to Castelli (1613)

- "One of these [errors] would be very serious and very frequent, namely, to want to limit oneself always to the literal meaning of the words; for there would thus emerge not only various contradictions but also serious heresies and blasphemies, and it would be necessary to attribute to God feet, hands, and eyes, as well as bodily and human feelings like anger, regret, hate, and sometimes even forgetfulness of things past and ignorance of future ones." (Finocchiaro trans.)

Galileo's Letter to Castelli (1613)

- "Thus, given that in many places Scripture is not only capable but necessarily in need of interpretations different from the apparent meaning of the words, it seems to me that in disputes about natural phenomena it [Scripture] should be reserved to the last place." (Finocchiaro trans.)

Understanding the Galileo Affair

- Galileo accepted the authority of Scripture.
- He also believed that Scripture needs interpretations.
  - A literal interpretation leads to contradictions.
- Because Scripture needs interpretations, Galileo thought that in scientific disputes ("in disputes about natural phenomena"), Scripture should be the last source of evidence.
  - Scientific disputes can be settled with theoretical and empirical work.
- For Galileo, the dispute over Copernicanism was a ***scientific*** dispute.
- So for him, theoretical and empirical evidence should matter more than Scripture.

Understanding the Galileo Affair

- Galileo's point of view might seem obvious to you, but as we saw earlier in the term, a disagreement over standards of evidence often arises because there can be another point of view on the same dispute.
- Let's look at Cardinal Bellarmine's view.

Cardinal Bellarmine's Letter to Foscarini (1615)

- "I say that if there were a true demonstration that the sun is at the center of the world and the earth in the third heaven [i.e., the third orbit around the sun], and that the sun does not circle the earth but the earth circles the sun, then one would have to proceed with great care in explaining the Scriptures that appear contrary, and say rather that we do not understand them [the Scriptures] than that what is demonstrated is false." (Finocchiaro trans.)

Cardinal Bellarmine's Letter to Foscarini (1615)

- "But I will not believe that there is such a demonstration, until it is shown me. Nor is it the same to demonstrate that by assuming the sun to be at the center and the earth in heaven one can save the appearances, and to demonstrate that in truth the sun is at the center and the earth in heaven; for I believe the first demonstration may be available, but I have very great doubts about the second, and in case of doubt one must not abandon the Holy Scripture as interpreted by the Holy Fathers." (Finocchiaro trans.)

Understanding the Galileo Affair

- Bellarmine accepts the authority of Scripture, and he also believes that Scripture needs interpretation.
  - Galileo and Bellarmine agree here.
- Bellarmine would also accept a scientific demonstration of the earth's motion, if there is one.
  - In such a case, he says that the Church should say that they do not understand the relevant parts of Scripture, rather than rejecting the scientific demonstration.
  - Galileo would agree with Bellarmine.
- But Bellarmine has different (and sophisticated) views about scientific demonstration.

Understanding the Galileo Affair

- Bellarmine distinguishes:

(1) Demonstration that the Copernican system predicts and explains the observational data.

> "to demonstrate that by assuming the sun to be at the center and the earth in heaven one can save the appearances"

(2) Demonstration that the Copernican system corresponds to reality.

> "to demonstrate that in truth the sun is at the center and the earth in heaven"

Understanding the Galileo Affair

- Bellarmine thinks that (1) can be available, but doubts that we can ever have (2).
  - Bellarmine's doubt is not unreasonable if you recall the epistemological difficulty raised by the correspondence theory of truth.
  - In this case, (2) would amount to going outside of the universe and compare the Copernican system and reality.

Understanding the Galileo Affair

- Now we might think that Bellarmine is misrepresenting science because science is inductive and does not deliver absolute proof like (2).
  - That is, science produces well-justified beliefs, but there is always room for doubt.
- But for Bellarmine, the dispute over Copernicanism was a ***theological***, not scientific, dispute.
- So he argues that when a proof like (2) is absent, the authoritative interpretations of Scripture should be upheld.