

ASTRONOMY 9: HISTORY OF COSMOLOGY

Handout #15

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Galileo

I. Giordano Bruno (1548–1600, Italy)

- Philosopher, victim of religious persecution (one of about two reputed scholars in 1500–1700)
- 1572: Ordained as priest
- Belief in infinite universe, multitude of worlds (Cusa, Digges)
- Other solar systems with worlds inhabited by beings similar to humans
- Pantheist, held that Jesus was merely a sorcerer
- Defended views as philosophical, not theological; refused to make a formal retraction
- Sentenced by Roman Inquisition, burned at stake for religious heresy in 1600
- Inspired later liberal humanist thought, anticipated ideas in modern cosmology (though his arguments were philosophical, not scientific)

II. Galileo Galilei (1564–1642, Italy)

- Major contributions to cosmological science:
 - Introduced telescope as essential tool for astronomy
 - Advocated heliocentric Copernican model
 - Stressed experimental methods in science
 - Mechanics: formulated principle of inertia
 - Also contributed to other scientific disciplines
- “Second-generation” Renaissance man, fully modern in outlook
- Wrote in Italian vernacular
 - Easily read, terse, scientific writing style (very different from others!)
 - Alternates between brilliant defenses of freedom of thought and sophistry, deception
 - Grand polemical style: builds up arguments for opponents’ views, then demolishes them and makes them look foolish
 - Creates a lot of enemies! Contempt for opponents’ intelligence
- 1609: Galileo makes a telescope
 - Theoretical ideas discussed around 1600 by Kepler and others
 - First telescopes made in Holland around 1608
 - Galileo constructed his based on reports of these
 - Set apart from others by improvements, made more powerful scopes
 - Gave 8× scope to Venetian senate for military defense, rewarded with tenure and doubled salary
 - Telescopic “discoveries”
 - A) Mountains, craters, valleys (“*maria*”, *seas*) on the Moon: celestial objects not perfect spheres!
 - B) Four moons orbiting Jupiter, a “mini-Copernican” system, “Medicean” stars, dubbed “satellites” by Kepler: composite motion of Earth’s Moon not an argument against Copernicus
 - C) Found many stars invisible to naked eye, Milky Way made of stars!
 - Announced in *Siderius Nuncius (Starry Messenger)*, immediate sensation
 - Later “discoveries”:
 - A) Two lobes around Saturn (scope not powerful enough to tell they were rings)
 - B) Spots on the Sun (Jesuit astronomer Scheiner argued were satellites, Galileo showed on or near Sun’s surface)
 - C) Venus goes through full set of phases
 - D) Comets (2, inaugurated 30 Years War): like Aristotelians, G. argued they were illusions: (cometary orbits very elliptical, so did not fit with original Copernican circular model!)

- Very jealous of priority, secretive: communicated discoveries in anagram form
- “You cannot help it ... that it was granted to me alone to discover all the new phenomena in the sky and nothing to anybody else. This is the truth which neither malice nor envy can suppress.”
- Galileo and Copernicanism
 - Taught heliocentric ideas of Copernicus
 - In letters, claimed belief at an early age
 - No committal to Copernicansim *in published work* until age 50
 - Galileo’s real fear (up to age 50 or so, no real threat of religious persecution): being laughed off the stage by mediocre Aristotelian professors!
 - Kepler encouraged him, apparently taken as reproach (G. very sensitive to criticism!)
 - Ignored Kepler’s ideas and preached the *original Copernican model*, with all its ugly epicycles!
- Copernicanism and the Church
 - 1610: No official position on cosmological systems
 - Models are to be considered scientific hypotheses, not “Truth”
 - Galileo blows up after hearing rumors of dinner-party conversations(!) where Copernicanism said to conflict with scripture (e.g., Grand Duchess Christina, 1615)
 - *Letter to Christina* (originally to student Castelli)
 - * Claims Copernican model is *factually true*
 - * Calls for reinterpretation of scripture
 - * Subtly shifts burden of proof to theologians: they must demonstrate Copernicanism is *false*, otherwise reinterpretation must happen by default!
 - * Church’s position: show us *proof* of theory, only then will we reinterpret
 - * Inaccurate copies of letter sent to Inquisition by G.’s opponents
 - Copernicus’ *Revolutions* placed on Index for 4 years until 9 sentences regarding “truth” of the model were changed
 - 1616: Cardinal Bellarmine to G.: do not “hold or defend” Copernican theory
- The Competing Cosmologies
 - Pope Urban VIII: admirer and supporter of G.
 - * Copernicanism may work, but all-powerful God could produce same phenomena by different means
 - 1630: *Dialog Concerning Two Chief World Systems*
 - * Characters: Salviati (G.’s spokesman), Sagredo (intelligent person), Simplicio (“simpleton”, Aristotelian)
 - * Simplicio gives the Pope’s argument \Rightarrow bad consequences for G.!
 - * Remains on Index until 1835
 - G. forced decision between Ptolemy and Copernicus, ignored Tycho’s model and Kepler’s ellipses
 - Ptolemaic system ruled out by phases of Venus, question really between Copernicus (+ Kepler) and Tycho
 - Defects in Copernicus: epicycles (ignoring Kepler), lack of stellar parallax (argument for Tycho), Sun not at exact center
 - Galilean moons showed composite motion, so why not let planets move around Sun plus Sun around Earth (Tycho)?
 - Galileo thought he had the required *proof* of the Copernican model: **theory of the tides** (really a self-delusion!)
 - * At midnight, orbital and rotational motions add: water “falls behind”
 - * At noon, subtract: water “rushes ahead”
 - * Contradicts G.’s own ideas about inertia!
 - * Predicts only one high tide per day, at exactly noon! (Actually two, times constantly shifting)
 - * Kepler had correctly guessed tides were due to Moon (G. dismissed as occult nonsense!)

- Galileo and the Inquisition
 - Questioned beginning in 1632, age 68
 - Proved that G. had “held, defended, and taught” Copernicanism as truth, called his opponents “mental pygmies” and “dumb idiots”
 - Afraid, defeated, and broken, renounces his beliefs
 - G. repeatedly denies what is in his own book, pretends he had not supported Copernicus since decree of 1616!
 - According to legend (probably untrue), mutters *eppur si muove*
 - Never went to prison, held in “house arrest” in a rather nice villa
 - Continues his most important work: the science of dynamics
- Contributions to mechanics (study of motion)
 - Culmination of work by earlier post-Aristotelians (e.g., Orseme)
 - 1609: Study of falling bodies: $d \propto t^2$, parabolic trajectories
 - **Inertia**: objects at rest stay at rest, objects in motion continue in motion (straight-line, constant speed), unless acted on by some external force
 - Force seen as necessary to *alter* motion, not sustain it as in Aristotle
 - Thought experiment of frictionless, inclined plane
 - Relativity of motion, simple addition of velocities
 - 1636: *Dialogues Concerning Two New Sciences*
- Died in 1642 (Newton born), bones of middle finger now displayed in Florence Museum for the History of Science
- Was the conflict between religion and science inevitable?
 - Probably not, more a result of individual personalities
 - Church had adapted before (spherical Earth, about 1000 AD)
 - Might have moved to Tycho’s model as a prelude to true heliocentric model, had G. not forced the issue
 - Lasting repercussions: hostility of Church towards scientific cosmology
 - G. not “rehabilitated” by Rome until 1992!