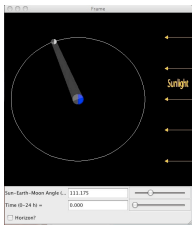
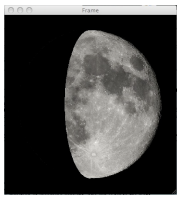
Exploring the Copernican Revolution through Computer Simulations





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Outline

- Overview of the Copernican Revolution Course
- Using the computer simulations: observations, Ancient Greeks, Copernicus, Tycho, Kepler, Galileo, and Newton
- Student Projects
- Student Response to Course
- Future Plans
- Resources

Overview of the Course

- Why teach a course on the Copernican Revolution to non-science majors?
  - Students already know the facts (Earth orbits the sun), but they don't know the reasons for believing this.
  - These students don't need to know cutting-edge astronomy – they need to understand how science works.
  - Students find the historical content (as well as the scientific content) interesting.

- Teaching methods
  - Active learning: students spend their class time working in groups of 3-4 completing activities (75 minutes) or labs (120 minutes). 24 students per section. Meet in lab room with 7 computers.
  - Activities and labs consists of worksheets with a sequence of questions the students must answer.
  - Answering the questions frequently requires working with a computer simulation (as well as other things).
  - I have developed 53 computer simulations for these activities and labs.

- Why use computer simulations?
  - Many students need a visual image in order to understand a concept.
  - Astronomical theories are abstract. The simulations let students see how the theories connect to observations.
  - Theories can be simulated in a virtual world even if they don't work in the real world. For example, students can see what the motion of a planet would look like if the planetary theory of Eudoxus were true.
  - Simulations are practical when real observations would be impractical. (Saturn's zodiacal period is 30 years...)
  - Students are comfortable with simulations and generally enjoy them.

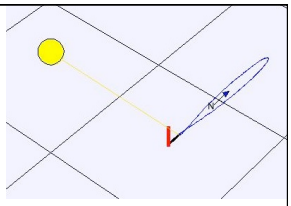
Observing the Skies

- Starry Night
  - Commercial software (various versions, cost is $80-250 per license).
  - Simulates the night sky in the past, present, and future.
  - Observations can be made from anywhere on Earth (and elsewhere).
  - Many (but unfortunately not all) of the features of this software are available in free programs like Celestia and Stellarium.

My Simulations

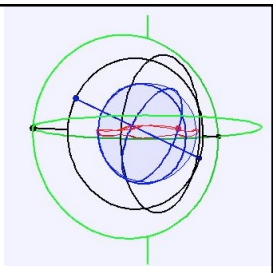
- All of my simulations are…
  - Java programs (so they can run on any computer).
  - created using the Easy Java Simulations package by Francisco Esquembre, which is part of the Open Source Physics project headed by Wolfgang Christian.
  - open-source and available for free.
- Now let's look at some examples.

Gnomon



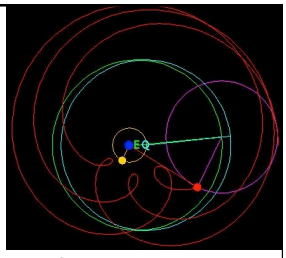
- Simulates the shadow produced by an upright stick at any time on any day of the year at any latitude on Earth.
- Where must you be for the noon sun to point North on some days and South on others?

Eudoxus



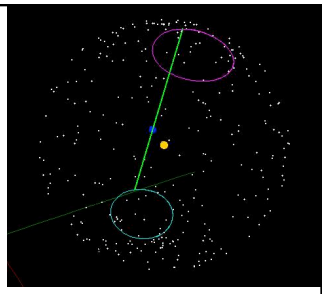
- Simulates the planetary theory of Eudoxus, which consists of linked spheres all centered on Earth.
- Can this model reproduce retrograde motion?

SuperiorPtolemaic



- Simulates Ptolemy's theory for the superior planets.
- How does Ptolemy ensure that Mars goes retrograde when it is in opposition (180 degrees from the sun)?

EarthParallax

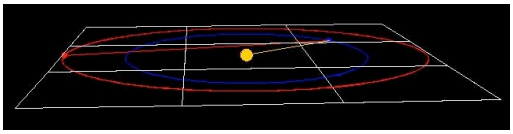


- Shows the movement of the celestial poles predicted by Copernicus' theory.
- How did Copernicus reconcile his theory with the absence of such motion?

All3Systems

- Compares simplified versions of the Copernican, Tychonic, and (scaled) Ptolemaic systems.
- Are these systems geometrically equivalent?

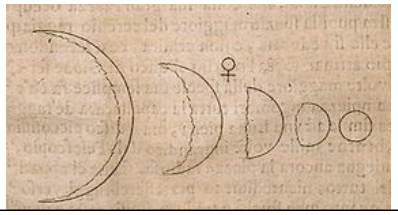
KeplerSystem



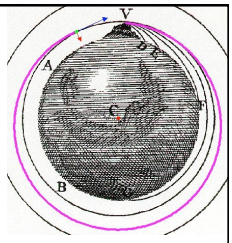
- Simulates the motion of Earth and one other planet using Kepler's three laws of planetary motion.
- How does Kepler achieve variations in ecliptic latitude (above/below the ecliptic plane)?

VenusPhases & VenusPhasesPt

- These two simulations show the phase of Venus for any location in its orbit using the Copernican and Ptolemaic systems.
- Assumes the Venus shines by reflecting sunlight.
- Which system agrees with Galileo's telescope observations of Venus?



NewtonsMountain



- Simulates a projectile launched from a TALL mountain. Motion follows Newton's laws of motion and gravitation.
- If the projectile is fired fast enough, will it orbit Earth like the moon?

Student Projects

- Project 1: construct Ptolemaic and Copernican orbits for imaginary inferior and superior planets (and home star / home planet) given observational data. Tests understanding of the main features of the two systems and understanding of how theories are connected to observation.
- Project 2: write a defense of the Copernican system against an Aristotelian attack. Tests understanding of Galilean/Newtonian physics and how it fits with the idea of a moving Earth.

Student Evaluations

- Overwhelmingly positive about the course and the simulations.
- Some negatives:
  - On simulations: "While I know it's hard to have labs about astronomy, constantly doing computer simulations gets old very fast."
  - On the historical approach: "I took this course with more intentions of learning about the science of astronomy, not the theories that came together to formulate today's astronomical views. I feel that learning about ancient astronomers who came up with flawed scientific ideas does not constitute an important subject for a general education science course."

Resources

- All simulations, activity handouts, and lab handouts are available from: facultyweb.berry.edu/ttimberlake/copernican
- Paul Wallace wrote a text for the course. I have made some modifications/additions. The text is not ready for publication but interested instructors can obtain a pre-publication version for review and possible use by emailing me: ttimberlake@berry.edu.

Future Plans

- Continue to improve the simulations and the textbook. Hopefully we will submit the book for publication in a few years.
- Find a way to incorporate more primary source material into the course.
- Develop a new course on the history of galactic astronomy from Galileo to Hubble. I will be writing my own textbook and I expect to create many new simulations for that course.