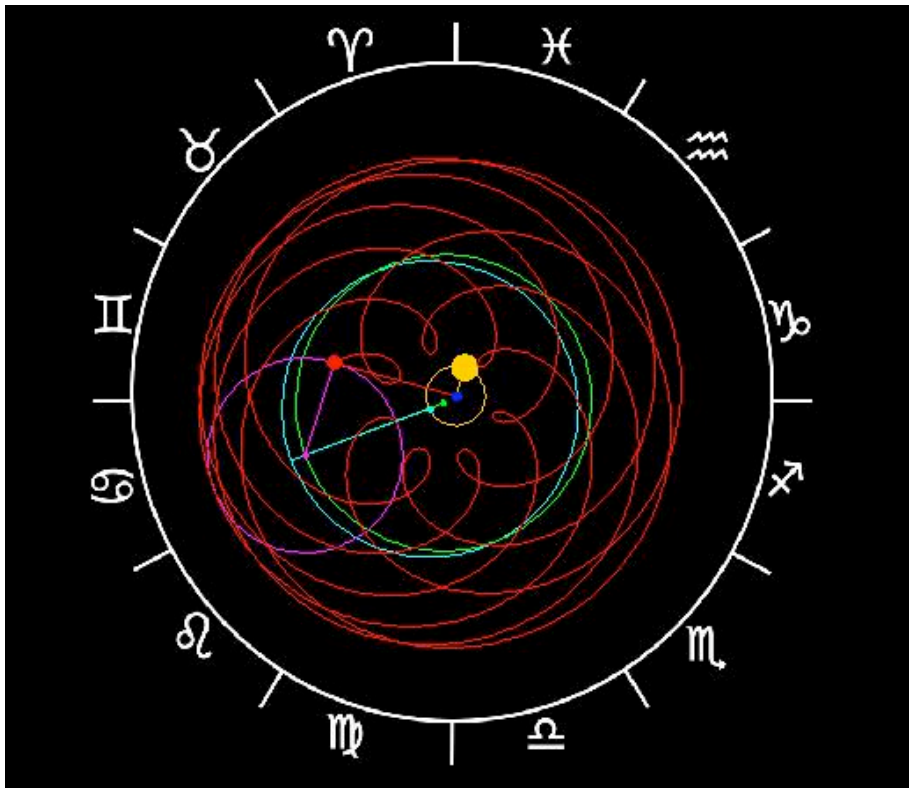
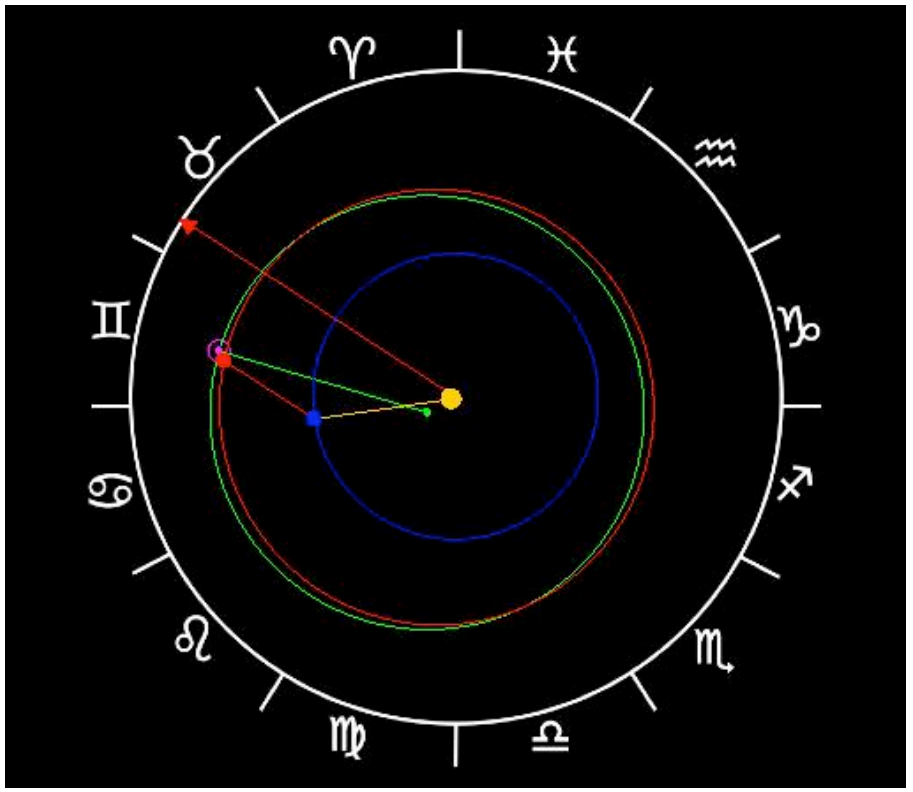
Using Computer Simulations to Explore the History of Astronomy





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BERRY COLLEGE

Outline

- Overview of the Copernican Revolution Course
- Examples of simulations: observations, Ancient Greek astronomy, Copernicus
- Scale of Universe Activity
- More examples: Galileo, Newton
- Resources
- Using *Easy Java Simulations* (EJS)

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  - Students find the historical content (as well as the scientific content) interesting.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 a wide variety of 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 (although many still prefer real-world activities).

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 (possibly all?) of the features of this software are available in free programs like Celestia and Stellarium.

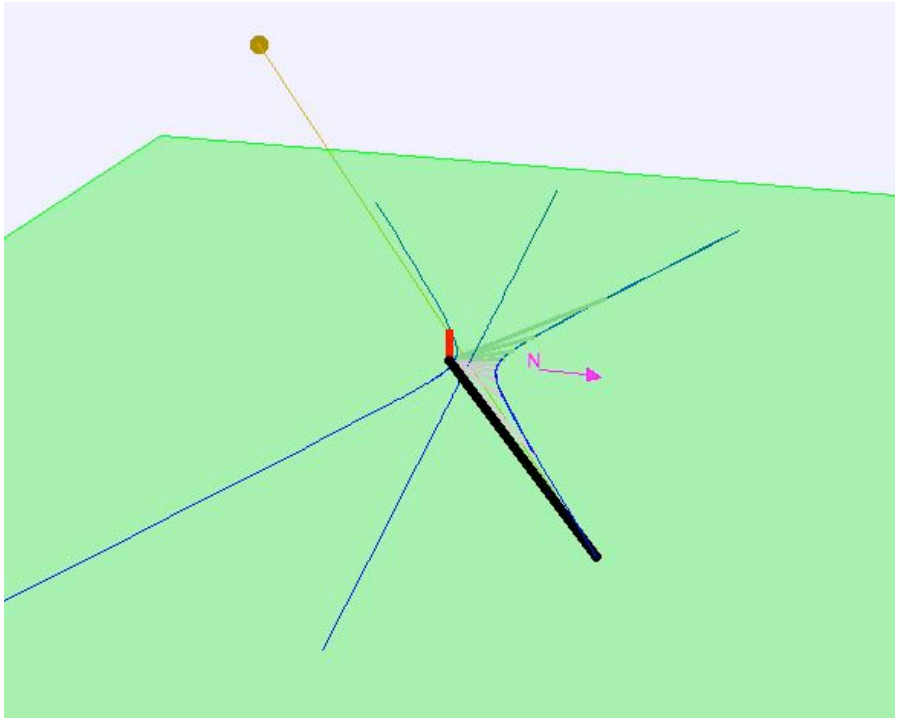
What We Observe

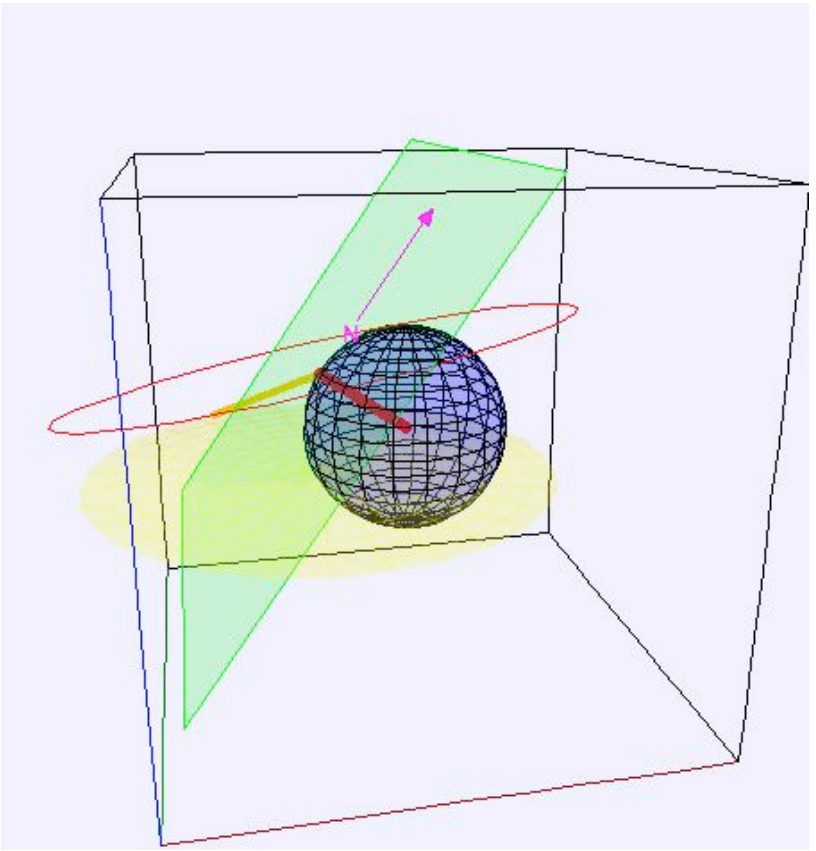
- 23 hour, 56 minute cycle of the stars.
- 24 hour cycle of Sun.
- Position of Polaris.
- Apparent motion and phases of Moon.
- Apparent motion of planets (retrograde motion, conjunction/opposition, changes in brightness).
- Precession of equinoxes.
- Sky from different locations on Earth.

My Simulations

- All of my simulations are…
  - Java programs (so in principle 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.

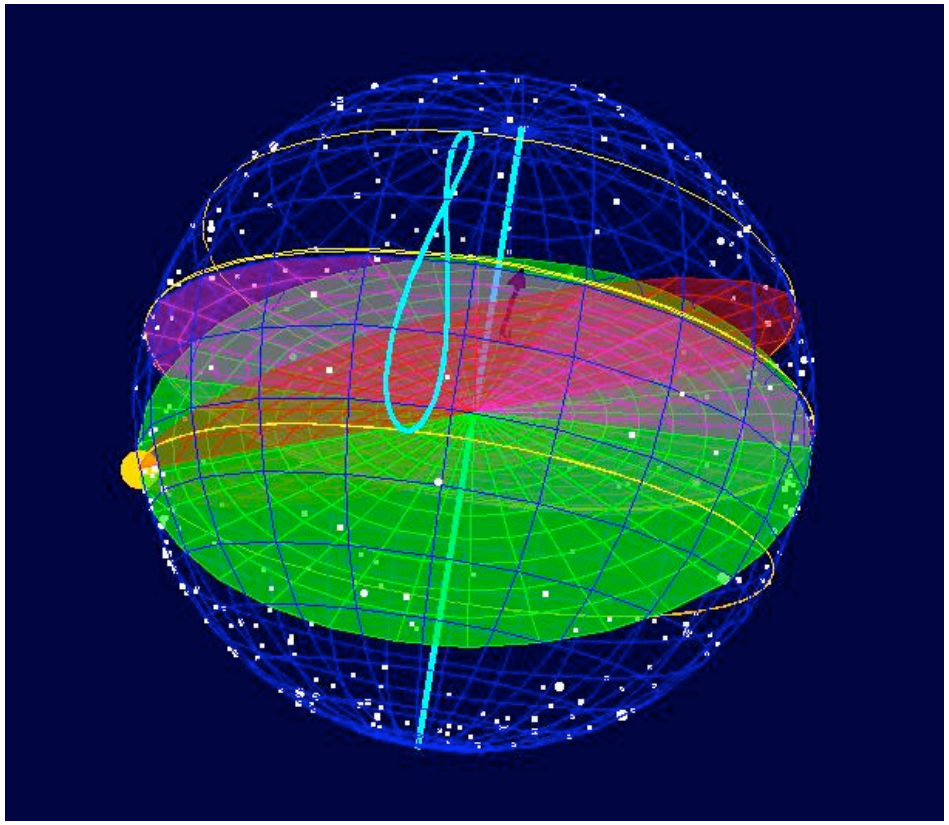
Gnomon

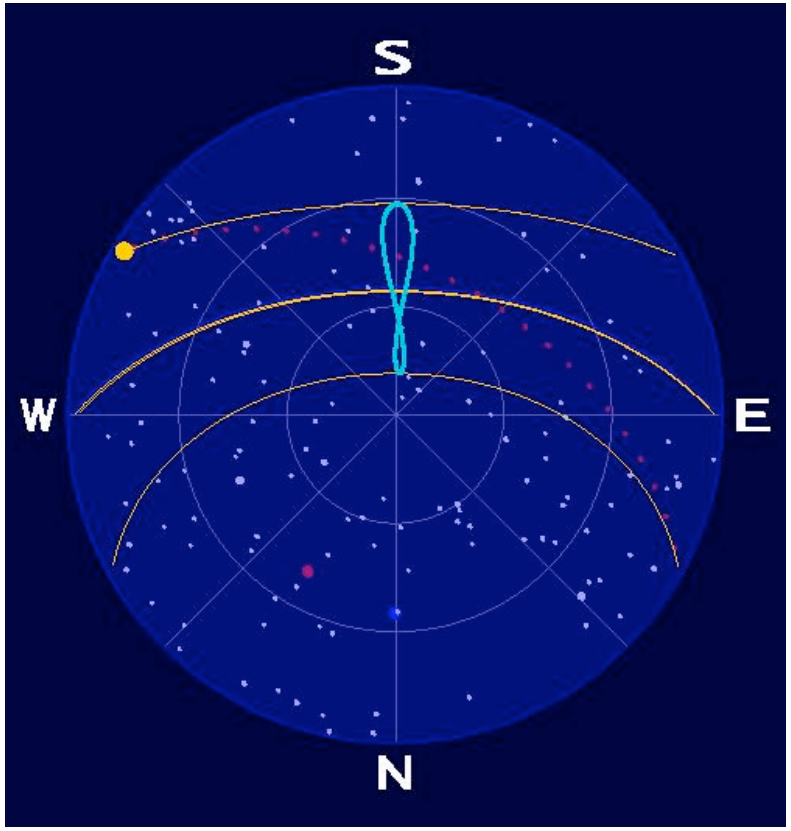




- Simulates the shadow produced by an upright stick at any time on any day of the year at any latitude on Earth.
- Where must you be for the noon sun to point North on some days and South on others?

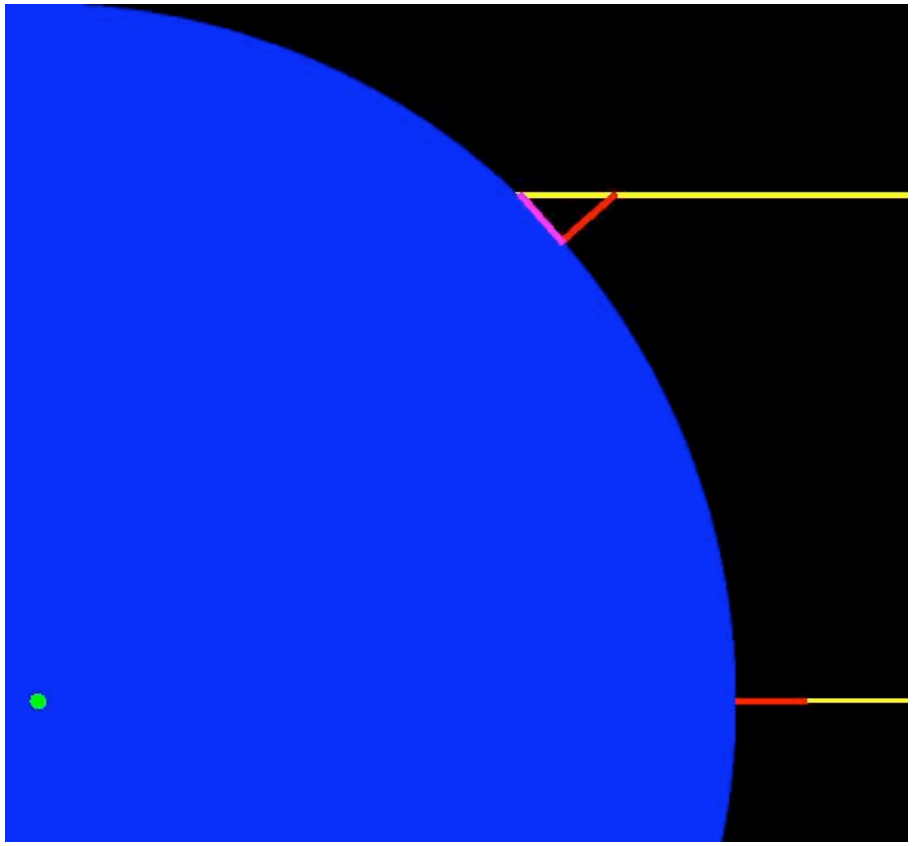
CelestialGlobe

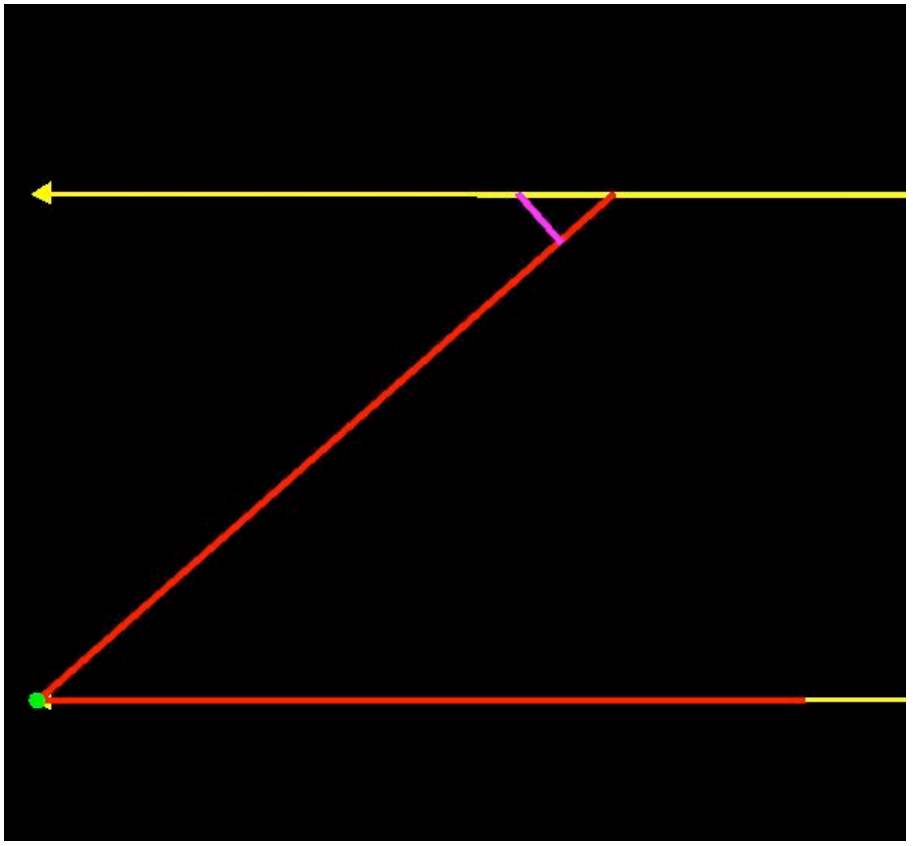




- A virtual celestial globe to show the sky at any time, on any day, from any latitude. Can change tilt of axis, eccentricity of orbit, and date (to show precession).

Eratosthenes

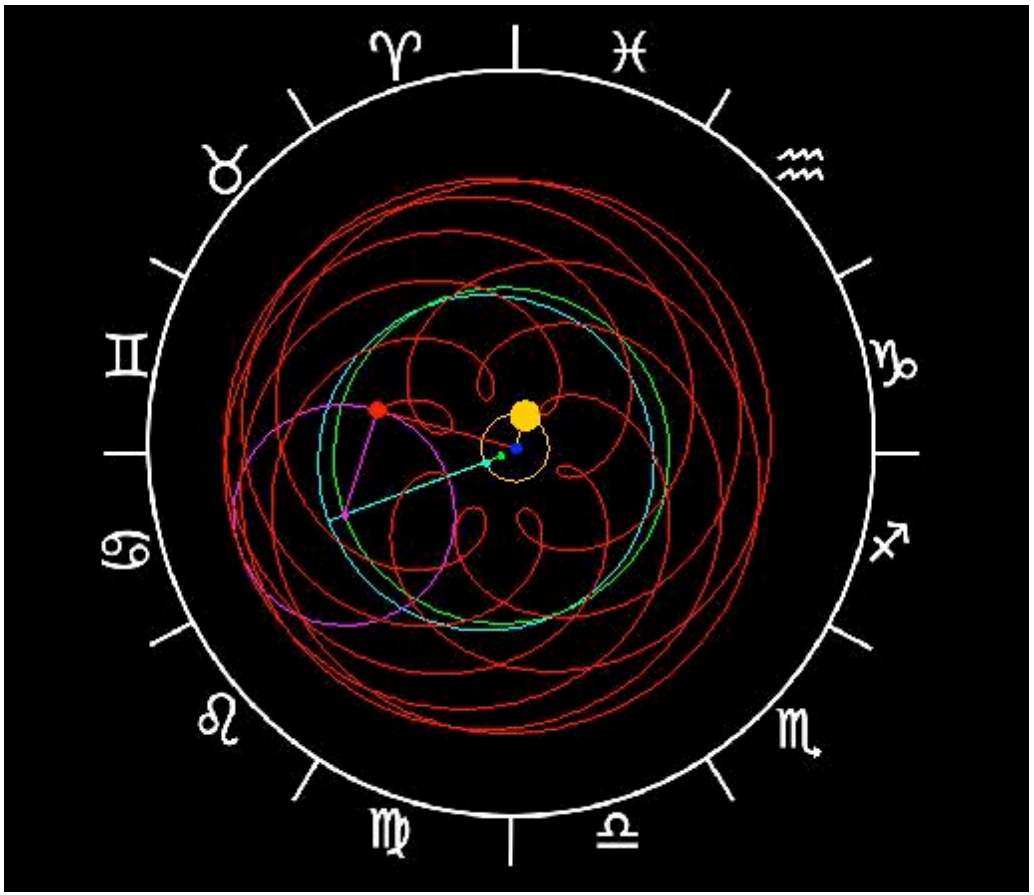




- Illustrates how Eratosthenes determined the radius of Earth.

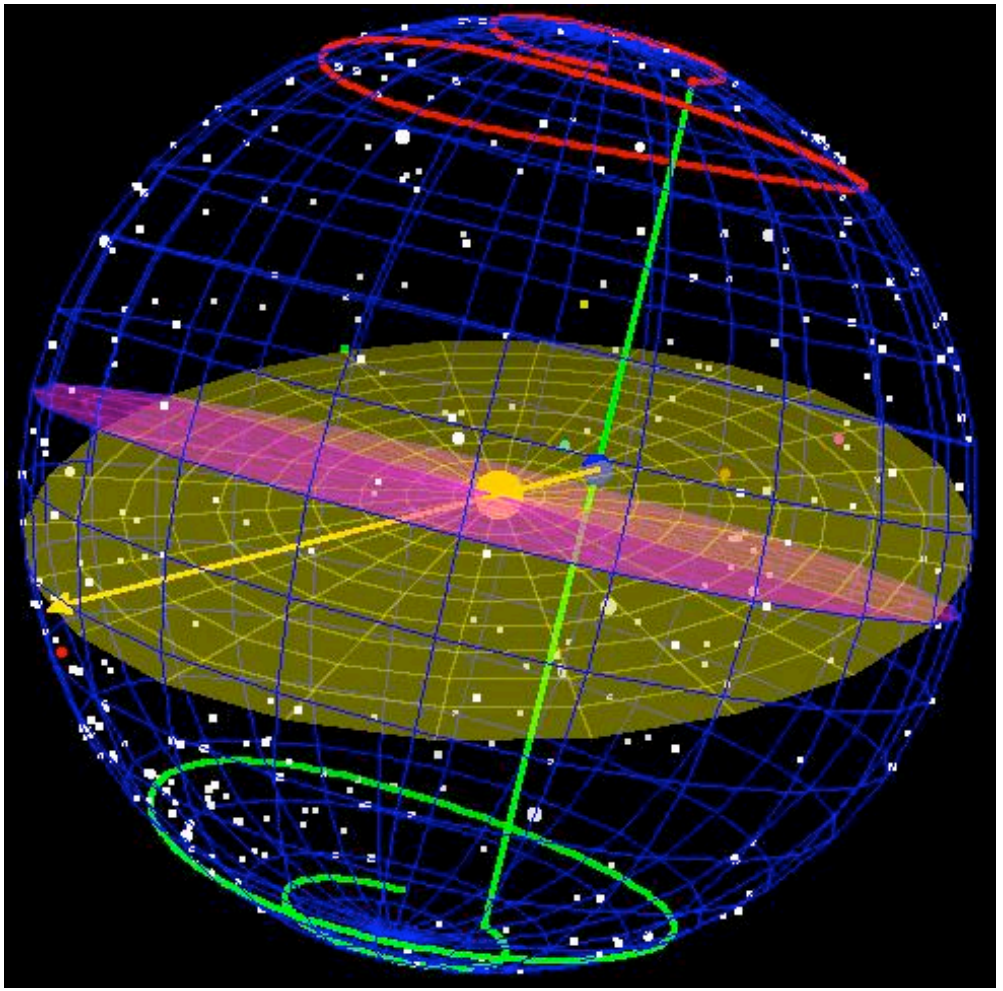
SuperiorPtolemaic

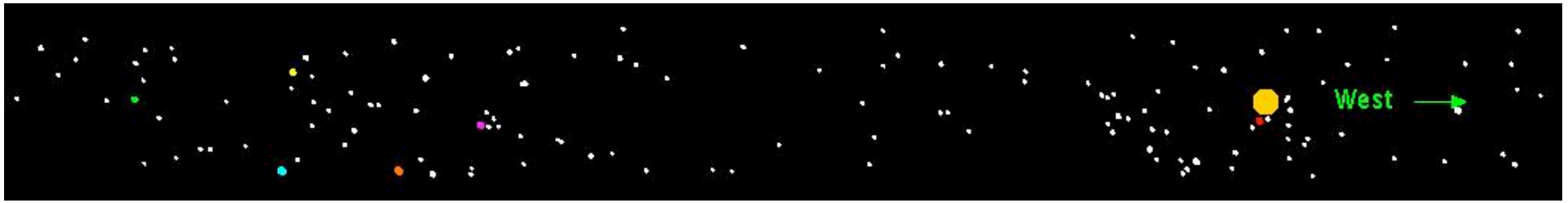
- Simulates Ptolemy's theory for the superior planets.
- How does Ptolemy ensure that Mars goes retrograde when it is in opposition (180 degrees from the sun)?



EarthOrbit

- Illustrates Copernicus' theory of Earth's orbital motion.
- How does Copernicus explain the seasons? Or the lack of annual parallax?

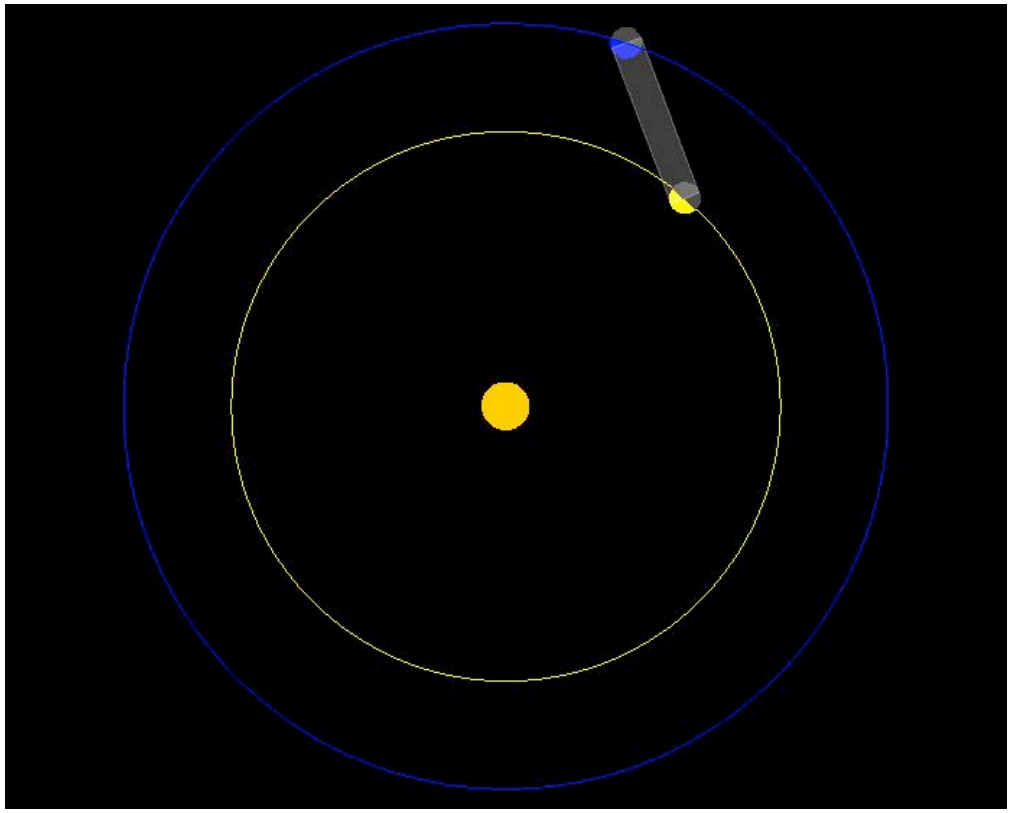


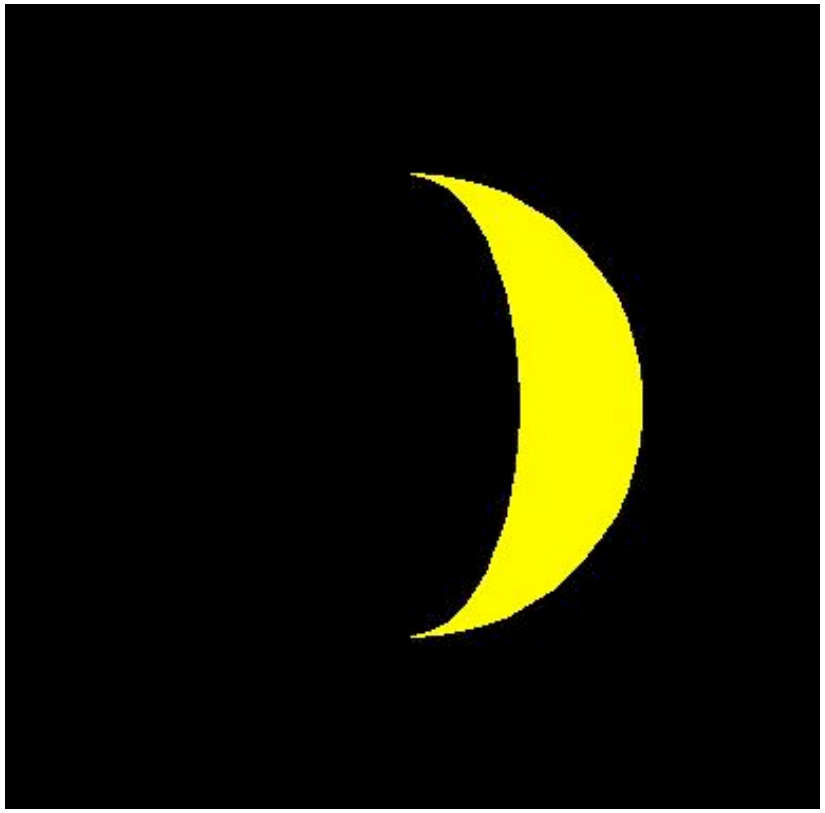


CopernicanSystem

- We will explore this simulation in detail by completing an activity in which we use observational data to determine the order of the planets in the Copernican system and the size of each planet's orbit (relative to Earth's orbit).

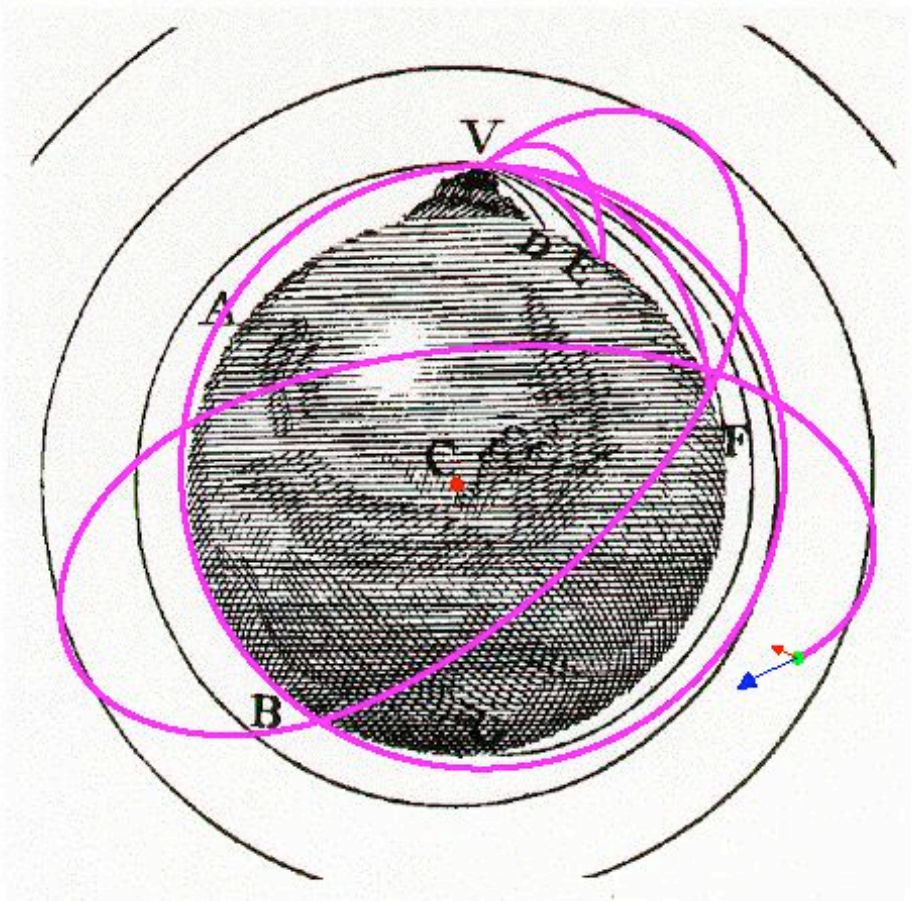
VenusPhases





- Shows the predicted 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?

Future Plans

- Improve more of the simulations and make them available on the web.
- Improve the textbook and submit it for publication.
- 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.

Resources

- My materials: all simulations, activity handouts, and lab handouts are available from:

  facultyweb.berry.edu/ttimberlake/copernican
- Book: Interested instructors can obtain a pre-publication version for review and possible use by emailing me: ttimberlake@berry.edu.
- EJS: wiki (www.um.es/fem/EjsWiki/) and upcoming book by WolfgangChristian.
- EJS/OSP simulations: www.compadre.org/osp/

(Very) Short Course on EJS

- Installing EJS.
- Modifying an existing model.
- Creating your own model.