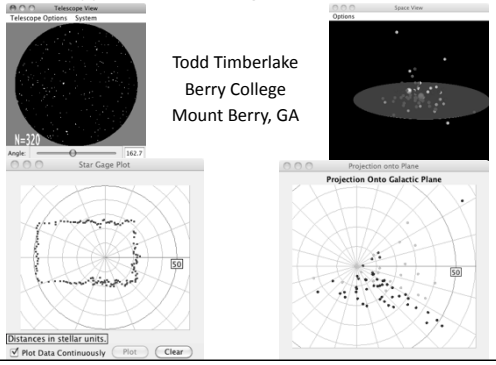
Astronomy, History, and Computer Simulations

An Approach to Teaching the Nature of Science



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Outline

- A quick description of my two courses.
- The role of computer simulations
- Learning about the nature of science with computer simulations
  - Assumptions
  - Classification
  - Coherence
- Teaching materials available online
- If there is time: a look at some other simulations.

My Courses

- *The Copernican Revolution*: planetary astronomy from Eudoxus to Newton.
- *The Scale of the Universe*: galactic astronomy and cosmology from Aristotle to Penzias and Wilson.
- Students spend class time working through activities based on the history of astronomy.
- They often use computer simulations to make (virtual) observations or visualize theories.
- The goal of these courses is to help students understand how scientists try to answer questions about the natural world (ie the "Nature of Science").

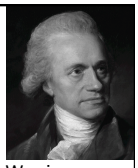
Why use computer simulations to teach astronomy?

- Any astronomy course:
  - Many students need a visual image in order to understand a concept.
  - Simulations are practical when real observations would be impractical.
- Historical course focusing on the nature of science:
  - Historical theories can be simulated in a virtual world even if they don't work in the real world.
  - Simulations let students see how theories and assumptions connect to observational data, so they can EVALUTE the theories/assumptions (and learn about the Nature of Science).
  - "A simulation is an experiment in a virtual Universe" – Martin Rees (as quoted by Liba Taub)

Simulating the Nature of Science

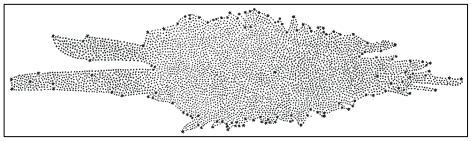
- Computer simulations highlight the role of assumptions, because assumptions must be built in to the simulation.
- You can build different versions of the simulations using different assumptions, so students can see how this impacts the interpretation of data.
- To evaluate a theory (and its assumptions), students must know to which data (objects) the theory applies. This highlights the role of classification.

Herschel's Milky Way



- Assumptions:
  1. Telescope can see to the edge of the Milky Way in any direction.
  2. Stars are distributed uniformly within the Milky Way system, then cease altogether at the edge.
  3. There is no absorption of starlight (related to 1 above).
- Classification: all distinct bright points are stars.
- Method: relative distance in any direction is proportional to the cube root of the star count.

Herschel's Star Gages



- Results: Milky Way is a flattened, split disk with Sun near the center. (cross section shown above)

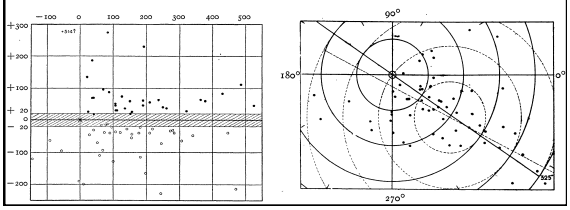
Shapley's Milky Way

- Assumptions:
  - Valid Cepheid period-luminosity relation.
  - The brightest stars in all globular clusters have about the same luminosity.
  - All globular clusters have about the same diameter.
  - There is no interstellar absorption.
- Classification:
  - Identify globular clusters.
  - Identify Cepheid variables.
  - Treat "cluster-type" variables as Cepheids.

- Method:
  - Nearest clusters: photometric distances based on period-luminosity relation.
  - More distant clusters: photometric distances based on brightest stars.
  - Most distant clusters: geometrical distances based on apparent diameters.

Shapley's Globular Clusters

- Results: Milky Way system is outlined by ellipsoidal distribution of globular clusters. Diameter of system is 100 kpc, with sun 20 kpc from center.



Coherence

- Why did Herschel's star gage results (and more sophisticated star count results like those of Kapteyn) disagree with Shapley's globular cluster results? Why did both disagree with results from studies of differential galactic rotation which placed the sun only 10 kpc from the center?
- "We look for methods that are all pointing in the same direction. We're looking for consistent results." – Martin Rees (quoted by Liba Taub).
- Absorption of starlight accounted for discrepancies and brought coherence to our picture of the Milky Way. Adding in absorption made all of the methods point in the same direction.

Teaching Materials

- My stuff: computer simulations and activity/ lab handouts available at
  facultyweb.berry.edu/ttimberlake/copernican
  and
  facultyweb.berry.edu/ttimberlake/galaxies
- Textbooks: instructors can obtain pre-publication versions for review and possible use by emailing me: ttimberlake@berry.edu.
- More free astronomy simulations at www.compadre.org/osp/.

Plea for Help

- Students have been very receptive to my course, but all of my materials need improvement.
- If you are interested in reading and critiquing (or even co-authoring?) my textbook(s) PLEASE let me know.
- If you are interested in teaching with my materials and providing feedback, PLEASE let me know.
- If you have expertise in assessing student understanding of the Nature of Science and would like to collaborate, PLEASE let me know.
- Contact: ttimberlake@berry.edu.