What is science?

- “ Science is a way of trying not to fool yourself” -- Richard Feynman
- Science is a process, not a collection of facts

Why do science?

- Curiosity
- Scientific understanding can lead to development of technology
  - Few examples: electronics, optics, medicine, etc., etc., etc.
- Understanding implications of what we do
- Improving condition of the world (once we can agree on what "improving" means)

What doesn't science do?

- Prejudge what outcomes of a question are going to be
- Make moral judgments of what is "better"

Observations

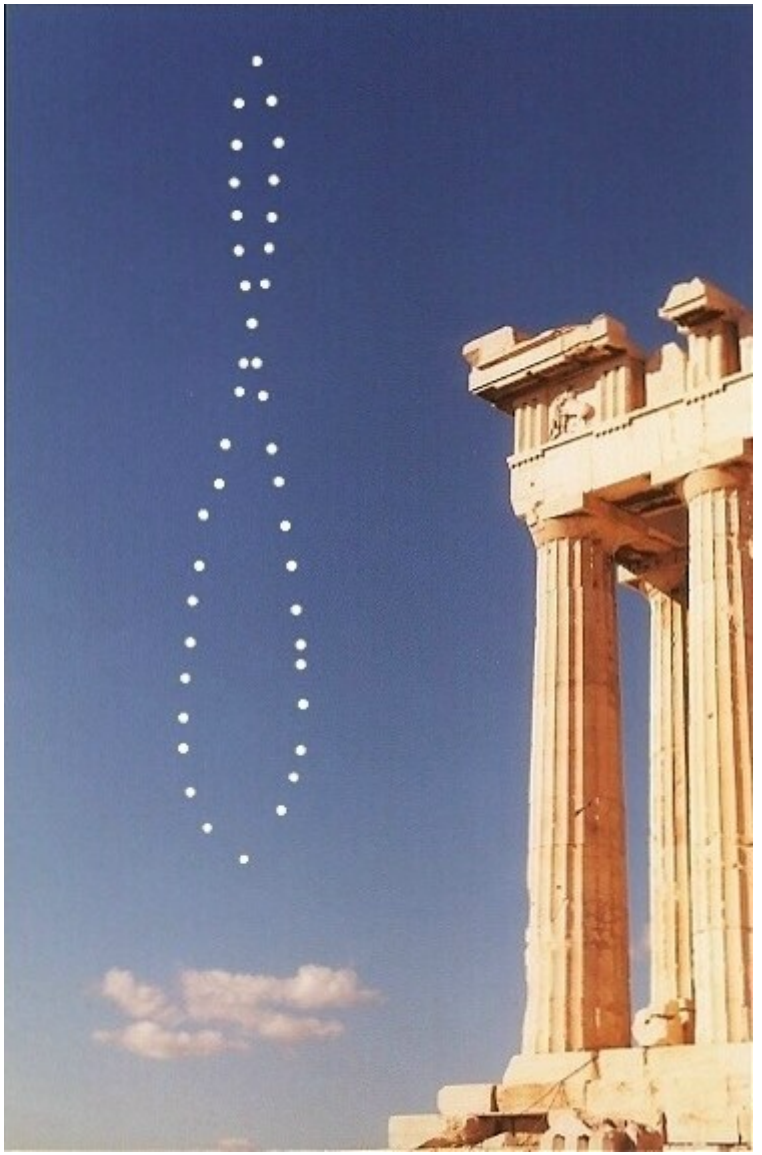
- Science uses data, or observations, to try to understand in a more general way, how things in the Universe work.
- Sometimes, it's challenging, and fun, to make observations. How do we know things? Are we sure that what we “know” is true?
- Ideas about “what's really going on” must match observations, and ideally, make predictions for future observations

Shape of the Earth: Data

Shape of the Earth: theories

- The Earth is flat
- The Earth is spherical
- Resolution:
  - What are the predictions for long range travel?
  - What are the predictions for view from a different vantage point?

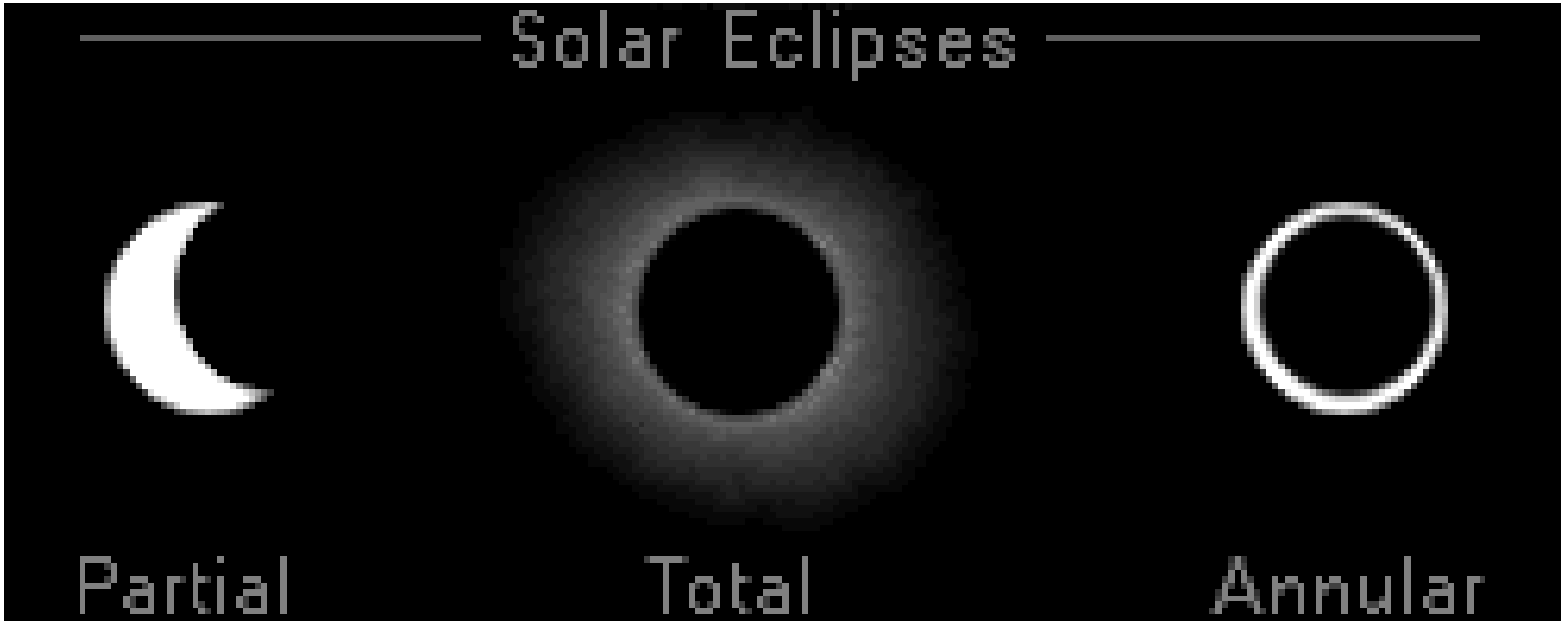
Earth/Sun motion: Data



Earth/Sun motion: theories

- The Sun goes around the Earth
- The Earth goes around the Sun
- Resolution:
  - How would stars and planets appear to move in the different models? How do they move?

Sizes of the Moon and Sun



Sun/Moon sizes: theories

- The Sun and the Moon are the same size
- The Sun is much bigger, but much farther away
- Resolution:
  - Figure out how to measure distances to Moon and Sun

Scientific theories

- Very hard to prove something is absolutely true
- Much easier to prove that it is false!
- A scientific theory: an idea about how things work that no one has managed to disprove, despite **intense** effort to do so
- Good scientific theories also:
  - Make predictions beyond the observations that motivated them, predictions that can be verified or falsified
  - Usually provide the simplest explanation of observed phenomena
- Examples: Gravity causes the Earth to orbit the Sun.

Hallmarks of good science

- Skepticism and qualification of opinions:
  - Skepticism is a critical component of science
  - Skepticism still must be backed up by data: the onus is on **you** to disprove something you don't want to believe in
- Lack of vested interest in the result
- Peer review
- Makes testable predictions, i.e. tries to explain something before you know what is going to happen
- Willingness, and even responsibility, to reconsider
- States not only what is known, but also what is unknown

Pseudoscience

- Unfortunately, “pseudo-scientific” theories have been becoming increasingly popular, and many people have difficulty distinguishing them from scientific theories
  - Perhaps motivated by the complexity of the modern world
- Examples:
  - “paranormal” phenemena
  - Psychics
  - Astrology
- The existence of pseudo-scientific theories often makes it more difficult to reap the benefits of scientific theories
  - Many pseudo-scientific theories are used to materially support their strongest proponents (charlatans!)

Hallmarks of pseudoscience

- Tries to explain things after they've already happened
- Unwillingness to relinquish theory even after observations fail to support it, often by continuing to add “revisions”
- Not peer reviewed
- Claims to understand things completely, rarely discuss what they don't explain

What is the difference between astronomy and astrology?

- Astrology: the position of stars and planets at the time of your birth affects the course of your future life
- Is astrology a science?
  - Is the idea a valid hypothesis?
  - Does the idea make testable predictions?
    - Do they work out?
  - Is there a mechanism that might explain astrology that also explains other things?

Do astrological predictions come true?

- NO
- Of course, some predictions will come true some of the time, but this is just a matter of probability and does not require any causal connection. Even statistically, astrology fails
- See references at:

/www.astrosociety.org/education/resources/pseudobib.html

Are there known mechanisms by which astrology might work?

- Four basic forces currently known to underly physical phenomena:
  - Gravitatational
  - Electromagnetic
  - Strong
  - Weak
- If you calculate the strength of these at time of birth, the contribution from planets is not important for any of these

- Astrology is a pseudo-science, not a science
- Is it harmless entertainment? Maybe, maybe not

What is astronomy?

- The science of studying objects in the sky
- Astronomy is based largely on observations
- Basic theories of physics are used to understand these observations
- Much is currently known, but much is unknown
- In this class, we'll try to remember about the scientific process, and not just the results:
  - How do we know?
  - How did we figure out?

What do astronomers do?

- Observations and data analysis
- Theoretical research
- Instrumentation
- Teaching
- Applications

Science in Society

- Are scientists always right?
  - If a scientific idea/prediction turns out to be wrong, does that invalidate science?
- Is anyone always right?