

Introduction to Astronomy

ASTRONOMY: Study of the universe using the laws of physics.

- uses the scientific method.
- involves huge numbers for distances, mass, and time.
- involves small numbers for describing phenomena at the atomic level.

Overview of the Universe

Solar System:

Eight (or Nine) planets, Sun, minor planets, moons, comets, meteoroids, and dust.

Terrestrial Planets: Mercury, Venus, Earth, and Mars

Characteristics: dense (rocky), few or no moons, thin atmospheres, weak magnetic fields, slow rotation, no rings.

Jovian Planets: Jupiter, Saturn, Uranus, Neptune

Characteristics: low density (gas), many moons, strong magnetic fields, fast rotation, rings.

Jupiter is the largest (10 times larger than the Earth).

Pluto is in a class by itself. Its properties are closer to those of the moons of Uranus and Neptune. The International Astronomical Union (IAU) demoted Pluto to minor planet status in August 2006 (some of us say it is still a planet).

Sun: a typical star (100 times larger than the Earth) powered by fusion of hydrogen atoms into helium atoms.

Mnemonic to memorize the order of the planets from the Sun:

My Very Educated Mother Just Showed Us ~~Nine Planets~~.
Nuts!!

IAU Definition of a Planet

A "planet" is a celestial body that:

- (a) Is in orbit around the Sun.
- (b) Has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a nearly round shape.
- (c) Has cleared the neighborhood around its orbit.

What's not a planet?

“Dwarf planets” (trans-Neptunian Obj? name TBD)

Orbits the Sun, round, big things ARE around it, not a satellite (i.e. moon)

Examples: Pluto, Ceres, Quaoar, Sedna, other Kuiper Belt Objects.

“Small Solar-System Bodies”

Anything else that orbits the Sun

Examples: Moons, Asteroids, Comets, Meteors/ites/oids, Dust

Problems with the official definition

Can you think of any problems with the definition?

What do we call the 200+ Jupiter-like things that orbit around other stars? (location matters?)

Can there be planets with no star?

What determines if it's round?

What determines if it's cleared its orbit?

Why don't moons count as “clearing its orbit?”

Can there be double planets?

Where do brown dwarfs begin and planets end?

Small Group Activity

Get into groups of three and revise the IAU definition of a planet by considering some or all of the problems that were listed. On the worksheet provided write an alternate definition for a planet. Everyone turns in a copy of the worksheet.

Time: 10 minutes.

Beyond The Solar System

Nearest star to the Sun is at a distance of 270,000 astronomical units (one astronomical unit is the distance from the Earth to the Sun, 1.48×10^8 km) or 4.3 light years. This distance is typical of distances between stars in our galaxy.

Stars are formed from interstellar clouds of dust and gas and evolve at rates that depend on their mass (massive stars evolve fast, less massive stars evolve slowly).

Low mass stars like our Sun die quietly as white dwarfs while high mass stars die violently through supernovae explosions resulting in neutron stars or black holes.

Star Clusters: can form from massive gas clouds. Clusters are of particular interest to astronomers since they reveal most of the information about stellar evolution.

Galaxies: Island universes consisting of hundreds of billions of stars plus dust and gas held together by gravity. Our own Milky Way Galaxy is a spiral like the nearest spiral M31 (Andromeda Galaxy).

Other types of galaxies include ellipticals, irregulars like the two satellites (Magellanic Clouds) to our own galaxy, radio galaxies, and quasars.

Most galaxies are found in clusters. Milky Way Galaxy belongs to the Local Cluster (~ 30 galaxies) which is just part of a larger cluster called the Local Supercluster.

Superclusters = clusters of clusters

Superclusters are separated by empty space called voids.

Scientific Method

The scientific method is a systematic approach to gathering measurements and observations in order to explain a physical phenomena in terms of a scientific theory. A model is a mathematical expression of a theory that scientists use to make predictions of a phenomena.

All scientific theories start out as a hypothesis, which is basically an untested theory. Over time scientists refine and test a hypothesis by making more measurements and observations. If the hypothesis holds up to the test of time it becomes a theory.

Methods of Scientific Reasoning:

Deductive Reasoning: predictions coming from a hypothesis. The scientist starts with a hypothesis and then makes measurement to test that idea which then leads to refinements to the hypothesis.

Inductive Reasoning: observations result in the formation of a model which is then tested and refined by further observations.

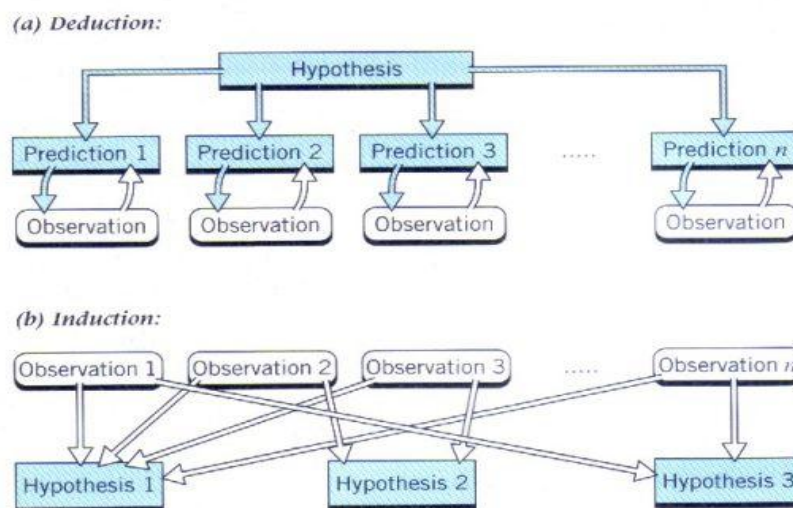


FIGURE 2-6. (a) The method of deduction, which begins with a hypothesis and deduces a variety of predictions and observations. (b) The method of induction, in which a number of observations produce hypotheses that allow explanation of past behavior and the prediction of future results.

Overall Process:

Observe/Measure -> Theorize -> Predict -> Test -> Modify (induction)

Or

Theorize -> Predict -> Observe/Measure -> Test -> Modify (deduction)

Dumb luck sometimes plays a role in new discoveries in science. We look for one thing but by accident find something else that is totally unexpected.

A hypothesis can become a theory if the evidence for its reliability becomes strong (repeatable and verifiable).

A theory is not fixed in time and it is not a fact or a truth..

Competing Theories: the simplest theory wins out (Occam's Razor).

Science vs. Pseudoscience

Game of Science: intellectual game with rules that must be followed. People that claim to be doing science but do not follow the rules are not practicing science, but are practicing pseudoscience.

Characteristics of Science:

1. Never-ending quest for knowledge.
2. Repeatable and Verifiable.
3. Rules of science require that a model or hypothesis make predictions, which are then tested and refined.
4. Hypothesis is always at risk.
5. Open to public scrutiny.
6. Theory – a hypothesis that has been tested a LOT and has passed them all. It can be wrong, but according to current research, that isn't likely. A theory can be said to be a hypothesis that has withstood the test of time.

Characteristics of Pseudoscience:

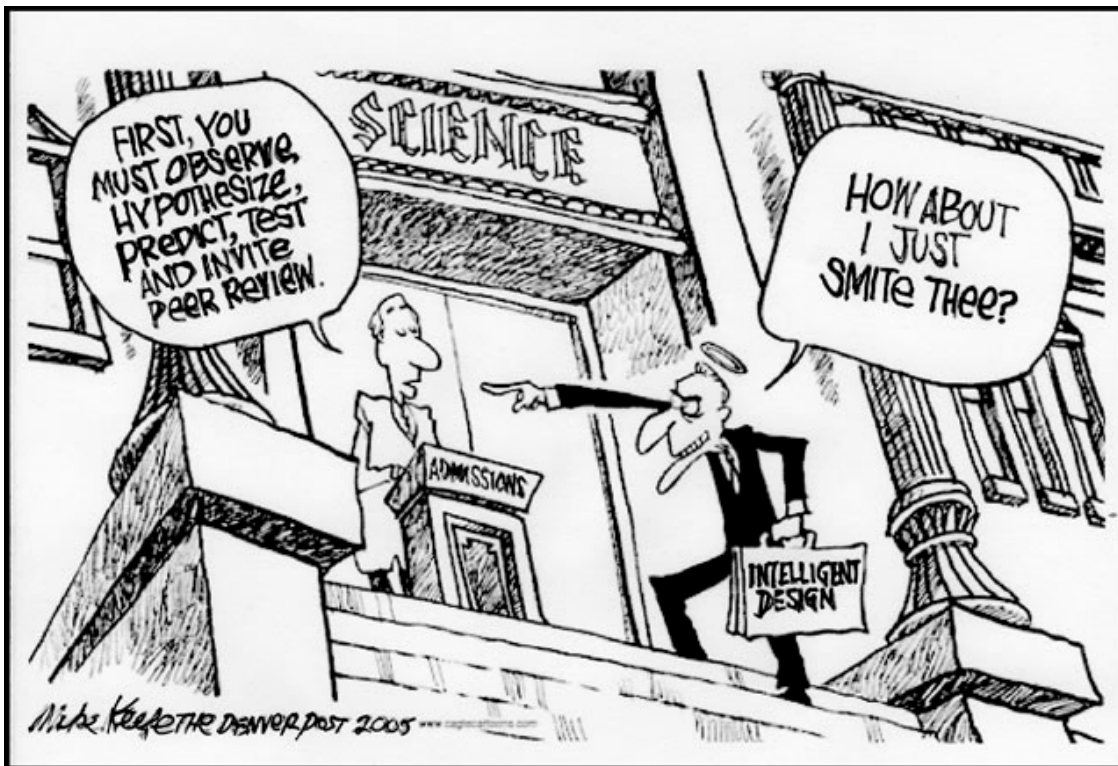
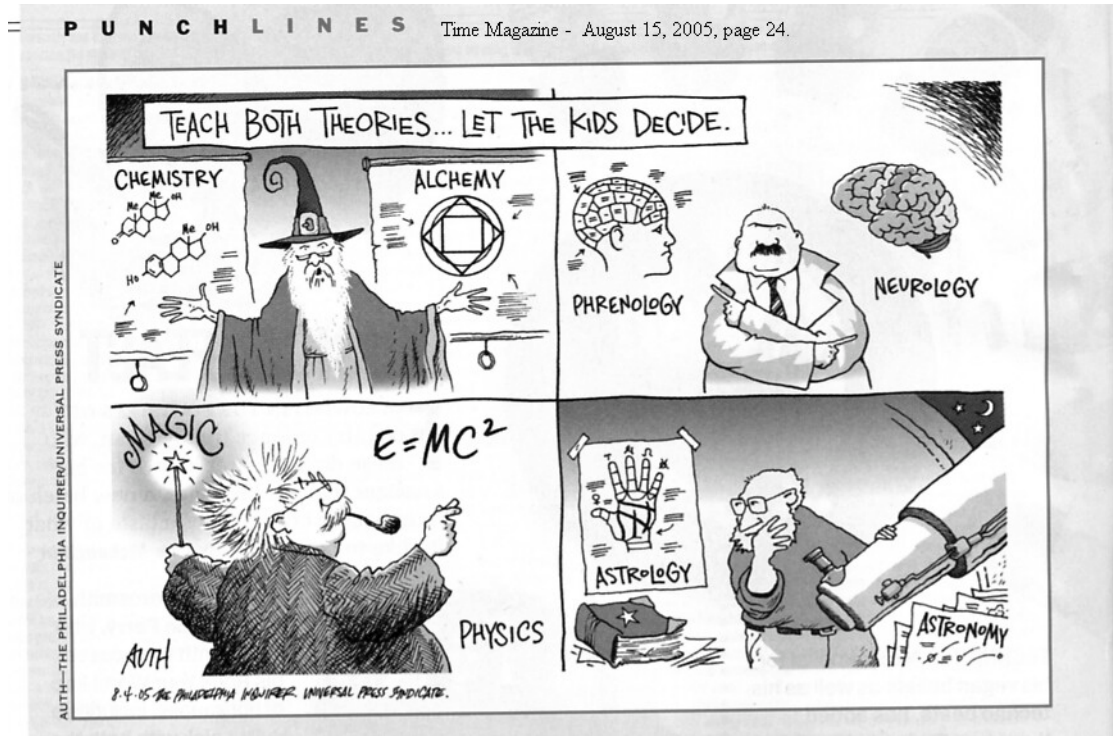
1. Not open to public scrutiny.
2. Hypothesis is never at risk (untestable).
3. Ignores evidence that does not support its hypothesis.
4. Overly simplistic answer to complex questions.
5. Does not do real research (ex. Institute of Creation Science).

Examples of Pseudoscience

1. Hollow Earth Society - believes that we live inside a hollow sphere. Two pieces of evidence that are claimed to support their view:
 - a. Geological survey from around 1900 that claimed the curvature of the earth in the Great Lakes region was concave.
 - b. Curvature of shoes results from walking inside a sphere.
2. Astrology - Claims that specific configurations of the Sun, planets, and constellations influence human affairs.

3. Creationism - The belief that the Earth along with the rest of the universe was created recently, within the last 10,000 years.

There have been efforts by creationists to give equal treatment to creationism in science classrooms. The dangers to science in this are many. In particular, it will undermine science by obscuring the principles of good science to future generations.



Scientists do not guess

Many people assume that Theory and Guess are synonymous.

Guess - any old random idea to explain observations.

Theory - a hypothesis that has stood the tests of time.

Concept Test

Turn to your neighbor and consider the following question.

The best test of a scientific hypothesis is how

- a. well it explains all known observations.
- b. well it agrees with known theories.
- c. simply explains all known observations.
- d. well it predicts new observations.
- e. easily it is transcribed into mathematical notation.

Scientific Notation

Numbers are expressed using factors and exponents (powers of ten). This helps scientists deal more easily with large or small numbers.

$$2 \times 10^5 = 200,000$$

factor exponent

Here the exponent reads as 10 to the 5th power or 100,000. Examples:

Examples:

$$1000 = 1 \times 10^3$$

$$0.001 = 1 \times 10^{-3}$$

$$10,000 = 1 \times 10^4$$

$$0.0001 = 1 \times 10^{-4}$$

$$15,200 = 1.52 \times 10^4$$

$$0.1234 = 1.234 \times 10^{-1}$$

$$402,000 = 4.02 \times 10^5$$

$$0.00075 = 7.5 \times 10^{-4}$$

What's in a million? One million seconds: 1×10^6 secs = 11.6 years

To multiply or divide numbers using scientific notation multiply. or divide the factors and then add or subtract the exponents.

Examples:

$$1.24 \times 10^3 \times 7.5 \times 10^2 = (1.24 \times 7.5) \times 10^{(3+2)} = 9.3 \times 10^5$$

$$3.5 \times 10^6 \times 5.5 \times 10^{-4} = (3.5 \times 5.5) \times 10^{(6-4)} = 19.25 \times 10^2$$

$$\frac{6 \times 10^4}{3 \times 10^3} = \frac{6}{3} \times 10^{(4-3)} = 2 \times 10^1 = 20$$

Orders of Magnitude

Orders of magnitude are related to scientific notation and powers of ten. It is useful for comparing the relative sizes and distances of objects.

One order of magnitude is a difference of a factor of ten.

Two orders of magnitude is a difference of a factor of 100

General rule for orders of magnitude: whenever anything is 10 times larger it is the same as if it were 10 times larger.

Orders of magnitude can quickly be determined by taking the difference between the exponents of two numbers (after taking the above rule into account).

Example:

$$2 \times 10^3 \text{ and } 8 \times 10^7$$

The difference in the order of magnitude between these numbers is 4 since the exponents differ by 4 orders of magnitude and the factors of the two numbers differ by a factor of 4 which is for practical purposes one more order of magnitude.

Cosmic Scale: If we compare the largest structures in the universe with the smallest objects in the universe we find that the difference is roughly 40 orders of magnitude.

Ranking Task: Sizes

Turn to your neighbor and take five minute to discuss and fill out the handout. Everyone turns in a completed handout.

Angles and Measurement

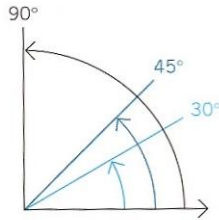


FIGURE 3-2. The sizes of various angles.

Basic unit of measurement is the degree, which is subdivided into 60 minutes of arc. Each minute of arc is subdivided into 60 seconds of arc ($1^\circ = 60' = 3600''$).

Customary notation for angles: $20^\circ 15'$ or 20.25°

Decimal degrees are more common since they are easier to use with a calculator. To convert minutes of arc to decimal minutes divide the minutes of arc by 60 and add to the number of degrees.

$$15/60 = 0.25$$

When converting an angle with both minutes and seconds of arc divide the seconds of arc by 3600 and add to the number of degrees.

Example: $20^\circ 30' 12'' = 20 + 30/60 + 12/3600 = 20 + 0.5 + 0.0033 = 20.5033^\circ$

Angular Size: the angle that an object appears to subtend.

$$\text{angular size} = 57.3^\circ \times \text{true size} / \text{distance}$$

Example: angular size of the Moon

$$\text{angular size} = 57.3^\circ \times 3475 \text{ km} / 385,000 \text{ km} = 0.52^\circ$$

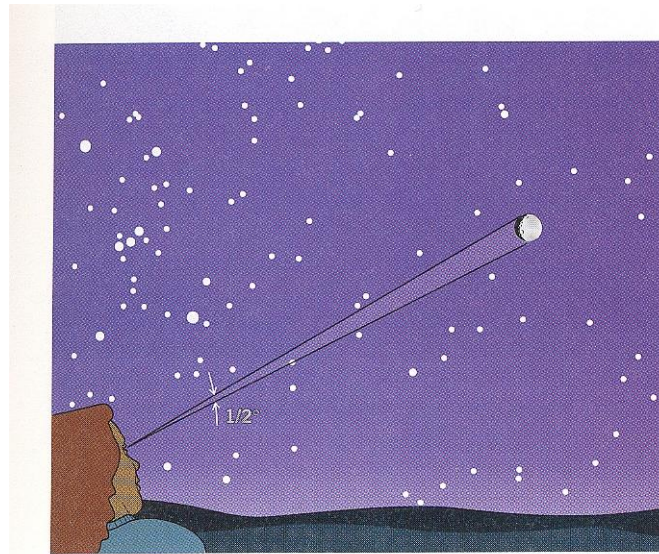


FIGURE 3-5. The angular size of the Moon.

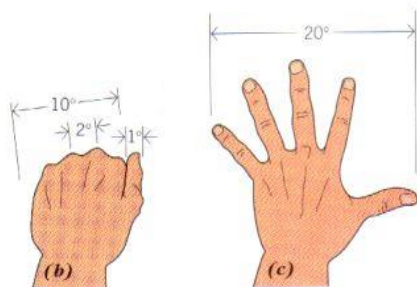
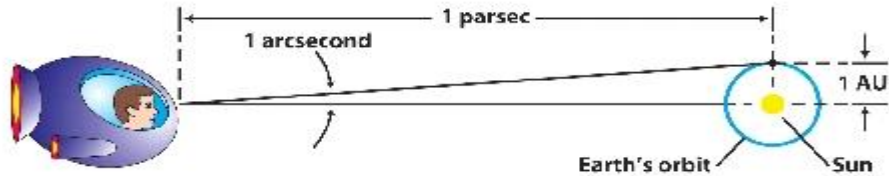


FIGURE 3-6. Using the human hand to measure angles roughly. (a) Extend the hand at arm's length and sight along it. (b) The thumb subtends about a degree, two knuckles about 2°, and the fist about 10°. (c) The hand subtends about 20°.

Astronomical Distances

Astronomical Unit: diameter of the Earth's orbit.

$$1 \text{ AU} = 1.5 \times 10^8 \text{ km}$$



Light Year: distance light travels in one year. Light years are used for measuring distances to nearby stars.

$$1 \text{ ly} = 9.46 \times 10^{12} \text{ km}$$

Parsec: distance two objects would have if 1 AU made angle of 1 arcsecond. Parsecs are used for measuring distances to nearby stars.

$$1 \text{ pc} = 3.26 \text{ ly}$$

Kiloparsec: used to measure distances within our Galaxy. $1 \text{ kpc} = 10^3 \text{ pc}$

Megaparsec: used to measure distances between galaxies. $1 \text{ Mpc} = 10^6 \text{ pc}$

Uncertainty in Measurement

All measurements have uncertainty.

Random Errors: scatter about the true value. The observer does nothing to cause these.

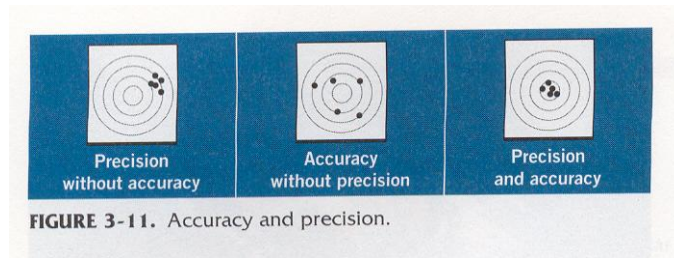
Systematic Errors: deviation to one side of the the true value caused by a mistake made by the observer.

Precision versus Accuracy

Precision without accuracy - small random errors but large systematic errors.

Accuracy without precision - small systematic errors but large random errors.

Precision with Accuracy - small random and small systematic errors.



Random errors can be estimated by averaging your measurements and taking 1/2 of the difference between the largest and smallest values. The final value is expressed as the average plus or minus the random error.

$$\text{average} \pm \text{random error}$$

Tools of Astronomy

1. Ground based telescopes
 - a. Refractors
 - b. Reflectors

2. Instruments attached to telescopes
 - a. Film cameras - not used much any more.
 - b. CCD cameras - do more than take pretty pictures.
 - c. Spectrographs - reveal what stars are made of.

3. Space based telescopes and instruments
 - a. Hubble Space Telescope
 - b. Compton Gamma Ray Observatory
 - c. Spitzer Infrared Telescope

4. Computers
 - a. Super computers
 - b. Personal computers

Amateur Astronomy

Astronomy is one of the only fields of science where amateurs can make a significant contribution.

1. Professional grade CCD cameras and large telescopes have become more affordable.
2. Personal computers and astronomical data reduction software are available to amateurs.
3. Fields where amateurs typically make contributions:
 - a. Comet Hunting.
 - b. Near Earth asteroid detection (ex. Kansas City Astronomical Society)
 - c. Observing transits of extrasolar planets.
 - d. Observations of variable stars.
 - e. Lunar occultations.