Introduction to Science and Mathematics

Physical Sciences
Broward College

Prepared for AST 1002

Horizons in Astronomy

What is Science?

- Science is the methodological study of systems.
- Science studies these systems on why they work, how they work, and the relationship of these systems.
- Science tries to ask questions that quantify (numbers; equations) the systems.

Scientific Method

- Brainstorm: Ask a Question
- Hypothesis: Testable Question
- Experiment: Testing the Question
- Theory: A Repeatable Experiment
- Law

Scientific Method

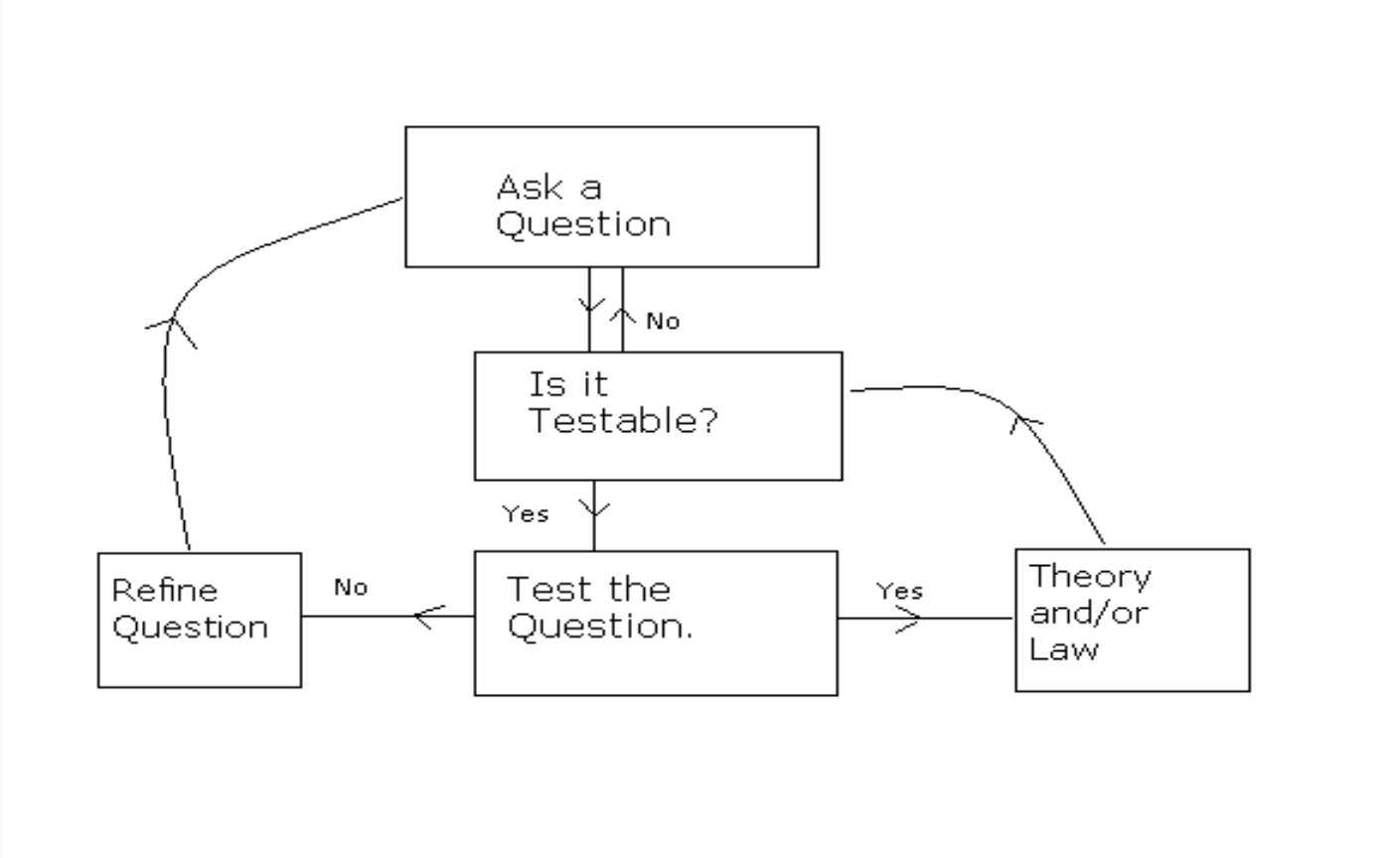


Figure 1. The Scientific Method

Types of Science

- Physical Sciences
  - Studies how physical phenomena work.
- Biological Sciences
  - Studies how biological phenomena work.
- Social Sciences
  - Studies how social systems (people) work.

Physical Sciences

- Astronomy
  - The study of how the planets, stars, galaxies, and universe work.
- Physics
  - The general study of how systems work individually and in connection.
- Chemistry
  - The study of how atoms combine and create compounds.
- Earth Sciences
  - The study of how the Earth and its atmosphere works

History of Measurement Systems

- Earliest systems were on the Indus Valley in Pakistan (3000 – 1500 BCE)
- Egyptian, Roman, and Indian systems were well documented
- Developed standards based on many different objects and people

English versus Metric

Both systems were developed and introduced when their mother countries were naval superpowers

- English
  - Introduced by Henry I and then completed by Henry VII and Elizabeth I, all of the Tudor Family in between 11^{th} – 16^{th} Century AD.
  - Based on the measurements of the royal family and objects in the empire

- Metric System
  - Introduced by France 1790
  - Used in most countries today via a treaty
  - Based on the powers of ten

English Measurement

Unit	English	Standard
Length	12 inches = 1 foot 3 feet = 1 yard 5,280 feet = 1 mile	3 barleycorn = 1 inch (Henry VIII) 1 yard = ½ arm span (Henry I) 8 furlongs = 1 mile (Elizabeth I)
Mass	1 pound	Based on the unit the stone
Time	60 seconds = 1 minute 60 minutes = 1 hour 24 hours = 1 day	Based on the movement of the heavens

Metric measurement

Unit	Metric	Standard
Length	1 meter	• 1/10,000,000 of distance between Equator and North Pole • 86 wavelength of Krypton
Mass	1 gram	Standard weight called the “Le Gran K”
Time	Same as English	• The movement of the heavens • Cesium electronic movement

Note: The Metric System has two standards; the Systems International which is Meters, Kilograms, and Seconds and Centimeters, Grams, and Seconds. In astronomy, we use systems.

English – Metric Conversions

- 1 mile = 1.609 km
- 1 inch = 2.5 cm
- 1 pound = 0.4526 kg
- 1 oz. = 28.35 g
- Temperature °Celcius =

  (Temperature °Farenheit-32) * 5 / 9

Temperature Scales

Celsius to Fahrenheit Scales – At zero degrees Celsius, water freezes.

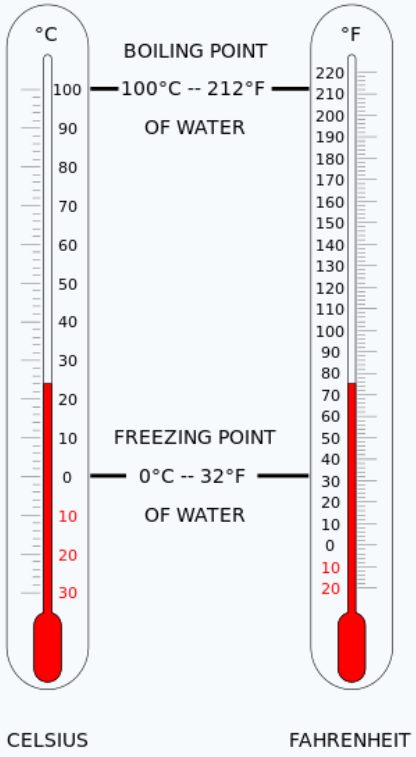


Figure 2. Celsius/Fahrenheit Thermometers (Wiki)

Celsius to Kelvin – At zero degrees Kelvin, the activity in the Universe stops.

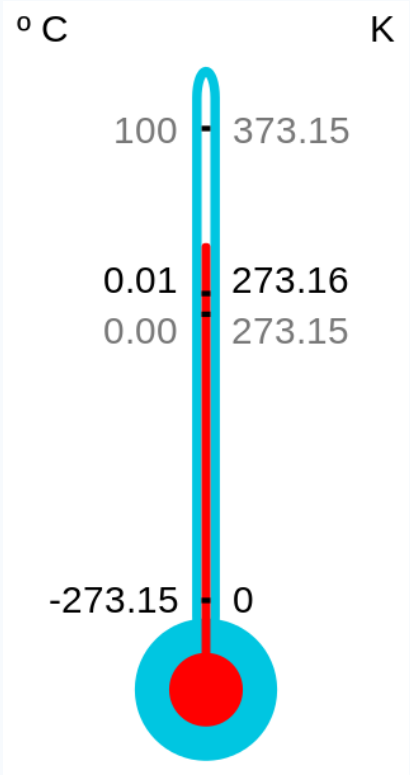


Figure 3. Celsius/Kelvin Thermometers (Wiki)

Conversion Example

- We want to find how many kilometers is 6 miles.
- We can do this for any different conversion

$$1\,mile = 1.609\,km$$

$$6\,miles\left(\frac{1.609\,km}{1\,mile}\right) = 9.654\,km$$

Symbols and Equations

- Equations
  - A symbolic representation of a relationship between variables
- Variables
  - A symbol representing a set of numbers
  - Independent versus Dependent variables
- Constants
  - A variable with a constant value
  - Example: speed of light

Order of Operations in Math

Please	Parentheses
Excuse	Exponents
My	Multiplication (left to right)
Dear	Division (left to right)
Aunt	Addition (left to right)
Sally	Subtraction (left to right)

Logarithmic Math

- Multiplication
  - $\log(ab) = \log(a) + \log(b)$
- Division
  - $\log\left(\frac{a}{b}\right) = \log(a) - \log(b)$
- Inverses
  - $-\log\left(\frac{b}{a}\right) = \log\left(\frac{a}{b}\right)$
- Coefficients
  - $loga^b = b * log(a)$
- Anti-Log
  - $10^{\log(a)} = a$

Order Operations example

Evaluate $3 * 2 + 5 * (5 - 3)^2$

- First do the Parentheses $3 * 2 + 5 * (2)^2$
- Second do the Exponent $3 * 2 + 5 * 4$
- Third do the Multiplication $6 + 20$
- Finally do the Addition $6 + 20 = 26$

Significant Figures and Scientific Notation

- Significant figures are non-zero digits in a number
  - The exception is when the zeros follow a decimal to the right of non-zero digits.
  - We typically use the least significant figures for our calculation.
- Scientific Notation is a compact way to express a very long large or small number.
  - Example: 3.00×10^8 m/s (the speed of light).
  - The decimal is between the first two significant digits.
  - The exponent is positive when we move the decimal to the left and negative when we move the decimal right.

Understanding Measurements

- We organize our measurements into the set we call data (plural of the Latin word datum).
  - Example: Length
    - 3 in, 4 in, 56 in (or 3 m, 4 m, 56 m)
  - Example: Area (Length X Length)
    - 6 in^2, 24 in^2, 54 in^2 (or 6 m^2, 24 m^2, 54 m^2)
  - Example: Volume (Length X Length X Length)
    - 1 in^3, 8 in^3, 27 in^3 (or 1 m^3, 8 m^3, 27 m^3)

Significant Figure and Scientific Notation Examples

- Tell me how many significant figure each number has:
  - 134 = 3 significant figures
  - 12,300 = 3 significant figures
  - 0.002345 = 6 significant figures
- Convert the numbers above to scientific notation
  - $134 = 1.34 X10^{2}$
  - $12,300 = 1.23 X 10^{4}$
  - $0.002345 = 2.345 X 10^{-3}$

The Big Three in word problems

- Identify the VARIABLES in the problem.
- Identify the EQUATION you need to solve the problem.
- Identify what SOLUTION will complete the problem.

Word Problem Example

Two substances fill up 54 cm^3 (Solution 1) and 20 cm^3 (Solution 2) and have masses of 4.0 grams and 10 grams, respectively. Which one will float?

- What are the VARIABLES? The four variables are the two volumes and the two masses.
- What is the EQUATION you need? The equation is the density equation.
- What is the SOLUTION to the problem? The solution is the smaller density.

Word Problem Solution

$$Variables: V1 = 54\ cm^3;\ V2 = 20\ cm^3; m1 = 4\ g; m2 = 10\ g$$

$$Equation: Density = \frac{M}{V}$$

$$Density1 = \frac{M1}{V1} = \frac{4.0\ g}{54\ cm^3} = 0.07\ \frac{g}{cm^3}$$

This one floats because it is smaller.

$$Density2 = \frac{M2}{V2} = \frac{10\ g}{20\ cm^3} = 0.5\ \frac{g}{cm^3}$$

What is Astronomy?

- The science of the study of physical properties of the planets, stars, galaxies, and the universe.
- The word comes from “astro” meaning star and “nomos” meaning name and/or law in Latin.
- Astronomy is different from astrology, which was the study of the motions of the celestial globe.

Types of Astronomers

- Observational
  - Observers at telescopes obtaining observations and modeling those observations.
- Theoretical
  - Theoreticians at computers finding new models for the observations.

Observational – Ground Based

Meyer-Womble Observatory; Mt Evans, Colorado (Altitude: 14,148 feet, Twin 28 inch Ritchey-Chretien Telescope)

Figure 4. Meyer-Womble Observatory

Southeastern Association for Research in Astronomy (SARA) Observatory; Kitt Peak, Arizona (Altitude: 6,800 feet, 36 inch Cassegrain Telescope

Figure 5. SARA Observatory

Observational – Space Based

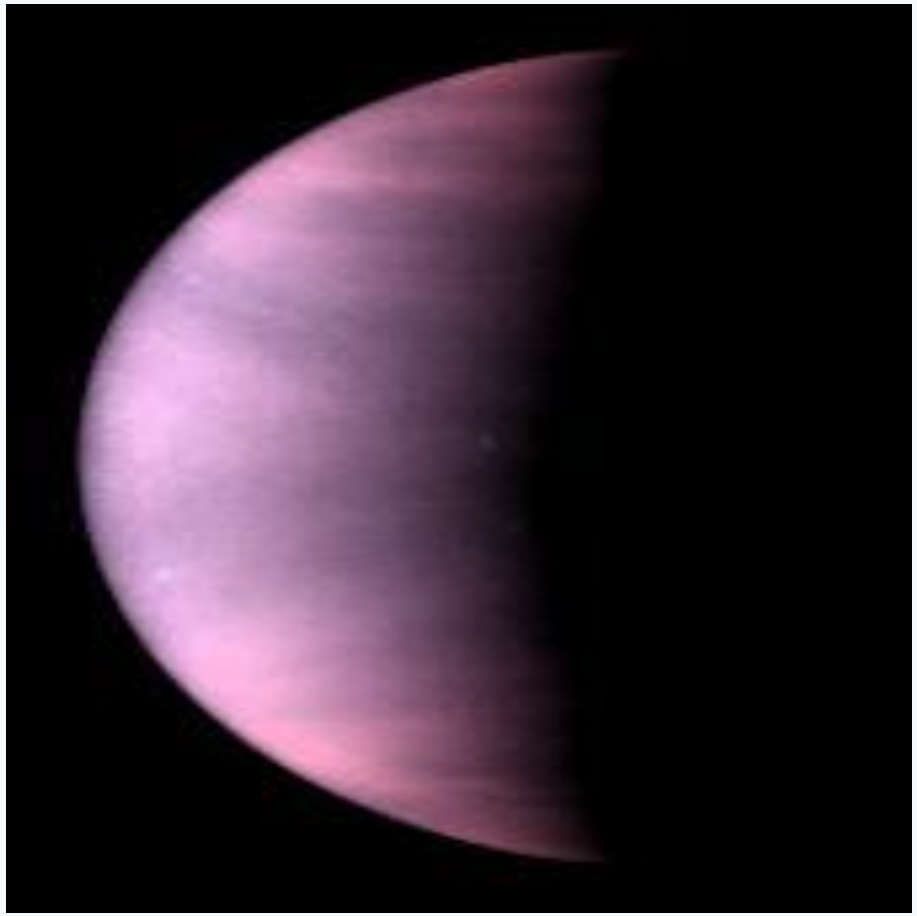


Figure 6. Venus from Hubble (Esposito, 1995)

- Venus imaged from Hubble Space Science Telescope.
- My favorite planet ☺!

Observational – Satellite Based

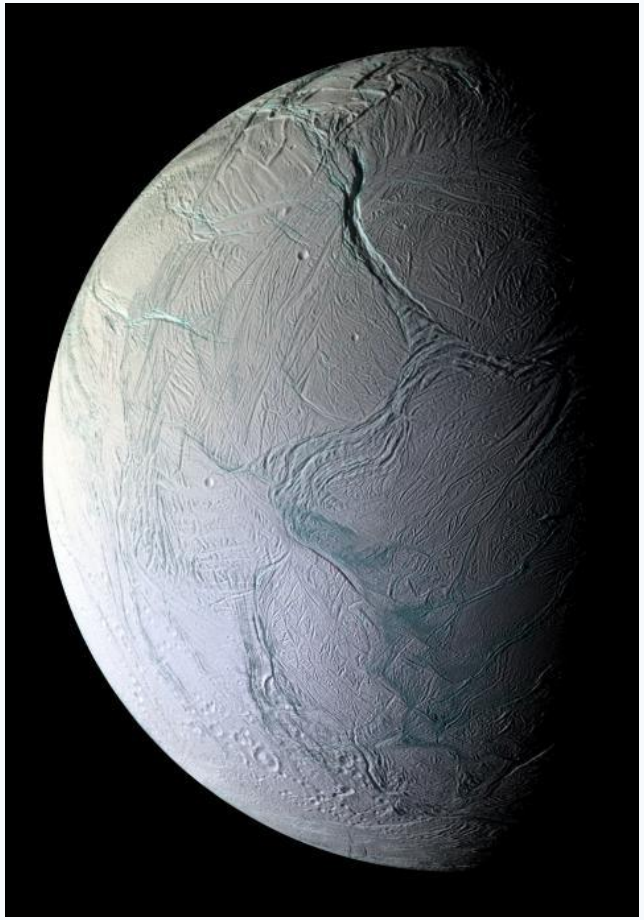
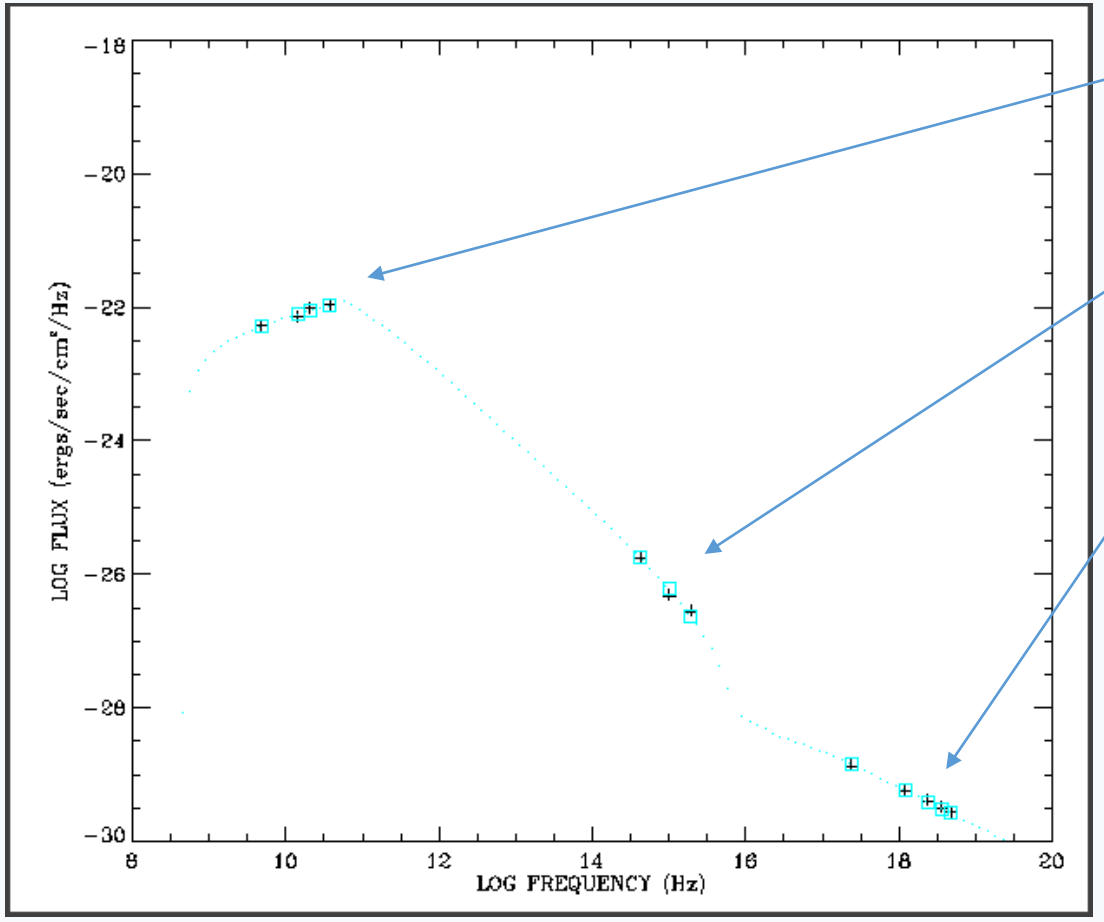


Figure 7. Enceladus from Cassini (NASA, 2008)

- Enceladus imaged from the Cassini Space Probe around Saturn
- Thought to have water under the icy surface

Theoretical – Observations..



Dusty Torus - Radio

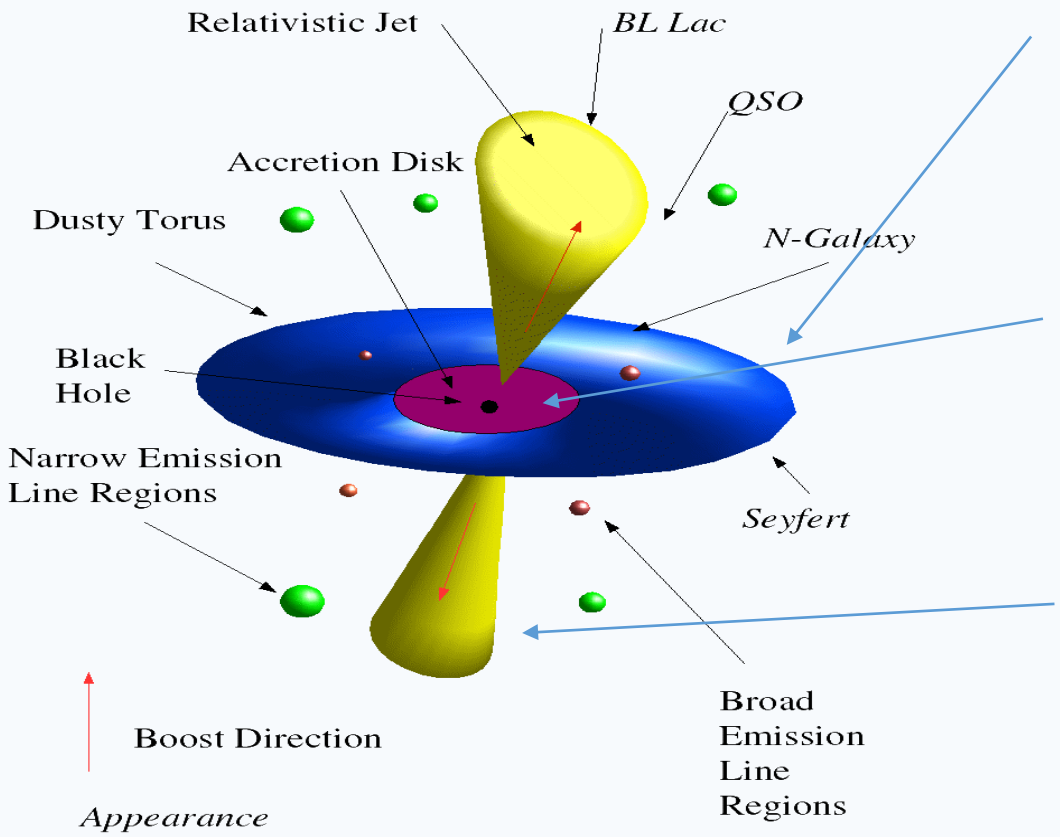
Accretion Disk - Visible

Relativistic Jet – X-Ray

The dimmer the region, the smaller the region is in the physical world.

Figure 8. Power Spectrum of 3C 345 (Webb, 1994)

Theoretical – Lead to Models of Active Galactic Nuclei



Dusty Torus - Radio

Accretion Disk - Visible

Relativistic Jet – X-Ray

Figure 9. Active Galactic Nuclei Model

Book/Course Image References

- Esposito, L., NASA (1995) Retrieved from: http://imgsrc.hubblesite.org/hu/db/images/hs-1995-16-gfull_jpg.jpg
- NASA/JPL/Space Science Institute (2008) Retrieved from: http://photojournal.jpl.nasa.gov/jpegMod/PIA11133_modest.jpg
- Webb, J.R., Schrader, C.R., Balonek, T.J., Crenshaw, D.M., Kazanas, D., Clements, S., Smith, A.G., Nair, A.D., Leacock, R.J., Gombola, P.P., Sadun, A., Miller, H.R., Robson, I., Fujimoto, R., Makino, F., Kii, T., Aller, H., Aller, M., Hughes, P., Valtoja, E., Terasranta, H., Salonnone, E., Tornikoski, M., Chism, W., (1994) *The Multifrequency Spectral Evolution of Blazar 3C 345 during the 1991 Outburst,* Astrophysical Journal, 422, 570 - 585

Wiki Commons/Wikipedia Image References

- Celsius/Fahrenheit Thermometers: "Thermometer CF" by User:Gringer - n /a. Licensed under Public Domain via Wikimedia Commons - https://commons.wikimedia.org/wiki/File:Thermometer_CF.svg#/media/File:Thermometer_CF.svg
- Celsius/Kelvin Thermometers: "CelsiusKelvin" by Celsius_kelvin_estandar_1954.png: Homo logosderivative work: kismalac - Celsius_kelvin_estandar_1954.png. Licensed under CC BY-SA 3.0 via Wikimedia Commons - https://commons.wikimedia.org/wiki/File:CelsiusKelvin.svg#/media/File:CelsiusKelvin.svg