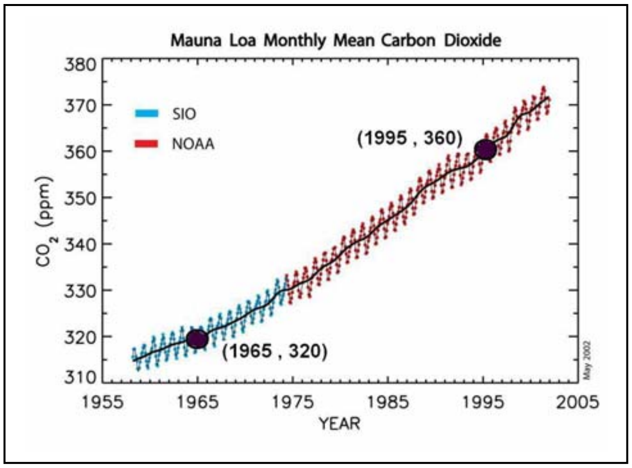
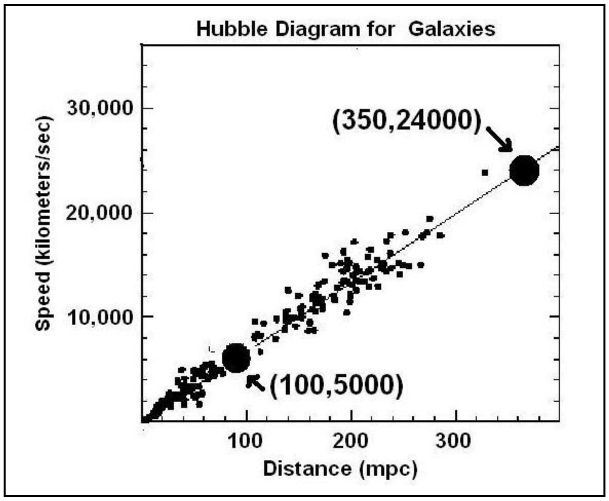
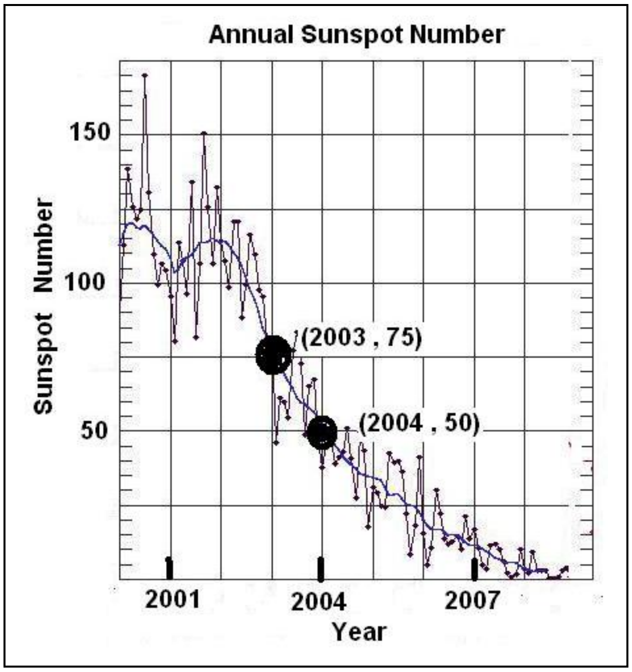
Rates and Slopes: An Astronomical Perspective







A 'rate' is defined as the ratio of two quantities which have different units of measurement.

For example, if you travel in a car 200 kilometers in 2 hours, the rate is R = 200 kilometers/2 hours or R = 100 kilometers/hour. You recognize this particular rate as just the speed of the car! Scientists work with other kinds of rates as well.

Graphically, a rate is a measure of the difference between two values along the Y-axis, divided by the difference between two corresponding values along the X-axis. It also represents the slope of a curve plotted on a graph.

For example, let's look at the top graph to the left. It shows how the amount of carbon dioxide in the atmosphere is increasing between 1955 and 2005. The two points along the data curve can be used to find the rate of change of the carbon dioxide in time, which is the slope of the line connecting these two points.

The change along the X-axis is just the difference '1995-1965' or +30 years. The difference along the Y-axis corresponding to these same years is just '360 ppm -320 ppm' or +40 ppm. The rate is then R = +40 ppm/+30 years or +1.3 ppm/year.

Note that we have kept careful track of the signs and units in the calculations. This is because rates can represent both increases (positive) or decreases (negative) changes.

Problem 1 - Calculate the Rate corresponding to the speed of the galaxies in the Hubble Diagram. (Called the Hubble Constant, it is a measure of how fast the universe is expanding).

Problem 2 - Calculate the rate of sunspot number change between the indicated years.

Answer Key

Problem 1 - Calculate the rate corresponding to the speed of the galaxies in the Hubble Diagram. (Called the Hubble Constant, it is a measure of how fast the universe is expanding).

Answer: The two points have coordinates (x1,y1) = (100 mpc, 5000 km/s) and (x2,y2) = (350 mpc, 24000 km/s). The difference in the y coordinates is y2-y1 = 24000-5000 = 19000km/s. The difference in the x coordinates is x2-x1 = 350 mpc - 100 mpc = 250 mpc. The Rate is then R = (19000km/sec) / (250 mpc) = **76 km/sec/mpc**. This is read as '76 kilometers per second per megaparsec'. Another way to write this complicated mixed-unit ratio is

$$H = 76 \; \frac{\text{km}}{\text{sec mpc}}$$

Problem 2 - Calculate the rate of sunspot number change between the indicated years.
Answer: The two points have coordinates (x1,y1) = (2003, 75 spots) and (x2,y2) = (2004, 50 spots). The difference in the y coordinates is y2-y1 = 50 spots - 75 spots = -25 spots. The difference in the x coordinates is x2-x1 = 2004 - 2003= 1 year. The Rate is then R = -25 spots / (1 year) = **-25 spots/year.**

This rate is negative because the number of spots is decreasing as time goes forward. This is reflected in the slope of the data being negative in the graph.