Our Expanding Universe!

Name	Speed (km/s)	Distance (megaparsecs)
SN 1990T	12,012	158.9
SN 1991S	16,687	238.9
SN 1991U	9,801	117.1
SN 1992AQ	30,253	467.0
SN 1992BP	23,646	309.5
SN 1992BO	5,434	77.9
SN 1992BS	18,997	280.1
SN 1993B	21,190	303.4
SN 1993O	15,567	236.1
SN 1993AH	8,604	119.7
SN 1993AC	14,764	202.3
SN 1994Q	8,691	127.8
SN 1995AC	14,634	185.6
SN 1995AK	6,673	82.4
SN 1996BL	10,446	132.7

Since 1930 astronomers have measured the distances and speeds of millions of galaxies in the universe. The earliest study conducted by Edwin Hubble of only a few hundred galaxies uncovered a remarkable relationship between the galaxy speeds and their distances.

Today, astronomers use exploding stars called Type 1A supernova to more accurately determine speeds and distances across the universe. The table to the left gives the speeds and distances of fifteen of these supernova.

Problem 1 – As accurately as you can, create a scatter plot of these supernova over the range from 0 to 35,000 km/s and from 0 to 500 million parsecs, with the distance in megaparsecs plotted along the horizontal axis. (Note: 1 megaparsec = 1 million parsecs or 3.26 million light years).

Problem 2 – Describe the pattern that you see. Is it linear? Non-linear? Are there significant outliers? Are speed and distance correlated? Anti-correlated?

Problem 3 – Draw a line that 'best fits' the data points in the scatter plot. What is the slope of this line, which astronomers call Hubble's Constant? What are the physical units of this slope?

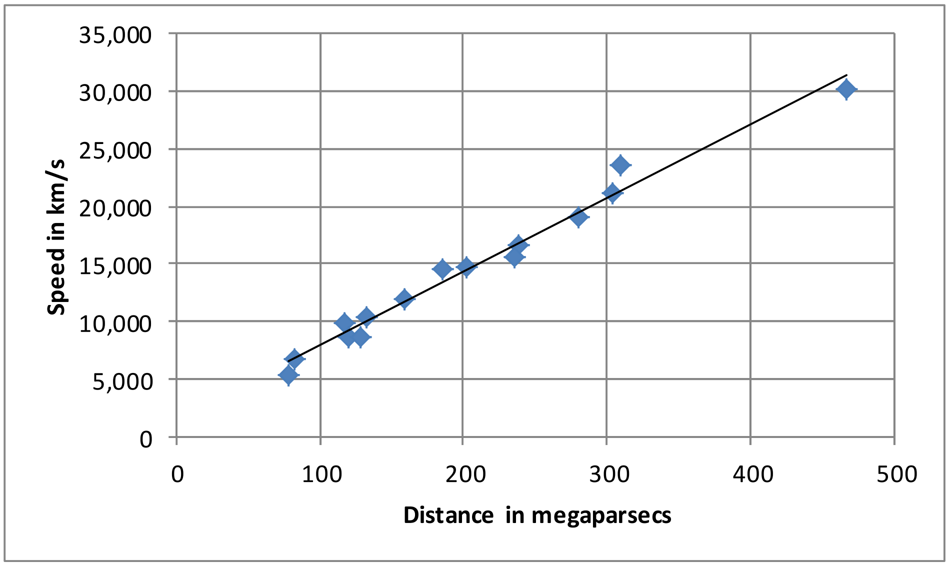
Problem 4 – Estimate an equation for the best-fit line and explain what the equation describes in terms of the data.

Problem 5 - The nearby quasar 3C273 has an apparent speed of 47,000 km/s. What would you estimate as its distance from the Milky Way in A) megaparsecs? B) light years?

Answer Key

The data table is adapted from http://ned.ipac.caltech.edu/level5/Sept01/Freedman/Freedman6.html

Problem 1 – As accurately as you can, create a scatter plot of these supernova over the range from 0 to 35,000 km/s and from 0 to 500 million parsecs, with the distance in megaparsecs plotted along the horizontal axis. (Note: 1 megaparsec = 1 million parsecs or 3.26 million light years).



Problem 2 – Describe the pattern that you see. Is it linear? Non-linear? Are there significant outliers? Are speed and distance correlated? Anti-correlated?

Answer: The trend of the data is for increasing speed to correspond to increasing distance so the data are correlated. The correlation is linear because it follows a straight line. SN1992BP seems to be an outlier in the data.

Problem 3 – Draw a line that 'best fits' the data points in the scatter plot. What is the slope of this line, which astronomers call Hubble's Constant? What are the physical units of this slope?

Answer: The slope that the students estimate should be close to what can be determined from the data by using the closest and farthest data points and calculating the ratio of speed/distance. Example: SN1992AQ has (30253, 467) and SN1992BO has (5434, 77.9) so the slope is (30253-5434)/(467-77.9) **= 63.8**. Because we are dividing speed (km/sec) by distance in megaparsecs, the physical unit of the slope is **kilometers per second per megaparcec**.

Problem 4 – Estimate an equation for the best-fit line, and explain what the equation describes in terms of the data.

Answer: Statistically, the best-fit linear regression for this collection of data is of the form **S = 64.2D + 1484** where S is the speed in kilometers/sec and D is the distance in megaparcecs. The students answers may differ depending on how they drew their lines. Students should be able to indicate that **the equation describes how the speed of a galaxy increases with its distance from Earth or the Milky Way**. Astronomers call this Hubble's Law.

Problem 5 - The nearby quasar 3C273 has an apparent speed of 47,000 km/s. What would you estimate as its distance from the Milky Way in A) megaparsecs? B) light years?

Answer: A) S = 47,000 km/s so from S = 64.2D + 1484 we have 47,000 = 64.2D +1484 and solving for D we get **708.9 megaparsecs**. B) 1 parsec = 3.26 light years so D=708.9 megaparsecs x 3.26 ly/pc = 2,311 million light years or **2.31 billion light years**.