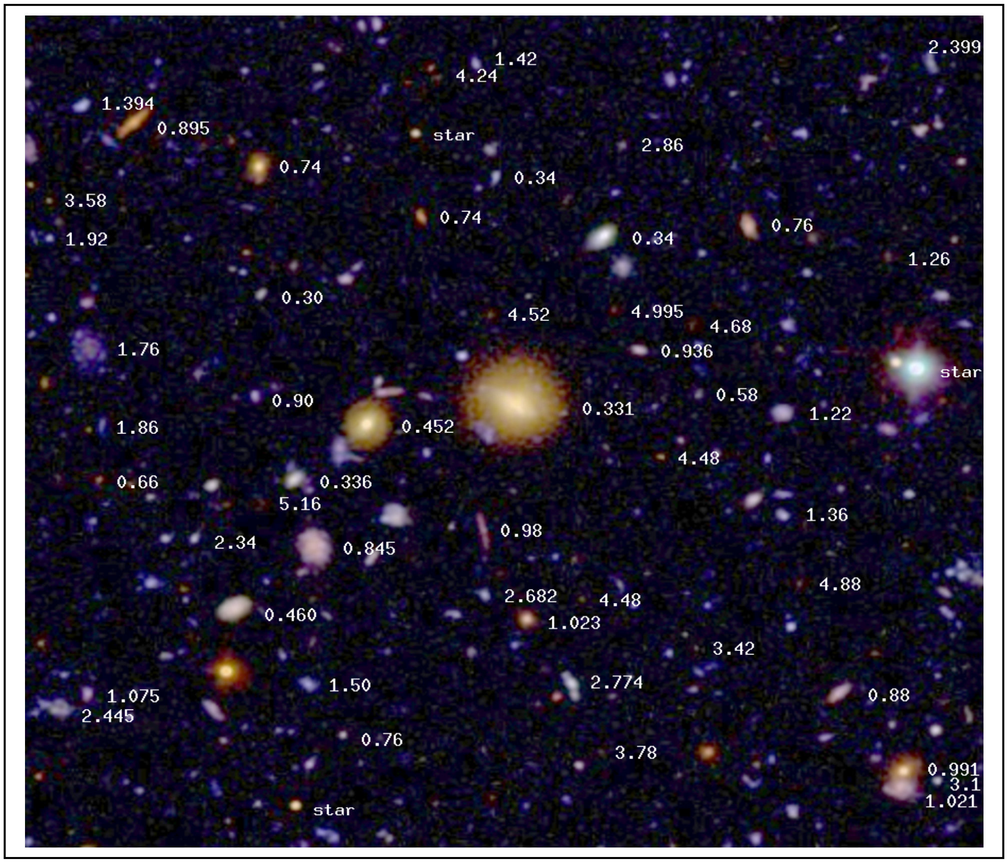
Name ______________________________

In 2004, astronomer Immo Appenzeller and his colleagues from Germany and the United States used the FORS camera at the ESA-VLT observatory in Chile to create a Deep Field image of a small piece of the sky. The goal of this research was to find the most distant, and therefore youngest, galaxies possible so that they could study how the earliest generations of stars in the universe were formed. They obtained the photograph below, and the redshifts are noted for some of the galaxies they were later able to identify and obtain spectra. (http://www.lsw.uni-heidelberg.de/users/jheidt/fdf/pics/pics.html).



Question 1: The numbers indicate the redshifts of the galaxies identified in the field. What does the histogram of the redshifts look like if you bin the number of galaxies at intervals of 0.5 in Z?

Question 2: What is the largest redshift seen for any galaxy in this field? What is the smallest? What is the average redshift? What are the mode and median redshifts?

Question 3: Use the redshift calculator at http://sa1.star.uclan.ac.uk/~cph/redshift.html to determine the time into the past (look-back time) that each galaxy image represents. For instance, the look-back time for our sun is 8.5 minutes, and the nearest star is 4.3 years. Use Omega-M = 0.3 and Lambda =0.7 with H0 = 71 km/sec/mpc which are the parameters that define our universe. Calculate from your answers to Question 2 the corresponding look-back times. Note that at 13.7 billion years, you are looking back to the formation of the universe in the Big Bang.

Question 4: Our best model for the universe indicates an age of 13.7 billion years. What is the longest look-back time you found for a galaxy in Question 3? How long after the Big Bang did this galaxy form?

Question 1: The numbers indicate the redshifts of the galaxies identified in the field. What does the histogram of the redshifts look like if you bin the number of galaxies at intervals of 0.5 in Z?
Answer: Count the number of galaxies in each interval of Z, and plot the histogram (bar graph).

Z	Number of galaxies
0.0 < Z < 0.5	6
0.5 < Z < 1.0	15
1.0 < Z < 1.5	8
1.5 < Z < 2.0	3
2.0 < Z < 2.5	3
2.5 < Z < 3.0	3
3.0 < Z < 3.5	2
3.5 < Z < 4.0	2
4.0 < Z < 4.5	3
4.5 < Z < 5.0	4
5.0 < Z < 5.5	1

Question 2: What is the largest redshift seen for any galaxy in this field? What is the smallest? What is the average redshift? What are the mode and median redshifts? **Answer: Largest redshift z= 5.16. Smallest redshift z= 0.30.**

Question 3: Use the redshift calculator at http://sa1.star.uclan.ac.uk/~cph/redshift.html to determine the time into the past (look-back time) that each galaxy image represents. For instance, the look-back time for our sun is 8.5 minutes, and the nearest star is 4.3 years. Use Omega-M = 0.3 and Lambda-=0.7 with H0 = 71 km/sec/mpc to represent our universe. Calculate from your answers to Question 2 the corresponding look-back times. Note that at 13.7 billion years, you are looking back to the formation of the universe in the Big Bang.
Answer: Largest redshift of z=5.16 yields a look-back time of 12.2 billion years. Smallest redshift z=0.30 yields a look-back time of 3.4 billion years.

Question 4: Our best model for the universe indicates an age of 13.7 billion years. What is the longest look-back time you found for a galaxy in Question 3? How long after the Big Bang did this galaxy form? **Answer: The longest look-back time was 12.2 billion years. This galaxy would have formed about 13.7-12.2 = 1.5 billion years after the Big Bang.**

Note to Teacher. The age of our Milky Way galaxy is between 12.0 and 12.8 billion years, so this distant galaxy formed about the same time as the Milky Way did. The age of our Earth, 4.5 billion years, and the light we are seeing from galaxies with a redshift of Z = 0.45 is about this old! Astronomers use the redshift and light travel age interchangeably.

Teachers: Have your students play with the online redshift calculator by trying different universes than our own (values for Lambda, Omega and Hubble constant) and see how a galaxy's estimated distance and look-back time depends on the kind of universe model you select. This is why, according to general relativity, you cannot determine distances INDEPENDENTLY of first assuming a geometry for the universe.