How many galaxies are there in the Universe?

This worksheet is adapted from an undergraduate exercise at
http://cosmos.phy.tufts.edu/~zirbel/laboratories/HDF.pdf

This picture was taken with the *Hubble Space Telescope*, and it is known as the *Hubble ultra-deep field*. The image results from an observation taken with the telescope trained on one tiny region of the sky for a total of 11.3 days. The picture enables astronomers to observe the very faintest and furthest galaxies in order to learn more about them. We are going to use it to estimate the total number of galaxies in the Universe.

You have been given a small square of the Hubble ultra-deep field with a side length corresponding to 1/80th of a degree.

1. What fraction of the sky does your image represent?

The square section shown corresponds to a solid angle of

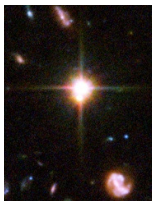
$$\frac{1}{80}\times\frac{1}{80}= \quad \text{.....} \quad \text{square degrees}$$

There are a total of 4.13 x 10^4 square degrees in the whole sky.

Number of images this size which would cover the whole sky = ...

Fraction of the sky this section represents = ...

2. How many galaxies in this section of sky?



Look at the image closely. Almost every one of the objects you see is a distant galaxy. (Any foreground stars are easily identifiable by the 'diffraction spike' pattern surrounding them, as shown on the right.) Count how many galaxies there are in each region of your image and fill in the table at the end of this worksheet. Average the number of galaxies for each individual grid square, and use this to get an estimate of the total number of galaxies in the photo.

Estimated total number of ..... galaxies in the photo

3. Estimate the total number of galaxies in the sky

You now have an estimate for the number of galaxies in the photo from the Hubble Space Telescope. You also know the size of this area of the sky in square degrees, and the area of the whole sky in square degrees. Use your results to get an estimate of the total number of galaxies in the universe.

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An estimate for the total number of galaxies in the Universe is .....

4. How certain are you of your result?

An estimate of the *uncertainty* in your result is an important part of the result.
Can you think of some reasons why your result may not be particularly accurate?

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How realistic do you think your answer is?

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5. So how many stars are in the Universe ?

Our Milky Way galaxy contains about 100 billion stars. It is slightly larger than average, so let us assume the average galaxy contains only 50 billion stars.

Remember: 1 billion = 10^9 = 1,000,000,000 = 1 thousand million

Estimate for total no. of stars in the universe = ...

6. How much mass is there in the Universe?

The Sun is a pretty average star, and has a mass of 2 x 10^{30} kg.

Estimated total mass of stars in the universe = ... kg

Now include a factor of 10 to account for all the dark matter (matter that has mass and gravity, but does not radiate light in any waveband).

Estimated total mass (including dark matter) in the Universe = ... kg

7. What is the density of the Universe?

We can now make an estimate for the density of matter in the Universe.

Remember : density = mass / volume

Assume that the universe is spherical, and has a radius R = 7.4 x 10^{26} m (how many light years is that?)

Using the formula for the volume of a sphere ($V = \frac{4}{3}\pi R^3$), calculate the volume of the universe (in m^3) and hence its density (in kg/m^3).

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The mass of a single Hydrogen atom is 1.7×10^{-27} kg, and its radius is approximately 10^{-10} cm. Assume that it is also spherical, and calculate its volume and density.

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How does this compare to the average density of the universe?

What does this imply about the Universe?

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Finally, what assumptions have you made in your calculations, and how realistic do you think these are?

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Results for counting galaxies

Region of image	No. galaxies counted in region	Region of image	No. galaxies counted in region	Region of image	No. galaxies counted in region
Total		**Total**		**Total**	